JNU MSc 2017

Q1. One hydrogen atom collides with a second hydrogen atom which is initially at rest in the laboratory. Both the atoms are in the ground state before the collision. What should be the minimum kinetic energy (in the laboratory frame) of the incident hydrogen atom so that one of the two atoms can be in its first excited state after the collision?

(a) $3.4\,eV$ (b) $5.1\,eV$ (c) $10.2\,eV$ (d) $13.6\,eV$

(e) $20.4\,eV$

Q2. A proton of kinetic energy $1880\,MeV$ is moving in a circular orbit in a plane perpendicular to a uniform magnetic field of strength 5 Tesla. What is the radius of the orbit?

(a) $75.6\ m$ (b) $3.1\,m$ (c) $5.3\ m$ (d) $1.8\,m$

(e) $24.3\,m$

Q3. Consider a planet, of radius $5000\,km$, which is entirely in the liquid state and has a uniform density of $5\,gm/cm^3$. The planet is in equilibrium under the action of gravitational forces and hydrostatic pressure. The pressure at the centre of the planet is

(a) $90\times10^9\ N/m^2$ (b) $360\times10^9\ N/m^2$

(c) $180\times10^9\ N/m^2$ (d) $270\times10^9\ N/m^2$

(e) $540\times10^9\ N/m^2$

[Hint: (i) Consider the equilibrium of a small volume element at a distance r from the centre and (ii) pressure on the surface is zero.]

Q4. Two events occur in the space time continuum. Event A has coordinates $(1\ m,\ 2m, 3m, 0s)$ and event B occurs at $\left(2m, 3m, 4m, \frac{10^{-8}}{3}s\right)$, where the 4^{th} coordinate gives the time in seconds. The proper distance between these two events is given by

(a) $2\,m$ (b) $\sqrt{3}\,m$ (c) $\sqrt{2}\ m$ (d) $3\,m$

(e) $1\ m$

Q5. An idealized ping-pong ball of mass m is bouncing on a recoilless table in one dimension. The energy of the ball is given by

(a) $-\frac{1}{3}$ (b) -1 (c) 3 (d) $\frac{2}{3}$

(e) 0

Q6. Newton's rings are formed between two biconvex lenses of equal radii of curvature by reflected high of wavelength $5000\ \overset{0}{A}$. If the distance between the 5^{th} and the 15^{th} rings is $0.085\ cm$, what is the radius of either lens?

(a) $109.7\ cm$ (b) $71.29\ cm$ (c) $107.9\ cm$ (d) $75.6\ cm$

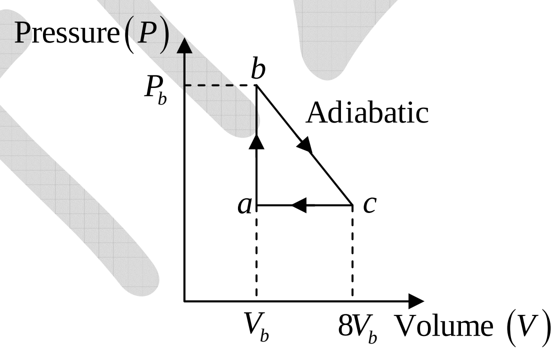
(e) $105.4\ cm$

Q7. The visible spectrum has wavelength in the range of $400\ nm$ to $700\ nm$. The angular spread of the first-order visible spectrum produced by a plane diffraction grating having 6000 lines cm^{-1}, when the light is incident normal to the grating is

(a) 8.9^0 (b) 9.9^o (c) 10.9^o (d) 11.9^o

(e) 12.9^o

Q8. One mole of a monatomic ideal gas is taken through the reversible cycle shown below. The path $b \to c$ is an adiabatic expansion process with $P_b = 10\ atm$ and $V_b = 1\times10^{-3}\ m^3$:



The efficiency of this cycle is closest to

(a) 0.75 (b) 0.83 (c) 0.41 (d) 0.39

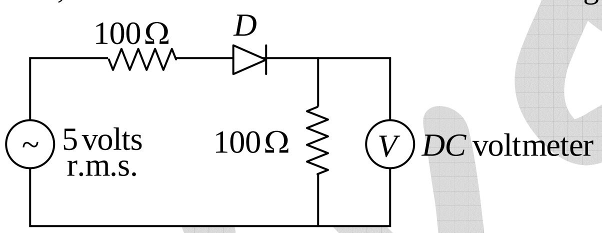
(e) 0.62

Q9. Two reversible engines are connected in series. The first one receives heat at $T^{o}K$ and rejects heat at $1527^{o}C$. The second one receives the heat rejected by the first at $1527^{o}C$ and then expels heat at $527^{o}C$. Find the temperature T for equal efficiencies of the two energies.

(a) $3240^{o}K$ (b) $2800^{o}K$ (c) $2054^{o}K$ (d) $1000^{o}K$

(e) $3100^{o}K$

Q10. In the following circuit, the diode D is ideal. What is the reading in the DC voltmeter?



