SAMPLE PAPER - 10

Class 11 - Physics

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

General Instructions:

1. There are 35 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 eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 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. In a direct impact, loss in kinetic energy is given by $\Delta K=\frac{M_1 M_2}{2(M_1+M_2)} \cdot (V_1-V_2)^2\left(1-k^2\right)$ with usual notations (except k). The quantity k will have a dimensional formula. **[1]**

   a) $[MLT^{-1}]$ b) $[M^0L^0T^0]$

   c) $[M^0L^2T^{-2}]$ d) $[M^0LT^{-1}]$

2. When a constant force is applied to a body moving with constant acceleration, power does not remain constant. For power to be constant, the force has to vary with speed as follows: **[1]**

   a) $F \propto v^2$ b) $F \propto \frac{1}{v}$

   c) $F \propto \frac{1}{\sqrt{v}}$ d) $F \propto v$

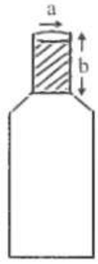
3. The moment of inertia of a body about a given axis is 1.2 kg $\times$ m^2. Initially, the body is at rest. In order to produce a rotational KE of 1500 joule, an angular acceleration of 25 rad/sec^2 must be applied about that axis for a duration of: **[1]**

   a) 4 s b) 2 s

   c) 8 s d) 10 s

4. A bottle has an opening of radius a and length b. A cork of length b and radius (a + Δa) where (Δa < < a) is compressed to fit into the opening completely (see figure). If the bulk modulus of cork is B and the frictional **[1]**

coefficient between the bottle and cork is μ then the force needed to push the cork into the bottle is:



a) $(2\pi\mu Bb)\Delta a$

b) $(4\pi\mu Bb)\Delta a$

c) $(\pi\mu Bb)a$

d) $(\pi\mu Bb)\Delta a$

5. The radius of a planet is $\frac{1}{4}$ of the earth's radius and its acceleration due to gravity is double that of the earth's acceleration due to gravity. How many times will the escape velocity at the planet's surface be as compared to its value on the earth's surface? **[1]**

a) 2

b) $\sqrt{2}$

c) $\frac{1}{\sqrt{2}}$

d) $2\sqrt{2}$

6. Two balloons are filled, one with pure He gas and other by air, respectively. If the pressure and temperature of these balloons are same, then the number of molecules per unit volume is: **[1]**

a) more in the He filled balloon

b) in the ratio of 1 : 4

c) more in air filled balloon

d) same in both balloons

7. An ideal gas A and a real gas B have their volumes increased from V to 2V under isothermal conditions. The increase in internal energy: **[1]**

a) will be same in both A and B

b) will be zero in both the cases

c) of B will be more than that of A

d) of A will be more than that of B

8. A uniform wire 20 metres long and weighing 50 newton hangs vertically. If g = 10 metres/sec^2, then the speed of the transverse wave at the middle point of the wire is: **[1]**

a) zero

b) 4 m/s

c) $10\sqrt{2}$ m/s

d) 10 m/s

9. A balloon of volume 1500 m^3 and weighing 1650 kg with all its equipment is filled with helium (density 0.2 kg/m^3). If the density of air is 1.3 kg/m^3, the pull on the rope tied to the balloon will be: **[1]**

a) 16.5 kg

b) zero

c) 300 kg

d) 1950 kg

10. A body weighs 72 N on the surface of the earth. What is the gravitational force on it, at a height equal to half the radius of the earth? **[1]**

a) 24 N

b) 30 N

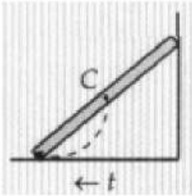
c) 48 N

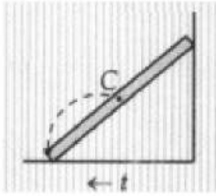
d) 32 N

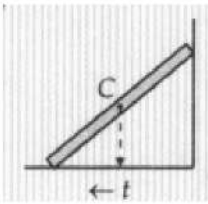
11. A ladder is leaned against a smooth wall and it is allowed to slip on a frictionless floor. Which figure represents trace of its centre of mass? **[1]**

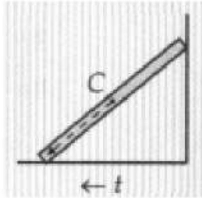
a)

b)





c) 

d) 

12. Three vessels of equal capacity have gases at the same temperature and pressure. The first vessel contains neon (monatomic), the second contains chlorine (diatomic), and the third contains uranium hexafluoride (polyatomic). The number of molecules: **[1]**

a) is the greatest in the vessel with uranium hexafluoride
b) is the greatest in the vessel with neon
c) is the same in all three vessels
d) is the greatest in the vessel with chlorine

13. A wave is propagating along x-axis and another wave is propagating along y-axis. If they superimpose each other, the initial phase between two waves is $\frac{\pi}{2}$ the resultant wave will be: **[1]**

a) Elliptical
b) Parabolic
c) Straight line
d) Circular

14. A monoatomic gas at a pressure P, having a volume V expands isothermally to a volume 2 V and then adiabatically to a volume 16F. The final pressure of the gas is : (Take $\gamma = \frac{5}{3}$) **[1]**

a) 64 P
b) $\frac{P}{64}$
c) 32 P
d) 16 P

15. If a person with a spring balance and a body hanging from it go up and up in an airplane, then the reading of the weight of the body as indicated by the spring balance will: **[1]**

a) go on decreasing
b) go on increasing
c) remain the same
d) first, increase and then decrease

16. **Assertion (A):** A cyclist always bends inwards while negotiating a curve. **[1]**
Reason (R): By bending he lowers his centre of gravity.

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.

17. **Assertion:** Spring balances show wrong readings after they had been used for a long time. **[1]**
Reason: On using for long time, spring balances loses its elastic strength.

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.

18. **Assertion (A):** The kinetic energy, with any reference, must be positive. **[1]**

Reason (R): In the expression for kinetic energy, the velocity appears with power 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.

Section B

19. Calculate the angle of **[2]**

i. 1^o (degree)

ii. 1' (minute of arc or arcmin) and

iii. 1" (second of arc or arc second) in radians.

