考試科目	普通物理(二)	所別	應用物理研究所 (8162) (8163)	考試時間	3月 6日(六)第四節

1. [*20 points*] **Short Answer Questions**

   (a) What emit electromagnetic radiation?

   (A) steady electric currents

   (B) rotating electric charges

   (C) oscillating electric dipoles

   (b) Which has more energy, a photon of ultraviolet radiation or a photon of infrared radiation?

   (c) An x-ray photon is scattered by an electron. What happens to the frequency of the scattered photon relative to that of the incident photon?

   (d) What is a scanning tunneling microscope (STM)? Explain how it works.

2. [*12 points*] **Electrostatics**

   A spherically symmetric charge distribution with total charge Q has charge density $\rho \propto 1/r$ for $r < R$ and $\rho = 0$ otherwise. Find the electric field and the electric potential everywhere in space (for $r \leq R$ and $r > R$). Take the potential to be zero at $r = \infty$.

3. [*12 points*] **Maxwell's equations**

   (a) A physicist claims to have found magnetic field lines as shown in Fig. 1. Is this finding consistent with Maxwell's equations? Justify your answer.

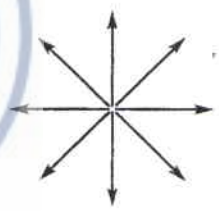

Fig. 1

   (b) Write the continuity equation expressing (local) charge conservation. Explain why the original form of Ampère's law, which does not include the displacement current term, contradicts the continuity equation.

4. [*9 points*] **Polarization of Light**

   Consider two beams of light, (A) and (B), described as follows:
   (A) a beam of fully linearly polarized light with the polarization direction making an angle of 45° with the vertical axis (the y axis); (B) an equal mixture of vertically polarized light (polarized in y) and horizontally polarized light (polarized in x).
   How would you design an experiment to distinguish these two beams?

5. [*10 points*] **Interference**

   Two waves of the same frequency ω are described by

$$\boldsymbol{E}_1(\boldsymbol{r},t) = \boldsymbol{E}_0 e^{i(\boldsymbol{k}_1\cdot\boldsymbol{r}-\omega t+\phi_1)}$$
$$\boldsymbol{E}_2(\boldsymbol{r},t) = \boldsymbol{E}_0 e^{i(\boldsymbol{k}_2\cdot\boldsymbol{r}-\omega t+\phi_2)},$$

   where the amplitude $\boldsymbol{E}_0$ and the wave vectors $\boldsymbol{k}_1$, $\boldsymbol{k}_2$ are constant real vectors. Determine the condition for constructive interference when the two waves are superposed.

備註	試題隨卷繳交

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6. [*15 points*] **Relativity**

(a) State the postulates upon which Einstein based his special theory of relativity.

(b) Maxwell's wave equation for the z-component of an electric field, E_z, propagating in the x-direction is

$$\frac{\partial^2 E_z(x,t)}{\partial x^2} - \frac{1}{c^2}\frac{\partial^2 E_z(x,t)}{\partial t^2} = 0,$$

where c is the speed of light. Is this equation invariant under a Galilean transformation to a reference frame moving with relative speed v in the x direction? Clearly show how you derive your answer.

7. [*12 points*] **Quantum Physics**

The figures below (Fig. 2) show normalized real wave functions at a certain time, plotted as $\psi(x)$ versus x, for a quantum particle confined to the one-dimensional region $-1 \le x \le 1$:

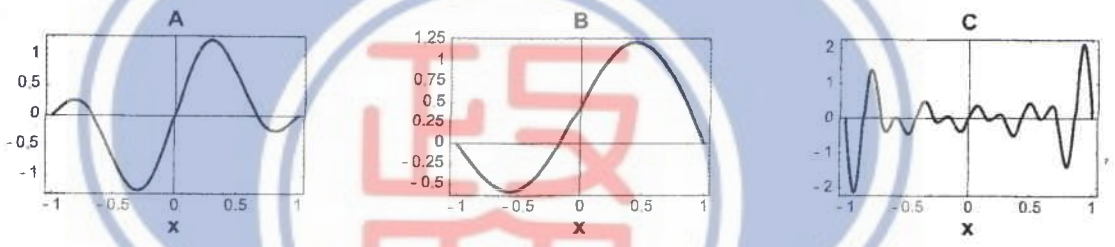

Fig. 2

(a) Which wave function (A, B, or C) will yield the largest expectation value of the position $\langle x \rangle$? Briefly give your reason.

(b) Which wave function (A, B, or C) will yield the largest value for $\langle x^2 \rangle$? Briefly give your reason.

8. [*10 points*] **Prerequisite Mathematics**

(a) Diagonalize the following matrix:

$$\begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}.$$

(b) Consider the differential equation

$$\frac{d^2 f(x)}{dx^2} + k^2 f(x) = 0, \quad \text{with } k > 0,$$

which satisfies the boundary conditions:

$$f(0) = f(\pi) = 0.$$

Find the condition for k such that this boundary value problem has a non-zero solution.

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