HIGHER SECONDARY FIRST YEAR EXAMINATION – MARCH 2024

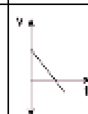
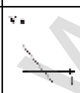
PHYSICS ANSWER KEY

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	TYPE – A	Q. No.	OPTION	TYPE – B
1	(b)	$(250 \pm 5)\Omega$	1	(b)	increases
2	(b)	increases	2	(c)	6 %
3	(d)	zero	3	(a)	
4	(a)	1.0 m	4	(d)	2 ms^{-2}
5	(c)	100 Hz and 6 m	5	(b)	pure rotation
6	(d)	2 ms^{-2}	6	(a)	1.0 m
7	(b)	pure rotation	7	(d)	$\sqrt{\frac{k_B}{8k_A}}$
8	(c)	Carbon-di-oxide	8	(a)	increase 4 times
9	(a)	decrease and increase	9	(d)	zero
10	(a)		10	(a)	decrease and increase
11	(c)	6 %	11	(c)	Carbon-di-oxide
12	(a)	$Jkg^{-1}K^{-1}$	12	(c)	100 Hz and 6 m
13	(d)	$\sqrt{\frac{k_B}{8k_A}}$	13	(d)	adiabatic
14	(d)	adiabatic	14	(b)	$(250 \pm 5)\Omega$
15	(a)	increase 4 times	15	(a)	$Jkg^{-1}K^{-1}$

PART – II

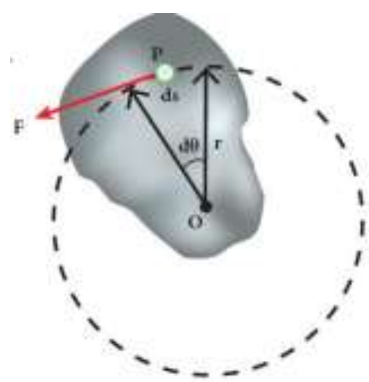
Answer **any six** questions. Question number **24 is compulsory.** 6x2=12

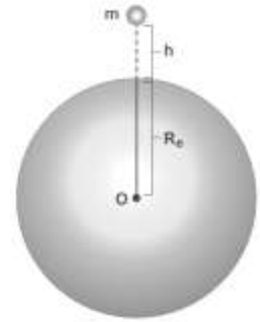
16	**Steel is more elastic than rubber** because the **steel has higher young's modulus than rubber**. That's why, if equal stress is applied on both steel and rubber, the steel produces less strain.	**2**	**2**
17	It is a quantity which is described by **both magnitude and direction.** Geometrically a vector is a directed line segment. **Examples Force, velocity, displacement, position vector, acceleration, linear momentum and angular momentum**	**1 ½** **½**	**2**
18	Centrifugal force is given by, $F_{cf} = \frac{mv^2}{r}$; $= \frac{60 \times 50 \times 50}{10}$; = 6 x 2500 **F_{cf} =15000 N**	**1** **1**	**2**
19	**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 molecules.**	**1** **1**	**2**
20	Translational velocity (v_{TRANS}) or velocity of centre of mass, v_{CM} = 5 m s^{-1} The radius is, R = 1.5 m and the angular velocity is, ω = 3 $rads^{-1}$ Rotational velocity, v_{ROT} = Rω v_{ROT} = 1.5×3; v_{ROT} = 4.5 ms^{-1} **As v_{CM} > Rω (or) v_{TRANS}> Rω, It is not in pure rolling, but sliding**	**1** **1**	**2**
21	**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 of the oscillator.** Such an oscillation or vibration is known as free oscillation or free vibration.	**2**	**2**
22	**Coefficient of restitution:** It is defined as the ratio of **velocity of separation (relative velocity) after collision to the velocity of approach (relative velocity) before collision**, i.e.,e = $\frac{\text{Velocity of separation (after collision)}}{\text{Velocity of approach (before collision)}}$; $\frac{(v_2 - v_1)}{(u_1 - u_2)}$	**2**	**2**

