Class XI Session 2024-25
Subject - Physics
Sample Question Paper - 9

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. Number of degrees present in one radian is **[1]**

a) 57.3^o b) 56.3^o

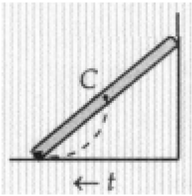
c) 58^o d) 56^o

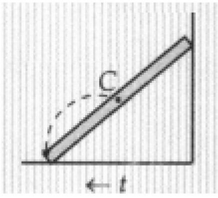
2. The displacement of the wave given by equation y(x, t) = a sin (kx - ωt + ϕ), where $\phi = 0$ at point x and t = 0 is same as that at point **[1]**

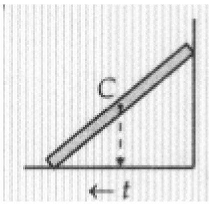
a) Both $x + \frac{2n\pi}{k}$ and $kx + 2n\pi$ b) $x + \frac{2n\pi}{k}$

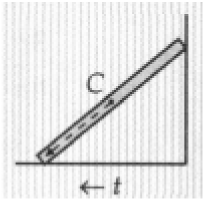
c) $x + 2n\pi$ d) $kx + 2n\pi$

3. 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) 

4. A liquid drop of radius R is broken up into N small droplets. The work done is proportional to(take $N^{\frac{1}{3}}$ >> 1). **[1]**

a) $N^{\frac{1}{3}}$

b) N

c) $N^{\frac{-2}{3}}$

d) $N^{-0.5}$

5. A man waves his arms, while walking. This is: **[1]**

a) to balance the effect of earth's gravity

b) to keep constant velocity

c) to increase the velocity

d) to ease the tension

6. Sound waves of wavelength λ travelling in a medium with a speed of v m/s enter into another medium where its speed is 2v m/s. The wavelength of sound waves in the second medium is **[1]**

a) 4λ

b) 2λ

c) $\frac{\lambda}{2}$

d) λ

7. A police jeep is chasing with velocity 45 km/h. A thief in another jeep is moving with 155 km/h. Police fires a bullet with a muzzle velocity of 180 m/s. The bullet strikes the jeep of the thief with a velocity **[1]**

a) 27 ms^{-1}

b) 150 ms^{-1}

c) 450 ms^{-1}

d) 250 ms^{-1}

8. A standing wave is represented by: **[1]**
y = a sin (100t) cos (0.01x),
where y and a are in millimetre, t in second and x in metre. Velocity of wave is:

a) not derived

b) 1 m/s

c) 10^4 m/s

d) 10^{-4} m/s

9. One large soap bubble of diameter D breaks into 27 bubbles having surface tension T. The change in surface energy is **[1]**

a) 2 πTD^2

b) 8 πTD^2

c) 4 πTD^2

d) πTD^2

10. An astronaut is standing on an asteroid when he accidentally drops a wrench. He observes that the gravitational acceleration on the asteroid is 2.4 m/s^2. If he had thrown the wrench at an upward angle instead, he would have found the gravitational acceleration on the asteroid to be: **[1]**

a) less than 2.4 m/s^2

b) downward at 2.4 m/s^2

c) greater than 2.4 m/s^2

d) toward him at 2.4 m/s^2

11. The angular momentum of a moving body remains constant, if **[1]**

a) net pressure is applied

b) net external torque is applied

c) net external force is applied

d) net external torque is not applied

12. Two identical metallic balls, whose temperatures are 200°C and 400°C respectively, are placed in an enclosure at 27° C. The ratio of heat-loss of the balls will be **[1]**

a) 1 : 4

b) $\frac{(473)^4-(300)^4}{(673)^4-(300)^4}$

c) 1 : 2

d) $\frac{(200)^4-(27)^4}{(400)^4-(27)^4}$

13. **Assertion (A):** According to the law of conservation of mechanical energy change in potential energy is equal and opposite to the change in kinetic energy. **[1]**

Reason (R): Mechanical energy is not a conserved quantity.

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:** Reversible system are difficult to find in real world. **[1]**

Reason: Most processes are dissipative in nature.

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.

15. **Assertion (A):** A force act upon the earth revolving in a circular orbit about the sun. Hence work should be done on the earth. **[1]**

Reason (R): The necessary centripetal force for the circular motion of the earth, comes from the gravitational force between earth and the sun.

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.

16. **Assertion (A):** When a body is dropped or thrown horizontally from the same height, it would reach the ground at the same time. **[1]**

Reason (R): Horizontal velocity has no effect on the 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. Write the equation of a progressive wave propagating along the positive x-direction, whose amplitude is 5 cm, frequency 250 Hz and velocity 500 ms^{-1}. **[2]**

18. Subtract 2.5×10^4 from 3.9×10^5 with due regard to significant figures. **[2]**

19. A famous relation in physics relates **moving mass** m to the **rest mass** m_o of a particle in terms of its speed v and the speed of light, c. (This relation first arose as a consequence of special relativity due to Albert Einstein). A boy recalls the relation almost correctly but forgets where to put the constant c. He writes: $m = \frac{m_0}{(1-v^2)^{\frac{1}{2}}}$. Guess where to put the missing c? **[2]**

20. A cyclist speeding at 18 km/h on a level road takes a sharp circular turn of radius 3 m without reducing the speed. The coefficient of static friction between the tyres and the road is 0.1. Will the cyclist slip while taking the turn? **[2]**

21. An artificial satellite is going round the earth, close to its surface. What is the time taken by it to complete one round? Given radius of the earth = 6400 km. **[2]**

OR

If the earth were made of lead of relative density 11.3, what then would be the value of acceleration due to gravity on the surface of the earth? Radius of the earth = 6.4×10^6 m and G = 6.67×10^{-11} Nm^2 kg^{-2}.

