CHAPTER 9 : Motion

Key Points and Concepts

- **Motion** is a change of position with respect to time. It can be described in terms of the distance moved or the displacement.
- If the position of an object does not change with time, it is said to be at rest.
- A physical quantity which has both magnitude and direction is called as **vector quantity**.
- A physical quantity which has only magnitude is called as **scalar quantity**.

Quantity (Type)	S.I. Unit
Mass (Scalar)	kg
Distance (Scalar)	metre (m)
Displacement (Vector)	metre (m)
Speed (Scalar)	m/s
Velocity (Vector)	m/s
Acceleration (Vector)	m/s^2

- The motion of an object could be uniform or non-uniform depending on whether its velocity is constant or changing.
- Understanding uniform motion in straight line and in circular path :

	Uniform motion in straight line	Uniform motion in circular path
(a)	The direction of motion of object does not change.	Direction changes continuously.
(b)	If an object moves with a constant speed, its acceleration is zero.	Acceleration is not zero even on moving with constant speed.

- **Speed** is the ratio of distance travelled to the time taken to cover that distance. S.I. unit of speed is m/s.
- **Average speed** of a body is the total distance travelled divided by the total time taken.
- **Velocity :**

$$\text{Velocity} = \frac{\text{Distance travelled in a specified direction}}{\text{Time taken}}$$

$$v = \frac{s}{t}$$ [Where 's' is the displacement and 't' is the time taken]

- **Average velocity** is the total displacement divided by the time taken.

- **Acceleration :**

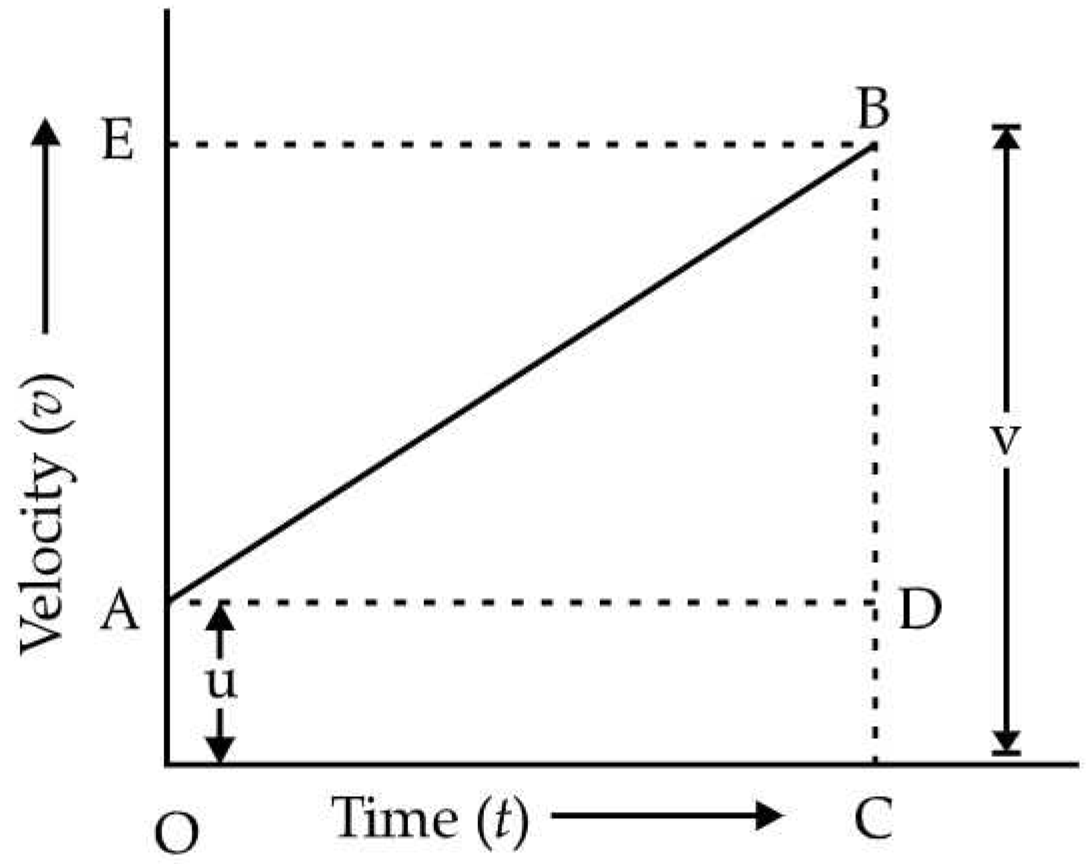
$$\text{Acceleration} = \text{Rate of change of velocity with time}$$

$$= \frac{\text{Change in velocity}}{\text{time}}$$

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

- Area of velocity time graph gives the value of displacement.
- If an object moves in a circular path with uniform speed, its motion is called **uniform circular motion**.

Important Equations



- **First Equation of Motion :**

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time}}$$

$$\Rightarrow \quad a = \frac{BD}{AD} = \frac{BD}{OC}$$

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

$$at = v - u \qquad \text{...(1)}$$

$$v = u + at \qquad \text{...(A)}$$

- **Second Equation of Motion :**

Area under velocity – time curve gives displacement

$$s = \text{area of rectangle } OADC + \text{area of triangle } ABD$$

$$= OA \times AD + \frac{1}{2} \times AD \times BD$$

$$= u(t-0) + \frac{1}{2}(t-0)(v-u) \qquad \text{...(2)}$$

Using equation (1) and (2)

$$s = ut + at^2 \qquad \text{...(B)}$$

- **Third Equation of Motion :**

Area under velocity – time curve gives displacement

$$s = \text{area of trapezium OABC}$$

$$= \frac{1}{2}(OA + BC) \times OC$$

$$= \frac{1}{2}(u + v) \times (t-0)$$

$$= \frac{1}{2}(v + u)t \qquad \text{...(3)}$$

Using first equation of motion

$$v = u + at$$

$$t = \frac{(v-u)}{a} \qquad \text{...(4)}$$

Using equation (4) in (3)

