Phys 112
Final Review

May 6, 2022

Logistics

Logistics

- Final: Wednesday, May 11, 12:00–3:00 p.m., Hugel 103

- Moodle Forum: I will monitor the Moodle Discussion and will try to provide prompt answers.

- For private questions, please do continue to use email.

- Topics: The final exam will be cumulative, incorporating topics covered throughout the semester.

- Time: The final will be designed to be completed in a 2-hour time period, but you may take the full 3-hour period if you wish.

- Equation sheet: You will be provided with a copy of the same equation sheet available on Moodle.

Content and Style

- Style: The final exam will be very similar to individual hour exams in style and format. Effectively, imagine two hour tests stapled together.

- It will contain a mix of problems of varying degrees of difficulty. Some problems might include qualitative as well as quantitative questions. Some problems may focus on a single topic or chapter, while others may include topics from several different chapters.

- Consult the posted notes on Moodle for the specific list of topics.

Waves

Mathematical Description of Waves

- $y(x, t) = A \cos \left(\dfrac{2\pi}{\lambda} x - \dfrac{2\pi}{T} t \right)$

- $v = \lambda f$

- $\omega = 2\pi f = \dfrac{2\pi}{T}$

- "y" can represent height of string, excess air pressure in a sound wave, electric or magnetic field, or whatever else is "waving."

- "v" is set by the physics of what's vibrating or oscillating.

- "f" (or equivalently λ) is set by how you excite it.

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Energy and Power

- For waves that spread out over an area A: $I = \dfrac{P}{A}$

- Surface area of a sphere: $A = 4\pi R^2$.

Electromagnetic Waves

- General features
- $\vec{E} \perp \vec{B}$
- $E = cB$
- $c = \dfrac{1}{\sqrt{\epsilon_0 \mu_0}}$
- Direction: $\vec{E} \times \vec{B}$
- Intensity: $I = \dfrac{1}{2} c \epsilon_0 E^2 = \dfrac{1}{2} c \epsilon_0 (cB)^2 = \dfrac{1}{2} c \epsilon_0 \cdot \dfrac{1}{\mu_0 \epsilon_0} B^2$

$$= \dfrac{1}{2\mu_0} c B^2$$

Matter Waves

- $\lambda = \dfrac{h}{p}$

- $E = \dfrac{p^2}{2m}$

$$p = mv$$

Combining Waves

- Standing waves: Boundary conditions set λ, and hence f.

- Draw pictures!

- Beats: $f_{beat} = |f_1 - f_2|$

    - Often a useful probe of slightly different f values.

Combining Waves – Interference

- Look at path length difference Δr compared to λ.

- Constructive: $\Delta r = m\lambda$

- Destructive: $\Delta r = \left(m + \dfrac{1}{2} \right) \lambda$

- Draw pictures to help calculate Δr!

Interference and Diffraction

- Look at path length difference Δr compared to λ.

- Single slit: $a \sin \theta = n\lambda$ *(Minima)*

- Multiple slits: $d \sin \theta = m\lambda$ *(Maxima)*

- $\sin \theta \approx \dfrac{y}{L} a$ (small angles). Draw a picture!

- Thin films: Consider *optical* path length nt as well as reflections; How do the two paths differ?

- Same ideas apply to any wave in similar geometries.
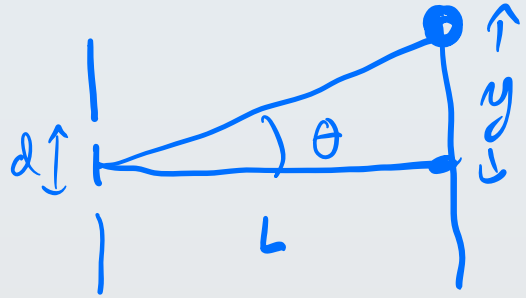
Geometric Optics

- Snell's Law $n_1 \sin \theta_1 = n_2 \sin \theta_2$ *No complex geometry*

- $\dfrac{1}{f} = \dfrac{1}{s} + \dfrac{1}{s'}$

- $m = \dfrac{h_i}{h_o} = -\dfrac{s'}{s}$

- Single lens systems only

- Draw clear sketches with clear labels.

Electric and Magnetic Forces and Fields

Sources of Electric Fields

- Calculate $\vec{E}$ for simple configurations.

  - Discrete point charges

  - Adding vectors

  - charged parallel plates

  - $E_x = -\frac{\Delta V}{\Delta x}$

- $\vec{F} = q_0 \vec{E}$

- Use $\vec{F} = m\vec{a}$ to determine motion.

- Be able to draw pictures

Electric Potential and Electric Potential Energy

- Calculate V for simple configurations.
  - Discrete point charges
  - charged parallel plates
  - Relations between $\vec{E}$ and V ($\vec{E}$ points from high V to low V.)
- $U = q_0 V$.
- Use conservation of energy
- Simple circuits: Batteries and Resistors
  - sketch and label currents and voltages
  - Use clear, consistent labels.

$$P = I \, \Delta V$$
$$\Delta V = I R$$
all same element

Magnetic Fields

- Calculate $\vec{B}$ for simple configurations.

    - Wires, loops, and solenoids

    - Right Hand Rule

    - Adding vectors

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

- $\vec{F} = I\vec{L} \times \vec{B}$

- Use $\vec{F} = m\vec{a}$ to determine motion.

- Be able to draw pictures

- Distinguish between currents that act as *sources* of B and currents that *respond* to an *external B*.

