Class XI Session 2023-24
Subject - Physics
Sample Question Paper - 10

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. If C and R denote capacitance and resistance, the dimensional formula of CR is **[1]**

a) not expressible in terms of MLT
b) $[M^0L^0T^{-1}]$
c) $[M^0L^0T^1]$
d) $[M^0L^0T^0]$

2. An organ pipe, open at both ends produces 5 beats per second when vibrated with a source of frequency 200 Hz. The second harmonic of the same pipe produces 10 beats per second with a source of frequency 420 Hz. The frequency of source is **[1]**

a) 210 Hz
b) 190 Hz
c) 205 Hz
d) 195 Hz

3. A Merry-go-round, made of a ring-like platform of radius R and mass M, is revolving with angular speed ω. A person of mass M is standing on it. At one instant, the person jumps off the round, radially away from the centre of the round (as seen from the round). The speed of the round afterwards is **[1]**

a) 2ω
b) 0
c) $\frac{\omega}{2}$
d) ω

4. The specific gravity of a material is: **[1]**

a) the ratio of its density to the density of water
b) the ratio of its mass to the density of water
c) the ratio of its mass to the mass of water
d) the ratio of its volume to the density of

water

5. The law of areas can be interprted as **[1]**

a) $\frac{\Delta A}{\Delta t} = \frac{L}{m}$

b) $\frac{\Delta A}{\Delta t} = \frac{1}{2}(r \times p)$

c) $\frac{\Delta A}{\Delta t} = \frac{2L}{m}$

d) $\frac{\Delta A}{\Delta t}$ = constant

6. A standing wave having 3 nodes and 2 antinodes is formed between two atoms having a distance of 1.21 A between them. The wavelength of the standing wave is: **[1]**

a) 1.21 $\mathring{A}$

b) 2.42 $\mathring{A}$

c) 3.63 $\mathring{A}$

d) 6.05 $\mathring{A}$

7. A 100 m long train is moving with a uniform velocity of 45 km/h. The time taken by the train to cross a bridge of length 1 km is: **[1]**

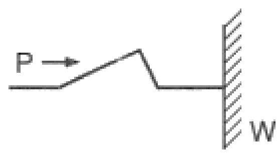
a) 78 s

b) 68 s

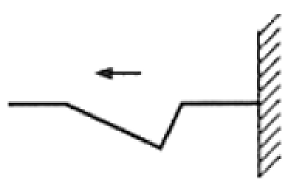
c) 58 s

d) 88 s

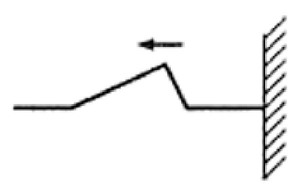
8. Figure shown here demonstrates a pulse P incident on a rigid wall. Which one of the following figures represents the reflected pulse correctly? **[1]**



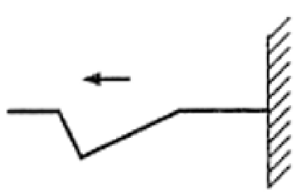
a)



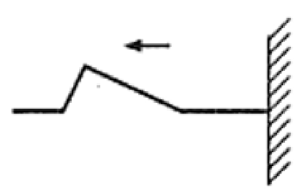
b)



c)



d)



9. If the work done in blowing a bubble of volume V is W, then the work done in blowing a soap bubble of volume 2V will be **[1]**

a) $\sqrt[3]{4}W$

b) W

c) $\sqrt{2}W$

d) 2W

10. Calculate the escape speed from the Earth for a 5000-kg spacecraft. mass of the earth = 6.0 $\times$ 10^{24} kg; radius of the earth = 6.4 $\times$ 10^6 m; G = 6.67 $\times$ 10^{-11} N m^2 kg^{-2}. **[1]**

a) 1.52 $\times$ 10^4 m/s

b) 1.32 $\times$ 10^4 m/s

c) 1.12 $\times$ 10^4 m/s

d) 1.72 $\times$ 10^4 m/s

11. A rod has length 3 m and its mass acting per unit length is directly proportional to distance x from one of its end, then its centre of gravity from that end will be at **[1]**

a) 1.5 m

b) 2.5 m

c) 2 m

d) 3.0 m

12. At a common temperature, a block of wood and a block of metal feel equally cold or hot. The temperatures of block and wood are **[1]**

a) greater than temperature of the body

b) less than the temperature of the body

c) either less than the temperature of the body or greater than temperature of the body.

d) equal to the temperature of the body

13. **Assertion:** The work done by a conservative force during a round trip is always zero. **[1]**
Reason: No force is required to move a body in a round trip.

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.

14. **Assertion (A):** First law of thermodynamics is based on energy conservation. **[1]**
Reason (R): Second law of thermodynamics put limitations on first law.

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

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

c) A is true but R is false.

d) A is false but R is true.

15. **Assertion (A):** Gravitational field intensity is zero both at centre and infinity. **[1]**
Reason (R): The dimensions of gravitational field intensity is $[LT^{-2}]$.

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.

16. **Assertion (A):** In uniform circular motion of a body, its linear speed remains constant. **[1]**
Reason (R): Total acceleration of the body has no radial component.

