IIT-JAM-PHYSICS 2023
UNIT TEST : EMT

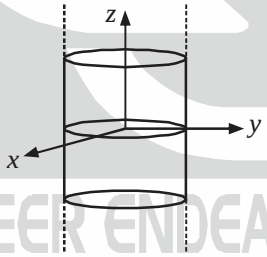
Time : 45 Minutes **Date : 19-06-2022**

Instructions:

- **Part-A** contains 10 Multiple Choice Questions (MCQ). Each question has 4 choices (a), (b), (c) and (d), for its answer, out of which **ONLY ONE** is correct. For each correct answer you will be awarded **2 marks**. For each incorrect answered **0.5 mark** will be deducted.
- **Part-B** contains 5 Multiple Select Questions (MSQ). Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which **ONE or MORE than ONE** is/are correct. For each correct answer you will be awarded **2 marks**, there is no negative marking in this section.
- **Part-C** contains 5 Numerical Answer Type (NAT) questions which contain **2 Marks** for each, and there is no negative marking.

[SECTION - A — MULTIPLE CHOICE QUESTIONS (MCQ)]

1. A long cylinder carries a surface charge density ($\sigma = \sigma_0 \cos\phi$), where σ_0 is a constant and ϕ is cylindrical coordinate. The electric field on the axis of the cylinder is

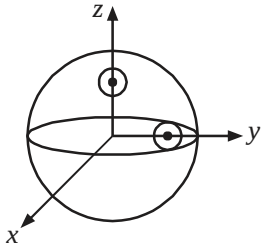


(a) $\frac{\sigma_0}{2\varepsilon_0}$ (b) $\frac{\sigma_0}{2\pi\varepsilon_0}$ (c) $\frac{\sigma_0}{\varepsilon_0}$ (d) $\frac{\sigma}{\pi\varepsilon_0}$

2. Q charge is uniformly distributed over a ring of radius R. The maximum electrostatics potential on the axis of the ring due to this charge distribution is V_0. The maximum electric field on this axis of the ring is

(a) $\frac{2V_0}{3\sqrt{3}R}$ (b) $\frac{3\sqrt{3}V_0R}{2}$ (c) $\frac{3\sqrt{3}V_0}{2R}$ (d) $\frac{4\sqrt{3}V_0}{R}$

3. A sphere of radius R has a uniform volume charge density ρ_0, centered at origin. Two smaller sphere of radius R and centres at $\left(0, \frac{R}{2}, 0\right)$ and $\left(0, 0, \frac{R}{2}\right)$ respectively, are cut out and removed from it. The electric field at the origin is



(a) Zero (b) $\frac{\sqrt{2}\rho_0 R}{384\varepsilon_0}$

(c) $\left(\frac{\rho_0 R^3}{3\varepsilon_0}\right)$ (d) $\frac{\rho_0 R^2}{2\varepsilon_0}$

4. Electric potential inside a sphere of radius R centered at origin is $V(r) = Ar^3 + \beta$. The electric field at a distance $r = 2R$ from the centre of the sphere is

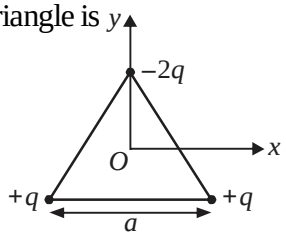
(a) $-\frac{3AR^2}{4}\hat{r}$ (b) $\frac{3AR^2}{4}\hat{r}$ (c) $-8AR^2\hat{r}$ (d) $8AR^2\hat{r}$

5. Two infinitely long wires carry linear charge density $+\lambda$ and $-\lambda$ passing through the points (0, 0, a) and $(0, 0, -a)$ and parallel to the y-axis. The electrostatics potential at (x, y, z) is

(a) $\frac{\lambda}{2\pi\varepsilon_0}\ln\left[\frac{x^2+(z+a)^2}{x^2+(z-a)^2}\right]$ (b) $\frac{\lambda}{2\pi\varepsilon_0}\ln\left[\frac{x^2+(y+a)^2}{x^2+(y-a)^2}\right]$

