Lecture 18
(Geometric Optics II
Thin Lenses)

Physics 2310-01 Spring 2020

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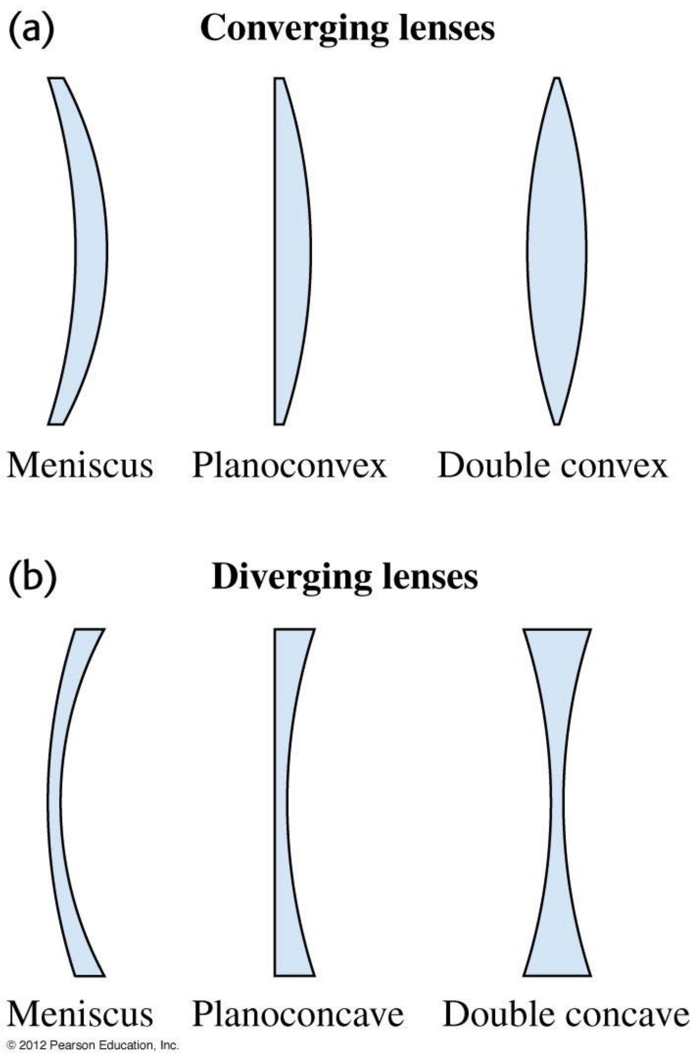
https://phet.colorado.edu/sims/geometric-optics/geometric-optics_en.html

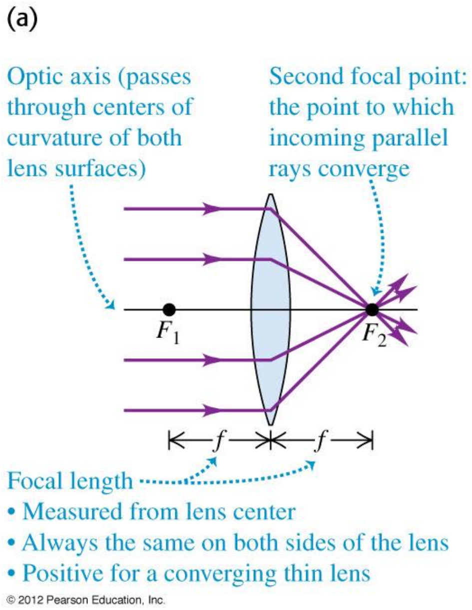
Thin Lenses

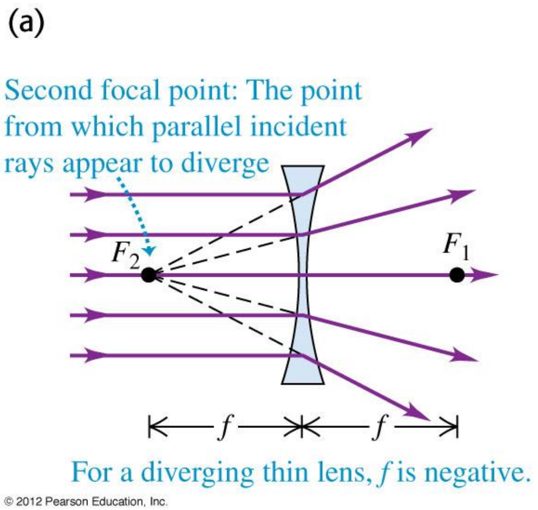
- A very commonly used optical device is the thin lens.
- The term “thin” is, of course, qualitative, and just means in this sense that we can ignore the thickness of the lens when ray tracing.
- Practically speaking, it means we trace the rays to the center plane of the lens and then refract them for both surfaces.
- We didn’t cover refraction from spherical surfaces, but will gloss over some aspects…



