FINAL JEE–MAIN EXAMINATION – APRIL, 2024

(Held On Saturday 06th April, 2024) **TIME : 9 : 00 AM to 12 : 00 NOON**

SECTION-A

31. To find the spring constant (k) of a spring experimentally, a student commits 2% positive error in the measurement of time and 1% negative error in measurement of mass. The percentage error in determining value of k is :

(1) 3% (2) 1%
(3) 4% (4) 5%

Ans. (4)

Sol. $T = 2\pi\sqrt{\frac{m}{k}}$

$T^2 \propto \frac{m}{k}$

$\frac{2\Delta T}{T}\% = \frac{\Delta m}{m}\% - \frac{\Delta k}{k}\%$

$\frac{\Delta k}{k}\% = \frac{\Delta m}{m}\% - \frac{2\Delta T}{T}\%$

$\frac{\Delta k}{k}\% = (-1)\% - 2(2)\% = |-5\%| = 5\%$

32. A bullet of mass 50 g is fired with a speed 100 m/s on a plywood and emerges with 40 m/s. The percentage loss of kinetic energy is :

(1) 32% (2) 44%
(3) 16% (4) 84%

Ans. (4)

Sol. $K_i = \frac{1}{2}m(100)^2$

$K_f = \frac{1}{2}m(40)^2$

$\%\text{loss} = \frac{|K_f - K_i|}{K_i} \times 100$

$= \frac{\left|\frac{1}{2}m(40)^2 - \frac{1}{2}m(100)^2\right|}{\frac{1}{2}m(100)^2} \times 100$

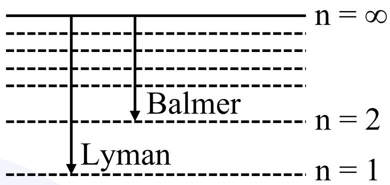
$= \frac{|1600 - 100\times 100|}{100} = 84\%$

33. The ratio of the shortest wavelength of Balmer series to the shortest wavelength of Lyman series for hydrogen atom is :

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

Ans. (1)

Sol



$\frac{1}{\lambda} = Rz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$\frac{\frac{1}{\lambda_L} = Rz^2\left(\frac{1}{1^2}\right)}{\frac{1}{\lambda_B} = Rz^2\left(\frac{1}{2^2}\right)}$

34. To project a body of mass m from earth's surface to infinity, the required kinetic energy is (assume, the radius of earth is R_E, g = acceleration due to gravity on the surface of earth) :

(1) $2mgR_E$ (2) mgR_E
(3) $\frac{1}{2}mgR_E$ (4) $4mgR_E$

Ans. (2)

Sol. $\frac{1}{2}mv_e^2 = \frac{GMm}{R_E}$

$g = \frac{GM}{R_E^2}$

$K = mgR_E$

35. Electromagnetic waves travel in a medium with speed of $1.5 \times 10^8\ ms^{-1}$. The relative permeability of the medium is 2.0. The relative permittivity will be :

(1) 5 (2) 1

(3) 4 (4) 2

Ans. (4)

Sol. $\frac{}{\varepsilon_0 \times \mu_0} \quad \frac{\frac{1}{v^2}}{\frac{1}{c^2}}$

$$\varepsilon_r \times \mu_r = \frac{c^2}{v^2}$$

$$\varepsilon_r \times 2 = \frac{(3\times10^8)^2}{(1.5\times10^8)^2}$$

$$\varepsilon_r \times 2 = 4$$

$$\varepsilon_r = 2$$

36. Which of the following phenomena does not explain by wave nature of light.

(A) reflection (B) diffraction

(C) photoelectric effect (D) interference

(E) polarization

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

(1) E only (2) C only

(3) B, D only (4) A, C only

Ans. (2)

Sol. (Theory)

Photoelectric effect prove particle nature of light.

