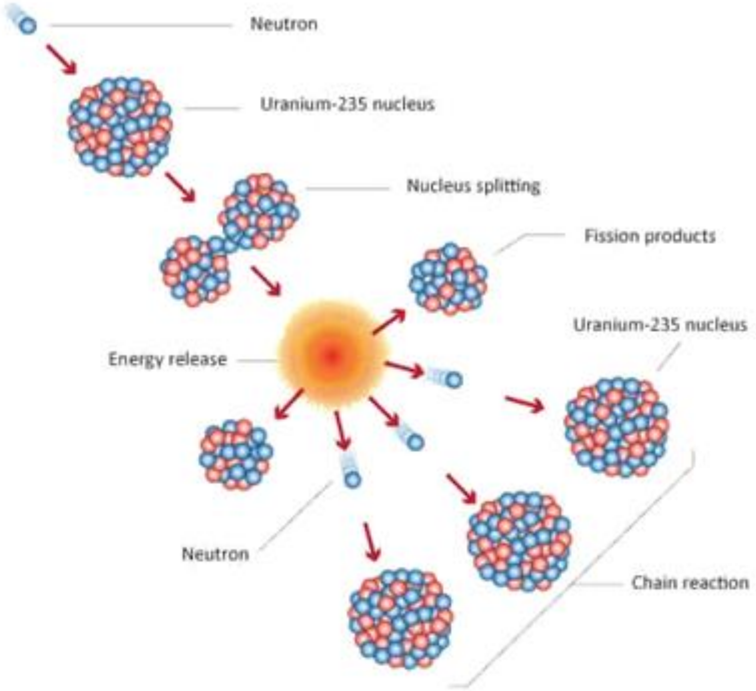
NUCLEAR REACTOR

- A *nuclear reactor* is a device in which nuclear chain reactions are initiated, controlled, and sustained at a steady rate.
- Currently, all commercial nuclear reactors are based on nuclear fission.
- There are different types of reactors based on the method of producing steam.

1. Light water reactors
2. Heavy water reactors (CANDU)
3. Breeder reactor

1. Light Water Reactors

- Nuclear fission for power production is carried out in nuclear power reactors in which the fission (splitting) of *uranium-235* or *plutonium* nuclei occurs. Each such event generates two radioactive fission product atoms of roughly half the mass of the nucleus fissioned, an average of 2.5 neutrons, plus an enormous amount of energy compared to normal chemical reactions.
- The neutrons, initially released as fast-moving, highly energetic particles, are slowed to thermal energies in a moderator medium. For a reactor operating at a steady state, exactly one of the neutron products from each fission is used to induce another fission reaction in a chain reaction.



1. Nuclear fuel rods: The fuel rod is made up of the isotope which undergoes fission by capturing neutrons. Uranium-235 is the most common isotope used for the process. As the natural abundance of uranium-235 is only 0.71% therefore in order to increase the concentration enrichment process is done.

(This situation could be improved by the development of breeder reactors, which convert uranium-238 (natural abundance 99.28%) to fissionable plutonium-239.)

2. Nuclear reactor core: It is the portion where the nuclear reactions take place as it contained the component of fuel. It contains low-enriched uranium, control systems and structural materials.

3. Moderator: As the number of neutrons, speed of the neutrons must be controlled, too. As uranium-235 nuclei are split more effectively by slow moving neurons therefore, the projectile neurons must be slowed down to optimum velocities and the substances which reduce the velocity are known as moderators. The commonly used moderators in the nuclear reactors are graphite or heavy water.

4. Coolant: The heat generated in the fission reaction is absorbed by coolant. Also if the nuclear reaction begins to go at faster rate emergency cooling is provided by the coolant. Because of the high thermal conductivities either water or liquid sodium is used as coolants. In some reactors helium gas is also used.

5. Control rods: To ensure that the reaction is carried out in a controlled manner there must be restriction in the number of neurons. Otherwise, uranium-235 would be fissioned at an abnormally high rate and releases excessive amount of energy as a result of which reactor temperature rises. Generally for this the control rods are made up of cadmium because the element is capable in absorbing neurons.

$$^{113}\mathrm{Cd} + {}^{1}\mathrm{n} \rightarrow {}^{113}\mathrm{Cd} + \gamma$$

6. Steam generator: The steam generator is used to generate steam from water with the help of heat exchangers in a nuclear reactor core. It is used to convert the mechanical energy obtained from steam turbine into electrical energy.

7. Steam turbine: The steam turbine is used to convert the heat energy of the steam into mechanical energy. The steam turbine is separately structured from the main reactor building.

8. Condenser: In nuclear power plant the function of the condenser is to condense the exhaust steam from turbine in order to increase the efficiency and also to convert the exhaust steam into water so that this water can be reused in the steam generator.

