CBSE Class 11 Physics
Sample Paper 02 (2019-20)

Maximum Marks: 70
Time Allowed: 3 hours

General Instructions:

1. All questions are compulsory. There are 37 questions in all.
2. This question paper has four sections: Section A, Section B, Section C and Section D.
3. Section A contains twenty questions of one mark each, Section B contains seven questions of two marks each, Section C contains seven questions of three marks each, and Section D contains three questions of five marks each.
4. There is no overall choice. However, internal choices have been provided in two questions of one mark each, two questions of two marks, one question of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.

Section A

1. The word Science originates from the Latin verb Scientia meaning

   a. to experience

   b. to observe

   c. to see

   d. to know

2. Multiplying a vector $\vec{v}$ by a positive real number λ

   a. gives a vector $\overrightarrow{v'} = \lambda\vec{v}$ in a direction opposite to $\vec{v}$

   b. gives a scalar that is λ times the polar angle of $\vec{v}$

c. gives a scalar that is λ times the magnitude of $\vec{v}$

d. gives a vector $\overrightarrow{v'}$ = $\lambda\vec{v}$ in the same direction as $\vec{v}$

3. One end of a string of length l is connected to a particle of mass m and the other to a small peg on a smooth horizontal table. If the particle moves in a circle with speed v, T is the tension in the string, the net force on the particle directed towards the centre is

a. T

b. $\mathrm{T}-\frac{\mathrm{mv}^2}{\mathrm{l}}$

c. $\mathrm{T}+\frac{\mathrm{mv}^2}{\mathrm{l}}$

d. 0

4. Which of the following algebraic operations on vectors not permissible?

a. adding a scalar component of the vector to the same vector

b. multiplying any vector by any scalar,

c. adding any two vectors

d. multiplying the sum of vectors A and B by a scalar

5. The total mechanical energy of a system is conserved if the

a. forces, doing work on it, are not conservative

b. forces, doing work on it, are damped

c. forces, doing work on it, are conservative

d. forces, doing work on it, are viscous

6. Material is said to be brittle if

a. material cross-section is significantly reduced at failure

b. fracture occurs soon after the elastic limit is passed

c. a large amount of plastic deformation takes place between the elastic limit and the fracture point

d. material elongates a lot before finally breaking

7. In which mode of heat transfer no medium is required?

a. conduction

b. radiation

c. convection

d. none of the three

8. A Carnot engine takes 2000 J of heat from a reservoir at 500 K, does some work, and discards some heat to a reservoir at 350 K. How much heat is discarded?

a. -1100 J

b. -1300 J

c. -1400 J

d. -1300 J

9. The molar specific heat at constant volume, C_v for diatomic gases is

a. $\frac{7}{2}R$

b. $\frac{5}{2}R$

c. R

d. $\frac{3}{2}R$

10. The fundamental frequency of an open pipe is N keeping the pipe vertical. It is submerged in water so that half of its length is filled with water. The fundamental frequency of air column is

a. 2N
b. N
c. 3N/4
d. N/2

11. Fill in the blanks:

    The motion in which a particle moves in a circular path is called ________.

OR

    Fill in the blanks:

    The motion of the stone in circular motion comes under _______ dimensional motion.

12. Fill in the blanks:

    When charges are in motion, they produce ________ resulting into forces on those moving charges.

13. Fill in the blanks:

    The net effect on maximum height of a projectile when its angle of projection is changed from 30° to 60°, keeping the same initial velocity of projection is ________.

14. Fill in the blanks:

    Within the elastic limit, the ratio of lateral strain to the longitudinal strain is called _________.

15. Fill in the blanks:

    The ratio of emissive power (e) of a body to the emissive power (E) of a body at the same temperature is called ________.

16. What is the unit vector perpendicular to the plane of vectors $\vec{A}$ and $\vec{B}$?

17. In an elastic collision of two billiard balls, which of the following quantities remain conserved during the short time of collision of the balls (i.e., when they are in contact).

a. Kinetic energy.
b. Total linear momentum? Give reason for your answer in each case

18. The height of the water level in a tank is H = 96 cm. Find the range of water stream coming out of a hole at depth H/4 from the upper surface of the water.

19. If air in a cylinder is suddenly compressed by a piston. What happens to the pressure of air?

20. Is Newton’s law of motion applicable for material waves? Is this applicable for electromagnetic waves?

OR

A steel wire 0.72 m long has a mass of 5.0×10^{-3} kg. If the wire is under r a tension of 60 N, what is the speed of transverse waves on the wire?

21. The displacement x of a particle moving in one dimension under the action of constant force is related to the time by the equation where x is in meters and t is in seconds. Find the velocity of the particle at (1) t = 3s (2) t = 6s.

22. A train is moving with a velocity of 30 km/h due East and a car is moving with a velocity of 40 km/h due North. What is the velocity of car as appear to a passenger in the train?

23. Define angular acceleration. Give its SI unit and dimensional formula. How is it related to linear (tangential) acceleration?

24. If earth has a mass 9 times and radius 4 times than that of a planet "P". Calculate the escape velocity at the planet 'P' if its value on earth is 11.2 kms^{-1}.

