Class XI Session 2024-25
Subject - Physics
Sample Question Paper - 7

Time Allowed: 3 hours **Maximum Marks: 70**

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study-based questions of four marks each and Section E contains three long answer questions of five marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

Section A

1. The time period T of a small drop of liquid (due to surface tension) depends on density ρ, radius r and surface tension S. The relation is: **[1]**

a) $\mathrm{T} \propto \frac{S}{\rho r}$

b) $\mathrm{T} \propto \rho r S$

c) $\mathrm{T} \propto \frac{\rho r}{S}$

d) $\mathrm{T} \propto \left(\frac{\rho r^3}{S}\right)^{1/2}$

2. A point source emits sound equally in all directions in a non-absorbing medium. Two points P and Qare at distances of 2 m and 3 m respectively from the source. The ratio of the intensities of the waves at P and Q is: **[1]**

a) 4 : 9

b) 2 : 3

c) 3 : 2

d) 9 : 4

3. For rotational equilibrium, **[1]**

a) $\sum_{i=1}^{n} \tau_{\text{net}} = 0$

b) Both $\sum_{i=1}^{n} \mathbf{F}_{\text{net}} = 0$ and $\sum_{i=1}^{n} \tau_{\text{net}} = 0$ are the necessary conditions for the rotational equilibrium

c) Both $\sum_{i=1}^{n} \mathbf{F}_{\text{net}}$ and $\sum_{i=1}^{n} \tau_{\text{net}} = 0$ are not necessary for rotational equilibrium

d) $\sum_{i=1}^{n} \mathbf{F}_{\text{net}} = 0$

4. A square wire frame of size L is dipped in a liquid. On taking out, a membrane is formed. If the surface tension of liquid is T, force acting on the frame will be **[1]**

a) 2 TL

b) 10 TL

c) 4 TL

d) 8 TL

5. Two particles of equal mass go around a circle of radius R under the action of their mutual gravitational attraction. The speed v of each particle is: **[1]**

a) $\sqrt{\frac{4Gm}{R}}$

b) $\frac{1}{2}\sqrt{\frac{Gm}{R}}$

c) $\sqrt{\frac{Gm}{R}}$

d) $\frac{1}{2R}\sqrt{\frac{1}{Gm}}$

6. When sound travels from air to water, which parameter does not change? **[1]**

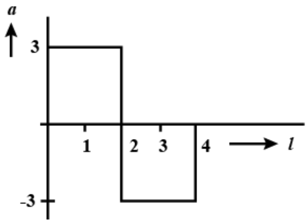
a) all of these

b) wavelength

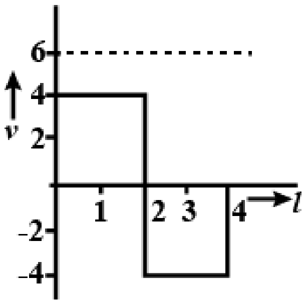
c) frequency

d) velocity

7. A particle starts from rest at t = 0 and undergoes an acceleration **a** in ms^{-2} with time **t** in seconds which is as shown here: **[1]**



Which one of one following plots represents velocity v in ms^{-1} verses time t in seconds?

a)


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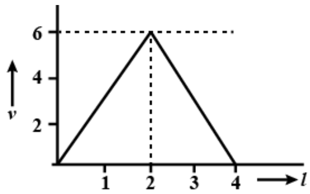

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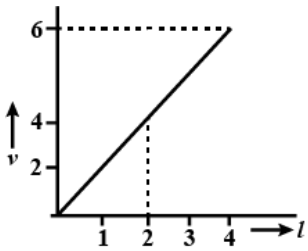

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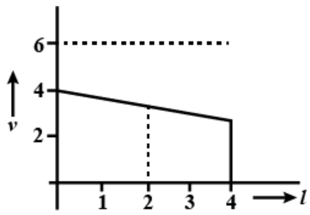


8. Two sound sources each emitting waves of wavelength λ are fixed a given distance apart and an observer moves from one source to another with velocity u. Then number of beats heard by him per second is **[1]**

a) $\frac{2u}{\lambda}$

b) $\frac{u}{2\lambda}$

c) $\frac{u}{\lambda}$

d) $\sqrt{u\lambda}$

9. When the adhesive force in the case of liquid and glass is greater than the cohesive forces between the liquid molecules, the shape of the meniscus of liquid in a capillary tube is? **[1]**

a) Plane

b) Circular

c) Convex

d) Concave

10. The reading of a spring balance corresponds to 100 N while situated at the north pole and a body is kept on it. The weight recorded on the same scale if it is shifted to the equator (take, g = $10m/s^2$ and radius of the earth, R = **[1]**

6.4×10^3m) is:

a) 106 N
b) 97.66 N
c) 110 N
d) 99.66 N

11. In rotation of a rigid body about a fixed axis is that in which: **[1]**

a) every particle of the body moves in a circle, which lies in a plane perpendicular to the axis and has its centre on the axis.
b) every particle of the body moves in an ellipse, which lies in a plane perpendicular to the axis and has its focii on the axis.
c) particles close to the axis have larger velocities.
d) every particle of the body moves at the same speed.

12. If the radius of a star is R and it acts as a black body, what would be the temperature of the star, in which the rate of energy production is Q? **[1]**

a) $\left(\frac{Q}{4\pi R^2\sigma}\right)^{-1/2}$
b) $\left(\frac{Q}{4\pi R^2\sigma}\right)^{1/4}$
c) $\left(\frac{4\pi R^2 Q}{\sigma}\right)^{1/4}$
d) $\frac{Q}{4\pi R^2\sigma}$

13. **Assertion (A):** Two springs of force constants k_1 and k_2 are stretched by the same force. If $k_1 > k_2$, then work done in stretching the first (W_1) is less than work done in stretching the second (W_2). **[1]**

Reason (R):$F = k_1x_1 = k_2x_2$

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

14. **Assertion (A):** Specific heat capacity and molar specific heat capacity both have same units. **[1]**
Reason (R): Specific heat capacity and molar specific heat capacity both do not depend on mass.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

15. **Assertion:** Earth is continuously pulling moon towards its centre but moon does not fall to earth. **[1]**
Reason: Attraction of sun on moon is greater than that of earth on moon.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
c) Assertion is correct statement but reason is wrong statement.
d) Assertion is wrong statement but reason is correct statement.

