PEARSON EDEXCEL IAL PHYSICS · YPH11

PHYSICS



EXAM QUESTION PACK

UNIT 4: NUCLEAR AND PARTICLE PHYSICS

SCORE	PERCENTAGE
/71	%

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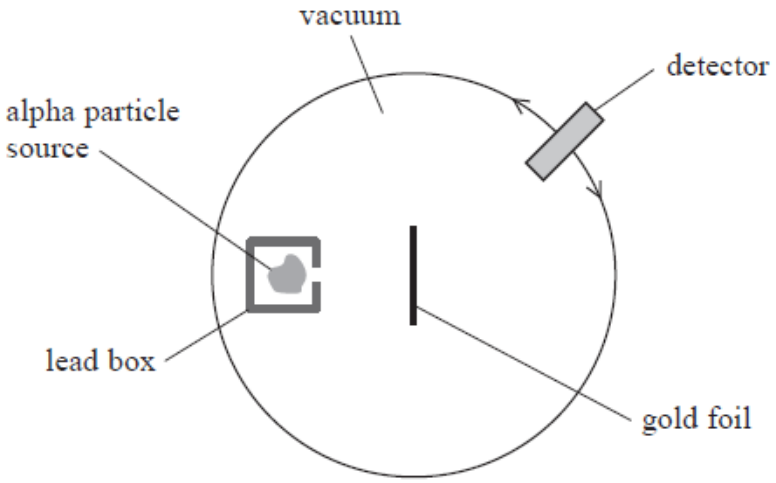
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Q1.

In the early 20th century, experiments were carried out in which alpha particles were directed towards thin gold foil.

A simplified diagram of the apparatus used is shown.



(a) State three observations and the corresponding conclusions made from the alpha particle scattering experiment.

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(b) One experiment used gold foil made from the gold isotope $^{197}_{79}\mathrm{Au}$. The alpha particles had an initial
kinetic energy of 4.7 MeV.

(i) Show that the closest distance these alpha particles can get to a gold nucleus is about 5×10^{-14} m.

(4)

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(ii) Calculate the strength of the electric field due to the gold nucleus at this distance.

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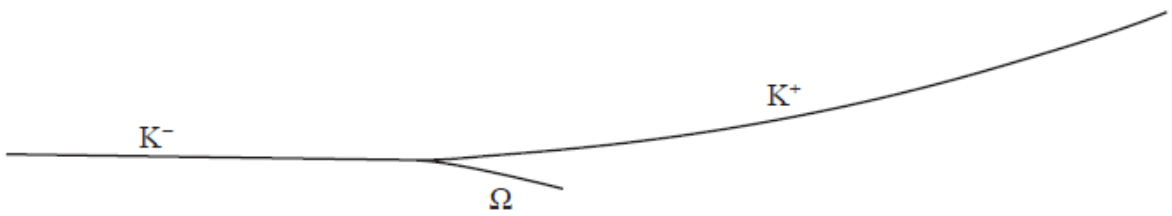
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Strength of electric field = ...

(Total for question = 13 marks)

Q2.

The diagram shows particle tracks in a detector. A negative K meson collided with a stationary proton. An omega baryon and a positive K meson were produced after the impact.



(a) Explain the process that enables a particle detector to detect charged particles.

(2)

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(b) (i) Describe the structure of a baryon and a meson.

(2)

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(ii) A magnetic field acts in the detector.

State the direction of the magnetic field.

(1)

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(iii) Deduce the charge and baryon number for the omega particle.

(3)

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* (c) The rest mass of the omega baryon is significantly larger than the rest mass of the proton.

Discuss how energy and momentum are conserved during this collision.

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(Total for question = 14 marks)

Q3.

Experiments with muons are taking place at Fermilab in the USA to improve our understanding of the standard model.

(a) The muon belongs to the same family of particles as the electron.

State how the muon is classified in the standard model.

(2)

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(b) A muon (μ) can be produced by the decay shown in this nuclear equation.

$$\pi^- \longrightarrow \mu^- + \bar{\nu}_\mu$$

State the names of the two other particles involved.

(2)

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(c) A website states: "The rest mass of a muon is 106 MeV / c^2, which is a little over 200 times that of an electron."

Deduce whether this statement is correct.

(3)

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(d) Muons are stored in a 'storage ring' at Fermilab. The website describes the ring as having a circumference of 44.7 m and using a magnetic field of flux density 1.45 T.

The website claims that this enables the storage ring to confine muons with a momentum of 3.10 GeV / c.

(i) Explain why the unit GeV / c is a valid unit for momentum.

(2)

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(ii) Deduce whether the website's claim is correct.

muon charge = -1.6×10^{-19} C
3.10 GeV/c = 1.65×10^{-18} N s

(3)

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(iii) Stationary muons are unstable and have a mean lifetime of a few microseconds.

Explain why muons in the ring are observed to have a much greater mean lifetime.

(2)

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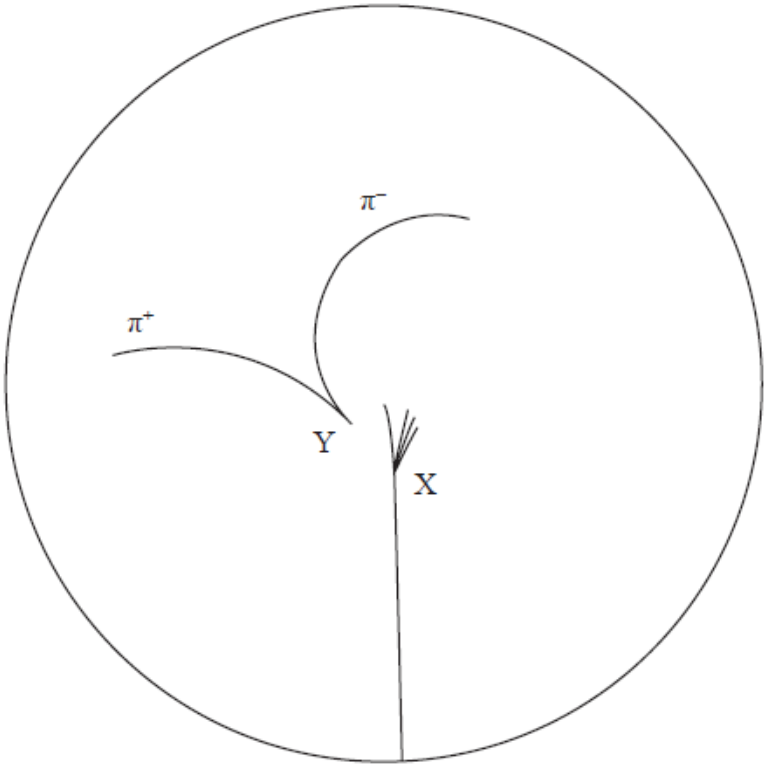
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(Total for question = 14 marks)

Q4.

The diagram shows the paths of particles in a circular particle detector. There is a magnetic field acting at right angles to the plane of the paper. The diagram is drawn to scale. 1 cm on the diagram represents 10 cm in the particle detector.

An antiproton enters the detector and collides with a stationary proton at X. Several particles are produced. One particle is a kaon (K^0). The kaon then decays into two pions (π^+ and π^-) at Y.



(a) Determine the momentum of the negative pion.

magnetic flux density of field in the detector = 7.0T

(4)

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Momentum = ...

(b) State two ways that the diagram shows the kaon is neutral.

(2)

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(c) The table shows the charge for the up quark and the down quark as a fraction of the charge on the proton.

Quark	Charge
u	+2/3
d	−1/3

Deduce the quark structure of the antiproton and the negative pion.

(2)

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Quark structure of the antiproton .....

Quark structure of the negative pion .....

(d) Calculate the mass of a proton in GeV/c^2.