25. Define modulus of elasticity and write its various types.

26. The earth constantly receives heat radiation from the sun and gets warmed up. Why does the earth not get as hot as the sun?

OR

A piece of paper wrapped tightly on a wooden rod is observed to get charred quickly when held over a flame as compared to a similar piece of paper when wrapped on a brass rod. Explain why?

27. What do you mean by degrees of freedom of a gas molecule? Write the number of degrees of freedom for a monatomic gas.

OR

At room temperature, a diatomic gas molecule has five degrees of freedom and at high temperature it has seven degrees of freedom, explain.

28. It is a well-known fact that during a total solar eclipse-the disk of the moon almost completely covers the disk of the sun. The distance of moon (r_{ME}) and sun (r_{SE}) from the earth surface is 3.84×10^8 m and 1.496×10^{11} m while the diameter of Sun is 1.390×10^9 m. Determine the approximate diameter of the moon.

29. A motor car starts from rest and accelerates uniformly for 10 s to a velocity of 20 m/s. After that car runs at a constant speed and is finally brought to rest in 40 m with a constant acceleration. Total distance covered is 640 m. Find the value of acceleration, retardation and total time taken.

30. A ball moving with a speed of 9 m/s strikes an identical ball at rest, such that after collision, the direction of each ball makes an angle of 30^0 with the original line of motion. Find the speed of the two balls after collision.

31. A particle is projected vertically upwards from the surface of Earth of radius R with a kinetic energy equal to half of the minimum value needed for it to escape. Find the height to which it rises above the surface of Earth.

32. A U-tube contains water and methylated spirit separated by mercury. The mercury columns in the two arms are in level with 10.0 cm of water in one arm and 12.5 cm of spirit in the other. What is the specific gravity of spirit?

OR

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

33. Calculate the amount of heat necessary to raise the temperature of 2 moles of He gas from 20^0C to 50^0C using:-

    i. Constant Volume Process
    ii. Constant Pressure Process

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

34. What correction was applied by Laplace in Newton's formula for speed of sound waves? Does it lead to correct value of speed of sound in air?

35. i. Define impulse. State its S.I. unit. State and prove impulse-momentum theorem.
    ii. A batsman deflects a ball by an angle of 45° without changing its initial speed which is equal to 54 km/h. What is the impulse imparted to the ball? (Mass of the ball is 0.15 kg.)

OR

A man of mass 70 kg stands on a weighing scale in a lift which is moving

i. upwards with uniform speed of 10 m/s?
ii. downwards with a uniform acceleration of 5 m/s^2?
iii. upwards with uniform acceleration of 5 m/s^2.

What would be the readings on the scale in each case? Also, What would be the reading if the lift mechanism failed and it hurtled down freely under gravity? When a man is standing on a weighing scale, it will read the normal reaction R as apparent weight.

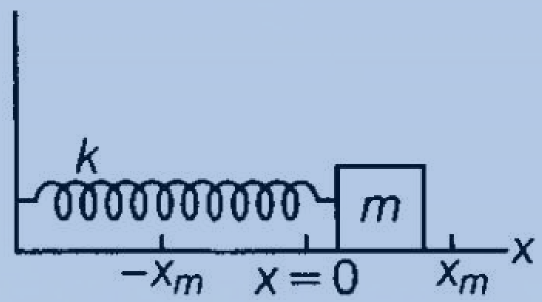
36. From a uniform disk of radius R, a circular hole of radius $\frac{R}{2}$ is cut out. The centre of the hole is at $\frac{R}{2}$ from the centre of the original disc. Locate the centre of gravity of the resulting flat body.

OR

Two discs of moments of inertia I_1 and I_2 about their respective axes (normal to the disc and passing through the centre), and rotating with angular speeds ω_1 and ω_2 are brought into contact face to face with their axes of rotation coincident.

a. What is the angular speed of the two-disc system?
b. Show that the kinetic energy of the combined system is less than the sum of the initial kinetic energies of the two discs. How do you account for this loss in energy? Take $\omega_1 \neq \omega_2$.

37. Consider a block of mass 700 g is fastened to a spring having spring constant of 70 N/m. Find out the following parameters if block is pulled a distance of 14 cm from its mean position on a frictionless surface and released from rest at t =0.



i. The angular frequency, the frequency and the period of the resulting motion.
ii. The amplitude of the oscillation.
iii. The maximum speed of the oscillating block.
iv. The maximum acceleration of the block.
v. The phase constant and hence the displacement function x (t).

OR

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

Solution

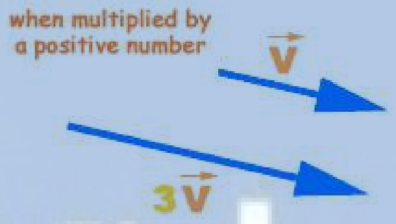
Section A

1. (d) to know

   Explanation: The phrase "scientia potentia est" (or "scientia est potentia" or also "scientia potestas est") is a Latin aphorism meaning "knowledge is power"

2. (d) gives a vector $\overrightarrow{v'} = \lambda\vec{v}$ in the same direction as $\vec{v}$

   Explanation: When a vector is multiplied by a positive number (for example 2, 3,5, 60 unit etc.) or a scalar only its magnitude is changed but its direction remains the same as that of the original vector.