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. Why is the sound produced in air not heard by a person deep inside the water? **[2]**

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

19. State the number of significant figures in the following : **[2]**

i. $0.007\ m^2$

ii. 2.64×10^{24} kg

iii. $0.2370\ g\ cm^{-3}$

iv. 6.320 J

v. $6.032\ N\ m^{-2}$

vi. $0.0006032\ m^2$

20. An electric bulb suspended from the roof of a railway train by a flexible wire shifts through an angle of 19°48', when the train goes horizontally round a curved path of 200 m radius. Find the speed of the train. **[2]**

21. A mass of 1 g is separated from another mass of 1 g by a distance of 1 cm. How many g^{-1}wt of force exists between them? **[2]**

OR

What are the conditions under which a rocket fired from the earth becomes a satellite of the earth and orbits in a circle?

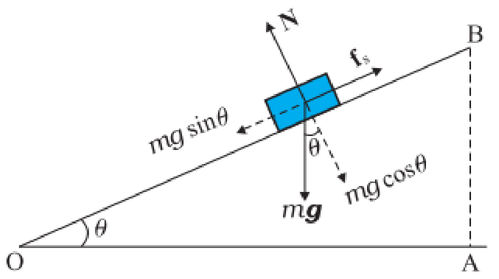
Section C

22. Two syringes of different cross-sections (without needles) filled with water are connected with a tightly fitted rubber tube. Diameters of the smaller and larger piston are 1.0 cm and 3.0 cm, respectively. **[3]**
    a. Find the force exerted on the larger piston when a force of 10 N is applied to the smaller piston.
    b. If the smaller piston is pushed in through 6.0 cm, how much does the larger piston move out?

23. Two absolute scales A and B have triple points of water defined to be 200 A and 350 B. If T_A and T_B are the triple points of water on the two scales, then find out the relation between T_A and T_B(Given, triple point of water on Kelvin scale is T_K = 273.15 K). **[3]**

24. Two buses A and B are at positions 50 m and 100 m from the origin at time t = 0. They start moving in the same direction simultaneously with a uniform velocity of 10 ms^{-1} and 5 ms^{-1}. Determine the time and position at which A overtakes B. **[3]**

25. A mass of 4 kg rests on a horizontal plane. The plane is gradually inclined until at an angle θ = 15° with the horizontal, the mass just begins to slide. What is the coefficient of static friction between the block and the surface? **[3]**



26. Calculate the amount of heat necessary to raise the temperature of 2 moles of He gas from 20^0C to 50^0C using:- **[3]**
    i. Constant Volume Process
    ii. Constant Pressure Process

    Here for, He gas; C_V = 1.5 R and C_P = 2.49R

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

28. Water flows through a horizontal pipe of which the cross - section is not constant. The pressure is 1cm of mercury where the velocity is 0.35m/s. Find the pressure at a point where the velocity is 0.65m/s. **[3]**

OR

A piece of wood of relative density 0.25 floats in a pail containing oil of relative density 0.81. What is the fraction of the volume of the wood above the surface of the oil?

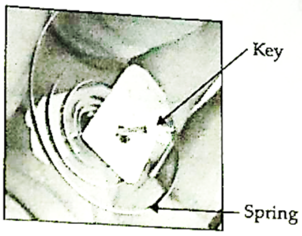
Section D

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

Clockwork refers to the inner workings of mechanical clock or watch (where it is known as "movement") and different types of toys which work using a series of gears driven by a spring. Clockwork device is completely mechanical and its essential parts are:

- A key (or crown) which you wind to add energy
- A spiral spring in which the energy is stored
- A set of gears through which the spring's energy is released. The gears control how quickly (or slowly) a clockwork machine can do things. Such as in mechanical clock/watch the mechanism is the set of hands that sweep around the dial to tell the time. In a clockwork car toy, the gears drive the wheels.

Winding the clockwork with the key means tightening a sturdy metal spring, called the mainspring. It is the process of storing potential energy. Clockwork springs are usually twists of thick steel, so tightening them (forcing the spring to occupy a much smaller space) is actually quite hard work. With each turn of the key, fingers do work and potential energy is stored in the spring. The amount of energy stored depends on the size and tension of the spring. Harder a spring is to turn and longer it is wound, the more energy it stores.



While the spring uncoils, the potential energy is converted into kinetic energy through gears, cams, cranks and shafts which allow wheels to move faster or slower. In an ancient clock, gears transform the speed of a rotating shaft so that it drives the second hand at one speed, the minute hand at $\frac{1}{60}$ of that speed, and the hour hand at $\frac{1}{3600}$ of that speed. Clockwork toy cars often use gears to make themselves race along at surprising speed.

(i) What is the meaning of **movement** of old age mechanical clocks?

a) The pendulum of the clock

b) The gears which move the hands of the clock

c) A spring and combination of gears which move the hands of the clock

d) The hands of the clock

(ii) What type of energy is stored in the spring while winding it?

a) Potential

b) Heat

c) Both kinetic and potential

d) Kinetic

(iii) When the spring of a clockwork uncoils

a) Kinetic energy is converted into potential energy

b) Potential energy is converted into kinetic

c) Potential energy is converted into heat, light and sound energy

d) Kinetic energy is converted into heat, light and sound energy

OR

In clockwork devices, ________ transform the speed of a rotating ________ to drive wheels slower or faster.

