locktronics

Simplifying Electricity

Energy and the environment

CP7122

MATRIX

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Worksheet 1

Measuring energy and power

In this course, we look at several aspects of the energy debate - energy supply, consumption and conservation. The Energy Meter is a useful tool for investigating all of these. In the home, you can use a meter, like the one shown in the lower picture, to monitor the electrical energy used by a particular device, such as the television, or fridge. To do so, you plug the meter into a mains electricity socket, and then plug the device into the meter. After that, you can watch how much energy it uses.

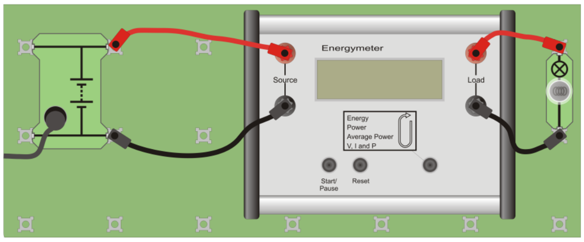
w1b

w1g

The first exercise shows you how to use the Energy Meter to measure a range of quantities, like energy, power, voltage and current.

Over to you:

- Connect the Energy Meter between the power supply carrier and a 6V 0.04A bulb, as shown in the picture.

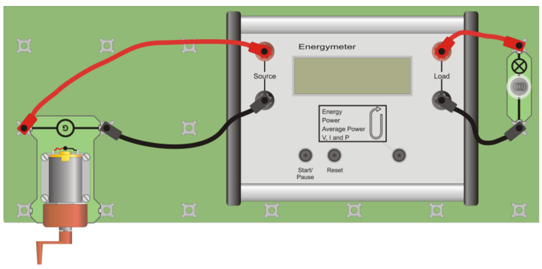


w1h

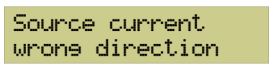
- Plug in the Energy Meter power supply, and switch on. The display shows the word 'Initialising...' for a few seconds
- Then, the display looks like the picture opposite.

w1j

- Set the 'Locktronics' power supply to 6V and switch on.
- Press the 'Start / Pause' button. The Energy Meter starts to record the energy transferred from the power supply to the bulb. At the lower right-hand corner of the display, an arrow '►' shows that the meter is continuing to measure.
- Press the 'Start / Pause' button again. The display freezes and the arrow turns to a '**P**' to show that the meter has paused.
- To clear the energy and power readings, press the 'Reset' button.
- Press the right-hand button on the Energy Meter. The display now shows other quantities - the power delivered to the bulb, the average power over the duration of the measurement, and finally, the voltage and current delivered to the bulb.
- Next, replace the power supply with the hand-cranked generator, as shown opposite.
- Set the Energy Meter to measure power.
- Turn the handle gently and try to keep the power reading steady.
- If you turn the handle the wrong way, the display shows the message shown opposite.



w1i



w1k

Worksheet 1

Measuring energy and power

So what?

Before we start the energy debate, let's review the quantities we wish to monitor:

Energy:

- makes things happen - moving, heating, lighting etc.;
- is measured in joules (J).

Power:

- is how much energy is delivered each second;
- is measured in watts (W).

Average Power:

- 'Average' means 'smooth out the variations'.

Voltage:

- measures the force pushing the electricity around the circuit;
- is like the size of the pump forcing water through a pipe.

Current:

- measures how much electricity flows around the circuit;
- is measured in amps (A)

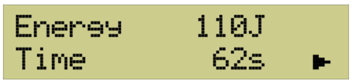
A lot of the measurements come with '**m**' in front. This means '**milli**' which means 'one thousandth', so one **milliamp** (**mA**) is the same as one-thousandth of an amp.
In other words:

1 joule = 1000mJ;
1 watt = 1000mW

Energy meter views

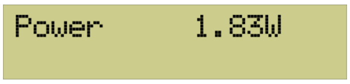
The Energy Meter has different modes to measure different quantities. You select the mode by pressing the function button.

Measuring energy



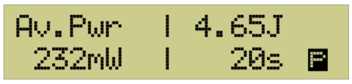
In this mode the meter shows the energy that has been transferred through the device in the time shown. You can use the start/stop and reset buttons to control the display.

Measuring power



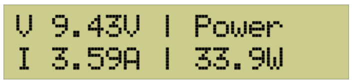
In this mode the meter shows the power transferred through the meter each instant.

Measuring average power



In this mode the meter shows the average power in the time shown, and the values used to calculate it .

Measuring voltage, current and power



In this mode the meter shows the voltage, current and power at each instant.

For your records:

Complete the following:

- Electric currents are measured in units called ....
- The unit of .... is the watt.
- One second = ... milliseconds.
- Energy is measured in ……………,
- .... = power x time.

Worksheet 2

Joules, watts and efficiency

In the modern world, we take energy and power for granted. Few of us appreciate just how

much we need for everyday activities, such as:

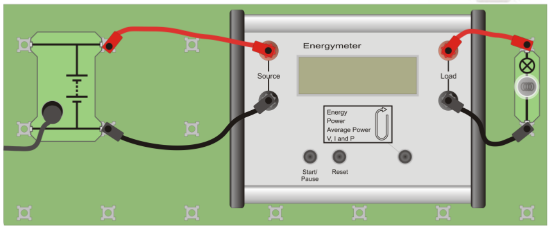
- lighting a bulb;
- running 100 metres ;
- flying to a holiday destination, etc.

A 'feel' for the size of the joule and the watt can make us more aware of our dependence on energy, and help us to reduce energy consumption.

These exercises aim to give you that 'feel', and introduce another important quantity, efficiency.

Over to you:

- Connect the Energy Meter to the power supply carrier and a 6V 0.04A bulb, as shown in the picture. (The bulb rating is stamped onto the side as the arrow shows.)
- Set the 'Locktronics' power supply to 6V and switch on.

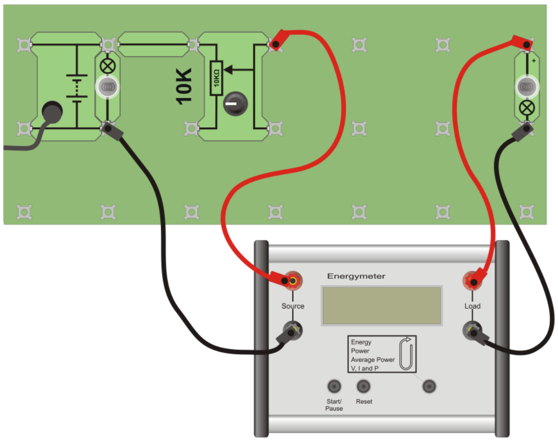


- Plug in the Energy Meter power supply, and switch on. The display shows the word '`Initialising...`' for a few seconds.
- Copy the following table:

Bulb	Current	Voltage	Power	Energy in 20s
6V 0.04A	A	V	W	J
6.5V 0.3A	A	V	W	J
LED	A	V	W	J

The white LED bulb looks similar to the incandescent bulbs—but there is no rating on the side and you can not see the filament.

- Select the current, voltage and power mode with the function button and Record current, voltage and power
- Press the function button to change to the power and energy mode and measure the energy transferred in 20 seconds. Then repeat this experiment for the 6.5V 0.3A bulb.



- Now build the second circuit shown in the diagram: put the bulb rated at 6.5V 0.3A across the battery, and use an LED bulb for the second bulb.
- Use the potentiometer to approximately match the brightness of the LED bulb to that of the 6.5V 0.3A bulb.
- Measure the current, voltage and power delivered to the second bulb, and record the results in the table.
- Then measure the energy transferred to the second bulb in 20 seconds, and record it in the table.

Worksheet 2
Joules, watts and efficiency

So what?

You should now be aware that the joule and the watt are quite small units:

- the power of the 6V 0.04A bulb is around a quarter of a watt;
- over 20 seconds it consumes around 5 joules of energy .

Think of this as one 'torchpower'. In future worksheets, we will compare other electrical devices to this standard of energy consumption.

The three bulbs used in the exercises were similar in brightness, after adjustment. That means that they produced similar amounts of light energy each second. In other words, their power output of light was roughly the same. However, their electrical power inputs were very different. Look at your table of results!

The 6V 0.04A and the 6.5V 0.3A bulbs use heated wire filaments to produce the light. This is a wasteful process, as much of the energy is used to heat the filaments to a high temperature. They are very good at giving off heat energy, but not much of the energy consumed is turned into light.

