| APPLIED PHYSICS-II (2ND SEMESTER DIPLOMA ENGG STUDENTS FROM SUMMER 2025 ONWARDS (Unit - 3 : ELECTROSTATICS) | | | |
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| **Sl. No.** | **Question** | **Taxonomy Level** | **Mark** |
| **1** | **State Coulombs' law of electrostatic and Write the mathematical expression for it.** | **Remembering Understanding** | **2** |
| **ANS** | Coulomb's law states that "the force of attraction or repulsion between two stationary point charges is directly proportional to the product of the magnitude of their charges and inversely proportional to the square of the distance between them." This force acts on the line that connects the two charges.<br>$Mathematically, F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$. Where $\varepsilon_0$ is called permittivity of free space. | | |
| **2** | **Define unit charge and write its SI unit.** | **Understanding Remembering** | **2** |
| **ANS** | One coulomb of charge (unit charge) is defined as that charge which when placed in air at a distance of 1 meter from an equal and similar charge repels it with a force of $9X10^9$ Newton.<br>The SI unit of charge is Coulomb (C). | | |
| **3** | **Define electric lines of force.** | **Remembering** | **2** |
| **ANS** | An electric line of force is a curve along which the unit positive charge moves away from the specified positive charge.<br>The tangent drawn on the electric line of force at a point will give direction of electric field at that point. | | |
| **4** | **Define electric flux and write its SI unit.** | **Remembering Understanding** | **2** |
| **ANS** | The total number of electric lines of force passing through a specific area inside an electric field is a measure of the electric flux through that area.<br>Its SI unit is $Nm^2$ /C | | |
| **5** | **Define electric potential difference and write its SI unit.** | **Remembering Understanding** | **2** |
| **ANS** | The amount of work done to move a unit positive charge from one point to another point inside the electric field is known as electric potential difference.<br>The SI Unit of electric potential difference is Volts (V). | | |
| **6** | **State Gauss' law and write its mathematical form.** | **Remembering Understanding** | **2** |
| **ANS** | Gauss' law states that "the total electric flux (ϕ) passing through any "closed surface" is $\frac{1}{\varepsilon_0}$ times of charge | | |

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| | enclosed by the surface".<br>Mathematically, $\phi = \frac{1}{\varepsilon_0} X\, q$ | | |
| 7 | **Define the term capacitance with its SI unit.** | **Remembering Understanding** | **2** |
| ANS | Capacitance of a capacitor is defined as the ability to store electric charge. It is measured by the ratio of change in charge to the difference in electric potential. Mathematically, $C = \frac{Q}{V}$<br>The SI unit of capacitance is the Farad (F). | | |
| 8 | **What is dielectric breakdown?** | **Understanding** | **2** |
| ANS | Dielectric breakdown is the phenomenon of failure of an insulating material to prevent the flow of current. When applied electrical field increases to a certain value ionization takes place inside the material which creates large number of electrons and ions.<br>Electrical discharge taking place in air is an example of dielectric break down which takes place at electric field $3 \times 10^6$ V/m. | | |
| 9 | **Define Electric potential.** | **Remembering** | **2** |
| ANS | Electric potential at a point is equal to the work done by external force in bringing the unit positive charge from infinity to a point inside the electric field without changing the kinetic energy | | |
| 10 | **Why do two electric lines of force never cross each other?** | **Understanding** | **2** |
| ANS | The tangent drawn on the electric line of force at a point will give direction of electric field at that point.<br>The **two electric lines of force** never intersect because the two tangents can be traced to the point of the intersection that will represent two different directions of the electric field at the same point which is practically not possible. | | |
| 11 | **Three capacitors of 2μF, 3μF and 5μF are connected in parallel. Calculate the resultant capacity of the combination.** | **Applying** | **2** |
| ANS | For capacitors connected in parallel, the resultant capacity is, $\mathbf{C = C_1 + C_2 + C_3}$<br>**Hence C = 2μF + 3μF + 5μF = 10 μF** | | |
| 12 | **Define dielectric constant.** | **Remembering** | **2** |
| ANS | The dielectric constant (also called the relative permittivity) of a material is the ratio of the electric field in a vacuum to the electric field in the material when the same charge is applied. It is a measure of the material's ability to reduce the effective electric field. | | |

