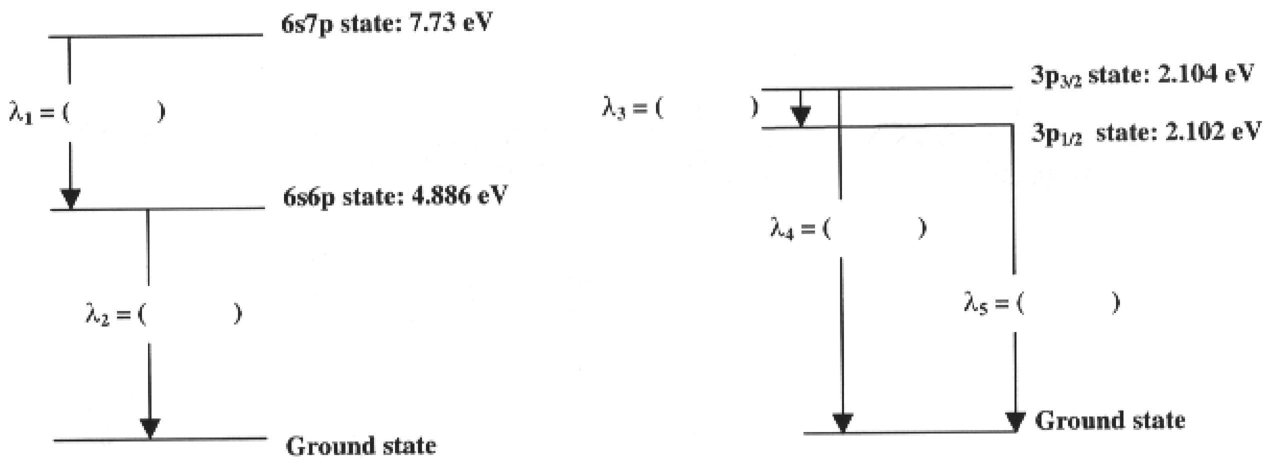
1) When an atom jumps from a higher energy state to a lower energy state it emits one photon. Energy level diagrams for Hg and Na are shown below. Fill out wavelengths for the photon emitted in each transition. [10 pts.]



Hg   Na

$$E = h\nu = \frac{hc}{\lambda} \qquad \lambda = \frac{hc}{E}$$

$$\lambda(nm) = \frac{1.24 \times 10^3}{E(eV)}$$

λ_1: $E = 2.844\,eV$ $\quad \lambda = 436.2\ nm$

λ_2: $E = 4.886\,eV$ $\quad \lambda = 253.8\ nm$

λ_3: $E = 0.002\,eV$ $\quad \lambda = 620{,}000\ nm = 620\ \mu m$

λ_4: $E = 2.104\,eV$ $\quad \lambda = 589.4\ nm$

λ_5: $E = 2.102\,eV$ $\quad \lambda = 589.9\ nm$

2) Consider a thin, spherical plano-convex lens having a radius of curvature of 50.0mm and an index of 1.5.

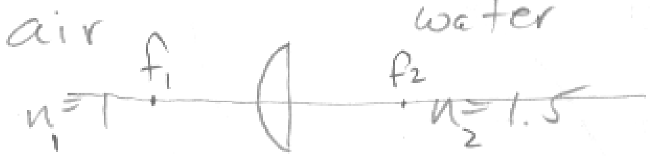
a) Determine the focal length in air. [5 pts.]

b) Suppose this lens is placed right on the surface of a tank of water. At what depth below the surface would a collimated light beam from above come to a focus? (The refractive index of water is 4/3.) [10 pts.]

a) $\frac{1}{f} = (n_e - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = 0.5 \frac{1}{50\,mm} = \frac{1}{100\,mm}$

