Reliable INSTITUTE
Unleashing Potential

JEE ADVANCED 2023

PAPER - 1

QUESTIONS & SOLUTIONS

4 JUNE, 2023

9:00 AM to 12:00 Noon

Duration : 3 Hours

SUBJECT - PHYSICS

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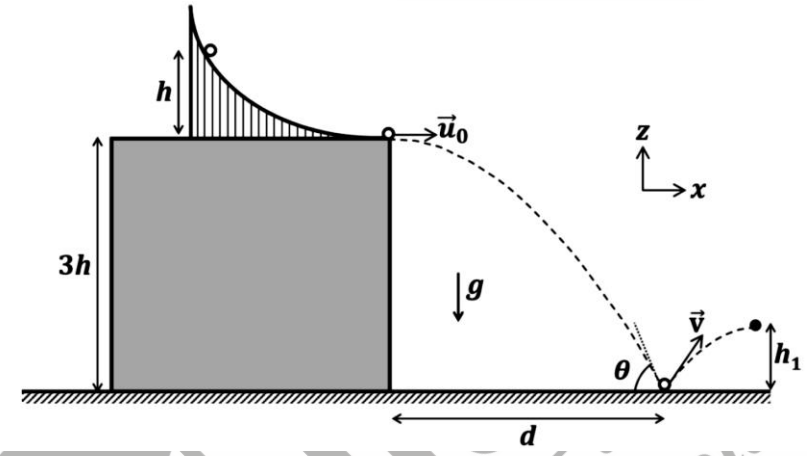
PHYSICS

1. A slide with a frictionless curved surface, which becomes horizontal at its lower end, is fixed on the terrace of a building of height 3 h from the ground, as shown in the figure. A spherical ball of mass m is released on the slide from rest at a height h from the top of the terrace. The ball leaves the slide with a velocity $\vec{u}_0 = u_0\hat{x}$ and falls on the ground at a distance d from the building making an angle θ with the horizontal. It bounces off with a velocity $\vec{v}$ and reaches a maximum height h_1. The acceleration due to gravity is g and the coefficient of restitution of the ground is $\frac{1}{\sqrt{3}}$. Which of the following statement(s) is (are) correct? **[JEE (Advanced)-2023, P-1; 4/60, –2]**

[Centre of Mass] [M]



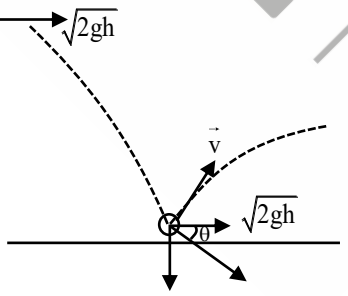
(A) $\vec{u}_0 = \sqrt{2gh}\hat{x}$ (B) $\vec{v} = \sqrt{2gh}(\hat{x} - \hat{z})$ (C) $\theta = 60^\circ$ (D) $d / h_1 = 2\sqrt{3}$

Ans. **(A,C,D)**

Sol. By energy conservation

(A) $\vec{u}_0 = \sqrt{2gh}\,\hat{x}$

(B) $\sqrt{2gh}$



$\vec{v} = \sqrt{2gh}\,\hat{x} + \sqrt{2gh}\hat{z}$

So, 'B' option is wrong.

(C) $\tan\theta = \frac{\sqrt{6gh}}{\sqrt{2gh}} = \sqrt{3}$

$\theta = 60°$

(D) $d = \sqrt{2gh}\sqrt{\frac{6h}{g}}$ $\frac{d}{h_1} = 2\sqrt{3}$

$$h_1 = \frac{\left(\sqrt{2gh}\right)^2}{2g} = h$$

2. A plane polarized blue light ray is incident on a prism such that there is no reflection from the surface of the prism. The angle of deviation of the emergent ray is $\delta = 60°$ (see Figure-1). The angle of minimum deviation for red light from the same prism is $\delta_{min} = 30°$ (see Figure-2). The refractive index of the prism material for blue light is $\sqrt{3}$. Which of the following statement(s) is(are) correct? **[JEE (Advanced)-2023, P-1; 4/60, –2]**

[Wave Optics] [M]

