

M.Sc. Examination 2018

Semester – III

Physics

Course: MPC-32

(Classical Electrodynamics & Plasma Physics-II)

Time: Three Hours

Full Marks: 40

Questions are of value as indicated in the margin.

Answer *any four* questions.

1. (a) Define the 4-velocity U^μ and 4-acceleration A^μ and obtain the mathematical expressions for them.

(b) Calculate $U^\mu U_\mu$, $A^\mu A_\mu$ and $U^\mu A_\mu$.

(c) The co-ordinate of a particle in an inertial frame S is given as, $x(t) = at + b \sin(\omega t)$, $y(t) = b \cos(\omega t)$, $z(t) = 0$. Calculate the particle's 4-velocity and 4-acceleration. **4+3+3**

2. (a) Consider the Compton scattering where an incoming photon of frequency ν strikes a stationary electron of rest mass m . The outgoing photon has a frequency ν' which recoils at an angle θ with the incoming direction. Derive a formula for the Compton shift using the principle of 4-momentum conservation.

(b) Justify if the following process is possible in free space, $e + \gamma \rightarrow e$ i.e. can an electron absorb a single photon with nothing else around.

(c) Consider an electro-magnetic 4-vector potential, $A^\mu = (0, 0, 0, a \cos(kx - \omega t))$ where a is a constant and k and ω have their usual meanings. Calculate $F_{\mu\nu}$ and $F_{\mu\nu} F^{\mu\nu}$. **3+3+4**

3. A line charge with density λ is distributed along the x axis in a frame S at rest.

(a) Calculate the electric field and magnetic field at any point due to it in S .

(b) Now consider an observer in S' frame which is moving with velocity $\vec{v} = v\hat{x}$. Calculate the electric and magnetic fields in the S' frame.

(c) Consider another observer in a frame S'' which is moving with velocity $\vec{v} = -v\hat{z}$. Calculate the electric and magnetic fields in the S'' frame. **2+4+4**

4. (a) Consider a point charge moving with relativistic velocity. Calculate the power radiated per unit solid angle $\frac{dP}{d\Omega}$ when the velocity and the acceleration of the point charge are perpendicular to each other.

(b) A point particle with charge q and rest mass m moves in a synchrotron under the action of an uniform magnetic field B . Show that if the speed v of the charge particle is assumed to be constant then the energy lost in electromagnetic radiation per revolution is, $\frac{\mu_0 |q|^3 \gamma^3 B v^2}{3mc}$.

(c) Consider a short dipole antenna carrying an alternating current $I = I_0 e^{-i\omega t}$. Find the total power radiated by this antenna. **4+3+3**

5. (a) Consider the Rayleigh scattering of an electromagnetic wave with $\vec{E}(\vec{r}, t) = E_0 e^{i(kz - \omega t)} \hat{x}$ by a bound electron of charge e , mass m and natural frequency ω_0 . Calculate the differential scattering cross section and the total scattering cross section.

(b) An electron is accelerated to 20 keV energy between anode and cathode separated by a distance of 5 cm . Find the total energy lost in radiation. **6+4**

6. (a) Calculate the Lienard-Wiechart potentials for a moving point charge using relativity.
(b) Consider an arbitrary distribution of charges and currents where the charge and current densities vary harmonically in time with angular frequency ω as, $\rho(\vec{r}, t) = \rho(\vec{r})e^{-i\omega t}$ and $\vec{J}(\vec{r}, t) = \vec{J}(\vec{r})e^{-i\omega t}$. Show that the dipole contribution to the vector potential in the far field or radiation zone is $\vec{A} = \frac{\mu_0}{4\pi r} \dot{\vec{p}}$, where \vec{p} is the dipole moment of the charge distribution. **5+5**
7. (a) Consider the motion of a charged particle in an axisymmetric magnetic field. Show that the magnetic moment of the charged particle remains invariant along the particle orbit.
(b) Explain the curvature drift.
(c) Why a curvature drift is always accompanied by a $\vec{\nabla}|\vec{B}|$ drift?
(d) Can the curvature drift and the $\vec{\nabla}|\vec{B}|$ drift occur in the same direction? **5+2+2+1**
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