HIGHER SECONDARY FIRST YEAR HALF-YEARLY EXAMINATION – DECEMBER 2023

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	(d)	LT^{-3}	9	(a)	friction
2	(c)	-12 units	10	(b)	decrease
3	(d)	The speed and magnitude of acceleration are constant	11	(a)	40 cm
4	(c)	Greater than 1	12	(c)	equal to the initial temperature
5	(b)	147.15 J	13	(b)	zero
6	(b)	1032	14	(c)	22/17
7	(b)	$\sqrt{\frac{10}{7}gh}$	15	(b)	$F=\beta x$
8	(a)	4.30			

PART – II

Answer any **six** questions. Question number **24** is compulsory. 6x2=12

16	**Relative error or fractional error:** The **ratio of the mean absolute error to the mean value**. Relative error = $\frac{\Delta a_m}{a_m}$	1 1	2

17	**Angular velocity (ω):** The rate of change of angular displacement is called angular velocity. The **unit of angular velocity is radian per second (rad s^{-1}).**	1½ ½	2
18	**Lami's Theorem:** The magnitude of each **force of the system is proportional to sine of the angle between the other two forces.** The constant of proportionality is same for all three forces. $\frac{\lvert\vec{F}_1\rvert}{\mathrm{Sin}\alpha} = \frac{\lvert\vec{F}_2\rvert}{\mathrm{Sin}\beta} = \frac{\lvert\vec{F}_2\rvert}{\mathrm{Sin}\gamma}$	2	2
19	Work done, W = $\int_{x_i}^{x_f} F(x)dx$ $= k\int_0^4 x^2dx\ ;\ \frac{64}{3}$ Nm	1 1	2
20	**Equilibrium:** i) A rigid body is said to be in **mechanical equilibrium when both its linear momentum and angular momentum remain constant.** ii) When all the forces act upon the object are balanced, then the object is said to be an equilibrium.	1 1	2
21	**Reynold's number:** Reynold's number(R_C) is **a dimensionless number, which is used to find out the nature of flow of the liquid. $R_C = \frac{\rho v D}{\eta}$** Where, ρ- density of the liquid, v –The velocity of flow of liquid. D- Diameter of the pipe, η - The coefficient of viscosity of the fluid.	1 1	2
22	$V_1 = 1m^3$, $V_2 = 2m^3$, $P = 1.01 \times 10^5\ Nm^{-2}$ $W = P\Delta V$; $= P(V_2 - V_1)$; $= 1.01\times10^5\ (2 - 1)$ $W = 1.01 \times 10^5$ J	1 1	2
23	**Moon has no atmosphere:** The escape speed of gases 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.**	2	2
24	$T \propto \sqrt{l}$; $T = \text{constant}\sqrt{l}$ $\frac{T_f}{T_i} = \sqrt{\frac{1+\frac{44}{100}l}{l}}$; $\sqrt{1.44} = 1.2$; Therefore, $T_f = 1.2\ T_i = T_i + 20\%\ T_i$	1 ½ ½	2

