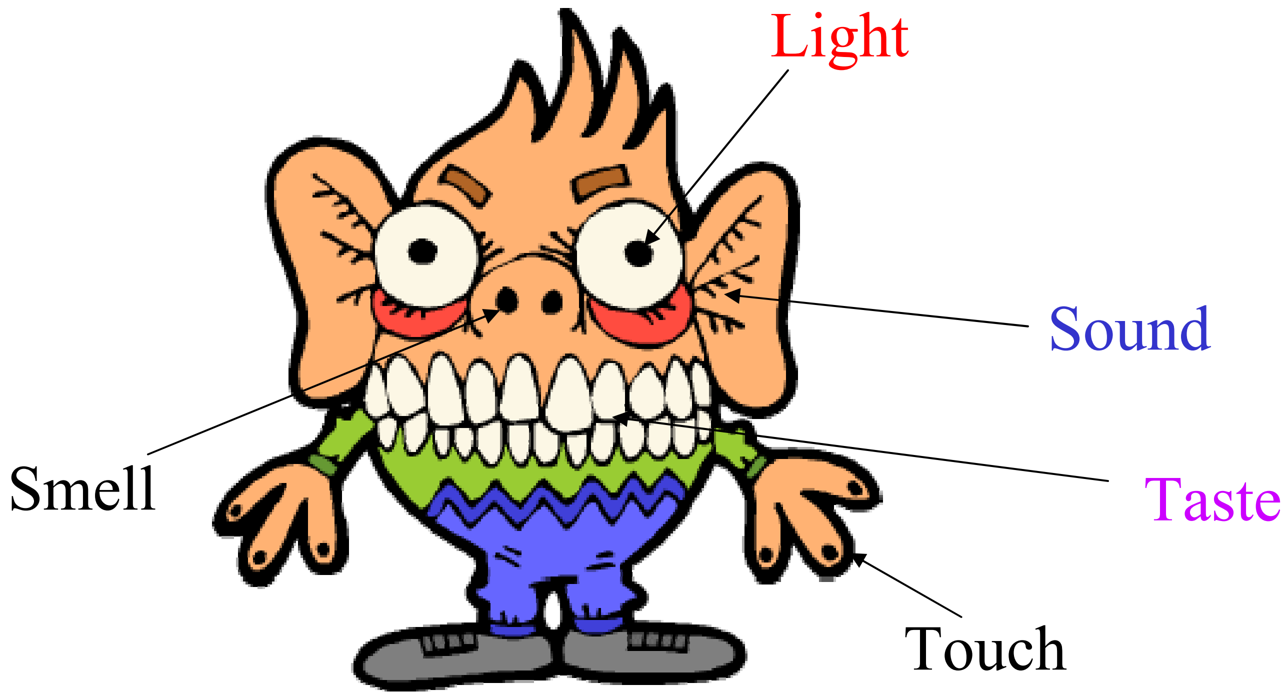
Human sensation

For us to see an object, the object has to send light to our eye.



Where light comes from

- Some objects can radiate light by itself.

- Some objects reflect light from other sources.

If an object cannot radiate light itself, and there is no other light source, the object cannot be seen.

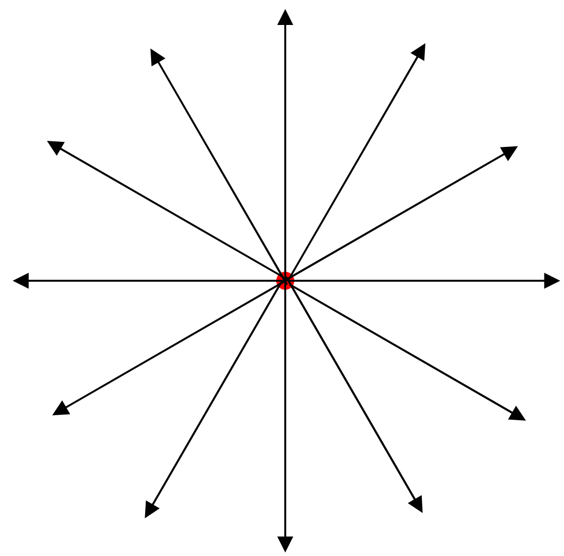
Point object

- A point object is an object small as a point (i.e. no size).
- A larger object is composed of many point objects.

Light from a point object

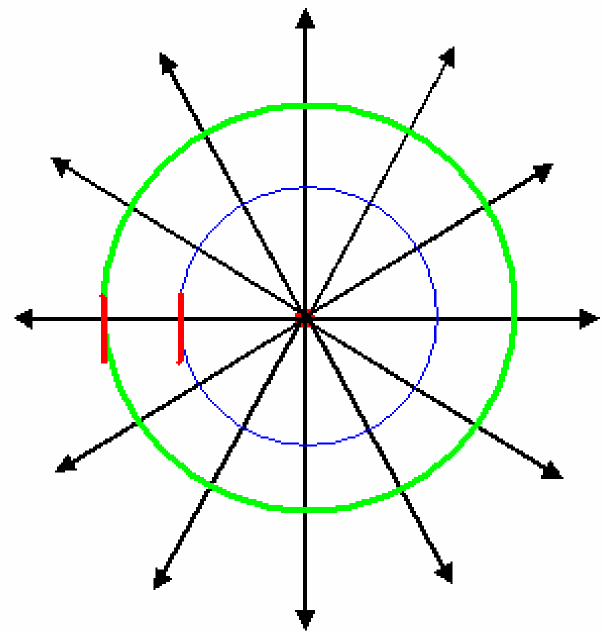
If a point source can give out light by itself, or if there is other light source:

The point object will send out light rays in all directions.



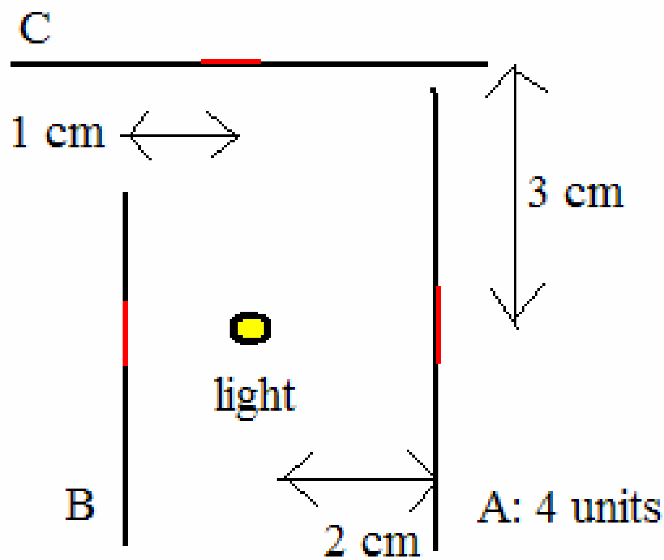
Intensity of Light from a Point Source

Consider two spheres surrounding a point source of light. The same amount of light will pass through both spheres. Since the surface area of a sphere of radius R is $4\pi R^2$, the fraction of the light passing through a small area A is $A/4\pi R^2$; i.e. the intensity of the light is inversely proportional to R^2.



The red patch on the blue sphere will have more light than the red patch on the green sphere.

Exercise



Consider 3 screens surrounding a point source of light. The intensity of light hitting the center of screen A (2 cm from the light) is 4 units. What is the intensity hitting the centers of screens B (1 cm from light) and C (3 cm from light)?

Solution

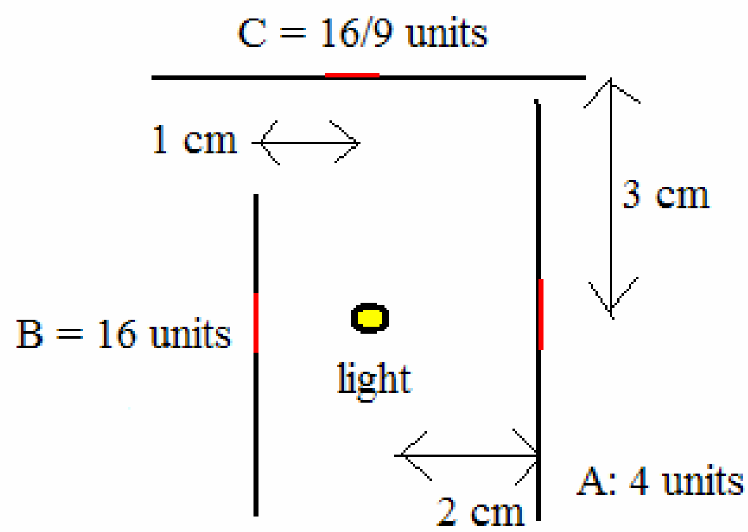
Use the relation that the intensity is inversely proportional to R^2:

$I_B/I_A = (R_A/R_B)^2$, so

$I_B = I_A\ (R_A/R_B)^2$,

$I_B = 4 \text{ units } (2\text{cm}/1\text{cm})^2$

$I_B = 16$ units.



Similarly, $I_c = I_A\ (R_A/R_c)^2$,

$I_c = 4 \text{ units } (2\text{cm}/3\text{cm})^2$

$I_B = 16/9$ units $= 1.78$ units.

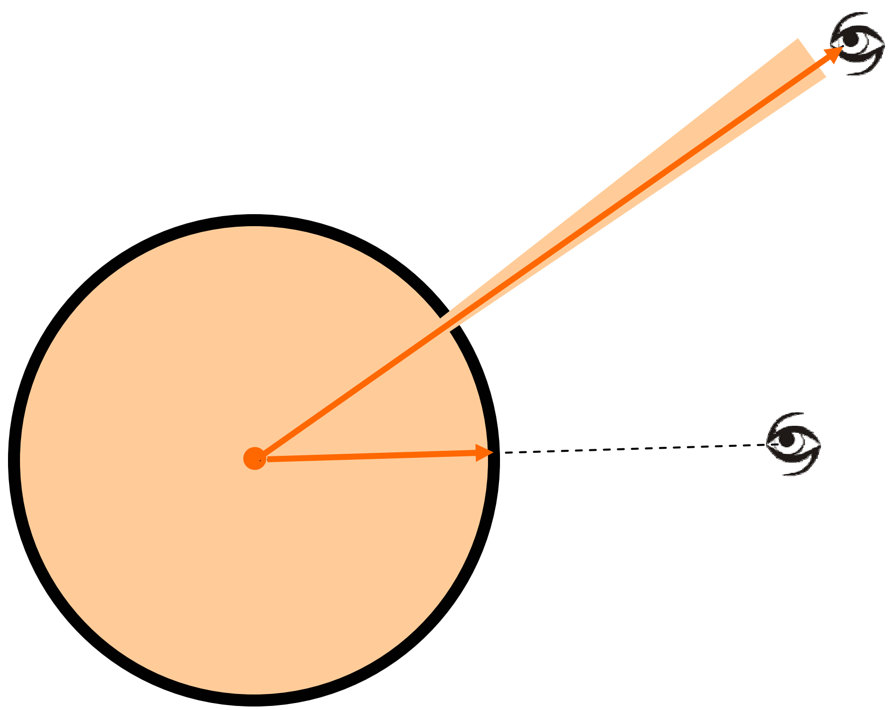
Properties of Light Rays

- A light ray is a perfect straight line.
- A light ray originates from a point object.
- A light ray extends indefinitely until it hits an (opaque) obstacle.
- For a point object to be seen, one of its light rays has to hit the eye.