$$s = \frac{1}{2}\frac{(v+u)(v-u)}{a}$$

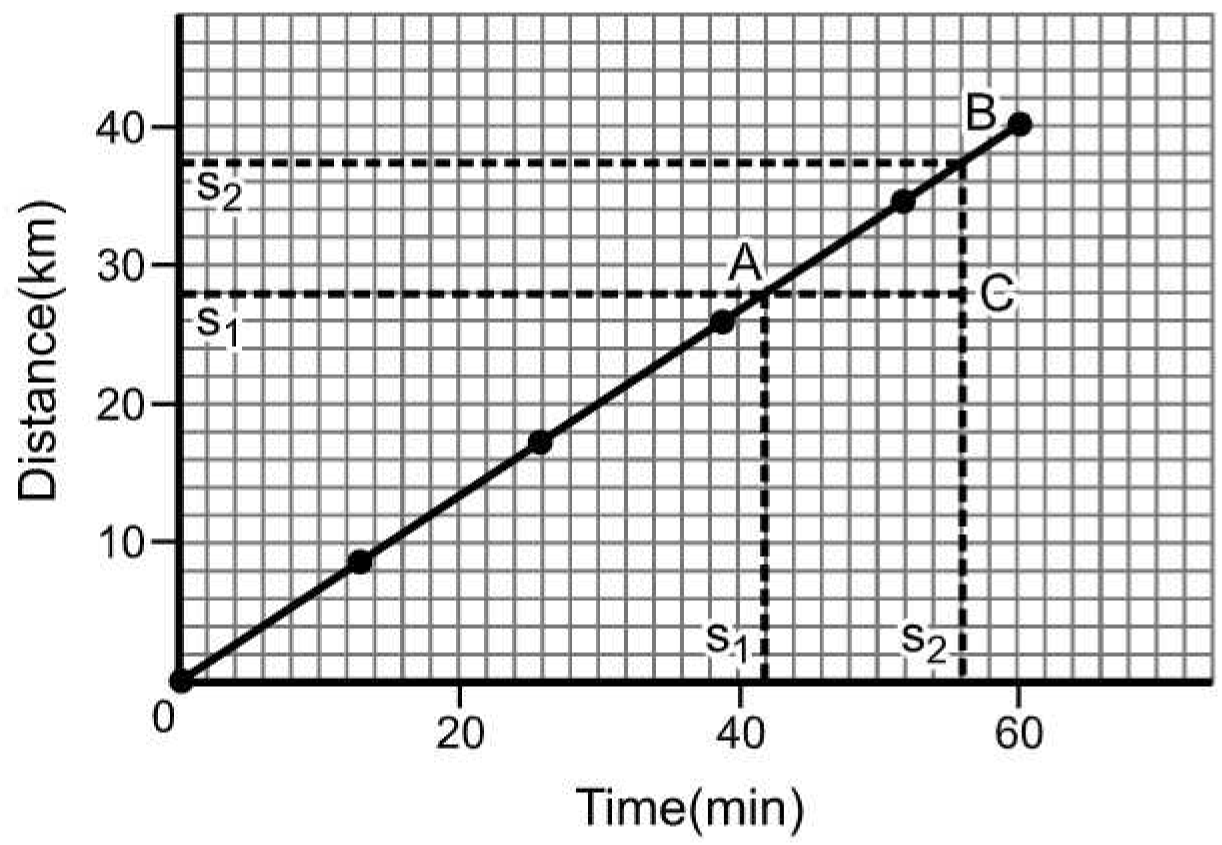
Using the identity $(A^2 - B^2) = (A - B)(A + B)$

$$2as = v^2 - u^2$$

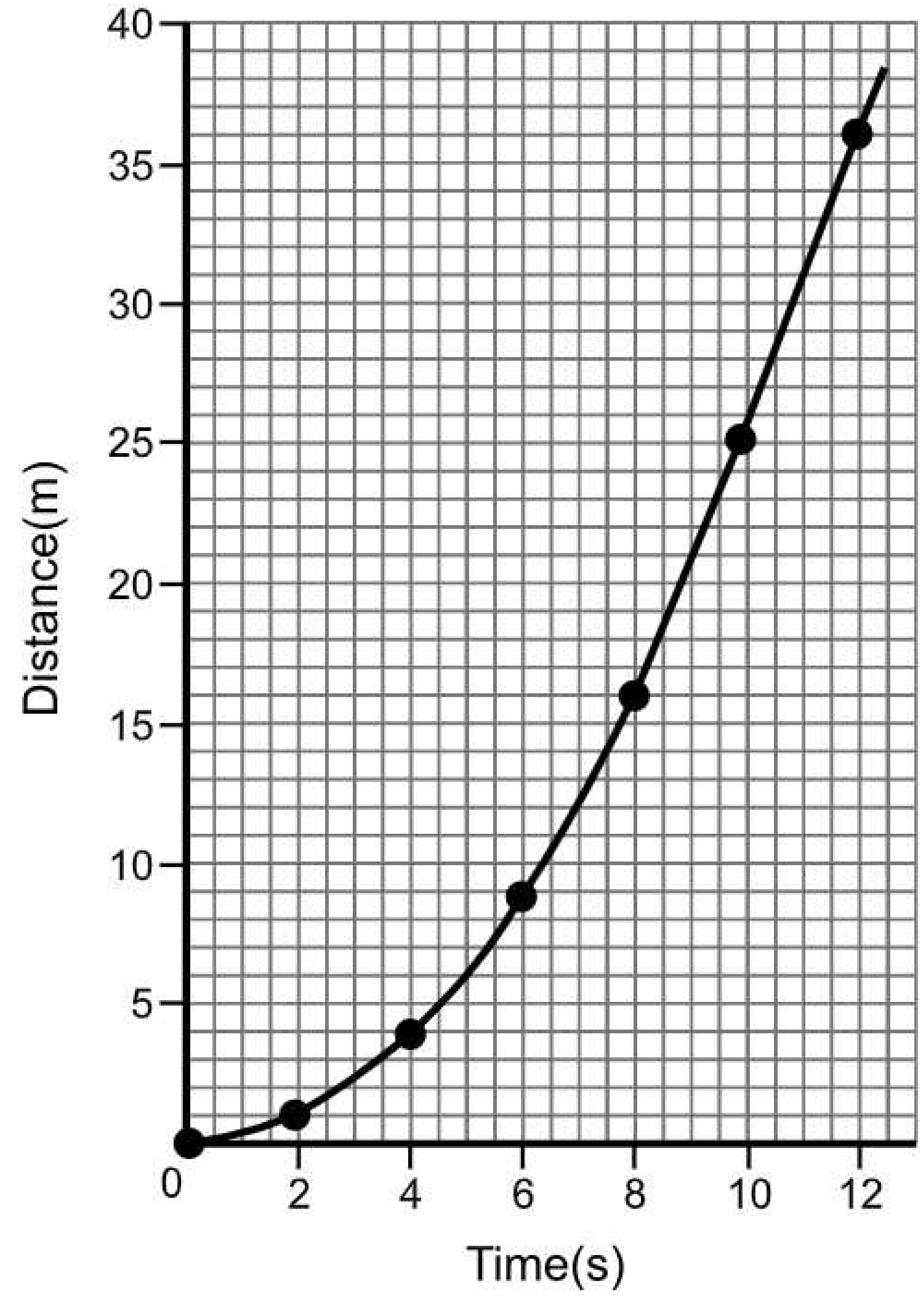
$$v^2 = u^2 + 2as \qquad \text{...(C)}$$

<u>**Important Graphs and Diagrams**</u>

- **Distance Time Graph of an object moving with uniform speed (linear) and non-uniform speed (non-linear) :**