PART – II

Answer **any six** questions. Question number **33 is compulsory.** 6x3=18

25	**Precision and accuracy with one example:** **Precision:** The **closeness of two or more measurements** to each other. **Accuracy:** The **closeness of a measure value to the actual value** of the object being measured is called accuracy. **Example:** The true value of a certain length is near **5.678 cm.** In one experiment, using a measuring instrument of resolution 0.1 cm, the **measured value is found to be 5.5 cm.** In another experiment using a measuring instrument of greater resolution, say 0.01 cm, the **length is found to be 5.38** cm. We find that the **first measurement is more accurate** as it is closer to the true value, but it has lesser precision. On the contrary, the **second measurement is less accurate,** but it is more precise.	1 1 1	3
26	Properties of Dot product or Scalar Product: 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. $\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}$ 3) The **vectors obey distributive law** i.e. $\vec{A} \cdot (\vec{B} + \vec{C}) = \vec{A} \cdot \vec{B} + \vec{A} \cdot \vec{C}$ 4) The angle between the vectors $\theta = \cos^{-1}\left[\frac{\vec{A} \cdot \vec{B}}{AB}\right]$ 5) The **scalar product of two vectors will be maximum** when Cos θ = 1, i.e. $\theta = 0^0$, i.e., when the vectors are parallel; $(\vec{A} \cdot \vec{B})_{max} = AB$ 6)The **scalar product of two vectors will be minimum**, when Cos θ = –1, i.e. $\theta = 180^0$ $(\vec{A} \cdot \vec{B})_{min} = -AB$ when the vectors are anti-parallel. 7) If **two vectors $\vec{A}$ and $\vec{B}$, are perpendicular** to each other than their scalar Product $\vec{A} \cdot \vec{B} = 0$, 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 $(\vec{A})^2 = \vec{A} \cdot \vec{A} = AA\cos\theta = A^2$. 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 $\hat{n}$, $\hat{n} \cdot \hat{n}$ = 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 $\hat{k}$, $\hat{\imath} \cdot \hat{\jmath} = \hat{\jmath}.\hat{k} = \hat{k}.\hat{\imath}$ = 1.1 Cos90^0 = 0 11) In terms of components the scalar product of $\vec{A}$ and $\vec{B}$ can be written As $\vec{A} \cdot \vec{B} = (A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k}) \cdot (B_x\hat{\imath} + B_y\hat{\jmath} + B_z\hat{k})$ $= A_xB_x + A_yB_y + A_zB_z$ 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 6 x ½ =3	3

<table>
<tr>
<td>27</td>
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<tr><th>Static friction</th><th>Kinetic friction</th></tr>
<tr><td>It **opposes the starting of motion**</td><td>It **opposes the relative motion** of the object with respect to the surface</td></tr>
<tr><td>**Independent of surface of contact**</td><td>**Independent of surface of contact**</td></tr>
<tr><td>μ_s **depends on the nature of materials** in mutual contact</td><td>μ_k depends on nature of materials and temperature of the surface</td></tr>
<tr><td>Depends on the magnitude of applied force</td><td>Independent of magnitude of applied force</td></tr>
<tr><td>It can take values from zero to $\mu_s N$</td><td>It can never be zero and always equals to $\mu_k N$ whatever be the speed (true <10 ms^{-1})</td></tr>
<tr><td>$f_s^{max} > f_k$</td><td>It is less than maximal value of static friction</td></tr>
<tr><td>$\mu_s > \mu_k$</td><td>Coefficient of kinetic friction is less than coefficient of static friction</td></tr>
</table>
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<td>Any 3
3x1=3</td>
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<td>28</td>
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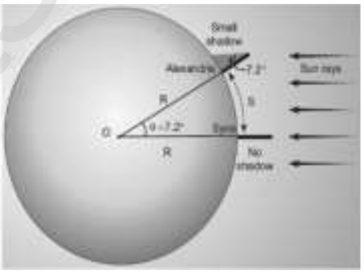
Eratosthenes method of finding the radius of Earth.

During noon time of summer solstice, the Sun's rays cast no shadow in the **city Syne which was located 500 miles away from Alexandria. At the same day and same time, he found that in Alexandria the Sun's rays made 7.2 degree with local vertical.** This difference of 7.2 degree was due to the curvature of the Earth.



The angle **7.2 degree is equivalent to $\frac{1}{8}$ radian. So, θ = $\frac{1}{8}$ rad.**

If S is the length of the arc between the cities of Syne and Alexandria, and if R is radius of Earth, then S = R θ = 500 miles, so radius of the Earth

R = $\frac{500}{\theta}$ miles , R = 500 $\frac{miles}{\frac{1}{8}}$ R = 4000 miles.

