25–1 Cameras, Film and Digital

The basic elements of a **camera** are a lens, a light-tight box, a shutter to let light pass through the lens only briefly, and in a traditional camera a piece of film (Fig. 25–1), or in a digital camera an electronic sensor. When the shutter is opened, light from external objects in the field of view is focused by the lens as an image on the film or sensor. Film contains light-sensitive chemicals that change when light strikes them. In the development process, chemical reactions cause the changed areas to turn opaque, so the image is recorded on the film.[†] You can see the image yourself if you remove the back of a conventional camera and view through a piece of tissue paper (on which an image can form) placed where the film should be with the shutter open.

PHYSICS APPLIED
The camera

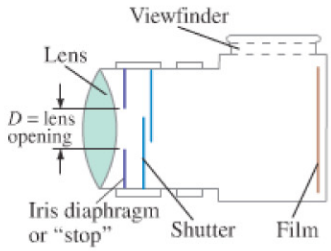


FIGURE 25–1 A simple camera.

Digital Cameras, CCD Sensors

In a **digital camera**, the film is replaced by a semiconductor sensor known as a **charge-coupled device (CCD)**. A CCD sensor is made up of millions of tiny pixels ("picture elements")—see Fig. 24–49. A 3-MP (3-megapixel) sensor[‡] would contain about 1500 pixels vertically by 2000 pixels horizontally over an area of perhaps 9 mm × 12 mm. Light reaching any pixel liberates electrons from the semiconductor. The more intense the light, the more charge accumulates during the brief exposure time. Conducting electrodes carry each pixel's charge (serially in time, row by row—hence the name "charge-coupled") to a central processor that stores the relative brightness of pixels, and allows reformation of the image later on a computer screen or printer.

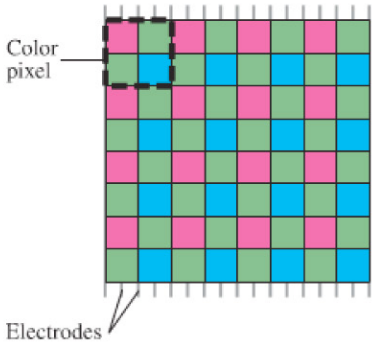
A CCD is fully reusable. Once the pixel charges are transferred to memory, a new picture can be taken.

Color is achieved by red, green, and blue filters over alternating pixels as shown in Fig. 25–2, similar to a color CRT or LCD screen. The sensor type shown in Fig. 25–2 contains twice as many green pixels as red or blue (green is claimed to have a stronger influence on the sensation of sharpness). The computer-analyzed color at each pixel is that pixel's intensity averaged with the intensities of the nearest-neighbor colors.

To reduce the amount of memory for each picture, compression programs can average over pixels, but with a consequent loss of sharpness, or "resolution."

PHYSICS APPLIED
Digital cameras

FIGURE 25–2 Portion of a typical CCD sensor. A square group of four pixels $\begin{matrix}R&G\\G&B\end{matrix}$ is sometimes called a "color pixel."



* Digital Artifacts

Digital cameras can produce image artifacts (errors in the image not present in the original, resulting from the imaging process). One example using the "mosaic" pixels of Fig. 25–2 is described in Fig. 25–3. Another technology uses a semitransparent silicon semiconductor layer system, exploiting the fact that different wavelengths of light penetrate silicon to different depths: each pixel is a sandwich of partly transparent layers, one for each color. The top layer can absorb blue light, allowing green and red light to pass through. The second layer absorbs green and the bottom layer detects the red. All three colors are detected by each pixel, resulting in better color resolution and fewer artifacts.

[†]This is called a *negative*, because the black areas correspond to bright objects and vice versa. The same process occurs during printing to produce a black-and-white "positive" picture from the negative. Color film has three emulsion layers (or dyes) corresponding to the three primary colors.

[‡]Each different color of pixel in a CCD is counted as a separate pixel. In contrast, in an LCD screen (Section 24–11), a group of three subpixels is counted as one pixel, a more conservative count.

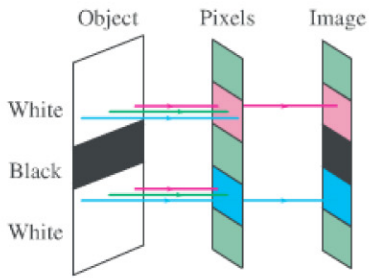


FIGURE 25–3 Suppose we take a picture that includes a thin black line (our object) on a white background. The image of this black line has a colored halo (red above, blue below) due to the mosaic arrangement of color filter pixels, as shown by the colors transmitted. Computer averaging can minimize color problems such as this (the green at top and bottom of image can be averaged with nearby pixels to give white or nearly so) but the image is consequently "softened" or blurred. The layered color pixel described in the text would avoid this artifact.