SSEKWE ROBERT

Third Edition

UNLOCKING O'LEVEL PHYSICS

SENIOR 3 & SENIOR 4

RESEARCH BOOK

PREFACE

Welcome to *Unlocking O'level Physics*! This book is a comprehensive and student-friendly resource designed to help Senior Three and Senior Four students excel in physics. Rooted in Uganda's new competence-based curriculum, it offers a structured and practical approach to mastering the subject, emphasizing skills that are essential for success in an ever-changing world.

Physics is not just a subject; it is the foundation of understanding how the universe works. From the smallest particles in atomic models to the vastness of stars and galaxies, physics connects us to the world around us. This book is crafted to make these connections exciting, accessible, and meaningful.

The topics covered in this book include: Linear and Non-linear motion, Refraction, Dispersion and Colour, Lenses and Optical Instruments, General Wave Properties, Sound Waves, Heat Quantities and Vapours, Stars and Galaxies, Satellites and Communications, Introduction to Current Electricity, Voltage, Resistance and Ohm's law, Electromagnetic Effects, Electric Energy, Distribution and Consumption, Atomic Models, Nuclear Processes, and Digital Electronics.

To ensure students gain a thorough understanding of these topics, this book includes:

- ☑ **Workable Examples and Exercises:** Each chapter is filled with solved examples that guide students step-by-step through problem-solving techniques, as well as practice exercises to reinforce learning.
- ☑ **Unique Diagrams and Pictures:** Visual aids are used extensively to clarify complex concepts and enhance retention. These illustrations are designed to align with the curriculum and stimulate interest.
- ☑ **Curriculum Alignment:** The book is tailored to meet all the requirements of the competence-based curriculum, ensuring that students acquire both theoretical knowledge and practical skills.

This book was developed to address the growing need for a solid understanding of physics in a world that increasingly relies on science and technology. Beyond academic success, the skills and knowledge gained from this book will empower students to think critically, solve real-world problems, and appreciate the role of physics in daily life.

As you explore the pages of *Unlocking O'level Physics*, you will discover a world of exciting phenomena and ground-breaking ideas. Whether you are solving problems in electricity, exploring the mysteries of space, or analysing motion, this book is your guide.

To the students, teachers, and lifelong learners who will use this book, we hope it inspires you to approach physics with curiosity, confidence, and determination. May it unlock your potential and serve as a stepping stone to even greater achievements in the future.
Physics is not just about formulas and equations—it's about understanding the beauty of the universe. Let this book be your key to unlocking the incredible opportunities that lie ahead.

Ssekwe Robert
Author

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Linear and Non-linear motion

S.3

By the end of this chapter, a learner should be able to;

(a) Understand and apply the relationship between speed, distance, and time.
(b) Understand the terms: linear motion, speed, average speed, acceleration, and be able to investigate resistance to motion.
(c) Know and use the equations of motion.
(d) Understand the acceleration of bodies moving in a circle and the effect of gravity and air resistance on moving bodies.
(e) Understand linear momentum and that it is conserved during collisions.
(f) Understand that momentum is conserved during a collision and the implication of this.
(g) Understand and apply newton's laws of motion.
(h) Understand the differences between vector and scalar quantities, and give examples of each.
(i) Understand that a number of forces acting on a body can be represented by a sign.

INTRODUCTION

Have you ever been on a bicycle ride and noticed how you move straight down the road when there's no turn? Or have you ever dropped a ball and watched it fall straight to the ground? These are examples of *linear motion*, which means movement along a straight path.
You always experience linear motion in your daily life. For example:

- When you walk or run on a straight track.
- When a car moves down a straight road.
- When an elevator or lift goes straight up or down.

Linear motion is all about objects moving in a straight line. It could be fast or slow, forward or backward. We can describe this motion using important ideas like **distance**, **displacement**, **speed**, **velocity**, and **acceleration**.

UNDERSTANDING THE TERMS USED IN LINEAR MOTION

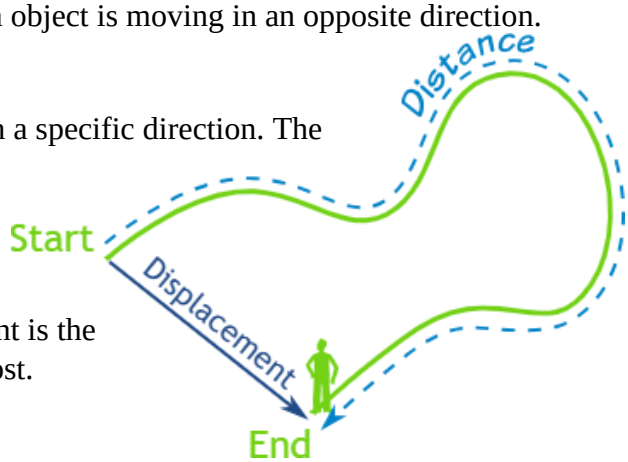
☑ ***Distance:***
This is the length of path moved by an object or it is the length between two points.
The SI unit of distance is a metre (m).

Note: While measuring distance between two points, the direction of path is not considered. Therefore, distance is a **scalar quantity**.
Distance is always positive even if the motion is forward or backward.

☑ ***Displacement:***
This is the distance moved by an object in a straight line in a specified direction.
The SI unit of displacement is a metre (m).

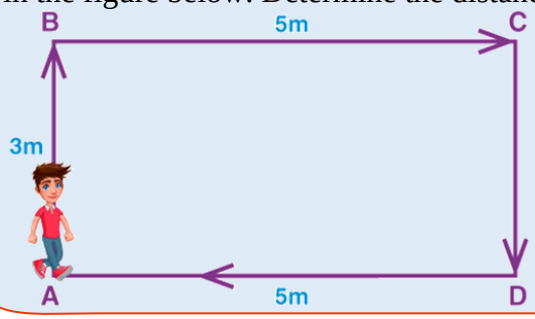
Note: While determining displacement between two points, the direction of path is considered. Therefore, displacement is a **vector quantity**.
Displacement can be negative or positive. It is negative if an object is moving in an opposite direction.

The person moves from the Starting point to the end point in a specific direction. The distance moved in that direction is called **displacement**.
Therefore, Displacement helps us focus on the *direct* path, not just how much ground was covered.
For example; A football player runs around the entire football field but ends up near the goalpost. The displacement is the straight-line distance from the starting position to the goalpost.



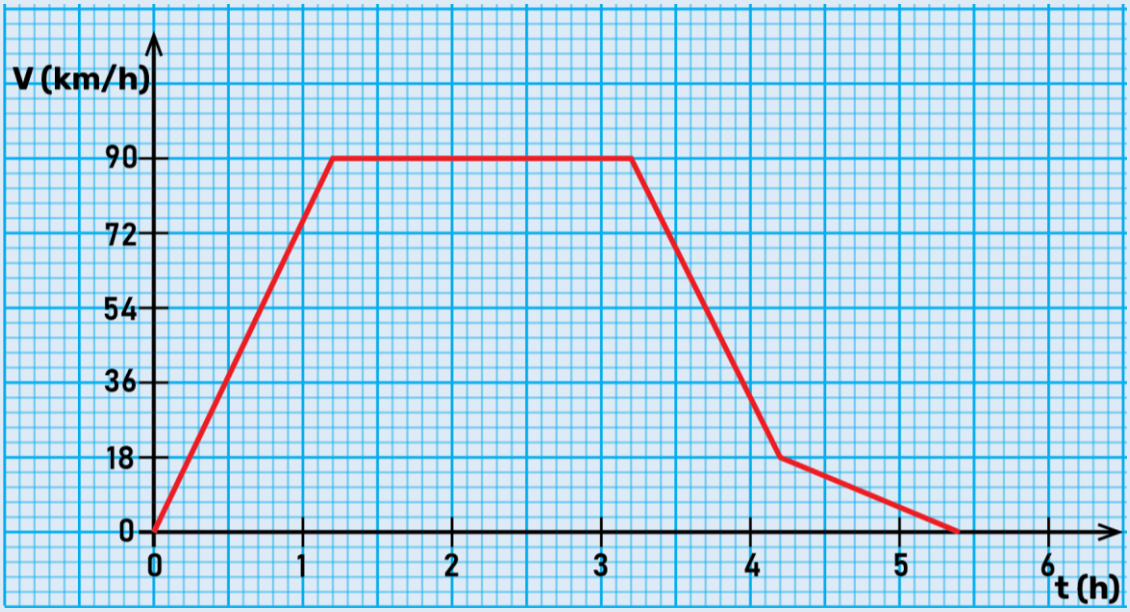
1 WORKED EXAMPLE

Mukasa moves around his house from corner A until he returns back to the starting position as shown in the figure below. Determine the distance and Displacement covered by Mukasa.



$$\textit{Distance covered} = 3 + 5 + 3 + 5 = 16m$$

$$\textit{Displacement} = 3 + 5 - 3 - 5 = 0m$$



On reaching the village, the taxi driver has requested for his payment. However, your father has refused to pay until he is helped to understand how the graph drawn by the machine is related to the distance travelled.

Task:

Help your father to;

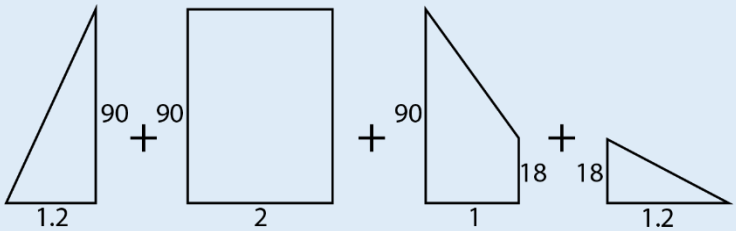
a) Understand the motion of the taxi from your home to the village.

b) Determine the amount of money he has to the taxi driver.

Solution:

a) The taxi started from rest at home and accelerated uniformly to a velocity of 90 km/h in 1.2 $hours$. It then maintained this velocity for another 2 $hours$. It then decelerated uniformly to a velocity of 18 km/h in 1 $hour$ and finally decelerated uniformly to rest at the village in 1.2 $hours$.

b)



$$\textbf{Total Distance} = \textbf{Area of triangle} + \textbf{Area of rectangle} + \textbf{Area of trapezium} + \textbf{Area of triangle}$$

$$Total\ Distance = \frac{1}{2}bh + (l \times w) + \frac{1}{2}h(a+b) + \frac{1}{2}bh$$

$$Total\ Distance = \frac{1}{2} \times 1.2 \times 90 + (2 \times 90) + \frac{1}{2} \times 1(18+90) + \frac{1}{2} \times 1.2 \times 18$$

$$Total\ Distance = 54 + 180 + 54 + 10.8$$

$$\textbf{Total Distance} = \mathbf{298.8\ km}$$

$$\textbf{Amount paid} = 298.8 \times 2500 = \mathbf{747{,}000}$$

My father had to pay $\boldsymbol{shs.\ 747{,}000}$ to the taxi driver for the whole journey.

❖ Newton's second law of motion:

It states that the rate of change of momentum of a body is directly proportional to the applied force and it takes place in the direction of force.

