1. Natural of physical world and measurement

1. Briefly explain the types of physical quantities.

Types of physical quantities :

1. Fundamental Quantity :

The quantity which can not be expressed in terms of other physical quantity is known as " fundamental or base quantity "

Example : mass , time , length

2. Derived Quantity :

The quantity that can be expressed in terms of fundamental quantities are called derived quantities.

Example : Area , volume , Force

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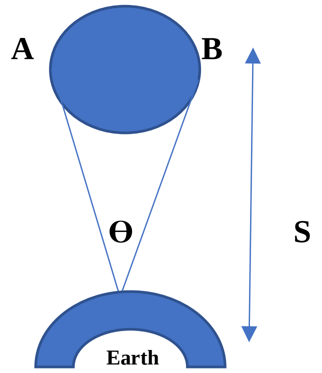
2. How will you measure the diameter of the moon using parallax method ?



* Let O be the observation point on earth.
* d is the diameter of the moon.
* s is the average distance between moon and earth.
* ϴ is called angle of parallax.

$$d = S \times \theta$$

* d can be calculated when S , ϴ are measured.

4.What are the limitations of dimensional analysis?

1. It gives no information about dimensionless constant . 1,2 , … π , e (Euler number)

2. It cannot decide whether the given quantity is a vector or scalar.

3.It cannot apply to an equation involves more than three physical quantities.

4. This method is not suitable to derive relations involves trigonometry , exponential and logarithmic quantities.

5.It can only check on whether a physical relation is dimensionally correct but not the correctness of the relation.

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5. Define precision and accuracy . Explain with one example.

Accuracy :

Accuracy refers to how far we are from true value.

Precision :

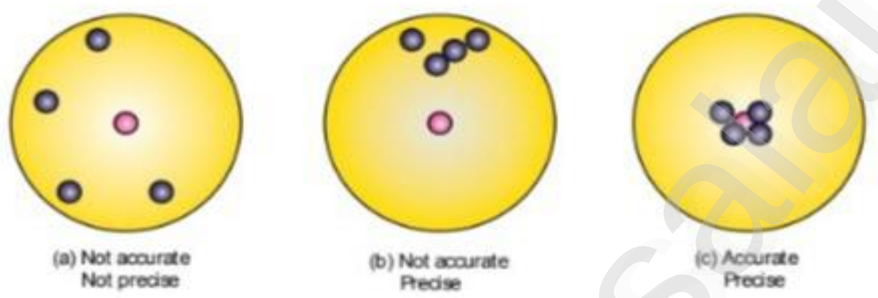
- **Precision refers to how well we measure.**
- **If a measurement is precise , it not be accurate.**

Example :

1. Not accurate Not precise

2. Not accurate but precise

3. Accurate precise



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3. Write the rules for determining significant figures.

Rules	Example	Significant Figure
1. All non zero digits	1342	Four
2. All zero between two non zero	2008	Four
3. All zero left of decimal point	30700.	Five
4. Number without decimal point	30700	Three
5. zeros are significant with measurement	30700 m	Five
6. All zero right decimal point	40.00	Four

---

6 . Define unit.

An arbitrarily chosen standard of measurement of quantity , which is accepted internationally is called unit of the quantity.

---

7. Define Rounding off.

- **Calculators are widely used now a days for calculations.**
- **Calculators has too many figures.**
- **Results have more significant figures.**
- **Numbers containing more than one uncertain number should be round off.**

8.Define dimensionless quantities.

<u>Dimensionless variable :</u>

Physical quantity which have no dimension but have variable.

Ex : Strain , Specific gravity

<u>Dimensionless constant :</u>

Physical quantity which have constant values but have no dimension.

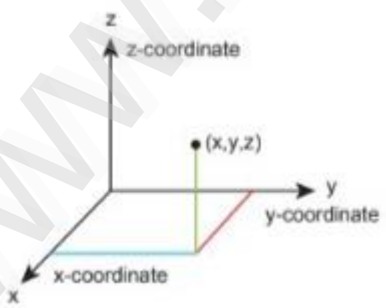
Ex : π , e (Euler's number)

---

2. Kinematics

1. What is meant by cartesian coordinate system ?

The frame of reference with respect to which the position of the object , is described in terms of position coordinates is called cartesian coordinate system.



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2. Define a scalar . Give examples .

It is a property which can be described only by magnitude.

Example : Distance , Mass , Speed

3. Define a vector . Give examples .

It is a quantity which can be described by both magnitude and direction.

Example : Force , Velocity , Displacement

---

4. Write a short note scalar product between two vectors.

The scalar product (dot product) of two vectors is defined as the product of the magnitude of both the vectors and the cosine of the angle between them.

$$\vec{A} \cdot \vec{B} = A\,B \cos \theta$$

---

5. Write a short note vector product between two vectors.

The vector product (Cross product) of two vectors is defined as another vector having magnitude equal to the product of the magnitudes of two vectors and the sine of the angle between them.

$$\vec{C} = \vec{A} \times \vec{B} = (A\,B \sin \theta)\, n$$

6.How do you deduce that two vectors are perpendicular ?

If two vectors A and B are perpendicular to each other then,

1. Scalar product : $\vec{A} \cdot \vec{B} = 0$

2. Because Cos 90^0 = 0

3. They are mutually orthogonal..

7.Define displacement and distance.

<u>Distance :</u>

- **Actual path travel by an object.**
- **Given interval of time during the motion.**
- **It is a positive scalar quantity.**

<u>Displacement :</u>

- **It is the difference between the final and initial position of the objects.**
- **Given interval of time during the motion.**
- **It is a vector quantity.**

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8. Define velocity and speed.

Velocity :

- Rate of change of position vector with respect to time.
- It is a vector quantity.
- $V = \lim_{\Delta t \to 0} \frac{\Delta r}{\Delta t} = \frac{dr}{dt}$

Speed :

- Distance travelled in unit time.
- It is positive scalar quantity.
- Magnitude of velocity v is called as speed.
- $v = \sqrt{v_x^2 + v_y^2 + v_z^2}$

---

9. Define acceleration.

- Rate of change of velocity.
- It is a vector quantity.
- SI unit : $m\,s^{-2}$
- Dimension : $M^0 L^1 T^{-2}$
- $a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$

---

10. What is the difference between velocity and average velocity ?

Velocity :

- Rate of change of position vector with respect to time.
- It is a vector quantity.
- $V = \lim_{\Delta t \to 0} \frac{\Delta r}{\Delta t} = \frac{dr}{dt}$

Average Velocity :

- Rate of change of displacement vector with respect to time.
- It is a vector quantity.
- $V_{avg} = \frac{\Delta r}{\Delta t}$

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11. Define radian.

Angle subtended at the center of a circle by an arc that is equal in length to the radius of the circle.

$$1 \text{ radian} = \frac{180}{\pi} \text{ degree} = 57.27^0$$

---

12. Define angular displacement and angular velocity.

Angular Displacement :

The angle described by the particle about the axis of rotation in a given time is called angular displacement.

$$\Theta = S / r \qquad \text{Unit : radian}$$

Angular Velocity :

- **The rate of change of angular displacement is called angular velocity.**
- **SI unit : rad s^{-1}**

$$\omega = \lim_{\Delta t \to 0} \frac{\Delta \Theta}{\Delta t} = \frac{d\Theta}{dt}$$

---

13. What is non uniform circular motion?

If the velocity changes in both speed and direction during the circular motion we get non uniform circular motion.

Ex : When the bob attached to a string moves in vertical circle , the speed of the bob is not same at all time.

14.Write down the kinematic equation for angular motion.

1. $\omega = \omega_0 + \alpha t$
2. $\omega^2 = \omega_0^2 + 2 \alpha \Theta$
3. $\Theta = \omega_0 t + \frac{1}{2} \alpha t^2$
4. $\Theta = \frac{(\omega_0 + \omega) t}{2}$

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15. Write down the expression for angle made by resultant acceleration and radius vector in the non uniform circular motion.

$$\tan \theta = \frac{a_t}{(v^2 / r)}$$

a_t ---------→ Tangential acceleration
v ---------→ Velocity of object
r ---------→ Radius vector

3.Laws of motion

1.Explain the concept of inertia . Write two examples each for inertia of motion , inertia of rest and inertia of direction.

Concept of inertia :

- Inertia means resistance to change its state.
- The inability of an object to move on its own or change its state of motion.

Inertia of rest :

The inability of an object to change its state of rest.
Ex : 1. Passengers experience backward push in sudden start of bus.
2. Tightening of seat belts in a car when it stops quickly.

Inertia of motion :

The inability of an object to change its state of motion.
Ex : 1. Passengers experience forward push in sudden brake of bus.
2. Ripe fruits fall from the trees in the direction of wind.

Inertia of direction :

The inability of an object to change its state of direction.
Ex : 1. A stone moves tangential to circle.
2. When a car moves towards left , we turn to right.

---

2. State Newton's second law.

The force acting on an object is equal to rate of change of its momentum.

$$\vec{F} = \frac{d\vec{p}}{dt}$$

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3. Define one Newton.

One newton is defined as the force which acts on 1 kg of mass to give an acceleration 1 m s^{-2} in the direction of force.

---

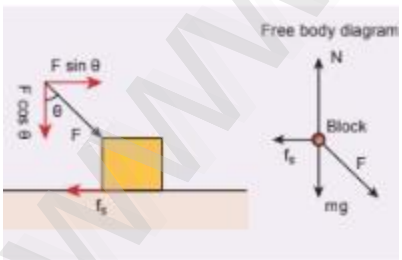
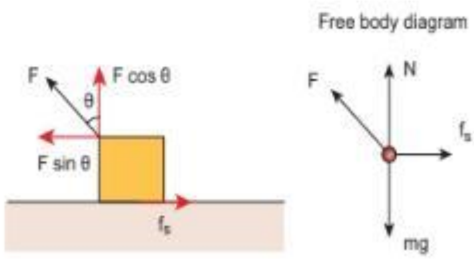
4. Show that impulse is the change of momentum,.

If a force F acts on the object in a very short interval of time Δt.

1. $F = \frac{dp}{dt}$
2. $dp = F\,dt$
3. $\int dp = F \int dt$
4. $p_f - p_i = F(t_f - t_i)$
5. $\Delta p = F\,\Delta t$
6. $J = \Delta p.$

---

4. Using free body diagram , show that it is easy to pull an object than to push it.

<table>
<tr><th>Push on object</th><th>Pull on object</th></tr>
<tr><td>$N_{PUSH} = mg + F\cos\theta$</td><td>$N_{PUSH} = mg + F\cos\theta$</td></tr>
<tr><td>$F\cos\theta$ → Perpendicular Component</td><td>$F\sin\theta$ → Parallel Component</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

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6. Explain various types of friction . Suggest a few methods to reduce friction.

Friction :

Friction is form of force . It always oppose the relative motion between an object and the surface where it is placed.

Types of friction :

1. **Static friction**
2. **Kinetic friction**

1. Static friction

- **The force which opposes the initiation of motion of an object on the surface.**
- **It does not depend upon area of contact.**
- **Coefficient of static friction μ_s**

$$0 \leq f_s \leq \mu_s N$$

2. Kinetic friction

- **If the external force acting on the object is greater than maximum static friction , the objects begin to slide.**
- **When an object slides , the surface exerts frictional force called ' Kinetic friction'**
- **It is also called ' sliding friction ' or Dynamic friction'**
- **Coefficient of kinetic friction is μ_k**

$$f_k = \mu_k N$$

Methods to reduce friction :

1. **By polishing surface**
2. **By using lubricant**
3. **By using ball bearings**

---

7. What is the meaning of " pseudo force " ?

- **Centrifugal force arise whenever the motion is analysed from rotating frame.**
- **The inertial motion of the object appears as centrifugal force in the rotating frame.**
- **It is called as " Pseudo Force "**
- **It acts outwards the canter of circle**
- $$F_{cf} = m a_{cf} = \frac{m v^2}{r}$$

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8.State the empirical laws of static and kinetic friction.

1. Empirical relation for magnitude of static frictional force.

$$0 \leq f_s \leq \mu_s N$$

2. The force of static friction can take any value from zero to μ_s N .

3. If the object is at rest and no external force is applied on the object , the static friction on the object is zero. $f_s = 0$.

4. If there is an external force applied parallel to the surface , then force of static friction exactly equal to external force. $f_s = F_{ext}$.

---

9. State Newton's third law.

Newton's third law states that every action there is an equal and opposite reaction.

$$\vec{F}_{12} = - \vec{F}_{21}$$

10.What are inertial frames ?

- **Newton's first law is valid only in certain special reference frame called 'inertial frame '**
- **If an object experiences no force , it moves with constant velocity or remains at rest.**
- **If an object is free from all forces then it moves with constant velocity or remains at rest when seen from inertial frame.**

---

11. Under what condition will a car skid on a levelled circular road ?

If static friction is not able to provide enough centripetal force to turn , the vehicle will start to skid.

$$\frac{m v^2}{r} > \mu_s m g$$

$$\mu_s < \frac{v^2}{r}$$

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4. Work , Energy , Power

1. Explain how the definition of work in physics is different from general perception.

- The term work refers to both physical as well as mental work.
- Any activity can generally be called as work.
- Work is said to be done by force when the force when the force applied on a body displaces it.
- Work and energy are equivalents.
- Work done is scalar quantity.
- SI UNIT : N m (or) joule
- Dimension : $M L^2 T^{-2}$

$$W = \vec{F} \cdot \vec{dr}$$

2.Write the various types potential energy . Explain the formulae.

1. **Gravitational Potential Energy :**

The energy possessed by the body due to gravitational force.

$$U = m g h$$

m → mass g → gravity h → height

2. **Elastic Potential Energy :**

The energy due to spring force and other similar forces give rise to elastic potential energy.

$$U = \frac{1}{2} k x^2$$

k → Force constant x → Displacement

3. **Electrostatic Potential Energy :**

The energy possessed due to electrostatic force.

$$U = \frac{1}{4 \pi \epsilon_0} q_1 q_2$$

q_1 q_2 → Charges r → distance

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3. Write the differences between conservative and non conservative forces. Give two examples.

<u>Conservative Force :</u>

1. Work done is independent of path.
2. Work done in a round trip is zero.
3. Total energy remains constant.
4. Work done is completely recoverable.
5. Force is negative gradient of potential energy.
6. Example : Spring force , Magnetic force

<u>Non conservative Force :</u>

1. Work done is dependent of path.
2. Work done in a round trip is not zero.
3. Energy is dissipated as heat energy.
4. Work done is not completely recoverable.
5. No such relation exists.
6. Example : Frictional force , Viscous force

---

4. Explain the characteristics of elastic and inelastic collision.

<u>Elastic Collision :</u>

1. Total momentum is conserved.
2. Total kinetic energy is conserved .
3. Forces involved are conservative forces.
4. Mechanical energy is not dissipated.

<u>Inelastic Collision :</u>

1. Total momentum is conserved.
2. Total kinetic energy is not conserved .
3. Forces involved are non conservative forces.
4. Mechanical energy is dissipated into heat and light.

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5. Define coefficient of restitution .

$$e = \frac{\text{Velocity of separation after collision}}{\text{Velocity of approach before collision}}$$

$$e = \frac{V_2 - V_1}{u_2 - u_1}$$

6.Define power.

* Rate of work done or energy delivered is called as " power "
* It is a scalar quantity.
* S I unit : Watt (1 W = J s^{-1})
* Dimension : $M L^2 T^{-3}$
* P = W / t

---

7. Define Law of conservation of energy.

- The law of conservation of energy states that energy can neither be created nor destroyed.
- It may be transformed from one form to another form.
- But total energy of an isolated system remains constant.

---

8. Define loss of kinetic energy in inelastic collision.

In perfectly inelastic collision , the loss in kinetic energy during collision is transformed to another form of energy like sound , thermal , heat , light etc.

K . E before collision : $K.E_i = \frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2$

K . E after collision : $K.E_f = \frac{1}{2} (m_1 + m_2) v^2$

Loss of K . E : $\Delta Q = K.E_i - K.E_f$

$$\Delta Q = \frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 - \frac{1}{2} (m_1 + m_2) v^2$$

$$\Delta Q = \frac{1}{2} \frac{m_1 m_2}{m_1 + m_2} (u_1 - u_2)^2$$

---

5. Motion of system of particles & Rigid bodies

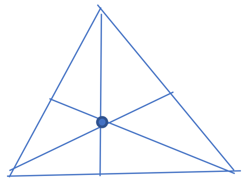
1.Define centre of mass.

- **The centre of mass of a body is defined as a point where the entire mass of the body appears to be concentrated.**
- **The centre mass is at the geometric centre of the body.**

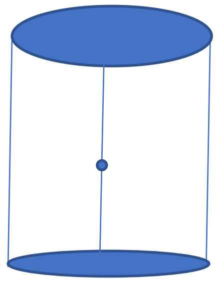
---

2. Find out of the centre of mass of the given geometrical structures.

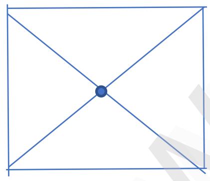
a) Equilateral triangle : centre of mass lies on centre



b) Cylinder : Centre mass lies on central axis



c) Square : Centre of mass lies in diagonal meet



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3. Define torque and mention its unit.

- **Torque is defined as the moment of external applied force about a point or axis of rotation.**
- **Torque is a vector quantity.**
- **It is called as pseudo vector.**
- **S I Unit : N m**

$$\vec{\tau} = \vec{r} \times \vec{F} = r\, F \sin\theta\ n$$

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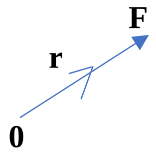
4. What are the conditions in which force can not produce torque ?

