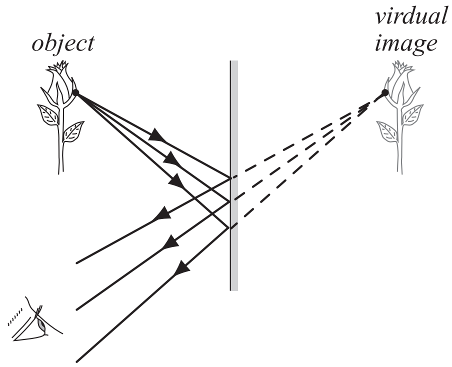
Geometric Optics
Answers and Explanations

1. D

A plane mirror creates a virtual image, located behind the mirror. With a virtual image, the rays of light do not intersect at the image point. The rays of light appear to originate from the image, diverging from the image point.

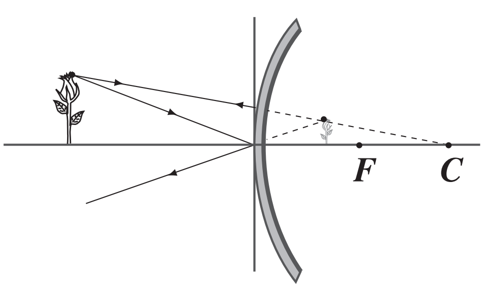


2. A

The magnification of the image produced by a lens or mirror is determined using the following formula where I is the distance of the image along the optical axis from the optical device and O is the object distance.

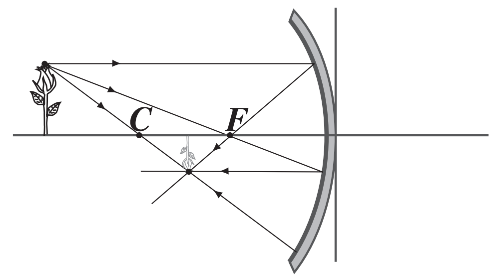
$$M = \frac{-I}{O}$$

If magnification is positive, the image is upright. If the absolute value of the magnification is less than 1, the image is diminished. In other words, with a magnification of 0.7, the optical device is producing an image which is diminished, upright, and virtual. This is the type of image produced by either a diverging lens or a convex mirror.



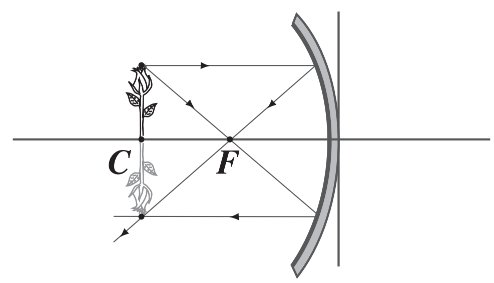
3. C

If the object distance with a concave mirror is greater than the center of curvature of the mirror, C (which also equals $2F$), the image produced will be real, inverted, and diminished.



4. A

If the object distance with a concave mirror is equal to the center of curvature of the mirror, C (which also equals $2F$), the image produced will be real, inverted, and same sized. The image distance will equal C.



5. B

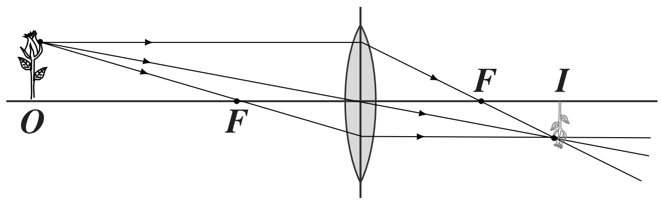
Although there is variety in the shape, converging lenses are thicker in the middle and thin at their upper and lower edges. Converging lenses have a positive focal length.

6. A

Diverging lenses are thinner in the middle. Diverging lenses have a negative focal length.

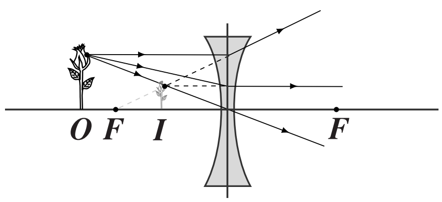
7. C

If the object distance with a converging lens is greater than $2F$, the image produced will be real, inverted, and diminished.



