# Photometry in imaging systems

When one wants to perform light measurements in imaging systems, it is done for some of the following reasons:

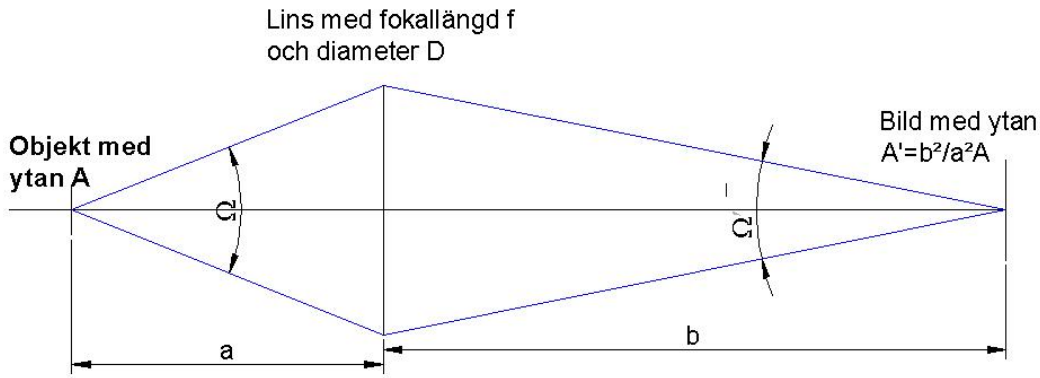
One wants to know whether the illuminance in a room is good enough for a given film/CCD

One wants to dimension a light setting

One wants to change the scene so the ”right” thing emerges

In principle one can always follow the flow path through the optical system and in this way calculate the illuminance on the film as a function of the luminance of the object.

In reality one usually utilizes the law of conservation of the luminance, which we will demonstrate below for a thin lens. The relation holds in fact also for lens systems provided that respective solid angles are calculated for entrance and exit pupils, respectively.




Let the luminance of the object be L and the luminance of the image (viewed from the right) be L’.

The flow from the object going through the lens can then be calculated from the definition of luminance.

$$L \equiv \frac{\Phi_v}{A\Omega} \quad \Rightarrow \quad \Phi_v = LA\Omega$$

The same flow will now after an ideal lens be collected at the image, i.e.

$$\Phi_v = \Phi_v' = L'A'\Omega' = \frac{L'b^2}{a^2}\Omega' A$$

where we have used that the area scale is the square of the length scale.

As for the solid angles we see that in the small angle approximation we have

$$\Omega = \frac{D^2}{4a^2} \quad and \quad \Omega' = \frac{D^2}{4b^2} \quad \Rightarrow \quad \Omega' = \Omega\frac{b^2}{a^2}$$

Which can be summarized as

$$1 \quad = \quad \frac{\Phi_v}{\Phi_v'} \quad = \quad \frac{L}{L'} \qquad \Rightarrow \qquad L \quad = \quad L'$$

The luminances of the image and the object are consequently equal, if no scattering and absorption losses are present in the lens.
We can use this to obtain the illuminance in the image plane:

$$E_v \quad = \quad \frac{\Phi_v}{A'} \quad = \quad \frac{\Phi_v \Omega'}{A' \Omega'} \quad = \quad L' \Omega' \quad = \quad L \frac{\pi D^2}{4b^2} \quad \approx \quad L \frac{\pi D^2}{4 f^2} \quad = \quad \frac{\pi L}{4(f-number)^2}$$

where the two rightmost equalities hold if one makes the common camera approximation: image distance = focal length.
This holds of course for the eye, too, and explains why the luminance determines how bright a surface will look like.