Section C

22. The manual of a car instructs the owner to inflate the tyres to a pressure of 200 kPa. **[3]**

i. What is the recommended gauge pressure?
ii. What is the recommended absolute pressure?
iii. If after the required inflation of the tyres, the car is driven to a mountain peak where the atmospheric pressure is 10% below that at sea level, what will the tyre gauge read?

23. A clock with an iron pendulum keeps the correct time at 20^o C. How much will it lose or gain if the temperature changes to 40^oC? Coefficient of cubical expansion of iron = 36×10^{-6} $^oC^{-1}$. **[3]**

24. A body starting from rest accelerates uniformly at the rate of 10 cms^{-2} and retards uniform y at the rate of 20 cms^{-2}. Find the least time in Which it can complete the journey of 5 km if the maximum velocity attained by the body is 72 kmh^{-1}. **[3]**

25. A 100 kg gun fires a ball of 1 kg horizontally from a cliff of height 500 m. It falls on the ground at a distance of 400 m from the bottom of the cliff. Find the recoil velocity of the gun. (acceleration due to gravity = 10 ms^{-2}). **[3]**

26. Explain with the suitable example that a reversible process must be carried slowly and a fast process is necessarily irreversible. **[3]**

27. Give the magnitude and direction of the net force acting on a stone of mass 0.1 kg, **[3]**

a. just after it is dropped from the window of a stationary train,
b. just after it is dropped from the window of a train running at a constant velocity of 36 km/h.
c. just after it is dropped from the window of a train accelerating with1 ms^{-2},
d. lying on the floor of a train which is accelerating with 1 ms^{-2}, the stone being at rest relative to the train.

Neglect air resistance throughout.

28. A glass plate of length 10 cm, breadth 4 cm and thickness 0.4 cm, weighs 20 g in air. It is held vertically with a long side horizontal and half the plate immersed in water. What will be its apparent weight? The surface tension of water = 70 dyne cm^{-1}. **[3]**

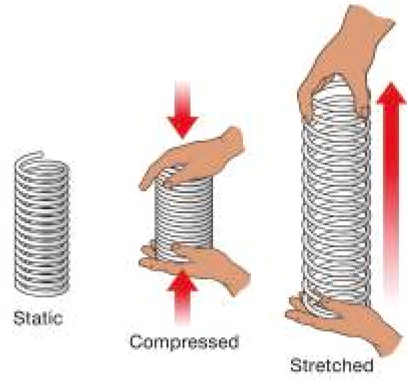
OR

Briefly explain Magnus effect.

Section D

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

Elastic potential energy is Potential energy stored as a result of the deformation of an elastic object, such as the stretching of a spring. It is equal to the work done to stretch the spring, which depends upon the spring constant k as well as the distance stretched



(a) If stretch in spring of force constant k is doubled, then the ratio of final to initial forces is:

a) 4:1 b) 1:4

c) 2:1 d) 1:2

(b) A light body and a heavy body have the same kinetic energy. which one has greater linear momentum?

a) light body b) both heavy and light body

c) Low body d) heavy body

(c) A spring is cut into two equal halves. How is the spring constant of each half affected?

a) becomes double b) becomes triple

c) becomes 1/4th d) becomes half

OR

When spring is compressed, its potential energy:

a) fall b) decrease

c) first increase then decrease d) increase

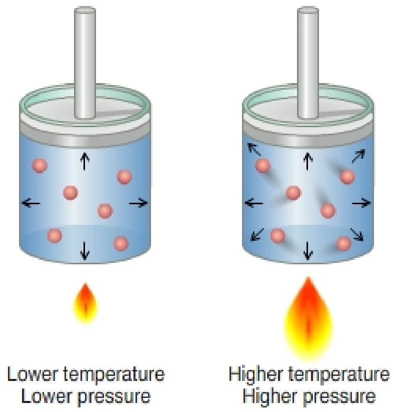
(d) What type of energy is stored in the spring of a watch?

a) potential energy b) Electrical energy

c) mechanical energy d) kinetic energy

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

In a gas the particles are always in a state of random motion, all the particles move at different speed constantly colliding and changing their speed and direction, as speed increases it will result in an increase in its kinetic energy.



(a) If the temperature of the gas increases from 300 K to 600 K then the average kinetic energy becomes:

a) same
b) becomes double
c) becomes half
d) become triple

(b) What is the average velocity of the molecules of an ideal gas?

a) Infinite
b) Same
c) Increase
d) Zero

(c) Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will ________.

a) decrease
b) Rises
c) increase
d) remains same

(d) Find the ratio of average kinetic energy per molecule of Oxygen and Hydrogen:

a) 1:1
b) 4:1
c) 1:2
d) 1:4

OR

The velocities of the three molecules are 3v, 4v, and 5v. calculate their root mean square velocity?

a) 4.0 v
b) 4.02 v
c) 4.08 v
d) 4.04 v

Section E

31. A cylindrical piece of cork of density of base area A and height h floats in a liquid of density ρ_l. The cork is depressed slightly and then released. Show that the cork oscillates up and down simple harmonically with a period $T = 2\pi\sqrt{\frac{h\rho}{\rho_l g}}$ Where ρ is the density of cork. (Ignore damping due to viscosity of the liquid). **[5]**

OR

Let us take the position of mass when the spring is unstretched as x = 0 and the direction from left to right as the positive direction of x-axis. Given x as a function of time t for the oscillating mass, if at the moment we start the stopwatch (t = 0), the mass is

i. at the mean position,
ii. at the maximum stretched position and
iii. at the maximum compressed position.

