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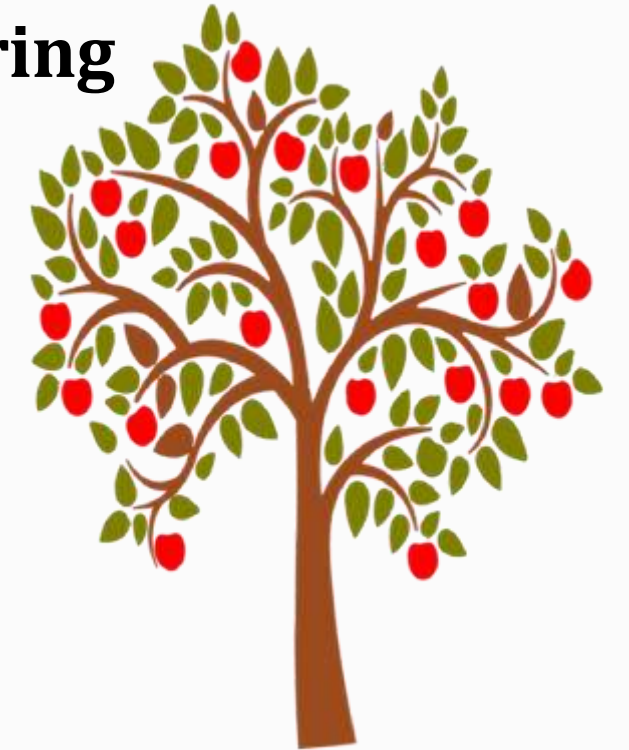
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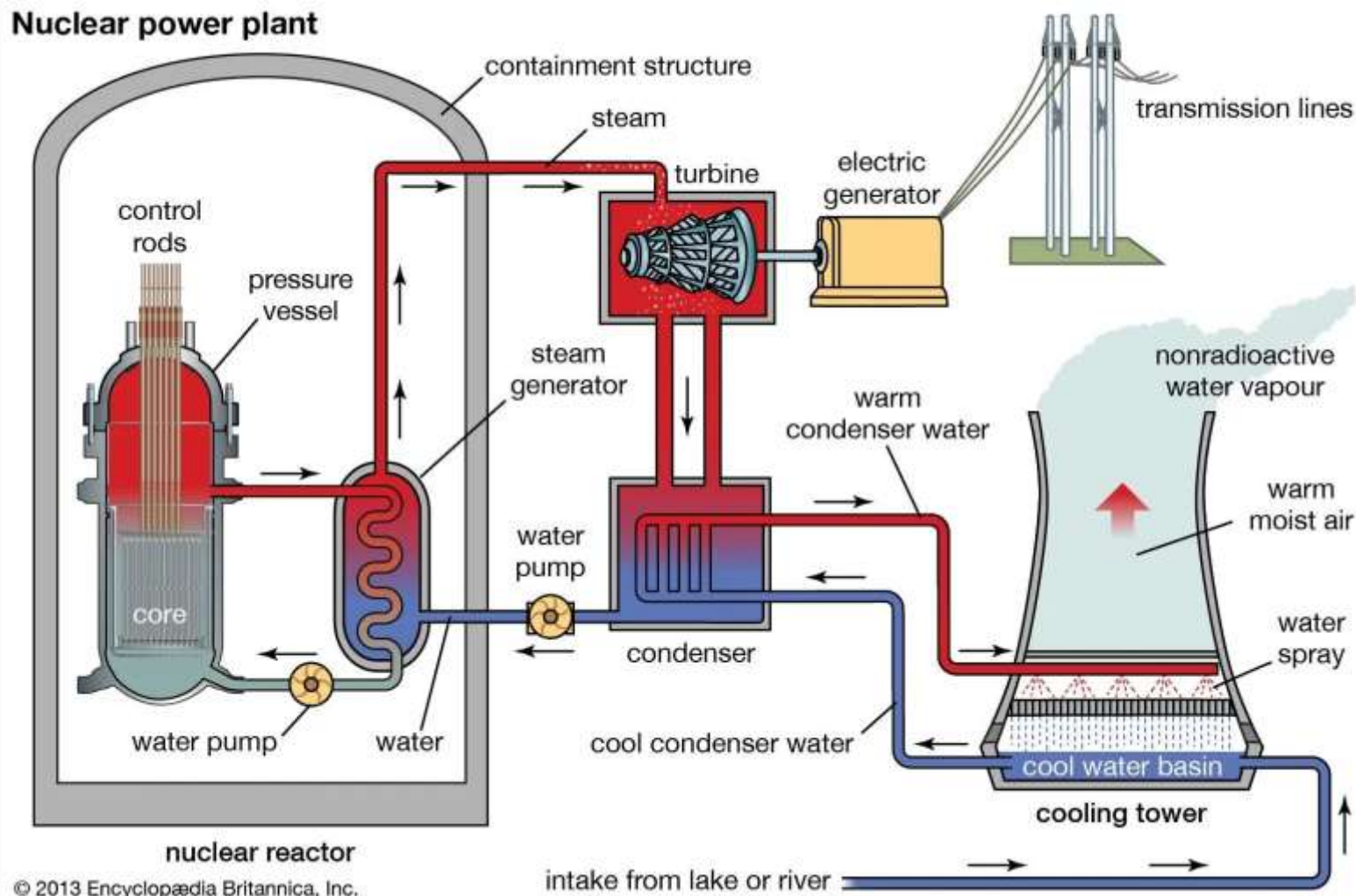