37. While measuring diameter of wire using screw gauge the following readings were noted. Main scale reading is 1 mm and circular scale reading is equal to 42 divisions. Pitch of screw gauge is 1 mm and it has 100 divisions on circular scale. The diameter of the wire is $\frac{x}{50}$ mm . The value of x is :

(1) 142 (2) 71

(3) 42 (4) 21

Ans. (2)

Sol. MSR = 1mm, CSR = 42, pitch = 1 mm

$$LC = \frac{\text{pitch}}{\text{No. of CSD}} = \left(\frac{1}{100}\right) = 0.01\text{mm}$$

Diameter = MSR + LC × CSD

Diameter = 1 + (0.01) × 42 mm

Diameter = 1.42 mm = $\frac{x}{50}$

$\therefore$ x = 71

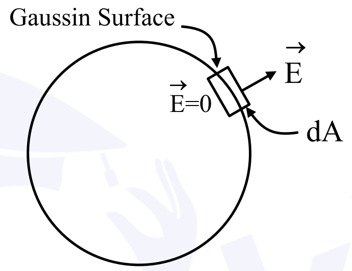
38. σ is the uniform surface charge density of a thin spherical shell of radius R. The electric field at any point on the surface of the spherical shell is :

(1) $\sigma/\epsilon_0 R$ (2) $\sigma/2\epsilon_0$

(3) σ/ϵ_0 (4) $\sigma/4\epsilon_0$

Ans. (3)

Sol.

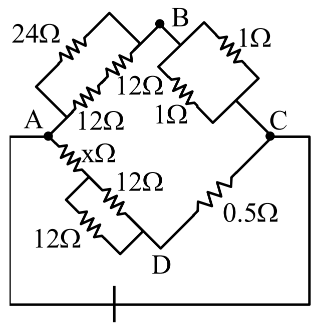


By Gauss law $\int \vec{E}\cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}$

$$EdA = \frac{\sigma \times dA}{\varepsilon_0}$$

$$E = \frac{\sigma}{\varepsilon_0}$$

39. The value of unknown resistance (x) for which the potential difference between B and D will be zero in the arrangement shown, is :

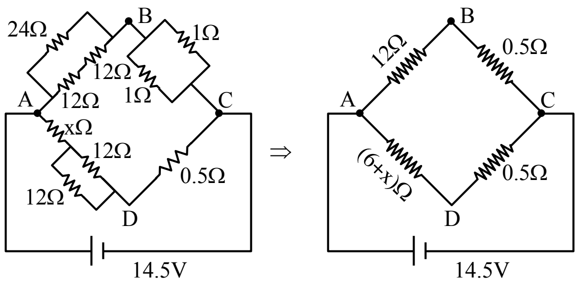


(1) 3 Ω (2) 9 Ω

(3) 6 Ω (4) 42 Ω

Ans. (3)

Sol.



In case of balanced Wheatstone Bridge

$$\frac{V_{AB}}{V_{AD}} = \frac{V_{BC}}{V_{CD}} \Rightarrow \frac{12}{6+x} = \frac{0.5}{0.5}$$

$x = 6\ \Omega$

40. The specific heat at constant pressure of a real gas obeying $PV^2 = RT$ equation is :

(1) $C_V + R$

(2) $\frac{R}{3} + C_V$

(3) R

(4) $C_V + \frac{R}{2V}$

Ans. **(4)**

Sol. $dQ = du + dW$

$CdT = C_V dT + PdV$ .....(1)

$\therefore\ PV^2 = RT$

P = constant

$P(2VdV) = RdT$

$$PdV = \frac{RdT}{2V}$$

Put in equation (1)

$$C = C_V + \frac{R}{2V}$$

41. Match **List I** with **List II**

	LIST I		LIST II
A.	Torque	I.	$[M^1L^1T^{-2}A^{-2}]$
B.	Magnetic field	II.	$[L^2A^1]$
C.	Magnetic moment	III.	$[M^1T^{-2}A^{-1}]$
D.	Permeability of free space	IV.	$[M^1L^2T^{-2}]$

Choose the **correct** answer from the options given below :

