Assignment-8

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I. Questions with one mark each

1) The electric field of an electromagnetic wave is given by $\mathbf{E} = 3\sin(kz - \omega t)\,\hat{x} + 4\cos(kz - wt)\,\hat{y}$. The wave is

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a) linearly polarized at an angle $\tan^{-1}\frac{4}{3}$ from the x-axis
b) linearly polarized at an angle $\tan^{-1}\frac{3}{4}$ from the x-axis
c) eliptically polarized in clockwise direction when seen travelling towards the observer
d) eliptically polarized in counter-clockwise direction when seen travelling towards the observer

2) The nuclear spin and parity of ${}^{40}_{20}Ca$ in its ground state is

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a) 0^+
b) 0^-
c) 1^+
d) 1^-

3) An infinitely long cylindrical shell has its axis coinciding with the z-axis. It carries a surface charge density $\sigma_0 \cos\phi$, where ϕ is the polar angle and σ_0 is a constant. The magnitude of electric field inside the cylinder is

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a) 0 b) $\frac{\sigma_0}{2\epsilon}$ c) $\frac{\sigma_0}{3\epsilon}$ d) $\frac{\sigma_0}{4\epsilon}$

4) Consider a three-dimensional crystal of N inert gas atoms. The total energy is given by $U(R) = 2N\epsilon\left[p\frac{\sigma}{R}^{12} - q\frac{\sigma}{R}^{6}\right]$, where p=12.13, q=14.45 and R is the nearest neighbour distance between two atoms. The two constants ϵ and R, have the dimensions of energy and length, respectively. The equilibrium separation between two nearest neighbour atoms in units of (rounded off to two decimal places) is

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5) The energy-wavevector $(E - k)$ dispersion relation for a particle in two dimensions is $E = Ck$, where C is a constant. If its density of states $D(E)$ is proportional to E^p then the value of p is _____

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6) A circular loop made of a thin wire has radius 2 cm and resistance 2 Ω. It is placed perpendicular to a uniform magnetic field of magnitude $|B| = 0.01$ Tesla. At time $t = 0$ the field starts decaying as $\mathbf{B} = \mathbf{B}_0 e^{t/t_0}$, where $t_0 = 1s$.The total charge that passes through a cross section of the wire during the decay is Q. The value of Q in μC (rounded off to two decimal places) is _____

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7) The electric field of an electromagnetic wave in vacuum is given by

$$\mathbf{E} = E_0 \cos\left(3y + 4z - 1.5 \times 10^9 l\right)\hat{x}$$

The wave is reflected from $z = 0$ surface. If the pressure exerted on the surface is $\alpha\epsilon_0 E_0^2$, the value of α (rounded off to one decimal place) is _____

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8) The Hamiltonian for a quantum harmonic oscillator of mass m in three dimensions is

$$H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 r^2$$

where ω is the angular frequency. the expectation of r^2 in the first excited state of the oscillator in units of $\frac{\hbar}{m\omega}$ (rounded off to one decimal place) _____

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9) The Hamiltonian for a particle of mass m is $H = \frac{p^2}{2m} + kqt$ where q and p are the generalized coordinate and momentum, respectively, t is time and k is a constant. For the initial condition, $q = 0$ and $p = 0$ at $t = 0$, $q(t) \propto t^{\alpha}$. The value of α is _____

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10) At temperature T Kelvin (K), the value of the Fermi function at an energy 0.5 eV above the Fermi energy is 0.01. Then T, to the nearest integer, is _____ ($k_B = 8.62 \times 10^{-5}$ eV/K)

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11) Let $|\psi_1\rangle = \binom{1}{0}$, $|\psi_2\rangle = \binom{0}{1}$ represent two possible states of a two-level quantum system. The state obtained by the incoherent superposition $|\psi_1\rangle$ and $|\psi_2\rangle$ is given by a density matrix that is defined as $\rho \equiv c_1|\psi_1\rangle\langle\psi_1 + c_2|\psi_2\rangle\langle\psi_2|$. If $c_1 = 0.4$ and $c_2 = 0.6$, the matrix element ρ_{22} (rounded off to one decimal place) is _____

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12) A conventional type-I superconductor has a critical temperature of 4.7 K at zero magnetic field and a critical magnetic field of 0.3 Tesla at 0 K. The critical field in Tesla at 2 K (rounded off to three decimal places) is_____

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II. Questions with two marks each

1) Consider the following Boolean expression:

$$\left(\overline{A} + \overline{B}\right)\left[\overline{A\,(B + C)}\right] + A\left(\overline{B} + \overline{C}\right)$$

It can be represented by a single three-input logic gate. Identify the gate.

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a) AND b) OR c) XOR d) NAND