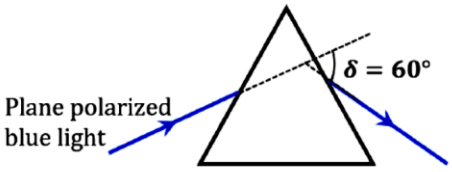


Figure-1

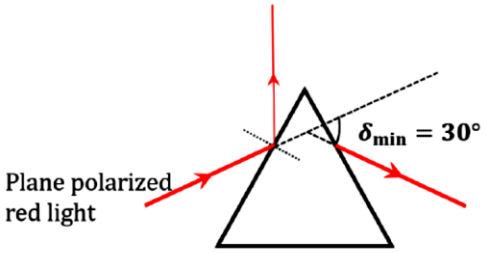
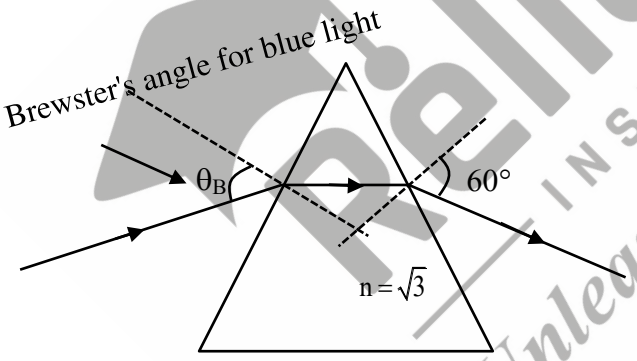


Figure-2

(A) The blue light is polarized in the plane of incidence.
(B) The angle of the prism is 45°.
(C) The refractive index of the material of the prism for red light is $\sqrt{2}$
(D) The angle of refraction for blue light in air at the exit plane of the prism is 60°.

Ans. **(A,C,D)**

Sol.



A option is correct by brewster's law

$$\tan\theta_B = \frac{n_P}{n_{air}} = \sqrt{3}$$

$\theta_B = 60°$
$i = 60°$
$\delta = 60°$
$\delta = i + e - A$
$e = A$
1. $\sin 60° = \sqrt{3} \sin r_1$
$r_1 = 30°$
$\sqrt{3} \sin(A - 30°) = \sin e$
$\sqrt{3} \sin(A - 30°) = \sin A$
$A = 60°$ (hit & trial)
'B' is wrong

in Red light

$30° = 2i - A$

$I = 45°$

1. $\sin 45° = n_R \sin\left(\frac{A}{2}\right)$

$n_R = \sqrt{2}$

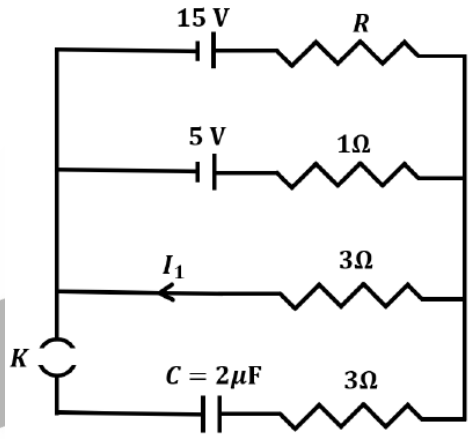
'C' is correct

'D' is correct

3. In a circuit shown in the figure, the capacitor C is initially uncharged and the key K is open. In this condition, a current of 1 A flows through the 1 Ω resistor. The key is closed at time $t = t_0$. Which of the following statement(s) is(are) correct? [Given: $e^{-1} = 0.36$]

[JEE (Advanced)-2023, P-1; 4/60, –2]

[Capacitance] [M]



(A) The value of the resistance R is 3 Ω.

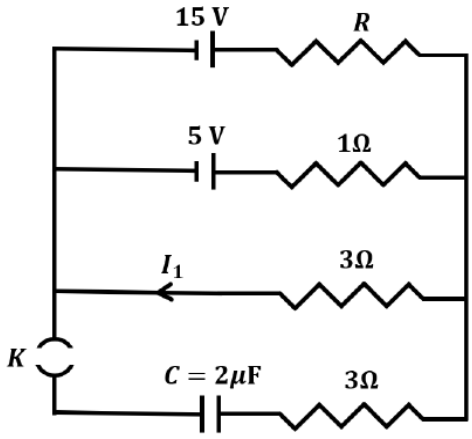
(B) For $t < t_0$, the value of current I_1 is 2 A.

(C) At $t = t_0 + 7.2$ μs, the current in the capacitor is 0.6 A.

(D) For $t \to \infty$, the charge on the capacitor is 12 μC.

Ans. (A,B,C,D)

Sol.



Initially

$$E_{eq} = \frac{\frac{15}{R} + \frac{0}{3}}{\frac{1}{R} + \frac{1}{3}} = \frac{45}{R+3}$$

$$\frac{E_{eq} - 5}{1 + \frac{45}{R+3}} = 1 \text{ (current in 1 } \Omega \text{ resistance)}$$