a) Shaft, spring

b) shaft, gear

c) Gear, Shaft

d) Spring, gear

(iv) More energy is stored in a spring if the

a) Spring is larger, harder and wound fur a longer time

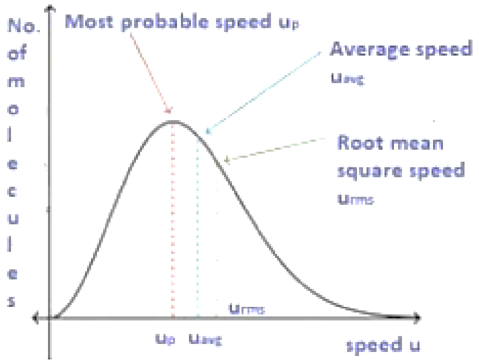
b) Spring is smaller, harder and wound for a shorter time

c) Spring is larger, harder and wound for a shurter time

d) Spring is larger, softer and wound for a shorter time

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

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



(i) Moon has no atmosphere because:

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

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

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

d) its surface temperature is 10^oC

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

a) ≤ 1

b) none of these

c) > 1

d) < 1

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

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

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

c) none of these

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

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

a) none of these

b) $v_0\sqrt{6}$

c) $v_0\sqrt{3}$

d) v_0

OR

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

a) 11 v

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

c) v

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

Section E

31. 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

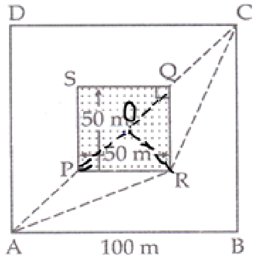
A second's pendulum is taken in a carriage. Find the period of oscillation when the carriage moves with an acceleration of 4 ms^{-2}

i. vertically upwards
ii. vertically downwards, and
iii. in a horizontal direction.

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

OR

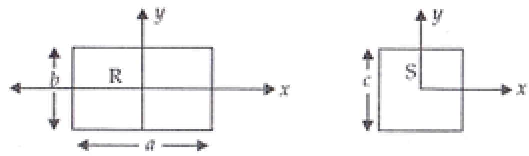
A man wants to reach from A to the opposite corner of the square C (as in figure). The sides of the square are 100 m. A central square of 50m $\times$ 50m is filled with sand. Outside this square, he can walk at a speed 1 m/s^{-1}. In the central square, he can walk only at a speed of vm/s (v<1) What is smallest value of v for which he can reach faster via a straight path through the sand than any path in the square outside the sand?



33. Three bodies, a ring, a solid cylinder and a solid sphere roll down the same inclined plane without slipping. They start from rest. The radii of the bodies are identical. Which of the bodies reaches the ground with maximum velocity? **[5]**

OR

A uniform square plate S (side c) and a uniform rectangular plate R (sides b, a) have identical areas and masses (Figure).



Show that

i. $\frac{I_{xR}}{I_{xs}} < 1$
ii. $\frac{I_{yR}}{I_{ys}} > 1$
iii. $\frac{I_{zR}}{I_{zs}} > 1$

Solution

Section A

1.

(c) $[M^0L^0T^1]$

Explanation: $[CR] = \frac{q}{V} \cdot \frac{V}{I} = \frac{q}{I}$

= $\frac{[IT]}{[I]}$ = $[M^0L^0T^1]$

2.

(c) 205 Hz

Explanation: Fundamental frequency of open pipe,

f = 200 $\pm$ 5 = 195 Hz or 205 Hz

Second harmonic of open pipe, 2f = 420 $\pm$ 10 = 410 Hz or 430 Hz

or f = 205 Hz or 215 Hz.

The common frequency is 205 Hz

3.

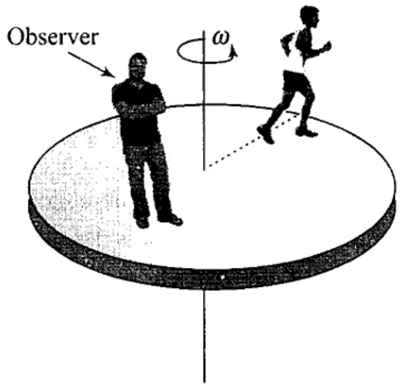
(d) ω

Explanation:

As no torque is exerted by the person jumping, radially away from the centre of the round (as seen from the round), let the total moment of inertia of the system is 21 (round + Person (because the total mass

is 2 M) and the round is revolving with angular speed wsince the angular momentum of the person when it jumps off the round is 1 ω the actual momentum of round seen from ground is 2|ω-| ω = |ω

So we conclude that the angular speed remains same, i.e ω



4. **(a)** the ratio of its density to the density of water

Explanation: The specific gravity of an object is the ratio between the density of an object to a reference liquid. Usually, this reference liquid is water, which has a density of 1 g/mL or 1 g/$cm^{3.}$

Water has a specific gravity equal to 1. Materials with a specific gravity less than 1 are less dense than water, and will float on the pure liquid; substances with a specific gravity more than 1 are denser than water and will sink.

5.

(d) $\frac{\Delta A}{\Delta t}$ = constant

Explanation: $\frac{\Delta A}{\Delta t}$= constant

6. **(a)** 1.21 $\overset{\circ}{A}$

Explanation: The given situation can be shown as Given the distance between the two atoms = 1.21 $\overset{\circ}{A}$

so, the wavelength of the standing wave is $\frac{\lambda}{2} + \frac{\lambda}{2} = \lambda$ = 1.21$\overset{\circ}{A}$

7.

