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EE24BTECH11034 - K Teja Vardhan

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1. The electric field component of a plane electromagnetic wave traveling in vacuum is given by $E(z,t) = E_0 \cos(kz - \omega t)\,\hat{i}$. The Pointing vector for the wave is

   (a) $\left(\frac{c\epsilon_0}{2}\right) E_0^2 \cos^2(kz - \omega t)\,\hat{j}$

   (b) $\left(\frac{c\epsilon_0}{2}\right) E_0^2 \cos^2(kz - \omega t)\,\hat{k}$

   (c) $c\epsilon_0 E_0^2 \cos^2(kz - \omega t)\,\hat{j}$

   (d) $c\epsilon_0 E_0^2 \cos^2(kz - \omega t)\,\hat{k}$

2. Consider a system having three energy levels with energies $0, 2\epsilon$, and 3ϵ, with respective degeneracies of 2, 2, and 3. Four bosons of spin zero have to be accommodated in these levels such that the total energy of the system is 10ϵ. The number of ways in which it can be done is ___________

3. The Lagrangian of a system is given by

$$L = \frac{1}{2}ml^2\left(\dot{\theta}^2 + \sin^2\theta\dot{\phi}^2\right) - mgl\cos\theta,$$

   where m, l, and g are constants.

   Which of the following is conserved?

   (a) $\sin^2\theta$

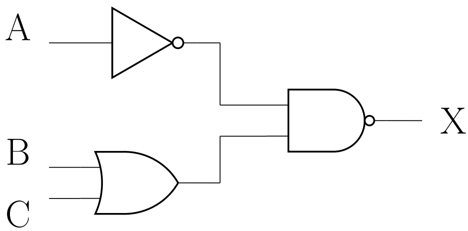
   (b) $\sin\theta$

   (c) $\frac{\phi}{\sin\theta}$

   (d) $\frac{\phi}{\sin^2\theta}$

4. Protons and α-particles of equal initial momenta are scattered off a gold foil in a Rutherford scattering experiment. The scattering cross sections for proton on gold and α-particle on gold are σ_p and σ_α, respectively. The ratio $\frac{\sigma_\alpha}{\sigma_p}$ is ___________

5. For the digital circuit given below, the output X is



(a) $\overline{A} + B \cdot C$

(b) $\overline{\overline{A}} \cdot (B + C)$

(c) $\overline{A} \cdot (B + C)$

(d) $A + (B \cdot C)$

6. The Fermi energies of two metals X and Y are 5 eV and 7 eV and their Debye temperatures are 170 K and 340 K, respectively. The molar specific heats of these metals at constant volume at low temperatures can be written as $(C_v)_X = \gamma_X T + A_X T^3$ and $(C_v)_Y = \gamma_Y T + A_Y T^3$, where γ and A are constants. Assuming that the thermal effective mass of the electrons in the two metals are same, which of the following is correct?

(a) $\frac{\gamma_X}{\gamma_Y} = \frac{7}{5}, \frac{A_X}{A_Y} = 8$

(b) $\frac{\gamma_X}{\gamma_Y} = \frac{7}{5}, \frac{A_X}{A_Y} = 1$

(c) $\frac{\gamma_X}{\gamma_Y} = \frac{5}{7}, \frac{A_X}{A_Y} = 8$

(d) $\frac{\gamma_X}{\gamma_Y} = \frac{5}{7}, \frac{A_X}{A_Y} = \frac{1}{8}$

7. A two-level system has energies zero and E. The level with zero energy is non-degenerate, while the level with energy E is triply degenerate. The mean energy of a classical particle in this system at a temperature T is

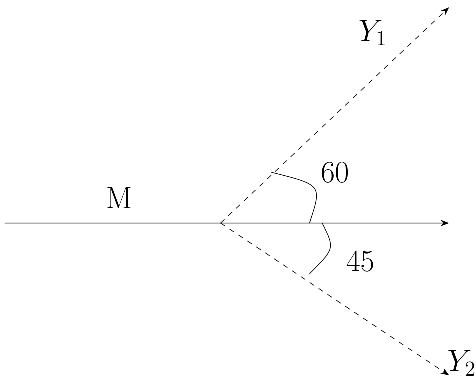
(a) $\frac{Ee^{-\frac{E}{k_B T}}}{1+3e^{-\frac{E}{k_B T}}}$

(b) $\frac{Ee^{-\frac{E}{k_B T}}}{1+e^{-\frac{E}{k_B T}}}$

(c) $\frac{3Ee^{-\frac{E}{k_B T}}}{1+e^{-\frac{E}{k_B T}}}$

(d) $\frac{3Ee^{-\frac{E}{k_B T}}}{1+3e^{-\frac{E}{k_B T}}}$

8. A particle of rest mass M is moving along the positive x-direction. It decays into two photons γ_1 and γ_2 as shown in the figure. The energy of γ_1 is 1 GeV and the energy of γ_2 is 0.82 GeV. The value of M in units of $\frac{GeV}{c^2}$ is ____________.



9. If x and p are the x components of the position and the momentum operators of a particle respectively, the commutator $\left[x^2, p^2\right]$ is

   (a) $i\hbar\,(xp - px)$
   (b) $2i\hbar\,(xp - px)$
   (c) $i\hbar\,(xp + px)$
   (d) $2i\hbar\,(xp + px)$

10. The xy plane is the boundary between free space and a magnetic material with relative permeability μ_r. The magnetic field in the free space is $\vec{B}_1 = B_1\hat{i} + B_2\hat{k}$. The magnetic field in the magnetic material is

    (a) $B_1\hat{i} + B_2\hat{k}$
    (b) $\mu_r B_1\hat{i} + \mu_r B_2\hat{k}$
    (c) $\frac{1}{\mu_r}B_1\hat{i} + B_2\hat{k}$
    (d) $B_1\hat{i} + \frac{1}{\mu_r}B_2\hat{k}$

11. Let $|l, m|$ be the simultaneous eigenstates of L^2 and L_z. Here L is the angular momentum operator with Cartesian components (L_x, L_y, L_z), l is the angular momentum quantum number and m is the azimuthal quantum number. The value of $|1,0|\,(L_x + iL_y)\,|1,-1|$ is

    (a) 0
    (b) $\hbar$
    (c) $\sqrt{2}\hbar$
    (d) $\sqrt{3}\hbar$

12. For the parity operator P, which of the following statements is **NOT true**?

    (a) $P' = P$

(b) $P^2 = -P$

(c) $P^2 = I$

(d) $P' = P^{-1}$

13. For the transistor shown in the figure, assume $V_{BE} = 0.7\,\text{V}$ and $\beta_{dc} = 100$. If $V_{in} = 5\,\text{V}$, V_{out} is ____________.