Celebration #2: Optics

Short Answer Questions (5 points each)

1) In the figure below, stick figure O stands in front of a thin, symmetric lens that is mounted within the boxed region; the central axis through the lens is shown. The four stick figures I₁ and I₄ suggest general locations and orientations for the images that might be produced by the lens. (The figures are only sketched in; neither their heights nor their distances from the lens are drawn to scale.)

![Ray-tracing diagram]

a) Which of the stick figures could not possibly represent images?

b) Of the possible images, which could be due to a converging lens?

c) Of the possible images, which could be due to a diverging lens?

d) Of the possible images, which would be virtual?

e) Of the possible images, which would involve negative magnification?

2) An object is placed 30.0 cm in front of a concave mirror with a focal length of 10.0 cm. Sketch a ray-tracing diagram with at least three rays that shows the approximate location and size of the image.
3) Monochromatic light of wavelength 650 nm is incident on two narrow slits and the interference pattern shown below is viewed on a screen. Point A is directly opposite a point midway between the two slits. What is the path length difference of the light that passes through the two slits for light that reaches the screen at points A, B, C, D, and E?

4) In the figure below, light travels from material a, through three layers of other materials with surfaces parallel to one another, and then back into another layer of material a. The refractions (but not the associated reflections) at the surfaces are shown.

a) In which material is the speed of light the greatest?

b) In which material is the speed of light the least?
5) The figure below shows a red line and a green line of the same order in the pattern produced by a diffraction grating. Would each of the following changes cause the lines to shift to the right, shift to the left, or remain in place.

- Decreasing the grating spacing $d$:
- Moving the screen closer to the slit:
- Decreasing the intensity of each light source:
- Immersing the entire apparatus in cooking sherry:
- Increasing the width of each slit (or ruling) without changing $d$:

6) An initially unpolarized beam of light is sent through a stack of four polarizing sheets, each with their polarization axis oriented as shown in the figure below. What fraction of the incident intensity is transmitted by the system?
Problems (10 points each)

Problem 1
A ray of light in air strikes a solid block of transparent material in which the speed of light is \(2.18 \times 10^8\) m/s. What is the largest angle of incidence \(\theta_a\) for which total internal reflection will occur at the vertical face (point A in the figure below)?
Problem 2
Two thin converging lenses are separated by 20.0 cm as shown in the figure below. The focal length of the first lens is 10.0 cm. The second lens is made of glass (n = 1.50) and each side of the lens had a radius of curvature of magnitude 17.5 cm. An object is placed 15.0 cm to the left of the first lens. (a) Find the location of the final image relative to the second lens. (b) What is the magnification of the final image? (c) Is the final image real or virtual, upright or inverted, and enlarged or reduced?
Problem 3
Light of wavelength $\lambda = 500.0$ nm is incident on a pair of double slits which are separated by a distance $d = 1.00$ mm. Each slit has a width $a = 2.00 \times 10^{-4}$ m and the interference pattern is displayed on a screen which is 2.50 away.

a) Using the small angle approximation, calculate the distance between the central bright fringe and the 2nd order ($m = 2$) bright fringe.

b) Calculate the distance between the central bright fringe and the 4th order ($m = 4$) dark fringe without using the small angle approximation.

c) How many interference maxima fall within the central diffraction envelope? How many interference maxima fall within either of the first side peaks in the diffraction envelope?

d) Qualitatively sketch the interference pattern ($I$ vs $\theta$) produced by this pair of slits.
Problem 4
In the figure below, $S_1$ and $S_2$ are identical sources of sound waves that have the same wavelength $\lambda$ but are **out of phase**. The sources are separated by distance $d = 30.00$ m. A person standing at $P_1$ a distance of $29.75$ m from $S_1$ detects constructive interference while a person standing at $P_2$ a distance of $40.00$ m from $S_1$ detects destructive interference. What is the wavelength of the sound wave?
**Problem 5**
When light of wavelength $\lambda = 550.0$ nm is incident on a diffraction grating, the second-order ($m = 2$) maximum occurs at an angle of $26.4^\circ$.

a) How many slits per cm are there for this grating?

b) How many total maxima will be observed for this wavelength?

c) If the screen is $2.50$ m away from the slits, what is the distance on the screen between the central maxima ($m = 0$) and the outermost maxima?
Problem 6
A spherical mirror is polished and reflective on both sides. When the convex side is used as a mirror, the magnification is $+1/4$. What is the magnification when the concave side is used as a mirror, the object remaining the same distance from the mirror?
Problem 7
In the figure below, a broad beam of light of wavelength 683 nm is sent directly downward through the top plate of a pair of glass plates. The plates are 120 mm long, touch at the left end, and are separated by a wire of diameter 0.048 mm at the right end. The air between the plates acts as a thin film. How many bright fringes will be seen by an observer looking down through the top plate?