2nd Semester Midterm(19-20)

Course Code: PHY 121,Course Title:Physics-II

Midterm Question Solve

1.(a) What do you understand by Fission Reactions? Explain the Fission Reaction Process with examples.

(b) Write down the essential components of a nuclear reactor with their important functions.

(c) Mention the types of Nuclear Reactors. Briefly describe the Boiling Water Reactor.

(d) What's are advantages and disadvantages of a Nuclear Power Plant.

ANSWER

(a) Fission reactions, specifically nuclear fission reactions, are a type of nuclear reaction in which the nucleus of an atom splits into two or more smaller nuclei, along with the release of a significant amount of energy. This process is the opposite of nuclear fusion, where small nuclei combine to form larger ones. Fission reactions are the basis for the operation of nuclear power plants and are also responsible for the immense energy release in nuclear weapons.

When large atomic nuclei are hit with neutrons they can become highly unstable if the neutron is absorbed by the nucleus. The larger unstable nucleus breaks into two smaller 'daughter' nuclei and also release more neutrons, as well as beta and alpha particles and gamma. The two smaller atoms formed are themselves usually unstable and radioactive. The nuclear fission equations below are a gross simplification of the process. This process is called nuclear fission and because it is accompanied by an enormous release of energy, it forms the basis of nuclear power. The radioisotopeUuranium-235 is particularly useful for energy generation by nuclear fission. Much of the energy released is initially the kinetic energy of the fission fragments, but collisions, radioactive decay etc. result in most of it changing to heat and some as electromagnetic radiation.

The process of fission occurs when a nucleus splits into smaller pieces. Fission can be induced by a nucleus capturing slow moving neutrons, which results in the nucleus becoming very unstable.

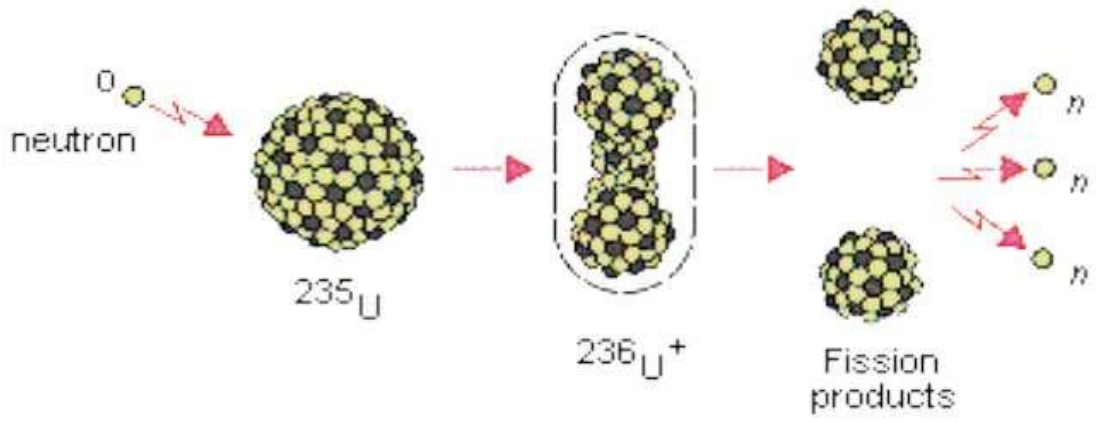

Figure-1: Fission Reactions Process

The following equations represent fission reactions, where n is neutron. All these fission reactions also release a large amount of energy.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\ {}^{1}_{0}n + Energy$$

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{131}_{50}Sn + {}^{103}_{42}Mo + 2\ {}^{1}_{0}n + Energy$$

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{52}Te + {}^{97}_{40}Zr + 2\ {}^{1}_{0}n + Energy$$

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{138}_{54}Xe + {}^{95}_{38}Sr + 3\ {}^{1}_{0}n + Energy$$

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{152}_{60}Nd + {}^{81}_{32}Ge + 3\ {}^{1}_{0}n + Energy$$

(b) A nuclear reactor is a system that contains and controls sustained nuclear chain reactions. Reactors are used for generating electricity, moving aircraft carriers and submarines, producing medical isotopes for imaging and cancer treatment, and for conducting research.

The essential components of a nuclear reactor are:

1. The core: The core of the reactor contains all of the nuclear fuel and generates all of the heat. It contains low-enriched uranium (<5% U-235), control systems, and structural materials. The core can contain hundreds of thousands of individual fuel pins.

2. The coolant: The coolant is the material that passes through the core, transferring the heat from the fuel to a turbine. It could be water, heavy-water, liquid sodium, helium, or something else. In the US fleet of power reactors, water is the standard.

3. The turbine: The turbine transfers the heat from the coolant to electricity, just like in a fossil-fuel plant.

4. The containment: The containment is the structure that separates the reactor from the environment. These are usually dome-shaped, made of high-density, steel-reinforced concrete. Chernobyl did not have a containment to speak of.