(d) 88 s

Explanation: Total distance = Length of train + Length of bridge

= (100 + 1000)m = 1100 m

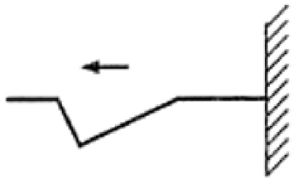
Speed = 45 km/h = 45 $\times \frac{5}{18}$ m/s = $\frac{25}{2}$ m/s

Time taken = $\frac{\text{Total distance}}{\text{Speed}}$

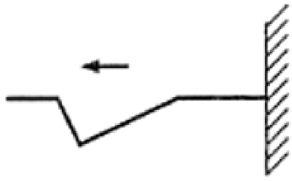
= $\frac{1100}{\frac{25}{2}}$ s = 88 s

8.

(c)



Explanation:



9. **(a)** $\sqrt[3]{4}W$

Explanation:

Work done to blow a bubble will be equal to its surface energy

W = S = surface area $\times$ surface tension S = A $\times$ T

Given that work done to blow a bubble of volume V is W.

W = S = surface area $\times$ surface tension, S = A $\times$ T for volume V

S = $4\pi r^2 \times$ T

S $\propto r^2$ but radius r $\propto$ Volume$(v)^{\frac{1}{3}}$

thus S $\propto (V)^{\frac{2}{3}}$

$\Rightarrow W \propto V^{\frac{2}{3}}$

$\Rightarrow$ thus if the volume is doubled

the W_2 becomes $(2)^{\frac{2}{3}} \Rightarrow (4)^{\frac{1}{3}} W_1$

thus $W_2 = \sqrt[3]{4}W_1$

10.

(c) 1.12×10^4 m/s

Explanation: We know, $V_{esc} = \sqrt{\frac{2GM}{R}}$

Here G = $6.67 \times 10^{-11} Nm^2kg^{-2}$

M = 6×10^{24} kg

R = 6.4×10^6 m

$\Rightarrow V_{esc} = \sqrt{\frac{2GM}{R}}$

$= \sqrt{\frac{2\times6.67\times10^{-11}\times6\times10^{24}}{6.4\times10^6}}$

$= \sqrt{\frac{12\times6.67\times10^7}{6.4}}$

= 1.12×10^4 m/sec

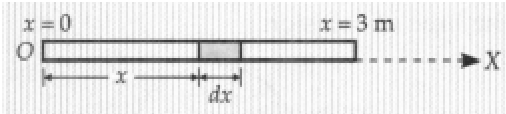
11.

(c) 2 m

Explanation:

Suppose the rod is placed along .x-axis. Consider a small element of thickness dx at distance x from its left end.

As the mass acting per unit length is directly proportional to distance x from one end, mass of the small element is dm = kx dx



The position of CM of the rod will be

$$x_{CM} = \frac{\int_0^3 x dm}{\int_0^3 dm}$$

$$= \frac{\int_0^3 kx^2 dx}{\int_0^3 kx dx}$$

$$= \frac{\left[\frac{x^3}{3}\right]_0^3}{\left[\frac{x^2}{2}\right]_0^3} = \frac{27}{3} \times \frac{2}{9} = 2\text{m}$$

12.

(d) equal to the temperature of the body

Explanation: The temperatures of the block and wood are equal to the temperature of the body as both feel equally hot or cold.

13.

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

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

14.

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

Explanation: Both A and R are true but R is not the correct explanation of A.

15.

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

Explanation: Gravitational field intensity at a point distance r from centre of earth is E = $\frac{GM}{r^2}$. When r = ∞, E = 0

When point is inside the earth, then

E = $\frac{G}{r^2} \times \frac{4}{3}\pi r^3 \rho = \frac{4\pi Gpr}{3}$

when r = 0, E = 0

16.

(c) A is true but R is false.

Explanation: A is true but R is false.

Section B

17. Because speed of sound in water is roughly four times the sound in air, hence refractive index

$u = \frac{\sin i}{\sin r} = \frac{Va}{Vw} = \frac{1}{4} = 0.25$

For, refraction $r_{max} = 90^o$, $i_{max} = 14^o$. Since $i_{max} \neq r_{max}$ hence, sounds get reflected in air only and person deep inside the water cannot hear the sound.

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.

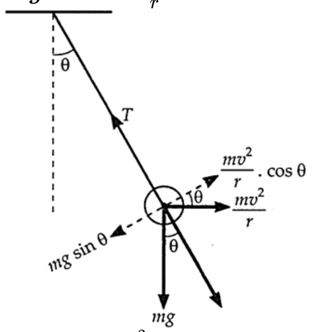
So, the answer will be 3.6×10^5

19.
- i. 1. If the number is less than one, then all zeros on the right of the decimal point are insignificant. This means that here, two zeros after the decimal are not significant. Hence, only 7 is a significant figure in this quantity.
- ii. 3. For the determination of significant values, we do not consider the power of 10 (Number is not less than 1). The digits 2, 6, and 4 are significant figures. Hence, It has 3 significant digits.
- iii. 4. Explanation: Significant figure- 2, 3, 7, 0. Trailing 0's is significant. These 0's increase the accuracy of the answer.
- iv. 4. From the condition of a significant figure, the zero after the decimal point comes after a non-zero number so it significant figure. The number of significant figures is 4.
- v. 4. Explanation: Significant figure- 6, 0, 3, 2. 0's between 2 non-zero digits are significant.

vi. 4. Explanation: Significant figure- 6, 0, 3, 2. Since **the number is less than 1.**

20. Various forces acting on the bulb are shown in figure. Resolving the forces along the length and perpendicular to the wire, we get

