



Questions

Q1.

The first cyclotron was created by E O Lawrence in 1931.

Lawrence obtained an expression for the time t for a particle of charge q and mass m to complete a circular path in a uniform magnetic field of magnetic flux density B .

The expression obtained by Lawrence is

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$$t = \frac{2\pi m}{Bq}$$

(a) (i) Derive this expression.

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(ii) In Lawrence's cyclotron, an alternating potential difference was used to accelerate particles to high energies.

Explain the significance of the expression obtained by Lawrence to the operation of a cyclotron.

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(Total for question = 15 marks)

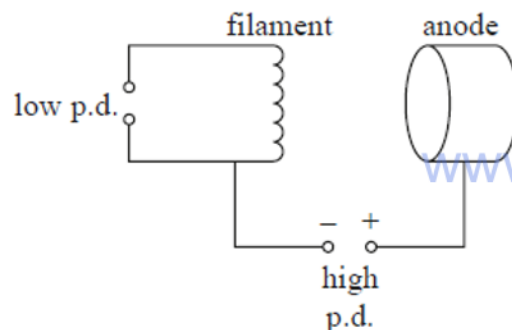
Q2.

The photograph shows a hospital radiotherapy machine that contains a linear accelerator (linac). The linac accelerates electrons to very high speeds for use in treating cancer. RocketRevise



(© Alexander Tihonov/Pearson Asset Library)

(a) The electrons used in the linac are produced by the filament in an electron gun, as shown in the diagram.

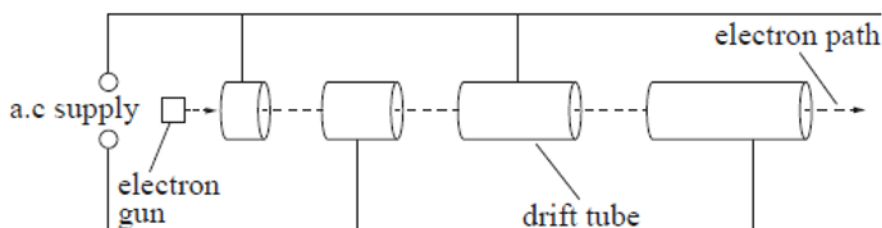


Name and describe the process in which electrons are produced by the filament.

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(b) The diagram shows part of a simplified linac.



An electron enters the linac from the electron gun with a speed of $2.5 \times 10^6 \text{ m s}^{-1}$. The electron passes through 60 drift tubes before emerging from the other end.

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(i) Calculate the energy of the electron as it emerges.

potential difference between adjacent drift tubes = 80 kV

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Energy of the electron =

(ii) For very high energy electrons, successive drift tubes have the same length.

Explain why.

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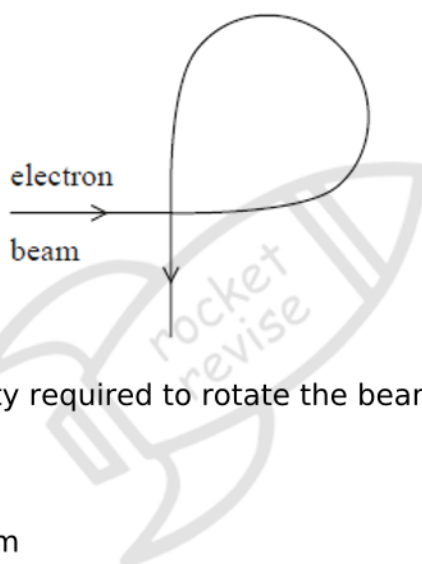
(c) Linacs used for radiotherapy operate by means of a standing wave formed within the linac.

Explain how standing waves are produced.

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(d) Electrons emerging from a standing wave linac must be directed towards the patient. Magnets are used to rotate the path of the electron beam through 270° .