23	**Limitations of dimensional analysis:** 1. This method gives **no information about the dimensionless constants** in the formula like 1, 2, ...π,e, etc. 2. This method **cannot decide whether the given quantity is a vector or a scalar.** 3. This method is **not suitable to derive relations involving** trigonometric, exponential and logarithmic functions. 4. It cannot be applied to an equation involving **more than three physical quantities.** 5. It **can only check on whether a physical relation is dimensionally correct** but not the correctness of the relation. For example, using dimensional analysis, $s = ut + \frac{1}{3}at^2$ is dimensionally correct whereas the correct relation is $s = ut + \frac{1}{2}at^2$	**2**	**2**
24	Work done on the system (by the person while stirring), W = −30 kJ = −30,000J Heat flowing out of the system, Q = −5 kcal = −5×4184 J =−20920 J Using First law of thermodynamics, ΔU = Q−W ΔU = −20,920 J− (−30,000) J ΔU = −20,920 J+30,000 **J = 9080 J** Here, the heat lost is less than the work done on the system, so the change in internal energy is positive.	1 1	2

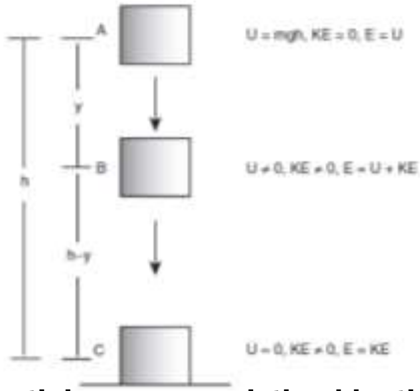
PART – III

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

25	**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

26	**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	3
27	**Factors affecting the surface tension of a liquid:** (1) **The presence of any contamination or impurities** considerably affects the **force of surface tension depending upon the degree of contamination.** (2) **The presence of dissolved substances** can also **affect the value of surface tension.** For example, **a highly soluble substance like sodium chloride (NaCl) when dissolved in water (H_2O) increases the surface tension of water.** But the sparingly soluble substance **like phenol** or **soap solution when mixed in water decreases the surface tension of water.** (3) **Electrification** affects the surface tension**. When a liquid is electrified, surface tension decreases. Since external force acts on the liquid surface due to electrification, area of the liquid surface increases** which acts against the contraction phenomenon of the surface tension. Hence, it decreases. (4) **Temperature** plays a **very crucial role in altering the surface tension of a liquid.** Obviously, the surface tension decreases linearly with the rise of temperature.	**Any 3 3x1 =3**	**3**

28	**Relation between 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 $P = \frac{2}{3}\frac{U}{V} = \frac{2}{3}u$ ---------------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. $P = \frac{1}{3}nm\overline{v^2} = \frac{1}{3}\rho\overline{v^2}$ --------------2 where ρ = nm = mass density (Note n is number density) Multiply and divide R.H.S of equation (2) by 2, we get $P = \frac{2}{3}\left(\frac{\rho}{2}\overline{v^2}\right)$ $P = \frac{2}{3}\overline{KE}$ --------------------3 From the equation (3), pressure is equal to 2/3 of mean kinetic energy per unit volume.	1 1 1	3
29	**Forced oscillation:** 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.	3	3
30	Given $y_1 = 5\sin(240\pi t)$ and $y_2 = 4\sin(244\pi t)$ Comparing with $y = A\sin(2\pi f_1 t)$, we get $2\pi f_1 = 240\pi \Rightarrow f_1 = 120Hz$; $2\pi f_2 = 244\pi \Rightarrow f_2 = 122Hz$ The number of beats produced is $\lvert f_1 - f_2 \rvert = \lvert 120 - 122 \rvert = \lvert -2 \rvert$ =2 beats per sec	1 1 1	3
31	**Fundamental or base quantities** are quantities which **cannot be expressed in terms of any other physical quantities**. These are **length, mass, time, electric current, temperature, luminous intensity and amount of substance.** **Quantities that can be expressed in terms of fundamental quantities** are called **derived quantities**. For example, **area, volume, velocity, acceleration, force**	1 ½ 1 ½	3

