Physics II S 2023 Crib Sheet Exam 1 Hayden Fuller Notes:

Culombs Law, conductors, insulators, polarization, induced charges, adding vector fields and forces

$\vec{F}_{1on2} = \vec{F}_{12} = -\vec{F}_{21} = q_2\vec{E}_1 = k\frac{q_1q_2}{r_{12}^2}\frac{\vec{r}_{12}}{r_{12}} = k\frac{q_1q_2}{r_{12}^2}\hat{r}_{12}$; $\vec{F}_{tot} = q_0\vec{E}_{tot}$; $\vec{E}_{tot}(X_0, y_0, z_0) = \int d\vec{E}(x', y', z') = \int k\frac{dq'(x',y',z')}{r_0'^2}\frac{\vec{r_0'}}{r_0'}$, $\vec{r_0'} = \vec{r}_0 - \vec{r'} = (x_0 - x')\hat{i} + \ldots$, $\vec{r'} = x'\hat{i} + \ldots$

distance away from line charge linearly, line starts at 0, at x=-D, $\vec{E} = -k\int_0^L \frac{\lambda dx'}{(D+x')^2}\hat{i}$, $V = k\lambda\ln(\frac{D+L}{D})$

with $\theta$ up from x axis, $r_x = x\cos\theta$, $r_y = y\sin\theta$, $r = \sqrt{r_x^2 + r_y^2}$, $k = 9 * 10^9 = \frac{1}{4\pi\epsilon_0}$, $\epsilon_0 = 8.85 * 10^{-12}$

Electric field for point charges, electric field for a continuous distribution of charge

$\vec{F}_E = q\vec{E}$; $\vec{E}_s = k\frac{q_s}{r^2}\frac{\vec{r}}{r} = k\frac{q_s}{r^2}\hat{r}$

Gauss's law and elecctric flux through a surface, Use of Gauss's law to find field

$\Phi_E = \oint \vec{E}\cdot d\vec{A} = \int E\cdot dA\cos\phi = \frac{Q_{encl}}{\epsilon_0}$, $\phi = \angle\vec{E} - d\vec{A}$, $d\vec{A} = dA\hat{n}$ net elec field $\vec{E} = 0$, $V = c$ within a cond.

gauss sphere: $\Phi_E = \oint \vec{E}(r)\cdot d\vec{A} = E(r)4\pi r^2$, $E(r) = k\frac{q}{r^2}$,

sphere radius R: outside or point charge: $V = k\frac{q}{r}$, $E = k\frac{q}{r^2}$ inside: cond: $V = k\frac{q}{R}$, $E = 0$, insulating: $E = k\frac{qr}{R^3}$

long thin wire: $E(r) = \lambda/(2\pi r\epsilon_0)$ thin flat sheet: $E = \sigma/(2\epsilon_0)$, stepped: go from in to out matching net $Q_in$

infinite plane w/ cylinder in it, $E = \sigma/\epsilon_0$

Electric potential for point charge, distribution. Electric field vs potential, equipotential. Potential for group of points, conservation of energy.

Change Elec Pot Engry $\Delta U = -\int_{\vec{r}_A}^{\vec{r}_B} q\vec{E}\cdot d\vec{s} = -W_{AB}$; Change Elec Pot $\Delta V = \frac{\Delta U_E}{q} = -\int_{\vec{r}_A}^{\vec{r}_B}\vec{E}\cdot d\vec{s}$ so $\Delta U_E = q\Delta V$

Point charge, $\Sigma$ for system $V(r) = \frac{kq}{r}$, $U_E = k\frac{q_1q_2}{R_{12}} + \ldots$; Field from pot: $E_x = -\Delta V = -\frac{\delta V}{\delta x} - \ldots$ .

work on closed path =0;

Caps, Dielectrics, steads state, equiv, energy storage, electric fielld energy density

$C = Q/V = \frac{\epsilon_0 A}{d} = kC_0$, ElcPotEnrInCap $U_E = .5QV = .5Q^2/C = .5CV^2$, EnrFieldDen $u_E = .5\epsilon_0E^2$, $E = \frac{\sigma}{k\epsilon_0}$, $V_1 = V\frac{C_{equiv}}{C_1}$

Current and densityJ, Resistance and itivity, Power relations and dissipation, DC steady state, KCVL Ohms

$I = \frac{dQ}{dT}$, $I = \vec{J}d\vec{A}$, $\vec{J} = qn\vec{v}_d = I/A$. $E = \rho J$, $V = IR$, $R = \rho L/A$, $P = IV = I^2R = V^2/R$; $V_{bat} =$ EMF $-Ir$

Temp: conductor: $\rho(T) = \rho_0 + \rho_0\alpha(T - T_0)$ semi: $\rho(T) = \rho_0 e^{(\frac{E_a}{kT})}$, $E_a =$ actiEngr, $k = 1.38e-23 =$ bolt const.

