Development of accelerators:

- 1870 · William Crookes- *Cathode rays*
- 1895 · J.J. Thomson- *Electrons.*
- 1896 · Röngten- *X-rays*
- 1909 · Rutherford- *Scattering of alpha particle on a gold foil*
- 1929 · E. O. Lawrence- *Cyclotron* (circular device)
- 1931 · Robert Jemison Van de Graaff - *Van de Graaff accelerator*
- 1932 · John D. Cockcroft and Ernest Walton- *Cockroft-Walton generator*
- 1940 · Donald W. Kerst - *Betatrons*

Definition

"A particle accelerator is a device that uses electromagnetic fields to propel charged particles to high speeds and to contain them in well-defined beams."

- They built for different purpose such as radiotherapy, ion implantation, industrial and biomedical researching.

Basic Principle

- All accelerators are based on the same principle, A charged particle accelerates between a gap between two electrodes when there is a potential difference between them.

<u>The Largest particle accelerator in the world ????</u>

The largest and most powerful particle accelerator in the world are:

- The RHIC (Relativistic Heavy Ion Collider)
- The Large Hadron Collider (LHC) at CERB

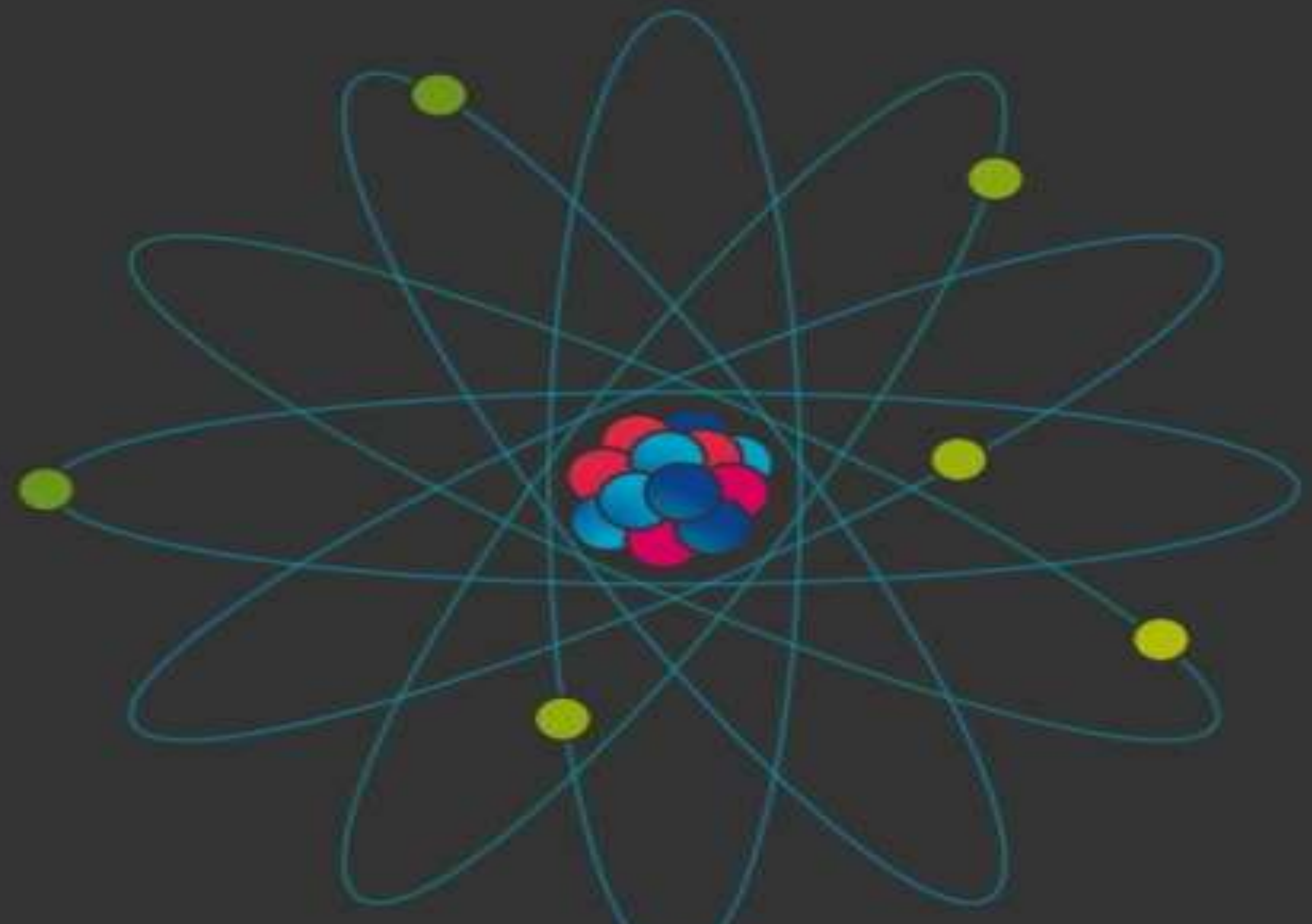
(Coastal Engineering Research Board)

- The Tevatron, are used for experimental particle physics.

Working of Particle accelerator

THE PARTICLES

On a basic level, particle accelerators produce a beam of charged particles that can be used for a variety of research purposes. Most often, the beam of particles is comprised of protons or electrons, charged subatomic particles. Sometimes, whole atoms of elements like gold or uranium, which are much heavier, are used.