In what way do these functions for SHM differ from each other, in frequency, in amplitude or the initial phase?

32. i. Analytically, find the resultant $\vec{R}$ of two vectors $\vec{A}$ and $\vec{B}$ inclined at an angle θ. **[5]**
ii. Find the angle between two vectors $\vec{P}$ and $\vec{Q}$ if resultant of the vectors is given by $R^2 = P^2 + Q^2$.

OR

i. Pick out only the vector quantities from the following: Temperature, pressure, impulse, time, power, charge.
ii. Show by drawing a neat diagram that the flight of a bird is an example of composition of vectors.
iii. A man is travelling at 10.8 km h^{-1} in a topless car on a rainy day. He holds his umbrella at an angle 37° to the vertical to protect himself from the rain which is falling vertically downwards. What is the velocity of the rain? [Given cos 37°= $\frac{4}{5}$]

33. A solid disc and a ring, both of radius 10 cm are placed on a horizontal table simultaneously, with initial angular speed equal to 10π rad s^{-1}. Which of the two will start to roll earlier? The co-efficient of kinetic friction is μ_k= **[5]**

0.2.

OR

Show that the angular momentum of a particle is the product of its linear momentum and moment arm. Also, show that the angular momentum is produced only by the angular component of linear momentum. What is the physical meaning of angular momentum?

Solution

Section A

1. **(a)** 57.3^o

   Explanation: We know that,

   π radian = 180^o

   1 radian = $\frac{180}{\pi} = \frac{180}{22} \times 7 = 57.3^o$

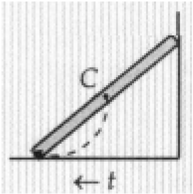
2. **(b)** $x + \frac{2n\pi}{k}$

   Explanation: y(x, 0) = a sin kx = a sin $(kx + 2\pi n)$

   = a sin k$\left(x + \frac{2n\pi}{k}\right)$

   $\Rightarrow$ The displacement at points x and $\left(x + \frac{2n\pi}{k}\right)$ are the same where, n = 1, 2, 3,...

3. **(a)**

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

4. **(a)** $N^{\frac{1}{3}}$

   Explanation: When a droplet of radius R is broken into N small droplets total volume will remain constant. Let the radius of small droplets be r. Then

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

   $r = \frac{R}{N^{\frac{1}{3}}}$

   work done will be equal to the change in surface energy, thus

   W = $S_f - S_i = N4\pi r^2 T - 4\pi R^2 T$

   W = $N4\pi\left(\frac{R}{N^{\frac{1}{3}}}\right)^2 T - 4\pi R^2 T$

   W = $4\pi R^2 T\left(N^{\frac{1}{3}} - 1\right)$

   if $N^{\frac{1}{3}}$ is very large thus it becomes

   W = $4\pi R^2 T N^{\frac{1}{3}}$

   thus

   $W \propto N^{\frac{1}{3}}$

5. **(a)** to balance the effect of earth's gravity

   Explanation: The waving of arms helps in keeping the centre of gravity at a suitable position. This helps the man to walk comfortably.

6. **(b)** 2λ

   Explanation: When wave passes from one medium to another its frequency (v) does not change, but its velocity and wavelength changes.

   $v = v\lambda$ or $v = \frac{v}{\lambda}$

   $\frac{v}{\lambda} = \frac{2v}{\lambda_2} \Rightarrow \lambda_2 = 2\lambda$

7.

(b) 150 ms^{-1}

Explanation: Relative speed of bullet with respect to thief's jeep,

= $(v_b + v_p) - v_t$

= 180 ms^{-1} + 45 ms^{-1} - 155 ms^{-1}

= 180 ms^{-1} + 45 $\times \frac{5}{18}$ ms^{-1} - 155 $\times \frac{5}{18}$ ms^{-1}

= 180 ms^{-1} - 305 ms^{-1}

= 150 ms^{-1}

8.

(c) 10^4 m/s

Explanation: y = A sin (100t) cos (0.01x)

$y = A \sin\left(\frac{2\pi}{T}t\right) \cos\left(\frac{2\pi}{\lambda}x\right)$

$\therefore \frac{2\pi}{T} = 100$ or T = $\frac{\pi}{50}$

$\frac{2\pi}{\lambda} = 0.01$ or $\lambda = 200\pi$

$v = \frac{\lambda}{T} = \frac{200\pi}{\frac{\pi}{50}} = 10^4$ m/s

9.

(c) 4 πTD^2

Explanation: Volume of 27 small bubbles = Volume of larger bubble

$27 \times \frac{4}{3} \times \pi r^3 = \frac{4}{3}\pi\left(\frac{D}{2}\right)^3$

$\therefore$ r = $\frac{D}{6}$

Increase in surface area,

= 2 [27 $\times$ 4π $\left(\frac{D}{6}\right)^2$ - 4π $\left(\frac{D}{2}\right)^2$] = 4 πD^2

Increase in surface energy, = Increase in surface area $\times$ surface tension

= 4 $\pi D^2 T$

10.

