Optics and Images

Lenses and Mirrors

Optics and Images

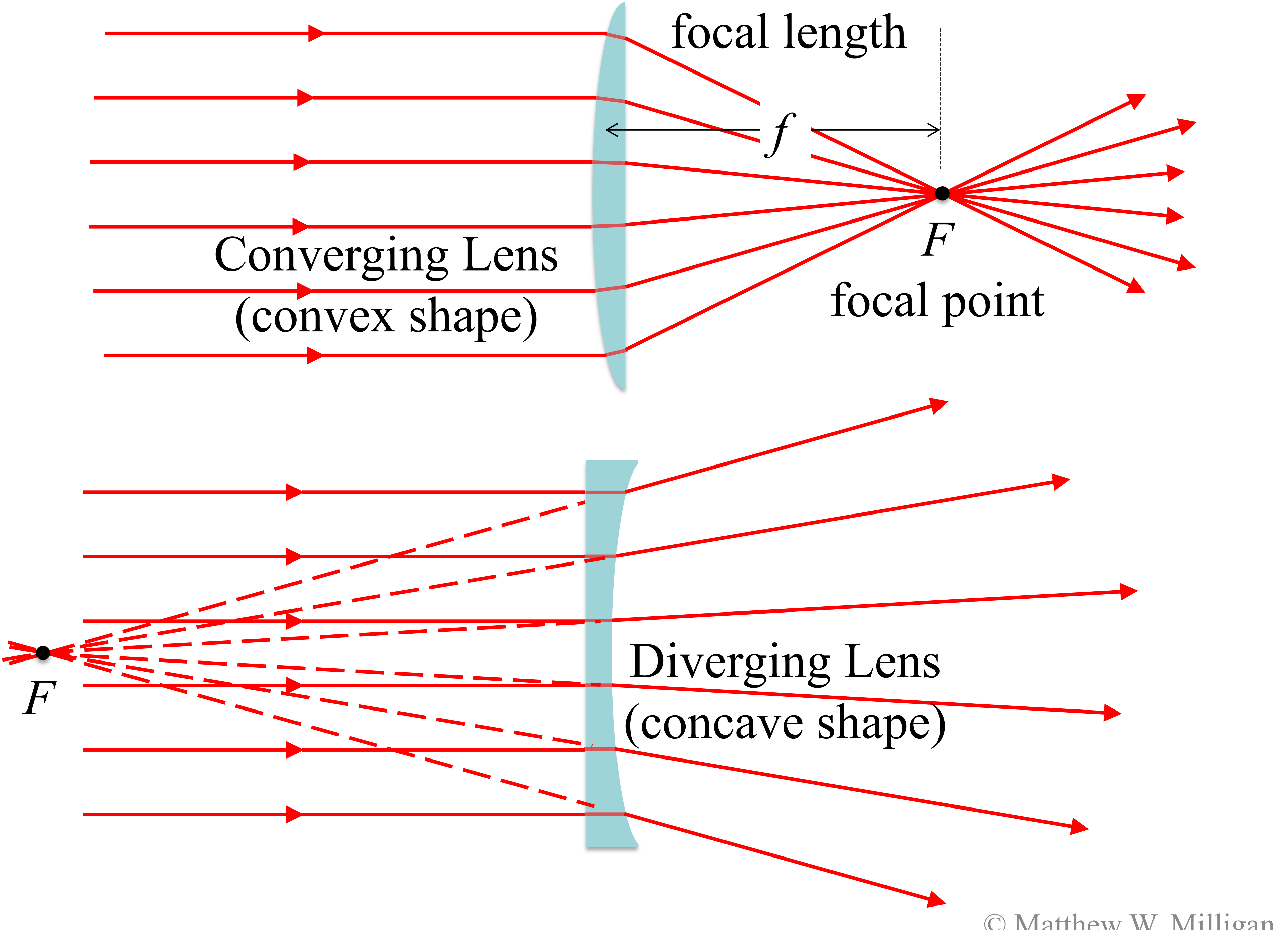
I. Reflection and Refraction
- Law of Reflection, Snell's Law
- index of refraction
- total internal reflection
- dispersion
- thin film interference

