Name: ____

Topic 8: Nuclear and Particle Physics Part 1

Date:

Time:

Total marks available:

Total marks achieved: ______

Questions

Q1.

Which of the following particles is an example of a fundamental particle?

- ☐ **A** nucleus
- ☐ **B** neutrino
- ☐ **C** pion
- ☐ **D** proton

(Total for question = 1 mark)

Q2.

When alpha particles are directed at a thin gold foil it is found that most of the alpha particles go straight through undeflected. However a very small number are scattered through angles greater than 90°.

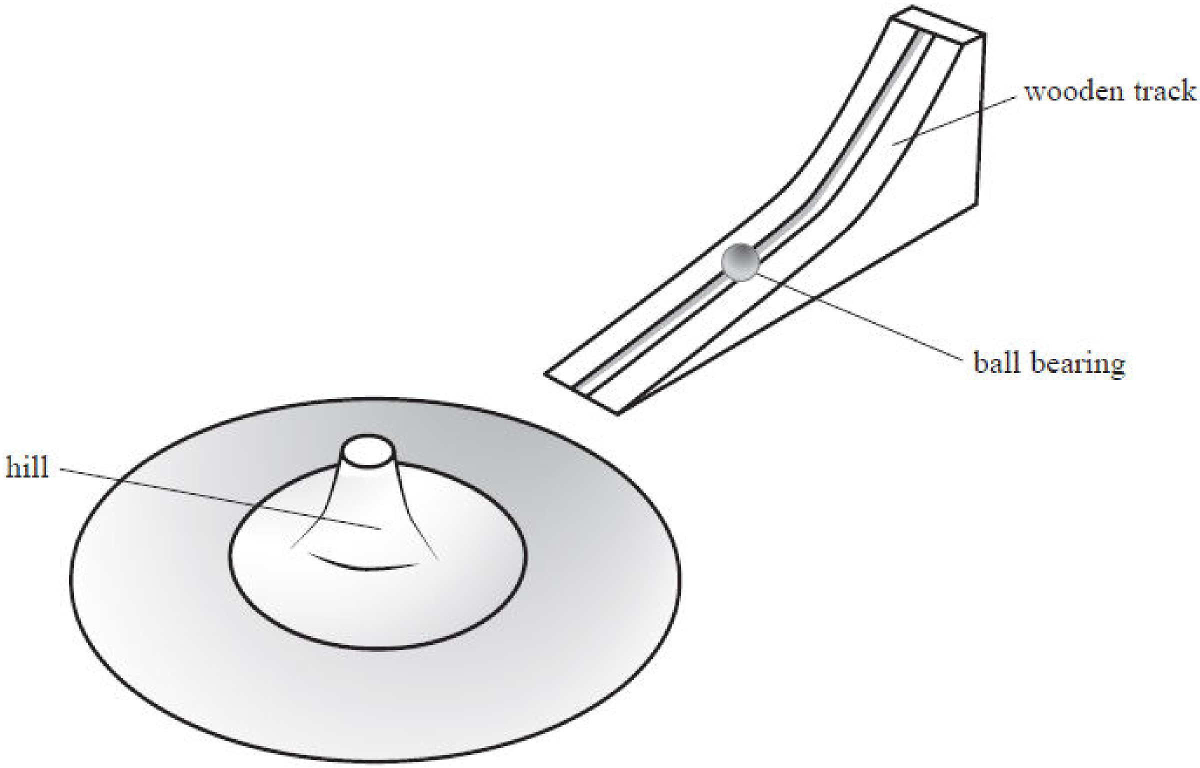
Which of the following is **not** a valid conclusion?

- ☐ **A** The atom is mainly empty space.
- ☐ **B** The nucleus must be positively charged.
- ☐ **C** The nucleus must contain most of the mass of the atom.
- ☐ **D** There is a large charge concentration in the centre of the atom.

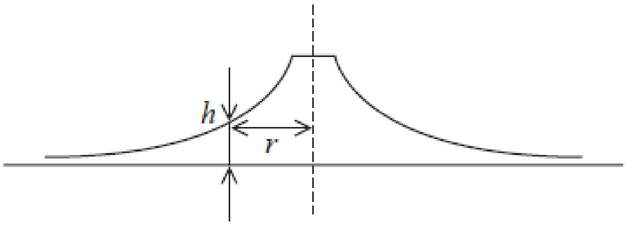
(Total for question = 1 mark)

Q3.

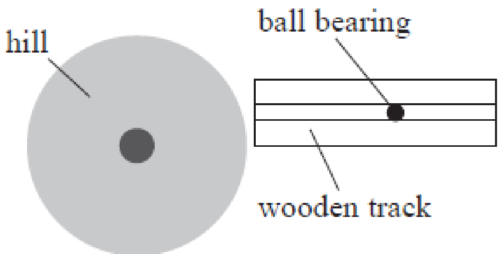
The diagram shows a model used to demonstrate alpha particle scattering. A ball bearing is set rolling on a wooden track. The track is positioned so that the ball bearing rolls onto a metal sheet with a curved surface known as a 'hill'.



The diagram shows a vertical cross-section through the hill. The surface is curved so that the height of a point *h* on the curved surface is inversely proportional to the distance *r* from the centre of the hill.



A plan view of the arrangement is shown.



The wooden track is moved to different positions and the ball bearing is released.

Describe the results of the alpha particle scattering experiment and how these can be demonstrated by moving the wooden track to different positions.

