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EE24BTECH11034 - K Teja Vardhan

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1. An infinite solenoid carries a time-varying current $I(t) = At^2$, with $A \neq 0$. The axis of the solenoid is along the z direction. $\hat{r}$ and $\hat{\theta}$ are the usual radial and polar directions in cylindrical polar coordinates. $\vec{B} = B_r\hat{r} + B_\theta\hat{\theta} + B_z\hat{z}$ is the magnetic field at a point outside the solenoid.

   Which one of the following statements is true?

   (a) $B_r = 0, B_\theta = 0, B_z = 0$
   (b) $B_r \neq 0, B_\theta \neq 0, B_z = 0$
   (c) $B_r \neq 0, B_\theta \neq 0, B_z \neq 0$
   (d) $B_r = 0, B_\theta = 0, B_z \neq 0$

2. A uniform volume charge density is placed inside a conductor with resistivity 10^{-2} Ωm. The charge density becomes $1/2.718$ of its original value after time in femtoseconds $\left(\varepsilon_0 = 8.854 \times 10^{-12}\ \frac{F}{m}\right)$.

3. Water freezes at 0°C at atmospheric pressure 1.01×10^5 Pa. The densities of water and ice at this temperature and pressure are 1000 $\frac{kg}{m}^3$ and 934 $\frac{kg}{m}^3$ respectively. The latent heat of fusion is $3.34 \times 10^5\ \frac{J}{kg}$. The pressure required for depressing the melting temperature of ice by 10°C is in .

4. The minimum number of NAND gates required to construct an OR gate is:

   (a) 2
   (b) 4
   (c) 5
   (d) 3

5. Consider a 2-dimensional electron gas with a density of 10^{19} m^{-2}. The Fermi energy of the system is eV .

   $\left(m_e = 9.31 \times 10^{-31}\ \text{kg}, h = 6.626 \times 10^{-34}\ \text{Js}, e = 1.602 \times 10^{-19}\ \text{C}\right)$

6. The total energy of an inert-gas crystal is given by $E(R) = \dfrac{0.5}{R^{12}} - \dfrac{1}{R^6}$, where R is the inter-atomic spacing in Angstroms. The equilibrium separation between the atoms is Angstroms .

7. Consider N non-interacting, distinguishable particles in a two-level system at temperature T. The energies of the levels are 0 and ϵ, where $\epsilon > 0$. In the high temperature limit ($k_B T \gg \epsilon$), what is the population of particles in the level with energy ϵ?

   (a) $\frac{N}{2}$
   (b) N
   (c) $\frac{N}{4}$
   (d) $\frac{3N}{4}$

8. Consider a one-dimensional potential well of width 3 nm. Using the uncertainty principle $\left(\Delta x \Delta p \geq \frac{\hbar}{2}\right)$, an estimate of the minimum depth of the well such that it has at least one bound state for an electron is :

   (a) $1 \mu eV$
   (b) 1 meV
   (c) 1 eV
   (d) 1 MeV

9. A free electron of energy 1 eV is incident upon a one-dimensional finite potential step of height 0.75 eV. The probability of its reflection from the barrier is .

10. Consider a metal with free electron density of 6×10^{22} cm^{-3}. The lowest frequency electromagnetic radiation to which this metal is transparent is 1.38×10^{16} Hz. If this metal had a free electron density of 1.8×10^{23} cm^{-3} instead, the lowest frequency electromagnetic radiation to which it would be transparent is $\times 10^{16}$ Hz .

11. An object travels along the x-direction with velocity $\frac{c}{2}$ in a frame O. An observer in a frame $O^{'}$ sees the same object travelling with velocity $\frac{c}{4}$. The relative velocity of $O^{'}$ with respect to O in units of c is .

12. The integral $\int_0^\infty x^2 e^{-x^2} dx$ is equal to .

13. The imaginary part of an analytic complex function is $v(x, y) = 2xy + 3y$. The real part of the function is zero at the origin. The value of the real part of the function at $1 + i$ is .