Test Series: CSIR NET/JRF Exam

Physical Sciences

Test Paper: Electromagnetic Theory

Instructions: 1. Attempt all Questions. **Max Marks: 135**

2. There is a negative marking of 1/4 for each wrong answer.

3. Each Question in section-A carry 3.5 marks.

4. Each Question in section-B carry 5 marks.

Section – A

Q.1. Let $\vec{a}$ & $\vec{b}$ be two distinct 3-d vectors. Then the component of $\vec{b}$ that is perpendicular to $\vec{a}$ is

(a) $\frac{\vec{a}\times(\vec{b}\times\vec{a})}{a^2}$ (b) $\frac{\vec{b}\times(\vec{a}\times\vec{b})}{b^2}$ (c) $\frac{(\vec{a}.\vec{b})\vec{b}}{b^2}$ (d) $\frac{(\vec{b}.\vec{a})\vec{a}}{a^2}$

Q.2. Consider the function $\int(x,y,z) = x^2 + y^2 - z^2$. What is the direction in which max change of the function takes place at the point (2, 2, 1)?

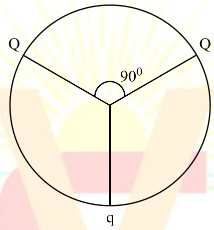
(a) $\frac{4\hat{\imath}+4\hat{\jmath}-2\hat{k}}{3}$ (b) $\frac{2\hat{\imath}+2\hat{\jmath}-\hat{k}}{6}$ (c) $\frac{2\hat{\imath}+2\hat{\jmath}-\hat{k}}{3}$ (d) $\frac{4\hat{\imath}+4\hat{\jmath}+2\hat{k}}{6}$

Q.3. A particle of mass m having a charge q moves in a circular orbit with speed v about an infinite line charge. What is the line charge density in terms of m, q & v ?

(a) $\lambda = \frac{2\pi\varepsilon_0 mv^2}{q}$ (b) $\lambda = \frac{4\pi\varepsilon_0 mv^2}{q}$ (c) $\lambda = \frac{8\pi\varepsilon_0 mv^2}{q^2}$ (d) $\lambda = \frac{2\pi\varepsilon_0 mv^2}{q^2}$

Q.4. Three charges are located on the circumference of radius R as shown in the fig. The Two charges Q subtend an angle 90^0 at the centre of the circle. The charge q is symmetrically placed with respect to the charges Q. If the electric field at the centre of the circle is zero.

What is the magnitude of Q?



(a) $\frac{q}{\sqrt{2}}$ (b) $\sqrt{2}\, q$

(c) 2q (d) 4q

Q.5. A constant electric field $\vec{E}$ is passing through the surface of an open hemisphere of radius R perpendicular to its base. What is the flux through curbed surface & base respectively?

(a) $+\pi R^2 |E|, -\pi R^2 |E|$ (b) $-\pi R^2 |E|, +\pi R^2 |E|$

(c) $0, \pi R^2 |E|$ (d) $\pi R^2 |E|, 0$

Q. 6. Suppose the electric field in the region is found to be $\vec{E} = kr^3\hat{r}$, in spherical co-ordinates where k is a constant. What is charge density?

(a) $3k\, \varepsilon_0 r^2$ (b) $\frac{3}{2}k\, \varepsilon_0 r^2$ (c) 0 (d) $5k\, \varepsilon_0 r^2$

Qs 7. If the electrostatic potential in spherical polar co-ordinates $\phi(r) = \phi_0 \bar{e}^{r/r_0}$ where ϕ_0 & are constants, then the charge density at a distance $r = r_0$ will be

(a) $\frac{\varepsilon_0\phi_0}{er_0{}^2}$ (b) $\frac{e\varepsilon_0\phi_0}{2r_0{}^2}$ (c) $\frac{-\varepsilon_0\phi_0}{er_0{}^2}$ (d) $\frac{-2\varepsilon_0\phi_0}{r_0{}^2}$

Q.8. A time-dependent current $\vec{I}(t) = kt\hat{z}$ (where k is a constant) is switched on at t = 0 in an infinite current-currying wire. The magnetic vector potential at a perpendicular distance ‘a’ from the wire is given (for time $t > a/c$) by

(a) $\hat{z}\,\frac{\mu_0 k}{4\pi c}\int_{-\sqrt{c^2t^2-a^2}}^{\sqrt{c^2t^2-a^2}} dz\,\frac{ct-\sqrt{a^2+z^2}}{(a^2+z^2)^{1/2}}$

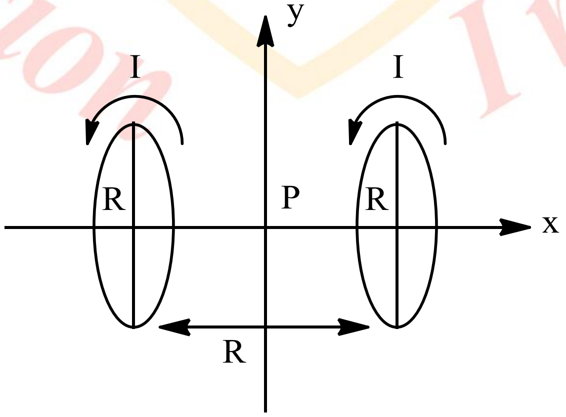
(b) $\hat{z}\,\frac{\mu_0 k}{4\pi}\int_{-ct}^{ct} dz\,\frac{t}{(a^2+z^2)^{1/2}}$

(c) $\hat{z}\,\frac{\mu_0 k}{4\pi c}\int_{-ct}^{ct} dz\,\frac{ct-\sqrt{a^2+z^2}}{(a^2+z^2)^{1/2}}$

(d) $\hat{z}\,\frac{\mu_0 k}{4\pi c}\int_{-\sqrt{c^2t^2-a^2}}^{\widehat{\sqrt{c^2t^2-a^2}}} dz\,\frac{t}{(a^2+z^2)^{1/2}}$

Q.9. A system of two co-axial circular coils carrying equal current I along same direction having equal radius R as shown in fig. The magnitude of magnetic field at the mid point P is

(a) $\frac{\mu_0 I}{2\sqrt{2}R}$ (b) $\frac{4\mu_0 I}{5\sqrt{5}R}$ (c) $\frac{8\mu_0 I}{5\sqrt{5}R}$ (d) 0



Q.10. What is the magnetic field of an infinite uniform surface current $\vec{k} = k\hat{x}$, flowing over the xy plane?

(a) $+\mu_0\, k\hat{y}\ for\ z < 0, -\mu_0\, k\hat{y}\ for\ z > 0$

(b) $+\frac{\mu_0}{2}\ k\hat{y}\ for\ z<0, -\frac{\mu_0}{2}\ k\hat{y}\ for\ z>0$

(c) $-\mu_0\ k\hat{y}\ for\ z<0, +\mu_0\ k\hat{y}\ for\ z>0$

(d) $-2\mu_0\ k\hat{y}\ for\ z<0, +2\mu_0\ k\hat{y}\ for\ z>0$

Section – B

Q.11. A charge distribution given by $\rho = \frac{k}{r}$ exists in an annular region between two spheres of radii R_1 & R_2. What is the electric field in the annular region?

(a) $\frac{k}{\varepsilon_0 r^2}\left(\frac{R^2{}_2 - R^2{}_1}{2}\right)$ (b) $\frac{k}{\varepsilon_0 r^2}\left(\frac{r^2 - R^2{}_1}{2}\right)$ (c) $\frac{k}{\varepsilon_0 r^2}\left(\frac{R^2{}_1 - R^2{}_2}{2}\right)$ (d) 0

Q.12. A charge distribution gives rise to an electric field $\vec{E} = \frac{E_0}{r^2}\ \bar{e}^{r/a}\hat{r}$, where a is a constant. What is the total charge in the distribution?

(a) $4\pi\varepsilon_0\ E_0\ \bar{e}^{R/a}$ (b) $8\pi\varepsilon_0\ E_0\ \bar{e}^{R/a}$ (c) $4\pi\varepsilon_0\ E_0\ \bar{e}^{2R/a}$ (d) 0

Q.13. A point charge q is located at a point P along the bisector of the angle between two semi-infinite grounded conducting planes at a distance d from the intersection of the planes. The angle between the planes is 60^0. What is the potential at a point S, located at a distance r from the intersection along the line joining P & S?

(a) $\frac{qd^3}{8\pi\varepsilon_0 r^4}$ (b) $\frac{qd^3}{32\pi\varepsilon_0 r^4}$ (c) $\frac{15qd^3}{32\pi\varepsilon_0 r^4}$ (d) $\frac{16qd^3}{32\pi\varepsilon_0 r^4}$

Q.14. A semicircular arc is placed in the xy plane such that its diameter is along the x-axis and centre at the origin. The arc carries a linear charge density of constant magnitude λ which is positive +ve in the first quadrant & -ve in the second quadrant. What is the field at the centre?

(a) $\frac{\lambda}{2\pi\varepsilon_0 R}$ (b) $\frac{\lambda}{4\pi\varepsilon_0 R}$ (c) 0 (d) $\frac{\lambda}{4\varepsilon_0 R}$

Q.15. What is the electric field at the centre of the base of a semicircle of radius R which has a charge density $\lambda = \lambda_0 \sin\theta$, where θ is the angle made by an element on the semicircle with the base?

