SHRI VIDHYABHARATHI MATRIC HIGHER SECONDARY SCHOOL,
SAKKARAMPALAYAM, ELACHIPALAYAM. NAMAKKAL DISTRICT.

PUBLIC EXAMINATION – MARCH - 2025 (QUESTION ANALYSIS)

	1 MARK		2 MARK		3 MARK		5 MARK		TOTAL		GRANT TOT
	B.B	INT	B.B	INT	B.B	INT	B.B	INT	B.B	INT	
1	1 + 1		1 EX-(1.13)				1		09	0	09
2	1	1		1 NP-14	1		1		09	03	12
3	1		1			1	1		08	03	11
4	1				1 EX-(4.1)		1(3)+	1(2) EX-(4.18)	07	02	09
5	1	1	1		1		1		11	01	12
6	1		1		1		1(3) 1(2) EX –(6.10)		11	0	11
7	1				1 EX.-(7.2)		1		09	0	09
8	1	1	1		1		1		11	01	12
9	1		1		1				06	0	06
10	1		1				1		08	0	08
11	1			1 NP - 1	1		1		09	02	11
	12	3	14	4	24	3	48	2	98	12	110

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PUBLIC EXAMINATION – MARCH– 2025
TENTATIVE ANSWER KEY

XI -PHYSICS **TOTAL MARKS : 70**

Q.N	PART – I		MARKS
	TYPE – A	TYPE – B	15X1=15
1.	d) $I = \frac{1}{3}Ml^2$	d) angular momentum	1
2.	d) angular momentum	b) the centre point of the circle	1
3.	c) sin (x+vt)	d) decrease	1
4.	b) the centre point of the circle	a) 785m, zero	1
5.	b) net force on the object is zero	d) 75J	1
6.	a) a straight line	c) πs	1
7.	a) average velocity	a) a straight line	1
8.	d) 75J	d) $I = \frac{1}{3}Ml^2$	1
9.	a) Velocity	a) average velocity	1
10.	a) 785m, zero	a) Velocity	1
11.	d) decrease	c) sin (x+vt)	1
12.	a) -9 ms^{-1} and 5 ms^{-1}	d) g = 25 ms^{-2}	1
13.	d) torque and energy	b) net force on the object is zero	1
14.	d) g = 25 ms^{-2}	a) -9 ms^{-1} and 5 ms^{-1}	1
15.	c) πs	d) torque and energy	1
	PART – II		
16.	**Newton's second law.** The force acting on an object is equal to the **rate of change of its momentum**. $\vec{F} = \frac{d\vec{p}}{dt}$ **(if formula only award 1 mark)**		2
17.	**PV diagram:** The P-V diagram is used to calculate the **amount of work done by the gas during expansion or on the gas during compression. The area under the PV diagram will give the work done during expansion or compression** The shape of PV diagram depends on the nature of the thermodynamic process.		2

18.	**Solution** Area of triangle = $\frac{1}{2}$ x base x height = $\frac{1}{2}[\vec{A} \times \vec{B}]$ $= \frac{1}{2}\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & -3 & 0 \\ 4 & 6 & 0 \end{vmatrix}$ $= \frac{1}{2}[(0-0)\hat{i} + (0-0)\hat{j} + (30+12)\hat{k}] = \frac{42}{2}\hat{k} = 21\hat{k}$ $= \sqrt{0^2 + 0^2 + 21^2} = 21$ = 21 square units	½ ½ ½ ½
19.	**Factors affecting the Mean Free Path:** ❖ 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 ❖ Mean free path increases with decreasing pressure of the gas and diameter of the gas molecules	1 1
20.	v = u + at $[LT^{-1}] = [LT^{-1}] + [LT^{-2}]\ [T]$ $[LT^{-1}] = [LT^{-1}] + [LT^{-1}]$ The dimensions of both sides are same	1 1
21.	**Two examples of torque in day –to-day life.** ❖ The opening and closing of a door about the hinges ❖ Turning of a nut using a wrench	1 1
22.	**Resonance: Give an example.** ❖ 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). 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	1½ ½
23.	**Gravitational field. Give its unit.** ❖ The gravitational field intensity(here after called as gravitational field) $\vec{E_1}$ at a point which is at a distance r from m_1 is defined as the gravitational force experienced by unit mass placed at that point. ❖ The unit of gravitational field is Newton per kilogram (N/kg) or ms^{-2} $\vec{E}_1 = -\frac{Gm_1}{r^2}\hat{r}$ **(if formula only award 1 mark)**	1½ ½
24.	**GIVEN** v = 900 m/s, t = 2 min or 120 s, f = $\frac{3000}{120}$ = 25 Hz, λ = ? **SOLUTION** v = fλ ⟹ λ = v / f = 900 / 25 = 36 m	1 ½ ½

