HIGHER SECONDARY FIRST YEAR QUARTERLY EXAMINATION – SEPTEMBER 2024

PHYSICS KEY ANSWER

Note:

1. Answers written with **Blue** or **Black** ink only to be evaluated.
2. Choose the most suitable answer in Part A, from the given alternatives and write the option code and the corresponding answer.
3. For answers in Part-II, Part-III and Part-IV like reasoning, explanation, narration, description and listing of points, students may write in their own words but without changing the concepts and without skipping any point.
4. In numerical problems, if formula is not written, marks should be given for the remaining correct steps.
5. In graphical representation, physical variables for X-axis and Y-axis should be marked.

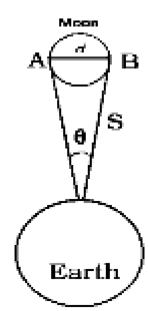
PART – I

Answer all the questions. **15x1=15**

Q. No.	Option	Answer	Q. No.	Option	Answer
1	(c)	9.86	9	(c)	-9 ms^{-1} and 5 ms^{-1}
2	(d)	$[ML^{-1}T^{0}]$	10	(a)	pure rotation
3	(a)	1.744 x 10^{-2} rad	11	(b)	$\sqrt{\frac{10}{7}gh}$
4	(a)	1	12	(b)	The mass of the satellite
5	(b)	g = 25 m s^{-2}	13	(b)	less than potential energy
6	(c)	greater than 1	14	(b)	constant
7	(d)	$\mu_s$mg cos θ	15	(a)	p = $\sqrt{2m\,(KE)}$
8	(a)	by the system against a conservative force			

PART – II

Answer **any six** questions. Question number **18** is compulsory. 6x2=12

16	**The diameter of the Moon using parallax method:** 1. It is possible to determine the size of any planet or moon once we know the distance S of the planet. 2. The image of every heavenly body (moon) is a disc when viewed through an optical telescope. 3. The angle θ between two extreme points A and B on the disc with respect to a certain point on the Earth is determined with the help of a telescope. 4. The angle θ is called the angular diameter of the planet. The linear diameter d of the moon is then given by d = distance × angular diameter d = s × θ 	2	2

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17	**Deduce that two vectors are perpendicular:** If two vector $\vec{A}$ and $\vec{B}$ are **perpendicular to each other their scalar product.** $\vec{A}.\vec{B}$ =0, because $\cos 90^0 = 0$.	1 1	2
18	$F_{cp} = \frac{mv^2}{r}$; $\frac{\frac{1}{4} x (2)^2}{3}$ F_{cp} = 0.333N	1 ½ ½	2
19	**Newton's Universal law of gravitation:** Newton's 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**. (or) $F \propto \frac{m_1 m_2}{r^2}$	2 1	2
20	**Difference between sliding and slipping:** **Sliding** is the case when $v_{CM} > R\omega$ **(or** $v_{TRANS} > v_{ROT}$**).** The translation is more than the rotation. **Slipping** is the case when $v_{CM} < R\omega$ **(or** $v_{TRANS} < v_{ROT}$**).** The rotation is more than the translation	1 1	2
21	**Gravitational potential:** The gravitational potential at a distance r due to a mass is defined as the **amount of work required to bring unit mass from infinity to the distance**.	2	2
22	**Power:** **The rate of work done or energy delivered.** Power (P) = $\frac{\text{Workdone (W)}}{\text{Time taken (t)}}$ S.I unit : **Watt**	1 ½ ½	2
23	**Significance of moment of inertia:** i) For rotational motion, moment of inertia is a measure of rotational inertia. ii) The moment of inertia of a body is not an invariable quantity. It depends not only on the mass of the body, but also on the way the mass is distributed around the axis of rotation.	1 1	2
24	**pseudo force:** **Centrifugal force** is called as a 'pseudo force'. **A pseudo force has no origin**. A pseudo force is **an apparent force** that acts on all masses whose motion is described using non inertial frame of reference such as a rotating reference frame.	2	2

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PART – II

Answer **any six** questions. Question number **28** is compulsory. 6x3=18

<table>
<tr><td>25</td><td>

<u>The rules for rounding off:</u>
1. If the digit to be dropped is smaller than 5, then the preceding digit should be left unchanged.
Ex. i) 7.32 is rounded off to 7.3 ii) 8.94 is rounded off to 8.9
2. If the digit to be dropped is greater than 5, then the preceding digit should be increased by 1
Ex. i) 17.26 is rounded off to 17.3 ii) 11.89 is rounded off to 11.9
3. If the digit to be dropped is 5 followed by digits other than zero, then the preceding digit should be raised by 1
Ex. i) 7.352, on being rounded off to first decimal becomes 7.4
ii) 18.159 on being rounded off to first decimal, become 18.2
4. If the digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is not changed if it is even
Ex. i) 3.45 is rounded off to 3.4 ii) 8.250 is rounded off to 8.2
5. If the digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is raised by 1 if it is odd
Ex. i) 3.35 is rounded off to 3.4 ii) 8.350 is rounded off to 8.4