On the other hand, the LED, (Light-Emitting Diode,) does not get particularly hot. It contains an advanced semiconductor crystal that gives out light directly, without getting hot. Most of the energy transferred to it is changed into light.

The term 'efficiency' describes how much of the energy consumed is converted into useful output. We can use the following formula to calculate it:

Energy efficiency = (useful energy output / total energy input) x 100%

A device that has an energy efficiency of 50%, converts only half of the energy it consumes into a useful output. The efficiency of most filament lamps is only around 10%.

For your records:

- Copy and then complete the table:

	Total energy input	Useful energy output	Efficiency
1	2000J	400J	
2		1kJ	10%
3	60kJ		15%
4		1MJ	20%

- How many times more efficient is the LED bulb than the 6V 0.04A bulb?
- Look up how much power a standard domestic light bulb uses.
- Estimate the total power used for lighting in your home.
- Using these answers, how much power could your home save if you switched to LED lighting?

Worksheet 3

Solar power

Energy is becoming more expensive. Oil, coal, gas - traditional energy resources, are running out. Burning fossil fuels causes global warming, and so we are urged to use less, to reduce our carbon footprint. The way forward is to find alternative 'clean' sources, and support energy saving.

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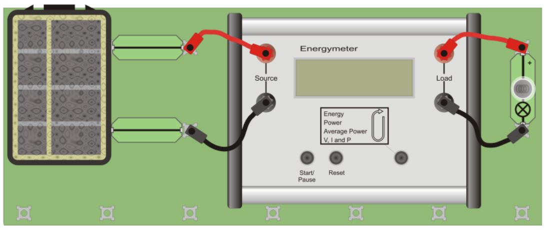
At present, the main alternative sources are:

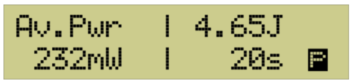
- nuclear power;
- hydroelectricity;
- wind energy;
- solar power;
- tidal power;
- geothermal energy.

This exercise looks at using solar power.

Over to you:



w3jd



w1e

- Connect the Energy Meter between the solar cell and a lamp unit containing the LED bulb. The picture shows you how to do this.
- Use the function button on the Energy Meter to select the average power and energy mode.
- Place the equipment in a shady part of the room, away from direct sunlight.
- Copy the table given below.
- Place a lamp 30 cm above the solar cell.
- Read the power generated, and record it in the first line of the table.
- Lower the lamp (or raise the baseboard,) to 25cm above the solar cell.
- Take the new power reading and write it in the second line of the table.
- Complete the table by doing the same thing at the other distances given.

Distance from solar cell in cm	**Power generated in mW**	**Energy used over 20s in mJ**
30		
25		
20		
15		
10		
5		

Worksheet 3
Solar power

So what?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Householders are urged to install photovoltaic (PV) solar cells on the roof to generate electrical power.

However, there are issues with this.

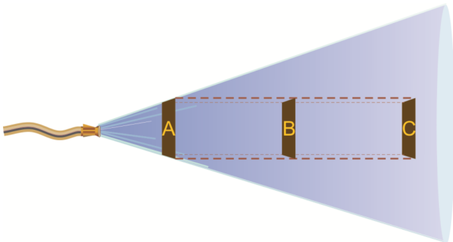
- How many solar cells?
- Must the roof face south?
- What is the best angle for the solar cells?
- Do they work on a cloudy day?

The investigations you just carried out provide some of the answers.

Here is a way to visualise what is happening:

The effect of distance:

Imagine a hosepipe squirting water. When a body is far away, (position C in the diagram,) much of the water misses it, and so it does not get very wet. As the body gets closer, (position B,) more of the water hits it, and so it gets wetter. By the time it reaches position A, all the water hits it. Moving closer to the hose does not make any difference, except that the water falls on a smaller area.

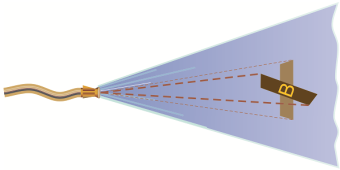


w2r

Light from the desk lamp shines in all directions. Only some hits the solar cell. As the lamp moves closer, more of the light hits it, and so it generates more power.

The effect of angle:

When the body is tilted, less water hits it, and so it does not get as wet. Do we see a similar effect with sunlight and the solar cell? With the solar cell, when the light hits it at an angle, less energy falls on it each second. Does this mean that it will generate less power?

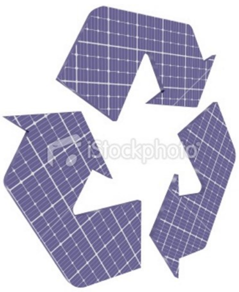


w2t

For your records:

- With the lamp at 15cm, how many solar cells are needed to power a 6V 0.04A torch bulb?
- What area of solar cell does your answer to the last question amount to, assuming that the output of a solar cell depends directly on its area, ?

w2m



- The picture is based on a familiar symbol. What does that symbol mean?
- Find out how oil, gas and coal formed originally. Write a clear explanation, using less than 100 words.
- List three alternative sources of energy, other than nuclear, and, for each one, describe a disadvantage of relying on it as a source of energy.
- Write a set of instructions to tell one of your classmates how to test whether the output of a solar cell depends on the angle at which it is positioned.

Worksheet 4
Wind power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Most of our electricity is generated in the same way, by rotating an electromagnet inside a coil of wire, in a device called an 'alternator'.

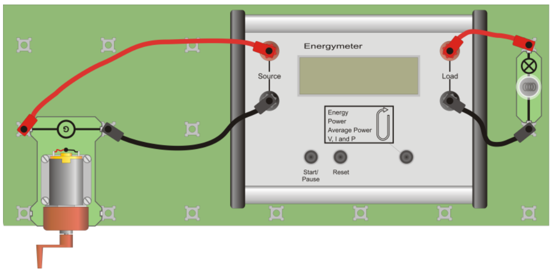
Both conventional power stations, and renewable energy systems use this technique. The only difference is the method used to rotate the electromagnet.

In coal and gas fired power stations, heat produces high-pressure steam, which rushes through turbines (propellers) attached to the electromagnet, spinning it inside the coil of wire.

In renewable systems, the turbine is driven by falling water, or wind, or waves, or by steam generated from heat released by nuclear reactions.

Over to you:

This investigation uses the hand-cranked generator to produce electricity. In the world of alternative energy, a similar generator would be turned by wind, or water power, as described above.



w1i

- Set up the arrangement shown in the picture, using a 6V 0.04A bulb.
- Set up the Energy Meter to display the voltage, current and power delivered to the lamp by the generator.
- Unscrew the bulb.
  Notice how easy it is to turn the generator handle.
  The Energy Meter shows that you are still generating a voltage, but no current, and so no power, as no load is connected.
- Now screw in a 6.5V 0.3A bulb. Turn the handle again.
  What do you notice about how easy it is to turn?
  Explain to your teacher why more effort is needed.
- Change the display on the meter so that it displays power and energy.
- Copy the table and complete it with your measurements.
- Now turn it faster. (You may need to hold the generator with one hand, and turn the handle with the other.) What do you notice about the power you are generating now?

Generator speed:	Power generated in mW	Energy generated in 20s
Slow		
Fast		

Worksheet 4
Wind power

So what?

Coal, oil and gas are becoming scarcer. Even worse - burning them in power stations produces carbon dioxide, thought to be a major cause of global warming. Recent changes in our energy habits have been driven by the need to reduce carbon dioxide emission.
Look at what has happened over the past five years:

Used for	Source	2004	2008
electricity generation	Wind	166.4	610.2
	Solar	0.3	1.5
	Hydroelectric	416.5	444.3
heat generation	Solar	24.6	55.7
	Geothermal	0.8	0.8

Source: Department of Energy and Climate Change

This table shows the UK energy consumption in 2004 and 2008 in terms of the equivalent number of thousands of tonnes of oil required to produce the same amount of energy. For example, to generate the same energy as that produced from geothermal sources would take 0.8 thousand tonnes of oil, i.e. 800 tonnes of oil per year.

