Physics 202, Exam Review II

Today’s Topics

- Final Exam Logistics
- Review (II) – Chapters 29-33 (+15,16): Maxwell’s Equations, Electromagnetic Waves, Optics

Final Exam Logistics

- Exam Time: Monday, May 10, 5:05 pm – 7:05 pm
- Rooms: 165 Bascom: Sections 304, 305, 307, 310, 321, 322, 324, 325, 326, 330 (Capecchi, Garcia, Kruse, Lim, Pettus)
  1310 Sterling: Sections 301, 302, 303, 308, 309, 323, 327, 329 (Poudel, Rudinger, Santander, Stuart)
- Bring: calculator, ruler, self-prepared formula sheets (3 single-sided sheets from previous midterms + 1 new single-sided sheet for new material
  Please know your student id # and your section #

Time-dependent circuits and fields

- Faraday’s law
- Lenz’ law (sign in Faraday’s law)
- Mutual inductance
- AC circuits
  - RL, RC, LC, RLC circuits
  - Impedance
- Driven AC circuits and resonance
  - Power dissipation in AC circuits
- Maxwell’s displacement current
- Maxwell’s equations

Electrodynamics

- Faraday’s law
- Lenz’ law (sign in Faraday’s law)
- Maxwell displacement current
- Maxwell’s equations
- Wave solutions to Maxwell’s equations
- Wave propagation, reflection, standing waves
- Speed of light from Maxwell’s equations
- Laws of light reflection and refraction from Huygen’s principle
Maxwell’s Equations

- **Gauss’ Law** \( \int_S E_n \, dA = \frac{1}{\varepsilon_0} Q_{\text{inside}} \)
- **Magnetic Gauss’ Law** \( \int_S B_n \, dA = 0 \)
- **Faraday’s Law** \( \oint_S E \, d\vec{l} = -\frac{d}{dt} \int_S B_n \, dA \)
- **Ampere-Maxwell Law** \( \oint_S B \, d\vec{l} = \mu_0 (I + I_d) \), with \( I_d = \frac{\varepsilon_0}{d} \int_S E_n \, dA \)

Wave equations

- **Speed of light from Maxwell’s equations**
- **Relationship between electric and magnetic fields in electromagnetic wave**
- **Energy in electromagnetic wave**
- **Momentum in electromagnetic wave**
- **Reflection, refraction, polarization**

Review of Optics Material

- Lenses and Mirrors
- Master Equation and Sign Conventions
- Image Formation
- Combination of Lenses
- Interference and Diffraction
- Double-Slit Experiment
- Thin Film Interference
- Single-Slit Diffraction
- Rayleigh Criterion

Image Formation Equation and Magnification

- **Parameters**
  - \( p \): object distance
  - \( q \): image distance
  - \( h \): object height
  - \( h' \): image height
  - \( M \): magnification
  - \( f \): focal length

- **Equations**
  - \( \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \)
  - \( q = \frac{fp}{p-f} \)
  - \( M = \frac{h'}{h} = -\frac{q}{p} = \frac{f}{f-p} \)

- **Sign Conventions**
  - If \(|M| < 1\) \( \Rightarrow \) Image < Object
  - If \(|M| > 1\) \( \Rightarrow \) Image > Object
  - If \(M < 0\) \( \Rightarrow \) Image \(\downarrow\downarrow\) Object
  - If \(M > 0\) \( \Rightarrow \) Image \(\uparrow\uparrow\) Object
Sign Conventions

<table>
<thead>
<tr>
<th></th>
<th>&gt;0</th>
<th>&lt;0</th>
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</thead>
<tbody>
<tr>
<td>f</td>
<td>concave mirrors</td>
<td>convex mirrors</td>
</tr>
<tr>
<td></td>
<td>converging lens</td>
<td>diverging lens</td>
</tr>
<tr>
<td>M=-i/o</td>
<td>inverted</td>
<td>upright</td>
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Image Formation by Concave Mirrors

Ray Diagrams with Lenses

- If image can be formed, only two rays are necessary to determine an image point.
- Useful rays:
  - Object ray pointing to the center (C)
    - image ray inline with the object ray
  - Object ray parallel to principal axis
    - image ray “pointing to” a focal point (F)
  - Object ray passing through a focal point
    - image ray parallel to principal axis.

Combination of Lenses

- Optical instruments typically use lenses in combination. When light passes through more than one lens, we find the image formed by the first lens becomes the object to the second lens, etc...

**Refraction and Total Internal Reflection**

- **Law of refraction:**
  \[ \frac{\sin \theta_2}{\sin \theta_1} = \frac{v_2}{v_1} = \frac{\lambda_2}{\lambda_1} \]
  
  if \( v_1 = c \) (in vacuum)

  **Note:** \( \theta_1 > \theta_2 \) if \( v_1 > v_2 \)

- **When light enters medium of lower index of refraction (\( n_1 > n_2 \)) at incident angle \( \theta \) larger than the critical angle \( \theta_c \) (\( \sin \theta_c = n_2/n_1 \)), no refraction will occur.

