Physics (Paper A)
JEE MAIN 2015

***Questions*: 1:-** As an electron makes a transition from an excited state to the ground state of a hydrogen – like atom/ion:

(A) Kinetic energy, potential energy and total energy decrease

(B) Kinetic energy decreases, potential energy increases but total energy remains same

(C) Kinetic energy and total energy decrease but potential energy increases

(D) Its kinetic energy increases but potential energy and total energy decrease

***Ans*:- (D)** As electron goes to ground state, total energy decreases.

TE = – KE

PE = 2TE

So, kinetic energy increases but potential energy and total energy decreases.

***Questions*: 2:-** The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$ Measured value of L is 20.0 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using wrist watch of 1 s resolution. The accuracy in the determination of g is:

(A) 3% (B) 1%

(C) 5% (D) 2%

***Ans*:- (A)**

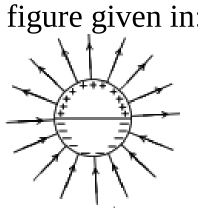
$$g = \frac{4\pi^2 L}{T^2}$$

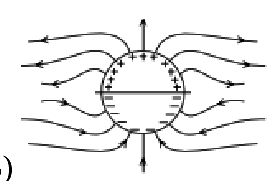
$$\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\left(\frac{\Delta T}{T}\right)$$

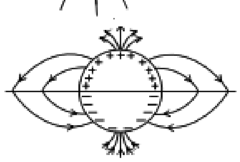
$$\frac{\Delta L}{L} = \frac{0.1}{20}, \frac{\Delta T}{T} = \frac{0.01}{0.9}$$

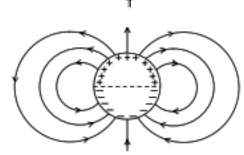
$$100\left(\frac{\Delta g}{g}\right) = 100\left(\frac{\Delta L}{L}\right) + 2 \times 100 \times \left(\frac{\Delta T}{T}\right) \simeq 3\%$$

***Questions*: 3:-** A long cylindrical shell carries positive surface charge σ in the upper half and negative surface charge –σ in the lower half. The electric field lines around the cylinder will look like figure given in: (figures are schematic and not drawn to scale)

(A) 

(B) 

(C) 

(D) 

***Ans*:- (D)** It originates from + Ve charge and terminates at – Ve charge. It cannot form close loop.

***Questions*: 4:-** A signal of 5 kHz frequency is amplitude modulated on a carrier wave of frequency 2 MHz. The frequencies of the resultant signal is/are:

(A) 2005 kHz, and 1995 kHz
(B) 2005 kHz, 2000 kHz and 1995 kHz
(C) 2000 kHz and 1995 kHz
(D) 2 MHz only

***Ans*:- (B)** $f_R = f_C + f_m$ = 2000 kHz + 5kHz = 2005 kHz

$f_R = f_C - f_m$ = 2000 kHz – 5kHz = 1995 kHz

So, frequency content of resultant wave will have frequencies 1995 kHz, 2000 kHz and 2005 kHz

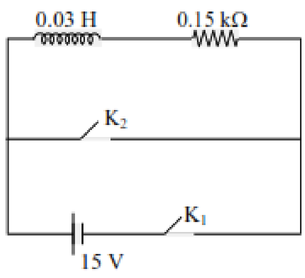
***Questions*: 5:-** Consider a spherical shell of radius R at temperature T. The black body radiation inside it can be considered as an ideal gas of photons with internal energy per unit volume $u = \frac{U}{V} \propto T^4$ and pressure $p = \frac{1}{3}\left(\frac{U}{V}\right)$. If the shell now undergoes an adiabatic expansion the relation between T and R is:

(A) $T \propto e^{-3R}$
(B) $T \propto \frac{1}{R}$
(C) $T \propto \frac{1}{R^3}$
(D) $T \propto e^{-R}$

***Ans*:- (B)**

$$dQ = dU + dW$$
$$dU = -pdV$$
$$\frac{dU}{dV} = -p = -\frac{1}{3}\frac{U}{V}$$
$$\frac{dU}{U} = -\frac{1}{3}\frac{dV}{V}$$
$$\ell nU = -\frac{1}{3}\ell nV + \ell nC$$
$$U \cdot V^{1/3} = C$$
$$VT^4 \cdot V^{1/3} = C'$$
$$T \propto \frac{1}{R}$$