Use $360^o = 2\pi$ rad, 1^o = 60' and 1' = 60".

20. A pull of 15 N is applied to a rope attached to a block of mass 7 kg lying on a smooth horizontal surface. The mass of the rope is 0.5 kg. What is the force exerted by the block on the rope? **[2]**

21. Show that an artificial satellite circling around the earth in an orbit of radius obeys Kepler's third law. **[2]**

OR

The sun attracts all bodies on the earth. At midnight, when the sun is directly below, it pulls on a body in the same direction as the pull of the earth on that body; at noon, when the sun is directly above, it pulls on a body in a direction opposite to the pull of the earth. Then will the weight of the body be greater at mid-night than at noon?

22. A wire is cut to half its original length. **[2]**

i. How would it affect the elongation under a given load?

ii. How does it affect the maximum load it can support without exceeding the elastic limit?

23. Calculate the number of degrees of freedom of molecules of hydrogen in 1 cc of hydrogen gas at NTP. **[2]**

OR

Derive the Boyle's law using kinetic theory of gases.

24. The displacement x of a particle moving in one dimension under the action of constant force is related to the time by the equation $t = \sqrt{x} - 3$ where x is in meters and t is in seconds. Find the velocity of the particle at **[2]**

1. t = 3s
2. t = 6s.

25. A hunter has a machine gun that can fire 50 g bullets with a velocity of 150 ms^{-1}. A 60 kg tiger springs at him with a velocity of 10 ms^{-1}. How many bullets must the hunter fire into the tiger in order to stop him in track? **[2]**

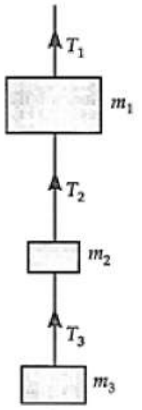
Section C

26. What amount of heat must be supplied to 2.0×10^{-2} kg of nitrogen (at room temperature) to raise its temperature by 45 °C at constant pressure? (Molecular mass of N_2 = 28; R = 8.3 J mol^{-1} K^{-1}.) **[3]**

27. The masses m_1, m_2 and m_3 of the three bodies shown in figure are 5, 2 and 3 kg respectively. Calculate the values of the tensions T_1, T_2 and T_3 when **[3]**

i. the whole system is going upward with an acceleration of 2 ms^{-2} and

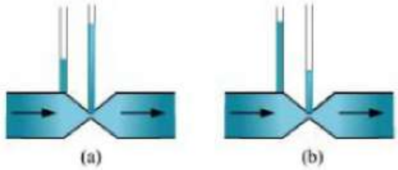
ii. the whole system is stationary. Given g = 9.8 ms^{-2}.



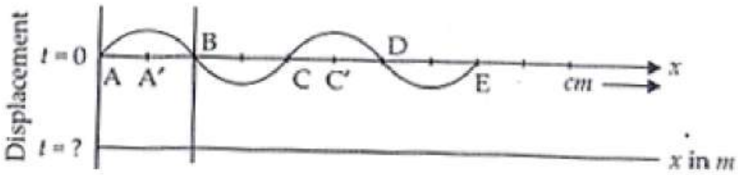
28. Find the work done in breaking a water drop of radius 1 mm into 1000 drops. Given the surface tension of water is 72×10^{-3} N/m? **[3]**

OR

Figures (a) and (b) refer to the steady flow of a (non-viscous) liquid. Which of the two figures is incorrect? Why?



29. The pattern of standing waves formed on a stretched string at two instants of time is shown in Figure. The velocity of two waves super-imposing to form stationary waves is 360 $ms^{-1}$and their frequencies are 256 Hz. **[3]**



a. Calculate the time at which the second curve is plotted.

b. Mark nodes and antinodes on the curve.

c. Calculate the distance between A′ and C ′.

OR

From the equation y - A sin $\frac{2\pi}{\lambda}(vt - x)$, establish the relation between particle velocity and wave velocity.

30. Give the Newton's law of cooling. Derive Newton's law of cooling using Stefan's law. **[3]**

Section D

31. Plot the corresponding reference circle for each of the following simple harmonic motions. Indicate the initial (t = 0) position of the particle, the radius of the circle, and the angular speed of the rotating particle. For simplicity, the sense of rotation may be fixed to be anticlockwise in every case: (x is in cm and t is in s). **[5]**

a. x = -2 sin (3t + $\frac{\pi}{3}$)

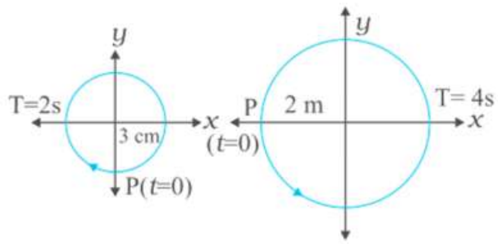
b. x = cos ($\frac{\pi}{6}$ – t)

c. x = 3 sin (2πt + $\frac{\pi}{4}$)

d. x = 2 cos πt

OR

In figures correspond to two circular motions. The radius of the circle, the period of revolution, the initial position, and the sense of revolution (i.e. clockwise or anti-clockwise) are indicated on each figure.



Obtain the corresponding simple harmonic motions of the *x*-projection of the radius vector of the revolving particle P, in each case.

32. A projectile is fired horizontally with a velocity of 98 ms^{-1} from the hill 490 m high. Find **[5]**

i. time taken to reach the ground

ii. the distance of the target from the hill and

iii. the velocity with which the projectile strikes the ground.

OR

A fighter plane is flying horizontally at an altitude of 1.5 km with a speed of 720 km/h. At what angle of sight (w.r.t horizontal) when the target is seen, should the pilot drop the bomb in order to attack the target?

<u>Main concept used:</u> u = 720 km/h = $720 \times \frac{5}{18}$ m/s = 200m/s

33. Find the centre of mass of a uniform **[5]**

i. half-disc,

ii. quarter-disc.

OR

a. A cat is able to land on its feet after a fall. Why?

b. If angular momentum moment of inertia is decreased, will its rotational K.E. be also conserved? Explain.