Proton
A stable subatomic particle with a positive charge.

Neutron
A neutral subatomic particle with no electric charge.

Electron
A stable subatomic particle with a negative charge, which is regarded as the basic unit of electric charge.

Atom
The smallest unit into which matter can be divided while still maintaining the characteristic properties of a chemical element.

THE ACCELERATOR

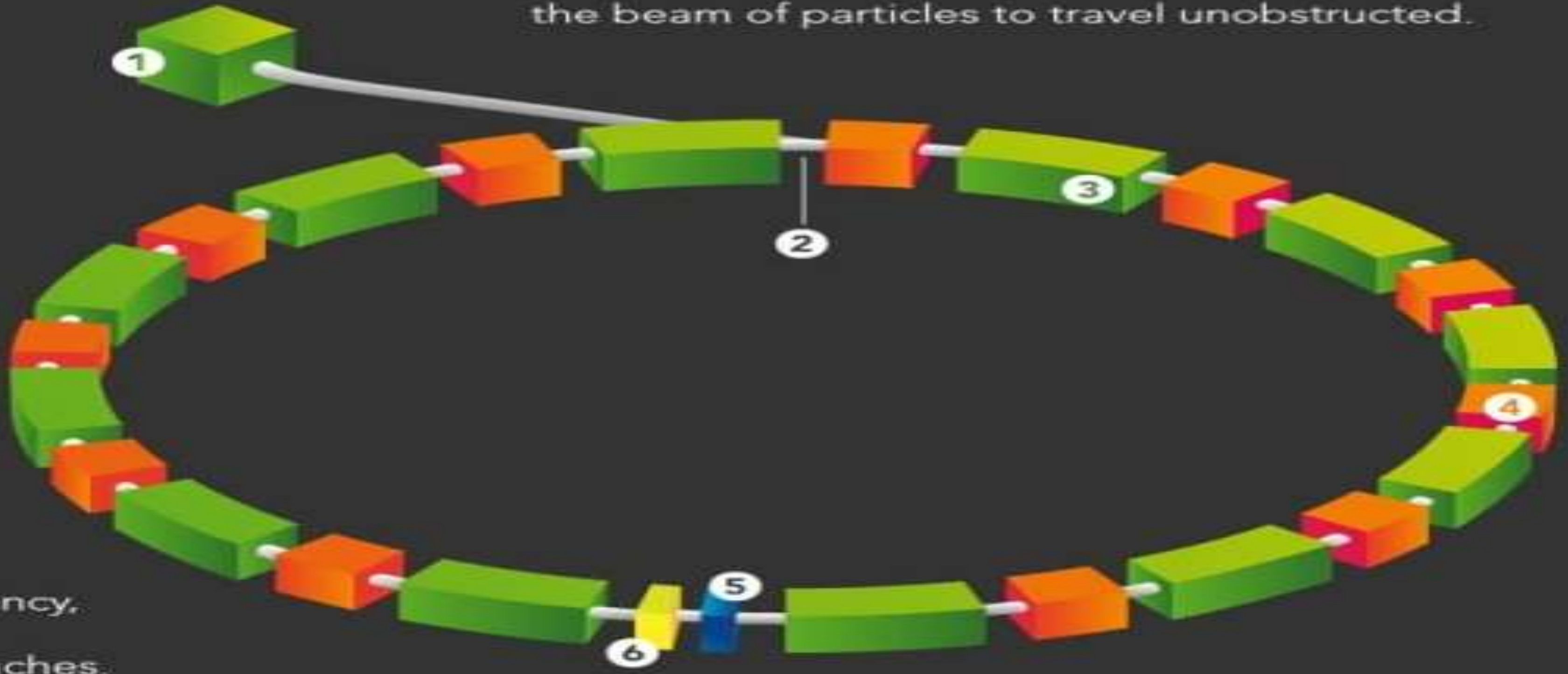
In a circular particle accelerator, the particles are repeatedly propelled through a circular pipe. With each pass, the strength of the electric fields increases, accelerating the beam of particles. When the particles have reached the desired energy level, a target is placed into their path, where a particle detector observes the collision.

1 Particle Source

The particle source provides the particles, such as protons or electrons, that are to be accelerated.

2 Beam Pipe

The beam of particles travels in a vacuum inside this metal pipe. It is important to maintain an air and dust free environment for the beam of particles to travel unobstructed.



3 Electromagnets

Electromagnets steer and focus the beam of particles while it travels through the vacuum tube.

4 Electric Fields

Electric fields spaced around the accelerator switch from positive to negative at a given frequency, creating radio waves that accelerate particles in bunches.

5 Targets

Particles can be directed at a fixed target, such as a thin piece of metal foil, or two beams of particles can be collided.

6 Detectors

Particle detectors record and reveal the particles and radiation that are produced by the collision between a beam of particles and the target.

Types of accelerators:

- Particle accelerators can be split into two fundamental types:

  1- electrostatic accelerators   2- oscillating field accelerators.

- **Electrostatic accelerators,** such as the **Cockcroft-Walton accelerator** and the **Van de Graaff accelerator** make use of what is known as an electrostatic field.

- Electrostatic fields are simply electric fields that do not change with time.