</td><td>Any 3
3x1=3</td><td>3</td></tr>
<tr><td>26</td><td>

<u>Newton's Third Laws:</u>
Newton's First Law:
Every object continues to be in the state of rest or of uniform motion (constant velocity) 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
$\vec{F} = \frac{d\vec{p}}{dt}$
Newton's third law : For every action there is an equal and opposite reaction.

</td><td>1
1
1</td><td>3</td></tr>
<tr><td>27</td><td>

<u>Differences between conservative and Non-conservative forces:</u>

<table>
<tr><th>Conservative forces</th><th>Non-conservative forces</th></tr>
<tr><td>Work done is independent of the path</td><td>Work done depends upon the path</td></tr>
<tr><td>Work done in a round trip is zero</td><td>Work done in a round trip is not zero</td></tr>
<tr><td>Total energy remains constant</td><td>Energy is dissipated as heat energy</td></tr>
<tr><td>Work done is completely recoverable</td><td>Work done is not completely recoverable</td></tr>
<tr><td>Force is the negative gradient of potential energy</td><td>No such relation exists.</td></tr>
<tr><td>Examples:
Elastic spring force, electrostatic force, magnetic force, magnetic force, gravitational force etc..</td><td>Examples:
Frictional forces, Viscous force</td></tr>
</table>

</td><td>Any 3
3x1=3</td><td>3</td></tr>
</table>

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28	(a) When the weight lifter lifts the mass, force and displacement are in the same direction, which means that the angle between them $\theta = 0^0$ .Therefore, the work done by the weight lifter, $W_{weight\ lifter} = F_w\, h \cos\theta = F_w\, h(\cos 0^0)$ $= 5000 \times 5 \times 1$; 25,000 joule ; $W_{weight\ lifter}$ = 25 kJ (b) When the weight lifter lifts the mass, the gravity acts downwards which means that the force and displacement are in opposite direction. Therefore, the angle between them $\theta = 180^0$ $W_{gravity} = F_g\, h \cos\theta$; $= mgh (\cos 180^0)$ $= 250 \times 10 \times 5 \times (-1)$; = – 12500 joule ; $W_{gravity} = -12.5$ kJ (c) The net work done (or total work done) on the object $W_{net} = W_{weight\ lifter} + W_{gravity}$ = 25 kJ – 12.5 kJ W_{net} = **12.5 kJ**	1 1 1	3
29	**<u>Geo-stationary and polar satellite:</u>** 1) The satellites orbiting the Earth have different time periods corresponding to different orbital radii. Can we calculate the orbital **radius of a satellite if its time period is 24 hours is calculated below.** Kepler's third law is used to find the radius of the orbit. $T^2 = \frac{4\pi^2}{GM_E}(R_E + h)^3$; $(R_E + h)^3 = \frac{GM_E T^2}{4\pi^2}$ $(R_E + h) = \left(\frac{GM_E T^2}{4\pi^2}\right)^{\frac{1}{3}}$ 2) Substituting for the **time period (24 hrs = 86400 seconds), mass, and radius of the Earth, h turns out to be 36,000 km**. Such satellites are called **"geo-stationary satellites"**, since they appear to be stationary when seen from Earth. 3) India uses the **INSAT group of satellites** that are basically Geo-stationary satellites for the purpose of telecommunication. Another type of **satellite which is placed at a distance of 500 to 800 km** from the surface of the Earth orbits the Earth from north to south direction. 4) This type of satellite that **orbits Earth from North Pole to South Pole** is called a polar satellite. The **time period of a polar satellite is nearly 100 minutes and the satellite completes many revolutions in a day.** 5) **A Polar satellite covers a small strip of area from pole to pole during one revolution**. In the next revolution it covers a different strip of area since the Earth would have moved by a small angle. In this way polar satellites cover the entire surface area of the Earth.	1 ½ ½ 1	3

