JEE ADVANCED 2014
PAPER 2
PHYSICS

Only One Option Correct Type

This section contains **TEN** questions. Each has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four option(s) is correct.

1. If λ_{Cu} is the wavelength of K_α X-ray line of copper (atomic number 29) and λ_{Mo} is the wavelength of the K_α X-ray line of molybdenum (atomic number 42), then the ratio $\lambda_{\text{Cu}}/\lambda_{\text{Mo}}$ is close to

(A) 1.99 (B) 2.14 (C) 0.50 (D) 0.48

Solution

From Moseley's law

$$\text{Using } \lambda \propto \frac{1}{(z-1)^2} \text{ we get } \frac{\lambda_{\text{cu}}}{\lambda_{\text{mo}}} = \frac{(Z_{\text{mo}}-1)^2}{(Z_{\text{cu}}-1)^2} \Rightarrow \left(\frac{41}{28}\right)^2 = 2.14$$

Hence, the correct option is (B).

2. A metal surface is illuminated by light of two different wavelengths 248 nm and 310 nm. The maximum speeds of the photoelectrons corresponding to these wavelengths are u_1 and u_2, respectively. If the ratio u_1: u_2 = 2:1 and hc = 1240 eV nm, the work function of the metal is nearly

(A) 3.7 eV (B) 3.2 eV

(C) 2.8 eV (D) 2.5 eV

Solution

From Einstein's photoelectric equation, we know

$$hv = hv_0 + \frac{1}{2}mv^2{}_{\max} \text{ or } \frac{hc}{\lambda} = \omega_0 + \frac{1}{2}mv^2{}_{\max}$$

$$\frac{1}{2}mv^2{}_{\max} = \frac{hc}{\lambda} - \omega_0$$

$$\frac{1}{2}mv_1^2 = \frac{hc}{\lambda_1} - \omega_0 \qquad (1)$$

$$\frac{1}{2}mv_2^2 = \frac{hc}{\lambda_2} - \omega_0 \qquad (2)$$

Dividing Eq. (1) by Eq. (2), we get

Given $\frac{u_1}{u_2} = 2$

$$\frac{u_1^2}{u_2^2} = \frac{\frac{hc}{\lambda_1} - \omega_0}{\frac{hc}{\lambda_2} - \omega_0}$$

Therefore,

$$\frac{4}{1} = \frac{\frac{hc}{\lambda_1} - \omega_0}{\frac{hc}{\lambda_2} - \omega_0} \Rightarrow \frac{4hc}{\lambda_2} - 4\omega_0 = \frac{hc}{\lambda_1} - \omega_0$$

$$hc = \frac{6.6 \times 10^{-34} \times s \times 10^8}{1.6 \times 10^{-19} \times 10^{-19}}$$

$$hc = 1240 \text{ eV nm}$$

Therefore,

$$\frac{4 \times 1240}{310} - \frac{1240}{248} = 3\omega_0$$

$$16 - 5 = 3\omega_0 \text{ or } 11 = 3\omega_0 \Rightarrow \omega_0 = 3.7 \text{ eV}$$

Hence, the correct option is (A).

3. Parallel rays of light of intensity $I = 912$ W m^{-2} are incident on a spherical black body kept in surroundings of temperature 300 K. Take Stefan–Boltzmann constant $\sigma = 5.7 \times 10^{-8}$ W m^{-2} K^{-4} and assume that the energy exchange with the surroundings is only through radiation. The final steady state temperature of the black body is close to

(A) 330 K (B) 660 K

(C) 990 K (D) 1550 K

Solution

Effective area of incident light = rs^2

Total energy per second = $912 \times \pi r^2$

From Stefan's law

$$E = Ae\sigma(T^4 - T_0^4)$$

For black body emissivity $e = 1$

$$A = 4\pi r^2$$

$$912 \times \pi r^2 = 4\pi r^2 \times 5.7 \times 10^{-8}[T^4 - 300^4]$$

$$(T^4 - 300^4) = \frac{912}{4 \times 5.7 \times 10^{-8}} = 40 \times 10^8$$

$$T^4 = 40 \times 10^8 + 3^4 \times 10^8$$

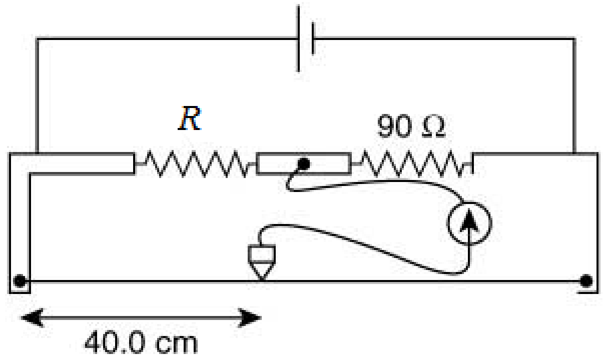
$$T^4 = (90 + 81) \times 10^8 \Rightarrow 121 \times 10^8$$

$$T = (121)^{1/4} \times 100 = \sqrt{11} \times 100 \Rightarrow 3.3 \times 100$$

$$T = 330 \text{ K}$$

Hence, the correct option is (A).

