AIPMT 2015 (Code: E) – DETAILED SOLUTION

Physics

1. If energy (E), velocity (V) and time (T) are chosen as the fundamental quantities, the dimensional formula of surface tension will be:

(1) $[EV^{-2}T^{-1}]$

(2) $[EV^{-1}T^{-2}]$

(3) $[EV^{-2}T^{-2}]$

(4) $[E^{-2}V^{-1}T^{-3}]$

Sol:
The dimensions for surface tension is given by

$$\text{Surface tension, } S = \frac{\text{Force}}{\text{Length}}$$

$$\Rightarrow [S] = \frac{[MLT^{-2}]}{[L]} = [ML^0T^{-2}]$$

Also, the dimensions of energy (E) and velocity (V) are given by

$[E] = [ML^2T^{-2}]$
$[V] = [LT^{-1}]$
Using dimensional equality on both sides, we get
$S = kE^aV^bT^c$
where k is a dimensionless constant

$\Rightarrow [ML^0T^{-2}] = [ML^2T^{-2}]^a [LT^{-1}]^b [T]^c$

$[ML^0T^{-2}] = [M^a][L^{2a+b}][T^{-2a-b+c}]$

$\Rightarrow a = 1$

Also,

$2a + b = 0$

$\Rightarrow b = -2$

and

$-2a - b + c = -2$

$\Rightarrow -2 + 2 + c = -2$

$c = -2$

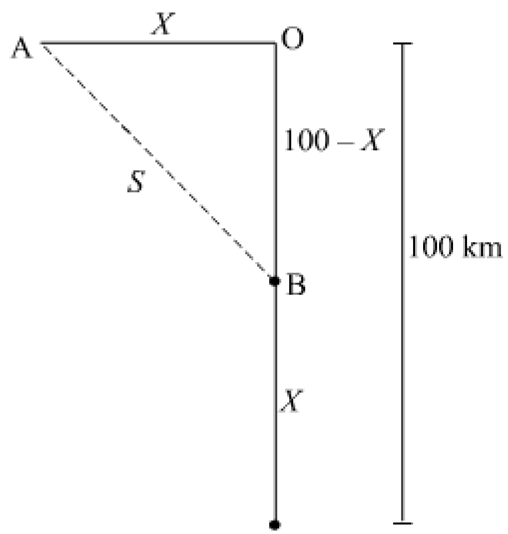
$\therefore [S] = [E^1 V^{-2} T^{-2}]$

Hence, the correct option is (3).

2. A ship A is moving Westwards with a speed of 10 km h^{-1} and a ship B 100 km South of A, is moving Northwards with a speed of 10 km h^{-1}. The time after which the distance between them becomes shortest, is:

(1) 0 h
(2) 5 h
(3) $52\sqrt{2}$ h
(4) $102\sqrt{2}$ h

Sol:
Let *t* be the time passed and *X* be distance covered by the two ships after which the distance between them becomes shortest.



Distance (S) between the ships is given by

$$s = \sqrt{(100-x)^2 + x^2}$$

For s to be minimum, $\frac{ds}{dx} = 0$

$$\Rightarrow \frac{ds}{dx} = \frac{1}{2\left[(100-x)^2 + x^2\right]^{-1/2}}\left[-2(100-x) + 2x\right] = 0$$

$$\Rightarrow 4x - 200 = 0$$

$$\Rightarrow x = 50 \text{ m}$$

So after both the ships have covered 50 m, distance between them becomes shortest. Time taken for it will

$$t = \frac{x}{10} = \frac{50}{10} = 5 \text{ h}$$

Hence, the correct option is (2).

3. A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to
$\upsilon(x)=\beta x^{-2n}$
where β and n are constants and x is the position of the particle. The acceleration of the particle as a function of x, is given by:

(1) $-2n\beta^2 x^{-2n-1}$
(2) $-2n\beta^2 x^{-4n-1}$
(3) $-2\beta^2 x^{-2n+1}$
(4) $-2n\beta^2 e^{-4n+1}$

Sol:

The velocity (v) as a function of position of the particle is given by
$\upsilon(x) = \beta x^{-2n}$ .....(i)

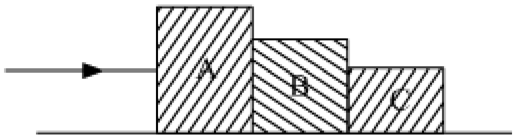
The acceleration (a) can be calculated as under:
$a = \frac{dv}{dt} = \left(\frac{dv}{dx}\right)\left(\frac{dx}{dt}\right) = \frac{dv}{dx} \times v$ .....(ii)

Differentiating (i) w.r.t x, we get
$\Rightarrow \frac{dv}{dx} = -2n\beta x^{-2n-1}$

Putting the above relation in equation (ii), we get
$\Rightarrow a = \left(-2n\beta x^{-2n-1}\right) \times \left(\beta x^{-2n}\right)$
$\Rightarrow a = -2n\beta^2 x^{-4n-1}$

Hence, the correct option is (2).

4. Three blocks A, B and C, of masses 4 kg, 2 kg and 1 kg respectively, are in contact on a frictionless surface, as shown. If a force of 14 N is applied on the 4 kg block, then the contact force between A and B is:

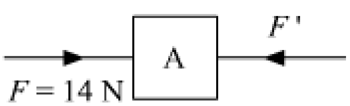


(1) 2 N
(2) 6 N
(3) 8 N
(4) 18 N

Sol:
Given that,
M_A = 4 kg, M_B = 2 kg, M_C = 1 kg
$M = M_A + M_B + M_C = 7$ kg
$F = Ma$
where F = Force
a = common acceleration of blocks

$F = 7a$
$14 = 7a$
$\Rightarrow a = 2$ m/s^2

Let F' be the contact force between A and B. Then from the free body diagram of block A, we get



$F - F' = 4a$
$14 - F' = 4 \times 2$
$14 - 8 = F'$
$F' = 6$ N

Hence, the correct option is (2).

5. A block A of mass m_1 rests on a horizontal table. A light string connected to it passes over a frictionless pulley at the edge of table and from its other end another block B of mass m_2 is suspended. The coefficient of kinetic friction between the block and the table is μ_k. When the block A is sliding on the table, the tension in the string is:

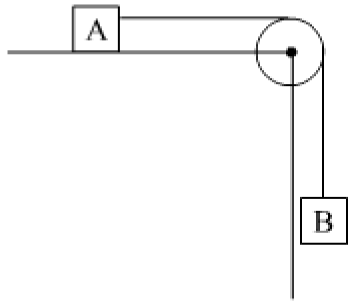
(1) $\frac{(m_2+\mu_k m_1)\,g}{(m_1+m_2)}$

(2) $\frac{(m_2-\mu_k m_1)\,g}{(m_1+m_2)}$

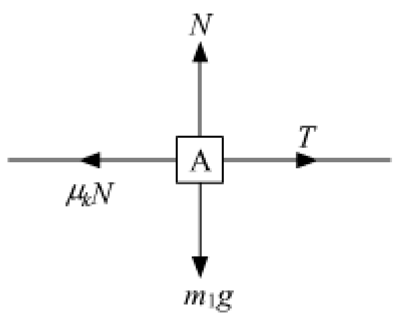
(3) $\frac{m_1 m_2(1+\mu_k)\,g}{(m_1+m_2)}$

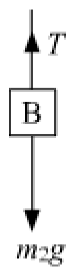
(4) $\frac{m_1 m_2(1-\mu_k)\,g}{(m_1+m_2)}$

Sol:
The given arrangement is



Let *T* be the tension in the string and *a* be the acceleration of the blocks. Then the free body diagrams of the blocks are given by





So, we have

$m_2 g - T = m_2 a$ .....(1)

$T - \mu_k m_1 g = m_1 a$ .....(2)

Multiplying (1) by m_1 and (2) by m_2, we get

$m_1m_2g - m_1T = m_1m_2a$ ......(3)

$Tm_2 - m_1\mu_k gm_2 = m_1m_2a$ .....(4)

Subtracting (4) from (3), we get

$m_1mg(1 + \mu_k) - T(m_1 + m_2) = 0$

$$\Rightarrow T = \frac{m_1m_2g(1+\mu_k)}{m_1+m_2}$$

Hence, the correct option is (3).