1 mile is equal to 1.609 km. So, he measured the radius of the Earth to be equal to **R = 6436 km, which is amazingly close to the correct value of 6378 km.**
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<tr>
<td>29</td>
<td>
i) Stress = $\frac{F}{A} = \frac{980}{10^{-6}}$; = 98 x 10^7 Nm^{-2}

ii) Strain = $\frac{Stress}{Y}$; $\frac{98 \times 10^7}{12 \times 10^{10}}$; =8.17 x 10^{-3}
</td>
<td>1 ½
1½</td>
<td>3</td>
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30	**Conservation of angular momentum with example.** 1) 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. $\tau = \frac{dL}{dt}$ if τ =0 then , L = Constant 2) As the **angular momentum is L = Iω, the conservation of angular momentum could further be written for initial and final situations** as, $I_i\omega_i = I_f\omega_f$ (or) Iω = constant 3) The above equations say that if I increase ω will decrease and vice-versa to keep the angular momentum constant. 4) There are several situations where the principle of conservation of angular momentum is applicable. 5) One striking Example: **The ice dancer spins slowly when the hands are stretched out and spins faster when the hands are brought close to the body. Stretching of hands away from body increases moment of inertia, thus the angular velocity decreases resulting in slower spin.** 6) When the **hands are brought close to the body**, the moment of inertia **decreases, and thus the angular velocity increases** resulting in faster spin.	1 1 1	3
31	**Applications of surface tension:** 1) **Oil pouring on the water** reduces surface tension. So that the **floating mosquitos' eggs drown and killed.** 2) Finely adjusted surface tension of the liquid makes droplets of desired size, which **helps in desktop printing, automobile painting and decorative items.** 3) **Specks of dirt are removed** from the cloth when it is washed in detergents added hot water, which has low surface tension. 4) **A fabric can be made waterproof, by adding suitable waterproof material (wax) to the fabric.** This increases the angle of contact due to surface tension.	Any 3 3x1=3	3
32	**The average kinetic energy and pressure:** The internal energy of the gas is given by U = $\frac{3}{2}$ NkT The above equation can also be written as U = $\frac{3}{2}$ PV Since PV = NkT $\mathbf{P = \frac{2}{3}\frac{U}{V} = \frac{2}{3}u}$ --------------1 From the equation (1), we can state that the pressure of the gas is equal to two thirds of internal energy per unit volume or internal energy density. u = $\frac{U}{V}$ Writing pressure in terms of mean kinetic energy density using equation. $\mathbf{P = \frac{1}{3}nm\overline{v^2} = \frac{1}{3}\rho\overline{v^2}}$ -------------2	1 1	3

	where ρ = nm = mass density (Note n is number density) Multiply and divide R.H.S of equation (2) by 2, we get $P = \frac{2}{3}\left(\frac{\rho}{2}\overline{v^2}\right)$ $\mathbf{P = \frac{2}{3}\overline{KE}}$ --------------------3 From the equation (3), pressure is equal to 2/3 of mean kinetic energy per unit volume	1	
33	$v = \omega\sqrt{A^2 - y^2}$; $v^2 = \omega^2(A^2 - y^2)$ Therefore, at position x_1 : $v_1^2 = \omega^2(A^2 - x_1^2)$ --------------1 Similarly, at position x_2 : $v_2^2 = \omega^2(A^2 - x_2^2)$ ----------------2 Subtracting (2) from (1), we get $v_1^2 = \omega^2(A^2 - x_1^2)$ - $v_2^2 = \omega^2(A^2 - x_2^2)$; $= \omega^2(x_1^2 - x_2^2)$ $\omega = \sqrt{\frac{v_1^2 - v_2^2}{x_2^2 - x_1^2}}$ T = $2\pi\sqrt{\frac{x_2^2 - x_1^2}{v_1^2 - v_2^2}}$ ------------3 Dividing (1) and (2), we get $\frac{v_1^2}{v_2^2} = \frac{\omega^2(A^2 - x_1^2)}{\omega^2(A^2 - x_2^2)}$ A = $\sqrt{\frac{v_1^2 x_2^2 - v_2^2 x_1^2}{v_1^2 - v_2^2}}$ -----------4 Dividing equation (3) and (4), we have $\frac{T}{A} = 2\pi\sqrt{\frac{x_2^2 - x_1^2}{v_1^2 x_2^2 - v_2^2 x_1^2}}$	1 1 1	3