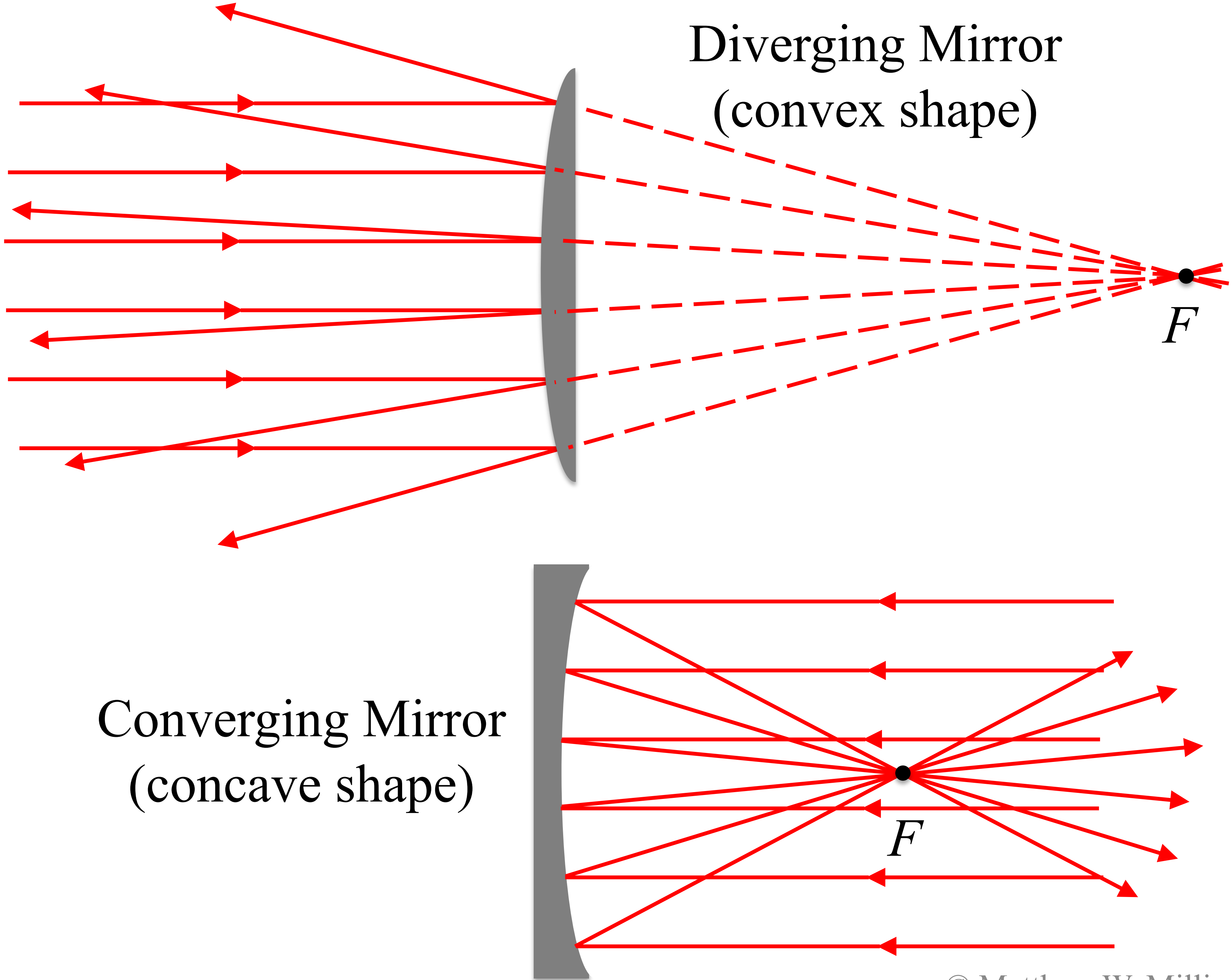
II. Lenses and Mirrors
- **formation of images**
- **equations: image vs. object**
- **ray diagrams**

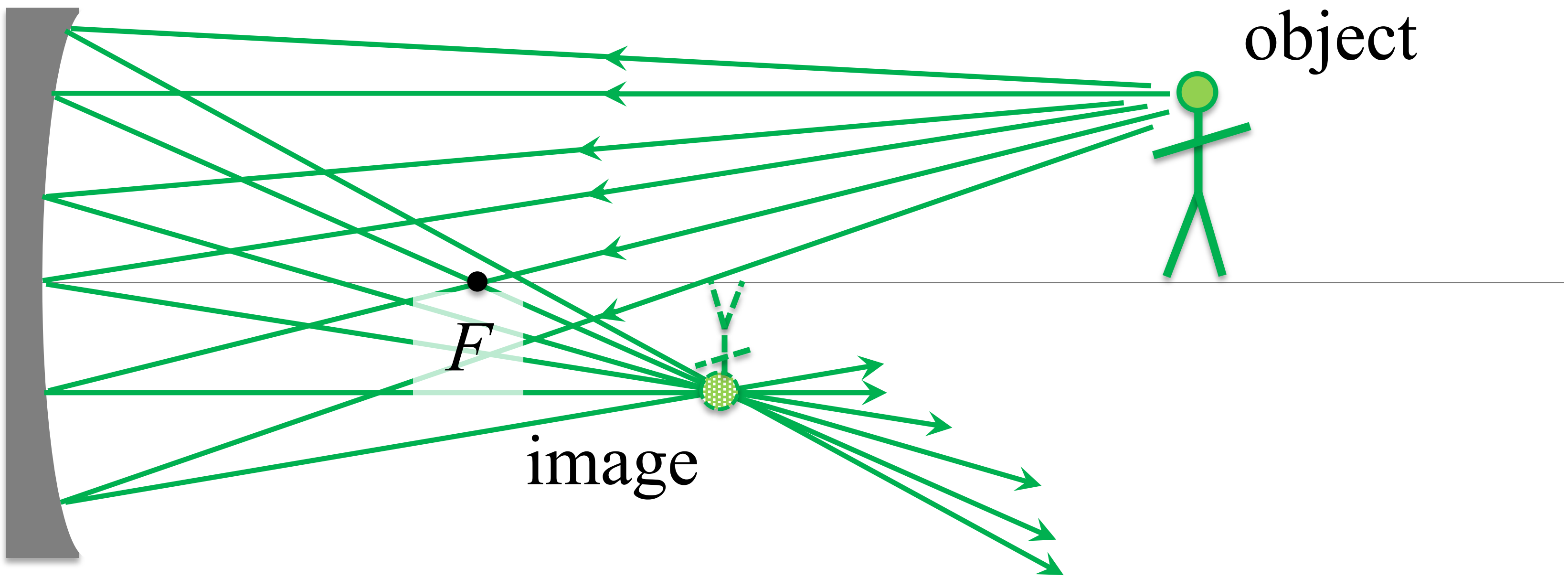
	The student will be able to:	HW:
1	State and apply laws of reflection and refraction, Snell’s Law, and solve related problems and/or describe qualitatively the phenomena of absorption, transmission, dispersion, and reflection of light undergoing a change in medium. ✓	1 – 7
2	Solve problems involving thin film interference by relating wavelength, film thickness, and indices of refraction to path difference and type of interference. ✓	8 – 10
3	Apply the ray model of light to explain and analyze formation of real and virtual images by plane, concave, and convex mirrors and solve related problems involving object and image distance, magnification, focal length and/or radius of curvature.	11 – 16
4	Apply the ray model of light to explain and analyze formation of real and virtual images by converging or diverging thin lenses and solve related problems involving object and image distance, magnification, focal length and/or radius of curvature.	17 – 23