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30	**Work done by torque:** i) Consider a rigid body rotating about a fixed axis. A point P on the body rotating about an axis perpendicular to the plane of the page. A tangential force F is applied on the body. ii) It produces a small displacement, ds on the body. The work done (dw) by the force is, dw = F ds iii) As the distance ds, the angle of rotation dθ and radius r, are related by the expression, ds = r dθ The expression for work done now becomes, dw = F ds; dw = F r dθ iv) The term (Fr) is the torque τ produced by the force on the body. dw = τdθ This expression gives the work done by the external torque τ, which acts on the body rotating about a fixed axis through an angle dθ.	1 1 1	3
31	**Properties of scalar products** 1) The product quantity $\vec{A}.\vec{B}$ **is always a scalar**. It is positive if the angle between the vectors is acute (i.e., < 90°) and negative if the angle between them is obtuse (i.e. 90°<θ< 180°). 2) The **scalar product is commutative**, i.e. $\vec{A}.\vec{B} = \vec{B}.\vec{A}$ 3) The **vectors obey distributive law** i.e. $\vec{A}.(\vec{B}+\vec{C}) = \vec{A}.\vec{B} + \vec{A}.\vec{C}$ 4) The angle between the vectors θ = $\cos^{-1}\left[\frac{\vec{A}.\vec{B}}{AB}\right]$ 5) The **scalar product of two vectors will be maximum** when Cos θ = 1, i.e. θ = 0^0, i.e., when the vectors are parallel; $(\vec{A}.\vec{B})_{max} = AB$ 6) The **scalar product of two vectors will be minimum**, when Cos θ = –1, i.e. θ = 180^0 $(\vec{A}.\vec{B})_{min} = -AB$ when the vectors are anti-parallel. 7) **If two vectors $\vec{A}$and $\vec{B}$, are perpendicular** to each other than their scalar Product $\vec{A}.\vec{B}$= 0, because Cos 90^0 =0. Then the vectors $\vec{A}$and $\vec{B}$. are said to be mutually orthogonal. 8) The scalar product of a vector with itself is termed as self–dot product and is given by $(\vec{A})^2 = \vec{A}.\vec{A}$ = AA Cos θ = A^2. Here angle θ = 0° The **magnitude or norm of the vector $\vec{A}$ is $\lvert\vec{A}\rvert$ = A = $\sqrt{\vec{A}.\vec{A}}$** 9) In case of a unit vector $\hat{n}$, $\hat{n}.\hat{n}$= 1 x 1 x Cos 0 = 1. For example, $\hat{\imath}.\hat{\imath} = \hat{\jmath}.\hat{\jmath} = \hat{k}.\hat{k} = 1$ 10) In the case of **orthogonal unit vectors** $\hat{\imath}$,$\hat{\jmath}$and $\hat{k}$, $\hat{\imath}.\hat{\jmath} = \hat{\jmath}.\hat{k} = \hat{k}.\hat{\imath}$ = 1.1 Cos90^0 = 0 11) In terms of components the scalar product of $\vec{A}$and $\vec{B}$can be written As $\vec{A}.\vec{B} = (A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k}).(B_x\hat{\imath} + B_y\hat{\jmath} + B_z\hat{k})$ $= A_xB_x + A_yB_y + A_zB_z$ with all other terms zero. The magnitude of vector $\lvert\vec{A}\rvert$ is given by $\lvert\vec{A}\rvert = A = \sqrt{A_x^2 + A_y^2 + A_z^2}$	Any 6 6x½ =3	3

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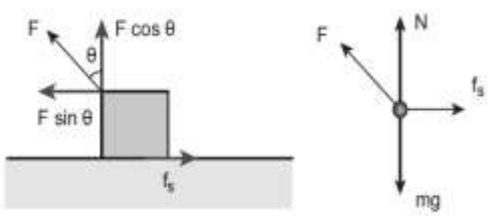
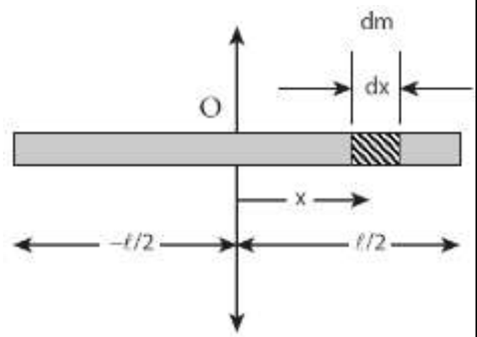
32	 N_{push} **= mg + F cosθ ------------1** The maximal static friction also increases and is equal to $f_s^{max} = \mu_s N_{Push} = \mu_s(mg + F\cos\theta)$ **-----2**  The total downward force acting on the object is N_{Pull} **= mg - F cosθ -------------3** Equation (3) shows that the normal force is less than N_{push}. From equations (1) and (3), **it is easier to pull an object than to push to make it move.**	1 ½ 1 ½	3
33	**Kinetic equations for linear motion:** 1. v = u + at 2. s = ut + ½ at² 3. v² = u² + 2as 4. s = $\frac{(u+v)t}{2}$ **Kinematic equations for angular motion:** 1.$\omega = \omega_0 + \alpha t$ 2. $\theta = \omega_0 t+\frac{1}{2}\alpha t^2$ 3. $\omega^2 = \omega_0^2 + 2\alpha\theta$ 4. $\theta = \frac{(\omega+ \omega_0)t}{2}$	1 ½ 1 ½	3