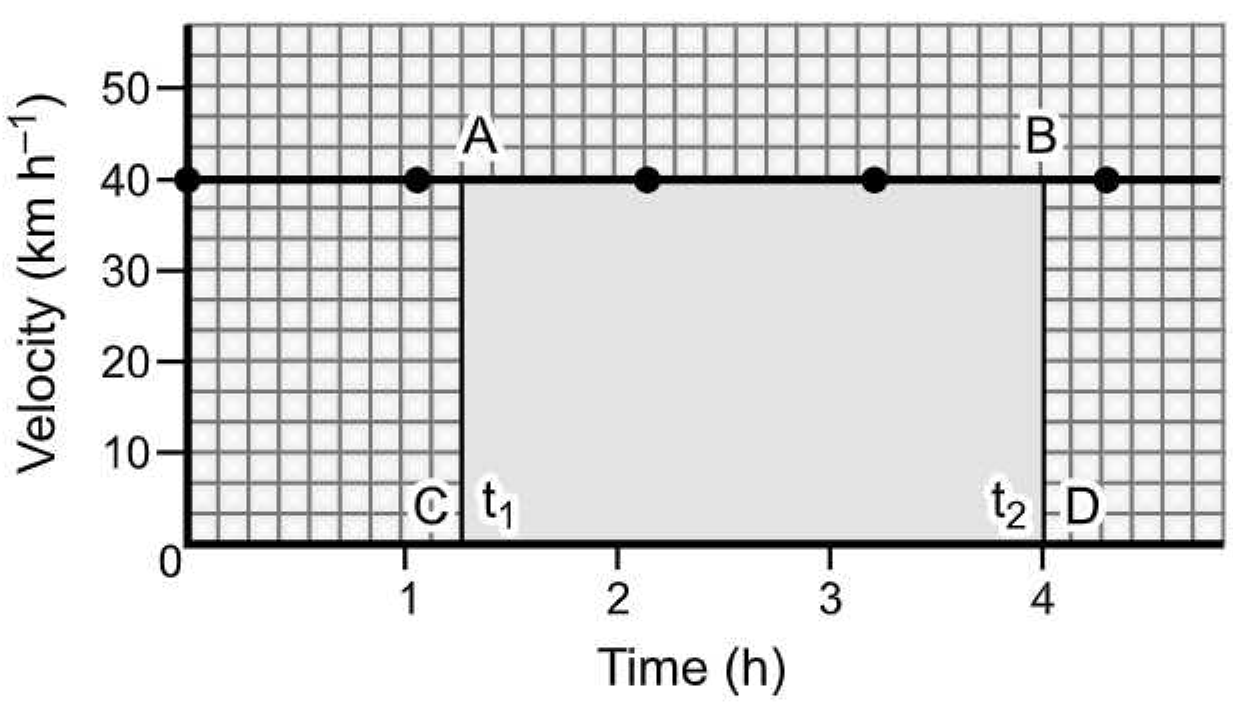


Uniform speed

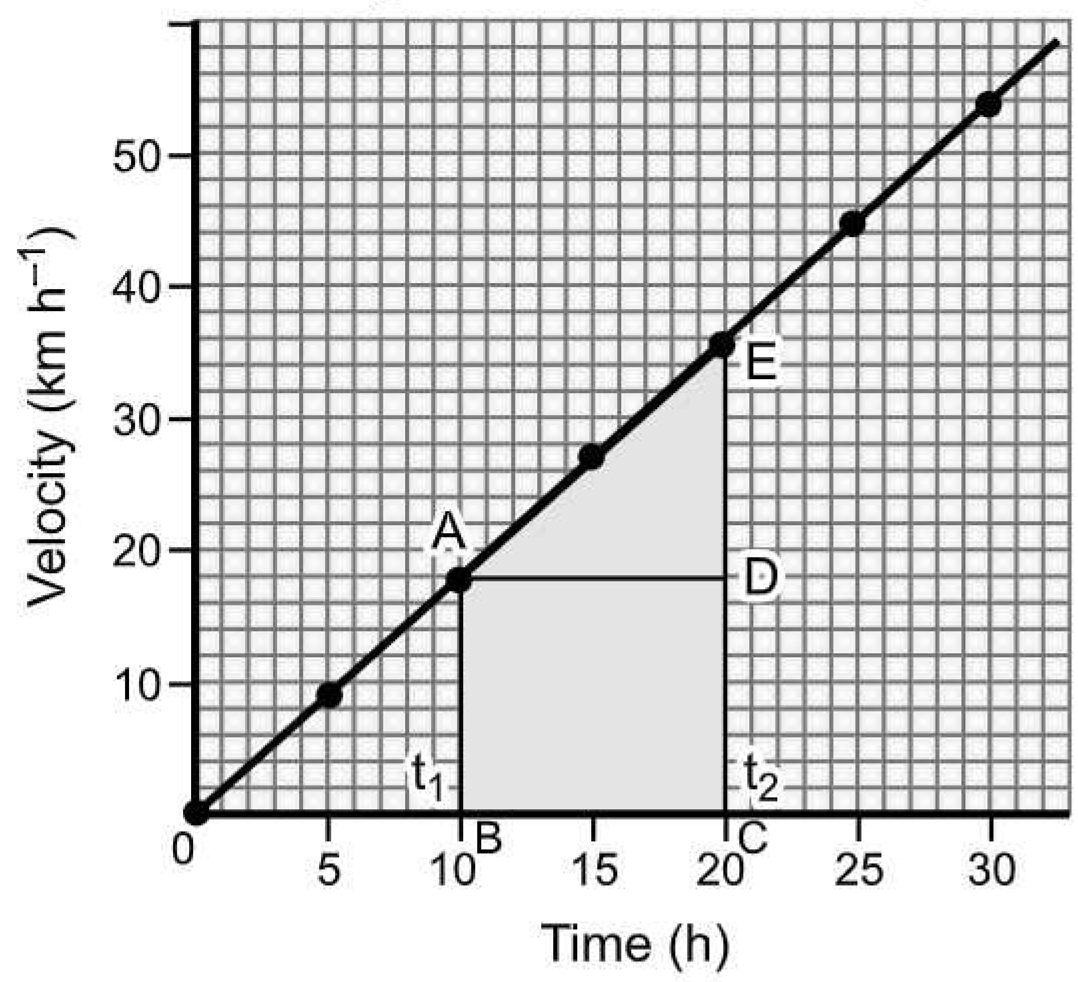


Non-Uniform speed

- **Velocity Time Graph for no acceleration and uniform acceleration (positive acceleration) :**

