ALL INDIA TEST SERIES

IIT - JAM – 2024 (Physics)

Full Length Test – 01

TIME: 3 HOURS **MAXIMUM MARKS: 100**

Section A: This section contains a total of 30 Multiple Choice Questions **(MCQ)** carrying one or two marks each. Each MCQ type question has four choices out of which only one choice is the correct answer.

There will be negative marking @ $\frac{1}{3}^{rd}$ for one marks MCQ and $\frac{2}{3}^{rd}$ negative marks for two marks MCQ for each wrong answer.

Section B: This section contains a total of 10 Multiple Select Questions **(MSQ)** carrying two marks each. Each MSQ type question is similar to MCQ but with a difference that there may be one or more than one choice(s) that are correct out of the four given choices. The candidate gets full credit if he/she selects all the correct answers only and no wrong answers.

Section C: This section contains a total of 20 Numerical Answer Type **(NAT)** questions carrying one or two marks each. For these NAT type questions, the answer is a signed real number which needs to be entered using the virtual keyboard on the monitor. No choices will be shown for these types of questions.

Note: There will be no negative marking for Section B and Section C.

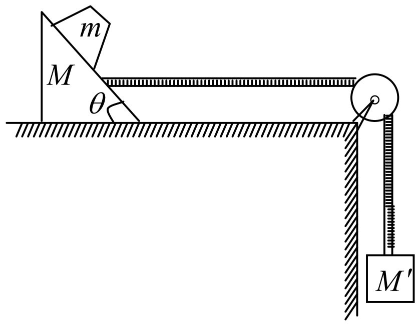
Multiple Choice Questions (MCQ)

Q1-Q10 Carry One Mark each. (1/3 negative marks for each wrong answer)

Q1. The electrostatic potential inside a charged spherical ball is given by $\phi = ar^2 + b$ where r is the distance from the centre; a, b are constants. Then the charge density inside ball is

(a) $-6a\varepsilon_0 r$ (b) $-24\pi a\varepsilon_0 r$ (c) $-6a\varepsilon_0$ (d) $-24\pi a\varepsilon_0 r$

Q2. Three blocks of masses m, M and M' are arranged as shown in figure. All surfaces are frictionless, pulley and strings are ideal. The mass M' of the hanging block which will prevent the smaller block (m) from shipping over the wedge will be:



(a) $\dfrac{M+m}{\cot\theta - 1}$ (b) $\dfrac{M-m}{\cot\theta - 1}$

(c) $\dfrac{M+m}{\cot\theta + 1}$ (d) $\dfrac{M-m}{M+m}\tan\theta$

Q3. The Laplace transform of $t^2 u(t-3)$ is given by

(a) $e^{-3s}\left[\dfrac{2}{s^3} - \dfrac{6}{s^2} + \dfrac{9}{s}\right]$ (b) $e^{-3s}\left[\dfrac{2}{s^3} + \dfrac{6}{s^2} - \dfrac{9}{s}\right]$

(c) $e^{-3s}\left[\dfrac{2}{s^3} + \dfrac{6}{s^2} + \dfrac{9}{s}\right]$ (d) $-e^{-3s}\left[\dfrac{2}{s^3} + \dfrac{6}{s^2} + \dfrac{9}{s}\right]$

Q4. For a binary half subtractor having two input A and B, the correct set of logical expression for the output $D = (A - B)$ and X (borrow) are

(a) $D = AB + \overline{A}\overline{B}, X = \overline{A}B$ (b) $D = \overline{A}B + A\overline{B}, X = A\overline{B}$

(c) $D = \overline{A}B + A\overline{B}, X = \overline{A}B$ (d) $D = AB + \overline{A}\overline{B}, X = A\overline{B}$

Q5. If heat is supplied to an ideal gas in an isothermal process, then which of the following is correct?