***Questions*: 6:-** An inductor (L = 0.03 H) and a resistor (R = 0.15 kΩ) are connected in series to a battery of 15V EMF in a circuit shown. The key K_1 has been kept closed for a long time. Then at t = 0, K_1 is opened and key K_2 is closed simultaneously. At t = 1 ms, the current in the circuit will be: ($e^5 \cong 150$)



(A) 67 mA
(B) 6.7 mA
(C) 0.67 mA
(D) 100 mA

***Ans*:- (C)**

When K_1 is closed and K_2 is open,

$$I_0 = \frac{E}{R}$$

when K_1 is open and K_2 is closed, current as a function of time 't' in L.R. circuit.

$$I = I_0 e^{-R\frac{t}{L}}$$

$$= \frac{1}{10}e^{-5} = \frac{1}{1500} = 0.67 \text{ mA}$$

***Questions*: 7:-** A pendulum made of a uniform wire of cross sectional area A has time period T. When an additional mass M is added to its bob, the time period changes to T_M. If the Young's modulus of the material of the wire is Y then $\frac{1}{Y}$ is equal to: (g = gravitational acceleration)

(A) $\left[\left(\frac{T_M}{T}\right)^2 - 1\right]\frac{Mg}{A}$

(B) $\left[1 - \left(\frac{T_M}{T}\right)^2\right]\frac{A}{Mg}$

(C) $\left[1 - \left(\frac{T}{T_M}\right)^2\right]\frac{A}{Mg}$

(D) $\left[\left(\frac{T_M}{T}\right)^2 - 1\right]\frac{A}{Mg}$

***Ans*:- (D)**

Time period, $T = 2\pi\sqrt{\frac{\ell}{g}}$

When additional mass M is added to its bob

$$T_M = 2\pi\sqrt{\frac{\ell + \Delta\ell}{g}}$$

$$\Delta\ell = \frac{Mg\ell}{AY}$$

$$\Rightarrow T_M = 2\pi\sqrt{\frac{\ell + \frac{Mg\ell}{AY}}{g}}$$

$$\left(\frac{T_M}{T}\right)^2 = 1 + \frac{Mg}{AY}$$

$$\frac{1}{Y} = \frac{A}{Mg}\left[\left(\frac{T_M}{T}\right)^2 - 1\right]$$

***Questions*: 8:-** A red LED emits light at 0.1 watt uniformly around it. The amplitude of the electric field of the light at a distance of 1 m from the diode is:

(A) 2.45 V/m

(B) 5.48 V/m

(C) 7.75 V/m

(D) 1.73 V/m

***Ans*:- (A)**

Intensity, $I = \frac{1}{2}\varepsilon_0 E_0^2 C$, where E_0 is amplitude of the electric field of the light.

$$\frac{P}{4\pi r^2} = \frac{1}{2}\varepsilon_0 E_0^2 C$$

$$E_0 = \sqrt{\frac{2P}{4\pi r^2 C\varepsilon_0}} = 2.45 \text{ V/m}$$

***Questions*: 9:-** Two coaxial solenoids of different radii carry current I in the same direction. Let $\vec{F}_1$ be the magnetic force on the inner solenoid due to the outer one and $\vec{F}_2$ be the magnetic force on the outer solenoid due to the inner one. Then:

(A) $\vec{F}_1$ s radially inwards and $\vec{F}_2$ is radially outwards

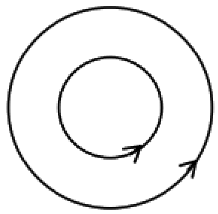
(B) $\vec{F}_1$ is radially inwards and $\vec{F}_2 = 0$

(C) $\vec{F}_1$ is radially outwards and $\vec{F}_2 = 0$

(D) $\vec{F}_1 = \vec{F}_2 = 0$

***Ans*:- (D)** Both solenoid are in equilibrium so, net Force on both solenoids due to other is zero.

So, $\vec{F}_1 = \vec{F}_2 = 0$



***Questions*: 10:-** Consider an ideal gas confined in an isolated closed chamber. As the gas undergoes an adiabatic expansion the average time of collision between molecules increases as V^q, where V is the volume of the gas. The value of q is: $\left(\gamma = \frac{C_P}{C_V}\right)$

