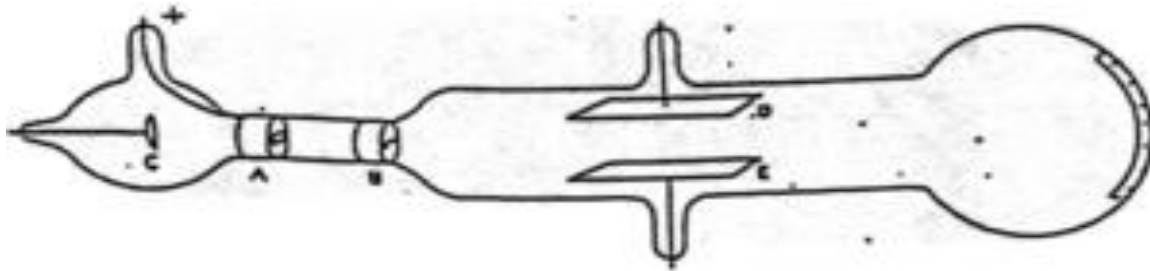# CYCLOTRON

NOBEL PRIZE 1939-ERNEST LAWRENCE

WHAT IS A PARTICLE ACCELERATOR?

Any device that accelerates charged particles to very high speeds using electric and/or magnetic fields.

This piece of the accelerator helped in the development of the atom bomb. Built in 1937 by Philips of Eindhoven it currently resides in the National Science Museum in London.

Thomson's illustration of the Crookes tube by which he observed the deflection of cathode rays by an electric field (and later measured their mass to charge ratio). Cathode rays were emitted from the cathode C, passed through slits A (the anode) and B (grounded), then through the electric field generated between plates D and E, finally impacting the surface at the far end
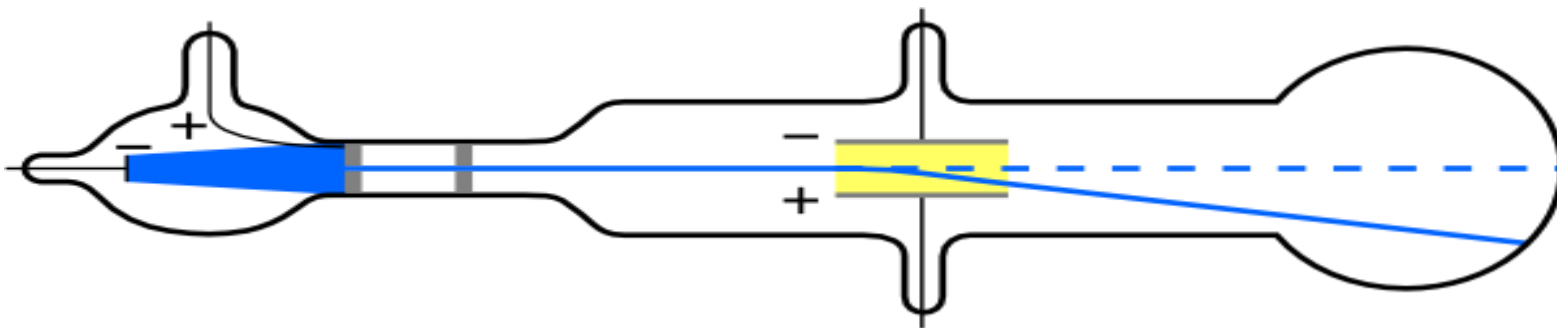
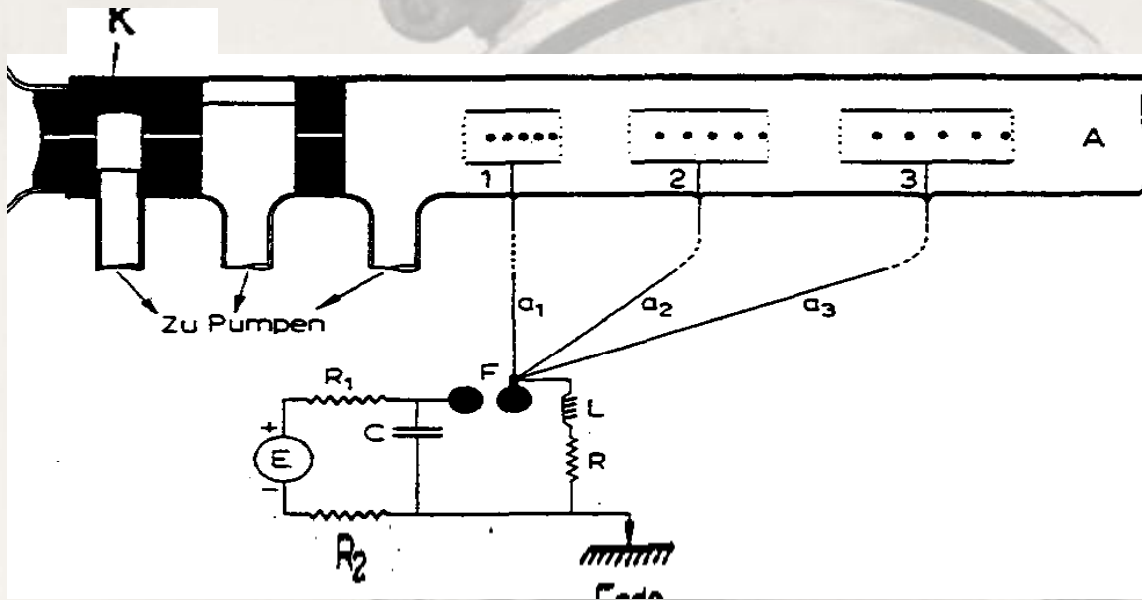# THE LINEAR ACCELERATOR

