National 5 Physics

Electricity and Energy

Notes

Name……………………………………………………………

Key Area Notes, Examples and Questions

Other Notes

Key Area: Conservation of Energy

Previous Knowledge

Types of energy
Rearranging mathematical relationships

Success Criteria

1.1 I can understand what is meant by the terms gravitational potential energy and kinetic energy.

1.2 I know the principle of "conservation of energy".

1.3 I can identify and explain the "loss" of energy when energy is transferred.

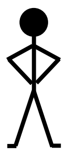
1.4 I can use the relationship $E_p = mgh$ to solve problems involving potential energy, mass, gravitational field strength and height.

1.5 I can use the relationship $E_k = \frac{1}{2}mv^2$ to solve problems involving kinetic energy, mass and speed.

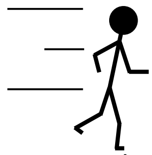
1.6 I can use the relationships for E_p and E_k to solve problems involving the conservation of energy.

1.1 I can understand what is meant by the terms gravitational potential energy and kinetic energy.

Kinetic Energy is the energy which an object possesses due to its motion.

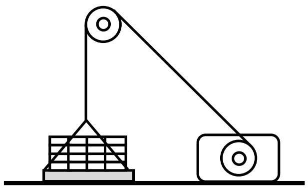


A stationary object has zero kinetic energy.

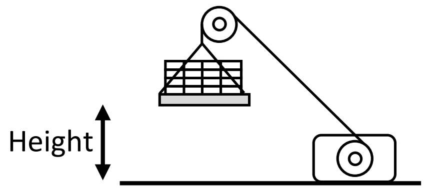


A moving object has kinetic energy.

Gravitational Potential Energy is the energy an object possesses due to its height in a gravitational field



An object on the ground has zero gravitational potential energy.



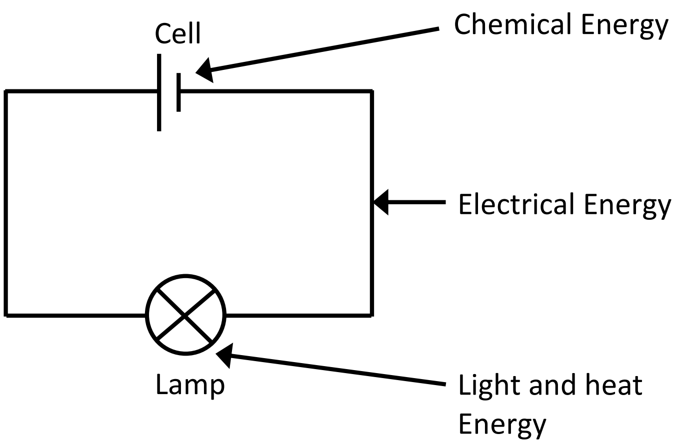
An object raised above the ground has gravitational potential energy.

There are many other types of energy e.g. light, heat, chemical, electrical, strain, sound, etc.

1.2 I know the principle of "conservation of energy".

The principle of conservation of energy states that energy is never created or destroyed. It is only converted from one form to another or transferred from one object to another. The total energy always remains the same.

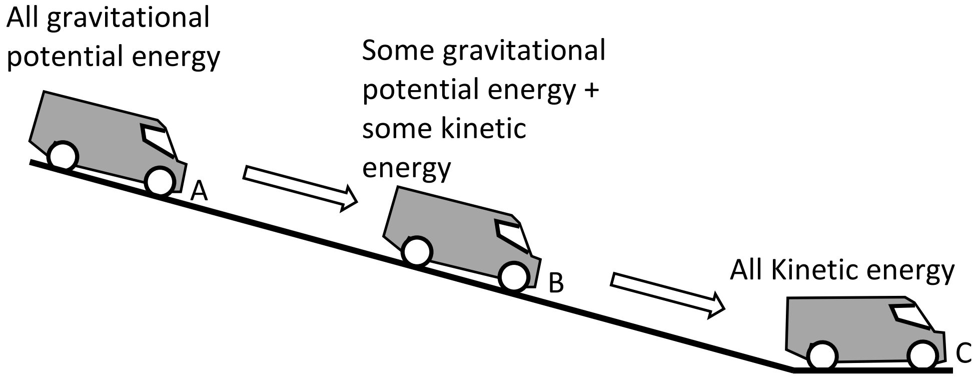
<u>Example – A lamp in an electrical circuit</u>



Chemical Energy stored in the cell
is converted to
Electrical energy in the wiring
is converted to
Light and heat energy in the lamp.

The total energy at any time does not change.

Example – A van rolling down a slope



Gravitational potential energy at the top of the slope is converted to **Kinetic energy** as the van moves down the slope.

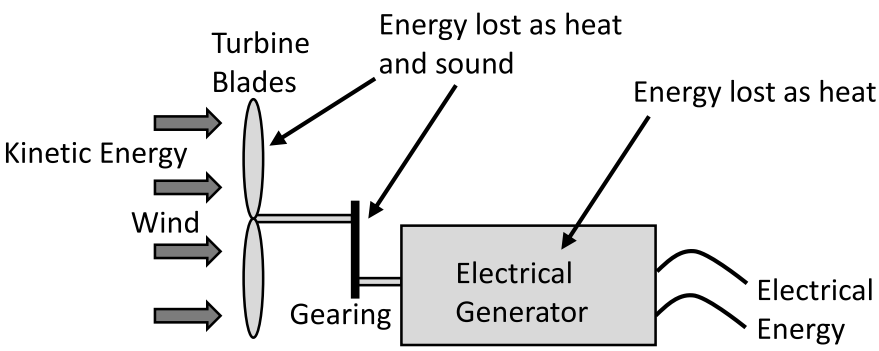
The total energy at points A, B and C is the same.

1.3 I can identify and explain the "loss" of energy when energy is transferred.

When energy is transformed from one form to another some of the energy is changed into useful forms of energy and some into unwanted forms. Energy changed into unwanted forms is called energy "loss". Remember energy cannot be destroyed so the total energy is always the same.

Example

In a wind turbine the electrical energy produced is less than the kinetic energy of the wind.



Only some of the original kinetic energy of the wind is transferred to the turbine blades. Some energy is lost as sound. More energy is lost as heat due to the friction between the air and the blades, friction in the gearing, friction and other electrical losses in the generator. As energy is conserved, the sum of all these lost energies and the electrical energy output is the same as the original kinetic energy of the wind.

Electricity and Energy Problem Book Page 37 Questions 110 to 112.

1.4 I can use the relationship $E_p = mgh$ to solve problems involving potential energy, mass, gravitational field strength and height.

Gravitational potential energy is related to the mass of an object, its height from the ground and the gravitational field strength.

$$E_p = mgh$$

m is the mass of the object (kg)

h is the height of object above the ground (m)

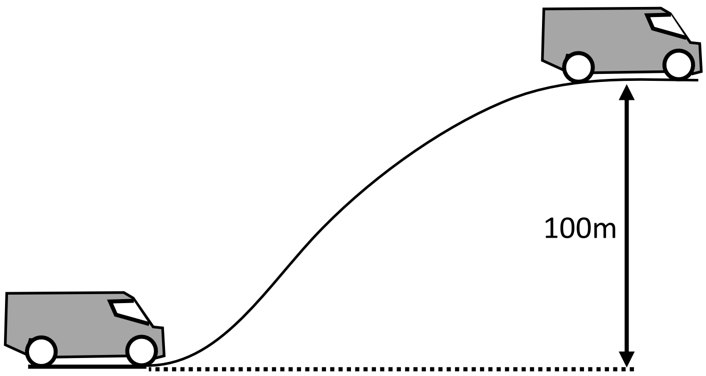
E_p is the gravitational potential energy (J)

g is the gravitational field strength (Nkg^{-1})
On the surface of the Earth $g = 9.8\text{Nkg}^{-1}$

Example
A 1000kg van drives up a large hill 100m high. Find the gravitational potential energy gained by the van

Solution
$E_p = ?$
$m = 1000\text{kg}$
$g = 9.8\text{Nkg}^{-1}$
$h = 100\text{m}$

$E_p = mgh$
$E_p = 1000 \times 9.8 \times 100$
$E_p = 98{,}0000\text{J}$



Example
A ball of mass 1.0kg is thrown into the air is reaches a maximum height then fall back to the ground. It's gravitational potential energy at its maximum height is 490J. Find the balls maximum height.
Solution
$E_p = 490\text{J}$
$m = 1.0\text{kg}$
$g = 9.8\text{Nkg}^{-1}$
$h = ?$

$E_p = mgh$

$490 = 1.0 \times 9.8 \times h$

$h = \frac{490}{1.0 \times 9.8}$

$h = 50\text{m}$

Electricity and Energy Problem Book Pages 37 and 38 Questions 113 to 118.

1.5 I can use the relationship $E_k = \frac{1}{2}mv^2$ to solve problems involving kinetic energy, mass and speed.

The kinetic energy of an object is related to its mass and its speed. Kinetic energy is given by

$$E_k = \frac{1}{2}mv^2$$

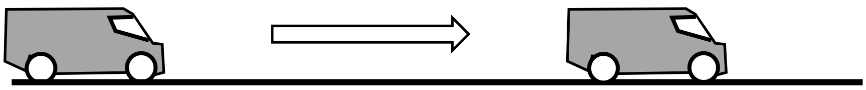
m is the mass of the object (kg)

E_k is the kinetic energy (J)

v is the speed of the object (ms^{-1})

<u>Example</u>

A 1000kg van accelerates from rest to $10ms^{-1}$. Find the kinetic energy of the moving van.



<u>Solution</u>

$E_k = ?$
$m = 1000kg$
$v = 10ms^{-1}$

$$E_k = \frac{1}{2}mv^2$$

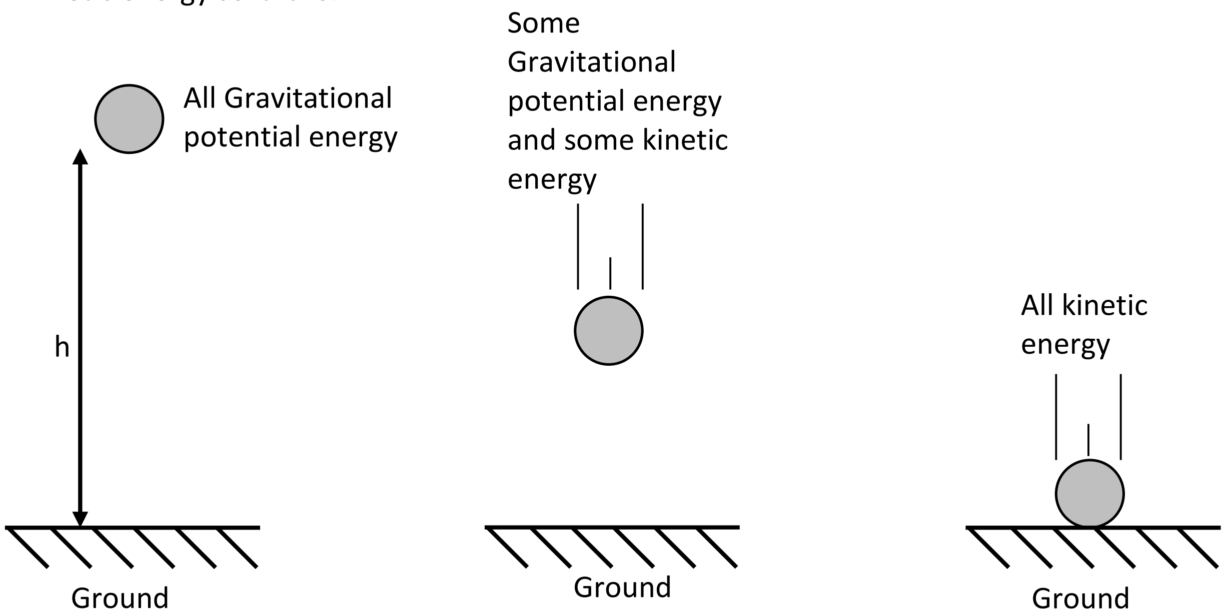
$$E_k = \frac{1}{2} \times 1000 \times 10^2$$

$$E_k = 50{,}000J$$

Electricity and Energy Problem Book Pages 38 and 39 Questions 119 to 126.

1.6 I can use the relationships for E_p and E_k to solve problems involving the conservation of energy.

When an object falls through a height its gravitational potential energy is converted to kinetic energy as it falls.