$$\frac{45}{R+3} = 1 + \frac{45}{R+3}$$

$$45 = R + 3 + 45$$

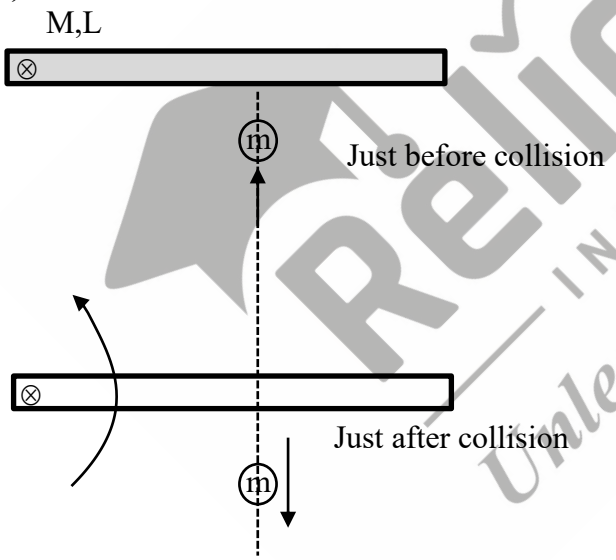
4. A bar of mass $M = 1.00$ kg and length $L = 0.20$ m is lying on a horizontal frictionless surface. One end of the bar is pivoted at a point about which it is free to rotate. A small mass $m = 0.10$ kg is moving on the same horizontal surface with 5.00 m s^{-1} speed on a path perpendicular to the bar. It hits the bar at a distance $L/2$ from the pivoted end and returns back on the same path with speed v. After this elastic collision, the bar rotates with an angular velocity ω. Which of the following statement is correct?

[JEE (Advanced)-2023, P-1; 3/60, –1]
[Rigid Body Dynamics] [M]

(A) ω = 6.98 rad s^{-1} and v = 4.30 m s^{-1}
(B) ω = 3.75 rad s^{-1} and v = 4.30 m s^{-1}
(C) ω = 3.75 rad s^{-1} and v = 10.0 m s^{-1}
(D) ω = 6.80 rad s^{-1} and v = 4.10 m s^{-1}

Ans. **(A)**

Sol.



angular momentum conservation about pivot

$$m(5)\frac{L}{2} = \frac{ML^2\Omega}{2} - mv\frac{L}{2}$$

$$\frac{1}{10} \times \frac{5}{2} = \frac{L}{3}\omega - \frac{1}{10} \times \frac{V}{2}$$

$$\frac{1}{4} = \frac{2\omega}{30} - \frac{v}{20}$$

$$15 = 4\omega - 3v$$

$$e = 1 = \frac{\omega\frac{L}{2} + v}{5}$$

$5 = \frac{\omega}{10} + v$ …(2)

$4\omega - 3v = 15$ …(3)

$4\omega - 3\left[5 - \frac{\omega}{10}\right] = 15$

$4\omega - 15 + \frac{3\omega}{10} = 15$

$4\omega + \frac{3\omega}{10} = 30$

$40\omega + 3\omega = 300$

$\omega = \frac{300}{43} = 6.97 \text{ rad/s}$

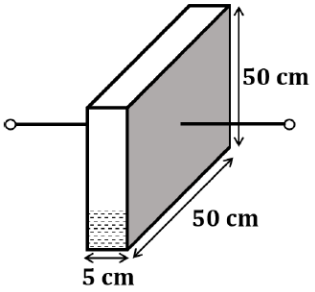
v = 4.3m/s

so option 'A' is correct

5. A container has a base of 50 cm × 5 cm and height 50 cm, as shown in the figure. It has two parallel electrically conducting walls each of area 50 cm × 50 cm. The remaining walls of the container are thin and non-conducting. The container is being filled with a liquid of dielectric constant 3 at a uniform rate of 250 $cm^3\ s^{-1}$. What is the value of the capacitance of the container after 10 seconds?

[**Given** : Permittivity of free space $\in_0 = 9 \times 10^{-12}\ C^2N^{-1}m^{-2}$, the effects of the non-conducting walls on the capacitance are negligible] **[JEE (Advanced)-2023, P-1; 3/60, –1]**

[Capacitance] [M]



(A) 27 pF (B) 63 pF (C) 81 pF (D) 135 pF

Ans. **(B)**

Sol. t = 10sec.

vol. of liquid in 2500 cm^3 so height of liquid is = 10cm

Capacitance = $C_{air} + C_{medium}$

$= \frac{\varepsilon_0 (40 \times 50)cm^2}{5cm} + \frac{3\varepsilon_0 (10 \times 50)cm^2}{5cm}$

$\frac{\varepsilon_0 \times 50}{5}[40 + 30]$

$= 700\varepsilon_0$

$= (700) \times 9 \times 10^{-12} \times 10^{-2}$

$= 63 \times 10^{-12}$ F

= 63pF

Option 'B' is correct

6. One mole of an ideal gas expands adiabatically from an initial state (T_A, V_0) to final state (T_f, $5V_0$). Another mole of the same gas expands isothermally from a different initial state (T_B, V_0) to the same final state (T_f, $5V_0$). The ratio of the specific heats at constant pressure and constant volume of this ideal gas is γ. What is the ratio T_A/T_B?

