Topic no. 66

Characteristic of lenses

The lens forming an image in the camera is a converging lens, the simplest form of which is a single biconvex (lentil-shaped) element. In theory such a lens makes a light beam of parallel rays converge to a point (the focus) behind the lens. The distance of this focus from the lens itself is the focal length, which depends on the curvature of the lens surfaces and the optical properties of the lens glass. An object at a very long distance (optically regarded as at "infinity") in front of the lens forms an inverted image in a plane (the focal plane) going through the focus. Light rays from nearer objects form an image in a plane behind the focal plane. The nearer the object, the farther behind the lens the corresponding image plane is located—which is why a lens has to be focused to get sharp images of objects at different distances.

FOCAL LENGTH AND IMAGE SCALE

The image scale, or scale of reproduction, is the ratio of the image size to the object size; it is often quoted as a magnification. When the image is smaller than the object, the magnification of the object is less than 1.0. If the image is $^{1}/_{20}$ the size of the object, for example, the magnification may be expressed either as 0.05 or as 1:20. For an object at a given distance, the scale of the image depends on the focal length of the lens (Figure 4). A normal camera lens usually has a focal length approximately equal to the diagonal of the picture format covered. A lens of longer focal length gives a larger scale image but necessarily covers less of the scene in front of the camera. Conversely, a lens of shorter focal length yields an image on a smaller scale but—provided the angle of coverage is sufficient (see below)—takes in more of the scene. Many cameras, therefore, can be fitted with interchangeable lenses of different focal lengths to allow varying the image scale and field covered. The focal length of a lens in millimetres (sometimes in inches) is generally engraved on the lens mount.

APERTURE

The aperture, or *f*-number, is the ratio of the focal length to the diameter of an incident light beam as it reaches the lens. For instance, if the focal length is 50 millimetres and the diameter of the incident light beam is 25 millimetres, the *f*-number is 2. This incident-beam diameter is often roughly the lens-diaphragm diameter, but it may be appreciably larger or smaller. The maximum aperture (*f*-number at the largest diaphragm opening) is also marked on the lens, usually in the form *f*:2, *f*/2, or 1:2.

ANGLE OF COVERAGE

A lens must cover the area of a camera's film format to yield an image adequately sharp and with reasonably even brightness from the centre to the corners of the film. A normal lens should cover an angle of at least 60°. A wide-angle lens covers a greater angle—about 70° to 90° or more for an ultra-wide-angle lens. A long-focus lens covers a smaller angle.

The angle of coverage depends on the lens design. Designations like "wide angle" or "narrow angle" are not necessarily synonymous with "short focus" and "long focus," as the latter terms refer to the focal length of the lens relative to the picture format.

Optical performance

A simple lens produces a very imperfect image, which is usually blurred away from the center. The image may have colour fringes around object outlines, and straight lines may be distorted. Such defects, called aberrations, can be eliminated—and even then not completely—only by replacing the single lens element by a group of elements of appropriate shape and separation. Aberrations arising from some of the lens elements then counteract opposite aberrations produced by other elements. The larger the maximum aperture, the greater the angle of coverage, and the higher the degree of correction aimed at, the more complex camera lenses become. Lens design for relative freedom from aberrations involves advanced computer programming to calculate the geometric parameters of every lens element. Some aberrations can also be corrected by making one or more of the surfaces of a lens system aspheric; *i.e.*, with the variable curvature of a paraboloid or other surface rather than the constant curvature of a spherical one.
Lenses usually consist of optical glass. Transparent plastics also have come into use, especially as they can be molded into elements with aspheric surfaces. They are, however, more sensitive to mechanical damage.

ABERRATIONS

There are a number of lens aberrations, each with its own characteristics. Chromatic aberration is present when the lens forms images by different-colored light in different planes and at different scales. Color-corrected lenses largely eliminate these faults. Spherical aberration is present when the outer parts of a lens do not bring light rays into the same focus as the central part. Images formed by the lens at large apertures are therefore unsharp but get sharper at smaller apertures.Curvature of field is present when the sharpest image is formed not on a flat plane but on a curved surface. Astigmatism occurs when the lens fails to focus image lines running in different directions in the same plane; in a picture of a rail fence, for instance, the vertical posts are sharp at a focus setting different from the horizontal rails. Another aberration, called coma, makes image points near the edges of the film appear as irregular, unsharp shapes. Distortion is present when straight lines running parallel with the picture edges appear to bow outward (barrel distortion) or inward (pincushion distortion).