<u>Example</u>

A 1.0kg ball is dropped from a height of 2.0m.

a. Find the gravitational potential energy of the ball before it is dropped.
b. Find the kinetic energy of the ball as it strikes the ground
c. Find the speed of the ball as it hits the ground.

<u>Solution</u>

a.
$E_p = ?$
$m = 1.0\text{kg}$
$g = 9.8\text{Nkg}^{-1}$
$h = 2.0\text{m}$

$E_p = mgh$
$E_p = 1.0 \times 9.8 \times 2.0$
$E_p = 20\text{J} \ \ (19.6\text{J})$

b. As all the gravitational potential energy is converted to kinetic energy
$E_k = E_p = 20\text{J}\ (19.6\text{J})$

c.
$E_k = 19.6\text{J}$
$m = 1.0\text{kg}$
$v = ?$

$$E_k = \frac{1}{2}mv^2$$
$$19.6 = \frac{1}{2} \times 1.0 \times v^2$$
$$v^2 = \frac{19.6}{\frac{1}{2} \times 1.0}$$
$$v = \sqrt{39.2}$$
$$v = 6.3\text{ms}^{-1}$$

OR

$$mgh = \frac{1}{2}mv^2$$

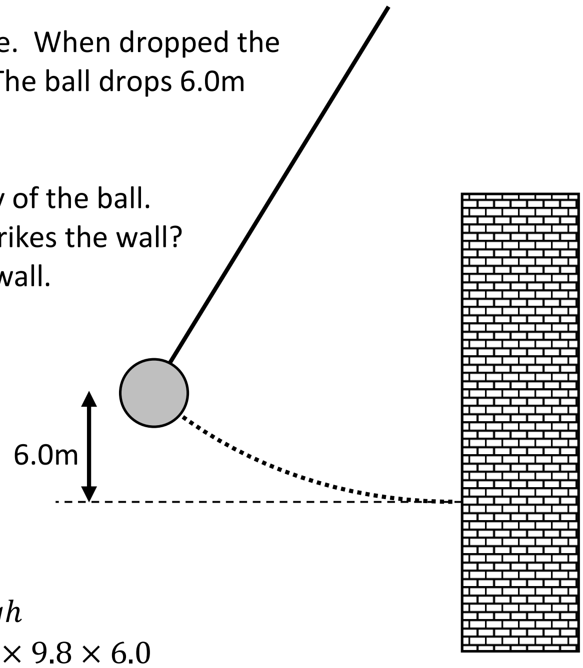
Mass cancels

$$gh = \frac{1}{2}v^2$$
$$v = \sqrt{2gh}$$
$$v = \sqrt{2 \times 9.8 \times 2.0}$$
$$v = 6.3\text{ms}^{-1}$$

Example

A 50kg wrecking ball is suspended from a crane. When dropped the ball swings through an arc and strikes a wall. The ball drops 6.0m is it swings.

a. Find the initial gravitational potential energy of the ball.
b. What is the kinetic energy of the ball as it strikes the wall?
c. Calculate the speed of the ball as it hits the wall.



Solution

a.

$E_p = ?$
$m = 50\text{kg}$
$g = 9.8\text{Nkg}^{-1}$
$h = 6.0\text{m}$

$E_p = mgh$
$E_p = 50 \times 9.8 \times 6.0$
$E_p = 2900\text{J}$ (2940J)

b. As all the gravitational potential energy is converted to kinetic energy
$E_k = E_p = 2900\text{J} \quad (2940\text{J})$

c.

$E_k = 2940\text{J}$
$m = 50\text{kg}$
$v = ?$

$$E_k = \frac{1}{2}mv^2$$
$$2940 = \frac{1}{2} \times 50 \times v^2$$
$$v^2 = \frac{2940}{\frac{1}{2} \times 50}$$
$$v = \sqrt{117.6}$$
$$v = 11\text{ms}^{-1} \quad (10.8\text{ms}^{-1})$$

OR

$$mgh = \frac{1}{2}mv^2$$
$$gh = \frac{1}{2}v^2$$
$$v = \sqrt{2gh}$$
$$v = \sqrt{2 \times 9.8 \times 6.0}$$
$$v = 11\text{ms}^{-1} \quad (10.8\text{ms}^{-1})$$

Electricity and Energy Problem Book Pages 40 to 42 Questions 127 to 132.

Key Areas: Electrical charge carriers, electric fields and potential difference (voltage)

Previous Knowledge

Positive and negative charges
Current and voltage

Success Criteria

2.1 I can define electric current as the electric charge transferred per unit time.

2.2 I can use the relationship $Q = It$ to solve problems involving charge, current and time.

2.3 I understand what is meant by an electric field.

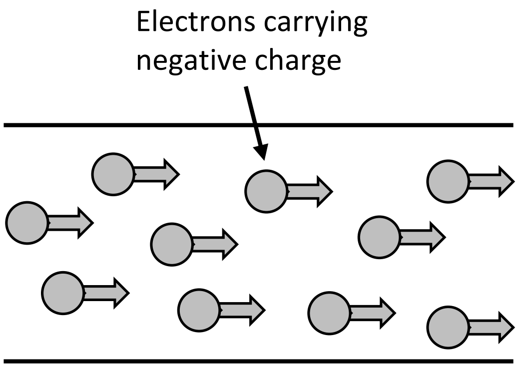
2.4 I know that an electric field produces a force on a charged particle and can find the direction of this force.

2.5 I know that the potential difference (voltage) of an electrical supply is a measure of the energy given to the charge carriers in a circuit.

2.6 I know the difference between direct current (d.c.) and an alternating current (a.c.).

2.1 I can define electric current as the electric charge transferred per unit time.

Electrons carry electrical charge. When electrons move through a wire they transfer charge from one place to another.
Electrical current is defined as the electric charge transferred per unit time (i.e. per second).



Current is the flow of electrical charges

2.2 I can use the relationship $Q = It$ to solve problems involving charge, current and time.

The charge transferred by and electric current is given by the relationship

$$Q = It$$

t is the time (s)

Q is the charge (C)

I is the current (A)

Example
Find the time for a charge of 0.50C to be transferred by an electric current of 0.80A.

Solution
$Q = 0.50\text{C}$
$I = 0.80\text{A}$
$t = ?$

$$Q = It$$

$$0.50 = 0.80 \times t$$

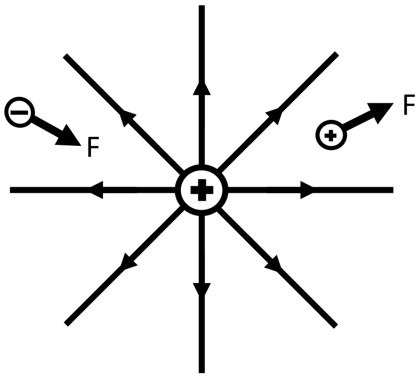
$$t = \frac{0.50}{0.80}$$

$$t = 0.63\text{s} \ \ (0.625\text{s})$$

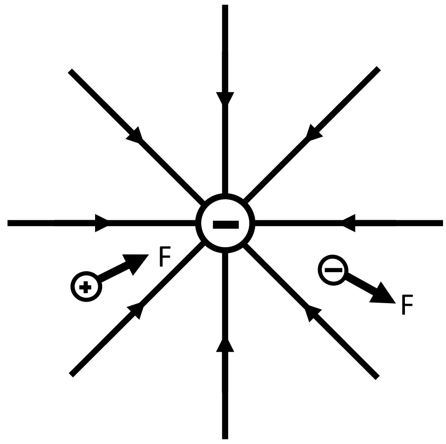
Electricity and Energy Problem Book Pages 1 and 2 Questions 1 to 8

2.3 I understand what is meant by an electric field.
2.4 I know that an electric field produces a force on a charged particle and I can find the direction of this force.

An electrical charge will produce an electric field in the space around it. This electric field will produce a force on a charged particle.
The electric field is represented by lines with an arrow showing the direction of the force produced on a positive particle. The force on negative particles will be in the opposite direction.



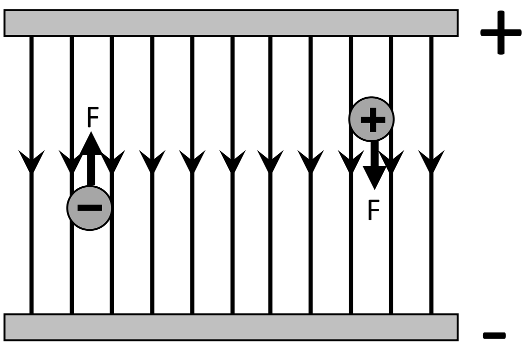
Single positive charge



Single negative charge

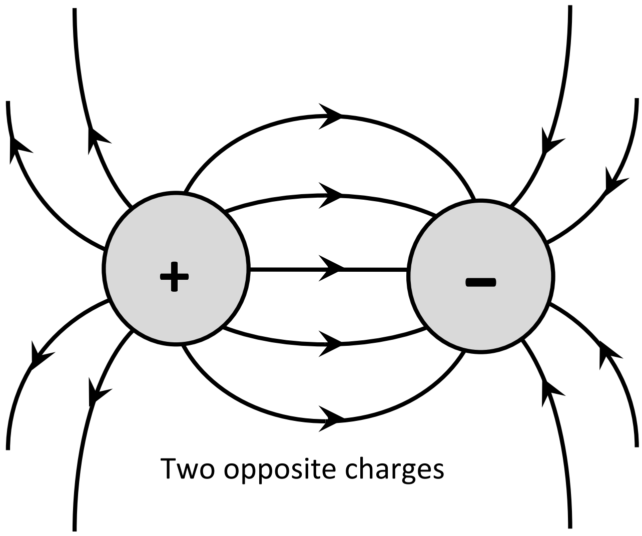
The force on a negative particle is in the opposite direction to the arrow on the field lines. i.e. away from a negative charge and towards a positive charge.

The force on a positive particle is in the same direction to the arrow on the field lines. i.e. away from a positive charge and towards a negative charge.



Parallel changed plates produce a uniform electric field between the plates.

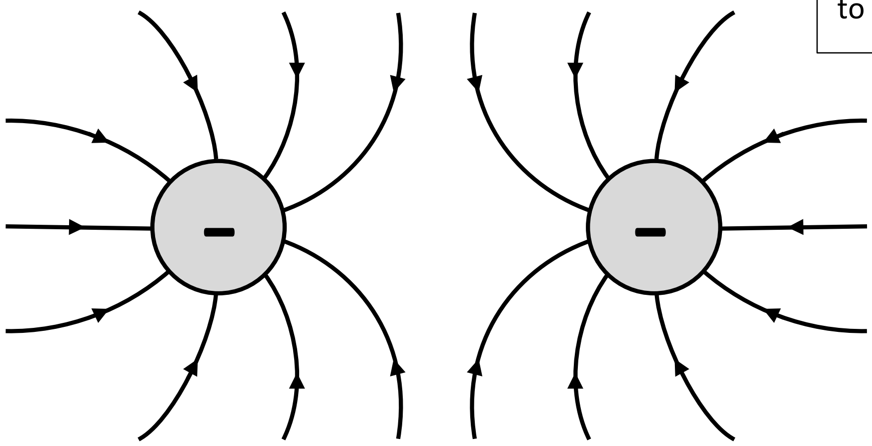
Electricity and Energy Problem Book Pages 2 and 3 Questions 12 to 16



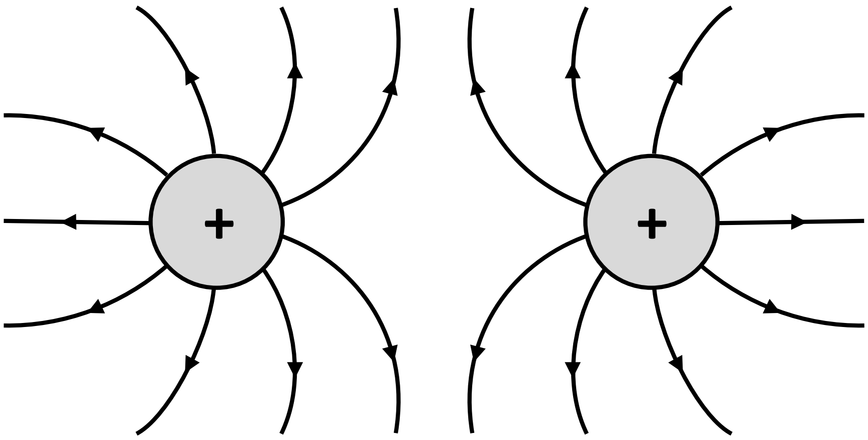
Two opposite charges

A **positively** charged particle will follow a path given by the direction of the arrows on the field lines.