(a) the internal energy of the gas will increase

(b) the gas will do positive work

(c) the gas will do negative work

(d) the process is not possible

Q6. The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy $6eV$ fall on it is $4eV$. The stopping potential, in volts, is

(a) 2 (b) 4 (c) 6 (d) 10

Q7. The intensity distribution due to Fraunhofer diffraction at a single slit is represented by

(a) $A^2 \frac{\sin^2 \beta}{\beta^2}$ (b) $4A^2 \frac{\sin^2 \beta}{\beta^2} \cos^2 r$

(c) $A^2 \frac{\sin^2 \beta}{\beta^2} N^2$ (d) $A^2 \frac{\sin^2 \beta}{\beta^2} \frac{\sin^2 Nr}{\sin^2 r}$

Q8. If $I = \sqrt{-1}$, then $4 + 5\left(\frac{-1}{2} + \frac{i\sqrt{3}}{2}\right)^{334} + 3\left(\frac{-1}{2} + \frac{i\sqrt{3}}{2}\right)^{365}$ is

(a) $1 - i\sqrt{3}$ (b) $-1 + i\sqrt{3}$ (c) $i\sqrt{3}$ (d) $-1\sqrt{3}$

Q9. The mutually perpendicular waves $E_x = 10\sin(20\pi t)$ and $E_y = 25\cos(10\pi t + \pi/4)$ is superimposed. The frequency of the combined motion is

(a) $7Hz$ (b) $7.2Hz$ (c) $7.5Hz$ (d) $8Hz$

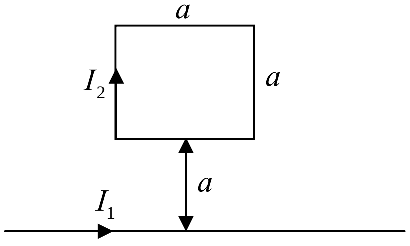
Q10. A given point in space the total light wave is composed of three phasons $P_1 = a,\ P_2 = \frac{a}{2}e^{i\theta}$ and $P_3 = \frac{a}{2}e^{-i\theta}$. The intensity of light at this point is

(a) $4a^2 \cos^2\left(\frac{\theta}{2}\right)$ (b) $4a^2 \cos^4\left(\frac{\theta}{2}\right)$ (c) $a^2 \cos^2(\theta)$ (d) $4a^2 \cos^2(2\theta)$

Multiple Choice Questions (MCQ)

Q11-Q30 Carry Two Mark each. (1/3 negative marks for each wrong answer)

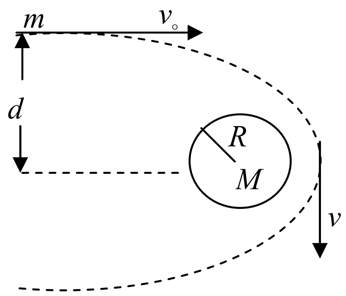
Q11. A square loop is placed near an infinite straight wire as shown in figure. The loop and wire carry a steady current I_2 and I_1 respectively. Then the force acting on the square loop is:



(a) $\frac{\mu_0 I_1 I_2}{2\pi a}$ (b) $\frac{\mu_0 I_1 I_2}{4\pi a}$

(c) $\frac{\mu_0 I_1 I_2}{2\pi}$ (d) $\frac{\mu_0 I_1 I_2}{4\pi}$

Q12. An asteroid is moving towards a planet of mass M and radius R, from a long distance with initial speed v_0 and impact parameter d. The minimum value of v_0 such that the asteroid does not hit the planet is:

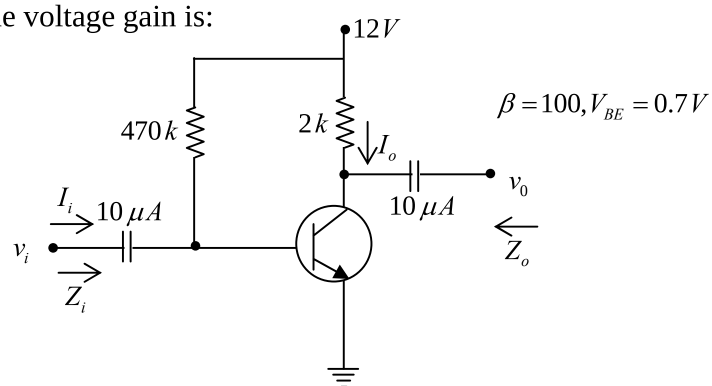


(a) $v_0 = \sqrt{\frac{2GMR}{d^2 - R^2}}$ (b) $v_0 = \sqrt{\frac{GMR}{d^2 - R^2}}$

(c) $v_0 = \sqrt{\frac{GMR}{2\left(d^2 - R^2\right)}}$ (d) $v_0 = \sqrt{\frac{GMR}{d^2}}$

Q13. For the network shown in figure the voltage gain is:

(use $r_e = \frac{26\,mV}{I_C}, r_o = \infty$)



(a) ≈ -187

(b) ≈ -280

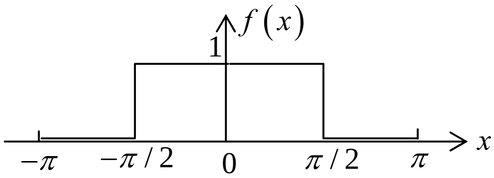
(c) ≈ -320

(d) ≈ -350

Q14. What is the speed v_n of the electron in the nth Bohr orbit of hydrogen atom, if v_1 is the speed of the electron in the first Bohr orbit?

(a) $v_1 n$ (b) $v_1 n^3$ (c) $\frac{v_1}{n}$ (d) $\frac{v_1}{n^3}$

Q15. The Fourier series of the periodic function $f(x)$ having period 2π as shown in figure:



(a) $f(x)=\frac{1}{2}-\frac{2}{\pi}\left[\cos x-\frac{1}{3}\cos 3x+\frac{1}{5}\cos 5x-+....\right]$

(b) $f(x)=\frac{1}{2}+\frac{2}{\pi}\left[\cos x+\frac{1}{3}\cos 3x+\frac{1}{5}\cos 5x-+....\right]$

(c) $f(x)=-\frac{1}{2}+\frac{2}{\pi}\left[\cos x-\frac{1}{3}\cos 3x+\frac{1}{5}\cos 5x-+....\right]$

(d) $f(x)=\frac{1}{2}+\frac{2}{\pi}\left[\cos x-\frac{1}{3}\cos 3x+\frac{1}{5}\cos 5x-+....\right]$

Q16. At equilibrium, there cannot be any free charge inside a metal. However, if you forcibly put charge in the interior then it takes some finite time to 'disappear' i.e. move to the surface. If the conductivity σ of a metal is $10^6(\Omega m)^{-1}$ and the permittivity $\varepsilon=8.85\times10^{-12}$ Farad/m, this time will be approximately:

(a) 10^{-5} sec (b) 10^{-11} sec (c) 10^{-9} sec (d) 10^{-17} sec

Q17. The dispersion law for a certain type of wave motion is $\omega=\left(c^2k^2+m^2\right)^{\frac{1}{2}}$, wher e ω is the angular frequency, k is the magnitude of the propagation vector, and c and m are constants. The group velocity of these waves approaches

(a) infinity as $k\to0$ and zero as $k\to\infty$

(b) infinity as $k\to0$ and c as $k\to\infty$

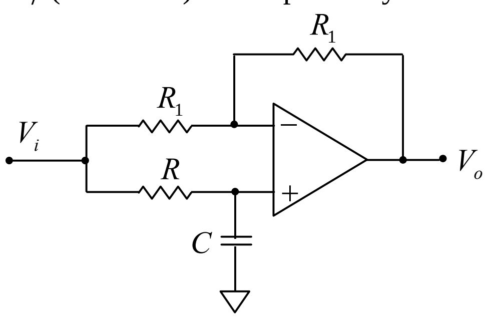
(c) zero as $k\to0$ and infinity as $k\to\infty$

