JEE MAIN 2024 SESSION-2

Paper with Solution

PHYSICS | 05th April 2024 _ Shift-1

SECTION – A

31. An alternating voltage of amplitude $40V$ and frequency $4kHz$ is applied directly across the capacitor of $12\mu F$. The maximum displacement current between the plates of the capacitor is nearly.

(1) 12A (2) 13A (3) 10A (4) 8A

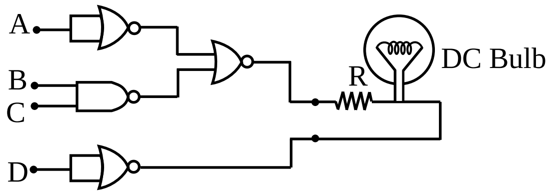
Sol. **1**

$i_d = i_c = \frac{V}{x_c} = v\omega c$

$i_d = 40 \times 2\pi \times 4 \times 10^3 \times 12 \times 10^{-6}$

$i_d \approx 12A$

32. Following gates section is connected in a complete suitable circuit.



For which of the following combination, bulb will glow (ON)

(1) A = 0, B = 0, C = 0, D = 1 (2) A = 1, B = 1, C = 1, D = 0

(3) A = 1, B = 0, C = 0, D = 0 (4) A = 0, B = 1, C = 1, D = 1

Sol. **3**

Bulb is only on when across the bulb, signals are opposite $\rightarrow$ 0, 1 or 1, 0

A $\rightarrow$ Signals are 0 and 0

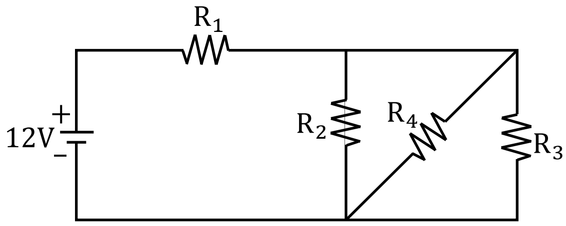
B $\rightarrow$ Signals are 1 and 1

C $\rightarrow$ Signals are 0 and 1

D $\rightarrow$ Signals are 0 and 0

So bulb is on is only option c

33. In the given figure $R_1 = 10\Omega, R_2 = 8\Omega, R_3 = 4\Omega$ and $R_4 = 8\Omega$. Battery is ideal with emf $12V$. Equivalent resistant of the circuit and current supplied by battery are respectively:



(1) 10.5Ω and 1.14A (2) 12Ω and 1A

(3) 10.5Ω and 1 A (4) 12Ω and 11.4A

Sol. **2**

$R_{eq} = 2 + 10 = 12\Omega$

and $i = \frac{12}{12} = 1A$

34. The angle between vector $\vec{Q}$ and the resultant of $\left(2\vec{Q}+2\vec{P}\right)$ and $\left(2\vec{Q}-2\vec{P}\right)$ is :

(1) $\tan^{-1}\left(2Q/P\right)$ (2) $\tan^{-1}\left(P/Q\right)$ (3) $0°$ (4) $\tan^{-1}\dfrac{\left(2\vec{Q}-2\vec{P}\right)}{2\vec{Q}+2\vec{P}}$

Sol. **3**

Resultant = $2\vec{Q}+2\vec{P}+2\vec{Q}-2\vec{P}=4\vec{Q}$

angle b/w $\vec{Q}$ and $4\vec{Q}$ is zero

35. If the collision frequency of hydrogen molecules in a closed chamber at 27°C is Z, then the collision frequency of the same system at 127°C is :

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

Sol. **4**

Collision frequency $\propto\sqrt{T}$

$\Rightarrow \frac{f_2}{f_1}=\sqrt{\frac{400}{300}} \Rightarrow f_2=\frac{2}{\sqrt{3}}f_1=\frac{2}{\sqrt{3}}Z$

36. An electron rotates in a circle around a nucleus having positive charge Ze. Correct relation between total energy (E) of electron to its potential energy (U) is :

(1) 2E = 3U (2) E = 2U (3) E = U (4) 2E = U

Sol. **4**

Total energy $E=\frac{-kze^2}{2r}$

Potential energy $u=\frac{-kze^2}{r}$

$\Rightarrow$ u = 2E

37. Given below are two statement :

Statement I : When a capillary tube is dipped into a liquid, the liquid neither rises nor falls in the capillary. The contact angle may be 0°.

Statement II : The contact angle between a solid and a liquid is a property of the material of the solid and liquid as well.

In the light of the above statement, choose the correct answer from the options given below.

