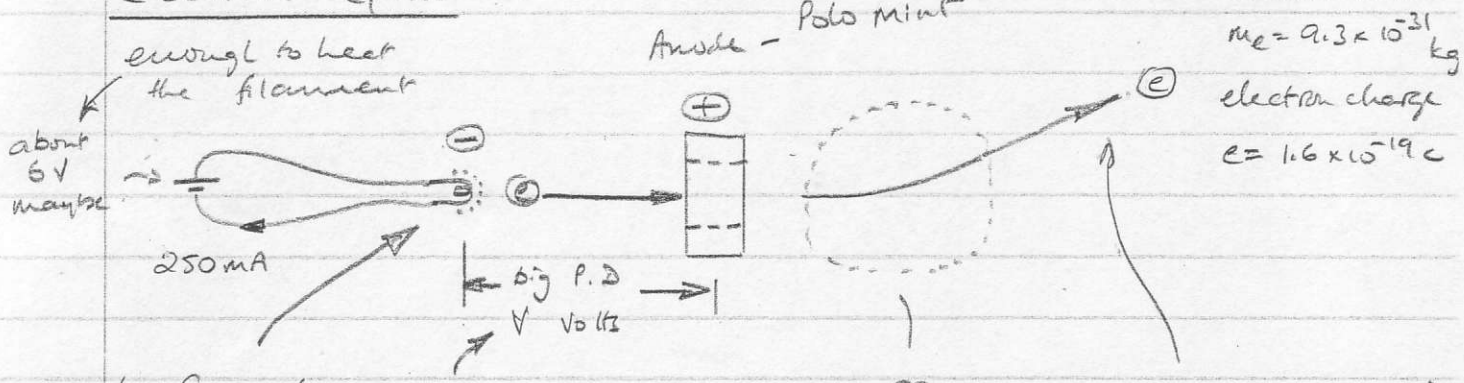
Particle Accelerators 1/3

Physics A2

A. Electron Gun — as in a TV or PC monitor



① hot filament, electrons vibrated just outside the metal surface

② electron accelerated by large p.d towards the + anode

Elec. P.E. → K.E

$eV = \frac{1}{2} m_e v^2$

③ electron "steered" by mag. field

④ electron carries on flying in a straight line through the vacuum

Questions

1. What power is supplied to the filament?

2. The filament is tungsten wire, diameter 0.08 mm, resistivity is 1.2×10^{-6} Ωm. How long is the tungsten filament?

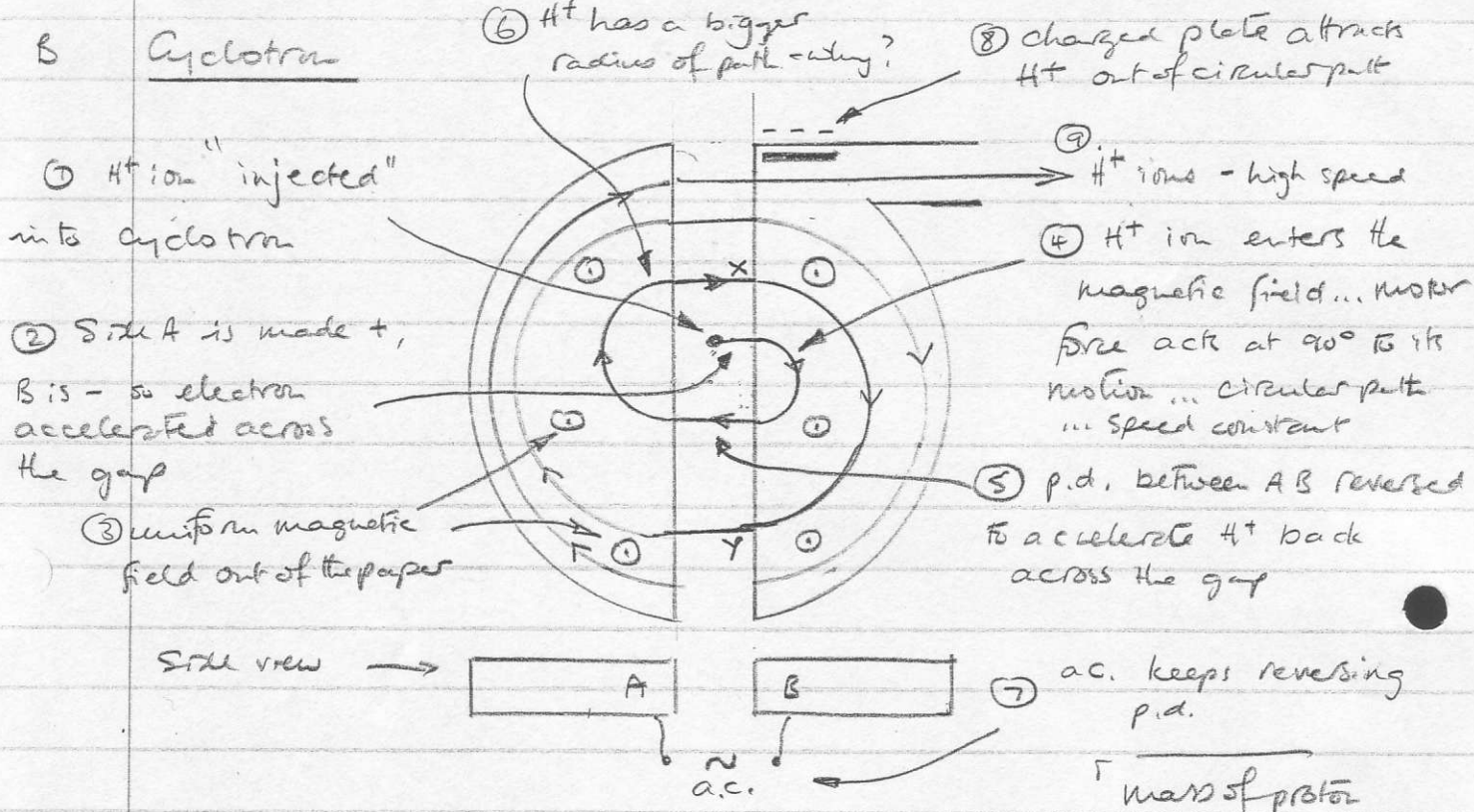
3. What electron velocity do you get with an accelerating p.d. of 1200 V?

4. What p.d. would accelerate an electron to the speed of light? (3×10^8 m/s)

5. What's the direction of the magnetic field in the diagram? Explain.

6. Why vacuum?

B Cyclotron



mass of proton
$m_p = 1.66 \times 10^{-27}$ kg
Stella @ 2.20 pint^{-1}
(and it's good!)
electron charge
$e = 1.6 \times 10^{-19}$ C

1. The gap between A and B is 5 cm, and the pd is 100,000 V.
   (a) What is the Electric field?
   (b) What is the H+ acceleration?

2. Explain why the H+ ion follows a circular path in the magnetic field – why don't it gain speed?

3. If the H+ ion has a speed of 3×10^7 m/s (at x) what magnetic flux density is needed to give it a path radius of 1.2 m?

4. How long does it take the H+ to follow the circular path + get to Y?

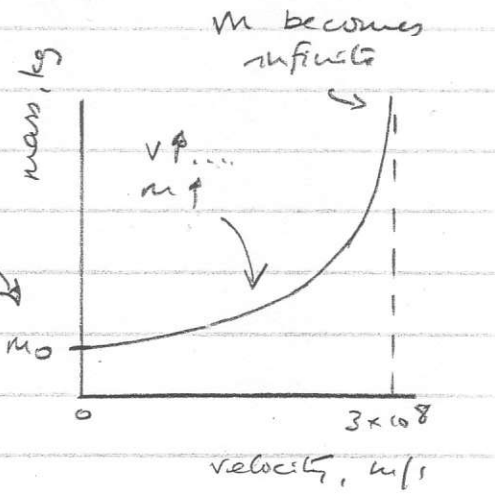
5. From this, estimate the frequency of ac needed.