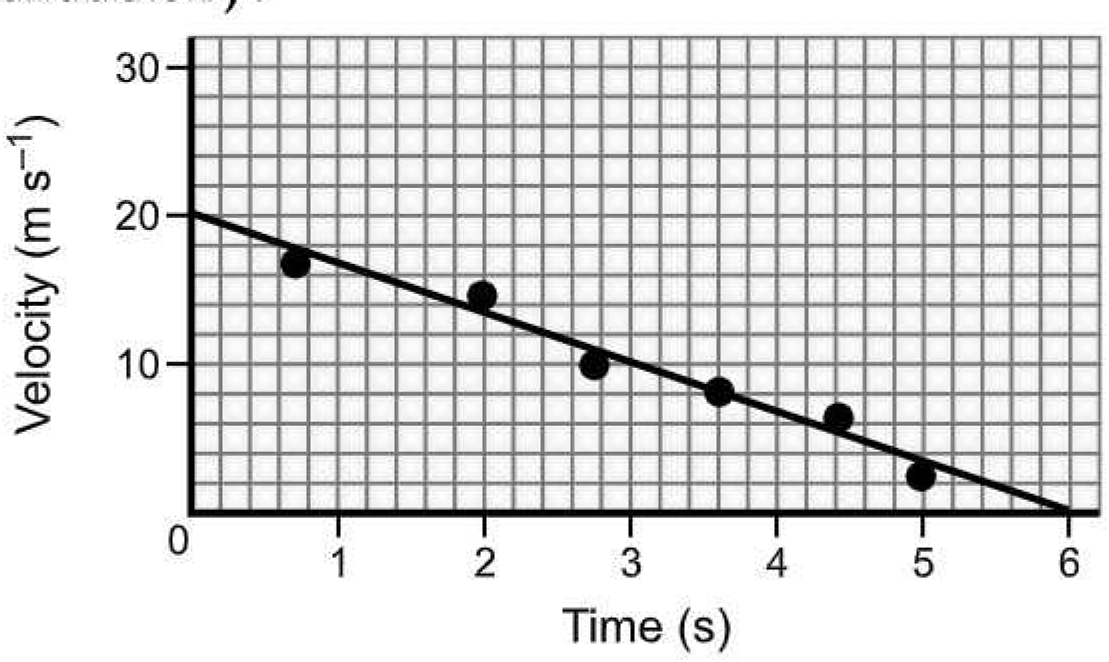


No acceleration

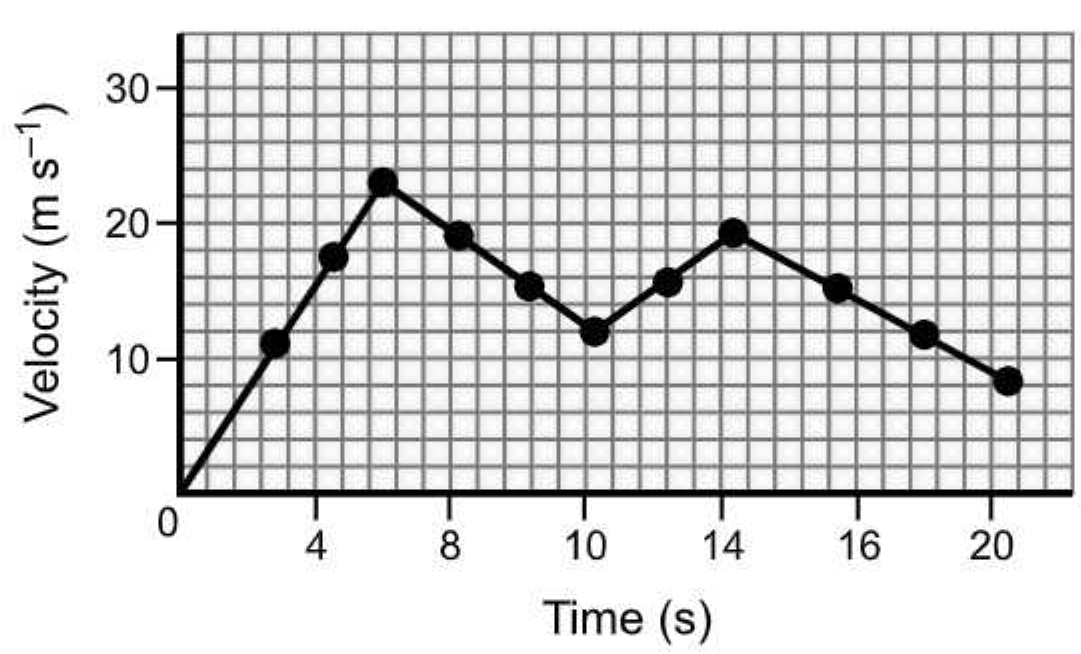


Uniform acceleration

- **Velocity Time Graph for non-uniformly accelerated motion (the first graph shows negative acceleration *i.e.* retardation) :**



Motion of an object whose velocity is decreasing with time



Non-uniform variation of velocity of the object with time

CHAPTER 10 : Force and Laws of Motion

Key Points and Concepts

- **Force** is a push or pull acting upon an object. It is also defined as the product of mass and acceleration.
- SI unit of force is kg m s^{-2}. This is also known as Newton and represented by the symbol N.
- **Difference between Balanced and Unbalanced Force :**

S.No.	Balanced force	Unbalanced force
(i)	The net effect produced by a number of forces on the body is zero.	The net effect produced by a number of forces on the body is non-zero.
(ii)	It can only bring a change in the shape of the body	It causes a change in state of rest or of uniform motion of the body.
(iii)	Example : Tug of war.	Example : Moving an object.

- **Newton's first law of motion :** An object continues to be in a state of rest or a body in motion will remain in uniform motion along a straight line unless acted upon by an unbalanced force.
- **Newton's second law of motion :** The rate of change of momentum of an object is directly proportional to the force and takes place in the same direction as the force.
- **Newton's third law of motion :** To every action, there is an equal and opposite reaction and they act on two different bodies.
- The momentum of an object is the product of its mass and velocity and has the same direction as that of the velocity. Its SI unit is kg m s^{-1}.
- **Law of conservation of momentum :** The sum of momentum of the two objects before collision is equal to the sum of momentum after the collision provided there is no external unbalanced force acting on them.
- By the law of conservation of momentum, $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
- The tendency of a body to oppose or resist any change in its state of rest or uniform motion is called **inertia** of the body.
- The tendency of a body to oppose any change in its state of uniform motion is known as **inertia of motion**. E.g., passengers fall forward when a fast moving bus stops suddenly.
- The tendency of a body to oppose any change in its direction of motion is known as **inertia of direction**. E.g., when a fast moving bus negotiates a curve on the road, passengers fall towards the centre of the curved road.
- **Recoil velocity :** The velocity with which the gun moves in the backward direction when fired.

- **Important Quantities**

	Quantity (Type)	S. I. Unit
(i)	Force (Vector)	Kg m/s^2 (or Newton (N))
(ii)	Momentum (Vector)	Kg m/s
(iii)	Acceleration due to gravity (g) (Vector)	m/s^2

- A force of one Newton produces an acceleration of 1 m/s^2 on an object of mass 1 kg.
- Value of g = 9.8 m/s^2
- Force of friction always opposes motion of objects.