Types of accelerators:

- The main disadvantage of using electrostatic fields is that very large electric fields need to be generated to accelerate particles to experimentally useful energies.
- **The Oscillating Field accelerator,** This type of accelerator requires electric fields that periodically change with time.
- It has allowed high energy physicists to accelerate particles to extremely high energies.

Types of accelerators:

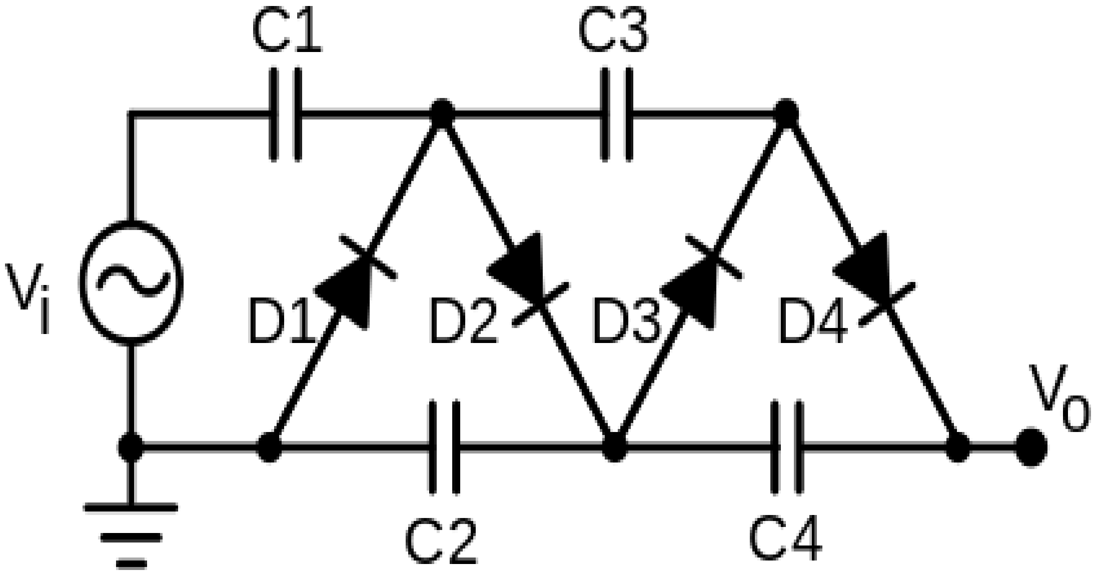
- Main categories of particle accelerators are detailed below:
- - The Cockcroft-Walton
- Van de Graaff Accelerators
- - The Linear Accelerator (Linac)
- - The Cyclotron
- - The Betatron
- - The Microtron
- - The Synchrocyclotron
- - The Synchrotron
- - The Storage Ring Collider

The Cockcroft-Walton

- In the early 1930’s, it was developed by John Cockcroft and Ernest Walton.
- The Cockcroft-Walton accelerator generated a high voltage by creating a complex electrical circuit called a **voltage multiplier cascade**, which became known as **Cockcroft-Walton generator**.

The Cockcroft-Walton

- Using their generator, Cockcroft & Walton were able to generate a voltage of **800kV (800,000V).**



The Cockcroft-Walton

- This voltage then accelerated protons along **an 8 foot vacuum tube**, where they then collided with a Lithium target.
- Cockcroft-Walton generators are still used in particle accelerators today for the initial acceleration of particles before they go on to larger accelerators.

Van de Graaff accelerator

- An eletrostatic machine used to accumulate charges on metal surface.
- A Van de Graaff accelerator consists of a large metallic

