JEE Main Online Exam 2019

Questions & Solutions

10th April 2019 | Shift - I

Physics

Q.1 A 25×10^{-3} m^3 volume cylinder is filled with 1 mol of O_2 gas at room temperature (300 K). The molecular diameter of O_2, and its root mean square speed, are found to be 0.3 nm and 200 m/s, respectively. What is the average collision rate (per second) for an O_2 molecule ?

(1) $\sim 10^{12}$ (2) $\sim 10^{10}$ (3) $\sim 10^{13}$ (4) $\sim 10^{11}$

Ans. **[1]**

Sol. collision frequency = $\frac{v_{av}}{\lambda}$

$$v_{av} = \sqrt{\frac{8}{3\pi}}\, v_{rms}$$

$$v_{av} = \sqrt{\frac{8}{3\pi}} \times 200$$

$$\lambda = \frac{RT}{\sqrt{2}\pi d^2 NP} \qquad \because P = \frac{RT}{V}$$

$$\lambda = \frac{V}{\sqrt{2}\pi d^2} = \frac{25\times 10^{-3}}{1.4\times\pi\times 9\times 10^{-20}}$$

put values frequency $\simeq$ 0. 2 $\times 10^{10}$/sec

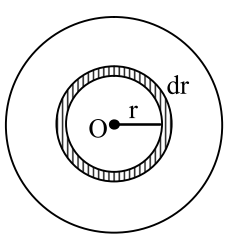
Answer by NTA is given as 10^{12} per sec.

Q.2 A thin disc of mass M and radius R has mass per unit area $\sigma(r) = kr^2$ where r is the distance from its centre. Its moment of inertia about an axis going through its centre of mass and perpendicular to its plane is :

(1) $\frac{2MR^2}{3}$ (2) $\frac{MR^2}{6}$ (3) $\frac{MR^2}{3}$ (4) $\frac{MR^2}{2}$

Ans. **[1]**

Sol.



assume a ring of radius r and with dr

$dI = (dm)r^2$

$$I = \int_0^R dm\ r^2 = \int_0^R \sigma(2\pi r)dr\ r^2$$

$$= 2\pi k \int_0^R r^5 dr$$

$$= 2\pi k\left(\frac{R^6}{6}\right) = \frac{\pi k R^6}{3}$$

mass of disc $\quad M = k\int_0^R 2\pi r^3\ dr$

$$M = k2\pi\left(\frac{R^4}{4}\right)$$

$$k = \frac{4M}{2\pi R^4}$$ put the value

$$I = \frac{\pi}{3}\left(\frac{4M}{2\pi R^4}\right)R^6$$

$$= \frac{2MR^2}{3}$$

Q.3 A moving coil galvanometer allows a full scale current of 10^{-4} A. A series resistance of 2 MΩ is required to convert the above galvanometer into a voltmeter of range 0-5 V. Therefore the value of shunt resistance required to convert the above galvanometer into an ammeter of range 0-10 mA is :

(1) 10 Ω (2) 500 Ω (3) 100 Ω (4) 200 Ω

Ans. **[Drop by NTA]**

Sol. $i_g = 0.1$ mA , V = 5V, $R = 2 \times 10^6$

$V = i_g(G + R)$

$5 = 0.1 \times 10^{-3}(G + R)$

$G + R = 5 \times 10^4$

$G = 5 \times 10^4 - 2 \times 10^6$

= Negative

Not possible

Q.4 An npn transistor operates as a common emitter amplifier, with a power gain of 60 dB. The input circuit resistance is 100 Ω and the output load resistance is 10 kΩ. The common emitter current gain β is .

(1) 10^2 (2) 10^4 (3) 60 (4) 6×10^2

Ans. **[1]**

Sol. $R_i = 100, R_o = 10^4$

Power gain $\Rightarrow 60 = 10 \log\left(\frac{P_o}{P_i}\right)$

$$\frac{P_o}{P_i} = 10^6 = \beta^2\frac{R_o}{R_i}$$

$\beta^2 = 10^6 \times \frac{R_i}{R_o}$

$= 10^6 \times \frac{100}{10^4}$

$\beta^2 = 10^4$

$\beta = 100$

Q.5 A current of 5 A passes through a copper conductor (resistivity = 1.7×10^{-8} Ωm) of radius of cross-section 5 mm. Find the mobility of the charges if their drift velocity is 1.1×10^{-3} m/s.