(c) $\frac{\lambda}{2\pi\varepsilon_0}\ln\left[\frac{x^2+y^2+(z+a)^2}{x^2+y^2+(z-a)^2}\right]$ (d) $\frac{\lambda}{2\pi\varepsilon_0}\ln\left[\frac{y^2+(z+a)^2}{y^2+(z-a)^2}\right]$

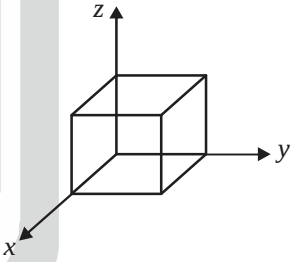
6. Three point charges $+q$, $+q$ and $-2q$ are placed at the vertices of an equilateral triangle of sides 'a' whose centroid is at origin as shown in the figure. The electric field at the centroid of the triangle is



(a) $\frac{9q}{4\pi\varepsilon_0 a^2}\hat{j}$ (b) $-\frac{9q}{4\pi\varepsilon_0 a^2}\hat{j}$

(c) $-\frac{9q}{4\pi\varepsilon_0 a^2}(\hat{i}+\hat{j})$ (d) $\frac{9q}{4\pi\varepsilon_0 a^2}(\hat{i}+\hat{j})$

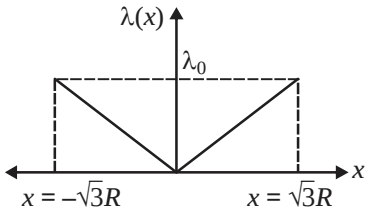
7. Consider a cube of side 'a' has its one corner at the origin and sides are parallel to the axis as shown in figure. There is an electric field in the region $\vec{E} = \left(\alpha x^2 yz\,\hat{i} + \beta xy^2 z\,\hat{j} + \gamma xyz^2\hat{k}\right)$, where α, β and γ are constants. The net electric flux passing through the cube is



(a) $\frac{(\alpha+\beta+\gamma)a^6}{8}$ (b) $\frac{(\alpha+\beta+\gamma)a^6}{4}$

(c) $\frac{(\alpha+\beta+\gamma)a^4}{4}$ (d) $\frac{(\alpha+\beta+\gamma)a^3}{3}$

8. Consider a wire of length $2\sqrt{3}R$ lies along x-axis and carries a linear charge density as shown in graph. The electric potential on the circle $y^2 + z^2 = R^2$ in the yz-plane at $x = 0$ is



(a) $\frac{\lambda_0}{\pi\varepsilon_0 R\sqrt{3}}$ (b) $\frac{\lambda_0}{2\sqrt{3}\pi\varepsilon_0}$ (c) $\frac{\sqrt{3}\lambda_0}{2\pi\varepsilon_0}$ (d) $\frac{\lambda_0}{\sqrt{3}\pi\varepsilon_0}$

9. Which of the following vector field can be an electrostatics field ?

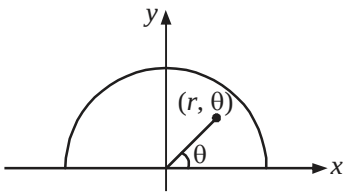
(a) $\vec{E} = ax^2y^2\,\hat{i}$ (b) $\vec{E} = a(\cos\phi\,\hat{\rho} - \sin\hat{\phi})$

(c) $\vec{E} = a(y\,\hat{i} - x\hat{j})$ (d) $\vec{E} = \frac{a}{r^2}\left[\hat{r}(1+\cos\phi) + \hat{\phi}\sin\phi\right]$

10. Consider a semi circular disk of radius R carries a surface charge density $\sigma = \sigma_0 \cos\theta\, r$. The electrostatic potential at the origin due to this charge distribution is

(a) $\frac{\sigma R}{2\varepsilon_0}$ (b) $\frac{\sigma R}{4\varepsilon_0}$

(c) Zero (d) $\frac{\sigma R^2}{2\varepsilon_0}$



[SECTION - B — MULTIPLE SELECTIVE QUESTIONS (MSQ)]

11. A circular ring of radius R has a linear charge density $\lambda = \lambda_0 \cos\theta$, where θ is the angle with respect to a fixed radius. Which of the following state(s) is/are ***correct***?