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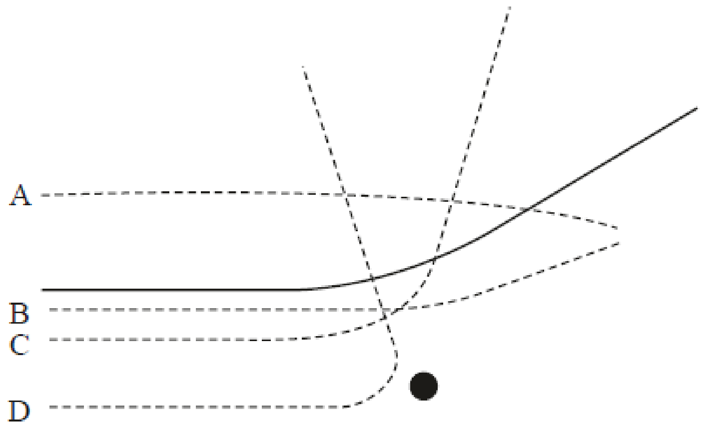
(Total for question = 4 marks)

Q4.

The solid line shows the path of an alpha particle as it passes close to a nucleus.



Another alpha particle approaches the nucleus with the same initial kinetic energy.

Which dashed path is possible for this alpha particle?

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for question = 1 mark)

Q5.

At the beginning of the 20th century, Rutherford carried out large-angle alpha particle scattering experiments using gold ($^{197}_{79}Au$) foil.

The vast majority of the alpha particles went straight through the foil whilst a few were deflected straight back.

Describe how the model of the atom changed, as a consequence of these experiments.

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(Total for question = 4 marks)

Q6.

Early in the twentieth century physicists observed the scattering of alpha particles after they had passed through a thin gold foil. This scattering experiment provided evidence for the structure of the atom.

(a) State why it is necessary to remove the air from the apparatus that is used for this experiment.

(1)

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(b) From the results of such an experiment give **two** conclusions that can be deduced about the nucleus of an atom.

(1)

Conclusion 1

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Conclusion 2

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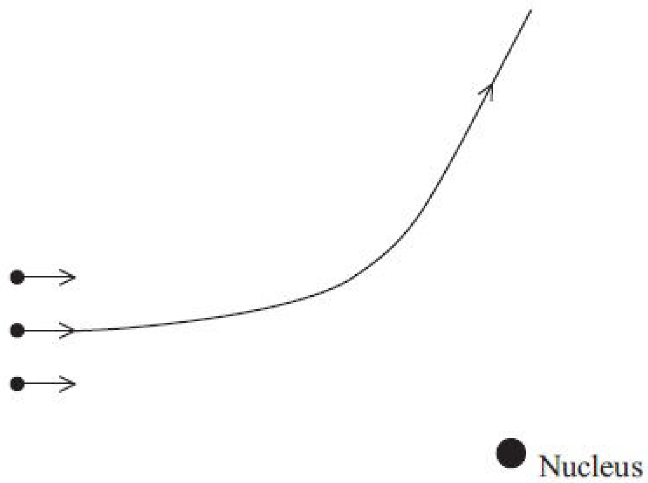
(c) The diagram shows three α-particles, all with the same kinetic energy. The path followed by one of the particles is shown.

Add to the diagram to show the paths followed by the other two particles.

(3)

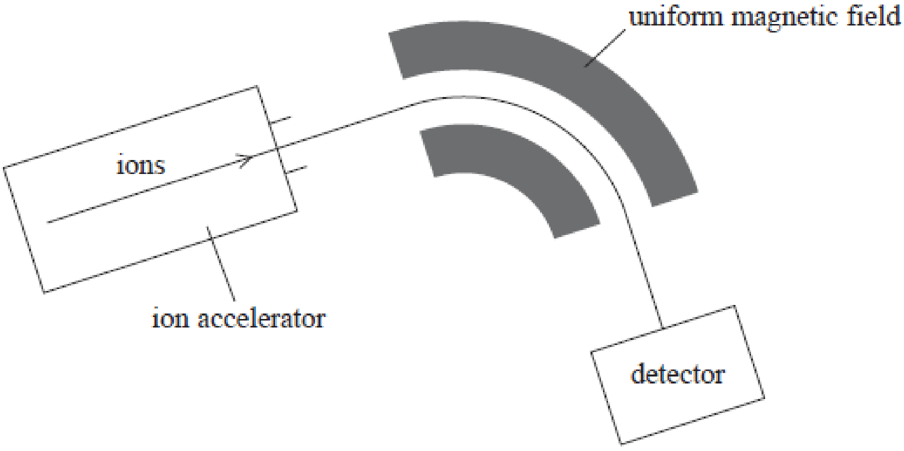


(Total for question = 6 marks)

Q7.

Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam.
This beam is passed into a region of uniform magnetic field and the ions are deflected by different amounts according to their mass.



Analysis of mass spectrometer data shows that chlorine exists in nature as two isotopes, chlorine-35 and chlorine-37.

In a mass spectrometer, chlorine-35 ions are accelerated through a potential difference of 8.50 kV to produce an ion beam.

Show that the speed of singly ionised chlorine-35 atoms is about 2.2×10^5 m s^{-1}.

mass of an ion of chlorine-35 = 34.97 u

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(Total for question = 4 marks)

Q8.

The equation $\Delta E = c^2 \Delta m$ can be used with data at the back of this paper to calculate

☒ **A** the kinetic energy of an electron.

☒ **B** the energy produced when a lambda particle decays.

☒ **C** the energy of the photons produced when a proton and an antiproton annihilate.

☒ **D** the mass of uranium that produces 50 MJ of energy in a nuclear reactor.

(Total for question = 1 mark)

Q9. The nucleus of one of the isotopes of nickel is represented by $^{60}_{28}Ni$.