Determine the magnetic flux density required to rotate the beam through 270° .

energy of electrons = 2.5 keV

radius of curvature of path = 61 mm

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Magnetic flux density =

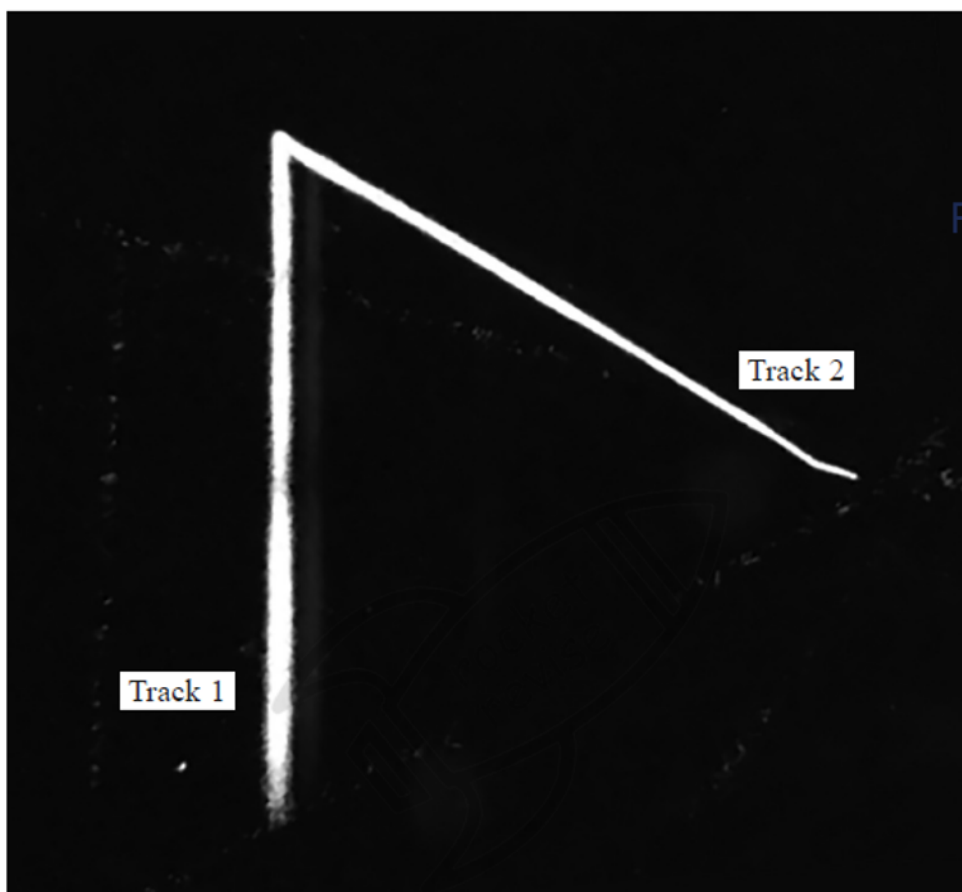
(Total for question = 14 marks)



Q3.

Cloud chambers are used to observe the paths of particles.

The photograph shows a pair of tracks made by alpha particles emitted when an atom of radon decays in a cloud chamber.



(a) The radon atoms do not leave tracks.

State a reason for this.

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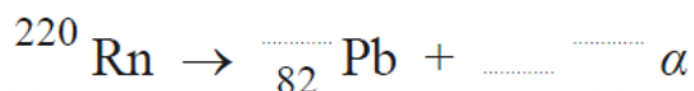
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(b) Radon decays by emitting an alpha particle, producing a polonium nucleus. The polonium then decays almost immediately by emitting another alpha particle, producing a lead nucleus.

(i) Complete the nuclear equation for this sequence of decays.

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(ii) The radon atom was stationary before the first alpha emission. The angle between the two



alpha tracks is 60° .

Sketch a vector diagram to show the momentum of the two alpha particles and the lead ion.

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(iii) Determine the magnitude of the velocity of the lead ion.

velocity of alpha particle emitted by radon = $1.74 \times 10^7 \text{ m s}^{-1}$

velocity of alpha particle emitted by polonium = $1.81 \times 10^7 \text{ m s}^{-1}$

mass of lead ion = $3.52 \times 10^{-25} \text{ kg}$

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Magnitude of velocity =

(c) The photograph shows another pair of tracks following radon decay.