A **negatively** charged particle will follow a path in the opposite direction to the arrows on the field lines.



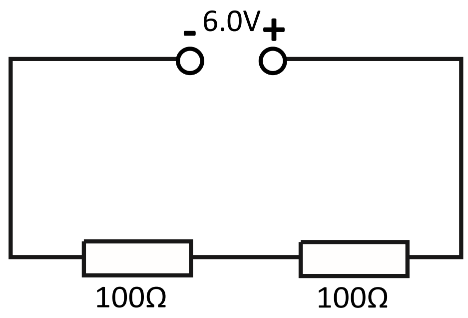
Two negative charges



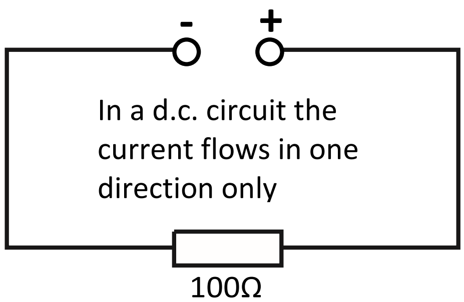
Two positive charges

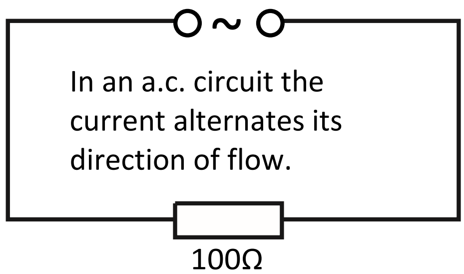
2.5 I know that the potential difference (voltage) of an electrical supply is a measure of the energy given to the charge carriers in a circuit.

In an electrical circuit the potential difference of an electrical supply is the energy given to each coulomb of change which passes through the supply. E.g. For the 6.0V supply shown 6.0J of energy is transferred from the supply to each coulomb of charge passing through the power supply. This energy is converted to heat energy in the resistors.

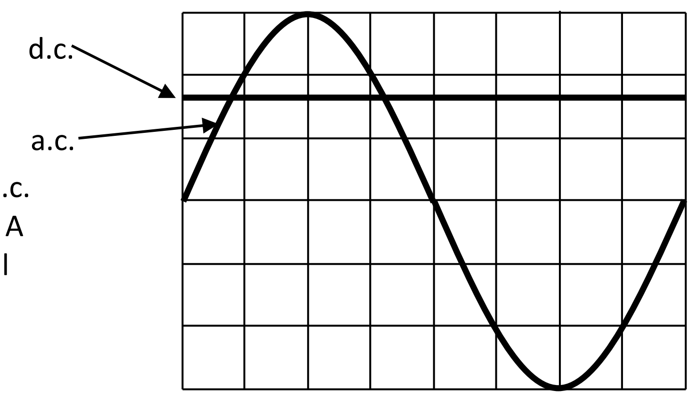


2.6 I know the difference between direct current (d.c.) and alternating current (a.c.).





On an oscilloscope screen an a.c. signal appears as a sine wave. A d.c signal appears as horizontal line.



Electricity and Energy Problem Book Page 2 Questions 9 to 11.

Key Area: Ohm’s Law

Previous Knowledge

Current and voltage and resistance

Success Criteria

3.1 I can use Ohm’s Law to solve problems involving potential difference (voltage), current and resistance.

3.2 I can describe an experiment to verify Ohm’s Law

3.3 I can use a voltage current graph to determine resistance.

3.4 I know the relationship between the temperature and resistance of a conductor.

3.1 I can use Ohm's Law to solve problems involving potential difference (voltage), current and resistance.

The relationship between voltage, current and resistance in circuits which contain resistors is given by Ohm's Law.

$$V = IR$$

R is the resistance (Ω)

V is the voltage (V)

I is the current (A)

<u>Example</u>
An element in an electric cooker draws 10A from a 230V mains supply.
Calculate the resistance of the heating element in the cooker.

<u>Solution</u>
$V = 230\text{V}$
$I = 10\text{A}$
$R = ?$

$$V = IR$$

$$230 = 10 \times R$$

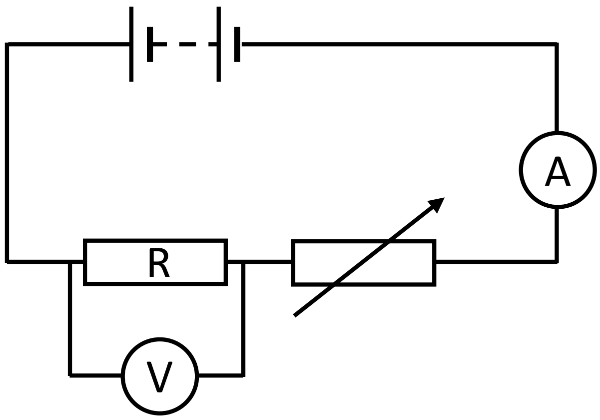
$$R = \frac{230}{10}$$

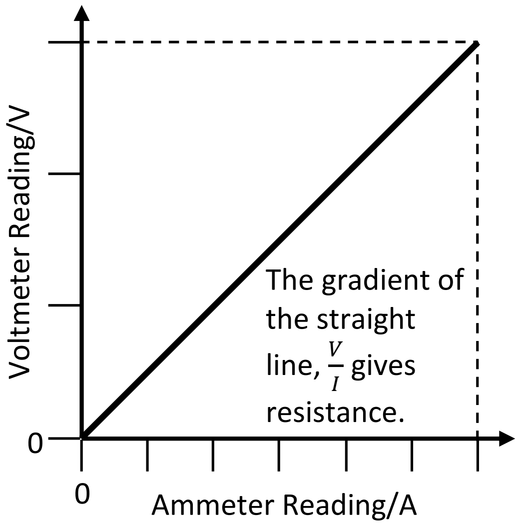
$$R = 23\Omega$$

Electricity and Energy Problems Book Pages 6 and 7 Questions 22 to 29
Page 8 Question 32

3.2 I can describe an experiment to verify Ohm's Law

the circuit shown below can be used to verify Ohm's Law. Adjusting the variable resistor to change the total circuit resistance will change the current in the circuit.





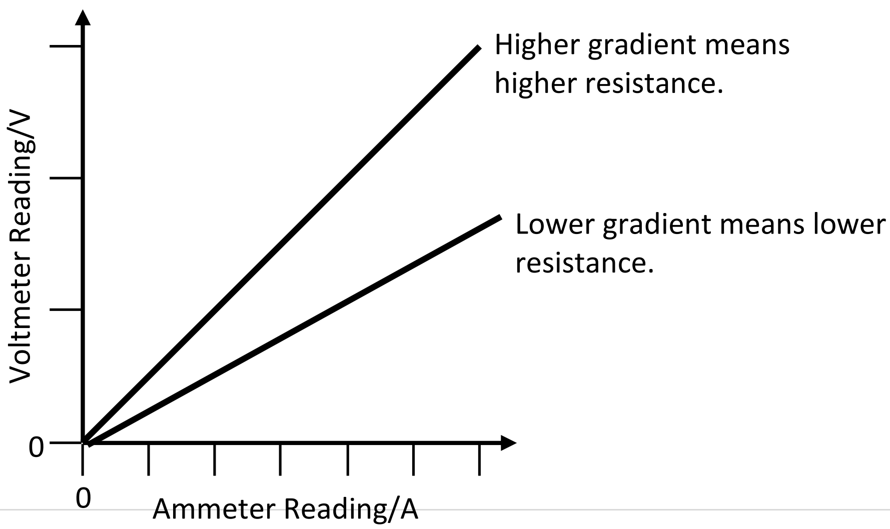
Ohm's Law can be written as

$$V = RI$$
$$y = mx + c$$

Comparing Ohm's Law to the straight line equation it can be seen that when *V* is plotted against *I* a straight line through the origin should be obtained.
When the experiment is performed the voltage across R against I is plotted a straight line through the origin will be obtained, verifying Ohm's Law.

3.3 I can use a voltage current graph to determine resistance.

Ohm's Law $V = IR$ can be rearranged for resistance giving $R = \frac{V}{I}$. From the best fit line on the graph any voltage divided by its corresponding current will give the resistance. From the best fit line on the graph in section 3.2 the gradient of the best fit line will also give the resistance.

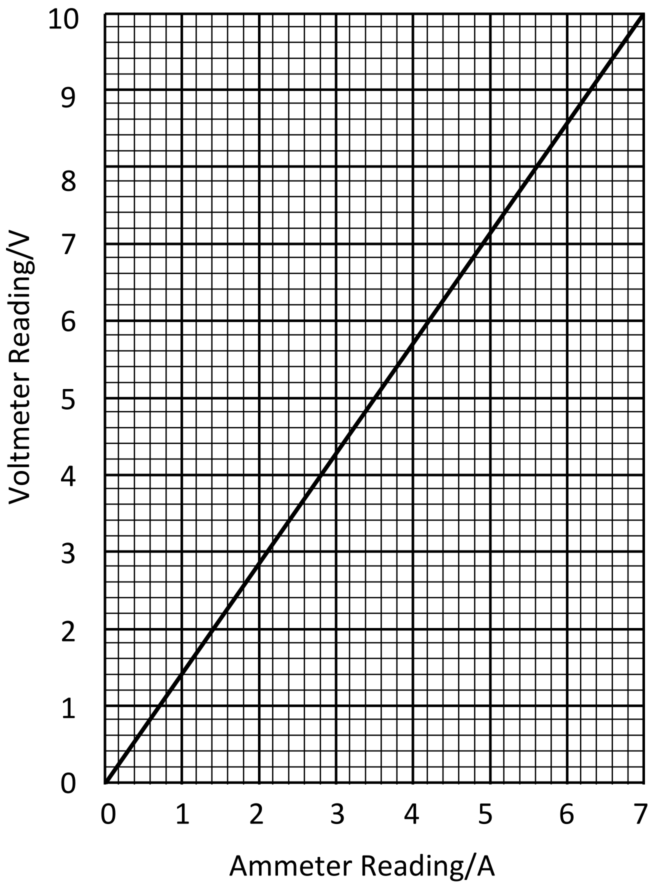


Example

The circuit shown above was setup, results obtained and a line graph drawn.

a. Using the graph below find the resistance of resistor R when the current is 1A, 3A, 5A and 7A .

b. State what happens to the size of the resistance as the current increases.



Solution

a. $\text{Resistance} = \frac{V}{I}$

$\text{At 1A, Resistance} = \frac{1.4}{1} = 1.4\Omega$

$\text{At 3A, Resistance} = \frac{4.3}{3} = 1.4\Omega$

$\text{At 5A, Resistance} = \frac{7.2}{5} = 1.4\Omega$

$\text{At 7A, Resistance} = \frac{10}{7} = 1.4\Omega$

b. Resistance is constant.

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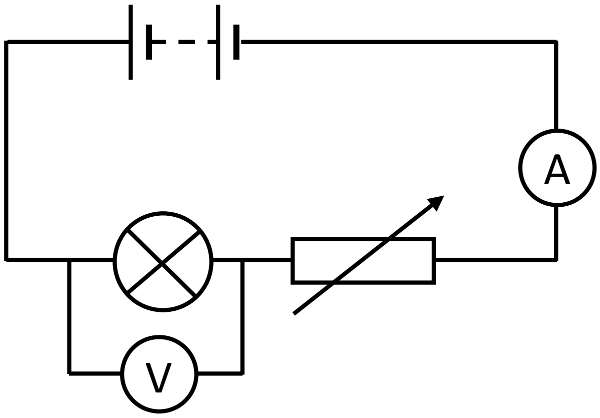
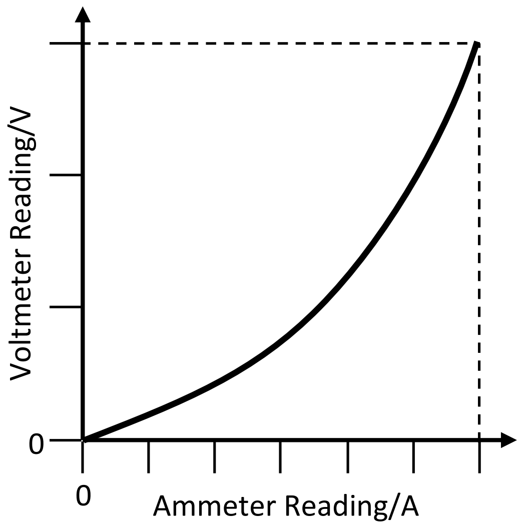
Page 8 Question 31
Page 9 Question 33
Pages 5 and 6 Questions 20 and 21.