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



or $\tan\theta = \frac{v^2}{rg}$

or $v = \sqrt{rg\tan\theta} = \sqrt{200 \times 9.8 \times \tan 19^\circ 48'}$

$= \sqrt{200 \times 9.8 \times 0.3600} = \sqrt{705.6}$

= 26.56 ms^{-1}

21. $F = G\frac{m_1 m_2}{r^2}$

$= (6.67 \times 10^{-8})\left(\frac{1\times1}{1^2}\right)$ dyne

$= 6.67 \times 10^{-8} dyne$ = $\frac{6.67\times10^{-8}}{980}$

$= 7 \times 10^{-11} g^{-1} wt$

OR

i. First the rocket should be given a sufficient vertical velocity so that it reaches a height at which it is supposed to revolve around the earth.

ii. At this height, the rocket must be given a horizontal orbital velocity given by $v_0 = \sqrt{\frac{GM}{R+h}}$

iii. The air resistance should be negligible at the height of its orbit.

Section C

22. a. Here, $A_1 = \pi\left(\frac{D_1}{2}\right)^2$, $A_2 = \pi\left(\frac{D_2}{2}\right)^2$

$A_1 = \pi\left(\frac{3}{2} \times 10^{-2}\right)^2 m^2$, $A_2 = \pi\left(\frac{1}{2} \times 10^{-2}\right)^2 m^2$, F_1=10N

$\therefore F_2 = \frac{A_2}{A_1}F_1 = \frac{\pi\left(\frac{3}{2}\times10^{-2}\right)^2}{\pi\left(\frac{1}{2}\times10^{-2}\right)^2} \times 10 \Rightarrow F_2 = 90N$,hence the force exerted by large piston is 90N

b. Volume covered by the movement of smaller piston inwards is equal to volume moved outwards due to the larger piston,

$\because$ Water is incompressible

$\therefore L_1A_1 = L_2A_2$

$L_2 = \frac{A_1}{A_2}L_1 = \frac{\pi\left(\frac{1}{2}\times10^{-2}\right)^2}{\pi\left(\frac{3}{2}\times10^{-2}\right)^2} \times 6 \times 10^{-2}$

$L_2 = 0.67 \times 10^{-2} m = 0.67 cm$

Atmospheric pressure is common to both pistons and has been ignored.

23. Triple point of water on absolute scale A, T_1 = 200 A

Triple point of water on absolute scale B, T_2 = 350 B

Triple point of water on Kelvin scale, T_K = 273.15 K

The temperature 273.15 K on Kelvin scale, T_K is equivalent to 200 A on absolute scale A, T_1.

i.e. $T_1 = T_K$

$\Rightarrow$ 200 A = 273.15 K

$\therefore A = \frac{273.15}{200}$

The temperature 273.15 K on Kelvin scale, T_K is equivalent to 350 B on absolute scale B, T_2.

i.e. $T_2 = T_K$

$\Rightarrow$ 350 B = 273.15

$\therefore B = \frac{273.15}{350}$

Now as T_A is triple point of water on scale A and

T_B is triple point of water on scale B.

$A \times T_A = B \times T_B$

$\Rightarrow \frac{273.15}{200} \times T_A = \frac{273.15}{350} \times T_B$

$\therefore T_A = \frac{200}{350} T_B$

$\Rightarrow T_A = \frac{4T_B}{7}$, this is the required relation between the triple points on the mentioned two scales of temperature.

24. Here we use the equation of motion for constant velocity in Cartesian form.

Given x_1 (0) = 50 m, x_2 (0) = 100 m,

v_1 = 10 ms^{-1}, u_2 = 5ms^{-1}

The positions of the two buses at any instant t are

x_1 (t) = x_1 (0) + v_1t = 50 + 10t

x_2 (t) = x_2 (0) + v_2t = 100 + 5t

When A overtakes B,

x_1 (t) = x_2 (t)

50 + 10t = 100 + 5t

or 5t = 50

t = 10 s

x_1 (10) = x_2 (10) = 150 m

Thus A overtakes B at a position of 150 m from the origin at time t = 10 s

25. The forces acting on a block of mass m at rest on an inclined plane are

i. the weight mg acting vertically downwards
ii. the normal force N of the plane on the block, and
iii. the static frictional force fs opposing the impending motion.

In equilibrium, the resultant of these forces must be zero. Resolving the weight mg along the two directions shown, we have mg sin θ = f_s, mg cos θ = N

As θ increases, the self-adjusting frictional force fs increases until at $\theta = \theta_{\max'}$ f_s achieves its maximum value,

$(f_s)_{\max} = \mu_s N$

Therefore,

$\tan\theta_{\max} = \mu_s$ or $\theta_{\max} = \tan^{-1}\mu_s$

When θ becomes just a little more than $\theta_{\max}$, there is a small net force on the block and it begins to slide.

Note that $\theta_{\max}$ depends only on μ_s and is independent of the mass of the block.

For $\theta_{\max} = 15^\circ$

$\mu_s = \tan 15^\circ$

= 0.27

26. i. Specific heat formula for constant volume process: Q1 = $nC_V\Delta T$

Here, n = no. of moles = 2 , C_V = specific heat at constant volume =1.5 R = 1.5 × 8.314 J / mol / ^{0}C final Temperature of gas = T_2 Initial temperature of gas = T_1 increase in temperature =$\Delta T = T_2 - T_1$ = 50 - 20 = 30 ^{0}C

$Q_1 = 2 \times 1.5 \times 8.314 \times 30$ = 748 Joule

ii. constant - Pressure case :-

$Q_2 = nC_P\Delta T$

n = 2 moles, C_P = 2.49 R = 2.49×8.314

increase in temperature = ΔT = 30^0 C

$Q_2 = 2 \times 2.49 \times 8.314 \times 30$

Q_2 = 1242J

Q_2 is more than Q_1 to increase the temperature of gas by same amount because In constant - pressure Process excess heat is supplied for the expansion of gas.