(1) 1.0 m^2/Vs (2) 1.8 m^2/Vs (3) 1.5 m^2/Vs (4) 1.3 m^2/Vs

Ans. **[1]**

Sol. $\rho = \frac{m}{ne^2\tau} = \frac{1}{ne\mu}$

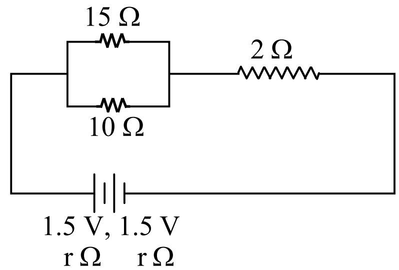
$i = neA\,v_d$

$n = \frac{i}{eAv_d}$

$\mu = \frac{Av_d}{i\rho} = \frac{1.1\times10^{-3}\times\pi\times25\times10^{-6}}{5\times1.7\times10^{-8}}$

$= \frac{17.27\times10^{-1}}{1.7} \approx 1.0\ m^2/Vs$

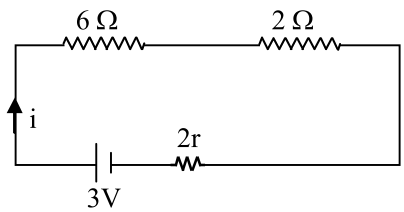
Q.6 In the given circuit, an ideal voltmeter connected across the 10 Ω resistance reads 2V. The internal resistance r, of each cell is :



(1) 1 Ω (2) 0.5 Ω (3) 1.5 Ω (4) 0 Ω

Ans. **[2]**

Sol.



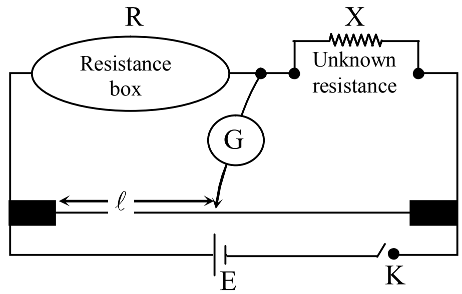
current $i = \frac{2}{6} = \frac{1}{3}$

$\frac{1}{3}(8 + 2r) = 3$

$2r = 1$

$r = 0.5\ \Omega$

Q.7 In a meter bridge experiment, the circuit diagram and the corresponding observation table are shown in figure.



Sl. No.	R (Ω)	ℓ (cm)
1.	1000	60
2.	100	13
3.	10	1.5
4.	1	1.0

Which of the reading is inconsistent ?

(1) 3 (2) 4 (3) 2 (4) 1

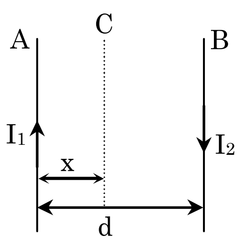
Ans. **[2]**

Sol. By using $\frac{X}{R} = \frac{100-\ell}{\ell}$

$X = R\left(\frac{100-\ell}{\ell}\right)$

The value of X for reading 4 is totally different

Q.8 Two wires A & B are carrying currents I_1 & I_2 as shown in the figure. The separation between them is d. A third wire C carrying a current I is to be kept parallel to them at a distance x from A such that the net force acting on it is zero. The possible values of x are :



(1) $x = \left(\frac{I_1}{I_1 - I_2}\right)d$ and $x = \frac{I_2}{(I_1 + I_2)}d$

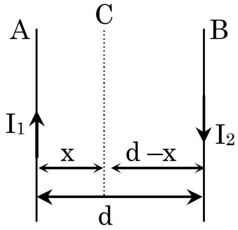
(2) $x = \pm \frac{I_1 d}{(I_1 - I_2)}$

(3) $x = \left(\frac{I_1}{I_1 + I_2}\right)d$ and $x = \frac{I_2}{(I_1 - I_2)}d$

(4) $x = \left(\frac{I_2}{I_1 + I_2}\right)d$ and $x = \left(\frac{I_2}{(I_1 - I_2)}\right)d$

Ans. **[2]**

Sol.



