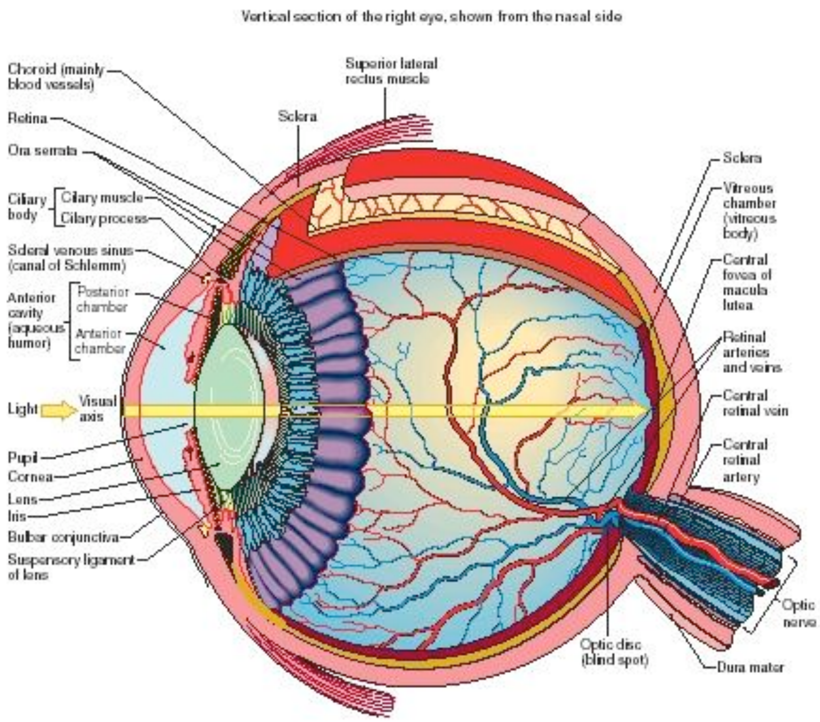
UCA Department of Physics and Astronomy

PHYS 3345: OPTICS

Exam 02: Chapters 04 – 06 03/03/08

Part 01: Conceptual Questions



Answer each of the following questions **clearly** and **concisely** on a separate sheet of paper. If necessary, use a sketch to illustrate. Plan to spend about 15 minutes answering this set of questions. Each question is worth **4 points**.

When you have completed these, submit your paper. You may then use your textbook to complete the problem solving portion of the exam.

1. Distinguish between Rayleigh and Mie scattering.

   The size of the scattering particle matters. A very small particle (on the order of a wavelength or smaller) causes Rayleigh scattering, which is strongly wavelength dependent. Mie scattering occurs with larger particles (bigger than wavelength), making it less dependent on the wave-length.

2. An e·m wave with components perpendicular $(E_o)_\perp$ and parallel $(E_o)_{||}$ is incident in air (n = 1) on a thick slab of glass (n > 1). Compare the relative phase shift of the reflected components ($\Delta\varphi = \varphi_\perp - \varphi_{||}$) for near–normal incidence (θ_i is small) to the relative phase shift for glancing incidence (θ_i approaches 90°).

   At near-normal incidence, $\varphi_\perp = \pi$ but $\varphi_{||} = 0$, so $\Delta\varphi = \varphi_\perp - \varphi_{||} = \pi$. The reflected component perpendicular leasds the reflected parallel component by ½ a wavelength. At glancing incidence, $\varphi_\perp = \pi$ and $\varphi_{||} = \pi$ as well, so $\Delta\varphi = \varphi_\perp - \varphi_{||} = 0$, and the reflected components are in phase.

3. Why does a transparent (colorless) medium reflect all visible frequencies equally?

   Resonant frequencies outside of visible range. For example, glass has resonant frequency in the UV, which means lower frequency visible light is not absorbed, but scattered. Blue light = short wavelength but high frequency. This means it will not penetrate as far into the medium, but it will be more effective (fewer scatterers, but each scatter is more energetic). Red light = long wavelength, low frequency. Greater penetration depth, so more atoms will scatter, but each event is at lower energy. Add it all up, and you have about as much energy reflected regardless of frequency.