Mathematically;

$$Force \propto Rate\ of\ change\ of\ momentum$$

$$Force \propto \frac{Change\ of\ momentum}{Time}$$

$$Force \propto \frac{Final\ momentum - Initial\ momentum}{Time}$$

$$F \propto \frac{mv - mu}{t}$$

$$F \propto \frac{m(v-u)}{t} \qquad But\ \ a = \frac{(v-u)}{t}$$

$$F \propto ma$$

$$\boldsymbol{F = kma} \qquad where\ k\ is\ a\ constant\ of\ proportionality$$

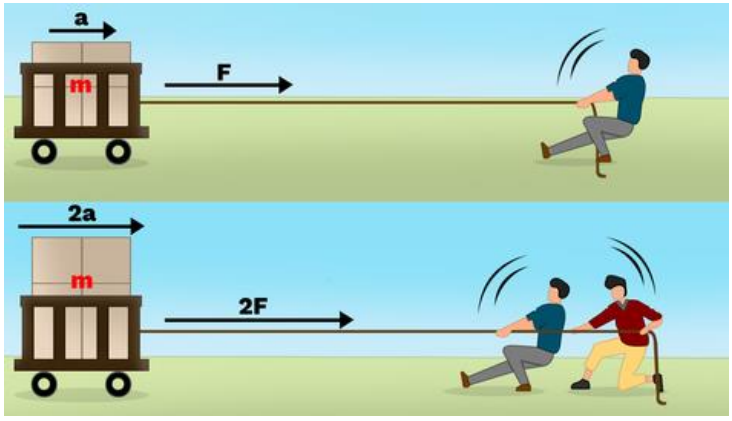
$$By\ definition\ of\ a\ Newton;\ If\ \ F = 1N,\ \ m = 1kg,\ \ a = 1ms^{-2}\ \ then\ k = 1$$

$$\boxed{\boldsymbol{F = ma}}$$

Newton's Second Law explains how the force acting on an object affects its acceleration (how fast it speeds up or slows down).

This law shows that:

- An increase in force makes an object accelerate faster.
- Lighter objects (with less mass) will accelerate more than heavier objects when the same force is applied.



APPLICATIONS OF NEWTON'S SECOND LAW OF MOTION

☑ When playing football, the stronger the kick, the faster the ball will move. This happens because a stronger kick applies more force to the ball, which causes it to accelerate more. According to Newton's Second Law, increasing the force acting on the ball results in greater acceleration, making the ball speed up faster.

☑ When you're in a supermarket, it's easier to push an empty cart than a loaded one. This is because the loaded cart has more mass, which makes it harder to accelerate. According to Newton's Second Law, a heavier object needs more force to speed up. So, to accelerate the loaded cart, you need to apply a larger force.

☑ If two people are walking and one is heavier than the other, the heavier person will walk slower. This happens because the heavier person has more mass, and with more mass, it's harder to accelerate. The lighter person requires less force to keep moving, so they can walk faster.

☑ In Formula 1 racing, the cars are designed to be as light as possible. This is because a lower mass allows the car to accelerate faster. The less mass the car has, the less force is needed to speed it up, which helps the car reach high speeds quickly.

Refraction, Dispersion and Colour

S.3

By the end of this chapter, a learner should be able to;

(a) understand that light may be refracted as it passes from one medium to another and that this has both consequences and uses.
(b) understand the concept of refractive index.
(c) understand the concept of total internal reflection.
(d) know that white light can be split into coloured light by refraction.
(e) know that white light results from the superimposition of light of all colours of the visible spectrum

(l) Measure the angle of refraction, r.
(m) Repeat the procedures e to l for values of $i = 30°, 40°, 50°, 60°$.
(n) Tabulate your results including values of $\sin i$ and $\sin r$.

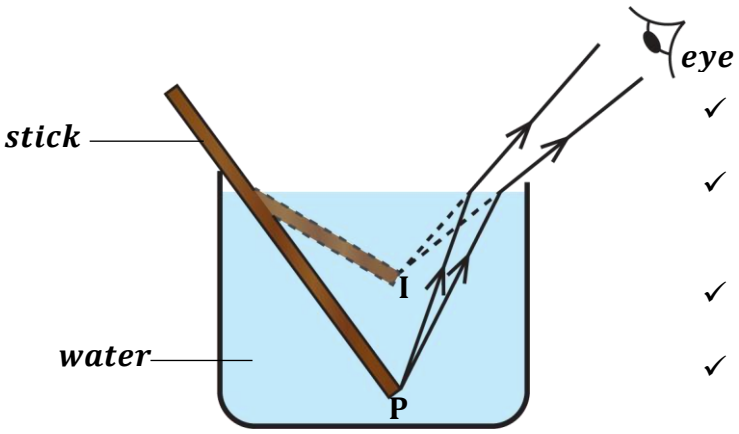
$i(°)$	$r(°)$	$\sin i$	$\sin r$
20°			
30°			
40°			
50°			
60°			

(o) Plot a graph of $\sin i$ against $\sin r$.
(p) Determine the slope of the graph. The slope of the graph is equal to the refractive index of the glass block.

EFFECTS OF REFRACTION IN OUR DAILY LIFE

Refraction causes light to change direction when it moves from one medium to another with a different optical density. This bending of light leads to various visual effects and phenomena that can alter how objects appear or how light behaves in different environments.
These effects include;

a) Bending of a stick immersed in water.



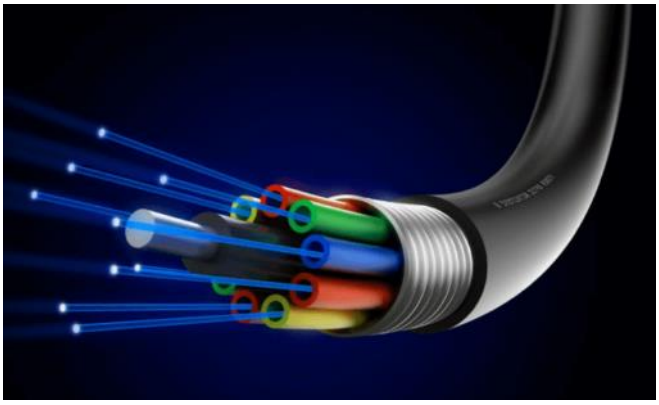
- ✓ Light rays from one end of the stick, **P**, move from water to air.
- ✓ As the light rays pass the water's surface, they are bent away from the normal because water is denser than air.
- ✓ When these rays reach the eye, they appear to be coming from a different point, **I**.
- ✓ This shift in the position of the rays makes the stick appear bent or displaced at the boundary between water and air.

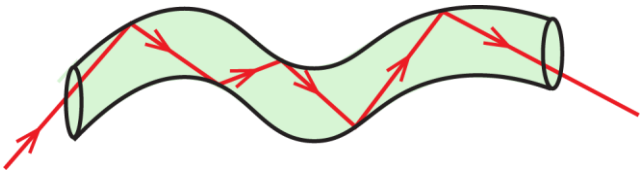
b) Twinkling of Stars at night.

- ✓ Stars twinkle at night because of the refraction of light in the Earth's atmosphere.
- ✓ The atmosphere has layers of air with different densities and temperatures.
- ✓ As light from a star passes through these layers, it is refracted (bent) in different directions.
- ✓ This bending causes the star's light to spread and its brightness to change, making it appear as if the star is twinkling.

b) Optical fibers:

An optical fiber is a thin transparent tube usually made of glass or plastic for transmitting light signals over long distances.
They use the principle of total internal reflection to transmit light without much loss of signal, making them good for communication and as medical instruments





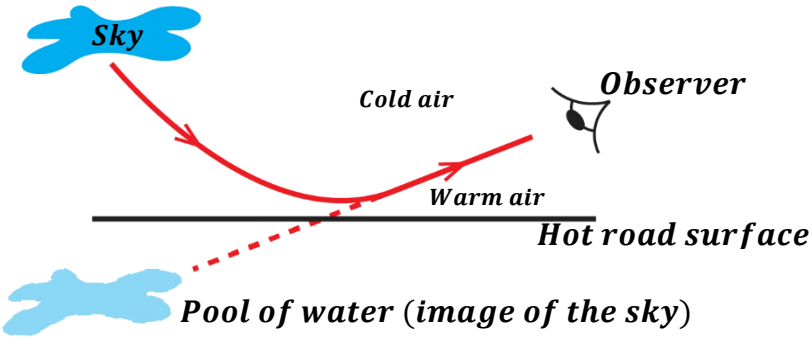
When light enters the optical fiber at one end with an angle of incidence greater than the critical angle, it undergoes total internal reflection at the inner wall boundary. This process continues as the light travels through the fiber, reflecting off the walls, until it emerges from the other end.

Application of optical fibers in daily life;

- They are used in telephones, television, and internet networks to transmit data over long distances at high speed.
- In medicine, optical fibers are used in endoscopes, allowing doctors to view the inside of a patient's body without the need for surgery.

c) Mirages:

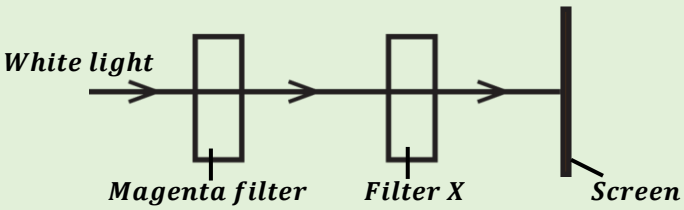
Mirages are common on hot days in deserts and on roads.



- ✓ On a hot day, the air near the road surface is much hotter and less dense than the cooler air above it.
- ✓ When light from the sky travels through the cooler air (above the road) and reaches the hotter air near the road, it is refracted (bent) away from the normal. This happens because light is moving from a denser medium (cool air) to a less dense medium (hot air).
- ✓ As the light continues to bend, if the angle of incidence exceeds the critical angle, the light undergoes total internal reflection.
- ✓ To the observer, the reflected rays appear to be coming from the road's surface hence forming a pool of water on the road surface which is actually the image of the sky.

Practice Exercise

1. What colour should filter X have so that red light is seen on the screen.



2. Explain the appearance of a student wearing a green sweater in a disco hall with yellow light.
3. Explain why an object why an object illuminated by white light appears black.
4. Explain why an object illuminated by white light appears
   i) Coloured
   ii) Black

Activity of Integration

After a rainy day, your father stands outside in the garden as the sun begins to shine through the clouds. He notices a circular band of colours forming in the sky. The circular band appears to have seven distinct colours: red, orange, yellow, green, blue, indigo, and violet. However, your father, who has heard rumours that such colours in the sky bring danger as they curve to ground, becomes worried and runs under the bed, fearing that the colours might be harmful and could take away his life.

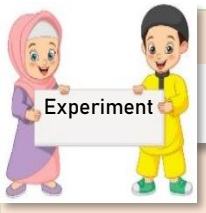
Task:
As a student of physics, help your father understand what's really happening in the sky. Explain to him whether these colours are dangerous and how they form and why they appear curved.

