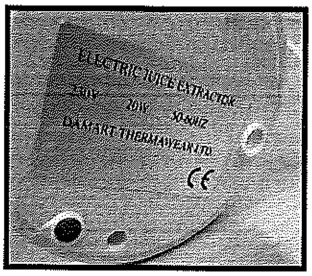
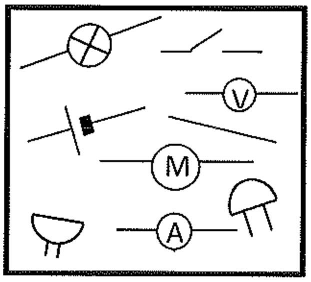
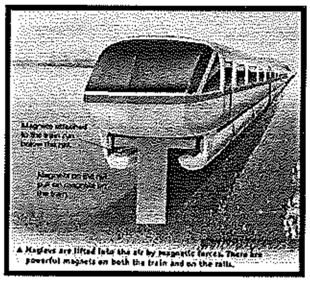
Our Lady's High School

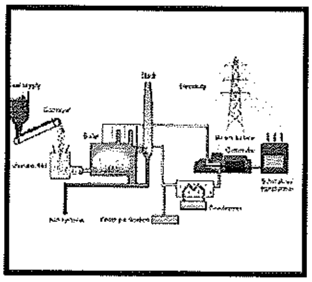
North Lanarkshire Council

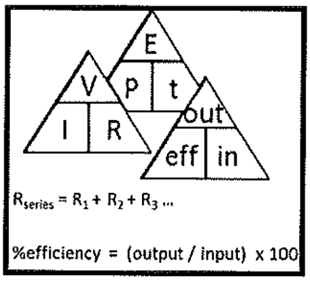
N5 Physics

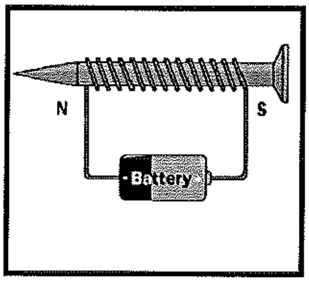


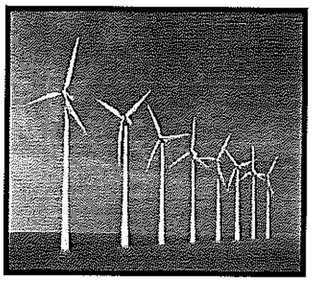


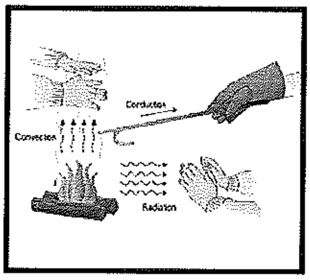












Electricity & Properties of Matter

Summary Notes

N5 Physics – Electricity and Properties of Matter Key Areas

Electrical Charge Carriers

- ☐ I can state the two types of electric charge.
- ☐ I can describe what happens when like and opposite charges are close together.
- ☐ I can define electrical current in terms of charge and time.
- ☐ I can solve problems using $Q = I\,t$.
- ☐ I can describe the difference between alternating and direct current.
- ☐ I can identify a source as a.c. or d.c. from an oscilloscope trace.

Potential Difference (Voltage)

- ☐ I can describe and explain what happens to a charged particle in an electric field.
- ☐ I can state what is meant by the potential difference (voltage) of a supply in terms of energy and charge carriers.

Ohm's Law

- ☐ I can use a voltage against current graph to calculate resistance.
- ☐ I can solve problems using $V = I\,R$.
- ☐ I can solve problems using $V_2 = \left(\frac{R_2}{R_1+R_2}\right) V_s$ and $\frac{V_1}{V_2} = \frac{R_1}{R_2}$.
- ☐ I can state what happens to the resistance of a conductor as its temperature increases.
- ☐ I can describe an experiment to verify Ohm's Law.

Practical Electrical and Electronic Circuits

- ☐ I can draw the symbols for a voltmeter, an ammeter and an ohmmeter can connect them correctly to measure voltage, current and resistance.
- ☐ I can draw or complete a circuit diagram showing how a voltmeter and an ammeter should be connected to calculate a particular resistance.
- ☐ I can recognise the symbol and state the function and application of the following standard electrical and electronic components: cell, battery, lamp, switch, resistor, variable resistor, voltmeter, ammeter, LED, motor, microphone, loudspeaker, photovoltaic cell, fuse, diode, capacitor, thermistor, LDR, relay and transistor (npn and n-channel enhancement mode MOSFET).

- ☐ I can describe the operation of both types of transistor in transistor switching circuits.
- ☐ I can state the four circuit rules for voltage and current in series and parallel circuits.
- ☐ I can solve problems using the four circuit rules.
- ☐ I can solve problems using $R_T = R_1 + R_2 + ...$ and $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + ...$ to find the total resistance of series, parallel and mixed circuits.
- ☐ I can predict the effect of adding an extra resistor in series or parallel on the total resistance of a circuit.

Electrical Power

- ☐ I can define power in terms of energy and time.
- ☐ I can solve problems using $P = \frac{E}{t}$.
- ☐ I can predict the effect of changing potential difference and/or resistance on the current in and power dissipated in components in a circuit.
- ☐ I can solve problems using $P = I\,V$, $P = I^2 R$ and $P = \frac{V^2}{R}$.
- ☐ I can select an appropriate fuse value when given the power rating of an electrical appliance.

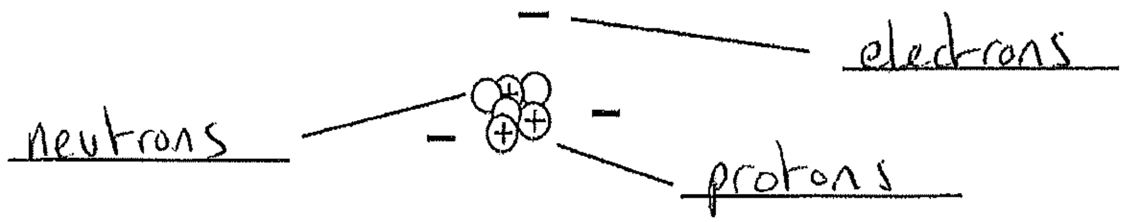
Gas Laws and the Kinetic Model

- ☐ I can define pressure in terms of force and area.
- ☐ I can solve problems using $p = \frac{F}{A}$.
- ☐ I can describe how the kinetic model accounts for the pressure of a gas.
- ☐ I can state the temperature of absolute zero in Kelvin and degrees Celsius.
- ☐ I can convert between Kelvin and degrees Celsius.
- ☐ I can explain the pressure-volume, pressure-temperature and volume-temperature laws in terms of the kinetic model.
- ☐ I can solve problems using $\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$.
- ☐ I can describe an experiment to verify the pressure-volume law (Boyle's Law).
- ☐ I can describe an experiment to verify the pressure-temperature law (Gay-Lussac's Law).
- ☐ I can describe an experiment to verify the volume-temperature law (Charles' Law).

Electric Charge

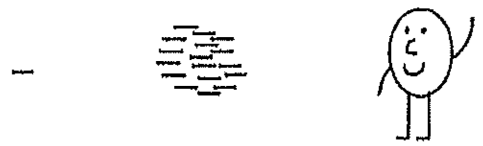
All matter is made from tiny particles called atoms. An atom has a tiny central core called the nucleus. The nucleus is made from protons which have a positive charge and neutrons which have no charge. Around the nucleus is a 'cloud' of electrons which have a negative charge.

The atom



If an atom loses electrons the atom becomes positively charged.
If an atom gains electrons the atom becomes negatively charged.

Each electron carries a tiny charge.
The symbol for charge is Q.
The unit for charge is Coulomb or C.
An electron's charge is so small it is difficult to measure. So we bundle billions of electrons together into 1 coulomb of charge.

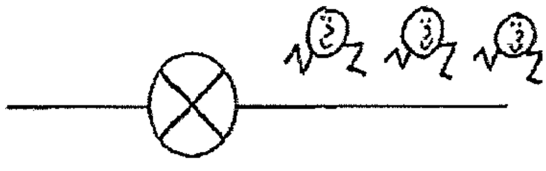


1 electron | 1 coulomb of charge | cartoon Coulomb

Electric Current.

Current is the number of coulombs of charge which pass a point each second. The symbol for current is I.
The unit of current is Amperes or A.

In this diagram 3C of charge pass through the bulb in 1s.
So the current is 3 A.

