



Senior 2 General Science (New curriculum)

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Senior 2

Term 3

THEME: SCIENCE AND ENERGY

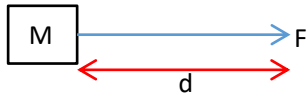
TOPIC 10: WORK, ENERGY AND POWER

Competency: the learner understands the relation between force, distance and time to work, energy and power and the various sources of energy.



Work

Work is the product of force (N) and distance (m) moved. This distance must be in the direction of the force. Consider a body of mass, M, being pulled on a smooth horizontal table by a force F through a distance, d.



$$\text{Work done} = F \times d$$

Units of work

The unit of work is Joule (J)

$$1\text{J} = 1\text{N} \times 1\text{m} \text{ or } \text{Nm}$$

Definition

A Joules is the work done when a force of 1N moves a body through a distance of 1m in the direction of force.

Examples 1

- (a) A boy pulls a body on a smooth table with a force of 2N through a distance of 5m. Calculate the work done

$$\begin{aligned} W &= F \times d \\ &= 2 \times 5 \\ &= 10\text{N} \end{aligned}$$

- (b) John lifts a mass of 45kg through a height of 8m. Calculate the amount of work done

$$\begin{aligned} \text{Force} &= mg \\ &= 45 \times 10 \\ &= 450\text{N} \end{aligned}$$

$$\begin{aligned} W &= F \times d \\ &= 450 \times 8 \\ &= 36,000\text{J} \end{aligned}$$

Exercise 10.1

- (a) Calculate the work done when a block of steel is pulled on the table with a force of 5N through 7.2m. [36J]
- (b) Bbosa lifts a bricks of mass 3kg through a height of 5m. Calculate the work done [150J]
- (c) A boy lifts a mass of 4kg through a height, h. The boy does work of 12,000J as he lifts the mass. Find the height h in meters. ($g = 10\text{ms}^{-2}$) [300m]
- (d) David rides a motorcycle with an engine that exerts a force of 400N and the work done by the motorcycle during the ride is 48kJ. Find the distance moved. [120m]
- (e) A girl of mass 50kg runs up a stair of 20steps each 8.0cm high. Find the work done by the girl { $g = 10\text{ms}^{-2}$ } [80J]

Energy

This is the ability to do work.

The S.I units of energy are joule.

There are various forms of energy which include the following

- Mechanical energy
- Light energy
- Chemical energy
- Heat energy
- Tidal energy
- Magnetic energy

Sources of energy

Energy sources as classified as renewable and non-renewable sources of energy

Renewable energy is power derived from natural sources that replenish themselves over time, such as sunlight, wind, water, and geothermal heat.

Types of Renewable Energy

- (i) **Solar Energy:** Captures sunlight using photovoltaic cells to generate electricity
- (ii) **Wind Energy:** Uses turbines to convert wind movement into electrical power.
- (iii) **Hydropower:** Harnesses the energy of flowing water, often through dams.
- (iv) **Geothermal Energy:** Utilizes heat from beneath the Earth's surface.
- (v) **Biomass Energy:** Converts organic materials like wood, crops, and waste into fuel.

Non-renewable energy comes from sources that **cannot be replenished** within a human lifetime. These resources are finite and will eventually run out, making them less sustainable than renewable alternatives.

Types of Non-Renewable Energy

- (i) **Fossil Fuels:** Includes coal, crude oil, and natural gas, formed over millions of years from decomposed organic matter.
- (ii) **Nuclear Fuels:** Uranium and plutonium are used in nuclear reactors to generate electricity.

Mechanical energy (M.E)

This is the total energy a body possesses by virtue of its position and motion. It is the sum of potential and kinetic energies.

Kinetic energy (K.E)

This is the energy possessed by a body by virtue of its motion. Kinetic energy increases with the speed of the body.

$$K.E = \frac{1}{2}mv^2 \text{ where } m = \text{mass in kg and } v = \text{velocity in m/s.}$$

Potential energy (P.E)

This is the energy possessed by a body by virtue of its position from a reference axis (or ground). It increases with height above the ground.

$P.E = mgh$ where m = mass in kg, g = acceleration due to gravity and h = height above ground in meters.

$$\begin{aligned} \text{Hence } M.E &= P.E + K.E \\ &= mgh + \frac{1}{2}mv^2 \end{aligned}$$

Examples 2

A ball of mass 2kg is resting on the top of a table of 5m. Find the potential energy possessed by the ball.

$$P.E = mgh = 2 \times 10 \times 5 = 100J$$

- (a) A stone of 50g possesses kinetic energy of 4.9J. find its speed.

$$K.E = \frac{1}{2}mv^2$$

$$\Rightarrow \frac{1}{2}mv^2 = 4.9$$

$$\frac{1}{2} \times \frac{50}{1000} v^2 = 4.9$$

$$v^2 = 4.9 \times 2 \times \frac{1000}{50} = 196$$

$$v = 14ms^{-1}$$

Exercise 10.2

- (a) A ball of mass 1kg is resting on top of a table of height h. if the potential energy stored in the ball is 70J, find the height of the table. [7m]
- (b) An arrow is released from a bow with kinetic energy of 3.2J. The mass of the arrow is 25g. Calculate its velocity. [16ms^{-1}]
- (c) John raised a mallet of 1kg to a height of 0.3m. Calculate the potential energy of the mallet. [3J]
- (d) Marry is 55kg walks at a speed of 2ms^{-1} . Calculate her kinetic energy while walking. [110J]

Principle of conservation of mechanical energy

In any mechanical system, mechanical energy is conserved provided there is no dissipative force acting on the system.

The **Law of conservation of energy** states that energy can neither be created nor destroyed; it is transformed into another form of energy. For instance, for a falling object;

Loss in potential energy = gain in kinetic energy

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

Example 3

A brick of mass 4kg resting on a wall falls freely to the ground through a vertical height of 3m. Calculate

- (a) Kinetic energy of the brick as it hits the ground

Kinetic energy = potential energy

$$= mgh$$

$$= 4 \times 10 \times 3$$

$$= 120\text{J}$$

- (b) Velocity with which the brick hits the ground ($g = 10\text{ms}^{-2}$)

$$\text{K.E} = \frac{1}{2}mv^2$$

$$\Rightarrow \frac{1}{2} \times 4 \times v^2 = 120$$

$$v^2 = 60$$

$$v = 7.75\text{ms}^{-1}$$

Exercise 10.3

- (a) A bullet of mass 0.02kg is fired with a speed of 40kmhr^{-1} . Calculate its kinetic energy. [1.2J]
- (b) A brick of 4kg resting on the top of house 10m high, falls freely to the ground. Find its
 - (i) Potential energy on the top of the house [400J]
 - (ii) velocity just before it strikes the ground. [14.1ms^{-1}]

Power

This is the rate of doing work or the rate of change of energy.

$$\text{Power} = \frac{\text{work done}}{\text{time taken}} = \frac{F \times d}{t} = Fv$$

Thus, power is proportional to velocity

The S.I units of power are Js^{-1} or watts

A watt is the rate of transfer of energy at 1 joule per second.

Example 4

- (a) Find the power if a mouse of mass 0.03 kg climbs through a distance of 2 m up a wall in 4 s.

$$\text{P.E gained} = mgh = 0.03 \times 10 \times 2 = 0.6\text{J}$$

$$\text{Power} = \frac{\text{work}}{\text{time}} = \frac{0.6}{4} = \mathbf{0.15W}$$

- (b) A force of 50N moves an object through a distance of 200m in 40s. Find the power expended

$$\text{Work} = F \times d = 50 \times 200 = 10,000\text{J}$$

$$\text{Power} = \frac{\text{work}}{\text{time}} = \frac{10,000}{40} = \mathbf{250W}$$

Exercise 10.4

- (a) A machine lifts a load of 5000N through a distance of 10m in 5s. The average power of the machine is [10,000W]
- (b) A crane lifts 4 bricks per minute through a height of 1.5 m. Find the power that is expended if each brick weighs 100 N. [10W]
- (c) A crane lifts a mass of 500kg through a height of 12m in 5s. Find the power output. [10,000W]
- (d) An engine is rated 1000W raises water through a vertical height of 50m in 10s. Find the weight of water raised. [200N]

Energy transformations

Energy transformation is the process of changing energy from one form to another. It is fundamental to life and technology because it allows energy to be used in different ways — from powering machines to sustaining living organisms.

Common Energy Transformations

- (i) **Chemical → Mechanical:** Food energy in our bodies is converted into muscle movement.

Example: Running, lifting objects.

- (ii) **Chemical → Heat:** Burning fuel releases heat energy.

Example: Firewood burning in a stove.

- (iii) **Electrical → Light:** Electricity powers bulbs to produce light.

Example: Street lighting.

- (iv) **Electrical → Mechanical:** Electric motors convert electricity into motion.

Example: Fans, washing machines.

- (v) **Solar → Chemical:** Plants use sunlight to make food through photosynthesis.

Example: Green leaves producing glucose.

- (vi) **Mechanical → Electrical:** Generators convert motion into electricity.

Example: Hydroelectric dams.

- (vii) **Light → Electrical:** Solar panels convert sunlight into electricity.

Example: Solar-powered homes.

Summary Table

Transformation	Energy Change	Example
Chemical → Mechanical	Food → Movement	Running
Chemical → Heat	Fuel → Heat	Firewood stove
Electrical → Light	Electricity → Light	Bulbs
Electrical → Mechanical	Electricity → Motion	Fan
Solar → Chemical	Sunlight → Glucose	Photosynthesis
Mechanical → Electrical	Motion → Electricity	Hydroelectric dam
Light → Electrical	Sunlight → Electricity	Solar panels

Everyday Importance

- ❖ **Human survival:** Food energy transformed into movement and heat.
- ❖ **Technology:** Machines rely on electrical-to-mechanical transformations.
- ❖ **Environment:** Photosynthesis sustains ecosystems.
- ❖ **Industry:** Factories use multiple energy conversions for production.

Key Insight

Energy transformations are the **bridge between natural processes and human technology**. They explain how the Sun powers life, how fuels drive engines, and how electricity lights our homes.

Exercise 10.5

Identify five example of energy transformation in daily life

Major Ways of Conserving Energy

- (i) **Renewable Energy Adoption:** Transitioning from fossil fuels to solar, wind, hydro, and geothermal energy reduces pollution and ensures long-term supply.
- (ii) **Energy Efficiency:** Using energy-efficient appliances, LED lighting, and smart grids minimizes waste. Retrofitting buildings with insulation and efficient HVAC systems saves significant power.
- (iii) **Policy and Regulation:** Governments can enforce efficiency standards, provide tax incentives for clean energy, and set renewable portfolio targets. Cap-and-trade systems limit emissions while encouraging innovation.
- (iv) **Technological Innovation:** Smart grids, battery storage, and AI-driven energy management optimize usage and integrate renewables more effectively.
- (v) **Behavioral Change:** Simple actions like turning off unused appliances, adjusting thermostats, and reducing unnecessary travel cut energy demand.
- (vi) **Energy Audits:** Regular checks in industries and households identify waste and recommend improvements.
- (vii) **Public Awareness:** Education campaigns encourage communities to adopt sustainable practices, especially in growing urban areas.

Comparison Table

Method	How It Works	Future Impact
Renewables	Replace fossil fuels	Clean, sustainable energy
Efficiency	Reduce waste via tech	Lower costs, less pollution
Policy	Enforce standards & incentives	Faster transition to green energy
Innovation	Smart systems & storage	Reliable renewable integration
Behavioral Change	Individual actions	Immediate demand reduction
Audits	Identify inefficiencies	Long-term savings
Awareness	Educate communities	Widespread adoption

Everyday Applications

- ❖ **Transport:** Electric vehicles, public transport, and cycling reduce fossil fuel use.
- ❖ **Industry:** Efficient machinery and recycling lower energy demand.
- ❖ **Homes:** Solar panels, efficient appliances, and insulation cut household bills.
- ❖ **Agriculture:** Solar irrigation and biogas reduce reliance on diesel pumps.

Risks & Challenges

- (i) **High upfront costs** for renewable infrastructure.
- (ii) **Policy inconsistency** across countries slows progress.
- (iii) **Public resistance** to lifestyle changes.
- (iv) **Storage limitations** for renewable energy.

Key Insight

Energy conservation is not just about saving electricity — it is about **securing a sustainable future**. By combining renewable energy, efficiency, strong policies, and responsible behavior, societies can reduce emissions, cut costs, and ensure reliable energy for billions of people.