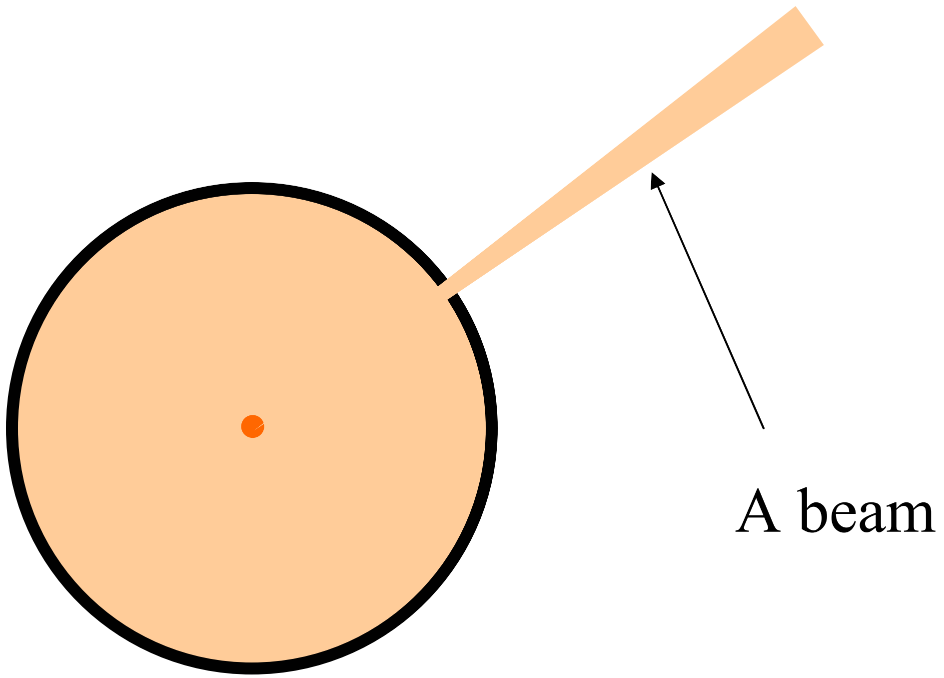
Conditions for a point object to be seen

- Either the point object can radiate light by itself or there are other light sources.
- There is no opaque obstacle blocking the straight line joining the point object and the eye.

An Example

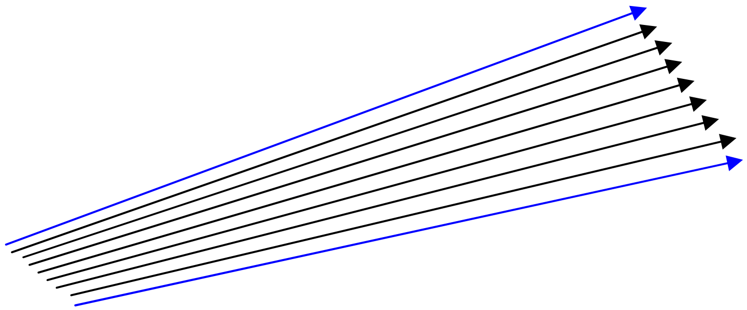


Light beam



Light beam

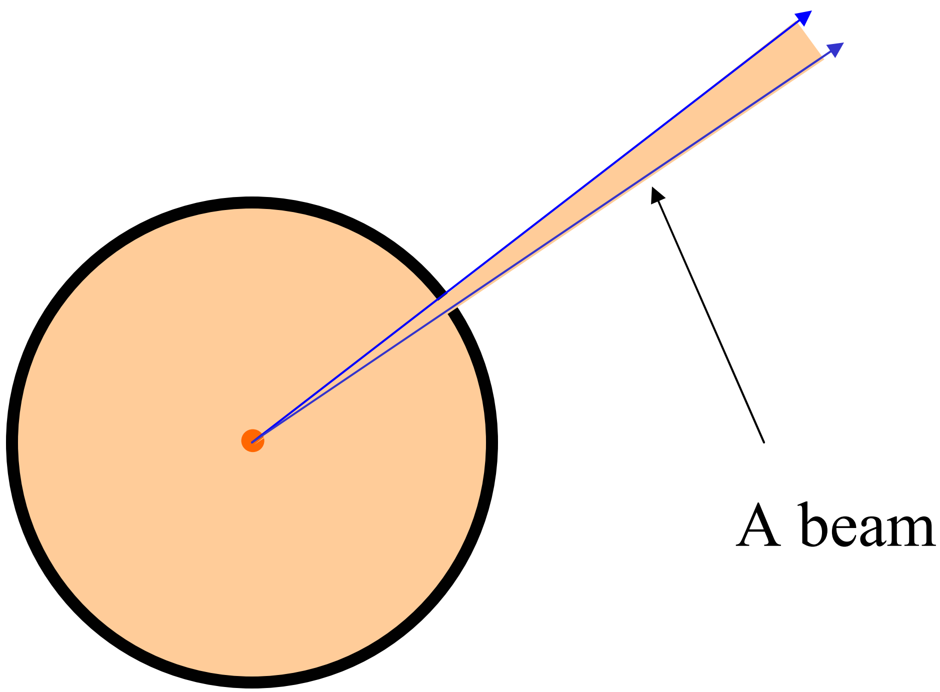
- A beam is a bundle of light rays.
- A beam can be outlined by extreme rays.



Beam from a flash light

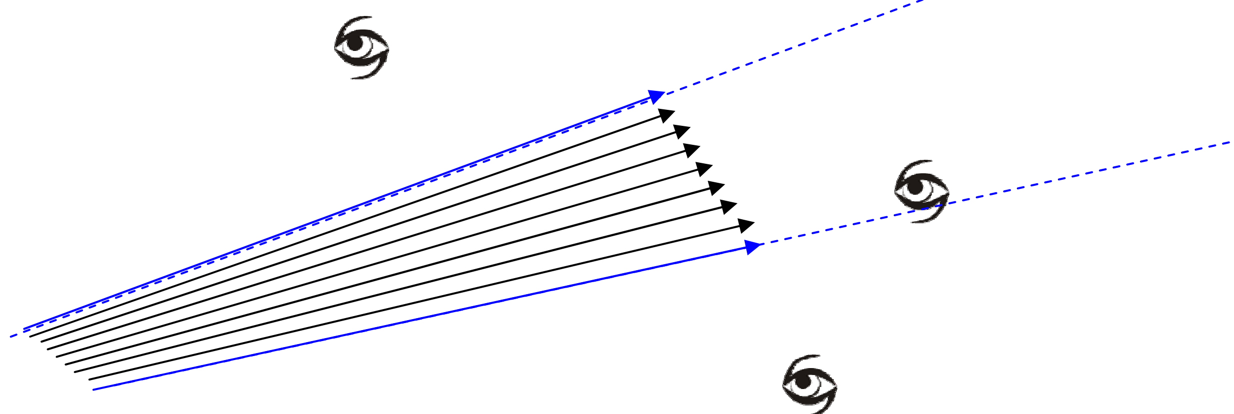
Beam from a laser

Light beam



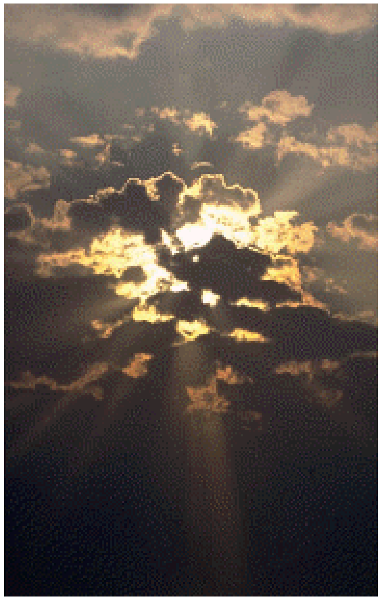
Seeing light ray?

- Light ray is a conceptual entity that we intend to represent it as a straight line in our drawing.
- Unlike a physical straight line, a light ray cannot be seen unless it hits your eye.
- Similarly, a beam cannot be seen unless some of its rays hit your eye.



