Nuclear Technology

The energy released by the change in the nucleus of atoms is known as nuclear energy.The changes in the nucleus of atoms is normally caused by either nuclear fusion or nuclear fission.

The technology that manipulates such changes in nucleus (nuclear reaction) of some specific elements and transform into energy is known as nuclear technology.

The energy released through the nuclear reaction is very high. For example, the fission of 1 kg of uranium-235 releases about 18.5 million kilowatt-hours heat.

Nuclear reactions naturally occur in chain reactions and hence keep releasing energy in continuity. In 1942, the Italian physicist Enrico Fermi first successfully produced the nuclear chain reaction.

What is Nuclear Fuel?

Nuclear fuel is the element that is used in nuclear power plants to produce heat to power the turbines.

Following are the major fuel elements −

- Uranium dioxide
- Plutonium
- Uranium nitride
- Uranium carbide
- Thorium

Application of Nuclear Technology

Following are the areas where Nuclear Technology is applied −

- Production of electric energy.
- Nuclear technology is also used in different industries. For example, manufacturing of plastics and in the sterilization of disposable products.
- Manufacturing of nuclear weapons for the defense forces of the country.
- Medicinal use. For example, radiotherapy for the treatment of malignant tumors.
- Frequently used in agricultural field to control pests, maximizing water resources, etc.
- Used to reduce the environmental and health consequences of large-scale use of fossil fuels.

Advantages of Nuclear Energy Production

Following are the Advantages of Nuclear Energy Production −

- Nuclear energy has the least impact on the environment, as it does not pollute air.
- Nuclear plant does not require a very large area for setup.
- Nuclear energy plant does not release greenhouse gases.
- Once constructed and made it operative, its maintenance cost is much cheaper

Disadvantages of Nuclear Energy Production

Following are the Disadvantages of Nuclear Energy Production −

- It is very expensive to set up a nuclear plant.
- Nuclear waste is very hazardous, as it remains radioactive for thousands of years.
- Though it is rare, but nuclear accident is highly fatal. For example, the Chernobyl disaster (about 30 thousand people died).

Important Points About Nuclear Power in India

Consider the following points about Nuclear Power in India −

- Nuclear power in India is the fourth-largest source of electricity after thermal, hydroelectric, and renewable sources (of electricity).
- India has 22 nuclear reactors operating in 8 nuclear power plants.
- The total installed capacity of nuclear power in India is 6780 MW. This produces 30,292.91 GWh of electricity.
- 6 reactors are under construction, which are expected to produce an additional 4,300 MW electricity.
- The nuclear power plant of Jaitapur (located in Maharashtra) is planned to start in collaboration with France. It is a 9900 MW project.
- The nuclear power plant of Kudankulam (located in Tamil Nadu) is an Indo-Russian collaboration. It is a 2000 MW project.
- The Apsara nuclear research reactor was India's first nuclear reactor inaugurated in 1957. This was set up with assistance from the UK.
- India's domestic uranium reserves are limited; hence, India imports uranium from Russia.
- Some other countries with which India has uranium supply agreements are Argentina, Mongolia, Kazakhstan, and Namibia.
- Furthermore, in 2011, the Atomic Minerals Directorate for Exploration and Research (AMD) of India has discovered large deposits of uranium in Tummalapalle belt located in Bhima River basin in Karnataka.

- In this region, about 44,000 tonnes of natural uranium has been discovered.

Nuclear Power Plants in Operation

The following table lists down the functional nuclear power plants −

Power Plant	Location	Total capacity (MW)	Operator
Rawatbhata	Rajasthan	1,180	NPCIL
Tarapur	Maharashtra	1,400	NPCIL
Kudankulam	Tamil Nadu	2,000	NPCIL
Kakrapar	Gujarat	440	NPCIL
Kalpakkam	Tamil Nadu	440	NPCIL
Narora	Uttar Pradesh	440	NPCIL
Kaiga	Karnataka	880	NPCIL

Nuclear Power Plants Under Construction

The following table lists down the nuclear power plants, which are under construction −

Power Plant	Location	Total capacity (MW)	Operator
Rajasthan Unit 7 & 8	Rajasthan	1,400	NPCIL
Kakrapar Unit 3 & 4	Gujarat	1,400	NPCIL
Madras (Kalpakkam)	Tamil Nadu	500	Bhavini

Kudankulam	Tamil Nadu	2,000	NPCIL

Planned Nuclear Power Plants

The following table lists down the planned nuclear power plant projects −

Power station	Location	Total capacity (MW)
Jaitapur	Maharashtra	9,900
Kovvada	Andhra Pradesh	6,600
t.b.d. (Mithi Virdi (Viradi))	Gujarat	6,600
t.b.d. (Haripur)	West Bengal	6,000
Gorakhpur	Haryana	2,800
Bhimpur	Madhya Pradesh	2,800
Mahi Banswara	Rajasthan	2,800
Kaiga	Karnataka	1,400
Chutka	Madhya Pradesh	1,400
Madras	Tamil Nadu	1,200
Tarapur	Maharashtra	300

India Nuclear Program: Nuclear Milestones: 1945-2018

1945: The Tata Institute of Fundamental Research Mumbai is inaugurated.