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| 13 | **Two capacitors of 3 F and 6 F are connected in series. Calculate the resultant capacity of the combination** | **Applying** | **2** |
| ANS | For capacitors connected in series, the resultant capacity is, $1/C = 1/C_1 + 1/C_2$<br><br>**Hence 1/C = (1/3)F + (1/6)F = (3/6)F= (1/2) F**<br><br>**=> C = 2 F** | | |
| 14 | **The Electrostatic force of attraction between two charged particles is F. If the distance between them is halved, then calculate the new Electrostatic force of attraction.** | **Applying** | **2** |
| ANS | The electrostatic force of attraction between two charged particles $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$<br>The distance between them is halved, r'=r/2<br>Then, the new electrostatic force of attraction between them = F' = $\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{(r/2)^2} = 4\left(\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}\right)$= 4F | | |
| 15 | **The work done in carrying a charge of 5 µC from point A to B is 8 mJ. Calculate the difference of potential between A & B.** | **Applying** | **2** |
| ANS | $Electric\ Potential = \frac{Work\ done}{Q}$<br>Hence, $V = \frac{W}{Q} = \frac{\mathbf{8\ mJ}}{\mathbf{5\ \mu C}} = 1.6\ X\ 10^3\ V = 1.6\ kV$<br>The difference of potential between A & B is 1.6 kV. | | |
| 16 | **State and explain Coulomb's law of electrostatics.** | **Remembering Applying** | **5** |
| ANS | Coulomb's law states that "the force of attraction or repulsion between two stationary point charges is directly proportional to the product of the magnitude of their charges and inversely proportional to the square of the distance between them." This force acts on the line that connects the two charges.<br><br>Let's consider two charges $q_1$ and $q_2$ , separated by distance 'r' then according to Coulomb's law<br>$F \propto q_1q_2$<br>$and\ F \propto \frac{1}{r^2}$<br>$Hence, F \propto \frac{q_1q_2}{r^2}$<br>=> $F = K\frac{q_1q_2}{r^2}$ | | |

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| | Where 'K' is constant of proportionality called as electrostatic constant.<br><br>When two charges are placed in free space then K in S.I. unit is given by<br><br>$K = \frac{1}{4\pi\varepsilon_0} = 9X10^9\ Nm^2/C^2$, where $\varepsilon_0$ is called as permittivity of free space.<br><br>$Therefore, \quad F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$. | | |
| 17 | **Write down properties of electric lines of force**. | **Applying** | **5** |
| **ANS** | **Properties of electric lines of force are :**<br><br>• The field lines never intersect each other because if they intersect at a point then at that point there will be two directions of electric field.<br>• The tangent drawn on the electric line of force at a point will give direction of electric field at that point.<br>• The field lines run perpendicular to the charge's surface. Both the magnitude of the charge and the number of field lines are proportional.<br>• The field lines begin (diverge) from the positive charge and conclude (converge) to the negative charge.<br>• Fig. (a) represents the **electric lines of force** for positive charge $q_0$ and Fig. (b) represents the **electric lines of force** for two equal and opposite charge kept at a distance.<br><br>Electric lines of force | | |

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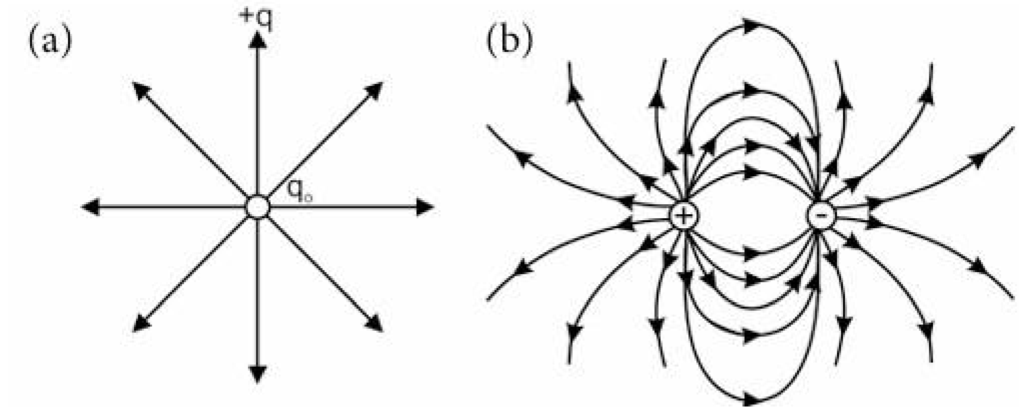
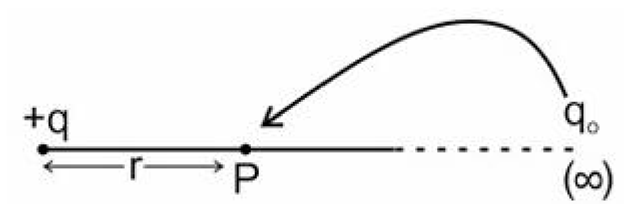
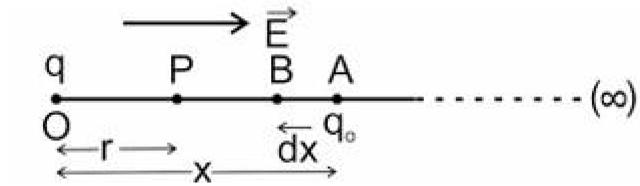
| |  | | |
| 18 | **i) Define Electric potential (V).**<br>**ii) Derive expression for electric potential due to a point charge.** | **Remembering**<br>**Applying** | **5 (2+3)** |
| **ANS** | i) Let q is a positive charge and $q_0$ is unit positive charge at infinite distance from q. The amount of work done in moving the unit positive test charge from infinity to a point P against the electric field is electric potential at point P.<br>$Electric\ Potential = \frac{Work\ done}{Charge}; V = \frac{W}{q_0}$<br>ii)<br>Electric potential due to point charge<br><br>Consider a positive charge q placed at the origin O. Now we will find the electric potential at point P at distance r from charge q. | | |

