PH2201 Physics IV

Mid-Semester Examination (Total: 20 marks)

Write only your answer (any *one* of the choices A, B, C or D) for each question next to the "Answer:" below that question. Date: February 22, 2019

Name: **Roll No.:**

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1. The raising (a_+) and lowering (a_-) operators of the 1D harmonic oscillator with mass m and frequency ω are defined as $a_\pm = \frac{1}{c_1}(\mp ip + m\omega x)$, where c_1 is a constant. By using the commutation relations $[x, p] = i\hbar$ and $[a_-, a_+] = 1$, what is the form obtained for the constant c_1? (4 marks)

   A. $(2\hbar m\omega)^{1/2}$

   B. $\sqrt{\frac{2\hbar}{m\omega}}$

   C. $\sqrt{\frac{m\omega}{2\hbar}}$

   D. $(2\hbar m\omega)^{-1/2}$

   Answer:

2. Spectral lines corresponding to radiation emitted due to a transition between the m^{th} and n^{th} levels of the Bohr atom is $\lambda^{-1} = R(n^{-1} - m^{-1})$, where the Rydberg constant $R = 1.1 \times 10^7 m^{-1}$. What is the frequency ν of the radiation for $n = 4$ and $m = 5$? (3 marks)

   A. $\nu = 1.65 \times 10^{16} s^{-1}$

   B. $\nu = 1.65 \times 10^{14} s^{-1}$

   C. $\nu = 3.3 \times 10^{14} s^{-1}$

   D. $\nu = 3.3 \times 10^{16} s^{-1}$

   Answer:

3. In conditions ideally suited to observing quantum effects, we wish to conduct a Young's double-slit experiment with a human of mass 80 kgs moving towards a wall with two doors spaced apart by 1m. What is the kinetic energy required for such a person? $h = 6.626 \times 10^{-34} J\leq$ (4 marks)

   A. 2.45×10^{-67} J

   B. 6.78×10^{-68} J

   C. 3.54×10^{-70} J

   D. 2.74×10^{-69} J

   Answer:

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4. ψ_1 and ψ_2 are eigenstates of operator $\hat{A}$ (observable A) with eigenvalues a_1 and a_2 respectively. ϕ_1 and ϕ_2 are eigenstates of operator $\hat{B}$ (observable B) with eigenvalues b_1 and b_2. The two sets of eigenstates are related according to the relations $\psi_1 = (3\phi_1 + 4\phi_2)/5$, $\psi_2 = (4\phi_1 - 3\phi_2)/5$. If the eigenstates ϕ_1 and ϕ_2 are normalized and orthogonal, what results do you find for the quantities $|\psi_1|^2$, $|\psi_2|^2$, $\psi_1^*\psi_2$ and $\psi_2^*\psi_1$? (4 marks)

   A. 1,1,0,0

   B. 0,1,0,1

   C. 1,0,0,1

   D. 0,0,1,1

   Answer:

5. The eigenfunctions of the 1D particle in a box problem of length a are given by $\psi_n = \sqrt{\frac{2}{a}}\sin(\frac{n\pi x}{a})$ What are the energy eigenvalues (E_n) obtained from the Schroedinger equation? (3 marks)

   A. $\frac{\hbar n\pi}{a}$

   B. $\frac{\hbar^2 n^2 \pi^2}{2ma^2}$

   C. $\frac{\hbar^2 a^2 \pi^2}{2mn^2}$

   D. $\frac{2m\hbar^2}{2\pi a^2}$

   Answer:

6. The Universe is filled with blackbody radiation at a temperature $T = 2.7K$. From the relation for the total energy density of blackbody radiation $\rho = aT^4$ (where $a = 7.56 \times 10^{-16}\mathrm{Jm^{-2}K^{-4}}$), what is the total energy density of the CMBR? (2 marks)

   A. $\rho = 2.04 \times 10^{-15} Jm^{-2}$

   B. $\rho = 5.51 \times 10^{-15} Jm^{-2}$

   C. $\rho = 4.01 \times 10^{-14} Jm^{-2}$

   D. $\rho = 3.65 \times 10^{-14} Jm^{-2}$

   Answer: