Physics 208 Exam 1 Review

**Exam 1**
Mon. Sep. 29, 5:30-7 pm, 2103 Ch (here)
Covers 21.5-7, 22, 23.1-4, 23.7, 24.1-5, 26-27
+ lecture, lab, discussion, HW
- Chap 21.5-7, 22: Waves, interference, and diffraction
- Chap 23: Reflection, refraction, and image formation
- Chap 24: Optical instruments
- Chap 26: Electric charges and forces
- Chap 27: Electric fields

**Properties of waves**
- Wavelength, frequency, propagation speed related as $\lambda f = v$
- Phase relation
  - In-phase: crests line up
  - $180^\circ$ Out-of-phase: crests line up with trough
- Time-delay leads to phase difference
- Path-length difference leads to phase difference

**Alternate Exam Time**
For students with scheduled class conflicts
- Tuesday Sep. 30, 5:45 pm - 7:15 pm
- Monday Sep. 29, 6:00 pm - 7:30 pm
- You must request one of these exam times by following the instructions at learn@uw. Check back to see if your request is approved.

**Ch 22, 21.5-7: Waves & interference**
- Path length difference and phase
  - different path length $\Rightarrow$ phase difference.
- Two slit interference
  - Alternating max and min due to path-length difference
- Phase change on reflection
  - $\pi$ phase change when reflecting from medium with higher index of refraction
- Interference in thin films
  - Different path lengths + reflection phase change

**Phase difference & interference**
- Path length difference $d$
- Phase difference $= d(2\pi / \lambda)$ radians
- Constructive for $2n\pi$ phase difference

![Diagram of interference pattern with light beam, foil, and recording plate]
You are listening to your favorite radio station, WOLX 94.9 FM (94.9x10^6 Hz) while jogging away from a reflecting wall, when the signal fades out. About how far must you jog to have the signal full strength again? (assume no phase change when the signal reflects from the wall)

Hint: wavelength = 3x10^{-8} m/s / 94.9x10^6 Hz

Destructive \Rightarrow 2x = \frac{\lambda}{2} \\
\Rightarrow x = \frac{\lambda}{4}

Constructive \Rightarrow make 2x = \frac{\lambda}{2} \\
\Rightarrow x = \frac{\lambda}{2}

x increases by \frac{\lambda}{4} = 3.16m/4 = 0.79m

\[ \lambda = 3.16 \text{ m} \]

A. 3 m  
B. 1.6 m  
C. 0.8 m  
D. 0.5 m

**Reflection phase shift**

- Possible additional phase shift on reflection.
- Start in medium with \( n_1 \), reflect from medium with \( n_2 \)
  - \( n_2 > n_1 \), 1/2 wavelength phase shift
  - \( n_2 < n_1 \), no phase shift
- Difference in phase shift between different paths is important.

**Thin film interference example**

- Coated glass in air, coating thickness = 275nm
- Incident white light 400-700nm
- Glass infinitely thick
- What color reflected light do you see?
- Both paths have 180° phase shifts
- So only path length difference is important

\[ 2t = m\lambda_{\text{air}} / n_{\text{film}} \]

\[ m = 1 \Rightarrow \lambda = 660nm \]
Thin Film Interference II

- Same coated glass underwater
- Now only one path has 180° phase shift

\[ 2t = (m + 1/2) \lambda / n_{\text{film}} \]
\[ \lambda_{\text{air}} = 2m_{\text{film}} \lambda / (m + 1/2) \]
\[ = 2(275\text{nm})(1.2)/(m + 1/2) \]

\( m=0 \) gives 1320 nm, too long.
\( m=1 \) gives 440 nm

Color changes underwater!

Diffraction from a slit

- Each point inside slit acts as a source
- Net result is series of minima and maxima
- Similar to two-slit interference.

Overlapping diffraction patterns

- Two independent point sources will produce two diffraction patterns.
- If diffraction patterns overlap too much, resolution is lost.
- Image to right shows two sources clearly resolved.

Circular aperture diffraction limited:

\[ \theta_{\text{min}} = 1.22 \frac{\lambda}{D} \]

Diffraction gratings

- Diffraction grating is pattern of multiple slits.
- Very narrow, very closely spaced.
- Same physics as two-slit interference.

\[ d \sin \theta_{\text{right}} = m \lambda, \ m = 0,1,2\ldots \]
\[ \sin \theta_{\text{right}} = m \frac{\lambda}{d} \]

Chap. 23-24: Refraction & Ray optics

- Refraction
- Ray tracing
  - Can locate image by following specific rays
- Types of images
  - Real image: project onto screen
  - Virtual image: image with another lens
- Lens equation
  - Relates image distance, object distance, focal length
- Magnification
  - Ratio of images size to object size

Refraction

- Occurs when light moves into medium with different index of refraction.
- Light direction bends according to \( n_1 \sin \theta_1 = n_2 \sin \theta_2 \)

Special case: Total internal reflection

Angle of incidence increasing
Transmission getting weaker

Critical angle when \( \theta_c = 90° \)
Reflection getting stronger

Angle of refraction
**Total internal reflection**

Total internal reflection occurs

A) at angles of incidence greater than that for which the angle of refraction = 90˚
B) at angles of incidence less than that for which the angle of refraction = 90˚
C) at angles of incidence equal to 90˚
D) when the refractive indices of the two media are matched
D) none of the above

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**Lenses: focusing by refraction**

1) Rays parallel to principal axis pass through focal point.
2) Rays through center of lens are not refracted.
3) Rays through F emerge parallel to principal axis.