Electricity generation in the UK:

In 2004 - the balance of electricity generation in the UK was as follows:

Source	Percentage of production
Gas	40%
Coal	33%
Nuclear	19.3%
Renewables	3.6%
Hydroelectricity	1.1%

Source: Department of Energy and Climate Change

- In 2009 - nuclear stations generated only 17.9% of the total electricity production
- By 2020 the UK government target is to generate 15% of the UK's energy from renewable resources.

For your records:

- How many solar cells would be needed to generate the same amount of energy as the hand cranked generator?

Use the Internet to find answers to the following questions, but use less than100 words for each!

1. What is 'global warming' and why is it a danger?
2. The alternator relies on electromagnetic induction (EMI). What is EMI?
3. Describe two disadvantages of wind power.
4. Energy storage is important in a system that uses large amounts of wind energy. Describe some of the options available for storing energy obtained from wind.

Worksheet 5

Storing energy

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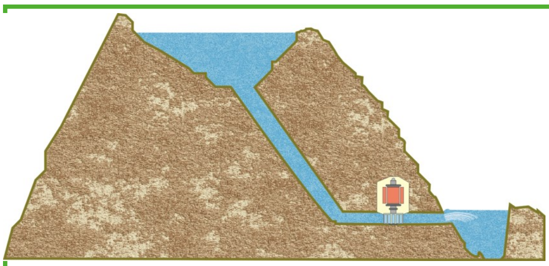
w4a



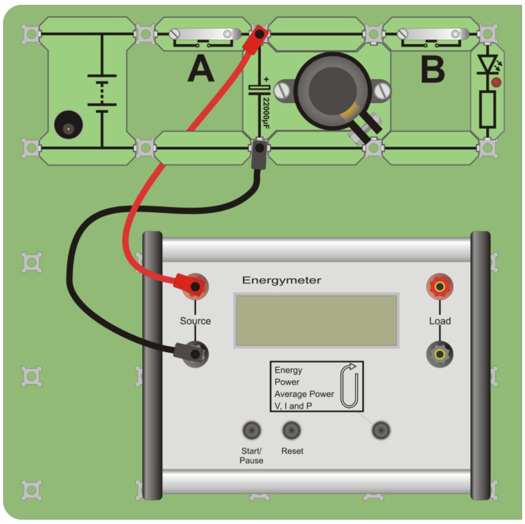
Demand for electricity varies all the time. It depends on the weather, what is on television, what time of day, and what day of the week it is, among other things.

Unfortunately, power stations cannot suddenly be switched on or off in response. They take many hours to activate fully.

The obvious answer is to store excess electricity and use it when demand increases, but that's not easy. One large-scale solution, called 'pump storage', uses surplus electricity to pump water from
a lower reservoir to a higher one. When demand rises, the water is allowed to fall back again and generate electricity.

On a much smaller scale, electrical energy can be stored in batteries, and in components called capacitors, shown in the picture opposite, which are the subject of this worksheet.

Over to you:



w4b

1. See the energy

- Set up the arrangement shown.
- The power supply set to 6V.
- The Energy meter is set to display voltage, current and power. We will use it to show the voltage across the capacitor.
- Switch on the power supply and press push switch **A**. Straightaway, the voltage across the capacitor rises up to the supply voltage. The capacitor is now fully charged.
- Release the switch to disconnect the power supply.
- Press push switch **B**.
  The light from the LED is provided by the energy stored in the capacitor.
- Watch the voltmeter reading. You can see the capacitor discharge as it loses energy.

2. Does it leak?

- Using the same circuit, press switch **A**. The capacitor charges up to the supply voltage.
- Release the switch to disconnect the power supply. Make a note of the voltage reading.
- Watch the voltmeter. Very slowly, the reading falls as charge 'leaks away' between the plates of the capacitor. The better quality the capacitor, the longer it keeps its energy.
- Measure and record the voltage after three minutes.

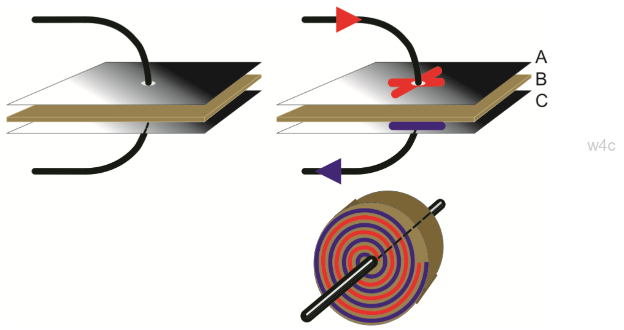
Over to you:

3. Charge it by hand.

- Replace the power supply carrier with the hand-cranked generator.
- Press switch **A** and turn the generator handle. You should see the voltmeter reading rise as the capacitor charges. If it does not, then turn the handle the other way round.
- When the capacitor has charged to around 6V, release the push switch, and stop winding. The capacitor may leak a little internally, but the voltmeter reading stays fairly steady.
- Next, press the same push switch again, but do not touch the generator handle. Notice what happens!

So what?

A capacitor consists of three sheets, A, B and C. Two of these, A and C, are metal plates, usually aluminium. The third, B, is a sheet of insulator, often known as the dielectric, which prevents the metal plates from touching and insulates them.



These plates are usually rolled up into a 'Swiss roll', and covered in a protective casing, with wires connected to each, as shown in the lower diagram.

Normally, the metal sheets are uncharged. When an electric current flows, one plate becomes positively charged, and the other negatively charged. This storage of charge is how the capacitor stores energy.

Using capacitors for storing energy presents two problems:

- they are only practical for storing relatively small amounts of energy;
- they suffer from 'leakage,' which means that they store energy only for a limited time.

For your records:

- Use your readings from part 2 to calculate the percentage of the total voltage lost through leakage in the first three minutes.

Answer all the questions below with clear explanations, but keep them as short as possible.

1. How is energy stored in a capacitor?
2. In what way is a battery different from a charged capacitor?
3. Use the internet to find out as much as you can about the Dinorwig power station, (or a different one that uses pump storage.)
   Present your results to the rest of the class in the form of a display.

Worksheet 6

How much can we store?

w5a

Capacitors are widely used in electronics.

In power supplies, they act as reservoirs of charge and energy, supplying the output when the mains supply falls away

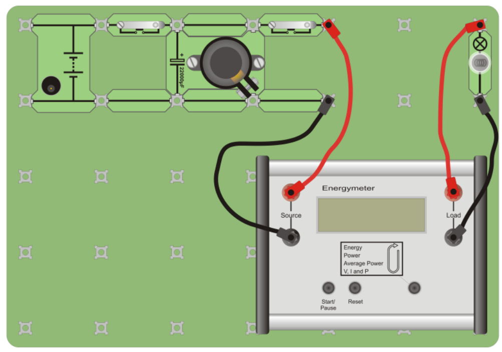
- not so much different from the way we are using them here.

This worksheet looks in more detail at the charging process.

Over to you:

1. A connection between energy stored and voltage?

- Set up the arrangement shown, using a 6V 0.04A bulb.
- The power supply is set it to 3V initially.
- Press push switch **A** to charge the capacitor.
- Reset the Energy Meter, and then press 'Start / Pause'.
- Press push switch **B**, to discharge the capacitor through the bulb. The Energy Meter now measures the energy transferred from the capacitor to the bulb.
- Wait until the energy reading stops changing - the capacitor has now discharged fully.
- Copy the first table.
- Read the energy transferred and record it in the table.
- Now carry out the same procedure, with the power supply set to 4.5V, then 6V, and finally, 9V. Complete the table with your results.



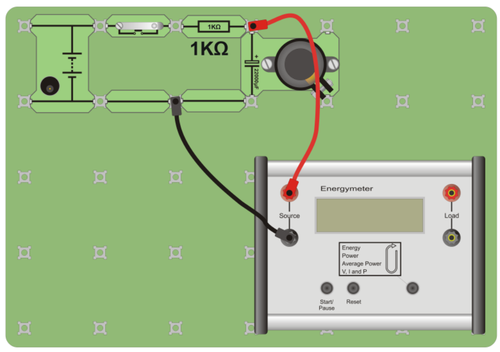
w5b

Capacitor voltage	Energy stored in mJ
3	
4.5	
6	
9	

2. A closer look at the charging process.

To see the charging process in more detail, we will slow it down by connecting a 1kΩ resistor in series with the power supply and the capacitor.