6. Two similar springs P and Q have spring constants K_P and K_Q, such that $K_P > K_Q$. They are stretched, first by the same amount (case a), then by the same force (case b). The work done by the springs W_P and W_Q are related as, in case (a) and case (b), respectively:

(1) $W_P = W_Q$; $W_P > W_Q$
(2) $W_P = W_Q$; $W_P = W_Q$
(3) $W_P > W_Q$; $W_Q > W_P$
(4) $W_P < W_Q$; $W_Q > W_P$

Sol:
In case (a), elongation (x) is same for both the springs. So, work done by springs P and Q is respectively given by

$$W_P = \frac{1}{2}K_P x^2 \text{ and}$$

$$W_Q = \frac{1}{2}K_Q x^2$$

$$\because K_P > K_Q$$

$$\therefore W_P > W_Q$$

In case (b), force of elongation (*F*) is same. The elongation of the springs is individually given by

$$x_P = \frac{F}{K_P} \text{ and}$$

$$x_Q = \frac{F}{K_Q}$$

$$\Rightarrow W_P = \frac{1}{2}K_P x_P^2 = \frac{1}{2}\frac{F^2}{K_P} \text{ and}$$

$$W_2 = \frac{1}{2}K_Q x_Q{}^2 = \frac{1}{2}\frac{F^2}{K_Q}$$

$$\therefore W_P < W_Q$$

Hence, the correct option is (3).

7. A block of mass 10 kg, moving in *x* direction with a constant speed of 10 ms^{-1}, is subjected to a retarding force F = 0.1*x* J/m during its travel from *x* = 20 m to 30 m. Its final KE will be:

(1) 475 J
(2) 450 J

(3) 275 J
(4) 250 J

Sol:
Mass of the block, *m* = 10 kg

Speed of the block, *v* = 10 ms^{-1}

Retarding force, *F* = 0.1 *x* J/m

According to work energy theorem, we have

Work done by force, $W = \Delta KE = KE_f - KE_i$

$$\Rightarrow W + KE_i = KE_f$$

$$\int_{20}^{30} -0.1x\,dx + \frac{1}{2} \times 10 \times 10^2 = KE_f$$

$$\Rightarrow \left[-0.1\frac{x^2}{2}\right]_{20}^{30} + 500 = KE_f$$

$$\Rightarrow -\frac{0.1}{2}(900 - 400) + 500 = KE_f$$

$$\Rightarrow -0.1 \times \frac{500}{2} + 500 = KE_f$$

$$\Rightarrow KE_f = -25 + 500 = 475 \text{ J}$$

Hence, the correct option is (1).

8. A particle of mass *m* is driven by a machine that delivers a constant power *k* watts. If the particle starts from rest the force on the particle at time *t* is:

(1) $\sqrt{\frac{mk}{2}}\, t^{-1/2}$

(2) $\sqrt{mk}\, t^{-1/2}$

(3) $\sqrt{2mk}\, t^{-1/2}$

(4) $\frac{1}{2}\sqrt{mk}\, t^{-1/2}$

Sol:
Mass of the particle = *m*
'*P*' is the power delivers by a machine then,

$P = Fv$ = constant = k .....(1)

If the particles moves with the acceleration '*a*', then
$F = ma = m\frac{dv}{dt}$ .....(2)
From (1) we have,

$$m\frac{dv}{dt}v = k$$

$$\Rightarrow \int v dv = \int \frac{k}{m} dt$$

$$\Rightarrow \frac{v^2}{2} = \frac{k}{m}t$$

$$\Rightarrow v = \sqrt{\frac{2k}{m}t}$$

Put the value of *v* in (2), we have,

$$F = m\frac{dv}{dt}$$

$$\Rightarrow F = m\sqrt{\frac{2k}{m}}\frac{1}{2}t^{-1/2}$$

$$\Rightarrow F = \sqrt{\frac{mk}{2}}t^{-1/2}$$

Hence, the correct option is (1).

9. Two particles of masses m_1, m_2 move with initial velocities u_1 and u_2. On collision, one of the particles get excited to higher level, after absorbing energy ε. If final velocities of particles be v_1 and v_2 then we must have:

(1) $m_1^2 u_1 + m_2^2 u_2 - \varepsilon = m_1^2 v_1 + m_2^2 v_2$

(2) $\frac{1}{2}m_1 u_1^2 + \frac{1}{2}m_2 u_2^2 = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2 - \varepsilon$

(3) $\frac{1}{2}m_1 u_1^2 + \frac{1}{2}m_2 u_2^2 - \varepsilon = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2$

(4) $\frac{1}{2}m_1^2 u_1^2 + \frac{1}{2}m_2^2 u_2^2 + \varepsilon = \frac{1}{2}m_1^2 v_1^2 + \frac{1}{2}m_2^2 v_2^2$

Sol:

Let, m_1, m_2 be the masses of the particles

u_1 and u_2 be the initial velocities of the particles

v_1 and v_2 be the final velocities of the particles

According to the conservation of energy

Initial total energy = Final total energy

$$\Rightarrow \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_2v_2^2 + \frac{1}{2}m_1v_1^2 + \varepsilon$$

$$\Rightarrow \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 + \varepsilon$$

$$\Rightarrow \boxed{\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 - \varepsilon = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2}$$

Hence, the correct option is (3).

10. A rod of weight *W* is supported by two parallel knife edges A and B and is in equilibrium in a horizontal position. The knives are at a distance d from each other. The centre of mass of the rod is at distance *x* from A. The normal reaction on A is :

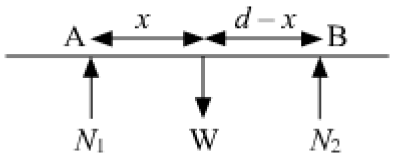
(1) $\frac{Wx}{d}$

(2) $\frac{Wd}{x}$

(3) $\frac{W(d-x)}{x}$

(4) $\frac{W(d-x)}{d}$

Sol:
Weight of the rod is *W.*
Distance between the two knifes is *d.*
If the distance of one knife from the centre of gravity is x, then the distance of the second knife from the centre of gravity is $(d - x)$



At equilibrium, force balance
$N_1 + N_2 = W$ .....(1)

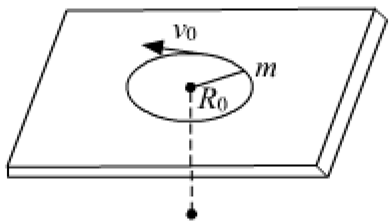
Torque balance about C.O.M. of rod
$N_1 x = N_2 (d - x)$

Putting value of N_2 from (1), we get

$$N_1 x = (W - N_1)(d - x)$$
$$\Rightarrow N_1 x = Wd - Wx - N_1 d + N_1 x$$
$$\Rightarrow N_1 d = W(d - x)$$
$$\Rightarrow \boxed{N_1 = \frac{W(d-x)}{d}}$$

Hence, the correct option is (4).

11. A mass *m* moves in a circle on a smooth horizontal plane with velocity v_0 at a radius R_0. The mass is attached to a string which passes through a smooth hole in the plane as shown.



The tension in the string is increased gradually and finally m moves in a circle of radius $\frac{R_0}{2}$. The final value of the kinetic energy is:

(1) mv_0^2

(2) $\frac{1}{4}mv_0^2$

(3) $2\ mv_0^2$

(4) $\frac{1}{2}mv_0^2$

Sol:

Let *m* be the mass of the particle.

Velocity of the particle is v_0.

Radius of the circle is R_0.

According to the conservation of angular momentum

$$mv_0R_0 = mv'\left(\frac{R_0}{2}\right)$$

$$\Rightarrow v' = 2v_0$$

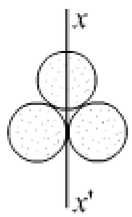
So, final kinetic energy is

$$K.E. = \frac{1}{2}mv'^2 = \frac{1}{2}m\left(2v_0\right)^2$$
$$= 2mv_0^2$$

Hence, the correct option is (3).

12. Three identical spherical shells, each of mass *m* and radius *r* are placed as shown in figure. Consider an axis XX' which is touching to two shells and passing through diameter of third shell.

Moment of inertia of the system consisting of these three spherical shells about XX' axis is:



(1) $\frac{11}{5}mr^2$

(2) 3 mr^2

(3) $\frac{16}{5}mr^2$

(4) 4 mr^2

Sol:
Let I_1, I_2 and I_3 be the moment of inertia of the three sphere.

