FINAL JEE–MAIN EXAMINATION – APRIL, 2024

(Held On Monday 08th April, 2024) **TIME : 9 : 00 AM to 12 : 00 NOON**

PHYSICS — TEST PAPER WITH SOLUTION

SECTION-A

31. Three bodies A, B and C have equal kinetic energies and their masses are 400 g, 1.2 kg and 1.6 kg respectively. The ratio of their linear momenta is :

(1) $1:\sqrt{3}:2$ (2) $1:\sqrt{3}:\sqrt{2}$

(3) $\sqrt{2}:\sqrt{3}:1$ (4) $\sqrt{3}:\sqrt{2}:1$

Ans. (1)

Sol. $KE = \frac{P^2}{2m}$

$P \propto \sqrt{m}$

Hence, $P_A : P_B : P_C$

$= \sqrt{400}:\sqrt{1200}:\sqrt{1600} = 1:\sqrt{3}:2$

32. Average force exerted on a non-reflecting surface at normal incidence is 2.4×10^{-4}N. If 360 W/cm^2 is the light energy flux during span of 1 hour 30 minutes. Then the area of the surface is:

(1) 0.2 m^2 (2) 0.02 m^2

(3) 20 m^2 (4) 0.1 m^2

Ans. (2)

Sol. Pressure $= \frac{I}{C} = \frac{F}{A}$

$\Rightarrow \frac{360}{10^{-4} \times 3 \times 10^8} = \frac{2.4 \times 10^{-4}}{A}$

$\Rightarrow A = 2 \times 10^{-2}\ m^2 = 0.02\ m^2$

33. A proton and an electron are associated with same de-Broglie wavelength. The ratio of their kinetic energies is:

(Assume h = 6.63×10^{-34} J s, $m_e = 9.0 \times 10^{-31}$ kg and m_p = 1836 times m_e)

(1) 1 : 1836 (2) $1 : \frac{1}{1836}$

(3) $1 : \frac{1}{\sqrt{1836}}$ (4) $1 : \sqrt{1836}$

Ans. (1)

Sol. λ is same for both

$P = \frac{h}{\lambda}$ same for both

$P = \sqrt{2mK}$

Hence,

$K \propto \frac{1}{m}$

$\Rightarrow \frac{KE_p}{KE_e} = \frac{m_e}{m_p} = \frac{1}{1836}$

34. A mixture of one mole of monoatomic gas and one mole of a diatomic gas (rigid) are kept at room temperature (27°C). The ratio of specific heat of gases at constant volume respectively is:

(1) $\frac{7}{5}$ (2) $\frac{3}{2}$

(3) $\frac{3}{5}$ (4) $\frac{5}{3}$

Ans. (3)

Sol. $\frac{(C_v)_{mono}}{(C_v)_{dia}} = \frac{\frac{3}{2}R}{\frac{5}{2}R} = \frac{3}{5}$

35. In an expression $a \times 10^b$:

(1) a is order of magnitude for $b \le 5$

(2) b is order of magnitude for $a \le 5$

(3) b is order of magnitude for $5 < a \le 10$

(4) b is order of magnitude for $a \ge 5$

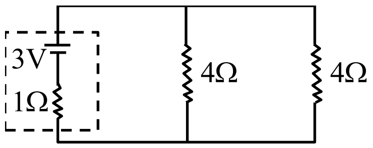
Ans. (2)

Sol. $a \times 10^b$

if $a \le 5$ order is b

$a > 5$ order is b + 1

36. In the given circuit, the terminal potential difference of the cell is :

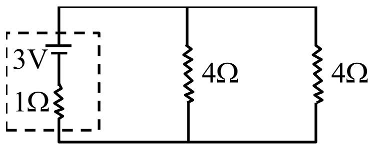


(1) 2 V (2) 4 V

(3) 1.5 V (4) 3 V

Ans. **(1)**

Sol.



