Final Exam study tips

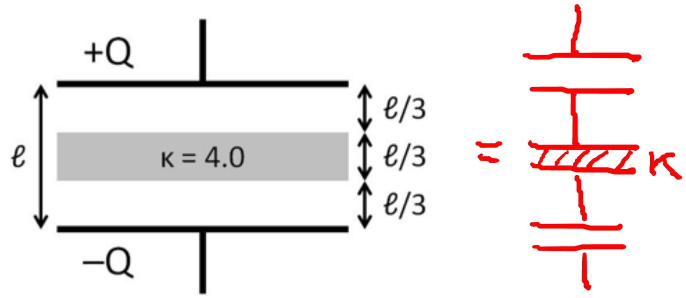
- How do you study for a Phys 102 exam?
  - Cramming DOES NOT work
  - Emphasize understanding concepts & problem solving, NOT memorization
  - Review lecture notes (ACTs), problem solver summary
  - Understand formula sheet (i.e. when to use and when NOT to use an equation) & know what each symbol means
  - Do practice exam problems (time yourself!)

Problem solving approaches

Physics 102 Exam 1 Fall 2013

The next two questions pertain to the following situation:

An isolated capacitor consists of two parallel plates carrying charge $\pm Q$, separated by a distance ℓ. Its capacitance is C_0. Suppose a slab of dielectric material with dielectric constant $\kappa = 4.0$ and width $\ell/3$ is inserted midway between the two plates, as shown in the figure below.



11. In terms of C_0, what is the new capacitance C_{new} with the dielectric slab?

a. $C_{new} = 4C_0$
b. $C_{new} = 4/3C_0$
c. $C_{new} = C_0$
d. $C_{new} = 2/3C_0$
e. $C_{new} = 1/4C_0$

The *not-so-good* approaches:

~~The "magic" equation:~~

~~"What equation will solve this problem? $C = \kappa C_0$?"~~

~~"Reasoning by analogy"/memorization:~~

~~"I remember a similar HW problem, and the answer was $3C_0/2$..."~~

The *good* approach:

Conceptual understanding/reasoning from basic principles

1. C_{new} equivalent to 3 series capacitors
2. $C = \kappa\varepsilon_0 A/d$, $1/C_{series} = 1/C_1 + 1/C_2 + \ldots$
3. Algebra

I. Electricity

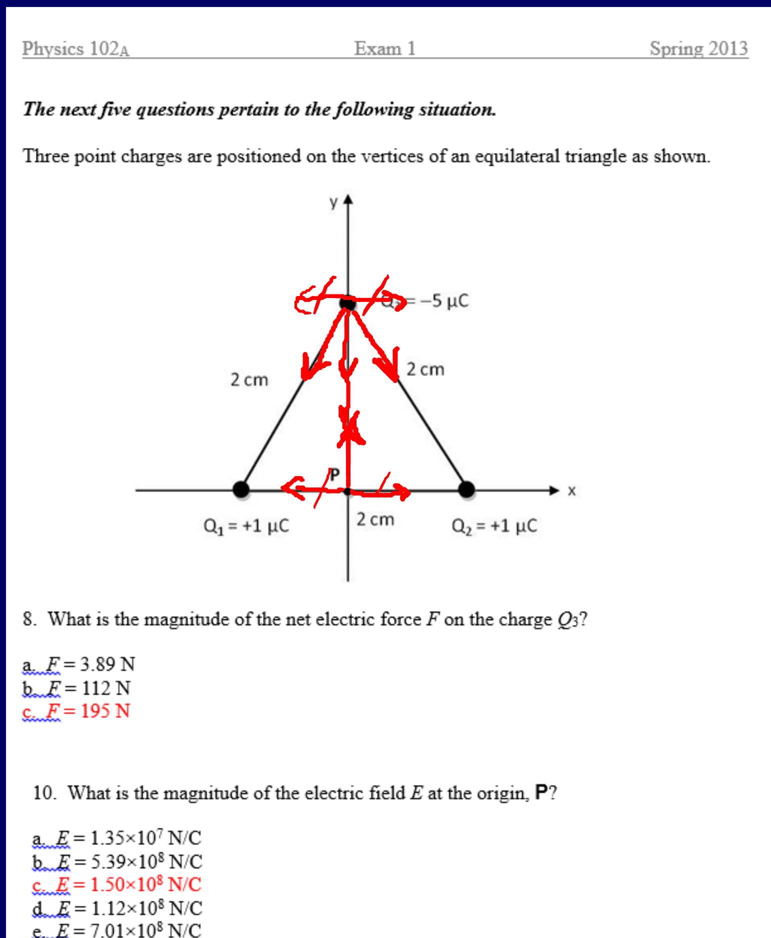
Lect. 1 – 7: Basic principles of electricity & applications (circuits)

(Exam I)

Four quantities: F, E, U_E, V

	Vector	Number ("scalar")
Property of interacting charges	**F** [N] Ex: $F = k\dfrac{q_1 q_2}{r^2}$	**U_E** [J] Also Work Ex: $U_E = k\dfrac{q_1 q_2}{r}$
Property of point in space	**E** [N/C]=[V/m] $E \equiv F/q$ Ex: $E = k\dfrac{q}{r^2}$	**V** [J/C]=[V] $V \equiv U_E/q$ Ex: $V = k\dfrac{q}{r}$

Example problem – vectors



Physics 102A Exam 1 Spring 2013

The next five questions pertain to the following situation.