(1) Both Statement I and Statement II are true
(2) Statement I is true and Statement II is false
(3) Statement I is false but Statement II is true
(4) Both Statement I and Statement II are false

Sol. **3**

Statement -1 is false because capillary rise is zero for angle of contact 90°

Statement-2 is true because angle of contact depend on both liquid and solid.

38. In hydrogen like system the ratio of coulombian force and gravitational force between an electron and a proton is in the order of:

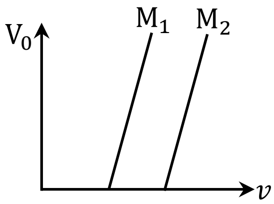
(1) 10^{39} (2) 10^{19} (3) 10^{29} (4) 10^{36}

Sol. **1**

$$\frac{\frac{k.e.e}{r^2}}{\frac{Gm_1m_2}{r^2}} = \frac{9\times10^9\times\left(1.6\times10^{-19}\right)^2}{6.67\times10^{-11}\times9.1\times10^{-31}\times1.67\times10^{-27}}$$

$= 2.27 \times 10^{39}$

39. Given below are two statements :



Statement I : Figure shows the variation of stopping potential with frequency (ν) for the two photosensitive materials M_1 and M_2. The slope gives value of $\frac{h}{e}$, where h is Planck's constant, e is the charge of electron.

Statement II : M_2 will emit photoelectrons of greater kinetic energy for the incident radiation having same frequency.

In the light of the above statements, choose the most appropriate answer from the options given below.

(1) Statement I is incorrect but Statement II is correct
(2) Both Statement I and Statement II are incorrect
(3) Both Statement I and Statement II are correct
(4) Statement I is correct and Statement II is incorrect

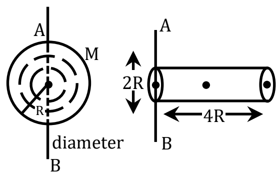
Sol. **4**

$$ev_s = h\nu + \phi \Rightarrow \frac{h}{e}\nu + \frac{\phi}{e}$$

slope = $\frac{h}{e}$

$\rightarrow$ Work function of M_2 is higher than M_1 so kinetic energy of emitted electron is less for M_2

40. Ratio of radius of gyration of a hollow sphere to that of a solid cylinder of equal mass, for moment of Inertia about their diameter axis AB as shown in figure is $\sqrt{8/x}$. The value of x is :



(1) 17 (2) 34 (3) 67 (4) 51

Sol. **3**

Hollow Sphere $\frac{2}{3}mR^2 = mk_1^2 \Rightarrow k_1 = \sqrt{\frac{2}{3}}R$

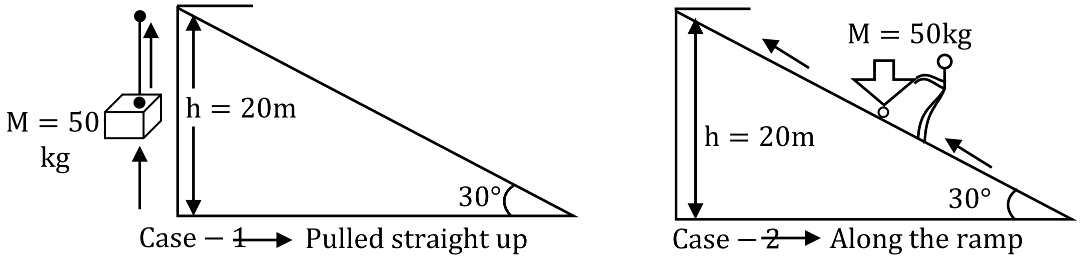
Solid cylinder $\frac{m(4R)^2}{3} + \frac{mR^2}{4} = mk_2^2$

$k_2 = \sqrt{\frac{67}{12}}R$

$\frac{k_1}{k_2} = \sqrt{\frac{2}{3} \times \frac{12}{67}} = \sqrt{\frac{8}{67}}$

$\Rightarrow x = 67$

41. A body of mass 50 kg is lifted to a height of 20m from the ground in the two different ways as shown in the figures. The ratio of work done against the gravity in both the respective cases, will be :



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

Sol. **4**

Work done by gravity is path independent so same work done in both paths

42. Time periods of oscillation of the same simple pendulum measured using four different measuring clocks were recorded as 4.62 s, 4.632 s, 4.6 s and 4.64 s. The arithmetic mean of these reading in correct significant figure is :

(1) 4.6 s (2) 5 s (3) 4.623 s (4) 4.62 s

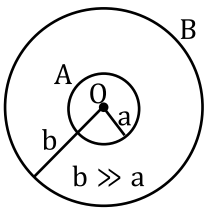
Sol. **1**

In four values least significant digit value is 4.6 so first round off every value according to this