23GET102 – Basic Civil and Mechanical Engineering
I CST/ I SEMESTER

UNIT IV : I.C Engines and Power Plant Engineering

Topic 8 :Nuclear power plants





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Nuclear Power Plants: Working Principle, Advantages, Disadvantages & Applications

Exploring the science, benefits, challenges, and real-world applications of nuclear energy in today's world.

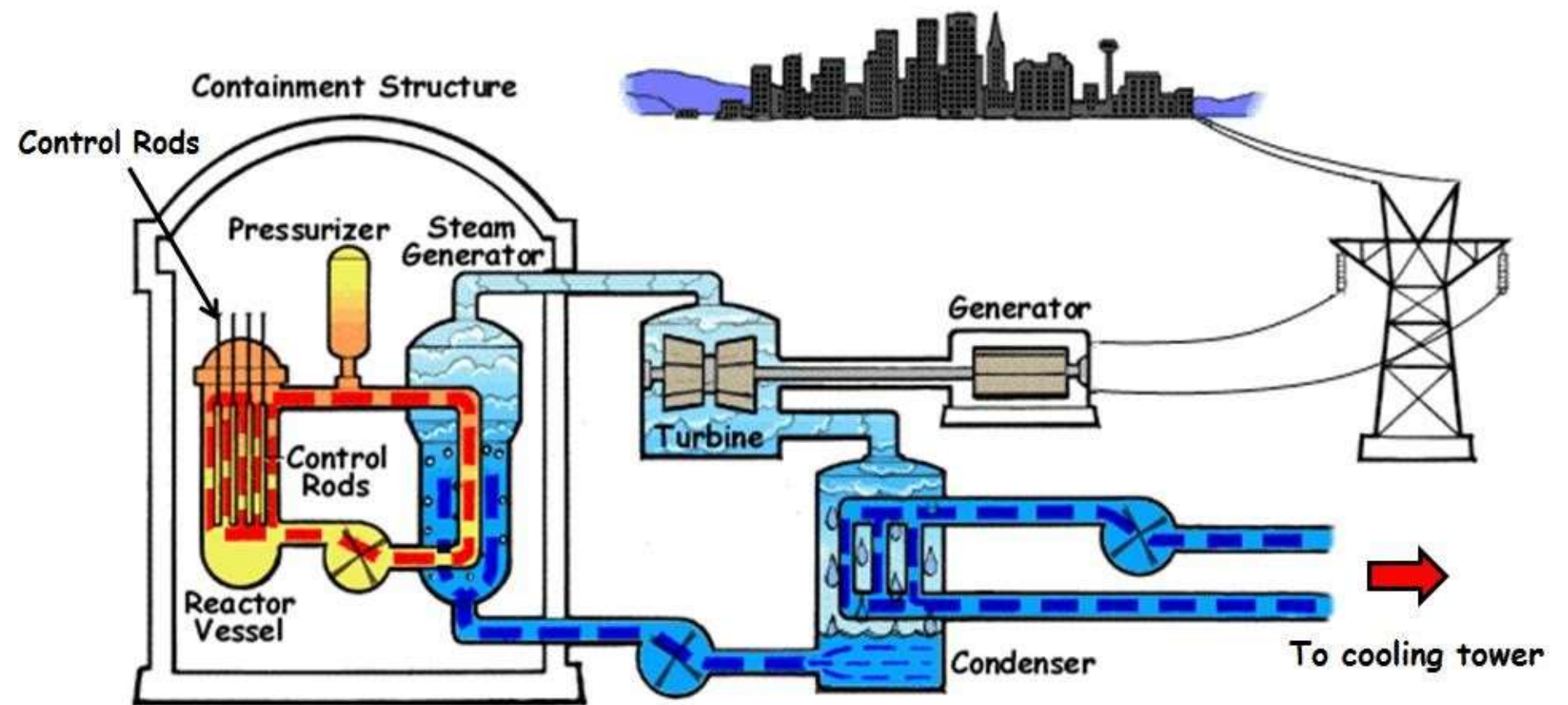
What is a Nuclear Power Plant?