Three point charges are positioned on the vertices of an equilateral triangle as shown.

8. What is the magnitude of the net electric force F on the charge Q_3?

a. $F = 3.89$ N
b. $F = 112$ N
c. $F = 195$ N

10. What is the magnitude of the electric field E at the origin, **P**?

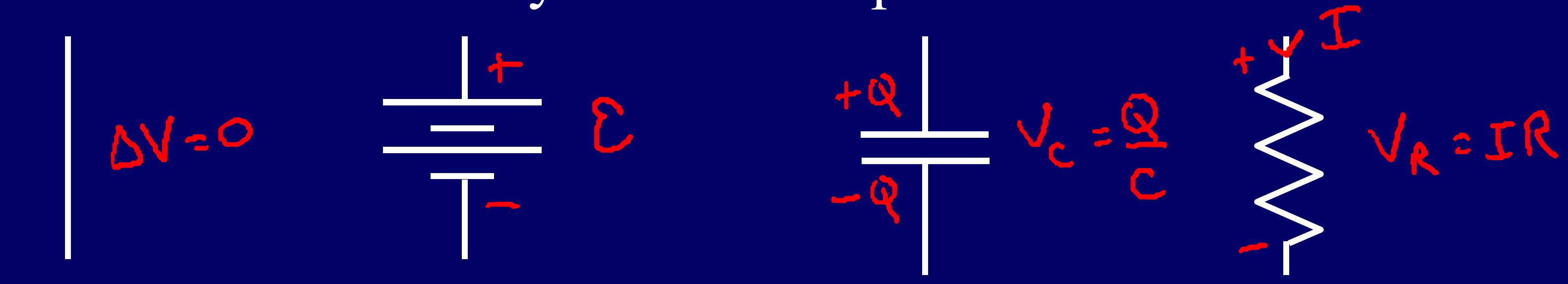
a. $E = 1.35\times10^7$ N/C
b. $E = 5.39\times10^8$ N/C
c. $E = 1.50\times10^8$ N/C
d. $E = 1.12\times10^8$ N/C
e. $E = 7.01\times10^8$ N/C

Basic principle of superposition:
Total force = Sum of individual forces
Total E-field = Sum of individual E-fields

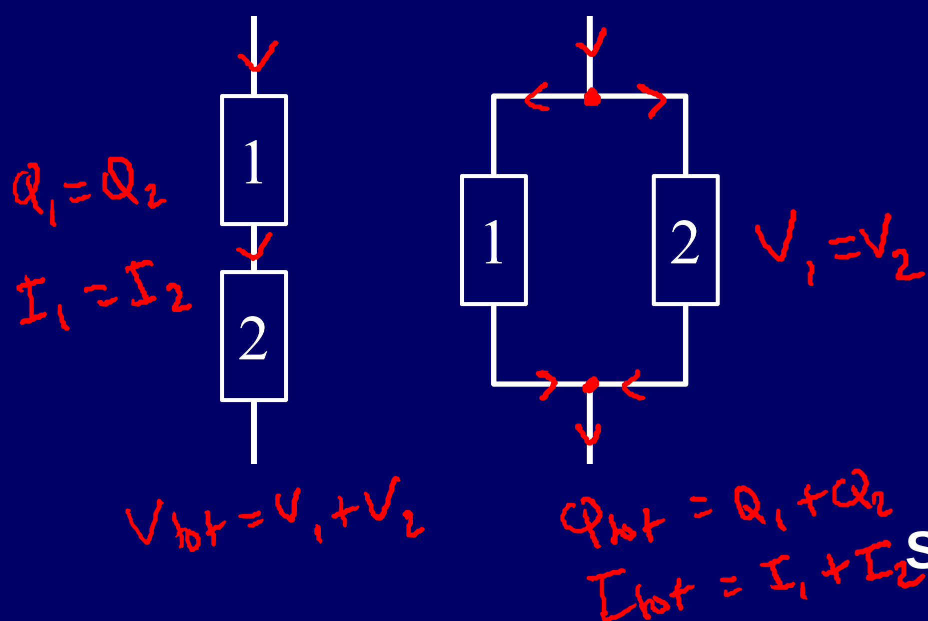
Vector addition
Add like components
Symmetry can simplify problem

Circuits & components

Wire Battery Capacitor Resistor



Series and parallel



Basic principles:

Conservation of charge (KJR)

