



Senior 3 General Science (New curriculum)

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Senior 3

Term 3

THEME: SCIENCE AND TECHNOLOGY

TOPIC 7: LINEAR AND NON-LINEAR MOTION

Competency: The learner should be able to use the data from measuring distances to calculate the speed and velocity of moving objects in daily life.



Linear motion

Deals with motion in a straight line

Terminologies

Distance(x) is the length between two points.

The SI unit is meters (m)

Displacement(x) is the length between two points in a specified direction.

The SI unit is meters (m)

Scalar and vector quantities

Scalar quantities are physical quantities that have **magnitude only**, but no direction, e.g. time, length, temperature, distance, speed etc.

Vector quantities are physical quantities that have **both magnitude and direction** e.g. force, velocity, displacement, momentum, acceleration etc.

Differences between distance and displacement

Distance	Displacement
It is the length between two points.	It is the length between two points in a specified direction.
Is a scalar quantity.	Is a vector quantity.

Speed

Speed is the rate of change of distance.

It is a scalar quantity because it has only magnitude but no direction

$$\begin{aligned}\text{Speed} &= \frac{\text{Distance(m)}}{\text{Time(s)}} \\ &= \frac{\text{m}}{\text{s}} = \text{ms}^{-1}\end{aligned}$$

∴ the SI unit of speed is **ms⁻¹**.

Other units include: **cms⁻¹**, **kmh⁻¹**, etc.

Changing cms⁻¹ to ms⁻¹

$$1\text{cm} = \frac{1\text{m}}{100}$$

$$\text{But } 1\text{cms}^{-1} = \frac{1\text{cm}}{1\text{s}} = \frac{1\text{m}}{100} \times 1\text{s}^{-1}.$$

$$\text{So } 1\text{cms}^{-1} = \frac{1}{100} \text{ms}^{-1}$$

Example: Change 800cms⁻¹ to ms⁻¹

$$800\text{cms}^{-1} = \frac{800}{100} = 8\text{ms}^{-1}$$

Changing kmh^{-1} to ms^{-1}

$$1\text{ kmh}^{-1} = \frac{1\text{km}}{1\text{h}} = \frac{1000\text{m}}{(60 \times 60)\text{s}} = \frac{1000}{3600} \text{ms}^{-1}$$

Example 1

Change 72kmh^{-1} to ms^{-1}

$$1\text{ kmh}^{-1} = \frac{1000}{3600} \text{ms}^{-1}$$

$$72\text{ kmh}^{-1} = 72 \times \frac{1000}{3600} \text{ms}^{-1} = 20\text{ms}^{-1}$$

Note: If the distance which a body covers is not the same at every interval of time then the term average speed is applied.

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

Example 2

Find the average speed of the car which travels 400m in 80s.

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Time taken}} = \frac{400\text{m}}{80\text{s}} = 5\text{ms}^{-1}$$

Example 3

A car is moving along a straight road through towns **X**, **Y** and **Z**. If the car maintains an average speed of 50kmh^{-1} between town **X** and **Y** which are 0.6km apart and maintains 72kmh^{-1} between town **Y** and **Z** which are 0.9km apart find

(a) time taken for the car to move from town **X** to **Z**

(b) the average speed of the car in ms^{-1} between town **X** and **Z**

Solution

$$\text{Using Average speed} = \frac{\text{distance travelled}}{\text{Time taken}}$$

For X and Y	For Y and Z
Time taken = $\frac{0.6}{50} = 0.012\text{h}$	Time taken = $\frac{0.9}{72} = 0.0125\text{h}$

Total time for the car to move from **X** to **Z** = $0.012 + 0.0125 = 0.0245\text{s}$.

Total distance = $0.9 + 0.6 = 1.5\text{km}$

Using Average speed between X and Z = $\frac{\text{distance travelled}}{\text{Time taken}} = \frac{1.5\text{km}}{0.0245\text{h}} = 61.2\text{kmh}^{-1}$.

$$1\text{kmh}^{-1} = \frac{1000}{3600} \text{ms}^{-1}$$

$$61.2\text{kmh}^{-1} = 61.2 \times \frac{1000}{3600} \text{ms}^{-1} = 17\text{ms}^{-1}.$$

Exercise 7.1

Convert the following into units indicated brackets

(i) 40ms^{-2} (kmh^{-1}) [144ms^{-1}]

(iii) 90kmh^{-1} (ms^{-1}) [25ms^{-1}]

(i2) 5ms^{-1} (kmh^{-1}) [18ms^{-1}]

(iv) 120ms^{-1} (cms^{-1}) [12000cms^{-1}]

Velocity

It is the rate of change of displacement.

It is a vector quantity since it has both magnitude and direction

$$\text{Velocity} = \frac{\text{displacement(m)}}{\text{time taken(s)}}$$

The SI units of velocity is m/s or ms^{-1}

Velocity is a vector quantity

Difference between velocity and speed

Velocity	speed
is the rate of change of displacement.	is the rate of change of displacement
is a vector quantity.	is a scalar quantity.

Types of velocities

(a) Initial velocity “u” is the velocity with which a body starts motion in a given time interval.

Note:

1. For a body starting from rest, the initial velocity “u” must be zero i.e. $u = 0\text{ms}^{-1}$.
2. For anybody starting motion means that the body is starting from rest $u = 0\text{ms}^{-1}$
3. For a body travelling with a certain velocity, X, the initial velocity for such a body will be that certain velocity x so, $u = X$ e.g. A car travelling at 20ms^{-1} , has $u = 20\text{ms}^{-1}$.

(b) **Final velocity: “v”** is the velocity with which a body ends motion for a given time interval.

Note: If a body is brought to rest, then the final velocity is zero i.e., $v = 0\text{ms}^{-1}$.

The units of velocity must either be ms^{-1} or kmh^{-1} or cms^{-1} .

Acceleration (a) is the rate of change in velocity with time.

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

Change in Velocity = Final velocity (v) - Initial Velocity (u)

The S.I unit for change in velocity is **m/s** or **ms⁻¹**

Example 4

A car starts from rest and it accelerates to 10ms⁻¹. Calculate the change in Velocity.

$$u=0\text{ms}^{-1} \quad v=10\text{ms}^{-1}$$

$$\text{Change in velocity} = v - u = 10 - 0 = \mathbf{10\text{ms}^{-1}}.$$

Note: The Velocity to which a body is accelerated becomes the final velocity for that given time interval.

From the definition of acceleration,

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time taken}}.$$

The SI unit' of acceleration is m/s² or ms⁻²

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

OR

$$\mathbf{v = u + at.}$$

This is called the first equation of motion

Example 5

A body starts from rest and accelerated uniformly at 2ms⁻² for 3s. Calculate the final Velocity.

Solution

$$\begin{aligned} v &= u + at \\ &= 0 + 2 \times 3 \\ &= 6 \text{ m/s} \end{aligned}$$

Example 6

A body travelling at 10ms⁻¹ is accelerated uniformly for 3 second 5ms⁻². Calculate the Velocity at the end of 5 seconds.

Solution

$$\begin{aligned} v &= u + at \\ &= 10 + 3 \times 5 \\ &= 25 \text{ m/s} \end{aligned}$$

Average Velocity

$$\text{Average velocity} = \frac{\text{Final velocity} + \text{initial velocity}}{2}$$

$$\text{But } v = u + at$$

$$\text{Average velocity} = \frac{u + at + u}{2}$$

$$\text{Average velocity} = \frac{2u + at}{2} = \frac{2u}{2} + \frac{at}{2}$$

$$\text{Average velocity} = u + \frac{1}{2}at$$

The S.I unit is ms^{-1} .

Example 7

A body travelling at 20ms^{-1} is accelerated for 4s at 5ms^{-2} . Calculate the average velocity,

Solution

$$u = 20\text{ms}^{-1}, a = 5\text{ms}^{-2}$$

$$\begin{aligned}\text{Average velocity} &= u + \frac{1}{2}at \\ &= 20 + \left(\frac{1}{2} \times 5 \times 4\right) \\ &= 30\text{ms}^{-1}\end{aligned}$$

NB: A decelerating body has a negative acceleration since velocity is decreasing.

Example 8

A car travelling at 90km/h is uniformly brought to rest in 40 seconds. Calculate the acceleration.

$$u = 90\text{kmh}^{-1} \text{ to } \text{ms}^{-1}$$

$$1\text{kmh}^{-1} = \frac{1000}{3600}$$

$$90\text{kmh}^{-1} = \frac{1000}{3600} \times 90 = 25\text{ms}^{-1}$$

$$\text{From, } v = u + at$$

$$0 = 25 + 40a$$

$$a = -625\text{ms}^{-2} \text{ (negative sign means deceleration)}$$

Displacement: "s" is length moved in specified direction.

Displacement, s = Average velocity $\times$ time taken

$$\text{But average velocity} = u + \frac{1}{2}at$$

$$s = (u + \frac{1}{2}at) \times t$$

$s = ut + \frac{1}{2}at^2$: This is the 2nd equation of motion

This equation is mainly used when the question involves distance and time

Example 9

A body starts from rest and accelerates uniformly for 3s at 2m/s^2 . Calculate the total distance covered

$$\text{From, } s = ut + \frac{1}{2}at^2$$

$$u = 0, \quad a = 2\text{ms}^{-2}, \quad t = 3\text{s}$$

$$\begin{aligned} s &= 0 \times 3 + \frac{1}{2} \times 2 \times 3 \times 3 \\ &= 9\text{m} \end{aligned}$$

Calculations involving deceleration

When calculating problem involving deceleration: it should be remembered that the value of “a” should be negative

Example 10

A body moving at 40ms^{-1} decelerates uniformly for 20s at 3ms^{-2} . Calculate distance covered

$$u = 40\text{ms}^{-1}, \quad a = -3\text{ms}^{-2}, \quad t = 20\text{s}$$

$$\begin{aligned} s &= ut + \frac{1}{2}at^2 \\ &= 40 \times 20 - \frac{1}{2} \times 3 \times 20 \times 20 \\ &= 800 - 600 \\ &= 200\text{m} \end{aligned}$$

Example 11

A car traveling at 40ms^{-1} is uniformly decelerated to 25ms^{-1} for 5s. Calculate the total distance covered.

