STELR CORE CURRICULUM

TEACHER RESOURCE

THE ATSE STELR PROJECT

This is a hands-on, inquiry-based, in-curriculum program designed for Year 9 or Year 10 students, on the theme of renewable energy. The students are introduced to this theme through exploration of the issue of global warming. A range of directed and student-designed practical investigations are an integral part of the program.

Schools participating in the STELR Project can select from three different curricula, all of which are closely aligned to the *Australian Curriculum: Science.*

1 The STELR Core Curriculum

This is a 6-10 week program designed for Year 9 or 10 students. The emphasis in this program is on the physical sciences.

Note: Optional preparatory experiments on basic electrical circuits, current and voltage are provided in the teacher resource. This program is designed to be accessible to all students.

2 The STELR Integrated Curriculum

This is a 10-12 week program designed for Year 9 or 10 students. In this curriculum, physical and chemical sciences are interwoven. Aspects of earth and space sciences and biological sciences are also included.

Note: Many of the experiments on electrical circuits, wind turbines and solar cells in this curriculum are the same as those in the core curriculum. However, this program includes a more extensive range of experiments, information and activities than the core program. Optional additional practical activities and teacher demonstrations are provided in the teacher resource.

3 The STELR Chemistry Curriculum

This is a 5-6 week chemistry program designed for Year 10 students who completed the STELR physical sciences program in the previous year.

Note: Many of the chemistry experiments in this curriculum are the same as those in the integrated curriculum. However, this program includes a greater range of chemistry experiments. Some of the practical activities are provided as optional practical activities in the integrated curriculum.

Resources

The resources provided for each of the three STELR curricula include a digital copy of the student booklet and the corresponding teacher guide. The digital copies of these six booklets are in both Word and pdf formats. Teachers can adapt the materials for the curriculum they select to suit their students. Digital copies of a number of PowerPoint presentations are also provided. Full colour hard copies of the student booklet and the accompanying teacher guide for the STELR Core Curriculum are also available.

These materials are fully supported by our dedicated website: www.stelr.org.au. Support materials on this website include background information on many aspects of global warming and energy resources, as well as careers information and pre-tests and post-tests.

FOR ALL ENQUIRIES ABOUT THE STELR PROJECT:

For general information about the STELR Project or STELR resources, or advice or support in running the STELR Program, please contact:

Peter Pentland
STELR Project and Education Program Manager
Australian Academy of Technological Sciences and Engineering (ATSE)

Email:	Peter.Pentland@atse.org.au
Phone:	(03) 9864 0906
Fax:	(03) 9864 0930
Postal address:	GPO Box 4055, Melbourne, VIC, 3001

TABLE OF CONTENTS

***** ‘SB pages 2—3’ refers to the matching pages in the STELR Core Curriculum student booklet.***

THE STELR PROJECT

THE ATSE STELR PROJECT: AIMS, HISTORY AND ACKNOWLEDGEMENTS

PROJECT OVERVIEW

Our vision

It is well-known that participation rates in the enabling sciences in the senior years of secondary schooling in Australia declined in the 1980s and 1990s, and levelled off over the next decade. One of the primary reasons for the lowered participation rates is that most secondary school students do not perceive the enabling sciences or mathematics as relevant to their lives, despite the manifest importance of science and technology in our modern society. As a consequence, a significant proportion of Australian students do not elect to study these subjects at senior levels.

STELR* aims to reverse these lowered participation rates by inspiring and enabling secondary school students to appreciate the role and potential of science, technology and mathematics in the world in which they live, and to learn from their journey of scientific inquiry the essence of evidence-based critical thinking.

STELR achieves this by tapping into the high level of concern the majority of students have about global warming and climate change, shown through surveys of students, using the **theme of global warming and renewable energy**. Since one of the most effective ways of reducing greenhouse gas emissions is the widespread adoption of renewable energy technologies, students see these technologies as being highly relevant to their lives.

STELR is designed to give all Year 9 or 10 students, whatever their background and abilities, the experience, confidence, skills and insights that will inspire and enable them to further their studies in the enabling sciences, mathematics and technology. Whether they eventually choose a career in these areas or not, STELR contributes to their science literacy skills, such as an appreciation of the role of science in society and of the utility of evidence-based thinking.

STELR operates within the curriculum so that ***all*** students at the year level participate in the program, not just selected students. It is our aspiration that ultimately all Australian students, including students who live in remote areas, will have the opportunity to participate in the STELR program.

STELR also inspires and empowers practising teachers to teach science more effectively. To help achieve this, STELR incorporates contemporary teaching and learning practices and, in particular, an inquiry-based learning approach that engages and challenges both students and teachers.

In addition, STELR provides extensive resources to all participating schools, including classroom equipment needed for the program, student and teacher booklets in print and electronic form, a website, teacher professional learning and ongoing teacher support. In this way the program is accessible to all – no school is disadvantaged.

STELR and the *Australian Curriculum: Science*

STELR is distinctive amongst state and national programs in that it is an excellent vehicle for fulfilling the aims of the *Australian Curriculum: Science,* published December 2010. It exemplifies an inquiry-based teaching approach and the development of a coherent learning program in which all three content strands – Science Inquiry Skills, Science as a Human Endeavour and Science Understanding – and the cross-curriculum aspects of the curriculum, are interwoven. STELR gives equal importance to, and achieves an ideal balance between, the three content strands.

In addition, through the study of global warming and the investigation of renewable energy resources, STELR demonstrates how the unifying ideas of sustainability, energy, evidence, models, explanations and theories can be developed. Moreover, STELR fosters the eight general capabilities considered to be inherent in science, while the knowledge and skills learned in other areas such as English, mathematics, technology and design are developed throughout.

*STELR is the acronym for Science and Technology Education Leveraging Relevance.

Aims

The primary aim of the STELR Project is to increase Australian student participation rates in physics, chemistry, biology and mathematics subjects at the upper secondary school level.

The secondary aims of the project are to:

1 Improve the level of science literacy and understanding in the community;

2 Prepare students to engage with science ideas and be knowledgeable about the way science and scientists work;

3 Increase the number of students choosing science and engineering careers to address the shortage of science and engineering graduates;

4 Increase students' awareness of careers in technological trades;

5 Improve the quality of science classroom teaching practices and enable teachers develop the confidence and skills that will help them deliver the new *Australian Curriculum: Science*; and

6 Use data from the National Solar Schools Program (NSSP) to underpin the development of data-processing and analysis skills in students (when this data becomes available).

Project history 2008-2011

From its inception, the STELR program was designed to be taught within the curriculum so that it is available to all students within the selected year level (Year 9 or Year 10) in each participating school.

Initial trials 2008-2009

To ensure that it was a program for all, the STELR Project was initially trialled in a small number of schools across Australia over 2008 and 2009. These were drawn from all sectors, with a mix of schools in the Government, Catholic and Independent sectors, from metropolitan and rural regions.

Teacher evaluation of the STELR program in these years showed that teachers believed the program had an overall positive effect on students' participation and engagement in learning science and on their perception of the relevance of science in their lives. There also was evidence of teacher change in practice and knowledge of and development of skills in contemporary teaching and learning approaches.

STELR Stage One Project (2010)

Following these trials, with the support of the Australian Government and our other sponsors, the STELR Program and resource materials were re-developed for implementation of the STELR Stage One Project (2010) in 183 schools across Australia. In this process of re-development, recommendations that were made in the evaluation report of the early trials were implemented.

Changes to the original set of resources included the design and production of:
• New, specialised, student-friendly, robust equipment;
• A new DVD that introduces global warming in an Australian context;
• A new student booklet and teacher booklet; and
• A comprehensive online testing program.

The 2010 student resources were written for the Year 10 level, since this is the level in which students select their subjects for senior years, and in which topics such as the measurement of electrical energy and electrical power are generally taught. However, to cater for schools that preferred to introduce STELR at Year 9, and to cater for a wide range of student backgrounds across the 2010 STELR schools, an extensive 'smorgasbord' of adaptable activities was provided in print and digital formats. It was expected that teachers would then select those activities that best suited their students and their school curriculum, adapting them if necessary.

In addition, two teachers from each STELR school were required to participate in our professional learning programs that were held in four major capital cities in March, 2010. Schools were also supported by professional mentors.

See Figures 1 and 2 on page 8 for photographs of participating students and teachers.

See pages 13-16 for examples of feedback from 2010 STELR schools.

Figure 1. Students trying out the resources.

Figure 2. Teachers at a STELR professional learning workshop.

STELR Project (2011)

As befits any professional organisation, ATSE has ensured that the STELR Project is constantly evaluated, reviewed and refined. As a result of this process, the STELR curricula and written resources developed for 2010 underwent further significant changes for 2011.

The STELR Project (2011) offered three different curricula, which are outlined at the start of this resource.

There were three major reasons for these changes. Our new curricula and new resources were designed to:

- Match the *Australian Curriculum: Science*, published in December 2010.
- Take into account constructive feedback from 2010 STELR schools, recommendations provided by the 2010 mentors and the recommendations provided by our national steering committee headed by Professor Russell Tytler that were informed by the evaluation study performed by a team headed by Professor Leonie Rennie, Dean of Postgraduate Studies at Curtin University.
- Re-introduce a chemical sciences component that had been present in the original trial materials but needed adaptation to address concerns raised in teacher feedback at that time.

In 2011, there were 185 STELR schools across Australia. Feedback from these schools has been very positive.

STELR Project (2012 onwards)

The STELR Project continues to evolve and grow. From 2012 an increasing number of schools are participating.

We continue to offer the three STELR curricula outlined at the start of this resource. The materials that were written for the 2011 STELR Core Program have undergone small editorial changes and the websites listed in the resources have been checked and updated. (The materials written for the STELR Integrated Program and the STELR Chemistry Program will undergo a similar review process later this year. Their current editions, however, will continue to be available.)

In addition, further resources have been added to the STELR website and more will be developed over the coming months.

Schools participating in the STELR Project need to select which of the three sets of student and teacher resources are best suited to their needs.

To enable teachers to make an informed choice between the three alternative STELR curricula, the program charts for the other two STELR curricula, and charts of how they fit in the with the *Australian Curriculum: Science,* are also provided in this resource (pages 39—42).

Acknowledgements

The ATSE STELR Project gratefully acknowledges the many STELR teachers, STELR mentors and education and industry experts who have contributed their ideas, advice, sample materials and other resources as the STELR program has evolved. Their contribution has been crucial to the success of the program and is greatly appreciated. We especially thank the staff and students of Box Hill Senior Secondary College and Northcote High School for trialling our new chemistry materials at the end of 2010, and providing very comprehensive advice.

Funding acknowledgements

The Australian Academy of Technological Sciences and Engineering gratefully acknowledges the support of numerous individuals and entities.

The STELR proof-of-concept program (2008) was made possible through the support of:
- Victorian Department of Education and Early Childhood Development
- Australian Academy of Technological Sciences and Engineering (ATSE)
- Australian Academy of Science (AAS)
- Individual Fellows of ATSE (Sir Arvi Parbo, Sir Rupert Myers, Robin Batterham, Alan Finkel)

The STELR Project pilot program (2009) was made possible through the support of:
- Queensland Department of Education, Training and the Arts
- South Australian Department of Education and Children's Services
- Tasmanian Department of Education
- Victorian Department of Education and Early Childhood Development,
- Victorian Department of Innovation, Industry and Regional Development
- Victorian Catholic Education Office
- Western Australian Department of Education & Training
- Hydro Tasmania
- Rio Tinto
- Aurora Energy
- Roaring 40s
- Transend Networks
- Alan and Elizabeth Finkel Foundation

The ATSE STELR Stage One Project (2010) was made possible through the principal support of the Australian Government, with substantial sponsorship provided by:
- Orica Pty Ltd
- The Australian Power Institute
- Rio Tinto

The STELR Project (2011) was made possible through the support of:
- Orica Pty Ltd
- The Australian Power Institute
- Rio Tinto

The STELR Project (2012) has been made possible through the support of:
- Orica Pty Ltd
- The Australian Power Institute
- The University of South Australia
- The University of Queensland
- COSMOS Magazine
- The South Australian Department of Education and Children's Services
- The Australian Capital Territory Department of Education and Training

We especially thank our sponsors for enabling us to commission sturdy, reliable equipment for students to perform their hands-on investigations.

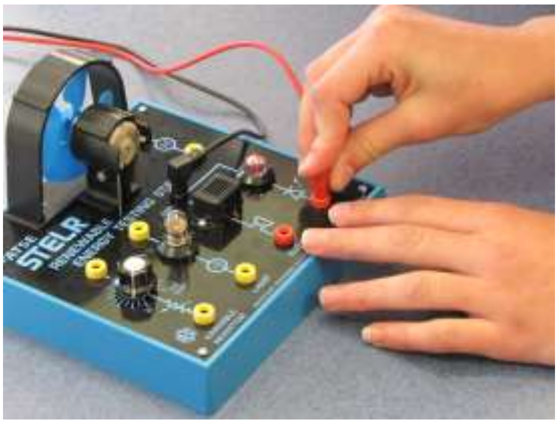


Figure 3: The STELR testing station

THE STELR PROJECT

THE STELR APPROACH TO TEACHING AND LEARNING

The philosophy behind the STELR approach

A much quoted review of Australian Science education (Goodrum, Hacking & Rennie, 2001) listed, as their first theme for an ideal science curriculum, that : ‘The science curriculum is **relevant to the needs**, concerns and personal experiences of students.’

They have argued more recently (Goodrum & Rennie, 2006) that: ‘Many students find the school science curriculum on offer to be **unimportant, disengaging, and irrelevant** to their life interests and priorities.’

Glen Aikenhead (2004) has argued that: ‘A recurring evidence-based criticism of traditional school science has been its **lack of relevance** for the everyday world’, and that we need to emphasise humanistic aspects of science in our curriculum and teaching.

For this reason, the main theme of the STELR program is the highly relevant context of **global warming and renewable energy**.

STELR has adopted a number of principles designed to engage students through evidence-based teaching approaches and strategies. These include:

- Scientific literacy;
- Inquiry-based learning;
- A socio-scientific focus;
- The representation of science as a human endeavour; and
- Embedded assessment.

Inquiry-based learning

Inquiry-based learning helps students to actively pursue and use science knowledge rather than experience it as pre-packaged and complete – to be accepted and practised. Thus, in the STELR program there are many points at which students raise questions and explore ideas.

In the introductory activities the principle used is ‘guided inquiry’, but students are later encouraged to shape their own inquiry around questions that interest them. This involves being able to design investigative approaches. These include experimental as well as web-based research approaches.

A core principle that has been used to describe inquiry is ‘explore before explain’, meaning that students are introduced to science ideas only after they have explored phenomena and raised questions implying a need for these.

Inquiry-based pedagogies:

- Involve students in initial exploration before ideas are introduced and explanations developed;
- Incorporate and value students' own questions;
- Involve open-ended investigation as part of the teaching sequence;
- Use activities to explore and develop ideas rather than simply demonstrate previously presented ideas; and
- Support students to create new knowledge.

See the outline of the principles of inquiry-based learning on pages 11-12.

The jigsaw approach

An integral part of the STELR program is the **jigsaw approach** to learning. Each student group or student pair becomes the class experts in particular aspects of renewable energy through practical and web-based investigations and various challenges, which they then communicate to the other members of their class. These activities involve students taking responsibility for the direction of their inquiry.

The 'interview about instances' teaching strategy

Many of the activities through which key concepts are introduced are based on the teaching strategy **interview about instances**. In this approach, some stimulus material, in such forms as a series of images, a DVD or demonstrations, is presented to the students and questions about the stimulus material are posed.

The role of the teacher is one of the questioner rather than the transmitter of answers. The teacher may find there is considerable variation in student thinking about the issues or concepts presented, or that alternative conceptions are presented.

Principles of inquiry-based learning

Engagement of students

An inquiry-based approach starts with engagement of the students prior to explaining. This serves several purposes:

- It provides a conflict between prior learning and the new more scientific understanding — such conflict will lead students to ask questions;
- It gets students' attention and focus; and
- It elicits and assesses prior knowledge. (Students may have constructed alternative conceptions.)

During this stage, students:
- ask questions
- show curiosity
- show interest

During this stage, teachers:
- create interest
- generate curiosity
- raise questions
- elicit responses

Exploration without teacher explanation

During this stage, students:
- ask questions
- hypothesise
- work without direct teacher input (but are guided)
- gather evidence
- record and organise information
- share observations
- make evidence-based claims
- draw conclusions
- work co-operatively and/or collaboratively

During this stage, teachers:
• encourage students to work co-operatively and/or collaboratively
• observe and listen as students interact
• ask thought-provoking questions
• allow students time to puzzle through and to explore
• act as a facilitator and/or consultant
• create a climate in which students ‘want to know’ and ‘want to learn’

Explanation

During this stage, students:
• draw on experiences to offer ideas and explanations in their own words
• use evidence to support ideas
• critically appraise explanations
• listen critically and respectfully to others
• reflect on and assess their understanding
• produce multiple representations of concepts to improve understanding

During this stage, teachers:
• elicit the students' explanations of concepts, definitions of words
• ask for evidence and clarification
• provide formal definitions, explanations and new labels
• use students’ experiences to build new concepts
• assess students’ developing understanding of concepts
• provide opportunities for students to represent their ideas in a variety of formats

Elaboration

During this stage, students:
• apply scientific terms, definitions
• apply understandings to new contexts
• use previous information to ask questions, propose solutions, make decisions and design investigations
• draw reasoned conclusions from the evidence
• check for understanding with their peers

During this stage, teachers:
• expect students to use appropriate scientific terms, labels and definitions
• expect students to use their understandings from explanations
• remind students of alternatives
• ask questions such as “What do you think?” and “Why do you think that?”

Assessment

During this stage, students:
• demonstrate their understanding of the ideas and concepts
• answer open-ended questions
• evaluate their progress
• ask questions
• participate in peer assessment

During this stage, teachers:
• elicit or diagnostically assess students’ prior knowledge and understanding
• develop the explicit language of science and mediate where students have conflict in their understanding
• use formative assessment or assessment of learning throughout a unit of work to evaluate student understanding, to provide feedback to students and to direct the learning program
• use summative assessment to identify the students’ congruence with the new understandings
• use conceptual mediation to overcome and reconcile alternative conceptions
• use a variety of assessment strategies

THE STELR PROJECT

SOME FEEDBACK AND IDEAS FROM STELR TEACHERS

Feedback from the 2008-2009 trials

Teachers involved in the STELR trial programs identified many significant benefits arising out of the inquiry-based learning in the STELR program. They included:

- A definite increase in the level of students' engagement with the material – this included more class discussion and willingness of students to contribute to discussions, as well as increased engagement with practical activities.

- More opportunities to connect what students were learning with current issues in the media and in their daily lives. Students gained insights into how science works in the real world.

- The opportunity for teachers to work as a team, to gain a broader understanding of the applications of science, and to undertake inquiry-based learning on a much larger scale than their time and resources would normally allow.

Feedback and ideas from 2010

Following are quotes from some of the teachers involved in 2010. Notice some of the creative ideas used in some of these schools! Also see the student feedback at one of these schools.

From Mark Darrell, Assistant Principal, *Mathematics and Science*, Hallett Cove School R-12, SA
President, Mathematics Association of South Australia

Given the decade-long decline in the number of students undertaking advanced studies in Mathematics and Science, it is timely to be able to implement a program that has the potential to significantly address the disengagement that students are expressing towards STEM subjects.

Although there is a range of programs on offer around the country that are attempting to address this situation, I believe that the STELR Program is best placed to create a sustainable impact.

It is imperative that we engage the students in a rigorous pursuit of in-depth understanding and appropriate skill development so that not only do we increase the number of students pursuing advanced studies, but also we raise the general level of mathematical and scientific literacy of the future populous at large.

At the school level we are well aware that the relationship between teachers and their students, as well as the use of appropriate pedagogies, are essential in the provision of an engaging and rigorous curricula. The desperate need for teacher professional development has been of ongoing concern, as has the lack of availability of high quality teacher resources that support the teachers in the provision of said curricula.

The thoroughness of thought and preparation that has obviously been put into the preparation and provision of the STELR Program goes a long way towards addressing both of the above mentioned concerns.

Introducing curriculum and pedagogical change has always proved difficult and frustratingly time-consuming at the school level. Teachers are, quite naturally, resistant to change unless they are able to perceive the potential benefits of implementing that change as well as feeling fully supported in the change process. By providing all necessary curriculum and teacher support materials, as well as the actual physical equipment, the STELR Program has made it quite easy for the science teachers to feel sufficiently confident to be prepared to implement such an inquiry-based, contextualised program.

The enthusiasm for the program expressed by the teachers, as well as the highly topical contexts around which the program was developed, makes it highly likely that the students will also find the program engaging. In fact, we believe that the provision of more units along similar lines to the current STELR program would go a long way towards ensuring that high quality science curricula, in line with the National Curriculum and utilising appropriate pedagogies, would be implemented across the country.

From Heather Omant, Curriculum Manager, Ogilvie High School, Tasmania
*(*Heather took up a new appointment at another school for 2011)*

I am curriculum manager at a large city high school in Hobart and we have taken part in this federally-funded program on renewable energy for 2 years.

The program is outstanding in encouraging students in the field of physics (we are an all-girls school) and also in making them aware of the problems around energy usage and the possible alternatives to fossil fuels. It also is a fantastic hands-on program which helps students to understand the processes of scientific inquiry. The materials and teachers' resources are excellent.

From Melody Gabriel, Head of Science, Northcote High School, Victoria

Staff members have been singing its praises. Not being able to teach all the lessons as we don't have the time, we selected a range of activities that would flow and allow students to get the intended overall understandings.

The STELR teachers are really enjoying teaching it. The materials are comprehensive and easy to follow by students and teachers. The equipment is great and easy to operate, and the support in terms of changes has been wonderful.

We supplied the students with their own booklets of the activities that they will be doing, and they are used well. The students are thoroughly enjoying the intensive hands-on approach, and that is really evident following a unit on genetics and evolution. It really mixes up the semester .

Next year we have to make serious changes to our Year 10 offerings, so we have decided to use the STELR as a whole unit, and teach from basic principles upwards. This support is offered in the book and staff felt it would have served the students well if we had had the time this year. This will be offered to all Y10 students and will be a pathway into VCE Physics.

All in all, great changes, staff and students feel supported and the resources are very user-friendly. Thanks!

From Louise Macfarlane, Science TLA Coordinator, Box Hill Senior Secondary College, Victoria

We have just received the fabulous new equipment from ASTE for the STELR Stage One Project. All of the science teachers here at BHSSC are excited about our ability to teach science with a student-centered, hands-on, inquiry-based approach using this equipment and the programs the ASTE STELR program provides.

In 2009, BHSSC was involved in the STELR pilot project and taught the STELR program to seven classes of Year 10 science students over six weeks. This year eight Year 10 science classes will participate in the STELR Project.

At BHSSC we have students who come to learn trades skills such as electrical, woodwork, fashion, art, hairdressing or music, as well as our specialty sports students. This being the case, science lessons need to have a hands-on approach to learning to engage students and get across concepts. This is exactly what STELR has provided.

At the end of the STELR pilot project students were surveyed and they loved the practical experiments on biofuels, energy transfer, solar cells and wind turbines and said they would not change anything about the project because it was fun. That is a huge vote of confidence for the project because when students are having fun they are engaged and they are learning.

As in all pilot programs, we found there were some improvements that could be made. All of the suggestions we made were listened to and acted upon promptly. This was from the little suggestions such as providing batteries in the anemometers, to creating an Australian and up-to-date version of the DVD 'An Inconvenient Truth'. The STELR produced DVD 'Global Warming. Cold Facts. Hot Science' is concise and relevant to the lives of Australian students. I am looking forward to sharing it with the students in a couple of weeks.

The STELR team made the process of teaching the STELR lessons easier by facilitating exchange of teaching materials between teachers, which saved a lot of time.

With the advice and support of the STELR team and the support of our Principal, Steve Cook, the electrical trades teacher, Charlie Gilbert , and Simon Hood at our tennis school, we have been able to extend the STELR Project to involve the whole BHSSC school community. Electrical trades students have added a wind turbine and solar panels to the roof of our canteen and are wiring up these green energy supplies to low energy lighting they are installing in the canteen. So we will have green energy installed by students for the students.

On STELR advice we applied for and accessed the Federal Solar in Schools $50,000 grant for solar panels and the $5000 state grant. So we will be installing $55,000 of solar panels on the MYTS tennis school roof this July. We will be able to inform the students and community about the green energy we will generate, and the benefits of decentralising the energy production and the use of non-polluting energy production. Excess energy will be fed back into the grid for the benefit of the community.

ASTE supplied the components for a model solar car race. Each pair of students in Year 10 science built their own model solar car. To our surprise the fashion students were as engaged as the trades students, with each car having its own style. Some film students even made a photo journey series of their model. This open-ended learning allowed individual learning journeys.

So in many ways we have benefited from the STELR program. This is only possible due to the enthusiasm and dedication of members of the STELR team. I hope you get the funding to continue with this excellent program. The student science environment is far more stimulating for students (and teachers) as a result of this fabulous program.

From Jane Ganfield, Science Teacher, Dongara District High School, WA

Our application

It’s windy in Dongara. In fact it’s really, really windy. While this is generally looked upon as a curse, for a change it actually was a bonus . . . Dongara is a perfect place to highlight the potential for sustainable energy use.

Dongara is a small town (population about 3000) with a small school. . . When we were told late last year that we were successful . . . our success and what it meant was published in the school newsletter and our local paper. The school, particularly the secondary students, was buzzing about what sort of equipment we would get. I think the students were also a little surprised, being a small school and winning all this gear. Any little boost that suggests that the little guys can be just as worthy and successful as the big guys is a great lesson for our students.

The professional learning

Early this year, successful school representatives met in Perth for two-days of professional learning. It was great to see that a variety of schools (big/small, country/city, public/private) were successful. . . The schools came from as far north as Newman and as far south as Busselton. All costs were covered, so representatives coming from a long way away weren't disadvantaged.

The professional learning went through the STELR philosophy and goals of the project . . and also involved using the equipment that we were given, as learning to use a whole new set of gear would obviously be time-consuming and would be used most effectively by teachers if shown how. An impromptu talk from a teacher at South Fremantle High School, a pilot STELR school, also gave a realistic perspective on how the gear worked in a classroom and school situation. Feedback from the pilot STELR schools was gratefully accepted. One of the main issues with the equipment originally was that it wasn't robust enough for curious students with the old "If I pull this bit really hard, is it gonna break?" mentality. This was rectified and a whole new set of gear constructed, and from my experience it's almost teenager-proof!

How we use STELR

The program is really flexible and teachers can choose to use all or none of the teacher and student resources and all or none of the equipment. I have almost completed a unit on Energy and Change using the STELR equipment with a group of Year 10 students. The students performed surprisingly well in the pre-test and haven't completed the post-test yet. I still have a few weeks left of the unit. I was a bit surprised about the lack of knowledge about the difference between the greenhouse effect, global warming and the ozone layer. I thought that being in the media so much that students would have a lot more understanding of the topic. The misconception that the depletion of the ozone layer has caused global warming was quite common. . .

Before doing the sustainable energy part of the course, we visited a wind farm just north of Dongara, close to the town of Walkaway. The students were (pardon the pun) absolutely blown away when they got there. There are 54 wind turbines at the wind farm we visited. They supply enough energy for 60 000 homes. We then estimated that to power Dongara we would only need 3 wind turbines. The effect was huge and a heated discussion was started on the way home as to why Dongara doesn't have wind turbines, where they should go, why WA doesn't have more wind turbines, etc. It was really great to see and hear. The pros and cons of wind turbines were discussed and the students learned a lot from their discussions with each other as there were differing opinions and varying degrees of understanding. The students' youthful enthusiasm was once again reignited.

After the visit to the wind farm, we spent a week looking at alternative energy sources. The students researched one alternative energy source then did a jigsaw to learn about all the other sources. We then used the wind turbines and solar panels and looked at how to get maximum power out of them. The Year 3's were then invited into the science laboratory as they were learning about energy, and had a competition. Each pair of Year 10 students was put with three or four Year 3's. The competition was for the Year 3's to create the wind turbine that created the most volts. The STELR equipment has different length blades and you can put in as many blades and blade combinations as you like.

The groups also 'played' outside with the solar panels, experimenting with angles and shade and making buzzers sound and lights glow. Both groups of students loved the activity and helped to increase enthusiasm towards Science.

On the last day of term the mainstream Year 10's had a competition against the SWL (vocational pathway) Year 10's to see who could make the fastest solar car. The equipment for the cars is not part of the STELR equipment but STELR is planning on including this kind of equipment into the kits in the future. The students were allowed to use one solar panel, one motor and any combination of wheels, pulleys and gears that they liked.

The learning and problem-solving that happened during the design process was immense. Some students' cars were going backwards, so they had to figure out that they needed to swap over wires. Others had a gear ratio that required more torque to get the car moving than what the motor could provide. Others designed intricate systems to make sure their car went in a straight line. Next time I would probably do little experiments beforehand such as the impact of the angle of the panel in relation to the sun and the voltage output. The students didn't seem to realize that getting the angle right was crucial. The students really embraced the challenge. It was reiterated to the SWL students that their problem-solving abilities and practical skills would be advantageous for the challenge, whereas the knowledge and technical side of the challenge may mean the mainstream group performed better. The challenge highlighted the fact that the strengths and skills possessed by the SWL group were just as useful as the more academic groups' skills and knowledge.

Feedback from some Year 10 students:

"I feel that using the STELR equipment has helped my learning a lot, because it's very "hands-on" and I understand how electricity works a lot easier now." **Zoe**

"I learnt more about how wind creates electricity and how solar systems work and I think it's a great way of teaching kids about Science." **Hayley**

"I find while using the STELR equipment I have learnt faster than copying out of a book." **Matt**

"The STELR equipment was interesting and fun to play around with. It showed that electricity can be produced in different ways, eg. wind turbines and solar panels". **Barry.**

Thank you

The Science Staff and students at our school would like to thank the STELR team and ATSE for helping to improve Science outcomes and enjoyment. It has had a huge impact on the students enthusiasm for Science, especially Energy and Change. It is amazing how two-days of PD, a teacher and student-friendly resource and some well thought-out equipment can make such a difference.

THE STELR PROJECT

ASSUMED LEARNING

In the writing of the STELR Integrated Curriculum, it is assumed that the students have the following background understanding and skills. These will then be reinforced and extended throughout the program.

Mathematical skills

- Measurement of length and angles
- Substitution of values into a formula
- Calculation of percentages
- Calculation of averages, including identifying and omitting outliers
- Drawing and interpreting graphs
- Selecting a suitable graph format for a particular set of data
- Conducting a survey and processing the responses using simple statistical tools

Science understandings

- The meaning of energy terms, including kinetic energy and potential energy
- The meanings of the terms electrical circuit, series circuit, parallel circuit, current and voltage
- The units of measurement of current and voltage

Science skills

- Setting up series and parallel circuits
- Interpreting and drawing circuit diagrams
- Measuring current and voltage
- Practical science inquiry skills, including making predictions and taking accurate, repeat measurements and recording them in tables
- Using basic science equipment carefully and safely

Note: If the students do not have a strong background in electrical circuits and the measurement of current and voltage, then three optional preliminary practical investigations are provided to help build the understandings and skills required. These investigations will also help develop practical inquiry skills and skills in using basic science equipment carefully and safely. The instructions for these optional experiments and advice on running them are provided in this teacher resource (pages172—202).

ICT skills

- Web research
- Developing PowerPoint presentations
- Setting up and using spreadsheet applications
- Using graphing software

Note: Experience in taking digital photos and videos would be an advantage.

THE STELR CORE CURRICULUM

OVERVIEW OF THE STELR CORE CURRICULUM

The STELR Core Curriculum has been written principally for the Year 9 level, although some schools may prefer to offer it at Year 10.

The design of the STELR Core Curriculum

The STELR Core Curriculum is designed to enable students to develop key understandings, skills and insights in a logical and systematic fashion, through a series of topics based on the theme of global warming and renewable energy.

These topics are principally drawn from the physical sciences and earth and space sciences, as shown in the STELR Core Curriculum Chart on page 20.

The STELR Core Curriculum is closely aligned with the *Australian Curriculum: Science*, not only in relation to the three content strands, but also in relation to its underlying philosophy, aims and emphasis on inquiry-based learning.

In fact, the *Australian Curriculum: Science* was informed by key international curriculum documents, including:
•*Re-imagining Science Education: Engaging students in science for Australia's future* (Tytler, 2007)
•*Australian School Science Education National Action Plan 2008 –2012* (Goodrum and Rennie, 2007)

As shown in the core program chart on page 19, the curriculum is designed to give equal importance to the three content strands. Woven around practical investigations and a range of class activities, it exemplifies how the three content strands can be interwoven into a coherent, logical program.

The practical investigations

The practical investigations enable students to build up a range of science inquiry skills and develop many relevant key science understandings. Students first undertake directed practical investigations and then assisted student-designed investigations. These enable the students to develop confidence and competence with the equipment and an understanding of experimental design. With this build-up of skills and experience, the students are finally able to pose their own inquiry question and design their own investigation on that question.

In schools where the students have little or no background experience in setting up and investigating basic electrical circuits, or in measurement of current and voltage, additional preliminary experiments are offered in this resource (pages 172—202) so that students can begin the STELR program with appropriate understandings and skills.

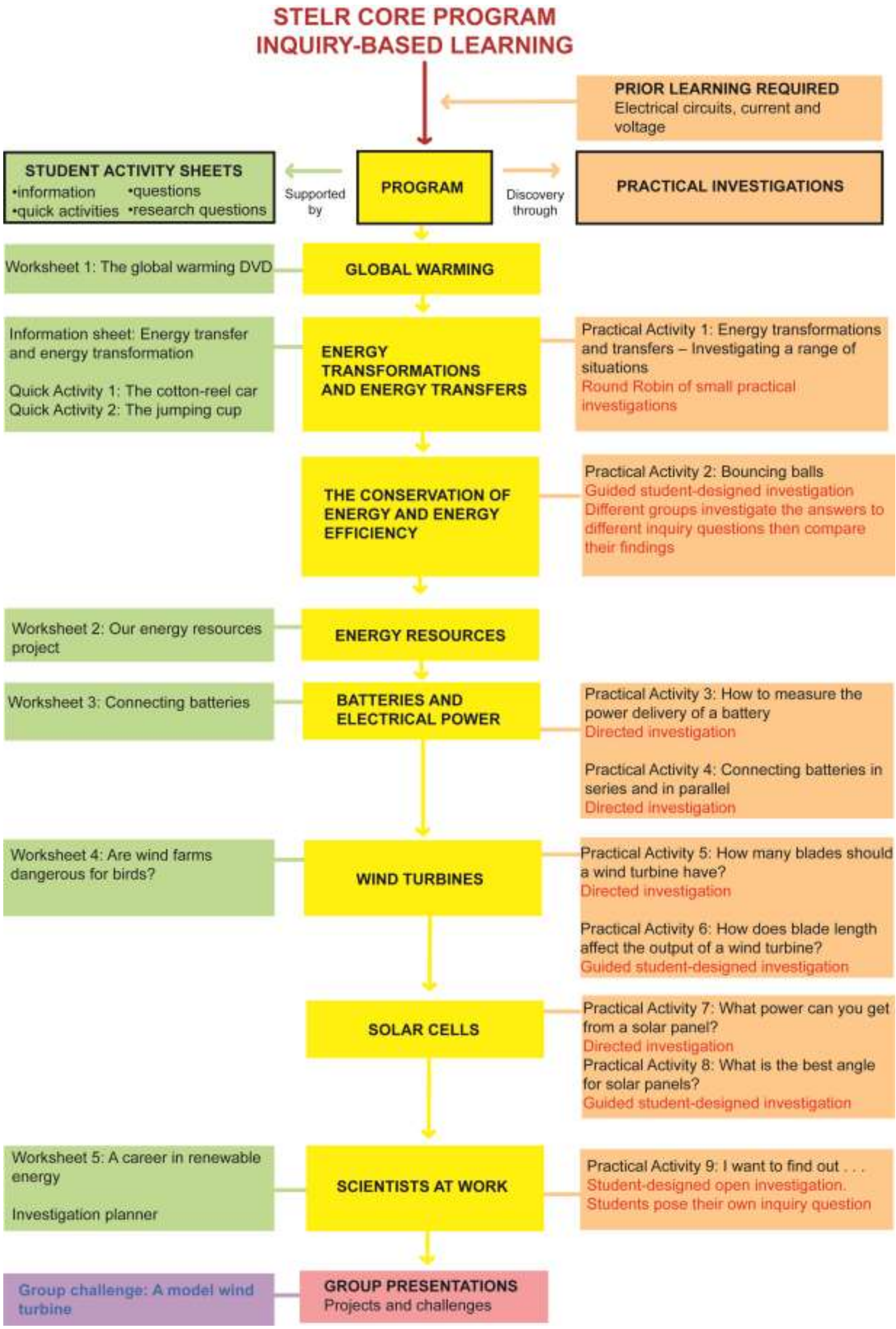
The student activity sheets

The student worksheets and quick activities offer students a range of experiences and tasks to enable them to develop key science understandings and thinking skills and to give them opportunities to explore issues that are relevant and meaningful to them, as well as possible future careers.

Personal development

By undertaking the STELR Core Curriculum, students will be given the opportunity to develop:

- Confidence and self-esteem
- An insight into how science is relevant to their future and how science can be challenging and fun
- Reasoning and reflection
- A disposition to ask questions, problem-solve and argue using evidence
- Communication skills
- Creativity and imagination
- An ability to collaborate with others and to work effectively in a team
- Effective time-management and organisational skills


STELR CORE PROGRAM
INQUIRY-BASED LEARNING
PRIOR LEARNING REQUIRED
Electrical circuits, current and voltage
STUDENT ACTIVITY SHEETS
•information •questions
•quick activities •research questions
Supported by
PROGRAM
Discovery through
PRACTICAL INVESTIGATIONS
Worksheet 1: The global warming DVD
GLOBAL WARMING
Information sheet: Energy transfer and energy transformation
Quick Activity 1: The cotton-reel car
Quick Activity 2: The jumping cup
ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS
Practical Activity 1: Energy transformations and transfers – Investigating a range of situations
Round Robin of small practical investigations
THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY
Practical Activity 2: Bouncing balls
Guided student-designed investigation
Different groups investigate the answers to different inquiry questions then compare their findings
Worksheet 2: Our energy resources project
ENERGY RESOURCES
Worksheet 3: Connecting batteries
BATTERIES AND ELECTRICAL POWER
Practical Activity 3: How to measure the power delivery of a battery
Directed investigation
Practical Activity 4: Connecting batteries in series and in parallel
Directed investigation
Worksheet 4: Are wind farms dangerous for birds?
WIND TURBINES
Practical Activity 5: How many blades should a wind turbine have?
Directed investigation
Practical Activity 6: How does blade length affect the output of a wind turbine?
Guided student-designed investigation
SOLAR CELLS
Practical Activity 7: What power can you get from a solar panel?
Directed investigation
Practical Activity 8: What is the best angle for solar panels?
Guided student-designed investigation
Worksheet 5: A career in renewable energy
Investigation planner
SCIENTISTS AT WORK
Practical Activity 9: I want to find out . . .
Student-designed open investigation.
Students pose their own inquiry question
Group challenge: A model wind turbine
GROUP PRESENTATIONS
Projects and challenges

THE STELR CORE CURRICULUM AND THE AUSTRALIAN CURRICULUM: SCIENCE

SCIENCE AS A HUMAN ENDEAVOUR

NATURE AND DEVELOPMENT OF SCIENCE

- Scientific understanding is contestable and is refined over time through a process of review by the scientific community.

USE AND INFLUENCE OF SCIENCE

Evidence-based critical thinking
- People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions

Solving contemporary issues
- Science understandings influence the development of practices in areas of human activity such as marine and terrestrial resource management
- Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations
- The values and needs of contemporary society can influence the focus of scientific research

Career opportunities
- People use understanding and skills from across the disciplines of science in their occupations
- Advances in sciences and emerging sciences and technologies can significantly affect peoples' lives, including generating new career opportunities

SCIENCE UNDERSTANDING

PHYSICAL SCIENCES

- Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems
- Forms of energy can be transferred in a variety of ways through different mediums
- Energy conservation in a system can be explained by describing energy transfers and transformations
- Earth's gravity pulls objects towards the centre of the Earth

EARTH AND SPACE SCIENCES

- Some of the Earth's resources are renewable, but others are non-renewable
- The theory of plate tectonics explains global patterns of geological activity and continental movement (*Context: Geothermal power stations)

CHEMICAL SCIENCES

- All matter is made of atoms, which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (*Context: Geothermal power stations)

SCIENCE INQUIRY SKILLS

Questioning and predicting

- Formulate questions or hypotheses that can be investigated scientifically

Planning and conducting

- Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods
- Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data

Processing and analysing data and information

- Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence

Evaluating

- Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data

Communicating

- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations

GROUP PRESENTATIONS

Communicating findings using scientific language and meaningful representations and making evidence-based arguments

THE STELR CORE CURRICULUM

MAP OF THE STELR CORE CURRICULUM AGAINST *THE AUSTRALIAN CURRICULUM: SCIENCE*

Following is an outline of how the STELR Core Curriculum fulfills much of the *Australian Curriculum: Science* at Years 9 and 10 and how it reinforces and extends a number of related aspects of the Years 7 and 8 curriculum. Also see the outline of the development of science inquiry skills (pages 25—26) and the curriculum chart on page 20.

Curriculum focus

By completing the STELR Core Curriculum, students further develop their understanding of important science concepts across the major science disciplines, within contemporary contexts that enhance a richer understanding of science. They are motivated and engaged through learning about current science research and its human application.

In particular, the students move from an experiential appreciation of the effects of energy to a more abstract understanding of the nature of energy.

Unifying ideas

The STELR Core Curriculum is centred on the following three unifying ideas:

- Sustainability
- Energy
- Evidence, models and theories

General capabilities

In the STELR Core Curriculum, students further develop skills in:

- **Literacy:** through different modes of communication, observing, investigating and discussing phenomena and issues in appropriate scientific and technical terms.
- **Numeracy:** through measurement, numerical calculations using formulas, analysis of data, graphing and interpretation of graphs and statistical procedures, in practical meaningful contexts.
- **ICT competence:** through the use of information, communication and digital technologies, for research, measurement and communication of their findings.
- **Critical and creative thinking:** through active scientific inquiry, analysis of issues and developing creative solutions, problem-solving, practical investigations and designing, building and testing a wind turbine.
- **Ethical behaviour:** through application of ethical principles and guidelines in their investigations and research, and evaluation of claims based on science.
- **Personal and social competence:** through collaborative team work, decision-making, and planning, performance and reporting of guided and student-designed practical investigations and major projects.

Cross-curriculum priority

In the STELR Core Curriculum, the cross-curriculum priority is sustainability, through the study of global warming and renewable energy technologies.

Links to other learning areas

Learning in the STELR Integrated Curriculum links strongly to English and Mathematics. It also links to Geography and Design and Technology.

Teaching, assessment and reporting

The STELR Core Curriculum is based on an inquiry-based model of teaching and learning. Through ongoing support provided to STELR teachers, the teachers are inspired and enabled to develop a balanced and engaging approach to teaching, using a context that is relevant and meaningful to students. Teachers are assisted with a range of modes of assessment and reporting.

Note: The Science Inquiry Skills prescribed for Years 9/10 are developed throughout the inquiry-based STELR program. For this reason they are listed separately. (See pages 25—26.)

THE STELR CORE CURRICULUM			THE AUSTRALIAN CURRICULUM: SCIENCE Foundation to Year 10
CORE TOPICS	**DEVELOPMENT OF SCIENCE UNDERSTANDING AND SCIENCE AS A HUMAN ENDEAVOUR**	**DEVELOPMENT OF SCIENCE INQUIRY SKILLS AND SCIENCE UNDERSTANDING**	**Science Understanding (SU), and Science as a Human Endeavour (SHE)**
GLOBAL WARMING	**The global warming DVD**		**SU (10)** • Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere — Investigating how human activity affects global systems — Explaining the causes and effects of the greenhouse effect — Investigating the effect of climate change on sea levels and biodiversity **SHE (7/8)** • Science understandings influence the development of practices in areas of human activity such as marine and terrestrial resource management • Science and technology contribute to finding solutions to a range of contemporary issues **SHE (9/10)** • Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community • People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions
ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS	**Energy transfer and energy transformation**	*Quick hands-on activities:* **•The cotton-reel car** **•The jumping cup** *Round Robin of small practical investigations:* **1 Energy transformations and transfers – Investigating a range of situations**	**SU(8)** • Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems **SU(10)** • Energy conservation in a system can be explained by describing energy transfers and transformations — Using models to describe how energy is transferred and transformed within systems

THE CONSERVATION OF ENERGY, AND ENERGY EFFICIENCY		*Guided student-designed investigation:* **2 Bouncing balls** *Different groups investigate the answers to different inquiry questions then compare their findings.*	**SU(10)** • Energy conservation in a system can be explained by describing energy transfers and transformations — Recognising that the Law of Conservation of Energy explains that total energy is maintained in energy transfers and transformations — Recognising that in energy transfer and transformation, a variety of processes can occur, so that the usable energy is reduced and the system is not 100% efficient — Using models to describe how energy is transferred and transformed within systems
ENERGY RESOURCES	**Our energy resources project**	*Group research projects – web, experts in the field, etc.* *Different groups investigate different energy resources in depth, including the social, environmental and technological issues surrounding their use. Over the class, different renewable and non-renewable energy resources should be investigated.* *This is supported by the background information provided on the STELR website, including an article on geothermal energy.* *Groups will then present their findings to the class at the end of the program.*	**SU (7)** • Some of the Earth's resources are renewable, but others are non-renewable **SU(9)** • All matter is made of atoms which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (*Context: Geothermal power stations) • The theory of plate tectonics explains global patterns of geological activity and continental movement (*Context:: Geothermal power stations) • Chemical reactions, including combustion, are important in both living and non-living systems and involve energy transfer (*Context: Fuels as energy resources) **SHE (7/8)** • Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations • Science understandings influence the development of practices in areas of human activity such as marine and terrestrial resource management **SHE (9/10)** • Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community • People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions • Advances in sciences and emerging sciences and technologies can significantly affect peoples' lives, including generating new career opportunities • The values and needs of contemporary society can influence the focus of scientific research
BATTERIES AND ELECTRICAL POWER	**Connecting batteries**	*Directed investigations:* **3 The power delivery of a battery** **4 Connecting batteries in series and parallel** *These are designed to prepare students for their investigations of wind turbines and solar panels.*	**SU(8)** • Energy appears in different forms and causes change within systems **SU(9)** • Chemical reactions are important in non-living systems and involve energy transfer (*Context: Chemical batteries)

WIND TURBINES	**Are wind farms really dangerous for birds?** ***Critical thinking activity***	*Directed investigation:* **5 How many blades should a wind turbine have?** *Guided student-designed investigation:* **6 How does blade length affect the output of a wind turbine?**	**SU(7)** • Some of the Earth's resources are renewable, but others are non-renewable **SU(8)** • Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems **SU(10)** • Energy conservation in a system can be explained by describing energy transfers and transformations — Recognising that in energy transfer and transformation, a variety of processes can occur, so that the usable energy is reduced and the system is not 100% efficient — Using models to describe how energy is transferred and transformed within systems **SHE (7/8)** • Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations • Science understandings influence the development of practices in areas of human activity such as marine and terrestrial resource management **SHE (9/10)** • Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community • People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions • The values and needs of contemporary society can influence the focus of scientific research
SOLAR CELLS		*Directed investigation:* **7 What power can you get from a solar panel?** *Different groups may investigate the answers to different inquiry questions then compare their findings.* *Guided student-designed investigation:* **8 What is the best angle for solar panels?**	
SCIENTISTS AT WORK	**20 A career in renewable energy** ***Research activity*** **GROUP PRESENTATIONS** **Projects and challenge**	*Student-designed open investigation:* **9 I want to find out...** *Students formulate their own inquiry question.*	**SU(10)** • Energy conservation in a system can be explained by describing energy transfers and transformations — Recognising that in energy transfer and transformation, a variety of processes can occur, so that the usable energy is reduced and the system is not 100% efficient **SHE (7/8)** • People use understanding and skills from across the disciplines of science in their occupations **SHE (9/10)** • Advances in sciences and emerging sciences and technologies can significantly affect peoples' lives, including generating new career opportunities • The values and needs of contemporary society can influence the focus of scientific research

THE STELR CORE CURRICULUM

THE DEVELOPMENT OF SCIENCE INQUIRY SKILLS IN THE STELR CORE CURRICULUM

Table 1. Directed practical activities

<table>
<tr><th rowspan="2">Science Inquiry Skill</th><th colspan="5">Code number of directed practical activity</th></tr>
<tr><th>1</th><th>3</th><th>4</th><th>5</th><th>7</th></tr>
<tr><td rowspan="2">Questioning and predicting
Formulate questions or hypotheses that can be investigated scientifically</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="5">In these directed laboratory investigations, students are provided with inquiry questions but are asked to predict outcomes.</td></tr>
<tr><td rowspan="2">Planning and conducting
Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="5">In these directed laboratory investigations, students do not plan or select the laboratory investigation methods. It is expected that teachers will raise ethical issues in the context of class discussions.</td></tr>
<tr><td rowspan="2">Planning and conducting
Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="5">In these directed laboratory investigations, students do not select the equipment but are trained to use it.</td></tr>
<tr><td>Processing and analysing data and information
Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies</td><td></td><td></td><td></td><td>✓</td><td>✓</td></tr>
<tr><td>Processing and analysing data and information
Use knowledge of scientific concepts to draw conclusions that are consistent with evidence</td><td></td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td rowspan="2">Evaluating
Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data</td><td></td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="5">In these directed laboratory investigations, this evaluation process is mostly carried out within the context of a class discussion.</td></tr>
<tr><td>Evaluating
Critically analyse the validity of information in secondary sources and evaluate the approaches used to solve problems</td><td colspan="5">This skill is applied in other activities instead of in these practical investigations.</td></tr>
<tr><td>Communicating
Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
</table>

Note: The teacher is expected to:

- **Decide when to use ICT to record and process results. Students should be exposed to as wide a range of different strategies as possible.**
- **Draw the class together at the end of each investigation to discuss such aspects of the investigation as their conclusions, explaining observations and patterns and relationships in numerical data and relating them to scientific concepts, sources of error and improvements that would reduce error, ways of reducing risk and critiquing reports, noting flaws in design and inconsistencies of data.**

Table 2. Student-designed practical activities

Science Inquiry Skill	Code number of practical activity			
	2 Guided	6 Guided	8 Guided	9 Open
Questioning and predicting Formulate questions or hypotheses that can be investigated scientifically	✓	✓	✓	✓
	In the guided student-designed laboratory investigations, students are provided with inquiry questions but are asked to predict outcomes.			
Planning and conducting Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods	✓	✓	✓	✓
	In these laboratory investigations, it is expected that teachers will raise ethical issues in the context of class discussions.			
Planning and conducting Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data	✓	✓	✓	✓
	In the guided student-designed laboratory investigations, students generally do not select the equipment.			
Processing and analysing data and information Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies	✓	✓	✓	✓
Processing and analysing data and information Use knowledge of scientific concepts to draw conclusions that are consistent with evidence	✓	✓	✓	✓
Evaluating Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data	✓	✓	✓	✓
Evaluating Critically analyse the validity of information in secondary sources and evaluate the approaches used to solve problems	As part of their class discussions, students should be asked to compare and evaluate their methodologies with those of other groups in the class, and also to do so in their reports where appropriate.			
Communicating Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations	✓	✓	✓	✓

THE STELR CORE CURRICULUM

HOW TO RUN THE STELR CORE PROGRAM

As stated earlier, the STELR Core Curriculum was written for Year 9, but can be used at Year 10. It is designed to meet many of the requirements of the *Australian Curriculum: Science*, published December 2010.

The advantage of this is that you can fulfill much of the *Australian Curriculum: Science* within a meaningful context.

To cater for the wide range of schools implementing the program, however, a variety of activities that can be used to introduce each new key topic has been provided.

In addition, to cater for schools that decide to use the STELR program to introduce students to electrical circuits, current and voltage, some optional introductory practical activities are provided in this teacher resource (pages 172—202). These are recommended in cases where students need a refresher course, since it is assumed that students have this background.

As the teacher, you must decide which of our three STELR Curricula you will deliver to your students, taking into account their background, your school's timetabling arrangements and other restrictions.

We would expect that the STELR Core Curriculum will take approximately 6—10 weeks.

NO TEACHER IS EXPECTED TO RUN EVERYTHING WE OFFER!

BUT WE DO ENCOURAGE YOU TO SELECT AS MUCH AS YOU CAN FROM OUR 'SMORGASBORD', SO THAT STUDENTS ARE GIVEN A RICH EXPERIENCE AND CAN GAIN THE MOST FROM THE PROGRAM.

WE ALSO STRONGLY ADVISE YOU TO RUN THE PROGRAM IN THE ONE TERM, AND AVOID SPLITTING IT ACROSS DIFFERENT TERMS, WHICH BREAKS THE CONTINUITY OF THE PROGRAM AND REDUCES ITS IMPACT.

The key ideas in the STELR Core Curriculum

The STELR Core Curriculum focuses on the following key ideas:

- Global warming and climate change
- Energy transformations and energy transfers
- The conservation of energy, useful energy and 'wasted' energy
- Energy efficiency
- Energy resources
- How scientists work – designing experiments
- Electrical circuits and electrical power
- Connecting energy sources in series and parallel
- Wind turbines and wind farms
- Solar cells and solar panels

The study of renewable energy resources includes an investigation of various careers in these industries and a critical examination of some of the issues related to these industries.

The practical activities

Overview

To a large extent the inquiry-based learning approach consists of first-hand practical investigations of a range of inquiry questions. These are in the form of directed investigations, guided student-designed investigations and an open student-designed investigation. Most are small group investigations; some are class experiments.

The optional challenge at the end of the program involves designing and building a model turbine and demonstrating how much electrical power it can deliver. This provides an opportunity for students to use their own initiative and creativity, apply their learning and develop strong skills in problem-solving, as well as in technology and design.

The directed practical activities

Purpose

Overall, the set of directed practical activities has been designed to:

- Model the way scientists work by providing experience in conducting hands-on investigations that are designed to explore one or more inquiry questions. This includes risk management, prediction and analysis of results, recording and displaying results effectively, identifying sources of error and evaluating the investigation.
- Reflect the principles of inquiry-based learning, by providing first-hand experiences through which new concepts are introduced and a greater depth of understanding of important concepts can be developed.
- Introduce or reinforce practical laboratory skills, including the use of the STELR equipment, so that students can develop competence and confidence.
- Develop good time-management, organisational and communication skills.
- Provide a strong background to enable students to design and perform their own relevant investigations.
- Foster the ability to work in collaboration and co-operation with others, by working in small groups and with the whole class.
- Foster important values, including open-mindedness and ethical practice.

Advice on running the directed practical activities

Teachers are advised to:

1 Vary the way in which the students record and process their experimental data. Students should be given the opportunity to use spreadsheets and graphing software for some of the investigations.

2 Trial each investigation before class, so that they know exactly what to expect and can predict problems that might arise in class. This will help streamline the process, reduce risk and avoid embarrassment.

3 Always ensure that the students are clear about what to do and how to set up and use the equipment. Also ensure that they perform the risk assessment first. Then monitor what they do throughout the investigation very closely to ensure that they comply with all expectations.

4 Always ensure that enough time is left at the end of each investigation (approximately 15 minutes) for a productive class discussion, in which student findings are compared, analysed, and evaluated and explanations are proposed, and further inquiry questions or improvements to the experimental design are suggested .

The student-designed activities

Purpose

Overall, the set of student-designed practical investigations has been designed to:

- Model the way scientists work by providing experience in designing and conducting hands-on investigations to explore the answer to one or more inquiry questions. This includes developing a hypothesis, identifying variables, designing fair tests, taking accurate measurements, identifying and managing risks, predicting and analysing results, recording and displaying results effectively, identifying sources of error and evaluating the investigation.
- Reflect the principles of inquiry-based learning, by providing first-hand experiences through which new concepts are introduced and a greater depth of understanding of important concepts is developed.
- Further train students in practical laboratory skills so that they can develop greater competence and confidence.
- Develop good time-management, organisational and communication skills.
- Foster the ability to work in collaboration and co-operation with others, through working in small groups and with the whole class.
- Foster important values, including open-mindedness and ethical practice.

Advice on running the student-designed activities

Teachers are advised to:

1 Encourage the students to make full use of appropriate ICT to record and process their experimental data. This includes the use of spreadsheets and graphing software.

2 Avoid advising the student on how to design and perform their own investigations, as they need to be given the freedom to be inventive and to use their own creativity and initiative, and to make their own mistakes. They will learn from their mistakes as well as from their successes.

Introducing a new key topic

Overview

For each new topic, a selection of some of the big ideas behind the topic is provided in the form of questions on the cover sheet for the topic in the student booklet. These are intended to stimulate discussion and to encourage students to pose some of their own big questions.

A range of ideas for introductory activities is provided in this resource, as part of the provisions for each key topic. Many of these activities are based on the teaching strategy **'Interview about instances'**. In this technique, some stimulus material, in such forms as a series of images, a DVD or demonstrations, is presented to the students and questions about the stimulus material are posed. Further ideas may be found in the teacher booklet for the STELR Integrated Curriculum.