Section E

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

2 friends started for a picnic spot, in two different cars. A drove his car at a constant velocity 60 km/h. B drove his car at a constant velocity 50 km/h.

The velocity of B relative to A is v_B- v_A

Similarly, the velocity of object A relative to object B is v_A-v_B

Their friend C was supposed to wait at a point on the road for a lift. Both of them forgot to pick up C. A and B reached the picnic spot within 2 hours and 2 hours 24 minutes respectively.

(i) What was the velocity of B relative to A?

(ii) What is the velocity of A relative to B?

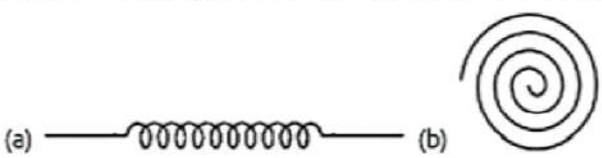
(iii) What are the velocities of A and B relative to C?

OR

Draw the Velocity vs. time plot for A?

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

There are many types of spring. Important among these are helical and spiral springs as shown in the figure.



Usually, we assume that the springs are massless. Therefore, work done is stored in the spring in the form of the elastic potential energy of the spring. Thus, the potential energy of a spring is the energy associated with the state of compression or expansion of an elastic spring.

(i) When the potential energy of a spring may be considered as zero?

(ii) The ratio of spring constants of two springs is 2 : 3. What is the ratio of their potential energy, if they are stretched by the same force?

(iii) The potential energy of a spring increases by 15 J when stretched by 3 cm. If it is stretched by 4 cm, What will be the increase in potential energy?

OR

The potential energy of a spring when stretched through a distance x is 10 J. What is the amount of work done on the same spring to stretch it through an additional distance x?

Solution

SAMPLE PAPER - 10

Class 11 - Physics

Section A

1. **(b)** $[M^0L^0T^0]$

   Explanation: It is clear that k should be dimensionless i.e.,

   $[1 - k^2] = M^0L^0T^0$

   Hence, $[k] = M^0L^0T^0$

2. **(b)** $F \propto \frac{1}{v}$

   Explanation: As a = $\frac{dv}{dt} = \frac{F}{m}$ = constant, hence on integration, we get;

   v = $\frac{F}{m}t$

   So, power, P = Fv = $\frac{F^2}{m}t$

   i.e., $P \propto t$

   For pow er to be constant, Fv = constant, i.e., $F \propto \frac{1}{v}$

3. **(b)** 2 s

   Explanation: $K_R = \frac{1}{2}I\omega^2 = \frac{1}{2}I(\alpha t)^2 = -\frac{1}{2}I\alpha^2t^2$

   $1500 = \frac{1}{2} \times 12 \times (25)^2t^2$

   or r^2 = 4 or t = 2s

4. **(b)** $(4\pi\mu Bb)\Delta a$

   Explanation: Stress = $\frac{\text{Normal force}}{\text{Area}} = \frac{N}{A} = \frac{N}{(2pa)b}$

   Stress = B $\times$ strain

   $\frac{N}{(2pa)b} = B\frac{2paDa'b}{pa^2b}$

   N = $B\frac{(2pa)^2Dab^2}{pa^2b}$

   Force needed to push the cork.

   f = mN = m4pbDaB = $(4\pi\mu Bb)\Delta a$

5. **(c)** $\frac{1}{\sqrt{2}}$

   Explanation: $V_s = \sqrt{2gR}$

   $\frac{V_{S_1}}{V_{S_2}} = \sqrt{\frac{g_1R_1}{g_2R_2}} = \sqrt{\frac{(2g)(R/4)}{(g)R}} = \frac{1}{\sqrt{2}}$

   $V_{S_1} = \frac{V_{S_2}}{\sqrt{2}}$

6. **(d)** same in both balloons

   Explanation: Assuming the balloons have the same volume, as PV = nRT, if P, V and T are the same, n, the number of moles present will be the same, whether it is He or air. Hence, number of molecules per unit volume will be same in both the balloons.

7. **(b)** will be zero in both the cases

   Explanation: There will be no change in the internal energy of the ideal gas. But for the real gas, the increase in internal energy takes place because of the work done against the intermolecular forces.

8. **(d)** 10 m/s

   Explanation: From the question 28, v = $\sqrt{\frac{T}{m}}$

   Weight of wire = 50 N,

   Mass of wire = (50/10) = 5 kg

   and length = 20 m

   $\therefore$ m = (5/20) = 0.25 kg/m

   At the middle point T = 25 N

   $\therefore$ v = $\sqrt{\frac{T}{m}}$ = $\sqrt{\frac{25}{0.25}}$ = $\sqrt{100}$

   = 10 m/s

9. **(b)** zero

Explanation: Let W = weight of the balloon and the weight of helium acting vertically downwards

F = upward force due to displaced air

T = pull on the rope

Then, T + W = F ...(i)

Now, W = 1650 + 1500 $\times$ 0.2 = 1650 + 300 = 1950 kg

and F = 1500 $\times$ 1.3 = 1950 kg

$\therefore$ T = F - W = 1950 - 1950 = 0

10. **(d)** 32 N

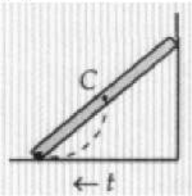
Explanation: $W_S = Mg_h = 72$ N

$W_S = Mg_h = \frac{mg_s}{\left(1+\frac{h}{R}\right)^2}$

$= \frac{72N}{\left(1+\frac{\frac{R}{2}}{2}\right)} = \frac{72}{\frac{9}{4}}$

$W_H = 32$ N

11. **(a)**



Explanation: The centre of mass remains at the centre of the ladder. Hence Fig. (a) represents the correct trace of CM.

12. **(c)** is the same in all three vessels

Explanation: Avogadro's law states that "equal volumes of all gases, at the same temperature and pressure, have the same number of molecules".

