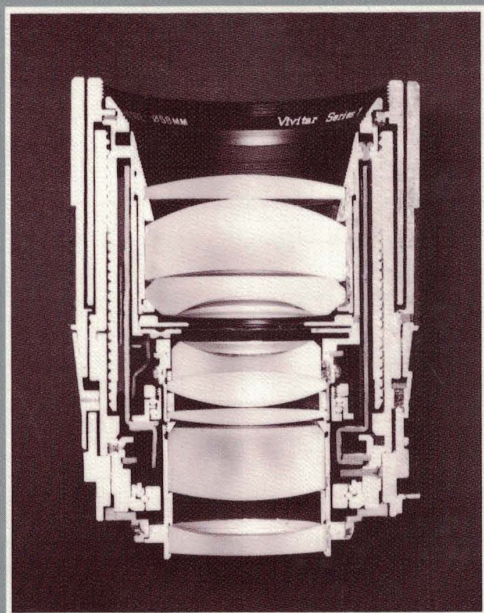


Optics in Photography



Rudolf Kingslake

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The Brightness of Images

The relation between the aperture of a lens and the brightness of the image produced by it on the photographic emulsion is often misunderstood, yet it is of the greatest importance to the photographer who wishes to make the best use of the equipment. The tremendous efforts of lens designers and manufacturers that have been devoted to the production of lenses of extremely high relative aperture are an indication of the need that exists for brighter images and "faster" lenses.

In this chapter, we are concerned with the flow of light from an object, through a lens, to the image. Several photometric terms must be understood before we can give a precise statement of this effect, and of the factors that control the brightness of the image projected on the film in a camera.

The *illumination* (illuminance) produced by a lamp at any distance from it is found by dividing the candle power of the lamp by the square of the distance (the inverse square law). Thus, a 50-candle lamp will produce, at a distance of 3 feet, an illumination of $50/9 = 5.6$ foot-candles. The illumination in a well-lighted factory or classroom may reach 50 foot-candles, and in motion-picture or television studios, illuminations as high as 200 to 300 foot-candles are common.

The term *flux* is used to express a quantity of light. The unit of flux is the lumen, defined as the amount of light falling on each square foot of a surface under an illumination of 1 foot-candle; hence, foot-candles and lumens per square foot are two ways of expressing the same thing. The convenience of this term may be seen by an example. Suppose we know that a certain 16mm projector emits 550 lumens. Then, if the projected image is 3×4 ft, the average illumination on the screen will be $550/12 = 46$ foot-candles; if the image is 5×6.6 ft, the illumination will be $550/(5 \times 6.6) = 16.7$ foot-candles, and so on.

The *brightness* (luminance) is the luminous power per unit area. Thus, a lamp has about 2500 candle power, but its brightness is thus about 25 candles per square foot. In a projection lamp, the brightness is much greater, but it is exceeded by the sun, which has a brightness of about 100,000 candles per square foot. The brightness of a surface is measured in millimillimillimeter, and by the surface area of the surface, 2000 candles per square millimeter.

At the other end of the scale, the brightness of a surface under ordinary room light is about 1 candle per square foot. Calculating the brightness

where k is the reflectivity of the surface, the illumination in foot-candles is k times the illumination in the room. The brightness of white paper is 1. This is equal to $14/930 = 0.015$ candles per square millimeter.

The formula (6.1) for the brightness of a surface is not always applicable. Sandblasted metal, metallic surfaces, and metallic surfaces tend to reflect light some angle equal to the angle of incidence. This is brighter than white paper, but it is duller than white paper in this chapter (page 135).

The inconvenience of the new brightness unit has been to $1/\pi = 0.32$ candles per square foot required to express the brightness of candles per square foot. It

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We conclude, therefore, that the brightness of a surface is the number of reflective and perfectly diffusive candles falling upon it.