Roll No.:

National Institute of Technology Delhi

B. Tech. (End-semester Examination, Feb. 2023)

Branch: ECE

Semester: 1^{st}

Title of the Course: Engineering Physics

Course Code: PHB101

Time: 3 Hours

Max. Marks: 50

Note: Attempt all questions. No unnecessary explanation is required in any question. **Please attempt all the questions in sequence only**. Assume suitable data, if found missing. Used symbols have their usual meaning.

Section-A (10 questions of 1 mark each. For multiple choice questions, only one choice is correct and no explanation is required. No negative marking)

A1. Which of these properties is not associated with the space derivatives of valid quantum mechanical wavefunction:

(a) Continuous **(b)** Normalized **(c)** Dispersive **(d)** Finite

A2. Which of these does not fit well with the particle nature of light:

(a) Diffraction **(b)** Photo-electric effect **(c)** Daune-Hunt law **(d)** Compton shift

A3. An electron has a momentum of 2 MeV/c. Its total energy will be:

(a) 0.511 MeV **(b)** 2 MeV **(c)** 2 .511 MeV **(d)** 2.064 MeV

A4. Which of these is not an example of Fraunhofer diffraction:

(a) Diffraction grating **(b)** Single-slit **(c)** Circular aperture **(d)** None of these

A5. The angle at which a light (propagating in air) ray be entirely polarized when reflected from surface of a glass (refractive index = 1.520)?

(a) 53.1° **(b)** 46.3° **(c)** 56.7° **(d)** 90°

A6. In a wedge-shape film interference experiment, which of these options is not true:

(a) Wedge inclination is of extremely small magnitude **(b)** Medium corresponding to wedge-shape film can be air

(c) Fringe pattern cannot be observed for a broadband light source **(d)** The fringes obtained are of equal thickness

A7. The color of the threshold wavelength for potassium with work-function 2.2 eV is:

(a) Blue **(b)** Violet **(c)** Yellow **(d)** Red

A8. Why would the intensity become half when unpolarized light is passed through a polaroid filter?

A9. Write down the expression and defining statement of Poynting's theorem for EM waves.

A10. Discuss the resolving power of a diffraction grating.

Section-B (5 questions of 2 marks each)

B1. A parallel beam of light of wavelength 500 nm is incident on a slit of width 0.2 mm. The Fraunhofer diffraction is observed on a screen placed at a focal plane of the convex lens of focal length 20 cm. Calculate the approximate distance between first two maxima. (*Draw suitable optical diagram for clear description of your answer*)

B2. Apply uncertainty principle to estimate the minimum energy of an electron in an atom of radium 53 pm.

B3. An electron is described by the following wave-function:

$$\psi(x) = \begin{cases} 0 & for\ x < 0 \\ Ce^{-x}(1 - e^{-x}) & for\ x > 0 \end{cases}$$

where 'x' is in nm and 'C' is a constant. Determine the value of 'C' that normalizes $\psi(x)$.

B4. The intensity of central maximum for a diffraction transmission grating is 10^6 times the incident intensity. The same grating can just resolve two nearby wavelengths in first order diffraction maxima. If one of those wavelengths is 400 nm then find out the possible value(s) of other wavelength. Provide appropriate justification to your answer.

B5. Write the energy values (in eV) for first 3 levels (n = 1, 2, and 3) of an electron in an infinite potential well of width 0.5 nm. Using Heisenberg uncertainty principle, discuss if these three energy levels of a finite potential well (width = 0.5 nm, potential energy outside well = 25 eV) will have lower or higher values compared to those of infinite potential well mentioned above.

Section-C (5 questions of 6 marks each)

C1. (a) From a Newton's rings experiment set-up (operated with a 500 nm wavelength source), the user had provided that the ratio of 9^{th} dark ring diameter (when the experiment is carried out in Gas-1) to 7^{th} bright ring diameter (when the experiment is carried out in Gas-2) is 1.23416. Find out the refractive index of Gas-2 with reference to Gas-1. (Write your answer upto 4 decimal places) (3)

(b) A beam of Light (λ = 550 nm) is incident on a slit of width 2 μm. If the intensity of central maximum is I_0, then determine the intensity at a point halfway between first two minima on the right side of central maximum. (*Show the corresponding optical diagram*) (3)

C2. (a) Discuss Compton's effect with appropriate diagram and equation (No derivation required). (2)

(c) An electromagnetic beam of wavelength 7.5 pm is scattered from an electron. Find out:

(i) Calculate the Compton wavelength of electron. (1)

(ii) Wavelength of the beam scattered at 45° (w.r.to incident direction) (1)

(iii) Maximum possible wavelength in the scattered beam. (1)

(iv) Maximum possible kinetic energy of the recoiled electron. (1)

C3. Write short notes on the following topics (with diagram): (3 + 3)

(*i*) Davisson-Germer Experiment (*ii*) Band theory of solids

C4. (a) Using the differential forms of Maxwell's equations in free space, prove that the speed of an electromagnetic wave in free space is equal to the speed of light in vacuum. (3)

(b) What should be the refractive index (upto 5 decimal places) and minimum thickness (in nm) of a material to be coated atop a flint glass lens (refractive index = 1.66 at λ = 500 nm) placed in H_2 gas environment (refractive index = 1.05 at λ = 500 nm) so that the structure can be used as a non-reflecting one? Provide appropriate justification to your answer. (3)

C5. (a) The differential form of Ampere's law is given by $\nabla \times \mathbf{B} = \mu_0 \mathbf{J}$, where **B** and **J** represent the magnetic field and current density, respectively. Discuss the modification required in above equation for non-steady currents and find out the modified Ampere's law. Provide a physical interpretation to this modified equation. (3)

(b) A magnetic field is applied to a circular loop (radius = a) of current-carrying wire. Further, the magnetic field direction is perpendicular to the plane of this loop. If the field follows a time-dependent variation as $B(t) = B_0 + bt$, then find out: (1 + 1 + 1)

(a) Magnetic flux across loop at t = 0 **(b)** Induced *emf* **(c)** Power dissipated due to loop resistance (R)

(**Given:** B_0 and b are positive constants)