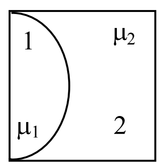
F_{net} on C = 0

$$\frac{\mu_0 I_1 I}{2\pi x} + \frac{\mu_0 I_2 I}{2\pi(d-x)} = 0$$

$$\frac{I_1}{x} = \frac{I_2}{x-d}$$

$$x = \frac{I_1 d}{I_1 - I_2}$$

Q.9 One plano-convex and one plano-concave lens of same radius of curvature 'R' but of different materials are joined side by side as shown in the figure. If the refractive index of the material of 1 is μ_1 and that of 2 is μ_2, then the focal length of the combination is :



(1) $\frac{R}{2-(\mu_1-\mu_2)}$ (2) $\frac{R}{2(\mu_1-\mu_2)}$ (3) $\frac{R}{\mu_1-\mu_2}$ (4) $\frac{2R}{\mu_1-\mu_2}$

Ans. **[3]**

Sol. $\frac{1}{r_1} = (\mu_1 - 1)\left(\frac{1}{\infty} - \frac{1}{-R}\right) = \frac{\mu_1 - 1}{R}$

$$\frac{1}{r_2} = \frac{\mu_2 - 1}{-R}$$

Therefore $\frac{1}{r_{eq}} = \frac{R}{\mu_1 - \mu_2}$

Q.10 A message signal of frequency 100 MHz and peak voltage 100 V is used to execute amplitude modulation on a carrier wave of frequency 300 GHz and peak voltage 400 V. The modulation index and difference between the two side band frequencies are :

(1) 0.25 ; 2×10^8 Hz

(2) 4 ; 1×10^8 Hz

(3) 4 ; 2×10^8 Hz

(4) 0.25 ; 1×10^8 Hz

Ans. **[1]**

Sol. $\omega_s = 2\pi f_s$, $f_s = 100 \times 10^6$, $E_s = 100$ V

$\omega_c = 2\pi f_c$, $f_c = 300 \times 10^9$ Hz, $E_c = 400$ V modulation index m $= \frac{E_s}{E_c} = \frac{100}{400} = 0.25$

side band $\Delta F = F_{max} - F_{min}$

$= (F_s + F_c) - (F_c + F_s)$

$= 10^8[(3000+1)-(3000-1)]$

$= 10^8(2) = 2\times 10^8$

Q.11 A cylinder with fixed capacity of 67.2 lit contains helium gas at STP. The amount of heat needed to raise the temperature of the gas by 20°C is : [Given that R = 8.31 J mol^{-1} K^{-1}]

(1) 748 J (2) 350 J (3) 374 J (4) 700 J

Ans. **[1]**

Sol. $Q = nC_vdT$

= 748 Joule

Q.12 A stationary source emits sound waves of frequency 500 Hz. Two observers moving along a line passing through the source detect sound to be of frequencies 480 Hz and 530 Hz. Their respective speeds are, in ms^{-1}, (Given speed of sound = 300 m/s)

(1) 12, 16 (2) 12, 18 (3) 16,14 (4) 8, 18

Ans. **[2]**

Sol. $n_A = \frac{n}{v}(v - v_A) = \frac{500}{300}[300 - V_A] = 480$

$300 - V_A = \frac{480\times 3}{5} = 288$

$V_A = 300 - 288 = 12$ m/s

similarly $n_B = \frac{n}{v}(v + v_B)$

$V_B = 18$ m/s

Q.13 Given below in the left column are different modes of communication using the kinds of waves given in the right column.

A.	Optical Fibre communication	P.	Ultrasound
B.	Radar	Q.	Infrared Light
C.	Sonar	R.	Microwaves
D.	Mobile Phones	S.	Radio Waves

From the options given below, find the most appropriate match between entries in the left and the right column.