Thin Lenses

- The simplest thin lenses have spherical surfaces and can be characterized by the following:
  - Center of curvatures for both surfaces.
  - ***Two*** focal points (on either side of the lens).
  - The axis of the lens.
- There are two general types of lenses:
  - Converging (thicker on axis than on edges).
  - Diverging (thinner on axis than on edges).



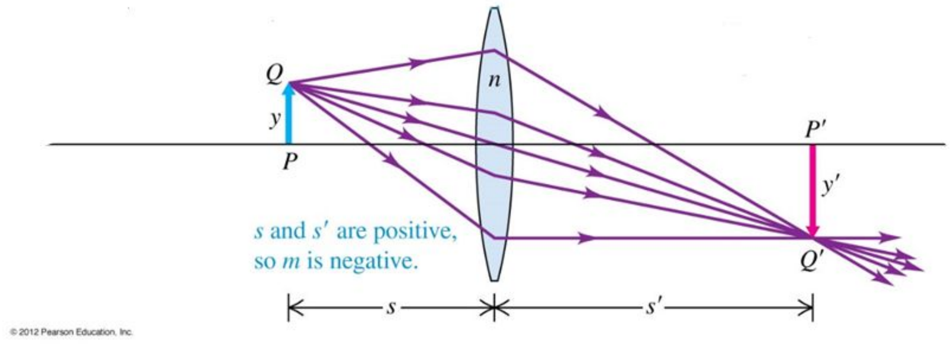


Thin Lens Equations

- Given the two refracting surfaces, we could work out the equations for the image position and magnifications based on the radii of curvatures and index of refraction of the material – it's done in the book, and is straightforward.
- It just ends up being the same as for spherical mirrors:

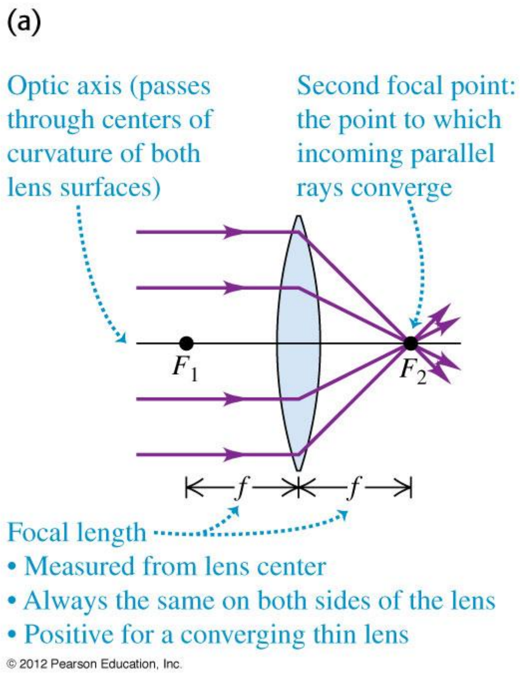
$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$$

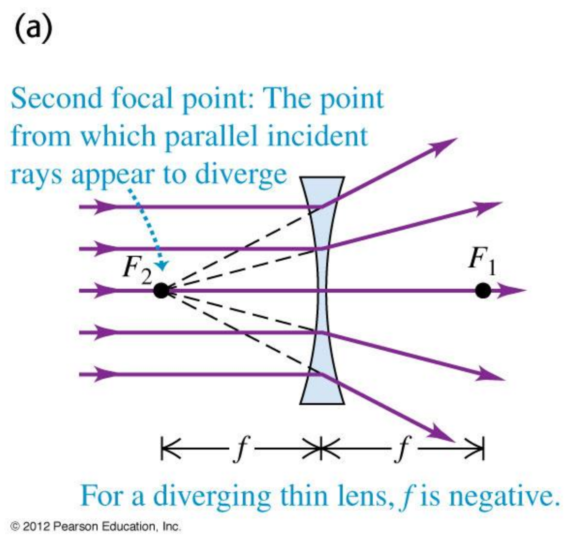
- And the magnification is also the same: $m=\frac{y'}{y}=-\frac{s'}{s}$



Sign Conventions

- Don’t forget sign conventions:
  - Object distance is positive if it is on the same side (of thin lens) as the incoming rays, else it is negative.
  - Image distance is positive if it is on the same side (of thin lens) as the outgoing rays, else it is negative.
  - Focal point is positive for converging, negative for diverging thin lenses.

