1. The power emitted by the sun as electromagnetic radiation (i.e. light, visible or not) is \(3.94 \times 10^{26}\) Watts. The Earth’s albedo, the percentage of light incident on the Earth that is reflected, is approximately 30%. Find the ratio of the gravitational force the sun exerts on the Earth to the force from the radiation pressure on the Earth from the sun’s light. The radius of the Earth is 6380 km, and the mass of the sun and Earth are \(1.99 \times 10^{30}\) and \(5.98 \times 10^{24}\) kg, respectively.

2. A solar sail is a large, perfectly reflective sheet of lightweight material that allows a spacecraft to accelerate by using the radiation pressure from the sun. A sail in the shape of a square of side 800 m is attached to a spacecraft; the mass of the spacecraft and sail is 400 kg. If the spacecraft is motionless, relative to the sun, when at a distance of 1.20 AU, what is its speed when it reaches a distance of 3.50 AU?

3. A light ray is incident on the left side of a glass prism in the shape of an isosceles triangle with height 20.0 cm and width 14.0 cm. The ray enters the glass, undergoes total internal reflection along the base, and then exits the right side of the glass, as shown in the diagram to the right. If the index of refraction of the glass is 1.56, find the maximum possible deviation of the ray (i.e. the angle between the original ray and the ray that exits the glass.)

4. In the diagram below, a light ray traveling in the vertical direction enters a circular piece of glass, travels a distance \(L = 160\) mm through the glass, and then exits the glass. The distance from the original path of the light to a parallel line that passes through the center of the circle is \(d = 70.0\) mm, and the total deviation of the light is \(36.0^\circ\). Find the radius of the circle and the index of refraction of the glass.

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Useful constants: \(c = 3.00 \times 10^8\) m/s \(2\mu_0 c = 754\) V²/W
5. A converging lens is used as a magnifying glass. When it is held a distance of 9.20 cm from a postage stamp, the width of the image of the stamp is 3.40 times the width of the stamp. Find the focal length of the lens.

6. An object is placed at x = 0. A converging lens with \( f_1 = 35.0 \text{ cm} \) is placed at x = 60.0 cm and a diverging lens with \( f_2 = -25.0 \text{ cm} \) is placed at x = 208 cm. For light that passes through both lenses, find:
   (a) the x-coordinate of the final image;
   (b) the overall magnification of the final image;
   (c) whether the final image is real or virtual;
   (d) whether the final image is inverted or upright.

7. An object is placed at x = 0. A converging lens with \( f_1 = 35.0 \text{ cm} \) is placed at x = 60.0 cm and a concave mirror with radius of curvature R = 48.0 cm is placed at x = 120 cm. Considering light that leaves the object, passes through the lens, reflects from the mirror and then passes back through the lens, determine:
   (a) the x-coordinate of the final image;
   (b) the overall magnification of the final image;
   (c) whether the final image is real or virtual;
   (d) whether the final image is inverted or upright.

8. A meniscus lens is to be made of plastic with \( n = 1.80 \). The concave surface is to have a radius of curvature of 13.0 cm. Find the radius of curvature of the convex surface if the lens is to be a:
   (a) diverging lens with a focal length of -40.0 cm, or
   (b) converging lens with a focal length of +54.0 cm.

9. A film of oil on water strongly reflects light of wavelength 460 nm and weakly reflects light of wavelength 670 nm. If the thickness of the film is 1.50 \( \mu \text{m} \), find the index of refraction of the oil, assuming that it is less than the index for water.

10. Titanium dioxide (TiO_2), with an index of refraction of 2.50, is one compound that is often used as a lens coating. A layer of TiO_2 is to be applied to a glass lens with index of refraction 1.65. The coating is designed to strongly reflect light at 315 nm (in the UV range) and strongly transmit light at 552 nm (in the middle of the visible range). Find the smallest thickness of TiO_2 that will meet these requirements.

11. The two Keck telescopes on Mauna Kea in Hawaii are among the largest optical telescopes on Earth. Each telescope is 10.0 m in diameter. If one of these telescopes is used to search for a “binary” star system, in which two stars orbit each other with a separation of 50.0 million km, at what maximum distance from Earth can the two stars be resolved by the telescope? Assume the stars emit light of wavelength 500 nm.

12. The crested goshawk is an amazing predator, as I learned a while ago from watching the Smithsonian channel. Like most raptors, it performs aerial reconnaissance and then attacks small, helpless animals on the ground. The show claimed the goshawk could spot its prey up to a few miles away. Which got me thinking... how big is its prey?? Assume the goshawk’s pupil has a diameter of 7.00 mm, that it sees light of wavelength 450 nm and that the prey is 5.00 km away (about 3 miles). What is the size of the smallest animal it can see at this distance? (The goshawk is a relatively small raptor, about 38 cm tall.)

**Answers**

1. \( 4.57 \times 10^{13} \)
2. 38.5 km/s
3. 145°
4. 93.1 mm, 1.47
5. 13.0 cm
6. 190 cm, -0.393, virtual, inverted
7. -69.2 cm, 1.88, real, upright
8. 21.9 cm, 10.0 cm
9. 1.23
10. 221 nm
11. 86.6 ly
12. 39.2 cm