1.5 EXERCISES

Fundamental properties of light

Ex 1.5.1. How many photons are emitted in 3 sec by a light source of power 2 W if the wavelength of the light in vacuum is 450 nm? Ans: 1.36×10^{19}.

Ex 1.5.2. The nearest star is approximately 4.2 light-years away from the Earth. How far is the distance in kilometers? Ans: 3.97×10^{13} km.

Ex 1.5.3. Slits at the circumference of a rotating circular disk of radius 3 cm are made so that the distance between the slits is 0.1 mm. A light ray leaves through one slit and is reflected off a mirror at 50-meters from the disk. Find the rotation speed so that the light will return through the adjacent slit. Ans: 1590 rev/sec.

Ex 1.5.4. Decide when you will have to use wave optics in the following situations. (a) A green laser light of wavelength 530 nm is incident on a mirror of size 30 cm. (b) A red laser light of wavelength 632 nm is incident on a molecule of size 100 nm. (c) A red laser light is incident on an E-coli cell of size 2 μm. (d) A radio wave of frequency 10^9 Hz is incident on a square aluminum plate of area 9 m^2. (e) A radio wave of frequency 10^9 Hz incident on a square aluminum plate of area 9 cm^2.

Ex 1.5.5. Luminance of Moon as observed at Earth is 3000 nits. What will be the luminance of moon if observed from half the distance to the moon? Ans: $12,000$ nits.

Ex 1.5.6. The luminance of a laptop monitor is 150 nits at the eye 25 cm from the screen. How much energy in Joules enters the eye in one hour if the cross-section of the pupil is assumed to be a circle of radius 5 mm? Ans: 1.55×10^{-5} J

Ex 1.5.7. Determine the speed of the yellow light in water, Plexiglas and flint glass. Ans: water: 2.25×10^8 m/s; plexiglas: 1.99×10^8 m/s; flint glass: 1.90×10^8 m/s.

Ex 1.5.8. What is the wavelength in water, Plexiglas and flint glass of a light of wavelength 589 nm in vacuum? Ans: 442 nm, 390 nm, 373 nm.

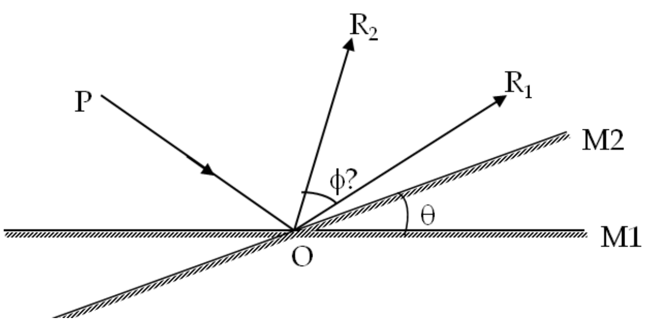
Ex 1.5.9. The average distance between the Earth and the Sun is 1.5×10^8 km. Find the time light takes to get from the Sun to the Earth. Ans: 500 s.

Ex 1.5.10. The irradiance of the sunlight on the Earth is approximately 1.4 kW/m^2. Determine the illuminance. Ans: 9.6×10^5 lx.

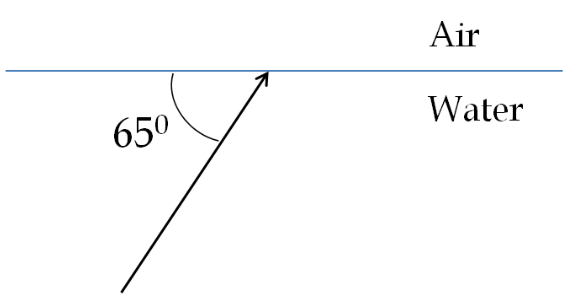
Ex 1.5.11. The irradiance of the sunlight on the Earth is approximately 1.4 kW/m^2. The average distance between the Earth and the Sun is 1.5×10^8 km. Determine the radiant intensity and luminous intensity of the Sun. Ans: 3.15×10^{22} kW/sr; 2.15×10^{28} cd.

