Question Paper

Exam Date & Time: 05-May-2018 (09:30 AM - 12:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

INTERNATIONAL CENTRE FOR APPLIED SCIENCES
END-SEMESTER THEORY EXAMINATION- MAY 2018
DATE:05.05.2018
TIME:09.30AM TO 12.30PM

Physics - I [PH 111]

Marks: 100 **Duration: 180 mins.**

Answer 5 out of 8 questions.

<u>PHYSICAL CONSTANTS</u>

Elementary charge e = 1.602×10^{-19}C

Electron constant $m_e = 9.11 \times 10^{-31}$kg

Boltzmann constant k = 1.38×10^{-23} J/K

Planck's constant h = 6.626×10^{-34} Js

Speed of light in vacuum c = 3×10^{8} m/s

Stefan – Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ W/m^{2}K^4

Wein's displacement constant b = 2.89×10^{-3} mK

Avogadro number NA = 6.023×10^{23}

1)

A) (i) What is interference of light waves? (ii) Draw a schematic plot of the intensity of light in double-slit interference against phase-difference. (4)

B) Derive an expression for intensity of diffraction pattern in the case of single-slit, using phasor diagram. (8)

C) (8)

(i) Find graphically the resultant E(t) of the following wave disturbances.

$E_1 = E_0 \sin \omega t$

$E_2 = E_0 \sin (\omega t + 15^o)$

$E_3 = E_0 \sin (\omega t + 30^o)$

$E_4 = E_0 \sin (\omega t + 45^o)$

(ii) A 0.880 MeV photon is scattered by a free electron initially at rest such that the scattering angle of the scattered electron is equal to that of the scattered photon ($\theta = \phi$). (a) Determine the angles θ & ϕ. (b) Determine the energy and momentum of the scattered electron and photon.

2) A) Explain the following terms with reference to lasers: (4)
(i) Population inversion
(ii) Metastable state

B) Explain the formation of Newton's rings and hence obtain an expression for the radius of m^{th} order bright ring. (8)

C) (i) Electrons are ejected from a metallic surface with speeds up to 4.60×10^5 m/s when light with a wavelength of 625 nm is used. (a) What is the work function of the surface? (b) What is the cut-off frequency for this surface? (8)
(ii) A 0.00160 nm photon scatters from a free electron. For what photon scattering angle does the recoiling electron have kinetic energy equal to the energy of the scattered photon?

3) A) (i) Explain Rayleigh-Jeans law. (4)
(ii) With reference to Rayleigh - Jeans law, explain 'ultraviolet catastrophe'.

B) Explain construction and working of ruby laser with necessary diagrams. (8)

C) (8)

(i) An FM radio transmitter has a power output of 150 kW and operates

(i) An FM radio transmitter has a power output of 150 kW and operates at a frequency of 99.7 MHz. How many photons per second does the transmitter emit?

(ii) A step index optical fibre 63.5 μm in core-diameter has a core of refractive index 1.53 and a cladding of index 1.39. Determine (a) the numerical aperture for the fibre, (b) the critical angle for core-cladding interface, (c) the acceptance cone half-angle (the maximum entrance angle) (d) the number of reflections in 1.0 m length of the fibre for a ray at the maximum entrance angle.

4) A) (i) Define Fermi energy level and write the expression for Fermi-Dirac distribution function. (4)

(ii) Sketch schematically the plots of Fermi function for zero kelvin and for temperature above zero kelvin.

B) Assuming the Fermi-Dirac distribution function, obtain an expression for the density of free-electrons in a metal with Fermi energy E_F, at zero K and, hence obtain expression for Fermi energy E_F in a metal at zero K. [Given: density-of-states function $g(E)dE = \frac{8\sqrt{2}\,\pi\, m^{3/2}}{h^3} E^{1/2}\, dE$] (8)

C) (i) An electron with kinetic energy E = 5.0 eV is incident on a barrier with thickness L = 0.20 nm and height U = 10.0 eV. What is the probability that the electron (a) Will tunnel through the barrier? (b) Will be reflected? (8)

(ii) Electrons are incident on a pair of narrow slits 0.060 μm apart. The 'bright bands' in the interference pattern are separated by 0.40 mm on a 'screen' 20.0 cm from the slits. Determine the potential difference through which the electrons were accelerated to give this pattern.

5) A) (i) Write the equations for uncertainty in (a) position and momentum (b) energy and time. (4)

(ii) What is diffraction grating? Write the grating equation.

B) What is quantum tunneling? Give a brief account of tunneling of a particle through a potential energy barrier. (8)

C) (i) Calculate, approximately, the relative (with respect to central maxima) intensities of the first three maxima in the single-slit diffraction pattern. (8)

(ii) A diffraction grating has 10^4 rulings uniformly spaced over 25.0mm. It is illuminated at normal incidence by yellow light from sodium vapor lamp which contains two closely spaced lines of wavelengths 589.00nm and 589.59nm. (a) At what angle will the first order maximum occur for the first of these wavelengths? (b) What is the angular separation between the first order maxima of these lines?

6) A) (i) Sketch schematically the graph of wavelength vs intensity of radiation from a blackbody. (4)

(ii) Explain (a) Stefan's law (b) Wien's displacement law

B) By solving the Schrödinger equation, obtain the wave-functions for a particle of mass m in a one-dimensional "box" of length L. (8)

C) (i) A converging lens 32mm in diameter has a focal length f of 24 cm. (a) What angular separation must two distant point objects have to satisfy Rayleigh's criterion? Assume that l = 550nm. (b) How far apart are the centers of the diffraction patterns in the focal plane of the lens? (8)

(ii) An electron is confined between two impenetrable walls 0.20 nm apart. Determine the energy levels for the states n =1 ,2 , and 3.

7) A) (i) Briefly explain BCS theory of superconductors. (4)

(ii) With necessary diagrams, explain doping in semiconductors.

B) Derive an expression for density-of-states. (8)

C) (i) Each atom of gold (Au) contributes one free-electron to the metal. The concentration of free-electron in gold is $5.90 \times 10^{28}/m^3$. Compute the Fermi Energy of gold. (8)

(ii) (a) Using the simple model of a particle in a box to represent an atom, estimate the energy (in eV) required to raise an atom from the state n =1 to the state n =2. Assume the atom has a radius of 0.10 nm and that the moving electron carries the energy that has been added to the atom. (b) Atoms may be excited to higher energy states by absorbing photon energy. Calculate the wavelength of the photon that would cause the transition from the state n =1 to the state n =2.

8) A) (i) Sketch intensity pattern for (a) Two-slit diffraction (b) Five-slit diffraction (4)

(ii) What is a wave function ? What is its physical interpretation ?

B) The wave function for H-atom in ground state is $\psi_{1s}(r) = \frac{1}{\sqrt{\pi a_0^3}} \exp\left(-\frac{r}{a_0}\right)$. Obtain an expression for the radial probability density of H-atom in ground state. Sketch schematically the plot of this vs. radial distance. (8)

C) (i) A glass optical fibre of refractive index 1.450 is to be clad with another to ensure total internal reflection that will contain light traveling within 5Â° of the fibre-axis. What maximum index of refraction is allowed for the cladding? (8)
(ii) A He-Ne laser emits light at a wavelength of 632.8 nm and has an output power of 2.3 mW. How many photons are emitted each minute by this laser when operating ?

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