4. During an experiment with ametre bridge, the galvanometer shows a null point when the jockey is pressed at 40.0 cm using a standard resistance of 90 Ω, as shown in the figure. The least count of the scale used in the meter bridge is 1 mm. The unknown resistance is

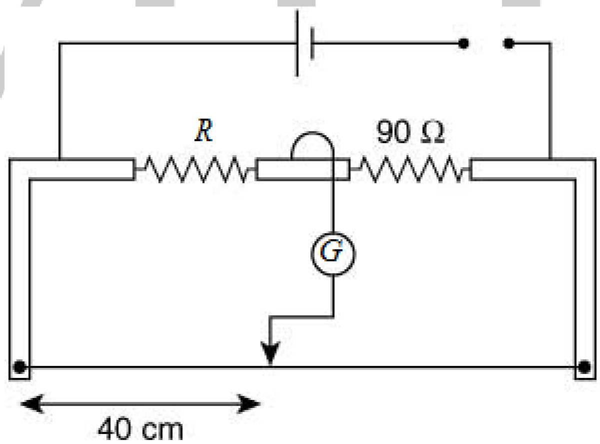


(A) 60 ± 0.15 Ω (B) 135 ± 0.56 Ω

(C) 60 ± 0.25 Ω (D) 135 ± 0.23 Ω

Solution

In balanced condition



$$\frac{R}{90} = \frac{40}{(100-4v)} = \frac{40}{60}$$

$$R = 60\ \Omega$$

In general

$$\frac{R}{90} = \frac{x}{(100-x)}$$

$$\log R = \log x + \log(100-x)$$

$$\frac{dR}{R} = \pm\frac{dx}{x} \pm \frac{dx}{(100-x)}$$

$$\frac{dR}{60} = \pm\frac{0.1}{40} \pm \frac{0.1}{60} \Rightarrow dR = \frac{0.6+0.4\times 60}{240}$$

$$= \frac{60}{240} \Rightarrow 0.25\Omega$$

$$(60 \pm 0.25)$$

Hence, the correct option is (C).

5. A planet of radius $R = \frac{1}{10}\times$ (radius of Earth) has the same mass density as Earth. Scientists dig a well of depth $\frac{R}{5}$ on it and lower a wire of the same length and of linear mass density 10^{-3} kg m^{-1} into it. If the wire is not touching anywhere, the force applied at the top of the wire by a person holding it in place is (take the radius of Earth = 6×10^6 m and the acceleration due to gravity of Earth is 10 m s^{-2})

(A) 96 N (B) 108 N

(C) 120 N (D) 150 N

Solution

As velocity will increase, centrifugal force will increase.

Radius of earth R_e = 6×10^6 m

Radius of planet = $\frac{R_e}{10} = 6\times 10^5$ m

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

$$g_p = \frac{4}{3}\pi G\frac{R_e}{10}\cdot\rho = \frac{g}{10} = \frac{10}{10} = 1\text{ m s}^{-2}$$

We know that $g' = g\left(1-\frac{d}{R}\right)$

Therefore, $g' = g_p\left(1-\frac{x}{R}\right)$ at depth x

Mass of element of will of length dx

$$dm = \lambda\, dx$$

Force on element

$$dF = dm\cdot g' \Rightarrow \lambda dx\cdot g_p\left(1-\frac{x}{R}\right)$$

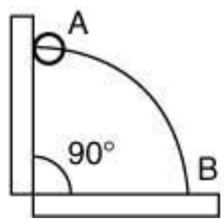
$$dF = \lambda g_p\left(1-\frac{x}{R}\right)dx$$

$$F = \lambda g_p \left[\int_0^{R/5} 1 \cdot dx - \int_0^{R/5} \frac{x}{R} dx \right] = \lambda . g_p \left[\frac{R}{5} - \frac{\cancel{R}^2}{25 \times 2 \cancel{R}} \right] \qquad (g_p = 1 \text{ m s}^{-2})$$

$$= \frac{10^{-3} \times 9 \times 6 \times 10^5}{50} = 108 \text{ N}$$

Hence, the correct option is (B).

6. A wire, which passes through the hole in a small bead, is bent in the form of quarter of a circle. The wire is fixed vertically on ground as shown in the below figure. The bead is released from near the top of the wire and it slides along the wire without friction. As the bead moves from *A* to *B*, the force it applies on the wire is



(A) always radially outwards.

(B) always radially inwards.

(C) radially outwards initially and radially inwards later.

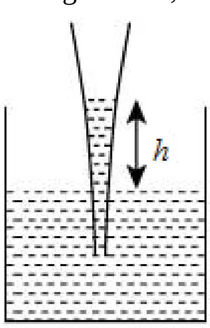
(D) radially inwards initially and radially outwards later.

Solution

Initially the bead exerts a radially inwards force which contributes to the centripetal force. A stage comes when $N = 0$, bead loses contact with the wire as then re-establishes it at the lower end of the hole. Here N starts to act radially outwards.

Hence, the correct option is (D).

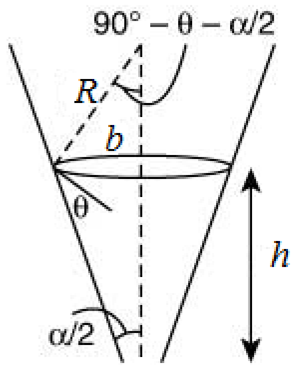
7. A glass capillary tube is of the shape of truncated cone with an apex angle α so that its two ends have cross sections of different radii. When dipped in water vertically, water rises in it to a height h, where the radius of its cross section is b. If the surface tension of water is S, its density is ρ, and its contact angle with glass is θ, the value of h will be (g is the acceleration due to gravity)



(A) $\frac{2S}{b\rho g}\cos(\theta-\alpha)$ (B) $\frac{2S}{b\rho g}\cos(\theta+\alpha)$

(C) $\frac{2S}{b\rho g}\cos(\theta-\alpha/2)$ (D) $\frac{2S}{b\rho g}\cos(\theta+\alpha/2)$

Solution



<AQ>Italicize '*α*' and *θ*.<AQ>

From the figure

$$b = R\cos\left(\theta+\frac{\alpha}{2}\right)$$

Excess pressure $\frac{2S}{R} = h\rho g$

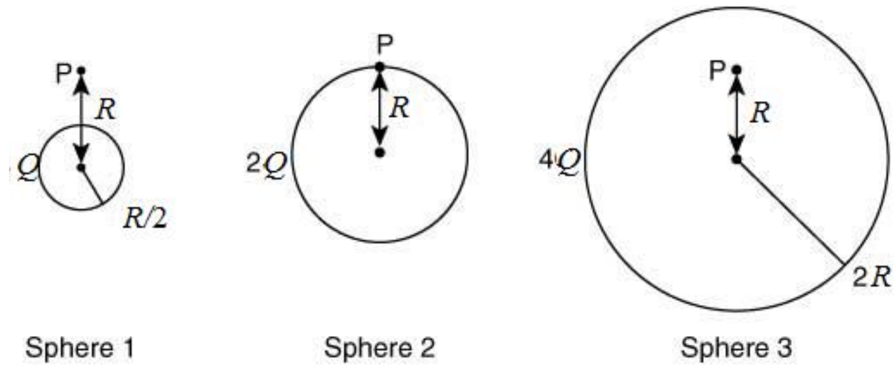
or

$$h\rho g = \frac{2s}{b}\cos\left(\theta+\frac{\alpha}{2}\right)$$

$$h = \frac{2s}{b\rho g}\cos\left(\theta+\frac{\alpha}{2}\right)$$

Hence, the correct option is (D).

8. Charges Q, $2Q$ and $4Q$ are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii $R/2$, R and $2R$, respectively, as shown in the below figure. If magnitudes of the electric fields at point P at a distance R from the centre of spheres 1, 2 and 3 are E_1, E_2 and E_3, respectively, then



(A) $E_1 > E_2 > E_3$ (B) $E_3 > E_1 > E_2$

(C) $E_2 > E_1 > E_3$ (D) $E_3 > E_2 > E_1$

Solution

In first two cases P is outside sphere.

Therefore,

$$E_1 = \frac{1}{4\pi E_0} \cdot \frac{Q}{R^2} \qquad (1)$$

$$E_2 = \frac{1}{4\pi E_0} \cdot \frac{2Q}{R^2} \qquad (2)$$

In case (iii) point P is inside

$$E_3 = \left(\frac{\rho}{3E_0}\right) r$$

$$\rho = \frac{4Q}{\frac{4}{3}\pi(2R)^3}$$

$$= \frac{12Q}{4\pi \cdot 8R^3} = \frac{3Q}{8\pi}$$

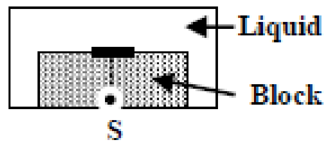
$$E_3 = \left(\frac{3Q}{\pi R^3}\right) \cdot R$$

$$E_3 = \frac{1}{4\pi E_0} \cdot \frac{Q}{2R^2} \qquad (3)$$

$$E_2 > E_1 > E_3$$

Hence, the correct option is (C).