Background information on most key topics is also provided in this resource, to assist the teacher. More information is available on the STELR website.

Note: An optional online pre-test for the STELR program is available in the student portal on the STELR website. Teachers can access the results of their students via the teacher portal.

Purpose

The introductory activities are designed to:

- Introduce each new area of the STELR Core Curriculum in a way that will involve all students and stimulate their interest.
- Enable the teacher to gauge what the students already know and understand of the concepts involved and any alternative conceptions they have, to assist in the planning of future lessons.
- Clarify or reinforce concepts or to understand new concepts.
- Promote effective communication and student confidence.

Advice on running the introductory activities

For some key topics, more than one idea for an introductory activity is provided. Teachers are advised to:

1 Select the activity that will best suit their students and time restrictions.

2 Use a variety of styles of introductory activities over the program, so that students remain engaged.

3 The role of the teacher should be one of the questioner rather than the transmitter of answers. The teacher may find there is considerable variation in student thinking about the issues or concepts presented, or that alternative conceptions are presented.

Incursions and excursions to places such as wind farms or hydroelectric or coal-fired power stations can also play a significant role in stimulating student interest and are highly recommended, as they can help make the program more exciting and more meaningful for the students. (See the feedback from a school that tried this on pages 15—16.)

In addition, solar panels and/or a wind turbine installed at the school can provide some excellent resource material and capture student interest. (See the feedback from a school that tried this on pages 14—15.)

The student activity sheets (worksheets, information sheets, etc.)

Overview

The student activity sheets in the student booklet offer students information, experiences and tasks to enable them to develop key science understandings and thinking skills and to give them opportunities to explore issues that are relevant and meaningful to them, and to be aware of possible future careers.

Where appropriate, advice and suggested answers to questions on these sheets are provided later in this resource.

NB It is assumed that the teacher will support the activity sheets with further material, including web links and some of the optional introductory activities.

Purpose

Overall, the set of student activity sheets is designed to:

- Enable the students to build up or extend and then apply their science skills, knowledge and understanding.
- Prepare students for a particular practical activity.
- Enable the students to develop insights into science as a human endeavour, and to challenge their thinking about important contemporary issues and future pathways and careers.
- Encourage students to undertake further research into a fascinating aspect of a topic.
- Outline the research project they will undertake.

Advice on using the student activity sheets

Teachers are advised to give students the opportunity to discuss and compare their responses to any set questions in small groups or as a class. This will help build up their communication skills and help clarify concepts. It also will provide the teacher with an insight into the student's understandings and any alternative conceptions they may hold. This will also be a chance to encourage the students to raise their own questions.

The group research projects

Overview

Students are required to work in groups to develop an in-depth knowledge of one particular energy resource through internet and other research. As the class experts in that energy resource, they then develop a presentation on that energy resource for the rest of the class.

This project is a based on the **jigsaw** teaching approach. In this approach different groups in the class become the class expert in some particular aspect of the topic of energy resources and then share their learning with other class members.

Purpose

The group research projects on energy resources have been designed to:

- Develop sound research and critical thinking skills.
- Enable students to use their own creativity and initiative, and their own natural talents and interests, as well as extending their understanding and skills.
- Provide an insight into the complexity of issues surrounding the supply of electricity to consumers.
- Develop good time-management, organisational and communication skills.
- Foster the ability to work in collaboration and co-operation with others.
- Foster important values, including open-mindedness.

Advice on managing the group research projects

Teachers are advised to:

1 Where possible, set up industry visits and help students establish contact with experts in the field, so that students have a wider variety of sources rather than just the internet. This can make the experience all the more relevant and meaningful.

2 Encourage the students to use a range of creative ways to present their findings.

3 Film the presentations and publicise the students' work in the school newsletter, so that the students can receive suitable recognition and accolades for their achievements.

The group challenge

Overview

Students have the opportunity to apply what they have discovered through their investigation of the STELR wind turbine by designing, building and testing their own model wind turbine.

Purpose

The group challenge has been designed to:

- Provide an opportunity for students to use their own creativity and initiative, and their own natural talents and interests, while extending their understanding and skills.
- Provide an opportunity for fun and celebration of student achievements — the culmination of all they have done in the program.

Advice

Teachers are advised to:

1. Take into account any restrictions within the overall school program in deciding whether this or an alternative challenge will be offered to the students.
2. Set up awards and publicity in the school newsletter and so on, so that the students can receive suitable recognition and accolades for their achievements.

The use of ICT in the STELR Core Curriculum

Overview

Students have the opportunity to use a range of technologies to conduct web research, to record process experimental results using spreadsheets and graphing programs and other technology such as video recorders and digital cameras, and to present their findings using a range of technologies, including PowerPoint presentations.

Advice

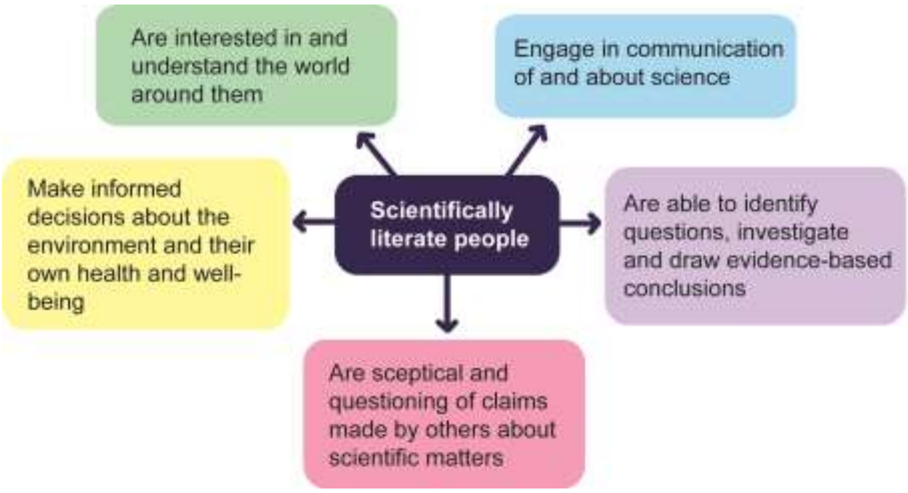
Teachers are advised to provide as many opportunities as possible for students to use the range of ICT available within the school.

This should include extensive use of the STELR website.

Teaching scientific literacy

Overview

The STELR Project prepares students to engage with science ideas in their work and their lives generally, as citizens. Leonie Rennie (2006) described scientifically literate citizens to have the following attributes:



The scientific literacy focus is strongly represented the in the STELR Core Curriculum as follows:

• Thinking and working scientifically are major aspects, with a particular emphasis on evidence-based thinking.

• Engaging with the science-technology-society interface is emphasised.

• Social, ethical and economic issues are incorporated into the learning.

• The nature of science and its contemporary setting is strongly represented.

• Students are supported to develop a critical, objective, committed stance.

Advice

Teachers are strongly advised to use every opportunity within the program to:

1 Foster the students' ability to think and work scientifically, through class discussions, activities and practical investigations.

2 Encourage evidence-based critical thinking about the issues of global warming and climate change and society's and their own use of energy resources, including an examination of statements and information disseminated in the public arena.

3 Foster an appreciation of the way science and technology can be used to identify and address global issues.

Assessment

Overview

It is expected that teachers will choose modes of internal assessment that suit the school and their students. Some assessment advice and assessment rubric proformas are included in this resource should teachers wish to use them for their assessment of students. These also are provided electronically in Word format so that teachers can adapt them to their needs.

In addition, multiple-choice item banks are available on the STELR website, which teachers will be able to access through the teacher portal. Teachers will be able to download these tests and select any questions they wish to use for pre-tests or post-tests. A pre-test and post-tests can be accessed by students through the student portal and the results reported to teachers through the teacher portal.

THE STELR CORE CURRICULUM

SAMPLE TEACHING TIMETABLE FOR THE CORE CURRICULUM

OVERVIEW

The sample teaching timetable provided on the next page:

- **Is based on sessions that are 45-60 minutes long.**
- **Includes a column for homework, so that students can receive a copy of the timetable as well.**
- **Assumes that formal assessment will be centered on practical work and project work. Tests are not included in this timetable. (They can be added by the teacher to the electronic version that is provided in Word format. See below.)**
- **Includes an optional set of three sessions at the start, which should be used if students do not have a strong, recent background in electrical circuits and/or the measurement of current and voltage. These optional sessions are highlighted to distinguish them from the core program.**

Note: The student versions and teacher guides to the three optional practical activities listed in these three sessions are on pages 172—202 of this book.

- **Contains optional sessions at the end, for schools that wish to offer the optional challenge. These sessions also are highlighted to distinguish them from the core program. Note that it may take longer than the number of sessions suggested, depending on to what extent the students will use class time to complete the challenge.**

Note: The electronic version of the sample teaching timetable provided in Word format can be downloaded from the teacher portal at: www.stelr.org.au. The teacher can then modify the timetable to suit the school's timetabling arrangements and the activities that the teacher decides to run, and also can insert appropriate dates. The timetable can then be submitted as part of any set of curriculum planning documents for that year level required by the school.

How to develop a timetable that is tailored to the school

1 Download the electronic copy of the sample timetable. Since the table in Word format, you can extend the length of rows and delete rows. You also can change column headings. You may even wish to delete one of the first two columns.

2 Delete any activities that you do not plan to run, and insert any other activities you do plan to run that are not listed, such as an excursion to a wind farm, or one or more tests. This means you may need to delete rows and/or insert new rows.

3 Insert the weeks or dates of the sessions in the first column of the timetable, to fit in with the school's timetabling arrangements. Highlight any 'doubles' in some way.

4 Adapt the number of activities per session to suit your students and the actual length of the sessions at the school, including allowing for sessions that are 'doubles'.

SAMPLE TIMETABLE FOR THE STELR CORE CURRICULUM

Note : Optional activities are shaded mauve or green.

WEEK	SESSION	TOPIC(S)	CLASS ACTIVITIES	STUDENT BOOK PAGES	HOMEWORK
	1	**Series and parallel circuits**	Practical Activity I: Series and parallel circuits		Complete the report on Practical Activity I
	2	**Measuring current**	Practical Activity II: Measuring current		Complete the report on Practical Activity II
	3	**Measuring voltage**	Practical Activity III: Measuring voltage		Complete the report on Practical Activity III
	4	**GLOBAL WARMING**	Introductory activity on global warming, including the global warming DVD, and discussion. Complete Worksheet 1: The global warming DVD	1—3	
	5	**ENERGY TRANSFORMATIONS AND TRANSFERS**	Introductory activity and discussion on energy transformations and energy transfers. Quick Activity 1: The cotton-reel car Quick Activity 2: The jumping cup	47	Make a flic-flac
	6	**ENERGY TRANSFORMATIONS AND TRANSFERS**	Practical Activity 1: Energy transformations and transfers – investigating a range of solutions	8—20	
	7	**CONSERVATION OF ENERGY & ENERGY EFFICIENCY**	Introductory activity and discussion on the conservation of energy and energy efficiency, and designing experiments	21 77, 81—82	
	8	**CONSERVATION OF ENERGY & ENERGY EFFICIENCY**	Practical Activity 2: Bouncing balls	22—27	Complete report of Practical Activity 2
	9	**ENERGY RESOURCES**	Introductory activity on renewable and non-renewable energy resources Worksheet 2: Our energy resources project - overview Planning group research projects	28—30	Research for group project
	10	**BATTERIES AND ELECTRICAL POWER**	Introductory activity on batteries and electrical power Practical Activity 3: The power delivery of a battery	31—35	Complete report of Practical Activity 3
	11	**ENERGY RESOURCES** **BATTERIES AND ELECTRICAL POWER**	Further planning and work on group projects Worksheet 3: Connecting batteries	28—30 36—38	Research for group project

	12	**BATTERIES AND ELECTRICAL POWER**	Practical Activity 4: Connecting batteries in series and in parallel	39—45	Complete report of Practical Activity 4
	13	**WIND TURBINES**	Introductory activity and discussion on wind turbines Further discussion on experimental design	46 74—75	
	14	**WIND TURBINES**	Practical Activity 5: How many blades should a wind turbine have?	47—56	Complete report of Practical Activity 4
	15	**WIND TURBINES**	Practical Activity 6: How does blade length affect the output of a wind turbine?	57, 81—82	Complete report of Practical Activity 5
	16	**WIND TURBINES**	Introduction to critical thinking Worksheet 4: Are wind farms dangerous for birds?	58—60	Further work on Worksheet 4
	17	**WIND TURBINES** **ENERGY RESOURCES**	Further discussion about the critical thinking activity Further work on group projects	58—60 28—30	Work on group project
	18	**SOLAR CELLS** **ENERGY RESOURCES**	Introductory activity and discussion on solar cells Further work on group projects	61 28—30	Work on group project
	19	**SOLAR CELLS**	Practical Activity 7: What power can you get from a solar panel?	62—74	Complete report of Practical Activity 7
	20	**SOLAR CELLS**	Practical Activity 8: What is the best angle for a solar panel?	75—76, 81—82	Complete report of Practical Activity 8
	21	**SCIENTISTS AT WORK**	Practical Activity 9: I want to find out . . . – planning and starting the investigation	78, 81—82	
	22	**SCIENTISTS AT WORK**	Practical Investigation 9: I want to find out . . . – completing the investigation	78, 81—82	Complete report of Practical Activity 9
	23	**SCIENTISTS AT WORK**	Discussion on careers in renewable energy Worksheet 5; A career in renewable energy	79	Complete Worksheet 5. Work on group project
	24	**ENERGY RESOURCES**	Final group work on energy resource project and presentation	28-30	Finalise group presentation
	25	**ENERGY RESOURCES**	**GROUP PRESENTATIONS***		
	26	**SCIENTISTS AT WORK**	Group Challenge	80	Work on group challenge

	27	**SCIENTISTS AT WORK**	Group Challenge	80	Work on group challenge
	28	**SCIENTISTS AT WORK**	**GROUP CHALLENGE PRESENTATIONS**		

***If the Group Challenge is undertaken, then the teacher may wish to combine the two sets of presentations.**

ALTERNATIVE

STELR

CURRICULA

The following charts outline

THE STELR INTEGRATED CURRICULUM

and

THE STELR CHEMISTRY CURRICULUM

and how they match

THE *AUSTRALIAN CURRICULUM: SCIENCE*

THE STELR INTEGRATED PROGRAM
INQUIRY-BASED LEARNING

PRIOR LEARNING REQUIRED
Electrical circuits, current and voltage

STUDENT ACTIVITY SHEETS •information •questions •activities •research questions	Supported by	PROGRAM	Discovery through	PRACTICAL INVESTIGATIONS	EXTENSIONS
1 Global warming and climate change 2 The global warming DVD 3 The carbon cycle 4 What's happening in our oceans?		**GLOBAL WARMING**		1 What's happening in our oceans? Directed investigation	•What is happening in the Maldives? (literacy exercise) •Sea-level rising (modelling)
5 Energy transformations and energy transfers 6 How do hydroelectric power stations work?		**ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS**		2 What energy transformations and energy transfers are happening here? Round Robin of small practical investigations	
7 What kinds of fuels are there? 8 Families of chemical reactions		**FUELS**		3 Producing bioethanol Directed investigation	•Distilling an ethanol mixture (practical investigation) •Producing biodiesel (teacher demonstration) •Which fuel produces the most energy? (teacher demonstration or student investigation)
9 The conservation of energy: useful energy and 'wasted' energy 10 How do scientists use graphs? 11 Coal-fired power stations - the inside story		**THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY**		4 Bouncing balls Guided student-designed investigtion Different groups investigate the answers to different inquiry questions then compare their findings	
12 Our energy resources project		**ENERGY RESOURCES**		Group research projects	
13 How do scientists work? 14 Investigation planner		**HOW SCIENTISTS WORK**		5 What conditions make a battery deliver the biggest voltage? Guided student-designed investigation	•Lemon power! (guided student-designed investigation)
15 Electrical power and electrical energy		**ELECTRICAL ENERGY AND ELECTRICAL POWER**		6 What energy and power is delivered by a STELR battery? Directed investigation	
16 Connecting batteries		**CONNECTING ENERGY SOURCES**		7 Connecting batteries in series and in parallel Directed investigation	
17 Wind farms 18 Are wind farms really dangerous for birds? Critical thinking activity		**WIND TURBINES**		8 How many blades should a wind turbine have? Directed investigation 9 What is the best blade length for a wind turbine? Guided student-designed investigation	
19 Solar cells and solar panels		**SOLAR CELLS**		10 What power can you get from a solar panel? Directed investigation. Different groups may investigate the answers to different inquiry questions then compare their findings 11 What is the best angle for solar panels? Guided student-designed investigation	•Measuring resistance (directed investigation) •Power and resistance (directed investigation) •What is the percentage energy efficiency of a solar cell? (directed investigation)
20 A career in renewable energy **GROUP PRESENTATIONS** Projects		**SCIENTISTS AT WORK**		12 I want to find out... •How do clouds affect the power delivered by a solar panel? ... Student-designed open investigation. Students select one. They can formulate their own inquiry questions. The above question is an example of an inquiry question they might investigate.	**GROUP CHALLENGE** A model wind turbine

THE STELR INTEGRATED CURRICULUM AND THE AUSTRALIAN CURRICULUM: SCIENCE

SCIENCE AS A HUMAN ENDEAVOUR

NATURE AND DEVELOPMENT OF SCIENCE

- Scientific understanding is contestable and is refined over time through a process of review by the scientific community.

USE AND INFLUENCE OF SCIENCE

Evidence-based critical thinking
- People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions

Solving contemporary issues
- Science understandings influence the development of practices in areas of human activity such as marine and terrestrial resource management
- Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations
- The values and needs of contemporary society can influence the focus of scientific research

Career opportunities
- People use understanding and skills from across the disciplines of science in their occupations
- Advances in sciences and emerging sciences and technologies can significantly affect peoples' lives, including generating new career opportunities

SCIENCE UNDERSTANDING

CHEMICAL SCIENCES

- Chemical change involves substances reacting to form new substances
- All matter is made of atoms, which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (*Context: Geothermal power stations)
- Chemical reactions involve rearranging atoms to form new substances
- Chemical reactions, including combustion and the reactions of acids, are important in both living and non-living systems, and involve energy transfer
- Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere.

PHYSICAL SCIENCES

- Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems
- Forms of energy can be transferred in a variety of ways through different mediums
- Energy conservation in a system can be explained by describing energy transfers and transformations
- Earth's gravity pulls objects towards the centre of the Earth

EARTH AND SPACE SCIENCES

- Some of the Earth's resources are renewable, but others are non-renewable
- The theory of plate tectonics explains global patterns of geological activity and continental movement (*Context: Geothermal power stations)

BIOLOGICAL SCIENCES

- Matter and energy flow through ecosystems

SCIENCE INQUIRY SKILLS

Questioning and predicting

- Formulate questions or hypotheses that can be investigated scientifically

Planning and conducting

- Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods
- Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data

Processing and analysing data and information

- Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence

Evaluating

- Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data

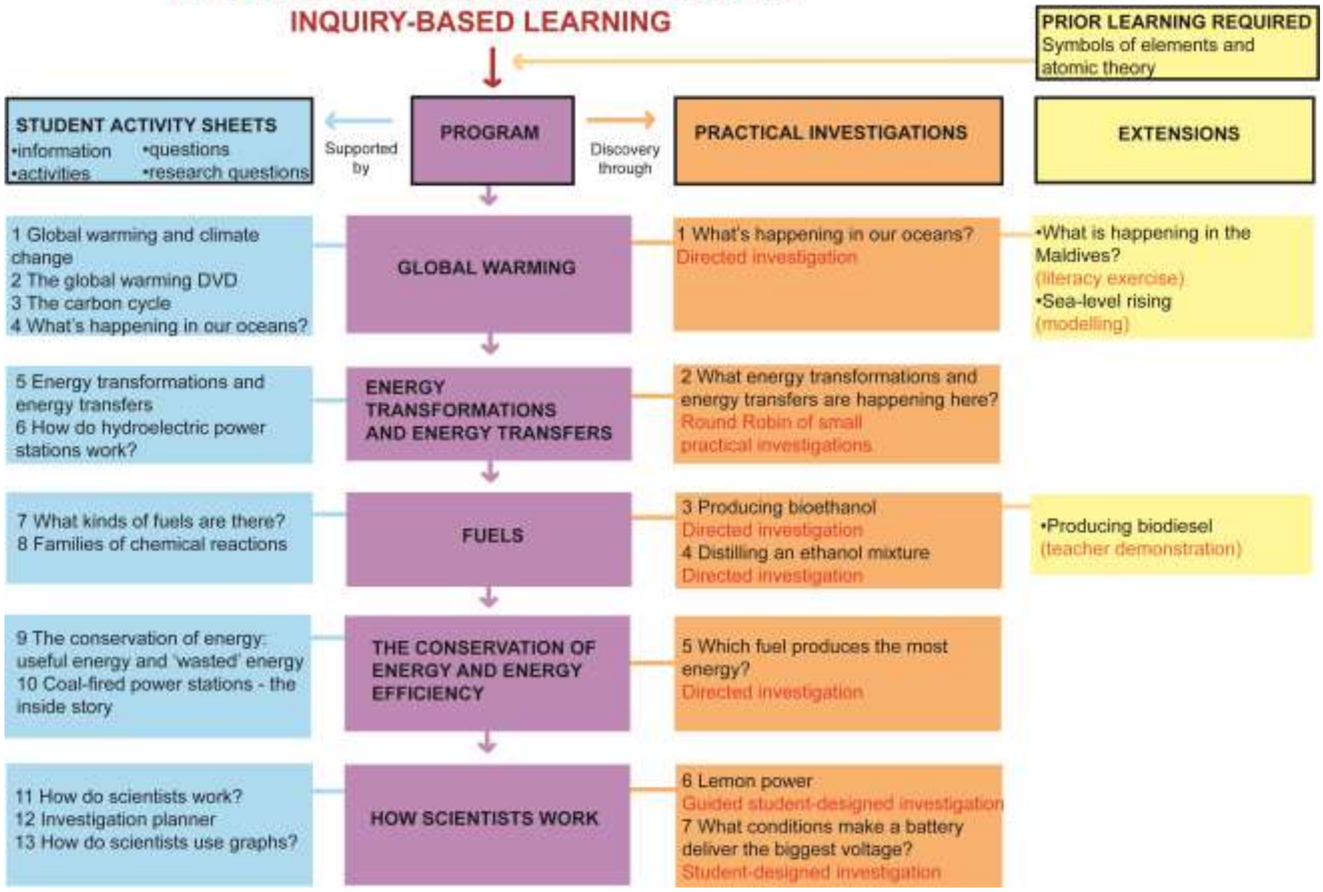
Communicating

- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations

GROUP PRESENTATIONS

Communicating findings using scientific language and meaningful representations and making evidence-based arguments

THE STELR CHEMICAL SCIENCES PROGRAM
INQUIRY-BASED LEARNING



THE STELR CHEMICAL SCIENCES CURRICULUM AND THE AUSTRALIAN CURRICULUM: SCIENCE

SCIENCE AS A HUMAN ENDEAVOUR

NATURE AND DEVELOPMENT OF SCIENCE

- Scientific understanding is contestable and is refined over time through a process of review by the scientific community.

USE AND INFLUENCE OF SCIENCE

Evidence-based critical thinking
- People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions

Solving contemporary issues
- Science understandings influence the development of practices in areas of human activity such as marine and terrestrial resource management
- Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations
- The values and needs of contemporary society can influence the focus of scientific research

Career opportunities
- People use understanding and skills from across the disciplines of science in their occupations
- Advances in sciences and emerging sciences and technologies can significantly affect peoples' lives, including generating new career opportunities

SCIENCE UNDERSTANDING

CHEMICAL SCIENCES

- Chemical change involves substances reacting to form new substances
- All matter is made of atoms, which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (*Context: Geothermal power stations)
- Chemical reactions involve rearranging atoms to form new substances
- Chemical reactions, including combustion and the reactions of acids, are important in both living and non-living systems, and involve energy transfer
- Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere.

PHYSICAL SCIENCES

- Energy appears in different forms including heat energy and potential energy, and causes change within systems
- Forms of energy can be transferred in a variety of ways through different mediums
- Energy conservation in a system can be explained by describing energy transfers and transformations

EARTH AND SPACE SCIENCES

- Some of the Earth's resources are renewable, but others are non-renewable
- The theory of plate tectonics explains global patterns of geological activity and continental movement (*Context: Geothermal power stations)

BIOLOGICAL SCIENCES

- Matter and energy flow through ecosystems

SCIENCE INQUIRY SKILLS

Questioning and predicting

- Formulate questions or hypotheses that can be investigated scientifically

Planning and conducting

- Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods
- Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data

Processing and analysing data and information

- Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence

Evaluating

- Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data

Communicating

- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations

GROUP PRESENTATIONS

Communicating findings using scientific language and meaningful representations and making evidence-based arguments

TEACHER SUPPORT DOCUMENTS FOR THE STELR CORE CURRICULUM STUDENT BOOKLET

INCLUDING:

BACKGROUND INFORMATION FOR THE TEACHER

HOW TO RUN THE STUDENT PRACTICAL ACTIVITIES

IDEAS FOR INTRODUCTORY ACTIVITIES FOR NEW TOPICS

SUGGESTED ANSWERS TO QUESTIONS

TOPIC: GLOBAL WARMING

BACKGROUND INFORMATION FOR THE TEACHER

Global warming is the term we use for the gradual increase in the average temperature at the Earth's surface that has occurred over the past century or so. Climate change is one of the consequences of global warming and will be discussed later.

Evidence for the increase in temperature

The following graph (Figure 1) shows there has been a gradual increase in the average annual temperature across Australia in the past century. The red graph shows the average maximum temperature for each year and the blue graph shows the average minimum temperature each year.

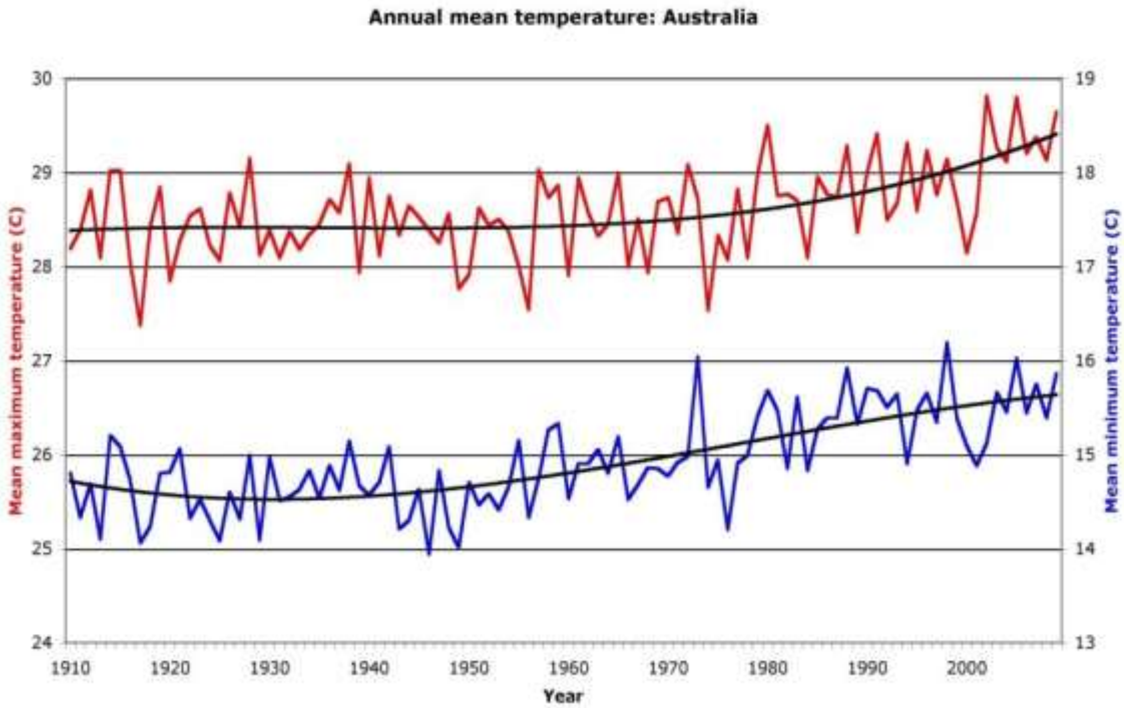


Figure 1.

*Notice the curve that traces through the middle of the red graph. This is called a **trend line** – a line that smoothes out the fluctuations to show the trend in values. The graph points for this trend line are calculated using statistical procedures. Similarly a trend line is drawn for the blue graph. It is clear that while the temperatures fluctuate (go up and down), there is an increase in the mean annual temperature.*

This increase in temperature everywhere across Australia also is shown in Figure 2 on page 45. The map, prepared by the Australian Bureau of Meteorology, shows the average *change* in temperature per 10 years over the past century for each region.

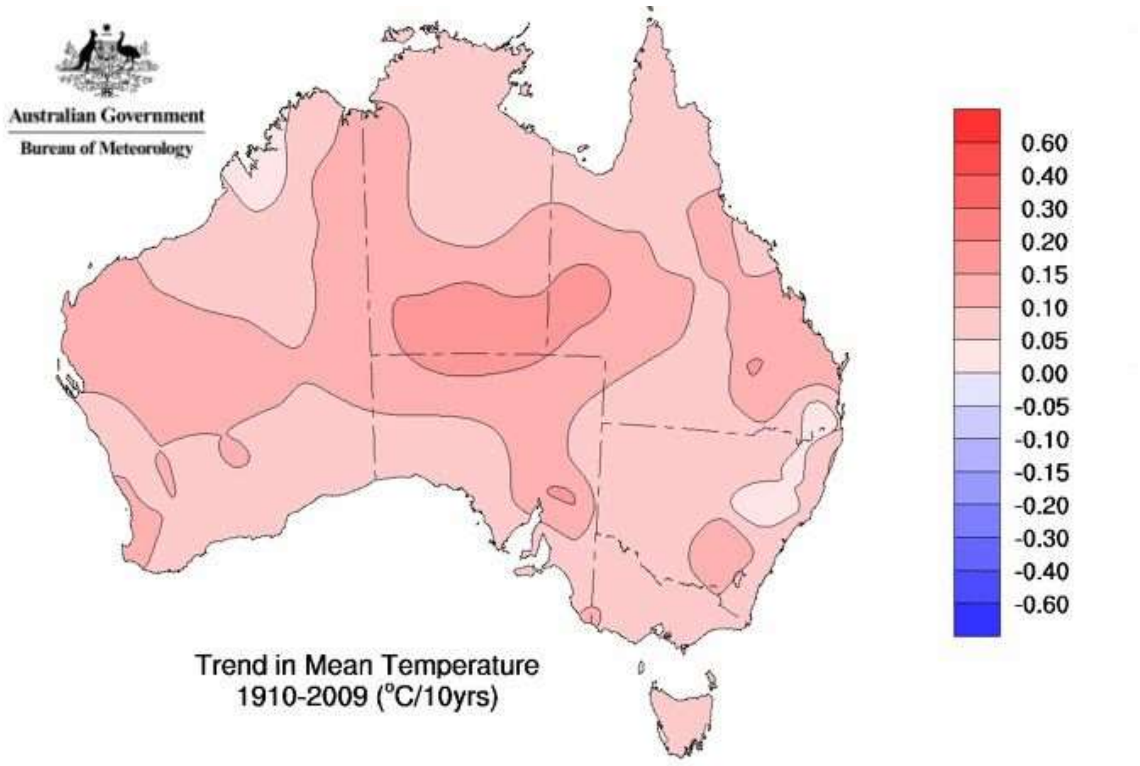


Figure 2.

Like Figure 1 for Australia, the next graph (Figure 3) shows that there has been a gradual net rise in average temperatures across all countries over the past 130 years.

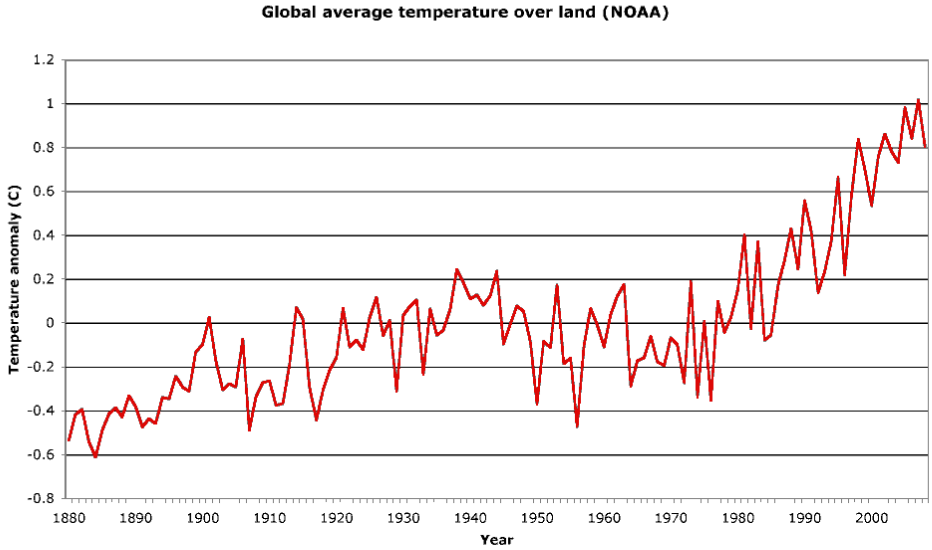


Figure 3.

Note: The vertical scale shows the 'temperature anomaly', not the actual average temperature. ***Temperature anomaly*** *is a measure of how much the temperature is higher or lower than a long-term average. For example, a value of +1 means the average temperature was 1 ºC higher than the average temperature observed over a long time. A value of -0.6 means the average temperature was 0.6 ºC lower than the average temperature observed over a long time. This kind of graph is used by climate scientists to analyse trends in global temperatures.*

The graph in Figure 3 was constructed from temperature data collected from a network of 6000 temperature stations across the globe. These are shown in the following map (Figure 4). The colours show how long the stations have been keeping records. Approximately 1650 of these stations have kept records for longer than 100 years.

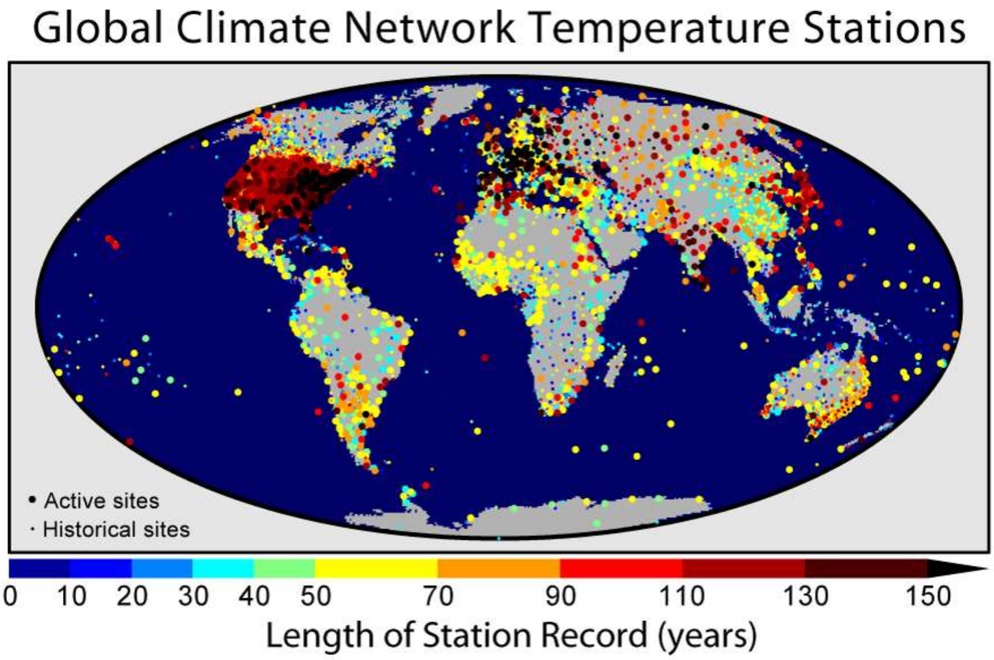


Figure 4. **Source:** http://en.wikipedia.org/wiki/Instrumental_temperature_record **Accessed:** 22 June 2010

The next graph (Figure 5) shows the same trend over the months September-February, with satellite data shown in red.

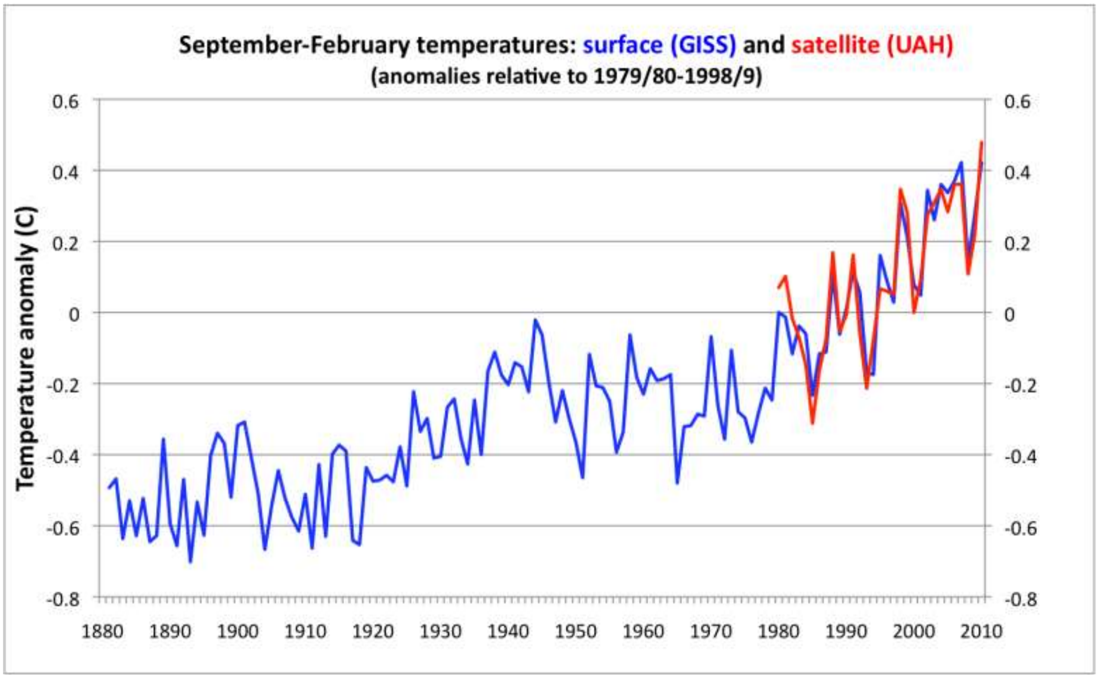


Figure 5.

We can only conclude that there is overwhelming, reliable evidence that there has been a gradual increase in the temperature at the Earth's surface over the past 130 years.

Acknowledgement: The above graphs were provided by Professor Neville Nicholls, of Monash University. Professor Nicholls is a Lead Author for the Intergovernmental Panel on Climate Change (IPCC), which was established in 1988.

Misleading information

It should be noted that some climate change deniers and climate change sceptics take small parts of these graphs – parts where the graph line goes down – and use them to 'prove' that global temperatures are not rising. This is misusing the data. Long term-trends need to be examined if we are to draw valid evidence-based conclusions about what is happening to temperatures on Earth.

What is the cause of this gradual temperature rise?

Scientific modelling by atmospheric scientists and meteorologists, using data they have collected from ice core studies and measurements of atmospheric temperatures and gas concentrations in the atmosphere, indicates that the increase in concentration of the greenhouse gases in the atmosphere above their natural levels is the prime cause of global warming**.**

Greenhouse gases include carbon dioxide and water vapour. A number of other gases in the atmosphere also act as greenhouse gases, although the percentage of them in the lower atmosphere is much less than that of carbon dioxide and water. These gases include methane and nitrous oxide. (See Table 1 below.)

Greenhouse gases

Greenhouse gases all have one thing in common: their molecules contain 3 or more atoms. This is shown in the Table 1.

Table 1. Some of the main gases present in the lower atmosphere

Gas	Approximate percentage in the air (if water vapour is removed)**	Chemical formula	Total number of atoms in each molecule	Is this a greenhouse gas?
Oxygen	20.9	O_2	2	No
Nitrogen	78.1	N_2	2	No
Argon	0.9	Ar	1*	No
Carbon dioxide	0.04	CO_2	3	**Yes**
Methane	0.0002	CH_4	5	**Yes**
Nitrous oxide	0.00003	N_2O	3	**Yes**

**** Argon is classified as a noble gas. Noble gases exist in Nature as individual atoms, not molecules.***

***** The percentage of water vapour in the air varies from place to place and at different times, but on average is about 1—4%. Its chemical formula is H_2O. It also is a greenhouse gas.***

The larger number of atoms in the molecules of greenhouse gases enables them to absorb infrared radiation radiated by the Earth's surface, and then emit some back to the surface. This warms the Earth even more.

Web research:

The graph of variations in atmospheric carbon dioxide concentration and temperature during the past 400 000 years in the CSIRO article at: http://www.cmar.csiro.au/e-print/open/holper_2001b.html is considered to provide reasonable evidence of a link between the temperature of the atmosphere and carbon dioxide levels in the air.

What is infrared radiation and why is it important?

The light energy that is radiated out in Space by the Sun is not just the light you can see. In fact, out in Space, unless you are looking directly at a star, you can only see what we call visible light when it reflects off objects, such as the Moon or the International Space Station, or when it is 'scattered' by particles, such as the particles in the Earth's atmosphere, and enters your eyes.

Figure 6. The International Space Station (ISS) hovering above Earth. CREDIT: Image supplied by NASA.

Notice the huge solar panels that help supply electrical power required to run the space station, and the astronaut on a spacewalk.

Besides visible light, the Sun also radiates out ultraviolet light (UV) and infrared light (IR). These cannot be seen with the unaided human eye. For this reason they are sometimes described as 'black light'. The whole range of radiation is known as the **electromagnetic spectrum**.

Figure 7 shows the electromagnetic spectrum. The Sun's radiation travels through Space in waves. For this reason the different parts of the spectrum are distinguished by the frequency of the waves, or their wavelength.

The highest energy radiation is gamma rays. Astronauts must be protected from this radiation when they go on a spacewalk, because it is highly penetrating. UV light has more energy than visible light, which is why it can be damaging if we are exposed to it too much. IR light has less energy than visible light, but is responsible for the warmth we feel. (Infrared lamps are used to warm bathrooms and to heat food.) Radio waves have very low energy.

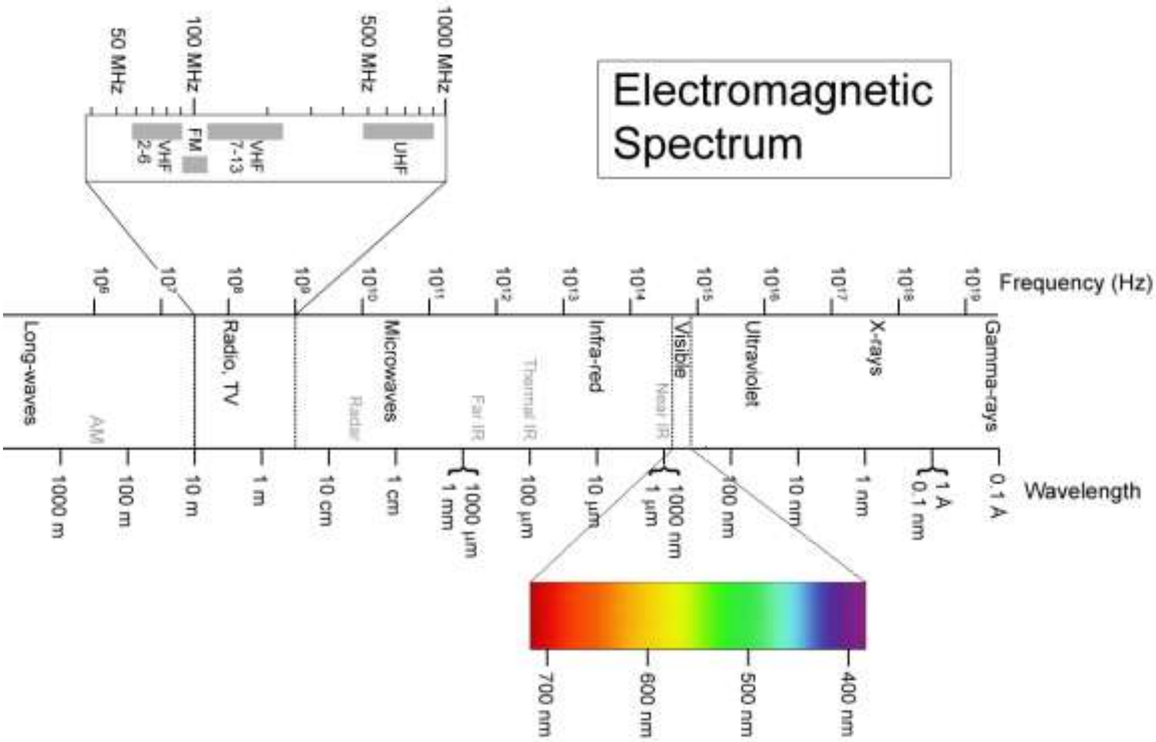


Figure 7. A schematic diagram of the electromagnetic spectrum.

Source: http://upload.wikimedia.org/wikipedia/commons/8/8a/Electromagnetic_Spectrum.png **Accessed:** 30 June 2010

Note in Figure 7: The band of wavelengths that match visible light has been expanded to show the colours that together make up visible light. Note there is actually a continual range of colours, not just the seven distinct colours listed in the well-known mnemonic for the colours of the rainbow 'ROYGBIV' (Red, Orange, Yellow, Green, Blue, Indigo and Violet). Likewise, the band of wavelengths that are involved in radio and TV waves has been expanded to show some of the different broadcasting bands.

Did you know?

Of the different wavelengths that make up visible light, blue light is scattered more that the other wavelengths by the particles in the atmosphere. This is why the Earth is seen from Space as having a blue 'halo', as shown on the far right of Figure 6.

When the Sun's radiation reaches Earth

Figure 8 shows what happens to the Sun's radiation as it reaches the Earth.

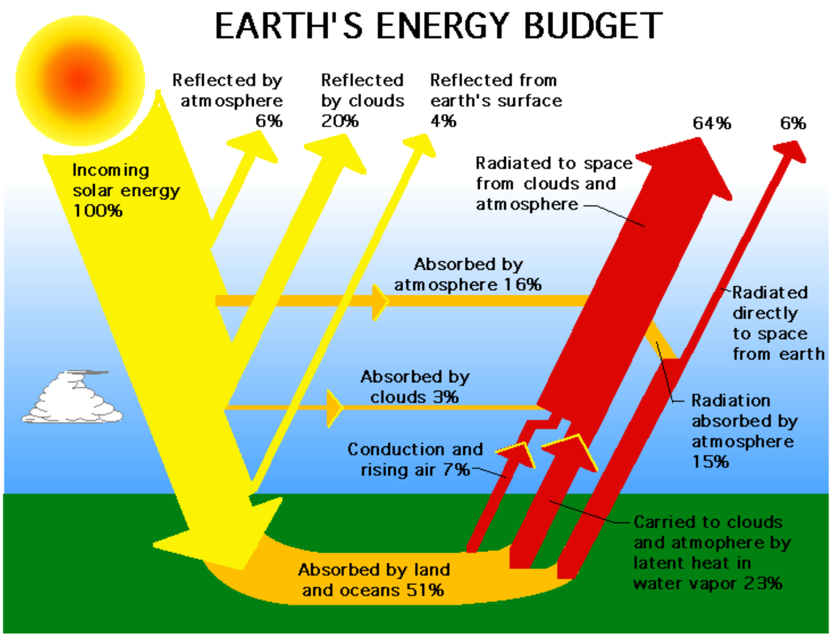


Figure 8. **Source:** http://eosweb.larc.nasa.gov/EDDOCS/images/Erb/components2.gif **Accessed:** 28 July 2010

Notice that when the system is in balance, the total energy going out from Earth into Space adds up to 100 %, which means it equals the total energy coming in.

When radiation from the Sun reaches the Earth:

- About 30% of the radiation is reflected back into Space by the particles in the atmosphere, clouds and the Earth's surface. [In Figure 8 we see it is (6 + 20 + 4) %, which adds up to 30 %.]
- Some is absorbed by the water vapour in the atmosphere and by clouds. Some (about 3%) is absorbed by the ozone layer. (This layer is not shown in this diagram.) This adds up to about 19 %.

The remaining 51 % of the Sun's energy is absorbed by the Earth's surface (land and oceans). If it kept being absorbed and none was ever given back out, the Earth would get hotter and hotter. The oceans would have boiled away long ago, and all our water would have evaporated!

Fortunately for us, this does not happen, because the Earth radiates heat energy in the form of infrared radiation back into the atmosphere. And ultimately the atmosphere radiates heat energy back into Space. What happens to this infrared radiation in the atmosphere is of crucial importance to life on Earth.

Did you know? **All objects emit infrared radiation. We can see this radiation with special glasses. This fact is used by search and rescue teams, wildlife observers and others who need to see in the dark, such as cave explorers. The view they see is in shades of green. An example of a cave seen using night vision is shown in Figure 9.** Figure 9. **Source:** http://www.milenb.com/gallery2/d/3922-3/Carlsbad_Cave_formation_night_vision.jpg **Accessed:** 30 June 2010	

The natural greenhouse effect

The **greenhouse effect** is the process whereby some of the infrared radiation emitted by the Earth's surface is 'trapped' by greenhouse gases, which helps moderate the temperatures at the Earth's surface.

The greenhouse effect has occurred naturally on Earth for millions of years, as our atmosphere has contained greenhouse gases ever since it first formed. For this reason this process, now known as the **natural greenhouse effect**, has enabled life to evolve on this planet. Without it, the temperatures experienced on Earth would be like those on the Moon, which is the same distance from the Sun as we are. This means it would be far too hot by day and far too cold by night for life as we know it to survive.

The Moon has no atmosphere and hence no greenhouse gases to help moderate the temperatures at its surface. This is why the average ground temperature on the Moon is -17 ºC, while on the Earth, which does have an atmosphere containing greenhouse gases, it is 16 ºC, which is 33 ºC higher.

In fact, when we say 'trapped', we mean that the molecules of greenhouse gases absorb some of the infrared radiation. They also emit some infrared radiation back to the Earth's surface. This makes the temperatures at the surface warmer than they otherwise would be.

The natural greenhouse effect is illustrated in Figure 10.

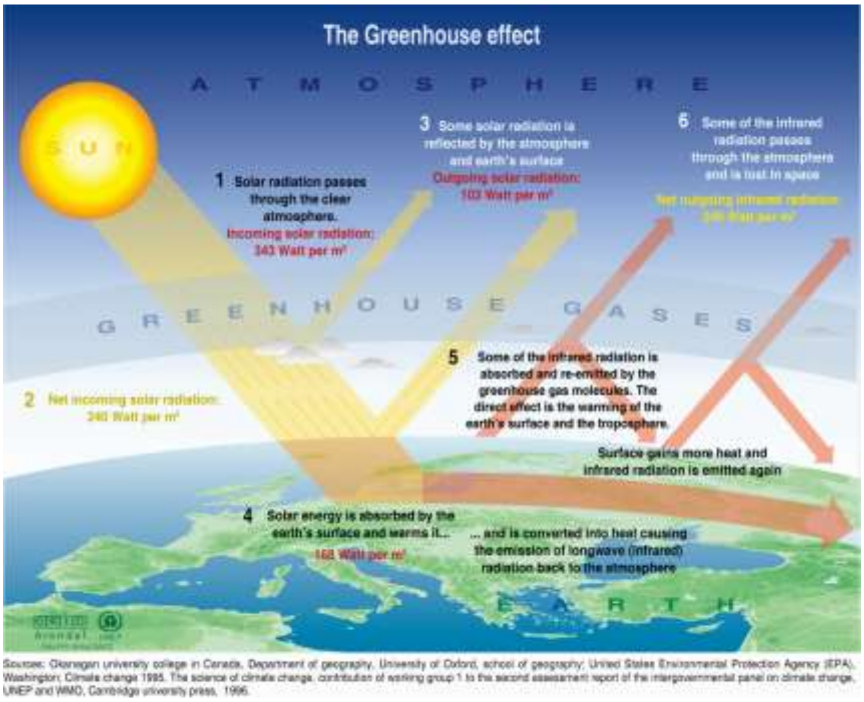


Figure 10. **Source*:*** maps.grida.no/go/graphic/greenhouse-effect **Accessed:** 23 June 2010

Cycling greenhouse gases

Over the millions of years in which the greenhouse gases have been present in the Earth's atmosphere, natural cycles have ensured that the proportion of the greenhouse gases in the atmosphere has remained steady. The 'cycles' consist of natural processes in which they are released into the air and other natural processes in which they are removed from the air.

Between the two kinds of processes, molecules of a particular gas are slowly and steadily cycled around. For example, the **carbon cycle** refers the processes in which carbon dioxide is released into the air and the processes in which it is removed from the air. **(See the diagram of the carbon cycle on page 57 in this resource.)**

One of the natural processes in which carbon dioxide is released into the air is **cellular respiration**, a chemical reaction that is summarised in the following word equation:

glucose + oxygen → carbon dioxide + water + energy

This reaction occurs in every cell within all those living organisms that undergo cellular respiration to obtain the energy they need to survive, including animals and plants. The carbon dioxide produced in this reaction is then released into the air, as it is a waste product that would be toxic to the cells if it were to accumulate within the cells.

One of the natural processes in which carbon dioxide is removed from the air is **photosynthesis**. This is a chemical reaction in which plants and certain other organisms absorb carbon dioxide from the air and water from the ground to produce glucose.

carbon dioxide + water + energy → glucose + oxygen

The energy required for photosynthesis is obtained from light. The reaction also requires the presence of chlorophyll.

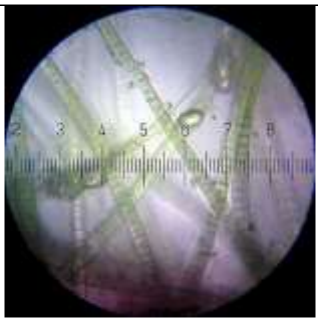
Did you know?

Plants are not the only life forms that undergo photosynthesis. Aquatic organisms known as cyanobacteria, for example, also undergo photosynthesis.

Figure 11. Cyanobacteria, seen under a microscope.

Source: http://upload.wikimedia.org/wikipedia/en/5/5a/20100422_235222_Cyanobacteria.jpg

Accessed: 10 July. 2010



Is there a balance?

Until the past century or so, all the natural processes in which greenhouse gases were released into the air and all the natural processes in which greenhouse gases were removed from the air balanced each other out. In other words, the gases were continually cycled around. As a result, the percentage of these gases in the atmosphere remained steady.

But now, the level of human activity we have today has altered this balance. Our large-scale burning of coal, natural gas and oil, our mass production of materials such as steel, cement and aluminium, and our huge piles of rotting garbage, not to mention burning trees to clear land or cutting them down to make goods (including paper), are releasing more greenhouse gas molecules into the air than can be removed by natural processes.

Even growing more and more rice and increasing the number of ruminant animals (animals that eat grass), such as sheep and cattle, to feed our increasing populations contributes to the problem. Rotting garbage, rice paddies and animals that eat grass and other plant material all produce huge amounts of methane gas, which is a far more potent greenhouse gas than carbon dioxide. (That is, a molecule of methane will emit more infrared radiation than a molecule of carbon dioxide.)

Insects that eat plant material or plant products such as wood or paper, add to this problem. Although each individual insect may only emit small amounts of methane, because there are billions of them, this adds up! Termites alone contribute hugely to the problem.

In addition, new very potent greenhouse gases such as nitrogen trifluoride, NF_3, are being introduced into the atmosphere as new technologies are developed.

Did you know?

Methane is produced by certain bacteria. In the case of rice paddies, bacteria break down dead plant material to obtain the nutrients they need. In the case of ruminant animals, bacteria live in their gut and break down the grass for them into a form they can digest. This is known as a symbiotic relationship, as both the animals and bacteria benefit from this arrangement. The methane is one of the waste products produced by the bacteria. (Unlike plants and animals, bacteria do not produce carbon dioxide as a waste product.)

The enhanced greenhouse effect and global warming

The **enhanced greenhouse effect** is the trapping of additional infrared radiation by the excessive amounts of greenhouse gases in the atmosphere that have been produced as a result of human activity. It is this process that many scientists are concerned about.

Likely consequences of global warming

Scientists use sophisticated computer models of the Earth that predict likely changes due to global warming. Some examples of the consequences of global warming include:

- **Climate change.** There are likely to be significant changes in climate around the world, including greater extremes of drought and heavy rainfall, and an increase in the severity of cyclones, typhoons and other extreme weather events.
- **Melting of polar icecaps and glaciers.** One consequence of this would be causing many species that are dependent on polar ice, such as the polar bear, to become endangered.
- **Change in weather patterns.** For example, some places may get more rain and storms while others may get less.
- **Increase in the temperature of the upper levels of the oceans.** One consequence of this would be damage to marine ecosystems due to the loss of species that cannot survive or cannot reproduce in the warmer water.
- **Rising sea levels.** This is mostly due to the expansion of the upper layers of the sea water due to the increase in temperature. The melting of the polar ice caps also contributes to this problem. This would result in the flooding of low-lying coastal areas. A large number of people would lose their homes and livelihoods.
- **The spread of tropical diseases.** Higher mean temperatures may lead to a wider spread of tropical diseases such as malaria, which is caused by a certain species of mosquito.
- **The spread of invasive species.** The change in climate is likely to lead to the movement of species that can cause damage to crops or stock. This could significantly reduce food supplies, which could lead to serious social problems. When people are hungry and desperate and either cannot access or cannot afford to purchase food from other regions, they could resort to uncontrolled use of toxic chemical sprays on crops and pasture, or to destroying more forests to obtain more land.