32	The law of conservation of energy states that **energy can neither be created nordestroyed. It may be transformed from one form to another but the total energy of an isolated system remains constant.** The figure illustrates that, if an object starts from rest at height h, the total energy is purely potential energy (U=mgh) and the kinetic energy (KE) is zero at h. **When theobject falls at some distance y, the potential energy and the kinetic energy are not zero**whereas, the total energy remains same as measured at height h. When the object is about to touch the ground, the potential energy is zero and total energy is purely kinetic. 	3	3
33	i) maximum height of the projectile, $h_{max} = \frac{u^2\sin^2\theta}{2g}$ $h_{max} = \frac{5^2 \sin 30^0 \sin 30^0}{2 \times 9.8}$; $= \frac{25 \times \left[\frac{1}{2}\right] \times \left[\frac{1}{2}\right]}{2 \times 9.8}$; $= \frac{25}{8 \times 9.8}$; $= \frac{25}{78.4}$; h_{max} = 0.3188m ii) Horizontal Range R = $\frac{u^2 \sin 2\theta}{g}$; $= \frac{u^2 2 \sin\theta \cos\theta}{g}$; $= \frac{5^2 \times 2 \sin 30^0 \cos 30^0}{9.8}$ $= \frac{25 \times 2 \left[\frac{1}{2}\right] \times \left[\frac{\sqrt{3}}{2}\right]}{9.8}$; $= \frac{25 \times 1.732}{2 \times 9.8} = \frac{43.300}{19.6}$; R = 2.21m	1½ 1½	3

PART – IV

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

34 (a) (i) (ii)	$\boldsymbol{v \propto l^a F^b m^c}$ ------------1 Dimension of v = [T-1] ; Dimension of l = [L] Dimension of F = [MLT-2] ; Dimension of m = [ML-1] Put these dimensional formula in equation 1 $[T^{-1}] \propto [L]^a [MLT^{-2}]^b [ML^{-1}]^c$ $[M^0L^0T^{-1}] \propto \left[M^{b+c} L^{a+b-c} T^{-2b}\right]$ Compare the powers of M, L and T on both sides, we get, b + c =0 ; c = - b ; **c = –** $\frac{1}{2}$ a + b – c =0 ; a + b + b = 0 ; a + 2$\left[\frac{1}{2}\right]$ = 0 ; **a = –1** –2b = – 1 ; **b =** $\frac{1}{2}$ Put the values of a, b and c in equation 1 $v \propto l^{-1} F^{\frac{1}{2}} m^{\frac{1}{2}}$; $v \propto \frac{F^{\frac{1}{2}}}{l\ m^{\frac{1}{2}}}$; $= \frac{1}{l}\left[\frac{F}{m}\right]^{\frac{1}{2}}$; $v = \frac{1}{l}\sqrt{\frac{F}{m}}$	1 1 1 1 1	5

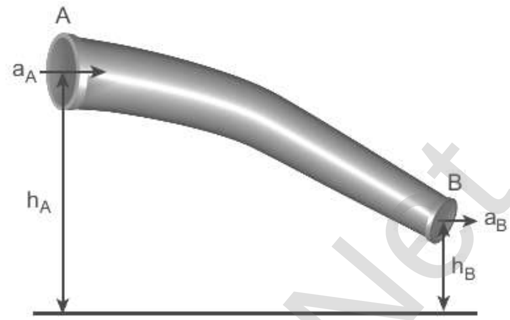
34 (b)

Bernoulli's theorem:

According to Bernoulli's theorem, **the sum of pressure energy, kinetic energy, and potential energy per unit mass of an incompressible, non-viscous fluid in a streamlined flow remains a constant**.

$\frac{P}{\rho} + \frac{1}{2}v^2 + gh =$ **Constant**, this is known as Bernoulli's equation.

Proof:



Let us consider a flow of liquid through a pipe AB as shown in Figure. Let Vbe the volume of the liquid when it enters Ain a time *t* which is equal to the volume of the liquid leaving *B* in the same time. Let a_A, $v_A$and $P_A$be the area of cross section of the tube, velocity of the liquid and pressure exerted by the liquid at *A* respectively. 1

Let the **force exerted by the liquid at Ais $F_A = P_A a_A$**

Distance travelled by the liquid in time t is $d = v_A t$

Therefore, the work done is $W = F_A d = P_A a_A v_A t$ 1

But **$a_A v_A t = a_A d = V$,** volume of the liquid entering at A.

