IMAGE PHOTOMETRY...GENERAL PROBLEMS

More difficult problems are indicated with an asterisk.

1.* On an optical bench a +10.00 D thin lens of 4 cm in diameter forms the image of a small light source on the optic axis of and 3 cm from the lens. A circular aperture, its center on the optic axis is placed between the light source and the lens just in front of the light source and moved slowly toward the lens while the illuminance of the image is monitored. That illuminance stays the same until the aperture is 1 cm from the lens. What is the diameter of the aperture?

2. The objective of a simple camera consists of a +8.00 D thin lens, four centimeters behind which is an iris diaphragm 0.8 centimeters in diameter. What is the f/number of the objective?

3.* A photographic objective consists of two +12.00 D thin lenses separated by six centimeters with an aperture stop 10 mm in diameter halfway between the lenses. What is the f/number of this objective?

4. What is the numerical aperture of a thick lens of 100 cm focal length and entrance pupil diameter 3 cm for an object 6 cm in front of the entrance pupil if the lens is in air.

5. Evaluate the integral below to show that

$$\int_0^{\rho} \frac{\rho}{(\rho^2 + v^2)^2}\, d\rho = \frac{\rho^2}{2v^2(v^2 + \rho^2)}.$$

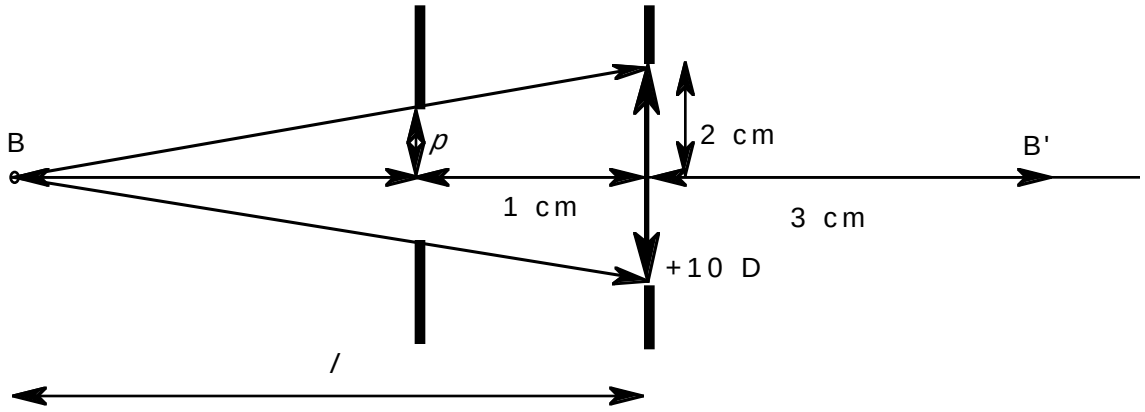
6. Show that if the entrance pupil of an optical system falls at its first principal point, equations (9) and (10) reduce to the more usual form of the fundamental paraxial equation for a thick lens system, equations (1) and (2).

7. A camera lens has 50 mm focal length, an entrance pupil which is an erect image of the aperture stop 10 mm in diameter and an exit pupil which is an inverted image of the aperture stop 7.5 mm in diameter. How far from the exit pupil is the image of a remote object?

8. An eye has 60 D of optical power and an entrance pupil 8 mm in diameter. If the ocular media absorb 40% of the light entering the eye, what is the retinal illuminance of the image formed of the sun which has a luminance of 1.6×10^6 lx? Assume aqueous and vitreous to have indices of 1.34.

ANSWERS to SELECTED PROBLEMS

1. Image illuminance starts to drop when the movable aperture becomes the entrance pupil, as shown in the diagram below. From the fundamental paraxial equation, l=4.3 cm. From similar triangles, ρ, the radius of the aperture is given by $\rho/(4.3\text{ cm}-1\text{ cm})=(2\text{ cm})/(4.3\text{ cm})$ so $\rho=1.5$ cm.



2. f/10.63

3. The focal length of the objective is +6.51 cm and the entrance pupil diameter is 1.563 cm, so this is an f/4 lens.

4. 0.24

7. 37.5 mm in front of the exit pupil

8. For this eye, the focal length is f'=1.34/60 D=22.33 mm. Transmittance of this eye is τ=0.6 so image illuminance is

$$E' = \pi(0.6)(1.6\times10^{6}\text{ lx})(1.34/1.00)^2[(4\text{ mm})/(22.33\text{ mm})]^2$$
$$= 1.74\times10^{5}\text{ lm/m}^2 = 0.174\text{ lm/mm}^2.$$