(b) downward at 2.4 m/s^2

Explanation: The acceleration will be downward at 2.4 m/s^2.

11.

(d) net external torque is not applied

Explanation: Angular momentum is conserved only in the absence of external torque.

12.

(b) $\frac{(473)^4-(300)^4}{(673)^4-(300)^4}$

Explanation: From Stefan Boltzmann's law,

$\frac{E_1}{E_2} = \frac{T_1^4 - T_0^4}{T_2^4 - T_0^4}$

$= \frac{(273+200)^4-(273+27)^4}{(273+400)^4-(273+27)^4}$

$= \frac{(473)^4-(300)^4}{(673)^4-(300)^4}$

13.

(c) A is true but R is false.

Explanation: For conservative forces, the sum of kinetic and potential energies at any point remains constant throughout the motion. It does not depend upon time, this is known as law of conservation of mechanical energy. According to this rule,

Kinetic energy + Potential Energy = E = Constant

or $\Delta T + \Delta U = 0$ or $\Delta T = -\Delta U$

14. **(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.

15.

(d) A is false but R is true.

Explanation: Because the earth is revolving in the circular orbit about the sun, hence the force acting on it is the centripetal force which is always perpendicular to the direction of motion of the earth. Hence work done by the force will be zero.

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

Explanation: Horizontal velocity provides the horizontal range. It does not affect the time taken in the vertical direction.

Section B

17. Here A = 5cm = 0.05m , v = 250 Hz, ν = 500 ms^{-1}

Wavelength, $\lambda = \frac{v}{\nu} = \frac{500}{250} = 2\text{ m}$

Period, $T = \frac{1}{v} = \frac{1}{250}s$

The equation for the given wave can be written as

y = $A\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) = 0.05\sin 2\pi\left(250t - \frac{x}{2}\right)$

or y = 0.05 sin $\times$ (500 t - x) metre

18. We have 3.9 $\times$ 10^5 − 2.5 $\times$ 10^4

= 3.9 $\times$ 10^5 − 0.25 $\times$ 10^5

= 3.65 $\times$ 10^5

But our answer should be rounded off up to two significant digits.

So, the answer will be 3.6 $\times$ 10^5

19. The given formula will be dimensionally correct only when the dimension of L.H.S will be same as that of R.H.S. This is only possible when the factor, $(1 - v^2)^{\frac{1}{2}}$ is dimensionless i.e., $(1 - v^2)$ is dimensionless. This can only possible when v^2 is divided by the square of another velocity term. And here that term is c^2. So, v^2 should be divided by c^2 to make the denominator of the fraction dimensionless. Hence, the correct relation is $m = \frac{m_0}{\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}}$ From this relativistic mass formula, one can easily see that when the velocity of a particle becomes comparable to the speed of light, its mass increases.

20. Speed of the cyclist

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

Given: Radius $r = 3m \quad \mu = 0.1$

The safe limit of velocity $v_s = \sqrt{\mu r g}$

So, $v_s = \sqrt{0.1 \times 10 \times 3} = 1.732\text{m/s}$

Since, cyclist rides at a faster speed than safe limit. So, the cyclist slips.

21. Here R = 6400 km = 6.4 $\times$ 10^6 m

g = 9.8 ms^{-2}

Orbital velocity near the earth's surface is

v_0 = $\sqrt{gR} = \sqrt{9.8 \times 6.4 \times 10^6}$ = 7918 ms^{-1}

Time period,

R = $\frac{2\pi R}{v_0} = \frac{2 \times 22 \times 6.4 \times 10^6}{7 \times 7918}$ = 5080 s

= 1.411 hour

OR

Density of the earth,

ρ = Relative density $\times$ density of water

= 11.3 $\times$ 10^3 kgm^{-3}

Acceleration due to gravity on the earth's surface,

g = $\frac{GM}{R^2} = \frac{G}{R^2} \cdot \frac{4}{3}\pi R^3 \times \rho = \frac{4}{3}\pi G R \rho$

= $\frac{4}{3} \times \frac{22}{7} \times 6.67 \times 10^{-11} \times 6.4 \times 10^6 \times 11.3 \times 10^3$

= 22.21 ms^{-2}

Section C

22. i. Recommended gauge pressure = Pressure recommended in the manual P_g = 200kPa.

ii. Recommended absolute pressure $P = P_a + P_g$ = 101 kPa + 200 kPa = 301 kPa.

[$\therefore$ Atmospheric pressure $P_a = 1.01 \times 10^5$ Pa = 101 kPa]

iii. At the mountain peak the atmospheric pressure is 10% below that at sea level, hence new atmospheric pressure

$P'_a = \frac{90}{100} \times 101$ kPa = 91 kPa.

Presuming that the absolute pressure in the tyre has not changed during the drive, the new gauge pressure

$P'_g = P - P'_a$ = 301 kPa - 91 kPa = 210 kPa.