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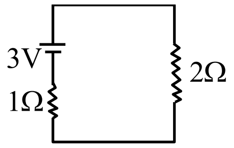


$i = \frac{3}{1+2} = 1A$

$v = E - ir$

$= 3 - 1 \times 1 = 2V$

37. Binding energy of a certain nucleus is 18×10^8 J. How much is the difference between total mass of all the nucleons and nuclear mass of the given nucleus:

(1) 0.2 μg (2) 20 μg

(3) 2 μg (4) 10 μg

Ans. **(2)**

Sol. $\Delta mc^2 = 18 \times 10^8$

$\Delta m \times 9 \times 10^{16} = 18 \times 10^8$

$\Delta m = 2 \times 10^{-8}$ kg = 20 μg

38. Paramagnetic substances:

A. align themselves along the directions of external magnetic field.

B. attract strongly towards external magnetic field.

C. has susceptibility little more than zero.

D. move from a region of strong magnetic field to weak magnetic field.

Choose the **most appropriate** answer from the options given below:

(1) A, B, C, D (2) B, D Only

(3) A, B, C Only (4) A, C Only

Ans. **(4)**

Sol. A, C only

39. A clock has 75 cm, 60 cm long second hand and minute hand respectively. In 30 minutes duration the tip of second hand will travel x distance more than the tip of minute hand. The value of x in meter is nearly (Take π = 3.14) :

(1) 139.4 (2) 140.5

(3) 220.0 (4) 118.9

Ans. **(1)**

Sol. $x_{min} = \pi \times r_{min}$

$= \pi \times \frac{60}{100}$ m.

$x_{second} = 30 \times 2\pi \times r_{second}$

$= 30 \times 2\pi \times \frac{75}{100}$

$x = x_{second} - x_{min}$

= 139.4 m

40. Young's modulus is determined by the equation given by $Y = 49000 \frac{m}{\ell} \frac{dyne}{cm^2}$ where M is the mass and ℓ is the extension of wire used in the experiment. Now error in Young modules(Y) is estimated by taking data from M-ℓ plot in graph paper. The smallest scale divisions are 5 g and 0.02 cm along load axis and extension axis respectively. If the value of M and ℓ are 500 g and 2 cm respectively then percentage error of Y is :

(1) 0.2 % (2) 0.02 %

(3) 2 % (4) 0.5 %

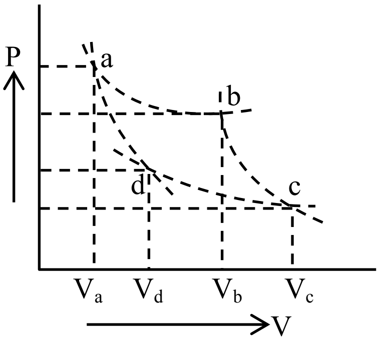
Ans. **(3)**

Sol. $\frac{\Delta Y}{Y} = \frac{\Delta m}{m} + \frac{\Delta \ell}{\ell}$

$= \frac{5}{500} + \frac{0.02}{2} = 0.01 + 0.01$

$\frac{\Delta Y}{Y} = 0.02 \Rightarrow \% \frac{\Delta Y}{Y} = 2\%$

41. Two different adiabatic paths for the same gas intersect two isothermal curves as shown in P-V diagram. The relation between the ratio $\frac{V_a}{V_d}$ and the ratio $\frac{V_b}{V_c}$ is:



(1) $\frac{V_a}{V_d} = \left(\frac{V_b}{V_c}\right)^{-1}$ (2) $\frac{V_a}{V_d} \neq \frac{V_b}{V_c}$

(3) $\frac{V_a}{V_d} = \frac{V_b}{V_c}$ (4) $\frac{V_a}{V_d} = \left(\frac{V_b}{V_c}\right)^2$

Ans. **(3)**

Sol. For adiabatic process

$TV^{\gamma-1} = \text{constant}$

$T_a \cdot V_a^{\gamma-1} = T_d \cdot V_d^{\gamma-1}$

$\left(\frac{V_a}{V_d}\right)^{\gamma-1} = \frac{T_d}{T_a}$

$T_b \cdot V_b^{\gamma-1} = T_c \cdot V_c^{\gamma-1}$

$\left(\frac{V_b}{V_c}\right)^{\gamma-1} = \frac{T_c}{T_b}$

$\frac{V_a}{V_d} = \frac{V_b}{V_c} \quad \left(\begin{matrix} \because T_d = T_c \\ T_a = T_b \end{matrix}\right)$

