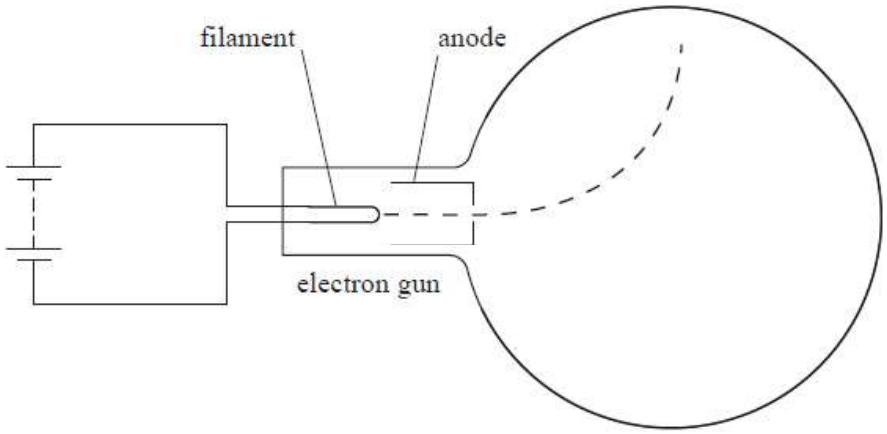
Q1.

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 an electron deflection tube.



Electrons are released by a filament and accelerated towards the anode, producing a beam. A magnetic field is applied, deflecting the beam as shown.

Which of the following causes electrons to be released from the filament?

☐ **A** beta decay

☐ **B** ionisation

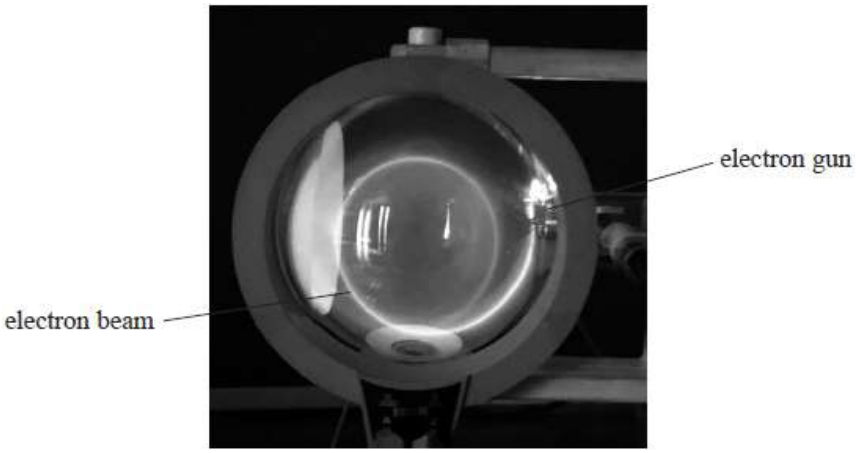
☐ **C** photoelectric effect

☐ **D** thermionic emission

(Total for question = 1 mark)

Q2.

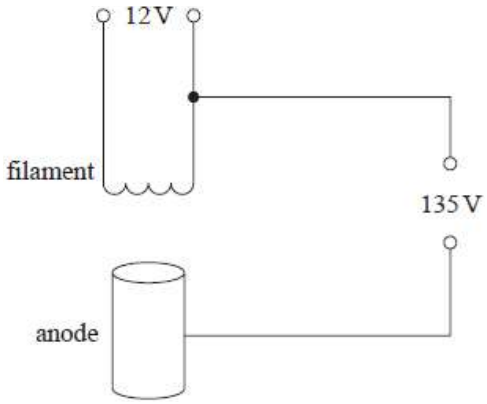
The photograph shows the path of an electron beam in a fine beam tube.



The fine beam tube contains helium gas at very low pressure. When electrons strike the helium atoms the resulting excitation is responsible for the glow tracing the path of the electron beam.

The electron beam is emitted downwards from an electron gun.

(a) The electron gun contains a heated filament above an anode as shown. There is a potential difference of 135 V between the anode and the filament.



(i) Describe how the electron beam is produced.

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(ii) Show that the speed of the electrons leaving the electron gun is about 7×10^6 m s^{-1}.

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(b) The electron beam follows the path shown in the photograph. A horizontal magnetic field is applied in the direction into the page.

(i) Show that a particle of momentum p follows a circular path of radius r given by

$$r = p/BQ$$

where Q is the charge on the particle and B is the magnetic flux density.