(1) A-I, B-III, C-II, D-IV

(2) A-IV, B-III, C-II, D-I

(3) A-III, B-I, C-II, D-IV

(4) A-IV, B-II, C-III, D-I

Ans. **(2)**

Sol. $[\vec{\tau}] = [\vec{r} \times \vec{F}] = [ML^2T^{-2}]$

$[F] = [qVB]$

$$\Rightarrow B = \left(\frac{F}{qV}\right) = \left[\frac{MLT^{-2}}{ATLT^{-1}}\right] = [MA^{-1}T^{-2}]$$

$[M] = [I \times A] = [AL^2]$

$$B = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

$$\Rightarrow [\mu] = \left[\frac{Br^2}{Idl}\right] = \left[\frac{MT^{-2}A^{-1} \times L^2}{AL}\right]$$

$$= [MLT^{-2}A^{-2}]$$

42. Given below are two statements :

Statement I : In an LCR series circuit, current is maximum at resonance.

Statement II : Current in a purely resistive circuit can never be less than that in a series LCR circuit when connected to same voltage source.

In the light of the above statements, choose the ***correct*** from the options given below :

(1) Statement I is true but Statement II is false

(2) Statement I is false but Statement II is true

(3) Both Statement I and Statement II are true

(4) Both Statement I and Statement II are false

Ans. **(3)**

Sol. **Statement-I**

$$I_m = \frac{V_m}{\sqrt{R^2 + (X_L - X_C)^2}}$$ at resonance $X_L = X_C$

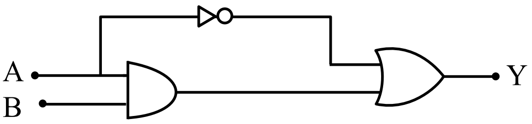
Thus, $I_m = \frac{V_m}{R}$

$\because$ Impendence is minimum therefore I is maximum at resonance.

Statement-II

$I = \left(\frac{V}{R}\right)$ in purely resistive circuit.

43. The correct truth table for the following logic circuit is :



Options :

(1)

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

(2)

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

(3)

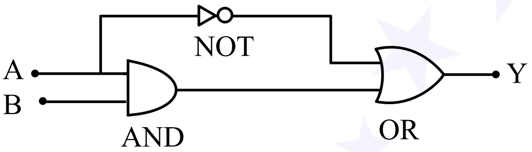
A	B	Y
0	0	1
0	1	1
1	0	0
1	1	0

(4)

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

Ans. **(2)**

Sol.



44. A sample contains mixture of helium and oxygen gas. The ratio of root mean square speed of helium and oxygen in the sample, is :

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

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

Ans. **(2)**

Sol. $V_{rms} = \sqrt{\frac{3RT}{M_w}}$

$$\Rightarrow \frac{V_{O_2}}{V_{He}} = \sqrt{\frac{M_{w,He}}{M_{w,O_2}}}$$

$$= \sqrt{\frac{4}{32}} = \frac{1}{2\sqrt{2}}$$

$$\frac{V_{He}}{V_{O_2}} = \frac{2\sqrt{2}}{1}$$

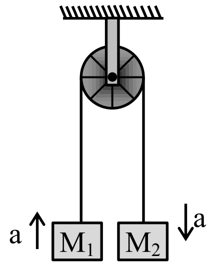
45. A light string passing over a smooth light pulley connects two blocks of masses m_1 and m_2 (where $m_2 > m_1$). If the acceleration of the system is $\frac{g}{\sqrt{2}}$, then the ratio of the masses $\frac{m_1}{m_2}$ is :

(1) $\frac{\sqrt{2}-1}{\sqrt{2}+1}$ (2) $\frac{1+\sqrt{5}}{\sqrt{5}-1}$

(3) $\frac{1+\sqrt{5}}{\sqrt{2}-1}$ (4) $\frac{\sqrt{3}+1}{\sqrt{2}-1}$

Ans. **(1)**

Sol. $a = \left(\frac{M_2 - M_1}{M_1 + M_2}\right)g$



$$\frac{g}{\sqrt{2}} = \left(\frac{M_2 - M_1}{M_1 + M_2}\right)g$$

$$(M_1 + M_2) = \sqrt{2}M_2 - \sqrt{2}M_1$$

$$\frac{M_1}{M_2} = \left(\frac{\sqrt{2}-1}{\sqrt{2}+1}\right)$$

46. Four particles A, B, C, D of mass $\frac{m}{2}$, m, 2m, 4m, have same momentum, respectively. The particle with maximum kinetic energy is :

(1) D (2) C

(3) A (4) B

Ans. **(3)**

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

Same momentum, so less mass means more KE.

