REV-01
MSP/01/05

2023/06

SET A

M.Sc. PHYSICS
SECOND SEMESTER
ELECTROMAGNETICS & PLASMA PHYSICS
MSP – 201 [REPEAT]

[USE OMR FOR OBJECTIVE PART]

Duration: 3 hrs. **Full Marks: 70**

Objective

Time: 30 min. **Marks: 20**

Choose the correct answer from the following: ***1X20=20***

1. Maxwell predicted the existence of electromagnetic waves from
   a. the relation $\nabla \cdot \overline{D} = \rho$
   b the relation $\nabla \cdot \overline{B} = 0$
   c. the two curl equations
   d. the continuity equation

2. For frequencies below the cut-off frequency for a particular mode, the $\overline{E}$ and $\overline{B}$ fields in a wave guide are_____with respect to distance along the direction of propagation of electromagnetic waves within the wave guide.
   a. Exponentially increasing fields
   b. Linearly increasing fields
   c. Linearly decreasing fields
   d. Exponentially attenuated fields

3. Which of the following relation is not correct? (The symbols have their usual meaning)
   a. $\nabla \cdot \overline{B} = 0$
   b. $\nabla \times \overline{E} = 0$
   c. $\nabla \cdot \overline{E} = \frac{\rho}{\varepsilon}$
   d. $\nabla \times \overline{H} = \overline{J} + \frac{\partial \overline{D}}{\partial t}$

4. In the relation $\overline{B} = \nabla \times \overline{A}$, $\overline{A}$ is called ($\overline{B}$ being magnetic flux density)
   a. Scalar potential
   b. Magnetic vector potential
   c. Electric field
   d. Magnetic field

5. Bremsstrahlung is a German word meaning
   a. Continuous radiation
   b. Strong radiation
   c. Weak radiation
   d. Braking radiation

6. Cerenkov radiation occurs when a charged particle passes through a dielectric medium with velocity_____the velocity of light in the medium.
   a. Greater than
   b. Smaller than
   c. Much smaller than
   d. Very much smaller than

7. When electromagnetic waves of wavelength in the visible region passes normally from air to glass, reflection coefficient R and transmission coefficient T are
   a. R=0, T=1
   b. R=0.1, T=0.9
   c. R=0.04, T=0.96
   d. R=0.5, T=0.5

8. Radiation fields ($\bar{E}$ & $\bar{H}$) of electric dipole radiation vary with distance r as
   a. $1/r$
   b. $1/r^2$
   c. $1/r^3$
   d. $1/r^4$

9. Electromagnetic wave tend to be scattered the most by an object that is
   a. Magnetic
   b. Reflective
   c. Conducting
   d. Same size as the wave

10. The day time sky is blue, on sunny days, because the atmosphere
   a. Is most efficient in scattering red light
   b. Absorb blue light
   c. Is more efficient in scattering blue light
   d. Absorb red light

11. The variation of refractive index of the medium with wavelength constitute the phenomena of
   a. Scattering
   b. Polarization
   c. Dispersion
   d. Reflection

12. Refractive index of a material is approximately equal to the square root of
   a. Electric permittivity
   b. Magnetic permeability
   c. Electric permittivity x magnetic permeability
   d. None

13. The number of atoms in a Debye sphere N_D is related to the Debye shielding length λ_D as
   a. $N_D \propto \lambda_D$
   b. $N_D \propto \sqrt{\lambda_D}$
   c. $N_D \propto \lambda_D^3$
   d. $N_D \propto 1/\lambda_D^3$

14. Suppose we have a vacuum chamber with electric field $E = 1\ kVm^{-1}$ perpendicular to magnetic field $B = 1\ mT$. The $E \times B$ drift speed for an electron inside the chamber is
   a. $10^6\ m/s$
   b. $10^3\ m/s$
   c. $1\ m/s$
   d. $10^{-3}\ m/s$

15. Drift of a gyrating particle in crossed gravitational and magnetic fields depends on the ratio
   a. $\frac{mv_\perp^2}{q}$
   b. $\frac{2mv_\perp^2}{q}$
   c. $\frac{m}{q}$
   d. $\frac{q}{m}$

16. For an ion acoustic wave, the phase velocity v_{ph} and group velocity v_g are related as
   a. $v_{ph} > v_g$
   b. $v_{ph} < v_g$
   c. $v_{ph} = v_g$
   d. $v_{ph} = -v_g$

