Teacher Resource Bank

GCE Physics B: Physics in Context

Additional Sample Questions (Specification B)

PHYB5 – Energy Under the Microscope

ADDITIONAL SAMPLE QUESTIONS

This document provides a directory of past questions from the legacy AQA GCE Physics Specification B; these questions may prove relevant/useful to both the teaching of the new AQA GCE Physics B: Physics in Context specification and the preparation of candidates for examined units. It is advisable when using these questions that teachers consider how these questions could relate to the new specification. Teachers should be aware of the different treatment of the Quality of Written Communication between the specifications.

For specific examples of the style and flavour of the questions which may appear in the operational exams, teachers should also refer to the Specimen Assessment Materials which accompany the specification.

A mark scheme has been produced which accompanies this document.

1. An ideal gas forms an isolated system. It now undergoes damages of state such that there is no change in its internal energy. Which other quantity must also remain unchanged.

A The temperature of the gas

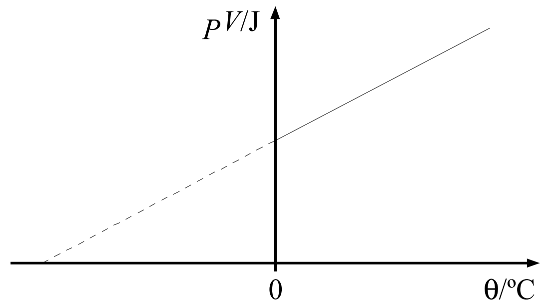
B The volume of the gas

C The pressure of the gas

D The total work done on or by the gas

(Total 1 mark)

2. The graph shows the relation between the product *pressure* × *volume, pV,* and temperature, θ, in degrees Celsius for 1 mol of an ideal gas for which the molar gas constant is R.



Which one of the following expressions gives the gradient of this graph?

A $\frac{1}{273}$

B $\frac{pV}{\theta}$

C $\frac{pV}{(\theta - 273)}$

D R

(Total 1 mark)

3. At a certain temperature, the root-mean-square speed of the molecules of a fixed volume of an ideal gas is c. The temperature of the gas is changed so that the pressure is halved. The root-mean-square speed of the molecules becomes

A $\frac{c}{4}$

B $\frac{c}{2}$

C $\frac{c}{\sqrt{2}}$

D 2c

(Total 1 mark)

4. Which one of the following is **not** an assumption about the properties of particles in the simple kinetic theory?

A $< c^2 >$ is the average speed of the particles

B The forces between the particles are negligible except when particles collide

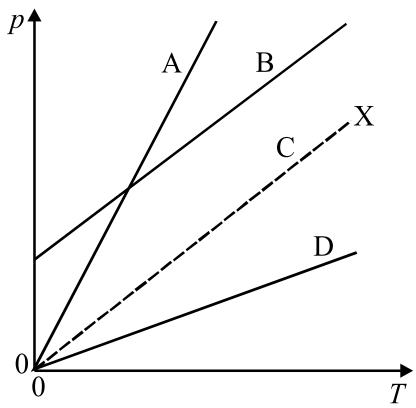
C The time spent by particles in collision is negligible compared with the time spent between collisions

D The volume of the particles is negligible compared to the volume of the container

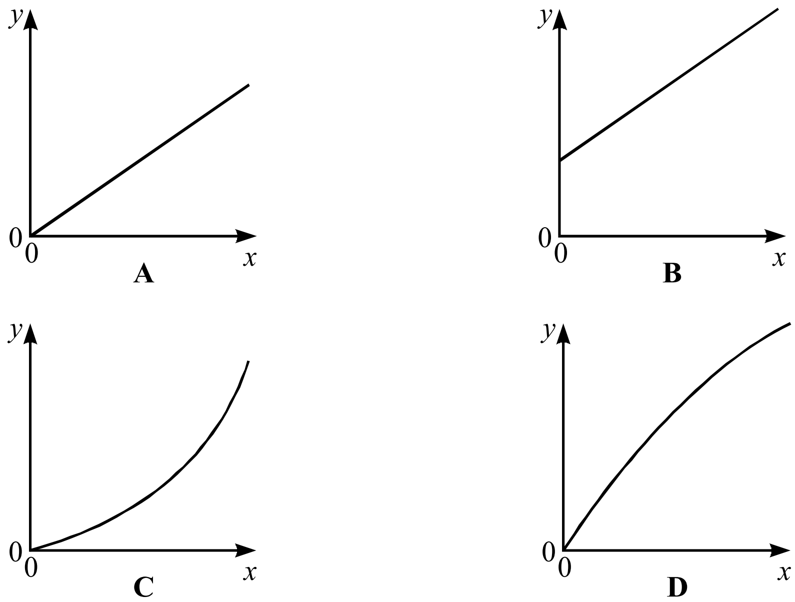
(Total 1 mark)

5. In the diagram the dashed line **X** shows the variation of pressure, p, with absolute temperature, T, for 1 mol of an ideal gas in a container of fixed volume.

Which line, **A**, **B, C** or **D** shows the variation for 2 mol of the gas in the same container?



6. Which one of the graphs below shows the relationship between the internal energy of an ideal gas (*y*-axis) and the absolute temperature of the gas (*x*-axis)?



(Total 1 mark)

7. The temperature of a room increases from 283 K to 293 K. The rms speed of the air molecules in the room increases by a factor of

A 1.02

B 1.04

C 1.41

D 2.00

(Total 1 mark)

8. A fixed mass of an ideal gas initially has a volume V and an absolute temperature T. Its initial pressure could be doubled by changing its volume and temperature to

A $V/2$ and $4T$

B $V/4$ and $T/2$

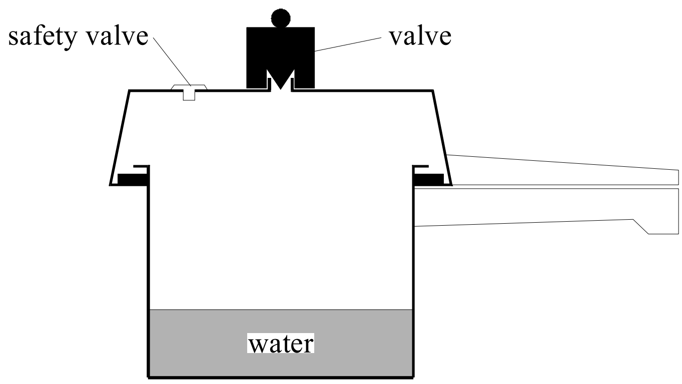
C $2V$ and $T/4$

D $4V$ and $2T$

(Total 1 mark)

9. The pressure cooker illustrated in the figure below consists of a 5.0 mm thick aluminium pan containing 1.4 kg of water, initially at 18 °C. The valve enables the pressure of the steam inside the pan, and hence the temperature at which the water boils, to be raised.

When the cooker is used, the water is boiled without the valve in place until the steam has pushed the air out from the space above the water. Before any steam escapes from the pan, the valve is put in place, trapping the steam. The cooker is heated until the temperature of the contents is 122 °C, by which time 4.8×10^{-3} kg of water has been changed into steam and is trapped in the space above the water.



(a) (i) Calculate the total energy required to heat the water in the pan from 18 °C to122°C and to produce 4.8×10^{-3} kg of steam.

The specific heat capacity of water $= 4.2 \times 10^{3}$ J kg^{-1} K^{-1}

The average specific latent heat of water $= 2.2 \times 10^{6}$ J kg^{-1}.

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(4)

(ii) In order to cool the contents of the pan, it is placed into a sink containing water at a temperature of 18°C. Calculate the initial rate of heat conduction through the walls and base of the pan. The area of the pan in contact with the cold water is
6.1×10^{-2} m^{2} and the thermal conductivity of aluminium is 2.2×10^{2} W m^{-1} K^{-1}.

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(3)

(iii) Sketch a graph on the axes below to show how the rate of heat conduction through the pan will vary with time in the situation described in the part (a)(ii). You should not attempt to make any further calculations to complete your sketch graph.

(1)

(iv) Explain the shape of your graph.

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(2)

(b) When the valve is fitted, steam pressure builds up in the space above the water as the steam temperature rises from 100 °C to 122 °C.

(i) Explain, in molecular terms, why the pressure exerted by the steam on the walls of the pan increases.

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(3)

(ii) Show that there is a mass of 4.8×10^{-3} kg of steam above the water when the temperature is 122 °C, the volume of the steam is 4.2×10^{-3} m^3 and its pressure is 2.1×10^{-5} Pa.

molar mass of water = 18 g mol^{-1}
molar gas constant, R = 8.3 J mol^{-1} K^{-1}

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(3)

(c) While the pressure cooker and its contents are at a temperature of 122 °C, the safety valve is pushed out of the lid by the steam pressure. Consider the air in the room to be a thermodynamic system. Explain, in terms of the first law of thermodynamics equation, any changes that will occur in the internal energy of the system. Identify the appropriate terms in the equation.

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(4)
(Total 20 marks)

10. A thermometer has a thermal capacity of 1.3 J K^{-1}. The initial temperature of the thermometer is 20°C. When used to measure the temperature of 40g of water, it measures 37 °C.

(a) Determine the energy absorbed by the thermometer when it is placed in the water.

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(2)

(b) Calculate the temperature change of the water as a result of introducing the thermometer.

specific heat capacity of water = 4.2×10^3 J kg^{-1} K^{-1}

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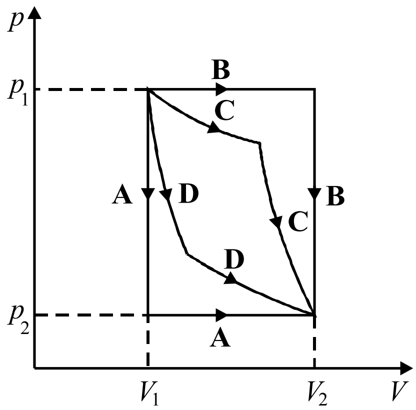
(2)
(Total 4 marks)

11. The diagram shows a *p*-*V* graph for a fixed mass of gas. The volume increases from V_1 to V_2 while the pressure falls from p_1 to p_2.



Which **one** of the paths **A**, **B, C** or **D** will result in the greatest amount of work being done by the gas?

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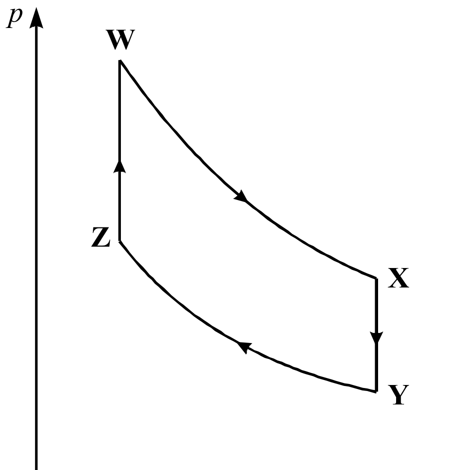
12. The diagram shows the *p*-*V* diagram of an ideal hot-air engine. **WX** and **YZ** are isothermal changes.



Which line of the table below correctly indicates the nature of the work done **on** or **by** the air in each part of the cycle?

	WX	**XY**	**YZ**	**ZW**
A	zero	by	zero	on
B	by	zero	on	zero
C	zero	on	zero	by
D	on	zero	by	zero

……………………………………………………………………………………

(Total 1 mark)

13. (a) The first law of thermodynamics may be written as:

$$\Delta U = Q + W$$

State the meaning of positive values for each of the symbols in this equation.

ΔU ....

Q ....

W ....

(3)

(b) For an isothermal change in an ideal gas:

(i) explain why $\Delta U = 0$;

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(1)

(ii) explain the effects on Q and W.