1948: The Atomic Energy Commission (AEC) is established under the direction of Dr. Homi J. Bhabha.

1950: Indian Rare Earths Limited (IREL) is established as a joint venture between the Government of India and Government of Travancore, Cochine. It is brought under the control of the Department of Atomic Energy in 1963.

1951: The first uranium deposit in India is discovered at **Jaduguda.**

1954: The Department of Atomic Energy (DAE) is created.

1957: India establishes the Atomic Energy Establishment, Trombay, which will be renamed the Bhabha Atomic Research Center (BARC) in 1967.

1962: Heavy water production begins at German-built Nangal plant.

1963: The United States and India sign an accord stipulating that the United States will supply enriched fuel to India's Tarapur nuclear power plant.

1967: Uranium mining operations begin at Jaduguda. A uranium mill is also established there.

1968: India refuses to join the Nuclear Nonproliferation Treaty.

1968: Nuclear Fuel Complex is established at Hyderabad under the DAE.

1969: Heavy Water Projects is established under the DAE. It is later renamed the Heavy Water Board.

1971: India establishes the Reactor Research Centre under the DAE. It is later renamed Indira Gandhi Centre for Atomic Research (IGCAR).

May 1974: India conducts an underground nuclear explosion at Pokhran, Rajasthan. India describes the test, codenamed "Smiling Buddha," as a "peaceful nuclear explosion." Estimates of the yield range from 8 to 12 kilotons.

May 1998: India conducts two rounds of nuclear weapon tests. After the first, Prime Minister Atal Behari Vajpayee announces that "**a fission device**, a low-yield device and a thermonuclear device" had been successfully tested in the Pokhran desert. Two days later

the government explodes two more sub-kiloton nuclear tests at the same testing range. The five underground tests range in yield from less than one kiloton to an estimated 45 kilotons.

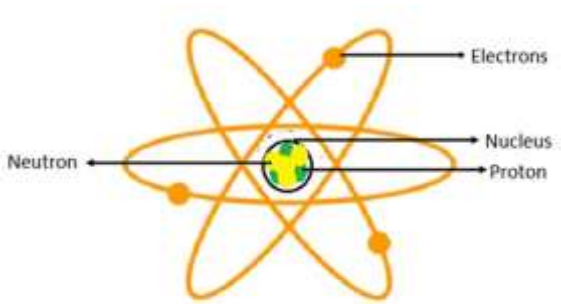
May 1998: President Clinton imposes economic sanctions on India after it refuses American demands to disavow future testing or deployment of nuclear weapons.

May 1998: Russia refuses to join other countries in punishing India for its nuclear tests.

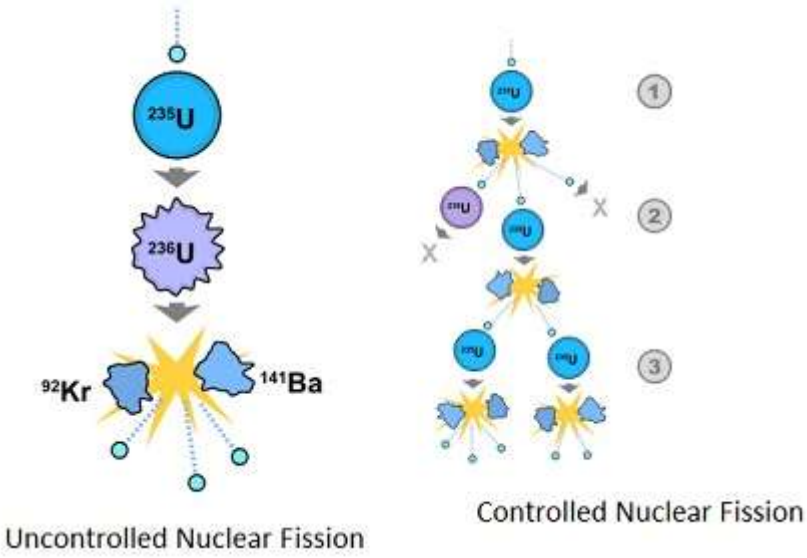
December 1998: Indian Prime Minister Atal Behari Vajpayee tells parliament that India's nuclear doctrine will be centered on two elements: a small but **credible deterrent,** and a **no-first-use policy.**

Nuclear Energy

Atom consists of **nucleus and electrons** in orbits.
The nucleus consists of protons (positively charged particles) and nuetrons (nuetrally charged particles)



Energy is obtained from the nucleus in the following methods



- **Nuclear Fusion:** Breaking a heavy nucleus into 2 or more smaller lighter nuclei
- **Nuclear Fission:** Combining 2 lighter nuclei to form a heavy nucleus
- **Uncontrolled chain reaction:** In an uncontrolled nuclear fission, a heavy nucleus in bombarded with a neutron. It splits into lighter nuclei releasing 2 or more neutrons. Each neutron again bombards nuclei of atom and splits further and further. The neutrons and thereby the fission reaction exponentially increase. **Eg : Atom bomb**
- **Controlled chain reaction** : In an controlled nuclear fission, a heavy nucleus in bombarded with a neutron. It splits into lighter nuclei releasing 2 or more neutrons. But in this case, except one neutron all the other neutrons are absorbed. So, only one neutron is left. This single neutron again bombards nuclei of atom and splits further and further. Again only one neutron is left behind and the others are absorbed. So, the reaction is controlled. **Eg: Nuclear generator.**
- In a nuclear generator, nuclear energy is harnessed in a controlled manner to generate electricity.

