1 A charged spherical conductor has a radius r. An electric field of strength E exists at the surface due to the charge.

What is the potential of the spherical conductor?

A $r^2 E$ ⬭

B $r E^2$ ⬭

C $\frac{E}{r}$ ⬭

D $r E$ ⬭

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ $\times r$

$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$

$\therefore Er$

(Total 1 mark)

2 A particle of mass m and charge q is accelerated through a potential difference V over a distance d.

What is the average acceleration of the particle?

A $\frac{qV}{md}$ ⬭

B $\frac{mV}{qd}$ ⬭

C $\frac{V}{mqd}$ ⬭

D $\frac{dV}{mq}$ ⬭

energy gained = qV

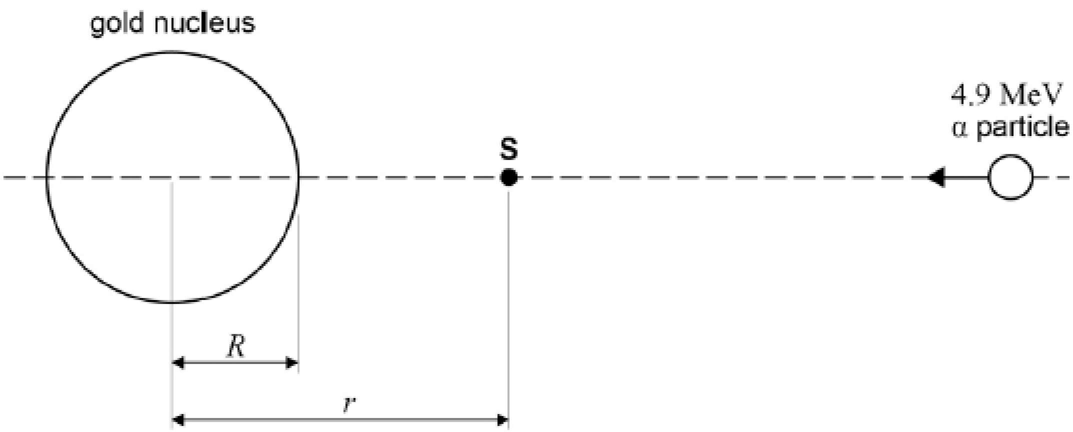
$\therefore qV = F \times d$

$\Rightarrow F = \frac{qV}{d}$

$\frac{F}{m} = a \quad \therefore a = \frac{qV}{md}$

(Total 1 mark)

3 An α particle with an initial kinetic energy of 4.9 MeV is directed towards the centre of a gold nucleus of radius R which contains 79 protons. The α particle is brought to rest at point **S**, a distance r from the centre of the nucleus as shown in the diagram below.



(a) Calculate the electric potential energy, in J, of the α particle at point **S**.

EPE = 4.9 MeV = $4.9 \times 10^{6} \times 1.6 \times 10^{-19}$ J

electric potential energy = 7.84×10^{-13} J

(2)

(b) Calculate r, the distance of closest approach of the α particle to the nucleus.

EPE = $7.84 \times 10^{-13} = \frac{1}{4\pi\varepsilon_0 r} Q_1 Q_2$

r = 4.64×10^{-14} m

(3)

(c) Determine the number of nucleons in the gold nucleus. $R = R_0 A^{1/3}$

R, radius of the gold nucleus = 7.16 × 10^{-15} m

R_0 = 1.23 × 10^{-15} m

$$\frac{7.16 \times 10^{-15}}{1.23 \times 10^{-15}} = A^{1/3}$$

number of nucleons = 197

(3)

(d) The target nucleus is changed to one that has fewer protons. The α particle is given the same initial kinetic energy.

Explain, without further calculation, any changes that occur to the distance r. Ignore any recoil effects.