So, the moment of inertia of the spheres about the axis passing through XX' is

$I = I_1 + I_2 + I_3$ .....(1)

$I_2 = I_3 = \frac{2}{3}mr^2 + mr^2 = \frac{5mr^2}{3}$

$I_1 = \frac{2}{3}mr^2$

Put the value of I_1, I_2 and I_3 in (1) we get

$$\therefore \ I = 2 \times 5\frac{mr^2}{3} + \frac{2}{3}mr^2$$

$$= \frac{12mr^2}{3} = 4mr^2$$

Hence, the correct option is (4).

13. Kepler's third law states that square of period of revolution (*T*) of a planet around the sun, is proportional to third power of average distance r between sun and planet i.e. $T^2 = Kr^3$ here *K* is constant.

If the masses of sun and planet are *M* and *m* respectively then as per Newton's law of gravitation force of attraction between them is $F = \frac{GMm}{r^2}$, here G is gravitational constant

The relation between G and K is described as:

(1) $GK = 4\pi^2$

(2) $GMK = 4\pi^2$

(3) $K = G$

(4) $K = \frac{1}{G}$

Sol:

Mass of the sun = *M*

Mass of the planet = *m*

Then the gravitational force between them is,

$$F = \frac{GMm}{r^2}$$

where, *r* is the average distance between sun and the planet

If the planet is revolve around the sun then, the centripetal force will balance the force acting between the planet and the sun.

Therefore,

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$\Rightarrow v^2 = \frac{GM}{r} \qquad .....(1)$$

Time period of revolution of the planet around the sun is:

$$T = \frac{2\pi r}{v}$$

On squaring both side,

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

Putting value of v^2 from (1), we get

$$\Rightarrow T^2 = \frac{4\pi^2 r^2}{\left(\frac{GM}{r}\right)}$$

$$\Rightarrow T^2 = \frac{4\pi^2 r^3}{GM} \qquad .....(2)$$

$$\Rightarrow T^2 = kr^3 \qquad .....(3)$$

From (2) and (3)

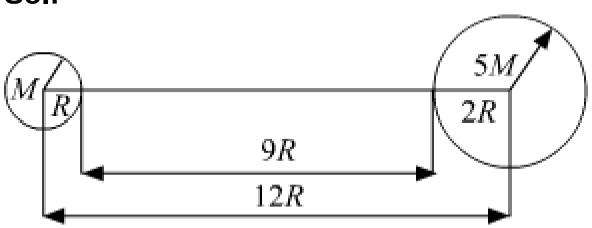
$$\frac{4\pi^2}{GM} = k \Rightarrow \boxed{GMK = 4\pi^2}$$

Hence, the correct option (2).

14. Two spherical bodies of mass *M* and 5*M* and radii *R* and 2*R* are released in free space with initial separation between their centres equal to 12*R*. If they attract each other due to gravitational force only, then the distance covered by the smaller body before collision is:

(1) 2.5 *R*
(2) 4.5 *R*
(3) 7.5 *R*
(4) 1.5 *R*

Sol:



Mass of one spherical body is *M* and having radii *R*
Mass of the second body is 5*M* and having radii 2*R*

Let the centre of mass from lie at distance *x* from body of mass *M*.
So,
$Mx = 5M(9R - x)$
$x = 45R - 5x$
$6x = 45R$
$2x = 15R$

x = 7.5R

Hence, the correct option is (3).

15. On observing light from three different stars P, Q and R, it was found that intensity of violet colour is maximum in the spectrum of P, the intensity of green colour is maximum in the spectrum of R and the intensity of red colour is maximum in the spectrum of Q. If T_P, T_Q and T_R are the respective absolute temperatures of P, Q and R, then it can be concluded from the above observations that:

(1) $T_P > T_Q > T_R$
(2) $T_P > T_R > T_Q$
(3) $T_P < T_R < T_Q$
(4) $T_P < T_Q < T_R$

Sol:
Wavelength of the violet colour is λ_v.
Wavelength of the red colour is λ_r.
Wavelength of the green colour is λ_g.

Temperature of the spectrum P is T_P.
Temperature of the spectrum Q is T_Q.
Temperature of the spectrum R is T_R.

We know that, $\lambda_r > \lambda_g > \lambda_v$ Then,
According to Wein's Displacement Law
$\lambda_m T = \text{Constant}$
where, λ_{max} = Wavelength of maximum intensity
T = Temperature of the blackbody
So, $T_r < T_g < T_v$
Where, T_r, T_g, T_v are the temperature of the respective colours spectrum.

So, we have $T_P > T_R > T_Q$

Hence, the correct option is (2).

16. The approximate depth of an ocean is 2700 m. The compressibility of water is 45.4×10^{-11} Pa^{-1} and density of water is 10^3 kg/m^3. What fractional compression of water will be obtained at the bottom of the ocean?

(1) 0.8×10^{-2}
(2) 1.0×10^{-2}
(3) 1.2×10^{-2}
(4) 1.4×10^{-2}

Sol:
Depth of the ocean, d = 2700 m
Compressibility of water, $k = 45.4 \times 10^{-11}$ Pa^{-1}.
Density of water is, $\rho = 10^3$ kg/m^3

Pressure at the bottom, $P = \rho g d$
$\Rightarrow P = 10^3 \times 10 \times 2700$
$\Rightarrow P = 27 \times 10^6$ Pa

∴ Fractional compression = Compressibility $\times$ Pressure
Fractional compression = $45.4 \times 10^{-11}\ Pa^{-1} \times 27 \times 10^6\ Pa$
Fractional compression = 1.2×10^{-2}

Hence, the correct option is (3).

17. The two ends of a metal rod are maintained at temperatures 100°C and 110°C. The rate of heat flow in the rod is found to be 4.0 J/s. If the ends are maintained at temperatures 200°C and 210°C, the rate of heat flow will be:

(1) 44.0 J/s
(2) 16.8 J/s
(3) 8.0 J/s
(4) 4.0 J/s

Sol:
Initially temperature difference is, $T_2 - T_1 = 110 - 100 = 10°C$
Finally temperature difference is, $T_2 - T_1 = 210 - 200 = 10°C$
As the temperature difference of both ends in both the cases are same i.e $10°C$.
The rate of heat flow will also remain same. Thus, the rate of flow of heat is 4.0 J/s.

Hence, the correct option is (4).

18. A wind with speed 40 m/s blows parallel to the roof of a house. The area of the roof is 250 m^2. Assuming that the pressure inside the house is atmospheric pressure, the force exerted by the wind on the roof and the direction of the force will be:
(P_{air} = 1.2 kg/m^3)

(1) 4.8×10^5 N, downwards
(2) 4.8×10^5 N, upwards
(3) 2.4×10^5 N, upwards
(4) 2.4×10^5 N, downwards

meritnation.com

Sol:

Applying Bernoullis theorem and assuming that density remains constant

$$P_1 + \frac{1}{2}\varrho v_1^2 = P_2 + \frac{1}{2}\varrho v_2^2$$

where P_1 is pressure inside the house

P_2 is the pressure outside the house

v_1 is the speed of air inside the house

v_2 is speed of air outside the house

Pressure difference,

$$P_1 - P_2 = \frac{1}{2}\varrho\left(v_2^2 - v_1^2\right)$$

$$\Rightarrow P_1 - P_2 = \frac{1}{2} \times 1.2\left(40^2 - 0^2\right) \quad \text{(As speed of air inside house is zero)}$$

$$\Rightarrow P_1 - P_2 = 960 \text{ N/m}^2$$

As, $P = \frac{F}{A}$

Therefore, the force acting on the roof is

$F = P \times A = 960 \times 250$

$$\Rightarrow F = 960 \times \frac{1000}{4}$$

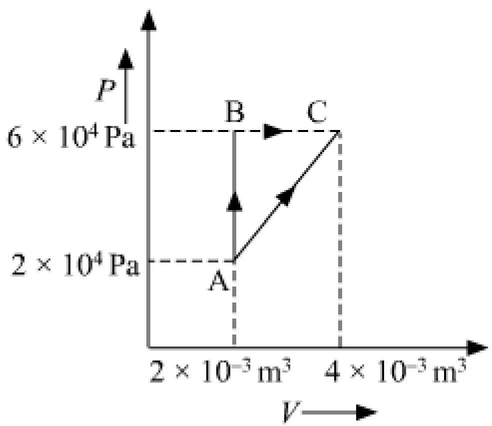
$$\Rightarrow F = 24 \times 10^4$$

$$\Rightarrow F = 2.4 \times 10^5 \text{ N}$$

This force is acting in the upward direction.