23. Time period of simple pendulum,

$T_{20} = 2$ s

Let T_{40} be the time period at 40°C. If l_0, l_{20}, l_{40} be the lengths of the pendulum at 0°C, 20°C and 40°C respectively, then

$$l_{20} = l_0(1 + 20\alpha)$$
$$l_{40} = l_0(1 + 40\alpha)$$
$$T_{20} = 2\pi\sqrt{\frac{l_{20}}{g}} = 2\pi\sqrt{\frac{l_0(1+20\alpha)}{g}}$$
$$T_{40} = 2\pi\sqrt{\frac{l_{40}}{g}} = 2\pi\sqrt{\frac{l_0(1+40\alpha)}{g}}$$
$$\therefore \frac{T_{40}}{T_{20}} = \sqrt{\frac{1+40\alpha}{1+20\alpha}} = (1+40\alpha)^{1/2}(1+20\alpha)^{-1/2}$$
$$= \left(1 + \frac{1}{2} \times 40\alpha\right)\left(1 - \frac{1}{2} \times 20\alpha\right) \text{ [Using Binomial theorem]}$$
$$= (1 + 20\alpha)(1 - 10\alpha) = 1 + 10\alpha$$

Fractional loss in time

$$= \frac{T_{40} - T_{20}}{T_{20}} = 10\alpha$$

$= 10 \times 1.2 \times 10^{-5} = 1.2 \times 10^{-4}$

As the temperature increases, time period also increases. The clock runs slow.

Time lost in 24 hours

$= 1.2 \times 10^{-4} \times 24 \times 3600 = 10.368$ s

24. i. For motion with uniform acceleration:

$u = 0$, $v = 72$ km^{-1} = 20 ms^{-1}, $a = 10$ cms^{-2} = 0.1 ms^{-2}, $t = t_1$ = ?, s = ?

As v = u + at

$\therefore$ $20 = 0 + 0.1 \times t_1$ or $t_1 = 200$ s

Also, $v^2 = u^2 + 2as$

$\therefore$ $20^2 = 0^2 + 2 \times 0.1 \times s$ or s = 2000 m = 2 km

ii. For motion with uniform retardation:

u = 20 ms^{-1}, v = 0, a = -20 cms^{-2} = -0.21 ms^{-2}, $t = t_2$ = ? s = ?

As v = u + at

$\therefore$ $0 = 20 - 0.2 \times t_2$

Again, $t_2 = 100$ s

Again, $v^2 = u^2 + 2as$

$\therefore$ $0 = 20^2 + 2 \times (-0.2)s$

or s = 1000 m = 1 km

Remaining part of journey = 5 - (2 + 1) = 2 km = 2000 m

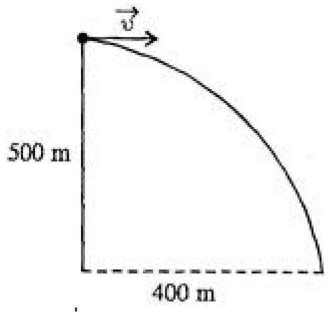
This journey occurs at the uniform maximum velocity of 20 ms^{-1}

iii. For motion with uniform velocity:

u = 20 ms^{-1}, s = 2000 m, $t = t_3$ = ?

Time, $t_3 = \frac{s}{u} = \frac{2000}{20}$ = 100 s

Total time = $t_1 + t_2 + t_3$ = 200 + 100 + 100 = 400 s

25. 

Let the horizontal speed of the ball is $u m s^{-1}$ its vertical component will be zero.

Consider the motion off ball vertically downward

Here, mass of ball, m_b=1kg, Mass of gun, M_G = 100 kg

u_b = initial velocity of ball,

v_b = final velocity of ball,

v_g = final velocity of gun

u = 0, s = h = 500 m, g = 10 s m^{-2}

$s = ut + \frac{1}{2}at^2$

$500 = a \times t + \frac{1}{2} \times 10t^2 \Rightarrow t^2 = \frac{500}{5} = 100$

$t = \sqrt{100} = 10$ sec

Horizontal distance covered by the ball is $x = u \times 10$

$400 = v \times 10 \Rightarrow v = 40m/\text{sec}$

By the law of conservation of momentum

$m_b u_j + M_G u_g = m_b v_b + M_G v_G$

$\Rightarrow m_b \times 0 + M_G \times 0 = 1 \times 40 + 100v_G$

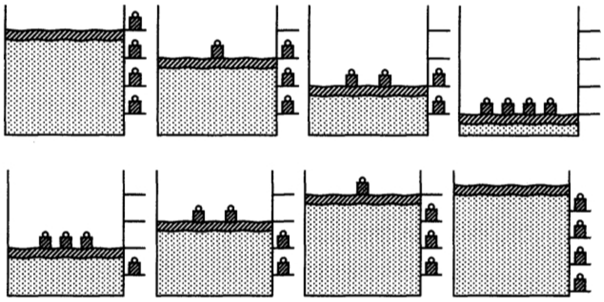
100 v_G = - 40

Recoil velocity of Gun= $\frac{-40}{100} m s^{-1} = \frac{-2}{5} m s^{-1}$ = - 0.4 ms^{-1} i.e opposite to the speed of ball.

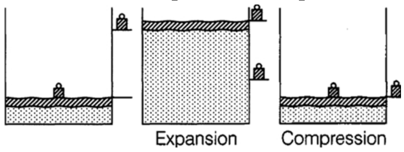
26. A reversible process must pass through equilibrium states which are very close to each other so that when process is reversed, it passes back through these equilibrium states.