Some of these consequences are already being observed!

Sea-level rising

Scientific data shows how much sea levels are already rising. The graph in Figure 12 on the next page shows the increase in Global Mean Sea Level from 1993 to 2010. This shows the average across all the oceans.

The world map in Figure 13 shows which areas of the ocean are rising more rapidly, and which are rising less rapidly. Notice that the northern parts of Australia are at the greatest risk of coastal flooding.

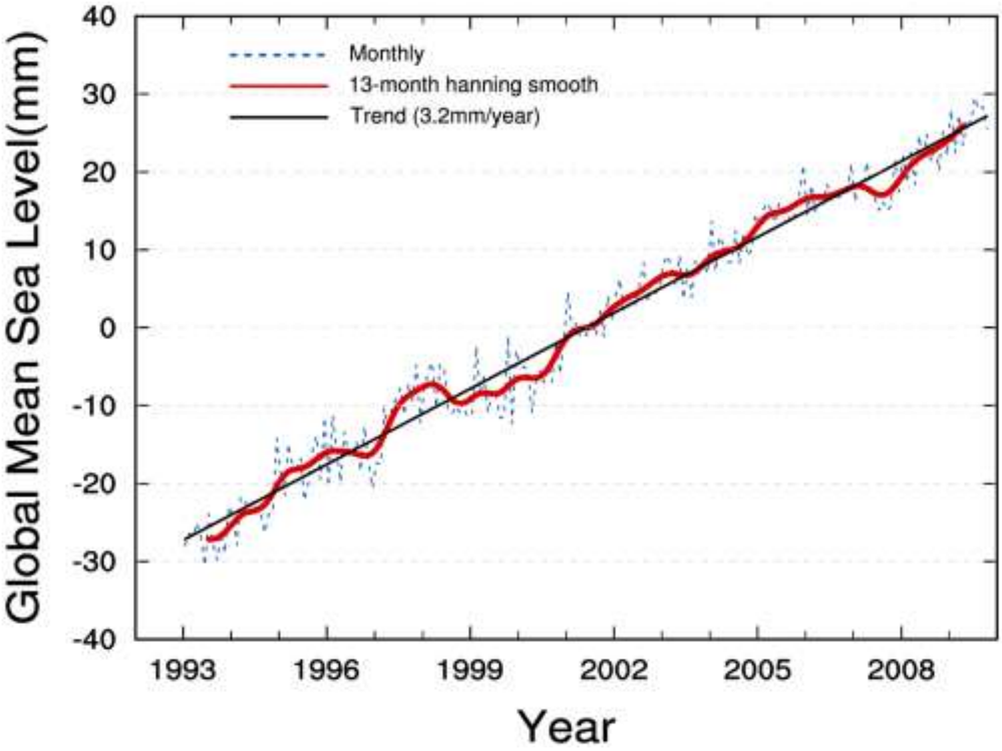


Figure 12. **Source:** http://en.wikipedia.org/wiki/File:Global_mean_sea_level.png **Accessed:** 24 June, 2010

This graph shows how much the sea level is above or below a long-term average.

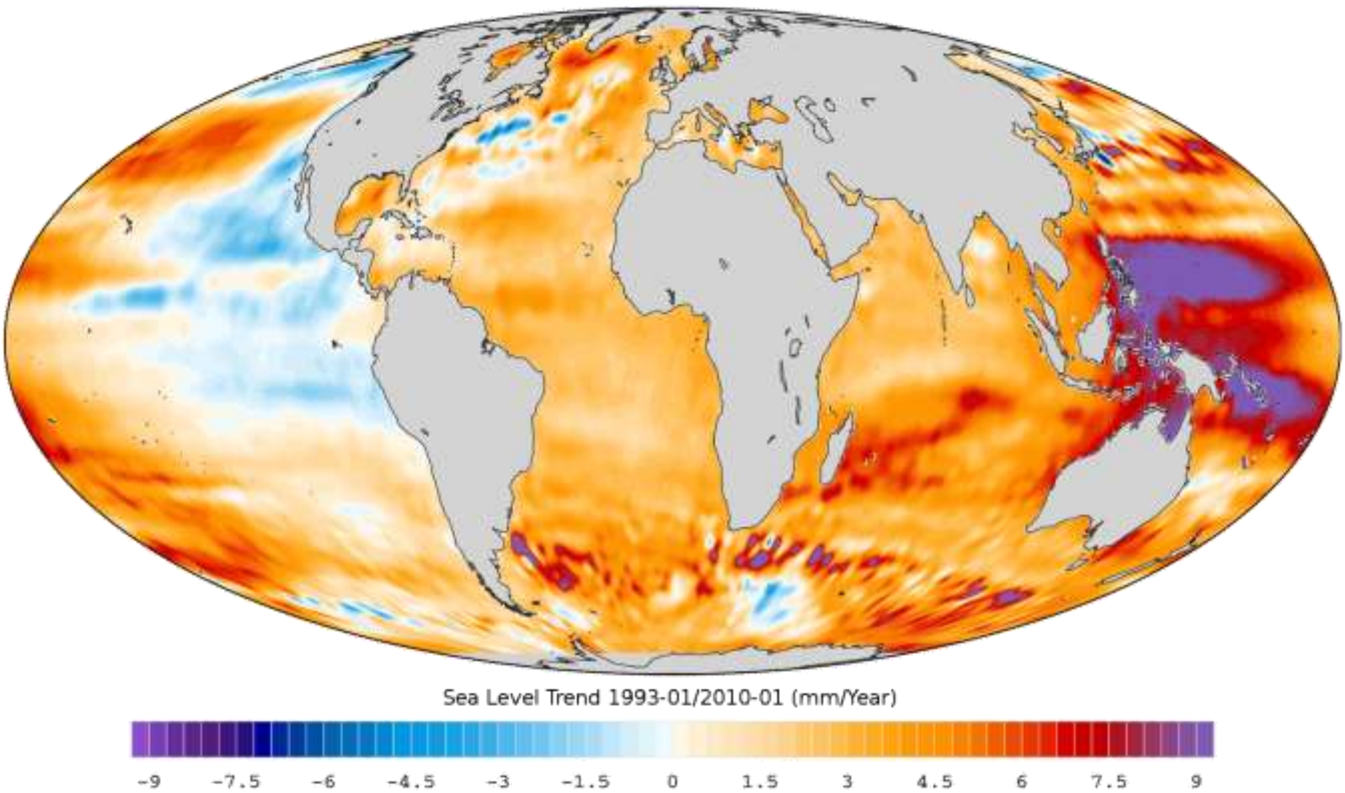


Figure 13. **Source:** http://upload.wikimedia.org/wikipedia/commons/6/69/NOAA_sea_level_trend_1993_2010.png **Accessed:** 24 June 2010

Melting of polar ice caps

One source of evidence for this is the large amount of satellite and other data collected by NASA scientists, some of whom are seen in Figure 14.

Figure 14. NASA scientists studying ice in the Arctic. PHOTO CREDIT: NASA

Web research – student activity

Visit: http://www.nasa.gov/topics/earth/features/arctic_thinice.html Find out what NASA scientists have discovered. View the animation. What is your conclusion?

Did you know?

The enhanced greenhouse effect is not the only factor contributing to global warming. The vast amount of heat radiated out by big cities, especially from their centre, and huge industrial complexes, also contributes to the problem. However, its effect is very, very small compared with the enhanced greenhouse effect.

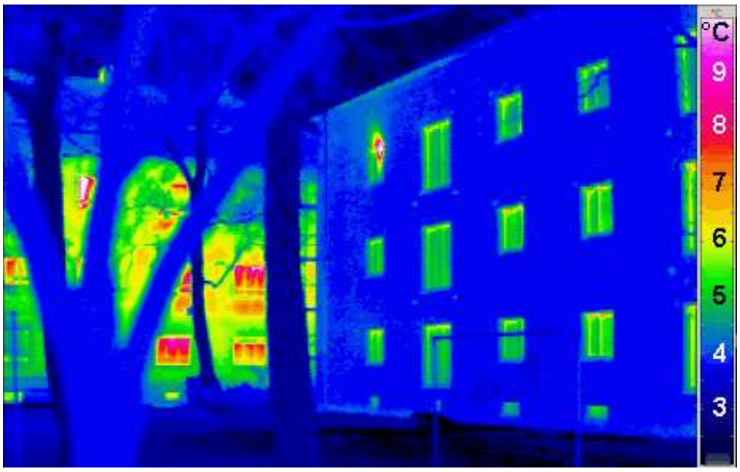


Figure 15. Source: http://en.wikipedia.org/wiki/File:passivhaus_thermogram_gedaemmt_ungedaemmt.png **Accessed:** 24 June, 2010

This image, known as a **thermogram**, was taken by a special infrared imaging technique in which the temperature of different regions is shown as different colours. This shows a building in the foreground which is well-insulated and not giving heat out into the environment (and so is termed a passive building), and a building in the background which is poorly insulated. Imagine what the thermogram of a fossil fuel power station would look like, with its furnaces and vast amounts of hot gases pouring out of chimneys!

Does the ozone layer have anything to do with global warming?

Many people mistakenly think that the 'holes' in the ozone layer cause global warming. This is not so. They are entirely separate problems.

The **ozone layer** is a layer within the stratosphere, about 16 km above the Earth's surface, in which ozone is present.

Very few elements exist in Nature as separate atoms. The atoms of most elements are normally joined in some way to other atoms. One way they can be joined up is to form molecules**. Molecules** are particles that are made up of two or more atoms that are stuck together by electrostatic forces.

Ozone is a form of oxygen. 'Normal' oxygen exists naturally as molecules that contain two oxygen atoms. This is why it has the chemical formula O_2. Ozone molecules contain an additional oxygen atom and so have the chemical formula O_3.

Both 'normal' oxygen and ozone are present in the ozone layer. But they are constantly reacting. The ozone molecules keep reacting with one another, forming 'normal' oxygen molecules, and 'normal' oxygen molecules keep reacting with each other, forming ozone molecules. This is depicted in Figure 16.

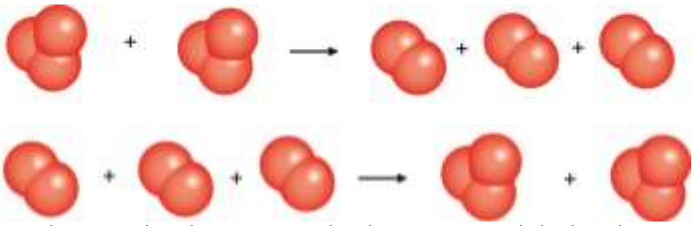


Figure 16. These models of molecules of ozone and oxygen show how ozone molecules are constantly broken down to normal oxygen, and then are produced again, within the ozone layer.

Each of these reactions uses some of the energy the Earth receives from the Sun. The energy is needed to overcome the electrostatic forces that stick the atoms together. Fortunately the energy that is needed to split the molecules is high-energy ultraviolet (UV) radiation. This is why the ozone layer absorbs a large proportion of the UV radiation that the Earth receives from the Sun. As a result, we are exposed to much less UV radiation.

Did you know?

While our skin needs some exposure to UV radiation in order to manufacture Vitamin D, too much exposure can cause problems such as skin cancers and cataracts.

A cataract is the clouding of the lens of the eye, as shown in Figure 17. Humans and most other animals are at risk of getting cataracts.

Figure 17. Untreated cataracts lead to blindness.
***Source*: http://www.sightsurgeryinternational.com/uploads/cataract_complete_cataract.jpg**
Accessed: 18 November, 2009

The 'holes' in the ozone layer

Normally the reactions shown in Figure 16 are in balance. This means that for every ozone molecule broken down to normal oxygen, another ozone molecule is made. Sometimes this balance is disturbed, however. As a result, in some parts of the ozone layer, especially in the region over the South Pole, the concentration of ozone (amount of ozone present in each litre of the air) has decreased. It has not disappeared altogether! Those areas in which the concentration of ozone is low are called **the holes in the ozone layer**.

The problem is that more UV radiation reaches the parts of Earth's surface that are located right under the 'holes'. This means more people and other animals will get skin cancer and cataracts in those regions. Hence the 'holes' are of great concern.

What causes the 'holes'?

The loss of ozone is caused by other chemical processes in which ozone molecules are broken down into normal oxygen. Some of these processes occur naturally, such as those that cause the big 'hole' over Antarctica. However, some are caused by chemicals produced by human activity. For example, one major cause was a family of chemicals commonly called CFCs. These were once widely used as propellants for aerosol sprays and as refrigerant gases because they are chemically stable. The problem with these is that each CFC molecule can last for more than100 years in the ozone layer, and during that time will 'destroy' billions of ozone molecules!

Once scientists realised this, many countries agreed to ban the use of CFCs. Their action has already made a huge difference to the problem. This is an excellent example of countries across the world taking action and working in cooperation with one another to reduce a global problem caused by human activity.

Ozone close the ground

There are other ways of making ozone besides the reaction making it in the ozone layer shown in Figure 16, page 65 of this resource. Ozone also is produced in other processes that occur at the Earth's surface. These include:

- Running photocopiers and other devices that use electronic flashes.
- The action of sunlight on the exhaust gases emitted by motor vehicles.

The ozone close to the ground is classified as a pollutant. When breathed in, it can cause many health problems, including difficulty in breathing.

It also contributes to global warming. Since ozone molecules at this level do contain 3 atoms, any ozone close to the surface acts as a greenhouse gas.

So although the ozone layer itself does not cause global warming, the ozone produced near the ground as a result of human activity does contribute to global warming.

Note to the teacher:

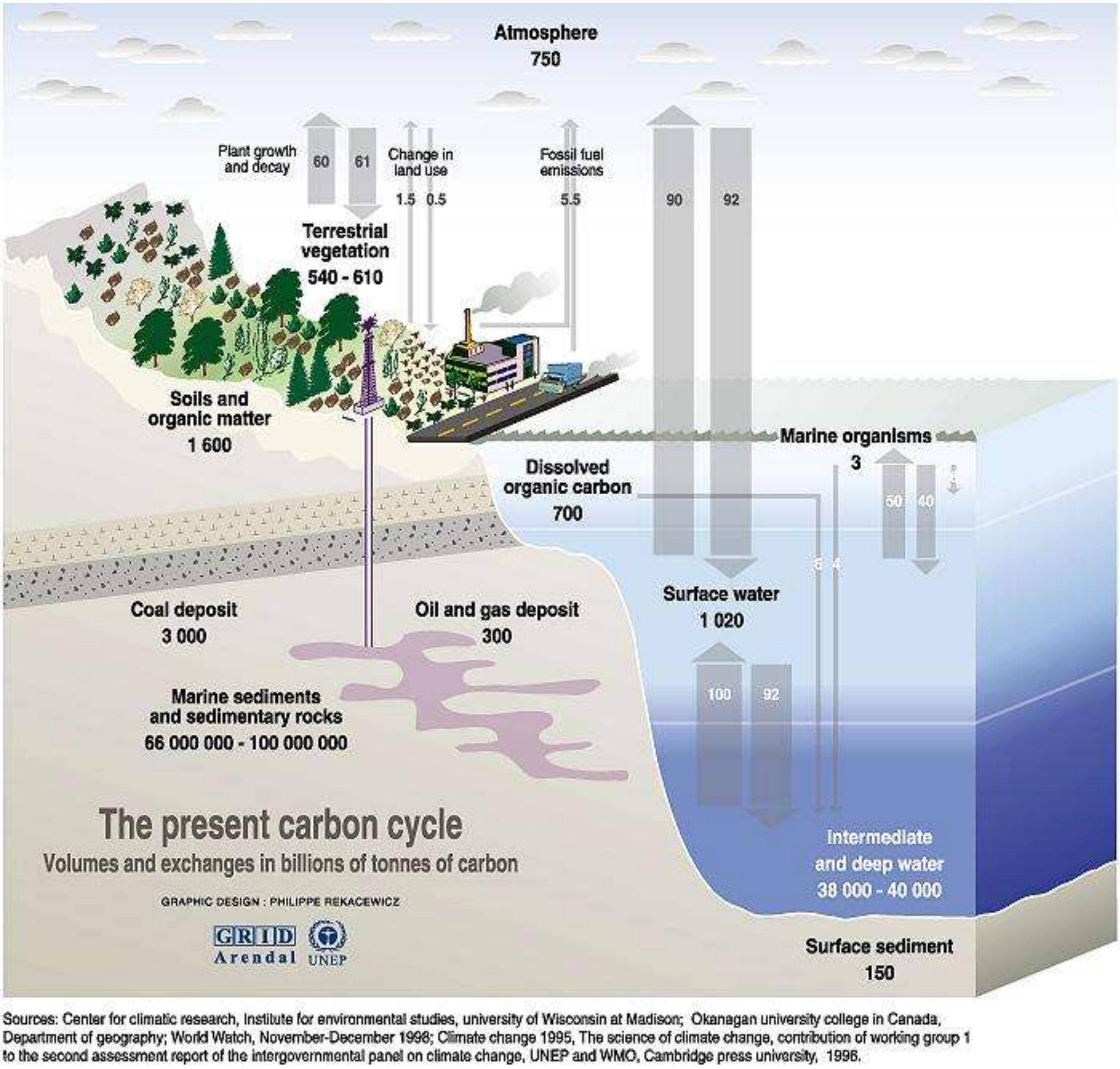
This background information on global warming is provided on the STELR website at www.stelr.org.au.

Teachers may find the schematic diagram of the carbon cycle shown on the next page helpful. (Alternative diagrams that are more suitable for students are available on the internet.)

Also see the flow chart that summarises the causes and consequences of global warming outlined on page 62 of this resource. (It also refers to ocean acidification, which is studied in the STELR Integrated Curriculum and the STELR Chemistry Curriculum.)

Note: The websites on global warming listed on pages 167—168 provide further very useful information on global warming, as well as the ozone layer.

THE CARBON CYCLE



Source: http://oceanworld.tamu.edu/resources/oceanography-book/Images/carboncycle.jpg
Date accessed: 9 February, 2011

Note: The advantage of this diagram is that it shows the cycling of carbon in more detail than most representations. However, it does not show emissions from industrial sources such as steelworks, aluminium smelters and cement manufacturing plants, or the contribution of processes such as the cellular respiration of animals. In addition, the numerical data need to be updated on a regular basis.

TOPIC: GLOBAL WARMING

GLOBAL WARMING – ALTERNATIVE CONCEPTIONS

SYNOPSIS

Studies into students' understanding of global warming, greenhouse effect and climate change have found that students across all levels of schooling have a general understanding that the greenhouse effect will cause changes in weather patterns and global warming. However, such studies also point out that there are several alternative conceptions that students, as well as the general public, hold about these areas of science.

COMMON ALTERNATIVE CONCEPTIONS

A common alternative conception among people of all ages is:

- Ozone layer depletion is a major cause of global warming. The hole in the ozone layer allows more radiation, which heats up the Earth, leading to global warming.

People often conceptualise the two phenomena of ozone depletion and greenhouse effect as being one. (See pages 55—56 of this resource for background information.) Therefore, the causes, impact on the environment and solutions to these quite separate phenomena are seen as the same. This leads to such alternative conceptions as:

- If the holes in the ozone layer get larger:
  - The greenhouse effect will get worse too.
  - There will be more flooding in the world.
- If the greenhouse effect gets larger:
  - More people will get skin cancer.
- The carbon dioxide and methane 'layer' traps UV radiation coming in from the ozone holes.
- Carbon dioxide causes global warming exclusively by destroying the ozone layer.
- Power stations and/or cars damage the ozone layer.
- Carbon dioxide destroys the ozone layer.
- Air pollution ruins the ozone layer, to the extent that the Sun's rays melt the poles and the sea level rises.
- People can recycle and repair the ozone layer by not driving cars.
- The greenhouse effect is made worse because of:
  - Acid in the rain.
  - Holes in the ozone layer
  - Radioactive waste from nuclear power stations.
- The holes in the ozone layer are made worse by:
  - Destroying rainforests.
  - Fumes from car exhausts.
  - Gases used for making some plastics.
  - Radioactivity from nuclear power stations.
  - Volcanoes blowing up.

Students don't distinguish between the natural greenhouse effect and the enhanced greenhouse effect, leading them to think that the greenhouse effect is bad for the environment. The natural greenhouse effect is essential for life as we know it. Without the natural greenhouse effect the Earth would be more than 30 degrees cooler.

OTHER ALTERNATIVE CONCEPTIONS ABOUT THE GREENHOUSE EFFECT

1 The greenhouse effect is a kind of atmospheric pollution.

2 The greenhouse effect is heat that does not come out or bounces back to the Earth because of an implicit barrier, which is formed by diverse substances like carbon dioxide, in some cases 'greenhouse gases'.

3 If the greenhouse effect gets bigger:

- More people will die of heart attacks.
- More people will get food poisoning.
- Some of our tap water will become unsafe to drink.
- There will be more earthquakes.

4 The greenhouse effect can be made smaller by:

- Eating healthy foods.
- Keeping beaches clean.
- Protecting rare plants and animals.
- Reducing starvation in the world.
- Reducing the number of nuclear bombs in the world.
- Using unleaded petrol.

SOME REPRESENTATIVE RESEARCH STUDIES

Anderson, B. & Wallin, A. (2000) *Students' understanding of the greenhouse effect, the societal consequences of reducing CO2 emissions and the problem of ozone layer depletion* Journal of Research in Science Teaching, 37(10), 1096—1111

Bord, R., Robert E. O'Connor, R. & Fisher, A. (2000) *In what sense does the public need to understand global climate change?* Public Understanding of Science, 9, 205—218

Boyes, E. & Stranisstreet, M. (1993) *The 'greenhouse effect': children's perceptions of causes, consequences and cures* International Journal of Science Education, 15(5), 531—552

Bulkeley, H. (2000) *Common knowledge? Public understanding of climate change in Newcastle, Australia*. Public Understanding of Science. 9, 313—333

Daniel, B., Stanisstreet, M. & Boyes, E. (2004) *How can we best reduce global warming? School students' ideas and misconceptions* International Journal of Environmental Studies, 61(2), pp. 211—222

Papadimitriou, V. (2004) *Prospective Primary Teachers' Understanding of Climate Change, Greenhouse Effect, and Ozone Layer Depletion* Journal of Science Education and Technology, Vol. 13, No. 2

Rye, A. J. (1997) *An investigation of middle school students' alternative conceptions of global warming* International Journal of Science Education, 19 (5), 527—551

TOPIC: GLOBAL WARMING

IDEAS FOR INTRODUCTORY ACTIVITIES ON GLOBAL WARMING

SYNOPSIS

These are ideas for optional classroom activities that may be tried before or after showing the Global Warming DVD. The time required for any of these could be half a lesson or longer, depending on how it is managed.

The first activity works very well, and ensures that all the students become actively involved. For this reason it works better than a formal debate, in which most of the class would be spectators only.

The second activity can be very worthwhile, since it can alert students to strong bias exhibited by some parts of the media. However, it may take too much time unless the students themselves are given the responsibility of collecting articles or record television programs.

The third activity can help students learn to distinguish between the causes and consequences of global warming. Research shows that visual representations are a very powerful and effective learning strategy.

Additional optional activities, such as modelling sea-level rising, are outlined in the teacher resource for the STELR Integrated Curriculum.

ADVICE ON INTRODUCING THE ISSUE OF GLOBAL WARMING

The following must be borne in mind for this topic:

1 It is important that there is some worthwhile discussion of global warming at the start of the STELR program, or the importance of developing renewable energy technologies will not be understood.

2 It is important to give the students opportunities to consider the big ideas of this topic, and to ask their own questions.

3 Global warming is an issue that concerns many students. It can be a very emotive issue for some, especially if they are very fearful of the future or are opposed to the actions or lack of action of particular countries or ethnic groups. It therefore needs to be handled sensitively. Insist that the students treat those who have other viewpoints with respect.

4 Some or all the students will have one or more alternative conceptions (or misconceptions) on this issue. Typical alternative conceptions are listed on pages 58—59. The teacher should be aware of these possible conceptions before starting this topic.

5 Often students of this age find it hard to separate causes and effects, especially if they have been protected time and again from the consequences of their own actions. (Some concerned educators refer to these students as the ‘bubble wrap’ generation.)

The flow chart activity may be useful for the teacher in helping the students sort out for themselves the flow-on effects of recent human activity, principally driven by the population explosion and unsustainable lifestyles.

OPTIONAL INTRODUCTORY ACTIVITY 1: TAKING A POSITION

Activity outline

This is a very lively form of debate that requires everyone to be involved.

Designate different parts of the room for different viewpoints on climate change. These viewpoints can be elicited from the students (their own views or the views they have heard expressed in their community and/or in the media).

Ask the students to move to the corner that best matches their viewpoint. (They cannot 'sit on the fence'!) Tell them they will need to defend this viewpoint.

Give each group a few minutes to produce a list of arguments and to elect a spokesperson to argue their case. Each spokesperson has two minutes to speak.

After the speakers have finished, have the class analyse their arguments.

- Were these arguments based on reliable evidence?
- Where did their ideas come from?

Then give the students the opportunity to move to another part of the room as a result.

Advice

Do not put students who have a problem with verbalising their thoughts in an embarrassing position in this activity. Maintain a positive and encouraging atmosphere.

OPTIONAL INTRODUCTORY ACTIVITY 2: MEDIA WATCH

Activity outline

Have the students collect newspaper cuttings about global warming, including opinion pieces, and put these on display. After the STELR curriculum is complete, have the class analyse the way the media has handled the issue over that time.

Advice

This activity may be time-consuming to maintain, and hence impractical in many schools. But if an extreme weather event or coastal flooding is occurring and receiving a large amount of media attention, teachers should capitalise on this if at all possible, even if the time over which media reports are gathered is restricted to a day or two. It is important for students to see how relevant science is to their daily lives.

OPTIONAL INTRODUCTORY ACTIVITY 3: VISUALISING THE CAUSES AND CONSEQUENCES OF GLOBAL WARMING

Activity outline

Divide the students into pairs. Give each pair a blank or partially completed flow chart with or without a list of missing words, and ask them to complete it. A sample final chart is provided on the next page.

The corresponding blank chart is available on the teacher portal of the STELR website at: www.stelr.org.au.

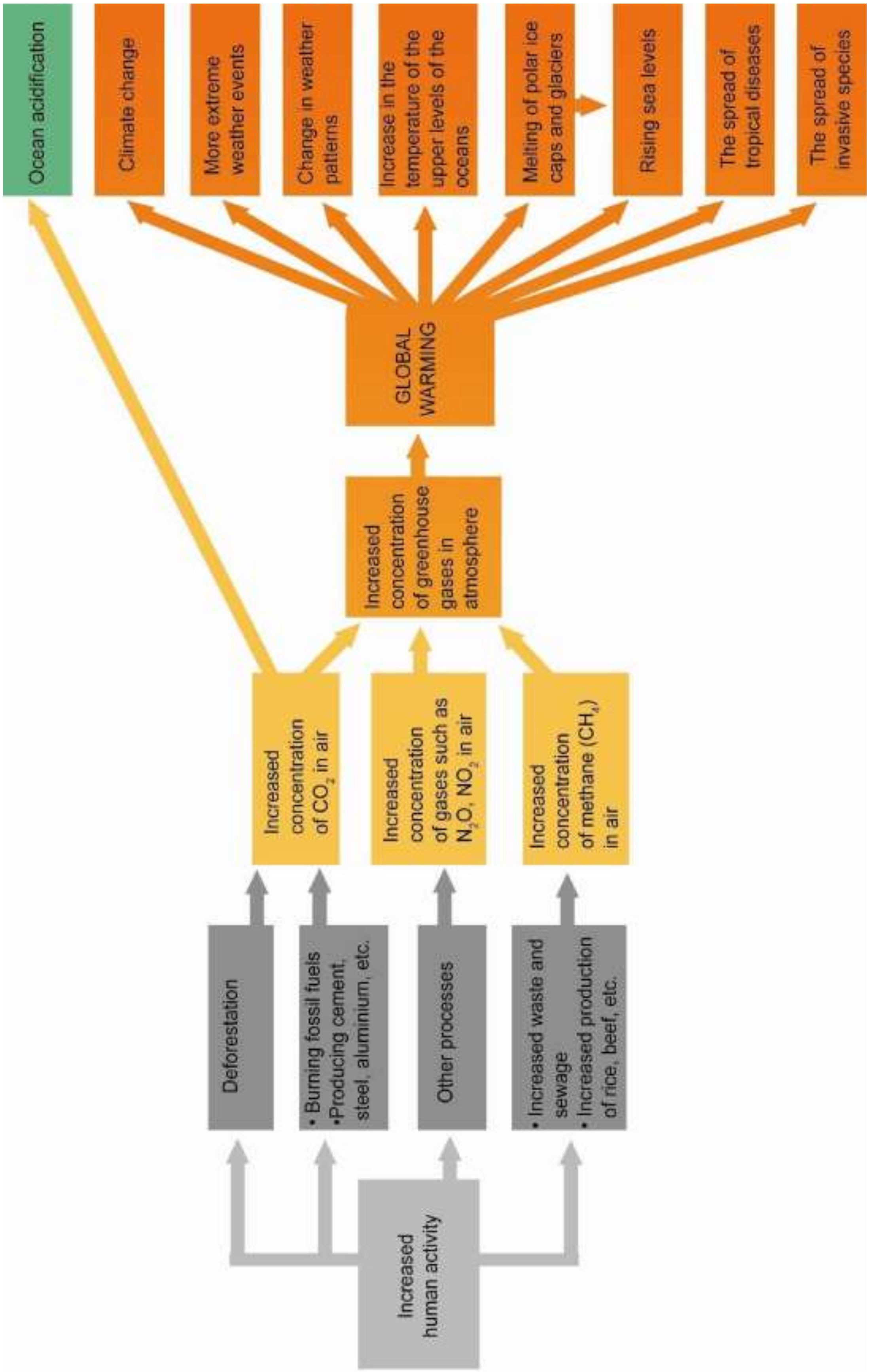
Advice

1 Students can add to the flow chart as well. For example, they could be asked to show the flow-on consequences of sea-level rising, more extreme weather events, and so on.

2 The teacher may prefer to have the students design and discuss their own flow chart. This would reveal their level of understanding of the causes and consequences of global warming.

3 If the model flow chart shown on the next page is used, the teacher may wish to remove the box on ocean acidification, unless this has been discussed. (See the student booklet of the STELR Integrated Curriculum or the STELR Chemistry Curriculum for more information on this problem.)

Sample flow chart showing the causes and consequences of global warming



TOPIC: GLOBAL WARMING

WORKSHEET 1: THE GLOBAL WARMING DVD – ADVICE

STUDENT BOOKLET pages 2—3

SYNOPSIS

This DVD was produced to introduce global warming using an Australian context and to stimulate class discussion.

The ensuing class discussion should help the teacher identify students' background knowledge and understandings, as well as any common alternative conceptions.

The follow-up concept map activity designed for pairs or small groups is an effective means of gauging the students' understanding of global warming, knowledge of the relevant terminology and their ability to connect ideas. It also will help identify alternative conceptions, which should then be discussed.

APPROXIMATE TIME REQUIRED

Approximately 50 —60 minutes, including discussions and drawing a concept map.

LIST OF MATERIALS REQUIRED

- STELR global warming DVD 'Global warming. Cold facts. Hot Science'
- Large sheets of poster paper and poster pens

PRACTICAL ADVICE AND HINTS

1 THE DVD

1 If the teacher decides to use the student worksheet as the basis for the follow-up discussion, then it is advisable to ask the students to read the stimulus questions prior to watching the DVD so that they can watch the DVD with these questions in mind. Alternatively, have the students devise their own list of questions through class discussion. Display these questions on a whiteboard so that the students can easily see them whilst viewing the DVD.

2 Show the STELR global warming DVD at least once and ask the students to write their responses to the questions, so that they can contribute actively to the follow-up class discussion.

3 After the students have viewed the DVD, elicit from them their responses to the stimulus questions, their understanding of the terms used in the DVD, their opinion of the DVD and any questions that they would have liked answered about global warming. Collect and display their different responses. If there is time, have the students complete the concept map.

2 THE CONCEPT MAP

1 Outline to the students the general principles of drawing a concept map:

- The 'key words' should be placed in boxes that are arranged on the page in such a way that they can be connected by sentences. Often this is in the form of a wheel with spokes.
- A key word can be a single word or a term such as 'global warming'.
- The boxes should be joined by lines on which sentences are written. For each line, the word(s) in the box at one end should be used to form the start of a sentence and the word(s) in the box at the other end of the line should end the sentence.
- There is no single right answer. However, some sentences are more helpful than others as they contain more information.

2 The concept maps should be drawn on large sheets of paper and displayed.

ADVICE FOR THE CLASSROOM

1 As stated on page 60, global warming is a very important issue which concerns many students. It can be a very emotive issue for some, especially if they are very fearful of the future or are opposed to the actions or lack of action of particular countries or ethnic groups. It therefore needs to be handled sensitively. Insist that the students treat those who have other viewpoints with respect.

2 The level of sophistication of the sentences in the concept maps will vary from student to student. Avoid placing students who have learning difficulties, or who have difficulty expressing themselves, in a position of embarrassment. If that is likely, do not put the responses on display, but instead display some of the most helpful sentences found without identifying the source.

TOPIC: ENERGY TRANSFORMATIONS AND TRANSFERS

BACKGROUND INFORMATION FOR THE TEACHER

Energy is associated with any change. It can be thought of as the ability to make something happen. It is *not* a force! A **force** is simply a push or a pull or a twist. There are many different forms of energy but two fundamental forms are **kinetic energy** and **potential energy**. Some common forms of energy are shown in the table below.

FUNDAMENTAL FORM OF ENERGY	MEANING	SPECIAL CASES: DISCUSSION	EXAMPLES
KINETIC ENERGY	Kinetic energy is the energy of moving objects.	**Mechanical energy** When a machine is working, its kinetic energy is sometimes called mechanical energy.	 Figure 1. When it is set spinning, a turbine has mechanical energy **Source:** http://montaraventures.com/pix/steam-turbine-blade.jpg **Accessed:** 17 November 2010
		Thermal energy/ heat energy The coldest possible temperature anywhere in the universe, -273 ºC, is termed Absolute Zero. Unless a substance is at this temperature, the atoms, ions or molecules present in the substance are moving in some way. The higher the temperature, the greater their average kinetic energy. Because it is related to their temperature, this energy is sometimes termed thermal energy or heat energy. ***Note:*** Any object that has thermal energy gives out infrared radiation (see page 50 of this resource).	 Figure 2. The water molecules in this glass of tap water have thermal energy. So do the atoms in the glass itself.
		Sound energy When sound is transmitted through air, or water or any other medium, the particles in the air, water or other medium begin to vibrate (move back and forth). When this occurs, we can hear the sound, so their kinetic energy is described as sound energy.	 Figure 3. When a drum is beaten, the vibrating drum skin sets the air particles near it into vibration. The air and the drum skin have sound energy. **Source:** http://www.drumresources.org/category/drummer-tips **Accessed :** 17 November 2010

POTENTIAL ENERGY	We can think of potential energy as stored energy.	**Gravitational potential energy** A raised object can fall downwards due to the force of gravity, if it is no longer held up. So we say it has gravitational potential energy.	 Figure 4. Water stored up high in the Gordon Dam, Tasmania, has gravitational potential energy.
		Elastic potential energy Any stretched or compressed elastic object can return to its natural shape if it is no longer prevented from doing so. So we say it has elastic potential energy.	 Figure 5. A stretched rubber band has elastic potential energy.  Figure 6. This spring has been compressed to test it. It has elastic potential energy.
		Chemical potential energy Any chemical substance that can react with other substances has the ability to release energy when it reacts . We say it has chemical potential energy.	 Figure 7. The gas in these cylinders can burn. It has chemical potential energy.

Note:

Electrical energy is the energy possessed by electrically charged particles, which may be associated with an electric current or stored charge.
Light energy is the energy of visible light, ultraviolet light, infrared light, X-rays and other forms of electromagnetic radiation.

CHANGING FROM ONE FORM OF ENERGY TO ANOTHER

Energy can be changed from one form to another. When this change occurs, the process is described as a **transformation** of energy. This is shown in the following example.

Energy transformations in a Bunsen burner

Figure 8. A lighted Bunsen burner (air-hole open)

The combustion reaction

The main gas present in the gas that burns in Bunsen burners is methane. The main chemical reaction occurring is:

methane + oxygen → carbon dioxide + water + energy

For this reaction:

- Methane and the oxygen (from the air) are the reactants. **Reactants** are the chemical species that react with one another and form new substances. They are always listed ***before*** the arrow.
- Carbon dioxide and water are the products. **Products** are the chemical species that are formed in the reaction. They are always listed ***after*** the arrow.

Because a flame is produced when the gas burns, this is classified as a **combustion reaction**.

NOTE: The energy 'produced' in the reaction is the result of the energy transformations that are involved in the reaction. It is NOT classified as a product!

This is summarised below.

methane + oxygen	→	carbon dioxide + water	+ energy
REACTANTS	ARROW	PRODUCTS	

The energy transformations involved in the combustion reaction

The energy transformations involved in this combustion reaction are more complex than those that occur when you switch on an incandescent light globe. When the gas burns, chemical potential energy is transformed into all of the following forms of energy:

- Light energy (seen as the flame)
- Heat energy (felt as the warmth of the flame)
- Sound energy (the sound of the flame)

These energy transformations can be represented in different ways. Figures 9 and 10 on page 68 illustrate two of the possible representations: a simple flow chart and a **Sankey diagram**. The Sankey diagram uses different arrow widths to show that the chemical potential energy of the reactants is mostly transformed into heat energy.

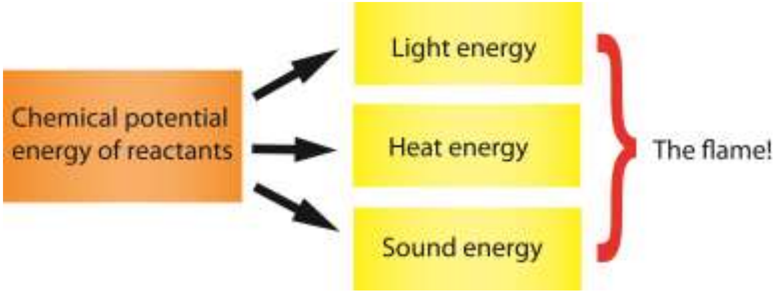


Figure 9. A flow chart representing the energy transformations occurring in a combustion reaction.

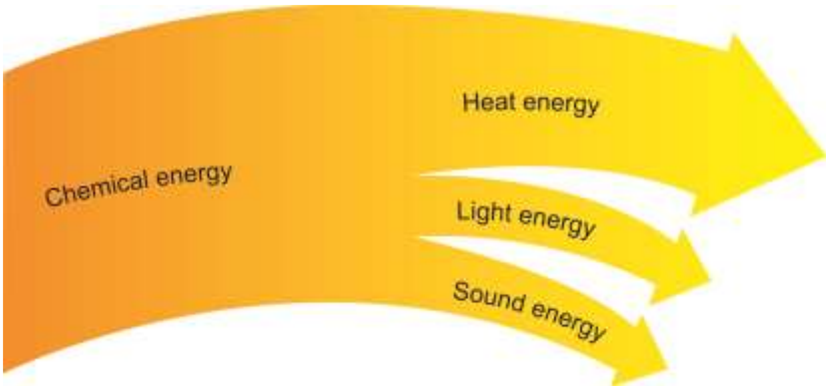


Figure 10. A Sankey diagram representing the energy transformations occurring in a combustion reaction. The chemical potential energy of the reactants is listed as 'chemical energy' for simplicity.

The Law of Conservation of Energy

During an energy transformation, no energy is created and no energy is destroyed. This is known as the **Law of Conservation of Energy**.

When gas burns, for example, the total amount of heat energy, light energy and sound energy produced is equal to the total amount of chemical potential energy that is transformed. The Sankey diagram in Figure 10 is designed to convey this lfact, by keeping the total arrow width the same.

Note: The above background information is provided as supplementary material to the information provided in the student booklet on page 5.

Further reference: See the website on energy listed on page 168 of this resource.

TOPIC: ENERGY TRANSFORMATIONS AND TRANSFERS

ENERGY - ALTERNATIVE CONCEPTIONS

SYNOPSIS

Studies into students' understanding of the concept of energy have found that students hold several alternative conceptions, confusing energy with force or movement or fuels, or believing, for example, that energy is just associated with eating foods.

COMMON ALTERNATIVE CONCEPTIONS

Some of the more common alternative conceptions include:

- Confusion between what is meant by the terms 'energy' and 'force'. Other terms, such as 'motion' and 'power', are also frequently used interchangeably with energy.
- Energy is a by-product of a situation that is generated, is active, and then disappears or fades. The law of conservation of energy is not well understood by students:
  - 'Conservation of energy' can sometimes be associated with everyday care not to waste energy, which differs from scientists' conservation of energy principle.
  - Energy is not an entity that is conserved because one has to pay for it. The energy required for devices such as light globes and engines gets consumed.
- Energy is only associated with movement of an object.
- Stationary objects relate to energy only from the perspective of an energy 'store'. For example, batteries, power stations, oil and coal store energy. Energy is therefore a causal agent, a source of activity based or stored within certain objects.
- Energy is related only to living things – an anthropocentric view. Living things get tired and less active without energy. Human energy is rechargeable through food or by resting. Some students have contradictory uses for human energy. For example, there may be the view that energy is built up as a result of sports training, but is expended in digging the garden.
- Energy is a concrete entity. In some circumstances, such as heating an object, energy is a fluid material that flows from hot objects to cooler ones.
  - Energy is associated with fluids or ingredients that are dormant and are released suddenly by a trigger.
- Energy is found in foods; it only gets harnessed when the food is eaten. Some students believe that 'high energy' foods convert directly into energy or somehow crack open to release their 'store of energy' when consumed.
- Energy is considered a fuel. Fuel is energy, rather than fuel is a *source* of energy.

SOME REPRESENTATIVE RESEARCH STUDIES

Kruger, C, Summers, M., Mant, J., Childs, A. & McNicholl, J. (1998) *Teaching Energy and Energy Efficiently Effectively*. Hatfield: Association for Science Education.

Kruger, C. (1990). *Some primary teachers' ideas about energy*. Physics Education, 25, pp. 86—91.

Liu, X. & McKeough, A. (2005). *Developmental Growth in Students' Concept of Energy: Analysis of Selected Items from the TIMSS Database*. Journal of Research in Science Teaching, 42, 5, 493–517.

Stylianidou, F., (1995), *Children's learning about energy and processes of change*, School Science Review 79, 91—97.

Trumper, R. (1993). *Children's energy concepts: A cross-age study. International Journal of Science Education*, 15 (2), pp. 139—148.

Warren, M. (1983). *Some alternative views of energy*, Physics Education 18, 213—217.

TOPIC: ENERGY TRANSFORMATIONS AND TRANSFERS

IDEAS FOR INTRODUCTORY ACTIVITIES ON ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS

SYNOPSIS

The teacher may decide to use the quick activities in the student booklet as a means of introducing this topic.

The first two optional alternative activities are additional ideas for ways in which you might introduce the concepts of energy, energy transformations and energy transfers. They will enable you to discover what the students already know and what alternative conceptions they may have.

The first activity is a PowerPoint presentation that covers a range of forms of energy. The second activity is a fun hands-on activity that can be used to stimulate discussion about energy and energy transformations. As an extension of this, or in place of this, you may like to try the third activity - an online simulation of the energy involved in a skate park. There is also reference to a You Tube video involving multiple energy transformations.

ADVICE ON INTRODUCING ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS

Rather than converging too quickly to the key science ideas, whichever activity you select, treat it as principally one in which ideas from the students are expressed, shared and discussed. But by the end of the discussion students should have at least begun to develop a common understanding of what energy is and of how energy changes from one form to another. They should also develop a common understanding of the meaning of different forms of energy.

OPTIONAL INTRODUCTORY ACTIVITY 1: IMAGES OF ENERGY (POWERPOINT PRESENTATION)

Activity outline

Show the students the series of PowerPoint slides on Energy provided on the ATSE STELR CD-ROM. Ask them to write down what kind of energy (or energies) they think each depicted object possesses. The PowerPoint presentation file includes some suggested questions.

At the end of the slide show, bring the class together to compare their answers. Include a discussion about whether their response concerning the rock changed when they saw the second slide showing its position.

Possible responses and some further stimulus questions that could be asked are shown in Table 1 on pages 71—72.

Elicit from the students what they understand by the terms they use, which may include kinetic energy and gravitational potential energy. Display their different ideas or understandings of the kinds of energy that were possessed by the objects and what these terms mean.

Time required

Approx 50 minutes (not including the follow-up activities)

Materials

• White board and data projector or other devices to display PowerPoint presentation

Note: Students require pen and paper or electronic means of recording their responses.

Discussion

Table 1. Discussion of slides

Slide	Comments	Further stimulus questions
2	Students may identify chemical potential energy, electrical energy, light energy and heat energy (the globe gets hot). They may consider this in terms of energy transformations: chemical potential energy to electrical energy to light energy and heat energy.	If the students do not realise that the battery contains chemicals, or do not list chemical potential energy, you could ask them: 'Where does the circuit get its energy from?'
3	Students may identify light energy, electrical energy and kinetic energy/mechanical energy. They may view this as a series of energy transformations.	Is energy created or destroyed as it changes form?
4	Students may identify chemical potential energy (of the grass), kinetic energy (cow chewing), thermal energy (the cow is warm), gravitational potential energy (of the cow), and so on. There is a common alternative conception amongst students that some or all of the food that animals eat is transformed into energy (that is, matter is converted to energy) and the rest is stored by the body or expelled from the body.	Can new atoms be made on Earth? If some of the atoms of the chemicals in food were converted into energy, would the Earth eventually run out of the atoms that plants and animals are made out of?
5	Students may identify electrical energy, heat energy and light energy or consider the energy transformations involved.	Where does the electrical energy come from?
6	The satellite is in a geostationary orbit, which means it is always located above one point on the Earth's rotating surface. The students may identify gravitational potential energy. They may consider the source of energy used to power the satellite (solar energy) and the forms of energy this is transformed into, such as electrical energy.	If it is geostationary, does the satellite have kinetic energy? Where does the satellite get its energy from that enables it to transmit signals and so on? What kind of energy would be required to transmit signals?
7	The students may identify elastic potential energy and kinetic energy. They may also identify heat/thermal energy, since the cotton reel toy gets hot as it moves over the surface, or the transfer of heat energy to the environment. They may identify the energy transformations involved. Watch out for the alternative conception that the kinetic energy is transformed into friction, due to rubbing against the surface or due to air resistance, thus equating energy and force.	When the toy stops moving, does it still have any energy? What other forms of energy has it been transformed into? If not, has its energy been destroyed?
8	For the jumping toy, the students may identify elastic potential energy, kinetic energy and gravitational potential energy. They may consider this in terms of the energy transformations involved. For the wheeled toys, the students may identify elastic potential energy and kinetic energy. They may also identify heat/thermal energy, since the wheels get hot, or the transfer of heat energy to the surrounding environment. They may consider this in terms of the energy transformations involved. Watch out for the alternative conception that the kinetic energy is transformed into friction in the wheels, thus equating energy and force.	When the jumping toy is half-way up, does it only have kinetic energy?
9	The students may identify gravitational potential energy and/or thermal energy. Watch out for the alternative conception that an object on the ground has no gravitational potential energy.	Would the large rock have more energy than a stone at the same spot? Why?
10	If the students did not identify gravitational potential energy for Slide 9, they should be encouraged to identify it now.	Would the rock have more energy than if it were down on the ground below? Why?

11	The students may identify gravitational potential energy and kinetic energy. They may say the twin up higher has greater gravitational potential energy and less kinetic energy that the twin further down the slope. They may also consider the energy transformation involved. Some may identify heat energy and its transfer to the environment.	Why would we compare twins? Would the twins have the same total amount of energy?
12	The students may consider chemical potential energy, kinetic energy and thermal energy, or the transformation of energy. Again, watch out for the common misconception outlined in Slide 4.	Does this mean that carbohydrates possess more chemical potential energy than other types of foods?

OPTIONAL INTRODUCTORY ACTIVITY 2: MAKING A FLIC-FLAC

Activity outline

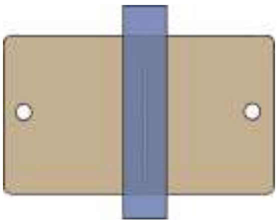
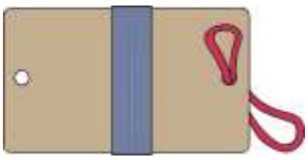
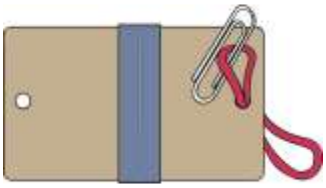
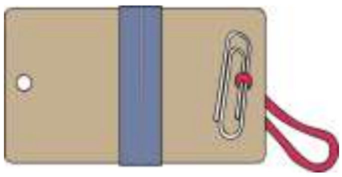
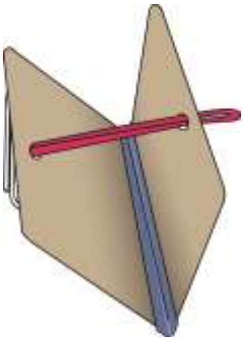
Make flic-flacs for the class, or show them how to make one then try it out, as shown in Table 2 below.

Elicit from the students what they understand by the terms they use. Ask the students to discuss, debate and/or display in some creative way their different ideas or understandings of the energy transformations that have taken place. The students should be encouraged to draw images or even ‘role play’ the energy transformations. Discuss the advantages and limitations of the different types of presentations.

At the end of the activity compare and discuss which methods of displaying the energy transformations work best.

Table 2. How to make a flic-flac

<table>
<tr>
<td>1 Line up the two halves of the card so that the holes are facing the outer edge.

Then place adhesive tape over the join both front and back, leaving a small gap between the cards so that they can be rotated easily.
</td>
<td>2 Fold over the tape so that it is flush with the edge of the card. Then fold the rubber band in half and thread an end through one of the holes, as shown.
</td>
<td>3 Thread the paperclip through the small loop created by the rubber band, as shown.
</td>
<td>4 Pull the rubber band tight, so that the paper clip is pressed against the card.
</td>
</tr>
<tr>
<td>5 Thread the other end of the rubber band through the second hole, as shown.
</td>
<td colspan="2">6 Tie a knot in the rubber band on the outside of the card so that the card automatically is folded into a triangular ‘tent’.
</td>
<td>7 Hold the flic-flac down flat on the bench so that the paperclip and knot are on the top surface, then slide your fingers off the flic-flac and watch it jump!</td>
</tr>
</table>

Time required

Approx 20—50 minutes, depending on the number of examples used (not including the follow-up activities)

Materials required

- STELR plastic flic-flac cards
- Paperclip
- Rubber band

Safety advice!

Ensure that the paperclips or rubber bands are not flicked into anyone's face.

Trial the activity first!

Advice

Limit the time spent on this activity. Students will have an opportunity to observe further examples of energy, energy transfers and energy transformations when they experiment with 'cotton-reel cars' and 'jumping cups' and in Practical Activity 2.

Discussion

The energy transformations occurring are shown as follows:

Elastic potential energy → Kinetic energy → Gravitational potential energy → Kinetic energy → Gravitational potential energy

When the device is released and shoots up into the air, its kinetic energy is transformed into gravitational potential energy. As it drops down again, its gravitational potential energy is transformed into kinetic energy. But even when it has dropped onto the bench or floor, it still has gravitational potential energy because it still can be lowered towards the Earth's centre.

OPTIONAL INTRODUCTORY ACTIVITY 3: ONLINE SIMULATION: ENERGY SKATE PARK

Activity outline

As an extension, the teacher may wish to use the simulation activity 'Energy Skate Park' as a stimulus for discussion.

Go to: http://phet.colorado.edu/index.php

When you enter the site, click on 'Play with sims'. On the menu that pops up on the left, select 'Physics' and then 'Work, Energy and Power'. You will then see the energy skate park simulation as one of the options.

OPTIONAL INTRODUCTORY ACTIVITY 4: OK GO RUBE GOLDBERG MACHINE

Activity outline

As an extension, the teacher may wish to use the You Tube video by OK Go as a stimulus for discussion.

Go to: http://www.youtube.com/watch?v=qybUFnY7Y8w

Watch the video and ask the students to identify some of the energy transformations that occur during the video clip.

TOPIC: ENERGY TRANSFORMATIONS AND TRANSFERS

RUNNING QUICK ACTIVITY 1: THE COTTON-REEL CAR

STUDENT BOOKLET page 6

Activity outline

Make a sample cotton-reel car by placing the rubber band on the little 'holder' at one end of the cotton reel, threading it through the hole at the other end, then inserting the dowel through the section of rubber band that protrudes, so that the rubber band cannot go back through the hole.

Next twist the dowel around until the rubber band is wound up tight. A completed cotton-reel car is shown on page 6 of the student booklet. Place it on a large bench top, let it go and watch what happens.

Then ask the students to discuss or debate or display in some way the energy transformations that they think have occurred, and/or complete the questions for this activity in the student booklet.

Time required

This will depend on whether you have the students make their own cotton-reel cars and then give them the opportunity to try modifying their design. A demonstration should only take a few minutes.

Materials

For demonstration or per student pair:

- STELR cotton-reel car
- Rubber band
- Dowelling

Safety advice!

If the floor is used in place of a bench top, ensure that the students do not trip on the 'car' as it moves about.

Advice

If they set up their own cotton-reel cars, students are likely to want to modify their designs to see if they make theirs go the furthest or the fastest. For example, they may change the length of the dowelling. This adds a real fun element to the activity, which is very worthwhile. Some modifications may cause the cars to go in circles.

In any discussion, elicit from the students what they understand by the terms they use. Compare and discuss which methods of displaying the energy transformations work best.

Discussion

The car works because the energy stored in the wound-up rubber band is transformed into kinetic energy as it unwinds. This is transferred to the 'wheels', causing them to rotate, which makes the car roll along.

The energy transformations in the cotton reel car could be represented as the following flowchart.

Elastic potential energy → **Kinetic energy** → **Heat energy**
(wound-up rubber band) *(rubber band unwinding, making 'car' roll)* *(transformation arising because of friction with surface)*

The first energy transformation occurs as the rubber band unwinds and the car moves forward.
The students may not think of the last energy transformation, but it explains why the car slows down and then stops.

TOPIC: ENERGY TRANSFORMATIONS AND TRANSFERS

RUNNING QUICK ACTIVITY 2: THE JUMPING CUP

STUDENT BOOKLET page 7

Activity outline

This is a fun stimulus activity that is designed to help students think further about energy and how transformation of energy and the conservation of energy might be represented.

The 'jumping cups' need to be carefully pressed down onto a smooth surface, then released. Pressing them down can take some practice. But when this is done successfully, the 'jumping cups' can jump some distance.

The students then need to identify the energy transformations that occurred and to think about how these might be represented.

Time required

This will depend on whether the class is taken outdoors for the activity. Experimenting with the jumping cups may only take a few minutes, but the subsequent discussion may take 10—15 minutes.

Safety advice!

Some schools have found it best to perform this activity outside, due to the height and distance the cups may jump. (This is only possible, however, if smooth surfaces are available to set the cups off.)

Advice

If the school does not have any 'jumping cups', the teacher may wish to demonstrate a similar toy or else substitute flic-flacs (see pages 72-73 in this resource).

Students are likely to set up challenges to see whose cup will jump the highest or furthest. This adds to the fun but should not be allowed to get out of hand.

In the follow-up discussion, elicit from the students what they understand by the terms they use. Compare and discuss which methods of displaying the energy transformations work best. But avoid getting caught up in complexities. Students should only be expected to identify straightforward energy transformations.

The third optional introductory activity, in which there is an online simulation of a skate park, is a good follow-up to this. See page 73 in this resource.

Discussion

The energy transformations in the jumping cup could be represented as follows:

The instant the cup jumps: **Elastic potential energy → Kinetic energy (+ Sound energy)**

As the cup moves upwards through the air: **Kinetic energy → Gravitational potential energy**

As the cup drops back down: **Gravitational potential energy → Kinetic energy**

When the cup hits a surface: **Kinetic energy → Heat energy (+ Sound energy + Elastic potential energy)**
(The cup deforms when it lands and makes a little noise, but the students may not think of these and should not be expected to do so at this early stage.)

The law of conservation of energy could be shown via a Sankey representation, in which the total arrow width remains constant. The teacher would need to show and discuss an example of these diagrams first, however.

TOPIC: ENERGY TRANSFORMATIONS AND TRANSFERS

RUNNING PRACTICAL ACTIVITY 1: ENERGY TRANSFORMATIONS AND TRANSFERS – INVESTIGATING A RANGE OF SITUATIONS

STUDENT BOOKLET pages 8—20

SYNOPSIS

This is a fun Round Robin activity for small groups in which the students rotate between different 'stations'. At each station they investigate a device or a process in which energy transfers and energy transformations take place. This will build on and reinforce their understanding of the concepts of energy, energy transfers and energy transformations.

