



**March 2000**

### **Activity 3: The Geometry of Lenses**

One of the most important parts of a camera is the lens. Lenses are clear, rounded pieces of glass or plastic that bend light to form pictures. Cameras that are used to make movies can use a variety of different lenses. Cinematographers must know how to pick the right lens to get just the effect they want when they shoot a scene. Different lenses are used for wide shots, medium shots, and close ups. This activity shows how geometry determines which lens does what.



Cameras use a lens to collect light and make a picture on the surface of the film. The lens bends light rays so that all the light from one point on an object in a scene comes together at a corresponding point on the film. For this to happen, the distance between the lens and the object and the distance between the lens and the film must be just right. When that happens, we say that the object is “in focus.” You can see this happen by holding a magnifying lens over a sheet of white paper on your desk and slowly moving the lens up and down. At some distance—anywhere from a few inches to a foot or more—you will see a picture of the ceiling light on your piece of paper. If you change the distance between the lens and the paper, the picture, or image, will become blurry and then disappear.

1. Measure the distance in millimeters between the lens and the paper when the image is sharpest, or in focus. That distance is called the “focal length.” It is usually represented by the letter  $f$ , as shown in Figure 1. Make a table of the focal lengths of the different lenses in your class or group.

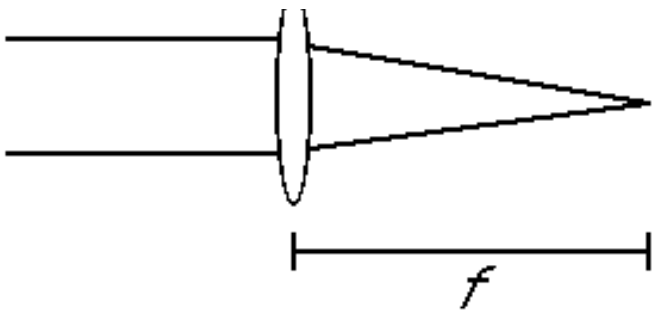


Figure 1. The focal length,  $f$ .

2. The diagram in Figure 2 shows the relationship between the size of an object and the size of the image of the object on the film. Angle  $A$  is called the "field of view." What do you know about the two triangles?

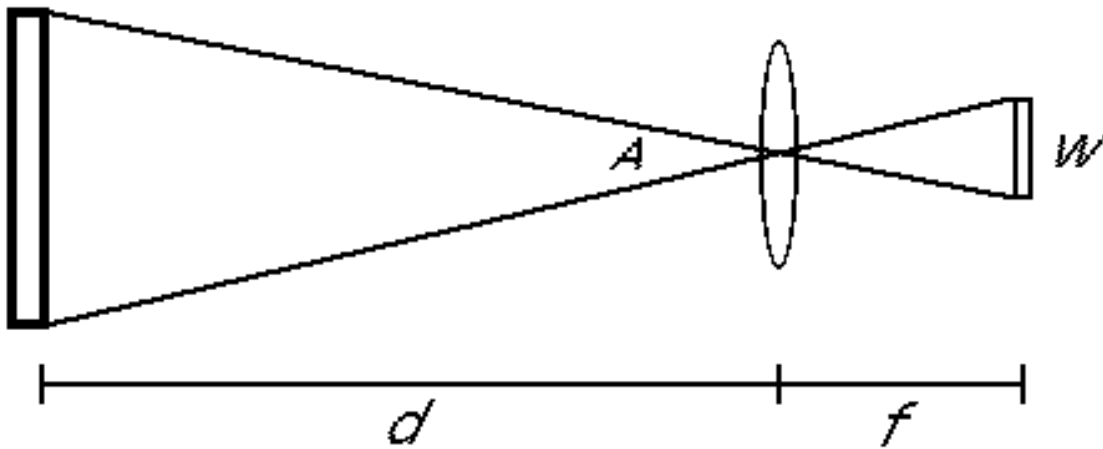


Figure 2. Diagram showing the relationship between the size of an object and its image on film.

3. When a movie maker is planning a shot, he or she has to pick a lens that will include all the action or just a part of it. How much of a scene the lens can see is determined by the triangle on the right, where the distance is the focal length and the base of the triangle is the usable width of the film. The usable width of 34 mm motion picture film is 21 mm. (The rest of the space is used up by the sprocket holes and sound Track.) The field of view is determined by the apex angle of an isosceles triangle whose base is the usable width and whose height is the focal length (see below). Draw the field of view triangle (see Figure 3) for the following lens sizes: 25 mm, 50 mm, 75 mm, and 100 mm. Measure the angle  $A$  with a protractor. If you know some trigonometry, try calculating  $A$ .

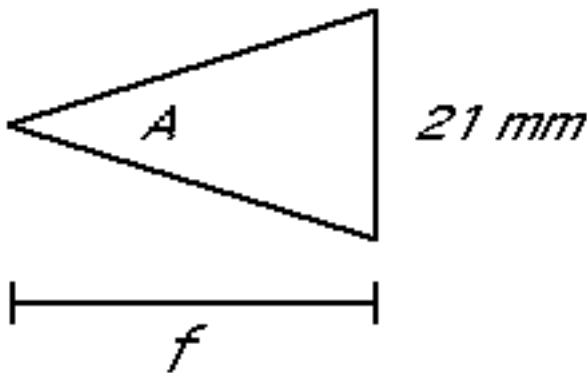


Figure 3. A view triangle for a lens size of 21 mm.

A movie maker must make sure the correct amount of light enters the camera. If too little light enters, the picture will seem too dark, and nothing in the shadows will be visible. If too much light enters, the picture will look washed out or overexposed. Film makers sometimes use too little or too much light to get artistic effects, but they always need to be in control of their light.

The amount of light that enters the camera is controlled by a gizmo called an iris diaphragm. It is placed behind the lens and creates a black surface with a hole in it. The hole is called the "aperture." The diaphragm is made out of a bunch of small, flat wedges that can be moved in and out to adjust the size of the aperture. The camera operator can adjust the size of the aperture. The area of the aperture determines the amount of light that enters the camera.

4. The camera operator set the diaphragm to 6 mm. What is the area of the aperture?
5. To darken a scene, the director tells the camera operator to reduce the aperture to 3 mm. By how much is the light reduced?
6. What aperture setting would cut the light level that was available at 6mm by a factor of two?
7. Lenses with different focal lengths will admit a different amount of light through the same aperture size. Can you explain why?
8. To make it easy to set the aperture size without worrying about the lens focal length, photographers mark the aperture control in something called f-numbers. The f-number is the focal length divided by the diameter of the hole. The f-number of 4 is written as  $f/4$  or sometimes  $f.4$ .
  - a. Which setting has a bigger aperture  $f/2$  or  $f/4$ ?
  - b. Which admits more light?
  - c. How much more?
9. To make it even easier to adjust light levels, all camera aperture controls have places where they click into place as you turn the control. These are called stops or f-stops. The stops are located so that each stop changes the light level by a factor of two. Starting with  $f/2$  and going to less light (smaller hole), what are the f-stop numbers? Round your answer to a single decimal place.
10. What f-stop number should you use to admit more light than  $f/2$ ? Not all cameras have this setting. Why?