3. (a) T

   Explanation: According to Newton's third law of motion, the net force on a rotating particle is equal to Tension in the String. As the action (ie force towards the centre) and reaction (tension in the string) are equal in magnitude and opposite in direction.

4. (a) adding a scalar component of the vector to the same vector

   Explanation: Although vectors and scalars represent different types of physical quantities, it is sometimes necessary for them to interact. While adding a scalar to a vector is impossible because of their different dimensions in space, it is possible to multiply a vector by a scalar.

5. (c) forces, doing work on it, are conservative

   Explanation: Mechanical energy is the sum of kinetic and potential energy in an object that is used to do work. In other words, it is energy in an object due to its motion or position, or both. In case of conservative forces total mechanical energy remains conserved because potential energy applicable only for conservative forces.

6. (b) fracture occurs soon after the elastic limit is passed

Explanation: If the ultimate strength and fracture points are close, it means very small plastic range beyond elastic limit, the material is said to be brittle.

7. (b) radiation

   Explanation: Heat transfer through radiation takes place in form of electromagnetic waves.

8. (c) -1400 J

   Explanation:

   $$\eta = \frac{T_H - T_L}{T_H} = \frac{500-350}{500} = \frac{150}{500} = 0.3 = 30\%$$

   Heat Discarded = $2000 \times \frac{70}{100} = 1400J$

9. (b) $\frac{5}{2}$ R

   Explanation:

   $$C_V = \frac{1}{2}Rf$$

   for diatomic gases f = 5

   $$C_V = \frac{5}{2}R$$

10. (b) N Explanation:

    $$f_n = \frac{nv}{2L}$$

    Thus frequency does not depend on medium.

11. circular motion

OR

one

12. Magnetic field

13. three times

14. Poisson's ratio

15. Emissivity

16. $\hat{n} = \frac{\vec{A} \times \vec{B}}{|\vec{A} \times \vec{B}|}$

17. When two billiard balls collide each other then their linear momentum and kinetic energy remains conserved. Because here it is considered that there is not any non-conservative force (like air resistance/friction on surface etc.) and speed of ball is not so high so that they deformed on collision.

18. The depth of hole below the upper surface of water,
$h = \frac{H}{4}$ = $\frac{96}{4} = 24cm$
The height of hole from ground,
$h' - 96 - 24 = 72cm$
Horizontal range $= 2\sqrt{h}\,h' = 2\sqrt{24 \times 72} = 48\sqrt{3}\ cm$

19. Since the sudden compression causes heating and rise in temperature and if the piston is maintained at same Position then the pressure falls as temperature decreases.

20. Newton's laws of motion are applicable for material waves but not applicable for electromagnetic waves. Since electromagnetic waves are produced by accelerated charges.

OR

Mass per unit length of the wire
$\mu = \frac{5.0 \times 10^{-3} \text{kg}}{0.72 \text{m}}$
= 6.9×10^{-3} kgm^{-1}
Tension, T = 60 N
Speed of the transverse wave through the wire, v = $\sqrt{\frac{T}{\mu}} = \sqrt{\frac{60}{6.9 \times 10^{-3}}}$ = 93 ms^{-1}

21. $t = \sqrt{x} - 3$
$\sqrt{x} = t + 3$
x = $(t + 3)^2$

 i. $v = \frac{dx}{dt} = 2(t + 3)$
 For $t = 3 v = 2(3 + 3) = 12 m/s$

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

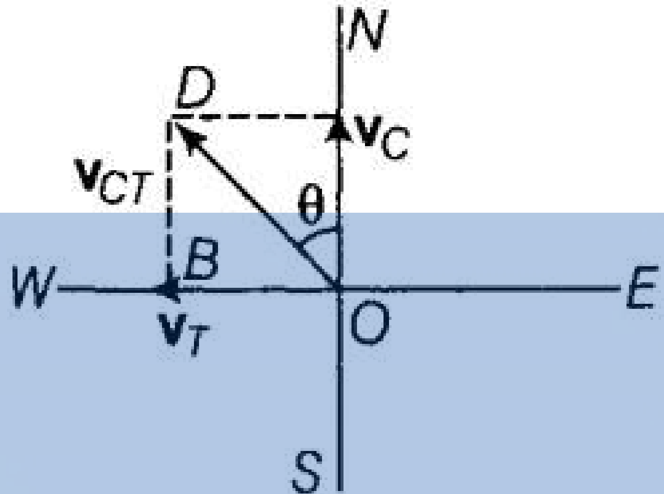
22. Given,

v_T =30 km/h due East

v_c =40 km/h due North

To find: v_{CT} = ?, θ = ?

According to the question,



From the figure, by Pythagoras theorem

$\mathbf{v}_{CT} = OD = \sqrt{OB^2 + BD^2} = \sqrt{v_T^2 + v_C^2}$

Then, $v_{CT} = \sqrt{(30)^2 + (40)^2} = \sqrt{900 + 1600}$ = 50 km/h

For a passenger in the velocity of car is 50 kmph

$\tan\theta = \frac{BD}{OB} = \frac{v_C}{v_T} \Rightarrow \tan\theta = \frac{30}{40}$

$\theta = \tan^{-1}\left(\frac{30}{40}\right) = 36°52'$ West of North

23. It is the rate of change of angular velocity with a time of an object in motion. The angular acceleration is also known as rotational acceleration. The acceleration vector, magnitude or length is directly proportional to the rate of change in angular velocity.