Solution

$$u = 40\text{ms}^{-1}, \quad v = 25\text{ms}^{-1}, \quad t = 5\text{s}$$

$$\text{From } v = u + at$$

$$25 = 40 + (a \times 5)$$

$$25 = 40 + 5a$$

$$a = -3\text{m/s}^2$$

$$\begin{aligned} s &= ut + \frac{1}{2}at \\ &= 40 \times 5 + \frac{1}{2} \times -3 \times 5 \times 5 \end{aligned}$$

$$= 200 - 37.5$$

$$= 162.5\text{m}$$

Third equation of motion

$$v^2 = u^2 + 2as$$

This equation is applied when time is not given and not required

Example 12

Calculate the final (maximum) velocity of a body travelling at 4ms^{-1} when it accelerates at 2ms^{-2} and covers a distance of 5m.

Solution

$$u = 4\text{ms}^{-1}, \quad a = 2\text{ms}^{-2}, \quad s = 5\text{m}$$

$$v^2 = u^2 + 2as$$

$$v^2 = 4^2 + 2 \times 2 \times 5$$

$$= \sqrt{36}$$

$$= 6\text{m/s}$$

Example 13

A body travelling at 90kmh^{-1} is retarded to rest at 20ms^{-2} . Calculate the distance covered.

Solution

$$u = 90\text{kmh}^{-1} \text{ to } \text{ms}^{-1}$$

$$1\text{kmh}^{-1} = \frac{1000}{3600} \text{ms}^{-1}$$

$$\therefore 90\text{kmh}^{-1} = 90 \times \frac{1000}{3600} = 25\text{ms}^{-1}$$

$$v^2 = u^2 + 2as$$

$$0^2 = 25^2 + 2 \times -20 \times s$$

$$s = 15.625$$

Uniform velocity

Is when the rate of change of displacement is constant.

Or

Uniform velocity is when displacement divided by time taken is constant

The S.I unit is ms^{-1} .

When a body moves with uniform velocity, initial velocity (u) must be equal to final velocity i.e., $V = u$. For instance, a car travelling with uniform velocity of 20ms^{-1} has $u = 20\text{ms}^{-1}$
When a body moves with uniform velocity, its acceleration is 0 i.e. $a=0$

Example 14

A car travelling with a uniform velocity of 20ms^{-1} for 6s. Calculate its acceleration.

Solution

$$u = 20\text{ms}^{-1}, t = 6\text{s}$$

$$v = u + at$$

$$20 = 20 + a \times 6$$

$$a = 0$$

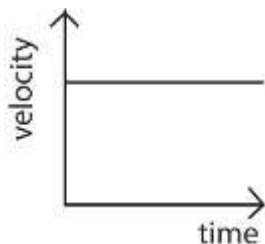
From the above example, it's noted that for a body moving with uniform velocity, its acceleration is 0 because the change in velocity becomes 0 as initial velocity is equal to final velocity.

Graphical presentation of uniform velocity

Uniform velocity can be represented on a 2 types of graphs

- (i) Velocity against time graph
- (ii) Distance against time

Velocity against time graph



Note: when a body maintains the same speed, it implies that it moves with uniform velocity.

Example 15

A car starts from rest and it accelerates uniformly for 5s at a rate of 4ms^{-2} . Calculate the final velocity.

Solution

$$u=0\text{ms}^{-1}, t=5\text{s}, a=4\text{ms}^{-2}, \quad v=?$$

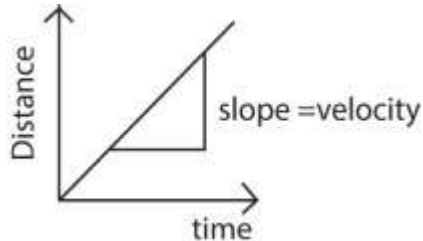
$$v=u + at$$

$$= 0 + 4 \times 5$$

$$=20\text{ms}^{-1}$$

The car then maintains the maximum speed for 6s. This implies that the maximum velocity of 20ms^{-1} becomes the uniform velocity for the 6s.

A distance time graph to for uniform velocity



Uniform acceleration

Uniform acceleration is when the rate of change in velocity with time is constant.

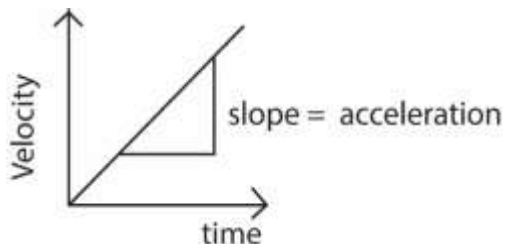
OR

Uniform acceleration is when the; change in velocity divided by time is constant.

When a body moves with uniform acceleration, the final velocity is not equal to initial velocity.

Uniform acceleration can be represented on velocity against time.

A velocity time graph for uniform acceleration



Example 16

A cyclist starts from rest and accelerates uniformly at 1m/s^2 for 20s.

Then maintains the maximum speed so reached for 1 minute and finally decelerates to rest uniformly for 10s. Draw a velocity against time graph for the motion of the body.

Solution

Stage1

$t=20\text{s}$

$u=0\text{m/s}$

Stage 2

$t=1\text{min}$

$1\text{min}=60\text{s}$

Stage3

$t=10\text{s}$

$u=20\text{m/s}$

$$a=1\text{m/s}^2$$

$$u = 20\text{m/s}$$

$$v=0\text{m/s}$$

$$v=???$$

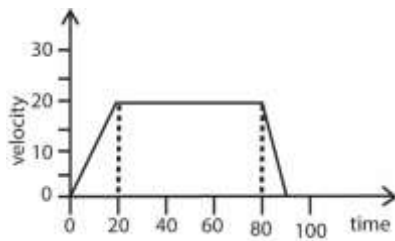
$$v = 20\text{m/s}$$

$$v=u+at$$

$$v=0+1 \times 20$$

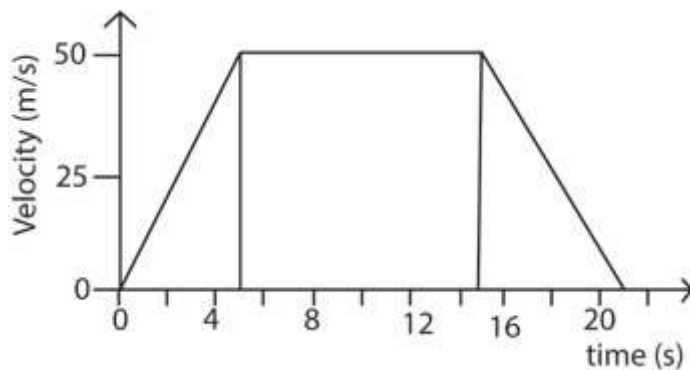
$$v=20\text{m/s}$$

A velocity against time graph



Example 17

Use the graph below to calculate the total distance covered.



Total distance= Area(C+B+S)

$$= \frac{1}{2} \times bh + lw + \frac{1}{2} \times bh$$

$$= \frac{1}{2} \times 5 \times 50 + 50 \times 10 + \frac{1}{2} \times 6 \times 50$$

$$= 125 + 500 + 150$$

$$= 775\text{m}$$

Exercise 7.2

1. (a) What do you understand by the following terms as applied to motion
 - (i) Uniform velocity
 - (ii) Uniform acceleration
- (a) The table below shows the variation of velocity with time for a body which has been thrown vertically upwards from the surface of the planet.

Velocity (ms ⁻¹)	8	6	4	2	0	-2
Time (s)	0	1	2	3	4	5

- (i) What does the negative velocity mean?
 - (ii) Plot a graph of velocity against time
 - (iii) Use the graph in (b)(i) to find the acceleration due to gravity on the planet [2ms⁻²]
 - (iv) If the body weighs 34N on earth, what is the planet? [6.8N]
2. (a) What is uniform acceleration?
(b) A car travelling at 20ms⁻¹ is accelerated for 10s at 2ms⁻². Calculate the total distance covered during this time. [300m]
3. (a) Define displacement.
(c) Two vehicles A and B accelerate uniformly from rest. Vehicle A attains maximum velocity of 30ms⁻¹ in 10s while vehicle B attains a maximum velocity of 40ms⁻¹ in the same time. Both vehicles maintain these velocities for 6seconds. They then decelerate such that A comes to rest after 6 seconds, while B comes to rest after 4s.
 - (i) Sketch on the same axes a velocity time graph of the vehicles
 - (ii) Calculate the velocity of each vehicle 18 seconds after the start. [20ms⁻¹]
 - (iii) How far will the two vehicles be from one another during this moment in (b)(ii) above. [120m]

Falling bodies

In a vacuum all bodies fall at the same rate. However in atmosphere different bodies fall at different rate because the air resistance is greater to light

Difference between acceleration and velocity

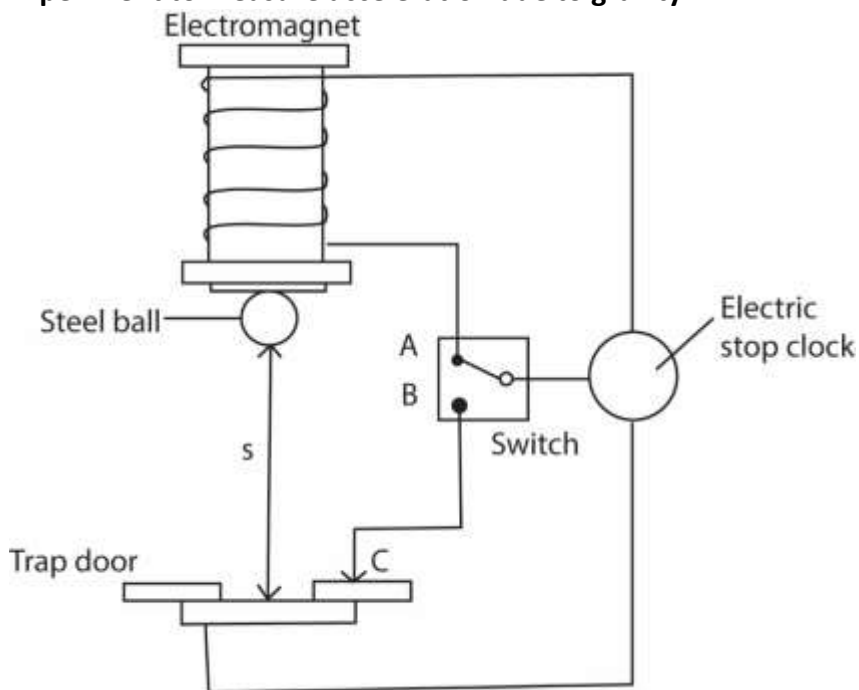
Velocity	Acceleration
(i) S.I unit is ms^{-1}	(i) SI unit is ms^{-2}
(ii) Is the rate of change of displacement	(ii) Is the rate of change of velocity with time

Acceleration due to gravity

Acceleration due to gravity is the rate change in velocity with time for a body falling freely under the force of gravity.