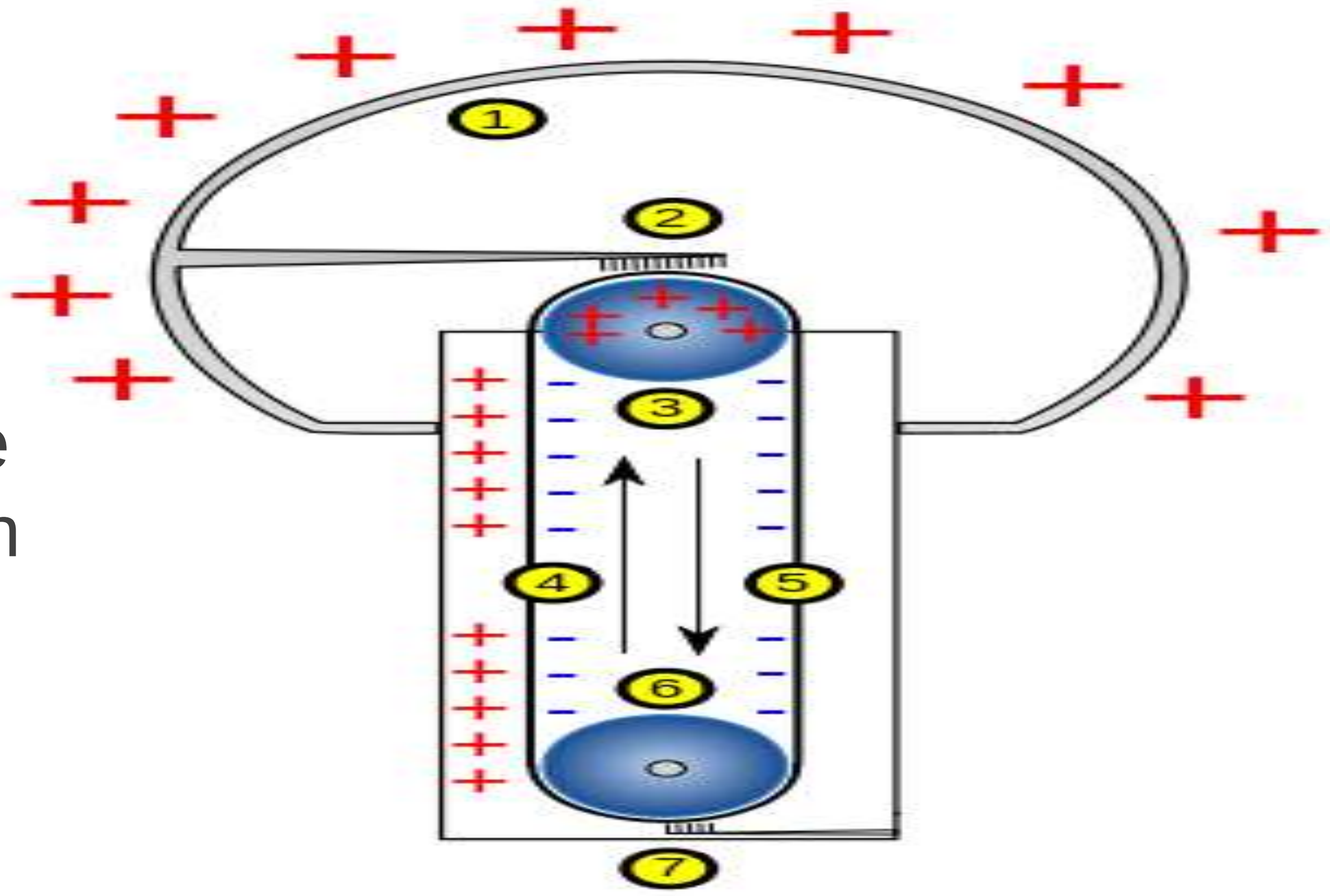
sphere (1).

- At the top of an insulating column. Within the column is a belt made from a conducting material (4 & 5) pulled taught over two pulleys (3 & 6).
- One of the pulleys is attached to an electric motor driving the belt (6), at either end of the belt is a brush of metallic wires (2 & 7),

Van de Graaff accelerator

- ➢ The lower brush (7) is attached to a voltage source which transfers a charge to the belt via the brush.

- ➢The belt then carries the charge up (4) to the second brush , which will transfer the charge to the large metal sphere known as the electrode.



Van de Graaff accelerator

- The charge build-up generated in the electrode results in a potential difference between the electrode and the ground.
- A particle can be accelerated using this potential difference, from the electrode, to the ground.