  \( \theta > \theta_c \) → Total internal reflection

**Interference of Light Waves**

- When two light waves meet at certain location, the resulting effect is determined by the superposition (i.e. sum) of the two individual waves.
  - e.g. Two light waves with same color and amplitude.
    \[ E_1 = E_0 \sin(\omega t - kx + \phi_{10}) = E_0 \sin(\omega t + \phi_1) \]
    \[ E_2 = E_0 \sin(\omega t - kx + \phi_{20}) = E_0 \sin(\omega t + \phi_2) \]

  \( E = E_1 + E_2 = 2E_0 \cos(\Delta \phi/2) \sin(\omega t + \phi/2) \)

  → Resulting amplitude: \( E_{\text{max}} = 2E_0 \cos(\Delta \phi/2) \)
    - Constructive interference: \( \Delta \phi = 0, \pm 2\pi, \pm 4\pi, \ldots \)
    - Destructive interference: \( \Delta \phi = \pm \pi, \pm 3\pi, \pm 5\pi, \ldots \)

  Q: If each incoming light beam has intensity \( I \), what is the resulting intensity when (1): constructive, (2): destructive?

**Two-Slit Diffraction**

- **Constructive:** \( \Delta \phi = 0\pi, 2\pi, 4\pi, \ldots \), or \( 2m\pi \), \( m=0,1,2\ldots \)

  \[ \frac{2\pi d}{\lambda} \sin \theta = 2m\pi \]

  Bright spots

- **Destructive:** \( \Delta \phi = \pi, 3\pi, 5\pi, \ldots \), or \( (2m+1)\pi \), \( m=0,1,2\ldots \)

  \[ \frac{2\pi d}{\lambda} \sin \theta = 2(m+1)\pi \]

  Dark spots
Possible Phase Change of 180° For Reflected Light

- When a light traveling in medium 1 of $n_1$ is reaches at a boundary with medium 2 of $n_2$:
  - The reflected light has a 180° phase shift if $n_1 < n_2$
  - There is no phase change for reflected light if $n_1 > n_2$
  - In any change, no phase shift for refracted light

Thin Film Interference

- Thin film splits light → split lights then interfere

Quiz: Constructive/destructive conditions?

Thin Film Interference

- Thin film splits light → split lights then interfere

Quiz: Constructive/destructive conditions?

Resolution of Single-slit and Circular Apparatus

- Two separate beams each smeared due to diffraction

Rayleigh’s Criterion

$\Delta \phi_{34} \sim 2\pi/\lambda_n (2t)$

$\Delta \phi_{12} \sim 2\pi/\lambda_n (2t) + \pi$

Single-slit diffraction

$y_2 = \frac{2\lambda}{D} \sin \theta_{dark}$

$y_1 = \frac{\lambda}{D} \sin \theta_{dark}$

$0 = \frac{\lambda}{D} \sin \theta_{dark}$

$-y_1 = -\frac{\lambda}{D} \sin \theta_{dark}$

$-y_2 = -\frac{2\lambda}{D} \sin \theta_{dark}$

Separation between minima $= \frac{\lambda}{D}$

$I = I_0 \left( \frac{\sin(\beta/2)}{\beta/2} \right)^2$

$\beta = \frac{2\pi}{\lambda} D \sin \theta$
An ac voltage is applied across a capacitor. Which figure best represents the magnetic field between the capacitor plates?

Which of the following statements contradicts one of Maxwell's equations?

A. A changing magnetic field produces an electric field.
B. The net magnetic flux through a closed surface depends on the current inside.
C. A changing electric field produces a magnetic field.
D. The net electric flux through a closed surface depends on the charge inside.
E. None of these statements contradict any of Maxwell's equations.
A ray of light passes from air into water, striking the surface of the water with an angle of incidence of 45º. Which of the following four quantities change as the light enters the water: (1) wavelength, (2) frequency, (3) speed of propagation, and (4) direction of propagation?

A. 1 and 2 only
B. 2, 3, and 4 only
C. 1, 3, and 4 only
D. 3 and 4 only
E. 1, 2, 3, and 4
Monochromatic light is incident on the prism at the proper angle for minimum deviation. The emergent ray passes through which point?

Two polarizers have their transmission axes at an angle $\theta$. Unpolarized light of intensity $I$ is incident on the first polarizer. What is the intensity of the light transmitted by the second polarizer?

A. $I \cos^2 \theta$
B. $0.5I \cos^2 \theta$
C. $0.25I \cos^2 \theta$
D. $I \cos \theta$
E. $0.25I \cos \theta$
Final Words of Advice

- Read all the questions – some are much harder than others, and they are not in order of difficulty.

- Recall that EM forces are typically not constant – they usually depend on position. Only in rare situations (inside parallel plate capacitor or long solenoid) are E and B uniform.
  - Moral – Beware of using forces rather than energy conservation to solve problems – the kinematics of uniformly accelerated motion rarely applies

- Remember: units, vector magnitude and direction

GOOD LUCK AND HAVE A GOOD SUMMER!!