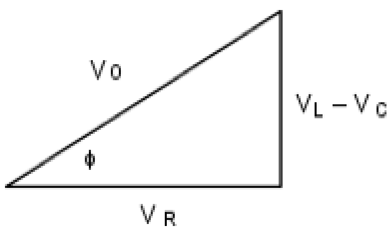
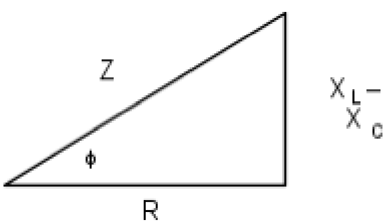
Electromagnetic waves

- Maxwell's equations are thusly:
- $\oint E \cdot dA = q/\epsilon_0$
- $\oint B \cdot dA = 0$ for a closed surface
- $\oint E \cdot dl = -\frac{d\Phi_B}{dt}$
- $\oint B \cdot dl = \mu_0 \left(I_c + \epsilon_0 \frac{d\Phi_E}{dt} \right)$
- $E_{max} = c \cdot B_{max}$
- Poynting vector (dir of propagating) = $\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$
- $V_p = -\omega / k$

AC circuits



- V_0 or V_{G0} = V across generator
- V_R = V across resistor
- V_L = V across inductor
- V_C = V across capacitor



- Z = impedance
- X_L = inductive reactance
- X_C = capacitive reactance
- R = resistance

- $I = I_0 \cos(\omega t)$
- $V_L = I + 90°$
- $V_C = I - 90°$
- V_R is in phase with I

- $V_{R0} = I_O R$
- $V_{C0} = X_C I_0$
  - $X_C = 1 / \omega C$
- $V_{L0} = X_L I_0$
  - $X_L = \omega L$
- $V_{G0} = I_0 Z$

- Avg power = $\frac{1}{2}VI \cos\phi$
- Resonance = $\omega_0 = \sqrt{\frac{1}{LC}}$

Current and resistance

- Current = I = charge per unit time
- Current density = J
- Resistivity = ρ = E / J
- V = IR
- R = ρL / A (L = length, A = cross-sectional area)
- Voltage across something with internal resistance = EMF - Ir
- Power = P = VI = I^2R = V^2 / R

Electric potential

- Electric potential energy = U = $\frac{qq_0}{4\pi\epsilon_0 r}$
- Electric potential = V = $\frac{U}{q_0} = \frac{q}{4\pi\epsilon_0 r}$
- Potential difference = $V_a - V_b = \int_a^b E\cos\phi dl$
- Equipotential surface is a surface where the potential has the same value at erry point.
- $E_x = -\frac{\delta V}{dx}$ and so on for the other components

B-fields

- Force on a particle in B-field: $\vec{F} = q(\vec{v} \times \vec{B})$ and $|\vec{F}| = q|\vec{v}||\vec{B}| \sin\theta$
- Particle orbiting B-field: $qvB = mv^2 / R$
- Charge in electric field has circular trajectory R = $\frac{mv}{|q|B}$
- Magnetic force on conductor of length l = $\vec{F} = I\vec{l} \times \vec{B}$
- Magnetic torque on current loop
  - $\tau = IBA\sin\phi$
  - $\vec{\tau} = \vec{\mu} \times \vec{B}$

Inductance

- Mutual inductance happens b/c of changing current: $EMF_2 = -M\frac{di_1}{dt}$
- Self inductance: EMF = $-L\frac{di_1}{dt}$
- Inductor w/ inductance L has energy U = $\frac{1}{2}LI^2$
- Magnetic energy density = u = $\frac{B^2}{2\mu}$
- Time for current in RL circuits to get to within 1/e of its final = L / R
- ω of LC circuits: $\sqrt{\frac{1}{LC}}$

E-fields

- $F = \frac{kqQ}{r^2}$
- $E = \frac{kQ}{r^2}$
- Flux = $\oint E \cdot dA = q/\epsilon_0$

Capacitors and capacitance

- Capacitance = C = $\frac{Q}{V_{ab}} = \epsilon_0 \frac{A}{d}$ k (k = dielectric constant, which is 1 in air)
- Energy required to charge capacitor to potential difference V and charge Q = $U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$
- Energy density = u = $\frac{1}{2}\epsilon_0 E^2$

Circuits

- Resistors in series
  - $I_1 = I_2 = I_3$
  - $V_{tot} = V_1 + V_2 + V_3$
  - $R_{tot} = R_1 + R_2 + R_3$
- Resistors in parallel
  - $V_1 = V_2 = V_3$
  - $\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
  - $I_{tot} = I_1 + I_2 + I_3$
- Resistors in parallel are the same as capacitors in series (and vice-versa)

Reflection

- $n_1 \sin\theta_1 = n_2 \sin\theta_2$
- Total internal reflection is when it bounces back

Polarization

- Polarizers resolve light's E-field into its components, effectively destroying all non-parallel-to-the-polarizer components.
- $E_f = E_0 \cos\theta$
- $I_f = I_0 \cos^2\theta$
- I is proportional to E^2

Induced fields

- Induced EMF in a closed loop = $-\frac{d\Phi_B}{dt}$.
- Induced current or EMF tends to oppose or cancel out the change that caused it.
- If a conductor moves in a B-field, it induces an EMF that is vBL (if L and v perp to B and each other)
- $\oint E \cdot dl = -\frac{d\Phi_B}{dt}$

Electric fields of various charge distributions

Charge distribution	*Point in electric field*	*Electric field magnitude*
Single point charge q	Distance from r to q	$E = \frac{q}{4\pi\epsilon_0 r^2}$
Charge q on a surface of conducting sphere with radius R	Outside sphere, r > R	$E = \frac{q}{4\pi\epsilon_0 r^2}$
	Inside sphere, r < R	E = 0
Infinite wire, charge per unit area λ	Distance r from wire	$E = \frac{\lambda}{2\pi\epsilon_0 r}$
Infinite conducting cylinder with radius R, charge per unit length λ	Outside cylinder, r > R	$E = \frac{\lambda}{2\pi\epsilon_0 r}$
	Inside sphere r < R	E = 0
Solid insulating sphere with radius R, charge Q distributed uniformly throughout volume	Outside cylinder, r > R	$E = \frac{Q}{4\pi\epsilon_0 r^2}$
	Inside sphere r < R	$E = \frac{Qr}{4\pi\epsilon_0 R^3}$
Infinite sheet of charge within unorm charge per unit area σ	Any point	$E = \frac{\sigma}{2\epsilon_0}$
Two oppositely charged conducting plates with surface charge densities +σ and -σ	Any point between the plates	$E = \frac{\sigma}{\epsilon_0}$

Magnetic fields

What?	*Field*
Moving charge	$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v} \times \hat{r}}{r^2}$
Current-carrying conductor	$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I d\vec{l} \times \hat{r}}{r^2}$
Long, straight, current-carrying conductor	$B = \frac{\mu_0 I}{2\pi r}$
Force between current-carrying conductors	$\frac{F}{L} = \frac{\mu_0 I I'}{2\pi r}$
Current loop	Circular loop: $B_x = \frac{\mu_0 I a^2}{2(x^2 + a^2)^{3/2}}$ Center of N circular loops: $B_x = \frac{\mu_0 N I}{2a}$

RC capacitor charging

$q = C\varepsilon(1 - e^{-t/RC}) = Q_f(1 - e^{-t/RC})$

$i = I_0 e^{-t/RC}$

RC capacitor discharging

$q = Q_0 e^{-t/RC}$

$i = I_0 e^{-t/RC}$