16. **Assertion (A):** In projectile motion, the vertical velocity of the particle is continuously decreased during its ascending motion. **[1]**
Reason (R): In projectile motion near earth surface, downward constant acceleration is present in vertical direction.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false. d) A is false but R is true.

Section B

17. State few important uses of the phenomenon of beats. **[2]**

18. If the value of universal gravitational constant in SI is 6.6×10^{-11} Nm^2kg^{-2}, then find its value in CGS system. **[2]**

19. A small steel ball of radius r is allowed to fall under gravity through a column of a viscous liquid of coefficient of viscosity η. After some time the velocity of the body attains a constant value v_T. The terminal velocity depends upon (i) the weight of the ball mg (ii) the coefficient of viscosity η and (iii) the radius of the ball r. By the method of dimensions, determine the relation expressing terminal velocity. **[2]**

20. A nucleus is at rest in the laboratory frame of reference. Show that if it disintegrates into two smaller nuclei, the products must be emitted in opposite directions. **[2]**

21. The acceleration due to gravity on the surface of the earth is 10 ms^{-2}. The mass of the planet Mars as compared to earth is $\frac{1}{10}$ and radius is $\frac{1}{2}$. Determine the gravitational acceleration of a body on the surface of Mars. **[2]**

OR

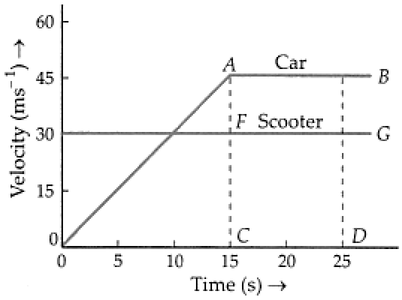
Two heavy spheres each of mass 100 kg and radius 0.10 m are placed 1.0 m apart on a horizontal table. What is the gravitational force and potential at the midpoint of the line joining the centres of the spheres? Is an object placed at that point in equilibrium? If so, is the equilibrium stable or unstable?

Section C

22. Briefly explain how does Bernoulli's principle help in explaining blood flow in human beings. What is the cause of a heart attack? **[3]**

23. Show that the coefficient of volume expansion for a solid substance is three times its coefficient of linear expansion. **[3]**

24. As soon as a car just starts from rest in a certain direction, a scooter moving with a uniform speed overtakes the car. Their velocity-time graphs are shown in Figure. Calculate **[3]**



i. the difference between the distances travelled by car and the scooter in 15 s
ii. the time when the car will catch up the scooter and
iii. the distance of car and scooter from the starting point at that instant.

25. If a car having speed 50 km/h can round the curve banked at an angle θ. Find out the value of θ, if radius of the curve is 40 m and consider the friction is negligible, [$\tan^{-1}$ (0.5) = 26.5] **[3]**

26. State first law of thermodynamics. Why is $C_p > C_v$? Derive the relation $C_p - C_v = R$ for an ideal gas. **[3]**

27. Two identical point masses, each of mass M are connected to one another by a massless string of length L. A constant force F is applied at the mid-point of the string. If l be the instantaneous distance between the two masses, what will be the acceleration of each mass? **[3]**

28. Two mercury droplets of radii 0.1 cm. and 0.2 cm. collapse into one single drop. What amount of energy is released? The surface tension of mercury $T = 435.5 \times 10^{-3}$ N m^{-1}. **[3]**

OR

Glycerine flows steadily through a horizontal tube of length 1.5 m and radius 1.0 cm. If the amount of glycerine collected per second at one end is $4.0 \times 10^{-3} \mathrm{kgs}^{-1}$, what is the pressure difference between the two ends of the tube? (Density of glycerine = $1.3 \times 10^{3} \mathrm{kgm}^{-3}$ and viscosity of glycerine = 0.83 Pa s). [You may also like to check if the assumption of laminar flow in the tube is correct].

Section D

29. **Read the text carefully and answer the questions:** **[4]**

In everyday life, the term work is used to refer to any form of activity that requires the exertion of mental or muscular efforts. In physics, work is said to be done by a force or against the direction of the force, when the point of application of the force moves towards or against the direction of the force. If no displacement takes place, no work is said to be done.

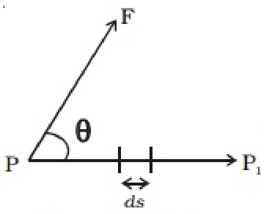


Fig. Work done by a force

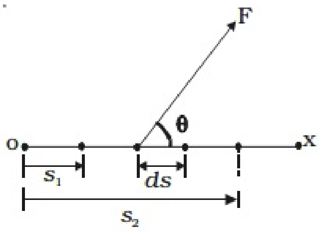


Fig. Work done by a constant force

(a) A box is pushed through 4.0 m across a floor offering 100 N resistance. How much work is done by the applied force?

a) 100 J
b) 300 J
c) 400 J
d) 200 J

(b) What is work done in holding a 15 kg suitcase while waiting for 15 minutes?

a) 22.5 J
b) zero
c) 225 J
d) 150 J

(c) Frictional forces are:

a) conservative forces
b) non-conservative forces
c) buoyant force
d) non buoyant force

OR

Force of 4N is applied on a body of mass 20 kg. The work done in 3rd second is:

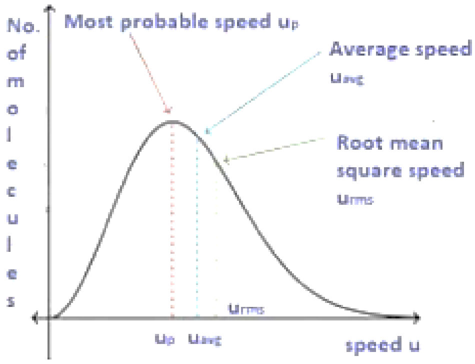
a) 6 J
b) 8 J
c) 4 J
d) 2 J

(d) When the body moves in a circular motion, net 'work' done is:

a) one
b) positive
c) negative
d) zero

30. **Read the text carefully and answer the questions:** **[4]**

Root mean square velocity (RMS value)is the square root of the mean of squares of the velocity of individual gas molecules and the Average velocity is the arithmetic mean of the velocities of different molecules of a gas at a given temperature.