PART – IV

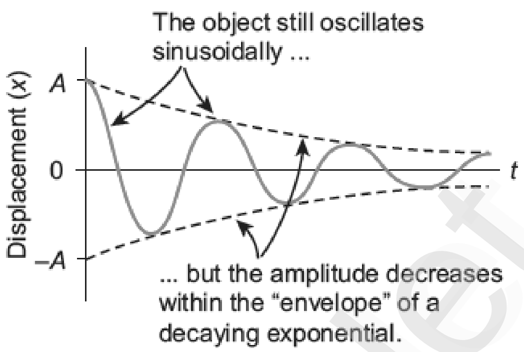
Answer **all** the questions. 5x5=25

34 (a)	**Velocity of a gun when a bullet is fired from it.** i) The force on each particle (Newton's second law) can be written as $\vec{F}_{12} = \frac{d\vec{p}_1}{dt}$ and $\vec{F}_{21} = \frac{d\vec{p}_2}{dt}$ ii) Here $\vec{p}_1$ is the momentum of particle 1which changes due to the force $\vec{F}_{12}$ exerted by particle 2. Further $\vec{p}_2$ is the momentum of particle 2. These changes due to $\vec{F}_{21}$ exerted by particle 1. $\frac{d\vec{p}_1}{dt} = -\frac{d\vec{p}_2}{dt}$; $\frac{d\vec{p}_1}{dt} + \frac{d\vec{p}_2}{dt} = 0$; $\frac{d}{dt}(\vec{p}_1 + \vec{p}_2) = 0$ iii) It implies that $\vec{p}_1 + \vec{p}_2$ = constant vector (always). iv) $\vec{p}_1 + \vec{p}_2$ is the total linear momentum of the two particles ($\vec{p}_{tot} = \vec{p}_1 + \vec{p}_2$). It is also called as total linear momentum of the system. Here, the two particles constitute the system. v) 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.	1 1 1 1 1	5

34 (b)

Types of oscillations.

Damped oscillations:



1) **During the oscillation of a simple pendulum, we have assumed that the amplitude of the oscillation** is constant and also the total energy of the oscillator is constant. But in reality, in a medium, 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 SHM decreases gradually indicating the loss of energy. The energy lost is absorbed by the surrounding medium.** This type of oscillatory motion is known as damped oscillation. 2

3) In other words, if an oscillator moves in **a resistive medium, its amplitude goes on decreasing and the energy of the oscillator is used to do work against the resistive medium.**

4) The motion of the oscillator is said to be damped and in this case, the **resistive force (or damping force) is proportional to the velocity of the oscillator.** 5

Examples (i) The oscillations of a pendulum (including air friction) or pendulum oscillating inside an oil filled container. (ii) Electromagnetic oscillations in a tank circuit. (iii) Oscillations in a dead beat and ballistic galvanometers.

Maintained oscillations:

1) **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 sustain oscillations.**

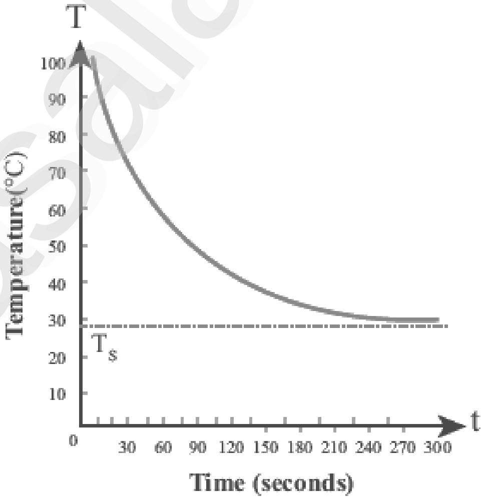
2) **By supplying energy from an external source, the amplitude of the oscillation can be made constant.** Such vibrations are known as maintained vibrations. 1