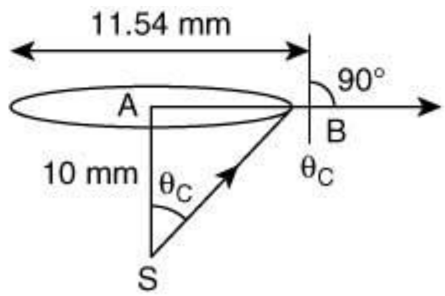
9. A point source S is placed at the bottom of a transparent block of height 10 mm and refractive index 2.72. It is immersed in a lower refractive index liquid as shown in the below figure. It is found that the light emerging from the block to the liquid forms a circular bright spot of diameter 11.54 mm on the top of the block. The refractive index of the liquid is



(A) 1.21 (B) 1.30

(C) 1.36 (D) 1.42

Solution



In ΔSAB

$$\tan\theta = \frac{AB}{AS} = \frac{\frac{11.54}{2}}{10}$$

$$\tan\theta = 0.577$$

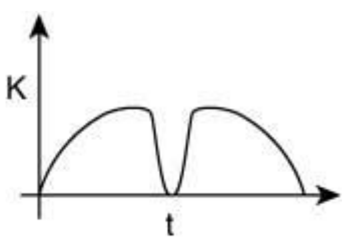
$$\theta_c = 30°$$

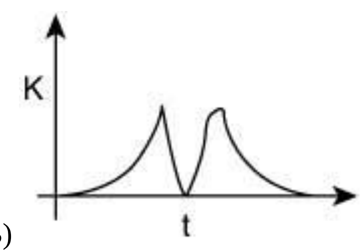
Using $\frac{\sin\theta_c}{\sin 90} = \frac{\mu l}{\mu b}$, we get

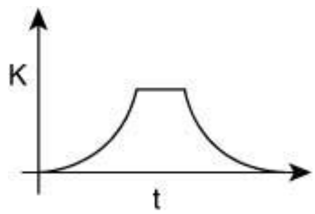
$$\sin\theta_c = \frac{\mu_l}{\mu_b} \text{ or } \mu_a = \mu_b \times \sin 30 = 2.72 \times \frac{1}{2} = 1.36$$

Hence, the correct option is (C).

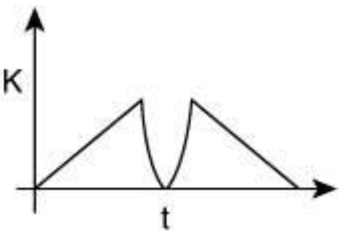
10. A tennis ball is dropped on a horizontal smooth surface. It bounces back to its original position after hitting the surface. The force on the ball during the collision is proportional to the length of compression of the ball. Which one of the following sketches describes the variation of its kinetic energy K with time t most appropriately? The figures are only illustrative and not to be scale.

(A) 

(B) 



(C)



(D)

Solution

When ball falls for time t, its velocity is $v = u + at = 0 + gt$ and $k = \frac{1}{2}mv^2$

$$k = \frac{1}{2}mg^2t^2$$

$$k \propto t^2$$

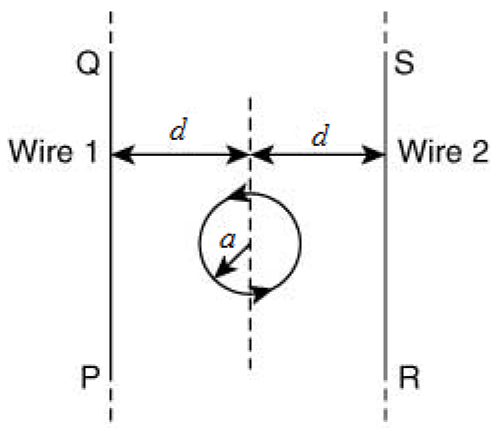
Graph is a parabola. During collision, it gets compressed and KE reduces till it becomes zero at maximum compression.

Hence, the correct option is (B).

Paragraph Type

This section contains **THREE** paragraphs, each describing theory, experiments, data etc. Based on each paragraph, there will be **TWO** questions. Each question has four options (A), (B), (C) and (D). **ONLY ONE** of these four option(s) is correct.

Paragraph for Questions 11 and 12: The figure shows a circular loop of radius a with two long parallel wires (numbered 1 and 2) all in the plane of the paper. The distance of each wire from the centre of the loop is d. The loop and the wires are carrying the same current I. The current in the loop is in the counter clockwise direction if seen from above.



<AQ>Italicise all variables<AQ>

11. When $d \approx a$ but wires are not touching the loop, it is found that the net magnetic field on the axis of the loop is zero at a height h above the loop. In that case

(A) current in wire 1 and wire 2 is the direction PQ and RS, respectively and $h \approx a$

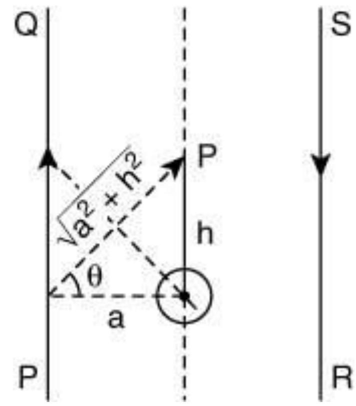
(B) current in wire 1 and wire 2 is the direction PQ and SR, respectively and $h \approx a$