PART – IV

Answer **all** the questions. 5x5=25

34. (a)	**Moment of inertia of a rod about its center and perpendicular to the rod:** 1) Let us consider a uniform rod of mass (M) and length (l) as shown in Figure. Let us find an expression for moment of inertia of this rod about an **axis that passes through the center of mass and perpendicular to the rod.** 2) **First an origin is to be fixed for the coordinate system** so that it coincides with the center of mass, which is also the geometric center of the rod. The rod is now along the x axis.  3) We take an infinitesimally small mass (dm) at a distance (x) from the origin. The moment of inertia (dI) of this mass (dm) about the axis is, **dI = (dm)x²** As the mass is uniformly distributed, the mass per unit length (λ) of the rod is, $\lambda = \frac{mass}{length}$; $\boldsymbol{\lambda = \frac{M}{l}}$ The (dm) mass of the infinitesimally small length as, dm = λdx = $\frac{M}{l}$dx. The moment of inertia (I) of the entire rod can be found by integrating dI, I = $\int dI = \int (dm)x^2$; $\int \left(\frac{M}{l}dx\right)x^2$; I = $\frac{M}{l}\int x^2 dx$ 4) As the **mass is distributed on either side of the origin, the limits for integration are taken from** $-\frac{l}{2}$ **to** $\frac{l}{2}$	1 1 1	5

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$$I = \frac{M}{l}\int_{-\frac{l}{2}}^{\frac{l}{2}} x^2 dx; = \frac{M}{l}\left[\frac{x^3}{3}\right]_{-\frac{l}{2}}^{\frac{l}{2}}$$ 1

$$I = \frac{M}{l}\left[\frac{l^3}{24} - \left(-\frac{l^3}{24}\right)\right]; = \frac{M}{l}\left[\frac{l^3}{24} + \frac{l^3}{24}\right]$$

$$I = \frac{M}{l}\left[2\left(\frac{l^3}{24}\right)\right] \;;$$

$$I = \frac{1}{12}ml^2$$ 1

34. (b)

Various types of errors:

Random error, systematic error and gross error are the three possible errors

Systematic errors:

Systematic errors are reproducible inaccuracies that are consistently in the same direction.

Instrumental errors:

When an **instrument is not calibrated properly** at the time of manufacture, these errors can be corrected by **choosing the instrument carefully.** 1

Imperfections in experimental technique or procedure:

These errors **arise due to the limitations in the experimental** arrangement. To overcome these, necessary correction has to be applied.

Personal errors:

These errors are due to individuals performing the experiment, may be due to **incorrect initial setting up of the experiment or carelessness** of the individual making the observation due to improper precautions 1

Errors due to external causes:

The **change in the external conditions** during an experiment can cause error in measurement. For example, **changes in temperature, humidity, or pressure during measurements** may affect the result of the measurement. 5

Least count error:

Least count is the smallest value that can be measured by the measuring instrument, and the error due to this measurement is least count error. 1

Random errors:

1. Random errors may arise due to **random and unpredictable variations** in experimental conditions like pressure, temperature, voltage supply etc. 1
2. Errors may also be due to **personal errors** by the observer who performs the experiment. Random errors are sometimes called **"chance error"**
3. It can be minimized by **repeating the observations a large number of measurements** are made and then the arithmetic mean is taken.