(A) $\frac{3\gamma-5}{6}$ (B) $\frac{\gamma+1}{2}$

(C) $\frac{\gamma-1}{2}$ (D) $\frac{3\gamma+5}{6}$

***Ans*:- (B)**

$$\text{Average time between collision} = \frac{\text{Mean free Path}}{V_{rms}}$$

$$t = \frac{\frac{1}{\pi d^2 N/V}}{\sqrt{\frac{3RT}{M}}}\ ;\ t = \frac{CV}{\sqrt{T}}\ \left(\text{where } C = \frac{\sqrt{M}}{\pi d^2 N\sqrt{3R}} = \text{constant}\right)$$

$$\Rightarrow\ T \propto \frac{V^2}{t^2}$$

For adiabatic

$$TV^{\gamma-1} = k$$

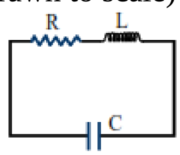
$$\frac{V^2}{t^2}V^{\gamma-1} = k$$

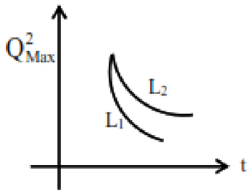
$$\frac{V^{\gamma+1}}{t^2} = k$$

$$t \propto V^{\frac{\gamma+1}{2}}$$

$$\text{so, } q = \frac{\gamma+1}{2}$$

***Questions*: 11:-** An LCR circuit is equivalent to a damped pendulum. In an LCR circuit the capacitor is charged to Q_0 and then connected to the L and R as shown.
If a student plots graphs of the square of maximum charge (Q^2_{max}) on the capacitor with time (t) for two different values L_1 and L_2 ($L_1 > L_2$) of L then which of the following represents this graph correctly? (Plots are schematic and not drawn to scale)



(A)


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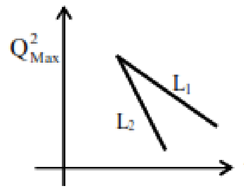
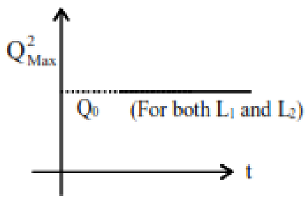
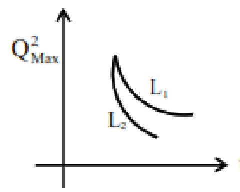


(C)


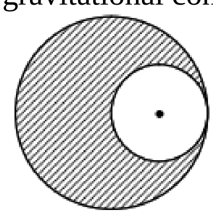
(D)


***Ans*:- (D)**

As $L_1 > L_2$, therefore $\frac{1}{2}L_1 i^2 > \frac{1}{2}L_2 i^2$,

$\therefore$ Rate of energy dissipated through R from L_1 will be slower as compared to L_2.

***Questions*: 12:-** From a solid sphere of mass M and radius R, a spherical portion of radius R/2 is removed, as shown in the figure. Taking gravitational potential V = 0 at r = ∞, the potential at the centre of the cavity thus formed is (G = gravitational constant)



(A) $-\frac{GM}{R}$
(B) $-\frac{2GM}{3R}$
(C) $-\frac{2GM}{R}$
(D) $\frac{-GM}{2R}$

***Ans*:- (A)**

$V_{required} = V_M - V_{M/8}$

$= -\frac{GM}{2R^3}\left[3R^2 - \frac{R^2}{4}\right] + \frac{GM/8}{2(R/2)^3}\left[3(R/2)^2\right]$

$= -\frac{11GM}{8R} + \frac{3GM}{8R} = -\frac{GM}{R}$.

***Questions*: 13:-** A train is moving on a straight track with speed 20 ms^{-1}. It is blowing its whistle at the frequency of 1000 Hz. The percentage change in the frequency heard by a person standing near the track as the train passes him is (speed of sound = 320 ms^{-1}) close to:

(A) 12 % (B) 18 %

(C) 24 % (D) 6 %

***Ans*:- (A)**

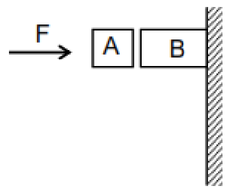
$$f_1 \text{ (train approaches)} = 1000\left(\frac{320}{320-20}\right) = 1000\left(\frac{320}{300}\right)\text{Hz.}$$

$$f_2\text{(train recedes)} = 1000\left(\frac{320}{320+20}\right) = 1000\left(\frac{320}{340}\right)\text{Hz.}$$

$$\Delta f = \left(\frac{f_1 - f_2}{f_1}\right)\times 100\% = \left(1 - \frac{300}{340}\right)\times 100\% = \frac{40}{340}\times 100\%$$

$$= 11.7\ \% \approx 12\ \%.$$

***Questions*: 14:-** Given in the figure are two blocks A and B of weight 20 N and 100 N respectively. These are being pressed against a wall by a force F as shown. If the coefficient of friction between the blocks is 0.1 and between block B and the wall is 0.15, the frictional force applied by the wall on block B is



