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QUESTION PAPER DESIGN 2020-21#

S. No.	Chapter	VSA/ AR/ Case Based (1 mark)	SA-I (2 marks)	SA-II (3 marks)	LA (5 marks)	Total
1.	Electrostatics	3(6)	1(2)	–	1(5)	6(16)
2.	Current Electricity	–	–	1(3)	–	
3.	Magnetic Effects of Current and Magnetism	2(2)	2(4)	–	–	8(17)
4.	Electromagnetic Induction and Alternating Current	1(1)	1(2)	1(3)	1(5)	
5.	Electromagnetic Waves	1(1)	–	–	–	8(18)
6.	Optics	3(6)	3(6)	–	1(5)	
7.	Dual Nature of Radiation and Matter	1(1)	–	1(3)	–	6(12)
8.	Atoms and Nuclei	2(2)	–	2(6)	–	
9.	Electronic Devices	3(3)	2(4)	–	–	5(7)
	Total	**16(22)**	**9(18)**	**5(15)**	**3(15)**	**33(70)**

1. Electric Charges and Fields
2. Electrostatic Potential and Capacitance
3. Current Electricity
4. Moving Charges and Magnetism
5. Magnetism and Matter
6. Electromagnetic Induction
7. Alternating Current
8. Electromagnetic Waves
9. Ray Optics and Optical Instruments
10. Wave Optics
11. Dual Nature of Radiation and Matter
12. Atoms
13. Nuclei
14. Semiconductor Electronics : Materials, Devices and Simple Circuits

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CHAPTER 1

Electric Charges and Fields

Syllabus
Electric Charges; Conservation of charge, Coulomb's law-force between two-point charges, forces between multiple charges; superposition principle and continuous charge distribution.
Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field.
Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet

CASE STUDY / PASSAGE BASED QUESTIONS

Questions 1-10 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

1

Coulomb's Law

Coulomb's law states that the electrostatic force of attraction or repulsion acting between two stationary point charges is given by

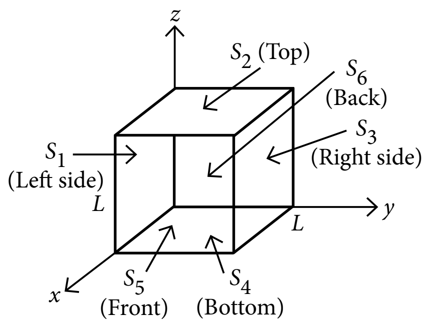
$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

where F denotes the force between two charges q_1 and q_2 separated by a distance r in free space, ε_0 is a constant known as permittivity of free space. Free space is vacuum and may be taken to be air practically.
If free space is replaced by a medium, then ε_0 is replaced by $(\varepsilon_0 k)$ or $(\varepsilon_0 \varepsilon_r)$ where k is known as dielectric constant or relative permittivity.

(i) In coulomb's law, $F = k\frac{q_1 q_2}{r^2}$, then on which of the following factors does the proportionality constant k depends?
(a) Electrostatic force acting between the two charges
(b) Nature of the medium between the two charges
(c) Magnitude of the two charges
(d) Distance between the two charges.

(ii) Dimensional formula for the permittivity constant $\varepsilon_0$of free space is
(a) $[M L^{-3} T^4 A^2]$
(b) $[M^{-1} L^3 T^2 A^2]$
(c) $[M^{-1} L^{-3} T^4 A^2]$
(d) $[M L^{-3} T^4 A^{-2}]$

(iii) The force of repulsion between two charges of 1 C each, kept 1 m apart in vaccum is
(a) $\frac{1}{9\times10^9}$ N
(b) 9×10^9 N
(c) 9×10^7 N
(d) $\frac{1}{9\times10^{12}}$ N



(i) Electric flux passing through surface S_6 is

(a) $-24\ \mathrm{N\ m^2\ C^{-1}}$ (b) $24\ \mathrm{N\ m^2\ C^{-1}}$ (c) $32\ \mathrm{N\ m^2\ C^{-1}}$ (d) $-32\ \mathrm{N\ m^2\ C^{-1}}$

(ii) Electric flux passing through surface S_1 is

(a) $-24\ \mathrm{N\ m^2\ C^{-1}}$ (b) $24\ \mathrm{N\ m^2\ C^{-1}}$ (c) $32\ \mathrm{N\ m^2\ C^{-1}}$ (d) $-32\ \mathrm{N\ m^2\ C^{-1}}$