Conservation of energy (KLR)

$$\Sigma I_{in} = \Sigma I_{out}$$

Current In = Current Out

$$\Sigma \Delta V = 0$$

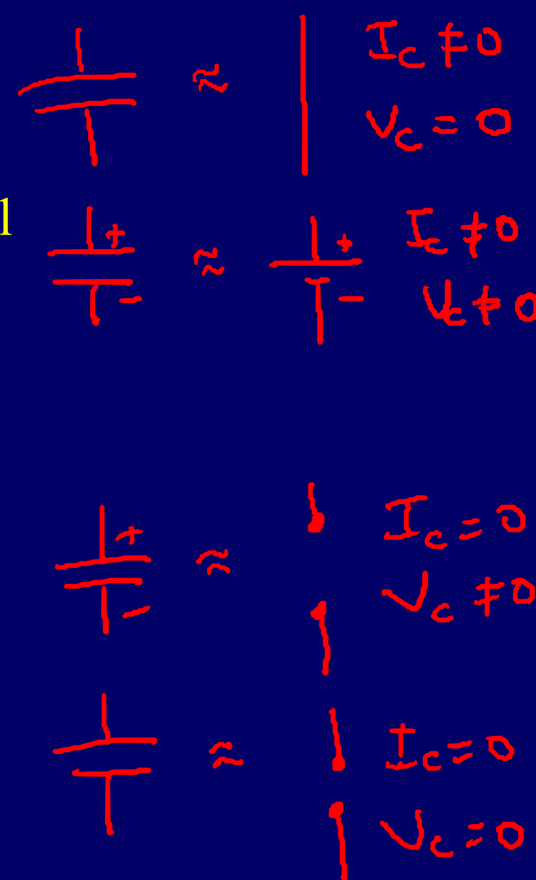
Sum of voltages around loop = 0

RC circuits charging & discharging

- Charge and voltage on Capacitors cannot change instantly: $V_C = Q/C$

- <u>Short term</u> behavior of Capacitor:
  - If the capacitor starts with no charge, it has no potential difference across it and acts as a wire
  - If the capacitor starts with charge, it has a potential difference across it and acts as a battery.

- <u>Long term</u> behavior of Capacitor: Current through a Capacitor is eventually zero.
  - If the capacitor is charging, when fully charged no current flows and capacitor acts as an open circuit
  - If capacitor is discharging, potential difference is zero and no current flows

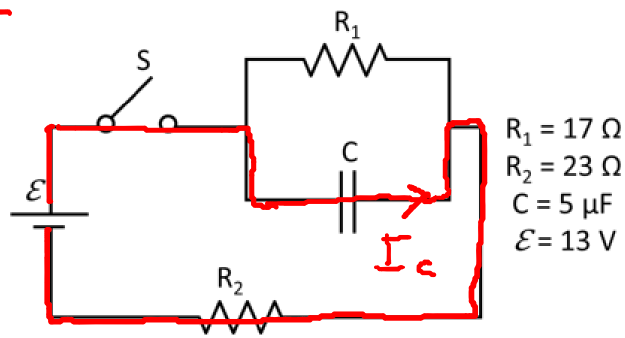


Example problem – RC circuit

Physics 102 Exam 1 Fall 2013

The next four questions pertain to the following situation:

Consider the following circuit. Initially the switch S is open and the capacitor C is fully discharged.



At $t = 0$, the switch is closed.

20. What is the current I_C through the capacitor C immediately after the switch is closed?

a. $I_C = 0$ A
b. $I_C = 0.355$ A
c. $I_C = 0.565$ A
d. $I_C = 0.705$ A
e. $I_C = 1.430$ A

Short term behavior of Capacitor:

If the capacitor starts with no charge, it has no potential difference across it and acts as a wire

$V_c = 0$, $I_c \neq 0$

C and R_1 are parallel:

$V_{R1} = V_C = 0$

So, I_{R1} through $R_1 = 0$

Kirchhoff Loop Rule (KLR):

$\varepsilon - I_C R_2 = 0$

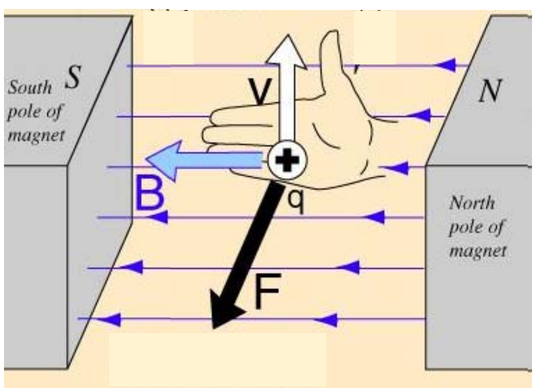
II. Magnetism

Lect. 8 – 13: Magnetism, induction, & applications (circuits)

(Exam II)

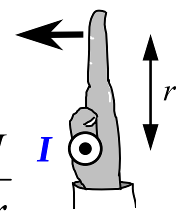
Summary of Right-Hand Rules

RHR 1	RHR 2	Alternate
Force on moving q, I	**B field from current I**	



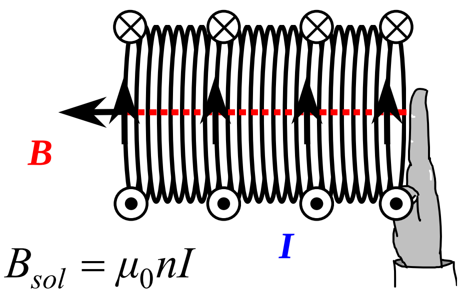
$$F = qvB\sin\theta$$
$$F = ILB\sin\theta$$