Mathematically, Angular acceleration, $\vec{\alpha} = \frac{d\overrightarrow{\omega}}{dt}$

If the axis of rotation is fixed, the direction of $\vec{\omega}$ and hence that of $\vec{\alpha}$ is fixed. In that case, the vector equation reduces to scalar equation $\alpha = \frac{d\omega}{dt}$

SI unit of angular acceleration is rad s^{-2} and its dimensional formula is $[T^{-2}]$. Angular acceleration $\vec{\alpha}$ and linear tangential acceleration $\vec{a}$ of a particle situated at $\vec{r}$ from the axis of rotation are related as $\vec{a} = \vec{\alpha} \times \vec{r}$

24. Given

$M_p = M_e/9$

$R_p = R_e/4$

escape velocity of earth is

$v_e = \sqrt{\frac{2GM}{R_e}}$

escape velocity of planet is

$v_p = \sqrt{\frac{2GM_p}{R_p}} M_p = \frac{M}{9}, R_p = \frac{R_e}{4}$

$\therefore v_p = \sqrt{2G\frac{M}{9} \times \frac{4}{R_e}}$

$= \frac{2}{3}\sqrt{\frac{2GM}{R_e}} = \frac{2}{3} \times 11.2 = \frac{22.4}{3}$

= 7.47 km/sec

25. Modulus of elasticity is defined as ratio of the stress to the corresponding strain produced, within the elastic limit.

E (Modulus of elasticity) $= \frac{\text{Stress}}{\text{Strain}}$

Types of Modulus of elasticity:-

i. Young's Modulus $= \frac{\text{Normal Stress}}{\text{Longitudinal Strain}}$
ii. Bulk Modulus $= \frac{\text{Normal Stress}}{\text{Volunetric Strain}}$
iii. Modulus of Rigidity $= \frac{\text{Tangential Stress}}{\text{Shearing Strain}}$

26. Because the earth is located at a very large distance from the sun, hence it receives only a small fraction of the heat radiation emitted by the sun. Further, due to loss of heat from the surface of the earth due to convection and radiation also, the earth does not become as hot as the sun.

OR

Wood is a bad conductor of heat and is unable to conduct away the heat. So, the paper quickly reaches its ignition point and is charred whereas, Brass is a good conductor of heat. It quickly conducts away the heat. So, the paper does not alter its ignition point easily.

27. Degrees of freedom of a gas molecule is the minimum number of coordinates (number of independent variables) required to completely specify the position (state of motion or energy) of it. For a monatomic gas e.g., He, Ne, etc., a molecule can have translational motion in any direction in the container and hence its speed v can be supposed to be consisting of three components v_x, v_y, and v_z along three principal axes and, thus, have three degrees of translational motion. A monatomic gas molecule does not possess rotational or vibrational motion. So, a total number of degrees of freedom per molecule of a monatomic gas is three only.

OR

At low temperature, a diatomic gas has three translational and two rotational degrees of freedom, making total number of degrees of freedom equal to 5.
But at high temperature, as the gas molecule starts to vibrate which give two additional degrees of freedom. In that case total number of degrees of freedom becomes 5+2 = 7.

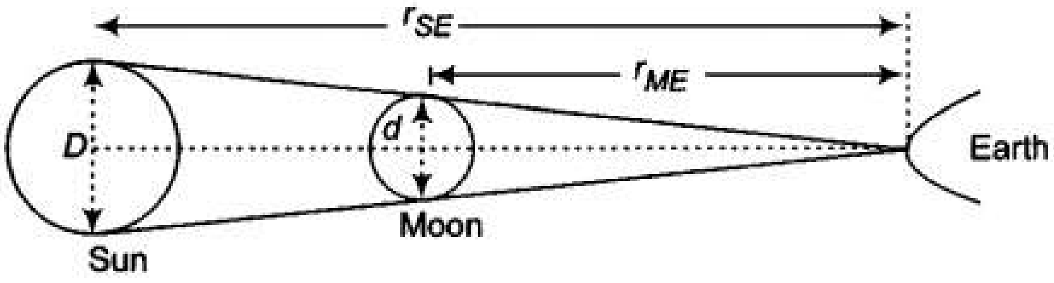
28. Given that,

Distance of the moon from the Earth (r_{ME})= 3.84×10^8 m

Distance of the sun from the Earth (r_{SE}) = 1.496×10^{11} m

Diameter of the sun (D) = 1.390×10^9 m
During the total solar eclipse, the disk of sun is completely covered by the disk of the moon.
Which implies that,

Angular diameter of the moon = Angular diameter of the sun, that is
$\frac{d}{r_{ME}} = \frac{D}{r_{SE}}$