4. For the transmission of an e·m wave at the interface between two media, what boundary conditions must always be met?

   The component of **E** parallel to the interface must be continuous across the interface. Perpendicular to the interface, ϵ**E** must be continuous.

5. If gold is opaque, why did Neil and Buzz have gold-coated space visors?

   The very thin coating was thick enough to reflect 70% of incoming e·m radiation (remember, no atmosphere on the moon, so Neil and Buzz got buzzed with the full strength of all solar frequencies!), but thin enough to permit enough visible light to transmit. Gold has a penetration depth of about 10nm in the infrared, so we're talking about a minimal amount of actual helmet bling.

6. Under what conditions (plural!) does a positive lens form a magnified image?

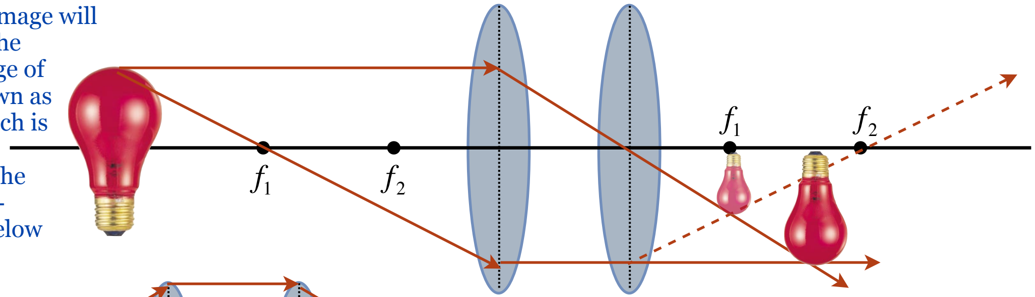
   When $0 < d_o < f$, the image will be virtual and magnified. When $f < d_o < 2f$, a magnified real image will be formed.

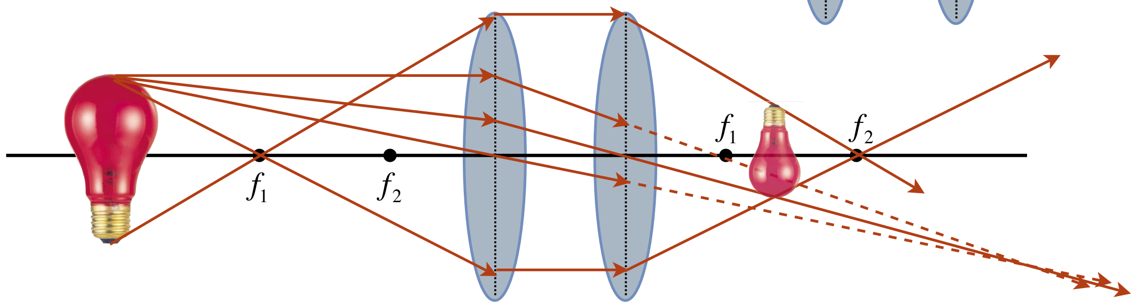
7. How many things can you find wrong with this ray diagram? List the mistakes.

   The incident ray parallel to the axis will not bend through center of lens 2. The ray through f_1 that emerges parallel to the axis will not split as shown at lens 2, the real portion is wrong, and the virtual portion has the correct path, but is not virtual (it's real). There will not be two images formed; the picture implies both a real and virtual (b/c of the dotted ray) image form simultaneously in separate locations (or possibly the large one is supposed to be the intermediate image formed as if L_2 was not there, but that's

Exam 02: Chapters 04 – 06 03/03/08
Part 01: Conceptual Questions

wrong too). A single real image will form, but not in either of the locations shown. The image of the base of the bulb is shown as right on the optic axis, which is also wrong. The base will image at a location above the optic axis. A correctly constructed image is shown below (see Figure 5.28, p 167).





8. What is longitudinal (as opposed to transverse) magnification? Why is M_L negative for a thin lens?

   By definition, $M_L = (dx_i)/(dx_o)$. This refers to the direction along the optic axis, so it tells you about any foreshortening of the image. For a thin lens, this will be negative: see the example that you did for homework. The tail of the real horse was farther from the lens than his nose, but in the image, the tail was closer and the nose was farther from the lens.

