[Electric Field & Charges]

[PHYSICS BY RAJAT SACHDEV] [9580951094]

① Coulomb's law of force

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

② Dielectric Constant / Relative Permittivity

$$\varepsilon_r \text{ or } K = \frac{\varepsilon}{\varepsilon_0} = \frac{F_{vac}}{F_{med}}$$

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③ Electric Field → $\vec{E} = \frac{\vec{F}}{q_0}$

④ Electric Field due to point charge

$$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$$

⑤ Volume charge density $\rho = \frac{dq}{dV}$

⑥ Surface charge density $\sigma = \frac{dq}{dS}$

⑦ Linear charge density $\lambda = \frac{dq}{dL}$

⑧ Dipole Moment $p = q \times 2a$

$2a$ = distance between two charge

⑨ Dipole Field at an axial point at distance r from the centre of the dipole is

$$E_{axial} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2pr}{(r^2 - a^2)^2}$$

when $r >> a$ $E_{axial} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{r^3}$

⑩ Dipole Field at an equatorial point

$$E_{equa} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{p}{(r^2+a^2)^{3/2}}$$

when $r >> a$

$$E_{equa} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{p}{r^3}$$

(11) Torque $\tau = pE \sin\theta$

(12) Electric Flux through a plane surface area S held in uniform electric field $\vec{E}$ is

$$\phi_E = \vec{E} \cdot \vec{S} = ES \cos\theta$$

(13) Gauss's theorem

$$\phi_E = \int_S \vec{E} \cdot d\vec{S} = \frac{q}{\varepsilon_0}$$

(14) Flux density $= \dfrac{\text{Total Flux}}{\text{Area}} = \dfrac{\phi_E}{S}$

(15) Electric Field of a long straight wire of uniform linear charge density λ,

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$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

r = perpendicular distance of the observation point from the wire

(16) Electric Field of an infinite plane sheet of uniform surface charge density σ,

$$E = \frac{\sigma}{2\varepsilon_0}$$

(17) Electric Field of two positively charged parallel plates with charge densities σ_1 and σ_2 such that $\sigma_1 > \sigma_2 > 0$

$$E = \pm \frac{1}{2\varepsilon_0}(\sigma_1 + \sigma_2) \quad \text{(outside the plates)}$$

$$E = \frac{1}{2\varepsilon_0}(\sigma_1 - \sigma_2) \quad \text{(Inside the plates)}$$

(18) Electric field of two equally and oppositely charged parallel plates.

$$E = 0 \quad \text{(For outside)}$$

$$E = \frac{\sigma}{\varepsilon_0} \quad \text{(For inside)}$$

(19.) Electric Field of a thin spherical shell of charge density σ and radius R

$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$ for $r > R$ (outside points)

$E = 0$ for $r < R$ (Inside points)

$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{R^2}$ for $r = R$ (At the surface)

Here $q = 4\pi R^2 \sigma$

(20.) Electric field of a solid sphere of uniform charge density ρ and radius R

$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$ for $r > R$ (outside points)

$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{qr}{R^3}$ for $r < R$ (Inside points)

$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{R^2}$ for $r = R$ (At the surface)

Here $q = \frac{4}{3}\pi R^3 \rho$

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[Electrostatice Potential & Capacitance]

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(1) Potential difference = $\frac{\text{Work done}}{\text{Charge}} = \frac{W}{q}$

(2) Electric Potential due to a point charge q at distance r from it

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

(3) Electric Potential at a point due to dipole

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{P\cos\theta}{r^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\vec{P}\cdot\vec{r}}{r^3}$$

(4) Electric field in a region can be determined from the electric potential by using relation

$$E = -\frac{dV}{dr}$$

$$E_x = -\frac{\partial V}{\partial x}, \quad E_y = -\frac{\partial V}{\partial y}, \quad E_z = -\frac{\partial V}{\partial z}$$

(5) Electric field between two parallel conductors

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

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(6) Electric potential energy of a system of two Point charges – $U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r_{12}}$

(7) Potential energy of an electric dipole in a uniform electric field

$$U = -pE(\cos\theta_2 - \cos\theta_1)$$

If initially the dipole is perpendicular to the field E, $\theta_1 = 90°$ and $\theta_2 = \theta$

$$U = -pE\cos\theta = -\vec{p}\cdot\vec{E}$$

If initially the dipole is parallel to the field E, $\theta_1 = 0°$ and $\theta_2 = \theta$

$$U = -pE(\cos\theta - 1) = pE(1 - \cos\theta)$$

(8) Capacitance of a spherical conductor of radius R

$$C = 4\pi \varepsilon_0 R$$

(9) $C = \frac{Q}{V}$

(10) Capacitance of parallel plate capacitor $C = \frac{\varepsilon_0 A}{d}$

(11) In series combination, charge on each capacitor is same but potential differences across the capacitors may be different.

