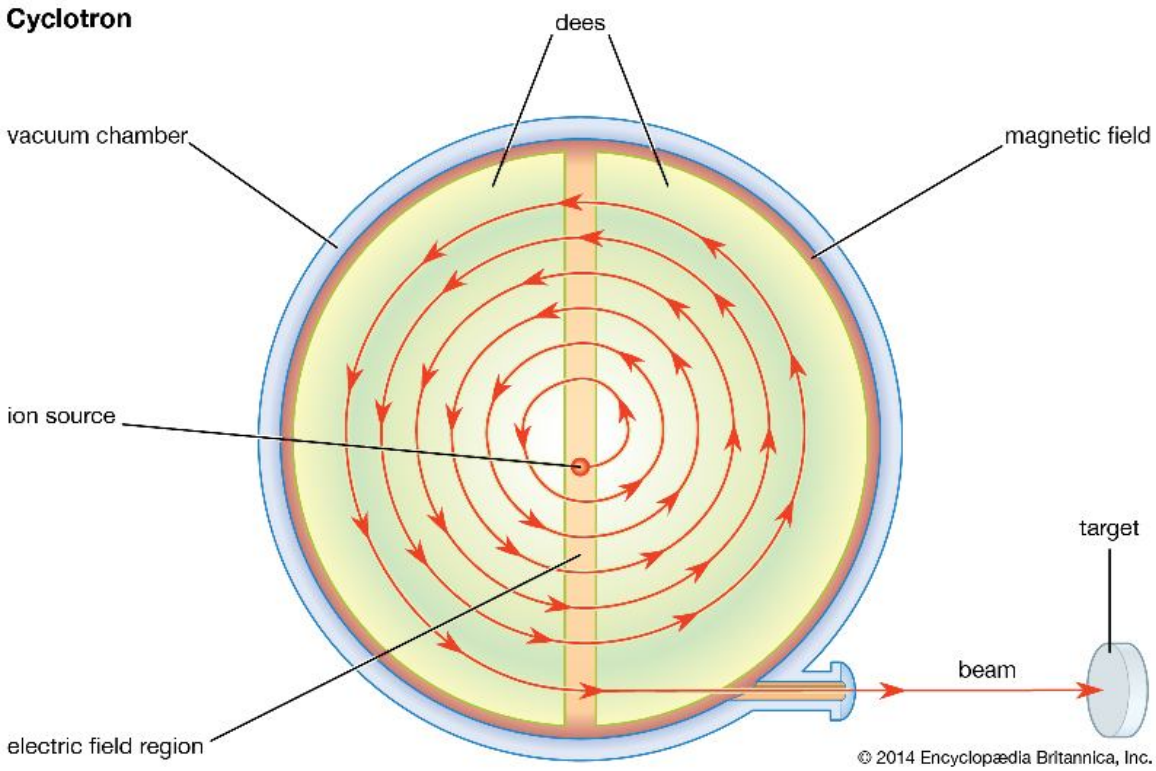
Cyclotron

Cyclotron can be defined as a type of particle accelerator in which charged particles accelerate outwards from the centre along a spiral path. These particles are held to a spiral trajectory by a static magnetic field and accelerated by a rapidly varying electric field.



Working Principle of Cyclotron

- A cyclotron accelerates a charged particle beam using a high frequency alternating voltage which is applied between two hollow “D”-shaped sheet metal electrodes known as the “dees” inside a vacuum chamber.
- The dees are placed face to face with a narrow gap between them, creating a cylindrical space within them for particles to move. Particles are injected into the center of this space.
- Dees are located between the poles of electromagnet which applies a static magnetic field B perpendicular to the electrode plane.
- The magnetic field causes the path of the particle to bend in a circle due to the Lorentz force perpendicular to their direction of motion.

- An alternating voltage of several thousand volts are applied between the dees. The voltage creates an oscillating electric field in the gap between the dees that accelerates the particles.
- The frequency of the voltage is set so that particles make one circuit during a single cycle of the voltage. To achieve this condition, the frequency must be set to particle's cyclotron frequency.

Expression for Cyclotron Frequency

$$f=qB/2\pi m$$

where,
B is the magnetic field strength
Q is the electric charge of the particle
m is the relativistic mass of the charged particle

Expression for Particle Energy

The energy of the particles depends on the strength of the magnetic field and the diameter of the dees.

The centripetal force required to keep the particles in a curved path is given by the formula:

$$Fc=mv^2 /R$$

The force is provided by the Lorentz's force F_B on the magnetic field B

$$FB=qvB$$

Equating these equations, we get

$$mv^2 /R =qvB$$

$$v=qBR /m$$

Hence, the output energy of the particles is given by the expression

$$E= q^2B^2R^2 / 2m$$