9. Why might you choose to increase or decrease the f/# of your camera lens (assuming you have a variable aperture)?

   Increasing or decreasing the aperture size will change the amount of light transmitted through the lens. A smaller f/# corresponds to a larger aperture, or more light-gathering. This would be preferable in low-light conditions. Larger f/# means smaller aperture. Increasing the f/# would be a response to bright conditions, to avoid over-exposure.

10. Why are objects in mirror closer than they appear? You know, in your side-view mirror.

    The mirror is not flat, is is convex. A convex lens can only form images that are smaller than the actual object. Your brain interprets the smaller image as being farther away than it really is. The mirror is convex not to confuse you, but because the curvature also increases the field of view.

11. Briefly describe the accommodation of the human eye.

    The crystalline lens of a relaxed eye is almost flat, so it's focal length is long (focus = clear on distant objects). To see nearby objects, the ciliary muscles pull the lens to increase its curvature, decreasing the focal length (focus = clear on close objects).

12. Distinguish between the near point and far point. Compare the far point of a myopic eye to that of a normal eye.

    When the crystalline lens has been curved as much as it can be, for the shortest focal length, the near point is that closest point at which an object can be focused. The relaxed eye, with least-curved lens and longest focus, defines the far point. Ideally, the far point would be at infinity, meaning that the eye could focus clearly on objects infinitely far away (book claims 5m is effectively infinity). A near-sighted eye has a far point considerably less than infinity. Compared to a normal eye, a myopic eye has a short far point.

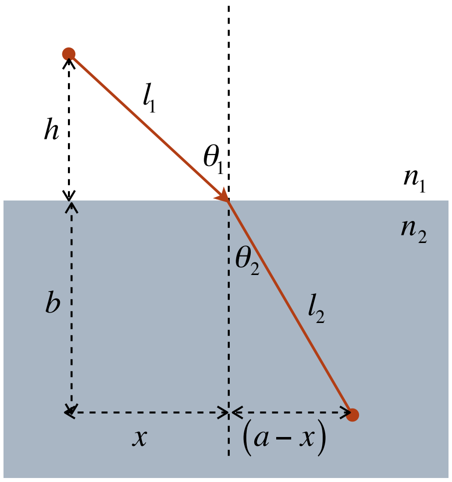
13. What are the six cardinal points of a lens system?

    Front (object) focus F_o, back (image) focus F_i, principal points H_1 and H_2, and nodal points N_1 and N_2. When a lens is completely immersed in a medium (final ray emerges into same medium as incident ray started in), $N_1 = H_1$ and $N_2 = H_2$.

UCA Department of Physics and Astronomy

Exam 02: Chapters 04 – 06 03/03/08
Part 02: Problem Solving

1. Use Fermat's Principle of Least Time to derive Snell's Law of Refraction.



$$t_1 = \frac{l_1}{v_1} \qquad t_2 = \frac{l_2}{v_2} \qquad t = t_1 + t_2 = \frac{l_1}{v_1} + \frac{l_2}{v_2}$$

$$t = \frac{\sqrt{x^2 + h^2}}{v_1} + \frac{\sqrt{(a-x)^2 + b^2}}{v_2}$$

$$\frac{dt}{dx} = \frac{x}{v_1\sqrt{x^2 + h^2}} + \frac{-(a-x)}{v_2\sqrt{(a-x)^2 + b^2}} = 0$$

$$\frac{\sin\theta_1}{v_1} = \frac{\sin\theta_2}{v_2} \qquad c\left(\frac{\sin\theta_1}{v_1}\right) = c\left(\frac{\sin\theta_2}{v_2}\right)$$

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

2. Light is normally incident in air on a medium with an unknown index of refraction. It is observed that 5% of the beam is reflected (**R = 0.05**). What is the index of the medium?

