Energy and Electricity
National 5 Physics

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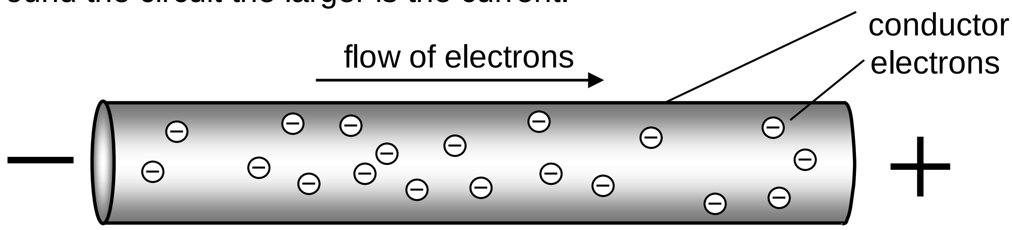
Electrical charge carriers and electric fields

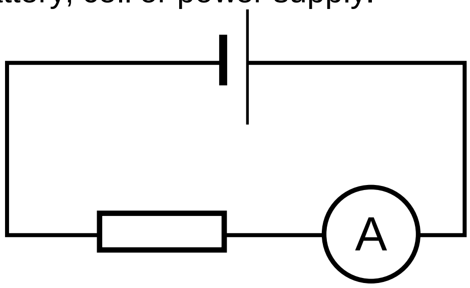
Electric charge

Electric charge is either positive or negative. Negative charge is made up of electrons and it is electrons which flow through a conductor when a current flows. In a conductor, there are electrons free to move. The more charge flows around the circuit the larger is the current.



Like charges (positive and positive or negative and negative) repel one another. Unlike charges (positive and negative) attract one another. Electrons flow from the negative terminal to the positive terminal. The potential difference or voltage which causes the flow of electrons is usually provided by a battery, cell or power supply.

The current in a circuit is a measure of the rate of flow of charge through it. Ammeters are always placed in series or in line with a component. It does not matter if the ammeter is before or after the component—the current is the same.



The charge flowing in a circuit can be calculated using the formula below.

$$\text{charge} = \text{current} \times \text{time} \qquad Q = I\,t$$

where Q = charge measured in coulombs (C)
I = current measured in amperes (A)
t = time measured in seconds (s)

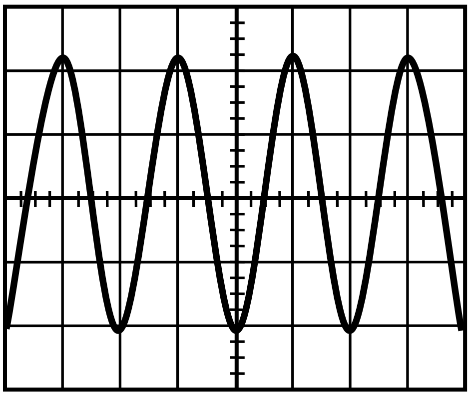
Worked example

A charge of 20 C passes through a circuit in 5 seconds. Calculate the current in the circuit.

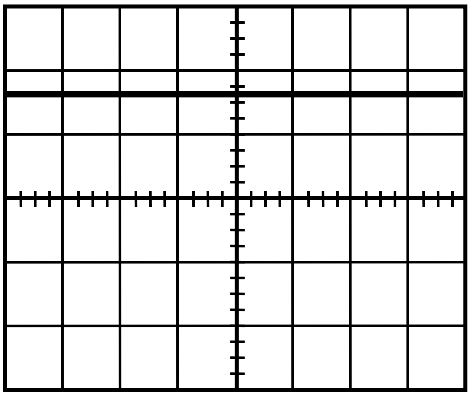
$$\text{charge} = \text{current} \times \text{time}$$
$$Q = I\,t$$
$$20 = I \times 5$$
$$I = \frac{20}{5}$$
$$= \underline{\underline{4\ \text{A}}}$$

Current can be either direct current (d.c.) or alternating current (a.c.). A d.c. supply has one continuous, steady current flowing in one direction only. In an a.c. supply the current constantly changes its value and changes direction flowing first one way then the other. The oscilloscope traces below what would be seen if connected to each type.

An a.c. supply



A d.c. supply



A d.c. supply would be from a cell or battery. An a.c. supply would be from a mains socket. Mains electricity is at a voltage of 230 V and a frequency of 50 Hz.

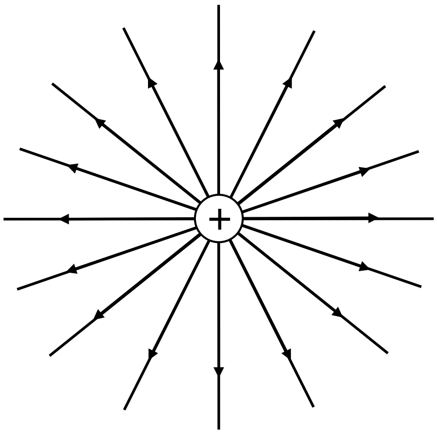
Electric Fields

Around any charged object there is an electric field or area in which an electric charge will experience a force. Electric fields are invisible but can be made visible using simple techniques.

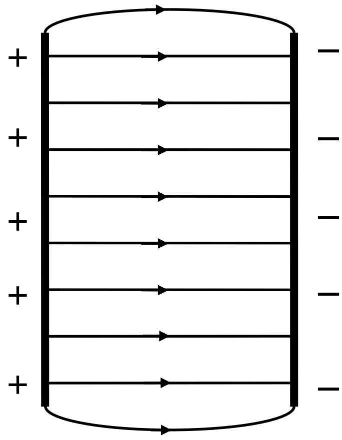
An electrode at a high voltage can be placed in a dish of oil. Sprinkling the oil surface with semolina powder or grass seeds will make the field lines visible. These line up along the electric field lines so making them visible.

The diagrams below show the shape of two electric fields. The spacing of the field lines indicates the strength of the field—where the lines are closer together the field is stronger.

Electric field around a positive charge



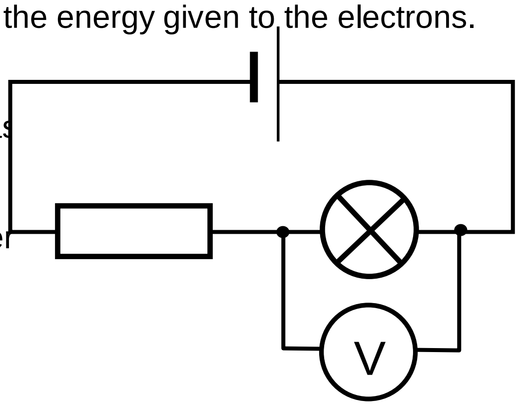
Electric field between two parallel plates



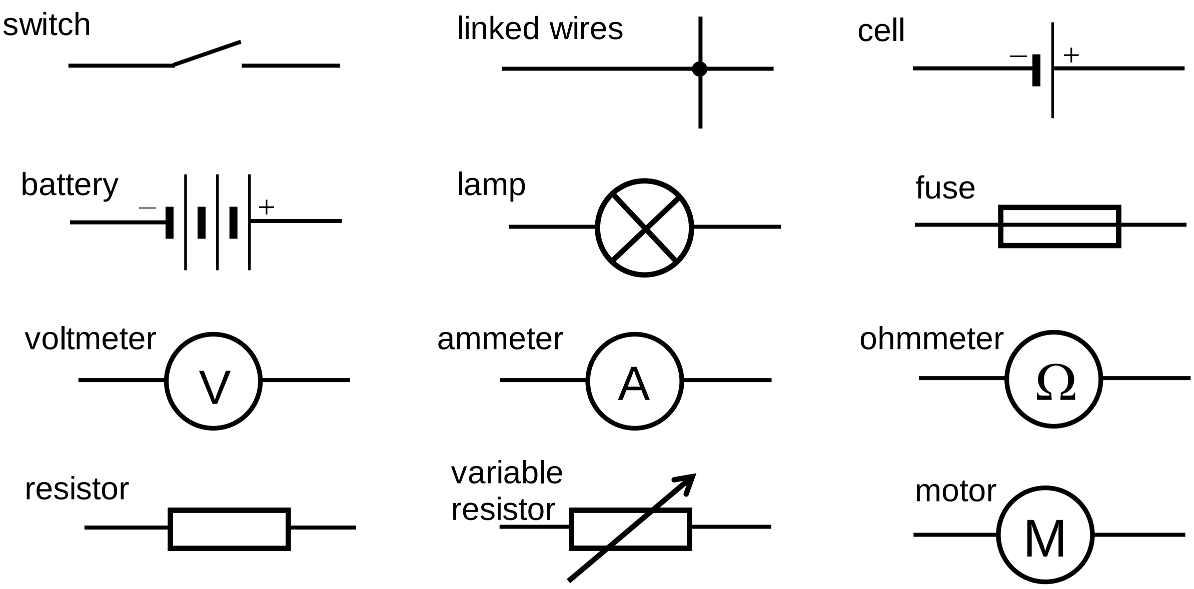
The field lines always point in the direction in which a positive charge would move.

Potential difference (voltage)
The energy for electrons to flow around a circuit comes from a voltage or potential difference provided by a power supply. Electrons will flow towards the positive connection of the power supply and away from the negative connection. The size of the potential difference or voltage is a measure of the energy given to the electrons.

Electrons loose energy as they flow through a component – it is changed into other forms such as heat or light. The energy lost by the charge (the voltage) is measured by connecting a voltmeter across either side of the component. The voltmeter in the circuit opposite will measure the voltage across the lamp.

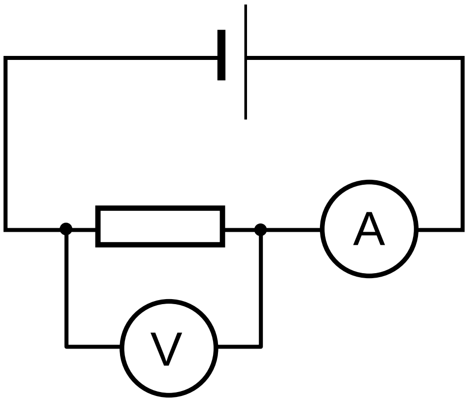


Circuits and Ohm's Law
Symbols are used to represent components in electrical circuits. Some of these are shown below.



The resistance of an electrical circuit can be investigated using a voltmeter and ammeter. They are connected as shown in the circuit below.

The voltage across the resistor and the current through it are measured for a range of voltages. The value of the resistor is the voltage divided by the current.



i.e. $\frac{V}{I}$ will give a constant value equivalent to the resistance of the circuit.

Thus voltage, current and resistance are related in the following formula:

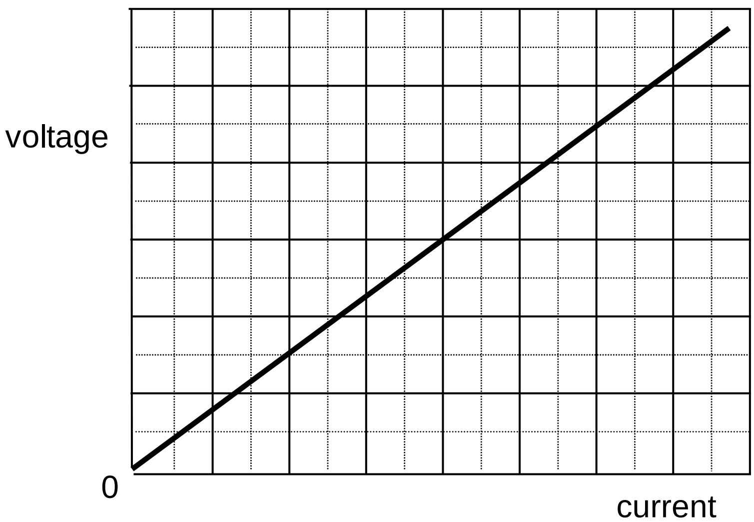
$$\text{voltage} = \text{current} \times \text{resistance} \qquad V = IR$$

where V = voltage measured in volts (V)
I = current measured in amperes (A)
R = resistance measured in ohms (Ω)

Worked example
A 12 V supply is connected to lamp which draws a current of 0·5 A. Calculate the resistance of the lamp.

$$\begin{aligned} \text{voltage} &= \text{current} \times \text{resistance} \\ V &= IR \\ 12 &= 0 \cdot 5 \times R \\ R &= \frac{12}{0 \cdot 5} \\ &= \underline{\underline{24\,\Omega}} \end{aligned}$$

If a graph of voltage against current is plotted, it will be a straight line through the origin. This is because the current is directly proportional to the voltage for a fixed resistance. Doubling the voltage across a resistor will double the current flowing through it.



An ohmmeter can also be used to measure the resistance of a resistor directly but it must be disconnected from any circuit before this can be done.

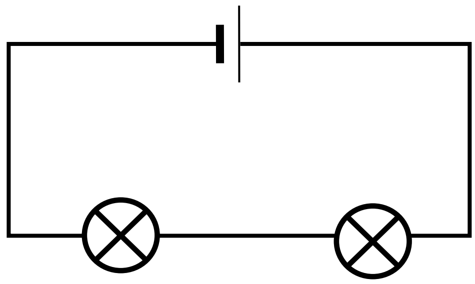
The resistance of a length of wire will depend upon several factors. The size of the resistance will depend upon:

- what material the wire is made from;
- the length of the wire—the longer it is the more its resistance;
- its cross sectional area (thickness)—the thinner the wire the more its resistance;
- its temperature—the hotter the wire the higher its resistance.

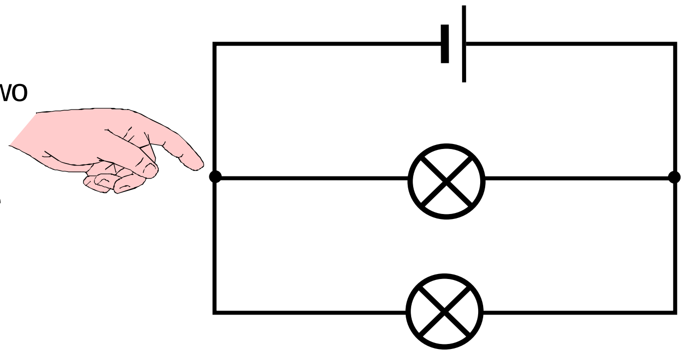
Series and parallel circuits

Circuits can be series or parallel or a combination of the two.

In a series circuit there is only one path through the components and back to the cell or battery.



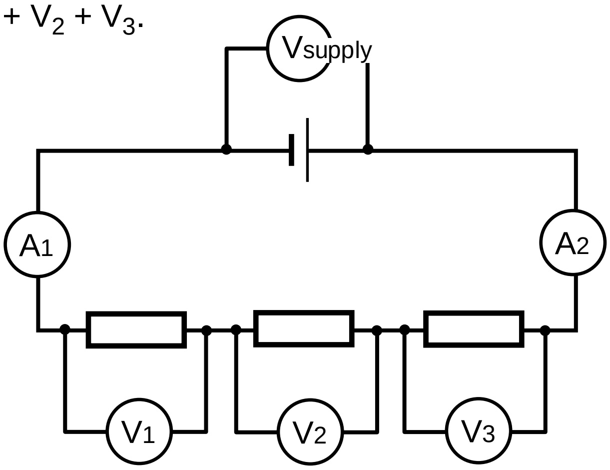
In a parallel circuit there are two or more paths around the circuit. There is at least one point in the circuit where there is a choice of paths.



Series Circuits

In the series circuit below the current is the same through all components. The readings on ammeters A1 and A2 will be the same.

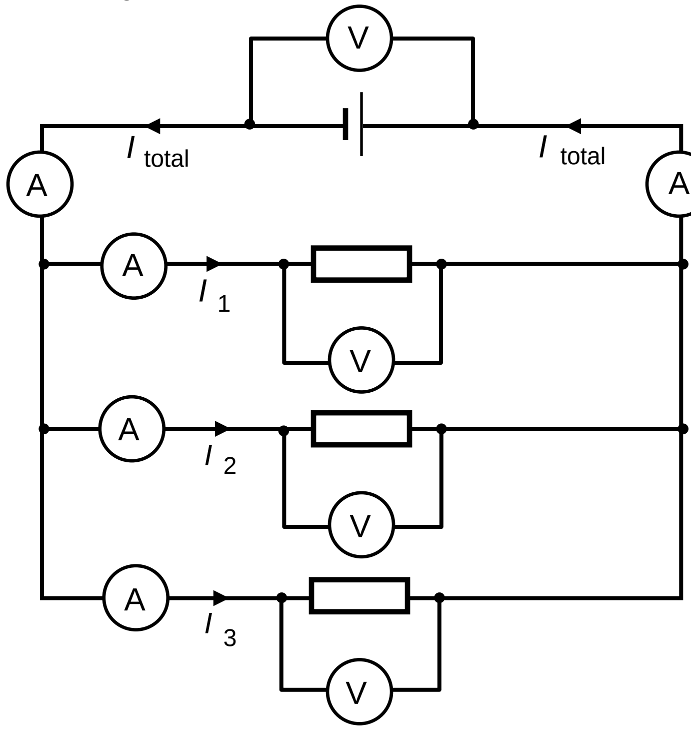
The supply voltage, V_{supply}, is split between the components in the circuit thus $V_{supply} = V_1, + V_2 + V_3$.



Parallel Circuits

In the parallel circuit below the voltage is the same across all components i.e. it will be the same as the supply voltage.

The current leaving the supply, I_{total}, is split between the components in the circuit
thus $I_{supply} = I_1, + I_2 + I_3$.



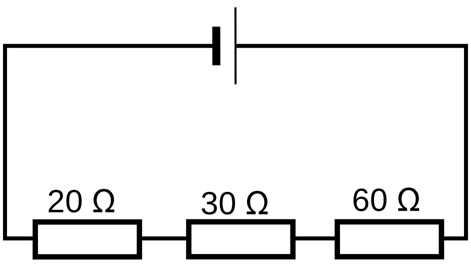
Resistors in Series and Parallel

Often two or more resistors are connected together in a circuit. This can either be in series or in parallel.

When adding resistors in series, the total resistance of the circuit increases—its as if the length of a piece of resistance wire was being made longer. When adding resistors in series use the formula:

$$R_{total} = R_1 + R_2 + R_3$$

The three resistors in the circuit opposite will have a total resistance of 110 Ω

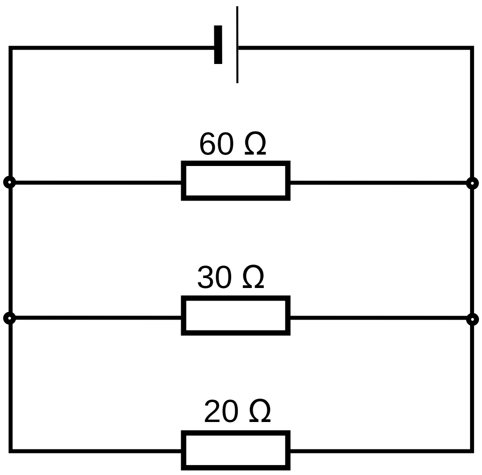


When adding resistors in parallel, the total resistance of the circuit always decreases—its as if a piece of resistance wire was being made thicker. The total resistance will always be less than the smallest resistance in the circuit.

When adding resistors in parallel use the formula:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

The three resistors in the circuit opposite will have a total resistance of 10 Ω



Here's how it's calculated.

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_{\text{total}}} = \frac{1}{60} + \frac{1}{30} + \frac{1}{20}$$

$$\frac{1}{R_{\text{total}}} = 0 \cdot 0167 + 0 \cdot 033 + 0 \cdot 05$$

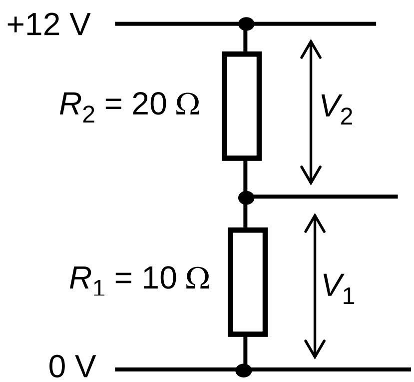
$$\frac{1}{R_{\text{total}}} = 0 \cdot 1$$

$$R_{\text{total}} = \frac{1}{0 \cdot 1}$$

$$R_{\text{total}} = 10\,\Omega$$

Voltage Dividers

Potential or voltage dividers are used to split a voltage. The voltage across any single resistor depends upon what proportion its resistance is of the total resistance of the circuit. Suppose we want to find the voltage across the two resistors in the circuit shown below.



The 12 V supply voltage will divide in proportion between the 10 Ω and 20 Ω resistors. The voltage across each resistor can be calculated as follows.

Total resistance of circuit = 20 Ω + 10 Ω = 30 Ω.

so, $V_1 = \frac{10}{30} \times 12$ and $V_2 = \frac{20}{30} \times 12$

$= 4\ V$ $= 8\ V$

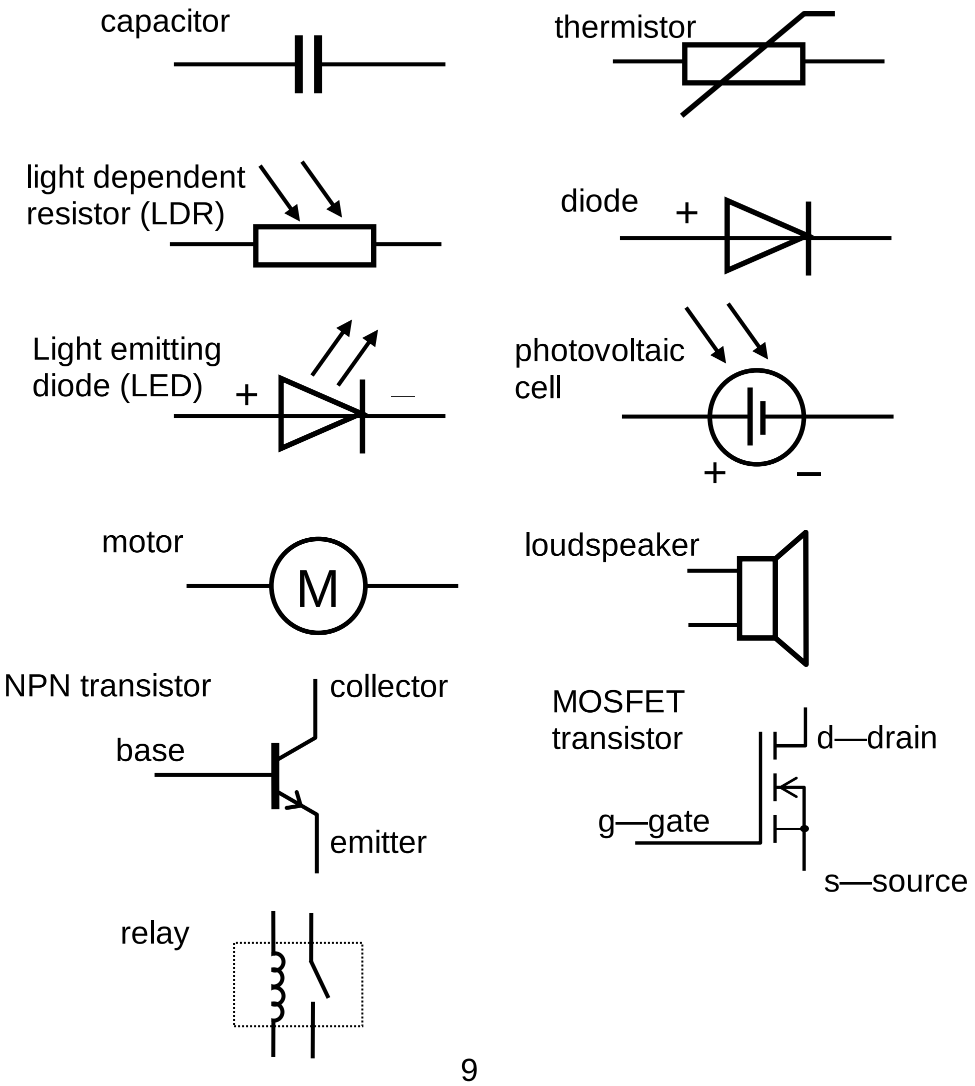
This can be put into a general formula $V_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times V_{supply}$

Electronic Circuits

Electronic components

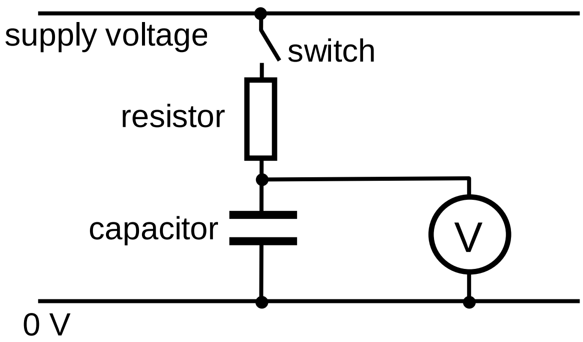
Electronic circuits consist of an input, a process and an output e.g. a calculator has a keyboard as the input, a microprocessor carries out the process part and the liquid crystal display is the output.

Symbols are used to represent electronic components. Some of these are shown below.



Capacitor:- these store electric charge and are often used in time delay circuits. When uncharged the voltage across a capacitor will be 0 V rising to the same voltage as the supply when fully charged.

The circuit below can be used to charge a capacitor.



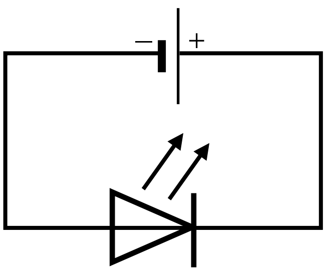
When the switch is closed the voltage across the capacitor will slowly increase. The time it takes for a capacitor to charge up depends upon the size of the capacitor and the size of the resistor. The larger they both are, the longer it takes for the capacitor to charge.

Thermistor:- a thermistor is a device which changes its resistance with temperature. Its resistance can decrease or increase with a rise in temperature but the commonest thermistors decrease their resistance as temperatures increase.

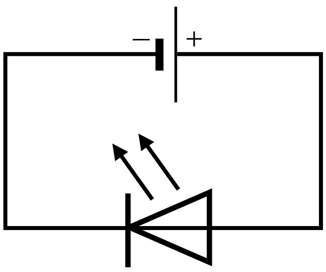
Light dependent resistors (LDR):- the resistance of an LDR alters as the light falling on it changes. Increasing the light level decreases the resistance.

Diode:- a diode only allows current to flow through it in one direction. The negative side of the diode must be connected to the negative of the power supply for it to conduct.

Light Emitting Diode (LED):- an LED converts electrical energy into light energy. It works from a low voltage using a small current. It will only operate in a circuit if connected the right way round i.e. its negative connection must be connected to the negative terminal of the power supply.



This LED will not light as it is connected to the cell the wrong way.



This LED will light, the negative side of the LED is connected to the negative terminal of the cell.

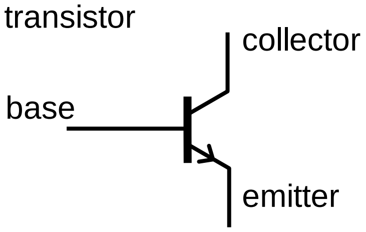
Photovoltaic cell:- This will convert light energy into electrical energy.

Motor:- an electric motor converts electrical energy into kinetic energy.

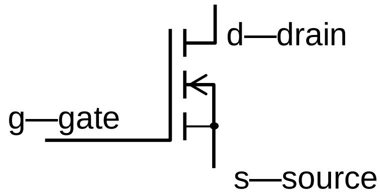
Loudspeaker:- a loudspeaker converts electrical energy into sound energy.

Transistor:- a transistor can be used as an electronic switch. All transistors have three connections and can either by NPN type or MOSFET type.

NPN transistor

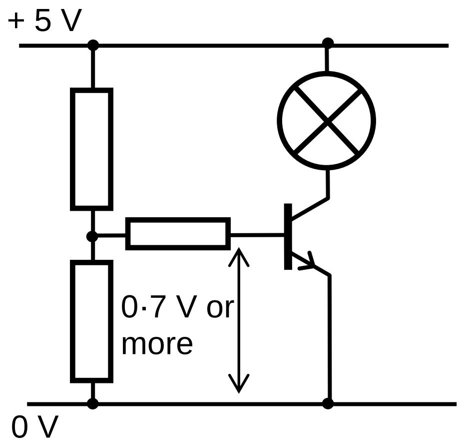


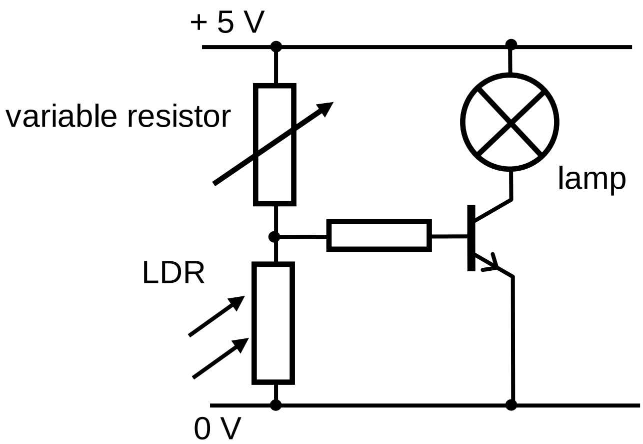
MOSFET transistor



How a transistor works

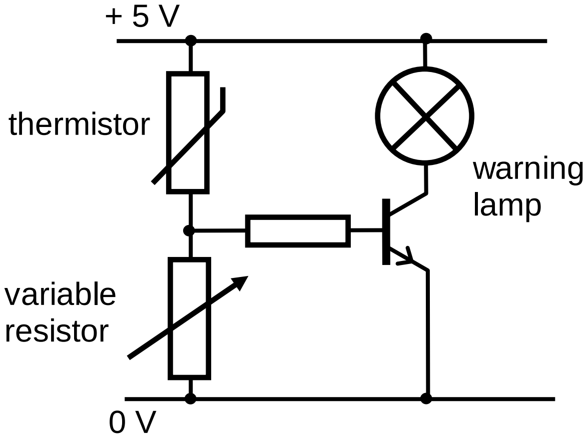
Consider an NPN transistor. By applying a voltage between the base and emitter the transistor can be made to conduct through the emitter and collector. The voltage required to switch on the transistor is 0·7 V or above. Potential divider circuits can often be used to achieve this in a variety of situations.



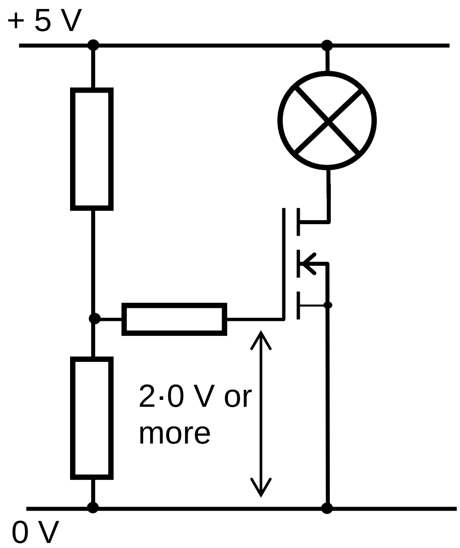


In the circuit opposite, the resistance of the LDR increases as it gets dark. The voltage across the LDR increases and once it is above 0·7 V, the transistor will switch the lamp on. Altering the value of the variable resistor can alter the light level at which the transistor switches on.

