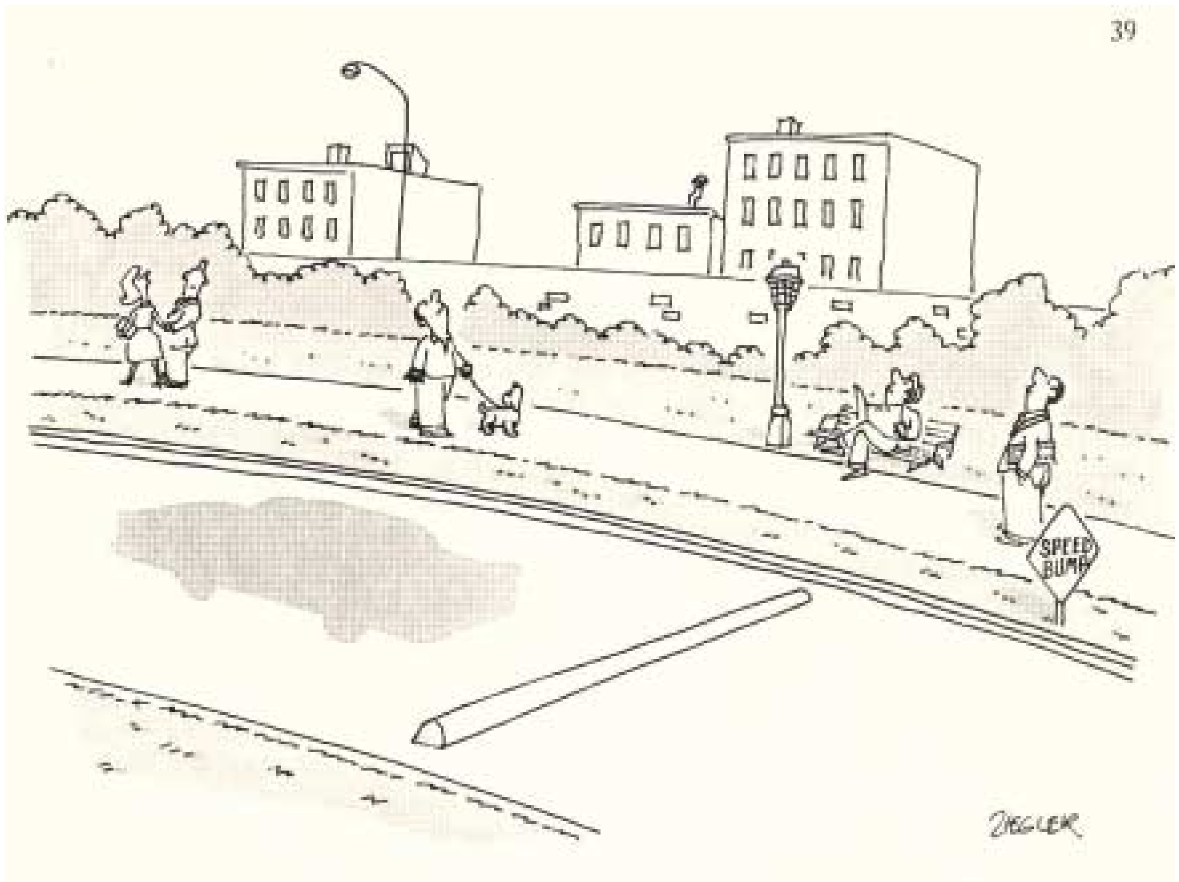
Review for final



Schedule

- Dec. 3-5 (Wed-Fri) – Review for final
- Dec. 3 (Wed) – HW set #12 due at 11pm
- Dec. 8 (Mon) – Corrections #3 due at 7am
- Dec. 8 (Mon) – Final Exam 5:45-7:45pm
  - Section 1 – N130 BCC (Business College)
  - Section 2 – 158 NR (Natural Resources)

Final Exam

- If >2 finals on Mon. may take make-up final exam on Tues. from 8-10am
  - Email Prof. Tollefson with list of other finals
- Allowed 3 sheets of notes (both sides) and calculator
- Covers Chapters 22-37, HW sets 1-12
- Exam will have 20 questions
- Need photo ID

Electric Fields

- Point change *q*

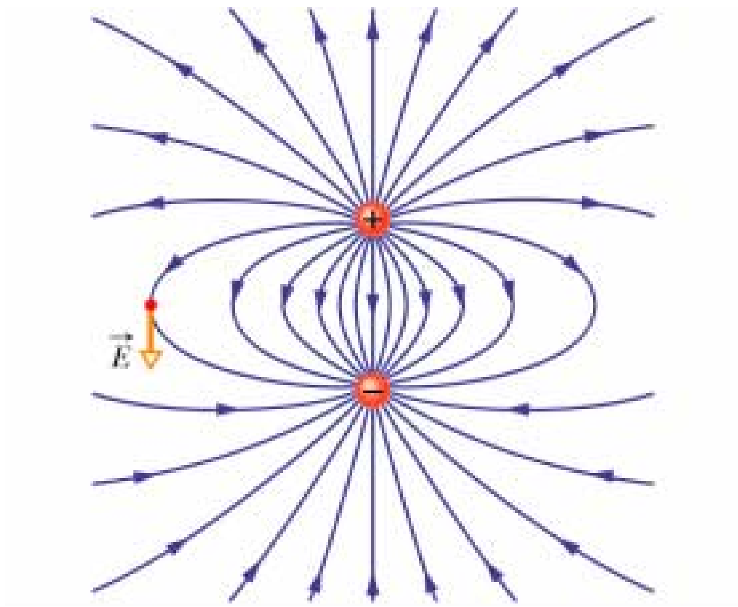
$$F = k\frac{|q||q_0|}{r^2} \qquad E = k\frac{q}{r^2} \qquad V = k\frac{q}{r}$$

- *E* points away from positive charges and towards negative charges
- Superposition principle (many charges)

