FINAL EXAM: Next Wed. May 13, 7-10pm (A1), Fri. May 15, 1:30-4:30pm (A2)
Three hours & 45-50 questions
Cumulative & covers material evenly (10-13 questions in each area):

ADDITIONAL STUDY RESOURCES:
Extra practice exam, optional homework #14
Extra office hours -> see website

Phys 102 – Lect. 29

Final exam review

Final exam study approaches

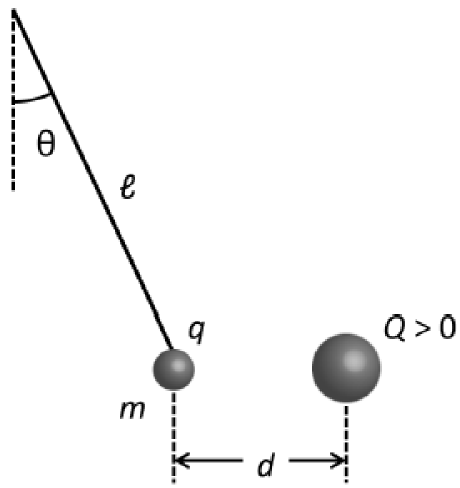
How do you study for a physics exam?

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

Review homework questions

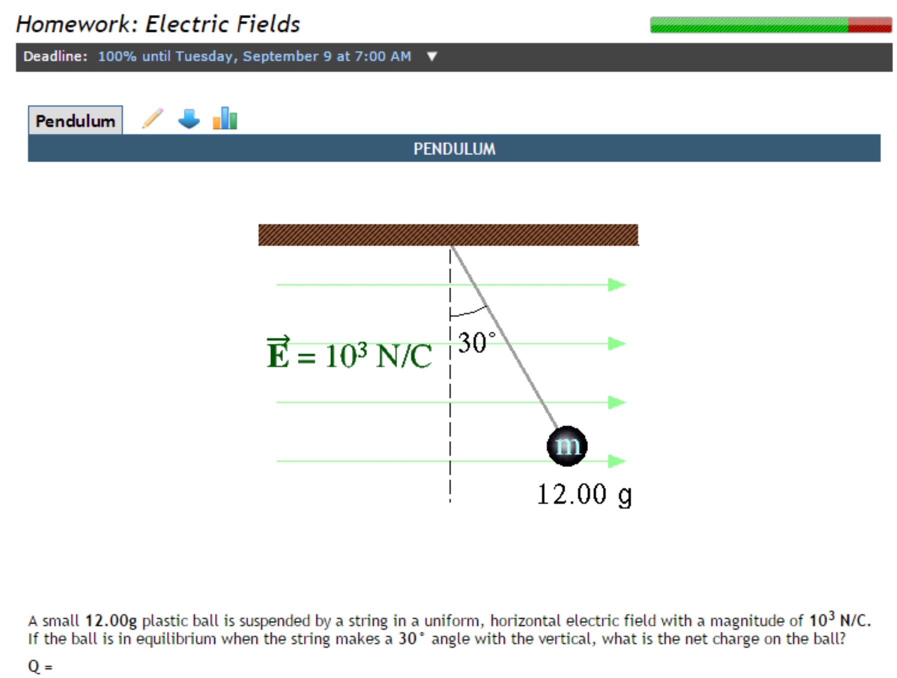
EX1

10) Consider a point charge of mass $m = 19$ g and charge $q = -6.2$ nC suspended from the ceiling by a massless and non-conducting string of length $l = 7$ cm. When another point charge of magnitude $Q = 8$ nC approaches, the hanging charge swings and comes to rest at an angle of $\theta = 20°$, as shown in the figure. Assume that the point charge q comes to rest at the same height as the point charge Q.



What must be the separation d between the charges?