[JEE (Advanced)-2023, P-1; 3/60, –1]
[KTG & Thermodynamics] [E]

(A) $5^{\gamma-1}$ (B) $5^{1-\gamma}$ (C) 5^{γ} (D) $5^{1+\gamma}$

Ans. **(A)**

Sol. $PV^{\gamma} = C$ for first case

$T_1V^{\gamma-1} = C$

$T_AV_0^{\gamma 1} = T_f(5V_0)^{\gamma-1}$ …(1)

for second case

$T_B = T_f$

Now $\frac{T_A}{T_B}$ means $\frac{T_A}{T_f}$

by equation (1)

$$\frac{T_A}{T_f} = \left(\frac{5V_0}{V_0}\right)^{\gamma-1} = 5^{\gamma-1}$$

So option 'A' is correct.

7. Two satellites P and Q are moving in different circular orbits around the Earth (radius *R*). The heights of P and Q from the Earth surface are h_P and h_Q, respectively, where h_P = R/3. The accelerations of P and Q due to Earth's gravity are g_P and g_Q, respectively. If g_P/g_Q = 36/25, what is the value of h_Q?

[JEE (Advanced)-2023, P-1; 3/60, –1]
[Gravitation] [E]

(A) 3R/5 (B) R/6 (C) 6 R/5 (D) 5 R/6

Ans. **(A)**

Sol. $$g_P = \frac{GM}{(R+h_P)^2}$$

$$g_Q = \frac{GM}{(R+h_Q)^2}$$

$$\frac{g_P}{g_Q} = \left(\frac{R+h_Q}{R+h_P}\right)^2 = \frac{36}{25}$$

$5(R+h_Q) = 6(R + h_P)$

$5h_Q = R + 6h_P$

$5h_Q = R + 6\frac{R}{3}$

$$h_Q = \frac{3R}{5}$$

Option is 'A' is correct.

8. A Hydrogen-like atom has atomic number Z. Photons emitted in the electronic transitions from level n = 4 to level n = 3 in these atoms are used to perform photoelectric effect experiment on a target metal. The maximum kinetic energy of the photoelectrons generated is 1.95 eV. If the photoelectric threshold wavelength for the target metal is 310 nm, the value of Z is _____.
[Given: hc = 1240 eV-nm and Rhc = 13.6 eV, where R is the Rydberg constant, h is the Planck's constant and c is the speed of light in vacuum] **[JEE (Advanced)-2023, P-1; 4/60]**

[Modern Physics] [M]

Ans. **3**

Sol. $13.6\times z^2\left[\frac{1}{9}-\frac{1}{16}\right]-\phi=\text{K.E}$

$\frac{13.6z^2\times 7}{16\times 9}-\phi=1.95$

$\frac{13.6z^2\times 7}{16\times 9}-4=1.95$

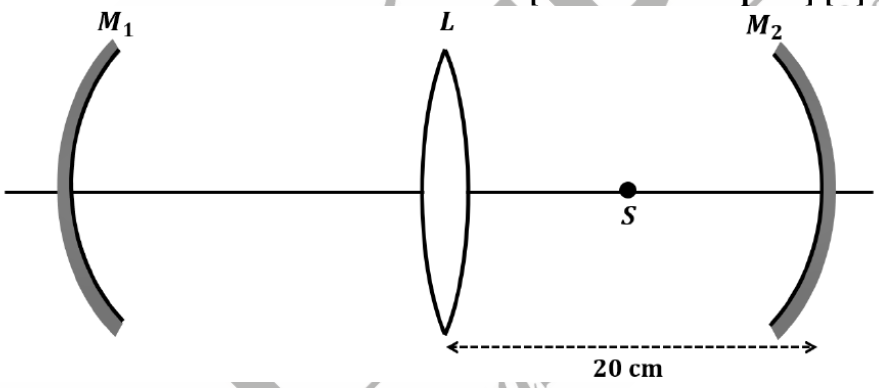
$\frac{13.6\times 7}{16\times 9}z^2=5.95$

$z^2=9$

$z=3$

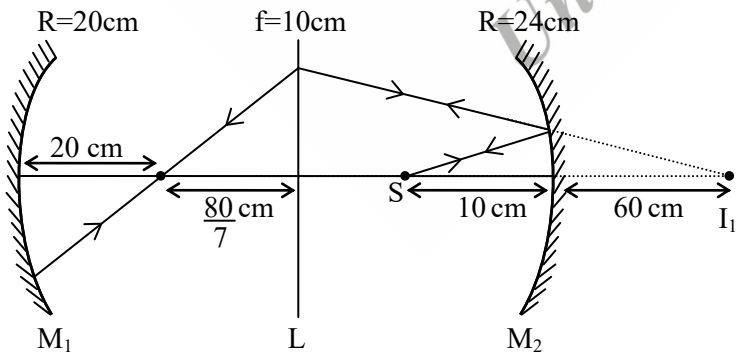
9. An optical arrangement consists of two concave mirrors M_1 and M_2, and a convex lens L with a common principal axis, as shown in the figure. The focal length of L is 10 cm. The radii of curvature of M_1 and M_2 are 20 cm and 24 cm, respectively. The distance between L and M_2 is 20 cm. A point object S is placed at the mid-point between L and M_2 on the axis. When the distance between L and M_1 is n/7 cm, one of the images coincides with S. The value of n is _____.