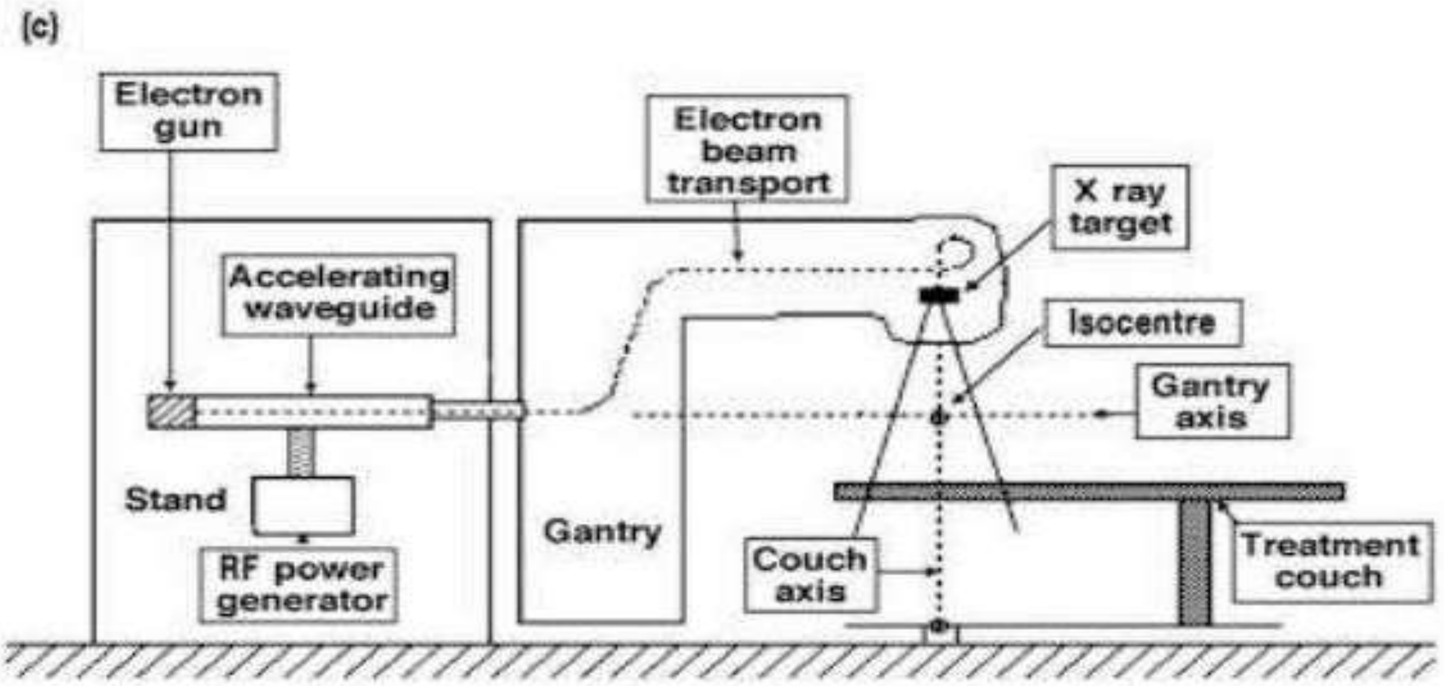
Linear accelerator

- The term linear accelerator means, charged particles travel in straight lines as they gain from an alternating electro-magnetic field.
- A linear accelerator (LINAC) is the device most commonly used for external beam radiation treatments for patients with cancer.

Working of Linear accelerator

- The linear accelerator uses microwave technology to accelerate electrons in a part of the accelerator called the "wave guide", then allows these electrons to collide with a heavy metal target. As a result of the collisions, high-energy x-rays are produced from the target.

LINAC (schematic diagram)



Linear accelerator

WHO OPERATES THIS EQUIPMENT ?

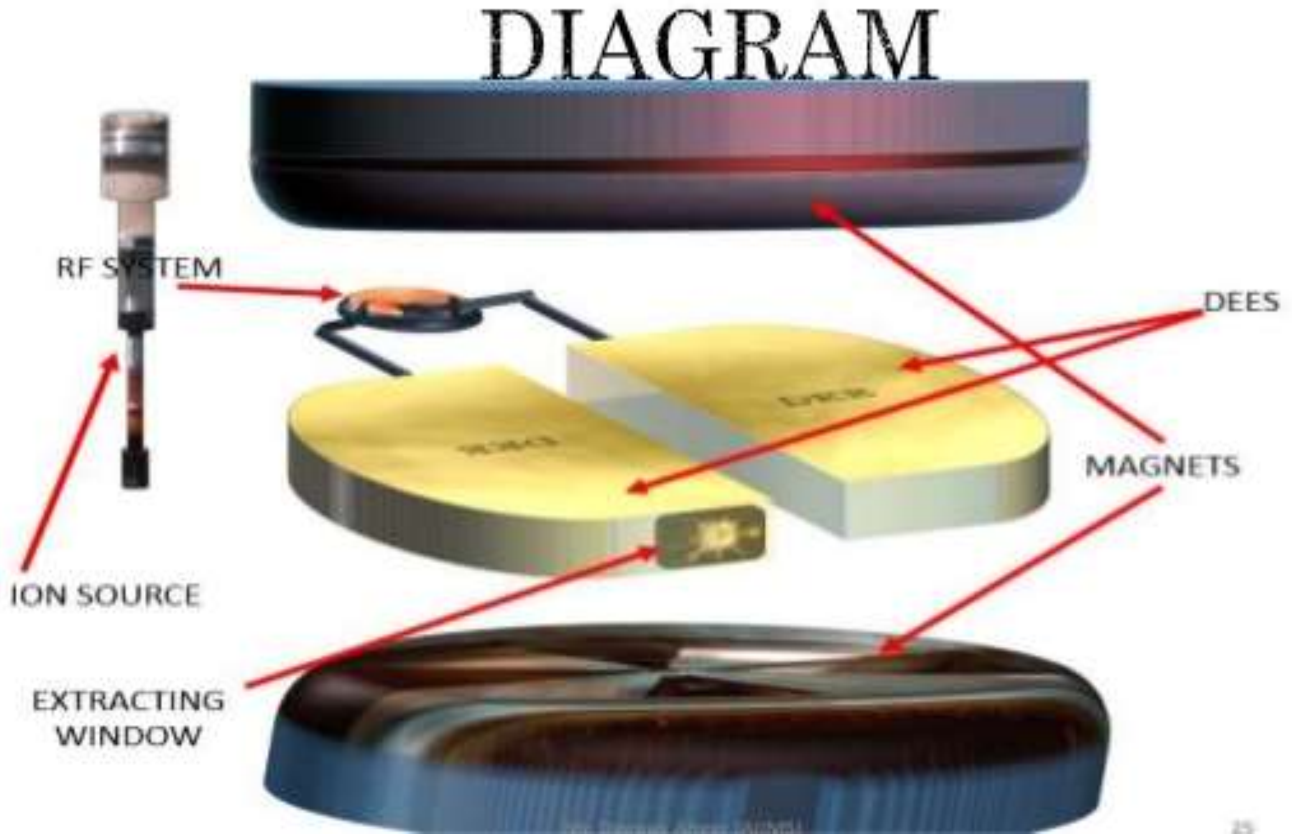
- The radiation oncologist .
- The medical radiation physicist.
- The dosimetrist .
- Radiation therapists .

Cyclotron accelerator

- E.O.Lawrence and M.S Livingston invented the cyclotron accelerator in 1934.
- "A **cyclotron accelerator** is a particle accelerator sends charged particles, which constantly accelerate through a "Dee" , through a circular path until they are (most likely) directed towards a designated target for a specific purpose."
- Lorentz's Force is the basic principle of Cyclotron.

