A-Level Physics

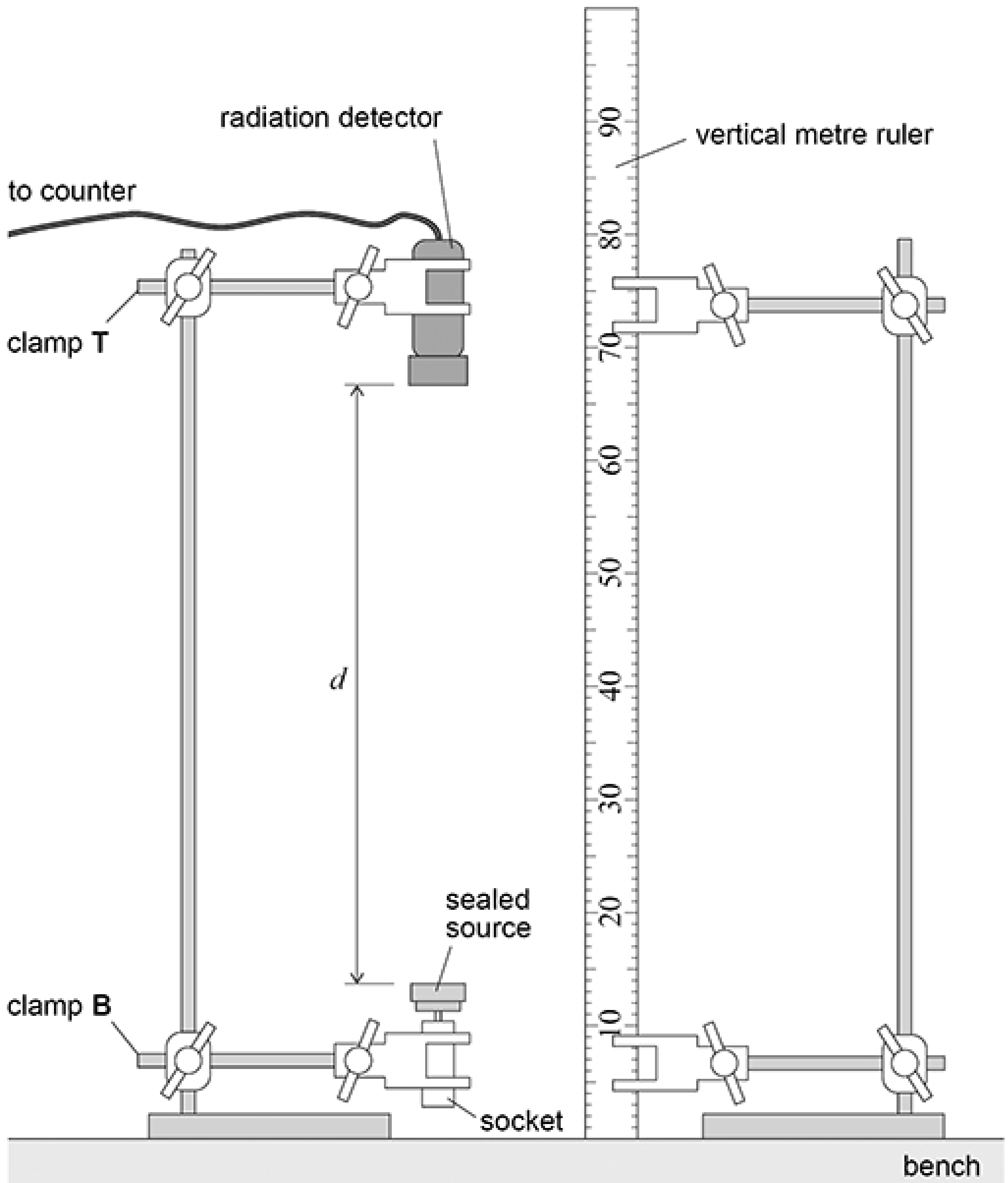
Alpha, Beta and Gama

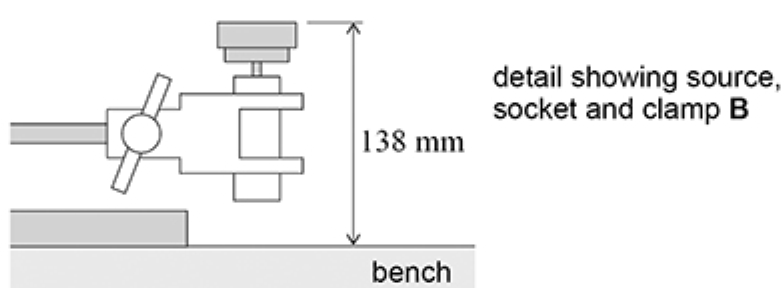
Question Paper

Time available: 71 minutes
Marks available: 48 marks

1. **Figure 1** shows apparatus used to investigate the inverse-square law for gamma radiation.

