Physics 220 2016	Optics Worksheet #1

(1) Suppose a converging lens has a focal length of f=10 cm, and an object of height 1 cm is placed in front of the lens at 5 cm. Characterize the resulting image.

(2) Suppose a converging lens has a focal length of f=10 cm, and an object of height 1 cm is placed in front of the lens at 15 cm. Characterize the resulting image.

(3) Suppose a converging lens has a focal length of f=10 cm, and an object of height 1 cm is placed in front of the lens at 10 cm. Characterize the resulting image.

(4) Show how to find the focal length of a converging lens in the absolute simplest way possible.

(5) Suppose a diverging lens has a focal length of f=10 cm, and an object of height 1 cm is placed in front of the lens at 10 cm. Characterize the resulting image.

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(1) Suppose a converging lens has a focal length of f=10 cm, and an object of height 1 cm is placed in front of the lens at 5 cm. Characterize the resulting image.

Solution: The thin lens equation says $\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$. Since the lens is converging, the sign of f is positive. We also have that s=+5 cm since the object is on the object side of the lens (it is a single lens system). We can then find s': $\frac{1}{s'}=\frac{1}{f}-\frac{1}{s}=\frac{1}{10}-\frac{1}{5}=\frac{1-2}{10}=\frac{-1}{10}$. So, s'=-10 cm which means it is on the object side of the lens. The magnification of the image is given by M=-s'/s=-(-10/5)=+2. We thus have the important characterization for the image: We find then that the final height of the image is +2 cm.

(a) it is upright (M>0)

(b) it is enlarged (|M|>1)

(c) The image is VIRTUAL since the image distance is negative.

(2) Suppose a converging lens has a focal length of f=10 cm, and an object of height 1 cm is placed in front of the lens at 15 cm. Characterize the resulting image.

Solution: The thin lens equation says $\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$. Since the lens is converging, the sign of f is positive. We also have that s=+15 cm since the object is on the object side of the lens (it is a single lens system). We can then find s': $\frac{1}{s'}=\frac{1}{f}-\frac{1}{s}=\frac{1}{10}-\frac{1}{15}=\frac{3-2}{30}=+\frac{1}{30}$. So s'=+30 cm. The magnification of the image is given by M=-s'/s=-30/15=-2. We thus have the important characterization for the image: we find that the final height of the image is -2 cm.

(a) it is inverted (M<0)

(b) it is enlarged (|M|>1)

(c) The image is REAL since the image distance is positive.

(3) Suppose a converging lens has a focal length of f=10 cm, and an object of height 1 cm is placed in front of the lens at 10 cm. Characterize the resulting image.

Solution: The thin lens equation says $\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$. Since the lens is converging, the sign of f is positive. We also have that s=+10 cm since the object is on the object side of the lens (it is a single lens system). We can then find s': $\frac{1}{s'}=\frac{1}{f}-\frac{1}{s}=\frac{1}{10}-\frac{1}{10}=0$. This means that s' is infinite (1/0). Therefore the only possible conclusion is that no image forms. The magnification is also infinite. We can't really say positive or negative, real or virtual here.

(4) Show how to find the focal length of a converging lens in the absolute simplest way possible.

Solution: The thin lens equation says $\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$. In the previous problem we saw that if the object was placed at the focal length, then no image resulted (or, the image distance was infinite). Let's view this the other way around. Suppose you have a point source of light at infinity (perhaps a star will suffice). Then 1/s=0 So s'=f. You will find an image focuses at the focal length of the lens. Thus, a very quick way of finding f for a converging lens is to find out where a distant image focuses.

(5) Suppose a diverging lens has a focal length of f=10 cm, and an object of height 1 cm is placed in front of the lens at 10 cm. Characterize the resulting image.

Solution: The thin lens equation says $\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$. Here, since the lens is diverging, the focal length is negative. Since this is a single lens system s is positive. We can now put this into the thin lens equation: $\frac{1}{s'}=\frac{1}{f}-\frac{1}{s}=\frac{-1}{10}-\frac{1}{10}=-\frac{2}{10}=-\frac{1}{5}$. Thus, s'=-5 cm. The magnification of the image is given by M=-(-5/10)=+1/2. We then have the characterization of the image:
(a) the image is upright (M>0)
(b) the image is reduced (|M|<1)
(c) the image is virtual (s'<0)

Notice the amazing results: there are 3 cases that can happen for the converging lens but only one thing can happen for the diverging lens, so long as we are dealing with single lens system.

This next part is important for lab!
Now if you have a virtual object at s=-5 cm, what happens?
Then, we have: $\frac{1}{s'}=\frac{1}{f}-\frac{1}{s}=-\frac{1}{10}-\frac{1}{-5}=-\frac{1}{10}+\frac{2}{10}=+\frac{1}{10}\Rightarrow s'=+10$
The magnification is $M=-\frac{s'}{s}=-\frac{10}{-5}=+2$
(a) the image is upright (M>0)
(b) the image is enlarged (|M|>1)
(c) the image is real (s'>0)

How can you create a virtual object? The answer: use a converging lens first. the image from the converging lens is projected behind a second lens and thus acts as the object for a second lens. This is why I can say that for single lens systems, the object distance is always positive.