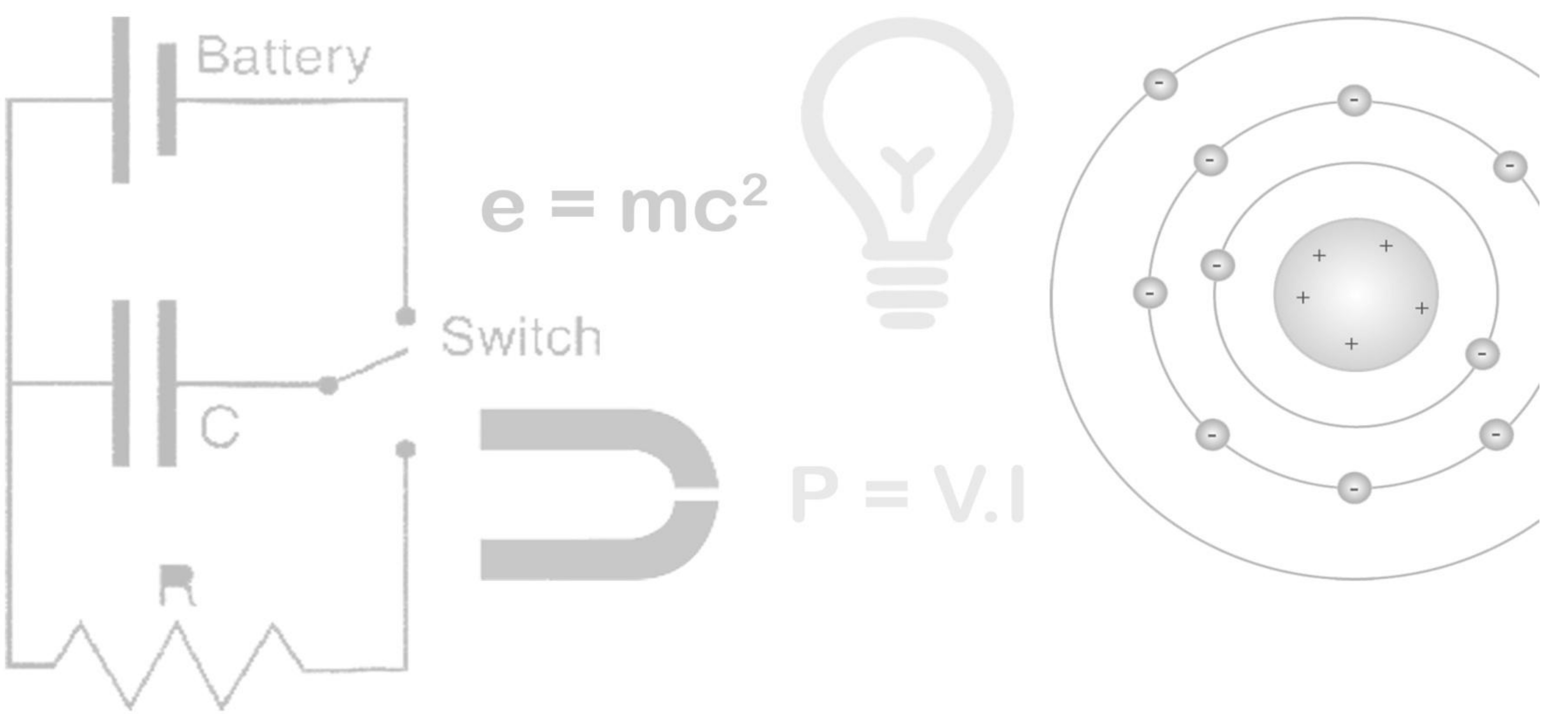
PHYSICS



Electric Charges and Fields

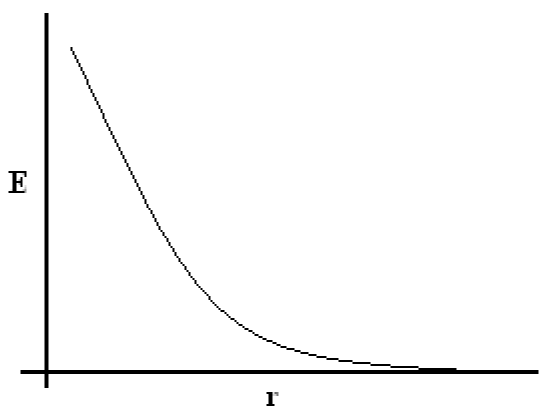
Top Formulae

Formula	Description
Quantisation of charge $Q = \pm ne$	Q = total charge (coulomb) e = charge on one electron (coulomb) n = number of electrons
The force between two charges q_1 and q_2 at a distance r from each other $\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$	F = force (newton) q_1 and q_2 = charges (coulomb) r = distance between charges (metre)
Superposition principle $\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots\ldots$	$\vec{F}$ = net force on the system (newton) $\vec{F}_1, \vec{F}_2$ and $\vec{F}_3 \ldots$ = different forces working on the system (newton)
Electric field strength $\vec{E}$ at a point r distance away from a point charge q $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$	$\vec{E}$ = electric field strength (volt/metre) r = distance from a point charge (metre) q = point charge (coulomb)
Electrostatic force $\vec{F}$ on a charge q inside the electric field $\vec{E}$ $\vec{F} = q\,\vec{E}$	$\vec{E}$ = electric field strength (volt/metre) $\vec{F}$ = electrostatic force (newton) q = point charge (coulomb)
Dipole moment $p = q \times 2a$	p = dipole moment (coulomb metre) q = one of the charges (coulomb) 2a = separation between two charges (metre)
Dipole field intensity on the axial line of the dipole $\lvert\vec{E}_1\rvert = \frac{2pr}{4\pi\varepsilon_0(r^2 - a^2)^2}$	$\lvert\vec{E}_1\rvert$ = electric field strength (volt/metre) p = dipole moment (coulomb metre) 2a = separation between two charges (metre) r = distance of the point from the centre of the dipole (metre)