(a) 3.18 volts (b) 2.25 volt (c) 4.50 volt

(d) 1.59 volt (e) 1.85 volt

Q11. Let $\vec{a}_1 = \hat{x}$ and $\vec{a}_2 = \left(\sqrt{3}\hat{x} + \hat{y}\right)$ be the primitive vectors of a two-dimensional lattice where $\hat{x}$ and $\hat{y}$ are orthogonal unit vectors. If one of the corresponding reciprocal vectors is $\vec{b}_2 = 4\pi\hat{y}$, then the other one is

(a) $\vec{b}_1 = 2\pi\left(\hat{x} + \sqrt{3}\hat{y}\right)$ (b) $\vec{b}_1 = 2\pi\left(-\hat{x} + \sqrt{3}\hat{y}\right)$

(c) $\vec{b}_1 = 2\pi\hat{x}$ (d) $\vec{b}_1 = 2\pi\left(\hat{x} - \sqrt{3}\hat{y}\right)$

(e) $\vec{b}_1 = 2\pi\sqrt{3}\hat{y}$

Q12. In the Debye model of the specific heat of solids, which of the following holds true?

(a) The photon frequencies are treated as independent of the wave vector and the low temperature specific heat behaves as $C_V \propto T^3$

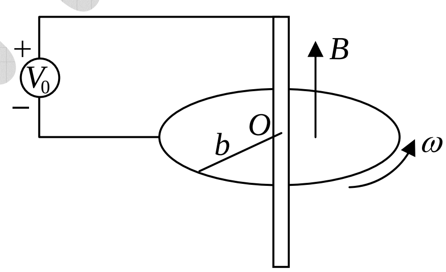
(b) Electron-electron repulsion is the key ingredient and the low temperature specific heat behaves as $C_V \propto T$

(c) The photon frequencies are taken to have the sound wave like dispersion and the low temperature specific heat behaves as $C_V \propto T^3$

(d) The specific heat due to lattice vibrations is temperature independent

(e) The photon frequencies are treated as independent of the wave vector and the low temperature specific heat behaves as $C_V \propto T$

Q13. A circular metal disk (Faraday disk generator) is rotating with a constant angular velocity ω in a uniform and constant magnetic field of flux density $\vec{B} = \hat{a}_z B_0$ that is parallel to the axis of rotation. Determine the open-circuit voltage (V_0) of the generator if the radius of the disk is b

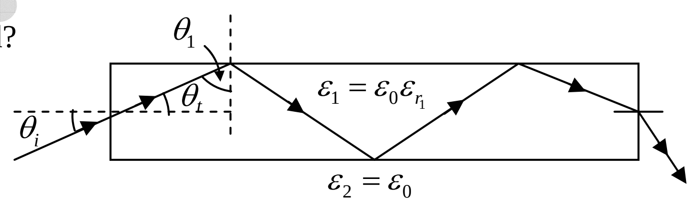


(a) $-\frac{\omega B_0 b^2}{2}$ (b) $\frac{\omega B_0 b^2}{2}$

(c) $\frac{\pi\omega B_0 b^2}{2}$ (d) $\pi\omega B_0 b^2$

(e) $-\frac{\omega B_0 b^2}{2\pi}$

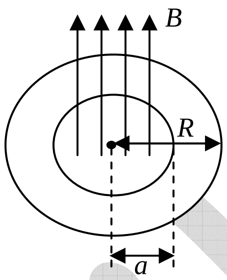
Q14. A dielectric rod of a transparent material can be used to guide light under the condition of total internal reflection. What is the minimum dielectric constant of guiding medium so that a wave incident on one end at any angle will be confined within the rod until it emerges from the other end?



(a) $\sqrt{2}$ (b) 1 (c) 2 (d)1.5

(e) 1.75

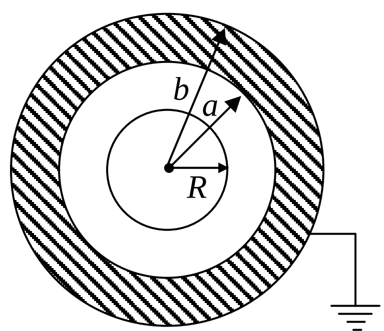
Q15. A wire carrying line-charge density λ is converted into a circular loop of radius R. Then it is suspended horizontally (with non conducting spokes) so that it is free to rotate in the horizontal plane. A uniform magnetic field $\vec{B}$ is applied in the central region (pointing up) out to radius $a\left(R>a\right)$. The angular momentum imparted to the loop when the field is turned off is given by



(a) πBa^2 (b) 0 (c) $\pi R^2\lambda a$ (d) $\pi\lambda a^2 Rb$

(e) $\pi B\lambda^2$

Q16. A metal sphere of radius R with charge q is surrounded by a thick concentric spherical shell of inner radius a and outer radius b. The shell is grounded. The potential at the centre of the sphere (with infinity as reference point) is given by



(a) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{b}+\frac{q}{R}-\frac{q}{a}\right)$ (b) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{R}\right)$

