

- 10 (a) A cyclotron is a device used to accelerate ions to very high speeds. Fig. 10.1 shows a diagram of a cyclotron viewed from above.

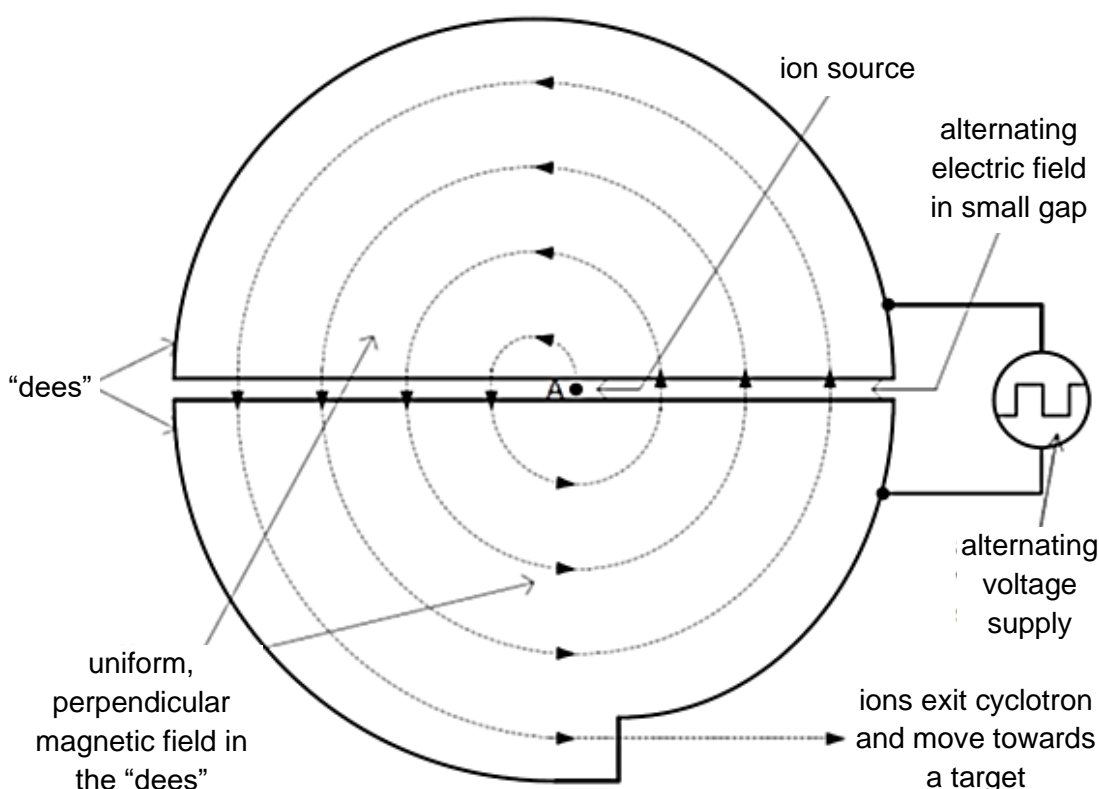


Fig. 10.1

During operation, the voltage supply provides an alternating potential difference to the small gap between the two semi-circular electrodes known as “dees”. This will ensure that the ions are accelerated each time they cross the gap.

On entering the “dees”, the uniform magnetic field caused the ions to move in a circular path. As the ions speed up, they travel in ever larger circles within the “dees”. Once the ions reach a sufficiently large speed, they exit through an outlet in one of the “dees”.

- (i) Show that the time T for an ion to complete one revolution is $\frac{2\pi m}{qB}$.

[2]

A helium nucleus of mass 6.88×10^{-27} kg and charge $2e$ is accelerated in the cyclotron by applying an alternating potential difference of 450 V across the “dees”. The magnetic flux density through the “dees” is 0.850 T.

- (ii) State the direction of the magnetic field within the dees such as to produce a path as shown in Fig. 10.1.

..... [1]

- (iii) Determine the frequency of the alternating voltage supply so that the helium nucleus is accelerated each time it crosses the gap between the “dees”.

$f =$ Hz [2]

- (iv) Determine the gain in kinetic energy of the helium nucleus after one revolution.

gain in K.E = J [2]

- (v) Hence, determine the speed of v of the helium nucleus after three revolutions.

$v =$ m s^{-1} [2]

- (vi) In Fig. 10.2, sketch the variation with time of the speed of the ion during the three revolutions. Note that values are not required.



Fig. 10.2

[2]

- (vii) Suggest an advantage of a cyclotron over linear accelerators which uses straight tubes with potential differences applied across them to accelerate ions.

.....
 [1]

- (b) A rolling axle of length 1.5 m is pushed along a pair of horizontal rails at a constant speed of 3.00 m s^{-1} . A 4.0Ω resistor is connected to the rails at points a and b as shown in Fig. 10.3. A 0.080 T uniform magnetic field is acting vertically downwards.

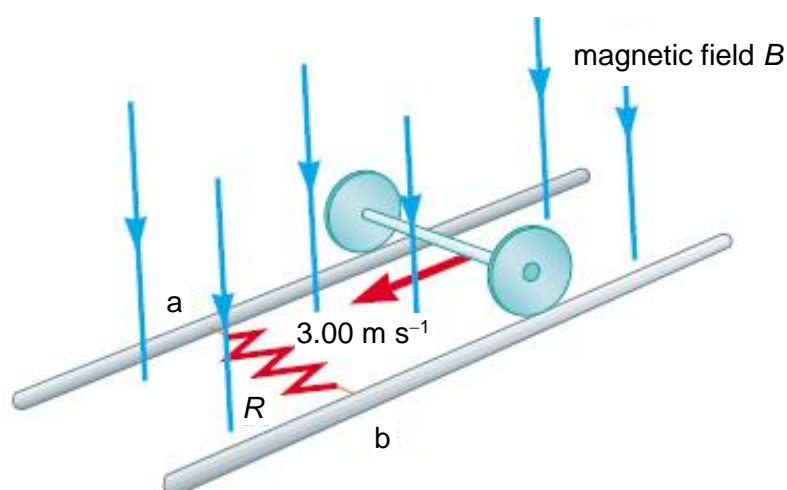


Fig. 10.3

- (i) Assuming that the rails and axle have negligible resistance, determine the induced current flowing through the resistor.

current = A [2]

- (ii) Label on Fig. 10.3, the end of the resistor with higher potential with a positive sign. [1]

- (iii) With reference to Lenz's law, explain why a horizontal force is required to keep the rod moving at constant speed.

.....

 [2]

- (iv) Hence, state how energy is conserved during the moving of the rod.

.....
 ...

 [1]

- (v) Determine the horizontal force that needs to be applied to the axle to keep it moving at a constant speed.

force = N [2]

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