PART – III

25. **Properties of vector (cross) product.**

(i) The vector product of any two vectors is always another vector whose direction is perpendicular to the plane containing these two vectors, i.e., orthogonal to both the vectors $\vec{A}$ and $\vec{B}$, even though the vectors $\vec{A}$ and $\vec{B}$ may or may not be mutually orthogonal.

(ii) The vector product of two vectors is not commutative, i.e.,

$$\vec{A}\times\vec{B} \neq \vec{B}\times\vec{A} \text{ But., } \vec{A}\times\vec{B} = -[\vec{B}\times\vec{A}]$$

$$|\vec{A}\times\vec{B}| = |\vec{B}\times\vec{A}| = AB\sin\theta$$

$\vec{A}\times\vec{B}$ and $\vec{B}\times\vec{A}$ the magnitudes are equal but directions are opposite to each other.

(iii) Th e vector product of two vectors will have maximum magnitude when sin θ = 1, i.e., θ = 90°

i.e., when the vectors $\vec{A}$ and $\vec{B}$ are orthogonal to each other.

$$\left(\vec{A}\times\vec{B}\right)_{max} = AB\hat{n}$$

(iv) Th e vector product of two non–zero vectors will be minimum when sinθ = 0, *i.e.*,θ = 0° *or* 180°

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

i.e., the vector product of two non–zero vectors vanishes, if the vectors are either parallel or antiparallel.

(v) The self–cross product, i.e., product of a vector with itself is the null vector

$$\vec{A}\times\vec{A} = AA\sin 0°\hat{n} = \vec{0}$$

In physics the null vector $\vec{0}$ is simply denoted as zero.

(vi) The self–vector products of unit vectors are thus zero.

$$\hat{i}\times\hat{i} = \hat{j}\times\hat{j} = \hat{k}\times\hat{k} = \vec{0}$$

(vii) orthogonal unit vectors, *i*ˆ, ˆ*j*,*k*ˆ, in accordance with the right hand screw rule:

$$\hat{i}\times\hat{j} = \hat{k},\ \hat{j}\times\hat{k} = \hat{i} \text{ and } \hat{k}\times\hat{i} = \hat{j}$$

Also, since the cross product is not commutative,

$$\hat{j}\times\hat{i} = -\hat{k},\hat{k}\times\hat{j} = -\hat{i} \text{ and } \hat{i}\times\hat{k} = -\hat{j}$$

(viii) In terms of components, the vector product of two vectors $\vec{A}$ *and* $\vec{B}$ is

$$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

$$= \hat{i}\left(A_yB_z - A_zB_y\right) + \hat{j}\left(A_zB_x - A_xB_z\right) + \hat{k}\left(A_xB_y - A_yB_x\right)$$

(ix) If two vectors $\vec{A}$ *and* $\vec{B}$ form adjacent sides in a parallelogram, then the magnitude of $\vec{A}\times\vec{B}$ will give the area of the parallelogram

(x) Since we can divide a parallelogram into two equal triangles as shown in the Figure, the area of a triangle with $\vec{A}$ *and* $\vec{B}$ as sides is $\frac{1}{2}|\vec{A}\times\vec{B}|$

(Any 6 points)

3

26.	**The postulates of kinetic theory of gases.** 1. All the molecules of a gas are identical, elastic spheres. 2. The molecules of different gases are different. 3. The number of molecules in a gas is very large and the average separation between them is larger than size of the gas molecules. 4. The molecules of a gas are in a state of continuous random motion. 5. The molecules collide with one another and also with the walls of the container. 6. These collisions are perfectly elastic so that there is no loss of kinetic energy during collisions. 7. Between two successive collisions, a molecule moves with uniform velocity. 8. The molecules do not exert any force of attraction or repulsion on each other except during collision. The molecules do not possess any potential energy and the energy is wholly kinetic. 9. The collisions are instantaneous. The time spent by a molecule in each collision is very small compared to the time elapsed between two consecutive collisions. 10. These molecules obey Newton's laws of motion even though they move randomly. **(Any 3 points)**	3
27.	***Solution*** Force, F = 25 N Displacement, dr = 15 m Angle between F and dr, $\theta = 30^0$ Work done**,** W=F dr cos,= **θ** $W=25 \times 15 \times \cos 30^0 = 25 \times 15 \times \frac{\sqrt{3}}{2}$ W=324.76J	 1 1 1
28.	**The geostationary and polar satellites.** 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? Kepler"s third law is used to find the radius of the orbit. $T^2 = \frac{4\pi^2}{GM_E}(R_E+h)^3 \quad (R_E+h)^3 = \frac{GM_E T^2}{4\pi^2}$ ❖ Substituting for the time period(24hrs=86400seconds),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**. $R_E + h = \left(\frac{GM_E T^2}{4\pi^2}\right)^{1/3}$ ❖ India uses the INSAT group of satellites that are basically geo-stationary satellites for the purpose of telecommunication.	 ½ 1