- Build the arrangement shown in the second diagram, with the power supply set to 6V.
- Start timing as you switch on the power supply.
- Record the voltage across the capacitor every fifteen seconds until it is fully charged.
- Copy the second table, and complete it with your readings.



w5c

Time in s	Capacitor voltage
0	0
15	
30	
45	
60	
75	
90	
105	
120	

So what?

Your results for the first investigation should confirm that:

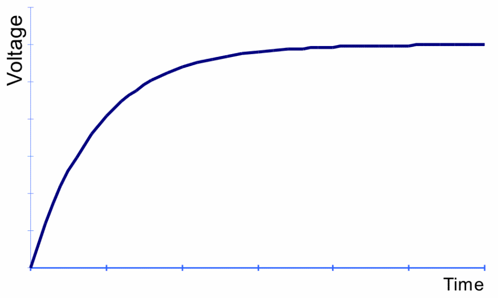
- the bigger the voltage, the greater the energy stored;
- when the voltage is doubled, the energy stored is four times greater.

(To check this second result, remember that the voltage in the third line of the table is double that in the first, and in the fourth line, the voltage is double that in the second line.
Look at the energy stored in each case. You should find that roughly four times as much energy is stored when the voltage is doubled.)

To see what is happening in the second investigation, you need to plot the results as a graph.

Draw a graph with ***voltage*** on the vertical axis, and ***time*** on the horizontal axis.
Mark the voltage axis in one volt steps, up to 7V. Mark the time axis in 15s steps, up to 120s.
Plot your measured points as fine pencil crosses

The shape of the graph is unusual - the voltage rises very quickly to begin with, and then it rises more and more slowly, eventually ending at the voltage of the device used to charge the capacitor.



The diagram opposite gives you the correct shape for this graph. Draw a smooth curve, like the one in the graph, using your measured points as a guide as to where the curve goes. Add labels to your graph, as in the diagram.

Here is a way to picture what is happening. Capacitors are like buckets that store charge.
Imagine trying to fill a bucket with soft fluffy balls. To begin with, it is easy, and you can pour in lots of them with very little effort. As the bucket fills, however, it becomes more difficult. You have to force more in, squashing them in. It takes more and more effort because the balls resist being squashed together. Pushing charge onto a capacitor works in the same way.

For your records:

Copy and complete the following statements:

- The bigger the voltage, the .... the energy stored in the capacitor.
- When the voltage is doubled, the energy stored is .... times greater.
- When the capacitor is charged, the voltage rises .... at first and then creeps up to the voltage of the ....

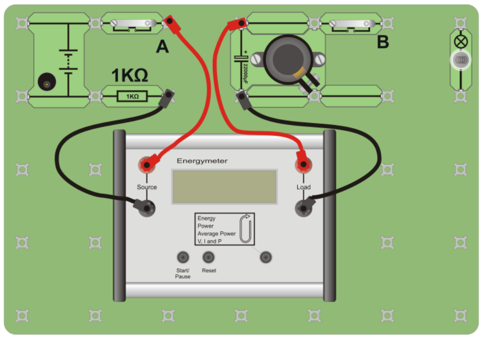
Worksheet 7
Energy storage efficiency

One of the problems with wind power and solar power is that they are neither reliable nor continuous. Because of this, energy storage is a major factor in building a useful national power system based on these forms of renewable energy.

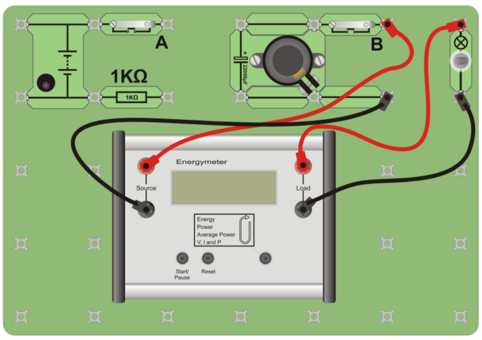
Even when we find a solution to storing energy, we face problems in terms of energy losses involved in the storage process itself.

In fact whenever we process electrical energy, by moving it, or transforming it into a different form, there is an energy loss. Understanding these losses and minimising them is an important part of system design.

Over to you:



- Build the circuit shown in the first diagram.
- Set the power supply to 6V.
- Set the Energy Meter to display energy transferred and time .
- Press the reset button on the Energy Meter and then press ‘Start / Pause’ - there is no energy flow at the moment.
- Press and hold down the push switch **A** .
  The Energy Meter measures the energy flowing from the power supply into the capacitor and the time taken to do so.
- Keep the switch pressed until the energy value stops increasing - the capacitor is now fully charged.
- Make a note of the total energy that has flowed.
- The capacitor will discharge very slowly when you release the switch. Move the Energy meter to the position shown in the second diagram as quickly as you can.
  It is now connected to measure the energy transferred from the capacitor to the bulb. The rest of the circuit is unchanged.



- Reset the energy meter.
- Press and hold down push switch **B**.
- Keep the switch pressed until the energy value displayed is steady - the capacitor is now fully discharged.
- Make a note of the energy that has flowed to the bulb.

Worksheet 7
Energy storage efficiency

So what?

We have already mentioned the use of pump-storage as a means of storing excess electricity. There are other systems - using the excess to compress air, or spin flywheels for example.


iStock_000013787970XSmall

One of the newest storage technologies is known as SMES - superconducting magnetic energy storage. It stores electric energy in the magnetic field generated by electric current flowing through a coiled wire.

If the coil used 'normal' conductors such as copper, the energy would be lost as heat due to the resistance of the coil. However, as the coil is superconducting, it has no resistance. However, it does need to be kept at a very low temperature and so refrigeration is needed.

There are still energy losses, but the overall efficiency can be as high as 97%. At the moment, these systems can store a few million joules of energy, but this is too small for large-scale energy storage.

You used a capacitor to store electrical energy. In worksheet 2, you compared the efficiency of different kinds of light bulb, and used the formula:

Energy efficiency = (useful energy output / total energy input) x 100%

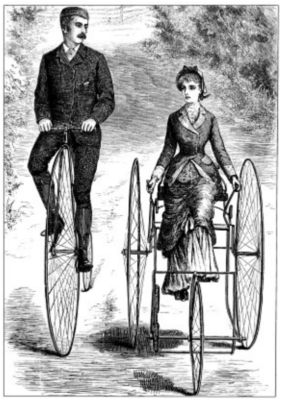
In the case of the capacitor, the total energy input is the energy transferred from the power supply to the capacitor, and the useful energy output is the energy transferred from the capacitor to the bulb.

For your records:

- Use your measurements to calculate the highest efficiency you have achieved for the capacitor energy storage system.
- Find out as much as you can about superconductivity. Produce a short (6 slide maximum,) PowerPoint display to show what you have learned.

Worksheet 8

Investigating energy and power



Earlier, you saw that a low-powered torch bulb uses around one quarter of a watt of power. In twenty seconds, it takes in around five joules of energy.

That's fine, but how much energy do you need to carry out everyday tasks?

You get your energy from the food you eat. How much food do you need to give you that energy?

We are all told to watch our energy consumption, and to reduce our carbon footprint. How much difference would it make to change to a car with a smaller engine? Should we travel by train instead?

In this worksheet you are going to research some of these questions.

Over to you:

This worksheet asks you to find answers to questions about power and energy. One way to find the information you need is to use the internet.

Power consumption:

Copy the table and complete it to show how much power the following items consume. Then calculate the equivalent in 'torchpowers' for each

Item	Power generated or consumed	Equivalent in 'torchpower'
A torch	250mW	1
A traditional (filament) room light bulb		
A 'low energy' room light bulb		
A cyclist at full speed		
A central heating boiler		
A horse galloping (i.e. 1 horse-power)		
A Ferrari (at maximum)		

Power generation:

Next, find out, from the internet or some other source, how much power is used by your country, and how much is generated by the each of the following types of power station. Copy the table and complete it with your findings.

Type	Typical output power in W	How many needed to power whole country
Hand-cranked generator		
Wind turbine		
Coal-fired power station		
Gas-fired power station		
Nuclear power station		
Micro hydro system		
Hydroelectric power station		

Worksheet 8
Investigating energy and power

locktronics

So what?

Energy and power are related, but different, as we have seen. Power is energy transferred in one second. At home, it may be fine to switch on a 100W lamp while you are in the room, but leaving it on when the room is empty wastes 100J of energy every second.

