General College Physics II (PHY 104)

Exam 3

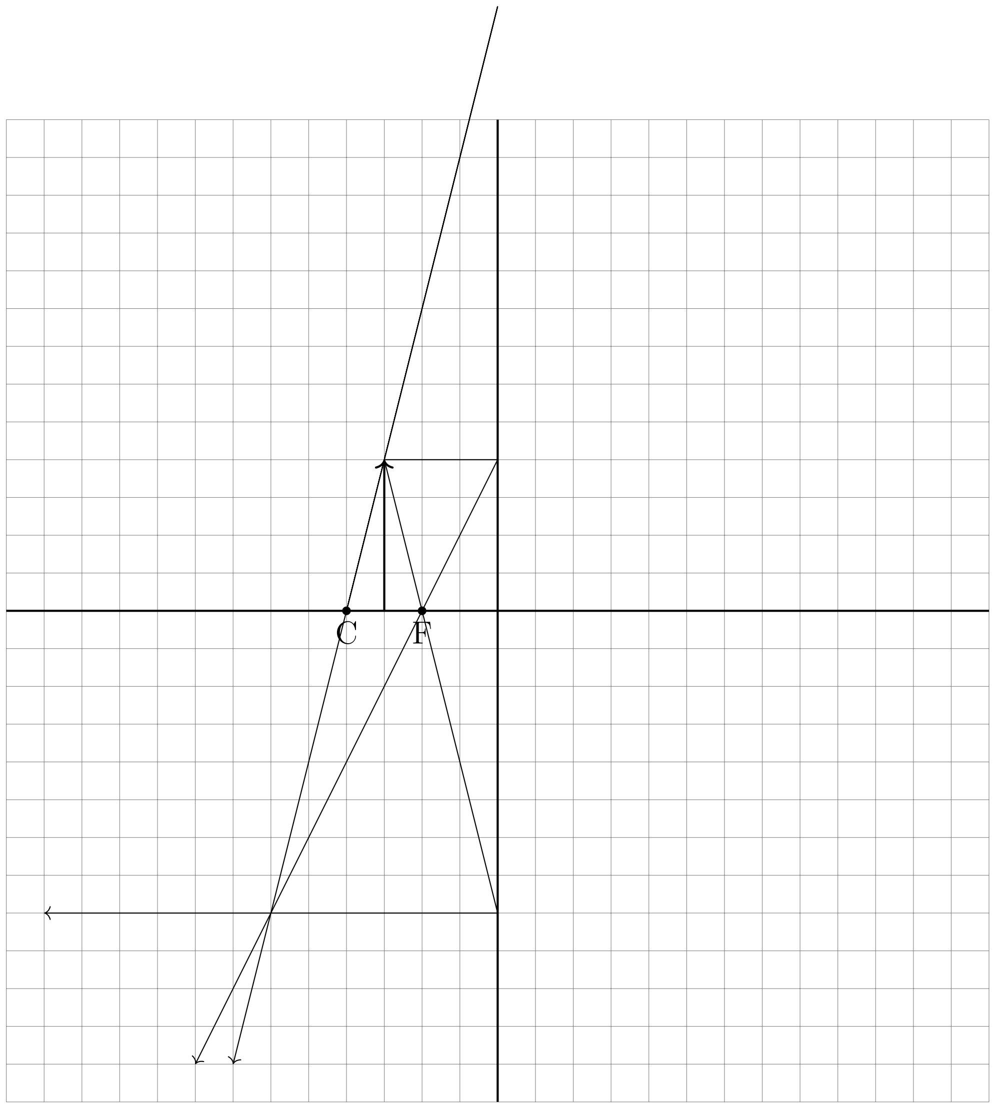
Spring 2025

Question 1 (4 points) Object 1 is placed by a concave mirror. A real image will form (a) if the object is inside the focal length, (b) if the object is outside the focal length, (c) regardless of where the object is, or (d) never. Object 2 is placed by a convex mirror. A real image will form (a) if the object is inside the focal length, (b) if the object is outside the focal length, (c) regardless of where the object is, or (d) never. Explain.

Object 1 will produce a real image (b) if the object is outside the focal length. For a concave mirror, when an object is outside of the focal length, a real image is produced. When an object is right at the focal point, the light rays exit the mirror traveling parallel to the central axis (horizontal). When an object is inside of the focal length, a virtual image is produced. These facts can be found from the thin lens equation if we remember the convention that a positive image distance means a real image, while a negative image distance means a virtual image.

Object 2 will produce a real image (d) never. A convex mirror will never produce a real image. In a convex mirror, the rays are already diverging when they hit the mirror, and they will be diverging even more after the reflection, so they cannot converge to form a real image.

Question 2 (4 points) Consider a concave mirror with radius 20 cm. An object is placed 15 cm in front of the mirror. Make a ray diagram that shows where an image would be formed. Is the image real or virtual? Is it inverted or upright?