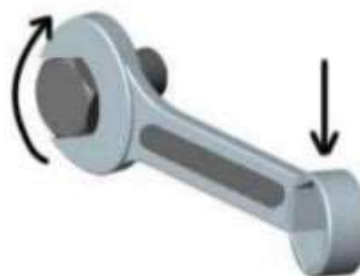
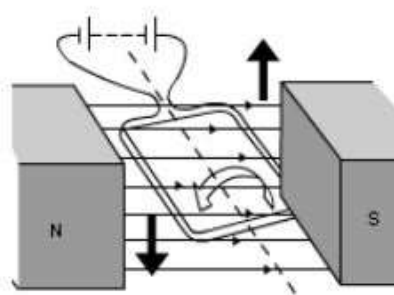
Exercise 10.6

Explain measures that can be taken to conserve energy for the future.

THEME: SCIENCE AND TECHNOLOGY

TOPIC 11: TURNING EFFECT OF FORCES, CENTER OF GRAVITY AND STABILITY

Competency: the learner investigates how turning effect of forces is related to stability of bodies.



The **turning effect of a force**, also known as **torque or moment of force**, refers to the force's ability to cause an object to rotate about a pivot or axis. It depends on two factors:

- (i) **Magnitude of the force:** The greater the force applied, the greater the turning effect.
- (ii) **Distance from the pivot:** A force applied farther from the pivot point creates a stronger turning effect.

Mathematically, torque (τ) is given by:

$$\tau = \text{Force} \times \text{Perpendicular Distance}$$

For example, when opening a door, pushing near the handle (far from the hinge) makes it easier compared to pushing near the hinge. This principle is crucial in machines, levers, and even human joints.

The turning effect is crucial in understanding concepts such as moments, center of gravity and stability.

Daily Applications of Turning Forces

- (i) **Opening doors:** The handle is far from the hinges (pivot), so a small push creates a large turning effect.
- (ii) **Using spanners:** A longer spanner increases leverage, making it easier to loosen tight nuts.
- (iii) **Steering bicycles/cars:** Turning the handlebars or steering wheel applies torque to change direction.
- (iv) **Swinging seesaws:** Children balance by applying forces at different distances from the pivot.
- (v) **Rowing boats:** Oars act as levers, with water providing resistance at the end.
- (vi) **Using scissors:** Fingers apply force at the handles, magnified at the blades to cut materials.
- (vii) **Pedaling bicycles:** Feet push pedals, creating torque that turns the chain and wheels.
- (viii) **Hammering nails with claw hammers:** The long handle multiplies force to pull nails out easily.

Summary Table

Application	Pivot/Axis	Effect of Turning Force
Door opening	Hinges	Small push opens door
Spanner	Nut	Easier loosening/tightening
Steering	Wheel axle	Changes direction
Seesaw	Center pivot	Balancing children
Rowing	Oarlock	Moves boat forward
Scissors	Screw joint	Cuts materials
Bicycle pedals	Crank axle	Rotates wheels
Claw hammer	Nail pivot	Pulls nails out

Everyday Importance of turning forces

- (i) **Household:** Doors, scissors, and hammers rely on torque.
- (ii) **Transport:** Steering and pedaling use turning forces.
- (iii) **Playgrounds:** Seesaws and swings depend on moments.
- (iv) **Workshops:** Spanners, screwdrivers, and drills all use torque.

Key Insight

Turning forces make **rotation and leverage possible**, allowing humans to perform tasks with less effort. They are the hidden principle behind tools, machines, and even simple daily actions like opening a door or riding a bicycle.

Exercise 11.1

Explain five examples of daily applications of turning forces.

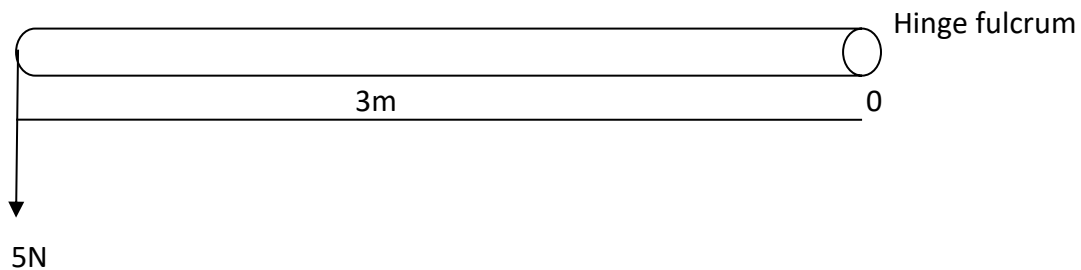
Moments

Moment a force is a product of a force and the perpendicular distance of the line of action of the force from the fulcrum (pivot).

Moment of a force = Force x perpendicular distance of the line of action of the force from the fulcrum

The SI unit of moment is Newton meter (NM). Moment is a vector quality.

Example 1



Calculate the moment of 5N

$F = 5\text{N}$ d from fulcrum = 3m

$$\begin{aligned}\text{Moment} &= F \times d \\ &= 5 \times 3 \\ &= 15 \text{ Nm}\end{aligned}$$

Factors affecting moments

The moment of a force depends on:-

- (i) The magnitude of a force

(ii) Perpendicular distance from the fulcrum

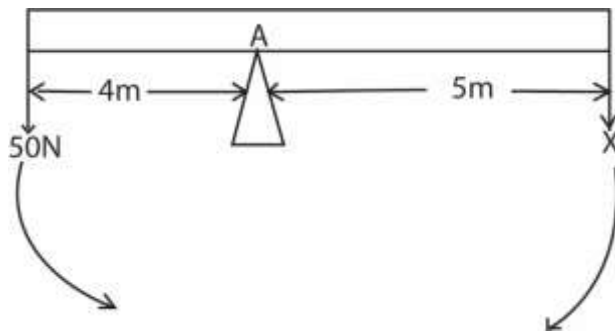
Law/Principle of moment

This states that when a body is in a state of equilibrium the sum of clockwise moments about any points is equal to the sum of anticlockwise moments about the point.

Sum of anti-clockwise moments about any point = Sum of clockwise moments about the point.

Example 2

Find the value of X in the figure below



Taking moment about A

Clockwise moments = $5x$

Anticlockwise moments = $50 \times 4 = 200\text{N}$

And by law of moment:

Sum of clockwise moments = Sum of anti-clockwise moment about any point

$$5x = 200$$

$$\frac{5x}{5} = \frac{200}{5}$$

$$x = 40\text{N}$$

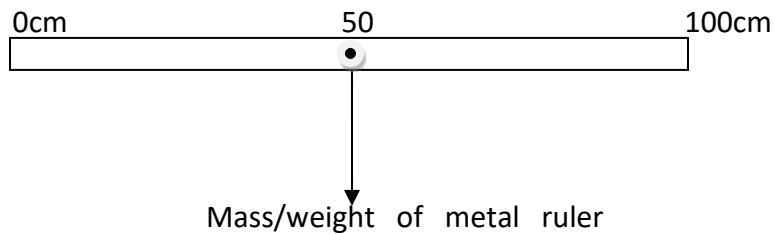
From the above it can be noted that it is easier to close the door by pushing it at a point as far away from the hinges as possible. Because the force applied can easily balance with the reaction at the hinges.

Note: When calculating moments about a point (pivot) all distances should be measured from that point

Finding the mass/weight of uniform body

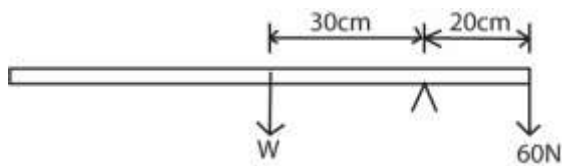
When a body is uniform, the mass or weight must act at the center.

For a uniform meter rule the center at which the mass of the meter rule must act is 50cm mark.



A meter rule is marked from 0-100cm mark. Its mass/weight must act in the middle which is 50cm mark. The mass or weight is calculated by applying the principle of moment.

Example 3



Find the weight W , of a uniform meter rule if a force of 60N at one end balances it as shown in the above figure

From the principle of moments

$$30 \times w = 60 \times 20$$

$$w = 40\text{N}$$

Example 4

Figure below shows a uniform meter rule of mass 0.1kg pivoted at the 80 cm mark. It balances horizontally when a mass P is hangs at the 95 cm mark. Find the value of P .



Take moments about the pivot

Mass a ruler = 0.1kg acts at 50cm mark

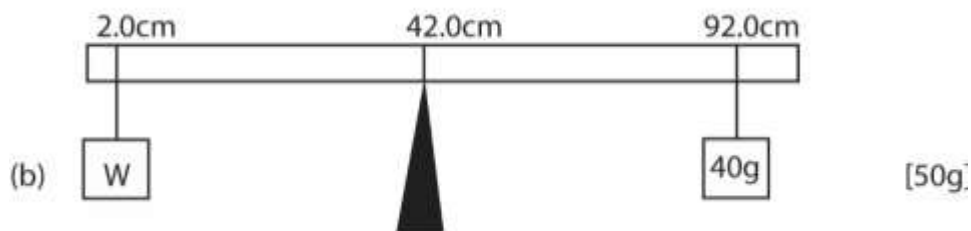
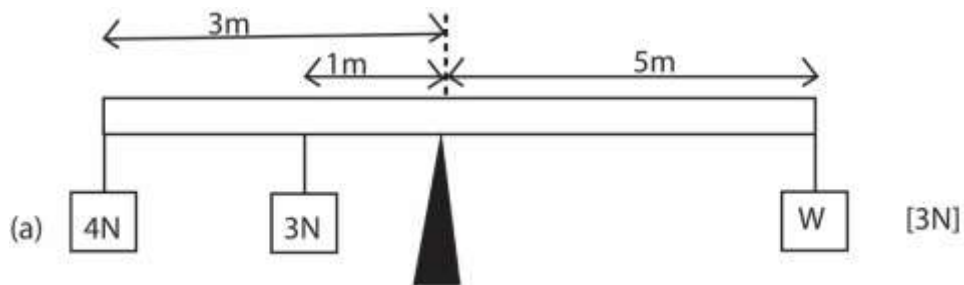
$$\Rightarrow 0.1 \times (80 - 50) = P \times (95 - 80)$$

$$P = \frac{0.1 \times 30}{15}$$

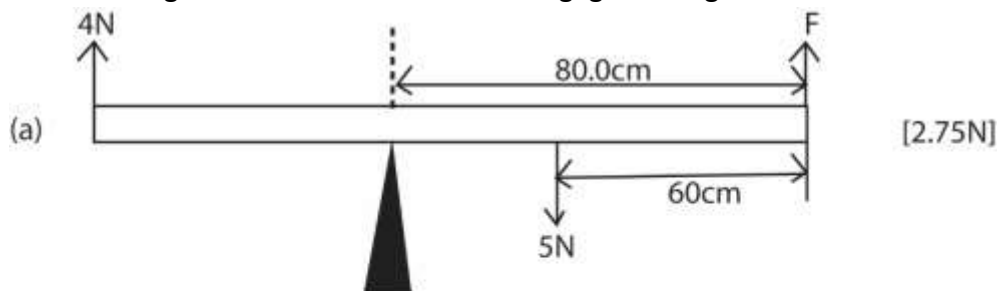
$$= 0.2kg$$

Exercise 11.2

1. Find the value of W in each case in the figure below



2. In each of the figure below a rod of 1m has negligible weight. Find the values of F.



Application of moments

- (i) **Levers** – Used in tools like crowbars, scissors, and seesaws to amplify force by increasing the distance from the pivot.
- (ii) **Gears and Machines** – Torque is essential in the functioning of bicycles, cars, and industrial machines.
- (iii) **Steering Wheels** – Turning a car's steering wheel requires torque; a larger wheel reduces effort.
- (iv) **Human Body** – Joints act as pivots, and muscles apply forces to create movement (e.g., bending an arm).
- (v) **Balancing** – A person balancing on a beam distributes weight to maintain equilibrium.
- (vi) **Bridge Design** – Engineers use moments to calculate load distribution and ensure stability.
- (vii) **Opening Doors** – Pushing near the handle requires less force than pushing close to the hinge.

Equilibrium

Equilibrium is the state in which all the forces acting on a body are balanced, so there is **no change in motion**. It is a key concept in physics, engineering, and daily life — explaining why objects stay still, move steadily, or remain stable.

Types of Equilibrium

- (i) **Static equilibrium:** Occurs when an object is at rest and all forces acting on it cancel out.

Example: A book resting on a table — gravity pulls down, the table pushes up equally.