13. **(d)** Circular

Explanation: Circular

14. **(b)** $\frac{P}{64}$

Explanation: First, isothermal expansion

PV = P'(2V) (For isothermal process, PV = constant)

$P' = \frac{P}{2}$

Then, adiabatic expansion

$P'(2V)^\gamma = P_f(16V)^\gamma$ (For adiabatic process, PV^γ = constant)

$\frac{P}{2}(2V)^{5/3} = P_f(16V)^{5/3}$

$P_f = \frac{P}{2}\left(\frac{2V}{16V}\right)^{5/3} = \frac{P}{2}\left(\frac{1}{8}\right)^{5/3} = \frac{P}{2}\left(\frac{1}{2^3}\right)^{5/3}$

$= \frac{P}{2}\left(\frac{1}{2^5}\right) = \frac{P}{64}$

15. **(a)** go on decreasing

Explanation: Initially, due to upward acceleration apparent weight of the body increases but then it decreases due to a decrease in gravity.

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

Explanation: By bending the cyclist obtains the necessary centripetal force. Though he also lowers his centre of gravity by bending, but it is not the correct explanation of assertion given in the question. Hence, both A and R are true but R is not the correct explanation of A.

17. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.

Explanation: Assertion and reason both are correct statements and reason is correct explanation for assertion.

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

Explanation: We know that the kinetic energy of a body is represented as $K = \frac{1}{2}mv^2$.

Here m represents the mass of the body that is taken into consideration and v is the velocity of the body.

Now it is known to us that the mass of a body is defined as the inertia of the body or the resistance that the body will show under a situation that demands a change in its motion. Hence we can say that the mass of the body cannot be negative in nature. So the only quantity in the formula of kinetic energy that is left out is the velocity. So it is the velocity that has to be positive or negative. But in the formula, as we can see that the velocity is in the square form.

It is known to us that the square of a positive as well as negative quantity is always positive. Hence the value of velocity is positive.

So we can say that kinetic energy is always positive.

Therefore, both assertion and reason are correct and the reason is the correct explanation of the assertion.

Section B

19. i. As $360^o = 2\pi$ rad

$\therefore 1^o = \frac{2\pi}{360} = 1.745 \times 10^{-2}$ rad

ii. $1^o = 60' = 1.745 \times 10^{-2}$ rad

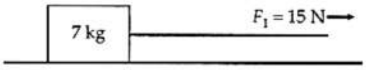
$\therefore 1' = 2.908 \times 10^{-4} \approx 2.91 \times 10^{-4}$ rad

iii. $1' = 60'' = 2.908 \times 10^{-4}$ rad

$\therefore 1'' = 4.847 \times 10^{-6}$ rad $\approx 4.85 \times 10^{-6}$ rad

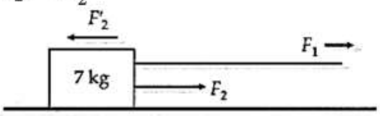
20. The situation is shown in figure. If acceleration a is produced in the block on applying a force of 15 N, then

$(7 + 0.5)a = 15$ or $a = \frac{15}{7.5} = 2$ ms^{-2}



As shown in figure, let F_2 be the force exerted by the block on the rope and F_2' be reaction of the rope on the block. According to Newton's third law of motion,

$F_2 = F_2'$



As F_2' is the only force acting on the block which has an acceleration of 2 ms^{-2}, so

$F_2 = F_2' = 7 \times 2 = 14$ N

21. Orbital velocity of a satellite is

$v = \sqrt{\frac{GM}{r}}$

Where M is the crass of earth

Time period of satellite $T = \frac{2\pi r}{v}$

$T = \sqrt{\frac{GM}{r}}$

$\mathrm{T} = 2\pi\sqrt{\frac{r^3}{GM}}$

$\mathrm{T}^2 = \frac{4\pi^2 r^3}{GM}$

$\frac{4\pi^2}{GM} = \mathrm{R}(\text{ constant })$

Thus $T^2 \propto r^3$

Hence proved.

OR

No, earth is a satellite of sun. Anybody placed on earth is also the satellite of sun. The body and the earth both will have the same acceleration towards the sun. Hence there will be no relative sun's gravitational acceleration between the body and the earth. That is, a body placed on earth will experience no gravitational effect due to the sun. It will experience a gravitational force only due to the earth. This will be weight of the body measured on the earth and will remain same for all the twenty-four hours.

22. Young's modulus, $Y = \frac{F}{A} \cdot \frac{l}{\Delta l}$

i. $\Delta l = \frac{F}{A} \cdot \frac{l}{Y}$ i.e., $\Delta l \propto l$

So when the wire is cut half to its original length, the extension is halved.

ii. Maximum load, $F = \frac{Y A \Delta l}{l}$

Here Y and A are constant. When the wire is cut to half its original length, there is no change on the value of $\frac{\Delta l}{l}$. Hence there is no effect on the maximum load.

23. Hydrogen molecule is diatomic so it has 3 translational degree of freedom and 2 rotational.

So degree of freedom in H_2 molecule = 3 + 2 = 5

For number of molecule in 1 cc

22.4 lit = 22400 cc H_2 gas at STP ahs = 6.023×10^{23}

1 cc H_2 gas at STP has $= \frac{6.023}{22400} \times 10^3$ molecule = 2.688×10^{19}

So total degree of freedom = $5 \times 2.688 \times 10^{19}$

$= 13.440 \times 10^{19} = 1.344 \times 10^{20}$

OR

According to Boyle's law, temperature remaining constant, the volume v of a given mass of a gas is inversely proportional to the pressure P i.e. PV = constant.

Now, according to kinetic theory of gases, the pressure exerted by a gas is given by:-

P = Pressure

V = Volume

$\overline{V}$ = Average Velocity

m = Mass of 1 molecule

N = No. of molecules

M = mN (Mass of gas)

$P = \frac{1mN\overline{V}^2}{3V}$

$P_V = \frac{1}{3}M\overline{V}^2$

24. Here, $t = \sqrt{x} - 3$

$\sqrt{x} = t + 3$

x = $(t + 3)^2$

i. $v = \frac{dx}{dt} = 2(t + 3)$

At t = 3 s, $v = 2(3 + 3) = 12m/s$

ii. At t = 6 s, $v = 2(6 + 3) = 18m/s$

25. Mass of bullet, m = 50 g = 0.05 kg

Velocity of bullet, v = 150 ms^{-1}

Mass of tiger, M = 60 kg

Velocity of tiger, V = 10 ms^{-1}

Let n be the number of bullets required to be pumped into the tiger to stop him in his track.

