

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:
- 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 16V. 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.  $1^\circ$  (degree)  
ii.  $1'$  (minute of arc or arcmin) and  
iii.  $1''$  (second of arc or arc second) in radians.

Use  $360^\circ = 2\pi$  rad,  $1^\circ = 60'$  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.  $t = 3$ s  
2.  $t = 6$ s.

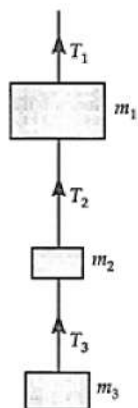
25. A hunter has a machine gun that can fire 50 g bullets with a velocity of  $150 \text{ ms}^{-1}$ . A 60 kg tiger springs at him with a velocity of  $10 \text{ ms}^{-1}$ . How many bullets must the hunter fire into the tiger in order to stop him in track? [2]

**Section C**

26. What amount of heat must be supplied to  $2.0 \times 10^{-2}$  kg of nitrogen (at room temperature) to raise its temperature by  $45^\circ\text{C}$  at constant pressure? (Molecular mass of  $\text{N}_2 = 28$ ;  $R = 8.3 \text{ J mol}^{-1} \text{ K}^{-1}$ .) [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]

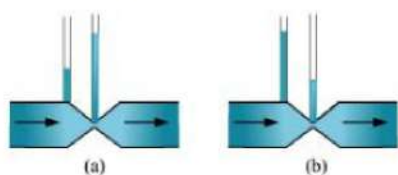
- i. the whole system is going upward with an acceleration of  $2 \text{ ms}^{-2}$  and  
ii. the whole system is stationary. Given  $g = 9.8 \text{ ms}^{-2}$ .



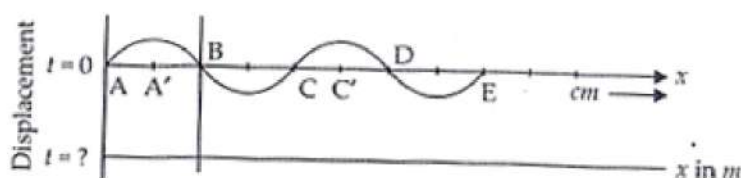
28. Find the work done in breaking a water drop of radius 1 mm into 1000 drops. Given the surface tension of water is  $72 \times 10^{-3} \text{ N/m}$  [3]

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  $360 \text{ ms}^{-1}$  and their frequencies are 256 Hz. [3]



- Calculate the time at which the second curve is plotted.
- Mark nodes and antinodes on the curve.
- 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]

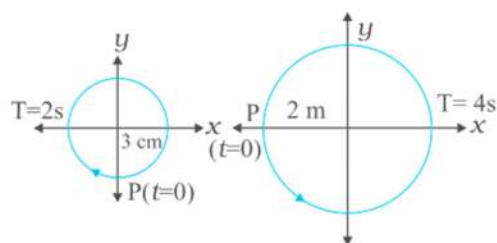
#### Section D

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]

- $x = -2 \sin (3t + \frac{\pi}{3})$
- $x = \cos (\frac{\pi}{6} - t)$
- $x = 3 \sin (2\pi t + \frac{\pi}{4})$
- $x = 2 \cos \pi t$

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  $98 \text{ ms}^{-1}$  from the hill  $490 \text{ m}$  high. Find [5]
- time taken to reach the ground
  - the distance of the target from the hill and
  - the velocity with which the projectile strikes the ground.

OR

A fighter plane is flying horizontally at an altitude of  $1.5 \text{ km}$  with a speed of  $720 \text{ km/h}$ . 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?

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

33. Find the centre of mass of a uniform [5]
- half-disc,
  - quarter-disc.

OR

- A cat is able to land on its feet after a fall. Why?
- 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  $60 \text{ km/h}$ . B drove his car at a constant velocity  $50 \text{ km/h}$ .

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.

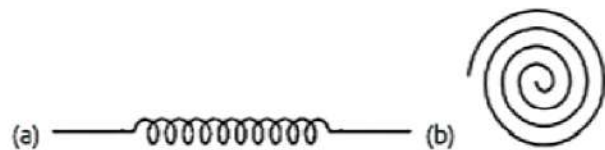
- What was the velocity of B relative to A?
- What is the velocity of A relative to B?
- What are the velocities of A and B relative to C?

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  $a = \frac{dv}{dt} = \frac{F}{m} = \text{constant}$ , 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 power to be constant,  $Fv = \text{constant}$ , i.e.,  $F \propto \frac{1}{v}$

3. **(b)** 2 s

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

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

or  $t^2 = 4$  or  $t = 2\text{s}$

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

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

Stress =  $B \times \text{strain}$

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

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

Force needed to push the cork.