Magnetic forces and fields

$\vec{F} = q\vec{v}\times\vec{B}$, finger velocity, curl field, thumb force, flip for negative. $\vec{F}_B = I\vec{L}\times\vec{B}$, $r = \frac{mv}{|q|B}$

misc

$W = q\Delta V$, Centripital force $F = mv^2/r$, $E = -\Delta V/d$, $V = kq/r$, $V = \Delta KE = -\Delta PE$, $KE = 0.5 * mv^2$

$F = ma$, earth south is north, use conventional, $\vec{c} = \vec{a}\times\vec{b}$, $|\vec{c}| = |\vec{a}||\vec{b}|\sin\theta_{ab}$, cross is det, dot is sum

RMS $= \sqrt{\sum(x^2)}$, %error = (act-exp)/exp

| | | | | |
|---|---|---|---|---|
| Force | $F$ | $kg * m/s^2$ | Newton | $N$ |
| Energy/Work | $U, KE\|W$ | $N * m, W * s$ | Joule | $J$ |
| Charge | $Q$ | $A * s$ | Coulomb | $C$ |
| Chg den linear | $\lambda$ | $C/m$ | – | $C/m$ |
| Chg den surface | $\sigma$ | $C/m^2$ | – | $C/m^2$ |
| Chg den volume | $\rho$ | $C/m^3$ | – | $C/m^3$ |
| Elec Field | $E$ | $N/C$ | – | $N/C$ |
| Elec Flux | $\Phi$ | $N * m^2/C$ | – | $Nm^2/C$ |
| Elec Potential | $V$ | $J/C, W/A$ | Volt | $V$ |
| Current | $I$ | $C/s$ | Amp | $A$ |
| Current density | $J$ | $I/m^2$ | – | $I/m^2$ |
| Resistance | $R$ | $V/A$ | Ohm | $\Omega$ |
| Resistivity | $\rho$ | $E/J, RA/L$ | – | $\Omega m$ |
| Power | $P$ | $VA, J/s$ | Watt | $W$ |
| Capacitance | $C$ | $Q/V$ | Farad | $F$ |
| Magnetic field | $B$ | $Ns/Cm, N/mA$ | Tesla | $T$ |
| Magnetic field | $\Phi$ | $Tm^2$ | Weber | $Wb$ |

Sources of magnetic fields, law of Biot-Savart for moving charges and current elements, Magnetic fields of current carrying wires and loops, Magnetic forces between conductors

field from point charge moving $\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\vec{r}}{r^3} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$, $B = \frac{\mu_0}{4\pi}\frac{qv\sin\theta}{r^2}$, velocity, radius to measurement, from current element Biot-Savart swap $q\vec{v} > \int Id\vec{l}$, right hand, thumb conventional current/positive charge. axis of loop: $B_x = \frac{\mu_0 Ia^2}{2(x^2+a^2)^{3/2}} = \frac{\mu_0\mu}{2\pi(s^2+a^2)^{3/2}}$, $\mu = IA$, $x =$ far -¿ $B = \frac{\mu}{x^3}$

Current same direction, fields oppose, attract. $F = L\frac{\mu_0 I_1 I_2}{2\pi r}$

Straight wire: $B = \frac{\mu_0 I}{2\pi r}$, Center of a loop: $B = \frac{\mu_0 I}{2r}$, inside: $\frac{\mu_0 I}{2\pi R^2}r$

Solenoid: inductancec: $L = \frac{\Phi_B}{i} = \frac{N\Phi_{B,loop}}{i} = \frac{NBA_{loop}}{i} = \frac{Nu_0 niA_{loop}}{i} = \mu_0 N\frac{N}{l}A_{loop} = \frac{\mu_0 N^2\pi r_s^2}{l} = \pi\mu_0 n^2 r_s^2 l$

inside a Solenoid: $B = \mu_0 nI$, voltage $\int_a^b \vec{E}_{nc}\cdot d\vec{l} = -\frac{d\Phi_B}{dt} = -L\frac{di}{dt}$, i from + to - increase, EMF

Ampere's law, calculating magnetic fields from ampere's law. Maagnetic moments and magnetism, magnetic force and torque on a current loop/magnetic moment

Ampere's law: $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}$ total field in a circular path around a wire is equal to $\mu_0$ times current enclosed current density $\vec{J}$, $I_{enc} = \int \vec{J}_{net}\cdot d\vec{A} = J\cdot A\cos\theta$

Magnetic moment: $\vec{\mu} = I\vec{A}$, current in loop times area of loop, right hand direction. Torque $\tau_{B,net} = \vec{\mu}\times\vec{B}$, right hand rule for spin direction

Magnetic flux, Faraday's law, Lenz's law, Electromagnetic Induction.

