Phys 102 – Lect. 29

Final exam review

Final exam study approaches

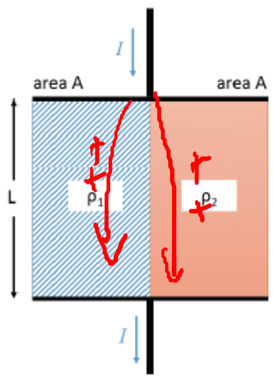
How do you study for a physics exam?

- Cramming DOES NOT work
- Emphasize <u>understanding concepts & problem solving, NOT memorization</u>
- Review pre-lecture & lecture <u>concepts</u> Summary discussion packets
- Review <u>problems</u>: ACTs, HW, exams
- Understand formula sheet (i.e. when to use and when NOT to use an eq'n) & <u>know what each symbol means</u>
- Do practice exam problems (time yourself!)

Problem solving approaches

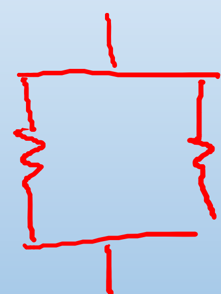
PHYS 102 Exams FALL 2014 Exam 2 (A)

1) A single resistor is made by attaching two blocks of different materials to two conducting plates, as shown in the figure. The two blocks have identical cross sectional areas $A = 1.5 \times 10^{-4}\ m^2$ and identical lengths $L = 0.1\ m$. The materials have different resistivities: $\rho_1 = 3 \times 10^{-8} \Omega \cdot m$ and $\rho_2 = 5 \times 10^{-8} \Omega \cdot m$. What is the total resistance R of the combined element?



a. $R = 42\ \mu\Omega$
b. $R = 13\ \mu\Omega$
c. $R = 53\ \mu\Omega$
d. $R = 0.83\ \mu\Omega$
e. $R = 21\ \mu\Omega$

52%



The *not-so-good* approaches:

The “magic” equation:

“What equation will solve this problem? R = ρL/A? V = IR?”

“Reasoning by analogy”/memorization:

“I remember a similar exam problem from SP10 EX1, and the answer was...”

The *good* approach:

Conceptual understanding / reasoning from basic principles

1. Charges are going to flow through both materials *in parallel*
2. R_{tot} equivalent to 2 || resistors
3. $1/R_{parallel} = 1/R_1 + 1/R_2 + \ldots$, $R = \rho L/A$
4. Algebra

Review lecture ACTs

EX3

The optical components shown are all made of the same material.

21) Which of the above has the largest magnitude of focal length $|f|$?

a. *Figure 1*
b. *Figure 3*
c. *Figure 2*
d. *Figure 4*
e. *Figure 5*

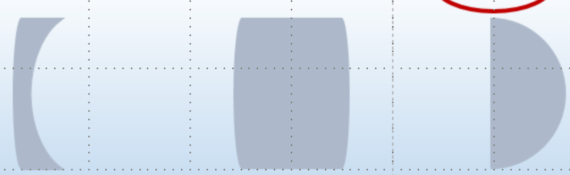
46%

ACT: Lens geometry

The following lenses are all made from the same material but have different geometry

Which lens has the shortest (positive) focal length?

A. B. C. D.



$f < 0$ | $f > 0$ | $f > 0$ | $f > 0$

49%

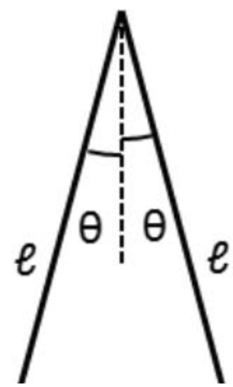
Converging/diverging = thick/thin in middle

More curved = more bending = shorter f

Review homework questions

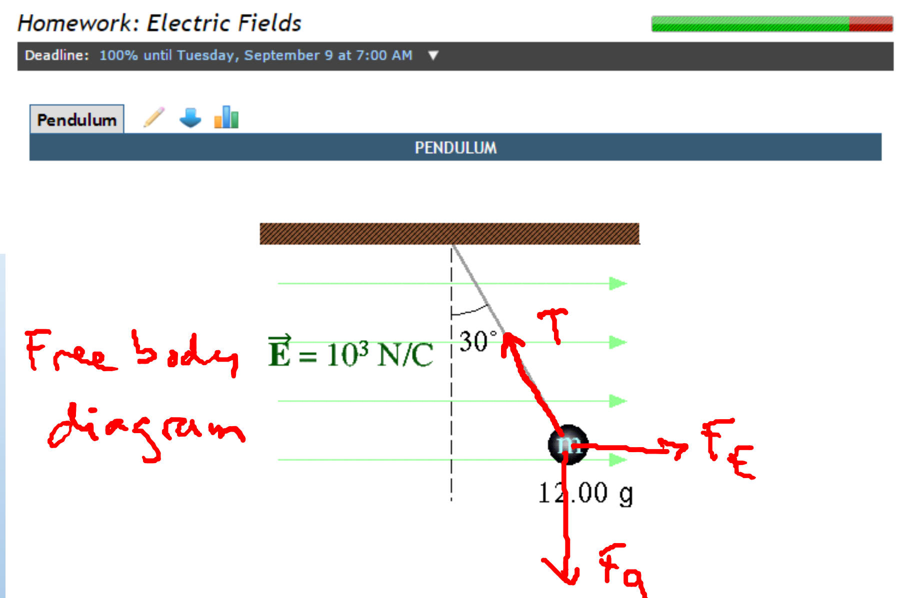
EX1

An electroscope is built by suspending two identically sized conducting spheres of mass $m = 0.02\ kg$ from thin wires of length $\ell = 15\ cm$ as shown in the figure. After charging, both spheres make an angle of $\theta = 15°$ relative to vertical and $Q_1 = Q_2$. (Note: in this problem, you may ignore any mass or charge from the thin wires.)