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

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

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

$$\frac{V_{S_1}}{V_{S_2}} = \sqrt{\frac{g_1 R_1}{g_2 R_2}} = \sqrt{\frac{(2g)(R/4)}{(g)R}} = \frac{1}{\sqrt{2}}$$

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

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

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

At the middle point  $T = 25$  N

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

$$= 10 \text{ m/s}$$



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

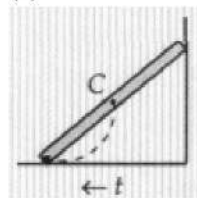
**Explanation:**  $W_S = Mg_h = 72$  N

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

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

$W_H = 32$  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,  $PV = \text{constant}$ )

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

Then, adiabatic expansion

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

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

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

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

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  $360^\circ = 2\pi \text{ rad}$

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

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

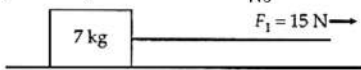
$$\therefore 1' = 2.908 \times 10^{-4} \approx 2.91 \times 10^{-4} \text{ rad}$$

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

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

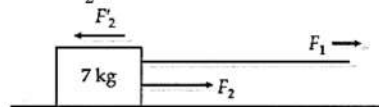
20. The situation is shown in figure. If acceleration  $a$  is produced in the block on applying a force of 15 N, then

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



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  $2 \text{ ms}^{-2}$ , so

$$F_2 = F'_2 = 7 \times 2 = 14 \text{ N}$$

21. Orbital velocity of a satellite is

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

Where  $M$  is the mass of earth

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

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

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

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

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

$$\text{Thus } T^2 \propto r^3$$

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,  $F = \frac{YA\Delta l}{l}$

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 has =  $6.023 \times 10^{23}$

1 cc  $H_2$  gas at STP has =  $\frac{6.023}{22400} \times 10^{23}$  molecule =  $2.688 \times 10^{19}$

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.  $PV = \text{constant}$ .

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

$P$  = Pressure

$V$  = Volume

$\bar{V}$  = Average Velocity

$m$  = Mass of 1 molecule

$N$  = No. of molecules

$M = mN$  (Mass of gas)

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

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

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

$$\sqrt{x} = t + 3$$

$$x = (t + 3)^2$$

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

$$\text{At } t = 3 \text{ s, } v = 2(3 + 3) = 12 \text{ m/s}$$

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

25. Mass of bullet,  $m = 50 \text{ g} = 0.05 \text{ kg}$

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

Mass of tiger,  $M = 60 \text{ kg}$

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

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

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

### Section C

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

Increase in temperature of gas =  $\Delta T = 45^\circ\text{C}$

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

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,  $C_P = \frac{7}{2}R$

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

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

by heat formula :

$$\Delta Q = nC_P \Delta T$$

$$= 0.714 \times 29.05 \times 45$$

$$= 933.38 \text{ J}$$

So 933.38 J is the amount of heat required to increase the temperature by  $45^\circ\text{C}$ .



27. i. The three bodies together are moving upward with an acceleration of  $2 \text{ ms}^{-2}$ . 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,

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

$$\text{or } T_1 = (m_1 + m_2 + m_3)(a + g)$$

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

$$= 118 \text{ N}$$

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

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

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

$$= 59 \text{ N}$$

For the motion of body of mass  $m_3$ , we have

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

$$= 35.4 \text{ N}$$

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

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

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

$$T_3 = m_3g = 3 \times 9.8 = 29.4 \text{ N}$$

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

Final Radius =  $r$

Since 1 drop breaks into 1000 small droplets, so

Initial volume = 1000  $\times$  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,  $r = \frac{R}{10} \rightarrow 1$ )

$$\text{Initial Surface Area} = 4\pi R^2$$

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

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

$$\text{Final Surface Area} = 1000 \times (4\pi r^2)$$

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

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

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

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

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

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  $\times$  Increase in surface Area

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

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

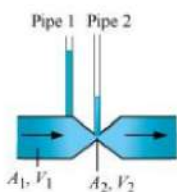
$$= 72 \times 4 \times \frac{22}{7} \times 10^{-3} \times 10^{-5} (1 - 10^{-1})$$

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

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

$$\text{Work Done} = 8.14 \times 10^{-6} \text{ J}$$

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:

$$A_1 V_1 = A_2 V_2$$

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,  $P + \frac{1}{2}\rho v^2 = \text{constant}$