How should we travel?

A litre of petrol releases about 35 mega joules (MJ) of energy in a car engine. Unfortunately, cars have a low energy efficiency, less than 20%, so only ~7MJ of each litre goes into moving the car. A car that averages 30 miles per gallon (= 9.5 litres/100km), needs 0.095 litres to travel one kilometre. If it carries two people, this converts to roughly 1.7MJ per person per kilometre.

For all forms of transport, there are many factors to consider:

- How many people are aboard?
- How quickly do they need to get there?
- Is the route congested, so that the vehicle will queue for long periods?
- Is the power plant well-maintained?

As a result, the data given below is only approximate.

- A train can achieve ~1.9MJ per passenger per kilometre.
- A bus can achieve ~0.3MJ per passenger per kilometre.
- An aircraft can achieve ~1.4MJ per passenger per kilometre

The QE2 passenger liner does ~15 metres to the gallon, but it can carry over 1700 passengers!

What about carbon dioxide (CO_2)?

Energy economy is one thing, but we are also urged to reduce the quantity of CO_2 we release through our activities. The journey from London to Edinburgh is around 650km long. The table shows how much CO_2 would be released by different modes of transport for this journey.

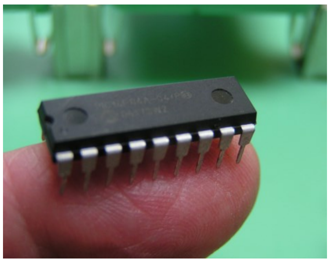
Mode	Kg of CO_2 per passenger
Car	71
Bus	10
Train	12
Aircraft	96

For your records:

1. Explain what is meant by the terms (a) carbon footprint and (b) carbon offset.
2. Find the equivalent petrol consumption in either miles per gallon, or litres per 100km for: (a) walking and (b) cycling.
3. How many joules of energy does 1calorie (really 1 kilocalorie) give you?
4. The recommended daily intake of energy for an active adult male is around 3000 calories. How far would he have to walk to 'burn off' this energy?
5. How much energy does your country 'use' in one year?
6. EU Countries aim to generate 15% of their energy needs from renewable sources by 2020. How many wind generators would it take to do this for your country?

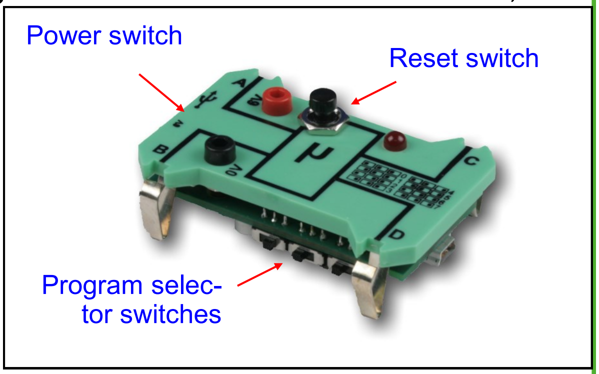
Worksheets 9 - 11

Using technology to save energy



In worksheet 2 you saw that new technology lighting components can be used to save a considerable amount of energy. If we are to further reduce our reliance on fossil fuels then we need to look at other ways of energy conservation. Using advanced control technology presents lots of opportunities as you will see here. The principle technology used here is a small computer or microcontroller. Microcontrollers are everywhere - microwave ovens, cars, remote controls, mobile phones, TVs, DVD players, printers, camcorders, washing machines etc. In reality, any device that interacts with the user has one buried inside.

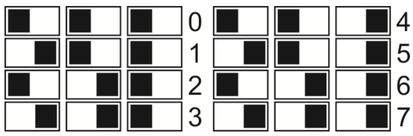
A microcontroller is a computer on a single chip, designed to control devices attached to it, guided by signals it receives from sensors and governed by a program stored in its memory.



The Locktronics kit includes a PIC microcontroller carrier, which can house up to eight programs. It runs on a 6V supply. For this module, it has been programmed to deliver a variety of control functions, depending on the program selected with the selector switches.

The selector switches:

Programs are chosen by moving the selector switches to the position shown on top of the PIC carrier, and in the diagram opposite.



Over to you:

We live in the world of the smart home, and smart office. Increasingly, electronics is being used to improve the way we live and work and to save energy. The next worksheets look at control system used to save energy in the home or at work. Each uses the PIC microcontroller to make decisions about when to use energy, and how much to use.

For your records:

For each worksheet:

- describe the task that the control system is carrying out;
- describe the tests that you perform and the results;
- think of a different situation where the control system could be used, and describe it.

Worksheet 9

Solar heating controller

Solar water heaters are a popular way of providing domestic hot water. Using them saves gas and electricity.

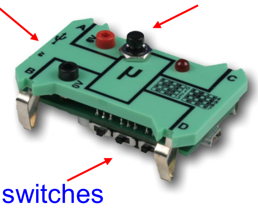
Usually sited on the house roof, they allow the sun to heat up the water inside them. This is pumped through a coiled pipe inside the hot water storage tank, heating up the water inside it. Usually, this supplements heating provided by gas or electricity.

However, we don't want hot water from the tank to be pumped through a cold solar panel on a night. It would cool down - not the idea at all. We want the pump to operate only when water in the solar panel is hotter than that in the hot tank. We need a control system.

Over to you:

This control system takes in the signals from two thermistors. One measures the temperature of the water in the hot water tank, and the other measures the temperature in the solar panel.

When the water in the panel is hotter than that in the tank, the system should turn on the pump so that the water in the tank gets hotter. Conversely when the water is hotter in the tank, the system should turn off the pump.

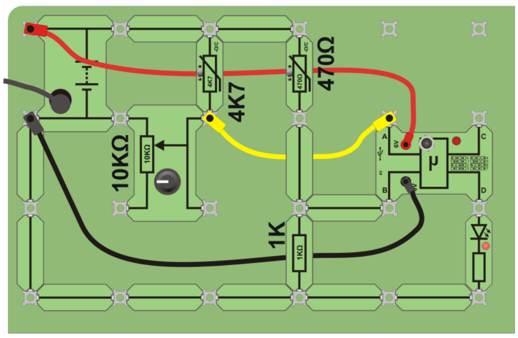


- Use the selector switches to select program 0.
- Set up the circuit, shown in the picture, with the DC power supply set to 6V. The LED represents the water pump. A variable resistor is included to allow fine adjustment.
- Press the reset button. Adjust the 'pot' so that the LED is only just turned off.
- Warm the thermistor connected to input **A** between your fingers. The LED should turn on.
  You have just created the situation where the water in the solar panel is hotter than that in the hot tank, and so the pump has turned on.
- Let the thermistor cool down again.
  The LED eventually turns off. In the real system, the water in the hot tank is now hotter than that in the solar panel.
  Perhaps it is night-time, or perhaps it is not a very sunny day.

PIC checklist

When using the PIC make sure that:

- the power switch is in the '6V' position;
- the selector switches are in the correct position;
- the LED on the PIC flashes three times on pressing the reset switch and then stays lit;
- your power supply is set to 6V
- you have connected the PIC +6V and 0V wires to each side of the battery terminals.



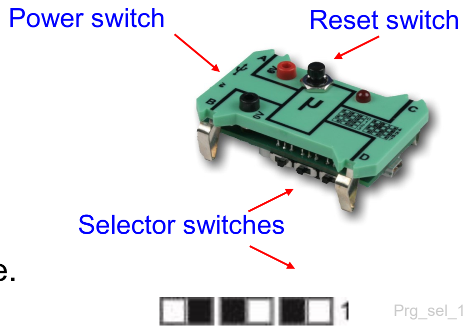
Worksheet 10
Lighting controller

An outside light helps you find your way around in the dark. It also warns when someone is prowling around outside.

Ideally, it operates only when it is dark, but does so automatically. It would waste energy if it ran all day.

The control system is similar to the one you used for controlling temperature. Instead of checking when a room is cold, the system checks when the light-level is low enough that the light should operate.

