How Telescopes Magnify

This diagram illustrates the light path for a refractor. The same principles also apply for a reflector, except that the incoming parallel rays converge by reflection upon a curved mirror rather than by going through a converging lens. By convention, the focal length of the objective (primary lens or mirror of the telescope) is F and the focal length of the eyepiece is f.

Since the objects we view are at infinity, the image from the objective (primary lens or mirror) is formed very nearly at the focal point of the objective, F_2. This image is reduced, real and inverted.

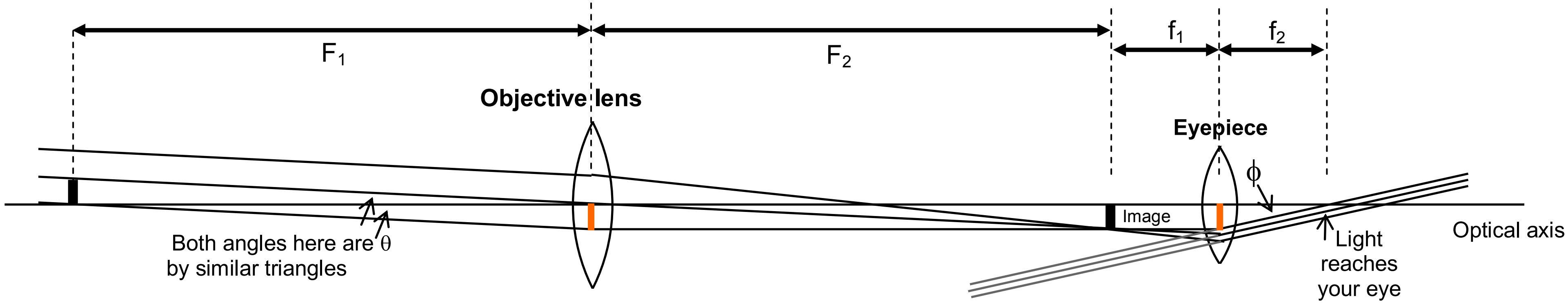
For the final image to also form at infinity, the “object” for the eyepiece, i.e. the primary image, must be at the focal point of the eyepiece, f_1. Here, the eyepiece is represented by a single converging lens, though in practice, most eyepieces have multiple lenses.

The angular magnification is then given by the ratio of angles ϕ to θ. Let the red lines shown on both lenses measure h. (Note: F_1 and F_2 are equal;f_1 and f_2 are also equal.)

$$\tan \phi = h / f_2$$
$$\tan \theta = h / F_1$$

Because the angles are “small”, the small angle approximation may be applied, where the magnitudes of angles (in radians) are approximately equal to the tangents of the angles. Thus, the ratio of angles ϕ / θ is equal to the inverse of the ratios of the focal lengths F/ f.
It is a simple matter to calculate magnification from:

$$\frac{\text{focal length of objective}}{\text{focal length of eyepiece}}$$



Angle θ could represent the angular separation between two stars or the diameter of a planet. In this diagram, it is the angular distance of a point object (such as a star) from the optical axis of the telescope (you can imagine this is another star). Note that because the object is at infinity, all the rays coming into the telescope from the point object are parallel.

The angle ϕ then represents the angular separation between the two stars when viewed through the eyepiece.
The light rays reaching your eye are parallel, so the virtual image appears to be at infinity.
It is enlarged and inverted.

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Reference: University Physics (9th Edition), by Young and Freedman, Addison-Wesley Publishing, 1996, pp1129-1130.