Here image is real, inverted, enlarged

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**Different object positions**

Object

Image (real, inverted)

These rays seem to originate from tip of a ‘virtual’ arrow.

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**Equations**

Relation between image distance object distance focal length

\[
\frac{1}{s'} + \frac{1}{s} = \frac{1}{f}
\]

Magnification = \( M = \frac{s'}{s} = \frac{\text{image height}}{\text{object height}} = \frac{s'}{s} \)

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**Question**

You want an image on a screen to be ten times larger than your object, and the screen is 2 m away. About what focal length lens do you need?

A. \( f \approx 0.1 \text{m} \)
B. \( f \approx 0.2 \text{m} \)
C. \( f \approx 0.5 \text{m} \)
D. \( f \approx 1.0 \text{m} \)

\[
\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}
\]

\( s' = 2 \text{ m} \)

\( \text{mag} = 10 \rightarrow s' = 10s \rightarrow s = 0.2 \text{m} \)

\( \frac{1}{0.2 \text{m}} \times \frac{1}{2 \text{m}} = 5.5 \times \frac{1}{f} \Rightarrow f = 0.18 \text{m} \)

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**Chapter 26: Electric Charges & Forces**

- Triboelectric effect: transfer charge
  - Total charge is conserved
- Vector forces between charges
  - Add by superposition
  - Drops off with distance as \( 1/r^2 \)
- Insulators and conductors
- Polarization of insulators, conductors
**Charges conductors & insulators**

- Two types of charges, + and -
  - Like charges repel
  - Unlike charges attract
- Conductor:
  - Charge free to move
  - Distributed over surface of conductor
- Insulator
  - Charges stuck in place where they are put

**Electric force: magnitude & direction**

- Electrical force between two stationary charged particles
  \[ F = \frac{k_e q_1 q_2}{r^2} \]
- The SI unit of charge is the coulomb (C), \( \mu C = 10^{-6} \) C
- 1 C corresponds to \( 6.24 \times 10^{18} \) electrons or protons
- \( k_e = \text{Coulomb constant} = 9 \times 10^9 \text{ N m}^2/\text{C}^2 = 1/(4\pi\varepsilon_o) \)
- \( \varepsilon_o = \text{permittivity of free space} = 8.854 \times 10^{-12} \text{ C}^2/\text{N m}^2 \)
- Directed along line joining particles.

**Forces add by superposition**

Equal but opposite charges are placed near a negative charge as shown. What direction is the net force on the negative charge?

- A) Left
- B) Right
- C) Up
- D) Down
- E) Zero

**Chapter 27: The Electric Field**

- Defined as force per unit charge (N/C)
- Calculated as superposition of contributions from different charges
- Examples
  - Single charge
  - Electric dipole
  - Line charge, ring of charge, sheet of charge
- Electric field lines
- Force on charged particles

**Electric field**

- \( F_e = qE \)
- If \( q \) is positive, \( F \) and \( E \) are in the same direction

Example: electric field from point charge

\[ E = \frac{(9 \times 10^9)(1.6 \times 10^{-19})}{(10^{-10})^2} \text{ N} = 2.9 \times 10^{11} \text{ N/C} \]
Electric field lines
- Local electric field tangent to field line
- Density of lines proportional to electric field strength
- Fields lines can only start on + charge
- Can only end on - charge (but some don’t end!).
- Electric field lines can never cross

Quick quiz: continuous charge dist.
Electric field from a uniform ring of charge.
The magnitude of the electric field on the x-axis
A. Has a maximum at x=0
B. Has a maximum at x=∞
C. Has a maximum at finite nonzero x
D. Has a minimum at finite nonzero x
E. Has neither max nor min

Force on charged particle
- Electric field produces force qE on charged particle
- Force produces an acceleration a = F_E / m
- Uniform E-field (direction & magnitude)
  produces constant acceleration if no other forces
- Positive charge accelerates in same direction as field
- Negative charge accelerates in direction opposite to electric field

Dipole in an electric field
- Dipole made of equal + and - charges
- Force exerted on each charge
- Uniform field causes rotation

Electric dipole
- Electric dipole moment
- Electric field magnitude drops off as 1/r^3

Electric torque on dipoles
Remember torque? τ = r × F, magnitude rF sinθ
Here there are two torques, both into page:
<table>
<thead>
<tr>
<th>F</th>
<th>qE</th>
<th>s/2</th>
<th>r sinθ</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>-qE</td>
<td>s/2</td>
<td>-r sinθ</td>
</tr>
<tr>
<td>Total torque is sum of these</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| \[ r = qE sinθ \] Torque on dipole in uniform field τ = r × E
A dipole is near a positive point charge in a viscous fluid. The dipole will

A. rotate CW & move toward charge
B. rotate CW & move away
C. rotate CCW & move toward
D. rotate CCW & move away
E. none of the above