Hence, the correct option is (3).

19. Figure below shows two paths that may be taken by a gas to go from a state A to a state C.



In process AB, 400 J of heat is added to the system and in process BC, 100 J of heat is added to the system. The heat absorbed by the system in the process AC will be:

(1) 380 J
(2) 500 J
(3) 460 J
(4) 300 J

Sol:
From the graph, initial and final points are same so

$\Delta U_{A \to B \to C} = \Delta U_{A \to C}$

since $A \to B$ is a process tasking place at constant volume,

Thus, work done $dW = PdV = 0$

$dW_{A \to B} = 0$

Hence, $dQ_{A \to B} = dU_{A \to B} = 400J \ (as\ dQ = dU + dW)$

As $B \to C$ is a process taking place at constant pressure,

$\Rightarrow dQ_{B \to C} = dU_{B \to C} + dW_{B \to C}$

given, $dQ_{B \to C} = 100$ J

$\Rightarrow 100 = dU_{B \to C} + 6 \times 10^4 \left(2 \times 10^{-3}\right)$ (from graph)

$\Rightarrow 100 = dU_{B \to C} + 12 \times 10$

$\Rightarrow dU_{B \to C} = 100 - 120 = -20$ J

Similarly $\Delta U_{A \to C} = dQ_{A \to C} - dW_{A \to C}$

$As,\ \Delta U_{A \to B \to C} = \Delta U_{A \to C}$

$\Delta U_{A \to B} - \Delta U_{B \to C} = dQ_{A \to C} - dW_{A \to C}$

$\Rightarrow 400 - 20 = dQ_{A \to c} - \left(2 \times 10^{+4} \times 2 \times 10^{-3} + \frac{1}{2} \times 2 \times 10^{-3} \times 4 \times 10^{+4}\right)$ (from graph)

$\Rightarrow 380\ J = dQ_{A \to C} - (40 + 40)$

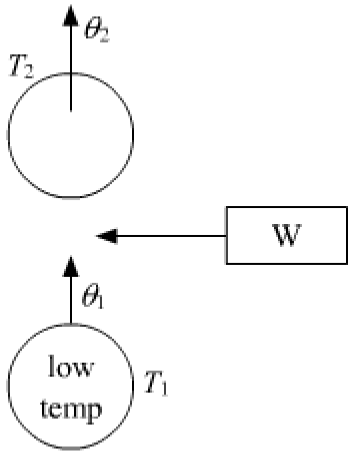
$\Rightarrow dQ_{A \to C} = 380 + 80 = 460J$

Hence, the correct option is (3).

20. A Carrnot engine, having an efficiency of $\eta = \frac{1}{10}$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is:

(1) 100 J
(2) 99 J
(3) 90 J
(4) 1 J

Sol:



we know that,

$$Q_1 + W = Q_2$$

or

$$W = Q_2 - Q_1$$

where W is the work done on the system

Q_1 is the energy absorbed from reservoir at lower temperature

Q_2 is the energy absorbed from higher temperature

we know effiiciency, η can be expressed as

$$\eta = 1 - \frac{T_1}{T_2}$$

where T_1 is tempearture of lower temperature reservoir and T_2 is the temnpearture of higher tempearture reservoir.

$$\frac{1}{10} = 1 - \frac{T_1}{T_2}$$

$$\boxed{\frac{T_1}{T_2} = 1 - \frac{1}{10} = \frac{9}{10}}$$

$$\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$$

$$\frac{Q_1 + w}{Q_1} = \frac{T_2}{T_1}$$

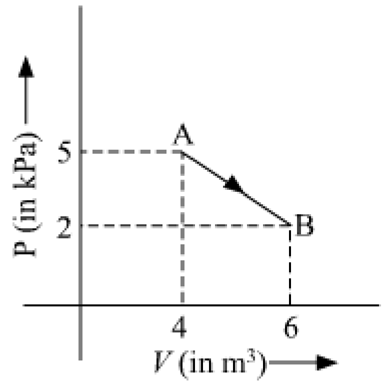
$$\frac{Q_1 + 10}{Q_1} = \frac{10}{9}$$

$$9Q_1 + 90 = 10Q_1$$

$$90 = Q_1$$

Hence, the correct option is (3).

21. One mole of an ideal diatomic gas undergoes a transition from A and B along a path AB as shown in the figure



The change in internal energy of the gas during the transition is :

(1) 20 kJ

(2) −20 kJ
(3) 20 J
(4) −12 kJ

Sol:
$\Delta U = nC_V\, dT$

where ΔU is change in internal energy of the system
C_V is the specific heat at constant volume
dT is the change in temperature
n is number of molecules per unit volume

As a diatomic molecule has 5 degrees of freedom, its specific heat is given by
$$C_V = \frac{5R}{2}$$

$$\therefore\ \Delta U = n\left(\frac{5R}{2}\right)\left(T_B - T_A\right)$$

$$\Rightarrow \Delta U = \frac{5nR}{2}\left(\frac{P_B V_B}{nR} - \frac{P_A V_A}{nR}\right)\left(\because PV = nRT\right)$$

$$\Rightarrow \Delta U = \frac{5}{2}\left(P_B V_B - P_A V_A\right)$$

$$\Rightarrow \Delta U = \frac{5}{2}\left(2\times 10^3 \times 6 - 5\times 10^3 \times 4\right)$$

$$\Rightarrow \frac{5}{2}\left(-8\times 10^{-3}\right)$$

$$\Rightarrow \Delta U = -20\ \text{kJ}$$

Hence, the correct option is (2).

22. The ratio of the specific heats $\frac{C_P}{C_v} = \gamma$ in terms of degrees of freedom (*n*) is given by :

(1) $\left(1+\frac{1}{n}\right)$

(2) $\left(1+\frac{n}{3}\right)$

(3) $\left(1+\frac{2}{n}\right)$

(4) $\left(1+\frac{n}{2}\right)$

Sol:

Specific heat of gas at constant volume, C_v, can be expressed as

$$C_v = \frac{n}{2}\mathrm{R}$$

where n is the degree of freedom

R is the gas constant

Specific heat of gas at constant pressure, C_p, can be expressed as

$$C_p = C_v + \mathrm{R} = \frac{n}{2}\mathrm{R} + \mathrm{R}$$

$$\Rightarrow C_p = \left(\frac{n}{2} + 1\right)\mathrm{R}$$

$$\therefore \gamma = \frac{C_p}{C_v} = \frac{\left(\frac{n}{2} + 1\right)\mathrm{R}}{\frac{n}{2}\mathrm{R}} = \frac{n+2}{n}$$

$$\Rightarrow \gamma = 1 + \frac{2}{n}$$

Hence, the correct option is (3).

23. When two displacements represented by $y_1 = a\sin(\omega t)$ and $y_2 = b\cos(\omega t)$ are superimposed the motion is:

(1) not a simple harmonic
(2) simple harmonic with amplitude $\frac{a}{b}$
(3) simple harmonic with amplitude $\sqrt{a^2 + b^2}$
(4) simple harmonic with amplitude $\frac{(a+b)}{2}$

Sol:
Given,
$y_1 = a \sin(\omega t)$
$y_2 = b \sin\left(\omega t + \frac{\pi}{2}\right)$
On superimposition,

$y = y_1 + y_2$
$y = a\sin(\omega t) + b\sin\left(\omega t + \frac{\pi}{2}\right)$
$\Rightarrow y = a\sin(\omega t) + b\sin(\omega t)\cos\left(\frac{\pi}{2}\right) + b\cos(\omega t)\sin\left(\frac{\pi}{2}\right)$
$\Rightarrow y = a \sin(\omega t) + b \cos(\omega t)$
Let $b\cos(\omega t) = A\cos\theta$ .....(1)
and $a\sin(\omega t) = A\sin\theta$ .....(2)
where θ and A are constants
$y = A\sin(\omega t + \theta)$
On squaring both (1) and (2), and adding we get
$A = \sqrt{a^2 + b^2}$
$\therefore y = \sqrt{a^2 + b^2}\sin(\omega t + \theta)$
which represents a simple harmonic motion with amplitude $\sqrt{a^2 + b^2}$

Hence, the correct option is (3).