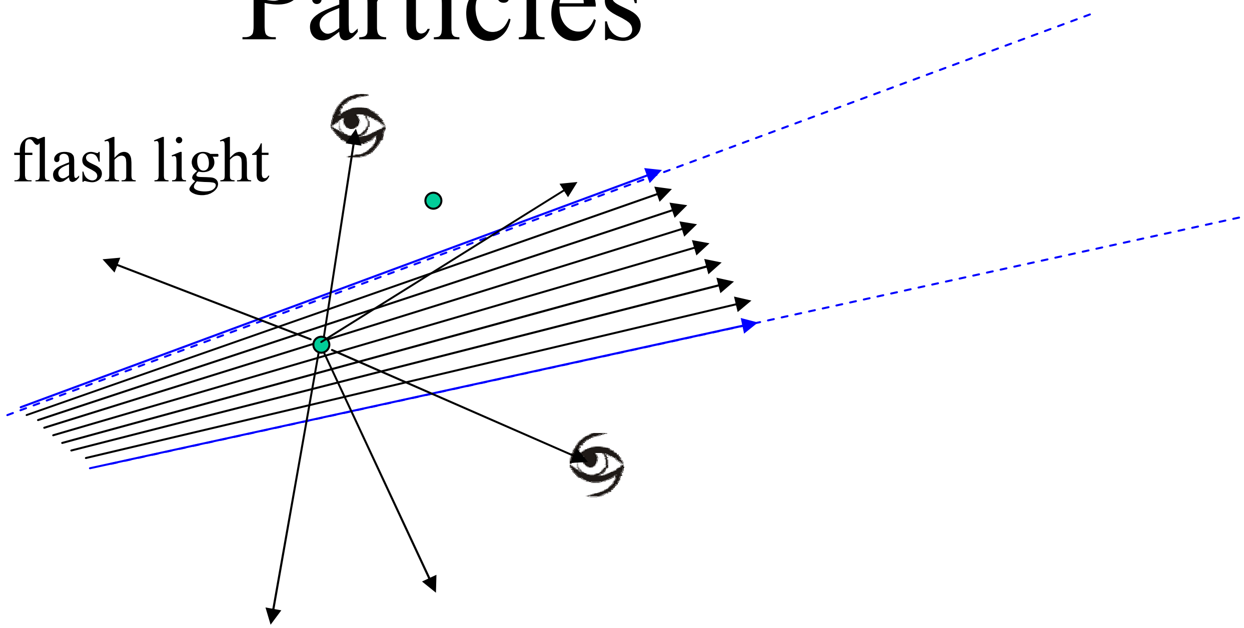
Beam from a flash light

Beams of Light



Beam Scattered (or Reflected) by Particles

Beam from a flash light



The original beam serves as a light source. The particles in the beam will become lighted point objects. What we are seeing are the lighted particles reflecting light to your eye and outlining the beam.

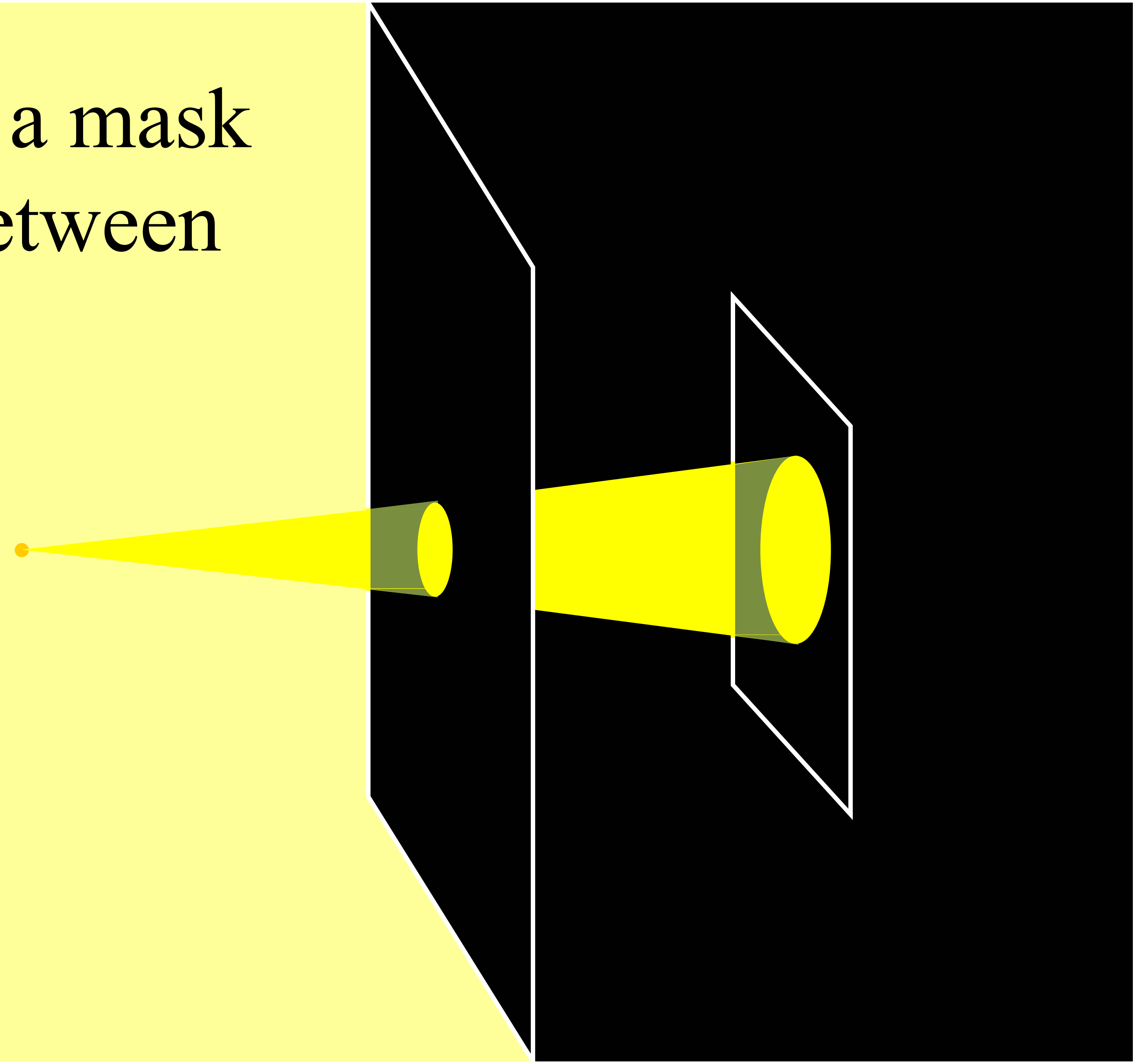
In summary

- A point source can either radiate light rays from itself, or reflect light rays from other sources.
- A point source sends out light rays in all directions.
- For the point source to be seen, one of these light rays has to reach one of our eyes.
- Light ray travels in straight lines.
- The intensity of the light is inversely proportional to the distance^2 from the source.