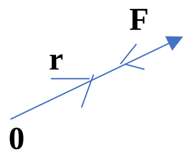
1. The torque is zero when r and F are parallel or antiparallel.

- **If parallel , then $\Theta = 0^0$ and $\sin 0^0 = 0$**



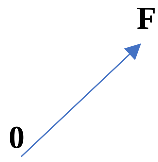
$\Theta = 0^0$; $\tau = 0$

- **If anti parallel , then $\Theta = 180^0$ and $\sin 180^0 = 0$**



$\Theta = 0^0$; $\tau = 0$

2. If torque is zero if the force acts at the reference point as r = 0 , $\tau = 0$



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5. Give any two examples of torque in day-to-day life

1. **Turning of a nut using wrench fully.**
2. **Opening a bottle cap.**
3. **Opening and closing a door about the hinges.**

---

6. What is the relation between torque and angular momentum?

An external torque on a ridge body fixed to an axis produces rate of change of angular momentum in the body about the axis.

$$\tau = I\alpha$$

$$\tau = I\frac{d\omega}{dt}$$

$$\tau = \frac{d(I\omega)}{dt}$$

$$\tau = \frac{dL}{dt}$$

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7. What is equilibrium ?

- When all the forces act upon the object are balanced, then the object is said to be an equilibrium.
- A rigid body is said to be in mechanical equilibrium when both its linear momentum and angular momentum remain constant.

---

8. How do you distinguish between stable and unstable equilibrium.

Stable equilibrium	Unstable equilibrium
1.Linear momentum and angular momentum are zero.	1.Linear momentum and angular momentum are zero.
2.The body tries to come back to equilibrium if slightly disturbed and released.	2.The body cannot come back to equilibrium if slightly disturbed and released.
3.The center of mass of the body shifts slightly higher if disturbed from equilibrium.	3.The center of mass of the body shifts slightly lower if disturbed from equilibrium.
4.Potential energy of the body is minimum and it increases if disturbed.	4.Potential energy of the body is not minimum and it decreases if disturbed.

---

9. Define couple. (or) Define moment of couple.

A pair of forces which are equal in magnitude but opposite in direction and separated by a perpendicular distance so that their lines od action do not coincide that causes a turning effect is called a couple.

---

10. State principle of moments.

Sum of the clockwise moments is equal to sum of the anti clock wise moments when a body is rotational equilibrium or algebraic sum of moments at any point is zero.

$$d_1 \; F_1 = d_2 \; F_2$$

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11. Define centre of gravity.

The centre of gravity of a body is the point at which the entire weight of the body acts irrespective of the position and orientation of the body.

---

12. Mention any two physical significance of moment of inertia.

1. For rotational motion, moment if inertia is a measure of rotational inertia.
2. The moment of inertia of a body is not an invariable quantity. Its depends not only on the mass of the body, but also on the way the mass is distributed around the axis of rotation.

---

13. What is radius of gyration?

The radius of gyration of an object is the perpendicular distance from the axis of rotation to an equivalent point mass, which would have the same mass as well as the same moment of inertia of the object.

- **Radius of gyration is a distance.**
- **Its unit is metre (m).**
- **Dimension is L.**
- $I = M K^2$
- **I → Moment of inertia**
- **M → Mass of the object**
- **K → Radius of gyration.**

---

14. State conservation of angular momentum.
When no external torque acts on the body, the net angular momentum of a rotating rigid body remains constant. This is known as law of conservation of angular momentum.

- **If** $\tau = 0$ **then** $L =$ **constant**
- $I\omega =$ **Constant**

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15. What are the rotational equivalents for the physical quantities, (1) mass and (2) force?

(1) For mass : Moment of inertia, $I = mr^2$
(2)For force : Torque $\tau = I\alpha$

---

16. What is the condition for pure rolling ?

- **Rolling is the combination of rotational and translational motions.**
- **V_{TRANS} and V_{ROT} are equal in magnitude and opposite in direction.**
- $V = V_{TRANS} - V_{ROT} = 0$
- $V_{TRANS} = V_{ROT}$
- $V_{TRANS} = V_{CM} = R\omega$
- $V_{CM} - R\omega = 0$
- **$V_{roll} = 0$ = translational velocity + tangential velocity due to rotation. $v - r\omega = 0$.**

---

17. What is the difference between sliding and slipping?

S.NO	Sliding	Slipping
1.	The translation is more than rotation.	The translation is more than rotation.
2.	Sliding also referred as forward slipping.	Sliding also referred as backward slipping.
3.	$V_{CM} > R\omega$	$V_{CM} < R\omega$
4.	$V_{TRANS} > V_{ROT}$	$V_{TRANS} < V_{ROT}$
5.	Ex : When sudden brake is applied in a moving vehicle.	Ex : When we suddenly start the vehicle from rest.

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6. Gravitation

1. State Kepler's three laws.

Law of orbits :

Each planet moves around the sun in an elliptical orbit with the sun at one of the foci.

- Closet point of planet to sun ⟶ Perihelion
- Farthest point of planet to sun ⟶ Aphelion

2. Law of area :

The radial vector (line joining the sun to a planet) sweeps equal areas in equal intervals of time.

- The planets travel *faster* when they *nearer* to the sun.
- The planets travel *slower* when they *farther* to the sun.
- To cover equal area (Δ A) in equal in equal intervals of time (Δ t)

3 Law of period :

The square of the time period of revolution of a planet around the sun in its elliptical orbit is directly proportional to the cube semi - major axis of the ellipse.

$$T^2 \propto a^3$$

---

2. State Newtons Universal law of gravitation.

Newtons law of gravitation states that a particle of mass M_1 attracts any other particle of mass M_2 in the universe with an attractive force. The strength of this force of attraction was found to be directly proportional to the product of their masses and is inversely proportional to the square of the distance between them.

$$\vec{F} = -\frac{G M_1 M_2}{r^2}\hat{r}$$

$G = 6.67 \times 10^{-11}\ N\,m^2\,kg^{-2}$

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3. Will the angular momentum of a planet be conserved ? Justify your answer.

The torque experienced by the Earth due to the gravitational force of the sun is given by

$$\vec{\tau} = \vec{r} \times \vec{F} = \vec{r} \times -\left(\frac{G M_S M_E \hat{r}}{r^2}\right) = 0$$

$$\tau = \frac{d\vec{L}}{dt} = 0 \quad \text{since } \vec{r} = r\hat{r}, \; \hat{r} \times \hat{r} = 0$$

- Angular momentum $\vec{L}$ is a constant vector.
- Angular momentum of the Earth about the sun is constant throughout the motion.

---

4. Define the gravitational field . Give its unit.

- The gravitational field due to a mass m at a point which is at a distance r from mass m is given by ,

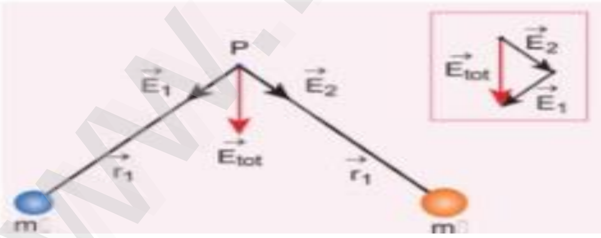
$$\vec{E} = -\frac{G m}{r^2}\hat{r}$$

- The gravitational field is defined as the gravitational force experienced by unit mass placed at that point. It is a vector quantity.

---

5. What is meant by superposition of gravitational field ?

Consider ' n ' particles of masses m_1 , m_2 ,….. m_n distributed in space at positions r_1 , r_2 ,….. r_n with respect to point P. The total gravitational field at a point P due to all the masses is given by the vector sum of the gravitational field due to the individual masses. This principle is known as superposition of gravitational fields.



$$\vec{E}_{total} = \vec{E}_1 + \vec{E}_2 + \dots \vec{E}_n$$

$$\vec{E}_{total} = -\frac{G m_1}{r_1^2}\hat{r}_1 - \frac{G m_1}{r_2^2}\hat{r}_2 \dots\dots \frac{G m_n}{r_n^2}\hat{r}_n = -\sum_{i=1}^{n} \frac{G m_i}{r_i^2}\hat{r}_i$$

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6. Define gravitational potential energy.

The gravitational potential energy of a system of two masses m_1 and m_2 separated by a distance r as the amount of work done to take the mass m_2 from a distance r to infinity assuming m_1 to be fixed in its position .

$$U = - \frac{G\, m_1\, m_2}{r}$$

---

7. Is potential energy the property of a single object ? Justify.

No , potential energy is a property of a system rather than of a single object due to its physical position. Because gravitation potential energy depends on relative position. So a reference level at which to set the potential energy equal to zero.

---

8. Define gravitational potential.

The gravitational potential at a distance r due to a mass m is defined as the amount of work required to bring unit mass from infinity to the distance r.

$$V = - \frac{G\, m}{r}$$

---

9. What is the difference between gravitational potential and gravitational potential energy .

S.NO	Gravitational potential	Gravitational potential energy
1.	The amount of work required to bring unit mass from infinity to the distance .	The amount of work done to take the mass m_2 from a distance r to infinity assuming m_1 to be fixed in its position .
2.	$V = - \frac{G\, m}{r}$	$U = - \frac{G\, m_1\, m_2}{r}$
3.	Unit : $J\ kg^{-1}$	Unit : Joule

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10. What is meant by escape speed in the case of the earth ?

The escape speed is defined as the minimum speed required by an object to escape from earth ' s gravitational field.

- **Escape speed of the earth is V_e = 11.2 km s^{-1}**
- **Radius of the earth is R_e = 6400 km**
- **Acceleration due to gravity 9.8 m s^{-2} .**

$$V_e = \sqrt{2 \, g \, R_e}$$

---

11. Why is the energy of a satellite (or any other planet) negative ?

1. Implies that the satellite is bound to the Earth and it cannot escape from the Earth.

2. As h approaches ∞ the total energy tends to zero. Its physical meaning is that the satellite is completely free from the influence of Earth's gravity and is not bound to Earth at large distances.

---

12. What are geostationary and polar satellites ?

<u>Geostationary Satellite :</u>

1. Geostationary satellites appear to be stationary , when seen from Earth.

2. Distance h turns out be 36,000 km.

3. India uses the INSAT group of satellites that are basically geostationary satellite.

4. They are used for purpose of telecommunication.

<u>Polar Satellite :</u>

1. Another type satellite which is placed at a distance of 500 to 800 km.

2. This type satellite that orbits Earth from pole to south pole .

3. The time period of polar satellite is nearly 100 minutes.

4. The satellites completes many revolution in a day.

5. A polar satellite covers small strip of area from pole to pole during one revolution.

---

13. Define weight.

The weight of an object W is defined as the that of upward force that must be applied to the object to hold it at rest or at constant velocity relative to the earth.

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14. Why is there no lunar eclipse and solar eclipse every month ?

Moon's orbit is tilted 5^0 with respect to earths orbit. Due to this 5^0 tilt, only during certain periods of the year , the sun , earth and moon align in straight line leading to either lunar eclipse or solar eclipse depending on the alignment.

---

15. How will you prove that earth itself is spinning ?

The earth's spinning motion can be proved by observing star's position over a night. Due to earth's spinning motion , the stars in sky appear to move in circular motion about the pole star.

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7. Properties of Matter

1. Define stress and strain.

Stress :

The force per unit area is called " stress " . Stress = $\frac{\text{Force}}{\text{Area}}$

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

SI Unit : $N\,m^{-2}$ Dimension : $M\,L^{-1}\,T^{-2}$

Strain :

The fractional change in the size of the object , when a force is applied , strain measures the degree of deformation.

Strain = $\frac{\text{Change in size}}{\text{Original size}}$

$$\varepsilon = \frac{\Delta l}{l}$$

---

2. State Hooke's law of elasticity.

Hooke's law is for a small deformation , when the stress and strain are proportional to each other.

Stress α strain

---

3. Define Poisson's ratio.

It is defined as the of relative contraction (Lateral strain) to relative expansion (longitudinal strain) . It is denoted by the symbol μ .

Poisson's ratio = $\frac{\text{lateral strain}}{\text{Longitudinal strain}}$

$$\mu = \frac{d / D}{l / L} = -\frac{L}{l} \times \frac{d}{D}$$

---

4. Explain elasticity using intermolecular forces.

- In a solid , interatomic forces bind two or more atoms together and the atoms occupy the positions of stable equilibrium.
- When a deforming force is applied on a body ,atoms are pulled apart or pushed closer.
- When deforming force is removed , interatomic forces of attraction or repulsion restore the atoms to their equilibrium positions.
- If a body regains its original shape / size after the removal of deforming force is called elastic and the property is called " elasticity "

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5. Which one of these is more elastic , steel or rubber ? Why ?

- **Steel is more elastic than rubber .**
- **An equal stress is applied to both steel and rubber , the steel produces less strain .**
- **So the Young's modulus is higher for steel than rubber.**
- **The object which higher Young's modulus is more elastic.**

---

6. A spring balance shows wrong readings after using for a long time . Why ?

This is because of continuous usage , the wire loses its elasticity and does not regain it original dimension . (Length) Because of this , it shows wrong readings.

---

7. What is the effect of temperature on elasticity ?

As the temperature of substance increases , its elasticity decreases.

---

8. Write down the expression for the elastic potential energy of a stretched wire.

<u>Elastic Energy :</u>

When a body is stretched , work is done against the restoring force. This work done is stored in the body in the form of " Elastic energy "

<u>Explanation :</u>

Let us consider a unstretched wire.

- **Length of the wire** ⟶ **L**
- **Force on the wire** ⟶ **F**
- **Area of cross section** ⟶ **A**
- **Extension in length** ⟶ l

<u>Derivation :</u>

Work done by the force F is equal to the energy gained by the wire.

1. Work done : W $= \int_0^l F\, dl$

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2. Young's Modulus : $Y = \frac{F}{A} \times \frac{L}{l}$

3. Force : $F = \frac{Y A l}{L}$

4. Work done : $W = \int_0^l \frac{Y A l}{L} dl$

5. $W = \frac{Y A}{L} \int_0^l l \, dl$

6. $W = \frac{Y A}{L} \left(\frac{l}{2} \right)^2$

7. $W = \frac{1}{2} \frac{Y A l}{L} l$

8. $W = \frac{1}{2} F l$

9. Work done = Elastic potential energy

10. Energy Density : Energy per unit volume = $\frac{\text{Elastic potential energy}}{\text{Volume}}$

$u = \frac{1}{2} \frac{F}{A} \frac{l}{L}$

$u = \frac{1}{2}$ x Stress x Strain

---

9. State Pascal's law in fluids.

" If the pressure in a liquid is changed at a particular point , the change is transmitted to the entire liquid without being diminished in magnitude".

---

10. State Archimedes principle.

It states that when a body is partially or wholly immersed in a fluid , it experiences an upward thrust equal to weight of the fluid displaced by it and its upthrust acts through the centre of gravity of the liquid displaced.

Upthrust or Buoyant force = Weight of liquid displaced

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11. What do you mean by upthrust or buoyancy ?

The upward force exerted by a fluid that opposes the weight of an immersed object in a fluid is called upthrust.

---

12. State the law of floatation.

A body will float in a liquid if the weight of the liquid displaced by the immersed part of the body equals the weight of the body.

Example :

A wooden object 300 kg (about 3000 N) floats in water displaces 300 kg of water.

---

13. Define coefficient of viscosity of a liquid.

The viscous force acting tangentially per unit area of a liquid layer having a unit velocity gradient in a direction perpendicular of flow the liquid.

$$F = -\eta A \frac{dv}{dx}$$

---

14. Distinguish between streamlined flow and turbulent flow.

Streamlined Flow :

1. When a liquid flows such that each particle of the liquid passing through a point moves along the same path with the same velocity as it predecessor then the flow of liquid .
2. Velocity of the particle at any point is constant.
3. It is steady or laminar flow.
4. The actual path taken by the particle of the moving fluid is called a streamline , which is a curve , the tangent to which at any point gives the direction of the flow of the fluid at that point.

Turbulent Flow :

1. When the speed of the moving fluid exceeds the critical speed v_c the motion becomes turbulent.
2. The velocity changes both in magnitude and direction from particle to particle.
3. The path taken by the particles in turbulent flow becomes erratic and whirlpool like circles called eddy current or eddies.

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15. What is Reynold's number ? Give its significance .

Reynold's number is dimensionless number which is used to find out the nature of the liquid Whether it is streamline or turbulent.

- Density of liquid - ρ
- Velocity of liquid - V
- Diameter of pipe - D
- Coefficient of viscosity - η

$$R_C = \frac{\rho V D}{\eta}$$

---

16. Define terminal velocity.

The maximum constant velocity acquired by a body while falling freely through a viscous medium is called terminal velocity.

---

17. Write down the expression for the stoke's force and explain the symbols involved in it.

Viscous force F acting on a spherical body of radius r depends directly on

i) Radius (r) of the sphere

ii) Velocity (v) of the sphere

iii) Coefficient of viscosity (η)

$$F = 6 \pi \eta r v$$

---

18. State Bernoulli's theorem.

The sum of pressure energy , kinetic energy and potential energy , kinetic energy and potential energy per unit mass of an incompressible non – viscous fluid in a streamlined flow remains a constant.

$$\frac{P}{\rho} + \frac{1}{2} v^2 + g h = \text{constant}$$

19.What are the energies possessed by a liquid ? Write down their equations.

A liquid in a steady flow can possess three kinds of energy.

i) Kinetic Energy : $KE = \frac{1}{2} m v^2$ ii) Potential Energy : $PE = m g h$

iii) Pressure Energy : $E_P = \frac{P}{\rho} m$

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20. Two streamlines cannot cross each other . Why ?

If two streamlines cross each other , the fluid particle at the point of intersection will have two different directions of flow . This will destroy the steady nature of the fluid flow.