42. Two planets A and B having masses m_1 and m_2 move around the sun in circular orbits of r_1 and r_2 radii respectively. If angular momentum of A is L and that of B is 3L, the ratio of time period $\left(\frac{T_A}{T_B}\right)$ is:

(1) $\left(\frac{r_2}{r_1}\right)^{\frac{3}{2}}$ (2) $\left(\frac{r_1}{r_2}\right)^3$

(3) $\frac{1}{27}\left(\frac{m_2}{m_1}\right)^3$ (4) $27\left(\frac{m_1}{m_2}\right)^3$

Ans. **(3)**

Sol. $\frac{\pi r_1^2}{T_A} = \frac{L}{2m_1}$ .... (1)

$\frac{\pi r_2^2}{T_B} = \frac{3L}{2m_2}$ .... (2)

$\Rightarrow \frac{T_A}{T_B} = 3.\frac{m_1}{m_2}.\left(\frac{r_1}{r_2}\right)^2$

$\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_1}{r_2}\right)^3 \Rightarrow \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{T_A}{T_B}\right)^{\frac{4}{3}}$

$\Rightarrow \frac{1}{27}.\left(\frac{m_2}{m_1}\right)^3 = \left(\frac{T_A}{T_B}\right)$

43. A LCR circuit is at resonance for a capacitor C, inductance L and resistance R. Now the value of resistance is halved keeping all other parameters same. The current amplitude at resonance will be now:

(1) Zero (2) double

(3) same (4) halved

Ans. **(2)**

Sol. In resonance Z = R

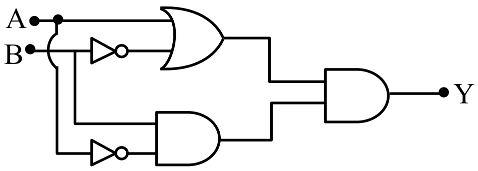
$I = \frac{V}{R}$

$R \rightarrow$ halved

$\Rightarrow I \rightarrow 2I$

I becomes doubled.

44. The output Y of following circuit for given inputs is :



(1) A•B(A + B) (2) A • B

(3) 0 (4) $\bar{A}$•B

Ans. (3)

Sol. By truth table

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	0

45. Two charged conducting spheres of radii a and b are connected to each other by a conducting wire. The ratio of charges of the two spheres respectively is:

(1) $\sqrt{ab}$ (2) ab

(3) $\frac{a}{b}$ (4) $\frac{b}{a}$

Ans. (3)

Sol. Potential at surface will be same

$$\frac{Kq_1}{a} = \frac{Kq_2}{b}$$

$$\frac{q_1}{q_2} = \frac{a}{b}$$

46. Correct Bernoulli's equation is (symbols have their usual meaning) :

(1) $P + mgh + \frac{1}{2}mv^2 = \text{constant}$

(2) $P + \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$

(3) $P + \rho gh + \rho v^2 = \text{constant}$

(4) $P + \frac{1}{2}\rho gh + \frac{1}{2}\rho v^2 = \text{constant}$

Ans. (2)

Sol. $P + \rho gh + \frac{1}{2}\rho V^2 = \text{constant}$

47. A player caught a cricket ball of mass 150 g moving at a speed of 20 m/s. If the catching process is completed in 0.1 s, the magnitude of force exerted by the ball on the hand of the player is:

(1) 150 N (2) 3 N

(3) 30 N (4) 300 N

Ans. (3)

Sol. $F = \frac{\Delta P}{\Delta t} = \frac{mv - 0}{0.1}$

$$= \frac{150 \times 10^{-3} \times 20}{0.1} = 30\,N$$

48. A stationary particle breaks into two parts of masses m_A and m_B which move with velocities v_A and v_B respectively. The ratio of their kinetic energies ($K_B : K_A$) is :

(1) $v_B : v_A$ (2) $m_B : m_A$

(3) $m_B v_B : m_A v_A$ (4) 1 : 1

Ans. (1)

Sol. Initial momentum is zero.