Lenses and Mirrors – Commonalities

- Lenses and mirrors with curved surfaces can be used to form images of objects.
- Light from a very distant object is redirected by a lens or mirror such that there is a point of intersection called the focal point.
- A **converging** lens or mirror gathers light and causes it to converge and concentrate at the focal point.
- A **diverging** lens or mirror causes light to diverge and spread out, appearing to originate at the focal point.

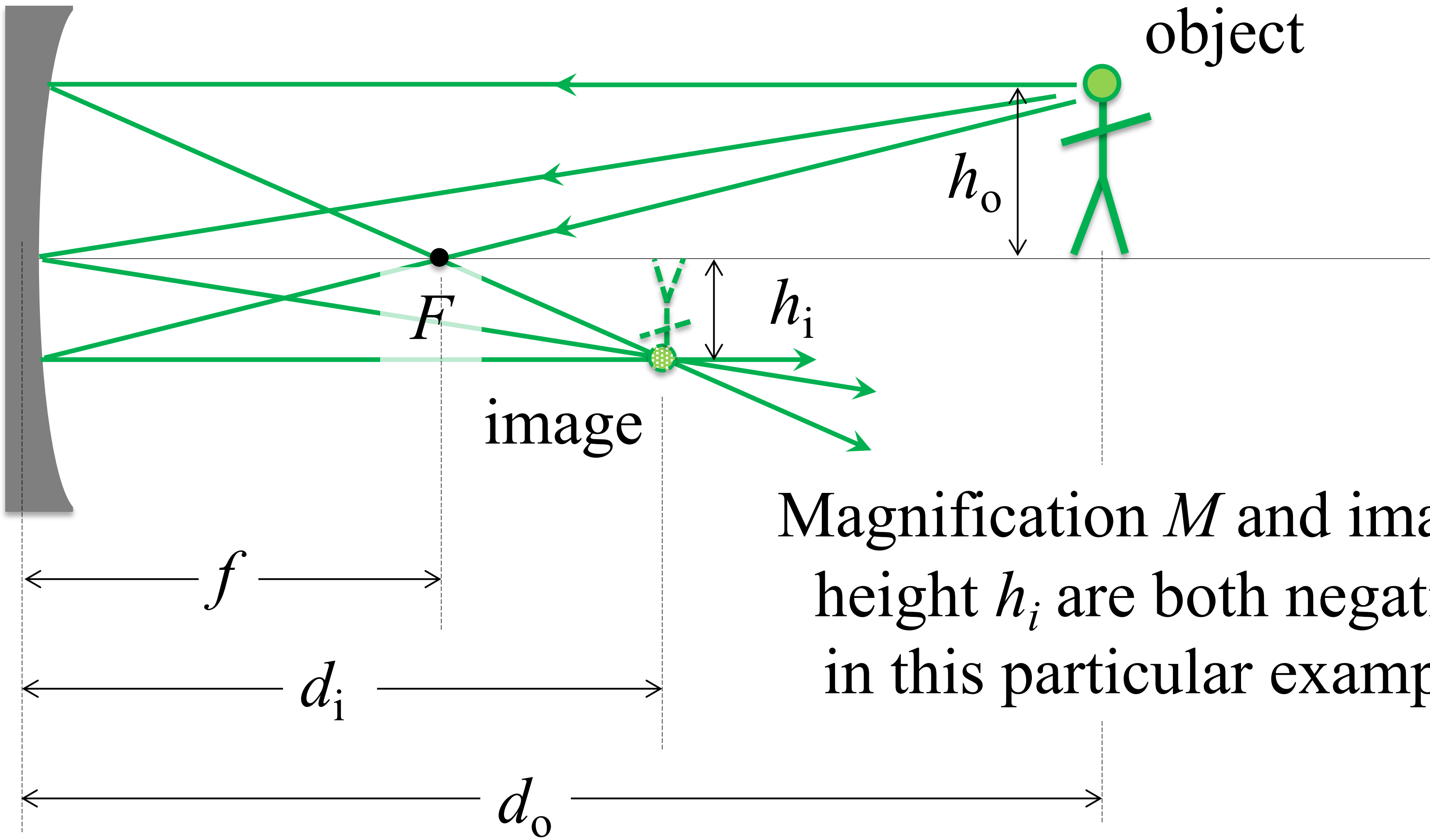

focal length
f
F
focal point
Converging Lens
(convex shape)
Diverging Lens
(concave shape)
F
© Matthew W. Milligan


Diverging Mirror
(convex shape)
F
Converging Mirror
(concave shape)
F



When the redirected rays of light actually converge and intersect, the resulting image can be projected onto a screen (and viewed that way) and it is referred to as a **real image**.