9. Containment structure: It is a screen which prevents the radiation from escaping out of the reactor, the salt of lead is used to absorb the radiation.

2. Heavy Water Reactors (CANDU)

- In CANDU reactors heavy water, D_2O, is used instead of H_2O, as the coolant and moderator. D_2O is a less effective moderator because of the larger deuterium mass, but deuterium absorbs neutrons much less than hydrogen. As a result, it is possible to maintain a chain reaction even with unenriched uranium (0.7% ^{235}U) if D_2O is used as the moderator.

- The water in the reactor circulates through a heat exchanger that generates steam from secondary water coolant, and this steam is then used to drive a turbine to generate electricity. Basically, the reactor is a conventional steam generator in which the heat source is fissioning uranium instead of burning coal. The amount of energy concentrated in uranium is vastly greater than that in coal.

3. Breeder Reactor

- A breeder reactor is one that generates more fissionable material than it consumes.

- The Fast Breeder Reactor (FBR) has a core of plutonium-239 surrounded by rods of U-238. The U-238 nuclei absorb neutrons from the core and are transformed into plutonium (P-239). For every four atoms of plutonium that are used up in the core of the breeder, five new plutonium atoms are made from the U-238. The reactor makes more plutonium than it uses.

- Not much Pu-239 is produced in this way, because the probability of the U-238 absorbing a neutron is maximal for fast neutrons, not the thermal neutrons for which a pressurized light-water fission reactor is designed. Efficient production of Pu-239 requires a "breeder" reactor, operating with fast neutrons.

- Unlike normal reactors which only use U-235 as their fuel, which is only available in scarce concentrations of around 0.7% of natural uranium without enrichment, breeder reactors also make use of natural U-238 which is much more common. They can use approximately 70% of the U-238 for production of power, whereas normal reactors can only use around 1% of it.

- The most common breeding is of Pu-239, which is bred through the process.

Nuclear Accidents

If the reaction temperature increases the sealed radioactive materials in the reactor core begins to melt and radioisotopes escape out to the environment. Accidents caused by use of such plants are classified into two types:

1. Reactivity excursion accidents
2. Loss of coolant accidents

1. Reactivity Excursion accidents

If the control rods are not used properly, the number of neutron is not controlled and number of projectile neutrons increases then the Uranium-235 nucleus begins to split abnormally at fast rates as a result of which temperature increases and melting of core takes place. The nuclear accident occurred at Chernobyl is the cause of reactivity excursion. This can be controlled by injecting a solution of boron compounds into the reactor. As it absorb the excess neutrons.

2. Loss of coolant accidents

This accident is occurred because of loss of coolant from the reactor core. The Three Mile Island accident is an example of loss of coolant. In this incident, the temperature rised and the coolant was not restored, therefore within a few seconds, the melting of core took place. Proper inspection of reactor equipment is the only possible prevention.

Disasters Caused By Nuclear Power Plant

- There are many accidents occurred due to establishment of large number of nuclear power plants. During the period of 1952-2009, 99 nuclear accidents have been recorded. These accidents includes incidents resulted in the loss of human life or property damage. Because the nuclear power plants are very large therefore the accidents result in a heavy money loss.

- It is estimated that at least 4 serious nuclear power accidents are expected in the period of 2005-2055 because of the growth of nuclear power in that period.

Level	Definition
7	Major accident
6	Serious accident
5	Accident with wider consequences
4	Accident with local consequences
3	Serious incident
2	Incident
1	Anomaly

Advantages and Disadvantages

- ✓ Nuclear power generation does emit relatively low amounts of carbon dioxide (CO_2). The emissions of green house gases and therefore the contribution of nuclear power plants to global warming is therefore relatively little.
- ✓ This technology is readily available, it does not have to be developed first.
- ✓ It is possible to generate a high amount of electrical energy in one single plant.

Advantages and Disadvantages

- x The problem of radioactive waste is still an unsolved one. The waste from nuclear energy is extremely dangerous and it has to be carefully looked after for several thousand years.
- x High risks: Despite a generally high security standard, accidents can still happen. It is technically impossible to build a plant with 100% security. A small probability of failure will always last. The consequences of an accident would be absolutely devastating both for human being as for the nature.

- During the operation of nuclear power plants, radioactive waste is produced, which in turn can be used for the production of nuclear weapons.
- The energy source for nuclear energy is Uranium. Uranium is a scarce resource, its supply is estimated to last only for the next 30 to 60 years depending on the actual demand.
- The time frame needed for formalities, planning and building of a new nuclear power generation plant is in the range of 20 to 30 years in the western democracies. In other words: It is an illusion to build new nuclear power plants in a short time.