BRAIN MAP

REVIEW-I

A QUICK OVERVIEW TO ELECTROSTATICS, CURRENT ELECTRICITY, MAGNETISM, EMI AND A.C.

ELECTROSTATICS

Capacitance,
$C = \frac{q}{V}$
Spherical capacitor, $C = 4\pi\varepsilon_0 R$

Parallel plate capacitor (Partially filled dielectric)
$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}}$

Energy stored in a capacitor,
$U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}qV$

Electric field
$\vec{E} = \frac{\vec{F}}{q_{test}} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$

Dipole field
$\vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}\hat{p}$, $\vec{E}_{equatorial} = \frac{-1}{4\pi\varepsilon_0}\frac{p}{r^3}\hat{p}$

Torque and work done
$\tau = pE\sin\theta$
$U = -pE\cos\theta$

Electric flux and Gauss's law
Electric flux, $\Delta\phi_E = \vec{E}\cdot\Delta\vec{S} = E\Delta S\cos\theta$
Gauss's law: $\phi_E = \frac{q_{net}}{\varepsilon_0}$

Due to a long straight wire
$E = \frac{\lambda}{2\pi\varepsilon_0 r}$

Electric field due to charged sphere $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ for $r > R$ (Outside point)
where, $q = \frac{4\pi}{3}R^3\rho$.

Due to an infinite plane sheet $E = \frac{\sigma}{2\varepsilon_0}$

Coulomb's law
Electric force between two point charges
$\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{q \cdot q'}{r^2}\hat{r}$

Electrostatic potential
$V = \frac{W}{q}$
$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

Equipotential surface
- $W_{net} = 0$
- $E \perp ds$
- Do not intersect each other

Electric potential due to electric dipole
$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$

MAGNETOSTATICS

Magnetic force
$\vec{F}_m = q(\vec{v} \times \vec{B})$
$F_m = qvB\sin\theta$

Cyclotron
Accelerates charged particles so they acquire high energies,
$f_c = \frac{qB}{2\pi m}$

Magnetic field due to a bar magnet
End-on, $B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$
Broadside-on, $B = \frac{\mu_0}{4\pi}\frac{m}{r^3}$

Torque and work done
$\tau = mB\sin\theta$
$U = -\vec{m}\cdot\vec{B} = -mB\cos\theta$

Moving Coil Galvanometer
Current sensitivity, $\frac{\phi}{I} = \frac{NAB}{k}$
Voltage sensitivity, $\frac{\phi}{V} = \left(\frac{NAB}{k}\right)\frac{1}{R}$

Galvanometer into voltmeter
$R = \frac{V}{I_g} - G$

Galvanometer into ammeter
$\frac{S}{G} = \frac{I_g}{I - I_g}$

Biot Savart law
$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$

Applications of Biot-Savart law
Field on the axis of a circular loop
$B = \frac{\mu_0 NIR^2}{2(R^2 + x^2)^{3/2}}$
Field at the centre of a loop
$B = \frac{\mu_0 NI}{2R}$

Earth's magnetism and magnetic properties of substances

Net magnetic field, $B = \sqrt{B_H^2 + B_V^2}$
Here, $B_H = B\cos\delta$, $B_V = B\sin\delta$
δ is the dip angle at the place.

Curie law, $\chi_m = \frac{C}{T}$
Curie-Weiss law, $\chi_m = \frac{C}{T - T_C}$ $(T > T_C)$

Ampere's circuital law
$\oint \vec{B}\cdot d\vec{l} = \mu_0 I$

Applications of Ampere's circuital law
Magnetic field due to a straight wire of infinite length,
$B = \frac{\mu_0}{2\pi}\frac{I}{R}$

Magnetic field inside a long solenoid, $B = \mu_0 nI$

CURRENT

A.C.

Based on principle of Electromagnetic Induction

Faraday law of EMI
$\varepsilon = \frac{-d\phi}{dt}$; $\phi = BA\cos\theta$

Electric generator and electric motor
Flux linked, $\phi = NBA\cos\omega t$
Instantaneous induced emf, $\varepsilon = \varepsilon_0\sin\omega t$

$\varepsilon = \varepsilon_0\sin\omega t$

Lenz's law
The direction of the induced current is such that it opposes the change that has induced it.

Motional emf
On a straight conducting wire, $\varepsilon = Bvl$
On a rotating conducting wire about one end
$\varepsilon = \frac{B\omega l^2}{2}$

Eddy current
The current induced in conductors when the magnetic flux linked with the conductor changes.

Emf induced in the coil/conductor, $\varepsilon = -L\frac{dI}{dt}$
Coefficient of self induction, $L = \frac{\varepsilon}{dI/dt}$
Mutual inductance, $M = \frac{\varepsilon}{dI/dt}$

Self inductance of a long solenoid
$L = \mu_0\mu_r n^2 Al$

Mutual inductance of two long coaxial solenoids
$M = \mu_0\mu_r\pi r_1^2 n_1 n_2 l$

Transformer
Efficiency of transformer,
$\eta = \frac{\text{output power}}{\text{input power}} = \frac{\varepsilon_s I_s}{\varepsilon_p I_p}$
When efficiency of transformer is 100%,
$\frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$
$= k$ (transformer ratio)

Energy stored in an inductor
$U_B = \frac{1}{2}LI^2$

Series *LCR* circuit
Impedance of series *LCR* circuit
$Z = \sqrt{R^2 + (X_L - X_C)^2}$, $\tan\phi = \frac{X_L - X_C}{R}$

Electric resonance
At resonance, $X_L = X_C$
$\therefore$ Resonance frequency
$\upsilon_r = \frac{\omega_r}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$

Power factor
$\cos\phi = \frac{P_{avg}}{I_{rms}V_{rms}}$

Q-factor of *LCR* circuit
$Q = \frac{\omega_r}{2\Delta\omega} = \frac{1}{R}\sqrt{\frac{L}{C}}$

D.C.

Ohm's law
$V = IR$,
Resistivity $\rho = \frac{RA}{l}$

Drift speed, $v_d = -\frac{eE}{m}\tau$
$I = neAv_d$, $R = \frac{ml}{ne^2\tau A}$ and $\rho = \frac{m}{ne^2\tau}$

Temperature dependence
$R_T = R_0[1 + \alpha(T - T_0)]$
Temperature coefficient of resistance, $\alpha = \frac{R_T - R_0}{R_0(T - T_0)}$

Heat energy, $H = I^2Rt$
Power, $P = I^2R = \frac{V^2}{R}$
For transmission cable, power loss
$P_C = I^2R_C = \frac{P^2R_C}{V_C^2}$, P = constant

Kirchhoff's rules
Junction Rule : Current entering = Current leaving, $\Sigma I = 0$.
Loop Rule : Total potential around any closed loop must be zero, $\Sigma\varepsilon + \Sigma IR = 0$

Wheatstone bridge
In balanced condition,
$\frac{R_1}{R_2} = \frac{R_3}{R_4}$

Potentiometer
Fall of potential, $V \propto l$, $V = Kl$
Here, $K = \frac{V}{l}$ = potential gradient

Meter bridge
Resistance of unknown resistor,
$R = \frac{Sl_1}{(100 - l_1)}$

Comparision of emfs of two cells,
$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$

Internal resistance of a cell
$r = R\left(\frac{\varepsilon}{V} - 1\right) = R\left(\frac{l_1}{l_2} - 1\right)$