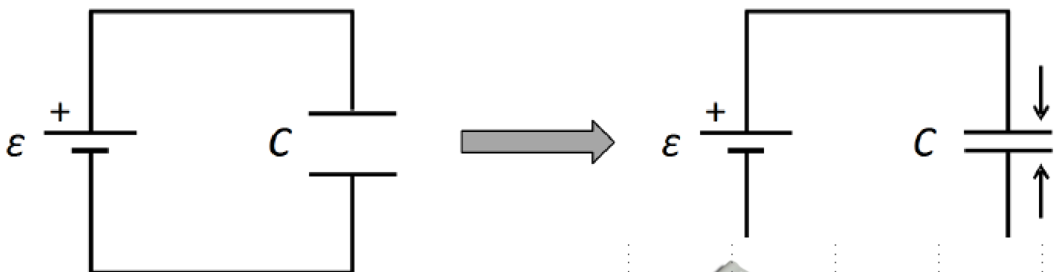
a. $d = 0.87$ mm
b. $d = 2.6$ mm 55%
c. $d = 4.4$ mm
d. $d = 1.3$ mm
e. $d = 9.6$ mm



Review lecture ACTs

EX2

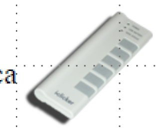
1) A parallel plate capacitor is connected to a 9 V battery, as shown below. At some time, the parallel plates are moved a small distance *closer* together.



What happens to the charge $Q \geq 0$ stored on the top ca
connected to the battery throughout.

a. Q increases 54%
b. Q remains the same
c. Q decreases

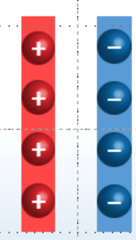
V const.



ACT: Parallel plates

A parallel plate capacitor carries a charge *Q*. The plates are then pulled a small distance further apart.

Q const.



What happens to the charge *Q* on each plate?

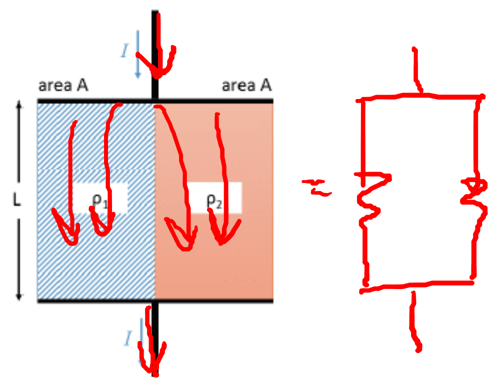
A. *Q* increases
56% B. *Q* stays constant
C. *Q* decreases

Charge is conserved! There are no wires for charges to flow through, so they stay on the capacitor plates

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

1. Electricity & circuits

Lects. 1 – 9

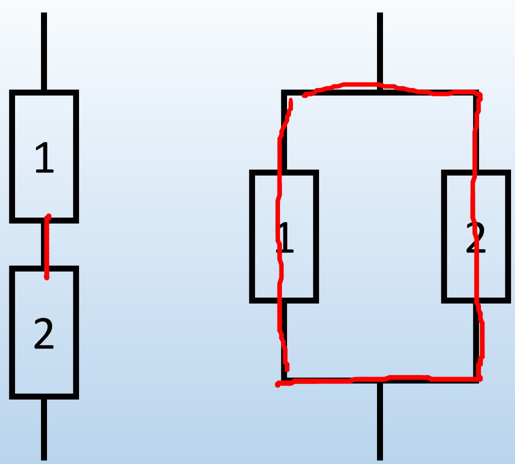
Relationship between F, E, U_E, V

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

Circuits & components

Wire Battery Capacitor Resistor

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)