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Deduce which track is for the first alpha particle emitted.

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(Total for question = 14 marks)

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Q4.

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 ☐.

The structure of nucleons can be investigated using electrons with high energies.

Which of the following is the reason why high energies are required?

- ☒ **A** to allow for the creation of new particles
- ☐ **B** to overcome the repulsive electrostatic forces
- ☐ **C** to produce a relativistic increase in particle lifetime
- ☐ **D** to produce short de Broglie wavelengths

(Total for question = 1 mark)

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Q5.

A positron and a muon travel at the same speed through a magnetic field.
The magnetic field is directed into the page.

Which of the following diagrams best represents the motion of the particles?



☐ **A** muon positron

☐ **B** muon positron

☐ **C** positron muon

☐ **D** positron muon

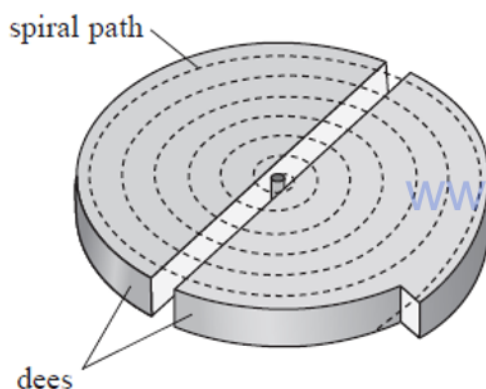
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(Total for question = 1 mark)

Q6.

Select one answer from A to D and put a cross in the box ☐. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.

A charged particle is accelerated in a spiral path in a cyclotron.



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Which of the following changes would increase the amount of energy transferred to the particle as it travels through 360° ?

- ☐ **A** increasing the distance between the dees
- ☐ **B** increasing the frequency of the potential difference across the dees



- ☐ **C** increasing the strength of the magnetic field within the dees
- ☐ **D** increasing the maximum potential difference across the dees

(Total for question = 1 mark)

Q7.

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 linac is a particle accelerator. It consists of drift tubes of increasing length with potential differences (p.d.) applied between them.

Which of the following is the reason the drift tubes are of increasing length?

- ☐ **A** So that the p.d. can have a constant frequency.
- ☐ **B** So that the particle gains the same amount of energy in each tube.
- ☐ **C** So that the p.d. between the tubes increases for each successive tube.
- ☐ **D** So that the time spent in each successive tube increases.

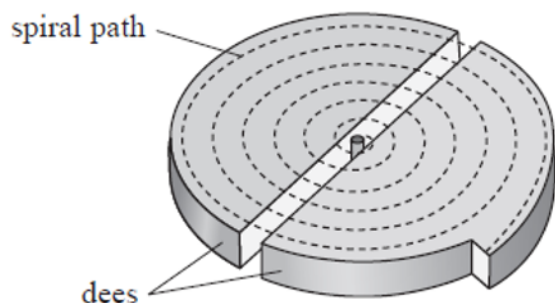
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Q8.

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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 ☐.

In a cyclotron, a charged particle is accelerated in a spiral path.



Which of the following increases as the radius of the spiral path increases?

- ☐ **A** The frequency of the alternating p.d. across the dees.
- ☐ **B** The magnetic flux density acting perpendicularly to the spiral path.
- ☐ **C** The potential difference between the dees.
- ☐ **D** The velocity of the charged particles.

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(Total for question = 1 mark)

Q9.

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 ☐.

Electrons can be used to probe the nuclei of atoms.

Which of the following best explains this?

- ☐ **A** Electrons can be accelerated to very high energies.
- ☐ **B** Electrons can be deflected by a magnetic field.
- ☐ **C** Electrons can be part of an atom.
- ☐ **D** Electrons can be released by thermionic emission.