(C) current in wire 1 and wire 2 is the direction *PQ* and *SR*, respectively and $h \approx 1.2a$

(D) current in wire 1 and wire 2 is the direction *PQ* and *RS*, respectively and $h \approx 1.2a$

Solution

When current in two wires is in opposite direction the total magnetic induction directed into page is given by



<AQ>Italicise all variables<AQ>

$$B = B_1 + B_2$$

$$B = 2B_1 \text{ (since } \vec{B}_1 = \vec{B}_2\text{)}$$

$$B = \frac{2\mu_0}{4\pi} \cdot \frac{2I}{\sqrt{(a^2+b^2)}} \cos\theta$$

$$= \frac{2\mu_0}{4\pi} \cdot \frac{2I}{\sqrt{b^2+h^2}} \cdot \frac{a}{\sqrt{a^2+b^2}}$$

$$B = \frac{\mu_0 Ia}{\pi(a^2+b^2)} \qquad (1)$$

Magnetic induction at *P* on axis of coil distant *h* from centre of drop of radius ‘*a*’.

$$B' = \frac{\mu_0}{4\pi} \cdot \frac{2\pi Ia^2}{(a^2+h^2)^{3/2}}$$

$$B' = \frac{\mu_0 Ia^2}{2(a^2+h^2)^{3/2}} \qquad (2)$$

If $B = B'$, from Eqs. (1) and (2), we get

$$\frac{\mu_0 Ia}{\pi(a^2+h^2)} = \frac{\mu_0 Ia^2}{2(a^2+b^2)^{3/2}}$$

$$\frac{1}{\pi} = \frac{a}{2(a^2+h^2)^{1/2}}$$

$$\frac{4}{\pi^2} = \frac{a^2}{(a^2+b^2)} \qquad \pi^2 = 9.8596$$

$$\frac{4}{9.8596} = \frac{a^2}{a^2 + h^2}$$

$$4h^2 = 5.8596$$

$$h = \sqrt{\frac{5.8596}{4}}a \cong 1.2a$$

Hence, the correct option is (C).

12. Consider $d \gg a,$ and the loop is rotated about its diameter parallel to the wires by 30° from the position shown in the below figure. If the currents in the wires are in the opposite directions, the torque on the loop at its new position will be (assume that the net field due to the wires is constant over the loop)

(A) $\frac{\mu_0 I^2 a^2}{d}$

(B) $\frac{\mu_0 I^2 a^2}{2d}$

(C) $\frac{\sqrt{3}\mu_0 I^2 a^2}{d}$

(D) $\frac{\sqrt{3}\mu_0 I^2 a^2}{2d}$

Solution

. Total magnetic induction:

$$B = B_1 + B_2 \Rightarrow 2B_1 \Rightarrow 2 \cdot \frac{\mu_0}{4\pi} \cdot \frac{2I}{d}$$

$$B = \frac{\mu_0 I}{\pi d} \qquad (1)$$

$$\vec{T} = NI(\vec{A} \times \vec{B})$$

$$T = N\, I\, AB \sin\theta \qquad (2)$$

$N = 1$; $\theta = 30°$; Area of loop

$$A = \theta a^2$$

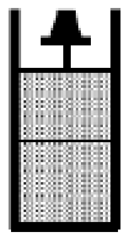
Equation (2) becomes

Therefore, $T = I \cdot a^2 \frac{\mu_0 I}{\pi d} \cdot \frac{1}{2}$

$$T = \frac{\mu_0 I^2 a^2}{2d}$$

Hence, the correct option is (B).

Paragraph for Questions 13 and 14: In the figure a container is shown to have a movable (without friction) piston on top. The container and the piston are all made of perfectly insulating material allowing no heat transfer between outside and inside the container. The container is divided into two compartments by a rigid partition made of a thermally conducting material that allows slow transfer of heat. The lower compartment of the container is filled with 2 moles of an ideal monatomic gas at 700 K and the upper compartment is filled with 2 moles of an ideal diatomic gas at 400 K. The heat capacities per mole of an ideal monatomic gas are $C_V = \frac{3}{2}R,\ C_P = \frac{5}{2}R,$ and those for an ideal diatomic gas are $C_V = \frac{5}{2}R,$ $C_P = \frac{7}{2}R.$



13. Consider the partition to be rigidly fixed so that it does not move. When equilibrium is achieved, the final temperature of the gases will be

(A) 550 K (B) 525 K

(C) 513 K (D) 490 K

Solution

T is final temperature, when equilibrium is reached

Heat gained = Heat lost

$$n_2 \cdot C$$

$$2 \times \frac{7R}{2} \times (T - 400) = 2 \cdot \frac{3R}{2} \cdot (700 - T)$$

$$7T - 2800 = 2100 - 3T$$

$$10T = 4900$$

$$T = 490 \text{ K}$$

Hence, the correct option is (D).