Thus, the **work done is the pressure energy (at A), $W = F_A d = P_A V$**

Pressure energy per unit volume at A = $\frac{\text{Pressure energy}}{\text{Volume}} = \frac{P_A V}{V} = P_A$

Pressure energy per unit mass at A = $\frac{\text{Pressure energy}}{\text{Mass}} = \frac{P_A V}{m} = \frac{P_A}{\frac{m}{V}} = \frac{P_A}{\rho}$ 1 5

Since m is the mass of the liquid entering at A in a given time, therefore, pressure energy of the liquid at A is $E_{PA} = P_A V = P_A V \times \left(\frac{m}{m}\right) = m\frac{P_A}{\rho}$

Potential energy of the liquid at A, $P_{EA} = mg\,h_A$,

Due to the flow of liquid, the **kinetic energy of the liquid at A, $KE_A = \frac{1}{2} m V_A^2$**

Therefore, the total energy due to the flow of liquid at A,

$E_A = EP_A + KE_A + PE_A$; **$E_A = m\frac{P_A}{\rho} + \frac{1}{2} mV_A^2 + mgh_A$**

Similarly, let a_B, v_B, and $P_B$be the area of cross section of the tube, velocity of the liquid, and pressure exerted by the liquid at B. Calculating the total energy at E_B, we get **$E_B = m\frac{P_B}{\rho} + \frac{1}{2} mV_B^2 + mgh_B$** 1

From the **law of conservation of energy, $E_A = E_B$**

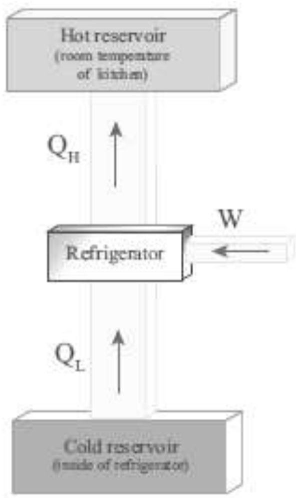
$E_A = m\frac{P_A}{\rho} + \frac{1}{2} mV_A^2 + mgh_A = E_B = m\frac{P_B}{\rho} + \frac{1}{2} mV_B^2 + mgh_B$

$\frac{P_A}{\rho} + \frac{1}{2} V_A^2 + gh_A = \frac{P_B}{\rho} + \frac{1}{2} V_B^2 + gh_B = $ constant 1

Thus, the above equation can be written as **$\frac{P}{\rho g} + \frac{1}{2}\frac{v^2}{g} + h = $ constant**

35 (a)	**<u>Work energy principle:</u>** 1) It states that work done by the force acting on a body is equal to the change produced inthe kinetic energy of the body. 2) Consider a body of mass m at rest on a frictionless horizontal surface. 3) The work (W) done by the constant force (F) for a displacement (s) in the same direction is, W = Fs ------------ (1) The constant force is given by the equation, F = ma --------- (2) The **third equation of motion** can be written as, $v^2 = u^2 + 2as$ $a = \frac{v^2-u^2}{2s}$ ----------------- (3) Substituting for a in equation (2), $F = m\left(\frac{v^2-u^2}{2s}\right)$ ------------ (4) Substituting equation (4) in (1), $W = m\left(\frac{v^2}{2s}s\right) - m\left(\frac{u^2}{2s}s\right)$ **W = ½ mv² – ½ mu²** ------------------- (5) **The expression for kinetic energy:** i) 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) ii) Kinetic energy of the body is always positive. From equations (5) and (6) **ΔKE = ½ mv² – ½ mu²** ---------------(7) thus, W = ΔKE iii) The expression on the right-hand side (RHS) of equation (7) is the change in kinetic energy (ΔKE) of the body. iv) 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:** 1. If the work done by **the force on the body is positive** then its **kinetic energy increases.** 2. If the work done by **the force on the body is negative** then its **kinetic energy decreases.** 3. If there is **no work done by the force** on the body then there is **no change** in its kinetic energy	1 1 1 1 1	**5**
35 (b)	**<u>Coefficient of performance:</u>** COP is a **measure of the efficiency of a refrigerator.** It is defined as the **ratio of heat extracted from the cold body (sink) to the external work done by the compressor W. COP = β =** $\frac{Q_L}{W}$ **Refrigerator:** A refrigerator is a **Carnot's engine working in the reverse order.**	2	**5**

Working Principle:



The working substance (gas) absorbs a quantity of heat Q_L from the cold body (sink) at a lower temperature T_L. **A certain amount of work W is done on the working substance by the compressor and a quantity of heat Q_H is rejected to the hot body (source) ie, the atmosphere at T_H.** When you stand beneath of refrigerator, you can feel warmth air. From the first law of thermodynamics, 2

we have $Q_L + W = Q_H$ 1

As a result, the cold reservoir (refrigerator) further cools down and the surroundings (kitchen or atmosphere) gets hotter.