[JEE (Advanced)-2023, P-1; 4/60]
[Geometrical Optics] [T]



Ans. **Possible answer 220, 80, 150**

Sol.



$\frac{1}{v_1}+\frac{1}{-10}=\frac{1}{12}=\frac{1}{v}=-\frac{1}{12}+\frac{1}{10}=\frac{-10+12}{120}=\frac{2}{120}=\frac{1}{60}$

$v_1=+60$ cm

$\frac{1}{v_1}+\frac{1}{-80}=\frac{1}{10}=\frac{1}{v_2}=\frac{1}{10}-\frac{1}{80}=\frac{8-1}{80}=\frac{7}{80}$

$v_2 = \frac{80}{7}$ cm

One possibility $-20 + \frac{80}{7} = \frac{140+80}{7} = \frac{220}{7} = \frac{n}{7} \Rightarrow n = 220$cm

$\Rightarrow$ other possibility = If image of 'L' is formed on pole of 'M_1'

$\frac{80}{7} = \frac{n}{7} = n = 80$

OR

Reflection from M_1.

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$\frac{1}{v} + \frac{1}{v} = \frac{1}{f} = 60$ cm

For lens

$v = \frac{uf}{u+f} = \frac{(-80)10}{-80+10} = \frac{80}{7}$cm

For image to form at S itself Ray after reflection from mirror 'M_2' must be PARALLEL to lens

$\therefore$ L must form image at focus of 'M_2'.

$\frac{n}{7} = 10 + \frac{80}{7} = \frac{150}{7}$

n = 150

10. In an experiment for determination of the focal length of a thin convex lens, the distance of the object from the lens is 10 ± 0.1 cm and the distance of its real image from the lens is 20 ± 0.2 cm. The error in the determination of focal length of the lens is n %. The value of n is _____.

[JEE (Advanced)-2023, P-1; 4/60]
[Error & Measurement] [E]

Ans. **1**

Sol. $u = 10 \pm 0.1$ cm

$v = 20 \pm 0.1$ cm

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} = \frac{1}{20} - \frac{1}{-10} = \frac{1+2}{20} = \frac{1}{f} = \boxed{f = \frac{20}{3}}$

$-\frac{1}{v^2} = \delta v + \frac{1}{u^2}\delta u = \frac{-1}{f^2}\delta f$

$\frac{\delta f}{f^2}_{N,..} = \frac{\delta u}{u^2} + \frac{\delta v}{v^2}$

$\frac{\delta f}{f^2} = \frac{0.1}{100} + \frac{0.2}{400} = \left(\frac{0.4+0.2}{400}\right) = \frac{0.6}{400}$

$\frac{\delta f}{f} = \frac{0.6}{400} \times \frac{20}{3}$

$\frac{\delta f}{f} \times 100\% = \frac{0.6}{400} \times \frac{20}{3} 100 = \frac{12}{12} = 1$

$\delta = 1\%$

11. A closed container contains a homogeneous mixture of two moles of an ideal monatomic gas ($\gamma = 5/3$) and one mole of an ideal diatomic gas ($\gamma = 7/5$). Here, γ is the ratio of the specific heats at constant pressure and constant volume of an ideal gas. The gas mixture does a work of 66 Joule when heated at constant pressure. The change in its internal energy is _____ Joule.

[JEE (Advanced)-2023, P-1; 4/60]
[KTG & Thermodynamics] [M]

Ans. 121

Sol. $f_{mix} = \frac{2\times3+1\times5}{3} = \frac{11}{3}$

$W = 66$

$\delta R\ \delta T = 66$

$\delta u = nc_v\ \delta T$

$\delta u = n\frac{f_{mix.}}{2}^{R}\ \delta T$

$\delta v = \frac{11}{3\times2}\times66$

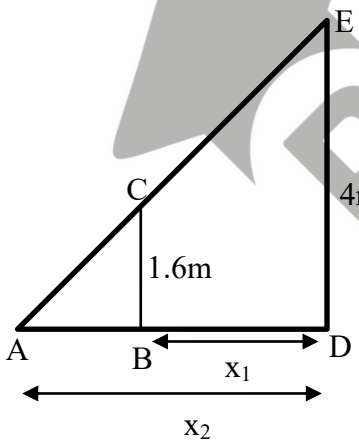
$\boxed{\delta v 121 \text{Joule}}$

12. A person of height 1.6 m is walking away from a lamp post of height 4 m along a straight path on the flat ground. The lamp post and the person are always perpendicular to the ground. If the speed of the person is 60 cm s^{-1}, the speed of the tip of the person's shadow on the ground with respect to the person is _____ cm s^{-1}.