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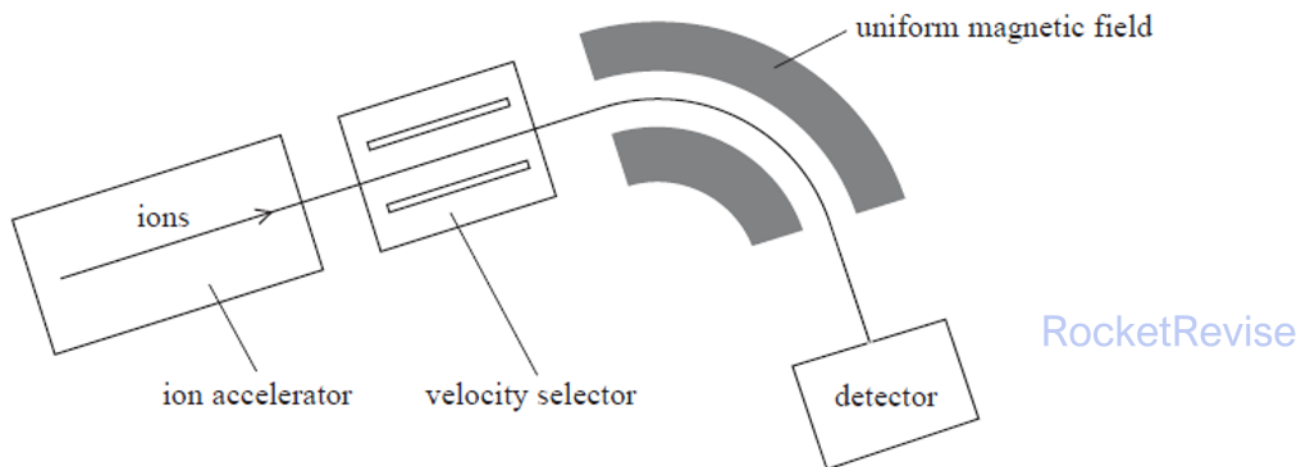
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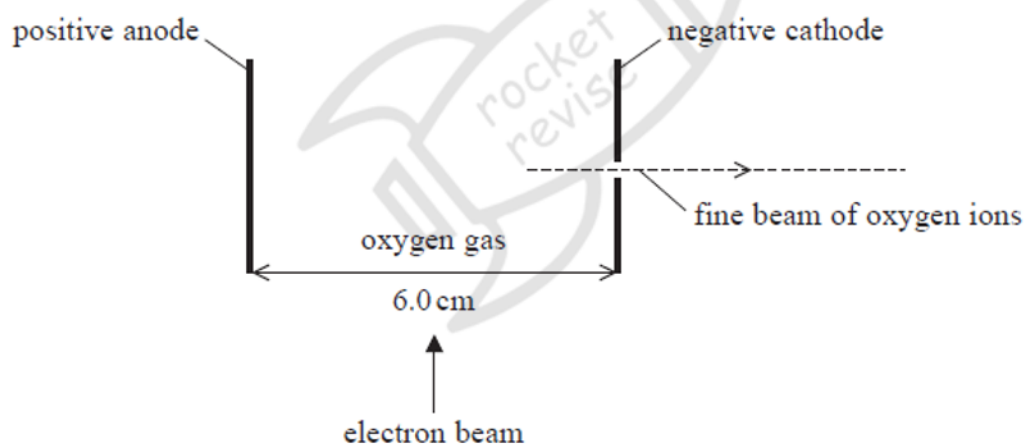
Q10.

Mass spectrometry is used to determine the masses of different isotopes of an element.

Atoms of the isotopes are ionised and accelerated. They pass through a velocity selector and into a region with a uniform magnetic field, as shown.



(a) An ion accelerator uses an electron beam to ionise atoms of oxygen gas. The positive ions are then accelerated across a high potential difference between an anode and a cathode, as shown in the diagram below. The cathode has a hole in it so that the accelerated ions may pass in a fine beam to the velocity selector.



(i) The electric field strength between the anode and cathode is $7.5 \times 10^5 \text{ V m}^{-1}$.

Calculate the potential difference between the anode and cathode.