Lenses and Optical Instruments

S.3

By the end of this chapter, a learner should be able to;

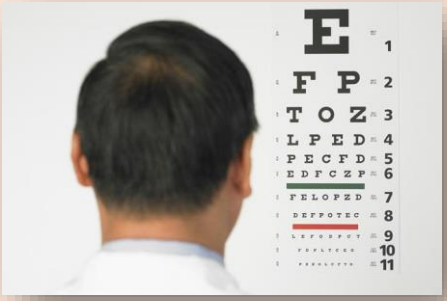
(a) know the properties of converging and diverging lenses, and how they are used in everyday life.
(b) understand how lenses are used in optical systems such as the magnifying glass, correcting sight in the human eye and in camera lenses



ASSESSING ACCOMODATION AT HOME

What you need

- A reading material
- A distant object like a chart clock on the wall



What to do:

Near Vision Test (Near Point):

(a) Hold the reading material at a comfortable distance in front of your eyes.
(b) Slowly move the material closer to your eyes.
(c) When the text becomes blurry, note the distance from your eyes. This is your near point. For a normal eye, it should be about 25 cm away.
(d) If the material remains clear even at a very close distance, your eyes may have strong accommodation.

Far Vision Test (Far Point):

(a) Look at a distant object (e.g., a clock on the wall).
(b) Your eyes should be able to focus on the object without strain. If you can see it clearly from a distance, your accommodation is functioning well for far vision.
(c) If you find that you need to struggle to see clearly at a distance, it could indicate a problem with far-point accommodation.

EYE DEFECTS AND THEIR CORRECTIONS

The human eye is an amazing organ that allows us to see the world around us. However, sometimes the eye may not function perfectly, leading to eye defects. These defects affect how we see things and can range from mild to severe. Some defects are present from birth, while others develop over time due to various factors such as aging or environmental conditions.
In most cases, eye defects can be corrected or managed with the help of eye glasses or spectacles, contact lenses, or in some cases, surgery.

There are two common eye defects namely;

- Short sightedness (Myopia)
- Long sightedness (Hypermetropia)

General Wave Properties

S.3

By the end of this chapter, a learner should be able to;

(a) understand that energy is transferred by waves, and these may be transverse or longitudinal.
(b) know and use the relationship between velocity, frequency, and wavelength.
(c) understand the propagation, properties, and uses of electromagnetic waves, and that white light is a mixture of frequencies but that light from a laser is a single frequency

INTRODUCTION

When you drop a small stone into a calm pond of water, the water around the point of impact gets disturbed forming ripples. These ripples move (propagate) outwards from the point of impact in concentric circles.

But have you noticed something interesting? The water itself doesn't move with the ripples. It only moves up and down! The ripples carry energy from the point where the stone fell outward across the water's surface, without carrying the water molecules along with them.

This is exactly how waves work! Waves are created when molecules of a medium (like water or air) are disturbed. They carry energy as they travel from one point to another, but the medium itself stays behind, vibrating in place.

What is a wave?

When you stand by the roadside, you feel the rush of air when a fast-moving car passes. This happens because the car disturbs the air particles around it. The disturbance moves through the air, and you feel it as a wave of energy.

Definition;

A **wave** is a disturbance that travels through a medium or space transferring energy from one point to another without causing any permanent displacement of the medium itself.

DID YOU KNOW?

The disturbance (waves) only carries energy from one point to another but it doesn't move the medium. For example; The waves due to an earthquake can travel several miles from the source but the ground where they pass doesn't move.

Waves in everyday life:

There are lots of waves all around us in everyday life. They play a big role in how we see, hear and even how we communicate. For example;

→ **Sound waves** move through air or other materials and make our eardrums vibrate so we can hear sounds.
→ **Light waves** are special waves made of photons, helping us see everything around us.
→ When you drop a stone into water, you see **water waves** spreading out from where it landed.
→ **Microwaves** are a type of wave we use to cook food quickly.
→ Phones use **radio waves** to send and receive calls, texts, and internet data.
→ **Infrared waves** are used in remote controls to send signals to TVs, air conditioners, and other devices.
→ During an earthquake, **seismic waves** transfer energy through the ground, causing it to shake.
→ **Ultrasound Waves** help doctors to create images of babies in the womb or to check for injuries inside the body.

How Waves Transfer Energy

Waves transfer their energy by making particles in a medium (like air, water, or solid) vibrate. The particles do not travel with the wave. They only move back and forth or up and down from where they are. This movement passes (transfers) energy from one particle to the next particle.

Sound Waves

S.3

By the end of this chapter, a learner should be able to;

(a) understand that sound is an example of a wave form that requires a medium through which to travel, and determine its velocity in air by the echo method

Heat Quantities and Vapours

S.3

By the end of this chapter, a learner should be able to;

(a) understand and use the concepts of heat capacity and latent heat.
(b) know and explain the implications of the high values of the specific latent heat and the specific heat capacity of water.
(c) carry out calculations and investigations on specific heat capacity and specific latent heat.
(d) understand the concept of latent heat and change of state, and use them to explain melting and boiling point.
(e) understand the meaning of saturated and unsaturated vapours, saturated vapour pressure, and how these terms relate to boiling and evaporation.
(f) appreciate the cooling effect of evaporation and how this contributes to maintaining constant body temperature

10 WORKED EXAMPLE

Allen leaves home for work at $7:20\ a.m.$ and must carry tea in a flask. One morning she needed to prepare the tea she carries but remembered that the only water she had in the house was 5 litres in a saucepan of $0.2\ kg$, stored in a deep freezer.
On removing the saucepan from the freezer, she realized all the water had turned into a block of ice. It was $7:00\ a.m.$, and she was worried about leaving late but decided to heat the saucepan containing the block of ice with her hot plate rated at $4.22\ kW$, until all the ice turned into water and the water boiled, ready for her tea.

Hint:
(S.H.C of saucepan = 900 $Jkg^{-1}K^{-1}$, S.H.C of water = 4,200 $Jkg^{-1}K^{-1}$, S.L.H. of fusion of ice = 336,000 Jkg^{-1}, Density of water =1000 kgm^{-3}, $Boiling\ point\ of\ water =$ 100°C $and\ the\ initial\ temperature\ of\ ice\ in\ the\ sauce\ pan =$ 0°C)

Task:
(a) Determine how long it took Allen to boil the tea.
(b) Explain whether or not Allen was able to leave home for work at 7:20 a.m.

Solution:
$1\ litre = 1000cm^3 = 0.001m^3$
$5\ litres = 0.001 \times 5 = 0.005m^3$

$\boldsymbol{Mass\ of\ water} = density \times Volume = 1000 \times 0.005 = \mathbf{5kg}$

<u>Heat energy required to melt ice at 0°C</u>
$H_1 = m_i l_f$
$\boldsymbol{H_1} = 5 \times 336000 = \mathbf{1680,000\ joules}$

<u>Heat energy required to raise temperature of melted water from 0°C to 100°C</u>
$H_2 = m_w c_w \Delta\theta$
$\boldsymbol{H_2} = 5 \times 4200 \times (100 - 0) = \mathbf{2,100,000\ joules}$

<u>Heat energy required to raise temperature of saucepan from 0°C to 100°C</u>
$H_3 = m_w c_w \Delta\theta$
$\boldsymbol{H_3} = 0.2 \times 900 \times (100 - 0) = \mathbf{18,000\ joules}$

$Total\ heat\ energy = \boldsymbol{H_1 + H_2 + H_3}$
$Total\ heat\ energy = \mathbf{1680000 + 2100000 + 18000 = 3798000\ joules}$

<u>Time taken to supply the heat energy</u>

$$Power\ of\ heater = \frac{Heat\ energy\ supplied}{time\ taken}$$

$$(4.22 \times 1000) = \frac{3798000}{t}$$

$$t = \frac{3798000}{4220} = 900s = 15\ minutes$$

(a) It took **15 minutes** to boil the tea.
(b) Allen started boiling the tea at 7:00 a.m. It was ready at **7:15 a.m.**, so she was able to leave home for work at 7:20 a.m.

Stars and Galaxies

S.3

By the end of this chapter, a learner should be able to;

(a) know the source of energy in stars and appreciate the importance of the energy produced by the sun to the people on Earth.
(b) appreciate that stars vary in colour and brightness.
(c) know that stars have life cycles and that the fate of stars (white dwarfs, neutron stars and black holes) depends on their initial size.

Satellites and Communication

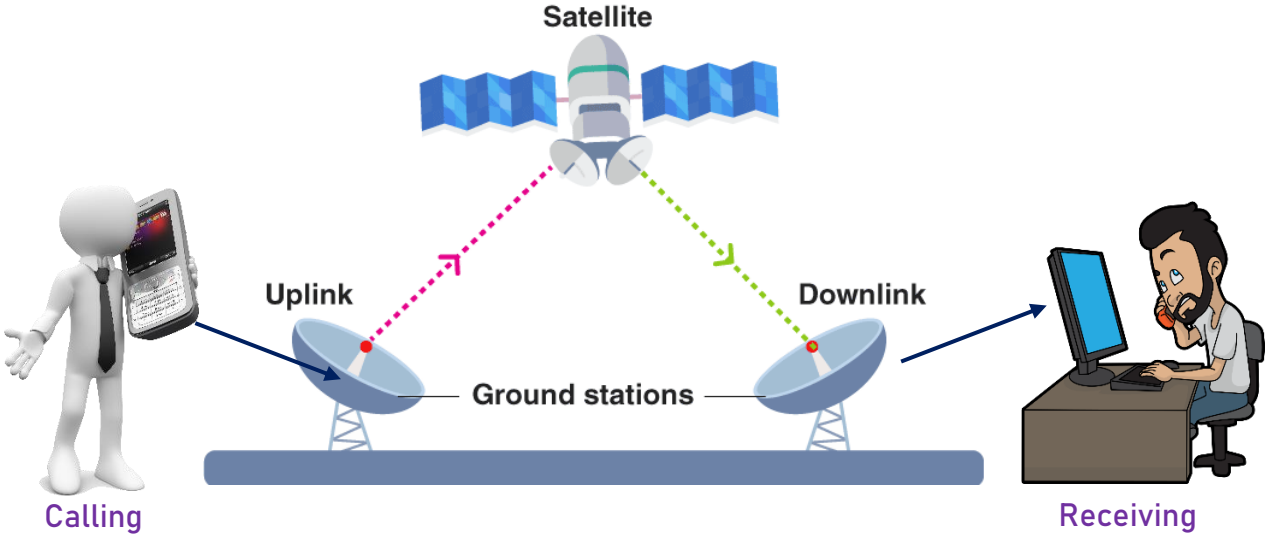
S.3

By the end of this chapter, a learner should be able to;

(a) understand what artificial satellites are and how we make use of them in research and in everyday life.
(b) appreciate the importance of space exploration.

How do Satellites enable communication?

- **Uplink**: A signal is sent from a ground station or a user's device (like a phone or TV) up to the satellite in space.
- **Transponder**: The satellite receives the signal and strengthens it using a device called a **transponder**.
- **Downlink**: The satellite sends the amplified signal back to Earth. It is then received by another ground station or a user's device, like a TV or GPS receiver.



