Indian Association for the Cultivation of Science
(Deemed to be University under *de novo* Category)

Master's/Integrated Master's-PhD Program/Integrated Bachelor's-Master's Program/PhD Course

Mid-Semester Examination - Spring 2024

Subject: Electricity, Magnetism and Optics | **Subject Code(s): PHS1201**
Full Marks: 25 | **Time Allotted: 2hr**

Instructions

(a) Attempt any **five** questions.

(b) For most of the questions the algebra will be self-explanatory; when some interpretation/description is needed, you can keep it brief but clear. There is no need to provide extensive description.

(c) The marks for each question is given against the question. If you find that you cannot answer part (a), say, of a question but can answer part (b) *assuming the result in part (a)*, you may do so and you will get credit for part (b).

1. *This question is about a plane EM wave from the sun, detected in your lab coordinate frame as* $\vec{A} = \vec{A}_0 \cos(\omega t - ky)$. *Answer each question below on this wave, carefully.*

   (a) What is the phase velocity of this wave? **(1 mark)**

   (b) In the lab frame, write down the explicit vector form of the amplitude $\vec{A}_0$ of the vector potential, i.e., in the form $\vec{A}_0 = A_{0x}\vec{e}_x + A_{0y}\vec{e}_y + A_{0z}\vec{e}_z$, where you clearly indicate which components are non-zero. **(1 mark)**

   (c) Using the equation $\vec{E} = -\partial\vec{A}/\partial t$ for the $\vec{E} - field$, what are the explicit components of this field, for this EM wave, in the lab frame? **(1 mark)**

   (d) Using the formula $\vec{B} = \nabla \times \vec{A}$ for the magnetic field $\vec{B}$, obtain the expression for the components of this field, for this EM wave, in the lab frame. **(1 mark)**

   (e) Calculate $\vec{E} \cdot \vec{B}$ for this EM wave. **(1 mark)**

2. *This question is about a point particle with charge* q, *and mass* m, *in this EM wave*

   (a) What should be the velocity of the particle such that it's magnetic potential energy is unaffected by its interaction with the wave? **(1 mark)**

   (b) If the particle moves with the velocity $\vec{v} = v_0\vec{e}_x$ in the lab frame, before it meets the wave, where v_0 is a constant, draw diagrams showing how it's velocity direction changes instantaneously in the lab frame, at the moment when it meets (a) the $\vec{E}$ field and (b) the $\vec{B}$, field due to the wave. **(2 marks)**

   (c) Calculate the net, instantaneous vector acceleration of the particle after it meets the wave, clearly showing it's components. **(2 marks)**

3. (a) In a Newton's ring experiment, the rings are formed using a source of light which has two wavelengths λ_1 and λ_2. If mth order dark ring due to λ_1 coincides with the $(m+1)$th order dark ring due to λ_2, prove that the radius of mth dark ring of λ_1 is equal to $\sqrt{\lambda_1\lambda_2 R/(\lambda_1 - \lambda_2)}$. Here R is the radius of curvature of the lower surface. **(2 marks)**

   (b) Consider a double slit experiment with a light containing two wavelengths 450 nm and 600 nm respectively. Find the least order at which a maximum of one wavelength falls exactly on a minimum of the other. **(3 marks)**

4. Suppose you have placed two polarizers at 90^o between their pass axis. Another polarizer is placed between them, which is rotated at a constant angular velocity ω about their common central axis. If un-polarized light of intensity I_0 is incident on the first polarizer, then what is the intensity of the transmitted light? **(5 marks)**

5. (a) Both Prism and diffraction grating disperse electromagnetic waves of different wavelengths. Compare their dispersive powers. **(2 marks)**

   (b) If we double the width of each slit in a diffraction grating, how will the diffraction pattern, as seen in the screen, changes? **(3 marks)**

6. Derive the lens equation for a thin lens using the Fermat's principle. **(5 marks)**