- (ii) **Dynamic equilibrium:** Occurs when an object moves at constant speed in a straight line — forces are balanced but motion continues.

Example: A car cruising at constant speed on a straight road.

Conditions for Equilibrium

- (i) **Sum of forces = 0:** No net force acts on the object.

$$\sum F = 0$$

- (ii) **Sum of moments = 0:** No net turning effect around any point.

$$\sum M = 0$$

Examples in Everyday Life

Situation	Type of Equilibrium	Explanation
Book on a table	Static	Forces balance vertically
Hanging picture frame	Static	Tension in strings balances weight
Car moving at constant speed	Dynamic	Engine force equals friction
Balanced seesaw	Static	Moments on both sides equal
Airplane cruising	Dynamic	Lift, thrust, drag, and weight balanced

Importance of Equilibrium

- (i) **Structural stability:** Keeps buildings, bridges, and furniture steady.
- (ii) **Mechanical design:** Ensures machines operate smoothly.
- (iii) **Human balance:** Helps us stand and walk upright.
- (iv) **Environmental systems:** Maintains balance in ecosystems and climate.

Key Insight

Equilibrium is the **foundation of stability** — whether in physics, nature, or human life. When forces and moments balance, motion becomes predictable and systems remain safe and steady.

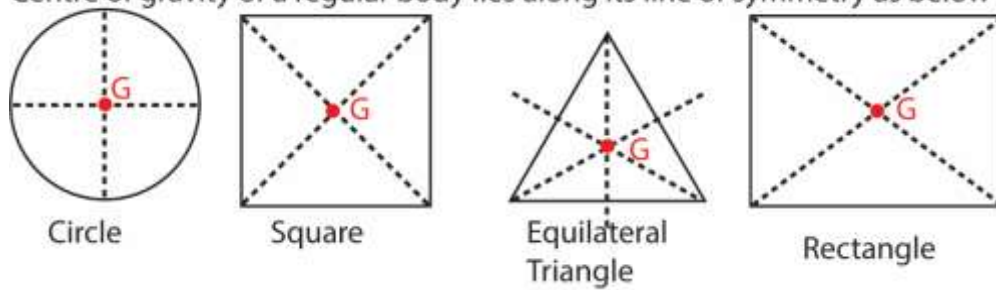
Center of gravity

This is a point where the resultant force of attraction of a body acts.

Center of gravity of regular object

For regular shape bodies, the center of gravity is at the geometric center of the body e.g. the center of gravity of a Uniform meter ruler is at 50cm mark, for circle, it is at the center. For a rectangular and square body it is at the point of intersection of the diagonals.

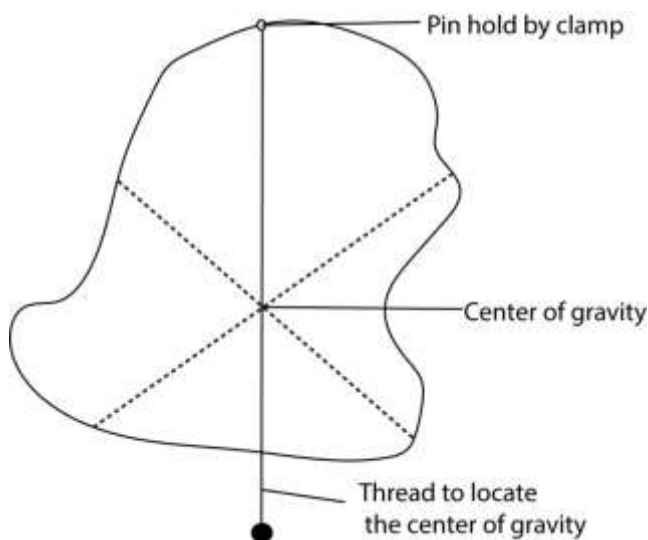
Centre of gravity of a regular body lies along its line of symmetry as below



Center of gravity of irregular body

The best way of finding the center of gravity of an irregular object is by use a plumb line. A plumb line is made from a thread of cotton with a loop at one end and a weight tied at other end.

For an irregular card board for instance, three small holes are made at well-shaped intervals around the edge of the card



A pin is then put through one of the holes and firmly by a clamp and stand so that the card board swings on it.

The card board will come to rest with its center of gravity below the point of support along the vertical line of plumb line.

The cardboard is hung through another hole, the point of interception of the two vertical lines is the center of gravity.

Application of center of gravity

1. cars have very heavy framed to lower center of gravity
2. Racing cars have wide wheel base to lower center of gravity.

Exercise 11.3

Explain how a center of gravity of irregular lamina can be determined

Couples

Couples are equal and opposite parallel forces.

Moment of couple = one of the forces x perpendicular distance between them.

A couple can only produce a rotation because it is not possible to find a single force to replace a couple as it can only be balanced by an equal and opposite couple.

Stability

There are three terms used in connection with stability:

- (i) Stable equilibrium.
- (ii) Unstable equilibrium.
- (iii) Neutral equilibrium.

Stable equilibrium

If the body in stable equilibrium is slightly displaced, the center of gravity of the body is raised. And when released, the body returns to its original position.

Unstable equilibrium

If the body in unstable equilibrium is slightly displaced, the center of gravity of the body is lowered. And when released, the body moves farther away from its original position.

Neutral equilibrium:

If the body in neutral equilibrium is slightly displaced, the center of gravity of the body is not raised or lowered. And when released, the body stays in its new position.

Application of stability

Stability plays a crucial role in various fields, ensuring balance and preventing unwanted movement. Here are some key applications:

- (i) **Architecture & Construction** – Buildings, bridges, and towers are designed with stability principles to resist forces like wind and earthquakes.

- (ii) **Vehicles** – Stability control in cars, motorcycles, and airplanes prevents tipping or rolling, improving safety.
- (iii) **Sports** – Athletes use stability techniques in gymnastics, weightlifting, and cycling for balance and performance.
- (iv) **Furniture & Equipment** – Chairs, ladders, and cranes are built with a low center of gravity to remain steady.
- (v) **Ships & Boats** – Ballast systems help ships stay stable in rough waters.
- (vi) **Human Posture** – Proper body alignment helps maintain balance and prevents injuries.

Factors Affecting Stability

- (i) **Center of gravity:** The lower the center of gravity, the more stable an object becomes.
Example: A wide-bottomed pot is harder to tip than a tall narrow one.
- (ii) **Base of support:** A wider base increases stability because it provides more area for balance.
Example: A tripod camera stand is steadier than a single pole.
- (iii) **Height of the object:** Taller objects are less stable because their center of gravity is higher.
Example: A tall tower sways more easily than a short building.
- (iv) **Weight distribution:** Evenly distributed weight improves stability; uneven weight causes tipping.
Example: A loaded truck with balanced cargo is safer than one with uneven load.
- (v) **Line of action of weight:** If the line of action passes through the base, the object remains stable; if it falls outside, the object topples.
Example: A leaning ladder falls when its line of action moves beyond its base.
- (vi) **Friction at the base:** High friction prevents slipping and increases stability.
Example: Rubber soles help people stand firmly.

Ways of Improving Stability

- (i) **Lowering the center of gravity:** Keep heavy parts of objects closer to the ground.
Example: Heavy machinery designed with weight at the bottom.
- (ii) **Widening the base of support:** Increase the area in contact with the ground.
Example: Tripods for cameras, wide shoes for athletes.
- (iii) **Balancing loads evenly:** Distribute weight equally to prevent tipping.
Example: Trucks loaded evenly, furniture arranged symmetrically.
- (iv) **Increasing friction at the base:** Use rough or rubber surfaces to prevent slipping.
Example: Rubber soles on shoes, anti-slip mats in bathrooms.

(v) **Reducing height of objects:** Shorter objects are less likely to topple.

Example: Low-rise furniture is steadier than tall, narrow shelves.

(vi) **Correct line of action of weight:** Ensure the line of gravity passes through the base.

Example: Leaning ladders placed properly to avoid falling.

Exercise 11.2

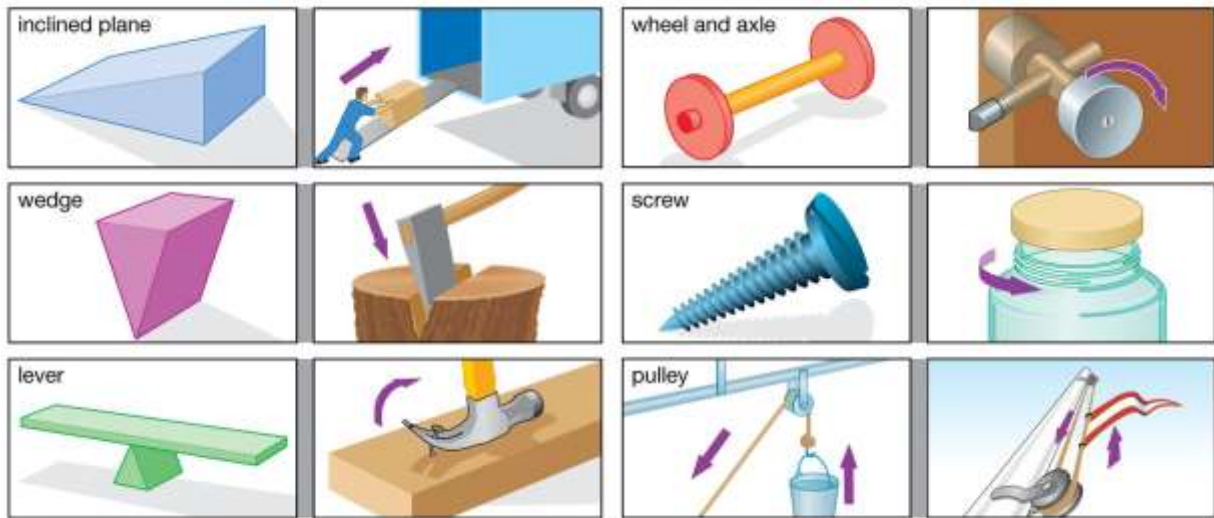
a) Give two applications of stability in daily life.

b) Describe five factors that affect stability.

THEME: SCIENCE AND TECHNOLOGY

TOPIC 12: SIMPLE MACHINES

Competency: The learner investigates how simple machines are used to make work easier and their application



Simple machines

These are devices that work with one movement and change the size and direction of force.

Examples of Simple Machines in Daily Life

- (i) **Lever:** A rigid bar that pivots on a fulcrum.
Examples: Seesaws, crowbars, scissors, claw hammers.
- (ii) **Inclined plane:** A sloping surface that reduces effort needed to lift objects.
Examples: Ramps, slides, staircases, ladder.
- (iii) **Wheel and axle:** A wheel attached to a central axle reduces friction and multiplies force.
Examples: Bicycles, cars, doorknobs.
- (iv) **Pulley:** A wheel with a rope or chain that changes the direction of force.
Examples: Flagpoles, cranes, window blinds.
- (v) **Wedge:** A device with a sharp edge that splits or cuts objects.
Examples: Knives, axes, chisels, nails.
- (vi) **Screw:** An inclined plane wrapped around a cylinder, converting rotational force into linear motion.
Examples: Jar lids, bolts, drills.