	Polar satellite ❖ **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.** ❖ 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.** ❖ APolarsatellitecoversasmallstripofareafrompoletopoleduringonerevolution.Int henext revolution it covers a different strip of are a 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
29.	**Conduction** • Conduction is the process of direct transfer of heat through matter due to temperature difference. When two objects are in direct contact with one another, heat will be transferred from the hotter object to the colder one. • The objects which allow heat to travel easily through them are called conductors. **Convection** • Convection is the process in which heat transfer is by actual movement of molecules in fluids such as liquids and gases. In convection, molecules move freely from one place to another. It happens naturally or forcefully. • Boiling water in a cooking pot is an example of convection. Water at the bottom of the pot receives more heat. Due to heating, the water expands and the density of water decreases at the bottom. Due to this decrease in density, molecules rise to the top. **Radiation:** • When we keep our hands near the hot stove we feel the heat even though our hands are not touching the hot stove. Here heat transferred from the hot stove to our hands is in the form of radiation. • We receive energy from the sun in the form of radiations. These radiations travel through vacuum and reach the Earth. It is the peculiar character of radiation which requires no medium to transfer energy from one object to another. Example: 1. Solar energy from the Sun. 2. Radiation from room heater.	1 1 1

30

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

(any three points) — 3

31. Since the antinodes are not exactly formed at the open end, we have to include a correction, called end correction *e*, by assuming that the antinode is formed at some small distance above the open end. $e\frac{L_2-3L}{2}$

(if formula only award 1 mark)

32. **Relation between torque and angular momentum?**

We have the expression for magnitude of angular momentum of a rigid body as, L=Iω. The expression for magnitude of torque on a rigid body is, $\tau = I\alpha$ — ½

We can further write the expression for torque as, $\tau = I\frac{d\omega}{dt}$ $\left(\alpha = \frac{d\omega}{dt}\right)$ — 1

Where, ω is angular velocity and α is angular acceleration. We can also write equation as,

$$\tau = \frac{d(I\omega)}{dt} = \frac{dL}{dt}$$ — 1

The above expression says that an external torque on a rigid body fixed to an axis produces rate of change of angular momentum in the body about that axis. This is the Newton's second law in rotational motion as it is in the form of $= \frac{dp}{dt}$which holds good for translational motion. — ½

33. We know that $\frac{F}{A} = Y \times \frac{\Delta L}{L}$

ΔL=$\left(\frac{F}{A}\right)\left(\frac{L}{Y}\right)$ — 1

=$\left(\frac{50}{1.25\times10^{-4}}\right)\left(\frac{10}{4\times10^{10}}\right)$ — 1

= 10^{-4}m — 1

PART – IV

34. a) **Various types of errors.**

- The uncertainty in a measurement is called an error. Random error, systematic error and gross error are the three possible errors.