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(ii) Calculate B.

diameter of circular path = 7.3 cm

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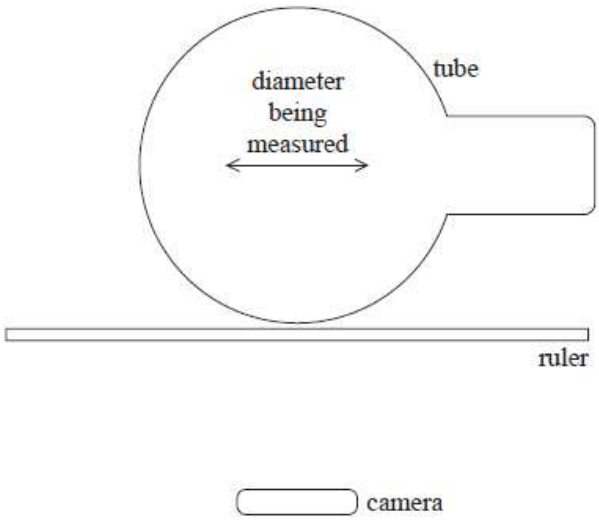
B = ...

(c) The diameter of the circular path was measured by holding a metre rule in front of the tube and taking a photograph, as shown.



Discuss the suitability of this method.

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(d) Suggest why the electron beam continues along a path of decreasing diameter with decreasing intensity.

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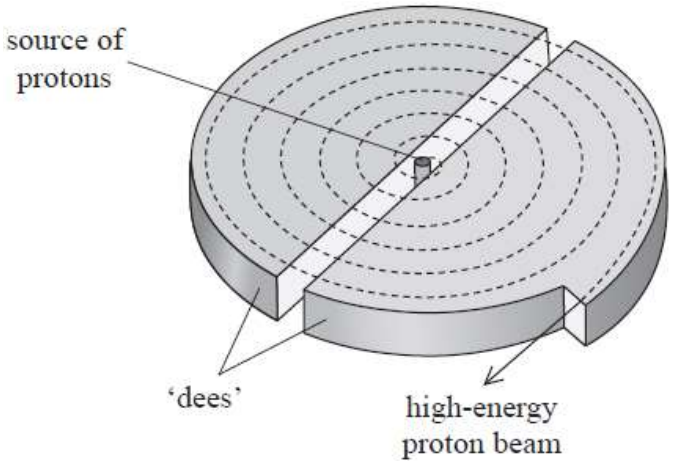
(Total for question = 12 marks)

Q3.

Cyclotrons can be used in hospitals and are used to produce a beam of protons.



* (a) Explain how the cyclotron accelerates the protons to a high energy.

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(b) Fluorine-18 $(^{18}_{9}\mathrm{F})$ is used for medical imaging. It can be produced by directing the high-energy proton beam at a solution containing oxygen-18 $(^{18}_{8}\mathrm{O})$ atoms.

(i) Another particle is produced when an oxygen nucleus changes into a fluorine nucleus by this process.

Determine which particle is produced by writing a nuclear equation.

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(ii) Calculate the force of electrostatic repulsion between a proton and an oxygen nucleus at a separation between their centres of 3.2×10^{-15} m.

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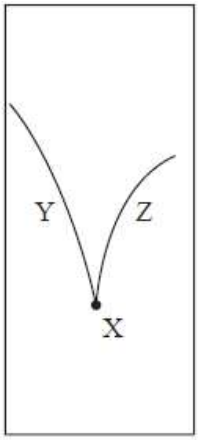
Force = ...

(Total for question = 12 marks)

Q4.

A moving pion decays into two particles Y and Z. This decay occurs at point X in a particle detector and the tracks observed are shown.



Which of the following is a valid conclusion from these tracks?

☒ **A** Momentum has not been conserved.

☒ **B** The pion is a neutral particle.

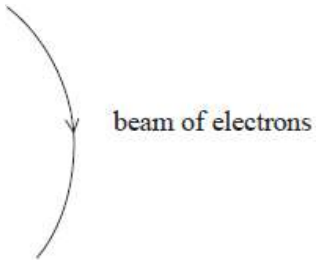
☒ **C** Y and Z have different masses.

☒ **D** Z is a negatively charged particle.

(Total for question = 1 mark)

Q5.

A beam of electrons is made to travel in a circular path by applying a magnetic field across the path of the beam.



Which of the following is the direction of the magnetic field required to maintain this circular path for the electron beam?