Straight wire

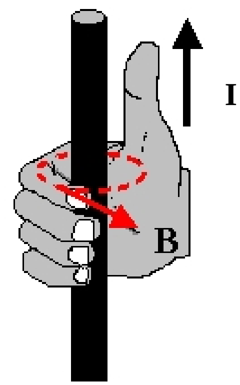


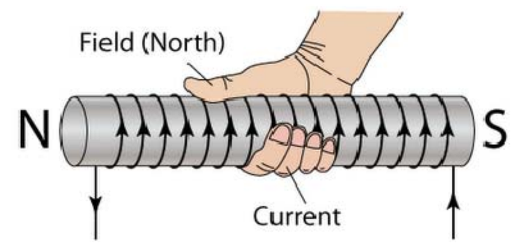
$$B_{wire} = \frac{\mu_0 I}{2\pi r}$$

Solenoid



$$B_{sol} = \mu_0 n I$$

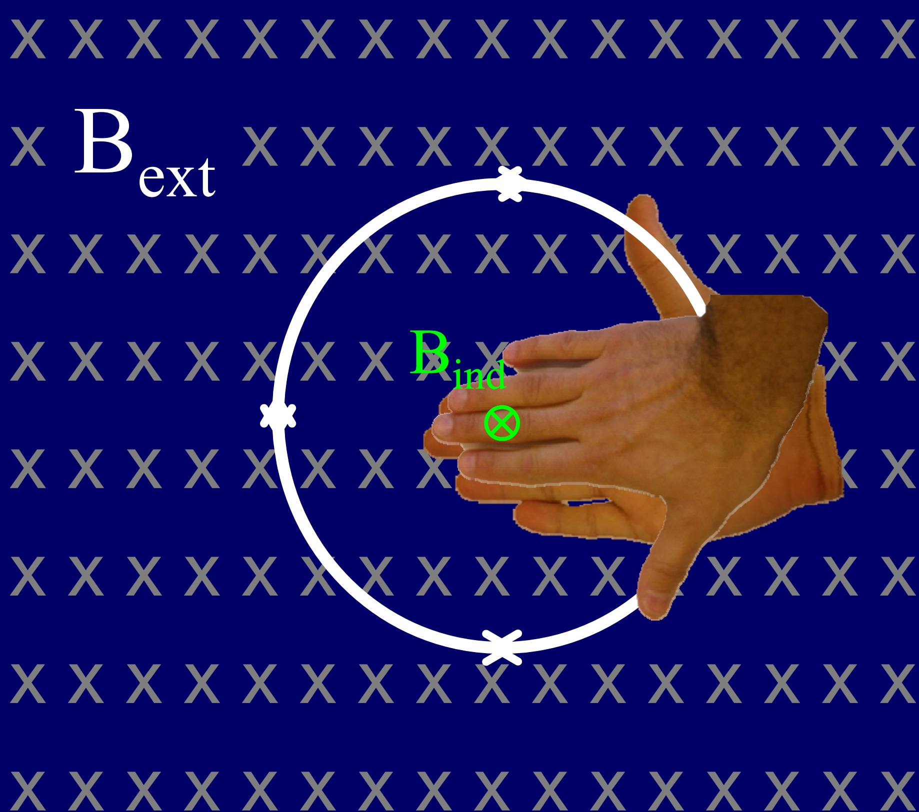




Faraday's and Lenz's Law

$$\varepsilon = -\frac{\Delta\Phi}{\Delta t} = -\frac{\Phi_f - \Phi_i}{t_f - t_i}$$

Lenz: Induced emf opposes change in flux



- If Φ increases:
  New EMF makes B_{ind} opposite B_{ext}
- If Φ decreases:
  New EMF makes B_{ind} along B_{ext}

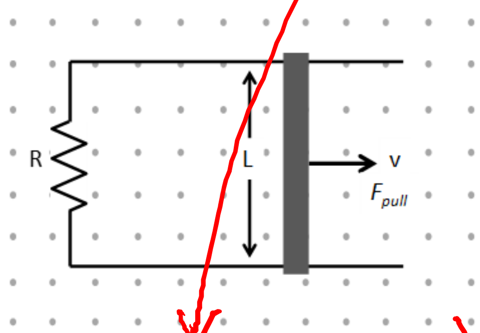
To get I → RHR2

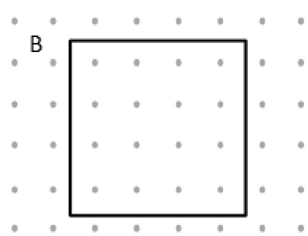
Faraday's Law

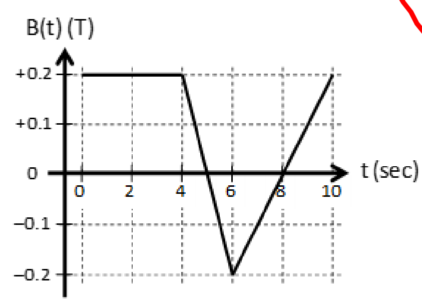
$$\varepsilon = -\frac{\Delta\Phi}{\Delta t} = -\frac{\Phi_f - \Phi_i}{t_f - t_i}$$