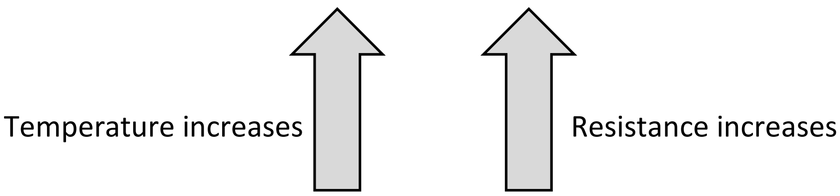
3.4 I know the relationship between the temperature and resistance of a conductor.

In the circuit shown below, adjusting the variable resistor to change the total circuit resistance will change the current in the circuit. As a greater current passes through the lamp the temperature of the conducting filament in the lamp will increase.
When the voltage across the lamp against I is plotted the line graph shown will be obtained.





The gradient of the graph increases as the current through the lamp increases. This means that the resistance of the conducting filament increases when its temperature is increased.



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Key Area: Practical Electrical and Electronic Circuits

Previous Knowledge

Current
Voltage
Resistance
Ohm's Law

Success Criteria

4.1 I know the circuit symbols for meters used to measure current, voltage and resistance and can and place them correctly in circuits.

4.2 I know the circuit symbol and function of the following components; cell, battery, lamp, switch, resistor, variable resistor, LED, motor, microphone, loudspeaker, photovoltaic cell, fuse, diode, capacitor, thermistor, LDR, relay, npn transistor, MOSFET.

4.3 I know the current and voltage relationships in series and parallel circuits.

4.4 I know the relationships between light level and resistance of an LDR and temperature and resistance of a thermistor.

4.5 I know that an NPN transistor and an n-channel enhancement MOSFET are used as switches in electronic circuits.

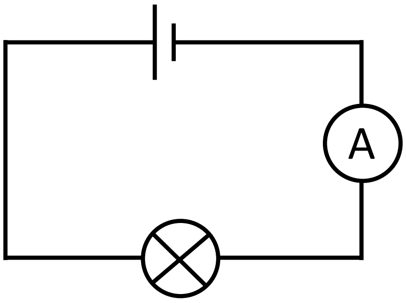
4.6 I can explain the function of a transistor in switching circuits.

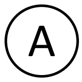
4.7 I can use the relationships $R_T = R_1 + R_2 + \cdots$ and $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

to solve problems involving the total resistance of resistors in series and parallel circuits.

4.8 I can solve problems involving resistors in a combination of series and parallel.

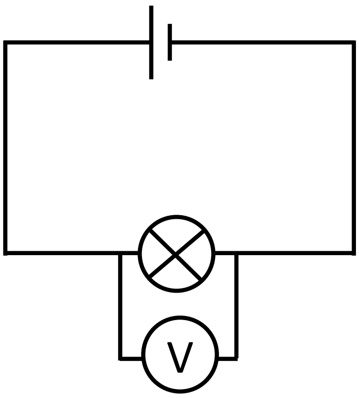
4.1 I know the circuit symbols for meters used to measure current, voltage and resistance and can place them correctly in circuits.



An ammeter has the circuit symbol 

Ammeters are connected in series.

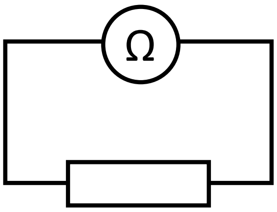
Ammeters measure current in amperes (A).



A voltmeter has the circuit symbol 

Voltmeters are connected in parallel.

Voltmeters measure voltage in volts (V).

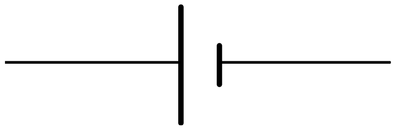
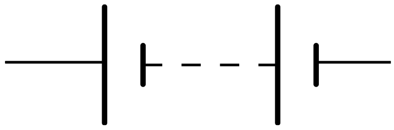
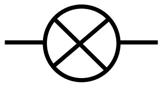
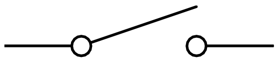
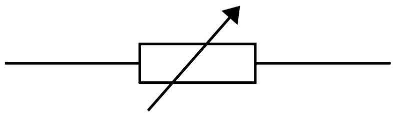
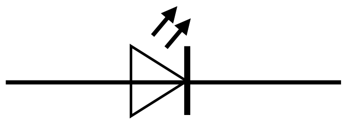
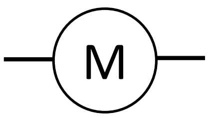
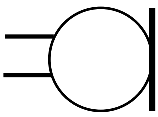


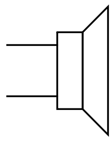
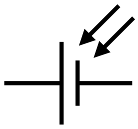
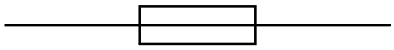
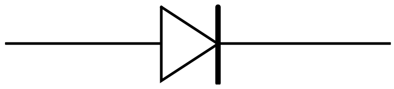
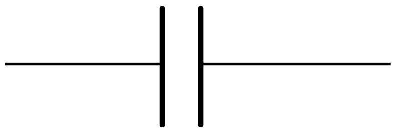
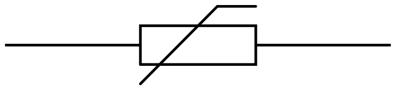
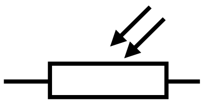
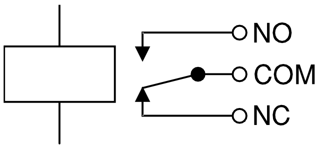
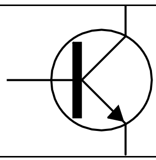
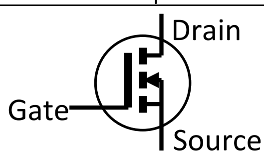
An ohmmeter has the circuit symbol 

Ohmmeters measure resistance in ohms (Ω).

4.2 I know the circuit symbol and function of the following components; cell, battery, lamp, switch, resistor, variable resistor, LED, motor, microphone, loudspeaker, photovoltaic cell, fuse, diode, capacitor, thermistor, LDR, relay, npn transistor, MOSFET.

Electronics Components

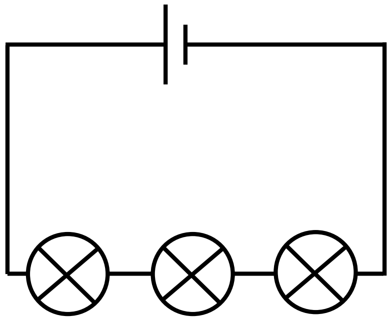
Name	Symbol	Function
Cell		Provides electrical energy
Battery		Provides electrical energy
Lamp		Converts electrical energy to light energy
Switch		Opens and closes a gap in the circuit
Resistor		Reduces the current in a circuit
Variable Resistor		Varies the current in a circuit
LED		Converts electrical energy into light energy
Motor		Changes electrical energy into kinetic energy
Microphone		Converts sound energy into electrical energy

Loudspeaker		Converts electrical energy into sound energy
Photovoltaic cell		Converts light energy into electrical energy
Fuse		Melts and creates a gap in the circuit when the current reaches a specified value
Diode		Allows current to flow in one direction only
Capacitor		Stores electrical energy
Thermistor		Changes resistance with changing temperature
LDR		Changes resistance with changing light level
Relay		Used to switch on and off one circuit from another circuit
Transistor (npn)		Electrically operated switch
Transistor (mosfet)		Electrically operated switch

Electricity and Energy Problems Book
Page 4 Questions 17 and 18.

4.3 I know the current and voltage relationships in series and parallel circuits.

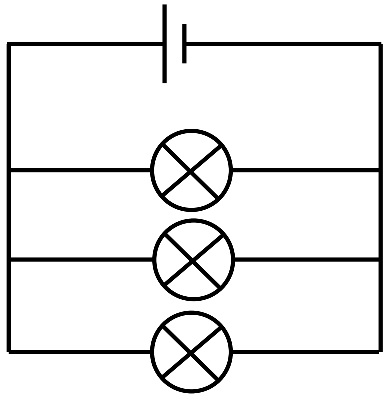
Series Circuit



A series circuit consists of a single loop (branch).

- The current is the same at all points.
- The voltage across each of the components adds up to the supply voltage.

Parallel Circuit



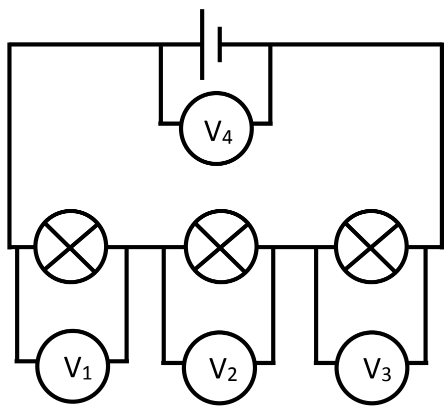
A parallel circuit consists of more than one loop (branch)

- The current in each of the branches add up to the supply current.
- The voltage in each of the branches is the same as the supply voltage.

In solving problems first identify which type of circuit you are dealing with; series or parallel. Then determine whether it is the current or voltage rule you will be using.

<u>Example</u>

In the circuit shown there are three identical bulbs. When $V_4 = 12V$ What are the voltage readings on $V_1, V_2, \text{and } V_3$



<u>Solution</u>

The circuit is a series circuit so the voltages across each bulb must add up to the supply voltage.
As the bulbs are identical the voltage across each must be the same.

$$V_1 = V_2 = V_3 = \frac{12}{3} = 4V$$

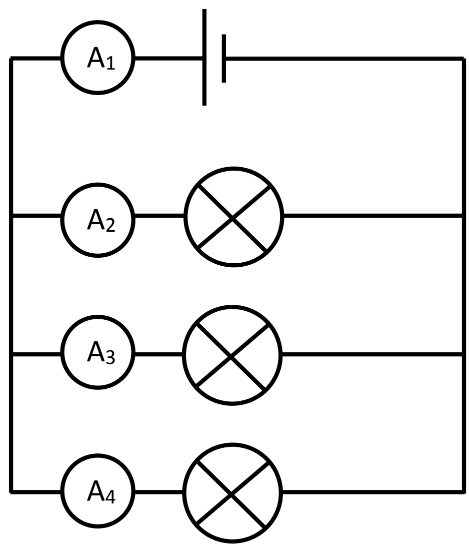
Example
In the circuit shown the reading on the ammeters A_1, A_2 and A_3 are

$A_1 = 4.0A$

$A_2 = 1.5A$

$A_3 = 1.0A$

Find the reading on A_4.



Solution
The circuit is a parallel circuit so the current in the branches must add up to the supply current.

$A_1 = A_2 + A_3 + A_4$

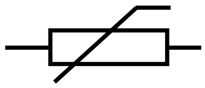
$4.0 = 1.5 + 1.0 + A_4$

$A_4 = 4.0 - (1.5 + 1.0)$

$A_4 = 1.5A$

Electricity and Energy Problems Book
Pages 10 and 11 Questions 34 and 35.

4.4 I know the relationships between; light level and resistance of an LDR, temperature and resistance of a thermistor.



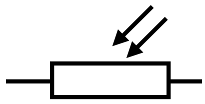
In a thermistor, an increase in temperature causes a decrease in resistance.

Temperature

up

Resistance

Down



In an LDR, an increase in light level causes a decrease in resistance.

Light level

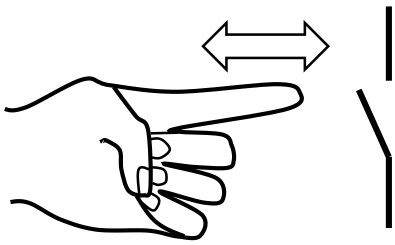
up

Resistance

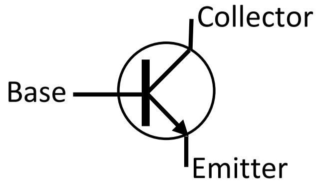
Down

4.5 I know that an NPN transistor and an n-channel enhancement MOSFET are used as switches in electronic circuits

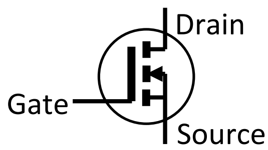
You need to be familiar with two types of transistor; the **npn transistor** and the **n-channel enhancement MOSFET**. Both act as switches in electronic circuits.