Which line correctly identifies a neutral atom of this isotope?

	Number of protons	Number of neutrons	Number of electrons
☒ A	28	32	28
☒ B	28	32	32
☒ C	28	60	28
☒ D	60	28	28

(Total for Question = 1 mark)

Q10. Select the row in the table that correctly identifies the composition of a $^{235}_{92}U^{+}$ ion.

		Number of protons	Number of neutrons	Number of electrons
☒	A	92	143	91
☒	B	92	143	92
☒	C	92	235	91
☒	D	93	235	92

(Total for Question = 1 mark)

Q11.

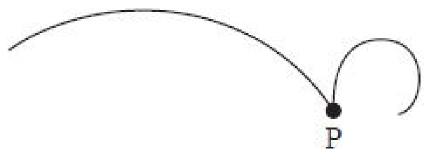
A radioactive isotope of aluminium is $^{25}_{13}\text{Al}$

Select the row in the table that correctly identifies a neutral atom of this isotope.

	Neutrons	Protons	Electrons
☒ **A**	12	13	12
☒ **B**	13	12	13
☒ **C**	13	12	12
☒ **D**	12	13	13

(Total for question = 1 mark)

Q12. The diagram shows the tracks from an event at a point P in a bubble chamber. A magnetic field is directed into the page.



The tracks cannot show the production of a proton-antiproton pair with equal kinetic energies because

☒ **A** the curvature is perpendicular to the magnetic field.

☒ **B** the tracks curve in different directions.

☒ **C** the tracks have different curvatures.

☒ **D** there is no track before point P.

(Total for Question = 1 mark)

Q13.

At the beginning of the 20th century, Rutherford carried out large-angle alpha particle scattering experiments using gold ($^{197}_{79}Au$) foil.

The vast majority of the alpha particles went straight through the foil whilst a few were deflected straight back.

In one experiment the alpha particles had an initial energy of 7.7 MeV.

Calculate the distance of closest approach of the alpha particles to the nucleus of a gold atom. Assume that the gold nucleus remains at rest.

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Distance of closest approach = ...

(Total for question = 4 marks)

Q14.

The neutral lambda Λ^0 particle is a baryon of mass 1116 MeV/c^2 and contains one strange quark.

The table shows quarks and their relative charge.

Quark	Charge / *e*
u	+2/3
d	–1/3
s	–1/3

Calculate the mass of the Λ^0 particle in kg.

(3)

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Mass of Λ^0 particle = ... kg

(Total for question = 3 marks)

Q15.

Pions belong to a group of particles called mesons. Pions can be used in a form of radiotherapy to treat brain tumours.

The mass of a pion is 140 MeV/c^2.

Calculate the mass of a pion in kg.

(3)

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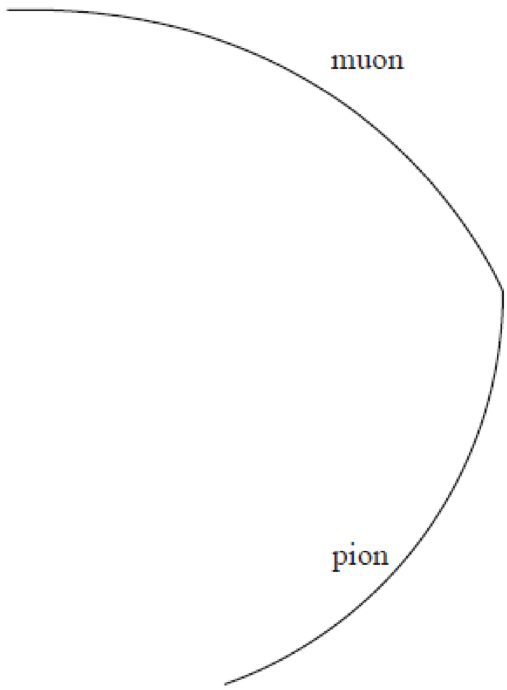
Mass = ...

Q16.

A negatively charged pion decays into a muon and an antineutrino. The diagram shows tracks in a particle detector formed in such an event.



Deduce whether the antineutrino is charged, giving two reasons for your decision.

(2)

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(Total for question = 2 marks)

Q17. Charged particles are travelling at a speed *v*, at right angles to a magnetic field of flux density *B*. Each particle has a mass *m* and a charge *Q*.

Which of the following changes would cause a decrease in the radius of the circular path of the particles?

- ☒ **A** an increase in *B*
- ☒ **B** an increase in *m*
- ☒ **C** an increase in *v*
- ☒ **D** a decrease in *Q*

(Total for Question = 1 mark)

Q18.

At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.

© Science Museum London

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

In his original experiments, Thompson determined the specific charge of a range of particles. His results indicated that the specific charge of an electron is about 2000 times bigger than that for a hydrogen ion.

Deduce what conclusion can be made from this information.

(1)

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(Total for question = 1 mark)

Q19.

* Particle accelerators accelerate particles to very high speeds before collisions occur.
New particles are created during the collisions.

Two particles of the same type can undergo two kinds of collision.

Fixed target: a high speed particle hits a stationary particle.

Colliding beams: two particles travelling at high speeds, in opposite directions, collide head-on.

By considering the conservation of energy and momentum, explain which type of collision is able to create a new particle with the largest mass.