Reflection and Refraction

Ex 1.5.12. A ray of light PO is incident on a plane mirror M1. If the mirror is rotated to a new orientation M2, the reflected ray rotates from OR$_1$ to OR$_2$. Find the relation between the angle of rotation of the mirror $\angle$M$_1$OM$_2$ and the angle $\angle$R$_1$OR$_2$. Ans: $\phi = 2\theta$.



Ex 1.5.13. A light bulb is immersed inside a water tank. A ray of light from the bulb is incident at the water/air interface at an angle of 65° from the horizontal interface. At what angle from the normal does the ray come out in the air? Ans: 34.3° from normal.



Ex 1.5.14. A ray of light is incident at 30° to the normal on a rectangular glass plate of width 5 cm, and emerges on the other side (see Fig. 1.23). Find (a) the direction of the emergent ray, and (b) the lateral displacement from the original direction. Use $n = 1.5$ for glass. Ans: $d = 0.97$ cm.

Ex 1.5.15. A ray of light consisting of two wavelengths of light (700 nm and 400 nm in air) is incident at 30° to the normal on a rectangular flint glass plate of width 5 cm, and emerges on the other side

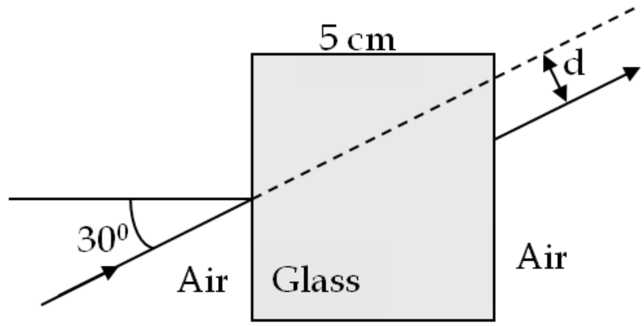


Figure 1.23: Exercise 1.5.14.

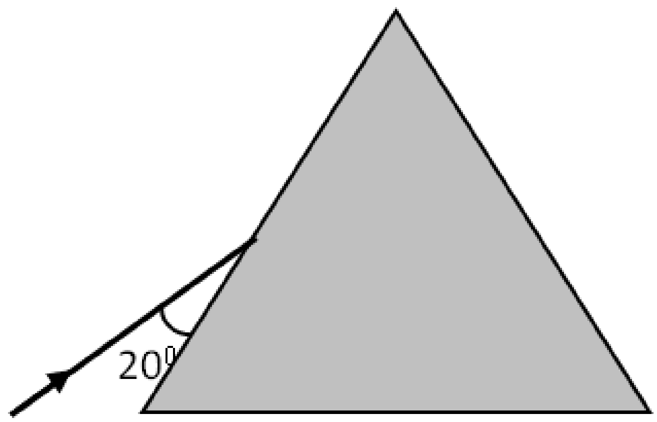


Figure 1.24: Exercise 1.5.16.

as indicated in Fig. 1.23 for Exercise 1.5.14. The refractive indices of flint glass for 700-nm and 400-nm light are 1.62 and 1.67 respectively. Find (a) direction(s) of the emergent ray, and (b) the lateral displacement(s) d from the original direction. (c) Using a protractor and a ruler, draw as accurately as you can the rays you found in exercise above. Ans: $d_{700} = 1.09$ cm ; $d_{400} = 1.14$ cm.

Ex 1.5.16. Use Snell's law and a protractor to find the direction of a 700-nm wavelength light passing through an equilateral triangular prism made of flint glass shown in the Fig. 1.24. Use $n = 1.62$ for the refractive index of the flint glass. Ans: Approx. 42° with respect to the normal on the second surface.

Ex 1.5.17. Use Snell's law and a protractor to find the direction of a 700-nm wavelength light passing through a triangular prism made of flint glass shown in Fig. 1.25.Use $n = 1.62$ for the refractive index of the flint glass.