Image Formed by Concave Mirror



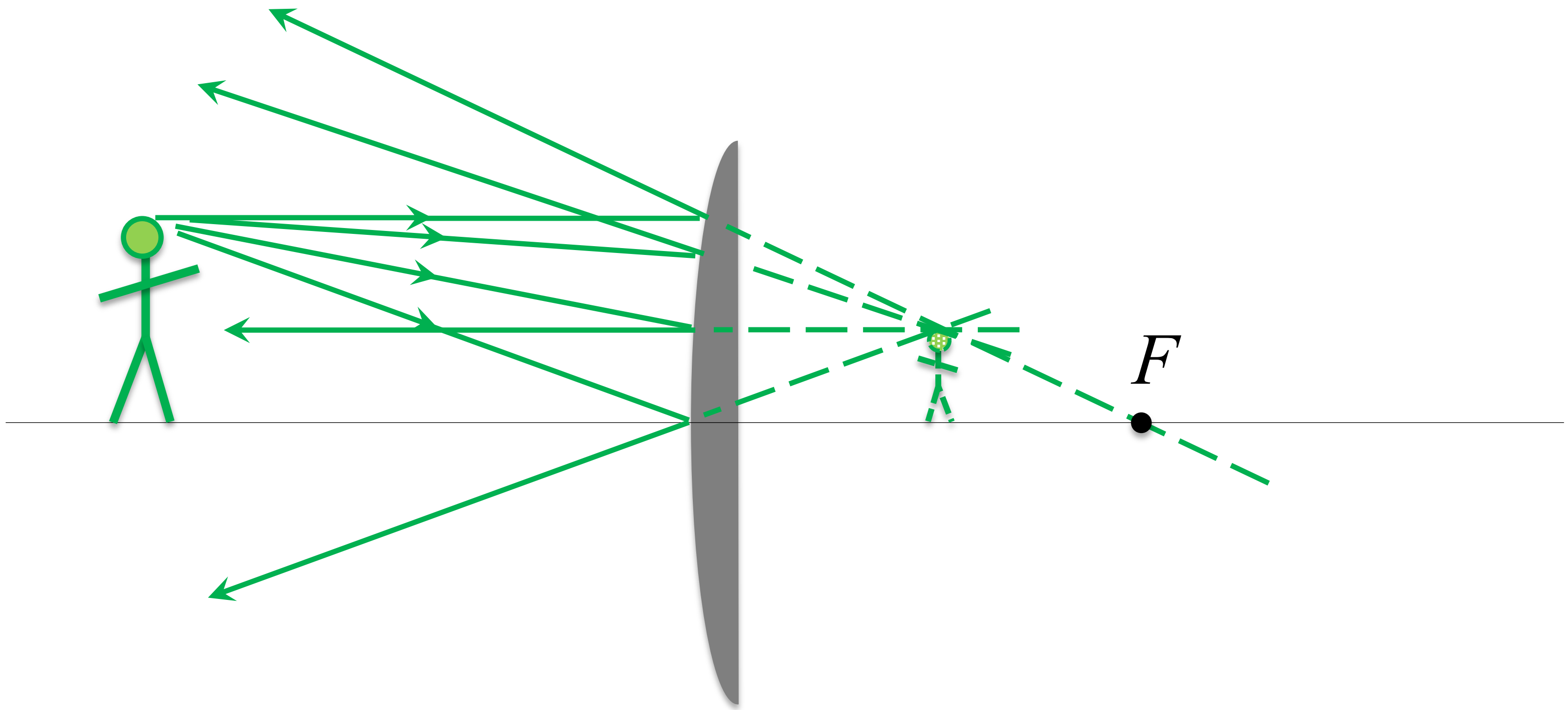
Magnification M and image height h_i are both negative in this particular example.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

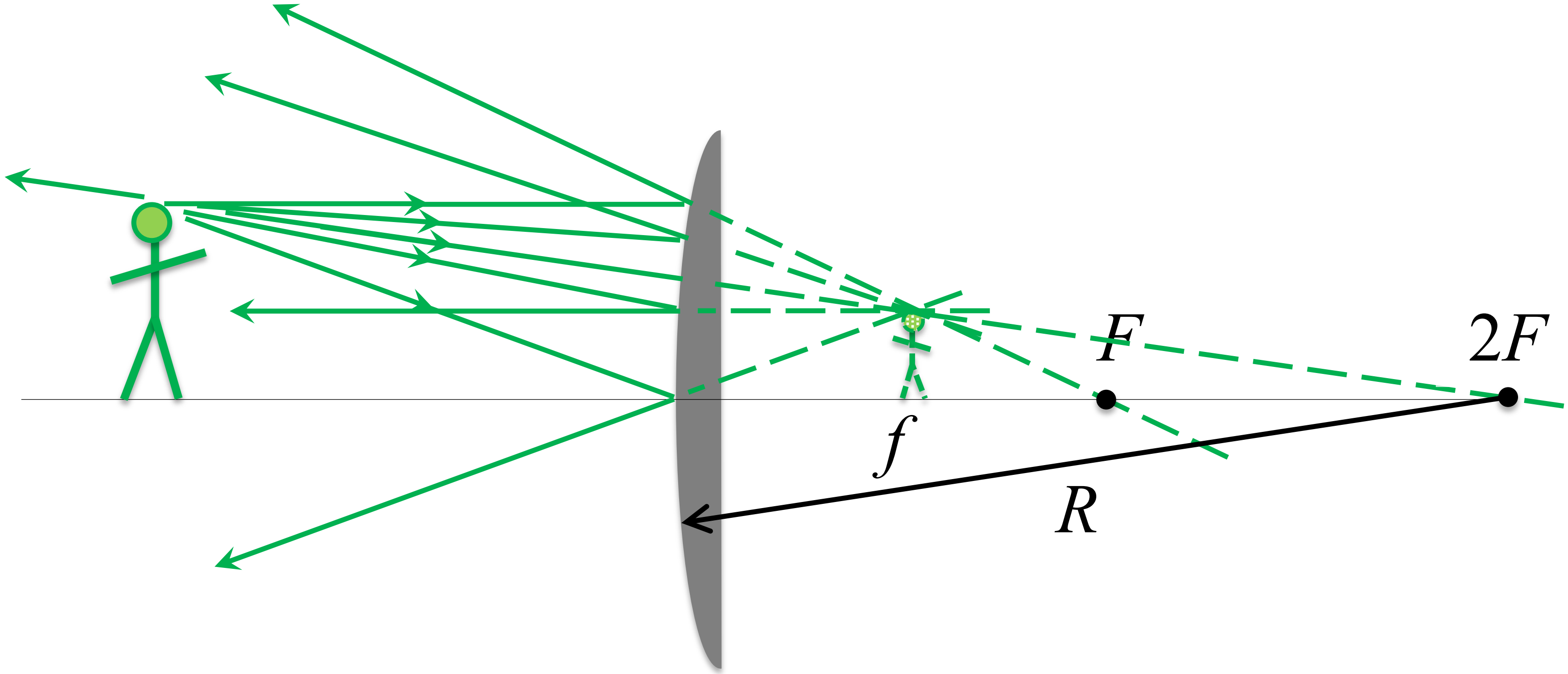
$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