(3)

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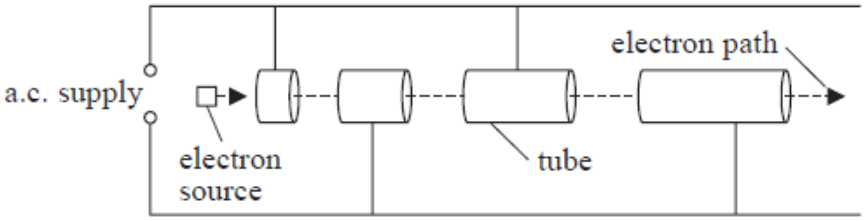
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Mass = ... GeV/c^2

(Total for question = 11 marks)

Q5.

Some particle physics experiments use electrons which are accelerated to very high energies by a linac. The diagram shows the first section of the linac.



*(a) Explain why the distances between consecutive tubes increase in the first section of the linac but are almost equally spaced in the last section of the linac.

(6)

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(b) In some experiments, a high-energy electron collides with a stationary atom. In other experiments beams of high-energy electrons, travelling in opposite directions, collide head-on. New particles can be created from collisions.

Deduce which type of collision is more likely to produce new particles with the largest mass.

(3)

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(Total for question = 9 marks)

Q6.

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.

(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 ☒.

Muons can travel at speeds close to the speed of light. At these speeds the lifetime and mass of a muon are different from those of a stationary muon.

Which row of the table describes the lifetime and the mass of a high-speed muon compared to a stationary muon?

		Lifetime	Mass
☒	**A**	shorter	smaller
☒	**B**	shorter	larger
☒	**C**	longer	smaller
☒	**D**	longer	larger

(Total for question = 1 mark)

Q8.

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 is a fundamental particle?

☒ **A** pion

☒ **B** proton

☒ **C** neutrino

☒ **D** neutron

(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 ☒.

A proton collides with an antiproton.

Which of the following could be produced by this collision?

☒ **A** $\pi^+ + n$

☒ **B** $\pi^- + p^+$

☒ **C** $\pi^+ + e^-$

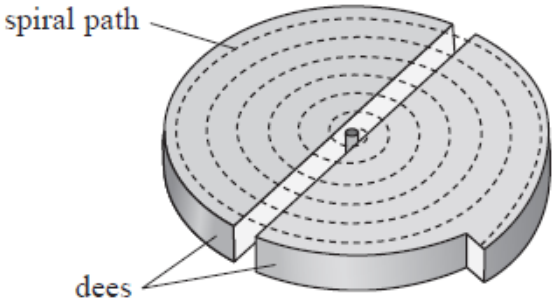
☒ **D** $\pi^+ + \pi^-$

(Total for question = 1 mark)

Q10.

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.

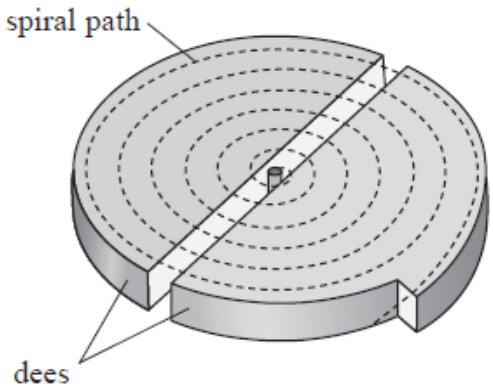
☒ **D** The velocity of the charged particles.

(Total for question = 1 mark)

Q11.

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.



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)

Q12.

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 ☒.

In the early 20th century experiments were carried out to measure the scattering of alpha particles after striking thin gold foil.

Which of the following could **not** be concluded from the results of these experiments?

☒ **A** The nucleus is charged.

☒ **B** The nucleus contains most of the mass of the atom.

☒ **C** The nucleus contains neutrons and protons.

☒ **D** The nucleus is very small compared to the atom.

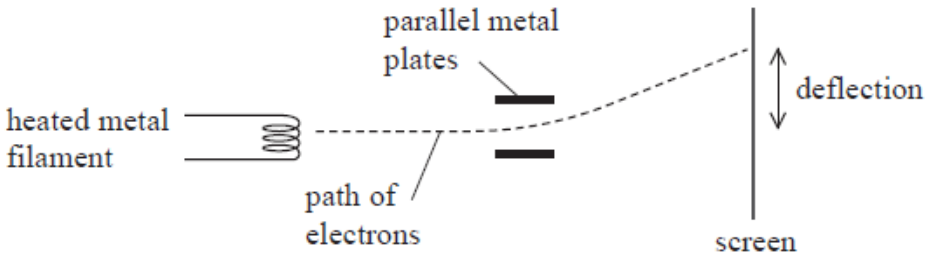
(Total for question = 1 mark)

Q13.

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 ☒.

This question refers to a cathode ray tube.

The diagram shows some of the components in a cathode ray tube.



Electrons are released from the heated metal filament.

Which of the following is the name of this process?

☒ **A** ionisation

☒ **B** photoelectric emission

☒ **C** relativistic effect

☒ **D** thermionic emission

(Total for question = 1 mark)

Q14.

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 ☒.

Which row in the table gives the charge and mass of an antiproton?

		Charge / C	Mass / kg
☒	**A**	1.6×10^{-19}	-9.11×10^{-31}
☒	**B**	-1.6×10^{-19}	9.11×10^{-31}
☒	**C**	1.6×10^{-19}	-1.67×10^{-27}
☒	**D**	-1.6×10^{-19}	1.67×10^{-27}

(Total for question = 1 mark)

Q15.

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 ☒.

$^{17}_{8}O$ is an isotope of oxygen.

Which row of the table gives the number of nucleons and the number of neutrons in an atom of $^{17}_{8}O$?

	Number of nucleons	Number of neutrons
☒ **A**	8	8
☒ **B**	8	9
☒ **C**	17	8
☒ **D**	17	9

(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Answer		Mark
a	Most alpha particles were undeviated **Or** Most particles pass through with little or no deviation	(1)	**6**
	Most of the atom is empty space (MP2 with reference to lack of deviation)	(1)	
	Few alpha particles were scattered by small angles	(1)	
	There is a concentration of charge in the atom (MP4 with reference to scattering)	(1)	
	Very few alpha particles were deviated by more than 90°	(1)	
	Most of the mass is concentrated in a small region of the atom **Or** Most of the mass is concentrated in nucleus (Accept Mass of nucleus much greater than mass of alpha particle) (MP6 with reference to back scattering)	(1)	

bi	Applies conversion factors for MeV to J (1) Use of $V = {}^{Q}/_{4\pi\varepsilon_0 r}$ (1) Use of $W=VQ$ (1) $r = 4.8 \times 10^{-14}$ (m) (1) <u>Example of calculation</u> $4.7\ \text{MeV} = 4.7 \times 10^{6}\ \text{eV} \times 1.6 \times 10^{-19}\ \text{J/eV} = 7.52 \times 10^{-13}\ \text{J}$ $7.52 \times 10^{-13}\ \text{J} = 8.99 \times 10^{9}\text{Nm}^2\text{C}^2 \times 2 \times 1.6 \times 10^{-19}\text{C} \times 79 \times 1.6 \times 10^{-19}\text{C}/r$ $r = 4.8 \times 10^{-14}\ \text{m}$	**4**
bii	Use of $E = {}^{Q}/_{4\pi\varepsilon_0 r^2}$ (1) With $Q = 79 \times 1.6 \times 10^{-19}$ (1) $E = 4.9 \times 10^{19}\ \text{NC}^{-1}$ (1) (use of show that value gives $E = 4.5 \times 10^{19}\ \text{NC}^{-1}$) allow ecf from (i) <u>Example of calculation</u> $E = 8.99 \times 10^{9}\text{Nm}^2\text{C}^2 \times 79 \times 1.6 \times 10^{-19}\ \text{C} / (4.8 \times 10^{-14})^2\ \text{m}^2$ $E = 4.9 \times 10^{19}\ \text{NC}^{-1}$	**3**
	Total for question	**13**

Q2.