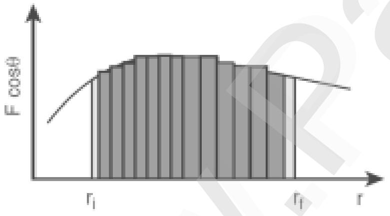
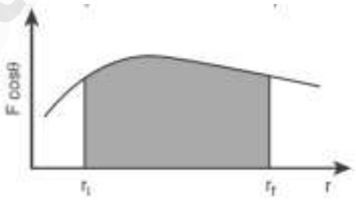
Example: The vibration of a tuning fork getting energy from a battery or from external power supply.

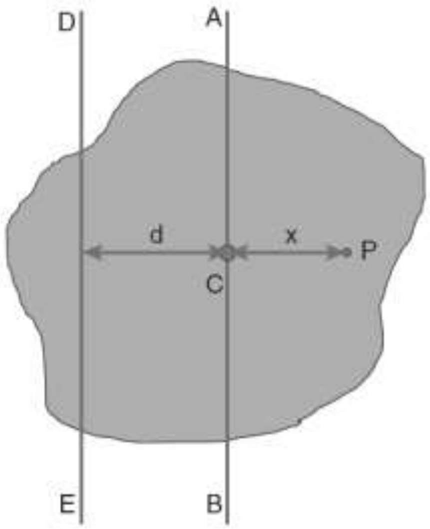
Forced oscillations:

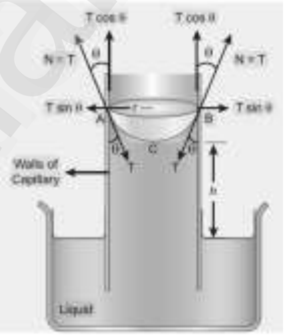
1) Any oscillator driven by **an external periodic agency to overcome the damping is known as forced oscillator or driven oscillator.**

2) In this type of vibration, **the body executing vibration initially vibrates with its natural frequency and due to the presence of external**

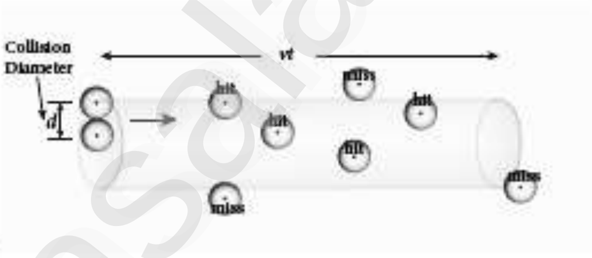
	periodic force, the body later vibrates with the frequency of the applied periodic force. Such vibrations are known as forced vibrations. **Example:** Sound boards of stringed instruments **Resonance:** 1) It is a special case of **forced vibrations where the frequency of external periodic force (or driving force) matches with the natural frequency** of the vibrating body (driven). 2) As a **result the oscillating body begins to vibrate such that its amplitude increases at each step and ultimately it has a large amplitude.** Such a phenomenon is known as resonance and the corresponding vibrations are known as resonance vibrations. **Example: The breaking of glass due to sound.**	1 1	
35 (a)	**Newton's law of cooling:** 1) Newton's law of cooling states that the **rate of loss of heat of a body is directly proportional to the difference in the temperature between that body and its surroundings .** $\frac{dQ}{dt}\ \alpha\ -(T-T)$ ------------ 1 2) The **negative sign indicates that the quantity of heat lost by liquid goes on decreasing with time**. Where, T = Temperature of the object T_s = Temperature of the surrounding.  From the **graph** in Figure, it is clear that **the rate of cooling is high initially and decreases with falling temperature.** 3) Let us consider an object of mass m and specific heat capacity s at temperature T. Let **Ts be the temperature of the surroundings.** If the temperature falls by a small amount dT in time dt, then the amount of heat lost is, **dQ = msdT** --------------- 2 4) Dividing both sides of equation (2) by $\frac{dQ}{dt} = \frac{msdT}{dt}$ -------------3 From Newton's law of cooling $\frac{dQ}{dt}\ \alpha\ -(T-T_S)$ $\frac{dQ}{dt} = -a(T-T_S)$ --------- 4 Where a is some positive constant. From equation (2) and (4) $-a(T-T_S) = ms\frac{dT}{dt}$ $\frac{dT}{(T-TS)} = -\frac{a}{ms}dt$ -------------------- 5	½ ½ 1 1 1	5