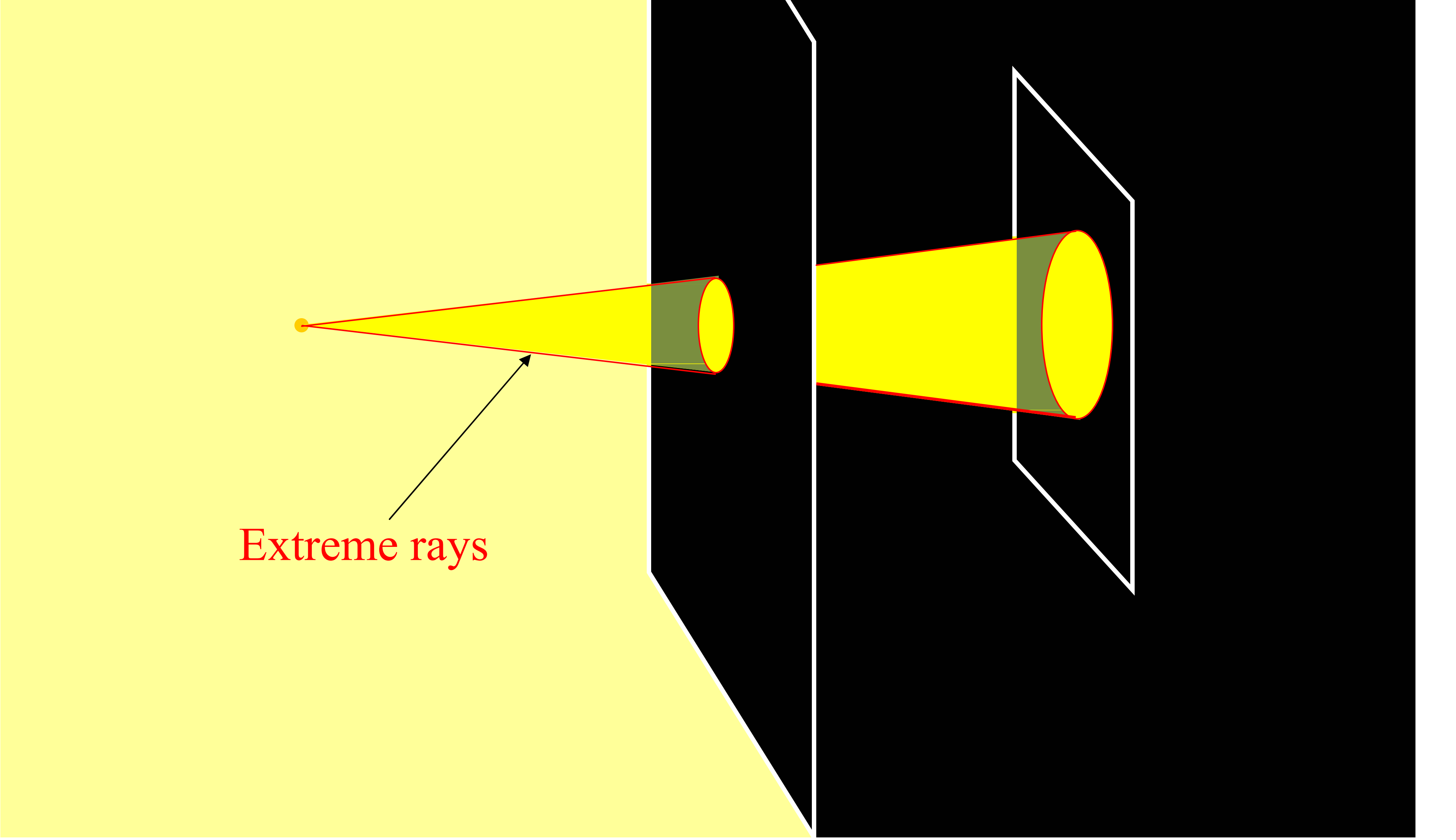
Point source and a screen

Point source and a screen

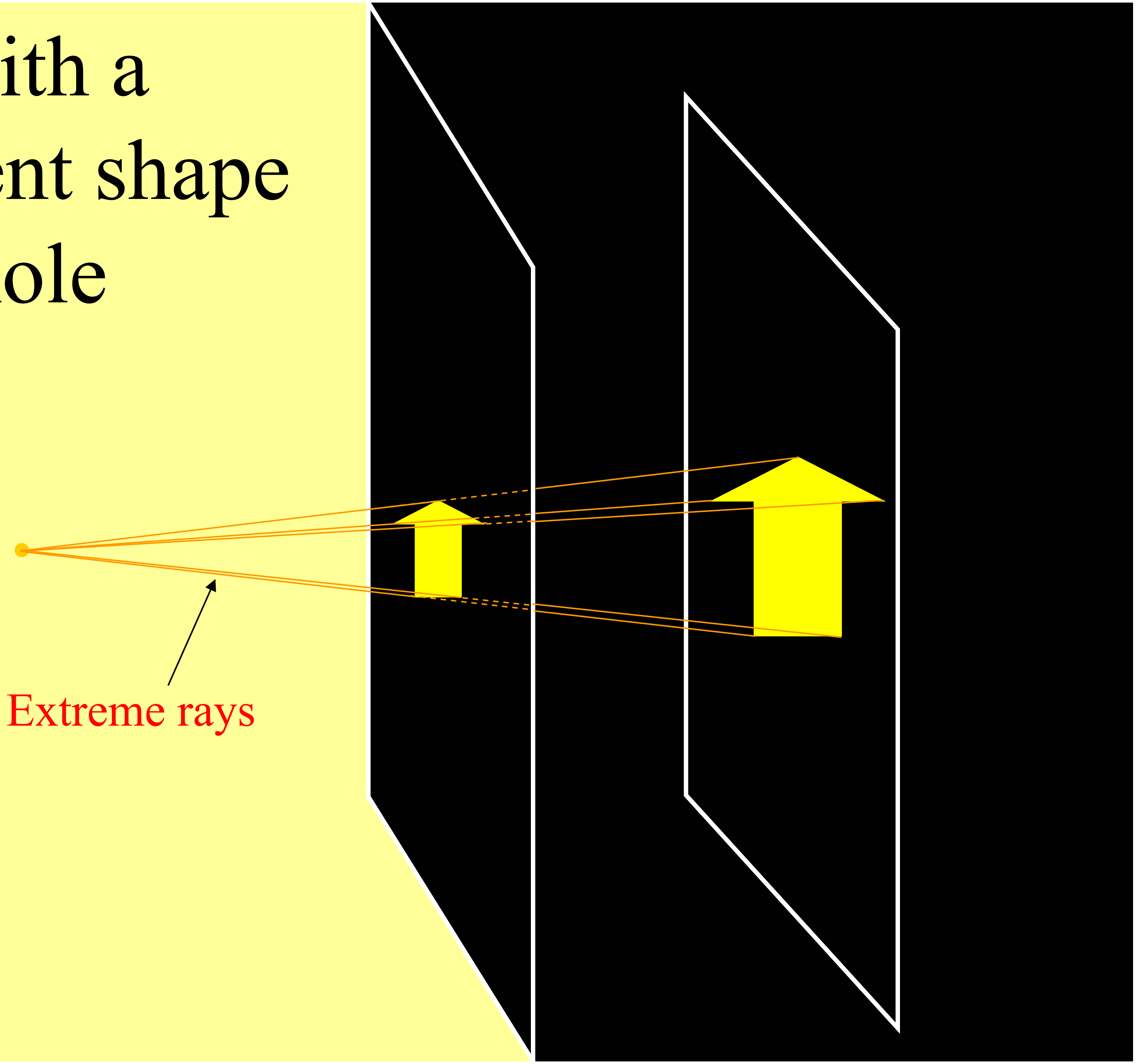
With a mask in between



Extreme Rays



With a different shape hole

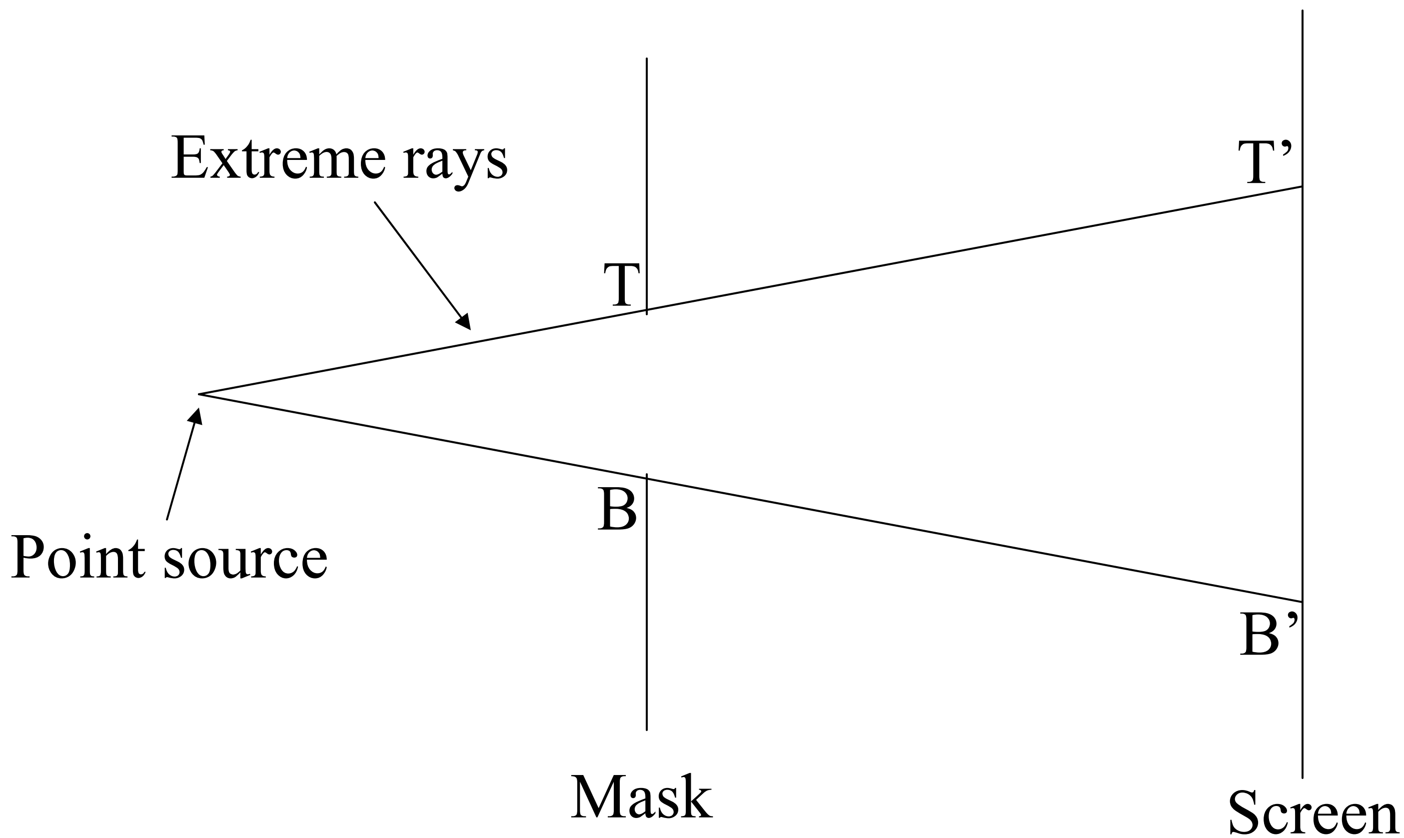


Summary

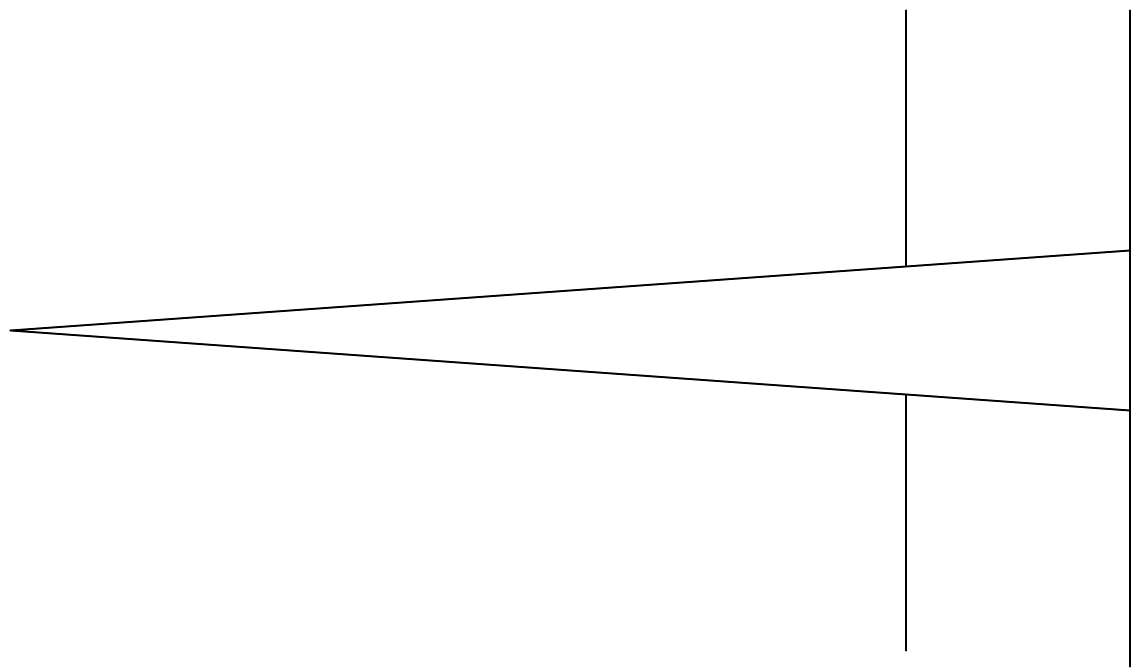
For a point source only:

- Point source send out light rays in all directions.
- Light rays travel in straight line.
- Extreme rays formed by straight lines joining the point source to the edge of the hole.
- Only rays enclosed by the extreme rays can go through the hole and hit the screen.
- Rays outside the region bound by the extreme rays will be blocked by the mask.
- Image on screen is a projection of the hole: they have the same shape and orientation.