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \ldots + \vec{F}_n$$

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \ldots + \vec{E}_n$$

$$V = \sum_{i=1}^{n} V_i$$



Electric Potential

- Electric potential from field

$$\Delta V = -\int_i^f \vec{E} \bullet d\vec{s}$$

- Constant field over distance *d*

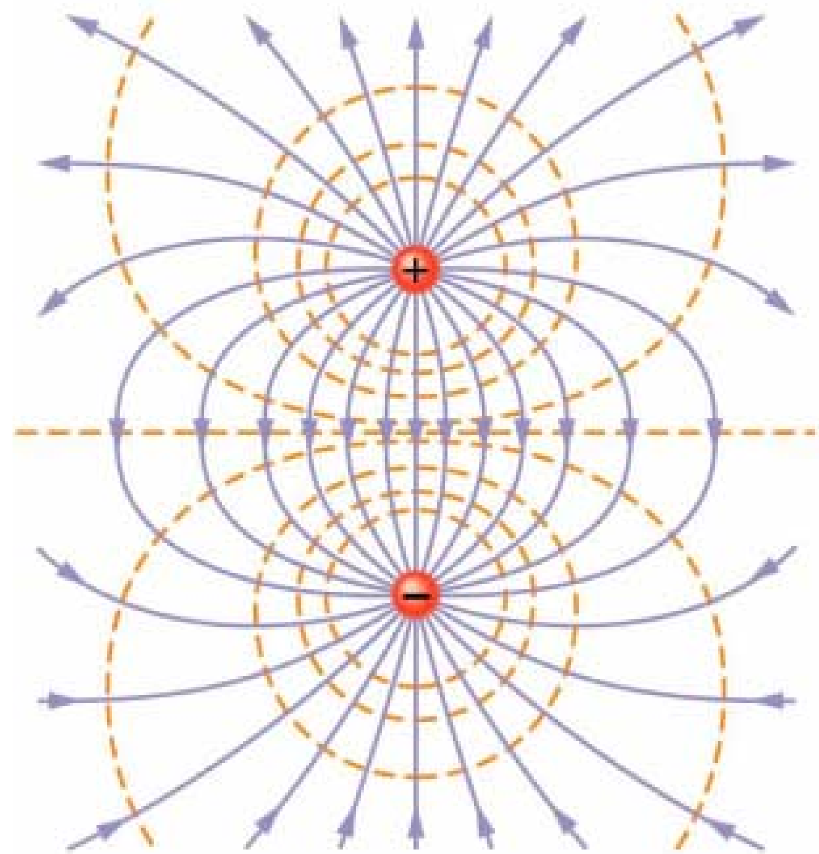
$$\Delta V = -Ed$$

- Work done moving charge q_0

$$W = q_0 \Delta V$$

Electric Potential

- Blue lines are the electric field
- Dashed lines are equipotential surfaces where all points are at the same potential
- V decreases by constant intervals from the positive charge to the negative charge



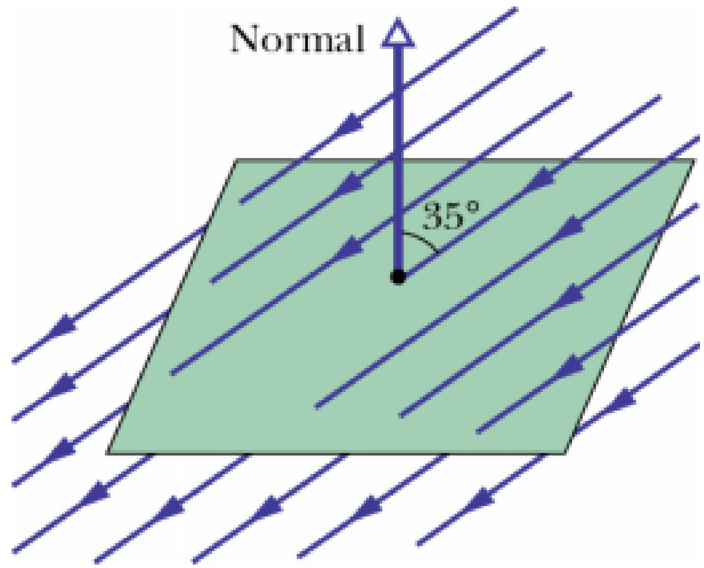
(c)

Guass' Law

- Electric flux

$$\Phi = \oint \vec{E} \bullet d\vec{A}$$

$$\vec{E} \bullet d\vec{A} = E\ dA \cos\theta$$



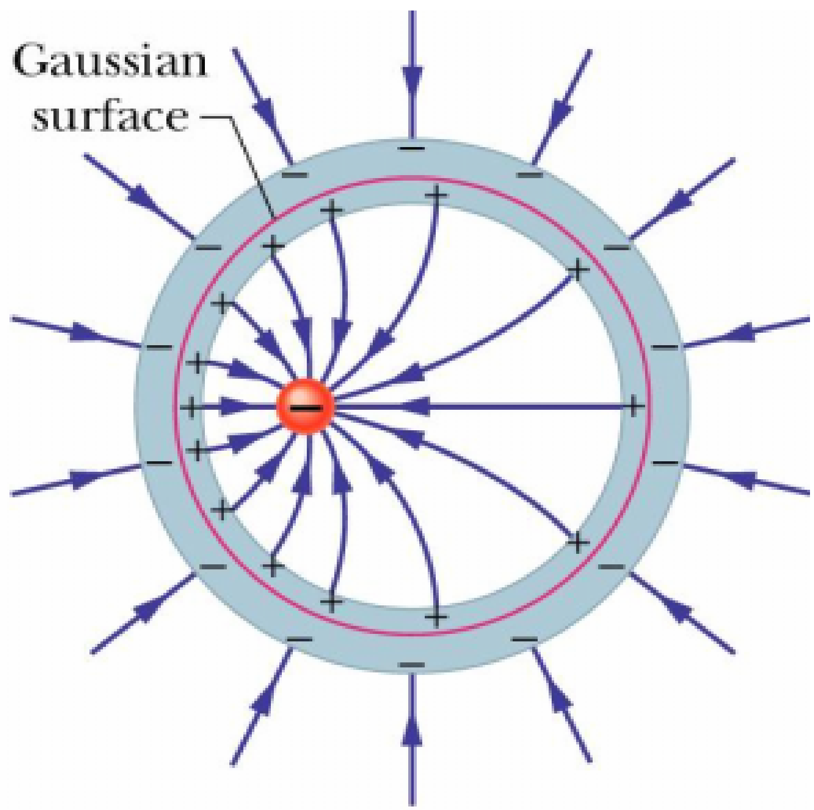
- Gauss' Law

$$\varepsilon_0 \Phi = \varepsilon_0 \oint \vec{E} \bullet d\vec{A} = q_{enc}$$

- Net charge q_{enc} is sum of all enclosed charges and may be +, -, or zero

Conductors (example)

- Charge q_1 inside
- *E=0* inside conductor
- Thus $\Phi=0$ for Gaussian surface (red line)
- So net charge enclosed must be 0
- Induced charge of $q_2 = -q_1$ lies on inner wall of conductor
- Shell is neutral so charge of $q_3 = -q_2$ on outer wall