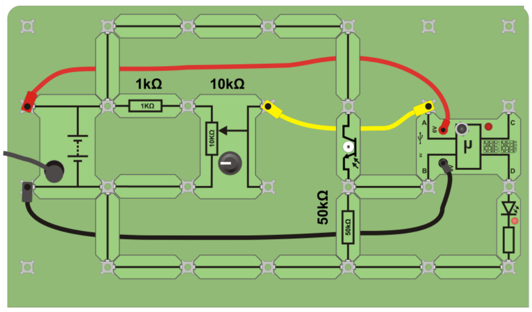
Over to you:



- Select program 1 on the Locktronics microcontroller.
- Set up the circuit, shown in the picture, with the DC power supply set to 6V.
- The thermistor used in the last worksheet is replaced by a light sensor, (phototransistor), shown in the second picture. It is part of a voltage divider with a 50kΩ resistor.
- Make sure you connect the phototransistor the right way around.
- The 'pot' is used to set the light-level at which the lamp operates.
- Press the reset button. The microcontroller now behaves as a light-activated switch.
- Test it as follows:
    - Turn the knob on the 'pot'. The lamp should turn on and off as you do so.
    - Turn it until the lamp is only just turned off.
    - Pass your hand over the light sensor to simulate darkness. The lamp should turn on.
    - Try other 'pot' settings. Notice that this changes the sensitivity of the system, meaning that it turns on at different light levels.

PIC checklist

When using the PIC make sure that:
- the power switch is in the '6V' position;
- the selector switches are in the correct position;
- the LED on the PIC flashes three times on pressing the reset switch and then stays lit;
- your power supply is set to 6V
- you have connected the PIC +6V and 0V wires to each side of the battery terminals.



Worksheet 11

Intelligent lighting systems

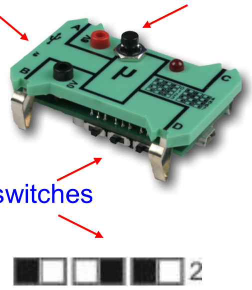
Using energy efficiently and in an environmentally friendly way is a major theme of most societies. Increasingly buildings are designed intelligently to minimise the amount of energy we use.

Here is an example. It is likely that the lights in your school are on even when no one is there. What a waste!

By using simple sensors and a microcontroller, we can control the lighting systems efficiently yet safely.

In this way we can make gy we do have to generate goes further.

Over to you:



This system has two sensors sensor: it consists of a light beam and light sensor, placed across a corridor, as well as a background light sensor.

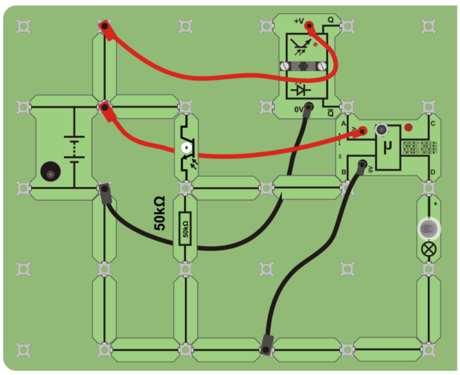
When the light beam is interrupted by someone walking past, the control system turns on the light, but only if it is dark.

- Select program 2 on the Locktronics microcontroller.
- Set up the circuit, shown in the picture, with the DC power supply set to 6V. Use the white LED bulb - note the polarity.
- Position the optoswitch so that it is easy to slide a piece of card into the slot to trigger the switch.
- Press the reset button.
  The microcontroller now controls the room lighting..
- Test it as follows:
  - cover the light sensor;
  - slide a card into the slot of the optoswitch
    and then remove it. The output of the microcontroller should go high and the LED, representing the
    corridor lights, should go on, for ten seconds and then go off.
- Make an estimate of:
  - the number of lights in your school;
  - the energy they consume in one year;
  - how much of the time the lights need to be on;
  - and finally, how much energy your school could save by adopting a control system like this.

PIC checklist

When using the PIC make sure that:

- the power switch is in the '6V' position;
- the selector switches are in the correct position;
- the LED on the PIC flashes three times on pressing the reset switch and then stays lit;
- your power supply is set to 6V
- you have connected the PIC +6V and 0V wires to each side of the battery terminals.



About this course

Introduction

The course is essentially a practical one. Locktronics equipment makes it simple and quick to construct and investigate electrical circuits. The end result can look exactly like the circuit diagram, thanks to the symbols printed on each component carrier.

Aim

The course raises issues about energy resources and consumption. It does so through a series of practical experiments which allow students to unify theoretical work with practical skills.

Prior Knowledge

It is recommended that students have followed the 'Electricity Matters 1' and 'Electricity Matters 2' courses, or have equivalent knowledge and experience of building simple circuits, and using multimeters.

Learning Objectives

On successful completion of this course the student will be able to:

- use an Energy meter to monitor energy and power consumption, and voltage and current in a device;
- distinguish between the terms 'energy' and 'power', and 'voltage' and 'current'.
- recall the units used to measure energy, power, voltage and current;
- recall that the prefix 'milli' means one-thousandth;
- explain the meaning of energy efficiency;
- perform calculations using formulae for power, energy and efficiency;
- name three alternative energy sources, and give a disadvantage for each as a reliable source of energy;
- explain the need for bulk energy storage in the electricity grid;
- describe how coal, oil and gas formed in the Earth;
- describe two factors that affect the output of a photovoltaic cell;
- list three ways in which turbines can be turned to generate electricity;
- explain the meaning of the term 'global warming';
- give two disadvantages of using wind power as a major source of electricity generation;
- outline the change in the preferred energy source used to generate electricity over the last seventy years;
- explain the fundamentals of and rationale behind 'pump storage';
- store electricity in a capacitor, and demonstrate that energy is stored in it;
- distinguish between energy storage in a capacitor and in a battery;
- relate the energy stored in a capacitor to the voltage across it;
- list four factors that affect efficient energy utilisation in transport systems;
- explain the terms *carbon footprint* and *carbon offset*;
- describe three situations where a microcontroller can improve the efficiency of energy use;
- devise experimental investigations based on the principle of a fair test.

Teacher’s guide

What the student will need:

To complete the Energy and the Environment course, the student will need the equipment shown in the table.

Power source:

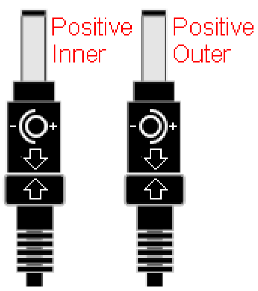
The investigations in this module require a DC power source.

The HP2666 is an adjustable ‘plug-top’ DC power supply offering output voltages of either 3V, 4.5V, 6V, 7.5V, 9V or 12V, with currents typically up to 1A.

This plugs into a LK8275 carrier (with a battery symbol printed on it.) The voltage is changed by turning the selector dial just above the earth pin until the arrow points to the required voltage. (The teacher may decide to make any adjustment necessary to the power supply voltage, or may allow students to make those changes.)

The Energy meter requires a 9V supply. This is supplied by a second HP2666 power supply with the output dial set to 9V. The connector on the lead of the HP2666 should be set to that the 2.1mm power jack has a positive inner voltage. Use connector type D. “**D**” is marked on one side, down by the pins, and “**5.0x2.1**” is marked on the other side.

Qty	Code	Description
1	HP4039	Clip on lid
2	HP2666	Adjustable power supply
1	HP5540	Deep tray
1	HP7750	Daughter tray foam insert
1	HP8766	Power supply for Energy meter
1	HP9564	62mm daughter tray
1	HP8600	Crash foam
1	LK6841	MES bulb, 12V, white LED
1	LK2347	MES bulb, 6V, 0.04A
1	LK2350	MES bulb, 6.5V, 0.3A
1	LK3662	Capacitor, 22,000uF, Electrolytic 16V
1	LK4000	Locktronics User Guide
1	LK4690L	USB reprogrammable PIC carrier with power leads
1	LK4893	Hand cranked generator
1	LK7290	Phototransistor
1	LK5202	Resistor - 1K, 1/4W, 5% (DIN)
1	LK6231	Resistor - 50K, 1/4W, 5% (DIN)
1	LK5214	Potentiometer, 10K (DIN)
15	LK5250	Connecting Link
1	LK5287	Automotive lampholder
2	LK5291	Lampholder
2	LK5401	Thermistor, 470 ohm, NTC (DIN)
2	LK5603	Lead - red - 500mm, 4mm to 4mm stackable
2	LK5604	Lead - black - 500mm, 4mm to 4mm stackable
1	LK5607	Lead - yellow - 500mm, 4mm to 4mm stackable
2	LK6207	Switch Press (morse key-type strip, push to make)
1	LK6492	Curriculum CD ROM
1	LK6635	LED- red, 5V (SB)
1	LK6707L	Slotted Opto Switch Carrier with Leads
1	LK7746	Solar cell
1	LK8275	Power supply carrier with battery symbol
1	LK8591	Energy Meter
1	LK8900	7 x 5 baseboard with 4mm pillars



Using this course:

It is expected that the series of experiments given in this course is integrated with teaching or small group tutorials which introduce the theory behind the practical work, and reinforce it with written examples, assignments and calculations.