---

21. Define surface tension of a liquid . Mention its S.I unit and dimension.

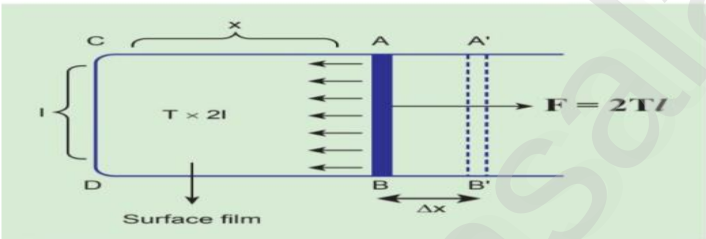
The surface tension of a liquid is defined as the energy per unit area of the surface of a liquid

$T = F / l$ S . I Unit : $N\ m^{-1}$ Dimension : $M T^{-1}$.

---

22. How is surface tension related to surface energy ?

Consider a rectangular frame of wire ABCD in a solution. Let AB be the movable wire. Suppose the frame is dipped in soap solution , soap film is formed which pulls the wire AB inward due to surface tension . Let F be the force due to surface tension.



1. <u>Force</u> : $F = (2T) l$

Here , 2 is introduced because it has two free surfaces.

2. <u>Work done</u> : $W = (2T) l\ \Delta x$

3. <u>Increase in area</u> : $\Delta A = (2l)\ \Delta x$

4. <u>Surface Energy</u> : $\frac{W}{\Delta A} = \frac{(2T) l\ \Delta x}{(2l)\ \Delta x} = T$

5. Surface energy per unit area is numerically equal to surface tension.

---

23. Define angle of contact for a given pair of solid and liquid.

The angle between the tangent to the liquid surface at the point of contact and the solid surface inside the liquid is known as the angle of contact between the solid and the liquid.

---

24. Distinguish between cohesive and adhesive forces.

<u>Cohesive Force :</u>

The force between the like molecules which holds the liquid together is called " cohesive"

Adhesive Force :

When the liquid is in contact with a solid , the molecules of these solid and liquid will experience an attractive force which is called " Adhesive force "

---

25. What are the factors affecting the surface tension of a liquid ?

1. Presence of contamination or impurities :

- **Surface tension depends the degree of contamination.**

2. Presence of dissolved substances :

- **It can also affect the value of surface tension.**
- **When Nacl dissolved in H_2O increases the surface tension of water.**

3. Electrification :

- **When a liquid is electrified , surface tension decreases.**

4. Temperature :

- **The surface tension decreases linearly with the rise of temperature. $T_t = T_0 \; 1 - \alpha t)$**

---

26. What happens to the pressure inside a soap bubble when air is blown into it ?

Pressure is greater inside the small build.

---

27. What do you mean by capillarity or capillary action ?

The rise or fall of a liquid in a narrow tube is called capillarity or capillary action.

---

28. A drop of oil placed on the surface of water spreads out. But a drop of water place on oil contracts to a spherical shape. Why ?

i) A drop of oil placed on the surface of water spreads . Since the force of adhesion between the water molecules dominates the cohesive force of the oil molecule. So oil drop in water spreads.

ii) The cohesive force of water molecule dominate the adhesive force between water & oil molecules. So drop of water contracts to spherical shape.

---

29. State the principle and usage of Venturi meter.

This device is used to measure the rate of flow of the incompressible fluid flowing through pipe. It works on the principle of Bernoulli's theorem.

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UNIT - 8

1. " An object contains more heat " - is it a right statement ? If not why ?

- Heat is the energy in transits and which flows from an object at higher temperature to an object at lower temperature.
- " An object has more heat " is wrong instead " object is hot " will be appropriate "

---

2. Obtain an ideal gas law from Boyle's and Charle's law.

Boyle's Law :

When the gas is kept at constant temperature , the pressure of the gas is inversely proportional to the volume. $P \ \alpha \ \frac{1}{V}$

Charle's Law :

When the gas is kept at constant pressure , the volume of the gas is directly proportional to the absolute temperature. $V \ \alpha \ T$

By combining these two equations : $PV = CT$

- The constant C as k times the number of particles N.
- K is the Boltzmann constant $1.381 \times 10^{-23} \ J \ K^{-1}$.

Ideal Gas Law : $PV = NkT$

---

3. Define one mole.

One mole of any substance is the amount of that substance which contains Avogadro's number (N_A) of particles . (Such as atoms or molecules)

---

4. Define specific heat capacity and give its unit.

Amount of heat energy required to raise the temperature of 1 kg of a substance by 1 kelvin

- or 1^0 C. S I Unit : $J \ Kg^{-1} \ K^{-1}$

$$S = \frac{1}{m}\left(\frac{\Delta Q}{\Delta T}\right)$$

- Amount of heat energy ⟶ ΔQ
- Change in temperature ⟶ ΔT
- Mass of the substance ⟶ m

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5. Define molar specific heat capacity .

Amount of heat energy required to increase the temperature of 1 mole of a substance by 1 kelvin or 1^0 C. S I Unit : J mol^{-1} K^{-1}

$$C = \frac{1}{\mu} \frac{\Delta Q}{\Delta T}$$

---

6. What is a thermal expansion ?

- **The tendency of matter to change in shape , area and volume due to a change in temperature.**
- **All three states of matter (solid , liquid and gas) expand when heated.**
- **When solid is heated , its atoms vibrate with higher amplitude about their fixed points.**
- **The relative change in the size of solids is small.**

---

7. Give the expressions for linear , area and volume thermal expansions.

1. Linear Expansion : $\alpha_L = \frac{\Delta L}{L_0 \Delta T}$

2. Areal Expansion : $\alpha_A = \frac{\Delta A}{A_0 \Delta T}$

3. Volume Expansion: $\alpha_V = \frac{\Delta V}{V_0 \Delta T}$

4. Coefficient of expansion → α_L , α_A , α_V

5. Change in length , Area , Volume → ΔL , ΔA , ΔV

---

8. Define latent heat capacity . Give its unit.

The amount of heat energy required to change the state of a unit mass of the material.

- **Latent heat capacity → L**
- **Amount of heat → Q**
- **Mass of substance → m**

$$L = \frac{Q}{m}$$

S I Unit : J Kg^{-1}

---

9. State Stefan - Boltzmann law.

Total amount of heat radiated per second per unit area of a black body is directly proportional to the fourth power of its absolute temperature.

$$E = \sigma T^4 \qquad \sigma = 5.67 \times 10^{-8} \ W\ m^{-2}\ K^{-4}$$

---

10. What is Wein's law ?

The wavelength of maximum intensity of emission of a black body radiation is inversely proportional to temperature of the black body.

$$\lambda_m = \frac{b}{T} \qquad b = 2.898 \times 10^{-3} \ m\ K$$

---

11. Define thermal conductivity. Give its unit.

The quantity of heat transferred through a unit length of a material in a direction normal to unit surface area due to a unit temperature difference under steady state conditions is known as " thermal conductivity " of a material.

$$\frac{Q}{t} = \frac{K A \Delta T}{L}$$

- **Coefficient of thermal conductivity → K**
- **S I unit : $J\ s^{-1}\ m^{-1}\ K^{-1}$ or $W\ m^{-1}\ K^{-1}$**

---

12. What is a black body ?

- **A black body is an object that absorbs all electro magnetic radiations .**
- **It is a perfect absorber and radiator of energy with no reflecting power.**
- **The sun is approximately taken as a black body.**
- **Any object above 0 K will emit radiation , sun also emits radiation.**

---

13. What is a thermodynamic system ? Give examples.

A thermodynamic system is a finite part of the universe. It is a collection of large

number of particles (atoms and molecules) specified by certain parameters called pressure (P) , Volume (V) and temperature (T) . The remaining part of the universe is called surrounding . Both are separated by a boundary.

Ex : **Bucket of water , Fish in the sea.**

---

14. What are the different types of thermodynamic systems ?

Open System :

It can exchange both matter and energy with the environment.

Closed System :

It can exchange energy but not matter with the environment.

Isolated System :

It can exchange neither energy nor matter with the environment.

---

15. What is meant by " thermal equilibrium " ?

Two systems are said to be in thermal equilibrium with each other if they are at the same temperature , Which will not change with time.

---

16. What is meant by state variable ? Give example.

- **In thermodynamics , the state of a thermodynamic system is represented by a set of variables called thermodynamic variable.**
- **The values of these variables completely describe the equilibrium state of a thermodynamic system.**

Ex : **Pressure , Temperature , Volume.**

---

17. What are intensive and extensive variables ?

Extensive Variable :

It depends on the size or mass of the system.

Ex : **Volume , Entropy , Total mass**

Intensive Variable :

It do not depend on the size or mass of the system.

Ex : **Density , Pressure , Temperature**

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18. What is an equation of state ? Give an example.

- The equation which connects the state variables in a specific manner is called " equation of state "
- A thermodynamic equilibrium is completely specified by these state variables by the equation of state.
- If the system is not in thermodynamic equilibrium then these equation cannot specify the state of the system.

Ex : Equation of state of Van der Walls equation. Real gases obey this equation at thermodynamic equilibrium.

---

19. State Zeroth law of thermodynamic equilibrium.

If two systems A and B are in thermodynamic equilibrium with a third system C then A and B are in thermodynamic equilibrium with each other.

---

20 . Define the internal energy of the system.

- The internal energy of a thermodynamic system is the sum of kinetic and potential energies of all the molecules of the system with respect to the center of mass of the system.
- Energy due to molecular motion including translational , rotational and vibrational motion is called internal kinetic energy (E_K)
- Energy due to molecular interaction is called internal potential energy (E_P).

Ex : Bond energy $U = E_K + E_P$

---

21. Are internal energy and heat energy the same ? Explain .

- No , but they are related . If heat energy is added to substance , its internal energy will increase.
- Internal energy is a measure of kinetic & potential energy possessed by particles

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in a substance.

- Heat energy concerns only transfer of internal energy from the hotter to colder body.

---

22. Define one calorie.

One calorie is defined as the amount of heat required at a pressure of 1std atmosphere to raise the temperature of 1 g of water at 1^0 C.

---

23. Did Joule converted mechanical energy to heat energy ? Explain.

- Yes , in his experiment , two masses were attached with a rope and a paddle wheel. When these masses fall through a distance h due to gravity , both the masses lose potential energy equal to 2 m g h.
- When the masses fall , the paddle wheel turns . Due to the turning of wheel inside water , frictional force comes in between the water and paddle wheel.
- This cause a rise in temperature of the water. This implies that gravitational potential energy is converted to internal energy of water.
- The temperature of water increases due to the work done by the masses . Joule was able to show that the mechanical work has the same effect as giving heat.

---

24. State the first law of thermodynamics .

Change in internal energy (ΔU) of the system is equal to heat supplied to the system (Q) minus the work done by the system (W) on the surroundings.

$$\Delta U = Q - W$$

---

26. Give the sign convention for Q and W.

- System gains heat → Q is positive
- System loses heat → Q is negative
- Work done on the system → W is positive
- Work done by the system → W is negative

---

27. Define the quasi - static process.

- **A quasi - static process is an *infinitely slow process* in which the system changes its variables (P , V , T) so slowly.**
- **Such that it remains in thermal , mechanical and chemical equilibrium with its surroundings through out.**
- **By this infinite slow variation the system is always almost close to equilibrium state.**

---

28. Give the expression for work done by the gas.

In general the work done by he gas by increasing the volume from V_i to V_f is given by

$$W = \int_{V_i}^{V_f} P\,dV$$

---

29. What is P V diagram ?

- **P V diagram is a graph between pressure P and volume V of the system .**
- **P V diagram is used to calculate the amount of work done by the gas during expansion or on the gas during compression.**

---

30. Explain why the specific heat capacity at constant pressure is greater than the specific heat capacity at constant volume.

- **Because when heat is added at constant pressure the substance expands & work.**
- **More amount of energy has to be supplied to a constant pressure to increase the system temperature by the same amount .**
- **Some of this energy is lost due to expansion work done by the system.**

---

31. Give the equation of state for an isothermal process.

The equation of state for isothermal process is given by P V = Constant

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32. Give an expression for work done in an isothermal process.

$$W = \mu R T \ln\left(\frac{V_f}{V_i}\right)$$

---

33. Express the change in internal energy in terms of molar specific heat capacity.

If Q is the heat supplied to mole of a gas at constant volume and if the temperature changes by an amount ΔT, We have

$$Q = \mu C_V \Delta T \rightarrow (1)$$

By applying the first law of thermodynamics for this constant volume process W = 0 since dV = 0 We have

$$Q = \Delta U - 0 \rightarrow (2)$$

Comparing the equations (1) and (2)

$$\Delta U = \mu C_V \Delta T$$

$$\mu C_V \Delta T = \Delta U$$

$$C_V = \frac{1}{\mu} \frac{\Delta U}{\Delta T}$$

$$\boxed{C_V = \frac{1}{\mu} \frac{dU}{dT}}$$

---

34. Apply first law for a) isothermal b) adiabatic c) isobaric processes.

S.No	Process	First Law
1.	Isothermal	$Q = W$
2.	Adiabatic	$\Delta U = W$
3.	Isobaric	$\Delta U = Q - P \Delta V$

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35. Give the equation of state for an adiabatic process.

$$P V^{\gamma} = \text{Constant}$$

- γ → Adiabatic exponent ($\gamma = C_P / C_V$)

---

36. Give an equation state for an isochoric process.

$$P = \left(\frac{\mu R}{V}\right) T$$

---

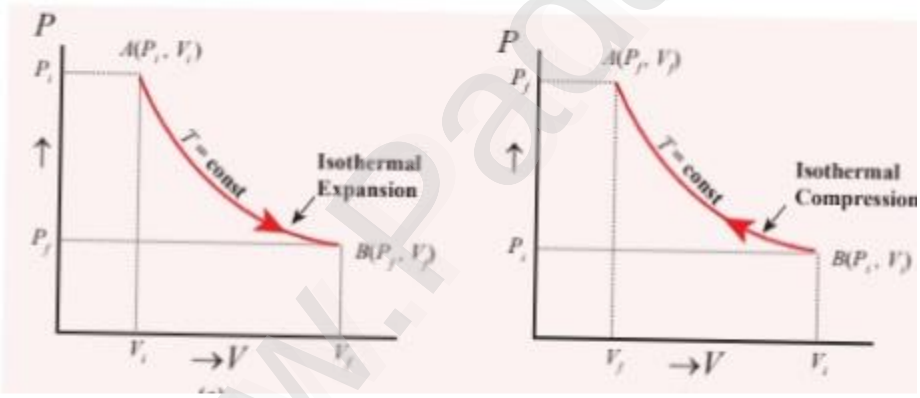
37. If the piston of a container is pushed fast inward . Will the ideal gas equation be valid in the intermediate stage ? If not , Why ?

- Decrease in volume leading to increase in temperature work is done on the gas.
- Ideal gas equation $P V = R T$
- When piston be pushed further the parameters V & R are taken as constant.
- The equation becomes $P = K T$ i.e ., $P \alpha T$

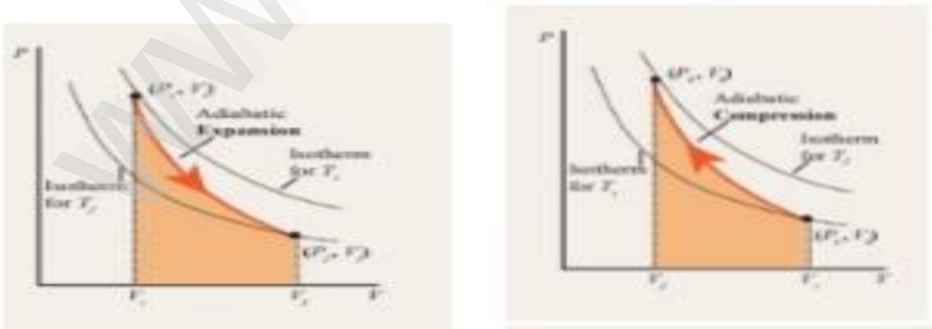
---

38. Draw the P V diagram for : a) Isothermal Process b) Adiabatic Process c) Isobaric Process d) Isochoric Process

a) Isothermal Process



b) Adiabatic Process



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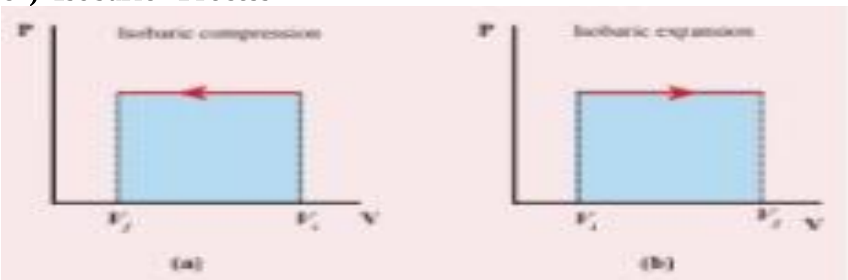
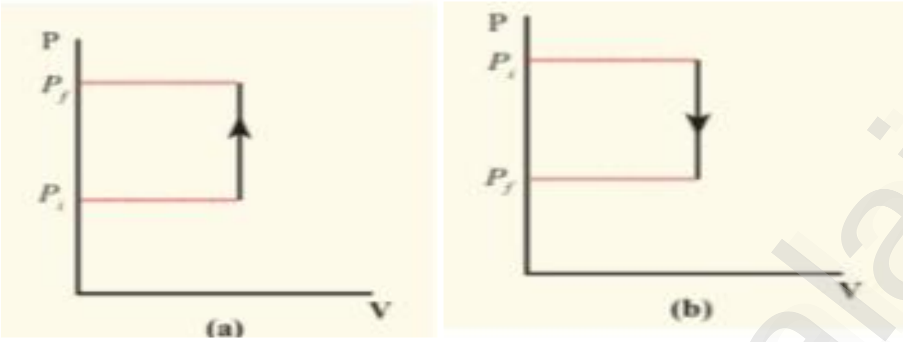
c) Isobaric Process



d) Isochoric Process



---

39. What is a cyclic process ?

- The thermodynamic system returns to its initial state after undergoing a series of changes.
- The system comes back to initial state , change in the internal energy is zero.
- Heat can flow in to system and flow in to system and flow out of the system.

