AS - Physics

This figure is called the solar constant and is a measure of the **intensity** of the Sun's radiation. Note that the unit of intensity will always be a unit of power divided by a unit of area.

The planet Neptune is 30 times further away from the Sun than the Earth. Hence, its solar constant will be $\frac{1}{900}$ of the Earth's solar constant. This is because the surface area of a sphere which has a 30 times larger radius will be 900 times larger. As waves spread out to cover a larger area, the intensity of the energy falls. This can be summarised by the expression:

$$\text{intensity} \propto \frac{1}{\text{distance}^2}$$

This is a statement of a law known as the inverse square law. Many effects reduce in this way. It is a feature of the geometry of three-dimensional space. Figure 2 shows how an area nine times larger is covered by a wave from a point source that travels three times further. If the power is spread over an area nine times larger then the intensity will be reduced to $\frac{1}{9}$ of the original value.

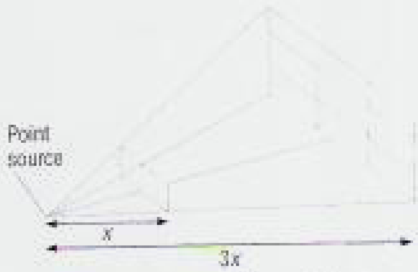

Figure 2 Waves spreading out from a single point only have $\frac{1}{9}$ of the intensity after travelling three times further

Relationship between wave amplitude and intensity

A displacement–time graph for two particles in a sound wave is shown in Figure 3. Both particles have the same frequency, but particle A has twice the **amplitude** of particle B. A tangent has been drawn on each graph at the point when the particles are at their mean positions. The gradients of these tangents give the speed for each particle.

From the graphs, you can see that the gradient of the tangent for particle A is twice that for particle B. Further analysis confirms that the speed of particle A is twice that of particle B, when at the mean position. A particle with twice the speed, will have four times the **kinetic energy**. For sound wave particles, four times the energy implies a wave of four times the intensity. This is true for all waves and gives us the following principle:

$$\text{intensity} \propto \text{amplitude}^2$$

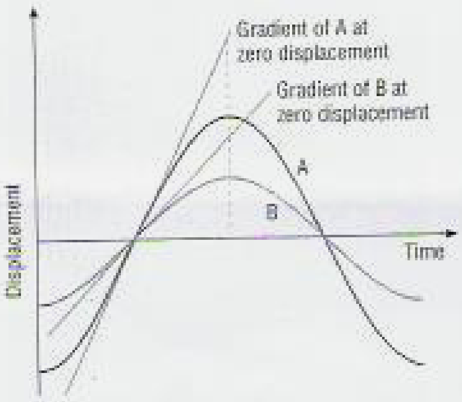

Figure 3 Displacement–time graph for two sound wave particles: 2 × amplitude: 2 × speed therefore 4 × kinetic energy

Questions

1. All electromagnetic waves travel at 3.0×10^8 m s^{-1} in space and more slowly in other substances. When visible light of wavelength 600 nm passes through glass its speed is about 2×10^8 m s^{-1}. Calculate:
   (a) the frequency, and
   (b) the wavelength of this light in glass.
2. (a) The receiving aerial for a UHF television is about 25 cm long. This is one half of the wavelength of the transmission. Calculate the frequency of the transmission.
   (b) Sound waves in air travel at 340 m s^{-1} on a warm day. The range of human hearing is 20 Hz to 20 000 Hz for a young person. Calculate the corresponding range of wavelengths.
   (c) Calculate the speed of the sound wave in question 1 on spread 2.4.2.
3. Two fishing floats, a distance of 4.5 m apart, bob up and down at 20 times per minute. The floats always move in antiphase. There is always at least one wave crest between the floats, but never more than two.
   (a) Show that the wavelength of the ripples on the river is 3.0 m. Hence, find the speed of the ripples on the surface.
   (b) Near the bank, the depth of the river halves. The speed v of water waves in shallow water of depth d is given by $v = \sqrt{gd}$, where g is 9.8 m s^{-2}.
      (i) What is the new frequency and wavelength of the waves near the bank?
      (ii) What is the depth of the river near the bank?