The worksheets should be printed / photocopied / laminated, preferably in colour, for the students' use. Students should be encouraged to make their own notes, and copy the results tables and sections marked 'For your records' for themselves. They are unlikely to need their own permanent copy of each worksheet.

Each worksheet has:

- an introduction to the topic under investigation;
- step-by-step instructions for the investigation that follows;
- a section headed 'So What', which aims to collate and summarise the results, and offer some extension work. It aims to encourage development of ideas, through collaboration with partners and with the instructor.
- a section headed 'For your records', which can be copied and completed in students' exercise books.

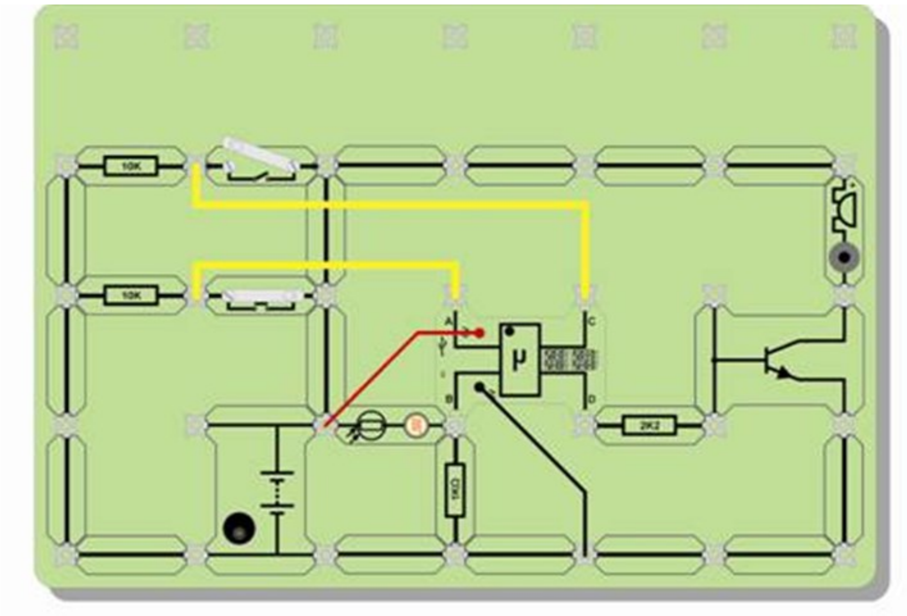
This format encourages self-study, with students working at a rate that suits their ability. It is for the instructor to monitor that students' understanding is keeping pace with their progress through the worksheets. One way to do this is to 'sign off' each worksheet, as a student completes it, and in the process have a brief chat with the student to assess grasp of the ideas involved in the exercises it contains.

Time:

It will take students between seven and nine hours to complete the investigations.
It is expected that a similar length of time will be needed to support the learning that takes place as a result.

Using the PIC microcontroller carrier:

The image shows how the PIC chip is powered.



PIC checklist

When using the PIC make sure that:

- the power switch is in the '6V' position;
- the selector switches are in the correct position;
- the LED on the PIC flashes three times on pressing the reset switch and then stays lit;
- your power supply is set to 6V
- you have connected the PIC +6V and 0V wires to each side of the battery terminals.

When introducing students to the equipment you will need to show them how to connect power to the PIC. The worksheets include a small checklist as shown above. If your students have trouble getting their programs working, then please run through this checklist first.

If you are an expert then you might like to know:

The Locktronics PIC microcontroller carrier has the following pin connections:

Locktronics Carrier Contact	Microcontroller Pin	Generic I/O	ADC Input	PWM Output
A	RA0	Y	Channel 0	N
B	RA1	Y	Channel 1	N
C	RC1	Y	N	Channel 1
D	RC2	Y	N	Channel 2

The three program selector switches are connected to pins RB0—RB2.

The LED onboard the carrier is connected to pin RA4. For all of the programs shipped with the LK4690 programmable PIC carrier RA4 flashes three times in succession on power up and then stays illuminated to indicate that power is supplied.

The USB cable detection pin is connected to pin RA5.

Worksheet	Notes for the Instructor	Timing
1	We start off with a look at a very powerful instrument, the Energy Meter. It offers the ability to measure the energy transferred to a device over a timed period, to measure the power and average power delivered to the device, and to measure the voltage across and current through the device. The students are shown how to use the various ranges on offer, first of all using a 6V 40mA bulb as a target, and then measuring the output of the hand-cranked generator. They are given thumbnail definitions of the quantities involved, though most teachers will supplement these with more detailed descriptions. They are given the names of the units used to measure these quantities - a common source of confusion. Similarly misunderstood are the prefixes. The treatment here is limited to 'milli' but the teacher might wish to extend it to 'kilo' at least, and possibly 'mega' and 'micro'. The important thing at this stage is that they can set up the meter to read the various quantities. The teacher should expand on the meaning and significance of these quantities and offer examples of energy transfer, for example, to support the work here.	20 - 30 mins
2	This worksheet gives further practice in using the Energy Meter. In addition, it aims to give students a grasp of the size of some of the units involved. Although the formula linking electrical power to current and voltage (P = I x V) is not mentioned, teachers may wish to introduce it here. Using a crude measure for light output - apparent brightness - the idea of energy efficiency is introduced. Three different bulbs, two incandescent and one a LED, are set up to produce the same brightness. The Energy Meter is used to compare their energy inputs, and that information is used to arrive at statements about their efficiency. Some students will notice that the 6V setting on the power supply can actually result in more than 6V. However, this has no effect on the outcome of the investigation. They can be praised for their powers of observation! Students record not only the power delivered to the bulbs, but also the energy delivered in a period of twenty seconds. Teachers can use these measurements to drive home the relationship between energy and power. The worksheet gives some information about how filament lamps produce light by heating the filament of resistance wire to a high temperature. The mechanism by which semiconducting crystals release light is much more complex, and irrelevant to the course. However, the teacher might wish to show examples of domestic LED lamps, or automotive lamps, or could draw the students' attention to the increasing use of LED displays in, for example, television sets and traffic lights. The worksheet ends with some practice in applying the efficiency formula, and in an exercise to estimate how much energy a household could save by using LED lights. (In general, students dislike the idea of estimating. They liken it to guessing, and regard it as unscientific. In reality, it is a vital and valid part of engineering and commerce. They should be encouraged to make clear what assumptions they are making.	30 - 40 mins

Worksheet	Notes for the Instructor	Timing
3	The topic is electricity generation using solar power. It could be the subject of a complete course! The aim here is to offer enough explanation for the student to make sense of the increasing use of photovoltaic (PV) solar power, and to show that it is not the reserve of equatorial countries only. They are encouraged to explore the factors that affect the output of the solar cell. The teacher might wish to extend this to issues like the time of day, or season, or prevailing weather. The class could set up long-term projects using some kind of datalogger to monitor the output of the solar cell over an extended period. There is plenty of material available on websites about the benefits and drawbacks of PV solar power. Some parents may already be using as a form of 'microgeneration' at home. Several governments offer financial incentives to do so. This could be the target of further research by the class, resulting, perhaps, in a display of the findings. Finally, students are directed to the Internet to research answers to a number of questions. Teachers may prefer to set this as homework. The final question aims to test the student's awareness of a fair test in science.	30 - 40 mins
4	The topic is electricity generation from alternative resources. (There is a distinction between 'alternative resources' and 'renewable resources' that the teacher may wish to explore. It could be the subject of a complete course! The aim here is to offer enough explanation for the student to make sense of one alternative form of electricity generation - wind power. Depending on their background, students may need a fuller treatment of electromagnetic induction and its application to electricity generation in the alternator. Students generally confuse turbines and alternators. Teachers should ensure that the distinction is clarified. The argument here is that the generation principle is the same, but the difference is in how the alternator is driven. In conventional stations, oil, gas or coal is burned to generate high-pressure steam which rushes through the turbines, forcing them to rotate. Nuclear power does the same thing, without involving burning. Huge quantities of heat energy are released when the nuclei of large elements, like uranium, break into smaller fragments. Geothermal energy sources may extract the high-pressure steam directly from the ground. In wind, tidal, wave and hydroelectric stations, the alternators are forced to rotate by other means, but the outcome is the same. Here, the process is simulated by a hand-cranked generator. In real life, the alternator could be turned by a turbine driven by steam, or by some other means. The output is measured using the Energy Meter. On the second page of the worksheet, some statistics show the changes that have taken place in the way we generate electricity. Where appropriate, this is a topic that the teacher can expand in great detail. Finally, students are directed to the Internet to research answers to a number of questions. Teachers may prefer to set this as homework.	30 - 40 mins