How phone call communication is possible

- When you make a phone call, your phone changes your voice into electrical signals and sends them as radio waves to the nearest ground station.
- The ground station sends these signals to a satellite in space using an **uplink channel**.
- The satellite sends the signals back to a ground station near the person you're calling through a **downlink channel**.
- The ground station then sends the signals to the other person's phone, where they are converted back into sound.

Describe how television stations broadcast pictures

- ✓ TV stations use cameras to capture moving pictures, turning them into electrical signals.
- ✓ TV providers, like DSTV, send these signals from a ground station as radio signals up to a satellite in space.
- ✓ The satellite receives the signals, amplifies them, and sends them back to Earth to different receivers.
- ✓ Viewers with satellite dishes and receivers pick up these signals.
- ✓ The signals are then sent to your TV, which converts them back into electrical and video signals.

How weather is predicted before it happens?

- Weather satellites orbit Earth and take pictures of clouds, storms, and weather patterns. These images show how clouds are forming and moving, which helps predict if it will rain, snow, or be sunny.
- Satellites can also measure the temperature of the air and the surface of the Earth. This helps scientists know if it's getting warmer or cooler in different areas, which is important for predicting weather changes.
- Satellites can track wind patterns high in the atmosphere. Knowing how fast and in what direction the wind is blowing helps predict weather changes, like when a storm is coming.

Introduction to Current Electricity

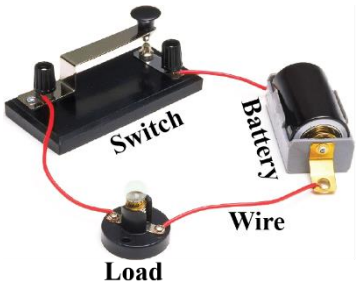
S.4

By the end of this chapter, a learner should be able to;

(a) Understand what e.m.f is.
(b) understand that cells convert chemical energy into electrical energy, producing current and also the force needed to create a flow of current in a circuit.
(c) understand that electric cells are very useful but have their limitations.
(d) understand the nature of electric current, its sources, what makes it flow around circuits and how and it is measured.
(e) know that some materials are electrical conductors and other are insulators.
(f) recognise, understand and apply knowledge of series and parallel circuits.
(g) appreciate that circuits may be represented as circuit diagrams consisting of an agreed set of symbols to represent components.

Components of an Electrical Circuit

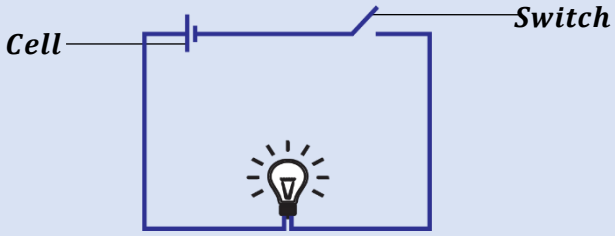
1. **Power Source**: Provides the energy for current to flow (e.g., a battery or generator).
2. **Conductors**: Wires or materials that allow electricity to flow through them.
3. **Load**: The device that uses the electrical energy, such as a bulb or motor.
4. **Switch**: Opens and closes the circuit to control the flow of electricity.



There are two states of a circuit namely;

Open circuit:

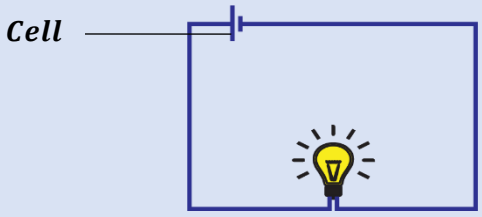
This a circuit in which current is not flowing to the load.



A circuit is **open** when there is a break or gap in the path, so electricity cannot flow. For example: when a switch is off, or a wire is disconnected.

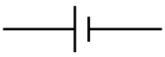
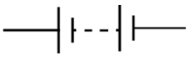
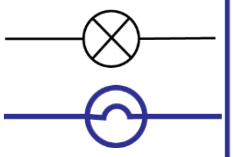
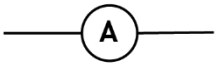
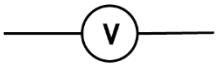
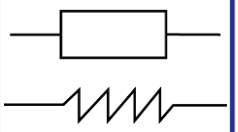
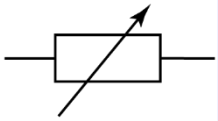
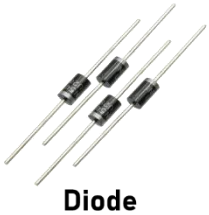
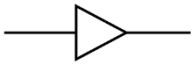
Closed circuit:

This is a circuit in which current is flowing to the load.



A circuit is **closed** when there is no break in the path, allowing electricity to flow. For example: when the switch is on, and all components are properly connected.

Common electrical components and their symbols

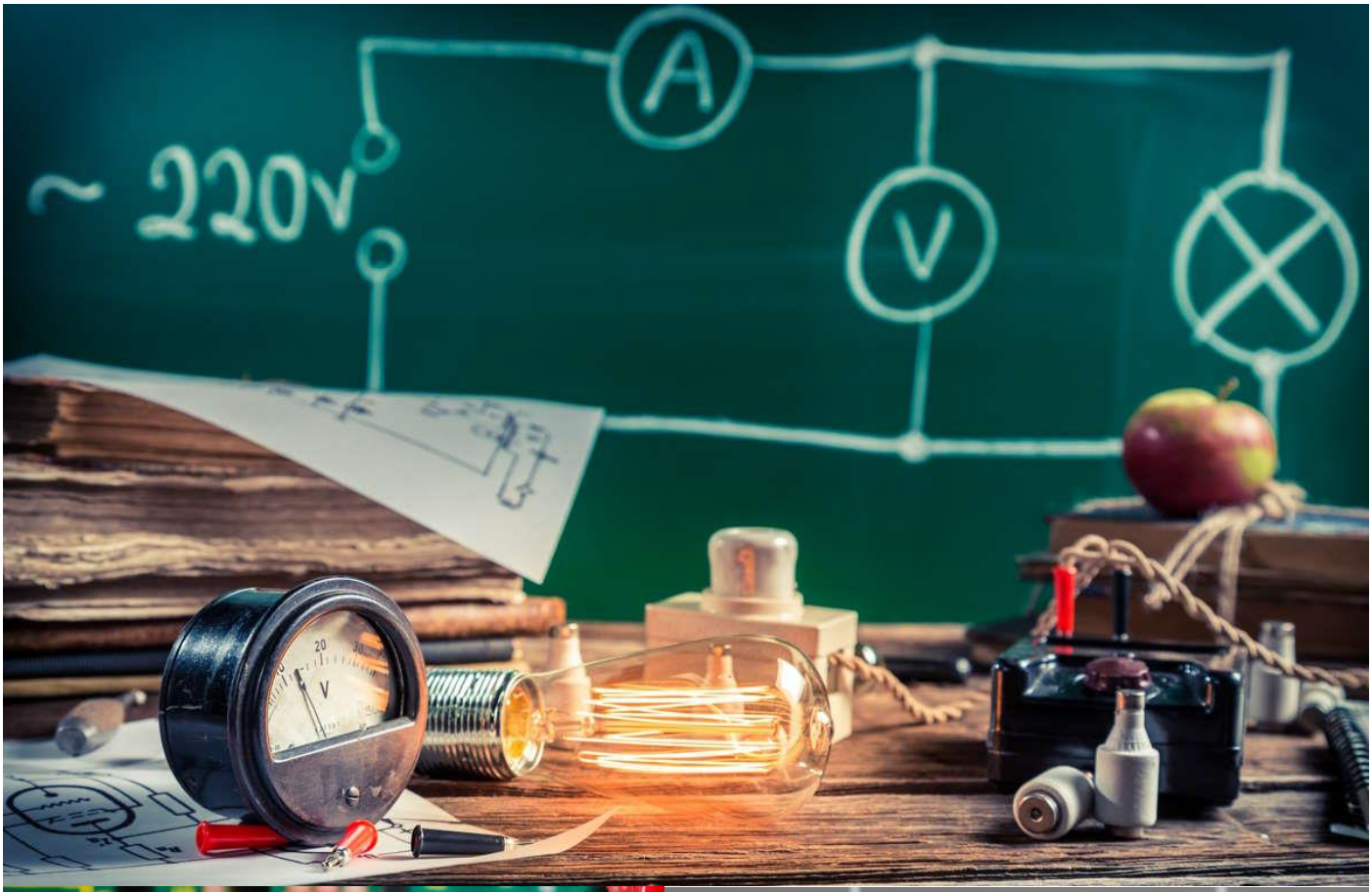
Component	Symbol	Component	Symbol	Component	Symbol
Switch		Dry cell		Battery	
Bulb/Lamp		Ammeter		Voltmeter	
Standard resistor		Variable resistor		 Diode	

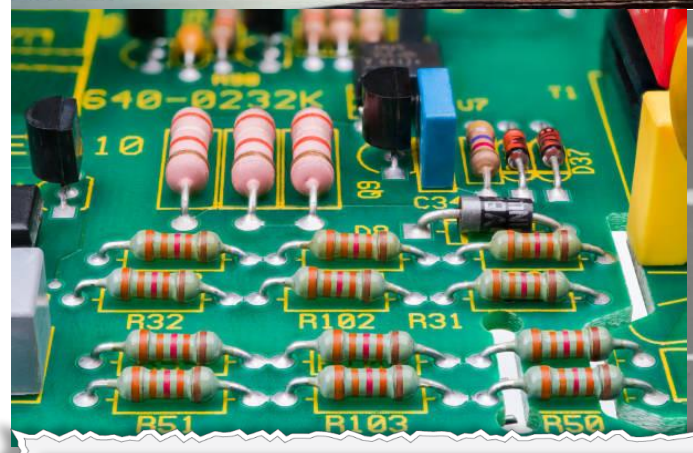
DID YOU KNOW?

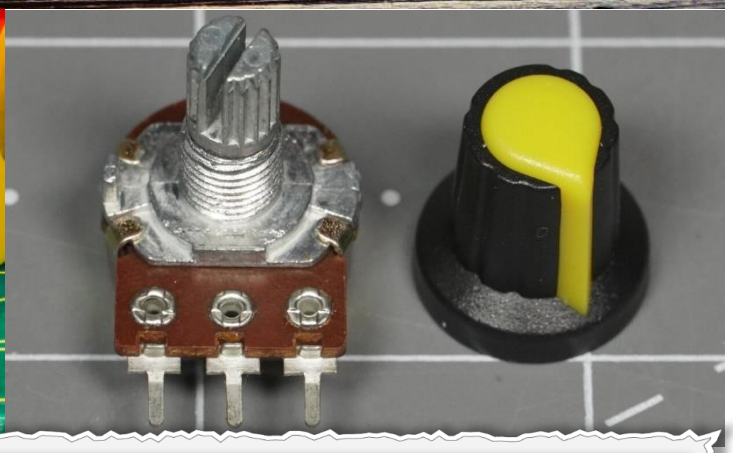
A short circuit is a low resistance path that allows current to flow quickly.
It occurs when two points in a circuit are directly connected without passing through the external components (like bulbs or resistors) so that current flows through a shorter distance. This causes a large amount of current to flow quickly, which can damage components of the circuit or cause overheating, sparks, or even fires.
To prevent short circuits, wires and components should be insulated and connected.