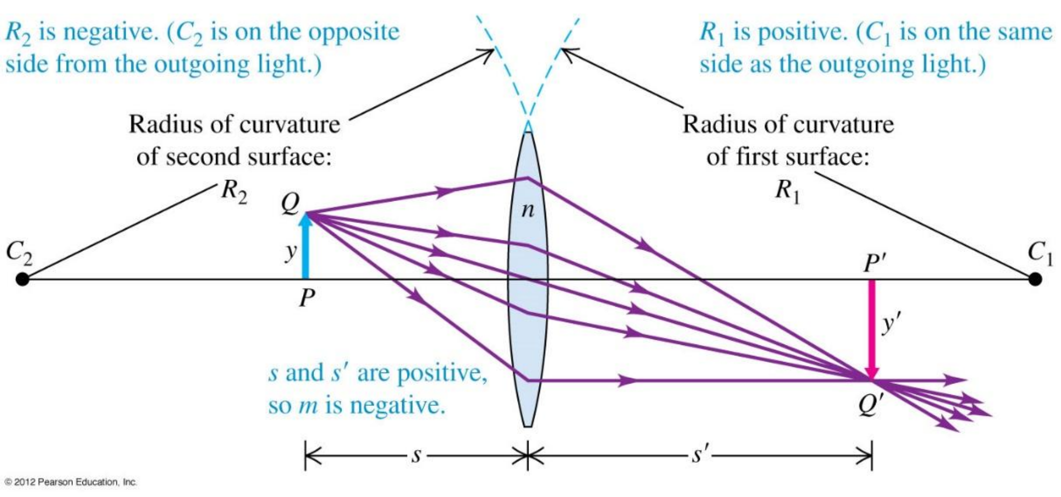




Lens Maker's Equation

- We could also work out the equation to determine the focal length of a thin lens given the radii of curvatures and the index of refraction of the material.
- Again, it's done in the book…