24. A particle is executing SHM along a straight line. It velocities at distances x_1 and x_2 from the mean position are V_1 and V_2, respectively. Its time period is :

(1) $2\pi\sqrt{\dfrac{x_1^2+x_2^2}{V_1^2+V_2^2}}$

(2) $2\pi\sqrt{\dfrac{x_2^2-x_1^2}{V_1^2-V_2^2}}$

(3) $2\pi\sqrt{\dfrac{V_1^2+V_2^2}{x_1^2+x_2^2}}$

(4) $2\pi\sqrt{\dfrac{V_1^2-V_2^2}{x_1^2-x_2^2}}$

Sol:

We know for a particle under SHM, velocity *V* of a particle is given by

$$V = -\omega a\left(1-\frac{x^2}{a^2}\right)^{1/2}$$

where ω is the angular velocity

a is amplitude

x is the displacement from mean position

or

$$V^2 = \omega^2\left(a^2 - x^2\right)$$

$$\Rightarrow V_1^2 = \omega^2\left(a^2 - x_1^2\right) \text{ .....}(1) \text{ and}$$

$$V_2^2 = \omega^2\left(a^2 - x_2^2\right) \text{ ....}(2)$$

Now subtacting (2) from (1), we get

$$V_1^2 - V_2^2 = \omega^2\left(x_2^2 - x_1^2\right)$$

$$\Rightarrow \omega = \sqrt{\frac{V_1^2 - V_2^2}{x_2^2 - x_1^2}}$$

$\therefore$ Time period, T is given by

$$T = \frac{2\pi}{\omega}$$

$$\Rightarrow T = 2\pi\sqrt{\frac{x_2^2 - x_1^2}{V_1^2 - V_2^2}}$$

Hence, the correct option is (2).

25. The fundamental frequency of a closed organ pipe of length 20 cm is equal to the second overtone of an organ pipe open at both the ends. The length of organ pipe open at both the ends is :

(1) 80 cm
(2) 100 cm
(3) 120 cm
(4) 140 cm

Sol:
For a closed organ pipe, frequency of vibration f_c is given by

$$f_c = \frac{v}{4l}$$

where *l* is the length of closed organ pipe.

Frequency of vibration for open organ pipe is given by

$$f_0 = \frac{v}{2l'}$$

where *l*' is the length of open organ pipe.

Given that, second overtone of an open organ pipe is equal to fundamental frequency of a closed organ pipe.

$$f_c = 3f_0$$

$$f_c = \frac{3v}{2l'}$$

$$\Rightarrow \frac{v}{4l} = \frac{3v}{2l'}$$

$$\Rightarrow l' = 6l$$

$$\Rightarrow l' = 6 \times 20$$

$$\Rightarrow l' = 120 \text{ cm}$$

Hence, the correct option is (3)

26. A parallel plate air capacitor of capacitance *C* is connected to a cell of emf *V* and then disconnected from it. A dielectric slab of dielectric constant *K*, which can just fill the air gap of the capacitor, is not inserted in it. Which of the following is **incorrect**?

(1) The potential difference between the plates decreases *K* times.
(2) The energy stored in the capacitor decreases *K* times.
(3) The change in energy stored is $\frac{1}{2}CV^2\left(\frac{1}{K}-1\right)$
(4) The charge on the capacitor is not conserved.

Sol:
Charge (q) on the capacitor of capacitance (C) when connected to cell of emf (V) is given by,

$q = CV$

$$\Rightarrow V = \frac{q}{C}$$

When dielectric slab of dielectric constant K is inserted, then new capacitance (C_2) will be

$C_2 = CK$

The charge on the capacitor will remain same even after disconnecting.

Energy before introducing the dielectric slab (U_1) is given by

$$U_1 = \frac{q^2}{2C}$$

Energy after introducing the dielectric slab $\left(U_2\right)$ is given by

$$U_2 = \frac{q^2}{2CK}$$

Difference in energy $\left(U\right)$ will be

$U = U_2 - U_1$

$$= \frac{q^2}{2C}\left(\frac{1}{K} - 1\right)$$

$$\Rightarrow U = \frac{1}{2}CV^2\left(\frac{1}{K} - 1\right)$$

Potential after introducing the dielectric slab is given by

$$V' = \frac{q}{CK}$$

$$\Rightarrow V' = \frac{V}{K}$$

Hence, the correct option is (4).

27. The electric field in a certain region is acting radially outward and is given by $E = Ar$. A charge contained in a sphere of radius 'a' centred at the origin of the field, will be given by:

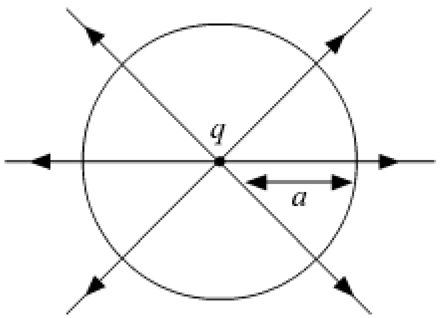
(1) $4\pi\varepsilon_0 Aa^2$

(2) $A\varepsilon_0 a^2$

(3) $4\pi\varepsilon_0 Aa^3$

(4) $\varepsilon_0 Aa^3$

Sol:



The electric field here is given by
$E = Ar$
$E = A \times a$
$\Rightarrow E = Aa$

Electric field due to charge contained in a sphere of radius a is given by

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}$$

As per given situation,

$$\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2} = Aa$$

$$\Rightarrow q = 4\pi\varepsilon_0 Aa^3$$

Hence, the correct option is (3).

28. A potentiometer wire has length 4 m and resistance 8 Ω. The resistance that must be connected in series with the wire and accumulator of e.m.f. 2 V, so as to get a potential gradient 1 mV per cm on the wire is :

(1) 32 Ω
(2) 40 Ω
(3) 44 Ω
(4) 48 Ω

Sol:
We have been given
Resistance of the potentiometer wire, R = 8 Ω
Emf of the accumulator, E = 2 V
Potential gradient, K = 1 mV
Potential due to wire of length 4 m = 1 × 400 = 400 mV = 0.4 V

Let the resistance R_1 must be connected in series with the wire to get potential gradient 1 mV per cm.

Now,

$$V = \frac{E}{R + R_1} \times R$$

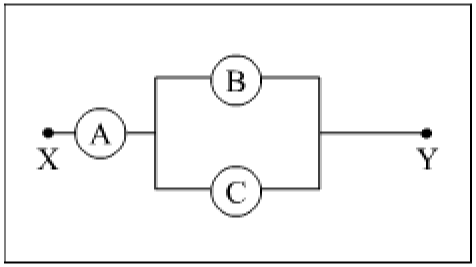
$$\Rightarrow 0.4 = \frac{2}{8 + R_1} \times 8$$

$$\Rightarrow 8 + R_1 = \frac{16}{0.4} = 40$$

$$\Rightarrow R_1 = 40 - 8 = 32\ \Omega$$

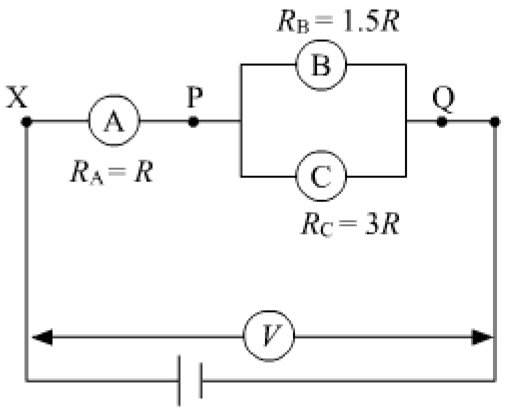
Hence, the correct option is (1).