Ex 1.5.18. Find the angle of deviation of a ray through an equilateral triangular glass prism of refractive index 1.55 if the angle of incidence is 70°.

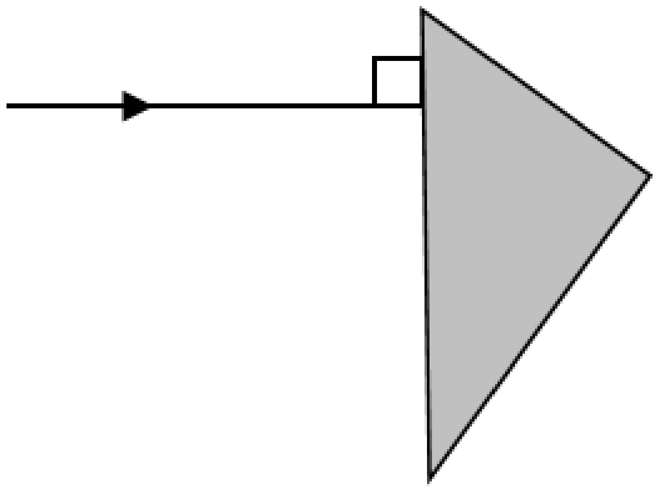


Figure 1.25: Exercise 1.5.17.

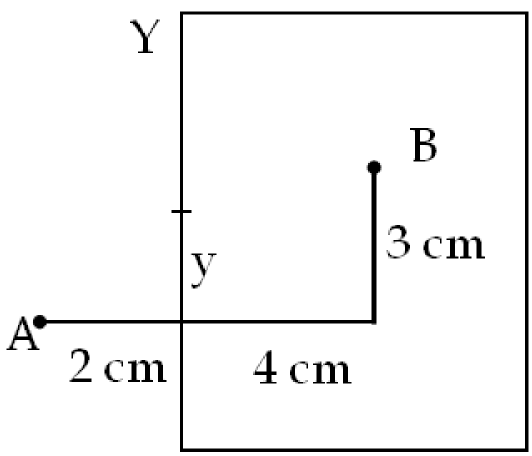


Figure 1.26: Exercise 1.5.20.

Fermat's Principle

Ex 1.5.19. What should be the value of a so that the integration of the following functions from $x = 0$ to $x = 1$ will be minimum. (a) $f(x) = a^2x^3 - ax$, (b) $f(x) = a^4x^3 - a^2x$. Ans: (a) $a = 1$; min; (b) a = -1, min; a =0 max; a = 1 max.

Ex 1.5.20. Using Fermat's principle, find the point where a ray from A in air must be incident at the air/glass interface Y so that the refracted ray passes through point B inside the glass as shown in Fig. 1.26. Use $n_{\text{glass}} = 1.5$. Ans: $y = 1.37$ cm .

Ex 1.5.21. Use Fermat's principle to find the location of point C on interface Y that a ray starting at A in air (refractive index =1) must pass upon entering water (refractive index = $\frac{4}{3}$) at B on the interface X (see Fig. 1.27).

Hint: Choose a coordinate system with origin at the center of the

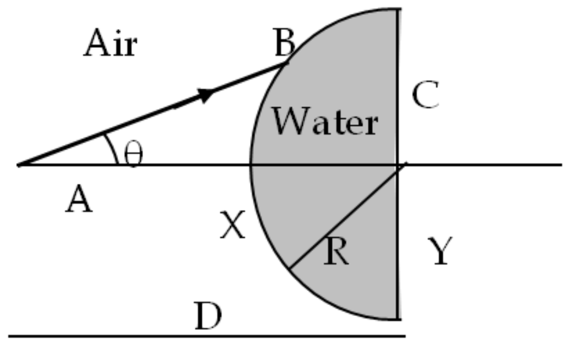


Figure 1.27: Exercise 1.5.21.

circle with y-axis pointed up towards C. Now the time from A to B to C will be a function of y. Minimizing this time with respect to y will give an equation for y which we solve to find the location of C.