According to the law of conservation of momentum,

Magnitude of the momentum of n bullets

= Magnitude of the momentum of tiger

or n $\times$ mv = MV or $n = \frac{MV}{mv} = \frac{60 \times 10}{0.05 \times 150}$ = 80.

Section C

26. Mass of nitrogen, m = 2.0×10^{-2} kg = $2.0 \times 10^{-2} \times 1000$ = 20 g

Increase in temperature of gas = ΔT = 45°C

Molecular mass of nitrogen = M = 28 gram gas constant, R = 8.3 J mol^{-1} K^{-1}

if m is mass of gas in grams

Number of moles = n = $\frac{m}{M}$

n = $\frac{2.0 \times 10^{-2} \times 10^3}{28}$ = 0.714

Molar specific heat at constant pressure for nitrogen, $C_P = \frac{7}{2}R$

= $\frac{7}{2} \times 8.3$

= 29.05 J $mol^{-1}K^{-1}$

by heat formula :

$\Delta Q = nC_p\Delta T$

= $0.714 \times 29.05 \times 45$

= 933.38 J

So 933.38 J is the amount of heat required to increase the temperature by 45^0C.

27. i. The three bodies together are moving upward with an acceleration of 2 ms^{-2}. The force pulling the system upward is T_1 and the downward force of gravity is $(m_1 + m_2 + m_3)g$.

According to Newton's second law,

$T_1 - (m_1 + m_2 + m_3)g = (m_1 + m_2 + m_3)a$

or $T_1 = (m_1 + m_2 + m_3)(a + g)$

$= (5 + 2 + 3)(2 + 9.8) = 10 \times 11.8$

= 118 N

Similarly, for the motion of the system $m_2 + m_3$, we can write

$T_2 = (m_2 + m_3)(a + g)$

$= (2 + 3)(2 + 9.8) = 5 \times 11.8$

= 59 N

For the motion of body of mass m_3, we have

$T_3 = m_3(a + g) = 3(2 + 9.8)$

= 35.4 N

ii. When the whole system is stationary, a = 0. From the above equations, we get

$T_1 - (m_1 + m_2 + m_3)g = 10 \times 9.8 = 98$ N

$T_2 = (m_2 + m_3)g = 5 \times 9.8 = 49$ N

$T_3 = m_3 g = 3 \times 9.8 = 29.4$ N

28. Initial Radius = R = 10^{-3} m (= 1 mm)

Final Radius = r

Since 1 drop breaks into 1000 small droplets, so

Initial volume = 1000 × Final Volume

$\frac{4}{3}\pi R^3 = 1000 \times \frac{4}{3}\pi r^3$

$R^3 = 10^3 r^3$

$r^3 = \frac{R^3}{10^3}$

On, taking cube root on both sides, $r = \frac{R}{10} \rightarrow 1)$

Initial Surface Area $= 4\pi R^2$

$= 4 \times \frac{22}{7} \times \left(10^{-3}\right)^2$

$= 4 \times \frac{22}{7} \times 10^{-5}\text{m}^2 \rightarrow 2)$

Final Surface Area $= 1000 \times \left(4\pi r^2\right)$

$= 1000 \times 4 \times \frac{22}{7} \times \left(\frac{10^{-3}}{10}\right)^2$ $r = \frac{R}{10}$) form eq ^{4} 1)

$= 4 \times \frac{22}{7} \times 10^{-3} \times 10^{\frac{1}{3}}$

$= 4 \times \frac{22}{7} \times 10^{-5}$ -3)

Increase in Surface Area = Final surface Area – Initial surface Area

$= 4 \times \frac{22}{7} \times 10^{-5} - 4 \times \frac{22}{7} \times 10^{-5}$ $(\rightarrow 4)$

as definition of surface energy says it is the energy associated with the intermolecular forces at the interface between two media.

Now, work Done = Surface Tension × Increase in surface Area

$= 72 \times 10^{-3} \times \left(4 \times \frac{22}{7} \times 10^{-5} - 4 \times \frac{22}{7} \times 10^{-5}\right)$ (from eq^4 4)

$= 72 \times 4 \times \frac{22}{7} \times 10^{-3}\left(10^{-5} - 10^{-6}\right)$

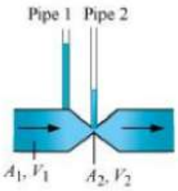
$= 72 \times 4 \times \frac{22}{7} \times 10^{-3} \times 10^{-5}\left(1 - 10^{-1}\right)$

Work Done $= 72 \times 4 \times \frac{22}{7} \times 10^{-5}\left(1 - \frac{1}{10}\right)$

$= 72 \times 4 \times \frac{22}{7} \times 10^{-3} \times \frac{9}{10}$

Work Done = 8.14×10^{-6}J

OR



Take the case given in figure (b).

Where, $A_1 \Rightarrow$ Area of pipe 1

$A_2 \Rightarrow$ Area of pipe 2

$V_1 \Rightarrow$ Speed of the fluid in pipe 1

$V_2 \Rightarrow$ Speed of the fluid in pipe 2

From the equation of continuity, we have:

$A_1V_1 = A_2V_2$

As the area of cross-section in the middle of the venturi meter is small,
the speed of the flow of liquid through this part should be more.
According to Bernoulli's principle for a flow in uniform horizontal tube, $P+\frac{1}{2}\rho v^2$ = constant
Thus if speed is more, the pressure should be less.
pressure is directly proportional to height of liquid column. Hence, the level of water in pipe 2 is less.
Therefore, figure (a) is not possible.