(a) Moon has no atmosphere because:

a) the escape velocity of the moon's surface is more than the r.m.s velocity of all molecules

b) it is far away from the surface of the earth

c) the r.m.s. velocity of all the gas molecules is more than the escape velocity of the moon's surface

d) its surface temperature is 10^oC

(b) For an ideal gas, $\frac{C_P}{C_V}$ is

a) ≤ 1

b) none of these

c) > 1

d) < 1

(c) The root means square velocity of hydrogen is $\sqrt{5}$ times that of nitrogen. If T is the temperature of the gas then:

a) $T(H_2) = T(N_2)$

b) $T(H_2) < T(N_2)$

c) $T(H_2) \neq T(N_2)$

d) $T(H_2) > T(N_2)$

(d) Suppose the temperature of the gas is tripled and N_2 molecules dissociate into an atom. Then what will be the rms speed of atom:

a) $v_0\sqrt{2}$

b) $v_0\sqrt{6}$

c) $v_0\sqrt{3}$

d) v_0

OR

The velocities of the molecules are v, 2v, 3v, 4v & 5v. The RMS speed will be:

a) 11 v

b) $v(12)^{11}$

c) v

d) $v(11)^{12}$

Section E

31. The motion of a particle executing simple harmonic motion is described by the displacement function, x (t) = A cos $(\omega_t + \omega)$. **[5]**

If the initial (t = 0) position of the particle is 1 cm and its initial velocity is ω cm/s, what are its amplitude and initial phase angle? The angular frequency of the particle is π s^{-1}. If instead of the cosine function, we choose the sine function to describe the SHM: x = B sin $(\omega t + a)$, what are the amplitude and initial phase of the particle with the above initial conditions.

OR

The bottom of a dip on a road has a radius of curvature R. A rickshaw of mass M left a little away from the bottom oscillates about the dip. Deduce an expression for the period of oscillation.

32. A bird is at a point P whose coordinates are (4m ,-1m, 5m). The bird observes two points P_1 and P_2 having coordinates (-1 m, 2 m, 0 m) and (1 m, 1 m, 4 m) respectively. At time t = 0, it starts flying in a plane of three positions, with a constant speed of $5ms^{-1}$ in a direction perpendicular to the straight line P_1P_2 till it sees P_1 and P_2 collinear at time t. Calculate t. **[5]**

OR

Establish the following vector inequalities:

i. $|\vec{a}+\vec{b}| \leq |\vec{a}|+|\vec{b}|$
ii. $|\vec{a}-\vec{b}| \leq |\vec{a}|+|\vec{b}|$

When does the equality sign apply?

33. A car weighs 1800 kg. The distance between its front and back axles is 1.8 m. Its centre of gravity is 1.05 m behind the front axle. Determine the force exerted by the level ground on each front wheel and each back wheel. **[5]**

OR

Determine the position of centre of mass of a uniform semicircular wire of radius R.

Solution

Section A

1.

(d) $\mathrm{T} \propto \left(\frac{\rho r^3}{S}\right)^{1/2}$

Explanation: Let T = $K\rho^a r^b S^c$

$\therefore$ [T] = $[ML^{-3}]^a [L]^b [MT^{-2}]^c$

or

$M^0L^0T^1 = M^{a+c}L^{-3a+b}T^{-2c}$

$\therefore$ a + c = 0, -3a + b = 0, -2c = 1

On solving, a = $\frac{1}{2}$, b = $\frac{3}{2}$, c = $-\frac{1}{2}$

Hence, $\mathrm{T} \propto \left(\frac{\rho r^3}{S}\right)^{1/2}$

2.

(d) 9 : 4

Explanation: Intensity = $\frac{\text{energy}}{\text{time} \times \text{area}} = \frac{\text{power}}{\text{area}}$

From a point source, energy spreads over the surface of a sphere of radius r.

$\therefore$ Intensity, I = $\frac{P}{A} = \frac{P}{4\pi r^2}$

or $I \propto \frac{1}{r^2}$

$\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$

3. **(a)** $\sum_{i=1}^{n} \tau_{\text{net}}$ = 0

Explanation: $\sum_{i=1}^{n} \tau_{\text{net}}$ = 0

4.

(d) 8 TL

Explanation: The membrane has two free surfaces.

Total force acting on the frame = Surface tension $\times$ perimeter $\times$ 2

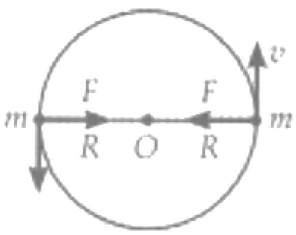
= T $\times$ 4 L $\times$ 2 = 8 TL

5.

(b) $\frac{1}{2}\sqrt{\frac{Gm}{R}}$

Explanation:

The two masses, separated by a distance 2 R, revolve about the common centre of mass O.



Centripetal force = Mutual gravitational attraction

$\frac{mv^2}{R} = \frac{Gm \times m}{(2R)^2}$

or $v^2 = \frac{GM}{4R}$

$\therefore v = \frac{1}{2}\sqrt{\frac{Gm}{R}}$

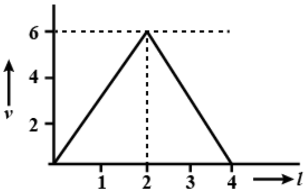
6.

(c) frequency

Explanation: Frequency remains unchanged when sound travels from air to water.

7.

(b)

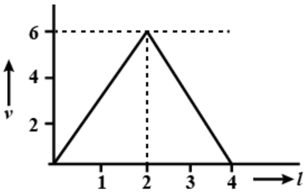


Explanation:

Area under a - t curve = Change in velocity

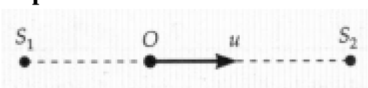
For constant acceleration, v $\propto$ t

As a is first +ve and then -ve, so the correct v - t graph is the one given in option.



8. **(a)** $\frac{2u}{\lambda}$

Explanation:



Number of extra waves received from S_2 per second $= +\frac{u}{\lambda}$

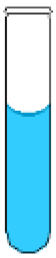
Number of lesser waves received from S_1 per second $= -\frac{u}{\lambda}$

$\therefore$ Beat frequency $= \frac{u}{\lambda} - \left(-\frac{u}{\lambda}\right) = \frac{2u}{\lambda}$

9.