Each group answers questions about all of the devices and processes they have investigated, as well as some general questions at the end. This is to enable students to think about what they are seeing, so that they can contribute meaningfully to the class discussion at the end.

No written reports need to be submitted, but this investigation should be followed up by a classroom or homework activity answering the general discussion questions on page 20 of the student booklet.

At some of the stations students are introduced to some of the equipment they will use in the rest of the STELR program, including the STELR model wind turbine and STELR model solar panel. This will help students to become familiar with and develop confidence and skills in using this equipment.

One station involving a simple and safe chemical battery is included to widen the scope of the investigation and provide students with an opportunity to investigate an energy transformation involving a chemical process.

Note: In the STELR Chemistry Curriculum, a number of these stations have been replaced with stations that involve chemical processes, including electrolysis and chemiluminescence. See the Appendix at the end of the teacher resource for the STELR Integrated Program for an outline of these stations and the accompanying teacher guide.

APPROXIMATE TIME REQUIRED

60 minutes, if students are to experience the majority of stations. They should spend about 10 minutes at each station; this time should include answering at least one of the questions.

BACKGROUND INFORMATION FOR THE TEACHER

Station C: A chemical battery

The chemical battery shown in Figure 3 page 12 of the student booklet is an early battery design. When (and only when) the circuit is complete, the more active metal present (zinc) gives up electrons. In the process Zn^{2+} ions are formed, which are soluble in water and hence migrate into the solution. Thus if the battery is run for long enough, you will clearly see the zinc electrode being 'eaten away' (corroded).

The electrons from the zinc electrode travel around the wires towards the copper electrode. Copper is a less active metal than zinc. The electrons then migrate down the copper electrode and react with water molecules that come in contact with its surface. This reaction splits the water molecules up, producing hydrogen gas (H_2) and hydroxide ions (OH^-). The hydrogen gas will be seen as small bubbles of gas forming around the copper electrode, which bubbles then rise to the surface.

Modern batteries are designed so that hydrogen gas is not produced, since this gas is explosive and hence hazardous. (Since this battery will only operating for a couple of minutes at a time, the small amount of hydrogen that will be produced will not be a safety concern.)

The role of the salt is to increase the conductivity of the water. (In the solution the electrical current consists of moving charged ions, not electrons.)

Substances that give up electrons during a chemical reaction are termed **reductants**, and substances that accept them are termed **oxidants**. An oxidant and a reductant must both be present in a battery if it is to produce an electrical current. In this case the reductant is zinc and the oxidant is water.

The balanced chemical equation for the net reaction is:

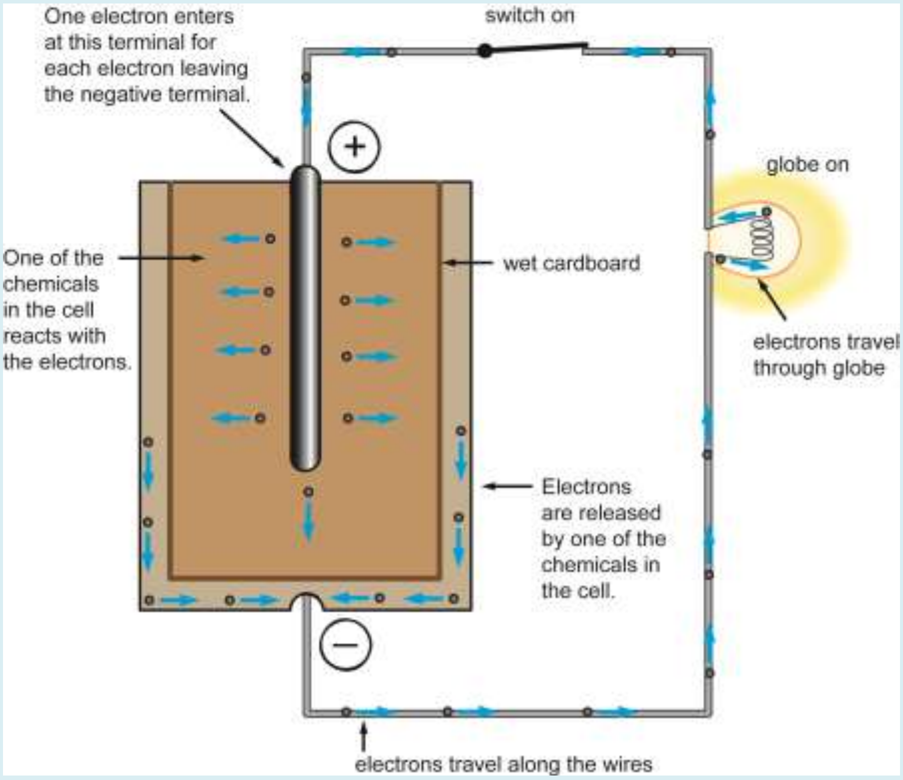
$Zn(s) + 2H_2O(l) \rightarrow Zn(OH)_2(s)^* + H_2(g)$

* If the reaction proceeds for sufficient time, a white precipitate of zinc hydroxide may be seen.

Station D: A commercial battery

Note: Like the battery in Station C, this is more correctly called a cell, not a battery. A battery consists of two or more cells connected together to deliver a higher power output.

Following is a schematic diagram of a simple commercial non-rechargeable cell at work. (This diagram is also shown on page 45 of the student booklet.)



In many commercial cells, such as the one shown in this diagram, the reductant also serves as the metal casing. (Generally this metal is zinc.) The oxidant is packed around the central electrode. When the circuit is complete, electrons are given up by reductant and enter the wire attached to the negative terminal. Electrons from the wire enter the positive terminal of the cell and are accepted by the oxidant.

The oxidant and reductant are always separated by a porous barrier because they would react spontaneously with one another if in direct contact. Electrons would transfer directly between them and the chemical potential energy of the reactants would be transformed into heat energy. By separating them, the electrons are forced to travel through the circuit instead. In this case the chemical potential energy of the reactants is transformed into useful electrical energy.

The barrier between the oxidant and reductant must be porous because it must allow the movement of ions between the electrodes so that the circuit is complete. The barrier can be as simple as some wet cardboard. The chemicals in the cell (other than the metals) are dissolved in a wet paste and not a watery solution, so that the cell is not too heavy

LIST OF MATERIALS REQUIRED

Station A: Mystery toys

- 2 x toys such as a wind-up car or music box or a battery-powered train that can light up, move and make a noise

Station B: A hand-cranked generator

- STELR testing station
- Motor generator with wheel
- Leads with a banana plug at each end connected to the terminals on the generator and to the MOTOR sockets on the testing station.

Practical advice:
Ensure that the magnet is facing the direction for which turning the wheel clockwise results in the fan turning clockwise.

Station C: A chemical battery

- Enough pairs of safety glasses for each group member
- Bottle containing 1 L of approx 0.5 M sodium chloride solution (30 g NaCl per litre)
- Copper electrode (or copper rod or copper strip)
- Zinc electrode (or zinc rod or zinc strip)
- 100 mL measuring cylinder
- 100 mL beaker
- Emery paper
- Wooden board
- Plastic tray
- Paper towel
- Two connecting leads (with banana plug at one end and alligator clip at the other)
- STELR multimeter

Practical advice:
1 If metal strips are used, ensure that they do not have sharp edges.
2 The metal should be sanded over the wooden board.
3 The beaker should be on the tray in case of spills.

Station D: A commercial battery

- STELR testing station
- STELR battery (or 2 x AA cells and holder) with leads that have banana plugs at each end connected to it

Practical advice:
Pre-test the battery to ensure that it works.

Station E: A model wind turbine

- STELR wind turbine, with six red blades inserted firmly at 45º, evenly spaced around the hub.
- Retort stand and bosshead
- Supplied fan
- STELR testing station
- Two leads with banana plug at each end

Practical advice:
1 Do not insert blades into a hub if it is on the turbine shaft.
2To insert the blades into a hub, loosen the tensioning knob or wing nut on the hub that holds them firmly in place. Insert the blades carefully at the correct angle, as shown in Figure 3 on page 50 of the student booklet. Press each blade into its hole as far as it can go, so its base is right against the hub. This may or may not produce a clicking sound. Then rotate it so that it is at an angle of 45º and its smooth side is facing the tensioning knob or wing nut. Ensure that the blades are evenly spaced. Once all the blades are inserted, tighten the knob or wing nut again. Note that if the blades are not inserted fully, the blades will be loose even if the tensioning screw or wing nut is screwed up as tightly as possible. This will create problems when the blades are spinning.

3 Insert the hub onto the turbine shaft correctly, as shown in Figure 4 on page 50 of the student booklet. Note that the correct shaft is the bottom shaft, which means that the wind turbine is ungeared.
4 Pre-test the circuit to ensure that it is connected the right way for the buzzer to work.

Station F: A solar panel

- STELR solar panel
- STELR testing station
- 3 x short yellow leads, 1 x red lead and 1 x black lead, each with a banana plug both ends
- 2 x halogen lamps and power pack (if direct sunlight cannot be used)

Practical advice:
1 This equipment should be set up fully connected, particularly since the students have not yet been reminded of, or introduced to, series and parallel circuits.
2 Connect the solar cell in series using the yellow leads to connect the cells. See Figures 8—10, pages 68—69, in the student booklet for how to do this.
3 Connect the red lead and black lead to the motor sockets on the testing station, as shown in Figure 6, page 18, in the student booklet.
4 If it is bright sunny day, use direct sunlight as the light source instead of the halogen lamps.

RISK MANAGEMENT

Teachers need to actively supervise this activity.
Note the following specific advice for the stations.

Station A: Mystery toys

Ensure that the students treat the toys very carefully and do not pull them apart or break them in their effort to determine how they work. This could lead to injuries.

Station B: A hand-cranked generator

1 Demonstrate how to crank the generator, using one hand to hold the unit onto the lab bench.
2 Ensure that the students do not damage or walk off with the drive belt! There are only 5 replacements in the STELR kit.
3 The magnet is designed to be removable to enable students to discover the important role it plays in the generator. But it is a very powerful magnet. Ensure that the students do not walk off with it.

Station C: A chemical battery

1 The chemicals used are generally regarded as very safe. The salt water is less concentrated than sea water. However, the teacher may be required by law to examine the MSDS (Material Safety Data Sheet) for each chemical present, and perform a risk assessment based on the information provided.
2 If metal strips are used rather than rods or bars, ensure that their edges are not sharp.
3 Ensure that the students do not injure themselves when sanding the metal and that they wear the safety glasses as instructed.
4 Ensure that the students only sand the previously dried metal electrodes over the wooden board. This should protect benches from damage.
5 Ensure that the students have the solution and beaker on the metal tray, to avoid spills.

Station D: A commercial battery

Students should be warned to avoid touching the two leads together, since this makes a short circuit and will quickly flatten the battery. Check that they follow this instruction.

Station E: A model wind turbine

1 Ensure that the students treat the wind turbine with great care, so that the blades, hub and motor are not damaged.
2 Ensure that the students do not put their fingers inside the safety cage of the large fan, or get long hair caught in it.
3 Make sure that the turbine blades are fitted tightly so that they cannot fly out when the turbine spins and injure students' eyes.
3 Make sure that the safety grill is secure on the fan. If necessary, use electrical ties to secure the grill.
4 Since this station requires the use of mains electricity for the large fan, ensure that there is no possibility of water getting near the circuits or switches and no possibility of short circuits being created.

Station F: A solar panel

1 If the halogen lamps are used as the light source, and not direct sunlight, ensure that there is no possibility of water getting near the circuits or switches and no possibility of short circuits being created.
2 Halogen lamps are prone to heating up with extended use. While the plastic housing is designed to prevent burns, students should be made aware of this risk.
3 Ensure that students treat the solar panel very carefully, especially if they move it around to keep it in sunlight.

ADVICE FOR THE CLASSROOM

See also the general advice about running practical activities on pages 28—29 of this resource.

Teachers are strongly advised to:

1 Ensure that students have been introduced to the concepts of energy, energy transfers and energy transformations prior to this investigation.
2 Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
3 Decide how to best manage the activity, particularly the size of each student group to avoid the problem of some students becoming spectators only. Groups of just two or three students are highly recommended. If necessary, set up two of each kind of station to accommodate this. Also determine the amount of time that can be spent at each station and how this will be managed.

Setting up:

Have the stations set up around the room.

Introducing the activity:

1 Elicit from the students what they already know about energy transformations and energy transfers

2 Tell the students they will be performing a 'Round Robin' of fun activities at different stations. Give them your directions about what groups they will be in, which station each group will start at, how you will signal the time to move to the next station, the direction in which they are to move when changing stations, and your expectations of their behaviour.

3 Show the students the different pieces of equipment, and demonstrate any key points about using the equipment.

4 Work through the safety precautions to be taken, eliciting as much as possible from the students.

5 It should be stressed that the students must negotiate as a group the answers to the questions at each station. Stress that the students will be expected to contribute some of their answers to the class discussion at the end of the session.

During the session:

Be very vigilant during the session.

Keep the groups moving around the stations according to the timetable that was set at the start of the session.

Watch that all students observe all of the agreed-upon procedures and safety precautions. This must include immediately wiping up any drips and spills from Station C.

When watching a group, ask the students questions about what they think is happening, or how the device works, and so on.

At the end of the session:

This part of the session is very important because it helps students clarify ideas in their mind, and helps develop communication skills and skills in analysis and evaluation.

Draw the students together to discuss and compare their findings. They could discuss what they discovered, any new ideas they had for ways of representing the energy transformations, what they found interesting or unexpected, and so on. Ensure that each group contributes to the discussion.

This part of the session should take about 10—15 minutes.

EXPECTED RESULTS

Station A: Mystery toys

Student response will depend on the toys.

Station B: A hand-cranked generator

Students should observe the following:

- There are two small LEDs at the back of the generator, next to the terminals. If the wheel is turned clockwise, the LED closest to the wheel goes on and the fan turns clockwise. If the wheel is turned anticlockwise, the LED furthest from the wheel goes on and the fan turns anticlockwise.
- The buzzer will only work if you reverse the leads or turn the wheel anticlockwise.
- The faster you turn the wheel, the faster the fan spins and the louder the buzzer sounds.
- When you turn the wheel, the copper coil spins in the same direction as the wheel.

Note: *The generator produces a direct current. The buzzer only works if the current flows in one particular direction through it.*

Station C: A chemical battery

Students should obtain a voltage reading.

If they leave the battery running instead of testing it very quickly, they also may observe bubbles forming around the copper electrode.

Note: *The bubbles are hydrogen gas – see the background information on page76 of this resource.*

Station D: A commercial battery

Students should observe the following:

- The fan rotates clockwise and the buzzer works.
- The fan works whichever way the leads are connected, but its direction of rotation reverses if the leads are reversed.
- The buzzer does not work if the leads are reversed.

Station E: A model wind turbine

Students should observe the following:

- The buzzer works when the large fan is set at Medium, but makes a soft noise. If the fan is turned to High, the buzzer is louder.
- The lamp works when the large fan is set at Medium, but is brighter when the fan is turned to High.

Station F: A solar panel

Student observations will depend on the intensity of the light shining on the solar panels. Very bright sunlight should make the fan spin faster and should make the lamp on the testing station shine more brightly than would be observed if the light source were the two halogen lamps.

The buzzer should work if the leads are connected the right way, and the lamp should go on.

SUGGESTED SOLUTIONS TO QUESTIONS

Note:

Students may represent the energy transformations in all of these devices as a list as shown in the suggested solutions, a flow chart or some other pictorial device of their own design (which may resemble a Sankey diagram, although these have not been introduced to the students).

Station A: Mystery toys

Student response will depend on the toys.

A wind-up car, for example, will contain a spring that will be coiled tighter when wound. When the winding is stopped, the spring will start to uncoil and return to its original shape. As it does, it causes a drive shaft to turn (via cogs), which makes the wheels of the toy turn.

For a wind-up car, the series of energy transformations could be:

Kinetic energy→ Elastic potential energy → Kinetic energy → Mechanical energy → Kinetic energy
(winder) (spring) (spring) (drive shaft) (wheels)

The unwinding of the spring that sets the successive parts of the car into motion, or the transfer of kinetic energy from the muscles of the hand to the winder, could be considered as a series of transfers of kinetic energy.

Note:
Some students may start with the chemical potential energy of their food then the kinetic energy of the muscles involved in winding up the toy. They may even consider the transformation of some of the kinetic energy of the wheels to heat energy due to friction. (Students should not be expected to include this, but should be acknowledged if they do suggest it.)

Station B: A hand-cranked generator

For the fan, if we start with the wheel, one representation of the series of energy transformations could be:

Mechanical energy → Electrical energy → Mechanical energy → Kinetic energy
(turning wheel) (generator) (drive shaft of fan) (fan)

For the buzzer, if we start with the wheel, one representation of the series of energy transformations could be:

Mechanical energy → Electrical energy → Sound energy
(turning wheel) (generator) (buzzer)

Note:
Some students may start with the chemical potential energy of their food then the kinetic energy of the muscles involved in turning the wheel. Some students may include transformation into heat energy due to friction and electrical resistance. (Students should not be expected to include this, but should be acknowledged if they do suggest any of these.)

Discussion questions:

1 *Examples of energy transfer include:*

- The transfer of electrical energy from the generator to the fan or buzzer, via the electrical circuit.
- The transfer of the mechanical energy of the wheel to the mechanical energy of the copper coil of the generator. *(Students may classify this as kinetic energy.)*

2 It reverses the direction of the current. You have to turn the wheel the opposite way or connect the leads the opposite way to before, to obtain the same results. The buzzer only works when the current travels through it in one direction.

3 [*Student response*]

4 [*Student response*]

Station C: A chemical battery

One representation of the energy transformation occurring could be:

Chemical potential energy → Electrical energy

Note:
Some students may consider the production of some heat energy (due to electrical resistance).

1 An example of an energy transfer is the transfer of electrical energy from one electrode to the other, via the electrical circuit.

2 [*Student response*]

Station D: A commercial battery

For the fan, one representation of the series of energy transformations could be:

Chemical potential energy → Electrical energy → Mechanical energy → Kinetic energy
(chemicals in battery) (battery) (drive shaft of fan) (fan)

For the buzzer, one representation of the series of energy transformations could be:

Chemical potential energy → Electrical energy → Sound energy
(chemicals in battery) (battery) (buzzer)

Note:
These have not taken into account any transformation of chemical potential energy or electrical energy into heat energy as the devices work. For example, due to the electrical resistance of the circuit components, some of the electrical energy will be converted to heat energy. (Students should not be expected to include this, but should be acknowledged if they do suggest this.)

Discussion questions:

1 *Examples of energy transfer include:*

- The transfer of electrical energy from the electrodes to the fan or buzzer, via the electrical circuit.
- The transfer of the kinetic energy of the fan to the air, causing a little breeze.
- The transfer of the sound energy of the buzzer to the air and to our ears.

2 [*Student response will depend on results*]

Station E: A model wind turbine

For the buzzer, one representation of the series of energy transformations could be:

Kinetic energy → Mechanical energy → Electrical energy → Sound energy
(wind) (turbine) (generator) (buzzer)

For the lamp, one representation of the series of energy transformations could be:

Kinetic energy → Mechanical energy → Electrical energy → Light energy
(wind) (turbine) (generator) (lamp)

Discussion questions:

1 *Examples of energy transfer include:*

- The transfer of electrical energy from the turbine to the fan or buzzer, via the electrical circuit.
- The transfer of the sound energy of the buzzer to the air and to our ears.

2 [*Student response*]

Station F: A solar panel

For the fan, one representation of the series of energy transformations could be:

Light energy → Electrical energy → Mechanical energy → Kinetic energy
(lamps or Sun) (solar panel) (drive shaft of fan) (fan)

For the lamp on the testing station, one representation of the series of energy transformations could be:

Light energy → Electrical energy → Light energy
(lamps or Sun) (solar panel) (lamp)

Discussion questions:

1 *Examples of energy transfer include:*

- The transfer of electrical energy from the solar panel to the buzzer or lamp, via the electrical circuit.
- The transfer of the sound energy of the buzzer to the air and to our ears.

2 [*Student response will depend on what was observed*]

3 [*Student response*]

DISCUSSION QUESTIONS FOR ALL STATIONS

1 *Possible student responses include:*

a Radio, CD player, iPod, etc.
b Lights in buildings or cars, torch, etc.
c Television, computer, mobile phone, etc.
d Radiator, electric stove, kettle, iron, etc.
e Wind turbine, bicycle
f Generator
g Electric motor, electric fan

2 For the water dropping down the pipes from the dam, the energy transformation occurring would be:

Gravitational potential energy → Kinetic energy

For the swiftly moving water turning the turbine, the energy transformation occurring would be:

Kinetic energy → Mechanical energy

For the generator, the energy transformation occurring would be:

Mechanical energy → Electrical energy

Examples of energy transfer include:

- The transfer of mechanical energy from the turbine to the spinning shaft then to the coils inside the generator.
- The transfer of electrical energy from the generator to the power lines.

3 [*Student response*]

TOPIC: CONSERVATION OF ENERGY & ENERGY EFFICIENCY

BACKGROUND INFORMATION FOR THE TEACHER

What is 'wasted' energy?

Energy can never be created or destroyed. This is known as the **law of conservation of energy**.

Therefore, even when an energy transformation takes place, the total energy before and after is the same.

The case of an incandescent light globe

When an incandescent globe light globe is turned on, the globe gets hot. This is because inside the globe, electrical energy is transformed into both light energy and heat energy. The law of conservation of energy states that the total amount of light energy and heat energy produced will equal the total amount of electrical energy that was transformed.

In the light globe, only a small percentage of the available electrical energy is transformed into light energy; the rest is transformed into heat energy, as shown in Figure 1. Since the heat energy is not used, it is regarded as **'wasted' energy**.

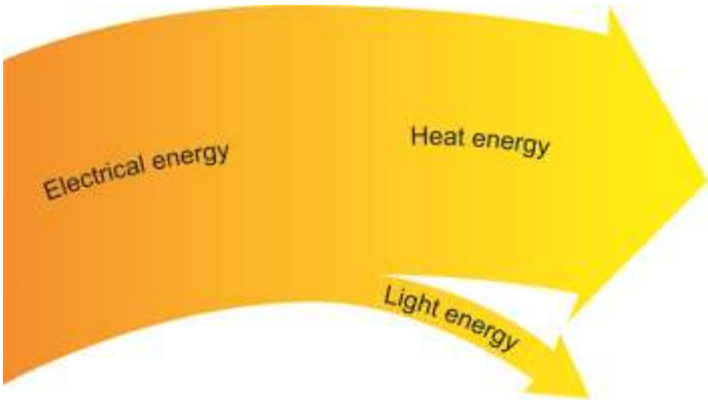


Figure 1. A Sankey diagram showing that in an incandescent light globe, most of the electrical energy has been transformed into heat energy. Only some is transformed into light energy.

The case of a mobile phone

Inside a mobile phone a number of energy transformations are taking place whilst it is being used. One is that the chemical potential energy of chemicals inside the battery is being transformed into electrical energy. However, because there is some resistance to the flow of an electrical current inside the battery, as well as in the wires, not all of the chemical potential energy is transformed into electrical energy. Some is transformed into heat energy. (This is one reason why your mobile phone gets hot when you keep holding it to your ear.) The heat energy produced is not useful, so is considered to be wasted energy.

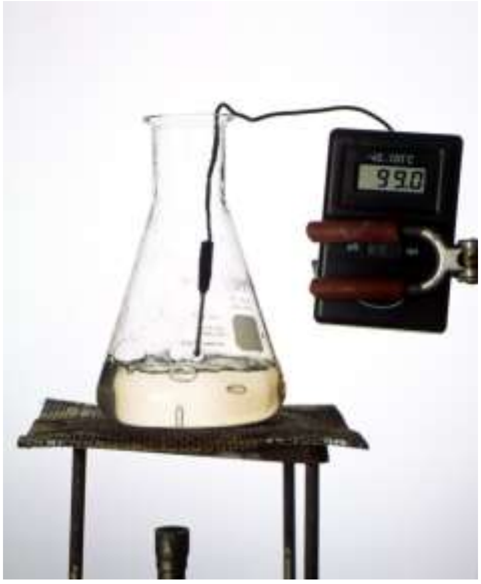
In general

These examples are typical of what occurs in an energy transformation. In every case:

- At least two different forms of energy are produced, one of which is heat energy.
- At least one of the forms of energy produced is not useful and so is regarded as wasted energy.

In most cases of energy transformations, the heat energy produced is wasted energy. However, heat energy is not the only form of energy that may be unable to be used in a particular process. For example, many processes produce a noise. In these cases the sound energy produced is wasted energy.

Dissipation of energy



When a solution is heated over a Bunsen burner, ideally all of the heat energy supplied by the Bunsen burner will be used to heat the solution.

Unfortunately this does not happen. The tripod, gauze mat, barrel of the Bunsen burner and the glass flask also get very hot. The air near the burner warms up as well.

The reason that they get hot is that some of the heat energy from the Bunsen burner is transferred to the metal in the tripod, gauze mat and barrel, and to the glass of the flask. Some is transferred to the air and a little is transferred to the temperature sensor.

The loss of useful energy due to energy transfer to other objects and materials in the environment is termed the **dissipation** of energy.

The dissipation of energy is another way energy can be wasted.

Figure 2. Heating a solution over a Bunsen burner.

Source: http://mirror-au-nsw1.gallery.hd.org/_exhibits/natural-science/_more1999/_more05/steam-condenses-near-100C-bunsen-burner-boiling-water-in-glass-beaker-white-backdrop-1-AJHD.jpg

Accessed: 28 January 2011

Measuring energy

The international metric unit (SI unit) used for energy is the **joule**, symbol **J**.

The joule can be used to measure all forms of energy. Another energy unit that is commonly used for electrical energy is discussed on page 108 of this resource.

Measuring large amounts of energy

As with other measurement units, standard prefixes can be used for the units used to measure large amounts of energy. The most commonly used prefixes are shown in Table 1.

Table 1. Common prefixes for energy

Prefix	Symbol	Factor	Example
kilo	k	1000	One kilojouke (kJ) is a thousand joules.
mega	M	1 000 000, i.e. 10^6	One megajoule (MJ) is a million joules.
giga	G	1 000 000 000, i.e. 10^9	One gigojoule (GJ) is a thousand million joules.
tera	T	1 000 000 000 000, i.e. 10^{12}	One terajoule (TJ) is a million million joules.

Percentage energy efficiency

Whenever any energy resource is used, the process involved requires at least one energy transformation. But no energy transformation is 100 per cent efficient. Energy is generally wasted as heat energy.

One way scientists can compare the performances of different energy resources is to measure their percentage energy efficiency. **Percentage energy efficiency** is a measure of the percentage of available energy that is useful. Ideally this should be as high as possible.

Percentage energy efficiency is measured by the formula:

$$\text{Percentage energy efficiency} = \frac{\text{amount of useful energy obtained}}{\text{original amount of energy available}} \times \frac{100}{1}$$

***Note:* The energy can be measured in any unit. However, the two amounts of energy must be measured in the *same* energy units.**

Examples of calculations

Example 1

Consider a particular incandescent light globe. Typically, only 5 % of the available electrical energy is transformed into useful light energy. The remaining 95 % is 'wasted' as heat energy, as shown in Figure 3.

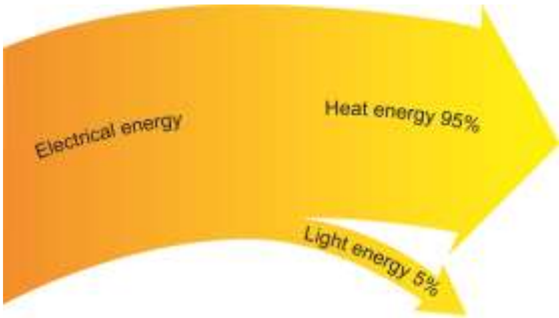


Figure 3. A Sankey diagram showing what percentage of the available electrical energy is transformed into light energy and what percentage is wasted as heat energy in a certain incandescent light globe.

We say that the percentage energy efficiency of the light globe is 5 %. This means that of each 100 joules of electrical energy transformed within the light globe, only 5 joules is transformed into useful light energy. (The remaining 95 joules is transformed into heat energy, which is not useful.)

Example 2

Consider the case of boiling water in a plastic electric kettle. In a certain experiment in which a scientist made a number of measurements, it was found that although 900 J of electrical energy was 'delivered' to the kettle, only 765 J of heat energy was absorbed by the water. Calculate the percentage energy efficiency of heating the water.

Solution

Original amount energy available = 900 J

Amount of useful energy obtained = 765 J

$$\text{Percentage energy efficiency} = \frac{\text{amount of useful energy obtained}}{\text{original amount of energy available}} \times \frac{100}{1}$$

$$= \frac{765}{900} \times \frac{100}{1}$$

$$= 85\%$$

This tells us that 85% of the available electrical energy was transformed into heat energy that was absorbed by the water; 15% was wasted (100 – 85 = 15).

This energy efficiency is quite high, and occurs because the kettle is made from a plastic which is a poor conductor of heat. That is, it is a good heat insulator, and prevents most of the heat energy from dissipating.

Interesting facts

1 LEDs are about ten times more efficient at transforming electrical energy into light energy than are incandescent light globes. Typically the percentage energy efficiency of an LED is about 50 %.

2 Photosynthesis is a very inefficient process. Sugar cane plants are more efficient at transforming light energy into chemical potential energy than almost all other plants, but even then the percentage energy efficiency is only about 4 %. This is shown in the following Sankey diagram.

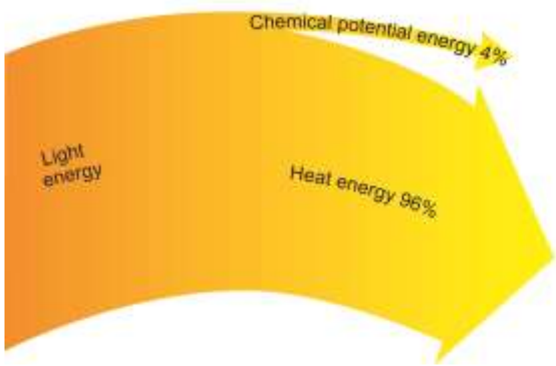


Figure 4. A Sankey diagram showing what percentage of the available light energy is transformed into chemical potential energy and what percentage is wasted as heat energy in a certain sugar cane plant.

3 The main energy transformations involved in producing petrol, and using it to drive a car, are shown in Figure 5.

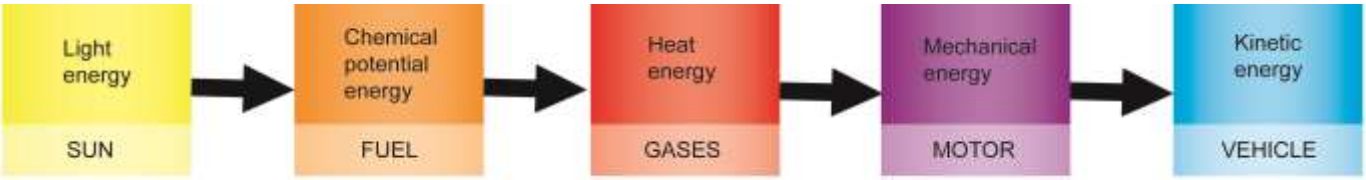


Figure 5. A flow chart showing the main energy transformations involved in running a petrol-driven car.

The two energy transformations shown in the middle of Figure 5 occur within the car motor. The gases are produced when the petrol burns. The percentage energy efficiency of the overall transformation of the chemical potential energy of the petrol into mechanical energy within the car motor is only around 30 %.

TOPIC: CONSERVATION OF ENERGY& ENERGY EFFICIENCY

IDEAS FOR INTRODUCTORY ACTIVITIES ON THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY

SYNOPSIS

The bouncing balls experiment can be used to introduce the concept of energy efficiency.

These two optional teacher demonstrations, however, show different examples of 'wasted' energy. They are intended to be a good discussion starter before launching into a discussion of percentage energy efficiency.

These activities will enable the teacher to identify whether any students still have alternative conceptions about what happens to energy as it undergoes transformations and to help the students gain a clearer understanding of the concepts involved.

The optional follow-up excursion would be a very powerful, memorable way for students to learn why energy efficiency is a very important criterion when comparing different energy resources.

ADVICE ON INTRODUCING THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY

1 Rather than converging too quickly to the key science ideas, whichever demonstration you select, treat it as principally one in which ideas from the students are expressed, shared and discussed. But by the end of the discussion, students should have at least begun to develop a common understanding of the conservation of energy and 'wasted' energy.

2 Flow charts are a very useful way to trace the series of energy transformations that might occur. These can be annotated to show where energy might be 'wasted'.

3 Through these discussions and their subsequent practical work it is important that students realise that:

- One key factor in determining the viability or suitability of energy resources is their energy efficiency.

- No energy transformation is 100 % efficient.

OPTIONAL INTRODUCTORY ACTIVITY 1: GENERATING AN ELECTRIC CURRENT

Activity outline

Set up the STELR hand-cranked generator connected to the lamp on the STELR testing station.

Ask the students whether they think all of the energy invested in turning the handle is transformed by the lamp into light. If not, where in the series of energy transformations occurring is the energy 'lost' (wasted)? Can energy just disappear? What happens to the 'wasted' energy?

Lead the discussion to other inefficient energy transformations, such as those that occur in car engines.

You need

- STELR hand-cranked generator
- STELR testing station
- Connecting wires

Discussion

In the arm used to crank the wheel, not all of the available chemical potential energy is transformed into the kinetic energy of the muscles; some is 'wasted' as heat energy. Some of the kinetic energy transferred to the wheel is transformed into heat energy instead of electrical energy, due to the internal resistance of the wires. In the lamp, most of the electrical energy is transformed into heat energy instead of light energy.

In most car engines, less than 30 % of the chemical potential energy of the fuel is transformed into the car's movement. For example, much of the heat energy produced during the combustion of the fuel is transferred to the surroundings, including the car engine; not all is used to expand the gases that push the pistons.

OPTIONAL INTRODUCTORY ACTIVITY 2: BOILING WATER

Activity outline

Heat an electric kettle of water, and/or boil water in a beaker over a Bunsen burner.

In the case of the kettle, ask the students to identify where some of the original supplied energy might be wasted. (They can consider the energy transformations and transfers that occur in the power station and along the power lines.)

In the case of the Bunsen burner, ask the students to identify where some of the energy supplied by burning the gas in oxygen might be 'wasted' – that is, not used to heat the water

You can also invite suggestions on how this energy wastage can be reduced.

You need

- Electric kettle – preferably metal; *and/or*
- Bunsen burner, beaker half-filled with water, tripod, gauze mat, heat mat, matches,

Discussion

For the kettle, some of the heat energy supplied by the heating element is transferred to the metal of the kettle and to the surroundings instead of being used to heat the water. This heat energy comes from the energy transformation that occurs in the heating element inside the kettle: Electrical energy → Heat energy.

If you trace back to the source of this electrical energy, then about 10 % of the electrical energy supplied by the power station is 'lost' during transmission, because it is transformed into heat energy due to the resistance of the wires. The further the school from the power station, the greater the percentage loss. (It may reach approximately 12—15 %.) Then there are all the ways in which the energy is 'wasted' at the power station itself, which will depend on what kind of power station it is.

For the Bunsen burner, when the gas burns, not all of its chemical potential energy is transformed into heat energy. Some is transformed into light energy and some into sound energy. Like the kettle, only some of the heat energy produced is transferred to the water; the remainder is transferred to the materials involved (such as the glass of the beaker, and the metal Bunsen burner barrel), and also to the surrounding air.

OPTIONAL FOLLOW-UP ACTIVITY

Consider arranging an excursion to the power station that supplies the area. Find out where in the process energy is wasted and what strategies are used to improve energy efficiency.

TOPIC: CONSERVATION OF ENERGY & ENERGY EFFICIENCY

DESIGNING EXPERIMENTS – INFORMATION FOR THE TEACHER

Advice for running student-designed investigations

The 'Bouncing Balls' student practical activity is an opportunity to introduce the principles of designing investigations. The teacher may elect to use it as a means of teaching students how to identify and control variables, take accurate measurements, and so on. The following information may assist in this. This will be valuable training for the other student-designed investigations later in the program.

The teacher also may wish to provide students groups with an enlarged copy of the Investigation Planner on pages 81—82 of the student booklet for planning their investigations.

Student versions of the following outline are provided in the student booklets for the STELR Integrated Curriculum and the STELR Chemistry Curriculum.

How scientists work

The process by which true scientists conduct their investigations, often called the scientific method**,** is summarised in Figure 1. This process is what distinguishes true scientists from **pseudo-scientists** - that is, people who pose as experts and promote their ideas but do not test their ideas and modify them in the light of the evidence those tests provide.

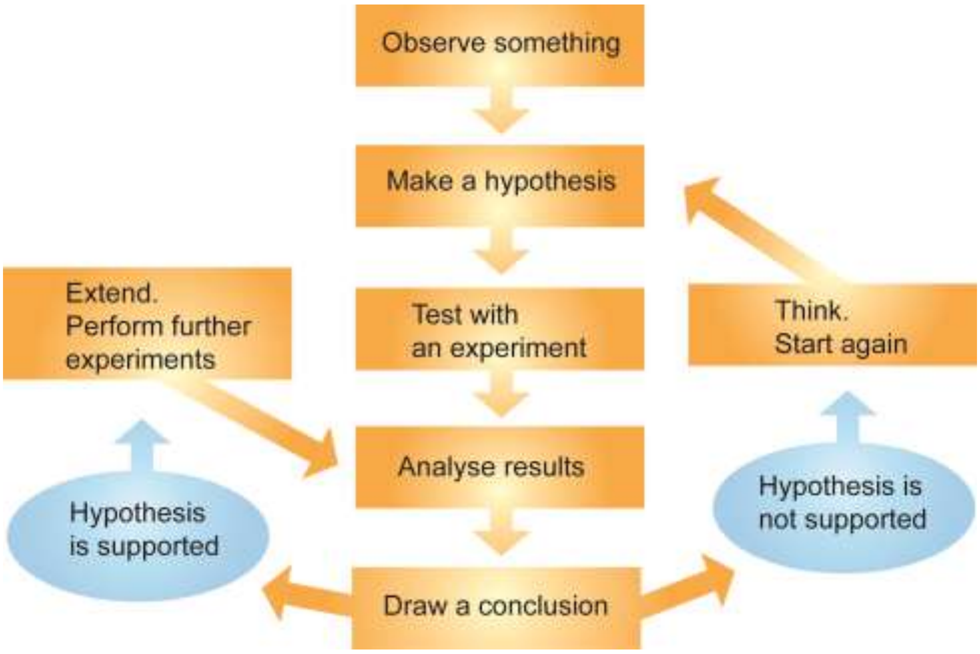


Figure 1. How scientists work.

What is a hypothesis and how is it different to a theory?

A **hypothesis** is a proposed explanation for some phenomenon or event that has been observed. A **scientific hypothesis** is one that can be tested by experiment.

Scientists usually have to modify their hypotheses many times, after new evidence is gathered by themselves or others. This is why the process that scientists use is shown in Figure 1 as a continual loop.

Some people think that 'hypothesis' is just another name for a theory. This is not the case for scientific hypotheses and scientific theories, although they are alike in some ways. Where they differ is in the amount of evidence on which they are based. This is shown in Table 1 on the next page.

Table 1. Scientific hypotheses and theories

Comparison	Scientific hypothesis	Scientific theory
Similarities	Proposed explanation for some phenomenon.	Proposed explanation for some phenomenon.
	Must be revised if any new data is obtained that does not support it.	Must be revised if any new data is obtained that does not support it.
Difference	Based on a limited number of observations.	Based on a huge amount of scientific evidence that has been collected over a long period of time.

Designing an investigation

The main steps are shown next.

Step 1: The aim of the investigation

Where possible, once scientists have an inquiry question they wish to investigate, they propose a hypothesis.

In designing any investigation, they first must decide precisely what they are trying to discover. This is called the **aim** of the experiment. This aim must be very specific and reflect the hypothesis.

Step 2: Identifying the variables

Once the aim is clear, scientists plan precisely how they will perform the experiment. The first step of this process is identifying what variables will be operating in the experiment. **Variables** are factors that may affect the outcome of an experiment. These may include factors such as temperature, the amount of light, and so on.

Step 3: Designing a fair test

Next one or more fair tests are designed. In a **fair test,** one variable at a time is tested. This is called the **test variable**. All other variables are controlled so that they do not change. This ensures that they cannot affect the results of the test so that the effect of the test variable can be identified.

Step 4: Planning to obtain reliable data

- Wherever it is possible, scientists always take relevant measurements so that they have objective evidence. **Objective evidence** is evidence that does not depend on people's judgement. No matter which scientist takes the measurement, the result should be the same (provided the same instruments are used).

- Scientists always have their work checked by other independent scientists before their findings are published in professional journals. If their findings are to be deemed reliable, any measurements they take must be able to be reproduced by other scientists who are performing the same experiment to check their work. So they need to choose the most accurate instrument available and to take their measurements very carefully.
- In addition, for the variable being tested, the experiment must be designed so that there is a sufficient amount of data to be able draw a reasonable conclusion about the effect of the variable. Ideally the data should be graphed so that any relationships are clear. The greater the amount of data, the more reliable the conclusion will be.

Thus scientists need to decide what and how many measurements they need to take, and the most accurate way they can take them.

Step 5: Performing a risk assessment

Once scientists have decided what tests they will do, what measurements they will take and how many, and what instruments they will use, they think very carefully about what risks will be involved and how they will minimise the risk.

To do this they gather information about the risks associated with the equipment they are using and any chemicals they will use or produce. The information sheets they obtain about chemicals are known as Material Safety Data Sheets (MSDS).

They then think through each step and imagine what could go wrong, and decide how they can avoid or reduce any safety risk involved. They also ensure that they know what to do should any accident occur and that they have any safety equipment that might be required.

Step 6: Ethical considerations

If scientists are proposing to perform investigations that involve testing living organisms or viruses, or even DNA samples, for medical, veterinary, biological or agricultural research, they must present their plans to an ethics committee for approval before they start their experiments. Likewise, if they are testing dangerous substances, such as radioactive substances, they are likely to be required to obtain approval for that research.

In addition, it is always important that scientists approach their research ethically. That is, they must report their results honestly, and not change them or delete some in order to 'prove' their hypothesis is correct. They must be willing to acknowledge if their hypothesis was incorrect or if there are errors in their work.

Likewise, they should acknowledge any assistance they have been given from any previous research or another scientist.

Performing the investigation

Once scientists know what they want to find out and how they will go about their experiment, and have the necessary permission where the research requires approval, they are ready to perform the experiment.

Processing the results

Generally at this stage the measurements are used to calculate quantities and/or draw graphs.

Following is some advice about performing calculations.

Advice on performing calculations

Where calculations are required, any formula that is used and all steps should be shown. This makes it easier for anyone examining the report to follow the logic and to identify any mistakes.

If many repeat calculations are required, it is best to show one sample calculation and devise a table to display the key 'in-between amounts' and final answers. This saves a lot of writing.

If an average is to be calculated, the average should not have more figures than the original measurements, since it cannot be more accurate than the collected data. For example, if each measurement has 2 decimal places, then the average must be rounded off to 2 decimal places.

Drawing a conclusion

Once the results have been processed a conclusion must be drawn. The **conclusion** is a statement of what was discovered.

The conclusion must:

• Answer the aim.

• Be based on the results that were actually obtained. This applies even if the results were not what were expected.

• Should include a statement about whether the hypothesis has been supported, or not.

Evaluating the experiment

This is the final step of the investigation. This evaluation should include:

- An evaluation of the results. How reliable are they? (This includes identifying sources of error.)
- An evaluation of the design of the experiment. This includes identifying ways in which the testing could have been improved.
- An outline of further tests that could be performed to more strongly support the conclusion or to further explore the factors involved.

NOTE: In this STELR program, it is assumed that students have not been introduced to significant figures. If they have, then teachers should point out that the final answer should not have more significant figures than any of the experimental data used to calculate it. In any case, students should be told to round answers off and not copy every digit off their calculator display.

TOPIC: CONSERVATION OF ENERGY & ENERGY EFFICIENCY

RUNNING PRACTICAL ACTIVITY 2: BOUNCING BALLS

STUDENT BOOKLET pages 22—27

SYNOPSIS

This is a fun class experiment. Different groups of students measure the heights of tennis balls as they bounce on different surfaces, or are dropped from different heights. Other groups investigate the heights of rebounds when different kinds of balls are bounced off a hard surface. Students then pool their results to determine which balls and surfaces and starting heights produce the greatest percentage energy efficiency of the bounce.

This provides students with an opportunity to:

- Build on and reinforce their understanding of the concepts of 'useful' and 'wasted' energy and energy efficiency in a familiar context (ball sports).
- Learn about and practise the principles of good experimental design, including multiple trials in data collection.

APPROXIMATE TIME REQUIRED

60 minutes

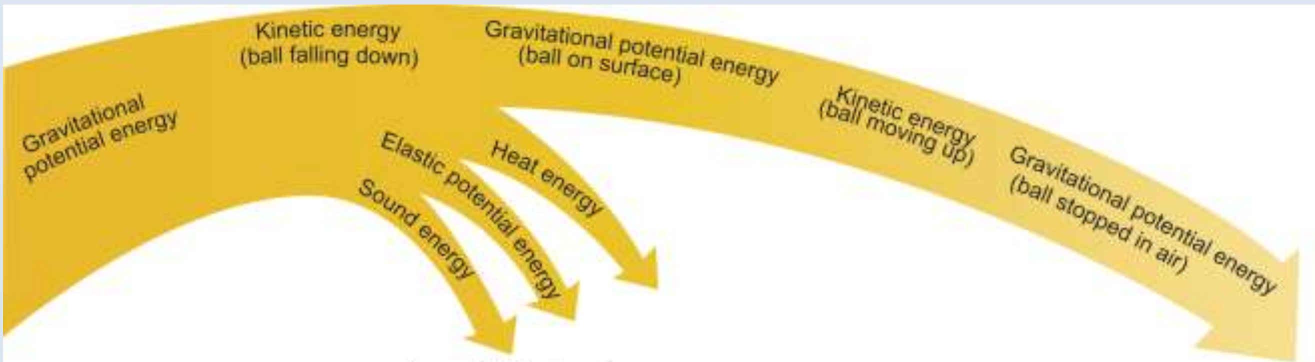
BACKGROUND INFORMATION FOR THE TEACHER

Bouncing balls

The following website is a very useful, comprehensive resource for teachers on the physics of bouncing balls. It includes a graph of the 'relative bounciness' of different kinds of balls when bounced on the same surface. (This would be a measure of the percentage energy efficiencies of their bouncing from the same height on the same surface.)

http://www.exploratorium.edu/baseball/bouncing_balls.html

One possible Sankey diagram that represents the energy transformations that occur when bouncing a ball is shown below.



A possible Sankey diagram

Why can bounce height be used to measure percentage energy efficiency?

Just before it falls from its new rebounded height, the gravitational potential energy of the ball at this height, compared with its gravitational potential energy at the Earth's surface, is given by:

E = mgh

where *E* = gravitational potential energy (joules)
m = mass of ball (kilograms)
g = gravitational field strength (newtons/kilogram, where the newton is a unit of force)
h = height above the surface (metres)

We can calculate the percentage energy efficiency of the bounce by substituting into the formula:

$$\text{Percentage energy efficiency} = \frac{\text{amount of useful energy obtained}}{\text{original amount of energy available}} \times \frac{100}{1}$$

However, because the ball does not change mass and the gravitational field strength is the same when the ball first drops and when it rebounds, these quantities will cancel out in the formula for percentage energy efficiency. This results in a simple formula for the percentage energy efficiency of a rebound. This is shown below.

$$\text{Percentage energy efficiency of rebound} = \frac{m \times g \times \text{(maximum height of ball when it rebounds)}}{m \times g \times \text{(height of ball before dropped)}} \times \frac{100}{1}$$

m **and** ***g*** **cancel, so:**

$$\text{Percentage energy efficiency of rebound} = \frac{\text{maximum height of ball when it rebounds}}{\text{height of ball before dropped}} \times \frac{100}{1}$$

Note: Because any unit conversion factors will also cancel out, the ball height can be measured in any length unit. It does not have to be stated in metres. Nevertheless, the two heights must be measured in the same units.

Also see the background information on designing experiments on pages 91-93 of this booklet.

LIST OF MATERIALS REQUIRED

Per student pair:

- Tennis ball (pairs in Group A or in Group B) or set of different balls (pairs in Group C)
- Metre ruler or digital device for measuring ball height
- Digital camera or video recorder (optional)
- Graph paper and pencils and rulers, or spreadsheeting and graphing software (optional)
- A3-sized copy of the Investigation Planner (pages 81—82 of the student booklet) (optional)

PRACTICAL ADVICE AND HINTS

1 The set of balls for pairs in Group C should include a tennis ball, and may also include a basketball, ping pong ball and soccer ball. Balls that are made of polymer materials designed to bounce at a very high efficiency are available in some retail outlets; it may be worthwhile to include one of these balls.

2 For pairs in Group A, a variety of surfaces could be provided and tested in the classroom, such as wooden boards, plastic and so on. They may also include outdoor surfaces such as grass, concrete, tiled or brick paving, and timber.

3 Check that the students have their calculators with them, or provide a set of calculators.

4 The provision of enlarged copies of the Investigation Planner will encourage a collaborative response and give students more space for writing.

RISK MANAGEMENT

Safety advice!

1 Normal precautions regarding supervision of students should be taken if any student groups are working outdoors.

2 Teachers need to actively supervise this activity.

Possible responses to the students' risk assessment activity are shown below.

Student activity sheet: Table 2

The facts	What might be the risks?	What precautions will we take?
1 Balls can damage things or cause injuries when they bounce.	Classroom windows and items in the classroom or where testing is conducted outside could get broken. Balls could hit people in the face when they bounce.	Only bounce balls in a controlled way in cleared areas. Stand back when the ball bounces – do not stand over it.
2 If a ball is bounced outdoors, it can roll away.	If the ball runs onto an area where there is traffic, anyone chasing it could be injured.	Only bounce balls in areas where there are barriers to control where they go.

ADVICE FOR THE CLASSROOM

Working in small groups of two or three gives students a greater opportunity to be actively engaged instead of merely being spectators in the activity. As a result, they are more likely to develop the skills and understandings that will help them in later investigations.

See also the general advice provided on pages 28—29 of this resource.

Teachers are strongly advised to:

1 Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
2 Decide how to best manage the activity, particularly how to divide the class, who should be in each group, what kinds of balls and surfaces will be manageable, what device would be best for measuring ball height, how to measure ball height consistently and accurately, whether to have the students design and draw up their own results tables or use spreadsheets, what kinds of graphs the students should draw, and where to conduct the activity.

Setting up:

Have a demonstration set of measuring equipment and a ball ready to perform a demonstration during the introductory discussion.

Introducing the activity:

1 Introduce this practical activity by eliciting from the students what they have already discovered about energy efficiency.
2 Work through the information on how energy is 'wasted' when a ball bounces, how ball height can be used to directly measure the percentage energy efficiencies of the bounces, and the sample calculation.
3 Outline the inquiry questions. Tell the students they will be performing a class experiment and pooling their results to answer the inquiry questions. Discuss how the class is to measure the ball height (distance between bottom of ball and surface), and how to avoid parallax error.
4 Elicit from the students what they already know about how scientists go about their experiments, variables, fair testing, and taking accurate measurements. Ask them how they would apply these principles to answering the inquiry questions they have been set. Discuss the ethics of scientific investigation. Distribute copies of the investigation planners if these are to be used.
5 Demonstrate the most important points about taking accurate and consistent measurements of ball heights, and avoiding parallax error (if this could occur with the measurement method to be used).
6 Elicit from the students what kinds of graphs would be suitable for displaying their results, and why they need to take repeat measurements and calculate averages.
7 Work through the risk assessment and safety precautions to be taken, eliciting as much as possible from the students.
8 Assign the pairs to their groups.
9 State your expectations of their behavior and the time limits they will work under.

During the session:

1 Ensure that the students follow the expected planning procedures before starting their experiment.
2 Watch that the students observe all of the agreed-upon procedures and safety precautions and are obtaining results in a timely manner.
3 When watching a particular student pair, ask questions about what they are predicting and observing, how they might explain their results, what might be sources of error and why the experiment is designed in this way.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report their findings and to display their graphs. They should discuss what they found interesting or unexpected, problems they encountered, their conclusions and their responses to some or all of the discussion questions. Ensure each group contributes to the discussion.

This part of the session should take about 10—15 minutes.

EXPECTED RESULTS

The percentage energy efficiencies of the bounces will depend on the balls and surfaces used. (See the website recommended on page 94 of this resource for data about different balls on same surface.)

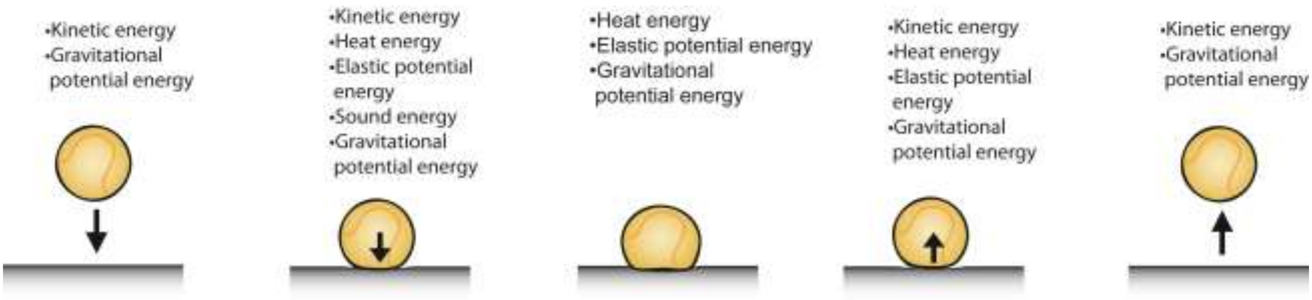
SUGGESTED SOLUTIONS TO DISCUSSION QUESTIONS

1 [*Student response will depend on the results*]

2 [*Student response will depend on the class results*]

3 *See the Sankey diagram on page 94 of this resource. Flow charts could centre on the instant of the bounce, with kinetic energy being transformed into gravitational potential energy and heat energy and elastic potential energy and sound energy.*

4 One possible set of sketches is shown below.



5 a $\frac{110}{200} \times \frac{100}{1} = 55\ \%$

b *This response should be based on the students' findings. It should be that the percentage energy efficiency of the rebound is lower for the softer surface, since a soft surface deforms more easily than a hard surface. More energy is 'wasted' in deforming the soft surface, leaving less energy for the ball's rebound.*

TOPIC: ENERGY RESOURCES

BACKGROUND INFORMATION FOR THE TEACHER

AT HYDROELECTRIC POWER STATIONS

See Figure 7 on page 20 of the student booklet for a schematic diagram of how a hydroelectric power station works.

What is a turbine?

Figure 1. Turbines at the Waddamana Power Station in Tasmania. This power station is no longer in operation. It has been converted to a museum. *Waddamana* is a Tasmanian Aboriginal word meaning 'noisy water'. PHOTO CREDIT: Hydro Tasmania.

A **turbine** looks like a giant fan. It is a machine that consists of a set of blades, 'scoops' or rotors that spin very fast when pushed by fast moving air, water or steam.

In hydroelectric power stations, the turbine is pushed around by fast-moving water that has flowed down pipes from a dam. One kind of turbine is made up of 'scoops', which 'catch' the water. This is known as a **Pelton turbine**. These are discussed in more detail on page 99. The orange and yellow turbine in the foreground of Figure 1 is an example of a Pelton turbine. (Its outer casing has been removed to show its design.)

In a working hydroelectric power station, the turbines are connected to a driving shaft. When they spin, they make the driving shaft spin very fast as well.

The Pelton wheel

The Pelton wheel is among the most efficient types of water turbines. It was invented by Lester Allan Pelton (1829-1908) in the 1870s, and is an impulse machine. That is, it uses the principle of Newton's second law to extract energy from a jet of fluid.

Many variations of impulse turbines existed prior to Pelton's design, but were very inefficient. The water leaving these wheels typically had high speed, and carried away much of the energy. Pelton modified this with a paddle geometry which ensures that when the rim runs at half the speed of the water jet, the water leaves the wheel with very little speed, making it a very efficient turbine.

Figure 2. An old Pelton wheel from Walchensee Power Plant, Germany.
Source: http://en.wikipedia.org/wiki/Pelton_wheel **Accessed:** 10 February 2010

The STELR equipment kit contains a Pelton wheel. Teachers may wish to use this in conjunction with the hand-cranked generator and the STELR testing station to demonstrate how it can be used to generate electricity.

What is a generator?

The spinning driving shaft causes a magnet to spin very fast inside a wire coil, or a wire coil to spin very rapidly around a giant magnet. This results in an electric current being generated (produced) within the coiled wire. The machine that consists of the magnet and wire coil is called a **generator**.

The electrical current

The electrical current produced then passes through a device called a **transformer**, in which its voltage is greatly increased. It then is transmitted via an **electricity grid** (network of electric wires) to the places where the electricity is to be used.