	Integrating equation (5) on both sides, $\int_0^\infty \frac{dT}{(T - TS)} = - \int_0^t \frac{a}{ms} dt$ In $(T - T_S) = \frac{a}{ms} t + b_1$ Where b_1 is the constant of integration. taking exponential both sides, we get, **$T = T_S + b_2 e^{\frac{a}{ms} t}$** . Here $b_2 = eb_1$ = Constant	1	
35 (b)	**Work done by a constant force and by a variable force.** i) When a constant force F acts on a body, the small work done (dW) by the force in producing a small displacement dr is given by the relation, dW= (F cosθ) dr ii) The total work done in producing a displacement from initial position **r_i** to final position **r_f** is, $W = \int_{r_i}^{r_f} dW$; $W = \int_{r_i}^{r_f} (F \cos\theta) dr = (F \cos\theta)$; $\int_{r_i}^{r_f} dr = (F \cos\theta)(r_f - r_i)$ iii) The graphical representation of the work done by a constant force. The area under the graph shows the work done by the constant force. **Work done by a variable force:** i) When the component of a variable force F acts on a body, the small work done (dW) by the force in producing a small displacement dr is given by the relation dW = (Fcos θ) dr [F cos θ is the component of the variable force F] where, F and θ are variables. ii) The total work done for a displacement from initial position r_i to final position r_f is given by the relation, $W = \int_{r_i}^{r_f} dW$; $= \int_{r_i}^{r_f} (F \cos\theta) dr$ iii) A graphical representation of the work done by a variable force. The area under the graph is the work done by the variable force.  	1 1 1 1 1	5
36 (a)	**Escape speed.** 1) Consider an object of mass M on the surface of the Earth. **When it is thrown up with an initial speed v_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. 2) When the object reaches a height far away from Earth and hence treated as approaching infinity, **the gravitational potential energy becomes zero [$U(\infty) = 0$] and the kinetic energy becomes zero as well.** Therefore, **the final total energy of the object becomes zero. This is for**	1 1	5

	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 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 $g = \frac{GM_E}{R_e}$ – – – – – – – – – – – – – – – – – – 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.	1 1 1	
36 (b)	**Parallel Axis Theorem**: i) Parallel axis theorem states that **the moment of inertia of a body about any axis is equal to the sum of its moment of inertia about a parallel axis through its center of mass and the product of the mass of the body and the square of the perpendicular distance between the two axes.** ii) If IC is the moment of inertia of the body of mass M about an axis passing through the center of mass, then the moment of inertia I about a parallel axis at a distance d from it is given by the relation $I = I_C + Md^2$ iii) let us consider a rigid body as shown in Figure. Its **moment of inertia about an axis AB passing through the center of mass is I_C.** DE is another axis parallel to AB at a perpendicular distance d from AB. The moment of inertia of the body about DE is I. We attempt to get an expression for I in terms of I_C. For this, let us consider a point mass m on the body at position x from its center of mass.  iv) The moment of inertia of the point mass about the axis DE is, $m(x + d)^2$. The moment of inertia I of the whole body about DE is the summation of the above expression.	1 1	5