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$



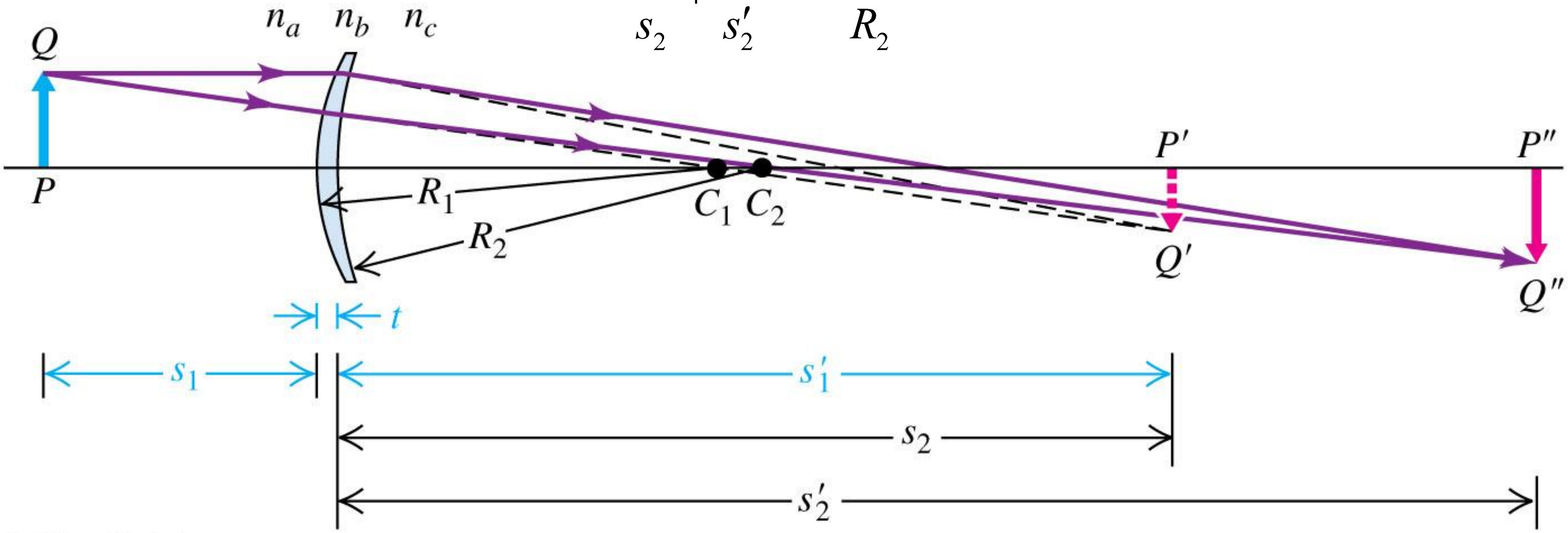
So, explain this…

Always know assumptions…

- Lens maker's equation assumes $n_a = n_c = 1$.

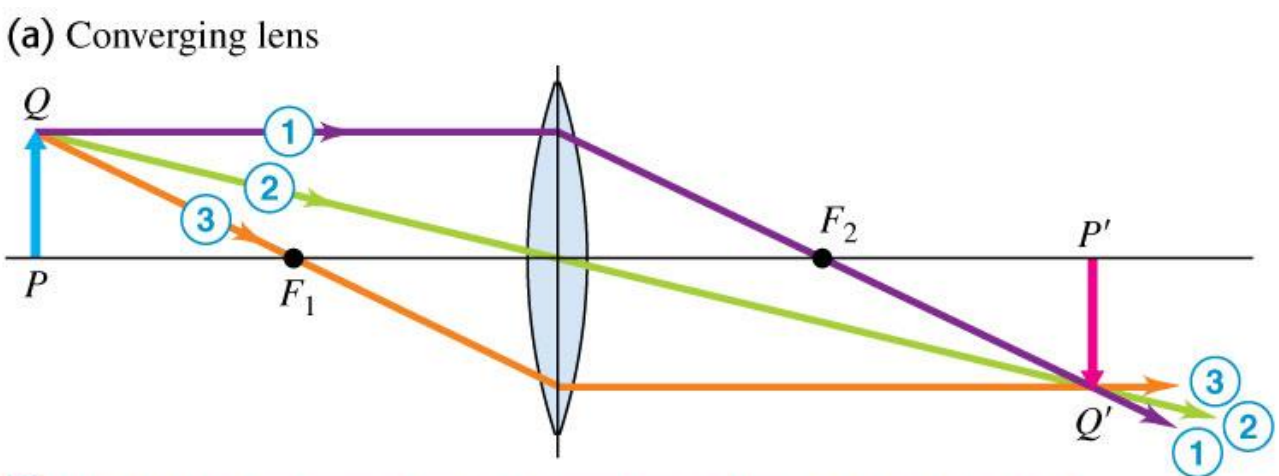
$$\frac{n_a}{s_1} + \frac{n_b}{s_1'} = \frac{n_b - n_a}{R_1}$$

$$\frac{n_b}{s_2} + \frac{n_c}{s_2'} = \frac{n_c - n_b}{R_2}$$



Graphical Methods

- The primary rays for thin lenses are very similar to the ones we chose for mirrors:
  - A ray that is parallel to the lens axis and then passes through the second focal point.
  - A ray through the center of the lens.
  - A ray that passes through the first focal point and then emerges parallel to the axis.



(1) Parallel incident ray refracts to pass through second focal point F_2.

(2) Ray through center of lens does not deviate appreciably.

(3) Ray through the first focal point F_1 emerges parallel to the axis.

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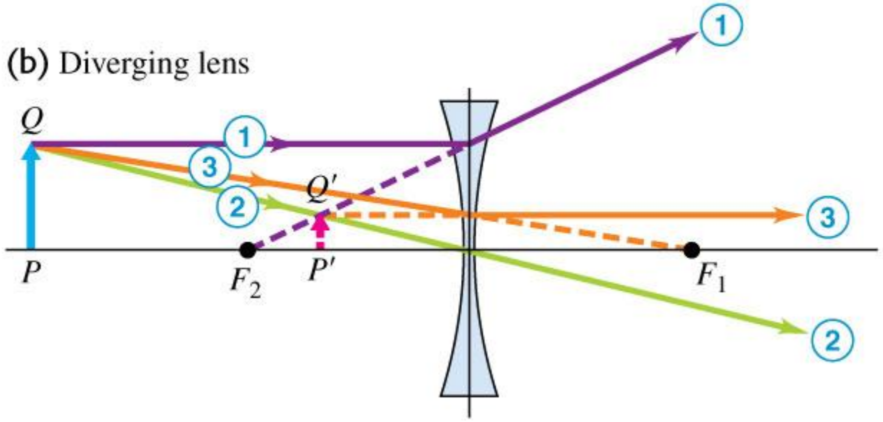


