OXFORD

INTERNATIONAL AQA EXAMINATIONS

Topic Test: OxfordAQA International A level Physics

Exponential Change

Name: _____

Class: _____

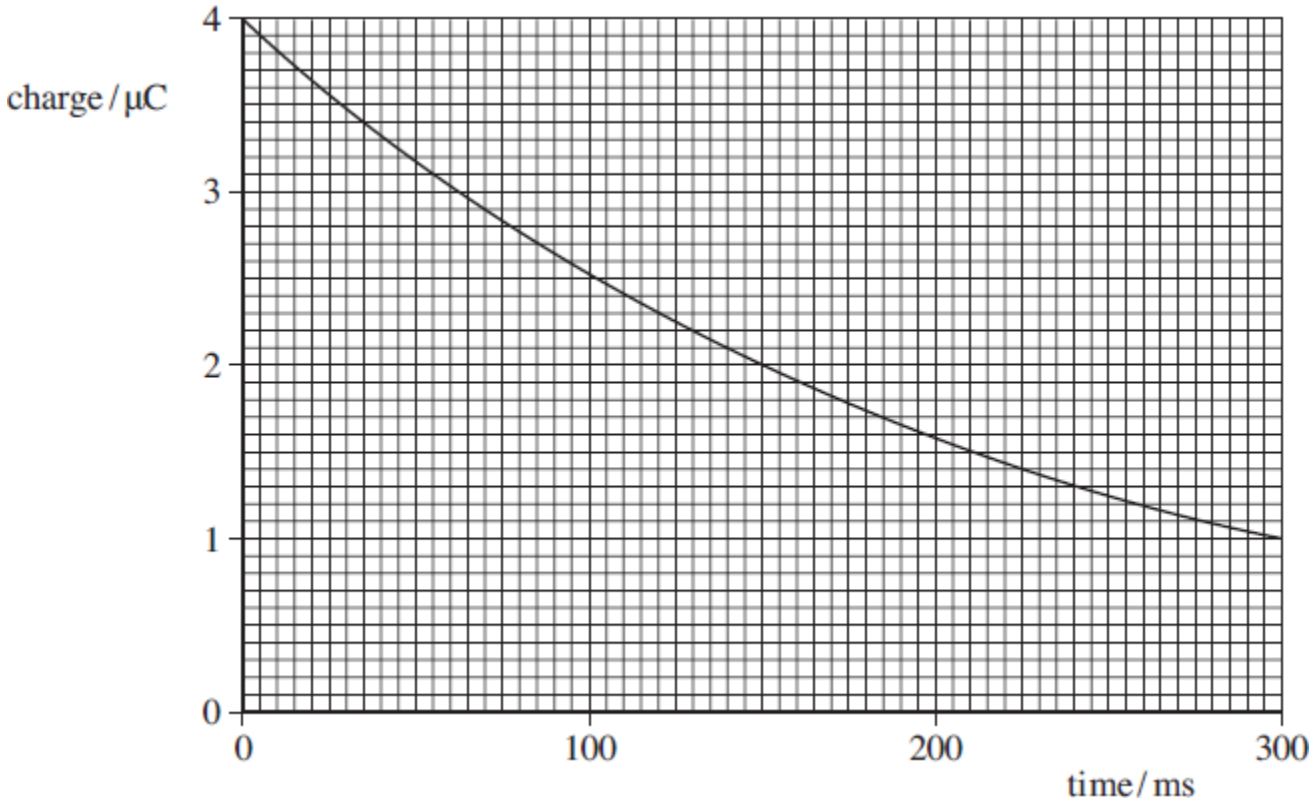
Date: _____

Time: **56 minutes**

Marks: **44 marks**

Comments:

1 The graph below shows how the charge stored by a capacitor varies with time when it is discharged through a fixed resistor.



(a) Determine the time constant, in ms, of the discharge circuit.

time constant _____ ms

(3)

(b) Explain why the rate of discharge will be greater if the fixed resistor has a smaller resistance.