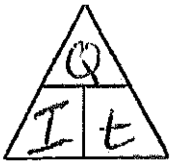


1 second

Current, Charge and time

Charge = current x time

Q = It



quantity	unit
Charge	C
Current	A
Time	s

Example 1. The current in a wire is 2.5A. How much charge will pass through the wire in 30s?

Q = ?
I = 2.5A
t = 30s.

$Q = It$

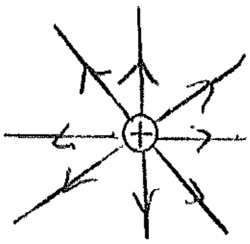
$Q = 2.5 \times 30$

$Q = \underline{\underline{75C}}$

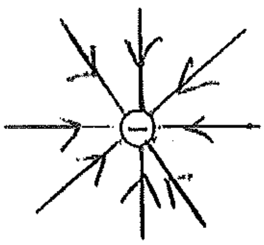
Electric Fields

Just like there is a gravitational force field around mass, there is an electrical force field around charged particles. The direction of an electric field is the direction a positive particle would travel if placed in the field.

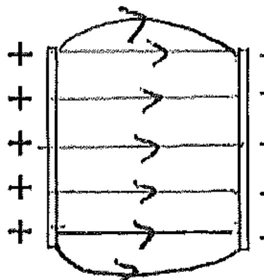
Draw the field lines in these diagrams.



point +ve charge

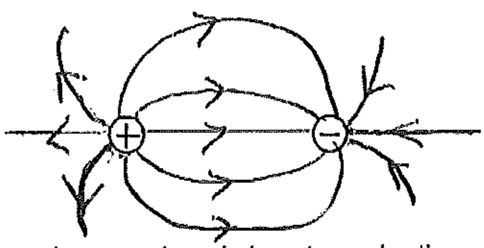


point -ve charge



parallel plates

uniform field.



two charges placed close to each other

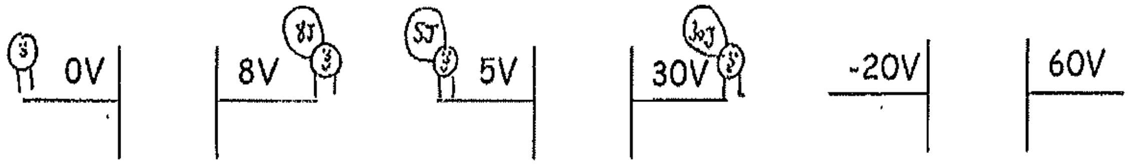
The closer the lines, the stronger the field.

Potential and Potential difference.

The amount of electrical energy a coulomb of charge has is defined by its voltage or potential difference. The difference between the potential a coulomb has at one point in a field and another is called the potential difference or V for short.

Potential and potential difference are measured in Volts or V.

The following diagrams show charged parallel plate. The voltage or potential at each plate is shown. For each parallel plate state the potential difference.



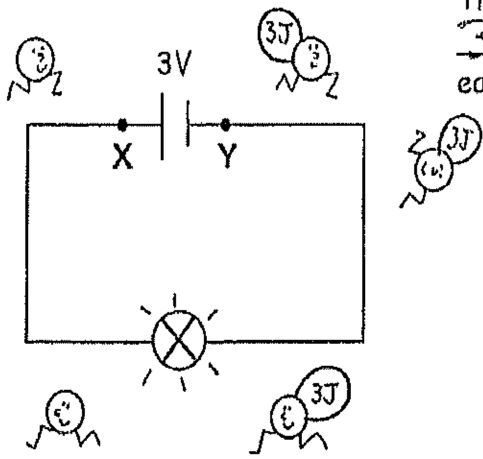
pd = 8V   pd = 25V   pd = 80V

Voltage

Because one plate of a battery is always at 0V the pd across the battery is the same as its voltage of the opposite plate.
The voltage of a cell tells you the amount of energy the cell gives or transfers to each coulomb of charge. The coulombs carry the energy round the circuit to the component. The voltage across the component is the amount of energy each coulomb gives up at the component.
The symbol for voltage is V. The unit of voltage is Volts or V

This 3V cell is connected to a bulb

The cell gives 3J of energy to each coulomb

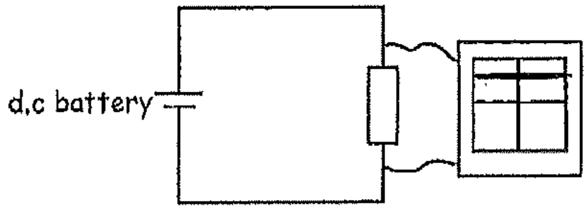


At the component each coulomb gives up 3J of energy.

At point X the coulombs have 0J energy = 0V of potential.
At point Y they have 3J of energy = 3V of potential.
The potential difference (pd) between two points = 3 V.

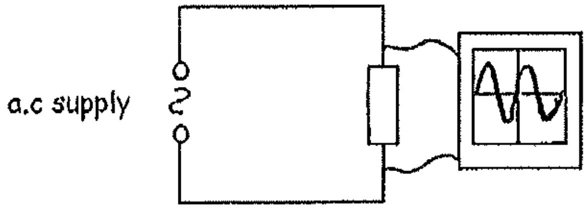
Direct current and alternating current

In a circuit with a dc battery the current is a constant size and travels in the same direction from the negative side of battery to the positive side.



Sketch what you would see on the oscilloscope trace

In a circuit with an alternating supply the current continually changes size and direction.
In British homes the current changes direction in kettles and TVs 100 times each second.
Mains frequency = 50 Hz



Mains voltage is 230V. (Peak voltage – ± 325V).

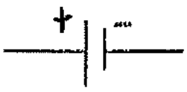
A car battery and a watch battery are dc supplies

Mains electricity in your house is an ac supply.

Electrical Components

Electrical circuits are made up of electrical components. Here are the circuit symbols for various electrical components.

(a)
wire

(b) 

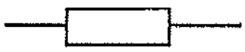
cell

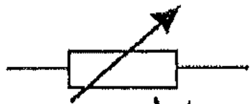
(c) 

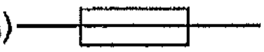
battery

(d) 
lamp/bulb

(e) 
switch

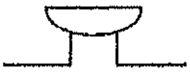
(f) 
resistor

(g) 
variable resistor

(h) 
fuse

(i) 

motor

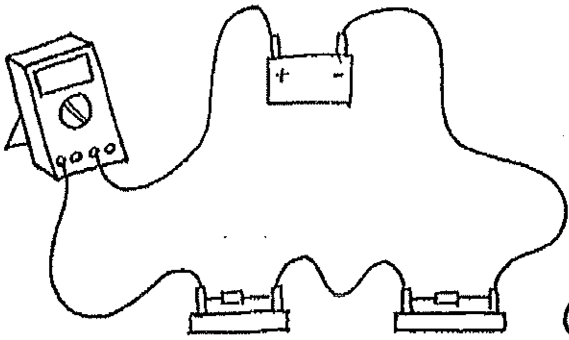
(j) 
buzzer

(k) 
loudspeaker.

Measuring Current.

Current is measured using an ammeter.

The ammeter measures the number of coulombs passing a point each second. The ammeter is placed in series in the circuit.



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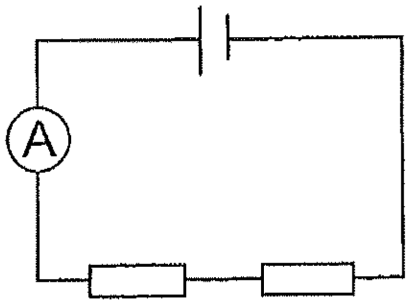


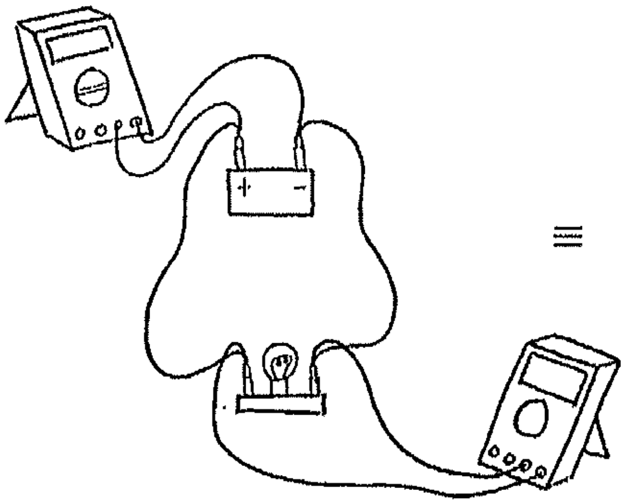
Current is measured in amperes, A.