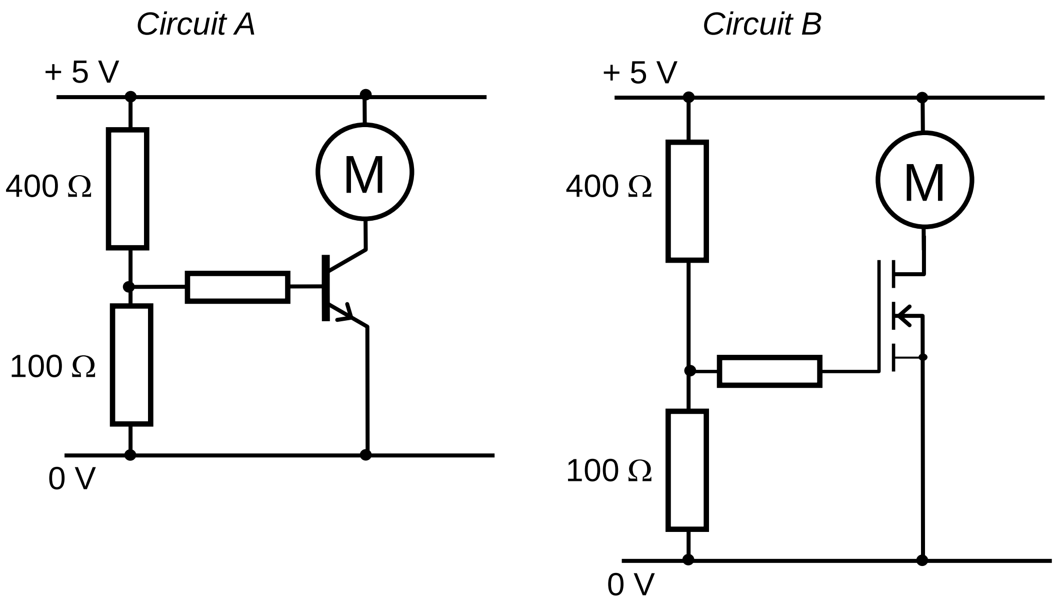
In the circuit opposite, the resistance of the thermistor will decrease as it gets hotter. The voltage across it decreases and so the voltage across the variable resistor will increase. Once it is above 0·7 V, the transistor will switch the warning lamp on.



A MOSFET transistor works in the same way as an NPN transistor. The only difference is that the voltage required to switch the transistor on is 2 V and over and this is applied between the gate and source connections. When this happens the transistor will conduct through the source and drain.



Worked example
Which of the two transistors shown below will be switched on, so operating the motor.



In both circuits, there will be 1·0 V across the 100 Ω resistor and 4·0 V across the 400 Ω resistor. In circuit A, the NPN transistor will be switched on and so will apply a voltage to the motor which will operate. In circuit B, the MOSFET transistor is not turned on as 1·0 V is not large enough.

Relay:- a small voltage applied to the input of the relay will activate an electro-mechanical switch which can be used to control a larger current or voltage.

Electrical Power

Energy consumption
Appliances in the home convert electrical energy into other forms.

- A television converts electrical energy into light and sound energy.
- A washing machine converts electrical energy into kinetic energy and heat energy.

The rate at which appliances use energy is termed their power and is measured in watts. If an appliance has a power of 1 watt it uses 1 joule of energy every second.

Appliances with high power ratings usually produce a lot of heat. Toasters, electric irons, kettles etc. usually have power ratings of over 1000 watts.

Calculating power
The power of an appliance can be calculated using the formula below.

$$\text{power} = \frac{\text{energy}}{\text{time}} \qquad P = \frac{E}{t}$$

where P = power measured in watts
E = energy measured in joules
t = time measured in seconds

Worked example
An electric heater with an output power of 1 kW is switched on for 5 minutes. Calculate the energy output from the heater.

$$\text{power} = \frac{\text{energy}}{\text{time}}$$
$$P = \frac{E}{t}$$
$$1000 = \frac{E}{300}$$
$$E = 1000 \times 300$$
$$= \underline{\underline{300\,000\,\text{J}}}$$

The power of an appliance can also be calculated using one of three formula involving the voltage, current and resistance of an appliance.

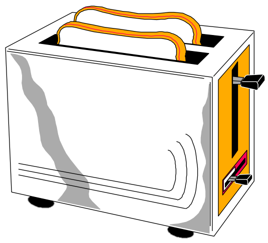
$$\text{power} = \text{current} \times \text{voltage} \qquad P = IV$$

where P = power measured in watts (W)
I = current measured in amperes (A)
V = voltage measured in volts (V)

This formula is especially useful when calculating the current drawn by an appliance so that the correct value of fuse can be chosen. A mains appliance will always have a rating plate attached which gives information about the voltage and power of the appliance.

> Voltage 230 V a.c. 50 Hz
> Power 2·2 kW
>
> Must not be used in bathrooms
> Do not cover heater

Worked example
Calculate the current drawn by a 805 W electric toaster connected to 230 V mains electricity.



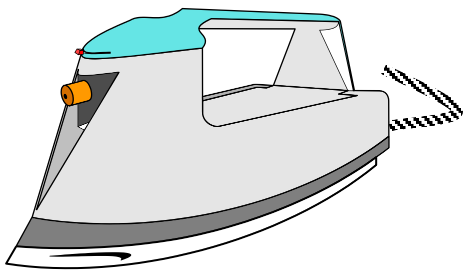
$$\text{power} = \text{current} \times \text{voltage}$$
$$P = I\,V$$
$$805 = I \times 230$$
$$I = \frac{805}{230}$$
$$= \underline{\underline{3 \cdot 5\ \text{A}}}$$

Linking power, current and resistance:

$$\text{power} = \text{current}^2 \times \text{resistance} \qquad P = I^2 R$$

where P = power measured in watts (W)
I = current measured in amperes (A)
R = resistance measured in ohms (Ω)

Worked example
The element of an electric iron has a resistance of 76 Ω. Calculate the current drawn by the iron if it has a power rating of 690 W



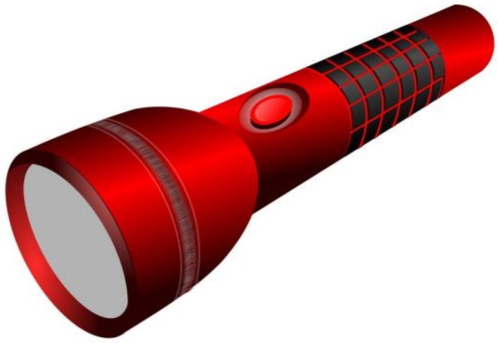
$$\text{power} = \text{current}^2 \times \text{resistance}$$
$$P = I^2\,R$$
$$690 = I^2 \times 76$$
$$I^2 = \frac{690}{76}$$
$$I^2 = \sqrt{9}$$
$$= \underline{\underline{3\ \text{A}}}$$

Power, voltage and resistance are linked with the formula:

$$\text{power} = \frac{\text{voltage}^2}{\text{resistance}} \qquad P = \frac{V^2}{R}$$

where P = power measured in watts (W)
V = voltage measured in volts (V)
R = resistance measured in ohms (Ω)

Worked example
A torch contains an LED lighting circuit with a resistance of 18 Ω and an output power of 2 W. Calculate the voltage of the torch power supply.



$$\text{power} = \frac{\text{voltage}^2}{\text{resistance}}$$

$$P = \frac{V^2}{R}$$

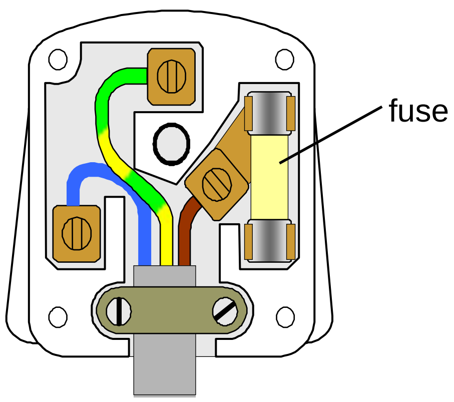
$$2 = \frac{V^2}{18}$$

$$V^2 = 2 \times 18$$

$$V = \sqrt{36}$$

$$= \underline{\underline{6\text{ V}}}$$

Fuses
A fuse can be found in every mains plug.



It consists of a thin strand of wire between two electrical contacts at each end. Fuses in mains plugs are usually in a ceramic tube so the wire cannot be seen. The function of the fuse is to protect the flex to the appliance. If too high a current flows through the flex due to a fault in the appliance, the fuse will ‘blow’ and cut off the supply of electricity. This prevents the flex overheating and possibly catching fire.

It is important that the correct size of fuse is fitted to the plug. It should normally be the next value of fuse above the normal current of the appliance. The current can be calculated using the formula $P = IV$. If an appliance normally drew 3 A then a 5 A fuse would be the best value to fit.

Conservation of energy

All the energy that exists in the universe is already there. It cannot increase or decrease. The law of Conservation of Energy states that energy cannot be created or destroyed, only changed from one form into another or transferred from one object to another.

There are lots of everyday examples of this.

If a snooker ball collides with a second snooker ball, the kinetic energy of the first ball is transferred to the second ball.

A cat that has climbed up a tree has gained potential energy. If it falls out of the tree the potential energy will be changed into kinetic energy.

Energy can be changed into useful forms e.g. an electric drill changes electrical energy into kinetic energy. Energy is often changed into non-useful forms. In the electric drill some of the electrical energy is wasted due to friction between the moving components which generates heat energy.

In a Formula 1 racing car, the chemical energy from the fuel is changed into kinetic energy but some is also wasted as heat. There will also be friction in the engine and other moving parts of the car such as the wheel axles and between the tyres and the road. Every time the driver brakes the kinetic energy of the car is changed into heat in the brakes.

Some friction we try to reduce. Air resistance is made smaller by making cars a more streamlined shape or by using oil and grease in the engine. Some friction is useful and we try to increase it. It is important to have maximum grip between the tyres and the road surface so the friction is increased by having a deep tread in the tyre.

Work

Work takes place when an object is moved by a force, the force transferring energy to the object.

If an archer pulls back the string on a bow and arrow, the work done on stretching the string and bow will be transferred to the arrow when it is fired.

The work done by a weightlifter in applying an upward force to the weights is transferred into the potential energy they gain.

When work is done against friction the energy will be transferred into heat.

Work can be calculated using the formula below.

work = force × distance in direction of force $\qquad E_w = F d$

where E_w = work measured in joules (j)
F = force measured in newtons (N)
d = distance measured in metres (m)

Worked example
A wheelbarrow is pushed a distance of 20 m by applying a force of 50 N. Calculate the work transferred.

Work = force × distance

$E_w = F d$

$E_w = 50 \times 20$

$= \underline{\underline{1000\ J}}$

Gravitational potential energy
If an object is lifted above the ground or above its normal rest position it gains gravitational potential energy. The gain in energy is equal to the work done in lifting it.

The formula for gravitational potential energy is:

gravitational potential energy = mass × gravitational field strength × height raised

$$E_p = m g h$$

where E_p = potential energy measured in joules (J)
m = mass measured in kilograms (kg)
g = gravitational field strength and on Earth is 9·8 N kg^{-1}
h = height measured in metres (m)

Worked example
A bucket of water is raised from a well. Calculate the depth of the well if the mass of the bucket and water is 15 kg and it gains 882 joules of potential energy.

$$\text{potential energy} = \text{mass} \times g \times \text{height}$$
$$E_p = m g h$$
$$882 = 15 \times 9 \cdot 8 \times h$$
$$h = \frac{882}{147}$$
$$h = \underline{\underline{6 \text{ m}}}$$

Kinetic energy
Any moving object will have kinetic energy. The greater the mass of the object or the higher its speed, the greater will be its kinetic energy. Kinetic energy can be calculated using the formula:

kinetic energy = ½ × mass × velocity^2 $\qquad E_k = ½ m v^2$

Note that it is only the velocity which is squared.

where E_k = kinetic energy measured in joules (J)
m = mass measured in kilograms (kg)
v = speed measured in m s^{-1}

Worked example
A cyclist has a mass of 60 kg.
Calculate her speed if she has 2430 J of kinetic energy.

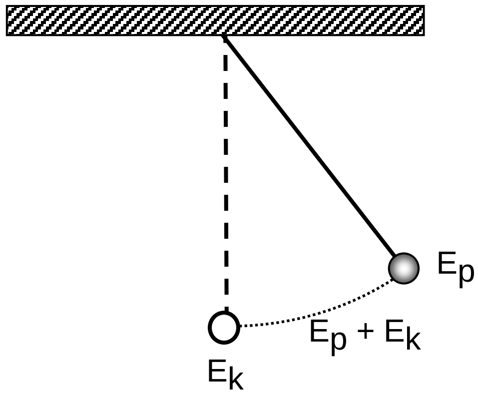
$$\text{kinetic energy} = \tfrac{1}{2} \times \text{mass} \times \text{velocity}^2$$
$$E_k = \tfrac{1}{2} m v^2$$
$$2430 = \tfrac{1}{2} \times 60 \times v^2$$
$$v = \sqrt{\frac{2430}{30}}$$
$$= \sqrt{81}$$
$$= \underline{\underline{9\ \text{m s}^{-1}}}$$


Picture by Stijn Desmedt

Conservation of Energy

On page 13 the conservation of energy was discussed. It is possible to use this principle in making calculations.

A pendulum bob has gravitational potential energy when pulled back. This changes to kinetic energy as it swings downwards becoming all kinetic energy at the lowest point of the bob



Worked example
A pendulum with a mass of 0·2 kg is pulled back so it is 0·1 m above its rest position. Calculate the speed of the pendulum at its lowest point.

$$\text{potential energy} = \text{kinetic energy}$$
$$E_p = E_k$$
$$m g h = \tfrac{1}{2} m v^2$$
$$0 \cdot 2 \times 9 \cdot 8 \times 0 \cdot 1 = \tfrac{1}{2} \times 0 \cdot 2 \times v^2$$
$$v^2 = \frac{0 \cdot 196}{0 \cdot 1}$$
$$v = \sqrt{1 \cdot 96}$$
$$\underline{\underline{v = 1 \cdot 4\ \text{m s}^{-1}}}$$

Gas Laws and the Kinetic Model

Pressure, Force and Area
Pressure in a gas is caused by the particles of gas colliding with a boundary such as a container wall. Pressure is also caused by a force pushing against something e.g. the pressure under your foot when you stand on the ground.

Pressure is defined as the force per unit area. It can be calculated using the formula

$$\text{pressure} = \frac{\text{force}}{\text{area}} \qquad p = \frac{F}{A}$$

where p = pressure in pascals (Pa) or newtons per square metre (N m^{-2})
F = force in newtons (N)
A = area in square metres (m^2)

Worked example
A hammer hits a nail with a downwards force of 300 N. Calculate the pressure under the point of the nail if the point of the nail has an area of 1×10^{-6} m^2.

$$p = \frac{F}{A}$$

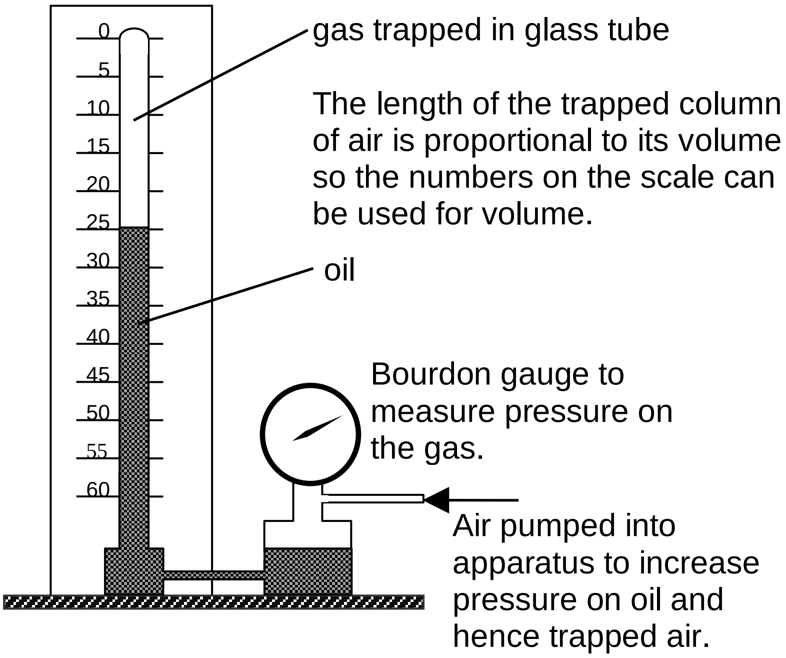
$$p = \frac{300}{1 \times 10^{-6}}$$

$$\underline{\underline{p = 3 \times 10^{8} \text{ Pa}}}$$

The pressure under objects can be deliberately reduced. Tractors working on soft ground have large wide tyres. The weight of the tractor is spread over a larger area which reduces the pressure under the tyres and prevents the tractor sinking into the ground.

The Gas Laws—Pressure and Volume

The relationship between the pressure and the volume of a gas can be found experimentally using the apparatus shown below.

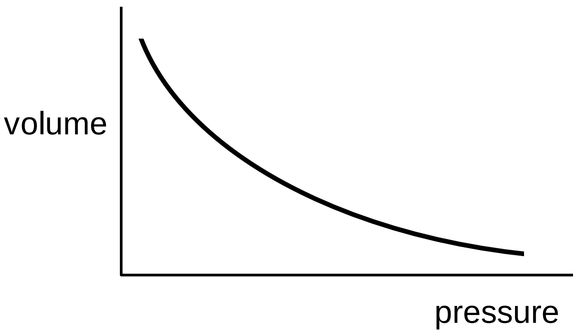


The mass of gas in the tube remains the same. Readings of the length of the gas column are taken from the scale at the side of the tube. Length readings can be used for volume as the volume of the gas is proportional to its length.

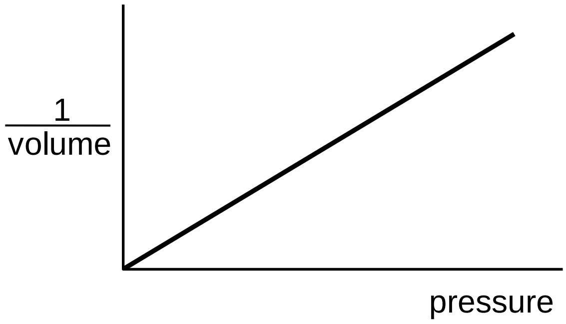
Between readings, air is pumped into the apparatus above the oil. Its pressure is recorded on the Bourdon gauge and the pressure on the oil is transferred to the trapped gas, compressing it.

The results obtained from the experiment produce a graph of pressure against volume

As the pressure increases the volume decreases.



If a graph of pressure against $\frac{1}{\text{volume}}$ is plotted then a straight line through the origin is produced showing that pressure is inversely proportional to pressure.



$$p \propto \frac{1}{V}$$

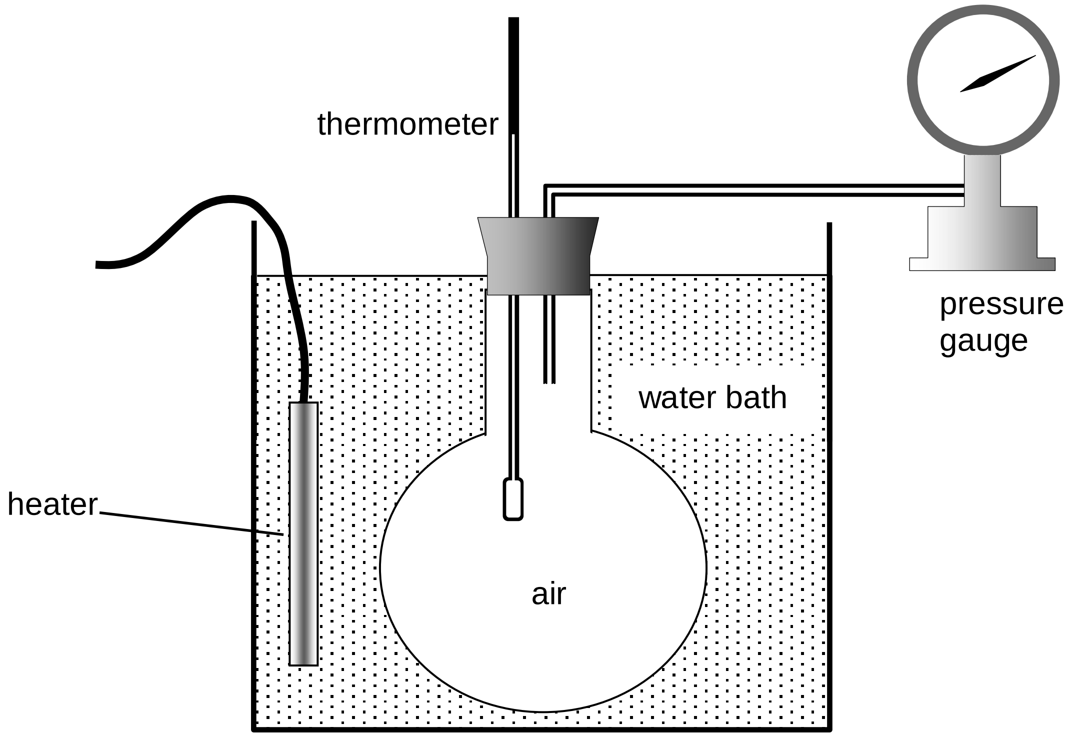
If a gas has initial conditions p_1 and V_1 and the pressure and volume are altered to p_2 and V_2 these are related by the equation

$$p_1V_1 = p_2V_2$$

Worked example
A weather balloon has a volume of 2·5 m³ when inflated at sea level where atmospheric pressure is 100 kPa. What will be the volume of the balloon when it has risen to a height where atmospheric pressure is only 40 kPa?

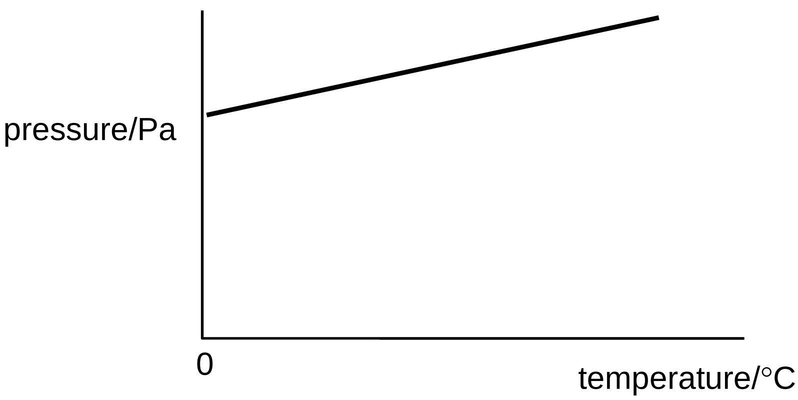
$$p_1V_1 = p_2V_2$$
$$100 \times 2 \cdot 5 = 40 \times V_2$$
$$V_2 = \frac{100 \times 2 \cdot 5}{40}$$
$$V_2 = 6 \cdot 25\,\text{m}^3$$

The Gas Laws—Pressure and Temperature
The relationship between the pressure and temperature of a gas can be investigated using the apparatus shown below.

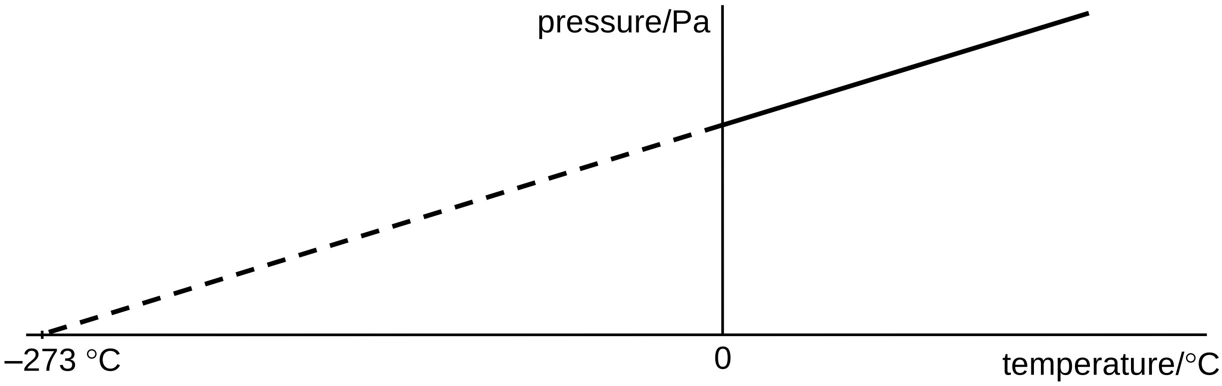


The flask containing a fixed mass of gas is submerged in a water bath and the temperature slowly increased using an immersion heater. This in turn raises the temperature of the gas within the flask. The pressure of the gas is measured using a Bourdon pressure gauge and the temperature of the gas is measured using a thermometer placed in the flask. The volume of the gas remains constant.

If a graph of pressure against temperature in °C is plotted from the results it is found that increasing the temperature of the gas increases the pressure. However, the relationship is not one of direct proportion.

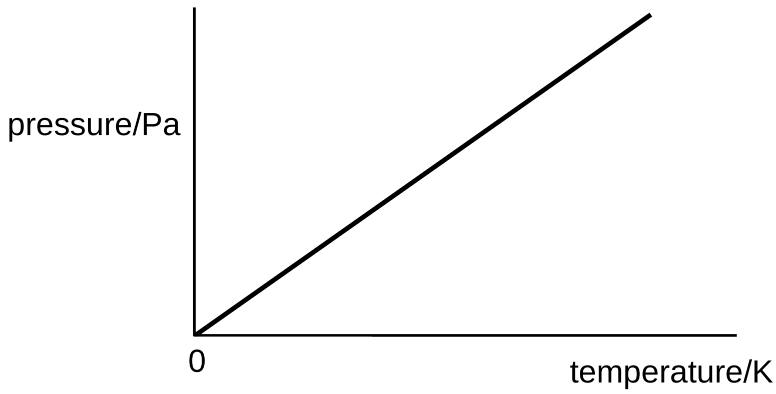


The graph can be extended backwards to the point where pressure is zero.



The temperature at which this happens is –273 °C. This is known as **absolute zero** and is the starting point or origin for a new temperature scale called the **kelvin** scale. (Absolute zero is the temperature at which the gas particles will cease to move and so exert no pressure.)

Plotting a graph of pressure against temperature in kelvin will produce a straight line through the origin.



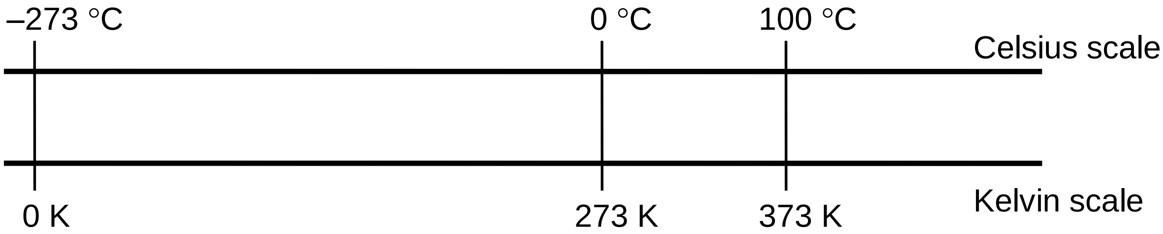
The results of the experiment above show that pressure is directly proportional to the temperature in kelvin for a fixed mass of gas with constant volume.

$$p \propto T \text{ in kelvin}$$

If a gas has initial conditions p_1 and T_1 and the pressure and temperature are altered to p_2 and T_2 these are related in the equation

$$\frac{p_1}{T_1} = \frac{p_2}{T_2} \text{ providing T is in kelvin}$$

Any gas law problem involving temperature must have the temperature in the kelvin scale. The size of the units are the same—1 °C is the same size as 1 K. The temperature scales simply have a different starting point. (Note the lack of the degree (°) symbol before K.)



To convert from the **celsius scale to the kelvin scale add 273** e.g. –10 °C = 263 K.

To convert from the **kelvin scale to the celsius scale subtract 273** e.g. 373 K = 100 °C.

Worked example
A calor gas cylinder is at a temperature of 17 ºC. The gas inside is at a pressure of 6 × 10⁵ Pa. The cylinder is left in direct sunshine on a hot day and the temperature of the gas rises to 47 ºC. Calculate the new pressure of the gas inside.

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$\frac{6 \times 10^5}{290} = \frac{p_2}{320}$$

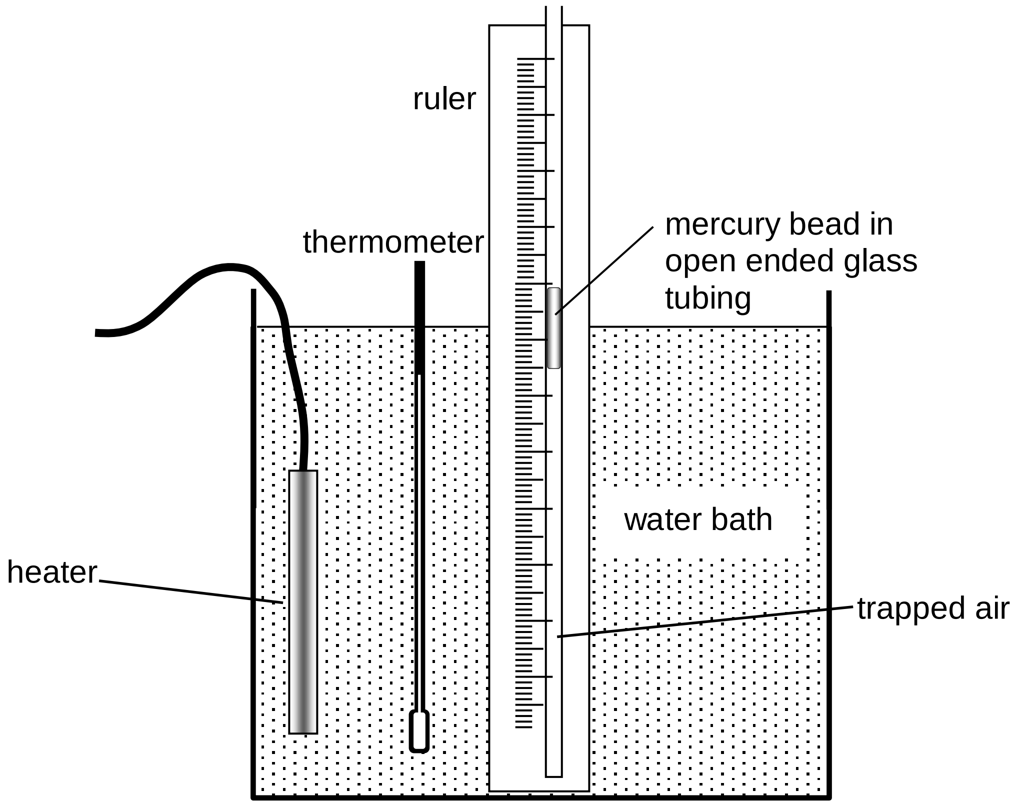
$$290\,p_2 = 6 \times 10^5 \times 320$$

$$p_2 = \frac{6 \times 10^5 \times 320}{290}$$

$$\underline{\underline{p_2 = 6 \cdot 62 \times 10^5 \text{ Pa}}}$$

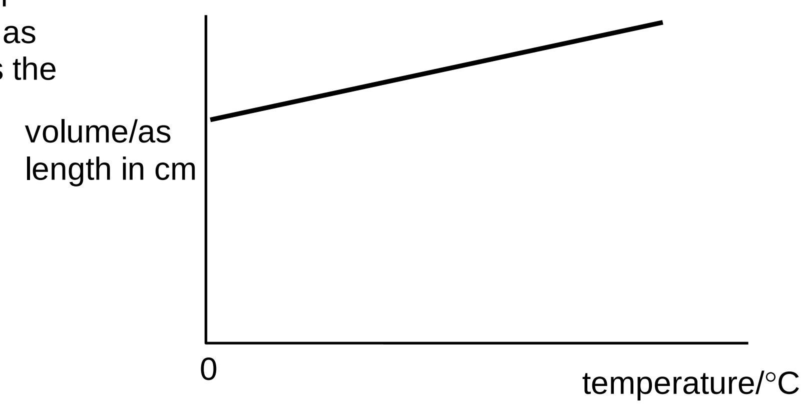
The Gas Laws—Volume and Temperature

An experiment can be carried out to investigate the relationship between the volume and temperature of a gas using the apparatus shown below. A fixed mass of gas is trapped in a glass tube by a bead of mercury which is free to move up and down the tube. This keeps the pressure of the gas constant.