(c) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{b}-\frac{q}{a}\right)$ (d) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{R}-\frac{q}{a}\right)$

(e) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{R}+\frac{q}{a}\right)$

Q17. A dust particle of mass $10^{-8}\ kg$ is at room temperature $(300\ K)$. Its de Broglie wavelength is nearest to

(a) $10^{-19}\ m$ (b) $10^{-15}\ m$ (c) $10^{-6}\ m$ (d) $10^{-9}\ m$

(e) $10^{-23}\ m$

Q18. A quantum particle is confined in a one-dimensional box defined by the potential, $V(x)=0$ for $0<x<L$, and $+\infty$ otherwise. The particle is in the ground state. What is the probability (P_+) that an experimenter will find it moving along the positive x direction? What would be the magnitude of momentum (p) of that motion?

(a) $P_+=0$ and $p=0$ (b) $P_+=\frac{1}{2}$ and $p=\frac{\pi}{L}$

(c) $P_+=\frac{1}{2L}$ and $p=\frac{\pi}{L}$ (d) $P_+=\frac{1}{2}$ and $p=0$

(e) $P_+=0$ and $p=\frac{\pi}{L}$

Q19. Let ΔE_n be the energy difference between two adjacent energy levels (E_n and E_{n+1}) for an electron confined to an one-dimensional infinite potential well. The ratio $\frac{\Delta E_n}{E_n}$ in the limit of large quantum number n is given by

(a) $\frac{2}{n}$ (b) $\frac{1}{n}$ (c) $\frac{1}{n^2}$ (d) 0

(e) $2n^2$

Q20. A photon is Compton-scattered off a stationary electron through an angle of 45°. If it's final energy is half the initial energy, the value of the initial energy in MeV is closest to

(a) 1.75 (b) 1.94 (c) 2.46

(d) 0.18 (e) 0.62

Q21. The line integral $I=\int_{\Gamma} F\cdot dx$ of the vector field $F=yzi+zxj+xyk$ is evaluated along the curve Γ parameterized by $(x=a\sin t, y=b\cos t, z=c)$ where a,b and c are constants. The value of I for $\frac{\pi}{4}\le t\le\frac{3\pi}{4}$ is

(a) abc (b) ab (c) bc (d) ac

(e) 0

Q22. The general solution of the ordinary differential equation $\frac{d^2y}{dx^2}+y+1=0$ is (A and B being constants)

(a) x^2+Ax+B (b) $A(x-1)^3+B$

(c) $A\sin x$ (d) $A\sin(x+B)$

(e) $A\cos x+B\sin x-1$

Q23. What is the residue of the complex function $f(z)=\exp\left(\frac{1}{z}\right)$ at $z=0$?

(a) 1 (b) 0 (c) undefined (d) e

(e) ∞

Q24. Consider a monatomic ideal (Boltzmann) gas in which the atoms carry magnetic moment μ. The gas is placed in a magnetic field $B\hat{z}$ pointing up. At a given temperature T, what is the average energy per atom due to the interaction with the magnetic field?

(Hint: Take into account that a certain fraction of atoms will have magnetic moment pointing up and a certain fraction will have them pointing down)

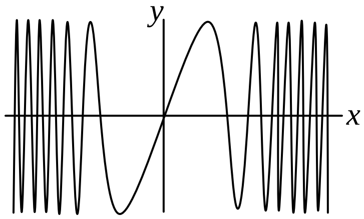
(a) $-\mu B\tanh\left(\frac{\mu B}{k_B T}\right)$ (b) $\mu B\tanh\left(\frac{\mu B}{k_B T}\right)$

(c) $-\mu B\sinh\left(\frac{\mu B}{k_B T}\right)$ (d) $\mu B\sinh\left(\frac{\mu B}{k_B T}\right)$

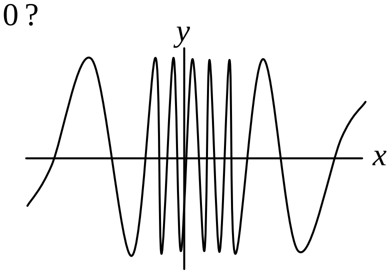
(e) $-\mu B\tan\left(\frac{\mu B}{k_B T}\right)$

Q25. Which of the following graphs gives the best schematic representation of the real-valued function $y = \sin(\sinh x)$ in an interval around $x = 0$?

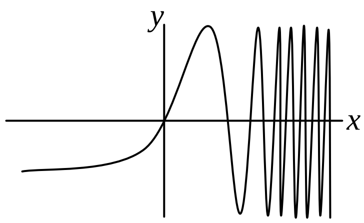
(a)



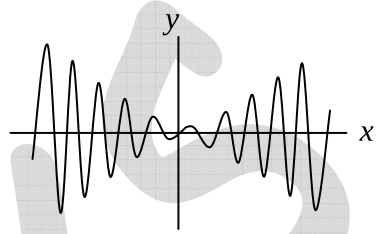
(b)



(c)



(d)



(e)