Levers

A lever is a rigid bar which is free to move about a fixed point, the Fulcrum or pivot

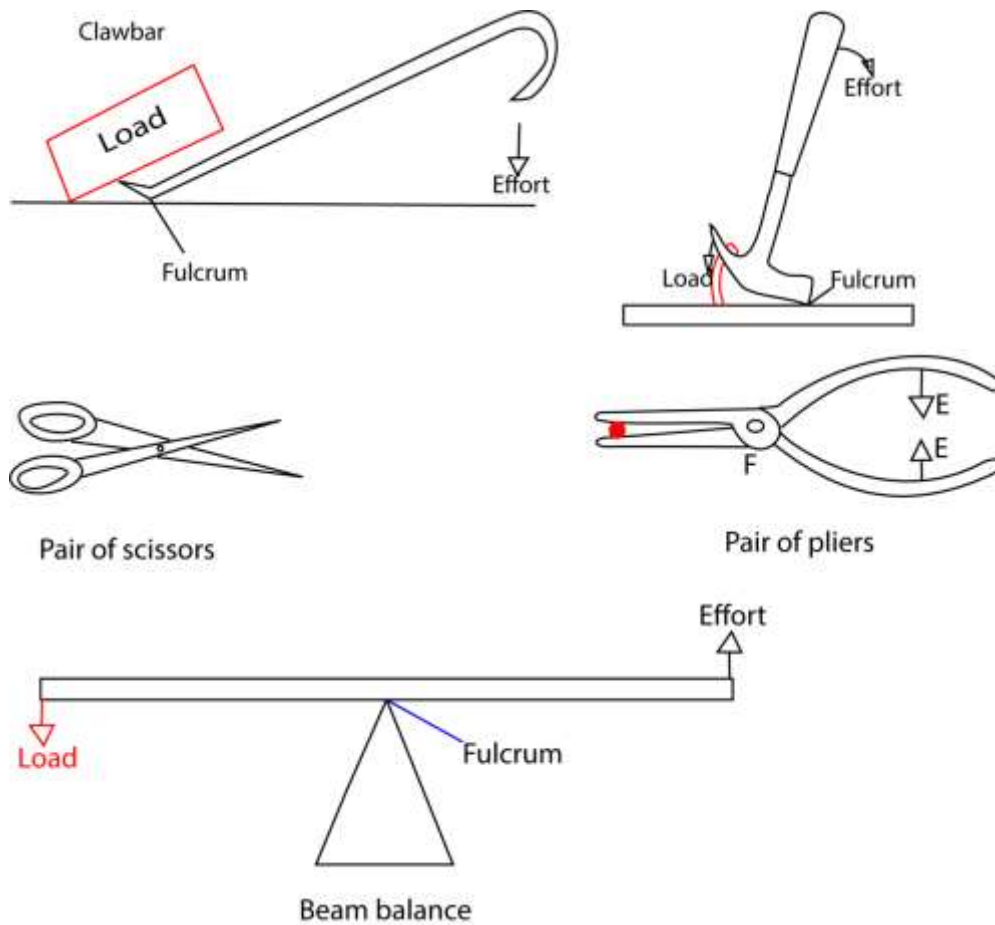
Levers are divided into three classes

- (i) The first class levers
- (ii) The second class lever and,
- (iii) Third class levers

(a) First class lever

This is a type of lever in which the fulcrum is between the effort and the load.

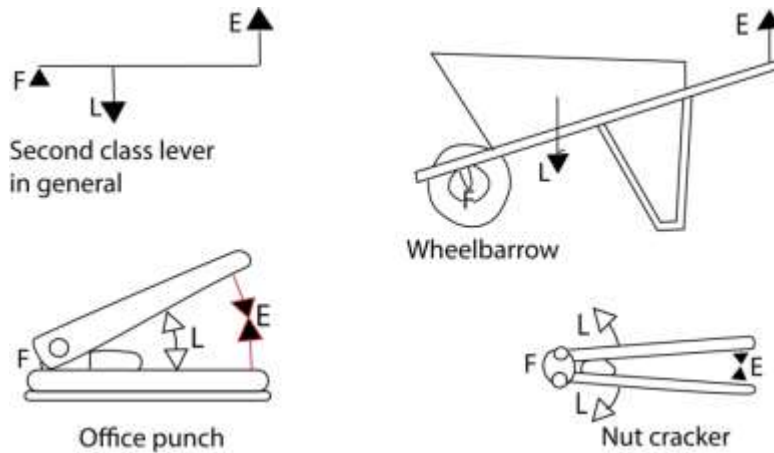
Examples of first class lever include Crow bar, scissor, beam balance, scissor and pair of pliers,



(b) Second class lever

Here the load is between the effort and fulcrum.

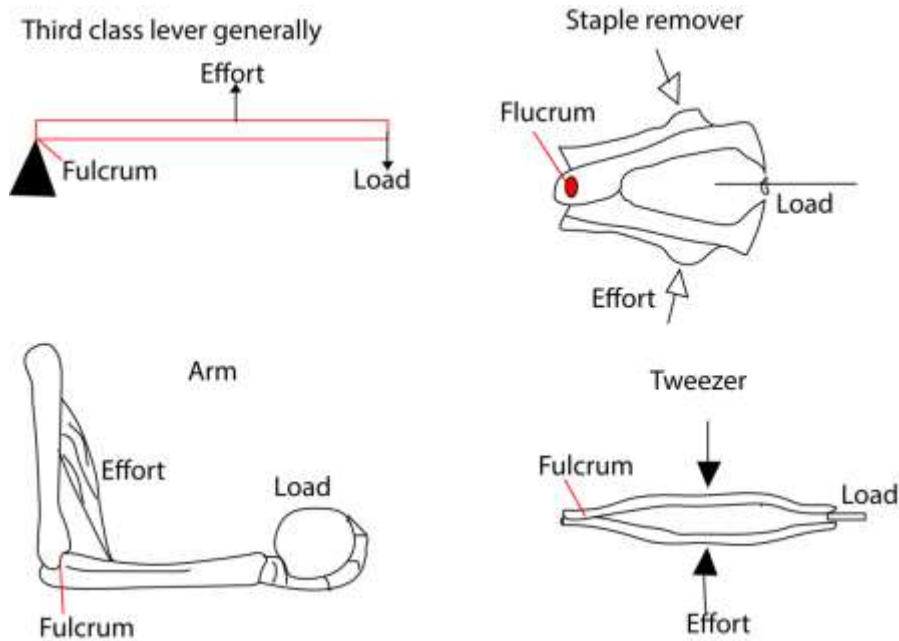
Examples are wheelbarrow, nut cracker and office punch



(c) Third class lever

Here the effort is between the load and fulcrum.

Examples are wheelbarrow, nut cracker and office punch



Mechanical advantage (M.A)

This is the ratio between the load and the effort applied. i.e., $M.A = \frac{\text{Load (L)}}{\text{Effort (E)}}$

Significance of mechanical advantage

The bigger the mechanical advantage the better the machine since small effort can lift a bigger load.

Factors that may lower mechanical advantage

- **Friction;** the higher the friction the lower the mechanical advantage
- **Weight of moving parts:** the heavier the parts the lower the mechanical advantage

Velocity ratio

This is the ratio of distance moved by effort over the distance moved by the load

$$\text{i.e. Velocity ratio (V.R)} = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$$

Velocity ratio has no units

Significance of velocity ratio

The bigger the velocity ratio the less effort required to do work and the more efficient the machine. Or the machine requires less effort to overcome a big load when effort moves a bigger distance compared to the load in a unit time.

Example 1

A load of 100N is raised through 6m when an effort of 40N moves through 24m.

Calculate

- (i) mechanical advantage
- (ii) velocity ratio

Solution

$$(i) \quad M.A = \frac{\text{Load (L)}}{\text{Effort (E)}} = \frac{100}{40} = 2.5$$

$$(ii) \quad \text{Velocity ratio (V.R)} = \frac{\text{distance moved by effort}}{\text{distance moved by load}} = \frac{24}{6} = 4$$

Pulleys

A pulley is a wheel with a groove ring which passes or string .

- The effort is applied to one end of the rope and the disk of the pulley rotate as the rope moves over it
- If there are several pulleys in a frame work, it is called a block

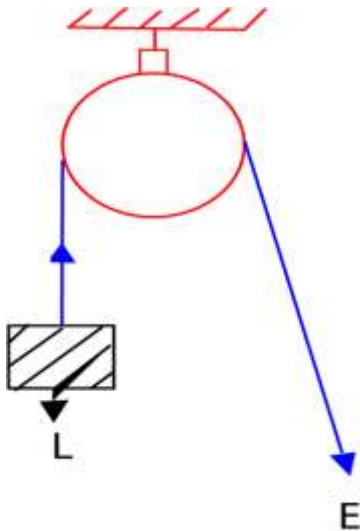
Types of pulleys

Pulleys may be categorized into

- Single fixed pulley
- Single movable pulley
- Block and Tackle system

Pulleys reduce the effort to lift an object by increasing the distance and /or direction over which the effort is applied.

(a) Single fixed Pulley



A single fixed pulley is as single wheel with concave grooves fixed to a support as shown in the figure above. A rope, chain or cable passes over the groove of the pulley. One end of the rope is attached to the load and the effort is applied at the other end.

If a user pulls down on one end of the rope (Effort), the other end (Load) will raise up an equal distance in the opposite direction

The primary benefit of a single fixed pulley is to change the direction of the effort to move a load to a point (such as the top of a flagpole) that cannot be reached by the user.

Characteristics of a fixed pulley system

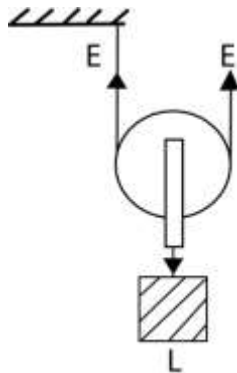
- It has one wheel inside the pulley
- The pulley is mounted to strong solid support
- Its mechanical advantage = 1
- Velocity ratio = 1
- It is a first class lever because the fulcrum is between the effort and the load
- Has uniform tension in the rope

Application of single pulley system

- Removing water from a well
- Lifting building material in the site

(b) A single movable Pulley

This is a pulley which moves along with the load attached to it. One end of the rope is tied to a fixed support and passes over the pulley and the other end where effort is applied makes a U-turn to the user as shown below.



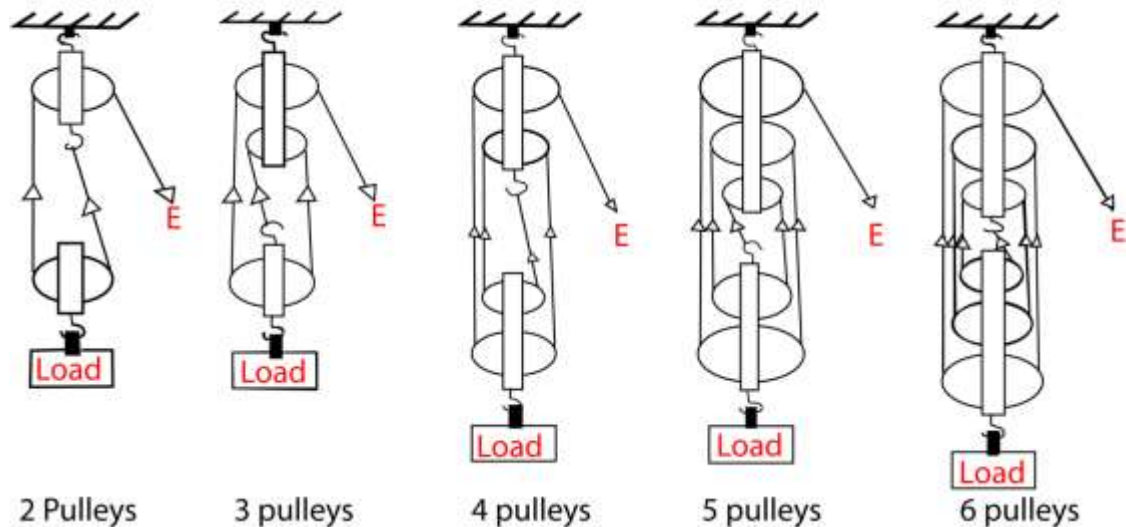
Characteristics of single fixed pulley

- Its mechanical advantage = 2, that is the effort required to lift the load is half the size of the load.
- Its velocity ratio = 2, that is the effort moves twice the distance moved by the load.

(c) Block and Tackle system

This is a pulley system consisting of both fixed and movable pulleys as shown below

Drawings showing Block and tackle systems



The framework of pulleys is called block and the rope passing over each pulley is called tackle.

Characteristics of block and tackle system

- Mechanical advantage (MA) = n (number of pulleys in the system)
- Velocity ratio (VR) = n (number of strings supporting the load or number of pulleys in the system)

Application of Block and Tackle

They are commonly used to raise or move load in

- Sailing
- Crane
- Lifts
- breakdown

Example 2

A force of 10N is required to raise a load, L , using a smooth (frictionless) and weightless block and tackle system of four pulleys. Calculate:

- a) Load

- b) M.A
- c) Effort distance if the load rises by 2m

Solution

Given

E = 10N, M.A = ?, Effort dis. ? Load distance = 2m L ? No of pulleys = 4

- a) in equilibrium

Downward force = upward force

$$L = 4E = 4 \times 10 = 40\text{N}$$

- b) mechanical advantage

$$\text{M.A} = \frac{\text{load}}{\text{effort}} = \frac{40}{10} = 4$$

- c) (Neglecting friction,

Work in put = work out put

Work done by effort = work done by load

Effort x effort distance = Load x distance

$$E \times E.d = L \times L.d$$

$$10 \times E.d = 40 \times 2$$

$$E.d = 8$$

Therefore, effort distance = 8m

Efficiency of machines

The efficiency of a machine indicates how well its input energy is converted to useful output energy or work.

$$\eta = \frac{MA}{VR}$$

$$\text{Efficiency} = \frac{\text{mechanical advantage}}{\text{Velocity ratio}}$$

In an ideal machine (with no friction), the efficiency = 1, also known as 100%.

Reasons Why Efficiency of machines < 100%

- (i) **Friction:** Moving parts rub against each other, converting energy into heat instead of useful work.

Example: Gears in a bicycle lose energy due to friction.

- (ii) **Heat loss:** Machines generate heat during operation, which dissipates into the environment.

Example: Car engines lose energy as heat.

- (iii) **Sound energy:** Vibrations produce sound, which is wasted energy.

Example: A noisy fan wastes part of its input energy.

- (iv) **Air resistance:** Moving objects face drag from air, reducing efficiency.

Example: Vehicles lose energy overcoming wind resistance.

- (v) **Wear and tear:** Old or poorly maintained machines lose efficiency due to worn-out parts.

Example: Rusty hinges require more effort to move.

- (vi) **Energy conversion losses:** No energy transformation is perfectly efficient; some energy always escapes in unwanted forms.

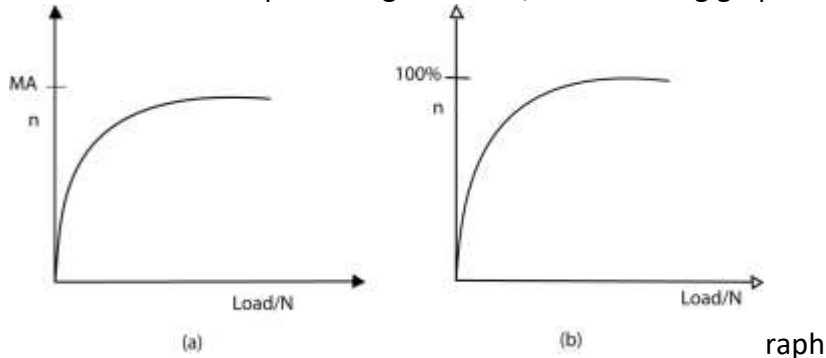
Example: Electric motors lose energy as heat and sound.

How can efficiency be increased

- a) Machines can be made more efficient by reducing friction. This usually is done by adding a lubricant, such as oil or grease, to surfaces that rub together
- b) For the case of pulleys, by making the string and the block plus the pulleys as light as possible.

Graphical relationship between M.A and Load

When M.A or n are plotted against load, the following graphs are obtained



Explanation of the shape of the graph

In both, a small increase in load cause high increase in M.A and efficiency, n . on further increase on the load, graphs begin to level as M.A and efficiency reach their maximum values and the remain constant.

The efficiency of the pulley sysytem increase with the load because when the load is small, the weight of the lower moving pulley block and friction is significant.

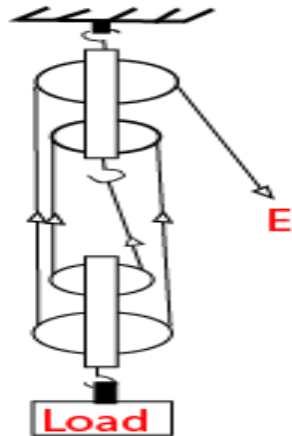
The weight of the lower movable pulley block and friction become negligible to the load as the size of the lad increases.

NB. For figure (a), the graph levels at the value of M.A. while (b), the graph levels below 100% for imperfect machine and levels at 100% for perfect machines

Example 3

- (a) Define the following terms
 - (i) Mechanical advantage
 - (ii) Velocity ration

- (b) The diagram in the figure shows a pulley system used to raise the load



- (i) What is the velocity ratio of the system
 - (ii) Find how far the load is raised if the effort moves down by 4m
 - (iii) Calculate the effort required to raise a load of 800N, if MA = 4
- (c) Explain what happens to efficiency of the system in (b) above if the load is much
- (i) Less than 800N
 - (ii) More than 800N
- (d) Draw a sketch graph to show how mechanical advantage of the system in (b) varies with the load
- (e) Give two practical applications where the pulleys are used.

Solution

- (a) (i) mechanical advantage is the ratio of load to effort
- (ii) Velocity ratio is the ratio of effort distance to load distance
- (b) (i) VR = number of pulleys = 5
- (ii) Effort distance = 4m, load distance = ?, V.R = 5

$$V.R = \frac{\text{Effort distance}}{\text{Load distance}} = 5 = \frac{4}{\text{load distance}}$$

$$\text{Load distance} = 0.8\text{m}$$

- (iii) E = ?, L = 800N, M.A = 4

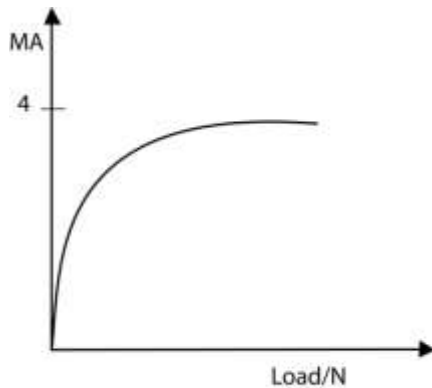
$$M.A = \frac{Load}{Effort} = 4 = \frac{800}{E}$$

$$E = 200N$$

$$(iv) \quad n = ?, \quad MA = 4, \quad V.R$$

$$n = \frac{M.A}{V.R} \times 100\% = \frac{4}{5} \times 100 = 80\%$$

(d)



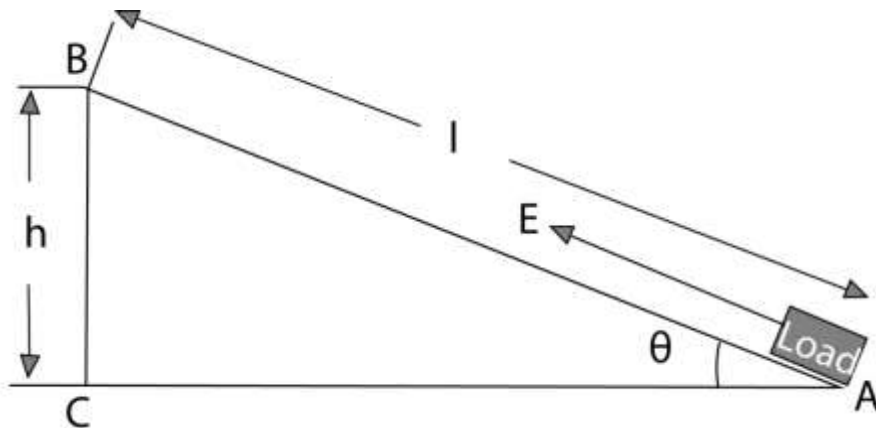
(a)

(c)

(d) they are used in cranes, breakdown, ships, for lifting

Inclined Plane

This refers to a type of a machine in which a plane is inclined to an angle to the horizontal such that one end is higher than the other by angle, θ .



- it used to lift heavy load by pulling/pushing it along the sloping surface.

- It is easier to carry the load along the slope than lifting it through the vertical height, h , since the weight of the load acts vertically downwards (and only a component of weight acts along the plane)
- In order to raise the load through a vertical height, h , the effort, E is applied through a longer distance, l , equal to the length of the plane.

Examples of inclined plane include

- (i) Slopping roads
- (ii) Stair case

Properties of inclined planes

$$M.A = V.R = \frac{l}{h}$$

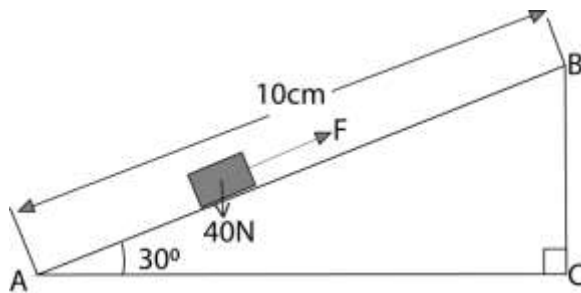
But $h = l \sin \theta$

$$MA = \frac{l}{l \sin \theta} = \frac{1}{\sin \theta}$$

Example 4

A load of 40N is pulled steadily from A to B along inclined plane by a force F as shown in the figure. Find the velocity ratio of the system.

A. 1.0 B. 1.2 C. 2.0 D. 4



$AC = 10 \text{ cm}$, $BC = ?$ $\theta = 30^\circ$

$BC = AC \times \sin 30 = 10 \times 0.5 = 5 \text{ cm}$

$$VR = \frac{AC}{BC} = \frac{10 \text{ cm}}{5 \text{ cm}} = 2$$

Alternatively

$$VR = \frac{1}{\sin 30} = 2$$

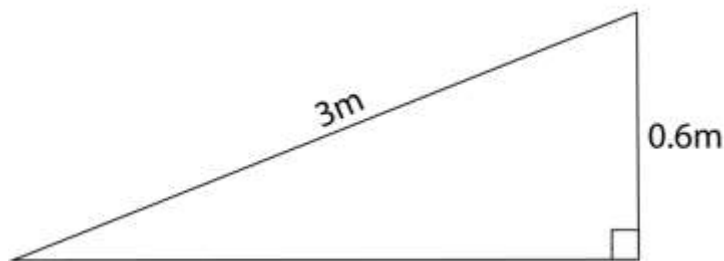
Answer is C

Example 5

A wooden plank 3m long is used to raise a load of 1200N through a vertical height of 60 cm. if the frictional force between the load and the plane is 40N. Calculate

- (a) The effort required
- (b) The mechanical advantage

Solution



Given: $L = 1200\text{N}$, $E = ?$, $l = 3\text{m}$, $h = 60\text{cm} = 0.6\text{m}$, friction force = 40N

- (a) Work input = work output + useless work done
Work done by effort = work done by load + work by frictional force
Effort $\times$ effort distance = Load $\times$ load distance + friction force $\times$ Effort distance

$$E \times 3 = 1200 \times 0.6 + 40 \times 3$$

$$E = 280\text{N}$$

- (b) $MA = \frac{L}{E} = \frac{1200}{280} = 4.3$

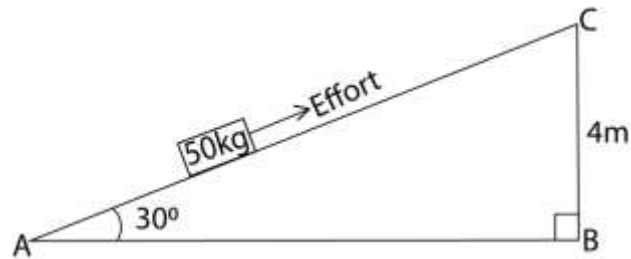
Example 6

A man uses the inclined plane to lift a 50 kg load through a vertical height of 4.0m. the inclined the incline plane makes an angle of 30° with the horizontal. If the efficiency of the plane is 72%, calculate

- (a) The effort needed to move the load up the inclined plane at a constant velocity

- (b) The work done against friction in raising the load through the height of 4.0m (take $g = 10\text{Nkg}^{-1}$)

Solution



Given

$$MA = \frac{L}{E} = \frac{1}{\sin 30} = 2 = \frac{50 \times 10}{E}$$

$$E = 250\text{N}$$

Let the actual effort used = x

$$\text{Efficiency} = \frac{250}{x} \times 100 = 72$$

$$X = 347.6\text{N}$$

Therefore effort = 347.2N

(b) work against friction = friction x Effort distance

$$= (347.2 - 250) \times AC \text{ N}$$

$$= 97.6 \times \frac{4}{\sin 30}$$

$$= 777.8\text{N}$$

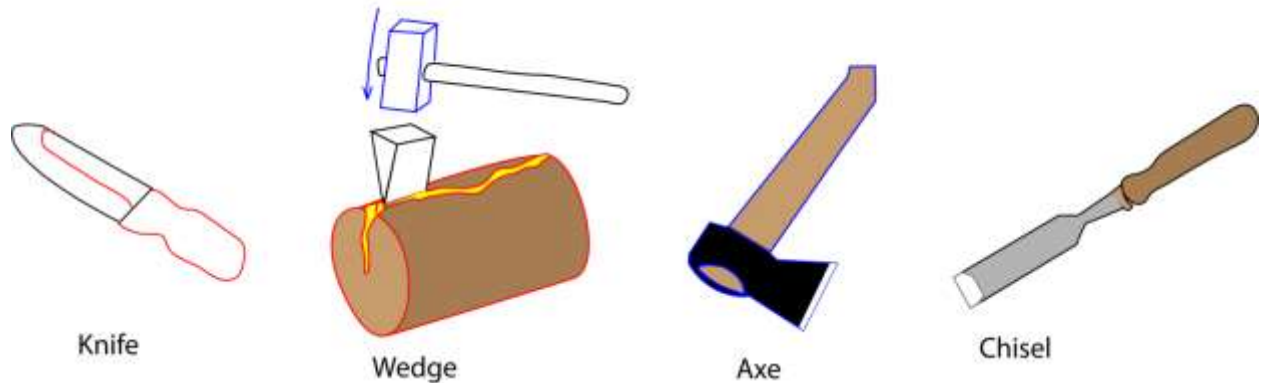
The Wedges

The wedge is a kind of simple machine which is an inclined plane having one or two sloping sides. With a wedge, the sloping surface is pushed through the material which is held still.