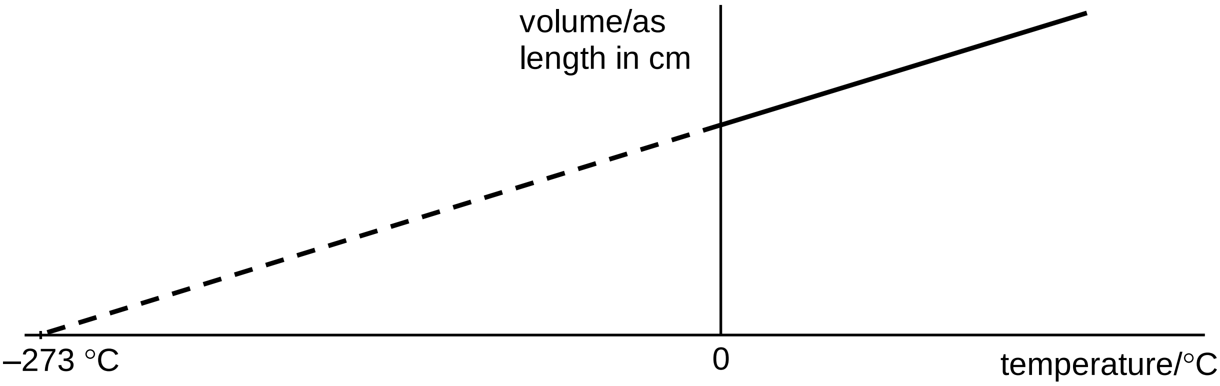
As the water is heated the trapped gas expands and pushes the mercury up the tube. The length of this trapped gas is taken as a measure of its volume (since the length of the gas is proportional to volume in a tube with a uniform cross section).

A graph of the results from this experiment show that as the temperature increases the volume increases.



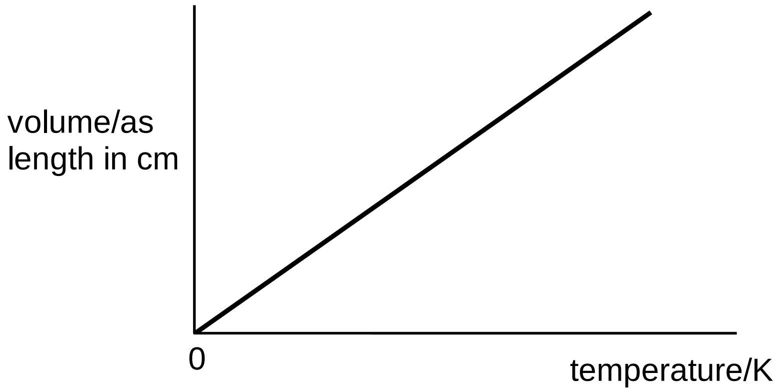
However, the relationship is not one of direct proportion.

The graph can be extended backwards to the point where the volume of the gas becomes zero.



The temperature at which this happens is –273 °C. This is known as **absolute zero** and is the starting point or origin for a new temperature scale called the **kelvin** scale. (Absolute zero is the temperature at which the gas particles will, in theory, have no volume.)

Plotting a graph of volume against temperature in kelvin will produce a straight line through the origin.



The results of the experiment above show that volume is directly proportional to the temperature in kelvin for a fixed mass of gas at constant pressure:

$$V \propto T \text{ in kelvin}$$

If a gas has initial conditions V_1 and T_1 and the volume and temperature are altered to V_2 and T_2 these are related in the equation

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \text{ providing } T \text{ is in kelvin}$$

Worked example
A sealed syringe contains 20 cm^3 of air at a temperature of 27 °C. The plunger of the syringe is able to move freely. The syringe is placed into a water bath at 100 °C. Calculate the new volume of the gas if pressure remains constant.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{20}{300} = \frac{V_2}{373}$$

$$V_2 \times 300 = 20 \times 373$$

$$\underline{\underline{V_2 = 24 \cdot 9 \text{cm}^3}}$$

The General Gas Equation
We now have three equations linking together the pressure, volume and temperature (in kelvin) of a gas.

$$p_1V_1 = p_2V_2 \qquad \frac{p_1}{T_1} = \frac{p_2}{T_2} \qquad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

These three equations can be combined into a single equation known as the general gas equation. This can be used with more complex situations where pressure, temperature and volume all change.

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

Remember, when using this equation always **convert the temperature into Kelvin** before carrying out any calculations.

Worked example
A weather balloon is released at ground level where the temperature is 27°C and the pressure is 100 kPa. The balloon has a volume of 3 m^3. What will be the volume of the balloon when it rises to a height where the pressure is 26 kPa and the temperature is –53°C?

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$\frac{100 \times 3}{300} = \frac{26 \times V_2}{220}$$

$$300 \times 26 \times V_2 = 100 \times 3 \times 220$$

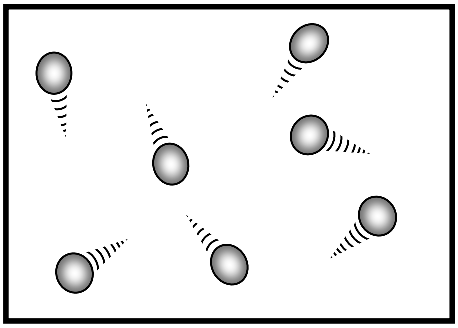
$$7800V_2 = 66000$$

$$\underline{\underline{V_2 = 8 \cdot 5 \text{ m}^3}}$$

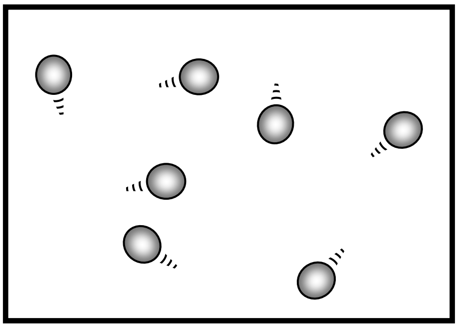
Kinetic Model of Gases

The particles of a gas can be thought of as being in constant motion. When they collide with the walls of a container they provide a small outwards force. The many, many collisions of the gas particles with the walls of a container which causes the pressure of a gas.

Pressure and temperature



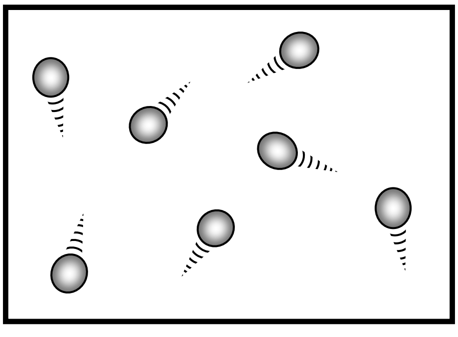
At a high temperature the gas particles have a lot of kinetic energy and move quickly. There are many collisions with the container walls, each collision producing more force on the wall.



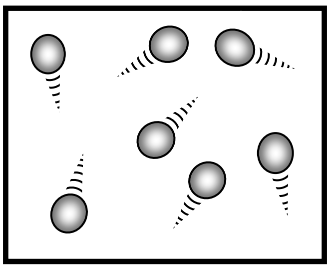
If the temperature of the gas is reduced the gas particles move more slowly with less kinetic energy. There are fewer collisions with the container walls and with less force than before so the pressure is less.

Pressure and volume

If a container holding a gas is sqeezed or compressed the pressure inside increases e.g. placing your finger over the end of a bicycle pump and pushing down the handle.

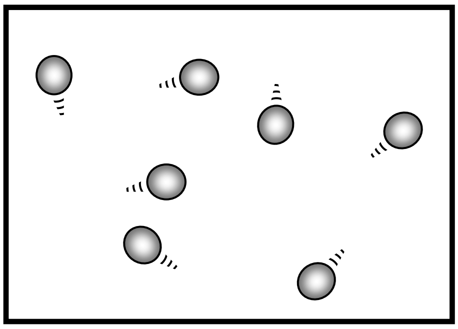


In a container with a large volume there are relatively fewer collisions with the container walls as the gas particles have further to travel between walls.

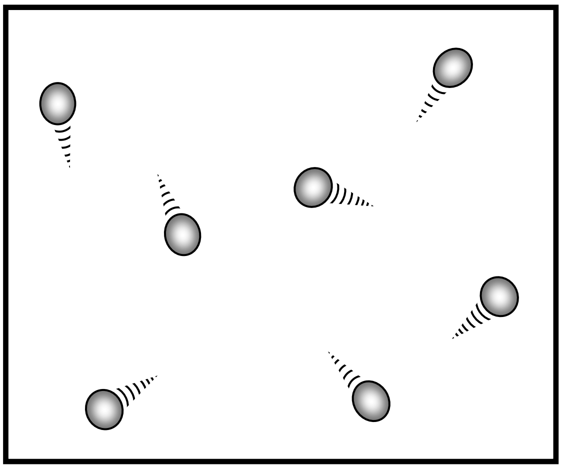


If the volume of the container is reduced there are more collisions with the container and so the pressure is greater.

Volume and temperature
Heating a container of gas will make it expand till the pressure inside is equal to the pressure outside the container.



The gas particles collide with the walls of the container pushing it outwards. Air particles outside push the walls inwards so a balance is achieved.



If the temperature of the gas is raised the gas particles have more kinetic energy and hit the walls more often and with more force. This pushes the container walls outwards till the pressure inside the container equals the pressure outside once more.

Specific Heat Capacity
When talking about heat and temperature it is important that the meaning of these words is clearly understood.

- heat is a form of energy transferred between objects at different temperatures. The greater the temperature difference between objects, the faster the transfer will take place.
- temperature is a measure of the hotness or coldness of an object and is defined as the mean or average kinetic energy of its particles—the hotter an object the more kinetic energy its particles will have.

Temperature is measured in degrees celsius or in kelvin. Heat is measured in joules.

Adding energy to materials will cause them to heat up. The rise in temperature will depend upon a number of factors however. The amount of energy added, the material the energy is added to and the mass of the material, will all have an effect.

For any material, the amount of energy required to increase the temperature of one kilogram by one degree Celsius is called its specific heat capacity (*c*).

These factors are linked together in the formula below:

heat energy = specific heat capacity × mass × change in temperature

$$E_h = c\,m\,\Delta T$$

where E_h = heat energy measured in joules (j)
c = specific heat capacity measured in joules per kilogram degree celsius (J kg^{-1} °C^{-1})
m = mass measured in kilograms (kg)
ΔT = change in temperature measured in degrees celsius (°C)

Worked example
A hot water bottle contains 1·5 kg of water at a temperature of 80 °C.
Calculate the energy it will lose if the water cools to 35 °C.
Specific heat capacity of water, c = 4180 J kg^{-1} °C^{-1}.

$$\text{heat energy} = \text{specific heat capacity} \times \text{mass} \times \text{change in temperature}$$

$$E_h = c\,m\,\Delta T$$

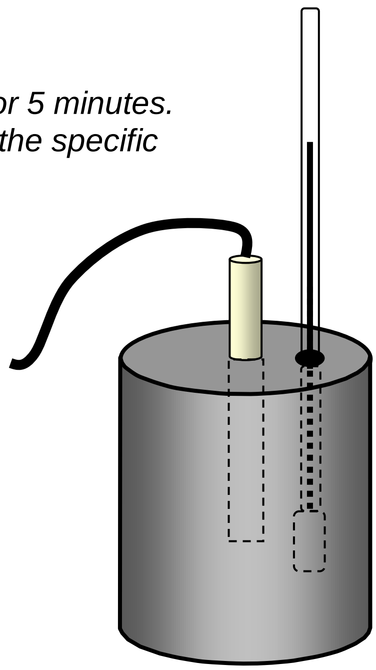
$$E_h = 4180 \times 1{\cdot}2 \times 45$$

$$\underline{\underline{E_h = 225\,720\ \text{J}}}$$

Energy conversions

Electrical energy is often converted into heat energy e.g. an electrical heater can be used to heat up a block of aluminium. Calculations can be carried out on the conversion of electrical energy into heat energy.

Worked example
A 1 kg aluminium block is heated using a 200 W heater for 5 minutes. Calculate the expected rise in temperature of the block if the specific heat capacity of aluminium is 902 J kg^{-1} °C^{-1}.



$$\text{Energy added} = \text{power} \times \text{time}$$

$$E_h = 200 \times 300$$

$$E_h = 60\,000\ \text{J}$$

$$\text{heat energy} = \text{specific heat capacity} \times \text{mass} \times \text{change in temperature}$$

$$E_h = c\,m\,\Delta T$$

$$60\,000 = 902 \times 1 \times \Delta T$$

$$\Delta T = \frac{60000}{902}$$

$$\underline{\underline{\Delta T = 66{\cdot}5\ ^\circ\text{C}}}$$

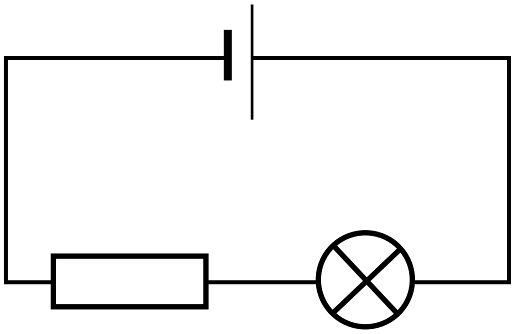
The actual rise in temperature would be less than that calculated above as there is no insulation around the metal block so it will lose heat.

Electrical charge carriers and electric fields

Electric charge

1. What moves through a conductor when a current flows through it?

2. Using correct symbols, redraw the circuit below showing how an ammeter would be positioned to measure the current flowing through the lamp.



Charge, current and time

3. State an equation that links charge, current and time.

4. Calculate the missing values in the table below.

Charge	***Current***	***Time***
(*a*)	2 A	20 s
(*b*)	100 mA	10 s
300 C	0·1 A	(*c*)
1040 C	13 A	(*d*)
3·0 C	(*e*)	60 s
9 C	(*f*)	3 minutes

5. Calculate the total charge which flows through a lamp drawing 100 mA for 200 s.

6. A current of 0·5 A flows through a circuit in a time of 10 s.

(*a*) Calculate the total charge flowing through the circuit.

(*b*) If a single electron carries a charge of $1{\cdot}6 \times 10^{-19}$ C, how many electrons flowed through the circuit?

7. Calculate the current flowing if 30 C of charge flows through a component in 10 s.

8. What time will it take for 500 C of charge to pass through a circuit if the current in the circuit is 500 mA?

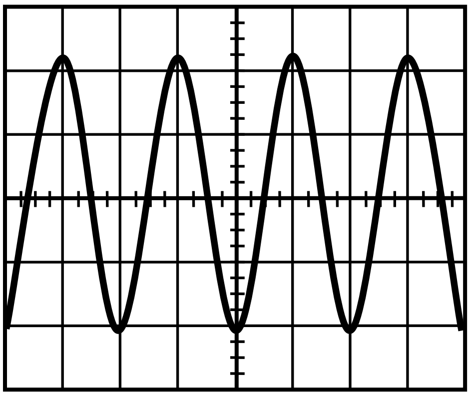
a.c. and d.c.

9. State a source of an a.c. supply and a d.c. supply.

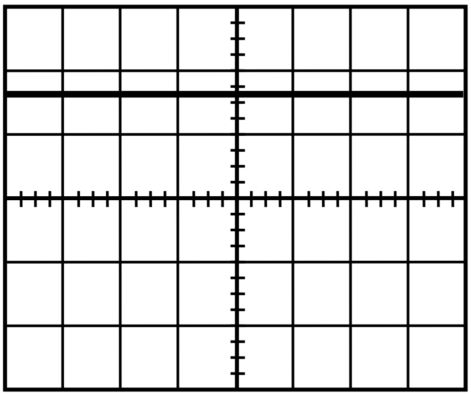
10. What frequency is the mains supply in Scotland?

11. State which of the oscilloscope traces below shows a d.c. and which an a.c. supply.

Trace 1



Trace 2



Potential difference (voltage)

12. Copy and complete the paragraph on potential difference and electric fields using the words given below.

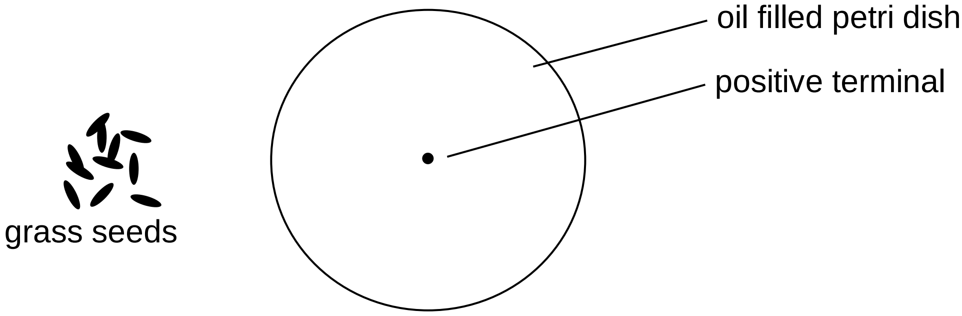
energy **negative** **voltage** **positive** **negative**

attracted **potential** **charge** **positive**

An object can have either negative or positive charge. Electrons have __________ charge, When a charged object is placed in an electric field, its movement will depend upon its __________ . A positive charge will be repelled by a _________ charge whilst a negative charge will be __________.

In a circuit, it is electrons which flow around the circuit. The energy for them to move comes from a __________ difference or __________ . Electrons will flow towards the __________ connection of a power supply and away from the __________ connection. The size of the potential difference or voltage is a measure of the __________ given to the electrons.

13. Electric fields are invisible. They can be shown by sprinkling grass seeds or semolina onto an oil filled petri dish to which an electric field is applied.



Draw the field that would be seen when the grass seeds are dropped onto the oil.

14. A Van De Graaff is charged up and the dome becomes positively charged. Describe what would be seen if:

A. a small negatively charged object was thrown at the dome and

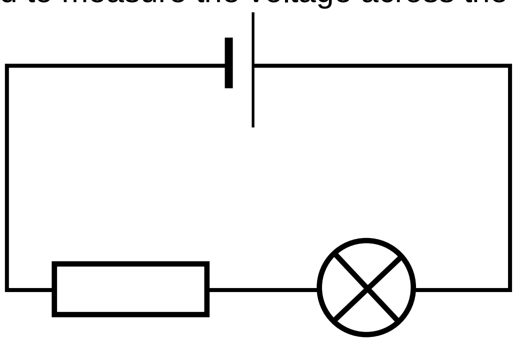
B. a small positively charged object was thrown at the dome.

15. A pupil stands on an insulated platform and touches the dome of a Van de Graaff generator. His hair is observed to ‘stand on end’.

(*a*) Explain this effect in terms of charges.

(*b*) Why must he stand on an insulated platform?

16. Using correct symbols, redraw the circuit below showing how a voltmeter would be positioned to measure the voltage across the lamp.

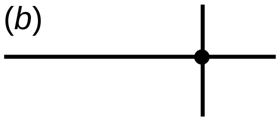


Ammeters, Voltmeters and circuits

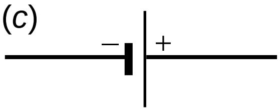
17. Identify the symbols of the electrical components shown below.

(*a*)

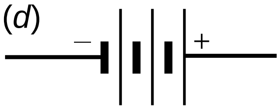
(*b*)



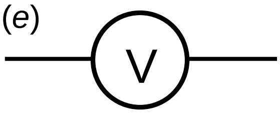
(*c*)



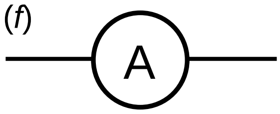
(*d*)



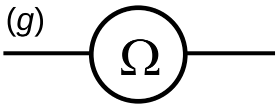
(*e*)



(*f*)

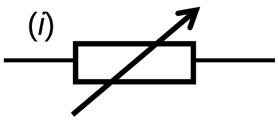


(*g*)

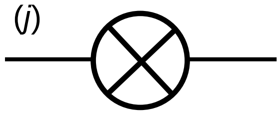


(*h*)

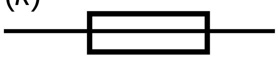
(*i*)



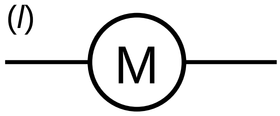
(*j*)



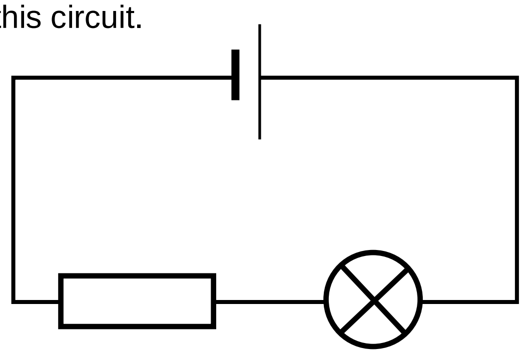
(*k*)



(*l*)



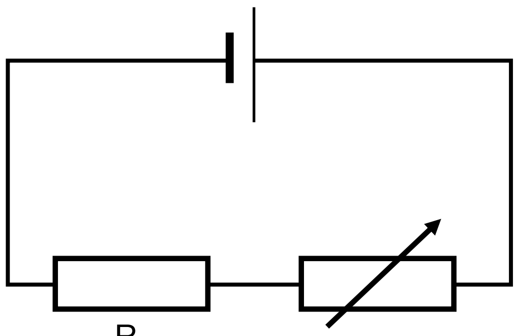
18. (*a*) A circuit is shown below. State the components that would be required to wire up this circuit.



(*b*) Redraw the circuit with a voltmeter and ammeter correctly positioned to measure the voltage across the lamp and the current through the lamp.

Ohm's Law

19. A pupil sets up a circuit to investigate how the voltage across a resistor affect the current through it. A variable resistor is used to change the current flowing through the resistor, R. The partially completed circuit is shown below.



(*a*) Copy the circuit above and add a voltmeter to measure the voltage across resistor, R, and the current through it.

(*b*) What will happen to the current flowing through R if the resistance of the circuit is increased by increasing the resistance of the variable resistor?

(*c*) The resistor is replaced by a length of wire. This is dipped into liquid nitrogen at a very low temperature.

(i) What effect will this have on the resistance of the wire?

(ii) State what will happen to the current flowing in the circuit as a result.

20. A class is asked to investigate the relationship between voltage and current for a conductor with fixed resistance. A circuit similar to that in question 19 is set up and pupils gather their results together. All the experiments used wire of the same length. Their averaged results are shown below.

Voltage in volts, V	2	4	6	8	10	12
Current in amps, I	0·25	0·5	0·75	1·0	1·25	1·5
V/I						

(*a*) Why is it a good idea for the class to combine all their results and find average values?

(*b*) Why must wire of the same length be used for each experiment.

(*c*) The pupils calculate a value for voltage divided by current.

(i) Copy the table above and complete the row headed V/I

(ii) What conclusion can be drawn from the results?

21. A pupil sets out to investigate the resistance of a conductor. The following apparatus is collected:

voltmeter;

ammeter;

variable voltage power supply;

resistor;

connecting leads.

(*a*) Draw a circuit diagram showing how the components can be connected to carry out the investigation.

(*b*) The results from the experiment are shown below.

Voltage in volts, V	1	2	3	4	5	6
Current in milliamps, I	51	105	148	200	250	298

Plot a graph of these results and use the graph to determine the resistance of the resistor used in the experiment.

22. State an equation that links voltage, current and resistance.

23. Calculate the missing values in the table below.

Voltage	***Current***	***Resistance***
(*a*)	0·5 A	20 Ω
(*b*)	4 A	15 Ω
230 V	8 A	(*c*)
12 V	0·02 A	(*d*)
230 V	(*e*)	500 Ω
12 V	(*f*)	60 Ω

24. A circuit is constructed using a power supply with a variable voltage output. It is connected to a fixed value of resistance. What will happen to the current in the circuit as the voltage is increased?

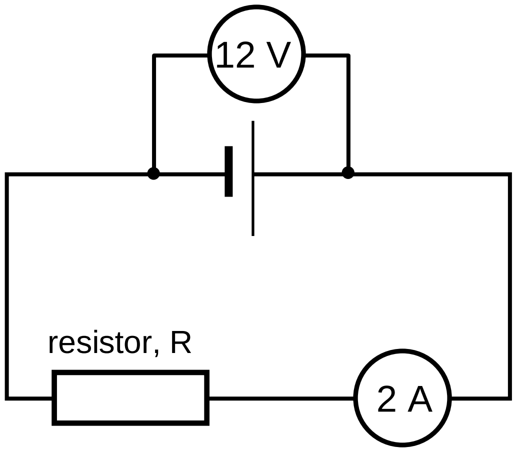
25. An electric kettle is connected to mains electricity at 230 V. A current of 5 A flows to the kettle when it is switched on. Calculate the resistance of the kettle element.

26. A 36 Ω resistor is connected to a 1·5 V supply. Calculate the current passing through the resistor.

27. An electric iron has a resistance of 76 Ω. Calculate the voltage across it when the current to the iron is 3·0 A.

28. A resistor with a value of 2200 Ω is connected to an electronic circuit. Calculate the current through it when a voltage of 2·2 V is applied across it.

29. Calculate the value of the resistor, R, in the circuit below.



30. A filament type electric light bulb has a resistance of 980 Ω when operating at normal brightness.

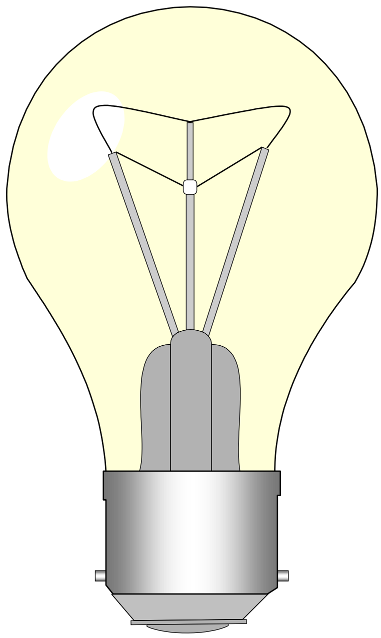
(*a*) Calculate the current through the light bulb when it is connected to a 230 V mains supply.

(*b*) Before it was switched on, the light bulb had a resistance of only 64 Ω.

(i) Suggest a reason for this difference in resistance.

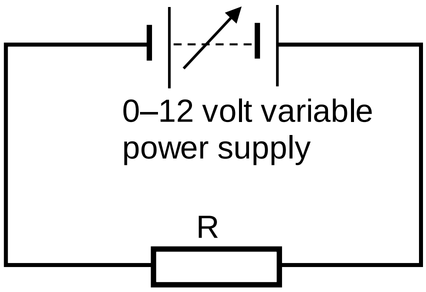
(ii) Calculate the current through the light bulb when it is first switched on.

(*c*) Light bulbs most often fail when switched on from cold. Can you suggest a reason why this should happen.



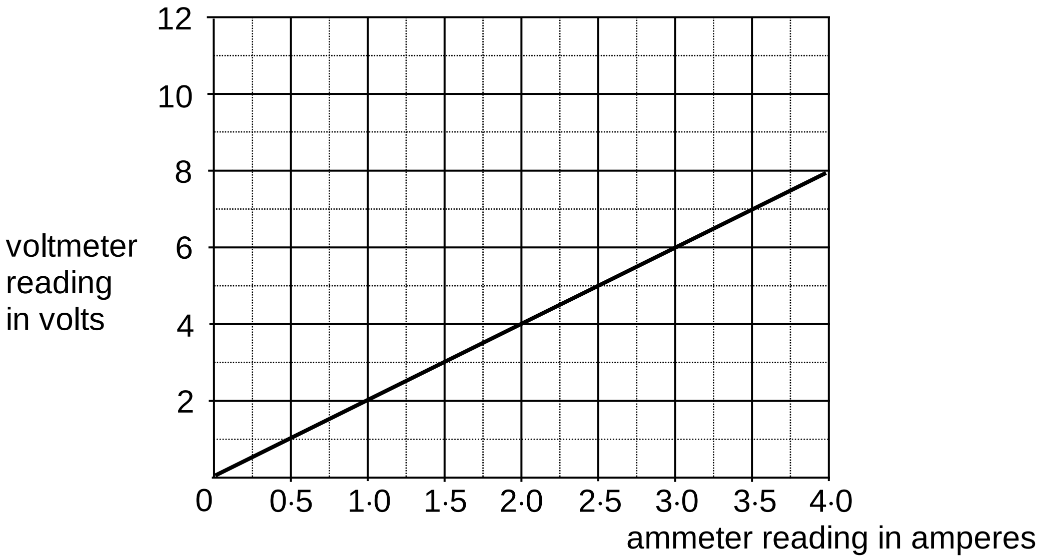
Extension Questions

31. A pupil sets up the circuit shown opposite. An ammeter and voltmeter are to be added to the circuit to make measurements so that the resistance of the resistor can be calculated.



(*a*) Redraw the circuit with the ammeter and voltmeter correctly positioned to make the readings.

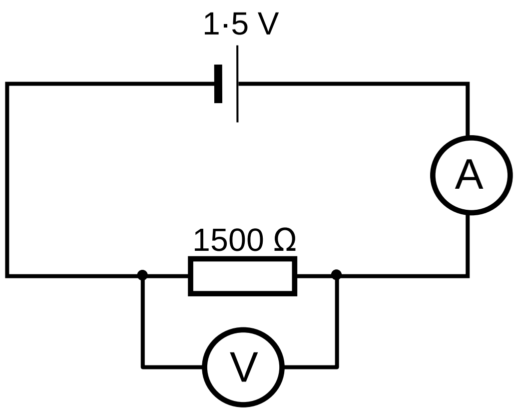
(*b*) Readings are taken from the ammeter and voltmeter as the power supply voltage is altered and a graph produced from the measurements.



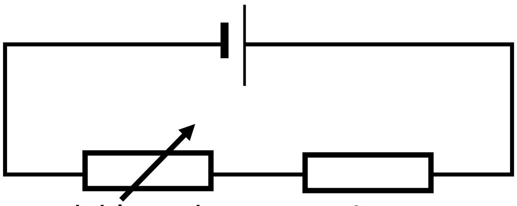
(i) What is the reading on the ammeter when the voltage across the resistor is 4 volts?

(ii) Taking readings from the graph, calculate the resistance of the resistor in the circuit.

32. Find by calculation, the readings that would be on the voltmeter and ammeter in the circuit below.



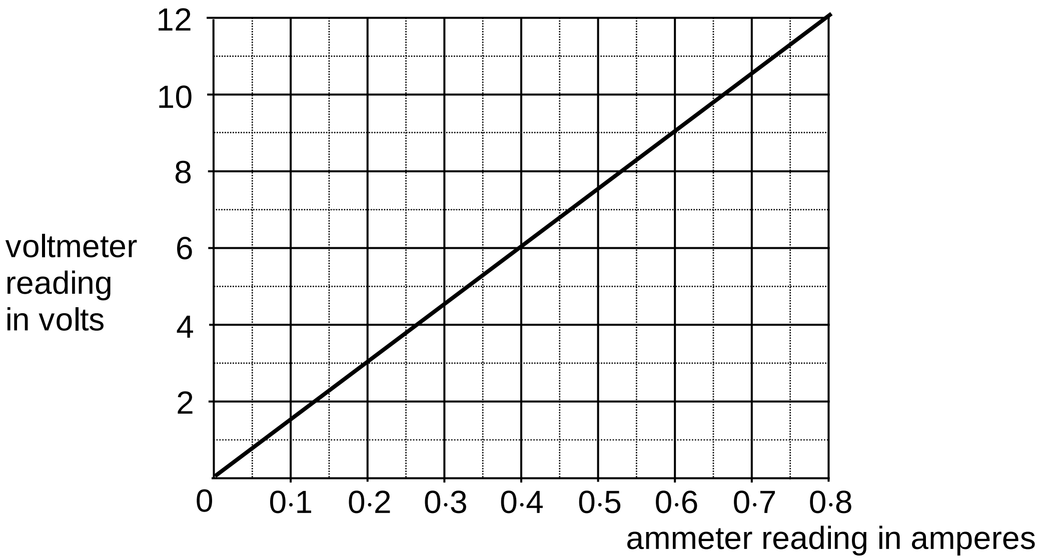
33. A pupil investigates the relationship between current and resistance in a circuit containing a resistor as shown below. A variable resistor in series with the resistor R, is used to change the current flowing in the circuit.



(*a*) What can be said about the value of the current flowing through the variable resistor and resistor R?

(*b*) Redraw the circuit and show, using the correct symbols, a correctly placed ammeter to measure the current through R and a correctly placed voltmeter to measure the voltage across R.

(*c*) A graph is produced from the results obtained from the experiment. Use these results to calculate the resistance of resistor R.

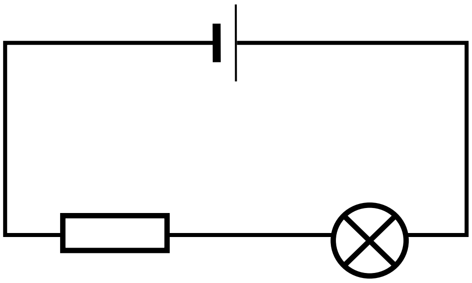


(*d*) The value of the variable resistor is now **increased**. What effect will this change have on the reading on the ammeter?