DT-Define



A nuclear power plant is a sophisticated thermal power station that converts the immense heat energy released from **nuclear fission** into electrical energy. Unlike conventional power plants that burn fossil fuels, nuclear plants harness the energy stored within atomic nuclei.

The process uses uranium-235 or thorium as fuel within a heavily shielded nuclear reactor. When these atoms split, they release tremendous amounts of heat—far more than any chemical reaction could produce.



How Does It Work? The Nuclear Fission Process

DT - Ideate



Nuclear Fission

Uranium-235 atoms absorb neutrons and split into smaller atoms, releasing 2-3 new neutrons plus enormous heat energy.

Steam Generation

Released heat converts water in the reactor vessel into high-pressure, high-temperature steam.

Mechanical Energy

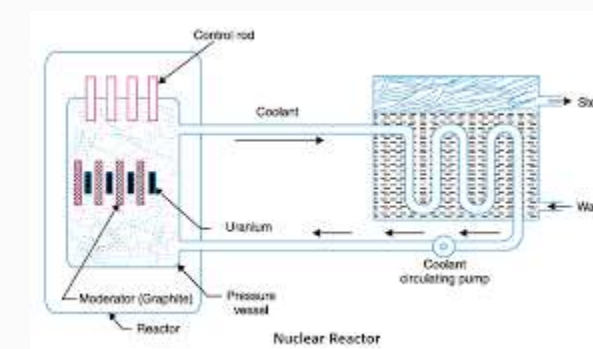
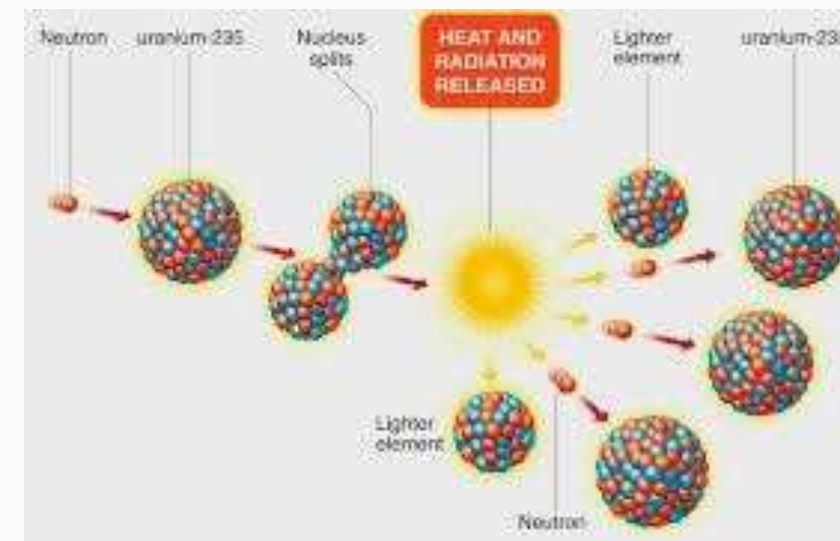
Pressurised steam spins massive turbine blades at high speeds, converting thermal energy to mechanical rotation.