Or Acceleration due to gravity = $\frac{\text{change in velocity}}{\text{time taken}}$

Experiment to measure acceleration due to gravity



Procedure

- Switch is in position A, the electromagnet holds up the small steel ball.
- The switch is moved quickly to B; the electromagnet releases; the steel ball and the clock starts timing.
- When the ball hits the trap door, the circuit is disconnected and the stop clock stops

Given that the distance moved is, s , and time taken is t the

$$s = \frac{1}{2}gt^2$$

$$g = \frac{2s}{t^2}$$

Example 19

A small iron ball dropped from the top of a vertical cliff takes 2.5 seconds to reach the bottom of the cliff. Find

(i) the speed with which it strikes the bottom.

$$\text{From } V = u + gt$$

$$V = 0 + 10 \times 2.5 = 25\text{ms}^{-1}$$

(ii) the height of the cliff

$$\text{From } v^2 = u^2 + 2gs$$

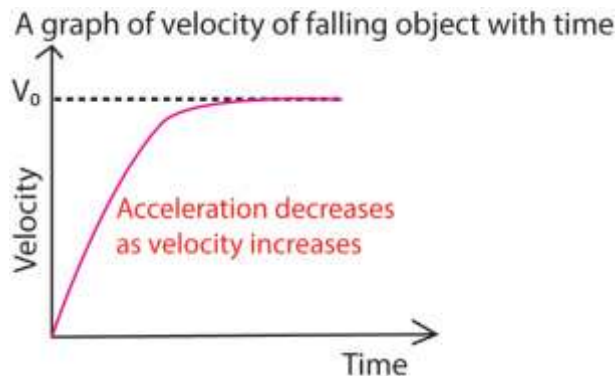
$$s = \frac{25^2}{2 \times 10} = 31.25\text{m}$$

Exercise 7.3

Describe a simple experiment to measure acceleration due to gravity.

Air resistance and motion

Air resistance—also known as *drag*—is a force that acts **opposite to the motion** of an object moving through air. It's a type of friction, and it plays a big role in how objects move, especially at higher speeds.



- As an object speeds up, **air resistance increases**. This is because the faster it moves, the more air particles it collides with.

- Eventually, a falling object may reach a point where the **force of air resistance equals the force of gravity** pulling it down. At this point, it stops accelerating and falls at a constant speed or **terminal velocity, V_0** .
- The **shape, size, and surface area** of an object affect how much air resistance it experiences. A flat sheet of paper falls slowly, while a crumpled one drops faster because it cuts through the air more easily.
- A heavier object attains a terminal velocity earlier than a lighter object.

Real-world examples:

- **Parachutes** use air resistance to slow a person's fall.
- **Cyclists** and race cars use streamlined shapes to reduce drag and move faster.
- **Skydivers** spread their limbs to increase air resistance and control their descent.

Momentum and mass

Momentum is the product of mass and velocity

The SI unit of momentum is kilogram meter per second (kgms^{-1})

Example 20

Calculate the momentum an object weighing 500g and moving at 72kmh^{-1} .

$$500\text{g} = \frac{500}{1000} = 0.5\text{kg}$$

$$72\text{kmh}^{-1} = \frac{72 \times 1000}{3600} = 20\text{ms}^{-1}$$

Momentum = mass x velocity

$$= 0.5 \times 20$$

$$= 10\text{kgms}^{-1}$$

Exercise 7.4

1. Calculate the momentum of

- (i) a man of 70kg running at a velocity of 5ms^{-1} [350kgms^{-1}]

- (ii) an elephant of mass 200kg running towards a hunter at speed of 6m/s. [1200kgms⁻¹]
2. At what speed would a 2.00×10^4 kg aircraft have to fly to have momentum of 1.60×10^9 mgms⁻¹. [80,000ms⁻¹]

Newton's laws of motion

Newton's first law of motion

Newton's First Law of Motion—also called the **Law of Inertia**—states:

An object at rest stays at rest, and an object in motion stays in motion at constant velocity, unless acted upon by an external force.

In simpler terms, things don't start moving, stop moving, or change direction all by themselves. Something has to cause that change.

Real-Life Applications of Newton's First Law:

- **Seatbelts in cars:** When a car suddenly stops, your body wants to keep moving forward due to inertia. Seatbelts apply the external force needed to stop you safely.
- **Tablecloth trick:** Pulling a tablecloth quickly from under dishes works because the dishes tend to stay at rest due to their inertia.
- **Roller coasters:** Once in motion, the cars keep moving along the track unless brakes or friction slow them down.
- **Elevators:** The smooth start and stop of an elevator rely on managing inertia to avoid sudden jerks.

Mass and inertia

Mass is a measure of how much matter an object contains. It's a **scalar quantity**, meaning it has magnitude but no direction, and it's measured in kilograms (kg). Mass doesn't change depending on location—whether on Earth, the Moon, or floating in space, the mass of an object stays the same.

Inertia is an object's **resistance to changes in its state of motion**. If something is at rest, it wants to stay at rest. If it's moving, it wants to keep moving in the same direction and speed—unless a force acts on it. This is the essence of Newton's First Law of Motion.

The Connection:

Mass is the **quantitative measure of inertia**. The more mass an object has, the more inertia it has. That means:

- A heavy truck is harder to start or stop than a bicycle.
- A bowling ball resists changes in motion more than a tennis ball.

So, in short: **mass tells us how much inertia an object has.**

Newton's second law of motion

Newton's Second Law of Motion explains how the motion of an object changes when a force is applied. It states:

The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

In simple terms: **Force = Mass × Acceleration, or $F = ma$.**

This means:

- If you apply more force to an object, it accelerates more.
- If the object is heavier (more mass), it accelerates less for the same force.

Real-Life Applications:

- **Pushing a shopping cart:** An empty cart accelerates more easily than a full one when pushed with the same force.
- **Kicking a ball:** A stronger kick (more force) makes the ball accelerate faster.
- **Car engines:** A more powerful engine applies more force, making the car accelerate quicker.
- **Rocket launches:** Rockets need massive force to overcome their huge mass and Earth's gravity.

Newton's third law of motion

Newton's Third Law of Motion states:

For every action, there is an equal and opposite reaction.

This means that whenever one object exerts a force on another, the second object exerts a force of the same magnitude but in the opposite direction on the first.

Real-Life Applications:

- **Walking:** When you push backward on the ground with your foot, the ground pushes you forward with equal force. That's what propels you ahead.
- **Swimming:** one pushes water backward with his arms and legs, and the water pushes him forward.
- **Rocket launch:** The rocket expels gas downward (action), and the gas pushes the rocket upward (reaction).
- **Jumping off a boat:** You push the boat backward, and it pushes you forward—causing the boat to drift away.
- **Recoil of a gun:** When a bullet is fired forward, the gun experiences a backward force, causing it to kick back.

This law is all about **interactions**—forces always come in pairs, and they act on different objects. It's the reason motion feels balanced and predictable, even in the most dynamic situations.

Principle of conservation of momentum

The **principle of conservation of momentum** states that:

> In a closed and isolated system, the total momentum before an interaction is equal to the total momentum after the interaction—provided no external forces act on it.

In simpler terms: **momentum is never lost or gained, only transferred.**

Real-life examples:

- **Collisions:** In car crashes or billiard ball hits, momentum is redistributed between objects.
- **Rocket propulsion:** As gases shoot out of the back, the rocket moves forward—momentum is conserved between the rocket and the exhaust.
- **Jumping off a boat:** You move forward, the boat moves backward—again, total momentum stays the same.

Types of collision

There are two types of collisions

1. Elastic Collision

- Both **momentum and kinetic energy are conserved**, i.e.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$\frac{1}{2}mu_1^2 + \frac{1}{2}mu_2^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2$$

- Objects bounce off each other without any lasting deformation or heat generation.
- Example: Two billiard balls striking each other.

2. Inelastic Collision

- Momentum is conserved**, but **kinetic energy is not**.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$\frac{1}{2}mu_1^2 + \frac{1}{2}mu_2^2 \neq \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2$$

- The objects **stick together** after impact.
- Some energy is lost as sound, heat, or deformation.
- Example: A lump of clay hitting and sticking to another lump.

Example 22

Two balls of mass 40kg and 20kg are travelling towards each other with velocities of 5ms^{-1} and 2ms^{-1} respectively. If after collision, the ball with mass 40kg travels at a velocity of 2ms^{-1} in the original direction, calculate the velocity of the second ball after collision. Identify the type of collision.

$m_1 = 40\text{kg}$, $m_2 = 20\text{kg}$, $u_1 = 5\text{ms}^{-1}$, $u_2 = -2\text{ms}^{-1}$ (negative because it is in opposite direction with u_1), $v_1 = 2\text{ms}^{-1}$ and $v_2 = ??$

By conservation of momentum

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$40 \times 5 + (20 \times -2) = 40 \times 2 + 20v_2$$

$$200 - 40 = 80 + 20v_1$$

$$20v_1 = 80$$

$$v_1 = 4\text{ms}^{-1}$$

Kinetic energy before and after collision

$$\begin{aligned}\text{Kinetic energy before collision} &= \frac{1}{2}mu_1^2 + \frac{1}{2}mu_2^2 \\ &= \frac{1}{2}40 \times 5^2 + \frac{1}{2}20 \times 2^2 \\ &= 540\text{J}\end{aligned}$$

$$\begin{aligned}\text{Kinetic energy after collision} &= \frac{1}{2}mv_1^2 + \frac{1}{2}mv_1^2 \\ &= \frac{1}{2}40 \times 2^2 + \frac{1}{2}20 \times 4^2 \\ &= 240\text{J}\end{aligned}$$

Since kinetic energy is not conserved, the collision is inelastic.