(d) zero as $k\to0$ and c as $k\to\infty$

Q18. A square matrix 3×3 is given by $A=\begin{bmatrix}2&0&0\\0&1&1\\0&1&1\end{bmatrix}$ is diagonalzed in eigenvector of matrix $S=\begin{bmatrix}1&0&0\\0&\frac{1}{\sqrt2}&\frac{1}{\sqrt2}\\0&-\frac{1}{\sqrt2}&\frac{1}{\sqrt2}\end{bmatrix}$. Which one of the following is matrix A in the diagonal form in the basis of S?

(a) $\begin{bmatrix}2&0&0\\0&2&0\\0&0&0\end{bmatrix}$ (b) $\begin{bmatrix}0&0&0\\0&2&0\\0&0&2\end{bmatrix}$ (c) $\begin{bmatrix}2&0&0\\0&0&0\\0&0&2\end{bmatrix}$ (d) $\begin{bmatrix}1&0&2\\0&1&0\\0&0&2\end{bmatrix}$

Q19. Consider the Op-Amp circuit shown in figure. If $V_i=V_1\sin(\omega t)$ and $V_o=V_2\sin(\omega t+\phi)$, then the minimum and maximum value of ϕ (in radians) are respectively



(a) $-\pi/2$ and $+\pi/2$

(b) 0 and $+\pi/2$

(c) $-\pi$ and 0

(d) $-\pi/2$ and 0

Q20. If $u=x+y+z, 2v=xyz, w=vx$ The Jacobian $\frac{\partial(u,v,\omega)}{\partial(x,y,z)}$· At the point $x=1, y=2, z=1$.

(a) $\frac{1}{2}$ (b) 1 (c) -1 (d) 2

Q21. A particle is moving in one dimension is a stationary state whose wave function

$$\psi(x) = \begin{cases} 0 & x < -a \\ A\left(1+\cos\dfrac{\pi x}{a}\right) & -a \le x \le a \\ 0 & x > a \end{cases}$$

What is value of A such that $\psi(x)$ is normalized?

(a) $\sqrt{\dfrac{2}{a}}$ (b) $\sqrt{\dfrac{1}{a}}$ (c) $\sqrt{\dfrac{2}{3a}}$ (d) $\sqrt{\dfrac{1}{3a}}$

Q22. When unpolarised light is incident on a glass plate at a particular angle, it is observed that the reflected beam is linearly polarized. What is the angle of the refracted beam with respect to the surface normal?

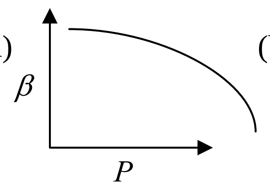
(a) 56.7°

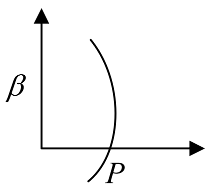
(b) 33.4°

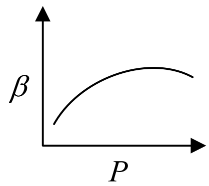
(c) 23.3°

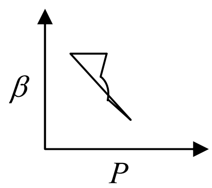
(d) The light is completely reflected and there is no refracted beam.

Q23. Which of the following graphs correctly represents the variation of isothermal compressibility (β_r) with P for an ideal gas at constant temperature?

(a) 

(b) 

(c) 

(d) 

Q24. A simple pendulum attached to the ceiling of stationary lift has a time period T. When the lift moves upward with distance covered as $y = \left(1.5m/s^2\right)t^2$, the time period of the pendulum will be

(a) $\sqrt{10/13}T$ (b) $\sqrt{6/5}T$ (c) $\sqrt{5/7}T$ (d) $\sqrt{5/6}T$

Q25. Consider a particle of mass m moving in one dimension under a force with potential $U(x)=k\left(2x^3-5x^2+4x\right)$ where $k>0$. If the particle oscillates about the stable equilibrium point then Time period of oscillation is given by

(a) $2\pi\sqrt{\frac{2m}{k}}$ (b) $\pi\sqrt{\frac{2m}{k}}$ (c) $2\pi\sqrt{\frac{m}{k}}$ (d) $\pi\sqrt{\frac{m}{k}}$

Q26. The internal energy $E(T)$ of a system at a fixed volume is found to depend on the temperature T as $E(T)=\frac{aT^2}{2}+\frac{bT^4}{4}$. Then the entropy $S(T)$, as a function of temperature, is

(a) $\frac{1}{2}aT^2+\frac{1}{4}bT^4$ (b) $2aT^2+4bT^4$ (c) $2aT+\frac{4}{3}bT^3$ (d) $aT+\frac{bT^3}{3}$

Q27. The solution of $\left(D^2-4D+3\right)y=3e^x\cos 2x$ is given by

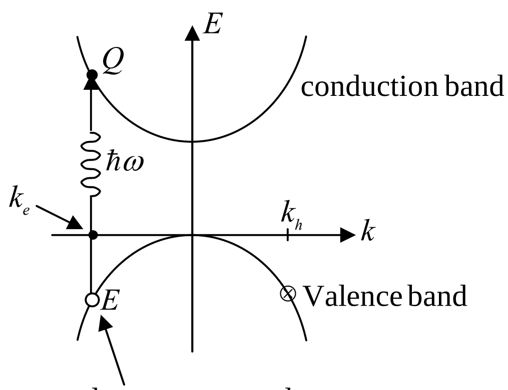
(a) $\Rightarrow y=c_1e^x+c_2e^{3x}-\frac{3}{8}e^x\left(\cos 2x-\sin 2x\right)$

(b) $\Rightarrow y=c_1e^x+c_2e^{3x}-\frac{3}{8}e^x\left(\cos 2x+\sin 2x\right)$

(c) $\Rightarrow y=c_1e^x+c_2e^{3x}-\frac{3}{8}e^{-x}\left(\cos 2x+\sin 2x\right)$

(d) $\Rightarrow y=c_1e^{-x}+c_2e^{-3x}-\frac{3}{8}e^x\left(\cos 2x+\sin 2x\right)$

Q28. Which of the following correctly represent the relation between electron and holes for given condition and valence band?



(a) $k_h=-k_e$

(b) $v_h=-v_e$

(c) $m_h=m_e$

(d) $E_h=E_e$

Q29. Eight spherical rain drops of the same mass and radius are falling down with a terminal speed of $6cms^{-1}$. If they coalesce to from one big drop, what will be its terminal speed? Neglect the buoyancy due to air.

(a) $1.5cms^{-1}$ (b) $6cms^{-1}$ (c) $24cms^{-1}$ (d) $32cms^{-1}$

Q30. Two radioactive materials x_1 and x_2 have decay constant 10λ and λ respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of x_1 to that of x_2 will be $1/e$ after a time:

(a) $\frac{1}{10\lambda}$ (b) $\frac{1}{11\lambda}$ (c) $\frac{11}{10\lambda}$ (d) $\frac{1}{9\lambda}$

Multiple Select Type Questions (MSQ)

Q31-Q40 Carry Two Marks each (No negative marking for any wrong answer)

Q31. A charge q is placed at the centre of an otherwise neutral dielectric sphere of radius a and relative permittivity ε_r. We denote the expression $q/4\pi\varepsilon_0 r^2$ by $E(r)$. Which of the following statements are true?

(a) The electric field inside the sphere, $r < a$, is given by $E(r)/\varepsilon_r$

(b) The field outside the sphere, $r > a$, is given by $E(r)$

(c) The total charge inside a sphere of radius $r > a$ is given by q.

(d) The total charge inside a sphere of radius $r < a$ is given by q.