29. A, B and C are voltmeters of resistance R, 1.5 R and 3R respectively as shown in the figure. When some potential difference is applied between X and Y, the voltmeter readings are V_A, V_B and V_C respectively. Then :



(1) $V_A = V_B = V_C$
(2) $V_A \neq V_B = V_C$
(3) $V_A = V_B \neq V_C$
(4) $V_A \neq V_B \neq V_C$

Sol:



As shown in figure, resistances R_B and R_C of voltmeters are in parallel. So, their equivalent resistance (R') will be

$$\frac{1}{R'} = \frac{1}{R_B} + \frac{1}{R_C}$$

$$\Rightarrow \frac{1}{R'} = \frac{1}{1.5R} + \frac{1}{3R}$$

$$\Rightarrow \frac{1}{R'} = \frac{2+1}{3R}$$

$$\Rightarrow R' = R$$

So, voltage across XP will be, $V_{XP} = V_A = iR$

Voltage across PQ, $V_{PQ} = V_B = V_C = iR$

$\therefore V_A = V_B = V_C$

Hence, the correct option is (1).

30. Across a metallic conductor of non-uniform cross section a constant potential-difference is applied. The quantity which remains constant along the conductor is :

(1) current density
(2) current
(3) drift velocity
(4) electric field

Sol:
If current *I* is flowing through the conductor of area *A,* then current density (*J*) is given by

$$J = \frac{I}{A} \quad .....(1)$$

Drift velocity (v_d) is given by

$$v_d = \frac{I}{nAe} = \frac{J}{ne} \quad .....(2)$$

Where *n* is number density of electron
e = charge on each electron

Electric field (*E*) is given by

$$E = \rho J \quad .....(3)$$

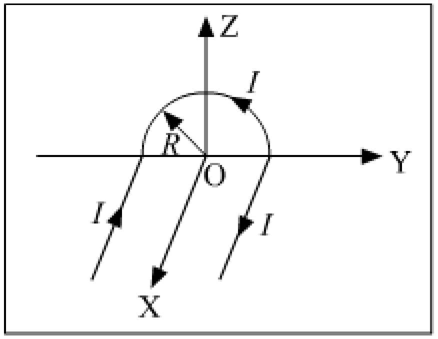
Where, ρ = resistivity of material

From equation (1), (2) and (3) we find that current density, drift velocity and electric field depends on the area of the conductor. Therefore, option (1), (2) and (3) is incorrect.

Even if the area of cross section of conductor is non uniform, the number of electrons flowing will be same, so current will be constant.

Hence, the correct option is (2).

31. A wire carrying current *I* has the shape as shown in adjoining figure. Linear parts of the wire are very long and parallel to X-axis while semicircular portion of radius *R* is lying in Y−Z plane. Magnetic field at point O is :



(1) $\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{R} (\pi\hat{i} + 2\hat{k})$

(2) $\vec{B} = -\frac{\mu_0}{4\pi} \frac{I}{R} (\pi\hat{i} - 2\hat{k})$

(3) $\vec{B} = -\frac{\mu_0}{4\pi} \frac{I}{R} (\pi\hat{i} + 2\hat{k})$

(4) $\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{R} (\pi\hat{i} - 2\hat{k})$

Sol:

Magnetic field due to wire parallel to the x axis is given by,

$$B_{\text{I}} = \frac{\mu_0}{4\pi} \frac{I}{R}(-\hat{k})$$

Magnetic field due to another wire parallel to the x axis is given by

$$B_{\text{III}} = \frac{\mu_0}{4\pi} \frac{I}{R}(-\hat{k})$$

Magnetic field due to half semicircular wire is given by

$$B_{\text{II}} = \frac{\mu_0 I}{4R} (\hat{i})$$

Magnetic field at the centre of the wire(B) will be

$$B = B_{\text{I}} + B_{\text{II}} + B_{\text{III}}$$

$$\Rightarrow B = \frac{\mu_0 I}{4R\pi} (-2\hat{k} + \pi i)$$

Hence, the correct option is (4).

32. An electron moving in a circular orbit of radius *r* make *n* rotations per second. The magnetic field produced at the centre has magnitude.

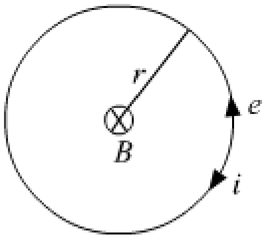
(1) $\frac{\mu_0 ne}{2\pi r}$

(2) Zero

(3) $\frac{\mu_0 n^2 e}{r}$

(4) $\frac{\mu_0 ne}{2r}$

Sol:



We have been given that an electron is revolving in a circular orbit of radius *r* and *n* be the rotation per second made by electron. Let *e* be the charge on each electron and *T* be its time period of revolution.
Electric current (*I*) is given by

$$I = \frac{e}{T}$$

$$\Rightarrow I = \frac{e}{\left(\frac{2\pi}{\omega}\right)} \quad \left(\because T = \frac{2\pi}{\omega}\right)$$

$$\Rightarrow I = \frac{\omega e}{2\pi}$$

$$\Rightarrow I = \frac{(2\pi n)e}{2\pi} \quad (\because \omega = 2\pi n)$$

$$\Rightarrow I = ne \quad .....(1)$$

Magnetic field at the centre of circular coil of radius R is given by

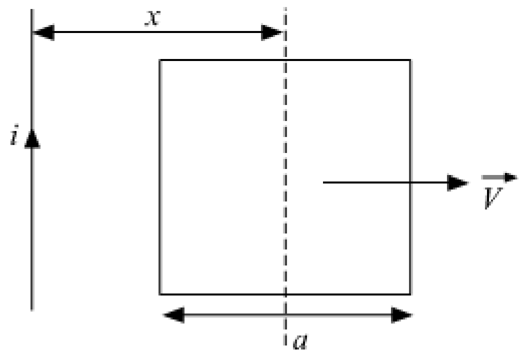
$$B = \frac{\mu_0 I}{2r}$$

From (1), we get

$$\Rightarrow B = \frac{\mu_0 ne}{2r}$$

Hence, the correct option is (4).

33. A conducting square frame of side '*a*' and a long straight wire carrying current *i* are located in the same plane as shown in the figure. The frame moves to the right with a constant velocity '*V*'. The emf induced in the frame will be proportional to :



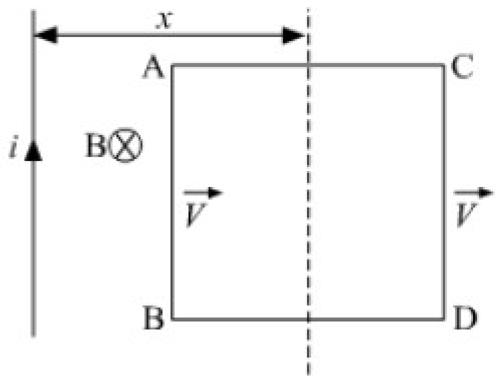
(1) $\frac{1}{x^2}$

(2) $\frac{1}{(2x-a)^2}$

(3) $\frac{1}{(2x+a)^2}$

(4) $\frac{1}{(2x-a)(2x+a)}$

Sol:



Potential difference across the AB is given by

$V_A - V_B = e_1 = B_1(a)v \quad \ldots(1)$

Where B_1 is magnetic field induction at AB

$$\text{But, } B_1 = \frac{\mu_0}{4\pi}\frac{2i}{\left(x - \frac{a}{2}\right)}$$

Substituting the value of B_1 in equation (1) we get,

$$e_1 = \frac{\mu_0 i}{2\pi\left(x - \frac{a}{2}\right)}av$$

Potential difference CD is given by

$V_C - V_D = e_2 = B_2(a)v$

But, $B_2 = \frac{\mu_0}{4\pi} \frac{2i}{\left(x + \frac{a}{2}\right)}$

$$e_2 = \frac{\mu_0 i}{2\pi\left(x + \frac{a}{2}\right)} av$$

Net potential difference in the loop is

$$\left(V_A - V_B\right) - \left(V_C - V_D\right) = e_1 - e_2$$

$$= \frac{\mu_0 iav}{2\pi}\left(\frac{1}{x - \frac{a}{2}} - \frac{1}{x + \frac{a}{2}}\right)$$

$$= \frac{\mu_0 iav}{2\pi}\left(\frac{2a}{\left(x - \frac{a}{2}\right)\left(x + \frac{a}{2}\right)}\right)$$

$$\propto \frac{1}{(2x - a)\,(2x + a)}$$

Hence, the correct option is (4).