Work done in displacing charge




According to definition of electric potential, the amount of work done to bring $q_o$ from infinity to that point P is equal to electric potential.

Consider $q_0$ at a point 'A' , then $F = \frac{1}{4\pi\varepsilon_0}\frac{qq_0}{x^2}$

Small work done in displacing charge $q_0$ from A to B is

$dw = \vec{F}\cdot\vec{dx} = F.dx.\cos 180° = -F.dx$

Or, $dw = -\frac{1}{4\pi\varepsilon_0}\frac{qq_0}{x^2}\,dx$

Or, $\int dw = -\frac{qq_0}{4\pi\varepsilon_0}\int\frac{1}{x^2}dx$

Or, $W = -\frac{qq_0}{4\pi\varepsilon_0}\int_\infty^r x^{-2}dx = -\frac{qq_0}{4\pi\varepsilon_0}\left[-\frac{1}{x}\right]_\infty^r = \frac{1}{4\pi\varepsilon_0}\frac{qq_0}{r}$

And $\frac{W}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

or $\boldsymbol{V} = \boldsymbol{\frac{1}{4\pi\varepsilon_0}\frac{q}{r}}$

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| **19** | **State Gauss' law and Derive expression for Gauss' law.** | **Remembering Applying** | **5** |

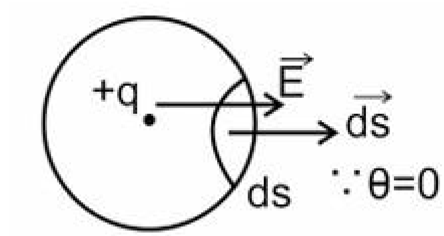
**ANS**

**Gauss' law:-**

Gauss' law states that "the total electric flux (ϕ) passing through any "closed surface" is times of charge enclosed by the surface".

If 'ds' make an angle 'θ' with electric field 'E', then electric flux through 'ds' is given by

$$d\phi = \vec{E}\cdot\vec{dS} = E\,ds\,\cos\theta$$
$$\Rightarrow \int d\phi = \int E\,ds\,\cos\theta$$
$$\Rightarrow \phi = \int E\,ds\,\cos\theta = \int E\,ds = E\int ds \quad (as\ \theta = 0°)$$
$$\Rightarrow \phi = \int \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\,ds = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\int ds = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} X 4\pi r^2$$
$$\Rightarrow \phi = \frac{1}{\varepsilon_0} X q$$