(d) Concave

Explanation: The formation of meniscus depends on cohesive and adhesive forces in a liquid. For water, adhesive forces are stronger than the cohesive forces, therefore, water in a container stick to the wall of the container and owing to the capillary action rises a little bit and form a concave meniscus.



When liquid water is confined in a tube, its surface (meniscus) has a concave shape because water wets the surface and creeps up the side.

10.

(d) 99.66 N

Explanation: $g_p - g_e = R\omega^2 = 3.37 \times 10^{-2}\ ms^{-2}$

$g_e = g_p - 3.37 \times 10^{-2}\ ms^{-2}$

$= (10 - 0.0337)\ ms^{-2}$

$W_e = mg_e = \frac{100}{10} \times 9.9663\ N = 99.66\ N$

11. **(a)** every particle of the body moves in a circle, which lies in a plane perpendicular to the axis and has its centre on the axis.

Explanation: When a rigid body rotates about a fixed axis, all particles of the body except those which lies on the axis of rotation, move along circular paths in a plane perpendicular to the axis.

12.

(b) $\left(\frac{Q}{4\pi R^2\sigma}\right)^{1/4}$

Explanation: From Stefan' law, the rate of energy radiated by the star acting as a black body is

$Q = \sigma A T^4 = \sigma \times 4\pi R^2 \times T^4$

$\therefore T = \left[\frac{Q}{4\pi R^2\sigma}\right]^{\frac{1}{4}}$

13. **(a)** Both A and R are true and R is the correct explanation of A.

Explanation: Both A and R are true and R is the correct explanation of A.

14.

(d) A is false but R is true.

Explanation: A is false but R is true.

15.

(c) Assertion is correct statement but reason is wrong statement.

Explanation: Assertion is correct statement but reason is wrong statement.

16. **(a)** Both A and R are true and R is the correct explanation of A.

Explanation: Both A and R are true and R is the correct explanation of A.

Section B

17. Some important uses of beats phenomenon are as follows:

i. Principle of beats enables us to tune one musical instrument by sounding it against a standard frequency.

ii. We may determine the frequency of a tuning fork by studying beats formed with another tuning fork of known frequency.

iii. Principle of beats is made use of in heterodyne method of radio reception.

18. G = 6.6 $\times$ 10^{-11} Nm^2 kg^{-2}

= 6.6 $\times$ 10^{-11} Ng^{-1} m^3 kg^{-2}

since,

1 kg = 10^3 g

1 m = 10^2 cm

Hence

= 6.6 $\times$ 10^{-11} (10^3 g) (10^2 cm)3 s^{-2}

= 6.6 $\times$ $10^{-11-3+3}$ g^{-1} cm^3 s^{-2}

= 6.6 $\times$ 10^{-8} g^{-1} cm^3 s^{-2}

19. Let v_T = $K(mg)^a \eta^b r^c$,

where K = a dimensionless constant.

Putting the dimensions of various quantities,

$LT^{-1} = [MLT^{-2}]^a\ [ML^{-1}T^{-1}]^b\ [L]^c$

or $M^0L^1T^{-1} = M^{a + b}L^{a - b + c}T^{-2a - b}$

Equating the powers of M, L and T on both sides, we get

a + b = 0, a - b + c = 1, - 2a - b = -1

On solving, a = 1, b = -1, c = -1

$\therefore$ $v_T = K(mg)^1\eta^{-1}r^{-1}$ or $v_T \propto \frac{mg}{\eta r}$

20. According to the principle of conservation of linear momentum, total momentum remains constant.

Before disintegration linear momentum = zero

After disintegration linear momentum = $m_1\overline{v_1} + m_2\overline{v_2}$

$\Rightarrow m_1v_1 + m_2v_2 = 0 \Rightarrow v_2 = -\frac{m_1v_1}{m_2}$

21. $g_e = \frac{GM_e}{r_e^2}$

$g_m = \frac{GM_m}{r_m^2}$

$\frac{g_e}{g_m} = \frac{M_e}{M_m} \times \frac{r_m^2}{r_e^2}$

$\frac{g_e}{g_m}$ = $\frac{10}{4}$

g_m = 4 ms^{-2}

OR

Gravitational potential at the midpoint of the line joining the centres of the two spheres is

$V=\frac{GM}{\frac{r}{2}}-\frac{GM}{\frac{r}{2}}=\frac{4GM}{r}$

$V=\frac{4\times6.67\times10^{-11}\times100}{0.1}$

= -2.68 $\times$ 10^{-7} J/kg

As the effective force on the body placed at mid-point is zero, so the body is in equilibrium. If the body is displaced a little towards either mass body from its equilibrium position, it will not return back to its initial position of equilibrium. Hence, the body is in an unstable equilibrium.

Section C

22. The blood flow in artery of a human being can be easily explained on the basis of Bernoulli's principle. The heart applies a pressure to maintain blood flow through the arteries.

In persons suffering with advanced heart condition, the artery gets constricted due to the accumulation of plaque on its inner walls. In order to drive the blood through this constriction a greater activity of the heart is required. The speed of the flow of the blood in this region is raised which lowers the pressure inside, and the artery may collapse due to this external pressure.

The heart exerts further pressure to open this artery and forces the blood through. As the blood rushes through the opening, the internal pressure once again drops leading to a repeat collapse. This may result in heart attack.

23. Consider a solid in the form of a rectangular parallelopiped of sides a, b, and c respectively $\therefore$ its volume $V=abc$.