$\therefore \quad d = D \times \frac{r_{ME}}{r_{SE}}$

Substituting the value of the constants and solving, we get

$= 139 \times 10^9 \times \frac{3.84 \times 10^8}{1.496 \times 10^{11}}$

= 3.5679 $\times$ 10^6 m

= 3.5679 $\times$ 10^3 m

= 3567.9 km = 3.567 $\times$ 10^6 m is the diameter of the moon. i.e. ~ 3500 km

29. Assume that x_1, x_2 and x_3 are the distances covered in three parts of the motion.

For First part of the motion, it is given that

u = 0, t = 10 s, v = 20 m/s

From the equation of motion we have, v = u + at

$\therefore 20 = 0 + a \times 10$

a = 2 m/s^2

Hence, Acceleration = 2 m/s^2

Also we know that, distance, x_1 = ut + $\frac{1}{2}$ at^2

$= 0 \times 10 + \frac{1}{2} \times 2 \times (10)^2$

= 100 m

For second part, we have

x_1 = 100 m, x_3 = 40 m

,Since x_1 + x_2 + x_3 = 640

100 + x_2 + x_3 = 640

or x_2 = 500 m

This distance is covered with a uniform speed of 20 m/s.

Therefore, Time taken = $\frac{500}{20}$ = 25 s

For third part of the motion, we have

u = 20 m/s, v = 0, x = x_3 = 40 m

As we know that, v^2 - u^2 = 2ax

$\therefore (0)^2-(20)^2=2\times a\times 40$

or, a = $-\frac{400}{80}=-5\mathrm{m/s}^2$

Hence, Retardation = 5 m/s^2

Time taken, t = $\frac{v-u}{a}=\frac{0-20}{-5}$ = 4 s

Total time taken = 10 + 25 + 4 = 39 s

30. Given, m_1 = m2 = m, u_1 = 9 m/s, u2 = 0

θ_1 = θ_2 = 30^0, v_1 = ?, v_2 = ?

According to principle of conservation of linear momentum, we have

m_1u_1 + m_2u_2 = m_1v_1 cos θ_1 + m_2v_2 cos θ_2

Along the direction of motion in x-axis, we have

m$\times$9 + 0 = mv_1 cos 30^0 + mv_2 cos 30^0

$9=v_1\frac{\sqrt{3}}{2}+v_2\frac{\sqrt{3}}{2}=\frac{(v_1+v_2)\sqrt{3}}{2}$

$v_1+v_2=\frac{18}{\sqrt{3}}$ ....(i)

Along a direction of motion in y-axis

$0+0=m_1v_1\sin\theta_1-m_2v_2\sin\theta_2$

$\Rightarrow$ mv_1 sin 30^0 = mv_2 sin 30^0 $\Rightarrow$ v_1= v_2 ....(ii)

Substitute the value from Eq. (ii) in Eq. (i), and find out values of v_1 and v_2 i.e.,

$2v_1=\frac{18}{\sqrt{3}}\Rightarrow v_1=\frac{9}{\sqrt{3}}\times\frac{\sqrt{3}}{\sqrt{3}}=\frac{9\sqrt{3}}{3}=3\sqrt{3}\mathrm{m/s}$

Hence, the two balls move with same velocity = $3\sqrt{3}$ m/s after collision.

31. We know that the expression for the escape velocity from the surface of Earth is given by:

$v_{es}=\sqrt{\frac{2GM}{R}}$ and corresponding K.E. of a body K_{es} = $\frac{1}{2}mv_{es}^2$ = $\frac{GMm}{R}$ ....(i)

As here, the body projected from the surface of Earth with a kinetic energy half of that needed to escape from Earth's surface, hence

The initial K.E of the body, K = $\frac{K_{es}}{2}$ = $\frac{GMm}{2R}$

and its P.E at the surface of Earth, U = -$\frac{GMm}{R}$

Therefore, the total initial energy of the body = K.E + P.E = $\frac{GMm}{2R}$ - $\frac{GMm}{R}$ = - $\frac{GMm}{2R}$ ....(ii)

Let the body goes up to a maximum height h from the surface of Earth, where its final K.E. = 0 and P.E = - $\frac{GMm}{(R+h)}$

Therefore now, total energy = 0 - $\frac{GMm}{(R+h)}$ = - $\frac{GMm}{(R+h)}$ ....(iii)

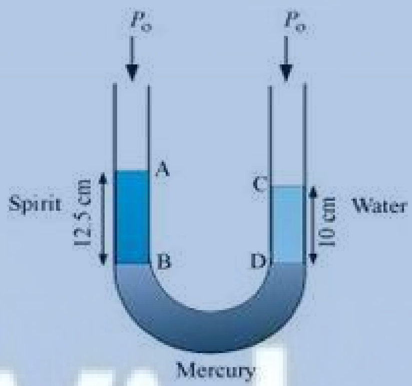
From conservation law of mechanical energy, we have

- $\frac{GMm}{2R}$ = - $\frac{GMm}{(R+h)}$

$\Rightarrow 2R = R + h$

$\Rightarrow h = R$

32. The given system of water, mercury, and methylated spirit is shown as follows:



Height of the spirit column, h_1 = 12.5 cm = 0.125 m

Height of the water column, h_2 = 10 cm = 0.1 m

P_0 = Atmospheric pressure

ρ_1 = Density of spirit

ρ_2 = Density of water

Pressure at point B = $P_0 + h_1\rho_1 g$

Pressure at point D = $P_0 + h_2\rho_2 g$

Pressure at points B and D is the same.