(1) A-R, B-P, C-S, D-Q (2) A-S, B-Q, C-R, D-P

(3) A-Q, B-S, C-R, D-P (4) A-Q, B-S, C-P, D-R

Ans. **[4]**

Sol. According to frequency

$A\rightarrow Q$; $B\rightarrow S$; $C\rightarrow P$; $D\rightarrow R$

Q.14 The electric field of a plane electromagnetic wave is given by

$\vec{E} = E_0 \hat{i} \cos(kz) \cos(\omega t)$

The corresponding magnetic field $\vec{B}$ is then given by :

(1) $\vec{B} = \frac{E_0}{C}\hat{k} \sin(kz)\cos(\omega t)$

(2) $\vec{B} = \frac{E_0}{C}\hat{j} \sin(kz)\sin(\omega t)$

(3) $\vec{B} = \frac{E_0}{C}\hat{j} \sin(kz)\cos(\omega t)$

(4) $\vec{B} = \frac{E_0}{C}\hat{j} \cos(kz)\sin(\omega t)$

Ans. **[2]**

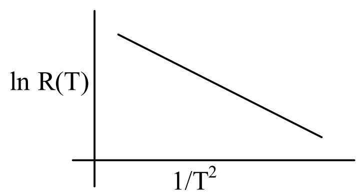
Sol. $\vec{E} = E_0 \cos kz \, \cos\omega t \, \hat{i}$

vibration of B = perpendicular to $\vec{E}$ and propagation of electro magnetic wave is in z direction. Hence the direction of vibration of $\vec{B}$ should be along $\hat{j}$.

$\frac{E_0}{B_0} = C$

$\vec{B} = \frac{E_0}{C} \sin\omega t \sin kz \, \hat{j}$

Q.15 In an experiment, the resistance of a material is plotted as a function of temperature (in some range). As shown in the figure, it is a straight line.



One may conclude that :

(1) $R(T) = R_0 e^{T^2/T_0^2}$

(2) $R(T) = \frac{R_0}{T^2}$

(3) $R(T) = R_0 e^{-T^2/T_0^2}$

(4) $R(T) = R_0 e^{-T_0^2/T^2}$

Ans. **[4]**

Sol. $y = -mx + c$

$\ln(R) = -\frac{m}{T^2} + c$

If $R = R_0 e^{\frac{-T_0^2}{T^2}}$

$\ln R = -\frac{T_0^2}{T^2} + \ln(R_0)$

satisfies the equation

Q.16 A transformer consisting of 300 turns in the primary and 150 turns in the secondary gives output power of 2.2 kW. If the current in the secondary coil is 10 A, then the input voltage and current in the primary coil are ;

(1) 440 V and 20 A

(2) 440 V and 5 A

(3) 220 V and 20 A

(4) 220 V and 10 A

Ans. **[2]**

Sol. $n_p = 300,\ n_s = 150$

$$\frac{i_s}{i_p} = \frac{n_p}{n_s}$$

$$\Rightarrow i_p = i_s \frac{n_s}{n_p} = 5A$$

$$P_s = V_s\, i_s \ \Rightarrow V_s = \frac{2.2\times10^3}{10} = 220$$

$$V_P = V_s \frac{n_P}{n_s} = 220 \times \frac{300}{150}$$

$= 440V$

Q.17 In a photoelectric effect experiment the threshold wavelength of light is 380 nm. If the wavelength of incident light is 260 nm, the maximum kinetic energy of emitted electrons will be :

Given $E\ (\text{in eV}) = \dfrac{1237}{\lambda(\text{in nm})}$

(1) 3.0 eV (2) 1.5 eV (3) 4.5 eV (4) 15.1 eV

Ans. **[2]**

Sol. $\phi_0 = \dfrac{1237}{380}$, $E = \dfrac{1237}{260}$ of photon

K·E of electron $kE = E - \phi_0 = 1.5$ eV

Q.18 The ratio of surface tensions of mercury and water is given to be 7.5 while the ratio of their densities is 13.6. Their contact angles, with glass, are close to 135° and 0°, respectively. It is observed that mercury gets depressed by an amount h in a capillary tube of radius r_1, while water rises by the same amount h in a capillary tube of radius r_2. The ratio (r_1/r_2), is then close to :