If the solid is heated so that its temperature rises by ΔT, then increase in its sides will be

$\Delta a=a\cdot\alpha\cdot\Delta T$, $\Delta b=b\cdot\alpha\cdot\Delta T$ and $\Delta c=c\cdot\alpha\cdot\Delta T$ or $a'=a+\Delta a=a(1+\alpha\cdot\Delta T)$, $b'=b+\Delta b,\ b(1+\alpha.\Delta T)$ and c' = c + Δc = c(1 + $\alpha.\Delta T$)

$\therefore$ New volume $V'=V+\ \Delta V=a'b'c'=abc(1+\alpha.\Delta T)^3$

$\therefore$ Increase in volume $\Delta V=V'-V$ = $\left[abc(1+\alpha\cdot\Delta T)^3-abc\right]$

$\therefore$ Coefficient of volume expansion $\gamma=\frac{\Delta V}{V\cdot\Delta T}$ = $\frac{abc(1+\alpha\cdot\Delta T)^3-abc}{abc\cdot\Delta T}$

$\therefore\gamma=\frac{(1+\alpha\cdot\Delta T)^3-1}{\Delta T}$

= $\frac{\left(1+3\alpha\cdot\Delta T+3\alpha^2\cdot\Delta T^2+\alpha^3\cdot\Delta T^3\right)-1}{\Delta T}$

= $3\alpha+3\alpha^2\Delta T+\alpha^3\cdot\Delta T^2$

As we know that α has an extremely small value for solids

$\therefore\gamma=3\alpha$

$\Rightarrow$ the coefficient of volume expansion of a solid is three times of its coefficient of linear expansion.

24. i. Distance travelled by car in 15 s = Area of $\triangle$OAC

= $\frac{1}{2}\times$ OC $\times$ AC = $\frac{1}{2}\times$ 15 $\times$ 45 = 337.5 m

Distance travelled by the scooter in 15 s = Area of rect. OEFC

= 15 $\times$ 30 = 450 m

Difference in the distances travelled = 450 - 337.5 = 112.5 m.

ii. After t = 15 s, relative velocity of the car w.r.t. the scooter = 45 - 30 = 15 ms^{-1}

$\therefore$ Time taken in covering a difference of 112.5 m

= $\frac{112.5\text{ m}}{15\text{ ms}^{-1}}$ = 7.5 s

$\therefore$ Time after which car will catch up the scooter = 15 + 7.5 = 22.5 s.

iii. Distance travelled by the scooter in 22.5 s

= 30 ms^{-1} $\times$ 22.5 s = 675 m.

So the car catches the scooter when both are at 675 m from the starting point.

25. Write the given quantity and the quantity to be known.

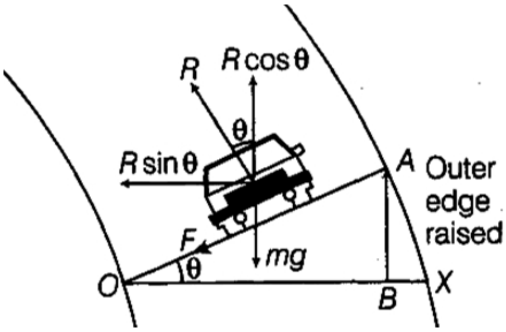
v = 50 km/h = 50 $\times$ $\frac{5}{18}$ m/s = 13.88 m/s

r = 40 m, θ = ?

Draw the FBD of the car.

Now, apply ΣF_g = may to the car

R cos θ - mg = 0 $\Rightarrow$ $\frac{mg}{cos\theta}$



Similarly, apply ΣF_x = ma_x to the car

R sin θ = $\frac{mv^2}{r}$

Put the value of R and then slove for θ

$\frac{mg}{cos\theta} \cdot sin\theta = \frac{mv^2}{r}$

$\Rightarrow \tan\theta = \frac{v^2}{rg}; \theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$

Put the all given values ot get θ

$\theta = \tan^{-1}\left[\frac{(13.88)^2}{40\times 9.8}\right] = \tan^{-1}(0.4917)$

$\theta = 26.18^o$

26. The first law of thermodynamics states that energy can be converted from one form to another, but cannot be created or destroyed. The most important and critical aspect of life revolves around the idea of energy.

The heat capacity at constant pressure C_P is greater than the heat capacity at constant volume C_v , because when heat is added at constant pressure, the substance expands and work.

The relation C_p - C_v = R for an ideal gas.

According to the first law of thermodynamics, q = $nC\Delta T$ ...(1)

Where q is the heat, n is the number of moles, C molar heat capacity and ΔT is the change in temperature.

At constant pressure, in the equation (1), then

$q_p = nC_p\Delta T$

The above equation is equal to the change in enthalpy, then

$q_p = nC_p\Delta T = \Delta H$ ...(2)

Similarly, at constant, volume, in equation (1), then

$q_v = nC_v\Delta T$

The above equation is equal to the change in internal energy, then

$q_p = nC_p\Delta T = \Delta U$ ...(3)

The formula for one mole of an ideal gas is,

$\Delta H = \Delta U + \Delta(pv)$ (pv = nRT) (For one mole n = 1)

Then the above equation is written as,

$\Delta H = \Delta U + \Delta(RT)$

By rearranging the above equation, then

$\Delta H = \Delta U + R\Delta T$ ...(4)

By substituting the equation (2) and equation (3) in the equation (4), then

$nC_p\Delta T = nC_v\Delta T + R\Delta T$

Here, n = 1, then the above equation is written as,

$C_p\Delta T = C_v\Delta T + R\Delta T$

By taking ΔT as a common term, then $C_p \times \Delta T = (C_v + R)\Delta T$

By cancelling the terms ΔT on both sides, then

$C_p = C_v + R$

By rearranging the above equation, then

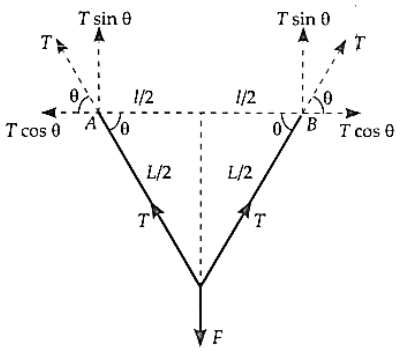
$C_p - C_v = R$

27. Figure shows the position of string at any instant after the application of a force F at the mid point. It also shows the various forces acting on the two masses at any instant. If tension T in the string is resolved into horizontal and vertical components, then

F = 2T sin θ ...(i)

and Ma = T cos θ ....(ii)

where a is the acceleration of each mass.