2. Magnetism

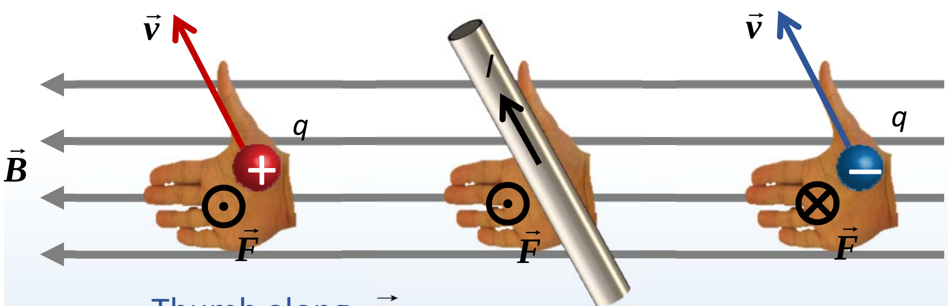
Lects. 10 – 15

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 $\vec{v}$

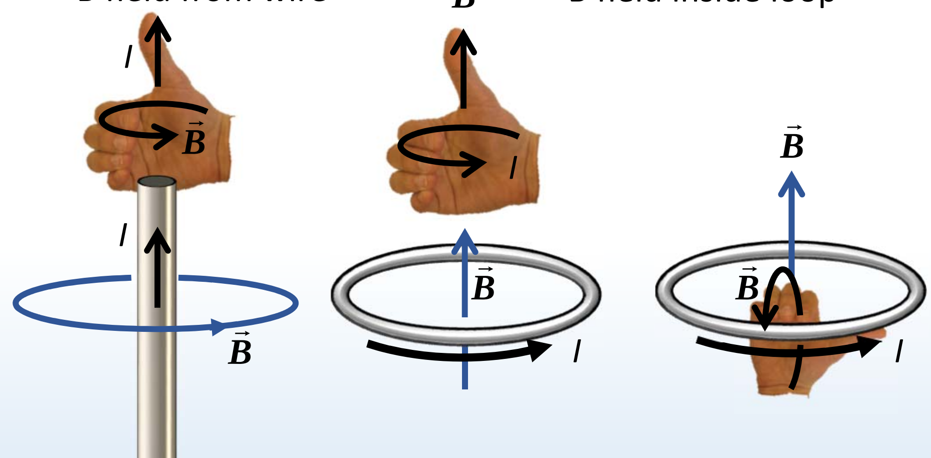
Fingers along $\vec{B}$

$\vec{F}$ on – q is *into palm*

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

B field from wire

B field inside loop



Thumb along *I*

Curl fingers along $\vec{B}$

Curl fingers along *I*

Thumb along $\vec{B}$

OR:

Thumb along *I*

Curl fingers along $\vec{B}$

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

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

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

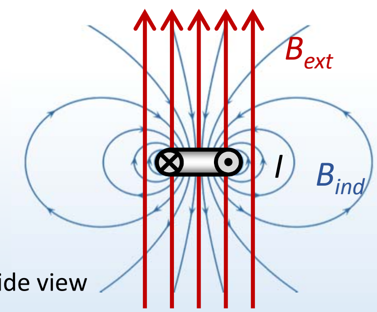
Lenz law

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

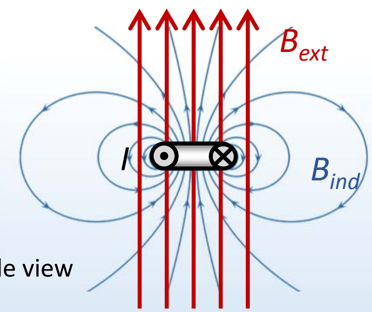
Top view



Side view

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

Top view

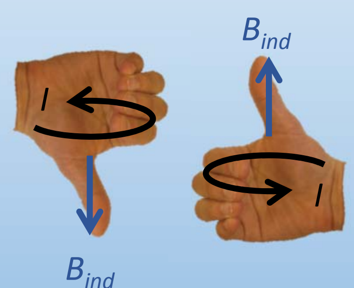


Side view

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}



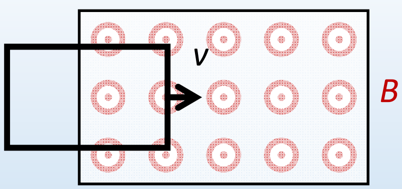
Faraday's law

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

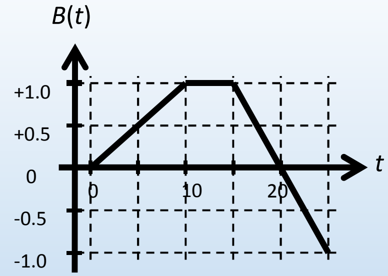
$$\varepsilon = -\frac{\Delta\Phi}{\Delta t}$$ ← Fundamental

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

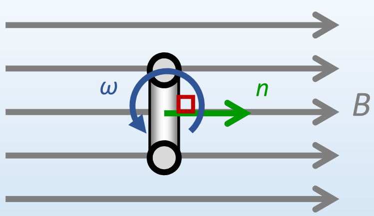
1. Area of loop
2. Magnetic field B
3. Angle φ