Electricity Production

Turbine drives generator through electromagnetic induction, producing electrical power for the grid.

Cooling & Recycling

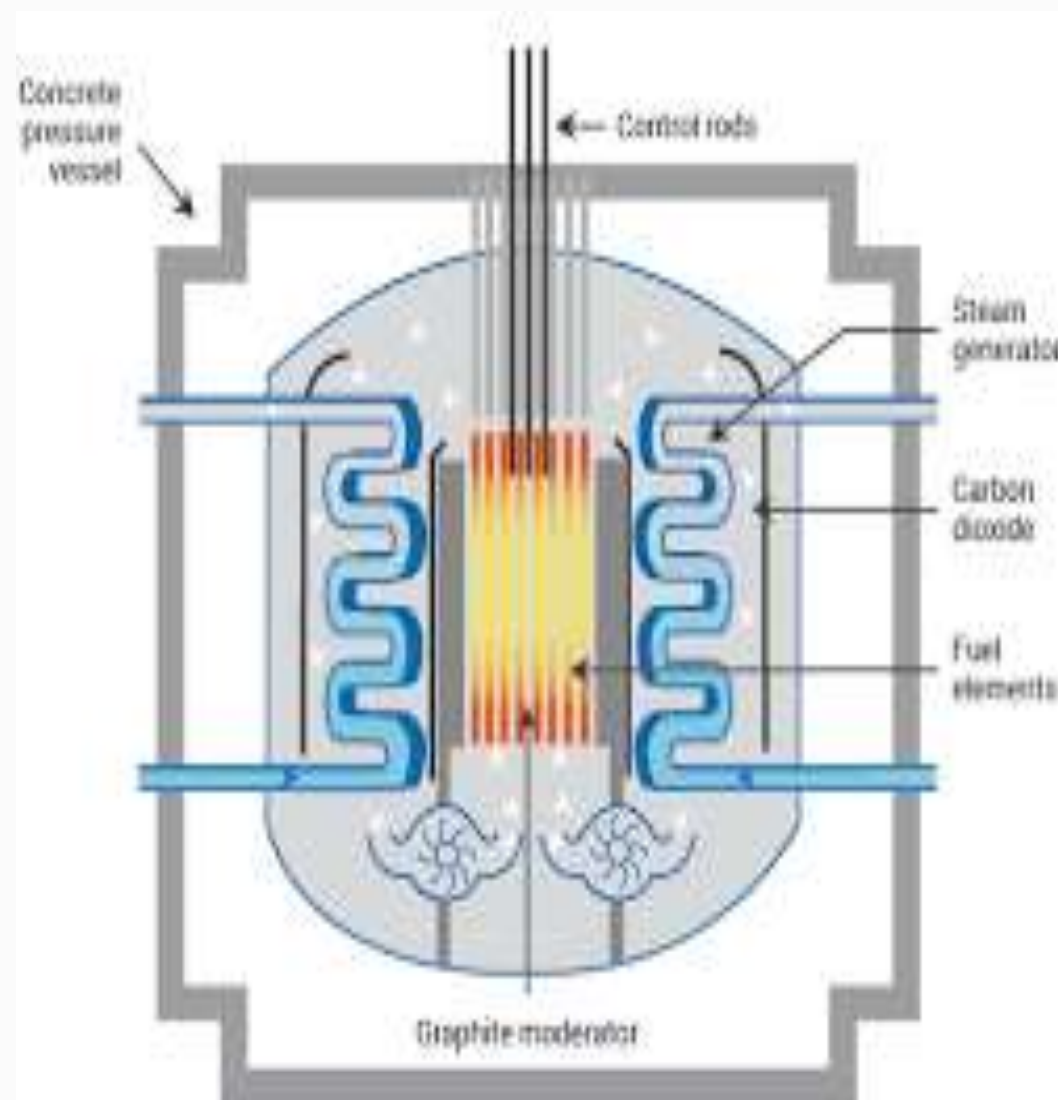
Cooling towers condense spent steam back to water, which returns to the reactor to repeat the cycle.