_____

_____

_____

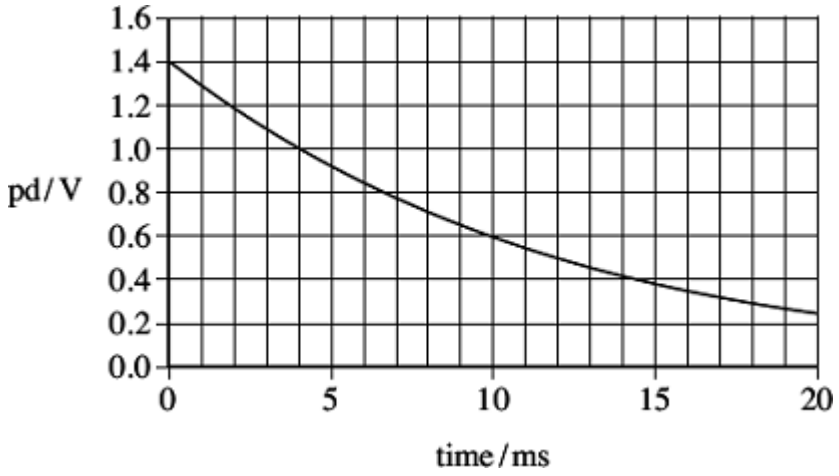
_____

_____

(2)

(Total 5 marks)

2 The figure below shows part of the discharge curve for a capacitor that a manufacturer tested for use in a heart pacemaker.



The capacitor was initially charged to a potential difference (pd) of 1.4 V and then discharged through a 150 Ω resistor.

(a) Show that the capacitance of the capacitor used is about 80 μF.

(3)

(b) Explain why the rate of change of the potential difference decreases as the capacitor discharges.

(3)

(c) Calculate the percentage of the initial energy stored by the capacitor that is lost by the capacitor in the first 0.015 s of the discharge.

energy lost _____%

(3)

(d) The charge leaving the capacitor in 0.015 s is the charge used by the pacemaker to provide a single pulse to stimulate the heart.

(i) Calculate the charge delivered to the heart in a single pulse.

charge _____C

(1)

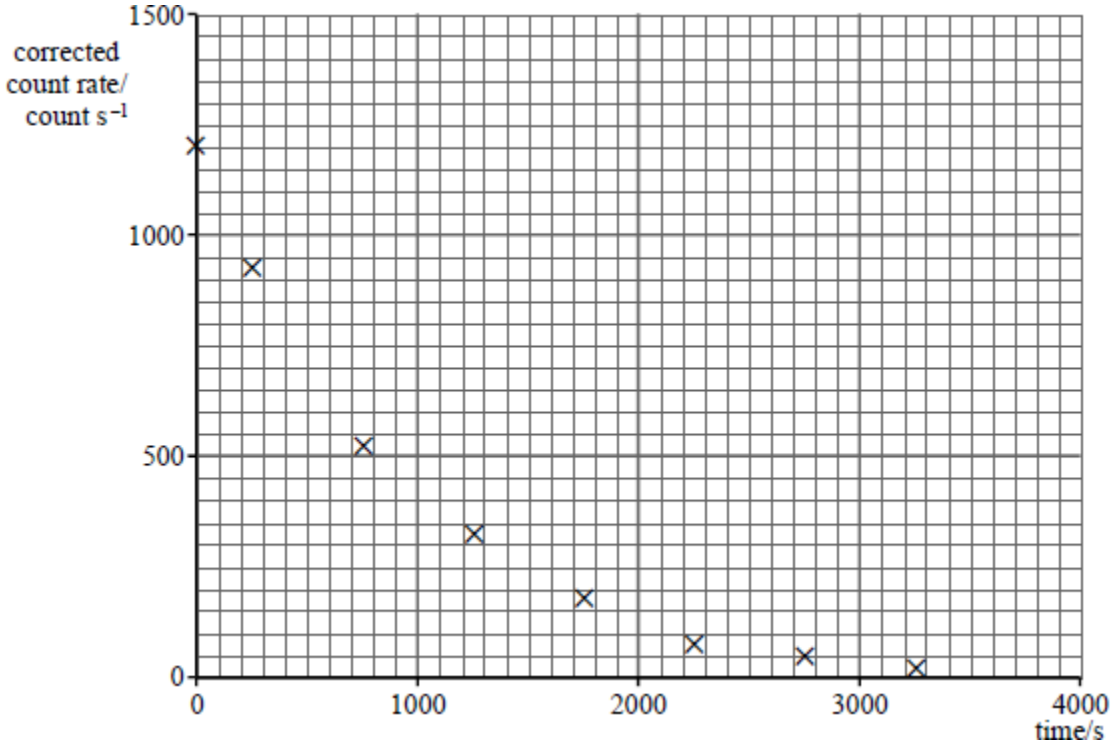
(ii) The manufacturer of the pacemaker wants it to operate for a minimum of 5 years working at a constant pulse rate of 60 per minute.
Calculate the minimum charge capacity of the power supply that the manufacturer should specify so that it will operate for this time.
Give your answer in amp-hours (Ah).