What energy transformations and energy transfers take place?

From the dam to the power station

The water in the dam possesses gravitational potential energy. When the water rushes down the pipes, the gravitational potential energy of the water is transformed into kinetic energy.

At the power station

By the time the water reaches the turbine, it is moving at a very high speed. When the water hits the blades of the turbine, it gives them a strong push, causing them to spin very fast. In the process, most of the kinetic energy of the water is transformed into the mechanical energy of the turbine. The water then flows through pipes to a lower part of the river.

The spinning turbine is connected to the generator, so its mechanical energy is transferred to the wire coils of the generator, which spin as a result. This causes an electric current to be produced within the wires. Hence within the generator, mechanical energy is transformed into electrical energy. The electrical energy is finally transferred to the consumers via the grid.

The energy transformations occurring in a hydroelectric power station could be represented as follows:

Gravitational potential energy → **Kinetic energy** → **Mechanical energy** → **Electrical energy**
(water stored in dam) *(water running down pipes)* *(spinning turbine)* *(generator)*

For further information about hydroelectric power stations, see the website listed on page 169 of this resource. A case study should be available on the STELR website by mid-2012.

COAL-FIRED POWER STATIONS

How much do we rely on coal as an energy resource?

The column graph in Figure 3 shows the energy resources used across the world in 2004. It is easy to see that coal plays a very important role in supplying the world's energy needs.

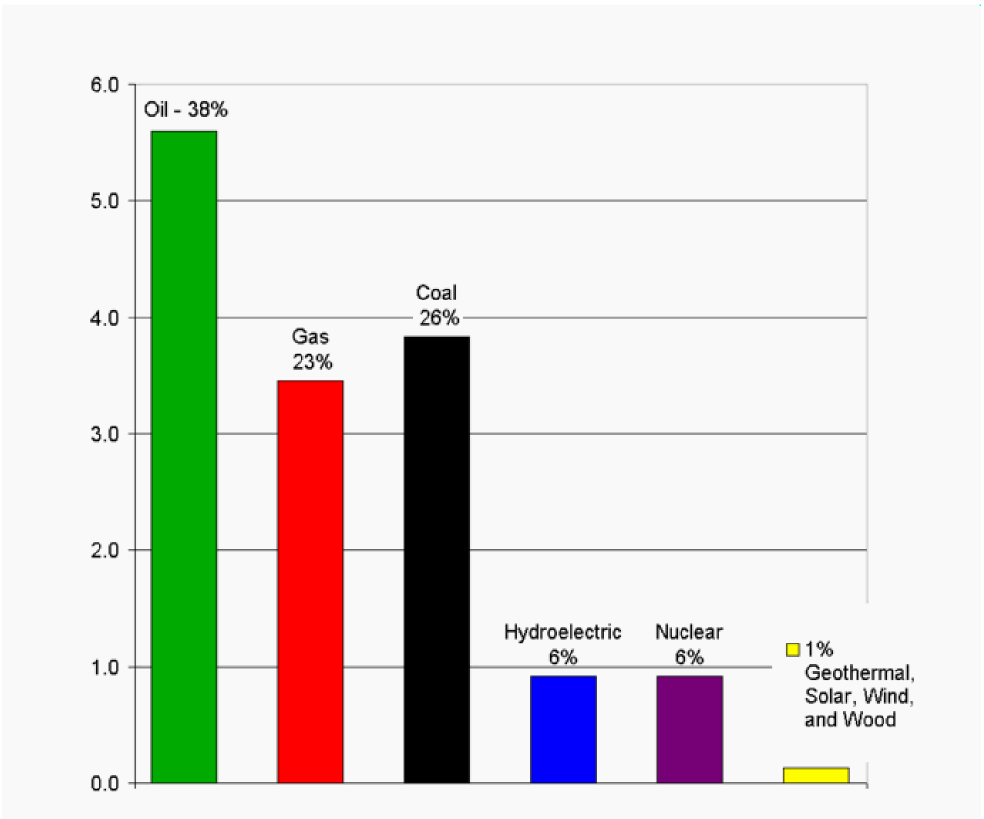


Figure 3. The percentage contribution of each energy resource to the total amount of energy used across the world in 2004.

In Australia, the percentage contribution of each energy resource is very different to the average percentage across the globe, shown in Figure 3. Table 1 shows what percentage of Australia's energy needs each major energy resource supplied in 2008.

Table 1. The contribution of different energy resources in supplying Australia's energy demands, 2008

Energy resource	Oil	Gas	Coal/peat	Hydroelectric	Nuclear	Geothermal/solar/wind	Biogas, etc.
Percentage contribution	30.3	19.8	44.5	0.8	0	0.4	4.2

Source: International Energy Agency (IEA), 2010

How does a coal-fired power station work?

Figure 4 shows the largest coal-fired power station in Victoria. It uses brown coal, which is mined nearby.

Figure 4. The Loy Yang coal-fired power station. The tall chimney stacks are above the furnaces. The huge curved towers with steam pouring from them, often mistaken for the pollution from the furnaces, are the cooling towers. PHOTO CREDIT: Loy Yang Power Station

The main stages

Figure 5 shows the main steps of the process that occurs at a coal-fired power station. This flow chart is explained next.

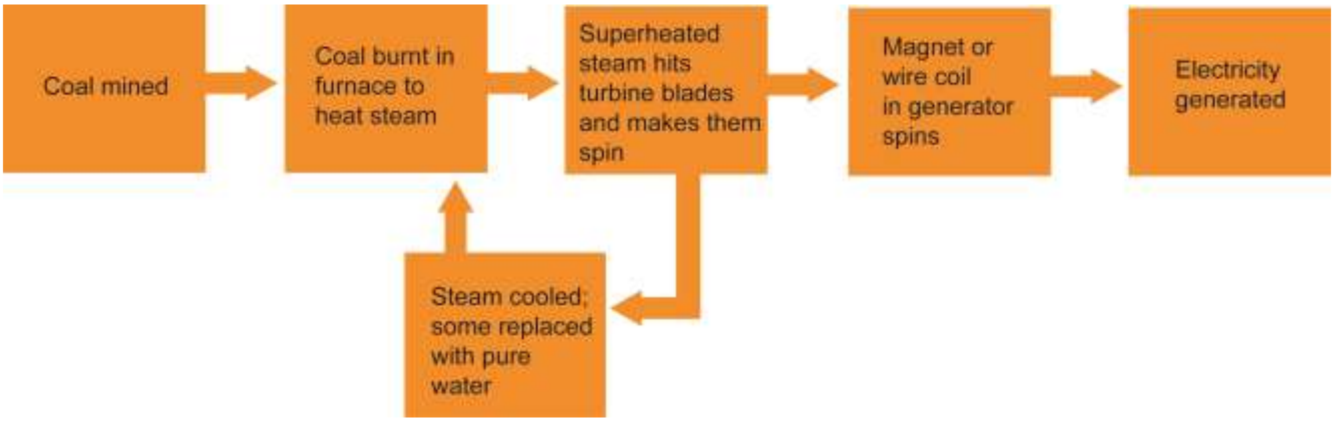


Figure 5. A flow chart for the generation of electricity at a coal-fired power station.

Burning the coal

Once it is mined, coal is crushed then burned in giant furnaces. (It may be partially dried first.) Steam is passed under pressure through pipes located inside each of the furnaces. Steam at normal pressure has a temperature of 100 ºC. Inside the furnaces, however, since the steam is under high pressure, it reaches a very high temperature (several hundred degrees). For this reason it is called **superheated steam**. The higher the temperature of a gas, the faster the gas particles move. The particles of superheated steam move very fast (35-100 metres per second).

Generating the electricity

The superheated steam is then directed onto the giant turbines. Since the steam hits the blades of each turbine at enormous speed and at high pressure, it makes the turbine spin extremely fast.

This in turn causes the magnet or the wire coil inside the generator to spin fast, which generates an electric current.

The cooling towers

Once the superheated steam has passed over the turbine blades, it now has less energy. It is cooler and at lower pressure. It then is passed through a huge cooling tower to be cooled further. (See the cooling towers in Figure 4.) This improves the efficiency of the re-heating process when the steam next passes through the hot furnace.

A little is 'bled off' and replaced with pure water, to help maintain the purity of the steam and hence protect the turbine blades. Then the steam goes around the 'circuit' again.

The energy transformations

Figure 6 shows the whole sequence of energy transformations that occur when electricity is generated from coal. Coal is classified as a **fossil fuel**.

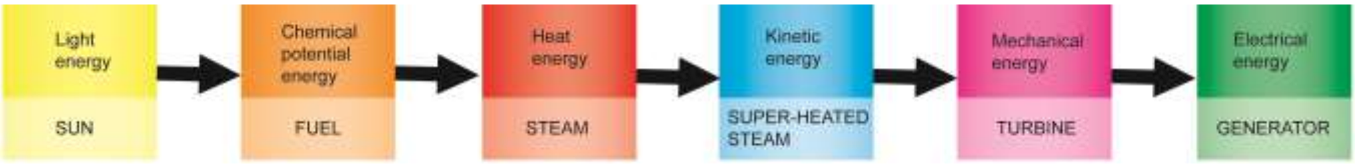


Figure 6. The main energy transformations that occur when electricity is generated at a coal-fired power station.

The emissions of a coal-fired power station

The main chemical reaction occurring when coal burns is:

carbon + oxygen → carbon dioxide + energy

This means that the main chemical substance being emitted from the tall chimney stacks above the furnaces is carbon dioxide gas, which is an invisible gas. A large amount of steam is also emitted, since coal has significant moisture content. Millions of tonnes of these two greenhouse gases are produced every day.

However, coal also contains compounds of nitrogen and sulfur, since the original plants that formed the coal contained compounds of these two elements. As a result, gases such as nitric oxide, NO, and sulfur dioxide, SO_2, are also produced. These gases react very rapidly with oxygen in the air and produce nitrogen dioxide, NO_2, which is a brown gas, and sulfur trioxide, SO_3.

Since a small number of other oxides of nitrogen and sulfur also are formed, the range of oxides of nitrogen and sulfur that move out into the atmosphere are given the general formulas NO_x and SO_x and are commonly known as ‘NOX and SOX’. (See Figure 7 below.)

					
Carbon dioxide CO_2	Water H_2O	Nitric oxide NO	Nitrogen dioxide NO_2	Sulfur dioxide SO_2	Sulfur trioxide SO_3
The main two gases emitted		**Examples of ‘NOX’ molecules**		**Examples of ‘SOX’ molecules**	

Figure 7. Models of the molecules of some of the gases emitted by coal-fired power stations. (Atoms partially ‘merge’ into each other when they join to form molecules.)
Key: The black sphere represents a carbon atom, the blue spheres represent nitrogen atoms, the yellow spheres represent sulfur atoms, and the red spheres represent oxygen atoms.

What is the problem with ‘NOX and SOX’?

Both ‘NOX and SOX’ present a number of big problems:

- They are toxic and some, especially SO_2, can induce an asthma attack in asthmatics.
- They are toxic to other animals and other living organisms. For example, SO_3 can enter the stomata (tiny pores) in the leaves of green plants. It then causes the leaves to turn brown and drop off, killing the plants.
- Most will dissolve in water, including in moisture in the air, and form acids, including nitric acid, HNO_3, and sulfuric acid, H_2SO_4, which are very strong, dangerous acids. When NOX and SOX gases dissolve in the moisture in the air, they form **acid rain** and **acid snow**. Whether it is acid rain or acid snow depends on the weather conditions. The pH of acid rain and acid snow is about 3 to 4.
- Those containing 3 or more atoms are greenhouse gases.

What can acid rain do?

Many large forests, great lakes and waterways have become ‘dead zones’ because of acid rain. That is, whole ecosystems have died out because their environment has become too acidic. Worse still, acid rain caused by one country can fall on another, even across the ocean!

In addition, acid rain eats into metals and slowly dissolves building materials such as marble and brickwork. A typical result is shown in Figure 8.

Figure 8. This carving has been damaged by acid rain.

Are coal-fired power stations the only source of ‘NOX and SOX’?

Coal-fired power stations are not the only source of ‘NOX and SOX’. Vehicles and metal smelters (places where metals are extracted from their ores) are two other major sources of these gases in the atmosphere. There are natural sources as well.

What is being done about this problem?

Needless to say, when scientists investigated acid rain and identified its causes and effects, most countries started to act to reduce the problem.

In countries like Australia, the Environment Protection Agency (EPA) sets strict limits on how much of these gases can be emitted into the air by coal-fired power stations. For this reason, a very high percentage of these gases are removed from the furnace gases before they are discharged into the air. Samples of air are regularly tested to ensure these regulations are obeyed. However, the problem is that there are ‘dirty’ coal-stations around the globe that still emit significant amounts of NOX and SOX and therefore contribute to the production of acid rain.

What is the overall percentage energy efficiency of coal-fired power stations?

Most Australian coal-fired power stations have a percentage energy efficiency of around 30 %.

No energy transformation is 100 % efficient. For this reason, one contributing factor to the low energy efficiency of coal-fired power stations is the large number of transformations that are required to produce electrical energy from the chemical potential energy of the coal.

However, a small number of power stations built recently in countries such as Germany, have a percentage energy efficiency of around 50 %. One way this much higher efficiency is achieved by using special ceramic pipes for the steam rather than metal pipes. This significantly reduces the amount of heat energy dissipated into the environment.

FURTHER INFORMATION ON ENERGY RESOURCES

See the STELR website for information about and case studies on a range of energy resources, including their advantages and disadvantages. These are in the public section of the website and are written for and can be accessed by students. They include geothermal power stations and biofuels.

Visit: www.stelr.org.au

Also see the websites on various energy resources listed on pages 168―170 of this book.

TOPIC: ENERGY RESOURCES

IDEAS FOR INTRODUCTORY ACTIVITIES ON ENERGY RESOURCES

SYNOPSIS

The teacher may wish to introduce the issue of what energy resources we use in the future by having the students discuss the big ideas on page 28 of the student book.

In addition, it may be useful to gauge what the students already know about different energy resources. In one of the optional introductory activities, students to work in pairs or small groups and construct Venn diagrams in which they classify and compare different energy resources, after working on a similar process for classifying foods.

In the other optional activity, students work online, calculating their ecological footprint or using a greenhouse gas calculator to examine how much greenhouse gases their household typically emits.

ADVICE ON INTRODUCING ENERGY RESOURCES

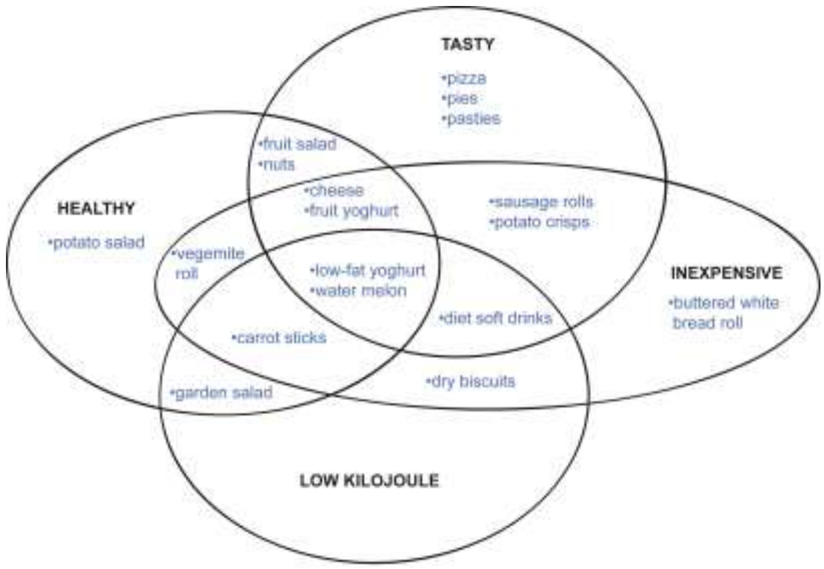
If it is at all possible, and if this has not already been done, arrange for the students to meet a scientist working in the field of renewable energy or to visit a power plant, wind farm, or other energy resource in the region, and see it in action and meet the experts-in-the-field who work there.

OPTIONAL INTRODUCTORY ACTIVITY 1: VENN DIAGRAM OF ENERGY RESOURCES

Activity outline

Outline the general principles of drawing a Venn diagram and work with the students to construct a Venn diagram based on foods sold in the school tuck shop /canteen. Decide as a group how the foods could be classified – such as whether they are healthy, low kilojoule, inexpensive, tasty. Then list 10 different foods and judge which categories they fall in. This could be simply achieved by placing symbols next to their name.

Were any foods in 3 or 4 categories? Were any foods in only one of these categories? Design a Venn diagram that allows each food to be placed in one location. A sample Venn diagram is shown below.



Sample Venn diagram for foods

Next brainstorm with the class how they might classify the different ways in which electricity is generated. Categories could include:

- Produces greenhouse gases
- Renewable
- Suited to large scale production
- Can quickly respond to changes in demand
- Produces harmful waste products

Distribute sheets of paper to pairs and ask them to write down all the ways in which electricity is generated that they can think of. They should then design and create a Venn diagram listing these energy sources in the categories agreed on by the class. Display and discuss the Venn diagrams produced by the class and any differences in judgments that are evident. Also discuss the advantages and disadvantages of this style of visual representation of information.

Time required

Approx 50 minutes

Materials

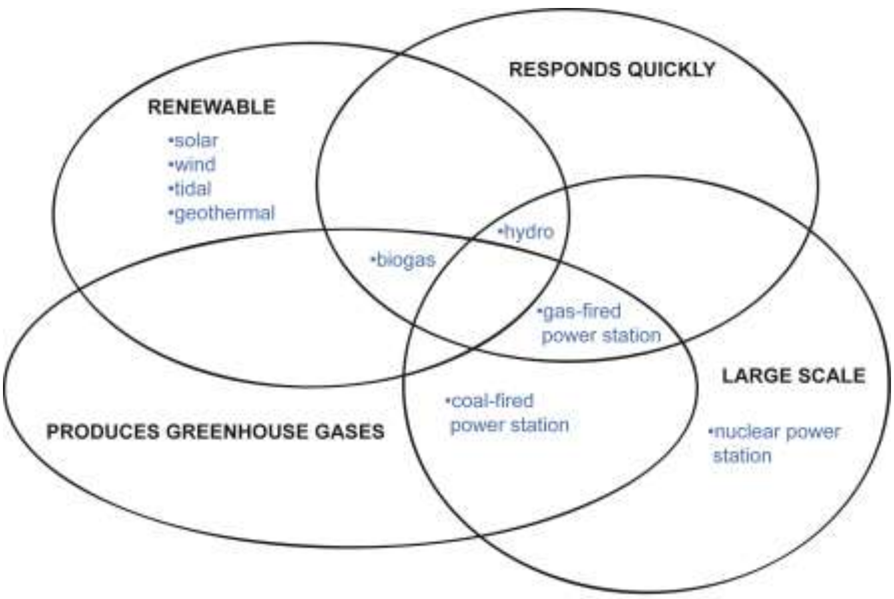
- Large sheets of paper and poster pens

Advice

This is an effective means of gauging the students' background knowledge of renewable and non-renewable energy sources that are suited to generating electricity, and what are some of their advantages and drawbacks. It also is an effective way of introducing the group projects on renewable energy resources.

Discussion

A possible Venn diagram of energy resources is shown below.



Sample Venn diagram for energy resources

Optional follow-up activity

Ask the students to create another way of representing the information and to compare the results.

OPTIONAL INTRODUCTORY ACTIVITY 2: ECOLOGICAL FOOTPRINT AND GREENHOUSE GAS CALCULATOR

Activity outline

Link the students to simulation activities on the web or a CD-ROM on topics such as our ecological footprints and calculating our greenhouse gas emissions using a greenhouse gas calculator. The following table lists some suitable resources.

Topic	Website	Comment
Our ecological footprint	http://www.epa.vic.gov.au/ecologicalfootprint/default.asp	This Australian site provides explanations, video interviews and an interactive calculator for working out how many hectares are required to sustain our lifestyle and hence how many 'Earths' would be needed if everyone on Earth followed this lifestyle.
Greenhouse gas calculator for the home etc.	http://www.epa.vic.gov.au/AGC/home.html	This Australian site provides an easy-to-use online calculator that was originally produced by the Australian Greenhouse Office. A tutorial on how to use the calculator, other teaching ideas and other information also are provided.

Time required

Approx 30-50 minutes (not including the follow-up activities)

Materials

- A computer lab or networked computers or interactive whiteboard

Advice

1 It is important that only reliable sources such as those listed above are used.

2 These activities can help stimulate discussion about the unsustainable amount of energy we consume. This can then lead to a worthwhile discussion of constructive solutions such as the use of renewable energy resources rather than non-renewable ones. It also promotes the reduction of our personal energy use. Students need to be aware that we all contribute to global warming and can all play a part in its reduction. Many will already be very aware of the ways they can do this. Provide the students with opportunities to discuss their ideas and any actions they are already taking.

3 The activity can be relatively short and 'snappy'. The first site listed above can be completed quite quickly. The teacher is advised to explore the sites and try the activities first.

Optional follow-up activity

The students could perform a survey of energy use in the school and initiate a change in the school culture. For example, they could consider solutions ranging from instituting a rule that classes turn off lights, electrical appliances, computers etc. when they do not require them, to changing light globes to low-energy ones, to promoting the installation of skylights to replace a number of light fittings with natural light sources.

TOPIC: ENERGY RESOURCES

WORKSHEET 2: OUR ENERGY RESOURCES PROJECT – ADVICE

STUDENT BOOKLET PAGES 29—30

ADVICE

Selection of energy resources

A wide range of energy resources has been listed. Some are classified as renewable and others are classified as non-renewable. Teachers need to bear in mind that it is easier to access relevant information on some energy resources than on others. For example, some are outlined in quite considerable detail on the STELR website; others are not. For other energy resources, the available information may be less accessible in both language and content. This needs to be taken into account when assessing the student projects.

Teaching and learning strategy

1 This project is based on the jigsaw approach to learning. Students will become the class experts on one particular energy resource, and then teach the rest of the class. Therefore teachers are strongly advised to insist that no two groups in the class investigate the same energy resource.

2 It is recommended that student groups contain no more than four students, to help ensure that each group member has significant responsibility within the group.

Time allocation

Students need to be given enough time in class as well as at home to complete the project to a sufficient depth. This is an opportunity for them to develop many skills, including research skills, team work, communication skills and analytical skills, and initiative and responsibility. It also enables them to explore a major issue of our time.

Group presentations

1 Allow enough lesson time for each group presentation, so that each group can use a range of creative modes to present their findings and do justice to the effort they made in performing the range of tasks, without taking so long that their audience loses interest.

2 Give each group a clear time limit and ensure they rehearse their presentation so that it fits within that limit and yet covers all aspects required.

3 Make a range of modes of presentation possible, so that students have every opportunity to demonstrate their ability to use a range of communication modes with creativity and style.

Cross-curriculum links

Teachers can build into this an opportunity for students to learn how to construct and carry out and process an objective, unbiased survey to identify the range of attitudes held in the school or local community. This is an important cross-curriculum opportunity, showing the students a real-life application of the statistical methods they learn in mathematics.

Assessment

It is recommended that the assessment of this is a major part of student assessment for this topic. See a sample assessment rubric for the group project on pages 164—165 of this book. Also see the sample proforma for student assessment of group presentations on page 166 of this book.

Websites

See the list of websites on different energy resources on pages 168—170 of this book.

Also see the list of possible relevant excursions on page 171 of this book.

TOPIC: BATTERIES AND ELECTRICAL POWER

BACKGROUND INFORMATION FOR THE TEACHER

The difference between power and energy

Sometimes the terms power and energy are quoted as though they mean the same thing. In fact they mean different things, although they are related.

Electrical energy is the energy possessed by electrically charged particles, which may be associated with an electric current or a stored charge. In the following discussions we will only consider electrical energy in relation to electrical circuits.

Electrical power is a measure of how much electrical energy is transformed per second in an electric circuit.

Units of energy and power

The most commonly used units for energy and power are shown in Tables 1 and 2. The relationship between these units and how to convert them is shown in Figures 1 and 2.

Table 1. Units of energy

Unit	Symbol	Comment
joule	J	This is the international metric unit (SI unit) used for energy. It can be used to measure all forms of energy.
watt-hour	Wh	• Used to measure electrical energy. • Since 1 watt is equivalent to 1 joule per second (see Table 2) and there are 3600 seconds in 1 hour, 1 watt-hour is equivalent to 3600 joules.
kilowatt-hour	kWh	• Used to measure larger amounts of electrical energy, such as the electrical energy delivered to a household. • The prefix *kilo* means a thousand, so 1 kWh = 1000 Wh.

Table 2. Units of electrical power

Unit	Symbol	Comment
watt	W	This is the international metric unit (SI unit) used for electrical power. It is equivalent to 1 joule per second.
megawatt	MW	• Used to measure the electrical power supplied by large scale energy resources, such as wind farms and power stations. • The prefix *mega* means a million, so 1 MW = 1 000 000 W.
kilowatt	kW	• Used to measure the electrical power supplied by small scale energy sources, such as large batteries and rooftop solar panels. • The prefix *kilo* means a thousand, so 1 kW = 1000 W.
milliwatt	mW	• Used to measure the electrical power delivered by small devices such as the STELR solar panel. • The prefix *milli* means a thousandth, so 1 mW = 0.001 W.

Figure 1. How to convert from one energy unit to another .

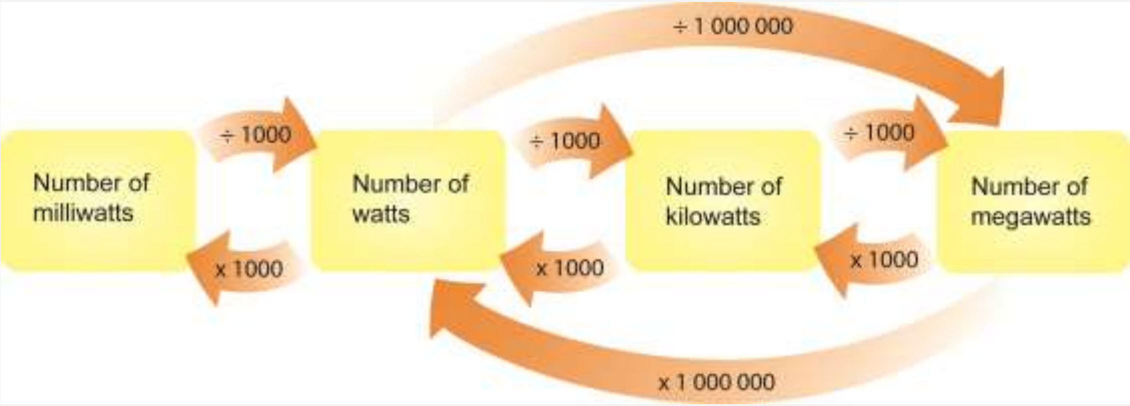


Figure 2. How to convert from one power unit to another .

Calculating electrical power and electrical energy

The electrical power delivered by an energy source can be calculated from the voltage across the energy source, and amount of current flowing in the circuit. The formula used is shown below:

$$P = VI$$

where ***P*** = electrical power, measured in watts (W)

V = voltage, measured in volts (V)

I = current, measured in amperes (A)

NOTE: If the current delivered is very small, it may be measured in miiliamps, mA. (A milliamp is one thousandth of an amp.) In this case the power will be measured in milliwatts, mW.

The total amount of electrical energy transformed in a given time can be calculated from the power and the time.

$$E = Pt$$

where ***E*** = total amount of electrical energy transformed in a given time, measured in joules (J)

P = electrical power, measured in watts (W)

t = total time for which the current has been flowing, measured in seconds (s)

Sample calculation

A globe was placed in an electric circuit in series with a model wind turbine. An ammeter and a voltmeter were placed into the circuit to measure the current and the voltage, respectively. The circuit diagram is shown in Figure 3. It was found that when the readings on the voltmeter and ammeter became steady, the voltage was 1.66 V and the current was 24.0 mA.

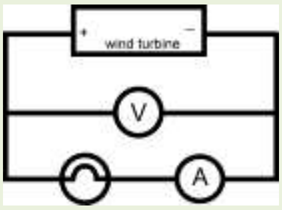


Figure 3.

a What power was being delivered by the model wind turbine? Give the answer in milliwatts.

b If the power delivered by the wind turbine remained steady over 10.0 minutes, measured using a stop-watch, what was the total amount of electrical energy delivered by the model turbine over that time? Give your answer in joules.*

***Calculation of electrical energy is not required in the STELR program, but may be of interest to the teacher.**

Solution:

a $P = VI$ where P = electrical power, in milliwatts

V = voltage = 1.66 V

I = current = 24.0 mA

Hence P = 1.66 x 24.0
= 66.1 mW

Answer: The power delivered by the model wind turbine was 66.1 mW.

b $E = Pt$ where E = total amount of electrical energy, in joules (J)

P = average power delivered over the time = 66.1 mW = 66.1 ÷ 1000 W = 0.0661 W

t = total time = 10.0 minutes = 10.0 x 60 s = 600 s

Hence E = 0.0661 x 600
= 39.7 J

Answer: The total electrical energy delivered was 39.7 J.

Note:

1 Advise students to quote the formula and the numbers that are to be substituted into it, as shown. This helps students to organise their thinking and to avoid mistakes.

2 Notice that the unit conversions were performed when listing the numbers to be substituted into the formula. (See the highlighted calculations.) This is the easiest place to do this.

3 Calculators should NOT be cleared between the successive steps of a calculation.

4 It is more correct to say that energy is transformed than to say it is 'delivered'. But in the student booklet the term 'delivered' is used, as it is easier for students to understand.

5 Notice in these calculations that since the data was quoted to 3 significant figures, the answers were rounded off to 3 significant figures.

FURTHER INFORMATION

For information on:

- **Electrical current and its units of measurement**, see page 182 in this resource.
- **Voltage and its units of measurement**, see page 193 in this resource.
- **How commercial batteries work**, see page 77 in this resource.
- **Power ratings of electrical devices**, see the website listed on page 169 of this resource.

TOPIC: BATTERIES AND ELECTRICAL POWER

RUNNING PRACTICAL ACTIVITY 3: THE POWER DELIVERY OF A BATTERY

STUDENT BOOKLET pages 32—35

SYNOPSIS

This experiment is designed to refresh student's knowledge of and skill in measuring electrical current and voltage, and to apply this in measuring the electrical power delivered by the battery.

It assumes that students have been introduced to electrical current and voltage not long before or just before they start the STELR program. If students do not have this background, or need to refresh their knowledge and skills, see pages 172—202 of this resource for the student editions of optional introductory experiments and their accompanying teacher guides.

APPROXIMATE TIME REQUIRED

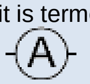
60 minutes

BACKGROUND INFORMATION FOR THE TEACHER

To measure electrical power accurately, current and voltage must be measured **simultaneously.**

See the background information on electrical power on pages 108—110 of this resource.

See the background information on electrical current on page 182 of this resource. When a multimeter is set to measure current, it is termed an ammeter. The circuit symbol for an ammeter is shown below.



See the background information on voltage on page 193 of this resource. When a multimeter is set to measure voltage, it is termed a voltmeter. The circuit symbol for a voltmeter is shown below.

LIST OF MATERIALS REQUIRED

Per student pair:

- STELR testing station
- 2 x STELR multimeters
- Switch
- STELR battery
- Connecting leads (with 'piggy-back' banana plugs)

PRACTICAL ADVICE AND HINTS

The equipment

1 Pre-test the batteries to ensure they are delivering about 3 volts.

2 An analog voltmeter can be used in place of a STELR multimeter set as a voltmeter, provided that students are taught how to use it correctly, including how to read the scales.

3 An analog milliammeter can be used in place of a STELR multimeter set as an ammeter, provided that students are taught how to use it correctly, including how to read the scales. (This is not recommended, however, given the sensitivity and cost of milliammeters.)

Connecting up the circuit shown in Figure 1 on page 32 of the student book

1 To connect the ammeter correctly, the lead connected to the COM socket on the STELR multimeter must be connected to the switch, which in turn must be connected to the negative terminal on the STELR battery. (The black lead shown in Figure 3 on page 34 of the student booklet is connected to the COM socket on the STELR testing station.)

The lead connected to the right-hand socket on the multimeter must connected to the socket just above the word LAMP on the testing station. (By convention this should be a red lead, as shown in Figure 3 on page 34 of the student booklet.)

If the ammeter is connected the wrong way round, the digital readout will have a negative sign in front of it.

If an analog milliammeter is used instead, its negative terminal must be connected to the switch, and its positive terminal must be connected to the socket just above the word LAMP on the testing station. If it is connected the wrong way round, the needle will move anticlockwise off the scale, which means no reading can be obtained.

5 To connect the voltmeter correctly, the lead connected to the COM socket on the STELR multimeter must be connected to the socket just above the word LAMP on the testing station.

The lead connected to the right-hand socket on the multimeter must connected to the other LAMP socket on the testing station.

If the voltmeter is connected the wrong way round, the digital readout will have a negative sign in front of it.

If an analog voltmeter is used instead, its negative terminal must be connected to the socket just above the word LAMP on the testing station. Its positive terminal must be connected to the other LAMP socket. If it is connected the wrong way round, the needle will move anticlockwise off the scale, which means no reading can be obtained.

RISK MANAGEMENT

Students should be actively supervised throughout this practical activity.

Possible responses to the students' risk assessment activity are shown below.

Student activity sheet: Table 1

The facts	What might be the risks?	What precautions will we take?
1 Multimeters are very sensitive digital instruments. They always should be placed correctly in the circuit. They should be turned off after use.	The multimeters could be accidentally dropped or set wrongly or placed the wrong way in a circuit.	Keep the multimeters well away from the edge of the bench. Have the teacher check the circuit and the multimeter settings before closing the switch.
2 The equipment can be permanently damaged if dropped or carelessly handled.	The equipment could be accidentally knocked off the bench if students lean over them or move books or bags near it.	Keep the equipment well away from the edge of the bench and do not lean on or over benches or move books or bags near them. Do not have other equipment or any liquids nearby.
3 Batteries can go flat if left on too long.	The batteries could go flat if the switches are left on too long.	Only close the switch for as long as it takes to read the instruments. Then disconnect the circuit and turn off the multimeters.

ADVICE FOR THE CLASSROOM

Working in small groups of two or three gives students a greater opportunity to be actively engaged instead of merely being spectators in the activity. As a result, they are more likely to develop the skills and understandings that will help them in later investigations.

See also the general advice provided on pages 28—29 of this resource.

Teachers are strongly advised to:

1 Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
2 Decide how to best manage the activity, particularly who should be in each group and whether the students will test the other devices on the testing station (which is worth doing if time permits, since it provides interesting results).

Setting up:

Have a set of the equipment to perform a demonstration during the introductory discussion.

Introducing the activity:

1 Introduce this practical activity by eliciting from the students what they know about electrical power, and about setting up electrical circuits and measuring current and voltage.
2 Work through the information and the sample calculation in the student booklet.
3 Demonstrate the most important points about setting up the circuit.
4 Work through the risk assessment and safety precautions to be taken, eliciting as much as possible from the students.
5 Assign the students to their groups.
6 State your expectations of their behavior and the time limits they will work under.

During the session:

1 With each group, whilst checking their circuits, ask students questions about why the ammeters and voltmeter are connected the way they are. Have them use their fingers to trace out the path taken by the electrical current and the small 'loop' that contains the voltmeter. Ask students to suggest some possible sources of error.
2 Watch that students observe all of the agreed-upon procedures and safety precautions and are obtaining results in a timely manner.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report their findings. They should discuss any problems they encountered and their conclusions. Ensure that each group contributes to the discussion. If they tried the other devices on the STELR testing station, discuss the results. This can be related to how much brighter traffic lights that contain LEDs are than the 300 W incandescent globes they have replaced. The added advantage is that they use far less power.

This part of the session should take about 10—15 minutes.

(See page 114 for expected results.)

EXPECTED RESULTS

The figures in the sample calculation on page 33 of the student booklet are a typical result for the incandescent globe on the testing station (labelled LAMP). The following table shows the typical orders of value for the different devices on the STELR testing station.

Typical orders of value for different devices on the STELR testing station

Measurement	Lamp	Buzzer	Fan	LED
Current (mA)	30	30	130	1.3
Voltage (V)	3	3	2.6	3
Power (mW)	100	100	340	4

It can be seen that:

- The fan draws far more power than the other three devices.
- The lamp and buzzer draw a very similar amount of power.
- The LED draws significantly less power than the other devices. This should interest the students, given how bright it is compared with the lamp. (A LED is about 10 times more efficient than an incandescent globe.)

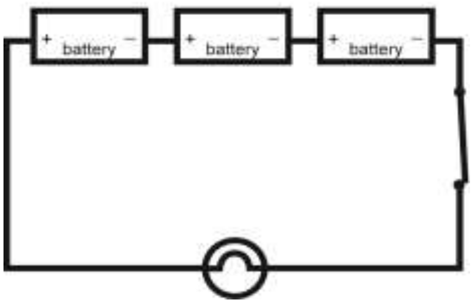
TOPIC: BATTERIES AND ELECTRICAL POWER

WORKSHEET 3: CONNECTING BATTERIES – SUGGESTED SOLUTIONS

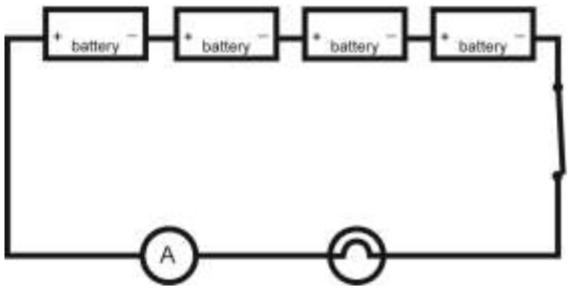
STUDENT BOOKLET PAGES 36—38

SUGGESTED SOLUTIONS TO DISCUSSION QUESTIONS

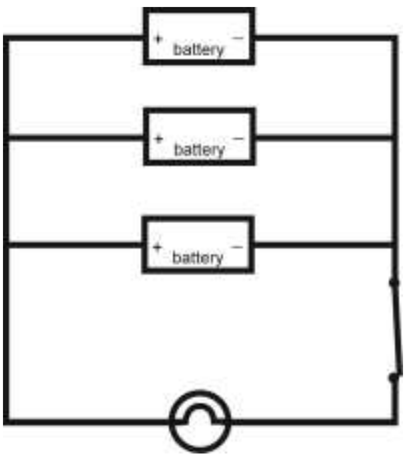
1a



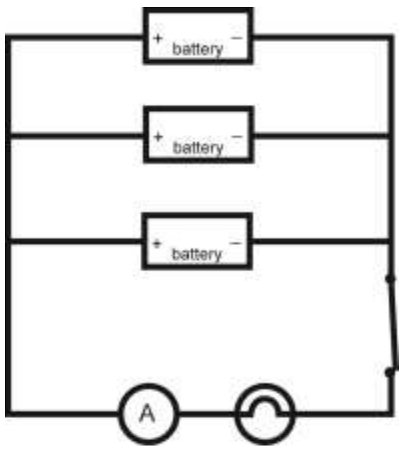
1b



2a



2b



Note: The suggested solutions to questions 2a and 2b should be shaded like Figure 8 on page 37 of the student booklet, except in this case there will be 3 colours. Each battery will have a different coloured line through it. Each coloured pathway will consist of one of the batteries and then the globe or globe and ammeter.

TOPIC: BATTERIES AND ELECTRICAL POWER

RUNNING PRACTICAL ACTIVITY 4: CONNECTING BATTERIES IN SERIES AND PARALLEL

STUDENT BOOKLET pages 39—45

SYNOPSIS

This experiment is designed to prepare students for the experiment in which they investigate the power delivered by a solar panel in which the solar cells are connected in series and in parallel (Practical Activity 7). It allows them to discover what difference it makes when batteries are connected in series and in parallel.

APPROXIMATE TIME REQUIRED

60 minutes

BACKGROUND INFORMATION FOR THE TEACHER

As stated in the guide to running Practical Activity 3 (page 111 of this resource), to measure electrical power accurately, current and voltage must be measured **simultaneously.**

When batteries are connected in series with a globe, the power they deliver to the globe increases as the number of batteries increases. As a result, the globe on the testing station glows more brightly than when just one battery is used.

In this case, the total voltage delivered, V_t, is the sum of the voltages delivered by each battery if it were the only battery present in the circuit:

$$V_t = V_1 + V_2 + V_3 + \ ...$$

The net current delivered also increases, but it is not as large as the sum of the currents delivered by each battery if it were the only battery present in the circuit. This is because the resistance *R* of the globe increases with the number of batteries in the circuit. If its resistance were constant, then according to Ohm's law $V = IR$, when the voltage delivered doubles, the current would also double.

This is the reason why cells are connected in series in batteries when a larger voltage is required. The STELR battery, for example, contains two 1.5 V cells connected in series, which enables it to deliver a voltage of 3 V. A 12 V lead-acid car battery contains six 2 V cells connected in series.

When batteries are connected in parallel, however, the net voltage and net current they deliver to the lamp is the same as if there were a single battery in the circuit. For this reason, the globe on the testing station looks no brighter than it does when just one battery is connected to it.

This means that the net power delivered to the lamp is not affected by inserting a second battery in parallel with the first. The difference it does make is that the batteries last much longer, because each of the two batteries is only delivering half the power it would deliver if in the circuit on its own. The reason for this is that each battery still delivers the same voltage but only half of the current it would deliver if in the circuit on its own. The net current is the sum of these two currents. (This can be demonstrated by inserting an ammeter along the wire between Battery B and Battery A in the circuit shown on page 40 of the student booklet.)

LIST OF MATERIALS REQUIRED

Per student pair:

- STELR testing station
- 2 x STELR multimeters
- Switch
- 2 x STELR batteries (labelled A and B)
- Connecting leads (with 'piggy-back' banana plugs)

PRACTICAL ADVICE AND HINTS

The equipment

1 Pre-test the batteries to ensure they are delivering about 3 volts. This experiment will not work well if the two batteries are delivering different voltages.

2 An analog voltmeter can be used in place of a STELR multimeter set as a voltmeter, provided that students are taught how to use it correctly, including how to read the scales.

3 An analog milliammeter can be used in place of the STELR multimeter set as an ammeter, provided that students are taught how to use it correctly, including how to read the scales. (This is not recommended, however, given the sensitivity and cost of these instruments.)

Connecting up the circuit shown in Figure 1 on page 39 of the student booklet

1 To connect the ammeter correctly, the lead connected to the COM socket on the STELR multimeter must be connected to the switch, which in turn must be connected to the negative terminal on the STELR battery. (The black lead shown in Figure 3 on page 42 of the student booklet is connected to the COM socket on the STELR testing station.)

The lead connected to the right-hand socket on the multimeter must connected to the socket just above the word LAMP on the testing station. (By convention this should be a red lead, as shown in Figure 3 on page 42 of the student booklet.)

If the ammeter is connected the wrong way round, the digital readout will have a negative sign in front of it.

If an analog milliammeter is used instead, its negative terminal must be connected to the switch, and its positive terminal must be connected to the socket just above the word LAMP on the testing station. If it is connected the wrong way round, the needle will move anticlockwise off the scale and no reading can be obtained.

5 To connect the voltmeter correctly, the lead connected to the COM socket on the STELR multimeter must be connected to the socket just above the word LAMP on the testing station.

The lead connected to the right-hand socket on the multimeter must connected to the other LAMP socket on the testing station.

If the voltmeter is connected the wrong way round, the digital readout will have a negative sign in front of it.

If an analog voltmeter is used instead, its negative terminal must be connected to the socket just above the word LAMP on the testing station. Its positive terminal must be connected to the other LAMP socket. If it is connected the wrong way round, the needle will move anticlockwise off the scale and no reading can be obtained.

RISK MANAGEMENT

Students should be actively supervised throughout this practical activity.

The precautions the students need to take are the same as for Practical Activity 3. See page 112 of this resource.

ADVICE FOR THE CLASSROOM

Working in small groups of two or three gives students a greater opportunity to be actively engaged instead of merely being spectators in the activity. As a result, they are more likely to develop the skills and understandings that will help them in later investigations.

See also the general advice provided on pages 28—29 of this resource.

Teachers are strongly advised to:

1 Ensure that the students have already completed Worksheet 3 before starting this activity.
2Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
3 Decide how to best manage the activity, particularly who should be in each group.

Setting up:

Set up the circuit in Figure 1 on page 39 of the student booklet ready for the introductory discussion.

Introducing the activity:

1 Introduce this practical activity by asking the students to individually or in pairs predict what will happen if a second battery is inserted into the circuit, in series or parallel with the first. Have the students write their responses on page 41 of the student booklet. You could survey the class to see what the different students or pairs think. But do not tell them if they are right or wrong. Tell them they will soon discover who was right. (This will help motivate the students.)
2 Remind the students of the previous experiment and the safety precautions that need to be taken, eliciting as much as possible from the students.
3 Assign the students to their groups.
4 State your expectations of their behavior and the time limits they will work under.

During the session:

1 With each group, whilst checking their circuits, ask questions about what the students are discovering and what explanations they can suggest.
2 Check that the students observe all of the agreed-upon procedures and safety precautions and are obtaining results in a timely manner.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report their findings. They should discuss which of their predictions came true, any problems they encountered, their conclusions and suggested explanations for their results. Ensure that each group contributes to the discussion.

This part of the session should take about 10—15 minutes.

EXPECTED RESULTS

Typical results are outlined below. (For explanations of these results, see the background information on page 116.)

Results for PART A: The voltage of each battery

Voltage for Battery A (volts)	Voltage for Battery B (volts)
2.91	2.99

Results and calculations for PART B

Battery arrangement	Brightness of globe	Voltage *V* (final steady value) (V)	Current *I* (final steady value) (mA)	Electrical power *P* (mW) *P = V x I*
Single battery	Dim	2.91	32.5	94.6
Two batteries in series	Bright	5.90	48.0	283
Two batteries in parallel	Dim	2.99	33.0	98.7

SUGGESTED ANSWERS TO DISCUSSION QUESTIONS

1 [*Answer depends on class results, but all groups should have obtained similar results*]

2 [*Student response*]

3 *The brightness of the globe should have been related to the power delivered.*

4 [Student response. Students cannot be expected to realise that the current delivered by the two batteries in parallel was half that of the current delivered when connected individually.]

TOPIC: WIND TURBINES

BACKGROUND INFORMATION FOR THE TEACHER

A **wind turbine** is rather like a giant fan. When the wind sets it spinning, it generates electricity. Wind turbines can range in size from small ones installed on large yachts and small buildings, to giant ones on wind farms.

A **wind farm** is a set of wind turbines that are linked together to supply electricity to a local community or to an electricity grid for a larger population. Many are located along coastlines where the winds are strong. The Woolnorth wind farm in Tasmania, shown in Figures 1 and 2, is an example of this.

Figure 1. A coastal view of the 140 MW Woolnorth Wind Farm, located on the far north-west coast of Tasmania where the Great Southern Ocean meets Bass Strait. Up until April 2008, this was the biggest wind farm operating in the southern hemisphere.
PHOTO CREDIT: Hydro Tasmania

Figure 2. A close-up view of some of the wind turbines at Studland Bay Wind Farm. The van at the base of one of the towers, and the cattle in the background, give some idea of their size.
PHOTO CREDIT: Hydro Tasmania

How do wind turbines work?

Wind turbines transform the kinetic energy of the wind into electrical energy. Figure 3 shows the key energy transformations that take place.

Figure 3. The main energy transformations that take place in a wind turbine.

The main steps are:

STEP 1: Moving air pushes against the blades of the turbine, which are tilted to the direction of the wind. This makes the blades spin. In the process, some of the kinetic energy of the moving air is transformed into the mechanical energy of the spinning blades. (The wind still has some kinetic energy as it flows away from the turbine.)

STEP 2: The shafts and the gears inside the gear box transfer the mechanical energy of the turbine to the generator. (The gears make the drive shaft to the generator spin faster than the shaft connected to the blade hub.)

STEP 3: The generator transforms mechanical energy into electrical energy.

Figure 4 shows a close-up view of a wind turbine. Figure 5 on the next page shows what wind turbines might look like on the inside.

Figure 4. A close-up view of a wind turbine at the Woolnorth wind farm.
PHOTO CREDIT: Hydro Tasmania.

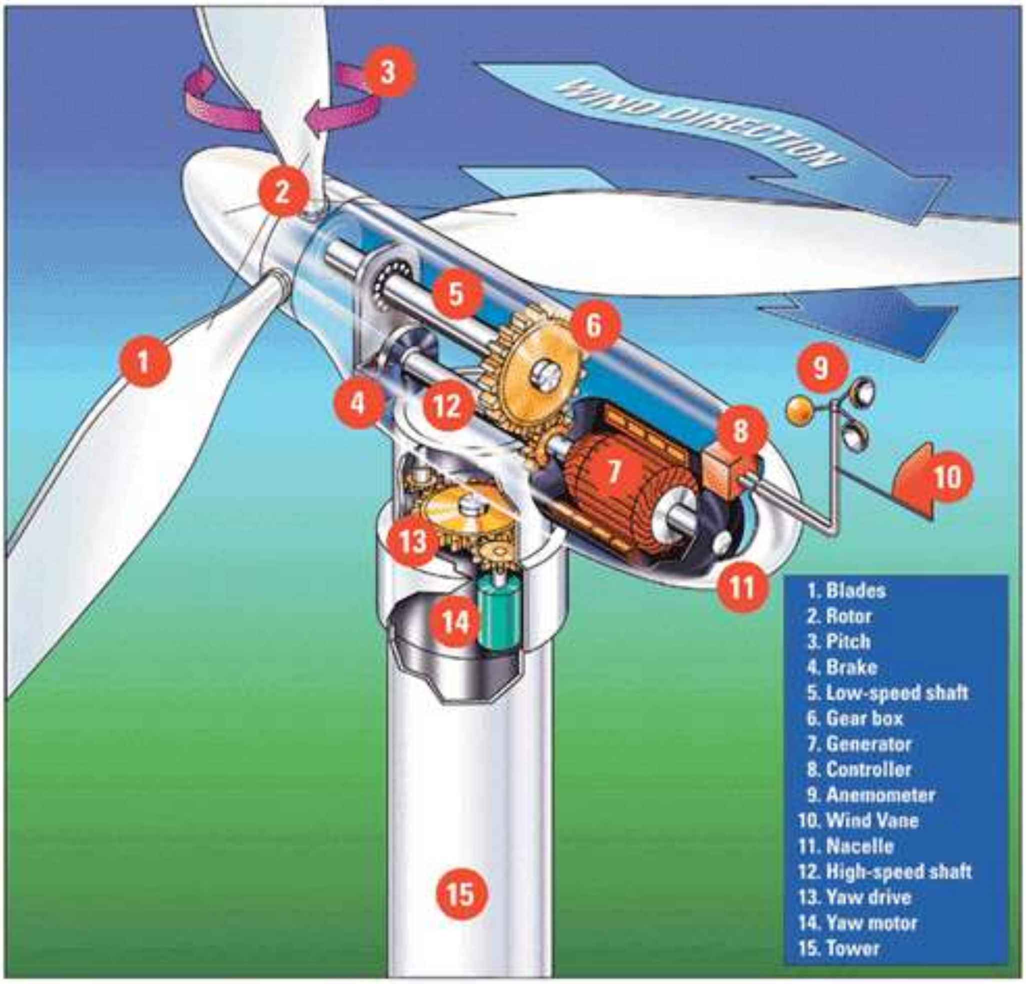


Figure 5. A wind turbine – an inside view.
Source: http://www.alliantenergykids.com/wcm/groups/wcm_internet/@int/@aekids/documents/image/022691.jpg
Accessed: 4 January, 2011

What is the best place to locate a wind farm?

Wind turbines must, of course, be located where there are steady strong winds - though not so strong that they would damage the turbines.

Wind turbines work most effectively when they operate in 'smooth air' (when the air particles are moving parallel to one another). If, say, 10% of air is travelling against the main direction of air motion, it will reduce the efficiency of the turbine by 20%, since it is cancelling out the energy of another 10% of the air movement.

Ideal sites for wind turbines therefore must be:
• Away from obstructions that may cause eddy currents, such as rocky outcrops, towers and forests
• At the highest point possible
• Clear space of approximately 10 times the height of local obstacles such as nearby buildings, hills or trees

The best place is on top of a smooth hilltop, where wind can concentrate and increase in speed.

This is shown in Figure 6 on the next page.

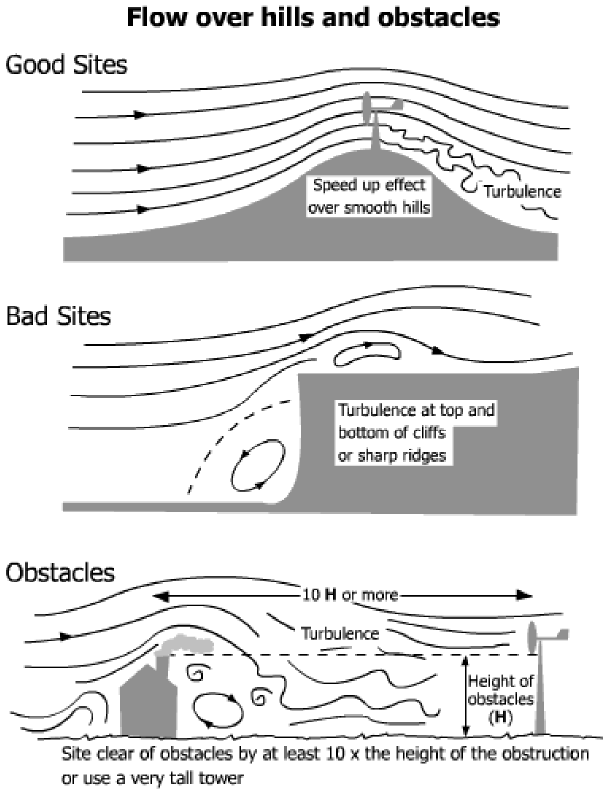


Figure 6. How the air moves over hills and obstacles**. Source:** http://www.bwea.com/you/siting.html **Accessed:** 21-01-2010

What determines how much power is generated by a wind turbine?

As we might expect, one factor determining the power generated is the wind speed. The power of the wind is proportional to the cube of the wind speed! This means that:

• If the wind speed were 2 times greater, the power available from the wind would be 8 times greater.

• If the wind speed were 3 times greater, the power available from the wind would be 27 times greater.

• If the wind speed were 10 times greater, the power available from the wind would be 1000 times greater.

However, it must be realised that wind turbines do not produce electricity all the time. Although the wind might be available for as much as 70 % of the time, it is often not strong enough to operate the wind turbine at full capacity. The combination of absence of wind and inadequate wind strength means that even in a good location the wind turbine, over the course of a year, will generate only about 30 % of the amount it could generate in a constant strong wind.

The amount of electrical power produced by a wind turbine doesn't only depend on the speed of the wind, and how smoothly it flows, however. It also depends on the way the turbine is built:

• The number of blades
• The length of the blades
• The shape of the blades
• The weight of the blades
• The pitch (angle) of the blades to the wind
• The height of the tower
• The gears used
• The type of generator used
• The computer system that controls the operation of the turbine and its power output (where this is used)

The energy efficiency of wind turbines

A good site might have a 35 % **capacity factor**. This means that the turbines will produce 35% of their capacity on average over a year.

Apart from problems with the wind itself, some of the kinetic energy of the wind is 'wasted', due to the fact some is transformed into heat energy (the gears and shafts get hot) and sound energy (the blades, gears and shafts make some noise as they spin). This is summarised in Figure 7.

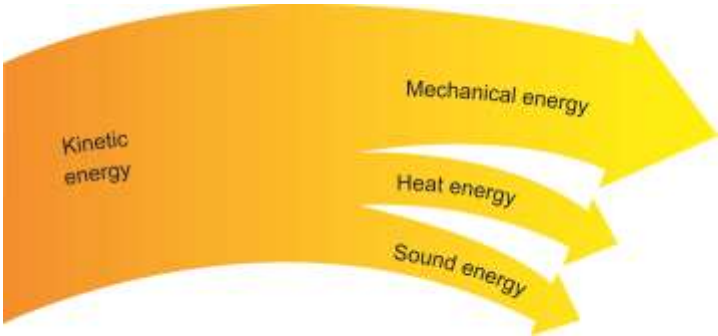


Figure 7. A Sankey diagram showing how some of the kinetic energy of the wind is transformed into a useful form of energy (mechanical energy) and some is transformed into forms of energy that are not useful (heat energy and sound energy).

What are the advantages of wind turbines?

The main advantages of wind turbines, once they are built*, are:

1 They are a **renewable** energy resource – there always will be wind!

2 They do not emit greenhouse gases or any other pollution.

3 They are more energy-efficient than most power stations that burn fossil fuels.

4 They are less costly to run than many other energy resources.

5 They can be established in remote areas where other energy resources are not practical, even in places like Antarctica and on ocean-going yachts.

*Greenhouse gases and other pollutants are produced during the manufacture, transport and installation of wind turbines, but once they have operated for a year or so, they will have compensated for this. Overall, wind turbines help reduce the amount of greenhouse gases emitted into the atmosphere.

Figure 8. A wind-diesel energy resource that was built by Australian scientist Dr Alan Langworthy and his company, Powercorp Pty. Ltd., at the Mawson base in Antarctica. Alan also has built wind turbines at the Murdoch and Scott bases. PHOTO CREDIT: Powercorp Pty. Ltd

What are the disadvantages of wind turbines?

