Physics 202, Exam Review 1

- Final Exam Logistics
- Final Exam Review, part 1: Ch 23-30

  Electrostatics, DC Circuits, Magnetostatics

- Homework 12 correction: problem #4

  1 W should be 1 kW

Final Exam

❑ Logistics:

Exam time: Friday Dec 21 at 10:05 am

Rooms: Ingraham 19 and Ingraham B10

19: 304,310,312,323,324,327
B10: 301,302,303,305,307,321,325,326,328,329,330

Bring: calculator,
4 formula sheets (double-sided, self-prepared)

Final Exam

❑ Topics covered:

70 -75% previous material (Ch 23-34, 16, 18)
25-30% new material (Ch 35-38)

❑ Format: multiple-part word problems (probably 7)

❑ Previous material:

Same topics, textbook sections covered as midterms

❑ Today's review: midterms 1 and 2 material
background, electrostatics, DC circuits, magnetostatics

Background Material

❑ Mechanics:

Anything that was asked of you on homework or previous midterms.

Kinematics of uniformly accelerated motion
Uniform circular motion, springs
Newton's Laws: statics and dynamics
Work-kinetic energy theorem, conservation of energy

Math:
vector algebra, scalar (dot) product, vector product
Calculus: differentiation, simple integration (1D only)

Electrostatics Topics

Calculating electric fields and potentials for discrete and continuous charge distributions.

3 methods:

1. Direct calculation of E field: integrate to get V.
2. Gauss's Law: obtain E (special cases), integrate to get V.
3. Calculate electric potential V: take derivatives to get E.

As before: you will not be asked to do nontrivial surface or volume integrals. You need to know how to do 1d integrals.

Example: linear charge distributions.
Example: Gauss's Law
(spherical symmetry, cylindrical symmetry, planar symmetry)

Electrostatics Topics

More Topics (not exhaustive):

Coulomb Forces and Potential Energy

Motion of charged particles in electric fields
(e.g. single particles, electric dipoles)

Electric field lines and equipotentials

Conductors in electrostatic equilibrium
conductors and Gauss's Law (previous examples)

Capacitance, Capacitors with dielectrics

Resistors, Capacitors, DC Circuits

Main topics:

Simplifying resistor or capacitor networks.
Using Kirchhoff's circuit law.

Also:

- **Definition of resistance and capacitance**
- **Ohm's Law**
- **electromotive force**
- **real and ideal batteries**
- **power in circuits.**

Magnetostatics Topics

1. **Calculating magnetic fields for current distributions.**
2. **Response to external magnetic fields**

2 methods for calculating B field:

1. **Biot-Savart: direct method**
2. **Ampere's Law: for special cases of high symmetry**

Recall direction -- right-hand rule(s)!

Example: linear current distributions (finite wire, current loop)
Example: Ampere's Law: solenoid, toroid, infinite wire

Ampere-Maxwell Law and displacement current
Magnetism in materials (only a problem like in the homework, if any)

Magnetostatics 2

Forces on moving charged particles, magnetic dipoles, and current distributions in external magnetic fields.

Lorentz Force Law.

Moving charge in uniform B field: helical motion

Applications:

- **Velocity Selector**
- **Mass Selector**
- **Hall Effect**

About the Final Exam

- Time: **10:05 A.M. FRI. DEC 21**
- Location:
  - INGRAHAM HALL B10
  - INGRAHAM HALL 19

  (If you are late, do not panic, come anyway.)
  McBurney students contact a Professor for special arrangement.
- 4 sheets, 8x11 1/2, handwritten, no Xerox, no direct copies of sample solutions,
- Any calculator is OK,
  - Do not use programming functionality
  - Absolutely no electronic communication
- One word on units: All final and intermediate results should have units. If a calculation is without units it will be OK. But when you achieve an intermediate result that you feel could be useful for partial credit you need to add units.

