Joel Primack - Review of Physics 5C – Spring 2008

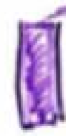
Lorentz force law $\vec{F} = q\vec{E} + q\vec{v}\times\vec{B}$ ⇒ units E $\frac{Nt}{C}$, B $\frac{Nt}{C\,m/s} = \frac{Nt}{A\cdot m} = \frac{Wb}{m^2} = T$

Maxwell Eq. 1 — Electric Gauss' law $\Phi_E = \oint \vec{E}\cdot d\vec{A} = \frac{Q}{\epsilon_0}$ ⇔ Coulomb's law $\vec{E} = \frac{q}{4\pi\epsilon_0}\frac{\hat{r}}{r^2}$

$E = \frac{\sigma}{2\epsilon_0}$ $E = \frac{\sigma}{\epsilon_0}$

Electric potential $V = \frac{kq}{r}$, $= k\int\frac{dq}{r}$; $E_x = -\frac{dV}{dx}$ ↖ $V = -E_x x$

Capacitance $C = \frac{Q}{V}$ parallel plates



dielectric const. κ $C = \frac{\kappa\epsilon_0 A}{d}$

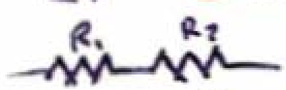
Stored energy $E_c = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2$ density $u_E = \frac{\epsilon_0}{2}E^2$

$C_{eq} = C_1 + C_2$

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$

Current $I = \frac{dQ}{dt} = JA = nqv_dA$, $R = \frac{\ell}{\sigma A} = \frac{\rho\ell}{A}$

Ohm's law $V = IR = E\ell = \frac{I}{A}AR$ ⇔ $E = J\rho$



$R_{eq} = R_1 + R_2$

$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

Power dissipated by resistor $P = IV = I^2R = V^2/R$

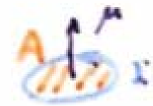
Kirchoff's rules
1. At each junction $\Sigma I_{in} = \Sigma I_{out}$ (Q cons)
2. Around each loop $\Sigma V = 0$ (E cons)

Capacitor discharging through resistor $Q(t) = Q_0 e^{-t/RC}$

$\vec{B}$ force on wire carrying I: $F = \int I \, d\vec{s} \times \vec{B}$

parallel wires $F/\ell = \mu_0 \frac{I_1 I_2}{2\pi a}$

Magnetic moment of current loop $\mu = IA$



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

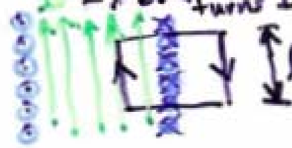
Cyclotron frequency $\omega = qB/m$ (indep. of v, r)

$= \epsilon_0 \frac{d\Phi_e}{dt}$ displacement current

Maxwell Eqs.

4 Ampere's law $\oint \vec{B} \cdot d\vec{s} = \mu_0 (I + I_d) \Leftrightarrow$ Biot-Savart law $d\vec{B} = \frac{\mu_0}{4\pi} I \frac{d\vec{s} \times \hat{r}}{r^2}$

$B = \mu_0 N_{turns} I/\ell$ long solenoid



2 Magnetic Gauss' law $\Phi_m = \oint \vec{B} \cdot d\vec{A} = 0$

3 Faraday's law $\oint_{P=\partial S} \vec{E} \cdot d\vec{s} = \mathcal{E}_{emf} = -\frac{d\Phi_m}{dt} = -\frac{d}{dt} \int_S \vec{B} \cdot d\vec{A}$

Lenz's law: induced emf opposes change in Φ_m

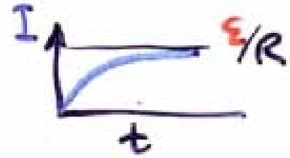
Self Inductance $L = N\Phi_m/I$ (coil) $= \mu_0 N^2 A/\ell$ (solenoid)

long solenoid

Induced emf $\mathcal{E} = -L \frac{dI}{dt}$

Stored energy $E_m = \frac{1}{2} L I^2$ magnetic energy density $u_m = \frac{1}{2\mu_0} B^2$

RL circuit 

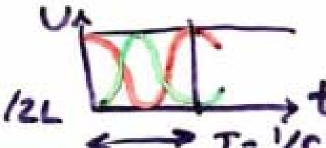


$I = \frac{\varepsilon}{R}\left(1 - e^{-Rt/L}\right)$

LC circuit 

= simple harmonic oscillator, $\omega = 1/\sqrt{LC}$

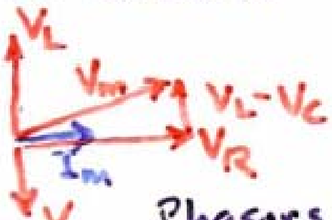
energy $U = \underline{U_C} + \underline{U_L} = \frac{Q_m^2}{2C}\cos^2\omega t + \frac{LI^2}{2}\sin^2\omega t$



$T = 1/f = 2\pi/\omega$

LRC circuit = damped harmonic osc 
$e^{-Rt/2L}$

ac circuits $I_{rms} = I_m/\sqrt{2}$, $V_{rms} = V_m/\sqrt{2}$ read by ac meters, $P_{av} = I_{rms}V_{rms}$



Phasors

Reactance: inductive $X_L = \omega L$, capacitive $X_C = 1/\omega C$

Impedance: $Z = V_m/I_m = \sqrt{R^2 + (X_L - X_C)^2}$ for LRC series

Power $P_{av} = I_{rms}^2 R = V_{rms}^2 R/Z^2$

Quality factor $Q_0 = \frac{\omega_0}{\Delta\omega} = \frac{2\pi E}{\Delta E}$ ← loss/period

Electromagnetic waves $\frac{\partial^2 E}{\partial x^2} = \underbrace{\mu_0\epsilon_0}_{=1/c^2}\frac{\partial^2 E}{\partial t^2}$, $\frac{\partial^2 B}{\partial x^2} = \mu_0\epsilon_0\frac{\partial^2 B}{\partial t^2}$

$E = E_m\cos(kx - \omega t)$, $B = B_m\cos(kx - \omega t)$, $B = E/c$, $k = \frac{2\pi}{\lambda}$, $\frac{\omega}{k} = \lambda f = c$

EM energy current density $\vec{S} = \vec{E}\times\vec{B}/\mu_0$, momentum of light $p = S/c$

= Poynting vector $S_{av} = E_m B_m/2\mu_0$