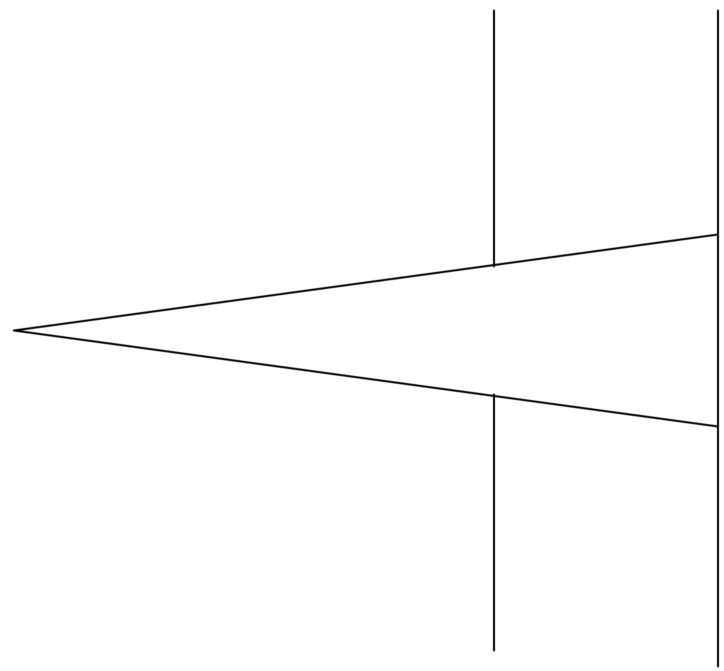
Schematic Diagram



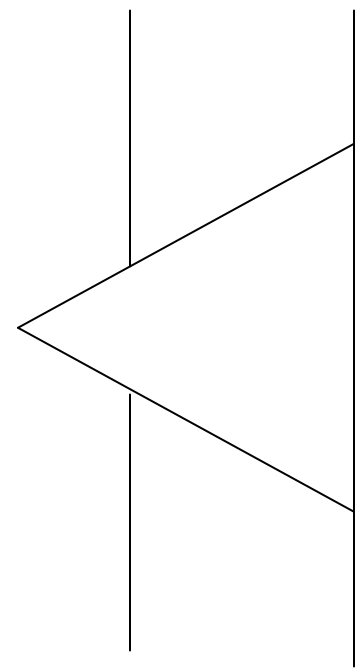
Example: Moving point source towards the mask

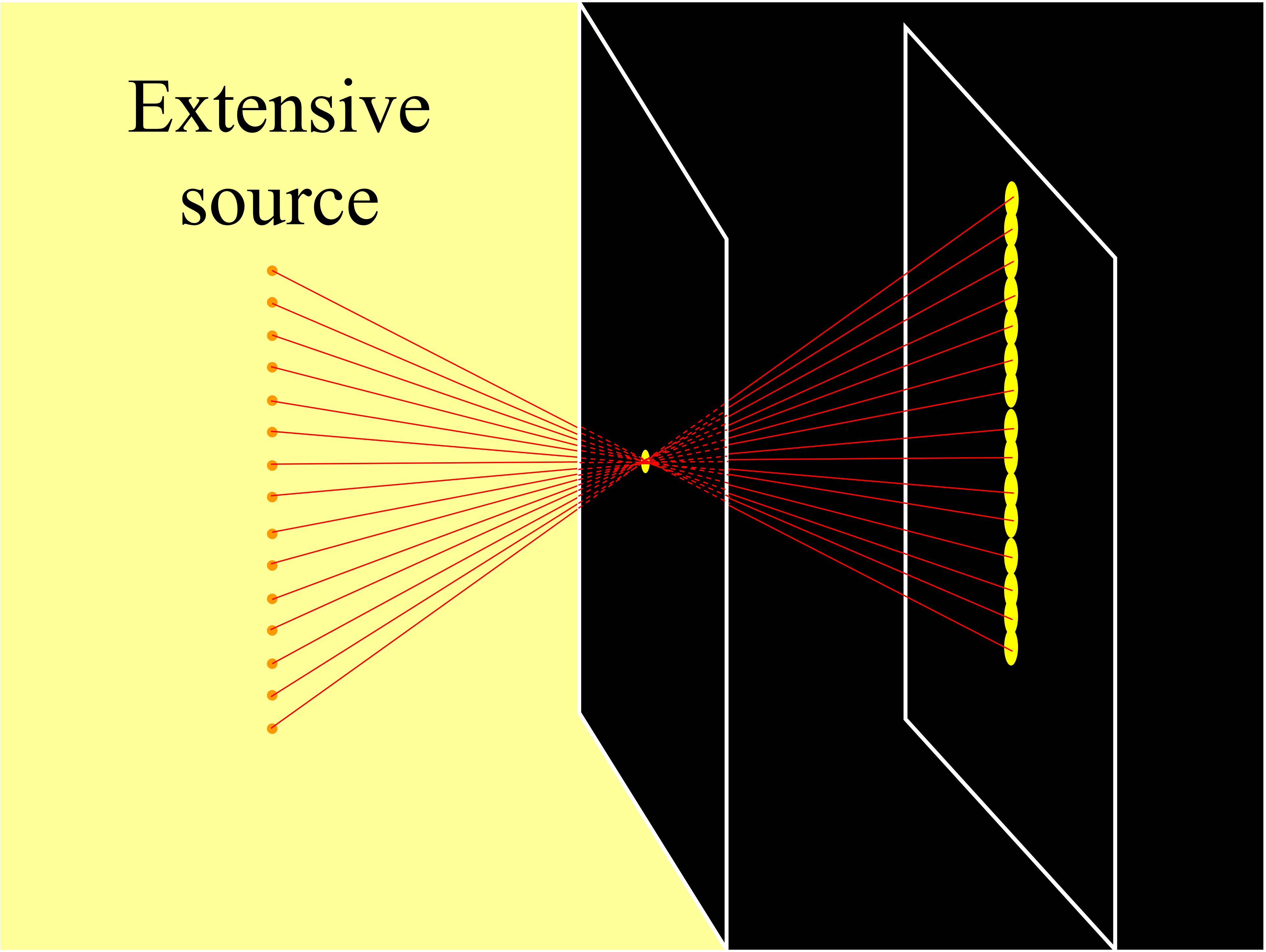


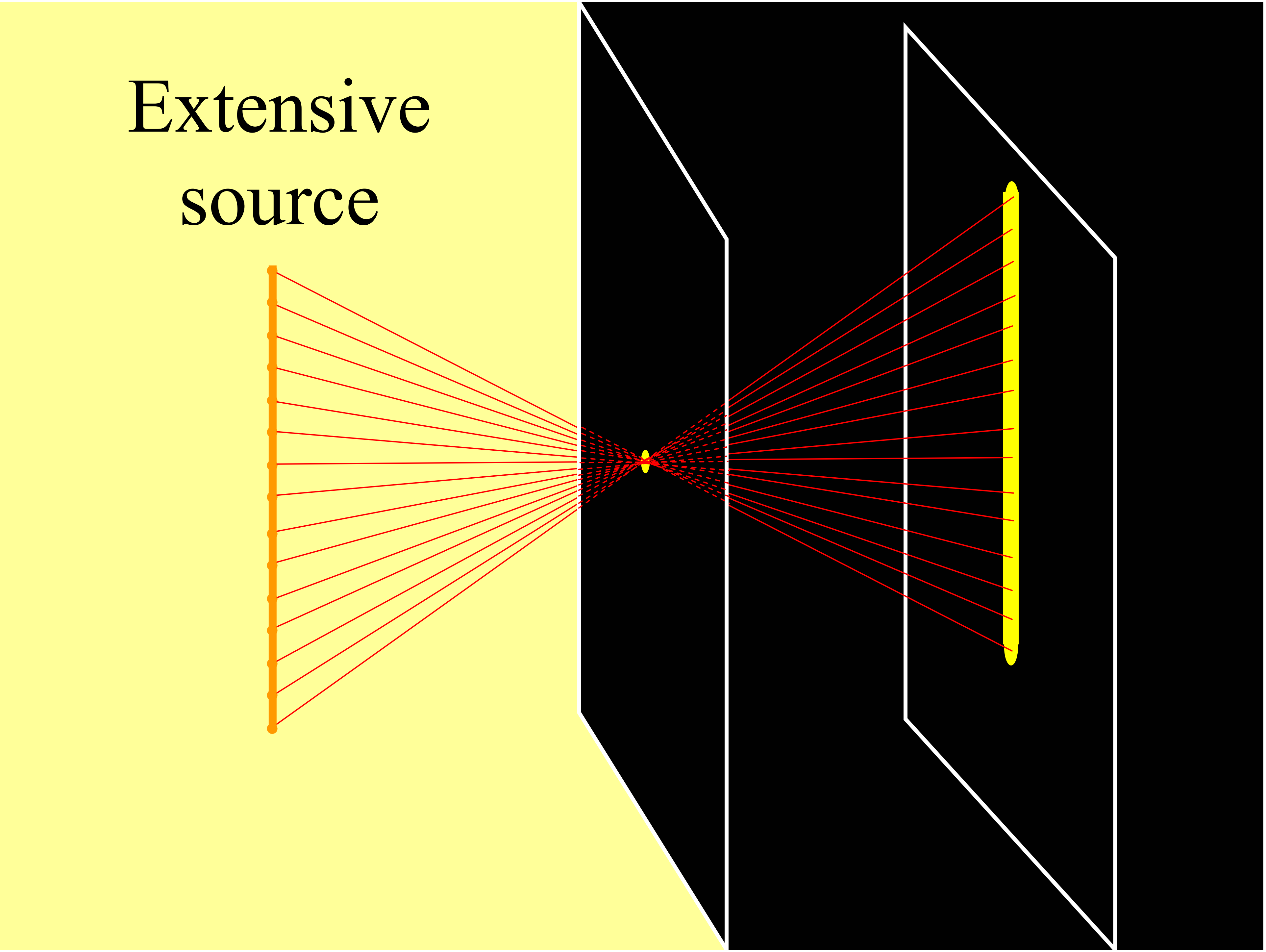
Example: Moving point source towards the mask