5. Cooling towers: Cooling towers are needed by some plants to dump the excess heat that cannot be converted to energy due to the laws of thermodynamics. These are the hyperbolic icons of nuclear energy. They emit only clean water vapor.

(c) There are very many different types of nuclear reactors with different fuels, coolants, fuel cycles, purposes.

- ❑ Pressurized Water Reactor

- ❑ Boiling Water Reactor
- ❑ Sodium Cooled Fast Reactor
- ❑ Canada Deuterium-Uranium Reactors (CANDU)
- ❑ Liquid Fluoride Thorium Reactor
- ❑ High Temperature Gas Cooled Reactor

Boiling Water Reactor

Second most common, the BWR is similar to the PWR in many ways. However, they only have one coolant loop. The hot nuclear fuel boils water as it goes out the top of the reactor, where the steam heads over to the turbine to spin it.

Properties:

(1) Simpler plumbing reduces costs

(2) Power levels can be increased simply by speeding up the jet pumps, giving less boiled water and more moderation. Thus, load-following is simple and easy.

(3) Very much operating experience has been accumulated and the designs and procedures have been largely optimized.

Construction:

● With liquid and gaseous water in the system, many weird transients are possible, making safety analysis difficult

● Primary coolant is in direct contact with turbines, so if a fuel rod had a leak, radioactive material could be placed on the

turbine. This complicates maintenance as the staff must be dressed for radioactive environments.

● Can’t breed new fuel -- susceptible to "uranium shortage"

● Does not typically perform well in station blackout events, as in Fukushima.

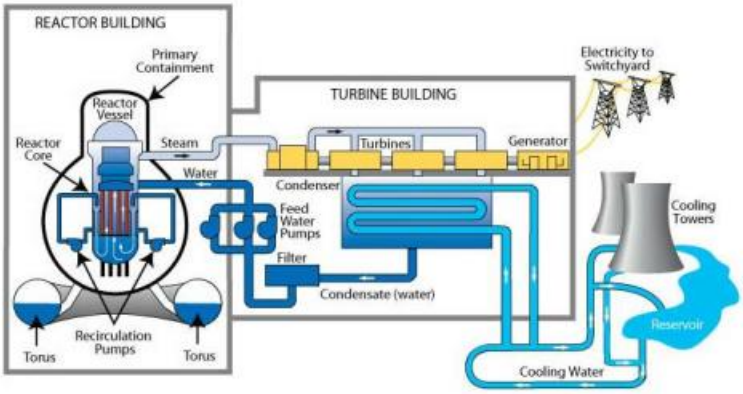

Figure-1: Boiling Water Reactor

(d) A nuclear power plant is a complex facility designed for the purpose of generating electricity through the controlled use of nuclear fission reactions. These power plants are a significant source of electrical energy in many countries and play a crucial role in meeting the world's energy needs. There are the advantages and disadvantages of a Nuclear Power Plant.

Advantages:

● Almost zero emissions (very low greenhouse gas emissions).
● They can be sited almost anywhere unlike oil which is mostly imported.
● The plants almost never experience problems if not from

human error, which almost never happens anyway because the plant only needs like 10 people to operate it.

- A small amount of matter creates a large amount of energy.
- A lot of energy is generated from a single power plant.
- Current nuclear waste in the US is over 90% Uranium. If reprocessing were made legal again in the US
- We would have enough nuclear material to last hundreds of years.
- A truckload of Uranium is equivalent in energy to 10,000+ truckloads of coal. (Assuming the Uranium is fully utilized.)
- A nuclear aircraft carrier can circle the globe continuously for 30 years on its original fuel while a diesel fueled carrier has a range of only about 3000 miles before having to refuel.
- New reactor types have been designed to make it physically impossible to melt down. As the core gets hotter the reaction gets slower, hence a run-away reaction leading to a melt-down is not possible.
- Theoretical reactors (traveling wave) are proposed to completely eliminate any long-lived nuclear waste created from the process.
- Breeder reactors create more usable fuel than they use.
- Theoretical Thorium reactors have many of the benefits of Uranium reactors while removing much of the risk for proliferation as it is impossible to get weapons-grade nuclear materials from Thorium.

Disadvantages:

● Nuclear plants are more expensive to build and maintain.
● Proliferation concerns - breeder reactors yield products that could potentially be stolen and turned into an atomic weapon.
● A lot of waste from early reactors was stored in containers meant for only a few decades, but is well past expiration and, resultingly, leaks are furthering contamination.
● Nuclear power plants can be dangerous to its surroundings and employees. It would cost a lot to clean in case of spillages.
● There exist safety concerns if the plant is not operated correctly or conditions arise that were unforeseen when the plant was developed, as happened at the Fukushima plant in Japan; the core melted down following an earthquake and tsunami the plant was not designed to handle despite the world's strongest earthquake codes.
● Mishaps at nuclear plants can render hundreds of square miles of land uninhabitable and unsuitable for any use for years, decades or longer, and kill off entire river systems.

THE END