So $\frac{m}{2}$ will have max. KE.

47. A train starting from rest first accelerates uniformly up to a speed of 80 km/h for time t, then it moves with a constant speed for time 3t. The average speed of the train for this duration of journey will be (in km/h) :

(1) 80 (2) 70

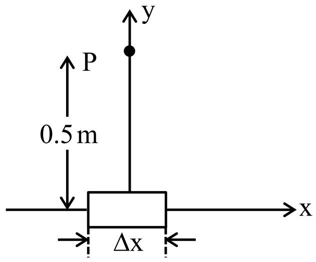
(3) 30 (4) 40

Ans. **(2)**

Sol. Average speed = $\dfrac{\text{total distance}}{\text{time taken}}$

$$= \frac{\frac{80\times t}{2} + 80\times 3t}{4t} = 70 \text{ km/hr.}$$

48. An element $\Delta l = \Delta x\hat{i}$ is placed at the origin and carries a large current I = 10A. The magnetic field on the y-axis at a distance of 0.5 m from the elements Δx of 1 cm length is :

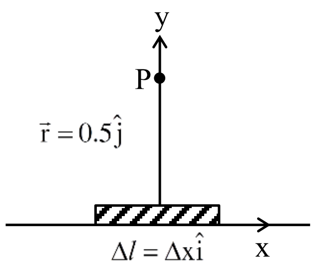


(1) 4×10^{-8}T (2) 8×10^{-8}T

(3) 12×10^{-8}T (4) 10×10^{-8}T

Ans. **(1)**

Sol.



$$\overrightarrow{dB} = \frac{\mu_0 I}{4\pi}\frac{(\vec{dl}\times\vec{r})}{r^3} \text{ (Tesla)}$$

$$= \frac{10^{-7}\times 10\times\left(\frac{1}{2}\times\frac{1}{100}\right)(+\hat{k})}{\left(\frac{1}{2}\right)^3} = 4\times10^{-8}\text{T }(+\hat{k})$$

49. A small ball of mass m and density ρ is dropped in a viscous liquid of density ρ_0. After sometime, the ball falls with constant velocity. The viscous force on the ball is :

(1) $mg\left(\frac{\rho_0}{\rho}-1\right)$ (2) $mg\left(1+\frac{\rho}{\rho_0}\right)$

(3) $mg(1-\rho\rho_0)$ (4) $mg\left(1-\frac{\rho_0}{\rho}\right)$

Ans. **(4)**

Sol. $mg - F_B - F_v = ma$

a = 0 for constant velocity

$mg - F_B = F_v$

$$F_v = mg - v\rho_0 g = mg - \frac{m}{\rho}\rho_0 g = mg\left(1-\frac{\rho_0}{\rho}\right)$$

50. In photoelectric experiment energy of 2.48 eV irradiates a photo sensitive material. The stopping potential was measured to be 0.5 V. Work function of the photo sensitive material is :

(1) 0.5 eV (2) 1.68 eV

(3) 2.48 eV (4) 1.98 eV

Ans. **(4)**

Sol. $eV_s = h\nu - \phi$

$0.5 \text{ V} = 2.48 - \phi$

work function $(\phi) = 2.48 \text{ V} - 0.5 \text{ V} = 1.98 \text{ V}$

SECTION-B

51. If the radius of earth is reduced to three-fourth of its present value without change in its mass then value of duration of the day of earth will be ________ hours 30 minutes.