Exercise 7.5

1. A bullet of mass 300g travelling at a speed of 8ms^{-1} hits a body of mass 450g moving in the same direction as the bullet at 1.5ms^{-1} . The bullet and the body move together after collision. Find the loss in kinetic energy. [Ans. 3.8025J]
2. A body of mass 50kg travelling at velocity 5ms^{-1} collides with a body of mass 30kg which is at rest. If the bodies now join and move together, find
 - (i) Their common velocity [3.125ms^{-1}]
 - (ii) Kinetic energy after collision [390.625J]

A body of mass 80kg travelling at a velocity of 30ms^{-1} collides and stick to a body of mass 30kg travelling in opposite direction at a velocity of 40ms^{-1} . Find the common velocity after impact. [10.91ms^{-1}]

THEME: SCIENCE AND ENERGY

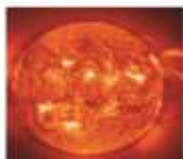
TOPIC: NATURE OF LIGHT, REFLECTION AND REFRACTION AT PLANE SURFACES

Competency: The learner understands the natural and artificial sources of light and how they behave.

LIGHT is a form of energy that enables us to see. An object is seen only when light from the object enters the eyes.

Sources of light

Natural sources of light



Sun



Stars



Volcanos



Lightning



Fire fly

Artificial sources of light



Candle



Lit Bulb



Fire



Kerosene lamp

Objects like sun, star, lamp etc. make their own light are called **luminous objects** while objects like moon that do not make their own light but reflect light from other sources to our eyes are called **nonluminous objects**.

Transmission of light

Light travels from its source to another place through vacuum or a medium.

The media of light include:

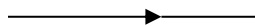
- (i) **Transparent Medium** is a substance that allows almost all the light to pass through it and objects are clearly seen through it. E.g. colourless water, paraffin, colourless glass.
- (ii) **Translucent medium** is one which allows some light to pass through it but objects are not clearly seen through it. E.g. cloudy liquid, frosted glass and oily paper.
- (iii) **Opaque medium** is one which does not allow light to pass through it at all.

Exercise 8.1

- (a) what is light?
- (b) state two sources of natural light and two sources of artificial light.
- (c) What is the meaning of transparent, translucent and opaque substances.

Rays and beams

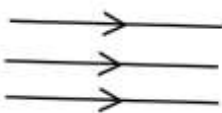
A ray is the direction of the path in which light travels. It is represented by a straight line with an arrow on it.



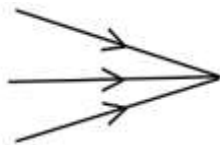
A beam is a collection of rays.

There are three kinds of beams:

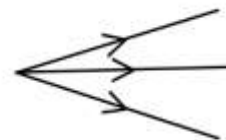
- (i) **Parallel beam.** is a collection of rays which do not meet at all.



(a) Parallel beam



(b) Converging beam



(c) Diverging beam

- (ii) **Convergent beam.**

Convergent beam is a collection of rays originating from different directions and ending up at the same point.

(iii) Divergent beam is a collection of rays which originate from one point and are spread out in different directions.

Rectilinear propagation of light

This is the property of light travelling in a straight-line when produced from a source. It is propagated (sent outward) and it travels in straight lines

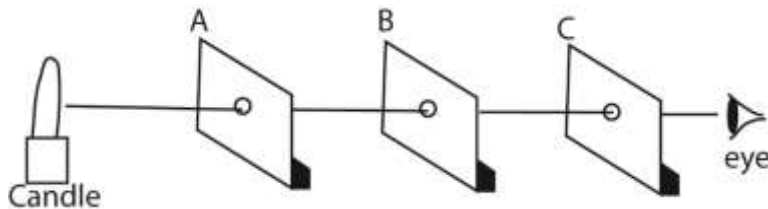
Exercise 8.2

Using diagrams, describe the following terms:

- (i) parallel beam
- (ii) Convergent beam
- (iii) divergent beam

Experiment to show that light travels in a straight line

Experiment I

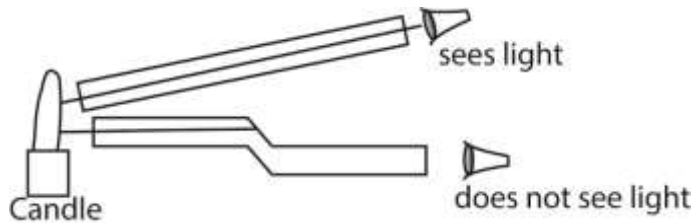


- (i) Equal square cards A,B and D are cut from piece of thick paper board each with a hole in the middle.
- (ii) When the card are arranged as shown above with their holes in a straight line light passes through and seen on the other end.
- (iii) If the middle card is displaced such that its hole is removed from the line, light is cut of from the other end

Conclusion: This shows that light travels in a straight line.

Experiment II

A candle light can be observed through a straight pipe but when the pipe is bent no light is seen



Experiment III

Formation of shadows and eclipses indicates that light travels in straight line.

Exercise 8.3

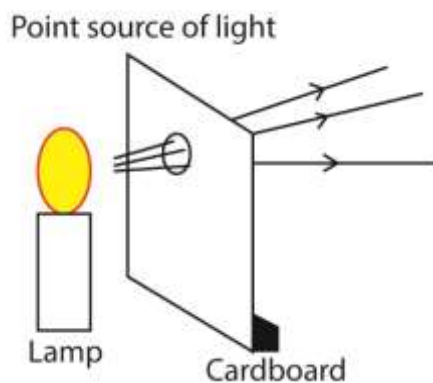
Describe an experiment to show that light travels in straight line.

Shadow

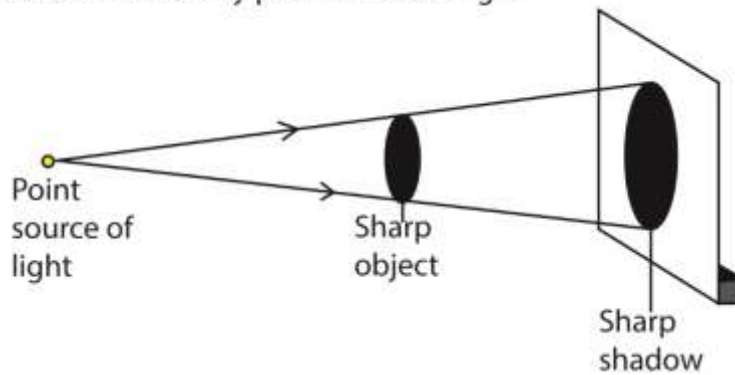
A shadow is formed when an object obstructs light. Shadows are formed because light travels in a straight line.

- (i) A Shadow is formed by a point source is equally sharp as shown below

A point source is a very small source of light. It can be obtained by placing a cardboard with a small hole in front of a lamp as shown.

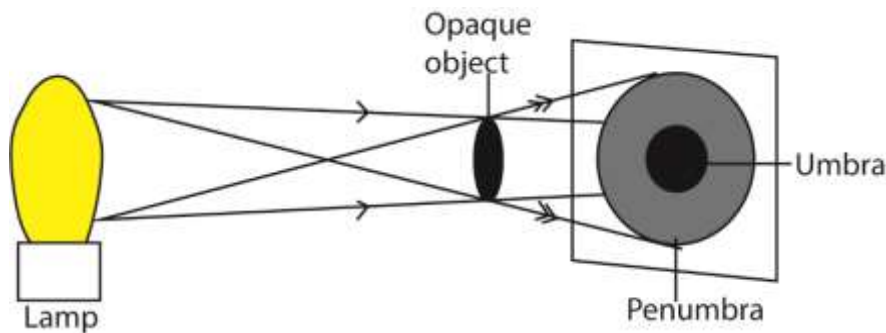


Shadow formed by point source of light



Note: For a point source, when the opaque object is moved near the source, the size of the shadow increases while when the object is moved near the screen, the size of the shadow decreases.

- (ii) A shadow produced by extended source of light has a dark patch (umbra) and a lighter outer patch (penumbra) as shown below



Umbra is a region of the shadow where no light reaches at all.

Penumbra is a region of the shadow where some light reaches.

Note that for an extended source, when the opaque object is moved near the source, then the size of the umbra decreases but the size of the penumbra increases. When the object is moved near the screen, the size of the umbra increases but the size of the penumbra decreases.

Eclipse

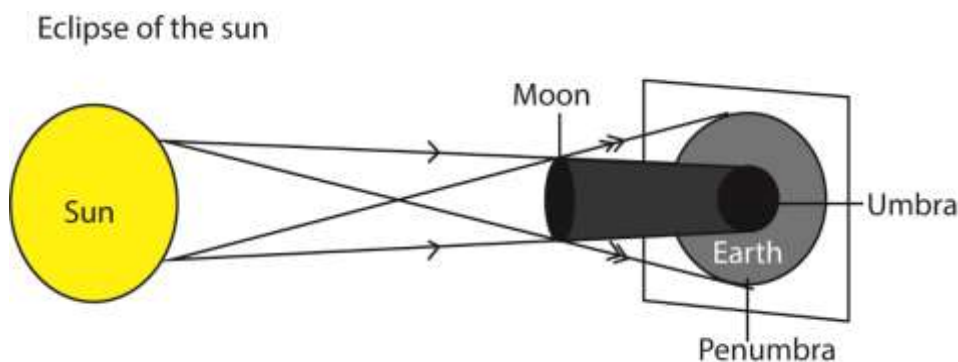
An eclipse occurs when the sun, moon and earth are in a straight line. There are three types of eclipses namely: solar, annular and lunar.

Solar eclipse

Solar eclipse also called eclipse of the sun occurs when the moon is between the sun and earth such that both umbra and penumbra reaches the earth.

The area on earth covered by the umbra has total eclipse and the sun cannot be seen at all.

The area covered by penumbra has partial eclipse and only part of the sun is seen.



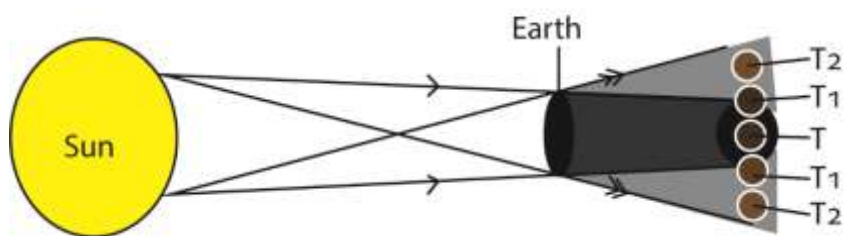
Lunar eclipse

Lunar eclipse is also called eclipse of the moon. Lunar occurs when the earth is between the sun and the moon.

