INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR
End-Autumn Semester 2019-20

Date of Examination: 22.11.2019 Session: AN Duration: 3Hrs Full Marks: 50
Subject No. : PH11001 Subject Name: PHYSICS
Department/Center/School: PHYSICS

Special Instructions:
*For the objective questions in PART-A, write only the correct option against the question number on the **first-page** of your answer booklet. Answers of the objective questions, written elsewhere will not be evaluated! In your answer script PART B and C must be separated. The values of useful physical constants are supplied at the end of the question paper.*

PART A (Objective Type Questions)

[Marks: 8×2 = 16]

Q1.

(i) A light wave falls normally to the surface of a glass block placed in the air. If the refractive index of the glass block is 1.5 then find out the ratio of reflectance (R) to transmittance (T) of the glass block. You can assume the refractive index of air is 1.

(a) 0.0417 (b) 0.0628 (c) 0.0791 (d) 0.0918

(ii) Interference pattern is obtained in Young's double slit experiment first with a monochromatic light of wavelength 650 nm and then 500 nm. Find out the ratio of the order of maxima of the two fringe patterns that will occur at the same angular displacement from the centre of the double slit.

(a) 5:13 (b) 10:13 (c) 10:26 (d) 5:26

(iii) A monochromatic light with a wavelength of λ = 600 nm passes through a single slit which has a width of 0.8 mm. If the screen is 1.6 meter away from the slit then calculate the width of the central maxima.

(a) 0.8 mm (b) 1.4 mm (c) 2.4 mm (d) 3.2 mm

(iv) A light wave of wavelength 600 *nm* falls on a transparent block from air with an angle of refraction 30°. If the reflected ray is completely polarized then find out the refractive index of the transparent block.

(a) 1.33 (b) 1.48 (c) 1.59 (d) 1.73

(v) Given that the de-Broglie wavelength of an electron and the wavelength of a photon are equal. If p is the momentum of the electron, E is the energy of the photon and c is the velocity of light, the magnitude of pc/E is:

(a) 1 (b) 2 (c) 10^{-8} (d) 10^{8}

(vi) Electrons are ejected from a photoelectric cell with a maximum kinetic energy of 1.20 eV. If the incident light has a wavelength of 400 nm, the work function of the metal is approximately:

(a) 1.3 eV (b) 2.9 eV (c) 1.8 eV (d) 3.2 eV

(vii) Which of the following functions would make satisfactory bound state wave functions for all values of the position r $(= \sqrt{x^2 + y^2 + z^2})$ where N and a are constants:

(a) N (b) Ne^{r^2/a^2} (c) $Ne^{ir/a}$ (d) $Ne^{-x/a}e^{-r^2/a^2}$

(viii) For a particle in an infinite square potential well, number of 'nodes' (zero crossing points) of the 5th excited state wave function is,

(a) 4 (b) 5 (c) 6 (d) 10

PART B (Subjective Type Questions)

Q2. (i) The ratio of the electric fields of two interfering coherent beam is α. Find out the visibility (V) of the fringes in terms of α.

(ii) Consider that a monochromatic source of light passes through three parallel slits, each separated by a distance d from its neighbour. The three waves have same amplitude E_o and angular frequency ω. Show that the resultant intensity at some point P on the screen can be written as, $I \propto \left[1 + 2\cos(k\Delta)\right]^2$, where $k = \frac{2\pi}{\lambda}$ and $\Delta = d\sin\theta$. The point P subtends an angle θ with the normal from the central slit.

[Marks: 3+4=7]

Q3. (i) A thin film of refractive index 1.33 and thickness 500 nm is exposed to white light (400-700 nm). Which wavelengths of the reflected beam, in the visible region, will interfere constructively? You can assume that the light falls normally to the surface of the thin film.

(ii) There is a shift of 10 fringes when a thin film of refractive index 1.5 is introduced in one of the arms of a Michelson interferometer. Calculate the thickness of the inserted thin film if the wavelength of the light used in the experiment is 600 *nm*.

(iii) In Newton's ring experiment the radius of the 4^{th} dark ring is found to be 6 *cm*. What will be the radius of 9^{th} dark ring?

[Marks: 2.5+2.5+2=7]

Q4. (i) The electric field components of a plane electromagnetic wave ($\vec{E}$) are given as, $E_x = \sqrt{3}E_0 \cos(kz - \omega t - \phi)$ and $E_y = E_0 \sin(kz - \omega t)$. If $\phi = \frac{\pi}{2}$ then find the angle between the electric filed $\vec{E}$ and x-axis.

(ii) Consider a double slit experiment with a monochromatic light of wavelength 600 *nm*. The individual slit width and separation between two slits are 0.1 *mm* and 0.4 *mm* respectively. If the interference pattern is formed 1 *meter* away from the double slit then find out the distance between the central maxima and second "*missing order*".

[Marks: 2+4=6]

PART C (Subjective Type Questions)

Q5. (a) For a hydrogen atom, write down the energy expression of n^{th} orbit in terms of it's ionization potential.

(b) For the Balmer series in hydrogen atom *i.e.*, the atomic transitions where final state of the electron is $n = 2$, what is the longest and the shortest wavelength in *nano-meter* unit? The ground state energy of the electron in hydrogen atom is given by -13.6 *eV*.

(c) In a Compton scattering experiment, the x-ray scatters by an angle of 60° and suffers a wavelength shift of 1.2×10^{-12} *meter*. Determine the wavelength shift if the x-ray scatters by an angle of 90°.

[Marks: 1+4+2=7]

Q6. (a) A wave function is given by $\psi(x) = A\,x\,(a - x)$ with $0 \le x \le a$. $\psi(x) = 0$ for other values of x.

(i) Normalize this wave function to find out the value of the constant A.
(ii) Calculate the expectation value of the position ($\hat{x}$) for this wavefunction.

(b) An electron trapped in an infinite square well potential suffers an energy change E in a transition from $n=5$ to $n=3$ energy level. What will be energy change (in terms of E) if the electron subsequently makes a transition from $n=3$ to the ground state?

[Marks: (2+2)+3=7]