Measuring Voltage

Voltage is measured in volts, V.

Voltage is measured using a voltmeter.

A voltmeter is placed across a component.



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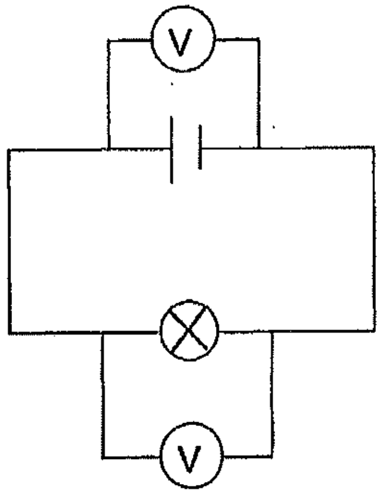


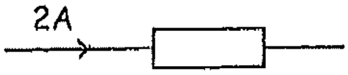
Resistance

All materials oppose the flow of current. This opposition to the flow of current is called resistance. The symbol for resistance is R. The unit of resistance is ohms or Ω.

4A

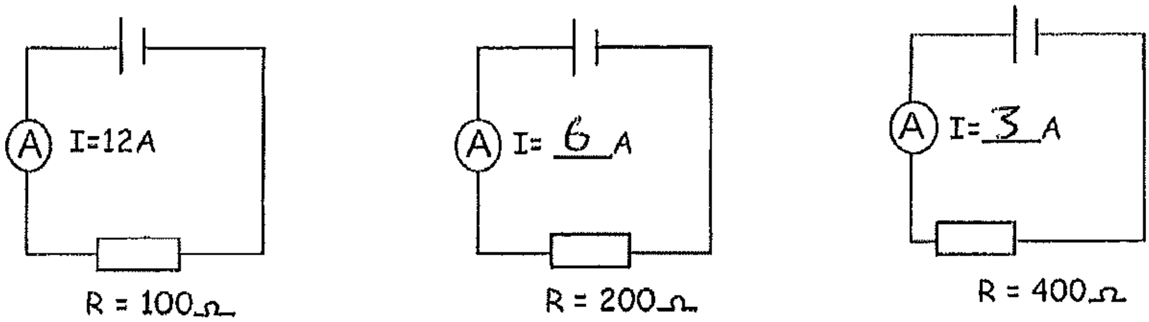
R = 10Ω

2A



This resistor is twice as difficult for the current to flow through so its R = 20Ω

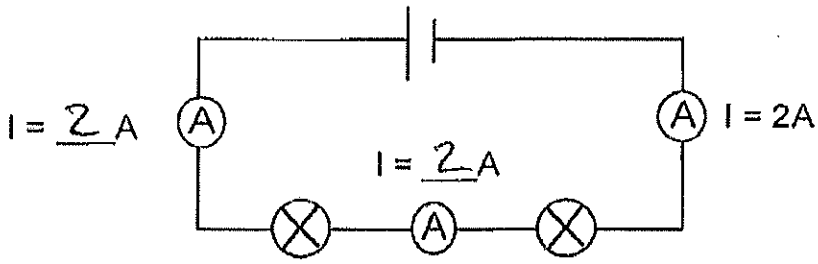
As the resistance of a circuit increases the coulombs find it more difficult to flow, so the current in the circuit decreases.



The higher the temperature of a component the greater its resistance so the lower the current passing through it.

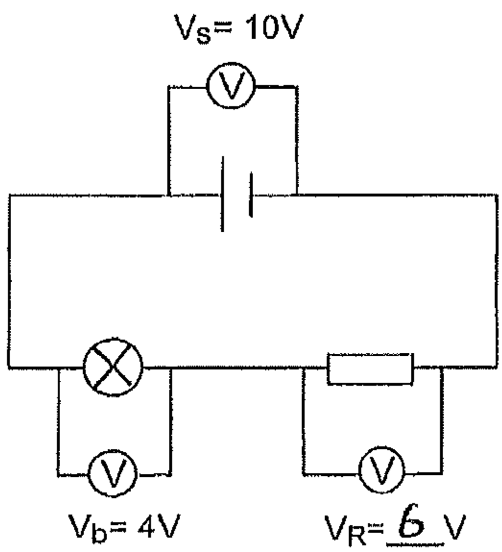
Current in a series circuit

In a series circuit there is only one path for the current to take. The current at all points in a series circuit is the same.



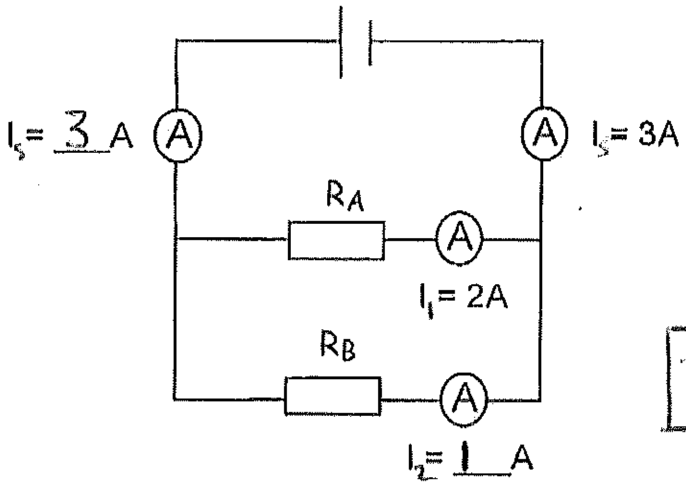
Voltage in a series circuit.

The voltage across each component in series adds up to the supply voltage.



Current in a parallel circuit.

In a parallel circuit there is more than one path for the current to take. The current in each branch adds up to the total current drawn from the supply

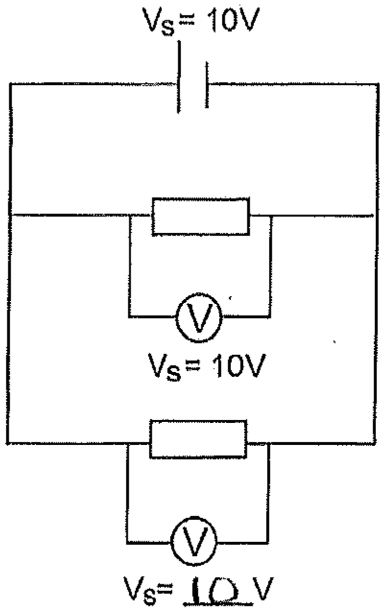


In this circuit resistor A has a smaller value than resistor B because more current flows through the branch it is in.

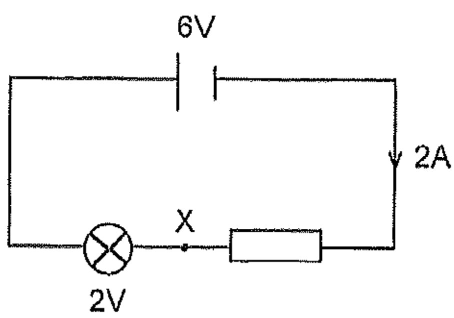
$I_s = I_1 + I_2 \ldots$

Voltage in a parallel circuit.

The voltage across each branch is the same and equal to the supply voltage. It does not matter the size of the resistance of each branch. The coulombs have only one device to pass through before getting back to the battery so they dump all their energy at the device.



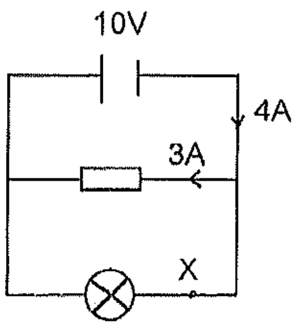
Ex Look at this series circuit



Current at point X = 2 A

Voltage across resistor = 4 V

Look at this parallel circuit



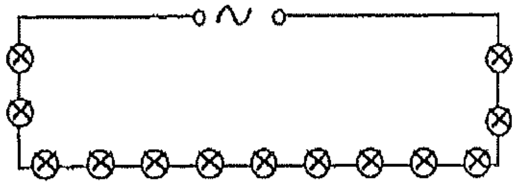
Current at point X = 1 A

Voltage across bulb and resistor = 10 V

Practical applications of series circuits

Wiring circuits in series is simple and therefore cheap.

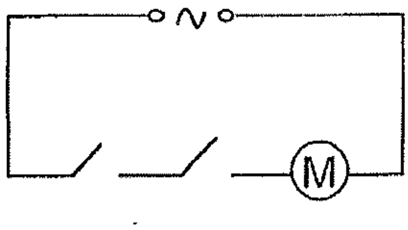
1. Christmas tree lights



The main problem with wiring anything in series is if one of the components breaks there is gap in the circuit so none of the other components will work.

2. Safety switches in devices

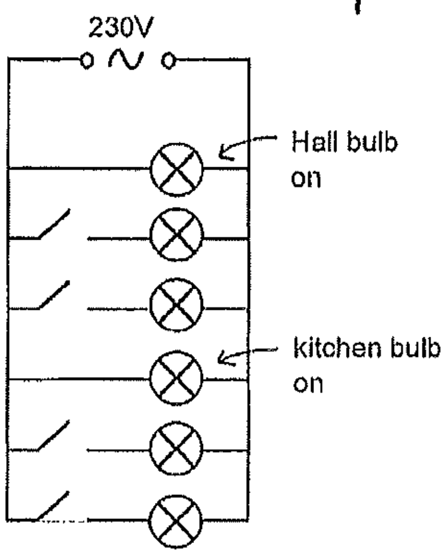
Some devices, for example electric saws or lawn mowers have two switches which must be switched on together. This makes it less likely that it would be switched on by accident.



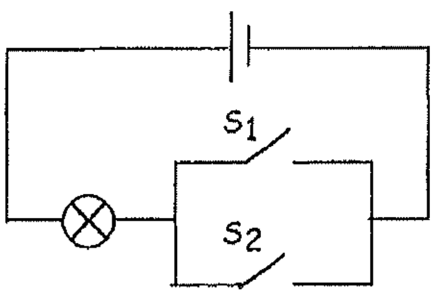
Practical applications of parallel circuits

When we wire components in parallel we can switch each branch on and off independently. Each branch gets the same voltage.

We wire the ceiling bulbs and plug points in our homes in parallel.



We can wire switches in parallel so we can choose how we switch devices on and off.

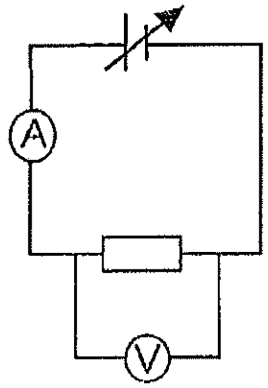


The bulb will light if switch 1 or 2 is closed

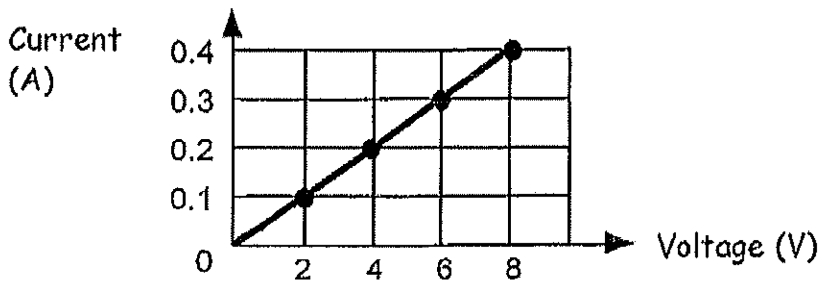
Ohm's Law

Ohm's law describes the relationship between the current through a component and the Voltage across the component.

By using a variable voltage supply we increase the voltage across the resistor. We use the ammeter to measure the current through the resistor and a Voltmeter to measure the voltage across the resistor



A graph of current vs voltage looks like this.



A graph showing a straight line passing through the origin means that current is directly proportional to the voltage.
ie if you double the voltage you double the current.
If you divide a voltage by its corresponding current we get a constant value.

$\frac{2}{0.1}$ = 20 $\frac{4}{0.2}$ = 20 $\frac{6}{0.3}$ = 20

$\frac{\text{Voltage}}{\text{Current}}$ = a constant value which we call the component's resistance

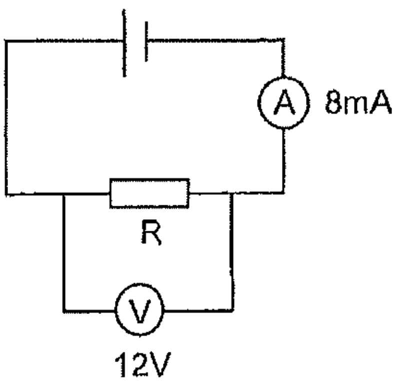
$$\frac{V}{I} = R$$

or $V = IR$

quantity	unit
Voltage	V
Current	A
Resistance	Ω

NB Not all components obey Ohm's law and if the temperature of a resistor increases its resistance actually increases.

Example The voltage across this resistor and current through it are shown. Calculate the resistance of the resistor.



$V = 12V$

$I = 8mA = 8 \times 10^{-3} A.$

$R = ?$ $V = IR$

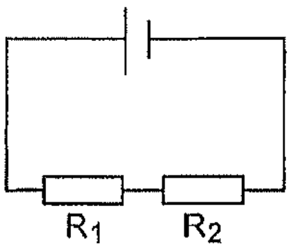
$R = \frac{V}{I}$

$R = \frac{12}{8 \times 10^{-3}}$

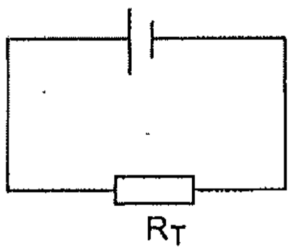
$R = 1500 \Omega$

Resistors in a series circuit.

In a series circuit the total resistance, R_T, is the sum of the individual resistors:

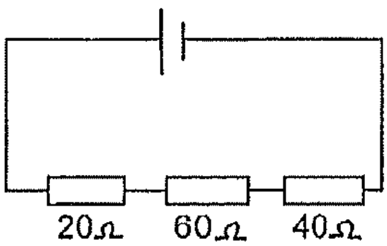


$R_T = R_1 + \underline{R_2}$ ≡



Because R_T is the equivalent resistance then the current in each circuit is the <u>same</u>.

Ex Here is a series circuit containing 3 resistors.



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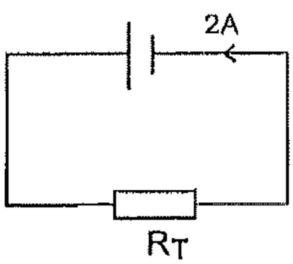


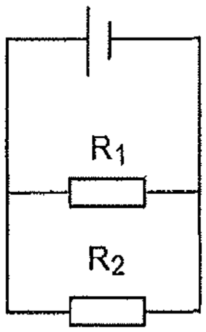
(a) What is the total resistance of this circuit R_T?

$R_T = R_1 + R_2 + R_3 \Rightarrow R_T = 20 + 60 + 40 \Rightarrow R_T = \underline{120 \Omega}$.

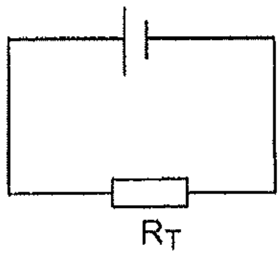
(b) If the current in the 2nd circuit is 2A. What is the current in the first circuit? 2A

Resistors in a parallel circuit

The total resistance of a parallel circuit is found using the formula



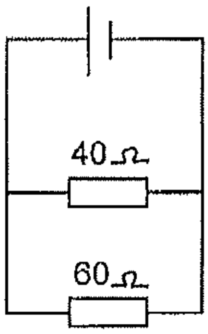
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} \equiv$$



Note that the total resistance is always smaller than the resistance of any of the individual branches.

Example A parallel circuit is set up a shown.

Calculate. (a) the total resistance of the circuit.
(b) the total current drawn from the battery.



(a) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_T} = \frac{1}{40} + \frac{1}{60}$ $\left(\frac{3}{120} + \frac{2}{120}\right)$

$\frac{1}{R_T} = 0{\cdot}025 + 0{\cdot}016666667$ $\left(\frac{5}{120}\right)$

$\frac{1}{R_T} = 0{\cdot}041666667$

$R_T = \frac{1}{0{\cdot}041666667}$ $\left(\frac{120}{5}\right)$

$R_T = 24\Omega$

b) $I = ?$
$V = 8V$
$R = 24\Omega$

$I = \frac{V}{R}$

$I = \frac{8}{24}$

$I = 0{\cdot}3A$

Energy

When electricity flows through a component some electrical energy is changed or transferred into another form of energy.