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  $v = 256 \text{ Hz}$

$$\text{Time period } T = \frac{1}{v} = \frac{1}{256} \text{ s} = 3.9 \times 10^{-3} \text{ s}$$

i. Time is taken to pass through mean position is

$$t = \frac{T}{4} = \frac{1}{40} = \frac{3.9 \times 10^{-3}}{4} \text{ s} = 9.8 \times 10^{-4} \text{ s}$$

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 ( $\lambda$ )

$$= \frac{v}{v} = \frac{360}{256} = 1.41 \text{ m}$$

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:

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

$$\text{or } y = A \sin(\omega t - kx),$$

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

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

$$\therefore \text{particle velocity } \frac{dy}{dt} = \frac{dA \sin(\omega t - kx)}{dt} = A \omega \cos(\omega t - kx)$$

$$\text{and } \frac{dy}{dx} = \frac{dA \sin(\omega t - kx)}{dx} = -A k \cos(\omega t - kx)$$

$$\therefore \text{wave velocity } v = \frac{dx}{dt} = \left( \frac{dy}{dt} \cdot \frac{-dx}{dy} \right) = \frac{\omega}{k}$$

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

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

$$E = \sigma (T^4 - T_0^4) \text{ where } \sigma \text{ is Stefan's constant}$$

$\therefore$  The total rate of loss of heat energy is given by

$$-\frac{dQ}{dt} = EA = \sigma A (T^4 - T_0^4)$$

Let  $T = T_0 + \Delta T$ , where  $\Delta T$  is small as compared to  $T_0$ , then

$$\begin{aligned}
 -\frac{dQ}{dt} &= \sigma A \left[ (T_o + \Delta T)^4 - T_o^4 \right] \\
 -\frac{dQ}{dt} &= \sigma A T_o^4 \left[ \left( 1 + \frac{\Delta T}{T_o} \right)^4 - 1 \right] \\
 -\frac{dQ}{dt} &= \sigma A T_o^4 \left[ 1 + 4 \cdot \frac{\Delta T}{T_o} - 1 \right] \\
 &= 4\sigma A T_o^3 \cdot \Delta T
 \end{aligned}$$

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

$$-\frac{dQ}{dt} = k \cdot \Delta T \text{ or } -\frac{dQ}{dt} = k(T - T_o)$$

which states Newton's law of cooling.

### Section D

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

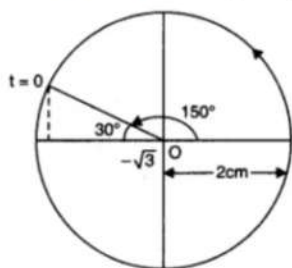
Radius of the reference circle,  $r =$  amplitude of SHM  $= 2$  cm,

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

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

The reference circle is, thus, as plotted below.



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

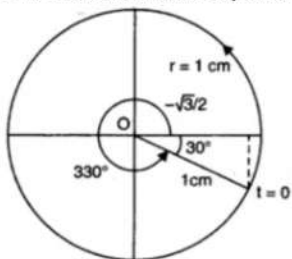
Radius of circle,  $r =$  amplitude of SHM  $= 1$  cm.

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

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

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

The reference circle is, thus as plotted below.



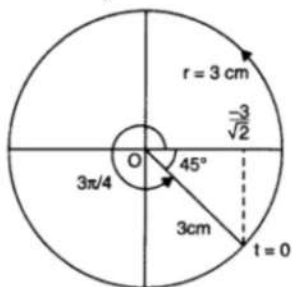
c.  $x = 3 \cos\left(2\pi t + \frac{\pi}{4} + \frac{\pi}{2}\right)$

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

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

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

Therefore, the reference circle is being shown below.



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

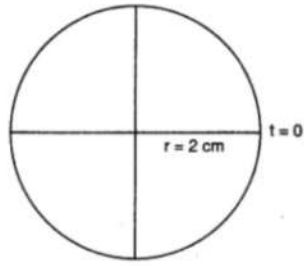
Radius of reference circle,  $r = 2$  cm and at  $t = 0$ ,  $x = 2$  cm



$$\therefore \omega t = \pi t \text{ or } \omega = \pi \text{ rad/s}$$

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

The reference circle is plotted below.