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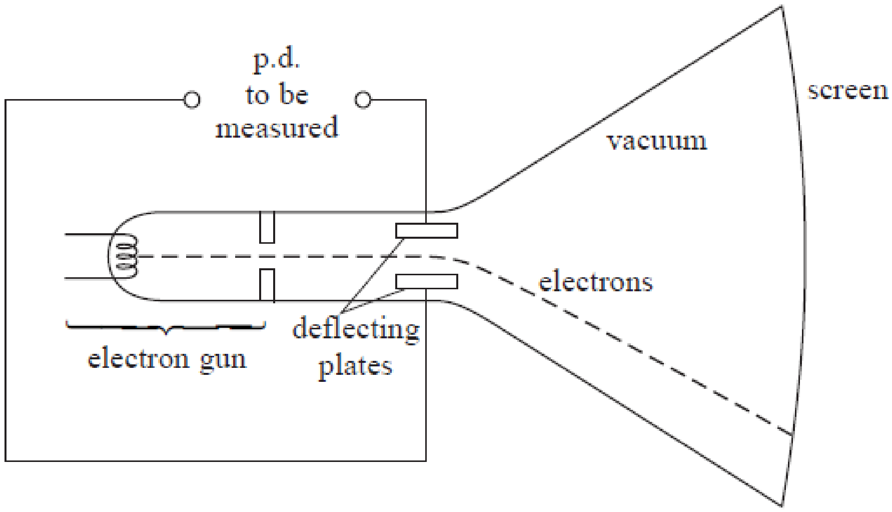
(Total for question = 6 marks)

Q20.

Cathode ray tubes are used in oscilloscopes.

The diagram shows a simplified cathode ray tube that can be used to determine the magnitude and polarity of a potential difference (p.d.).

The cathode ray tube consists of an electron gun, a pair of deflecting plates and a fluorescent screen.



(a) The electron gun includes a filament. When this filament is heated, electrons are released and are accelerated by a p.d. of 1.5 kV to form an electron beam.

(i) Name the process by which electrons are released from the heated filament.

(1)

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(ii) Show that the maximum velocity of the electrons is about 2×10^7 m s^{-1}.

(2)

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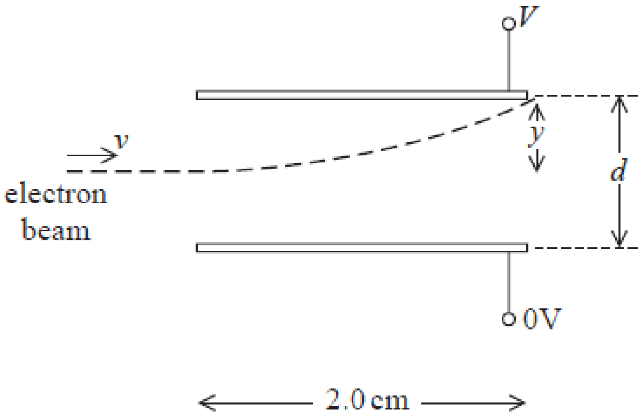
(b) The electron beam then enters a uniform electric field between the two parallel horizontal deflecting plates. The magnitude and direction of the deflection is determined by the p.d. *V* that is applied across the plates.

The diagram shows one possible path of the electron beam as it passes between the plates.



(i) Show that the acceleration of an electron, of mass *m* and charge *Q*, is given by

$$\frac{VQ}{dm}$$

(2)

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(ii) Calculate the magnitude of the vertical deflection y of the beam as it leaves the plates.

V = 50 V
d = 0.01 m

(5)

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y = ...

(c) A laboratory oscilloscope with the time base turned off operates in the same way as this simplified cathode ray tube. A student uses an oscilloscope in this way to monitor an alternating p.d. of 53 V_{rms}

On the grid, draw the trace that would be seen on the screen.

(4)

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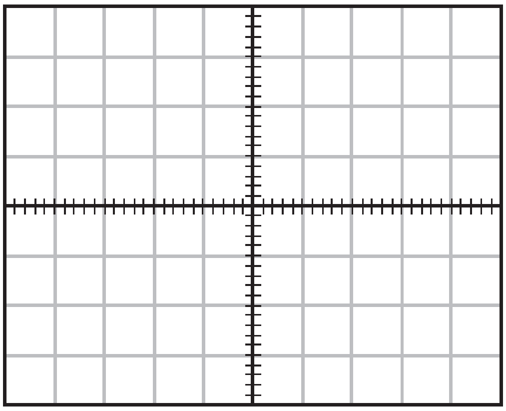


1 square = 25 V

(Total for question = 14 marks)

Q21.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A proton has a mass of 1.67×10^{-27} kg.

Which of the following shows the conversion of this mass to GeV/c^2 ?

☐ **A** $\dfrac{1.67 \times 10^{-27} \times 1.60 \times 10^{-10}}{(3.00 \times 10^{8})^2}$

☐ **B** $\dfrac{1.67 \times 10^{-27} \times 1.60 \times 10^{-19}}{(3.00 \times 10^{8})^2}$

☐ **C** $\dfrac{1.67 \times 10^{-27} \times (3.00 \times 10^{8})^2}{1.60 \times 10^{-10}}$

☐ **D** $\dfrac{1.67 \times 10^{-27}}{1.60 \times 10^{-10} \times (3.00 \times 10^{8})^2}$

(Total for question = 1 mark)

Q22. A cyclotron is a type of particle accelerator. It consists of two metal Dees which are connected to a high frequency voltage supply and are in a strong magnetic field.

The particles change their speed because

☒ **A** of the magnetic field they are in.