Some of the disadvantages of wind turbines are:

- The electrical power delivered by wind turbines varies because both wind speed and direction vary. Sometimes the wind speed is too low to even start rotation. Therefore they can only be used to provide some of the electrical power people need.
- They can be damaged by very strong winds and also corroded by salt in the air when located near the sea.
- It can be costly to connect them to the electricity grid, due to the distances involved.
- Some people think they spoil the landscape, which could have a negative impact on the local tourist industry.
- They need to have flashing lights on the top to warn the pilots of any aircraft that fly overhead of their presence. Some people who live close by complain that the flashing lights disturb their sleep.
- In many countries, most of their wind turbines are located offshore, usually because people do not want them across the land. This is a much more expensive location, because the turbines are more costly to install and to maintain, because of problems such as corrosion of metal parts by sea water and damage from the constant movement of waves and sand. This means the electricity they generate is more expensive than that generated by coal-fired power stations.
- There may be some impact on local bird populations and other species, such as bats.

The noise issue

Some people believe the sound produced by wind turbines is annoying or even harmful.

However, tests conducted by Danish sound engineers on many wind turbines in Denmark have shown that the loudness of sound heard in any location depends on wind direction and speed. The engineers reported that they often could not detect any sound above normal natural levels in areas near wind turbines. Even when they could, the loudness of the sound was not of a level that would harm people's hearing.

They also found that no infrasound was produced by the wind turbines they tested. Infrasound is low frequency sound that cannot be detected by the human ear. It is thought to cause a number of health problems.

What say do local communities have?

Many local communities, or the majority of members of local communities, are very happy to have a wind farm installed near them. Usually farming communities, they benefit from the jobs such developments bring into their area.

Moreover, wind turbines are often installed on farms and provide the farmers with extra income. Cattle and sheep still graze peacefully under them (as shown in Figure 2 on page 120).

However, Aboriginal sacred sites in the region must be respected and avoided.

ANIMATION OF HOW WIND TURBINES WORK

This animation on how wind turbines work provided by the US Department of Energy:

http://www1.eere.energy.gov/wind/wind_animation.html

FURTHER INFORMATION ON WIND TURBINES

See the list of websites on wind power on page 169 of this resource.

TOPIC: WIND TURBINES

IDEAS FOR INTRODUCTORY ACTIVITIES ON WIND TURBINES

SYNOPSIS

The ideal introductory activity on wind turbines is, of course, a site visit, if a wind farm or significant wind turbine is located at or near the school.

The optional introductory activity outlined here involves measuring and mapping wind speed and direction at different locations around the school, to determine if there is a suitable location for a wind turbine on the school grounds.

ADVICE ON INTRODUCING WIND TURBINES

The optional excursion and the optional activity outlined below will both require time. The optional activity also requires the use of electronic anemometers and a wind sock or other device to determine wind direction. The teacher will need to weigh these demands against the potential benefits.

If time is limited, the teacher may prefer to show students an animation of how wind turbines work and discuss them in general terms, or show and discuss the PowerPoint presentation provided on the ATSE STELR CD-ROM. (See the background information on wind turbines on pages 120-125 of this resource.)

OPTIONAL INTRODUCTORY ACTIVITY: MAPPING THE SCHOOL'S WIND RESOURCE

Activity outline

Set the electronic anemometers to read wind speed in metres per second.

Discuss with the students how the wind speed and wind direction will be measured and recorded. Demonstrate how to read the anemometers.

Divide the students into groups and have them move around the school site to take their readings. This should include taking readings between buildings.

Pool the data collected to produce a map of the wind resource at the school.

Discuss the implications of the data for establishing a wind turbine at the school.

You need

- Electronic anemometers
- Devices for determining wind direction

Discussion

Students should discover that wind speeds increase between buildings. Depending on the topography of the school and its location, they may also find that the wind flows better at higher points where there are no obstacles setting up eddy currents. See the background information about the best sites for wind turbines on pages 122-123 of this resource.

TOPIC: WIND TURBINES

RUNNING PRACTICAL ACTIVITY 5: HOW MANY BLADES SHOULD A WIND TURBINE HAVE?

STUDENT BOOKLET pages 47—56

SYNOPSIS

This directed investigation gives students the opportunity to measure the power delivered by the STELR model wind turbine, and to determine how this is affected by the number of blades. The control of other variables, such as the length of the blades and the angle at which they are tilted, is emphasised to reinforce the principles of the experimental design and fair testing.

This experiment also builds up student understanding of how wind turbines work.

APPROXIMATE TIME REQUIRED

60 minutes

BACKGROUND INFORMATION FOR THE TEACHER

The number of blades that delivers the delivers the greatest amount of power depends on other factors, such as their weight, surface area, angle, shape, and so on. For the giant wind turbines on a wind farm, the weight of the turbine blades is a significant factor, which is why the turbines only have three blades. But small turbines may have more than three blades.

Table 1 shows the largest power delivery of a STELR wind turbine in one trial.

Table 1. Largest values of power delivered overall, compared with largest value of power delivered when the blades are set at 45 º

Blade length (cm)	7.5	7.5	10	10	15	7.5	10	15	10	7.5
Angle of blade (º)	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	45	45
Number of blades	4	3	4	6	3	6	3	4	12	4
Power delivered (mW)	43	35	35	35	35	32	32	32	14	13

It can be seen that the most significant parameter was the blade angle. Where this was 22.5 º, it was the interplay between blade length and number of blades that determined the power output. The power output was far less when the blade angle was 45 º.

Students will investigate the effect of number of blades in this Practical Activity. They may choose to investigate the effect of blade angle in the student-designed investigation of wind turbines (Practical Activity 6) or in the open student-designed investigation (Practical Activity 9).

See also the background information on wind turbines on pages 120-125 of this resource.

LIST OF MATERIALS REQUIRED

Per student pair:

- STELR testing station
- 2 x STELR multimeters
- 6 x 150 mm turbine blades set into a hub at 45 º
- Extra 150 mm turbine blades
- Tape measure or meter ruler
- Graph paper or spreadsheeting and graphing software
- STELR model wind turbine
- Connecting leads (with ‘piggy-back’ banana plugs)
- Three-speed electric fan
- Retort stand and bosshead
- Masking tape to mark position of fan & turbine (optional)

PRACTICAL ADVICE AND HINTS

The voltmeter and ammeter

1 An analog voltmeter can be used in place of the STELR multimeter set as a voltmeter, provided that students are taught how to use it correctly, including how to read the scales.

2 An analog milliammeter can be used in place of the STELR multimeter set as an ammeter, provided that students are taught how to use it correctly, including how to read the scales. (This is not recommended, however, given the sensitivity and cost of these instruments.)

Setting the blades into the hub

1 Teachers are strongly advised to provide the six blades already set into the hub. This will speed up the session considerably. It may even be worthwhile having different plastic tubs set up, one with hubs containing two blades, one with hubs containing three blades, and so on. However, there are two drawbacks to doing this. The first is that it introduces a new variable: the hubs may not perform in exactly the same way as each other. The second is that the students need to learn to insert blades for themselves for the next practical activity and possibly also for the open student-designed investigation (Practical Activity 9.)

2 Do not insert blades into a hub if it is on the turbine shaft.

3 To insert the blades into a hub, loosen the tensioning knob or wing nut on the hub that holds them firmly in place. Insert the blades carefully at the correct angle, as shown in Figure 3 on page 50 of the student booklet. Press each blade into its hole as far as it can go, so its base is right against the hub. This may or may not produce a clicking sound. Then rotate it so that it is at an angle of 45 º and its smooth side is facing the tensioning knob or wing nut. Ensure that the blades are evenly spaced. Once all the blades are inserted, tighten the knob or wing nut again. Note that if the blades are not inserted fully, the blades will be loose even if the tensioning screw or wing nut is screwed up as tightly as possible. This will create problems when the blades are spinning, including possible injuries if they fly into a student's eyes.

Setting up the wind turbine and circuit shown in Figure 1 on page 47 of the student booklet

1 Ensure that the students screw the bosshead firmly when the shaft is inserted into it, and that they insert the hub, once it has the correct number of blades, onto the lower shaft, so that the wind turbine is ungeared. They can then loosen the bosshead a little on the retort stand to move it up or down until the hub of the wind turbine is at the same height as the hub on the three-speed fan. The bosshead should then be tightened.

2 The diagram clearly shows how to connect the circuit. However:
- ***If the ammeter or voltmeter is connected the wrong way round, the digital readout will have a negative sign in front of it.***
- ***If an analog milliammeter or voltmeter is used, and is connected the wrong way round, the needle will move anticlockwise off the scale and no reading can be obtained.***

3 Make sure that the safety grill is secure on the three-speed fan. If necessary, use electrical ties to secure the grill.

Setting up the room

Avoid placing the fans too close together, or locating them in a strong draft. This may create too much wind turbulence, which may make it difficult to obtain reliable results around the room.

Running the experiment

1 The rotational speed of the turbine will vary over time; a steady reading is therefore not possible. It is best to let the turbine reach as steady a speed as possible, then quickly take the readings.

2 It can be useful to place masking tape on the bench to mark the positions of the fan and turbine, so that they can be kept at a constant distance apart.

3 Ensure that the turbines do not vibrate excessively, as this may reduce their efficiency. If one does vibrate excessively, first check that all the blades were properly inserted into the hub. If they were inserted correctly, the vibration may be caused by the fact that the blades are not identical and are not completely balanced. These vibrations can be reduced by adding small amounts of Blu-Tak to balance the turbine (like in a car wheel balance).

RISK MANAGEMENT

Students should be actively supervised throughout this practical activity.

Possible responses to the students' risk assessment activity are shown below.

Student activity sheet

The facts	What might be the risks?	What precautions will we take?
1 The model wind turbines could break if mishandled.	The model wind turbine could be accidentally dropped or set up wrongly.	Keep the equipment well away from the edge of the bench and do not lean on or over benches or move books or bags near them. Do not have other equipment or any liquids nearby. Have the teacher check the set-up and the circuit before turning on the three-speed fan.
2 Inserting the blades into the hub of the model wind turbine, or pulling them out, can cause breakages as well as hand injuries.	If this is not done according to the instructions, the equipment may break and people may cut their hand or perhaps break a bone in their hand.	Follow the step-by-step instructions very carefully. Do not try to do this too quickly. If necessary, ask the teacher to demonstrate this again.
3 If the blades are not inserted firmly into the hubs, they may fly out at a high speed whilst the turbine is spinning, and cause eye injuries.	If the hubs are not properly inserted and carefully tested before starting them spinning, someone could get a serious eye injury.	Have the teacher check that the blades are set into the hub correctly before placing it on the shaft of the wind turbine, then again after it is on the shaft. If there still is concern, wear safety glasses.
4 A fast-spinning electric fan will be used in this experiment.	If fingers or long hair get caught in the fan, someone could be seriously injured. Since the fan is an electrical device connected to mains electricity, someone could get electrocuted if there is water around or the lead gets pulled.	Tie long hair up and keep well away from the fan. Only use a fan that has a protective cage around it. Be very careful with the lead to the fan. Do not have water nearby.

ADVICE FOR THE CLASSROOM

Working in small groups of two or three gives students a greater opportunity to be actively engaged instead of merely being spectators in the activity. As a result, they are more likely to develop the skills and understandings that will help them in later investigations.

See also the general advice provided on pages 28—29 of this resource.

Teachers are strongly advised to:

Trial the activity prior to the class, to identify problems the students might encounter, judge the time they need and decide how to best manage the activity, particularly who should be in each group.

Setting up:

Have one set of equipment ready for a demonstration of how to set it up during the introductory discussion.

Introducing the activity:

1 Introduce this practical activity by outlining the inquiry questions and asking the students to individually or in pairs predict what number of blades will deliver the greatest power. But do not tell them if they are right or wrong. Tell them they will soon discover who was right. (This will help motivate the students.)

2 Demonstrate how to insert blades into the turbine hub and how to set up the wind turbine, according to the advice in Practical Advice and Hints on page 128 of this resource. Then connect it to the circuit with further discussion.
3 Advise the students that the distance between the fan and turbine of 50 cm was chosen because it yields the best results. Discuss why this distance must be kept constant. It may be helpful to put masking tape on the bench to outline the position of the fan to help students maintain this constant distance. Also advise the students to wait until the turbine gets up to speed and its speed steadies as much as possible, before taking a reading. They should note that even then, the readings will fluctuate and they should use their judgment about the best reading to take.
4 Discuss the design of the graph the students need to draw. Emphasise why the graph points should not be joined.
5 Discuss the safety precautions that need to be taken, eliciting as much as possible from the students.
6 Assign the students to their groups.
7 State your expectations of their behavior and the time limits they will work under.

During the session:

1 Be very vigilant. Check that the students are setting up the equipment correctly. (See the Practical Advice and Hints on page 128 of this resource for advice for trouble-shooting.)
2 With each group, whilst checking their equipment and circuit, ask the students questions about what they are discovering and what explanations they can suggest.
3 Watch that the students observe all of the agreed-upon procedures and safety precautions and are obtaining results in a timely manner.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report their findings. They should discuss which of their predictions came true, any problems they encountered, their conclusions and suggested explanations for their results. Ensure that each group contributes to the discussion.

This part of the session should take about 10—15 minutes.

EXPECTED RESULTS

These results are likely to surprise the students. Most will have predicted that the optimum number of blades is 3. (See the background information for the teacher on page 127 of this resource.)

Sample results for 150 mm blades set at 45 º

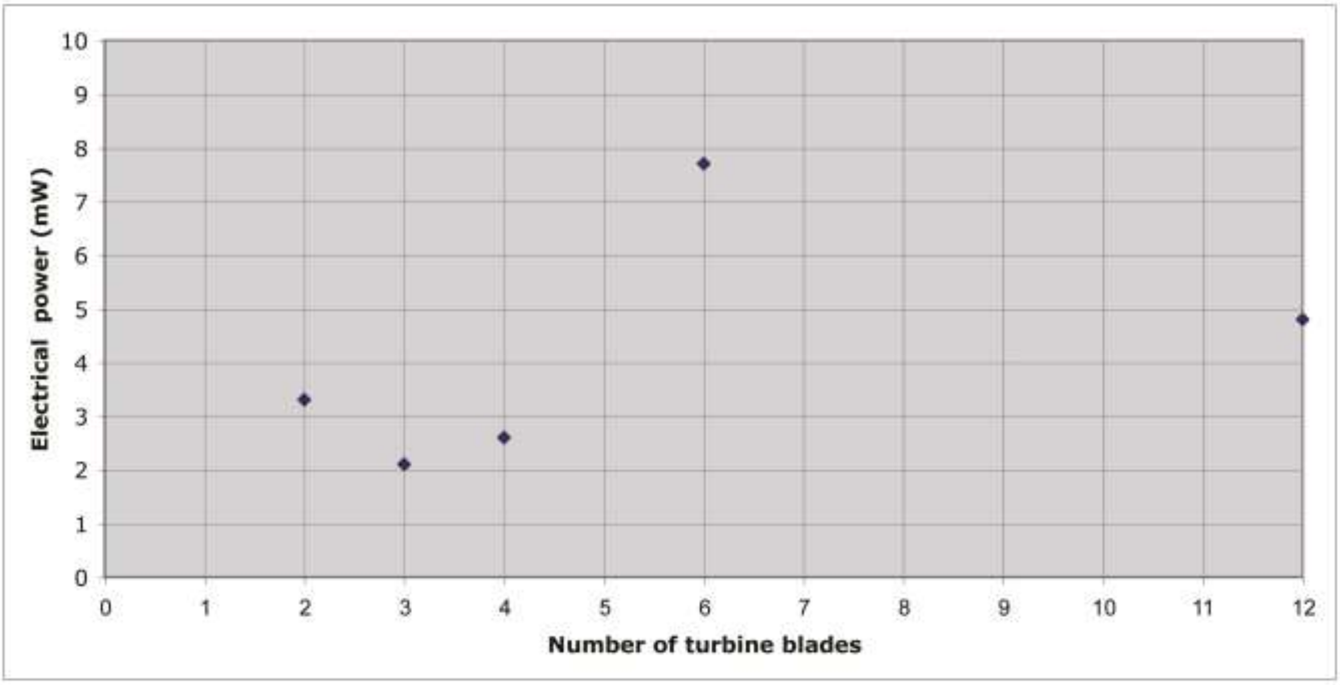
Number of turbine blades	Voltage *V* (V)	Current *I* (mA)	Electrical power *P* (mW)
12	0.40	12.0	4.8
6	0.57	13.5	7.7
4	0.29	8.9	2.6
3	0.23	9.0	2.1
2	0.37	9.0	3.3

Corresponding table of values for the graph of electrical power against the number of turbine blades

Number of turbine blades	2	3	4	6	12
Electrical power (mW)	3.3	2.1	2.6	7.7	4.8

The corresponding graph is shown on the next page.

Sample graph of electrical power against the number of blades



SUGGESTED ANSWERS TO DISCUSSION QUESTIONS

Discussion questions for Part A:

1 [*Student response*]

2 Decreasing the speed of the fan should decrease the power delivered by the wind turbine.

General discussion questions:

1 [*Student response*; *students may suggest that 6 blades gives more blade area available for the wind to push than the lower number of blades, while for 12 blades the extra area cannot compensate for the extra weight that has to be pushed.]*

2 This will depend on the class results. Any difference in group results can be explained by the fact that no two groups will have exactly the same conditions. There will be:

- Small differences in the supplied equipment
- Small differences in the distance between the fan and turbine
- Fluctuations in the wind speed and wind direction

Other sources of error include:

- Instrumental error in the ammeter and voltmeter
- The angle of the blades was not able to be measured and finely controlled

3 a The variables that were kept the same were:

- The length and shape of the blades (which should mean their weight was also the same)
- The angle of the blades to the wind
- The position and speed of the fan creating the wind

b The variable that could not be completely controlled was the wind speed and direction. This was not measured. Movement around the room, fans turning on and off, fluctuations in the power delivered to the fan, and so on, all will have affected the result for the power delivered. Where the wind was more turbulent or slower, the power delivered would have decreased.

4 If the blades were shorter they would not be as heavy, so would be easier for the wind to push them around. But they would have a smaller surface area to be pushed. So it is unlikely that the same results would be obtained.

5 If the blades were set at a different angle, the amount of push they get from the wind would be different so the power delivered would be different.

6 As the turbine spins very rapidly, it is important that the weight is distributed evenly around or it is likely to be damaged. One blade in a hub cannot have an evenly distributed weight as there is no blade to counterbalance it. The STELR turbine does not allow 5 or 7 blades to be evenly spaced around in the circular hub. Hence this number of blades cannot result in an even distribution of weight.

7 As they are so heavy, more than 3 blades might be too hard to push around. This would mean that less electrical power would be delivered than for 3 blades.

TOPIC: WIND TURBINES

RUNNING PRACTICAL ACTIVITY 6: HOW DOES BLADE LENGTH AFFECT THE OUTPUT OF A WIND TURBINE?

STUDENT BOOKLET page 57

SYNOPSIS

This is a guided student-designed investigation that builds on the experience the students gained in Practical Activity 5 and in the bouncing balls experiment (Practical Activity 2). Students need to have performed both of these experiments to gain the most out of this experiment.

This practical activity provides valuable training for students in experimental design, which should help prepare them for their open student-designed investigation (Practical Activity 9).

Students will explore this inquiry question at different levels. Most are likely to retain the 45 ^{o} angle of the blades, but some may wish to trial other angles. Teachers are advised to counsel them against trialling other angles, since it can be a question they pose for the open student-designed investigation.

Some groups may select just a single number of blades (say 6). This would produce only 3 sets of data, however. Others may check whether the result changes with the number of blades.

APPROXIMATE TIME REQUIRED

60 minutes

BACKGROUND INFORMATION FOR THE TEACHER

See the background information on designing experiments, on pages 91—93 of this resource.

See the background information on the power delivered by a STELR wind turbine on page 127 of this resource.

LIST OF MATERIALS REQUIRED

Per student pair:

- STELR testing station
- 2 x STELR multimeters
- 12 x 150 mm turbine blades
- 12 x 75 mm turbine blades
- Retort stand and bosshead
- Masking tape to mark position of fan & turbine (optional)
- A3-sized copy of the Investigation Planner (pages 81-82 of the student booklet)
- STELR model wind turbine
- Connecting leads (with ‘piggy-back’ banana plugs)
- 12 x 100 mm turbine blades
- Three-speed electric fan
- Tape measure or meter ruler
- Graph paper or spreadsheeting and graphing software

PRACTICAL ADVICE AND HINTS

See page 128 of this resource.

RISK MANAGEMENT

Students should be actively supervised throughout this practical activity. See the risk assessment on page 129 of this resource.

ADVICE FOR THE CLASSROOM

Working in small groups of two or three gives students a greater opportunity to be actively engaged instead of merely being spectators in the activity. As a result, they are more likely to develop the skills and understandings that will help them in later investigations.

See also the general advice provided on pages 28—29 of this resource.

Teachers are strongly advised to:

Trial the activity prior to the class, to identify problems the students might encounter, to judge the time they need and to decide how to best manage the activity, particularly who should be in each group.

Setting up:

Since the students should have gained experience in setting up the STELR model wind turbine in the previous practical activity, no demonstration should be required.

Introducing the activity:

1 Introduce this practical activity by outlining the inquiry question and telling the students they are to design their own experiment to discover the answer.
2 Assign the students to their groups and give them an investigation planner. They should complete the first page of this.
3 State your expectations of their behavior and the time limits they will work under.

During the session:

1 Ensure that the students do not start the experiment until they have submitted their investigation planner and had it approved.
2 Be very vigilant. Check that the students are setting up the equipment correctly. (See the Practical Advice and Hints on page 128 of this book for advice for trouble-shooting.)
3 With each group, whilst checking their equipment and circuit, ask the students questions about whether they are having any problems with the design of the experiment and what modifications they have made (if any), what they are discovering and what explanations they can suggest. Check that they are only changing one variable at a time.
4 Check that the students observe all of the agreed-upon procedures and safety precautions and are obtaining results in a timely manner.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report their findings. They should discuss which, if any, of their predictions came true, any problems they encountered, their conclusions and suggested explanations for their results. Ensure that each group contributes to the discussion.

This part of the session should take about 10—15 minutes.

EXPECTED RESULTS

These results are likely to surprise the students. Some will have predicted that the longer the blades, the greater the power output, because this provides the greatest surface area for the wind to push. Others will predict that shorter blades will deliver the most power, because they weigh less. (See the background information for the teacher on page 127 of this resource.)

As stated at the start, some student groups may generate only three sets of results. Others may generate a larger number by testing different numbers of blades. The following tables show the results for three different length blades. These will be drawn on the same graph.

Sample results for blades set at 45 º

Blade length (mm)	Number of turbine blades	Voltage *V* (V)	Current *I* (mA)	Electrical power *P* (mW)
150	12	0.40	12.0	4.8
	6	0.57	13.5	7.7
	4	0.29	8.9	2.6
	3	0.23	9.0	2.1
	2	0.37	9.0	3.3
100	12	0.80	17.2	14
	6	0.72	15.4	11
	4	0.72	15.4	11
	3	0.60	14.2	8.5
	2	0.30	10.3	3.1
75	12	0.81	15.0	12
	6	0.50	10.4	5.2
	4	0.85	15.7	13
	3	0.75	13.0	9.8
	2	0.60	13.0	7.8

Table of values for the graph of electrical power against length of turbine blades, for 12 blades set at 45º

Length of turbine blade (mm)	75	100	150
Electrical power (mW)	12	14	4.8

Table of values for the graph of electrical power against length of turbine blades, for 6 blades set at 45º

Length of turbine blade (mm)	75	100	150
Electrical power (mW)	5.2	11	7.7

Table of values for the graph of electrical power against length of turbine blades, for 4 blades set at 45º

Length of turbine blade (mm)	75	100	150
Electrical power (mW)	13	11	2.6

Table of values for the graph of electrical power against length of turbine blades, for 3 blades set at 45º

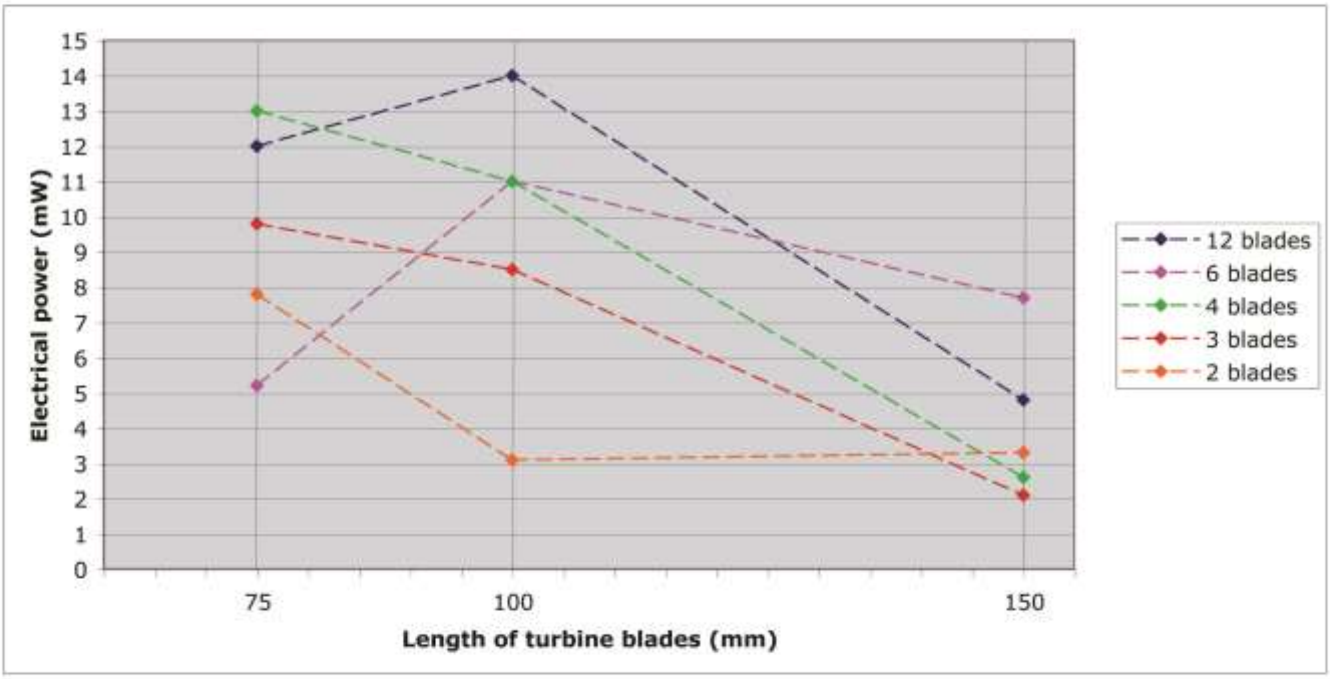
Length of turbine blade (mm)	75	100	150
Electrical power (mW)	9.8	8.5	2.1

Table of values for the graph of electrical power against length of turbine blades, for 2 blades set at 45º

Length of turbine blade (mm)	75	100	150
Electrical power (mW)	7.8	3.1	3.3

The corresponding graph is shown below.

Graph of electrical power against length of turbine blades, for different numbers of blades



About this graph: Although blade length theoretically is a continuous quantity, as is electrical power, because the data was limited to three lengths the graph points have only been joined with broken lines. (The in-between values cannot be certain.)

It can be seen that for 6 or 12 blades, the greatest power output is achieved with the 100 mm blades. But for 2, 3 or 4 blades, the greatest power output is achieved with 75 mm blades.

SUGGESTED ANSWERS TO DISCUSSION QUESTIONS

1 [*Student response will depend on the results obtained]*

2 [*Student response will depend on the results obtained]*

3 [*Student response will depend on the results obtained; a thinking student might point out that the results may be very different if the blade angle were different.]*

4 Student responses need to be consistent with their results. Shorter blades weigh less but present less surface area to the wind.

TOPIC: WIND TURBINES

WORKSHEET 4: ARE WIND FARMS DANGEROUS FOR BIRDS?– ADVICE AND POSSIBLE RESPONSES

STUDENT BOOKLET PAGES 58—60

ADVICE

This can be a very emotive issue for students who live near wind farms. Communities can be very divided on this issue. Responses can range from the kind of placards shown in the photograph on page 46 of the student booklet, to strong support of and lobbying for more wind farms. Outline the rules for critical thinking and emphasise the importance of basing arguments on objective scientific evidence. Also insist that the students show respect for those who have different views on this issue.

SUGGESTED SOLUTIONS TO RESEARCH QUESTIONS

1 For large commercial wind turbines, the towers are 60—90 m tall. Three blades, which are each about 20—40 m in length, rotate at about 10—22 revolutions per minute. Blade tip speeds are up to 320 kilometres per hour. (The largest wind turbine used at present delivers up to 6 MW. Its height is 198 m and its diameter is 126 m.)

2 In the US it has been estimated that between 100 million and 1 billion birds die each year as a result of colliding with windows in residential and commercial buildings.

3 In the US it has been estimated that 50—100 million birds die each year as a result of colliding with cars and trucks.

4 In the US it has been estimated that more than 100 million birds die each year as a result of being attacked by cats.

5 In the US it has been estimated that 10 000—40 000 birds die each year as a result of colliding with wind turbines. Most of these have been in one particular region (Altamont Pass in California) and have been attributed to the topography, the location in relation to the local bird population and the major flight path of certain migratory birds, and the older, inefficient design of the wind turbines in this region.

6 In the US in 2007, 4654 pedestrians were killed.

SUGGESTED RESPONSES TO REFLECTION QUESTIONS

1—4 *Student response*

5 *Student response. Students may consider the impact of the lack of cars on employment, involvement in sports and recreation, ability to obtain medical help in the event of accidents or illness, and social contacts. They may consider the impact of the ban on cats on the emotional health and well-being of many people, especially isolated elderly.*

6 *Student response. Students may raise points such as putting the issue into a wider perspective. What are the main dangers to birds?*

7 *Student response. Students might consider the facts that there are far more wind turbines in the US. Australian wind turbines are of a newer design, so are likely to pose less danger than the more deadly older wind turbines in some regions of the US. Hence it is likely that there are far fewer bird deaths due to wind turbines here. Therefore the statement makes the problem sound far worse than it is.*

8 *Student responses may include: Was the Minister motivated by election issues for his party in that region? Were the Minister and his party being criticised in the media for insufficient action on environmental issues at that time, or other bigger issues, so they needed to distract the public with an action that would gain public sympathy? What were the motives or those who lobbied the minister on this issue?*

9 *Student response. Students might conclude that feral and domestic cats, vehicles, loss of habitat, the use of pesticides, and so on, are more likely to pose a danger to the birds and cause their extinction than wind turbines.*

10 *Student response. Students might consider the fact that instead we could turn to nuclear power plants to meet our increasing energy demands, with their attendant risks, in order to reduce our greenhouse gas emissions.*

TOPIC: SOLAR CELLS

BACKGROUND INFORMATION FOR THE TEACHER

What are solar cells and solar panels?

Solar cells, also known as **photovoltaic cells** or **PV cells**, are devices that convert solar energy directly into electrical energy. **Solar energy** is the energy we receive from the Sun.

A **solar panel** consists of a set of solar cells connected in series and/or in parallel to produce a desired voltage and current. The solar cells are set into a frame.

A **solar array** (also known as a PV cell array) is set of solar panels connected in a grid like those in Figure 1**.** Solar arrays are used on the rooftops of buildings, including homes and schools, to help meet their energy requirements.

Figure 1. The solar array on the rooftop of Mossman State High School, Queensland. This STELR school is part of the Australian National Solar Schools Program (NSSP).

Sometimes solar arrays can generate more electricity than is required. The excess electrical energy produced can be sold back into the electricity grid, when the solar system is connected into it.

Meeting the world's demand for electrical power

Global demand for electrical power is increasing all the time. In 2006 it was about 16 TWe; this is expected to rise to about 18 TWe by 2030. (See Table 1 on the next page for information about this unit of electrical power.)

It has been claimed that this global demand could be met by covering the areas shown as black in the map on the next page with solar panels (Figure 2). In determining this, it is assumed that the solar panels covering the 'black spot' regions of the world in Figure 2 would be operating at 8 % energy efficiency. That is, just 8 % of the light energy reaching the panels would be transformed into electrical energy. (The remaining 92 % of the light energy would be transformed into heat energy.) This is a typical value for the percentage energy efficiency of silicon-based solar panels, although new technologies have achieved greater efficiencies.

Three countries in particular have taken the ability of solar cells to meet their energy needs very seriously, and have extensive areas covered by solar panels, far more than all the other countries combined. They are Germany, Japan and the US.

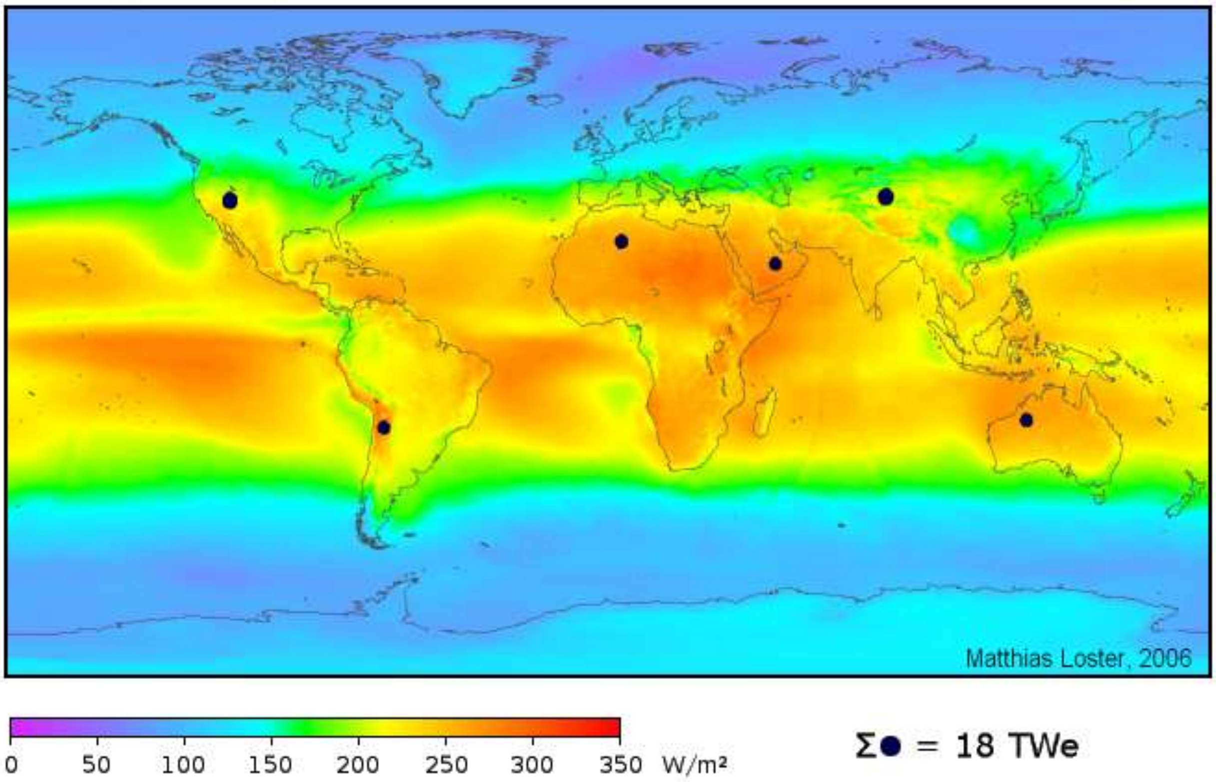


Figure 2. A map of the world, coloured to show how much solar power reaches the Earth's surface in each region, measured in watts per square metre. **Source:** http://en.wikipedia.org/wiki/File:Solar_land_area.png **Accessed:** 17 August 2010

About this map

- **Solar power is the amount of solar energy that is delivered per second. A value of 250 watts per square metre means every square metre of surface in that region receives 250 watts of solar power (i.e. 250 joules of solar energy per second).**
- **The symbol "Σ• = 18 TWe" means that the total amount of electrical power you would get from all the solar panels covering all the 'black spot areas' would be 18 terawatts. (See Table 1 on the next page for more information about this unit of measurement.)**
- **The values of solar power in the map are average values taken from readings over the period 1991—1993, for 24 hours a day. They take into account the effect of cloud cover over that period.**

What is a TWe?

This unit of electrical power is explained in Table 1.

Table 1 Metric units of electrical power

Unit of electrical power	Symbol	Relative value	Commonly used to measure:
watt	W	This is equivalent to 1 joule of electrical energy delivered per second. It is the standard international unit for power	The electrical power required to run household appliances such as light globes and microwave ovens.
kilowatt	kW	1 kW = 1000 W = 10^3 W	The electrical power delivered by a small-scale energy resource, such as a solar array.
megawatt	MW	1 MW = 1 000 000 W = 10^6 W	The electrical power delivered by a large-scale energy resource, such as a coal-fired power station.
terawatt	TW *Or* TWe	1 TW = 1 000 000 000 000 W = 10^{12} W	The total electrical power demanded across the world. ***Note:*** *• The small 'e' in TWe is often used to distinguish electrical power from other forms of power, such as solar power.* *• The prefix 'tera' comes from a Greek word meaning 'monster'.*

How do solar cells work?

Solar cells transform solar energy into electrical energy. This can be represented as follows:

Solar energy → Electrical energy

The main steps involved are:

STEP 1: Light consists of little 'parcels' or 'packets' of energy called **photons**. When photons shine on a solar cell, they are absorbed by the cell. This causes the cell to release electrons.

STEP 2: The liberated electrons enter wires and travel around an electrical circuit. The resulting electrical current is in the form of a direct current (DC).

The more intense the light, the greater the number of electrons liberated per second and the greater the amount of electrical power produced.

How are rooftop solar systems set up?

A **rooftop solar system** is the name given to the solar array on the roof of a building, together with the electrical circuit that must be set up to link the solar array to the electrical circuitry in the building.

As stated above, the electrical current produced by a solar cell is a direct current. However, electrical appliances operate on an alternating current (AC), a current which continually switches the direction in which it flows. For this reason a device known as an **inverter** must be inserted into a rooftop solar system to convert the direct current into an alternating current. It is usually located next to the meter box, as shown in Figure 3 on the next page.

← **A utility pole is another name for a power pole**

Figure 3. How a PV (solar) array and an inverter are connected into household wiring.

Source: http://www.cobaltpower.com/images/house_conceptual.jpg **Accessed:** 24 August. 2010

The electrical energy generated that is not needed at the time can be:

1 'Stored' in a bank of batteries that are connected into the solar system, so that it is available at night, or

2 'Fed' into the power grid (if the building is connected into one).

When a building is in a remote area, and is not connected into a power grid, the bank of batteries is necessary to store the electrical energy for night-time, when the solar panels cannot generate electricity.Batteries store electrical energy by transforming it into chemical potential energy. When the battery is connected to a complete electric circuit, such as when the lights are turned on, the chemical potential energy is transformed back into electrical energy.

When electrical energy is fed back into power grid, a meter measures the electrical energy that has been supplied.

Types of solar cell

How a solar cell works depends on whether it is a silicon-based solar cell or another type of solar cell, such as an organic solar cell (which is made up of plastics), or a dye-sensitised solar cell (also known as a Grätzel cell).

Different research teams across the world are doing some very exciting work using different designs and different technologies, including nanotechnology, in the hope of developing solar cells that not only cost less, but also are:

- More efficient (convert a greater the proportion of the energy from the Sun into electrical energy)
- More environmentally friendly (made from less harmful substances, consume less of the Earth's resources, produce less wastes when manufactured)
- Able to be used in a wider variety of applications

Some research projects involve developing flexible, light solar cells that can be part of clothing or a back pack used by people such as hikers and field workers. Others involve developing windows and roofs that can act as solar panels.

Only conventional silicon-based solar cells are discussed here, because they are the main ones being used across the world today.

Silicon-based solar cells

Even silicon-based solar cells are not all the same, in fact. There are a number of different types, and researchers are developing new technologies all the time in order to improve their energy efficiency. What they do have in common, however, is that the material that releases electrons when light shines on it is mostly made from the element silicon. This is a very abundant element on Earth. Sand, for example, is made from silicon.

One kind of silicon-based solar cell has two wafer-thin layers of silicon sandwiched together, as shown in Figure 4.

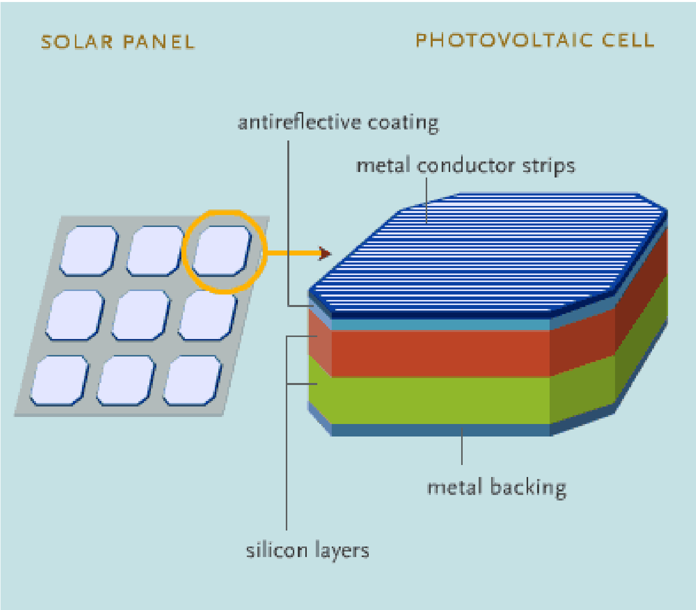


Figure 4. Inside one kind of silicon-based solar cell.

Source: http://www.pbs.org/wgbh/nova/solar/images/insi-01.gif **Accessed:** 24 August 2010

The two silicon layers you can see in the cell in Figure 4 are both made from highly purified silicon. Of these two layers, the top layer is the one exposed to the light. This is made up of a material that releases electrons when it absorbs light energy.

Animation of a silicon-based solar cell in action

Visit www.stelr.org.au/renewable-energy and click on 'Solar Electricity'. Click on the link to the animation on how solar cells work in the background information on solar cells.

Energy efficiency of solar panels

Photovoltaic cells can never be 100% efficient. Silicon crystal cells have a maximum theoretical efficiency of 28 %.The relatively low percentage energy efficiency of solar cells has to do with the nature of light and the way electrons are bound to the atoms in the solar cells.

Light can be modelled as packets of energy called photons. When a photon hits an electron in a PV cell many things can happen.

- The photon will not have enough energy to remove the electron from its atom. The photon's energy will be transformed into thermal energy. The cell heats up.
- The photon has just enough energy to remove the electron from its atom. The electron will contribute to the current of the cell.
- The photon has more than enough energy to remove the electron from its atom. The electron will contribute to the current of the cell, but the photon's excess energy will again be transformed into thermal energy. The cell heats up.
- The photon does not interact with an electron. The photon's energy will be transformed into thermal energy in the cell.

What are some advantages and disadvantages of solar panels?

These are summarised in Table 2.

Table 2 Some advantages and disadvantages of solar panels

Advantages of solar panels	Disadvantages of solar panels
They are a renewable energy resource. Solar energy will be available for millions of years, and there is more than enough to supply all of the world's energy needs.	The amount of electrical power they generate varies all the time, due to the changing position of the Sun in the sky, changing cloud cover, dust, and so on.
Solar energy is free and solar panels have a long life. (They can last up to 50 years.) Therefore they are a good long term investment.	They are expensive to install. Many people cannot afford this.
Whilst operating, solar panels do not produce greenhouse gases or other pollutants. And as they last for up to 50 years, they soon more than compensate for the greenhouse gases emitted in making them, especially if they replace polluting forms of lighting such as kerosene lamps.	Silicon-based solar panels contain some toxic materials, and energy is required to extract and transport the raw materials, and to manufacture, transport and install the panels, which means that greenhouse gases and various pollutants are produced at these stages.
They operate without noise.	Some people do not like their appearance on roofs (although work is now being done to incorporate them into the structure of new buildings).
They can be used in areas where there is no access to an electricity grid, including remote areas and Space.	They do not produce electrical power at night. In homes, this is the time when the demand for electrical power is greatest.
The heat energy also produced can be used to heat water.	They have low energy efficiency.

FURTHER INFORMATION

CAREER PROFILES

Go to the careers page on the STELR website at www.stelr.org/au/career-profiles to see the career profiles of:

- Nicole Kuepper, who is conducting research in new solar cell technologies
- Chris Wilson, who has played an important part in installing rooftop solar systems on important large buildings, including those featured in the case study on greener cities.

INFORMATION ABOUT SOLAR CELLS, SOLAR PONDS, ETC.

See the additional information on solar cells on the STELR website at http://www.stelr.org.au/solar-electricity/ . Also see the list of websites on pages 169—170 of this resource.

HOW SOLAR CELLS ARE MAKING A DIFFERENCE IN THIRD WORLD COUNTRIES

Visit: http://www.stelr.org.au/solar-electricity/ . Then click on the Case Study: 'Lighting The World'. Find out how some Australian engineers are making a huge difference with their solar lamps.

HOW ROOFTOP SOLAR SYSTEMS ARE HELPING CITIES BECOME GREENER

Go to the same section of the STELR website and click on the Case Study: 'Greener Cities'. Find out how one of Australia's most well-known actors and some iconic buildings are now helping reduce our greenhouse emissions.

HOW SOLAR ENERGY CAN BE CONCENTRATED AND STORED

Go to the same section of the STELR website and click on the case study on concentrating and storing solar energy.

TOPIC: SOLAR CELLS

IDEAS FOR INTRODUCTORY ACTIVITIES ON SOLAR CELLS

SYNOPSIS

This optional introductory activity explores one possible useful application of solar cells – providing the electrical energy needed to split up water into hydrogen and oxygen.

This is a teacher demonstration. Some universal indicator solution is added to the water to help reveal the other products of the electrolysis. Students will be fascinated to see the colour changes it undergoes.

On a larger scale, hydrogen and oxygen produced from the electrolysis of water is used for a hydrogen-oxygen fuel cell, which can deliver electrical power continuously because the reactants are fed in continuously. On the International Space Station, for example, these fuel cells are used to supply the power needed to keep the electrical systems running. And the only product of the reaction is drinking water!

ADVICE ON INTRODUCING SOLAR CELLS

This topic should be introduced by eliciting from the students what applications they have seen of solar cells. These can include small solar panels that power garden lights, road signs, racing cars, yachts, and so on.

The optional activity outlined below is quite fast, very safe and widens the students' horizons by alerting them to yet another application of solar cells as well as to another energy resource – hydrogen-oxygen fuel cells.

Alternatively, students could be shown solar racing cars or solar-powered boats in action, or if the school has solar panels installed, they could be taken to see the meter that measures their output.

Note: Videos of the electrolysis of water using solar panels can be found on the internet. Use 'electrolysis of water video using solar panel' as the key search words.

OPTIONAL INTRODUCTORY ACTIVITY: THE ELECTROLYSIS OF WATER

Activity outline

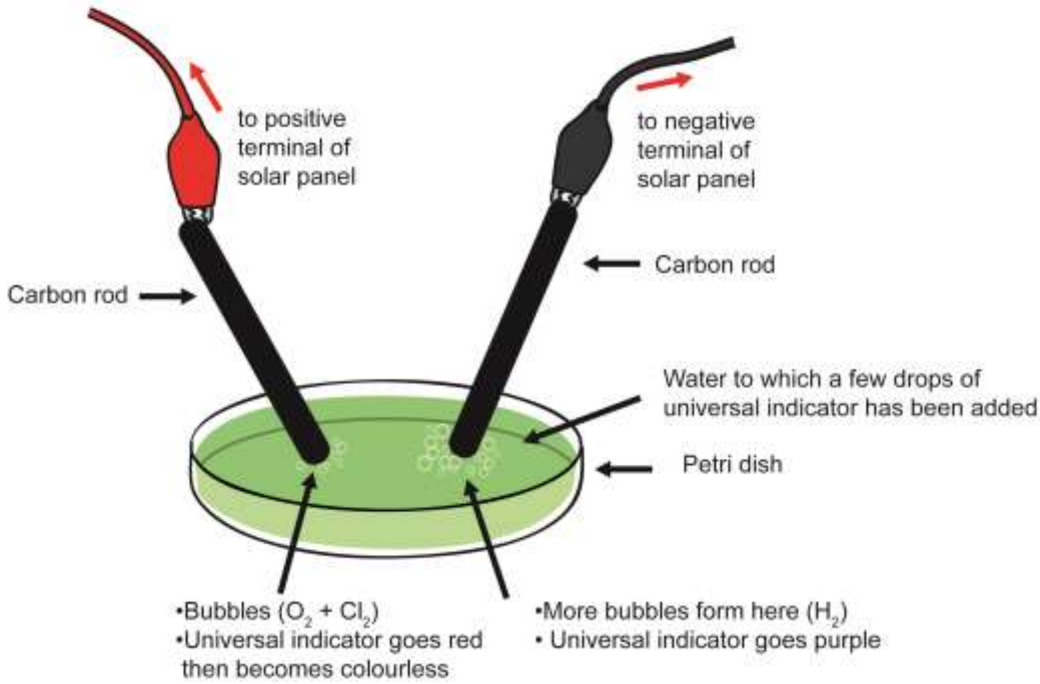
Connect the solar cells in series, as shown on pages 68-69 of the student booklet.

Half-fill a Petri dish with 0.1 M saline solution then add a few drops of universal indicator solution to it. (The salt is added to improve the electrical conductivity of the water.)

Connect the black and red wires on the solar panel (shown in Figure 10 on page 69 of the student booklet),to graphite electrodes. Then insert the electrodes into the Petri dish, as shown in the diagram on the next page. The Petri dish can be placed on an overhead projector or under a camera to show students a close-up view. .

Place the solar panel in direct bright sunlight if possible. Otherwise shine the two halogen lamps onto it.

See whether sufficient electrical energy can be produced to cause the water to break down into hydrogen and oxygen. This will be indicated by the formation of bubbles at the surfaces of the electrodes. This process is termed the electrolysis of water. (*Electrolysis* literally means 'splitting by electricity'.)



The experimental set-up
Note: Colour changes in the indicator, as described in the annotations to the diagram and on the next page, are not shown here.

You need

- Large Petri dish
- Small dropper bottle of universal indicator solution
- Solar panel
- 2 x halogen lamps and powerpack (if necessary)
- 20 mL of 0.1 M saline solution (5.9 g NaCl per 100 mL)
- 2 x graphite electrodes (carbon rods)
- Connecting leads (two with an alligator clip at one end)

Discussion

The net balanced chemical equation for the electrolysis of water is:

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$$

The oxygen is produced at the positive electrode (the electrode connected to the red lead on the solar panel). An acid (H^+ ions) also is produced at this electrode, which turns the indicator near the electrode a red colour.

The hydrogen is produced at the negative electrode (the electrode connected to the black lead on the solar panel). A base (OH^- ions) also is produced at this electrode, which turns the indicator near the electrode a purple colour. There should be more bubbling at this electrode, because twice as much hydrogen gas as oxygen gas is produced, as shown in the above equation.

Interestingly, once the electrolysis is stopped, if the solution is stirred, the indicator should return to its green colour, because the acid and base neutralise each other. (The H^+ ions and OH^- ions react to produce H_2O.)

However, in practice this is unlikely to be observed because the concentration of the chloride ions in the solution is probably too high. Because of their presence, chlorine gas should be produced at the positive electrode as well as oxygen. The chlorine not only will be detected by its odour, but also by the fact that the indicator around the positive electrode will soon turn colourless due to the bleaching action of chlorine.

Note:

1 The very small amount of chlorine produced in this teacher demonstration should not cause any safety concern. The chlorine concentration will be far lower than that encountered at any chlorinated swimming pool.

2 Sodium hydroxide and chlorine are produced industrially on a large scale by the electrolysis of concentrated sodium chloride solution (known as brine). The net reaction is: $2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + Cl_2(g)$

TOPIC: SOLAR CELLS

RUNNING PRACTICAL ACTIVITY 7: WHAT POWER CAN YOU GET FROM A SOLAR PANEL?

STUDENT BOOKLET pages 62—74

SYNOPSIS

This directed investigation experiment gives students the opportunity to measure the electrical power delivered by the STELR solar panel. After measuring the power delivered by a single solar cell, half of the class groups connect the four solar cells in series, and the other half connect them in parallel, to measure and compare their power output. This task division not only saves time and repetition, but also models the jigsaw approach to learning, enabling students to become class experts who then share their knowledge.

This builds on the understanding and skills gained in Practical Activity 4: Connecting batteries in series and parallel, which was designed to prepare students for this activity.

APPROXIMATE TIME REQUIRED

60 minutes

BACKGROUND INFORMATION FOR THE TEACHER

In order to meet a particular load, PV cells must be connected in a combination of series and parallel, to supply the required current and voltage. The electrical power delivered by most roof installations of solar panels is of the order 1-1.5 kW

The relationship between the voltages and currents delivered by solar cells should be as follows:

Solar cells in series

Total output voltage is the sum of the individual voltages of the cells: $V_t = V_1 + V_2 + \ldots$

Current is the SAME throughout the circuit: $I_t = I_1 = I_2 = \ldots$

Solar cells in parallel

Output voltage is the SAME as if there were just one cell: $V_t = V_1 = V_2 = \ldots$

Total current is the sum of the individual currents: $I_t = I_1 + I_2 + \ldots$ **(Note: I_1 etc. are smaller than that for a single cell)**

The effect of temperature on the power output of a solar cell

The ambient temperature will have an effect on the results of this experiment. In general, the lower the temperature, the greater is its power output. There is some data about the effect of temperature on the performance of different types of solar cells in the following website, including graphs. (See the table of websites on page 169 for an overview of this website.)

http://www.ata.org.au/wp-content/renew/101_solar_panel_buyers_guide.pdf

LIST OF MATERIALS REQUIRED

Per student pair:

- STELR testing station
- 2 x STELR multimeters
- 2 x lamps
- STELR solar panel
- Connecting leads (with ‘piggy-back’ banana plugs)
- Power pack
- Masking tape to mark position of solar panel and lamps on bench (optional)

PRACTICAL ADVICE AND HINTS

The voltmeter and ammeter

1 An analog voltmeter can be used in place of a STELR multimeter set as a voltmeter, provided that students are taught how to use it correctly, including how to read the scales.

2 An analog milliammeter can be used in place of the STELR multimeter set as an ammeter, provided that students are taught how to use it correctly, including how to read the scales. (This is not recommended, however, given the sensitivity and cost of these instruments.)

Setting up the circuit shown in Figure 5 on page 65 of the student booklet

1 The diagram clearly shows how to connect the circuit. For both the ammeter and voltmeter, the lead connected to the negative terminal of the ammeter and the voltmeter should be connected to the negative terminal of the solar cell (the black socket). In the case of the STELR multimeter, the negative terminal is the COM socket. However:

- ***If the ammeter or voltmeter is connected the wrong way round, the digital readout will have a negative sign in front of it.***
- ***If an analog milliammeter or voltmeter is used, and is connected the wrong way round, the needle will move anticlockwise off the scale and no reading can be obtained.***

2 If there is bright sunlight, this should be used as the light source shining on the solar cell instead of the halogen lamps. It then should be used for the rest of the experiment for valid comparisons. If, however, the intensity of the sunlight is markedly fluctuating, then this should be avoided as the results will not be comparable.

Setting up the room

Avoid placing the halogen lamps and power packs anywhere near water or sinks.

Running the experiment

1 The intensity of the light shining on the solar panels will vary over time; hence steady readings of current and voltage are unlikely. It is best to wait until they are as steady as possible before recording current and voltage.

2 It can be useful to place masking tape on the bench to mark the positions of the lamps and the solar panel, so that they can be kept at a constant distance apart.

RISK MANAGEMENT

Students should be actively supervised throughout this practical activity.

Possible responses to the students' risk assessment activity are shown below.

Student activity sheet

The facts	What might be the risks?	What precautions will we take?
1 Multimeters are very sensitive digital instruments	The multimeters could be accidentally dropped or set wrongly or placed the wrong way in a circuit.	Keep the multimeters well away from the edge of the bench. Have the teacher check the circuit and the multimeter settings before closing the switch.
2 The solar panel could break if mishandled.	The solar panel could be accidentally knocked off the bench if students lean over them or move books etc. near it.	Keep the solar panel well away from the edge of the bench and do not lean on or over benches or move books or bags near it.
3 The lamps get very hot.	If the lamps are accidentally touched, burns could result.	Avoid going near the lamps. Turn them on only when required. Do not pack them away until they have cooled.
4 The lamps are connected to a power pack, which in turn is connected to a mains electricity power point.	If water or metal objects are near the power point or power pack, they could cause someone to be electrocuted!	Don't have any water near the lamps, power packs or power point. Do not put metal objects near the power point and be careful not to pull the leads.

ADVICE FOR THE CLASSROOM

Working in small groups of two or three gives students a greater opportunity to be actively engaged instead of merely being spectators in the activity. As a result, they are more likely to develop the skills and understandings that will help them in later investigations.

See also the general advice provided on pages 28—29 of this resource.

Teachers are strongly advised to:

Trial the activity prior to the class, to identify problems the students might encounter, judge the time they need and decide how to best manage the activity, particularly who should be in each group and which groups will investigate the solar cells connected in series and which will investigate the solar cells connected in parallel.