Dividing (ii) by (i), we get

$\frac{\cos\theta}{2\sin\theta} = \frac{Ma}{F}$

or $\cot\theta = \frac{2Ma}{F}$

or $\frac{l/2}{\sqrt{(L/2)^2-(l/2)^2}} = \frac{2Ma}{F}$

or $\frac{2Ma}{F} = \frac{l}{\sqrt{L^2-l^2}}$

or $a = \frac{F}{2M}\left(\frac{l}{\sqrt{L^2-l^2}}\right)$

28. Energy due to surface Tension $E = \sigma\Delta A$

By law of conservation of mass, volume of drop $V_1 + V_2 = V$

$r_1 = 0.1cm = 0.1 \times 10^{-2}m = 10^{-3}m$

$r_2 = 0.2\mathrm{cm} = 2 \times 10^{-3}\mathrm{m}$

$\Delta A = 4\pi r_1^2 + 4\pi r_2^2 - 4\pi R^2 = 4\pi\left[r_1^2 + r_2^2 - R^2\right]$

R is the radius of new drop formed by the combination of two smaller drops.

$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi r_1^3 + \frac{4}{3}\pi r_2^3$

$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi\left[r_1^3 + r_2^3\right] \Rightarrow R^3 = r_1^3 + r_2^3$

$R^3 = \left[\left(1 \times 10^{-3}\right)^3 + \left(2 \times 10^{-3}\right)^3\right] = \left[10^{-9} + 8 \times 10^{-9}\right] = 9 \times 10^{-9}$

$\mathrm{R} = 2.1 \times 10^{-3}\mathrm{m}$

$E = \Delta A\sigma = 4 \times 3.14\left[\left(10^{-3}\right)^2 + \left(2.0 \times 10^{-3}\right)^2\right.$

$\left.-\left(2.1 \times 10^{-3}\right)^2\right] \times 435.5 \times 10^{-3}$

$E = 4 \times 3.14 \times 435.5 \times 10^{-3} \times \left(10^{-3}\right)^2\left[1 + 4 - (2.1)^2\right]$

$= 4 \times 3.14 \times 435.5 \times 10^{-9}[5 - 41];$

$E = 1742.0 \times 3.14 \times 10^{-9}[0.59] = 5469.88 \times 0.59 \times 10^{-9}$

$E = 3227.23 \times 10^{-9} = 32.2723 \times 10^{-7}J$

$E = 32.27 \times 10^{-7}J$

Energy is released due to formation of bigger drop from smaller drops because final area will be smaller than former case.

OR

Length of the horizontal tube is given by, l = 1.5 m

Radius of the tube is, r = 1 cm = 0.01 m

Diameter of the tube is given by, d = 2r = 0.02 m

Glycerine is flowing at a rate of $4.0 \times 10^{-3}\mathrm{kgs}^{-1}$.

$M = 4.0 \times 10^{-3}\mathrm{kg}s^{-1}$

Density of Glycerine is given by, $\rho = 1.3 \times 10^3\mathrm{kgm}^{-3}$

Viscosity of Glycerine is given by, η = 0.83 Pa s

Volume of Glycerine flowing per sec is given by :

$V = \frac{M}{\rho}$

$= \frac{4.0\times10^{-3}}{1.3\times10^3}$

$= 3.08 \times 10^{-6}\mathrm{m}^3 s^{-1}$

According to Poiseville's formula, we have the relation for the rate of flow:

$V=\frac{\pi p r^4}{8\eta l}$

Where, p is the pressure difference between the two ends of the tube

$\therefore p=\frac{V8\eta l}{\pi r^4}$

$=\frac{3.09\times10^{-8}\times8\times0.83\times1.5}{\pi\times(0.01)^4}$

$=9.8\times10^2 Pa$

Reynolds' number is given by the relation:

$R=\frac{4\rho V}{\pi d\eta}$

$=\frac{4\times1.3\times10^3\times3.08\times10^{-5}}{\pi\times(0.02)\times0.83}=0.3$

Reynolds' number is about 0.3. Hence, the flow is laminar.

Section D

29. **Read the text carefully and answer the questions:**

In everyday life, the term work is used to refer to any form of activity that requires the exertion of mental or muscular efforts. In physics, work is said to be done by a force or against the direction of the force, when the point of application of the force moves towards or against the direction of the force. If no displacement takes place, no work is said to be done.

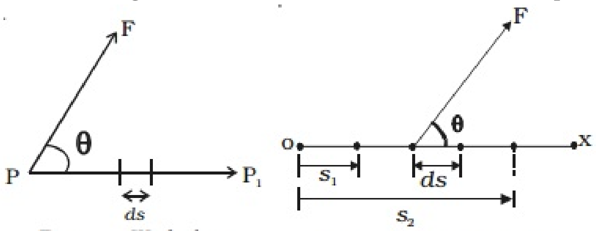


Fig. Work done by a force

Fig. Work done by a constant force

(i) **(c)** 400 J
Explanation: 400 J

(ii) **(b)** zero
Explanation: zero

(iii) **(b)** non-conservative forces
Explanation: non-conservative forces

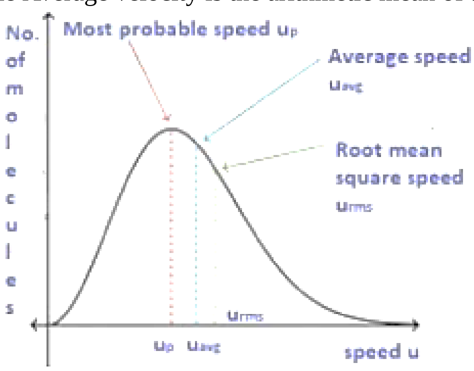
OR

(d) 2 J
Explanation: 2 J

(iv) **(d)** zero
Explanation: zero

30. **Read the text carefully and answer the questions:**

Root mean square velocity (RMS value)is the square root of the mean of squares of the velocity of individual gas molecules and the Average velocity is the arithmetic mean of the velocities of different molecules of a gas at a given temperature.



(i) **(c)** the r.m.s. velocity of all the gas molecules is more than the escape velocity of the moon’s surface
Explanation: The r.m.s. velocity of all the gas molecules is more than the escape velocity of the moon’s surface.