Then, it is again decompressed or it passes through same equilibrium states, system can be restored to its initial state without any change in surroundings.

e.g. If a gas is compressed as shown



But a reversible process can proceed without reaching equilibrium in intermediate states.



27. a. When stone is dropped just after from the window of a stationary train,

Force on stone is given by, F = Force due to gravity = mg = 0.1 kg $\times$ 10 m/s^2 = 1 N in the vertically downward direction.

b. As the train is running with constant velocity, acceleration is zero in horizontal direction i.e. direction of motion of train. Hence no force in horizontal direction. So, only force due to gravity in vertically downward direction exists. In this case too, force is same as in (a) i.e., F = 1 N downwards.

c. Net Force is given by, F = Force due to gravity = mg = 0.1 k g $\times$ 10 m/s^2 = 1 N

$\therefore$ F = 1 N vertically downwards

d. Here, acceleration is given by a = 1 ms^{-2} in horizontal direction towards the motion of train and the stone being at rest relative to the train,

Hence, net force is given by F = ma = 0.1 $\times$ 1 = 0.1 N.

28. Here l = 10 cm, b = 4 cm, t = 0.4 cm, m = 20 g, σ = 70 dyne cm^{-1}

Various forces acting on the plate are

i. Weight of the plate acting vertically downwards,
= mg = 20 $\times$ 980 dyne = 20 g f

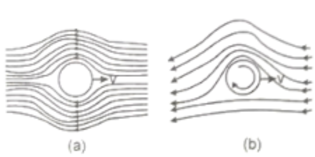
ii. Force due to surface tension acting vertically downwards,
F = $\sigma \times$ Length of plate in contact with water
= $\sigma \times$ 2 (length + thickness)
= 70 $\times$ 2 (10 + 0.4) = 70 $\times$ 20.8 dyne
= $\frac{70\times20.8}{980}$ g f = 1.4857 g

iii. Upwards thrust due to liquid = Weight of the liquid displaced
= Volume of liquid displaced $\times$ density $\times$ g
= (l $\times$ $\frac{b}{2}$ $\times$ t) $\times \rho \times$ g
= (10 $\times$ $\frac{4}{2}$ $\times$ 0.4) 1 $\times$ 980 dyne
= $\frac{8\times980}{980}$ g f = 8g f
$\therefore$ Apparent weight = 20 + 1.4857 - 8 = 13.4857 g f

OR

Magnus effect, generation of a sidewise force on a spinning cylindrical or spherical solid immersed in a fluid (liquid or gas) when there is relative motion between the spinning body and the fluid. It is responsible for the “curve” of a served tennis ball or a driven golf ball and affects the trajectory of a spinning artillery shell.

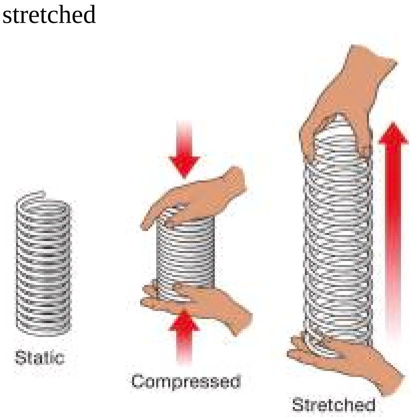
A spinning object moving through a fluid departs from its straight path because of pressure differences that develop in the fluid as a result of velocity changes induced by the spinning body. The Magnus effect is a particular manifestation of Bernoulli's theroem, fluid pressure decreases at points where the speed of the fluid increases. In the case of a ball spinning through the air, the turning ball drags some of the air around with it. Viewed from the position of the ball, the air is rushing by on all sides. The drag of the side of the ball turning into the air (into the direction the ball is traveling) retards the airflow, whereas on the other side the drag speeds up the airflow. Greater pressure on the side where the airflow is slowed down forces the ball in the direction of the low-pressure region on the opposite side, where a relative increase in airflow occurs.



Section D

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

Elastic potential energy is Potential energy stored as a result of the deformation of an elastic object, such as the stretching of a spring. It is equal to the work done to stretch the spring, which depends upon the spring constant k as well as the distance stretched



(i) **(c)** 2:1

Explanation: 2:1

(ii) **(d)** heavy body
Explanation: heavy body

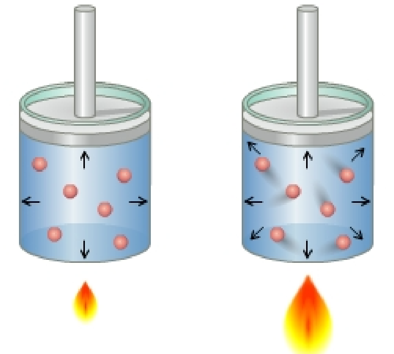
(iii) **(a)** becomes double
Explanation: becomes double

OR

(d) increase
Explanation: increase

(iv) **(a)** potential energy
Explanation: potential energy

30. **Read the text carefully and answer the questions:**
In a gas the particles are always in a state of random motion, all the particles move at different speed constantly colliding and changing their speed and direction, as speed increases it will result in an increase in its kinetic energy.