Voltage, Resistance and Ohm's law

S.4



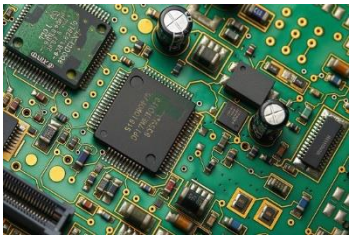




By the end of this chapter, a learner should be able to;

(a) understand electrical resistance, how it is measured, its relationship to current and voltage, and the factors that affect it.
(b) know the function and use of a diode, transistor, thermistor, LDR. LED and potentiometer

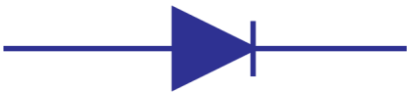
BASIC ELECTRONIC COMPONENTS



Electronic components are small devices used in circuits to control the flow of electricity. They are like the building blocks of modern technology, helping us create radios, computers, lights, and many other useful devices. The important components include: the diode, transistor, thermistor, LDR, LED, and potentiometer. Each of these components has a special job and helps circuits work in different ways.

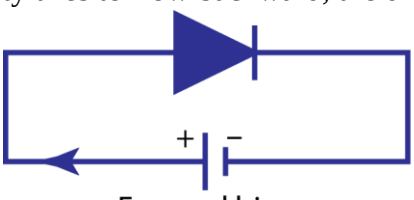
DIODE

A diode is an electronic component that allows current to flow in only one direction. It is made from semiconductor materials like silicon.

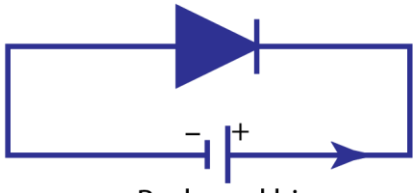


How a diode works:

- ✓ When electricity flows in the correct direction, the diode allows it to pass. (This is called forward bias)
- ✓ If electricity tries to flow backward, the diode blocks it. (This is called backward bias)



Forward bias



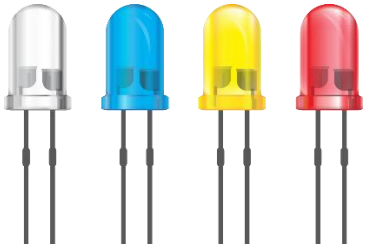
Backward bias

Applications of Diodes

→ Diodes are used to convert alternating current (AC) to direct current (DC) in power supplies. Therefore, they are used as rectifiers.

→ Diodes are used in circuits to control the flow of current and protect devices from damage i.e., they stop current from going in the wrong direction.

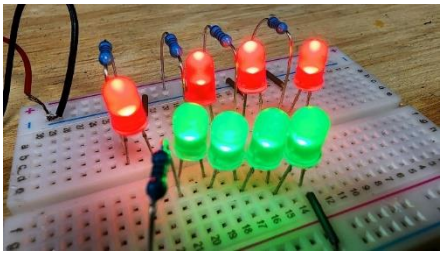
LIGHT EMITTING DIODE (LED)



A LED is a type of diode that produces (emits) light when electricity flows through it.

LEDs can emit light in various colours, such as red, blue, green, or white, depending on the material used.

They are highly efficient, whereby they use very little electricity compared to other types of lights, and they last for a long time.

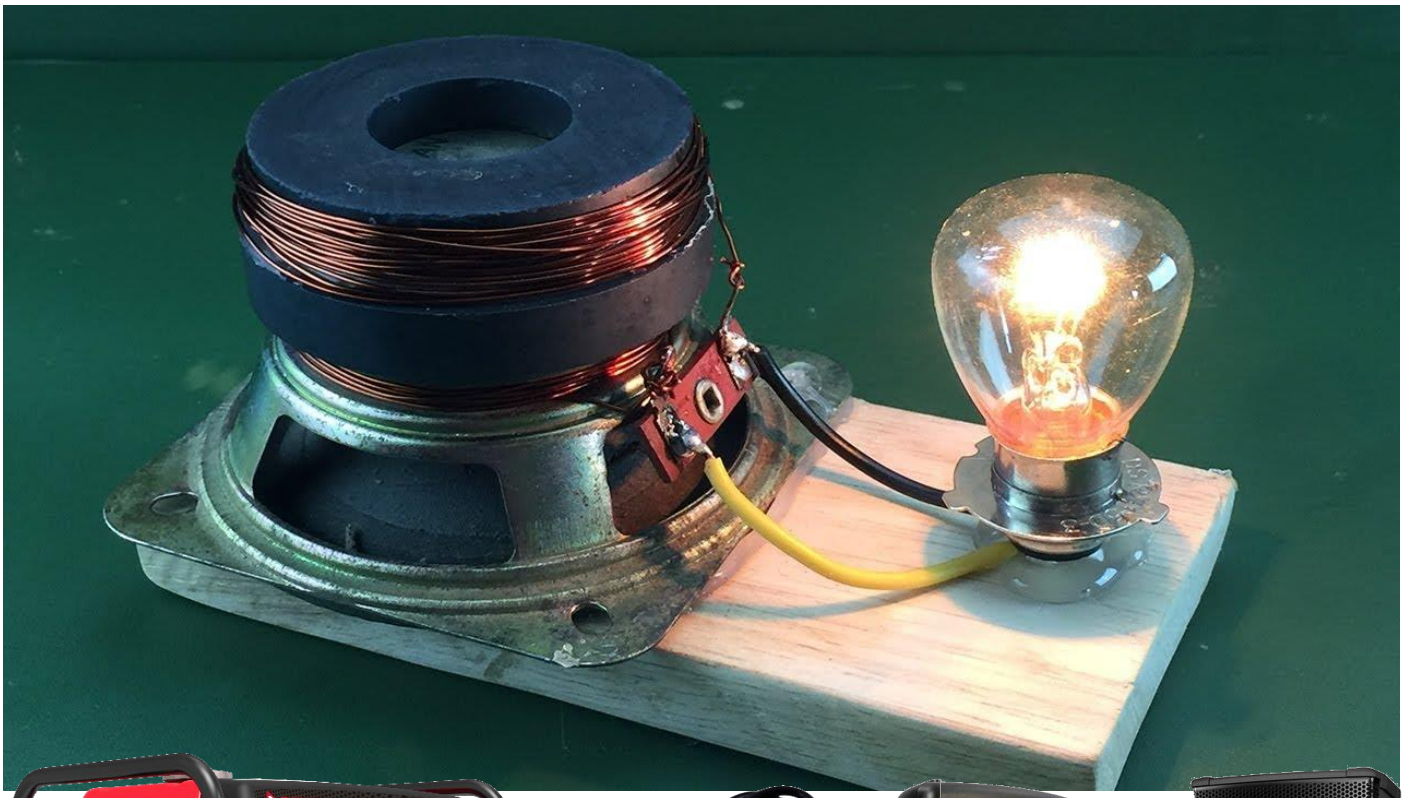


How a LED Works:

- ✓ When electricity flows in the correct direction, the LED lights up. This happens when the LED is in forward bias.
- ✓ When electricity flows in the backward direction, the LED blocks current and does not emit light. This happens when the LED is in reverse bias.

Electromagnetic Effects

S.4



By the end of this chapter, a learner should be able to;

(a) investigate the behaviour of magnets and magnetic fields.
(b) understand that a current carrying conductor produces a magnetic field that can be detected.
(c) understand the application of electromagnets in devices such as motors, bells, and generators.
(d) understand the difference between a.c. and d.c
(e) know how a.c. and d.c. can be interconverted using rectifiers and inverters.
(f) understand the action and applications of transformers.

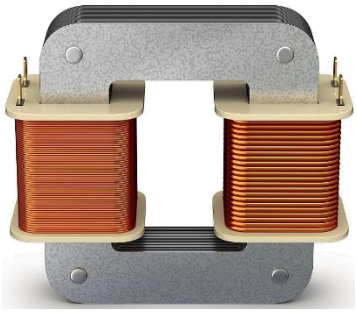
Note: Mutual induction is applied in the operation of transformers.

TRANSFORMERS

Many electrical appliances and consumers require different amounts of voltage. Some devices require a high voltage and others require a low voltage. This therefore, requires an efficient mechanism for increasing or decreasing voltage. This is achieved by using a ***transformer***. Transformers are amazing devices that help us use electricity more efficiently. They play a crucial role in bringing electricity from power stations to our homes, schools, and businesses.
Transformers help by changing the voltage of electricity: they can increase the voltage of electricity (at power stations) to travel long distances and then decrease it to a safe level for us to use (at consumer points).

Definition:

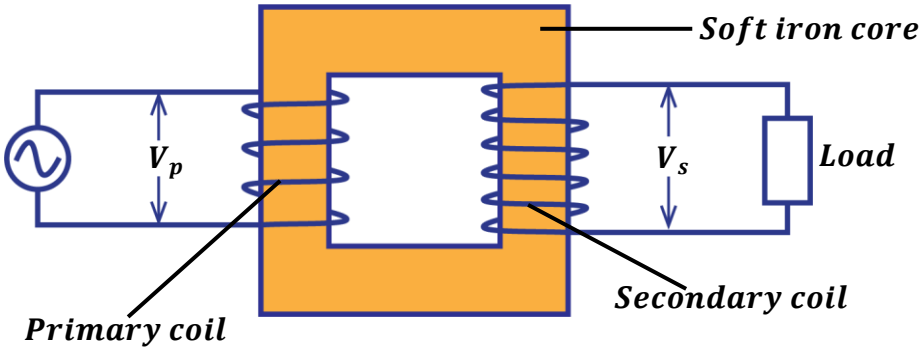
A **transformer** is an electric device that is used to step up (increase) or step-down (decrease) voltage.



Transformers are normally used in electrical appliances e.g., radio receivers, TV sets, battery chargers etc. where the input voltage has to be changed.
An example of a transformer is **a phone and laptop charger** which steps down the voltage from the source to a small value that is suitable for charging phone and laptop batteries.

Structure of a transformer:

It consists of a laminated soft iron core around which primary and secondary coils are wound.
The soft iron core helps to transfer the magnetic field between the primary and secondary coils.



How a transformer works:

- When alternating voltage $\mathbf{V_p}$ is applied to the primary coil, alternating current (changing current) flows through the primary coil.
- The alternating current creates a changing magnetic field around the primary coil.
- This changing magnetic field travels through the soft iron core and links up with the secondary coil.
- A voltage, $\mathbf{V_s}$ is induced in the secondary coil.
- The voltage induced in the secondary coil can be different from the voltage in the primary coil due to the difference in the number of turns in each coil.

TYPES OF TRANSFORMERS:

There are two types namely;

- Step up transformer
- Step down transformer

Electric Energy Distribution and Consumption

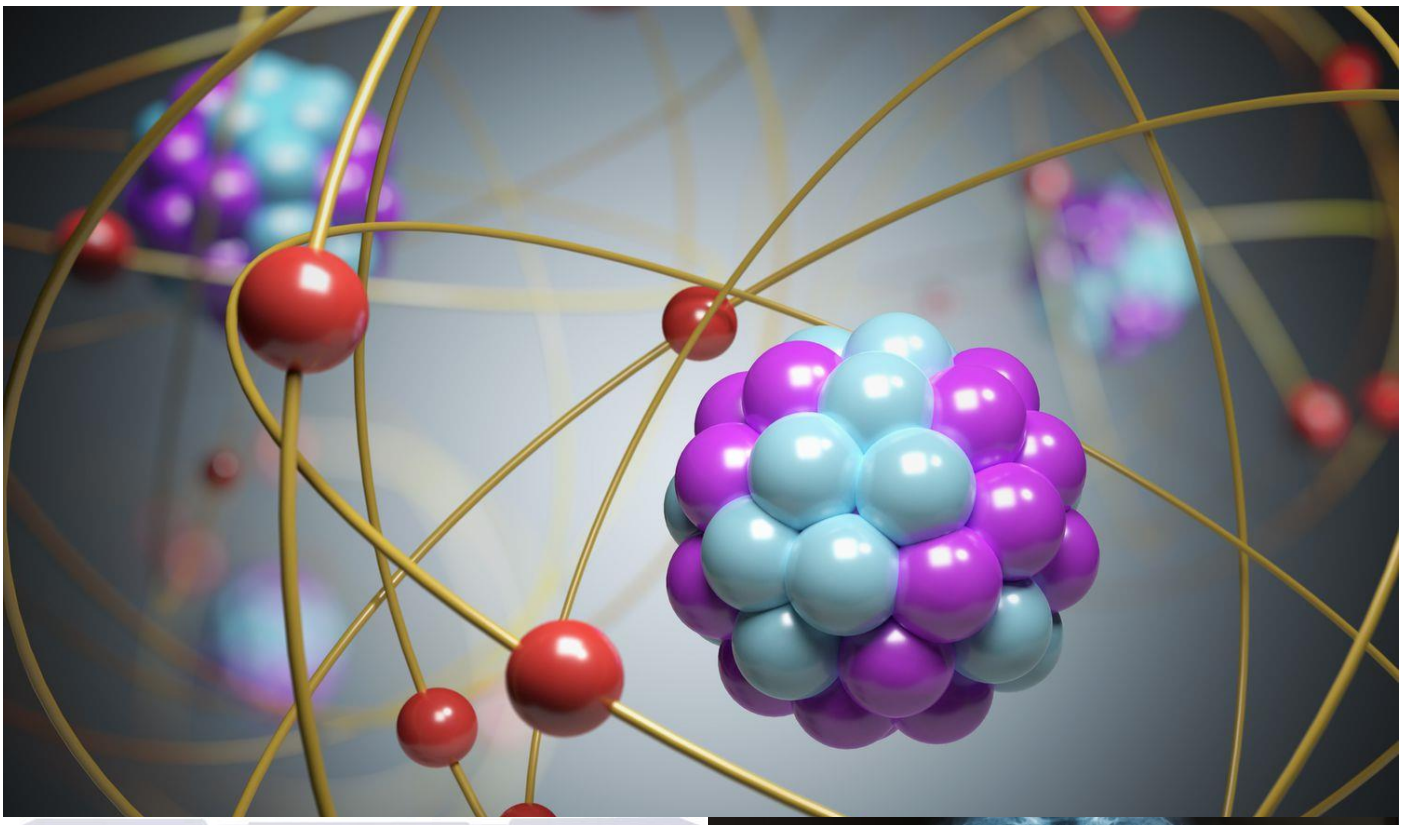
S.4

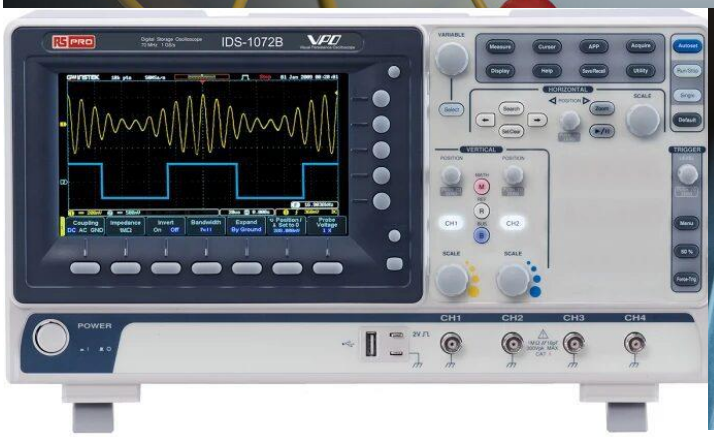
By the end of this chapter, a learner should be able to;

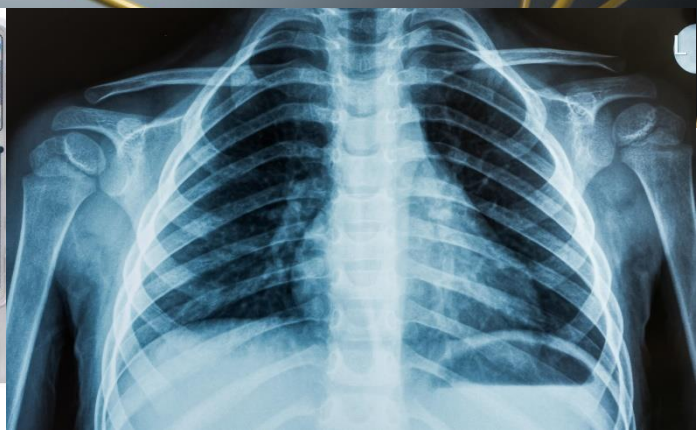
(a) understand the distribution of electricity from the source to consumer units.
(b) understand the energy transformations in common domestic electrical devices and how energy can be saved.
(c) understand how to use mains electricity safely and know the insulation colour codes used in domestic wiring.
(d) know the dangers of mains electricity and understand how these may be minimised by safety devices, and by sensible precautions.
(e) know how to read a domestic electricity meter and its significance.
appreciate the importance of the use of energy saving appliances

Atomic Models

S.4





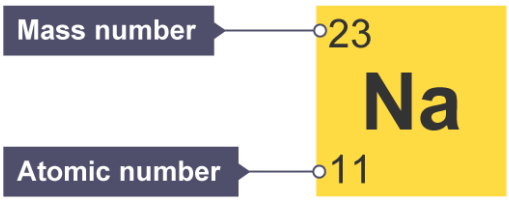


By the end of this chapter, a learner should be able to;

(a) understand the structure of an atom in terms of a positive nucleus and negative electrons.
(b) understand the terms: atomic number, mass number, and isotopes, and use them to represent different nuclides.
(c) understand the methods by which electrons are ejected from /matter atoms and how

REPRESENTING DIFFERENT ATOMS

Every atom of an element has got a unique symbol that represents it.
An atom of an element X is represented as;



Atomic number, Z:
This is the number of protons in the nucleus of an atom.

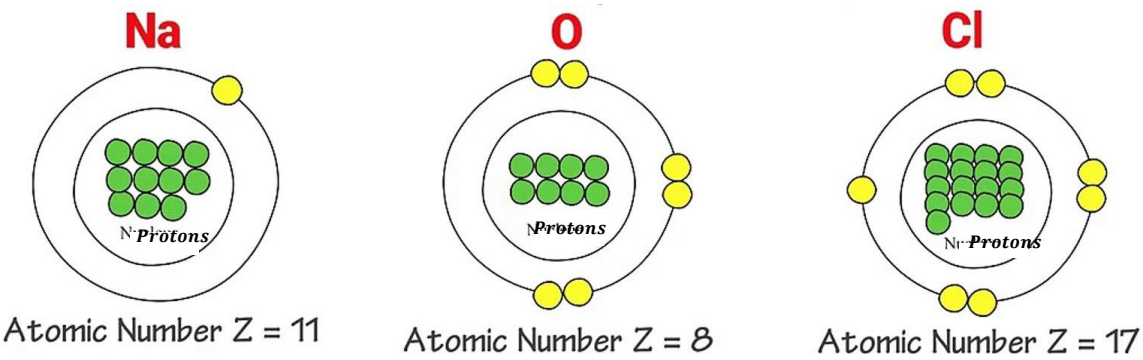
$$Atomic\ number, \boldsymbol{Z} = Number\ of\ protons$$

E.g.; Hydrogen has an atomic number of 1 because it has one proton in its nucleus.

Mass number [atomic mass], A: (nucleon number):
This is the total number of protons and neutrons in the nucleus of an atom.

$$Mass\ number = Number\ of\ protons + Number\ of\ neutrons$$

$$\boldsymbol{A = Z + n}$$



1 WORKED EXAMPLES

(a) Given a chloride atom $^{35}_{17}\boldsymbol{Cl}$. Find the number of electrons in the atom.

$A = Z + n \quad where\ A = 35, Z = 17$

$n = 35 - 17$

$n = \mathbf{18\ neutrons}$

$Number\ of\ electrons = Number\ of\ protons = Atomic\ number\ Z = \mathbf{17\ electrons}$