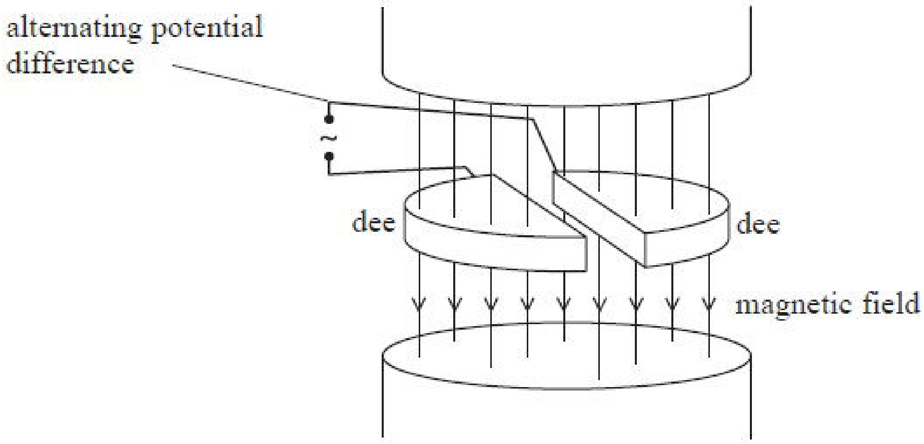
☒ **B** the voltage supply is alternating.

☒ **C** there is a potential difference between the two Dees.

☒ **D** the magnetic field is at right angles to the Dees.

(Total for Question = 1 mark)

Q23. * The diagram shows the basic structure of a cyclotron.



With reference to the magnetic field and the alternating potential difference explain how the cyclotron produces a beam of high speed particles.

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(Total for Question = 4 marks)

Q24.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

Which of the following particle equations is correct for the decay of a proton within a nucleus?

☐ **A** $p \rightarrow n + \beta^{+}$

☐ **B** $p \rightarrow p + \beta^{+}$

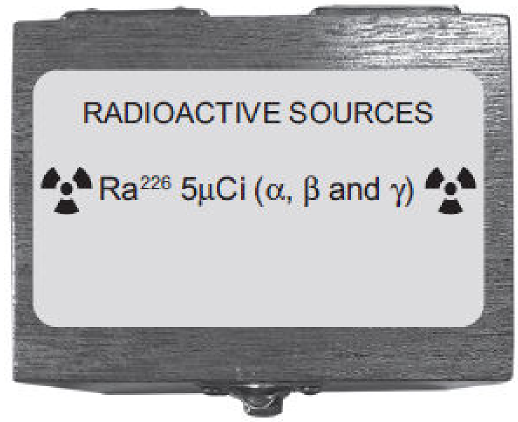
☐ **C** $p \rightarrow n + \beta^{+} + v$

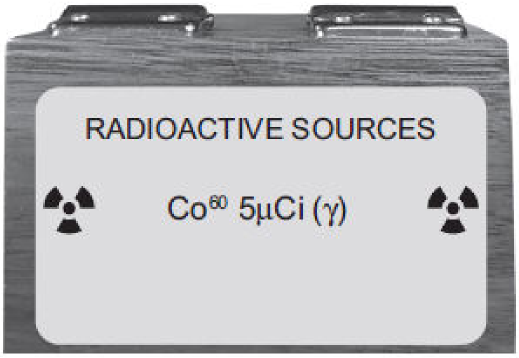
☐ **D** $p \rightarrow p + \beta^{+} + v$

(Total for question = 1 mark)

Q25.

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





The isotope Ra 226 undergoes a series of decays until it produces the stable isotope Pb 206.

Determine the number of α particles and β particles emitted during this process to complete the nuclear equation.

(3)

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$$^{226}_{88}\text{Ra} \rightarrow \, ^{206}_{82}\text{Pb} + \ldots\ldots \times \, ^{\ldots}_{\ldots}\alpha + \ldots\ldots \times \, ^{\ldots}_{\ldots}\beta$$

Q26.

Tomatoes can be made into a puree.

The tomato puree has a mass of 0.444 kg and boils at 101°C. 175kJ of energy are supplied to bring it to its boiling point from a temperature of 21°C.

Determine the specific heat capacity of the puree.

(2)

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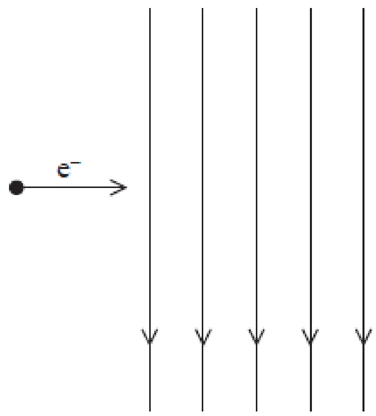
Specific heat capacity = ...

(Total for question = 2 marks)

Q27.

An electron travelling horizontally enters a uniform electric field which acts vertically downwards as shown in the diagram.



Which of the following statements is **incorrect**?

☒ **A** The electron follows a parabolic path.

☒ **B** The electron accelerates while in the field.

☒ **C** The electric force on the electron acts downwards.

☒ **D** The speed of the electron increases.

(Total for question = 1 mark)

Q28.

A high energy proton collides with a stationary proton and a π^0 particle is produced.
The equation for the reaction is

$$p + p \rightarrow p + p + \pi^0$$

(i) Explain why the proton must have a high energy in order for this reaction to occur.

(2)

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(ii) The rest mass of the π^0 is $\frac{1}{7}$ of the rest mass of a proton.

In this reaction the total kinetic energy of the particles decreases.

Calculate the minimum decrease in kinetic energy if the reaction is to occur.

rest mass of proton = 938 GeV/c^2

(2)

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Minimum decrease in kinetic energy = ...

Q29.

Phosphogypsum is a by-product in the manufacture of fertiliser. It is slightly radioactive because of the presence of radium-226, a radioisotope with a half-life of 1600 years.