Magnetic flux $\Phi_B = \int \vec{V}\cdot d\vec{A} = \int BdA\cos\theta$, Faraday's law: EMF from changing Mflux $\epsilon = \oint \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\Phi_B$, for $N$ loops, $\cdot N$. Lenz's law, this EMF induces oposing(attracting) magnetic field. B increase up, EMF and i cw, induced B down, net small B up

Displacement current, Maxwell's equations: "displacement current" is built up charge, $I_d = \epsilon_0\frac{d}{dt}\Phi_E$, fixed Ampere's $\oint \vec{B}\cdot d\vec{l} = \mu_0(I_c + I_d)_e nc = \mu_0 I_{c,enc} + \mu_0\epsilon_0\frac{d}{dt}\Phi_{E,enc}$

Maxwell's: Gauss's for $\vec{E}$: $\oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\epsilon_0}$ for $\vec{B}$: $\oint \vec{B}\cdot d\vec{A} = 0$

Faraday stationary: $\oint \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\Phi_B$, Ampere stationary: $\oint \vec{B}\cdot d\vec{l} = \mu_0(i_c + \epsilon_0\frac{d}{dt}\Phi_E)_e nc$

Self and mutual Inductance, EMF and current in circuits, Magnetic field energy and energy density

self inductance: $\Phi_B = Li$, $L = \frac{\Phi_B}{i}$, Mutual: $M = M_{12} = \frac{N_1\Phi_{B1}}{i_2} = M_{21} = \frac{N_2\Phi_{B2}}{i_1}$, $\frac{d\Phi_B}{dt} = \frac{d}{dt}Li = L\frac{di}{dt}$, $\epsilon_L = -L\frac{di}{dt}$, $\epsilon_1 = -M\frac{di_2}{dt}$

magnetic energy in an inductor $U_B = 0.5Li^2$, region in field $\vec{B}$ has energy density $u_B = \frac{U_B}{v} = \frac{B^2}{2\mu_0}$

Circuit Transients, RC, RL, LC, and RLC. Charactaristic decay times and oscillation frequencies

$I(C) = C\frac{dV_C}{dt}$, $V(L) = L\frac{dI_L}{dt}$

RC: charge $q(t) = C\epsilon(1 - e^{-t/RC})$, $i = \frac{dq}{dt}$, $i(t) = \frac{\epsilon}{R}e^{-t/RC}$ discharge: $q(t) = Q_0 e^{-t/RC}$, $i(t) = -\frac{Q_0}{RC}e^{-t/RC}$

RL: charge $i(t) = \frac{\epsilon}{R}(1 - e^{-tR/L})$, discharge $i(t) = i_0 e^{-tR/L}$

LC: Q(C) $q(t) = Q\cos(\omega t + \phi)$, I(L) $i(t) = \frac{dq}{dt} = -\omega Q\sin(\omega t + \phi)$, $\omega = 1/\sqrt{LC}$ $T = \frac{2\pi}{\omega}$, $\omega = 2\pi * \omega$, $U_E = \frac{(q(t))^2}{2C}$, $U_B = 0.5L(i(t))^2$, $U_{tot} = U_E + U_B = \frac{Q^2}{2C}$, $L\frac{di}{dt} = -\frac{q}{C}$, $\frac{d^2q}{dt^2} = -\frac{1}{LC}q$

Alternating current circuits, phasors, reactance, impedance, resonance, power, transformers

AC: $RMS = \frac{1}{\sqrt{2}}max$, $X_L = \omega L$, $V_L$ is 90 ahead, $X_C = \frac{1}{\omega C}$, $V_C$ is 90 behind

$i(t) = I\cos(\omega t)$, L: $V_L(t) = \omega LI\cos(\omega t + \pi/2) = V_L\cos(\omega t + \pi/2)$

series LRC AC: $V = \sqrt{V_R^2 + (V_L - V_C)^2} = I\sqrt{R^2 + (X_L - X_C)^2}$, *net* impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$

current phasor is shared, $V_R$ matches, $V_L$ leads 90, $V_C$ lags 90, $V_S = VR + VL + VC$, some phase inbetween $\phi$, $\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$, resonance: at $\omega_0$, $X_L = X_C$, $Z = R$,

$q(t) = Qe^{-t/\tau_d}\cos(\omega' t + \phi)$, $\tau_d = 2L/R$, $\omega' = \sqrt{\frac{1}{LC} - (\frac{R}{2L})}^2$

Power: $P_{average} = 0.5V_{amp}I_{amp}\cos\phi_{V-I} = V_{RMS}I_{RMS}\cos\phi_{V-I}$, $\cos\phi = R/Z$ for series LRC

Transformer: $\frac{V2}{V1} = \frac{N2}{N1}$