

7 In pair production, a high energy photon creates a particle-antiparticle pair.

In one interaction, a photon produces an electron and a positron.

Which of the following gives the photon energy, in joules?

- A $9.11 \times 10^{-31} \times (3 \times 10^8)^2$
- B $1.67 \times 10^{-27} \times (3 \times 10^8)^2$
- C $2 \times 1.67 \times 10^{-27} \times (3 \times 10^8)^2$
- D $2 \times 9.11 \times 10^{-31} \times (3 \times 10^8)^2$

(Total for Question 7 = 1 mark)

2 The standard quark-lepton model includes particles called mesons.

Which of the following is a meson?

- A photon
- B pion
- C positron
- D proton

(Total for Question 2 = 1 mark)

1 An electron gun produces a beam of electrons in a vacuum tube. The electrons are released from a metal filament using a current.

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

- A beta decay
- B excitation
- C photoelectric effect
- D thermionic emission

(Total for Question 1 = 1 mark)

4: In the upper atmosphere, high-energy cosmic rays collide with molecules of air to produce muons. The average speed of these muons is v .

The average lifetime of these muons is greater than the average lifetime of stationary muons.

Which of the following gives the reason for this increase in average lifetime?

- A $v > c$
- B $v = c$
- C $v \approx c$
- D $v \ll c$

(Total for Question 4 = 1 mark)

1 The nucleus of an isotope of osmium (Os) contains 76 protons and 190 neutrons.
Which of the following can be used to represent this isotope?

- A ${}^{266}_{76}\text{Os}$
- B ${}^{190}_{76}\text{Os}$
- C ${}^{76}_{190}\text{Os}$
- D ${}^{76}_{266}\text{Os}$

(Total for Question 1 = 1 mark)

5 Cyclotrons use electric fields and magnetic fields to give particles very high energy.
Which of the following statements is true for charged particles in cyclotrons?

- A The particles are accelerated by electric fields and magnetic fields.
- B The particles follow circular paths of constant radius.
- C The electric field changes direction when the particles are in the gap between the dees.
- D The magnetic field changes direction when the particles are in the gap between the dees.

(Total for Question 5 = 1 mark)

6 A pion can decay into two leptons.
Which of the following decays is possible?

- A $\pi^- \rightarrow e^- + \nu_e$
- B $\pi^0 \rightarrow e^- + \bar{\nu}_e$
- C $\pi^0 \rightarrow e^+ + \bar{\nu}_e$
- D $\pi^+ \rightarrow e^+ + \nu_e$

(Total for Question 6 = 1 mark)

3 Which row of the table shows a fundamental particle and a non-fundamental particle?

	Fundamental	Non-fundamental
<input type="checkbox"/> A	alpha	neutron
<input type="checkbox"/> B	lepton	meson
<input type="checkbox"/> C	proton	electron
<input type="checkbox"/> D	quark	muon

(Total for Question 3 = 1 mark)

- 5 In alpha particle scattering experiments, alpha particles were directed at very thin gold foil.

Some alpha particles were deflected through angles up to 180° .

Which of the following could explain this observation?

- A Strong electrostatic forces act on the alpha particles.
- B The atom is mainly empty space.
- C The charge is evenly distributed in the atom.
- D The gold foil was very thin.

(Total for Question 5 = 1 mark)

- 1: An isotope of astatine has the symbol ${}_{85}^{213}\text{At}$.

Which row of the table shows the number of protons and the number of neutrons in a nucleus of this isotope?

	Protons	Neutrons
<input type="checkbox"/> A	213	85
<input type="checkbox"/> B	85	128
<input type="checkbox"/> C	213	128
<input type="checkbox"/> D	85	213

(Total for Question 1 = 1 mark)

- 3 A nucleus of ${}_{19}^{38}\text{K}$ emits a β^+ particle.

Which row of the table shows the proton number and nucleon number of the nucleus that is produced?

	Proton number	Nucleon number
<input type="checkbox"/> A	18	39
<input type="checkbox"/> B	18	38
<input type="checkbox"/> C	20	38
<input type="checkbox"/> D	20	37

(Total for Question 3 = 1 mark)

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box .
If you change your mind, put a line through the box and then
mark your new answer with a cross .

DO NOT WRITE IN THIS AREA

1 Which of the following is the number of neutrons in a nucleus of $^{121}_{51}\text{Sb}$?

- A 51
- B 70
- C 121
- D 172

(Total for Question 1 = 1 mark)

7 A particle has mass $6.5 \text{ MeV}/c^2$.

Which of the following gives the mass, in kg, of the particle?

- A $\frac{6.5 \times 1.6 \times 10^{-19}}{(3 \times 10^8)^2}$
- B $\frac{6.5 \times 1.6 \times 10^{-13}}{(3 \times 10^8)^2}$
- C $\frac{6.5 \times (3 \times 10^8)^2}{1.6 \times 10^{-19}}$
- D $\frac{6.5 \times (3 \times 10^8)^2}{1.6 \times 10^{-13}}$

(Total for Question 7 = 1 mark)

8 Cyclotrons accelerate charged particles to high speeds. Cyclotrons use electric fields and magnetic fields.

Which of the following statements is **not** correct?

- A The magnetic field is at right angles to the velocity of the particles.
- B The magnetic fields in the dees keep the particles following circular paths.
- C The particles are accelerated by electric fields between the dees.
- D The particles are accelerated by electric fields inside the dees.

(Total for Question 8 = 1 mark)

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10 A proton and an anti-proton travel in opposite directions towards each other.

Each particle has energy of 450 GeV.

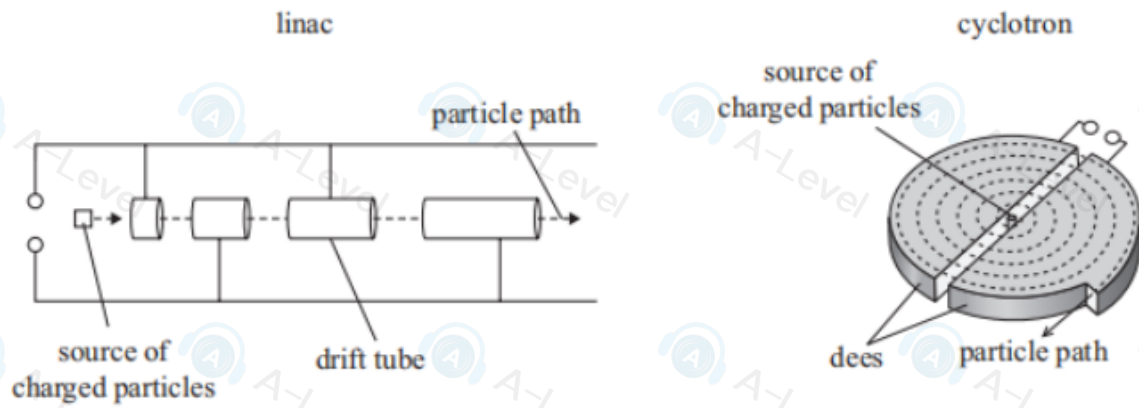
When the particles collide, they annihilate and create a particle-antiparticle pair.

Which of the following expressions gives the maximum mass, in kg, of the antiparticle produced?

- A $\frac{450 \times 10^6 \times 1.6 \times 10^{-19}}{2 \times (3.00 \times 10^8)^2}$
- B $\frac{450 \times 10^6 \times 1.6 \times 10^{-19}}{(3.00 \times 10^8)^2}$
- C $\frac{450 \times 10^9 \times 1.6 \times 10^{-19}}{(3.00 \times 10^8)^2}$
- D $\frac{2 \times 450 \times 10^9 \times 1.6 \times 10^{-19}}{(3.00 \times 10^8)^2}$

(Total for Question 10 = 1 mark)

16: The simplified diagrams show a linac and a cyclotron. Both machines are used to accelerate charged particles.



*(a) Explain how these machines use a potential difference to accelerate charged particles.

(6)

Handwriting practice lines consisting of ten horizontal dashed lines for writing the answer.

DO NOT WRITE IN THIS AREA

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21 Pions are created in the upper atmosphere when high-energy cosmic rays interact with nuclei. Pions are mesons and they quickly decay to muons. Muons are leptons with a mass of $106 \text{ MeV}/c^2$.

(a) Give a possible quark structure of a pion.

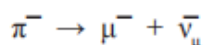
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(b) The equation shows a pion decaying into a muon and an antineutrino.



Energy and momentum must be conserved in this decay.