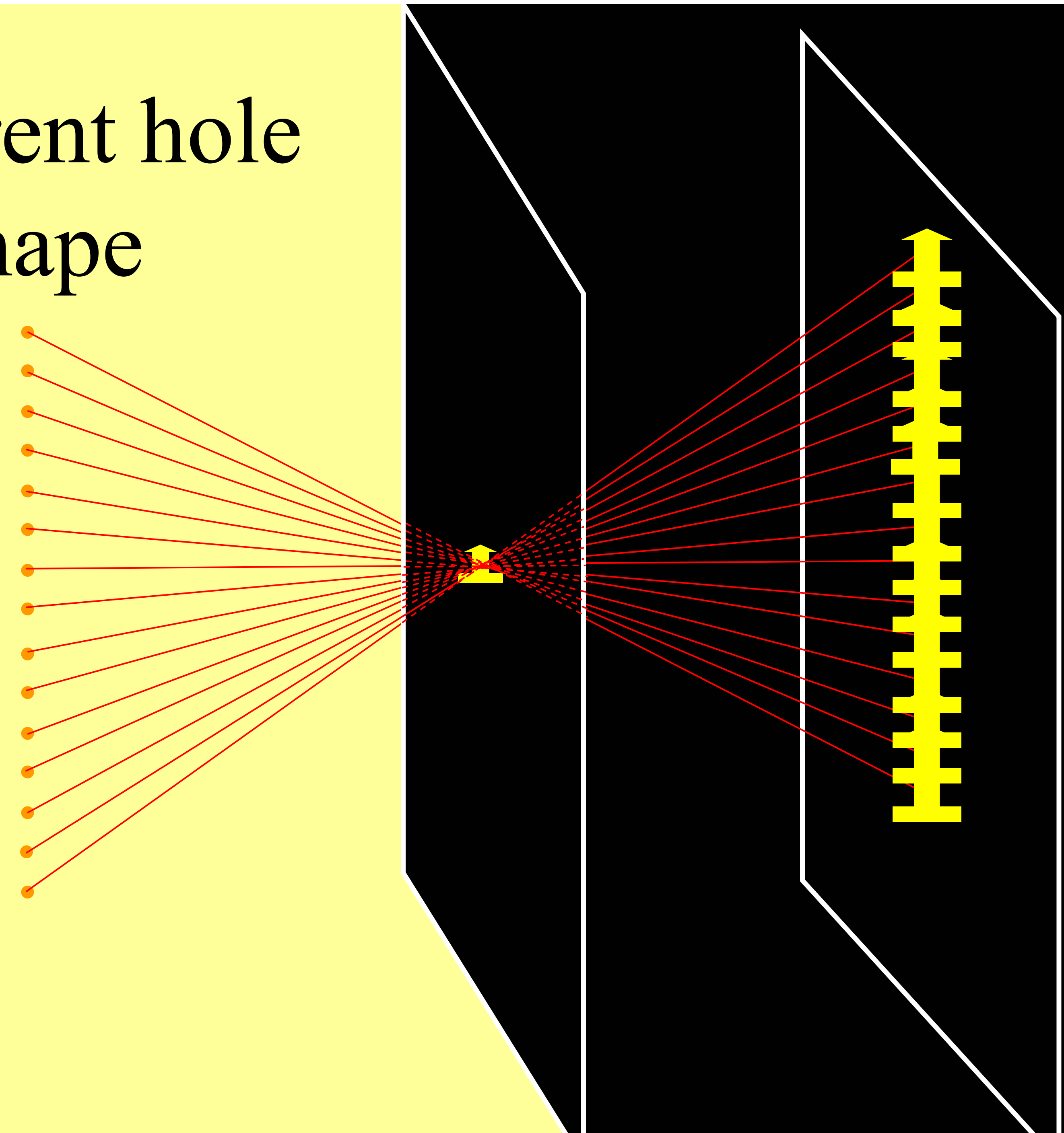
Example: Moving point source towards the mask