minimum capacity _____Ah

(2)

(Total 12 marks)

3 A Geiger-Muller tube and counter were used to detect β^- particles emitted by a source during a radioactivity experiment. The diagram below shows the **corrected** count rate detected by the counter plotted against time since the beginning of the experiment.



(a) Draw on the graph the curve that best fits these data.

Use the graph to determine the half-life of the radioactive source as accurately as you can.

Half-life _____

(3)

(b) State why the count rate has to be corrected before it is plotted on the graph.

(2)

(c) Explain how the graph and your final answer for the half-life would change if the correction were **not** applied.

(2)

(d) Describe, giving reasons, how you would determine an accurate value for the correction.

(3)

(Total 10 marks)

4 Thallium–208 is a radioactive nuclide with a half-life of 183 s.
It decays to a stable nuclide, lead–208

At time $t = 0$, a pure sample of thallium–208 contains 6.5×10^{20} nuclei.

(a) Define decay constant.

_____

_____

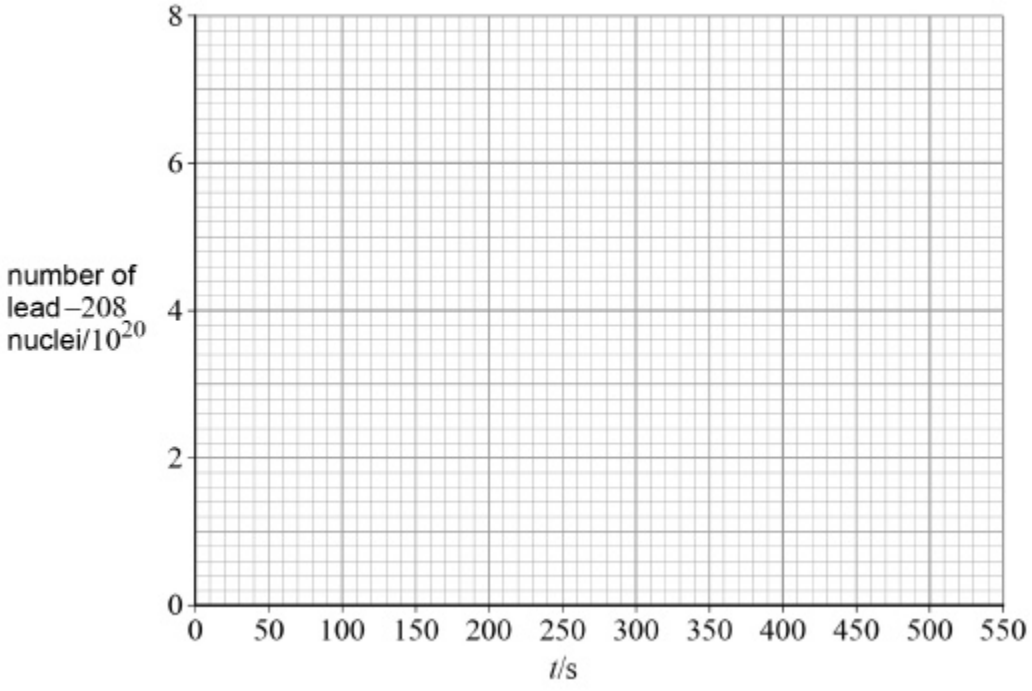
(1)

