Problem 1

An object of size $h$ (the vertical arrow) is at a distance 5 cm from a concave mirror (focal length $f = 10$ cm).

a) Calculate the image distance. What is the size of the image in terms of $h$? Specify if the image is upright or inverted, real or virtual. [2 points]

\[ d_o = 5; \quad f = +10 \]
\[ \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{10} - \frac{1}{5} = \frac{-1}{10} \Rightarrow d_i = -10 \text{ cm} \]

Image is virtual and upright.

b) Sketch two rays to justify your answers in part a) [2 points]

(see above) Any 2 of following:

Ray 1 goes through C (center of curvature)

Ray 2 is incident parallel to axis, on reflection goes parallel to axis after reflection through F.

b) The object is moved to the left away from the mirror until it is at a great distance (say 1000 m). Where is the new image? [2 points]

As $d_o \to \infty$

\[ d_i \to f \]
Problem 2

All the sunlight incident (normally) on a large concave mirror is focussed on a cup of water. The average intensity $\bar{S}$ of the light (before it hits the mirror) is $1000 \text{ W/m}^2$. The area $A$ of the mirror equals $3 \text{ m}^2$. [Some universal constants: $c = 3 \times 10^8 \text{ m/s}$, $\varepsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$, $\mu_0 = 4\pi \times 10^{-7} \text{ Tm/A}$, $e = 1.6 \times 10^{-19} \text{ C}$.]

a) How much energy (in Joules) is delivered to the water in 5 seconds? [2 points]

$$\bar{S} = 1000 \text{ W/m}^2$$

Power incident $P = \bar{S} A = 3000 \text{ W}$

In 5 s., energy delivered $U = 3000 \times 5 = 15,000 \text{ J}$. 

b) What is the maximum value of the electric field $E$ in the sunbeam just before it hits the collecting mirror? [2 points]

$$\bar{S} = \frac{1}{2} \varepsilon_0 c E_0^2$$

$$E_0 = \sqrt{\frac{2\bar{S}}{\varepsilon_0 c}} = \sqrt{8.68} \frac{N}{C}$$

$$\bar{S} = \varepsilon_0 c E_{rms}^2 \rightarrow E_{rms} = 614 \frac{N}{C} \text{ acceptable as well}$$

Rewrite and sign the Honor Pledge: "I pledge my honor that I have not violated the Honor Code during this examination."