17. The Alfven waves in a compressible, conducting fluid of density ρ_m immersed in a magnetic field of strength B_0 is given by (symbols have their usual meanings)

a. $v_A = \sqrt{\frac{B_0}{\mu_0 \rho_m}}$
b. $v_A = \frac{B_0}{\sqrt{\mu_0 \rho_m}}$
c. $v_A = \frac{\rho_m}{\sqrt{\mu_0 B_0}}$
d. $v_A = \frac{1}{\mu_0}\sqrt{\frac{B_0^2}{\rho_m^2}}$

18. In a magnetic field of intensity B_0 the magnetic stress experienced by the plasma particles is equivalent to a tension (symbols have their usual meanings)

a. B_0^2/μ_0
b. $B_0^2/2\mu_0$
c. $\sqrt{B_0^2/\mu_0}$
d. $B_0/\sqrt{\mu_0 \varepsilon_0}$

19. Consider an infinite cylindrical column of conducting fluid plasma with axial current density $J_z(r)\hat{z}$ and a resulting azimuthal magnetic induction $B_\theta(r)\hat{\theta}$. The force which produces radial constriction of the plasma column is the

a. centrifugal force
b. $q(\vec{v} \times \vec{B})$ force
c. $\nabla \vec{B}$ force
d. $\vec{J} \times \vec{B}$ force

20. In 4-vector notation, the continuity equation can be written as (where A^μ and J^μ are the magnetic vector potential and current density respectively)

a. $\partial_\mu^2 A^\mu = -\mu_0 J^\mu$
b. $\partial_\mu J^\mu = 0$
c. $\partial_\mu A^\mu = 0$
d. $\partial_\mu J^\mu = -\frac{\rho}{\epsilon_0}$

-- --- --

Descriptive

Time: 2 hrs. 30 min. **Marks: 50**

[Answer question no.1 & any four (4) from the rest]

1. **a.** Show that the dispersion relation for electron plasma wave is given by 8+2=10

$$\omega^2 = \omega_p^2 + \frac{3}{2} K_B^2 v_{th}^{2h}$$

Hence show the graphical representation of the variation of plasma frequency ω with wave vector k. (symbols have their usual meanings)

b. How does the dispersion relation for electron plasma wave differ from that for ion acoustic waves?

2. **a.** In a magnetic mirror, the trajectory of a charged particle makes an angle θ_0 with the magnetic field line. Show that the mirror ratio R_m is given by 6+2+2 =10

$$\frac{1}{R_m} = \frac{B_0}{B_m} = \sin^2 \theta_m.$$

Here $B_0$is the strength of the magnetic field at the centre and $B_m$is the strength of the magnetic field at the throat of the magnetic mirror system.

b. A plasma with an isotropic velocity distribution is placed in a magnetic mirror trap with mirror ratio $R_m = 4$. Find the value of pitch angle θ_m.

c. Electron plasma waves are propagated in a uniform plasma with $K_B T_e = 100\ eV$, $n = 10^8\ m^{-3}$ and $M = M_H = 1.67 \times 10^{-27}\ kg$. If frequency f is 1.1 GHz, what is the wavelength in cm? (symbols have their usual meanings)

3. **a.** Starting from electromagnetic field tensor $G^{\mu\nu}$, derive Maxwell's second equation $\vec{\nabla}.\vec{B} = 0$. 6+4=10

b. Show that the equation $\vec{\nabla}.\vec{B} = 0$ is Lorentz invariant.

4. **a.** Derive the differential scattering cross section formula for the scattering of electromagnetic waves by a free electron. 7+3=10

b. Explain normal and anomalous dispersion of electromagnetic waves.

5. a. TEM waves cannot propagate within a single-conductor waveguide- Justify. **4+6=10**

b. For TE_{mn} mode propagating within a single-conductor waveguide, obtain an expression for the corresponding cut-off frequency.

6. For electromagnetic radiation from an oscillating electric dipole, obtain an expression for the total power radiated. Hence explain the blueness of the sky. **8+2=10**

7. a. The reflection of electromagnetic waves at the surface of a perfect conductor show that the wave is totally reflected with a 180^0 phase shift. **8+2= 10**

b. Justify-excellent conductors make good mirrors.

8. a. Consider two concentric spherical conducting shells separated by a perfect dielectric material and kept at two different electrostatic potentials. Obtain expressions for potential and electric field at a point within the dielectric. Hence obtain an expression for the capacitance of the system when radius of the outer shell tends to infinity. **4+2+4=1 0**

b. What do you mean by retarded potential? Explain obtaining the necessary relation for it.

= = *** = =