Access Tuition

A-Level Physics

Alpha, Beta and Gama

Mark Scheme

Time available: 71 minutes
Marks available: 48 marks

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1. (a) finds d by reading position of (lower end of) detector;
subtracts 138 mm or wtte $_1$✓

for $_1$✓ allow 'reads / measures height of detector' / 'distance from detector to bench';

*reject 'measures height of clamp **T***

if 'subtracts 138' is not seen; allow

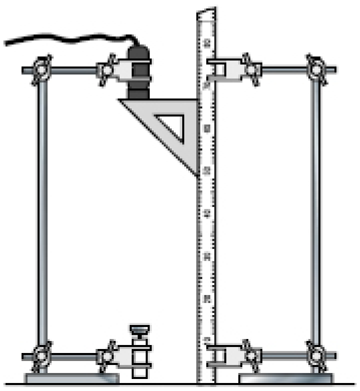
'subtract distance from source to bench' / 'between source and bench' / 'height of source from ground' / 'position of top / open end / mouth of source';

allow 'measures height of the detector and the source and finds difference';

condone 'reversed' subtraction

annotates **Figure 1** to show suitable use of a recognisable set-square $_2$✓

for $_2$✓ expect a <u>triangular</u> 90° set-square in contact with a vertical edge of the ruler, top edge aligned with open end of the detector, eg



condone use of recognisable T-square in contact with vertical edge etc

2

(b) background count rate correct $_1$✓

for $_1$✓ accept any of:

background count rate = 0.7(0) / $\frac{630}{900}$ (s^{-1})

OR

background count in 100 s = 70

OR

background count in 300 s = 210

1

working leading to correct Rc_2✓

for $_2$✓ [cao] ≥ 2 sf R_C = 0.33 (s^{-1})

reject R_C = 0.30 if their uncorrected count has been rounded to 1.0

1

(c) attempts two calculations that would lead to a conclusion $_1$✓

for $_1$✓ the result of at least one calculation of $d^2 \times R_C$ or of $d \times \sqrt{R_C}$ must be correct to 2 sf (see table) otherwise withhold both marks;

allow use of d in m but reject POT error;

allow 1 sf $d^2 \times R_C$ for use of R_C = 0.3;

*allow 530^2 × their **(b)** result*

a reasoned judgement that the evidence does not support the prediction $_2$✓

d / mm	380	530	Δ%
R_C / s^{-1}	0.76	0.33	
$d^2 \times R_C$	$1.1(0) \times 10^5$	9.27×10^4	18%
$d \times \sqrt{R_C}$	331 / 330	305 / 310	8.4%

d / mm	380	530	Δ%
R_C / s^{-1}	0.76	0.3 (1 sf)	
$d^2 \times R_C$	$1.1(0) \times 10^5$	$8(.43) \times 10^4$	29%
$d \times \sqrt{R_C}$	331 / 330	$3.(0) \times 10^2$	14%

for $_2$✓ two correct calculations of $d^2 \times R_C$ or $d \times \sqrt{R_C}$, both must be correct to 2 sf

OR

one correct calculation of $d^2 \times R_C$ or of $d \times \sqrt{R_C}$ correct to 2 sf and an appropriate reverse-working calculation;

the statement rejecting the prediction should be supported by a calculation of the percentage difference between the results of their calculations (see Δ% in table);

condone weaker 'large' / 'significant differences' (between calculation results);

reject 'prediction not correct' because 'values are different' / 'not constant' / 'not close enough'

2

(d) lower / adjust the position of the detector / clamp **T** $_1$✓

*for $_1$✓condone 'lower clamp' (this implies clamp **T** since **B** cannot be lowered further)*

*allow 'remove source using tongs while adjusting detector / clamp **T** otherwise $_2$✗*

1

to maximise distance between the experimenter and the source or wtte

OR

to reduce (limit) exposure (time) of the experimenter to radiation or wtte $_2$✓

for $_2$✓ allow 'not going (too) close (to source)'

reject 'don't touch / make contact with source'

suggesting using lead shielding is neutral

*allow $_{12}$✓ for 'remove source or wtte using tongs to maximise distance etc before moving **B** upwards'*