Important Equations

- **Derivation of force from Newton's Second Law of Motion :**

  Mathematical formulation : If a body of mass (m), moving with velocity (u) accelerates uniformly for time (t), so that its velocity changes to v, then

$$\text{Initial momentum } p_1 = mu$$

$$\text{Final momentum } p_2 = mv$$

$$\begin{aligned}\text{Change in momentum } &= p_2 - p_1 \\ &= mv - mu \\ &= m(v-u)\end{aligned}$$

According to second law of motion, force

$$F \propto \frac{\text{change in momentum}}{\text{time}}$$

$$F \propto \frac{p_2 - p_1}{t} \qquad \text{we know that}$$

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

$$F = \frac{km(v-u)}{t}$$

$$F = kma \qquad (\text{Here } k = 1)$$

Thus, $$F = ma$$

CHAPTER 11 : Gravitation

Key Points and Concepts

- **Gravitation** is the force of attraction between two objects in the universe.
- **Universal Law of Gravitation :** It states that the force of attraction between two bodies is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.
- Value of Gravitational Constant $G = 6.67 \times 10^{-11}\ Nm^2kg^{-2}$
- Value of acceleration due to gravity (g) $= 9.8\ m/s^2$
- Radius of Earth = 6400 km = 6.4×10^6 m
- **Difference between g and G :**

S. No.	Acceleration due to gravity (g)	Universal gravitational constant (G)
1.	Acceleration due to gravity is the acceleration acquired by a body due to the earth's gravitational pull on it.	Gravitational constant is numerically equal to the force of attraction between two masses of 1 kg that are separated by a distance of 1 m.
2.	g is a vector quantity.	G is a scalar quantity.
3.	It is different at different places on the surface of the earth. Its value also varies from one celestial body to another.	The 'G' is a universal constant i.e., its value is the same (*i.e.* $6.7 \times 10^{-11}\ N\ m^2\ kg^{-2}$) everywhere in the universe.

- The force of gravity decreases with altitude. It also varies on the surface of the earth, decreasing from poles to the equator.
- The state when an object does not weigh anything is called weightlessness.
- **Free fall :** The motion of a body under the influence of force of gravity alone is called a 'free fall'.
- **Quantities :**

Quantity (Type)	S.I. Unit
Mass (Scalar)	kg
Weight (Vector)	kg m/s^2 [or Newton (N)]
Gravitational Force (Vector)	kg m/s^2 [or Newton (N)]
Gravitational Constant (G)	Nm^2/kg^2
Acceleration due to gravity (g) (Vector)	m/s^2

- Mass is the quantity of matter present in the body.
- Weight of the body is the force with which the earth attracts the body.
- Mass of a body does not change but weight of a body is different at different places.
- **Projectile :** Any object thrown into space with some initial velocity and which moves thereafter under the influence of gravity alone is called a 'projectile'. The path of a projectile is a parabola. Its horizontal range is maximum when the angle of projection is 45°.

Important Equations

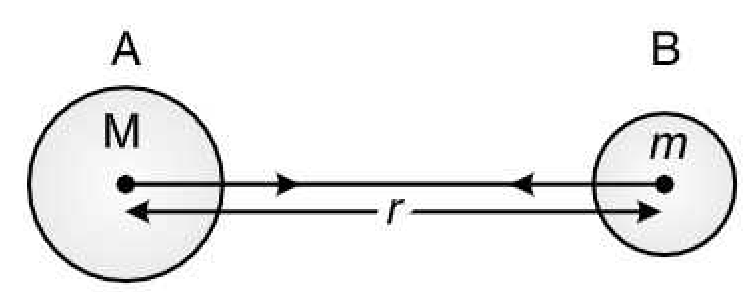
- **Universal Law of Gravitation :**

Let the two bodies 'A' and 'B' be of masses 'M' and 'm' respectively, which are separated by a distance 'r'.

According to Universal law of Gravitation,

Then, $$F \propto M \times m \quad ...(i)$$

and $$F \propto \frac{1}{r^2} \quad ...(ii)$$



Combining (i) and (ii),

$$F \propto \frac{M \times m}{r^2}$$

$$F = G\frac{M \times m}{r^2}$$

where 'G' is called universal gravitational constant.

The numerical value of G = 6.67×10^{-11} Nm^2 kg^{-2}

- **Relation between g and G :**

As we know, according to Newton's law of gravitation, the force of attraction between the earth and the body is given by

$$F = GmM / r^2 \quad ...(1)$$

This force produces an acceleration 'g', called acceleration due to gravity in the body of mass m.

So, from Newton's second law,

$$F = mg \quad ...(2)$$

From equation (1) and (2), we get

$$mg = \frac{GM\,m}{r^2}$$

or $$g = \frac{GM}{r^2} \quad ...(3)$$

- **Calculation for the value of g:**

$$g = \frac{GM}{r^2}$$

$$= \frac{6.67\times10^{-11}\ \text{Nm}^2\ \text{kg}^{-2}\times6\times10^{24}\ \text{kg}}{(6.4\times10^6\ \text{m})^2} = 9.8\ \text{ms}^{-2}$$

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CHAPTER 12 : Floatation

- **Thrust** is the force acting on an object perpendicular to the surface.
- The upward force exerted by a liquid on the body which is immersed in the liquid is known as the **upthrust or buoyant force**.
- Objects having density less than that of the liquid in which they are immersed, floats on the surface of the liquid. If the density of the object is more than the density of the liquid in which it is immersed, then it sinks in the liquid.
- **Archimedes principle :** When a body is immersed partly or completely in a fluid (or liquid) it experiences an upthrust which is equal to the weight of the fluid displaced by the body.
- Density = Mass/Volume
- $\text{Pressure} = \frac{\text{Thrust}}{\text{Area}}$
- $\text{Relative density} = \frac{\text{Density of substance}}{\text{Density of water at 4 °C}} = \frac{\text{Weight of any volume of substance}}{\text{Weight of any volume of water}}$

- **Quantities and Units :**

Quantities	S.I. Units
Volume	m^3
Force	N (Newton)
Pressure	Pa (Pascal) *i.e.*, N/m^2
Thrust	N
Density	Kg/m^3
Relative Density	No unit

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CHAPTER 13 : Work and Energy

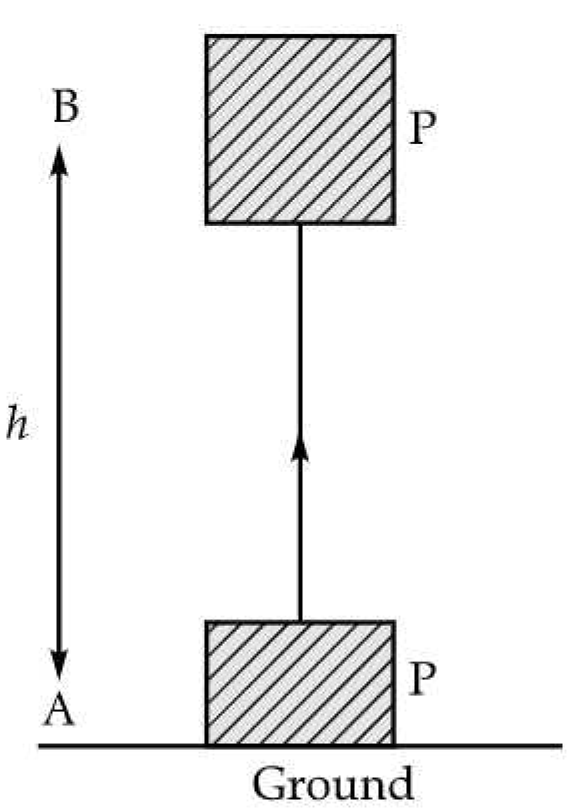
Key Points and Concepts

- **Work** is done when a force acting on a body produces displacement in it. It is equal to the product of force and displacement in the direction of force.
- Work is a scalar quantity. Its SI unit is Joule.
- **One joule** (J) is the amount of work done by an object when a force of one newton displaces it by one metre along the line of action of force.
- Work done is positive, if the angle between force and displacement is acute or when the displacement is in the direction of the applied force.
- Work done is negative, if the angle between force and displacement is obtuse or when the force acts opposite to the direction of displacement.
- Work done on an object by a force would be zero, if the displacement of the object is zero.
- An object having a capability to do work is said to possess energy.
- **Power** is defined as the rate at which work is done.
- **Average power** is obtained by dividing the total energy consumed by the total time taken.
- **Quantities and Units :**