OR

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

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

$\Rightarrow$  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

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

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

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

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

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

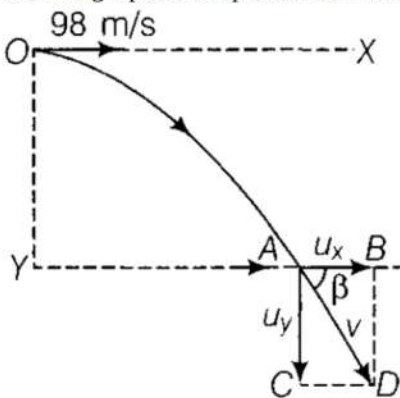
$\Rightarrow$  At time  $t = 0$ , OP makes an angle  $\pi$  with the x-axis, in the anticlockwise direction. Hence, phase angle,  $\Phi = +\pi$

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

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

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

32. From the given figure,  $YO = 490 \text{ m}$ . A body projected horizontally from O with velocity  $u = 98 \text{ ms}^{-1}$  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

$$y_0 = 0, y = 490 \text{ m}, u_y = 0, a_y = 9.8 \text{ m/s}^2, t = T$$

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

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

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

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

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

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

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

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

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

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

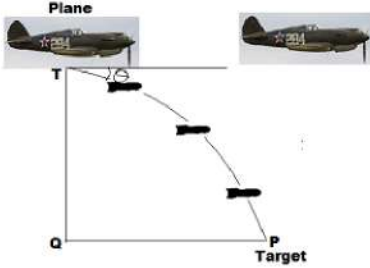
$\therefore$  The magnitude of the resultant velocity is given by

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

And the direction of the resultant velocity is given by

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

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 :  $u = 0$ ,  $H = 1.5 \text{ km} = 1500 \text{ m}$ ,  $g = + 10 \text{ m/s}^2$

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

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

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

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

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

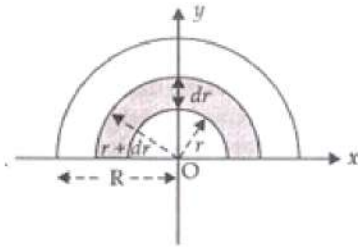
$$\tan \theta = \frac{TQ}{PQ} = \frac{1500}{2000\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{15\sqrt{3}}{20 \times 3} = \frac{\sqrt{3}}{4}$$

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

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

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

33. Let mass of half disc is  $M$ .



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

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

$$= \pi r dr$$

$$\therefore \text{Mass of elementary Ring } dm = \frac{2M}{\pi R^2} \cdot \pi r dr$$

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

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

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

$$y_{cm} = \frac{1}{M} \int_0^R y dm = \frac{1}{M} \int_0^R \frac{2r}{\pi} \times \frac{2M}{R^2} r dr$$

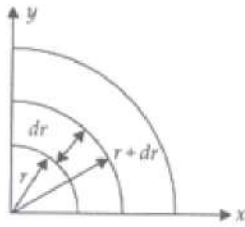
$$= \frac{1}{m} \cdot \frac{4M}{\pi R^2} \int_0^R r^2 dr = \frac{4}{\pi R^2} \left[ \frac{r^3}{3} \right]_0^R = \frac{4}{3\pi R^2} \cdot R^3$$

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

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

ii. Mass per unit area of quarter disc

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



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

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

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

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

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

OR

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

As  $I\omega = \text{constant}$  (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  $\omega$  to  $\omega'$

$\Rightarrow I\omega = I'\omega'$  ( $\because I\omega = \text{constant}$  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

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

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

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

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

$$v_B - v_A = 50 - 60$$

$$= -10 \text{ km/h}$$

(ii) The velocity of A relative to B is

$$v_A - v_B = 60 - 50 = 10 \text{ km/h}$$

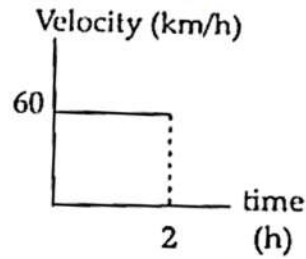
(iii) Since C is in stationary position, his velocity was 0.

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

OR

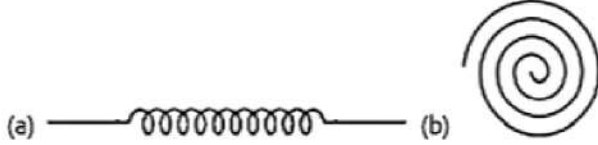


Velocity time graph is as shown below



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  $x_1 = x_2$

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

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

here  $x_1 = 3 \text{ cm}$  and  $x_2 = 4 \text{ cm}$

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

here  $E_1 = 15 \text{ J}$

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

OR

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

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

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

on increasing the distance  $x$  more

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

so increase in potential energy =  $E_2 - E_1 = (2 - \frac{1}{2}) KX^2$

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

so work required =  $30 - 10 = 20 \text{ Joule}$