(i) **(b)** becomes double
Explanation: becomes double

(ii) **(d)** Zero
Explanation: Zero

(iii) **(d)** remains same
Explanation: remains same

(iv) **(a)** 1:1
Explanation: 1:1

OR

(c) 4.08 v
Explanation: 4.08 v

Section E

31. This numerical can be solved using concept of Simple Harmonic Motion of floating object in which an object is dipped into the liquid and released by pushing it down,due to increased buoyant force it will move upward due to which excess force will push it downward.This repeated up and down movement of the object is governed by the laws of Simple Harmonic Motion assuming viscous forces are absent.
so area of the cork = A
Height of the cork = h
Density of the liquid = ρ_l
Density of the cork = ω
In equilibrium:
Weight of the cork = Weight of the liquid displaced by the floating cork
Let the cork be depressed slightly by x. As a result, some extra water of a certain volume is displaced. Hence, an extra up-thrust acts upward and provides the restoring force to the cork.
Up-thrust = Restoring force, F = Weight of the extra water displaced
F = –(Volume $\times$ Density $\times$ g)
Volume = Area $\times$ Distance through which the cork is depressed
Volume = Ax

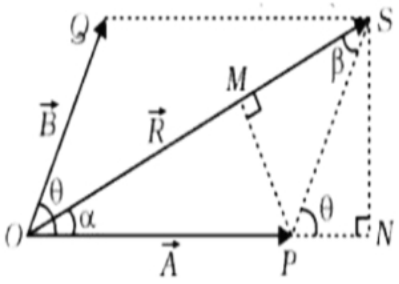
$\therefore F=-A\times\rho_l g$
According to the force law:
F = kx
$k=\frac{F}{x}$
Where, k is a constant
$k=\frac{F}{x}=-A\rho_l g$ ...(ii)
The time period of the oscillations of the cork:
$T=2\pi\sqrt{\frac{m}{k}}$ ....(iii)
Where,
m = Mass of the cork
= Volume of the cork $\times$ Density
= Base area of the cork $\times$ Height of the cork $\times$ Density of the cork
= Ahρ
Hence, the expression for the time period will be -
$T=2\pi\sqrt{\frac{Ah\rho}{A\rho_l g}}=2\pi\sqrt{\frac{h\rho}{\rho_l g}}$
From the above expression it is proved that time period of the fork does not depend on the mass of the object rather depends on specific gravity of the cork and height of the cork and acceleration due to gravity.

OR

Assuming the standard equation
x(t) = Asin (ωt + ϕ)

i. When t = 0, x = 0 [mean position]
   $\Rightarrow$ 0 = Asin ($\omega\times$ 0 + ϕ)
   Asin ϕ = 0 [as A $\neq$ 0]
   or sinϕ = 0 $\therefore$ ϕ = 0
   $\therefore$ Required function is
   x(t) = Asin(ωt + 0) or x(t) = Asin ωt
   where, $\omega=\sqrt{\frac{k}{m}}=\sqrt{\frac{1200}{3.0}}$ = 20 rad/s
   $\therefore$ x(t) = Asin 20t or x(t) = 2sin 20t
ii. When t = 0, x = + A (maximum stretched position)
   x(t) = Asin(ωt + ϕ) at t = 0 and x = +A
   +A = A sin(ω x 0 + ϕ) or 1 = sin $\phi\Rightarrow\phi=\frac{\pi}{2}$
   $\therefore$ x(t) = Asin$\left(\omega t+\frac{\pi}{2}\right)$
   = A cos ωt = A cos 20t = 2 cos 20t
iii. When the spring is at maximum compressed position.
   At t =0, x(t) = -A
   $\Rightarrow$ -A = Asin($\omega\times$ 0 + ϕ) or -1 = sinϕ or ϕ = $\frac{3\pi}{2}$
   So, the equations only differ in initial phase and in no other factors.

32. Let two vectors A and B are inclined at an angle θ as shown in figure, Extend the vector A and drop perpendicular from S on vector A,As diagonal represents the resultant vector so OS is the magnitude of resultant vector.



i. In $\triangle$PSN,
   $\frac{SN}{SP}$ = sinθ
   so SN = SP sin θ = B sin θ
   $\frac{PN}{SP}$ = cos θ

PN = SP cos θ = B cos θ

In $\triangle$OSN, $OS^2 = ON^2 + NS^2$

$OS^2 = (OP + PN)^2 + SN^2$

$R^2 = (A + B\cos\theta)^2 + (B\sin\theta)^2$ $R^2 = A^2 + B^2 + 2AB\cos\theta$

R = $\sqrt{A^2 + B^2 + 2AB\cos\theta}$

The direction of result tan vector can be found by

tan $\alpha = \frac{SN}{ON} = \frac{B\sin\theta}{A+B\cos\theta}$we have nothing to do with the magnitude R.

ii. Let θ be the angle between the vectors $\vec{P}$ and $\vec{Q}$, Then Result $\tan t$ vector magnitude is given as

R = $\sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

$R^2 = P^2 + Q^2 + 2PQ\cos\theta$ ...(i)

but it is given,

$R^2 = P^2 + Q^2$ ...(ii)

from (i) and (ii)

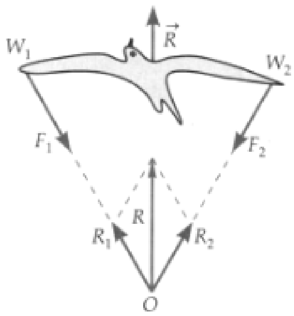
2PQ cos θ = 0

therefore the angle between two vector $\theta = 90^o$

OR

i. Impulse

ii. Flight of a bird. When a bird flies, it pushes the air with forces F_1 and F_2 in the downward direction with its wings W_1 and W_2. The lines of action of these two forces meet at point O. In accordance with Newton's third law of motion, the air exerts equal and opposite reactions R_1 and R_2. According to the parallelogram law, the resultant R of the reactions R_1 and R_2 acts on the bird in the upward direction and helps the bird to fly upward.



