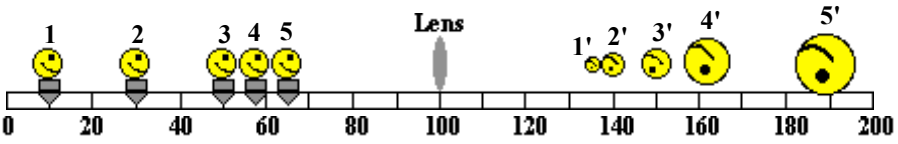
Magnification Lab

Some students are doing a lab to quantify the dependence of the magnification of an image upon the object distance and the focal length of a lens. The **object distance (d_o)** is the distance between an object and the lens. The focal length provides a measure of how curved a lens is; the more curved the lens is, the smaller the focal length. The **focal length (f)** is the distance from the focal point (**F**) to the lens. The **magnification (M)** of an image is the ratio of the image's height compared to the object's height. Magnification values are negative for inverted images.

The students mark a *smiley face* upon a light bulb and mount it along a 2-meter stick. They place the lens at the 100-cm mark. They project the image of the light bulb onto a sheet of paper and measure the image height (h_i). The set up is shown in **Figure 1**. The object and image positions are labeled. Object positions 1, 2, 3, 4, and 5 result in images 1', 2', 3', 4' and 5'. The results for several trials with three different focal lengths are shown in **Table 1**.

Figure 1



(The divisions on the 2-meter stick are10-cm apart; every 20-cm is labeled.)

Table 1

f = 10 cm		
d_o (cm)	h_i (cm)	| M |
40.0	1.1	0.39
35.0	1.2	0.43
30.0	1.4	0.50
25.0	2.0	0.71
20.0	2.8	1.00
15.0	5.6	2.00
17.0	3.6	1.29
23.0	2.1	0.75
12.0	8.9	3.18

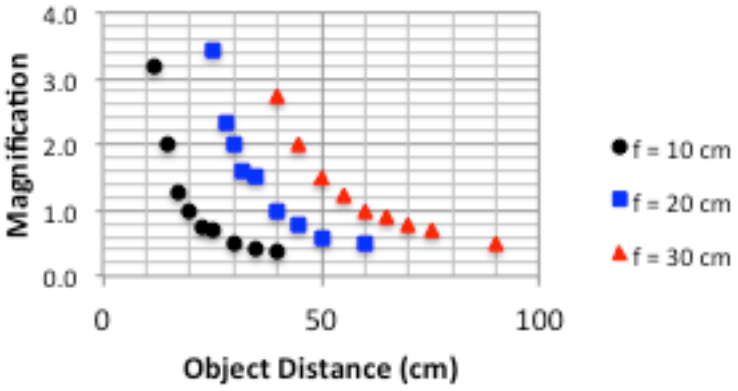
f = 20 cm		
d_o (cm)	h_i (cm)	| M |
50.0	1.6	0.57
45.0	2.2	0.79
40.0	2.8	1.00
35.0	4.3	1.54
30.0	5.6	2.00
25.0	9.6	3.43
28.0	6.5	2.32
32.0	4.5	1.61
60.0	1.4	0.50

f = 30 cm		
d_o (cm)	h_i (cm)	| M |
40.0	7.7	2.75
45.0	5.6	2.00
50.0	4.2	1.50
55.0	3.4	1.21
60.0	2.8	1.00
65.0	2.5	0.89
70.0	2.2	0.79
75.0	2.0	0.71
90.0	1.4	0.50

The students plotted their values of magnification versus object distance for the three different lenses. The plot is shown in **Figure 2**.

Use the data and plot to answer the next several questions.

Figure 2



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Questions:

1. Based on **Figure 1**, how does the distance from the image to the lens change as the object moves closer to the lens?
   a. The image distance increases as the object moves closer to the lens.
   b. The image distance decreases as the object moves closer to the lens.
   c. The image distance is not affected by changes in the distance from object to lens.
   d. The object distance first decreases and then increases as the object moves closer to the lens.