$$R = \left(\frac{n_t - n_i}{n_t + n_i}\right)^2$$

$$\sqrt{R} = \frac{n_t - n_i}{n_t + n_i}$$

$$\sqrt{R} = \frac{n_t - 1}{n_t + 1}$$

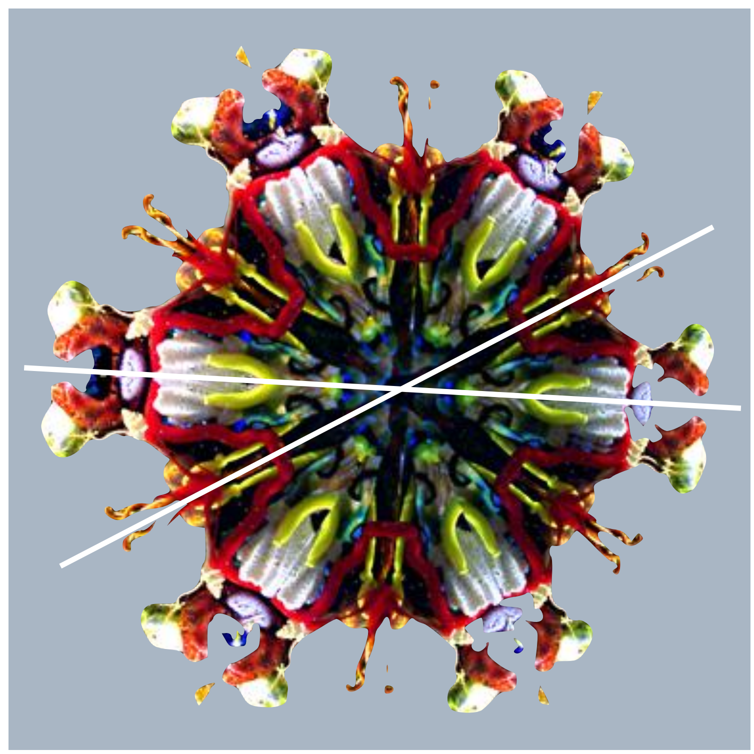
$$\sqrt{0.05}(n_t + 1) = n_t - 1$$

$$(1 - 0.224)n_t = 1 + 0.224$$

$$n_t = 1.58$$

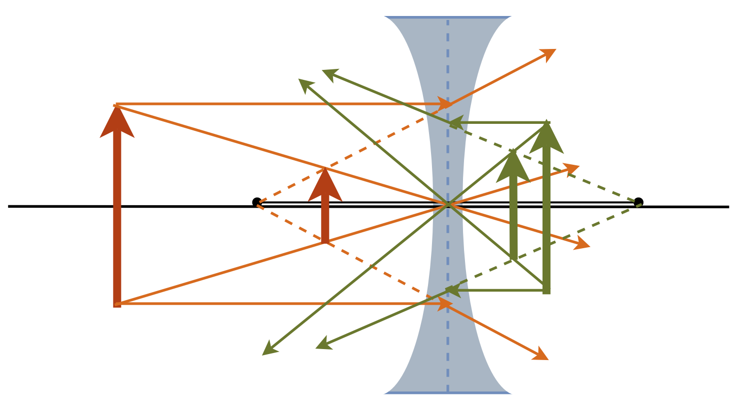
3. Determine the angle between the mirrors of the kaleidoscope shown on the right.

$$\theta = \frac{360°}{12} = 30°$$

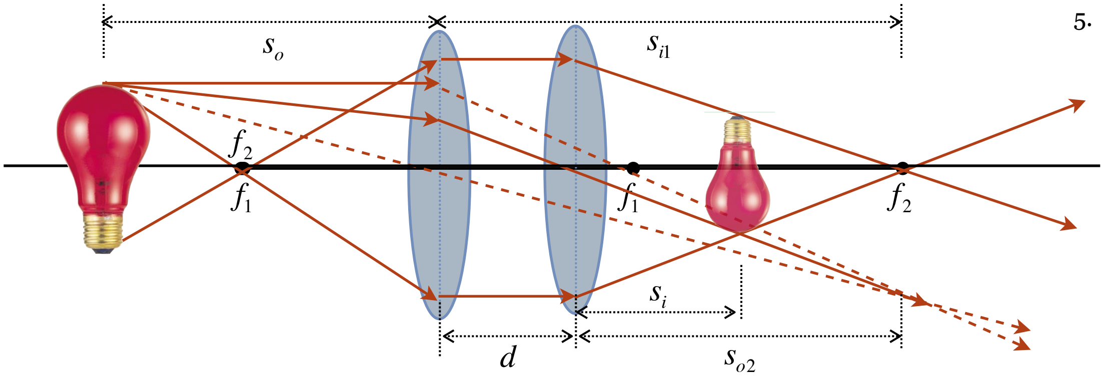


4. Use a ray diagram (or more than one diagram if you need to, for the sake of clarity) to prove that a diverging lens cannot form a real image.