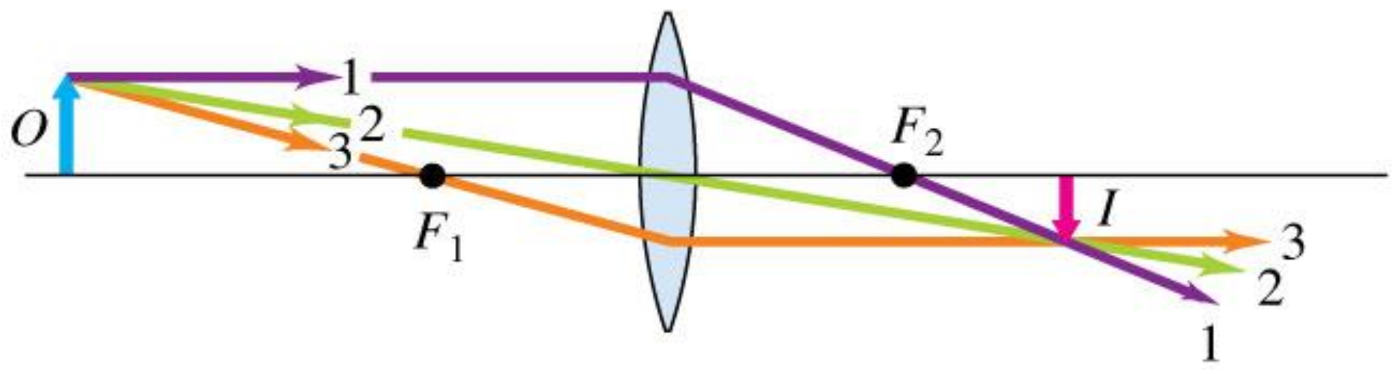
(1) Parallel incident ray appears after refraction to have come from the second focal point F_2.

(2) Ray through center of lens does not deviate appreciably.

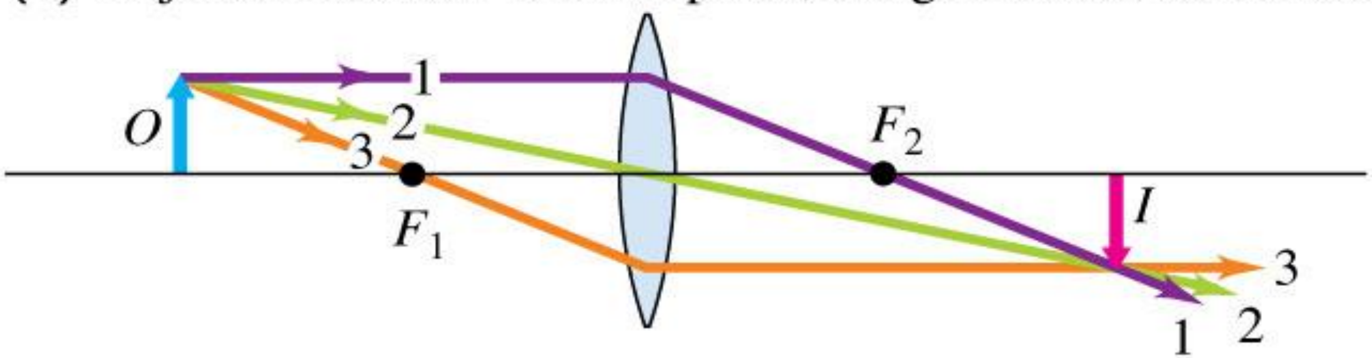
(3) Ray aimed at the first focal point F_1 emerges parallel to the axis.