Diagram of linear accelerator from Professor G. Ising's pioneer publication (1924) of the principle of multiple acceleration of ions.

Principle of operation of a linear accelerator. A great many electrodes are separated by small gaps and placed along a straight line. There is no magnetic field that changes the direction of the particles being accelerated. When particles move inside the field-free region of a given electrode, the direction of the accelerating electric field is reversed so that particles are always accelerated in the gaps between the electrodes.
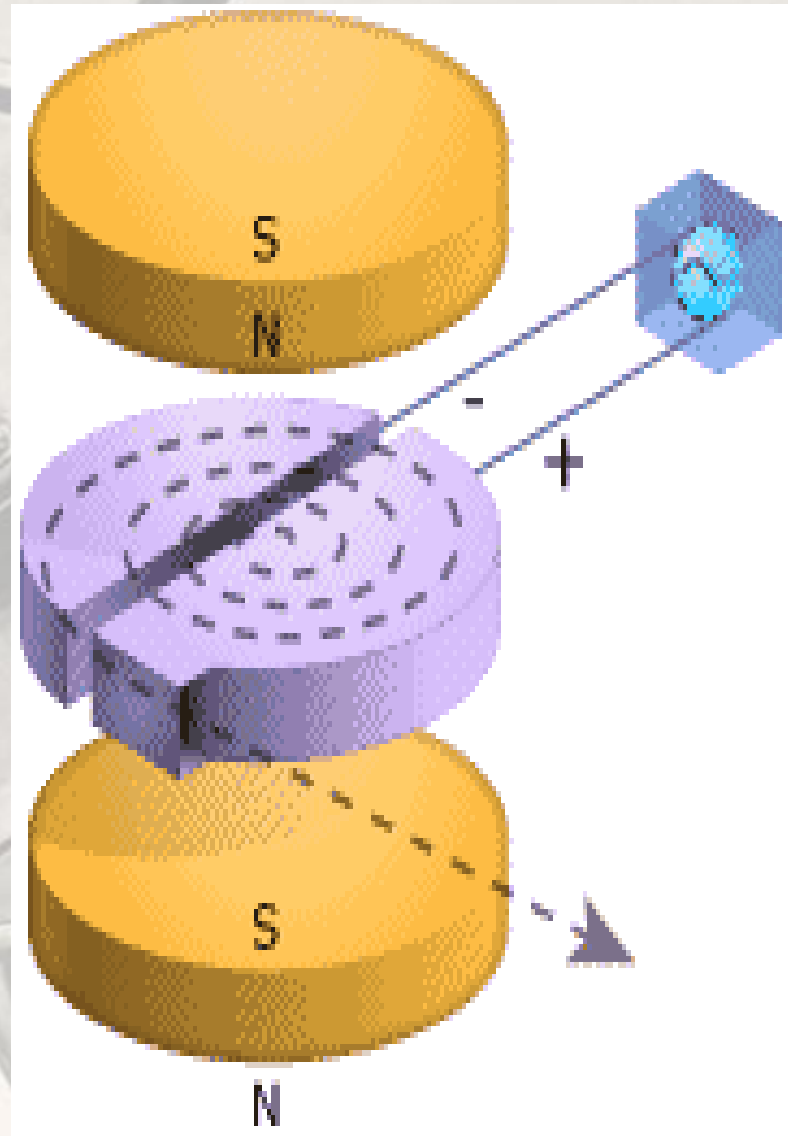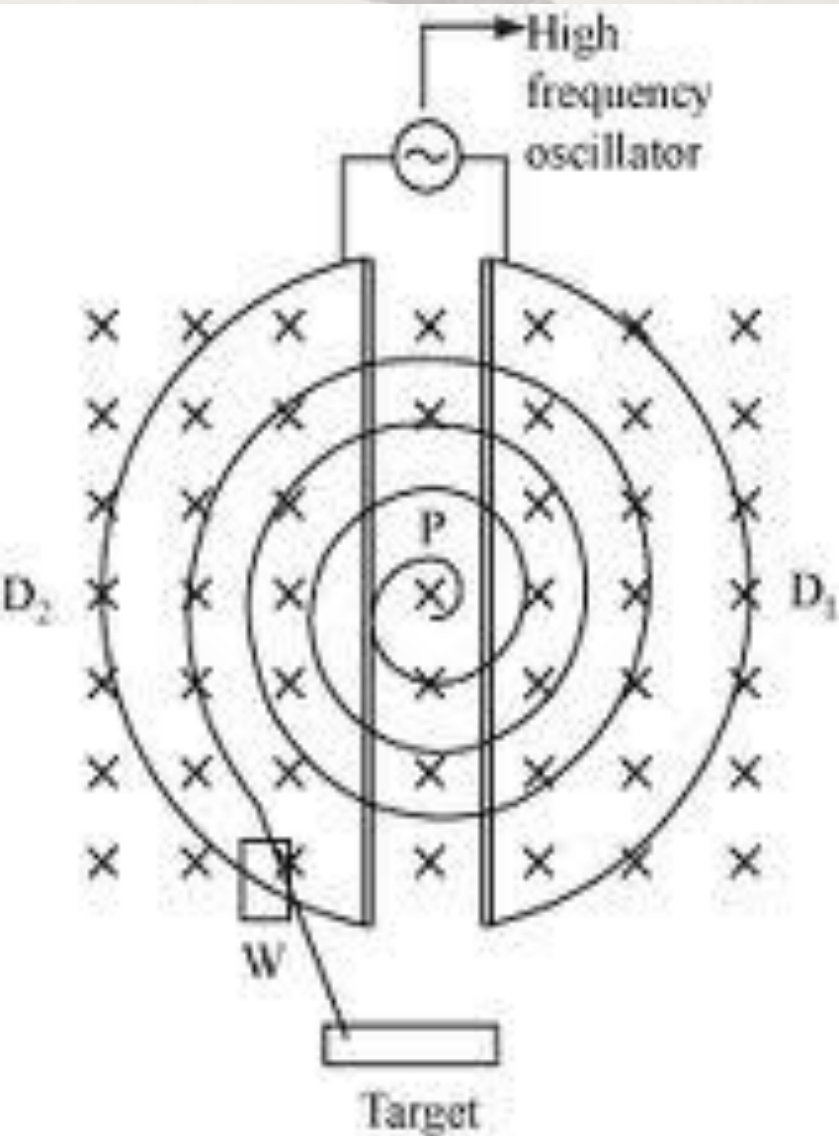
LAWRENCE'S CYCLOTRON
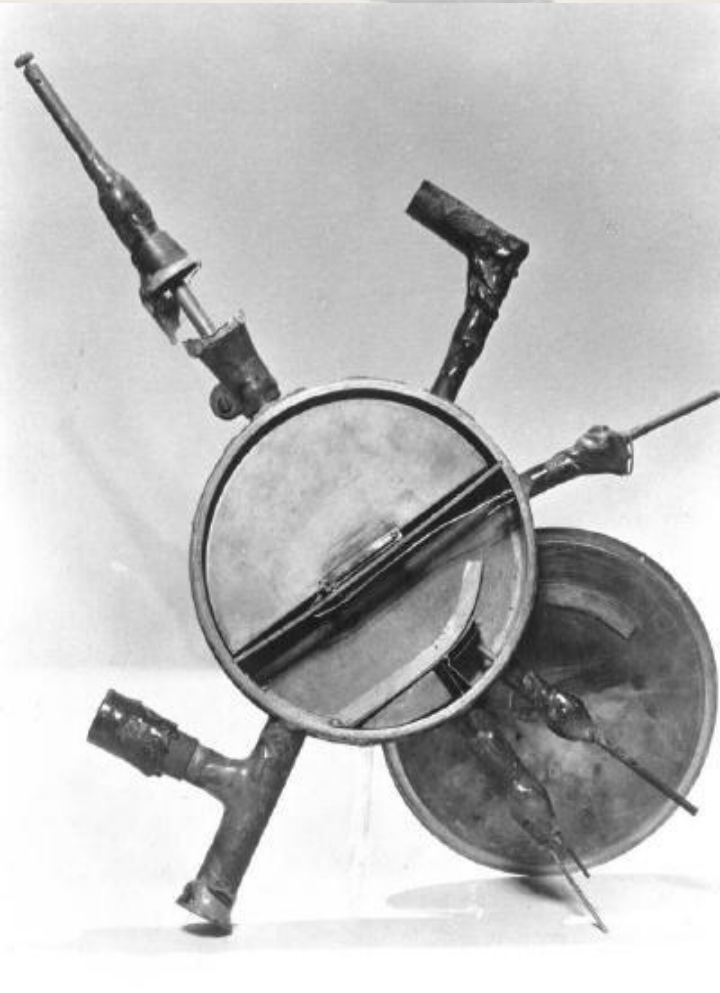
❖In 1929, Ernest Lawrence developed the first circular accelerator