The image is produced at $d_i = 30$ cm. The image is real and inverted.

Question 3 (4 points) Monochromatic red light is incident on a double slit, and the interference pattern is viewed on a screen some distance away. Explain how the fringe pattern would change if the red light source is replaced by a blue light source.

Blue light has a shorter wavelength than red light. Looking at the two-slit interference equation,

$$\#\lambda\text{s} = \frac{d \sin\theta}{\lambda},$$

and supposing that d and $\#\lambda$s remain the same, if λ decreases then $\sin\theta$ decreases, which means θ decreases. If θ decreases, that means the separation between adjacent bright spots is decreasing, which means the spacing between fringes is smaller with blue light compared to red light.

Question 4 (4 points) Consider a pattern of fringes on a screen produced by two-slit interference. If the slit separation is increased, what happens to the spacing between the (bright) fringes? (Does it increase, decrease, or stay the same?) Explain how you know.

Looking at the two-slit interference equation,

$$\#\lambda\text{s} = \frac{d \sin\theta}{\lambda},$$

and supposing that λ and $\#\lambda$s remain the same, if d increases then $\sin\theta$ decreases, which means θ decreases. If θ decreases, that means the separation between adjacent bright spots decreases, which means the spacing between fringes is smaller for a larger slit separation than it is for a small slit separation.

Problem 1 (8 points) Light from a lamp 3.0 m above the surface of a pool of water hits the water at an angle 10° above the surface of the water. If the pool is 1.0 m deep, find the total time it takes the light to travel from the lamp to the bottom of the pool. (Hint: First find the distance the light travels in air and the distance it travels in water.)

The distance light travels in air is (it will help to draw a picture)

$$d_1 = \frac{3 \text{ m}}{\sin 10^\circ} = 17.2763 \text{ m}.$$

The time it takes light to travel this distance is

$$t_1 = \frac{17.2763 \text{ m}}{3 \times 10^8 \text{ m/s}} = 5.763 \times 10^{-8} \text{ s}.$$

The light hits the water at an angle of 10° above the surface of the water, so the angle of incidence is 80°, since we measure angles for Snell's law from the perpendicular to the surface. We use Snell's law

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

with $n_1 = 1$, $n_2 = 1.33$, and $\theta_1 = 80^\circ$. This gives

$$\theta_2 = \sin^{-1}\left(\frac{(1)(\sin 80^\circ)}{1.33}\right) = 47.77^\circ.$$

The distance the light travels in water is (it will help to draw a picture)

$$d_2 = \frac{1 \text{ m}}{\cos 47.77^\circ} = 1.4879 \text{ m}.$$

The speed of light in water is

$$v_2 = \frac{c}{n} = \frac{3 \times 10^8 \text{ m/s}}{1.33} = 2.254 \times 10^8 \text{ m/s}.$$

The time it takes light to travel this distance is

$$t_2 = \frac{1.4879 \text{ m}}{2.254 \times 10^8 \text{ m/s}} = 6.60 \times 10^{-9} \text{ s}.$$

The total time is

$$t = t_1 + t_2 = 6.423 \times 10^{-8} \text{ s}.$$

Problem 2 (8 points) The third-order bright fringe of 610 nm light is observed at an angle of 29° when the light falls on two narrow slits. How far apart are the slits?

Using the 2-slit interference equation

$$\#\lambda\text{s} = \frac{d \sin\theta}{\lambda}$$

with $\#\lambda\text{s} = 3$, $\theta = 29°$, and $\lambda = 610$ nm, we get

$$d = \frac{(\#\lambda\text{s})\lambda}{\sin\theta} = 3775 \text{ nm}.$$

Problem 3 (8 points) Consider a thin film of soap on a larger piece of crown glass. Above the soap film is air. Find the two smallest thicknesses of soap film ($n = 1.33$) that will produce destructive interference for light of wavelength 500 nm.

Using the thin-film interference equation,

$$\#\lambda\text{s} = \frac{2tn}{\lambda_0} + \left\{ \begin{array}{c} 1/2 \\ 0 \end{array} \right\} + \left\{ \begin{array}{c} 1/2 \\ 0 \end{array} \right\},$$

we have

$$\#\lambda\text{s} = \frac{2t(1.33)}{500 \text{ nm}} + 1/2 + 1/2,$$

so

$$t = \frac{(500 \text{ nm})(\#\lambda\text{s} - 1)}{2(1.33)}.$$

We want destructive interference, so $\#\lambda$s should be a half integer. If we try $\#\lambda\text{s} = 1/2$, we will get a negative thickness, which doesn't make any sense. So, we should use $\#\lambda\text{s} = 3/2$ and $\#\lambda\text{s} = 5/2$.

The two smallest thicknesses are 93.98 nm and 281.95 nm.