Ans. **(13)**

Sol. By conservation of angular momentum

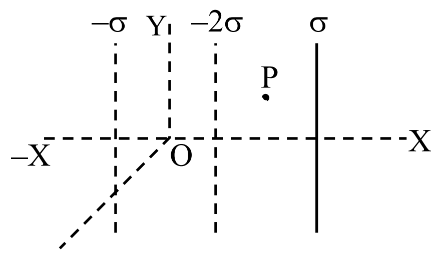
$I_1\omega_1 = I_2\omega_2$

$$\left(\frac{2}{5}MR^2\right)\frac{2\pi}{T} = \frac{2}{5}M\left(\frac{3}{4}R\right)^2\frac{2\pi}{T}$$

$$\frac{1}{T_1} = \frac{9}{16T_2}$$

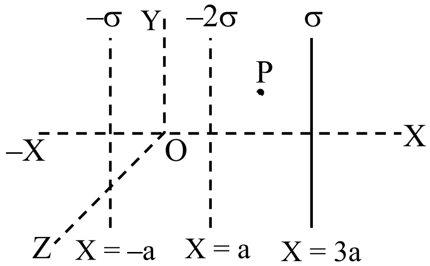
$$\frac{1}{T_2} = \frac{9}{16}\times T_1 = \frac{9}{16}\times 24\text{hr} = \frac{27}{2}\text{hr} = 13 \text{ hr } 30 \text{ mins.}$$

52. Three infinitely long charged thin sheets are placed as shown in figure. The magnitude of electric field at the point P is $\frac{x\sigma}{\epsilon_0}$. The value of x is ________ (all quantities are measured in SI units).



Ans. **(2)**

Sol.



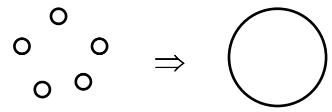
$$\vec{E}_P = \left(\frac{\sigma}{2\varepsilon_0} + \frac{2\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}\right)(-\hat{i})$$

$$= -\frac{2\sigma}{\varepsilon_0}\hat{i}$$

53. A big drop is formed by coalescing 1000 small droplets of water. The ratio of surface energy of 1000 droplets to that of energy of big drop is $\frac{10}{x}$. The value of x is _________.

Ans. **(1)**

Sol.



$$1000\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$$10r = R$$

$$R = 10r$$

$$\frac{\text{S.E. of 1000 drops}}{\text{S.E. of Big drop}} = \frac{1000(4\pi r^2)T}{4\pi R^2 T}$$

$$= \frac{1000\times r^2}{(10r)^2} = 10 = \frac{10}{x}$$

$$\therefore \quad x = 1$$

54. When a dc voltage of 100V is applied to an inductor, a dc current of 5A flows through it. When an ac voltage of 200V peak value is connected to inductor, its inductive reactance is found to be $20\sqrt{3}\,\Omega$. The power dissipated in the circuit is _________W.

Ans. **(250)**

Sol. For DC voltage

$$R = \frac{V}{I} = \frac{100}{5} = 20\,\Omega$$

for AC voltage

$$X_L = 20\sqrt{3}\,\Omega$$

$$R = 20\,\Omega$$

$$Z = \sqrt{X_L^2 + R^2} = \sqrt{3\times 400 + 400} = 40\,\Omega$$

Power = $i_{rms}^2 R$

$$= \left(\frac{V_{rms}}{Z}\right)^2 \times R = \left(\frac{\frac{200}{\sqrt{2}}}{40}\right)^2 \times 20 = 250\,W$$

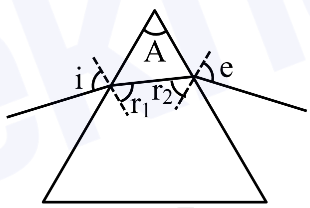
55. The refractive index of prism is $\mu = \sqrt{3}$ and the ratio of the angle of minimum deviation to the angle of prism is one. The value of angle of prism is _________°.

Ans. **(60)**

Sol. For δ_{min}

$$i = e$$

$$r_1 = r_2 = \frac{A}{2}$$



$$\frac{\delta_{min}}{A} = 1$$

$$\frac{2i - A}{A} = 1$$

$$2i = 2A$$

$$i = A$$

Snell's law

$$1 \times \sin i = \mu \sin r$$

$$\sin i = \mu \sin\left(\frac{A}{2}\right)$$

$$\sin A = \mu \sin\left(\frac{A}{2}\right)$$

$$2\sin\frac{A}{2}\cos\frac{A}{2} = \sqrt{3}\sin\left(\frac{A}{2}\right)$$

$$\cos\left(\frac{A}{2}\right) = \frac{\sqrt{3}}{2}$$

$$\therefore \frac{A}{2} = 30°$$

$$\therefore A = 60°$$

56. A wire of resistance R and radius r is stretched till its radius became r/2. If new resistance of the stretched wire is x R, then value of x is _________.

