國立成功大學

112學年度碩士班招生考試試題

編　號：40

系　所：光電科學與工程學系

科　目：近代物理

日　期：0207

節　次：第 1 節

備　註：不可使用計算機

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※ 考生請注意：本試題不可使用計算機。　請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. (9%) Please illustrate the following terminologies.
   (a) Compton effect
   (b) Photoelectric effect
   (c) Correspondence principle

2. (12%) Black body radiation
   (a) In the Rayleigh-Jeans theory for black body radiation, the energy E is a continuous variable. Considering the Boltzmann probability distribution $\mathrm{P(E)} = Ae^{-E/kT}$, please prove the average total energy is kT, in which A is a constant, k is Boltzmann's constant, and T is temperature.
   (b) Write Plank's postulate and drive the average total energy at the frequency ν in the Plank theory.
   (c) Plot the Rayleigh-Jeans spectrum and Plank's spectrum in a figure, and compare the spectra as $\nu \to \infty$ and in the low frequency.

3. (14%) Particles and waves
   (a) Assuming that the kinetic energies of the electron and α particle are the same, please find the ratio of de Broglie wavelength between the electron and α particle.
   (b) A stone of mass m is dropped from the height of S to hit a target in the floor. Based on the uncertainty principle, show that the stone will miss the crack by an average distance of the order of $(\hbar/m)^{1/2}(S/g)^{1/4}$, where g is the acceleration due to gravity and $\hbar$ is the Plank's constant dividing by 2π.

4. (15%) Consider the potential

$$\mathrm{V(x)} = \begin{cases} 0, & x < 0 \\ V_1, & 0 \le x \le a \\ V_2, & x > a \end{cases}$$

   where $0 < V_1 < V_2$ and a particle of total energy $E > V_2$ approaching $x = 0$ in the direction of increasing x. Obtain the solution to the time independent Schroedinger equation. Further, show that its probability of passing into the region $x > a$ is unity if a equals an integral or half-integral number of de Broglie wavelengths in the region $0 \le x \le a$.

5. (15%) An electron in the Coulomb field of a proton is in a state described by the wave function

$$\frac{1}{6}\left[4\Psi_{100}(\vec{r}) + 3\Psi_{211}(\vec{r}) - \Psi_{210}(\vec{r}) - \sqrt{10}\Psi_{2,1,-1}(\vec{r})\right]$$

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[$\Psi_{nlm}(\vec{r})$ is the eigenfunction of H with eigenvalue $-\frac{13.6}{n^2}eV$]

(a) What is the expectation value of the energy?

(b) What is the expectation value of L^2?

(c) What is the expectation value of L_z?

6. (10%) The density of states gives the number of allowed electron (or hole) states per volume at a given energy. It is essential for determining the carrier concentrations and energy distributions of carriers within a semiconductor Please derive the expressions for the density of states for the electron gas in two dimensional system $D(E)_{2D}$.

7. (10%) Energy level diagram and Laser

(a) Please use the energy level diagram to explain the "absorption", "stimulated emission", and "spontaneous emission".

(b)What are the advantages of a four-level laser over a three-level laser?

8. (10%) According to quantum mechanics, electromagnetic radiation of frequency υ can be regarded as consisting of photons of energy $h\upsilon$.

[Planck's constant $h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s}$]

(a) What is the energy range of visible photons (400 nm to 700 nm)?

(b) At a given power of an electromagnetic wave, do you expect a classical wave description to work better for radio frequencies, or X-rays? Why?

9. (5%) The 2022 Nobel prizes in Physics was awarded for developments in quantum mechanics. Please describe briefly the significant achievements and their possible applications.