Examples of wedges are: Knife, axe, chisel, needle, nail, razor blade

Uses of wedges include: Cutting, pitching

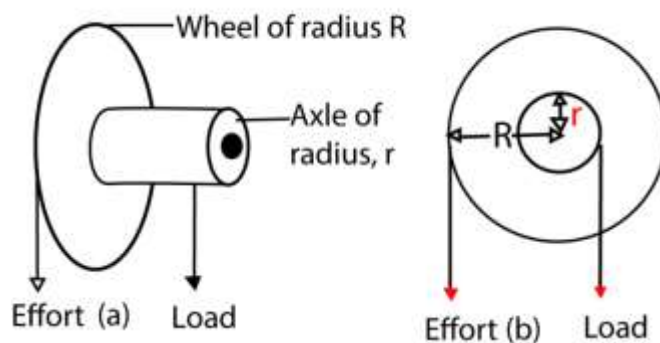
Examples of wedges



Wheel and axle

A wheel and axle is a type of simple machine made up of a wheel and axles rigidly attached to each other so that they turn together about an axis.

The effort is applied to the larger wheel and the load is raised by string attached to the axle of small diameter as show below:



For one complete turn, the load and effort move through distances equal to the circumference of the wheel and axle respectively.

Characteristic of Wheel and axle

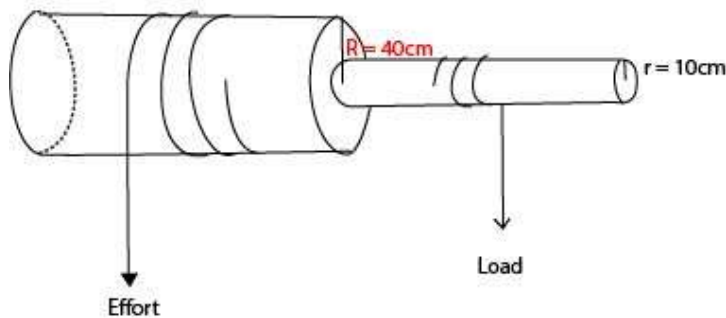
$$MA = VR = \frac{R}{r}$$

Uses of wheel and axle

- (i) The car steering wheel
- (ii) Screw driver
- (iii) Windlass (used to raise a heavy bucket of water in a well).

Example 7

The figure below shows a wheel and axle system. When an effort of 300N is applied, a load of 900N is raised through a distance of 1.0m.



Calculate

- (a) Velocity ratio
- (b) The efficiency of the machine

Solution

$$VR = \frac{R}{r} = \frac{40}{10} = 4$$

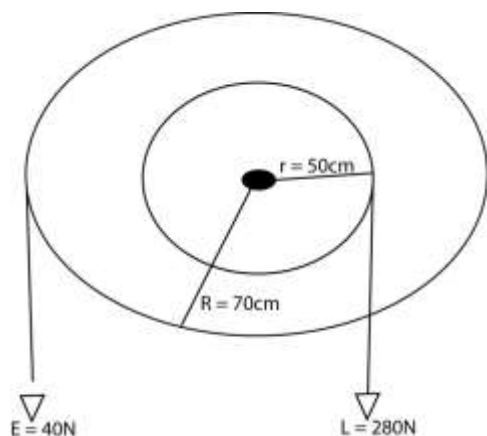
$$(b) \text{ efficiency} = \frac{M.A}{V.R} \times 100$$

$$= \frac{L}{E} \times \frac{1}{V.R} \times 100 = \frac{900}{300} \times \frac{1}{4} \times 100 = 75\%$$

Example 8

A wheel and axle is used to raise a load of 280N by a force of 40N applied to the rim of the wheel. If the radii of the wheel and axle are 70cm and 5cm respectively, calculate the M.A, V.R and the efficiency.

Solution



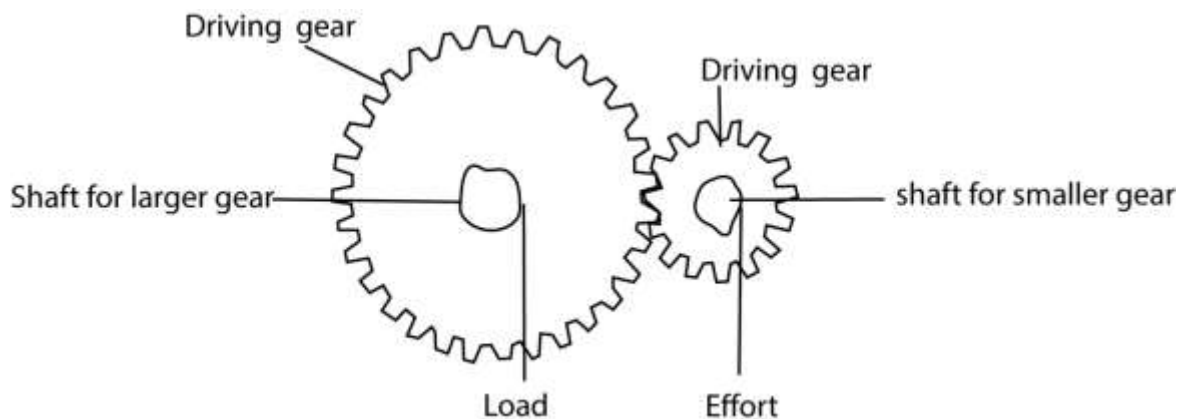
$$M.A = \frac{\text{load}}{\text{effort}} = \frac{280}{40} = 7$$

$$V.R = \frac{R}{r} = \frac{70}{50} = 14$$

$$\text{Efficiency} = \frac{M.A}{V.R} \times 100 = \frac{7}{14} \times 100 = 50\%$$

Gears

A gear is a device which consists of a set of toothed wheels. Gears change the direction and speed of rotation. They are similar to wheel and axle. In gear wheel, the effort and the load are applied to the shafts connected to gear.



$$\text{Velocity ratio} = \frac{\text{Number of teeth in the driven wheel}}{\text{Number of teeth in the driving wheel}}$$

The velocity ratio of gears depends on which gear wheel is the effort applied.

Torque may be applied to the smaller gear in order to increase the torque and decrease the rate of rotation of the larger gear.

Or

Torque may be applied to the larger gear in order to decrease torque and increase the rate of rotation in the smaller gear.

Example 9

Two gear wheels A and B with 20 and 10 teeth respectively lock into each other. They are fastened on axles of equal diameter such that a weight of 100N attached to a string wound around one axle raises a load of 160N attached to a string wound around the other axles.

Calculate

(a) (i) the velocity ratio

(ii) The efficiency of the system when a small gear wheel is the driven gear

(b) (i) the velocity ratio

(iii) The efficiency of the system when a big gear wheel is the driven gear

Solution

$$(a) \text{ i) } V.R = \frac{\text{Number of teeth in the driven wheel}}{\text{number of teeth in the driving wheel}} = \frac{10}{20} = 0.5$$

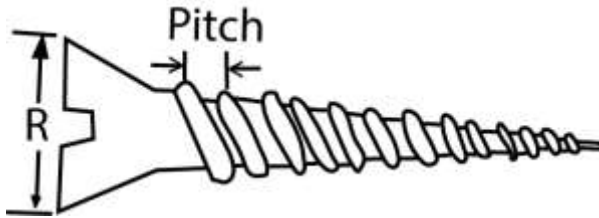
$$(ii) \text{ Efficiency, } n = \frac{M.A}{V.R} \times 100 = \frac{L}{E} \times \frac{1}{V.R} \times 100 = \frac{160}{100} \times \frac{1}{0.5} \times 100 = 320\%$$

$$(b) \text{ (i) } V.R = \frac{\text{Number of teeth in the driven wheel}}{\text{number of teeth in the driving wheel}} = \frac{20}{10} = 2$$

$$(ii) \text{ Efficiency, } n = \frac{M.A}{V.R} \times 100 = \frac{L}{E} \times \frac{1}{V.R} \times 100 = \frac{160}{100} \times \frac{1}{2} \times 100 = 80\%$$

The screw

A screw may be considered as continuous inclined plane wound round a cylindrical threaded rod.



- The distance between two successive threads is called a pitch
- In one revolution, the screw moves forward (or backward) through a distance of equal to one pitch.
- Effort distance equals the circumference of the screw head ($2\pi R$)
- Load distance equals the length of the pitch.
- When a screw is combined with lever can be uses as a jack for lifting heavy loads such cars

The velocity ration of screws

The V.R of the screw is given by the formula = $\frac{\text{Distance moved by the effort}}{\text{distance move by the load}}$

$$V.R = \frac{2\pi R}{\text{screw pitch}}$$

$$\text{M.A of screw} = \frac{2\pi R}{\text{screw pitch}} \text{ (ignoring friction)}$$

Example 10

- (a) In a screw jack the length of the handle is 24cm and the screw pitch is 2mm.if it is used to raise a car of mass 2000kg, calculate
- The effort required
 - The V.R
 - The M.A
- (b) Comment the value of M.A obtained in (a)(iii) above
(Take $g = 10\text{ms}^{-2}$, $\pi = 3.14$)

Solution

$$L = 24 \text{ cm} = \frac{24}{100} = 0.24\text{m}, \text{ pitch} = 2\text{mm} = \frac{2}{1000} = 0.002\text{m}, L = 2000 \text{ kg} = 2000 \times 10 = 20000\text{N}, E = ?$$

$$(i) \quad \text{Effort} \times 2\pi l = \text{Load} \times \text{screw pitch}$$

$$\begin{aligned} \text{Effort} &= \frac{\text{Load} \times \text{screw pitch}}{2\pi l} \\ &= \frac{20000 \times 0.002}{2 \times 3.14 \times 0.24} = 26.54\text{N} \end{aligned}$$

$$(ii) \text{ and } (ii) \quad V.R = M.A = \frac{2\pi l}{\text{screw pitch}} = \frac{2 \times 3.14 \times 0.24}{0.002} = 753.6$$

(b) $MA = VR$ because the screw jack is assumed to be perfect, i.e. frictionless

NB in practice the effort must be higher than 26.54N in order to overcome friction

Example 11

A car weighing 1600 kg is lifted with a jack-screw of 11mm pitch. If the handle is 28cm from the screw, find the force applied.