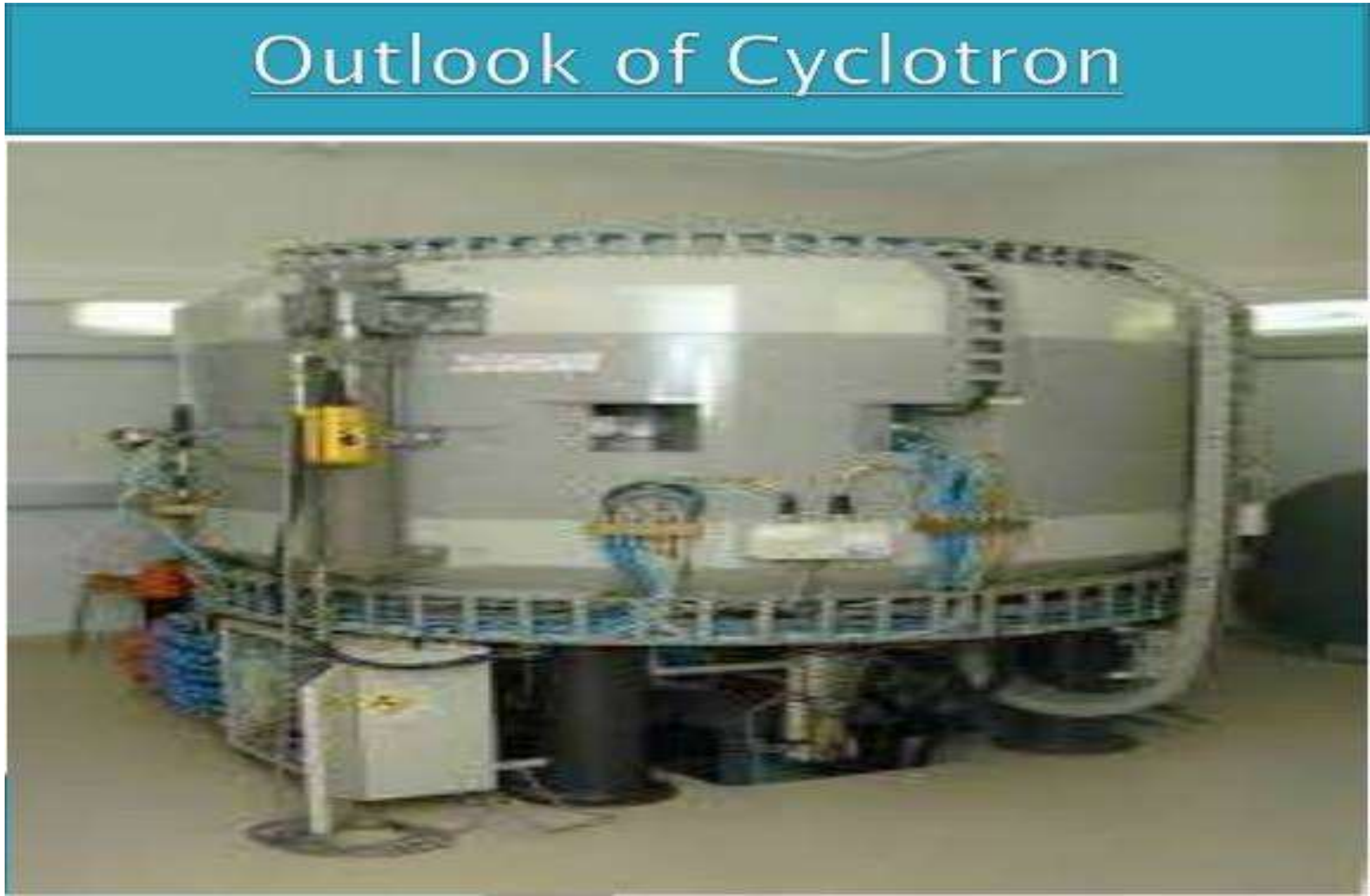
Cyclotron accelerator

- Basic Components of Cyclotron:
  - Magnetic system
  - Ion source system
  - Dees
  - RF system
  - Extraction system
  - Vaccum system
  - Target assembly