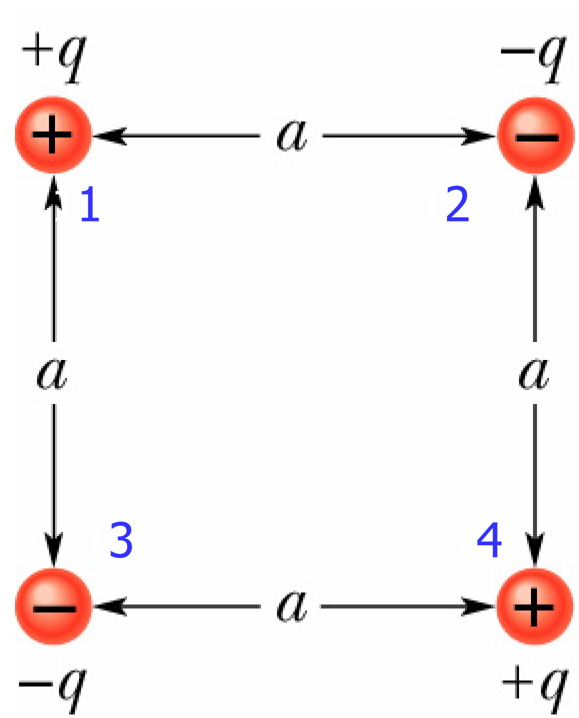
Electric Potential Energy

- Work required to assemble the charges

$$U = U_{12} + U_{13} + U_{14}$$
$$+ U_{23} + U_{24} + U_{34}$$

- where etc

$$U_{12} = k\frac{q_1 q_2}{d}$$



Motion in a B Field

- Force on a charged particle due to a magnetic field is

$$\vec{F}_B = q\vec{v} \times \vec{B}$$

- F_B does not change the speed (magnitude of v) or kinetic energy of particle

- Charged particles moving with $v \perp$ to a B field move in a circular path with radius, r

$$r = \frac{mv}{qB}$$

- Force on a current carrying wire due to a magnetic field is

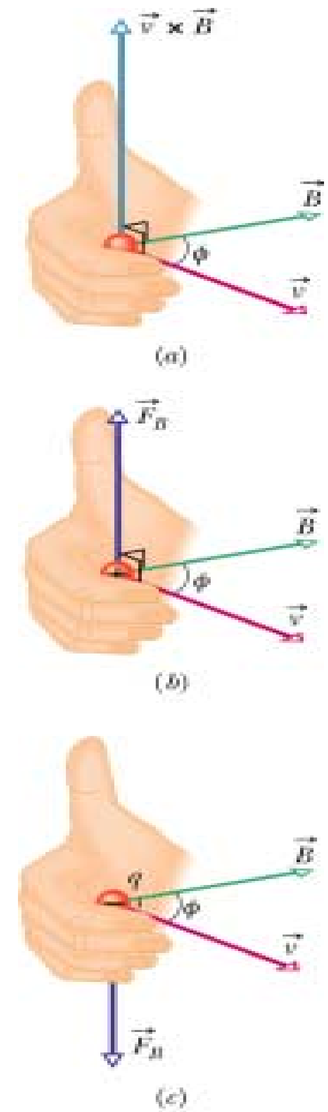
$$\vec{F}_B = i\vec{L} \times \vec{B}$$

Motion in a B Field

$$\vec{F}_B = q\vec{v} \times \vec{B}$$

- Right-hand rule – For positive charges - when the fingers sweep v into B through the smaller angle ϕ the thumb will be pointing in the direction of F_B

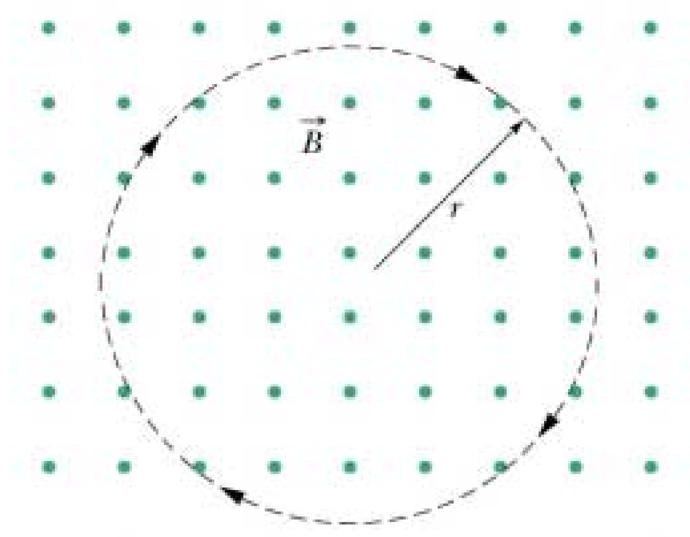
- For negative charges F_B points in opposite direction



Motion in a B Field

- Circular motion $$r = \frac{mv}{qB}$$

- Period (time for one revolution) $$T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$$



- Frequency (the number of revolutions per unit time) $$f = \frac{1}{T}$$

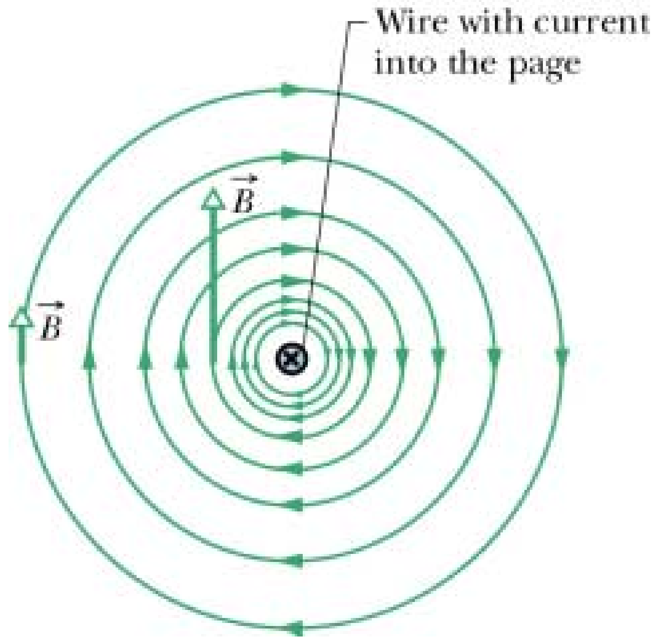
- Angular frequency: $$\omega = 2\pi f$$