(b) Calculate the number of nuclei of thallium–208 nuclei that decay between $t = 0$ and $t = 400$ s.

number of nuclei = _____

(3)

(c) Sketch on the axes below a graph of the variation with time of the number of lead–208 nuclei in the sample.



(2)

(Total 6 marks)

5 The carbon content of living trees includes a small proportion of carbon-14, which is a radioactive isotope. After a tree dies, the proportion of carbon-14 in it decreases due to radioactive decay.

(a) (i) The half-life of carbon-14 is 5740 years.
Calculate the radioactive decay constant in yr^{-1} of carbon-14.

decay constant _____ yr^{-1}

(1)

(ii) A piece of wood taken from an axe handle found on an archaeological site has 0.375 times as many carbon-14 atoms as an equal mass of living wood.
Calculate the age of the axe handle in years.

age _____ yr

(3)

(b) Suggest why the method of carbon dating is likely to be unreliable if a sample is:

(i) less than 200 years old,

_____

_____

_____

(ii) more than 60 000 years old.

_____

_____

_____

(2)

(Total 6 marks)

6 In naturally-occurring carbon, most of the atoms are stable but one atom in 10^{12} is the radioactive isotope $^{14}_{6}C$. The decay constant for $^{14}_{6}C$ is 3.8×10^{-12} s^{-1}.
Carbon dioxide molecules each contain one atom of carbon.

What is the activity of the carbon in 0.25 mol of naturally-occurring carbon dioxide?

A 0.57 Bq ⬭

B 2.3 Bq ⬭

C 5.7×10^{11} Bq ⬭

D 2.3×10^{12} Bq ⬭

(Total 1 mark)

7 Radioactive decay is considered to be:

A spontaneous because all nuclei of a particular nuclide have different decay constants. ⬭

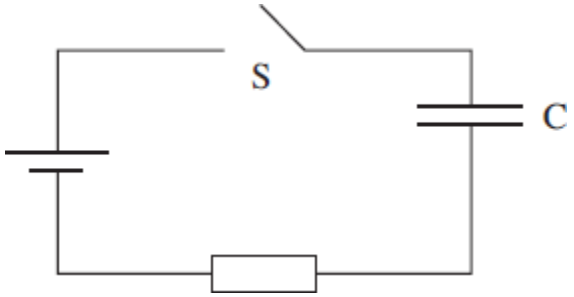
B random because it is not possible to predict whether a nucleus will emit an alpha particle, a beta particle or a gamma ray. ⬭

C random because it is not possible to predict when a particular nucleus will decay. ⬭

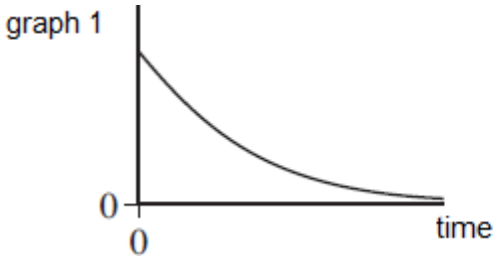
D spontaneous because it happens suddenly when triggered by an event. ⬭

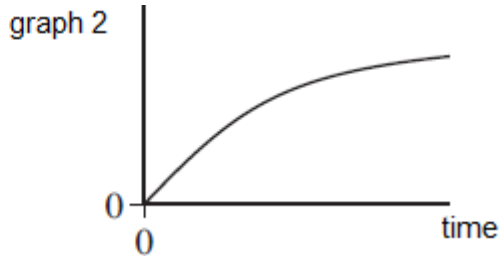
(Total 1 mark)

8 In the circuit shown the capacitor C charges when switch S is closed.



Which line, **A** to **D**, in the table gives a correct pair of graphs showing how the charge on the capacitor and the current in the circuit change with time after S is closed?