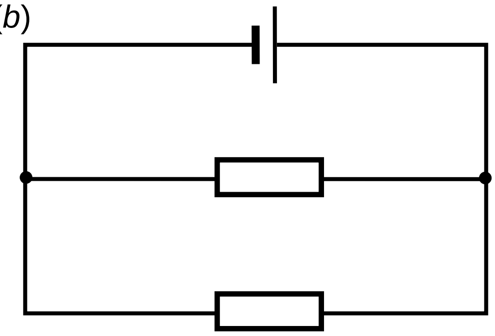
Series and parallel circuits

34. State which of the following circuits are series circuits and which are parallel circuits.

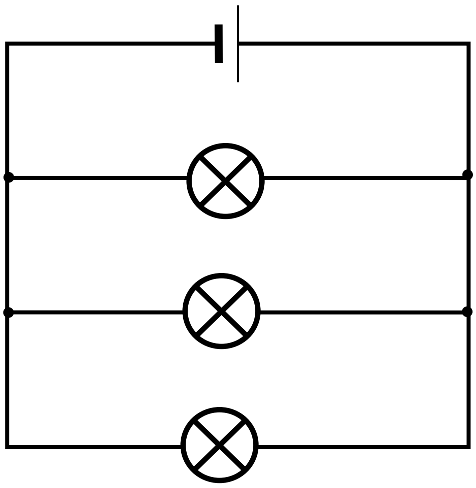
(*a*)



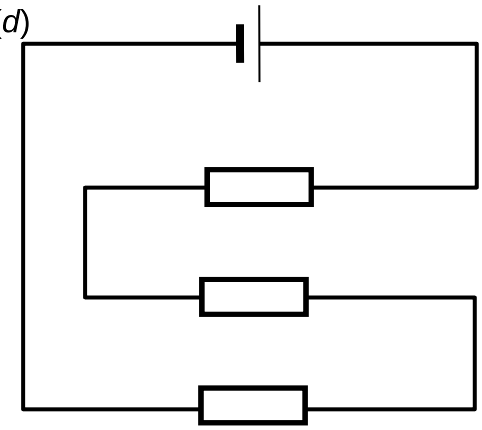
(*b*)



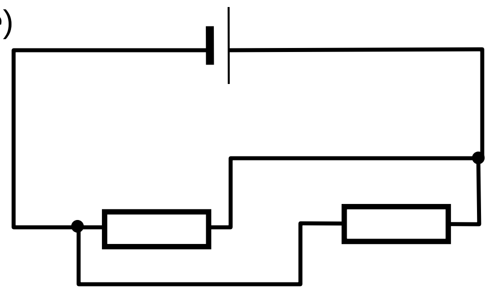
(*c*)



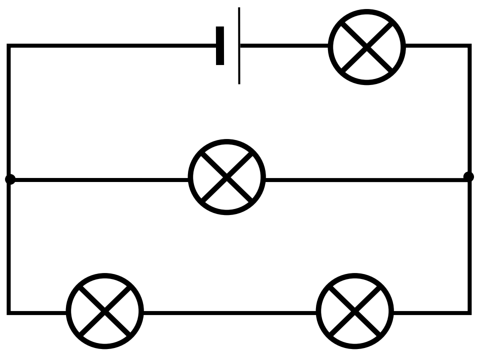
(*d*)



(*e*)

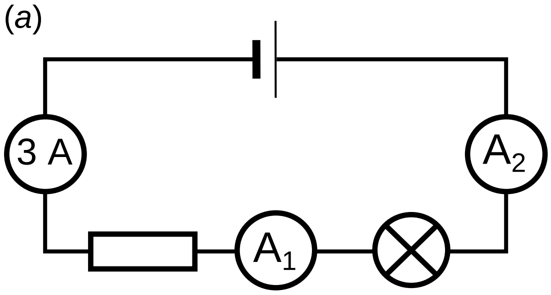


(*f*)

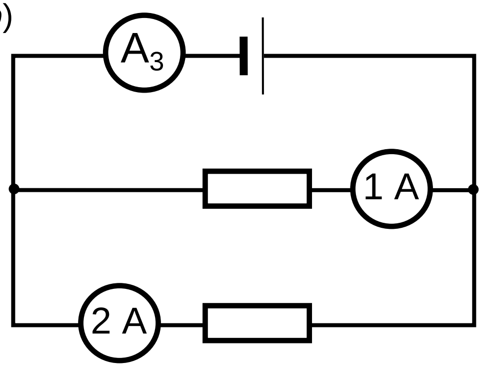


35. Look at the circuits below. Use your knowledge of how current and voltage behave in series and parallel circuits to find the readings on the ammeters and voltmeters.

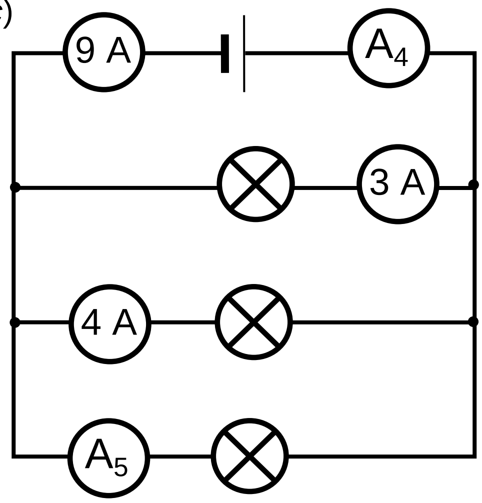
(*a*)



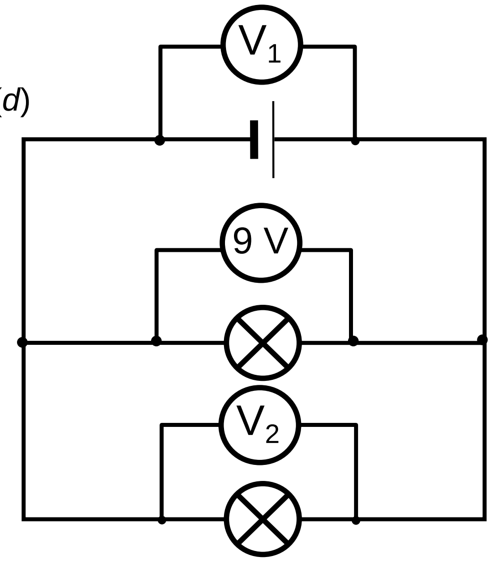
(*b*)



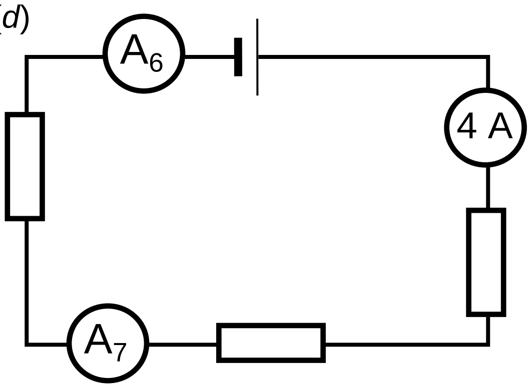
(*c*)



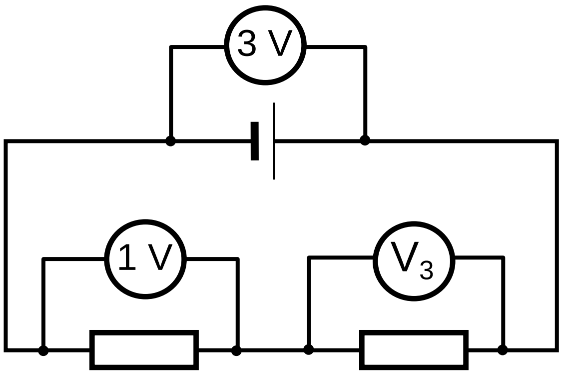
(*d*)



(*d*)



(*e*)



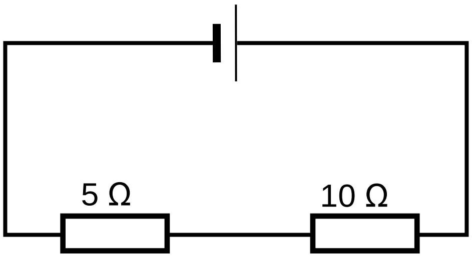
Resistors in series and parallel

36. Write down a formula that can be used to find the total resistance of three resistors connected in series.

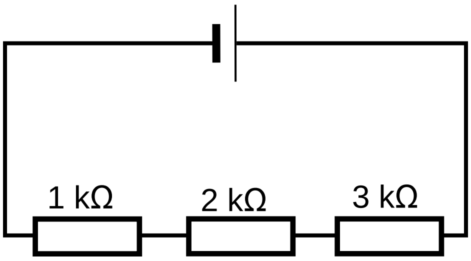
37. Write down a formula that can be used to find the total resistance of three resistors connected in parallel.

38. The circuit diagrams below show resistors connected in series. Calculate the total resistance of the circuits.

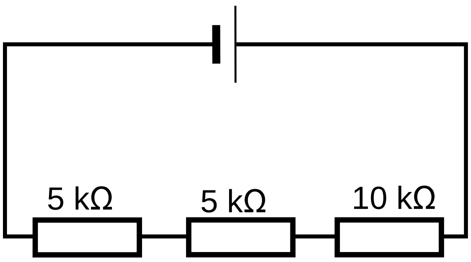
(*a*)



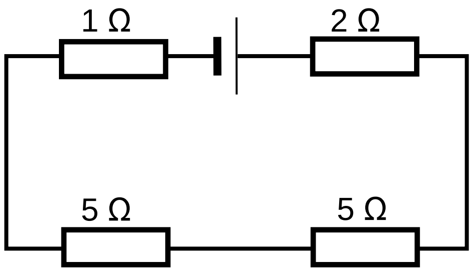
(*b*)



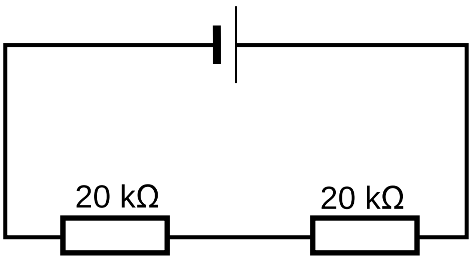
(*c*)



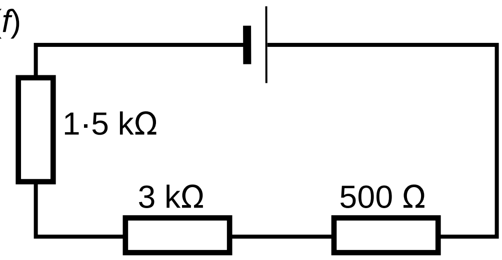
(*d*)



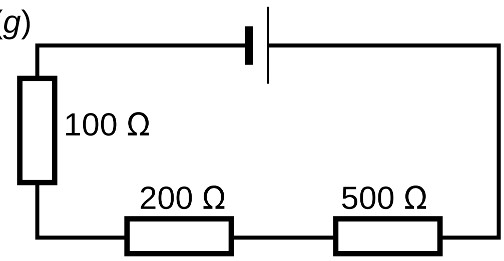
(*e*)



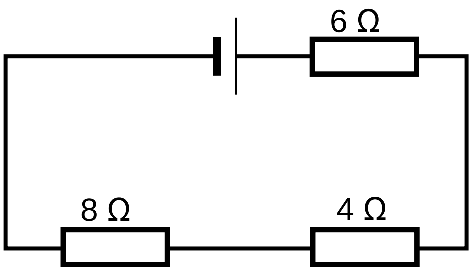
(*f*)



(*g*)

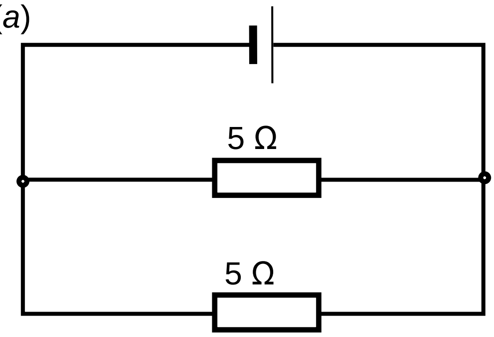


(*h*)

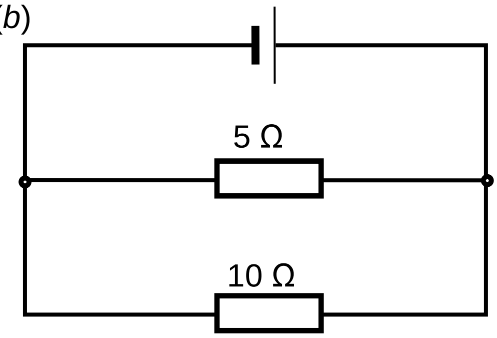


39. The circuit diagrams below show resistors connected in parallel. Calculate the total resistance of the circuits.

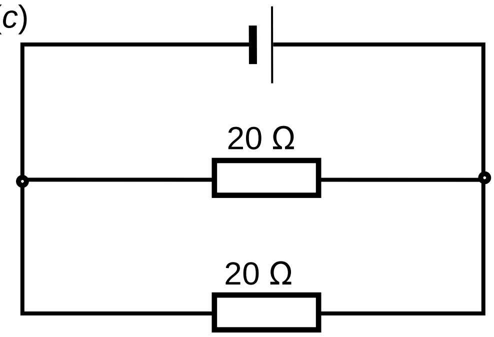
(*a*)



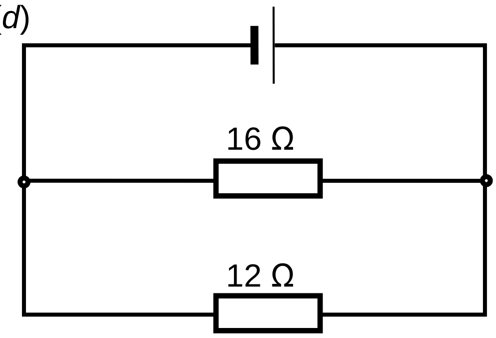
(*b*)



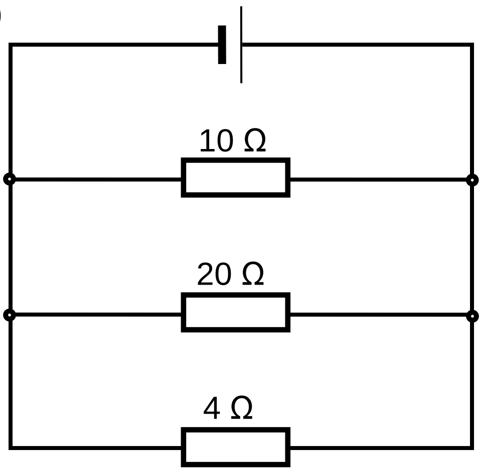
(*c*)



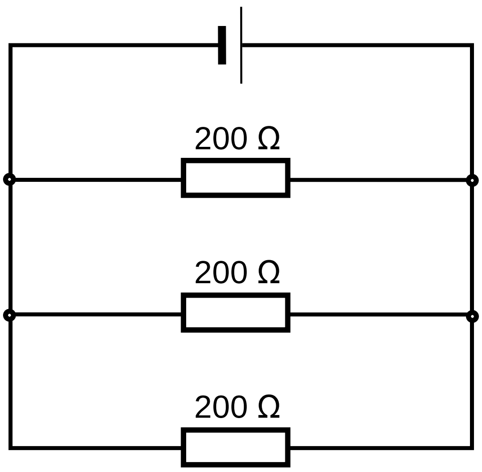
(*d*)



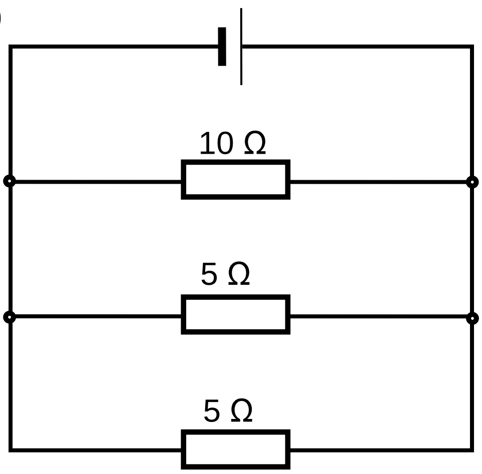
(*e*)



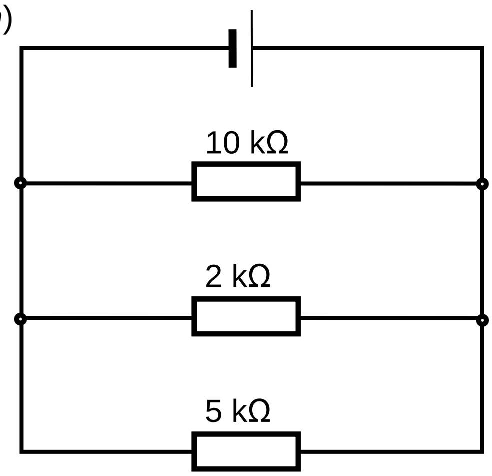
(*f*)



(*g*)

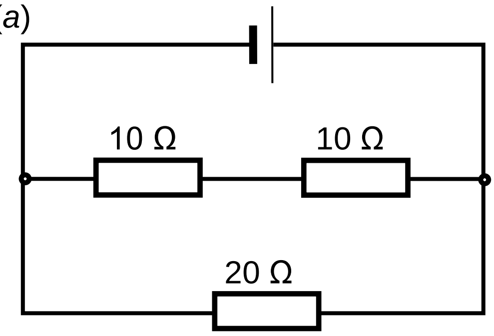


(*h*)

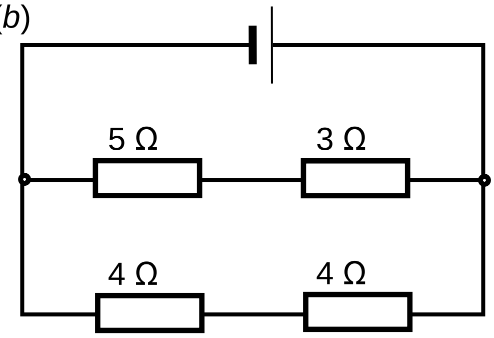


40. The circuit diagrams below show resistors connected in a mixture of series and parallel. Calculate the total resistance of the circuits.

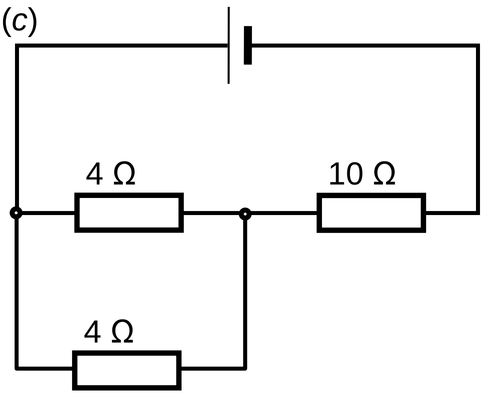
(*a*)



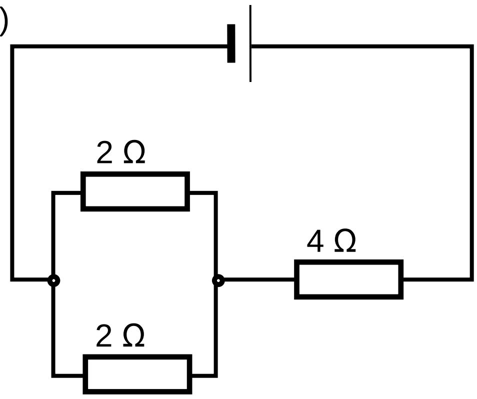
(*b*)



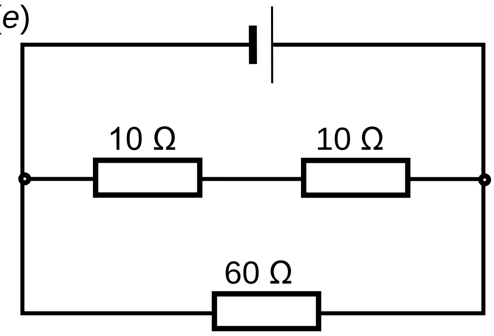
(*c*)



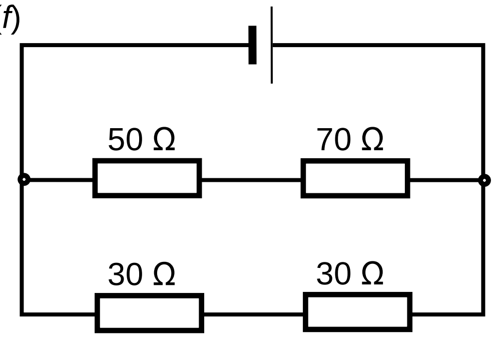
(*d*)



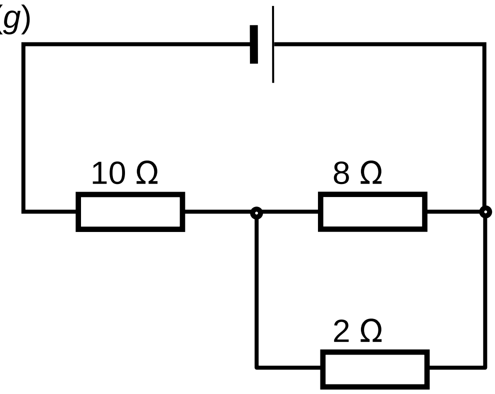
(*e*)



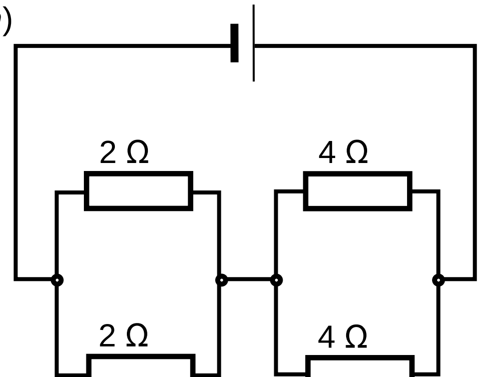
(*f*)



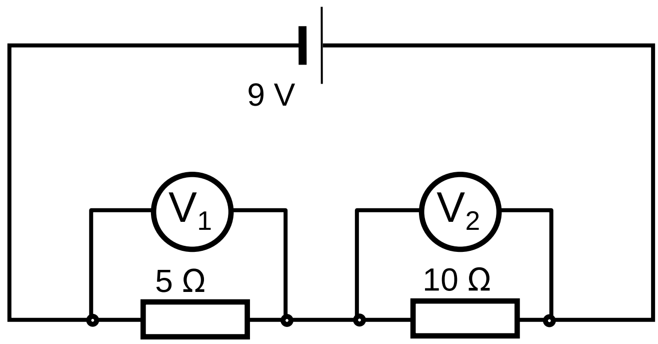
(*g*)



(*h*)



41. A circuit consists of two resistors connected in series.



(*a*) Calculate the total resistance of the circuit.

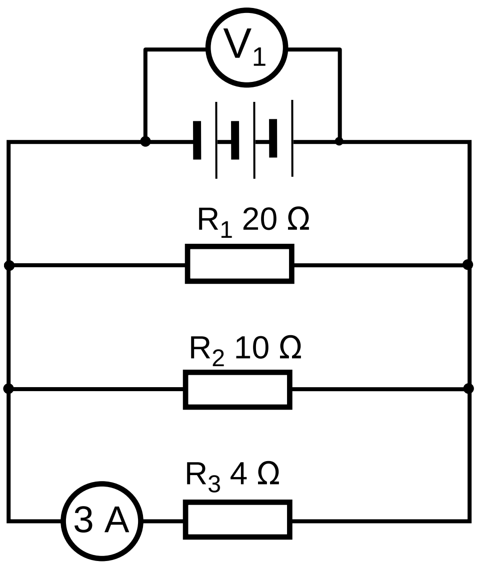
(*b*) A 9 V cell is used as the power source. Calculate the current in the circuit

(*c*) Calculate the readings on:

(i) Voltmeter V_1;

(ii) Voltmeter V_2.

42. A pupil connects three resistors as shown in the circuit opposite.



(*a*) Calculate the total resistance of the circuit.

(*b*) The current through the 4 Ω resistor is 3 A. Calculate the voltage across R_3.

(*c*) State the voltage across R_1 and R_2.

(*d*) State the reading on meter V_1.

(*e*) Calculate the current through:

(i) Resistor R_1;

(ii) Resistor R_2.

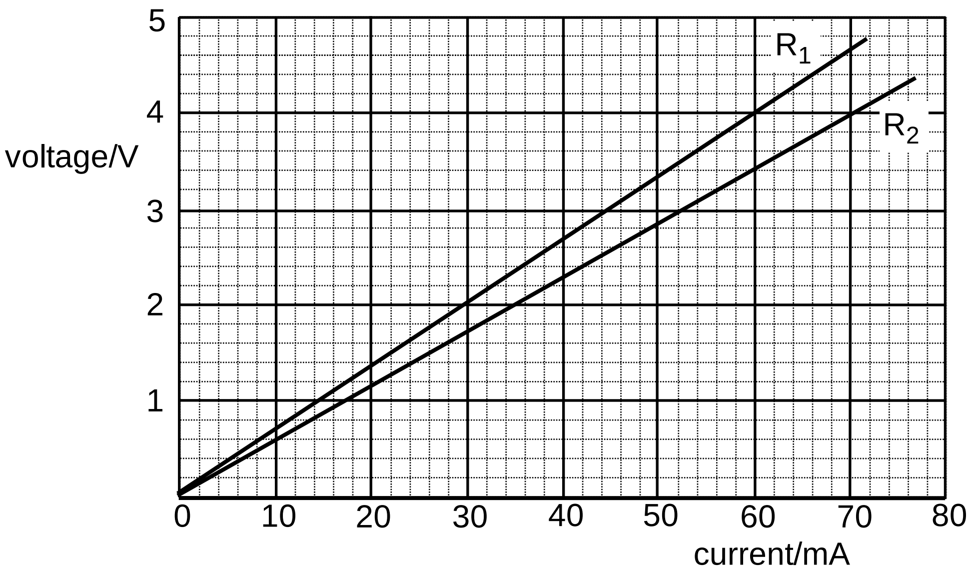
Extension Questions

43. An electronics company supplies resistors in packets of ten. The resistors should be within 5% of their stated value.

(*a*) (i) The stated value of the resistors is 60 Ω. Calculate 5% of 60 Ω.

(ii) What is the allowed range of values for the resistors.

(*b*) A pupil takes two of the resistors and, after connecting them to a power supply, measures the current through the resistors at various values of voltage. The graph obtained is shown below.



(i) Use the graphs to find the value of R_1 and R_2.

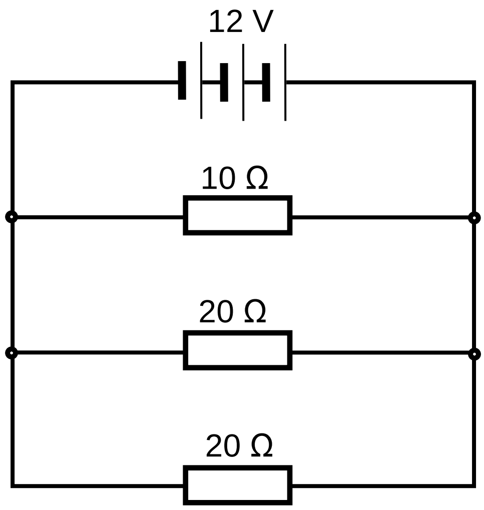
(ii) State if the resistors fall within the allowable range.

(*c*) Three 60 Ω resistors are connected in parallel. Calculate their total resistance.

(*d*) A pupil needs a 150 Ω resistor to complete an electronics project but only has 60 Ω resistors available.

Show how a number of 60 Ω resistors could be connected together to provide the correct resistance.

44. A pupil connects three resistors in parallel as shown below.



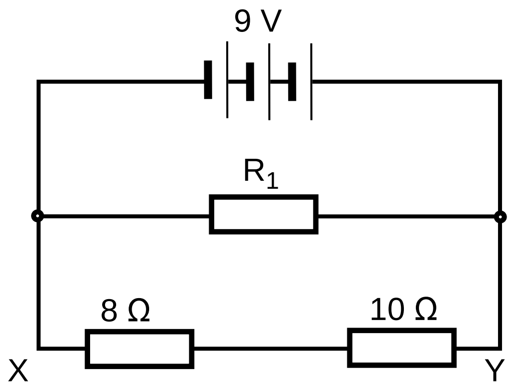
(*a*) (i) Calculate the total resistance of the circuit.

(ii) Calculate the current leaving the power supply.

(iii) One of the resistors develops a fault and no longer conducts. State and explain the effect this will have on the current leaving the power supply.

(*b*) Another pupil suggests placing a voltmeter across each of the resistors in turn to find which is faulty. Comment on the effectiveness of this suggestion.

45. Examine the circuit shown below.



(*a*) State the voltage between points X and Y.

(*b*) The voltage across the 8 Ω resistor is 4 V. Calculate the voltage across the 10 Ω resistor.

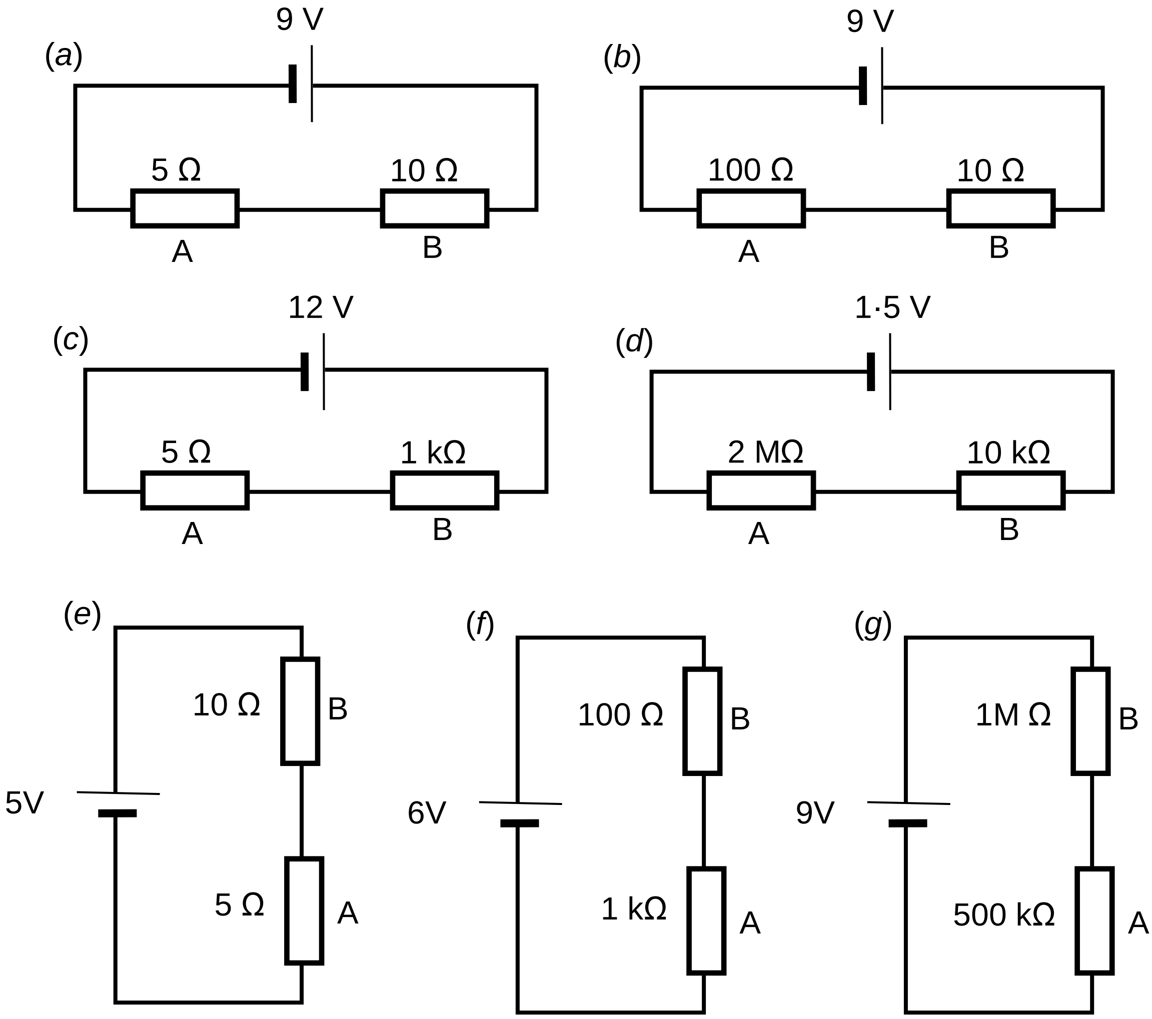
(*c*) Calculate the total resistance between points X and Y.