$4.62 \rightarrow 4.6,\ 4.632 \rightarrow 4.6,\ 4.6 \rightarrow 4.6,\ 4.64 \rightarrow 4.6$

$T_{avg} = \frac{4.6 + 4.6 + 4.6 + 4.6}{4} = 4.6$

43. Two conducting circular loops A and B are placed in the same plane with their centres coinciding as shown in figure. The mutual inductance between them is :



(1) $\frac{\mu_0 \pi b^2}{2a}$ (2) $\frac{\mu_0 \pi a^2}{2b}$ (3) $\frac{\mu_0}{2\pi} . \frac{b^2}{a}$ (4) $\frac{\mu_0}{2\pi} . \frac{a^2}{b}$

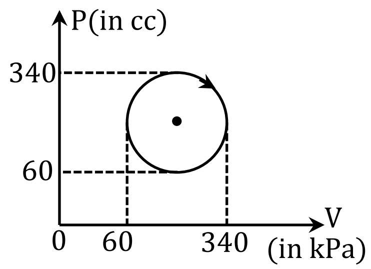
Sol. **2**

Magnetic flux through smaller loop

$\phi = \left(\frac{\mu_0 i}{2b}\right) . \pi a^2 = Mi$

$M = \frac{\mu . \pi a^2}{2b}$

44. The heat absorbed by a system in going through the given cyclic process is :



(1) 431.2 J (2) 616 J (3) 61.6 J (4) 19.6 J

Sol. **3**

θ = W = area enclosed

$$\theta = \pi ab = \frac{\pi(2a)(2b)}{4}$$

$$\theta = \frac{\pi\left(280\times10^{3}\right)\left(280\times10^{-6}\right)}{4}$$

$\theta \approx 61.6J$

45. If G be the gravitational constant and u be the energy density then which of the following quantity have the dimensions as that of the $\sqrt{uG}$.

(1) Force per unit mass (2) Gravitational potential

(2) pressure gradient per unit mass (4) Energy per unit mass

Sol. **1**

$G \to M^{-1}L^{3}T^{-2}$ and $u \to ML^{-1}T^{-2}$

$\sqrt{uG} \to LT^{-2}$

$$\frac{f}{m} = LT^{-2}$$

46. A simple pendulum doing small oscillations at a place R height above earth surface has time period of T_1=4s. T_2 would be it's time period if it is brought to a point which is at a height 2R from earth surface. Choose the correct relation [R = radius of earth] :

(1) $3T_1 = 2T_2$ (2) $T_1 = T_2$ (3) $2T_1 = T_2$ (4) $2T_1 = 3T_2$

Sol. **1**

$$T = 2\pi\sqrt{\frac{\ell}{g}} = 2\pi\sqrt{\frac{\ell r^2}{GM}} = 2\pi\sqrt{\frac{\ell}{GM}}r$$

$$\Rightarrow \frac{T_2}{T_1} = \frac{r_2}{r_1} = \frac{3R}{2R} \Rightarrow 2T_2 = 3T_1$$

47. Match List I with List II :

	List I		List II
(A)	Kinetic energy of planet	(I)	$-GMm/a$
(B)	Gravitation Potential energy of sun-planet system	(II)	$GMm/2a$
(C)	Total mechanical energy of planet	(III)	$\frac{Gm}{r}$
(D)	Escape energy at the surface of planet for unit mass object	(IV)	$-GMm/2a$

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

Sol. 2

Potential energy = $-\frac{GMm}{a}$

Total energy = $-\frac{GMm}{2a}$

kinetic energy = $\frac{GMm}{2a}$

Escape energy = $\frac{GMm}{r}$

48. Light emerges out of a convex lens when a source of light kept at its focus. The shape of wavefront of the light is :

(1) both spherical and cylindrical
(2) plane
(3) cylindrical
(4) spherical

Sol. 2

Emerging rays are parallel so plane wave front

49. In a co-axial straight cable, the central conductor and the outer conductor carry equal currents in opposite directions. The magnetic field is zero :

(1) outside the cable
(2) in between the two conductors
(3) inside the inner conductor
(4) inside the outer conductor

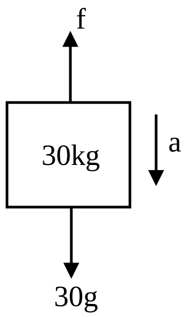
Sol. 1

By ampere's haw, net current is zero for loop enclosed complete cable so net magnetic field is zero outside the cable