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

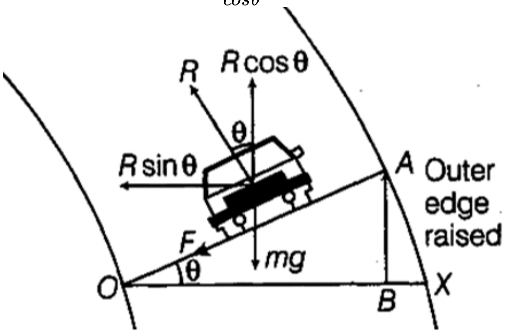
v = 50 km/h = 50 × $\frac{5}{18}$ m/s = 13.88 m/s

r = 40 m, θ = ?

Draw the FBD of the car.

Now, apply ΣF_g = may to the car

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



Similarly, apply ΣF_x = ma$_x$ to the car

R sin θ = $\frac{mv^2}{r}$

Put the value of R and then slove for θ

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

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

Put the all given values ot get θ

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

θ = 26.18^o

28. At one point, P_1 = 1 cm of Hg

= 0.01m of Hg

= 0.01 × (13.6 × 10^3) × 9.8 Pa

Velocity, V_1 = 0.35m|s

At another point, P_2 = ?

V_2 = 0.65m|s

Density of water, s = 10^3 Kg | m^3

According to Bernoulli's theorem,

$P_1 + \frac{1}{2}sV_1^2 = P_2 + \frac{1}{2}sV_2^2$

$P_2 = P_1 - \frac{1}{2}s\left(V_2^2 - V_1^2\right)$

$= 0.01 \times 13.6 \times 10^3 \times 9.8 - \frac{1}{2} \times 10^3\left((0.65)^2 - (0.35)^2\right)$

$= 13.6 \times 10^1 \times 9.8 - \frac{1}{2} \times 10^3(0.4225 - 0.1225)$

$= 1332.8 - \frac{1}{2} \times 10^3 \times (0.3)$

= 1332.8 - 0.15 × 10^3

= 1332.8 - 150

= 1182.8 Pa or $\frac{1182.8}{9.8\times 13.6\times 10^3} m$ of Hg

P_2 = 0.00887 m 0f Hg

OR

Density of wood, ρ = 0.25 × 10^3 kgm^{-3}

Density of oil, ρ' = 0.81 × 10^3 kg m^{-3}

According to the law of floatation,

Weight of the piece of wood = Weight of liquid displaced

or $V\rho g = V'\rho' g$

or $\frac{V'}{V} = \frac{\rho}{\rho'} = \frac{0.25\times 10^3}{0.81\times 10^3}$ = 0.31

i.e. fraction of volume of the wood submerged under the oil = 0.31

∴ Fraction of volume of the wood above the surface of the oil = 1 - 0.31 = 0.69

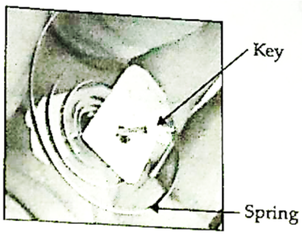
Section D

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

Clockwork refers to the inner workings of mechanical clock or watch (where it is known as "movement") and different types of toys which work using a series of gears driven by a spring. Clockwork device is completely mechanical and its essential parts are:

- A key (or crown) which you wind to add energy
- A spiral spring in which the energy is stored
- A set of gears through which the spring's energy is released. The gears control how quickly (or slowly) a clockwork machine can do things. Such as in mechanical clock/watch the mechanism is the set of hands that sweep around the dial to tell the time. In a clockwork car toy, the gears drive the wheels.

Winding the clockwork with the key means tightening a sturdy metal spring, called the mainspring. It is the process of storing potential energy. Clockwork springs are usually twists of thick steel, so tightening them (forcing the spring to occupy a much smaller space) is actually quite hard work. With each turn of the key, fingers do work and potential energy is stored in the spring. The amount of energy stored depends on the size and tension of the spring. Harder a spring is to turn and longer it is wound, the more energy it stores.



While the spring uncoils, the potential energy is converted into kinetic energy through gears, cams, cranks and shafts which allow wheels to move faster or slower. In an ancient clock, gears transform the speed of a rotating shaft so that it drives the second hand at one speed, the minute hand at $\frac{1}{60}$ of that speed, and the hour hand at $\frac{1}{3600}$ of that speed. Clockwork toy cars often use gears to make themselves race along at surprising speed.

(i) **(c)** A spring and combination of gears which move the hands of the clock

Explanation: Movement refers to the inner workings of mechanical clock using a series of gears driven by a spring.

(ii) **(a)** Potential

Explanation: Winding the spring means tightening a sturdy metal spring. It is the process of storing potential energy (forcing the spring to occupy a much smaller space) is actually quite hard work. With each turn of the key, fingers do work and potential energy is stored in the spring.

(iii) **(b)** Potential energy is converted into kinetic

Explanation: When the spring uncoils, the potential energy is converted into kinetic energy through gears, cams, cranks and shafts which allow wheels to move faster or slower.