Worksheet	Notes for the Instructor	Timing
5	Life would be so much easier if only we could store energy on a large scale! Our demand for electricity depends on the weather, time of day, day of the week and lifestyle factors like what is on television. Unfortunately, conventional and nuclear power stations cannot be switched on and off like light bulbs. They take many hours to bring up to full output, and many hours to turn off. A whole industry has built up to match electricity supply and demand. One solution uses surplus electricity to pump water up hill. Later, when demand rises, that water can be allowed to fall back down, through turbines to generate 'extra' electricity to try to satisfy demand. That is the basis of 'pumped storage' power stations. However, such sophistication comes at a high price in terms of initial construction costs and the inefficiencies involved in running the system. Pumped storage systems do not lend themselves to hands-on investigations. Instead, students are introduced to small scale energy storage, using capacitors. This initial investigation of capacitors covers the storage of energy, leakage and the use of alternative sources to charge the capacitor. In terms of energy storage, the charged capacitor is used to power a LED, and in doing so the students can see the voltage across the capacitor fall as it loses energy. Leakage is demonstrated briefly, and the link between 'quality' of capacitor and leakage is mentioned but not explored. The hand-cranked generator is used to charge the capacitor, and the students witness its dual role as motor as well as generator when they press the switch again after the capacitor is charged. Some details about the structure of a capacitor are given. The teacher may wish to expand on this, and discuss the significance of the area of the plates and the thickness of the dielectric. Again, students are directed to the Internet to research answers to a number of questions. Another possible homework exercise!	30 - 40 mins
6	This worksheet looks in more detail at energy storage in capacitors. While it may be more common to use rechargeable batteries as small-scale energy supplies, much of the principle is identical, and the process involved is similar. The charging process for batteries is less efficient, and so less obvious when such small amounts of energy are involved. Even with a capacitor, the efficiency of the charging process is low, 50% at maximum. This is not mentioned, in the interests of simplicity. Where students question this, the teacher may want to be armed with an answer. To begin with, students look for a relationship between the voltage across the capacitor and the amount of energy stored. The Energy meter measures the energy transferred to a bulb. In one case, the voltage delivered is higher than the rated voltage of the bulb, but nothing untoward happens, as the voltage soon drops. In reality, the bulb is simply a resistor, but it is a bit more visual! The energy stored can be shown to depend on the voltage squared, but all that is expected of students here is that they recognise that the bigger the voltage the greater the energy stored. Students go on to look at how the voltage across the capacitor changes with time during the charging process. It may be beneficial to have them working in pairs for this so that one can record the readings while the other calls them out. The resulting graph is an exponential growth curve, though again, this is not discussed. It gives an opportunity for students to hone their graph-plotting skills. For their records, they complete some statements about their findings.	30 - 40 mins

Worksheet	Notes for the Instructor	Timing
7	The general aim here is to show that all forms of energy storage come with an energy cost. In this case, students measure the efficiency of an energy storage system using a capacitor. There are two parts to the investigation. In the first, students measure how much energy is needed to charge up the capacitor. In the second, they measure how much energy is transferred to the bulb. If the storage were perfect, i.e. 100% efficient, these quantities would be the same. Students should be urged to move from one part to the other as quickly as possible, without sacrificing care. The reason is that the capacitor will 'leak' charge between its plates while they are making the modifications to the circuit. This will actually make the energy loss greater. The teacher should take care to ensure that the electrolytic capacitor is connected correctly, as it can be damaged, and give off fumes, if connected the wrong way round. Similarly, while encouraging the students to press on at speed, it is important that the Energy Meter is connected the right way round in the second stage. The worksheet goes on to outline several techniques used for the large-scale storage of electricity. Some use advanced technology and concepts like superconductivity. The students are given the task of finding out what they can about this. There is scope for an open-ended, and perhaps co-operative investigation into the effect of the series resistance on efficiency.	30 - 40 mins
8	This is a research activity which aims to reinforce ideas developed in the course. It links to topics like diet and nutrition, and to ethical transport issues as well as to electricity generation. There are no right answers to most of the questions. Students should be encouraged to discuss their answers, most of which are estimates, and should be seen as that. The internet is a rich source of information on these topics, and the task may be seen as a filtering exercise, as some of these topics will generate thousands of 'hits' on the browser. Students should be encouraged to be selective, and to interpret and re-write what they find in their own words.	15 mins

Worksheet	Notes for the Instructor	Timing
9 - 11	The following worksheets look at how microcontrollers can control our use of energy. Students may want to know more about these devices. The debate should probably start with computers. At their heart is the microprocessor, the 'brains' that control the flow of information, and process data following instructions in a program. Students may well be aware that computers require memory - ROM and RAM - the former used in part to store a program, the latter to run it, and to allow the microprocessor to store the results of calculations. Ultimately, computers take information from the outside world, via the keyboard and mouse, and return results to the outside world via monitor, printer etc. The microcontroller is a slimmed-down version of the same. It is designed to control output devices using information gleaned from sensors attached to its inputs. It follows instructions given as a program. It has some memory, not much but enough for the tasks it is designed to do. It is slower than a microprocessor, but that is not a problem, as it works faster then the mechanical output devices it operates. Above all, it is physically small, a single chip solution, and cheap. As a result, they are everywhere. A car with even a standard specification probably contains dozens of them, controlling the ABS, engine management, electric windows, headlamps etc. A list of common uses for these devices is given in the worksheet. The 'Locktronics' PIC component comes with programs already stored in memory. Three selector switches decide which of these runs, when the reset switch is pressed. Students should be shown how to select and initiate a program. Full instructions on what to build and how to test each program are given in the following worksheets.	15 mins
9	The microprocessor does not care how the signals at its inputs are generated. For this exercise, they come from two temperature-sensing units. Solar collectors are increasingly common. The idea is that water is pumped through the solar collector to be heated up. It then flows through a heat exchanger, coiled pipe inside the hot water storage tank to heat up the domestic hot water inside it. A control system is needed because the hot tank also contains a secondary form of heating, often an electrical immersion heater, which is used when there is a high demand for hot water, or when the sun is not shining strongly enough. We don't want water heated, expensively, by the supplementary heater to circulate through a cold solar collector. That is where the control system is important. It turns off the water pump when the temperature in the hot tank is greater than that in the solar collector. The program 'switches on' the output when the voltage from one temperature-sensing unit - the solar collector - is bigger than that from the other in the hot tank.	

Worksheet	Notes for the Instructor	Timing
10	The same program is used again. The voltages at the inputs are generated in a different way. This time, a phototransistor is used in a light-sensing unit to convey information about the light level outside the building to the control system. A threshold voltage is set on the 'pot'. When the latter is bigger, which means that it is getting dark, the microcontroller outputs a high voltage, which we use to turn on a lamp. The circuit uses a LED as the output device, but a higher power bulb, and a higher voltage, could be used if the microcontroller output drives a relay. Again, teachers have the option of highlighting this use, and giving examples of circuits that use relays to run devices at different supply voltages, or not. Either route works. It depends on what learning outcomes are chosen for the course.	20 - 35 mins
11	This system switches on the lights only when it is dark AND someone is present. The program has a built-in delay which keeps the lights on for ten seconds. In a real system, that delay could be longer, or the system could wait until everyone had left before switching off the lights. The circuit uses a LED to represent the corridor/classroom lights. As in the last example, the microcontroller could operate a relay, allowing more powerful output devices to be controlled. All we are doing here is exploring the principle of the control system.	

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