About the Final Exam

- **There will be some multiple choice questions and quizzes worth 15 to 20% of the points**
- **There will be about 6 or 7 problems plus a set of quizzes and multiple choice questions.**
- **About 1/3 of the problems will be related to new material that was not covered yet in exam 3. That includes the following chapters: 35, 36, 37*, 38*, specifically:**
  - **Chapter 35: all**
  - **Chapter 36: primarily 36.1 to 36.5, combination of lenses possible, but no details on 36.6 to 36.10.**
  - **Chapter 37:**
  - **Chapter 38.1 to 38.3**
- **The homework problems provide a good reference for the final exam.**
- **For the problems concerning the syllabus Chapters 23 - 33 and 16-18 consider the problems from the previous exams and the homework problems as a useful reference.**
- **Conceptual problems will be important, too. The problems will be similar in style to the problems in the Midterm exams 1, 2, 3.**

Faraday's Law

- **"the emf induced in a circuit is directly proportional to the time rate of change of the magnetic flux through the circuit"**

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

$\mathcal{E}$ = induced emf,
= induced potential difference

$$\Phi_B = \int \mathbf{B} \cdot d\mathbf{A}$$

- In practice often: $\Phi_B = BA \cos\theta$
- The induced emf is then: $\varepsilon = -\, d/dt\, (BA \cos\theta)$

Ways of Inducing an emf

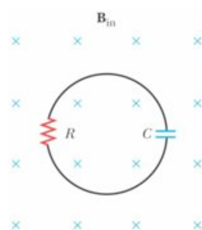
- The magnitude of B can change with time
- The area enclosed by the loop can change with time
- The angle θ between B and the normal to the loop can change with time
- Any combination of the above can occur

Lenz's Law:
- "Oppose change"

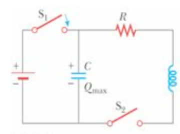
- Faraday's law indicates that the induced emf and the change in flux have opposite algebraic signs
- Lenz's law: ***the induced current in a loop is in the direction that creates a magnetic field that opposes the change in magnetic flux through the area enclosed by the loop***

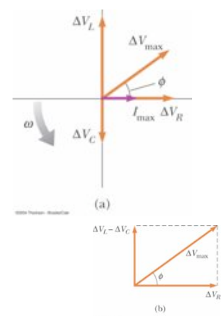
$$\varepsilon = -\frac{d\Phi_B}{dt}$$

- **Problem 3: As shown in the figure, a circular circuit loop of area A containing a resistor R and a capacitor C is placed inside a uniform magnetic field. The plane of the loop is normal to the field. At t=0, the magnetic field starts to increase at a constant rate dB/dt=K.**



The *RLC* Circuit



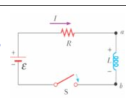


Kirchoff's rule gives:

$$L\frac{dI}{dt} + RI + + \frac{Q}{C} = 0$$

$$L\frac{d^2Q}{dt^2} + R\frac{dQ}{dt} + \frac{Q}{C} = 0$$

RL Circuit, Analysis



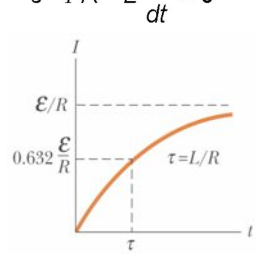
- Applying Kirchhoff's loop rule to the previous circuit gives

$$\varepsilon - IR - L\frac{dI}{dt} = 0$$

- Looking at the current and doing some math (whiteboard), we find

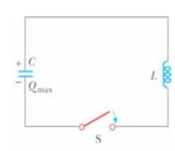
- where $\tau = L / R$

$$I = \frac{\varepsilon}{R}\left(1 - e^{-Rt/L}\right)$$



LC Circuits

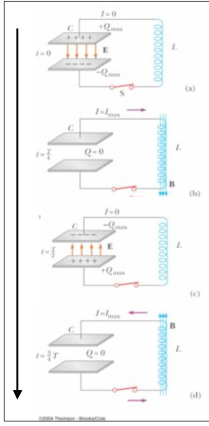
- Assume the capacitor is initially charged and then the switch is closed
- Assume no resistance and no energy losses to radiation
- The current in the circuit and the charge on the capacitor oscillate between maximum positive and negative values
- With zero resistance, no energy is dissipated.