(iii) The surfaces that have zero flux are

(a) S_1 and S_3 (b) S_5 and S_6 (c) S_2 and S_4 (d) S_1 and S_2

(iv) The total net electric flux through all faces of the cube is

(a) $8\ \mathrm{N\ m^2\ C^{-1}}$ (b) $-8\ \mathrm{N\ m^2\ C^{-1}}$ (c) $24\ \mathrm{N\ m^2\ C^{-1}}$ (d) zero

(v) The dimensional formula of surface integral $\oint \vec{E}\cdot d\vec{S}$ of an electric field is

(a) $[\mathrm{M\,L^2\,T^{-2}\,A^{-1}}]$ (b) $[\mathrm{M\,L^3\,T^{-3}\,A^{-1}}]$

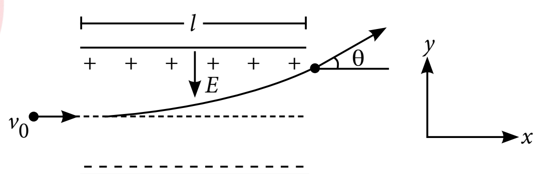
(c) $[\mathrm{M^{-1}\,L^3\,T^{-3}\,A}]$ (d) $[\mathrm{M\,L^{-3}\,T^{-3}\,A^{-1}}]$

4

Motion of Charged Particle in Uniform Electric Field

When a charged particle is placed in an electric field, it experiences an electrical force. If this is the only force on the particle, it must be the net force. The net force will cause the particle to accelerate according to Newton's second law. So

$$\vec{F}_e = q\vec{E} = m\vec{a}$$



If $\vec{E}$ is uniform, then $\vec{a}$ is constant and $\vec{a} = q\vec{E}/m$. If the particle has a positive charge, its acceleration is in the direction of the field. If the particle has a negative charge, its acceleration is in the direction opposite to the electric field. Since the acceleration is constant, the kinematic equations can be used.

(i) An electron of mass m, charge e falls through a distance h metre in a uniform electric field E. Then time of fall,

(a) $t = \sqrt{\dfrac{2hm}{eE}}$ (b) $t = \dfrac{2hm}{eE}$ (c) $t = \sqrt{\dfrac{2eE}{hm}}$ (d) $t = \dfrac{2eE}{hm}$

(iv) The electric flux through a closed surface area S enclosing charge Q is ϕ. If the surface area is doubled, then the flux is

(a) 2ϕ (b) $\phi/2$ (c) $\phi/4$ (d) ϕ

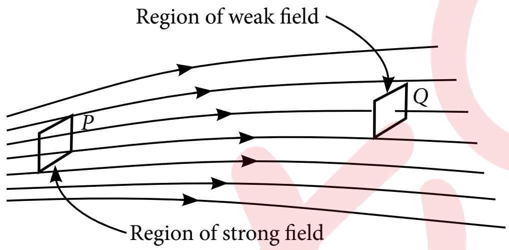
(v) A Gaussian surface encloses a dipole. The electric flux through this surface is

(a) $\frac{q}{\varepsilon_0}$ (b) $\frac{2q}{\varepsilon_0}$ (c) $\frac{q}{2\varepsilon_0}$ (d) zero

7

Relation between Strength of Electric Field and Density of Lines of Force

Electric field strength is proportional to the density of lines of force *i.e.*, electric field strength at a point is proportional to the number of lines of force cutting a unit area element placed normal to the field at that point. As illustrated in the given figure, the electric field at P is stronger that at Q.



(i) Electric lines of force about a positive point charge are

(a) radially outwards (b) circular clockwise

(c) radially inwards (d) parallel straight lines.

(ii) Which of the following is false for electric lines of force?

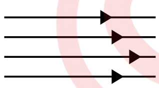
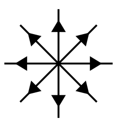
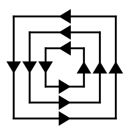
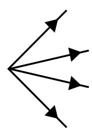
(a) They always start from positive charges and terminate on negative charges.

(b) They are always perpendicular to the surface of a charged conductor.

(c) They always form closed loops.

(d) They are parallel and equally spaced in a region of uniform electric field.

(iii) Which one of the following pattern of electric line of force in not possible in filed due to stationary charges ?

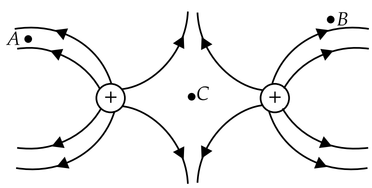
(a)  (b)  (c)  (d) 

(iv) Electric lines of force are curved

(a) in the field of a single positive or negative charge (b) in the field of two equal and opposite charges

(c) in the field of two like charges (d) both (b) and (c).