(b) State the composition of the atom $^{235}_{92}\boldsymbol{U}$

$Atomic\ number = 92$

$Mass\ number = 235$

$Number\ of\ neutrons = 235 - 92 = 143$

$Number\ of\ electrons = 92$

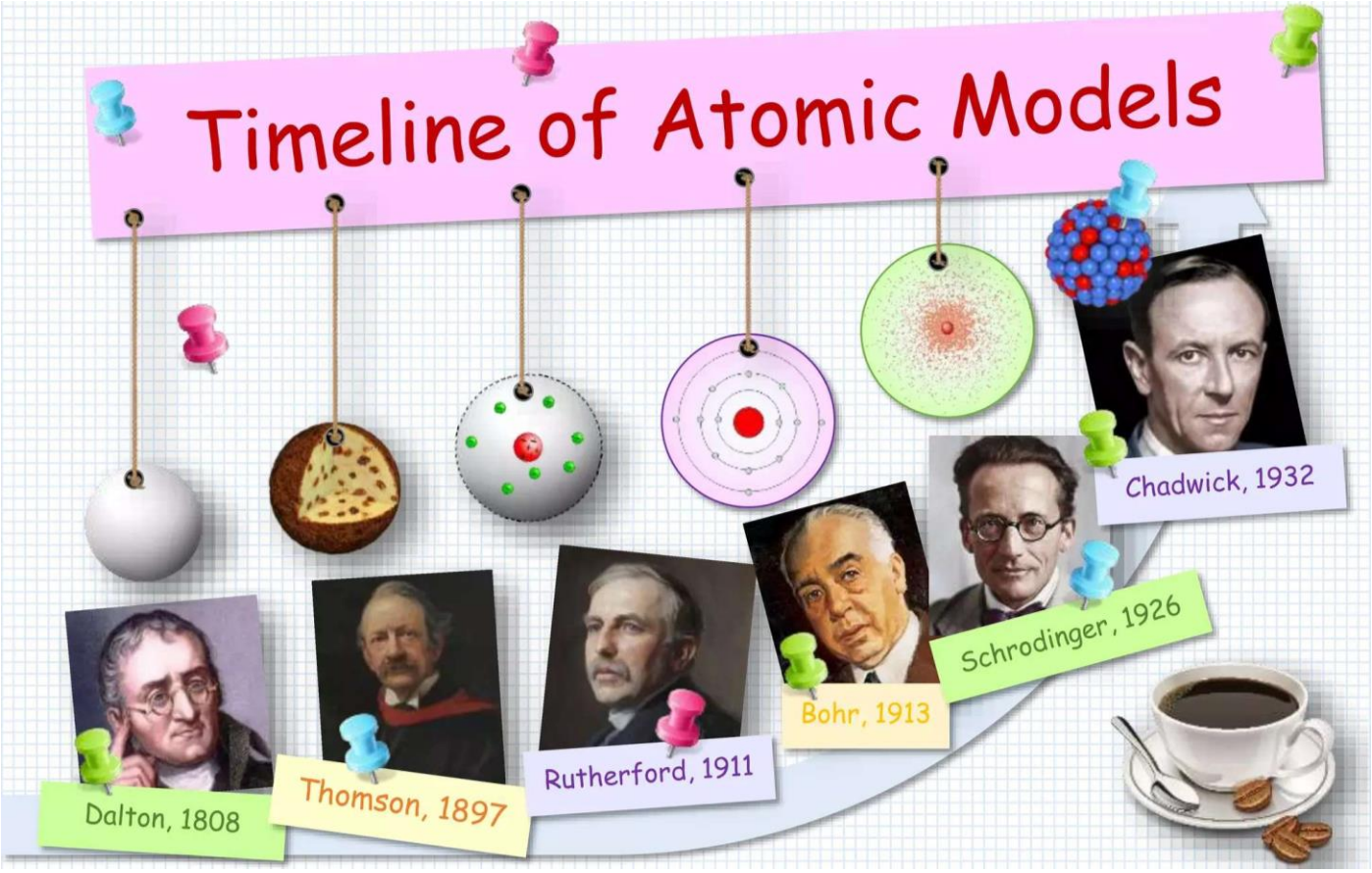
$Number\ of\ protons = 92$

(c) Carbon, C has 6 electrons and 6 neutrons. Write down the symbol of Carbon nuclide.

$Atomic\ number = 6$

$Mass\ number = 6 + 6 = 12$

$^{35}_{17}\boldsymbol{Cl}$



The model of the atom has been developed over the years as advances have been made in scientific methods and technology. The work of many scientists over the years has contributed to the model of the atom we use today. They made several experiments to come up with what we know today.

Dalton's model

John Dalton a scientist made his observations from the experiments he conducted about atomic models and proposed the following;

- All matter is made up of atoms which are tiny and solid spheres.
- Atoms are indivisible.
- Atoms can neither be created nor destroyed.
- Elements are made up of identical (similar) atoms.
- Atoms of the same element have the same mass. The mass of each atom varies from element to element.

Limitation: Dalton's model did not explain the existence of subatomic particles (protons, neutrons, and electrons) or the internal structure of the atom.

Rutherford's model

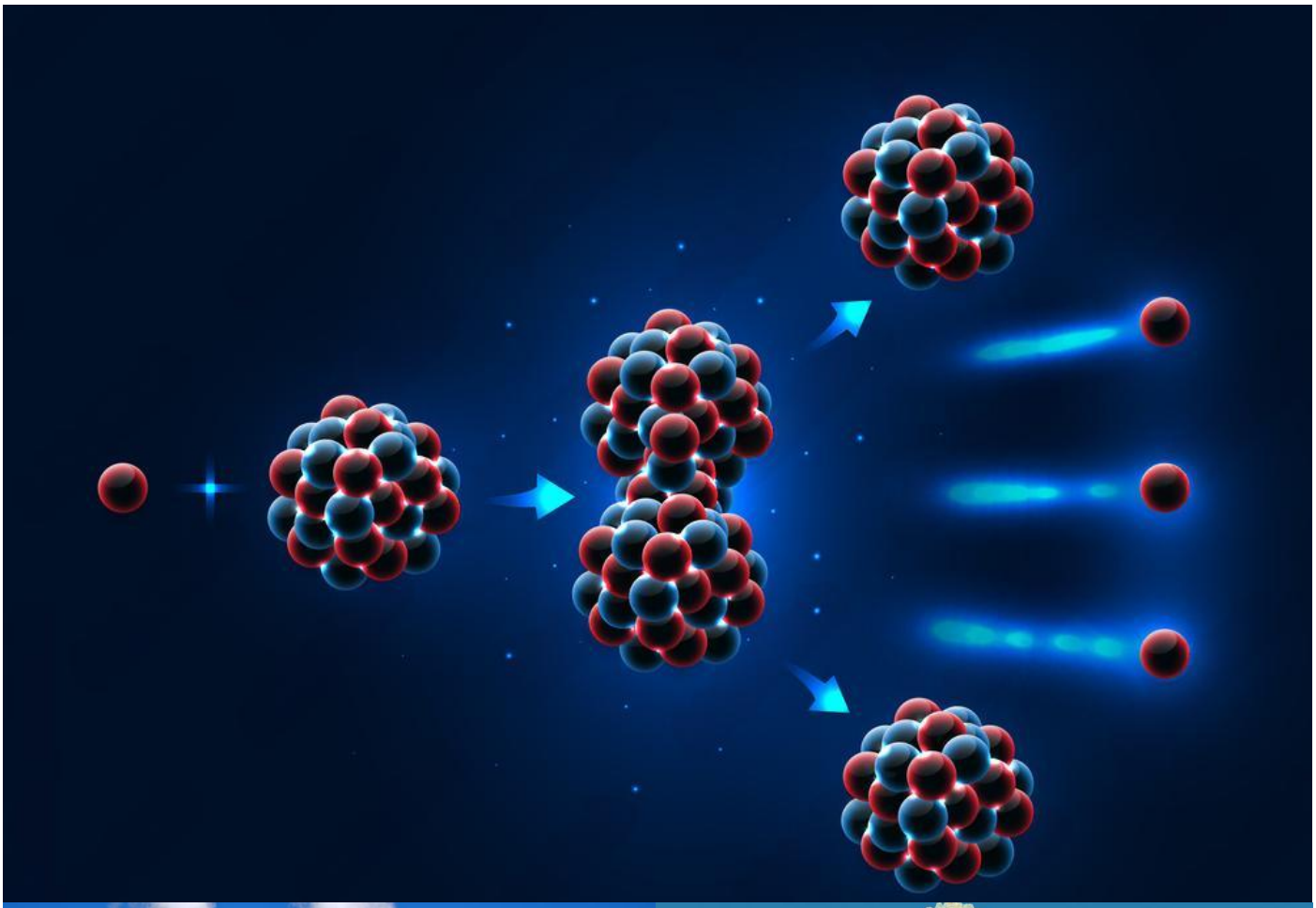
In the early 20th century, the scientist Ernest Rutherford conducted experiments on the behaviour of alpha particles and from his observations, he proposed the following;

- Atoms have a central nucleus that contains most of the atom's mass and positive charge.
- The negatively charged electrons surround the nucleus of an atom. He also claimed that the electrons surrounding the nucleus revolve around it with very high speed in circular paths. He named these circular paths as orbits.
- Most of the atom is empty space, with the nucleus being tiny compared to the overall size of the atom.

Limitations: Rutherford's model couldn't explain why electrons, which are negatively charged, don't collapse into the positively charged nucleus due to electrostatic attraction.

Nuclear Processes

S.4



By the end of this chapter, a learner should be able to;

(a) understand the processes of nuclear fission and fusion and the associated energy changes.
(b) understand the spontaneous and random nature of nuclear decay and interpret decay data in terms of half-life.
(c) know the applications of radioactivity and the dangers associated with exposure to radioactive materials.
(d) understand and appreciate that there are significant social, political, and environmental dimensions associated with use of nuclear power.

Note:
Activity is the number of disintegrations (decays) of a radioactive material occurring per unit time. The activity of a sample decreases over time as the amount of radioactive material decreases.

DID YOU KNOW?

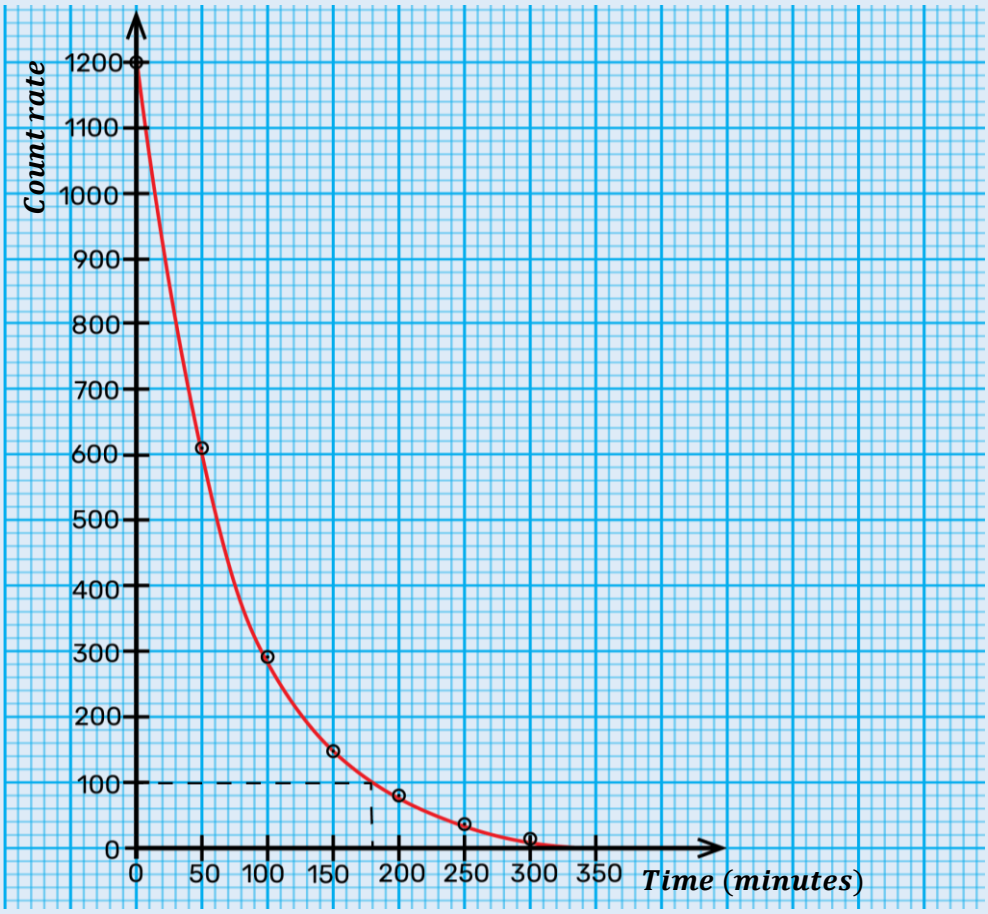
Radioactive materials decay over time. As they decay, their radiation levels decreases until they reach the same level as the background radiation in the environment. This means that when radiations from a radioactive material matches the background radiation value, the radioactive material becomes safe and no longer harmful.