14. Now consider the partition to be free to move without friction so that the pressure of gases in both compartments is the same. Then total work done by the gases till the time they achieve equilibrium will be

(A) 250 R (B) 200 R

(C) 100 R (D) –100 R

Solution

Heat lost by mono atomic gas = Heat gained by diatomic gas

$$2\times\frac{5}{2}R\times(700-T) = 2\times\frac{7}{2}R(T-400)$$

$$3500 - 5T = 7T - 2800$$

$$12T = 6300 \text{ or } T = 525 \text{ K}$$

Work done by mono atomic gas = $n_1R\Delta T$ ($PV = nRT$)

= $2 \times R \times (700 - 525)$ ΔT is negative

= $-350R$

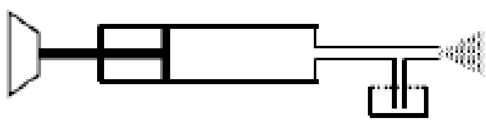
Work done by diatomic gas = $n_2R\cdot\Delta T$

= $2R\,(525 - 400) = 250\,R$. There is gain in temp.

Network done = $-350 + 250 = -100R$ ΔT is positive

Hence, the correct option is (D).

Paragraph for Questions 15 and 16: A spray gun is shown in the below figure where a piston pushes air out of a nozzle. A thin tube of uniform cross section is connected to the nozzle. The other end of the tube is in a small liquid container. As the piston pushes air through the nozzle, the liquid from the container rises into the nozzle and is sprayed out. For the spray gun shown, the radii of the piston and the nozzle are 20 mm and 1 mm, respectively. The upper end of the container is open to the atmosphere.



15. If the piston is pushed at a speed of 5 mm s^{-1}, the air comes out of the nozzle with a speed of

(A) $\sqrt{\frac{\rho_a}{\rho_l}}$ (B) $\sqrt{\rho_a\rho_l}$

(C) $\sqrt{\frac{\rho_l}{\rho_a}}$ (D) ρ_l

Solution

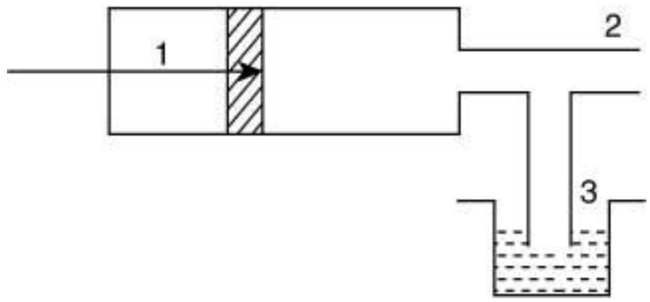
For horizontal flow, Bernoulli's theorem becomes

$$\frac{p}{\rho} + gh + \frac{1}{2}v^2 = k'$$

$$p + \frac{1}{2}\rho v^2 = k \quad (h = 0)$$

Between points 1 and 2

$$p_1 - p_2 = \frac{1}{2}\rho_a v_a^2$$



Between points 2 and 3

$$p_3 - p_2 = \frac{1}{2}\rho_e v_e^2$$

Since $p_1 = p_3$

Therefore,

$$\frac{1}{2}\rho_q v_e^2 = \frac{1}{2}\rho_a v_a^2$$

$$\frac{v_e}{v_a} = \sqrt{\frac{\rho_a}{\rho_e}}$$

Hence, the correct option is (C).

16. If the density of air is ρ_a and that of the liquid ρ_l, then for a given piston speed the rate (volume per unit time) at which the liquid is sprayed will be proportional to

(A) 0.1 ms^{-1}

(B) 1 ms^{-1}

(C) 2 ms^{-1}

(D) 8 ms^{-1}

Solution

From equation of continuity

$$a_1 v_1 = a_2 v_2$$

$$\pi(0.2)^2 \times 0.005 = \pi(0.01)^2 \times v_2$$

$$400 \times 0.005 = v_2$$

$$v_2 = 2 \text{ m s}^{-1}$$

Hence, the correct option is (A).

Matching List Type

This section contains **FOUR** questions, each having two matching lists. Choice for the correct combination of elements from List-I and List-II are given as options (A), (B), (C) and (D), out of which **ONLY ONE** is correct.

17. A person in a lift is holding a water jar, which has a small hole at the lower end of its side. When the lift is at rest, the water jet coming out of the hole hits the floor of the lift at a distance of 1.2 m from the person. In the following, state of the lift's motion is given in List I and the distance where the water jet hits the floor of the lift is given in List II. Match the statements from List I with those in List II and select the correct answer using the code given below the lists.