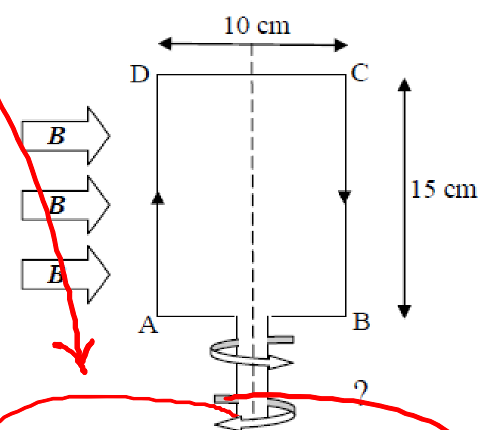
Since Φ= B A cos(ϕ), 3 things can change Φ

Area of loop | **Magnetic field B** | **Angle ϕ**









$$\varepsilon_{bar} = BLv$$

$$\varepsilon = -\frac{\Delta\Phi}{\Delta t} = -\frac{\Phi_f - \Phi_i}{t_f - t_i}$$

$$\varepsilon_{gen} = \varepsilon_{max} \sin \omega t = \omega NAB \sin \omega t$$

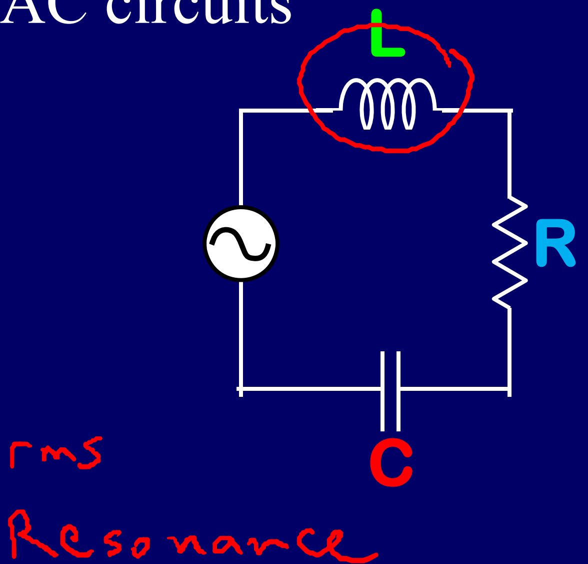
Ex: sliding bar, moving loop

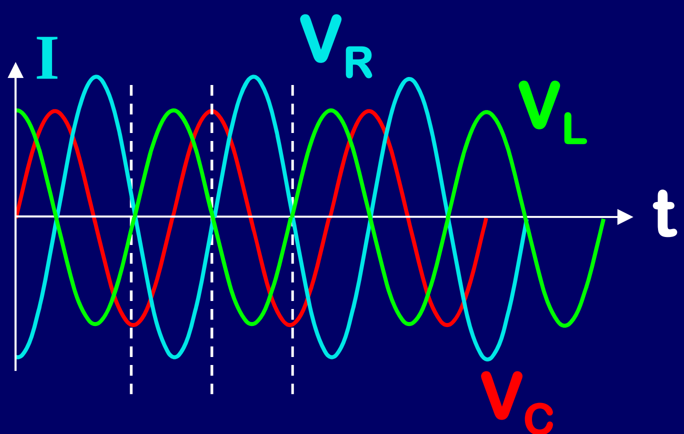
Ex: graph problem

Ex: generator

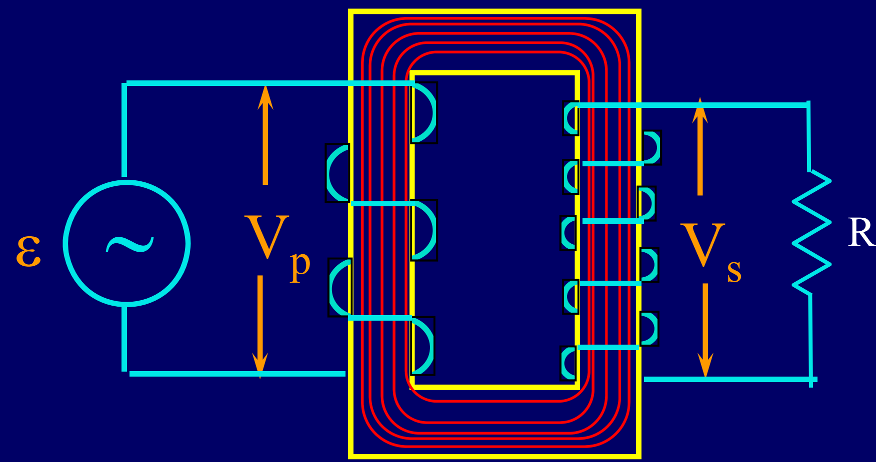
Applications

AC circuits





Transformers

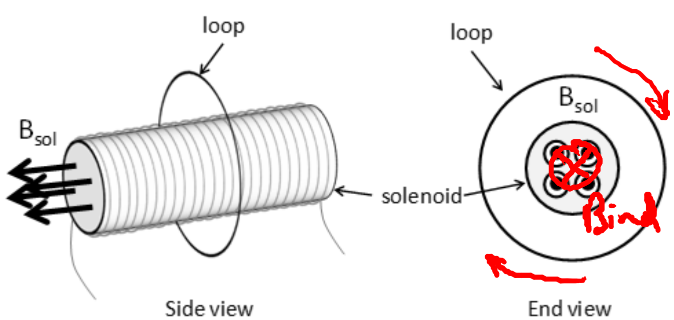


Example problem – Induction

Physics 102 Exam 2 Fall 2013

The next two questions pertain to the following situation:

A single circular loop of wire of radius r_{loop} = 11 cm is placed around a very long solenoid. The solenoid has a radius r_{sol} = 4.8 cm and n = 10,000 turns/m of wire. A current I runs through the solenoid, generating a magnetic field B_{sol} in the direction shown below. The current increases at a rate of 1.5 A/s.



7. In which direction does the induced current flow around the loop?

a. Clockwise
b. Counterclockwise
c. There is no induced current

8. What is the magnitude of the induced EMF |ε| in the loop?

a. |ε| = 0.136 mV
b. |ε| = 0.527 mV
c. |ε| = 1.63 mV
d. |ε| = 3.72 mV
e. |ε| = 7.91 mV

If Φ increases:

New EMF makes B_{ind} opposite B_{ext} $= B_{sol}$

RHR2 for current direction

B changes:

$$\varepsilon = -\frac{\Delta\Phi}{\Delta t} = -\frac{\Phi_f - \Phi_i}{t_f - t_i}$$

$$\Phi = BA\cos(\phi) = B_{sol} A_{sol}$$

$$B_{sol} = \mu_0 n I$$

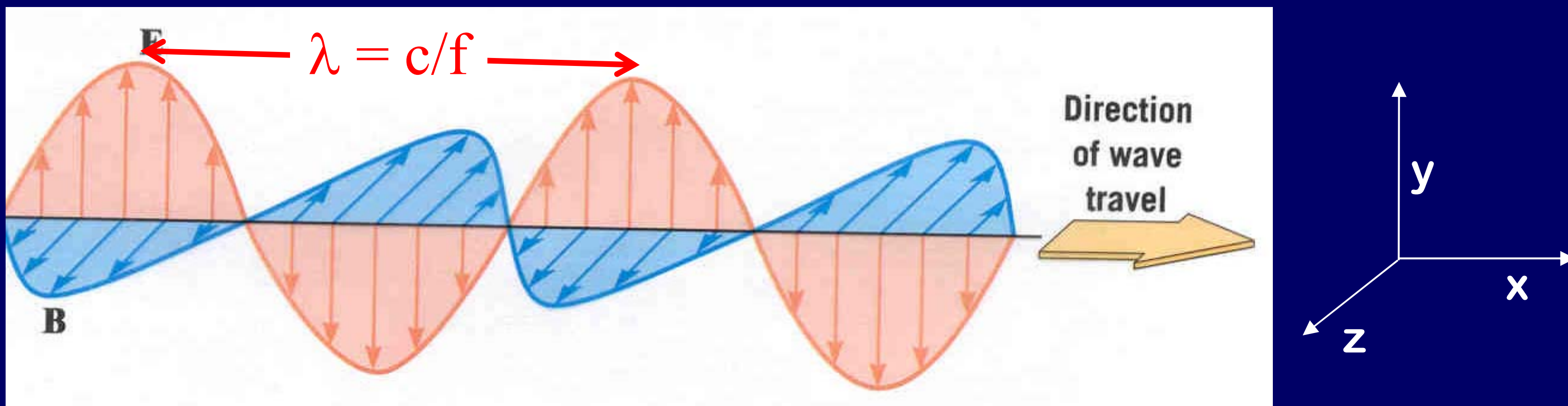
$$\varepsilon = \mu_0 n A_{sol} \frac{\Delta I}{\Delta t}$$

III. Electromagnetic waves

Lect. 14 – 21: Light, reflection, refraction & diffraction

(Exam II & III)