(1) 2/3 (2) 4/5 (3) 2/5 (4) 3/5

Ans. **[3]**

Sol. $h_{Hg} = h_{water}$

$$h = \frac{2T\cos\theta}{R\rho g}$$

$$\frac{R_{Hg}}{R_w} = \frac{2}{5} = 0.4$$

Q.19 A proton, an electron, and a helium nucleus, have the same energy. They are in circular orbits in a plane due to magnetic field perpendicular to the plane. Let r_p, r_e and r_{He} be their respective radii, then,

(1) $r_e < r_p < r_{He}$ (2) $r_e > r_p = r_{He}$ (3) $r_e < r_p = r_{He}$ (4) $r_e > r_p > r_{He}$

Ans. **[3]**

Sol. $r = \dfrac{\sqrt{2mE}}{Bq}$ $E = \text{same}$

$$r \propto \frac{\sqrt{m}}{q}$$

proton $\dfrac{\sqrt{m_p}}{q_p} = \dfrac{\sqrt{m_\alpha}}{q_\alpha}$, He^{+2}

$\therefore r_p = r_{He}$

For electron $\frac{\sqrt{m_e}}{q_e} < \frac{\sqrt{m_p}}{q_p}$ proton

$\therefore\ r_e < r_p = r_{He}$

Q.20 A particle of mass m is moving along a trajectory given by

$x = x_0 + a\cos\omega_1 t$

$y = y_0 + b\sin\omega_2 t$

The torque, acting on the particle about the origin , at t = 0 is :

(1) $-m(x_0 b\omega_2^2 - y_0 a\omega_1^2)\hat{k}$ (2) Zero

(3) $+my_0 a\omega_1^2\hat{k}$ (4) $m(-x_0 b + y_0 a)\omega_1^2\hat{k}$

Ans. **[3]**

Sol. $x = x_0 + a\cos\omega_1 t$

$y = y_0 + b\sin\omega_2 t$

$\vec{r} = x\hat{i} + y\hat{j}$

acceleration $\vec{a} = \frac{d^2\vec{r}}{dt^2}$

$\vec{\tau} = \vec{r}\times\vec{F}$

$= (\vec{r}\times\vec{a})\,m$

$= (my_0 a\omega_1^2)\hat{k}$

Q.21 The value of acceleration due to gravity at Earth's surface is 9.8 ms^{-2}. The altitude above its surface at which the acceleration due to gravity decreases to 4.9 ms^{-2}, is close to : (Radius of earth = 6.4×10^6 m)

(1) 6.4×10^6 m (2) 2.6×10^6 m (3) 1.6×10^6 m (4) 9.0×10^6 m

Ans. **[2]**

Sol. $g_h = \frac{g}{\left(1+\frac{h}{R}\right)^2}$, $g_h = \frac{g}{2}$

$\left(1+\frac{h}{R}\right)^2 = 2$

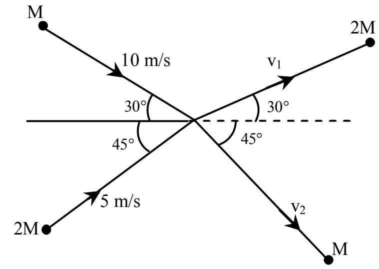
$1+\frac{h}{R} = \sqrt{2}$

$h = R(\sqrt{2}-1)$

$= (1.4-1)\times 64\times10^5$ m

$= 2.6\times10^6$ m

Q.22 Two particles, of masses M and 2M, moving, as shown, with speeds of 10 m/s and 5 m/s, collide elastically at the origin. After the collision, they move along the indicated directions with speeds v_1 and v_2, respectively. The values of v_1 and v_2 are nearly :