This chain reaction is carefully controlled to maintain steady heat output, ensuring safe and continuous electricity generation.

DT - Prototype

Key Components of a Nuclear Power Plant



Nuclear Reactor Core

The heart of the plant containing fuel rods filled with uranium pellets. This is where controlled fission occurs, generating intense heat.



Control Rods

Made of neutron-absorbing materials like boron or cadmium, these rods regulate the fission rate by controlling neutron flow.



Steam Generator & Turbine

Heat exchangers create steam, which drives turbine blades to convert thermal energy into mechanical rotation.



Cooling System

Removes excess heat from the reactor and condenses steam. Essential for preventing overheating and maintaining safety.

Advantages of Nuclear Power Plants



1

Exceptional Energy Density

Just 1 kilogramme of uranium-235 produces energy equivalent to approximately **4,500 tonnes of coal**—making it the most concentrated energy source available.

2

Minimal Carbon Emissions

During operation, nuclear plants produce virtually **zero greenhouse gas emissions**, making them crucial for climate change mitigation strategies.

3

Reliable Baseload Power

Nuclear plants operate continuously with capacity factors exceeding **90%**, providing stable electricity regardless of weather conditions.

4

Land-Efficient Technology

Requires significantly **less land area** than solar or wind farms to generate equivalent power output.

5

Long-Term Energy Security

Abundant uranium reserves ensure **decades of fuel availability**, reducing dependence on imported fossil fuels.

Disadvantages of Nuclear Power Plants

Nuclear Energy: Environmental Impact at a Glance

Exploring the Impacts of Nuclear Energy

Environmental Impact:
 Low Greenhouse Gas Emissions: Nuclear power emits **30 times less CO2** than coal.
 High Energy Output: One uranium fuel pellet generates as much energy as **17,000 cubic feet of natural gas**.
 One nuclear reactor requires between **1,514L and 2,725L** litres of water per MWh, equating to billions of gallons of water per year.

A Global Perspective:
 11% Nuclear Power contributes to the world's electricity.
 450 Nuclear reactors are in operation worldwide.
 470 Nuclear energy saves carbon dioxide emissions annually.
 92% Highest capacity factor among energy sources, operating at maximum power most of the time.

USA, France, China, Russia and South Korea

Safety:
 Deaths per TWh for nuclear energy are only **0.07**, compared to higher rates for fossil fuels.
 Nuclear power is one of the **safest** forms of energy.

Comparative CO2 Emissions:
 Nuclear: **12 grams CO2/kWh**
 Coal: **820 grams CO2/kWh**
 Natural Gas: **490 grams CO2/kWh**

Waste Management:
 95% of used nuclear fuel can be recycled.
 Radioactive waste can remain hazardous for thousands of years.

For a sustainable future, the balance between benefits and challenges of nuclear energy must be carefully managed.

High Capital Investment

Construction costs run into **billions of dollars**, with lengthy building periods spanning 8-12 years before operation begins.