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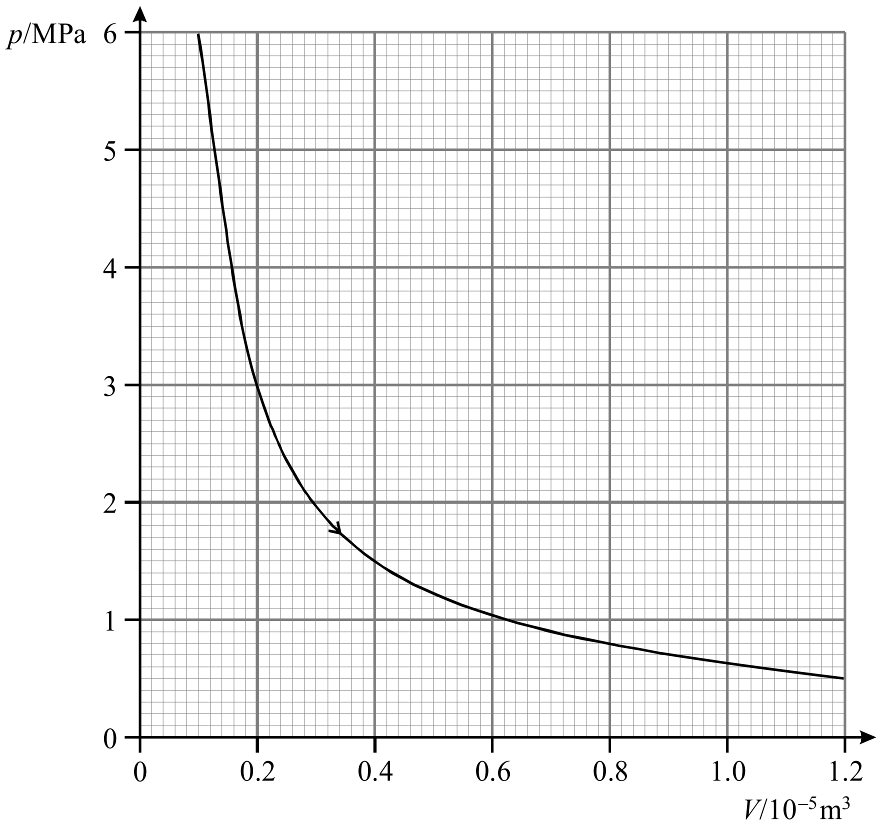
(2)

(c) The diagram below shows an isothermal expansion for 1.2×10^{-3} mol of an ideal gas.



(i) Show that the temperature at which this expansion occurs is approximately 600 K.

molar gas constant, $R = 8.3$ J mol^{-1} K^{-1}

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(2)

(ii) Add to the diagram above a second line to show the expansion of the ideal gas at a temperature of 400 K. Show how you have chosen your values.

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(4)
(Total 12 marks)

14. (a) **Figure 5** shows two isothermal *p*-*V* graphs for a fixed mass of an ideal gas trapped in a cylinder by a piston.

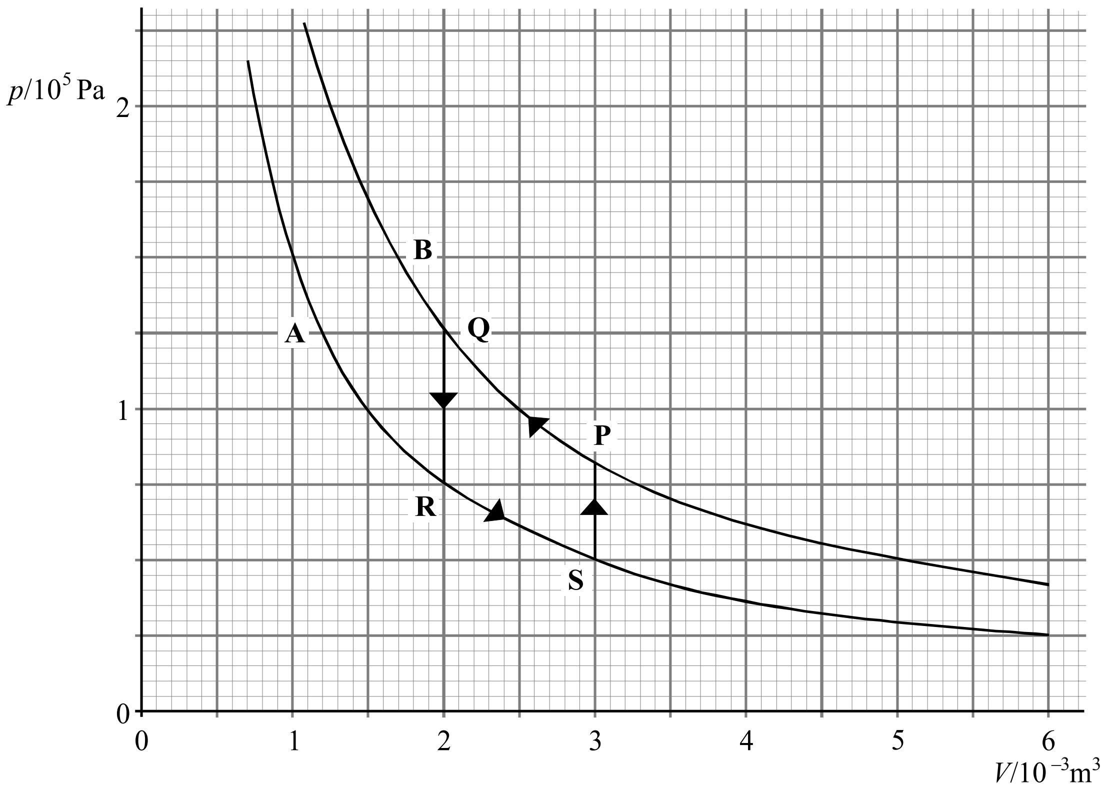

Figure 5

(i) Isothermal A is for a temperature of 340 K. Calculate the temperature for isothermal **B**.
Show your reasoning clearly.

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(2)

(ii) Use data from the graph to determine the number of moles of gas in the container.

universal gas constant, R = 8.3 J mol^{-1}K^{-1}.

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(3)

(b) The gas is taken around the cycle of changes **PQRSP** shown by the arrows on **Figure 5**.

(i) Calculate the work done during the cycle.

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(3)

(ii) State and explain whether this work is done on or by the gas.

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(2)

(iii) The molar heat capacity of the gas at constant volume is 20 J $mol^{-1}K^{-1}$. Calculate ΔU, the decrease in internal energy of the gas for the change **QR**.

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(2)

15. An alpha particle moves at one-tenth the velocity of a beta particle. They both move through the same uniform magnetic field at right angles to their motion.

The magnitude of the ratio $\dfrac{\text{force on the alpha particle}}{\text{force on the beta particle}}$ is

A $\dfrac{1}{4}$

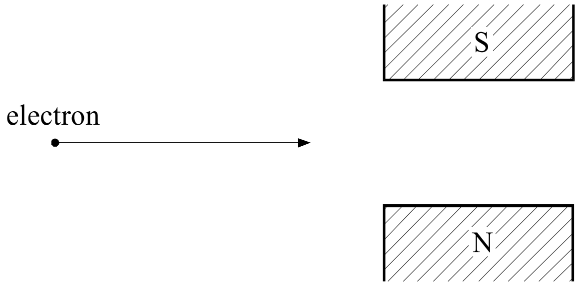
B $\dfrac{1}{5}$

C $\dfrac{1}{10}$

D $\dfrac{1}{20}$

(Total 1 mark)

16. An electron moves into a region of uniform magnetic flux density between the poles of a magnet as shown in the diagram.



The deflection of the electron will be

A towards the pole marked **S**

B towards the pole marked **N**

C perpendicular to the plane of the paper towards you

D perpendicular to the plane of the paper away from you

(Total 1 mark)

17. (a) Explain why a particle is accelerating even when it is moving with a uniform speed in a circular path.

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(2)

(b) **Figure 1** shows a schematic diagram of a proton synchrotron. This is a device for accelerating protons to high speeds in a horizontal circular path.

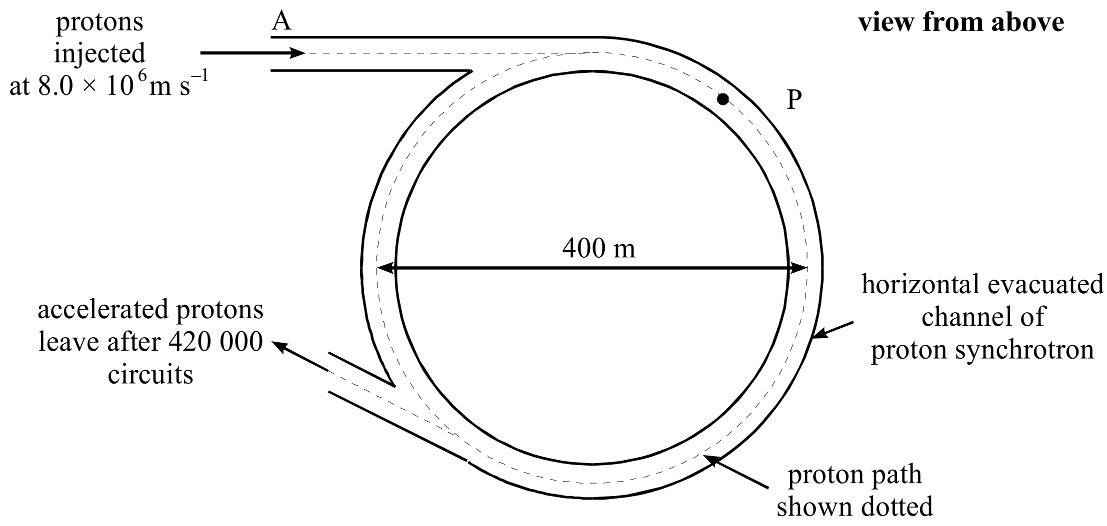

Figure 1

In the synchrotron the protons of mass 1.7×10^{-27} kg are injected at point **A** at a speed of 8.0×10^6 m s^{-1}. The diameter of the path taken by the protons is 400m.

(i) Show on **Figure 1** the direction of the force required to make a proton move in the circular path when the proton is at the position marked **P**.

(1)

(ii) Calculate the force that has to be provided to produce the circular path when the speed of a proton is 8.0×10^6 m s^{-1}.

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(2)

(iii) Sketch on **Figure 2** a graph to show how this force will have to change as the speed of the proton increases over the range shown on the *x*-axis. Insert an appropriate scale on the force axis.

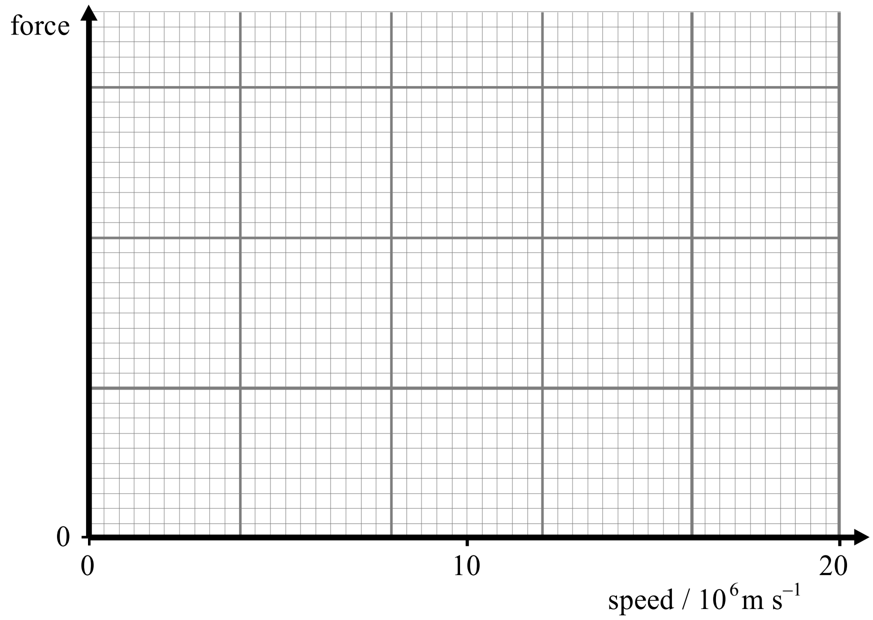

Figure 2

(2)

(c) Before reaching their final energy the protons in the synchrotron in part (b) travel around the accelerator 420 000 times in 2.0 s.

acceleration of free fall, $g = 9.8$ m s^{-2}

(i) Calculate the total distance travelled by a proton in the 2.0 s time interval.