$f = \underline{100\,mm}$

b)



$$\frac{f_1}{n_1} = \frac{f_2}{n_2}$$

$$f_2 = \frac{n_2}{n_1} f_1 = \frac{4}{3} \cdot 100 = 133\,mm$$

for collimated light input, $d_1 \to -\infty$

$d_2 = f_2 = \underline{133\,mm}$

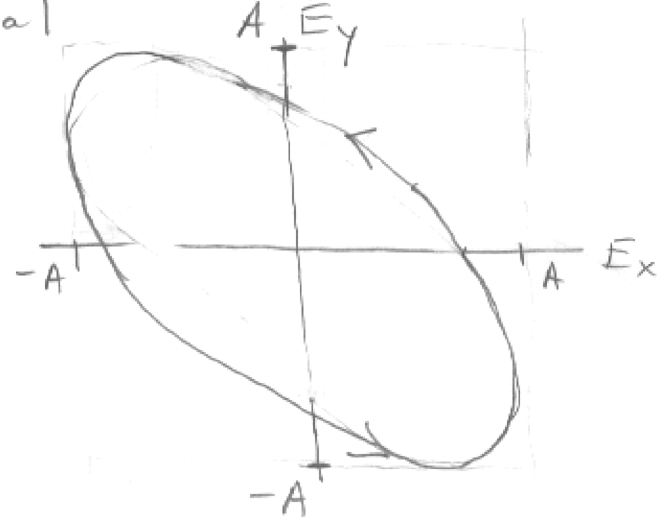
3) Consider the following transverse, monochromatic light fields:

$E_x = A\sin(\omega t - kz)$, $E_y = A\sin(\omega t - kz - 3\pi/4)$

a) Is the polarization linear, circular or elliptical? Draw a vector diagram indicating the trajectory of the electric field vector at a given point in space. k is the wave number, $2\pi/\lambda$. [10 pts.]

b) When an unpolarized light beam passes through two polarizers whose axes of transmission are parallel, a photodetector reads 30 units. If the first polarizer is then turned through 45 degrees, while the second polarizer remains fixed, what will the detector read? [10 pts.]

a) elliptical



b) $30\cos^2\frac{\pi}{4} = 15$

4) You are the lens designer for a hot new video display startup company in Fremont. You must design a 2 lens system to project an uninverted image with a magnification of 25 onto a screen 125 cm away from the top-secret display device invented by the company founder. The mechanical designer tells you that Lens 1 must be located exactly 20 cm away from the object, but you have freedom to choose where to place Lens 2. The purchasing department already bought 5000, 10 cm focal length lenses that fit into the mechanical mount for Lens 1. Your job is determine the focal length and position for Lens 2. Give your answer for its position in terms of the separation between Lens 1 and Lens 2. [20 pts.]