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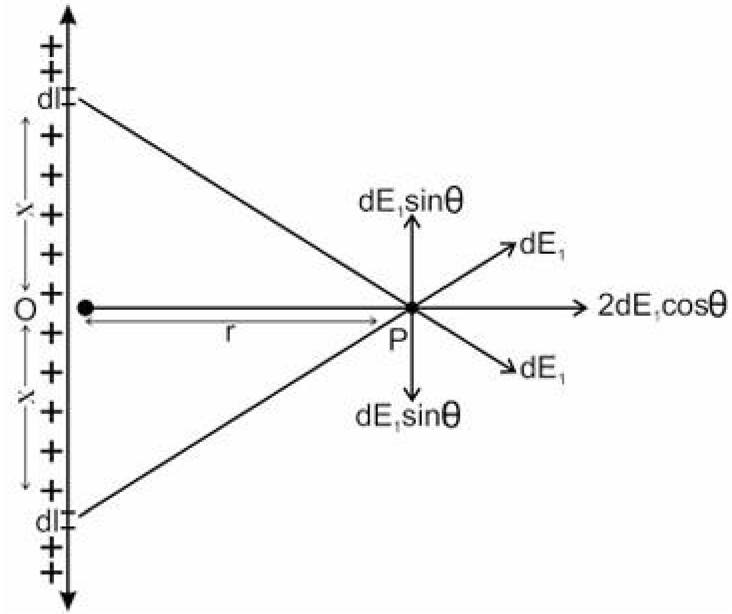
| 20 | **Calculate electric field due to an infinity long straight charged wire using Gauss' law.** | **Applying** | **5** |

**ANS**

**Electric field due to an infinity long straight charged wire** :-

Consider a thin infinitely long straight wire having a uniform linear charge density 'λ' (quantity of charge per unit length. First, we find the direction of electric field by line charge distribution. Let us consider a point P at r distance from point O in linear charge distribution. We can also assume two small charge element dl at x distance above and below point O.

From the Fig (a), the resultant electric field at point P due to both charge element is perpendicular to the line charge.



Direction of electric field due to long straight charged wire

Hence by symmetry, the field "E" of the line charge is directed normally outwards and its magnitude is determined with help of Gauss' law.

To determine the field at a distance r from the line charge we choose a cylindrical Gaussian surface of radius r and length l. It consists of three surface S1 , S2 and S3 First, we calculate for S3 surface, let us consider a small surface ds in S3 and electric flux through surface ds,

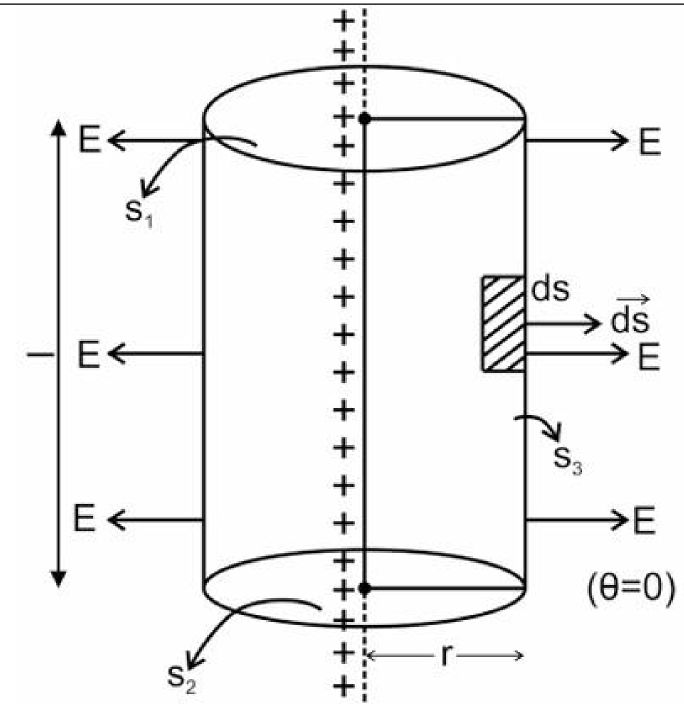
$$\int d\phi = \int E\, ds\, \cos\theta$$

$$\phi = \int E\, ds\, \cos\theta = \int E\, ds = E\int ds \quad (as\ \theta = 0°)$$

For whole cylindrical surface

$$\phi = E\ X\ 2\pi r l$$

Also, by Gaussian Theorem, $\phi = \frac{1}{\varepsilon_0} X q$




Electric field due to an infinitely long straight charged wire by Gauss' law

Now, $E \; X \; 2\pi r l = \frac{1}{\varepsilon_0} X q$

And $\boldsymbol{E} = \frac{\mathbf{1}}{\mathbf{2}\boldsymbol{\pi}\boldsymbol{\varepsilon}_{\mathbf{0}}}\frac{\mathbf{q}}{\boldsymbol{rl}} = \frac{\mathbf{1}}{\mathbf{2}\boldsymbol{\pi}\boldsymbol{\varepsilon}_{\mathbf{0}}}\frac{\boldsymbol{\lambda}}{\boldsymbol{r}}$ [here, $\frac{q}{l} = \lambda$, *linear charge density*]

The magnitude of the outward electric field at any point on surface $S_3$ is given above.

