PHY2054 Formulas

Chapter 15 (Electric forces and fields, Gauss' law)

Coulomb's Law $\mathbf{F} = \frac{kQq}{r^2}\hat{\mathbf{r}} \equiv \frac{Qq}{4\pi\varepsilon_0 r^2}\hat{\mathbf{r}}$ (point charge) $\hat{\mathbf{r}}$ = unit vector from Q to q.

Electric field $\mathbf{F} = q\mathbf{E}$ (general) $\mathbf{E} = \frac{kQ}{r^2}\hat{\mathbf{r}} \equiv \frac{Q}{4\pi\varepsilon_0 r^2}\hat{\mathbf{r}}$ (single point charge Q)

$\mathbf{E} = \sum_i \frac{kq_i}{r_i^2}\hat{\mathbf{r}}_i$ (sum over point charges)

Gauss' law $\Phi_E = \sum_i \mathbf{E}_i \cdot \mathbf{A}_i = \frac{Q_{\text{encl}}}{\varepsilon_0}$ $\Phi_E =$ "electric flux"

Chapter 16 (Electric potential, capacitors)

Work $W = \mathbf{F}\cdot\left(\mathbf{x}_f - \mathbf{x}_i\right) = K_f - K_i = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2$

Conservative force $U_f - U_i = -\mathbf{F}\cdot\left(\mathbf{x}_f - \mathbf{x}_i\right) = -\left(K_f - K_i\right) \rightarrow U_i + K_i = U_f + K_f$ (energy conservation)

Electric potential $V = \frac{U}{q}$ (general) $V = \frac{kQ}{r} \equiv \frac{Q}{4\pi\varepsilon_0 r}$ (point charge Q)

Potential difference $\Delta V \equiv V_f - V_i = -\mathbf{E}\cdot\left(\mathbf{x}_f - \mathbf{x}_i\right)$

Capacitors $C = \frac{\varepsilon_0 A}{d}$ $q = CV$ $U_E = \tfrac{1}{2}CV^2 = \frac{q^2}{2C}$ (energy) $u_E = \tfrac{1}{2}\varepsilon_0 E^2$ (energy density)

Capacitors (cont) $E \rightarrow \frac{E}{\kappa}$ $V \rightarrow \frac{V}{\kappa}$ $C \rightarrow \kappa C$ $C_{\text{eq}} = C_1 + C_2$ (parallel) $\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2}$ (series)

Chapter 17 – 18 (Electric current, circuits)

Current $i \equiv \frac{\Delta q}{\Delta t}$ (basic def) $i = Aen_e v_d$ (drift velocity)

Resistance $V = iR$ $R = \frac{\rho L}{A}$ $R_{\text{eq}} = R_1 + R_2$ (series) $\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2}$ (parallel)

Temp dependence $\rho - \rho_0 = \rho_0\alpha\left(T - T_0\right)$

RC circuits $\tau_{RC} = RC$ $q = q_{\max}\left(1 - e^{-t/\tau_{RC}}\right)$ $i = i_{\max}e^{-t/\tau_{RC}}$ (charging)

$q = q_{\max}e^{-t/\tau_{RC}}$ $i = i_{\max}e^{-t/\tau_{RC}}$ (discharging)

Circuits (1) Current entering junction = current leaving junction (2) $\sum_i V_i = 0$ (over loop)

Power in circuit $P = iV$ (general power eqn) $P = i^2 R$ (power lost in resistor)

Chapter 19 (Magnetic fields)

Magnetic force	$F = qvB\sin\phi$ (charge) $F = iLB\sin\phi$ (current in wire)
Magnetic moment	$\mu = NiA$ (current loop of area A)
	$\tau = \mu B\sin\theta$ (torque) $U = -\vec{\mu}\cdot\mathbf{B} = -\mu B\cos\theta$ (potential energy)
Generating B field	$\sum_i B_{\parallel}\Delta\ell = \mu_0 i_{\text{enc}}$ (Ampere's law) $B = \dfrac{\mu_0 i}{2\pi r}$ (long wire)
	$B = \dfrac{\mu_0 i}{2R}$ (circular loop) $B = \dfrac{\mu_0 i\phi}{4\pi R}$ (partial loop) $B = \mu_0 ni$ (solenoid)

Force between currents $F_{ab} = \dfrac{\mu_0 i_a i_b L}{2\pi d}$ L = length of wires, d = distance between them

Chapter 20 – 21 (Induction, RLC circuits)

Magnetic flux	$\Phi_B = \mathbf{B}\cdot\mathbf{A} = BA\cos\theta$ (constant B, flat surface)
Induction	$\mathcal{E} = -\dfrac{\Delta\Phi_B}{\Delta t}$ (Faraday's law) $\mathcal{E} = -N\dfrac{\Delta\Phi_B}{\Delta t}$ (multi-loop)
Motional emf	$\mathcal{E} = B\ell v$ (motional emf) $\mathcal{E} = NBA\omega\sin\omega t$ (rotating loop in B field)
Inductance	$L = N\Phi_B / i$ (def) $L = \mu_0 n^2 Al$ (solenoid) $v_L = L\,di/dt$ $v_1 = M_{12}\,di_2/dt$
LR circuit	$\tau_{LR} = L/R$ $i = i_0\left(1 - e^{-t/\tau_{LR}}\right)$ (current charging) $i = i_0 e^{-t/\tau_{LR}}$ (current decay)
Energy	$U_B = \frac{1}{2}Li^2$ (energy in inductor) $u_B = B^2/2\mu_0$ (energy density)
AC circuits	$\omega_0 = 1/\sqrt{LC}$ (resonant ω) $\mathcal{E} = \mathcal{E}_m\sin(\omega_d t)$ $i = I_m\sin(\omega_d t - \phi)$ (driven circuit)
	$X_L = \omega L$ $X_C = 1/\omega C$ (reactances) $\tan\phi = \dfrac{X_L - X_C}{R}$ (lag angle)
	$Z = \sqrt{R^2 + (X_L - X_C)^2}$ (impedance) $I_m = \dfrac{\mathcal{E}_m}{Z}$
	$I_{\text{rms}} = \dfrac{I_m}{\sqrt{2}}$ $\mathcal{E}_{\text{rms}} = \dfrac{\mathcal{E}_m}{\sqrt{2}}$ $P_{\text{ave}} = \mathcal{E}_{\text{rms}} I_{\text{rms}}\cos\phi = I_{\text{rms}}^2 R$
Inst./max voltages	$v_L = L\,di/dt$ $v_C = q/C$ $v_R = iR$ $V_L = I_m X_L$ $V_C = I_m X_C$ $V_R = I_m R$
Transformer	$\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$ (voltage ratio) $V_p i_p = V_s i_s$ (power in ideal transformer)
	$R_{eq} = (N_p / N_s)^2 R$ (impedance matching)