

1 Midterm Exam Information, 12 October 2006

Allowed materials: One side of one page of notes, lenses from your Optics Discovery Kit, UNPROGRAMMED calculator

You may use your own paper, or I will supply unlined (printer) paper and a stapler

MAKE SURE TO LIST UNITS IN ANSWERS (e.g., millimeters, meters, seconds)

ADVICE: Make sketches before using equations; if you need to use an equation, write it down in its “general” form **FIRST**, then plug in the numbers.

1.1 Topics to be covered

The imaging chain

1. Energy Source: identify the spectrum of different sources, rays and waves, energies of different wavelengths, X rays, UV, visible, IR, Radio, $E = \frac{hc}{\lambda}$, generation by thermal mechanism (broadband radiation), generation by atomic transitions (spectral lines, e.g., lasers). Interactions of energy with matter: transmission, reflection, scattering, absorption
2. Object:
3. Propagation and Collection: optics, rays and waves, pinhole camera, optics equation, magnification. Drawing systems with pinhole or one lens. Pinhole camera image is inverted and may be larger or smaller than object. Positive and negative focal lengths, real and virtual images, difference between *focal length* (distance from lens to focal point) and *focal point* (location in space where rays converge if object is infinite distance away); optical image may be upright or inverted, depends on imaging equation:

$$\frac{1}{z_1} + \frac{1}{z_2} = \frac{1}{f}$$

$$M_t = -\frac{z_2}{z_1}$$

For a lens with object distance z_1 and fixed focal length f , there is only one image distance z_2 . For pinhole camera, images are formed at all distances z_2 and the magnification equation still applies.

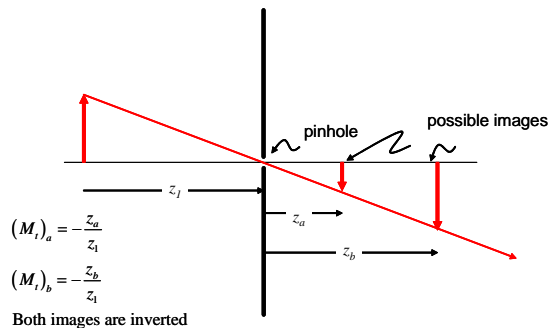


Image magnification depends on image distance

Imaging with pinhole

Pinholes create images of objects that emit light with wavelengths that can be absorbed but

not refracted, lenses work for wavelengths that can be refracted, i.e., wavelengths for which the refractive index $n > 1.0$

$$n \equiv \frac{c}{v} \geq 1.0$$

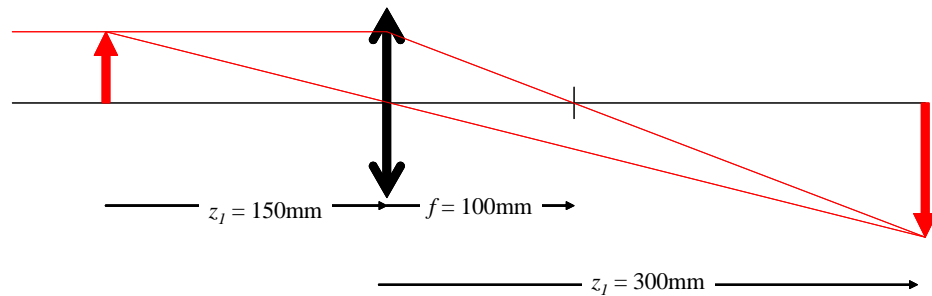
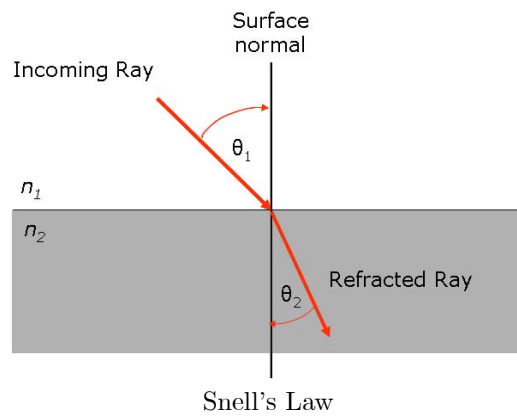
$$c \cong 3 \times 10^8 \frac{\text{m}}{\text{s}}$$

$$\text{for glass, } n \cong 1.5 \quad (1.4 \leq n \leq 1.6)$$

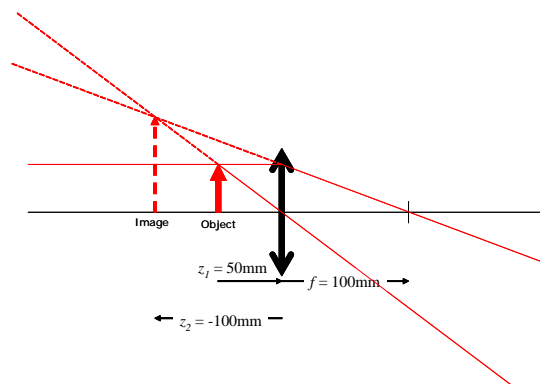
$$\text{for water, } n \cong 1.33 \cong \frac{4}{3}$$

Snell's law :

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



Real image from positive lens if $z_1 > f$, $z_2 > f$. Image is inverted and magnified



Virtual image from positive lens if $z_1 < f$, $z_2 < 0$: (magnifying glass), upright magnified image.

Can also image with mirrors, but we did not cover this in much detail.

4. Sensor (detector): human eye (will be covered in detail in link #8), photochemical (photographic film) or photoelectronic (e.g., CCD or CMOS sensor), pixels, resolution, how CCDs work (bucket brigade and counting electrons), sources of defects in CCD images (thermal “noise,” bad pixels creating bad lines in image)
5. Image Processing: creating image from sensor (i.e., developing the image from an emulsion), changing the values in the image to reduce noise or enhance edges. Histograms, used to enhance (“stretch”) contrast; *local averaging* to reduce noise, but blurs edges; *local differencing* to enhance edges but also enhance noise; *image sharpening* to enhance edges while retaining gray values of objects, while enhancing noise.
6. Compression, storage, transmission: “quantity” of data in digital image (= Number of Rows \times Number of Columns \times Number of bits per pixel), *bandwidth* = number of pixels per second $\div 2$ *compression* reduces the number of bits by discarding some data. In many images, can discard some data in ways that allow full recovery of data – lossless (error-free) compression. Often discard data that eye cannot easily see (subjectively lossless compression), may also discard data that can be seen – lossy compression. Transmission: video, convert 2-D time-varying signal to 1-D time-varying signal by *raster scanning*, transmit and reconstruct at receiver. Transmit black-and-white image with full resolution and color channels with only partial resolution. JPEG compression (divide image into blocks, different coding for each block, human visual system is less sensitive to mistakes in “busy” regions, less data is needed in “smooth” regions)
7. (yet to be covered, not on this test) Displays
8. (yet to be covered, not on this test) Perception

Applications of imaging systems

1. photographs
2. medical X rays
3. weather satellites
4. surveillance
5. astronomical imaging
6. television
7. ...