	$I = \Sigma m(x + d)^2$ This equation could further be written as, $I = \Sigma m(x^2 + d^2 + 2xd)$ $I = \Sigma(mx^2 + md^2 + 2dmx)$ **$I = \Sigma mx^2 + \Sigma md^2 + 2d\Sigma mx$** v) Here, Σmx^2 is the moment of inertia of the body about the center of mass. Hence, $I_C = \Sigma mx^2$ The term, $\Sigma mx = 0$ because, x can take positive and negative values with respect to the axis AB. The summation (Σmx) will be zero Thus, **$I = I_C + \Sigma md^2$; $I_C + (\Sigma m)d^2$** vi) Here, Σm is the entire mass M of the object ($\Sigma m = M$) **$I = I_C + Md^2$** Hence, the parallel axis theorem is proved.	1 1 1	
37(a)	**The surface tension of a liquid by capillary rise method.**  Consider a capillary tube which is held vertically in a beaker containing water; **the water rises in the capillary tube to a height h due to surface tension.** The surface tension force F_T, acts along the tangent at the point of contact downwards and its reaction force upwards. Surface tension T, is resolved into **two components i) Horizontal component Tsinθ and ii) Vertical component Tcosθ acting upwards**, all along the whole circumference of the meniscus. **Total upward force = (Tcosθ) (2πr) = 2πrTcosθ** Where θ is the angle of contact, *r* is the radius of the tube. Let ρ be the density of water and *h* be the height to which the liquid rises inside the tube. Then, $\left(\begin{matrix}\text{the volume of}\\ \text{liquid column in}\\ \text{the tube, V}\end{matrix}\right) = \left(\begin{matrix}\text{Volume of the liquid}\\ \text{column of radius r}\\ \text{height h}\end{matrix}\right) + \left(\begin{matrix}\text{Volume of liquid of}\\ \text{radius r and height}\\ \text{r} - \text{Volume of the}\\ \text{hemisphere of radius r}\end{matrix}\right)$ $V = \pi r^2 h + \left(\pi r^2 x\, r - \frac{2}{3}\pi r^3\right) \Rightarrow \pi r^2 h + \frac{1}{3}\pi r^3$ The upward force supports the weight of the liquid column above the free surface, therefore, $2\pi r T\cos\theta = \pi r^2\left(h + \frac{1}{3}r\right)\rho g \Rightarrow T = \frac{r\left(h + \frac{1}{3}r\right)\rho g}{2\cos\theta}$ If the capillary is a very fine tube of radius (i.e., radius is very small) then $\frac{r}{3}$ can be neglected when it is compared to the height h. Therefore, $T = \frac{r\rho gh}{2\cos\theta}$	1 1 1 1 1	5

37 (b)	**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.** Dimensional formula for ½ $mv^2 = [M][LT^{-1}]^2 = [ML^2T^{-2}]$ Dimensional formula for mgh = $[M][LT^{-2}][L]=[ML^2T^{-2}]$ $[ML^2T^{-2}] = [ML^2T^{-2}]$ **Both sides are dimensionally the same, hence the equations ½ mv^2 = mgh is dimensionally correct.**	3 2	5
38 (a)	**kinematic equations of motion for constant acceleration.** Consider an object moving in a straight line with uniform or constant acceleration 'a'. Let **u be the velocity of the object** at time t = 0, and v be velocity of the body at a later time t. **Velocity - time relation:** 1) The acceleration of the body at any instant is given by the **first derivative of the velocity with respect to time**, a = $\frac{dv}{dt}$ or dv = a .dt Integrating both sides with the condition that as time changes from 0 to t, **the velocity changes from u to v**. For the constant acceleration, $\int_u^v dv = \int_0^t adt$ $= a \int_u^v dt \Rightarrow [v]_u^v = a\,[t]_0^t$ --------(1) v – u = at (or) v = u + at **Displacement – time relation:** 2) The velocity of the body is given by **the first derivative of the displacement with respect to time**. v = $\frac{ds}{dt}$ or ds = v dt and since v = u + at We get ds = (u + at)dt . **Assume that initially at time** t = 0, the particle started from the origin. At a later time, t, the particle displacement is s. Further assuming that acceleration is time independent, we have $\int_0^s ds$ $= \int_0^t udt + \int_0^t atdt$ or s = ut + ½ at^2 -------------(2) **Velocity – displacement relation:** 3) The acceleration is given by the **first derivative of velocity with respect to time**. a = $\frac{dv}{dt} = \frac{dv}{ds}\frac{ds}{dt} = \frac{dv}{ds}v$ [since ds / dt = v where s is distance traversed] This is rewritten as a = $\frac{1}{2}\frac{dv^2}{ds}$ or ds = $\frac{1}{2a}d(v^2)$ 4) Integrating the above equation, using the fact when the velocity changes from u^2 to v^2, displacement changes from 0 to s, we get $\int_0^s ds$ $= \int_u^v \frac{1}{2a} d(v^2)$; s = $\frac{1}{2a}(v^2 - u^2)$; $v^2 = u^2 + 2as$ -----------(3)	1 ½ 1 1	5

