

M.Sc. PHYSICS  
FIRST SEMESTER  
ELECTRODYNAMICS  
MSP – 104

**SET  
A**

[USE OMR FOR OBJECTIVE PART]

Duration: 1:30 hrs.

Full Marks: 35

( Objective )

Time: 15 mins.

Marks: 10

Choose the correct answer from the following:

1×10=10

1. The potential for a quadrupole goes like (at large distances)

- |    |                        |    |                        |
|----|------------------------|----|------------------------|
| a. | $V \sim \frac{1}{r}$   | b. | $V \sim \frac{1}{r^2}$ |
| c. | $V \sim \frac{1}{r^3}$ | d. | $V \sim \frac{1}{r^4}$ |

2. In 2D, the Laplace's equation reads as (symbols have their usual meanings)

- |    |   |    |   |
|----|---|----|---|
| a. | $\frac{\partial V}{\partial x} + \frac{\partial V}{\partial y} = 0$                           | b. | $\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} = 0$               |
| c. | $\frac{\partial^2 V}{\partial x \partial y} + \frac{\partial^2 V}{\partial y \partial x} = 0$ | d. | $\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} = \rho/\epsilon_0$ |

3. If  $V$  has azimuthal symmetry, it will be independent of

- |    |        |    |                       |
|----|--------|----|-----------------------|
| a. | $r$    | b. | $\theta$              |
| c. | $\phi$ | d. | both $r$ and $\theta$ |

4.  $f(z, t)$  represents a wave of fixed shape traveling in the  $z$  direction at speed  $v$ .

One of the following forms does not represent a wave. Which one?

- |    |                       |    |                   |
|----|-----------------------|----|-------------------|
| a. | $Ae^{-b(z-vt)^2}$     | b. | $Ae^{b(bz^2+vt)}$ |
| c. | $\frac{A}{b(z-vt)^2}$ | d. | $A \sin[b(z-vt)]$ |

5. For an electromagnetic (EM) plane wave  $\hat{n}$  and  $\hat{k}$  are the polarization vector and the direction of wave vector, respectively. One of the followings is true. Choose the right one.

- |    |                                |    |                             |
|----|--------------------------------|----|-----------------------------|
| a. | $\hat{n} \times \hat{k} = 0$   | b. | $\hat{n} \cdot \hat{k} = 0$ |
| c. | $\hat{n} \cdot \hat{k} \neq 0$ | d. | None of these               |

6. If  $R$  is the reflection coefficient and  $T$  is the transmission coefficient, then

- |    |             |    |             |
|----|-------------|----|-------------|
| a. | $R + T = 1$ | b. | $R + T < 1$ |
| c. | $R + T > 1$ | d. | $R + T = 0$ |

7. The allowed gauge transformations for the scalar and vector potentials are

a.  $A' = A + \nabla\lambda, V' = V - \frac{\partial\lambda}{\partial t}$

b.  $A' = A - \nabla\lambda, V' = V + \frac{\partial\lambda}{\partial t}$

c.  $A' = A + \nabla\lambda, V' = V + \frac{\partial\lambda}{\partial t}$

d.  $A' = A - \nabla\lambda, V' = V - \frac{\partial\lambda}{\partial t}$

8. In the Lorentz gauge, we pick

a.  $\nabla \cdot A = 0$

b.  $\nabla \cdot A = -\mu_0\epsilon_0 \frac{\partial V}{\partial t}$

c.  $\nabla \cdot A = \mu_0\epsilon_0 \frac{\partial V}{\partial t}$

d. None of these

9. The invariant interval  $I$  is

a.  $c^2t^2 + x^2 + y^2 + z^2$

b.  $c^2t^2 - x^2 - y^2 - z^2$

c.  $-c^2t^2 - x^2 - y^2 - z^2$

d.  $-c^2t^2 + x^2 + y^2 + z^2$

10. An interval is timelike, if

a.  $I < 0$

b.  $I > 0$

c.  $I = 0$

d. None of these

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**( Descriptive )**

Time : 1 hr. 15 min.

Marks : 25

*[ Answer question no.1 & any two (2) from the rest ]*

1. The intensity of sunlight hitting the earth is about  $1300 \text{ W/m}^2$ . If sunlight strikes a perfect absorber, what pressure does it exert? How about a perfect reflector? What fraction of atmospheric pressure does this amount to? [1atm= $101325 \text{ N/m}^2$ ] 2+2+1=5

2. A sphere of radius  $R$ , centered at the origin, carries charge density 4+6=10
- $$\rho(r, \theta) = k \frac{R}{r^2} (R - 2r) \sin \theta,$$

Where  $k$  is a constant, and  $r, \theta$  are the usual spherical coordinates.

- i. Show that for the approximate potentials for the points far from the sphere, the monopole and dipole contributions are zero.
- ii. Find the quadrupole contribution to the approximate potential for points on the  $z$  axis, far from the sphere.

[Help:  $V(\vec{r}) = \frac{1}{4\pi\epsilon_0} \sum_{n=0}^{\infty} \frac{1}{r^{(n+1)}} \int (r')^n P_n(\cos \theta') \rho(\vec{r}') d\tau'$ ]

3. a. Show that the standing wave  $f(z, t) = A \sin(kz) \cos(kvt)$  satisfies the wave equation  $\frac{\partial^2 f}{\partial z^2} = \frac{1}{v^2} \frac{\partial^2 f}{\partial t^2}$ . 3+3+4=10

b. Express the standing wave  $f(z, t) = A \sin(kz) \cos(kvt)$  as the sum of a wave traveling to the left and a wave traveling to the right.

c.  $\tilde{f}_v(z, t) = \tilde{A} e^{i(kz - \omega t)} \hat{x}$  and  $\tilde{f}_h(z, t) = \tilde{A} e^{i(kz - \omega t)} \hat{y}$  represent vertical and horizontal polarized waves respectively. Draw them properly indicating the propagation directions and the displacements.

4. The potentials for a particular charge and current distributions are 5+4+1=10

$$V = 0, \quad A = \begin{cases} \frac{\mu_0 k}{4c} (ct - |x|)^2 \hat{z} & \text{for } |x| < ct \\ 0 & \text{for } |x| > ct \end{cases}$$

Where  $k$  is a constant and  $c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$ .

- i. Find the electric and magnetic fields and plot them as a function of  $x$ .  $[E = \nabla V - \frac{\partial A}{\partial t}]$
  - ii. Show that the computed electric and magnetic fields satisfy the Maxwell's first two equations.
  - iii. What is the charge density in the present case?
5. a. Event  $A$  happens at point  $(x_A = 5, y_A = 3, z_A = 0)$  and at time  $t_A$  given by  $ct_A = 15$ ; event  $B$  occurs at  $(10, 8, 0)$  and  $ct_B = 5$ , both in system  $S$ . 3+2+1+4=10
- i. What is the invariant interval between  $A$  and  $B$ ?
  - ii. Is there an inertial system in which they occur simultaneously? If so, find its velocity (magnitude and direction) relative to  $S$ .
  - iii. Is there an inertial system in which they occur at the same point? If so, find its velocity relative to  $S$ .

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