*changes to the position of source / clamp **B** without the use of tongs loses both marks*

1

(e) determines $10^a - 10^b$ where a and b are (any) plotted values of log (d / mm) $_1$✓

use of $\Delta d = \dfrac{10^a - 10^b}{n}$ where n is 1, 2, 3 or 4;

Δd in range 47(.0) to 53(.0) (mm) $_2$✓

insist on a and b ≥ 2 dp; allow read-off errors ± one square;

expect $\dfrac{10^{2.52} - 10^{2.11}}{4} = 50(.6)$ (mm);

allow $_{12}$✓for $\dfrac{e^a - e^b}{n}$ *leading to Δd correct for their values*

$_2$✓is contingent on $_1$✓ie there is no credit for an unsupported answer

2

(f) suitable analysis $_1$✓

for $_1$✓ log R_C = −2 log d + log k seen; minus sign essential

1

appropriate use of **Figure 2** $_2$✓

*for $_2$✓ draw best-fit line **and** measure gradient;*

allow implication that a (linear) best-fit line is drawn and the gradient is being measured, eg 'check gradient of best-fit line';

condone m = gradient

1

processing and conclusion $_3$✓

for $_3$✓ states that the prediction is confirmed if the gradient / m is ≈ −2

OR

*prediction is **not** confirmed if the gradient is ≠ −2*

condone 'the gradient should be −2 (to confirm prediction)'I

*(**no** ECF for m = (+)2 if denied in $_1$✓ for missing − sign)*

*allow $_{123}$✓ prediction is **not** confirmed if the best-fit line is a curve*

reject 'prediction is confirmed if the best-fit line is straight' / 'there is a negative gradient' / 'because ' k is constant'

1

(g) $t_d = 1.96 \times 10^{-4}$ (s) ✓

minimum 2 sf; accept 196 μs;

calculation should be $\frac{102 - 100}{102 \times 100}$ so only accept

*2.0×10^{-4} (s) / 200 μs only if **rounding up***

($\frac{100 - 98}{100 \times 98}$ gives $t_d = 2.04 \times 10^{-4}$ (s))

1

(h) random nature of decay or wtte $_1$✓

for $_1$✓ condone 'the source emits (photons) sporadically' / 'unpredictably';

reject explanation based on exponential decay

reject 'decay occurs by chance' / 'source does not emit photons at a constant rate' / 'photons decay' / 'decay is spontaneous / inconsistent'

1

idea that more than one photon may arrive per 0.01 s interval

OR

idea that no photon may arrive during per 0.01 s interval

OR

photons 'arrive randomly' / 'do not arrive at a steady rate or wtte $_2$✓

$_2$✓ is contingent on $_1$✓

(if no other answer given) allow $_{12}$✓ for:

'only counts 50 since detector still 'dead' at 0.01 s so only 'sees' odd-numbered photons';

use of formula to show R_1 = 50 is neutral

1

[16]

2. (a) nuclear fallout / testing / weapons / nuclear accidents / Chernobyl / nuclear waste / nuclear medicine / X-rays / specific uses of radioactive sources eg medical tracers CT scan etc. / cosmic rays as a result of air travel ✓
(Any source of radiation that an individual may encounter which would not have existed 100 years ago)

No mark for general answers such as 'medical' or Nuclear Power / nuclear plant.

If a list is given all must be correct but ignore generalisations such as medical or nuclear power.

1

(b) (i) I_{15CCR} = 2050 – 40 = 2010 ✓

Use of inverse square law eg $I_{CCR90} = I_{CCR15}\left(\frac{d_{15}}{d_{90}}\right)^2$ √ = 2010 × (0.15 / 0.90)^2 = 55.8

I_{90CR} = 55.8 + 40

I_{90CR} = 96 counts min^{-1} ✓

regardless of order:

1st mark subtraction of background in original data

2nd mark is for using inverse square function

3rd mark is for the answer

3

(ii) (reduce impact of) random error / decrease the (percentage) uncertainty / improve the statistics (because the percentage error is proportional to the inverse square-root of the count) ✓ (owtte)

The answer must be an uncertainty related statement and not increases reliability / accuracy or increased chance of a reading (although these ideas can accompany a correct answer) Ignore comparisons with the background count.