B Fields from Currents

- *B* field a distance *R* from a long straight wire carrying current *i*

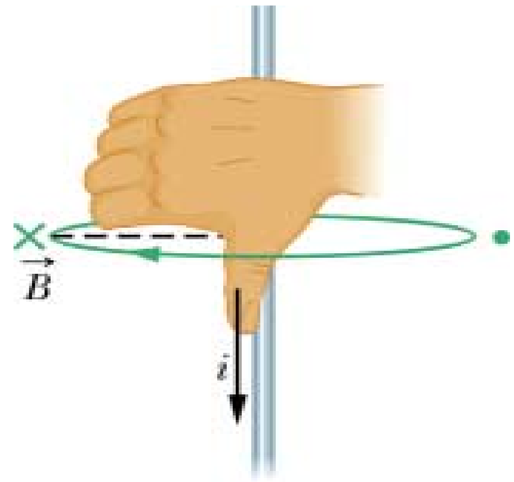
$$B = \frac{\mu_0 i}{2\pi R}$$

- *B* field is tangent to magnetic field lines



B Fields from Currents

- right-hand rule
- Point thumb in direction of current flow
- Fingers will curl in the direction of the magnetic field lines due to current



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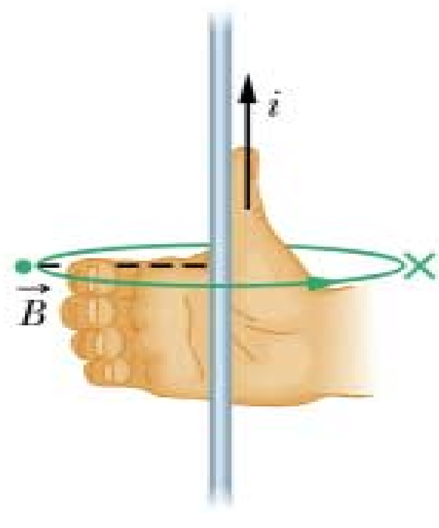
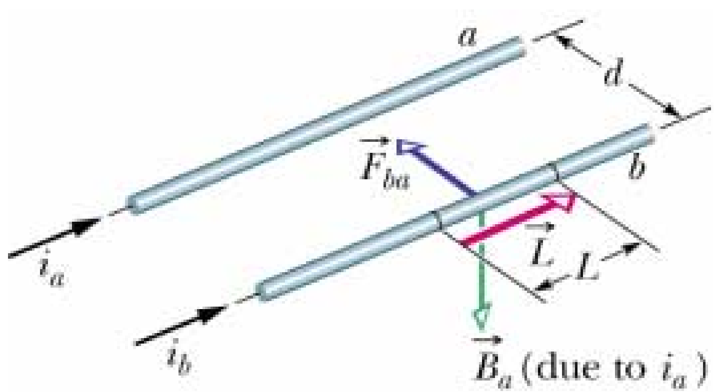


B Fields from Currents

- Force on a wire carrying current, i_1, due to *B* of another parallel wire with current i_2

$$F = \frac{\mu_0 L i_1 i_2}{2\pi d}$$

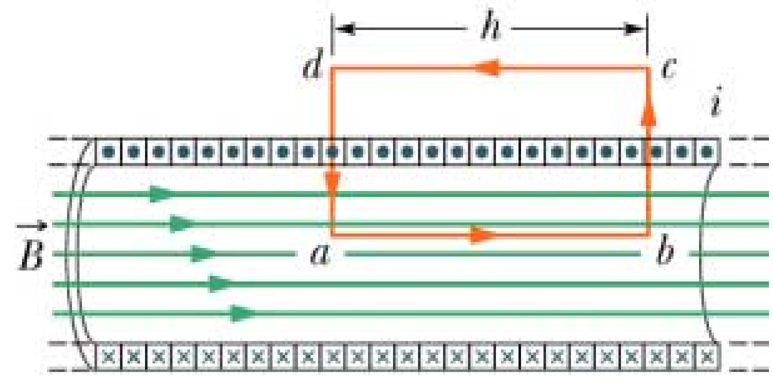
- Force is attractive if current in both wires are in the same directions
- Force is repulsive if current in both wires are in the opposite directions



B Fields from Currents

- For ideal solenoid:

$$B = \mu_0 i n$$



n is the number of turns/length

Faraday's Law

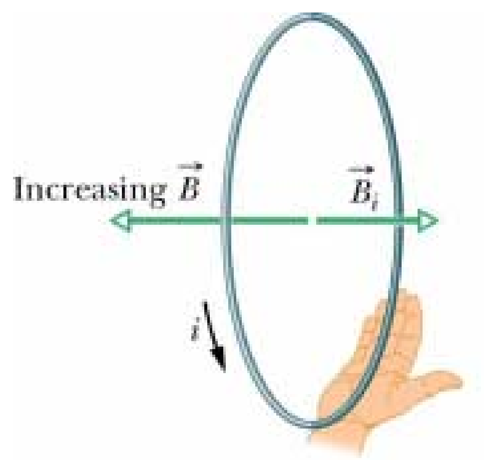
- Magnetic flux

$$\Phi_B = \int \vec{B} \bullet d\vec{A} = BA\cos\theta$$

- Faraday's law (N loops)

$$E = -N\frac{d\Phi_B}{dt}$$

- Lenz's law – induced emf gives rise to a current whose *B* field opposes the change in flux that produced it



Faraday's law

- We can change the magnetic flux through a loop (or coil) by:
  - Changing magnitude of *B* field within coil
  - Changing area of coil, or portion of area within *B* field
  - Changing angle between *B* field and area of coil (e.g. rotating coil)

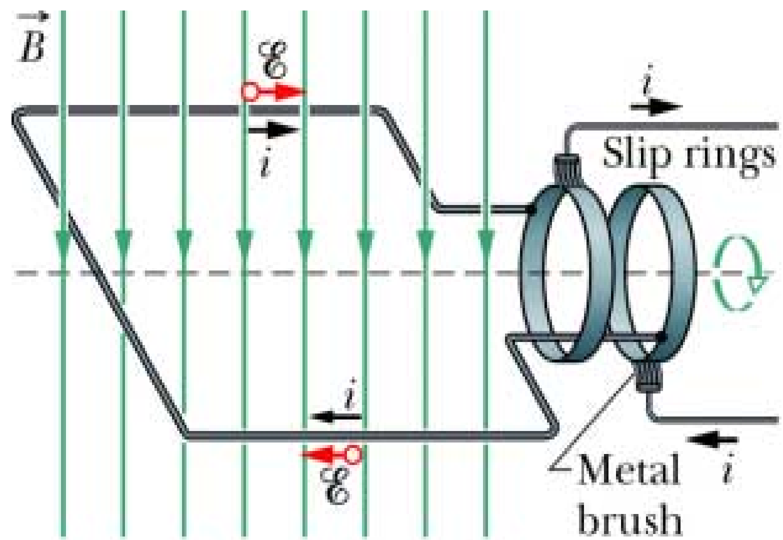
$$E = -NA\cos\theta \frac{dB}{dt}$$

$$E = -NB\cos\theta \frac{dA}{dt}$$

$$E = -NBA\frac{d(\cos\theta)}{dt}$$

Generators

- Generator with N turns of area A and rotating with constant angular velocity, ω