Setting up:

Have one set of equipment ready for a demonstration of how to set it up during the introductory discussion.

Introducing the activity:

1 Introduce this practical activity by outlining the inquiry questions and asking the students to individually or in pairs predict what way of connecting the solar cells will deliver the greatest power – in series or in parallel? But do not tell them if they are right or wrong. Tell them they will soon discover who was right. (This will help motivate the students.)
2 Demonstrate how to connect the circuit in Figure 5 on page 65 of the student booklet. It is probably better to gather students around the first group that is ready to connect the solar cells in series to show this to the other students doing the same, and likewise for the groups connecting the solar cells in parallel, rather than spending time at this point.
3 Advise the students that they need to ensure that the angle of the solar panel and its distance from the lamps must be kept constant, ask them to suggest the reason for this (which is to maintain a constant light intensity as much as possible).
4 Discuss the safety precautions that need to be taken, eliciting as much as possible from the students.
5 Assign the students to their groups.
6 State your expectations of their behavior and the time limits they will work under.

During the session:

1 Be very vigilant. Check that the students have made their predictions before they start and that they are setting up the equipment correctly. (See the Practical Advice and Hints on page 147 of this resource for advice for trouble-shooting.)
2 As stated above, watch out for an opportunity to demonstrate connecting the solar cells in series to those groups who need to see this, and connecting the solar cells in parallel to the remaining groups.
3 With each group, whilst checking their equipment and circuits, ask the students questions about what they are discovering and what explanations they can suggest.
4 Check that the students observe all of the agreed-upon procedures and safety precautions and are obtaining results in a timely manner.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report and compare their findings. They should discuss which of their predictions came true, any problems they encountered, their conclusions and suggested explanations for their results. Ensure that each group contributes to the discussion.

This part of the session should take about 10—15 minutes.

EXPECTED RESULTS

Sample results

Solar cell arrangement	Voltage *V* (V)	Current *I* (mA)	Electrical power *P* (mW)
Single solar cell	0.538	14.0	7.5
4 solar cells connected in series	1.68	26.4	44.3
4 solar cells connected in parallel	0.538	13.8	7.4

It can be seen that connecting the solar cells in series delivers far more power than connecting them in parallel.

Note:

1 As the cells get hotter they deliver less power.

2 The students cannot control the ambient light, so light intensity is not controlled.

SUGGESTED ANSWERS TO DISCUSSION QUESTIONS

The variables (page 64 of the student booklet):

The variables operating include:

- The intensity of the light shining on the panel
- The angle of the panel to the light
- The temperature
- The internal resistance of each cell
- The kind of solar cell being tested
- The number of solar cells operating and where there is more than one operating, the way in which they are connected
- How clean the solar cells are –where there is any dust or greasy deposits on their surface

The variable being tested is highlighted above.

General discussion questions:

1 [*Student response will depend on class results*]

2 *Student response will depend on class results*]

3 [*Student response]*

4 [*Student response]*

5 *Any difference in group results can be explained by the fact that no two groups connecting the solar cells in the same way will have exactly the same conditions. There will be:*

- Small differences in the supplied equipment
- Small differences in the distance between the solar panel and the lamps
- Small differences in the angle of tilt of the solar panels
- Fluctuations in the intensity of the light shining on the solar panels, which will be different for each group
- Instrumental error in the ammeter and voltmeter, which will be different for each group
- Differences in groups' decisions regarding when the readings were steady

TOPIC: SOLAR CELLS

RUNNING PRACTICAL ACTIVITY 8: WHAT IS THE BEST ANGLE FOR A SOLAR PANEL?

STUDENT BOOKLET pages 75—76

SYNOPSIS

This is a guided student-designed investigation that builds on the experience the students gained in Practical Activities 2, 6 and 7.

This practical activity provides further valuable training for students in experimental design, which should help prepare them for their open student-designed investigation (Practical Activity 9).

APPROXIMATE TIME REQUIRED

60 minutes

BACKGROUND INFORMATION FOR THE TEACHER

Designing experiments

See the background information on designing experiments, on pages 91—93 of this resource.

Tilt angle

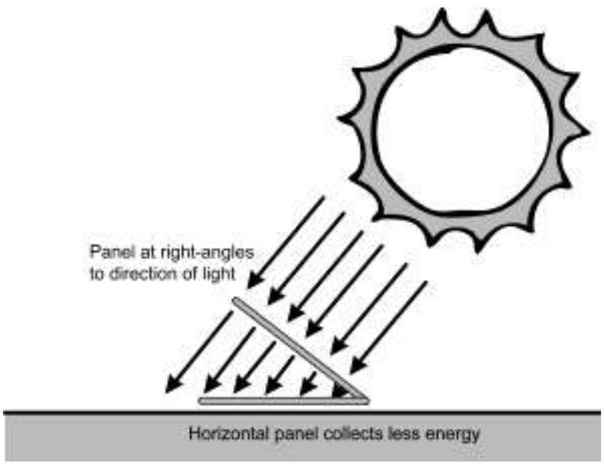


Figure 1. The ideal tilt angle for a solar panel.

Ideally the best angle for a solar panel is one in which the panel is perpendicular to the Sun's rays, so that the intensity of the light is a maximum. The problem with this is that the angle of the Sun's rays to a fixed point on the Earth's surface depends on the latitude of the fixed point, the time of day and the season.

The seasons

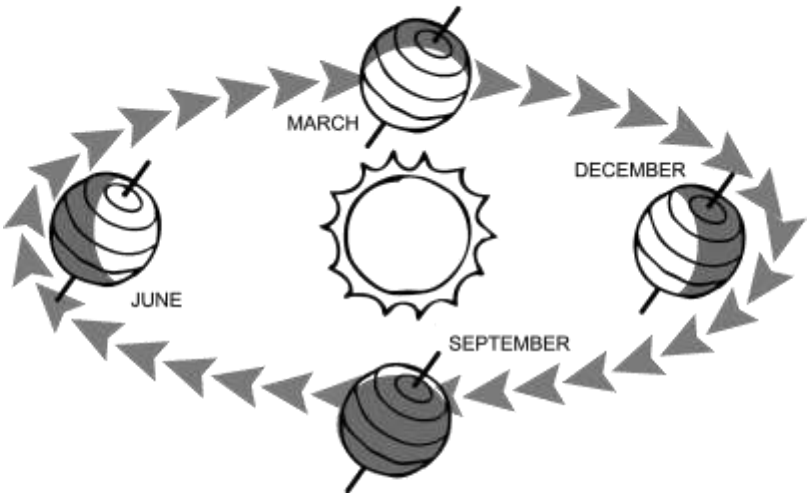


Figure 2. Earth's seasonal movement around the Sun.

The changes in the seasons are caused by the tilt of the Earth's axis to the plane of the Earth's orbit as it moves around the Sun. The angle of the axis to the vertical remains fixed at 23.5º and affects the times of sunrise and sunset, and the variation in the Sun's altitude in the sky throughout the day for all positions on the Earth's surface.

As shown in Figure 2, in December, the South Pole is pointing more towards the Sun. As a result, the southern hemisphere has longer periods of daylight and the light has greater intensity than that reaching the northern hemisphere. It is the opposite way around in June, when the South Pole points away from the Sun. This is why there is more solar energy available in the southern hemisphere in our summer period than in our winter period, and why the seasons are the opposite in the northern and southern hemispheres.

Figure 3 shows the apparent pathway of the Sun over a point in the southern hemisphere over summer and winter.

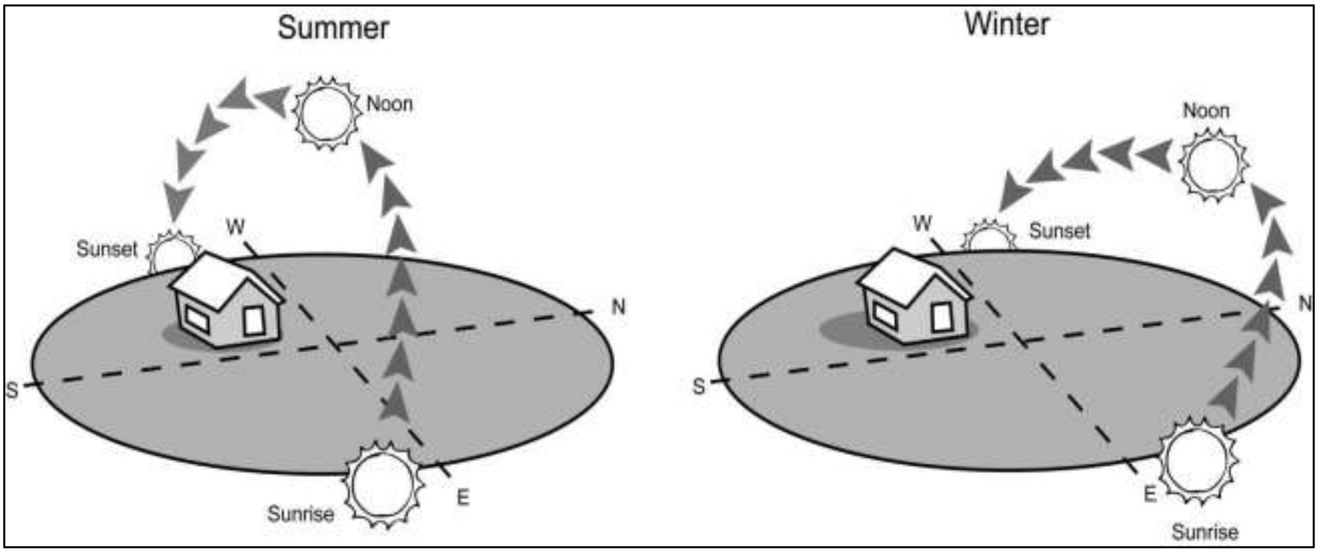


Figure 3. The apparent path of the Sun over a particular point on the Earth's surface in the southern hemisphere.

Atmospheric reduction of sunlight

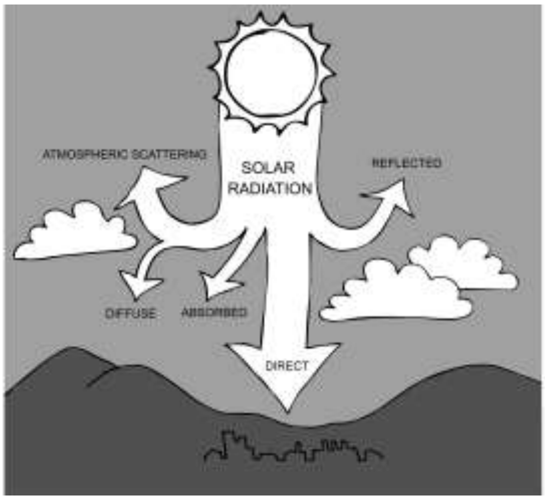


Figure 4. A schematic diagram of what happens to the energy radiated out by the Sun as it enters the Earth's atmosphere.

The intensity of light is also linked to the distance that the Sun's rays travel through the atmosphere. The amount of sunlight absorbed and scattered by air particles, including dust and water vapour, depends on the distance the light travels through the atmosphere. For this reason, the maximum intensity of sunlight at the top of mountains is higher than at sea level, and is greater at the Equator than it is near the poles.

Figure 5 shows why sunlight is less intense when the Sun is not directly overhead.

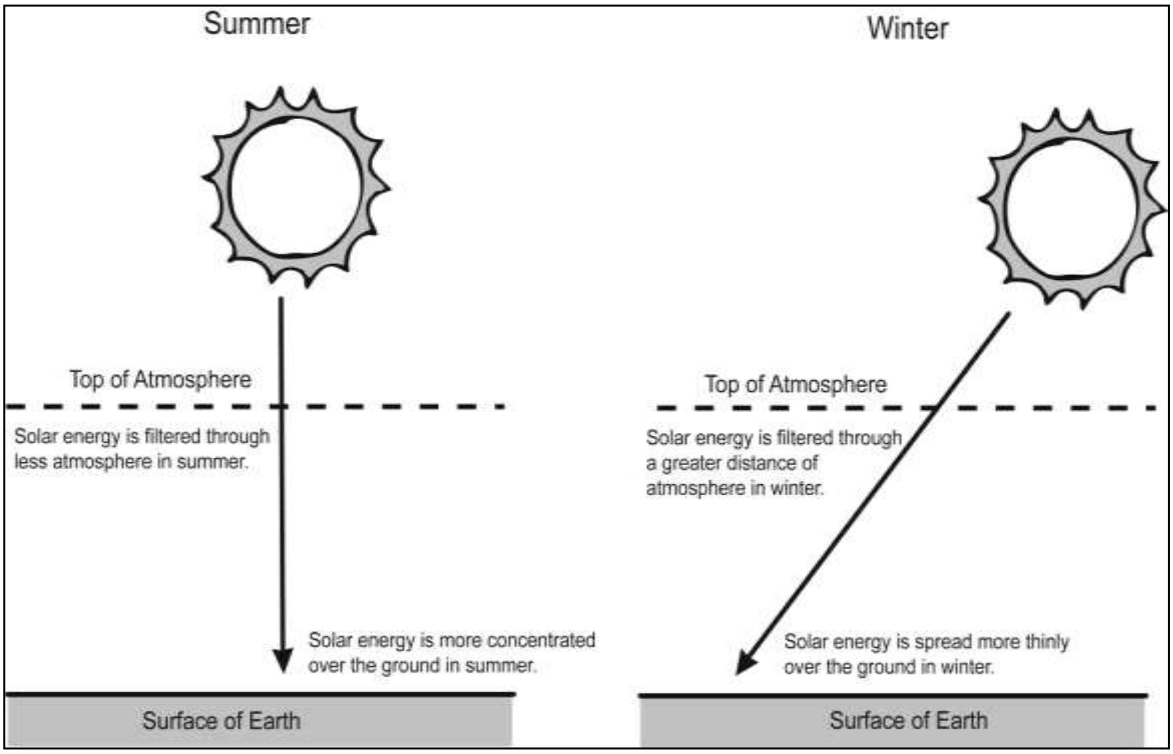


Figure 5. The effect of atmospheric particles on the intensity of sunlight in summer and winter.

LIST OF MATERIALS REQUIRED

Per student pair:

- STELR testing station
- 2 x STELR multimeters
- 2 x lamps
- Large protractor
- STELR solar panel
- Connecting leads (with ‘piggy-back’ banana plugs)
- Power pack
- Graph paper or spreadsheeting and graphing software
- A3-sized copy of the Investigation Planner (pages 81 and 82 of the student booklet)
- Masking tape to mark position of solar panel and lamps on bench (optional)

PRACTICAL ADVICE AND HINTS

See page 147 of this resource

Students need to be end-on when measuring the angle of tilt of the solar panel, so that they avoid parallax error.

Ideally this investigation is best performed with the solar panels out-of-doors in direct sunlight. This can then inform them about the best angles for installation of solar panels in their locality. If this is used, then the solar panels should be positioned so that they directly face the Sun.

RISK MANAGEMENT

Students should be actively supervised throughout this practical activity. See the risk assessment on page 147 of this resource.

ADVICE FOR THE CLASSROOM

Working in small groups of two or three gives students a greater opportunity to be actively engaged instead of merely being spectators in the activity. As a result, they are more likely to develop the skills and understandings that will help them in later investigations.

See also the general advice provided on pages 28—29 of this resource.

Teachers are strongly advised to:

Trial the activity prior to the class, to identify problems the students might encounter, judge the time they need and decide how to best manage the activity, particularly who should be in each group.

Setting up:

Since the students should have gained experience in setting up the STELR solar panel in the previous practical activity, no demonstration should be required.

Introducing the activity:

1 Introduce this practical activity by outlining the inquiry question and telling the students they are to design their own experiment to discover the answer.
2 Assign the students to their groups and give them an investigation planner. They should complete the first page of this.
3 State your expectations of their behavior and the time limits they will work under.

During the session:

1 Ensure that the students do not start the experiment until they have submitted their investigation planner and had it approved.
2 Be very vigilant. Check that the students are setting up the equipment correctly. (See the Practical Advice and Hints on page 147 of this resource for advice for trouble-shooting.)
3 With each group, whilst checking their equipment and circuit, ask the students questions about whether they are having any problems with the design of the experiment and what modifications they have made (if any), what they are discovering and what explanations they can suggest. Check that they are only changing one variable at a time.
4 Check that the students observe all of the agreed-upon procedures and safety precautions and are obtaining results in a timely manner.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report their findings. They should discuss which of their predictions came true, any problems they encountered, their conclusions and suggested explanations for their results. Ensure each group contributes to the discussion.

This part of the session should take about 10—15 minutes.

EXPECTED RESULTS

Student results will depend on whether the students use the lamps or the Sun as a light source. If they use the Sun, then their results will depend on their latitude, the season, and so on. The best angle of tilt of the solar panel should be at 90º to the light source. (See the background information on page 150 of this resource.)

SUGGESTED ANSWERS TO DISCUSSION QUESTIONS

1 [*Student response. Students should realise that the best angle should lead to the greatest intensity of light.*]

2 [*Student response will depend on class results.*]

3 [*Student response; factors such as trialing the test on different days and collecting more data points will lead to more reliable conclusions*.]

4 [*Student response will depend on class results and whether the lamps or the Sun was used as the light source*.]

Find out!

In the southern hemisphere, solar panels are generally installed so they face north.

Most rooftop solar systems on sloping roofs are installed at the same angle as the pitch of the roof, for practical reasons. Installers say that a difference of 15 º in the tilt angle does not make a significant difference to the power output.

A solar tracking device can be attached to a solar panel to ensure it tracks the Sun and is kept at the optimum angle at all times.

CALCULATING THE BEST ANGLE

For a useful calculator of the best angle, visit the following website:
http://solarelectricityhandbook.com/solar-angle-calculator.html

But note that their angle of tilt is measured to the vertical, and that many locations on Australia are not listed.

TOPIC: SCIENTISTS AT WORK

RUNNING PRACTICAL ACTIVITY 9: I WANT TO FIND OUT . . .

STUDENT BOOKLET page 78

SYNOPSIS

This is an open-ended student-designed investigation that builds on the experience that students have gained in the previous practical activities.

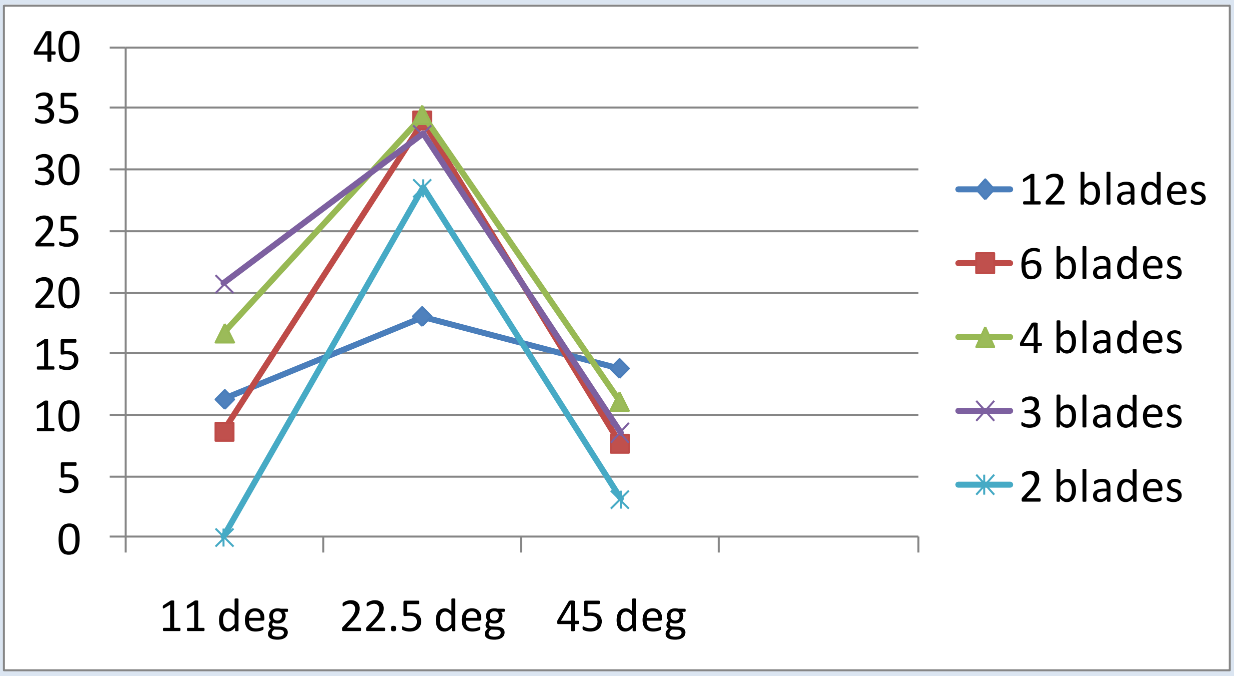
This practical activity provides further valuable training for students in designing and performing experiments and communicating their findings.

APPROXIMATE TIME REQUIRED

60—120 minutes, depending on the inquiry question selected by the student.

BACKGROUND INFORMATION FOR THE TEACHER

Should students elect to test the effect of blade angle on the power output of a STELR model wind turbine, the following graph shows typical results.



Graph of power output (mW) against blade angle for different numbers of 100 mm (10 cm) blades

Note: Even though the angle of the blades should theoretically be a continuous quantity, in-between values of angles were not possible to achieve. For this reason, strictly speaking, the graph points should not be joined. They have only been joined to show the trends more clearly, since so many data points were plotted.

ADVICE

1 Ensure that different groups are investigating different inquiry questions, so that their work is more likely to be original and so that the groups can become the class experts on that question.

2 Take photographs or videos of the students at work, so their work can receive recognition and accolades within the school community.

3 Since this should be the culmination of all their practical work in STELR, teachers should consider using this as part of the formal assessment.

See the sample assessment proforma for science inquiry skills on pages 162—163 of this resource.

TOPIC: SCIENTISTS AT WORK

WORKSHEET 5: A CAREER IN RENEWABLE ENERGY- ADVICE

STUDENT BOOKLET PAGE 79

ADVICE

If it is at all possible, arrange for a scientist who is investigating global warming, or who is working in research for a particular renewable energy, to talk to the students about what they are researching and how they go about their research, either at school or, even better, at the location where they conduct their research.

It would be very helpful if this were a young, enthusiastic female scientist. This may help overcome common mistaken perceptions about scientists' ages, gender and personalities.

It would also be helpful for students to learn that research work is often conducted in various exciting places, not just laboratories.

Encourage the students to ask questions and to record the session on video recorder or other recording device.

Appoint students to introduce the scientist and to thank him or her at the end.

See page 171 of this resource for a list of possible excursions and the website details for each organisation.

TOPIC: SCIENTISTS AT WORK

RUNNING THE GROUP CHALLENGE: A MODEL WIND TURBINE

STUDENT BOOKLET PAGE 80

SYNOPSIS

This challenge gives students the opportunity to apply all the science inquiry skills and understandings that they have gained through the STELR program, their skills in design, technology, communication and time-management, and their creativity and initiative, to design, build and test a model wind turbine.

Many students will find this great fun, which can help motivate students to consider a career in design and technology, or in science or engineering. (Ideas for alternative challenges are available on the STELR website.)

APPROXIMATE TIME REQUIRED

The class time required will depend on whether some of the work will be done in the students' own time.

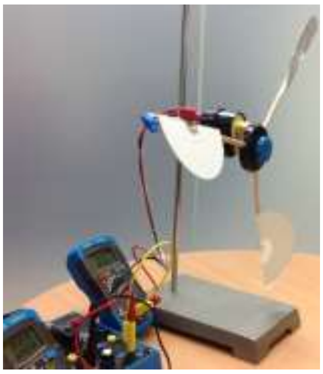
LIST OF MATERIALS STUDENTS MAY REQUIRE

Per student pair:

- Three-speed fan
- STELR testing station
- STELR hubs
- Pack of wooden dowels
- Connecting cables with 'piggy-back' banana plugs
- 2 x digital multimeters
- STELR wind turbine
- Packets of STELR wind turbine blades
- Retort stand, clamp and bosshead
- Masking tape
- Graph paper or spreadsheeting and graphing software
- A3-sized copy of the Investigation Planner (pages 81—82 of the student booklet)

PRACTICAL ADVICE AND HINTS

1 Students may use the STELR wind turbine and modify the existing blades by attaching pieces to them with masking tape. These additional pieces can include blank CD-ROMS cut up into segments.



Alternatively, students may bring other materials from home to build their own model wind turbine. An example is shown in the image on page 158. This was designed to test whether curved blades deliver a greater power output than flat blades.

2 Students should also have log books to record all of their investigations, designs and modifications and the reasoning behind them.

RISK MANAGEMENT

Students should submit their own risk assessment as part of the process.

For any work completed in the classroom, students should be actively supervised throughout. In particular they will need to take great care if handling sharp metal pieces or cutting objects that produce sharp edges.

ADVICE FOR THE CLASSROOM

It is imperative to give students free reign to design their own way of performing the experiment. They will learn many valuable skills from thinking about how they will do it, using their own ingenuity and initiative solving any problems they encounter, and so on. This can lead to a far greater sense of accomplishment and ownership than performing a directed experiment.

Teachers should be actively supervising the students as they perform their experiments and asking questions like:

- Explain to me what you are doing here.
- What have you found so far?
- Why do you think that is happening?
- What do you expect to happen when you try . . .?
- Have you encountered any problems so far? How did you solve them?
- What graphs do you think you can draw from the information you have gathered so far?

Group presentations

The presentations are very important because they will help build student confidence and sense of achievement. The students will all learn greatly from one another.

This is another case where teachers should film the proceedings so student achievement can be suitably acknowledged, not only in the school community but perhaps also in the wider community.

It is worth considering:
- **Creating a final display of wind turbines for the rest of the school community to see.**
- **Trying the model wind turbines out-of-doors in the windiest place in the school.**
- **Creating a series of awards, not only for the greatest power output but also for originality of design, and so on.**

SUPPORT

DOCUMENTS

FOR

TEACHERS

INCLUDING:

ASSESSMENT PROFORMAS

WEBSITES AND EXCURSIONS

OPTIONAL PRELIMINARY CIRCUIT TRAINING

ASSESSMENT ADVICE

The assessment modes selected by the teacher will depend on the requirements of the school and of the state or territory in which the school is located.

It is important that the students are informed at the outset about how they will be assessed in the STELR Program. They should be provided with a written statement of the assessment tasks and requirements and a copy of any assessment rubrics or other assessment charts that will be used for particular tasks, before they perform the tasks, so that they have a clear understanding of what is expected.

At the same time, it is important that this program is not assessment-driven. Its overarching goal is to inspire, encourage and enable the students to study science subjects at the senior level and to consider careers in science and engineering. The students' enjoyment of the program and hence their attitudes toward science will be diminished if their overriding concern is whether each aspect is to be assessed and if they believe that what they do only matters if it is to be assessed.

Following are three sample assessment rubrics, one for science inquiry skills, one for the group projects and one for peer assessment of presentations. Their format and wording will need to be modified according to the school and state requirements. Teachers may wish to copy and paste the first two onto a blank word document, then change them to landscape orientation.

ASSESSMENT RUBRIC - SCIENCE INQUIRY SKILLS

STUDENT NAME: ______________________________ **CLASS:** __________

Science inquiry skill	Undeveloped	Developing	Proficient	Exemplary
Designing an experiment	The student can: • Develop a testable hypothesis with assistance. • Show some understanding of the variables operating. • With assistance can design simple fair tests and select equipment suited to the purpose.	The student can: • Develop a testable hypothesis with assistance. • Identify some variables with assistance. • Design simple fair tests and select equipment suited to the purpose.	The student can: • Develop a testable hypothesis. • Identify a number of variables and, with assistance, design an experimental investigation a procedure in which these are tested one at a time and repeat trials are conducted. • Select equipment suited to the purpose. • Suggest some ways to reduce risk in the investigation.	The student can: • Develop a testable hypothesis based on prior observations and/or secondary sources. • Design an experimental investigation, including using repeat trials and replicates, independently identifying and controlling variables and selecting equipment suited to the purpose. • Suggest a number of ways to reduce risk in the investigation that show insight into the specific risks involved.
Collection of data	The student can: • With assistance, collect data in a consistent and ethical manner, including using ICT where possible. • Use equipment and materials safely, with assistance and advice.	The student can: • With assistance, collect data in a consistent and ethical manner, including using ICT where possible. • Use a wide range of equipment and materials safely.	The student can: • Collect data in a consistent and ethical manner, including using ICT where possible. • Use a wide range of equipment and materials safely and show consideration of the safety of others.	The student can: • Collect data in a consistent, efficient and ethical manner, including using ICT where possible. • Use a wide range of equipment and materials safely and manage the working environment for the safety of self and others.
Recording and processing data	The student can: • Record some data in provided tables with accuracy. • With assistance, construct graphs with reasonable accuracy.	The student can: • Record data in provided tables accurately. • With assistance, construct graphs with accuracy. • Use simple statistical tools to process and analyse data, with assistance.	The student can: • Select and design tables and graphs for the recording and analysis of **some** data. • Record data in provided tables accurately. • Construct graphs with accuracy. • Use simple statistical tools to process and analyse data with accuracy.	The student can: • Select and design tables and graphs for the recording and analysis of data. • Record data efficiently and accurately. • Construct graphs with accuracy • Use simple statistical tools to process and analyse data with accuracy.
Analysis and evaluation of data	The student can: • Draw conclusions from observations, evidence and data, and relate this to hypotheses, with assistance. • With assistance, identify sources of error in the investigation method.	The student can: • Draw conclusions from observations, evidence and data, and relate this to hypotheses and scientific concepts, with assistance. • With assistance, Identify sources of error in the investigation method.	The student can: • Draw conclusions from observations, evidence and data, and relate this to hypotheses and scientific concepts. • Identify sources of error in the investigation method and suggest specific improvements that would reduce error.	The student can: • Draw conclusions or explain interactions from observations, evidence and data, and relate this to hypotheses and scientific concepts. • Identify sources of error in the investigation method and suggest specific improvements that would reduce error. •Critique reports of investigations noting any flaws in design or inconsistencies of data.

Communication of findings	The student can: • With assistance, communicate findings using scientific language and meaningful representations and make evidence-based arguments.	The student can: • Communicate findings using scientific language with a fair degree of accuracy and using some meaningful representations. • With assistance, make evidence-based arguments.	The student can: • Communicate findings using scientific language with a good degree of accuracy and fluency, and using meaningful representations. • Make evidence-based arguments.	The student can: • Communicate findings using scientific language with a high degree of fluency and accuracy, and using meaningful representations and make evidence-based arguments.

Overall evaluation with comment/evidence:

Teacher's signature: ____

Date: ______________________________

ASSESSMENT RUBRIC – GROUP PROJECTS

STUDENT NAME: ____ **CLASS:** __________

NAMES OF GROUP MEMBERS: ____

RENEWABLE ENERGY RESOURCE INVESTIGATED: ____________________________

Aspect	Undeveloped	Developing	Proficient	Exemplary
The science and technology behind the energy resource	The group: • Showed little evidence of suitable research. • Displayed a limited understanding of the science and technology behind their chosen renewable energy resource.	The group: • Researched this aspect to some degree. • Displayed some understanding of the science and technology behind their chosen renewable energy resource.	The group : • Researched this aspect to a reasonable depth. •Displayed a good understanding of the science and technology behind their chosen renewable energy resource and communicated this with clarity.	The group: • Researched this aspect in depth. • Displayed a thorough understanding of the science and technology behind their chosen renewable energy resource and communicated this in a logical way with clarity and fluency, including an explanation of unfamiliar terms.
The benefits and problems associated with the energy resource, and community views	The group: • Showed little evidence of suitable research. • Presented conclusions that were based on insufficient evidence and analysis.	The group : • Researched this aspect to some degree. • Applied some critical thinking skills to draw their conclusions.	The group: • Researched this aspect to a reasonable depth. • Presented some evidence-based arguments and applied some critical thinking skills to draw their conclusions.	The group : • Researched this aspect in depth. • Presented evidence-based arguments and applied well-developed critical thinking skills to draw their conclusions.
The uses of the energy resource and its likely future	The group: • Showed little evidence of suitable research. • Presented conclusions that were based on insufficient evidence and analysis.	The group : • Researched this aspect to some degree. • Applied some critical thinking skills to draw their conclusions.	The group: • Researched this aspect to a reasonable depth. • Presented some evidence-based arguments and applied some critical thinking skills to draw their conclusions.	The group : • Researched this aspect in depth. • Presented evidence-based arguments and applied well-developed critical thinking skills to draw their conclusions.
Presentation of findings	The group: • Presented some findings using a small number of visual aids. • Showed some understanding of their subject. • Was sometimes audible and sometimes established eye contact with their audience.	The group : • Showed some evidence of preparing for their presentation. • Presented their findings using some visual aids. • Showed some understanding of their subject and were able to answer some questions. • Was generally audible and generally established eye contact with their audience.	The group: • Prepared well for their presentation. • Presented their findings in an engaging way, making use of a range of visual and other communication aids. • Showed good understanding of their subject and were able to answer questions clearly. • Was audible, established eye contact with their audience and involved their audience.	The group: • Prepared thoroughly for their presentation. • Presented their findings in a creative and engaging way, making full use of a range of visual and other communication aids. • Showed a thorough understanding of their subject, answering questions confidently. • Was clearly audible, established good eye contact with their audience and involved their audience to a great degree.

Student contribution to group	The student: • Co-operated with the group most of the time. • Contributed to most aspects of the project.	The student : • Co-operated well with the group. • Contributed to all aspects of the project.	The student: • Co-operated very well with the group and showed well-developed time management skills. • Contributed well to all aspects of the project.	The student: • Co-operated well with the group and showed initiative and well-developed leadership and time management skills. • Contributed fully to all aspects of the project.

Comment: ____

____

Teacher's signature: ____________________________________ Date: __________________________

STUDENT ASSESSMENT OF GROUP PRESENTATIONS

NAMES OF GROUP MEMBERS: ____

Criterion	Needs improvement	Satisfactory	Very good	Excellent
Voice projection	Most of the group spoke too softly and/ or too quickly.	It was difficult to hear parts of the presentation.	Most of the group's voices were clear and able to be heard.	All the group's voices were clear and projected well.
Engagement with the audience	Most of the group members did not seem confident or enthusiastic or aware of their audience.	Some of the group members did not seem confident or enthusiastic or very aware of their audience.	Most group members appeared confident and enthusiastic and maintained good eye contact with the audience. They made a good effort to interest and involve all the audience.	All group members were confident, lively and enthusiastic and maintained good eye contact with the audience. They made a real effort to interest and involve all the audience.
Response to questions from the audience	The group members did not encourage the audience to ask questions, and found it difficult to answer questions.	The group members did not encourage the audience to ask questions, but answered most questions quite clearly.	The group members encouraged the audience to ask questions, and answered most questions clearly and confidently.	The group members encouraged the audience to ask questions, and answered the questions clearly and confidently.
Use of different communication aids to the presentation	The group used some visual aids in their presentation, but these were sometimes difficult to see or needed more work to be beneficial.	The group used some communication aids in their presentation, but these needed more work to be beneficial.	The group used some well-prepared communication aids to help make their presentation interesting and clear.	The group used a good variety of well-prepared communication aids. Their presentation was interesting, clear and very creative.
Knowledge of material	The group needed to provide a lot more information.	The group provided some interesting relevant facts but needed to explain them more clearly.	The group provided a number of interesting relevant facts and explained the ideas and terms well.	The group provided many interesting relevant facts and explained the ideas and terms very clearly.
Logical development of material	The group tended to jump around with their presentation, making it difficult to follow. Some of the content did not appear to be relevant.	The group needed to organise their material into a more logical order and to give a more balanced coverage of the different aspects. Some of the content did not appear to be relevant.	The group presented the material in quite a logical and balanced way. All or most of the content was relevant to their topic.	The group presented the materials in a very logical , balanced way. All the content was relevant to their topic.

Signed: ________________________________ Print name: ________________________________

WEBSITES AND EXCURSIONS

WEBSITES FOR TEACHERS

Topic	Website	Comment
Global warming	http://www.cmar.csiro.au/e-print/open/holper_2001b.html	This 6 page information sheet provides an excellent overview of global warming, the greenhouse effect, greenhouse gases, etc. It provides data and graphs that show the build-up of greenhouse gases in the atmosphere, and likely consequences. Written in June 2001, it was reviewed in 2008 and still is a very useful resource.
	http://www.science.org.au/nova/016/016key.htm	This is part of the website of the Australian Academy of Science. It provides an excellent overview of global warming in language suited to teachers and students, ideas for lessons, related sites, and other useful resources.
	http://www.nasa.gov/multimedia/podcasting/GlobalTemperature09.html	This is a podcast from NASA. It features a recently released new analysis by climate scientists at NASA's Goddard Institute for Space Studies (GISS) of global average temperatures that show 2009 was tied as the second warmest year ever recorded.
	http://www.csiro.au/Organisation-Structure/Flagships/Climate-Adaptation-Flagship/ClimateAdaptationFlagshipOverview.aspx	This is an approx 4-minute video produced by the CSIRO's Climate Adaptation National Research Flagship. It is an excellent documentary about how we can adapt to climate change in Australia. Links for many excellent resources are also provided.
	http://www.csiro.au/en/Outcomes/Climate.aspx	This is the starting page to the CSIRO resource on this issue. It contains an excellent video about how climate change is threatening the Southern Ocean, which lasts almost 8 minutes. It also provides links to further information and other resources.
	http://www.csiro.au/science/Managing-Species-Ecosystems.html	This is an interesting outline of the likely impact of climate change on Australia's ecosystems, with further worthwhile links provided.
	http://www.csiro.au/science/SustainableCitiesAndCoasts.html	This is an overview of the likely impact of climate change on urban and coastal communities and the research CSIRO is undertaking to help the communities solve these challenges.
	http://www.nasa.gov/home/hqnews/2011/mar/HQ_11-090_Amazon_Forest.html	This is a fascinating news bulletin from NASA about the effect of drought on the greenness of trees in the Amazon forest, which could cause loss of trees and hence contribute to global warming.
	http://www.nasa.gov/home/hqnews/2010/nov/HQ_10-308_Global_Lakes.html	This is a very interesting NASA article on their study of the effect of global warming on a large number of major lakes across the world.
	http://news.theage.com.au/breaking-news-world/oceans-in-distress-mass-extinctions-20110621-1gc8i.html	This is an interesting newspaper item about oceans in distress and consequences such as mass extinctions, due to the combined effects of global warming and pollution.
	http://www.csiro.au/multimedia/Methane-Clathrate.html	This is a fascinating podcast about the problem of methane locked away in permafrost and in the ocean floors. Global warming can cause this ice-like material to be released as a methane gas, which is a far more potent greenhouse gas than carbon dioxide.
	http://www.nasa.gov/mission_pages/icebridge/index.html	This is an excellent web link to NASA's Antarctic 2011 Ice Bridge Campaign – a study of sea ice etc. to see how much Antarctica is being affected by climate change.
	http://www.nasa.gov/multimedia/imagegallery/image_feature_1549.html	This is an exceptional image of the Earth from NASA, showing snow cover in November 2009. The text accompanying the image is very informative. (See also the following link.)

	http://www.nasa.gov/home/hqnews/2011/jan/HQ_11-014_Warmest_Year.html	This NASA news bulletin reports on 2010 as the warmest year on record, with other interesting data and links.
	http://data.giss.nasa.gov/gistemp/	This is a fascinating site that provides recent data on the surface temperatures across the world collected by NASA over the past few years. It includes very useful graphs and animations.
	http://www.sciencedaily.com/releases/2009/03/090317125217.htm	This is a very interesting media release about the significant but largely unknown role played by diatoms in fixing carbon in the oceans and how this may change with increasing ocean temperature. The media release has links to related articles. This news source also has tabs for 'Earth and Climate', and 'Matter and Energy', and a search engine for other specific topics.
	http://www.ucsusa.org/global_warming/science/global-warming-faq.html	This website of the Union of Concerned Scientists from the US provides answers to some frequently asked questions on the science of global warming, and is worth looking at.
	http://www.ipcc.ch/	The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organisation and the United Nations Environment Program. The IPCC issued its first set of reports on the science of climate change, likely impacts and response strategies in 1990. The latest report (fourth) was in 2007 and can be found at this site. (The fifth report is now underway.) The site also has other valuable information.
	http://www.climatechange.gov.au/publications/#renewable	This is part of the website of the Australian Government's Department of Climate Change. It shows many valuable resources that are available.
	http://www.theage.com.au/national/scientists-to-tackle-scepticism-20100614-ya7j.html	This is a newspaper article about Australian scientists getting together to try to re-assert the science in climate change and to overcome scepticism about global warming and its causes and consequences.
	http://www.bom.gov.au/info/GreenhouseEffectAndClimateChange.pdf	This is a very comprehensive and useful 78 page booklet on the greenhouse effect and climate change produced by the Australian Government Bureau of Meteorology.
Ozone layer and atmospheric pollutants	http://macuv.gsfc.nasa.gov/	This very useful NASA website provides 'the results and ongoing data studies for the study of ozone and other gases, aerosols, radiances, and ultraviolet radiation, and what has been learned about atmospheric pollution and air quality from the international science missions making these measurements.'
Energy	http://www.teachersdomain.org/resource/hew06.sci.phys.maf.lpenergy	This is an excellent teacher resource. It contains ideas for lessons and many valuable links, including to excellent animations such as one that shows the transformation between kinetic energy and potential energy on a rollercoaster in the form of a pie chart that depicts the relative amounts of each form of energy at each point along the track. These animations can also be downloaded.
Energy efficiency	http://www.rsc.org/chemistryworld/News/2011/September/08091102.asp	This is an article about glass that responds to the temperature of the environment, making it a promising material for energy efficient windows. On cold days, the windows would prevent heat escaping and on hot days, the windows would reflect infrared radiation, keeping the room inside cool. This glass has been developed by scientists in China and the US.
Range of energy resources	http://serc.carleton.edu/NAGTWorkshops/energy/visuals.html	This is an excellent website that provides videos about a range of different energy resources, including how they work. In particular there is a very interesting video of a German experiment in which solar panels have been installed everywhere possible near Munich, including along the length of the highway, to maximize its potential contribution to their energy needs.
	http://www.infinitepower.org/lessonplans.htm.	This part of the website of the Texas State Energy Conservation Office provides lesson plans, worksheets and other useful resources for teachers. It caters for students of different age groups.
	http://www.carboncommentary.com/2011/05/16/1933	This is an interesting analysis of the potential use of tides to generate electricity in Britain.

Commentaries about energy	theconversation.edu.au	Launched in March 2011, ‘The Conversation’ is an independent source of information, analysis and commentary from the university and research sector. It has an environment and energy tab which links to some worthwhile articles.
	http://beyondzeroemissions.org/	Beyond Zero Emissions is a not-for-profit organisation dedicated to promoting renewable energy. It has won awards for its work. Its activities include providing many worthwhile resources and running many seminars with highly respected experts as guest speakers.
Geothermal power stations	http://www.ga.gov.au/image_cache/GA10663.pdf	This is a very helpful article accompanied by clear diagrams about how this energy resource works, where it is established in Australia, and its possible future development in Australia.
Hydroelectric power stations	http://www.hydro.com.au/energy	This is an excellent website that shows in simple terms how hydroelectric power works, aided by a very useful animation that shows hydroelectric power in the context of the water cycle. Another part of the site shows the location of all the hydroelectric power stations in Tasmania. In addition, there is an article about wind power. Again, this is shown in a wider context of wind.
Biofuels	http://www.sciencedaily.com/releases/2009/06/090622165830.htm	This is a very interesting media release about the possible harvesting oil from diatoms, with the aid of solar panels. They are thought to have greater potential than oil seeds. The media release has links to related articles. This news source also has tabs for ‘Earth and Climate’, and ‘Matter and Energy’, and a search engine for other specific topics.
Power ratings	http://www.choice.com.au/Reviews-and-Tests/Technology/Computers-and-accessories/Green-computing/Computer-energy-costs/Page/Power%20usage.aspx	This site lists the electrical energy ‘consumed’ by computers, plasma TVs and other various electronic appliances, when used and when on stand-by, weekly, monthly and yearly. The approximate cost also is included in the tables.
Wind power	http://www.mste.uiuc.edu/ projects/wind	This site provides a worthwhile wind power curriculum. It is a joint project of the Office for Mathematics, Science and Technology Education, the College of Engineering, the University of Illinois, and 4-H and models the ‘learning by doing’ approach. It ‘includes several small projects that are designed to teach about the wind and its uses while introducing engineering design and engaging learners in doing, testing, reflecting and revising’. This is provided in the form of an activity booklet and a facilitator guide.
	http://www.windpoweringamerica.gov/schools.asp	This is part of the website of the US Department of Energy. It provides useful links to information about wind power, the installation of wind turbines at schools across the US through the ‘Wind Energy for Schools’ project, and lesson plans and other teacher resources.
	http://www.fortiswindenergy.com/faq	This is part of a website operated by a British supply company. It gives answers to frequently asked questions about wind turbines, for the general public.
Solar power	http://www.nanosolar.com/	This is the website of one of several companies developing solar cells that have a very different composition and structure to traditional silicon-based solar cells. Nanosolar cells are constructed and manufactured in a very different way using nanotechnology. It includes a very worthwhile video that starts off talking about future energy needs and the importance of renewables.
	http://www.ata.org.au/wp-content/renew/101_solar_panel_buyers_guide.pdf	This is a very comprehensive website that provides details of different kinds of solar panels and objective reports of performance data.
	http://www.csiro.au/science/Ultra-Battery.html	This interesting CSIRO site outlines their latest research on a battery that not only will be suited to hybrid vehicles but also has the potential to store the energy from renewable energy resources such as solar. cells.
	http://en.wikipedia.org/wiki/Solar_pond	This provides fascinating information about another way to use the energy of the Sun, using salt ponds.
	http://inhabitat.com/2010/07/22/worlds-first-molten-salt-solar-plant-produces-power-at-night/	This is a fascinating introduction to the use of molten salt to store solar energy as heat energy. In this case the stored heat energy is used to heat water that is used to drive turbines. Links to related sites are provided.

	http://inhabitat.com/chicagos-willis-tower-to-become-a-vertical-solar-farm/	This is a fascinating account of plans to convert one of the tallest buildings into the world into a solar plant, by using its windows as solar cells. Links to related sites are provided.
	http://beyondzeroemissions.org/blog/spain-now-producing-24-hour-solar-power-110708	This is a fascinating article about solar thermal energy, which is a much more efficient energy resource than solar cells.
Live solar data	http://www.dkasolarcentre.com.au/flash/processmap.html	This map of a large solar display centre in Alice Springs shows how much electrical power each solar array in the centre is delivering at the time of accessing the website, as well as how many houses it is powering, as well as the total power output of all the solar arrays present.

NOTE:

1 Other websites are listed in some activity ideas and some of the other support material in this Teacher Resource.

2 Some of these websites are suitable for students. Websites for students are listed on the STELR website.

3 The teacher also is advised to access the digital curriculum resources provided by Education Services Australia. The access pathway to their learning objects, videos and other resources depends on the State or territory. In some states and the territories it is: www.scootle.edu.au. Other states have their own education access portals. Use the advanced search in your education authority's portal by using key words such as global warming. For example, they have available an excellent video: R11443 'Climate change: coral reefs on the edge'. This is a 26 minute video about coral bleaching, and ocean acidification.

WEBSITES AND EXCURSIONS

POSSIBLE EXCURSIONS

Place	Website	Comment
Wind farm	http://en.wikipedia.org/wiki/List_of_wind_farms_in_Australia	It can be very worthwhile to visit a wind farm, if the wind farm management is willing to cater for visitors. This website lists the wind farms operating in Australia, their location and capacity. You can click on each one for further information.
CSIRO Energy Centre, NSW	http://www.det.csiro.au/energycentre/	The CSIRO Energy Centre is located in Newcastle, NSW. The building models an ecologically sustainable design. The website shows a range of useful information and provides contact details.
Display of sustainable technologies in NSW	http://www.futureworld.org.au/	This display centre exhibits technologies for a sustainable world in an innovative way. Located in Warrawong, NSW, the centre also offers hands-on programs for secondary students.
Snowy Hydroelectric Scheme display centre in NSW	http://www.snowyhydro.com.au	An information and education centre that offers educational programs and interactive displays on hydroelectric power is run by Snowy Hydro Limited in Cooma, NSW. Click on 'Education program' for details.
Renewable energy display centres in WA	http://www.energy.wa.gov.au/3/3550/64/demonstration_sites.pm	This website of the Office of Energy, Government of WA, lists a range of renewable energy display centres that are available for school excursions. Contact details are provided.
Large-scale solar display in Alice Springs	http://www.desertknowledge.com.au	This solar technology demonstration display centre showcases different solar technologies in various configurations. It was built to meet the needs of Australians living in desert regions.
Energy park in Melbourne	http://www.ceres.org.au	This organisation has a large site in Brunswick which includes an energy park. A variety of activities is provided for students, who can also view other sustainable practices in action. Incursions also are available.
Coal-fired power stations in Victoria	http://www.powerworks.com.au	This organisation offers a variety of educational programs on electricity, energy and in particular the mining of coal and coal-fired power stations at its display centre in Morwell. A tour of a mine and a large coal-fired power station can be included in the program.
Renewable energy sites in Queensland	http://www.cleanenergy.qld.gov.au	The Department of Clean Energy of the Government of Queensland operates this site which provides information about a range of locations for geothermal power stations and other renewable energy resources in Queensland as well as its solar schools project.

OPTIONAL PRELIMINARY CIRCUIT TRAINING

OVERVIEW OF THE OPTIONAL PRELIMINARY CIRCUIT TRAINING

SYNOPSIS

The optional circuit training practical investigations are designed for those students who have little or no background in electric circuits, or who would benefit from a refresher course. This will enable them to work through the STELR program with greater confidence and knowledge and understanding of the concepts of series and parallel circuits, current and voltage.

Although they are directed experiments, they provide the students with many opportunities to predict their results in the next step based on their observations and measurements in previous steps. This not only engages the students but also promotes analysis and understanding. Application questions are provided to reinforce understanding.

DETAILS

The optional practical activity on series and parallel circuits

This experiment introduces students to setting up and testing series and parallel circuits, to help them understand the differences between them. They also learn to interpret and draw circuit diagrams. It includes fun challenges that give students the opportunity to apply their knowledge to solving puzzles.

The optional practical activity on measuring current

This experiment is designed to introduce students to the concept of electrical current, its definition, how it is measured, its units of measurement and what factors affect the amount of current flowing in a given series or parallel circuit.

The optional practical activity on measuring voltage

This experiment is designed to introduce students to the concept of potential difference or voltage, its definition, how it is measured, its units of measurement and what factors affect the voltage across different circuit components in a given series or parallel circuit.

OPTIONAL STUDENT PRACTICAL ACTIVITY I:
SERIES AND PARALLEL CIRCUITS

Partners ____ **Date** ____________

Inquiry questions:

1 Can globes remain on (lit) if one globe is unscrewed from its holder when they are connected in series or in parallel?

2 Does the position of the switch in the circuit affect what globes go on?

3 What happens to the brightness of the globes when an extra globe is connected into a series circuit?

4 What happens to the brightness of the globes when an extra globe is connected in parallel with the other two?

Introduction

An **electrical circuit** is a continuous pathway in which an electric current flows from one terminal of a source of electrical energy, through wires and various other objects, and back to the other terminal. The objects through which the electrical current flows, including the wire, are called the **components** of the circuit.

A **series circuit** is one in which the electric current can only travel along one continuous path.

A **parallel circuit** is one in which the electric current can travel along more than one continuous path. Each path must include the source of electrical energy, of course.

An example of a series circuit and of a parallel circuit and the matching conventional circuit diagrams are shown in Figures 1—4.

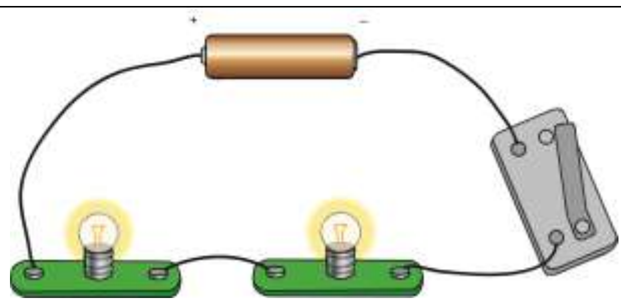


Figure 1: **A series circuit** containing a single battery, a switch and two globes**.**

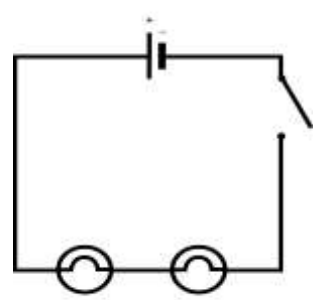


Figure 2: A circuit diagram for the series circuit shown in Figure 1.

Notice that a rectangle is used to represent the circuit. The key to the symbols is shown in Figure 4.

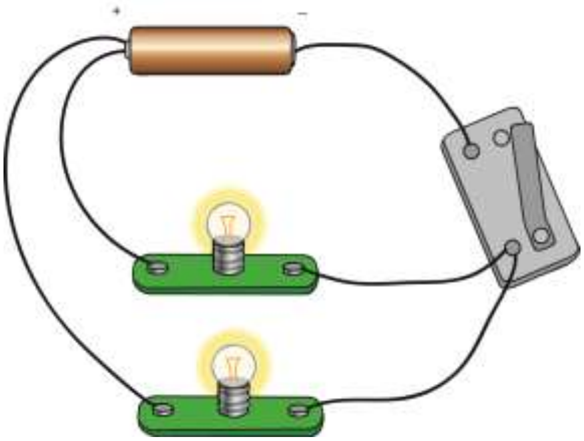


Figure 3: A circuit containing a single battery, a switch and two globes that are **in parallel** with one another.

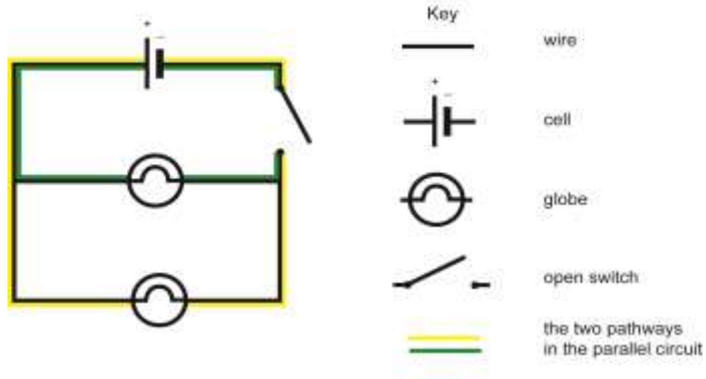


Figure 4: The circuit diagram for the circuit shown in Figure 3, and key to the circuit symbols.

A cell is the scientific name for a single battery. An open switch is one that is switched off. A closed switch is one that is switched on. It has a different symbol to that of an open switch; this symbol is shown below in Figure 5.

Figure 5: The circuit symbol for a closed switch.

Predicting the outcomes of this experiment

Before you start:

Suppose you set up the series circuit in Figure 1.

a Will either globe go on if the switch is moved from where it is now to between the two globes, then closed and opened? Explain why you think this.

____

____

b What do you think will happen to the other globe if you move the switch back to where it was, then unscrew one of the globes from its holder? Will it go on when the switch is closed? Explain why you think this.

____

____

c What do you think will happen to the brightness of the globes when you screw the second globe back into its holder then connect a third globe in series with the other two? Assume that the switch is closed. Explain why you think this.

____

____

2 Suppose you set up the parallel circuit in Figure 3.

a How bright do you think the globes will be in this case, compared with the globes in Figure 1, when the switch is closed? Explain why you think this.

____

____

b What will happen to the globes if the switch is placed along a third pathway instead of where it is now, like in Figure 6, then closed? Explain why you think this. Figure 6 shows this circuit before the switch is closed.

____

____

____

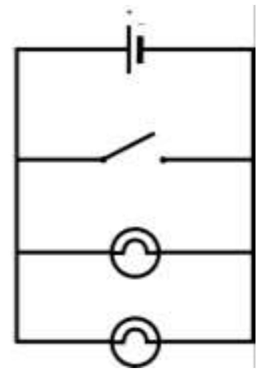


Figure 6

c What do you think will happen to the other globe if you put the switch back to where it was, then unscrew one of the globes from its holder? Will it go on when the switch is closed? Explain why you think this.

____

____

d What do you think will happen to the brightness of the globes when you screw the second globe back into its holder then connect a third globe in parallel with the other two? Assume that the switch is closed. Explain why you think this.

____

____

What you need

- STELR battery (or two 1.5 V cells in a holder)
- 3 x 1.5 V globes
- Connecting leads
- Switch

Note: Make sure that you use identical globes.

What to do and what you discover

PART A: Testing a series circuit

Inquiry question 1: Can globes remain on if one globe is unscrewed from its holder when they are connected in series?

Inquiry question 2: Does the position of the switch in the circuit affect what globes go on?

Inquiry question 3: What happens to the brightness of the globes when an extra globe is connected into a series circuit?