[JEE (Advanced)-2023, P-1; 4/60]
[Mathematical Tools] [E]

Ans. 40

Sol.



Δ ABC and ΔADE is similar

$\frac{4}{x_2} = \frac{1.6}{x_2 - x_1}$

$x_2 = \frac{x_1}{0.6}$

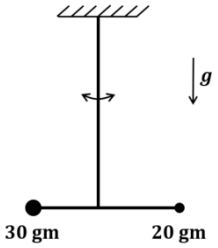
$v_2 = \frac{v_1}{0.6} = \frac{60}{0.6} = 100\,\text{cm/s}$

$v_{2/1} = v_2 - v_1 = 100 - 60 = 40\text{cm/s}$

Ans.= 40

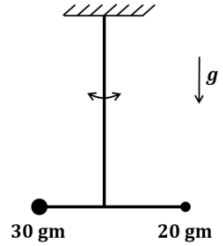
13. Two point-like objects of masses 20 gm and 30 gm are fixed at the two ends of a rigid massless rod of length 10 cm. This system is suspended vertically from a rigid ceiling using a thin wire attached to its center of mass, as shown in the figure. The resulting torsional pendulum undergoes small oscillations. The torsional constant of the wire is 1.2×10^{-8} N m rad^{-1}. The angular frequency of the oscillations in $n \times 10^{-3}$ rad s^{-1}. The value of n is _____.

[JEE (Advanced)-2023, P-1; 4/60]
[Simple Harmonic Motion] [E]



Ans. 10

Sol.



$r_1 = \frac{20}{50} \times 10$

$= 4$ cm

$r_2 = \frac{30}{50} \times 10$

$\tau = -c\theta$

$= -1.2 \times 10^{-8}\ \theta$

$7 = 2\pi\sqrt{\frac{I}{c}}$

$\infty = \sqrt{\frac{c}{I}}$

$I = 30 \times 10^{-3} \times (4 \times 10^{-2})^2 + 20 \times 10^{-3} \times (6 \times 10^{-2})^2$

$= 30 \times 10^{-3} \times 16 \times 10^{-4} + 20 \times 10^{-3} \times 36 \times 10^{-4}$

$= (30 \times 16 + 20 \times 36) \times 10^{-7}$

$= 1200 \times 10^{-7} = 12 \times 10^{-5}$

$\infty = \sqrt{\frac{c}{I}} = \sqrt{\frac{1.2 \times 10^{-5}}{12 \times 10^{-5}}} = \sqrt{\frac{10^{-9}}{10^{-5}}} = \frac{1}{\sqrt{10^4}}$

$= \frac{1}{100} = \frac{10}{100} = 10 \times 10^{-9}$

14. List-I shows different radioactive decay processes and List-II provides possible emitted particles. Match each entry in List-I with an appropriate entry from List-II, and choose the correct option.

[JEE (Advanced)-2023, P-1; 3/60; –1]
[Nuclear Physics] [E]

List-I	**List-II**
(P) $^{238}_{92}U \rightarrow ^{234}_{91}Pa$	(1) one α particle and one β^+ particle
(Q) $^{214}_{82}Pb \rightarrow ^{210}_{82}Pb$	(2) three β^- particles and one α particle
(R) $^{210}_{81}T\ell \rightarrow ^{206}_{82}Pb$	(3) two β^- particles and one α particle
(S) $^{228}_{91}Pa \rightarrow ^{224}_{88}Ra$	(4) one α particle and one β^- particle
	(5) one α particle and two β^+ particles

सूची-I में विभिन्न रेडियोसक्रिय क्षय प्रक्रम प्रदर्शित है तथा सूची-II में उत्सर्जित होने वाले सम्भावित कण प्रदर्शित है। सूची-I में दी गई प्रविष्ठियों को सूची-II की उचित प्रविष्ठियों से सुमेलित करके सही विकल्प का चयन कीजिये।

[JEE (Advanced)-2023, P-1; 3/60; –1]
[Nuclear Physics] [E]

List-I	**List-II**
(P) $^{238}_{92}U \rightarrow ^{234}_{91}Pa$	(1) एक α कण व एक β^+ कण
(Q) $^{214}_{82}Pb \rightarrow ^{210}_{82}Pb$	(2) तीन β^- कण व एक α कण
(R) $^{210}_{81}T\ell \rightarrow ^{206}_{82}Pb$	(3) दो β^- कण व एक α कण
(S) $^{228}_{91}Pa \rightarrow ^{224}_{88}Ra$	(4) एक α कण व एक β^- कण
	(5) एक α कण व दो β^+ कण