	i) Systematic errors • Systematic errors are reproducible in accuracies that are consistently in the same direction. These occur often due to a problem that persists throughout the experiment. Systematic errors can be classified as follows **1) Instrumental errors** • When an instrument is not calibrated properly at the time of manufacture, instrumental errors may arise. If a measurement is made with a meter scale whose end is worn out, the result obtained will have errors. These errors can be corrected by choosing the instrument carefully. **2) Imperfections in experimental technique or procedure** • These errors arise due to the limitations in the experimental arrangement. As an example, while performing experiments with a calorimeter, if there is no proper insulation, there will be radiation losses. This results in errors and to overcome these, necessary correction has to be applied. **3) 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. **4) 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. The instrument's resolution hence is the cause of this error. Least count error can be reduced by using a high precision instrument for the measurement.	2
	ii) Random errors • Random errors may arise due to random and unpredictable variations in experimental conditions like pressure, temperature, voltage supply etc. Errors may also be due to personal errors by the observer who performs the experiment. • Random errors are sometimes called **"chance error".** When different readings are obtained by a person every time he repeats the experiment, personal error occurs. For example, consider the case of the thickness of a wire measured using a screw gauge. The readings taken may be different for different trials. • In this case a large number of measurements are made and then the arithmetic mean is taken. If n number of trial readings are taken in an experiment, and the readings are $a_1, a_2, a_3, \ldots\ldots\ldots\ldots a_n$. The arithmetic mean is $a_m = \frac{a_1 + a_2 + a_3 + \ldots\ldots\ldots\ldots a_n}{n}$ $a_m = \frac{1}{n}\sum_{i=1}^{n} a_i$ • Usually this arithmetic mean is taken as the best possible true value of the quantity. Certain procedures to be followed to minimize experimental errors, along with examples are shown in	1½

	iii) Gross Error The error caused due to the shear carelessness of an observer is called gross error. For example (i) Reading an instrument without setting it properly. (ii) Taking observations in a wrong manner without bothering about the sources of errors and the precautions. (iii) Recording wrong observations. (iv) Using wrong values of the observations in calculations. These errors can be minimized only when an observer is careful and mentally alert.	1½
or 34. (b)	**Newton's formula for speed of sound waves in air** ❖ Sir Isaac Newton assumed that when sound propagates in air, the formation of compression and rarefaction takes place in a very slow manner so that the process is isothermal in nature. ❖ That is, the heat produced during compression (pressure increases, volume decreases), and heat lost during rarefaction (pressure decreases, volume increases) occur over a period of time such that the temperature of the medium remains constant. ❖ Therefore, by treating the air molecules to form an ideal gas, the changes in pressure and volume obey Boyle's law, Mathematically ❖ PV = Constant ❖ Differentiating equation , we get $PdV + VdP = 0$ or, $P = -V\frac{dP}{dV} = B_T$ ❖ where, B_T is an isothermal bulk modulus of air. Substituting, the speed of sound in air is $v_T = \sqrt{\frac{B_T}{\rho}} = \sqrt{\frac{P}{\rho}}$ ❖ Since P is the pressure of air whose value at NTP (Normal Temperature and Pressure) is 76 cm of mercury, we have $P = (0.76 \times 13.6 \times 10^3 \times 9.8)\ N\ m^{-2}$ $\rho = 1.293\ kg\ m^{-3}$ here ρ is density of air. ❖ Then the speed of sound in air at Normal Temperature and Pressure (NTP) is $v_T = \sqrt{\frac{(0.76 \times 13.6 \times 10^3 \times 9.8)}{1.293}}$	½ ½ ½ ½

But the speed of sound in air at 0 °C is experimentally observed as 332 ms^{-1} which is close upto 16 % more than theoretical value (Percentage error is

$= 279.80\ m\ s^{-1} \approx 280\ ms^{-1}$ (theoretical value) ½

$$\frac{(332-280)}{332} \times 100\% = 15.6\%\ )$$

- This error is not small.

Laplace's correction

- Laplace satisfactorily corrected this discrepancy by assuming that when the sound propagates through a medium, the particles oscillate very rapidly such that the compression and rarefaction occur very fast.
- Hence the exchange of heat produced due to compression and cooling effect due to rarefaction do not take place, because, air (medium) is a bad conductor of heat. Since, temperature is no longer considered as a constant here, sound propagation is an adiabatic process.
- By adiabatic considerations, the gas obeys Poisson's law (not Boyle's law as Newton assumed), which is

$$PV^{\gamma} = \text{constant}$$ ½

where, $\gamma = \frac{C_P}{C_v}$ ½

which is the ratio between specific heat at constant pressure and specific heat at constant volume.