Demonstrations

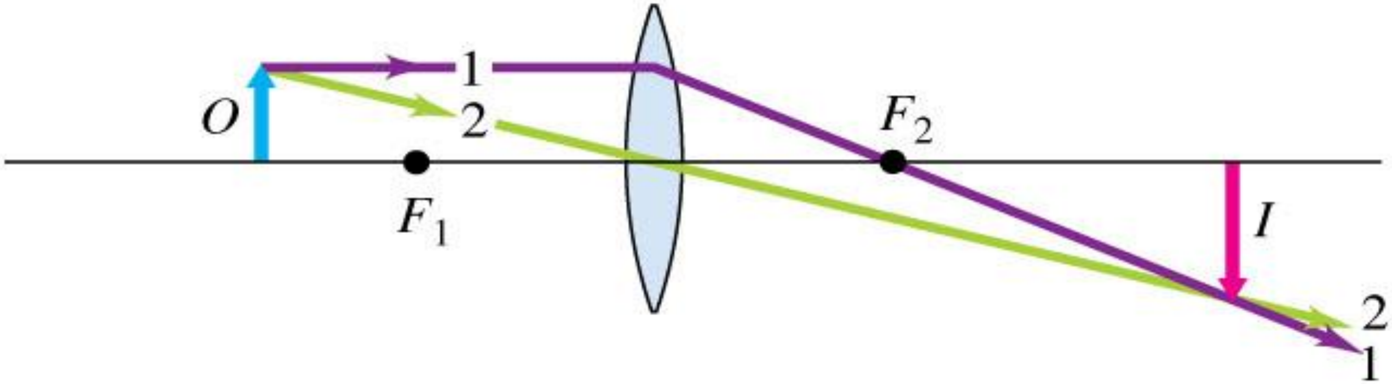
(a) Object O is outside focal point; image I is real.



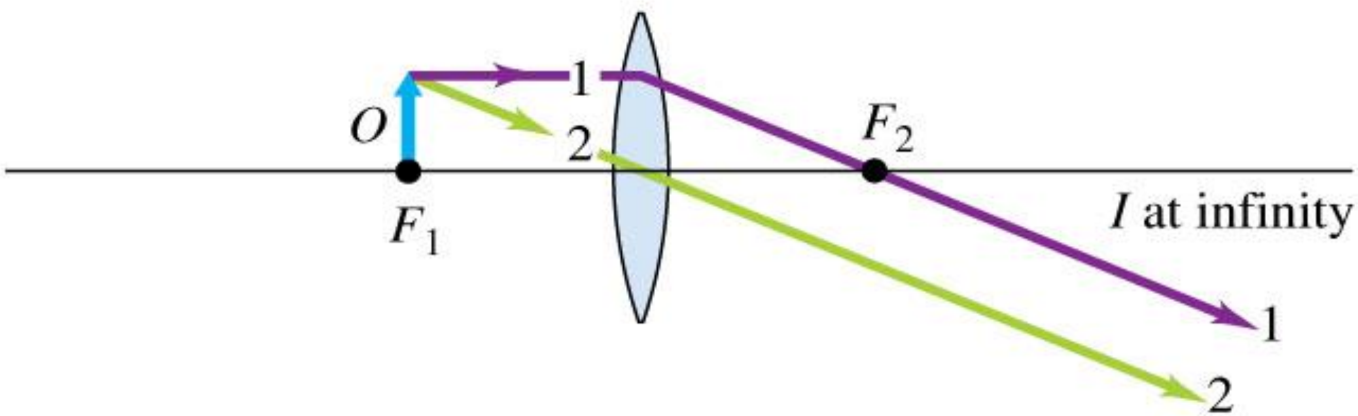
(b) Object O is closer to focal point; image I is real and farther away.