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(2)

(ii) Unless a vertical force is applied the protons would fall as they move through the horizontal channel.

Calculate the distance a proton would fall in two seconds.

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(2)

(iii) Determine the force necessary to prevent the vertical movement.

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(1)
(Total 12 marks)

18. **Figure 1** shows the plan view of a cyclotron in which protons are emitted in between the dees. The protons are deflected into a circular path by the application of a magnetic field. **Figure 2** shows a view from in front of the cyclotron.

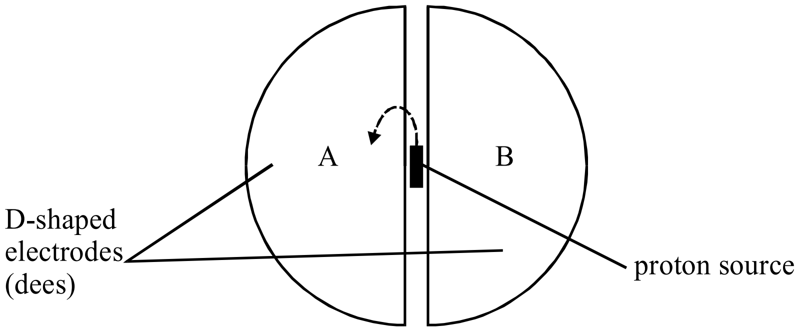

Figure 1

Figure 2

(a) (i) Mark on **Figure 2** the direction of the magnetic field in the region of the dees such that it will deflect the proton beam in the direction shown in **Figure 1**.

(2)

(ii) Show that the velocity of the proton, v, at some instant is given by:

$$v = \frac{Ber}{m}$$

where m is the proton mass, r the radius of its circular path, B the magnetic flux density acting on the proton and $+e$ the proton charge.

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(2)

(iii) Write down an equation for the time T for a proton to make a complete circular path in this magnetic field.

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(2)

(iv) Explain how your equation leads to the conclusion that T is independent of the speed with which the proton is moving.

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(1)

(b) In addition to this magnetic field there is an electric field provided between the dees. This accelerates the proton towards whichever dee is negatively charged. An alternating potential difference causes each dee to become alternately negative and then positive. This causes the proton to accelerate each time it crosses the gap between the dees.

(i) Describe and explain the effect the acceleration has on the path in which the proton moves.

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(2)

(ii) In terms of T, write down the frequency with which the pd must alternate to match the period of motion of the proton.

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(1)

(c) (i) Calculate the velocity of a proton of energy 0.12 keV.

the proton mass, $m = 1.7 \times 10^{-27}$ kg
the magnitude of the electronic charge, $e = 1.6 \times 10^{-19}$ C

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(3)

(ii) Calculate the de Broglie wavelength of the 0.12 keV proton.

the Planck constant, $h = 6.6 \times 10^{-34}$ J s

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(3)

(iii) Name the region of the electromagnetic spectrum which has an equivalent wavelength to that of the proton.

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(1)
(Total 17 marks)

19. **Figure 2** shows part of a linear accelerator, which accelerates ions along the axis of a line of hollow cylindrical electrodes (**A-D**). Alternate electrodes are connected together and an alternating voltage is applied to them such that the ions are accelerated by the electric field in between each adjacent pair of electrodes.

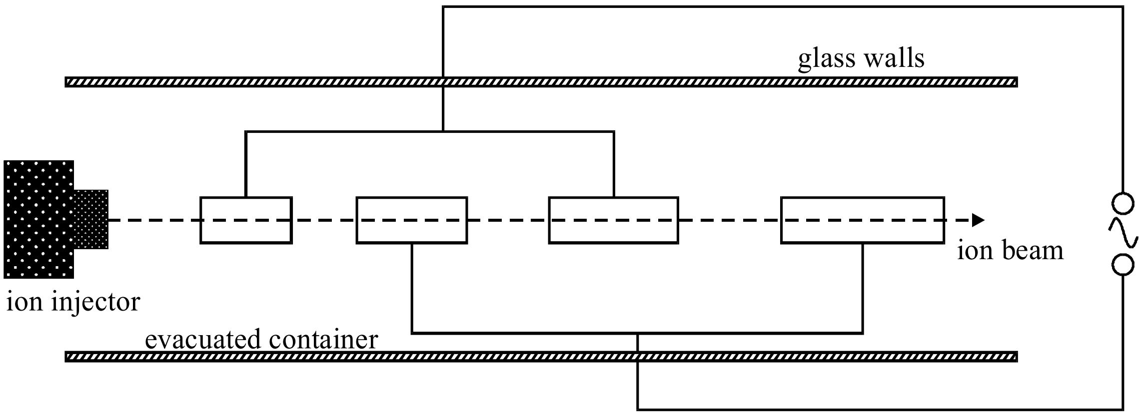
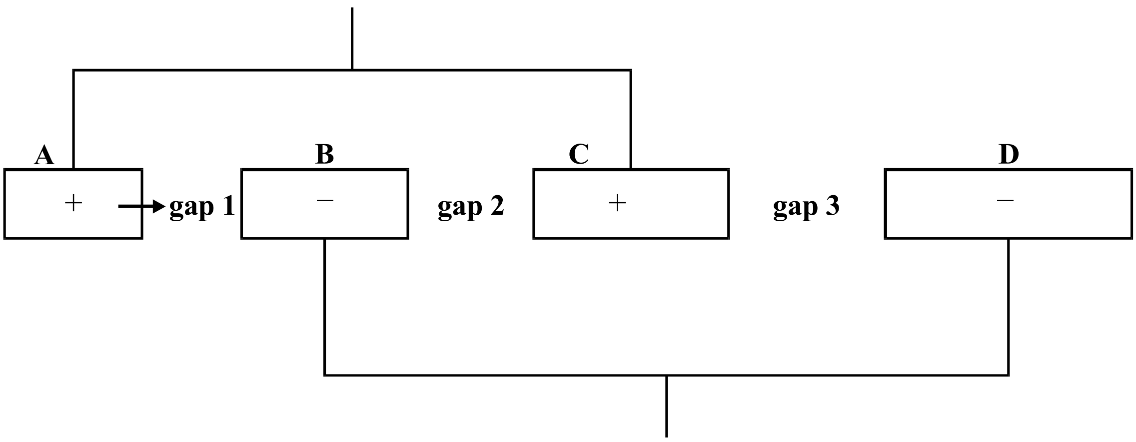


Figure 2

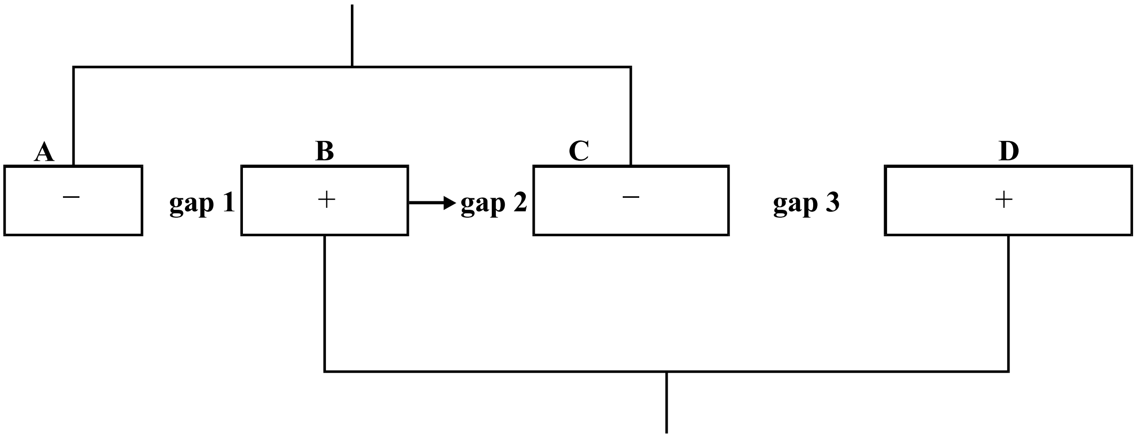
Positive ions are accelerated in the following sequence:

Step 1
The positive ion accelerates across **gap 1** in a very short time when the voltage is at a peak. Electrode **B** is negative with respect to electrode **A**.



Step 2
The ion moves at constant speed in electrode **B** for nearly half a period of the alternating voltage.
The polarity of the electrodes reverses whilst the ion is inside **B**.

Step 3
The positive ion emerges from **B** and accelerates across **gap 2** because electrode **C** is now negative with respect to **B**.



(a) Explain why the ions do not accelerate whilst they are inside the cylindrical electrodes.

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(2)

(b) The following data relates to an experiment using mercury ions (Hg^+):

accelerating voltage between adjacent pairs of electrodes	= 71Kv
frequency of the alternating voltage	= 4.0MHz
charge on a mercury ion	= 1.6×10^{-19}C
mass of mercury ion	= 3.35×10^{-25}kg

(i) Show that each mercury ion gains kinetic energy of approximately 1.1×10^{-14} J as it accelerates between a pair of electrodes.

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(2)

(ii) Ions are injected into electrode **A** with an initial velocity of $2.1 \times 10^5 ms^{-1}$. Show that the velocity of a mercury ion as it enters electrode **B** is about $3.3 \times 10^5 ms^{-1}$.

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(4)

(iii) At each gap ions are accelerated for a time equivalent to 5% of the alternating voltage period. Calculate the force on a mercury ion as it accelerates in **gap 1**.

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(4)

(iv) Calculate the electric field strength across **gap 1**. Assume that the electric field is uniform whilst the ion is accelerating.

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(2)

(v) Calculate the length of **gap 1**.

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(2)

(vi) Calculate the length of electrode **B**.

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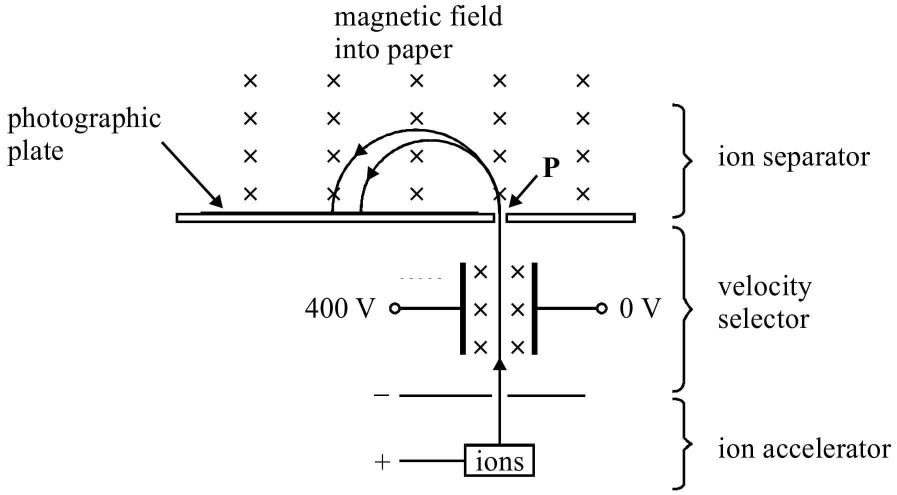
(3)

20. The diagram below shows a diagram of a mass spectrometer.



(a) The magnetic field strength in the velocity selector is 0.14 T and the electric field strength is 20 000 V m^{-1}.

