Physics II S 2023 Crib Sheet Exam 3 Hayden Fuller

EXAM 1

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

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

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

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 $u_E = .5\epsilon_0 E^2$, $E = \frac{\sigma}{k\epsilon_0}$, $V_1 = V\frac{C_{equiv}}{C_1}$

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

EXAM 2

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: $L = \frac{\Phi_B}{i} = \frac{N\Phi_{B,loop}}{i} = \frac{NBA_{loop}}{i} = \frac{Nu_0niA_{loop}}{i} = \mu_0 N\frac{N}{l}A_{loop} = \frac{\mu_0 N^2\pi r_s^2}{l} = \pi\mu_0 n^2 r_s^2 l$

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 μ_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 ϕ, $\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$, resonance: at ω_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: $\frac{V2}{V1} = \frac{N2}{N1}$

EXAM 3

EM basics: $\frac{\delta B_z}{\delta x} = -\epsilon_0\mu_0\frac{\delta E_y}{\delta t}$, $\frac{\delta B_z}{\delta t} = -\frac{\delta E_y}{\delta x}$, $\epsilon_0\mu_0\frac{\delta^2 E_y}{\delta t^2} = \frac{\delta^2 E_y}{\delta x^2}$, $\epsilon_0\mu_0\frac{\delta^2 B_z}{\delta t^2} = \frac{\delta^2 B_z}{\delta x^2}$, $E_m = cB_m$
Poynting vector $\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$, Intensity $I = c\frac{1}{2}\epsilon_0 E_m^2 = c\frac{1}{2\mu_0}B_m^2 = P/A = P/(4\pi r^2)$
result wave of form $E_{tot} = E_m \cos(-\omega t + \frac{\Delta\phi}{2})$, interference result magnitude $E_m = 2E_0\cos(\frac{\Delta\phi}{2})$

EM waves and Light, index of refraction, Wave fronts and rays, hygen's principle, polarization, malus's law
Radiation pressure $p_{rad} = S_{av}/c = I/c$, $*2$ for reflection. Polarization, $I = I_0\cos^2(\phi)$.
$c = \omega/k = \lambda f = \lambda/T$;
Index of refraction $v_n = c/n = f/\lambda_n$, $\lambda_n = \lambda/n$
Huygens principle, wave is source of wavelets. Polarization: $I = 0.5 * I_0$, $I = I_0(\cos^2(\phi))$

interference: $I = 4I_0\cos^2(\Delta\phi/2)$, $I_0 = 0.5c\epsilon_0 E_0^2$, $d * n$, $\Delta\phi = 2\pi(n_1L_1 - n_2L_2)/\lambda$,
double slit $y_m = m\lambda D/d$, diffraction grating: $d\sin\theta = m\lambda$

Diffraction, single slit diffraction pattern and intensity, two slit interference with difraction, circular apertures, resolution
slits: $I = I_0[\frac{\sin(\beta/2)}{(\beta/2)}]^2\cos^2(\alpha/2) = I_0$ *single slit*double slit, $\beta = \frac{2\pi a}{\lambda}\sin\theta$, $\alpha = \frac{2\pi d}{\lambda}\sin\theta$
double slit: I=above, max $y_m * d = Dm\lambda$, $d\sin\theta = m\lambda$, min $(m + 0.5)$
single slit: I=above, min $y_m = D\tan\theta_m$, $a\sin\theta = m\lambda$, max $0and(m + 0.5)$, small slit long wavelength get one wide max
circular pinhole: first dark ring $\sin\theta_1 = 1.22\lambda/D$, $\theta_R = \sin^{-1}(1.22\lambda/D)$, approx at small angle $\theta_R = 1.22\lambda/D$, distinguishable if max of second is outside first min of first

special relativity, frames of refrence, lorentz factor, time dialation, length contraction, relativistic momoentum and energy, energy and mass units
$\gamma = 1/\sqrt{1 - (v/c)^2}$. moving clock appears to orun slowly, things look shorter. Length viewed L of moving object actaul length L_0, $L = 1/\gamma L_0$, $x' = \gamma(x - ut)$, $t' = \gamma(t - ux/c^2)$

momentum $p = \gamma mv$, $KE = (\gamma - 1)mc^2$, $Energytotal = K + E_0 = (\gamma - 1)mc^2 + mc^2 = \gamma mc^2$. $E^2 = (pc)^2 + (mc^2)^2$
$m = E_0/(c^2)$, $1eV = 1.6 * 10^-19J$