36 (a) **Vertical motion:**

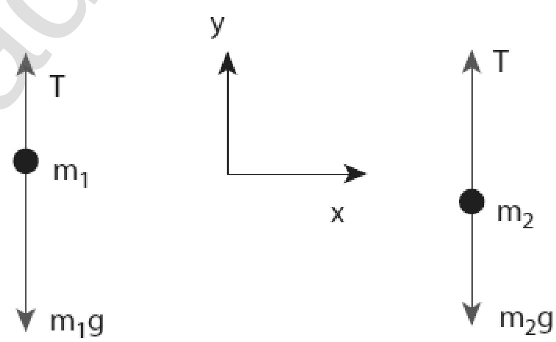
i) Consider **two blocks of masses m_1 and m_2 ($m_1 > m_2$)** connected by a light and inextensible string that passes over a pulley.

ii) Let the tension in the string be T and acceleration *a*. When the system is released, both the blocks start moving, m_2 vertically upward and m_1 downward with same acceleration. The gravitational force m_1g on mass m_1 is used in lifting the mass m_2. 1

Applying Newton's second law for mass m_2,

$T\hat{j} - m_2g\hat{j} = m_2a\hat{j}$

iii) The left-hand side of the above equation is the total force that acts on m_2 and the right-hand side is the product of mass and acceleration of m_2 in y direction.



By comparing the components on both sides, we get

$T - m_2g = m_2a$ ------------ (1) 1 5

Similarly, applying Newton's second law for mass m_1

$T\hat{j} - m_1g\hat{j} = -m_1a\hat{j}$

As mass m1 moves downward ($-\hat{j}$), its acceleration is along($-\hat{j}$)

iv) By comparing the components on both sides, we get 1

$T - m_1g = -m_1a$; $m_1g - T = m_1a$ ------------ (2)

Adding equations (1) and (2), we get

$m_1g - m_2g = m_1a + m_2a$; $(m_1 - m_2)g = (m_1 + m_2)a$ ------- (3)

From equation (3), the acceleration of both the masses is

$a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) g$ -----(4)

If both the masses are equal ($m_1 = m_2$), from equation (4) a = 0

v) This shows that if the masses are equal, there is no acceleration and the system as a whole will be at rest. To find the tension acting on the string,

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substitute the acceleration from the equation (4) into the equation (1).

$$T - m_2g = m_2\left(\frac{m_1 - m_2}{m_1 + m_2}\right)g\ ;\ T = m_2g + m_2\left(\frac{m_1 - m_2}{m_1 + m_2}\right)g \quad \text{--- (5)}$$

By taking m2g common in the RHS of equation (5)

$$T = m_2g\left(1 + \frac{m_1 - m_2}{m_1 + m_2}\right);$$

$$T = m_2g\left(\frac{m_1 + m_2 + m_1 - m_2}{m_1 + m_2}\right)$$

$$T = \left(\frac{2m_1m_2}{m_1 + m_2}\right)g$$

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(b)</td>
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Kepler's three laws:

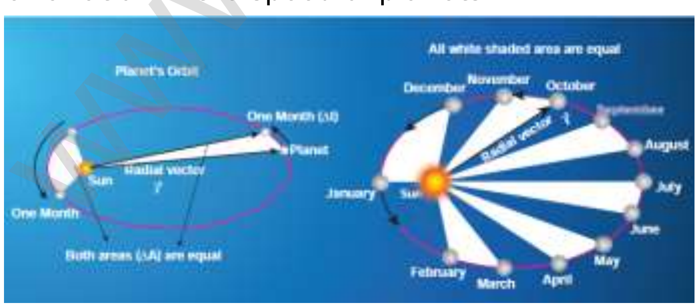
1. **Law of orbits:** Each planet moves around the Sun in an **elliptical orbit with the Sun at one of the foci.**

The **closest point of approach of the planet to the Sun 'P' is called perihelion** and the **farthest point 'A' is called aphelion.** The semi-major axis is 'a' and semi-minor axis is 'b'. In fact, both Copernicus and Ptolemy considered planetary orbits to be circular, but Kepler discovered that the actual orbits of the planets are elliptical.