Ray Diagrams – Mirrors

- A ray parallel to principle axis reflects through focus, ray through focus reflects parallel.
- A ray through a point at twice the focal length reflects in opposite direction. (For a spherical mirror this is the center of the sphere.)
- *Every* ray hitting *any* point follows law of reflection!



When the redirected rays of light do not actually converge or intersect the resulting image cannot be projected onto a screen (nor viewed that way) and it is referred to as a **virtual image**.



The point at twice the focal length aligns with rays that reflect off the surface in the opposite direction. For spherical mirrors this point is the center of the sphere and $f = \frac{1}{2} R$.

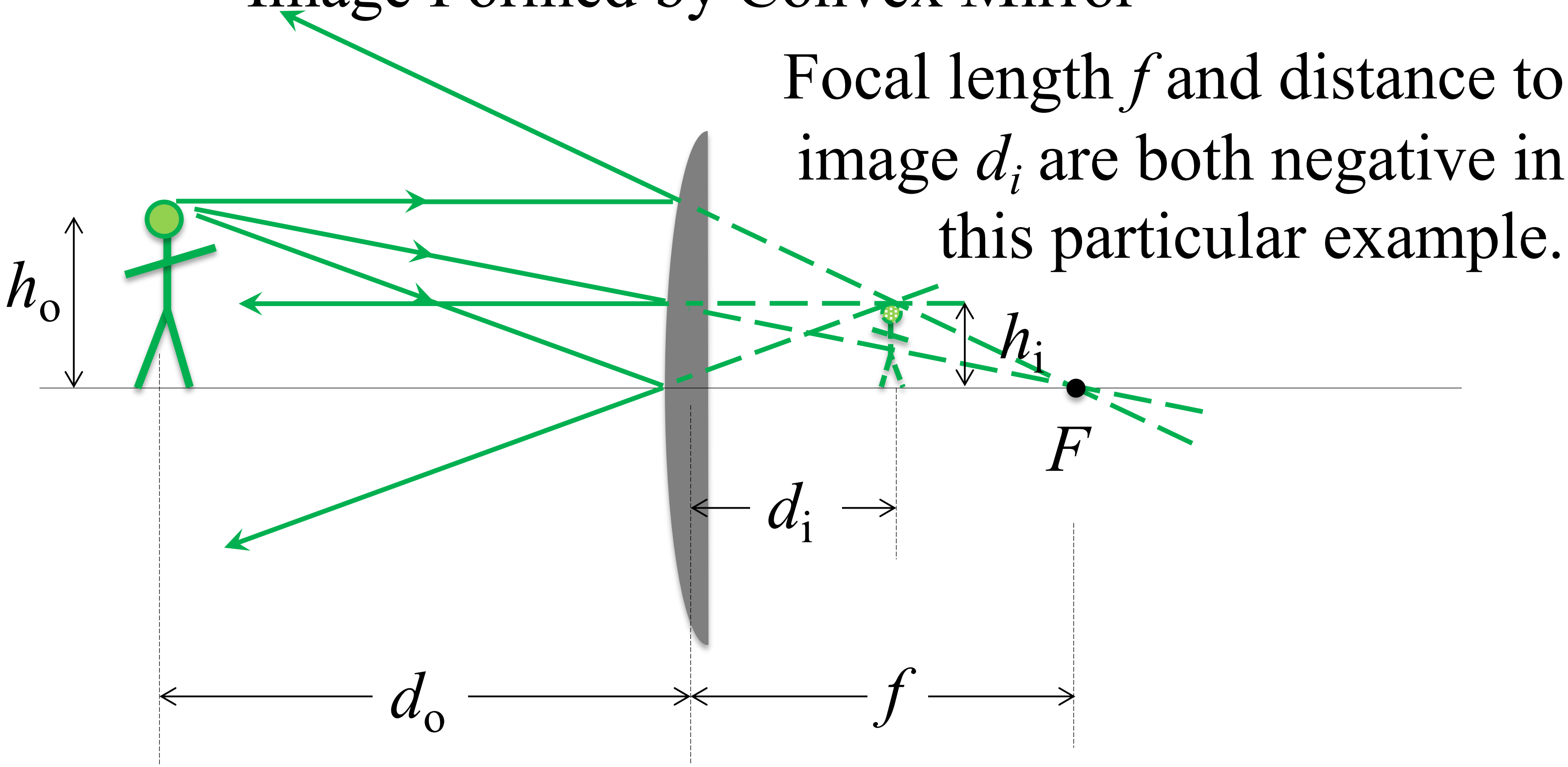
Equations Lenses and Mirrors

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

	quantity is *negative*...
d_o = distance to object	
d_i = distance to image	...for virtual images
h_o = height of object	
h_i = height of image	...if image is inverted
M = magnification	...for inverted images
f = focal length	...for diverging lens/mirror

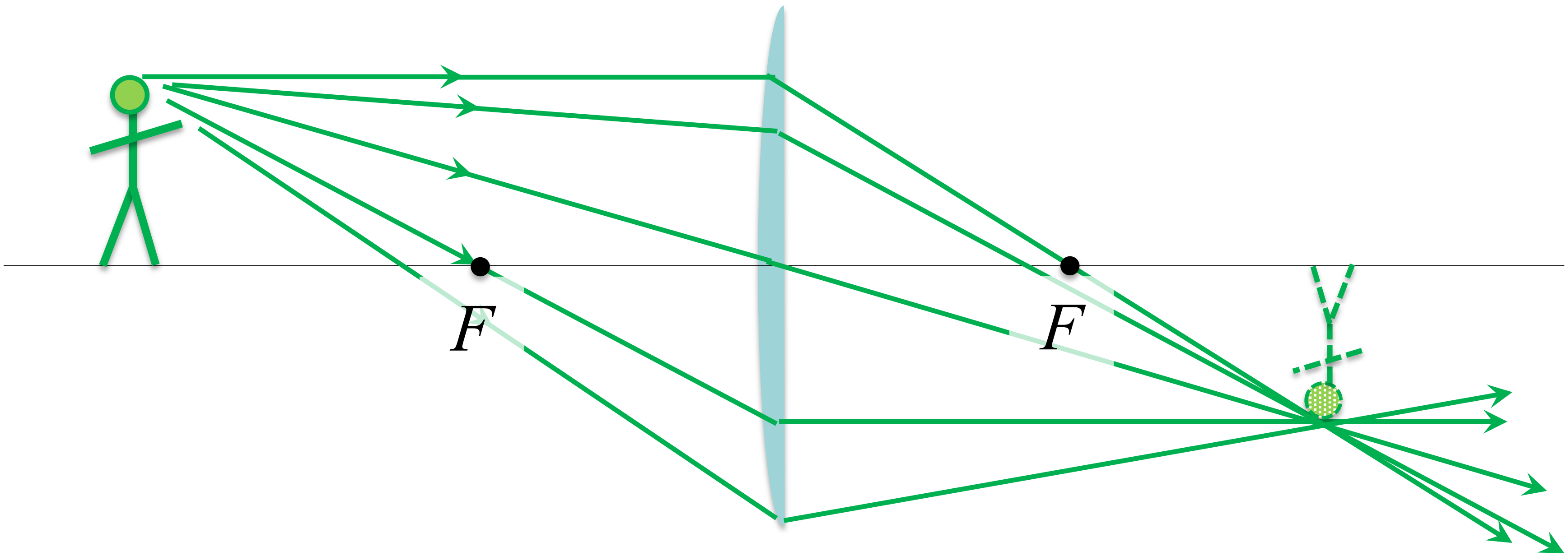
Image Formed by Convex Mirror



$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}$$

$$M=\frac{h_i}{h_o}=-\frac{d_i}{d_o}$$

	The student will be able to:	HW:
1	Model light and other types of electromagnetic radiation as a transverse wave of electric and magnetic fields and analyze graphs and/or functions to solve related problems and explain related phenomena such as polarization, absorption, production, intensity, etc.	✓ 1 – 5
2	Model diffraction and interference of light involving slits or gratings by Huygen's principle and analyze and solve problems relating geometry of openings to patterns of interference.	✓ 6 – 18
3	State and apply laws of reflection and refraction, Snell's Law, and solve related problems and/or describe qualitatively the phenomena of absorption, transmission, and reflection of light undergoing a change in medium.	✓ 19 – 25
4	Apply the ray model of light to explain and analyze formation of real and virtual images by plane, concave, and convex mirrors and solve related problems involving object and image distance, magnification, focal length and/or radius of curvature.	✓ 26 – 31
5	Apply the ray model of light to explain and analyze formation of real and virtual images by converging or diverging thin lenses and solve related problems involving object and image distance, magnification, and/or focal length.	32 – 38