(*d*) Calculate the current flowing between X and Y in the circuit.

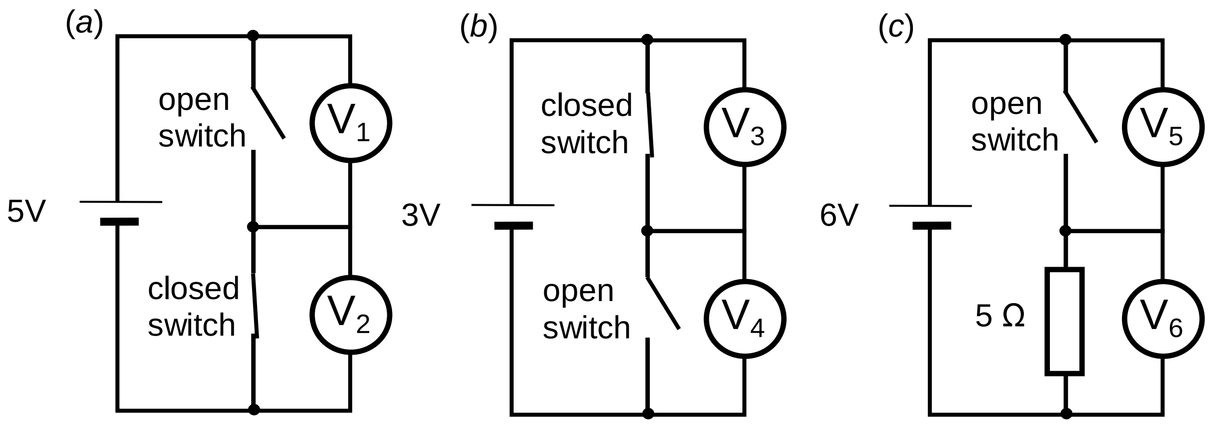
(*e*) The current through R_1 is 1·5 A. Calculate the resistance of R_1.

46. If two resistors are in series across a supply the voltage will be divided between them. The higher the resistance the larger the share of voltage across that resistance.

State which resistor in the circuit diagrams below will have the larger voltage across it.

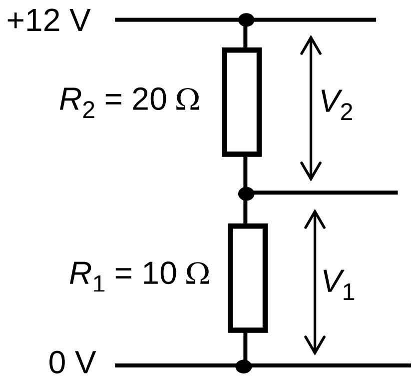


47. A switch which is open will have infinite resistance, a closed switch will have zero resistance. Use this information to state the voltages across the switches in the following circuits.



48. Read the passage below on voltage dividers.

Potential or voltage dividers are used to divide a voltage. It may use a mixture of resistors, variable resistors and devices such as thermistors or light dependent resistors. The voltage across any single resistor depends upon what proportion its resistance is of the total resistance of the circuit. Suppose we want to find the voltage across the two resistors in the circuit shown below.



The 12 V supply voltage will divide in proportion between the 10 Ω and 20 Ω resistors. The voltage across each resistor can be calculated as follows.

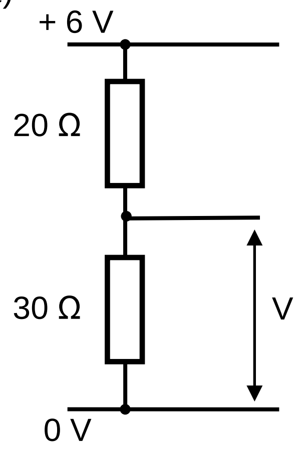
Total resistance of circuit = 20 Ω + 10 Ω = 30 Ω.

so, $V_1 = \frac{10}{30} \times 12 = 4\text{ V}$ *and* $V_2 = \frac{20}{30} \times 12 = 8\text{ V}$

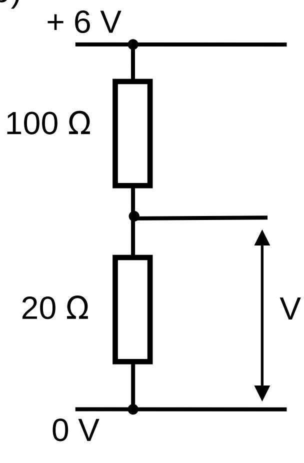
This can be put into a general formula $V_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times V_{supply}$

Use the above information to calculate the voltage, V, in each of the following voltage dividers.

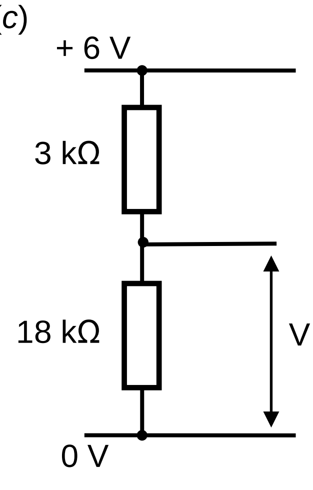
(*a*)



(*b*)



(*c*)



Electronic circuits

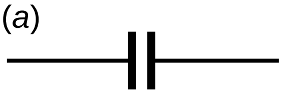
49. Match the symbols of the following electrical components with the symbols shown below.

diode loudspeaker thermistor

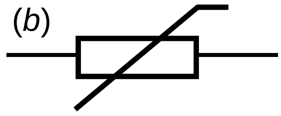
light dependent resistor photovoltaic cell transistor

motor relay LED capacitor

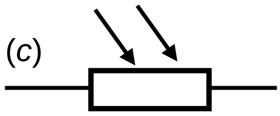
(*a*)



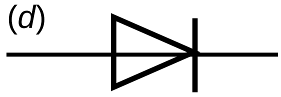
(*b*)



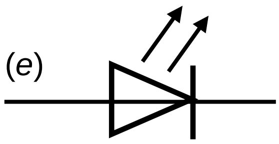
(*c*)



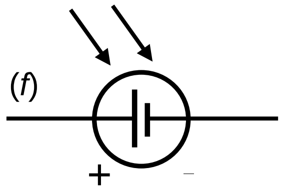
(*d*)



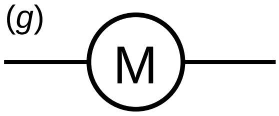
(*e*)



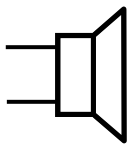
(*f*)



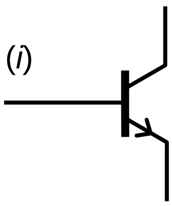
(*g*)



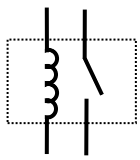
(*h*)



(*i*)



(*j*)



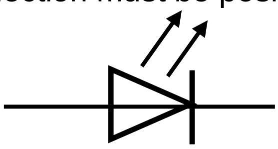
50. Some of the devices in question 49 are input devices and some are output devices. Copy and tick the appropriate box to show which is which. The first is done for you.

Device	***Input device***	***Output device***
(*a*) loudspeaker		✓
(*b*) capacitor		
(*c*) LED		
(*d*) LDR		
(*e*) thermistor		
(*f*) relay		

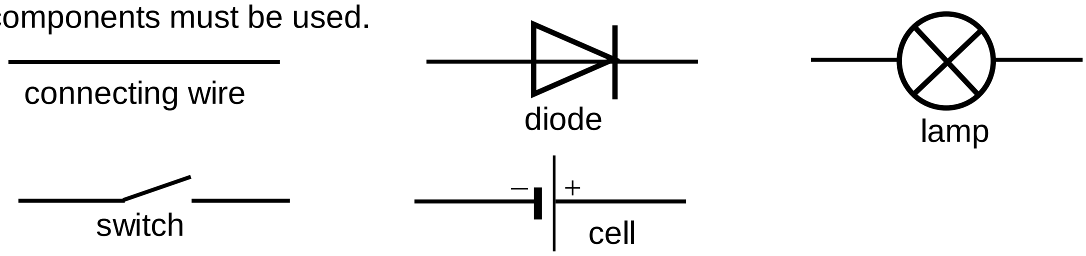
51. The table below lists a number of electronic devices. Copy and complete the table to show the energy input and the energy output.

Device	***Input energy***	***Output energy***
(*a*) loudspeaker		
(*b*) LED		
(*c*) LDR		
(*d*) thermistor		
(*e*) relay		
(*f*) motor		
(*g*) photovoltaic cell		

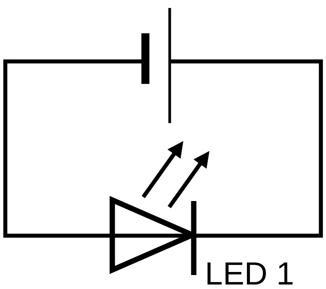
52. The circuit symbol for a light emitting diode is shown below Copy the symbol and indicate which connection must be positive and which negative for the LED to light.

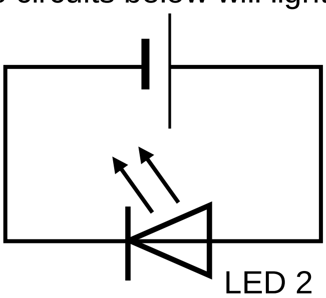


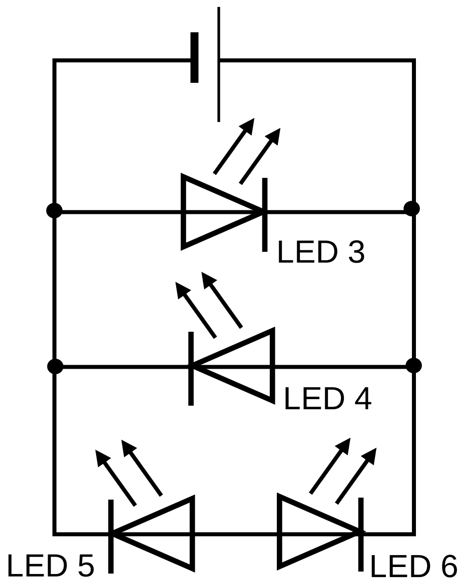
53. The list of components shown below are available to a pupil. Use these to construct a circuit diagram which will allow the lamp to light. All the components must be used.



54. State which of the LEDs in the circuits below will light.







55. Draw the symbol for a capacitor and state its function.

56. A capacitor is connected to a 12 V power supply in series with a resistor.

(*a*) What will be the voltage across the capacitor when it is:

(i) fully charged;

(ii) uncharged.

(*b*) The resistor is replaced with one with a larger resistance. State the effect this has on:

(i) the time it takes to charge;

(ii) the final charge stored on the capacitor;

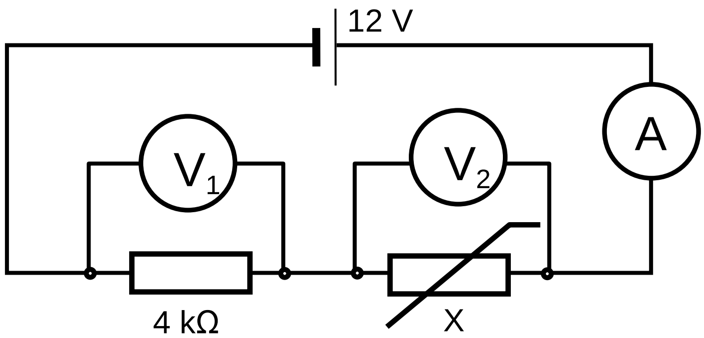
(iii) the final voltage across the capacitor.

57. Copy and complete the paragraph on electronic components using the words given below.

resistance temperature decreases increases does not change

A resistor will normally have a resistance which __________. The resistance of some devices will change according to certain factors. The resistance of a thermistor changes with __________. For most thermistors, as the temperature increases its resistance __________. LDRs change their __________ with changing levels of light. As the light levels decrease, the resistance of the LDR __________.

58. Look at the circuit diagram opposite.



(*a*) Name component X.

(*b*) The ammeter indicates a current of 2 mA. Calculate the voltage reading on the voltmeter V_1.

(*c*) Calculate the voltage reading on V_2.

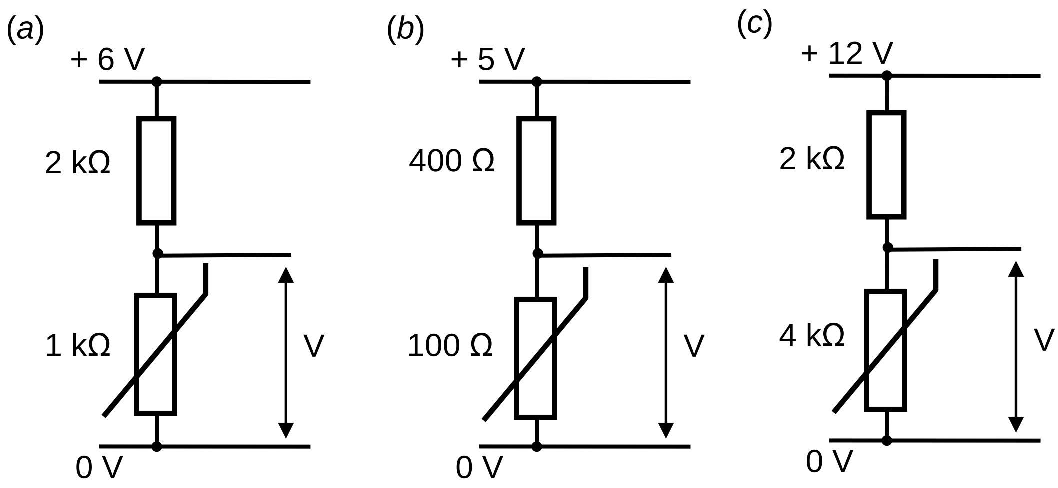
(*d*) Calculate the resistance of component X.

(*e*) State what will happen to the reading on the ammeter if:

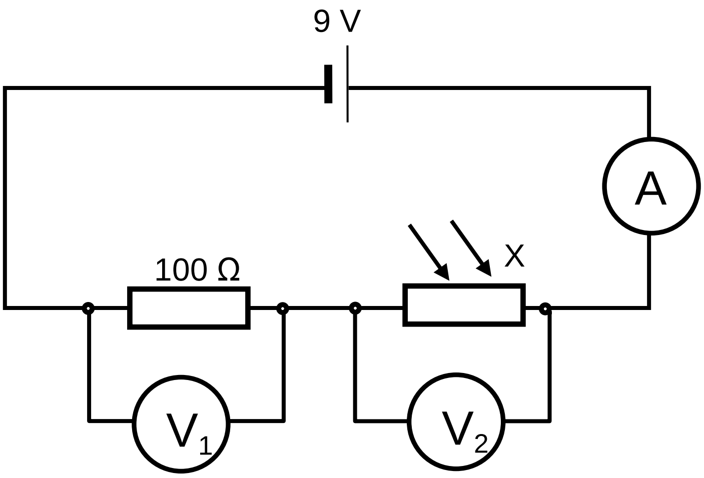
(i) the temperature of the 4 kΩ resistor rises;

(ii) the temperature of component X rises

59. Each of the circuits below contain a resistor and thermistor. Calculate the voltage across the thermistor in each one.



60. Look at the circuit diagram below.



(*a*) Name component X.

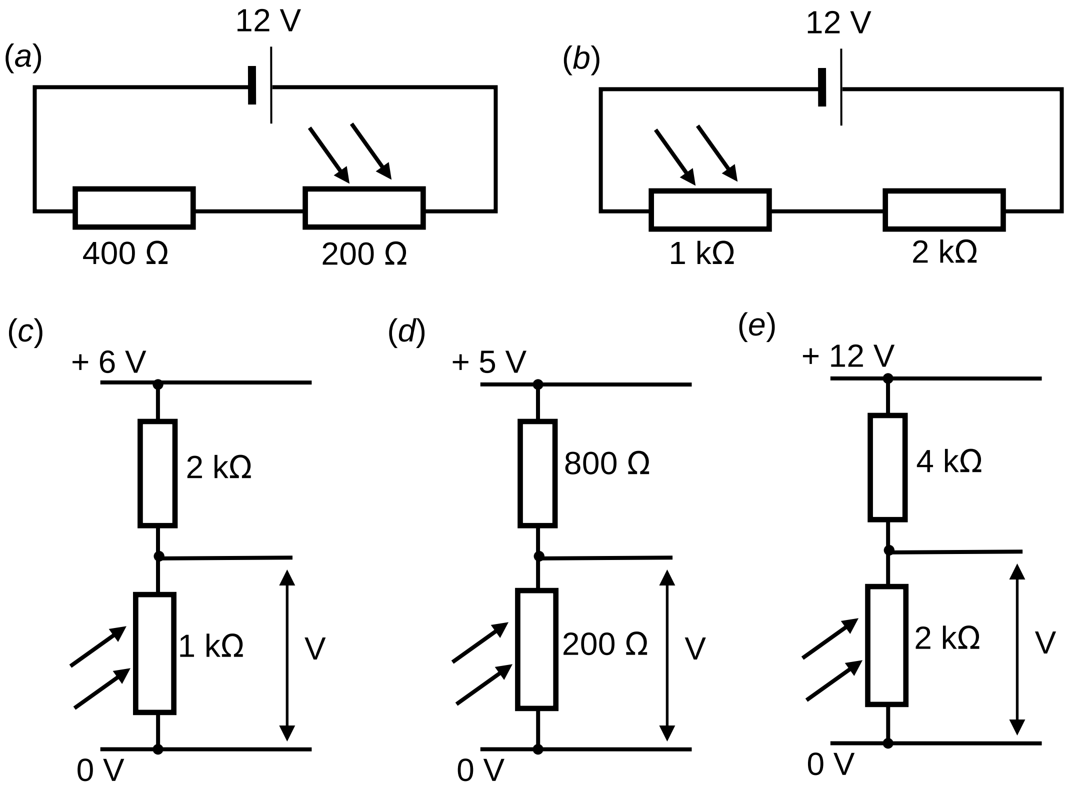
(*b*) The ammeter indicates a current of 30 mA. Calculate the voltage reading on the voltmeter V_1.

(*c*) Calculate the voltage reading on V_2.

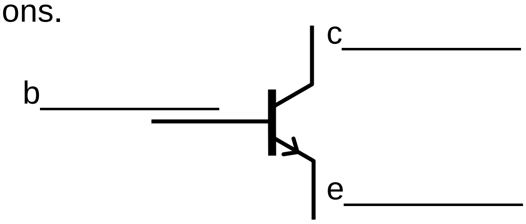
(*d*) Calculate the resistance of component X.

(*e*) State what will happen to the reading on the ammeter if the light level falling on component X increases.

61. Each of the circuits below contain a resistor and alight dependent resistor (LDR). Calculate the voltage across the LDR in each one.



62. Copy the circuit symbol for a NPN transistor and give the full name of the three connections.

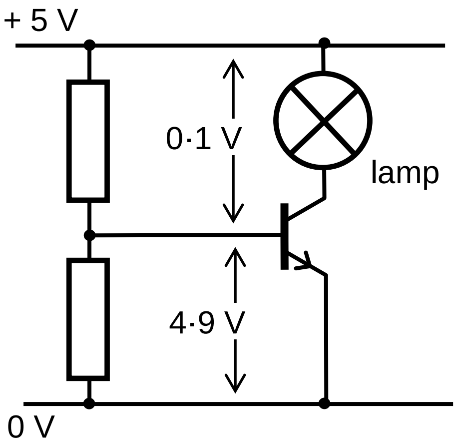


63. Here are some statements about NPN transistors. State which are true and which are false.

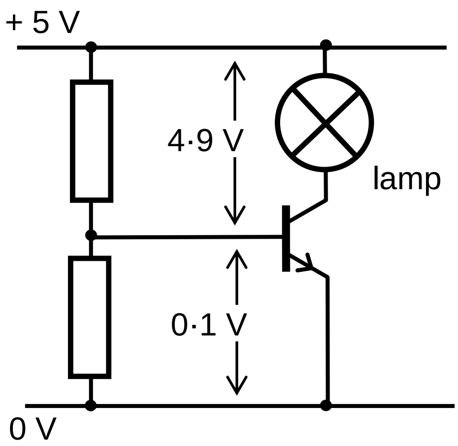
1. NPN transistors can be used as an electronic switch.
2. NPN transistors are used to convert an a.c. supply to a d.c. supply.
3. NPN transistors are 'switched on' by a voltage between the base and emitter.
4. NPN transistors are 'switched on' by a voltage between the emitter and collector.
5. A NPN transistor which is on conducts through the emitter and collector.
6. A voltage of 0·7 V and above switches on a NPN transistor.
7. NPN transistors conduct very large currents.

64. For each of the circuits below, state whether the lamp connected to the NPN transistor is alight or not.

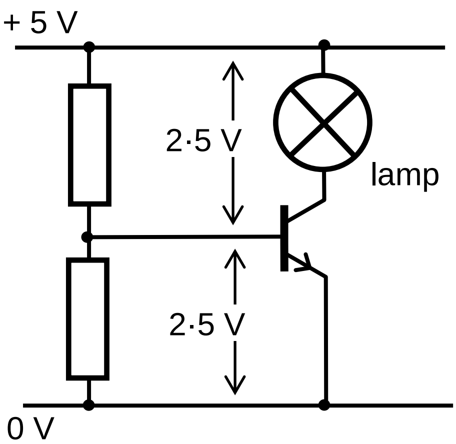
(*a*)



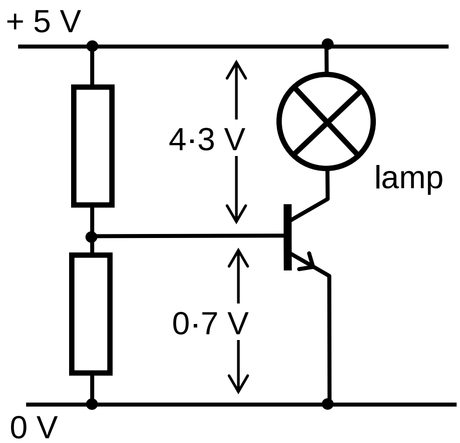
(*b*)



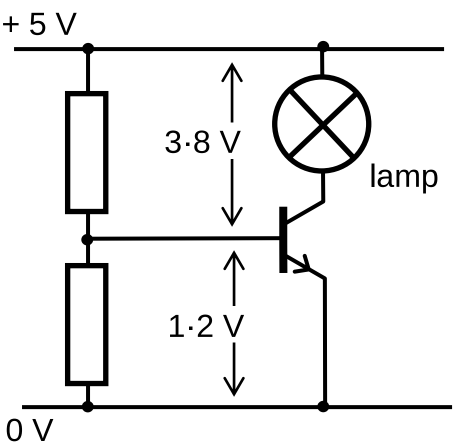
(*c*)



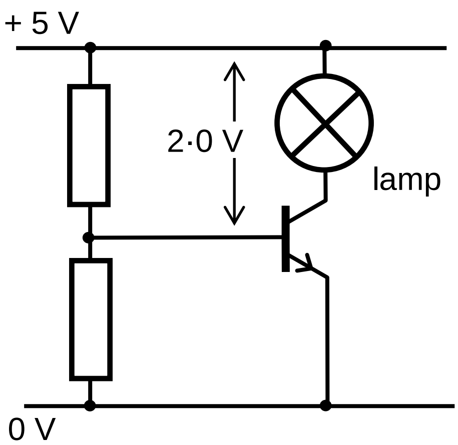
(*d*)



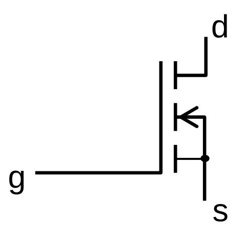
(*e*)



(*f*)



65. Look at the circuit symbol opposite.



(*a*) Name the component.

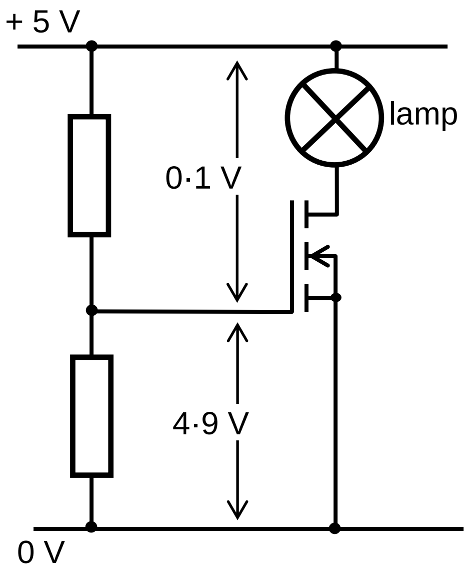
(*b*) Name the component connections labelled g, d and s.

66. Here are some statements about MOSFET transistors. State which are true and which are false.

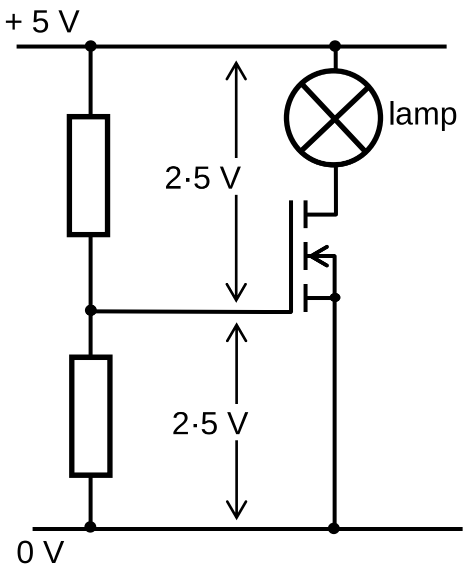
1. MOSFET transistors can be used as an electronic switch.
2. MOSFET transistors are used to convert a d.c. supply to an a.c. supply.
3. MOSFET transistors are ‘switched on’ by a voltage between the source and drain.
4. MOSFET transistors are ‘switched on’ by a voltage between the gate and source.
5. A MOSFET transistor which is on conducts through the source and drain.
6. A voltage of 2·0 V and above switches on a MOSFET transistor.
7. MOSFET transistors conduct very large currents.

67. For each of the circuits below, state whether the lamp connected to the MOSFET transistor is alight or not.

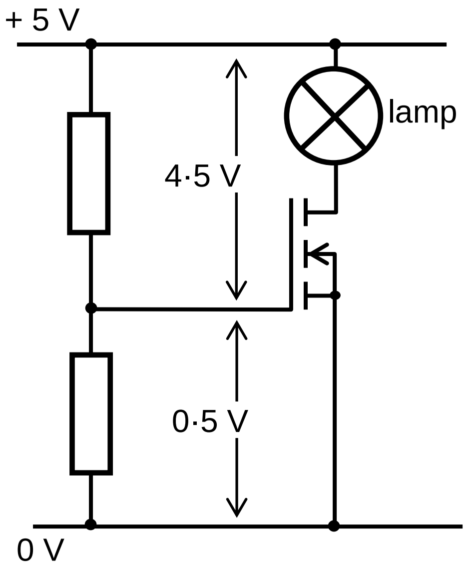
(*a*)



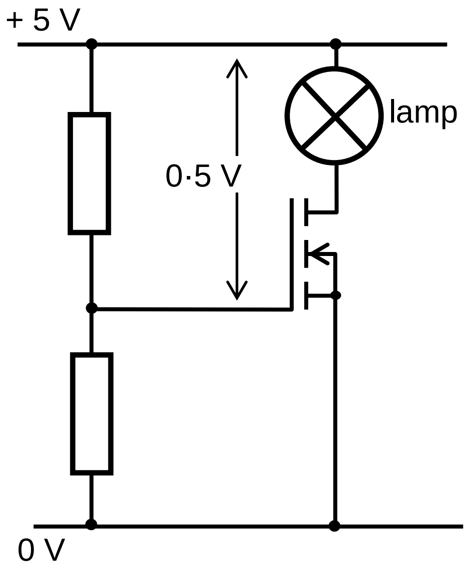
(*b*)



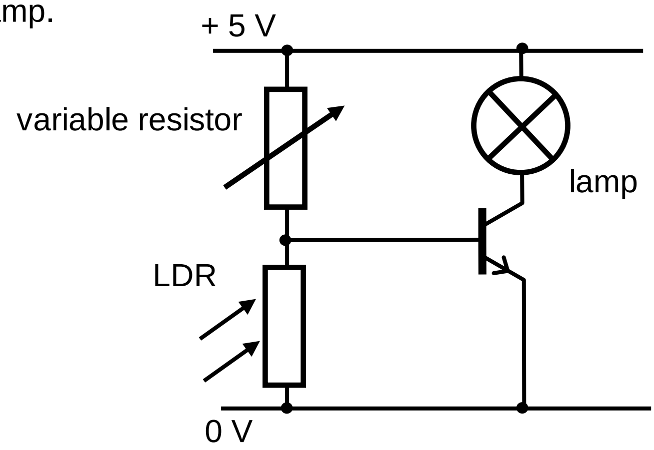
(*c*)



(*d*)



68. An electronic circuit containing a light dependent resistor is used to switch on a small lamp.

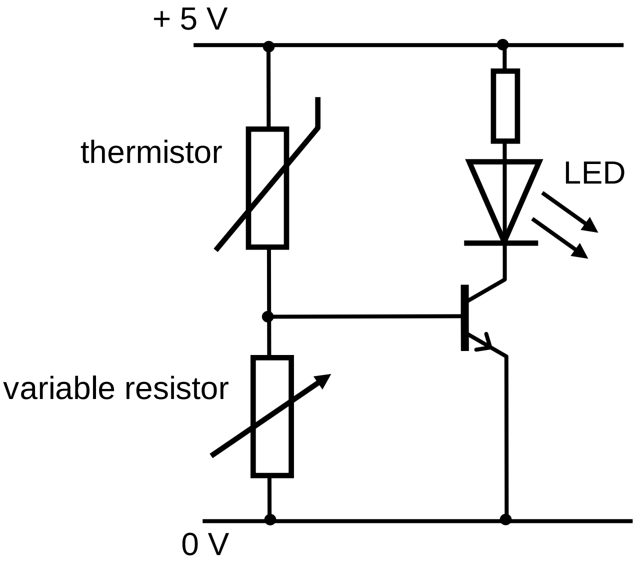


(*a*) When will the LDR have the greatest resistance – in the dark or in the light?

(*b*) At night, the variable resistor is adjusted till the lamp just comes on. What must be the minimum voltage across the LDR for this to happen?

(*c*) Why will the lamp switch off when it is daylight?

69. A thermistor is used to in a circuit to switch on a LED in a refrigerator if its temperature rises above a pre-set level.



(*a*) What happens to the resistance of the thermistor as its temperature rises?

(*b*) (i) What will happen to the voltage across the thermistor if its resistance falls?

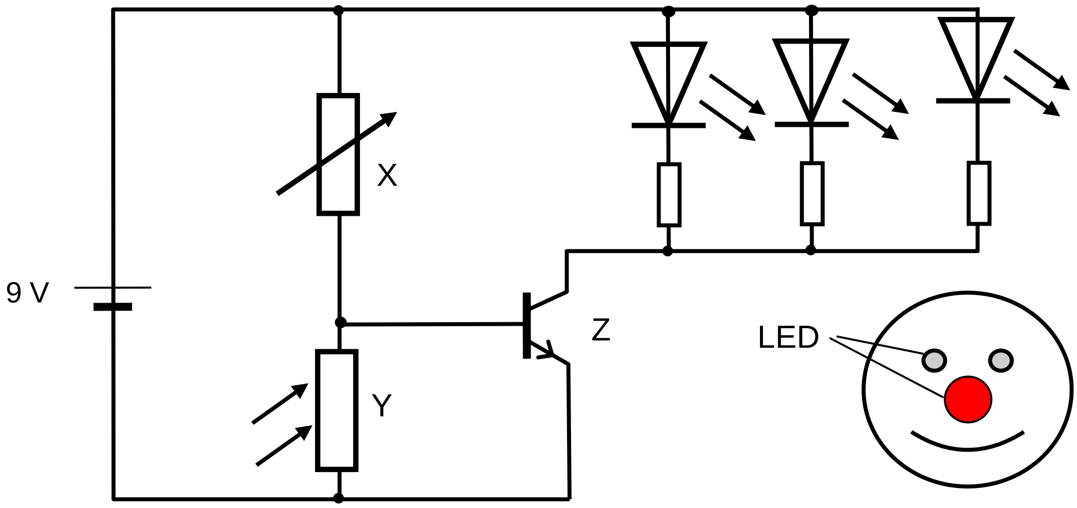
(ii) If the resistance of the thermistor falls, what will happen to the voltage across the variable resistor?