29. Given, frequency of the wave v = 256 Hz
Time period $T=\frac{1}{v}=\frac{1}{256}s=3.9\times10^{-3}=s$
   i. Time is taken to pass through mean position is
   $t=\frac{T}{4}=\frac{1}{40}=\frac{3.9\times10^{-3}}{4}s \ =9.8\times10^{-4}s$
   ii. Nodes are A, B, C, D, E (i.e., zero displacements)
   Antinodes are A', C' (i.e., maximum displacement)
   iii. It is clear from the diagram A' and C' are consecutive hence separation = wavelength (λ)
   $=\frac{v}{v}=\frac{360}{256}=1.41\mathrm{m}$

OR

The velocity with which the wave travels in space is called the wave velocity , whereas particle velocity is the velocity with which the particles are vibrating to transfer the energy in form of a wave. The relation between wave velocity and particle velocity is given as:

The given wave equation is y = A sin $\frac{2\pi}{\lambda}(vt-x)$ = A sin $\left(\frac{2\pi v}{\lambda}t-\frac{2\pi}{\lambda}x\right)$

or y = A sin (ωt - kx),

because $2\pi\frac{v}{\lambda}=2\pi v$ = ω = angular frequency

and $\frac{2\pi}{\lambda}$ = k = propogation constant.

$\therefore$ particle velocity $\frac{dy}{dt}$ =$\frac{dA\sin(wt-kx)}{dt}$ =A ω cos (ωt - kx)

and $\frac{dy}{dx}$ =$\frac{dA\sin(wt-kx)}{dx}$ = -AK cos (ωt - kx)

$\therefore$ wave velocity v = $\frac{dx}{dt}$ = ($\frac{dy}{dt}$. $\frac{-dx}{dy}$) = $\frac{\omega}{k}$

Hence we conclude that particle velocity $\frac{dy}{dt}$ = (-$\frac{dy}{dx}$) $\times$ wave velocity

Here $\frac{dy}{dx}$ is the slope of displacement position graph for given wave motion.

$\therefore$ Particle velocity = - (slope of displacement - position graph) $\times$ wave velocity.

30. Newton's law of cooling states that the rate of heat loss of a body is directly proportional to the difference in the temperatures between the body and its surroundings.
Newton's law of cooling can be obtained from Stefan's law as given below:
If a hot body of surface area A is maintained at a temperature T and the surroundings be at temperature T_0, then, as per Stefan's law, energy radiated by the hot body per unit surface area per unit time is
$E=\sigma\left(T^4-T_0^4\right)$ where σ is Stefan's constant
$\therefore$ The total rate of loss of heat energy is given by
$-\frac{dQ}{dt}$ = $EA=\sigma A\left(T^4-T_0^4\right)$
Let T = T_0 + ΔT, where ΔT is small as compared to T_0, then

$-\frac{dQ}{dt} = \sigma A\left[(T_o + \triangle T)^4 - T_o^4\right]$

$-\frac{dQ}{dt} = \sigma A T_0^4\left[(1 + \frac{\Delta T}{T_0})^4 - 1\right]$

$-\frac{dQ}{dt} = \sigma A T_0^4\left[1 + 4 \cdot \frac{\Delta T}{T_0} - 1\right]$

$= 4\sigma A T_0^3 \cdot \Delta T$

As $4\sigma A T_0^3$ is a constant quantity (say k), we can write the above relation as :-

$-\frac{dQ}{dt} = k.\Delta T$ or $-\frac{dQ}{dt} = k(T - T_0)$

which states Newton's law of cooling.

Section D

31. a. $x = 2\cos\left(3t + \frac{\pi}{3} + \frac{\pi}{2}\right)$

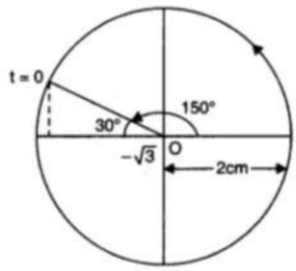
Radius of the reference circle, r = amplitude of SHM = 2 cm,

At t = 0, $x = -2\sin\frac{\pi}{3} = \frac{-2\sqrt{3}}{2} = -\sqrt{3}$ cm

Also $\omega t = 3t \therefore \omega = 3$ rad/s

$\cos\phi_0 = -\frac{\sqrt{3}}{2}$, $\phi_0 = 150^o$

The reference circle is, thus, as plotted below.



b. $x = \cos\left(t - \frac{\pi}{6}\right)$

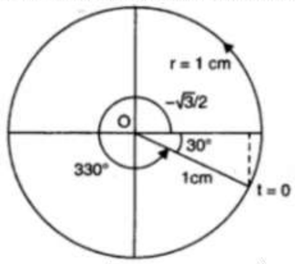
Radius oif circle, r = amplitude of SHM = 1 cm.

At t = 0, $x = \cos\frac{\pi}{6} = \frac{\sqrt{3}}{2}$ cm

Also $\omega t = 1t \Rightarrow \omega = 1$ rad/s

$\cos\phi_0 = \frac{\sqrt{3}}{2}, \quad \phi_0 = -\frac{\pi}{6}$

The reference circle is, thus as plotted below.



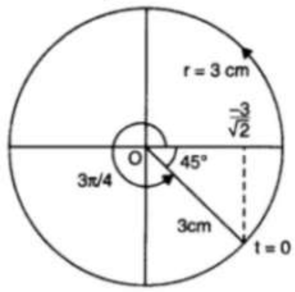
c. $x = 3\cos\left(2\pi t + \frac{\pi}{4} + \frac{\pi}{2}\right)$

Here, radius of reference circle, r = 3 cm and at t = 0, $x = 3\sin\frac{\pi}{4} = \frac{\sqrt{3}}{2}$ cm

$\omega t = 2\pi t \Rightarrow \omega = 2\pi$ rad/s

$\cos\phi_0 = \frac{\frac{\sqrt{3}}{2}}{3} = -\frac{1}{\sqrt{2}}$

Therefore, the reference circle is being shown below.



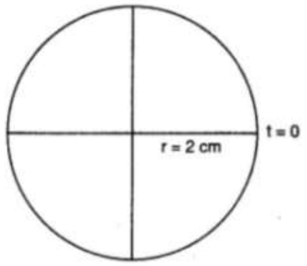
d. $x = 2\cos\pi t$

Radius of reference circle, r = 2 cm and at t = 0, x = 2 cm

$\therefore \omega t=\pi t$ or $\omega=\pi$ rad/s

$\cos \phi_0=1, \phi_0=0$

The reference circle is plotted below.