(1)

☒ **A** out of the page

☒ **B** into the page

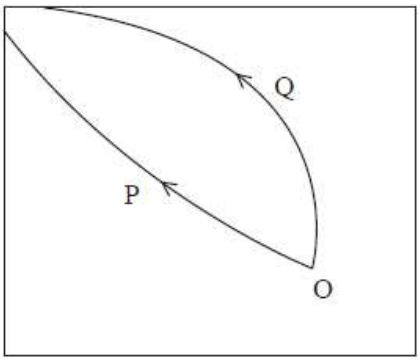
☒ **C** left to right

☒ **D** right to left

(Total for question = 1 mark)

Q6.

The diagram shows the tracks in a particle detector. A lambda particle has decayed at O and two particles P and Q were created.



Which of the following is a correct statement about momentum in this decay?

☐ **A** The total momentum of the system is zero.

☐ **B** The momentum of P is equal to the momentum of Q.

☐ **C** The sum of the momenta of P and Q must equal zero.

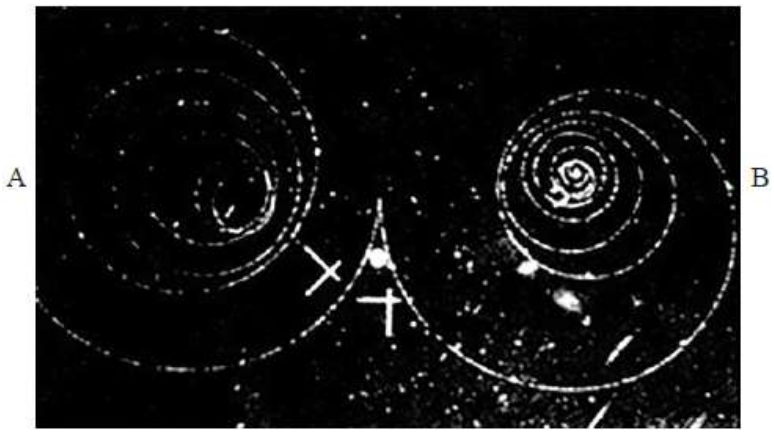
☐ **D** The sum of the momenta of P and Q must equal that of the lambda particle.

(Total for question = 1 mark)

Q7.

A high-energy gamma photon enters a bubble chamber and produces an electron-positron pair.

The photograph shows the tracks of the electron and the positron. The gamma photon enters from the top of the photograph.



(a) State why the photon leaves no track.

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(b) The magnetic field acts into the page.

State with justification whether track A or track B is the track of the electron.

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*(c) Explain the shape of the electron-positron tracks.

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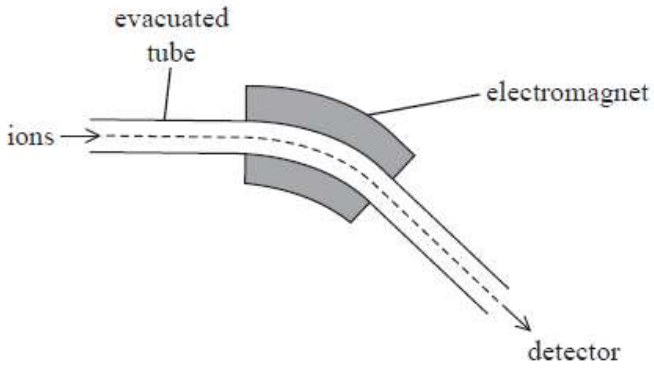
(Total for question = 7 marks)

Q8.

A mass spectrometer is a device used to identify atoms by measuring the mass–charge ratio $\frac{m}{Q}$ of their ions.

Ionised atoms in a vacuum are accelerated from rest through a potential difference *V* and then enter an evacuated tube.



(a) An ion of mass *m* is accelerated to a velocity *v*.
Show that the mass–charge ratio of the ion is given by

$$\frac{m}{Q} = \frac{2V}{v^2}$$

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*(b) The electromagnet shown in the diagram provides a magnetic field which is used to deflect the ion along the tube of the spectrometer.

Explain how a magnetic field can be used to deflect the ion into a circular path.

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(c) An atom of bromine is ionised by the removal of one electron. It is accelerated through a potential difference of 3.0 kV and then enters the tube. The ionised atom is deflected by a magnetic field of magnetic flux density 0.15 T.

Calculate the radius of curvature *r* of the tube.

mass of bromine ion = 80 u

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r = ...

(Total for question = 9 marks)