POINT LIGHT SOURCES and LUMINOUS INTENSITY

DEFINITION OF INTENSITY

Consider a very small source of light radiating luminous flux. The source might radiate uniformly in all directions (an isotropic source), like a small, very hot, ball bearing, but generally more flux will leave in some directions than others (a non isotropic source), as with a light filament. We may characterize this very small or "point" source of light by its intensity, I, which is defined as the amount of luminous flux radiated into a unit solid angle or

$$I = dF/d\omega \tag{1}$$

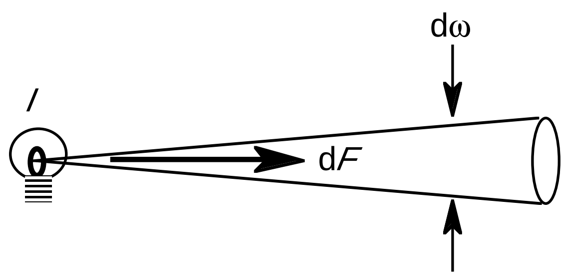

Figure 1. The intensity, I, of the light filament is $dF/d\omega$, where dF is the flux radiated into solid angle $d\omega$. A different value of intensity could result if the solid angle were taken in a different direction since, in general, more flux is radiated in some directions than others.

(See figure 1.) The actual intensity measured will depend on the direction of the solid angle. For instance, the intensity measured from the side of a light filament is greater than that measured from one of its ends. The unit of luminous intensity is the candela (abbreviated cd) which is dimensionally the same as a lumen per steradian. (Older literature will give intensity in candles. For all practical purposes the candle and candela are identical.)

INVERSE SQUARE LAW OF PHOTOMETRY

Let's measure the luminous flux from a point source indirectly using an illuminance meter. Assume the meter is a distance r from the source and that the normal to the meter head makes an angle ϕ with the line from the source to the meter. Further, assume that the area of the meter head is small enough that the flux is uniform over its surface. The illuminance of the meter head is, by definition,

$$E=\mathrm{d}F/\mathrm{d}A,$$

where flux $\mathrm{d}F$ falls on a meter head of area $\mathrm{d}A$. But from (1) the flux falling on the meter is

$$\mathrm{d}F=I\mathrm{d}\omega$$

where ω is the solid angle subtended by the meter head at the light source. Combining these last two equations,

$$E=I(\mathrm{d}\omega/\mathrm{d}A).$$

Using $\mathrm{d}\omega/\mathrm{d}A=\cos\phi/r^2$, our final result becomes

$$E=I\cos\phi/r^2. \tag{2}$$

Equation (2) is an inverse square law analogous to Coulomb's law of electrostatics or to the law of gravitational attraction. But (2) is rather more complicated since it depends on the orientation of the receiving surface.

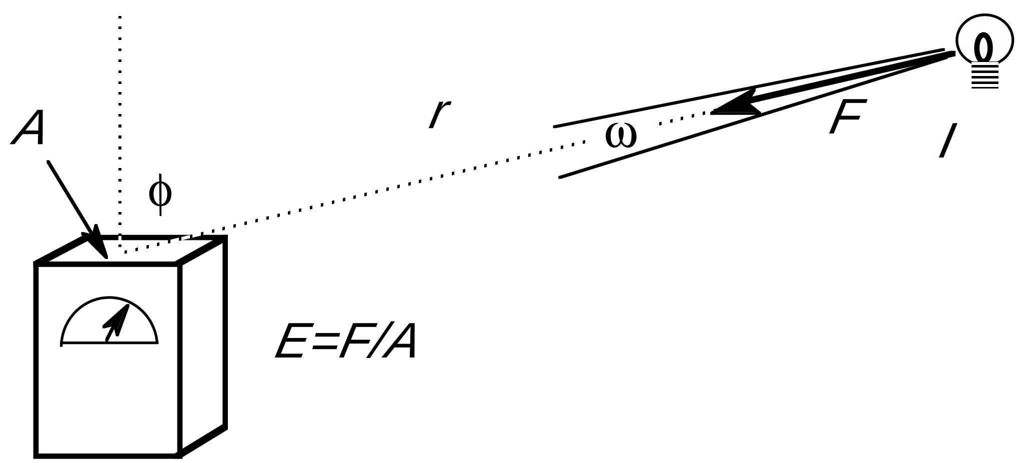

Figure 2. The illuminance of a surface due to a point source of intensity I is $E=I\cos\phi/r^2$ where r is the distance from source to surface and ϕ designates the relative orientation of the surface.

Note that the left hand side of (2) has illuminance units such as lumens per square foot or lumens per square meter, while the right hand side has units of candelas per square foot or candelas per square meter. Dimensionally, then, we can write the equation

$$\text{lumens/ft}^2 \approx \text{candelas/ft}^2 \equiv \text{foot-candela}$$
$$\text{lumens/m}^2 \approx \text{candelas/m}^2 \equiv \text{meter-candela} \equiv \text{lux}.$$

The foot-candela and meter-candela are unfortunately named since they actually have the dimensions of candelas per unit area rather than candela times length, as the names would imply. Much time in the study of photometry can be wasted on the perverse proliferation of units. Nonetheless, most manufacturers prefer ft-cd and lux (abbreviated lx) as units of illuminance and designate the scale readings on illuminance meters accordingly.

If light from two or more sources strikes a meter the cumulative effect is just the sum of the individual effects, i.e. illuminance is additive. Strictly speaking, this only applies to incoherent light sources since interference effects may take place with coherent sources. But since all ordinary sources are incoherent, we're usually safe in assuming illuminance additivity.