Figure 1





A sealed source that emits gamma radiation is held in a socket attached to clamp **B**. The vertical distance between the open end of the source and the bench is 138 mm. A radiation detector, positioned vertically above the source, is attached to clamp **T**.

A student is told **not** to move the stands closer together.

(a) Describe a procedure for the student to find the value of d, the vertical distance between the open end of the source and the radiation detector.

In your answer, annotate above the figure to show how a set-square can be used in this procedure.

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(2)

(b) Before the source was brought into the room, a background count C_b was recorded.

C_b = 630 counts in 15 minutes

With the source and detector in the positions shown in the figure above, d = 530 mm. Separate counts C_1, C_2 and C_3 are recorded.

C_1 = 90 counts in 100 s
C_2 = 117 counts in 100 s
C_3 = 102 counts in 100 s

R_C is the mean count rate corrected for background radiation.

Show that when d = 530 mm, R_C is about 0.3 s^{-1}.

(2)

(c) The apparatus is adjusted so that d = 380 mm.
Counts are made that show R_C = 0.76 s^{-1}.

The student predicts that:

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

where k is a constant.

Explain whether the values of R_C in parts (b) and (c) support the student's prediction.

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(2)

(d) Describe a safe procedure to reduce d. Give a reason for your procedure.

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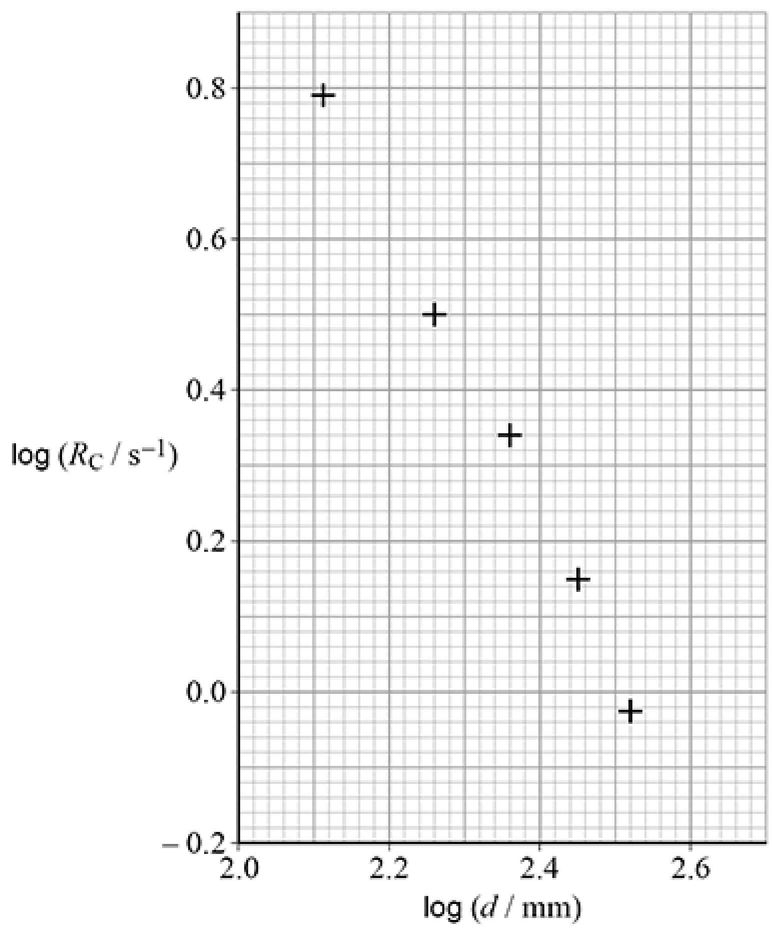
(2)

The student determines R_C for further values of d.
The values of d change by the same amount Δd between each measurement.
Figure 2 shows these data.

Figure 2



(e) Determine Δd.

Δd = ________________ mm

(2)

(f) Explain how the student could confirm whether the graph above supports the prediction:

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

No calculation is required.

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(3)

When a gamma photon is detected by the detector, another photon cannot be detected for a time t_d called the dead time.

It can be shown that:

$$t_d = \frac{R_2 - R_1}{R_1 \times R_2}$$

where R_1 is the measured count rate
R_2 is the count rate when R_1 is corrected for dead time error.