(i) Define the unit for magnetic flux density, the tesla.

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(2)

(ii) Show that the velocity selected is independent of the charge on an ion.

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(2)

(iii) Show that the velocity selected is about 140 km s^{-1}.

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(1)

(b) A sample of nickel is analysed in the spectrometer. The two most abundant isotopes of nickel are $^{58}_{28}$Ni and $^{60}_{28}$Ni. Each ion carries a single charge of +1.6 × 10^{-19} C.

mass of a proton or neutron = 1.7 × 10^{-27} kg

The $^{58}_{28}$Ni ion strikes the photographic plate 0.28 m from the point **P** at which the ion beam enters the ion separator.

Calculate:

(i) the magnetic flux density of the field in the ion separator;

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(3)

(ii) the separation of the positions where the two isotopes hit the photographic plate.

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(2)
(Total 10 marks)

21. In a television cathode ray tube, electrons are accelerated through a potential difference of 12 kV in a vacuum before striking the screen.

(a) (i) Calculate the speed of an electron accelerated through this potential difference.

charge on electron = –1.6 × 10^{-19} C
mass of electron = 9.1 × 10^{-31} kg

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(2)

(ii) The beam current is 25 mA. Calculate the number of electrons that strike the screen in one second.

charge on electron = -1.6×10^{-19} C

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(2)

(b) The electron beam is deflected in the television tube by a changing magnetic field produced by currents in coils placed around the tube.

(i) Explain how this changing magnetic field can lead to induction effects in other electrical circuits in the television.

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(2)

(ii) Explain how this changing magnetic field could lead to faults in these other electrical television circuits.

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(1)

(iii) The electron beam is moved from the left-hand side of the screen to the right-hand side by uniformly varying the field from -3.5×10^{-4} T to $+3.5 \times 10^{-4}$ T in a time of 50 μs. Each turn of a 250-turn coil of wire in this changing field has an area of 4.0×10^{-3} m^2.

Calculate the **maximum** emf that can appear in the 250-turn coil.

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(3)

(iv) Explain why the answer to part (b)(iii) is a maximum value.

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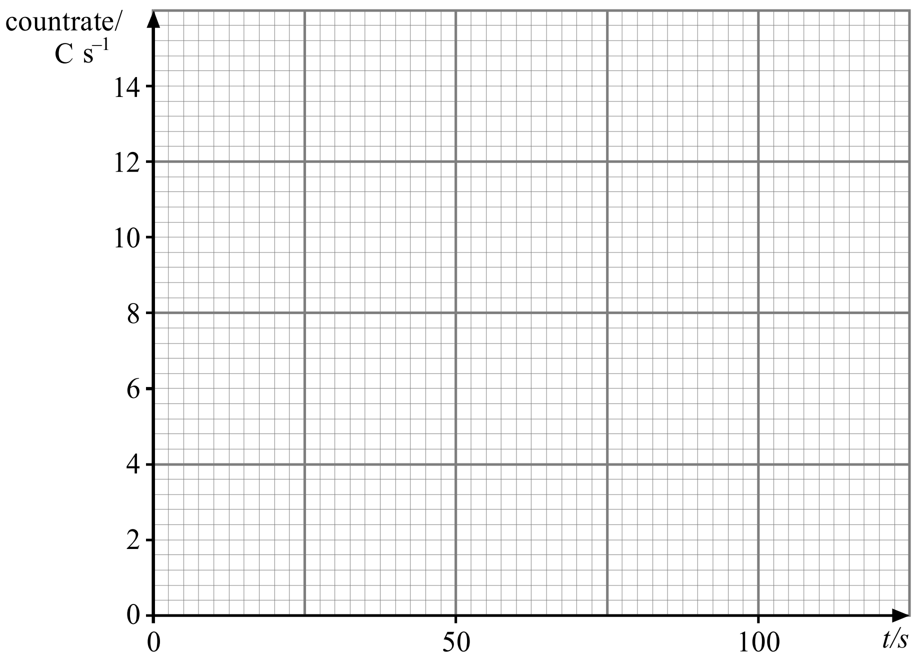
(2)
(Total 12 marks)

22. The table shows the count rate from a radioactive isotope. The background count rate is 0.4 counts s^{-1}.

Time, *t* / s	0	30	60	90	120
Count rate /C s^{-1}	14.0	9.6	6.6	4.6	3.2

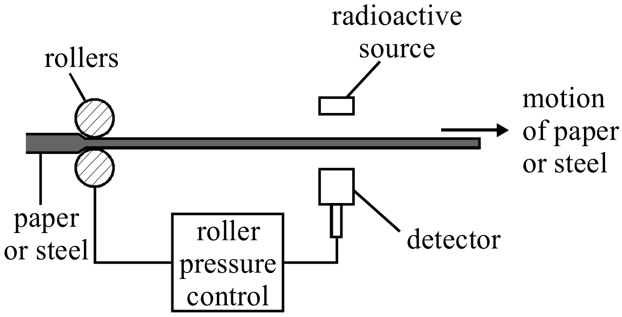
Plot a graph of the **corrected count rate** against time and use it to determine the half-life of the isotope.



Half-life ....

(Total 5 marks)

23. The diagram below shows an arrangement used to maintain a constant thickness of sheet paper or steel as it is being rolled. A radioactive source and detector are used to monitor the thickness.



(a) Explain briefly how this arrangement works.

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(3)

(b) Alpha, beta or gamma sources could be selected for use in such an arrangement.

State which source should be selected in each case and explain briefly why the others would not be suitable.

Paper:

Source selected ....

Reasons why the others are unsuitable ....

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Steel:

Source selected ....

Reasons why the others are unsuitable ....

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(4)

(c) Cobalt-60 is commonly used as a source in such applications. This has a half-life of 5.3 years. When fresh the source contains 5.0×10^{20} radioactive atoms.

For it to be useful the source has to have an activity of at least 1.5×10^{12} Bq.

(i) What is meant by an activity of 1 Bq?

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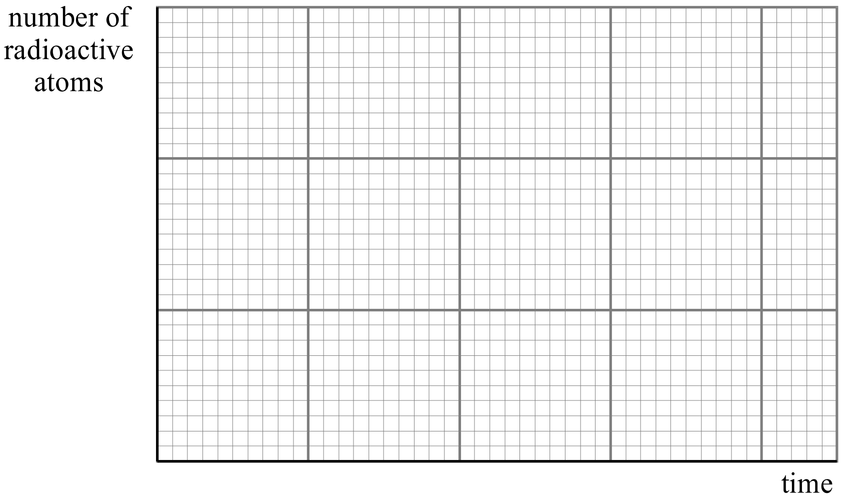
(1)

(ii) Draw a graph showing the number of radioactive atoms in the source over a period of 3 half-lives. Include suitable scales on the axes.



(2)

(iii) Determine the decay constant of cobalt-60 in s^{-1}.

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(2)

(iv) After what time will it be necessary to replace the source?

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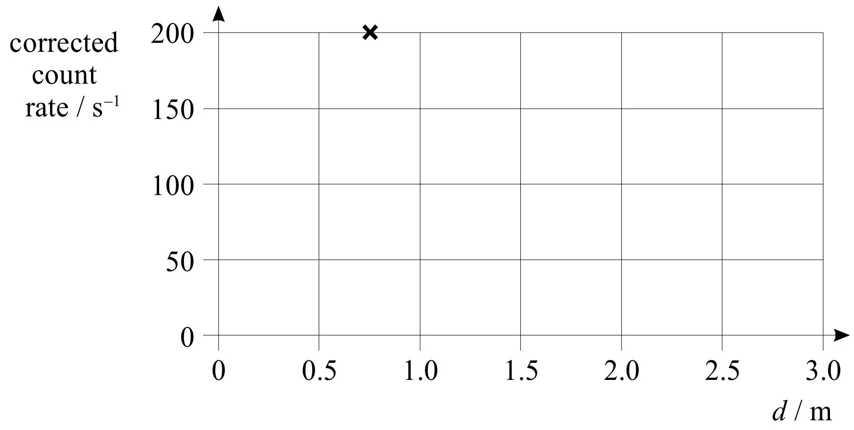
(3)

(Total 15 marks)

24. A detector and counter are used to measure the count rate from a gamma source.

(a) Complete the graph to show how the corrected count rate will vary with the distance, *d*, between the source and the detector. One point has been plotted. To complete the graph accurately, you should perform a suitable calculation to determine the position of one other point on the graph.



(2)

(b) (i) State what is meant by *corrected* count rate.

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(1)

(ii) State **one** means by which you would ensure that the measurement of count rate is accurate.

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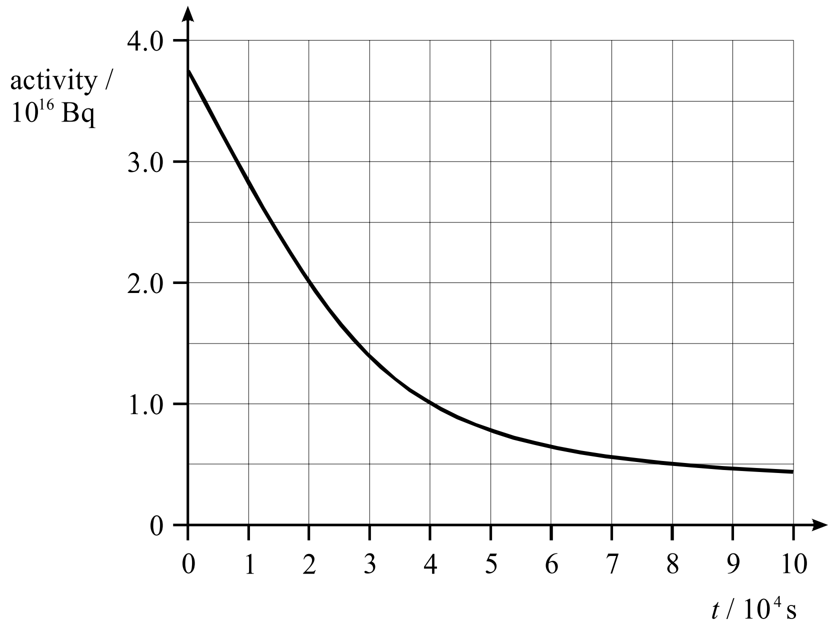
(1)
(Total 5 marks)

25. An isotope of technetium is a gamma emitter used by doctors as a tracer in the human body. It is injected into the patient's blood stream. Scanners outside the body measure the gamma activity, enabling the blood flow to be monitored.

(a) The graph shows the variation of activity with time, t, for a sample of the isotope.



(i) Use data from the graph to determine the half–life of the technetium isotope.

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(3)

(ii) The decay constant of the technetium isotope is 3.2×10^{-5} s^{-1}. Use data from the graph and the equation $A = \lambda N$ to calculate the number of nuclei of the radioactive technetium isotope present at time $t = 0$.

....

....

(2)

(b) (i) State why an alpha emitter would not be suitable in this application.

....

....

(1)

(ii) State why the half–life of the technetium isotope makes it suitable for this application.

....

....

(1)

(c) State and explain how the presence of the technetium isotope may do some damage to the patient.

....

....

....

....