	List I	List II
P.	Lift is accelerating vertically up.	**1.** $d = 1.2$ m
Q.	Lift is accelerating vertically down with an acceleration less than the gravitational acceleration.	**2.** $d > 1.2$ m
R.	Lift is moving vertically up with constant speed.	**3.** $d < 1.2$ m
S.	Lift is falling freely.	**4.** No water leaks out of the jar

Code:

(A) P-2, Q-3, R-2, S-4

(B) P-2, Q-3, R-1, S-4

(C) P-1, Q-1, R-1, S-4

(D) P-2, Q-3, R-1, S-1

Solution

Horizontal range = Velocity of out flow × Time taken

$$H = \sqrt{2gh} \times \sqrt{\frac{2h}{g}}$$

$$h = \frac{1}{2}gt^2$$

$$t = \sqrt{\frac{2h}{g}}$$

$$H = \sqrt{2h}$$

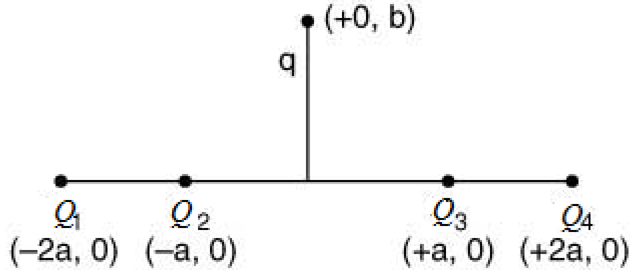
It is independent of value of acc. Due to gravity, it may be g, $(g + a)$ or $(g - a)$.

For free fall $g' = (g - g) = 0$

$v = 0$, so liquid will not flow

Hence, the correct option is (C).

18. Four charges Q_1, Q_2, Q_3 and Q_4 of same magnitude are fixed along the x axis at $x = -2a, -a, +a$ and $+2a$, respectively. A positive charge q is placed on the positive y axis at a distance $b > 0$. Four options of the signs of these charges are given in List I. The direction of the forces on the charge q is given in List II. Match List I with List II and select the correct answer using the code given below the lists.



<AQ>Italicize all variables<AQ>

	List I	List II
P.	Q_1, Q_2, Q_3, Q_4 all positive	**1.** $+x$
Q.	Q_1, Q_2 positive; Q_3, Q_4 negative	**2.** $-x$
R.	Q_1, Q_4 positive; Q_2, Q_3 negative	**3.** $+y$
S.	Q_1, Q_3 positive; Q_2, Q_4 negative	**4.** $-y$

Code:

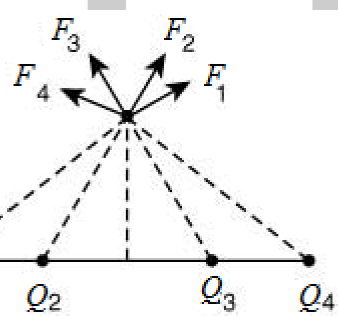
(A) P-3, Q-1, R-4, S-2

(B) P-4, Q-2, R-3, S-1

(C) P-3, Q-1, R-2, S-4

(D) P-4, Q-2, R-1, S-3

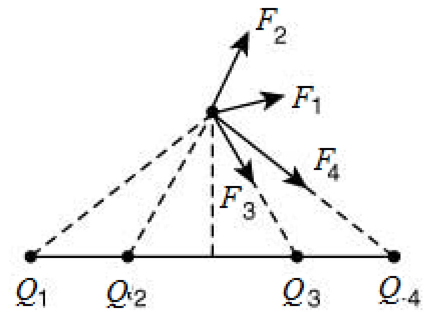
Solution



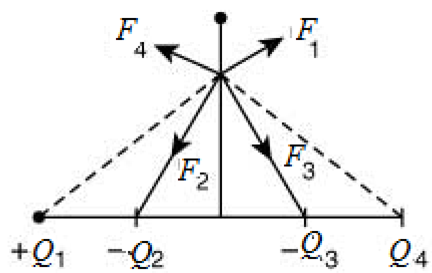
$$|\vec{F}_1| = |\vec{F}_4|$$

$$|\vec{F}_2| = |\vec{F}_3|$$

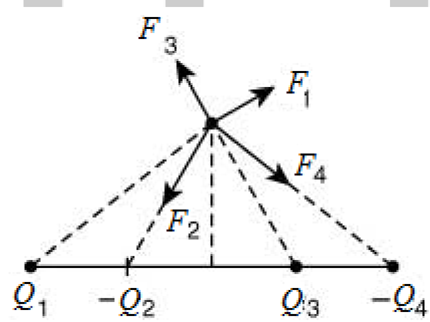
Horizontal camps will cancel out. Net force will be along + y axis



Vertical camps of (F_1 and F_4); (F_2 and F_3) will cancel. Net force will be along + x-axis.



Horizontal camps of F_1 and F_4 will cancel as $|\vec{F}_1| = |\vec{F}_4|$. Horizontal camps of F_2 and F_3 will cancel as $|\vec{F}_2| = |\vec{F}_3|$ vertical camp due to negative charges is more (distance being less).



Therefore, net force is along y-axis $|\vec{F}_1| = |\vec{F}_4|$

Vertical camps will cancel and horizontal camps get added along +x-axis

$$|\vec{F}_2| = |\vec{F}_3|$$

Vertical camps get cancelled and horizontal camps are along – x-axis

Net force is along – x-axis.