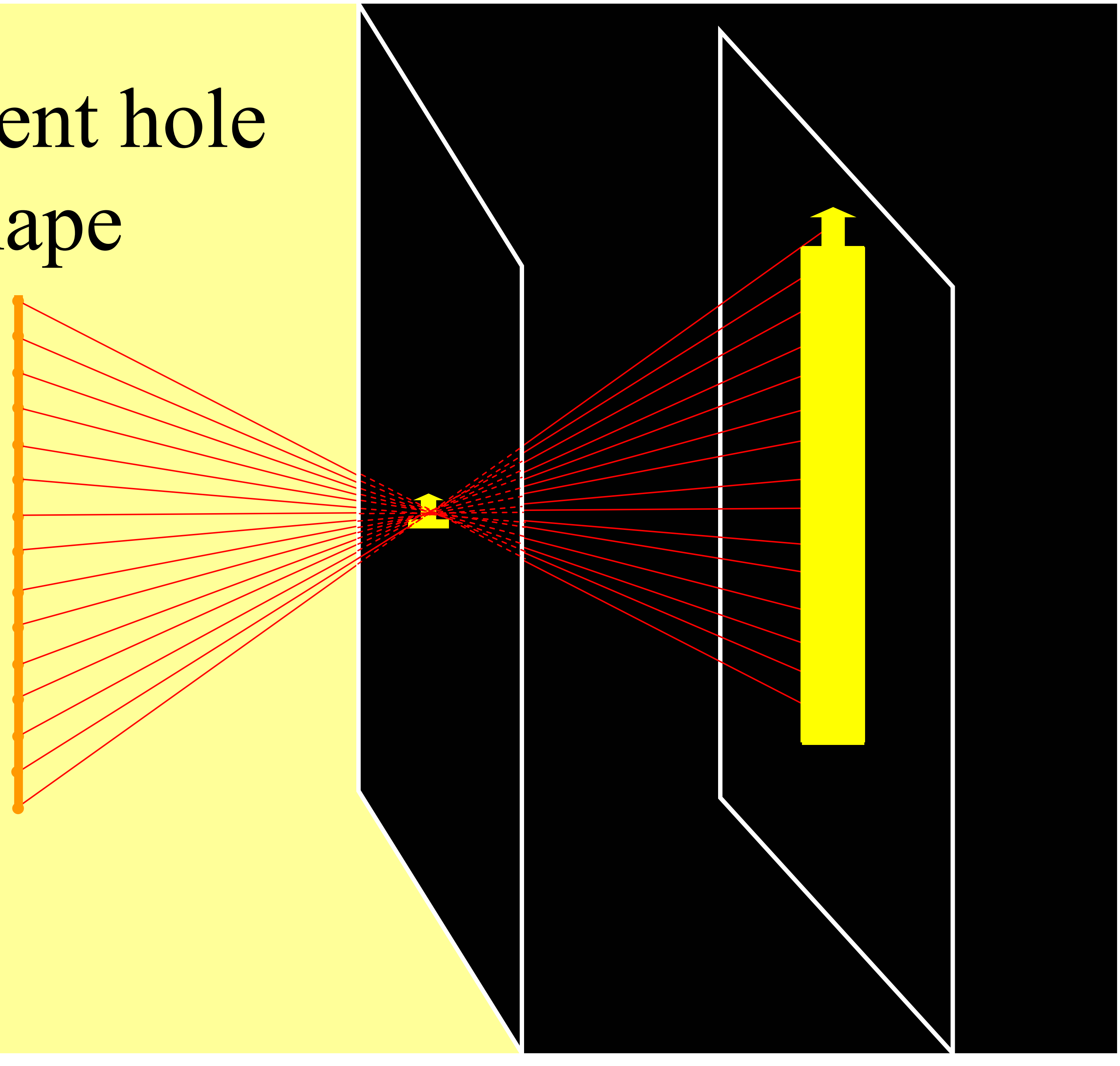

Extensive
source


Extensive
source

Different hole shape



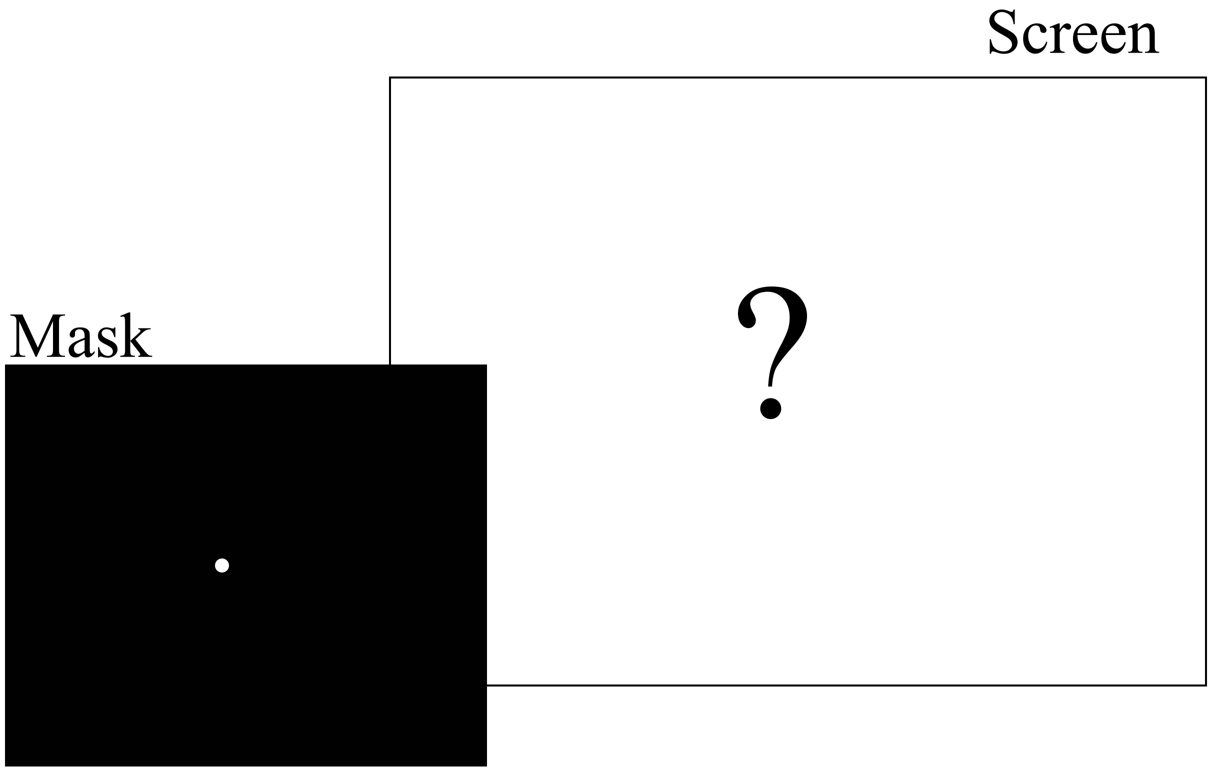
Different hole shape



Summary

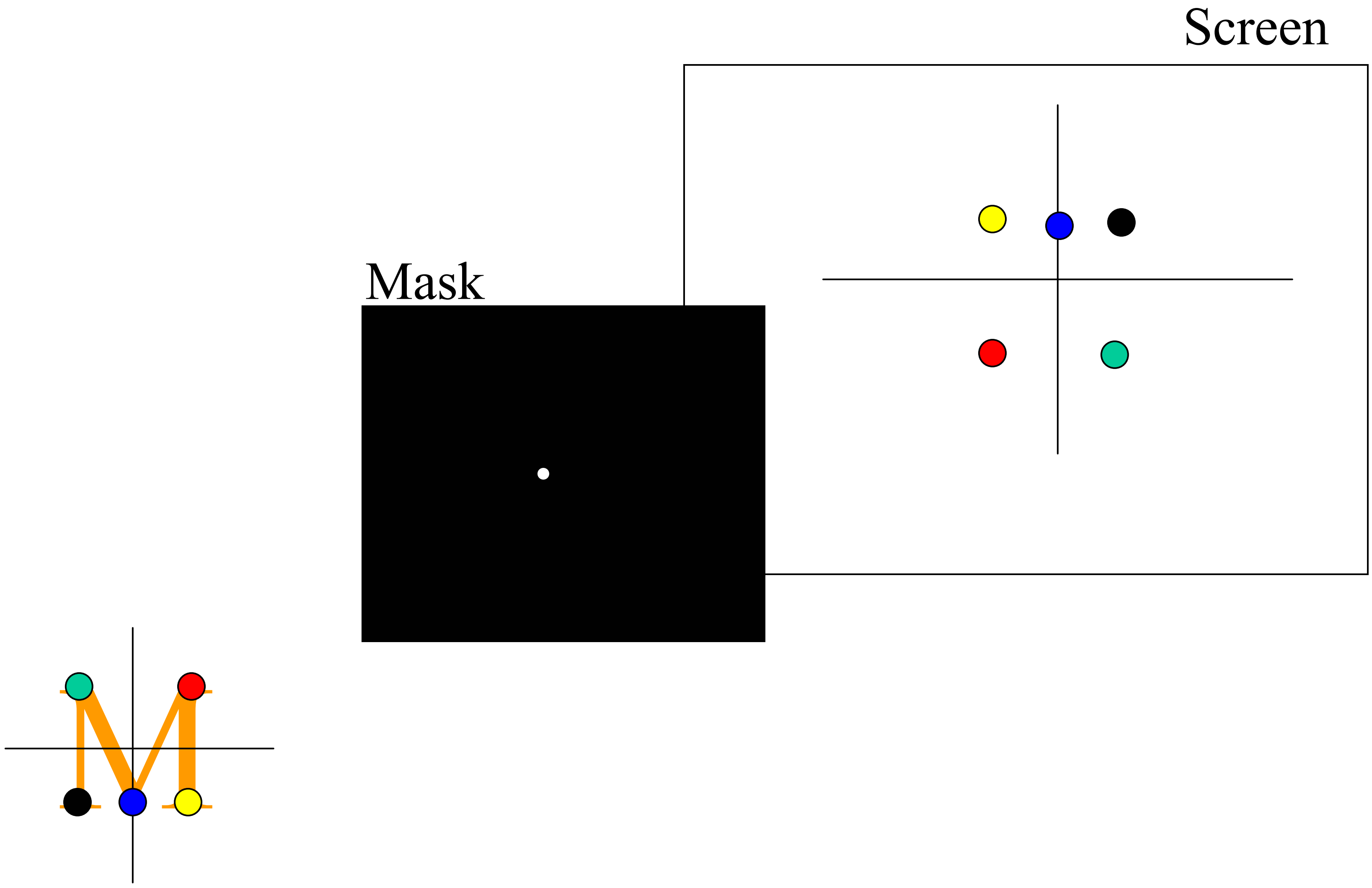
- An extensive source is formed by many many point sources.
- Every point source projects a spot of the same shape and orientation as the hole of the mask.
- The projection on the screen is an *inverted image* of the extensive light source.
- The aperture size, and therefore the spot size determines how blurred is the image on the screen.