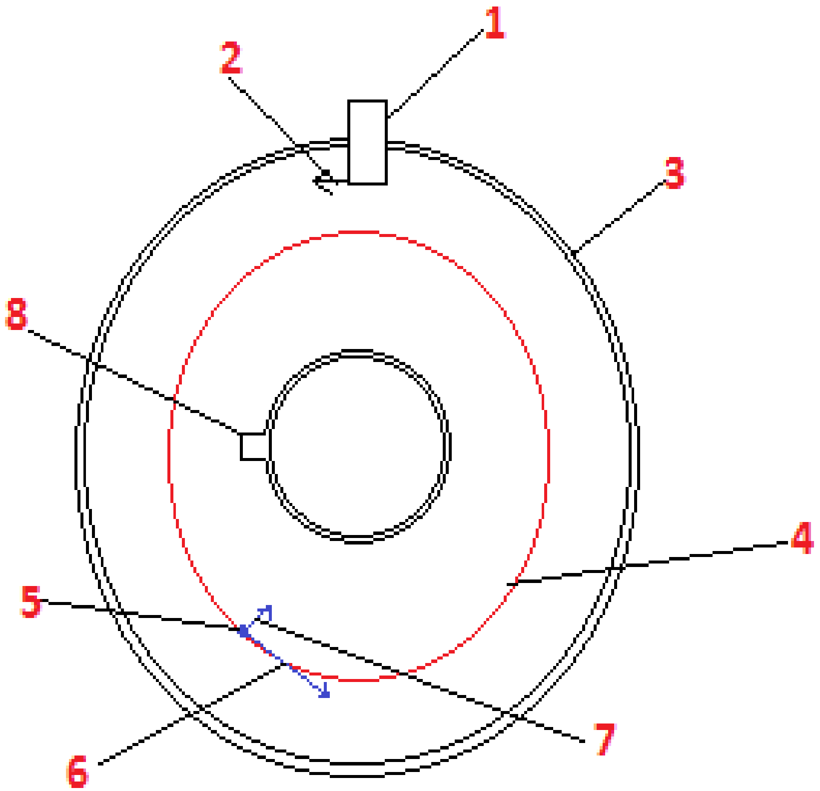
Cyclotron accelerator

- **Working :**
  - Production of charged particle
  - Acceleration of charged particle
  - Extraction of beam
  - Bombardment of target



The Betatron

- Invented in1940 by Donald Kerst.
- The development of the Betatron was driven by the demand for high energy X-rays and gamma rays.
- The Betatron consists of a main ring, a doughnut shaped vacuum chamber, known as the doughnut chamber (3) , in which electrons (2 & 5), produced by an electron gun (1) within the chamber, are accelerated.



The Betatron

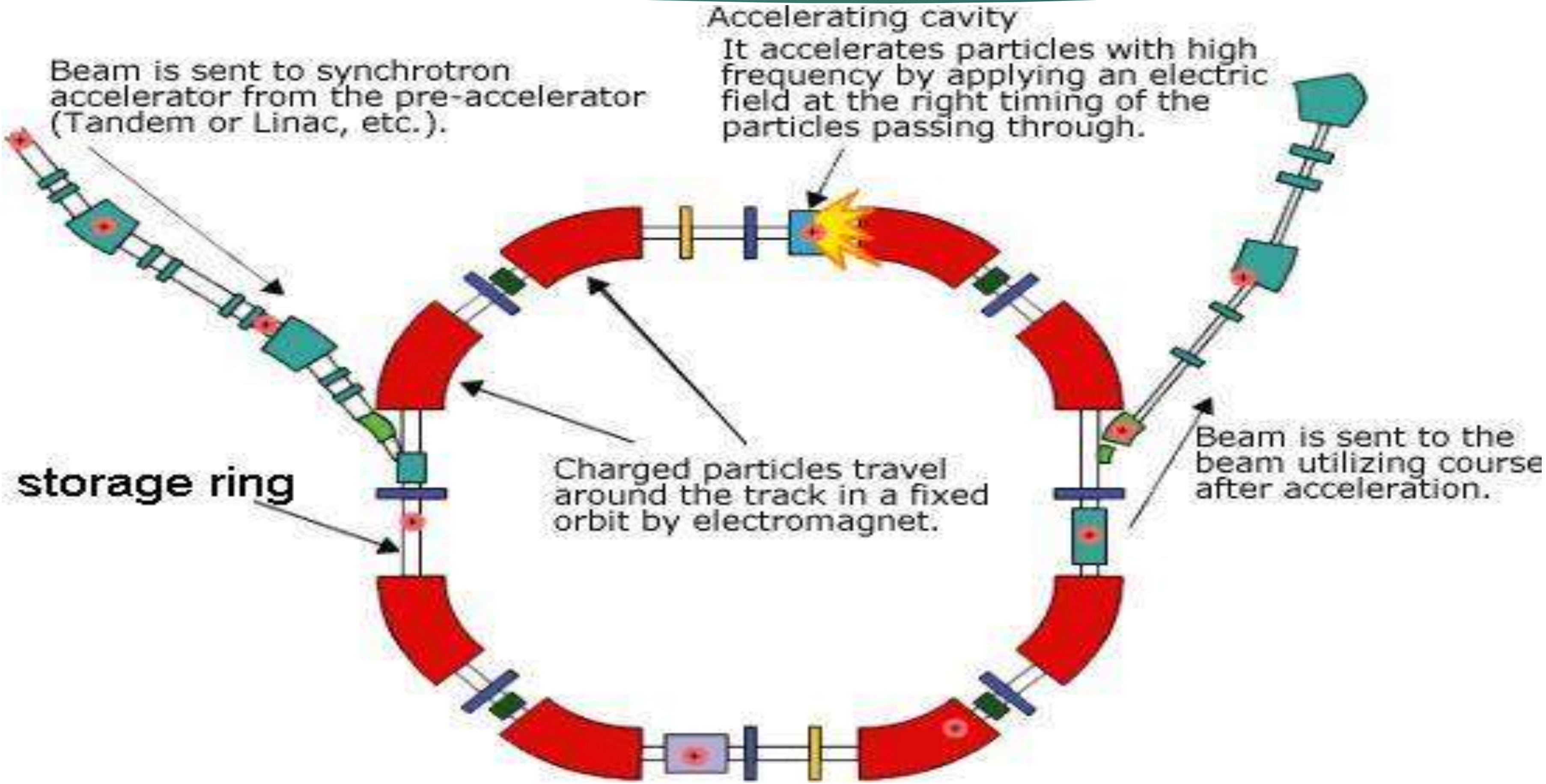
- The chamber is set up between the two poles of an electromagnet driven by an AC current which results in a constantly changing magnetic field.
- The changing magnetic field means a changing magnetic flux across the doughnut chamber which produces an electromotive force (6) which will accelerate the electrons.
- The electrons in the chamber maintain a constant radius of orbit (4) whilst being accelerated, due to the centripetal force (7) generated by the particle motion.
- Once accelerated, the electrons are directed out of the doughnut chamber, or inwards, towards a metal target (8) to produce X-rays.