During the eclipse of the moon the earth's shadow is cast on the moon such that when the moon is at position "T," total eclipse occurs, in position "T₁" partial eclipse occurs and when

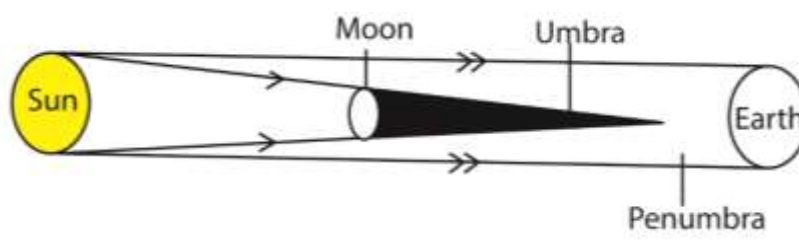
the moon is in position "T₂" no eclipse occurs but the moon is less bright than usual.

Eclipse of the moon



Annular eclipse

Annular eclipse of the sun occurs when the sun is very far from earth and the moon is between the earth and the sun such that umbra does not reach the earth but only penumbra reaches earth.



Note: Total eclipse of the moon lasts longer than total eclipse of the sun because for total eclipse of moon, the earth which is in the middle is larger than moon in the eclipse of the sun.

Exercise 8.4

Explain how

- (i) a shadow is formed
- (ii) eclipse of the moon is formed

Fluorescence and phosphorescence

Fluorescence is a substance, which absorbs energy and immediately releases the energy in the form of light.

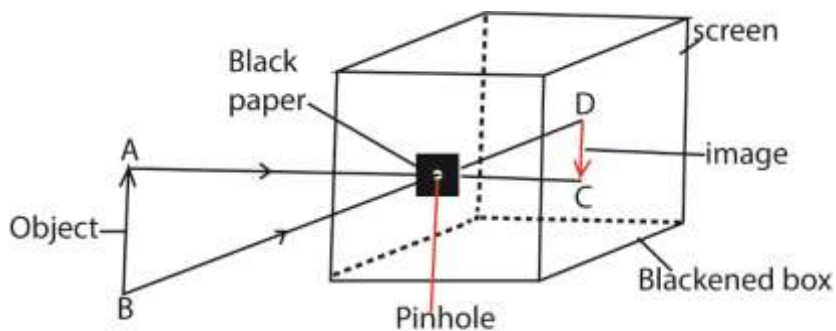
Example of such a substance is Zinc sulphide. The screen of a T.V and C.R.O are made of a fluorescent substance.

Phosphorescence is a substance which absorbs the energy falling on it, stores it, and when energy stops falling on it, it releases it in the form of light. An example of such a substance is calcium sulphide.

Pinhole camera

A pinhole camera works on the property of light travelling in a straight line.

A pinhole camera consists of a closed blackened box with a small hole on one face and a screen of tracing paper on the opposite face. The box of pinhole camera is blackened inside to prevent reflections inside the box.



Properties of images formed by pinhole camera

- (i) It is real i.e. it can be produced on the screen. It is formed by real rays of light reaching the screen.
- (ii) It is inverted

Factors affecting the properties of image formed by pinhole camera

- (i) When the distance between the object and the pin hole is reduced the image becomes bigger but less bright because the image is spread over a larger area and vice versa
- (ii) When the distance between the pin hole and screen is increase the image becomes bigger but becomes less bright because an image is spread over a bigger area. And vice versa

- (iii) When the pin hole is enlarged, the image becomes blurred but brighter because of too much light entering

Linear magnification

Linear magnification is the ratio of image size to object size.

Or: **Linear magnification** is the ratio of image distance to object distance.

$$\text{Magnification} = \frac{\text{magnification}}{\text{height of objects}} = \frac{CD}{AB}$$

$$\text{Magnification} = \frac{\text{distance of image from pinhole}}{\text{distance of object from pinhole}}$$

So larger magnification is obtained when the object is nearer the pin-hole and smaller magnification is produced when the object is farther away.

Example 1.

Calculate the height of a building 150m away from a pinhole camera which produces an image 5cm high if the distance between pin hole and screen is 10cm.

Object distance = 150m

Image height = 5cm = 0.05m

Image distance = 10cm = 0.1m

$$\text{Linear magnification} = \frac{\text{image height}}{\text{object height}} = \frac{\text{image distance}}{\text{object distance}}$$

$$= \frac{0.05}{h} = \frac{0.1}{150}$$

$$h=75\text{m}$$

Example 2

The length of a pin-hole camera is 25cm. An object 2m height is placed 10m from the pin-hole. Calculate the height of the image produced and its magnification.

Solution

$$\text{Image distance} = 25\text{cm} = 0.25\text{m}$$

$$\text{Object height} = 2\text{m}$$

$$\text{Object distance} = 10\text{m}$$

$$\text{Linear magnification} = \frac{\text{image height}}{\text{object height}} = \frac{\text{image distance}}{\text{object distance}}$$

$$\frac{\text{image height}}{2} = \frac{0.25}{10}$$

$$\text{Image height} = \frac{0.25}{10} \times 2$$

$$= 0.05\text{m} = 5\text{cm}$$

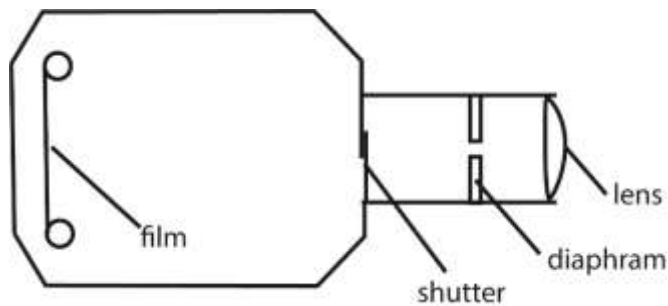
$$\text{Linear magnification} = \frac{\text{image distance}}{\text{object distance}} = \frac{0.25}{10}$$

$$= 0.025$$

Exercise 8.5

- (a) With aid of a diagram show how an image is formed by a pinhole camera
- (b) State the properties of an image formed by a pinhole camera
- (c) State the factors that determine the size of the image formed by pinhole camera

Lens camera



- ❖ The lens focused light from the object on to film
- ❖ The diaphragm controls the amount of light reaching the film
- ❖ The shutter controls the exposure time of light reaching the film

Differences between a pinhole camera and a lens camera

- ❖ in a pinhole camera the image is always focused while in a lens camera the image is brought to focus by adjusting the position of the lens.
- ❖ In pinhole camera the intensity of light entering is fixed while in a lens camera the intensity of light entering is controlled by a shutter or diaphragm.
- ❖ In a pinhole camera the image distance is fixed while in a lens camera the image distance is not fixed.

Differences between the lens of a camera and eye

- ❖ The distance between the lens and retina is fixed while that between the lens and film in camera is variable
- ❖ The focal length of the eye's lens is variable while that of a camera is fixed
- ❖ Eye lens is living while the camera lens is artificial

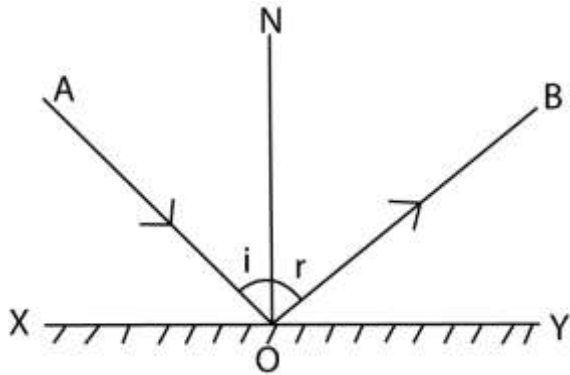
Exercise 8.6

Give differences between a lens camera and an eye.

Reflection of light

Reflection is the process by which light energy falling on a body or surface bounces off. The surface from which reflection occurs is called the reflecting surface.

Types of rays



Incident ray (AO) is a ray of light from source of light falling on to the reflecting surface.

Reflected ray (OB) is a ray of light which has been bounced off from the reflecting surface.

Normal (ON) is one which is at 90° with the reflecting surface. So this is incident and reflected along the same path

Angle of reflection (r) is the angle made by the reflected ray with the normal at the point of incidence on the reflecting surface.

Angle of Incidence (i) is the angle made by the incident ray with the normal at the point of incidence on the reflecting surface.

The laws of reflection

First law of reflection states that the incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane.

Second law of reflection states that the angle of incidence is equal to angle of reflection.

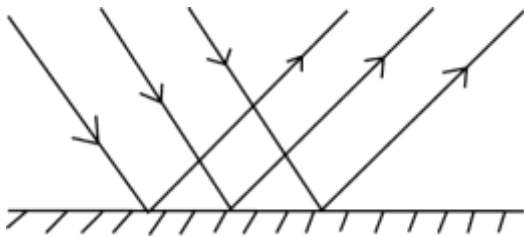
Types of reflection

There are two types of reflection namely:

- ❖ Regular reflection.
- ❖ Irregular reflection.

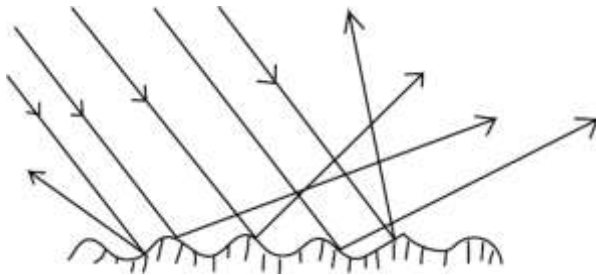
Regular reflection

Regular reflection occurs when a parallel incident beam strikes a smooth reflecting surface and a parallel reflected beam is obtained. Example of smooth plane surface is a plane mirror.



