Final Exam information

• Wednesday, June 6, 2012, 9:30 am - 11:18 am

• Location: in recitation room

• Comprehensive (covers all course material)

• 35 multiple-choice questions --> 175 points

• Closed book and notes

• Make up your own equation sheet (same rules as midterm)
Chapter 26

The Refraction of Light: Lenses and Optical Instruments
26.8 The Thin-Lens Equation and the Magnification Equation

Thin lens equation
\[ \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \]

Magnification equation
\[ m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \]

These equations are identical to the mirror equations!

The sign conventions are similar to those for mirrors, but there are a few differences……..
Summary of Sign Conventions for Lenses

\[ f \] is + for a converging lens.
\[ f \] is – for a diverging lens.

\[ d_o \] is + if the object is to the left of the lens.
\[ d_o \] is – if the object is to the right of the lens.*

\[ d_i \] is + for an image formed to the right of the lens (real image).
\[ d_i \] is – for an image formed to the left of the lens (virtual image).

\[ m \] is + for an upright image.
\[ m \] is – for an inverted image.

* can occur in the case of imaging with more than one lens.
Example. The Real Image Formed by a Camera Lens

A 1.70-m tall person is standing 2.50 m in front of a camera. The camera uses a converging lens whose focal length is 0.0500 m. (a) Find the image distance and determine whether the image is real or virtual. (b) Find the magnification and height of the image on the film.

(a) \[
\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{0.0500 \text{ m}} - \frac{1}{2.50 \text{ m}} = 19.6 \text{ m}^{-1}
\]

\[d_i = 0.0510 \text{ m} \quad \text{real image, since } d_i > 0\]

(b) \[
m = -\frac{d_i}{d_o} = -\frac{0.0510 \text{ m}}{2.50 \text{ m}} = -0.0204 \quad \text{image inverted, since } m < 0
\]

\[h_i = mh_o = (-0.0204)(1.70 \text{ m}) = -0.0347 \text{ m}\]
Example. The Virtual Image Formed by a Diverging Lens
An object is placed 7.10 cm to the left of a diverging lens whose focal length is \( f = -5.08 \) cm. (a) Find the image distance and determine whether the image is real or virtual. (b) Obtain the magnification.

(a) \[
\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{(-5.08 \text{ cm})} - \frac{1}{(7.10 \text{ cm})} = -0.338 \text{ cm}^{-1}
\]

\[d_i = -2.96 \text{ cm} \quad \text{virtual image, since } d_i < 0\]

(b) \[
m = \frac{-d_i}{d_o} = \frac{-(-2.96 \text{ cm})}{(7.10 \text{ cm})} = 0.417 \quad \text{image upright, since } m > 0 \\
\quad \text{and reduced since } |m| < 1\]
26.9 Lenses in Combination

In a two-lens system, the image produced by one lens serves as the object for the next lens. This setup can be used as a microscope.

**Strategy:**
1) Use the lens equation to find the first image from the first lens.

2) Use the first image as the object for the second lens and use the lens equation again with the second lens to find the final image.
Example. A Microscope -- Two lenses in combination
The objective and eyepiece of the microscope in the figure are both converging lenses and have focal lengths of \( f_o = 15.0 \) mm and \( f_e = 25.5 \) mm. A distance of 61.0 mm separates the lenses. An object is placed \( d_{o1} = 24.1 \) mm in front of the objective. Find the final image distance and the final magnification by the microscope.

**Lens 1 (objective):**
\[
1/d_{i1} = 1/f_o - 1/d_{o1} = 1/(15.0 \text{ mm}) - 1/(24.1 \text{ mm}) = 0.0252 \text{ mm}^{-1}
\]
\[\Rightarrow d_{i1} = 39.7 \text{ mm} \quad \text{real image since } d_{i1} > 0\]

**Lens 2 (eyepiece):**
\[
d_{o2} = 61.0 \text{ mm} - d_{i1} = 61.0 \text{ mm} - 39.7 \text{ mm} = 21.3 \text{ mm}
\]
\[
1/d_{i2} = 1/f_e - 1/d_{o2} = 1/(25.5 \text{ mm}) - 1/(21.3 \text{ mm}) = -0.0077 \text{ mm}^{-1}
\]
\[\Rightarrow d_{i2} = -130 \text{ mm} \quad \text{final image is virtual since } d_{i2} < 0\]

**Final magnification of microscope:**
\[
m = m_1 m_2 = (-d_{i1}/d_{o1})(-d_{i2}/d_{o2}) = (-39.7/24.1)(130/21.3)
\]
\[= (-1.65)(6.10) = -10.1 \quad \text{magnified and inverted}\]