11.5 - THE INTENSITY OF WAVES

LEARNING OBJECTIVES

Your Specification states…

Demonstrate knowledge, understanding, and application of:

- → intensity of a progressive wave $I = \frac{P}{A}$
- → intensity $\propto$ (amplitude)^2.

WHAT IS INTENSITY?

- The intensity of a progressive wave is defined as the radiant power passing through a surface per unit area. The units are Wm^{-2}.

The equation for intensity, $I = \frac{Power}{Surface\ area} = \frac{P}{A}$

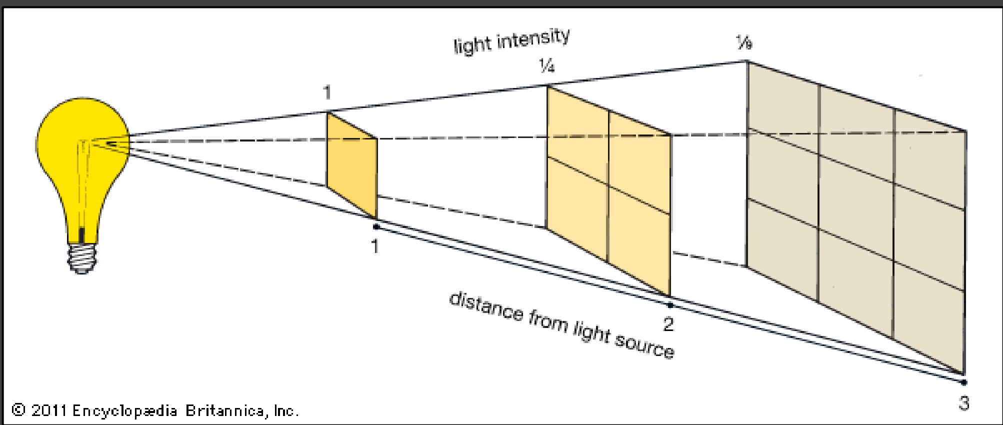
The total radiant power at a distance, r, from a point source of a progressive wave is spread out over an area equal to the surface area of a sphere. The energy (and so power) is dispersed uniformly in all directions.

This gives us the equation: $I = \frac{P}{4\pi r^2} = \frac{E}{(4\pi r^2)t}$

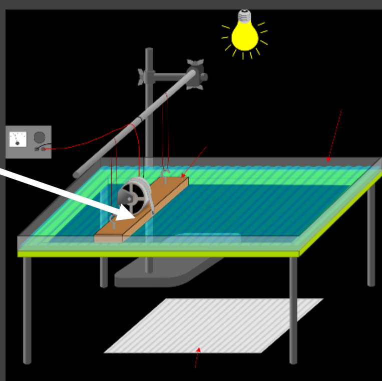
Where, I = intensity, P = Radiant power, E = Energy transferred, r = radius (distance from the point source), t = time

The intensity and the distance from the point source emitting the energy/radiation/wave follow an inverse square law. This is a very common relationship I physics.

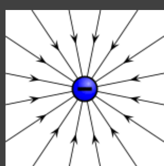
When the distance is doubled, the same amount of energy per second (radiant power) will cover an area that is four times as large. This means that doubling distance will decrease the intensity by a factor of four.



This relationship is true for all waves from a **point source** and **radial fields.** However, the same model cannot be applied if the waves are emitted from one plane in the same direction, e.g. waves generated by an oscillating bar in a ripple tank, because these waves are uniform and do not disperse unless diffracted.



The inverse square law applies to sound, light (EM radiation), radial gravitational fields and radial electric fields.



WORKED EXAMPLE

The intensity of light at 1.3m from a spherical lamp bulb is 1.0 Wm^{-2}. Calculate:

a) The power output of the lamp
b) The power output of the lamp

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

$\therefore P = 1.0 \, X \, 4\pi(1.3)^2$

P = 21 W (2 s.f.)

b) $I = \frac{21.237\ldots}{4\pi(0.7)^2}$

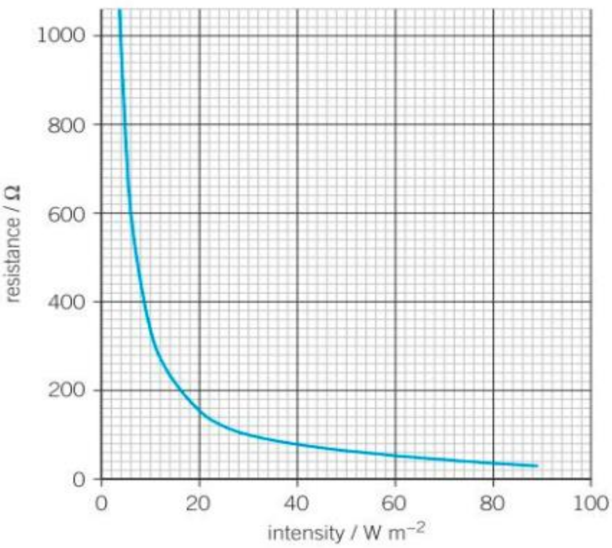
$I = 3.4 \, Wm^{-2}$ (2 s.f.)

POSSIBLE PRACTICAL INVOLVING INTENSITY

Intensity and LDRs

We can use an LDR to investigate how the intensity varies with distance from a constant power source (like a simple filament lamp).

In order to determine the intensity a **calibration curve** is used. Each LDR has its own calibration curve that allows the user to convert the resistance of the LDR into intensity.



▲ **Figure 3** *Calibration curve for an LDR*

THE RELATIONSHIP BETWEEN INTENSITY AND AMPLITUDE

The amplitude of a wave decreases as the wave spreads out (**disperses**) from a source. It is because the energy of a progressive wave is directly proportional to the (amplitude)^2 that the intensity of a progressive wave is also proportional to the square of the amplitude:

$I \propto A^2$ OR $I = kA^2$, where k is a constant of proportionality

If the amplitude of a wave is halved, the intensity decreases by a factor of four.