VECTORS

Electric Field E

- Electric field strength E at a given point is defined as the electric force per unit positive charge that acts on a small test charge placed at that point.
- Direction of the field is given by the direction of the electric force experienced by a positive test charge placed at that point.
- A small test charge does not distort the electric field.
- Unit: N C^{-1} or V m^{-}

Electric Force F_E

- For a positive charge, the direction of the electric force is in the direction of the electric field.
- For a negative charge, the direction of the electrostatic force is opposite to the direction of the electric field.
- Unit: N

Relationship between force and field: $F_E = qE$

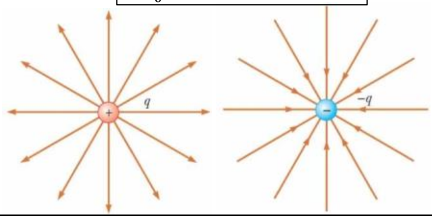
For Point Charges (Electric Field)

- Magnitude of the electric field due to a point charge

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$r: distance\ of\ separation$

$\varepsilon_0: 8.85 \times 10^{-12} Fm^{-1}$



For Point Charges (Electric Force)

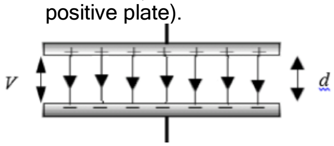
- Coulomb's Law states that the magnitude of the electric force between two point charges is proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between them.

$$F_E = \frac{|Q_1||Q_2|}{4\pi\varepsilon_0 r^2}$$

- Formula only gives the magnitude of the force
- Force can be attractive (unlike charges) or repulsive (like charges)
- Force acts along the line joining the two charges

For a Parallel Plate System (Electric Field)

- Electric field is uniform within the plates, hence field lines are parallel and uniformly spaced:
- E-field lines goes from high potential to low potential (hence from more positive to less positive plate).



- Magnitude of E-field

$$E = \frac{\Delta V}{d}$$

$\Delta V: potential\ difference\ between\ the\ plates$

$d: distance\ between\ the\ plates$

For a Parallel Plate System (Electric Force)

$$F_E = qE = q\frac{\Delta V}{d}$$

- Since the E-field is uniform, the force on a point charge placed in the field anywhere between the parallel plates is also constant
- Magnitude of electric force is usually much greater than that of gravitational force, hence charge will typically experience uniform acceleration motion in the direction of the electric force.

$$a = \frac{F_E}{m} = \frac{qE}{m} = q\frac{\Delta V}{md}$$

- A charged particle projected at an angle to the electric field will move in parabolic path.

SCALARS

Electric Potential V

- Electric Potential V at a point in an electric field is defined as the work done per unit positive charge, by an external force, in moving a small test charge from infinity to that point in the electric field without a change in kinetic energy.
- V is set to zero at Infinity
- Can be positive or negative depending on the field.
- Unit: V or J C^{-1}

Electric Potential Energy U

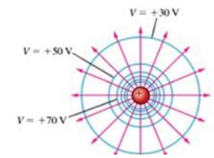
- The electric potential energy, U of a charge at a point in an electric field is defined as the work done by an external agent in moving the charge from infinity to that point without any change in kinetic energy.
- U is set to zero at infinity
- Can be positive or negative
- Magnitude of the energy is path independent, it is only dependent on the initial and final positions
- Unit: J

Relationship between potential and potential energy: $U = qV$

For Point charges: (Electric Potential)

- Electric potential due to a point charge is given by

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$



- Must substitute the sign of the charge Q
- Positive charge produces a positive potential around itself; negative charge produces a negative potential
- Equipotential lines are always perpendicular to the E-field lines.

For Point Charges (Electric Potential Energy)

- Electric potential energy due to two point charges is given by

$$U = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$$

- Must substitute the sign of the charges

For a Parallel Plate System (Electric Potential)

- Since the E-field is uniform, the potential along the field decreases linearly

Work done by external agent at constant speed

- Work done by external agent in moving a charge q at constant speed between two points changes the U of the system and is given by

$$\Delta U = q(V_f - V_i) = F_{ext}S$$

For + ΔU: work done by external agent is positive

For - ΔU: work done by external agent is negative

Allowing an isolated charge to move freely in an electric field

- Apply COE:

$$Gain\ in\ KE = Loss\ in\ U$$

$$KE_f - KE_i = q(V_i - V_f)$$

Relationship between Force and Potential energy $F_E = -\frac{dU}{dr}$

Relationship between field and potential $E = -\frac{dV}{dr}$