(12) In parallel combination, potential difference on each capacitor is same but the charges on the capacitors may be different.

(13) Energy stored in capacitor

$$U = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} qV$$

(14) Energy stored per unit volume or the energy density of the electric field of a capacitor

$$u = \frac{1}{2} \varepsilon_0 E^2$$

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(15) Electric field between capacitor plates $E = \frac{q}{\varepsilon_0}$

(16) Capacitance of a parallel plate capacitor filled with a dielectric of dielectric constant k

$$C = kC_0 = \frac{\varepsilon_0 kA}{d}$$

(17) Effect of dielectric with battery disconnected from the capacitor

$$Q = Q_0,\ V = \frac{V_0}{K},\ E = \frac{E_0}{K},\ C = KC_0,\ U = \frac{U_0}{K}$$

(18) Effect of dielectric with battery connected across the capacitor $Q = KQ_0,\ V = V_0,\ E = E_0,\ C = KC_0$ & $U = KU_0$

[Current Electricity]

[PHYSICS BY RAJAT SACHDEV] [9580951094]

① Electric Current $I = \frac{Q}{t}$

② $Q = ne$, $I = \frac{ne}{t}$

③ In case of an electron revolving in a circle of radius r with speed v, period of revolution of the electron is

$$T = \frac{2\pi r}{v}$$

Current at any point of the orbit is

$$I = e\nu = \frac{ev}{2\pi r}$$

④ Resistance of a uniform conductor $R = \frac{\rho l}{A}$

⑤ Resistivity or specific Resistance $\rho = \frac{RA}{l}$

⑥ Conductance $= \frac{1}{R}$

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⑦ Conductivity $\sigma = \frac{1}{\rho} = \frac{l}{RA}$

⑧ Current density $j = \frac{I}{A}$

⑨ Current in terms of drift velocity $I = neAv_d$

⑩ Current density $j = nev_d$

⑪ In terms of relaxation time τ,

$$R = \frac{ml}{ne^2\tau A} \quad \text{and} \quad \rho = \frac{m}{ne^2\tau}$$

⑫ Relation between current density and electric field

$$\vec{j} = \sigma\vec{E} \quad \text{or} \quad \vec{E} = \rho\vec{j}$$

This is vector form of ohm's law.

(13) Mobility, $\mu = \frac{v_d}{E} = \frac{q\tau}{m}$

(14) Electric Current, $I = neAv_d = neA\mu E$

(15) Conductivity of metallic conductor $\sigma = ne\mu_e$

(16) Conductivity of a semiconductor $\sigma = ne\mu_e + pe\mu_p$

(17) EMF of a cell, $\mathcal{E} = \frac{W}{q}$

(18) For a cell of internal resistance r, the emf is

$$\mathcal{E} = V + Ir = I(R+r)$$

(19) Terminal P.d. of a cell, $V = IR = \frac{\mathcal{E}R}{R+r}$

(20) Terminal p.d. when a current is being drawn from the cell

$$V = \mathcal{E} - Ir$$ [sign of I -ve to +ve]

(21) Terminal p.d. when the cell is being charged

$$V = \mathcal{E} + IR$$ [sign of I +ve to -ve]

(22) Internal resistance of the cell

$$r = R\left[\frac{\mathcal{E} - V}{V}\right]$$

(23) For n cells in series

$$I = \frac{n\mathcal{E}}{R + nr}$$

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(24) For n cells in parallel

$$I = \frac{n\mathcal{E}}{nR + r}$$

(25) For mixed grouping

$$I = \frac{mn\mathcal{E}}{mR + nr}$$

R = external Resistance
r = internal resistance

n = no. of cells in series in one row
m = no. of rows of cells in parallel

(26.) Heat produced by electric current

$$H = I^2Rt \text{ J} = \frac{I^2Rt}{4.18} \text{ Cal}$$

$$H = Vit \text{ J} = \frac{Vit}{4.18} \text{ Cal}$$

(27.) Electric Power, $P = \frac{W}{t} = Vi = I^2R = \frac{V^2}{R}$

(28.) Electric energy, $W = Pt = Vit = I^2Rt$

(29.) Kirchhoff's law

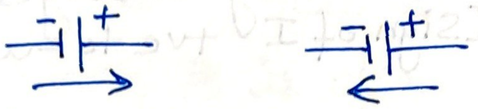
$\Sigma I = 0$ [KCL] [Law of Conservation of charge]