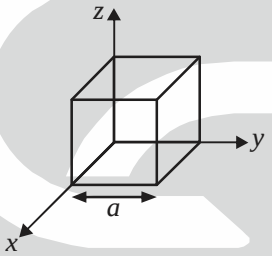
(a) The electrostatics field is zero at the centre of the ring.

(b) The electrostatics potential is zero at the centre of the ring.

(c) Total charge on the ring is zero.

(d) The electrostatics potential on the axis of the ring is zero.

12. Electric field in space is given by $\vec{E} = \alpha\,\hat{i} + \beta\,\hat{j} + \gamma\, z\,\hat{k}$, where α, β and γ are some constants. A cube of side 'a' lies in space with its one corner at the origin as shown in the figure below. Choose the correct statement(s).



(a) The electric flux through the surface $z = 0$ is non-zero.

(b) The electric flux through the surface $z = a$ is zero.

(c) The electric flux through the surface $x = a$ is non-zero.

(d) The total enclosed charge inside the cube is $\gamma a^3 \varepsilon_0$.

13. A long cylinder of length l, a total charge $+q$ is uniformly distributed over its surface, is surrounded by a cylindrical thin shell of total charge $-2q$ uniformly distributed over its surface. Which of the following option(s) is/are ***correct***?

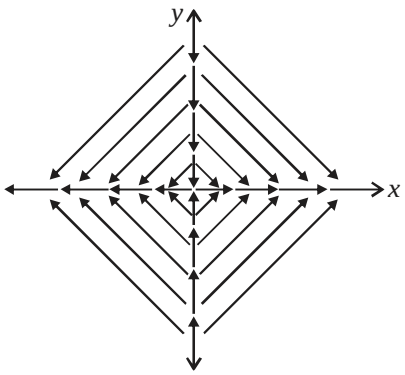
(a) Electric field at a point outside the cylindrical shell is $\frac{q}{2\pi\,\varepsilon_0\, lr}$, radially inward.

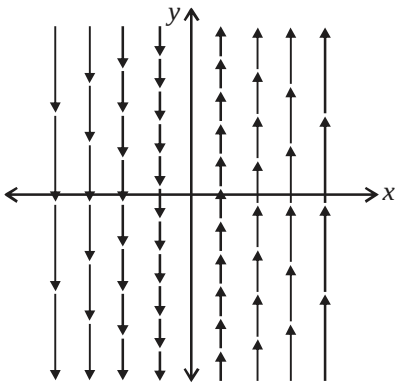
(b) Electric field at a point outside the cylindrical shell is $\frac{q}{2\pi\,\varepsilon_0\, r}$, radially inward.

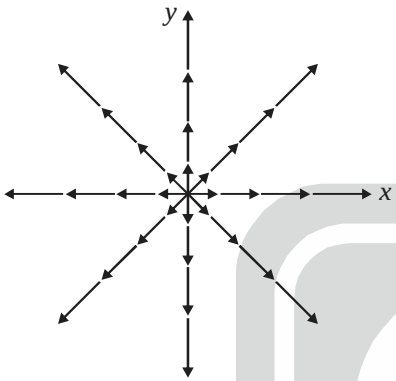
(c) Electric field in the region between two cylinders is $\frac{q}{2\pi\,\varepsilon_0\, lr}$, radially outward.

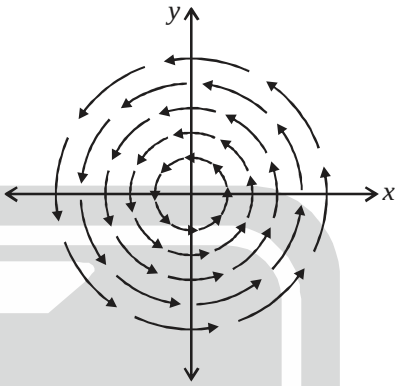
(d) Electric field in the region between two cylinders is $\frac{q}{2\pi\,\varepsilon_0\, lr}$, radially inward.