It must be stored securely as long as the activity of the radium-226 it contains is greater than 0.4 Bq per gram of phosphogypsum.

Radium-226 decays to radon-222 by alpha emission.

Determine the energy released in MeV in the decay of a single nucleus of radium-226.

(5)

mass of radium-226 nucleus = 225.97713 u

mass of radon-222 nucleus = 221.97040 u
mass of α particle = 4.00151 u

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Energy released = ... MeV

(Total for question = 5 marks)

Q30.

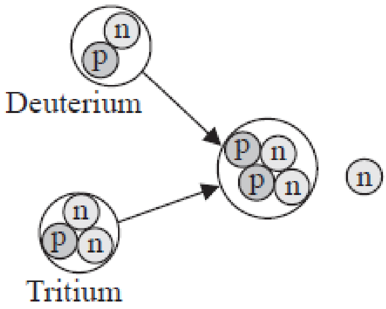
The following passage is adapted from a recent article in a British newspaper:

"Every year, one typical coal-fired power station devours several million tonnes of fuel and produces even more carbon dioxide. That volume of carbon dioxide is damaging the atmosphere and, in the longer term, the fuel will run out. It is clear that the world needs an alternative for generating energy.

Nuclear fusion looks like offering a solution to the problem. Using the equivalent of a bath tub of water, fusion has the potential to deliver the same amount of energy as 100 tonnes of coal. There would be no carbon dioxide emission, it would be inherently very safe, and would not produce any significant radioactive waste."

(Adapted from an article in The Observer newspaper, Sunday 16th September 2012)

(a) The latest proposed fusion reactor will fuse deuterium and tritium, which are isotopes of hydrogen. This fusion reaction is illustrated below.



(i) Complete the nuclear equation below to represent this fusion reaction.

(2)

$$\underset{\cdots}{\overset{\cdots}{}}\text{H} + \underset{\cdots}{\overset{\cdots}{}}\text{H} \rightarrow \underset{\cdots}{\overset{\cdots}{}}\text{He} + \underset{\cdots}{\overset{\cdots}{}}\text{n}$$

(ii) Calculate the energy released in the fusion of one deuterium nucleus with one tritium nucleus.

Particle	Mass / GeV/c^2
Proton	0.938272
Neutron	0.939566
Deuterium	1.875600
Tritium	2.808900
Helium	3.727400

(2)

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Energy released = ...

(iii) Explain why most of the energy released in the fusion of one deuterium nucleus with one tritium nucleus is transferred to kinetic energy of the neutron.

(3)

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(b) A sample of tritium is produced. Tritium is unstable and decays by β^- emission with a half-life of 12.3 years.

Calculate the time taken, in years, for the activity of the sample to fall to 10% of its initial value.

(3)

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Time taken = ... years

*(c) The article states that "it would be inherently very safe, and would not produce any significant radioactive waste."

Comment on this statement and outline the technical difficulties of producing a practical nuclear fusion reactor.

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(Total for question = 15 marks)

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q2.

Question Number	Answer	Mark
	B	1

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	Maximum of 4 marks for MP1,3,5 and any one of MP2,4 or 6		
	• a few alpha's reflect straight back (1)	accept deflect through large angles/more than 90°	
	• can be represented by the ball bearing being directly aimed at the centre of the "hill" (1)	MP2 dependent on being linked to MP1	
	• some alpha's slightly deflected/through small angles (1)		
	• can be represented by the ball bearing being aimed close to the centre line of the hill (1)	MP4 dependent on being linked to MP3	
	• Many/most alpha's undeflected (1)		
	• can be shown by aiming the ball bearing so that it touches/misses the edge of the hill (1)	MP6 dependent on being linked to MP5	4 Max

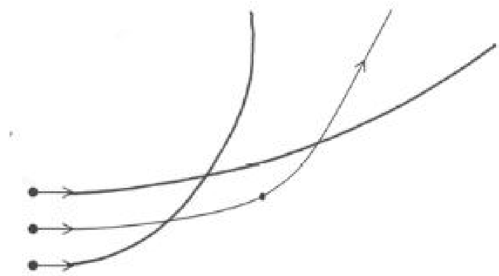
Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	Before scattering experiment: • atom containing equally distributed mass/charge (1) After experiment: • very small nucleus containing (almost all) the mass of the atom (1) • atom mainly empty space (1) • nucleus is charged (1)	alt: reference to 'plum pudding model'	4

Q6.

Question Number	Answer		Mark
(a)	To prevent interaction/deflection/collision of the alpha particle with the air. [do not accept: 'don't get in the way' . 'cause ionisation'. 'interfere with'. Looking for a definite interaction between the alpha and the air molecules. Accept air particles]	**(1)**	**1**
(b)	**MAX TWO** Nucleus (very) much smaller than separation of nuclei **Or** nucleus (very) much smaller than the atom Nucleus is charged (don't penalise if candidate says positively charged) Nucleus is (very) dense **Or** nucleus is massive **Or** nucleus contains most of the mass (no credit for candidates referring to the atoms and not the nucleus.)	**(1)** **(1)** **(1)**	**2**
(c)	**Top Particle** Path curves up with less deflection than for particle shown and must cross the printed line. **Or** a straight path. **Bottom Particle** Path curves up with more deflection than for particle shown Greatest curvature before greatest curvature of particle shown. (dependent mark) <u>Example</u> 	**(1)** **(1)** **(1)**	**3**

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $W = QV$ **(1)** • Use of $KE = \frac{1}{2}mv^2$ **(1)** • Use of 1u = 1.66×10^{-27} kg **(1)** • v = 2.16×10^5 (m s^{-1}) **(1)**	Example of calculation: $\frac{1}{2}mv^2 = eV$ $\therefore v = \sqrt{\frac{2 \times 1.6 \times 10^{-19}\,\text{C} \times 8.5 \times 10^3\,\text{V}}{(34.97 \times 1.66 \times 10^{-27})\,\text{kg}}} = 2.16 \times 10^5\,\text{m s}^{-1}$	**4**

Q8.