(v) The figure below shows the electric field lines due to two positive charges. The magnitudes E_A, E_B and E_C of the electric fields at points A, B and C respectively are related as



(a) $E_A > E_B > E_C$ (b) $E_B > E_A > E_C$ (c) $E_A = E_B > E_C$ (d) $E_A > E_B = E_C$

23. **Assertion (A) :** A point charge is lying at the centre of a cube of each side . The electric flux emanating from each surface of the cube is $\frac{1}{6}^{\text{th}}$ of total flux.
Reason (R) : According to Gauss theorem, total electric flux through a closed surface enclosing a charge is equal to $1/\varepsilon_0$ times the magnitude of the charge enclosed.

24. **Assertion (A) :** A point charge is brought in an electric field. The field at a nearby point is increase, whatever be the nature of the charge.
Reason (R) : The electric field is independent of the nature of charge.

25. **Assertion (A) :** For charge to be in equilibrium, sum of the forces on charge due to rest of the two charges must be zero.
Reason (R) : A charge is lying at the centre of the line joining two similar charges each which are fixed. The system will be in equilibrium if that charge is one fourth of the similar charges.

26. **Assertion (A) :** If a conducting medium is placed between two charges, then electric force between them becomes zero.
Reason (R) : Reduction in a force due to introduced material is inversely proportional to its dielectric constant.

27. **Assertion (A) :** In electrostatics, electric lines of force can never be closed loops, as a line can never start and end on the same charge.
Reason (R) : The number of electric lines of force originating or terminating on a charge is proportional to the magnitude of charge.

28. **Assertion (A) :** If a point charge q is placed in front of an infinite grounded conducting plane surface, the point charge will experience a force.
Reason (R) : This force is due to the induced charge on the conducting surface which is at zero potential.

29. **Assertion (A) :** Charge is quantized.
Reason (R) : Charge which is less than 1 C is not possible.

30. **Assertion (A) :** The electric flux emanating out and entering a closed surface are 8×10^3 and 2×10^3 V m respectively. The charge enclosed by the surface is 0.053 μC.
Reason (R) : Gauss's theorem in electrostatics may be applied to verify.

HINTS & EXPLANATIONS

1. **(i) (b):** The proportionality constant k depends on the nature of the medium between the two charges.

(ii) (c) : As, $[\varepsilon_0] = \frac{1}{4\pi F} \cdot \frac{q_1 q_2}{r^2} = \frac{[\text{AT}]^2}{[\text{M L T}^{-2}][\text{L}^2]}$
$$= [\text{M}^{-1}\,\text{L}^{-3}\,\text{T}^4\text{A}^2]$$

(iii) (b)

(iv) (d): $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{d^2}$

$$\therefore\ (10\times10^{-3})\times10 = \frac{(9\times10^9)\times q^2}{(0.6)^2}$$

or $q^2 = \frac{10^{-1}\times0.36}{9\times10^9} = 4\times10^{-12}$

or $q = 2\times10^{-6}\text{ C} = 2\ \mu\text{C}$

(v) (b)

2. **(i) (d)**

(ii) (b): From, $q = ne$, $n = \frac{q}{e} = \frac{3.2\times10^{-18}}{1.6\times10^{-19}} = 20$

As n is an integer, hence this value of charge is possible.

(iii) (d): Charge on the body is $q = ne$

$\therefore$ No. of electrons present on the body is

$\therefore$ Electric flux through the hemisphere $= \frac{1}{2}\frac{q}{\varepsilon_0}$

$$= \frac{10\times10^{-6}}{2\times8.854\times10^{-12}} = 0.56\times10^{6}\text{ N m}^2\text{ C}^{-1}$$

$$\approx 0.6\times10^{6}\text{ Nm}^2\text{ C}^{-1} = 6\times10^{5}\text{ N m}^2\text{ C}^{-1}$$

(iv) (d): As flux is the total number of lines passing through the surface, for a given charge, it is always the charge enclosed Q/ε_0. If area is doubled, the flux remains the same.

(v) (d): As net charge on a dipole is
$(-q+q) = 0$
Thus, when a gaussian surface encloses a dipole, as per Gauss's theorem, electric flux through the surface,

$$\oint \vec{E}\cdot d\vec{S} = \frac{q}{\varepsilon_0} = 0$$

7. (i) (a)

(ii) (c): Electric lines of force do not form any closed loops.

(iii) (c): Electric field lines can't be closed.