It would reduce as F ↓ (since protons down) so needs more distance for same EK to convert to EPE

(2)

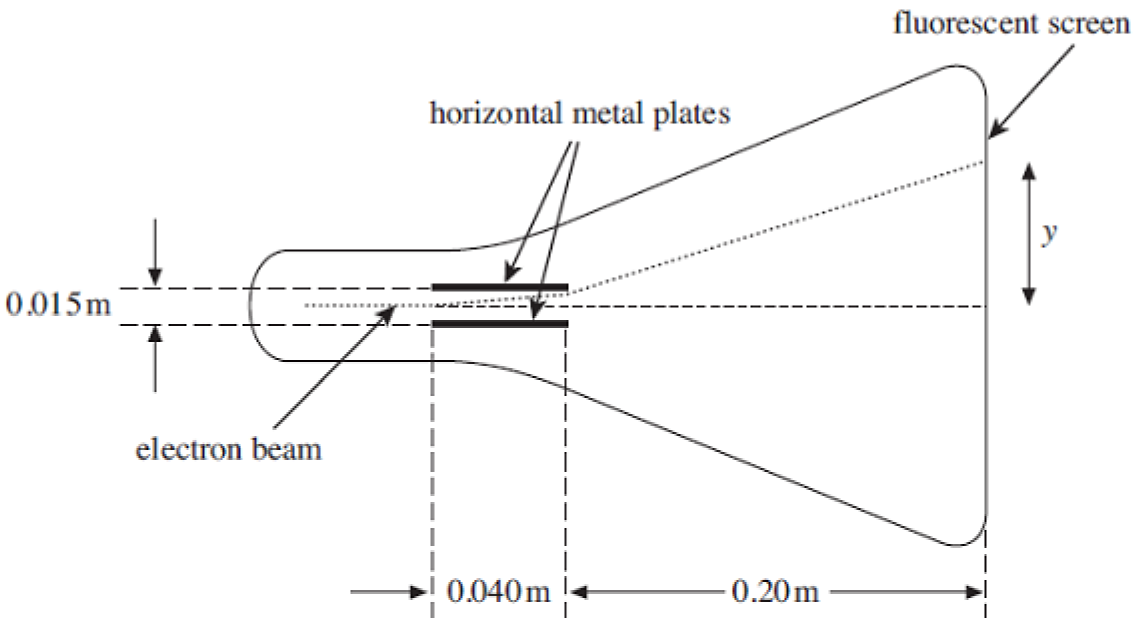
(Total 10 marks)

4 (a) Describe how a beam of fast moving electrons is produced in the cathode ray tube of an oscilloscope.

small coil is heated and electrons boil off by thermionic emission. These negative electrons are accelerated towards a positive anode

(3)

(b) The figure below shows the cathode ray tube of an oscilloscope. The details of how the beam of electrons is produced are not shown.



The electron beam passes between two horizontal metal plates and goes on to strike a fluorescent screen at the end of the tube. The plates are 0.040 m long and are separated by a gap of 0.015 m. A potential difference of 270 V is maintained between the plates.An individual electron takes 1.5×10^{-9} s to pass between the plates.The distance between the right-hand edge of the plates and the fluorescent screen is 0.20 m.

(i) Show that the vertical acceleration of an electron as it passes between the horizontal metal plates is approximately 3.2×10^{15} ms^{-2}.

$E = \frac{V}{d}$ $\quad \frac{F}{m} = a$ $\quad q$

$E = eV \Rightarrow \frac{eV}{d} = F \Rightarrow \frac{eV}{md} = a$

(3)

3.16×10^{15} ms^{-2}

(ii) Show that the vertical distance travelled by an electron as it passes between the horizontal metal plates is approximately 3.6 mm.

$s = ut + \frac{1}{2}at^2$

$= \frac{1}{2} \times 3.16 \times 10^{15} \times (1.5 \times 10^{-9})^2$

3.555×10^{-3} m

(2)

(iii) Show that the vertical component of velocity achieved by an electron in the beam by the time it reaches the end of the plates is approximately 4.7×10^6 m s^{-1}.