(ii) **(c)** > 1
Explanation: > 1

(iii) **(b)** $T(H_2) < T(N_2)$

Explanation: $T(H_2) < T(N_2)$

(iv) **(b)** $v_0\sqrt{6}$

Explanation: $v_0\sqrt{6}$

OR

(d) $v(11)^{12}$

Explanation: $v(11)^{12}$

Section E

31. Displacement of the particles is given by -

y = a sin wt

Here a is the amplitude of oscillation and $2\pi/\omega$ is the period of oscillation and ω is the angular frequency of the wave.

Initially, at t = 0:

Displacement, x = 1 cm

Initial velocity, v = ω cm/sec.

Angular frequency, ω = π rad/s^{-1}

It is given that:

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

$1 = A\cos(\omega \times 0 + \phi) = A\cos\phi$

$A\cos\phi = 1$ ...(i)

Velocity, $v = \frac{dx}{dt}$

$\omega = -A\omega\sin(\omega t + \phi)$

$1 = A\sin(\omega \times 0 + \phi) = A\sin\phi$

$A\sin\phi = -1$ ....(ii)

Squaring and adding equations (i) and (ii), we get:

$A^2\left(\sin^2\phi + \cos^2\phi\right) = 1 + 1$

$A^2 = 2$

$\therefore A = \sqrt{2}\text{cm}$

Dividing equation (ii) by equation (i), we get:

$\tan\phi = -1$

$\therefore \phi = \frac{3\pi}{4}, \frac{7\pi}{4}, \ldots\ldots$

SHM is given as:

$x = B\sin(\omega t + a)$

Putting the given values in this equation, we get:

$1 = B\sin[\omega \times 0 + a]$

B sin a = 1 ….(iii)

Velocity, $v = \omega B\cos(\omega t + a)$

Substituting the given values, we get:

$\pi = \pi B\sin a$

B sin a = 1 ...(iv)

Squaring and adding equations (iii) and (iv), we get:

$B^2\left[\sin^2 a + \cos^2 a\right] = 1 + 1$

$B^2 = 2$

$\therefore B = \sqrt{2}\text{cm}$

Dividing equation (iii) by equation (iv), we get:

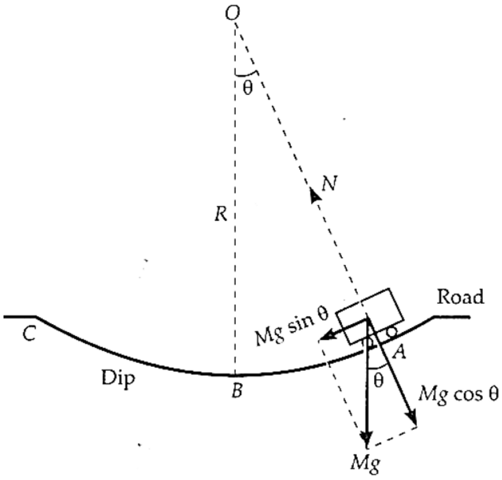
$\frac{B\sin a}{B\cos a} = \frac{1}{1}$

$\tan a = 1 = \tan\frac{\pi}{4}$

$a = \frac{\pi}{4}, \frac{5\pi}{4}, \ldots\ldots$

OR

As shown in the figure, let the rickshaw of mass M be at position A at any instant and $\angle$AOB = θ.



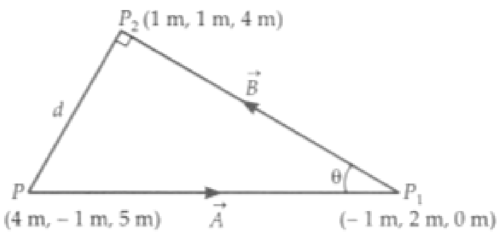
Forces acting on the rickshaw at position A are

i. Weight Mg acting vertically downwards.
ii. The normal reaction N of the road.

The weight Mg can be resolved into two rectangular components:

i. Mg cos θ perpendicular to the road. It balances the normal reaction N.
ii. Mg sin θ tangential to the road. It is the only unbalanced force acting on the rickshaw which acts towards the mean position B.
Hence the restoring force is
F = -Mg sin θ
For small θ, $\sin\theta \simeq \theta = \frac{\text{Arc}}{\text{Radius}}$ = $\frac{AB}{R} = \frac{y}{R}$
$\therefore$ F = $-\frac{Mg}{R}y$ i.e, F $\propto$ y
Hence the motion of the rickshaw is simple harmonic with force constant,
k = $\frac{Mg}{R}$
Time period,
T = $2\pi\sqrt{\frac{M}{k}} = 2\pi\sqrt{\frac{M}{Mg/R}}$ = $2\pi\sqrt{\frac{R}{g}}$

32. The situation is shown in figure. The bird flies in a direction perpendicular to line P_1 P_2. Suppose it reaches the point Q in time t (after starting from point P) where it sees P_1 and P_2 as collinear.



Let $\overrightarrow{PP}_1 = \vec{A}, \quad \vec{P}_1\vec{P}_2 = \vec{B}, \angle PP_1P_2 = \theta$ and PQ = d
As $|\vec{A}\times\vec{B}| = |\vec{A}||\vec{B}|\sin\theta$
$\therefore \quad \sin\theta = \frac{|\vec{A}\times\vec{B}|}{|\vec{A}||\vec{B}|}$
Now $\vec{A} = (-1-4)\hat{i} + (2+1)\hat{j} + (0-5)\hat{k}$
But $\vec{A} = (-1-4)\hat{i} + (2+1)\hat{j} + (0-5)\hat{k}$
$= -5\hat{i} + 3\hat{j} - 5\hat{k}$
and $\vec{B} = (1+1)\hat{i} + (1-2)\hat{j} + (4-0)\hat{k}$
$= 2\hat{i} - \hat{j} + 4\hat{k}$

$$\therefore \quad \vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -5 & 3 & -5 \\ 2 & -1 & 4 \end{vmatrix}$$

$= (12-5)\hat{i} + (-10+20)\hat{j} + \hat{k}(5-6)$
$= 7\hat{i} + 10\hat{j} - \hat{k}$
$\therefore |\vec{A}\times\vec{B}| = \sqrt{7^2+10^2+1^2} = 12.25 \text{ m}^2$

and $|\vec{B}| = \sqrt{2^2 + 1^2 + 4^2}$ = 4.583 m

$\therefore \quad d = \frac{12.25}{4.583}$ = 2.67 m

Time taken by bird to reach the point Q will be

$t = \frac{d}{v} = \frac{2.67}{5}$ = 0.5346 s

OR

i. If θ be the angle between $\vec{a}$ and $\vec{b}$, then

$|\vec{a} + \vec{b}| = \sqrt{|\vec{a}|^2 + |\vec{b}|^2 + 2|\vec{a}||\vec{b}|\cos\theta}$