$P_0 + h_1\rho_1 g = h_2\rho_2 g$

$\frac{\rho_1}{\rho_2} = \frac{h_2}{h_1}$

$= \frac{10}{12.5} = 0.8$

Therefore, the specific gravity of spirit is 0.8.(specific gravity of any liquid is the ratio of liquid's density to water)

OR

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

33. 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 $\times$

8.314 J / mol / ^{0}C final Temperature of gas = T_2 Initial temperature of gas = T_1 increase in temperature =ΔT = 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.

34. Laplace applied a correction in Newton's formula, $\left[v = \sqrt{\frac{B_{isohermal}}{\rho}}\right]$ for speed of sound in gaseous media. Laplace argued that the compressions and rarefactions are taking place under the adiabatic condition on account of the following two reasons :

i. Gases are non-conducting in nature.
ii. Compressions and rarefactions are taking place so rapidly that there is practically no chance to exchange heat with the surrounding medium.

Thus, according to Laplace, v = $\sqrt{\frac{B_{\text{ndiahatic}}}{\rho}}$

We know that under adiabatic conditions PV^γ = constant

$\therefore P \cdot \gamma V^{\gamma-1} dV + dP \cdot V^\gamma = 0$

$\Rightarrow V^{\gamma-1}[V \cdot dP + \gamma P dV] = 0$

$\Rightarrow \gamma P = -\frac{dP}{(dV/V)} = B_{\text{adiabatic}}$, where γ is the ratio of two principal specific heats of a given gas. Hence, as per the Laplace modified formula, we have

$v = \sqrt{\frac{\gamma P}{\rho}}$

For air at STP conditions P = 1.013×10^5 Pa, ρ = 1.293 kg m^{-3} and for air γ = 1.41

$\therefore$ Speed of sound in air at STP, v = $\sqrt{\frac{1.41 \times 1.013 \times 10^5}{1.293}}$ = 332 ms^{-1}

The value so obtained resembles completely with experimentally determined value of the speed of sound in air. Hence, it is the correct relation.

35. i. When a force acts on a body or on a system or on a particle for some time, then the product of the force and the time interval is called impulse.

Impulse $\overline{I} = \overline{F} \times t$

S.I. Unit - NS

Impulse is a vector quantity directed along the average force $\overline{F}av$.

Impulse of a force is equal to the change in momentum of the body.

According to Newton's second law

$\overline{F} = \frac{d\overline{p}}{dt}$

or $d\overline{p} = \overline{F}dt$

Say, due to application of a force $\overline{F}$, the momentum of a body changes from $\overline{P}_1$ to $\overline{P}_2$ in the time interval 0 to t. i.e. At t = 0 $\overline{P} = \overline{P}_1$ and at

$t = t$, $\overline{P} = \overline{P_2}$

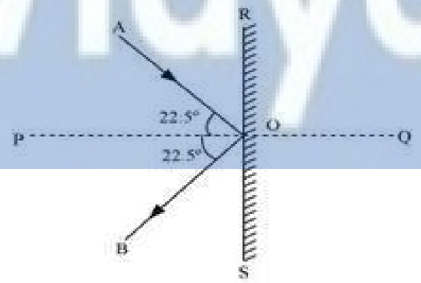
$\int_{\overline{P_1}}^{\overline{P_2}} d\overline{p} = \int_0^t \overline{F}dt$

$\overline{P}_2 - \overline{P}_1 = \overline{F}t$

$\overline{P}_2 - \overline{P}_1 = \overline{I}$

$[\because \overline{F}t = \overline{I}(\text{ Impulse })]$

ii. The given situation can be represented as shown in the following figure. In this case the speed of the ball remains same, but direction of velocity changes.



Where,

AO = Incident path of the ball

OB = Path followed by the ball after deflection

∠AOB = Angle between the incident and deflected paths of the ball = 45°

∠AOP = ∠BOP = $45^0/2$ = 22.5° = θ

Magnitude of initial and final velocities of the ball = v

Horizontal component of the initial velocity = v cos θ along PO

Vertical component of the initial velocity = v sin θ along RO

Horizontal component of the final velocity = v cos θ along OP
Vertical component of the final velocity = v sin θ along OS
The vertical components of velocities suffer no change. The horizontal components of velocities are in the opposite directions.
Final linear momentum of the ball of mass m, P_2 = $mv\ cos\theta$, along OP and initial linear momentum of the ball, P_1 = $mv\ cos\theta$, along PO = $-mv\ cos\theta$, along OP
$\therefore$ Impulse imparted to the ball by the bat = Change in the linear momentum of the ball = P_2 - P_1
$= mv\cos\theta - (-mv\cos\theta)$
$= 2mv\cos\theta, directed\ along\ OP$
Mass of the ball, m = 0.15 kg
Velocity of the ball, v = 54 km/h = (54×5)/18 m/s = 15 m/s
$\therefore$ Impulse = $2 \times 0.15 \times 15\cos 22.5^\circ$ = 4.16 kg m/s, directed along OP.