9) What is the magnitude of the charge $|Q_1|$?

a. $|Q_1| = 8.4 \times 10^{-8}\ C$
b. $|Q_1| = 1.6 \times 10^{-7}\ C$
c. $|Q_1| = 5 \times 10^{-8}\ C$
d. $|Q_1| = 3.9 \times 10^{-8}\ C$
e. $|Q_1| = 1.9 \times 10^{-7}\ C$ 48%



A small 12.00g plastic ball is suspended by a string in a uniform, horizontal electric field with a magnitude of 10^3 N/C. If the ball is in equilibrium when the string makes a 30° angle with the vertical, what is the net charge on the ball?

Q =

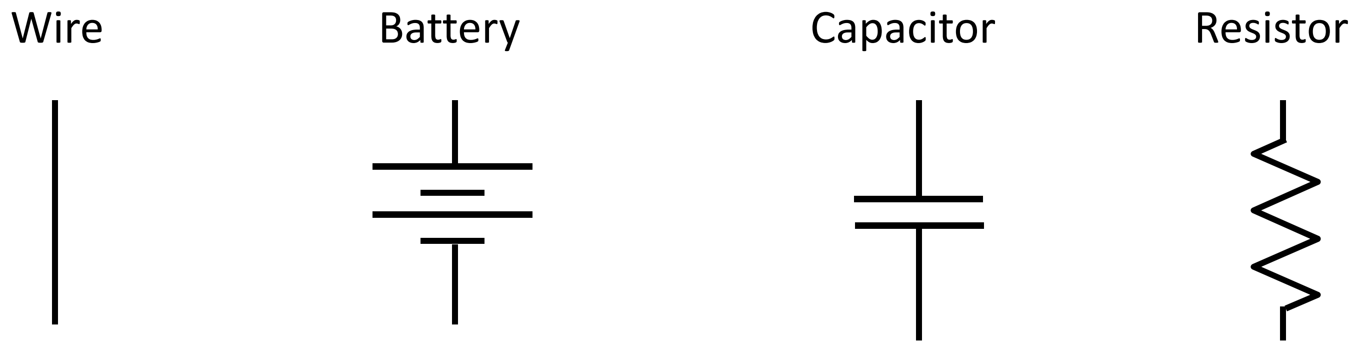
1. Electricity & circuits

Lects. 1 – 9

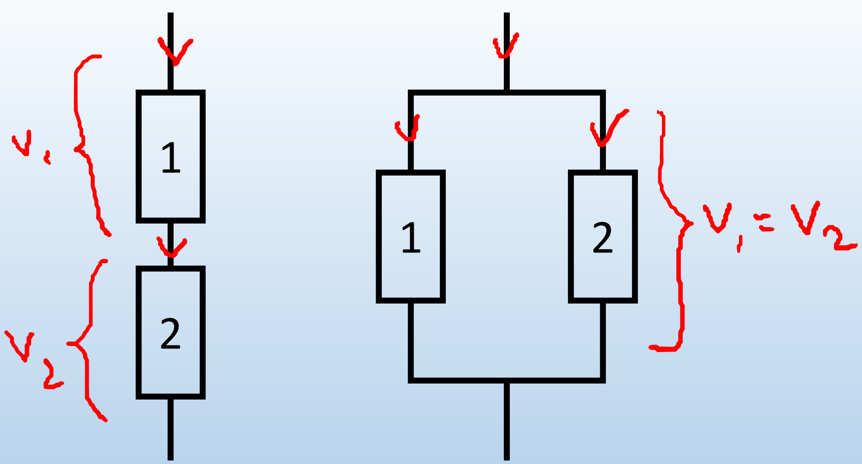
Relationship between F, E, U_E, V

	Vector		Number ("scalar")
Property of interacting charges	*F* [N] Ex: $F = k\dfrac{q_1 q_2}{r^2}$	$W_E = F\Delta r\cos\theta = -\Delta U_E$	U_E [J] Ex: $U = k\dfrac{q_1 q_2}{r}$
	$\vec{\mathbf{E}} \equiv \vec{\mathbf{F}}/q$		$V \equiv U_E/q$
Property of point in space	*E* [N/C]=[V/m] Ex: $E = k\dfrac{q}{r^2}$	*E* points from high to low *V*	*V* [J/C]=[V] Ex: $V = k\dfrac{q}{r}$

Circuits & components



Series and parallel



Basic principles:

Conservation of charge (KJR)

Conservation of energy (KLR)

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

Current In = Current Out

$$\sum \Delta V = 0$$

Sum of voltages around loop = 0

Summary: charging & discharging

- Charge (and therefore voltage, since $V_C = Q/C$) on capacitors cannot change instantly
- *Short term* behavior of capacitor:

  If the capacitor is *charging*, current I_C drives charge onto it, $Q = 0$ and increasing (acts like a wire)

  If the capacitor is *discharging*, current I_C drives charge off of it, $Q > 0$ and decreasing (acts like a battery)
- *Long term* behavior of capacitor:

  If the capacitor is fully *charged*, $I_C = 0$ and Q is maximum (acts like an open circuit)