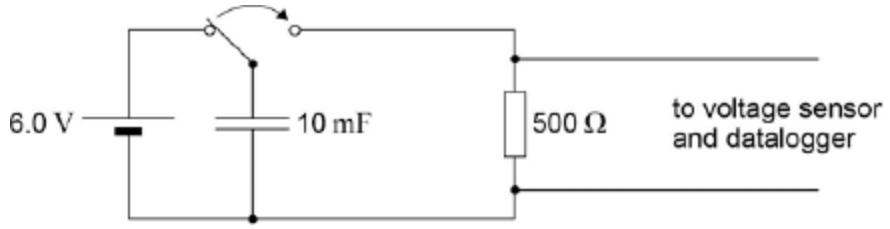




	charge	**current**
A	graph 1	graph 1
B	graph 1	graph 2
C	graph 2	graph 2
D	graph 2	graph 1

(Total 1 mark)

9 A voltage sensor and a datalogger are used to record the discharge of a 10 mF capacitor in series with a 500 Ω resistor from an initial pd of 6.0 V. The datalogger is capable of recording 1000 readings in 10 s.



After a time equal to the time constant of the discharge circuit, which one of the rows gives the pd and the number of readings made?

	Potential difference / V	Number of readings	
A	2.2	50	⬭
B	3.8	50	⬭
C	3.8	500	⬭
D	2.2	500	⬭

(Total 1 mark)

10 A capacitor discharges through a 22 kΩ resistor. It takes 0.75 s for the potential difference across the capacitor to fall from 8.0 V to 4.0 V.

What is the capacitance of the capacitor?

A 34 μF ⬭

B 49 μF ⬭

C 68 μF ⬭

D 98 μF ⬭

(Total 1 mark)

Mark schemes

1 (a) ($Q = Q_0 e^{-t/RC}$ gives)$1.0 = 4.0e^{-300/RC}$ ✓

from which $\frac{300}{RC} = \ln 4$ ✓ and time constant RC = 220 (216) (ms) ✓

[Alternative answer:
time constant is time for charge to decrease to Q_0 /e [**or** 0.37 Q_0] ✓
4.0/e = 1.47 ✓

reading from graph gives time constant = 216 ± 10 (ms) ✓

In alternative scheme, 4.0/e = 1.47 subsumes 1st mark. Also, accept $T_{½}$ = 0.693 RC (or = ln 2 RC) for 1st mark.

3

(b) current is larger (for given *V*)(because resistance is lower)
[**or** correct application of *I = V / R]* ✓
current is rate of flow of charge
[**or** correct application of *I =Δ Q / Δt]*

larger rate of flow of charge (implies greater rate of discharge)
[**or** causes larger rate of transfer of electrons from one plate back to the other] ✓

[Alternative answer:
time constant (or *RC*) is decreased (when *R* is decreased) ✓
explanation using $Q = Q_0 e^{-t/RC}$ **or** time constant explained ✓]

Use either first or alternative scheme; do not mix and match.
Time constant = RC is insufficient for time constant explained.

max 2

[5]

2 (a) time to halve = 0.008 s or two coordinates correct

C1

$C = T_{1/2}/(0.69 \times 150)$ or eg $0.4 = 1.4\ e^{-0.015/150C}$

A1

77 μF (consistent with numerical answer)

A1

3

(b) **max 3 from**

as capacitor discharges:

pd decreases

B1

current through resistor decreases (since $I \propto V$)