Question Number	Answer	Mark
	C	**1**

Q9.

Question Number	Answer	Mark
	A	**1**

Q10.

Question Number	Answer	Mark
	A	**1**

Q11.

Question Number	Answer	Mark
	D	1

Q12.

Question Number	Answer	Mark
	C	**1**

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $V = Q/4\pi\varepsilon_0 r$ **(1)** • Conversion MeV to J **(1)** • Use of $V = W/Q$ **(1)** • $r = 3.0 \times 10^{-14}$ m **(1)**	allow for $Q = 2$ or 79, accept $V = kQ/r$ Must use $e = 1.6 \times 10^{-19}$ C to convert atomic number to C <u>Example of calculation</u>: $7.7 \times 10^6 \text{eV} \times 1.6 \times 10^{-19} \text{J eV}^{-1}$ $= 8.99 \times 10^9 \text{N m}^2\text{C}^{-2} \times 2 \times 79 \times (1.6 \times 10^{-19}\text{ C})^2 \div r$ $r = 2.27 \times 10^{-7} \div 7.7 \times 10^6$ $r = 2.95 \times 10^{-14}$ m	**4**

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
	• converts eV using 1.6×10^{-19} (1) • divides by c^2 i.e. $(3 \times 10^8)^2$ (1) • mass = 2.0×10^{-27} kg (1)	<u>Example of calculation</u> $m = \dfrac{1116 \text{V} \times 10^6 \times 1.6 \times 10^{-19} \text{C}}{(3 \times 10^8 \text{m s}^{-1})^2}$ $m = 2.0 \times 10^{-27}$ kg	**3**

Q15.

Question Number	Answer	Mark
	Conversion to Joules by × 1.6×10^{-19} (C) (1) Divide by $(3 \times 10^{8})^{2}$ (1) Mass = 2.49×10^{-28} kg (1) <u>Example of calculation</u> Mass = 140×10^{6} eV × 1.6×10^{-19} J eV^{-1} / $(3 \times 10^{8}$ m s$^{-1})^{2}$ Mass = 2.49×10^{-28} kg	3

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
	• it does not leave a track so it is not charged (1) • the charge before the decay is -1 (the pion) and after is -1 (the muon) + 0 (the antineutrino) so it is not charged (1)	Not charged should appear in MP1 or MP2 to get 2 marks	2

Q17.

Question Number	Answer	Mark
	A	1

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• The hydrogen ion must be (about 2000 times) more massive than the electron • **Or** the electron must be (about 2000 times) less massive than the hydrogen ion (1)	Accept "proton" for "hydrogen ion"	1

Q19.

Question Number	Answer		Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Max 6** **Fixed target** There is momentum before the collision so there must be momentum after the collision. So particle(s) created must have some kinetic energy So not all KE converted to mass **Colliding beams** (If particles have the same mass and speed), total initial momentum is zero Momentum after collision will be zero If one stationary particle is created All of the kinetic energy of the particle is converted to mass	 (1) (1) (1) (1) (1) (1) (1)	6
	Total for question		**6**

Q20.

Question Number	Answer	Additional guidance	Mark
(a)(i)	thermionic emission		**(1)**

Question Number	Acceptable Answer		Additional guidance	Mark
(a)(ii)	• equate $\frac{1}{2}mv^2$ and VQ • $v = 2.3 \times 10^7$ m s^{-1}	(1) (1)	Example of calculation: $E = 1500\text{ V} \times 1.6 \times 10^{-19}\text{ C} = 2.4 \times 10^{-16}\text{ J}$ $v = \sqrt{\frac{2 \times 2.4 \times 10^{-16}\text{ J}}{9.11 \times 10^{-31}\text{ kg}}} = 2.3 \times 10^7$ m s^{-1}	**(2)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(i)	• use of $F = EQ$ and $E = \frac{V}{d}$ OR see $F = \frac{VQ}{d}$ • equate $F = ma$ and $F = EQ$	(1) (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• use of speed = distance/time (1) • t = 8.7 × 10^{-10} (s) (1) • use of a = $\frac{VQ}{dm}$ (1) • use of $s = ut + \frac{1}{2}at^2$ (1) with u = 0 and vertical acceleration to find s • s = 3.3 × 10^{-4} m (1)	Example of calculation: $t = \frac{0.02\ \text{m}}{2.3\times10^7\ \text{m s}^{-1}} = 8.7 \times 10^{-10}\ \text{s}$ $s = \frac{1}{2} \times \left(\frac{50\ \text{V} \times 1.6 \times 10^{-19}\ \text{C}}{0.01\ \text{m} \times 9.11 \times 10^{-31}\ \text{kg}}\right) \times (8.7 \times 10^{-10}\ \text{s})^2$ $s = 3.3 \times 10^{-4}$ m	**(6)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	• use of $V = V_0/\sqrt{2}$ (1) • vertical line (1) • positive and negative deflection shown (1) • maximum deflection 75 V (1)	Example of calculation: $V_0 = 53\ \text{V} \times \sqrt{2} = 75\ \text{V}$	**(4)**

Q21.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C $\frac{1.67 \times 10^{-27} \times (3.00 \times 10^8)^2}{1.60 \times 10^{-10}}$	A,B and D all contain numerical errors	**1**

Q22.