---

40. What is meant by a reversible and irreversible processes ?

<u>Reversible Processs:</u>

- If it possible to retrace the path in the opposite direction in such a way that the system and surroundings pass through the same as in the initial , direct process.

<u>EX</u> : A quasi static isothermal expansion of gas , slow compression and expansion of a spring.

<u>Irreversible Process:</u>

- All natural processes are irreversible.
- Irreversible process cannot be plotted in a P V diagram.

- These process cannot have unique values of pressure , temperature at every stage of the process.

---

41. State Clausius form of the second law of thermodynamics.

" Heat always flows from hotter object to colder object spontaneously " This is known as the Clausius form of the second law of thermodynamics.

---

42. State Kelvin - Planck statement of second law of thermodynamics.

It is impossible to construct a heat engine that operates in a cycle whose sole effect is to convert the heat completely into work . This implies that no heat engine in the universe can have 100 % efficiency.

---

43. Define heat engine .

Heat engine is a device which takes which takes heat as input and converts this heat in to work by undergoing a cyclic process.

---

44. What are processes involves in a Carnot engine ?

There are four reversible processes involved in Carnot's engine. There are

1. **Step A to B :** Quasi -static isothermal expansion from (P_1 , V_1 , T_H) to (P_2 , V_2 , T_H)
2. **Step B to C :** Quasi -static adiabatic expansion from (P_2 , V_2 , T_H) to (P_3 , V_3 , T_L)

#. **Step C to D :** Quasi -static isothermal compression from (P_3 , V_3 , T_L) to (P_4 , V_4 , T_L)

4. **Step D to A :** Quasi -static adiabatic compression from (P_4 , V_4 , T_L) to (P_1 , V_1 , T_H)

---

45. Can the given heat energy be completely converted to work in a cyclic process ? If not , when can the heat can completely converted to work ?

i) No , in a cyclic process the complete energy is not completely converted into work , as it violate second law of thermos dynamics.

ii) In an isothermal process the whole heat can be converted into work . For an isothermal process d Q = d T which shows that whole heat can be converted into work.

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46. State the second law of thermodynamics in terms of entropy .

" For all the processes that occur in nature (Irreversible process) the entropy always increases . For reversible process entropy will not change " .

Entropy determines the direction in which natural process should occur.

---

47. Why does heat flow from a hot object to a cold object ?

Because entropy increases when heat flows from hot object to cold object.

---

48. Define the coefficient of performance .

It is defined as the ratio of heat extracted from the cold body to the external from the cold body to the external work done by the compressor .

$$COP = \beta = \frac{Q_L}{W}$$

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UNIT - 9

1. What is the microscopic origin of pressure ?

With the help of kinetic theory of gases , the pressure is linked to the velocity of molecules.

$$P = \frac{1}{3}\frac{N}{V} m \overline{v}^2$$

- Mass of the molecule → m
- Avogadro number → N
- Average velocity → $\overline{v}$
- Volume of molecule → V

---

2. What is the microscopic origin of temperature ?

Average K.E / molecule K.E = ε = $\frac{3}{2}$ N k T

---

3. Why moon has no atmosphere ?

The escape speed of gasses on the surface of moon is much less than the root mean square speeds of gases due to low gravity . Due to this , all the gases escape from the surface of the moon.

---

4. Write the expression for rms speed , average speed and most probable speed of a gas molecule.

RMS Speed : $V_{rms} = \sqrt{\frac{3KT}{m}} = 1.732\sqrt{\frac{KT}{m}}$

Average Speed : $\overline{V} = \sqrt{\frac{8KT}{m}} = 1.60\sqrt{\frac{KT}{m}}$

Most Probable Speed : $V_{mp} = \sqrt{\frac{2KT}{m}} = 1.414\sqrt{\frac{KT}{m}}$

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5. What is the relation between the average kinetic energy and pressure ?

The internal energy of the gas is given by

$$U = \frac{3}{2} N K T$$

$$U = \frac{3}{2} P V T \quad (P V = N K T)$$

$$P = \frac{2}{3} \frac{U}{V}$$

$$P = \frac{2}{3} u \quad (u = U / V)$$

Pressure of the gas is equal to two thirds of internal energy per unit volume or internal energy density.

Pressure of the gas :

$$P = \frac{1}{3} n m \overline{v}^2$$

$$P = \frac{1}{3} \rho \overline{v}^2 \quad (\rho = n m)$$

Multiply and divide R . H . S of eqn by 2

$$P = \frac{2}{3} \left(\frac{\rho \overline{v}^2}{2} \right)$$

$$\boxed{P = \frac{2}{3} \overline{K.E}}$$

---

6 . Define the term degrees of freedom.

The minimum number of independent coordinates needed to specify the position and configuration of a thermodynamical system in space is called the degree of freedom of the system.

---

7. State the law of equipartition of energy .

According to kinetic theory , the average kinetic energy of system of molecules in thermal equilibrium at temperature T is uniformly distributed to all degrees of freedom so that

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each degree of freedom will get 1 / 2 K T of energy . This is called law of equipartition of energy.

---

8. Define mean free path and write down its expression.

Average distance travelled by the molecule between collisions is called is called mean free path (λ)

$$\text{Mean free path} = \frac{\text{Distance travelled}}{\text{Number of collisions}}$$

$$\lambda = \frac{1}{\sqrt{2}\,\pi\, d^2\, \rho}$$

---

9. Deduce Charle's law based on kinetic theory .

From the equation ,

$$P = \frac{2}{3}\frac{U}{V}$$

$$P = \frac{2}{3} u \quad (u = U / V)$$

We get , $P V = \frac{2}{3} U$

For a fixed pressure , the volume of the gas is proportional to internal energy of the gas and the average kinetic energy of the gas and the average kinetic energy is directly proportional to absolute temperature .

$$V \propto T$$

$$\frac{V}{T} = \text{Constant}$$

---

9. Deduce Boyle's law based on kinetic theory .

From the equation ,

$$P = \frac{2}{3}\frac{U}{V}$$

$$P = \frac{2}{3} u \quad (u = U / V)$$

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We get , $PV = \frac{2}{3} U$

But the internal energy of an ideal gas is equal to N times the average kinetic energy (ε) of each molecule , $U = N\varepsilon$

For a fixed temperature , the average translational kinetic energy ε will remain constant. It implies that ,

$$PV = \frac{2}{3} N\varepsilon$$

$$PV = \text{Constant}$$

---

11 . Deduce Avogadro's law based on kinetic theory.

- **This law states that at constant temperature and pressure , equal volumes of all gases contain the same number of molecules . For two different gases at the same temperature and pressure .**
- **According to kinetic theory of gases ,**

$$P = \frac{1}{3}\frac{N_1}{V} m_1 \overline{v_1}^2 = \frac{1}{3}\frac{N_2}{V} m_2 \overline{v_2}^2 \quad \text{--------} \quad (1)$$

Where $\overline{v_1}^2$ and $\overline{v_2}^2$ are the mean square speed for two gases and N_1 and N_2 are the number of gas molecules in two different gases.

- **At the same temperature , average kinetic energy per molecule is the same for two gases.**

$$\frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_2 v_2^2 \quad \text{--------} \quad (2)$$

- **Dividing (1) by (2) We get $N_1 = N_2$. This is Avogadro's law.**

---

12. List the factors affecting the mean free path.

1. **Mean free path increases with increasing temperature . As the temperature increases , the average speed of each molecule will increase. It is the reason why the smell of hot sizzling food reaches several meter away than smell of cold food.**
2. **Mean free path increases with decreasing pressure of the gas and diameter of the gas molecule.**

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13. What is the reason for Brownian motion ?

1. **According to kinetic theory , any particle suspended in a liquid or gas is continuously bombarded from all the directions so that the mean free path is almost negligible.**
2. **This leads to the motion of the particles in a random and zig - zag manner.**

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UNIT - 10

1. What is meant by periodic and non - periodic motion ? Give any two examples for each motion.

Periodic Motion :

Any motion which repeats itself in a fixed time interval is known as periodic motion.

EX : 1. Hands in pendulum clock 2. Heart beat of a person

Non - Periodic Motion :

Any motion which does not repeats itself after regular interval of time is known as Non - periodic motion.

EX : 1. Oscillations of loaded spring 2. Vibrations of tuning fork

---

2. What is meant by force constant of a spring ?

Force constant is defined as force per unit displacement.

Ex : 1. Oscillations of loaded spring 2. Vibrations of a tuning fork

---

3. Define time period of simple harmonic motion.

The time period is defined as the time taken by a particle to complete one oscillation . It is usually denoted by T . For one complete revolution , the time taken is t = T

$$T = \frac{2\pi}{\omega}$$

---

4. Define frequency of simple harmonic motion.

- The number of oscillations produced by the particle per second is called frequency. $f = 1 / T$. S I Unit is hertz (Hz) or s^{-1}.
- The number of revolutions per sec is called angular frequency .
- Angular frequency and frequency are related by $\omega = 2\pi f$. S I unit is rad s^{-1}.

---

5. What is an epoch.

The displacement time t = 0 s , the phase $\phi = \phi_o$ is called epoch (initial epoch)

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ϕ_o is called the angle of epoch.

---

6. Write short notes on two springs connected in series.

Consider only two springs whose spring constant are k_1 and k_2 and which can be attached to a mass m. The results thus obtained can be generalized for any number of springs in series.

For springs in series connection : $-k_1 x_1 = -k_2 x_2 = F$

$$x_1 = -\frac{F}{k_1} \qquad x_1 = -\frac{F}{k_2}$$

Effective spring constant : $-\frac{F}{k_1} - \frac{F}{k_2} = -\frac{F}{k_s}$

$$k_s = \frac{k_1 k_2}{k_1 + k_2}$$

---

7. Write short notes on two springs connected in parallel.

Consider only two springs of spring constants k_1 and k_2 attached to a mass m. The results can be generalized to any number of springs in parallel.

$$F = -k_1 x - k_2 x$$

$$F = -k_p x$$

$$K_p = k_1 + k_2$$

---

8. Write down the time period of simple pendulum.

The angular frequency of this oscillator is ,

$$\omega^2 = \frac{g}{l} \qquad \omega = \sqrt{\frac{g}{l}} \qquad \text{rad s}^{-1}$$

Frequency of oscillation

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}} \quad \text{in Hz}$$

Time period of oscillation

$$T = 2\pi\sqrt{\frac{l}{g}} \quad \text{in sec}$$

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9. State the laws of simple pendulum.

i) Law of length :

For a given value of acceleration due to gravity , the time period of a simple pendulum is directly proportional to the square root of length of the pendulum.

$$T \propto \sqrt{l}$$

ii) Law of acceleration :

For a fixed length , the time period of a simple pendulum is inversely proportional to the square root of acceleration due to gravity.

$$T \propto \frac{l}{\sqrt{g}}$$

---

10. Write down the equation of time period for linear period for linear harmonic oscillator.

From Newton's second law , we can write the equation for the particle executing simple harmonic motion

$$m \frac{d^2 x}{d t^2} = - k x$$

$$\frac{d^2 x}{d t^2} = - \frac{k}{m} x$$

$$a = \frac{d^2 x}{d t^2} = - \omega^2 x$$

1. Angular Frequency : $\omega = \sqrt{\frac{k}{m}}$

2. Frequency : $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

3. Time Period : $T = 2\pi\sqrt{\frac{m}{K}}$

---

11. What is meant by free oscillation ?

When the oscillator is allowed to oscillate by displacing its position from equilibrium position , it oscillates with a frequency which is equal to the natural frequency which is equal to the oscillator . Such an oscillation is known as free oscillation .

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12. Explain damped oscillation . Give an example.

1. Due to the presence of friction and air drag , the amplitude of oscillation decreases as time progresses.
2. It implies that the oscillation is not sustained and the energy of the S H M decreases gradually indicating the loss of energy.
3. The energy lost is absorbed by the surrounding medium . This type of oscillatory motion is known as damped oscillation.

Examples :

1. Oscillation of a pendulum (including air friction)
2. Electromagnetic oscillation in a tank circuit.
3. Oscillations in a dead beat and ballistic galvanometers.

---

13. Define forced oscillation . Give an example.

In this type of vibration , the body executing vibration initially vibrates with its natural frequency and due to the presence of external periodic force , the body later vibrates with the frequency of the applied periodic force. Such vibrations are known as forced vibration.

Ex : Sound board of stringed instruments.

---

14. What is meant by maintained oscillations ? Give an example.

While playing in swing , the oscillations will stop after a few cycles , this is due to damping. To avoid damping we have to supply a push to sustained oscillations. By supplying energy from an external source , the amplitude of the oscillation can be made constant. Such vibrations are known maintained vibration.

Ex : The vibration of a tunning fork getting energy from a battery or from external power supply.

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15. Explain resonance . Give an example.

The frequency of external periodic force matches with the natural frequency of the vibrating body. As a result the oscillating body begins to vibrate such that its amplitude increases at each step and ultimately it has a large amplitude.

<u>Ex :</u> The breaking of glass due to sound.

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UNIT - 11

1. What is meant by waves ?

The disturbance which carries energy and momentum from one point in space to another point in space without the transfer of the medium is known as a wave.

---

2. Write down the types of waves.

i) Mechanical Wave :

Waves which require a medium for propagation are known as mechanical wave.

EX : Sound waves , Ripples formed on water surface.

ii) Non - mechanical Wave :

Waves which do not require medium for propagation are known as mechanical wave.

EX : Light waves , Infra red rays

Waves can be classified into two types :

1. Transverse wave 2. Longitudinal wave

---

3. What are transverse wave ? Give one example.

In transverse wave motion , the constituent of the medium oscillate or vibrate about their mean position in a direction perpendicular to the direction of propagation of waves.

EX : Light (Electromagnetic wave)

---

4. What are longitudinal wave ? Give one example.

In longitudinal wave motion , the constituent of the medium oscillate or vibrate about their mean position in a direction parallel to the direction of propagation of waves.

Ex : Sound waves travelling in air

---

5. Define wavelength.

- **For transverse waves , the distance between two neighbouring crests or trough is known as the " wavelength ".**

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- For longitudinal waves , the distance between two neighbouring compressions or rarefactions is known as the wavelength .
- S I unit of wave length is meter.

---

6. Write down the relation between frequency , wavelength and velocity of a wave.

Dimension of wave length is $[\lambda] = L$

$$\text{Frequency} = \frac{1}{\text{Time period}}$$

Dimension of frequency is $[f] = \frac{1}{[T]} = T^{-1}$

Relation between frequency & wavelength :

$$[\lambda f] = [\lambda][f] = L\ T^{-1} = [\text{Velocity}]$$

$$\boxed{\lambda f = v}$$

- Wave velocity is the distance travelled by a wave in one second.
- Wave velocity is called as " phase velocity "

---

7. What is meant by interfere of waves ?

Interference is a phenomenon in which two waves superimpose to form a resultant wave of greater , lower or the same amplitude.

---

8. Explain the beat phenomenon.

- When two or more waves superimpose each other with slightly different frequencies , then a sound of periodically varying amplitude at a point is observed . This phenomenon is known as beats .
- The number o f amplitude maxima per second is called beat frequency.
- If we have two sources , then their difference in frequency gives the beat frequency.
- Number of beats per second $n = |f_1 - f_2|$ per second

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9. Define intensity of sound and loudness of sound .

- The sound power transmitted per unit area taken normal to the propagation of the sound wave.
- The loudness of sound is defined as " the degree of sensation of sound produced in the ear or the perception of sound by the listener .

---

10. Explain Doppler effect.

When the source and the observer are in relative motion with respect to each other and to the medium in which sound propagates , the frequency of the sound wave observed is different from the frequency of the source. This phenomenon is called " Doppler effect ".

---

11. Explain red shift and blue shift in Doppler effect.

The spectral lines of the star are found to shift towards red end of the spectrum then the star is receding away from the earth. Similarly if the spectral lines of the star are found to shift towards the blue end of the spectrum then the star is approaching earth.

---

12. What is meant by end correction in resonance air column apparatus ?

The antinodes is not exactly formed at the open end , but a small distance above be open end. This is called " end correction "

To computer the end correction : $L_1 + e = \frac{\lambda}{4}$ and $L_2 + e = \frac{3\lambda}{4}$

---

13. Sketch the function y = x + a . Explain your sketch.

i) A combination of constant and direct.

ii) A fixed amount is added at regular intervals.

iii) y = x + a , a suitable conclusion statement would be that,

1. y is linear with a
2. y varies linearly with x.
3. Y is a linear function of x y is the intercept.

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14. Write down the factors affecting velocity of sound in gases.

1. Pressure 2. Temperature 3. Density 4. Humidity 5. Wind

---

15. What is meant by an echo ? Explain.

1. An echo is a reception of sound produced by the reflection of sound waves from a wall , mountain or other obstructing surfaces. The speed of sound in air at 20^0 C is 344 m s^{-1} .

2. If we shout at a wall which is at 344 m away , then the sound will take 1 second to reach the wall.

3. After reflection , the sound will take one more second to reach us.

4. We hear the echo after two seconds only.

5. Time gap or time interval between each sound is (1 / 10 $)^{th}$ of second is 0.1 s

6. The minimum distance from a sound reflecting wall to hear an echo at 20^0 C is 17.2 m .

$$\text{Velocity} = \frac{\text{Distance Travelled}}{\text{Time taken}} = \frac{2d}{t}$$

$$2d = 344 \times 0.1 = 34.4$$

$$d = 17.2 \text{ m}$$

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Lesson 1

1. (i) Explain the use of screw gauge and vernier calliper in measuring smaller distances.