Synchrotron

At very high energies, the particles travel close to the speed of light and their motion is now described by relativistic equations and their travel time is no longer the same for each semi-circle.

To overcome this, careful synchronisation is needed to make the electrodes change their polarity as the particles pass through each acceleration section. The magnetic field is increased to keep the moving particles in a moving circle of constant radius.

The Synchrotron

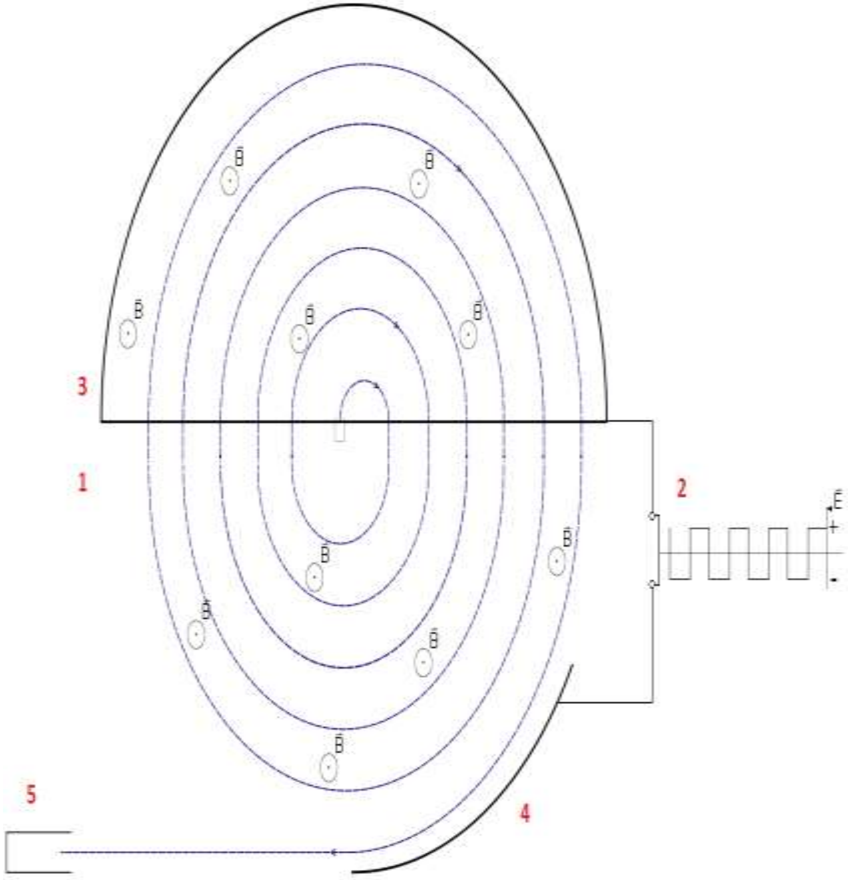


The Synchrocyclotron

- The Synchrocyclotron is a modification of the classic Cyclotron design developed to overcome the relativistic limitations on the classic Cyclotron
- The Synchrocyclotron differs from the classic Cyclotron in that the frequency of the AC voltage does not remain constant, it synchronises with the orbit frequency of the accelerated particle.

The Synchrocyclotron

- The modified Cyclotron had one of the D-shaped electrodes removed (1). The particle is accelerated in the same way as in a Cyclotron except that the RF generator responsible for producing the AC voltage which accelerates the particle is replaced with a variable frequency RF generator (2) so that the AC frequency can be synchronised with orbital frequency of the particle. The AC voltage is applied across the remaining D-shaped electrode (3) and a new deflecting electrode (4) which is responsible for directing the particle out of the accelerator and towards a target (5).



Applications of Particle accelerators:

- **Semi-conductors:**

  The semi-conductor industry relies on accelerator technology to implant ions in silicon chips, making them more effective in consumer electronic products such as computers, smart phones and MP3 players.

- **Clean air and water:**

  Studies show that blasts of electrons from a particle accelerator are an effective way to clean up dirty water, sewage sludge and polluted gases from smokestacks.

Applications of Particle accelerators:

- **Medical diagnostics:**

  Accelerators are needed to produce a range of radioisotopes for medical diagnostics and treatments that are routinely applied at hospitals worldwide in millions of procedures annually.

- **Shrink wrap:**

  Industry uses particle accelerators to produce the sturdy, heat-shrinkable film that keeps such items as turkeys, produce and baked goods fresh and protects board games, DVDs, and CDs.

Applications of Particle accelerators:

DNA research:

Synchrotron light sources allowed scientists to analyze and define how the ribosome translates DNA information into life, earning them the 2009 Nobel Prize in Chemistry. Their research could lead to the development of new antibiotics.

Cancer therapy:

When it comes to treating certain kinds of cancer, the best tool may be a particle beam. Hospitals use particle accelerator technology to treat thousands of patients per year, with fewer side effects than traditional treatments.