Question Number	Answer	Mark
	C	**1**

Q23.

Question Number	Answer		Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Alternating p.d. max 2** Electric field/ p.d. accelerates particles **Or** Electric field /p.d. gives particles energy Constant time period **Or** constant frequency Polarity of dees switches every half cycle **Or** P.d. switches every half cycle **Magnetic field max 2** Magnetic field/force at right angles to particles path Maintains circular motion (whilst in dees) **Or** Experiences centripetal force/acceleration (whilst in dees) Radius of circle increases as particles get faster	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**4**
	Total for question		**4**

Q24.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A *is not correct because lepton number is not conserved* B *is not correct because charge conservation is not obeyed* D *is not correct because charge conservation is not obeyed*	$p \rightarrow n + \beta^{+} + \nu$	1

Q25.

Question Number	Acceptable answers	Additional guidance	Mark
	• correct values of *A* and *Z* for α and β • 5 α • 4 β	Example of calculation: $^{226}_{88}Ra \rightarrow ^{206}_{82}Pb + x\, ^{4}_{2}\alpha + y\, ^{0}_{-1}\beta$ $226 - 206 = 4x$ $x = 5$ $88 - 82 - (5 \times 2) = -y$ $y = 4$ $^{226}_{88}Ra \rightarrow ^{206}_{82}Pb + 5\, ^{4}_{2}\alpha + 4\, ^{0}_{-1}\beta$	**(3)**

Q26.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\Delta E = mc\Delta\theta$ with a temperature change of 80°C **(1)** • $c = 3.94 \times 10^3\ \mathrm{J\,kg^{-1}\,C^{-1}}$ **(1)**	Example of calculation: Temperature rise = (101 – 21)°C $175000\ \mathrm{J} = 0.444\ \mathrm{kg} \times c \times (101 - 21)\mathrm{C}$ $c = 3.94 \times 10^3\ \mathrm{J\,kg^{-1}\,C^{-1}}$	**2**

Q27.

Question Number	Answer	Mark
	C	**1**

Q28.

Question Number	Acceptable Answer	Additional guidance	Mark
(i)	An explanation that makes reference to the following points: • energy conserved (1) • so energy needed over and above rest energy of proton in order to provide the mass of the π^0 particle (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(ii)	• calculates rest energy of π^0 (1) • 134 GeV (1)	Example of calculation: $E_k = \frac{938 \text{ GeV}}{7} = 134$ GeV	**(2)**

Q29.

Question Number	Acceptable answers	Additional guidance	Mark
	• attempt to determine mass difference between radium and radon-plus-alpha (1) • conversion to kg (1) • Use of $\Delta E = c^2 \Delta m$ (1) • Use of 1.6×10^{-19} factor (1) • Answer = 4.87 (MeV) (1)	$\Delta m = 225.97713\text{u} - (221.97040\text{u} + 4.00151 \text{ u})$ $= 5.22 \times 10^{-3}$ u $= 5.22 \times 10^{-3} \times 1.66 \times 10^{-27}$ kg $= 8.67 \times 10^{-30}$ kg $\Delta E = c^2 \Delta m = (3 \times 10^8 \text{ m s}^{-1})^2 \times 8.67 \times 10^{-30}$ kg $= 7.80 \times 10^{-13}$ J ΔE in MeV $= 7.80 \times 10^{-13}$ J $\div 1.6 \times 10^{-19}$ C $= 4.87$ MeV	5

Q30.

Question Number	Answer		Mark
(a)(i)	Top line correct	(1)	
	Bottom line correct	(1)	2
	$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$		
(a)(ii)	Attempt at mass deficit calculation	(1)	
	ΔE = 0.0175 GeV (accept 2.8×10^{-12} J)	(1)	2
	Example of calculation:		
	$\Delta m = (3.7274 + 0.939566 - 2.8089 - 1.8756)$ GeV/c^2 = 0.0175 GeV/c^2		
	ΔE = 0.0175 GeV		
(a)(iii)	Momentum is conserved	(1)	
	Mass of neutron is smaller, so speed is greater	(1)	
	$E_k = ½ mv^2$, so E_k is larger	(1)	
	Or		
	Momentum is conserved	(1)	
	$E_k = p^2/2m$	(1)	
	m of neutron is smaller, so E_k is larger	(1)	3

(b)	Use of $\lambda = \frac{\ln 2}{t_{½}}$	(1)	
	Use of $A = A_0 e^{-\lambda t}$	(1)	
	t = 41 (years)	(1)	3
	Example of calculation:		
	$\lambda = \frac{\ln 2}{t_{½}} = \frac{0.693}{12.3 \text{ year}} = 0.0563 \text{ year}^{-1}$		
	$A = A_0 e^{-\lambda t} \quad \therefore t = \frac{\ln\left(A/A_0\right)}{-\lambda} = \frac{\ln(0.1)}{-0.0563 \text{ year}^{-1}} = 40.9 \text{ years}$		

* (c)	**QWC – Work must be clear and organised in a logical manner using technical wording where appropriate** There is little possibility of a runaway fusion reaction (unlike fission) There would not be any radioactive waste produced in the fusion process **Or** the flux of neutrons would produce radioactive isotopes when absorbed by materials in the reactor A very/extremely high temperature (plasma) is required Plasma must not touch reactor walls, so strong magnetic fields are required If plasma touches the walls of the reactor its temperature falls (and fusion stops)	 **(1)** **(1)** **(1)** **(1)** **(1)**	**5**
	Total for question		**15**