Ans. (16)

Sol. We know $R = \frac{\rho l}{A}$, $R \propto \frac{l}{r^2}$

As we starch the wire, its length will increase but its radius will decrease keeping the volume constant

$$V_i = V_f$$

$$\pi r^2 l = \pi \frac{r^2}{4} l_f$$

$$l_f = 4l$$

$$\frac{R_{new}}{R_{old}} = \left(\frac{4l}{\frac{r^2}{4}}\right)\frac{r^2}{l} = 16$$

$$R_{new} = 16R$$

$\therefore$ x = 16

57. Radius of a certain orbit of hydrogen atom is 8.48 Å. If energy of electron in this orbit is E/x, then x = _________.

(Given a_0 = 0.529Å, E = energy of electron in ground state)

Ans. (16)

Sol. We know

$$r = 0.529\frac{n^2}{Z} \Rightarrow \mathbf{8.48 = 0.529\frac{n^2}{1}}$$

$n^2 = 16 \Rightarrow n = 4$

We know

$$E \propto \frac{1}{n^2}$$

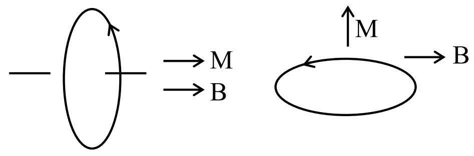
$$E_{n^{th}} = \frac{E}{16}$$

x = 16

58. A circular coil having 200 turns, 2.5×10^{-4} m^2 area and carrying 100 μA current is placed in a uniform magnetic field of 1 T. Initially the magnetic dipole moment $(\vec{M})$ was directed along $\vec{B}$. Amount of work, required to rotate the coil through 90° from its initial orientation such that $\vec{M}$ becomes perpendicular to $\vec{B}$, is _________ μJ.

Ans. (5)

Sol.



initial final

We know

$W_{ext} = \Delta U + \Delta KE$ $\quad (P.E. = -\vec{M}\cdot\vec{B})$

$= -\vec{M}\cdot\vec{B}_f + \vec{M}\cdot\vec{B}_i + 0$

$= -MB\cos 90 + MB\cos 0$

= MB

= NIAB

$= 200 \times 100 \times 10^{-6} \times \frac{5}{2} \times 10^{-4} \times 1 = 5\mu J$

59. A particle is doing simple harmonic motion of amplitude 0.06 m and time period 3.14 s. The maximum velocity of the particle is _______ cm/s.

Ans. (12)

Sol. We know

$v_{max} = \omega A$ at mean position

$= \frac{2\pi}{T}A = \frac{2\pi}{\pi} \times 0.06 = 0.12$ m/sec

v_{max} = 12 cm/sec

60. For three vectors $\vec{A} = (-x\hat{i} - 6\hat{j} - 2\hat{k})$, $\vec{B} = (-\hat{i} + 4\hat{j} + 3\hat{k})$ and $\vec{C} = (-8\hat{i} - \hat{j} + 3\hat{k})$, if $\vec{A}\cdot(\vec{B}\times\vec{C}) = 0$, them value of x is _________.

Ans. (4)

Sol. $$\vec{B}\times\vec{C} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -1 & 4 & 3 \\ -8 & -1 & 3 \end{vmatrix} = 15\hat{i} - 21\hat{j} + 33\hat{k}$$

$\vec{A}\cdot(\vec{B}\times\vec{C}) = (-x\hat{i} - 6\hat{j} - 2\hat{k})\cdot(15\hat{i} - 21\hat{j} + 33\hat{k})$

0 = –15x + 126 – 66

15x = 60

x = 4