Solution

$$V.R \text{ of the screw} = \frac{\text{circumference of the handle}}{\text{Pitch}}$$

$$\text{Neglecting friction, } MA = VR = \frac{L}{E}$$

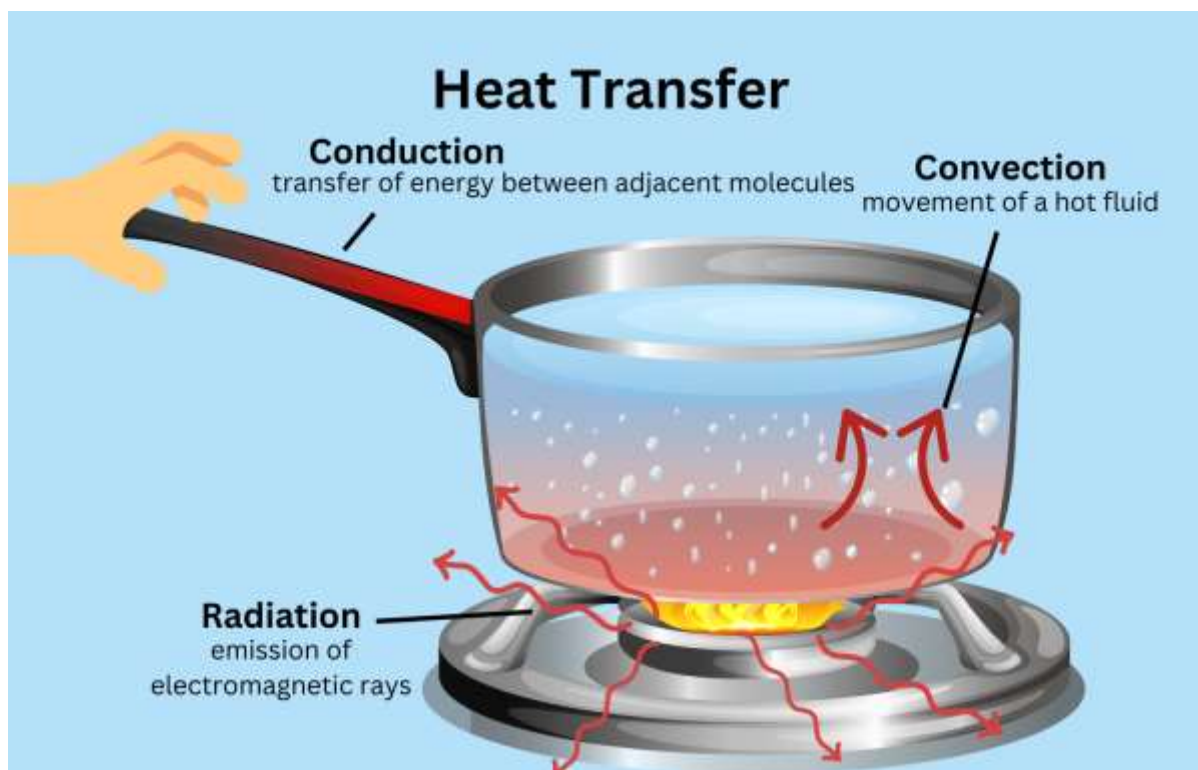
$$\frac{1600}{E} = \frac{2\pi R}{\text{pitch}} = \frac{2 \times 3.14 \times 0.28}{0.011}$$

$$E = 10\text{N}$$

THEME: SCIENCE AND ENERGY

TOPIC 13: HEAT TRANSFER

Competency: The learner understands the modes of heat transfer and their application



Heat transfer

Heat transfer is the flow of heat energy from a region of high temperature to a region of low temperature. There are three ways by which heat can be transferred namely;

- Conduction
- Radiation
- Convection.

Conduction

Conduction is the flow of heat through matter from a region of higher temperature to one of lower temperature without movement of matter as a whole

Conduction in Solids

Heat transfer in Solids can occur as a result of;

- (i) Excess energy of vibrations being passed from one atom to another.
- (ii) The excess Kinetic energy given to the free electrons near the source of heat is carried by these electrons as they move to colder region.

Note:

For heat to be transferred by conduction there should be a material medium. Metals are good conductors of heat because metals are made up of atoms having free electrons that are loosely held.

Examples of metals which are good conductors are:

1. Aluminum 2. Iron 3. Copper.

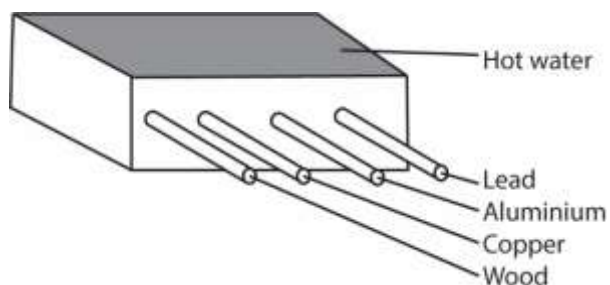
- New utensils or kettles, Saucepans boilers, radiators are made of metals because metals are good conductors of heat as their atoms have free electrons that are loosely held.
- Non-metals, according to Kinetic theory do not have free electrons that are loosely held so that heat does not pass through them easily.
- This is why non-metals are called bad conductors or insulators e.g. plastics, cork, wood.

Rate of heat transfer

The rate of heat transfer along a metal bar depends on the following factors:

- (i) Type of metal: Some metals are better conductors of heat than others.
- (ii) The temperature difference (gradient) between the ends.
- (iii) The length; short metals conduct faster than long metal
- (iv) Cross section area of the metal bar. Metals with large cross section area conduct heat much faster than metal with small cross section area.

Comparing the conductivities of different metals.

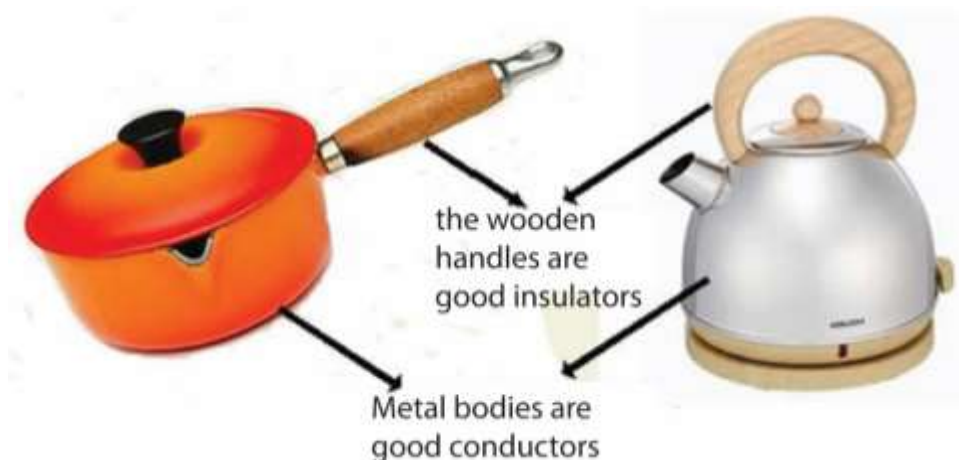


The rate of conduction is compared by dipping the ends of four rods coated with wax in hot water. The rods are identical but made of different materials.

After a short while, the wax begins to melt along the rods. It melts fastest along the copper rods and slowest along wood.

This shows that copper is the best conductor and wood is the poorest of them.

Bad and Good conductors and their applications



- (i) Good conductors are materials that allow heat or electricity to pass through them easily.

Applications of good conductor of heat

Good conductors of heat play a crucial role in many every day and industrial applications. Here are some key uses:

- **Cooking utensils and cookware:** Materials like copper and aluminum are used in pots, pans, and kettles to ensure quick and even heating. Copper is one of the best conductors but aluminium is usually used in making cooking utensils because it is much cheaper.
- **Heat exchangers:** Used in air conditioning, refrigeration, and power plants to efficiently transfer heat between two mediums.
- **Electronics cooling:** Metal heat sinks in computers and other electronic devices help dissipate heat to prevent overheating.
- **Automobile engines:** Engine components, including radiators, use metals like aluminum to effectively manage and dissipate heat.
- **Manufacturing and metalworking:** Industries use heat-conductive materials for welding, forging, and molding processes.
- **Solar energy systems:** Copper and aluminum play an essential role in solar panels and water heating systems, helping absorb and transfer heat efficiently.
- **Medical applications:** Devices like surgical tools and heat therapy equipment rely on excellent heat conduction for functionality.

A metal always feels cold when touched on a cold day because it loses heat from the body and transfers it to the surrounding very fast.

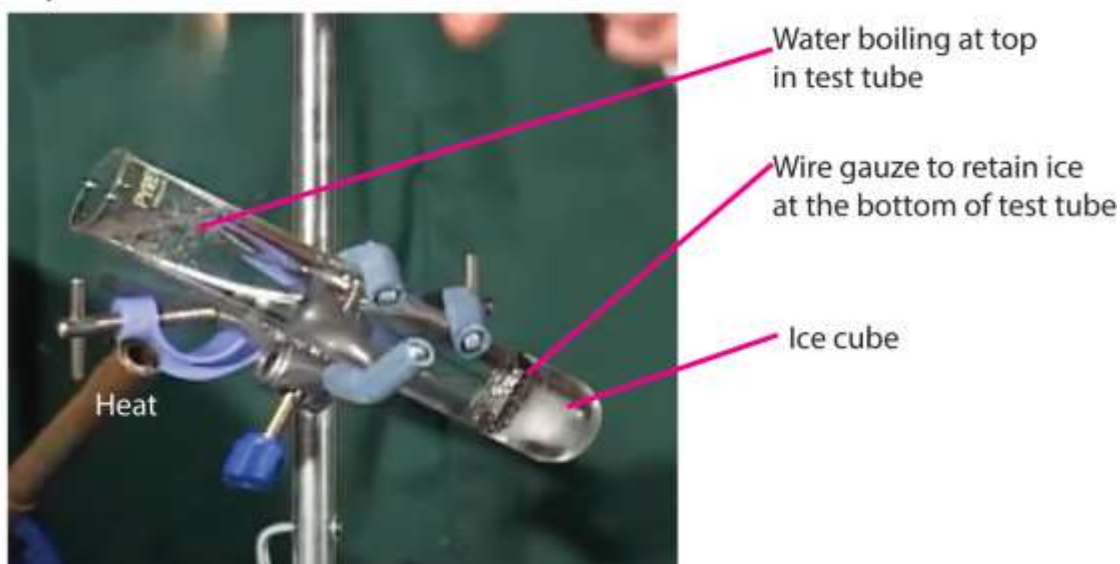
- (ii) Bad conductors also called Insulators are materials that do not allow heat or electricity to pass through them easily.

Application of insulators in daily life

Insulators play a crucial role in protecting us from heat, electricity, and sound in everyday life.

- **Cooking utensils:** Handles of pots and pans are often made of wood or plastic to prevent burns.
- **Home insulation:** Materials like fiberglass and foam help maintain indoor temperatures by reducing heat transfer.
- **Clothing:** Wool, fleece, and thermal fabrics trap body heat, keeping us warm in cold weather.
- **Automobile interiors:** Special insulating materials help reduce heat and noise inside vehicles.
- **Building construction:** Walls, ceilings, and floors use insulators to improve energy efficiency and soundproof rooms.
- **Refrigerators and freezers:** Insulated walls help retain cold temperatures and save energy.
- **Soundproofing:** Foam and other materials are used in studios, theaters, and homes to minimize noise pollution.
- **Medical applications:** Insulating materials are used in protective gloves, surgical tools, and medical storage.

Experiment to show that water is a bad conductor of heat



Ice is placed in a test tube, followed a wire gauze and water and heated as shown above

Observations

Water boils at the top while ice remains at the bottom

Conclusion

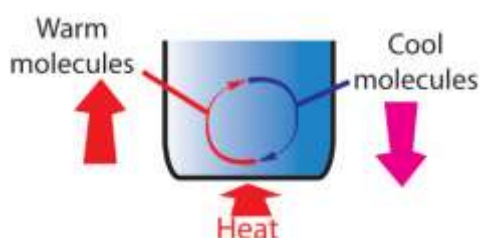
Water is a poor conductor of heat because heat transfer does not occur between boiling water to melt the ice

Convection

Convection is the flow of heat through fluid from a region of higher temperature to one of lower temperature by the movement of the fluid itself. Heat transfer by convection occurs in liquids and gases or fluids.

Convection current

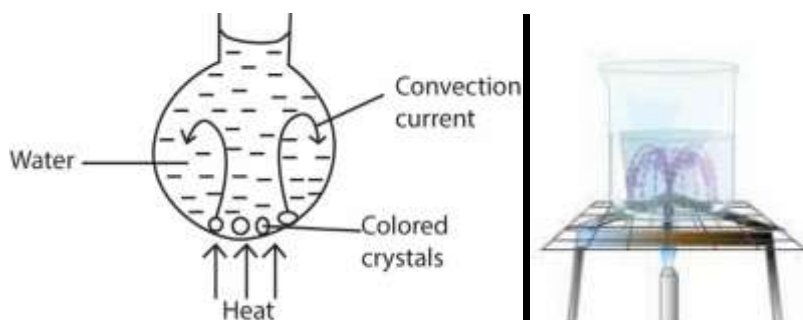
Convection current is the cyclic motion of rising hot fluid and falling cold fluid.



Explanation of convection current.

When the fluid is heated it expands and becomes less dense. The heated fluid is forced upward by the surrounding cooler fluid which moves under it. As the warm fluid rises, it gives heat to the surrounding cooler fluid.