6 WORKED EXAMPLE

Casual workers in a certain factory suspect that some of the bi-products from the factory in which they work. Some of the workers have very itchy skins and constant headaches and one of them has suspected it could be radioactive. It has also curiosity about what else they can use radioactive materials for and how best to handle them. Upon measuring the activity of the biproducts from the factory, they recorded the activity results in the table below.

Activity (Count rate)	1200	610	290	148	80	38	15
Time (min.)	0	50	100	150	200	250	300

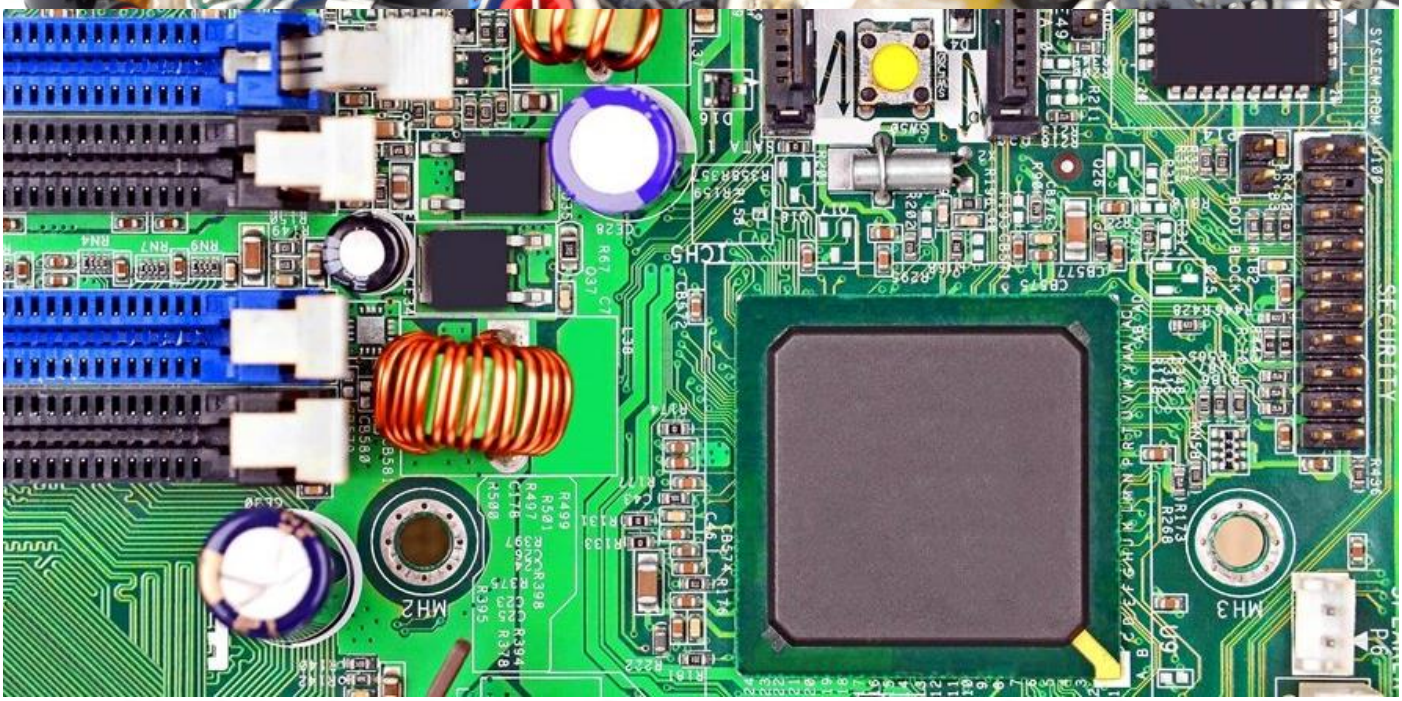
Hint: $Background\ radiation\ =\ 100\ counts\ per\ minute.$
Using a graph, determine when it is safe to dispose off the bi-products immediately.
Solution:



It will be safe to dispose off the bi-products after 180 minutes

Digital Electronics

S.4



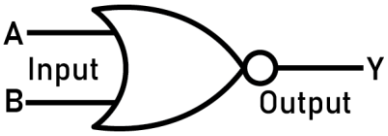
By the end of this chapter, a learner should be able to;

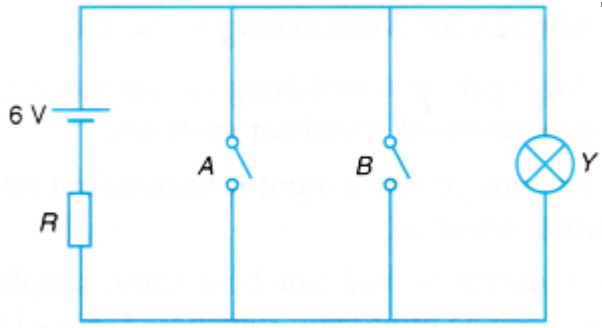
(a) understand how resistors are used to make potential dividers in control and logic circuits.
(b) understand elementary logic and memory circuits that exploit devices such as bistable and astable switches, logic gates and resistors as potential dividers.
(c) know that logic circuits are able to store and process binary information and that this can be exploited in an increasingly wide variety of digital instruments.

NOR GATE:

This is a combination an OR gate followed by a NOT gate. The output is true (1) if both inputs are false (0). Therefore;

→ If any input is **1** (true), the output will be **0** (false).
→ If both inputs are **0** (false), the output will be **1** (true).





The Boolean expression of an NOR gate is $Y = \overline{A + B}$

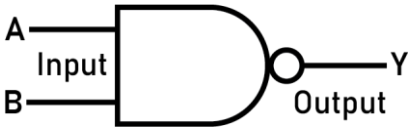
Truth table

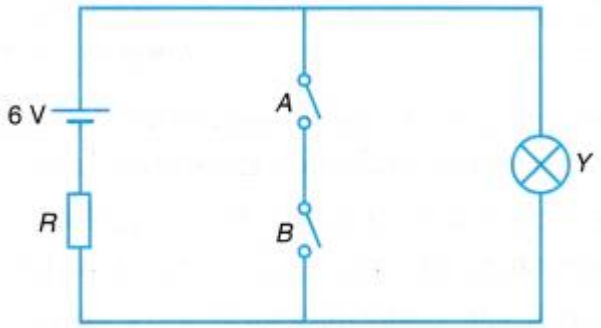
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

NAND GATE:

This is a combination of an AND gate followed by a NOT gate. The output is false (0) if both inputs are true (1) otherwise its true. Therefore;

→ If any input is **0** (false), the output will be **1** (true).
→ If both inputs are **1** (true), the output will be **0** (false).





The Boolean expression of an NOR gate is $Y = \overline{A + B}$

Truth table

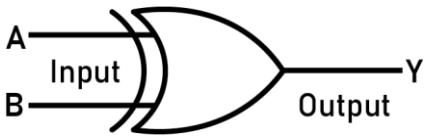
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

XOR (exclusive-OR) GATE:

The output is true if either, but not both, of the inputs are true. The output is false if both inputs are "false" or if both inputs are true. Therefore;

→ If both inputs are different, the output will be **1** (true).
→ If both inputs are the same, the output will be **0** (false).

The Boolean expression of an XOR gate is $Y = A \oplus B$



Truth table

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

WAVES AND LIGHT

ITEM 1:
Students in a particular class visited a laboratory where there were two light bulbs: one white and one red. They observed a glass tank filled with water, which had a white base at the bottom. Modifications were made to the tank to create a shallow end on one side using glass material.
The students were surprised when they struck the water's surface at the shallow end with a long rectangular rod at a frequency of $80\ Hz$. They noticed that the spacing between successive crests of the waves changed from $2.5cm$ to $5cm$. They were also disturbed by the distortion of the ripples as they hit the tank walls.
Additionally, they were surprised to see the tank base turning black when it was replaced with a yellow sheet, and the red lights were switched on.

Hint: The glass tank would break if the velocity of the waves that hit it is greater than $20\ ms^{-1}$.

Task: Use your knowledge of physics to:
(a) Determine if the ripple tank will break.
(b) Explain the reason for the change in the distance between the ripples and its impact on the velocity of the ripples.
(c) Explain what distorted the waves and how it could have been reduced.
(d) Explain why the yellow sheet changed colour when the red lights were switched on.

ITEM 2:
A man went to a clinic for a tooth extraction and brought his 10-year-old son with him. The dentist was very busy and asked the nurse to find an optical instrument with different radii of curvature that could provide the best magnification to assist in the procedure.
The average length of an adult human tooth is $2\ cm$, and the dentist advised the nurse to position the tooth $40\ cm$ away from the optical instrument for the best results.
Later that evening, when the man returned home, the 8-year-old boy narrated the events loudly to their neighbours in the next room. Even though the neighbours had closed their door and were preparing to sleep, they could clearly hear the boy's story.

Hint: Available optical instruments were concave mirror of radius of curvature $20cm$ and convex lens of the same focal length of radius of curvature $15cm$.

Task: As a learner of physics;
(a) Advise the nurse on the optical instrument that would best extract the tooth.
(b) Explain why the neighbours were able to hear the boy's conversation even though their door was closed.

ITEM 3:
People who regularly visit an entertainment hall are disappointed with the quality and loudness of the sound produced by the sound system. The system creates sound waves with a wavelength of $4\ cm$. They believe the sound is harmful to their ears.
Those sitting at the front of the hall, near the speakers, complain that they hear two sounds: a loud sound and a faint one. This causes distortion in the sound they hear. Additionally, the people feel that the stage bulbs should be replaced with laser lights. The hall owner, however, doesn't understand why the change is necessary.

Hint: Speed of sound in air is $330\ ms^{-1}$

Task: Use your knowledge of physics to:
(a) Determine if the sound from the speakers could damage their ears.
(b) Explain what causes the distortion of the sound and how it can be reduced.
(c) Help the owner of the hall understand why laser lights are preferred over electric bulbs.

ITEM 4:
A war broke out in a mountainous area surrounded by small bodies of water. The soldiers communicated by throwing stones into the water to warn each other about danger ahead. Unfortunately, this method also alerted their enemies. One of the soldiers had small plane mirrors and a torn paper box in his bag. The leader sent spies to look behind the hills to see if the enemy was hiding there, but many spies were captured and killed. The soldiers didn't know how to solve this problem. The enemy troops had a radio call that was used for communication and wave forms of wave length were produced on the receiver's computer clearly indicating the amplitude, period and time taken for the wave to reach the receiver at the headquarter. One afternoon, it threatened to rain and bright colours of different kind spread in the skies. This scared the soldiers even more.