Differentiating equation on both the sides, we get

$$V^{\gamma}\, dP + P\,(\gamma V^{\gamma-1}\, dV) = 0$$

$$\text{or,} \quad \gamma P = -V\frac{dp}{dV} = B_A$$ ½

where, B_A is the adiabatic bulk modulus of air. Now, substituting, the speed of sound in air is ½

$$v_A = \sqrt{\frac{B_A}{\rho}} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\gamma}\, v_T$$

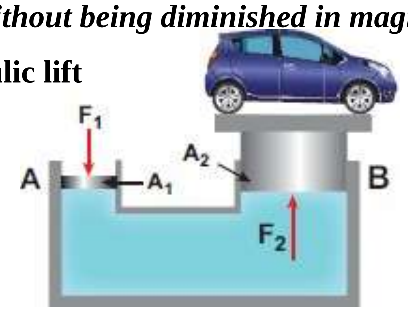
- Since air contains mainly, nitrogen, oxygen, hydrogen etc, (diatomic gas), we take $\gamma = 1.47$. Hence, speed of sound in air is ½

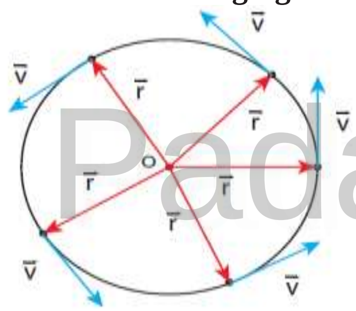
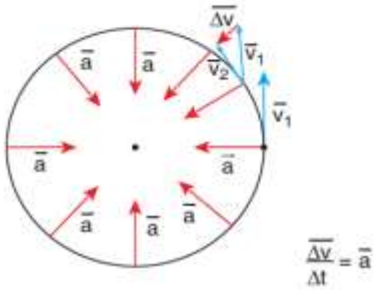
$v_A = (\sqrt{1.47})(280\ m\ s^{-1})$

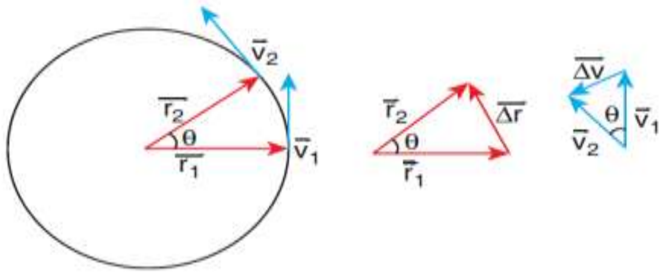
$= 331.30\ m\ s^{-1}$, which is very much closer to experimental data.

35. a) **Need for banking of tracks.**

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

	• To avoid this problem, usually **the outer edge of the road is slightly raised compared to inner edge. This is called banking of roads or tracks.** This introduces an inclination, and the angle is called banking angle. • Let the surface of the road make angle θ with horizontal surface. Then the normal force makes the same angle θ with the vertical. • When the car takes a turn, there are two forces acting on the car: a) Gravitational force mg (downwards) b) Normal force N (perpendicular to surface) We can resolve the normal force into two components. $N \cos\theta$ and $N \sin\theta$. The component $N \cos\theta$ balances the downward gravitational force 'mg' and component $N \sin\theta$ will provide the necessary centripetal acceleration. By using Newton second law	1
	 **(Free body diagram only)**	1
	$N\cos\theta = mg$ $N\sin\theta = \frac{mv^2}{r}$	1
	By dividing the equations we get $\tan\theta = \frac{v^2}{rg}$ $v = \sqrt{rg\tan\theta}$	1
	 • The banking angle θ and radius of curvature of the road or track determines the safe speed of the car at the turning. If the speed of car exceeds this safe speed, then it starts to skid outward but frictional force comes into effect and provides an additional centripetal force to prevent the outward skidding. At the same time, if the speed of the car is little lesser than safe speed, it starts to skid inward and frictional force comes into effect, which reduces centripetal force to prevent inward skidding. However if the speed of the vehicle is sufficiently greater than the correct speed, then frictional force cannot stop the car from skidding	1
35. (OR) b)	**Pascal's law in fluids.** ❖ The French scientist Blaise Pascal observed that the pressure in a fluid at rest is the same at all points if they are at the same height. Statement of Pascal's law is ***If the pressure in a liquid is changed at a particular point, the change is transmitted to the entire liquid without being diminished in magnitude.***	2
	<u>Application of Pascal's law</u> Hydraulic lift 	1

