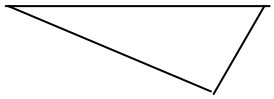
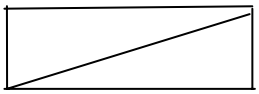
Question Number	Answer	Mark
1	QWC i and iii – Spelling of technical terms must be correct and the answer must be organised in a logical sequence Observations: Most alpha went straight through **(1)** Some deflected **(1)** (Very) few came straight back/large angle **(1)** Conclusions: Atom mainly (empty) space **(1)** Nucleus contains most of the mass **(1)** (Nucleus) very small/tiny **(1)** (Nucleus) charged /positive **(1)**	**QWC** **5 max**
	Total for question	**5**

Question Number	Answer		Mark
2(a)	Only (moving) charged particles are deflected by a magnetic field **Or** Only charged particles can be accelerated to produce a beam	**(1)** **(1)**	**1**
2(b)	Into the page	**(1)**	**1**
2(c)	Use of $F = mv^2/r$ **Or** use of $r = p/BQ$ Use of $F = Bqv$ **Or** use of $p = mv$ $m = 6.64 \times 10^{-26}$ kg <u>Example of calculation</u> $mv^2/r = Bqv$ $m = Bqr/v = (0.673\ \text{T} \times 1.6 \times 10^{-19}\ \text{C} \times 7.40 \times 10^{-2}\ \text{m}) / 1.20 \times 10^{5}\ \text{m s}^{-1}$ $m = 6.64 \times 10^{-26}$ kg	**(1)** **(1)** **(1)**	**3**
2(d)	Semicircle drawn starting from same initial point <u>and</u> a smaller radius	**(1)**	**1**
	Total for question		**6**

Question Number	Answer	Mark
***3**	(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 **(1)** Constant time period **Or** constant frequency **(1)** Polarity of dees switches every half cycle **Or** P.d. switches every half cycle **(1)** **Magnetic field max 2** Magnetic field/force at right angles to particles path **(1)** Maintains circular motion (whilst in dees) **Or** Experiences centripetal force/acceleration (whilst in dees) **(1)** Radius of circle increases as particles get faster **(1)**	**4**
	Total for question	**4**

Question Number	Answer		Mark
***4(a)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Electric field** Provides a force on the proton/particle Which accelerate the proton/particle **Or** gives energy to the protons/particles **Magnetic field** Provides a force on a moving proton **Or** Provides a force at right angles to the direction of motion (of the protons) Acts as a centripetal force **Or** produces circular motion **Additional detail about either field** E field across gap only **Or** The idea that the E field is reversed /alternates every half cycle **Or** B field perpendicular to the Dees (this mark may be awarded from a diagram)	**(1)** **(1)** **(1)** **(1)** **(1)**	**5**
4(b)	Division by e (ignore powers of 10 error) multiplication by c^2 Mass = 0.14 (GeV/c^2) Example of calculation Mass = (2.5 × 10^{-28} kg × 9 × 10^{16} m^2 s^{-2})/1.6 × 10^{-19} C Mass = 0.14 × 10^9 eV/c^2 = 0.14 GeV/c^2	**(1)** **(1)** **(1)**	**3**
4(c)	2/3 charge of a proton **Or** 2/3 charge of a positron **Or** 2/3 positive value of the charge on an electron **Or** 2/3e^+	**(1)**	**1**
4(d)(i)	Particle: K^- — Quark combination: $\bar{s}u$ **(1)** Particle: K+ — Quark combination: $\bar{u}s$ **(1)** Particle: K0 — Quark combination: $\bar{s}d$ or $\bar{d}s$ **(1)**		**3**
4(d)(ii)	Mass-energy is conserved **Or** a comment about $E = mc^2$ Appropriate reference to colliding particles having mass and kinetic energy The extra mass comes from the kinetic energy.	**(1)** **(1)** **(1)**	**3**
	Total for question		**15**

Question Number	Answer	Mark
5(a)	(Total / sum of) Kinetic energy conserved	**(1)**
5(b)	These diagrams could appear in part c and should be credited in (b)   [allow first mark for any triangle or parallelogram ie do not insist on right angle] right angle labelled or approximately by eye / diagonal should be labelled "before" or "initial" or appropriately recognisable as incoming particle	**(1)** **(1)**
5(c)	KE as formula eg ½ mu^2 = ½ mv^2 + ½ ms^2 / $p^2/2m = p^2/2m + p^2/2m$ Recognition of "Pythagoras"	**(1)** **(1)**
5(d)(i)	Electric field Does work on proton/applies a force /repel/attract qV / Fd / Eq	**(1)** **(1)** **(1)**
5(d)(ii)	Mass of incoming proton larger (than rest mass) Due to moving near speed of light/high speed/high energy/relativistic Alt answer : image not in plane of two protons after the event	**(1)** **(1)** **(2)** **(max 2)**
5(e)	Out of the plane of paper	**(1)**
	Total for question	**11**

Question Number	Answer		Mark
6(a)	Arrow(s) downwards	**(1)**	**1**
6(b)	Use of $E = V/d$ Use of $F = EQ$ $F = 5.1 \times 10^{-16}$ N Example of calculation $F = (160\text{ V} \times 1.6 \times 10^{-19}\text{ C})/ 5.0 \times 10^{-2}\text{ m}$ $F = 5.12 \times 10^{-16}$ N	**(1)** **(1)** **(1)**	**3**
6(c)	Between the plates there is an acceleration/force which is vertical/upwards Constant horizontal velocity Outside the plates no (electric) field /force acts **Or** Outside the plates speed so large that gravitational effect negligible	**(1)** **(1)** **(1)**	**3**
6(d)(i)	Release of (surface) electrons due to heating	**(1)**	**1**
6(d)(ii)	Use of $E_k = ½mv^2$ Use of $V = W/Q$ p.d. = 410 V Example of calculation $E_k = 9.11 \times 10^{-31}\text{ kg} \times (1.2 \times 10^{7}\text{ m s}^{-1})^2/2$ $E_k = 6.56 \times 10^{-17}$ J p.d. = $(6.56 \times 10^{-17}\text{ J})/(1.6 \times 10^{-19}\text{ C})$ p.d. = 410V	**(1)** **(1)** **(1)**	**3**
	Total for question		**11**

Question Number	Answer	Mark
7(a)	At least 3 parallel straight lines ALL Equispaced (except ignore a large gap in middle) [be firm] Arrow left to right	**(1)** **(1)** **(1)**
7(b)	Use of eV [eg 1.6 x10^{-19} or 2000/4000] (=) ½ mv^2 Use of 2000	**(1)** **(1)** **(1)**
7(c)	Use of $v = s/t$ [eg = 1.5 / 23 (x 10^{-6})] (= 65000) Sub into previous equation m = 1.5 x 10^{-25} kg	**(1)** **(1)** **(1)**
7(d)	Some of the molecules in sample will travel further/less/not midway Duration of laser pulse Might emerge not horizontal Molecules may be doubly/integer ionised Time very small Not perfect vacuum / collides with other molecules	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(max2)**
	Total for question	**11**