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

- $y(x, t) = A \cos\left(\frac{2\pi}{\lambda}x - \frac{2\pi}{T}t\right)$
- $v = \lambda f$
- $\omega = 2\pi f = \frac{2\pi}{T}$
- "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.

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: $I = \dfrac{1}{2} c \epsilon_0 E^2$

Matter Waves

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

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: $\Delta r = \left(m + \frac{1}{2}\right)\lambda$
- 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)*
- $\sin\theta \approx \frac{y}{L}a$ (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 $n_1 \sin\theta_1 = n_2 \sin\theta_2$
- $\dfrac{1}{f} = \dfrac{1}{s} + \dfrac{1}{s'}$
- $m = \dfrac{h_i}{h_o} = -\dfrac{s'}{s}$
- 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.

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 $\Delta E = hf = \frac{hc}{\lambda}$
- $hc = 1240\,\text{eV nm}$
- Intensity: $I = \frac{P}{A}$

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 $\implies$ only certain energy photons emitted or absorbed.

Atomic Physics

- $r_n = n^2 a_0$
- $E_n = -\frac{13.6\,\text{eV}}{n^2}$
- Change in energy level ΔE can be accompanied by a photon with energy $\Delta E = hf = \frac{hc}{\lambda}$
- Collisional excitations—conservation of energy

Nuclear Physics

- α decay: ${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A-4}_{Z-2}\mathrm{Y} + {}^{4}_{2}\mathrm{He}$
- β decay: ${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z+1}\mathrm{Y} + \mathrm{e}^{-} + \bar{\nu}_e$
- Reverse β decay: ${}^{A}_{Z}\mathrm{X} + \mathrm{e}^{-} \rightarrow {}^{A}_{Z-1}\mathrm{Y} + \nu_e$
- γ decay: ${}^{A}_{Z}\mathrm{X}^{\star} \rightarrow {}^{A}_{Z}\mathrm{X} + \gamma$
- $\Delta E = (\Delta m)c^2$
- $(1\,\mathrm{u})c^2 = 931.5\,\mathrm{MeV}$

Nuclear Physics

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

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.