Radioactive Waste Challenge

Spent fuel remains hazardous for thousands of years, requiring secure, long-term storage solutions that remain unresolved globally.

Catastrophic Accident Risk

Events like **Chernobyl (1986)** and **Fukushima (2011)** demonstrate potential for devastating accidents with long-lasting consequences.

Complex Operations

Demands **highly trained personnel**, sophisticated safety systems, and continuous monitoring—increasing operational complexity.

Limited Load Flexibility

Not ideal for **rapid power adjustments**, making it less suitable for peak demand management compared to gas turbines.

<https://www.youtube.com/watch?v=M6xuOpGiVKA>

Environmental & Safety Concerns



Long-Lived Radioactive Waste

High-level waste remains dangerously radioactive for **thousands to millions of years**, requiring geological repositories deep underground. No country has fully operational permanent disposal facilities yet.

Nuclear Proliferation Risks

Nuclear technology and materials can potentially be diverted for **weapons development**, raising international security concerns and requiring strict safeguards.

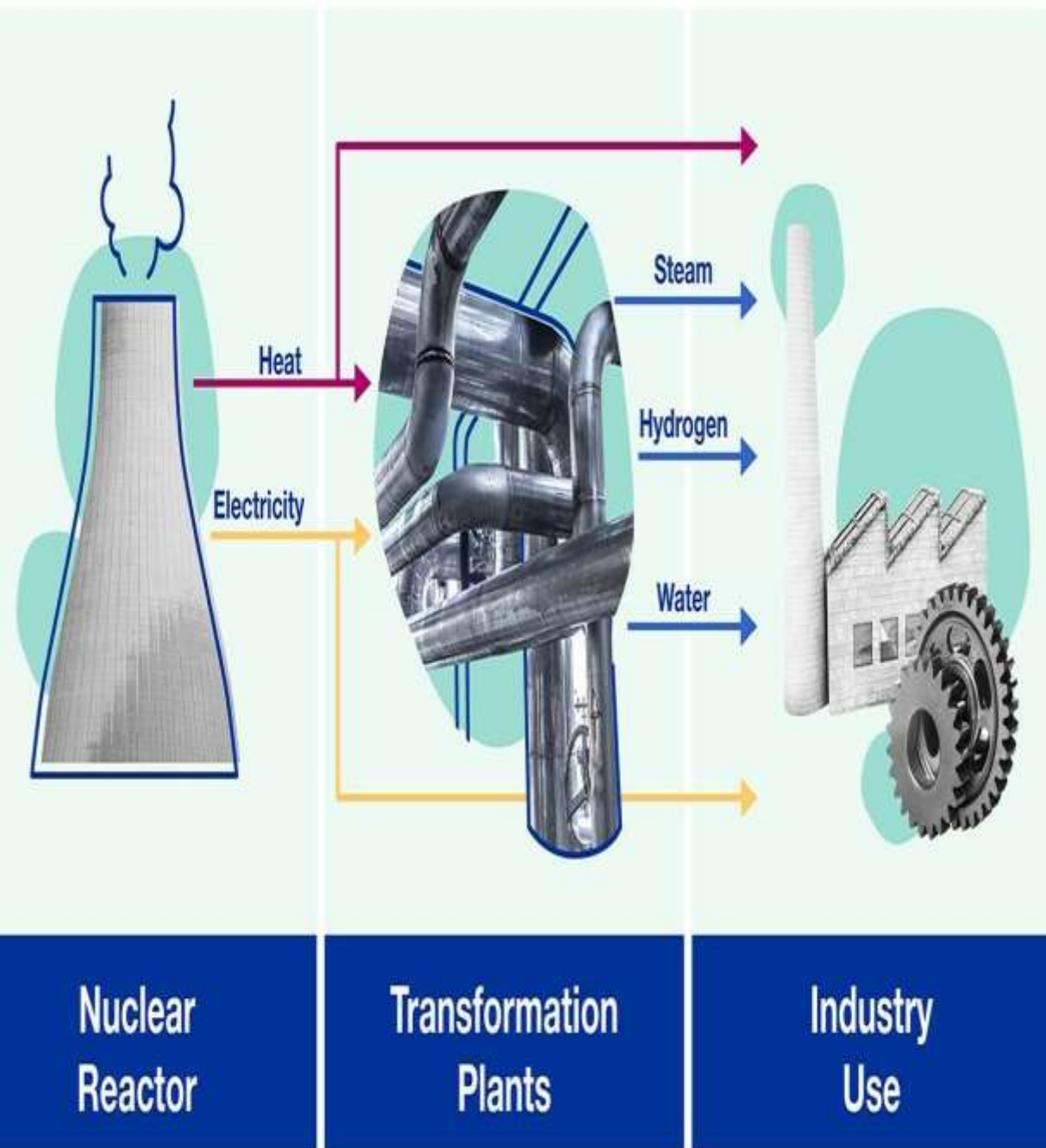
Thermal Water Pollution

Cooling systems discharge heated water into rivers or seas, affecting **aquatic ecosystems** by altering water temperature and reducing dissolved oxygen levels.