Hence, the correct option is (A).

19. Four combinations of two thin lenses are given in List I. The radius of curvature of all curved surfaces is *r* and the refractive index of all the lenses is 1.5. Match lens combinations in List I with their focal length in List II and select the correct answer using the code given below the lists.<COMP: Please change numbering from P–S to (A)–(D) and 1–4 to (P)–(S).>

List I	List II
P. 	1. $2r$
Q. 	2. $r/2$
R. 	3. $-r$
S. 	4. r

Code:

(A) P-1, Q-2, R-3, S-4

(B) P-2, Q-4, R-3, S-1

(C) P-4, Q-1, R-2, S-3

(D) P-2, Q-1, R-3, S-4

Solution

Using lens maker's formula

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f_{eff}} = \frac{1}{f_1} + \frac{1}{f_2}$$

Case P: $\frac{1}{f} = 0.5\left(\frac{1}{r} - \frac{1}{-r}\right)$

$r = f$

Therefore, $\frac{1}{f_{eff}} = \frac{1}{r} + \frac{1}{r}$

$f_{eff} = \frac{r}{2}$

$P \rightarrow (2)$

Case Q: $\frac{1}{f} = 0.5\left(\frac{1}{\infty} - \frac{1}{-r}\right) = \frac{1}{2r}$

$$\frac{1}{f_{eff}} = \frac{1}{2r} + \frac{1}{2r}$$

$f_{eff} = r$

$Q \rightarrow (4)$

Case R: $\frac{1}{f} = 0.5\left(\frac{1}{\infty} - \frac{1}{r}\right) = \frac{-1}{2r}$

$$\frac{1}{f_{eff}} = -\frac{1}{2r} - \frac{1}{2r}$$

$f_{eff} = -r$

$R \rightarrow (3)$

Case S: $\frac{1}{f_{eff}} = \frac{1}{r} - \frac{1}{2r} = \frac{1}{2r}$

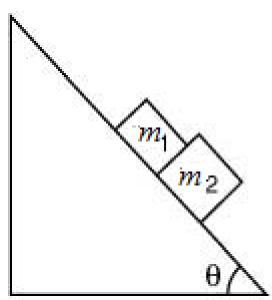
$f_{eff} = 2r$

$S \rightarrow (1)$

Hence, the correct option is (B).

20. A block of mass $m_1 = 1$ kg another mass $m_2 = 2$ kg, are placed together (see figure) on an inclined plane with angle of inclination θ. Various values of θ are given in List I. The coefficient of friction between the block m_1 and the plane is always zero. The coefficient of static and dynamic friction between the block m_2 and the plane are equal to $\mu = 0.3$. In List II expressions for the friction on the block m_2 are given. Match the correct expression of the friction in List II with the angles given in List I, and choose the correct option. The acceleration due to gravity is denoted by g.

[**Useful information:** tan (5.5°) ≈ 0.1; tan (11.5°) ≈ 0.2; tan (16.5°) ≈ 0.3]



List I **List II**

P.	$\theta = 5°$	**1.** $m_2 g \sin\theta$
Q.	$\theta = 10°$	**2.** $(m_1 + m_2)g \sin\theta$
R.	$\theta = 15°$	**3.** $\mu m_2 g \cos\theta$
S.	$\theta = 20°$	**4.** $\mu(m_1 + m_2)g \cos\theta$

Code:

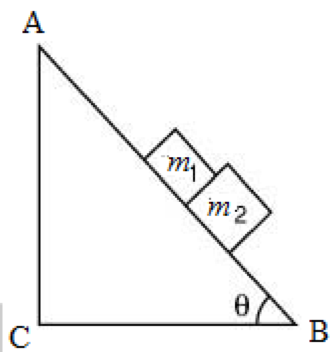
(A) P-1, Q-1, R-1, S-3

(B) P-2, Q-2, R-2, S-3

(C) P-2, Q-2, R-2, S-4

(D) P-2, Q-2, R-2, S-3

Solution



Comp. of weight along *AB*

$$= m_1 g \sin\theta + m_2 g \sin\theta$$

$$= (m_1 + m_2)g \sin\theta \qquad \text{(i)}$$

Force of friction along *BA*

$$= \mu_1 m_1 g \cos\theta + \mu_2 m_2 g \cos\theta \qquad (\mu_1 = 0)$$

$$= \mu_2 m_2 g \cos\theta \qquad \text{(ii)}$$

$$(m_1 + m_2)g \sin\theta = \mu_2 m g \cos\theta$$

$$\tan\theta = \frac{\mu m_2}{(m_1 + m_2)} \Rightarrow \frac{0.3 \times 2}{1 + 2} \Rightarrow 0.2$$

Angle of sliding comes to be (11° – 30°)

At 5° and 10°, block will not slide and static friction is balancing $(m_1 + m_2)g \sin\theta$

For $\theta = 15°$ (>11.5°) block will slide and friction is $\mu m_2 g \cos\theta$.

Hence, the correct option is (D).