Explain two other conservation laws that apply to this decay.

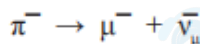
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(c) Calculate the mass, in kg, of a muon.

(3)

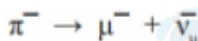
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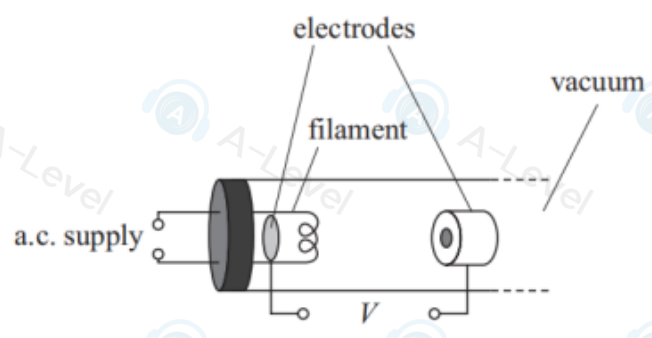
(d) When at rest, pions have an average lifetime of 26 ns. When produced in the upper atmosphere, high-energy pions have a speed of up to $0.99c$.

Explain how the average lifetime of these high-energy pions compares with the lifetime of pions at rest.

You do not need to carry out any calculations.

(2)

14 A cathode ray tube can be used to demonstrate the properties of electrons. In the cathode ray tube, a beam of electrons is produced using the arrangement shown.



(a) Explain why electrons are released when there is a current in the filament. (2)

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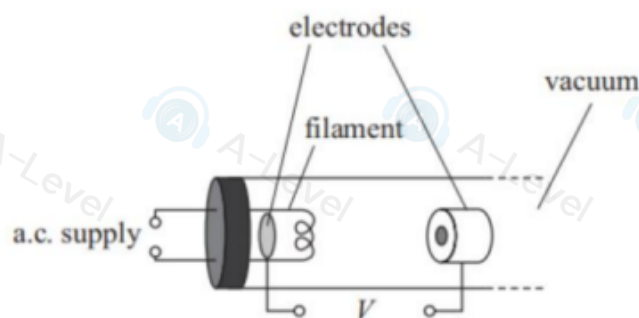
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- 14 A cathode ray tube can be used to demonstrate the properties of electrons. In the cathode ray tube, a beam of electrons is produced using the arrangement shown.



- (a) Explain why electrons are released when there is a current in the filament. (2)

- (b) In one cathode ray tube, the electrons in the beam had a de Broglie wavelength of 2.65×10^{-11} m.

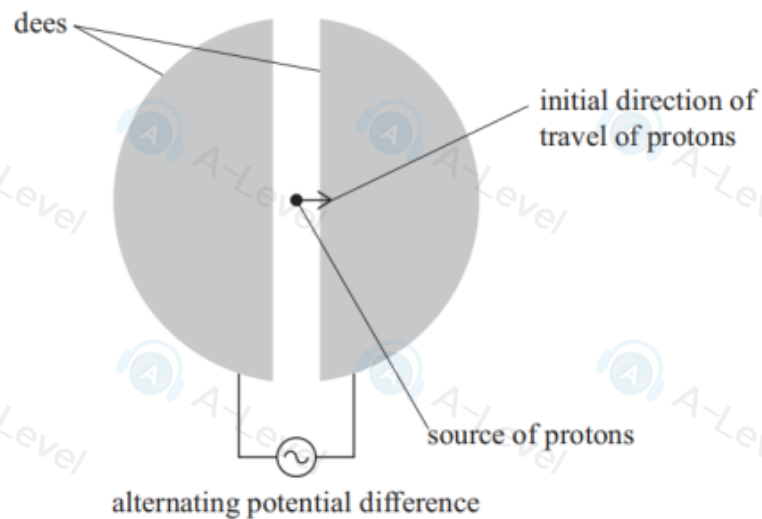
Calculate the potential difference V required to accelerate these electrons between the electrodes.

(4)

$V =$ _____

(Total for Question 14 = 6 marks)

- 17 A simplified diagram of a cyclotron is shown. In the cyclotron, protons gain energy. Protons are produced in the source and initially travel in the direction shown.



A magnetic field is applied perpendicular to the dees. The magnetic field direction is into the page.