OR

a. $\Rightarrow$ Time period is given by, T = 2 s

$\Rightarrow$Amplitude is given by, A = 3 cm

$\Rightarrow$At time, t = 0, the radius vector OP makes an angle $\frac{\pi}{2}$ with the positive x-axis, i.e., phase angle

$\Rightarrow \phi=\frac{\pi}{2}$

$\Rightarrow$ Therefore, the equation of simple harmonic motion for the x-projection of OP, at time t, is given by the displacement equation: hence

$\Rightarrow x=A \cos \left[\frac{2 \pi t}{T}+\phi\right]$

$=3 \cos \left(\frac{2 \pi t}{2}+\frac{\pi}{2}\right)=-3 \sin \left(\frac{2 \pi t}{2}\right)$

$\therefore x=-3 \sin \pi t \mathrm{cm}$

b. $\Rightarrow$ Time period is given by, T = 4 s

$\Rightarrow$Amplitude is given by , a = 2 m

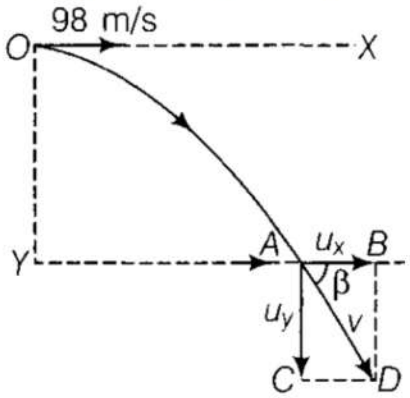
$\Rightarrow$At time t = 0, OP makes an angle π with the x-axis, in the anticlockwise direction. Hence, phase angle, $\Phi=+\pi$

$\Rightarrow$ Therefore, the equation of simple harmonic motion for the x-projection of OP, at time t, is given as below:

$\Rightarrow x=a \cos \left(\frac{2 \pi t}{T}+\phi\right)=2 \cos \left(\frac{2 \pi t}{4}+\pi\right)$

$\therefore x=-2 \cos \left(\frac{\pi}{2} t\right) m$

32. From the given figure, YO = 490 m. A body projected horizontally from O with velocity u = 98 ms^{-1} hits the ground at position A following a parabolic path as shown in the figure.



i. Let T be the time of flight of the projectile.

Taking vertical downward motion of projectile from O to A, we have

y_0 = 0, y = 490 m, u_y = 0, a_y = 9.8 m/s^2, t = T

From equation of kinematics, $y = y_0 + u_y t + \frac{1}{2} a_y t^2$

$\Rightarrow 490=0+0 \times T+\frac{1}{2} \times 9.8 \times T^2=4.9 T^2$

or $T=\sqrt{\frac{490}{4.9}}=10 \mathrm{s}$

ii. Taking horizontal motion(i.e, motion along OX axis) of projectile from O to A,we have

x_0 = 0, x = R (say), u_x = 98 m/s, t = T =10 s , a_x = 0 (as there is no acceleration along horizontal)

As, $x=x_0+u_x t+\frac{1}{2} a_x t^2$

$\therefore \quad R=0+98 \times 10+\frac{1}{2} \times 0 \times 10^2$ = 980 m

iii. Let v_x, v_y be the horizontal and vertical component velocity of the projectile at point A.

Using the relation, $v_x = u_x + a_x t = 98 + 0 \times 10 = 98$ m/s, which is represented by AB.

Similarly, $v_y = u_y + a_y t = 0 + 9.8 \times 10 = 98$ m/s as represented by AC

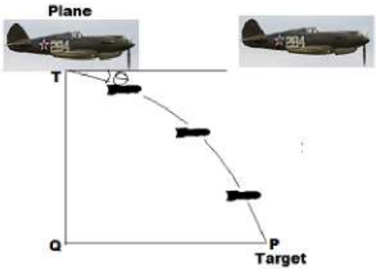
$\therefore$ The magnitude of the resultant velocity is given by

$v = \sqrt{v_x^2 + v_y^2} = \sqrt{98^2 + 98^2} = 98\sqrt{2}$ m/s

And the direction of the resultant velocity is given by

$\tan\beta = \frac{v_y}{v_x} = \frac{98}{98} = 1$ or $\beta = 45^\circ$ with the horizontal.

OR



Let the pilot drops the bomb in **t** second before the point **Q**, vertically up the target **T**.

The horizontal velocity of the bomb will be equal to the velocity of the fighter plane, but the vertical component of it is zero.

So, in time **t** bomb must cover the vertical distance **TQ** as free fall with the initial velocity zero.

Given that : $u = 0$, $H = 1.5\ km = 1500m$, $g = +10m/s^2$

By Using the equation, $H = ut + \frac{1}{2}gt^2$, we get

$1500 = 0 + \frac{1}{2}10t^2$

$t = \sqrt{\frac{1500}{5}} = \sqrt{300} = 10\sqrt{3}s$

$\therefore$ Distance covered by plane or bomb in this time **t**, is given by PQ = ut

$PQ = 200 \times 10\sqrt{3} = 2000\sqrt{3}\ m$

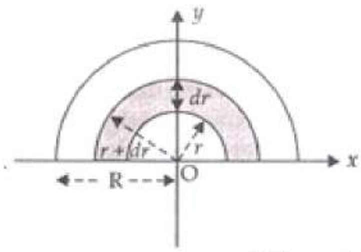
$\tan\theta = \frac{TQ}{PQ} = \frac{1500}{2000\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{15\sqrt{3}}{20\times3} = \frac{\sqrt{3}}{4}$