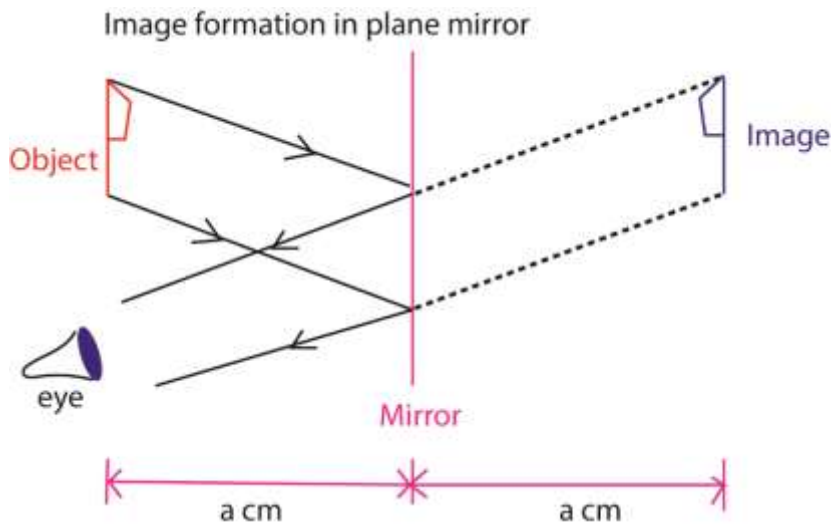
Irregular or diffused reflection

Diffuse reflection occurs when a parallel incident beam strikes a rough surface and a scattered reflected beam is obtained.



The images formed by a plane mirror

An image in a plane mirror is formed by reflection of light as shown below



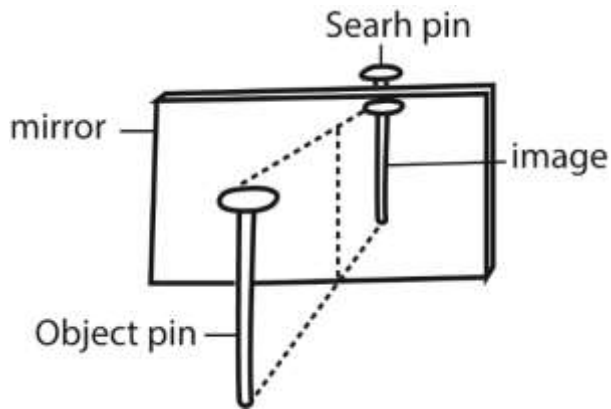
Properties of image formed by a plane mirror

- (i) It is **virtual**, i.e. it cannot be produced on the screen and is formed by imaginary rays.
- (ii) It is **Lateral inverted**, i.e., the right of the object is the left of the image and the left of the object is the right of the image
- (iii) Same size as the object
- (iv) Same distance from the mirror as the object
- (v) It is erect

Note: The linear magnification produced by a plane mirror is **1** since Image distance from the mirror is equal to object distance from the mirror. And the image size is equal to the object size.

Formation of image by no parallax in plane mirror

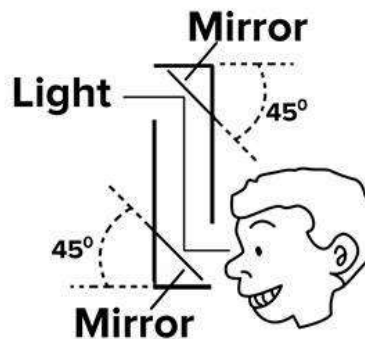
- (i) Obtain a sheet of paper and draw a mirror line.
- (ii) Place the mirror on the line as shown.
- (iii) Place the pin at least 5 cm from the mirror and obtain another pin (search pin)
- (iv) Move the search pin behind the mirror to locate the position of the image where there is **no parallax** and place your second pin.



Exercise 8.7

Give properties of images formed by plane mirrors.

The periscope



A **periscope** is an optical instrument used to observe objects from a concealed position, typically over or around obstacles. It operates on the principle of **light reflection**, using mirrors or prisms placed at **45-degree angles** to redirect light to the observer.

Uses of a Periscope

- **Submarines:** Allows sailors to see above water while remaining submerged.
- **Military applications:** Used in trenches and armored vehicles for surveillance.
- **Science and industry:** Helps monitor hazardous environments like nuclear reactors.
- **Tanks and armored vehicles:** Enables soldiers to view surroundings without exposure.
- **Observation towers:** Used in security and wildlife monitoring.

Exercise 8.8

1. (a) with the aid of a diagram, explain the laws of reflection of light.
(b) State three application of reflection of light.
2. With aid of a diagram explain how solar eclipse forms
3. Mention the properties of images formed by the pinhole camera.
4. Distinguish between natural and artificial sources of light giving two examples of each.
5. Using a diagram explain the properties of a shadow formed from extended source of light

Refraction of light

Refraction of light is the bending of light rays when they pass from one medium to another of different density (e.g., air to water, or glass to air). This happens because the speed of light changes in different media.

Causes

Light travels faster in less dense media (air) and slower in denser media (water, glass).

The change in speed causes bending toward or away from the normal line.

Applications of Refraction

- (i) **Lenses** → Used in spectacles, microscopes, telescopes, and cameras.
- (ii) **Prisms** → Split white light into its spectrum (rainbow colors).
- (iii) **Mirages** → Optical illusion in deserts caused by refraction of light through hot air layers.
- (iv) **Vision correction** → Glasses and contact lenses bend light to focus properly on the retina.
- (v) **Underwater objects** → Appear closer or displaced due to bending of light.

Summary Table

Aspect	Explanation
Definition	Bending of light when changing medium
Cause	Change in speed of light
Examples	Lenses, prisms, mirages, vision correction
Effect	Objects appear displaced or magnified

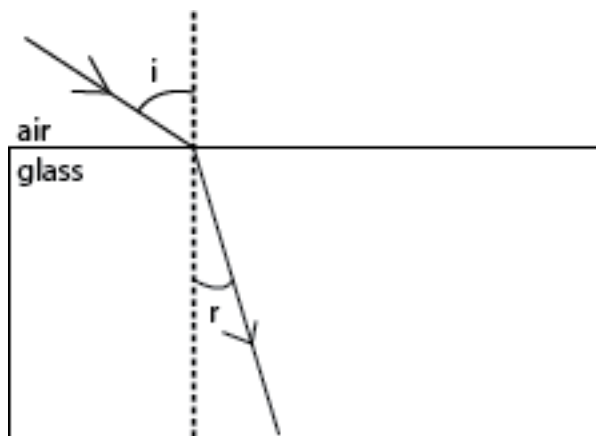
Everyday Insight

- ❖ A stick dipped in water looks **bent or broken** because of refraction.
- ❖ Rainbows form when sunlight is refracted and dispersed in water droplets.
- ❖ Fishermen see fish at a different position than they actually are due to refraction in water.

Key Insight: Refraction explains many natural phenomena and is the foundation of optical instruments. It shows how light's speed and direction are influenced by the medium it travels through.

The laws of refraction of light

Consider refraction of light at the interface between air and glass below



First Law of Refraction

The **incident ray**, the **refracted ray**, and the **normal** at the point of incidence all lie in the same plane.

Second Law of Refraction (Snell's Law)

States that: $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$

Where:

- i = angle of incidence
- r = angle of refraction
- v_1, v_2 = speeds of light in the two media
- n_1, n_2 = refractive indices of the two media
- **Meaning:** Light bends **towards the normal** when entering a denser medium (e.g., air $\rightarrow$ glass), and **away from the normal** when entering a rarer medium (e.g., glass $\rightarrow$ air).

Exercise 8.9

State the laws of refraction of light

THEME: SCIENCE AND ENVIRONMENT

TOPIC 9: ECOSYSTEM

Competency: The learner understands how living and non-living organisms relate to one another and the impact of human activities on the climate and environment



Ecology

Ecology is the branch of biology that studies the relationships between living organisms and their environment. It explains how plants, animals, and humans interact with each other and with physical factors like air, water, and soil.

Levels of Ecology

- ❖ **Organism** → Study of individual species and their adaptations.
- ❖ **Population** → Group of organisms of the same species in a given area.
- ❖ **Community** → Different populations interacting in one area.
- ❖ **Ecosystem** → Interaction of living organisms with abiotic factors (soil, water, climate).
- ❖ **Biosphere** → Global ecological system integrating all living beings and their environments.

Importance of Ecology

- (i) Helps in **conservation of biodiversity**.
- (ii) Guides **sustainable use of resources**.
- (iii) Explains **climate change impacts**.
- (iv) Supports **agriculture and forestry**.
- (v) Promotes **environmental awareness**.

Summary Table

Aspect	Explanation
Definition	Study of organisms and environment
Levels	Organism, population, community, ecosystem, biosphere
Importance	Conservation, sustainability, climate awareness

Everyday Insight

In Uganda, ecology is vital for managing **forests, wetlands, and wildlife**. It helps balance human needs (agriculture, settlement) with conservation of species like gorillas, elephants, and fish in Lake Victoria.

Key Insight: Ecology teaches us that **life is interconnected** — protecting the environment means protecting ourselves.

Exercise 9.1

- (a) What is ecology?
- (b) Give the importance of studying ecology.

Key ecological terms

(i) Habitat

The **natural home or environment** where an organism lives.

Example: A fish's habitat is water; a lion's habitat is the savanna.

(ii) Niche

The **role or function** of an organism in its ecosystem.

Includes how it gets food, interacts with other species, and survives.

Example: Bees' niche is pollination and honey production.

(iii) **Population**

A group of organisms of the **same species** living in a given area.

Example: All zebras in Queen Elizabeth National Park form a population.

(iv) **Community**

All the **different populations** living together in one area.

Example: Lions, zebras, elephants, and plants in a savanna form a community.

(v) **Producers**

Organisms that **make their own food** through photosynthesis.

Example: Green plants, algae.

They form the base of the food chain.

(vi) **Consumers**

Organisms that **depend on others for food**.

Types:

- **Primary consumers:** Herbivores (e.g., cows, rabbits).
- **Secondary consumers:** Carnivores (e.g., lions).
- **Tertiary consumers:** Top predators (e.g., eagles).

(vii) **Decomposers**

Organisms that **break down dead matter** into nutrients.

Example: Fungi, bacteria, earthworms.

They recycle nutrients back into the soil for producers.

Everyday Insight

In Uganda, wetlands provide a **habitat** for fish, birds, and insects. Communities of organisms interact — plants as **producers**, fish as **consumers**, and bacteria as **decomposers** — maintaining ecological balance.