$v = u + at = 3.16 \times 10^{15} \times 1.5 \times 10^{-9}$

4.74×10^6 m/s

(2)

(iv) Calculate the vertical displacement, *y*, of the electron beam from the centre of the screen. Give your answer in m.

$v = \frac{d}{t}$ Speed leaves plates $= \frac{0.04}{1.5 \times 10^{-9}} = 26.76 \times 10^6$ m/s

Time to arrive at screen $= \frac{0.2}{26.7 \times 10^6} = 7.5 \times 10^{-9}$ s

vertical displacement ______________________ m

(3)

(Total 13 marks)

$\therefore d = 7.5 \times 10^{-9} \times 4.74 \times 10^{6}$

$= 35.55 \times 10^{-3}$ m

add to 6ii $= 0.039$ m

Mark schemes

1 **D**

[1]

2 **A**

[1]

3 (a) 1eV = 1.6×10^{-19} J

kinetic energy = $1.6 \times 10^{-19} \times 4.9 \times 10^{6} = 7.8(4) \times 10^{-13}$ J ✓

ke lost = pe gained = $7.8(4) \times 10^{-13}$ J ✓

2

(b) using $V = Q / 4\pi\varepsilon_0 r$ and $E_p = qV$

$r = qQ/4\pi\varepsilon_0 E_p$ ✓

$= (2 \times 1.6 \times 10^{-19})(79 \times 1.6 \times 10^{-19})/4\pi \times 8.85 \times 10^{-12} \times 7.84 \times 10^{-13}$ ✓

$r = 4.67(4.64) \times 10^{-14}$ m ✓

3

(c) $A = (R/R_0)^3$ ✓

$= (7.16 \times 10^{-15} / 1.23 \times 10^{-15}\ \text{m})^3$ ✓

= 197 placed on the dotted line ✓

3

(d) *r* gets smaller ✓

less force so needs to travel further to lose same initial ke ✓

Fewer protons means that r will be smaller when alpha particle has the same electrostatic potential energy (as initial kinetic energy)

2

[10]

4 (a) thermionic emission / by heating

B1

cathode heated / heating done by electric current / overcoming work function

B1

Must mention anode for third mark

anode which is positive wrt cathode / accelerated by electric field between anode and cathode

B1

3

(b) (i) one relevant equation seen: $E = V/d$ / $F = Ee$ / $a = F/m$

B1

Equation should be in symbols

$$a = \frac{1.6 \times 10^{-19} \times 270}{9.1 \times 10^{-31} \times 0.015} \quad / \; F = 2.88 \times 10^{-15}$$

B1

Substitution may be done in several stages

3.16×10^{15} (m s^{-2})

B1

Must be more than 2 sf

3

(ii) $s = (ut) + \frac{1}{2} at^2$ or $v = u + at$ and $s = v_{av}t$ OR $s = vt$ used

B1

Appropriate symbol equation seen and used for 1st mark

3.56×10^{-3}m

B1

Expect at least 3 sf but condone 3.6 for candidates who use $a = 3.2 \times 10^{15}$

2

(iii) $v = u + at$ / $v = at$ $v^2 = u^2 + 2as$ used

B1

May also use $eV = \frac{1}{2}mv^2$

4.74×10^6 m s^{-1} to at least 3 sf

B1

Allow 4.8 (2 or more sf) – consistent with use of $a = 3.2 \times 10^{15}$

2

(iv) $t = 7.5 \times 10^{-9}$ s seen or used

C1

May use ratios for 1st 2 marks: $s_v/s_h = v_v/v_h$ *C1*

3.53 × 10^{-2} *(m)* *A1*

3.53 × 10^{-2} (m) **ecf** for wrong *t*

A1

adds 3.56 × 10^{-3} (m) to their 3.53 × 10^{-2}

B1

clipped with b(i) and b(ii)

Allow reasonable rounding

3

[13]