Gross Error:

The error caused due to the shear **carelessness of an observer** is called gross error. These errors can be minimized only when an observer is **careful and mentally alert.** 1

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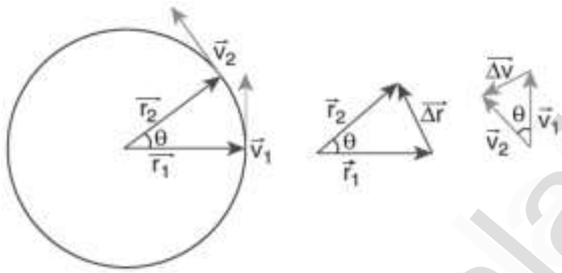
35 (a)

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

ii) Let the directions of position and velocity vectors shift through the same angle θ in a small interval of time Δt, 1

iii) For uniform circular motion, r = $|\vec{r_1}| = |\vec{r_2}|$ and v = $|\vec{v_1}| = |\vec{v_2}|$. If the particle moves from position vector $\vec{r_1}$ to $\vec{r_2}$, the displacement is given by $\Delta\vec{r} = \vec{r_2} - \vec{r_1}$ and the change in velocity from $\vec{v_1}$ to $\vec{v_2}$ is given by $\Delta\vec{v} = \vec{v_2} - \vec{v_1}$. 1

iv) The magnitudes of the displacement Δr and of Δ*v* satisfy the following relation $\frac{\Delta r}{r} = -\frac{\Delta v}{v} = \theta$ 1



1

v) Here the negative sign implies that Δ*v* points radially inward, towards the center of the circle. $\Delta v = v\left(\frac{\Delta r}{r}\right)$ then, $a = \frac{\Delta v}{\Delta t} = \frac{v}{r}\left(\frac{\Delta v}{\Delta t}\right)$; $= -\frac{v^2}{r}$ 1

vi) For uniform circular motion *v* = ω*r*, where ω is the angular velocity of the particle about the center. Then the centripetal acceleration can be written as a = − ω²*r*

Total: 5

35 (b)

Work – energy Theorem:

It states that work done by the force acting on a body is equal to the change produced in the kinetic energy of the body.

Consider a body of mass m at rest on a frictionless horizontal surface.

The work (W) done by the constant force (F) for a displacement (s) in the same direction is,

W = Fs ------------ (1) 1

The constant force is given by the equation, F = ma --------- (2)

The **third equation of motion** can be written as, $v^2 = u^2 + 2as$ 1

$$a = \frac{v^2 - u^2}{2s} \text{ ----------------- (3)}$$

Substituting for a in equation (2), $F = m\left(\frac{v^2-u^2}{2s}\right)$ ------------ (4)

Substituting equation (4) in (1), $W = m\left(\frac{v^2}{2s}s\right) - m\left(\frac{u^2}{2s}s\right)$ 1

W = ½ mv² – ½ mu² ----------------- (5)

The expression for kinetic energy:

The term ½ (mv²) in the above equation is the kinetic energy of the body of mass (m) moving with velocity (v). **KE = ½ mv²**---------------- (6)

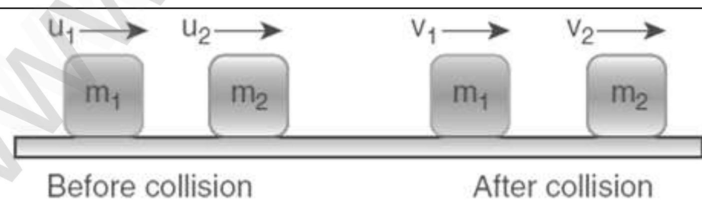
Kinetic energy of the body is always positive. 1

From equations (5) and (6)

ΔKE = ½ mv² – ½ mu² ---------------(7) thus, W = ΔKE

Total: 5

	The expression on the right-hand side (RHS) of equation (7) is the change in kinetic energy (ΔKE) of the body. This implies that **the work done by the force on the body changes the kinetic energy of the body**. This is called work-kinetic energy theorem. significance of kinetic energy in the work – kinetic energy theorem: If the work done by **the force on the body is positive,** then its **kinetic energy increases.** If the work done by **the force on the body is negative,** then its **kinetic energy decreases.** If there is **no work done by the force** on the body then there is **no change** in its kinetic energy	1	
36 (a)	**Escape speed:** Consider an object of mass M on the surface of the Earth. **When it is thrown up with an initial speedv_i , the initial total energy of the object** is $E_i = \frac{1}{2} MV_i^2 - \frac{GMM_E}{R_E}$ ------------- 1 Where M_E, is the mass of the Earth and R_E - the radius of the Earth. The term $-\frac{GMM_E}{R_E}$ is the potential energy of the mass M. When the object reaches a height far away from Earth and hence treated as approaching infinity, **the gravitational potential energy becomes zero [U (∞) = 0] and the kinetic energy becomes zero as well**. Therefore, **the final total energy of the object becomes zero. This is for minimum energy and for minimum speed to escape**. Otherwise Kinetic energy can be non-zero. $E_f = 0$, According to the law of energy conservation, $E_i = E_f$ ------- 2 Substituting (1) in (2) we get, $\frac{1}{2} MV_i^2 - \frac{GMM_E}{R_E} = 0$ $\frac{1}{2} MV_i^2 = \frac{GMM_E}{R_E}$ -------------- 3 The escape speed, the minimum speed required by an object to escape Earth's gravitational field, hence replace, V_i with V_e. i.e, $\frac{1}{2} MV_e^2 = \frac{GMM_E}{R_E}$ $V_e^2 = \frac{GMM_E}{R_E} \cdot \frac{2}{M}$; $V_e^2 = \frac{2GM_E}{R_E}$ ------------ 4 Using $g = \frac{GM_E}{R_e^2}$ – – – – – – – – – – – – – – – – – – 5 $V_e^2 = 2gR_E$; $V_e = \sqrt{2gRE}$ ------------ 6 From equation (6) the escape speed depends on two factors: **acceleration due to gravity and radius of the Earth**. It is completely independent of the mass of the object. $Ve = \sqrt{2gR_E}$; $Ve = 11.2\ kms^{-1}$		5