Dipole field intensity on the equatorial line of the dipole $\left\|\vec{E}_2\right\| = \frac{p}{4\pi\varepsilon_0(r^2+a^2)^{3/2}}$	$\left\|\vec{E}_2\right\|$ = electric field strength (volt/metre) p = dipole moment (coulomb metre) 2a = separation between two charges (metre) r = distance of the point from the centre of the dipole (metre)
Torque on dipole inside the electric field is $\vec{\tau} = \vec{p} \times \vec{E}$	$\vec{E}$ = electric field strength (volt/metre) p = dipole moment (coulomb metre) $\vec{\tau}$ = torque (newton metre)
Flux $\Delta\phi = \vec{E}.\Delta\vec{S}$	$\vec{E}$ = electric field strength (volt/metre) $\Delta\vec{S} = \Delta S\,\hat{n}$ = area element (metre^2) $\Delta\phi$ = flux (weber)
Gauss's law: $\phi = \frac{q}{\varepsilon_0}$	ϕ = electric flux through a closed surface (weber) S = area of closed surface (metre^2) q = total charge enclosed by S (coulomb)
Application of Gauss's law: Electric field due to a thin infinitely long straight wire of uniform linear charge density $\vec{E} = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r}\hat{n}$	λ = linear charge density (coulomb/metre) r = perpendicular distance of the point from the wire (metre) $\vec{E}$ = electric field intensity (volt/metre) $\hat{n}$ = radial unit vector
Electric field due to an infinite thin plane sheet of uniform surface charge density $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$	σ = surface charge density (coulomb/metre^2) $\vec{E}$ = electric field intensity (volt/metre) $\hat{n}$ = unit vector normal to the plane
Electric field due to a thin spherical shell uniform surface charge density $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r} \qquad (r \geq R)$ $\vec{E} = 0 \qquad (r < R)$	σ = surface charge density (coulomb/metre^2) $\vec{E}$ = electric field intensity (volt/metre) r = distance of the point from the centre of the shell R = radius of the shell q = total charge on the shell

Top Concepts

- Like charges repel and unlike charges attract.
- Conductors allow movement of electric charge through them, while insulators do not.
- Quantisation of electric charge means that total charge (q) of a body is always an integral multiple of a basic quantum of charge (e), i.e. q = ne, where n = 0, ±1, ±2, ±3….
- Additivity of electric charges: Total charge of a system is the algebraic sum of all individual charges in the system.
- Conservation of electric charges: Total charge of an isolated system remains unchanged with time.
- Superposition principle: The forces with which two charges attract or repel each other are not affected by the presence of a third (or more) additional charge(s).
- The electric field E at a point due to a charge configuration is the force on a small positive test charge q placed at the point divided by a magnitude $|q|/ 4 \pi \varepsilon_0 r^2$; it is radially outwards from q, if q is positive, and radially inwards, if q is negative.
- E at a point varies inversely as the square of its distance from charge Q. The plot of E v/s r will appear like the figure given below.



- Coulomb's law: The mutual electrostatic force between two point charges q_1 and q_2 is proportional to the product q_1q_2 and inversely proportional to the square of the distance r_{21} separating them.

  $\vec{F}_{21}$ (force on q_2 due to q_1) $= \frac{k(q_1q_2)}{r_{21}^2}\hat{r}_{21}$

  where $\hat{r}_{21}$ is a unit vector in the direction from q_1 to q_2 and $k = \frac{1}{\pi\varepsilon_0}$ is the constant of proportionality.
- An electric field line is a curve drawn in such a way that the tangent at each point on the curve gives the direction of electric field at that point.

- Important properties of field lines are
  (i) Field lines are continuous curves without any breaks.
  (ii) Two field lines cannot cross each other.

  (iii) Electrostatic field lines start at positive charges and end at negative charges. They cannot form closed loops.

- The electric flux $\phi = \int d\phi = \int \vec{E}.d\vec{S}$ is a dot product, and hence, it is scalar.

  $\Delta\phi$ is positive for all values of $\theta < \frac{\pi}{2}$.

  $\Delta\phi$ is negative for all values of $\theta > \frac{\pi}{2}$.

- Gauss's law: The flux of the electric field through any closed surface S is $1/\varepsilon_0$ times the total charge enclosed by S.

  $$\phi = \int \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$$

- The electric field outside the charged shell is as though the total charge is concentrated at the centre. The same result is true for a solid sphere of uniform volume charge density.
  The electric field is zero at all points inside a charged shell.

  Graphical plot of $\vec{E}$ versus *R* inside the spherical shell: