1) **(a)** In a radioactivity experiment, background radiation is taken into account when taking corrected count rate readings in a laboratory. One source of background radiation is the rocks on which the laboratory is built. Give **two** other sources of background radiation.

source 1 ....

source 2 ....

(1 mark)

(b) A γ ray detector with a cross-sectional area of $1.5 \times 10^{-3}\,m^2$ when facing the source is placed 0.18 m from the source.
A corrected count rate of 0.62 counts s^{-1} is recorded.

(b) (i) Assume the source emits γ rays uniformly in all directions.
Show that the ratio

$$\frac{\text{number of } \gamma \text{ photons incident on detector}}{\text{number of } \gamma \text{ photons produced by source}}$$

is about 4×10^{-3}.

(2 marks)

(b) (ii) The γ ray detector detects 1 in 400 of the γ photons incident on the facing surface of the detector.
Calculate the activity of the source. State an appropriate unit.

answer = ... unit ....

(3 marks)

(c) Calculate the corrected count rate when the detector is moved 0.10 m further from the source.

answer = ... counts s^{-1}

(3 marks)

2) A radioactive source used in a school laboratory is thought to emit α particles and γ radiation. Describe an experiment that may be used to verify the types of radiation emitted by the source. The experiment described should allow you to determine how the intensity of radiation varies with distance in air or with the thickness of suitable absorbers.

Your answer should include:

- the apparatus you would use and any safety precautions you would take
- the measurements you would make
- how the measurements would be used to reach a final decision about the emitted radiation.

The quality of your written communication will be assessed in your answer.

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(6 marks)

3) The radiation from a radioactive source is detected using the apparatus illustrated in Fig. 9.1.

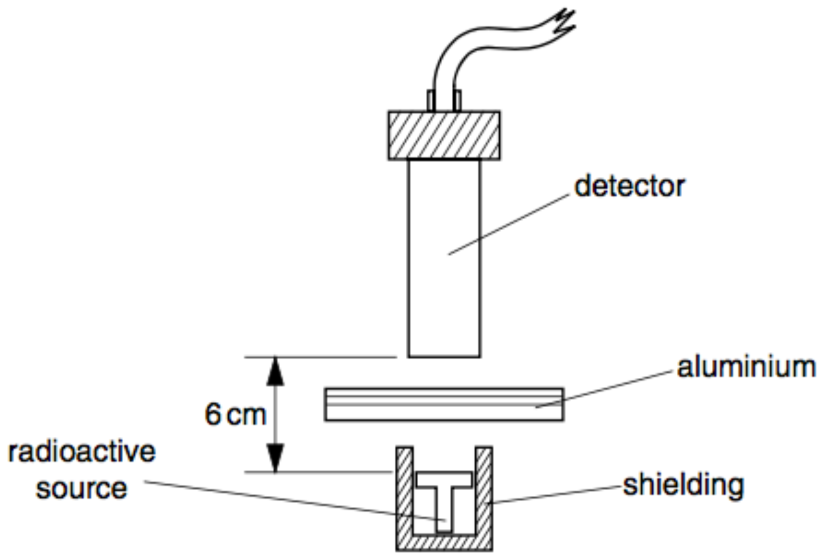

Fig. 9.1

Different thicknesses of aluminium are placed between the source and the detector. The count rate is obtained for each thickness. Fig. 9.2 shows the variation with thickness *x* of aluminium of the count rate.

Fig. 9.2

(a) Suggest why it is not possible to detect the presence of the emission of α-particles from the source.

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....[1]

(b) State the evidence provided on Fig. 9.2 for the emission from the source of

(i) β-particles,

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(ii) γ-radiation.

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[4]

4)

A radioactive source was placed facing a Geiger-Müller tube. An experiment was carried out to investigate how the count rate registered by the tube varied with the thickness of a lead absorber placed between the source and the tube.

The equipment was set up as shown in Fig. 2.1.

