9 Dangers associated with exposure to radiation have been recognised for many years. As a result of these hazards, measures have been adopted to reduce exposure to radiation to as low a level as possible. One such measure is to shield individuals from radioactive source using radiation absorbing materials.

Experiments have been carried out to investigate the effectiveness of materials as absorbers of γ-ray photons. One possible experiment is illustrated in Fig. 9.1.

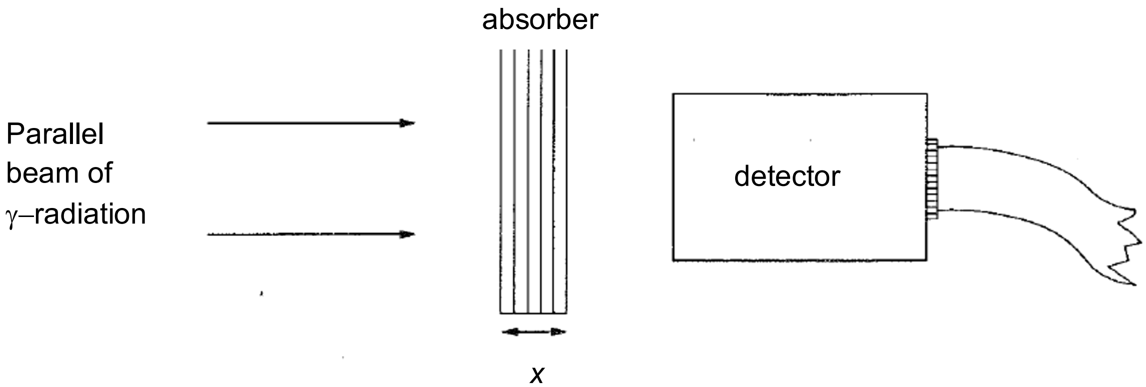

Fig. 9.1

The count-rate C_x of γ-ray photons is measured for various thicknesses x of the absorber, together with the count-rate C_0 for no absorber. Fig. 9.2 shows the variation with thickness x of the ratio C_x/C_0 for lead.

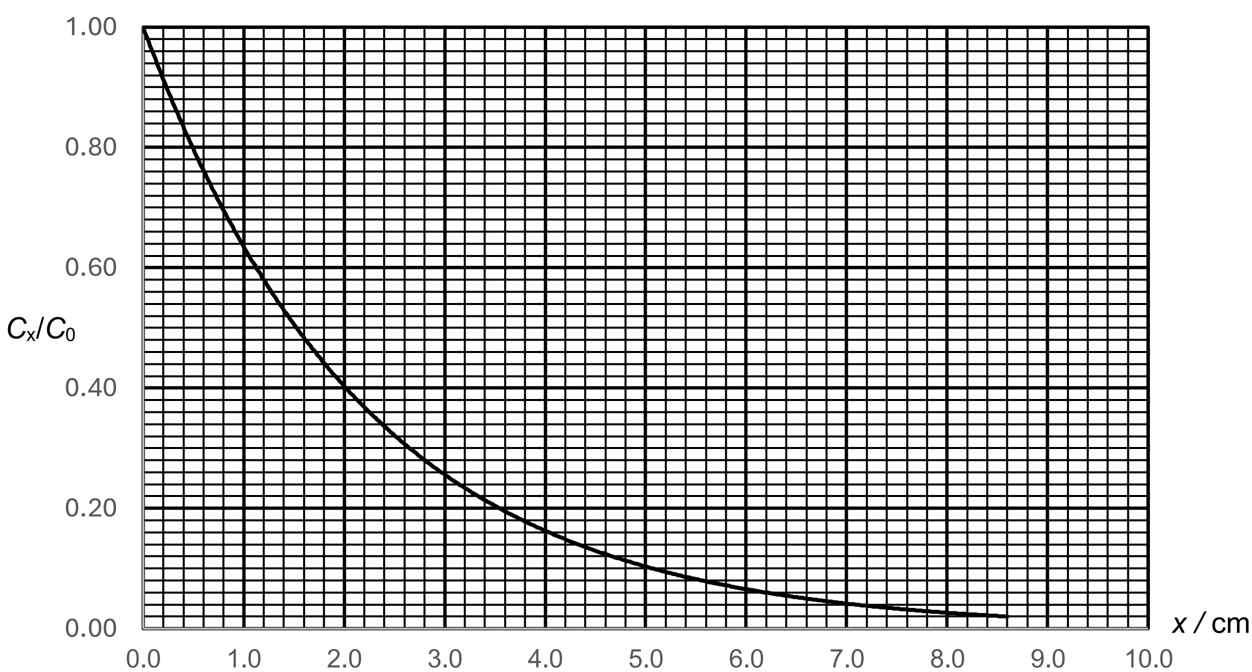

Fig. 9.2

(a) Use Fig. 9.2 to deduce that, theoretically, complete shielding is not possible.

....

.... [1]

(b) Fig. 9.2 indicates that there may be an exponential decrease of the ratio C_x/C_0 with thickness x. In order to test this suggestion, a graph of $\ln(C_x/C_0)$ against x is plotted. This is shown in Fig. 9.3.

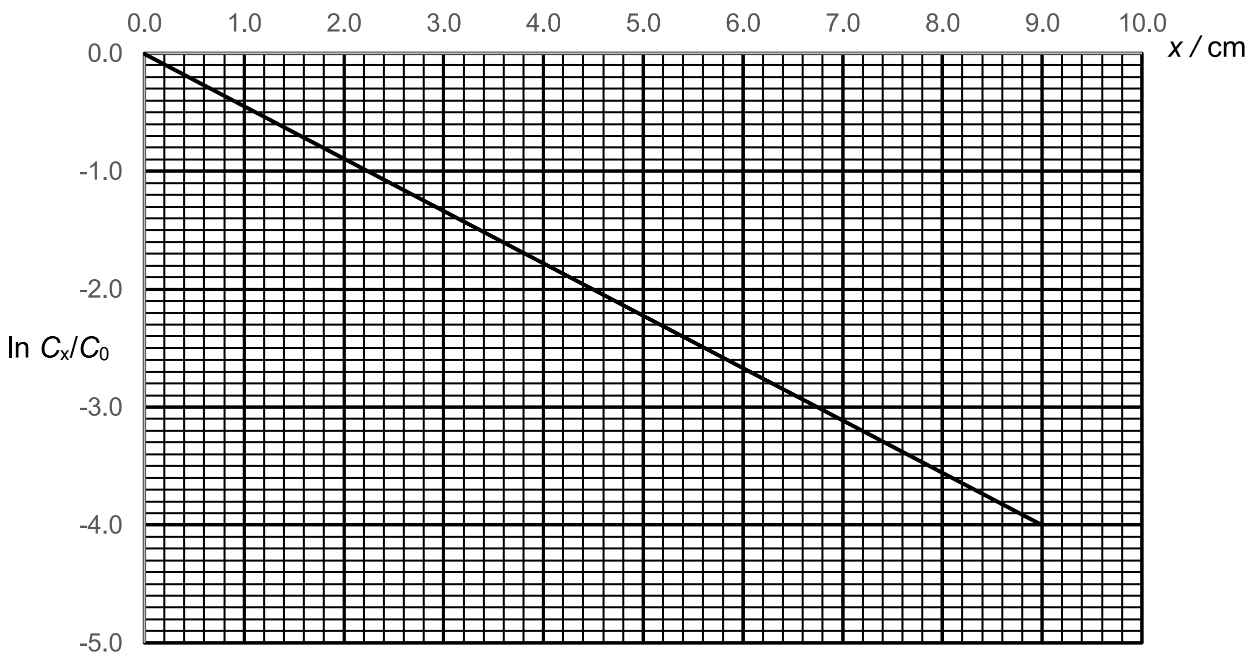

Fig. 9.3

(i) Show that Fig. 9.3 indicates a relationship of the form

$$C_x = C_0 e^{-\mu x}$$

where μ is a constant. Explain your working clearly.

....

....

.... [2]

(ii) The constant μ is known as the linear absorption coefficient. Use Fig. 9.3 to calculate a value of μ for lead.

μ = ... cm^{-1} [2]

(c) The linear absorption coefficient μ has been found to depend on photon energy and on the absorbing material itself. For γ-ray photons of one energy, μ is different for different materials.

In order to assess absorption of γ-ray photons in matter such that the material of the absorber does not have to be specified, a quantity known as the mass absorption coefficient μ_m is calculated. μ_m is given by the expression

$$\mu_m = \frac{\mu}{\rho}$$

where ρ is the density of the absorbing material.

Values of μ for 2.75 MeV photons and of ρ for different materials are given in Fig. 9.4.

material	μ / cm^{-1}	ρ / g cm^{-3}	μ_m / ....
aluminium	0.095	2.70	0.035
tin	0.267	7.28	0.037
lead	....	11.3	....

Fig. 9.4

On Fig. 9.4,

(i) give a unit for μ_m, [1]

(ii) use your answer to **(b)(ii)** to complete the table of values for lead. [1]

(d) Research is currently ongoing for a new building material M which can also be used for shielding. The density of M is 2.4×10^{3} kg m^{-3}.

(i) By calculating an average value for μ_m, show that the linear absorption coefficient μ for 2.75 MeV photons in material M is approximately 0.09 cm^{-1}.

[2]

(ii) By reference to Fig. 9.2 and the equation given in **(b)(i)**, calculate the approximate thickness of material M which would provide the same level of shielding, for 2.75 MeV photons, as a thickness of 4.0 cm of lead.

thickness = …………………. cm [3]

END OF PAPER