(A) P → 4, Q → 3, R → 2, S → 1 (B) P → 4, Q → 1, R → 2, S → 5
(C) P → 5, Q → 3, R → 1, S → 4 (D) P → 5, Q → 1, R → 3, S → 2

Ans. (A)

Sol. (P) $^{238}_{92}U \longrightarrow ^{234}_{92}Pa + ^{4}_{2}He + ^{0}_{-1}\beta$

1α & $1\beta^-$

(Q) $^{214}_{82}Pb \longrightarrow ^{210}_{82}Pb + ^{4}_{2}He + 2^{0}_{-1}\beta$

1α & $2\beta^-$

(R) $^{210}_{81}T\ell \longrightarrow ^{206}_{82}Pb + ^{4}_{2}He + 3^{0}_{-1}\beta$

1α & $3\beta^-$

(S) $^{228}_{91}Pa \longrightarrow ^{224}_{88}Ra + ^{4}_{2}He + _{+1}\beta$

1α & $1\beta^+$

15. Match the temperature of a black body given in List-I with an appropriate statement in List-II, and choose the correct option.

[Given: Wien's constant as 2.9×10^{-3} m-K and $\frac{hc}{e} = 1.24 \times 10^{-6}$ V-m]

[JEE (Advanced)-2023, P-1; 3/60; –1]
[Heat Transfer] [M]

List-I		**List-II**
(P) 2000 K	(1)	The radiation at peak wavelength can lead to emission of photoelectrons from a metal of work function 4 eV.
(Q) 3000 K	(2)	The radiation at peak wavelength is visible to human eye.

(R) 5000 K

(S) 10000 K

(3) The radiation at peak emission wavelength will result in the widest central maximum of a single slit diffraction.

(4) The power emitted per unit area is 1/16 of that emitted by a blackbody at temperature 6000 K.

(5) The radiation at peak emission wavelength can be used to image human bones.

(A) P → 3, Q → 5, R → 2, S → 3

(B) P → 3, Q → 2, R → 4, S → 1

(C) P → 3, Q → 4, R → 2, S → 1

(D) P → 1, Q → 2, R → 5, S → 3

Ans. (C)

Sol. (Q) 3000 k

$\lambda_m \times 3000 = 2.9 \times 10^{-3}$

$\lambda_m = \frac{2.9}{3} \times 10^{-6}$

$= 0.97 \times 10^{-6}$ m $= 97 \times 10^{-8}$ m

$= 970 \times 10^{-9}$ m

= 970 nm

= 9700 Å

(R) 5000 K

$\lambda_m = \frac{2.9 \times 10^{-3}}{5 \times 10^3} = \frac{2.9}{5} \times 10^{-6}$

$= 0.58 \times 10^{-6}$

$= 58 \times 10^{-8}$

$= 580 \times 10^{-9}$

= 580 nm → visible

(R) 5000 K

$\lambda_m = \frac{2.9 \times 10^{-3}}{5 \times 10^3} = \frac{2.9}{5} \times 10^{-6}$ m

$= \frac{29}{5} \times 10^{-6}$ m $= 0.5 \times 10^{-6}$ m

$= 58 \times 10^{-8}$

$= 5.8 \times 10^{-9}$

$E = \frac{hC}{\lambda} = \frac{5 \times 1.24 \times 10^{-6} eV}{2.9 \times 10^{-6}}$

$= \frac{5 \times 1.24}{2.9} = 2.13$

(S) 10,000 K

$\lambda_m = \frac{2.9 \times 10^{-3}}{10,000}$

$= 2.9 \times 10^{-7}$ m

$= 29 \times 10^{-8}$ m

$E = \frac{hC}{\lambda} = \frac{1.24 \times 10^{-6} eV}{29 \times 10^{-8}}$

$= \frac{124}{29} = 4.275 eV$

16. A series LCR circuit is connected to a 45 sin(ωt) Volt source. The resonant angular frequency of the circuit is 10^5 rad s^{-1} and current amplitude at resonance is I_0. When the angular frequency of the source is $\omega = 8 \times 10^4$ rad s^{-1}, the current amplitude in the circuit is 0.05 I_0. If L = 50 mH, match each entry in List-I with an appropriate value from List-II and choose the correct option.

[JEE (Advanced)-2023, P-1; 3/60; –1]
[Alternating Current] [M]

List-I	**List-II**
(P) I_0 in mA	(1) 44.4
(Q) The quality factor of the circuit	(2) 18
(R) The bandwidth of the circuit in rad s^{-1}	(3) 400
(S) The peak power dissipated at resonance in Watt	(4) 2250
	(5) 500

(A) P → 2, Q → 3, R → 5, S → 1 (B) P → 3, Q → 1, R → 4, S → 2
(C) P → 4, Q → 5, R → 3, S → 1 (D) P → 4, Q → 2, R → 1, S → 5

Ans. (B)

Sol. Given

$L = 50 \times 10^{-3}$ H.