A bulb changes electrical energy into light + heat energy
An electric heater changes electrical energy into heat energy.
A loudspeaker changes electrical energy into sound energy.

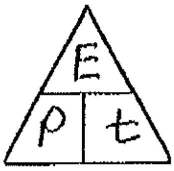
The symbol for energy is E and the units are Joules or J.

Power

The power of an electrical component tells us how much electrical energy it transfers or changes into another form each second.
The symbol for power is P and the unit is Watts or W.
A 12W bulb changes 12J of electrical energy into 12 J of light and heat energy each second.

$$\text{Power} = \frac{\text{Energy}}{\text{time}}$$

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



quantity	unit
Power	Watt
Energy	Joule
Time	second

Example A kettle is rated at 2000W. How much electrical energy does it convert or transfer in 3mins.

$E = Pt$

$E = 2000 \times 180$

$E = 3.6 \times 10^5$ J

3 minutes = 3×60s = 180s

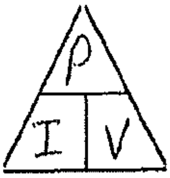
Power + Fuses.

Appliances with a power less than 700W usually use a 3A fuse. 700W or more usually use a 13A fuse.

Linking power to current and voltage.

Power = Current x Voltage

P = IV



quantity	unit
Power	Watt
Voltage	Volt
Current	Ampere

Example A hair dryer has a power rating of 1.2kW. If it is plugged into the mains the voltage is 230V. Calculate the current flowing through the hair dryer

1·2 kW = 1200W

$P = IV$

$I = \frac{P}{V}$

$I = \frac{1200}{230}$

$I = \underline{\underline{5 \cdot 2\,A}}$

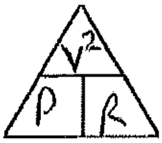
Two more useful power equations

By combing the equations P = IV and V = IR we can create two more useful equations.

$P = I^2R$

quantity	unit
Power	Watt
Current	Ampere
Resistance	Ohm

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



quantity	unit
Power	Watt
Voltage	Volt
Resistance	Ohm

Many devices use energy very quickly so they have very high power ratings. If the power rating is in kW - remember to change k to $\times 10^3$.

Example An electric drill with a resistance of 24Ω is plugged into the mains. (V = 230V) What is the power of the drill?

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

$$P = \frac{230^2}{24}$$

$$P = \underline{2204.2\,W}$$

Example A heater has a power rating of 4.8kW. If the resistance of the heater is 11Ω calculate the current flowing through the heater.

$$4.8kW = 4800W$$

$$P = I^2R$$

$$4800 = I^2 \times 11$$

$$I^2 = \frac{4800}{11} = 436.36$$

$$I = \sqrt{436.36} = \underline{20.9A}$$

Energy Transformations

Energy is a master of disguise. It can take many forms. Here are some forms of energy:

Light energy	Comes from the sun or electric bulbs or candles etc.
Heat energy	Comes from the sun. burning fuel. All object give off some.
Sound energy	Created when particles vibrate against one another.
Chemical energy	Energy stored in fuel like coal, petrol and human fuel - food.
Electrical energy	Energy that flows through electrical cables.
Kinetic energy	Energy found in objects which are moving.
Gravitational potential energy	Energy gained by objects which have risen in height
Mechanical potential energy	Energy stored in wound up clockwork toys or stretched elastic bands or springs.
Nuclear energy	Energy found in the nucleus of atoms.

One of the most important laws in physics is the 1st law of thermodynamics:

Energy cannot be made or destroyed but it can be transformed from one form to another.

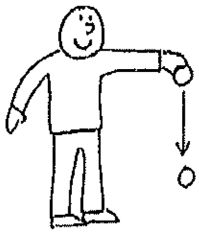
When energy is transferred from one system to another work has been done.

Revision : Here are two formula that let you calculate an amount of energy:

Kinetic energy	$E_k = \frac{1}{2} m v^2$
Gravitational potential energy	$E_p = mgh$

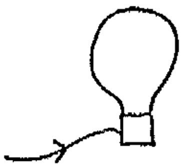
State the main energy transfers in these examples. Ignore energy losses in these examples

A. Ball being dropped



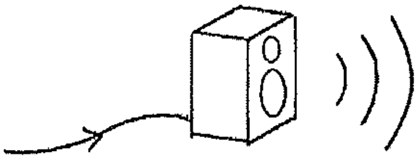
Gravitational potential → Kinetic energy

B Light Bulb



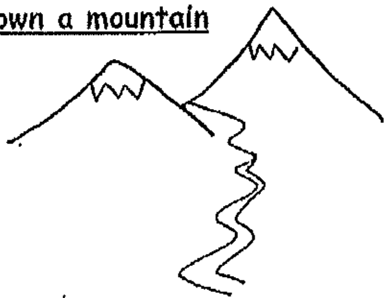
Electrical → light energy

C Loudspeaker



Electrical → Sound energy

D Water running down a mountain

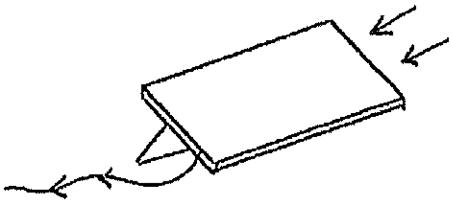


Gravitational potential → Kinetic

E Burning a lump of Coal

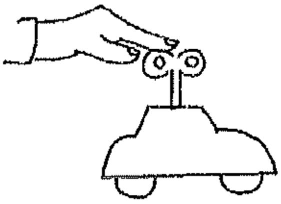
Chemical potential → heat + light energy

F **Solar Cells**



Light ⟶ Electrical energy

G. **A wind up toy**



Kinetic	⟶	potential	⟶	kinetic
In the moving fingers of person turning key.		stored in coil		when car is let go

Revision

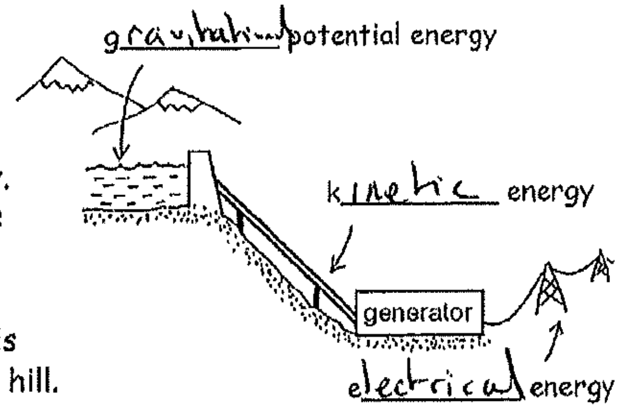
When we heat an object we can calculate the amount of heat energy we are transferring to to the object using

$$E_h = mc\Delta T$$

m = mass
c = specific heat capacity
ΔT= change in temperature

Hydroelectric Power Stations

In a hydroelectric power station the water high up in the reservoir in the mountains has gravitational potential energy. When it falls down through the pipes it gains kinetic energy. The generator at the bottom of the hill turns this kinetic energy into electrical energy. The water is collected in a reservoir at the bottom of the hill.



At night the generator is put in reverse and uses cheap electricity to pump the water back up to the top reservoir in preparation for the demand the next day.

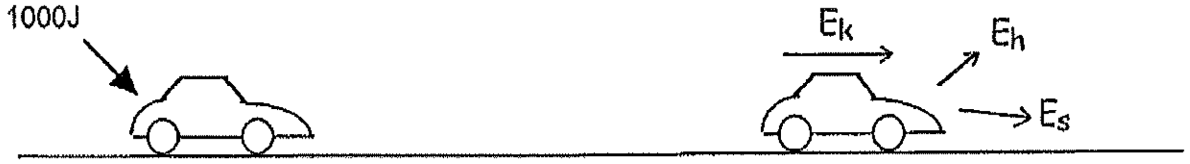
Useful and Waste Energy.

When energy is transferred, not all the starting energy is transferred to the form you want. Some of the energy is transferred to waste forms of energy.

For example you put 1000J of chemical energy into your car in the form of petrol. It would be great if your car could change all this 1000J of chemical energy into 1000J of kinetic energy. (No lost energy)
During the journey you may only transfer 400J of this 1000J into kinetic energy, which is the useful output energy you want. A force called friction will transfer the other 600J of chemical energy into heat and sound.

We call these, waste forms of energy. The output energy is made up from useful forms and waste forms.