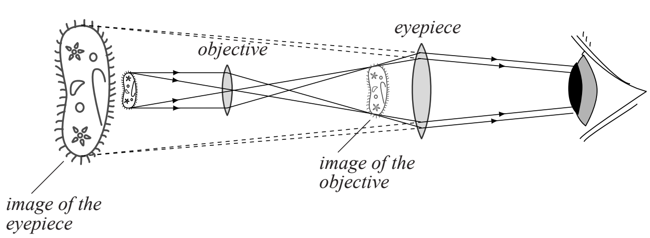
8. A

The image produced by a single diverging lens is always diminished, upright and virtual (DUV).



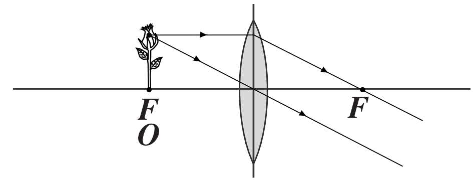
9. A

To understand systems of two or more lenses such as the compound microscope, take it one step at a time. The image of the first lens serves as the 'object' of the second. A compound microscope consists of two converging lenses, an objective lens and an eyepiece lens. The object is situated just beyond the focal length of the objective lens, producing a real inverted image. This image serves as the 'object' for the eyepiece lens, just within its focal length. The eyepiece produces a enlarged virtual image of the inverted real image of the objective.



10. D

When the distance of the object from a converging lens is equal to the focal length, no image is formed.



11. C

The lens equation relates the focal length, image distance, and object distance for an optical device.

$$\frac{1}{F} = \frac{1}{I} + \frac{1}{O}$$

Alternatively, we can express $1/F$ as the power of the lens, D, in diopters (m^{-1}). The lens equation is often expressed:

$$D = \frac{1}{I} + \frac{1}{O}$$

For our problem then:

$$25\ m^{-1} = \frac{1}{I} + \frac{1}{.08\ m}$$

$$25\ m^{-1} = \frac{1}{I} + 12.5\ m^{-1}$$

$$\frac{1}{I} = 12.5\ m^{-1}$$

$$I = .08\ m$$

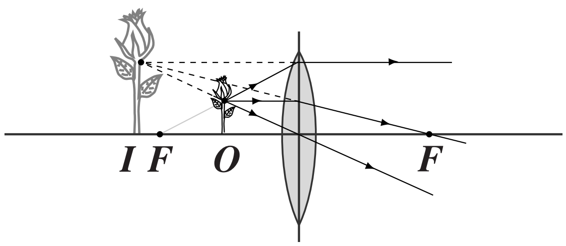
To determine magnification:

$$M = \frac{-I}{O} = \frac{-.08m}{.08m} = -1$$

Note that with a power of 25 diopters, our lens has a focal length of 4cm. When the object distance is equal to $2F$ with a converging lens (positive focal length), the image is real, inverted and same sized.

12. C

A magnifying glass is a converging lens. To observe an object, you position a magnifying glass above the object so that the object is nearer to the lens than the focal length of the lens. For an object placed nearer to the converging lens than the focus, the image produced is enlarged, upright, and virtual.



In our problem, the magnifier is placed 20cm above the object, and it is magnified 5×. This corresponds to an image distance of -100cm. (A negative image is a virtual image).

$$M = 5 = \frac{-I}{O} = \frac{-1.0\text{ m}}{.20\text{ m}}$$

Knowing the image distance for a given object, we can determine the focal length of the magnifying glass to be 25cm.

$$\frac{1}{F} = \frac{1}{I} + \frac{1}{O}$$

$$\frac{1}{F} = \frac{-1}{1.0\text{ m}} + \frac{1}{.20\text{ m}}$$

$$F = .25\text{ m}$$

13. B

Chromatic aberration is a failure of a lens to focus all colors to the same point. It is caused by dispersion, ie. the refractive index of the lens varies with the frequency of light. Chromatic aberration manifests itself as "fringes" of color along boundaries within the image. Chromatic aberration can be minimized by assembling a compound lens from materials with differing dispersion properties. The most common type is an achromatic doublet, with elements made of crown and flint glass.

14. B

The optical power of the relaxed human eye is approximately 60 diopters (m^{-1}), a fact presented in the passage. The focal length of a lens is the reciprocal of its power in diopters.