Now $|\vec{a} + \vec{b}|$ will be maximum when

$\cos\theta = 1$ or $\theta = 0$

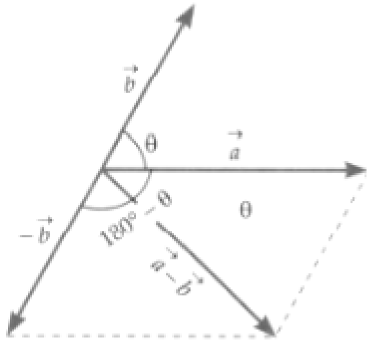
$\therefore |\vec{a} + \vec{b}|_{\max} = \sqrt{|\vec{a}|^2 + |\vec{b}|^2 + 2|\vec{a}||\vec{b}|\cos 0^\circ}$

$= \sqrt{(|\vec{a}| + |\vec{b}|)^2} = |\vec{a}| + |\vec{b}|$

Hence $|\vec{a} + \vec{b}| \leq |\vec{a}| + |\vec{b}|$

The equality sign in applicable when $\theta = 0^o$ i.e., when $\vec{a}$ and $\vec{b}$ are in the same direction.

ii. If θ is the angle between $\vec{a}$ and $\vec{b}$, then the angle between $\vec{a}$ and $-\vec{b}$ will be ($180^o - \theta$), as shown in figure.



$\therefore \quad |\vec{a} - \vec{b}| = |\vec{a} + (-\vec{b})|$

$= \sqrt{|\vec{a}|^2 + |-\vec{b}|^2 + 2|\vec{a}||-\vec{b}|\cos(180^\circ - \theta)}$

$= \sqrt{|\vec{a}|^2 + |\vec{b}|^2 - 2|\vec{a}||\vec{b}|\cos\theta}$

$\left[\because |-\vec{b}| = |\vec{b}|, \cos(180^\circ - \theta) = -\cos\theta\right]$

$|\vec{a} - \vec{b}|$ will be maximum when $\cos\theta = -1$ or $\theta = 180^o$

$\therefore |\vec{a} - \vec{b}|_{\max} = \sqrt{|\vec{a}|^2 + |\vec{b}|^2 - 2|\vec{a}||\vec{b}|\cos 180^\circ}$

$= \sqrt{(|\vec{a}| + |\vec{b}|)^2} = |\vec{a}| + |\vec{b}|$

Hence $|\vec{a} - \vec{b}| \leq |\vec{a}| + |\vec{b}|$

The equality sign is applicable when $\theta = 180°$

33. Weight of car = 1800 Kg

Distance of COG from front axle = 1.05 m

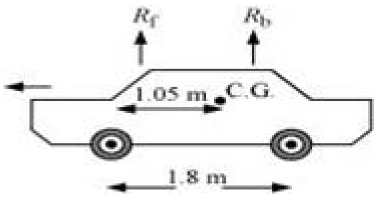
Distance of COG from back axle = 1.8 - 1.05 = 0.75 m

Vertical forces are balanced ,

So,At translational equilibrium:

$R_1 + R_2 = mg$

$R_1 + R_2 = 1800 \times 9.8 = 17640$



R_1 and R_2 are the forces exerted by the level ground on the front and back wheels respectively.

Angular momentum about centre of gravity is zero.

So,

$R_1(1.05) = R_2(1.8 - 1.05)$

$R_1 \times 1.05 = R_2 \times 0.75$
$\frac{R_1}{R_2} = \frac{0.75}{1.05} = \frac{5}{7}$
$\frac{R_1}{R_2} = \frac{7}{5}$
$R_1 = 1.4\ R_2$ …..(ii)

Solving equations (i) and (ii), we get:

$1.4\ R_2 + R_2 = 17640$

$R_2 = \frac{17640}{2.4} = 7350\text{N}$

$\therefore R_1 = 17640 - 7350 = 10290$ N

Therefore, the force exerted on each front wheel $= \frac{R_1}{2} = \frac{7350}{2} = 3675N$, and

The force exerted on each back wheel $= \frac{R_2}{2} = \frac{10290}{2} = 5145N$

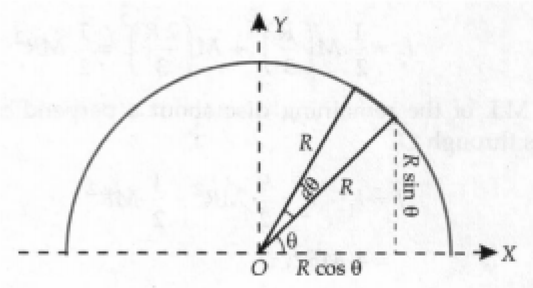
OR

Centre of mass of a uniform semicircular wire (half ring). Let M be the mass and R the radius of a uniform semicircular wire. Take its centre O as the origin, the line joining its ends as X -axis and Y -axis in its plane. We consider a small element of the wire of angular thickness d θ and its radius making an angle θ with the X -axis. Then the length of this element will be $Rd\theta$.

Mass per unit length of the wire $= \frac{M}{\pi R}$

Mass of the small element of length $Rd\theta$

$dm = \frac{M}{\pi R} \times Rd\theta = \frac{M}{\pi} d\theta$



By symmetry, the x-coordinate of the semicircular wire be zero.

$x_{CM} = 0$

The y-coordinate of the centre of mass will be

$y_{CM} = \frac{1}{M} \int ydm = \frac{1}{M} \int_0^{\pi} R \sin\theta \times \frac{M}{\pi} d\theta$
$= \frac{R}{\pi} \int_0^{\pi} \sin\theta d\theta = -\frac{R}{\pi} [\cos\theta]_0^{\pi}$
$= -\frac{R}{\pi} [-1 - 1] = \frac{2R}{\pi}$

Hence, the centre of mass lies at $\left(0, \frac{2R}{\pi}\right)$