$\varepsilon = -BLv$



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



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

Situation dependent

3. Light & optics

Lects. 16 – 23

Light summary

Properties of electromagnetic waves

Relation between E, B, f, λ

Energy density, power & intensity $I = \frac{\langle P \rangle}{A} = c\langle u_{tot} \rangle = c\varepsilon_0 E_{rms}^2$

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

Ray model of light

Reflection $\theta_i = \theta_r$

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

Mirrors $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ $m \equiv \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

Signs!

Lenses (alone, in combination)

The eye (nearsightedness, farsightedness)

Interference

Constructive and destructive interference

Diffraction & resolution

Example: the eye

Extra practice

The next two questions pertain to the following situation.

A nearsighted person has a far point of 40 cm unaided. She wears corrective glasses and the lenses are 2 cm in front of her eyes.

1. What kind of lenses must she wear so that she can see objects very far away (at ∞) clearly?

a. diverging lens
b. converging lens

Corrective lenses

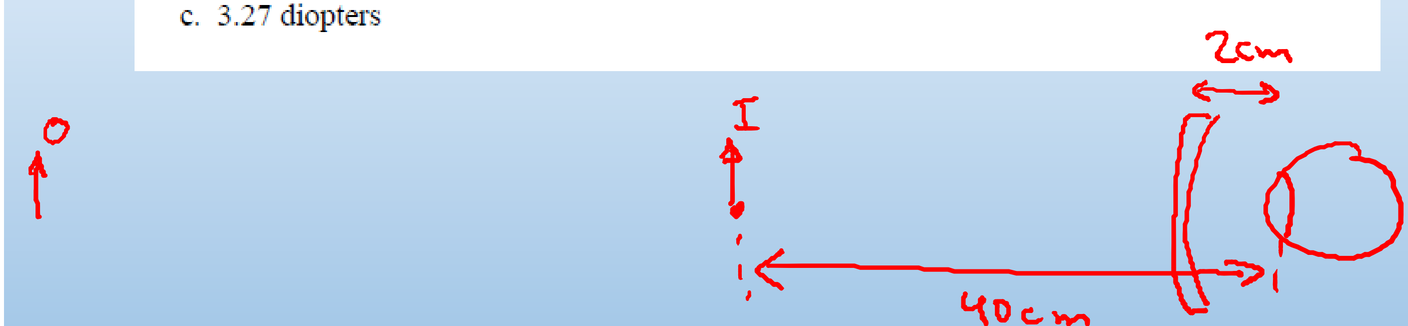
Creates image of object at far (or near) point, where nearsighted (or farsighted) eye can see it

Signs!

2. What must be the magnitude of the refractive power $|P|$ of the corrective glasses in diopters (1 diopter ≡ 1/m)?

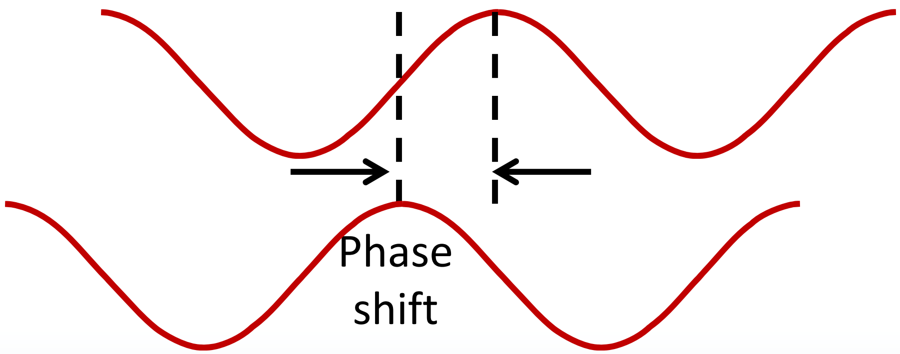
a. 2.63 diopters
b. 1.91 diopters
c. 3.27 diopters

