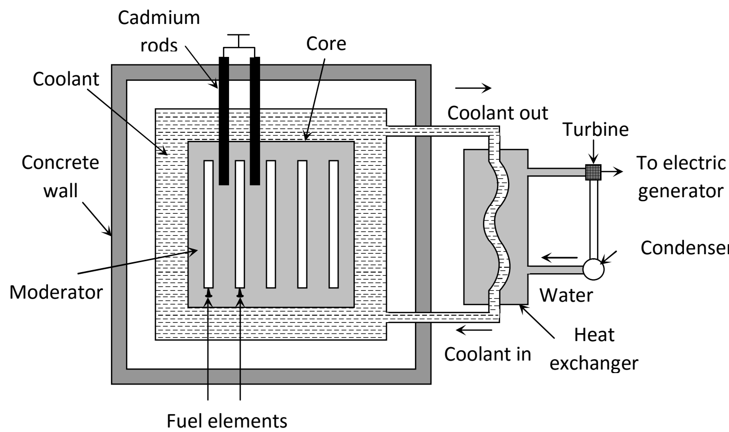
Nuclear Reactor.

A nuclear reactor is a device in which nuclear fission can be carried out through a sustained and a controlled chain reaction. It is also called an atomic pile. It is thus a source of controlled energy which is utilized for many useful purposes.



(1) Parts of nuclear reactor

(i) Fissionable material (Fuel): The fissionable material used in the reactor is called the fuel of the reactor. Uranium isotope (U235) Thorium isotope (Th232) and Plutonium isotopes (Pu239, Pu240 and Pu241) are the most commonly used fuels in the reactor.

(ii) Moderator: Moderator is used to slow down the fast moving neutrons. Most commonly used moderators are graphite and heavy water (D2O).

(iii) Control Material: Control material is used to control the chain reaction and to maintain a stable rate of reaction. This material controls the number of neutrons available for the fission. For example, cadmium rods are inserted into the core of the reactor because they can absorb the neutrons. The neutrons available for fission are controlled by moving the cadmium rods in or out of the core of the reactor.

(iv) Coolant: Coolant is a cooling material which removes the heat generated due to fission in the reactor. Commonly used coolants are water, CO2 nitrogen etc.

(v) Protective shield: A protective shield in the form a concrete thick wall surrounds the core of the reactor to save the persons working around the reactor from the hazardous radiations.

Note: It may be noted that Plutonium is the best fuel as compared to other fissionable material. It is because fission in Plutonium can be initiated by both slow and fast neutrons. Moreover it can be obtained from U^{238}.

Nuclear reactor is firstly devised by Fermi.

Apsara was the first Indian nuclear reactor.

(2) Uses of nuclear reactor

(i) In electric power generation.

(ii) To produce radioactive isotopes for their use in medical science, agriculture and industry.

(iii) In manufacturing of PU^{239} which is used in atom bomb.

(iv) They are used to produce neutron beam of high intensity which is used in the treatment of cancer and nuclear research.

Note: A type of reactor that can produce more fissile fuel than it consumes is the breeder reactor.

Nuclear fusion

In nuclear fusion two or more than two lighter nuclei combine to form a single heavy nucleus. The mass of single nucleus so formed is less than the sum of the masses of parent nuclei. This difference in mass results in the release of tremendous amount of energy

$$_1H^2 + _1H^2 \rightarrow _1H^3 + _1H^1 + 4\,MeV$$

$$_1H^3 + _1H^2 \rightarrow _2He^4 + _0n^1 + 17.6\,MeV$$

or

$$_1H^2 + _1H^2 \rightarrow _2He^4 + 24\,MeV$$

For fusion high pressure (≈ 106 atm) and high temperature (of the order of 107 K to 108 K) is required and so the reaction is called thermonuclear reaction.

Fusion energy is greater than fission energy fission of one uranium atom releases about 200 MeV of energy. But the fusion of a deutron $({}_1H^2)$ and triton $({}_1H^3)$ releases about 17.6 MeV of energy. However the energy released per nucleon in fission is about 0.85 MeV but that in fusion is 4.4 MeV. So for the same mass of the fuel, the energy released in fusion is much larger than in fission.

Plasma: The temperature of the order of 108 K required for thermonuclear reactions leads to the complete ionization of the atom of light elements. The combination of base nuclei and electron cloud is called plasma. The enormous gravitational field of the sun confines the plasma in the interior of the sun.

The main problem to carryout nuclear fusion in the laboratory is to contain the plasma at a temperature of 108K. No solid container can tolerate this much temperature. If this problem of containing plasma is solved, then the large quantity of deuterium present in sea water would be able to serve as in-exhaustible source of energy.

Note:To achieve fusion in laboratory a device is used to confine the plasma, called Tokomak.

Stellar Energy

Stellar energy is the energy obtained continuously from the sun and the stars. Sun radiates energy at the rate of about 1026 joules per second.

Scientist Hans Bethe suggested that the fusion of hydrogen to form helium (thermo nuclear reaction) is continuously taking place in the sun (or in the other stars) and it is the source of sun's (star's) energy.

The stellar energy is explained by two cycles

Proton-proton cycle	Carbon-nitrogen cycle
${}_1H^1 + {}_1H^1 \rightarrow {}_1H^2 + {}_1e^0 + Q_1$	${}_1H^1 + {}_6C^{12} \rightarrow {}_7N^{13} + Q_1$
${}_1H^2 + {}_1H^1 \rightarrow {}_2He^3 + Q_2$	${}_7N^{13} \rightarrow {}_6C^{13} + {}_{+1}e^0$
${}_2He^3 + {}_2He^3 \rightarrow {}_2He^4 + 2{}_1H^1 + Q_3$	${}_1H^1 + {}_6C^{13} \rightarrow {}_7N^{14} + Q_2$

$4\ {}_1H^1 \rightarrow {}_2He^4 + 2\ {}_{+1}e^0 + 2\gamma + 26.7\ MeV$	${}_1H^1 + {}_7N^{14} \rightarrow {}_8O^{15} + Q_3$ ${}_8O^{15} \rightarrow {}_7N^{15} + {}_1e^0 + Q_4$ ${}_1H^1 + {}_7N^{15} \rightarrow {}_6C^{12} + {}_2He^4$ $4\ {}_1H^1 \rightarrow {}_2He^4 + 2\ {}_1e^0 + 24.7\ MeV$

About 90% of the mass of the sun consists of hydrogen and helium.