Experiment to demonstrate convection current in liquids



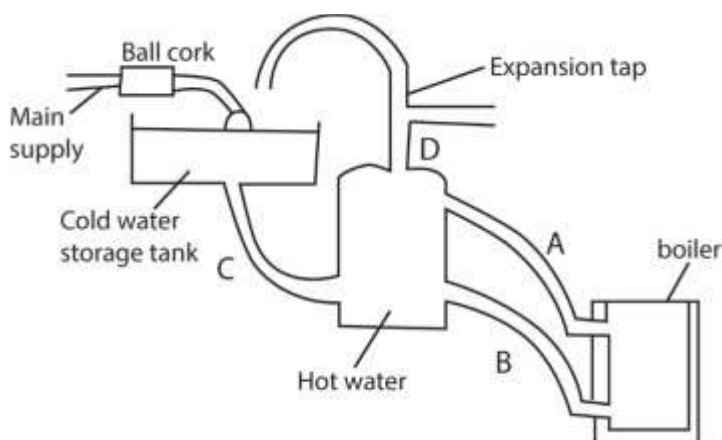
When the flask is heated from the bottom as shown, the colored solution of water raises upwards from the crystals and on reaching the top, it spreads as shown in the diagram. The

solution raises because on heating, it expands and becomes less dense, so it is forced upwards by the nearby cooler water,

Difference between convection and conduction

Conduction	Convection
Heat is transferred from a region of higher temperature to that of lower temperature without the movement of matter itself	Heat is transferred from a region of higher to one of lower the temperature by movement of matter as a whole.

Application of convection current to Hot water Domestic supply system.



How it works

(a) Boiler

When working a convection current of less dense hot water from the boiler raises up through pipe A to the hot water tank. At the same time the denser cold water flows through pipe B from the hot water tank to the boiler.

(b) Circulation

A circulation is set up in the hot water tank involving filling hot water from top downwards. When a volume of hot water flows to the hot water tank through pipe A, an equal volume of cold water flows to the boiler through pipe B. At the same time an equal volume flows through pipe C to the hot water tank.

Pipe A leaves the boiler at the top and enters the hot water tank at the top because it carries less dense hot water

Pipe B is connected to the bottom of the hot water tank and to the bottom of the boiler because it carries more dense cold water,

The expansion pipe D allows escape:

- (i) of dissolved air which comes out of the water when it is heated.
- (ii) of steam, if the water is boiled.

If the expansion pipe is not there;

- (i) The dissolved air which comes out when water is heated causes air-lock in the pipe,
- (ii) The steam if the water is boiled causes explosion.

Convection in gases

Convection in gases produces wind, sea and breezes

Convection currents

Convection currents in the atmosphere are caused by uneven heating of the Earth's surface, leading to rising warm air and sinking cool air. These currents drive cloud formation, winds, storms, and long-term climate patterns.

Causes of Convection Currents

- ❖ **Solar heating:** The Sun heats the Earth's surface unevenly (land vs. water, equator vs. poles).
- ❖ **Density differences:** Warm air becomes less dense and rises; cool air is denser and sinks.
- ❖ **Surface variations:** Dark soil, rocky terrain, or urban areas heat faster than forests or oceans.
- ❖ **Moisture content:** Humid air rises more easily, fueling cloud formation.
- ❖ **Geography:** Mountains, valleys, and coastlines influence local convection patterns.

Effects of Convection Currents

- ❖ **Cloud formation:** Rising warm air cools and condenses into cumulus or cumulonimbus clouds.
- ❖ **Thunderstorms:** Strong convection creates heavy rain, lightning, and hail.
- ❖ **Wind patterns:** Air movement redistributes heat, forming breezes and trade winds.
- ❖ **Rainfall distribution:** Convection drives tropical rainfall and monsoons.
- ❖ **Temperature regulation:** Helps balance heat between equator and poles.

Relation to Weather and Climate

- ❖ **Daily weather:** Afternoon thunderstorms in tropical regions (like Uganda) are caused by strong surface heating.
- ❖ **Seasonal climate:** Monsoons and wet/dry seasons depend on convection-driven circulation.
- ❖ **Global climate:** Large-scale convection cells (Hadley, Ferrel, Polar) shape wind belts and rainfall zones worldwide.
- ❖ **Extreme events:** Hurricanes, cyclones, and tornadoes are powered by intense convection.

Summary Table

Cause	Effect	Weather/Climate Impact
Solar heating	Warm air rises	Afternoon storms
Density differences	Cool air sinks	Wind circulation
Moisture	Clouds form	Rainfall
Surface variations	Uneven heating	Local breezes
Geography	Airflow altered	Mountain rains

Key Insight

Convection currents are the **engine of weather and climate**. They explain why Uganda experiences **afternoon thunderstorms**, why monsoons bring seasonal rains, and why global wind belts distribute heat across the planet.

Radiation

Radiation is the flow of heat from one place to another by means of electromagnetic waves. Heat energy is transferred from the sun to the earth by means of radiation. Radiation is the means by which heat can travel through the vacuum.

Note

The energy from the hot body is called Radiant energy.

The heat transfer by radiation does not need a material medium,

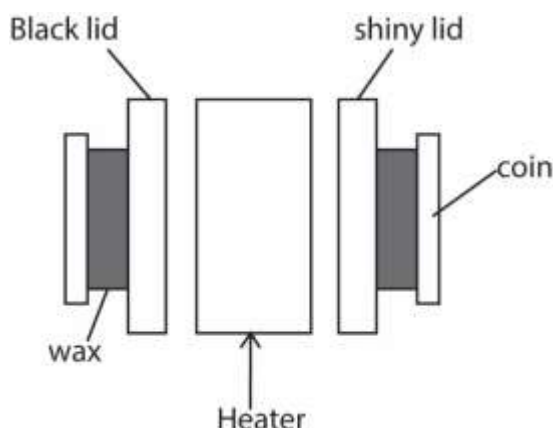
Radiation is emitted by all bodies above absolute Zero.

Good and bad absorbers

Shiny surfaces are bad absorbers of radiation while dull black surfaces are good absorbers.

This implies that shiny surfaces reflect most of the heat radiations instead of absorbing. The dull black surfaces absorb most of the heat radiations and reflect very few.

Experiment to show absorbing of radiations in surfaces



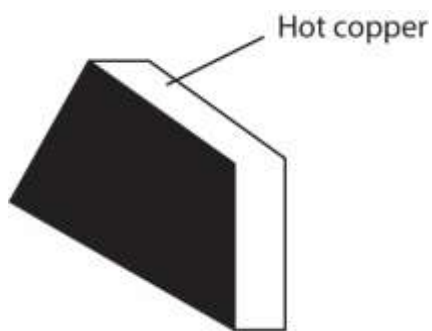
When the heater is placed midway as shown above so that the same amount of radiation is received by the two surfaces. It will be observed that after a few minutes the wax on the

black lid melts and the coin falls off before that of the shiny lid. This indicates that dull black surfaces are better absorbers.

Application of absorbers

- (i) Buildings in hot countries are painted white and roof surfaces are shiny because white and shiny surfaces are bad absorbers of heat radiation.
- (ii) Reflectors on electric devices are made up of polished metals because they have good reflecting properties.

Good and Bad emitter



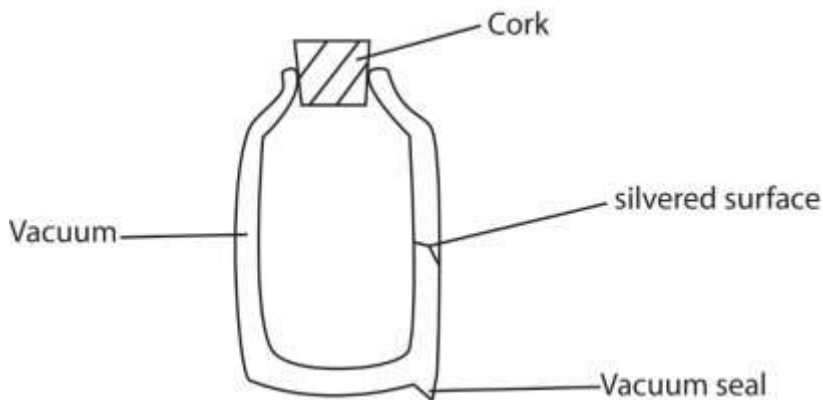
If the backs of the hands are held on either side of the sheet, one first feels much heat from the black surface. This shows that a black surface is a better emitter of heat than a shiny one.

In short, black surfaces are good absorbers as well as good emitters of heat radiations. Shiny surfaces or polished surfaces are bad absorbers as well as bad emitters of heat radiations.

Applications

- (i) Cooling fins on the heat exchanger of refrigerators are painted black so that they emit heat more quickly,
- (ii) Tea pots and kettles are polished so that they keep heat longer as polished surfaces are poor emitters of heat radiation.

Vacuum flask



A thermos flask also called vacuum flask keeps hot liquids hot and cold liquids cold. This is because heat losses and gain are minimized.

Heat losses by conduction; convection and radiation are minimized by the Vacuum flask as follows:

- Conduction and Convection are minimized by the Vacuum since for heat to be transferred by these ways, a material medium is required.
- Convection from the hot liquid upward to the outside is reduced by the cork which also reduces heat losses by conduction because it is a poor conductor of heat.
- Radiation is also minimized by the two silvered surfaces since they are bad emitters.

However, when a hot liquid is kept in the vacuum flask for a long time, it cools because at a small rate, heat is lost by conduction convection and radiation.

Examples of Heat Radiation in Daily Life

- Sunlight warming Earth:** The Sun radiates heat that warms land, water, and air — essential for life.
- Fireplace or bonfire:** Heat radiates outward, warming people nearby without direct contact.
- Electric heaters:** Radiant heaters emit infrared waves that warm objects and people directly.
- Cooking:** Microwaves and ovens use radiation to heat food.

- (v) **Human body:** Our bodies radiate heat, which can be detected by infrared cameras and thermometers.
- (vi) **Car parked in the sun:** Radiation heats the interior, making it hot even if windows are closed.
- (vii) **Campfire embers:** Glowing coals radiate heat long after flames die down.

Applications of Heat Radiation

Example	Application	Benefit
Sunlight	Solar panels	Renewable energy
Fireplace	Home heating	Comfort in cold weather
Electric heater	Indoor heating	Direct warmth
Cooking	Microwave ovens	Fast food preparation
Human body	Thermal imaging	Medical & security uses
Car in sun	Passive heating	Demonstrates greenhouse effect

Everyday Importance of radiation

- **Solar energy:** Radiation powers solar panels, reducing reliance on fossil fuels.
- **Weather and climate:** Radiation from the Sun drives atmospheric circulation and climate.
- **Medical technology:** Infrared thermometers and scanners rely on body heat radiation.
- **Safety:** Thermal cameras detect fires or intruders by spotting heat radiation.

Key Insight

Heat radiation is a **silent, invisible energy transfer** that warms us, cooks our food, powers solar technology, and even helps in medicine and security. It's one of the most vital processes linking the Sun, Earth, and human life.

Greenhouse effect

The **greenhouse effect** is the process by which certain gases in Earth's atmosphere trap heat from the sun, preventing it from escaping into space. This natural phenomenon helps maintain Earth's temperature, making it habitable. However, human activities—such as burning fossil fuels—have increased greenhouse gas concentrations, leading to global warming

Global warming

Global warming refers to the long-term increase in Earth's average surface temperature due to human activities, primarily the burning of fossil fuels, deforestation, and industrial emissions. This leads to the accumulation of greenhouse gases like carbon dioxide and methane, which trap heat in the atmosphere.

Consequences of global warming

The consequences of **global warming** are far-reaching and impact ecosystems, weather patterns, and human societies. Some key effects include:

- (i) **More frequent and severe weather:** Rising temperatures intensify storms, heat waves, floods, and droughts, leading to widespread damage.
- (ii) **Melting ice and rising sea levels:** The Arctic is warming **four times faster** than the rest of the planet, causing ice loss and unpredictable weather patterns.
- (iii) **Threats to biodiversity:** Many species struggle to adapt to changing climates, leading to habitat loss and extinction risks.
- (iv) **Food and water shortages:** Droughts and extreme weather disrupt agriculture and freshwater supplies, affecting food security worldwide.
- (v) **Health risks:** Increased heat waves, air pollution, and disease outbreaks pose serious health concerns for vulnerable populations.
- (vi) **Economic impacts:** Climate-related disasters cost billions in damages, affecting infrastructure, agriculture, and global economies.

Revision questions

1. (a) Differentiate between conduction and radiation.
(b) Describe an experiment to show convection in liquids
2. Explain how vacuum flask minimizes heat losses.
3. Describe an experiment to show how the heat radiated from hot object depends on the nature of the surface.
4. Explain the followings
 - (a) Metals feel colder on touch
 - (b) A cool breeze blows from the sea on hot day

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