❖This cyclotron was only 4 inches in diameter, and contained two D-shaped magnets separated by a small gap

❖An oscillating voltage created an electric field across the small gap, which accelerated the particles as they went around the accelerator

WORKING OF THE CYCLOTRON

MATHEMATICS OF A CYCLOTRON
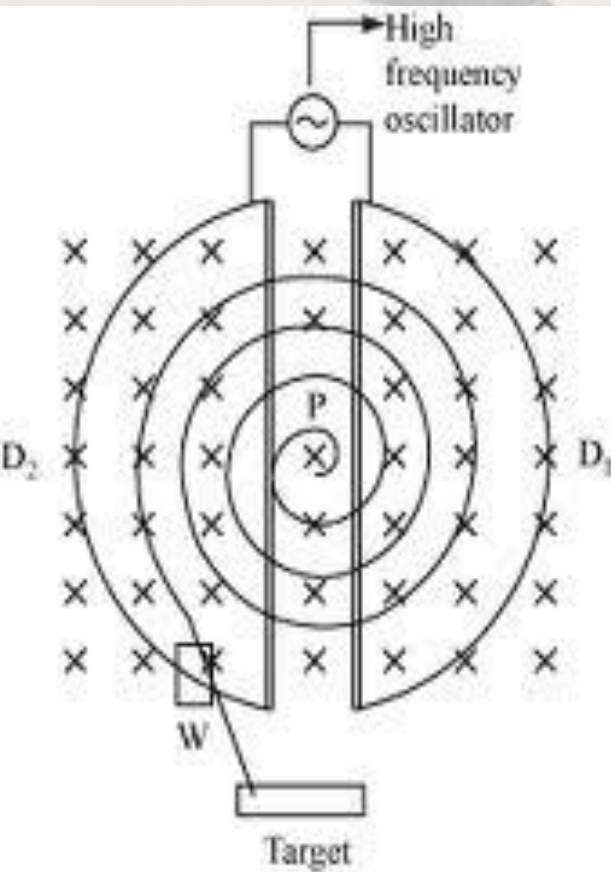
❖ The proton moves in a circular path of radius:
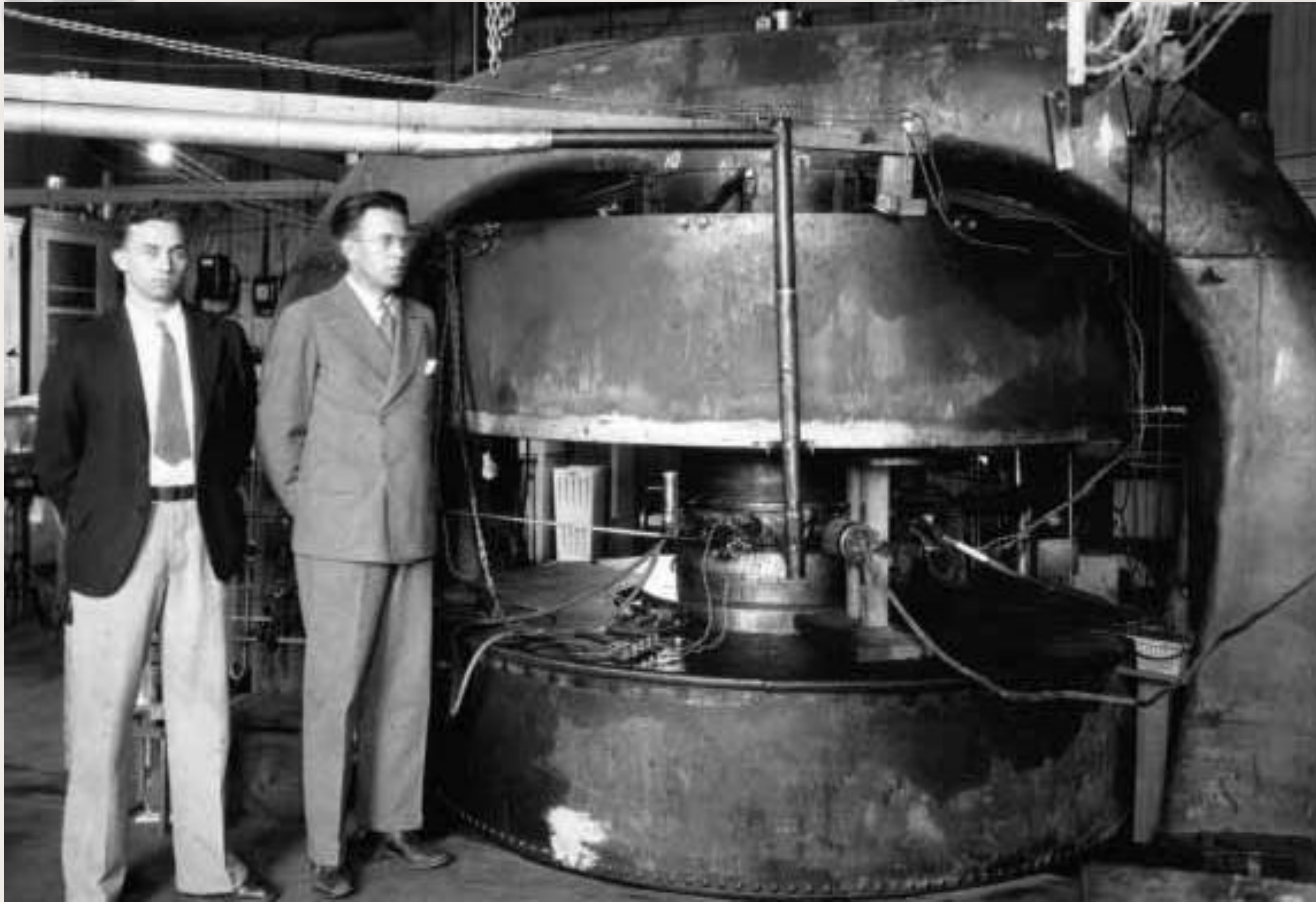
$$r = mv/qB$$

❖ Frequency

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

❖ Resonance condition

$$f = f_{osc}$$

Or

$$qB = 2\pi m f_{osc}$$

M. Stanley Livingston and Ernest O.Lawrence, with their 27-inch cyclotron at Berkeley Radiation Laboratory. (Courtesy Lawrence Berkeley National Laboratory)

LIMITATIONS OF THE CYCLOTRON

❖ **Cannot accelerate neutral particles**

❖ **Not useful in accelerations of electrons**

❖ **With increased velocity, the beam gets out of phase with the oscillating electric field.**

APPLICATIONS OF THE CYCLOTRON

❖ **Important research tools in nuclear physics**

❖ **Used for medical purposes e.g. radiation surgery and therapy**

The separated sector cyclotron in Vancouver, provides 600 MeV negative hydrogen ions and it is the largest of all cyclotrons. The picture shows the gap inside which the ions are accelerated.