Q32. In a one-dimensional harmonic oscillator, ϕ_0, ϕ_1 and ϕ_2 are respectively the ground, first and the second excited states. These three states are normalized and are orthogonal to one another. ψ_1 and ψ_2 are two states defined by $\psi_1 = \phi_0 - 2\phi_1 + 3\phi_2$, $\psi_2 = \phi_0 - \phi_1 + \alpha\phi_2$, where α is a constant

(a) The value of α, when ψ_1 is orthogonal to ψ_2 is 1

(b) The value of α, when ψ_1 is orthogonal to ψ_2 is -1

(c) For the value of α determined, when ψ_1 and ψ_2 are orthogonal, the average value of state ψ_2 is $3\hbar\omega$

(d) For the value of α determined ψ_1 and ψ_2 are orthogonal average value on state ψ_2 is $\frac{3}{2}\hbar\omega$

Q33. Consider the following statements related to kinetic theory of gases. Which of the following options is/are correct?

(a) The molecules of a gas are all alike in size and shape and are hard, smooth, spherical particles.

(b) The size of the molecules is very small compared to the volume occupied by the gas.

(c) The molecules exert no appreciable force on one another except during a collision.

(d) The collisions of the molecules with the walls of the vessel are inelastic.

Q34. Pick out the correct alternative (s)

(a) The radius of gyration of a thin disc about any diameter is $\frac{R}{2}$, where R is the radius of the disc.

(b) The radius of gyration of a circular disc about a tangent in its plane is $\frac{\sqrt{5}}{2}R$, where R is the radius of the disc.

(c) The radius of gyration of a thin rod about an axis through its one end and perpendicular to the rod is $\frac{L}{\sqrt{3}}$, where L is the length of the rod.

(d) The radius of gyration of a rectangular lamina of sides l and b about an axis through its centre and perpendicular to its plane is $\frac{1}{2}\sqrt{\frac{l^2+b^2}{3}}$.

Q35. The relation between the nuclear radius (R) and mass number (A), given by $R = 1\cdot 2A^{1/3}\, fm$, implies that

(a) The central density of nuclei is independent of A.

(b) The volume energy per nucleon is a constant.

(c) The attractive part of the nuclear force has a long range.

(d) The nuclear force is charge independent.

Q36. A steady current I flows along an infinitely long hollow cylindrical conductor of radius R. This cylinder is placed coaxially inside an infinite solenoid of radius $2R$. The solenoid has n turns per unit length and carries a steady current I. Consider a point P at a distance r from the common axis. The correct statement(s) is (are)

(a) In the region $0 < r < R$, the magnetic field is non-zero

(b) In the region $R < r < 2R$, the magnetic field is along the common axis.

(c) In the region $R < r < 2R$, the magnetic field is tangential to the circle of radius r, centered on the axis.

(d) In the region $r > 2R$, the magnetic field is non-zero.

Q37. Which of the following statement is correct about interference in reflected wave?

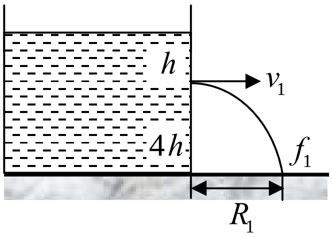
(a) reflected wave interfere due to path length differences

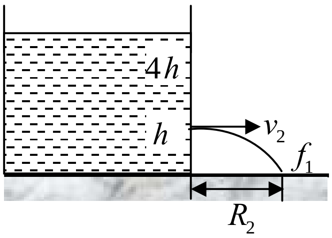
(b) reflected wave can also interfere when path length is also constant

(c) reflected wave can also interfere due to phase changes upon reflection

(d) reflected wave can also interfere even when there is no phase changes upon reflection

Q38. In two figures





(a) $v_1 / v_2 = 2$ (b) $v_1 / v_2 = 1/4$ (c) $R_1 = R_2$ (d) $t_1 / t_2 = 2$

Q39. Which of the following statements are correct for a monochromatic wave?