A switch opens or closes a gap in a circuit allowing a current to flow when closed.



For an NPN transistor applying 0.7V or more to the base switches the transistor on. This allows current to flow between the collector and the emitter.



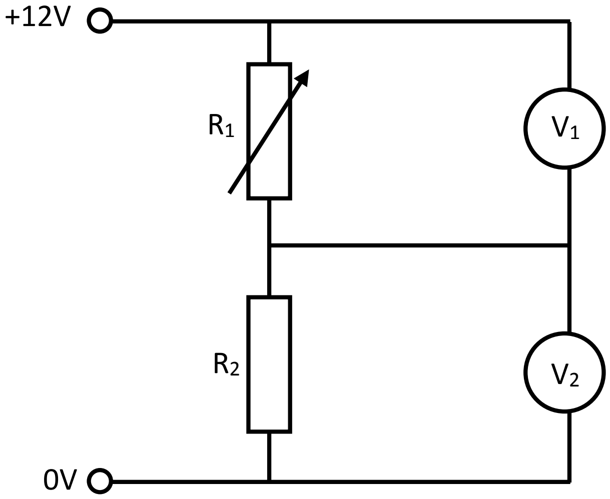
For a MOSFET applying 2.0V or more to the gate switches the transistor on. This allows current to flow between the drain and the source.

Electricity and Energy Problems Book Page 24 Questions 62 and 63.
Pages 25 and 26 Questions 65 and 66.

4.6 I can explain the function of a transistor in switching circuits.

Switching circuits involve using a change in the voltage across a component to switch on and off a transistor. When switched on this transistor then allows current to pass through to another device such as a motor, buzzer, relay, heater etc.

Variation of Voltage with resistance in Series Circuits



In the series circuit shown $V_1 + V_2 = 12V$ as voltages add up to the supply voltage

If the resistance of R_1 is increased the voltage V_1 must also increase.

If V_1 has increased, then V_2 must decrease if the total is to remain at 12V.

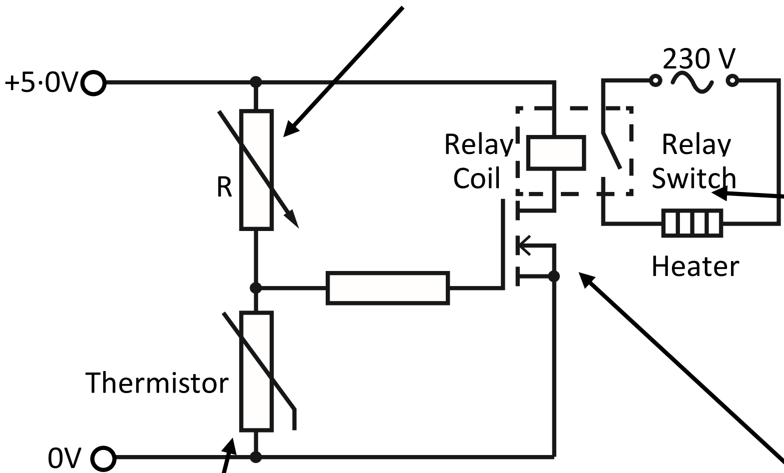
Electricity and Energy Problems Book Page 18 Question 46

When explaining switching circuits you will need to use your knowledge of thermistors or LDRs, transistors and voltages in series circuits.

Example Switching Circuit 1

The following circuit will turn on a heater when the temperature reduces.

The variable resistor adjusts the temperature at which the heater switches on.



The current flowing through the transistor switches on the relay and the heater.

When the temperature reduces the resistance of the thermistor increases.
As the resistance of the thermistor increases the voltage across the thermistor increases.

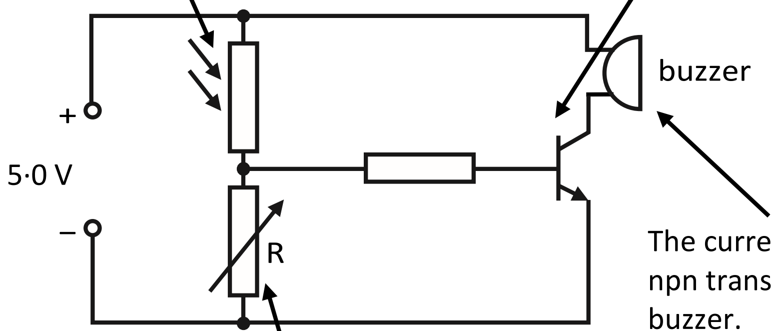
When the voltage across the thermistor reaches 2.0V the mosfet transistor switches on.

Example Switching Circuit 2

The following circuit switches on a buzzer when the light level increases.

When the light level increases the resistance of the LDR decreases.
As the resistance of the LDR decreases the voltage across the LDR decreases and the voltage across the variable resistor increases.

When the voltage across the variable resistor reaches 0.7V the transistor switches on.



The current flowing through the npn transistor switches on the buzzer.

The variable resistor adjusts the light level at which the buzzer switches on.

Electricity and Energy Problems Book
Page 25 Question 64
Pages 26 to 29 Question 67 to 72.

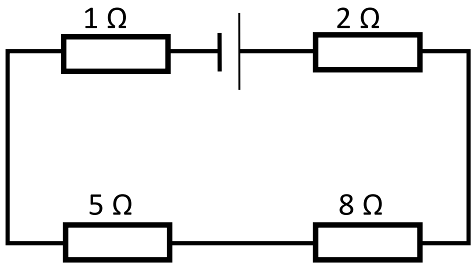
4.7 I can use the relationships $R_T = R_1 + R_2 + \cdots$ and $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$ to solve problems involving the total resistance of resistors in series and parallel circuits.

To solve problems in circuits it is usually necessary to find the total resistance in the circuit.

Resistors in series

When resistors are placed in series in a circuit the relationship $R_T = R_1 + R_2 + R_3 + \ ...$ can be used to find the total resistence R_T. This relationship can be extended to find the total resistance for any number of resistors in series.

<u>Example</u>
Find the total resistance in the series circuit shown.



<u>Solution</u>

$R_T = R_1 + R_2 + R_3 + \ R_4$

$R_T = 1 + 2 + 5 + 8$

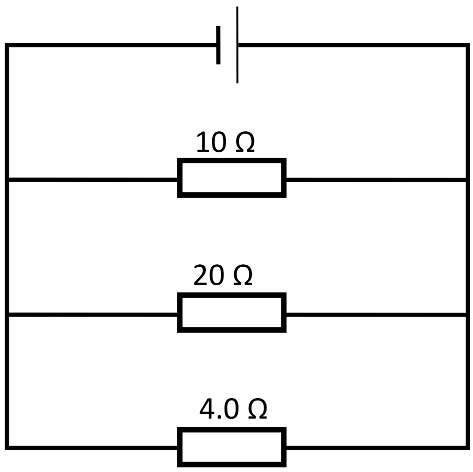
$R_T = 16\Omega$

Check: In a series circuit the total resistance must be greater than the largest resistance.

Resistors in parallel

When resistors are placed in parallel in a circuit the relationship $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$ can be used to find the total resistance R_T. This relationship can be extended to find the total resistance for any number of resistors in parallel.

<u>Example</u>
Find the total resistance in the parallel circuit shown.



<u>Solution</u>

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R_T} = \frac{1}{10} + \frac{1}{20} + \frac{1}{4.0}$

$\frac{1}{R_T} = 0.4$

$R_T = \frac{1}{0.4}$

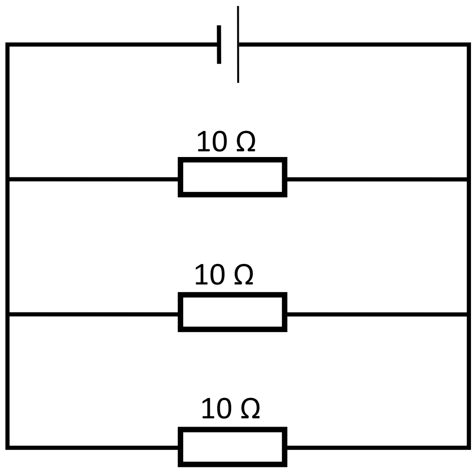
$R_T = 2.5\Omega$

Check: In a parallel circuit the total resistance must be less than the smallest resistance.

Resistors in Parallel Shortcut

When **ALL** the resistors in a parallel circuit have the same resistance, the total resistance is given by dividing the resistance of one resistor by the number of resistors.

Example
Find the total resistance of the circuit shown.



Solution

$$R_T = \frac{10}{3} = 3.3\Omega$$

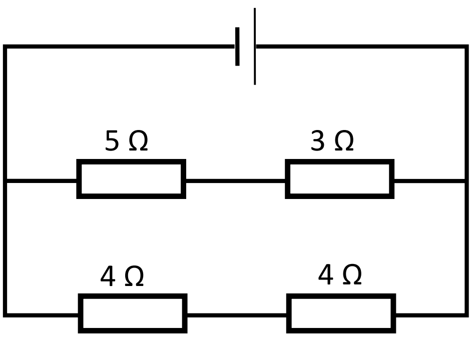
Electricity and Energy Problems Book
Pages 12 and 13 Questions 36 to 39
Page 14 Question 32

4.8 I can solve problems involving resistors in a combination of series and parallel.

In more complicated resistor problems, you will be required to use the relationships for both series circuits and parallel circuits.

Example
Find the total resistance in the circuit shown.

Solution



Top branch $R = 5 + 3 = 8\Omega$

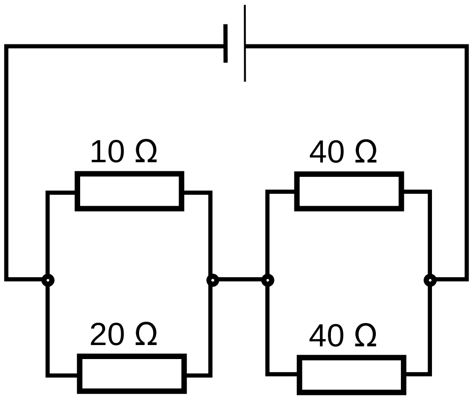
Bottom branch $R = 4 + 4 = 8\Omega$

Using the parallel resistor shortcut

$$R_T = \frac{8}{2} = 4\Omega$$

Version 1.0

Example
Find the total resistance of the circuit shown



Solution

Left side resistors

$$\frac{1}{R} = \frac{1}{10} + \frac{1}{20}$$

$$R = 6.7\Omega$$

Right side resistors

$$R = \frac{40}{2} = 20\Omega$$

$$R_T = 6.7 + 20 = 26.7\Omega$$

Electricity and Energy Problems Book Page 14 Question 40.

Key Area: Electrical Power

Previous Knowledge

Current
Voltage
Resistance
Energy types; heat, light, sound, etc.

Success Criteria

5.1 I can define electrical power in terms of electrical energy and time.

5.2 I can solve problems involving energy power and time using the relationship $P = \frac{E}{t}$.

5.3 I can solve problems involving power, potential difference (voltage), current and resistance in electrical circuits.

5.4 I can state the effect of changing potential difference and resistance on the current in an power developed across components in a circuit.

5.5 I can select an appropriate fuse rating given the power rating of an electrical appliance.

5.1 I can define electrical power in terms of electrical energy and time.

Electrical power is defined as the electrical energy transferred per second. This can also be written as the relationship

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

Energy in Joules (J)

Time in Seconds (s)

Power in Watts (W)

5.2 I can solve problems involving energy power and time using the relationship $\boldsymbol{P = \frac{E}{t}}$.

<u>Example</u>
A 60W light bulb is run for 2.0hours. Calculate the energy converted by the bulb in this time.

<u>Solution</u>
$E = ?$
$P = 60\text{W}$
$t = 2.0\text{hours} = 2 \times 60 \times 60 = 7200\text{s}$

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

$$60 = \frac{E}{7200}$$

$$E = 60 \times 7200$$

$E = 430{,}000\text{J}$ (432000J rounded to two significant figures)

Electricity and Energy Problems Book
Pages 30 and 31 Questions 73 to 80.