(1) 3.2 m/s and 12.6 m/s (2) 3.2 m/s and 6.3 m/s

(3) 6.5 m/s and 6.3 m/s (4) 6.5 m/s and 3.2 m/s

Ans. **[3]**

Sol. using momentum conservation in x direction

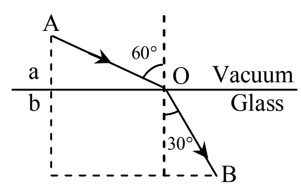
$m \times 10 \cos 30° + 2 \text{ m} \cos 45° = mv_2 \cos 45° + 2m\, v_1 \cos 30°$

in y direction

$2m\,(5) \sin 45° - m \times 10 \sin 30° = 2m\, v_1 \sin 30° - mv_2 \sin 45°$

solving equation $v_1 = 6.5$ m/s , $v_2 = 6.3$ m/s

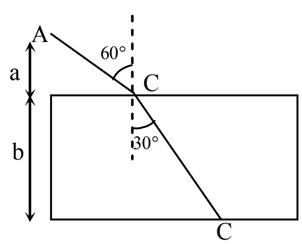
Q.23 A ray of light AO in vacuum is incident on a glass slab at angle 60° and refracted at angle 30° along OB as shown in the figure. The optical path length of light ray from A to B is :



(1) 2a + 2b (2) $\frac{2\sqrt{3}}{a} + 2b$ (3) $2a + \frac{2b}{3}$ (4) $2a + \frac{2b}{\sqrt{3}}$

Ans. **[1]**

Sol.

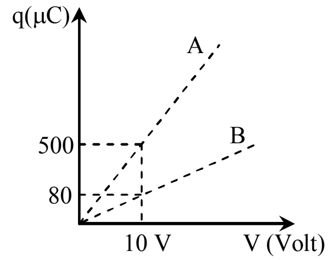


$AC = \frac{a}{\cos 60°}$, $BC = \frac{b}{\cos 30°}$, $\mu = \frac{\sin 60°}{\sin 30°}$

path = AC + μBC

= 2a + 2b

Q.24 Figure shows charge (q) versus voltage (V) graph for series and parallel combination of two given capacitors. The capacitance are :



(1) 50 μF and 30 μF (2) 40 μF and 10 μF (3) 20 μF and 30 μF (4) 60 μF and 40 μF

Ans. **[2]**

Sol. In series $\dfrac{C_1C_2}{C_1+C_2} = \dfrac{q}{V} = \dfrac{80}{10} = 8 \times 10^{-6}$

In parallel $C_1 + C_2 = \dfrac{q}{V} = \dfrac{500}{10} = 50 \times 10^{-6}$

$C_1C_2 = 400 \times 10^{-6}$

$C_1 + C_2 = 50 \times 10^{-6}$

$C_1 = 10\ \mu F,\ C_2 = 40\mu F$

Q.25 A ball is thrown upward with an initial velocity V_0 from the surface of the earth. The motion of the ball is affected by a drag force equal to $m\gamma v^2$ (where m is mass of the ball, v is its instantaneous velocity and γ is a constant). Time taken by the ball to rise to its zenith is :

(1) $\dfrac{1}{\sqrt{\gamma g}}\tan^{-1}\left(\sqrt{\dfrac{\gamma}{g}}V_0\right)$

(2) $\dfrac{1}{\sqrt{2\gamma g}}\tan^{-1}\left(\sqrt{\dfrac{2\gamma}{g}}V_0\right)$

(3) $\dfrac{1}{\sqrt{\gamma g}}\sin^{-1}\left(\sqrt{\dfrac{\gamma}{g}}V_0\right)$

(4) $\dfrac{1}{\sqrt{\gamma g}}\ln\left(1+\sqrt{\dfrac{\gamma}{g}}V_0\right)$

Ans. **[1]**

Sol. $a = -(g + \rho v^2) = \dfrac{dv}{dt}$

$\int_{V_0}^{V}\dfrac{dv}{g+\rho v^2} = -\int_0^t dt$

By integrating

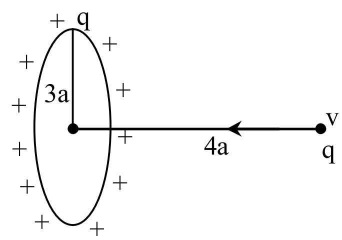
$t = \dfrac{1}{\sqrt{g\gamma}}\ \tan^{-1}\left[\sqrt{\dfrac{\gamma}{g}}V_0\right]$