- Kirchoff's loop rule:

$$-\frac{Q}{C} - L\frac{dI}{dt} = 0$$

LC oscillator



- Initially energy stored in the electric field in the capacitor
- Then energy transferred to B-field

$$U = \frac{Q^2}{2C}$$

- And so forth ….

$$U = \frac{1}{2} L \cdot I^2$$

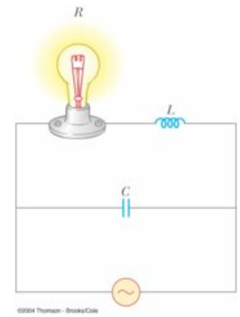
Quick Quiz 33.6

Consider the AC circuit in this figure. The frequency of the AC source is adjusted while its voltage amplitude is held constant. The lightbulb will glow the brightest at

(a) high frequencies

(b) low frequencies

(c) The brightness will be same at all frequencies.

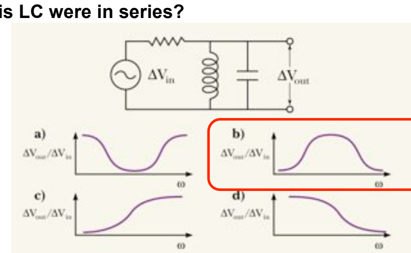


QUICK QUIZ 33.5

(For the end of section 33.9)

For the circuit below, which graph best represents the ratio of output voltage to input voltage as a function of frequency?

What is LC were in series?



Waves

- $v = \lambda / T = f\lambda$
- Basic wave function

$$y(x,t) = A\sin\left[2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right] \qquad k = \frac{2\pi}{\lambda} \qquad \omega = \frac{2\pi}{T}$$

- If $x \neq 0$ at $t = 0$, the wave function can be generalized to
  $y = A \sin (k\,x - \omega t + \phi)$
  where ϕ is called the phase constant. See exam problem.
- The power is the rate at which the energy is being transferred:

$$\wp = \frac{\Delta E}{\Delta t} = \frac{\frac{1}{2}\mu\omega^2 A^2 \lambda}{T} = \frac{1}{2}\mu\omega^2 A^2 v$$

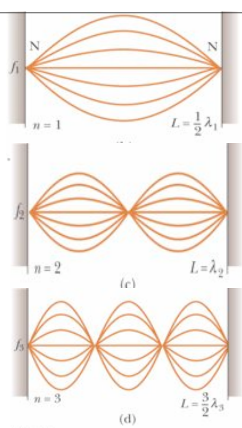
- Wave equation:

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

Standing Waves in a String

- The wavelengths of the normal modes for a string of length L fixed at both ends are
  $\lambda_n = 2L / n \quad n = 1, 2, 3, \ldots$
- The natural frequencies are

- $f_n = nf_1 = n\frac{v}{2L} = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$



Electromagnetic waves

- From Maxwell's one can derive the wave equations:

$$\frac{\partial^2 E}{\partial x^2} = \mu_o \varepsilon_o \frac{\partial^2 E}{\partial t^2} \quad \text{and} \quad \frac{\partial^2 B}{\partial x^2} = \mu_o \varepsilon_o \frac{\partial^2 B}{\partial t^2}$$

- Substituting the values for μ_o and ε_o gives c = 2.99792 x 10^8 m/s

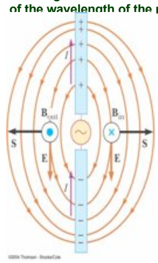
$$v = c = \frac{1}{\sqrt{\mu_o \varepsilon_o}}$$