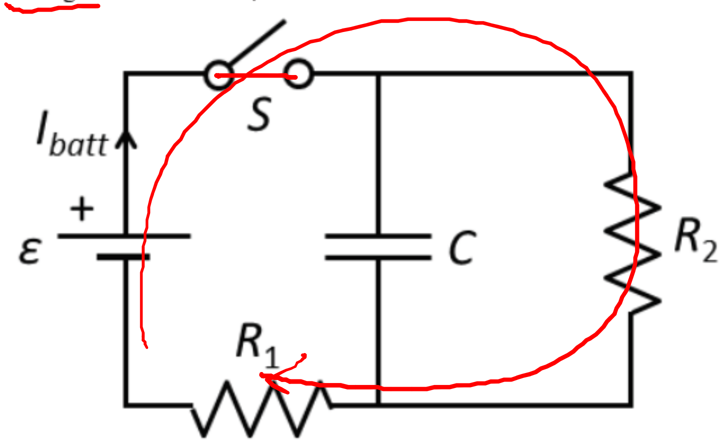
  If the capacitor is fully *discharged*, $I_C = 0$ and Q is minimum (acts like an open circuit)

Example: RC circuits

EX2

The next three questions pertain to the situation described below.

Consider the following RC circuit: $R_1 = 3\ k\Omega$, $R_2 = 6\ k\Omega$, $C = 0.4\ \mu F$, and $\varepsilon = 9\ V$. Initially the capacitor is uncharged. At some time, the switch is closed.



15) What is the current out of the battery, I_{batt}, immediately after the switch is closed?

a. $I_{batt} = 1\ mA$
b. $I_{batt} = 3\ mA$
c. $I_{batt} = 1.5\ mA$
d. $I_{batt} = 0\ mA$
e. $I_{batt} = 22\ mA$

52%

16) What is the current out of the battery, I_{batt}, a long time after the switch is closed?

a. $I_{batt} = 1.5\ mA$
b. $I_{batt} = 22\ mA$
c. $I_{batt} = 0\ mA$
d. $I_{batt} = 3\ mA$
e. $I_{batt} = 1\ mA$

58%

Short term behavior of capacitor:
The capacitor is *charging*: current I drives charge onto it, $Q = 0$ and increasing (acts like a wire)

$$\frac{Q}{C} = V_C = 0 = V_{R_2} = I_2 R_2 \quad (I_2 \to 0)$$

$$KLR: \ \varepsilon - I_{batt} R_1 = 0$$

Long term behavior of capacitor:
The capacitor is fully *charged*: current $I_C = 0$ and Q is maximum (acts like open circuit)

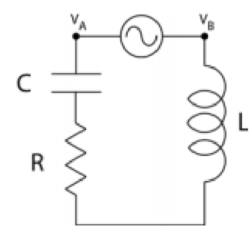
$$KLR: \ \varepsilon - I_{batt}(R_1 + R_2) = 0$$

NOT ON THE FINAL EXAM

SP14 EX2

The next three questions pertain to the situation described below.

The series LRC circuit is driven by a voltage generator with V(t) = 12sin(260t) Volts. The remaining circuit elements have the following values; R = 12.5 Ω, C = 8.5 × 10^{-5} F and L = 0.25 H.



10) The voltage across the generator ___________ the current through the generator.

Explain using reactance for L and C

a. lags
b. leads
c. is in phase with

11) Which of the following circuit elements has the largest peak voltage across it?

Explain using reactance and R

a. Resistor
b. Generator
c. Capacitor

12) What is the average power delivered by the generator?

Start with formula, show all values you use.

a. $P_{average}$ = 3.3 W
b. $P_{average}$ = 1.65 W
c. $P_{average}$ = 2.33 W

We did not cover AC circuits with R, C, L in class this semester, so it will not be on the final

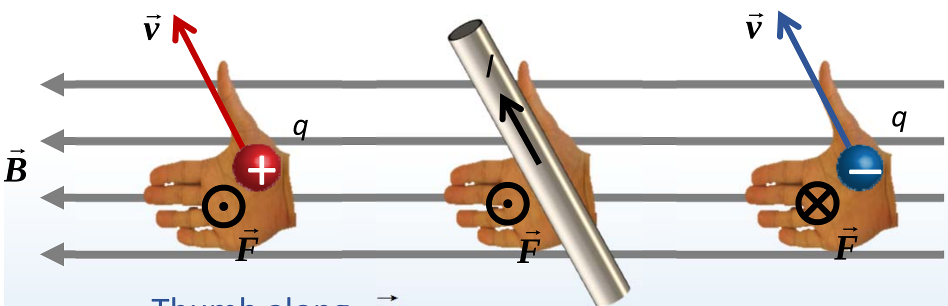
2. Magnetism

Lects. 10 – 15

Magnetism summary

Type I: RHR for *forces* on moving charges and currents

Moving + charges and currents   Moving – charges



Thumb along $\vec{v}$
Fingers along $\vec{B}$
$\vec{F}$ on + q is *out of palm*

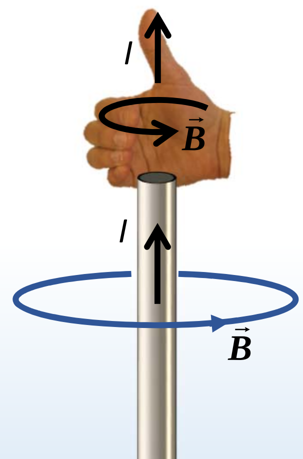
Thumb along $\vec{v}$
Fingers along $\vec{B}$
$\vec{F}$ on – q is *into palm*