(2)
(Total 9 marks)

26. (a) Sodium-21 ($^{21}_{11}$Na) decays to neon-21 ($^{21}_{10}$Ne). A nucleus of neon-21 is stable.

(i) State the names of the particles emitted when a sodium-21 nucleus decays.

....

....

(2)

(ii) How many neutrons are there in a nucleus of neon-21?

....

(1)

(b) **Figure 1** shows how the activity A of a freshly prepared sample of sodium-21 varies as it decays. **Figure 2** shows how N, the number of sodium-21 nuclei, varies with time t during the same time interval.

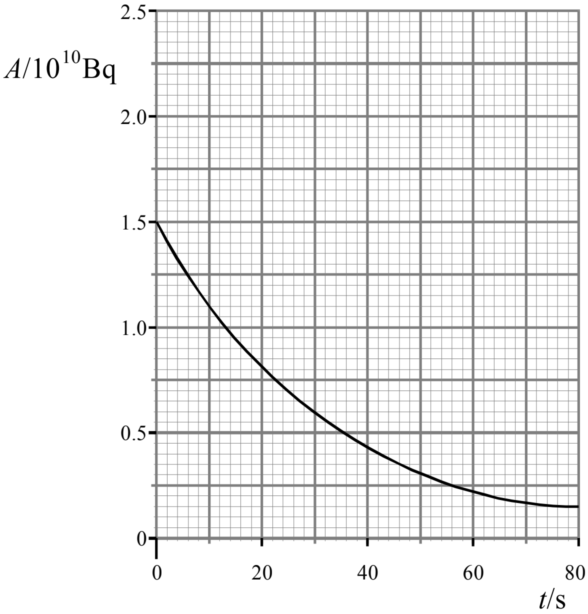


Figure 1

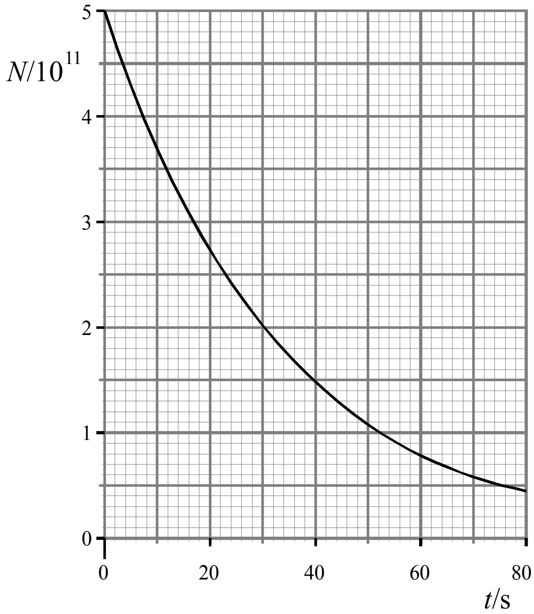


Figure 2

(i) Use the graphs to find the number of active sodium nuclei and the corresponding activity one half-life after $t = 0$. Hence find the probability of decay of a sodium-21 nucleus.

....

....

Probability of decay ....

(3)

(ii) The total energy produced when a sodium-21 nucleus decays is 5.7×10^{-13} J. Calculate the number of radioactive atoms in a sample that is producing 2.6 mJ of energy each second.

....

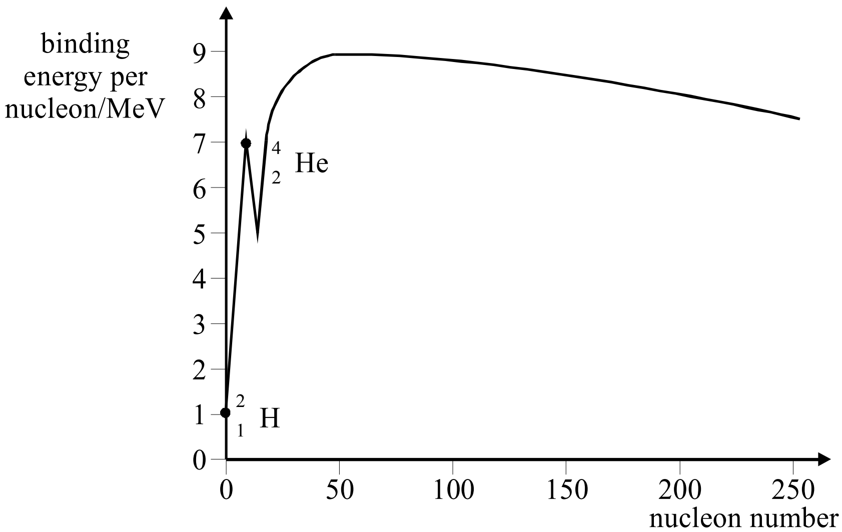
....

Number of radioactive atoms ....

(3)

(Total 9 marks)

27. The diagram below shows the variation of nuclear binding energy per nucleon with nucleon number.



(a) (i) State what is meant by the phrase *nuclear binding energy.*

....

....

....

(2)

(ii) Use the diagram above to explain, in terms of binding energy, why the formation of ${}^{4}_{2}\text{He}$ (helium) by the fusion of two ${}^{2}_{1}\text{H}$ (heavy hydrogen) nuclei results in the production of energy.

....

....

....

(2)

(iii) Use data from the diagram above to estimate the amount of energy, in MeV, released when two ${}^{2}_{1}\text{H}$ nuclei fuse.

....

....

....

(3)

(b) The reaction in part (a)(iii) takes place in a star that is moving away from the Earth at a speed of 8.0×10^6 m s^{-1}.

(i) Assuming that all the energy is released as a single gamma ray, determine its wavelength.

charge on an electron $e = -1.6 \times 10^{-19}$ C
Planck constant $h = 6.6 \times 10^{-34}$ J s
speed of electromagnetic radiation $c = 3.0 \times 10^8$ m s^{-1}

....

....

....

(3)

(ii) Calculate the difference between the frequency of the gamma ray that would be measured by an observer on Earth and the actual frequency. State whether this would be an increase or a decrease.

....

....

....

(3)
(Total 13 marks)

28. Deuterium ($^{2}_{1}H$) and tritium ($^{3}_{1}H$) nuclei will fuse together, as illustrated in the equation below.

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{A}_{Z}X + \text{neutron}$$

(a) State the nucleon number and the proton number for the product of the reaction which has been written as X in the equation.

nucleon number ....

proton number ....

(2)

(b) The masses of the particles involved in the reaction are:

mass of ${}^{2}_{1}\text{H}$ = 3.34250×10^{-27} kg

mass of ${}^{3}_{1}\text{H}$ = 5.00573×10^{-27} kg

mass of ${}^{A}_{Z}\text{X}$ = 6.62609×10^{-27} kg

mass of neutron = 1.67438×10^{-27} kg

(i) Explain why energy is released during this reaction.

....

....

....

....

(2)

(ii) Calculate the amount of energy released when a deuterium nucleus fuses with a tritium nucleus.

The speed of electromagnetic radiation. $c = 3.0 \times 10^{8}$ m s^{-1}

....

....

....

....

(3)
(Total 7 marks)

29. (a) Uranium-238 decays by alpha emission to thorium-234. The table shows the masses in atomic mass units, u, of the nuclei of uranium-238 ($^{238}_{92}U$), thorium-234, and an alpha particle (helium-4).

Element	**Nuclear mass/u**
Uranium-238	238.0002
Thorium-234	233.9941
Helium-4, alpha particle	4.0015

1 atomic mass unit, u = 1.7×10^{-27} kg
speed of electromagnetic radiation, c = 3.0×10^{8} m s^{-1}
the Planck constant, h = 6.6×10^{-34} J s

(i) How many neutrons are there in a uranium-238 nucleus?

....
(1)

(ii) How many protons are there in a nucleus of thorium?

....
(1)

(b) (i) Determine the mass change in kg when a nucleus of uranium-238 decays by alpha emission to thorium-234.

....

....

....
(2)

(ii) Determine the increase in kinetic energy of the system when a uranium-238 nucleus decays by alpha emission to thorium-234.

....

....

....
(2)

(c) Wave particle duality suggests that a moving alpha particle (mass 6.8×10^{-27} kg) has a wavelength associated with it. One alpha particle has an energy of 7.0×10^{-13} J.

Calculate:

(i) the momentum of the alpha particle;

....

....

....

(2)

(ii) the wavelength associated with the alpha particle.

....

....

....

(2)

(Total 10 marks)

30. **Figure 1** shows the general relationship between the nuclear binding energy per nucleon (B) and nucleon number (*A*).

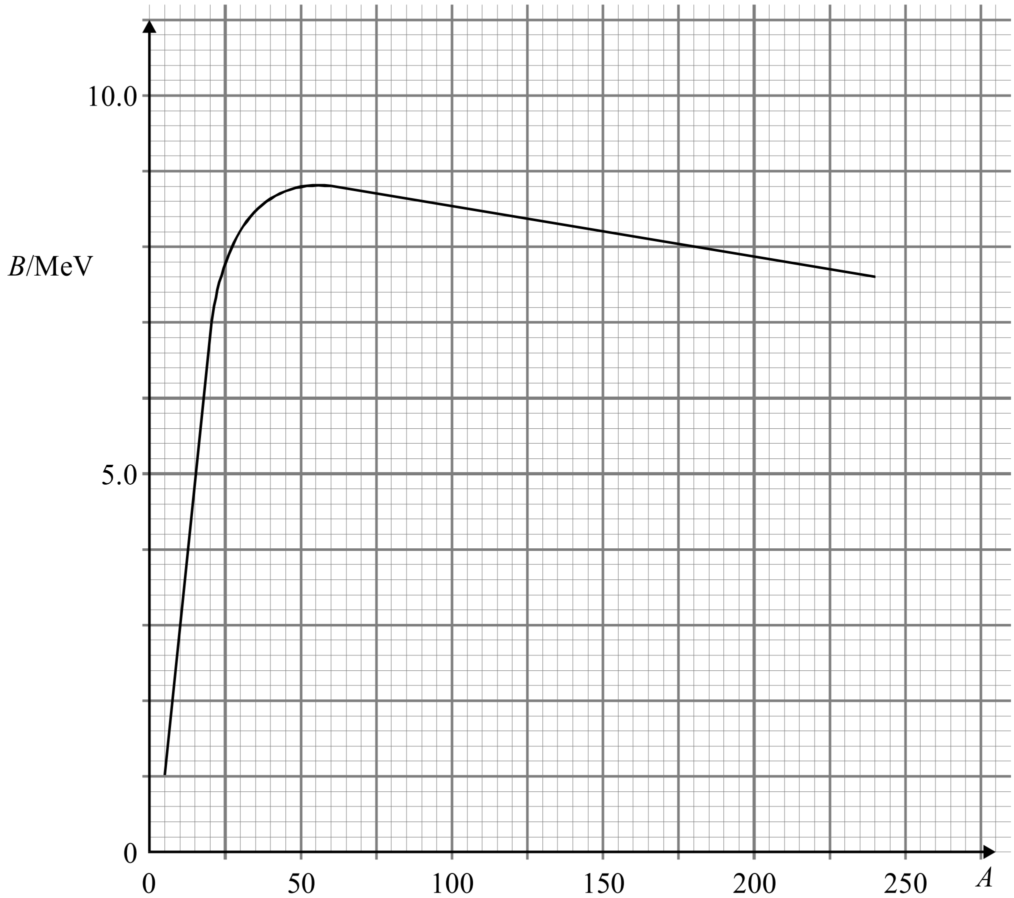


Figure 1

(a) (i) Mark **Figure 1** with the letter S to show the nucleon number and the nuclear binding energy per nucleon for the nuclide with the most stable nuclear structure.

(1)

(ii) Write down the nucleon number and the nuclear binding energy per nucleon for this nuclide.

....

....

(1)

(iii) Calculate the total binding energy of this nuclide.

....

....