photons, photoelectric effect, stopping potential, Einstein's photoelectric equation, work function, intensity in the photon model, photon momentum and the compton experiment, intro to wave particle duality
$KE_{max} = eV_0$, induvidual photon energy $E = hf$, $KE = hf - \phi$, $V_0 = hf/e - \phi/e$, V_0 vs f, slope h/e, intercept $-\phi/e$
I=power/area=energy/(time*area), for photons $I = N * hf/(t * A) = F * E$ =photon flux * photon energy.
$E^2 = (pc)^2$, $p = E/c = hf/c = h/\lambda$
compton experiment: $\lambda' - \lambda = h/(mc)(1 - \cos\phi)$, λ' =after collision, ϕ =scatter angle, m=electron
duallity, it exists.
$x = 1.60218 * 10^{-19}$; $E : eV = xJ$; $p : eV/c = x^2 kgm/s$; $m : eV/c^2 = x^3 kg$
Nuclear binding energy: $E_B = (ZM_H + NM_N -{}^A_Z M)c^2$, M_H =hydrogen mass, M_N =neutron mass, $N = A - Z$ =neutrons, ${}^A_Z M$ =mass of atom, Z=atomic number, A=isotope mass number ; rest energy of nucleus $= E_0 - E_B$
$A + B \rightarrow C + D$, $E_A + E_B = E_C + E_D + Q$, $Q = (M_A + M_B - M_C - M_D)c^2$
magnitude charge of an electron, 1eV in J, $e = 1.60218 * 10^{-19}$
$h = 6.62607 * 10^{-34}$; $m_e = 9.10938 * 10^{-31}$; $m_p = 1.6726 * 10^{-27}$; $m_n = 1.6749 * 10^{-27}$
$\mu_0 = 4\pi * 10^-7$; $\epsilon_0 = 1/(\mu_0 c^2) = 8.854 * 10^{-12}$
one atomic mass unit $u = 1.6605 * 10^{-27}$; electron rest energy $m_e c^2 = 0.51099 MeV$

EXAM FINAL

wave particle duality: $\hbar = h/(2\pi)$
single slit: triangle where base= p_x, height= p_y, hypotenuse= p, $\theta = \delta$, small angle $\theta \approx \sin\theta = \lambda/a$, $p_x \approx p$, $\delta \approx \tan\delta = p_y/p$
uncertianty: $\Delta p_y \Delta y \geq \hbar/2$, $\Delta E \Delta t \geq \hbar/2$, $\Delta E = h\Delta f$
matter waves: $\lambda = h/p = h/(mv) = h/\sqrt{2mK}$, $f = E/h$
wave functions: 1D motion mass m, wave function Ψ, potential energy U, $\frac{\hbar^2}{2m}\frac{\delta^2\Psi(x,t)}{\delta x^2} + U(x)\Phi(x,t) = i\hbar\frac{\delta\Psi(x,t)}{\delta t}$
$U = 0$: $\Psi(x,t) = Ae^{i(kx - \omega t)} = A\cos(kx - \omega t) + iA\sin(kx - \omega t)$, wave number $k = 2\pi/\lambda$, $p = \frac{h}{\lambda} = \hbar k$, $\omega = 2\pi f$, $E = hf = \hbar\omega$
wave packets: Real $\Psi(x,t)$ is sin, Imagingary $\Psi(x,t)$ is cos, $2\pi/k_{av} = \lambda_{av}$ is one period, x is whole length of packet
Δx is possible positions, width of wave.
$|\Psi|^2 = \Psi_r^2 + \Psi_i^2 \geq 0$, pos of find part betw x and $x + dx$ is $P(x, x + dx, t) = |\Phi(x,t)|^2 dx$, $P(x_1, x_2, t) = \int_{x_1}^{x_2} |\Psi(x,t)|^2 dx$
possible Prob functions: 1)must be unity, area = 1. 2)single valued fucntion. 3)continuous. 4)spatial derivative continuous
$\Delta k \Delta x \approx 1$
$\Psi(x,t) = \psi(x)e^{iEt/\hbar}$, $|\Psi(x,t)|^2 = \Psi(x,t) \cdot \Psi(x,t)^* = |\psi(x)|^2$
distortion: $L_{felt} = \frac{1}{\gamma}L_0$ and it doesn't take as long to travel as it seems. $\Delta t = \gamma\Delta t_0$, feels like $\Delta t_0 = \frac{1}{\gamma}\Delta t = \frac{1}{\gamma}\frac{26cyrs}{.90c}$
kg to eV: $m = m\frac{c^2}{c^2} = \frac{kg*(m/s)^2}{c^2} \cdot \frac{1eV}{1.6*10^{-19}J}$
PUT UNITS EVEN IF YOU DON'T KNOW THE ANSWER