	❖ A practical application of Pascal's law is the hydraulic lift which is used to lift a heavy load with a small force. It is a force multiplier. It consists of two cylinders A and B connected to each other by a horizontal pipe, filled with a liquid. They are fitted with frictionless pistons of cross sectional areas A_1 and A_2 ($A_2 > A_1$). ❖ Suppose a downward force F is applied on the smaller piston, the pressure of the liquid under this piston increases to P (where $P = F_1 / A_1$). ❖ But according to Pascal's law, this increased pressure P is transmitted undiminished in all directions. So a pressure is exerted on piston B. ❖ Upward force on piston B is $$F_2 = P \times A_2 = \frac{F_1}{A_1} \times A_2 \Rightarrow F_2 = \frac{A_2}{A_1} \times F_1$$ ❖ Therefore by changing the force on the smaller piston A, the force on the pistonB has been increased by the factor and this **factor A_2 / A_1 is called the mechanical advantage of the lift.**	½ 1 ½
36. a)	**Centripetal acceleration** • **In uniform circular motion the velocity vector turns continuously without changing its magnitude (speed),**  • Note that the length of the velocity vector is not changed during the motion, implying that the speed remains constant. • Even though the velocity is tangential at every point in the circle, the acceleration is acting towards the center of the circle. This is called centripetal acceleration. It always points towards the center of the circle.  • The centripetal acceleration is derived from a simple geometrical relationship between position and velocity vectors	1 (any one of the diagram) 1



- Let the directions of position and velocity vectors shift through the same angle θ in a small interval of time Δt, as shown in Figure. For uniform circular motion

$r = |\vec{r}_1| = |\vec{r}_2|$ and

$v = |\vec{v}_1| = |\vec{v}_2|$.

- If the particle moves fro 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

- The magnitudes of the displacement Δr and of Δ*v* satisfy the following relation

$$\frac{\Delta r}{r} = -\frac{\Delta v}{v} = \theta$$

- Here the negative sign implies that Δ*v* points radially inward, towards the center of the circle. — 1

$$\Delta v = -v\left(\frac{\Delta r}{r}\right)$$

$$\text{Then,} \quad a = \frac{\Delta v}{\Delta t} = -\frac{v}{r}\left(\frac{\Delta r}{\Delta t}\right) = -\frac{v^2}{r}$$

- For uniform circular motion *v* = ω*r*, where ω is the angular velocity of the particle about the center. Th en the centripetal acceleration can be written as — 1

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

36 (OR) b)

- In the modern technological world, the role of automobile engines plays a vital role in for transportation.
- In motor bikes and cars there are engines which take in petrol or diesel as input, and do work by rotating wheels.
- Most of these automobile engines have efficiency not greater than 40 %. The second law of thermodynamics puts a fundamental restriction on efficiency of engines. Therefore understanding heat engines is very important.

Reservoir:

- It is defined as a thermodynamic system which has very large heat capacity. By taking in heat from reservoir or giving heat to reservoir, the reservoir‟s temperature does not change. — 1
- **Example:**Pouringatumblerofhotwaterintolakewillnotincreasethetemperatureofth

e lake. Here the lake can be treated as a reservoir.

- When a hot cup of coffee attains equilibrium with the open atmosphere, the temperature of the atmosphere will not appreciably change. The atmosphere can be taken as a reservoir.

Wecan defineheat engineas follows.

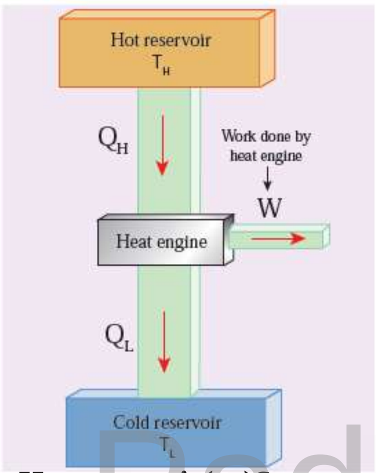
- *Heatengineisadevicewhichtakesheatasinputandconvertsthisheatintoworkbyundergoing a cyclic process.*
- Aheatenginehasthreeparts:

  (a) Hot reservoir

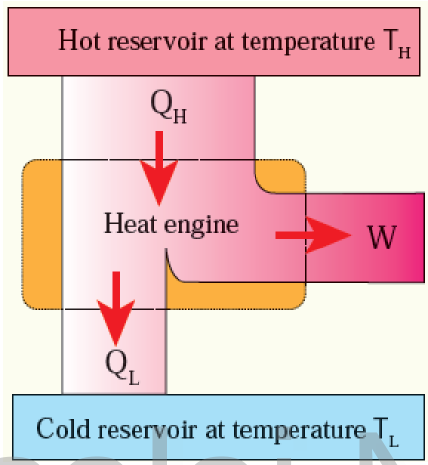
  (b) Working substance

  (c) Cold reservoir

- A Schematic diagram for heat engine is given below in the figure



(OR)



1

1. Hot reservoir(or)Source:

It supplies heat to the engine.