14. Which of the following vector field(s) can represent electrostatics field ?

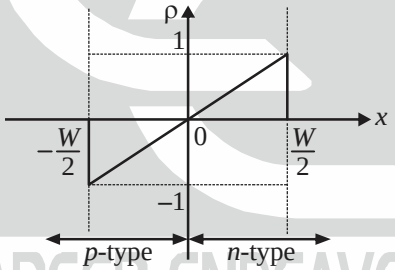
(a) 

(b) 

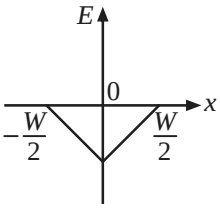
(c) 

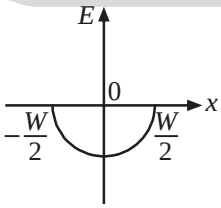
(d) 

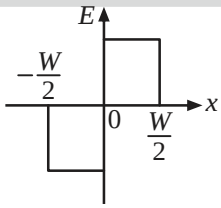
15. A semiconductor *pn* junction at thermal equilibrium has the space charge density $\rho(x)$ profile as shown in the figure.

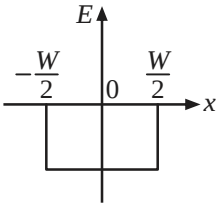


The figure that best depicts the variation of the electric field E with x is (W denotes the width of the depletion layer, and electric field is zero outside the depletion layer).

(a) 

(b) 

(c) 

(d) 

[SECTION - C — NUMERICAL ANSWER TYPE QUESTIONS (NAT)]

16. If $\vec{E} = a(y+x)\hat{i} + b(x+y)\hat{j} - 4z\hat{k}$ represents an electrostatics field in a charge free origin, then the value of '*b*' is _____. [Your answer should be an integer]

17. A solid sphere of radius R has volume charge density $\rho(r) = \beta r^3$, where 'r' is the distance from the centre of the sphere and β is a constant. The potential difference between centre and surface $(V_c - V_s)$, is _____ $\left(\beta R^5 / 3\varepsilon_0\right)$.

[Your answer should be upto one decimal place]

18. Consider a long cylinder of radius R carries a volume charge density $\rho(r) = \rho_0\left(1 - \frac{r^2}{R^2}\right)$. Electric field will be maximum at 'r' is equal to _____R. [Your answer should be upto 2 decimal places]

19. Consider three concentric spherical shell of radius R, $2R$ and $3R$ respectively, carry charges Q, $2Q$ and $3Q$. If the potential at the centre is V_c and potential on the outer surface is V_c', then the ratio of V_c/V_c' is _____. [Your answer should be upto one decimal place]

20. Consider an infinite thin shut $z = 0$, carries a uniform surface charge density σ_0. The required work done to displaced a point charge q from $(0, 0, 2d)$ to $(0, 0, d)$ is _____ $(\sigma d/\varepsilon_0)$.
[Your answer should be upto 1st decimal place]

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Time : 45 Minutes **Date : 19-06-2022**

ANSWER KEY

PART-A [Multiple Choice Questions (MCQ)]

1. (a)	**2.** (a)	**3.** (b)	**4.** (a)	**5.** (a)
6. (a)	**7.** (b)	**8.** (b)	**9.** (b)	**10.** (c)

PART-B [Multiple Select Questions (MSQ)]

11. (b), (c), (d)	**12.** (c), (d)	**13.** (a), (c)	**14.** (a), (c)	**15.** (b)

PART-C [Numerical Answer Type (NAT)]

16. (2)	**17.** (0.1)	**18.** (0.80 to 0.82)	**19.** (1.4 to 1.6)	**20.** (0.5)