50. A wooden block of mass 5kg rests on a soft horizontal floor. When an iron cylinder of mass 25 kg is placed on the top of the block, the floor yields and the block and the cylinder together go down with an acceleration of 0.1 ms^{-2}. The action force of the system on the floor is equal to :

(1) 294 N (2) 196 N (3) 297 N (4) 291 N

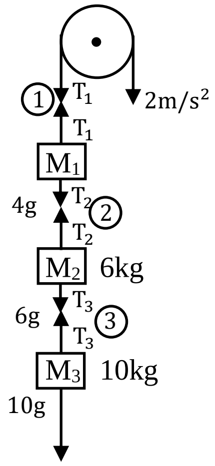
Sol. **4**



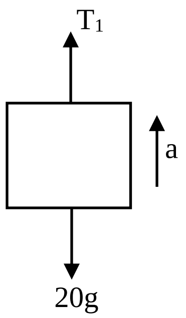
$30g - f = 30a = 30(0.1)$
$F = 30g - 3$
with $g = 10$ $\quad f = 297$ N
with $g = 9.8$ $\quad f = 291$ N
Nothing is given so $g = 9.8$

SECTION – B

51. Three blocks M_1, M_2, M_3 having masses 4 kg, 6 kg and 10 kg respectively are hanging from a smooth pully using rope 1, 2 and 3 as shown in figure. The tension in the rope 1, T_1 when they are moving upward with acceleration of $2ms^{-2}$ is ______________ N(if $g = 10$ m/s^2).

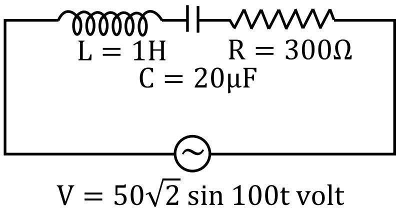


Sol. **240**



$T_1 - 20g = 20a = 20 \times 2$
$T_1 = 240N$
Ans. 240

52. An ac source is connected in given series LCR circuit. The rms potential difference across the capacitor of $20\mu F$ is ________________ V.



Sol. **50**

$$X_C = \frac{1}{20\times10^{-6}\times100} = 500\Omega\,,\ XL = 1 \times 100 = 100\Omega$$

$$Z = \sqrt{400^2 + 300^2} = 500\Omega$$

$$i_{rms} = \frac{50}{500} = \frac{1}{10}A$$

$$V_{C_{rms}} = i_{rms}X_C = \frac{1}{10}\times500 = 50V$$

53. The electric field between the two parallel plates of a capacitor of $1.5\mu F$ capacitance drops to one third of its initial value in $6.6\mu s$ when the plates are connected by a thin wire.
The resistance of this wire is _________ Ω. (Given, log 3 =1.1)

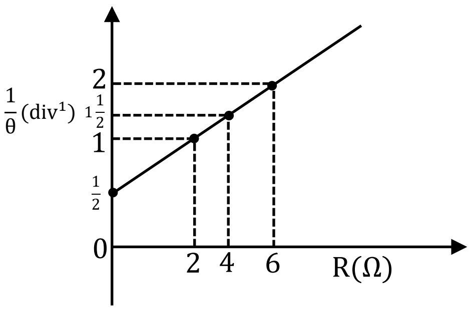
Sol. **4**

$$E = \frac{\theta}{A\in_0} \Rightarrow E\alpha\theta \Rightarrow E = E_0e^{-t/RC}$$

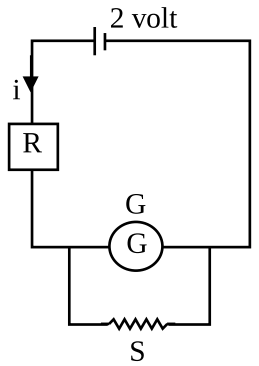
$$\Rightarrow t = RC\ \ln\frac{E_0}{E} \Rightarrow 6.6\times10^{-6} = R\left(1.5\times10^{-6}\right)\ln3$$

$$\Rightarrow R = \frac{66}{15lIn3} = \frac{66}{15\times1.1} = 4\Omega$$

54. In the experiment to determine the galvanometer resistance by half-deflection method, the plot of $1/\theta$ vs the resistance (R) of the resistance box is shown in the figure. The figure of merit of the galvanometer is ________ $x10^{-1}$ A/division. [The source has emf 2V]