It is always maintain data high temperature T_H

2. Working substance:

It is a substance like gas or water, which converts the heat supplied into work.

A simple example of a heat engine is a steam engine. In olden days steam engines were used to drive trains. The working substance in these is water which absorbs heat from the burning of coal. The heat converts the water into steam. This steam is does work by rotating the wheels of the train, thus making the train move.

3. Cold reservoir(or)Sink: 1½

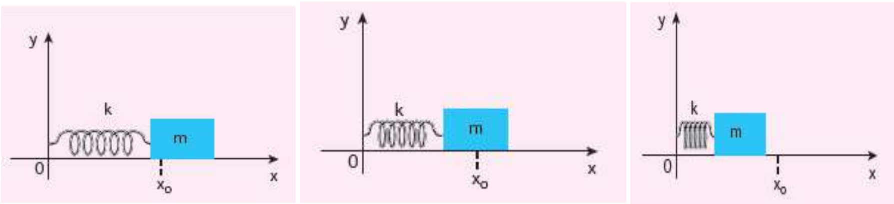
The heat engine ejects some amount of heat (Q_L) in to cold reservoir after it doing work. It is always maintained at a low temperature T_L.

For example, in the automobile engine, the cold reservoir is the surroundings at room temperature. The automobile ejects heat to these surroundings through a silencer.

	• The heat engine works in a cyclic process. After a cyclic process it returns to the same state. Since the heat engine returns to the same state after it ejects heat, the change in the internal energy of the heat engine is zero. • The efficiency of the heat engine is defined as the ratio of the work done (output) to the heat absorbed (input) in one cylic process. • Let the working substance absorb heat Q_H units from the source and reject Q_L units to the sink after doing work W units • We can write Input heat=Work done + ejected heat $Q_H = W + Q_L$ $W = Q_H - Q_L$ $\eta = \frac{output}{input} = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H}$ $\eta = \frac{output}{input} = \frac{W}{Q_H} = 1 - \frac{Q_L}{Q_H}$ • Then the efficiency of heat engine • Note here that Q_H, Q_L and W all are taken as positive, a sign convention followed in this expression. Since $Q_L < Q_H$, the efficiency (η) always less than 1. This implies that heat absorbed is not completely converted into work. The second law of thermodynamics placed fundamental restrictions on converting heat completely into work.	½ 1
37. (a)	❖ Consider a system containing a block of mass m attached to a mass less spring with stiffness constant or force constant or spring constant k placed on a smooth horizontal surface (frictionless surface). ❖ Let x_0 be the equilibrium position or mean position of mass m when it is left undisturbed. Suppose the mass is displaced through a small displacement x towards right from its equilibrium position and then released, it will oscillate back and forth about its mean position x_0. ❖ Let F be the restoring force (due to stretching of the spring) which is proportional to the amount of displacement of block. For one dimensional motion, mathematically, we have $F \propto x$ $F = -k x$ where negative sign implies that the restoring force will always act opposite to the direction of the displacement. This equation is called Hooke"s law. ❖ Notice that, the restoring force is linear with the displacement (i.e., the exponent of force and displacement are unity). This is not always true; in case if we apply a very large stretching force, then the amplitude of oscillations	½ ½

becomes very large (which means, force is proportional to displacement containing higher powers of x) and therefore, the oscillation of the system is not linear and hence, it is called non-linear oscillation.

- We restrict ourselves only to linear oscillations throughout our discussions, which means Hooke‟s law is valid (force and displacement have a linear relationship).



1

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

$$m\frac{d^2x}{dt^2} = -kx$$

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

½

- Comparing the equation with simple harmonic motion equation, we get which means the angular frequency or natural frequency of the oscillator is

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

½

- The frequency of the oscillation is

$$T = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}} \text{ seconds}$$

1

- and the time period of the oscillation is

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \text{ Hertz}$$

1

- Notice that *in simple harmonic motion, the time period of oscillation is independent of amplitude*. This is valid only if the amplitude of oscillation is small. The solution of the differential equation of a SHM may be written as

$$x(t) = A\sin(\omega t + \varphi)$$

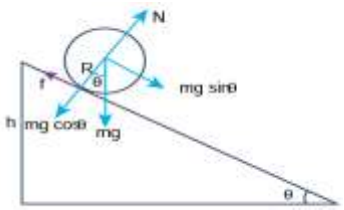
$$x(t) = A\cos(\omega t + \varphi)$$

where A, ω and ϕ are constants. General solution for differential equation is $x(t) = A\sin(\omega t + \varphi) + B\cos(\omega t + \varphi)$ where A and B are contants.

