

TAP 315-2: Comparing intensities for lamps

Comparing brightness

A low-power lamp at close range can often appear as bright as a high-power lamp much further away. Similar reasoning is used to calculate the brightness of stars.

Two filament lamps

Here you compare two incandescent filament lamps; one marked 2.5 V, 0.3 A and a second 100 W, 240 V. Assume that approximately 20% of the power dissipated by the lamps results in visible photons being emitted uniformly, and that both are being run at normal brightness.

1. Estimate the brightness of the 100 W lamp from 3 metres away, which is the luminous flux density in W m^{-2}
2. Calculate how close you must be to the 2.5 V lamp to see it as being the same flux density?

Two floodlights

This question is about a 3 W bicycle headlight and a 300 W exterior security floodlight. Both the floodlight and the headlight have approximately the same shaped beam, a cone that covers approximately 1 / 10 of a sphere.

3. Estimate the flux density of the bicycle lamp from 20 metres away.
4. Your pupil has a diameter of approximately 0.01 m.
How much light enters your eyeball per second?
5. The floodlight looks just as bright as the bicycle lamp.
How far away is it?

Practical advice

All these questions involve use of the inverse square law, sameness of beam shape being crucial in the questions about the floodlights.

Answers and worked solutions

1. 20 W as light, spread over a sphere, of radius 3 m:

$$I = \frac{20 \text{ W}}{4 \times \pi \times r^2}$$

$$I = \frac{20 \text{ W}}{4 \times \pi \times 3 \times 3 \text{ m}^2}$$

$$I = 0.18 \text{ W m}^{-2}$$

2. Power as light = 2.5 V x 0.3 A x .02 = 0.15 W.

This must spread over a sphere, to give a flux density of 0.19 W m⁻².

$$I = \frac{P}{4\pi r^2}$$

$$r = \sqrt{\frac{P}{4\pi I}}$$

$$r = \sqrt{\frac{0.15 \text{ W}}{4 \times \pi \times 0.18 \text{ W m}^{-2}}}$$

$$r = 0.26 \text{ m.}$$

3. 3 W as light, focused onto 1 / 10 of sphere, of radius 20 m:

$$I = \frac{P}{4\pi r^2}$$

$$I = \frac{3 \text{ W}}{4 \times \pi \times (20 \text{ m})^2 \times 0.1} = 6 \text{ mW m}^{-2}$$

4. The pupil is catching light at 6 mW m⁻²:

$$P = I \times A$$

$$P = I \times \pi r^2$$

$$P = 6.0 \times 10^{-3} \text{ W m}^{-2} \times \pi \times 0.005^2 \text{ m}^2$$

$$P = 4.7 \times 10^{-7} \text{ W.}$$

5. The floodlight is 100 times more powerful than a cycle light:

$$I = \frac{P_f}{4\pi r_f^2} = \frac{P_b}{4\pi r_b^2}$$

$$\frac{300}{r_f^2} = \frac{3}{r_b^2}$$

$$\frac{r_f^2}{r_b^2} = \frac{300}{3}$$

$$\frac{r_f}{r_b} = 10$$

The floodlight is 10 times further away, 200 m.

External reference

This activity is taken from Advancing Physics chapter 12, 40S