Nuclear Reactor

Nuclear reactor helps to carry out controlled chain reaction and also produce energy in sustained manner. Produced energy can be used to produce electric energy.

Nuclear Fuel

Nuclear fuel is the fissionable material used in nuclear reactor. Generally, U-233, U-235 and Pu- 239 is taken as nuclear fuel in form of cylindrical rods arranged in regular pattern in the active reactor core.

Moderator

Slow moving neutron have more tendency to facilitate fission reaction rather than the fast-moving neutrons. Average energy of neutron produced in fission of U-235 is 2 MeV. these are the fast neutrons and have low tendency to cause fission. In order to facilitate fission reaction there is need to slow down the neutrons. The job is done by moderator in nuclear reactor, In nuclear reactors **water, solid graphite or heavy water are used as moderators.**

Control Rods

The rods have the ability to absorb neutrons. Therefore, the nuclear reaction can be controlled thereby bringing down the multiplication factor down unity.

Safety Rod

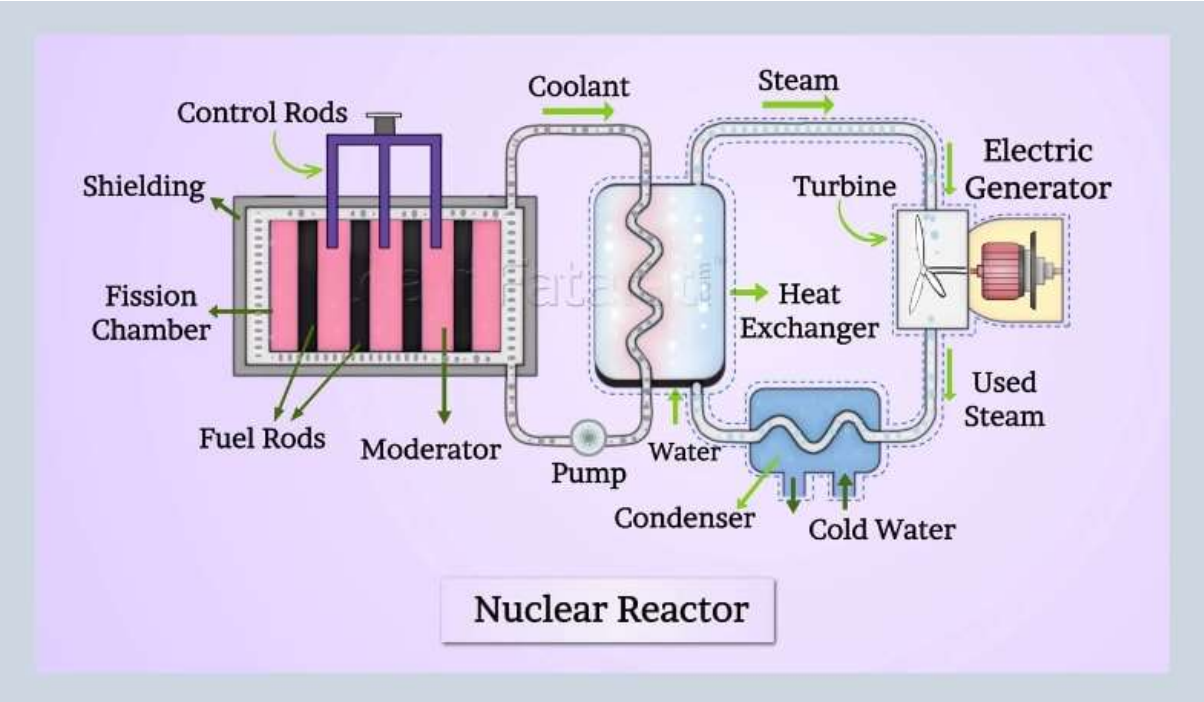
In addition to control rods, the reactors are provided with safety rods. These rods can be inserted into reactor in order to bring value of K below unity. Hence, it keeps power generation safe.

Coolant

Heat produced in the core is absorbed by coolant. Later this energy is passed to water in heat exchanger. Thus, it produces steam. The steam is used to drive turbine coupled with electric generator and thus, electric energy is produced. In general water or heavy water is used as coolant. In case of high temperature, liquid sodium is used as coolant.

Shielding

Nuclear fission produces hazardous radiations, therefore, nuclear reactor is kept in concrete walls of 2 m to 2.5 m thick. This prevents radiations from reaching outside environment.



Nuclear Reactor