5.3 I can solve problems involving power, potential difference (voltage), current and resistance in electrical circuits.

In electrical circuits power can be calculated from **any two** of the following; current, voltage and resistance.
There are three forms of the power equation

$$P = IV$$

Voltage in Volts (V)

Power in Watts (W)

Current in Amperes (A)

Use this relationship when dealing with the quantities **power**, **current** and **voltage**.

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

Voltage in Volts (V)

Power in Watts (W)

Resistance in Ohms (Ω)

Use this relationship when dealing with the quantities **power**, **voltage** and **resistance.**

$$P = I^2R$$

Resistance in Ohms (Ω)

Power in Watts (W)

Current in Amperes (A)

Use this relationship when dealing with the quantities **power**, **current** and **resistance.**

<u>Example</u>
A 1500W iron runs using a mains voltage of 230V
a. Find the current in the heating element of the iron.
b. Find the resistance of the heating element of the iron.

<u>Solution</u>
a.
$P = 1500\text{W}$
$V = 230\text{V}$
$I = ?$

Choose the relationship containing *P, V and I*.

$P = IV$

$1500 = I \times 230$

$$I = \frac{1500}{230}$$

$I = 6.52\text{A}$ (6.522A) rounded to three significant figures.

b.

$P = 1500\text{W}$
$V = 230\text{V}$
$R = ?$

Choose the relationship containing *P, V and R*.

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

$$1500 = \frac{230^2}{R}$$

$$R = \frac{230^2}{1500}$$

$$R = 35.3\Omega$$

OR

Choose the relationship $V = IR$

$$230 = 6.522 \times R$$

$$I = \frac{230}{6.522}$$

$$I = 35.3\Omega$$

Electricity and Energy Problems Book
Pages 31 to 34 Questions 81 to 100.

5.4 I can state the effect of changing potential difference (voltage) and resistance on the current in an power developed across components in a circuit.

Potential Difference, Current and Power
Ohm's Law can be rearranged to give

$$I = \frac{V}{R}$$ For a fixed value of resistance, increasing in the voltage will increase the current.

Using the power relationship $P = \frac{V^2}{R}$

$$P = \frac{V^2}{R}$$ For a fixed value of resistance, increasing in the voltage will increase the power.

Resistance, Current and Power
From Ohm's Law

$$I = \frac{V}{R}$$ For a fixed value of voltage, increasing in the resistance will decrease the current.

Using the power relationship $P = \frac{V^2}{R}$

$$P = \frac{V^2}{R}$$ For a fixed value of voltage, increasing in the resistance will decrease the power.

5.5 I can select an appropriate fuse rating given the power rating of an electrical appliance.

Fuses protect the electrical wiring of an appliance from overheating when there is a fault. Faults in appliances can lead to short circuits. This causes a large current to flow through the fuse. The thin wire in the fuse will melt at its current rating e.g. 3A or 13A. Once melted the appliance is disconnected from the mains supply.

The power rating of an appliance will be given on its rating plate.

110 - 250V
50Hz to 60Hz
1000W
Model No. 354

The power rating can be used to find the correct size of fuse for the appliance using the 720W rule.

- Use a 3A fuse for appliances rated up to 720W
- Use a 13A fuse for appliances rated over 720W

<u>Example</u>

Complete the table showing which size of fuse should be fitted to the appliances

Appliance	Fuse size
1500W Iron	
50W Television	
2000W Kettle	

<u>Solution</u>

Use the 720W rule

Appliance	Fuse size
1500W Iron	13A
50W Television	3A
2000W Kettle	13A

Electricity and Energy Problems Book
Page 32 Questions 101 to 104.

Key Area: Specific Heat Capacity

Previous Knowledge

Units of temperature and heat energy.

Success Criteria

6.1 I know that different materials require different quantities of heat to raise the temperature of a unit mass by one degree Celsius and can use this to define specific heat capacity.

6.2 I know that the temperature of a substance is a measure of the mean kinetic energy of its particles.

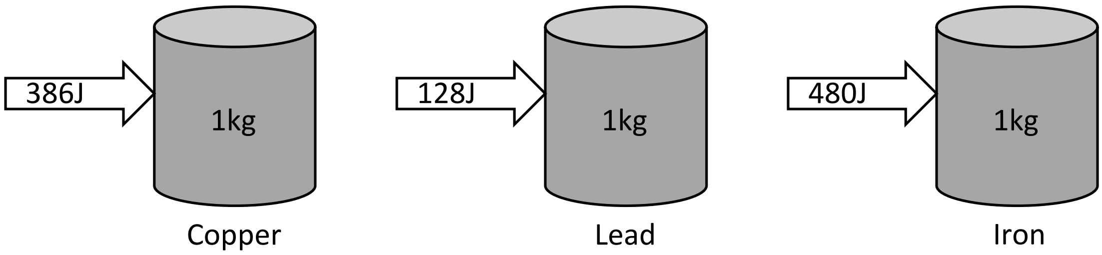
6.3 I can explain the connection between temperature and heat energy.

6.4 I can use the relationship $E = cm\Delta T$ to solve problems involving mass, heat energy, temperature change and specific heat capacity.

6.5 I can use the principle of conservation of energy to determine heat transfer.

6.1 I know that different materials require different quantities of heat to raise the temperature of a unit mass by one degree Celsius and can use this to define specific heat capacity.

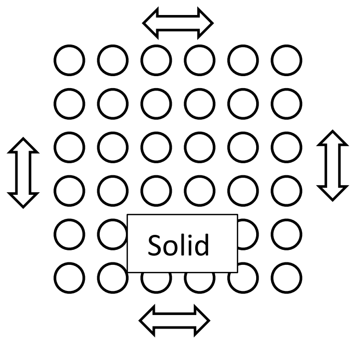
To raise the temperatures of different materials of the same mass by 1°C, different quantities of heat are required.



386J is required to raise the temperature of 1kg of copper by a temperature of 1°C	128J is required to raise the temperature of 1kg of lead by a temperature of 1°C	480J is required to raise the temperature of 1kg of iron by a temperature of 1°C

The energy required to heat 1kg of a substance by 1°C is called the **specific heat capacity**. The specific heat capacities of other materials are given in the data sheet at the end of these notes.

6.2 I know that the temperature of a substance is a measure of the mean kinetic energy of its particles.



The particles (atoms or molecules) in all materials are in constant motion. As there is a range of speeds of the particles in any material so there is a range in the kinetic energy of the particles. The temperature of a substance is a measure of the mean kinetic energy of its particles.

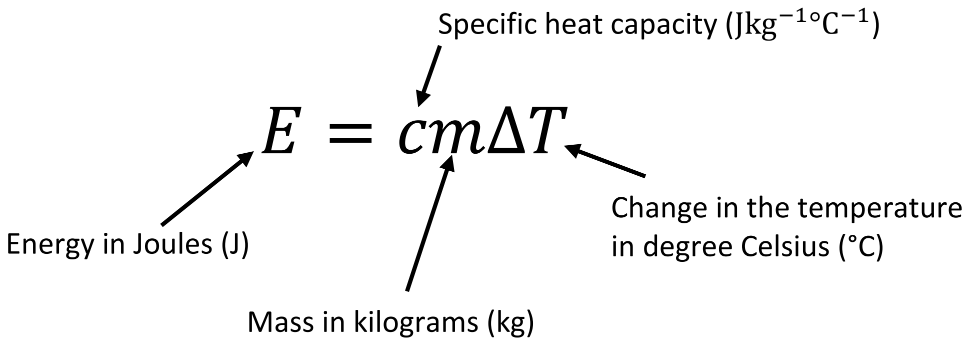
6.3 I can explain the connection between temperature and heat energy.

Temperature is a measure of the mean kinetic energy of the particles in a substance. Heat energy is the **total** energy of the motion of all the particles in a substance. The total heat energy depends on the temperature, the mass and the specific heat capacity of the substance.

e.g. Compare a cup of hot tea at 90°C and a swimming pool at 20°C. The mass of the tea is much smaller than the mass of the water in the swimming pool. So although the temperature of the tea is greater than the swimming pool the total energy in the swimming pool will be greater.

Electricity and Energy Problems Book Page 54 Question 179.

6.4 I can use the relationship $E = mc\Delta T$ to solve problems involving mass, heat energy, temperature change and specific heat capacity.



<u>Example</u>
Find the minimum energy required to heat a kettle containing 0.90kg of water at 20°C to boiling point at 100°C.

<u>Solution</u>

$E = ?$
$m = 0.90\text{kg}$
$c = 4180\text{Jkg}^{-1}°\text{C}^{-1}$
from the data sheet
$\Delta T = 100 - 20 = 80°\text{C}$

$E = cm\Delta T$

$E = 4180 \times 0.9 \times 80$

$E = 3.0 \times 10^5\text{J}$

Electricity and Energy Problems Book
Page 55 Questions 180 to 184.

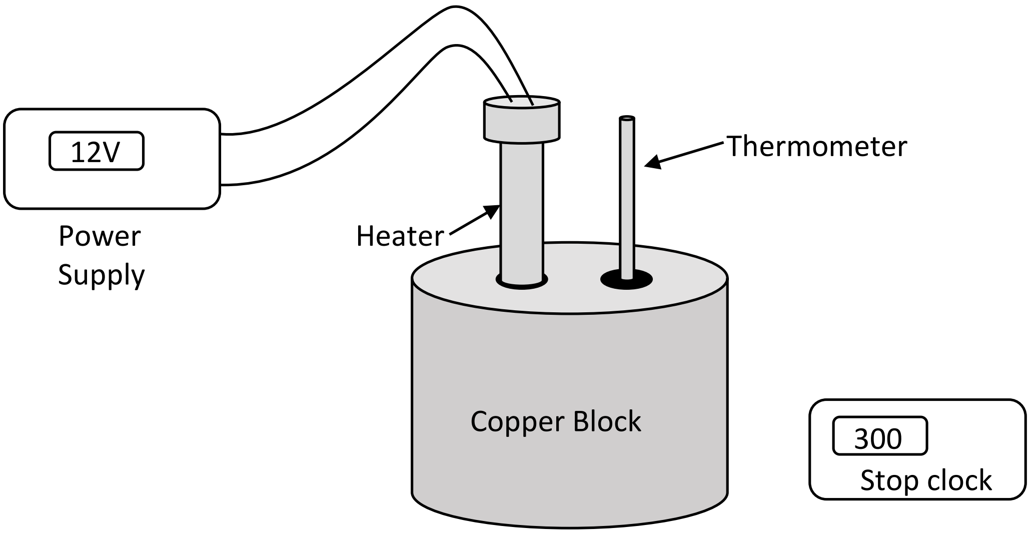
6.5 I can use the principle of conservation of energy to determine heat transfer.

When a substance is heated, the energy supplied can be in a different form e.g. In an electrical heater, the energy supplied is electrical energy which it transformed into heat energy. The principle of conservation of energy can be used to solve problems involving energy being transformed from one type to heat.

<u>Example</u>

A 50W heater heats a 1.0kg block of copper for 2.0minutes.

- **a.** Find the temperature rise of the block.
- **b.** The actual temperature rise will be less than calculated in part a. Explain why.
- **c.** How could the arrangement be improved so that the temperature rise was closer to that obtained in part a.



<u>Solution</u>

a.

$P = 50\text{W}$

$m = 1.0\text{kg}$

$t = 2.0\text{minutes} = 2.0 \times 60 = 120\text{s}$

$c = 386\text{Jkg}^{-1}{}^{\circ}\text{C}^{-1} - \text{from the data sheet}$

Calculate the energy supplied

$E = Pt$

$E = 50 \times 120$

$E = 6000\text{J}$

$$\text{E} = \text{cm}\Delta\text{C}$$

$$6000 = 386 \times 1.0 \times \Delta T$$

$$\Delta T = \frac{6000}{1.0 \times 386}$$

$$\Delta T = 16^{\circ}\text{C} \quad (15.54^{\circ}\text{C})$$

b. As the block is heating, some energy will be lost to the environment. Less energy will remain in the block producing a smaller a temperature rise.

c. Insulate the block.

Electricity and Energy Problems Book Page 56 and 57 Questions 185 to 188.