OR

(c) Gear, Shaft

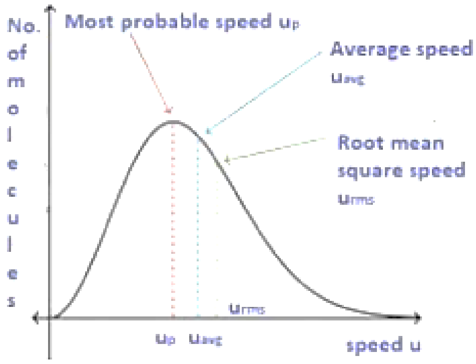
Explanation: In an ancient clock, gears transform the speed of a rotating shaft so that it drives the second hand at one speed, the minute hand at $\frac{1}{60}$ of that speed, and the hour hand at $\frac{1}{3600}$ of that speed. Clockwork toy cars often use gears to make themselves race along at surprising speed.

(iv) **(a)** Spring is larger, harder and wound fur a longer time

Explanation: With each turn of the key, fingers do work and potential energy is stored in the spring. The amount of energy stored depends on the size and tension of the spring. Harder a spring is to turn and longer it is wound, the more energy it stores.

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

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



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

Explanation: The r.m.s. velocity of all the gas molecules is more than the escape velocity of the moon's surface.

(ii) **(c)** > 1

Explanation: > 1

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

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

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

Explanation: $v_0\sqrt{6}$

OR

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

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

Section E

31. 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

Time period of a pendulum,

T = $2\pi\sqrt{\frac{l}{g}}$

For second's pendulum, T = 2s

$\therefore$ 2 = $2\pi\sqrt{\frac{l}{g}}$ or 1 = $\pi\sqrt{\frac{l}{g}}$

or 1 = $\pi^2\frac{l}{g}$ $\therefore$ l = $\frac{g}{\pi^2} = \frac{9.8}{\pi^2}$

i. When the carriage moves up with an acceleration a = 4 ms^{-2}, the time period is

T_1 = $2\pi\sqrt{\frac{l}{g+a}}$ = $2\pi\sqrt{\frac{9.8}{\pi^2(9.8+4)}}$

= $\frac{2\pi}{\pi}\sqrt{\frac{9.8}{13.8}}$ = 2 × 0.843 = 1.69 s

ii. When the carriage moves down with an acceleration a = 4 ms^{-2}, the time period is

T_2 = $2\pi\sqrt{\frac{l}{g-a}}$ = $2\pi\sqrt{\frac{9.8}{\pi^2(9.8-4)}}$

= $2\sqrt{\frac{9.8}{5.8}}$ = 2 × 1.299 = 2.59 s

iii. When the carriage moves horizontally, both g and a are at a right angle to each other, hence the net acceleration is

a' = $\sqrt{g^2+a^2} = \sqrt{(9.8)^2+(4)^4}$

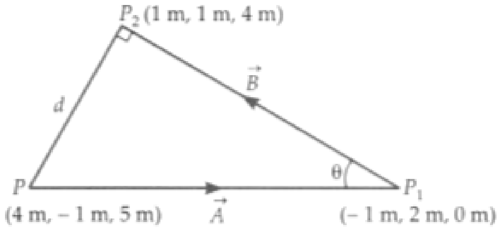
= $\sqrt{96.04+16} = \sqrt{112.04}$ = 10.58 ms^{-2}

The time period will be

T_3 = $2\pi\sqrt{\frac{l}{a'}} = 2\pi\sqrt{\frac{9.8}{\pi^2\times 10.58}}$

= 2 × 0.96 = 1.92 s

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



Let $\overrightarrow{PP_1} = \vec{A}$, $\vec{P_1}\vec{P_2} = \vec{B}, \angle PP_1P_2 = \theta$ and PQ = d

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

$\therefore \quad \sin\theta = \frac{|\vec{A}\times\vec{B}|}{|\vec{A}||\vec{B}|}$

Now $\vec{A} = (-1-4)\hat{i} + (2+1)\hat{j} + (0-5)\hat{k}$

But $\vec{A} = (-1-4)\hat{i} + (2+1)\hat{j} + (0-5)\hat{k}$

$= -5\hat{i} + 3\hat{j} - 5\hat{k}$

and $\vec{B} = (1+1)\hat{i} + (1-2)\hat{j} + (4-0)\hat{k}$

$= 2\hat{i} - \hat{j} + 4\hat{k}$

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

$= (12-5)\hat{i} + (-10+20)\hat{j} + \hat{k}(5-6)$

$= 7\hat{i} + 10\hat{j} - \hat{k}$

$\therefore |\vec{A}\times\vec{B}| = \sqrt{7^2+10^2+1^2} = 12.25\ m^2$

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

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

Time taken by bird to reach the point Q will be

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

OR

Let us first calculate the lengths of PQ and AC , $PQ = \sqrt{50^2 + 50^2} = 50\sqrt{2}$

$AC = \sqrt{100^2 + 100^2} = 100\sqrt{2}$

Time(T_1) taken through path $A \rightarrow P \rightarrow Q \rightarrow C$

$T_1 = \frac{(AP+QC)}{1m/s} + \frac{PQ}{v}$

$T_1 = \frac{AC-PQ}{1} + \frac{PQ}{\nu} = 100\sqrt{2} - 50\sqrt{2} + \frac{50\sqrt{2}}{v}$