$$F = |q| vB \sin\theta \qquad F = ILB \sin\theta$$

$$\tau_{loop} = NIAB \sin\theta = \mu B \sin\theta$$

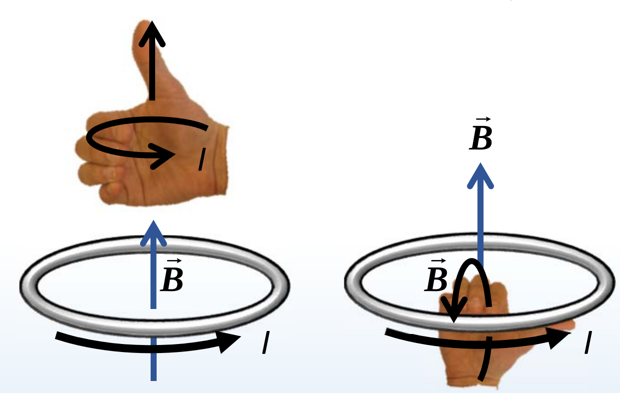
Type II: RHR for *magnetic fields* generated by currents

B field from wire



Thumb along *I*
Curl fingers along $\vec{B}$

B field inside loop



Curl fingers along *I*
Thumb along $\vec{B}$

OR:

Thumb along *I*
Curl fingers along $\vec{B}$

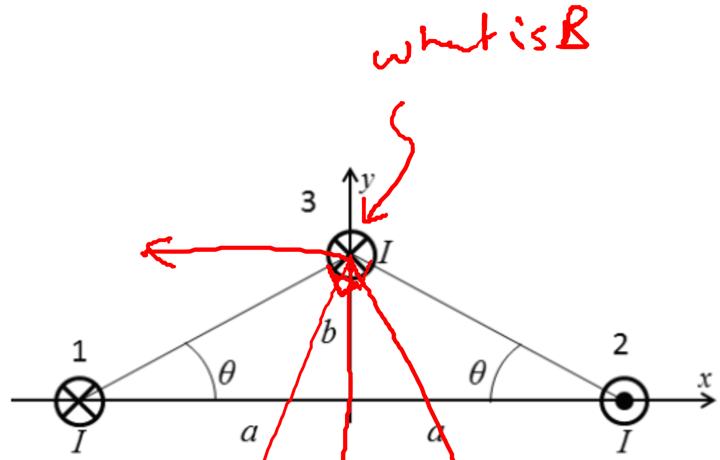
$$B_{wire} = \frac{\mu_0 I}{2\pi r} \qquad B_{sol} = \mu_0 n I$$

Example: Magnetic fields

EX2

Three long, straight wires, are arranged as shown in the figure:

$a = 3.5\ m$, $b = 2\ m$ and $\theta = 30^{o}$. Each wire carries a current $I = 8.8$ A



23) What is the direction of the net force on one meter of Wire 3 due to the other two wires?

a. +*x-direction*
b. *0*
c. +*y-direction*
d. -*y-direction*
e. -*x-direction*

38%

RHR II:
B fields from wire 1 & 2 at position of wire 3

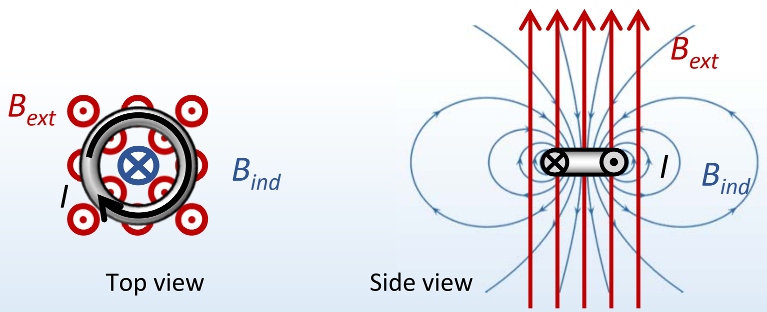
RHR I:
F on wire 3 due to B field from wire 1 & 2

Lenz law

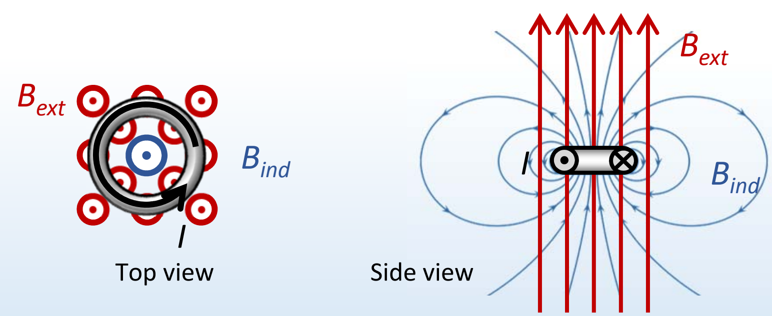
Induced EMF ε *opposes change* in flux Φ

1. Is Φ *increasing*, *decreasing*, or *constant*?

2. If Φ increases:
   ε induces B field *opposite* external B field



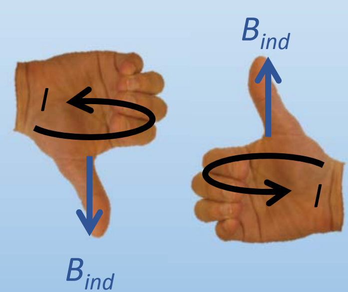
If Φ decreases:
ε induces B field *along* external B field



