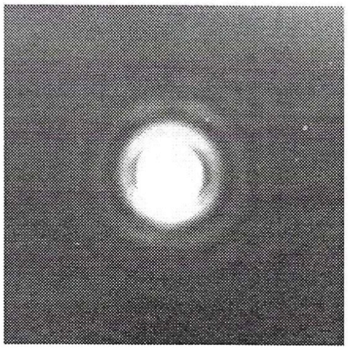
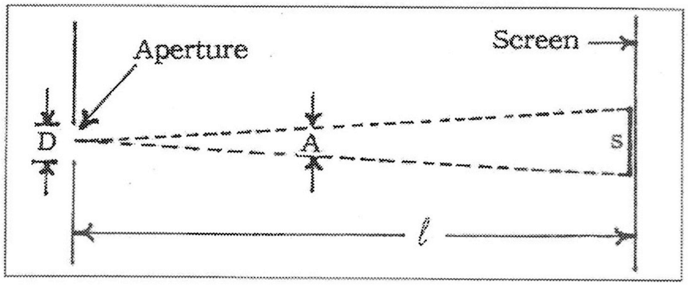
1. *Diffraction by a Circular Aperture*. We will begin with the classical case of diffraction by a circular aperture. This is the case that has long concerned astronomers, microscopists, photographers, and others who use light for technical or scientific purposes. The fundamental problem is the effect of such an aperture on the image of a point source, such as a star. While this may seem to be a very limited case, it must be remembered that *any* image is simply the sum of its myriad points! The photograph at the right shows the image of the diffraction pattern of a laboratory pinhole; the set-up was almost exactly like the one you will use. Notice that the image consists of a central disc surrounded by a series of circular "diffraction fringes." While it is not evident in the photo, in a good optical system the central disc will contain about 85% of the total energy of the image; i. e., it is far brighter than the surrounding fringes, as you will see during the experiment. The central disc is often referred to as the *Airy disc* in honor of the British Astronomer Royal, Sir George Airy, who called attention to its importance in star images.



The lens of a telescope or microscope is certainly not a "pinhole," but such lenses are nevertheless circular apertures, and they produce diffraction just as a pinhole does. The photo at the right could in fact be a greatly magnified view of the image of a star at the focus of an astronomical telescope. *It is this diffraction of light, due to the wave nature of light, that limits the ability of telescopes and microscopes to see fine detail.* Even photographers must exercise caution; if a camera (or enlarger) lens is "stopped down" to too small an aperture, the image will blur due to diffraction.

Since most of the light is concentrated in the Airy disc, it is the size of this disc that determines the resolving power or ability to see detail in an image; the smaller the Airy disc, the finer the detail that can be seen. Optical theory predicts that the *angular* diameter $\mathbf{A}$ of the Airy disc (as seen from the lens or the pinhole) will be $\mathbf{A = 2.44\lambda/D}$ where $\boldsymbol{\lambda}$ is the wavelength of the light and $\mathbf{D}$ is the diameter of the lens or pinhole. Notice that the Airy disc shrinks as the lens (or pinhole) becomes larger. A big telescope produces smaller star images than a little telescope! This is why the large instrument can see more detail. If we want to know the *linear* size of the Airy disc, we can calculate it with the help of the diagram at the right. Let $\mathbf{s}$ be the diameter of the disc, defined as the diameter of the first dark circle, while $\boldsymbol{\ell}$ is the distance from the lens or pinhole to the image. Then, since $\mathbf{A}$ is in radians, $\mathbf{A} = \mathbf{s}/\,\boldsymbol{\ell}$ and we find that $\mathbf{s} = \mathbf{2.44}\,\boldsymbol{\lambda\ell}\,/\mathbf{D}$.



Let's now undertake a laboratory test of these relations. Set up your laser on a bench exactly 2 meters from your screen. Clamp a clean sheet of paper on the screen. You are provided with 3 pinholes in a slide mount that fits in a special stand.

Place the pinholes an inch or two in front of the laser. The largest pinhole is big enough to accommodate the entire laser beam. Line up your apparatus so the laser beam