(A) 80 N (B) 120 N

(C) 150 N (D) 100 N

***Ans*:- (B)** Normal force on block A due to B and between B and wall will be F.

Friction on A due to B = 20 N

∴ Friction on B due to wall = 100 + 20 = 120 N

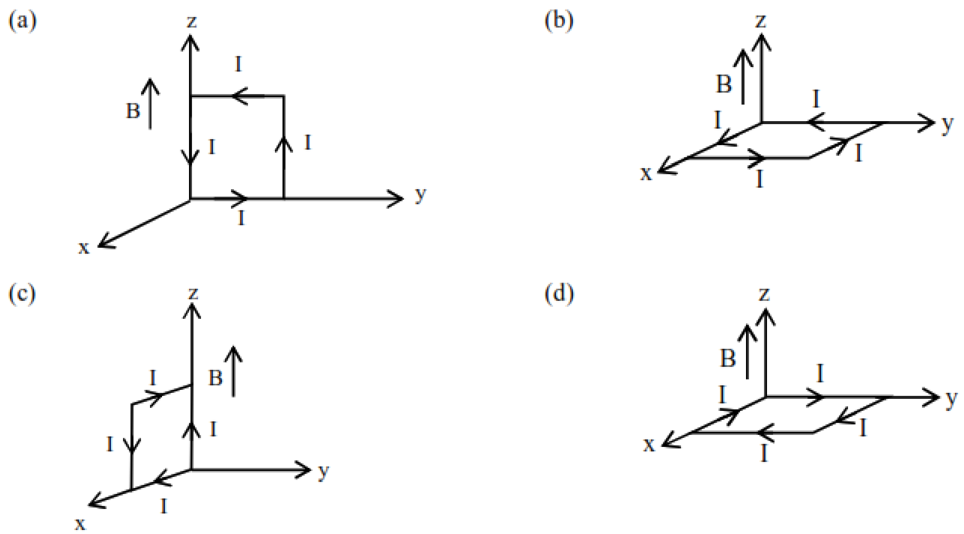
***Questions*: 15:-** Distance of the centre of mass of a solid uniform cone from its vertex is z_0. If the radius of its base is R and its height is h then z_0 is equal to:

(A) $\frac{3h}{4}$ (B) $\frac{5h}{8}$

(C) $\frac{3h^2}{8R}$ (D) $\frac{h^2}{4R}$

***Ans*:- (A)** $Z_0 = h - \frac{h}{4} = \frac{3h}{4}$

***Questions*: 16:-** A rectangular loop of sides 10 cm and 5 cm carrying a current I of 12 A is placed in different orientations as shown in the figures below:



If there is a uniform magnetic field of 0.3 T in the positive z direction, in which orientations the loop would be in (i) stable equilibrium and (ii) unstable equilibrium?

(A) (a) and (c), respectively (B) (b) and (d), respectively

(C) (b) and (c), respectively (D) (a) and (b), respectively

***Ans*:- (B)**

Since $\vec{B}$ is uniform, only torque acts on a current carrying loop. $\vec{\tau} = (I\vec{A}) \times \vec{B}$

$\vec{A} = A\hat{k}$ for (b) and $\vec{A} = -A\hat{k}$ for (d).

$\therefore \quad \vec{\tau} = 0$ for both these cases.

The energy of the loop in the $\vec{B}$ field is : $U = -I\vec{A} \cdot \vec{B}$, which is minimum for (b).

***Questions*: 17:-** In the circuit shown, the current in the 1Ω resistor is:

(A) 0 A (B) 0.13 A, from Q to P

(C) 0.13 A, from P to Q (D) 1.3 A, from P to Q

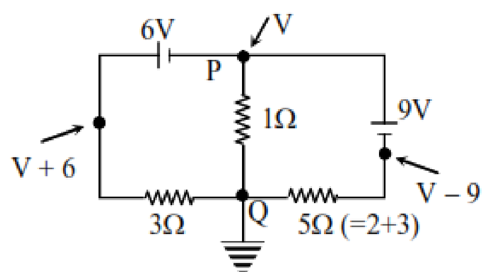
***Ans*:- (B)**

Taking the potential at Q to be 0 and at P to be V, we apply Kirchoff's current law at Q:

$$\frac{V+6}{3} + \frac{V}{1} + \frac{V-9}{5} = 0$$

$$V = -\frac{3}{23} = -0.13 \text{ volt}$$

The current will flow from Q to P.