1

(iii) use (sensible) absorber between source and detector ✓ (sensible absorber means it must have a noticeable effect e.g. 1mm of metal / aluminium sheet / 5mm perspex but do not allow metal foil / paper sheets. Also its effect must not be so great that it reduces the gamma rays noticeably)

(These two marks are independent)

β shown by count rate falling when sheet of aluminium absorber is used ✓ Or (using the existing apparatus)

Compare the results (at various distances) in air with the expected inverse square law ✓

Below the range of beta law does not work but above range it does. ✓

2nd mark no mark given if count rate falls to zero as γ is still present

(magnetic deflection is not common but if seen.

Use of magnetic deflection ✓ correct deflection of beta from the beam ✓)

(If a cloud chamber is suggested. Observe the tracks in a cloud chamber ✓ beta tracks have varying lengths or they are curly / not straight ✓

(The value of the range of beta is not a marking point so accept 15 – 80 cm if a number is given)

2

[7]

3. (a) A α particles ✓

[auto mark question]

1

(b) (i)

type of radiation	Typical range in air / m
α	0.04 ✓
β	0.40 ✓

Allow students to use their own distance units in the table
α allow 0.03 → 0.07 m
β allow 0.20 → 3.0 m.
If a range is given in the table use the larger value.
A specific number is required e.g. not just a few cm.

2

(ii) reference to the <u>inverse</u> square law of (γ radiation)
or
reference to lowering of the solid angle (subtended by the detector as it moves away)
or
radiation is spread out (over a larger surface area as the detector is moved away) ✓

(owtte)
Ignore any references to other types of radiation.
Any contradiction loses the mark. For example, follows inverse square law so intensity falls exponentially.

1

(c) dust may be <u>ingested / taken into the body / breathed in</u> ✓

First mark for ingestion not just on the body

causing (molecules in human tissue / cells) to be <u>made cancerous / killed / damaged</u> by <u>ionisation</u> ✓

Second mark for idea of <u>damage</u> from <u>ionisation</u>

2

[6]

4. (a) any 2 from:

the sun, cosmic rays, radon (in atmosphere), nuclear fallout (from previous weapon testing), any radioactive leak (may be given by name of incident) nuclear waste, carbon-14 ✓

1

(b) (i) (ratio of area of detector to surface area of sphere)

$$\text{ratio} = \frac{0.0015}{4\pi(0.18)^2}\ ✓$$

0.0037 ✓ (0.00368)

2

(ii) activity = 0.62/(0.00368 × 1/400) give first mark if either factor is used.

67000 ✓ Bq accept s^{-1} or decay/photons/disintegrations s^{-1} but not counts s^{-1} ✓ (67400 Bq)

3

(c) (use of the inverse square law)

$$\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$$ or calculating k = 0.020 from $I = k/x^2$ ✓

$$I_2 = 0.62 \times \left(\frac{0.18}{0.28}\right)^2$$ ✓ 0.26 counts s^{-1} ✓(allow 0.24-0.26)

3

[9]

5. (a) (i) α (radiation) **(1)**

(ii) γ (radiation) **(1)**

2

(b) (i) the radiation needs to pass through the body (to be detected) **(1)**

(ii) (otherwise) the activity of the source becomes too weak (during measurements) **(1)**

(iii) the decaying source may remain in the body for a long time and could cause damage **(1)**
[or the activity of the source will be low unless a large quantity is used ($T_{1/2} \propto 1/\lambda$)]

3

(c) corrected count rate at 0.2 m (= 2550 - 50) = 2500 (c min^{-1}) **(1)**
corrected count rate at least distance (= 6000 - 50) = 5950 (c min^{-1}) **(1)**

use of $I = k\frac{I_0}{x^2}$ (or in the form $\frac{I_1}{I_2} = \left(\frac{x_2}{x_1}\right)^2$) **(1)**

(allow C.E. for using uncorrected count rate)

gives least distance = $0.20 \times \left(\frac{2500}{5950}\right)^{1/2}$ **(1)**

least distance = 0.13 m **(1)**

5

[10]