2016	Physics **250:** 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 is at a distance s_0 from a converging lens of focal length f (s_o>f). The object is moving towards the lens with a speed v. How fast is the point at which the image would form be moving at all times?

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(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?

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

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?

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

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

(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 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:

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

The image is : [virtual: unmagnified: inverted]

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

$$\frac{1}{s'}=\frac{1}{f}-\frac{1}{s}=\frac{1}{+5}-\frac{1}{-10}=\frac{2}{10}+\frac{1}{10}=+\frac{3}{10}\Rightarrow s'=+\frac{10}{3}=+3.33\,cm:M=-\frac{s'}{s}=-\frac{+3.33}{-10}=+0.333$$

The image is : [real: reduced: upright]

(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.

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

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

The image is: [real : enlarged: upright].

(6) An object is at a distance s_0 from a converging lens of focal length f (s_o>f). The object is moving towards the lens with a speed v. How fast is the point at which the image would form be moving at all times?

$$\frac{1}{s'}=\frac{1}{f}-\frac{1}{s}=\frac{s_0-vt-f}{f(s_0-vt)}\Rightarrow s'=\frac{f(s_0-vt)}{s_0-vt-f}$$

The speed of the image is given by:

$$v'=\frac{ds'}{dt}=\frac{f(-v)}{s_0-vt-f}-\frac{f(s_0-ve)}{(s_0-vt-f)^2}(-v)=-\frac{fv}{[s_0-vt-f]}\left[1-\frac{s_0-vt}{s_0-vt-f}\right]=\frac{f^2v}{[s_0-vt-f]^2}$$

At one point, this speed will be infinite. There is not really any information contained in this fact so it does not violate relativity. I have, however, been very careful with my words in the statement of this problem. When does the speed become infinite?

This is when

$$s_0-vt-f=0\Rightarrow vt=s_0-f\Rightarrow t=\frac{s_0-f}{v}$$

What is the object location at this time?

$$s=s_0-vt=s_0-v\left(\frac{s_0-f}{v}\right)=s_0-s_0+f=f$$

.

When the object reaches the focal length, the point at which the image forms would move infinitely fast (it would take light a while to catch up with this point).