(1)

(b) A fusion reaction in which two protons combine to form a deuterium nucleus is summarised by the equation:

$$ {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + {}^{0}_{1}\mathrm{e} + v + 1.44\mathrm{MeV} $$

(i) State what the following symbols represent.

${}^{0}_{1}\mathrm{e}$..

v..

(2)

(ii) By considering charge, baryon number and lepton number for each side of the equation show that this reaction satisfies the conservation laws for these quantities.

....

....

....

(3)

(iii) The protons in this reaction may need to be at a temperature approaching 1 GK in order for this reaction to occur. Explain why such a high temperature may be needed.

....

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....

....

(2)

(iv) Subsequently two ã-ray photons are released, each with an energy of 0.51MeV.
Calculate the wavelength of these photons.

Planck constant	$= 6.6 \times 10^{-34}$ J s
charge on an electron	$= -1.6 \times 10^{-19}$ C
speed of electromagnetic waves in free space	$= 3.0 \times 10^{8}$ ms^{-1}

....

....

....

(3)

(c) With reference to **Figure 1** explain why the fission of a heavy nucleus is likely to release more energy than when a pair of light nuclei undergo nuclear fusion.

You may wish to sketch the general shape of **Figure 1** in order to aid your explanation.

Two of the 7 marks in this question are available for the quality of your written communication.

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(7)

31. A nucleus of plutonium ($^{240}_{94}\mathrm{Pu}$) decays to form uranium (U) and an alpha-particle (α).

(a) Complete the equation that describes this decay:

$$^{240}_{94}\mathrm{Pu} \rightarrow$$

(2)

(b) (i) Show that about 1 pJ of energy is released when one nucleus decays.

mass of plutonium nucleus	$= 3.98626 \times 10^{-25}$ kg
mass of uranium nucleus	$= 3.91970 \times 10^{-25}$ kg
mass of alpha particle	$= 6.64251 \times 10^{-27}$ kg
speed of electromagnetic radiation	$= 2.99792 \times 10^{8}$ m s^{-1}

....

....

....

....

(3)

(ii) The plutonium isotope has a half-life of 2.1×10^{11} s. Show that the decay constant of the plutonium is about 3×10^{-12} s^{-1}.

....

....

....

(2)

(iii) A radioactive source in a school laboratory contains 3.2×10^{21} atoms of plutonium. Calculate the energy that will be released in one second by the decay of the plutonium described in part (b)(i).

....

....

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....

(3)

(iv) Comment on whether the energy release due to the plutonium decay is likely to change by more than 5% during 100 years. Support your answer with a calculation.

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(4)
(Total 14 marks)

32. (a) A parallel plate capacitor is made from overlapping metal plates with an air gap in between. State two ways of increasing the capacitance of the capacitor.

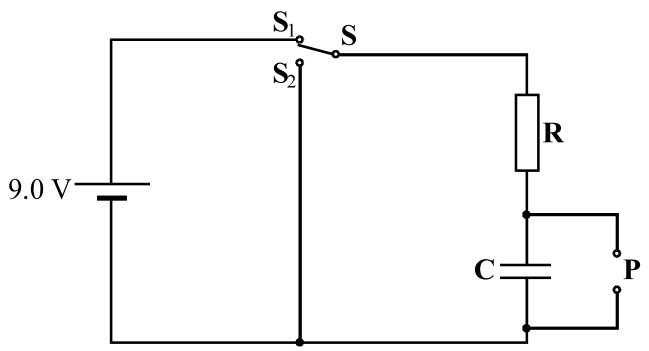
....

....

....

(2)

(b) The circuit shown in the figure below is used to provide a time delay for a burglar alarm. This time delay allows the house owner to switch off the alarm before it sounds.



The opening of a door changes the switch S from position $\mathbf{S}_1$ to position $\mathbf{S}_2$. The alarm, connected to the output connections **P**, is designed to sound when the voltage across the capacitor **C** falls to 5.0 V.

(i) The capacitance of the capacitor **C** is 470 μF. The time delay between the moving of the switch to position $\mathbf{S}_2$ and the alarm sounding is 60 s.

Calculate the resistance of the resistor **R**.

....

....

....

....

(4)

(ii) Sketch a graph to show the variation in voltage V across the capacitor **C** with time t, from the moment when the switch makes contact with the position $\mathbf{S}_2$.

(2)

(iii) State and explain how you would modify the circuit so that the delay was 90 s instead of 60 s. You can gain up to 2 marks in this question for good written communication.

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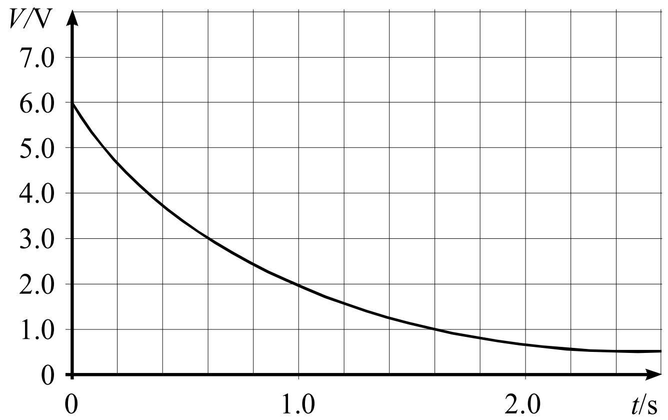
(6)
(Total 14 marks)

33. The graph shows the variation of potential difference *V* with time *t* across a 470μF capacitor discharging through a resistor.



The resistance of the resistor is approximately

A 900Ω

B 1300Ω

C 1900Ω

D 4700Ω

(Total 1 mark)

34. **Figure 1** shows a circuit used to investigate the charging of a capacitor. The supply has an emf of 12.0V and negligible internal resistance. Charging commences when the switch **S** is closed. **Figure 2** shows how the potential difference across capacitor varies with time as it is charging.

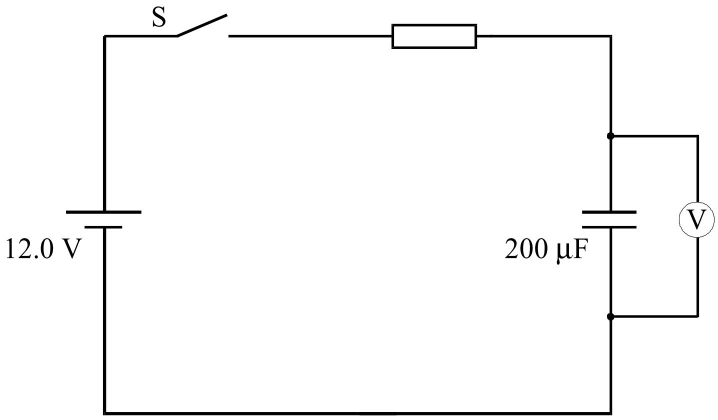


Figure 1

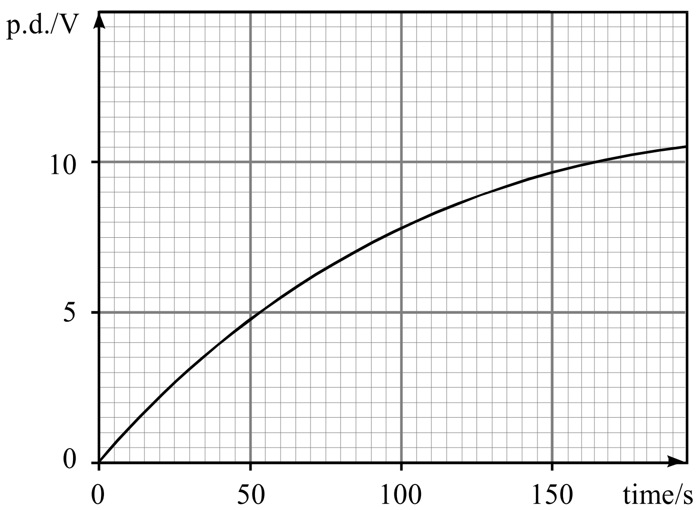


Figure 2

(a) (i) State the final steady potential difference across the capacitor

....

(1)

(ii) Determine the time taken for the potential difference across the capacitor to reach half the maximum value.

....

....

(1)

(ii) Calculate the value of the resistor used in the circuit in **Figure 1**.

....

....

....

(2)

(iv) Calculate the initial charging current when the switch **S** is closed. Show clearly how you arrive at your answer.

....

....

....

(2)

(b) A 100 μF capacitor is added in series with the 200 μF capacitor in **Figure 1**.

(i) Calculate the effective capacitance of the combination.

....

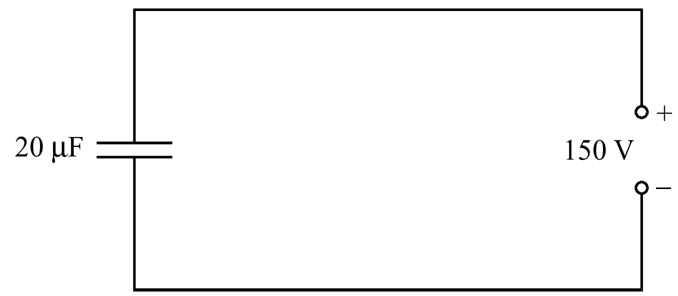
....

(2)

(ii) Draw, on **Figure 2,** a graph to show how the potential difference across the combination varies with time when the combination is charged.

(2)
(Total 10 marks)

35. The diagram below shows a 2.0 μF capacitor connected to 150 V supply.



(a) Calculate the charge on the capacitor.

....

....

(2)

(b) (i) Suggest a graph that could be drawn in order to calculate the energy stored in the capacitor by finding the area under the graph.

....

....

(1)

(ii) Calculate the energy stored by the capacitor when it has a pd of 150 V across it.

....

....

....

(2)

(c) The charged capacitor is removed from the power supply and discharged by connecting a 220 kΩ resistor across it.

(i) Calculate the maximum discharge current.

....

....

(1)

(ii) Show that the current will have fallen to 10% of its maximum value in a time of approximately 1 s.

....

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....

(4)

(d) A pair of identical capacitors are connected across a dc power supply and connected (i) in series and (ii) in parallel. The energy stored in each arrangement is different. State and explain which arrangement stores the greater energy. Two of the 5 marks in this question are for the quality of your written communication.