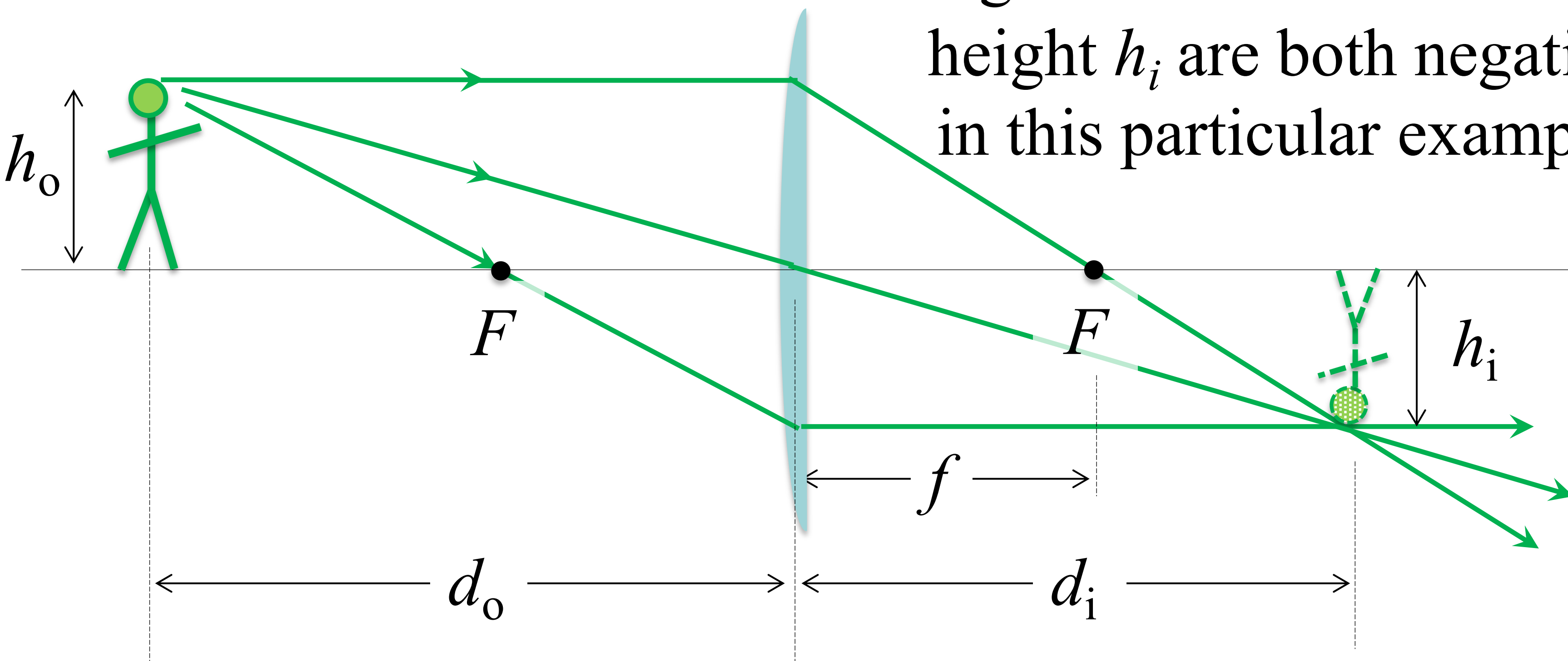

F
F

Ray Diagrams – Lenses

- Because light can travel through the lens in both directions there is a focal point on either side – the focal length is the same in either direction.
- A ray parallel to the principle axis is redirected through *one* focus, a ray through the *other* focus is redirected parallel.
- A ray through the center of the lens emerges with direction unchanged. (Because sides are parallel there.)
- *Every* ray hitting *any* part of the lens follows Snell's Law at each side of the lens!

Image Formed by Convex Lens

Magnification M and image height h_i are both negative in this particular example.