B1

rate at which charge leaves the capacitor decreases (since $I = \Delta Q/\Delta t$)

B1

rate of change of charge is proportional to rate of change of pd
(since $V \propto Q$)

B1

condone quicker discharge when pd is larger

B1

3

(c) energy stored $\propto V^2$ or use of $\frac{1}{2} CV^2$
or initial energy = 78.4 (or 75.5) μJ
or final energy using V = 0.38–0.4 0 V
(answer in range 5.6 – 6.4 μJ)

C1

fraction remaining = $(0.4/1.4)^2$ or 0.072 – 0.081
or energy lost = 72 μJ

C1

91.8 to 92.8% lost

A1

3

(d) (i) charge = 77 μC to 82 μC

B1

1

(ii) charge required = $77 \times 10^{-6} \times 5 \times 3.15 \times 10^{7}$ (= 12128 C)
or 1A–h =3600 C

C1

3.36(3.4) Ah

A1

2

[12]

3 (a) Draw curve in on graph (at least one point missed)

B1

Clear use of graph to determine half-life

B1

[repeat and average required]
Answer in range 650 ± 50 s [600–700]

B1

(b) Mention of background radiation

B1

because this increases the count rate

B1

(c) Curve displaced upwards

B1

leading to half-life that is too long

B1

(d) Take count with source absent

B1

Over long time (5+ min) or Average several times (3

or more) and…

B1

Because background is small or subtract correction
Or correction is negative

B1

[10]

4 (a) Probability of decay per unit time ✓

Condone ratio of activity to number of nuclei present

1

(b) Uses $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ or 3.79×10^{-3} seen

Uses $N = N_0 e^{-\lambda t}$ or $1.4(3) \times 10^{20}$ seen

5.1 or 5.07×10^{20}

3

(c) Correct general shape starting at origin and appearing to become asymptotic ✓

Points to look for: (0, 0) (183, 3.25) (366, 4.88) (400, 5.07) (549, 5.69)

1 correct data point and smooth curve that is asymptotic at 6.5 ✓

2

[6]

5 (a) (i) λ (= ln 2 / $T_{1/2}$ = 0.693 / 5740) = 1.2×10^{-4} (yr^{-1}) ✓

(1.21×10^{-4} yr^{-1})

only allow 3.83×10^{-12} s^{-1} if the unit has been changed
working is not necessary for mark

1

(ii) (use of $N_t = N_o e^{-\lambda t}$ and activity is proportional to N

$A_t = A_o e^{-\lambda t}$)

0.375 = exp - ($1.21 \times 10^{-4} \times t$) ✓

$t = \frac{\ln\left(\frac{1}{0.375}\right)}{1.21 \times 10^{-4}}$ ✓

t = 8100 or 8200(yr) ✓

1st mark substitution, allow EC from (i)

2nd mark rearranging, allow EC from (i)

Allow $t / T_{1/2} = 2^n$ approach

3rd mark no EC (so it is not necessary to evaluate a CE)
so max 2 for a CE
full marks can be given for final answer alone. A minus in the final answer will lose the last mark

3

(b) (i) (it is difficult to measure accurately)
the small drop / change in activity / count-rate
the small change / drop in the ratio of C-14 to C-12 ✓

the activity would be very small / comparable to the background
or the ratio of C-14 to C-12 is too small
or there are too few C-14 atoms
or there is very little decay
or the level of C-14 (in the biosphere) is uncertain (this long ago) ✓

1st mark needs some reference to a change in count-rate or activity for the mark

be lenient in 2nd mark
in reading a script assume C-14 is the subject. Eg 'there is little activity to work with' scores mark. Also allow any reasonable suggestion. Eg carbon may have been removed by bonding to surrounding material
Don't allow, 'All the carbon has decayed'

2

[6]

6 A

[1]

7 C

[1]

8 D

[1]

9 D

[1]

10 B

[1]