Quantities	SI Units
Work (Scalar)	J (Joule)
Energy (Scalar)	J (Joule)
Power (Scalar)	W (Watt)

- **Mechanical energy** is the energy which is possessed by an object due to its motion or its stored energy of position.
- There are two forms of energy : Kinetic energy and potential energy.
- Kinetic energy is the energy of motion.
- Potential energy is the stored energy due to position.
- **Derivation of Potential Energy :**

$$\text{Work done (W)} = F \times s = ma \times s = m \times g \times h = mgh \text{ (Potential energy)}$$



- **Derivation of Kinetic energy :**

$$W = Fs = mas. \quad \text{.... (1)}$$
$$v^2 - u^2 = 2as$$
$$v^2 = 2as, \text{ when } u = 0$$
$$s = \left(\frac{v^2 - u^2}{2a}\right) \quad \text{.... (2)}$$

Putting the value of s from equation (2) in equation (1) we get,

$$W = ma \times \left(\frac{v^2 - u^2}{2a}\right)$$

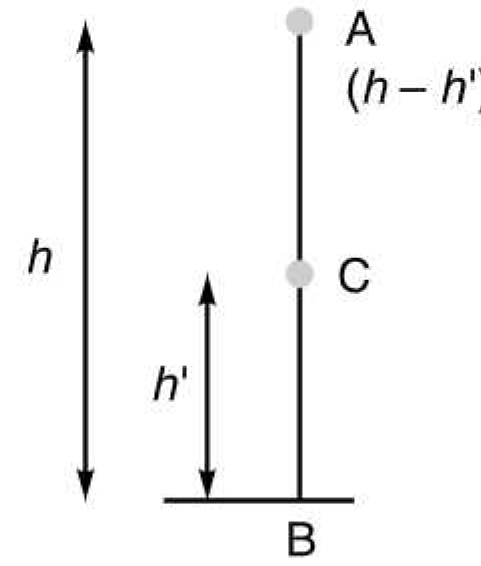
or $$W = \frac{1}{2} m \times (v^2 - u^2)$$

If the object is starting from its stationary position, that is, $u = 0$, then

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

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

➢ **Law of Conservation of Energy :** Energy can neither be created nor destroyed, but can be transformed from one form to another.



At A, P.E. $= mgh$, K.E. $= 0$

$$E = mgh. \quad \text{.... (1)}$$

At C, P.E. $= mgh'$

Using
$$v^2 = u^2 + 2g(h - h')$$
$$v^2 = 0 + 2g(h - h')$$
$$v^2 = 2g(h - h')$$
$$\text{K.E.} = \frac{1}{2}mv^2 = \frac{1}{2}m2g(h - h') = mg(h - h') \quad \text{...(2)}$$

At C, $E = \text{K.E.} + \text{P.E.} = mg(h - h') + mgh'$

From eq. (1), $E' = mgh$ .... (3)

At B, using
$$v^2 = u^2 + 2gh$$
$$v^2 = 0 + 2gh$$
$$v^2 = 2gh$$

At B, P.E. $= 0$, K.E. $= \frac{1}{2}mv^2$

$$\text{K.E} = \frac{1}{2}mv^2 = \frac{1}{2}m\,(2gh) = mgh \quad \text{.... (4)}$$
$$E = \text{P.E.} + \text{K.E.} = 0 + mgh = mgh \quad \text{.... (5)}$$

∴ Equation (1), (3) and (5) are same.

➢ **Some important formulae :**

- The amount of work done, $W = Fs \cos \theta$
- If $\theta = 90°$, $W = Fs \cos 90°$
  $= 0$, as $\cos 90° = 0$
- Law of conservation of energy
  $$\frac{1}{2}mv^2 + mgh = \text{constant}$$
- Power (P) $= \dfrac{\text{Energy spent (E)}}{\text{Time taken (t)}}$
- 1 watt = 1 joule/second *or* 1 W = 1 J/s
- 1 kW = 1000 W
- 1 kW = 1000 J/s
- 1 kWh = 3.6×10^6 J
- 1 hp = 746 W = 0.746 kW

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CHAPTER 14 : Sound

Key Points and Concepts

- **Difference between Longitudinal and Transverse Waves :**

S.No.	Longitudinal waves	Transverse waves
1.	In longitudinal waves, the individual particles of the medium move in a direction parallel to the direction of propagation of the disturbance.	In a transverse wave, particles do not oscillate along the line of wave propagation, but oscillate up and down about their mean position.
2.	Wave travels in the form of compression and rarefaction.	Wave travels in the form of crest and trough.
3.	e.g. Sound waves.	e.g. Light waves.

- **Sound** is a wave motion, produced by a vibrating source.
- A medium is necessary for the propagation of sound waves.
- **Sound** is a longitudinal wave in which the particles of medium move along the direction of motion of wave.
- Sound travels faster in solids than in air. The speed of sound in solids is much more than the speed of sound in liquids or gases.
- **Characteristics of wave :** Wavelength, frequency and time period.
- The distance between two consecutive compressions or two consecutive rarefactions is called the **wavelength**.
- **Frequency** is defined as the number of oscillations per second.
- The time taken by the wave to complete one oscillation is called the **time period**, T.
- Sound gets reflected at the surface of a solid or liquid and follows the laws of reflection.
- **Echo** is a sound or sounds caused by the reflection of sound waves from a surface back to the listener.
- **Reverberation** is the phenomenon of overlapping of sound caused by multiple reflections.
- Reverberation causes the overlapping of several reflected waves.
- The audible range of hearing for average human beings is in the frequency range of 20 Hz – 20 kHz.
- Sound of frequency less than 20 Hz is known as infrasound and greater than 20 kHz is known as ultrasound.
- **Application of ultrasound :**

  (i) To clean parts located in hard-to-reach places,

  (ii) Detect cracks and flaws in metal blocks,

  (iii) Medical devices,

  (iv) SONAR.
- SONAR stands for Sound Navigation and Ranging and it works on the principle of reflection of sound waves.
- The SONAR technique is used to determine the depth of the sea and to locate under water hills, valleys, submarines, icebergs, sunken ships, etc.