Key Area: Gas Laws and the Kinetic Model

Previous Knowledge

Units of force.
How to calculate areas

Success Criteria

7.1 I can describe how the kinetic model accounts for the pressure of a gas.

7.2 I can define pressure as $p = \frac{F}{A}$

7.3 I can solve problems involving pressure, force and area.

7.4 I know the relationship between Kelvin and Degree Celsius temperature scales and the absolute zero of temperature.

7.5 I can convert between Degrees Celsius and Kelvin

7.6 I can explain pressure-volume in terms of the kinetic model and describe an experiment to verify this law.

7.7 I can explain pressure-temperature Law in terms of the kinetic model and describe an experiment to verify this law.

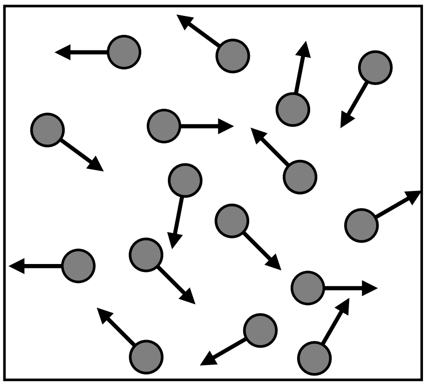
7.8 I can explain pressure-volume in terms of the kinetic model and describe an experiment to verify this law.

7.9 I can use the relationships $p_1V_1 = p_2V_2$ $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ $\frac{V_1}{T_1} = \frac{V_2}{V_1}$ to solve problems involving pressure, volume and temperature of a fixed mass of gas.

7.10 I can use the relationship $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ to solve problems involving pressure, volume and temperature of a fixed mass of gas.

7.1 I can describe how the kinetic model accounts for the pressure of a gas.

Particles of a gas are constantly moving at high speed in all directions. When placed in a container the particles will strike each other and the walls of the container. This will produce a force on the walls. The total force exerted on the walls divided by the area of the wall is called pressure. When the particles are moving faster they exert a greater force on the walls and so produce a higher pressure. When there are a greater number of particles striking the walls, there is a greater force produced giving a greater pressure.



7.2 I can define pressure as $p = \frac{F}{A}$

Pressure is force per unit area.

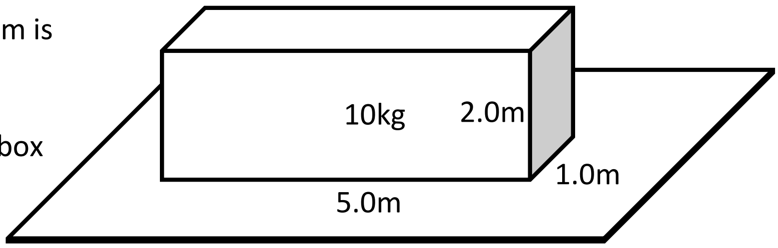
$$p = \frac{F}{A}$$

- F — Force in Newtons (N)
- p — Pressure in Pascals (Pa)
- A — Area in square metres (m^2)

7.3 I can solve problems involving pressure, force and area.

<u>Example</u>

A 10kg box of dimensions 5m by 2m by 1m is placed on the ground.



a. Find the pressure exerted by the box on the ground.

b. Which side of the box should be placed on the ground to give the maximum pressure.

Solution

a.

$m = 10\text{kg}$
$A = 5.0 \times 1.0 = 5.0\text{m}^2$
$g = 9.8\text{Nkg}^{-1}$

The force acting downwards is the weight
$w = mg$
$w = 10 \times 9.8 = 98N$
$w = 98\text{N}$

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

$$p = \frac{98}{5.0}$$

$p = 20\text{Pa}$ (19.6Pa to 2 significant figures)

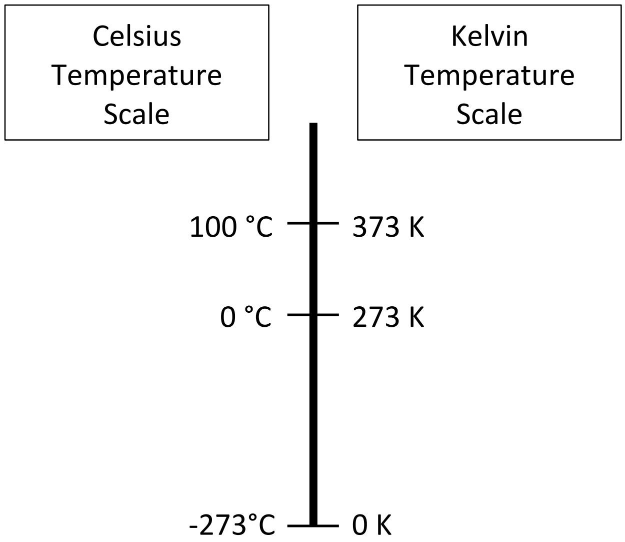
b. As $P = \frac{F}{A}$ the largest pressure will be obtained from the side with the smallest area.

Smallest area$= 2.0 \times 1.0 = 2.0\text{m}^2$

Electricity and Energy Problems Book
Pages 43 and 44 Questions 133 to 140.

7.4 I know the relationship between Kelvin and Degree Celsius temperature scales and the absolute zero of temperature.

The Celsius and Kelvin temperature scales have the same degree interval e.g. a change in temperature of 1°C is the same as a change in temperature of 1 K. The Kelvin scale starts at -273°C, which is the lowest possible temperature.



At 0 K (-273°C) particles in the material will have slowed to a point where their motion cannot be reduced any further. This is the lowest possible temperature and is called **absolute zero**.

7.5 I can convert between Degrees Celsius and Kelvin

Converting between Degrees Celsius and Kelvin
To convert from Kelvin to Degrees Celsius subtract 273
To convert from Degrees Celsius to Kelvin add 273.

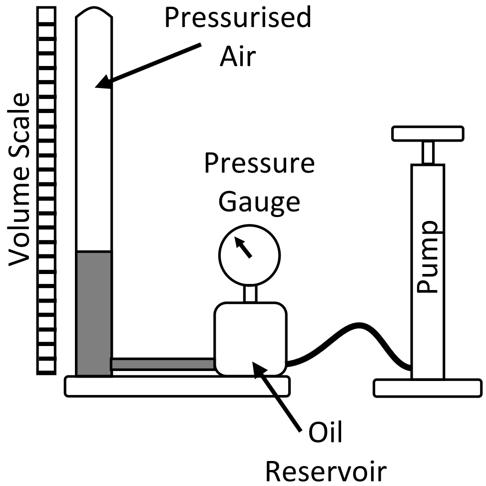
<u>Example</u>
Convert
a. 20°C to Kelvin
b. 191K to Degrees Celsius

<u>Solution</u>
a. $20 + 273 = 293\text{K}$
b. $191 - 293 = -82°\text{C}$

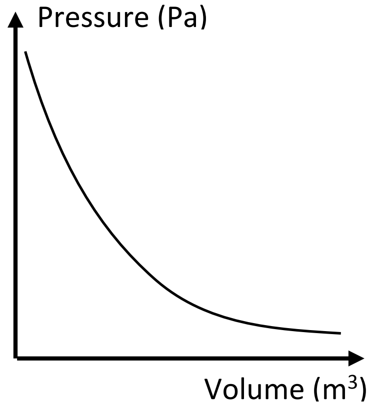
Electricity and Energy Problems Book
Pages 46 and 47 Questions 149 to 151.

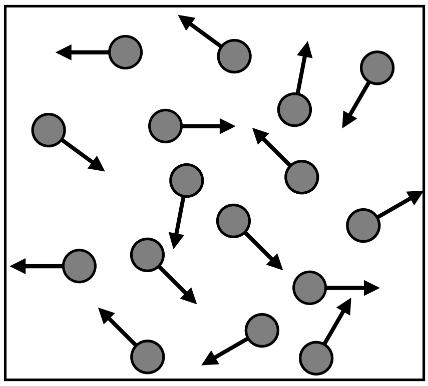
7.6 I can explain pressure-volume in terms of the kinetic model and describe an experiment to verify this law.

Pressure-Volume (Boyle's Law)
The equipment shown is used to verify Boyle's Law.
The mass of the air is kept constant and temperature of the air is allowed cool to room temperature. The pressurised air is within a glass cylinder. The pump is used to change the pressure of oil in a reservoir which flows through to the glass cylinder pressurising the air. The scale on the side of the glass cylinder is used to measure the volume of the air.
The graph obtained will show the curve shown in the graphs below.

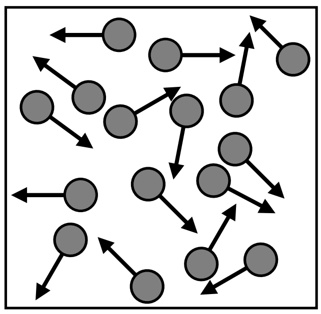


For a fixed mass of gas at constant temperature, as the volume of a gas is increased the pressure decreases.





High volume, low volume

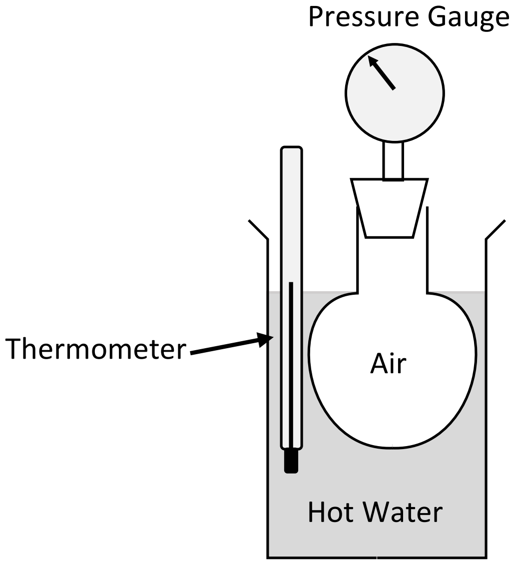


Low volume, high pressure

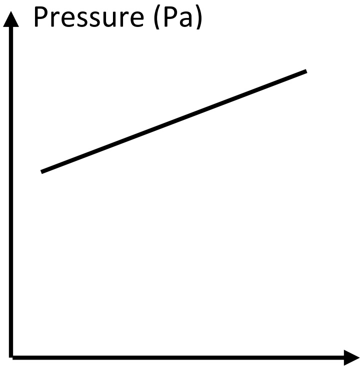
As the volume of a fixed mass of gas at constant temperature is increased the frequency which the particles strike the wall of the container increases. This increased strike frequency increases the force on the walls. As $p = \frac{F}{A}$ this increases the pressure.

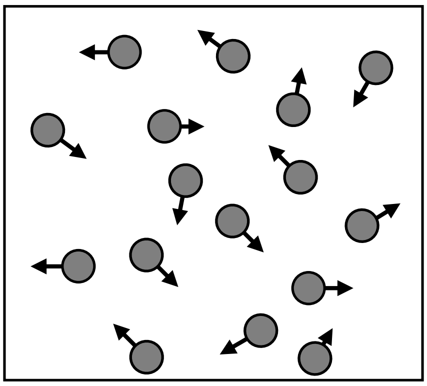
7.7 I can explain pressure-temperature Law in terms of the kinetic model and describe an experiment to verify this law.

Pressure-Temperature (Gay-Lussac's Law)
The equipment shown is used to confirm Gay-Lussac's Law. The mass of the air is kept constant and the volume fixed. The hot water is allowed to cool. The temperature and pressure readings are taken at regular intervals. The graph obtained from pressure against temperature will give the straight line shown below.

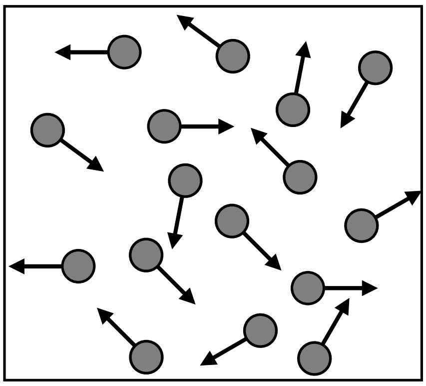


For a fixed mass of gas at constant volume as the temperature of the gas is increased the pressure increases.