Screw Gauge :

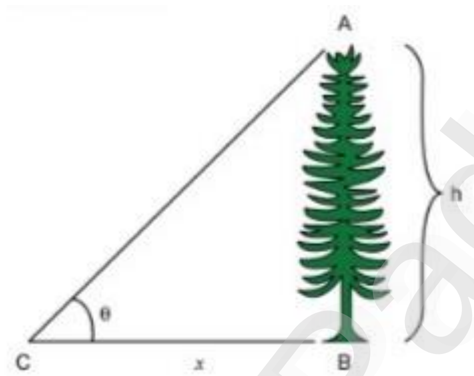
1. Used to measure object dimension about 50 mm.
2. Principle of instrument : i) Linear motion ii) Circular motion
3. Least count of screw gauge is 0.01 mm.

Vernier Calliper :

1. It is a versatile instrument.
2. Used to measure : i) Diameter of hole ii) Depth of hole
3. Least count of vernier is 0.01 cm.

(ii) Triangulation method to measure larger distance

Diagram :



Formula :

$$h = x \tan \theta$$

Theory :

1. Height of the tree AB = h .
2. Base distance BC = x
3. Point of observation is C.
4. Angle of elevation θ = < ACB .

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5. **From triangle ABC ,**

$$\tan \theta = \frac{AB}{BC}$$

6. $$\tan \theta = \frac{h}{x}$$

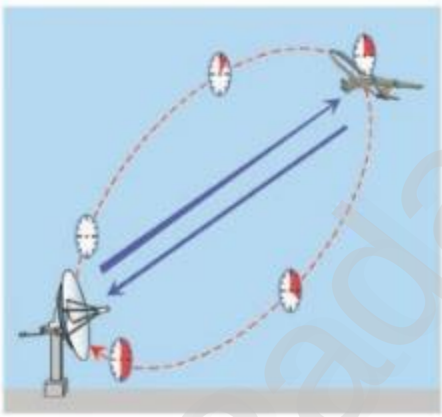
7. $$\frac{h}{x} = \tan \theta$$

8. $$h = x \tan \theta$$

9. By knowing the distance x , Ɵ then h can be determined.

(iii) Radar method to measure larger distance :

Diagram :



Formula :

$$d = \frac{v \times t}{2}$$

Theory :

1. Radar means " Radio detection and ranging " .
2. Used to measure large distance.
3. Radio waves send to transmitters .
4. Radio waves detect by receiver.
5. Distance : $d = \frac{v \times t}{2}$

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2. Explain in detail the various types of errors.

Error : **Uncertainty in a measurement is called as error.**

Types of error :

1. **Random Error**
2. **Systematic Error**
3. **Gross Error**

1. Systematic Error :

i) Reproducible Error
ii) Inaccuracy Error

Types of systematic error :

1. Instrumental Error :

- **Error due to instrumental manufacture .**
- **Example : Meter scale whose end worn out.**

2.Imperfection Error :

- **Error due to experiment limitation .**
- **Example : Experiment with calorimeter.**

3. Personal Error :

- **Error due to personal and individual .**
- **Example : Carelessness of individual.**

4. External Cause Error:

- **Error due to external cause .**
- **Example : Humidity, Pressure .**

5. Least Count Error:

- **Smallest value measured by instrument .**
- **Example : L.C of screw gauge 0.01 mm.**

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Random Error:

1. **Error due to random condition.**
2. **Also known as "Chance Error"**

Gross Error:

1. **Recording wrong observation.**
2. **Wrong values in calculations.**

---

3. What do you mean by propagation error? Explain the propagation errors in addition and multiplication.

The various possibilities of the propagation or combination of errors in maths operation.

1) Error in sum of quantities:

1. **Two quantities** ⟶ $A \, , \, B$
2. **Error in quantities** ⟶ $\Delta A \, , \, \Delta B$
3. **Sum of quantities** ⟶ $Z = A + B$
4. **Error in sum** ⟶ ΔZ
5. **Measured value of** $A = A \pm \Delta A$
6. **Measured value of** $B = B \pm \Delta B$

$$Z = A + B$$

$$Z \pm \Delta A = A \pm \Delta A + B \pm \Delta B$$

$$\boxed{\Delta Z = \Delta A + \Delta B}$$

" The maximum possible errors in the sum of the quantities is equal to the sum of the absolute errors in the individual quantities "

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2) **Error in multiplication of quantities:**

1. Two quantities ⟶ A , B
2. Error in quantities ⟶ ΔA , ΔB
3. Sum of quantities ⟶ Z = A B
4. Error in sum ⟶ Δ Z
5. Measured value of A = A ± Δ A
6. Measured value of B = B ± Δ B

$$Z = A B$$

$$Z \pm \Delta A = (A \pm \Delta A)(B \pm \Delta B)$$

$$Z \pm \Delta A = A B \pm A \Delta B \pm B \Delta A \pm B \Delta B$$

$$\frac{\Delta Z}{Z} = \pm \left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right)$$

" The maximum fractional error in the product of the quantities is equal to the sum of the fractional errors in the individual quantities "

4.Write a short notes on the following

a) Unit b) Rounding off c) Dimensionless quantities

a) Unit

An arbitrarily chosen standard of measurement of quantity , which is accepted internationally is called unit of the quantity.

b) Rounding off

* Calculators are widely used now a days for calculations.
* Calculators has too many figures.
* Results have more significant figures.
* Numbers containing more than one uncertain number should be round off.

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c) Dimensionless quantities :

Dimensionless variable :

Physical quantity which have no dimension but have variable.

Ex : Strain , Specific gravity

Dimensionless constant :

Physical quantity which have constant values but have no dimension.

Ex : π , e (Euler's number)

---

5. Explain the principle of homogeneity of dimension . What are its uses ? Give example.

Principle of homogeneity of dimension :

It states that the dimensions of all the terms in physical expression should be same.

Applications / Uses of Principle of homogeneity of dimension :

1. **Convert physical quantity from one system of units to another.**
2. **Check the dimensional correctness of a given physical equation.**
3. **Establish relations among various physical quantities.**

1. Conversion of physical quantity :

Convert the numerical value of physical quantity from one system of unit into other unit.

$$n_1 \, [\, M_1^a \;\; L_1^b \;\; T_1^c \,] \;=\; n_2 \, [\, M_2^a \;\; L_2^b \;\; T_2^c \,]$$

Quantity	Power	One System	Another System
Mass	a	M_1	M_2
Length	b	L_1	L_2
Time	c	T_1	T_2

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2. Check the dimensional correctness of physical quantity

$$V = u + a\,t$$

$$[LT^{-1}] = [LT^{-1}] + [LT^{-2}]\,[T]$$

$$[LT^{-1}] = [LT^{-1}] + [LT^{-1}]$$

- **Dimension of both sides are equal.**
- **This equation is dimensionally correct.**

3. Establish the relation among physical quantity

- **If the physical quantity Q depends on Q_1, Q_2, Q_3**
- **Q is proportional to Q_1, Q_2, Q_3**
- $Q \;\alpha\; Q_1^a\; Q_2^b\; Q_3^c$
- $Q = K\; Q_1^a\; Q_2^b\; Q_3^c$

K -------------------- Dimensionless Constant.

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Lesson 2

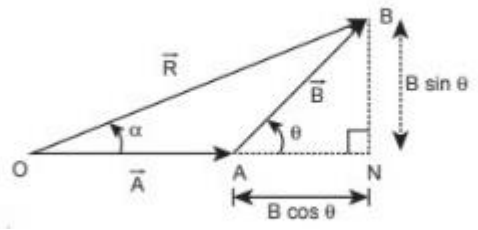
1. Explain in detail the triangle law of addition .

Triangle law of addition :

The vectors $\vec{A}$ and $\vec{B}$ two adjacent sides of triangle then resultant is given by the third side of the triangle.

$$\vec{R} = \vec{A} + \vec{B}$$

Diagram :



From Figure :

OA = A	AB = B	OB = R
AN = B cos Θ	BN = B sin Θ	

1. Magnitude of resultant vector

Triangle OBN

1. $OB^2 = ON^2 + BN^2$
2. $OB^2 = (OA + AN)^2 + BN^2$
3. $OB^2 = OA^2 + AN^2 + 2\ OA\ .\ AN + BN^2$
4. $R^2 = A^2 + B^2 \cos^2 \Theta + 2\ A B \cos \Theta + B^2 \sin^2 \Theta$
5. $R = \sqrt{A^2 + B^2 + 2\ A B \cos \Theta}$

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2. Direction of resultant vector

Triangle OBN

1. $\tan \alpha = \frac{BN}{ON}$

2. $\tan \alpha = \frac{BN}{OA + AN}$

3. $\tan \alpha = \frac{B \sin \theta}{A + B \cos \theta}$

---

2. Discuss the properties of scalar and vector product.

Scalar Product :

1. Product of the magnitudes of both the vectors and cosine of angle between them.

$$\vec{A} \cdot \vec{B} = A\, B \cos \theta$$

2. Scalar product is commutative $\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}$

3. Distributive law $\vec{A} \cdot (\vec{B} + \vec{C}) = \vec{A} \cdot \vec{B} + \vec{A} \cdot \vec{C}$

4. Unit Vector : $\hat{i} \cdot \hat{i} = \hat{j} \cdot \hat{j} = \hat{k} \cdot \hat{k} = 1$

5. Orthogonal : $\hat{i} \cdot \hat{j} = \hat{j} \cdot \hat{k} = \hat{k} \cdot \hat{i} = 0$

6. Scalar product is maximum when $\theta = 0^0$ then $\cos \theta = 1$

$$(\vec{A} \cdot \vec{B})_{max} = A\, B$$

7. Scalar product is minimum when $\theta = 180^0$ then $\cos \theta = -1$

$$(\vec{A} \cdot \vec{B})_{min} = -\, A\, B$$

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Vector Product :

1. Product of the magnitudes of both the vectors and sine of angle between them.

$$\vec{C} = \vec{A} \times \vec{B} = (A\ B \sin \Theta)\ \hat{n}$$

2. Vector product is not commutative $\vec{A} \times \vec{B} \neq \vec{B} \times \vec{A}$

3. Unit Vector : $\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0$

4. Orthogonal : $\hat{i} \times \hat{j} = \hat{K}$; $\hat{j} \times \hat{k} = \hat{i}$; $\hat{k} \times \hat{i} = \hat{j}$;

5. Vector product is maximum when $\Theta = 90^0$ then $\sin \Theta = 1$

$$(\vec{A} \times \vec{B})_{max} = A\ B$$

6. Vector product is minimum when $\Theta = 0^0$ then $\sin \Theta = 0$

$$(\vec{A} \times \vec{B})_{min} = 0$$

7. Self cross product is null vector.

$$\vec{A} \times \vec{B} = A\ A \sin 0^0\ \hat{n} = 0$$

---

3. Derive the kinematic equation of motion for constant acceleration.

1. Velocity - Time relation

- $a = \frac{dV}{dt}$
- $dV = a\ dt$

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- $\int_u^v dV = a \int_0^t dt$
- $[v]_u^v = a\,[t]_0^t$
- $v - u = at$
- $v = u + at$

2.Displacement - Time relation

- $v = \frac{ds}{dt}$
- $ds = v\,dt$
- $ds = (u + at)\,dt$
- $\int_0^s ds = \int_0^t (u + at)\,dt$
- $\int_0^s ds = \int_0^t u\,dt + a\int_0^t t\,dt$
- $S = ut + \frac{1}{2} a t^2$

3. Velocity - Displacement relation :

- $a = \frac{dv}{dt}$
- $a = \frac{dv}{dt} \frac{ds}{ds}$
- $a = \frac{dv}{ds} \frac{ds}{dt}$
- $a = \frac{dv}{ds} v$

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- $a \int_0^s ds = \int_u^v v \, dv$
- $a s = \frac{v^2 - u^2}{2}$
- $2 a s = v^2 - u^2$
- $v^2 = u^2 + 2 as$

4. $S = ut + \frac{1}{2} a t^2$

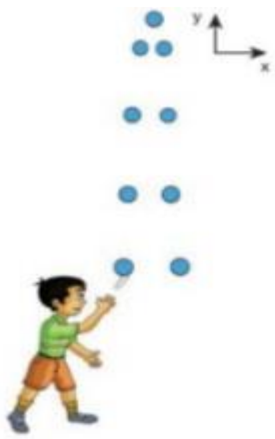
- $at = v - u$
- $s = ut + \frac{1}{2} vt - \frac{1}{2} ut$
- $s = \frac{1}{2} ut + \frac{1}{2} vt$
- $S = \frac{(u + v) t}{2}$

4.Derive the equation of motion for a particle

a) Falling vertically b) Projected vertically.

a) Falling Vertically

b) Projected Vertically



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a) **Falling vertically**

- Consider an object of mass m falling from a height h.
- Let us choose downward direction as positive y – axis.

Kinematics equation :

- $v = u + at$
- $v^2 = u^2 + 2as$
- $S = ut + \frac{1}{2} a t^2$

Body at rest u = 0

- $v = gt$
- $v^2 = 2gy$
- $y = \frac{1}{2} g t^2$

Particle reach ground t = T and y = h

$v^2 = 2gh$ $\quad$ $v_{ground} = \sqrt{2gh}$

$h = \frac{1}{2} g t^2$ $\quad$ $T = \sqrt{\frac{2h}{g}}$

b) Projected vertically a = - g

- $V = u - gt$
- $V^2 = u^2 - 2gy$
- $S = ut - \frac{1}{2} g t^2$

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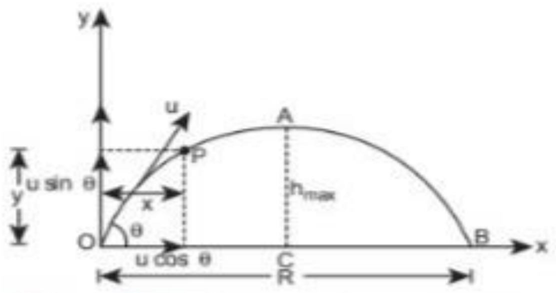
5. Derive the equation of motion , range and maximum height reached by the particle thrown at an oblique angle with respect to horizontal direction.

Diagram :



Maximum Height :

The maximum vertical distance travelled by the projectile during its journey.

Vertical part of motion :

- $V_y{}^2 = u_y{}^2 - 2\ a_y\ S$

$V_y = 0$

$u_y = u \sin \Theta$

$a = -g$

$S = h_{max}$

- $V_y{}^2 = u_y{}^2 - 2\ a_y\ S$
- $0^2 = (u \sin \Theta)^2 + 2(-g)\ h_{max}$
- $0 = u^2 \sin^2 \Theta - 2\ g\ h_{max}$
- $2\ g\ h_{max} = u^2 \sin^2 \Theta$
- $h_{max} = \dfrac{u^2 \sin^2 \Theta}{2\ g}$

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Horizontal Range :

The maximum horizontal distance between the point of projection and the point of on the horizontal plane where the projectile hits the ground.

Range = Horizontal component of velocity X Time of flight

$$R = u\cos\theta \times \frac{2u\cos\theta}{g}$$

$$R = \frac{2u^2\sin\theta\cos\theta}{g}$$

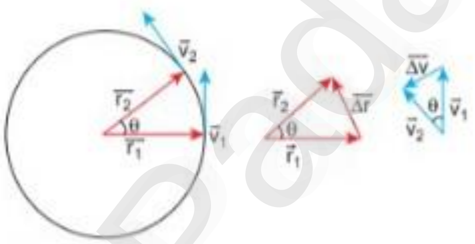
$$R = \frac{u^2\sin 2\theta}{g}$$

---

6. Derive the expression for centripetal acceleration.

The centripetal acceleration is derived from a simple geometrical relationship between position and velocity vector .

Diagram :



Formula

$$a = -\frac{v^2}{r}$$

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For uniform circular motion

1. Position Vector : $r = |\vec{r_1}| = |\vec{r_2}|$

2. Velocity Vector : $v = |\vec{v_1}| = |\vec{v_2}|$

3. Change in position : $\Delta r = \vec{r_2} - \vec{r_1}$

4. Change in velocity : $\Delta v = \vec{v_2} - \vec{v_1}$

5. Angle : $\Theta = \frac{\Delta r}{r} = - \frac{\Delta v}{v}$

6. Negative sign implies that Δ v points radially inward , towards centre of the circle.

7. $- \frac{\Delta v}{v} = \frac{\Delta r}{r}$

8. $\Delta v = - \frac{v}{r} \Delta r$

9. $\frac{\Delta v}{\Delta t} = - \frac{v}{r} \frac{\Delta r}{\Delta t}$

10. $a = - \frac{v}{r} v$

$$a = - \frac{v^2}{r}$$

11. Relation between linear and angular velocity

$$a = - \frac{r^2 \omega^2}{r} = - \omega^2 r$$

$$a = - \omega^2 r$$

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7. Derive the expression for total acceleration in the non uniform circular motion.

Non Uniform Circular motion :

If the speed of the object in circular motion is not constant , then we have non – uniform circular motion.

For Example :

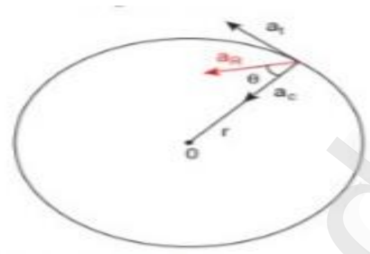
When the bob attached to a string moves in vertical circle , the speed of the bob is not same at all time.