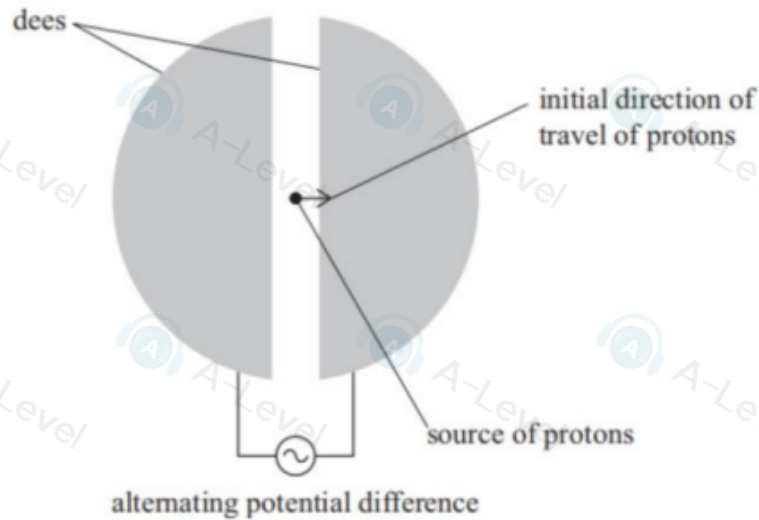
- (a) Add to the diagram to show the path of the protons as they gain energy in the cyclotron.

(2)

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- (b) The frequency f of the alternating potential difference applied to the dees is given by the equation

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

where

m is the mass of the proton

B is the magnetic flux density

q is the charge on the proton.

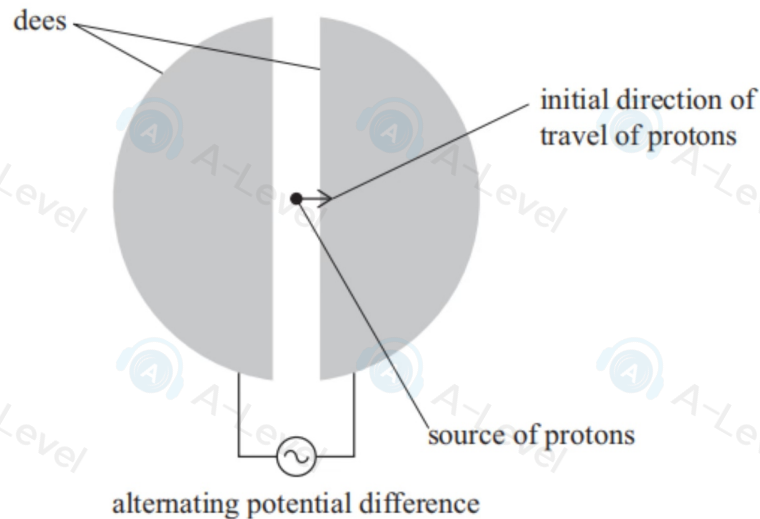
Calculate the time a proton spends in one of the dees.

$$B = 0.55 \text{ T}$$

(3)

Time = _____

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(3)

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- *(c) Explain how the cyclotron increases the energy of the protons.

You should refer to the alternating potential difference and the magnetic field.

(6)

- 14 According to the standard quark-lepton model, most of the visible matter in the universe consists of quarks and leptons.

The table shows six types of quark and their charges.

Quark	Charge/ e
up, charm, top	$+2/3$
down, strange, bottom	$-1/3$

- (a) State the quark structure of baryons and of mesons.

(2)

Baryon

Meson

- (b) Scientists have proposed the existence of particles called leptoquarks. Leptoquarks have both baryon number and lepton number and decay to a quark and a lepton.

- (i) One type of leptoquark has charge $+5e/3$

Determine the baryon number and the lepton number for this leptoquark.

Include the suggested quark and lepton in your working.

(5)

- (ii) Scientists search for new particles using high energy particle collisions.

The highest energy particle collisions involve colliding protons moving in opposite directions, each with energy 6800 GeV.

It is estimated that 11% of the total energy of a collision could be converted to the mass of a new particle.

Show that the maximum mass of a particle that can be produced is about 3×10^{-24} kg.

(3)

- (iii) Leptoquarks have not yet been observed.

Suggest why leptoquarks have not yet been observed.

(1)