Key Insight: These terms show how life is interconnected. **Habitats provide space, niches define roles, populations and communities form networks, and producers, consumers, and decomposers sustain the cycle of life.**

Exercise 9.2

Give the meanings of the following terms in ecology

- (i) Habitat
- (ii) Niche
- (iii) Population
- (iv) Community
- (v) ecosystem

Ecosystems

An **ecosystem** is a natural unit made up of living organisms (plants, animals, microorganisms) interacting with each other and with non-living components (air, water, soil, climate) in a balanced way. It shows how energy flows and nutrients cycle in nature.

Definition

An ecosystem is the **interaction between biotic (living) and abiotic (non-living) components** in a given environment.

Components of an Ecosystem

Biotic (Living)

- **Producers:** Plants and algae that make food through photosynthesis.
- **Consumers:** Animals that eat plants or other animals.
- **Decomposers:** Fungi and bacteria that recycle nutrients.

Abiotic (Non-living)

- **Climate:** Temperature, rainfall, sunlight.
- **Soil:** Provides minerals and support for plants.
- **Water:** Essential for all life.
- **Air:** Supplies oxygen and carbon dioxide.

Types of Ecosystems

- (i) **Terrestrial:** Forests, grasslands, deserts.
- (ii) **Aquatic:** Freshwater (lakes, rivers) and marine (oceans, seas).
- (iii) **Artificial:** Man-made systems like farms, aquariums, and gardens.

Functions of Ecosystems

- (i) **Energy flow:** Sunlight → producers → consumers → decomposers.
- (ii) **Nutrient cycling:** Recycling of carbon, nitrogen, and water.
- (iii) **Habitat provision:** Ecosystems provide homes for organisms.
- (iv) **Climate regulation:** Forests and oceans influence rainfall and temperature.

Exercise 9.3

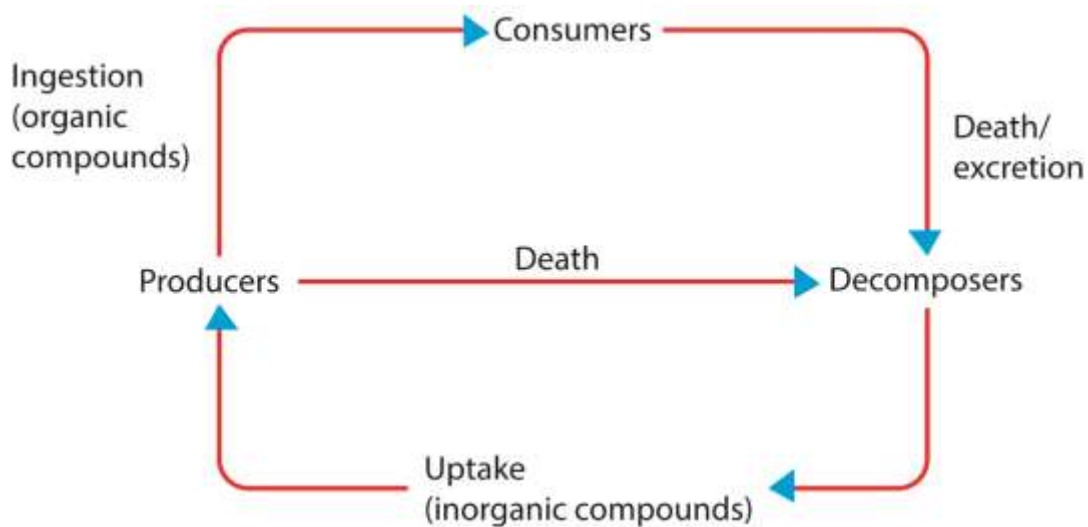
- (a) What is an ecosystem?
- (b) State the composition of an ecosystem.
- (c) Suggest the functions of an ecosystem.

Cycling of matter

In almost all ecosystem, the organisms fall into three nutritional groups.

- producers
- Consumers
- Decomposers

These are related as follows;



Organic material synthesized by the **producers** are eaten and assimilated by the **consumers**, All the organic materials incorporated into the bodies of the **Producers and consumers** are eventually broken down into inorganic materials. These are then rebuilt into organic compound by the synthesis activity of the producers.

Energy flow in an ecosystem

Unlike nutrient recycling in ecosystem energy flows in one direction from the sun, to the produces, to consumers and finally lost as heat to the environment.

Food Chain

A food chain is a sequence of organisms with arrows pointing from organisms being eaten to organism that eats it.

Example of food chain

Grass → Grasshopper → Chicken → Man

Each stage of the food chain is known as a **trophic level**, the first trophic level being occupied by the **autotrophic organisms**, the primary producers. The organisms of the second trophic level are called **primary consumer**, those of the third level are **secondary consumer** and so on.

Exercise 9.4

Construct three more food chains around your school

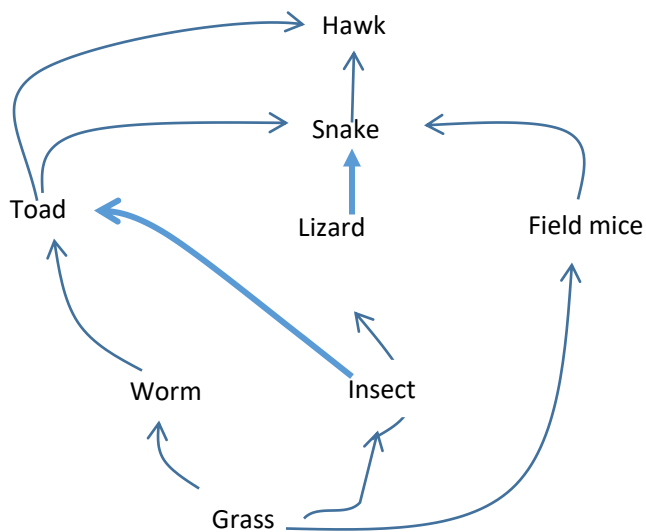
Significance:

- (i) Explains direct feeding relationships.
- (ii) Shows energy transfer step by step.
- (iii) Useful for simple ecosystems.

Food webs

Is feeding relationship showing organisms feeding on more than one organisms.

Example of a food web



Exercise 9.5

Construct a food web in a freshwater ecosystem.

Significance:

- (i) Shows complex interactions.
- (ii) Provides stability — if one species declines, others can fill the gap.
- (iii) Reflects biodiversity and resilience of ecosystems.

Associations in biological communities



Organisms in an ecosystem interact with each other in a variety of ways. These include competition, predation, symbiosis, parasitism, mutualism and commensalism.

Competitions

In an ecosystem, organisms compete because the environmental resources such food, shelter, water, light and nutrients are limited.

Types of competition

- (i) **Intraspecific competition** is a type of competition among individuals of the same species such those between zebras. Organisms of the same species may compete for food, shelter, mates and space.
- (ii) **Interspecific competition** is a type of competition among individuals of the different species such those between zebras and buffaloes. Organisms of the different species may compete for food, shelter and space but not mates.

Predation

This relationship in which one organism lives the other dies instantly. For example lion the predator kills the zebra (prey) instantly.

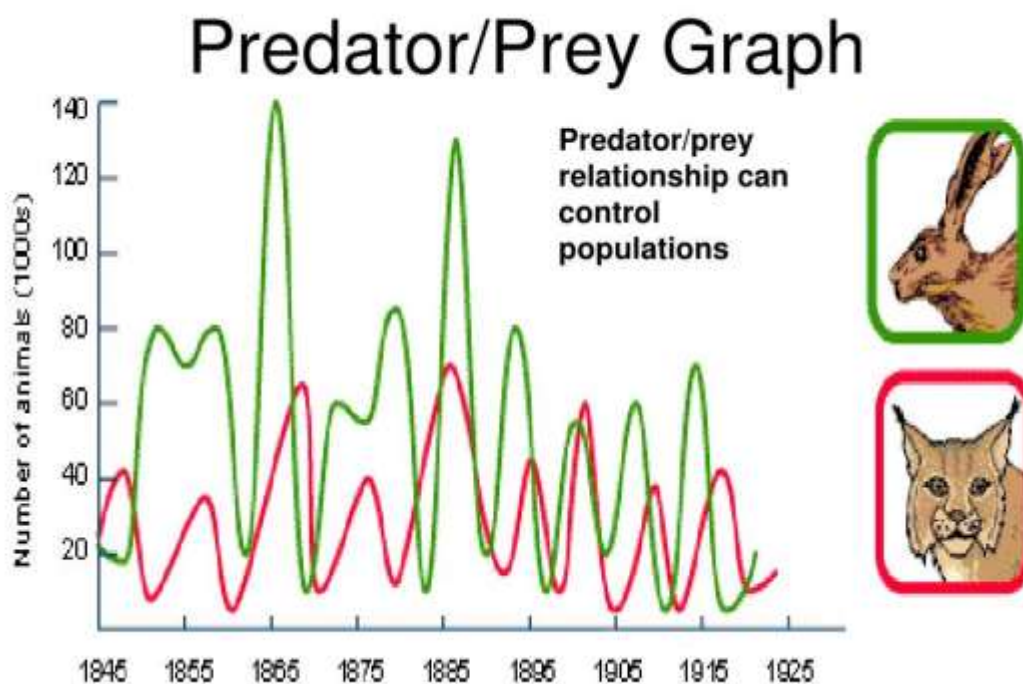


A **predator** is an organism that hunts and kills another of different species for food.

A **prey** is an organism killed by another of different species for food.

Description of predator – prey relationship

The number of predators and prey often fluctuate in cycles. When prey populations increase, predator numbers may rise, but if prey decline, predators may struggle to find food and die off as illustrated in the graph below



Adaptations of predators to catch the prey

Physical Adaptations

- (i) **Sharp Teeth & Claws** – Carnivores like lions, wolves, and eagles have strong jaws and sharp claws to grasp and kill prey.
- (ii) **Camouflage** – Some predators, like tigers and polar bears, blend into their environment to ambush prey unnoticed.
- (iii) **Powerful Muscles & Speed** – Cheetahs, for example, have specialized muscles for explosive speed to chase down prey.
- (iv) **Venom & Toxins** – Snakes, spiders, and some marine creatures like jellyfish inject venom to immobilize their prey.
- (v) **Keen Senses** – Owls have exceptional night vision, sharks detect vibrations in water, and wolves use their acute sense of smell to locate prey.