ω at resonance $= 10^5$ rad/s.

at $\omega = 8 \times 10^4$ rad/s

$I = 0.05I_0 = \frac{I_0}{20}$. $\omega_{Reso} = \frac{1}{\sqrt{LC}}$.

$10^5 = \frac{1}{\sqrt{50\times10^{-3}c}}$ $c = 2 \times 10^{-9}$ f

for $\omega = 8 \times 10^4$ rad/s.

$X_L = \omega L = 4000\ \Omega$

$X_c = \frac{1}{\omega c} 6250\Omega$

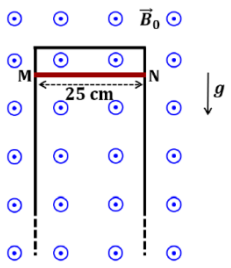
$Z\sqrt{R^2 + (6250 - 4000)^2}$

$I = \frac{45}{Z} = \frac{I_0}{20} \Rightarrow \frac{45}{\sqrt{R^2 (2250)^2}} = \frac{I_0}{20} \Rightarrow \frac{45}{\sqrt{R^2 + (2250)^2}} \frac{45}{R(20)}$

$R \approx \frac{225}{2}$

17. A thin conducting rod MN of mass 20 gm, length 25 cm and resistance 10 Ω is held on frictionless, long, perfectly conducting vertical rails as shown in the figure. There is a uniform magnetic field $B_0 = 4$ T directed perpendicular to the plane of the rod-rail arrangement. The rod is released from rest at time t = 0 and it moves down along the rails. Assume air drag is negligible. Match each quantity in List-I with an appropriate value from List-II, and choose the correct option.
[Given: The acceleration due to gravity g = 10 m s^{-2} and $e^{-1} = 0.4$]

[JEE (Advanced)-2023, P-1; 3/60; –1]
[EMI] [E]



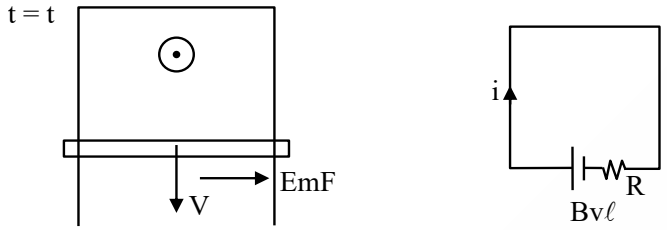
List-I **List-II**

(P) At $t = 0.2$ s, the magnitude of the induced emf in Volt (1) 0.07
(Q) At $t = 0.2$ s, the magnitude of the magnetic force in Newton (2) 0.14
(R) At $t = 0.2$ s, the power dissipated as heat in Watt (3) 1.20
(S) The magnitude of terminal velocity of the rod in m s−1 (4) 0.12
(5) 2.00

(A) P → 5, Q → 2, R → 3, S → 1 (B) P → 3, Q → 1, R → 4, S → 5
(C) P → 4, Q → 3, R → 1, S → 2 (D) P → 3, Q → 4, R → 2, S → 5

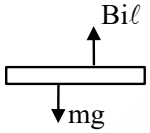
Ans. (D)

Sol.



$i.\frac{B v \ell}{R}$

FBD



$$mg - Bi\ell = m\frac{dv}{dt}$$

$$mg - \frac{B^2 v \ell^2}{R} = \frac{mdv}{dt}$$

$$\frac{mgR}{B^2\ell^2} - v = \frac{mR}{B^2\ell^2}\frac{d\theta}{dt}$$

Putting values

$$2 - v = .2\frac{dv}{dt}$$

$$\int 5dt = \int \frac{dv}{2-V} \quad \Rightarrow \quad 5t = -\ell n\left(\frac{2-v}{2}\right)$$

$$e^{-5t} = 1 - \frac{v}{2}$$

$$v = 2\,(1 - e^{-5t})$$

At $t = .2$

$v = 2\,(1 - e^{-5\times.2})$

$= 1.2$ m/s

(P) EMF = $B v \ell$

$= 4\,(1.2)\,\frac{1}{4} = 1.2$ v … (3)

(Q) $BIL = 4(.12)\left(\frac{1}{4}\right)$ $\left[i = \frac{Bv\ell}{R} = \frac{1.2}{10} = .12A\right]$

$= .12$ N …. (4)

(R) Power = $I^2R = (.12)^2 \times 10 = .144$ watt …. (2)

(S) Terminal speed

$\therefore$ v at $t = \infty$

$v = 2(1 - e^{-5t})$

as $t \to \infty$ $v \to 2$ …. (5)

Option (D)

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