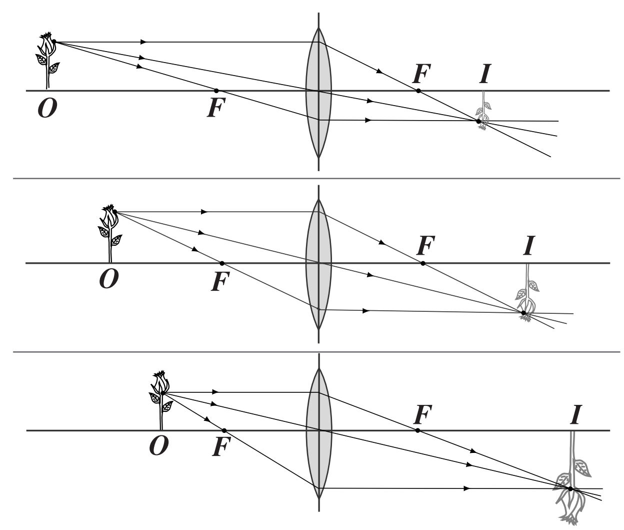
$$D = \frac{1}{F}$$

$$60\text{ m}^{-1} = \frac{1}{F}$$

$$F = \frac{1}{60}\text{ m} \sim 15\text{ mm}$$

15. D

An individual with hyperopia has difficulty seeing near objects. To understand hyperopia, it's very helpful to visualize what occurs with image distance (the real inverted image formed by a converging lens) as the object is moved closer to the lens. Notice as the object is moved closer, the image moves further away from the lens on the other side.



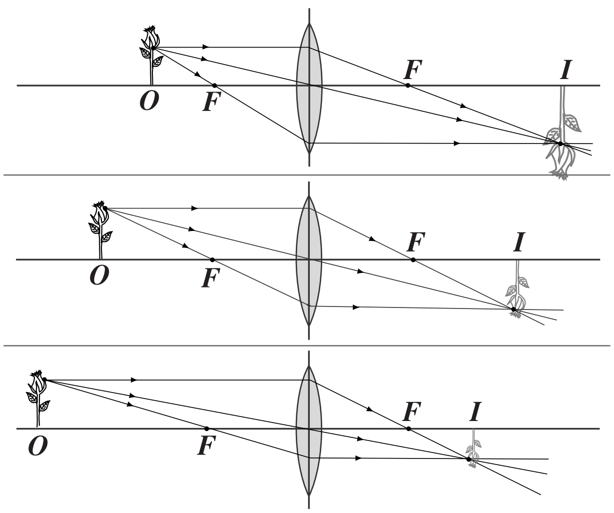
The cause of hyperopia is often that the eyeball is too short. In other words, the distance between the refractive elements (corena and lens) and the retina is too short, so for near objects the focused real image would be behind the retina. Accommodation is not sufficient to shorten the focal length of the eye and pull the image forward onto the retina. Light that originated from the same object point instead is landing at different locations on the retina. The result is blurry vision.

16. D

Contraction of the ciliary muscle reduces the tension on the fibers of the ciliary zonule and causes the lens to curve or become more spherical. This increases the optical power of the eye, accommodating for near vision.

17. D

An individual with myopia has difficulty seeing far objects. To understand myopia, it's very helpful to visualize what occurs with image distance as the object is moved further away from the lens. Notice as the object is moved further away, the image moves closer to the lens on the other side.



The cause of myopia is often that the eyeball is too long (or the eye has too short a focal length). For far objects, the retina would need to be further in for a focused image to land on it. Light that originated from the same object point instead is landing at different locations on the retina. The result is blurry vision for far objects.

18. C

To repair the astigmatism, the corrective lenses adjust the focal length in the horizontal plane to match the vertical focal length. To a person with normal vision the glasses would appear out of focus in the horizontal plane but not in the vertical plane.

19. A

Myopia or nearsightedness is the inability of the eye to focus on distant objects. It is the result of either a bulging cornea or too long an eyeball. With myopia the image distance for distant objects is in front of the retina.

The cure for the nearsighted eye is to equip it with a diverging lens. This spreads the light rays, shifting the focal length further back, so that the image will land on the retina. A diverging lens has a negative focal length, so its power in diopters will likewise be negative. −1.0 to −3.0 diopters is the range of the typical prescription for mild myopia.