(a) Wave speed is affected by changing frequency

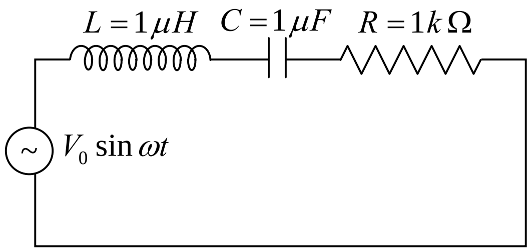
(b) Amplitude of a wave is unrelated to the wave speed

(c) Doubling the amplitude of the wave causes the power to be larger by a factor of 4

(d) Changing the amplitude of wave changes to the frequency of the wave.

(d) wave frequency ω is independent of amplitude 'a'. This is a wrong option

Q40. In the circuit shown $L = 1\mu H, C = 1\mu F$ and $R = 1k\Omega$. They are connected in series with an a.c. source $V = V_0 \sin \omega t$ as shown. Which of the following options is/are correct?



(a) The frequency at which the current will be in the phase with the voltage is independent of R.

(b) At $\omega \sim 0$ the current flowing through the circuit becomes nearly zero.

(c) At $\omega >> 10^6\ rad\ s^{-1}$, the circuit behave like a capacitor.

(d) The current will be in phase with the voltage if $\omega = 10^4\ rad\ s^{-1}$

Numerical Answer Type Questions (NAT)

Q41-Q50 Carry One Mark each (No negative marking for any wrong answer).

Q41. In a cyclotron, α-particles are accelerated using RF source of frequency $15\,MHz$. The frequency of RF source if α-particles are replaced by $_2He^3$ particle is _________ MHz

Q42. Two frames, O and O', are in relative motion. O' is moving with respect to O at a speed $c/2$, where c is the speed of light. In frame O, two separate events occur at (x_1, t_1) and (x_2, t_2). In frame O', these events occur simultaneously. The value of $(x_2 - x_1)/(t_2 - t_1)$ is αc then the value of α ________is

Q43. Decimal equivalent of the binary number $(1011.111)_2$ is_____________

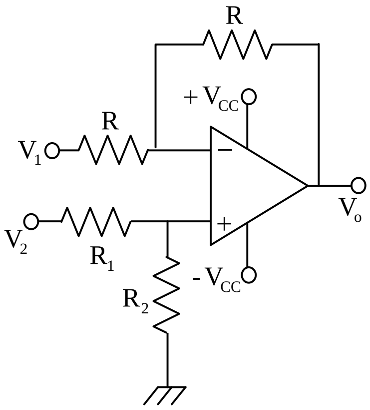
Q44. The muon has mass $105\,MeV/c^2$ and mean life time $2.2\,\mu s$ in its rest frame. The mean distance traversed by a muon of energy $315\,MeV$ before decaying is approximately _____________ km

Q45. The flux linked with a coil at instant $'t'$ is given by $\phi = 10t^2 - 50t + 250$. The magnitude of induced emf at $t = 3s$ is____________volts

Q46. The number of nearest neighbors for 5thnearest atom is FCC crystal are_________

Q47. Two protons are confined to a cubic box, whose sides have length $10^{-12}\,m$. The minimum kinetic energy of the $\alpha \times 10^{-17}\,J$. If the mass of proton is $1.67 \times 10^{-27}\,kg$ and Planck's constant is $6.63 \times 10^{-34}\,Js$, then the value of α is___________

Q48. In the following circuit, for the output voltage to be $V_0 = (-V_1 + V_2/3)$ the ratio R_1/R_2 is____________



Q49. In YDSE, the two slits act as coherent sources of equal amplitude A and wavelength λ. In another experiment with the same set up, the two slits are sources of equal amplitude A and wavelength λ, but are incoherent. The ratio of intensity of light at the midpoint of the screen in the first case to that in the second case is ___________

Q50. In a typical human body, the amount of radioactive ^{40}K is 3.24×10^{-5} percent of its mass. The activity due to ^{40}K in a human body of mass $70\,kg$ is_____________kBq.