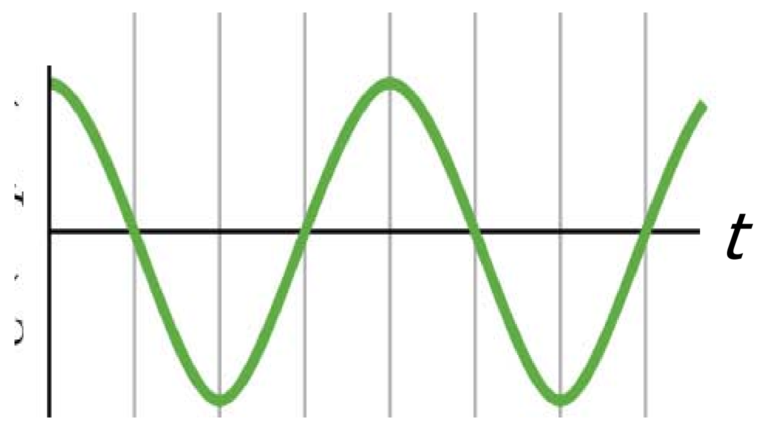


- Magnetic flux is

$$\Phi_B = BA\cos\omega t$$

- Emf is

$$E = NBA\omega\sin\omega t$$



Circuits

- Current $$i = \frac{dq}{dt}$$
- Resistors
  - Ohm's law $$V = iR$$
  - Power lost $$P = iV = i^2 R = \frac{V^2}{R}$$

Circuits

- Definition of capacitance: $$C = \frac{q}{V}$$
- Parallel plates of area *A* and separation *d*

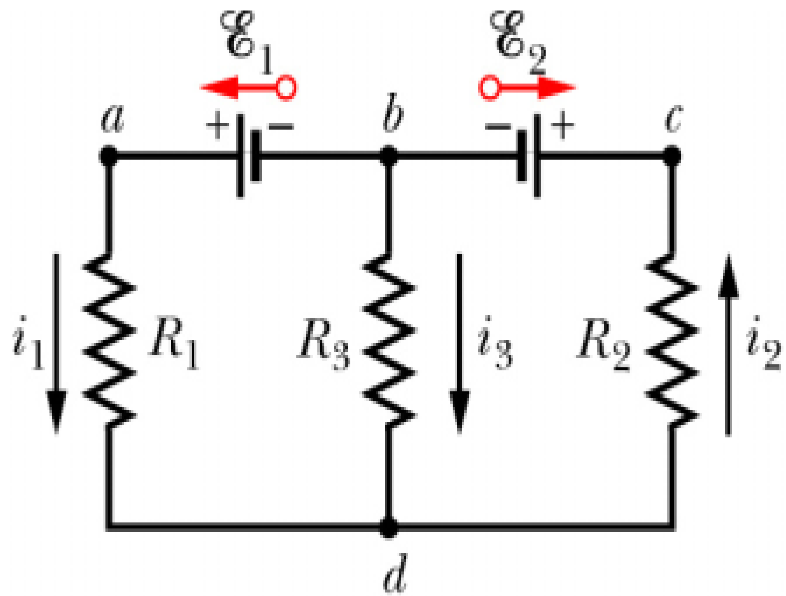
$$C = \frac{\varepsilon_0 A}{d}$$

Circuits

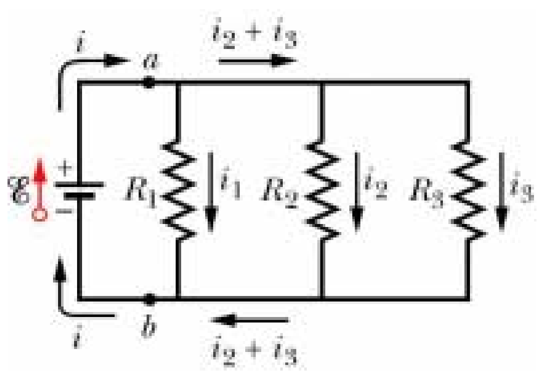
- Junction rule:

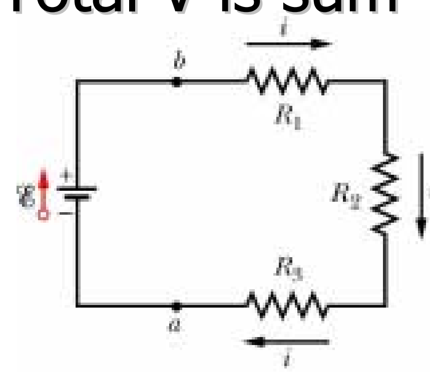
$$i_{in} = i_{out}$$

- Loop rule: sum of potential changes around each loop is zero



Circuits	Parallel	Series
• Capacitors	$C_{eq} = \sum_{i}^{n} C_i$ • V same on each • Total q is sum	$\frac{1}{C_{eq}} = \sum_{i}^{n} \frac{1}{C_i}$ • q same on each • Total V is sum
• Resistors	$\frac{1}{R_{eq}} = \sum_{i}^{n} \frac{1}{R_i}$ • V same on each	$R_{eq} = \sum_{i}^{n} R_i$ • i same in each • Total V is sum





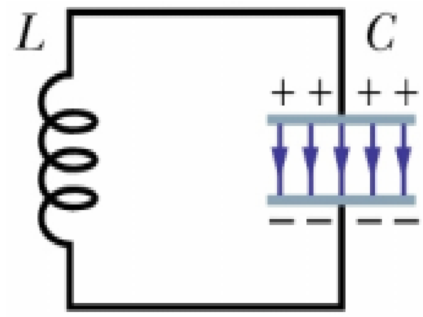
Elements of RLC circuits

	Resistor	Inductor	Capacitor
Energy stored	$U = 0$	$U_B = \frac{1}{2}Li^2$	$U_E = \frac{1}{2}\frac{q^2}{C}$
Voltage change	$V = (-)iR$	$V = -L\frac{di}{dt}$	$V = (-)\frac{q}{C}$
Power lost	$P = i^2R$	$P = 0$	$P = 0$