OR

Given, the mass of man, m = 70 kg
In each case, the weighing scale will read the reaction R for the action force W (weight of the man),
i.e. the apparent weight of the man.

i. As lift is moving upward with a uniform speed, therefore, its acceleration a = 0
$\therefore$ Normal reaction W = R = m g = 70×10 N = 700 N
W acts vertically downwards and R acts vertically upwards.
$\therefore$ Reading on weighing scale = $= \frac{700}{10} = 70$kg force
ii. When the acceleration of the lift, $a = 5\text{m/s}^2(\downarrow)$, then the net acceleration is (g - a) = $5m/s^2$
$\therefore$ Normal reaction, R = m (g -a) = 70(10 - 5)N
$= 70 \times 5\text{N} = 350\text{N}$
$\therefore$ Reading on weighing scale = $\frac{350\text{N}}{10\text{m/s}^2} = 35$kg-force
iii. Acceleration of the lift, a = 5 $m/s^2(\uparrow)$, then the net acceleration is (g + a) = 15 m/s^2
$\therefore$ R = m (g + a)
= 70(10 + 5) = 1050 N

$\therefore$Reading on weighing scale = $\frac{1050\text{N}}{10\text{m/s}^2} = 105$ kg-force

Acceleration of the lift when it is falling freely under the effect of gravity, then

$a = g(\downarrow)$

$\therefore$ R = m(g - a) = m(g - g) = 0

$\therefore$ Reading on weighing scale = 0 kg-force

36. The centre of mass of an object is the point at which the object can be balanced. Mathematically, it is the point at which the torques from the mass elements of an object sum to zero. The centre of mass is useful because problems can often be simplified by treating a collection of masses as one mass at their common centre of mass. The weight of the object then acts through this point.

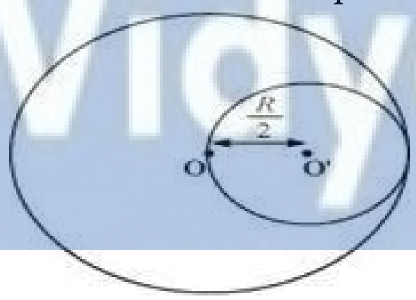
To solve this problem, first we assume that the whole disc was present whose centre of mass lies at the origin from which a small disc was cut out. So CM of remaining portion and cut out disc will lie exactly at the origin i.e Centre of Mass of the original disc at x = 0

Mass per unit area of the original disc = σ

Radius of the original disc = R

Mass of the original disc, $M = \pi R^2 \sigma$

The disc with the cut portion is shown in the following figure:



Radius of the smaller disc $= \frac{R}{2}$

Mass of the smaller disc, $M' = \pi \left(\frac{R}{2}\right)^2 \sigma = \frac{1}{4}\pi R^2 \sigma = \frac{M}{4}$

Let O and O' be the respective centers of the original disc and the disc cut off from the original. As per the definition of the centre of mass, the centre of mass of the original disc is supposed to be concentrated at O, while that of the smaller disc is supposed to be concentrated at O'.

It is given that:

$OO' = \frac{R}{2}$

After the smaller disc has been cut from the original, the remaining portion is

considered to be a system of two masses. The two masses are:
M (concentrated at O), and
$\left(-M' = \frac{M}{4}\right)$ concentrated at O'
(The negative sign indicates that this portion has been removed from the original disc.)
Let x be the distance through which the centre of mass of the remaining portion shifts from point O.
The relation between the centers of masses of two masses is given as:
$x = \frac{m_1 r_1 + m_2 r_2}{m_1 + m_2}$
For the given system
$x = \frac{M \times 0 - M \times \left(\frac{R}{2}\right)}{M + (-M')}$ (here M' is M/4)
$= \frac{\frac{-M}{4} \times \frac{R}{2}}{M - \frac{M}{4}} = \frac{-MR}{8} \times \frac{4}{3M} = \frac{-R}{6}$

Note that shift in Centre of Mass is very less(only 0.16 R or $\frac{R}{6}$) as removed portion has very less mass as compared to the remaining portion.
(The negative sign indicates that the centre of mass gets shifted toward the left of point O and lies at $\frac{R}{6}$ left towards origin.)

OR

1. **Conservation of angular momentum** is a physical property of a spinning system such that its spin remains constant unless it is acted upon by an external torque; put another way, the speed of rotation is constant as long as net torque is zero.
   Moment of inertia of disc I = I_1
   Angular speed of disc $I = \omega_1$
   Moment of inertia of disc II = I_2
   Angular speed of disc II = ω_2
   Angular momentum of disc $I, L_1 = I_1\omega_1$
   Angular momentum of disc $II, L_2 = I_2\omega_2$
   Total initial angular momentum, $L_i = I_1\omega_1 + I_2\omega_2$
   When the two discs are joined together, their moments of inertia get added up.
   Moment of inertia of the system of two discs, I = $I_1 + I_2$

Let ω be the angular speed of the system.