(g) The distance between the source and the detector is adjusted so that d is very small and R_1 is 100 s^{-1}.
On average, two of the gamma photons that enter the detector every second are not detected.

Calculate t_d for this detector.

t_d = _______________ s

(1)

(h) A student says that if 100 gamma photons enter a detector in one second and t_d is 0.01 s, all the photons should be detected.

Explain, with reference to the nature of radioactive decay, why this idea is **not** correct.

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(2)

(Total 16 marks)

2. (a) The exposure of the general public to background radiation has changed substantially over the past 100 years.
State **one** source of radiation that has contributed to this change.

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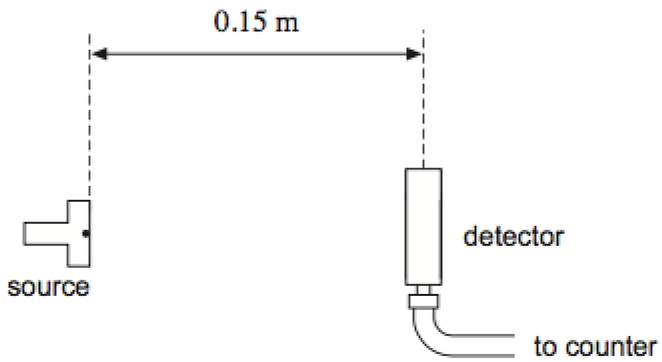
(1)

(b) A student measures background radiation using a detector and determines that background radiation has a mean count-rate of 40 counts per minute. She then places a γ ray source 0.15 m from the detector as shown below.



With this separation the average count per minute was 2050.

The student then moves the detector further from the γ ray source and records the count-rate again.

(i) Calculate the average count-rate she would expect to record when the source is placed 0.90 m from the detector.

count-rate = ____________________ min^{-1}

(3)

(ii) The average count per minute of 2050 was determined from a measurement over a period of 5 minutes. Explain why the student might choose to record for longer than 5 minutes when the separation is 0.90 m.

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(1)

(iii) When the detector was moved to 0.90 m the count-rate was lower than that calculated in part **(b)(i)**. It is suggested that the source may also emit β particles.

Explain how this can be checked.

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(2)

(Total 7 marks)

3. (a) Which ionizing radiation produces the greatest number of ion pairs per mm in air? Tick (✓) the correct answer.

α particles	
β particles	
γ rays	
X−rays	

(1)

(b) (i) Complete the table showing the typical maximum range in air for α and β particles.

Type of radiation	**Typical range in air / m**
α	
β	

(2)

(ii) γ rays have a range of at least 1 km in air.

However, a γ ray detector placed 0.5 m from a γ ray source detects a noticeably smaller count-rate as it is moved a few centimetres further away from the source.

Explain this observation.

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(1)

(c) Following an accident, a room is contaminated with dust containing americium which is an α−emitter.

Explain the most hazardous aspect of the presence of this dust to an unprotected human entering the room.

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(2)

(Total 6 marks)

4. (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)

(b) A γ ray detector with a cross-sectional area of 1.5×10^{-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.

(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)

(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)

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

answer = ____________________ counts s^{-1}

(3)

(Total 9 marks)

5. (a) State which type of radiation, α, β or γ,

(i) produces the greatest number of ion pairs per mm in air,

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(ii) could be used to test for cracks in metal pipes.

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(2)

(b) Specific radioisotope sources are chosen for tracing the passage of particular substances through the human body.

(i) Why is a γ emitting source commonly used?

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(ii) State why the source should **not** have a very short half-life.

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(iii) State why the source should **not** have a very long half-life.

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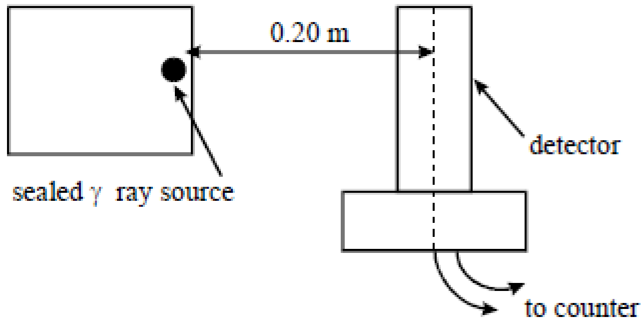
(3)

(c) A detector, placed 0.20 m from a sealed γ ray source, receives a mean count rate of 2550 counts per minute. The experimental arrangement is shown in the diagram below. The mean background radiation is measured as 50 counts per minute.



Calculate the least distance between the source and the detector if the count rate is not to exceed 6000 counts per minute.

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(5)

(Total 10 marks)