# Exam 3

Your Name:

## Instructions

Solve each of the following problems to the best of your abilities, showing all your work. The exam is worth 100 points total and is calibrated for one class period. Once you have completed the exam, hand it to me, and you can leave for the day.

Good luck!

(5 points) If you look down into a clear body of water like a lake, objects appear to be closer to the surface than they really are. Why is this the case?

Light which bounces off of the objects is refracted at the surface between the water and air. This bending of light rays makes it seem like objects are closer to the surface than they really are.

(5 points) What is the electromagnetic spectrum? Is it the same thing as visible light?

The EM spectrum is the full range of wavelengths / frequencies that electromagnetic waves can have. It includes visible light as well as other regions including radio waves, microwaves, x-rays, gamma rays, etc. Visible light is a type of EM radiation, but not all EM radiation is visible light.

(30 points) An electromagnetic wave is given by the following equation:

$$\vec{E}(x,\ t)\ =\ \left(100\ \frac{N}{C}\right)\sin\left[\left(1.0\ \times 10^{2}\ \frac{1}{m}\right)x\ -\ \left(2.5\ \times 10^{10}\ \frac{rad}{s}\right)t\ +\ (0.15\ rad)\right]\hat{z}$$

a. (5 points) What is the phase of the wave?

0.15 rad

b. (5 points) In which direction is the wave polarized?

Z direction

c. (5 points) What is the angular frequency of the wave?

$$2.5 \times 10^{10}\ \frac{rad}{s}$$

d. (5 points) What is the wavelength of the wave?

0.0628 m

e. (5 points) Is the wave traveling in the +x or –x direction?

+x direction

f. (5 points) What is the speed of the wave?

$$v\ =\ \frac{\omega}{k} = 2.5 \times 10^{8}\ \frac{m}{s}$$

(30 points) An object with a height of 15 cm is placed 30 cm in front of a diverging lens with a focal length of 10 cm in magnitude.

a. (5 points) What is the image distance?

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \Rightarrow q = \left(\frac{1}{-10\ cm} - \frac{1}{30\ cm}\right)^{-1} = -7.5\ cm$$

b. (5 points) What is the magnification of the final image?

$$M = -\frac{q}{p} = -\frac{-7.5\ cm}{30\ cm} = \frac{1}{4}$$

c. (5 points) What is the height of the final image?

$$h = \frac{15\ cm}{4} = 3.75\ cm$$

d. (5 points) Is the image real or virtual?

Virtual

e. (5 points) Is the image in front of or behind the lens?

In front of the lens

f. (5 points) Why do I start my light rays from the top of the object when I draw ray diagrams?

You can start the light rays from any point on the object. However, by starting them at the top of the object, you can see where the image of the top of the object would be located, thus making it easier to draw the image as a whole.

(5 points) What is the critical angle between air (n = 1.00) and water (n = 1.30)?

$$(1.00)\sin 90^\circ = (1.30)\sin\theta$$

$$\sin\theta = \frac{1}{1.3}$$

$$\theta = 0.878\, rad$$

(5 points) What is spherical aberration? How might you resolve spherical aberration in an optical system?

Spherical aberration occurs when the outer edges of a lens do not bring light rays into the same focus as the central part of the lens. In other words, the focus is not one specific point – the lens focuses light at different points depending on where the light is directed.

(5 points) An electromagnetic wave has an electric field with an amplitude of 500 V/m. What is the energy density of the wave?

$$U = \epsilon_o E^2 = 2.2 \times 10^{-6}\ \frac{J}{m^2}$$

(15 points) Light, initially polarized at +10 degrees with respect to the z-axis, passes through a linear polarizing filter. The filter is oriented at an angle of +35 degrees with respect to the z-axis. What is the intensity of light that passes through the filter?

Note, this question should really say “what percentage of the light passes through” since I did not give the initial intensity.

$$I_f = I_o \cos^2(35^\circ - 10^\circ)$$

$$\frac{I_f}{I_o} = \cos^2(25^\circ) = 0.82$$