  Mechanism of hearing : Outer ear 'pinna' collects sound from the surroundings and passes through the auditory canal. When a compression of the medium reaches the ear drum the pressure increases on the outside of the membrane and forces the eardrum inward. Eardrum vibrates and transmits amplitude vibrations to inner ear.

  Inner ear converts these pressure waves into electrical signals. These signals are converged to the brain via auditory nerve and the brain interprets them as sound.

- Three bones of ear–hammer, anvil and stirrup.
- **Quantities and Units :**

Quantities	SI Units
Velocity	m/s
Time	s (sec)
Frequency	Hz (hertz) *i.e.,* s^{-1}
Wavelength	m

Important Formulae

- Frequency and time period are related as follows :

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

- Speed,

$$v = \frac{\text{Distance}}{\text{Time}}$$

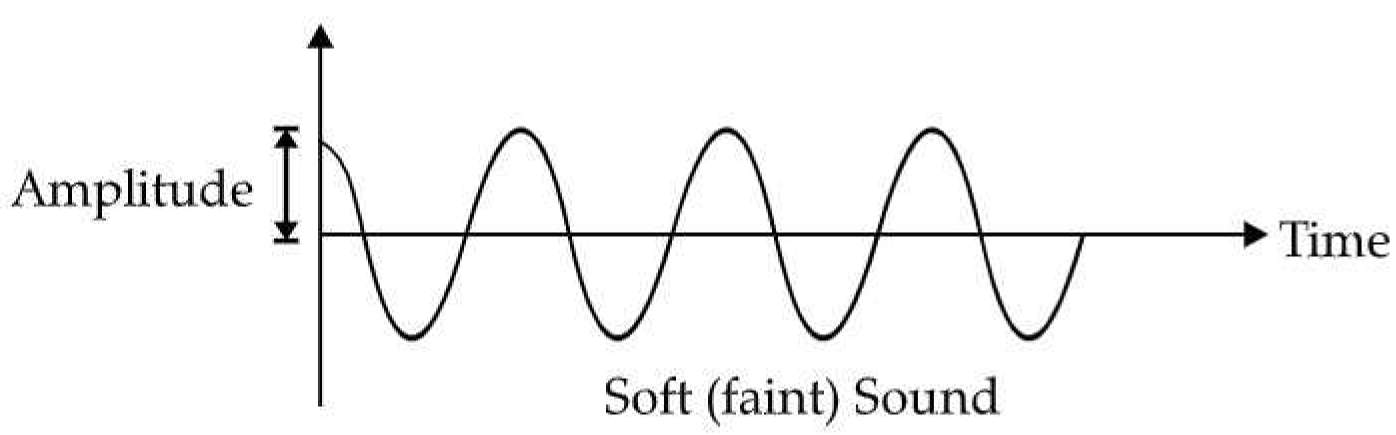
$$v = \frac{\lambda}{T}$$

- The wave velocity (v), frequency of the wave (f) and its wavelength (λ) are related by the formula,