Properties of EM Waves



Energy [J], Power [W], Intensity [W/m^2] $S = P/A = c\varepsilon_0 E^2_{rms}$

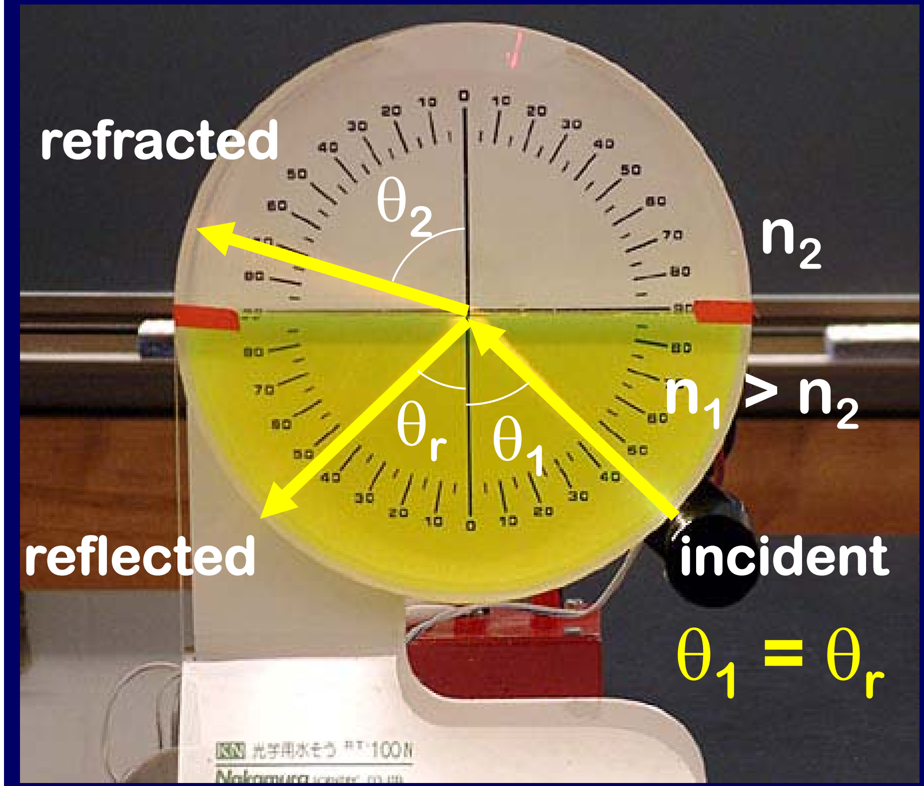
Polarization $E_{transmitted} = E_{incident} \cos(\theta)$

$S_{transmitted} = S_{incident} \cos^2(\theta)$

Light & matter

Objects >> λ, Light described as a ray

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



Dispersion
Total internal reflection

Mirrors & lenses

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$m \equiv \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

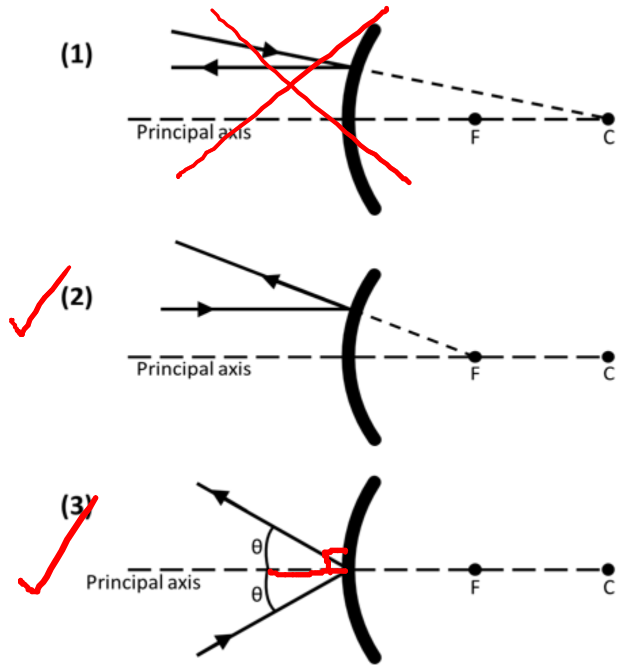
Ray tracing:

1) Parallel to p.a. → through f
2) Through f → parallel to p.a.
3) Through center

Example problem – reflection

Physics 102 Exam 3 Fall 2013

5. Which of the following figures correctly represents a ray reflected off a convex mirror?



a. (1)
b. (2)
c. (3)
d. ~~(1) and (2)~~
e. (2) and (3)

Ray tracing:

2) Through f → parallel to p.a.

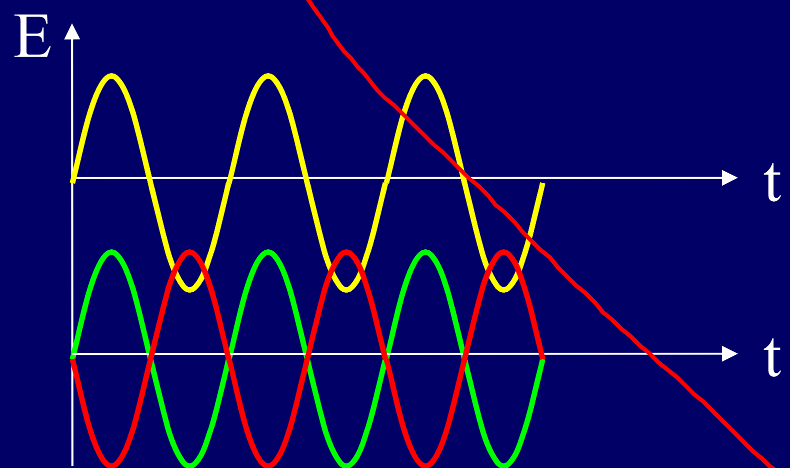
Also, law of reflection:

$$\theta_1 = \theta_r$$

Interference & diffraction

Objects ~ λ, Light described as a wave

Phase shift → Path length difference



λ/2 phase shift – destructive interference
No phase shift – constructive interference