The orange object lies at $d_o > f$, and the real rays clearly diverge on the right (image) side of the lens. A second object (green) placed at a distance $d_o < f$ also results in real rays diverging on the left (image) side of the lens. There is no object location for which a real image can be formed.



Exam 02: Chapters 04 – 06 03/03/08
Part 02: Problem Solving



5. Two positive thins lenses with focal lengths $\mathbf{f_1}$ **= 30cm** and $\mathbf{f_2}$ **= 50cm** are separated by **20 cm.** An object is placed on the optical axis **50 cm** in front of lens 1. Locate the final image and calculate its transverse magnification.

$$\frac{1}{s_o}+\frac{1}{s_{i1}}=\frac{1}{f_1}$$

$$\frac{1}{50\text{cm}}+\frac{1}{s_{i1}}=\frac{1}{30\text{cm}}$$

$$s_{i1}=75\text{cm}$$

$$s_{o2}=d-s_{i1}=-55\text{cm}$$

$$\frac{1}{s_{o2}}+\frac{1}{s_i}=\frac{1}{f_2}$$

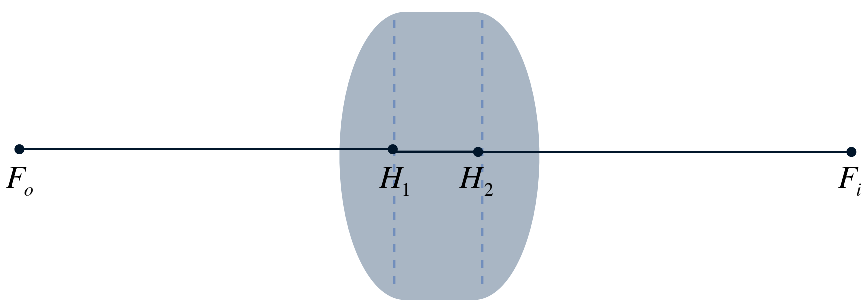
$$\frac{1}{-55\text{cm}}+\frac{1}{s_i}=\frac{1}{50\text{cm}}$$

$$s_i=26.2\text{cm}$$

$$M=\left(-\frac{s_{i1}}{s_o}\right)\left(-\frac{s_i}{s_{o2}}\right)$$

$$M=\left(-\frac{75}{50}\right)\left(-\frac{26.2}{-55}\right)=-0.71$$

6. A thick bi-convex lens is made of glass ($\mathbf{n_L}$ **= 1.50**). Both radii of curvature are **50.0cm** (watch your sign convention), and the lens itself is **5.00cm** thick. Locate the principle planes of this lens and determine its focal length.



$$\frac{1}{f}=(n_L-1)\left(\frac{1}{R_1}-\frac{1}{R_2}+\frac{(n_L-1)d}{n_LR_1R_2}\right)$$

$$\frac{1}{f}=(1.50-1)\left(\frac{1}{50\text{cm}}-\frac{1}{-50\text{cm}}+\frac{(1.50-1)(5\text{cm})}{(1.50)(50\text{cm})(-50\text{cm})}\right)$$

$$f=50.8\text{cm}$$

$$h_1=-\frac{f(n_L-1)d}{n_LR_2}$$

$$h_1=-\frac{(50.8\text{cm})(1.50-1)(5\text{cm})}{(1.50)(-50\text{cm})}=+1.69\text{cm}$$

$$h_2=-\frac{f(n_L-1)d}{n_LR_1}$$

$$h_2=-\frac{(50.8\text{cm})(1.50-1)(5\text{cm})}{(1.50)(50\text{cm})}=-1.69\text{cm}$$