Input energy **Output energy**

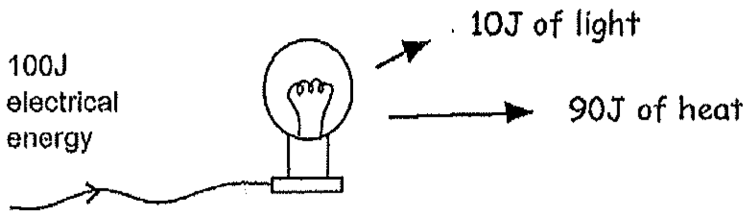


Useful energy / Wasted energy

1000J Chemical → 400J of Kinetic energy + 500J of heat
100 J of sound

A filament bulb is very wasteful.

Input energy **Output energy**



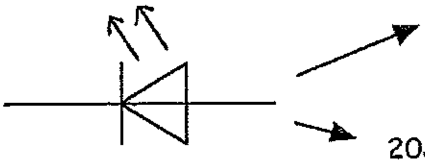
Useful energy / Wasted energy

100J Electrical → 10J of Light + 90 J of heat

An LED bulb is much less wasteful.

Input energy | **Output energy**

100J of electrical energy



80J of light

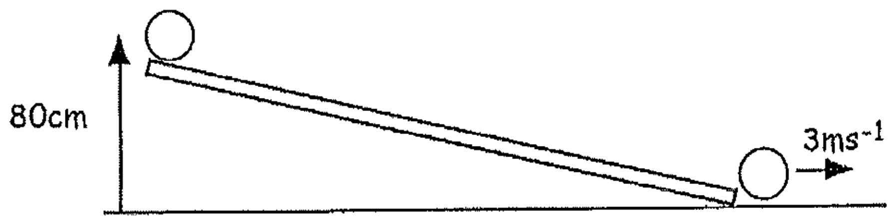
20J of heat

	Useful energy		Wasted energy
100J Electrical →	80J of Light	+	20J of heat

In many energy transfers the force of friction is responsible for transferring a lot of the useful input energy into heat energy.

Example A 0.2kg ball, starting at rest, rolls down the following slope. At the bottom of the slope the speed of the ball is $3ms^{-1}$.

(a) Calculate the gravitational potential energy it loses as it rolls down the slope. (ie how much grav pot energy does it have at top'
(b) Calculate the kinetic energy at the bottom of the slope.
(c) How much energy has been wasted as it rolls down the slope?
(d) Which force has been acting to transfer this energy?
(e) If the length of the slope is 2m calculate the size of the frictional force acting on the ball.



$80cm = 0.8m$

a) $E_p = mgh$

$E_p = 0.2 \times 9.8 \times 0.8$

$E_p = \underline{1.6\,J}$

b) $E_K = \frac{1}{2}mv^2$

$E_K = \frac{1}{2}(0.2) \times 3^2$

$E_K = \underline{0.9\,J}$

c) Energy lost $= 1.6 - 0.9 = \underline{0.7\,J}$

d) Friction

e) $E_w = Fd$

$F = \frac{E_w}{d}$

$F = \frac{0.7}{2}$

$F = \underline{0.35\,N}$

Example A 200W heater is switched on for 30mins and supplies heat energy to a beaker containing 4kg of water. The water's temperature rises from 20°C to 35°C. ($c_{water} = 4180 J kg^{-1} °C^{-1}$)

(a) How much electrical energy was used by the heater?
(b) How much heat energy is absorbed by the water?
(c) How much energy has been wasted?

a) $E = Pt$

$E = 200 \times 1800$

$E = 3.6 \times 10^5 J$

30 minutes = 30 × 60s = 1800s

b) $E_H = cm\Delta T$

$E_H = 4180 \times 4 \times 15$

$E_H = 250800 J$

$\Delta T = 35°C - 20°C = 15°C$

c) 360000 − 250800 = 109,200 J

Electronic systems

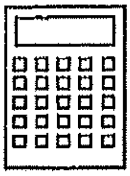
All complicated electronic devices can be reduced down to an input device, a process device and an output device.

The **input device** starts the system. It usually picks up some external signal and converts it into an electrical signal.

The **process device** changes the electrical signal coming from the input device in some way. For example an amplifier makes a signal stronger.

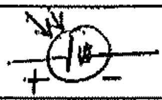
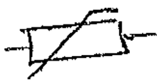
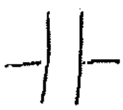
The **output device** changes the altered electrical signal from the process device into a useful signal.

Example A calculator

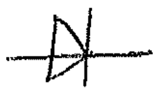


Input device: switch → Process Device: microprocessor → Output device: LED screen

Input devices.

Device	Circuit symbol	Energy transfer or function
Microphone		sound to electrical energy
Thermocouple		heat to electrical energy
Photovoltaic cell		light to electrical energy
Thermistor		A resistor whose resistance decreases as the temperature rises.
LDR (light dependent resistor)		A resistor whose resistance decreases as the light level rises.
Capacitor		Stores electrical charge and can be used to produce a time delay.

Output devices

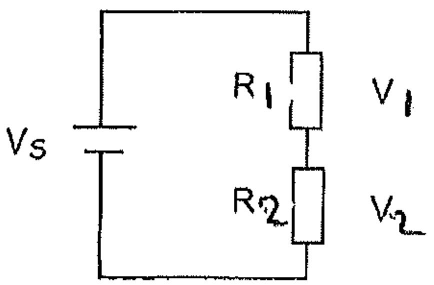
Device	Circuit symbol	Energy transfer or function
Bulb		Electrical to light
LED		Electrical to light
Motor		Electrical to kinetic
Loudspeaker		Electrical to sound
Diode		Allows current to flow only in one direction.
Relay		An electromagnet and switch which allow dangerous high voltage circuits to be switched on safely.

Voltage Divider

A voltage divider is a voltage supply in series with two or more resistors. The voltage divider takes a large supply voltage and divides into separate voltages.

In this circuit a 12V supply is to be divided across two resistors. If the resistors have the same value then the voltage across each resistor = 6 V.

If the resistors are different values we can use the voltage divider formula.

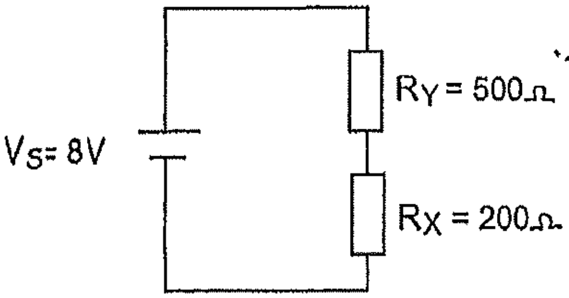


$$V_1 = \frac{R_1}{R_1 + R_2} \times V_s$$

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

If you know the voltage across resistor 1 then the voltage across resistor 2, V_2, is found as follows $V_2 = V_s - V_1$.

Example Calculate the voltage across resistors X and Y in this circuit.



Y

$$V_1 = \frac{R_1}{R_1 + R_2} \times V_s$$

$$= \frac{500}{500 + 200} \times 8$$

$$V_1 = 5.71 \text{ V} \qquad V_y = \underline{5.71V}$$

X

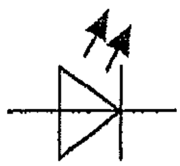
$$V_s = V_1 + V_2$$

$$8 = 5.71 + V_2$$

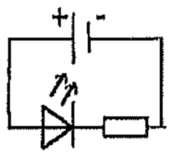
$$V_2 = 8 - 5.71$$

$$= 2.29 \text{ V} \qquad V_x = \underline{2.29V}$$

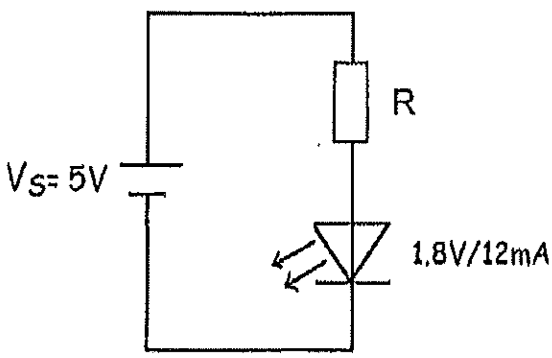
LED (Light Emitting Diode)



An LED will only work when the triangle side is connected to the positive side of your battery.
An LED is a sensitive device so a resistor is placed in series with it to limit the current and prevent it being damaged.