36 (b)	**Inclined plane, angle of friction is equal to angle of repose:** If 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 which resists its motion. This force is called the frictional force which always opposes the relative motion between an object and the surface** where it is placed. Consider an inclined plane on which an object is placed. Let the angle which this plane makes with the horizontal be θ . For small angles of θ , the object may not slide down. As **θ is increased, for a particular value of θ , the object begins to slide down.** This value is called angle of repose. Hence, the angle of repose is the angle of inclined plane with the horizontal such that an object placed on it begins to slide. Consider the various forces in action here. The **gravitational force mg is resolved into components parallel (mg sin θ) and perpendicular (mg cos θ) to the inclinedplane.** **The component of force parallel to the inclined plane (mg sin θ) tries to move theobject down**. The component of force perpendicular to the inclined plane (mg cos θ) is balanced by the Normal force (N). $\mathbf{N = mg \cos\theta}$ -------------(1) When the object just begins to move, the static friction attains its maximum value, $f_s = f_s^{max} = \mu_s$ N. This friction also satisfies the relation $\mathbf{f_s^{max} = \mu_s \, mg \sin\theta}$ ------------ (2) Equating the right hand side of equations (1) and (2), we get $\mathbf{(f_s^{max}) / N = \sin\theta / \cos\theta}$ From the definition of angle of friction, we also know that $\mathbf{\tan\theta = \mu_s}$ in which **θ** is the angle of friction.	1 1 1 1 1	5
37 (a)	**Applications of Dimensional Analysis.** 1. Convert a 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. $[M] [LT^{-1}]^2 = [M] [LT^{-2}] [L]$ $[ML^2T^{-2}] = [ML^2T^{-2}]$ **(or)** The given equation is dimensionally correct	3 2	**5**
37 (b)	 Consider two elastic bodies of masses m_1 and m_2 moving in a straight line (along positive x direction) on a frictionless horizontal surface. In order to have collision, we assume that the mass m_1 moves faster than mass m_2 i.e.,$\mu_1 > \mu_2$ For elastic collision, the total linear momentum and kinetic energies of the two bodies before and after collision must remain the same. From the law of conservation of linear momentum, Total momentum before collision (*pi*) = Total momentum after collision (*pf*) $\mathbf{m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2}$ ——— (1) (or)		5

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$\mathbf{m_1(u_1 - v_1) = m_2(v_2 - u_2)}$ ---------------- (2) 1

For elastic collision,

Total kinetic energy before collision KE_i = Total kinetic energy after collision KE_f

$\mathbf{\frac{1}{2} m_1u_1^2 + \frac{1}{2} m_2u_2^2 = \frac{1}{2} m_1v_1^2 + \frac{1}{2} m_2v_2^2}$ ———— **(3)**

After simplifying and rearranging the terms,

$m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2)$

Using the formula, $a^2 - b^2 = (a + b)(a - b)$, we can rewrite the above equation as

$\mathbf{m_1(u_1 + v_1)(u_1 - v_1) = m_2(v_2 + u_2)(v_2 - u_2)}$--------- (4)

Dividing equation (4) by (2) gives, 1

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

$\mathbf{u_1 + v_1 = v_2 + u_2}$, Re-arranging $\mathbf{u_1 - u_2 = v_2 - v_1}$ -------------- (5)

Equation (5) can be rewritten as $(u_1 - u_2 = -(v_1 - v_2)$

This means that for any elastic head on collision, the relative speed of the two elastic bodies after the collision has the same magnitude as before collision but in opposite direction. Further note that this result is independent of mass.