If Φ is constant:
ε is zero, no induced B field

3. Type II RHR gives current direction

   Curl fingers along I
   Thumb along B_{ind}



Faraday's law

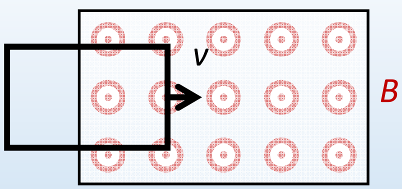
Faraday's law: "Induced EMF" = rate of change of magnetic flux

$$\varepsilon = -\frac{\Delta\Phi}{\Delta t}$$

Fundamental

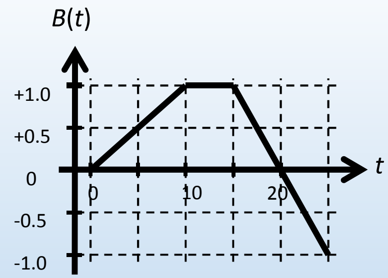
Since $\Phi = BA\cos\varphi$, 3 things can change Φ

1. Area of loop



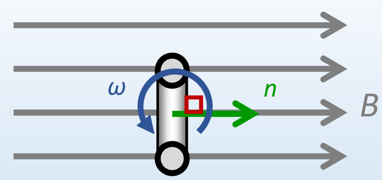
$$\varepsilon = -BLv$$

2. Magnetic field *B*



$$\varepsilon = -\frac{\Delta B}{\Delta t}A$$

3. Angle φ



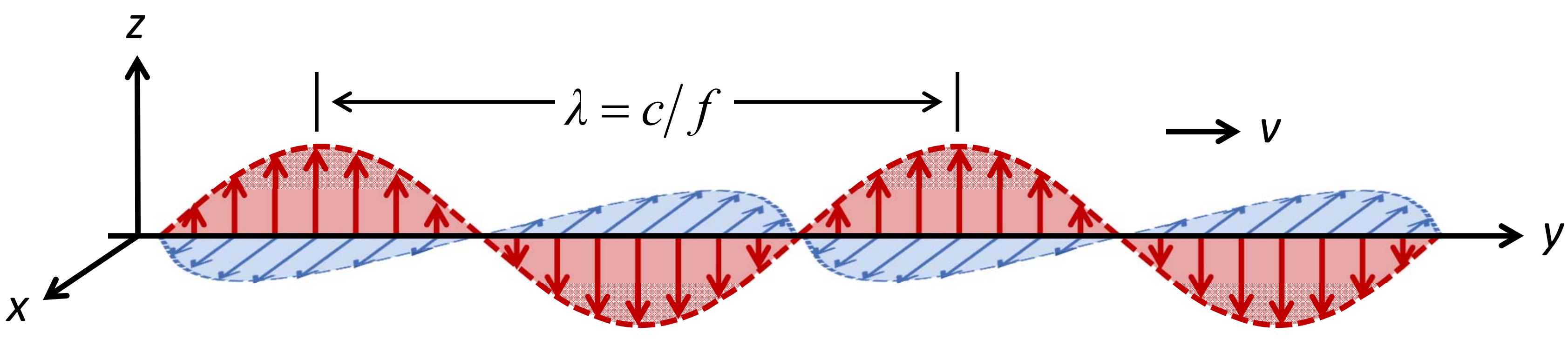
$$\varepsilon(t) = \omega NBA\sin\omega t$$

Situation dependent

3. Light & optics

Lects. 16 – 23

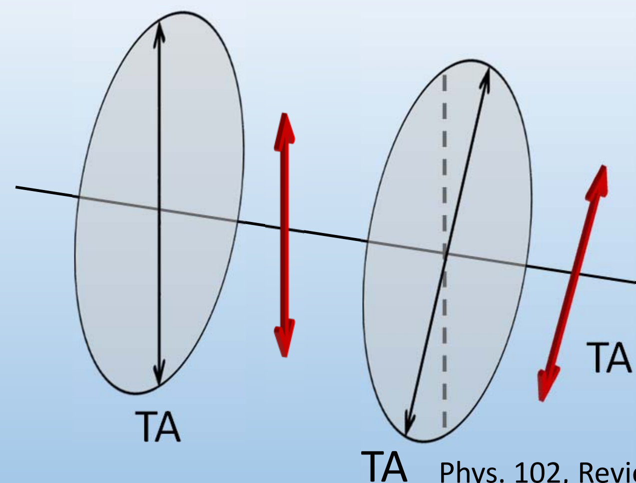
Light as a wave



Energy density [J/m^3], Power [W], Intensity [W/m^2] $$I = \frac{\langle P \rangle}{A} = c\langle u_{tot} \rangle = c\varepsilon_0 E_{rms}^2$$

