Today's Topics
- Wave Nature of Lights: Interference
- Light as Waves
- Double-Slit Interference
- Multi-Slit Interference

About the Final Exam (1)
- The exam will be on 2:45-4:45pm, Wednesday, Dec 19th (room allocation to be announced)
  - It will be exactly 120 minutes.
- Four (3+1) 8 1/2 x 11" formula sheets are allowed.
  - Must be prepared by yourself. (no photocopying, downloading of lecture notes/exam solutions/examples, etc.)
- Any calculator is fine.
  - Do not use programming functionality.
  - Absolutely no communication functionality.
- A 2B pencil for Scantron. (and a ruler for possible ray diagrams)
- All special arrangements must be pre-approved. Requests, on solid excuses, must be made by 11:00pm Friday Dec 7th.

About the Final Exam (2)
- The Exam is cumulative.
  - ~50% for new chapters (35, 36, 37, 38)
  - ~50% for old chapters (23-34)
- There will be 30 multiple-choice problems.
- New chapters since Exam 3
  - Chapter 35: Principles of Ray Optics
    - 35.1-35.8
  - Chapter 36: Image Formation (Mirrors and Lens)
    - 36.1-36.10 (36.5 Lens aberration: conception only)
  - Chapter 37: Waves Optics, Interferences
    - 37.1-37.7
  - Chapter 38: Diffraction
    - 38.1-38.6

Review Lectures
- Review 1: Given on Sep 27th
- Review 2: Given on Oct 25th
- Review 3: Given on Nov 20th
  - Those reviews won't be repeated. Slides can be found on course web.
- Review 4 (optics): Friday, Dec 14th.
  - 5:45pm and 7:00pm. (identical sessions)
Reminder: Light and Optics

- **Nature of Lights**
  - Lights as rays
  - Lights as EM waves: f, λ, φ, ν, A, interference ...
  - Lights as group of photons

- **Optics: Physics of lights**
  - Geometric Optics: Treat light as rays (Ch. 35,36) → Ray approximation.
  - Wave Optics: Wave properties becomes important. Interferences, diffraction...(Ch. 37,38)

Reminder: Light Waves

- **Nature of Lights:**
  - Rays (classical), EM waves ç, Photons ç.

- **Review: Electromagnetic plane waves**

\[ E = E_{\text{max}} \sin(\omega t-kx+\phi), \quad B = B_{\text{max}} \sin(\omega t-kx+\phi), \quad E/B = c \]

- As the E component and B component of an EM wave are 100% correlated, we can use just one of them to represent an EM wave.

Quick Reviews

- **Superposition Principle (ch. 18).**
  - when two waves, \( y_1(x,t) \) and \( y_2(x,t) \) meet, the resulting wave is the algebraic sum of the two waves: \( y(x,t) = y_1(x,t) + y_2(x,t) \)

- **Intensity of an EM wave (ch. 34)**
  - \( I = \frac{S}{c} = E_{\text{max}}^2 = B_{\text{max}}^2 \)

Useful Math Formulas

- **\( \sin(\alpha+\beta) = \sin\alpha\cos\beta + \cos\alpha\sin\beta \)**
- **\( \cos(\alpha+\beta) = \cos\alpha\cos\beta - \sin\alpha\sin\beta \)**
- **Small angle approximations:**
  - \( \sin\theta \sim \theta, \tan\theta \sim \theta \), when \( \theta \sim 0 \)

- **Long distance approximation:** \( d \sim L^2\theta \), when \( L >> d \)

- **\( \cos(0) = 1, \cos\pi = -1, \cos2\pi = 1, \ldots \)**
  - \( \cos\alpha = \cos3/2\pi = \cos5/2\pi = 0 \ldots \)**
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.

- Two light waves with same color and amplitude.
  \[ E_1 = E_0 \sin(\omega t - kx + \phi_1) \]
  \[ E_2 = E_0 \sin(\omega t - kx + \phi_2) \]

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

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

It all depends on \( \Delta \phi \)!

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

Test of the Wave Nature of Light:

Double-Slit Experiment

- Rays or Waves?
- Diffraction & interference
  If lights behave as rays
  If lights behave as waves

Young’s Famous Double-Slit Experiment

Thomas Young (1803)

- See demo
**One More Review (ch. 18)**

**Path Length And Path Length Difference**

- Remember a Phy201 problem like this?

- For two interfering waves coming through different paths the phase difference:
  \[ \phi = k(r_1 - r_2) + \Delta \phi_{\text{at\ the\ source}} \] (why? see board)

  where \( r_1 \) and \( r_2 \) are path lengths,
  \( \Delta r = (r_1 - r_2) \) is called path length difference.

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**Double-Slit Experiment Explained**

- The experiment can be easily explained by interference.

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

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

**Bright spots**

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

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

**Dark spots**

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**Quantitatively**

\[ \Delta \phi = k(r_1 - r_2) = kd \sin \theta = \frac{2\pi d}{\lambda} \sin \theta \]

\[ I = I_0 \cos^2 \left( \frac{2\pi d \sin \theta}{\lambda} \right) \]
# Multi-Slit Interference

- # secondary maxima = $N - 2$
- Higher $N \rightarrow$ more suppression on secondary minima
- (Grating: $N > 1000$, highly sensitive to $\lambda$, good for measuring $\lambda$.)

Self reading: Phasor Method (Not to be examined)