Q.26 A uniformly charged ring of radius 3a and total charge q is placed in xy-plane centred at origin. A point charge q is moving towards the ring along the z-axis and has speed v at z = 4a. The minimum value of v such that it crosses the origin is :

(1) $\sqrt{\frac{2}{m}}\left(\frac{1}{5}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$ (2) $\sqrt{\frac{2}{m}}\left(\frac{2}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$ (3) $\sqrt{\frac{2}{m}}\left(\frac{1}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$ (4) $\sqrt{\frac{2}{m}}\left(\frac{4}{15}\frac{q^2}{4\pi\varepsilon_0 a}\right)^{1/2}$

Ans. **[2]**

Sol.



$$\frac{1}{2}mv^2 = \Delta PE$$

$$= \frac{2kq^2}{15a}$$

$$v = \sqrt{\frac{4}{15m}\frac{kq^2}{a}}$$

Q.27 Two coaxial discs, having moments of inertia I_1 and $\frac{I_1}{2}$, are rotating with respective angular velocities ω_1 and $\frac{\omega_1}{2}$, about their common axis. They are brought in contact with each other and thereafter they rotate with a common angular velocity. If E_f and E_i are the final and initial total energies, then $(E_f - E_i)$ is :

(1) $\frac{I_1\omega_1^2}{6}$ (2) $\frac{3}{8}I_1\omega_1^2$ (3) $-\frac{I_1\omega_1^2}{12}$ (4) $-\frac{I_1\omega_1^2}{24}$

Ans. **[4]**

Sol. conservation of angular momentum

$L_i = L_F$

and kinetic energy = $\frac{1}{2}I\omega^2$

put the value KE = $-\frac{I_1\omega_1^2}{24}$

Q.28 n moles of an ideal gas with constant volume heat capacity C_V undergo an isobaric expansion by certain volume. The ratio of the work done in the process, to the heat supplied is :

(1) $\frac{nR}{C_V + nR}$ (2) $\frac{nR}{C_V - nR}$ (3) $\frac{4nR}{C_V + nR}$ (4) $\frac{4nR}{C_V - nR}$

Ans. **[1]**

Sol. In isobaric process w = nRdT

$$w = Q - \Delta U$$

$$Q = nC_p dT$$

$$\frac{w}{Q} = \frac{nRdT}{nC_p dT} = \frac{R}{C_p} = \frac{R}{C_V + R}$$

$$= \frac{nR}{nC_V + nR}$$

$$= \frac{nR}{C_V + nR}$$

Q.29 Two radioactive materials A and B have decay constants 10 λ and λ, respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of A to that of B will be 1/e after a time

(1) $\frac{1}{10\lambda}$ (2) $\frac{11}{10\lambda}$ (3) $\frac{1}{9\lambda}$ (4) $\frac{1}{11\lambda}$

Ans. **[3]**

Sol. $\lambda_1 = 10\lambda$, $\lambda_2 = \lambda$

$$\frac{N_1}{N_2} = \frac{e^{-10\lambda t}}{e^{-\lambda t}} = e^{-9\lambda t} = e^{-1}$$

$$t = \frac{1}{9\lambda}$$

Q.30 The displacement of a damped harmonic oscillator is given by

$x(t) = e^{-0.1t} \cos(10\pi t + \varphi)$. Here t is in seconds.

The time taken for its amplitude of vibration to drop to half of its initial value is close to :

(1) 4 s (2) 13 s (3) 7 s (4) 27 s

Ans. **[3]**

Sol. $\frac{A_0}{2} = A_0 e^{-0.1t}$

$t = 10 \ln(2)$

$= 7$ sec