(-) means sign relative to the direction of current flow

LC Circuits

- Charge $$q = Q\cos(\omega t)$$
- Current $$i = \frac{dq}{dt} = -Q\omega\sin(\omega t)$$
- Angular frequency $$\omega = \sqrt{\frac{1}{LC}}$$
- No power loss



RLC Circuits

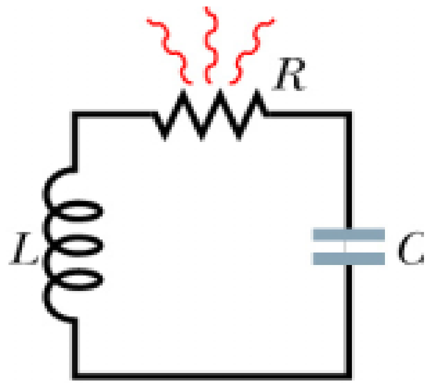
- Charge on capacitor

$$q = Qe^{-Rt/2L}\cos(\omega' t)$$

- Angular frequency

$$\omega' = \sqrt{\omega^2 - (R/2L)^2}$$

- Natural frequency $\omega = \sqrt{\dfrac{1}{LC}}$

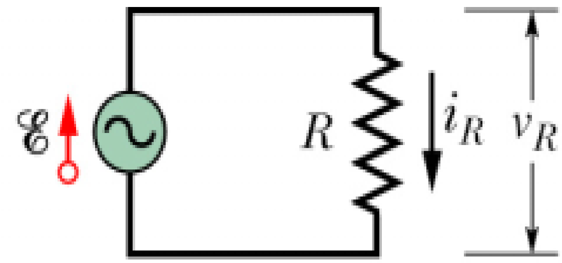


AC Circuits

$$E = E_m \sin \omega_d t, \quad \omega_d = \text{driving frequency}$$

Resistive load

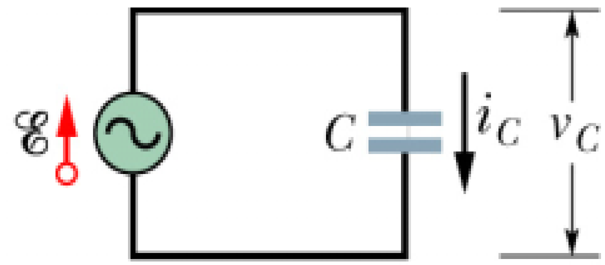
$$I_R = \frac{V_R}{R}$$



Capacitive load

$$I_C = \frac{V_C}{X_C}$$

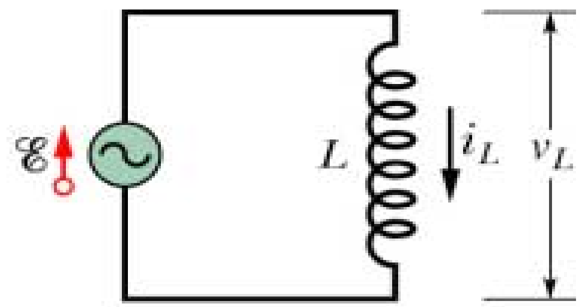
$$X_C = \frac{1}{\omega_d C}$$



Inductive load

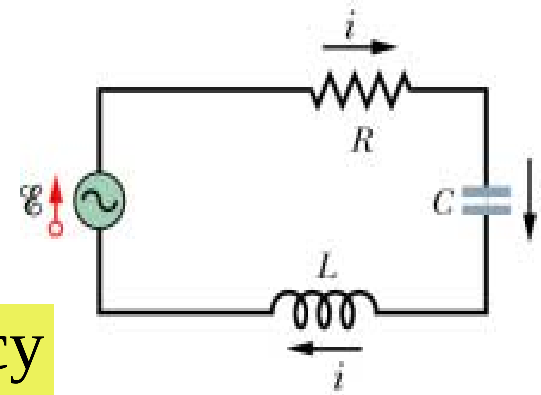
$$I_L = \frac{V_L}{X_L}$$

$$X_L = \omega_d L$$



X is the reactance

AC Circuits



- Input $E = E_m \sin\omega_d t, \quad \omega_d = \text{driving frequency}$
- Current (same everywhere) $i = I\sin(\omega_d t - \phi)$
- Solution $I = \dfrac{E_m}{Z}$ $\tan\phi = \dfrac{X_L - X_C}{R}$ $\dfrac{X_L}{X_C} = \dfrac{(\omega_d)^2}{\omega^2}$
- Z is the impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$
- I is maximum on resonance where

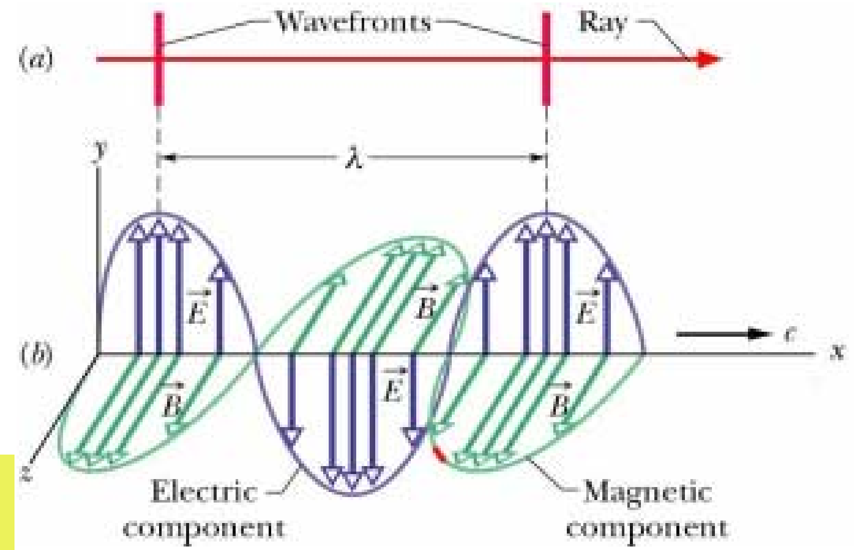
$X_L = X_C$ $Z = R$ $\omega_d = \omega$

EM Waves

$$E = E_m \sin(kx - \omega t)$$

$$B = B_m \sin(kx - \omega t)$$

$$v = c = f\lambda = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3\times10^8\,\mathrm{m/s}$$