***Questions*: 18:-** A uniformly charged solid sphere of radius R has potential V_0 (measured with respect to ∞) on its surface. For this sphere the equipotential surfaces with potentials $\frac{3V_0}{2}, \frac{5V_0}{4}, \frac{3V_0}{4}$ and $\frac{V_0}{4}$ have radius R_1, R_2, R_3 and R_4 respectively. Then

(A) $R_1 \neq 0$ and $(R_2 - R_1) > (R_4 - R_3)$ (B) $R_1 = 0$ and $R_2 < (R_4 - R_3)$

(C) $2R < R_4$ (D) $R_1 = 0$ and $R_2 > (R_4 - R_3)$

***Ans*:- (B, C)**

The potential at the centre $= k\dfrac{Q}{\frac{4}{3}\pi R^3}\displaystyle\int_0^R \frac{4\pi r^2 dr}{r} = \frac{3}{2}\frac{kQ}{R} = \frac{3}{2}V_0\ ;\ k = \frac{1}{4\pi\varepsilon_0}$

$\therefore\quad R_1 = 0$

Potential at surface, $V_0 = \dfrac{kQ}{R}$

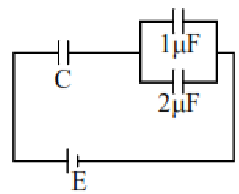
Potential at $R_2 = \dfrac{5V_0}{4} \Rightarrow R_2 = \dfrac{R}{\sqrt{2}}$

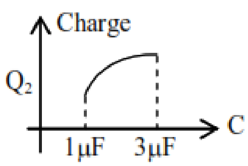
Potential at R_3, $\dfrac{kQ}{R_3} = \dfrac{3}{4}\dfrac{kQ}{R} \Rightarrow R_3 = \dfrac{4R}{3}$

Similarly at R_4, $\dfrac{kQ}{R_4} = \dfrac{kQ}{4R} \Rightarrow R_4 = 4R$

$\therefore$ Both options (2) and (3) are correct.

***Questions*: 19:-** In the given circuit, charge Q_2 on the 2 μF capacitor changes as C is varied from 1 μF to 3 μF Q_2 as a function of 'C' is given properly by : (figures are drawn schematically and are not to scale)



(A)


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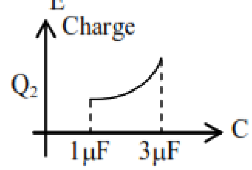
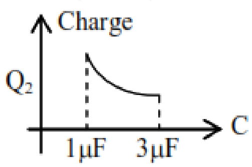


(C)


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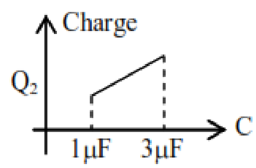


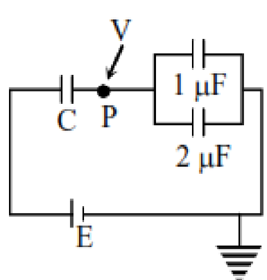
***Ans*:- (A)**

Let the potential at P be V,

Then, C (E–V) = 1×V+2×V (we take C in μF)

Or, $V = \dfrac{CE}{3+C}$

$\therefore\quad Q_2 = \dfrac{2CE}{3+C}$



***Questions*: 20:-** A particle of mass m moving in the x direction with speed 2v is hit by another particle of mass 2m moving in the y direction with speed v. If the collision is perfectly inelastic, the percentage loss in the energy during the collision is close to

(A) 50%
(B) 56%
(C) 62%
(D) 44%

Ans:- **(B)**

$$E_{initial} = \frac{1}{2}m(2v)^2 + \frac{1}{2}2m(v)^2 = 3mv^2$$

$$E_{final} = \frac{1}{2}3m\left(\frac{4}{9}v^2 + \frac{4}{9}v^2\right) = \frac{4}{3}mv^2$$

$$\therefore \quad \text{Fractional loss} = \frac{3-\frac{4}{3}}{3} = \frac{5}{9} = 56\%$$