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Potential difference =

(ii) A stationary oxygen ion is formed half-way between the anode and cathode with a charge of $+1.6 \times 10^{-19} \text{ C}$.

Show that the velocity of the ion as it passes through the hole in the cathode is about $5 \times 10^5 \text{ m s}^{-1}$



s^{-1} .

mass of oxygen ion = $2.7 \times 10^{-26} \text{ kg}$

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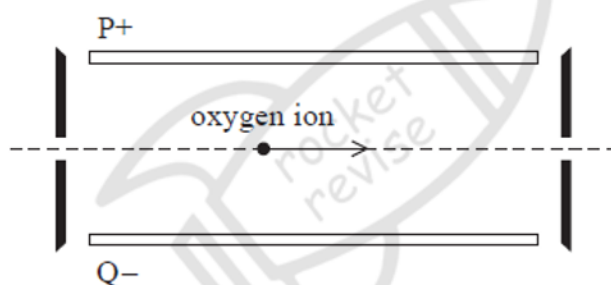
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(b) Oxygen ions enter the velocity selector with a range of velocities. The velocity selector allows ions with a specific velocity to travel in a straight line, as shown. Plate P is positive and plate Q is negative.



(i) A uniform electric field between the plates acts on an oxygen ion. A uniform magnetic field acts so that the magnetic force on the oxygen ion is in the opposite direction to the electric force.

Explain the direction of the magnetic field.

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(ii) The velocity selector is used to produce a beam of oxygen ions travelling in a straight line with a speed of $5.0 \times 10^5 \text{ m s}^{-1}$.

Calculate the magnetic flux density of the magnetic field that is required.

electric field strength between plates = $10\,500 \text{ N C}^{-1}$

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Magnetic flux density =

(c) After passing through the velocity selector, a beam of oxygen ions with the same velocity enters a region of uniform magnetic flux density. Different isotopes of oxygen can be present in the beam.

Explain why the detector will only detect one particular isotope.

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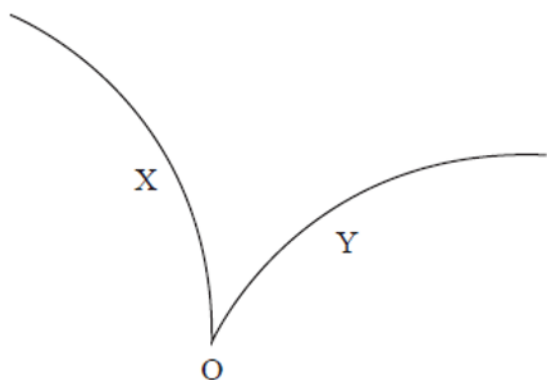
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(Total for question = 14 marks)

Q11.

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 particle detector shows tracks produced by two particles X and Y. The particles were created by the decay of a kaon at O.



Which of the following can be concluded from the tracks?

- ☒ **A** A magnetic field acts into the page.
- ☒ **B** X is a positively charged particle.
- ☒ **C** Y is an electron.
- ☒ **D** X and Y have opposite charge.

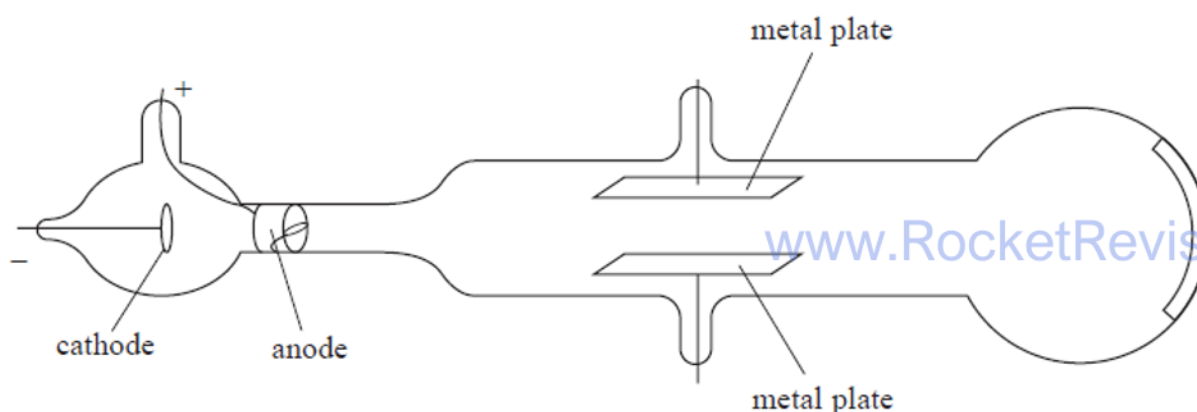
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(Total for question = 1 mark)