Total final angular momentum, $L_f = (I_1 + I_2)\,\omega$

Using the law of conservation of angular momentum, we have:

$L_i = L_f$

$$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\,\omega$$

$$\therefore \omega = \frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}$$

2. **Mechanical energy** is the sum of the potential and kinetic energies in a system. The principle of the conservation of mechanical energy states that the total mechanical energy in a system (i.e., the sum of the potential plus kinetic energies) remains constant as long as the only forces acting are conservative forces.

   Kinetic energy of disc I, $E_1 = \frac{1}{2} I_1\omega_1^2$

   Kinetic energy of disc II, $E_2 = \frac{1}{2} I_2\omega_2^2$

   Total initial kinetic energy, $E_i = \frac{1}{2}\left(I_1\omega_1^2 + I_2\omega_2^2\right)$

   When the discs are joined, their moments of inertia get added up.

   Moment of inertia of the system, $I = I_1 + I_2$

   Angular speed of the system = ω

   Final kinetic energy E_f:

   $$= \frac{1}{2}(I_1 + I_2)\,\omega^2$$

   $$= \frac{1}{2}(I_1 + I_2)\left(\frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}\right)^2 = \frac{1}{2}\frac{(I_1\omega_1 + I_2\omega_2)^2}{I_1 + I_2}$$

   $$\therefore E_i - E_j$$

   $$= \frac{1}{2}\left(I_1\omega_1^2 + I_2\omega_2^2\right) - \frac{(I_1\omega_1 + I_2\omega_2)^2}{2(I_1 + I_2)}$$

   $$= \frac{1}{2}I_1\omega_1^2 + \frac{1}{2}I_2\omega_2^2 - \frac{1}{2}\frac{I_1^2\omega_1^2}{(I_1 + I_2)} - \frac{1}{2}\frac{I_2^2\omega_2^2}{(I_1 + I_2)} - \frac{1}{2}\frac{2I_1I_2\omega_1\omega_2}{(I_1 + I_2)}$$

   $$= \frac{1}{(I_1 + I_2)}\left[\frac{1}{2}I_1^2\omega_1^2 + \frac{1}{2}I_1I_2\omega_1^2 + \frac{1}{2}I_1I_2\omega_2^2 + \frac{1}{2}I_2^2\omega_2^2\right.$$
   $$\left.-\frac{1}{2}I_1^2\omega_1^2 - \frac{1}{2}I_2^2\omega_2^2 - I_1I_2\omega_1\omega_2\right]$$

   $$= \frac{I_1I_2}{2(I_1 + I_2)}\left[\omega_1^2 + \omega_2^2 - 2\omega_1\omega_2\right]$$

   $$= \frac{I_1I_2(\omega_1 - \omega_2)^2}{2(I_1 + I_2)}$$

   All the quantities on RHS are positive.

   $$\therefore E_i - E_f > 0$$

Thus, $E_f < E_i$

Hence, the kinetic energy of the combined system is less than the sum of the initial kinetic energies of the two discs.
The loss of KE can be attributed to the frictional force that comes into play when the two discs come in contact with each other.

37. i. The angular frequency is given by
$\omega=\sqrt{\frac{k}{m}}=\sqrt{\frac{70\mathrm{N/m}}{0.700\mathrm{kg}}}$ = 10 rad/s
Frequency, $f=\frac{\omega}{2\pi}=\frac{10}{2\pi}\simeq 1.59\mathrm{Hz}$
The time period, T = $\frac{1}{f}=\frac{1}{1.59}$ = 0.63 = 630 ms

ii. The maximum amplitude of the oscillation = maximum displacement
$\therefore x_m$ =14 cm =0.14 m

iii. The maximum speed of the oscillation v_m is given by
$v_m = \omega x_m$ =10 $\times$ 0.14 =1.4 m/s

iv. The magnitude of maximum acceleration of the block is given by
$a_m = \omega^2 x_m$ =100 $\times$ 0.14 =14 m/s^2
At time t = 0, the block is located at position, $x = x_m$

v. Then, from general equation of oscillation, $x(t) = x_m \cos(\omega t+\phi)$
$\Rightarrow x_m = x_m\cos(0\times\omega+\phi)$
$\therefore \cos\phi = 1 \Rightarrow \phi = 0$
The required displacement function of the given oscillation with all the above values becomes,
$x(t) = x_m\cos(\omega t+\phi)$
$\Rightarrow$ x(t) $= 0.14\times\cos(10t+0)$
$\Rightarrow$x(t) = 0.14 cos 10t

OR

Consider a simple harmonic progressive wave travelling along the positive direction of x-axis. At any instance t,the displacement of the particles of medium situated at the origin is given by -

y = a sin wt

here a is the amplitude of oscillation and $2\pi/w$ is the period of oscillation and w is the angular frequency of the wave.

Initially, at t = 0:

Displacement, x = 1 cm

Initial velocity, v = ω cm/sec.

Angular frequency, ω = π rad/s^{-1}

It is given that:

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

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

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

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

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

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

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

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

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

$A^2 = 2$

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

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

$\tan\phi = -1$

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

SHM is given as:

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

Putting the given values in this equation, we get:

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

B sin a = 1 ....(iii)

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

Substituting the given values, we get:

$\pi = \pi B\sin a$

B sin a = 1 ...(iv)

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

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

$B^2 = 2$

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

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

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

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

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