

PHY 2005 Applied Physics 2 - Summer 2011
Solutions to Suggested Homework Problems (Chapter 25)

Questions and Exercises

2. Let the time interval required for Galileo's friend to open the cover be t' . If this time interval is negligible, the light travels a distance $2D$ during time interval t . Thus the speed is $2D/t$. Since t' is not negligible compared to t , this measurement was not accurate. The actual speed must be $2D/(t - t')$. However, $t - t'$ is very small and very difficult to estimate.

5. The straight-wire antenna must be oriented vertically because it must be in the same direction as the electric field, which drives the charges in the receiving wire. A loop antenna must be perpendicular to the magnetic field because the change in magnetic flux causes induced current. Therefore, it should be placed in the planes spanned by the electric field and the direction of travel of the EM waves.

11. Decreasing area A of your pupil reduces flux $\Phi = EA$ coming into your eye. Note luminous efficiency is a property of a light source itself, luminous intensity measures the brightness of the source in a particular direction on the direction, and illuminance is a measure of brightness per unit area.

13. When unpolarized light beam is incident on a polarizer, half of the energy passes through it and the most of the rest is absorbed in the polarizer. The absorbed energy is converted to the internal energy of the polarizer, thus its temperature rises. The analyzer is heated up most if it is crossed with the polarizer because most of the energy carried by the light beam is absorbed in it. It is not heated up if it is parallel with the polarizer because the beam is completely transmitted.

Problems

3. The frequency of the beam is $f = c/\lambda = 5.09 \times 10^{14}$ Hz. The frequency of EM waves does not change according to the media. Therefore, the wavelength of the beam in water is $\nu = f\lambda = 442$ nm.

8. Resonance frequency in an LC circuit is given by $f = 1/(2\pi\sqrt{LC})$. Solving the equation for the inductance, the needed inductance is $L = 1/(4\pi^2 f^2 C) = 5.74 \times 10^{-16}$ H.

9. The diameter d_1 of the lightbulb and pinhole makes an isosceles, and the diameter d_2 of the image and pinhole also makes another isosceles. These two isosceles are similar. Therefore, their ratios of the base to the height are the same. We have $d_1/h_1 = d_2/h_2 \Rightarrow d_2 = (h_2/h_1)d_1 = 2.67$ cm.

11. We choose our origin at the center of the bulb and let $x_1 = 2$ m and $x_2 = 3$ m. To calculate the length of the umbra, we draw the ray that starts from the top of the bulb $y_1 = 0.25$ m and passes through the top of the meter stick $y_2 = 0.5$ m. Expressing the slope of the ray with the half length of the umbra L , we get $(y_2 - y_1)/x_1 = (L - y_2)/x_2 \Rightarrow L = y_2 + (y_2 - y_1)(x_2/x_1) = 0.875$ m. The length of the umbra is $2L = 1.75$ m. To find the length of penumbra, we draw another ray that starts from the bottom of the bulb and passes through the top of the meter stick. The two rays, the bulb and the wall make two similar triangles. The similarity leads to: $(2y_1)/x_1 = l/x_2 \Rightarrow l = 0.75$ m, where l is the half length of the penumbra. The length of penumbra is $2l = 1.50$ m.

14. The energy incident on the panel in a unit time is $P = IA$. Since only 8 % is utilized, the output power of the panel is $P_{out} = 0.08P = 0.08IA = 2144$ W. Since $P_{out}/P_{bulb} = 35.7$, we can light up to 37 lightbulbs.

17. By definition, luminous intensity is given by $I = \Phi/\Omega$. Since the bulb is considered isotropic, the solid angle is $\Omega = 4\pi$. Hence the luminous flux of the bulb is $\Phi = I\Omega = 503 \text{ lm}$.

20. The solid angle is $\Omega = A/r^2 = 0.015432 \text{ sr}$. This is approximate in two ways. First, the flat area A must be replaced by the area of the curved surface of the sphere, which is larger than the flat area. Second, r is not the distance from the source to the flat surface, but to the curved surface.

25. Intensity is inversely proportional to the square of the distance from the sun. The ratio of the intensity at Mercury to that at the Earth is $I_M/I_E = r_E^2/r_M^2 \Rightarrow I_M = I_E (r_E^2/r_M^2) = 8.96 \times 10^3 \text{ W/m}^2$.

31. Since the total energy carried by the beam is conserved, the flux through the whole cross section of the beam is constant. Hence we have $E_1 A_1 = E_2 A_2 \Rightarrow E_2 = E_1 (A_1/A_2) = 5000 \text{ lx}$.

36. The luminous power of the bulb that would give the required illuminance $E = \Phi/(4\pi h^2)$ is $\Phi = 4\pi h^2 E = 3.620 \times 10^3 \text{ lm}$. The power of the bulb is $P = \Phi/(\Phi/P) = 181 \text{ W}$.

41. The original illuminance and the illuminance after replacing bulbs are, respectively, $E_1 = P_1/(4\pi r_1^2)$ and $E_2 = P_2/(4\pi r_2^2)$, where r_1 is the original height and r_2 is the final height. The problem indicates that $E_2 = 3E_1$. Hence we have $3 = E_2/E_1 = (P_2/r_2^2)/(P_1/r_1^2) \Rightarrow r_2 = r_1 \sqrt{(P_2/(3P_1))} = 2.98 \text{ ft}$.

44. When the light bulb is $h = 4 \text{ ft}$ above the table, the intensity of illumination (illuminance) is expressed as $E_1 = P/(4\pi h^2)$, where P is the power of the bulb. After sliding the sheet over distance d , then the distance between the bulb and the sheet is $r = \sqrt{d^2 + h^2}$, and the illuminance is $E_2 = P \cos \theta / (4\pi r^2) = Ph / (4\pi r^3)$. Since the illuminance changes by a factor of $1/4$, we have $1/4 = E_2/E_1 = (h/r^3)/(1/h^2) = h^3/r^3 \Rightarrow r = h(\sqrt[3]{4}) = 6.35 \text{ ft}$. Therefore, the horizontal displacement is $d = \sqrt{r^2 - h^2} = 4.93 \text{ ft}$.