The Magnitude of electric field at Surface $S_1$ and $S_2$ will be zero as the angle between the electric field vector and the area vector of each surface is $90^0$.

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| 21 | **i) Define Capacitance and write its SI unit.**<br>ii) **Derive expression for capacitance of a parallel plate capacitor.** | **Remembering<br>Understanding<br>Applying** | **5 (2+3)** |

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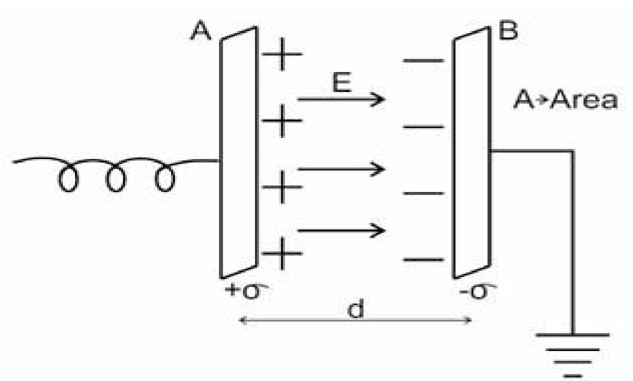
| ANS | **i)** Capacitance is the ability of an object to store electric charge. It is measured by the ratio of change in charge to the difference in electric potential. Mathematically, $C = \frac{Q}{V}$<br>The SI unit of capacitance is the Farad (F).<br>**ii) Capacitance of a parallel plate capacitor :-**<br>It consists of two large plane parallel conducting plates, separated by a small distance d<br>Electric field between the plates $E = \frac{\sigma}{\boldsymbol{\varepsilon_0}}$ ; $\boldsymbol{\sigma}$ = surface charge density<br><br><br>Parallel plate capacitor<br>For a uniform electric field $E = \frac{V}{\mathbf{d}}$<br>Or $V = Ed = \frac{\sigma}{\boldsymbol{\varepsilon_0}} X d = \frac{Qd}{\boldsymbol{\varepsilon}_0 A}$ $\{as\ \sigma = \frac{Q}{A}\}$<br>Again, $C = \frac{Q}{\mathbf{V}} = \frac{\boldsymbol{\varepsilon}_0 A}{d}$<br>Thus, for a parallel plate capacitor,<br>$C\ \ \alpha\ A\ area$<br>$C\ \ \alpha\ \frac{1}{d}\ distance$<br>$C\ \ \alpha\ \boldsymbol{\varepsilon_0}\ permittivity\ of\ medium\ between\ plates.$ | |

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| 22 | **Derive an expression for electric field due to uniformly charged plane sheet.** | **Understanding** | 5 |

**ANS**

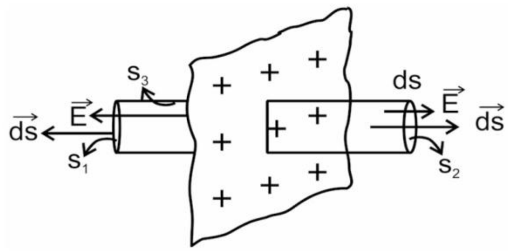


**Fig 3.12** Electric field due to uniformly charged plane sheet

Consider +q charge is given to an infinite sheet so that charge will uniformly distributed over the surface having surface charge density 'σ' (quantity of charge per unit area).

Due to uniform distribution of charge, electric field can be calculated by drawing a Gaussian surface in the form of cylinder. The cylinder consists of surface $S_1$, $S_2$ and $S_3$. First, we calculate for Surface $S_1$ and $S_2$

So electric flux through *ds* on both surface ($S_1$ and $S_2$ )

$$d\emptyset = 2\vec{E}.\vec{ds}$$

$$\int d\emptyset = 2\int Eds\,cos(0)$$

$$\emptyset = 2E\int ds$$

$$\left[\int ds = Stotal\ surface\ Area\right]$$

$$\emptyset = 2ES$$

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| | Then<br><br>Also, by Gauss'Law<br><br>$$\emptyset = \frac{q}{\epsilon_0}$$<br>$$2ES = \frac{q}{\epsilon_0}$$<br>$$E = \frac{q}{2\epsilon_0 S}$$<br>[Surface charge density $\sigma = \frac{q}{S}$]<br>$$E = \frac{q}{2\epsilon_0}$$<br>The Magnitude of electric field at Surface $S_3$ is zero as the angle between the electric field vector and the area vector of surface $S_3$ is $90^0$ | |