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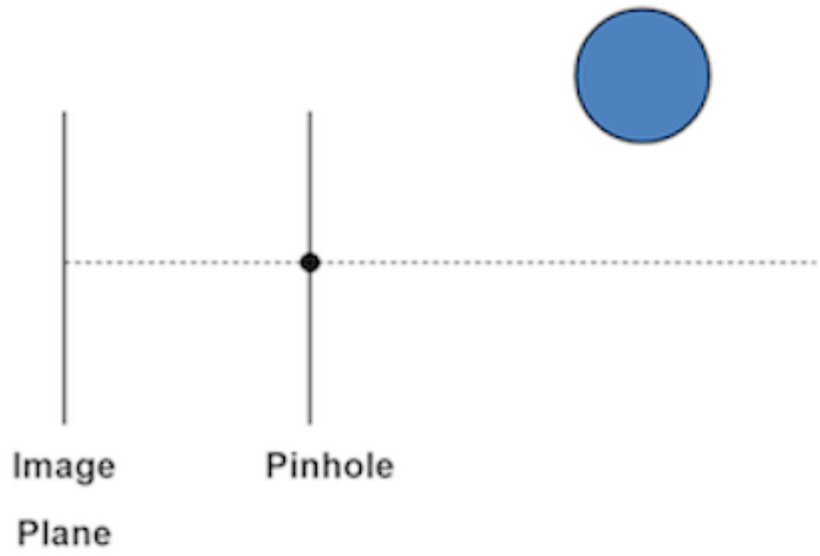
1. **1 / 1 point**



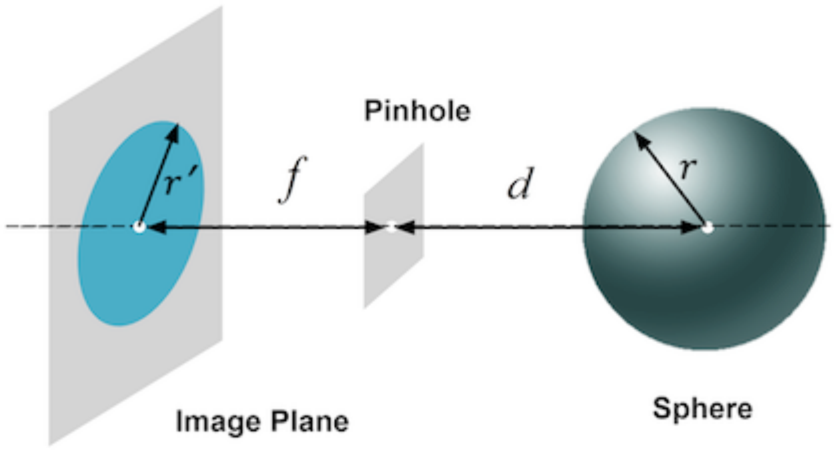
The shape of the image of the off-axis sphere imaged by a pinhole camera is:

Hint: Try to find the points in the sphere which will be visible from the pin hole. What 2D shape will it be? (Refer to the geometry of a circle's tangent.)

- ○ A circle
- ○ A square
- ○ A point
- ◉ An ellipse

Correct
The boundary of the sphere as seen from the pinhole is a circle. This circle produces a cone of rays that passes through the pinhole. Since the cone is titled (off-axis), its intersection with the image plane is an ellipse.

2. **2 / 2 points**



The image of a sphere of radius r placed on the optical axis of a pinhole camera is a circle with radius r'. If the distance d of the center of the sphere from the pinhole is doubled, the radius r' of the image of the sphere is:

- ( ) Exactly doubled
- ( ) Exactly halved
- ( ) Unchanged
- (●) None of the above.

Correct

This one is a bit tricky! At first glance, one might be tempted to believe that since the distance of the sphere is doubled, the radius of its image will be halved. However, the circular boundary of the image of the sphere is the projection of a circle on the sphere that lies at a distance $d' < d$ from the pinhole. This is because the great circle on the sphere at the distance d is "self-occluded" by the sphere. The projected circle corresponds to points on the sphere for which rays drawn from the pinhole are tangential to the sphere. So, when the sphere is moved away from the pinhole by d, the distance of the projected circle is slightly more than doubled.

3. Consider a pinhole camera with an effective focal length of 2. If the pinhole is located at the origin and the image plane is given by z = 2, then the 3D image coordinates of the scene point (-4, 4, -2) are: **2 / 2 points**

- ( ) (4, 2, 1)

(1, -1, 2)

(4, -4, 2)

(2, 2, 2)

Correct

Direct application of perspective projection equations to the scene point coordinates.

$$(x, y, z) \rightarrow \left(\frac{f}{z}x, \frac{f}{z}y, f\right)$$

4.

2 / 2 points

How many vanishing points are produced by the edges of this opaque cube from a fixed viewpoint?