(*c*) What is the effect on the transistor if the voltage across the variable resistor increases above 0·7 V?

(*d*) How can the temperature at which the LED comes on be controlled?

Extension Questions

70. A pupil designs a night light for his little sister. It consists of a happy face with LEDs for the nose and eyes which come on when it gets dark. The circuit for the light is shown below.



(*a*) Name the components labelled X, Y and Z.

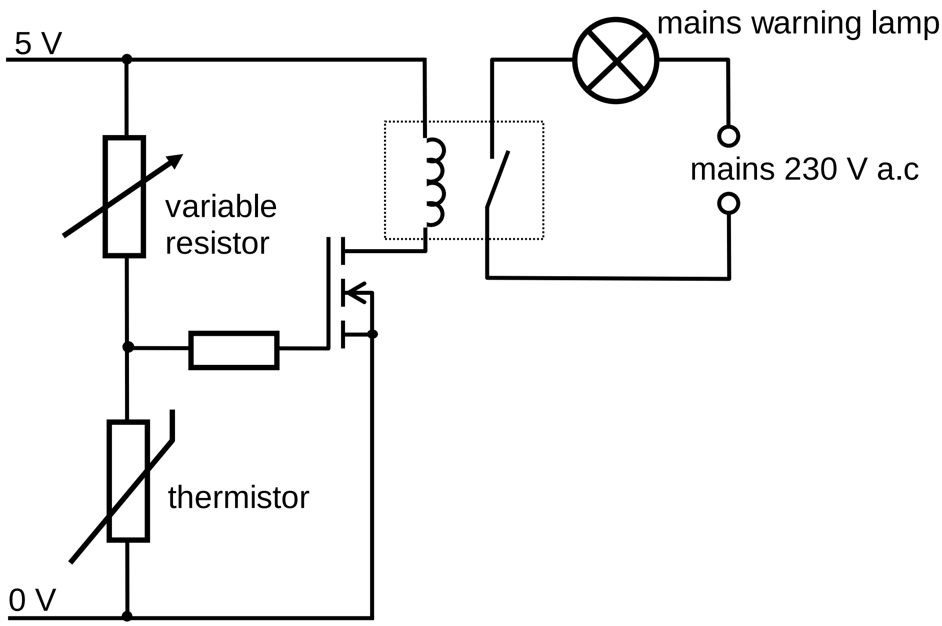
(*b*) (i) What will happen to the resistance of Y when it is placed in the dark.

(ii) State what will happen to the voltage across Y as a consequence.

(iii) Explain the effect this has on the LEDs.

(*c*) What would be the effect of reversing the connections to the LEDs?

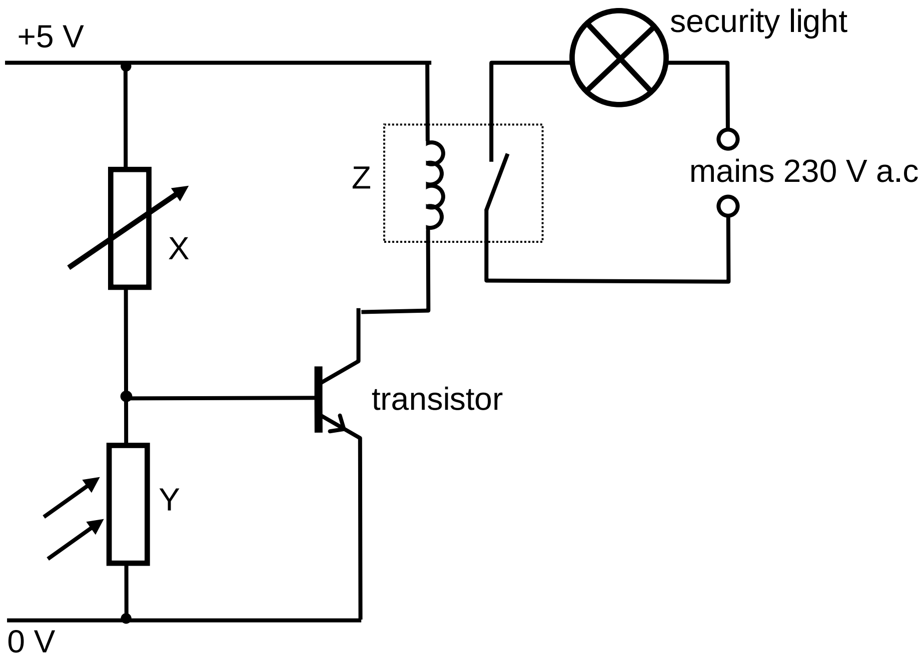
71. A pupil is asked to design a circuit that will switch on a warning lamp when the temperature in a chilled warehouse rises above a certain value.
The circuit she designed is shown opposite.
The resistance of the thermistor increases as its temperature increases.



(*a*) Explain why the warning light comes on as the temperature of the warehouse rises.

(*b*) Explain why MOSFET transistor cannot be used directly to light the lamp.

72. A pupil is asked to design a circuit that will switch on a high powered security spotlight when it gets dark. The circuit she designed is shown below.



(*a*) Name components labelled X, Y and Z.

(*b*) Explain why the security light will come on when it gets dark.

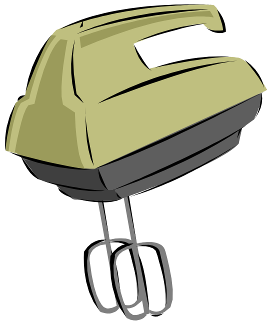
(*c*) How can the light levels at which the security light comes on be altered?

(*d*) Give two reasons why the transistor cannot be used to switch on the security light directly.

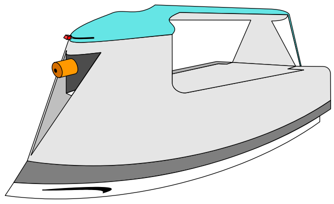
Electrical Power

73. Shown below are three common objects that convert electrical energy.

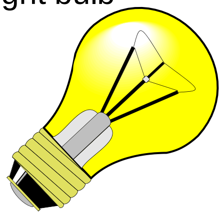
food mixer



iron



light bulb



(*a*) State the energy conversion that takes place for each appliance.

(*b*) Give an estimate for the power (joules per second) for ach appliance.

74. Several appliances which use electrical energy are listed below.

radio electric oven television table lamp curling tongs.

(*a*) Rank the appliances with the one which uses most energy first and the least energy last.

(*b*) Possible power ratings for the appliances are given below. Match an appropriate power rating with each appliance.

10 W 8000 W 750 W 300 W 60 W

(*c*) What do appliances which have a high power rating have in common?

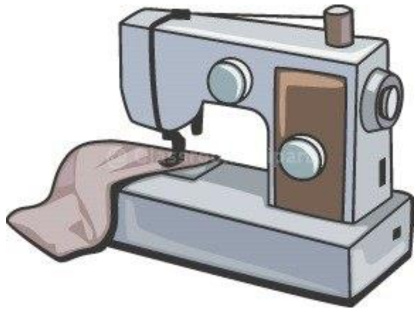
75. State an equation that links power, energy and time.

76. Calculate the missing values in the table below.

Power	***Energy***	***Time***
(*a*)	100 J	10 s
(*b*)	2000 J	2 s
40 W	4000 J	(*c*)
2000 W	120 000 J	(*d*)
10 W	(*e*)	100 s
1200 W	(*f*)	300 s

77. Calculate the power of an appliance which consumes 200 J of energy in 100 s.

78. A sewing machine has a power rating of 100 W. Calculate the time it will operate for on 3000 J of energy.



79. A steam iron consumes 32 000 J of energy in 40 s. Calculate the power of the iron.

80. A washing machine has an average power of 600 W over its was cycle.

(*a*) How many joules of energy are used during a wash cycle lasting 30 minutes.

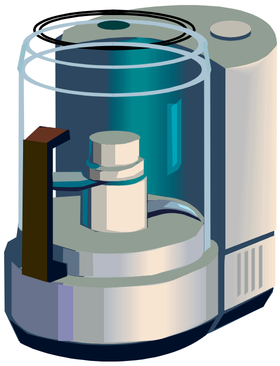
(*b*) At times, the power rating of the washing machine is much higher than the average of 600 W. Suggest a reason for this.

81. State an equation that links power, current and voltage.

82. Calculate the missing values in the table below.

Power	***Current***	***Voltage***
(*a*)	3 A	230 V
(*b*)	0·5 A	12V
1150 W	5 A	(*c*)
60 W	5 A	(*d*)
2·5 kW	(*e*)	230 V
2 W	(*f*)	12 V

83. A food processor draws a current of 2 A. Calculate the power of the processor if it is connected to the mains supply at 230 V.



84. A mains appliance draws a current of 6 A. Calculate its power.

85. What current will be drawn by a low voltage 12 V, 50 W light bulb.

86. A small hand held torch has a power of 3 W. Calculate the voltage of the supply if the current to the torch filament is 500 mA.

87. A mains hair drier is rated at 1200 W

(*a*) What will be the current to the hair drier when operating at its maximum power?

(*b*) The drier contains a fan and heating elements. Which of these will consume the most power?

88. State an equation that links power, current and resistance.

89. Calculate the missing values in the table below.

Power	***Current***	***Resistance***
(*a*)	3 A	30 Ω
(*b*)	0·5 A	60 Ω
800 W	5 A	(*c*)
60 W	5 A	(*d*)
690W	(*e*)	76 Ω
6 W	(*f*)	24 Ω

90. A heating element has a resistance of 57·5 Ω and draws a current of 4 A. Calculate its power.

91. What current will be drawn by a low voltage 48 W light bulb which has a resistance of 3 Ω.

92. A circuit has a resistance of 4 kΩ. Calculate the power of the circuit if the current flowing in the circuit is 3 mA.

93. A 100 Ω resistor used in a circuit is rated at 0·5 W. What is the maximum current that can flow through it if used at its maximum rating?

94. A portable camping heater has a power rating of 920 W. It is connected to a mains power point at 230 V.

(*a*) What will be the current to the heater when it is operational?

(*b*) Calculate the resistance of the heating element.

95. State an equation that links power, voltage and resistance.

96. Calculate the missing values in the table below.

Power	***Voltage***	***Resistance***
(*a*)	230 V	40 Ω
(*b*)	12 V	10 Ω
1000 W	100 V	(*c*)
60 W	230 V	(*d*)
2·0 kW	(*e*)	5 Ω
0·5 W	(*f*)	200 Ω

97. An electric fan is connected to the mains at 230 V. Calculate its operational resistance if it has a power of 50 W.

98. An electric kettle is rated at 2·2 kW. Calculate the resistance of the element if it is connected to the mains at 230 V.

99. A low voltage spotlight used in a kitchen operates from 12 V. Calculate the power of the lamp if it has a resistance of 3 Ω.

100. A 12V, 36 W light bulb is connected to a 12 V supply. Calculate the resistance of the filament.

Fuses

101. Draw the symbol for a fuse.

102. By law, the plug of every electrical appliance sold in the UK must have the correct size of fuse fitted. Explain the purpose of the fuse in the plug.

103. What is the danger if too large a fuse being used in a plug?

104. Fuses for plugs are most commonly available as 3 A, 5 A and 13 A values.

(*a*) Calculate the current that is normally used by the following appliances and then state which size fuse would be used in the plug. All the appliances are connected to the mains at 230 V.

(i) A 60 W table lamp.

(ii) A 2kW electric heater.

(iii) An 800 W microwave oven.

(iv) A 500 W fridge-freezer.

(*b*) Why would a 3 A fuse be unsuitable for an 850 W mains sandwich toaster?

Image courtesy of John Kasawa/FreeDigitalPhotos.net

Extension Questions

105. (*a*) A current flows through a resistor in a circuit. It produces 288 J of energy in 2 minutes. Calculate the power of the resistor.

(*b*) When electrical energy flows through the resistor it is changed into another form. State what this is.

106. A fan heater operates from the mains. It has a power rating of 2 kW.

(*a*) What is the value of mains voltage?

(*b*) Calculate the resistance of the heating element.

107. A physics teacher has a new kitchen installed and decides to find the total power of all the appliances in the kitchen. These are listed below.

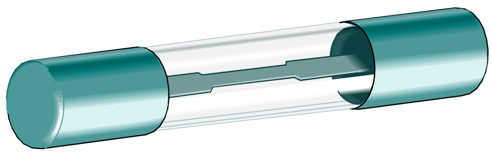
Oven and hob	7000 W
Cooker hood	500 W
Dishwasher	1200 W
Fridge-freezer	450 W
Microwave	700 W
Washing machine	500 W

(*a*) Calculate the total power consumption if all appliances are on simultaneously.

(*b*) Calculate the total current supplied to the oven and hob.

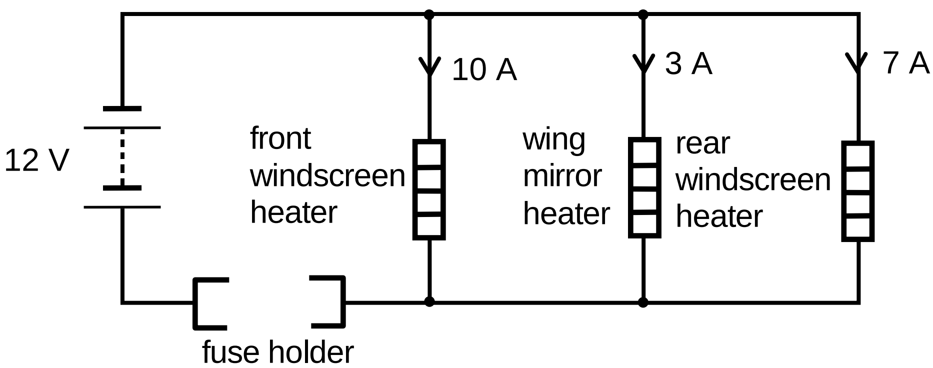
(*c*) Why must the oven and hob have separate cabling rather than being supplied by a mains socket like the other appliances?

108. A car contains several electrical circuits powered from the 12 V car battery. They are protected by a fuse like the one shown opposite.



(*a*) Draw the circuit symbol for a fuse and state its function in a circuit.

(*b*) One circuit in the car supplies power to a range of heating elements in the windscreens and door mirrors as shown below.



(i) What is the minimum rating of fuse which could be used to protect this circuit?

(ii) Calculate the power of the rear windscreen heater.

109. The rating plate shown below is found on an portable oil filled radiator.

> Voltage 230 V a.c. 50 Hz
> Power 2·2 kW
>
> Must not be used in bathrooms
> Do not cover heater

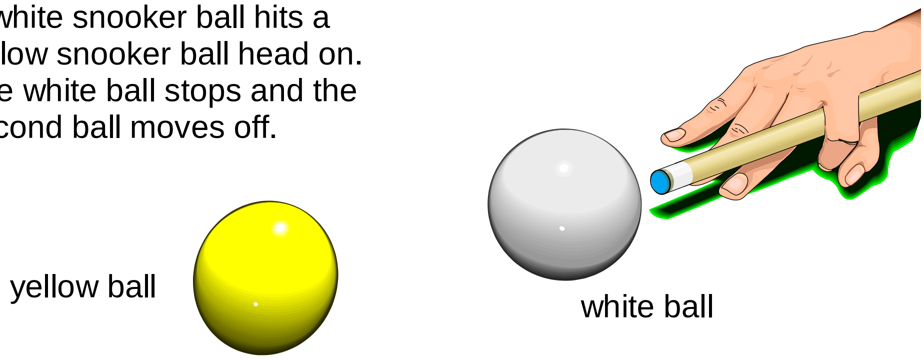
(*a*) The flex to the radiator is protected by a fuse in the plug. Calculate the current drawn by the radiator element and state what size of fuse would be appropriate.

(*b*) Calculate the resistance of the element.

Conservation of energy

110. State the principle of conservation of energy.

111. A white snooker ball hits a yellow snooker ball head on. The white ball stops and the second ball moves off.



(*a*) State the energy transfer which took place.

(*b*) The yellow and white balls have the same mass but the yellow ball moves slightly more slowly than the white ball. Explain why.

112. A hydro-electric power station stores water behind a dam. The water flows downhill through pipes to turn the turbine and generator which produces the electricity.

(*a*) State the energy change when:

(i) the water runs down hill through the pipe.

(ii) the generator produces electricity.

(*b*) In each instance in part (*a*), some of the energy is lost. Explain where these energy losses occur in (i) and (ii).

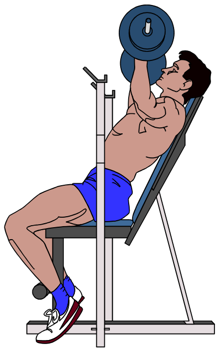
Potential energy

113. State an equation that links potential energy, mass and height.

114. Calculate the missing values in the table below.

Potential energy	***Mass***	***Height***	***g***
(*a*)	3 kg	20 m	9·8 N kg^{-1}
(*b*)	0·5 kg	5 m	9·8 N kg^{-1}
392 J	2 kg	(*c*)	9·8 N kg^{-1}
78·4 J	200 g	(*d*)	9·8 N kg^{-1}
147 J	(*e*)	3 m	9·8 N kg^{-1}
2·45 J	(*f*)	0·25 m	9·8 N kg^{-1}

115. A weightlifter pushes up weights with a mass of 80 kg. Calculate their gain in potential energy if they are raised a height of 0·6 m.



116. A 200 g mass is lifted onto a table. How high must the table be if the mass is to gain 12·25 J of potential energy?

117. A skydiver is at a height of 3000 m. What will be his mass if he has 1·47 MJ of potential energy?

118. On the Apollo missions to the moon in the 1970s, an astronaut dropped a hammer with a mass of 0·8 kg to the ground.

(*a*) Calculate the potential energy of the hammer on the earth if it is dropped from a height of 1·5 m.

(*b*) If the hammer is dropped from the same height on the moon, what will be its potential energy if the value of g on the moon is 1·6 N kg^{-1}

Kinetic energy

119. State an equation that links kinetic energy, mass and speed.

120. A lorry is used to collect waste from houses for recycling.

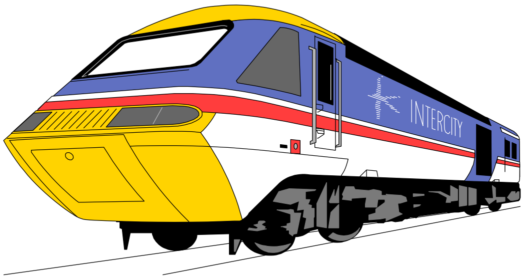
(*a*) Assuming the lorry drives at the same speed, what will happen to its kinetic energy as it collects more and more waste. Give a reason for your answer.

(*b*) The lorry increases its speed. How will this affect its kinetic energy?

121. Calculate the missing values in the table below.

Kinetic Energy	***Mass***	***Speed***
(*a*)	2 kg	4 m s^{-1}
(*b*)	80 kg	0·5 m s^{-1}
16 J	4 kg	(*c*)
1000 J	80 kg	(*d*)
360 000	(*e*)	30 m s^{-1}
2 kJ	(*f*)	20 m s^{-1}

122. A train has a mass of 900 × 10^3 kg. Calculate the kinetic energy of the train if it is travelling at 30 m s^{-1}.



123. Andy Murray can serve a tennis ball at 145 miles per hour which is 65 m s^{-1}. Calculate the kinetic energy of the ball if its mass is 0·058 kg.

124. A car is travelling at 20 m s^{-1} and has 120 000 J of kinetic energy. Calculate the mass of the car.

125. A ball with a mass of 0·5 kg is released at the top of a slope. It rolls down the slope and at the foot has 2·25 J of kinetic energy.

(*a*) Calculate the speed the ball was travelling at.

(*b*) Where did the ball get its kinetic energy from?

126. A fork lift truck is moving packing cases about a factory.

(*a*) Calculate the kinetic energy of the truck if it is travelling at 0·5 m s^{-1} and has a total mass of 1800 kg.

(*b*) If the driver allows the fork lift truck to 'free-wheel' it gradually slows down. Where has its kinetic energy gone to?

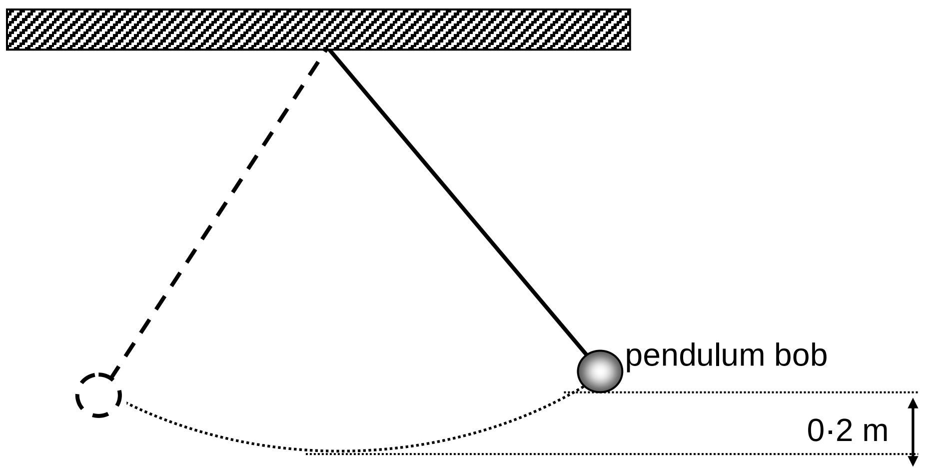
Potential and kinetic energy transfer

127. A student throws a basket ball through the hoop in a game of basket ball. The ball rests on the hoop momentarily before falling through it to the ground. The hoop is 3·0 m above the ground.

(*a*) Calculate the potential energy of the ball as it falls through the hoop. The ball has a mass of 0·5 kg.

(*b*) Calculate the maximum speed of the ball as it falls to the ground.

128. A pendulum is raised 0·2 m above its rest position as shown below. The pendulum has a mass of 0·2 kg.

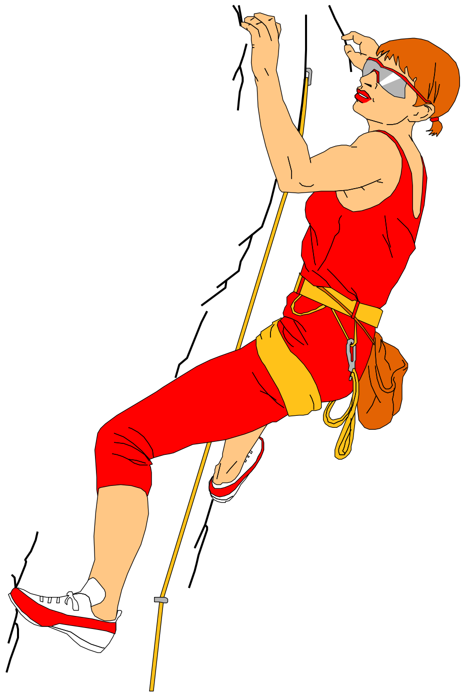


(*a*) Calculate the potential energy of the pendulum when it is pulled back.

(*b*) State the maximum kinetic energy the bob will have as it swings after being released.

(*c*) The pendulum does not rise as high on the other side of the swing. Explain why.

129.



A climber has a mass of 60 kg. As she is climbing she slips and falls from the rock face. Fortunately she is attached by a rope.

At the end of her fall, her speed has reached 12 m s^{-1}.

(*a*) Calculate the kinetic energy the climber has at the end of her fall.

(*b*) Assuming no energy is lost during her fall, what distance did she drop before the rope stopped her?

Extension Questions

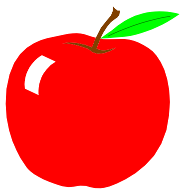
130. During a game of volleyball, a player knocks a ball vertically into the air.

(*a*) The ball travels upwards at 8 m s^{-1}. Calculate its kinetic energy if it has a mass of 0·3 kg.

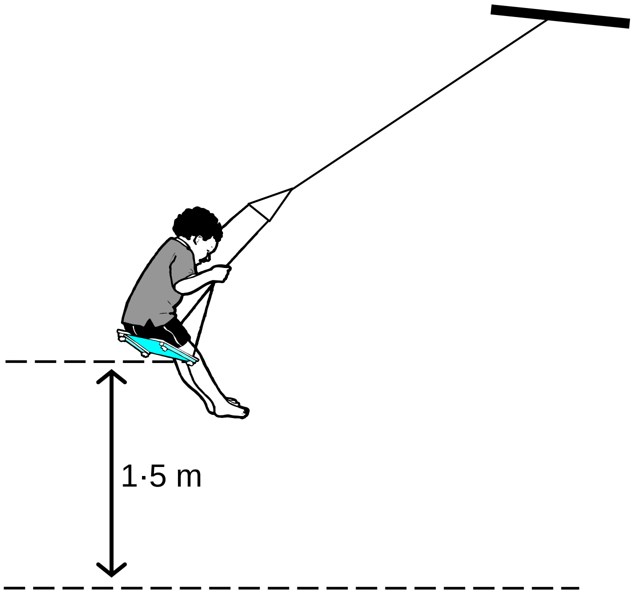
(*b*) (i) Calculate the height the ball would reach if there were no energy losses.

(ii) The height the ball actually reaches is less than that calculated in part (i). Explain why this is.

131. A pupil drops an apple from a height of 1·5 m. Calculate the speed with which it hits the ground assuming there are no energy losses during its fall.



132. A pupil is using a swing in a play park. At the top of his swing he is 1·5 m above the lowest point of the swing. The child has a mass of 20 kg.



(*a*) Calculate the potential energy of the child at the top of his swing.

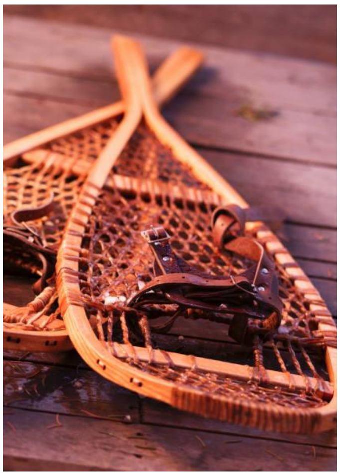
(*b*) (i) What will be the kinetic energy of the child at the lowest point of his swing?

(ii) Calculate the speed of the child when at the lowest point of his swing.

(*c*) The child notices that if he sits still, the swing will never rise up to as high a point as he started from. Explain this observation.

Pressure, force and area

133. An Eskimo wears snow shoes to walk on soft snow. Explain how these are able to stop him sinking into the snow.



134. A sharp knife is able to slice a tomato much more easily than a blunt knife. Explain the physics behind this fact.

135. Ladies stiletto heels may be very fashionable but they are notorious for damaging floors by leaving indentations, especially on wooden flooring. Explain why this happens.

136. State an equation that links pressure, force and area.

137. Calculate the missing values in the table below.

Pressure	***Force***	***Area***
(*a*)	100 N	4 m^2
(*b*)	20 N	0·5 m^2
50 kPa	750 N	(*c*)
1×10^5 Pa	1000 N	(*d*)
2×10^5 Pa	(*e*)	0·05 m^2
100 kPa	(*f*)	0·2 m^2

138. A large book has an area of 0·015 m^2. Calculate the pressure under the book if the downward pressure it exerts due to its weight is 10 N.

139. A mechanical digger exerts a downwards force of 12 000 N. Its caterpillar tracks cover an area of 3·0 m^2. Calculate the pressure the digger exerts on the ground.

140. A map pin has a point which has an area of 1×10^{-7} m^2

(*a*) What will be the pressure below the point when the pin is pressed with a force of 10 N?

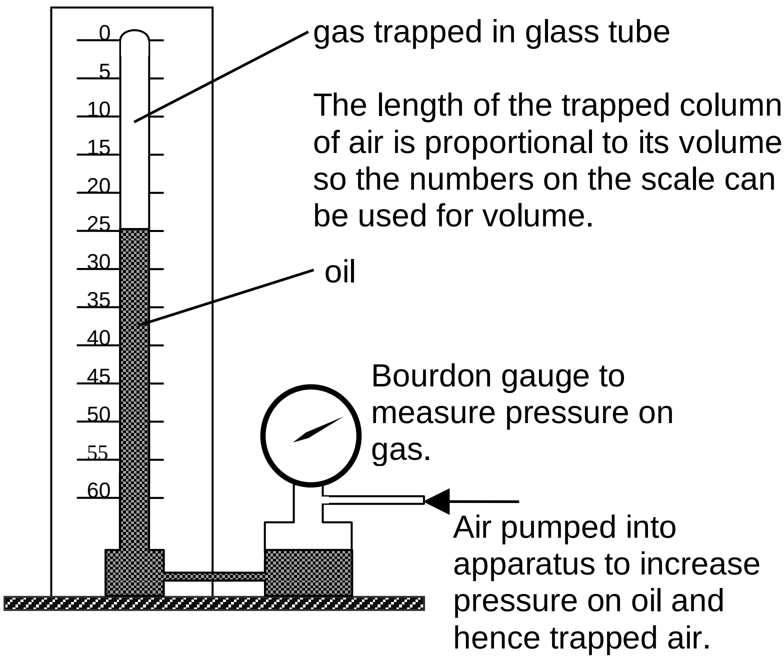
(*b*) Explain why a sharp point to the pin makes it very easy to push into a pin board.

Extension Questions

141. A ballerina stands on one toe during a dance. The ballerina has a weight of 450 N. Make suitable estimates of the area of her shoe in contact with the ground and hence calculate the pressure which will be exerted on the floor by her foot.

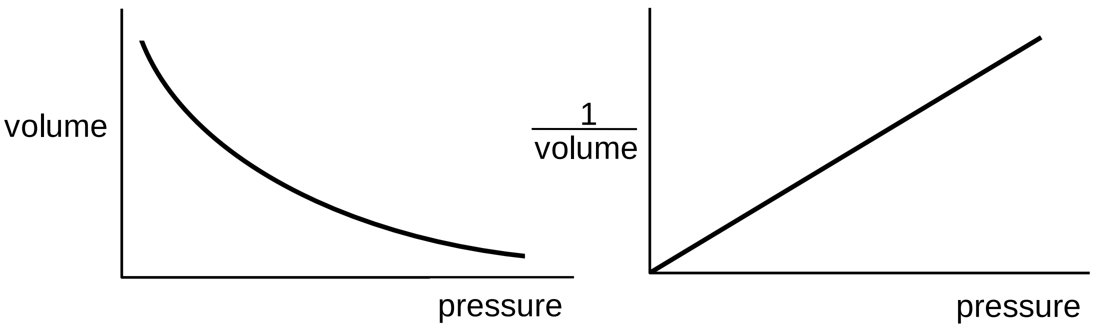
Pressure and volume

142. A class carries out an experiment to find the relationship between the pressure on a gas and its volume. The apparatus used is shown opposite.



(*a*) The volume, temperature and pressure of a gas are all linked. Which quantity is kept constant in this experiment.

(*b*) Graphs of pressure against volume and pressure against $\frac{1}{\text{volume}}$ are plotted from the results as shown below. State the relationship between the pressure and volume of the gas in the tube.

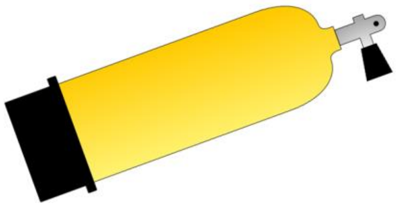


143. Give an equation that can be used to relate the changing pressure and volume of a fixed mass of gas.

144. Calculate the missing values in the table below.

Pressure p_1	***Volume V_1***	***Pressure p_2***	***Volume V_2***
1×10^5 Pa	0·5 m^3	(*a*)	4 m^3
2×10^5 Pa	1 m^3	(*b*)	0·01 m^3
200 kPa	5×10^{-3} m^3	600 kPa	(*c*)
1000 kPa	4 litres	50 kPa	(*d*)
(*e*)	1×10^{-3} m^3	$0·5 \times 10^5$ Pa	5×10^{-3} m^3
(*f*)	2 litres	2×10^5 Pa	10 litres
50 kPa	(*g*)	500 kPa	0·5 m^3
15 kPa	(*h*)	5 kPa	0·2 litres

145. A gas cylinder has a volume of 0·001 m^3. The gas it contains is at a pressure of
3×10^6 Pa. Calculate the volume of gas that would be released at atmospheric pressure of 1×10^5 Pa.