Rewriting the above equation for v_1 and v_2 ,

$v_1 = v_2 + u_2 - u_1$ ----------- (6) or $\mathbf{v_2 = u_1 + v_1 - u_2}$ ---------------(7)

To find the final velocities $v_1$and v_2: 1

Substituting equation (7) in equation (2) gives the velocity of m_1 as

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

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

$m_1u_1 - m_1v_1 = m_2u_1 + m_2v_1 - 2m_2u_2$

$m_1u_1 - m_2u_1 + 2m_2u_2 = m_1v_1 + m_2v_1$

$(m_1 - m_2)u_1 + 2m_2u_2 = (m_1 + m_2)v_1$ **(or)**

$$v_1 = \left(\frac{m_1 - m_2}{m_1+m_2}\right)u_1 + \left(\frac{2m_2}{m_1+m_2}\right)u_2 \text{ ---------(8)}$$

Similarly, by substituting (6) in equation (2) or substituting equation (8) in equation (7), we get the final velocity of m_2 as

$$v_2 = \left(\frac{2m_1}{m_1+m_2}\right)u_1 + \left(\frac{m_2 - m_1}{m_1+m_2}\right)u_2 \text{ ---------- (9)}$$ 1

Case 1: When bodies has the same mass i.e., $\mathbf{m_1 = m_2}$,

Equation (8) –→ $v_1 = (0)u_1 + \left(\frac{2m_2}{2m_2}\right)u_2$; $\mathbf{v_1 = u_2}$ ----------- (10)

Equation (9) –→ $v_2 = \left(\frac{2m_1}{2m_1}\right)u_1 + (0)u_2$; $\mathbf{v_2 = u_1}$ ----------- (11)

The equations (10) and (11) show that in **one dimensional elastic collision, when two bodies of equal mass collide after the collision their velocities are exchanged.**

Case 2: When bodies have the same mass i.e., $\mathbf{m_1 = m_2}$, and second body (usually called target) is at rest **(u_2 = 0)**,

By substituting $\mathbf{m_1 = m_2}$ **and** $\mathbf{u_2 = 0}$ in equations (8) and equations (9) we get,

From equation (8) –→ $v_1 = 0$ -------------(12) 1

From equation (9) –→ $v_2 = u_1$ ------------- (13)

Equations (12) and (13) show that when the first body comes to rest the second body moves with the initial velocity of the first body.

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Case 3: The first body is very much lighter than the second body

$\left(m_1 \ll m_2, \frac{m_1}{m_2} \ll 1\right)$ then the ratio $\frac{m_1}{m_2} \approx 0$. And also if the target is at rest ($u_2=0$)

Dividing numerator and denominator of equation (8) by m_2, we get

$$v_1 = \left(\frac{\frac{m_1}{m_2}-1}{\frac{m_1}{m_2}+1}\right) u_1 + \left(\frac{2}{\frac{m_1}{m_2}+1}\right)(0);\ v_1 = \left(\frac{0-1}{0+1}\right)u_1;\ \mathbf{v_1 = -u_1} \text{ ------------(14)}$$

Similarly, Dividing numerator and denominator of equation (9) by m_2, we get

$$v_2 = \left(\frac{2\frac{m_1}{m_2}}{\frac{m_1}{m_2}+1}\right) u_1 + \left(\frac{1-\frac{m_1}{m_2}}{\frac{m_1}{m_2}+1}\right)(0)\ ;\ v_2 = (o)u_1 + \left(\frac{1-\frac{m_1}{m_2}}{\frac{m_1}{m_2}+1}\right)(0)\ ;\ \mathbf{v_2 = 0} \text{ ----- (15)}$$

The equation (14) implies that **the first body which is lighter returns back rebounds) in the opposite direction with the same initial velocity as it has a negative sign.**

The equation (15) implies that **the second body which is heavier in mass continues to remain at rest even after collision**. For example, if a ball is thrown at a fixed wall, the ball will bounce back from the wall with the same velocity with which it was thrown but in opposite direction.