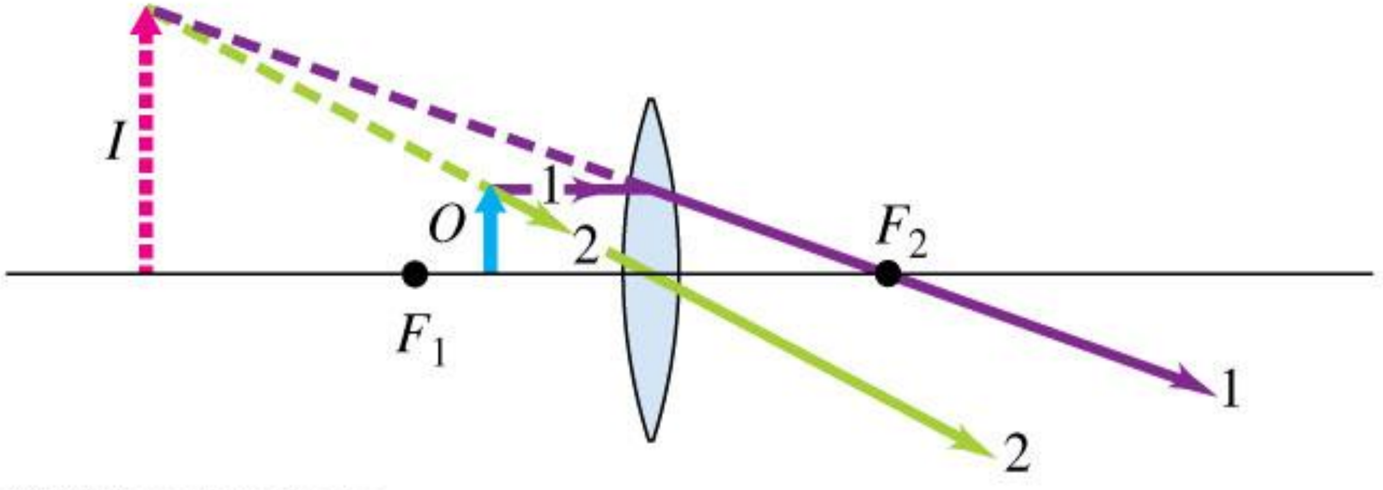
(c) Object O is even closer to focal point; image I is real and even farther away.



(d) Object O is at focal point; image I is at infinity.



(e) Object O is inside focal point;
image I is virtual and larger than object.



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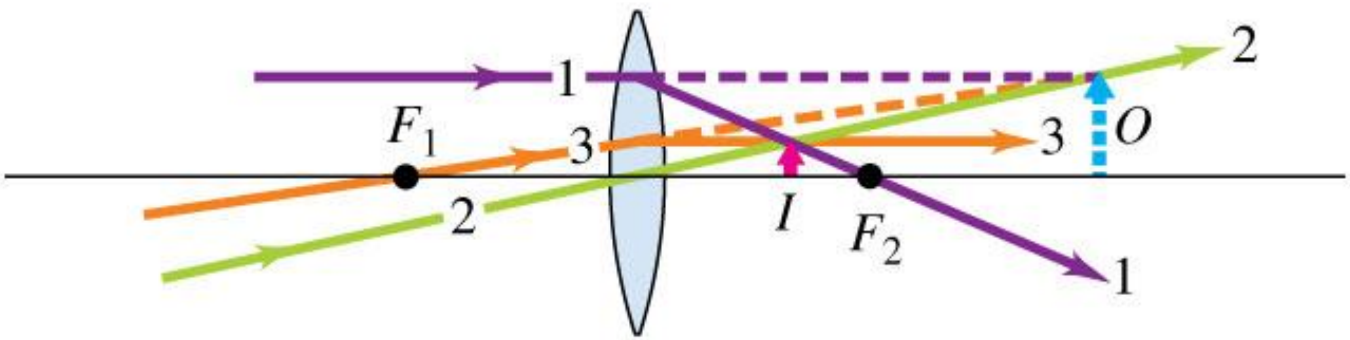
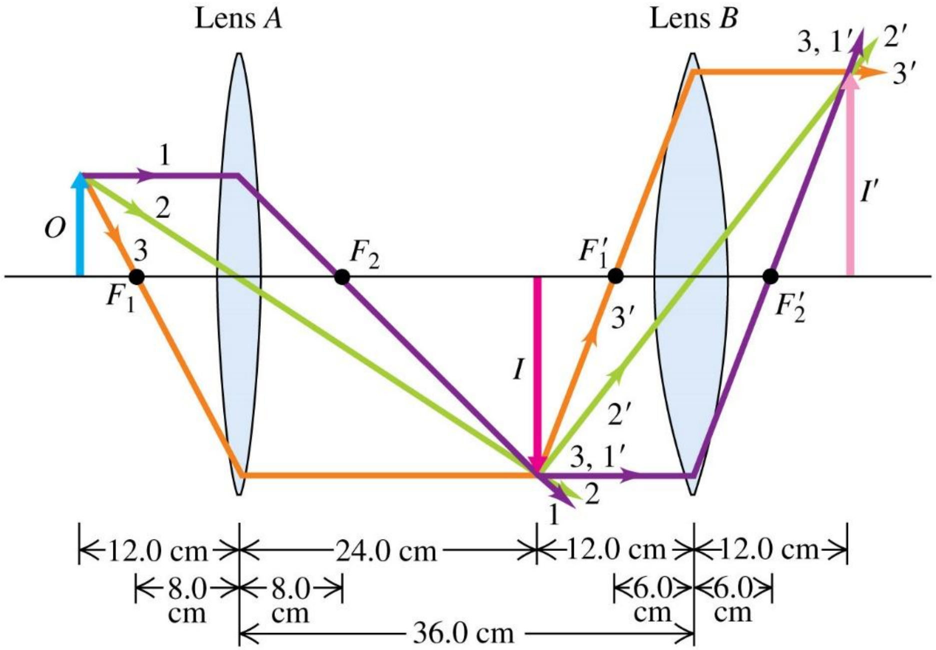
(f) A virtual object O (light rays are *converging* on lens)