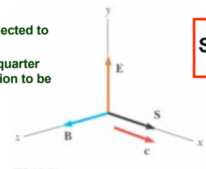
- Solution :
  - $E = E_{max} \cos (kx - \omega t + \Phi)$
  - $B = B_{max} \cos (kx - \omega t + \Phi)$
- With the wavenumber $k = 2\pi/\lambda$, *and* angular frequency is $\omega = 2\pi f$

$$\frac{\omega}{k} = \frac{2\pi f}{2\pi/\lambda} = \lambda f = c \qquad \frac{E_{max}}{B_{max}} = \frac{\omega}{k} = \frac{E}{B} = c$$

Production of em Waves by an Antenna

- This is a *half-wave* antenna
- Two conducting rods are connected to a source of alternating voltage
- The length of each rod is one-quarter of the wavelength of the radiation to be





$$\mathbf{S} \equiv \frac{1}{\mu_o}\mathbf{E}\times\mathbf{B}$$

$$I = S_{av} = \frac{E_{max}B_{max}}{2\mu_o} = \frac{E_{max}^2}{2\mu_o c} = \frac{c\,B_{max}^2}{2\mu_o}$$

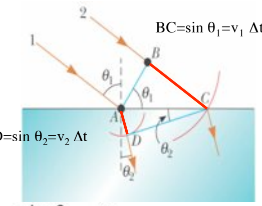
Radiation pressure: P=S/c for Absorbing case. 2 x for reflection. See last exam problem

Light

- Nature of light
  - Wave (and particle)
  - Speed of light

The 2 laws of geometric optics

- Reflection
- Refraction
  - Snell's Law



Related

- Dispersion
- Total internal reflection
- Fermat principle

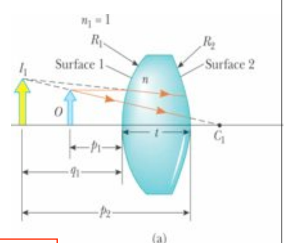
$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$$

$$\text{But } \frac{\sin\theta_1}{\sin\theta_2} = \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1}$$

$$\text{and so } n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Lens Makers' Equation

- The focal length of a thin lens is the image distance that corresponds to an infinite object distance
  - This is the same as for a mirror
- The lens makers' equation is



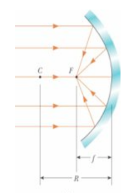
$$\frac{1}{p} + \frac{1}{q} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f}$$

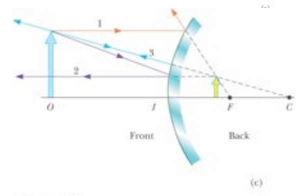
Mirrors

- Mirrors
- Images
- Ray diagrams
  - Keep track of signs
  - Real or virtual (ray going through)?
  - Before or behind

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

- example



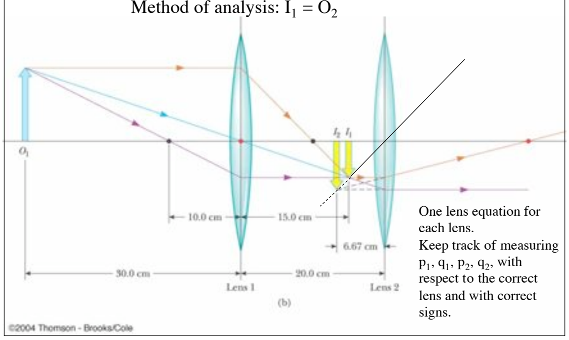


Similarities

- Mirror equation
- Lens equation

Combination of Thin Lenses

Method of analysis: $I_1 = O_2$



One lens equation for each lens.
Keep track of measuring p_1, q_1, p_2, q_2, with respect to the correct lens and with correct signs.