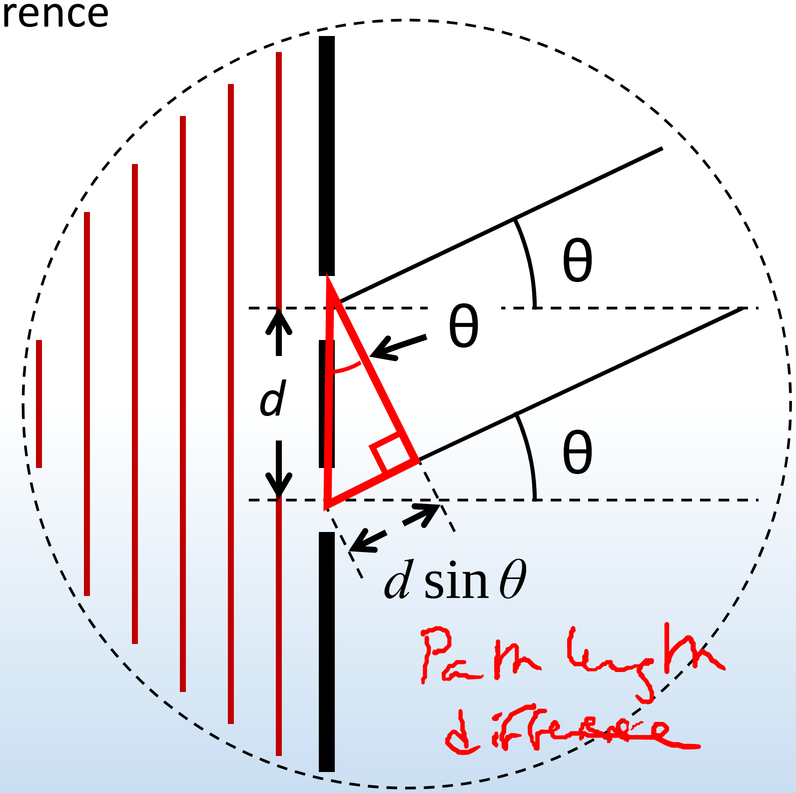
$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} = P$$



Light as a wave (again)

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

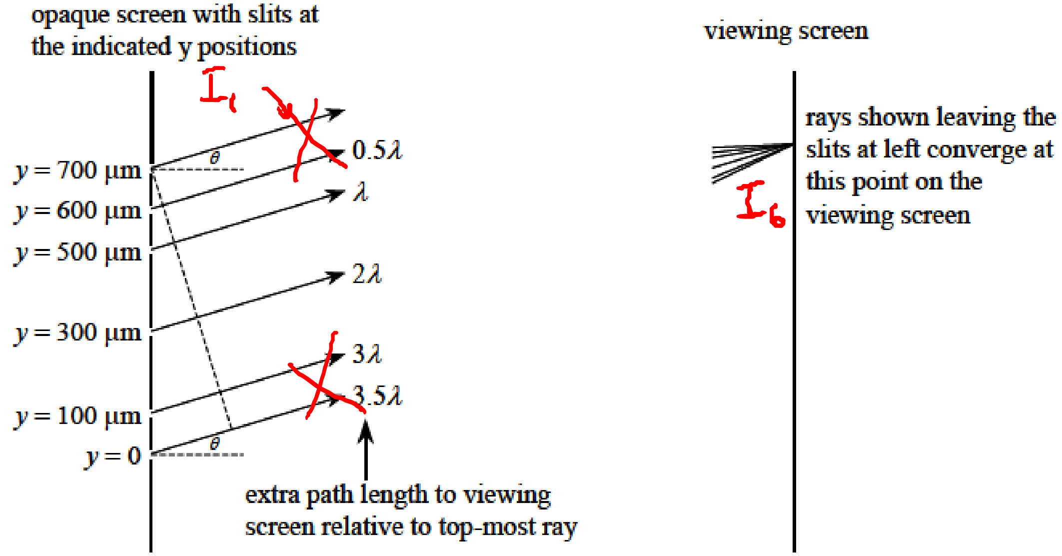
$m = 0, \pm 1, \pm 2 \ldots$

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

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

Example: Interference

Extra practice



6. The ***intensity*** of the light measured at the point of convergence of the rays is I_6. If the intensity of light out of one slit is I_1, what is the ratio of the intensities I_6 / I_1?

a. $I_6 / I_1 = 0$.
b. $I_6 / I_1 = 2$.
c. $I_6 / I_1 = 4$.
d. $I_6 / I_1 = 9$.
e. $I_6 / I_1 = 36$.