Sol. **0.5**



Reading of Galvanometer

$$i_g = \left(\frac{S}{G+S}\right) i = \left(\frac{S}{G+S}\right)\left(\frac{2}{R+\frac{GS}{G+S}}\right)$$

$$i_g = \frac{2S}{R(G+S)+GS} = C\theta = \frac{C}{y}$$

Now y axis $\frac{1}{\theta} = y$ and x-axis R

$$\Rightarrow y = \frac{(G+S)C}{2S}.R + \frac{C\theta S}{2S} = \frac{(G+S)C}{2S}R + \frac{CG}{2}$$

$$\frac{CG}{2} = \frac{1}{2} \Rightarrow CG = 1 \text{ and Slope} = \frac{1}{4} = \frac{(G+S)C}{2S} \Rightarrow \frac{C(G+S)}{S} = \frac{1}{2}$$

55. Three capacitors of capacitances $25\mu F, 30\mu F$ and $45\mu F$ are connected in parallel to a supply of 100V. Energy stored in the above combination is E. When these capacitors are connected in series to the same supply, the stored energy is $\frac{9}{x}$ E. The value of x is ______.

Sol. **86**

G = 25 + 30 + 45 = 100 μF, $\frac{1}{C_2} = \frac{1}{25} + \frac{1}{30} + \frac{1}{45} \Rightarrow C_2 = \frac{450}{43}$ μF

Energy $E = \frac{1}{2}CV^2$

$$\frac{E_2}{E_1} = \frac{C_2}{C_1} = \frac{450/43}{100} = \frac{9}{86} \Rightarrow E_2 = \frac{9}{86}E$$

56. The density and breaking stress of a wire are $6\times10^4 kg/m^3$ and $1.2\times10^8 N/m^2$ respectively. The wire is suspended from a rigid support on a planet where acceleration due to gravity is $\frac{1^{rd}}{3}$ of the value on the surface of earth. The maximum length of the wire with breaking is ________ m (take, $g = 10m/s^2$).

Sol. **600**

Maximum tension is at top most point let area of wire is A and length l

$T = mg' \Rightarrow \sigma A = \rho Al.gl_3 \Rightarrow l = \frac{3\sigma}{\rho g}$

$l = \frac{3 \times 1.2 \times 10^8}{6 \times 10^4 \times 10} = 600$

57. If three ohelium nuclei combine to form a carbon nucleus then the energy released in this reaction is _________ $\times 10^{-2}$ MeV. (Given $1u = 931 MeV / c^2$, atomic mass of helium = 4.002603u)

Sol. **727**

$3{}_2^4He \rightarrow {}_6^{12}C + \theta$

$\theta = [3M_{He} - M_e]c^2 = [3 \times 4.002603 - 12][931]$

$\theta = 727 \times 10^{-2}$ Mev

58. In Young's double slit experiment, carried out with light of wavelength 5000 $\overset{o}{A}$, the distance between the slits is 0.3 mm and the screen is at 200 cm from the slits. The central maximum is at $x = 0cm$. The value of x for third maxima is _________ mm.

Sol. **10**

$x = \frac{3\lambda D}{d} = \frac{3 \times 5000 \times 10^{-10} \times 2}{0.3 \times 10^{-3}} = 10 \times 10^{-3} m = 10 mm$

59. A 2A current carrying straight metal wire of resistance 1Ω, resistivity $2 \times 10^{-6} \Omega m$, area of cross-section $10mm^2$ and mass 500 g is suspended horizontally in mid air by applying a uniform magnetic field $\vec{B}$. The magnitude of B is ____________________ $\times 10^{-1}$T (given, g = 10 m/s^2)

Sol. **5**

$R = \frac{\rho \ell}{A} \Rightarrow \ell = \frac{RA}{\rho} = \frac{1 \times 10 \times 10^{-6}}{2 \times 10^{-6}} = 5$

$i \ell B = mg \Rightarrow B = \frac{mg}{i\ell}$

$B = \frac{(0.5)(10)}{2 \times 5} = 5 \times 10^{-1} T$

60. A body moves on a frictionless plane starting from rest. If S_n is distance moved between t = n – 1 and t = n and S_{n-1} is distance moved between t = n – 2 and t = n – 1, then the ratio $\frac{S_{n-1}}{S_n}$ is $\left(1 - \frac{2}{x}\right)$ for n = 10. The value of x is _____________.

Sol. **19**

$S_n = \frac{1}{2}a(n)^2 - \frac{1}{2}a(n-1)^2 = \frac{1}{2}a(2n-1)$

$S_{n-1} = \frac{1}{2}a(2 \times (n-1) - 1) = \frac{1}{2}a(2n-3)$

$\frac{S_{n-1}}{S_n} = \frac{2n-3}{2n-1} = 1 - \frac{2}{2n-1} = 1 - \frac{2}{20-1} = 1 - \frac{2}{19}$

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