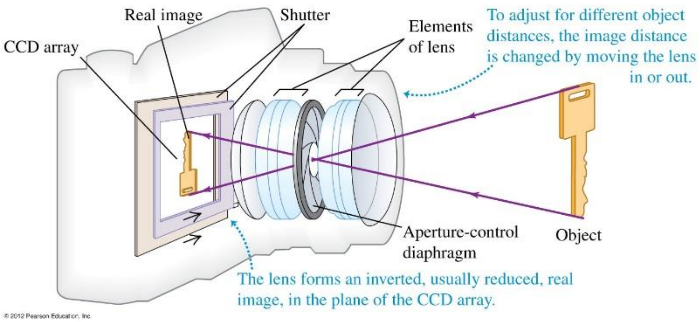
Multiple Lenses

- Again, the image from one lens can be used as the object for another lens – doesn't matter if the first image is real or virtual.

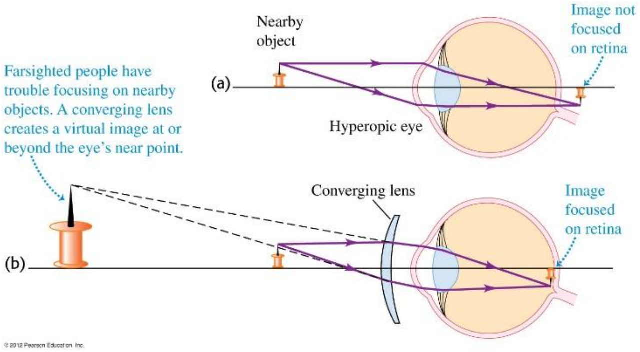


Practicum

- Of course, there are many practical uses for optics, from cameras…



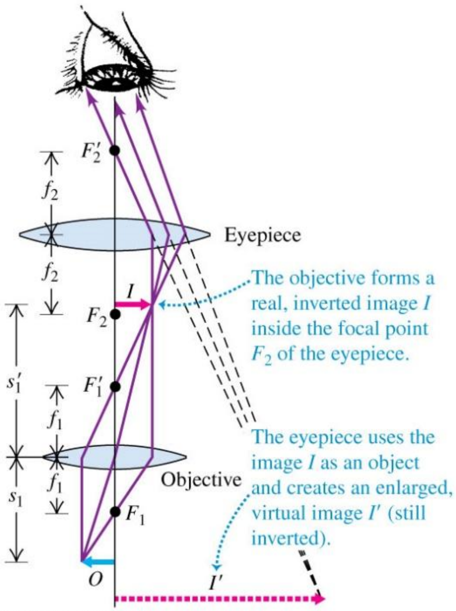
- Eyeglasses…



Practicum

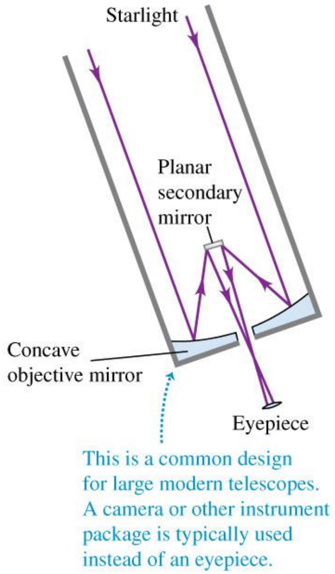
- Microscopes…

(b) Microscope optics



- Telescopes…

(c)



(d)