6. Why do circular paths get progressively bigger?

TLM May 08

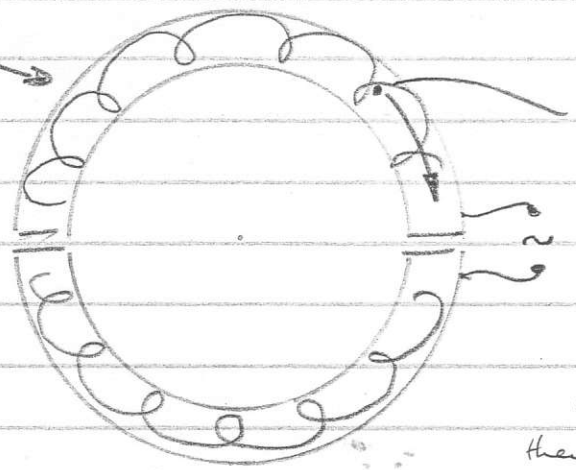
C. Relativity strikes.

The trouble is .... mass is not constant, but increases with velocity ... becoming infinite at the speed of light.



D The synchrotron – key points

$$m \text{ at } V \text{ m/s} = \frac{m_0 - \text{rest mass}}{\sqrt{1 - \frac{V^2}{c^2}}} \quad c = \text{light speed}$$



particles moving close to speed of light
(Say $V = 1 \times 10^8 = \frac{c}{3}$ and mass = 105% of m_0)

As V↑ .... m↑

So as particle cycle round they build up mass rather than speed

Synchrotrons used to store particles at v. high speeds until ready to be released – "storage rings"

SLN
Thy '02

ANSWERS

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Physics A2

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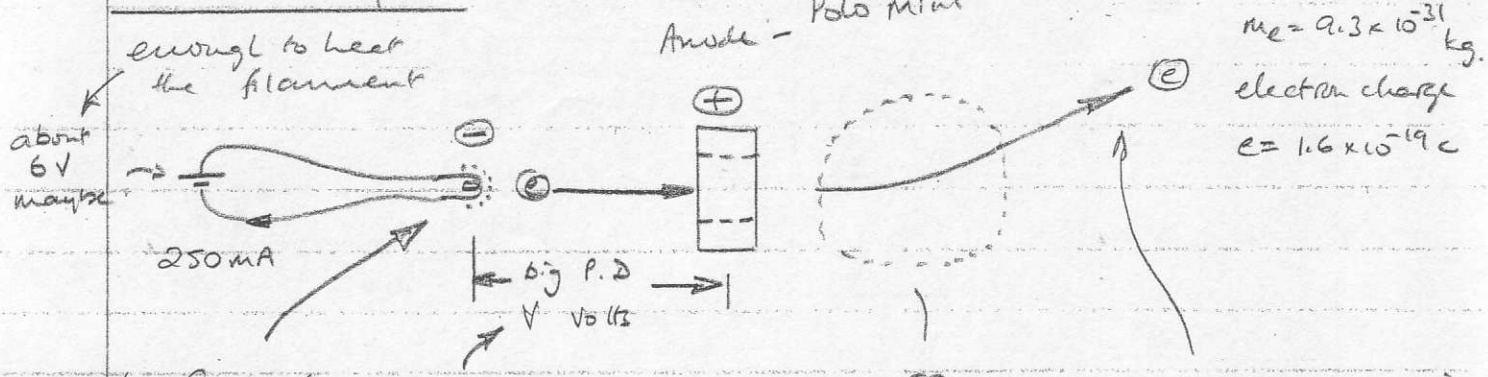


electron mass $m_e = 9.3 \times 10^{-31}$ kg.