$T_1 = 50\sqrt{2} + \frac{50\sqrt{2}}{2} = 50\sqrt{2}(1 + \frac{1}{v})$

Time taken along the path $A \rightarrow R \rightarrow C = \frac{(AR+RC)}{1} = 2AR = T_2$,

Using Pythagoras theorem, we get

$AR^2 = AO^2 + OR^2 = (\frac{100\sqrt{2}}{2})^2 + (\frac{50\sqrt{2}}{2})^2$ = 5000 + 1250 = 6250

$AR = \sqrt{6250} = 25\sqrt{10}$ s

$T_2 = 2 \times 25\sqrt{10}s = 50\sqrt{10}s$

For $T_{sand} < T_{outside}$, we have

$50\sqrt{2}[1 + \frac{1}{v}] < 50\sqrt{10}$

$[1 + \frac{1}{v}] < \sqrt{5}$

$\frac{1}{v} < \sqrt{5} - 1$

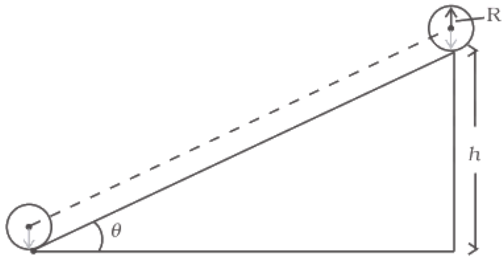
$v < \frac{1}{(\sqrt{5}-1)} = \frac{3.3}{4} = 0.83m/s$

v < 0.82 m / s

33. We assume conservation of energy of the rolling body, i.e. there is no loss of energy due to friction etc. The potential energy lost by the body in rolling down the inclined plane (= mgh) must, therefore, be equal to kinetic energy gained. (See Fig.) Since the bodies start from rest the kinetic energy gained is equal to the final kinetic energy of the bodies. From eq.

$K = \frac{1}{2}mv_{cm}^2\left(1 + \frac{k^2}{R^2}\right)$, where v is the final velocity of (the centre of mass of) the body.

Equating K and mgh,



$mgh = \frac{1}{2}mv^2\left(1 + \frac{k^2}{R^2}\right)$

or $v^2 = \left(\frac{2gh}{1+k^2/R^2}\right)$

Note is independent of the mass of the rolling body;

For a ring, $k_2 = R_2$

$v_{ring} = \sqrt{\frac{2gh}{1+1}}$,

$= \sqrt{gh}$

For a solid cylinder $k^2 = \frac{R^2}{2}$

$v_{\text{disc}} = \sqrt{\frac{2gh}{1+1/2}}$

$= \sqrt{\frac{10gh}{7}}$

Among the given three bodies, the solid sphere has the greatest and the ring has the least velocity at the bottom of the inclined plane.

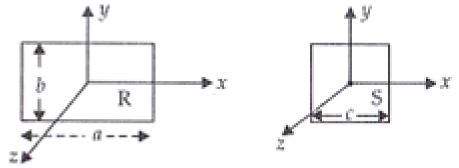
OR

Moment of inertia, in physics, quantitative measure of the rotational inertia of a body- i.e., the opposition that the body exhibits to having its speed of rotation about an axis altered by the application of a torque (turning force). The axis may be internal or external and may or may not be fixed. The moment of inertia (*I*), however, is always specified with respect to that axis and is defined as the sum of the products obtained by multiplying the mass of each particle of matter in a given body by the square of its distance from the axis. The unit of moment of inertia is a composite unit of measure. In the International System (SI), m is expressed in kilograms and *r* in metres, with I (moment of inertia) having the dimension kilogram-metre square.

$m_R = m_S = m$

Area of square = Area of rectangle

$c^2 = ab$ ...(i)



a. $\because I = mr^2$

$$\frac{I_{xR}}{I_{xz}} = \frac{m \cdot \left(\frac{b}{2}\right)^2}{m\left(\frac{c}{2}\right)^2} = \frac{b^2}{4}\frac{4}{c^2} = \frac{b^2}{c^2}$$

$\because c > b$ [from (i)]

Or $c^2 > b^2$

$1 > \frac{b^2}{c^2} : \frac{I_{xR}}{I_{xs}} < 1$

Hence proved.

b. $\frac{I_{yR}}{I_{ys}} = \frac{m\left(\frac{a}{2}\right)^2}{m\left(\frac{c}{2}\right)^2} = \frac{a^2}{4} \cdot \frac{4}{c^2} = \frac{a^2}{c^2}$

$\because a > c \Rightarrow \frac{a^2}{c^2} > 1$

$\frac{I_{yR}}{I_{ys}} > 1$

c. $I_{\text{zR}} - L_{zs} = m\left(\frac{d_R}{2}\right)^2 - m\left(\frac{ds}{2}\right)^2$

$I_{zR} - I_{zS} = \frac{m}{4}\left[d_R^2 - d_S^2\right] = \frac{m}{4}\left[a^2 + b^2 - 2c^2\right]$

$\therefore I_{zR} - I_{zS} = \frac{m}{4}\left(a^2 + b^2 - 2ab\right) = \frac{m}{4}(a-b)^2 \quad (c_2 = ab)$

$\therefore I_{zR} - I_{zS} > 0 \because \frac{m}{4}(a-b)^2 > 0$

$\Rightarrow \frac{I_{\text{zR}}}{I_{zS}} > 1$ Hence proved.