Q12.

(a) In 1897 J J Thomson demonstrated that electrons are small negative particles.

The diagram shows the apparatus used by Thomson.



(Source: J.J. Thomson © Philosophical Magazine, 44, 293 (1897))

A potential difference V was applied across the metal plates, producing an electric field between them.

A magnetic field of flux density B was applied at right angles to the electric field.

Electrons were emitted from the cathode and accelerated towards the anode. The electrons



moved between the metal plates with a speed v .

Thomson adjusted B until the electric and magnetic forces on the electrons were equal and opposite, so the electrons passed between the metal plates in a straight line.

(i) The plates are separated by a distance d .

Show that the speed v of the electrons is given by

$$v = \frac{V}{Bd}$$

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(ii) An experiment was carried out using similar apparatus.

Show that v was about $3 \times 10^7 \text{ m s}^{-1}$.

$$d = 1.5 \text{ cm}$$

$$B = 5.5 \times 10^{-4} \text{ T}$$

$$V = 231 \text{ V}$$

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(iii) When the electric field between the plates is switched off the electrons move in a circular path of radius 39 cm, due to the magnetic field.

The accepted value for the charge per unit mass of an electron is $1.8 \times 10^{11} \text{ C kg}^{-1}$.

Deduce whether the charge per unit mass of an electron calculated using data from this experiment is consistent with the accepted value.

$$B = 5.5 \times 10^{-4} \text{ T}$$

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(b) In 1927 J J Thomson's son directed beams of electrons at thin films of metal.

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The photograph shows one of the patterns observed.



Explain how this pattern changed scientists' understanding about the nature of electrons.

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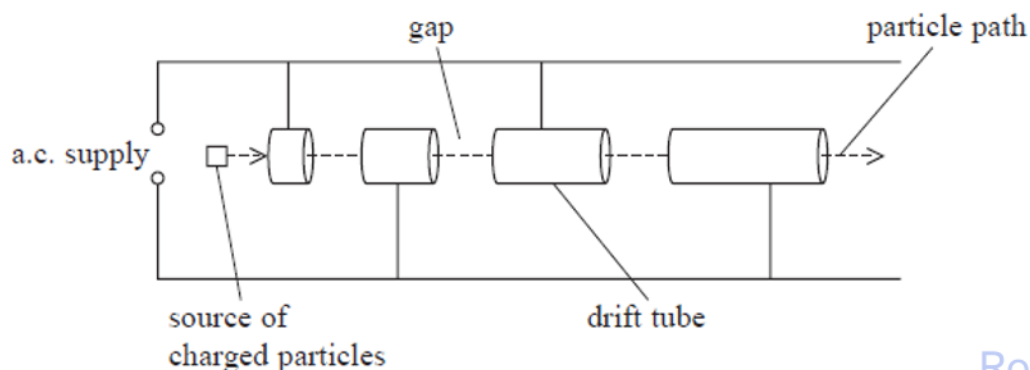
(Total for question = 11 marks)



Q13.

Linacs and cyclotrons both accelerate charged particles to very high speeds.

(a) The diagram shows a linac.



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Explain the use of electric fields in a linac.

You should refer to the frequency of the a.c. supply.