	5) We can also derive the displacement s in terms of initial velocity u and final velocity v. From the equation (1) we can write, at = v – u Substitute this in equation (2), we get s = ut + ½ (v – u)t $s = \frac{(u+v)t}{2}$ ---------------(4) The equations (1), (2), (3) and (4) are called kinematic equations of motion, and have a wide variety of practical applications. **Kinematic equations:** $v = u + at$; $s = ut + \frac{1}{2} at^2$; $v^2 = u^2 + 2as$; $s = \frac{(u+v)t}{2}$	1 ½	
38 (b)	**Expression for mean free path** 1) We know from postulates of **kinetic theory that the molecules of a gas are in random motion and they collide with each other**. Between two successive collisions, a molecule moves along a straight path with uniform velocity. 2) This path is called mean free path. Consider a system of molecules each with diameter d. Let n be the number of molecules per unit volume. Assume that **only one molecule is in motion and all others** are at rest as shown in the Figure.  3) If a molecule moves with average speed v in a time t, the distance travelled is vt. In this **time t, consider the molecule to move in an imaginary cylinder of volume $\pi d^2 vt$.** 4) It collides with **any molecule whose center is within this cylinder. Therefore, the number of collisions is equal to the number of molecules in the volume of the imaginary cylinder**. It is equal to $\pi d^2 vtn$. The total path length divided by the number of collisions in time t is the mean free path. Mean free path = $\frac{\text{Distance travelled}}{\text{Number of collisions}}$; $\lambda = \frac{vt}{n\pi d^2 vt} = \frac{1}{n\pi d^2}$ ------------ 1 5) Though we have assumed that **only one molecule is moving at a time and other molecules are at rest, in actual practice all the molecules are in random motion.** So the average relative speed of one molecule with respect to other molecules has to be taken into account. After some detailed calculations (you will learn in higher classes) the correct expression for mean free path. $\lambda = \frac{1}{\sqrt{2}n\pi d^2}$ ---------------- 2 6) The equation (1) implies that **the mean free path is inversely proportional to number density. When the number density increases the molecular collisions increases** so it decreases the distance travelled by the molecule before collisions.	1 1 1 1 1	5

	Case1: Rearranging the equation (2) using 'm' (mass of the molecule) $\lambda = \frac{m}{\sqrt{2}\pi d^2 mn}$ But mn=mass per unit volume = ρ (density of the gas) $\lambda = \frac{m}{\sqrt{2}\pi d^2 \rho}$ Also we know that PV = NkT P = $\frac{N}{V}$ kT = nkT ; n = $\frac{P}{kT}$ Substituting n = $\frac{P}{kT}$ in equation (2), we get $\lambda = \frac{kT}{\sqrt{2}\pi d^2 P}$	1	