6 Fig. 6.1 shows a plan view of a cyclotron, which is a device used to accelerate charged particles to high speeds. Protons are emitted between two semicircular discs called dees.

A uniform magnetic field is applied within the dees to cause the protons to move in a circular path. In between the dees there is a rapidly changing electric field applied that attracts the proton to the opposite dee.

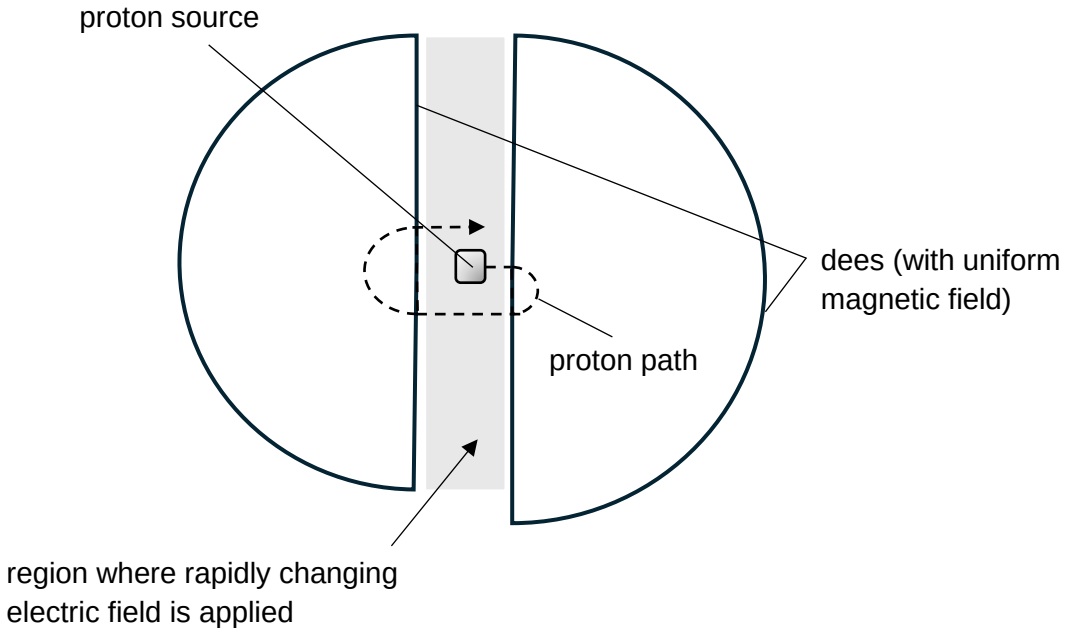

Fig. 6.1

(a) State the direction of the magnetic field in the dees.

…….. [1]

(b) Show that the time taken for a proton to enter and leave the semicircular dee is given by the expression:

$$t_D = \frac{\pi m}{Bq}$$

where m is mass of the proton mass, B is the magnetic flux density acting on the proton and q is the charge of the proton.

[3]

(c) State the effects of the magnetic field and electric field separately on the speed of the proton.

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…….. [2]

(d) State the expression for the time interval between the change in direction of the electric field.

……..... [1]

(e) The proton source in Fig. 6.1 is now replaced by another source that emits particles that have the same mass as a proton but are oppositely charged.

State and explain the effect, if any, on the path and the value of t_D in **(b)** when **it first enters** the magnetic field compared to that of a proton.

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…….. [3]