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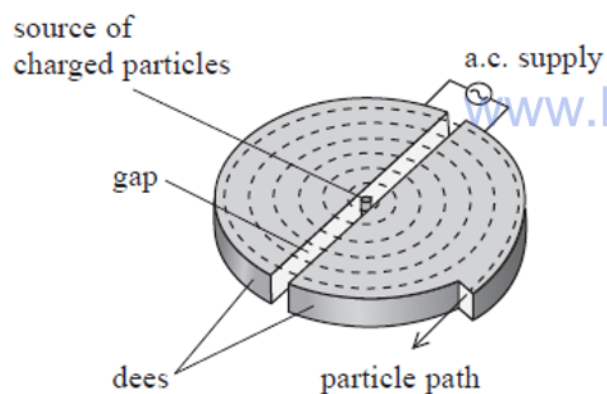
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(b) The diagram shows a cyclotron.



Explain why a magnetic field is applied at right angles to the dees in the cyclotron.

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Q14.

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 ☐.

Scientists use particles with high energy to investigate the structure of nucleons.

Which of the following statements is **not** a reason why particles with high energy are required?

- ☐ **A** to allow forces between particles to be overcome
- ☐ **B** to ensure particles have a very high momentum
- ☐ **C** to ensure particles have a very small de Broglie wavelength
- ☐ **D** to provide sufficient energy for the production of new particles

(Total for question = 1 mark)

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Q15.

In the 1930s, scientists investigated collisions of alpha particles with protons to determine whether the collisions were elastic.

The diagrams show an alpha particle before and after a collision with a stationary proton. The proton moves off at an angle θ to the original direction of the alpha particle.

Before collision



Not to scale

Not to scale

original direction of α particle

10.2°

θ

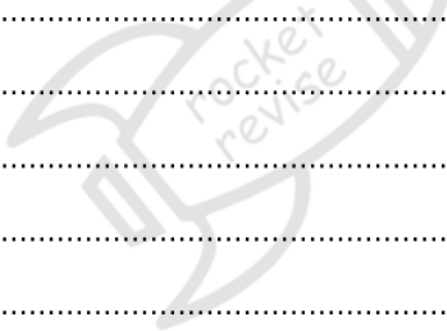
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Q16.

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 ☐.

The diagram shows the paths of two charged particles, X and Y, moving at the same speed in a uniform magnetic field.



Which row of the table describes the properties of Y compared with the properties of X?

	Mass of Y	Charge of Y
☐ A	greater than	the same as
☐ B	less than	greater than
☐ C	the same as	less than
☐ D	greater than	less than

(Total for question = 1 mark)



Q17.

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 ☐.

The tubes of a linear accelerator (linac) get progressively longer along the length of the linac.

Which of the following is the reason for this?

- ☒ **A** The frequency of the applied potential difference decreases.
- ☐ **B** The frequency of the applied potential difference increases.
- ☐ **C** The particles gain mass as they accelerate.
- ☐ **D** The particles must spend the same time in each tube.

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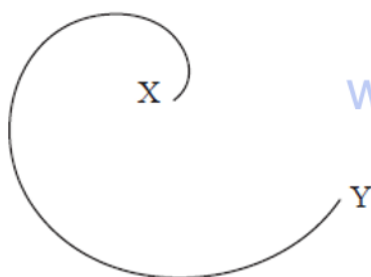
(Total for question = 1 mark)

Q18.

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 ☐.

The diagram shows the track of a charged particle in a magnetic field.

The magnetic field is directed into the page.



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Which of the following particles could create this track?

- ☐ **A** a muon travelling from X to Y
- ☐ **B** a positron travelling from Y to X
- ☐ **C** a π^+ travelling from X to Y



- ☐ **D** an electron travelling from Y to X

(Total for question = 1 mark)

Q19.

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 statements is true for a cyclotron?

- ☐ **A** A cyclotron can be used to accelerate neutrons.
- ☐ **B** A cyclotron uses a magnetic field to increase the speed of particles.
- ☐ **C** A cyclotron uses an alternating potential difference at a constant frequency.
- ☐ **D** A cyclotron uses an electric field to keep particles moving in a circular path.

(Total for question = 1 mark)