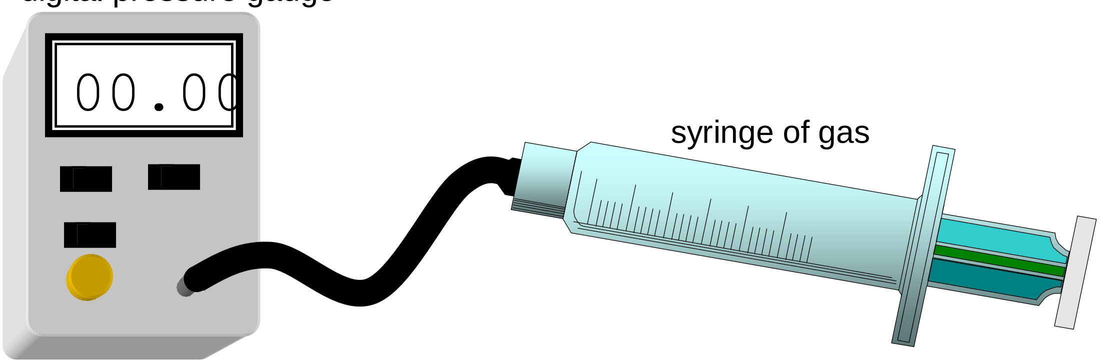
146. A scuba diver is working at a depth where the pressure is 4×10^5 Pa. Bubbles released when she breathes out rise to the surface, expanding as they do so.

(*a*) Explain why the bubbles expand as they rise.

(*b*) The volume of each air bubble as the diver breathes out is 2×10^{-6} m^3. At the water surface the pressure is 1×10^5 Pa. Calculate the volume of each bubble when it reaches the surface.

147. A canister contains 0·002 m^3 of gas at a pressure of 6×10^5 Pa. What will be the volume of the gas at 2×10^5 Pa?

148. A class perform an experiment to find the relationship between the volume and pressure of a gas. A syringe is connected to a digital pressure gauge as shown below.



The pupils record the following results from the experiment.

Pressure in kPa	***Volume in cm³***	$\frac{1}{\textbf{Volume}}$
100	14·7	
150	9·9	
200	7·4	
250	5·9	
300	4·9	

(*a*) Copy and complete the table by calculating the value of 1/volume for these results.

(*b*) Plot a graph of pressure against 1/volume and state the relationship between them.

(*c*) Calculate the gas pressure in the syringe if its volume was reduced to 2 cm^3.

Kelvin scale

149. When dealing with gases and temperature, a temperature scale called the Kelvin scale is used. Each division on the Kelvin scale is the same size as divisions on the Celsius scale.

(*a*) The temperature of a gas increases by 20 °C. What is the increase in temperature of the gas in Kelvin?

(*b*) What temperature is 0 K in degrees Celsius?

150. Convert the following temperatures from the Celsius scale to the Kelvin scale.

(*a*) 0 °C

(*b*) 27 °C

(*c*) 127 °C

(*d*) –273 °C

(*e*) –173 °C

(*f*) 77 °C

(*g*) –127 °C

(*h*) 346 °C

(*i*) 18 °C

(*j*) 100 °C

151. Convert the following temperatures from the Kelvin scale to the Celsius scale.

(*a*) 0 K

(*b*) 273 K

(*c*) 293 K

(*d*) 300 K

(*e*) 373 K

(*f*) 173 K

(*g*) 323 K

(*h*) 50 K

(*i*) 623 K

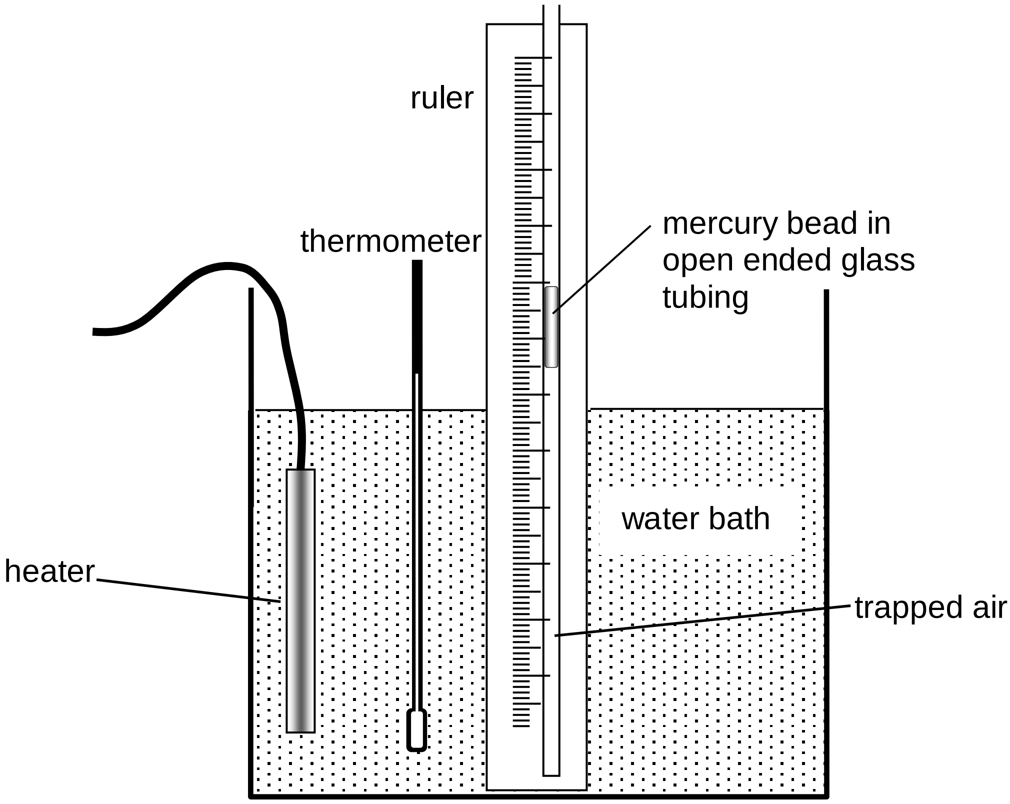
(*j*) 450 K

152. Explain what is meant by the temperature ‘absolute zero’.

153. What is the temperature of ‘absolute zero’ in the Kelvin and Celsius scales?

Volume and temperature

154. The relationship between temperature and volume can be investigated using the apparatus shown below. A mass of air is trapped in a glass tube by a bead of mercury. The mercury is free to move as the air expands. The length of the trapped air is proportional to its volume.



Some pupils record the following results from the experiment.

Temperature in °C	***Temperature in K***	***Volume (length of air column)***
20		21·5
40		22·9
60		24·4
80		25·9
100		27·3

(*a*) Copy and complete the table by calculating the temperature of the air in Kelvin.

(*b*) Plot a graph of volume against temperature in Kelvin and state the relationship between them.

154. (continued)

(*c*) The teacher tells the pupils that the set up of the experiment could be improved. Make a suggestion of how this could be done.

(*d*) The temperature of the water is cooled by adding ice and salt to the water. This lowers the temperature of the trapped air to –10 °C. Calculate the length of the gas column at this temperature.

155. Give an equation that can be used to relate the temperature and volume of a fixed mass of gas.

156. Calculate the missing values in the table below.

Volume V_1	***Temperature*** T_1	***Volume*** V_2	***Temperature*** T_2
0·5 m^3	200 K	2·0 m^3	(*a*)
6 litres	300 K	(*b*)	600 K
(*c*)	350 K	0·02 m^3	250 K
2 litres	(*d*)	12 litres	300 K
0·5 m^3	27 °C	2·0 m^3	(*e*)
1·5 m^3	17 °C	(*f*)	127 °C
(*g*)	27 °C	5 m^3	327 °C
4 litres	(*h*)	30 litres	27 °C

157. A sealed syringe contains 20 cm^3 of air at a temperature of 27 °C.

(*a*) Convert the temperature into the Kelvin scale.

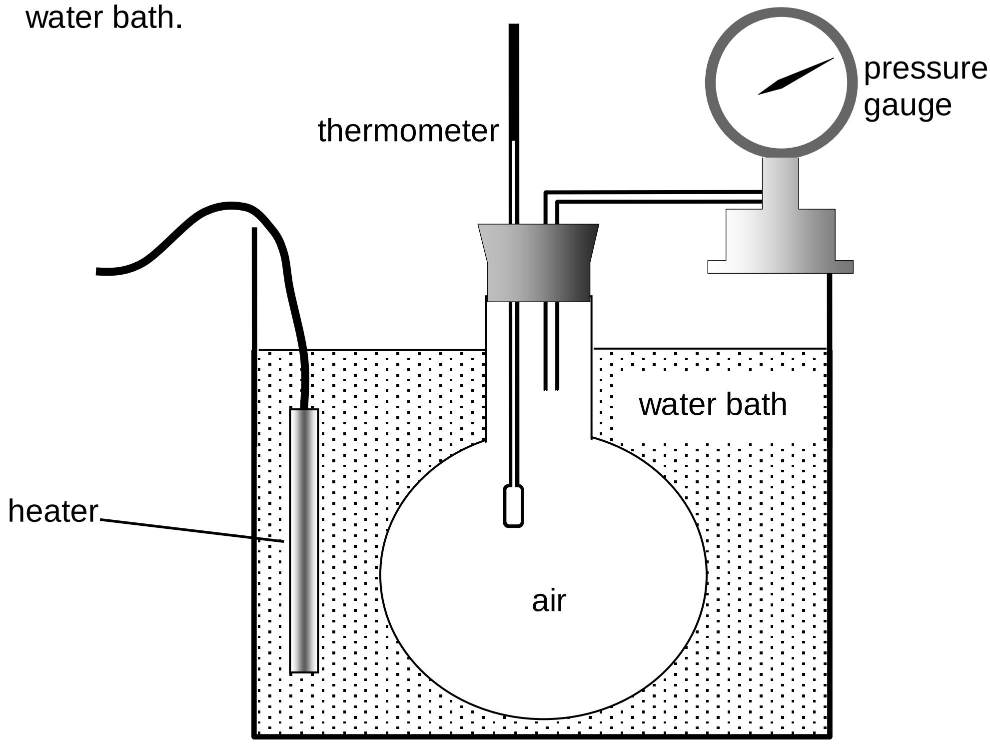
(*b*) Calculate the new volume the air in the syringe will occupy if the plunger can freely move and the syringe is placed in hot water at a temperature of 77 °C.

158. A gas occupies a volume of 10 litres at a temperature of 300 K. What volume would it occupy at 600 K?

159. A mass of gas occupies 1 m^3 at a temperature of 27 °C. Assuming no change in pressure, what would be the volume of the gas if it expanded at a temperature of 227 °C?

Pressure and temperature

160. The relationship between temperature and pressure can be investigated using the apparatus shown below. A mass of air in a flask is heated in a water bath.



Pupils record the following results from the experiment.

Temperature in °C	***Temperature in K***	***Pressure in kPa***
10		100
20		104
30		107
40		111
50		114
60		118

(*a*) Copy and complete the table by calculating the temperature of the air in Kelvin.

(*b*) Plot a graph of pressure against temperature in Kelvin and state the relationship between them.

160. (continued)

(*c*) Although pressure and temperature varied in this experiment, two factors were kept constant. What were these?

(*d*) By looking at the diagram of the apparatus used, can you suggest two ways in which the experiment could be improved to obtain more accurate results.

161. Give an equation that can be used to relate the temperature and pressure of a fixed mass of gas.

162. Calculate the missing values in the table below.

Pressure p_1	***Temperature*** T_1	***Pressure*** p_2	***Temperature*** T_2
2×10^5 Pa	300 K	4×10^5 Pa	(*a*)
100 kPa	200 K	(*b*)	600 K
(*c*)	350 K	5×10^5 Pa	250 K
$2{\cdot}0 \times 10^5$ Pa	(*d*)	$1{\cdot}8 \times 10^5$ Pa	300 K
200 kPa	27 °C	800 kPa	(*e*)
1×10^5 Pa	17 °C	(*f*)	127 °C
(*g*)	27 °C	150 kPa	327 °C
1×10^5 Pa	(*h*)	4×10^5 Pa	27 °C

163. A motorist checks the pressure of the air in his car tyre on a cold morning and finds it is $3{\cdot}0 \times 10^5$ Pa. The temperature of the air in the tyre is 2 °C. After a journey on the motorway the temperature of the air has risen to 57 °C. Calculate the pressure of the air now.

164. A cylinder of gas is at a temperature of 17 °C. The gas is at a pressure of 100 kPa. Calculate the pressure of the gas if its temperature rises to 75 °C.

165. A mass of gas is held in a flask at –20 °C and a pressure of 89 kPa. Calculate the pressure of the gas if its temperature rises to 60 °C.

166. A gas cylinder holds gas at a temperature of 27 °C at a pressure of $5{\cdot}0 \times 10^5$ Pa. A safety valve will operate at $9{\cdot}0 \times 10^5$ Pa if the gas heats up. At what temperature would this occur?

Kinetic model

167. Which of the following statements about a gas is/are true or false.

A. A gas has a fixed shape and a fixed volume.

B. A gas has a fixed shape but not a fixed volume

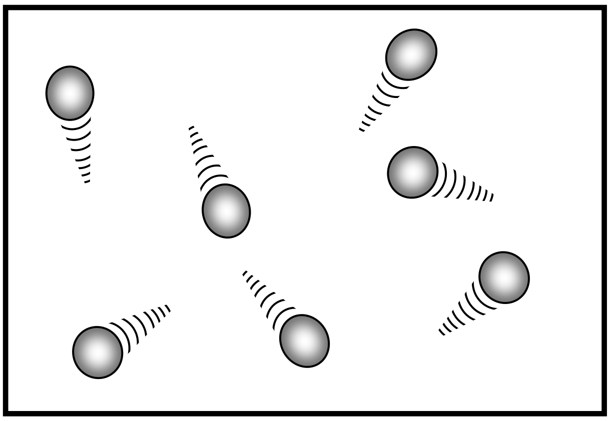
C. A gas has a fixed volume but not a fixed shape.

D. A gas has neither a fixed shape or volume.

E. The particles in a gas can increase and decrease in size.

F. The particles in a gas can increase and decrease in speed.

168. The diagram opposite shows how gas particles in a container. (particles greatly enlarged)



(*a*) What will happen to when the particles collide with the walls of the container?

(*b*) The temperature of the gas is raised. How does this affect the movement of the gas particles?

(*c*) (i) What happens to the pressure inside the container if the gas is heated?

(ii) Explain why any changes in the pressure take place.

169. A metal canister of gas is cooled. State the effect has this on the pressure inside the container and explain your answer.

170. A weather balloon is made of a very stretchy material and filled with helium gas.

(*a*) As the balloon rises, how will the pressure inside the balloon compare with the pressure outside.

(*b*) The air at higher altitudes is 'thinner'. What will happen to the volume of the balloon as it rises?

171. Explain, in terms of the kinetic theory of gases, why a gas trapped in a cylinder causes pressure.

172. Air is pumped into a car tyre. Explain why this increases the pressure in the tyre.

173. An empty aluminium drinks can is attached to a vacuum pump. As the air is pumped out of the can, the sides of the can collapse. Explain, in terms of the kinetic theory of gases, why this happens.

174. Explain, using the kinetic theory of gases, why a gas will expand as its temperature increases.

Extension questions

175. A diver carries a gas cylinder with a volume of 0·015 m^3. The air it contains is at a pressure of 2 × 10^7 Pa.

(*a*) Calculate the volume of air available to her at a depth where the pressure is 4 × 10^5 Pa.

(*b*) As the diver heads for the surface, she finds she has to breathe out continuously. Explain why this happens.

176. A mass of gas is held in a sealed container.

(*a*) The temperature of the gas is increased. Sketch the graph of pressure against temperature in Kelvin for the gas.

(*b*) Use the kinetic theory of gases to explain the changes in pressure which take place.

(*c*) The pressure of the gas in the container is 2·8 × 10^5 Pa at a temperature of 27 °C. What would be the pressure of the gas if its temperature was raised to 127 °C?

177. The catering galley of an aircraft is stocked on the ground with sealed cartoons of Pringles. The volume of the packaging gas in the cartons is 180 cm^3 and the air pressure on the ground is 100 kPa.

(*a*) When flying at its cruising altitude the cabin pressure in the aircraft is 80 ka. Calculate the volume the packaging gas would occupy at this pressure if allowed to freely expand.

(*b*) The packaging gas is contained in the cardboard carton. The lid of the carton is pushed outwards. Explain, in terms of the kinetic theory of gases, why this happens.

178. An equation known as the General Gas Equation can be used to solve problems where pressure, volume and temperature all change. The equation is

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

Use the general gas equation to solve the following problems. (Remember to convert temperatures to the Kelvin scale if appropriate).

(*a*) A fixed mass of gas occupies 3 litres at a pressure of 200 kPa and a temperature of 300 K. Calculate the volume of the gas if the pressure is reduced to 100 kPa and its temperature increased to 600 K.

(*b*) A bubble of gas escapes from the sea floor where the temperature is 1 °C and the pressure 20×10^6 Pa. At the sea surface the temperature is 17 °C and the pressure 1×10^5 Pa. Calculate the new volume of the bubble if its volume on the sea floor was 1×10^{-9} m^3.

(*c*) During an experiment in a science class, a student collects 0·45 litres of hydrogen chloride gas at a pressure of 100 kPa and at a temperature of 17 °C. Calculate the volume of the gas at 0 °C and 101·3 kPa?.

Specific Heat Capacity

179. Copy and complete the paragraph on heat and specific heat capacity using the words given below.

mass **heat** **temperature** **kinetic** **specific**

The __________ of a substance is a measure of the average __________ energy of the molecules of the substance. Temperature can be measured directly using a thermometer.

__________ is the amount of thermal energy a substance contains, measured in joules. The amount of heat energy a substance contains depends upon a number of factors including its temperature and __________. Different substances also require different amounts of energy to produce a particular rise in temperature. This is called their __________ heat capacity.

Specific heat capacity is defined as the energy required to raise the temperature of 1 kg of the substance by 1 °C. If heat energy is added to a substance its molecules gain kinetic energy and as a result the temperature of the substance rises.

180. Give an equation that relates heat energy, change in temperature, mass and specific heat capacity.

181. Calculate the missing values in the table below.

Energy added	***Specific heat capacity***	***Mass***	***Change in temperature***
(*a*)	4180 J kg^{-1} °C^{-1}	2 kg	20 °C
3608 J	(*b*)	0·1 kg	40 °C
8000 J	500 J kg^{-1} °C^{-1}	(*c*)	80 °C
31 500 J	2100 J kg^{-1} °C^{-1}	3 kg	(*d*)
(*e*)	530 J kg^{-1} °C^{-1}	0·2 kg	18 °C
4800 J	2400 J kg^{-1} °C^{-1}	100 g	(*f*)

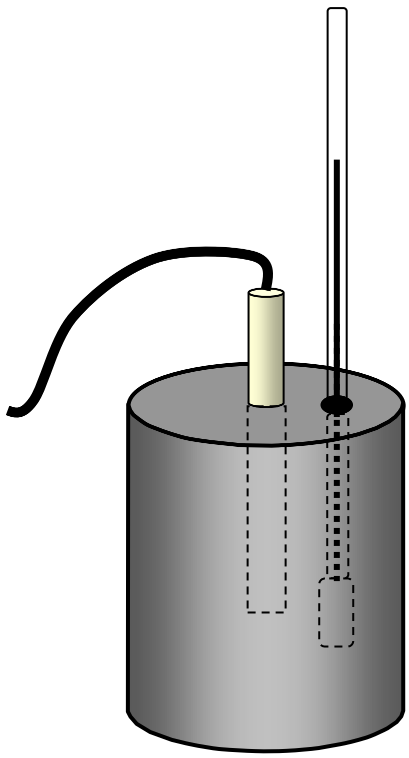
182. A copper block has a mass of 1·3 kg. Calculate the energy required to raise its temperature from 25 °C to 45 °C if copper has a specific heat capacity of 380 J/kg°C.

183. A hot water bottle contains 0·8 kg of water at a temperature of 70 °C. How much energy will the bottle loose if its temperature falls to 40 °C? (specific heat capacity of water = 4180 J kg^{-1} °C^{-1})

184. A pupil adds 10 000 J of energy to an aluminium block using an electrical heater. The block has a mass of 1 kg.

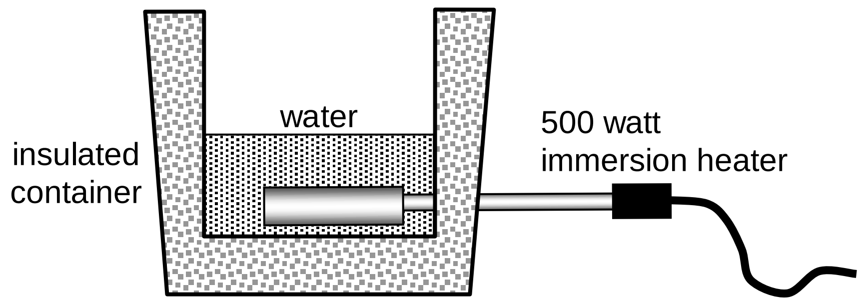
(*a*) The temperature of the block increases from 20 °C to 28 °C. Calculate the specific heat capacity of aluminium using the results from this experiment.

(*b*) The pupil looks up a data sheet to discover the correct value is 902 J/kg°C. Give a reason why his calculated value may have been incorrect.



Extension questions

185. A small container of water is surrounded by thick insulation. The container holds 0·3 kg of water at a temperature of 20 °C. A 500 W immersion heater is placed in the water.

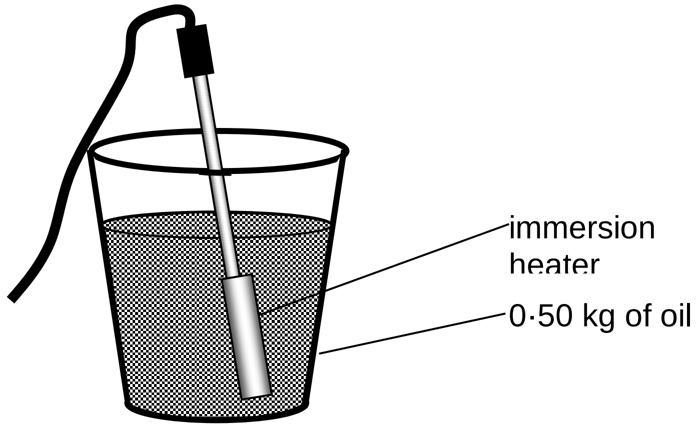


(*a*) Calculate the heat energy required to raise the temperature of the water to 60 °C. (Specific heat capacity of water = 4180 J kg^{-1} $°C^{-1}$)

(*b*) Calculate the time it will take to produce this increase in temperature assuming no energy is lost to the surroundings.

(*c*) Even though the container is insulated, heat is still lost to the surroundings. State one way in which this loss could be reduced.

186. A beaker contains 0·5 kg of oil. An electric heater rated at 500 W is used to heat the oil from 20 °C to 80 °C.



(*a*) Calculate the heat energy added to the oil if the heater is switched on for 180 s.

(*b*) Calculate the value of the specific heat capacity of the oil that these results give.

(*c*) The actual value for the specific heat capacity of the oil is 2000 J kg^{-1} $°C^{-1}$. Give a reason why the answer obtained from the experiment was not accurate.

187. A mains immersion heater is used to heat the water in a hot water tank. It holds 200 kg of water.

(*a*) Show, by calculation, that 29·26 MJ of energy will be required to raise the temperature of the water by 35 °C. The specific heat capacity of the water is 4180 J/kg°C.

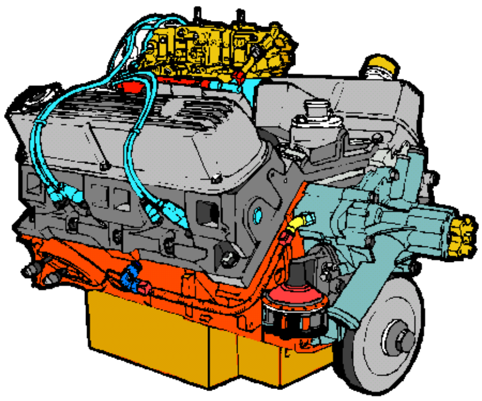
(*b*) The immersion heater operates at 230 V and draws a current of 30 A.

(i) Calculate the power of the heater.

(ii) How long does it take the heater to heat the water assuming no heat is lost?

(*c*) Although 29 MJ of energy went into raising the temperature of the water, the actual energy required to be produced by the heater was 36·25 MJ due to energy losses. Calculate the percentage efficiency of the process.

188. A car engine is kept cool by water being pumped around the engine block, loosing the heat picked up at the car radiator.



(*a*) The mass of the water in the cooling system is 3·0 kg. Calculate its rise in temperature if the energy removed is 960 000 J. (Specific heat capacity of water = 4180 J/kg°C)

(*b*) A new coolant has a specific heat capacity of 3000 J/kg°C. Would you expect this to be more or less effective at removing heat from the engine. Give reasons for your answer.

Reducing Energy waste

189. A leaflet explains ways in which a householder can save energy and reduce their energy bills.

(*a*) Look at the suggestions listed below and for each one, describe how it will be able to reduce the energy being used.

A. Turn out the lights when not in the room.

B. Don't overfill your kettle.

C. Only use a dishwasher when full.

D. Insulate your walls and loft.

E. Don’t leave appliances on standby.

F. Reduce the use of labour saving electrical gadgets.

G. Choose energy efficient appliances.

H. Fit double glazing.

I. Fit insulation around the hot water storage tank.

J. Have showers instead of baths.

K. Switch energy supplier.

L. Turn down room thermostats.

(*b*) Which of the advice above is likely to save most money?

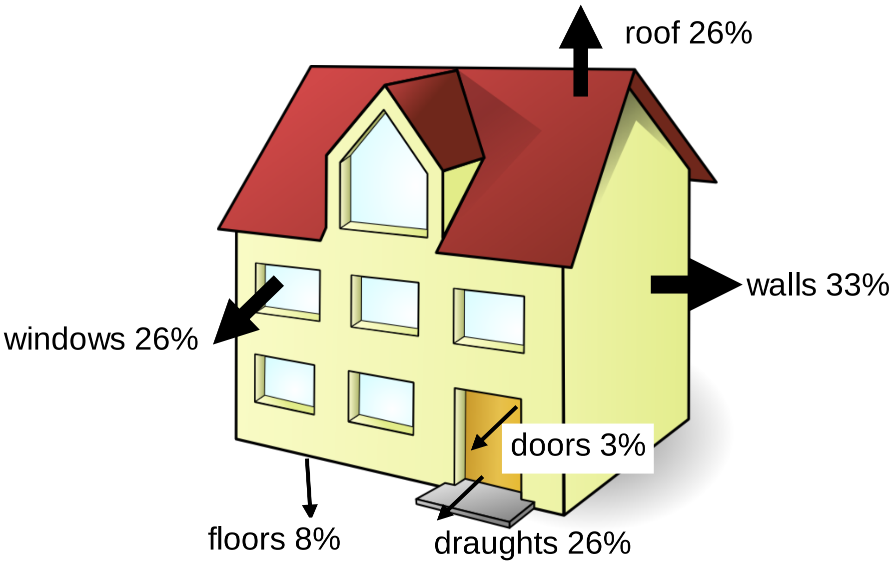
190. Thermal images can be used to show the heat being lost through different parts of a house. Light areas of the image are hotter and dark areas colder. In the image below, the block of flats on the right of the picture is newly built. The flats on the left behind the trees was built in the 1970s.

Photograph by Passivhaus Institut

(*a*) Which area(s) of the modern block is loosing most heat?

(*b*) Which block, the new or the older, is loosing most heat? Suggest a reason for your answer.

191. The diagram below shows the typical energy losses from a house.



(*a*) Where is most energy lost from the house?

(*b*) The householder spends £1500 each year on heating the house. Listed below are some of the energy saving measures that could be installed and their cost. Suggest which you would be most likely to choose if you were the householder and give reasons for your choice.

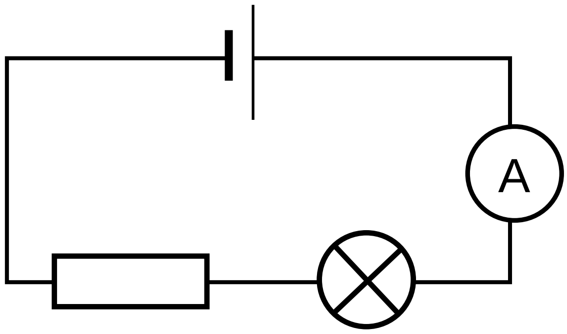
Measure	***cost***
Fit draught excluders	£120
Insulate roof	£300
Lay carpets in downstairs rooms	£1200
Replace doors	£1500
Fit double glazed windows	£8000
Insulate walls with cavity foam	£5500

Electrical charge carriers and electric fields

Electric charge

1. Electrons

2. Ammeter can be placed anywhere in series in the circuit.



3. Q = It

4. (*a*) 40 C
(*b*) 1 C
(*c*) 3000 s
(*d*) 80 s
(*e*) 0·05 A
(*f*) 0·05 A

5. 20 C

6. (*a*) 5 C
(*b*) $3{\cdot}125 \times 10^{19}$

7. 3 A

8. 1000 s

a.c. and d.c.

9. a.c. - mains d.c. – cell or battery.

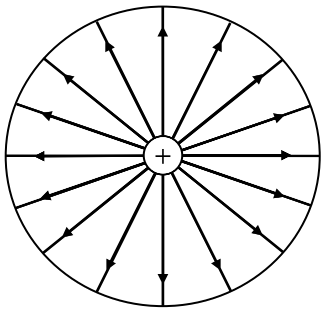
10. 50 Hz

11. Trace 1 is a.c. and trace 2 is d.c.

12. An object can have either negative or positive charge. Electrons have **negative** charge, When a charged object is placed in an electric field, its movement will depend upon its **charge**. A positive charge will be repelled by a **positive** charge whilst a negative charge will be **attracted**.

In a circuit, it is electrons which flow around the circuit. The energy for them to move comes from a **potential** difference or **voltage**. Electrons will flow towards the **positive** connection of a power supply and away from the **negative** connection. The size of the potential difference or voltage is a measure of the **energy** given to the electrons.

13.



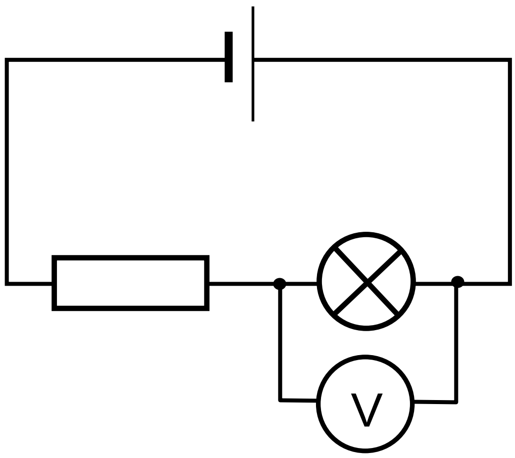
14. A. It would be attracted to the dome.

B. It would be repelled away from the dome.

15. (*a*) The hair picks up the same charge as the dome. As like charges repel, the air strands are repelled from one another.

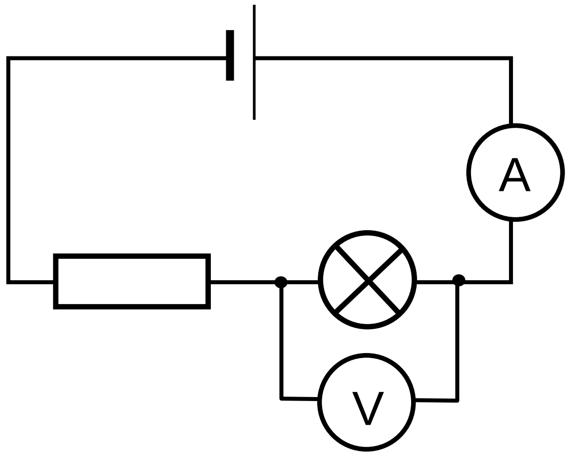
(*b*) If he stood on the ground the charge would flow to earth and he would not become charged.

16.



