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The Inverse Square Law

All waves (sound, light, gamma rays) obey the inverse square law .... provided the source can be regarded as a point source and there is no absorption of energy.

That is

$$I = \frac{k}{d^2}$$

so a graph of I against the reciprocal of d^2 should give a straight line graph through the origin with a slope k.

Use the apparatus provided to test this theory.

If you do not obtain the predicted graphs consult the photocopies.

THE INVERSE SQUARE LAW FOR γ-RAYS

A point source of γ-rays emits in all directions about the source. It follows that the intensity of the γ-radiation decreases with distance from the source because the rays are spread over greater areas as the distance increases. This decrease in intensity is distinct from that produced by absorption.

Consider a point source of γ-rays, situated in a vacuum so that there is no absorption. The radiation spreads in all directions about the source, and therefore when it is a distance d from the source it is spread over the surface of a sphere of radius d and area $4\pi d^2$. If E is the energy radiated per unit time by the source, then the intensity of the radiation (= energy per unit time per unit area) is given by I, where

$$I = E/(4\pi d^2) \qquad \text{i.e.} \quad I \propto 1/d^2$$

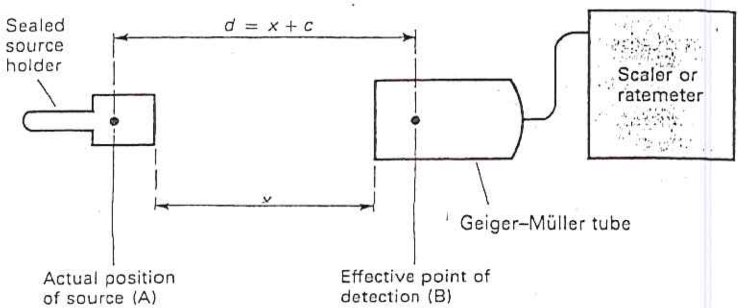
Thus the intensity varies as the inverse square of the distance from the source. The law is entirely true in vacuum. The absorption of γ-rays by air at atmospheric pressure is very slight, and therefore the inverse square law can be taken to hold over large distances in air.

Note The inverse square law holds for α-particles and β-particles in vacuum providing they are coming from a point source. The law does not apply to these particles in air because air absorbs them.

EXPERIMENTAL VERIFICATION OF THE INVERSE SQUARE LAW FOR γ-RAYS

The experimental arrangement is shown in Fig. 1.5. γ-rays may be absorbed at any point in the Geiger–Müller tube. Nevertheless, it is as if they are all absorbed at a single point (B). Neither the location of this point nor that of the source (A) are known and this makes it impossible to measure d directly. There is no real difficulty though, since, as can be seen from Fig. 1.5, $d = x + c$ and x is measurable and c, though unknown, is constant.

Fig. 1.5
Apparatus to verify the inverse square law for γ-rays



The aim is to verify that

$$I \propto \frac{1}{d^2}$$

i.e. $$I \propto \frac{1}{(x+c)^2} \qquad [1.$$

Since I is proportional to the **corrected count rate** R (i.e. the actual count ra minus the background count rate), equation [1.4] can be rewritten as

$$R \propto \frac{1}{(x+c)^2}$$

i.e. $$x + c = \frac{k}{R^{1/2}}$$

where k is a constant of proportionality

i.e. $$x = kR^{-1/2} - c$$

If a plot of x against $R^{-1/2}$ turns out to be linear, the inverse square law has bee verified. The intercept when $R^{-1/2}$ is zero gives c – see Fig. 1.6.

Fig. 1.6
Graph to verify the inverse square law for γ-rays