$\Sigma IR = \Sigma \varepsilon$ [Loop Rule] [law of conservation of energy]

(30) Sign convention for applying loop rule

(i) take traversal (clockwise or anticlockwise)

(ii)



$V = +\varepsilon$ $V = -\varepsilon$

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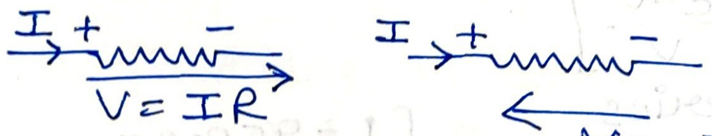
(iii)



$V = IR$ $V = -IR$

(31.) For a balanced wheatstone bridge $\frac{P}{Q} = \frac{R}{S}$

[Magnetic Effect of Current]

[PHYSICS BY RAJAT SACHDEV] [9580951094]

① Biot - Savart law $dB = \frac{\mu_0}{4\pi} \frac{I\,dl \sin\theta}{r^2}$

② Magnetic field due to a straight conductor of finite length

$$B = \frac{\mu_0 I}{4\pi a} (\sin\phi_1 + \sin\phi_2)$$

③ Magnetic field due to an infinitely long straight conductor

$$B = \frac{\mu_0 I}{2\pi a}$$

④ Magnetic field at the centre of a circular loop

$$B = \frac{\mu_0 I}{2r}$$

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⑤ Ampere's circuital law, $\oint \vec{B} \cdot \vec{dl} = \mu_0 I$

When B is directed along tangent to every point on closed curve L, $BL = \mu_0 I$

⑥ Magnetic field due to straight solenoid

(i) At a point well inside the solenoid

$$B = \mu_0 n I$$

(ii) At either end of the solenoid

$$B_{end} = \frac{1}{2} \mu_0 n I$$

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n = no. of turns per unit length

⑦ Magnetic field inside a toroidal solenoid $B = \mu_0 n I$

Magnetic field outside the toroid $B = 0$

⑧ Force on a charge q moving with velocity v in a magnetic field at an angle θ

$$F = qvB \sin\theta$$

(9) Electric force on a charge $F_e = qE$

(10) In a perpendicular magnetic field, the charge follows a circular path

$$qvB = \frac{mv^2}{r} \quad \text{or} \quad r = \frac{mv}{qB}$$

$$T = \frac{2\pi m}{qB} \quad \text{and} \quad f = \frac{qB}{2\pi m}$$

(11.) When $\vec{v}$ makes angle θ with $\vec{B}$, the charge follows helical path

$$r = \frac{mv_\perp}{qB} = \frac{mv\sin\theta}{qB}$$

$$T = \frac{2\pi r}{v_\perp} = \frac{2\pi m}{qB}$$

Pitch of helix, $h = v_{\parallel} T = v\cos\theta \cdot T = \frac{2\pi m v\cos\theta}{qB}$

(12) K.E. gained by an electron when accelerated through a potential difference V

$$\frac{1}{2}mv^2 = eV$$

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$$v = \sqrt{\frac{2eV}{m}}$$

(13) Force per unit length $f = \frac{\mu_0 I_1 I_2}{2\pi r}$

(14) Force on length l of one of the wire

$$F = \frac{\mu_0 I_1 I_2 l}{2\pi r}$$

(15) Torque on a current loop in a magnetic field

$$\tau = NIBA\sin\theta = mB\sin\theta$$

$m = NIA$ = magnetic dipole moment of current loop

$$\vec{\tau} = \vec{m} \times \vec{B}$$

(16) In a moving coil galvanometer

Current $I = \frac{K}{NBA} \cdot \alpha$ [☏-9580951094]

Deflection produced $\alpha = \frac{NBA}{K} \cdot I$

(17.) Figure of merit, $G = \frac{1}{\alpha} = \frac{K}{NBA}$

(18) Current sensitivity, $I_S = \frac{\alpha}{I} = \frac{NBA}{K}$

(19) Voltage sensitivity, $V_S = \frac{\alpha}{V} = \frac{\alpha}{IR} = \frac{NBA}{KR}$

(20) For conversion of a galvanometer into ammeter the shunt resistance

$$R_S = \frac{I_g}{I - I_g} \times R_g \quad , \quad I_g = \frac{R_S}{R_g + R_S} \times I$$