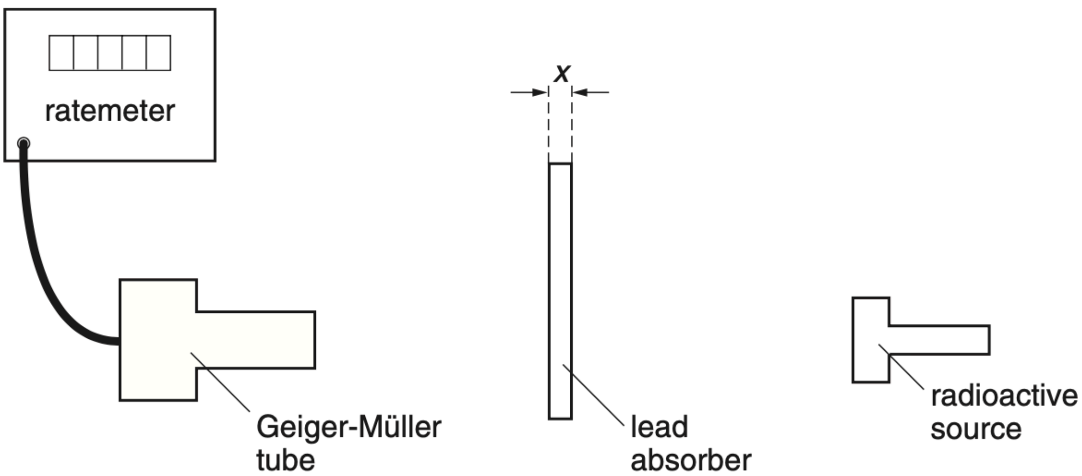


Fig. 2.1

The count rate R reaching the Geiger-Müller tube from the source was recorded for different thicknesses x of the lead absorbers.

Values of x and R are given in Fig. 2.2.

x / m	R / s^{-1}	
0.0050	750 ± 20	
0.0100	580 ± 20	
0.0150	430 ± 20	
0.0200	330 ± 20	
0.0250	250 ± 20	
0.0300	190 ± 20	

Fig. 2.2

It is suggested that R and x are related by the formula

$$R = R_0 e^{-\rho\eta x}$$

where R_0 is the count rate with no absorbers, ρ is the density of lead and η is a quantity called the mass absorption coefficient.

(a) If a graph of ln R against x were plotted, what quantities in the above equation would the gradient and y-intercept represent?

gradient = ...

y-intercept = ... [1]

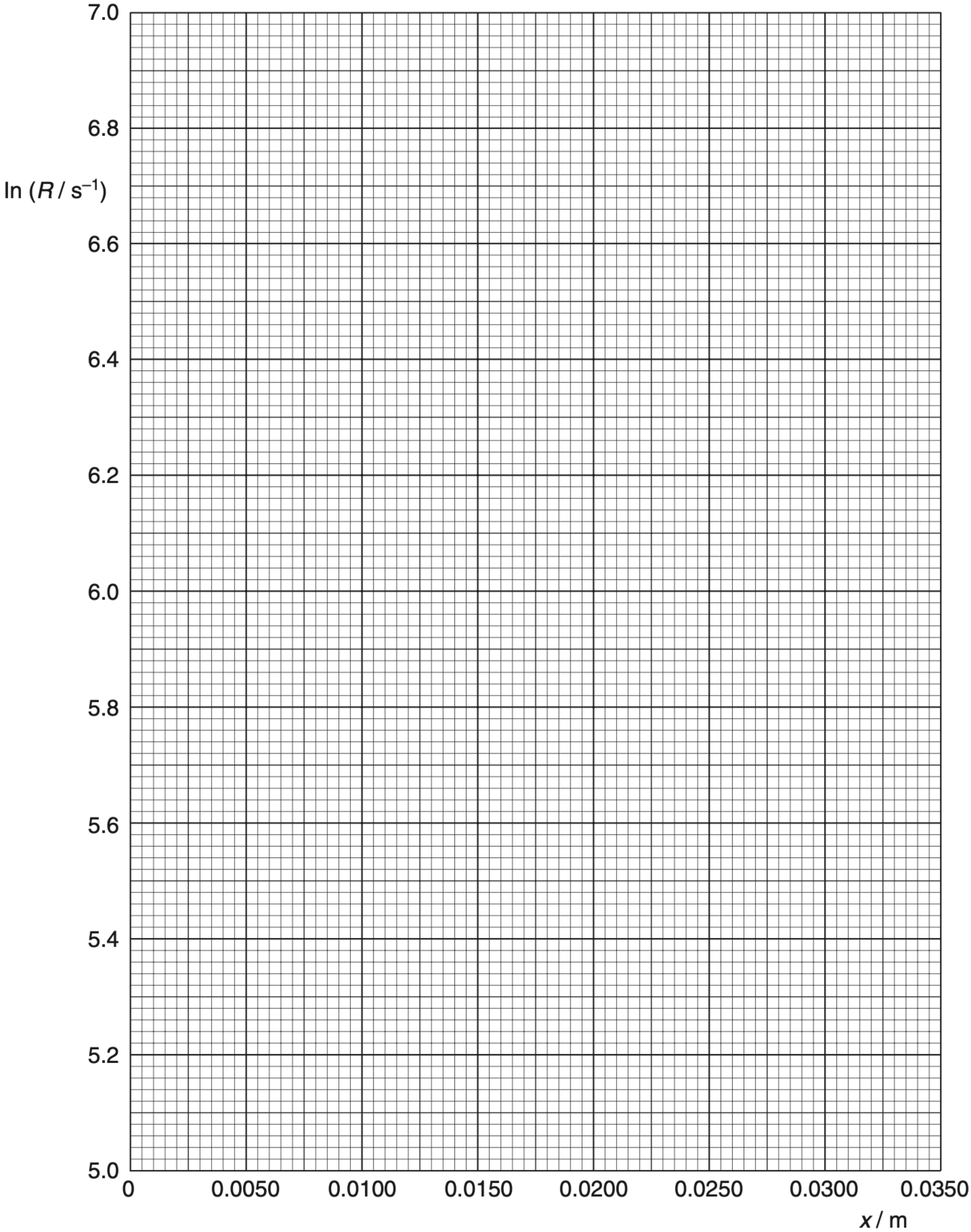
(b) Calculate and record values of ln R in the table. Include in the table the absolute errors in ln R. [3]

(c) **(i)** Plot a graph of ln R on the y-axis against x on the x-axis. Include error bars for ln R. [2]

(ii) Draw the best-fit straight line and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

(iii) Determine the gradient of the best-fit line. Include the error in your answer.

gradient = ... [2]



7.0
6.8
ln (R / s^{-1})
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
0
0.0050
0.0100
0.0150
0.0200
0.0250
0.0300
0.0350
x / m

(d) The density of lead is given as 11 300 kg m^{-3}. Using the answer to **(c)(iii)** determine the value of η. Include the error in your value. Include an appropriate unit.

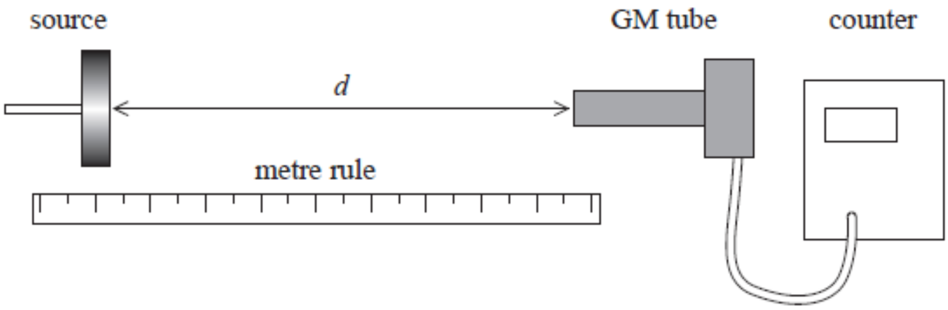
η = ... [3]

(e) Use your answer from **(d)** to determine the thickness of lead required to reduce R to 10% of R_0. Include the error in your value.

x = ... m [2]

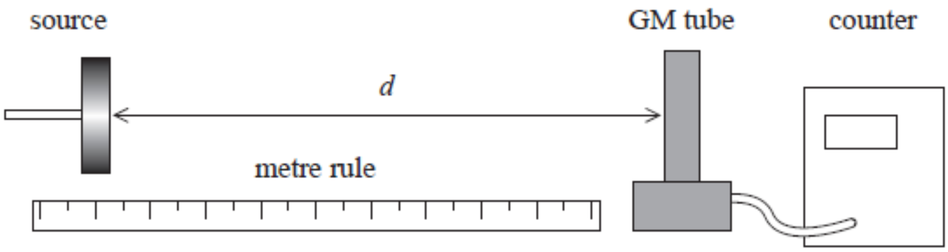
Q5.

A student investigated the way in which gamma radiation spreads out from a source.
He placed a cobalt-60 source in a source holder and set up a Geiger-Müller (GM) tube a short distance *d* away. He connected the GM tube to a counter as shown.



The student recorded the count for 2 minutes.

His teacher turned the GM tube through 90° so that the side of the tube faced the source as shown below.



(i) Explain why this arrangement could lead to more accurate data.

(2)

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(ii) Explain another modification to the experimental method which would improve the accuracy of the data.

(2)

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(Total for question = 4 marks)

Q6.

The photograph shows the containers of two radioactive sources kept in a school.

The school is required to make a safety inspection of the sources every year.

(i) Explain how the sources can be tested to ensure that each source is in the correct container.

(4)

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(ii) Explain a safety precaution that must be applied during this procedure.

(2)

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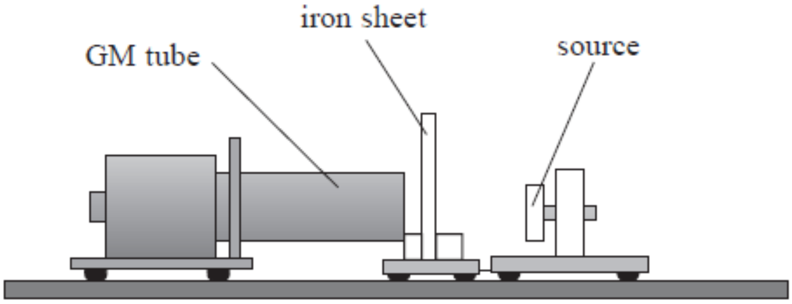
Q7.

A student investigated the absorption of gamma radiation by iron. She placed a gamma source in a holder and set up a Geiger-Müller (GM) tube a short distance away. She placed thin sheets of iron between the GM tube and the source as shown.



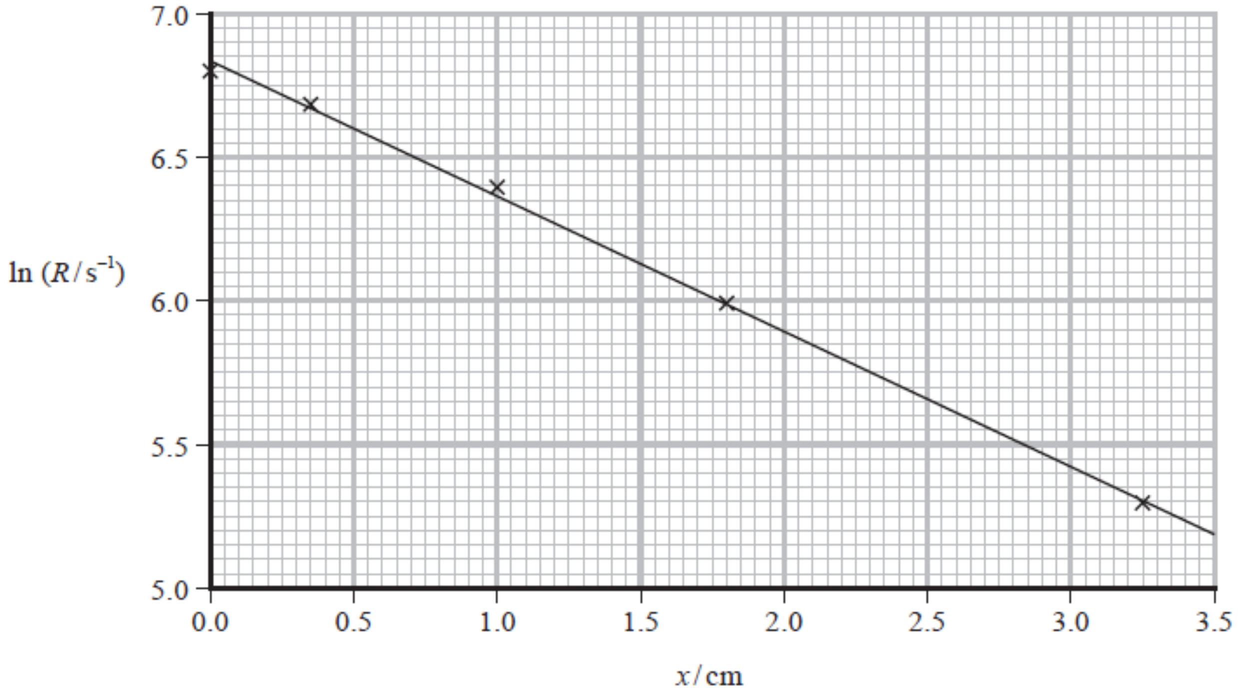
The student used five different thicknesses of iron and determined the count rate for each thickness.

The count rate with no iron sheet in place is R_0. After passing through an iron sheet of thickness x the count rate R is given by the equation

$$R = R_0 e^{-\mu x}$$

where μ is a constant.

The student used her data to plot a graph.



The student used the gradient of the graph to determine a value for μ and used this to estimate the half-value thickness for the iron. This is the thickness of iron that would reduce the count rate to R_0 / 2.

The student used a source that emitted gamma rays of energy 1.1 MeV.

Deduce whether the data the student obtained confirms this energy value.

half-value thickness for 1.1 MeV gamma rays in iron = 1.5 cm

(6)

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(Total for question = 6 marks)

Q8.

Cobalt-60 is a source of gamma radiation. Gamma radiation can be used to sterilise medical equipment.

(a) (i) Complete the nuclear equation for the decay of cobalt-60 to nickel.

$$^{60}_{27}\text{Co} \rightarrow \,^{\dots}_{\dots}\text{Ni} + \,^{\dots}_{\dots}\beta^- + \,^{0}_{0}\bar{\nu}_e$$

(2)

(ii) Suggest why the majority of the energy released is shared between the β^- particle and the antineutrino.

(1)

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(b) The activity of a cobalt-60 source is 4.07×10^{14} Bq initially.

When used for sterilising, the source is replaced when the activity drops below 1.85×10^{14} Bq.

Calculate the time in years until the source should be replaced.

half-life of cobalt-60 = 5.27 years
1 year = 3.16×10^{7} s

(3)

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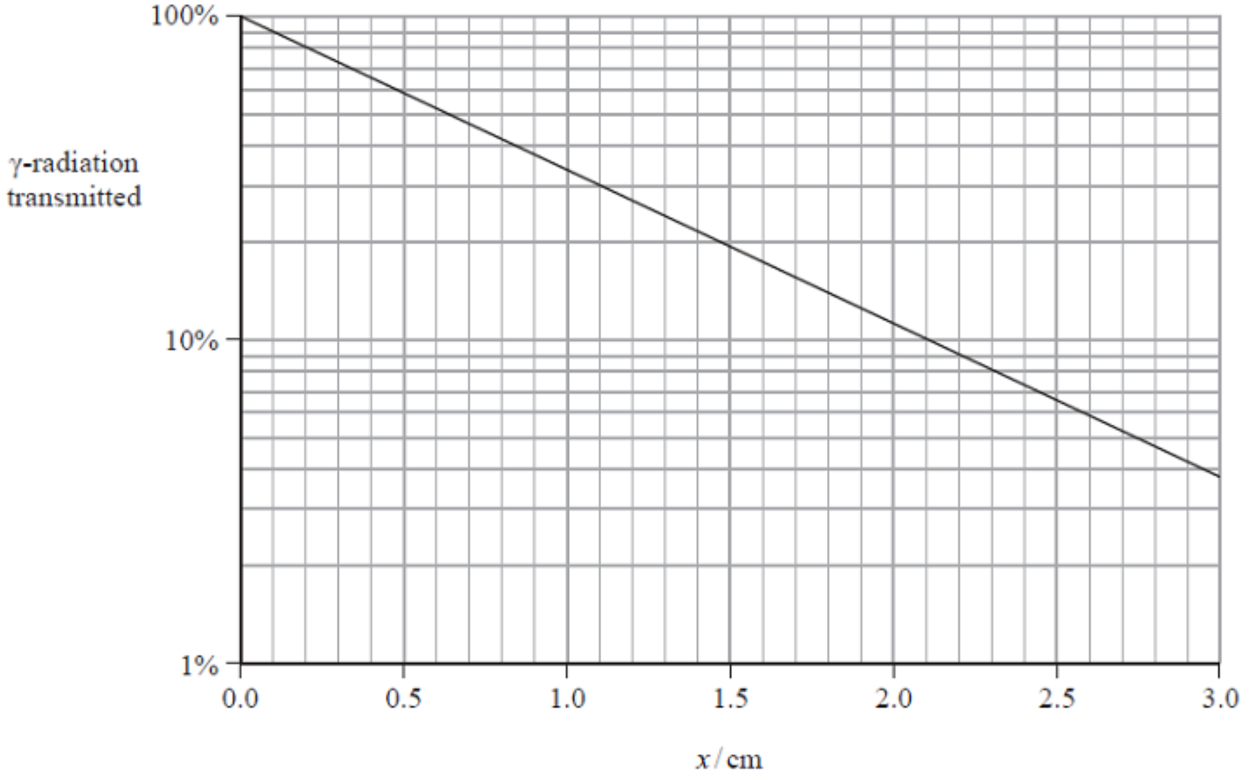
Time until source should be replaced = ... years

(c) When in use the cobalt-60 source is shielded with lead. The graph shows how the transmission of γ-radiation depends upon the thickness x of the lead shielding.



The count rate from a source must be reduced from 4.0×10^{14} Bq to 1.2×10^{14} Bq.

Deduce whether lead shielding of thickness 1.0 cm would be sufficient to achieve this.

(3)

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(Total for question = 9 marks)