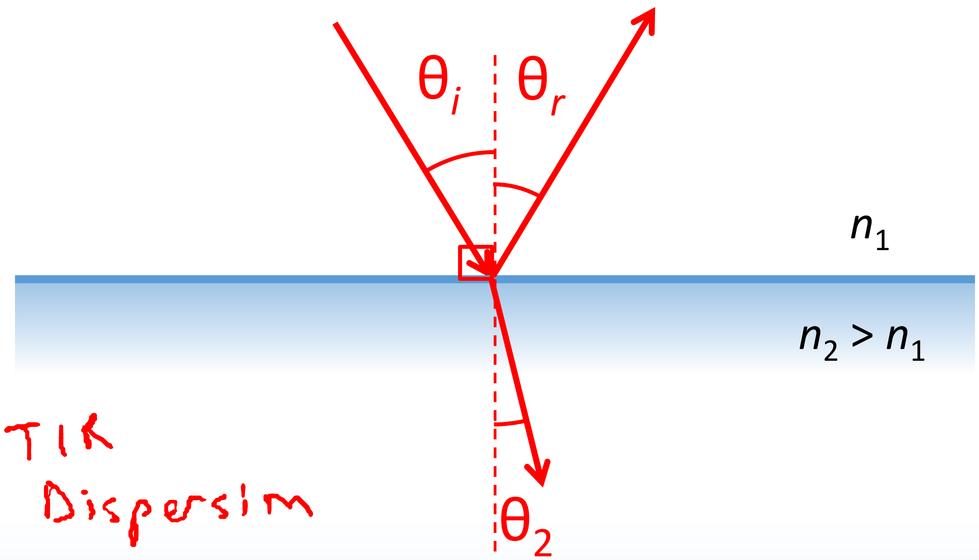
Polarization: $$\left|\vec{\boldsymbol{E}}_{trans}\right| = \left|\vec{\boldsymbol{E}}_{inc}\right| \cos\theta$$

$$I_{trans} = I_{inc} \cos^2\theta$$



Light as a ray

objects $\ll \lambda$



Reflection $\theta_i = \theta_r$

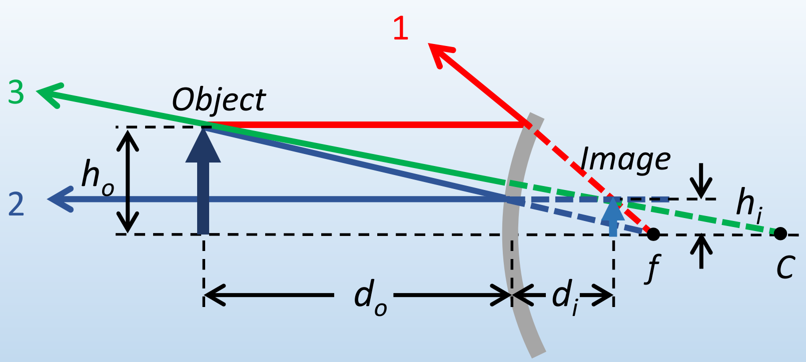
Refraction $v = \dfrac{c}{n}$

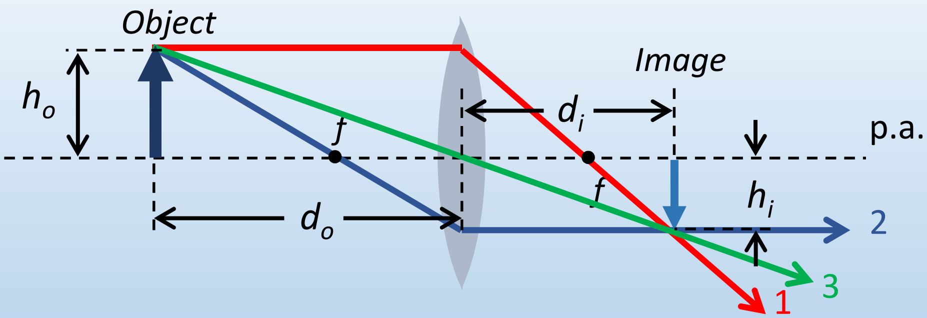
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

→ TIR

→ Dispersim

Mirrors & Lenses





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

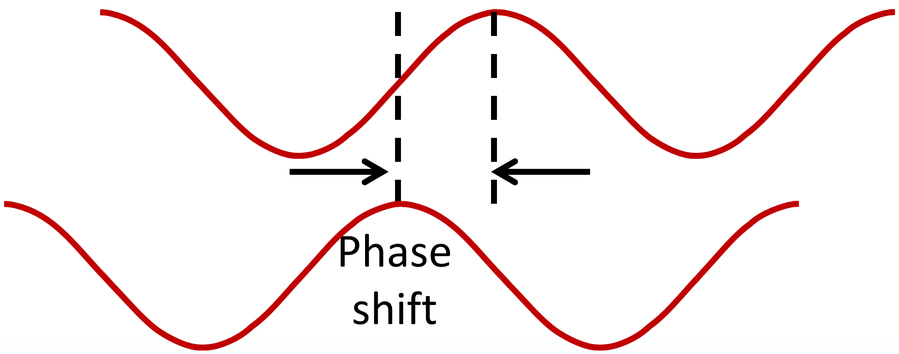
$$m \equiv \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

Optical instruments (including the eye)

Light as a wave (again)