34. A resistance 'R' draws power 'P' when connected to an AC source. If an inductance is now placed in series with the resistance, such that the impedance of the circuit becomes 'Z', the power drawn will be:

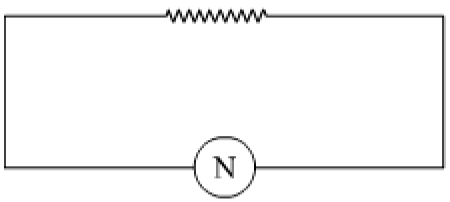
(1) $P\left(\frac{R}{Z}\right)^2$

(2) $P\sqrt{\frac{R}{Z}}$

(3) $P\left(\frac{R}{Z}\right)$

(4) *P*

Sol:



When only resistance is connected to the AC source, then power (*P*) is given by

$P = V_{rms} i_{rms}$ .....(1)

Where V_{rms} = voltage across the resistance

But, $V_{rms} = i_{rms} R$

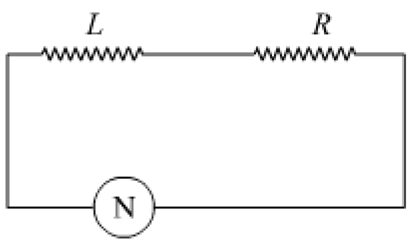
$$\Rightarrow i_{rms} = \frac{V_{rms}}{R}$$

Substituting in (1) we get

$$P = V_{rms} \times \frac{V_{rms}}{R}$$

$$\Rightarrow P = \frac{V_{rms}^2}{R}$$

$$\Rightarrow V_{rms}^2 = PR$$



When inductance is also connected to the circuit, then power (P_1) in ac circuit is given by

$$P_1 = V_{rms} i_{rms} \cos\phi$$

$$\Rightarrow P_1 = V_{rms} \times \frac{V_{rms}}{Z} \times \frac{R}{Z}$$

$$\Rightarrow P_1 = V_{rms}^2 \frac{R}{Z^2}$$

$$\Rightarrow P_1 = PR \frac{R}{Z^2} \quad \left(\because V_{rms}^2 = PR\right)$$

$$\Rightarrow P_1 = P \frac{R^2}{Z^2}$$

Hence, the correct option is (1).

35. A radiation of energy '*E*' falls normally on a perfectly reflecting surface. The momentum transferred to the surface is (*C* = Velocity of light):

(1) $\frac{E}{C}$

(2) $\frac{2E}{C}$

(3) $\frac{2E}{C^2}$

(4) $\frac{E}{C^2}$

Sol:

Let *v* be the frequency and *λ* be the wavelength of the incident radiation.

Energy (*E*) is given by

$$E = h\nu$$

$$\Rightarrow E = \frac{hc}{\lambda}$$

Momentum of incident light(P_i) will be

$$= \frac{h}{\lambda} = \frac{E}{c}$$

Momentum of reflected light(P_r) will be

$$P_r = \frac{-h}{\lambda} = \frac{-E}{c}$$

Change in momentum (ΔP) is

$$\Delta P = P_r - P_i = \frac{-2E}{c}$$

Momentum transfered to the surface $= -\Delta\vec{P}_{light} = \frac{2E}{c}$

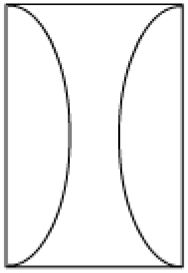
Hence, the correct option is (2).

36. Two identical thin plano-convex glass lenses (refractive index 1.5) each having radius of curvature of 20 cm are placed with their convex surfaces in contact at the centre. The intervening space is filled with oil of refractive index 1.7. The focal length of the combination is :

(1) −20 cm
(2) −25 cm

(3) −50 cm
(4) 50 cm

Sol:
Given,
Radius of curvature of plano-convex lens, R = 20 cm
Refractive index of plano-convex lens, μ = 1.5



Using lens maker formula, focal length of the plano convex lens (f) is given by

$$\frac{1}{f}=(\mu_1-1)\left[\frac{1}{R}\right]$$

$$\Rightarrow\frac{1}{f}=(1.5-1)\left[\frac{1}{R}\right]$$

$$\Rightarrow\frac{1}{f}=\frac{0.5}{R}$$

Focal length of the concave part of the lens(f_{concave}) is given by

$$\frac{1}{f_{\text{concave}}}=(\mu_2-1)\left(\frac{-1}{R}-\frac{1}{R}\right)$$

$$\Rightarrow\frac{1}{f_{\text{concave}}}=(1.7-1)\left[\frac{-1}{R}-\frac{1}{R}\right]$$

$$\Rightarrow\frac{1}{f_{\text{concave}}}=\frac{-0.7\times 2}{R}=\frac{-1.4}{R}$$

Equivalent focal length (f_{eq}) will be

$$\frac{1}{f_{eq}}=\frac{0.5}{R}-\frac{1.4}{R}+\frac{0.5}{R}$$

$$\Rightarrow\frac{1}{f_{\text{eq}}}=\frac{-0.4}{R}=\frac{-0.4}{20}$$

$$\Rightarrow f_{\text{eq}}=-50\text{ cm}$$

Hence, the correct option is (3).

37. For a parallel beam of monochromatic light of wavelength 'λ', diffraction id produced by a single slit whose width '*a*' is of the order of the wavelength of the light. If '*D*' is the distance of the screen from the slit, the width of the central maxima will be:

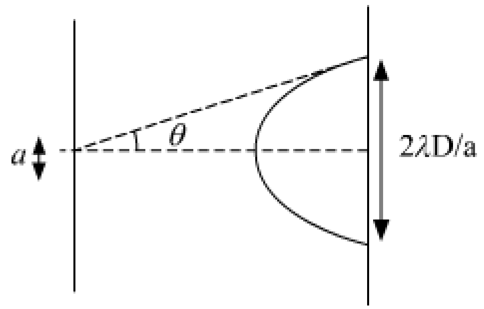
(1) $\frac{2D\lambda}{a}$

(2) $\frac{D\lambda}{a}$

(3) $\frac{Da}{\lambda}$

(4) $\frac{2Da}{\lambda}$

Sol:



width of central maxima is basically distance between first secondary minimum on both sides

$a \sin\theta = \lambda$

$\sin\theta = \frac{\lambda}{a}$

as θ is small , $\sin\theta \sim \theta$

$\frac{y}{D} = \frac{\lambda}{a}$

$y = \frac{\lambda D}{a}$

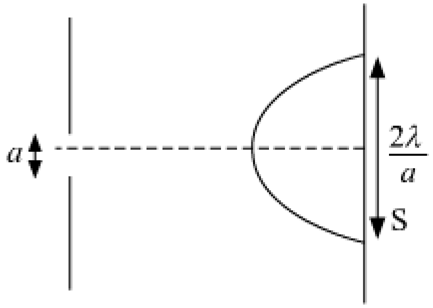
width of centeral maxima is $\frac{2\lambda D}{a}$

Hence, the correct option is (1).

38. In a double slit experiment, the two slits are 1 mm apart and the screen is placed 1 m away. A monochromatic light of wavelength 500 nm is used. What will be the width of each slit for obtained ten maxima of double slit within the central maxima of single slit pattern?

(1) 0.2 mm
(2) 0.1 mm
(3) 0.5 mm
(4) 0.02 mm

Sol:
Given,
d = 1 mm = 1×10^{-3} m
D = 1 m
$\lambda = 500 \times 10^{-9}$ m



$\frac{2\lambda}{a} = 10\left(\frac{\lambda D}{d}\right)$ (width of central maxima is equal to width of 10 maxima)

$\Rightarrow a = \frac{2d}{10\,D}$

$\Rightarrow a = \frac{2\times10^{-3}}{10\times1}$

$\Rightarrow a = 2\times10^{-4}\ m$

$a = 0.2\ mm$

Hence, the correct option is (1)

39. The refracting angle of a prism is *A*, and refractive index of the material of the prism is cot (*A/2*). The angle of minimum deviation is :

(1) 180° − 3*A*
(2) 180° − 2*A*
(3) 90° − *A*
(4) 180° + 2*A*

Sol:

meritnation.com

$we\ know,$

$$\mu = \frac{sin\left(\frac{A+\delta}{2}\right)}{sin\left(\frac{A}{2}\right)}\text{(Prism formula)}$$

$$cot\ \frac{A}{2} = \frac{sin\left(\frac{A+\delta}{2}\right)}{sin\left(\frac{A}{2}\right)}\ \text{(given)}$$

$$\Rightarrow \frac{cos\left(\frac{A}{2}\right)}{sin\left(\frac{A}{2}\right)} = \frac{sin\left(\frac{A+\delta}{2}\right)}{sin\left(\frac{A}{2}\right)}$$

$$\Rightarrow sin\left(\frac{\pi}{2}-\frac{A}{2}\right) = sin\left(\frac{A}{2}+\frac{\delta}{2}\right)$$

$$\Rightarrow \delta = \pi - 2A$$

Hence, the correct option is (2)