Question Number	Answer	Mark
a	(the particle is) ionising **Or** it knocks electrons out of atoms in its path (1) A track is formed by the ionised particles produced (1)	2
bi	A baryon is three quarks (or three antiquarks) (1) A meson is an anti-quark and a quark (1)	2
bii	into the page/paper (1)	1
biii	charge: applies charge conservation (1) omega baryon charge −1 (1) baryon number: before = 1 identified as the proton so the omega particle = 1 (1)	3

* c	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.	6

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	Max linkage mark available	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

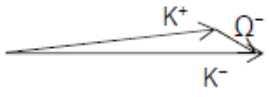
Indicative content:
Energy:
IC1 As (Rest) mass-energy of proton and kaon + Initial E_k = (rest) mass-energy of omega and kaon + kinetic energies of both particles
Or (Total) mass-energy conserved

IC2 Incoming K^- had **high** kinetic energy

IC3 some of this initial kinetic energy converted to mass of the omega particle (– mass of proton)

IC4 $\Delta E = \Delta mc^2$

momentum:
IC5 momentum of K^- = sum of x components of $K^+ + \Omega^-$
Or vector sum of momentum of $K^+ + \Omega^-$ = momentum of K^-
Or an attempt to sketch a triangle of vectors
eg



IC6 y component of K^+ equals y component Ω^-
Or
all vectors correctly labelled

	Total for question	**14**

Q3.

Question Number	Answer		Mark
a	It is a lepton	(1)	2
	It is a fundamental particle **Or** second generation	(1)	
b	negative pion	(1)	2
	muon anti-neutrino	(1)	
c	Use of $\Delta E = c^2 \Delta m$	(1)	3
	Divide mass of muon by mass of electron **Or** multiplies the mass of an electron by 200	(1)	
	Mass of muon is 207 times that of an electron so true statement **Or** 200 times electron mass is 1.82×10^{-28} kg which is just under 1.88×10^{-28} kg so it is correct	(1)	
	Example of calculation $\text{mass} = \frac{106\ \text{MeV}/c^2 \times 10^6 \times 1.6\times10^{-19}\text{JeV}^{-1}}{(3\times10^8)^2\ (\text{m s}^{-1})^2} = 1.88\times10^{-28}\ \text{kg}$ $\text{mass} = \frac{1.88\times10^{-28}\text{kg}}{9.11\times10^{-31}\text{kg}}$ mass =207 times that of an electron		
di	A unit of energy is GeV **Or** a unit of mass is GeV/c^2	(1)	2
	The unit of momentum is the same as the unit of energy/velocity so GeV divided by c = GeV/c **Or** The unit of momentum is the same as the unit of mass × velocity so GeV/c^2 × c = GeV/c	(1)	
dii	Use of Circumference = $2\pi r$	(1)	3
	Use of $r = p / BQ$	(1)	
	Show that a momentum of 1.65 x 10^{-18} N s is consistent with the correct radius (7.11 m) by determination of p, r, B or Q and statement that it is correct	(1)	
	Example of calculation $r = 44.7\ \text{m} / 2\pi = 7.11\ \text{m}$ $r = \frac{1.65\times10^{-18}\text{N s}}{1.45\ \text{T}\times1.6\times10^{-19}\text{C}} = 7.11\ \text{m}$		
diii	muons travelling close to speed of light	(1)	2
	relativistic effect on particle lifetime	(1)	
	Total for question		14

Q4.

Question Number	Answer	Mark
a	Determines correct radius from measurements from the paper (accept measurement of line between ends of arc as diameter) (1) Applies scale to measured distance - (1) Use of $r = p/BQ$ (1) $p = 1.9 \times 10^{-19}$ Ns (range 1.6×10^{-19} Ns to 1.9×10^{-19} Ns) (1) Example of calculation radius 17 mm so actually 170 mm (range 14 mm to 17 mm) $p = 0.17\ \text{m} \times 7.0\ \text{T} \times 1.6 \times 10^{-19}\text{C}$ $p = 1.90 \times 10^{-19}$ Ns (140 mm → $p = 1.57 \times 10^{-19}$ Ns)	**4**
b	Kaon does not leave a track (1) pions have opposite charge and charge is conserved (1)	**2**
c	Antiproton: $\bar{u}\,\bar{u}\,\bar{d}$ **Or** antiup antiup antidown (1) negative pion: $\bar{u}\,d$ **Or** antiup down (1) (Quarks can be listed in any order for each particle)	**2**
d	Use of $\Delta E = c^2 \Delta m$ (1) Conversion from J to eV (1) mass = 0.94 (GeV/c^2) (1) Example of calculation $\Delta E = (3 \times 10^8\ \text{m s}^{-1})^2 \times 1.67 \times 10^{-27}\ \text{kg} = 1.503 \times 10^{-10}$ J $\Delta E = 1.503 \times 10^{-10}$ J / 1.60×10^{-19} J/eV = 9.39×10^8 eV mass = 0.94 GeV/c^2	**3**
	Total for question	**11**