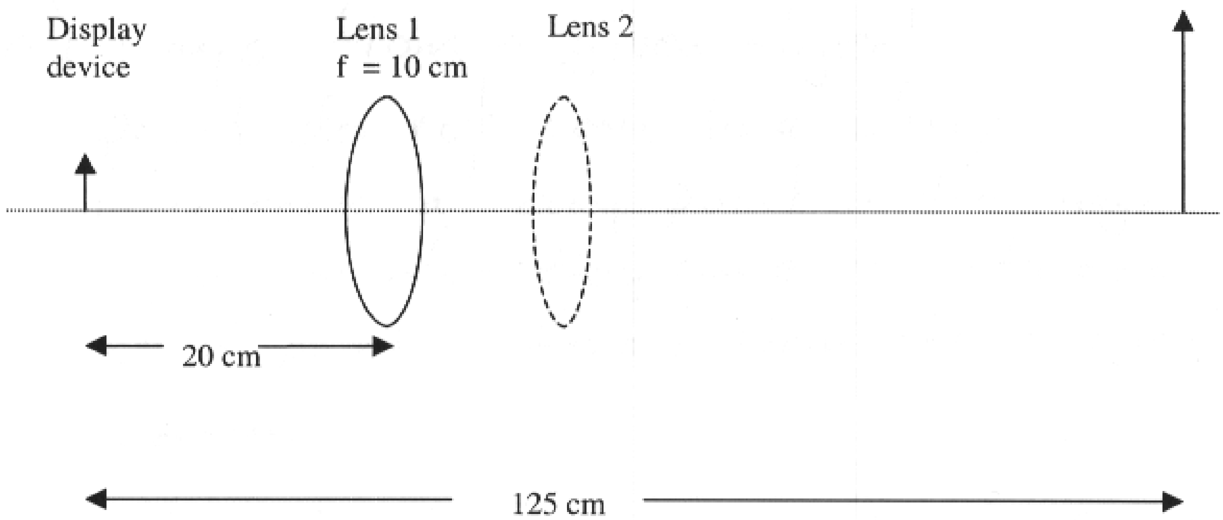


Image formed by Lens 1

$\frac{1}{d_2} = \frac{1}{10} - \frac{1}{20} = \frac{1}{20}$ $d_2 = 20$, so $M_1 = -1$

For Lens 2, total remaining distance from Lens 1 image is 85 cm.

$-d_1 + d_2 = 85$

we need $M_2 = -25$, so $\frac{d_2}{d_1} = -25$

$-d_1 - 25 d_1 = 85 \rightarrow d_1 = -\frac{85}{26} = -3.269$ cm

$d_2 = -25 d_1 = 81.725$ cm

separation is 23.269 cm

$\frac{1}{f} = \frac{1}{d_2} - \frac{1}{d_1} \rightarrow$ $f = 3.143$ cm

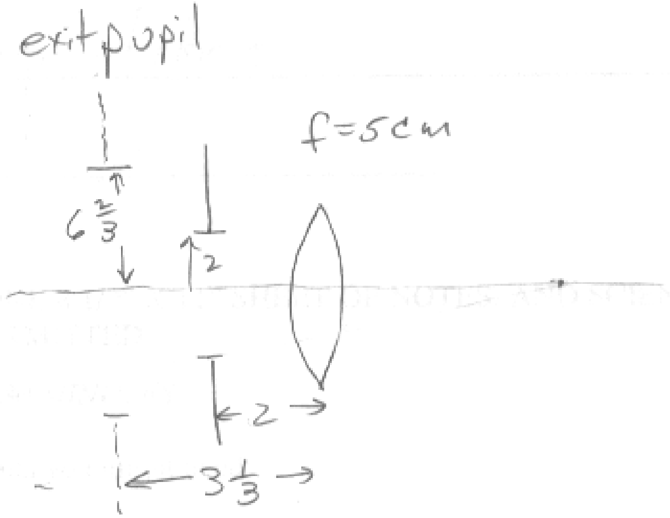
5) Describe in words the general effect of lens aberrations

a) in a ray picture, [10 pts.]
b) and in a wave picture. [10 pts.]
[Hint: Just give a general description. You need not show specifics for any particular type of aberration.]

a) Rays from a given object point do not come to a sharp intersection at any point in the image space, or else they come to intersection at a point different from the desired location.

b) The shape of the wavefront produced at the lens output does not conform to that of a spherical wave converging to the proper image point.

6) A thin lens with focal length f = +5 cm, and diameter of 5 cm has a 4 cm diameter aperture stop located 2 cm in front of it (toward the object). Locate the position and diameter of the exit pupil of the system. [15 pts.]



$d_1 = -2 \qquad f = 5$

$$\frac{1}{d_2} = \frac{1}{f} + \frac{1}{d_1} = \frac{1}{5} - \frac{1}{2} = -\frac{3}{10} =$$

$$d_2 = -\frac{10}{3}$$

$$M = \frac{d_2}{d_1} = -\frac{10/3}{2} = -\frac{5}{3}$$

Pupil diameter $= \frac{5}{3} \cdot 4 = \frac{20}{3} = 6\frac{2}{3}$ cm

located $3\frac{1}{3}$ cm in front of the lens