Inverted image

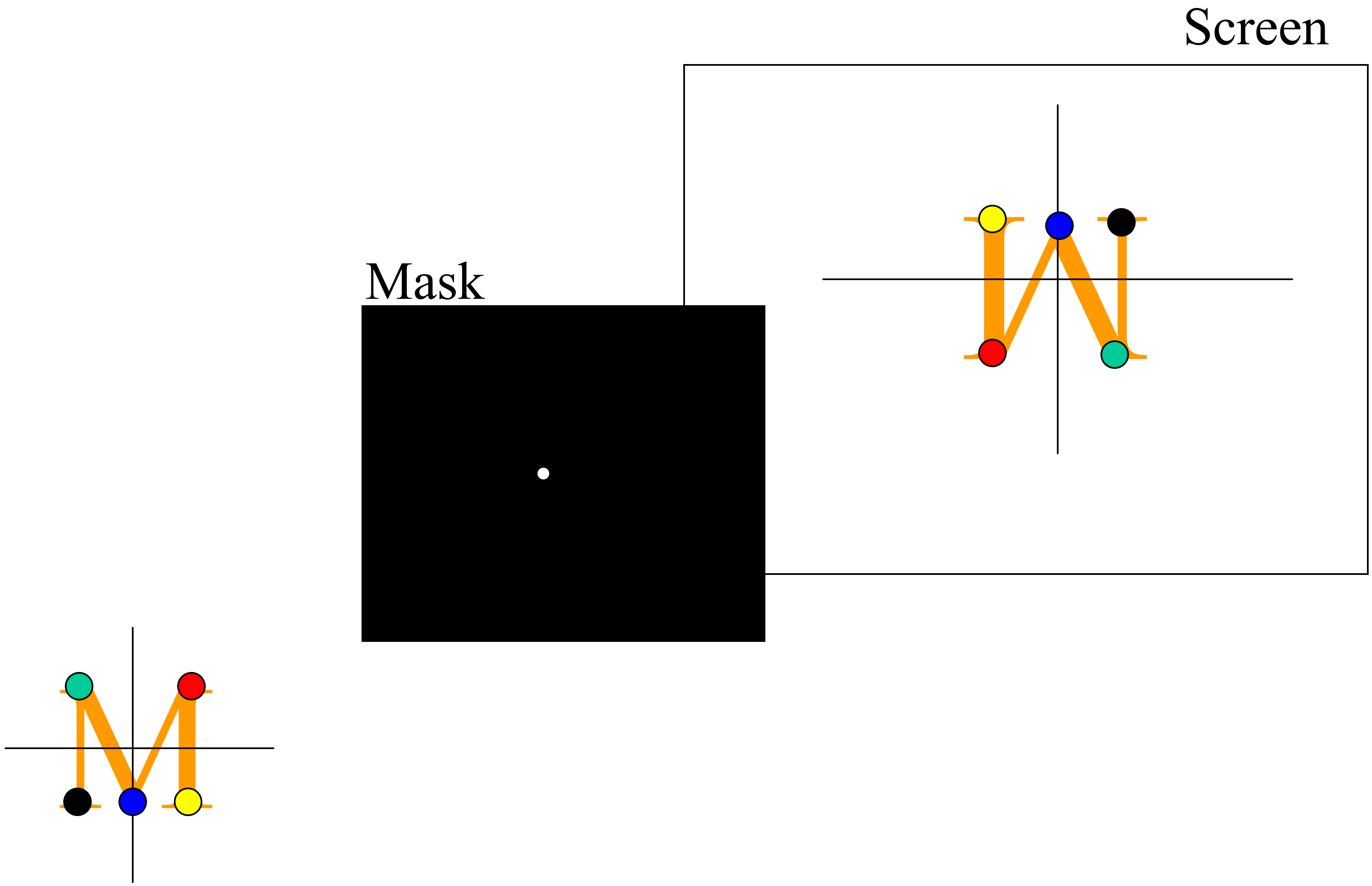


M

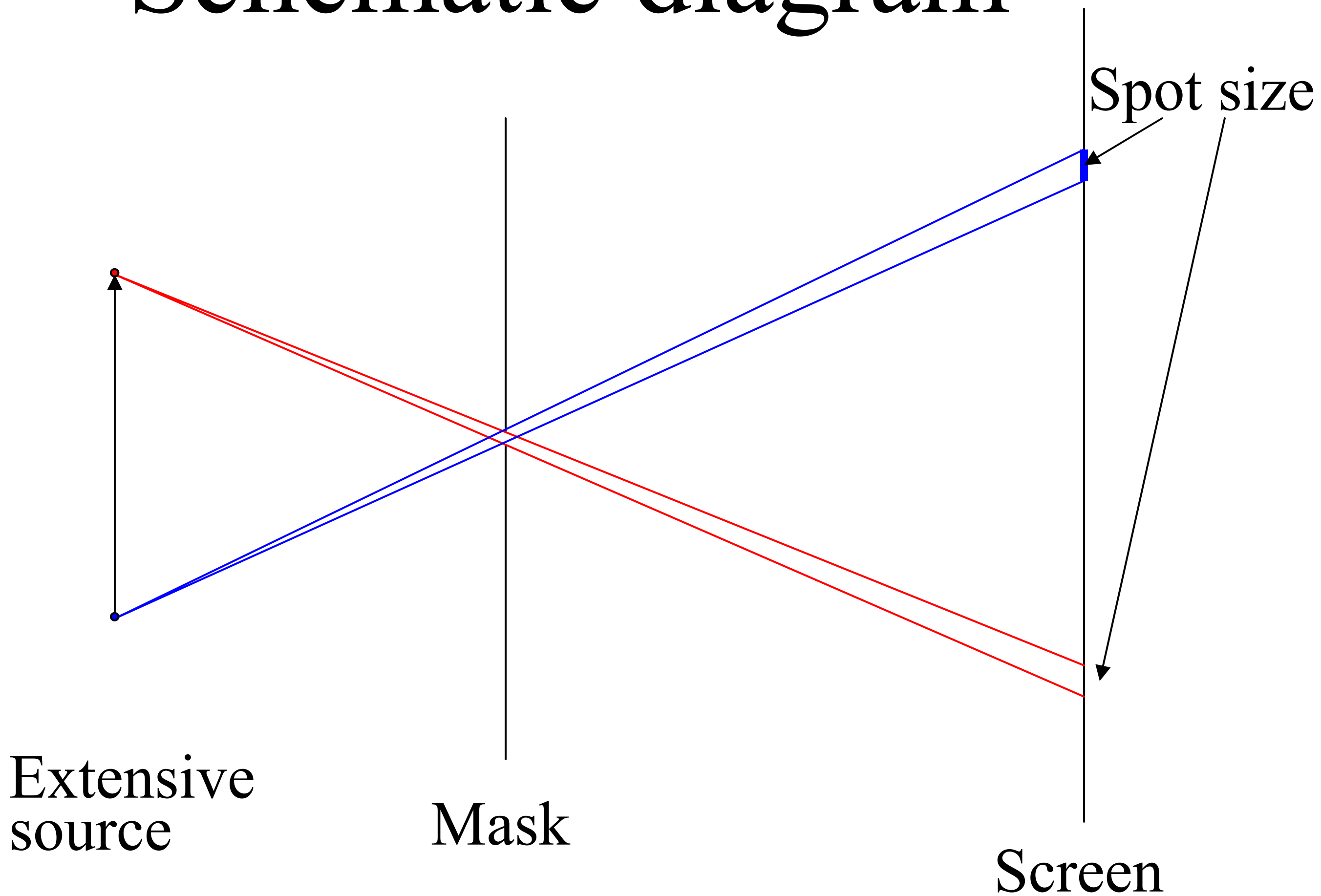
Inverted image



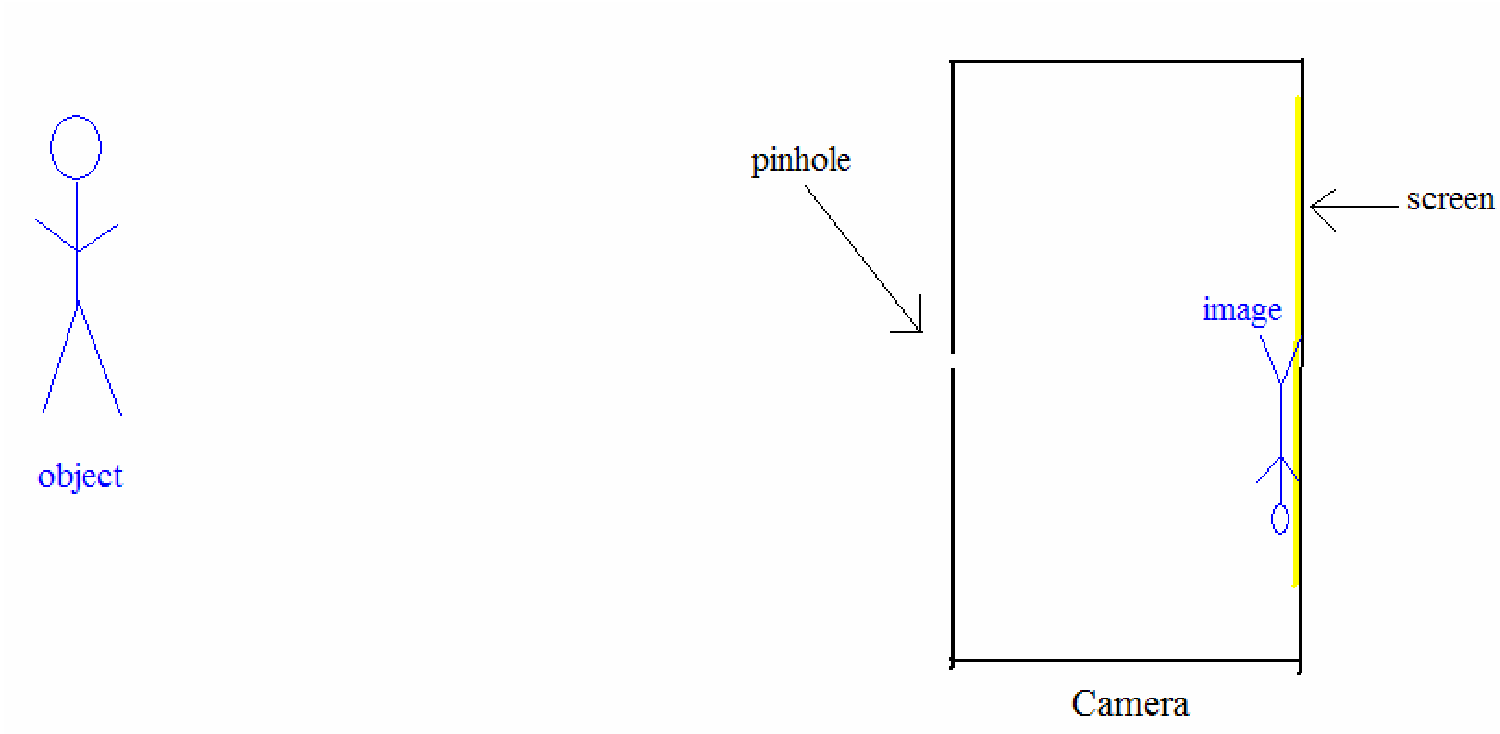
Inverted image



Schematic diagram

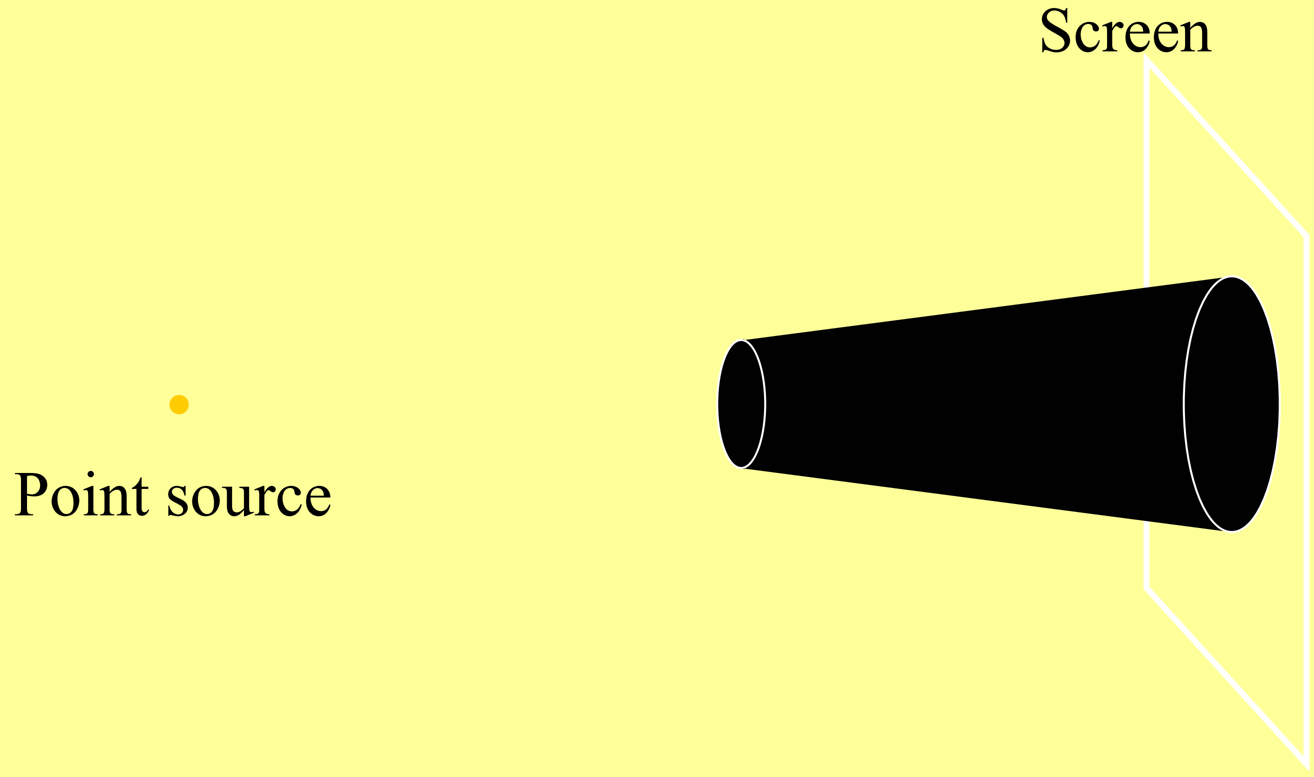


Pinhole Camera



This is the basis of the *pinhole camera*. If film is placed over the screen, and a fast shutter only allows light to enter the "*aperture*" (i.e. the pinhole) for a brief instant (to prevent overexposure of the film), the image can be captured (and saved for your grandchildren).

Shadow



Shadow

For a point source only:

- Point source sends out light rays in all directions.
- Light rays travel in straight lines.

Consider the extreme rays formed by straight lines joining the point source to the edge of the object forming the shadow.

- Rays enclosed by the extreme rays will be blocked by the object.
- Only rays outside the region bound by the extreme rays can pass and hit the screen.

Speed of Light

Light "travels" in straight lines →

How fast does it travel?

Experiment:

Speed of Light = 300,000,000 meters/second

= 186,000 miles /second.

Earth's diameter = 7900 miles – it would take only 0.04 seconds for a light ray to travel through the earth (if it were transparent)!

But What is Light ?

This basic question raged for hundreds of years. Isaac Newton thought it was a beam of very light particles. Others thought it was a wave disturbance (like sound or ocean waves), traveling through space.

Experiments in early 19th century showed that it was in fact a wave, but “what is waving”?

Electromagnetic Waves

In late 19 century, it was shown (James Maxwell) that light was a form of "electromagnetic" wave – i.e. an oscillating electric and magnetic disturbance. Other types of electromagnetic waves are radio waves, infrared waves, ultraviolet waves, and x-rays. They all have the same speed.

1905: Albert Einstein showed that nothing could travel faster than an electromagnetic wave – i.e. the speed of light is the fastest possible speed.

Light and Quantum Mechanics

Continuing experiments showed that although light travels as a wave, it also sometimes acts like particles when it interacts with matter (atoms). Our present understanding is that light has a "dual nature", with both particle and wave attributes. This is the amazing atomic (and subatomic) world of quantum mechanics!