37. (b)

- Let us assume a round object of mass m and radius R is rolling down an inclined plane without slipping as shown in Figure.

½

	• There are two forces acting on the object along the inclined plane. One is the component of gravitational force (mg sinθ) and the other is the static frictional force (f). • The other component of gravitational force (mg cosθ) is cancelled by the normal force (N) exerted by the plane. As the motion is happening along the incline, we shall write the equation for motion from the free body diagram (*FBD*) of the object.  	1
	• For translational motion, mg sinθ is the supporting force and f is the opposing force, $mg\sin\theta - f = ma$ …………. (1)	½
	• For rotational motion, let us take the torque with respect to the center of the object. Then mg sinθ cannot cause torque as it passes through it but the frictional force f can set torque of Rf. $Rf = I\alpha$	½
	• By using the relation, a = rα, and moment of inertia I = mK^2, we get, $Rf = mK^2\frac{a}{R}; \quad f = ma\left(\frac{K^2}{R^2}\right)$	½
	• Now equation becomes, $mg\sin\theta - ma\left(\frac{K^2}{R^2}\right) = ma$ $mg\sin\theta = ma + ma\left(\frac{K^2}{R^2}\right)$	1
	$a\left(1+\frac{K^2}{R^2}\right) = g\sin\theta$ • After rewriting it for acceleration, we get, $a = \frac{g\sin\theta}{\left(1+\frac{K^2}{R^2}\right)}$ ……………. (2)	1
38. (a)	**(i) Power** • Power is a measure of how fast or slow a work is done. Power is defined as the rate of work done or energy delivered. • Unit = Js^{-1}, W Power (p) = x=$\frac{work\ done\ (W)}{time\ taken\ (t)}$ **(if formula only award 1 mark)** (ii) Power. P = 75 W Time of usage, t=8 hour x30 days = 240 hours Electrical energy consumed is the product of power and time of usage.	2 1

	=Pxt =75 watt x240 hour = 18000 watt hour (or) 18 kilowatt hour = 18 kWh 1 electrical unit = 1kWh Electrical energy =18 unit	1 ½ ½
38. (b)	• (i) The total energy of a satellite orbiting the Earth at a distance h from the surface of Earth is calculated as follows; The total energy of the satellite is the sum of its kinetic energy and the gravitational potential energy. The potential energy of the satellite is, $U=-\frac{GM_sM_E}{R_E+h}$ • Here M_s - mass of the satellite, M_E - mass of the Earth, R_E - radius of the Earth. The Kinetic energy of the satellite is $K.E=\frac{1}{2}M_sv^2$ • orbital speed of the satellite and is equal to Substituting the value of v, the kinetic energy of the satellite becomes $v=\sqrt{\frac{GM_E}{(R_E+h)}}$ Therefore, the total energy of the satellite is $K.E=\frac{1}{2}\frac{GM_EM_s}{(R_E+h)}$ $E=\frac{1}{2}\frac{GM_EM_s}{(R_E+h)}-\frac{GM_sM_E}{(R_E+h)}$ $E=-\frac{GM_sM_E}{2(R_E+h)}$ • **The negative sign in the total energy implies that the satellite is bound to the Earth and it cannot escape from the Earth**. • As h approaches ∞, the total energy tends to zero. Its physical meaning is that the satellite is completely free from the influence of Earth"s gravity and is not bound to Earth at large distances. **(ii) Energy of the moon orbiting the Earth:** $E_m=-\frac{GM_EM_m}{2R_m}$ where M_E is the mass of Earth 6.02×10^{24} kg; M_m is the mass of Moon 7.35×10^{22}kg; and R_m is the distance between the Moon and the center of the Earth $3.84\times10^5 km$ $G=6.67\times10^{-11}Nm^2kg^{-2}$. $E_m=-\frac{6.67\times10^{-11}\times6.02\times10^{24}\times7.35\times10^{22}}{2\times3.84\times10^5\times10^3}$ $E_m=-38.42\times10^{-19}\times10^{46}$ $E_m=-38.42\times10^{27}$ Joule	½ ½ ½ ½ ½ ½ 1 ½ ½

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