$\tan\theta = \frac{1.732}{4} = 0.433 = \tan^{-1}23^\circ\ 42'$

$\Rightarrow \theta = 23^\circ 42'$

Thus the bomb should be thrown at an angle $23^\circ 42'$

33. Let mass of half disc is M.



i. Area of element $= \frac{\pi}{2}\left[(r+dr)^2 - r^2\right]$

$= \frac{\pi}{2}\left[r^2 + dr^2 + 2rdr - r^2\right]$

$= \pi rdr$

$\therefore$ Mass of elementary Ring $dm = \frac{2M}{\pi R^2}.\pi rdr$

$\text{dm} = \frac{2M}{R^2}r.dr$

Let (x, y) are the co-ordinates of c.m. of this strip $(x, y) = \left(0, \frac{2r}{\pi}\right)$

$x = x_{cm} = \frac{1}{M}\int_0^R xdm = \int_0^R 0dm = 0$

$y_{cm} = \frac{1}{M}\int_0^R ydm = \frac{1}{M}\int_0^R \frac{2r}{\pi} \times \frac{2M}{R^2}rdr$

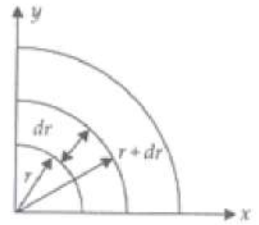
$= \frac{1}{m} \cdot \frac{4M}{\pi R^2}\int_0^R r^2dr = \frac{4}{\pi R^2}\left[\frac{r^3}{3}\right]_0^R = \frac{4}{3\pi R^2} \cdot R^3$

$y_{cm} = \frac{4R}{3\pi}$

So centre of mass of circular half disc $= \left(0, \frac{4R}{3\pi}\right)$

ii. Mass per unit area of quarter disc

$\sigma = \frac{M}{\frac{\pi R^2}{4}} = \frac{4M}{\pi R^2}$.



Area of element = $\frac{1}{2}$

dm = $\frac{1}{2}\pi r dr \times \sigma = \frac{2Mr}{R^2}dr$

$X_{cm} = \int_0^R x dm = \frac{4R}{3\pi}$

Similarly $Y_{cm} = \frac{4R}{3\pi}$

center of mass = $(\frac{4R}{3\pi}, \frac{4R}{3\pi})$

OR

a. When cat lands on the ground, it stretches its tail as a result its moment of inertia increases

As $I\omega$ = constant (In the absence of external torque,angular momentum of the system remains constant)

$\therefore$ Angular speed will be small due to increase in moment of inertia and the cat is able to land on its feet without any harm as it provides enough time for cat to land on the ground.

b. Let moment of inertia of a system decrease from I to I'

Then angular speed increase from ω to ω'

$\Rightarrow I\omega = I'\omega'$ ($\because I\omega$ = constant because in the absence of external torque angular momentum of the system remains conserved)

$\omega' = \frac{I\omega}{I'}$

Kinetic Energy of rotation of the system

$KE = \frac{1}{2}I'\omega'^2$

$KE = \frac{1}{2}I'\left(\frac{I\omega}{I'}\right)^2$

$\mathrm{K.E} = \frac{1}{2}\frac{\mathrm{I}^2\omega^2}{\mathrm{I}'}$

As I' < I

$\therefore$ Kinetic Energy of the system has increased which means it will not remain constant.

Section E

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

2 friends started for a picnic spot, in two different cars. A drove his car at a constant velocity 60 km/h. B drove his car at a constant velocity 50 km/h.

The velocity of B relative to A is v_B- v_A

Similarly, the velocity of object A relative to object B is v_A-v_B

Their friend C was supposed to wait at a point on the road for a lift. Both of them forgot to pick up C. A and B reached the picnic spot within 2 hours and 2 hours 24 minutes respectively.

(i) The velocity of B relative to A is

v_B - v_A = 50 - 60

= -10 km/h

(ii) The velocity of A relative to B is

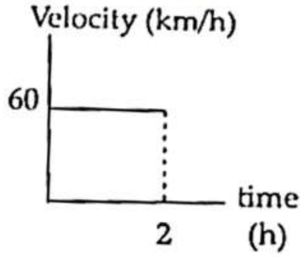
v_A - v_B = 60 - 50 = 10 km/h

(iii) Since C is in stationary position, his velocity was 0.

Hence the velocity of A relative to C is 60 - 0 = 60 km/h and the velocity of B relative to C is 50 - 0 = 50 km/h.

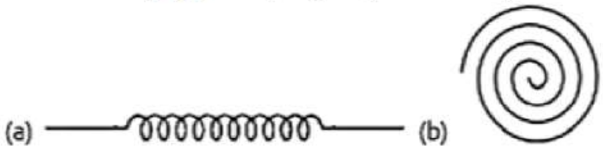
OR

Velocity time graph is as shown below



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

There are many types of spring. Important among these are helical and spiral springs as shown in the figure.



Usually, we assume that the springs are massless. Therefore, work done is stored in the spring in the form of the elastic potential energy of the spring. Thus, the potential energy of a spring is the energy associated with the state of compression or expansion of an elastic spring.

(i) It may be considered as zero, when the spring is in normal position.

(ii) $\frac{E_1}{E_2} = \frac{k_1 x_1^2}{k_2 x_2^2}$

here $x_1 = x_2$

so $\frac{E_1}{E_2} = \frac{k_1}{k_2} = \frac{2}{3}$

(iii) $\frac{E_1}{E_2} = \frac{k\ x_1^2}{k\ x_2^2}$

here $x_1 = 3$ cm and $x_2 = 4$ cm

so $\frac{E_1}{E_2} = \frac{x_1^2}{x_2^2} = \frac{9}{16}$

here $E_1 = 15$ J

so $E_2 = \frac{16}{9} \times E_1 = \frac{16}{9} \times 15 = 26.7$ J

OR

$\frac{E_1}{E_2} = \frac{kx_1^2}{kx_2^2}$

$E = \frac{1}{2}kx^2$

if distance = x, $E_1 = \frac{1}{2}kx^2 = 10$ J

on increasing the distance x more

$E_2 = \frac{1}{2}k(2x)^2 = 2kx^2$

so increase in potential energy = $E_2 - E1 = (2 - \frac{1}{2}) KX^2$

$= \frac{3}{2}Kx^2 = 3 \times \frac{1}{2}kx^2 = 3 \times 10 = 30$ Joule

so work required = 30 - 10 = 20 Joule