Formula :

1. $a_R = \sqrt{a_t^2 + \left(\frac{v^2}{r}\right)^2}$

2. $\tan \theta = \frac{a_t}{(v^2 / r)}$

Diagram :



Acceleration :

1. Centripetal acceleration : $a_c = \frac{v^2}{r}$
2. Tangential acceleration : a_t
3. Resultant acceleration : a_R
4. $a_R^2 = \sqrt{a_t^2 + a_c^2}$
5. $a_R = a_t^2 + a_c^2$
6. $a_R = \sqrt{a_t^2 + \left(\frac{v^2}{r}\right)^2}$
7. Angle : $\tan \theta = \frac{a_t}{a_c}$

$\tan \theta = a_t / (v^2 / r)$

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LESSON - 3

1. Prove the law of conservation of linear momentum . Use it to find the recoil velocity of a gun when bullet is fired from it.

Law Of Conservation of Linear Momentum :

- **If there are no external forces acting on the system , then the total linear momentum of the system ($\vec{p}_{tot}$) is always a constant vector.**
- **The total linear momentum of the system is conserved in time.**

Explanation :

When two particles interact with each other , they exert equal and opposite forces on each other.

Particle 1 exert force on particle 2 ⟶ $\vec{F}_{21}$

Particle 2 exert force on particle 1 ⟶ $\vec{F}_{12}$

By Newton's 3rd Law : $\vec{F}_{21} = -\vec{F}_{12}$

By Newton's 2nd Law :

$$\vec{F}_{21} = \frac{d\vec{p}_1}{dt}$$

$$\vec{F}_{12} = \frac{d\vec{p}_2}{dt}$$

$$\vec{F}_{21} = -\vec{F}_{12}$$

$$\frac{d\vec{p}_2}{dt} = -\frac{d\vec{p}_1}{dt}$$

$$\frac{d\vec{p}_1}{dt} + \frac{d\vec{p}_2}{dt} = 0$$

$$\frac{d}{dt}(\vec{p}_1 + \vec{p}_2) = 0$$

$$\vec{p}_{tot} = \vec{p}_1 + \vec{p}_2 = \text{Constant}$$

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Recoil momentum of gun :

- **Consider the firing of a gun.**
- **The system is Gun + Bullet**

Initially

- **Gun and bullet are at rest.**
- **Total linear momentum is zero.**

Before Firing

- **Momentum of the bullet is $\vec{p}_1$**
- **Momentum of the gun is $\vec{p}_2$**
- **Total linear momentum is Zero.**
- $\vec{p}_1 + \vec{p}_2 = 0$

After Firing

- **Momentum of the bullet is $\vec{p}_1$ to $\vec{p}_1'$**
- **Momentum of the gun is $\vec{p}_2$ to $\vec{p}_2'$**
- **Total linear momentum is Zero.**
- $\vec{p}_1' + \vec{p}_2' = 0$

Law of conservation of linear momentum

- **Total linear momentum has to be zero after the firing also.**
- **When the gun is fired , a force is exerted by the gun on the bullet in forward direction.**
- **The momentum of the gun is exactly equal , but in opposite direction to the momentum of the bullet.**
- **This is the reason after firing , the gun suddenly moves backward with the momentum ($-\vec{p}_2$)**
- **It is called as " recoil momentum ".**
- **This is an example of conservation of linear momentum.**

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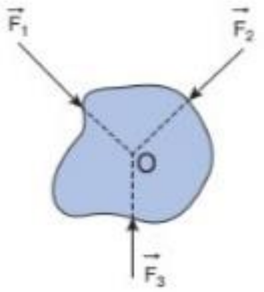
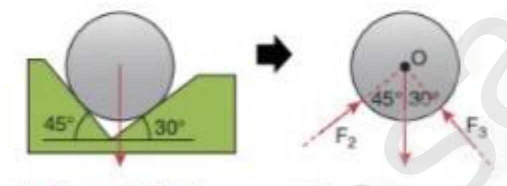
2. What are concurrent forces ? State Lami's theorem.

Concurrent Force :

- Collection of forces is said to be concurrent if the lines of forces act at a common point.
- Concurrent forces need not be in the same plane.
- If they are in same plane , they are concurrent as well as coplanar forces.



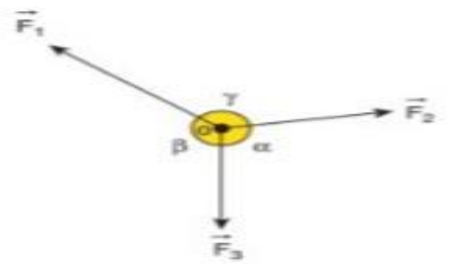


Concurrent forces

Lami's Theorem :

" If the system of three concurrent and coplanar forces is in equilibrium , then Lami's theorem states that the magnitude of each force of the system is proportional to the sine of the angle between the other two forces. The constant of proportionality is Same for all three forces ".

- Let us consider three coplanar and concurrent forces $\vec{F}_1$, $\vec{F}_2$, $\vec{F}_3$ which act at a common point O .
- If the point is in equilibrium , then according to Lami's theorem



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$$|\vec{F_1}| \ \alpha \ \sin \alpha$$

$$|\vec{F_2}| \ \alpha \ \sin \beta$$

$$|\vec{F_3}| \ \alpha \ \sin \gamma$$

$$\frac{|F_1|}{\sin \alpha} = \frac{|F_2|}{\sin \beta} = \frac{|F_3|}{\sin \gamma}$$

- **Lami's theorem is useful to analyse the forces acting on object which are in static equilibrium.**

---

3. Explain the motion of blocks connected by a string in

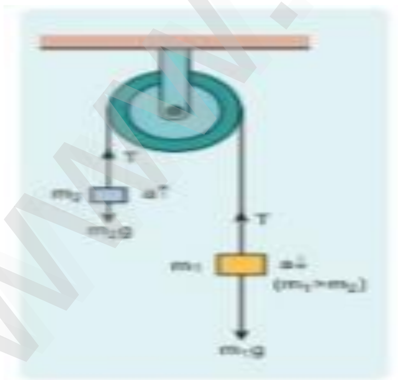
i) Vertical motion ii) Horizontal motion

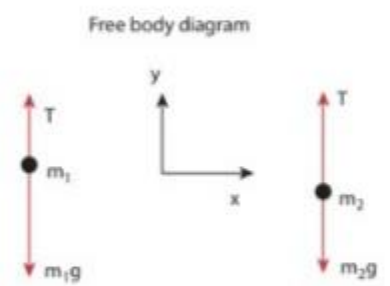
<u>Motion of connected bodies :</u>

- **When objects are connected by strings and a force F is applied either vertically or horizontally or along an inclined plane.**
- **It produces a tension T in the string , which affects the acceleration to an extent.**

<u>i) Vertical Motion :</u>

- **Consider two blocks of masses m_1 and m_2 ($m_1 > m_2$)**
- **They are connected by a light and inextensible string that passes over a pulley.**
- **When the system is released , both the blocks start moving .**
- **m_2 moves vertically upward and m_1 moves downward with same acceleration a .**





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Derivation :

1. Applying Newton's second law

For mass m_2

$T\,j - m_2 g\, j = m_2 a\, j$

$T - m_2 g = m_2 a$

For mass m_1

$T\,j - m_1 g\, j = - m_1 a\, j$

$T - m_1 g\, j = - m_1 a$

$m_1 g - T = m_1 a\, j$

2. Adding the above two equations

$$\cancel{T} - m_2 g + m_1 g - \cancel{T} = m_2 a + m_1 a$$

$$m_1 g - m_2 g = m_2 a + m_1 a$$

$$(m_1 - m_2)\, g = (m_2 + m_1)\, a$$

$$(m_2 + m_1)\, a = (m_1 - m_2)\, g$$

$$a = \frac{(m_1 - m_2)\, g}{(m_2 + m_1)}$$

3. Tension acting on the string

$$T - m_2 g = m_2 a$$

Substitute acceleration value in above equation

$$T - m_2 g = m_2 \left(\frac{m_1 - m_2}{m_2 + m_1}\right) g$$

$$T = m_2 g \left(\frac{m_1 - m_2}{m_2 + m_1}\right) + m_2 g$$

$$T = m_2 g \left(1 + \frac{m_1 - m_2}{m_2 + m_1}\right)$$

$$T = m_2 g \left(\frac{\cancel{m_2} + m_1 + m_1 - \cancel{m_2}}{m_2 + m_1}\right)$$

$$T = m_2 g \left(\frac{2 m_1}{m_2 + m_1}\right)$$

$$\boxed{T = \left(\frac{2 m_1 m_2}{m_1 + m_2}\right) g}$$

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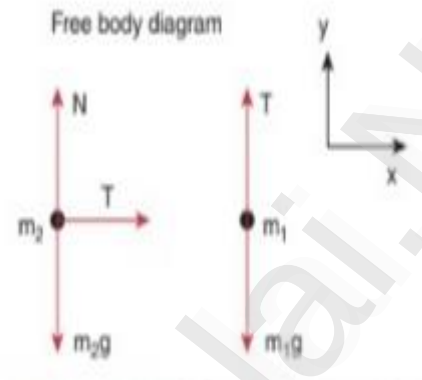
ii) Horizontal Motion :

- In this case mass m_2 is kept on a horizontal table and mass m_1 is hanging through a small pulley .

- If m_1 moves with an acceleration a downward then m_2 also moves with the same acceleration a horizontally.

Diagram :



Forces acting on mass m_2 :

1. Downward gravitational force ($m_2 g$)
2. Upward normal force exerted by the surface (N)
3. Horizontal tension exerted by the string (T)

Forces acting on mass m_1 :

1. Downward gravitational force ($m_1 g$)
2. Tension acting upwards (T)

Derivation :

1. Applying Newton's second law

For mass m_1	For mass m_2
$T\,j - m_1 g\, j = -m_1 a\, j$	$T\, i = m_2 a\, i$
$T - m_1 g = -m_1 a$	$T = m_2 a$

2. $m_2 a - m_1 g = -m_1 a$

$$m_2 a + m_1 a = m_1 g$$

$$(m_2 + m_1)\, a = m_1 g$$

$$a = \frac{m_1 g}{(m_2 + m_1)}$$

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Tension in the string :

$$T = \left(\frac{m_1 \ m_2}{m_1 + m_2} \right) g$$

- **Tension in the string for horizontal motion is half of the tension for vertical motion for same set of masses and strings.**

Applications in industries :

- **The ropes used in conveyor belts (horizontal motion) work for longer duration than those of cranes and lifts (vertical motion)**

---

4. Briefly explain the origin of friction . Show that in an inclined plane , angle of friction is equal to angle of repose. (or)

9. Describe the method of measuring angle of repose .

Origin of friction :

- **The origin of friction is electromagnetic interaction between the atom of the surfaces which are touching each other .**
- **It is a very gentle force in the horizontal direction is given to an object at rest on the table , it does not move .**
- **It is because of the opposing force exerted by the surface on the object and the surface where its placed.**
- **This force is called the frictional force which always opposes the relative motion between an object and the surface where it is placed .**
- **If the force applied is increased , the object moves after a certain limit.**

Angle of friction equal to angle of repose :

- ✓ **Consider an object placed in an inclined plane. Let the angle θ makes with horizontal plane.**
- ✓ **For small angle of θ , the object may not slide down . As θ is increased for particular value the object begins to slide down . This value is called " Angle of repose "**

Formula :

$$\tan \theta = \mu_s$$

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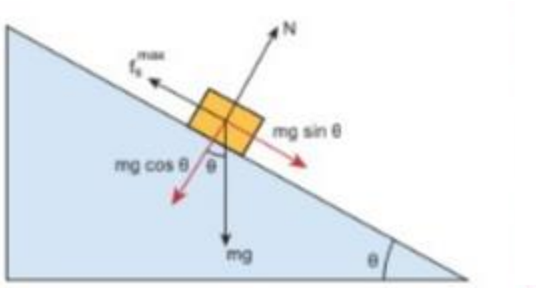
Diagram :



Gravitational Force :

Gravitational force mg resolved into two components.

i) Parallel component : mg sin θ

ii) Perpendicular component : mg cos θ

Normal Force :

The component of force perpendicular to inclined plane is balanced by the normal force.

$$N = mg \cos\theta \longrightarrow (1)$$

Static Friction :

The component of force parallel to the inclined plane tries to move the object down. When the object just begins to move , the static friction attain its maximum value.

$$f_s^{max} = \mu_s N \longrightarrow (2)$$

Sub eqn (1) in eqn (2)

$$f_s^{max} = \mu_s mg \cos\theta \longrightarrow (3)$$

From Free body diagram :

$$f_s^{max} = mg \sin\theta \longrightarrow (4)$$

Dividing eqn (4) by (3)

$$\frac{f_s^{max} = mg \sin\theta}{f_s^{max} = \mu_s mg \cos\theta}$$

$$1 = \frac{\tan\theta}{\mu_s}$$

$$\boxed{\tan\theta = \mu_s}$$

$$\tan\theta = \mu_s$$

"Angle of repose is same as the angle of friction "

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5. State Newton's three laws and discuss their significance .

Newton's First Law :

Every object continues to be in the state of rest or of uniform motion unless there is external force acting on it.

Newton's Second Law :

The force acting on an object is equal to the rate of change of its momentum.

$$\vec{F} = \frac{d\vec{p}}{dt} = m\vec{a}$$

Newton's Second Law :

For every action there is an equal and opposite reaction.

$$\vec{F}_{12} = -\vec{F}_{21}$$

Discussion on Newton's Laws :

1. Newton's laws are vectors laws.

$$\vec{F} = m\vec{a}$$

$$F_x \hat{i} + F_y \hat{j} + F_z \hat{k} = m a_x \hat{i} + m_y \hat{j} + m a_z \hat{k}$$

- **The acceleration along the x direction depends only on the component of force acting along x – direction.** $F_x = m a_x$
- **The acceleration along the y direction depends only on the component of force acting along y – direction.** $F_y = m a_y$
- **The acceleration along the z direction depends only on the component of force acting along z – direction.** $F_z = m a_z$

2. The acceleration experienced by the body at time t depends on the force which acts on the body at that instant of time. It does not depend on the force which acted on the body before the time t.

$$\vec{F}(t) = m\vec{a}(t)$$

3. In general the direction of a force may be different from the direction of motion.

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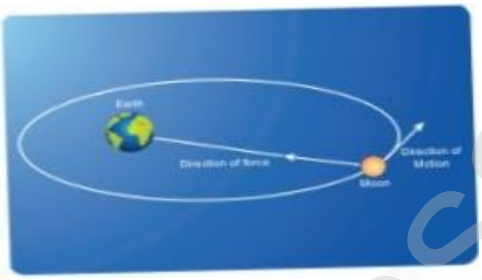
Case 1 : Force and motion in the same direction

When an apple falls towards the Earth , the direction of motion of the apple and that of force are in same direction.

Case 2 : Force and motion not in the same direction

The moon experiences a force towards the earth. But it actually moves in elliptical orbit. In this case , the direction of the force is different from the direction of motion.



Case 3 : Force and motion in opposite direction

If an object is thrown vertically upward the direction of motion is upward but gravitational force is downward.

Case 4 : Zero net force but there is motion

When raindrop gets detached from the cloud it experiences both downward gravitational force and upward air drag force . As it descends towards the earth , the upward air drag force increases and cancel downward gravity. Then raindrop moves at constant velocity till it touches the surface of the earth. Hence the raindrop comes with zero net force , with zero acceleration but with non zero terminal velocity.

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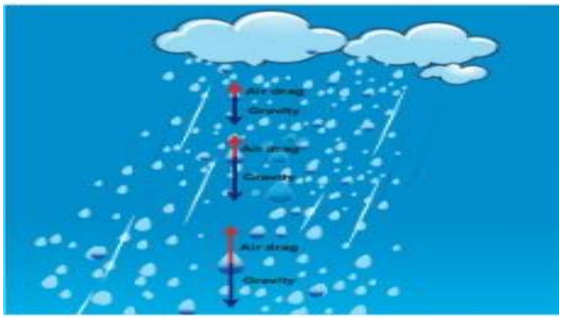
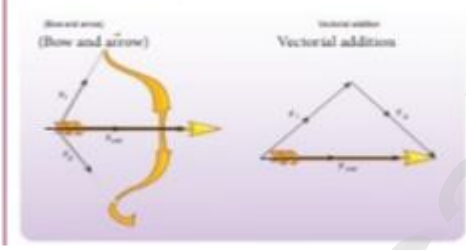


4. If multiple forces $\vec{F}_1$, $\vec{F}_2$, $\vec{F}_3$ ……. $\vec{F}_n$ act on the same body , the total force $\vec{F}_{net}$ is equivalent to the vectorial sum of the individual forces.

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots\ldots + \vec{F}_n = m\vec{a}$$

Example

Bow and arrow



5. Newton's second law can also be written as

$$\vec{F} = m \frac{d^2\vec{r}}{dt^2}$$

The acceleration is the second derivative of position vector of the body.

---

7. Briefly explain centrifugal force with suitable examples.

<u>Centrifugal Force :</u>

- Centrifugal force is called as " pseudo force " .
- Pseudo force has no origin.
- It arises due to the non inertial nature of the frame considered.
- To use Newton's first and second laws in the rotational frame of reference , we include pseudo force.
- This centrifugal force appears to act on the object with respect to rotating frames.

<u>Example :</u>

- Consider the case of a whirling motion of a stone tied to a string.
- The stone has angular velocity ω in the inertial frame .