1

2

3

∞

Correct

The cube has three sets of parallel lines in the 3D world. Each of these produces a vanishing point.

5. A focused imaging system has a magnification m and uses a lens with focal length f. The distance between the image plane and the object plane is: **3 / 3 points**

- ○ $\frac{m-f}{f}$
- ◉ $(m+2+\frac{1}{m})f$
- ○ $\frac{1+m}{f}$
- ○ $m \cdot f$

Correct

This is directly obtained from the expressions for the Gaussian Lens Law and magnification.

$$\frac{1}{f} = \frac{1}{i} + \frac{1}{o}$$
$$\Rightarrow \frac{i}{f} = 1 + \frac{i}{o} = 1 + m$$
$$\Rightarrow \frac{o}{f} = \frac{o}{i} + 1 = \frac{1}{m} + 1$$
$$\Rightarrow i + o = \left(m + 2 + \frac{1}{m}\right) f$$

6. Consider a camera with a single lens with focal length f. If the object distance is o and the image distance is i, the magnification is: **1 / 1 point**

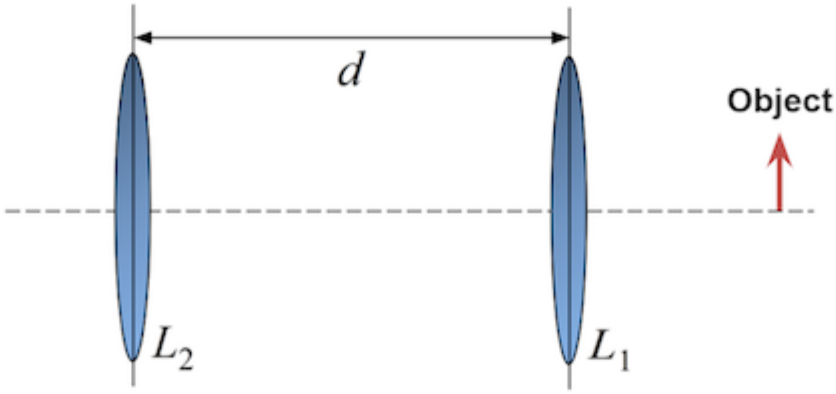
- ○ $m = \frac{1}{i} + \frac{1}{o}$
- ○ $m = \frac{i-o}{i+o}$
- ○ $m = 2f$
- ◉ $m = \frac{i}{o}$

Correct

See derivation of magnification for a lens camera.

7.

2 / 2 points



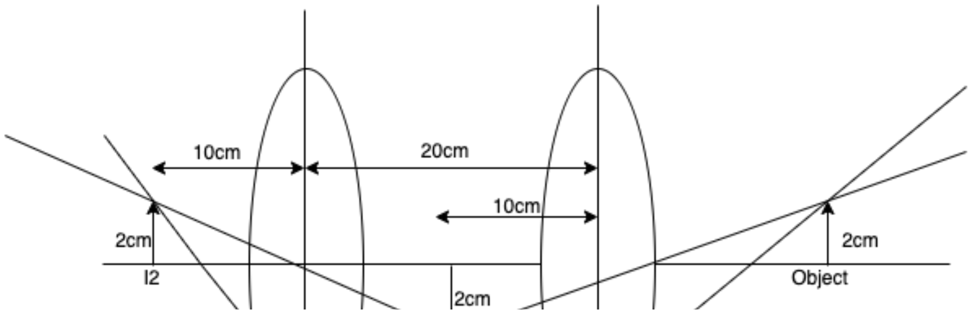
In this two-lens system, both lenses have the same focal length f = 5 cm and are separated by d = 20 cm. If the object is 2 cm tall and placed 10 cm away from lens L_1, how tall would its image behind lens L_2 be?

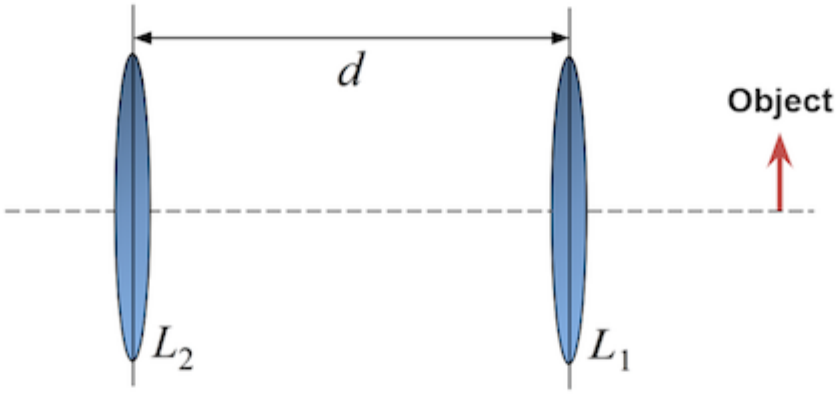
- ○ 5 cm
- ○ 4 cm
- ○ 3 cm
- ◉ 2 cm

Correct

Lens L_1 forms an inverted image of the object behind it. Using the Gaussian Lens Law, we find that this inverted image is 2 cm tall and 10 cm behind L_1. Since the two lenses are separated by 20 cm, the inverted image acts like an object that is 10 cm in front of lens L_2.The final (upright) image is therefore formed 10 cm behind L_2 and is 2 cm tall. The total magnification of the two-lens system is therefore 1, and the height of the final image is 2 cm.