$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

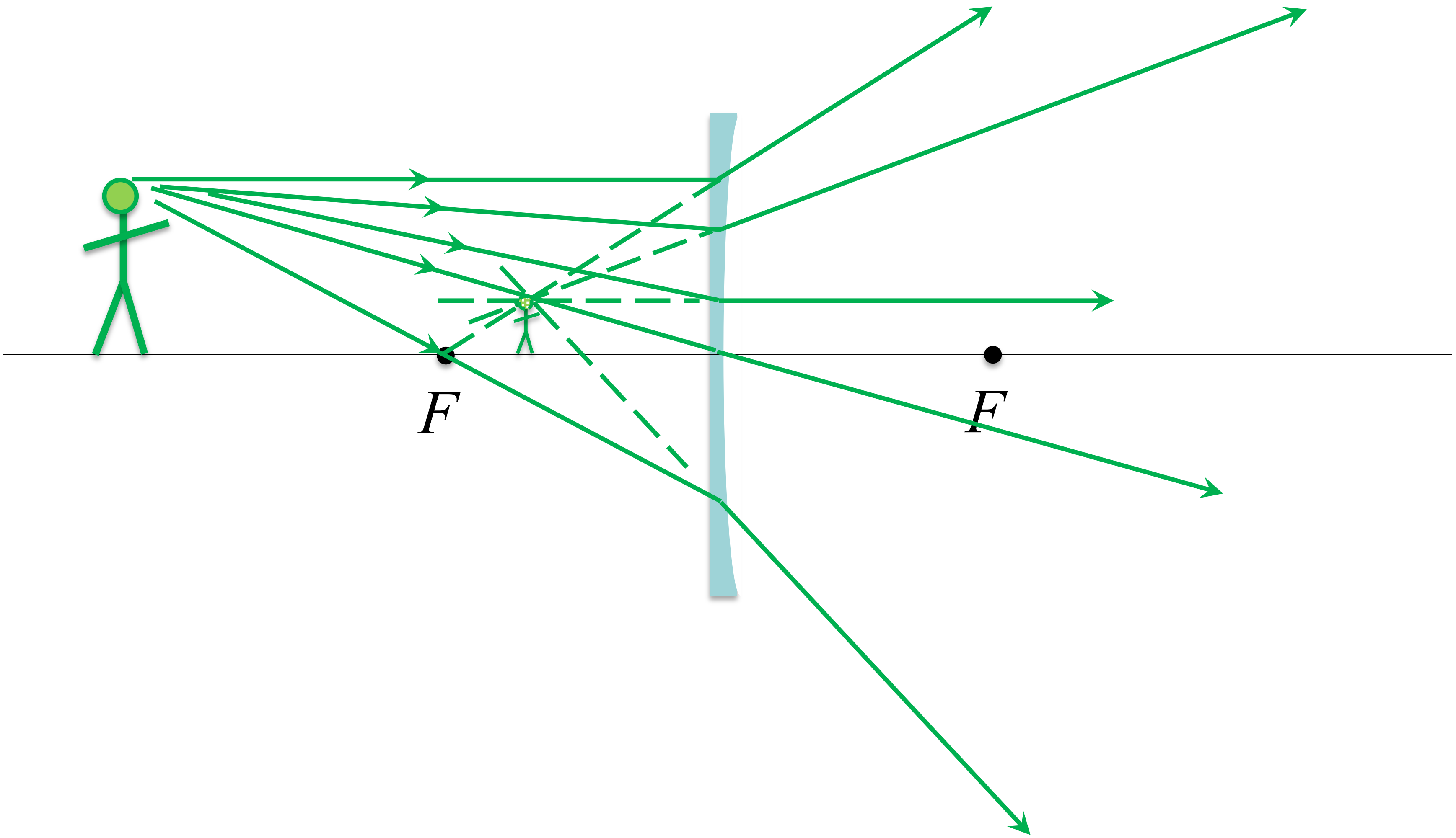
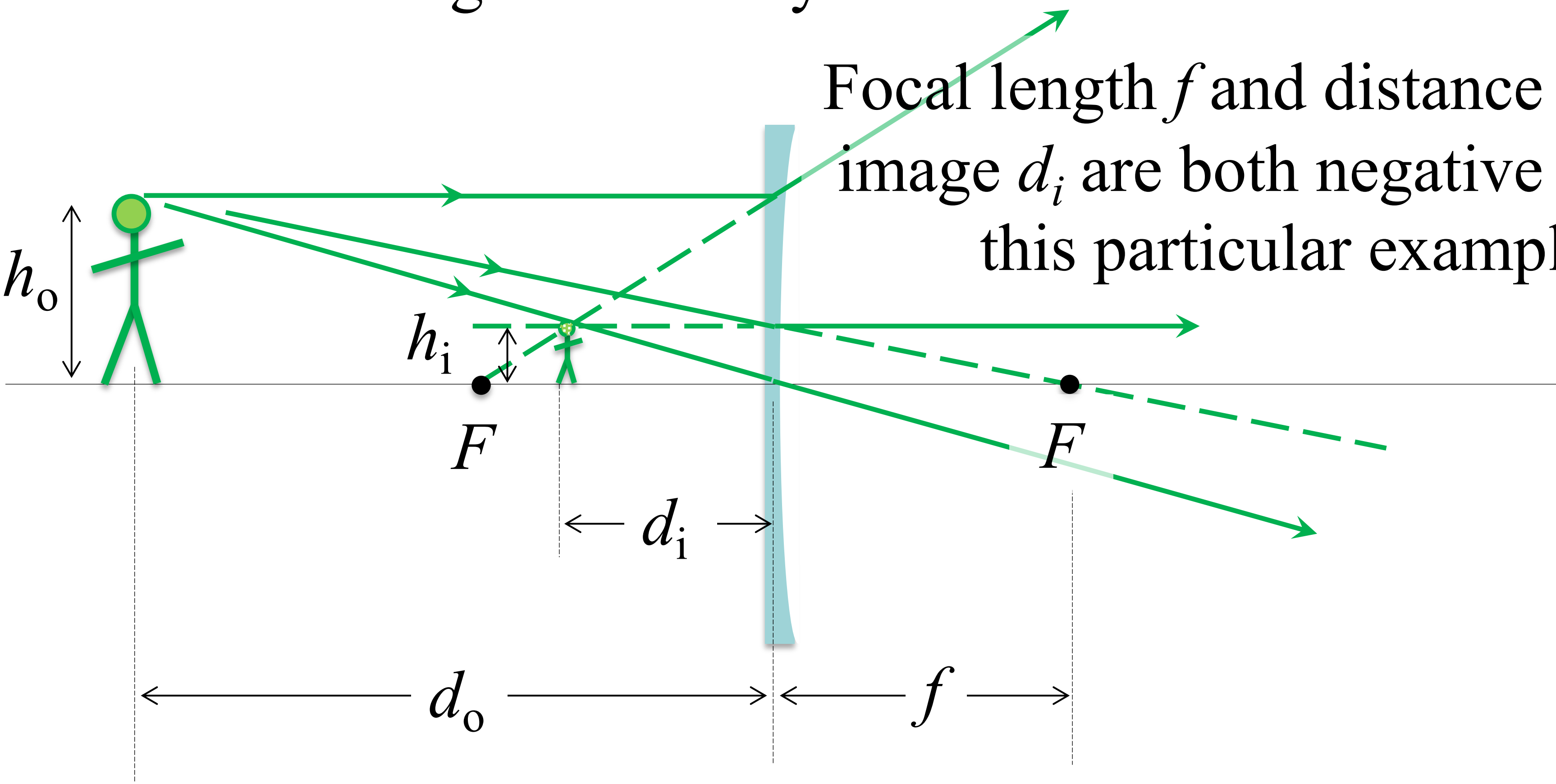

F
F

Image Formed by Concave Lens



Focal length f and distance to image d_i are both negative in this particular example.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$