(a) $\frac{\lambda_0}{2\pi\varepsilon_0 R}$ (b) $\frac{\lambda_0}{8\pi\varepsilon_0 R}$ (c) $\frac{\lambda_0}{8\varepsilon_0 R}$ (d) 0

Q.16. A spherical shell of radius R, carrying a uniform surface charge σ, is set spinning at angular velocity ω. The vector potential it produces at point r is

(a) Constant inside and varies as r outside

(b) Varies as r inside and constant outside

(c) Varies as r inside and $1/r^2$ outside

(d) Varies as 1/r inside and r outside

Q.17. An infinite solenoid with its axis of symmetry along the z-direction carries a steady current I. The vector potential $\vec{A}$ at a distance r from the axis is

(a) Is constant inside and varies as r outside the solenoid

(b) Varies as r inside and is constant outside the solenoid

(c) Varies as 1/r inside and as r outside the solenoid

(d) Varies as r inside and as 1/r outside the solenoid

Q.18. Consider an infinite conducting sheet in the x-y plane with a time dependent current density $kt\hat{\imath}$, where k is a constant. The vector potential at (x,y,z) is given by $\overrightarrow{A} = \frac{\mu_0 k}{4c}(ct-z)^2\hat{\imath}$. The magnetic field $\vec{B}$ is

(a) $\frac{\mu_0 kt}{2}\,\hat{\jmath}$ (b) $-\frac{\mu_0 kz}{2c}\,\hat{\jmath}$ (c) $-\frac{\mu_0 k}{2c}(ct-z)\,\hat{\imath}$ (d) $-\frac{\mu_0 k}{2c}(ct-z)\,\hat{\jmath}$

Q.19. The scalar and vector potential $\phi(\vec{x},t)$ & $\vec{A}(\vec{x},t)$ are determined up to a gauge transformation $\phi \longrightarrow \phi' = \phi - \frac{\partial\xi}{\partial t}$ and $\vec{A} \to \vec{A}' = \vec{A} + \vec{\nabla}\xi$ where ξ is an arbitrary continuous and differentiable function of $\vec{x}$ & t. If we further impose the Lorentz gauge condition $\vec{\nabla}.\vec{A} + \frac{1}{c}\frac{\partial\phi}{\partial t} = 0$ then a possible choice for the gauge function $\xi(\vec{x},t)$ is (where ω, $\vec{k}$ are nonzero constants with $w = c|\vec{k}|$)

(a) $\cos wt\ \cos \vec{k}.\vec{x}$ (b) $\sin wt\ \cos \vec{k}.\vec{x}$

(c) $\cosh wt\ \cos \vec{k}.\vec{x}$ (d) $\cosh wt\ \cosh \vec{k}.\vec{x}$

Q.20. A non-relativistic particle of mass m and charge e, moving with velocity $\vec{v}$ and acceleration $\vec{a}$, emits radiation of intensity I. What is the intensity of the radiation emitted by a particle of mass m/2, charge 2e, velocity $\vec{v}/2$ and acceleration $\overrightarrow{2a}$?

(a) 16 I (b) 8 I (c) 4 I (d) 2 I

Q.21. The magnetic vector potential $\vec{A}(\vec{a})$ corresponding to a uniform magnetic field $\vec{B}$ is taken in the form

$$\vec{A} = \frac{1}{2}\vec{B} \times \vec{r}$$

where $\vec{r}$ is the position vector. If the electric field has the time-dependent form $\vec{E} = \vec{E}_0(\vec{r})e^{\hat{\imath}wt}$, where w is a constant, the gauge choice corresponding to this potential is a

(a) Lorentz gauge (b) Coulomb gauge

(c) Non-liner gauge (d) Time-varying gauge

Q.22. An observer in an inertial frame finds that at a point P the electric field vanishes but the magnetic field does not. This implies that in any other inertial frame the electric field $\vec{E}$ and the magnetic field $\vec{B}$ satisfy

(a) $|\vec{E}|^2 = |\vec{B}|^2$ (b) $\vec{E}.\vec{B} = 0$ (c) $\vec{B} \times \vec{B} = 0$ (d) $\vec{E} = 0$

Q.23. For a guided wave between two infinite conducting planes separated by a distance of 0.25 m. What is the cutoff frequency for the TM20 mode?

(a) .8GHz (b) 1.2GHz (c) 3.4GHz (d) 4.6 GHz

Q.24. In above problem (Q.23) , If the operating frequency is 3 GHz. What is the phase velocity of the wave?

(a) 1.36×10^6 m/s (b) 2.84×10^6 m/s (c) 3.27×10^8 m/s (d) 4.68×10^8 m/s

Q.25. For a guided wave between two infinite conducting planes separated by a distance of 0.2m. If the operating frequency is 3.3 GHz. What are the total number of distinct modes that can travel in the guide?

(a) 1 (b) 4 (c) 5 (d) 9