8. **3 / 3 points**





In this two-lens system, lens L_1 with focal length f_1 and lens L_2 with focal length f_2 are separated by $d = 2f_1$. What is the focal length f of the system?

- ○ $\frac{f_1 f_2}{f_1 + f_2}$
- ◉ $\frac{f_1 f_2}{f_2 - f_1}$
- ○ $\frac{1}{f_2} + \frac{1}{f_1}$
- ○ $\frac{1}{f_2} - \frac{1}{f_1}$

Correct

Imagine placing an object very far away from the lens: $o \to \infty, \lim_{o \to \infty} \frac{1}{o} = 0.$

Then, the intermediate image will be rendered at $i = f_1$ according to the Gaussian Lens Law. Since $d = 2f_1$, this also means that the intermediate image is f_1 away from L_2 and hence according to the Gaussian Lens Law, the final image would be rendered at:

$$\frac{1}{f_2} = \frac{1}{i} + \frac{1}{f_1}$$

$$i = \frac{f_1 f_2}{f_1 - f_2}$$

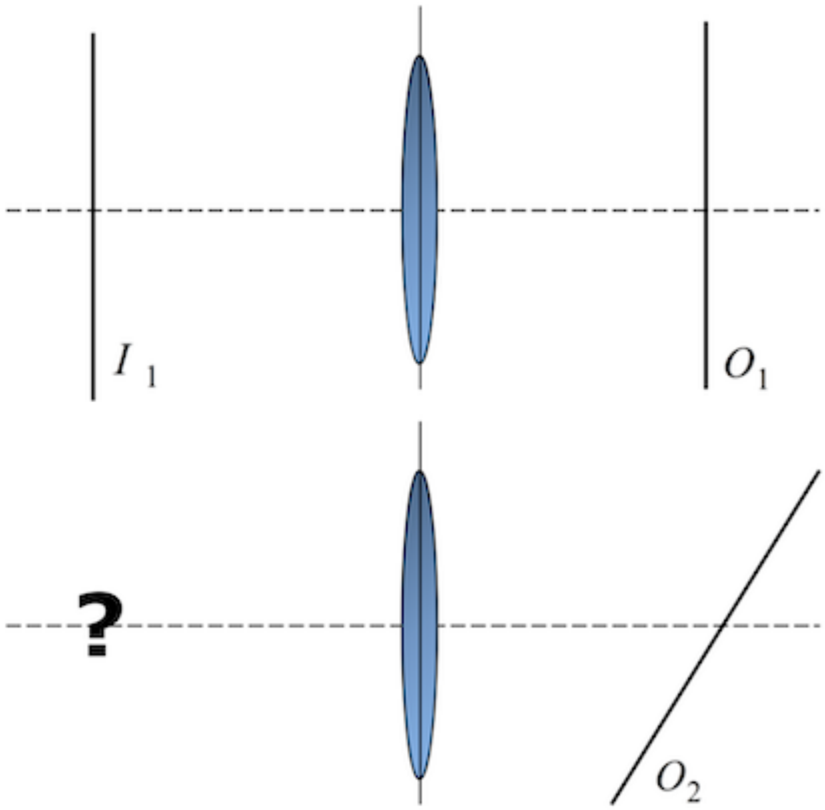
This is, in effect, the focal length of the entire system: since $o \to \infty, \lim_{o \to \infty} \frac{1}{o} = 0$, then $i = \frac{f_1 f_2}{f_1 - f_2}$.

Also, note that the image is inverted in-between the two lenses, therefore the sign of the focal length will be negated, $f = -i = \frac{f_1 f_2}{f_2 - f_1}$.

To generalize, the effective focal length (F) of the two-lens system is given by the following equation:
$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$

9.

1 / 1 point



We know the focused image of a vertical line O_1 is a vertical line I_1. The focused image of the tilted line O_2 is a:

- (●) Tilted line
- ( ) Curve
- ( ) Point
- ( ) Vertical line

Correct

Use an equation of the line for the object. Then use the Gaussian Lens Law to find the equation of the focused image of the line. This too turns out to be a line. Additionally, the tilt of the image line is in the opposite direction of the object line. The above phenomenon is called the *Scheimpflug principle*.

10. **1 / 1 point**

What is the lens effect you see in this image?

- ○ Chromatic aberration
- ○ Radial distortion
- ◉ Vignetting
- ○ Tangential Distortion

Correct
Note that the image gets darker as you move away from the center.