Path length difference
= $m\lambda$ (constructive)
= $(m + ½)\lambda$ (destructive)

Intensity of light
Each beam of light contributes E field, $I \propto E^2$ (Lect. 22 ACT!)

4. Modern physics

Lects. 23 – 28

Quantum mechanics

Wave-particle duality

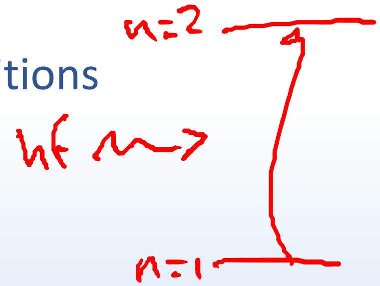
Matter waves – particle as a wave (de Broglie)
Photons – light as a particle (photoelectric effect)

$$\lambda = \frac{h}{p}$$

Bohr model

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

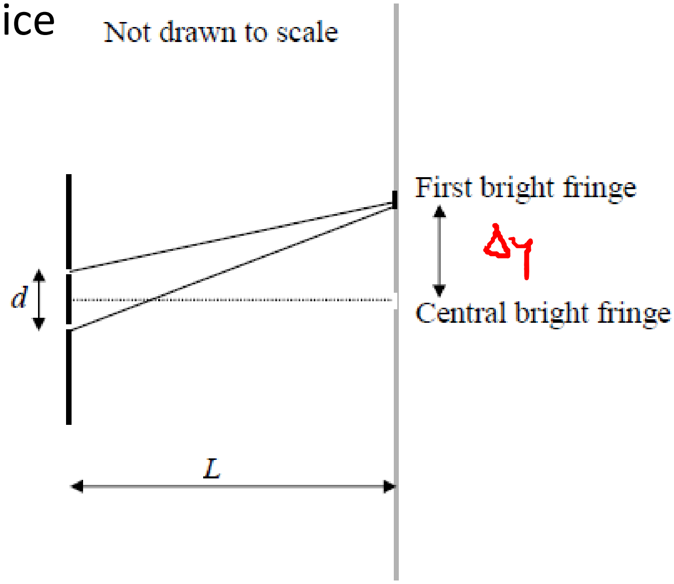
quantum numbers (n, ℓ, m_ℓ, m_s), Pauli exclusion principle, magnetic properties of atoms

Nuclear & particle physics

structure of nucleus & nucleons
decay processes (α, β, γ) & rates, binding energy
quark model

Example: wave-particle duality

Extra practice



Wave-particle duality

$\lambda = h/p$

Young's double slit

$d\sin\theta = m\lambda$ (maxima)

15. An electron beam of energy 2 eV is incident on two slits separated by a distance d = 100 nm. A screen is placed L = 2 m away from the slits. What is the separation between the first interference maximum and the center line? (The mass of the electron is 511 keV/c^2.)

a. 6.5 mm
b. 17.3 mm
c. 36.2 mm

Example: quantum numbers

Extra practice

The next two questions pertain to the following situation:

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 $-3/2$.

21. 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. O with 8 electrons

Quantum numbers

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

Pauli exclusion principle

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

Example: quantum atom

Extra practice

22. Consider a beam of hydrogen atoms in the ground state ($n = 1$) in this universe where the electron has spin 3/2. The atoms are placed in a uniform B field. How many possible energy levels can the atoms be in?

a. 1
b. 2
c. 4
d. 6
e. 8

Quantum numbers

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

$m_s = +3/2, +1/2, -1/2, -3/2$

Orbital & spin magnetic moment

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

$\vec{\mu}_s = -\frac{ge}{2m_e}\vec{S}$

Energy of aligning magnetic moment

$U = -\mu_s B \cos\theta = +\frac{geB}{2m_e} S_z = +\frac{geB}{2m_e} m_s \hbar$