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(5)
(Total 15 marks)

Teacher Resource Bank

GCE Physics B: Physics in Context

Additional Sample Questions (Specification B)

Mark Scheme

PHYB5 – Energy Under the Microscope

1.	A				**[1]**
2.	D				**[1]**
3.	C				**[1]**
4.	A				**[1]**
5.	A				**[1]**
6.	A				**[1]**
7.	A				**[1]**
8.	B				**[1]**
9.	(a)	(i)	$E = mc\Delta\theta$ **or** $E = mL$	C1	
			heat used to raise temperature of water = 6.12×10^5 J	C1	
			latent heat = 1.1×10^4 J	C1	
			total = 6.2×10^5 J	A1	4
		(ii)	$\frac{Q}{t} = \frac{Ak\Delta\theta}{l}$	C1	
			correct substitution	C1	
			2.8×10^5 W	A1	3
		(iii)	graph of correct shape intercepting y-axis but not intercepting ×-axis or reducing to zero gradient	B1	1
		(iv)	rate of heat transfer reduces because temperature difference reduces	B1	
			temperature difference reduces as water in pressure cooker cools **and** water in sink gets warmer	B1	2

	(b)	(i)	pressure determined by (rate of) change of momentum (of molecules striking the wall)	B1	
			more molecules (as more steam produced)	B1	
			molecules moving faster (at higher temperatures) - **not** just higher KE	B1	
			there are more collisions per second / more frequent collisions	B1	max 3
		(ii)	$PV=n\mathrm{R}T$ **or** mRT/M_r	B1	
			T = 395 K seen or used	B1	
			multiplies by 18×10^{-3}	B1	3
	(c)	all terms defined including direction		B1	
		steam heats the air		B1	
		(expanding) steam does work on air		B1	
		ΔU is positive / internal energy increases because both Q and W are positive			
		condone ΔU is positive because $W = 0$ and U is positive		B1	4
10.	(a)	energy = heat capacity × temperature change		C1	
			22 J	A1	2
	(b)	$E = mc\theta$		C1	
			0.13 K condone °C / $\frac{\text{their(i)}}{168}$ (allow e.c.f. from (i))	A1	2
					[4]
11.	B				
					[1]
12.	B				
					[1]
13.	(a)	**increase** in internal energy		B1	
		heat / thermal energy supplied to the system or energy supplied to system by heating		B1	
		work done **on** the system		B1	
	(b)	(i)	constant temperature	B1	
		(ii)	heat supplied to system = work done by system (or on surroundings)	B1	
			work done on the system = heat transferred to surroundings (or from system)	B1	
	(c)	(i)	$pV = nRT$	M1	
			choice of point on curve and correct substitution giving e.g., 602(K) or 581(K) (all half a small square tolerance)	A1	

		(ii)	**smooth** curve below first curve not touching curve of axes	B1	
			correct point (need not be marked as dot provided curve passes through correct point – e.g. (0.2, 2))	B1	
			2nd correct point e.g. (0.4.,1)	B1	
			supporting evidence – e.g., p_1V_1 or pV = 4 (=3.98)	B1	
					[12]
14.	(a)	(i)	Suitable method clear $\frac{p_1V_1}{p_2V_2}=\frac{T_1}{T_2}$ or $\frac{p_1}{p_2}=\frac{T_1}{T_2}$ or $\frac{V_1}{V_2}=\frac{T_1}{T_2}$ **or** calculate n = 0.053 and substitutes in $pV = nRT$	C1	
			555 to 580 K (567 K) depending on data used from graph	A1	2
		(ii)	Corresponding values of p and V read correctly for either graph	C1	
			Substitutes data in $pV = nRT$; ignore powers of 10	C1	
			0.053 mol (answer will have range dependent on accuracy of graph drawing)	A1	3
	(b)	(i)	Attempt to find area enclosed	C1	
			Number of squares = 80 ± 6 small squares 3 to 3.4 large squares **or** energy per square = 0.5 J	C1	
			40 J (± 3 J)	A1	3
		(ii)	work done ON the gas	M1	
			more work is done on the gas when compressing than by the gas when expanding **or** work done = $p\ \Delta V$ and compression is at higher pressure	A1	2
		(iii)	Change in internal energy, $\Delta U = nc_v\Delta\theta$ (condone Q or W) or Statement that no work is done (on or by the gas) since $\Delta V = 0$ or volume is constant **or** $W = 0$ since $\Delta V = 0$)	C1	
			their (a)(ii) × 20 × (their temperature change) (1.06 × their ΔT) 240 to 250 J (241J to 244 J if correct)	A1	2
					[12]
15.	B				**[1]**
16.	D				**[1]**

17.	(a)		acceleration is (rate of) change of velocity **or** velocity is a vector **or** velocity has magnitude and direction	B1	
			velocity is changing since direction is changing (must be clear that it is the velocity that is changing direction)	B1	
			allow 1 mark for 'it would move in a straight line at constant speed if it were not accelerating' **do not allow** 'because there is a force acting' 'because direction is changing'		2
	(b)	(i)	arrow toward centre of circle at **P**	B1	1
		(ii)	$F = mv^2/r$ **or** $mr\omega^2$ **or** numerical equivalent (r must be 200 m)	C1	
			5.4×10^{-16}N	A1	2
		(iii)	graph showing correct curvature with F plotted correctly (e.c.f. for **F**) (should be between 5×10^{-14} and 6×10^{-16} N	B1	
			double v, quadruple F (should be possible to do these tasks to ±½ a square)	B1	2
	(c)	(i)	circumference = 1256 m or $2\pi r \times 420\ 000$ (allow e.c.f. for incorrect r from (b)(ii))	C1	
			distance travelled = 5.3×10^8 m	A1	2
		(ii)	$s = ½\ gt^2$ **or** $ut + ½at^2$	C1	
			19.6m (20m)	A1	2
		(iii)	$mg = 1.7\ (1.67) \times 10^{-26}$ N	B1	1
					[12]

18.	(a)	(i)	vertical field line(s) directed downwards	B1 B1	
		(ii)	mv^2/r and Bev seen equated and correctly rearranged	M1 A1	
		(iii)	$v = \frac{2\pi r}{T}$ or equivalent	M1	
			$T = \frac{2\pi m}{Be}$	A1	
		(iv)	no v in the equation for T (m, B and e all independent of v)	B1	
	(b)	(i)	proton spirals outwards/suitable diagram as v ↑ r ↑	B1 B1	
		(ii)	$f = 1/T$	B1	
	(c)	(i)	conversion of keV to J (1.92×10^{-17}) use of ½ mv^2 1.50×10^5 ms^{-1}	C1 A1	

		(ii)	$\lambda = \frac{h}{p}$		
			$p = mv$ or substituted values	C1	
			2.6×10^{-12} m	A1	
		(iii)	*y*-rays or X-rays or answer consistent with candidate's λ	B1	
					[17]
19.	(a)		no electric field / no pd within electrode	B1	
			hollow cylinder/ conductor at constant potential	B1	2
	(b)	(i)	equation ($E_k = eV$) or substituted values seen	M1	
			1.14×10^{-14} no u.p.	A1	2
		(ii)	attempt to apply conservation of energy	C1	
			k.e. of injected ions + gain in k.e. = new k.e.	C1	
			new k.e. = 1.84×10^{-14} (J)	C1	
			3.31×10^5 ms^{-1} (3.35×10^5 ms^{-1})	A1	4
		(iii)	$\Delta v = 1.2 \times 10^5$ (ms^{-1})	C1	
			$T = 1/f = 2.5 \times 10^{-7}$ (s)	C1	
			$t = 0.05 \times 2.5 \times 10^{-7}$ (s)	C1	
			$F = 3.22 \times 10^{-12}$ N (3.35×10^{-13} N) or $F = ma$ correctly used with candidate's values	A1	4
		(iv)	$E = F/Q$ or correctly substituted values	C1	
			2.01×10^7 NC^{-1} e.c.f. (2.09×10^7 NC^{-1})	A1	2
		(v)	$E = \frac{\Delta V}{\Delta x}$ or $s = ut + ½ at^2$ etc or substituted values	C1	
			3.5 mm e.c.f. (3.4 mm)	A1	2
		(vi)	product of 3.3×10^5 ms^{-1} and **any** t	C1	
			$t = 1.12 \times 10^{-7}$ s	C1	
			0.037 m	A1	3
					[19]
20 .	(a)	(i)	1 N per A per m **or** 1 Wb m^{-2} **or** quotes: $B = F/IL$ with terms defined **or** induced $EMF = \Delta BAN/t$ with terms defined **or** a slightly flawed attempt at the definition in statement form	C1	
			It is the flux density (perpendicular to a wire) that produces a force of 1N per m on the wire when the current is 1A **or** $B = F/IL$ **and** 1 T is flux density when F = 1N; I = 1A and L = 1 m **or** induced $EMF = \Delta BAN/t$ and 1 T is the flux change when emf = 1V for A=1 N=1 and t=1 or similar	A1	2

		(ii)	force on charge due to E field , $F_E = Eq$ **or** Vq/d **and** force due to B field, $F_B = Bqv$ **or** $Eq=Bqv$	B1	
			$= Bqv$; cancels q **and states explicitly** $v = \frac{E}{B}$ **or** $v = \frac{V}{dB}$	B1	2
		(iii)	$v = 20000/0.14$ (seen) **or** 143×10^3 m s^{-1}	B1	1
	(b)	(i)	$Bqv = mv^2/r$ or $r = mv/Bq$ (allow e instead of q)	C1	
			mass of ion = $1.7 \times 10^{-27} \times 58$ (may be in equation) **or** (9.86×10^{-26} kg seen) **or** radius = 0.14 m (may be in equation)	C1	
			Substitutes and arrives at 0.62 to 0.63 T	A1	3
		(ii)	Calculates new radius (0.145 m) or diameter (0.288 m) using $r \propto m$ or otherwise **allowing ecf**	C1	
			0.010 m (condone 0.01 m) or 0.0096 – 0.0097 m (Allow 0.0079 m or 0.008 m due to use of different sfs for B and v)	A1	2
					[10]
21.	(a)	(i)	equates eV and ½ mv^2	C1	
			$[v = \sqrt{(2Ve/m)}] = 6.5 \times 10^7$ m s^{-1}	A1	
		(ii)	$\boldsymbol{25mC/1.6 \times 10^{-19}}$	C1	
			$\boldsymbol{= 1.56 \times 10^{17}\ s^{-1}}$	A1	
	(b)	(i)	Changes in flux linkage mentioned OWTTE	B1	
			produces an induced emf; *allow induced current*	B1	
		(ii)	leads to heating effects, damage, additional magnetic fields etc	B1	
		(iii)	$\Delta B = 7 \times 10^{-4}$ T	C1	
			$\Delta(NBA) = 7 \times 10^{-4} \times 250 \times 0.004$	C1	
			$E = \Delta(NBA)/\Delta t = 7 \times 10^{-4} \times 250 \times 0.004/50 \times 10^{-6} = 14$ V	A1	
		(iv)	Any valid suggestion for flux reduction	C1	
			Coil and field perpendicular (for max value)	A1	
					[12]
22.	corrected count rates calculated:		13.6, 9.2, 6.1, 4.2, 2.8	M1	
	plotting correct			A1	
	axes labelled with quantities and units			B1	
	smooth curve drawn			B1	
	52 s (+/– 2 s)			B1	
					[5]

23.	(a)	thicker material absorbs more particles		B1	
		count rate (number detected) falls if material is thicker		B1	
		fall in count rate produces change to adjust process to produce thinner material / restore to original thickness		B1	3
		allow 1 mark for 'change in thickness changes count rate and rollers adjust to compensate'			
	(b)	use a beta source		M0	
		alphas would be absorbed by paper		A1	
		gammas would not be affected		A1	
		use a gamma source		M0	
		beta would be absorbed completely		A1	
		alphas would be absorbed completely		A1	
		allow beta if candidate includes statement about the steel sheet being thin			4
	(c)	(i)	1 disintegration/decay/particle emitted per second (per unit time) **not** one count per second	B1	1
		(ii)	correct curvature starting at 5×10^{20}; time scale inserted up to 15 (unit not necessary) **or** labelled $T_{1/2}$, $2T_{1/2}$, $3T_{1/2}$	M1	
			sensible scales (not multiples of 3); correct number of atoms at each half-life; reasonable curve and unit for time	A1	2
		(iii)	half-life = 0.69 / decay constant	C1	
			$4.1 - 4.2 \times 10^{-9}$(s^{-1})	A1	2
		(iv)	$A = (-)\lambda N$	C1	
			number of R / A atoms when activity is 1.5×10^{12} Bq = 3.6×10^{20}	C1	
			correct time read from graph	A1	
			(2.5 y / 920 days / 8.0×10^{7} s)		
			or determines original activity **or** final number of atoms 2.1×10^{12} Bq **or** 3.6×10^{20} allow ecf from (iii)	C1	
			$N = N_0 e^{-\lambda t}$ **or** $A = A_0 e^{-\lambda t}$	C1	
			940 d or 2.6 y (answer depends on where rounding off has been done)	A1	3
					[15]

