Exercises on mirrors and telescopes

MIRRORS

Exercise 1(partly from Hecht's Optics, chap5, ex5.63):

A man whose face is 25cm away looks into the bowl of a soupspoon and sees his image reflected with a magnification of -0.064. Determine the radius of curvature of the spoon. He turns the spoon on the other side. What will he see?

Answers : R=30 mm, gy=+0.057

Exercice 2 (from Hecht ex 5.64):

In an amusement park a large upright convex spherical mirror is facing a plane mirror 10.0m away. A girl 1.0 m tall standing midway between the two sees herself twice as tall in the plane mirror as in the spherical one. In other words, the angle subtended at the observer by the image in the plane mirror is twice the angle subtended by the image in the spherical mirror. What is the focal length of the latter?

Answer : R=5 m

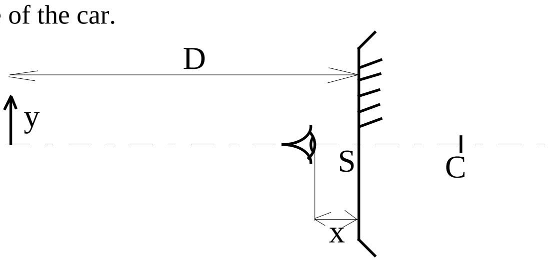
Exercise 3 (from Hecht ex 5.61):

A device used to measure the radius of curvature of the cornea of the eye is called a keratometer. This is useful information when fitting contact lenses. In effect, an illuminated object is placed a known distance from the eye, and the image reflected off the cornea is observed. The instrument allows the operator to measure the size of that virtual image. If the magnification is found to be 0.037X when the object distance is set at 100mm, what is the radius of curvature?

Answers : cornea is convex with R=7.68mm.

Exercice 4:

A driver looks into his rear view mirror at the image of a car behind him. Knowing the real size of this car, he will estimate the distance at which this car is from the size of the image on his retina. We want to compare the cases of a convex rear view mirror with the case of a plane one. We will call x the distance from the observer to the mirror, D the distance from the mirror to the car behind, R the radius of curvature of the spherical mirror and y the size of the car.



In the case of a convex mirror, calculate the estimated distance d_1 by the driver and the difference $\Delta d=d_1-d$ from the real distance d, where d=x+D (sum of the distance from the observer to the mirror and of the distance from the mirror to the car behind, corresponding to the case of a plane rear view mirror), as a function of x, R and D. Numerical values will be x=1m, D=10m and R=2m.

Comment on the dependance of Δd with the different parameters. What are the advantage and drawback of the convex mirror?

Answers : $\Delta d=2xD/R$, 10 m.

TELESCOPES

Exercise 5:

Sort the following telescopes according to the size of the image they make of the same planet :

- Canada-France-Hawaii: Cassegrain, radius of primary mirror 27m, secondary 18.665m, distance 8.566m
- Bernard Lyot telescope of the pic du Midi: Cassegrain, primary 19.972m, secondary 4.465m, distance 8.184m
- spatial telescope Hubble: Cassegrain, primary 11.04m, secondary 1.358m, distance 4.906m
- amateur telescope (Edmunds Scientific catalog): Newton, primary with focal length 445mm.

The last amateur telescope is equipped with a 28mm eyepiece : what is the magnification of the whole instrument ? Another eyepiece is available to get a magnification of 75: what is its focal length ?

Exercise 6:

To make a Cassegrain telescope with focal length 1000mm, we use a primary concave mirror M_1 with radius of curvature 1000mm and diameter 140mm and a secondary convex mirror M_2 with radius of curvature 720mm and diameter 60mm. Set up the whole system, in particular calculate the magnification of the imaging through M_2, the distance M_1M_2 and the position of the second focal point F' of the telescope.

Make a drawing with scale 1/10 along x and ½ along y of the telescope. Construct on it the path of a bundle of rays coming from an object at infinity on axis and show the position of H'. Determine the aperture and the field of view (bright and total fields).

We detect the image on a CCD detector with 10x10µm pixels. What is the hyperfocal distance of the telescope? What is the depth of field if we look at an object at 200 meters ?

Exercise 7:

Same questions as exercise 6 above with a Gregorian telescope, with focal length 3150mm (absolute value), made of a primary concave mirror M_1 with radius of curvature 700mm and diameter 200mm and a secondary concave mirror M_2 with radius of curvature 90mm and diameter 30mm.