Behavioral Adaptations

- (i) **Pack Hunting** – Wolves, lions, and wild dogs hunt in groups to overwhelm larger prey.
- (ii) **Ambush Hunting** – Crocodiles and leopards lie in wait, using patience and stealth to launch surprise attacks.
- (iii) **Luring Techniques** – Some predators, like anglerfish, use bioluminescent "bait" to attract unsuspecting prey.
- (iv) **Trap Setting** – Spiders weave webs to capture insects, while pitcher plants use modified leaves to trap prey.

Adaptations of prey to avoid predators

Physical Defenses

- (i) **Camouflage** – Many animals blend into their surroundings to avoid detection. Examples include chameleons, leaf insects, and Arctic foxes in snowy environments.
- (ii) **Mimicry** – Some species imitate dangerous or toxic organisms to deter predators, such as harmless butterflies resembling poisonous species.
- (iii) **Protective Structures** – Armored bodies, spikes, and tough shells help prevent attacks. Examples include porcupines, pangolins, and tortoises.

Behavioral Strategies

- (i) **Speed & Agility** – Many prey animals, like gazelles and rabbits, rely on quick movements to escape from predators.
- (ii) **Herding & Flocking** – Group behavior helps animals avoid predators through confusion and collective defense, seen in zebras, fish schools, and bird flocks.
- (iii) **Playing Dead** – Some animals, like opossums, pretend to be lifeless to discourage predators that prefer live prey.

Exercise 9.7

- (a) Explain the meanings of a predator and prey
- (b) Give five adaptations of predators and five adaptations of the preys.

Chemical & Sensory Defenses

- **Venom & Toxins** – Some prey species release toxic chemicals or venom to repel attackers, like poison dart frogs and skunks.
- **Emitting Sounds** – Some animals, such as warning calls in meerkats or ultrasonic distress signals in insects, communicate danger to deter predators.
- **Bad Tasting or Smelly Secretions** – Certain prey, like millipedes and sea cucumbers, produce foul-tasting or stinky substances to avoid being eaten.

Mutualism

Examples of mutualism associations



Mutualism is an association between two organism of different species in which both organisms benefit. Sometimes both organisms become so dependent on each other that they are unable to survive independently. Examples of mutualism associations are nitrogen-fixing bacteria in legumes, lichen and mycorrhiza.

- (i) The nitrogen-fixing bacteria (*Rhizobium*) are found in the root nodules of leguminous plants. In this association, the *Rhizobium* obtain food, shelter and protection from leguminous plant while plant get nitrates fixed by bacteria.
- (ii) Bacteria and protozoa in the rumen of ruminant animals: These microorganisms secrete cellulose digesting enzyme that breakdown cellulose to glucose in the rumen of ruminant. In return, the micro-organisms get shelter and also use part of the digested food in the rumen.

- (iii) **Mycorrhiza** refers to the symbiotic association between fungi and plant roots, benefiting both organisms. The fungi help the plants absorb nutrients, especially phosphorus, while the plants provide carbohydrates to the fungi.
- (iv) **Lichen** is an association between algae and fungi. In this association, the fungi depends on oxygen and carbohydrates produced by algae during photosynthesis. On the other hand, the algal gets water, carbon dioxide, mineral salt and protection from dessication, from the fungi

Exercise 9.8

Using any three examples, explain the meaning of mutualism.

Commensalism

Examples commensalism



Barnacles on Whales



Epiphytic Plant on Tree



Nest on a tree



Cattle Egrets & cows

This is a relationship between two organisms. One of the two organisms, the commensal benefits from the association, while the other organism usually the larger partner, neither lose nor gain. Examples of commensalism include

Barnacles on Whales – Barnacles attach to the skin of whales, gaining transportation and access to nutrient-rich waters, while the whale remains unaffected.

Epiphytic Plants & Trees – Some plants, like orchids and bromeliads, grow on trees for support and access to sunlight without taking nutrients from the tree.

Birds Nesting in Trees – Birds build nests in tree branches for shelter, but the tree itself experiences no harm or benefit.

Cattle Egrets & Livestock – Egrets follow grazing cattle, feeding on insects stirred up by the animals' movements without affecting the cattle.

Parasitism

A parasite is an organism that lives on or in another organism from which feed. A parasite which lives on the surface of its host is called an **ecto-parasite** and that lives inside it's called an **endoparasite**. Most species, including human, harbor parasites that reduce their health and may cause death.

Challenges faced by a parasite

- (i) Locating a new host
- (ii) Overcoming host rejection
- (iii) Entering a host

Parasitic adaptations

Parasite show many different adaptations of overcoming these challenges, depending on whether they are ecto-parasites (e.g. tick) or endo-parasites (tapeworm).

- (i) Many endoparasites show degeneration, or even total loss of certain organs which reduces their energy and material requirements and hence a reduced burden on their host. For example, gut parasites like the tapeworms lack an alimentary canal.
- (ii) Many parasites especially ecto-parasites have attachment devices such as sucker, hooks or anchors enabling them to cling to the host. Tapeworm has hooks and suckers to anchor on host digestive canal.
- (iii) Some parasites have penetrative devices for gaining entrance into the host and its cells. For example, miracidum larva of the liver fluke, has a slender tip on to which open a group of glands which secrete tissue- digesting enzymes. By softening the tissue, the enzyme enables the larva to bore into the foot of a freshwater snail the intermediate host.
- (iv) Gut parasite live in a particularly hazardous environment. They typically have protective device which protects their being harmed by the host's digestive processes. These devices include the possession of a thick protective cuticle, the secretion of large quantities of mucus and the production of inhibitory substances which locally inactivate the host's digestive enzymes.
- (v) To protect themselves from the host's immune system, some parasites such as the blood fluke, schistosoma, that cause, bilharzia, synthesizes chemicals, which switch

of the host's immune system; The parasite coat's itself with molecules which the host recognizes as self.

- (vi) Parasite overcome a problem of moving from one host to another by a number of strategies, one of which is to wait until the host mates. The various organism responsible for sexually transmitted diseases in human spread in the same manner
- (vii) Many parasites employ a secondary or intermediate host which conveys the parasite from one primary host to another. Thus, the Anopheles mosquito transfers the malaria parasites from one person to another.
- (viii) To raise the probability of success vast number of offspring are produced
- (ix) The parasites may have a dormant resistant stage in its life cycle to survive adverse conditions until a suitable host is found.
- (x) Some parasites are closely linked with their host that their tissue are actually interconnected.
E.g., certain plant parasites such as mistletoes plug into other plants and tap off nutrients from the host's tissue.

Importance of parasites

Parasites might have a bad reputation, but they play crucial roles in ecosystems and even benefit human health in some ways. Here's why parasites are important:

Ecological Balance

- **Regulate Populations** – Parasites help control host populations, preventing species from becoming overly dominant.
- **Increase Biodiversity** – By influencing food chains and predator-prey interactions, parasites contribute to greater ecosystem diversity.
- **Drive Evolution** – Host species develop adaptations to resist parasites, leading to evolutionary changes and stronger immune systems.

Medical & Scientific Benefits

- **Potential Treatments** – Some parasites, like hookworms, are studied for their ability to modulate the immune system and could help treat allergies and autoimmune diseases.

- **Research in Disease Control** – Parasites help scientists understand disease transmission, aiding in the fight against malaria, sleeping sickness, and other illnesses.
- **Diseases:** Some parasites cause diseases for example malaria, bilharzia, nagana and sleeping sickness.

Environmental Role

- **Decomposers & Nutrient Cycling** – Some parasites contribute to breaking down dead material, playing a role in nutrient recycling.
- **Indicators of Ecosystem Health** – The presence or absence of certain parasites can signal environmental changes, helping scientists monitor ecological health.

Exercise 9.9

1. Match the associations with their correct meaning using line

Parasitism is an intimate association or relationship between two or more organisms of different species

Commensalism is an association between two organisms of different species in which both organisms benefit

Mutualism is a relationship between organisms of different species in which one benefits and the other organism neither benefits or is harmed.

Symbiosis is an association between two organisms of different species in which one organism obtains nourishment from another organism which suffers harm

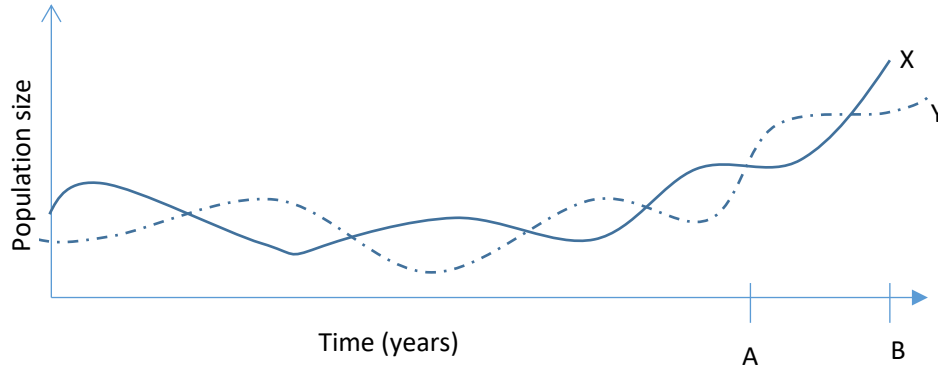
2. The population of two animal species A and B in a game park was monitored by a warden, after four weeks, for a period of thirty-two weeks. The population of each animal species was recorded in the table below. Use the information in the table to answer the questions that follow.

Time (weeks)	4	8	12	16	20	24	28	32
Population of animal A	10	20	28	330	20	10	22	32
Population of animal B	5	10	15	25	28	15	11	20

- (a) Represent the above information on a suitable graph.
- (b) Identify the animal which represents a prey and one that represents predator.
- (c) Give reasons for your answers in (b) above

(d) Explain the changes in animal population with time

3. Figure 6 shows changes in the size of a population of a producer and consumer in a lake over time.



- (a) State which curve represents the
- (i) Producer
 - (ii) Consumer
- (b) Explain the interaction between the two populations before point A.
- (c) Suggest how human activities could result in the interaction of the population between points A and B
4. (a) What is a parasite?
- (b) List five adaptations of parasites.

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