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- **If the motion of the stone is observed from which is also rotating along with the stone with same angular velocity ω then , the stone appears to be at rest.**
- **Inward centripetal force - m ω^2 r.**
- **There must be an equal and opposite force that acts on the stone.**
- **Outward centripetal force + m ω^2 r.**
- **The total force acting on the stone in a rotating frame is equal to zero.**
- $- m\omega^2 r + - m\omega^2 r = 0$
- **This outward force + m ω^2 r is called the centrifugal force.**
- **The word " centrifugal " means " flee from centre "**
- **The centrifugal force appears to act on the particle , only when we analyse the motion from a rotating frame.**

---

8. Briefly explain " rolling friction "

- **One of the important applications is suitcase with rolling on coasters.**
- **Rolling wheels makes it easier than carrying luggage .**
- **When an object moves on a surface , essentially it is sliding on it.**
- **But wheels move on the surface through rolling motion.**
- **In rolling motion when a wheel moves on a surface , the point of contact with surface is always at rest .**
- **Since the point of contact is at rest , there is no relative motion between the wheel and surface.**
- **Hence the frictional force is very less.**
- **At the same time if an object without a wheel , there is a relative motion between the object and the surface.**
- **As a result frictional force is larger. This makes it difficult to move the object.**

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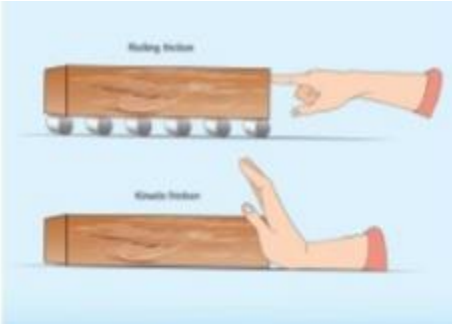

- **Ideally in pure rolling , motion of the point of contact with the surface should be at rest , but in practice it is not so.**
- **Due to the elastic nature of the surface at the point of contact there will be some deformation on the object at this point on the wheel or surface.**
- **Due to this deformation , there will be minimal friction between wheel and surface .**
- **It is called " rolling friction ". It is much smaller than kinetic friction.**

---

10. Explain the need for banking of tracks.

<u>Banking of tracks :</u>

- **In a levelled circular road , skidding mainly depends on the co efficient of static friction μ_s .**
- **The coefficient of static friction depends on the nature of the surface which has a maximum limiting value.**

<u>Diagram :</u>

<u>To avoid the problem :</u>

The outer edge of the road is slightly raised compared to inner edge is called " banking of roads or tracks " and the angle is called " banking angle ".

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Theory

- Let the surface of the road make angle θ with horizontal surface .
- Then the normal force makes the same angle θ with the vertical.
- When the car takes a turn , there are two forces acting on the car.

Forces acting on the car :

- Gravitational force acts downward (mg)
- Normal force perpendicular to surface (N)

Normal Force :

- Normal force resolved into two components.
- N cos θ balances the downward gravitational force mg
- N sin θ provides the necessary centripetal acceleration.

By using Newton's second law :

$$N \cos\theta = mg \longrightarrow (1)$$

$$N \sin\theta = \frac{m v^2}{r} \longrightarrow (2)$$

Eqn (2) % by (1)

$$\frac{N \sin\theta}{N \cos\theta} = \frac{m v^2}{r} \times \frac{1}{mg}$$

$$\tan\theta = \frac{v^2}{r g}$$

$$v^2 = r g \tan\theta$$

$$\boxed{v = \sqrt{r g \tan\theta}}$$

The banking angle θ and radius of curvature of the road or track determines the safe speed of the car at the turning.

If the speed of car exceeds safe speed

Then it starts to skid outward but frictional force comes into effect and provides additional centripetal force to prevent the outward skidding .

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If the speed of car lesser than safe speed

Then it starts to skid inward and frictional force comes into effect which reduces centripetal force to prevent the inward skidding .

If the speed of car greater than correct speed

Then the frictional force cannot stop the car from skidding.

---

6. Explain the similarities and differences of centripetal and centrifugal forces.

S. NO	Centripetal Force	Centrifugal force
1.	It is a real force .	It is a pseudo force or fictitious force.
2.	Real force and has real effects.	Pseudo force but has real effects.
3.	Acts in both inertial and non - inertial frames	Acts only in rotating / non – inertial frame.
4.	Origin of centripetal force is interaction between two objects.	Origin of centrifugal force is inertia. It does not arise from interaction.
5.	It is exerted on the body by the external agencies like gravitational force , tension in the String , normal force etc.	It cannot arise from gravitational force , tension in the String , normal force etc.
6.	It acts towards the axis of rotation or centre of the circle in circular motion.	It acts outwards from the axis of rotation or radially outwards from the centre of the circular motion.
7.	In inertial frames centripetal force has to be included when free body diagrams are drawn.	In inertial frames there is no centrifugal force. In rotating frames , both centripetal and centrifugal force have to be included when free body diagrams are drawn.
8.	$\lvert F_{CP} \rvert = m\omega^2 r = \frac{m v^2}{r}$	$\lvert F_{Cf} \rvert = m\omega^2 r = \frac{m v^2}{r}$

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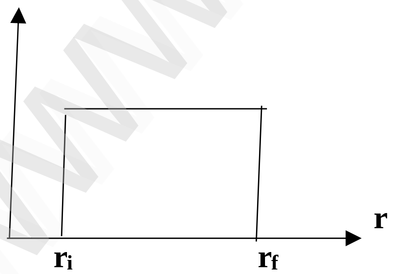
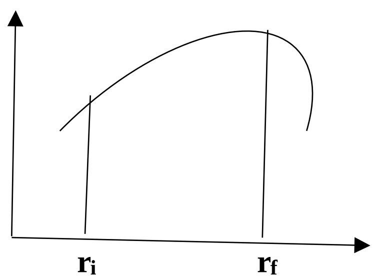
LESSON 4

1.Explain with graphs the difference between work done by a constant force and by a variable force.

Work done by a constant force	Work done by a variable force
1. Constant Force → F	1. Variable Force → F
2. Small work done → d W	2. Small work done → d W
3. Small displacement → d r	3. Small displacement → d r
4. Initial Position → r_i	4. Initial Position → r_i
5. Final Position → r_f	5. Final Position → r_f
6. Work done : $\int_{r_i}^{r_f} dW = F \cos \Theta \int_{r_i}^{r_f} dr$	6. Work done : $\int_{r_i}^{r_f} dW = \int_{r_i}^{r_f} F \cos \Theta \, dr$
7. $W = F \cos \Theta \, (r_f - r_i)$	7. $W = \int_{r_i}^{r_f} F \cos \Theta \, dr$
8. **Graph :** F cos Θ 	8. **Graph:** F cos Θ 

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2.State and explain work energy principle . Mention any three examples for it.

Work Energy principle :

Work done by the force on the body changes the kinetic energy of the body. This is called as work energy theorem.

- **Let us consider a body of mass at rest on frictionless horizontal surface.**

1. Work done : $W = F . s$
2. Constant Force : $F = m a$
3. Equation of motion : $v^2 = u^2 + 2 a s$

$$2 a s = v^2 - u^2$$

$$a = \frac{v^2 - u^2}{2 s}$$

4. $F = m \left(\frac{v^2 - u^2}{2 s} \right)$

5. $W = m \left(\frac{v^2 - u^2}{2 s} \right) s$

6. $W = m \left(\frac{v^2 - u^2}{2} \right)$

7. $W = \frac{1}{2} m v^2 - \frac{1}{2} m u^2$

8. $W = \Delta$ K.E

Work done	Kinetic Energy
Positive	Increases
Negative	Decreases
No Work done	No Kinetic energy

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3. Arrive at an expression for power and velocity.

Work done by a force $\vec{F}$ for a displacement $\vec{dr}$ is $W = \int \vec{F} \cdot \vec{dr}$

L.H.S

$$W = \int dW = \int \frac{dW}{dt}\, dt$$

R.H.S

$$\int \vec{F} \cdot \vec{dr} = \int \left(\vec{F} \cdot \frac{\vec{dr}}{dt} \right) dt = \int \left(\vec{F} \cdot \vec{v} \right) dt$$

Derivation :

1. $\int \frac{dW}{dt} \cdot dt = \int \left(\vec{F} \cdot \vec{v} \right) dt$

2. $\int \left(\frac{dW}{dt} - \vec{F} \cdot \vec{V} \right) dt = 0$

3. $\int \frac{dW}{dt} - \vec{F} \cdot \vec{v} = 0$

4. $\frac{dW}{dt} = \vec{F} \cdot \vec{v} = P$

---

4. Arrive at an expression for elastic collision in one dimension and discuss various cases.

Diagram:

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Theory :

Consider two elastic bodies of masses m_1 and m_2 moving in a straight line on a frictionless horizontal surface.

Mass and Velocity

Mass	Initial Velocity	Final Velocity
m_1	u_1	v_1
m_2	u_2	v_2

Momentum

Collision	Mass m_1	Mass m_2	Total Momentum
Before Collision	$P_{i1} = m_1 u_1$	$P_{i2} = m_2 u_2$	$P_i = m_1 u_1 + m_2 u_2$
After Collision	$P_{f1} = m_1 v_1$	$P_{f2} = m_2 v_2$	$P_f = m_1 v_1 + m_2 v_2$

Kinetic Energy

Collision	Mass m_1	Mass m_2	Total Kinetic Energy
Before Collision	$K.E_{i1} = \frac{1}{2} m_1 u_1^2$	$K.E_{i2} = \frac{1}{2} m_2 u_2^2$	$K.E_i = \frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2$
After Collision	$K.E_{f1} = \frac{1}{2} m_1 v_1^2$	$K.E_{f2} = \frac{1}{2} m_2 v_2^2$	$K.E_f = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$

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Law Conservation of Momentum :

1. $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$

2. $m_1 u_1 - m_1 v_1 = m_2 v_2 - m_2 u_2$

3. $m_1 (u_1 - v_1) = m_2 (v_2 - u_2)$ -------------- (1)

For Elastic Collision :

1. $\frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$

2. $\frac{1}{2} m_1 u_1^2 - \frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_2 v_2^2 - \frac{1}{2} m_2 u_2^2$

3. $\frac{1}{2} m_1 (u_1^2 - v_1^2) = \frac{1}{2} m_2 (v_2^2 - u_2^2)$

4. $m_1 (u_1 + v_1)(u_1 - v_1) = m_2 (v_2 + u_2)(v_2 - u_2)$ ------- (2)

Equation (2) % (1)

5. $\frac{m_1 (u_1 + v_1)(u_1 - v_1)}{m_1 (u_1 - v_1)} = \frac{m_2 (v_2 + u_2)(v_2 - u_2)}{m_2 (v_2 - u_2)}$

6. $u_1 + v_1 = v_2 + u_2$

7. $v_2 = u_1 + v_1 - u_2$ -------------------- (3)

To find final velocity :

Sub equation (3) in (1)

8. $m_1 (u_1 - v_1) = m_2 (u_1 + v_1 - u_2 - u_2)$

9. $m_1 (u_1 - v_1) = m_2 (u_1 + v_1 - 2u_2)$

10. $m_1 u_1 - m_1 v_1 = m_2 u_1 + m_2 v_1 - 2 m_2 u_2$

11. $m_1 u_1 - m_2 u_1 + 2 m_2 u_2 = m_1 v_1 + m_2 v_1$

12. $(m_1 - m_2) u_1 + 2 m_2 u_2 = (m_1 + m_2) v_1$

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Formula :

1. $$v_1 = \frac{(m_1 - m_2)}{(m_1 + m_2)} u_1 + \frac{2 m_2}{(m_1 + m_2)} u_2$$

2. $$v_2 = \frac{2 m_1}{(m_1 + m_2)} u_1 + \frac{(m_2 - m_1)}{(m_1 + m_2)} u_2$$

Case 1 : When bodies have same mass $m_1 = m_2$

$$V_1 = u_2 \text{ and } v_2 = u_1$$

Case 2 : When bodies have same mass $m_1 = m_2$ but second body is at rest

$$V_1 = 0 \text{ and } v_2 = u_2$$

Case 3 : First body lighter than second body $m_1 < m_2$: $m_1 / m_2 = 0$; $u_2 = 0$

$$V_1 = - u_1 \text{ and } v_2 = 0$$

Case 4 : Second body lighter than First body $m_2 < m_1$: $m_2 / m_1 = 0$; $u_2 = 0$

$$V_1 = u_1 \text{ and } v_2 = 2 u_1$$

---

5. What is inelastic collision ? In which way it is different from elastic collision . Mention few examples.

Elastic Collision :

1. Total momentum is conserved.
2. Total kinetic energy is conserved .
3. Forces involved are conservative forces.
4. Mechanical energy is not dissipated.

Inelastic Collision :

1. Total momentum is conserved.
2. Total kinetic energy is not conserved .
3. Forces involved are non conservative forces.
4. Mechanical energy is dissipated into heat and light.

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Total Kinetic Energy

Before Collision = After Collision

K.E Before Collision - K.E After Collision = Loss in energy during collision = ΔQ

Example :

When a clay putty is thrown on moving vehicle , the clay putty sticks to moving vehicle and they move together with same velocity.

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UNIT - 5

1. Explain the types of equilibrium with suitable examples.

1. Translational Equilibrium :

- Linear momentum is constant.
- Net force is zero.

2. Rotational Equilibrium :

- Angular momentum is constant.
- Net torque is zero.

3. Static Equilibrium :

- Linear momentum and angular momentum are *zero*.
- Net force and torque are zero.

4. Dynamic Equilibrium :

- Linear momentum and angular momentum are *constant*.
- Net force and torque are zero.

5. Stable Equilibrium :

- Linear momentum and angular momentum are zero.
- The body tries to come back to equilibrium if slightly disturbed and released.
- The centre of mass of the body shifts slightly *higher* if disturbed from equilibrium.
- Potential energy of the body is minimum and it increases if disturbed.

6. Unstable Equilibrium :

- Linear momentum and angular momentum are zero.
- The body *cannot* come back to equilibrium if slightly disturbed and released.
- The centre of mass of the body shifts slightly *lower* if disturbed from equilibrium.
- Potential energy of the body is *not* minimum and it increases if disturbed.

7. Neutral Equilibrium :

- Linear momentum and angular momentum are zero.
- The body remains at the same equilibrium if slightly disturbed and released.
- The centre of mass of the body *does not* shifts slightly higher if disturbed from equilibrium.
- Potential energy of the body remains *same* even if disturbed.

---

2. Explain the method to find the centre of gravity of a irregularly shaped lamina.

Centre of gravity :

The point at which the entire weight of the body acts irrespective of the position and orientation of the body.

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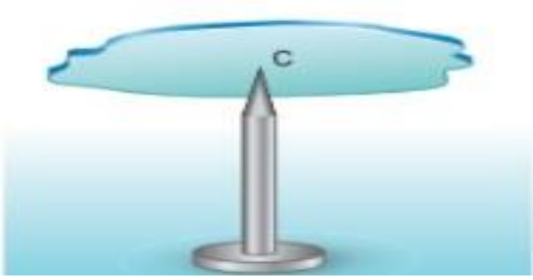
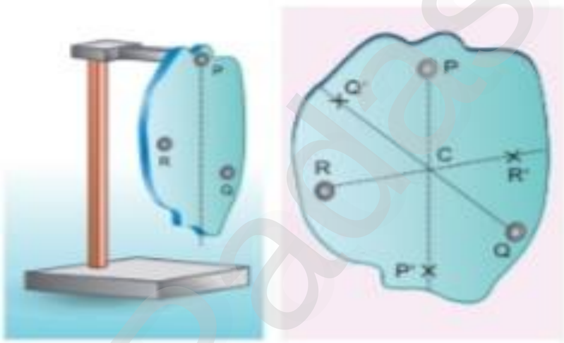
Method to find centre of gravity of a irregularly shaped lamina :

Method 1 :



- **The lamina remains horizontal when pivoted at the point where the net gravitational force acts , which is at the centre of gravity.**
- **When a body is supported at the centre of gravity , the sum of the torques acts on all point masses of the rigid body becomes zero.**
- **The weight is compensated by the normal reaction force exerted by the pivot.**
- **The body is in static equilibrium and hence it remains horizontal.**

Method 2 :



- **There is also another way to determine the centre of gravity of an irregular lamina.**
- **If we suspend the lamina from different points like P , Q , R .**
- **The vertical lines PṔ , QQ́ , RŔ all pass through the centre of gravity.**
- **Reaction force acting at the point of suspension and the gravitational force acts on the centre of gravity cancel each other.**
- **The torques caused by them also cancel each other.**

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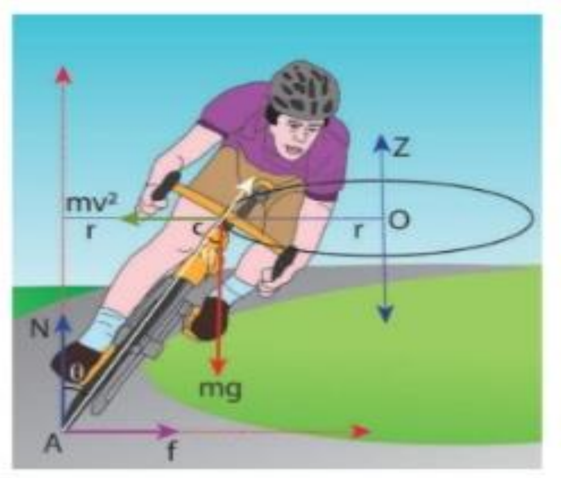
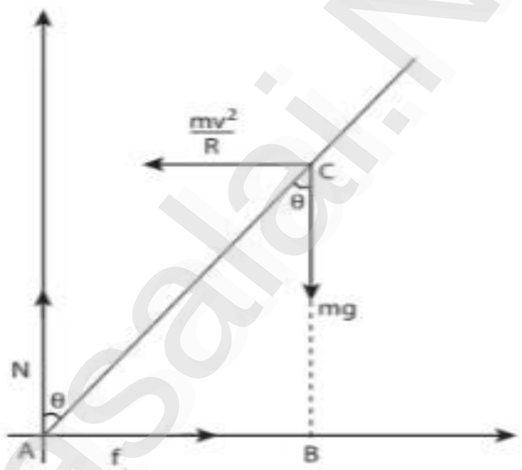
3. Explain why a cyclist bends while negotiating a curved road ? Arrive at the expression for angle of bending for a given velocity.