electron charge $e = 1.6 \times 10^{-19}$ C

① hot filament, electrons vibrated just outside the metal surface

② electron accelerated by large p.d towards the + anode

Elec. P.E. → K.E

$eV = \frac{1}{2} m_e v^2$

③ electron "steered" by mag. field

④ electron carries on flying in a straight line through the vacuum

Questions

1. What power is supplied to the filament? $P = IV = 250 \times 10^{-3} \times 6$
$= 1.5$ W.

2. The filament is tungsten wire, diameter 0.08 mm, resistivity is 1.2×10^{-6} Ωm. How long is the tungsten filament?

$R = V/I = 6/0.25 = 24\ \Omega$

$A = \pi r^2 = \pi \times (0.04 \times 10^{-3})^2 = 5.03 \times 10^{-9}\ m^2$

$R = \rho l / A \Rightarrow l = RA/\rho = \frac{24 \times 5.03 \times 10^{-9}}{1.2 \times 10^{-6}}$

$= 0.100$ m $= 10$ cm. (1)

3. What electron velocity do you get with an accelerating p.d. of 1200 V? elec P.E. → KE

$eV = \frac{1}{2} m_e v^2 \Rightarrow v^2 = 2eV/m_e$

$= \frac{2 \times 1.6 \times 10^{-19} \times 1200}{9.3 \times 10^{-31}} \approx 4.13 \times 10^{14}$

$v = 2.03 \times 10^7$ m/s

4. What p.d. would accelerate an electron to the speed of light? (3×10^8 m/s)

$V = \frac{m_e v^2}{2e} = 9.3 \times 10^{-31} \times (3 \times 10^8)^2 / 2 \times 1.6 \times 10^{-19}$

$= 2.62 \times 10^5$ Volts

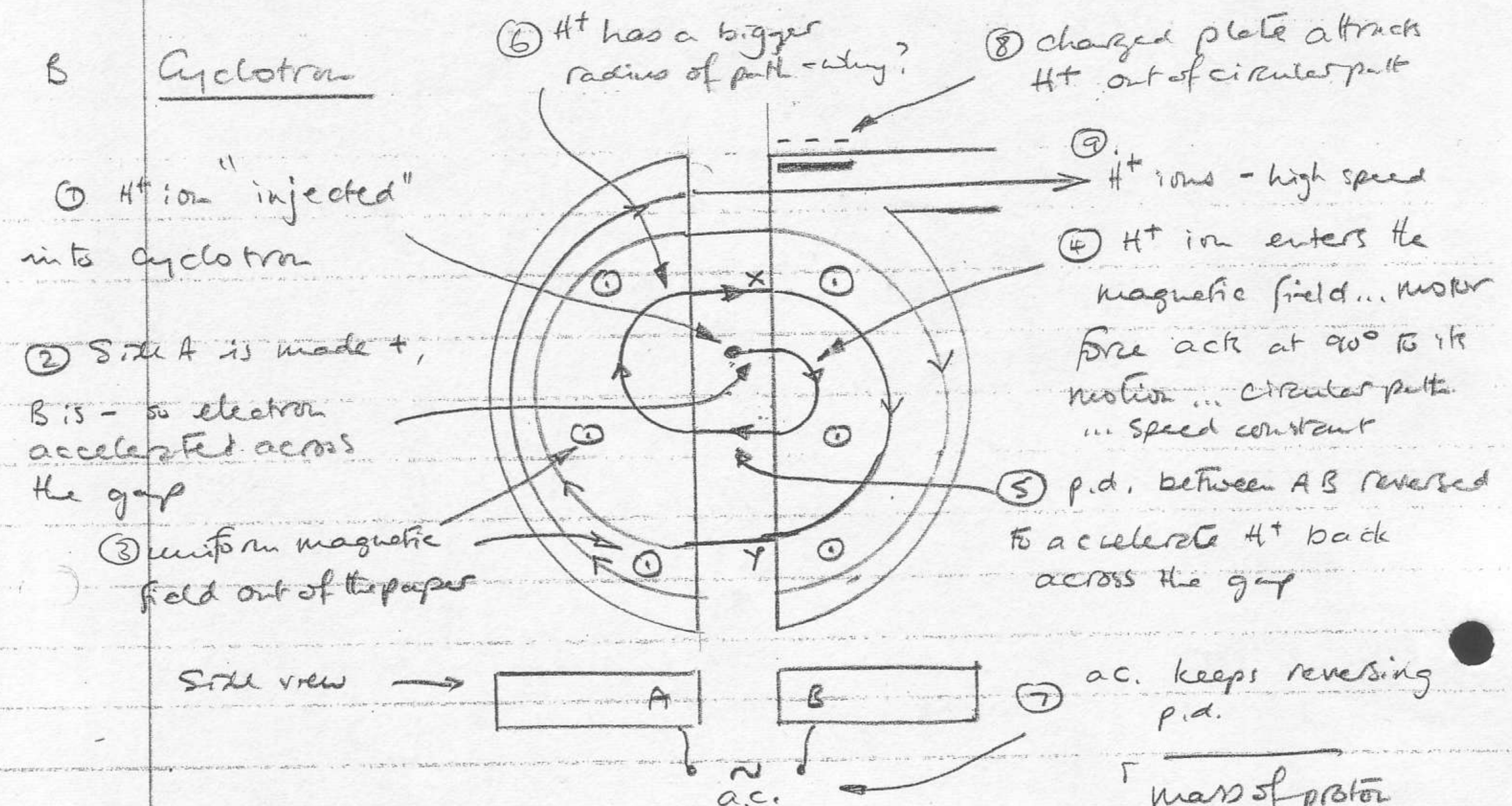
5. What's the direction of the magnetic field in the diagram? Explain.