Q5.

Question Number	Answer	Mark
* a	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded.	6

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	Indicative content: IC1 Electrons accelerate in the gaps IC2 Frequency of a.c. supply is constant IC3 Time taken for an electron to travel between (consecutive) tubes is constant (and they are accelerating) IC4 Reference to $s = vt$, e.g. electrons travel further in a fixed time with a higher speed IC5 (In the last section of the linac) the electron approaches the speed of light IC6 Speed becomes (almost) constant so distance travelled in a fixed amount of time becomes (almost) constant	

b	**Max 2 from:** Reference to $E=mc^2$ (1) There will be more kinetic energy available (for same accelerating p.d.) with colliding beams (1) (Total) momentum of two beams is zero before collision **Or** single beam and stationary target has (net) momentum before collision (1) **AND** All of the kinetic energy of the two beams available (to be converted to mass) so colliding beams more likely to produce particle with larger mass **Or** So with single beam particle(s) must have momentum after collision so less energy available (to be converted to mass) so lower mass particles produced (1) **Or** So with single beam particle(s) must have kinetic energy after collision so less energy available (to be converted to mass) so lower mass particles produced	**3max**
	Total for question	**9**

Q6.

Question Number	Answer	Mark
	The only correct answer is **A** *B is not correct because this isn't relevant* *C is not correct because this isn't relevant* *D is not correct because this isn't relevant*	**(1)**

Q7.

Question Number	Answer	Mark
	The only correct answer is **D** *A is not correct because lifetime and mass increase at speed close to c* *B is not correct because lifetime and mass increase at speed close to c* *C is not correct because lifetime and mass increase at speed close to c*	**(1)**

Q8.

Question Number	Answer	Mark
	The only correct answer is **C** *A is not correct because a pion consists of quarks* *B is not correct because a proton consists of quarks* *D is not correct because a neutron consists of quarks*	**(1)**

Q9.

Question Number	Answer	Mark
	The only correct answer is **D** *A is not correct because this does not conserve charge* *B is not correct because this does not conserve baryon number* *C is not correct because this does not conserve lepton number*	**(1)**

Q10.

Question Number	Answer	Mark
	The only correct answer is **D** *A is not correct because the frequency should be constant* *B is not correct because the magnetic field should be constant* *C is not correct because the p.d. should be constant*	**(1)**

Q11.

Question Number	Answer	Mark
	The only correct answer is **D** *A is not correct because this would not change the energy* *B is not correct because this would not change the energy for one revolution* *C is not correct because this would not change the energy*	**1**

Q12.

Question Number	Answer	Mark
	The only correct answer is **C** *A is not correct because this was a correct conclusion* *B is not correct because this was a correct conclusion* *D is not correct because this was a correct conclusion*	**1**

Q13.

Question Number	Answer	Mark
	The only correct answer is **D** *A is not correct because the process described is thermionic emission* *B is not correct because the process described is thermionic emission* *C is not correct because the process described is thermionic emission*	1

Q14.

Question Number	Answer	Mark
	The only correct answer is **D** *A is not correct because this is the mass of an electron* *B is not correct because this is the mass of an electron* *C is not correct because this is the charge of a proton*	1

Q15.

Question Number	Answer	Mark
	The only correct answer is **D** *A is not correct because 8 is the number of protons* *B is not correct because 8 is the number of protons* *C is not correct because 8 is the number of protons*	1