24.	(a)		curve drawn of approximately correct general shape curve shows inverse square law e.g. includes the point (3.0 , 12.5) **or** (1.5, 50) **or** (2.0, 28.1)	C1 A1	 2
	(b)	(i)	measure and deduct background count (rate)	B1	1
		(ii)	count for large periods (to ensure large *N*) **or** repeat counts and average	 B1	 1 **[4]**
25.	(a)	(i)	correct construction method seen on graph or quotes appropriate values from the graph 2.0×10^4s to 2.4×10^4s allow 1 or2 s.f. repeats and averages	 C1 A1 B1	 3
		(ii)	$A = 3.7$ or 3.8×10^{16} (Bq) at $t = 0$ 1.2×10^{21}	C1 A1	 2
	(b)	(i)	alpha will not penetrate the body or risk to patient from ionisations	B1	1
		(ii)	long enough half life to make measurements / short enough half life so does not remain long in body	 B1	 1
	(c)		causes ionisations / damage to cell/cell nucleus / body tissue / DNA	B1 B1	 2 **[9]**
26.	(a)	(i)	positron / positive electron / beta + (**not** β^+)	B1	
			(electron) neutrino	B1	2
			(condone as ecf 'antineutrino' if electron or beta$^-$ stated for other particle) **–1 from total for each additional particle but condone neon-21**		
		(ii)	11	B1	1
	(b)	(i)	activity after 1 half life = 0.75×10^{10} (Bq) (half of 1.5×10^{10})	B1	
			number of particles after 1 half life = 2.5×10^{11} *N* corresponds to their *A* The above may be seen substituted in $\lambda = A/N$	 B1	
			divides their activity by their number of nuclei; answer + unit (probability = 0.03 s^{-1} gets 2) (no sf penalty) **OR** Arrives at correct answer using half life = 21 to 23 s and $\lambda = 0.69/t_{1/2}$	 B1	 3
		(ii)	number of particles emitted per second, activity = $4.56\ (4.6) \times 10^9$	C1	
			time read from graph 2 consistent with their activity or their activity/(i) (i.e. numerical substitution correct) (may be by implication in answer)	C1	
			number of particles (cao) $(1.5–1.6) \times 10^{11}$	A1	3 **[9]**

27.	(a)	(i)	idea of nuclear 'glue'	C1	
			work needed to separate nucleons	A1	2
		(ii)	binding energy (per nucleon) is increased	B1	
			change in binding energy is equivalent to the energy released	B1	2
		(iii)	data extraction hydrogen 1 MeV, Helium 7MeV / nucleon	C1	
			subtraction of answers	C1	
			multiplication by number of nucleons to give 24 MeV	A1	3
	(b)	(i)	correct conversion of energy in MeV to J (3.84×10^{-12} J) (e.c.f. from (a)(iii))	B1	
			energy = hf and $c = f\lambda$	C1	
			5.2×10^{-14} m	A1	3
		(ii)	frequency changes by factor of 0.027	C1	
			frequency = 5.7×10^{21} Hz	C1	
			change in frequency = $0.027 \times 5.7 \times 10^{21}$ Hz = 1.5×10^{20} Hz / decrease	A1	3
					[13]

28.	(a)		nucleon number 4	B1	
			proton number 2	B1	2
	(b)	(i)	mass of products is less than mass of reactants/binding energy per nucleon increases / mass defect increases / 'loss' of mass	B1	
			change in mass converted to energy	B1	2
		(ii)	change in mass = 4.8×10^{-29} kg	C1	
			$E = mc^2$	C1	
			4.3×10^{-12} J (4.30×10^{-12} J)	A1	3
			(if truncated sig. figs used only 2nd mark available)		
					[7]

29.	(a)	(i)	146	B1	1
		(ii)	90	B1	1
	(b)	(i)	0.0046 u **or** 4.0061 u	B1	
			their mass change in u × 1.7×10^{-27} **or** 7.8×10^{-30} **or** 6.8×10^{-27} kg	B1	2
		(ii)	$E = mc^2$ (**or** recalls 1 u = 931 MeV)	C1	
			their (i) $\times 9 \times 10^{16}$ $6.9 - 7.0 \times 10^{-13}$ **or** 4.82 MeV	A1	2

	(c)	(i)	speed determined correctly from their (ii) (1.43×10^7 m s^{-1}) **or** $p^2/2m = E$ **or** $E = ½\ mv^2$ **and** momentum (p) = mv	C1	
			$9.5 – 9.8 \times 10^{-20}$ kg ms^{-1}	A1	2
		(ii)	wavelength = h/mv	C1	
			their value of h / their (i) $6.6 – 6.9 \times 10^{-15}$ m	A1	2
					[10]
30.	(a)	(i)	mark at peak of graph	B1	1
		(ii)	B =8.8 MeV; allow A in range 53 to 57 (B and A both must be correct)	B1	1
		(iii)	B value x A value in MeV	B1	1
	(b)	(i)	${}^{0}_{1}e$ positron	B1	
			v neutrino	B1	2
		(ii)	**Q: 1 + 1 → 1 + 1 (+ 0 + 0)**	B1	
			B: 1 + 1 → 2 + 0 (+ 0 + 0)	B1	
			L: 0 + 0 → 0 + –1 + 1 + 0	B1	3
		(iii)	protons need high (kinetic) energy/k.e. determined by temperature	B1	
			proton energy must be sufficient to overcome the electrostatic repulsion between (similarly charged) protons	B1	2
		(iv)	conversion to joules (8.16×10^{-14} J)	B1	
			equation(s) or substitution	C1	
			2.43×10^{-12} m	A1	3
	(c)		fission involves splitting into two or more less massive nuclei fusion involves two lighter nuclei combining to form a slightly heavier nucleus both processes result in net decrease in binding energy which is released as k.e. of reaction products both processes lead to increased b.e.p.n. increase in b.e.p.n. is greater for lighter nuclei undergoing fusion the binding energy of a massive nucleus is greater than that of lighter nucleus because it has more nucleons net reduction in binding energy during the fission of a heavier nucleus is much greater than that occurring during the fusion of two light nuclei	B5 max	
			the use of physics is accurate, the answer is fluent/well argued with few errors in spelling, punctuation and grammar **(must gain at least 2 for Physics)**	**Q2**	

			the use of physics is accurate but the answer lacks coherence or the spelling, punctuation and grammar are poor **(must gain at least 1 for Physics)**	**Q1**	
			the use of the physics is inaccurate, the answer is disjointed with significant errors in spelling punctuation and grammar.	**Q0**	7
					[20]
31.	(a)		236/92/U	B1	
			4/2/α [4/2/He]	B1	
	(b)	(i)	Equation correct **or** Evaluates mass difference (1.349×10^{-29} kg)	B1	
			Uses $E = mc^2$	B1	
			to yield energy (1.21 pJ)	B1	
		(ii)	uses $t_{½} = [\log_e 2/\lambda] = 0.69/2.1 \times 10^{11}$	M1	
			to yield $\lambda = 3.29 \times 10^{-12}$ s^{-1}	C1	
		(iii)	uses $A = \lambda N$ [$= 1.05 \times 10^{10}$] **or** $N_1 = N_0e^{-\lambda t}$	C1	
			uses $A \times 1.21 \times 10^{-12}$ **or** $(N_0 - N_1) \times 1.21 \times 10^{-12}$	C1	
			= 12.7 mJ	A1	
		(iv)	$A = A_0e^{-\lambda t}$	C1	
			$0.95 = e^{-3.29 \times 10-12\, t}$ [or log expression]	C1	
			$t = 1.56 \times 10^{10}$ s = 495 years	C1	
			correct deduction from candidate answer	B1	
			or		
			100 y = 3.19×10^9 s	C1	
			$A = A_0e^{-\lambda t} = 1.056 \times 10^{10}\ e^{-0.0104}$ [ecf from first mark]		C1
			$A = 1.046 \times 10^{10}$ [ecf from first mark]	C1	
			Change is 1 part in 105 OWTTE so no significant change	B1	
			or		
			Half life calc/fractional change/2^n/99% left so no sig change		
			or		
			further alternative		
					[14]
32.	(a)		reduce spacing	B1	
			increase area of overlap	B1	
			introduce a material such as polythene/mica	B1	Max 2
	(b)	(i)	$V = V_0e^{-t/RC}$	C1	
			$5 = 9e^{-60/RC}$	C1	
			RC = 102 s	A1	
			R = candidate's RC/C 220 (217) kΩ	B1	4
		(ii)	correct curvature	B1	
			values correctly indicated on both axes at $t = 0$ and $t = 60$ s	B1	2

		(iii)	increase *RC* or supply voltage	B1	
			the time constant is the same	B1	
			reasonable attempt to define how large the voltage should be	B1	
			obtains supply voltage = 12 V	B1	4
			or for increased *C* or *R*, time constant is larger	B1	
			the value should be increased by factor of 1.5	B1	
			new C = 700 μF **or** new R = 330 kΩ	B1	
			the use of Physics terms is accurate, the answer is fluent / well argued with few errors in spelling, punctuation and grammar	2	
			the use of Physics terms is accurate, but the answer lacks coherence or the spelling, punctuation and grammar are poor	1	
			the use of Physics terms is inaccurate, the answer is disjointed, with significant errors in spelling, punctuation and grammar	0	
			Max 2		
					[14]
33.	C				
					[1]
34.	(a)	(i)	12V	B1	1
		(ii)	65 s – 70 s *allow e.c.f. from (i)* and accept 65 – 70 even if (a)(i) is incorrect	B1	1
		(iii)	65 = 0.69 *CR*	C1	
			R = (470 – 510 kΩ *allow e.c.f. from (a)(ii)*	A1	
			or time to reach 63% of max (7.6 V) = 95 s	C1	
			time constant = *CR* leading to R = 470 kΩ	A1	
			*(**or** equivalent using 10.5 as maximum pd)*		2
		(iv)	$I = V/R$ and use of correct voltage *allow e.c.f. (a)(i) or 12 V*	C1	
			23.5 → 26 μA (400 kΩ and 10.5 V gives same value)	A1	
			or attempts to determine initial gradient of graph (0.14 V s^{-1})		
			and multiply by capacitance (200 μF)	C1	
			26 μA	A1	2
	(b)	(i)	$1/C_T = 1/C_1 + 1/C_2$ or numerical equivalent implying use of parallel form condone substitution errors	C1	
			67μF	A1	2
		(ii)	curve showing charging consistent with their (b)(i) aiming for 12 V or their (a)(i) if faster	M1	
			t value about 1/3 of original at same voltage or consistent with their (b)(i)	A1	
			e.g. 5 V reached after 15 – 20 s		2
					[10]
35.	(a)		$Q = CV$ or correctly substituted values ignoring powers	C1	
			0.30 mC	A1	

(b)	(i)	$V\uparrow$ vs $Q\rightarrow$ (only)	B1
	(ii)	½ CV^2 or ½ QV or ½ Q^2/C or correctly substituted values ignoring powers	C1
		2.25×10^{-2} J (e.c.f. from (a))	A1
(c)	(i)	0.68(2) mA (c.a.o.)	B1
	(ii)	either $I = I_0 e^{\frac{-t}{RC}}$ or equivalent	M1
		substitution of values (including $I/I_0 = 0.1$ which is ok here)	A1
		logs taken	A1
		1.01 s	A1
		or $I = I_0 e^{\frac{-t}{RC}}$ or equivalent	M1
		correct value for I at 1s (≈ 0.07 mA) e.c.f. I_0	A1
		ratio of $\frac{I}{I_0}$ shown	A1
		comment that this is approximately 10%	A1
(d)		parallel combination stores more energy	B1
		correct comparison of capacitance in series and parallel*	B1
		statement of constant voltage and reference to ½ CV^2*	B1
		The use of Physics terms is accurate; the answer is fluent/well argued with few errors in spelling, punctuation and grammar and 2 or 3 marks for Physics. The use of Physics terms is accurate but the answer lacks coherence or the spelling, punctuation and grammar are poor and a minimum of 1 mar for Physics. The use of Physics terms is inaccurate; the answer is disjointed with significant errors in spelling, punctuation and grammar.	max 2

[15]

(*) max 1 if these are answered qualitatively