40. A certain metallic surface is illuminated with monochromatic light of wavelength, λ. The stopping potential for photo-electric current for this light is $3V_0$. If the same surface is illuminated with light of wavelength 2λ, the stopping potential is V_0. The threshold wavelength for this surface for photo-electric effect is:

(1) 6λ
(2) 4λ
(3) $\frac{\lambda}{4}$
(4) $\frac{\lambda}{6}$

Sol:

Einstein's photoelectric equations we have

$$\frac{hc}{\lambda} = h\nu = \phi + eV_0$$

So,

$$\frac{hc}{\lambda} = \phi + e(3V_0) \qquad .....(1)$$

$$\frac{hc}{2\lambda} = \phi + eV_0$$

$$\frac{hc}{\lambda} = 2\phi + 2eV_0 \qquad .....(2)$$

From $(2) - (1)$, we get

$$\Rightarrow 0 = \phi - eV_0$$

$$\phi = eV_0$$

Substituting this in (1), we get

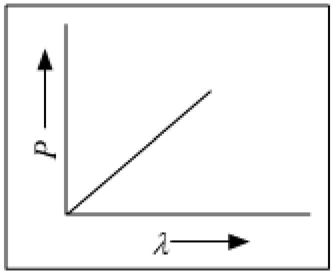
$$\frac{hc}{\lambda} = 4\phi$$

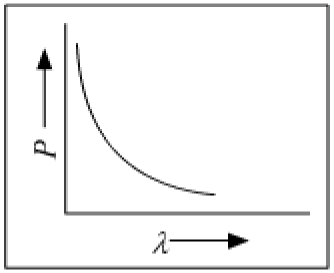
$$\Rightarrow \frac{hc}{\phi} = 4\lambda$$

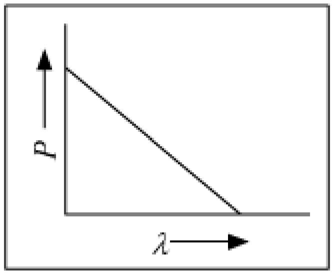
$$\Rightarrow \lambda_T = \frac{hc}{\phi} = 4\lambda$$

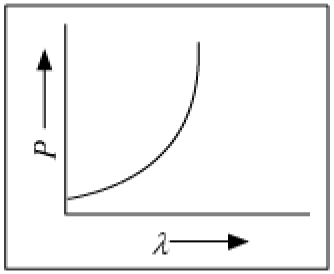
Hence, the correct option is (2)

41. Which of the following figures represent the variation of particle momentum and the associated de-Broglie wavelength ?

(1) 

(2) 

(3) 

(4) 

Sol:
According to De-Broglie relation,

$$\lambda = \frac{h}{p}$$
$$p\lambda = h$$
where h = Planks constant

This equation looks like $(yx = c)$ which shows in the graph.

Hence, the correct option is (3).

42. Consider 3rd orbit of He^{+} (Helium), using non-relativistic approach, the speed of electron in this orbit will be [given K= 9×10^{9} constant, Z = 2 and h (Planck's Constant) = 6.6×10^{-34} J s]
(1) 2.92×10^{6} m/s
(2) 1.46×10^{6} m/s
(3) 0.73×10^{6} m/s
(4) 3.0×10^{8} m/s

Sol:

Given:

Atomic number of the helium, $Z = 2$,

Planck's Constant, 'h' = 6.6×10^{-34} J s

$K = 9 \times 10^{9}$

n = 3

Energy of electron in He^{+} 3rd orbit = $-13.6 \times \frac{Z^2}{n^2} eV$

$$E_3 = -13.6 \times \frac{4}{9} eV$$

$$\Rightarrow E_3 = -13.6 \times \frac{4}{9} \times 1.6 \times 10^{-19} \text{ J}$$

In Bohr's model : $E_3 = -K.E_3$

$$\therefore 9.7 \times 10^{-19} J = \frac{1}{2} m_e v^2$$

$$v = \sqrt{\frac{2 \times 97 \times 10^{-19}}{9.1 \times 10^{-31}}} = 1.46 \times 10^6 \text{ m/sec}$$

Hence, the correct option is (2)

43. If radius of the ${}^{27}_{13}Al$ nucleus is taken to be R_{Al} the the radius of ${}^{125}_{53}Te$ nucleus is nearly :

(1) $\left(\frac{53}{13}\right)^{1/3} R_{Al}$

(2) $\frac{5}{3} R_{Al}$

(3) $\frac{3}{5}R_{Al}$

(4) $\left(\frac{13}{53}\right)^{1/3} R_{Al}$

Sol:

Radius of the nucleus, R =R_0 $A^{1/3}$

Atomic mass of the Aluminium, A_1 = 27

Atomic mass of the of the Tellurium, Te, A_2 = 125

Therefore,

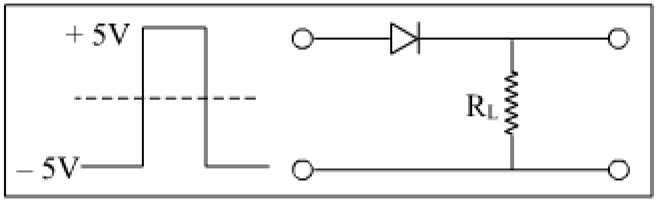
$$\frac{R_{Al}}{R_{Te}} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{27}{125}\right)^{1/3}$$

$$\frac{R_{Al}}{R_{Te}} = \left(\frac{3^3}{5^3}\right)^{\frac{1}{3}} = 3/5$$

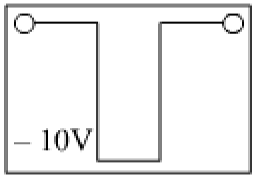
$$\boxed{R_{Te} = \frac{5}{3}R_{Al}}$$

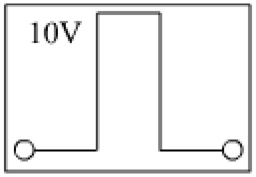
Hence, the correct option is (2).

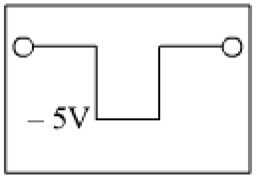
44. If in a p-n junction, a square input signal of 10 V is applied, as shown,

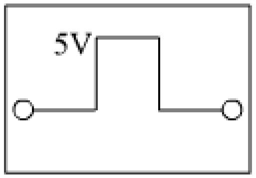


then the output across R_L will be :

(1) 

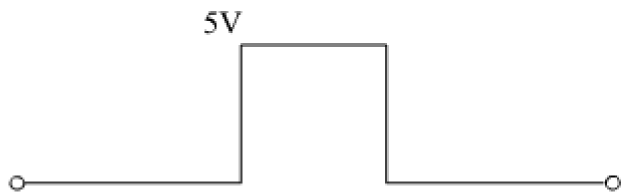
(2) 

(3) 

(4) 

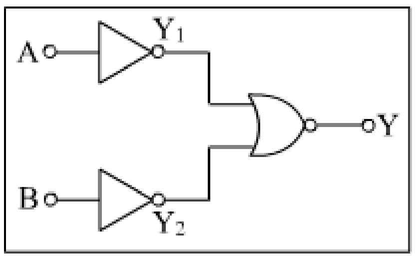
Sol:

Because of +5V, it supports the forward bias of the diode and its block the -5V, Hence the output across the load resistance R_L looks like:



Hence, the correct option is (4).

45. Which logic gate is represented by the following combination of logic gates ?



(1) OR
(2) NAND
(3) AND
(4) NOR

Sol:
Since it is a two input logic gates, so we must have inputs like,

A	B	Y_1	Y_2	Y
0	0	1	1	0
0	1	1	0	0
1	0	0	1	0
1	1	0	0	1

Its output 'Y' shows that it is a AND gate.

Hence, the correct option is (3).