2. **Law of area:**

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

In Figure, the white shaded portion is the area DA swept in a small interval of time Dt, by a planet around the Sun. Since the Sun is not at the center of the ellipse, *the planets travel faster when they are nearer to the Sun and slower when they are farther from it, to cover equal area in equal intervals of time.* Kepler discovered the law of area by carefully noting the variation in the speed of planets.



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 of the semi-major axis of the ellipse.** $T^2 \propto a^3$; $\frac{T^2}{a^3}$ = constant

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37(a) **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 1

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. 2

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 at² -------------(2)

Velocity – displacement relation: 5

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 1

a = $\frac{1}{2}\frac{dv^2}{ds}$ or ds = $\frac{1}{2a}$ d(v²)

4) Integrating the above equation, using the fact when the velocity changes from u² to v², displacement changes from 0 to s,

we get $\int_0^s ds = \int_u^v \frac{1}{2a} d(v^2)$;

s = $\frac{1}{2a}$ (v² – u²);

v² = u² + 2as ------------(3)

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 1

Substitute this in equation (2), we gets = 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:

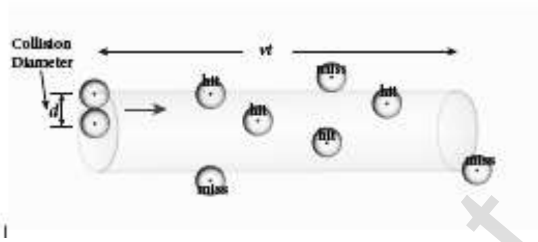
v = u + at ; s = ut + ½ at² ; v² = u² + 2as ; s = $\frac{(u+v)t}{2}$

37 (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.



1

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 πd^2vt.**

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 πd^2vtn. The total path length divided by the number of collisions in time t is the mean free path.

1

Mean free path = $\dfrac{\textbf{Distance travelled}}{\textbf{Number of collisions}}$; $\boldsymbol{\lambda = \dfrac{vt}{n\pi d^2vt} = \dfrac{1}{n\pi d^2}}$ ------------- 1

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.

5

$\boldsymbol{\lambda = \dfrac{1}{\sqrt{2}n\pi d^2}}$ ------------------ 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

Case1: Rearranging the equation (2) using 'm' (mass of the molecule)

$\boldsymbol{\lambda = \dfrac{m}{\sqrt{2}\pi d^2mn}}$ But mn=mass per unit volume = ρ (density of the gas)

$\lambda = \dfrac{m}{\sqrt{2}\pi d^2\rho}$ Also we know that PV = NkT

P = $\dfrac{N}{V}$ kT = nkT ; n = $\dfrac{P}{kT}$

1

Substituting n = $\dfrac{P}{kT}$ in equation (2), we get $\boldsymbol{\lambda = \dfrac{kT}{\sqrt{2}\pi d^2P}}$

38 (a) **Uniform ring**:

1) Consider a **uniform ring of mass M and radius R.** To find the moment of inertia of the **ring about an axis passing through its center** and perpendicular to the plane, let us take an infinitesimally small mass (dm) of length (dx) of the ring. **1**

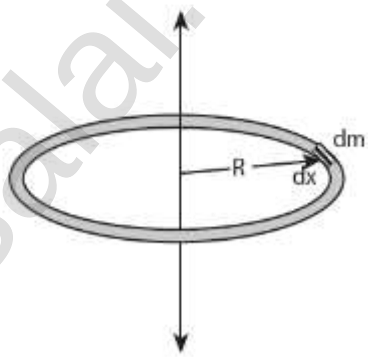
2) This (dm) is located at a distance R, which is the radius of the ring from the axis as shown in Figure. The moment of inertia (dI) of this small mass (dm) is, **dI = (dm)R²**

The **length of the ring is its circumference (2πR)**. As the mass is uniformly distributed, the mass per unit length (λ) is,

$\lambda = \frac{mass}{length}$; $\lambda = \frac{M}{2\pi R}$ **1**

The (dm) mass of the infinitesimally small length as,

dm = λ, dx = $\frac{M}{2\pi R}$dx.