(21.) Resistance of an ammeter $R_A = \frac{R_g R_S}{R_g + R_S}$

(22.) For conversion of a galvanometer into a volt-meter, the value of high series resistance

$$R = \frac{V}{I_g} - R_g \quad , \quad I_g = \frac{V}{R_g + R}$$

(23.) Resistance of a voltmeter $R_V = R_g + R$

[Electromagnetic Induction]

[PHYSICS BY RAJAT SACHDEV] [9580951094]

① Magnetic flux $\phi = BA\cos\theta = \vec{B}\cdot\vec{A}$

② Induced emf $\varepsilon = -N\frac{d\phi}{dt}$

③ Average Induced emf $\varepsilon = -N\frac{\phi_2-\phi_1}{t}$

④ Induced Current $I = \frac{|\varepsilon|}{R}$

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⑤ For Self-induction $\phi = LI$

⑥ Self induced emf $\varepsilon = -L\frac{dI}{dt}$

⑦ For mutual induction $\phi = MI$

⑧ Mutual induced emf $\varepsilon = -M\frac{dI}{dt}$

⑨ Self-inductance of long solenoid

$$L = \frac{\mu_0 N^2 A}{l} = \mu_0 n^2 A l$$

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⑩ Mutual inductance of two closely wound solenoids

$$M = \frac{\mu_0 N_1 N_2 A}{l} = \mu_0 n_1 n_2 A l$$

[Alternating Current]

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① Instantaneous value of a.c.

$$I = I_0 \sin \omega t$$

② Average or mean value of a.c. over half cycle

$$I_{av} = \frac{2}{\pi} I_0 = 0.637 I_0$$

I_0 = peak value or maximum value

③ Effective or rms or virtual value of a.c.

$$I_{eff} \text{ or } I_{rms} \text{ or } I_v = \frac{1}{\sqrt{2}} I_0 = 0.707 I_0$$

④ For alternating voltages, we have

$$\mathcal{E} = \mathcal{E}_0 \sin \omega t \,,\quad \mathcal{E}_{av} = 0.637\,\mathcal{E}_0 \,,\quad \mathcal{E}_{rms} = \frac{1}{\sqrt{2}} \mathcal{E}_0$$

⑤ For an a.c. circuit containing inductor only

(i) inductive reactance $X_L = \omega L = 2\pi f L$

(ii) Current Amplitude, $I_0 = \frac{\mathcal{E}_0}{X_L} = \frac{\mathcal{E}_0}{\omega L}$ [☏-9580951094]

(iii) Effective current, $I_{rms} = \frac{\mathcal{E}_{rms}}{X_L} = \frac{\mathcal{E}_{rms}}{\omega L} = \frac{\mathcal{E}_0}{\sqrt{2}\cdot \omega L}$

⑥ For an a.c. circuit containing capacitor only

(i) Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

(ii) Current amplitude $I_0 = \frac{\mathcal{E}_0}{X_C} = \frac{\mathcal{E}_0}{1/\omega C}$

(iii) Effective current

$$I_{rms} = \frac{\mathcal{E}_{rms}}{X_C} = \frac{\mathcal{E}_{rms}}{1/\omega C} = \frac{\mathcal{E}_0}{\sqrt{2}\cdot 1/\omega C}$$

⑦ Impedence, $Z = \frac{\mathcal{E}_{rms}}{I_{rms}} = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + \omega^2 L^2}$

⑧ Current, $I_{rms} = \frac{\mathcal{E}_{rms}}{Z}$

(9) Phase angle ϕ is given by

$$\tan\phi = \frac{X_L}{R} = \frac{\omega L}{R}, \quad \cos\phi = \frac{R}{Z}$$

(10) Impedence of C-R circuit

$$Z = \frac{\varepsilon_{rms}}{I_{rms}} = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$$

(11) Current, $I_{rms} = \frac{\varepsilon_{rms}}{Z}$ [6-9580951094]

(12) Phase angle ϕ is given by

$$\tan\phi = \frac{X_C}{R} = \frac{1/\omega C}{R}, \quad \cos\phi = \frac{R}{Z}$$

(13) Impedence of series LCR Circuit

$$Z = \frac{\varepsilon_{rms}}{I_{rms}} = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

(14) Phase angle ϕ between current and voltage is given by

$$\tan\phi = \frac{X_L - X_C}{R} \quad \text{or} \quad \cos\phi = \frac{R}{Z}$$

(15) Resonant frequency of L-C-R series circuit ($X_L = X_C$)

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

(16) Magnetic energy stored in the inductor at any instant

$$U_B = \frac{1}{2} L I^2$$

$$U_B^{max} = \frac{1}{2} L I_0^2$$