B.Sc. Part-III (Honours) Examination, 2020

Subject: Physics

Paper: IX

(Old Syllabus)

Time: 2 Hours **Full marks: 50**

The figures in the margin indicate full marks
Candidates are required to give their answers in their own words
as far as practicable.

Group-A

Answer *any three (03)* questions: 10×3=30

1. (a) Compton scattering takes place between a photon of wavelength λ and an electron of mass *m*, which is at rest in the laboratory frame. If $\lambda^{/}$ is the wavelength of the photon after the scattering, find an expression of ($\lambda^{/}$- λ) in terms of the scattering angle φ.

(b) If the value of $\lambda^{/}$ with $\varphi=120^0$ is twice of that with $\varphi=60^0$, what is the value of λ in nanometer?

(c) Find the value of Compton wavelength. 10

2. (a) An inertial frame $O^{/}$ has velocity (v, 0, 0) with respect to another inertial frame O. If ($x^{/}$, $y^{/}$, $z^{/}$, $t^{/}$) and (x, y, z, t) are the space-time co-ordinates of an event in $O^{/}$ and O respectively. Write the equations which connect these two sets of co-ordinates.

(b) Using the equations in (a), obtain (i) the aberration of light from a distant star in terms of the earth's velocity v_e, (ii) the frequency $\nu^{/}$ of a light pulse received in $O^{/}$, which has been transmitted in O with frequency ν. 10

3. A one-dimensional square well potential barrier of height V_0 and length *a* is defined by,

$$\begin{aligned} V_0(x) &= 0 && \text{for } x < 0 && \textit{(Region I)} \\ &= V_0 && \text{for } 0 \le x \le a && \textit{(Region II)} \\ &= 0 && \text{for } x > a && \textit{(Region III)} \end{aligned}$$

Find the expressions for the reflection and the transmission co-efficient for E< V_0. Hence plot transmission coefficient with the energy of the particle. (E indicates the energy of the particle). 10

P. T. O.

4. (a) Write down the Schrödinger equation for the hydrogen atom in spherical polar coordinates, with the coulomb potential.

(b) Separate the equation in (a) by the standard procedure into three equations corresponding to the coordinates r, θ and φ.

(c) What are the possible values of the l and m_l, quantum numbers when the principal quantum number n =3? 10

5. (a) Draw a simple schematic diagram of the Geiger-Müller counter with necessary connections for detection and counting the radioactive radiation. Briefly describe different parts.

(b) Draw the characteristic curve for the Geiger-Müller counter showing the plateau region. Briefly discuss how the shape of the curve arises.

(c) What is the necessity of quenching? Describe how quenching can be achieved using the quenching agent in a self-quenching counter. 10

Group-B

Answer *any four (04)* questions: 5×4=20

1. Consider the hydrogen atom placed in an external, uniform, weak magnetic field **B** along the z-axis. Taking into account the spin of the electron and the spin-orbit interaction, show that the magnetic energy of the atom, when itS total angular momentum quantum number is j, is $g_j m_j B \mu_B$, where g_j is the Lande's g-factor, m_j is the angular momentum projection quantum number and μ_B is the Bohr magneton. 5

2. (a) Derive an expression for the rotational energy levels of a diatomic molecule in terms of the rotational quantum number J and the moment of inertia I about an axis passing through the center of mass and perpendicular to a line joining the atoms.

(b) Given the value of I, for CO is 1.46×10^{-46} Kg m^2, find the lowest rotational energy of this molecule in electron-volt.

3. The frame $O^{/}$ moves with respect to the frame O in the positive x-direction with uniform velocity v. Obtain the Lorentz transformation equations involving the components of the electric and magnetic fields in these two frames of reference.

P. T. O.

4. (a) Write the one-dimensional time-independent Schrödinger equation with potential V(x) for two energy eigen values E_n, E_k and corresponding eigen functions ψ_n and ψ_k.

(b) Using these two equations show that

(i) the energy eigen values are real,

(ii) different energy eigen functions are orthogonal. 5

5. Consider the states ψ_{em} and $(L_x + iL_y)\psi_{em}$ as the simultaneous eigen states of both the operators L^2 and L_z ($\vec{L}$ is the orbital angular momentum). If the eigen values of L^2 and L_z for ψ_{em} are $l(l+1)\hbar^2$ and $m\hbar$ respectively, then find the corresponding eigen values of the state $(L_x + iL_y)\psi_{em}$. (Symbols have their usual significance)

6. (a) Why is the α or the β-disintegration of a nucleus usually followed by the emission of one or more γ-rays?

(b) In the case of interaction of γ-rays with matter, what kind of atomic electrons are emitted as photoelectrons? Give reasons for your answer.

(c) What is the minimum energy of a γ-ray photon, which can create an electron-hole pair? Why is the pair creation not possible in vacuum? 5