Now, the moment of inertia (I) of the entire ring is,

I = $\int dI = \int (dm) R^2$;

$\int \left(\frac{M}{2\pi R} dx\right) R^2$ **1**

I = $\frac{MR}{2\pi} \int dx$ **5**

To cover the entire length of the ring,

the limits of integration are taken from 0 to 2πR **1**

I = $\frac{MR}{2\pi} \int_0^{2\pi R} dx$; = $\frac{MR}{2\pi} [x]_0^{2\pi R}$;

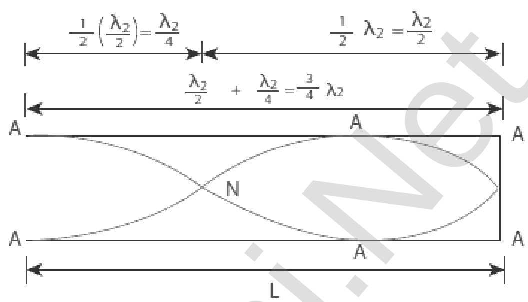
= $\frac{MR}{2\pi} [2\pi R - 0]$

I = MR² **1**

38 (b)

<u>Closed organ pipes:</u>

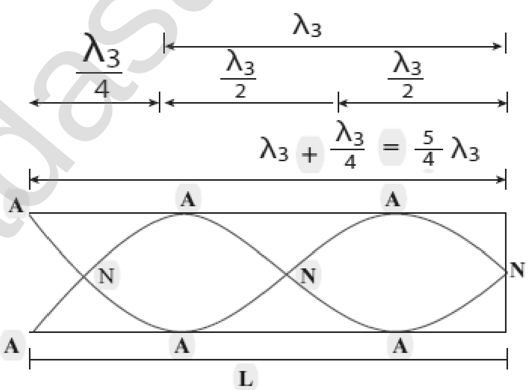
1) It is a pipe with one end closed and the other end open. If one end of a pipe is closed, the wave reflected at this closed end is 180° out of phase with the incoming wave. 1
2) Thus there is **no displacement of the particles at the closed end. Therefore, nodes are formed at the closed end and anti-nodes are formed at open end.**
3) Consider the simplest mode of vibration of the air column called the fundamental mode. **Anti-node is formed at the open end and node at closed end.** From the Figure, let L be the length of the tube and the wavelength of the wave produced. For the fundamental mode of vibration, we have, 1



$L = \frac{\lambda_1}{4}$ or $\lambda_1 = 4L$; The frequency of the note emitted is

$f_1 = \frac{v}{\lambda_1} = \frac{v}{4L}$ **which is called the fundamental note.**

4) The frequencies higher than fundamental frequency can be produced by blowing air strongly at open end. Such frequencies are called overtones.



The Figure 2 shows the second mode of vibration having two nodes and two anti-nodes. $4L = 3\lambda_2$ $L = \frac{3\lambda_2}{4}$ or $\lambda_2 = \frac{4L}{3}$ 1

The frequency of this $f_2 = \frac{v}{\lambda_2} = \frac{3v}{4L} = 3f_1$

is called **first over tone**, since here, the frequency is **three times the fundamental frequency** it is called **third harmonic.** 1

5) The Figure 3 shows third mode of vibration having three nodes and three anti-nodes. $4L = 5\lambda_3$ $L = \frac{5\lambda_3}{4}$ or $\lambda_3 = \frac{4L}{5}$

The frequency of this $f_3 = \frac{v}{\lambda_3} = \frac{5v}{4L} = 5f_1$ is called **second over tone**, and since **n = 5** here, this is called **fifth harmonic.**

6) Hence, the closed organ pipe has only odd harmonics and frequency of the nth harmonic is $f_n = (2n+1)f_1$. **Therefore, the frequencies of harmonics are in the ratio** $f_1 : f_2 : f_3 : f_4 : ... = 1 : 3 : 5 : 7 : ...$ 1

5