Example. A 1.8V/12mA LED is to be placed in a circuit with a 5V supply. Calculate the size of resistor required for the LED to work at its given rating.



$$V_s = V_{LED} + V_R$$

$$5 = 1.8 + V_R$$

$$V_R = 5 - 1.8$$

$$= 3.2 \text{ V}$$

$$R = \frac{V_R}{I}$$

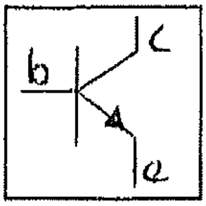
$$= \frac{3.2}{12 \times 10^{-3}}$$

$$= 267 \Omega$$

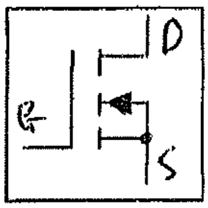
Transistors

A transistor is an electronic switch. It is designed to come on when a certain voltage is applied across it.

We will look at two types of transistors.



b - base
c - collector
e - emitter



G - Gate
D - Drain
S - Source

This is an npn transistor

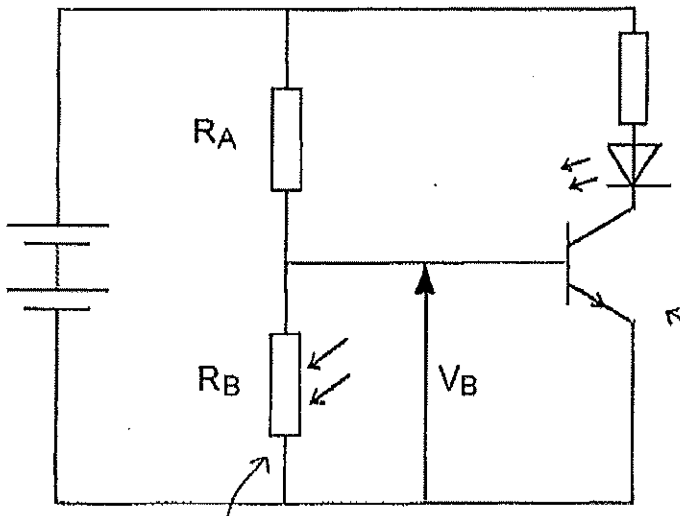
0·7 V to switch on

This is a MOSFET (metal oxide semiconductor field effect transistor) 2V to switch on

Control circuits.

We use transistors in control circuits. A control circuit is just an electronic circuit. It looks complicated but it is quite easy to understand.

Supply voltage



This is the bit that gets switched on. It's the output device

The transistor is the process device. It switches on when V_B rises above 0·7 V

The LDR is the input device

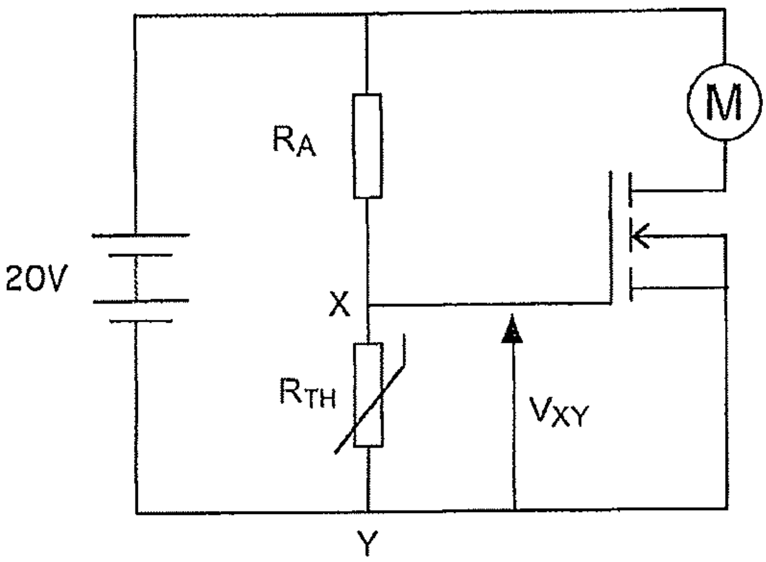
The resistors A an B act as a voltage divider dividing up the supply voltage. Because the resistor B is an LDR then its resistance can change as the light level changes. Therefore the output voltage V_B could change.
In dark, resistance R_B increases ⇒ voltage V_B increases.
When the voltage V_B across the bottom resistor gets above 0·7 V the transistor switches on.

When the transistor is on it now lets current flow up through the LED and it lights up.

Example

Explain how the following circuit can switch on the motor of a central heating system when the temperature falls below a certain level.

The mosfet switches on when V_{XY} is equal to or greater than 1·8V



As the temperature decreases the resistance of the thermistor increases. Therefore the voltage V_{XY} increases.

When V_{XY} reaches 1·8 V the transistor switches on and current flows through the motor and it starts spinning.

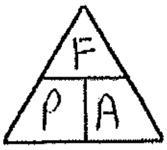
If you want the motor to come on when the temperature increases then swap round R_A and RTH.

Pressure.

The pressure acting on a surface is defined as the force acting on 1 m^2 of surface area.

$$\text{Pressure} = \frac{\text{force exerted}}{\text{surface area}}$$

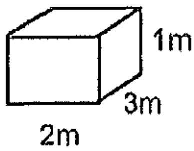
$$P = \frac{F}{A}$$



quantity	unit
Pressure	Pa
Force	N
Area	m^2

Example The following box of mass 20kg sits on the floor.

(a) What is the force the box exerts on the floor?
(Hint - what is its weight?)
(b) What is area over which the force acts?
(c) Calculate the pressure the box exerts on the floor?



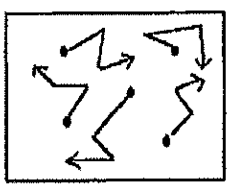
(a) $W = mg$
$= 20 \times 9.8$
$= 196\ N$

(b) $A = l \times b$
$= 2 \times 3$
$= 6\ m^2$

(c) $P = \frac{F}{A}$
$= \frac{196}{6}$
$= 32.7\ Pa$

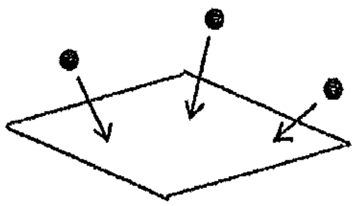
Describing a Gas.

A gas is made from particles which are far apart. The particles are in continuous random motion in all directions.



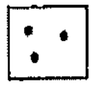
Pressure of a gas. (Pascals Pa)

When these randomly moving particles hit a surface they exert a force. So gas pressure is the total force the particles exert over an area of 1 m^2.

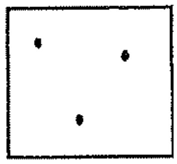


Volume of a Gas (m^3 or cm^3)

The volume of a gas is the space taken up by the gas. The volume of a gas can be taken as the volume of the container it is in.



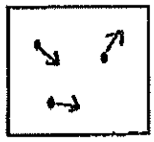
small volume



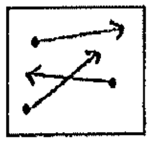
Big volume

Temperature of a gas (°C) or (K)

The temperature of a gas is a measure of how fast the particles in the gas are moving.



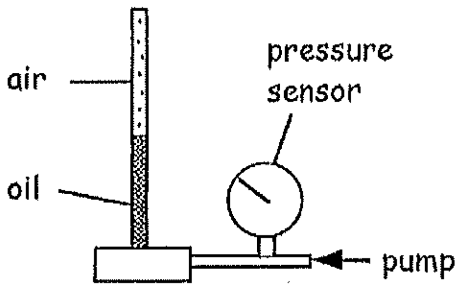
cold gas



hot gas

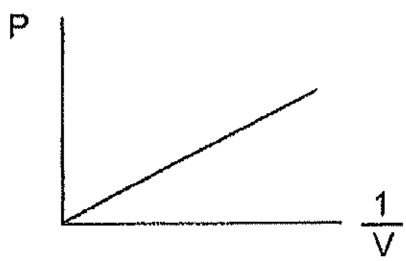
Pressure and Volume. (Boyle's Law)

This apparatus is used to find the relationship between the volume of a gas and its pressure.



A pump is used to apply a force to the oil. The oil in turn applies a force to the air and the air squashes or compresses.
The volume of the air and its pressure are noted at intervals

The results allow the following graphs to be produced.



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

$$P = \frac{k}{V}$$

$$PV = k$$

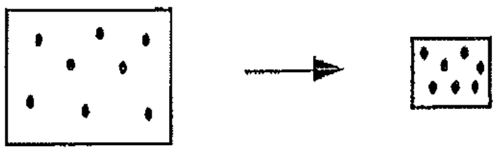
$$P_1V_1 = P_2V_2$$

Boyle's Law

For a fixed mass of gas at a constant temperature the pressure is inversely proportional to its volume.

Explanation using Kinetic Theory.

As the volume of the container decreases the surface area the particles are hitting also decreases.



The particles hit the walls more often so the total force exerted increases. P = F/A so as Force increases and area decreases the pressure increases

Example A gas container of volume $5m^2$ contains a gas at a pressure 120kPa. What is the new pressure of the gas if the volume of the container is decreased to $2m^2$?

$$P_1V_1 = P_2V_2$$

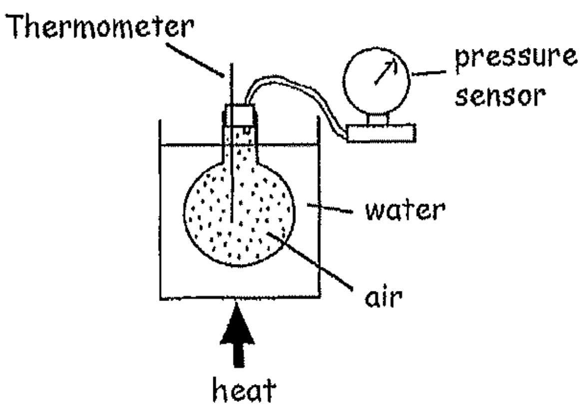
$$120\times10^3 \times 5 = P_2 \times 2$$

$$P_2 = \frac{120\times10^3\times5}{2}$$

$$= 3\times10^5\ Pa$$

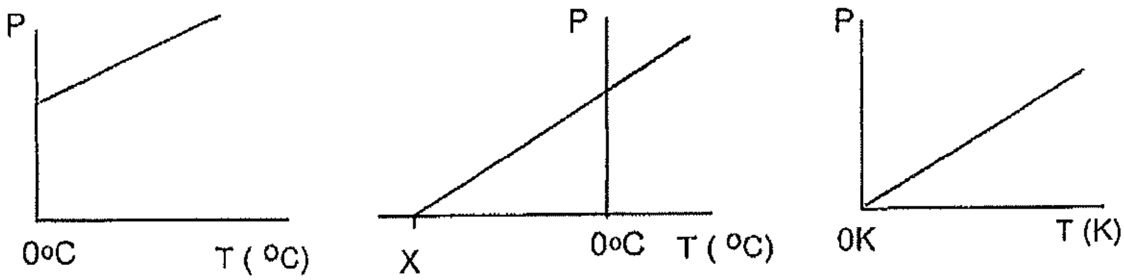
Pressure and Temperature (Pressure Law)

This apparatus is used to find the relationship between the temperature of a gas and its pressure.



The water is heated. The heat is transferred evenly to the air in the flask. As the air is heated the temperature and pressure of the gas are noted.

The results allow the following graphs to be produced.



The value X is -273 °C. This temperature is called absolute zero , It is the temperature at which the pressure of a gas is zero. This means that the particles have lost all their kinetic energy and therefore have stopped moving. You cannot cool a substance below -273 °C

Lord Kelvin then created a new temperature scale based upon zero being -273°C. He called this temperature 0Kelvin or 0K. A change of 1°C is equal to a change of 1K

Converting °C to K add 273 ie 30°C = 30 +273 = 303 K

Converting K to °C subtract 273 ie 400K = 400 - 273 = 127 °C

Lord Kelvin noticed that if you made -273°C zero temperature then the graph of pressure vs temperature (measured in Kelvin) is a straight line going through the origin. This means that

$$P \propto T \text{ (in Kelvin)}$$

$$P = kT \qquad (k = \text{constant})$$

$$\frac{P}{T} = k$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

The Pressure Law.

For a fixed mass of gas at a constant volume the pressure is directly proportional to its temperature measured in units called kelvin.

Explanation using Kinetic Theory.

As the temperature of the gas increases the particles gain more Kinetic energy and move about faster.

Therefore the particles hit the walls of the container harder and more often. Both factors increase the force exerted on the walls. As P = F/A, so if Force increases therefore the pressure also increases.

Example. The pressure and temperature of a gas in a container is 108kPa and 20°C, The gas is then heated up to a temperature of 200°C. Calculate the new pressure of the gas.

$T_1 = 20^\circ C$
$= 293\ K$

$T_2 = 200^\circ C$
$= 473\ K$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

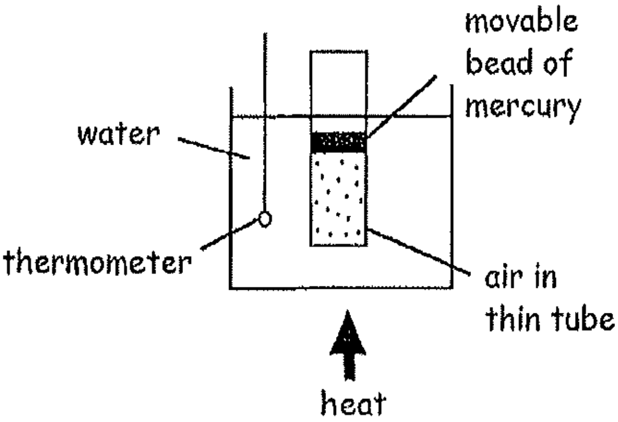
$$\frac{108 \times 10^3}{293} = \frac{P_2}{473}$$

$$P_2 = \frac{108 \times 10^3 \times 473}{293}$$

$$= 1.74 \times 10^5\ Pa$$

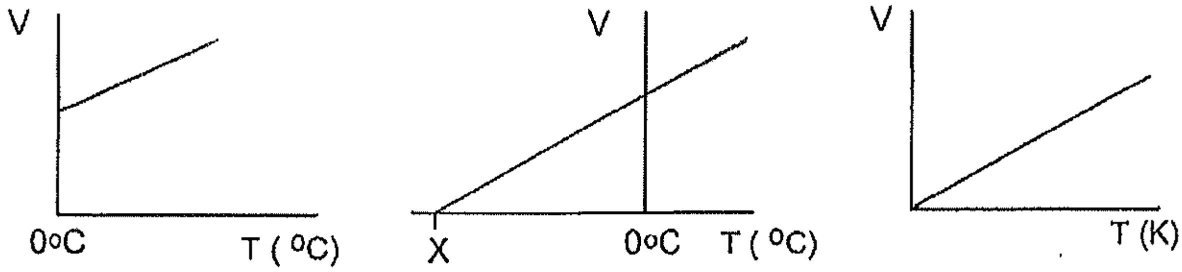
Volume and Temperature (Charles' Law)

This apparatus is used to find the relationship between the temperature of a gas and its volume.



The air is in a thin tube capped with a mercury bead. The water is heated and the heat is transferred evenly to the air. The bead of mercury is free to move upwards if the force on it increases. As the air is heated its temperature and volume are noted.

The results allow the following graphs to be produced



X = -273 °C

$V \propto T$ (KELVIN)

$V = kT$

$$\frac{V}{T} = k$$

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

Charles' Law

For a fixed mass of gas at a constant pressure the volume is directly proportional to its temperature measured in Kelvin

Explanation using Kinetic Theory.

As the temperature increases the particles gain more kinetic energy and hit the mercury bead harder and more often. This causes the bead to move up and the volume increase. Now because the volume increases the particles hit the walls less often so the pressure reduces back to its original value.

Example The volume of gas in a syringe with a movable piston is $12cm^3$ at a temperature of 25°C. The gas is heated to a temperature of 75°C. Calculate its new volume.

$T_1 = 25°C = 298 K$ $T_2 = 75°C = 348 K$

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

$$\frac{12}{298} = \frac{V_2}{348}$$

$$V_2 = \frac{12 \times 348}{298}$$

$$= 14 cm^3$$

Combined Gas equation

In most real life situations all three quantities change at the same time. We can combine the 3 gas laws to create a General gas law.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Example A gas occupies a volume of 40l at a temperature of 40°C and a pressure of 120kPa. If the temperature rises to 150°C and the pressure rises to 230kPa calculate the new volume of the gas.

$T_1 = 40^\circ C$ $\quad$ $T_2 = 150^\circ C$

$= 313\ K$ $\quad$ $= 423\ K$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{120 \times 10^3 \times 40}{313} = \frac{230 \times 10^3 \times V_2}{423}$$

$$V_2 = \frac{120 \times 10^3 \times 40}{313} \times \frac{423}{230 \times 10^3}$$

$$= 28.2\ L$$