6. Why vacuum?
no heavy molecules O_2, N_2 to collide with electrons.

ANSWERS!

Particle Accelerators ... 2/3 Physics A2

B Cyclotron



mass of proton
$m_p = 1.66 \times 10^{-27}$ kg
Stella @ 2.20 pint^{-1}
(and it's good!)
electron charge
$e = 1.6 \times 10^{-19}$ C

1. The gap between A and B is 5 cm, and the pd is 100,000 V.

(a) What is the Electric field? $E = V/d = 100{,}000 / 5 \times 10^{-2}$
$= 2 \times 10^{6}$ V/m N/C

(b) What is the H^+ acceleration? $F_E = QE = 1.6 \times 10^{-19} \times 2 \times 10^{6} = 3.2 \times 10^{-13}$
$a = F/m = \frac{3.2 \times 10^{-13}}{1.66 \times 10^{-27}} = 1.93 \times 10^{14}$ m/s^2

2. Explain why the H^+ ion follows a circular path in the magnetic field — why don't it gain speed?
F_m always at 90° to path .... changes direction, ... not speed ...
... constant force → circular path.
(to centre)

3. If the H^+ ion has a speed of 3×10^{7} m/s (at X) what magnetic flux density is needed to give it a path radius of 1.2 m?
$F = \frac{mv^2}{r}$
$F_m = F_c$
$BQv = \frac{m_p v^2}{r} \Rightarrow B = \frac{m_p v}{rQ} = \frac{1.66 \times 10^{-27} \times 3 \times 10^{7}}{1.2 \times 1.6 \times 10^{-19}} = 0.26$ Tesla (Wb/m^2)

4. How long does it take the H^+ to follow the circular path + get to Y?
$D = vt \Rightarrow T = D/v = \frac{\pi r}{3 \times 10^{7}} = \frac{\pi \times 1.2}{3 \times 10^{7}} = 1.26 \times 10^{-7}$ sec

5. From this, estimate the frequency of ac needed. $f = \frac{1}{1.26 \times 10^{-7}} = 7.96 \times 10^{6}$ Hz

6. Why do circular paths get progressively bigger?

Parts C and D — no answers needed.

RDT
Tony 02
+10.13