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

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

36) Can the following scalar and vector potentials describe an electromagnetic field?
$\phi(\bar{x},t) = 3xyz - 4t$
$\bar{A}(\bar{x},t) = (2x - \omega t)\,\hat{i} + (y - 2z)\,\hat{j} + \left(z - 2xe^{i\omega t}\right)\hat{k}$
where ω is a constant.

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

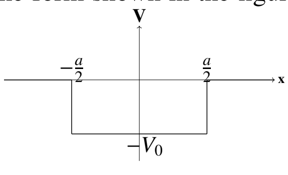
37) For a particle of mass m in a one-dimensional harmonic oscillator potential of the form $V(x) = \frac{1}{2}m\omega^2 x^2$, the first excited energy eigenstate is $\psi(x) = xe^{-ax^2}$. The value of a is

a) $m\omega/4\hbar$ b) $m\omega/3\hbar$ c) $m\omega/2\hbar$ d) $2m\omega/3\hbar$

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

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

39) 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) $\frac{2\pi^2 h^2}{ma^2} < V_0 < \frac{9\pi^2 h^2}{ma^2}$
b) $\frac{\pi^2 h^2}{ma^2} < V_0 < \frac{2\pi^2 h^2}{ma^2}$
c) $\frac{2\pi^2 h^2}{ma^2} < V_0 < \frac{8\pi^2 h^2}{ma^2}$
d) $\frac{2\pi^2 h^2}{ma^2} < V_0 < \frac{50\pi^2 h^2}{ma^2}$

40) An atomic state of hydrogen is represented by the following wavefunction:
$\psi(r,\theta,\phi) = \frac{1}{\sqrt{2}}\left(\frac{1}{a_0}\right)^{\frac{3}{2}}\left(1 - \frac{r}{2a_0}\right)e^{-r/2a_0}\cos\theta.$
where a_0 is a constant. The quantum numbers of the state are

a) $l = 0, m = 0, n = 1$
b) $l = 1, m = 1, n = 2$
c) $l = 1, m = 0, n = 2$
d) $l = 2, m = 0, n = 3$

41) 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) $\{0, \pm 1, \pm 2, \pm 3, \ldots\}$
b) $\left\{\frac{1}{2}, 1, \frac{3}{2}, 2, \frac{5}{2}, \ldots\right\}$
c) $\left\{0, \pm\frac{1}{2}, \pm 1, \pm\frac{3}{2}, \pm 2, \pm\frac{5}{2}, \ldots\right\}$
d) $\left\{-\frac{1}{2}, \frac{1}{2}\right\}$

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

a) 487
b) 470
c) 467
d) 417

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

a) 185
b) 190
c) 195
d) 200

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

45) A system has energy levels $E_0, 2E_0, 3E_0, \ldots,$ 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

46) 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$3\,^1D_2$
b) $3\,^1S_0, 3\,^1P_1$ and$3\,^1D_2$
c) $3\,^3P_2, 3\,^3P_0$ and$3\,^3D_3$
d) $2\,^3S_1, 3\,^3D_2$ and$3\,^3D_1$

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

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

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

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

49) The allowed rational 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 μ, some of the atoms of one element are replaced by a heavier isotope, such that the reduced mass is changed to 1.05μ. In the rotational spectrum of the system, the shift in the spectral line, corresponding to a transition $J = 4 \to J = 5$, is

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

50) 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.

51) 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_l is the g-factor of the hydrogen nucleus, the frequency, at which resonance absorption takes place, is given by

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