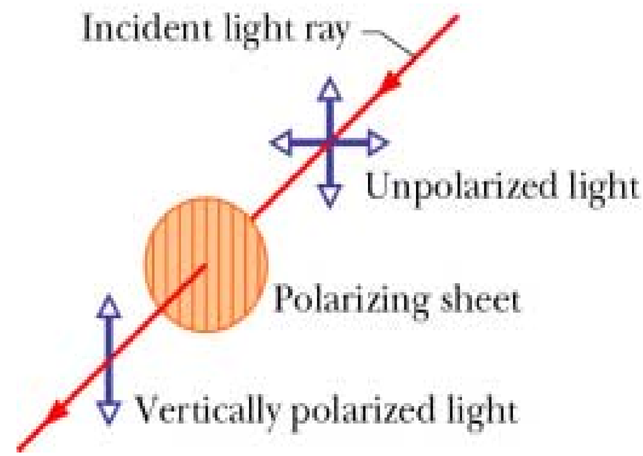


Direction and power per unit area $\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$

Intensity $I = \frac{1}{2\mu_0 c}E_m^2$

Pressure $p_r = \frac{I}{c}$ absorption, $p_r = \frac{2I}{c}$ reflection

Polarization



- Polarization is the direction of the *E* field

- Intensity of unpolarized light with intensity I_0 after hitting a polarizing sheet

$$I = \frac{1}{2} I_0$$

- Intensity of polarized light with intensity I_0 after hitting a polarizing sheet

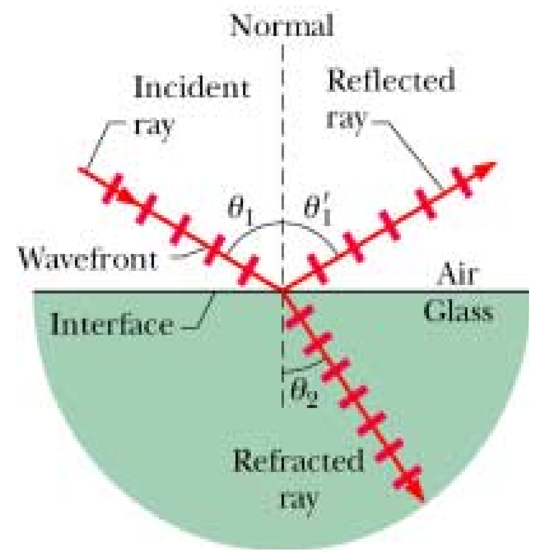
$$I = I_0 \cos^2 \theta$$

Reflection & Refraction

- Reflection: $\theta_1' = \theta_1$

- Refraction (Snell's law)

$$n_2 \sin\theta_2 = n_1 \sin\theta_1$$



- Index of refraction

$$n = \frac{\text{speed in vacuum}}{\text{speed in medium}} = \frac{c}{v}$$

$$\omega_1 = \omega_2$$

$$\frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

- Critical angle (no refracted wave)

$$\theta_C = \sin^{-1}\frac{n_2}{n_1}$$

Mirrors

- Plane – flat mirror
- Concave – caved in towards object
- Convex – flexed out away from object

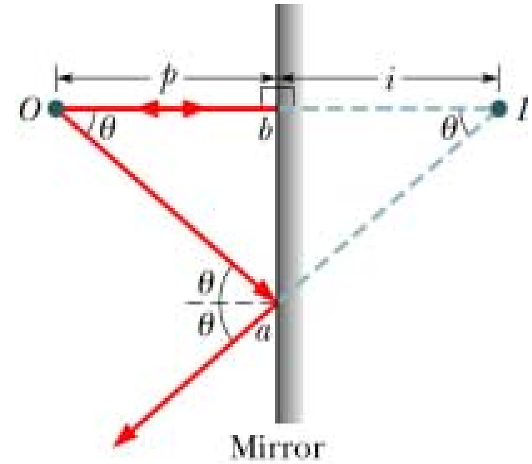
$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$$

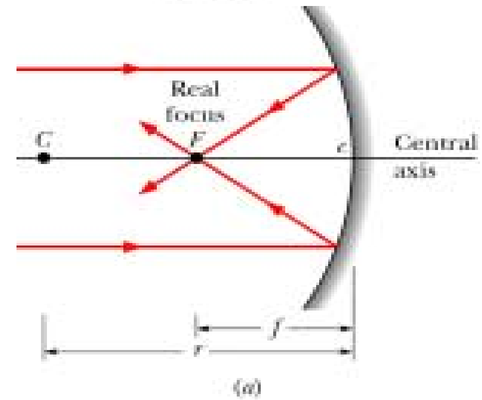
$$f = \tfrac{1}{2} r$$

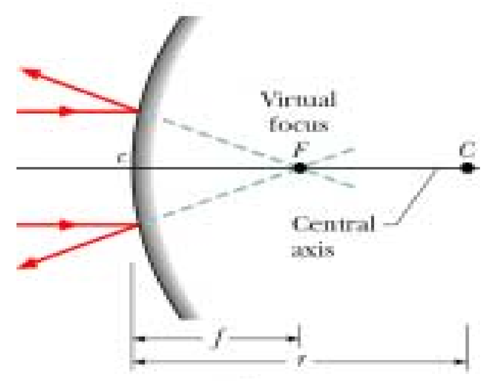
  - r = radius of curvature
  - f = focal length, f>0 concave, f<0 convex
  - p = position of object
  - i = position of image
- real images on side where object is
- virtual images on opposite side
- lateral magnification:

$$|m| = \frac{h'}{h}$$

$$m = -\frac{i}{p}$$



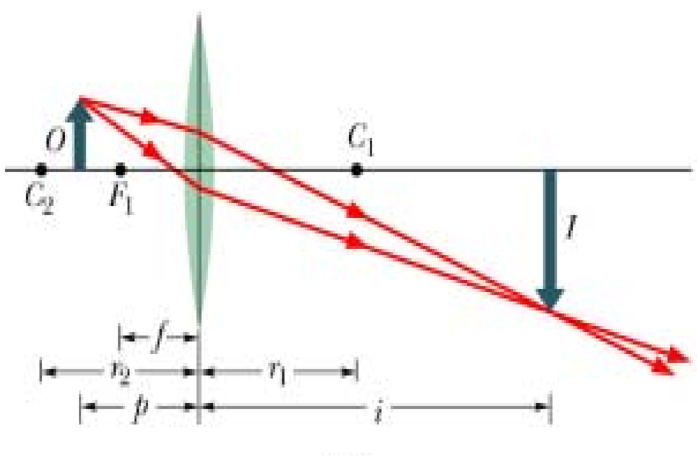


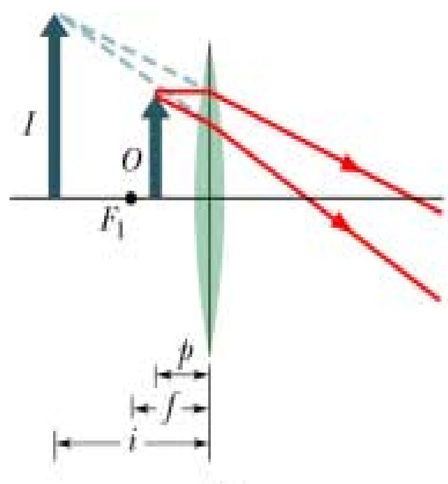


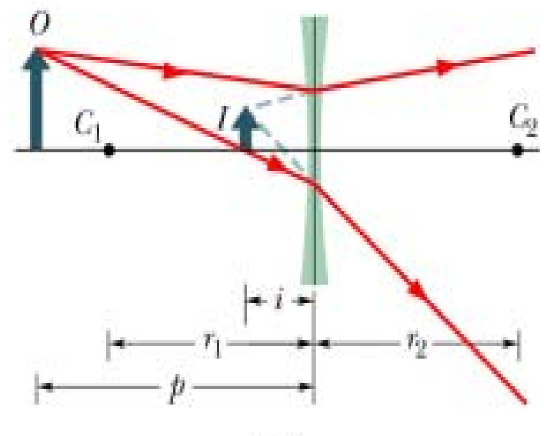
Thin Lenses

- Real images: opposite side - virtual images: same side
- Diverging lens (f<0): smaller, same orientation, virtual images
- Converging lens (f>0): both real and virtual images
- Image position and magnification: $$\frac{1}{p}+\frac{1}{i}=\frac{1}{f}$$ $$m=-\frac{i}{p}$$
- Lens maker's equation:

$$\frac{1}{f}=(n-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$$





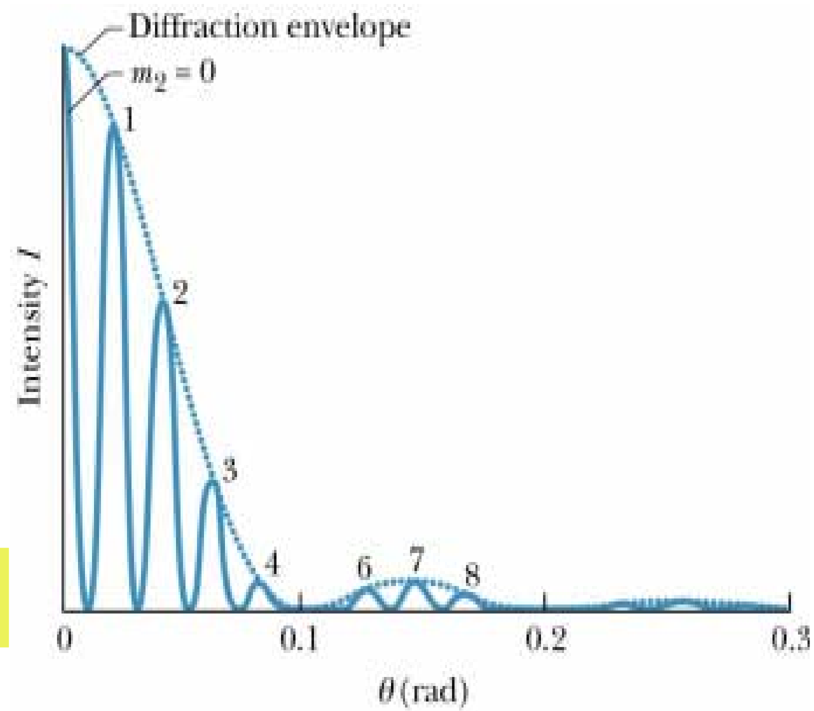


Interference and Diffraction

- Diffraction minima given by

(a=slit width) $a \sin\theta' = m'\lambda$

$$y' = \frac{m'\lambda D}{a}, \quad m' = 1,2\ldots$$



- Two-slit maxima given by

(d=slit separation) $d \sin\theta = m\lambda$

$$y = \frac{m\lambda D}{d}, \quad m = 0,1,2\ldots$$

- Small angles $\sin\theta = \theta \ \ (\theta \text{ in radians})$

Thin Films

- Phase change at interface
  - Refraction at interface (the transmitted wave) never changes phase
  - Reflection gives a phase change

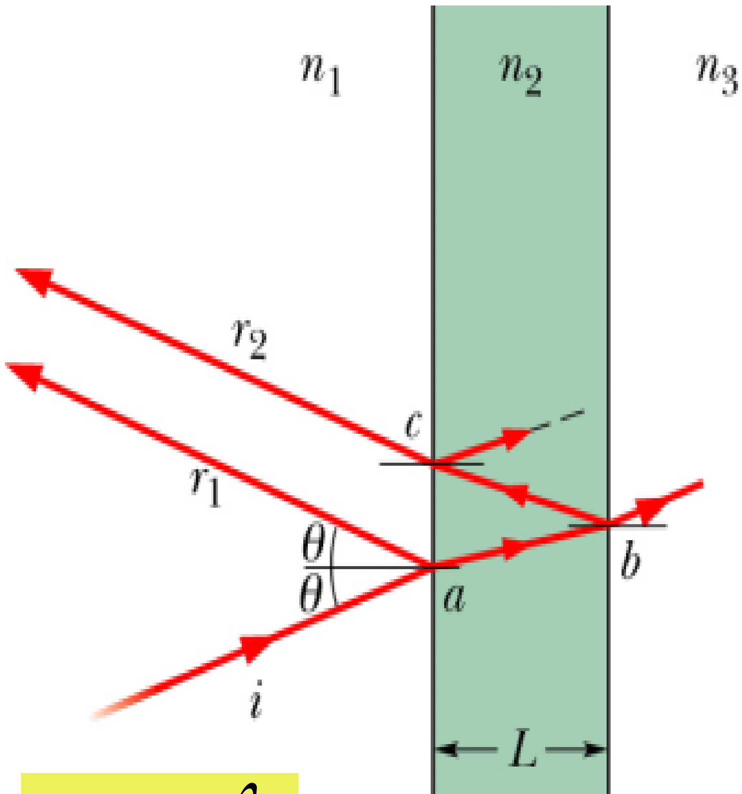
$$\tfrac{1}{2}\lambda \text{ if } n_1 < n_2$$

- Phase change due to path a-b-c in material n_2 over a total length 2L
  - 1 and 2 are in phase if

$$2L = m\lambda_{n2}, \quad m = 0,1,2...$$

  - 1 and 2 are out of phase if

$$2L = (m + \tfrac{1}{2})\lambda_{n2}, \quad m = 0,1,2...$$



$$\lambda_{n2} = \frac{\lambda}{n_2}$$