Low temperature, low pressure



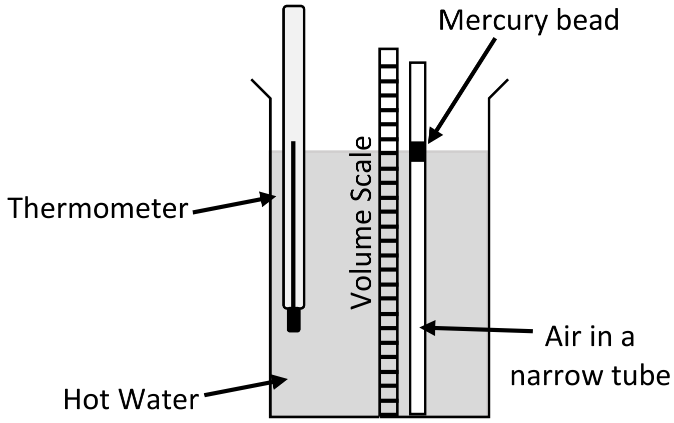
High temperature, high pressure

As the temperature of a fixed mass of gas at constant volume is increased the speed at which the particles strike the wall of the container increases. This increased strike speed increases the force on the walls. As $p = \frac{F}{A}$ this increases the pressure.

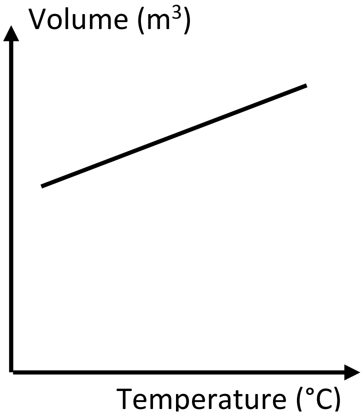
7.8 I can explain pressure-volume in terms of the kinetic model and describe an experiment to verify this law.

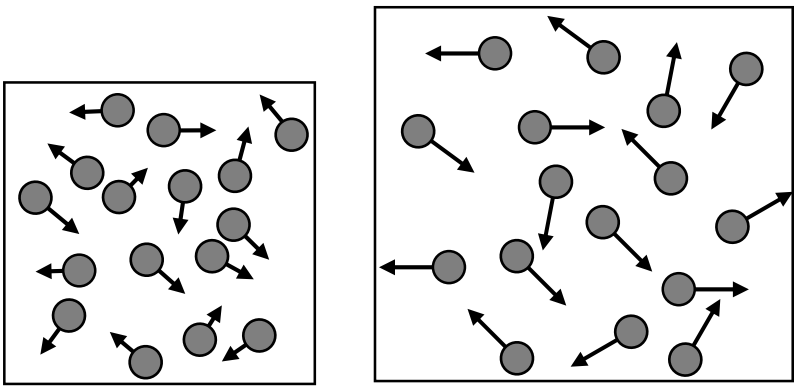
Volume-Temperature (Charles' Law)

The equipment shown is used to confirm Charles' Law. The mass of the air is kept constant. The mercury bead can move up or down the tube to keep the pressure of the air constant. The hot water is allowed to cool. The temperature and volume readings are taken at regular intervals. The graph obtained from volume against temperature will give the straight line shown below.



For a fixed mass of gas at constant pressure as the temperature of the gas is increased the volume increases.





Low temperature, low pressure High temperature, high volume

As the temperature of a fixed mass of gas at constant pressure is increased the speed at which the particles strike the wall of the container increases. This increased strike speed increases the force on the walls and, as the pressure is constant, pushes the wall outwards increasing the volume.

Electricity and Energy Problems Book
Pages 52 and 53 Questions 167 to 174.

7.9 I can use the relationships $p_1V_1 = p_2V_2$, $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ and $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ to solve problems involving pressure, volume and temperature of a fixed mass of gas.

$p_1V_1 = p_2V_2,$

This relationship is used when there is

- A fixed mass of gas
- A **constant temperature**

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

This relationship is used when there is

- A fixed mass of gas
- A **constant volume**

Note
When using these relationships, temperatures must be in Kelvin.

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

This relationship is used when there is

- A fixed mass of gas
- A **constant pressure**

Example using $p_1V_1 = p_2V_2$

A bicycle pump compresses $1.2 \times 10^{-4}\mathrm{m}^3$ of air at a constant temperature. Initially the air is at an atmospheric pressure of $1.0 \times 10^5\mathrm{Pa}$. This is compressed to a volume of $1.0 \times 10^{-5}\mathrm{m}^3$. Find the pressure to which the air is compressed.

Solution

$p_1 = 1.0 \times 10^5\mathrm{Pa}$
$p_2 = ?$
$V_1 = 1.2 \times 10^{-4}\mathrm{m}^3$
$V_2 = 1.0 \times 10^{-5}\mathrm{m}^3$

$$p_1V_1 = p_1V_2$$

$$1.0 \times 10^5 \times 1.2 \times 10^{-4} = p_2 \times 1.0 \times 10^{-5}$$

$$p_2 = \frac{1.0 \times 10^5 \times 1.2 \times 10^{-4}}{1.0 \times 10^{-5}}$$

$$p_2 = 1.2 \times 10^6\mathrm{Pa}$$

Electricity and Energy Problems Book
Pages 44 and 46 Questions 141 to 148.

Example using $\dfrac{p_1}{T_1} = \dfrac{p_2}{T_2}$

A sealed flask filled with a gas at a room temperature of 20°C and an atmospheric pressure of $1.0 \times 10^5\mathrm{Pa}$ is heated to 80°C. Find the pressure in the flask when heated.

Solution

When using the gas law relationships **temperatures must be converted to Kelvin.**

$p_1 = 1.0 \times 10^5\mathrm{Pa}$
$p_2 = ?$
$T_1 = 20°\mathrm{C} = 293\mathrm{K}$
$T_2 = 80°\mathrm{C} = 353\mathrm{K}$

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

$$\frac{1.0 \times 10^5}{293} = \frac{p_2}{353}$$

$$p_2 = \frac{1.0 \times 10^5 \times 353}{293}$$

$$p_2 = 1.2 \times 10^5\mathrm{Pa}$$

Electricity and Energy Problems Book
Pages 50 and 51 Questions 160 to 166.

Example using $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

A balloon has a volume of $4.2 \times 10^{-3}\text{m}^3$ at a temperature of 18°C and at an atmospheric pressure of $1.0 \times 10^5\text{Pa}$. Find the volume of the balloon when it is placed in a freezer at $-22°\text{C}$.

Solution

$V_1 = 4.2 \times 10^{-3}\text{m}^3$
$V_2 = ?$
$T_1 = 18°\text{C} = 291\text{K}$
$T_2 = -22°\text{C} = 251\text{K}$

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

$$\frac{4.2 \times 10^{-3}}{291} = \frac{V_2}{251}$$

$$V_2 = \frac{4.2 \times 10^{-3} \times 251}{291}$$

$$V_2 = 3.6 \times 10^{-3}\text{m}^3$$

Electricity and Energy Problems Book
Pages 48 and 49 Questions 154 to 159.

7.10 I can use the relationship $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ to solve problems involving pressure, volume and temperature of a fixed mass of gas.

The three gas laws can be combined into a single relationship $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$. This relationship is only used when pressure, volume and temperature have all changed.

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

A weather balloon is launched at ground level and rises to a height of 18km. During this time both the pressure and the temperature of the gas in the balloon decreases. Use the information shown below to find the volume of the balloon at a height of 18km

At Ground Level

$p_1 = 1.0 \times 10^5 \text{Pa}$
$V_1 = 7.0\text{m}^3$
$T_1 = 15°\text{C}$

At 18km

$p_2 = 7.5 \times 10^3 \text{Pa}$
$T_2 = -20°\text{C}$

Solution

Convert the temperatures to Kelvin.

$T_1 = 15°\text{C} = 288\text{K}$
$T_2 = -20°\text{C} = 253\text{K}$

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

$$\frac{1.0 \times 10^5 \times 7.0}{288} = \frac{7.5 \times 10^3 \times V_2}{253}$$

$$V_2 = \frac{1.0 \times 10^5 \times 7.0 \times 253}{288 \times 7.5 \times 10^3}$$

$$V_2 = 82\text{m}^3$$

Electricity and Energy Problems Book
Page 54 Question 178.

Quantities, Units and Multiplication Factors

Quantity	**Quantity Symbol**	**Unit**	**Unit Abbreviation**
Area	*A*	Metre Squared	m^2
Charge	*Q*	Coulomb	C
Current	*I*	Ampere	A
Energy	*E*	Joule	J
Force	*F*	Newton	N
Gravitational field strength	*g*	Newton per kilogram	Nkg^{-1}
Height	*h*	metre	m
mass	*m*	kilogram	kg
Pressure	*p*	Pascal	Pa
Resistance	*R*	Ohm	Ω
Specific heat capacity	*c*	Joule per kilogram per degree Celsius	$\mathrm{Jkg}^{-1}{}^{\circ}\mathrm{C}^{-1}$
Speed	*v*	metre per second	ms^{-1}
Temperature	*T*	Degree Celsius	$^{\circ}\mathrm{C}$
Time	*t*	Second	s
Voltage (potential difference)	*V*	Volt	V
Volume	*V*	Metre cubed	m^3

Prefix Name	Prefix Symbol	Multiplication Factor
Pico	p	$\times 10^{-12}$
Nano	n	$\times 10^{-9}$
Micro	μ	$\times 10^{-6}$
Milli	m	$\times 10^{-3}$
Kilo	k	$\times 10^{3}$
Mega	M	$\times 10^{6}$
Giga	G	$\times 10^{9}$
Tera	T	$\times 10^{12}$

You **WILL NOT** be given the tables on this page in any tests or the final exam.

Relationships Sheet

You will be given this sheet in all tests and the final exam.

$E_p = mgh$

$E_k = \frac{1}{2}mv^2$

$Q = It$

$V = IR$

$R_T = R_1 + R_2 + \ldots$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

$V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_s$

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$

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

$P = IV$

$P = I^2R$

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

$E_h = cm\Delta T$

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

$\frac{pV}{T} = \text{constant}$

$p_1V_1 = p_2V_2$

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

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

$d = vt$

$v = f\lambda$

$T = \frac{1}{f}$

$A = \frac{N}{t}$

$D = \frac{E}{m}$

$H = Dw_R$

$\dot{H} = \frac{H}{t}$

$s = vt$

$d = \bar{v}t$

$s = \bar{v}t$

$a = \frac{v - u}{t}$

$W = mg$

$F = ma$

$E_w = Fd$

$E_h = ml$

DATA SHEET

You will be given this sheet in all tests and in the final exam.

Speed of light in materials

Material	*Speed* in m s^{-1}
Air	$3{\cdot}0 \times 10^8$
Carbon dioxide	$3{\cdot}0 \times 10^8$
Diamond	$1{\cdot}2 \times 10^8$
Glass	$2{\cdot}0 \times 10^8$
Glycerol	$2{\cdot}1 \times 10^8$
Water	$2{\cdot}3 \times 10^8$

Gravitational field strengths

	Gravitational field strength on the surface in N kg^{-1}
Earth	9·8
Jupiter	23
Mars	3·7
Mercury	3·7
Moon	1·6
Neptune	11
Saturn	9·0
Sun	270
Uranus	8·7
Venus	8·9

Specific latent heat of fusion of materials

Material	*Specific latent heat of fusion* in J kg^{-1}
Alcohol	$0{\cdot}99 \times 10^5$
Aluminium	$3{\cdot}95 \times 10^5$
Carbon Dioxide	$1{\cdot}80 \times 10^5$
Copper	$2{\cdot}05 \times 10^5$
Iron	$2{\cdot}67 \times 10^5$
Lead	$0{\cdot}25 \times 10^5$
Water	$3{\cdot}34 \times 10^5$

Specific latent heat of vaporisation of materials

Material	*Specific latent heat of vaporisation* in J kg^{-1}
Alcohol	$11{\cdot}2 \times 10^5$
Carbon Dioxide	$3{\cdot}77 \times 10^5$
Glycerol	$8{\cdot}30 \times 10^5$
Turpentine	$2{\cdot}90 \times 10^5$
Water	$22{\cdot}6 \times 10^5$

Speed of sound in materials

Material	*Speed* in m s^{-1}
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Tissue	1500
Water	1500

Specific heat capacity of materials

Material	*Specific heat capacity* in J kg^{-1} °C^{-1}
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Ice	2100
Iron	480
Lead	128
Oil	2130
Water	4180

Melting and boiling points of materials

Material	*Melting point* in °C	*Boiling point* in °C
Alcohol	−98	65
Aluminium	660	2470
Copper	1077	2567
Glycerol	18	290
Lead	328	1737
Iron	1537	2737

Radiation weighting factors

Type of radiation	*Radiation weighting factor*
alpha	20
beta	1
fast neutrons	10
gamma	1
slow neutrons	3
X-rays	1