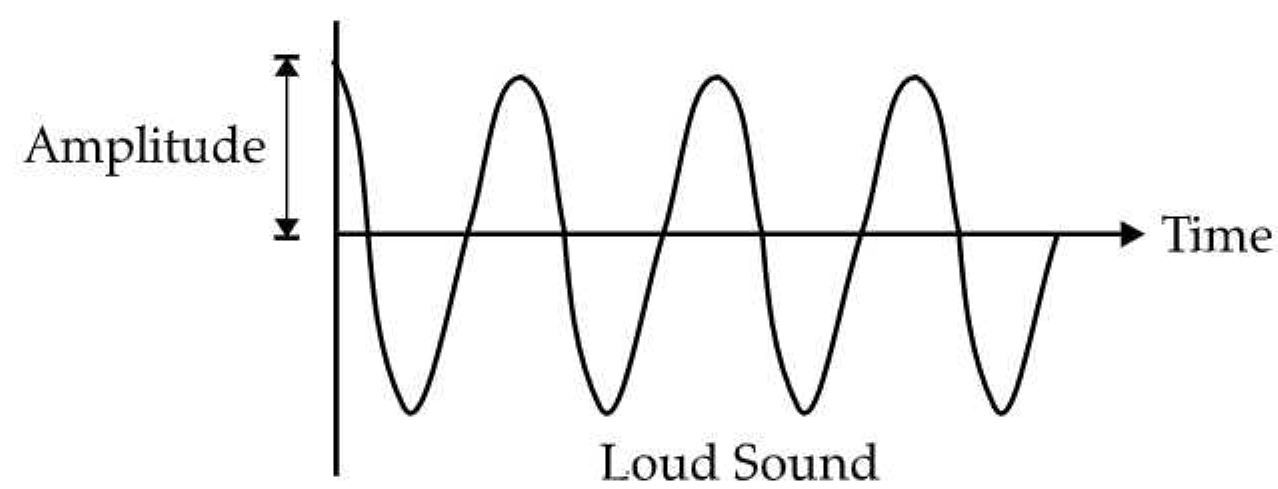
$$v = f\lambda$$

Important Graphs and Diagrams

- **Soft Sound and Loud Sound**

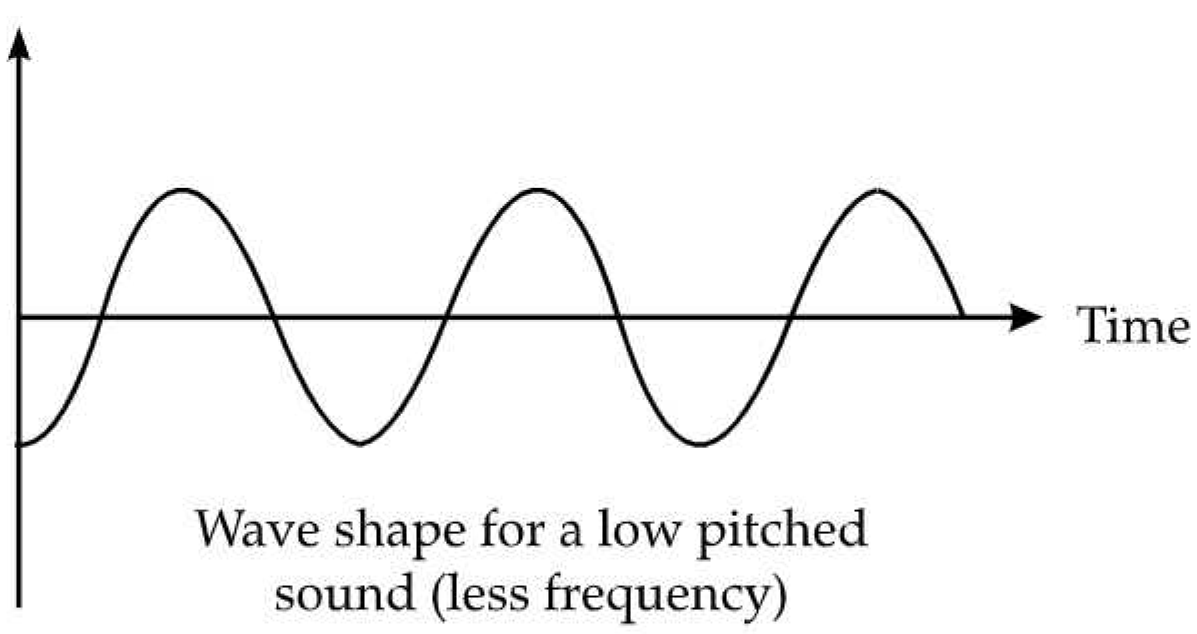


Soft (faint) Sound

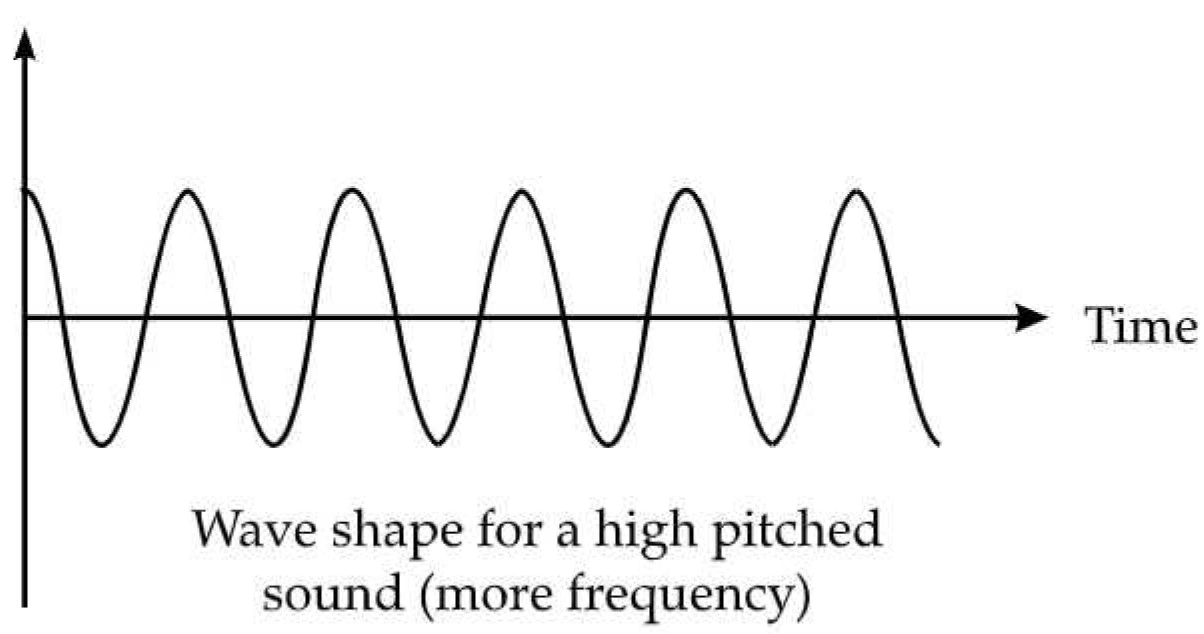


Loud Sound

- **Low pitched and High pitched Sound**

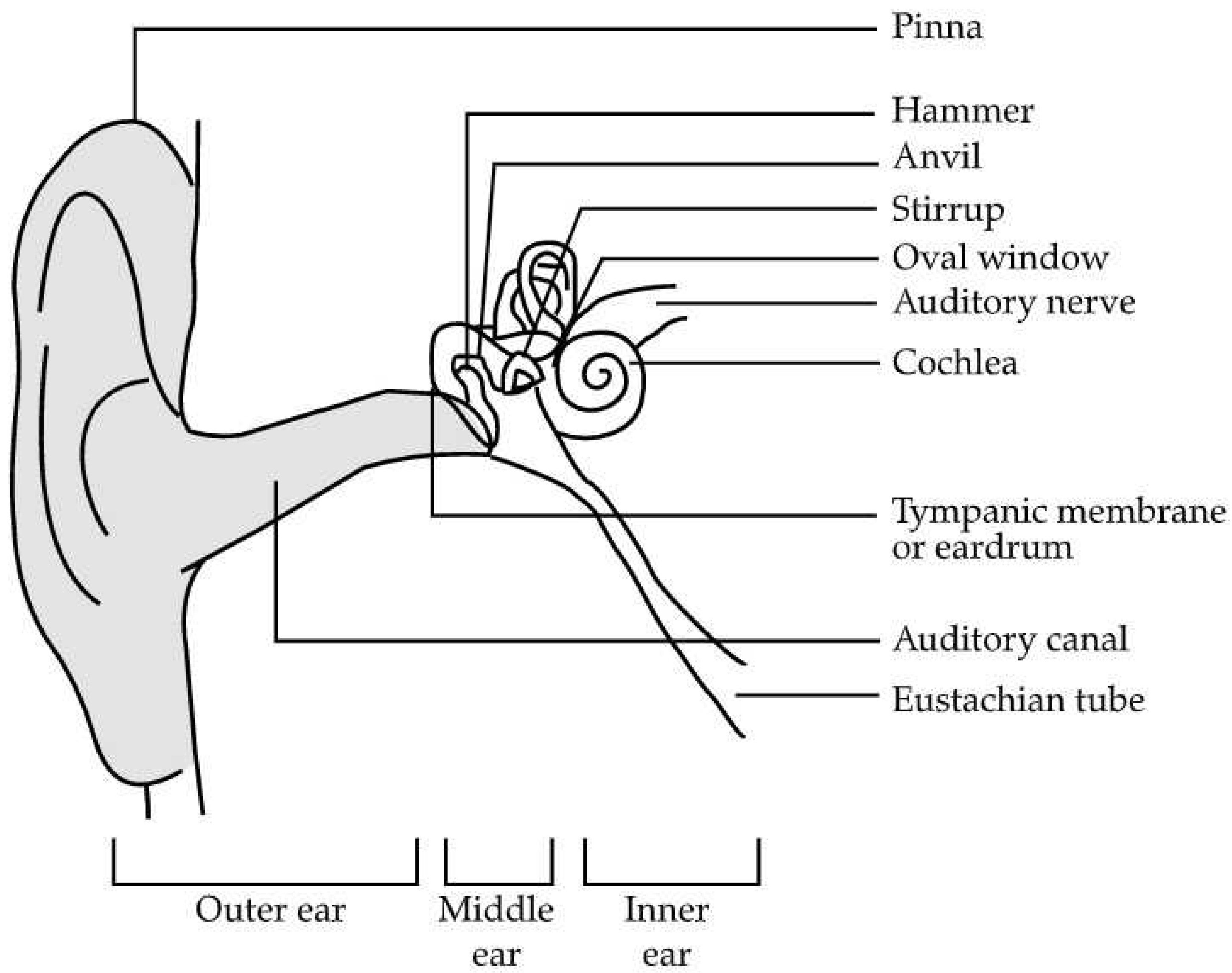


Wave shape for a low pitched sound (less frequency)



Wave shape for a high pitched sound (more frequency)

- **Auditory parts of human ear**



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