Hence $|P_A| = |P_B|$

$\Rightarrow m_A v_B = m_B V_B$

$$\frac{(KE)_A}{(KE)_B} = \frac{\frac{1}{2}m_A v_A^2}{\frac{1}{2}m_B v_B^2} = \frac{v_A}{v_B}$$

$$\frac{(KE)_B}{(KE)_A} = \frac{v_B}{v_A}$$

49. Critical angle of incidence for a pair of optical media is 45°. The refractive indices of first and second media are in the ratio:

(1) $\sqrt{2}:1$ (2) 1 : 2

(3) $1:\sqrt{2}$ (4) 2 : 1

Ans. (1)

Sol. $\sin\theta_c = \frac{\mu_R}{\mu_d} = \frac{\mu_2}{\mu_1}$

$\sin 45° = \frac{\mu_2}{\mu_1}$

$\Rightarrow \frac{1}{\sqrt{2}} = \frac{\mu_2}{\mu_1}$

$\Rightarrow \frac{\mu_1}{\mu_2} = \frac{\sqrt{2}}{1}$

50. The diameter of a sphere is measured using a vernier caliper whose 9 divisions of main scale are equal to 10 divisions of vernier scale. The shortest division on the main scale is equal to 1 mm. The main scale reading is 2 cm and second division of vernier scale coincides with a division on main scale. If mass of the sphere is 8.635 g, the density of the sphere is:

(1) 2.5 g/cm^3 (2) 1.7 g/cm^3

(3) 2.2 g/cm^3 (4) 2.0 g/cm^3

Ans. **(4)**

Sol. Given 9MSD = 10VSD

mass = 8.635 g

LC = 1 MSD – 1 VSD

$LC = 1\text{ MSD} - \frac{9}{10}\text{MSD}$

$LC = \frac{1}{10}\text{MSD}$

LC = 0.01 cm

Reading of diameter = MSR + LC × VSR

= 2 cm + (0.01) × (2)

= 2.02 cm

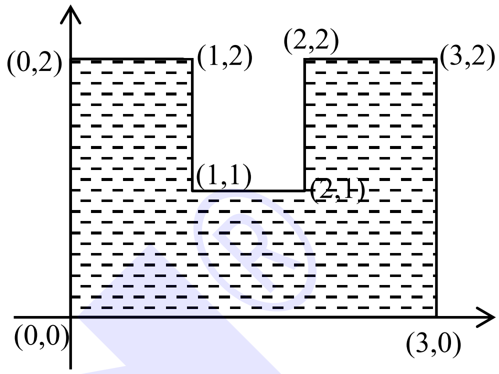
$\text{Volume of sphere} = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3 = \frac{4}{3}\pi\left(\frac{2.02}{2}\right)^3$

$= 4.32\text{ cm}^3$

$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{8.635}{4.32} = 1.998 \sim 2.00\text{g}$

SECTION-B

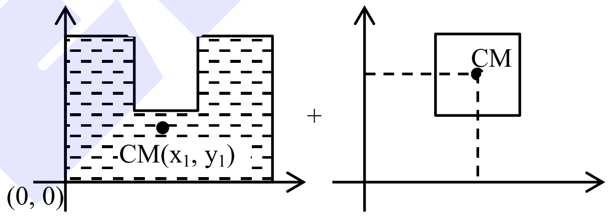
51. A uniform thin metal plate of mass 10 kg with dimensions is shown. The ratio of x and y coordinates of center of mass of plate in $\frac{n}{9}$. The value of n is_______.



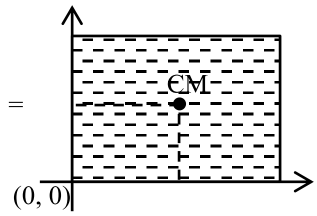
Ans. **(15)**

Sol. $m_1 = \sigma \times 5 = 10$ Kg

$m_1 = \sigma \times 5 = 10\text{Kg}$ $m_2 = \sigma \times 1 = 2\text{Kg}$



$m_3 = \sigma \times 6 = 12\text{Kg}$



$\Rightarrow m_1x_1 + m_2x_2 = m_3x_3$

$10x_1 + 2(1.5) = 12(1.5) \Rightarrow x_1 = 1.5$ cm

$\Rightarrow m_1y_1 + m_2y_2 = m_3y_3$

$10y_1 + 2(1.5) = 12 \times 1 \Rightarrow y_1 = 0.9$ cm

$\frac{x_1}{y_1} = \frac{1.5}{0.9} = \frac{15}{9}$

n = 15

52. An electron with kinetic energy 5 eV enters a region of uniform magnetic field of 3 μT perpendicular to its direction. An electric field E is applied perpendicular to the direction of velocity and magnetic field. The value of E, so that electron moves along the same path, is_______ NC^{-1}.

(Given, mass of electron = 9×10^{-31} kg, electric charge = 1.6×10^{-19}C)

Ans. **(4)**

Sol. For the given condition of moving undeflected, net force should be zero.

$qE = qVB$

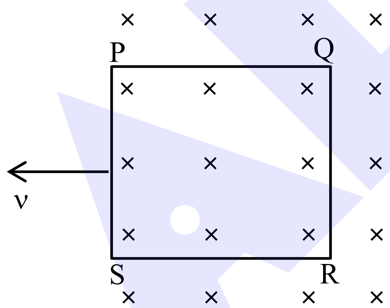
$E = VB$

$$= \sqrt{\frac{2\times KE}{m}} \times B$$

$$= \sqrt{\frac{2\times5\times1.6\times10^{-19}}{9\times10^{-31}}} \times 3\times10^{-6}$$

$= 4$ N/C

53. A square loop PQRS having 10 turns, area 3.6×10^{-3} m^2 and resistance 100 Ω is slowly and uniformly being pulled out of a uniform magnetic field of magnitude B = 0.5 T as shown. Work done in pulling the loop out of the field in 1.0 s is _________ $\times 10^{-6}$ J.



Ans. **(3)**

Sol. $\in = NB\ell v$

$$i = \frac{\in}{R} = \frac{NB\ell v}{R}$$

$$F = N(i\ell B) = \frac{N^2B^2\ell^2 v}{R}$$

$$W = F\times\ell = \frac{N^2B^2\ell^3}{R}\left(\frac{\ell}{t}\right)$$

$A = \ell^2$

$$W = \frac{(10\times10)(0.5)^2\times(3.6\times10^{-3})^2}{100\times1}$$

$W = 3.24 \times 10^{-6}$ J

54. Resistance of a wire at 0 °C, 100 °C and t °C is found to be 10 Ω, 10.2 Ω and 10.95 Ω respectively. The temperature t in Kelvin scale is______.

Ans. **(748)**

Sol. $R = R_0(1 + \alpha\Delta T)$

$$\frac{\Delta R}{R_0} = \alpha\Delta T$$

Case-I

0 °C → 100 °C

$$\frac{10.2-10}{10} = \alpha(100-0) \qquad \text{..... (1)}$$

Case-II

0 °C → t °C

$$\frac{10.95-10}{10} = \alpha(t-0) \qquad \text{...... (2)}$$

$$\Rightarrow \frac{t}{100} = \frac{0.95}{0.2} = 475^\circ C$$

$t = 475 + 273 = 748$ K

55. An electric field, $\vec{E} = \frac{2\hat{i}+6\hat{j}+8\hat{k}}{\sqrt{6}}$ passes through the surface of 4 m^2 area having unit vector $\hat{n} = \left(\frac{2\hat{i}+\hat{j}+\hat{k}}{\sqrt{6}}\right)$. The electric flux for that surface is _________ V m.