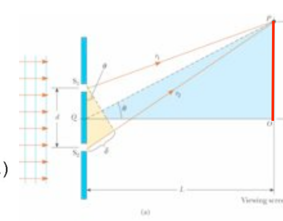
Interference Equations

- **For bright fringes**

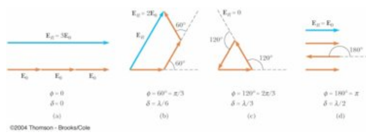
$$y_{bright} = \frac{\lambda L}{d} m \quad (m = 0, \pm1, \pm2 \ldots)$$

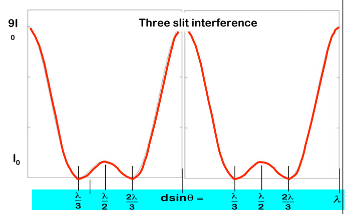
- **For dark fringes**

$$y_{dark} = \frac{\lambda L}{d}\left(m + \frac{1}{2}\right) \quad (m = 0, \pm1, \pm2 \ldots)$$



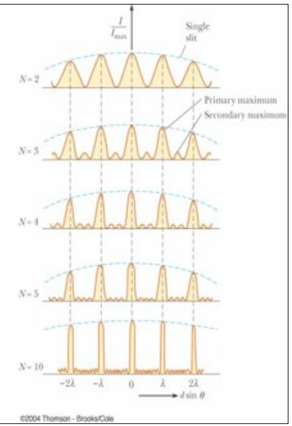
Three Slits, Phasor Diagrams





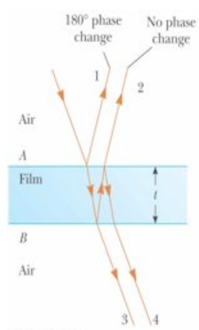
Multiple-Slits, Intensity Graphs

- The primary maxima are nine times more intense than the secondary maxima
  - The intensity varies as E_R^2
- For *N* slits, the primary maxima is N^2 times greater than that due to a single slit



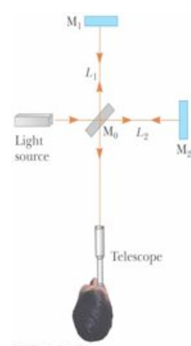
Interference in Thin Films

- Ray 1: phase change of 180°
- Ray 2: no phase change
- Ray 2 also travels an additional distance of 2*t* before the waves recombine
- For constructive interference
  - $2nt = (m + 1/2)\lambda$ (m = 0, 1, 2 …)
- For destructive interference
  - $2nt = m\lambda$ (m = 0, 1, 2 …)



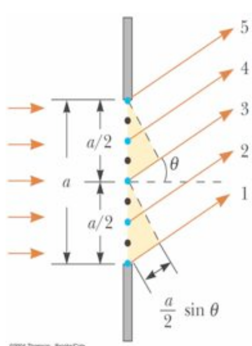
Michelson Interferometer, Schematic

- A ray of light is split into two rays by the mirror M_o
  - The mirror is at 45° to the incident beam
  - The mirror is called a *beam splitter*
- It transmits half the light and reflects the rest

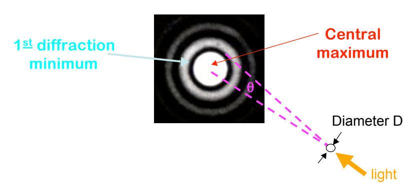


Single-Slit Diffraction

- According to Huygens's principle, each portion of the slit acts as a source of light waves
- Therefore, light from one portion of the slit can interfere with light from another portion
- Wave 1 travels farther than wave 3 by an amount equal to the path difference
  - (a/2) sin θ
- If this path difference is exactly half of a wavelength, the two waves cancel each other and destructive interference results
- In general, *destructive interference* occurs for a single slit of width *a* when
- $\sin\theta_{dark} = m\lambda / a$
  - $m = \pm 1, \pm 2, \pm 3, \ldots$



Diffraction from Circular Aperture



Maxima and minima will be a series of bright and dark rings on screen

First diffraction minimum is at $\sin\theta = 1.22\frac{\lambda}{D}$