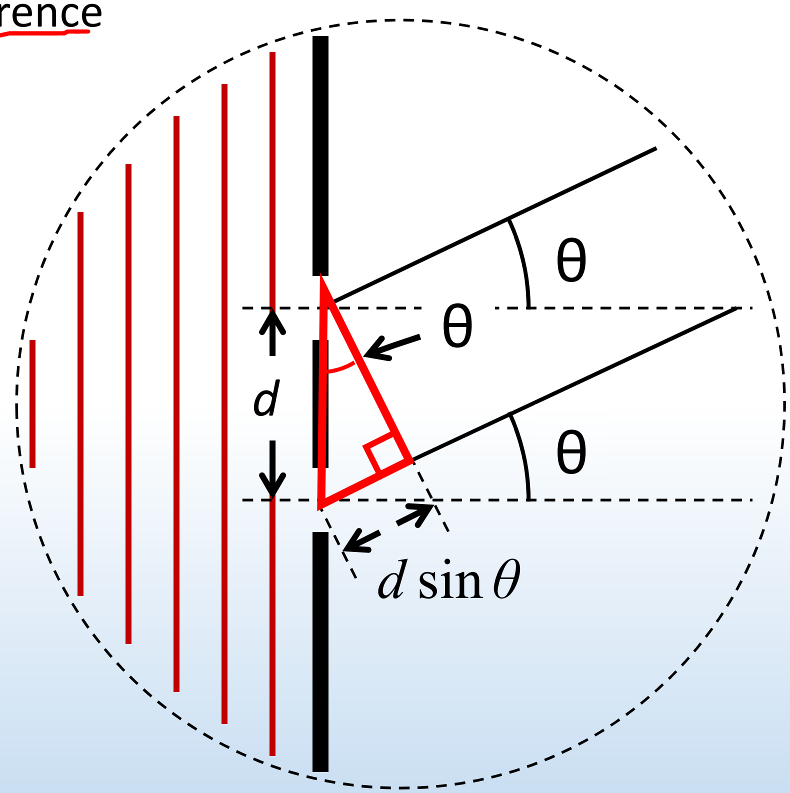
object ~ λ

Interference: phase shift & path length difference



Constructive: phase shift of $m\lambda$

Destructive: phase shift of $(m + \frac{1}{2})\lambda$



Two & multiple slit maxima $d\sin\theta_m = m\lambda$

Two slit minima $d\sin\theta_m = (m+\frac{1}{2})\lambda$

$\Big\} \; m = 0, \pm 1, \pm 2 \ldots$

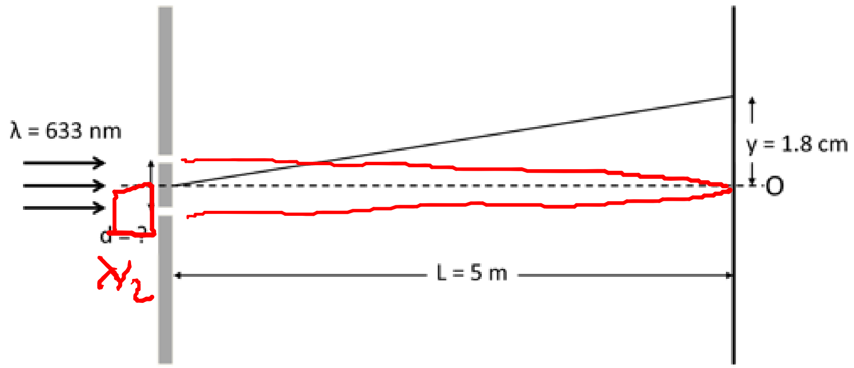
Single slit minima $a\sin\theta_m = m\lambda \quad m = \pm 1, \pm 2 \ldots$

Circular aperture minimum $D\sin\theta_1 = 1.22\lambda$ → resolution

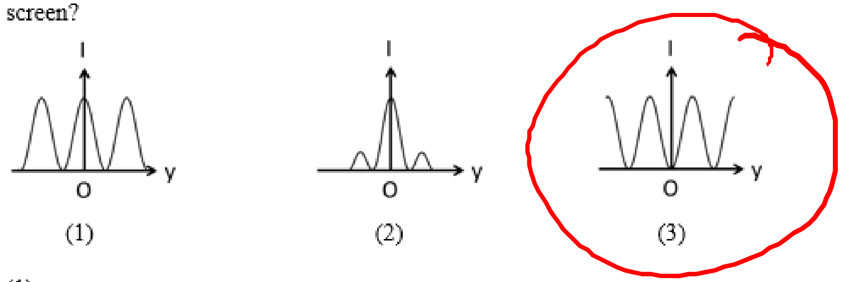
Example: Young's double slit

FA13 EX3

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)

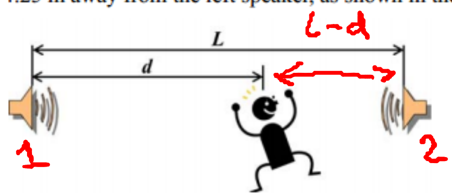
Path length difference
Young's double slit: $d\sin\theta = m\lambda$
At O, waves travel same path length

But, there's a phase shift
Bottom wave shifted by $\lambda/2$
So, destructive interference at O

Example: interference

SP14 EX3

Two speakers are separated by a distance L = 6.8 m. You are standing between the speakers a distance d = 4.25 m away from the left speaker, as shown in the figure below.



$\lambda = \frac{v}{f}$

25) At first, each speaker emits a tone of frequency of 500 Hz. Then, each speaker emits a tone of frequency of 1000 Hz. Which of the tones, if any, will be the loudest? (Note: the speed of sound in air is 340 m/s.)

a. They will be equally loud.
b. The 500 Hz tone.
c. The 1000 Hz tone.

Path length difference:
Wave from left speaker travels *d*, wave from right speaker travels *L – d*

Path length diff. 1 and 2 $= d - (L-d)$

$= 2d - L \begin{cases} = m\lambda & \text{constr.} \\ = (m+\frac{1}{2})\lambda & \text{destr.} \end{cases}$

$= 8.5 - 6.8$

$= 1.7 = (2.5)\lambda_{500}$ destr.

