

# 2007-PH

EE24BTECH11027 - satwikagv

1) An electromagnetic wave with  $\mathbf{E}(z, t) = E_0 \cos(\omega t - kz)\hat{i}$  is traveling in free space and crosses a disc of radius 2 m placed perpendicular to the z-axis. If  $E_0 = 60 \text{Vm}^{-1}$ , the average power, in Watt, crossing the disc along the z-direction is

- a) 30                      b) 60                      c) 120                      d) 270

2) Can the following scalar and vector potentials describe an electromagnetic field?

$$\phi(\vec{x}, t) = 3xyz - 4t$$

$$\mathbf{A}(\vec{x}, t) = (2x - \omega t)\hat{i} + (y - 2z)\hat{j} + (z - 2xe^{i\omega t})\hat{k}$$

where  $\omega$  is a constant.

- a) Yes, in the Coulomb gauge.                      c) Yes, provided  $\omega = 0$ .  
b) Yes, in the Lorentz gauge.                      d) No.

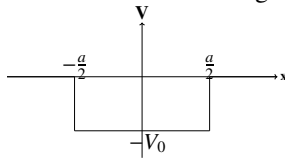
3) For a particle of mass  $m$  in a one-dimensional harmonic oscillator potential of the form  $V(x) = \frac{1}{2}m\omega^2 x^2$ , the first excited energy eigenstate is  $\psi(x) = xe^{-ax^2}$ . The value of  $a$  is

- a)  $\frac{m\omega}{4\hbar}$                       b)  $\frac{m\omega}{3\hbar}$                       c)  $\frac{m\omega}{2\hbar}$                       d)  $\frac{2m\omega}{3\hbar}$

4) If  $[x, p] = i\hbar$ , the value of  $[x^3, p]$  is

- a)  $2i\hbar x^2$                       b)  $-2i\hbar x^2$                       c)  $3i\hbar x^2$                       d)  $-3i\hbar x^2$

5) There are only three bound states for a particle mass  $m$  in a one-dimensional potential well of the form shown in the figure. The depth  $V_0$  of the potential satisfies



- a)  $\frac{2\pi^2\hbar^2}{ma^2} < V_0 < \frac{9\pi^2\hbar^2}{4ma^2}$                       c)  $\frac{2\pi^2\hbar^2}{ma^2} < V_0 < \frac{8\pi^2\hbar^2}{ma^2}$   
b)  $\frac{\pi^2\hbar^2}{ma^2} < V_0 < \frac{2\pi^2\hbar^2}{ma^2}$                       d)  $\frac{2\pi^2\hbar^2}{ma^2} < V_0 < \frac{50\pi^2\hbar^2}{ma^2}$

6) An atomic state of hydrogen is represented by the following wavefunction:

$$\psi(r, \theta, \phi) = \frac{1}{\sqrt{2}} \left( \frac{1}{a_0} \right)^{\frac{3}{2}} \left( 1 - \frac{r}{2a_0} \right) e^{-\frac{r}{2a_0}} \cos \theta.$$

where  $a_0$  is a constant. The quantum numbers of the state are

a)  $l = 0, m = 0, n = 1$

c)  $l = 1, m = 0, n = 2$

b)  $l = 1, m = 1, n = 2$

d)  $l = 2, m = 0, n = 3$

7) Three operators  $X, Y$  and  $Z$  satisfy the commutation relations

$$[X, Y] = i\hbar Z, [Y, Z] = i\hbar X, [Z, X] = i\hbar Y.$$

The set of all possible eigenvalues of the operator  $Z$ , in units of  $\hbar$ , is

a)  $\{0, \pm 1, \pm 2, \pm 3, \dots\}$

c)  $\{0, \pm \frac{1}{2}, \pm 1, \pm \frac{3}{2}, \pm 2, \pm \frac{5}{2}, \dots\}$

b)  $\{\frac{1}{2}, 1, \frac{3}{2}, 2, \frac{5}{2}, \dots\}$

d)  $\{-\frac{1}{2}, \frac{1}{2}\}$

8) A heat pump working on the Carnot cycle maintains the inside temperature of a house at  $22^\circ\text{C}$  by supplying  $450\text{kJ s}^{-1}$ . If the outside temperature is  $0^\circ\text{C}$ , the heat taken, in  $\text{kJ s}^{-1}$ , from the outside air is approximately