Two-slit interference
N-slit interference
Single-slit diffraction
Diffraction from circular aperture

Thin-film interference

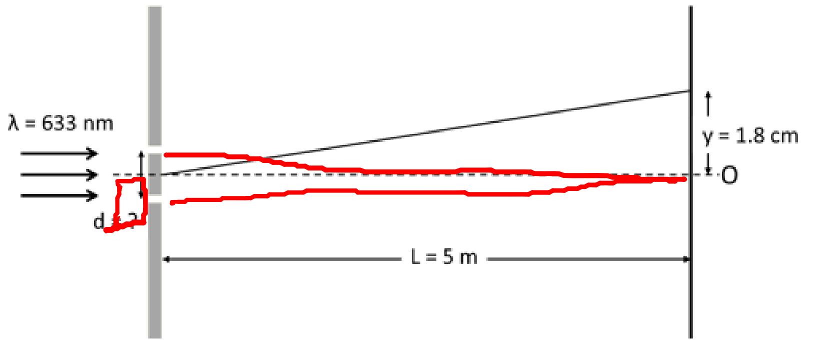
Reflection

Example problem – interference

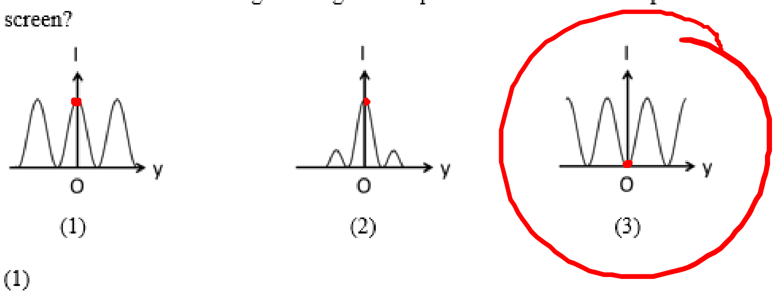
Physics 102 Exam 3 Fall 2013

The next two questions pertain to the following situation:

In the following experiment, light of wavelength λ = 633 nm from a red laser illuminates a double slit. An interference pattern is observed on a screen placed 5 m away. (You may use the small angle approximation throughout.)



19. A material is inserted just behind the bottom slit that causes the bottom ray to be shifted by λ/2. Which of the following drawings best represents the interference pattern seen on the screen?



a. (1)
b. (2)
c. (3)

Path length difference

Young's double slit: $d\sin\theta = m\lambda$

At O, waves travel same path length

But, there's a phase shift

Bottom wave shifted by λ/2

So, destructive interference at O

IV. Modern physics

Quantum mechanics, nuclear physics
& special relativity
(on FINAL!)

Quantum mechanics

Wave-particle duality

Photons – light as a particle (Blackbody, photoelectric) $E = hf = hc/\lambda$

Electron diffraction – particle as a wave (de Broglie) $\lambda = h/p$

Quantum/Bohr model of atom

Quantum numbers, Pauli exclusion principle, electronic transitions

Nuclear physics

Decay processes/rates, binding energy

Example problem – QM

Physics 102 Extra practice problems Fall 2013

40. If an electron has a spin of 3/2, its spin quantum number m_S could have the following four values: m_S = +3/2, +1/2, -1/2, and -3/2. If this were true, the first element with a filled shell would be the first of the noble gasses and it would be

a. He with 2 electrons
b. Li with 3 electrons
c. Be with 4 electrons
d. C with 6 electrons
e. 0 with 8 electrons

Quantum numbers

$n = 1, 2, 3\ldots$ $\ell = 0, 1, \ldots n-1$ $m_\ell = -\ell \ldots 0, 1, \ldots \ell$ $m_s = +3/2, +1/2, -1/2, -3/2$

Pauli exclusion principle

no two electrons can be in the same quantum state, i.e. same quantum numbers

$n=1, \ell=0, m_\ell=0 \quad m_s = +3/2, +1/2, -1/2, -3/2$

Special Relativity

- Two postulates
  - Laws of physics the same in all inertial reference frames
  - Speed of light = c for everyone
- Time intervals
  - Δt_o is in reference frame where events are at rest, "on train". **"proper time"**
  - Δt is measured between same events in reference frame in which train is moving, i.e. "on ground" $\Delta t > \Delta t_o$

$$\Delta t_0 = \Delta t \sqrt{1 - \frac{v^2}{c^2}}$$

- Length intervals
  - L_o is in the reference frame where object is at rest **"proper length"**
  - L is length of moving object using ruler that is not moving $L < L_o$

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

Example problem – relativity

Physics 102 Extra practice problems Fall 2013

Fall 98

38. A spaceship is constructed at the factory to be 75 meters long. After it is launched into space, it travels past the earth with a speed that is 0.6 of the speed of light. How long does the spaceship appear to be according to the crew of the spaceship and according to people on earth?

	crew	people on earth
a.	75m	75m
b.	75m	94m
c.	75m	60m
d.	60m	75m
e.	60m	60m

Length contraction

Crew observe proper length L_0 (object at rest relative to observer)

People on earth observe $L < L_0$

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$