$= 5\,\lambda_{1000}$ constr.

$\lambda_{500} = \frac{340}{500} = 0.68$

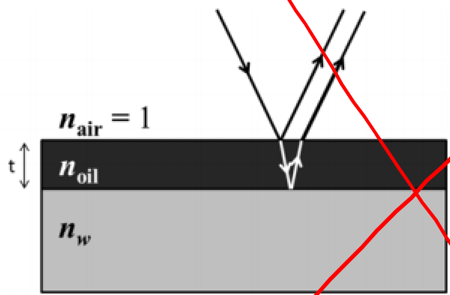
$\lambda_{1000} = \frac{340}{1000} = 0.34$

NOT ON THE FINAL EXAM

SP14 EX3 Interference from thin films

The next two questions pertain to the situation described below.

A thin film of oil (n_{oil} = 1.5) of thickness t = 240 nm is floating on top of a puddle of water (n_w = 1.3) as shown in the figure.



20) For which of the following wavelengths λ (in vacuum) of light incident on the film will **destructive** interference be observed?

a. λ = 480 nm
b. λ = 720 nm
c. λ = 624 nm

21) A film of oil of the same thickness t = 240 nm is resting on top of a block of plastic ($n_{plastic}$ = 1.8). If light of wavelength λ = 480 nm is incident on the oil, what type of interference will be observed?

a. Destructive
b. Constructive

We did not cover this in class this semester, so this type of problem will not be on the final exam

4. Modern physics

Lects. 23 – 28

Quantum mechanics

Wave-particle duality

Matter waves – particle as a wave (deBroglie) $\lambda = \frac{h}{p}$

Photons – light as a particle (photoelectric effect) $E = hf = \frac{hc}{\lambda}$

Bohr model

H-atom – single e^- atoms

quantized orbits & energies, electronic transitions

$$E_n = -13.6\,\text{eV}\,\frac{Z^2}{n^2} \qquad r_n = \frac{n^2}{Z} a_0$$

Quantum model

quantum numbers (n, ℓ, m_ℓ, m_s), Pauli exclusion principle, magnetic properties of atoms

Nuclear & particle physics

structure of nucleus & nucleons

decay processes (α, β, γ) & rates, binding energy

Example: quantum numbers

Extra practice

35. Imagine a universe where the electron has a spin of 3/2. Its spin quantum number m_S could then 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 gases 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

Normal: $n = 1$, $\ell = 0$, $m_\ell = 0$; $+\frac{1}{2}$, $-\frac{1}{2}$

Imaginary: $+\frac{3}{2}$, $+\frac{1}{2}$, $-\frac{1}{2}$, $-\frac{3}{2}$

Quantum numbers

n = 1, 2, 3... ℓ = 0, 1, ... n–1 m_ℓ = –ℓ ... , –1, 0, 1, ... ℓ

Pauli exclusion principle

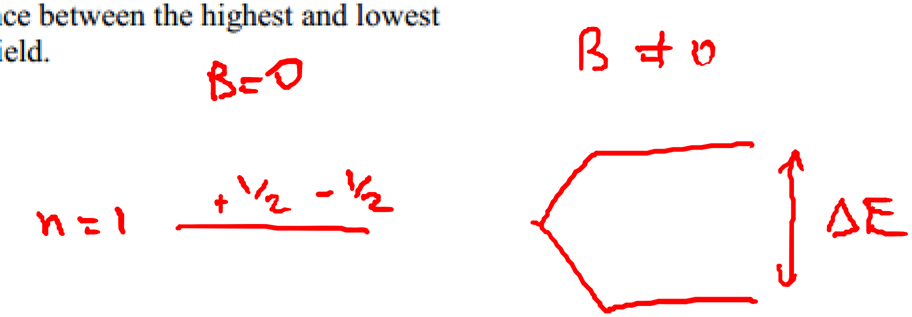
no two electrons can be in the same quantum state, i.e. same quantum numbers

Example: quantum atom

Extra practice

36. Consider a hydrogen atom in the n = 1 state. The atom is placed in a uniform B field of magnitude 2.5 T. Calculate the energy difference between the highest and lowest electronic energy levels in the presence of the B field.

a. 9.3×10^{-5} eV
b. 29×10^{-5} eV
c. 11.6×10^{-5} eV



Quantum numbers

$n = 1, 2, 3\ldots \quad \ell = 0, 1, \ldots\, n-1 \quad m_\ell = -\ell \ldots, -1, 0, 1, \ldots\, \ell$

Orbital & spin magnetic moment

$\mu_\ell \propto \ell$ (orbital) and $\mu_s \propto s$ (spin)

Energy of aligning magnetic moment

$U = -\mu_s B \cos\theta$

Example: nuclear decay

Extra practice

39. The nucleus of nitrogen $^{14}_{7}N$ has a mass of 13,040 MeV/c^2. What is the binding energy of this nucleus? (The mass of the proton is 938.3 MeV/c^2, and that of the neutron is 939.5 MeV/c^2)

a. 2.2 MeV
b. 15.4 MeV
c. 47.9 MeV
d. 80.7 MeV
e. 104.6 MeV

$$m_{N} = Z m_p + N m_n - E_{bind} \quad (Z = 7,\ N = 14-7)$$

$$E_{bind} = 7 m_p + 7 m_n - m_{N}$$

Binding energy & mass defect

Mass of nucleus is smaller than sum of components by the binding energy