Case 4: The second body is very much lighter than the first body

$\left(m_2 \ll m_1, \frac{m_2}{m_1} \ll 1\right)$ then the ratio $\frac{m_2}{m_1} \approx 0$. And also if the target is at rest ($u_2=0$)

Dividing numerator and denominator of equation (8) by m_1, we get

$$v_1 = \left(\frac{1-\frac{m_2}{m_1}}{1+\frac{m_2}{m_1}}\right)u_1 + \left(\frac{2\frac{m_2}{m_1}}{1+\frac{m_2}{m_1}}\right)(0)\ ;$$

$$v_1 = \left(\frac{0-1}{0+1}\right)u_1 + \left(\frac{0}{1+0}\right)(0)\ ;\quad \mathbf{v_1 = u_1} \text{ --------------------(16)}$$

Similarly, Dividing numerator and denominator of equation (14) by m_1, we get

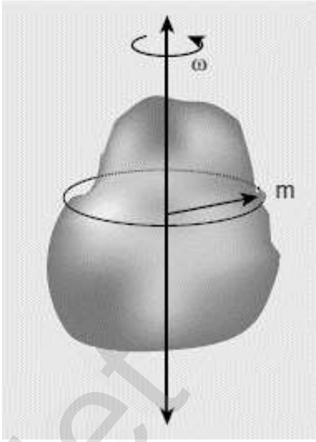
$$v_1 = \left(\frac{2}{1+\frac{m_2}{m_1}}\right) u_1 + \left(\frac{\frac{m_2}{m_1}-1}{1+\frac{m_2}{m_1}}\right)(0)\ ;\quad v_2 = \left(\frac{2}{1+0}\right)u_1;\ v_2 = 2u_1 \text{ ------(17)}$$

The equation (16) implies that **the first body which is heavier continues to move with the same initial velocity.**

The equation (17) suggests that **the second body which is lighter will move with twice the initial velocity of the first body.**

It means that **the lighter body is thrown away from the point of collision.**

(Any two cases = 1 Marks)

38 (a)	**Kinetic Energy in Rotation:** Let us consider a rigid body rotating with angular velocity ω about an axis as shown in Figure. Every particle of the body will have the same angular velocity ω and different tangential velocities v based on its positions from the axis of rotation.  Let us choose a particle of mass mi situated at distance ri from the axis of rotation. It has a tangential velocity v_i given by the relation, $v_i = r_i\,\omega$. The kinetic energy KE_i of the particle is, $KE_i = ½\, m_i v_i^2$ Writing the expression with the angular velocity, $KE_i = \frac{1}{2} m_i(r_i\omega)^2$; $= \frac{1}{2}(m_i r_i^2)\omega^2$ For the kinetic energy of the whole body, which is made up of large number of such particles, the equation is written with summation as $KE = \frac{1}{2}(\Sigma m_i r_i^2)\omega^2$ Where, the term $\Sigma m_i r_i^2$ is the moment of inertia I of the whole body. $I = \Sigma m_i r_i^2$ Hence, the expression for KE of the rigid body in rotational motion is, $KE = \frac{1}{2} I\omega^2$ This is analogous to the expression for kinetic energy in translational motion $KE = \frac{1}{2} MV^2$ **Relation between rotational kinetic energy and angular momentum:** The angular momentum of a rigid body is, L = Iω The rotational kinetic energy of the rigid body is, $KE = ½\, I\omega^2$ By multiplying the numerator and denominator of the above equation with I, we get a relation between L and KE as, $KE = \frac{1}{2}\frac{I^2\omega^2}{I}$; $= \frac{1}{2}\frac{(I\omega)^2}{I}$; $KE = \frac{L^2}{2I}$	1 1 1 2	5

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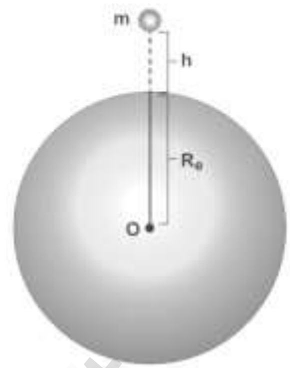
38 (b)	**Variation of g with altitude:** Consider an object of mass m at a height h from the surface of the Earth. Acceleration experienced by the object due to Earth is $\mathbf{g' = \frac{GM}{(R_e+h)^2}}$ $g' = \frac{GM}{R_e^2\left(1+\frac{h}{R_e}\right)^2}$; $g' = \frac{GM}{R_e^2}\left(1+\frac{h}{R_e}\right)^{-2}$  If $h << R_e$. We can use Binomial expansion. Taking the terms upto first order $g' = \frac{GM}{R_e^2}\left(1-2\frac{h}{R_e}\right)$; $\mathbf{g' = g\left(1-2\frac{h}{R_e}\right)}$ We find that $\mathbf{g' < g}$. This means **that as altitude h increases the acceleration due to gravity g decreases.**	1 1 1 1 1	5

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