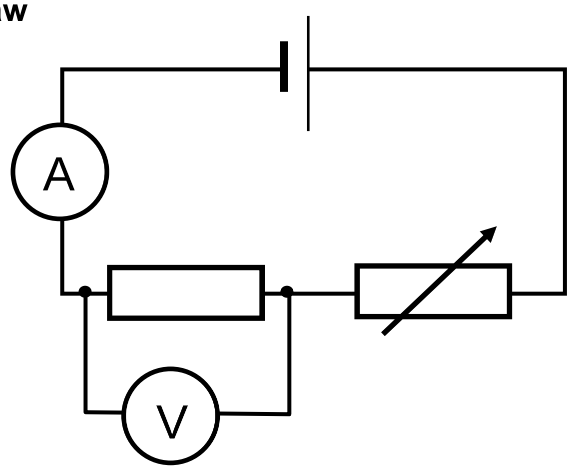
17. (*a*) Switch
(*b*) Connected wires
(*c*) Cell
(*d*) Battery
(*e*) Voltmeter
(*f*) Ammeter
(*g*) Ohmmeter
(*h*) Resistor
(*i*) Variable resistor
(*j*) Lamp
(*k*) Fuse
(*l*) Motor

18. (*a*) Cell, connecting wire, resistor, lamp.
(*b*) Ammeter can be anywhere in circuit as long as it is in series with the lamp.



Ohm's Law

19. (*a*)



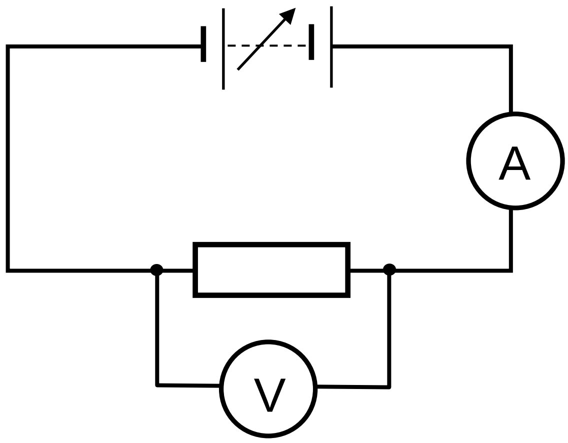
(*b*) Current will decrease.
(*c*) (i) Resistance will decrease.
(ii) Current will increase.

20. (*a*) It will reduce the error caused by poor readings.
(*b*) Different lengths of wire would have different resistances.
(*c*) (i)

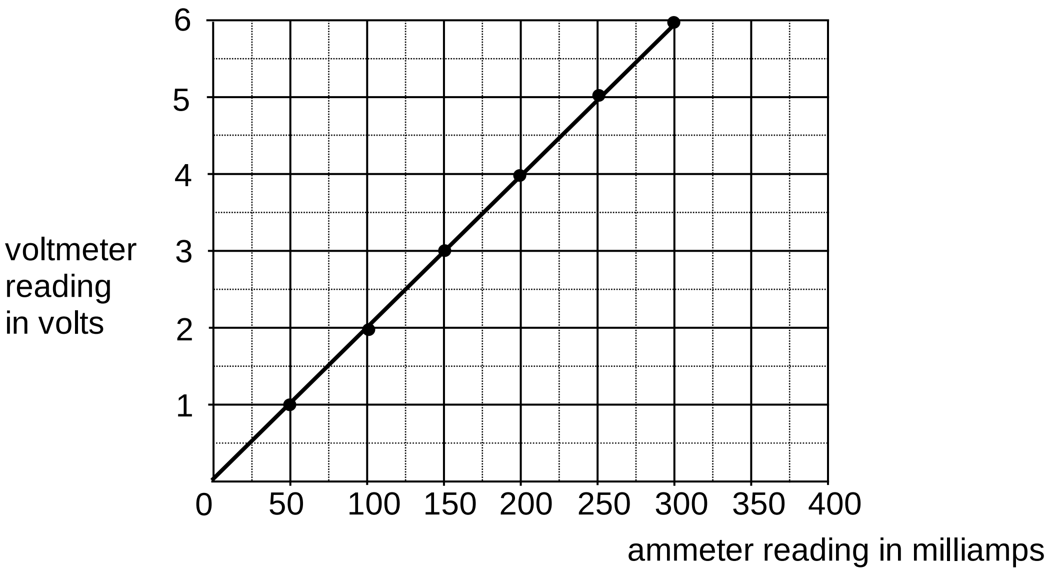
Voltage in volts, V	2	4	6	8	10	12
Current in amps, I	0·25	0·5	0·75	1·0	1·25	1·5
V/I	8·0	8·0	8·0	8·0	8·0	8·0

(ii) The wire has a resistance of 8·0 Ω.

21. (*a*)



(*b*) 20 Ω



22. V = IR

23. (*a*) 10 V
(*b*) 60 V
(*c*) 28·75 Ω
(*d*) 600 Ω
(*e*) 0·46 A
(*f*) 0·2 A

24. Current increases.

25. 46 Ω

26. 0·042 A

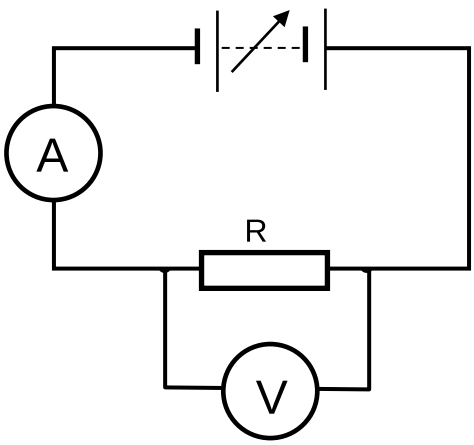
27. 228 V

28. 1 mA

29. 6 Ω

30. (*a*) 0·23 A
(*b*) (i) Resistance has increased as the filament became hotter.
(ii) 3·6 A
(*c*) This is when the current through the filament is highest.

31. (*a*)

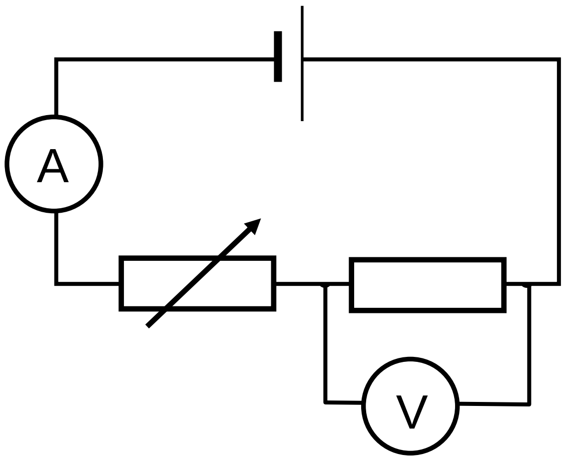


(*b*) (i) 2·0 A
(ii) 2 Ω

32. Voltmeter reading = 1·5 V, ammeter reading = 1 x 10^{-3} A or 1 mA.

33. (*a*) The current will be the same.

(*b*)



(*c*) 15 Ω

(*d*) Ammeter reading will decrease.

34. Series (*a*) and (*d*) Parallel (*b*), (*c*) and (*e*). (*f*) is a mixture of series and parallel.

35. (*a*) $A_1 = 3$ A, $A_2 = 3$ A

(*b*) $A_3 = 3$ A

(c) $A_4 = 9$ A, $A_5 = 2$ A

(*d*) $V_1 = 9$ V , $V_2 = 9$ V

(e) $A_6 = 4$ A, $A_7 = 4$ A

(*f*) $V_3 = 2$ V

Resistors in series and parallel

36. $R_{total} = R_1 + R_2 + R_3$

37. $$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

38. (*a*) 15 Ω

(*b*) 6 kΩ

(*c*) 20 kΩ

(*d*) 13 Ω

(*e*) 40 kΩ

(*f*) 5 kΩ

(*g*) 800 Ω

(*h*) 18 Ω

39. (*a*) 2·5 Ω
(*b*) 3·3 Ω
(*c*) 10 Ω
(*d*) 6·86 Ω
(*e*) 2·5 Ω
(*f*) 66·7 Ω
(*g*) 2 Ω
(*h*) 1·25 kΩ

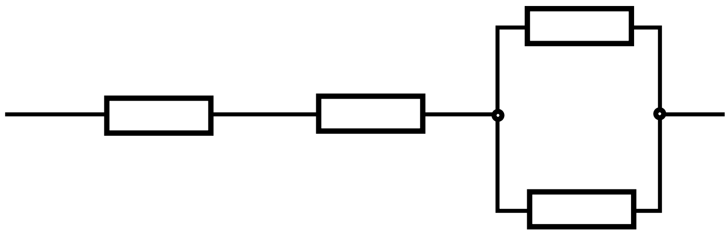
40. (*a*) 10 Ω
(*b*) 4 Ω
(*c*) 12 Ω
(*d*) 5 Ω
(*e*) 15 Ω
(*f*) 40 Ω
(*g*) 11·6 Ω
(*h*) 3 Ω

41. (*a*) 15 Ω
(*b*) 0·6 A
(*c*) (i) 3 V
(ii) 6 V

42. (*a*) 2·5 Ω
(*b*) 12 V
(*c*) 12 V
(*d*) 12 V
(*e*) (i) 0·6 A
(ii) 1·2 A

Extension Questions

43. (*a*) (i) 3 Ω
(ii) 57 – 63 Ω
(*b*) (i) R_1 = 66·7 Ω, R_2 = 57·1 Ω
(ii) R_1 is outside the allowable range, R_2 is within the allowable range.
(*c*) 20 Ω
(*d*)



44. (*a*) (i) 5 Ω
(ii) 2·4 A
(iii) The current will decrease as the total resistance of the circuit will increase, no matter which resistor fails.
(*b*) It will not work as all the voltmeters will read 12 V, even across the faulty resistor.

45. (*a*) 9 V
(*b*) 5 V
(*c*) 18 Ω
(*d*) 0·5 A
(*e*) 6 Ω

46. (*a*) B
(*b*) A
(*c*) B
(*d*) A
(*e*) B
(*f*) A
(*g*) B

47. (*a*) V_1 = 5 V , V_2 = 0 V
(*b*) V_3 = 0 V , V_4 = 3 V
(*c*) V_5 = 6 V , V_6 = 0 V

48. (*a*) 3·6 V
(*b*) 1 V
(*c*) 5·14 V

Electronic circuits

49. (*a*) Capacitor
(*b*) Thermistor
(*c*) Light dependant resistor (LDR)
(*d*) Diode
(*e*) Light emitting diode (LED)
(*f*) Photo voltaic cell
(*g*) Motor
(*h*) Loudspeaker
(*i*) Transistor
(*j*) Relay

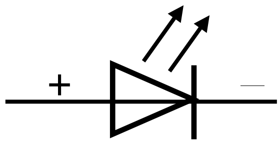
50.

Device	***Input device***	***Output device***
(*a*) loudspeaker		✓
(*b*) capacitor	✓	
(*c*) LED		✓
(*d*) LDR		✓
(*e*) thermistor	✓	
(*f*) relay		✓

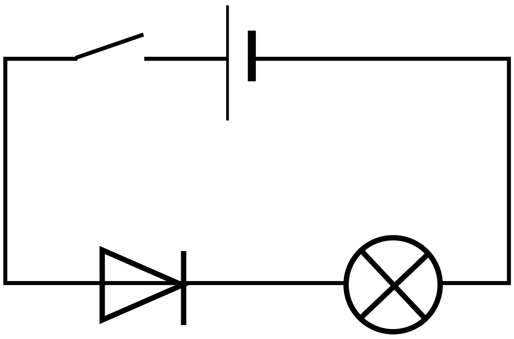
51.

Device	***Input energy***	***Output energy***
(*a*) loudspeaker	electrical	sound
(*b*) LED	electrical	light
(*c*) LDR	light	electrical
(*d*) thermistor	heat	electrical
(*e*) relay	electrical	kinetic
(*f*) motor	electrical	kinetic
(*g*) photovoltaic cell	light	electrical

52.

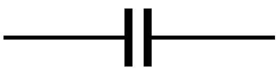


53.



54. LED 2, LED 4

55. A capacitor will store charge. When fully charged it will have a voltage across it equal to the charging voltage.



56. (*a*) (i) 12 V
(ii) 0 V
(*b*) (i) It will take longer.
(ii) No effect.
(iii) No effect.

57. A resistor will normally have a resistance which **does not change**. The resistance of some devices will change according to certain factors. The resistance of a thermistor changes with **temperature**. For most thermistors, as the temperature increases its resistance **decreases**. LDRs change their **resistance** with changing levels of light. As the light levels decrease, the resistance of the LDR **increases**.

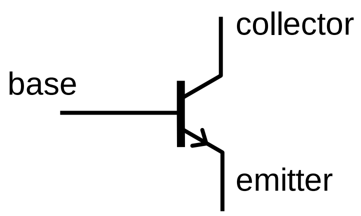
58. (*a*) Thermistor
(*b*) 8 V
(*c*) 4 V
(*d*) 2 kΩ
(*e*) (i) No change.
(ii) Current increases.

59. (*a*) 2 V
(*b*) 1 V
(*c*) 8 V

60. (*a*) Light dependent resistor
(*b*) 3 V
(*c*) 6 V
(*d*) 200 Ω
(*e*) Current increases.

61. (*a*) 4 V
(*b*) 4 V
(*c*) 2 V
(*d*) 1 V
(*e*) 4 V

62.



63. 1. True
2. False
3. True
4. False
5. True
6. True
7. False

64. (*a*) Yes
(*b*) No
(*c*) Yes
(*d*) Yes
(*e*) Yes

(*f*) Yes

65. (*a*)MOSFET transistor.
(*b*) g – gate, d – drain, s – source.

66. 1. True
2. False
3. False
4. True
5. True
6. True
7. False

67. (*a*) Yes
(*b*) Yes
(*c*) No
(*d*) Yes

68. (*a*) In the dark.
(*b*) 0·7 V
(*c*) Resistance of LDR falls and so the voltage across it falls, switching off the transistor.

69. (*a*) It will decrease.
(*b*) (i) The voltage will decrease.
(ii) It will increase.
(*c*) The transistor will be switched on.
(*d*) By adjusting the variable resistor.

Extension Questions

70. (*a*) X - Variable resistor
Y - Light dependent resistor
Z - Transistor
(*b*) (i) The resistance will increase.
(ii) The voltage will increase.
(iii) The transistor will be switched on and the LEDs will light.
(*c*) They would not light.

71. (*a*) As the temperature of the thermistor rises the voltage across it increases. This switches on the MOSFEt transistor when it is over 2 V. There will now be a voltage across the relay which switches on the warning lamp connected to the mains.
(*b*) it operates at low voltage whilst the lamp operates at mains voltage.

72. (*a*) X - Variable resistor
Y - Light dependent resistor
Z - Relay
(*b*) As it gets dark the resistance of the LDR increases. This increases the voltage across it which switches on the transistor. The transistor switches on the relay which turns on the security light.
(*c*) Alter the value of the variable resistor.
(*d*) It operates at 5 V and not mains voltage. The transistor cannot supply a large current. The transistor operates on a d.c. supply and the security light an a.c. supply.

Electrical Power

73. (*a*) Food mixer - Electrical energy into kinetic energy
Iron - Electrical energy into heat energy
Light bulb - Electrical energy into heat and light energy
(*b*) Food mixer - Approximately 400 W
Iron - Approximately 1000 W
Light bulb - Approximately 60 W

74. (*a*) Electric oven, curling tongs, television, table lamp, radio.
(*b*) Electric oven - 8000 W, curling tongs - 750 W, television - 300 W, table lamp - 60 W, radio - 10 W.
(*c*) They produce heat.

75. $P = \frac{E}{t}$

76. (*a*) 10 W
(*b*) 1000 W
(*c*) 100 s
(*d*) 60 s
(*e*) 1000 J
(*f*) 360 000 J

77. 2 W

78. 30 s

79. 800 W

80. (*a*) 1 080 000 J
(*b*) This is when the washing machine is heating the water.

81. P = IV

82. (*a*) 690 W
(*b*) 6 W
(*c*) 230 V
(*d*) 12 V
(*e*) 10·87 A
(*f*) 167 mA

83. 460 W

84. 1380 W

85. 4·2 A

86. 6 V

87. (*a*) 5·2 A
(*b*) The heater.

88. $P = I^2R$

89. (*a*) 270 W
(*b*) 15 W
(*c*) 32 Ω
(*d*) 2·4 Ω
(*e*) 3 A
(*f*) 0·5 A

90. 920 W

91. 4 A

92. 0·036 W

93. 0·07 A

94. (*a*) 4 A
(*b*) 57·5 Ω

95. $P = \frac{V^2}{R}$

96. (*a*) 1322 W
(*b*) 14·4 W
(*c*) 10 Ω
(*d*) 882 Ω
(*e*) 100 V
(*f*) 10 V

97. 1058 Ω

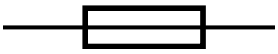
98. 24 Ω

99. 48 W

100. 4 Ω

Fuses

101.



102. The fuse prevents too large a current flowing through flex to the appliance and causing it to overheat.

103. A large current might flow to the appliance overheating the flex and the fuse not blow. This could cause a fire.

104. (*a*) (i) 0·26 A, 3 A fuse
(ii) 8·7 A, 13 A fuse
(iii) 3·5 A, 5 A fuse
(iv) 2·2 A, 3 A fuse
(*b*) The normal current exceeds 3 A at 3·7 A.

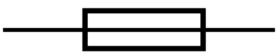
Extension Questions

105. (*a*) 2·4 W
(*b*) Heat energy

106. (*a*) 230 V
(*b*) 26.45 Ω

107. (*a*) 10350 W
(*b*) 30·4 A
(*c*) It requires a greater current than the 13 A a socket can supply.

108. (*a*)



(*b*) (i) 20 A
(ii) 84 W

109. (*a*) 9·6 A, use a 10 or 13 A fuse
(*b*) 24 Ω

Conservation of energy

110. Energy can neither be created or destroyed, only changed from one form to another.

111. (*a*) Kinetic energy into kinetic energy.
(*b*) Some energy lost as heat and sound.

112. (*a*) (i) Potential energy into kinetic energy.
(ii) Kinetic energy into electrical energy.
(*b*) (i) Friction as water flows through pipes.
(ii) electrical losses in generator and friction between moving parts.

Potential energy

113. E_p = mgh

114. (*a*) 588 J
(*b*) 24·5 J
(*c*) 20 m
(*d*) 40 m
(*e*) 5 kg
(*f*) 1 kg

115. 470·4 J

116. 6·25 m

117. 50 kg

118. (*a*) 11.76 J
(*b*) 1·92 J

Kinetic energy

119. $E_k = ½m \times v^2$

120. A lorry is used to collect waste from houses for recycling.
(*a*) Its E_k increases as the mass of the lorry increases.
(*b*) E_k increases.

121. (*a*) 16 J
(*b*) 10 J
(*c*) 2·8 m s^{-1}
(*d*) 5 m s^{-1}
(*e*) 800 kg
(*f*) 10 kg

122. $4·05 \times 10^8$ J

123. 122·5 J

124. 600 kg

125. (*a*) 3 m s^{-1}
(*b*) The potential energy of the ball.

126. (*a*) 225 J
(*b*) It is converted into heat due to friction.

Potential and kinetic energy transfer

127. (*a*) 14·7 J
(*b*) 7·7 m s^{-1}

128. (*a*) 0·39 J
(*b*) 0·39 J
(*c*) The swing losses energy due to air resistance and friction.

129. (*a*) 4320 J
(*b*) 7·3 m

Extension Questions

130. (*a*) 9·6 J
(*b*) (i) 3·3 m
(ii) There are energy losses due to air resistance.

131. 5·4 m s^{-1}

132. (*a*) 294 J
(*b*) (i) 294 J
(ii) 5·4 m s^{-1}
(*c*) There are energy losses due to air resistance and friction.

Pressure, force and area

133. The downward force from the Eskimo's weight is spread over a larger area which reduces the pressure under his feet.

134. A sharp knife will have a smaller area at the edge of the blade meaning the pressure under the blade is greater.

135. The heel of the shoe has a very small area compared to a normal shoe. This means the ladies weight is spread over a very small area which increases the pressure under her heel.

136. $$p = \frac{F}{A}$$

137. (*a*) 25 Pa
(*b*) 40 Pa
(*c*) 0·015 m^2
(*d*) 0·01 m^2
(*e*) 10 000 N
(*f*) 20 000 N

138. 667 Pa

139. 4000 N

140. (*a*) 1×10^8 Pa

(*b*) The small surface area of the pin point means that there will be a large pressure under it for any given force.

Extension Questions

141. Estimated area of foot in contact with ground approximately
$5\ cm^2 = 2{\cdot}5 \times 10^{-3}\ m^2$
Pressure = $1{\cdot}8 \times 10^5$ Pa

Pressure and volume

142. (*a*) Temperature.

(*b*) $p \propto \frac{1}{V}$

143. $p_1V_1 = p_2V_2$

144. (*a*) $1{\cdot}25 \times 10^4$ Pa
(*b*) 2×10^7 Pa
(*c*) $1{\cdot}67 \times 10^{-3}\ m^3$
(*d*) 80 litres
(*e*) $2{\cdot}5 \times 10^5$ Pa
(*f*) 10×10^5 Pa
(*g*) $5\ m^3$
(*h*) 0·07 litres

145. $0{\cdot}03\ m^3$

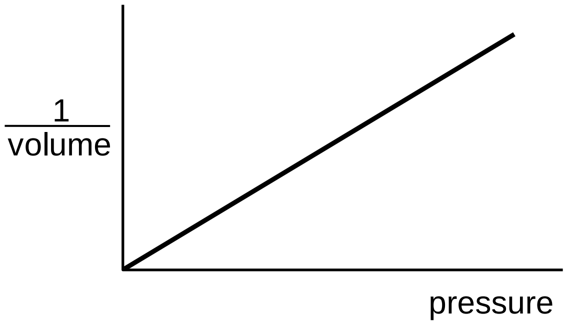
146. (*a*) The surrounding water pressure decreases as the bubbles rise allowing them to expand.
(*b*) $8 \times 10^{-6}\ m^3$

147. $0{\cdot}006\ m^3$

148. (*a*)

Pressure in kPa	***Volume in cm³***	**1 / *Volume***
100	14·7	0·068
150	9·9	0·101
200	7·4	0·135
250	5·9	0·169
300	4·9	0·204

(*b*)



(*c*) 735 kPa

Kelvin scale

149. (*a*) 20 K
(*b*) –273 °C

150. (*a*) 273 K
(*b*) 300 K
(*c*) 400 K
(*d*) 0 K
(*e*) 100 K
(*f*) 350 K
(*g*) 146 K
(*h*) 619 K
(*i*) 291 K
(*j*) 373 K

151. (*a*) –273 °C
(*b*) 0 °C
(*c*) 20 °C
(*d*) 27 °C
(*e*) 100 °C
(*f*) –100 °C
(*g*) 50 °C
(*h*) –223 °C
(*i*) 350 °C
(*j*) 177 °C

152. Absolute zero is the lowest achievable temperature where the kinetic energy of the molecules making up a gas will be zero.

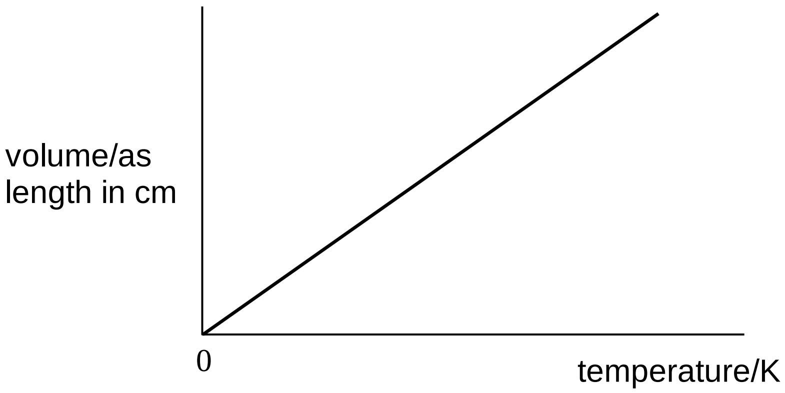
153. 0 K and –273 °C

Volume and temperature

154. (*a*)

Temperature in °C	***Temperature in K***	***Volume (length of air column)***
20	293	21·5
40	313	22·9
60	333	24·4
80	353	25·9
100	373	27·3

(*b*)



$V \propto T$ when temperature is in Kelvin

(*c*) Have more of the tube under water. The water could also be stirred to create an even temperature in the water and give time for the temperature to stabilise between readings.

(*d*) 19·3

155. $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ providing T is in kelvin

156. (*a*) 800 K

(*b*) 12 litres

(*c*) 0·028 m^3

(*d*) 50 K

(*e*) 1200 K (927 °C)

(*f*) 2·07 m^3

(*g*) 2·5 m^3

(*h*) 40 K (–233 °C)

157. (*a*) 300 K
(*b*) 23·3 cm^3

158. 20 litres

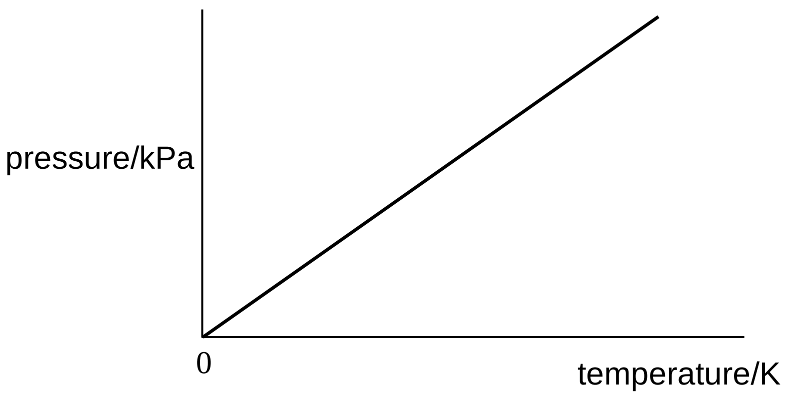
159. 1·67 m^3

Pressure and temperature

160. (*a*)

Temperature in °C	***Temperature in K***	***Pressure in kPa***
10	283	100
20	293	104
30	303	107
40	313	111
50	323	114
60	333	118

(*b*)



$P \propto T$ when temperature is in Kelvin

(*c*) The mass of gas in the flask and its volume.
(*d*) Have the flask totally under the water and have the pressure gauge as close as possible to the flask.

161. $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ *providing* T *is in kelvin*

162. (*a*) 600 K
(*b*) 300 kPa
(*c*) 7×10^5 Pa
(*d*) 333 K
(*e*) 1200 K (927 °C)
(*f*) $1·38 \times 10^5$ Pa
(*g*) 75 kPa
(*h*) 75 K (–198 °C)

163. $3·6 \times 10^5$ Pa

164. 120 kPa

165. 117 kPa

166. 540 K (267 °C)

Kinetic model

167. A. False
B. False
C. False
D. True
E. False
F. True

168. (*a*) They produce an outwards force on the container walls.
(*b*) The particles will move faster.
(*c*) (i) The pressure increases.
(ii) The gas particles move faster and collide with the container walls more often and with greater kinetic energy. They hit the walls of the container harder and produce a greater outwards force.

169. Gas particles in the container slow down when it is cooled. They collide with the container walls less often and with less force so decreasing the gas pressure in the canister.

170. (*a*) It will be greater.
(*b*) The balloon expands will the pressure inside and outside are the same.

171. The gas particles collide with the walls of the container. This produces an outwards force on the container wall causing the pressure.

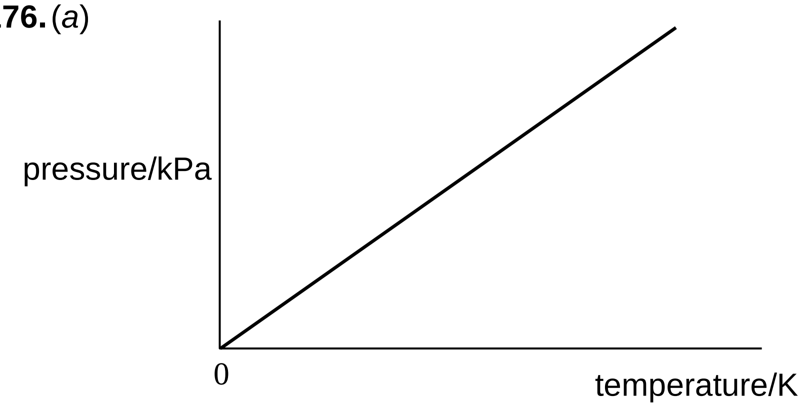
172. The increased mass of gas in the tyre means there are more air particles colliding with the walls of the tyre so creating a greater pressure.

173. The removal of air from the can means there are less gas particles colliding with the wall of the can compared to the air particles outside the can. This means there is a pressure pushing the can sides inwards.

174. The gas particles gain more kinetic energy as the temperature of the gas rises. This means they hit the container walls more often and with greater force so increasing the pressure.

175. (*a*) 0·75 m^3
(*b*) The air in her lungs expands as the pressure decreases as her depth reduces.

176. (*a*)



(*b*) Gas particles have more kinetic energy as the temperature of the gas increases. This means they hit the container walls more often and with greater force so increasing the pressure.

(*c*) $3{\cdot}7 \times 10^5$ Pa

177. (*a*) 225 cm^3

(*b*) As the pressure in the aircraft cabin decreases there are more collisions by gas particles with the Pringles container on the inside than on the outside. This causes an outwards pressure on the carton.

178. (*a*) 12 litres

(*b*) $2{\cdot}1 \times 10^{-7}$ m^3

(*c*) 0·42 litres

Specific Heat Capacity

179. The **temperature** of a substance is a measure of the average **kinetic** energy of the molecules of the substance. Temperature can be measured directly using a thermometer.

Heat is the amount of thermal energy a substance contains, measured in joules. The amount of heat energy a substance contains depends upon a number of factors including its temperature and **mass**. Different substances also require different amounts of energy to produce a particular rise in temperature. This is called their **specific** heat capacity.

Specific heat capacity is defined as the energy required to raise the temperature of 1 kg of the substance by 1 °C. If heat energy is added to a substance its molecules gain kinetic energy and as a result the temperature of the substance rises.

180. $E_h = c\, m\, \Delta T$

181. (*a*) 167 200 J
(*b*) 902 J/kg°C
(*c*) 0·2 kg
(*d*) 5 °C
(*e*) 1908 J
(*f*) 20 °C

182. 9880 J

183. 100 320 J

184. (*a*) 1250 J/kg°C
(*b*) The block would loose heat energy to the surrounding air.

185. (*a*) 50 160 J
(*b*) 100·3 s
(*c*) Place an insulated lid on the container.

186. (*a*) 90 000 J
(*b*) 3000 J/kg°C
(*c*) There is no insulation around the container so it will loose a lot of heat to the surrounding air.

187. (*a*) 29·26 MJ
(*b*) (i) 6900 W
(ii) 4241 s (70 minutes)
(*c*) 81 %

188. (*a*) 76·6 °C
(*b*) It would be less effective as the new coolant cannot absorb as much energy for the same rise in temperature.

Reducing Energy waste

189. (*a*) A. Leaving lights on when no-one is there uses unnecessary energy.
B. If you heat more water than you need then the energy used to heat the excess water is wasted.
C. If the dishwasher is not full it will be used more often which uses energy unnecessarily.
D. Most heat escapes through the walls and roof
E. Even though standby is low power, lots of appliances can use up energy especially since they are on 24/7.
F. Doing things yourself keeps you fitter and doesn't use electricity eg. hand hedge clippers in the garden, hand whisk in the kitchen.
G. The same type of appliance can use quite different amounts of energy so look for A rated appliances.
H. Heat lost through windows can be reduced by double glazing.
I. The hot water tank will constantly lose heat as its hotter than its surroundings. If its will lagged this will slow losses down.
J. Showers use less hot water which you pay to heat so this saves energy.
K. Different energy suppliers have different rates. There can be better prices from competitors.
L. The hotter a room, the faster it will lose energy. Turning the room thermostat down means it loses heat less quickly.

(*b*) D. Insulating the walls and roof.

190. (*a*) The windows and doors.
(*b*) The older block is loosing more heat. The insulation put in when the house was built (if at all) will not be as great as the new building.

191. (*a*) The walls.
(*b*) Insulate the roof as this is where most energy is lost but it does not cost much money to do.