	Physics 220: Worksheet 20	Name: ________________

(1) A lens produces a virtual image of an object which is upright and 2 cm high when a 1 cm high object is placed 20 cm from the lens. What is the focal length of the lens and what is the image position?

(2) A lens produces a real image of an object which is inverted and 2 cm high when a 1 cm high object is placed 20 cm from the lens. What is the focal length of the lens and what is the image position?

(3) Some examples of virtual objects:
Suppose a virtual object is located 10 cm behind a diverging lens with a focal length of 5 cm. Characterize the resulting image.

(4) Suppose a virtual object is located 10 cm behind a converging lens with a focal length of 5 cm. Characterize the resulting image.

(5) Where must an object be located if a real image at 10 cm results from a diverging lens with a focal length of 15 cm? Characterize the resulting image if the object is upright.

(6) An object moves from a point s_0 to s_1 in front of a converging lens of focal length f (s_0>f and s_1>f). What is the distance that the image moves through? As an example, calculate this for f=10 cm, s_0=40 cm and s_1=20 cm.

	Physics 220: Worksheet 20	Name: ________________

(1) A lens produces a virtual image of an object which is upright and 2 cm high when a 1 cm high object is placed 20 cm from the lens. What is the focal length of the lens and what is the image position?

$M = \frac{h'}{h} = +2 = -\frac{s'}{s} = -\frac{s'}{+20} \Rightarrow s' = -40$

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \Rightarrow \frac{1}{+20} - \frac{1}{40} = \frac{2-1}{40} = \frac{1}{40} = \frac{1}{f} \Rightarrow f = +40\,\text{cm}$

Notice that it’s not possible here to have a real image in this situation.

(2) A lens produces a real image of an object which is inverted and 2 cm high when a 1 cm high object is placed 20 cm from the lens. What is the focal length of the lens and what is the image position?

$M = \frac{h'}{h} = -2 = -\frac{s'}{s} = -\frac{s'}{+20} \Rightarrow s' = +40$

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \Rightarrow \frac{1}{+20} + \frac{1}{+40} = \frac{2+1}{40} = \frac{3}{40} = \frac{1}{f} \Rightarrow f = +\frac{40}{3} = +13.3\,\text{cm}$

(3) Some examples of virtual objects:
Suppose a virtual object is located 10 cm behind a diverging lens with a focal length of 5 cm. Characterize the resulting image.

Since the object is virtual, we have $s = -10\,\text{cm}$. This could have been created as the result of a second lens. Now we can find the image position from the thin lens equation:

$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{-5} - \frac{1}{-10} = -\frac{2}{10} + \frac{1}{10} = -\frac{1}{10} \Rightarrow s' = -10\,\text{cm}$

$M = -\frac{s'}{s} = -\frac{-10}{-10} = -1$

The image is : $\left[\text{virtual} : \text{unmagnified} : \text{inverted}\right]$

(4) Suppose a virtual object is located 10 cm behind a converging lens with a focal length of 5 cm. Characterize the resulting image.

$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{+5} - \frac{1}{-10} = \frac{2}{10} + \frac{1}{10} = +\frac{3}{10} \Rightarrow s' = +\frac{10}{3} = +3.33\,\text{cm}$

$M = -\frac{s'}{s} = -\frac{+3.33}{-10} = +0.333$

The image is : $\left[\text{real} : \text{reduced} : \text{upright}\right]$

(5) Where must an object be located if a real image at 10 cm results from a diverging lens with a focal length of 15 cm? Characterize the resulting image if the object is upright.

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \Rightarrow \frac{1}{s} = \frac{1}{f} - \frac{1}{s'} = \frac{1}{-15} - \frac{1}{+10} = \frac{-2-3}{30} = -\frac{5}{30} = -\frac{1}{6} \Rightarrow s = -6\,\text{cm}$

$M = -\frac{s'}{s} = -\frac{+10}{-6} = +1.67$

The image is: $\left[\text{real} : \text{enlarged} : \text{upright}\right]$

(6) An object moves from a point s_0 to s_1 in front of a converging lens of focal length f (s_0>f and s_1>f). What is the distance that the image moves through? As an example, calculate this for f=10 cm, s_0=40 cm and s_1=20 cm.

$$\frac{1}{s_0}+\frac{1}{s'}=\frac{1}{f}\Rightarrow\frac{1}{{}_0s'}=\frac{1}{f}-\frac{1}{s_0}\Rightarrow\frac{1}{{}_0s'}=\frac{s_0-f}{fs_0}\Rightarrow{}_0s'=\frac{fs_0}{s_0-f}$$

$$\frac{1}{s_1}+\frac{1}{s'}=\frac{1}{f}\Rightarrow{}_1s'=\frac{fs_1}{s_1-f}$$

$$\Rightarrow\Delta s'={}_1s'-{}_0s'=\frac{fs_1}{s_1-f}-\frac{fs_0}{s_0-f}=f\left[\frac{s_1s_0-s_1f-s_1s_0+s_0f}{[s_1-f][s_0-f]}\right]=\frac{f^2[s_0-s_1]}{[s_1-f][s_0-f]}$$

Suppose f=10 cm, s_0=40 cm and s_1=20 cm. Then

$$\Delta s'=100\frac{20}{30(10)}=\frac{2000}{300}=+\frac{20}{3}\text{cm}=+6.67\,\text{cm}$$

Calculating the individual image positions here, however, is probably the safest way to approach this type of problem.

$$\frac{1}{{}_0s'}=\frac{1}{10}-\frac{1}{40}=\frac{4-1}{40}=+\frac{3}{40}\Rightarrow{}_0s'=+13.33\,\text{cm}$$

The first image is located at: $\frac{1}{{}_1s'}=\frac{1}{10}-\frac{1}{20}=\frac{2-1}{20}=+\frac{1}{20}\Rightarrow{}_1s'=+20\,\text{cm}$

$$\Rightarrow\Delta s'=[20-13.33]=+6.67\,\text{cm}$$

You can recognize that the image moves away from the lens (this is the positive direction) since as you approach the focal point of a lens, the image forms at infinity (it actually does not, therefore form).