Ans. **(12)**

Sol. $\phi = \vec{E}\cdot\vec{A}$

$$= \left(\frac{2\hat{i}+6\hat{j}+8\hat{k}}{\sqrt{6}}\right)\cdot4\left(\frac{2\hat{i}+\hat{j}+\hat{k}}{\sqrt{6}}\right)$$

$$= \frac{4}{6}\times(4+6+8) = 12\,Vm$$

56. A liquid column of height 0.04 cm balances excess pressure of soap bubble of certain radius. If density of liquid is 8×10^3 kg m^{-3} and surface tension of soap solution is 0.28 Nm^{-1}, then diameter of the soap bubble is________cm.

(if $g = 10\ ms^{-2}$)

Ans. (7)

Sol. $\rho g h = \dfrac{4S}{R}$

$\Rightarrow R = \dfrac{4 \times 0.28}{8 \times 10^3 \times 10 \times 4 \times 10^{-4}}$

$\Rightarrow \dfrac{0.28}{8} m = \dfrac{28}{8} cm$

$\Rightarrow R = 3.5$ cm

Diameter = 7 cm

57. A closed and an open organ pipe have same lengths. If the ratio of frequencies of their seventh overtones is $\left(\dfrac{a-1}{a}\right)$ then the value of a is _____.

Ans. (16)

Sol. For closed organ pipe

$f_c = (2n+1)\dfrac{v}{4\ell} = \dfrac{15v}{4\ell}$

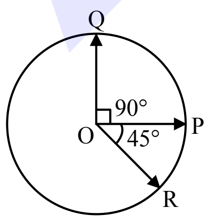
For open organ pipe

$f_o = (n+1)\dfrac{v}{2\ell} = \dfrac{8v}{2\ell}$

$\dfrac{f_c}{f_o} = \dfrac{15}{16} = \dfrac{a-1}{a}$

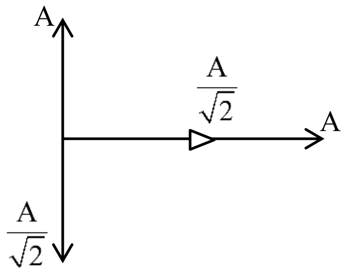
$\Rightarrow a = 16$

58. Three vectors $\overrightarrow{OP}, \overrightarrow{OQ}$ and $\overrightarrow{OR}$ each of magnitude A are acting as shown in figure. The resultant of the three vectors is $A\sqrt{x}$. The value of x is _____.



Ans. (3)

Sol.



$\vec{R} = \left(A + \dfrac{A}{\sqrt{2}}\right)\hat{i} + \left(A - \dfrac{A}{\sqrt{2}}\right)\hat{j}$

$|\vec{R}| = \sqrt{\left(A + \dfrac{A}{\sqrt{2}}\right)^2 + \left(A - \dfrac{A}{\sqrt{2}}\right)^2} = \sqrt{3}A$

59. A parallel beam of monochromatic light of wavelength 600 nm passes through single slit of 0.4 mm width. Angular divergence corresponding to second order minima would be _____$\times 10^{-3}$ rad.

Ans. (6)

Sol. $\sin\theta \simeq \theta \simeq \dfrac{2\lambda}{b}$

$= \dfrac{2 \times 600 \times 10^{-9}}{4 \times 10^{-4}} = 3 \times 10^{-3}$ rad

Total divergence = $(3 + 3) \times 10^{-3} = 6 \times 10^{-3}$ rad

60. In an alpha particle scattering experiment distance of closest approach for the α particle is 4.5×10^{-14} m. If target nucleus has atomic number 80, then maximum velocity of α-particle is _______$\times 10^5$ m/s approximately.

($\dfrac{1}{4\pi\epsilon_0} = 9 \times 10^9$ SI unit, mass of α particle = 6.72×10^{-27} kg)

Ans. (156)

Sol. $v = \sqrt{\dfrac{4KZe^2}{m r_{min}}}$

$= \sqrt{\dfrac{4 \times 9 \times 10^9 \times 80}{6.72 \times 10^{-27} \times 4.5 \times 10^{-14}}} \times 1.6 \times 10^{-19}$

$= 9.759 \times 10^{25} \times 1.6 \times 10^{-19}$

$= 156 \times 10^5$ m/s