2. What is the object distance for object position 2 in **Figure 1**?
   a. 25 cm
   b. 30 cm
   c. 70 cm
   d. 75 cm

3. What is the image distance when the object is placed at position 1 in **Figure 1**?
   a. 10 cm
   b. 33 cm
   c. 90 cm
   d. 133 cm

4. At what object position in **Figure 1** is the image the same size as the object?
   a. Object position 1
   b. Object position 2
   c. Object position 3
   d. Object position 4
   e. Object position 5

5. Based on **Table 1**, what focal length would cause the image of the bulb to be the same size as the bulb when the bulb is placed 60.0 cm from the lens?
   a. A 10 cm focal length.
   b. A 20 cm focal length.
   c. A 30 cm focal length.
   d. None of the lenses would do this.

6. Suppose that a lens has a 40.0 cm focal length. Where must the object be placed in order for the image to be the same size as the object?
   a. The object must be placed 20.0 cm from the lens.
   b. The object must be placed 40.0 cm from the lens.
   c. The object must be placed 80.0 cm from the lens.
   d. This will occur if the object is placed any distance greater than 40.0 cm from the lens.

7. Based on **Table 1**, what focal length would cause the image of the bulb to be magnified by a factor of 2.0 when the bulb is placed 45.0 cm from the lens?
   a. A 10 cm focal length.
   b. A 20 cm focal length.
   c. A 30 cm focal length.
   d. None of the lenses would do this.

8. Use the information in **Table 1** to summarize a generic rule that states how far from a lens that an object must be placed in order to produce an inverted image that is magnified by a factor of two.
   a. The object must be placed 1.5 focal lengths from the lens.
   b. The object must be placed 2.0 focal lengths from the lens.
   c. The object must be placed 3.0 focal lengths from the lens.
   d. No such rule can be made since the distance varies with the focal length.

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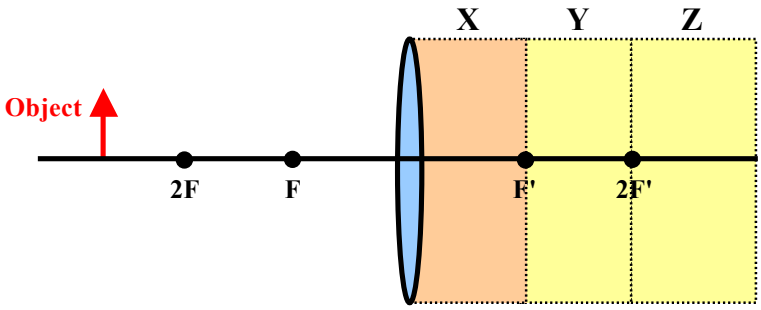
9. Based on **Table 1**, what focal length would cause the image of the bulb one-half the size as the object when the bulb is placed 90.0 cm from the lens?
   a. A 10 cm focal length.
   b. A 20 cm focal length.
   c. A 30 cm focal length.
   d. None of the lenses would do this.

10. What object distance would result in the formation of an image with a magnification (absolute value) of 2.0 when placed in front of a lens with a 30-cm focal length?
   a. 30 cm
   b. 45 cm
   c. 60 cm
   d. 90 cm

11. Based on **Table 1**, what object distance would result in the formation of an image with a magnification (absolute value) of 3.0 when placed in front of a lens with a 20-cm focal length?
   a. Approximately 26 cm
   b. Approximately 42 cm
   c. Approximately 60 cm
   d. Approximately 360 cm

12. What is the magnification (absolute value) of the image when the object distance is equal to *three focal lengths*?
   a. The magnification is 0.5.
   b. The magnification is 1.0.
   c. The magnification is 2.0.
   d. The magnification depends on the focal length.

13. The diagram below shows a lens with a marked focal point (**F**), a second marked point twice as far away from the lens (**2F**), and an object. The points **F'** and **2F'** on the right side of the lens are the same distance from the lens as points **F** and **2F**. Three regions are marked on the opposite side of the lens.



Which one of the following statements correctly describes the image if point **F** were 20 cm from the lens?
   a. The image is located in **Region X**, and has an | M | value greater than 1.0.
   b. The image is located in **Region Y**, and has an | M | value less than 1.0.
   c. The image is located in **Region Z**, and has an | M | value greater than 1.0.
   d. The image is at the boundary of **Region Y** and **Z**, and has an | M | value equal to 1.0.

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