Bending of cyclist

- Let us consider a cyclist negotiating a circular level road of radius r with a speed v.
- The cycle and the cyclist are considered as one system with mass m.
- The centre gravity of the system is C and circle centre is O.

Diagram :





Theory :

- Let us choose the line OC as X – axis and the vertical line through O as Z – axis.
- The system as a frame is rotating about Z - axis.
- The system is at rest in this rotating frame.
- In rotating frame pseudo force acts on the system
- This force will act through the centre of gravity.

Forces acting on the system :

1. Gravitational force (mg)
2. Normal force (N)
3. Frictional force (f)
4. Centrifugal force (mv^2 / r)

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As the system is in equilibrium :

In the rotational frame of reference ,

Net external external force and net external torque must be zero.

- **Torque due to the gravitational force :**
  - **About the point A is mg AB**
  - **It causes clockwise turn.**
  - **And it is taken as negative.**

- **Torque due to the Centrifugal force :**
  - **About the point B is mg** $\frac{mv^2}{r}$ **BC**
  - **It causes anticlockwise turn.**
  - **And it is taken as positive.**

Derivation :

1. $-mg\,AB + \frac{mv^2}{r}\,BC = 0$

2. $mg\,AB = \frac{mv^2}{r}\,BC \longrightarrow (1)$

3. From Δ ABC

4. $\sin\theta = \frac{AB}{AC}$

5. $AB = AC\sin\theta \longrightarrow (2)$

6. $\cos\theta = \frac{BC}{AC}$

7. $BC = AC\cos\theta \longrightarrow (3)$

8. Sub eqn (2) and (3) in (1)

$$mg\,AB = \frac{mv^2}{r}\,BC$$

$$\not{m}g\,\not{A}\not{C}\sin\theta = \frac{\not{m}v^2}{r}\,\not{A}\not{C}\cos\theta$$

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9. $$\frac{\sin\theta}{\cos\theta} = \frac{v^2}{rg}$$

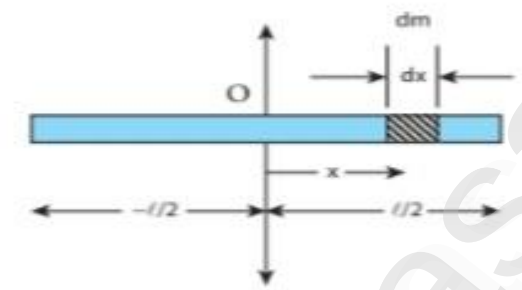
10. $$\tan\theta = \frac{v^2}{rg}$$

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

---

4. Derive the expression for moment of inertia of a rod about its centre and perpendicular to the rod.

Diagram :



Theory :

- Let us consider a uniform rod of mass (M) and length (l)
- The rod about an axis passes through centre of mass and perpendicular to the rod.
- The rod is along the x - axis and geometric center is O.
- Infinitesimal small mass (dm) at a distance (x) from the origin.

Moment of inertia of a rod :

1. $dI = (dm)\, x^2 \longrightarrow (1)$
2. Linear mass density = mass per unit length
3. For mass M : $\lambda = \frac{M}{l} \longrightarrow (2)$
4. For mass dm : $\lambda = \frac{dm}{dx}$
5. $dm = \lambda\, dx \longrightarrow (3)$

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6. Sub eqn (2) in (3)

$$dm = \frac{M}{l} dx \longrightarrow (4)$$

7. Sub eqn (4) in (1)

$$dI = \left(\frac{M}{l}\right) dx \quad x^2$$

8. $$\int dI = \int (dm)\, x^2$$

9. $$I = \int \frac{M}{l}\, dx \quad x^2$$

10. $$I = \frac{M}{l} \int x^2 dx$$

11. As the mass is distributed on either side of the origin , the limits for integration are taken from $-l / 2$ to $l / 2$

12. $$I = \frac{M}{l} \int_{-l/2}^{l/2} x^2 dx$$

13. $$I = \frac{M}{l} \left[\frac{x^3}{3}\right]_{-l/2}^{l/2}$$

14. $$I = \frac{M}{3l} \left(\frac{l^3}{2^3} - \left(\frac{-l^3}{2^3}\right)\right)$$

15. $$I = \frac{M}{3l} \left(\frac{l^3}{8} + \frac{l^3}{8}\right)$$

16. $$I = \frac{M}{3l} \left(\frac{2l^3}{8}\right)$$

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17. $I = \frac{1}{12} M l^2$

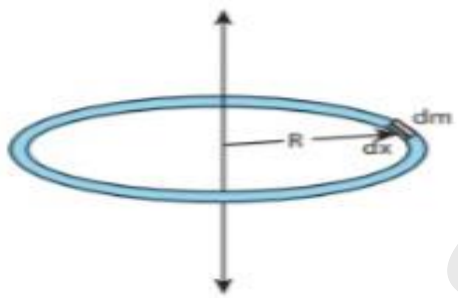
Moment of inertia of a uniform rod :

$$I = \frac{1}{12} M l^2$$

---

5. Derive the expression for moment of inertia of a ring about an axis passing through the centre and perpendicular to the plane.

Diagram :



Theory :

- Let us consider a uniform ring of mass (M) and radius (R)
- Moment of inertia of the ring about an axis passes through its centre and perpendicular to the plane.
- Infinitesimal small mass (dm) of length (dx) of the ring.
- This (dm) is located at a distance R , which is the radius of the ring from the axis.

Moment of inertia of a rod :

1. $dI = (dm) R^2$ ⟶ (1)

2. Linear mass density = mass per unit length

3. For mass M : $\lambda = \frac{M}{2\pi R}$ ⟶ (2)

4. For mass dm : $\lambda = \frac{dm}{dx}$

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5. $dm = \lambda \, dx \longrightarrow (3)$

6. Sub eqn (2) in (3)

$$dm = \frac{M}{2\pi R} dx \longrightarrow (4)$$

7. Sub eqn (4) in (1)

$$\int dI = \int (dm) R^2$$

8. $$I = \frac{M}{2\pi R} \int (dx) R^2$$

9. $$I = \frac{MR}{2\pi} \int dx$$

10. To cover the entire length of the ring , the limits for integration from 0 to $2\pi R$

11. $$I = \frac{MR}{2\pi} \int_0^{2\pi R} dx$$

12. $$I = \frac{MR}{2\pi} \left(x \right)_0^{2\pi R}$$

13. $$I = \frac{MR}{2\pi} \left(2\pi R - 0 \right)$$

14. $$I = \frac{MR}{2\pi} \left(2\pi R \right)$$

15. $$I = M R^2$$

Moment of inertia of a uniform ring :

$I = MR^2$

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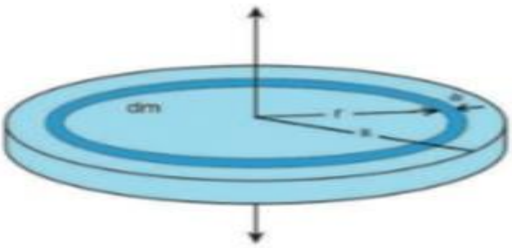
6. Derive the expression for moment of inertia of uniform disc about an axis passing through the center and perpendicular to the plane.

Diagram :



Theory :

- **Let us consider a uniform disc of mass (M) and radius (R)**
- **This disc is made up of many infinitesimally small rings.**
- **Infinitesimal small mass (dm) and thickness (dr) and radius (r) .**

Moment of inertia of a rod :

1. $dI = (dm)\, r^2 \longrightarrow (1)$

2. Surface mass density = mass per unit area

3. For mass M : $\sigma = \dfrac{M}{\pi R^2} \longrightarrow (2)$

4. For mass dm : $\sigma = \dfrac{dm}{2\pi r \ dr}$

5. Area of the elemental ring = length x thickness = $2\pi r\, dr$

6. $dm = \sigma\, 2\pi r\, dr \longrightarrow (3)$

7. Sub eqn (2) in (3)

$$dm = \frac{M}{\pi R^2}\, 2\pi r\ dr$$

8. $dm = \dfrac{2M\ r\ dr}{R^2} \longrightarrow (4)$

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9. Sub eqn (4) in (1)

$$\int dI = \int (dm)\, r^2$$

10. $I = \left(\frac{2M}{R^2}\right) \int (r\,dr)\, r^2$

11. $I = \frac{2M}{R^2} \int r^3\, dr$

12. The limits for integration are taken from 0 to R

13. $I = \frac{2M}{R^2} \int_0^R r^3\, dr$

14. $I = \frac{2M}{R^2} \left(\frac{r^4}{4}\right)_0^R$

15. $I = \frac{2M}{4R^2} \left(R^4 - 0\right)$

16. $I = 1\, M\, \frac{R^2}{2}$

Moment of inertia of a uniform disc :

$$I = \frac{1}{2} M R^2$$

---

7. Discuss conservation of angular momentum with example .

Conservation of angular momentum :

When no external torque acts on the body , the net angular momentum of a rotating rigid body remains constant. This is known as law of conservation of angular momentum.

Derivation :

1. Angular momentum : $L = I\,\omega$

2. Torque : $\tau = \frac{dL}{dt}$

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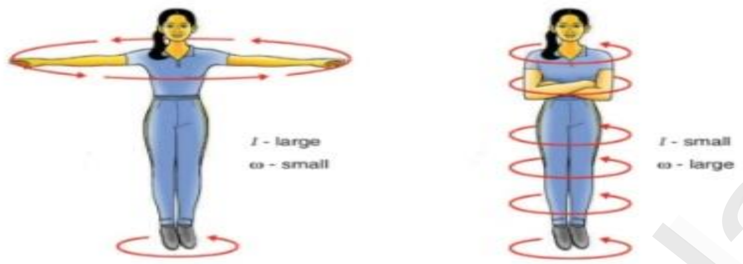
3. If $\tau = 0$ then , L = constant
4. Angular momentum kept as constant.
5. If I increases then ω will decreases and vice – versa.

$$I \omega = \text{constant}$$
$$I_i \omega_i = I_f \omega_f$$

Example :



1. An ice dancer spins slowly when the hands are stretched out and spins faster when the hands are brought close to the body.
2. Stretching of hands away from body resulting in slower spin
   - Increases moment of inertia
   - Decreases angular velocity
3. Stretching of hands brought close to the body resulting in faster spin
   - Decreases moment of inertia
   - Increases angular velocity

A diver while in air , curls the body close to decrease the moment of inertia , which in turn helps to increase the number of somersaults in air.

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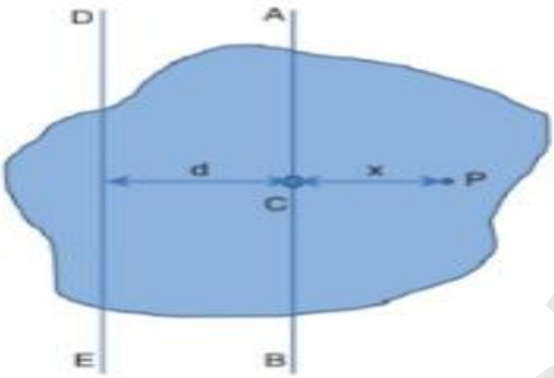
8. State and prove parallel axis theorem.

Parallel Axis Theorem :

The moment of inertia of a body about any axis is equal to sum of its moment of inertia about a parallel axis through its centre of mass and the product of the mass of the body and the square of the perpendicular distance between the two axes.

Diagram :



- **I_C is the moment of inertia of the body of mass M about an axis passing through the centre of mass.**
- **Moment of inertia I about a parallel axis at a distance d from it is given by the relation,**

$$I = I_C + M d^2$$

Theory :

1. **Let us consider a rigid body .**
2. **Moment of inertia about an axis AB passing through centre mass is I_C.**
3. **Moment of inertia about an axis DE passing through centre mass is I.**
4. **Consider a point mass m on the body at position x from its centre of mass.**
5. **Moment of inertia about a parallel axis at a distance d .**

Derivation :

1. $I = \Sigma\, m\, (x + d)^2$
2. $I = \Sigma\, m\, (x^2 + d^2 + 2\,x\,d)$
3. $I = \Sigma\, (m\, x^2 + m\, d^2 + 2\,m\,x\,d)$

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4. $I = \Sigma m x^2 + \Sigma m d^2 + 2 d \Sigma m x$

5. Moment of inertia of the body about centre of mass : $I_C = \Sigma m x^2$

6. Σm is the entire mass M of the object : $\Sigma m = M$

7. $\Sigma m x$ will be zero. $\Sigma m x = 0$ because x can take positive and negative values w.r.t the axis AB.

8. $I = I_C + M d^2$

9. Hence , the parallel axis theorem is proved.

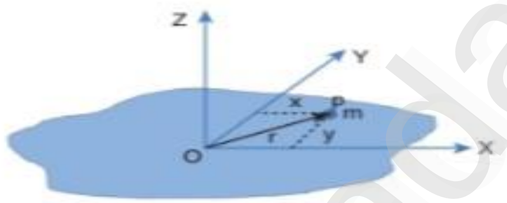
---

9. State and prove perpendicular axis theorem.

Perpendicular Axis Theorem :

The moment of inertia of a plane laminar body about an axis perpendicular to its plane is equal to sum of its moment of inertia about two perpendicular axes lying in the plane of the body such that all the three axes are mutually perpendicular and have a common point.

Diagram :



- Let the X and Y axes lie in the plane and Z – axis perpendicular to the plane of the laminar object.
- Moment of inertia about X and Y - axes are I_X and I_Y.
- Moment of inertia about Z - axis is I_Z .
- The perpendicular axis theorem could be expressed as , $I_Z = I_X + I_Y$

Theory :

1. Let us consider a plane laminar object of negligible thickness on which lies the origin (O).
2. The X and Y axes lie on the plane and Z - axis is perpendicular to it.
3. The lamina is considered to be made up of a large particles of mass m.

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4. Let us choose one such particle at a point P which has coordinates (x , y) At a distance r from O.
5. Moment of inertia of the particle about Z – axis is $m\ r^2$. ($r^2 = x^2 + y^2$)
6. Moment of inertia of the entire lamina about Z - axis as , $I_Z = \Sigma\ m\ r^2$

Derivation :

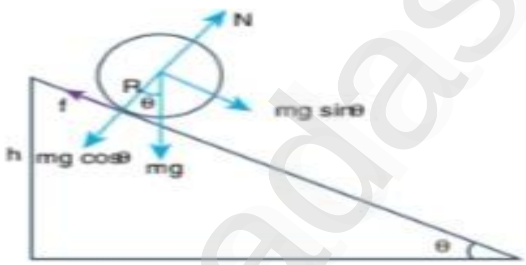
1. $I = \Sigma\ m\ r^2$
2. $I = \Sigma\ m\ (x^2 + y^2)$
3. $I = \Sigma\ m\ x^2 + \Sigma\ m\ y^2$
4. Moment of inertia about Y – axis : $I_Y = \Sigma\ m\ x^2$
5. Moment of inertia about X – axis : $I_X = \Sigma\ m\ y^2$
6. $I = I_X + I_Y$

Thus , the perpendicular axis theorem is proved.

---

10. Discuss rolling on inclined plane and arrive at the expression for the acceleration.

Diagram :



Theory :

- Let us assume a round object of mass m and radius R.
- Let it is rolling down an inclined plane without slipping.
- There are two forces acting on the object along the inclined plane.
- One is the component of gravitational force m g sin θ .
- Other is the static frictional force f .
- Other is the component of gravitational force m g cos θ .
- Other is the normal force N exerted by the plane .
- We can write the equation for motion from the free body diagram of the object.

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Derivation :

1. For translational motion ,
   - Supporting force ⟶ $m\,g\,\sin\theta$
   - Opposing force ⟶ f
2. $m\,g\,\sin\theta - f = ma$ ⟶ (1)
3. For rotational motion ,
   - Frictional force ⟶ f
   - Torque ⟶ $\tau = R\,f$
4. Relation between torque and angular acceleration

$$\tau = I\,\alpha$$

$$I\,\alpha = R\,f \longrightarrow (2)$$

5. Moment of inertia : $I = m\,K^2$

   Angular acceleration : $a = r\,\alpha$

$$\alpha = a / R$$

6. $$R\,f = I\,\alpha$$

$$R\,f = m\,K^2\left(\frac{a}{R}\right)$$

$$f = m\,K^2\left(\frac{a}{R^2}\right) \longrightarrow (3)$$

7. Sub eqn (3) in eqn (1)

$$m\,g\,\sin\theta - f = m\,a$$

$$m\,g\,\sin\theta - m\,K^2\left(\frac{a}{R^2}\right) = m\,a$$

$$m\,g\,\sin\theta - m\,a\left(\frac{K^2}{R^2}\right) = m\,a$$

$$m\,g\,\sin\theta = m\,a\left(\frac{K^2}{R^2}\right) + m\,a$$

$$\cancel{m}\,g\,\sin\theta = \cancel{m}\,a\left(\frac{K^2}{R^2} + 1\right)$$

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$$a = \frac{g \sin\theta}{\left(1 + \frac{K^2}{R^2}\right)}$$

Acceleration of rolling of round object in an inclined plane :

$$a = \frac{g \sin\theta}{\left(1 + \frac{K^2}{R^2}\right)}$$

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