Coupling of Electric and Magnetic Fields

- Faraday's Law
    - Lenz's law: Be able to explain the direction of the induced current.
    - Be able to calculate the induced emf
- Electromagnetic Waves

Modern Physics

Photons

- Change in energy level ΔE can be accompanied by a photon with energy
  $$\Delta E = hf = \frac{hc}{\lambda}$$
- $hc = 1240\,\text{eV}\,\text{nm}$ *Units !*
- Intensity: $I = \dfrac{P}{A}$

Matter Waves

- $\lambda = \dfrac{h}{p}$

- $E = \dfrac{1}{2}mv^2 = \dfrac{p^2}{2m}$

- Particle in a box $\Longleftrightarrow$ vibrating string

- Discrete energy states $\Longrightarrow$ only certain energy photons emitted or absorbed.

Atomic Physics

- $r_n = n^2 a_0$

- $E_n = -\dfrac{13.6 \, \text{eV}}{n^2}$

- Change in energy level ΔE can be accompanied by a photon with energy
  $\Delta E = hf = \dfrac{hc}{\lambda}$

- Collisional excitations—conservation of energy

Nuclear Physics

- α decay: $^A_Z X \rightarrow ^{A-4}_{Z-2} Y + ^4_2 He$

- β decay: $^A_Z X \rightarrow ^A_{Z+1} Y + e^- + \bar{\nu}_e$

- Reverse β decay: $^A_Z X + e^- \rightarrow ^A_{Z-1} Y + \nu_e$

- γ decay: $^A_Z X^\star \rightarrow ^A_Z X + \gamma$

- $\Delta E = (\Delta m) c^2$

- $(1\,u) c^2 = 931.5\,\text{MeV}$

Nuclear Physics

- $N = N_0 \left(\dfrac{1}{2}\right)^{\frac{t}{t_{1/2}}}$

- $N = N_0 e^{-\frac{t}{\tau}}$

Problem Strategies

- Know what the letters mean on the equation sheet.

- Read the whole problem carefully.

- Make a big sketch with clear labels.

- Try expressing in words what is happening—what is the story?

- Read equations as sentences, not just jumbles of symbols.

- Be able to explain a logical chain of reasoning.

- Pay attention to units. They can sometimes be a clue about how to approach a problem. (*e.g.* note that Intensity has units of W/m^2, while power has units of W.)

- Reread any written explanations to make sure they say what you meant to say.
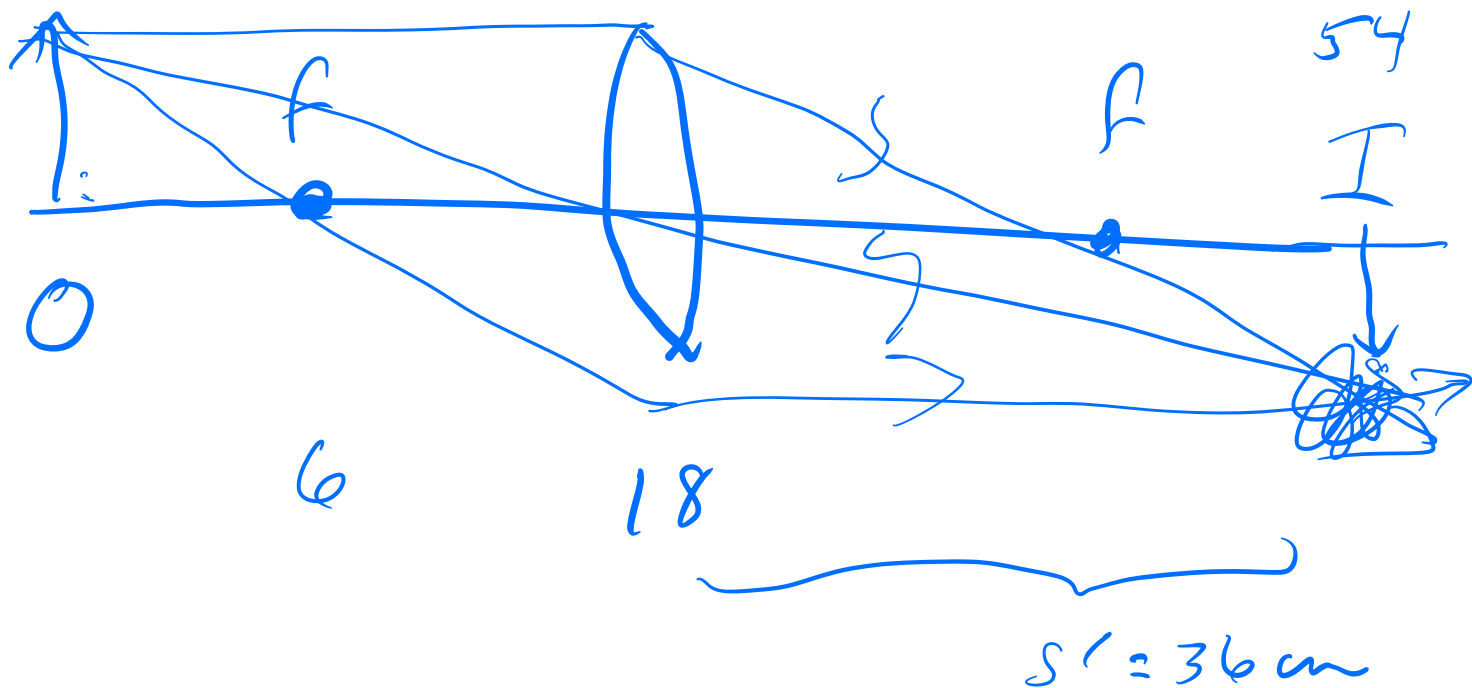
$$S = 18 \text{ cm}$$

$$f = 12 \text{ cm}$$

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{12} - \frac{1}{18} = \frac{1}{36}$$

$$s' = 36 \text{ cm}$$

at 36 cm past lens = 54 cm on bench