(iv) (d)

(v) (a)

8. (i) (a): As τ = either force $\times$ perpendicular distance between the two forces
$= qaE\sin\theta$ or $\tau = PE\sin\theta$
or $\tau = \vec{P}\times\vec{E}$ $\quad(\because\ qa = P)$

(ii) (c) : The maximum torque on the dipole in an external electric field is given by
$\tau = pE = q(2a)\times E$
Here, $q = 1\ \mu\text{C} = 10^{-6}$ C, $2a = 2$ cm $= 2\times10^{-2}$ m,
$E = 10^5$ N C^{-1}, $\tau = ?$
$\therefore\ \tau = 10^{-6}\times2\times10^{-2}\times10^{5} = 2\times10^{-3}$ N m

(iii) (d): When θ is 0 or 180°, the τ is minimum, which means the dipole moment should be parallel to the direction of the uniform electric field.

(iv) (c): Net force is zero and torque acts on the dipole, trying to align p with E.

(v) (a): Torque, $\tau = pE\sin\theta$ and potential energy, $U = -pE\cos\theta$

9. (i) (a): Gauss's law is applicable for any closed surface. Gauss's law is most useful in situation where the charge distribution has spherical or cylindrical symmetry or is distributed uniformly over the plane. Whereas electric dipole is a system of two equal and opposite point charges separated by a very small and finite distance.
So both statements are correct.

(ii) (b): According to Gauss's law, the electric flux through the sphere is

$$\phi = \frac{q_{in}}{\varepsilon_0} = \frac{8.85\times10^{-13}\text{C}}{8.85\times10^{-12}\text{ C}^2\text{ N}^{-1}\text{ m}^{-2}} = 0.1\text{ N C}^{-1}\text{ m}^2$$

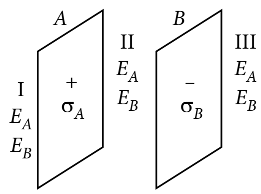
(iii) (c): For uniformly volume charge density, $E = \frac{\rho r}{3\varepsilon_0}$
$E \propto r$

(iv) (a): $r = 25$ cm $= 0.25$ m, $\sigma = \frac{3}{\pi}$ C/m^2

As, $\sigma = \frac{q}{4\pi r^2} \Rightarrow q = 4\pi\times(0.25)^2\times\frac{3}{\pi} = 0.75$ C

(v) (b): The line charge density at a point on a line is the charge per unit length of the line at that point
$$\lambda = \frac{dq}{dL}$$
Thus, the SI unit for λ is C m^{-1}.

10. (i) (d): There are two plates A and B having surface charge densities,



$\sigma_A = 17.0\times10^{-22}$ C/m^2
on A and $\sigma_B = -17.0\times10^{-22}$ C/m^2 on B, respectively.
According to Gauss' theorem, if the plates have same surface charge density but having opposite signs, then the electric field in region I is zero.

$$E_{\text{I}} = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

(ii) (d): The electric field in region III is also zero.

$$E_{\text{III}} = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

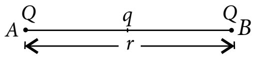
(iii) (c) : In region II or between the plates , the electric field

$$E_{\text{II}} = E_A - E_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

$$= \frac{\sigma(\sigma_A \text{ or } \sigma_B)}{\varepsilon_0} = \frac{17.0\times10^{-22}}{8.85\times10^{-12}}$$

25. (c) : According to Coulomb's law, $F = k\dfrac{Q_1Q_2}{r^2}$.
The force on q due to A,

$$F_A = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{(r/2)^2} \text{ to the right}$$



Due to B,

$$F_B = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{(r/2)^2} \text{ to the left.}$$

$\therefore$ Their sum is zero whether q is $+\dfrac{Q}{4}$ or $-\dfrac{Q}{4}$ or any other value.

Therefore, it is not true that the third charge has to be $Q/4$ only. It can be any value.

26. (a) : The dielectric constant of any material is $K = \dfrac{E_0}{E} = \dfrac{F_0/q}{F/q} = \dfrac{F_0}{F} \Rightarrow F = \dfrac{F_0}{K}$, where F_0 is force when conductor is not present between the charge. F is a force after introduction of conductor between charges. Since dielectric constant of a conducting medium is infinity therefore $F = 0$.

27. (b) : Electrostatic field lines of force can never form any closed loop. Because electric field originate from positive charge and terminates on negative charge.

28. (a)

29. (c) : The charge q on a body is given as $q = ne$ where n is any integer positive or negative.
The charge on the electron is $q = 1.6 \times 10^{-19}$ C which is less than 1 C.

30. (a) : According to Gauss's theorem in electrostatics,
$\phi = q/\varepsilon_0$
$q = \varepsilon_0\phi = 8.85 \times 10^{-12}\,[8 \times 10^3 - 2 \times 10^3]$
$= 53.10 \times 10^{-9}$ C $= 0.053$ μC.

☺☺☺