Flight of a bird.

iii. v_R = 10.8 km h^{-1} = 3 ms^{-1}

Given: $\cos 37^\circ = \frac{4}{5} \therefore \tan 37^\circ = \frac{3}{4}$

But $\tan 37^o = \frac{v_R}{v_M}$ or $\frac{3}{4} = \frac{v_R}{3ms^{-1}}$

or $v_R = \frac{9}{4}$ = 2.25 ms^{-1}

33. Radii of the ring and the disc, *r* = 10 cm = 0.1 m

Initial angular speed, ω_z =10 π rad s^{-1}

Coefficient of kinetic friction, μ_k= 0.2

Initial velocity of both the objects, u = 0

Motion of the two objects is caused by frictional force. As per Newton's second law of motion, we have frictional force, *f* = *ma*

μ_k mg = ma

Where,

a = Acceleration produced in the objects

m = Mass

$\therefore a = \mu_k$ g … (*i*)

As per the first equation of motion, the final velocity of the objects can be obtained as:

v = *u* + *at*

$= 0 + \mu_k gt$

$= \mu_k gt \ldots$ (*ii*)

The torque applied by the frictional force will act in a perpendicularly outward direction and cause a reduction in the initial angular speed.

Torque, T= - Iα

α = Angular acceleration

u_z mgr = -Iα

$\therefore a=\frac{-\mu_k mgr}{I}$ ....(iii)

Using the first equation of rotational motion to obtain the final angular speed:

$\omega=\omega_e+at$

$=\omega_x+\frac{-\mu_k mgr}{I}t$ ......(iv)

Rolling starts when linear velocity, *v* = *ru*

$\therefore v=r\left(\omega_0-\frac{\mu_k gmrt}{I}\right)$ ......(v)

Equating equations (*ii*) and (*v*), we get:

$\mu_k gt=r\left(\omega_0-\frac{\mu_k gmrt}{I}\right)$

$=r\omega_0-\frac{\mu_i gmr^2 t}{I}$ ....(vi)

For the ring $I=mr^2$

$\therefore \mu_k gt=r\omega_0-\frac{\mu_k gmr^2 t}{mr^2}$

$=r\omega_0=u_k-\frac{u_k gmr^2 t}{mr^2}$

$2\mu_{\dot{k}} gt=r\omega_0$

$\therefore t_r=\frac{r\omega_0}{2\mu_k g}$

$=\frac{0.1\times10\times3.14}{2\times0.2\times9.8}=0.80s$ ......(vii)

For the ring $I=\frac{1}{2}mr^2$

$\therefore \mu_k gt_d=r\omega_0-\frac{\mu_k gmr^2 t}{\frac{1}{2}mr^2}$

$=r\omega_0-2\mu_k gt$

$3\mu_k gt_d=r\omega_0$

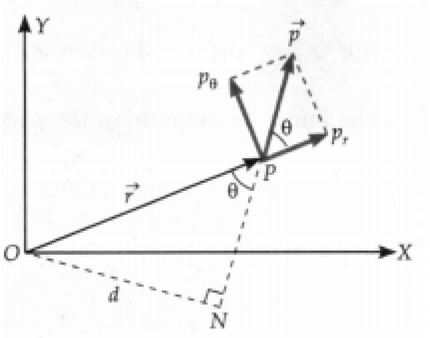
$\therefore t_d=\frac{r\omega_0}{3\mu_k g}$

$=\frac{0.1\times10\times3.14}{3\times0.2\times9.8}=0.53s$ ......(viii)

Since$t_d>t_r$, the disc will start rolling before the ring.

OR

Physical meaning of angular momentum. Consider a particle P of mass m whose position vector relative to the origin O is $\vec{r}$. Suppose the momentum vector $\vec{p}$ of the particle makes angle θ with the position vector $\vec{r}$ as shown in Fig.



Draw ON perpendicular to the line of action of linear momentum $\vec{p}$. From right angled ΔONP, we get

$\frac{ON}{OP}=\frac{d}{r}=\sin\theta$ or $d=r\sin\theta$

This is the perpendicular distance of the line of action of linear momentum from the point of rotation O and is called moment arm of the momentum.

The magnitude of the angular momentum about the point O is

$L=rp\sin\theta=p(r\sin\theta)=pd$

Angular momentum = Linear momentum × moment arm

This is the physical meaning of angular momentum. According to it, angular momentum is the moment of linear momentum and is a measure of the turning motion of the object. In contrast to it, we know that

Torque = Force × moment arm

Thus torque is the moment of force and is a measure of the turning effect of force.
Moreover, as shown in Fig. the momentum vector $\vec{p}$ can be resolved into two rectangular components:

i. Radial component, p_r along the direction of the position vector $\vec{r}$.

ii. Angular or tangential component, p_θ perpendicular to $\vec{r}$

or Angular momentum = Angular component of linear momentum
Hence only the angular component and not the radial component of the linear momentum contributes towards the angular momentum.