Instructions for Part A

Step	What to do
1	Set up the circuit shown in Figure 1, except use the STELR battery in place of the single battery. Does either globe go on whilst the switch is open? Now close the switch for just a few seconds. Are the globes bright or dim? Is this what you predicted? **In the results table below, record your observations, then open the switch so that the battery does not go flat.**
2	Unscrew one of the globes from its holder. What happens to the other globe when you close the switch for a few seconds? Is it on or off? If it is on, is it brighter or dimmer than before? Is this what you predicted? **Record your observations, then screw the globe back into its holder and open the switch.**
3	Move the switch to between the two globes. What happens to the globes when it is open then closed for a few seconds? Are they on or off? If they are on, are they bright or dim? Is this what you predicted? **Record your observations, then move the switch back to where it was and leave it open.**
4	Connect a third globe into the circuit, next to the other two. Then close the switch for a few seconds. What happens to the brightness of the globes? Is this what you predicted? **Record your observations, then open the switch.**

Results for Part A

Step	Switch open or closed?	Globe(s) on or off?	Globe(s) bright or dim (if on)?	Prediction correct?
1 **Switch & 2 globes**	**Open**			
	Closed			
2 **One globe unscrewed**	**Closed**			
3 **Switch between globes**	**Open**			
	Closed			
4 **Add third globe**	**Closed**			

Conclusion for Part A

What is your answer to Inquiry question 1: Can globes remain on if one globe is unscrewed from its holder when they are connected in series?

____

What is your answer to Inquiry question 2: Does the position of the switch in the circuit affect what globes go on?

____

What is your answer to Inquiry question 3: What happens to the brightness of the globes when an extra globe is connected into a series circuit?

____

PART B: Testing a parallel circuit

Inquiry question 1: Can globes remain on if one globe is unscrewed from its holder when they are connected in parallel?

Inquiry question 2: Does the position of the switch in the circuit affect what globes go on?

Inquiry question 4: What happens to the brightness of the globes when an extra globe is connected in parallel with the other two?

Instructions for Part B

Step	What to do
1	Set up the circuit shown in Figure 3, except use the STELR battery in place of the single battery. Does either globe go on whilst the switch is open? Now close the switch for just a few seconds. Are the globes bright or dim? Is this what you predicted? **In the results table on the next page, record your observations, then open the switch so that the battery does not go flat.**
2	Unscrew one of the globes from its holder. What happens to the other globe when you close the switch for a few seconds? Is it on or off? If it is on, is it brighter or dimmer than before? Is this what you predicted? **Record your observations, then screw the globe back into its holder and open the switch.**
3	Move the switch so that the circuit is the same as shown in Figure 6. The switch is now on a separate path to the two globes. What happens to the globes when it is open then closed for a few seconds? Are they on or off? If they are on, are they bright or dim? Is this what you predicted? **Record your observations, then move the switch back to where it was and leave it open.**
4	Connect a third globe into the circuit, in parallel to the other two like the switch was in Step 3. Then close the switch for a few seconds. What happens to the brightness of the globes? Is this what you predicted? **Record your observations, then open the switch.**

Results for Part B

Step	Switch open or closed?	Globe(s) on or off?	Globe(s) bright or dim (if on)?	Prediction correct?
1 2 globes in parallel	Open			
	Closed			
2 One globe unscrewed	Closed			
3 Switch on 3rd path	Open			
	Closed			
4 3 globes in parallel	Closed			

Conclusion for Part B

What is your answer to Inquiry question 1: Can globes remain on if one globe is unscrewed from its holder when they are connected in parallel?

____

What is your answer to Inquiry question 2: Does the position of the switch in the circuit affect what globes go on?

____

What is your answer to Inquiry question 4: What happens to the brightness of the globes when an extra globe is connected in parallel with the other two?

____

PART C: Fun challenge

Can you set up circuits that contain one cell, three globes and one switch, which obey the following conditions?

In each case, when you have succeeded, draw a circuit diagram of the circuit that worked.

Try explaining why it worked. You may annotate your circuit diagrams to show your explanation.

1 When the switch is closed, one globe is brighter than the other two.

2 When the switch is closed, all three globes light up, but when it is open one globe remains on.

3 When the switch is closed, none of the globes are lit, but when it is open, they all light up.

Discussion questions

1 Compare your results with those obtained by the rest of the class. Did you all draw the same conclusions?

2 Did any of the results surprise you? If so, which ones? Can you suggest an explanation?

3 Would Christmas lights be in parallel circuits or a series circuit? State your reasoning.

OPTIONAL PRELIMINARY CIRCUIT TRAINING

RUNNING OPTIONAL PRACTICAL ACTIVITY I: SERIES AND PARALLEL CIRCUITS

Pages 173—178 of this resource

SYNOPSIS

This optional experiment is designed to introduce students to series and parallel circuits and to circuit diagrams, or to refresh their memory of these. This will help prepare them for their work on electrical circuits in the STELR program.

It includes making predictions and solving fun challenges. Most students, particularly those who love solving puzzles, enjoy these aspects, especially if any of their predictions come true and they can solve one or more of the puzzles. For many it may be the first time they are asked to predict what will happen or to solve a puzzle of this kind.

APPROXIMATE TIME REQUIRED

60 minutes

LIST OF MATERIALS REQUIRED

Per student pair:

- STELR battery (or two 1.5 V cells in a holder)
- Connecting leads
- 3 x 1.5 V globes
- Switch

PRACTICAL ADVICE AND HINTS

1 Pre-test the batteries to ensure they are delivering about 3 volts.

2 Ensure that student pairs are able to obtain a set of three identical globes, so that they can obtain reliable results.

3 Watch that the students do not turn on the batteries for more than a few seconds, or they will go flat.

4 If globes do not go on when they should, first check that all connections are tight. If they are, then one of the globes may have 'blown' and will need to be replaced.

5 It is particularly important that in Step 3 of Part B, Step 2, the switch is only briefly closed, because it creates a path of much lower resistance. As a result, almost all the current travels along this path and only a negligible amount travels along the other two paths - not enough to make the globes light up. That is, a short circuit is created. This will drain the battery very quickly and also cause it and the switch and wires connected to the switch to heat up. This also is an issue with the challenges.

RISK MANAGEMENT

Students should be actively supervised throughout this practical activity.

SAFETY WARNING

1 Globes can get hot, so should not be handled unless they are cool.

2 When the short circuit is briefly created, warn the students that they must not touch the wire in the circuit containing the switch, as it will get very hot and they could get burnt. They also could experience a tingle in their hands. Do NOT substitute a power pack for the battery! They may receive a more substantial electric shock and/or burn and the power pack could be damaged.

ADVICE FOR THE CLASSROOM

Working in small groups of two or three gives students a greater opportunity to be actively engaged instead of merely being spectators in the activity. As a result, they are more likely to develop the skills and understandings that will help them in later investigations.

See also the general advice provided on pages 28—29 of this resource.

Teachers are strongly advised to:

1 Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
2 Decide how to best manage the activity, particularly who should be in each group and whether you can allow time for the challenges, which are very worthwhile.

Setting up:

Have a set of the equipment to perform a demonstration during the introductory discussion.

Introducing the activity:

1 Introduce this practical activity by eliciting from the students what they know about electrical circuits.
2 Demonstrate the most important points about setting up the first series and parallel circuit, but **do not** close the switch at any point, so that the students are not denied the pleasure of making then testing their predictions.
3 Advise the students to check the connections and that the globes are screwed properly into their holders if their circuits do not work. If this does not solve the problem, a cell or globe may be faulty and require replacement.
4 Assign the students to their groups.
5 State your expectations of their behavior and the time limits they will work under.

During the session:

1 With each group, whilst checking their circuits, ask the students questions about what they are discovering and how they might explain why their predictions came true or did not come true.
2 Watch that the students are following instructions and are obtaining results in a timely manner.

At the end of the activity:

This part of the session is very important because it will help the students to clarify ideas and develop communication skills.

Draw the students together to report their findings. This is an opportunity for students to show how they solved the challenges. The discussion questions also could be considered at this point, or else set for homework. Ensure that each group contributes to the discussion.

This part of the session should take about 10—15 minutes.

EXPECTED RESULTS

The following results should be obtained.

Results for Part A

Step	Switch open or closed?	Globe(s) on or off?	Globe(s) bright or dim (if on)?	Prediction correct?
1	**Open**	Both off	N/A	*Student responses will depend on what they predicted and what they observed*
	Closed	Both on	Dim	
2	**Closed**	Remaining globe is off	N/A	
3	**Open**	Both off	N/A	
	Closed	Both on	Dim	
4	**Closed**	All on	Dimmer than when there are two globes only	

Results for Part B

Step	Switch open or closed?	Globe(s) on or off?	Globe(s) bright or dim (if on)?	Prediction correct?
1	**Open**	Both off	N/A	*Student responses will depend on what they predicted and what they observed*
	Closed	Both on	Bright	
2	**Closed**	Remaining globe is on	Bright	
3	**Open**	Both on	Bright	
	Closed	Both off	N/A	
4	**Closed**	All on	As bright as when there are two globes	

Part C

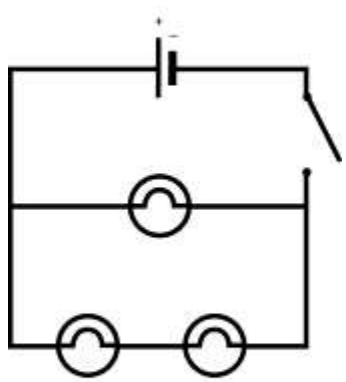


Figure 7: A circuit that meets the requirements of Challenge 1.

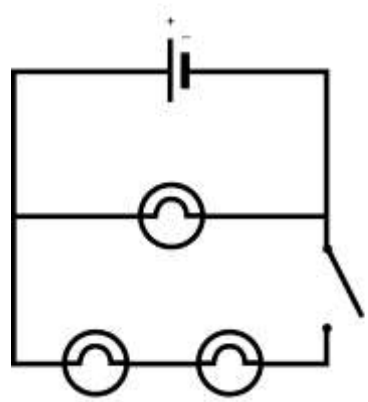


Figure 8: A circuit that meets the requirements of Challenge 2.

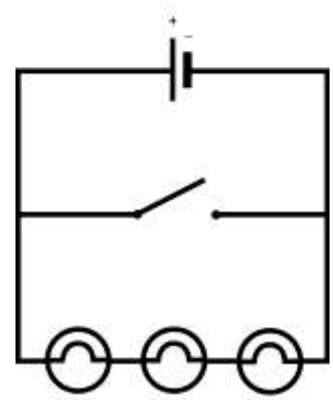


Figure 9: A circuit that meets the requirements of Challenge 3.

Alternatively, all three globes could be in parallel with the switch.

SUGGESTED SOLUTIONS TO DISCUSSION QUESTIONS

1 [*Student response*]

2 [*Student response*]

3 Christmas lights are in parallel, because this enables them to all be bright and also to remain on if one ‘blows’.

OPTIONAL STUDENT PRACTICAL ACTIVITY II: MEASURING CURRENT

Partners ____ **Date** ____________

Inquiry questions

1 Is the amount of current flowing in a series circuit the same all around the circuit?
2 What happens to the current when an extra globe is connected into a series circuit?
3 Is the amount of current flowing along each separate path of a parallel circuit the same?
4 Is the amount of current flowing along a path related to how bright the globes are along that path?

Introduction

An **electrical circuit** is a continuous pathway in which an electrical current flows from one terminal of a source of electrical energy through wires and various other circuit components and back to the other terminal.

When the circuit components are made of metal, the electrical current flowing though them consists of moving **electrons**. These extremely tiny particles have a negative charge and acn travel through metal.

Every electron that moves in the circuit carries a certain tiny amount of electrical charge. There are countless billions of electrons moving within a circuit, so all these tiny charges add up.

Current is a measure of the total amount of electrical charge passing through a particular point in the circuit every second. The symbol used for current is ***I*** and its unit is the **ampere**, often abbreviated to **amps**, symbol **A**.

The instrument used to measure current is called an **ammeter**. An ammeter is always placed along the path for which the current is to be measured. You will be shown how to use the ammeter in this investigation.

Figure 1 shows the STELR multimeter when it is turned OFF.

When the dial is rotated clockwise to the blue section, it acts as an ammeter and is now called an ammeter.

In the STELR program, when you experiment with the solar cells and wind turbines, you will connect the leads to the ammeter as shown in Figure 1. You will then rotate the dial to the '200m' setting. At this setting, the largest current it will read is 200 mA.

mA is the symbol for a milliamp. It is one thousandth of an ampere.
For example, a current of 25 mA = 25 ÷ 1000 A = 0.025 A.

For this experiment, however, you will use the 10A setting, in which case the red lead shown in Figure 1 will need to be moved from the socket on the right to the 10A socket on the left. (The black lead will still be in the socket in the centre.)

In this case the largest current it will read is 10 A.

The symbol for an ammeter in a circuit diagram is:

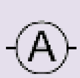


Figure 1

Predicting the outcomes of this experiment

Before you start:

1 Suppose you set up the series circuit in Figure 2.

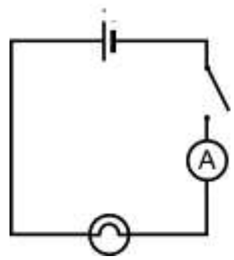


Figure 2

a When the switch is closed, do you think the amount of current flowing in the circuit will be the same all around the circuit, or might it be greater near the battery or some other part? Discuss. Explain why you think this.

____

____

b What do you think will happen to the amount of current flowing in the circuit if you add another globe in series with the first? Explain why you think this.

____

____

2   Suppose you set up the circuit in Figure 3.

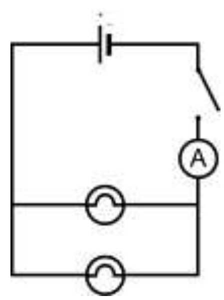


Figure 3

Highlight the two different paths in the circuit in two different colours. Would you expect the current flowing through each globe to be the same? Explain why you think this.

____

____

What you need

- STELR battery (or two 1.5 V batteries in a holder)
- Connecting leads
- STELR multimeter (or other multimeter or ammeter)
- 2 x 1.5 V globes
- Switch

Note: Ensure that the globes you use are identical.

What to do and what you discover

PART A. Measuring the current in a series circuit

Inquiry question 1: Is the amount of current flowing in a series circuit the same all around the circuit?
Inquiry question 2: What happens to the current when an extra globe is connected into a series circuit?
Inquiry question 4: Is the amount of current flowing along a path related to how bright the globes are along that path?

Instructions for Part A

Step	What to do
1	Set up the circuit shown in Figure 2, except use the STELR battery in place of the single battery. Have the ammeter set for a reading. (Remember to use the 10A socket for the red lead and the 10A setting on the blue scale, as stated next to Figure 1.) Have your teacher check the circuit. Whilst waiting for your teacher, copy the circuit diagram (Figure 2) in the table below. Once the circuit and the ammeter setting are checked, close the switch for just a few seconds and read the ammeter. **Record the current and how bright the globe is. Then open the switch so that the battery does not go flat.**
2	Now try placing the ammeter between the battery and the switch then between the globe and the battery. Only close the switch on a few seconds each time. Does this make any difference to the amount of current recorded? Was your prediction correct? **Draw the circuit diagram for the two other ammeter positions. Record the current and how bright the globe is for each circuit. Then return the ammeter to its first position and keep the switch open.**
3	Next add another globe to the circuit. Close the switch for a few seconds. Does this make any difference to the amount of current recorded? Was your prediction correct? **Draw the circuit diagram. Record the current and how bright the globe is. Move the switch back to where it was and leave it open.**

Results for Part A

Step 1 **Circuit in Figure 2**	**Step 2** **Ammeter moved to two other positions in the circuit**		**Step 3** **Two globes in circuit**
Circuit diagram: **Current:**	**Circuit diagram:** **Current:**	**Circuit diagram:** **Current:**	**Circuit diagram:** **Current:**
Brightness of globe:	**Brightness of globe:**	**Brightness of globe:**	**Brightness of globes:**

Conclusion for Part A

What is your answer to Inquiry question 1: Is the amount of current flowing in a series circuit the same all around the circuit?

What is your answer to Inquiry question 2: What happens to the current when an extra globe is connected into a series circuit?

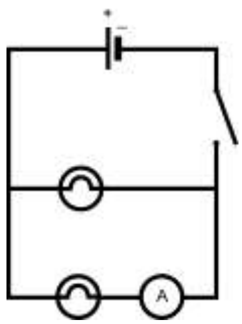
What is your answer to Inquiry question 4: Is the amount of current flowing along a path related to how bright the globes are along that path?

PART B. Measuring the current in a parallel circuit

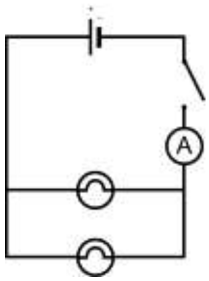
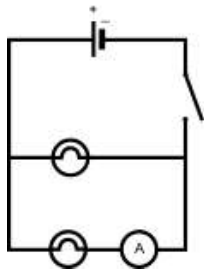
Inquiry question 3: Is the amount of current flowing along each separate path of a parallel circuit the same?

Inquiry question 4: Is the amount of current flowing along a path related to how bright the globes are along that path?

Instructions for Part B

Step	What to do
1	Set up the circuit shown in Figure 3, except use the STELR battery in place of the single battery. Have the ammeter set at 10 A for a reading. Have your teacher check the circuit. Once it is checked, close the switch for just a few seconds and read the ammeter. **In the results table on the next page, record the current and how bright the globes are, then open the switch so that the battery does not go flat.**
2	Look at Figure 3 again. Your highlighting should show that the ammeter is in both paths at the same time. Now move it so that it is only in one path, as shown in Figure 4. Close the switch for just a few seconds and read the ammeter. What do you notice about this reading?  Figure 4 **Record your results. Ensure that the switch is open so the battery does not go flat.**
3	Move the ammeter so that it is next to the other globe and only in its path. Trace around the wires with your fingers to be certain of this. What do you think the current will be this time? Close the switch for a few seconds to see. Was your prediction correct? **Draw the circuit diagram and record your results. Ensure that the switch is open so the battery does not go flat.**

Results for Part B

Step 1 Circuit in Figure 3	Step 2 Circuit in Figure 4	Step 3 Ammeter next to other globe
 **Current:**	 **Current:**	**Circuit diagram:** **Current:**
Brightness of globes:	**Brightness of globes:**	**Brightness of globes:**

Conclusion for Part B

What is your answer to Inquiry question 3: Is the amount of current flowing along each separate path of a parallel circuit the same?

What is your answer to Inquiry question 4: Is the amount of current flowing along a path related to how bright the globes are along that path?

What can you conclude from the first two results?

Part C. Challenge activity

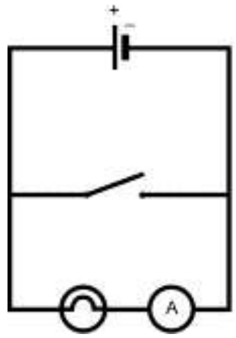


Figure 5

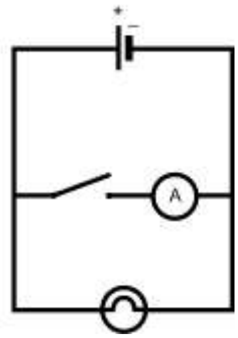


Figure 6

Suppose you were to set up the circuit in Figure 5. Notice that the ammeter is in the path containing the globe.

Predict what the current reading will be when the switch is open and when it is then closed.

Switch open : ____ Switch closed: ___________________________

Explain why you think this.

____

Now suppose you were to set up the circuit in Figure 6. Notice that the ammeter has been moved to the path containing the switch.

Predict what the current reading will be this time, when the switch is open and when it is then closed.

Switch open: ____ Switch closed: ___________________________

Explain why you think this.

____

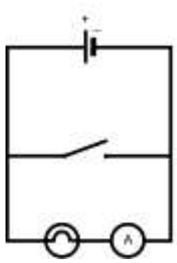
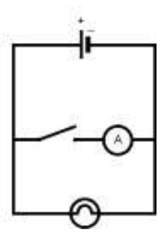
Once you have made your predictions, try each circuit in turn and see.

WARNING: BEFORE YOU CLOSE THE SWITCH FOR THE CIRCUIT IN FIGURE 6, ASK YOUR TEACHER TO CHECK YOUR CIRCUIT AND YOUR AMMETER SETTING!

Only close the switch for 1—2 seconds for each circuit!

Record your results in the table below.

Results for Part C

Circuit	**Current**	**Circuit**	**Current**
 Figure 5	**Switch open**	 Figure 6	**Switch open**
	Switch closed		**Switch closed**

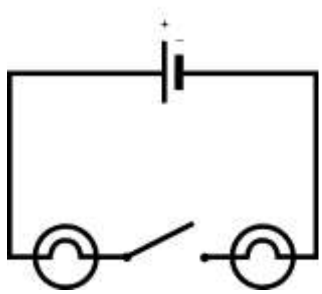
Were your predictions correct? If not, what might explain this?

Suggest why the current readings were very different to those recorded in Part B.

Find out more!

When the switch was closed in this activity, you created a short circuit. Find out what the term 'short circuit' means and why it is dangerous.

Discussion questions



1

Figure 7

Consider the circuit shown in Figure 7. Which statements about this circuit are correct? Rewrite any incorrect statement to make a true statement. (Assume that the globes are identical.)

A This is classified as a series circuit.

B The current is largest just next to the negative terminal of the battery.

C When the switch is closed, the current passing through each globe is the same.

D When the switch is open, both globes will go out.

E If one more globe is placed in the circuit, the current would be less.

2

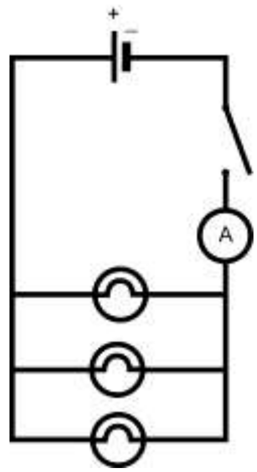


Figure 8

a Colour Figure 8 in different coloured pens to show the different paths along which the current can flow.

b Predict the brightness of each globe if the switch were closed. (Assume that the globes are identical.)

____

c If the switch were closed, what would be true of the current flowing through each globe?

____

d If the switch were open, what would be true of the current flowing through each globe?

____

e If the ammeter recorded a current of 0.09 A, what current would be flowing through the globe at the bottom of the diagram? Explain your reasoning.

____

OPTIONAL PRELIMINARY CIRCUIT TRAINING

RUNNING OPTIONAL PRACTICAL ACTIVITY II: MEASURING CURRENT
Pages 182—189 of this resource

SYNOPSIS

This optional experiment is designed to introduce students to the measurement of electrical current, or to refresh their memory of this. This will help prepare them for the range of experiments in which they measure electrical power in the STELR program.

It includes making predictions and a challenge. This not only helps engage the students but also trains them in analytical thinking. The challenge also is a powerful means of alerting students to the dangers of short circuits.

BACKGROUND INFORMATION

In the student version of this experiment, electrical current is described as a movement of electrons. It should be pointed out that strictly speaking, it is a movement of charge. In electrical conductors such as molten salts and salt solutions, it is the movement of ions (charged atoms or groups of atoms). For example, in molten sodium chloride, it is the movement of Na^+ ions and Cl^- ions.

APPROXIMATE TIME REQUIRED

60 minutes

LIST OF MATERIALS REQUIRED

Per student pair:
- STELR battery (or two 1.5 V cells in a holder)
- Connecting leads
- STELR multimeter (or other multimeter or ammeter)
- 2 x 1.5 V globes
- Switch

PRACTICAL ADVICE AND HINTS

1 Pre-test the batteries to ensure they are delivering about 3 volts.

2 Ensure that student pairs are able to obtain two identical globes, so that they can obtain reliable results.

3 It is preferable to use the STELR multimeter set as an ammeter to prepare students for the STELR program. If an analog ammeter is used instead, students will need to be trained in how to use it and how to read its scales.

4 Watch that the students do not turn on the batteries for more than a few seconds, or they will go flat.

5 The reason for using the 10 A scale on this occasion is that quite large currents will be obtained if Part C is attempted. A multimeter will not register a reading if the setting is too low.

6 If globes do not go on when they should, first check that all connections are tight. If they are tight, then one of the globes may have 'blown' and will need to be replaced.

7 In Part C it is particularly important that the switch is only closed very briefly, because this creates a short circuit. This will drain the battery very quickly and can damage the ammeter if it is at the wrong setting. Ensure that the students' circuits and ammeter settings are checked before they attempt this.

RISK MANAGEMENT

Students should be actively supervised throughout this practical activity.

SAFETY WARNING

1 Globes can get hot, so should not be handled unless they are cool.

2 When the short circuit is briefly created, warn the students that they must not touch the wire in the circuit containing the switch, as it will get very hot and they could get burnt. They also could experience a tingle in their hands. Do NOT substitute a power pack for the battery! They may receive a more substantial electric shock and/or burn and the power pack could be damaged.

Note: Multimeters are sensitive instruments and students must learn to be extremely careful with them. Ensure that they are not too close to the edge of the bench.

ADVICE FOR THE CLASSROOM

Working in small groups of two or three gives students a greater opportunity to be actively engaged instead of merely being spectators in the activity. As a result, they are more likely to develop the skills and understandings that will help them in later investigations.

See also the general advice provided on pages 28—29 of this resource.

Teachers are strongly advised to:

1 Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
2 Decide how to best manage the activity, particularly who should be in each group and whether you can allow time for the challenge in Part C. (The challenge is very worthwhile.)

Setting up:

Have a set of the equipment to perform a demonstration during the introductory discussion.

Introducing the activity:

1 Introduce this practical activity by eliciting from the students what they know about electrical current and ammeters.
2 Demonstrate the most important points about how to measure current with the ammeter they will use, and connecting it into a circuit. Show how to take the reading for Step 1 of Part A, as this will not affect their predictions.
3 Advise the students to check the connections and to check that the globes are screwed properly into their holders if their circuits do not work. If this does not solve the problem, a cell or globe may be faulty and require replacement.
4 Assign the students to their groups.
5 State your expectations of their behavior and the time limits they will work under.

During the session:

1 With each group, whilst checking their circuits, ask the students questions about what they are discovering and how they might explain why their predictions came true or did not come true.
2 Check that the students are following instructions and are obtaining results in a timely manner.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report and discuss their findings. Ensure each group contributes to the discussion.

This part of the session should take about 10—15 minutes.

EXPECTED RESULTS

The following results should be obtained.

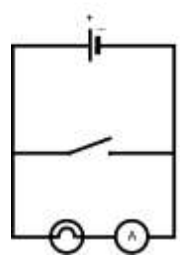
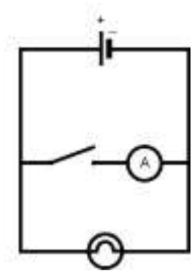
Results for Part A

Step 1 Circuit in Figure 2	Step 2 Ammeter moved to two other positions in the circuit	Step 3 Two globes in circuit
The current will depend on the voltage delivered by the battery and the resistance of the particular globes used. It should be less than 0.5 A. *The globe should be bright.*	*The current should be the same as in Step 1, no matter where the ammeter is placed along the circuit.* *The globe should be bright.*	*The current should decrease and the globes should be much dimmer than the first globe as a result. This is because you now have two globes drawing on the electrical energy available, and the total resistance of the circuit (globes, wires and switch) has increased. (The current will not be exactly half of the previous value. It is likely to be a bit more than half.)*

Results for Part B

Step 1 Circuit in Figure 3	Step 2 Circuit in Figure 4	Step 3 Ammeter next to other globe
The current should be greater than in the series circuit and the globes should be brighter than the two globes in series as a result. This is because more electrical energy is now provided. (The current will not be exactly double the previous value.)	*The current should be half the previous value in each of the two paths of the circuit (if the globes are identical).* *The globes should remain bright.*	

Results for Part C

Circuit	Current	Circuit	Current
 Figure 5	**Switch open** *The current should be similar to that in Step 1 for Part A, since effectively there is just one path. (A switch has similar resistance to a wire so its absence in this series circuit will make little difference.)*	 Figure 6	**Switch open** *The ammeter will not record a reading because the path in which it is placed is 'broken'.*
	Switch closed *The current will be very small – the ammeter is not likely to register a reading at the setting used.*		**Switch closed** *Since this is a short circuit, the current will possibly be as high as 3-4 A, causing the wires to heat momentarily.*

SUGGESTED SOLUTIONS TO DISCUSSION QUESTIONS

1 *The correct statements are: A, C, D and E. Statement B should say: The current is the same throughout the circuit.*

2 a *Student diagrams should show three different-coloured paths. The cell must be in each path.*
b All would be bright.
c It would be the same, and a third of the value of the current recorded by the ammeter.
d No current would flow through them, as the switch is in all three circuits, so no circuit would be complete.
e 0.03 A because the current would 'divide' equally between the three identical pathways.

OPTIONAL STUDENT PRACTICAL ACTIVITY III: MEASURING VOLTAGE

Partners ____ **Date** ____________

Inquiry questions

1 How is the voltage across a set of globes in a series circuit related to the voltage across the battery?

2 How is the voltage across a set of globes in parallel with one another related to the voltage across the battery?

Introduction

In an electric circuit, electric potential is the amount of electric potential energy per unit of charge. **Potential difference** is a measure of the difference in electric potential between any two points in the circuit. The greater this difference, the greater the electrical energy available in the circuit.

The symbol for potential difference is ***V*** and its unit is the **volt**, symbol **V**. For this reason potential difference is often simply called **voltage**. (Notice that the symbol for voltage is in italics but the symbol for its unit is not.)

The label of batteries you purchase for various portable electrical devices generally show that they will each deliver a voltage of 1.5 V. Whatever voltage the battery is supposed to deliver, it will decrease over time, because the chemicals inside it that react and 'produce' the electrical energy in the process are used up. Even rechargeable cells or batteries have a limited number of cycles, which is why they have a limited life.

The instrument used to measure voltage is called a **voltmeter**. Alternatively, a multimeter can be used in its voltmeter mode, in which case it is then called a voltmeter. It has the advantage of being able to measure large and small voltages. You will be shown how to use the voltmeter you are using in this investigation.

How voltmeters are connected into a circuit

A voltmeter is different from an ammeter in one important aspect. While an ammeter must be placed in series in the circuit for which the current is to be measured, so that the electric current flows through it, a voltmeter must be placed in parallel, across the part of the circuit for which voltage is to be measured. Only a very tiny current should flow through a voltmeter – just enough to make it work.

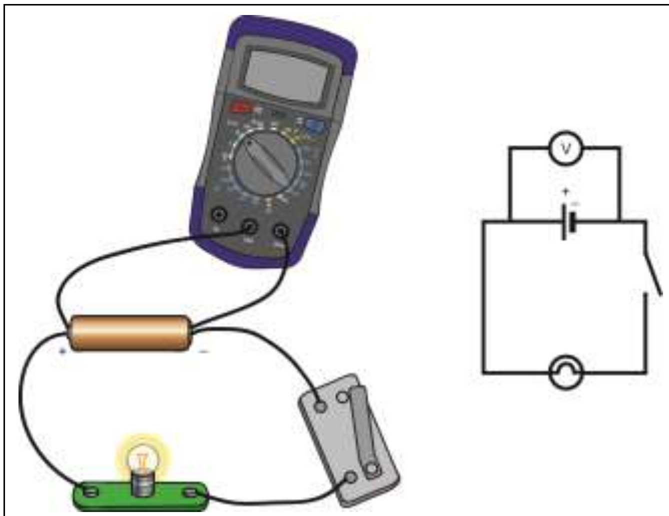


Figure 1

How a voltmeter must be connected to measure the voltage across the battery in a series circuit, and the matching circuit diagram.

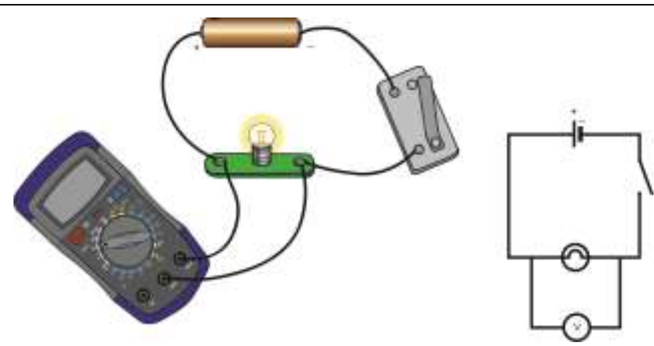


Figure 2

How a voltmeter must be connected to measure the voltage across a globe in a series circuit, and the matching circuit diagram.

Notice the symbol for a voltmeter in a circuit diagram is:

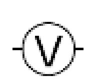


Figure 3 shows the STELR multimeter when it is turned OFF.

When the dial is rotated anticlockwise to the white section, it acts as a voltmeter.

In the STELR program, and in this experiment, you will connect the leads to the voltmeter as shown in Figure 3, then rotate the dial to the '20' setting.

At this setting, the largest voltage it will read is 20 V.

Figure 3

Predicting the outcomes of this experiment

In this experiment you will make predictions as you work through the different steps.

What you need

- STELR battery (or two 1.5 V batteries in a holder)
- Connecting leads
- STELR multimeter (or other multimeter or voltmeter)
- 3 x 1.5 V globes labelled I, II and III
- Switch

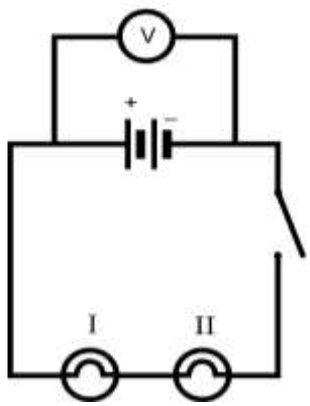
Note: Ensure that the globes you use are identical in shape and size.

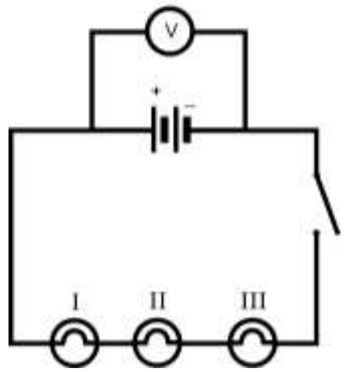
What to do and what you discover

PART A. Measuring voltages in a series circuit

Inquiry question 1: How is the voltage across a set of globes in a series circuit related to the voltage across the battery?

Instructions for Part A

Step	What to do
1	Set up the series circuit shown in Figure 4. Connect the voltmeter so that it will measure the voltage across the battery, as shown in the circuit diagram. **Notice the symbol for the battery in this circuit diagram. This shows that there are two 1.5 V batteries connected together in series in the holder.**  Figure 4 Before you close the switch, have your teacher check the circuit and your voltmeter setting. Whilst waiting for your teacher, predict what the voltage will be: ______________ Once your teacher has checked your circuit, close the switch for just a few seconds and measure the voltage. Did your prediction come true? **Record the voltage in the results table on the next page. Make sure that the switch is open so that the battery does not go flat.**
2	You will now measure the voltage across each globe in turn. First draw the two circuit diagrams for measuring the voltage across globe in the space below, and predict what you think the voltage might be. (Hint: See Figure 2). **Measuring the voltage across Globe I** **Measuring the voltage across Globe II** Predicted voltage: __________ Predicted voltage: __________
3	Set up the first circuit you drew in Step 2. Have your teacher check that you have set up your circuit correctly. Then close the switch for just a few seconds and record the voltmeter reading in the results table in the next page. Was your prediction correct? Do you now want to change your prediction for Globe II?

4	Set up the second circuit you drew in Step 2. Have your teacher check that you have set up your circuit correctly. Then close the switch for just a few seconds and record the voltmeter reading in the results table in the next page. Was your prediction correct?
5	Given your results, suppose the third globe, Globe III, is inserted into the circuit, as shown in Figure 5. Predict what the voltmeter reading for the voltage across the battery will be in this case.  Figure 5 Then close the switch for just a few seconds and record the voltmeter reading in the results table in the next page. Was your prediction correct?
6	Given your result, predict what the voltage will be across each globe in turn. Then make the appropriate changes to the circuit and close the switch for a few seconds to measure it. Record the voltmeter readings. Was your prediction correct?

Results for Part A

Number of globes in series circuit	Voltage across the battery (V)	Voltage across the globes (V)		
2		I	II	
3		I	II	III

Conclusion for Part A

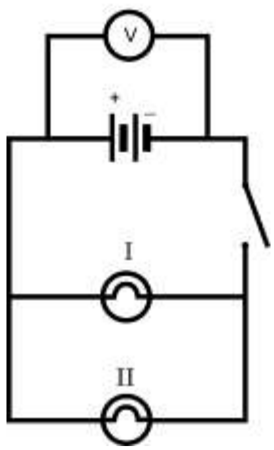
What is your answer to Inquiry question 1: How is the voltage across a set of globes in a series circuit related to the voltage across the battery?

____

PART B. Measuring voltage in a parallel circuit

Inquiry question 2: How is the voltage across a set of globes in parallel with one another related to the voltage across the battery?

Instructions for Part B

Step	What to do
1	Set up the parallel circuit shown in Figure 6. Before you close the switch, have your teacher check the circuit. Make any necessary adjustments to the voltmeter and the circuit. Then close the switch for a few seconds and measure the voltage across the battery.  Figure 6 **Record the voltage in the results table below. Make sure that the switch is open so the battery does not go flat.**
2	You will now measure the voltage across each globe in turn. Predict what this will be: Globe I: _________ Globe II: ______ Move the voltmeter so that it is only across Globe I. Close the switch for a few seconds and measure and record the voltage across the globe. Was your prediction correct? Do you now want to change your prediction for Globe II?
3	Now move the voltmeter so that it is only across Globe II. Close the switch for a few seconds and measure and record the voltage across the globe. Was your prediction correct?

Results for Part B

Voltage across the battery (V)	Voltage across the globes (V)	
	I	**II**

Conclusion for Part B

What is your answer to Inquiry question 2: How is the voltage across a set of globes in parallel with one another related to the voltage across the battery?

____

Part C. Challenge: What if globes are in series AND in parallel?

What do you expect to happen to the voltage across the battery and across the globes if you set up the circuit shown in Figure 7? This is a parallel circuit, but one path contains Globe II and Globe III in series with one another. Show the readings you expect next to the battery and globes in the diagram.

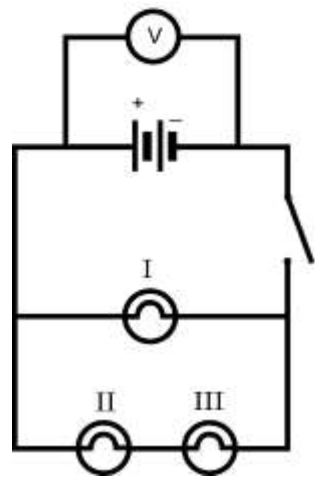


Figure 7

After recording your predictions, set up the circuit and move the voltmeter around to measure the voltage across each globe and across the battery. **Show the voltages in another colour next to your predictions.**

Were your predictions correct? _______

What can you conclude from your results?

____

Did your results surprise you? Can you suggest an explanation for what you discovered?

____

Discussion questions

1 Was the voltage across the battery the same as the label suggested? If not, suggest a reason for the difference.

____

2 Given your results, for the circuit diagrams in Figures 8–11, state what you expect the voltage across the globe to be. Put your answer next to each globe.

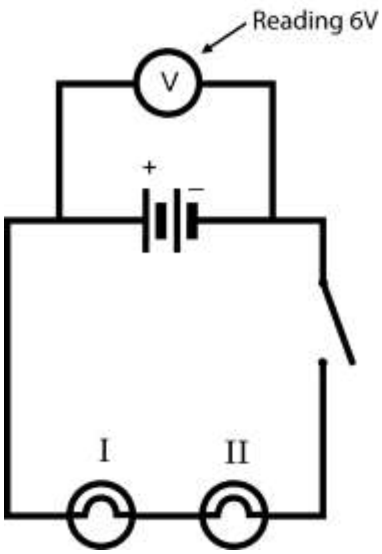


Figure 8

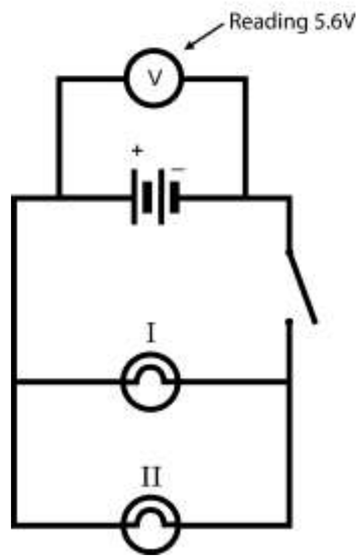


Figure 9

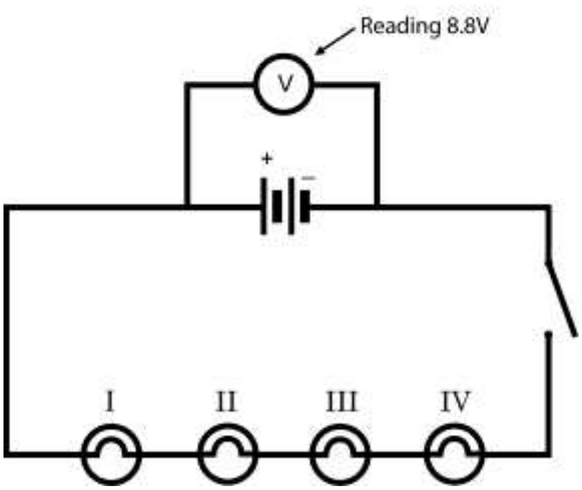


Figure 10

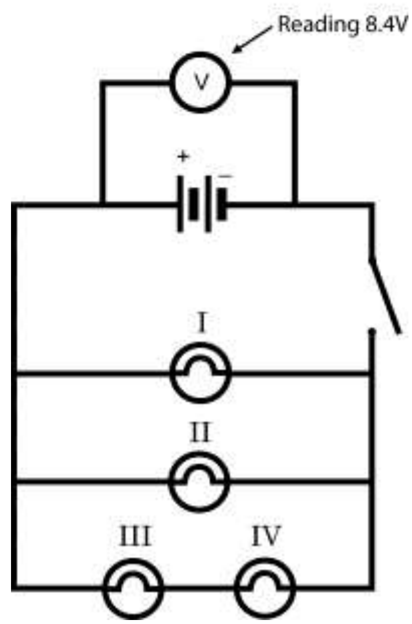


Figure 11

OPTIONAL PRELIMINARY CIRCUIT TRAINING

RUNNING OPTIONAL PRACTICAL ACTIVITY III: MEASURING VOLTAGE
Pages 193-199 of this resource

SYNOPSIS

This optional experiment is designed to introduce students to the measurement of voltage, or to refresh their memory of this. This will help prepare them for the range of experiments in which they measure electrical power in the STELR program.

At each stage they are required to use their previous results to predict voltages in the next circuit they set up, then to test whether their prediction is correct. The activity also includes a challenge. This not only helps engage the students but also trains them in analytical thinking.

APPROXIMATE TIME REQUIRED

60 minutes

LIST OF MATERIALS REQUIRED

Per student pair:

- STELR battery (or two 1.5 V batteries in a holder)
- Connecting leads
- STELR multimeter (or other multimeter or voltmeter)
- 3 x 1.5 V globes
- Switch

PRACTICAL ADVICE AND HINTS

1 Pre-test the batteries to ensure that they are delivering about 3 volts.

2 Ensure that student pairs are able to obtain sets of three identical globes, so that they can obtain reliable results.

3 It is preferable to use the STELR multimeter set as a voltmeter to prepare students for the STELR program. If an analog voltmeter is used instead, students will need to be trained in how to use it and how to read its scales.

4 Watch that the students do not turn on the batteries for more than a few seconds, or they will go flat.

5 If globes do not go on when they should, first check that all connections are tight. If they are tight, one of the globes may have 'blown' and will need to be replaced.

6 if students are not sure whether they have set up circuits correctly, have them trace the paths with their fingers. The voltmeter should always be on its own little 'loop' across the device across which it is measuring the voltage.

RISK MANAGEMENT

Students should be actively supervised throughout this practical activity.

SAFETY WARNING

Globes can get hot, so should not be handled unless they are cool.

Note: Multimeters are sensitive instruments and students must learn to be extremely careful with them. Ensure that they are not too close to the edge of the bench.

ADVICE FOR THE CLASSROOM

Working in small groups of two or three gives students a greater opportunity to be actively engaged instead of merely being spectators in the activity. As a result, they are more likely to develop the skills and understandings that will help them in later investigations.

See also the general advice provided on pages 28—29 of this resource.

Teachers are strongly advised to:

1 Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
2 Decide how to best manage the activity, particularly who should be in each group and whether you can allow time for the challenge in Part C.

Setting up:

Have a set of the equipment to perform a demonstration during the introductory discussion.

Introducing the activity:

1 Introduce this practical activity by eliciting from the students what they know about voltage and voltmeters.
2 Demonstrate the most important points about how to measure voltage with the voltmeter they will use, and connecting it into a circuit. Show how to take the reading for Step 1 of Part A, as each battery will give a slightly different reading.
3 Advise the students to check the connections and to check that the globes are screwed properly into their holders if their circuits do not work. If this does not solve the problem, a cell or globe may be faulty and require replacement.
4 Assign the students to their groups.
5 State your expectations of their behavior and the time limits they will work under.

During the session:

1 With each group, whilst checking their circuits, ask the students questions about what they are discovering and how they might explain why their predictions came true or did not come true.
2 Watch that the students are following instructions and are obtaining results in a timely manner.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report and discuss their findings. Ensure each group contributes to the discussion.

This part of the session should take about 10—15 minutes.

EXPECTED RESULTS

Typical results for Part A

Number of globes in series circuit	Voltage across the battery (V)	Voltage across the globes (V)		
2	3.2	I 1.6	II 1.6	
3	3.3	I 1.1	II 1.1	III 1.1

Note:
1 The values will depend on the battery and the resistance of the globes. The voltage across the globes will only be the same if they have identical resistance.
2 The voltage of the battery may or may not be the same when the extra globe is added. The figures above were chosen for their divisibility, but for fresh 3 V batteries the results should be similar to these.
3 It can be seen that when there are two identical globes in series, the voltage across them is half the voltage across the battery. When there are three identical globes in series, the voltage across them is one third of the voltage across the battery.

Typical results for Part B

Voltage across the battery (V)	Voltage across the globes (V)	
3.2	I 3.2	II 3.2

Note:
1 The values will depend on the battery and the resistance of the globes.
2 It can be seen that when there are two globes in parallel, the voltage across them is the same as the voltage across the battery. (This will still be true if a third globe is added in parallel to the first two.)

Typical results for Part C

Voltage across the battery (V)	Voltage across the globes (V)		
3.2	I 3.2	II 1.6	III 1.6

Note:
1 The values will depend on the battery and the resistance of the globes.
2 Since Globes II and III are in series with each other, the voltage across each is half that of the voltage across Globe I, which will be the same as the voltage across the battery.

SUGGESTED SOLUTIONS TO DISCUSSION QUESTIONS

1 The voltage could be less than 3 V if the battery has been stored for a while, or used, as batteries run down. If it is fresh and unused it may be a little more than 3 V.

2

Figure 8: 3 V across each globe.

Figure 9: 5.6 V across each globe.

Figure 10: 2.2 V across each globe.

Figure 11: 8.4 V across each of Globe I and Globe II and 4.2 V across each of Globe III and Globe I.

OPEN INQUIRY QUESTIONS

Wind Turbine Open Inquiry Questions

While doing the wind turbine investigations in the STELR Core Program Student Book, many open inquiry questions arise that students can investigate by designing and carrying out their own investigations. These could include:

- What is the best pitch (angle) for the blades?
- Is it better to have the reinforcing ridge of the blade facing towards or away from the wind?
- How can I configure the blades to give the maximum power output of the generator?
- What is the effect of wind speed on the output of the generator?
- What is the minimum wind speed needed to start turning the turbine for different blade configurations? Is this affected by using gears?
- What is the effect of using gears on the power output of the generator?
- Does the shape of the blade affect the power output?
- Can I model vertical wind turbines with this equipment?
- What is the effect of load resistance on the power output of the turbine for a given wind speed?
- How does the surrounding topography affect the power output of the turbine?

Solar Cells Open Inquiry Questions

While doing the solar cells investigations in the STELR Core Program Student Book, many open inquiry questions arise that students can investigate by designing and carrying out their own investigations. These could include:

- What is the efficiency of a STELR solar cell at transforming light energy into electrical energy?
- Do all photovoltaic (solar) cells have the same percentage efficiency?
- How is the power output of a solar cell or panel affected by clouds and shadows?
- How is the power output of a solar cell or panel affected by dirt and other solid pollutants?
- How is the output voltage or power of a solar panel affected by the temperature of the cells?
- How is the output voltage or power of a solar panel affected by the direction of the light striking the panel?
- What is the best direction to mount solar panels?
- How are individual cells connected in commercial solar panels?

STELR EQUIPMENT PACKS

Contents

Schools participating in the STELR Project receive class sets of specifically designed and Australian manufactured laboratory equipment, including solar panels and model wind turbines, to run the program.

A class set should be sufficient to run four classes.

STELR Student Equipment Kit #1 contents	
Description	Quantity/Kit
Solar panel module	1
Load module	1
Light source 12V 25W	2
Power source 12V. 4A. AC	1
Multimeters	2
Switch	1
Wind turbine rotor and generator	2
Clamping hub for wind turbine vanes	2
150 mm long vanes	15
100 mm medium vanes	15
75 mm short vanes	15
“Cotton reel” racer with band	4
Battery power source	2
Connecting cables with 4 mm plugs	8

STELR Teacher Kit #2 contents	
Description	Quantity/Kit
Hand driven generator base	1
Spare belts for generator	3
Water wheel assembly complete	1
Clear vinyl hose for water feed.	1
Vial of 10 spare lamps	1
Jumping cups	20

Extra equipment	
Electric fans to provide wind source	6 recommended per class set

The electric fans are to provide wind source. These are sold separately.

Ordering Replacement Parts

Spare parts can be purchased directly from our supplier:

INDUSTRIAL EQUIPMENT & CONTROL PTY. LTD.
61-65 McCLURE ST. THORNBURY VIC 3071
AUSTRALIA

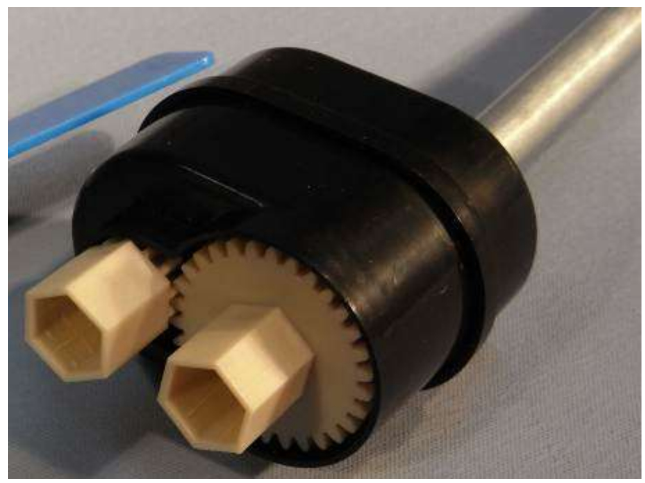
Tel: 61 (0)3 9497 2555
Fax: 61 (0)3 9497 2166
Email: iec@iecpl.com.au
Website: www.iecpl.com.au

Images of Selected Items

Student Kit #1 (10 per class set) and items from the teacher kit


ATSE
STELR
PROJECT
RENEWABLE
ENERGY KIT
ST090-01
12V
OVERLOAD
PROTECTED
4.5A MAX


STELR
ST050-01
-2.05
HOLD
OFF
10A
COM
VΩmA




+ 3V −
STELR
BATTERY
STD10-01
MADE IN AUSTRALIA


STELR
WIND SOURCE

Replacement Parts Price List and Codes (subject to change)

DESCRIPTION	CODE NO.	UNIT	A $ LIST
STELR BATTERY P/SUPPLY, 2x'AA', 4mm SOCKETS	ST 010-01	EACH	7.90
STELR CABLE, 30cm, WITH BANANA PLUGS, YELLOW	ST 020-02	EACH	3.10
STELR CABLE, 60cm, WITH BANANA PLUGS, BLUE	ST 020-03	EACH	3.50
STELR CABLE, 60cm, WITH BANANA PLUGS, BROWN	ST 020-04	EACH	3.50
STELR CABLE, 60cm, WITH BANANA PLUGS, GREEN	ST 020-05	EACH	3.50
STELR CABLE, 60cm, WITH BANANA PLUGS, GREY	ST 020-06	EACH	3.50
STELR CABLE, 60cm, WITH BANANA PLUGS, RED/BLACK PAIR	ST 020-07	PAIR	8.40
STELR CABLES, SET/11,WITH BANANA PLUGS	ST 020-01	SET/11	38.00
STELR CARTON FOR KIT#1, WITH SET OF DIVIDERS	ST 030-01	EACH	8.00
STELR COTTON REEL MOTOR ,BLUE	ST 040-02	EACH	2.80
STELR COTTON REEL MOTOR ,GREEN	ST 040-01	EACH	2.80
STELR COTTON REEL MOTOR ,RED	ST 040-03	EACH	2.80
STELR COTTON REEL MOTOR, YELLOW	ST 040-04	EACH	2.80
STELR COTTON REEL RODS, WOOD, SET/6	ST 040-06	SET/6	2.80
STELR COTTON REEL RUBBER BAND SET/6	ST 040-05	SET/6	1.80
STELR METER, MULTIMETER, W/BACKLIGHT, AUTO POWER OFF	ST 050-01	EACH	14.00
STELR MIRROR, PLASTIC, FLAT,160x168mm	ST 060-01	EACH	3.50
STELR P/SUPPLY, 240/6V/12V. 4A (RUNS 2xLAMPS)	ST 090-01	EACH	50.00
STELR SOLAR CELL PANEL, 4xCELLS	ST 070-01	EACH	49.50
STELR SOLAR CELL TEST PANEL,100ohm RHEOSTAT LOAD	ST 080-15	EACH	8.60
STELR SOLAR CELL TEST PANEL,BUZZER ONLY	ST 080-13	EACH	3.00
STELR SOLAR CELL TEST PANEL,LAMP,LED,BUZZR,MOTOR	ST 080-01	EACH	89.50
STELR SOLAR CELL TEST PANEL,MOTOR ONLY	ST 080-05	EACH	3.80
STELR SOLAR CELL TEST PANEL,PROPELLOR ONLY	ST 080-07	EACH	1.10
STELR SOLAR CELL TEST PANEL,RED LED ONLY	ST 080-11	EACH	2.20
STELR SOLAR CELL TEST PANEL,RESISTORS ONLY	ST 080-09	EACH	1.50
STELR SOLAR LIGHT SOURCE,12V,25W,QI LAMP	ST 100-01	EACH	22.00
STELR SOLAR LIGHT SOURCE, SPARE LAMP 12V, 25W, REFL.	ST 100-02	EACH	4.50
STELR SOLAR LIGHT SOURCE, SPARE SOCKET KEEPER	ST 100-05	EACH	0.40
STELR SWITCH,TOGGLE,SPST IN HOUSING	ST 105-01	EACH	11.40
STELR WINDMILL FAN HUB ASS'Y,FOR UP TO 12 VANES	ST 110-01	EACH	8.20
STELR WINDMILL GENERATOR UNIT,2.5:1 GEAR RATIO	ST 120-01	EACH	24.00
STELR WINDMILL HUB ADAPTOR (OLD TO NEW)	ST 115-01	EACH	0.80
STELR WINDMILL VANES, LONG, RED, SET/15	ST 140-01	SET/15	8.50
STELR WINDMILL VANES, MEDIUM ,BLUE, SET/15	ST 140-02	SET/15	7.80
STELR WINDMILL VANES, SHORT, YELLOW, SET/15	ST 140-03	SET/15	6.75
STELR, CARTON FOR KIT#2, WITH SET OF DIVIDERS	ST 200-01	EACH	7.00
STELR, FLOOR FAN,16" HIGH VELOCITY, 220/240V	ST 210-01	EACH	55.00
STELR, GENERATOR/ MOTOR, DC,HAND DRIVEN, INCL. MAGNET	ST 220-01	EACH	70.00
STELR, HAND CRANK GENERATOR BASE	ST 225-01	EACH	12.00
STELR, GENERATOR/MOTOR, DC, LAMP LOAD PCB WITH PLUGS	ST 220-02	EACH	8.50
STELR, GENERATOR/MOTOR, SPARE BELT	ST 220-03	EACH	2.20
STELR, GENERATOR MOTOR, SPARE LAMPS,2.5Vx200mA	ST 220-04	SET/4	1.30
STELR, LAMPS,VIAL/10 LAMPS, 3V 50mA	ST 250-01	SET/10	3.20
STELR, LAMPS, VIAL/10 LAMPS, 6V 50mA	ST 250-02	SET/10	3.20
STELR, METER, ANEMOMETER	ST 260-01	EACH	48.00
STELR, METER, I.R. THERMOMETER (no laser)	ST 270-01	EACH	35.00
STELR, METER,LUX,TO 50,000	ST 280-01	EACH	28.00
STELR, TOY, JUMPING JACKS, BAG/10	ST 285-01	SET/10	9.00
STELR, WATER WHEEL ASS'Y,WITH CHUTE, HOSE BARB	ST 290-01	EACH	32.00
STELR, WATER WHEEL HOSE, VINYL, CLEAR, 8x11mm,1M	ST 290-02	EACH	2.70