(Round of to 2 decimal places)

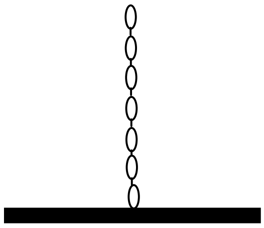
Half life of $^{40}K = 3.942\times10^{6}$ sec, Avogadro's number $N_A = 6.022\times10^{23}mol^{-1}$

Numerical Answer Type Questions (NAT)

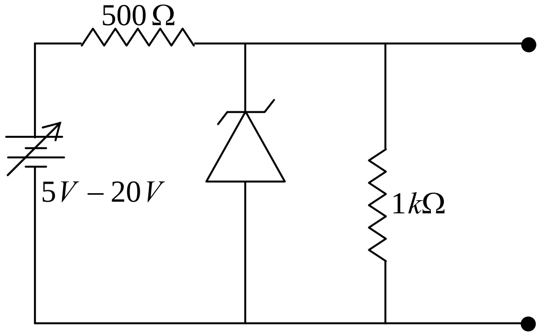
Q51-Q60 Carry Two Mark each (No negative marking for any wrong answer).

Q51. A thin uniform ring carrying charge Q and mass M rotates about its axis. The ratio of magnetic dipole moment to the angular momentum of this ring is $\alpha\dfrac{Q}{M}$. Then the value of α is__________

Q52. A uniform chain of mass m and length l hangs on a thread and touches the surface of a table by its lower end. If the force exerted by the table on the chain when half of its length has fallen is $\alpha\, mg$, then the value of α is__________ (The fallen part does not form heap).



Q53. A variable power supply $(5\,V - 20\,V)$ is connected to a Zener diode specified by a breakdown voltage of $10\,V$ (see figure). The ratio of the maximum power to the minimum power dissipated across the load resistor is _________



Q54. Three identical spin-$\frac{1}{2}$ fermions are to be distributed in three non-degenerate distinct energy levels. The number of ways this can be done is_________

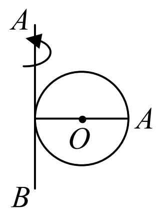
Q55. In an experiment on charging of an initially uncharged capacitor, an RC circuit is made with the resistance $R = 10k\Omega$ and the capacitor $C = 1000\mu F$ along with a voltage source of $3V$. The magnitude of the displacement current through the capacitor (in μA), 5 seconds after the charging has started, is ___________

Q56. The phase velocity of deep-water wave is given by

$$v^2 = \frac{g\lambda}{2\pi} + \frac{2\pi\sigma}{\rho\lambda}$$

where $g = 9.8\,ms^{-2}$, $\rho = 1000\,kgm^{-3}$, and $\sigma = 7.2\times10^{-2}\,Nm^{-1}$. The group velocity of the waves in non dispersive medium is___________$cm/\sec$.

Q57. A disc of mass $8\,kg$ and radius $2\,m$ is rotating about the axis AB, that is tangent to the disc. If the linear speed of point A on the periphery of the disc is $20\,m/s$, then the kinetic energy of the disc is _________ J.



Q58. If equation of state is given by $P = \frac{RT}{V-b}\exp\left(-\frac{a}{RTV}\right)$ then critical volume $V_c =$_______b.

Q59. Two gravitating bodies A and B with masses m_A and m_B, respectively, are moving in circular orbit. Assume that $m_B \gg m_A$ and let the radius of the orbit of body A be R_A. If the body A is losing mass adiabatically, its orbital radius R_A is proportional to $\frac{1}{m_A^{\alpha}}$.

Then the value of α is given by __________

Q60. What a tap is closed, the monometer attached to the pipe leads $3.5\times10^5\,Nm^{-2}$. When the type is opened the reading of monometer falls to $3.0\times10^5\,Nm^{-2}$. The velocity of water in the pipe is____________m/s

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