a) 487

b) 470

c) 467

d) 417

9) The vapour pressure  $p$  (in mm of Hg) of a solid, at temperature  $T$ , is expressed by  $\ln p = 23 - \frac{3863}{T}$  and that of its liquid phase by  $\ln p = 19 - \frac{3063}{T}$ . The triple point (in Kelvin) of the material is

a) 185

b) 190

c) 195

d) 200

10) The free energy of a photon gas is given by  $F = -\left(\frac{a}{3}\right)VT^4$ , where  $a$  is a constant. The entropy  $S$  and the pressure  $P$  of the photon gas are

a)  $S = \frac{4}{3}aVT^4, P = \frac{a}{3}T^4$

c)  $S = \frac{4}{3}aVT^4, P = \frac{a}{3}T^3$

b)  $S = \frac{1}{3}aVT^4, P = \frac{4a}{3}T^3$

d)  $S = \frac{1}{3}aVT^4, P = \frac{4a}{3}T^4$

11) A system has energy levels  $E_0, 2E_0, 3E_0, \dots$ , where the excited states are triply degenerate. Four non interacting bosons is  $5E_0$ , the number of microstates is

a) 2

b) 3

c) 4

d) 5

12) In accordance with the selection rules for electric dipole transitions, the  $4^3P_1$  state of helium can decay by photo emission to the states

a)  $2^1S_0, 2^1P_1$  and  $3^1D_2$

c)  $3^3P_2, 3^3P_0$  and  $3^3D_3$

b)  $3^1S_0, 3^1P_1$  and  $3^1D_2$

d)  $2^3S_1, 3^3D_2$  and  $3^3D_1$

13) If an atom is in the  $^3D_3$  state, the angle between the its orbital and spin angular momentum vectors ( $\mathbf{L}$  and  $\mathbf{S}$ ) is

- a)  $\cos^{-1} \frac{1}{\sqrt{3}}$       b)  $\cos^{-1} \frac{2}{\sqrt{3}}$       c)  $\cos^{-1} \frac{1}{2}$       d)  $\cos^{-1} \frac{\sqrt{3}}{2}$

14) The hyperfine structure of  $Na(3^2P_{\frac{3}{2}})$  with nuclear spin  $I = \frac{3}{2}$  has

- a) 1 state      b) 2 states      c) 3 states      d) 4 states

15) The allowed rotational energy levels of a rigid hetero-nuclear diatomic molecule are expressed as  $\epsilon_j = BJ(J+1)$ , where  $B$  is the rotational constant and  $J$  is a rotational quantum number.

In a system of such diatomic molecules of reduced mass  $\mu$ , some of the atoms of one element are replaced by a heavier isotope, such that the reduced mass is changed to  $1.05\mu$ . In the rotational spectrum of the system, the shift in the spectral line, corresponding to a transition  $J = 4 \rightarrow J = 5$ , is

- a)  $0.475 B$       b)  $0.50 B$       c)  $0.95 B$       d)  $1.0 B$

16) The number of fundamental vibrational modes of  $CO_2$  molecule is

- a) four: 2 are Raman active and 2 are infrared active.  
b) four: 1 are Raman active and 3 are infrared active.  
c) three: 1 are Raman active and 2 are infrared active.  
d) three: 2 are Raman active and 1 are infrared active.

17) A piece of paraffin is placed in a uniform magnetic field  $H_0$ . The sample contains hydrogen nuclei of mass  $m_p$ , which interact only with external magnetic field. An additional oscillating magnetic field is applied to observe resonance absorption. If  $g_I$  is the  $g$ -factor of the hydrogen nucleus, the frequency, at which resonance absorption takes place, is given by

- a)  $\frac{3g_I e H_0}{2\pi m_p}$       b)  $\frac{3g_I e H_0}{4\pi m_p}$       c)  $\frac{g_I e H_0}{2\pi m_p}$       d)  $\frac{g_I e H_0}{4\pi m_p}$