Rigorous Safety Protocols

Multiple redundant safety systems, continuous monitoring, **strict regulatory oversight**, and emergency preparedness plans are essential to minimise accident risks.

Applications of Nuclear Power



Electricity Generation

The primary application—nuclear power supplies approximately **10% of global electricity**, with some nations relying on it for majority of their power needs.



Naval Propulsion

Powers nuclear submarines and aircraft carriers, enabling them to operate for **months without refuelling** and travel vast distances underwater.



Medical Applications

Produces vital **radioisotopes** used in cancer treatment, diagnostic imaging (PET scans), and sterilisation of medical equipment.



Research & Industry

Research reactors support **scientific experiments**, materials testing, neutron radiography, and production of industrial isotopes.

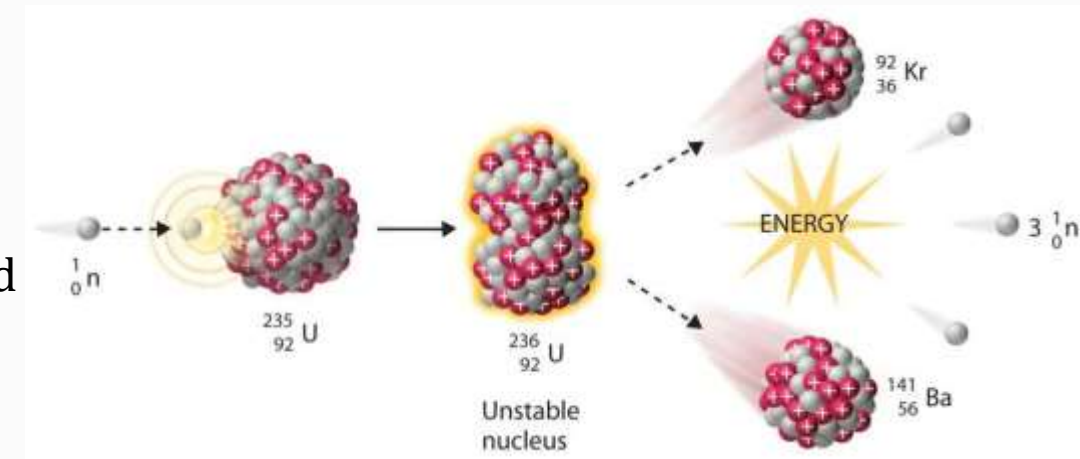
Assessment- Quiz

1. The Chain Reaction Puzzle Question:

Fill in the blanks: In a nuclear reactor, a heavy nucleus such as ___ splits into smaller nuclei, releasing ___ and ___.

Answer: ✓ Uranium-235, energy, and neutrons.

Explanation: When uranium-235 undergoes fission, it releases energy as heat and additional neutrons that sustain the chain reaction.

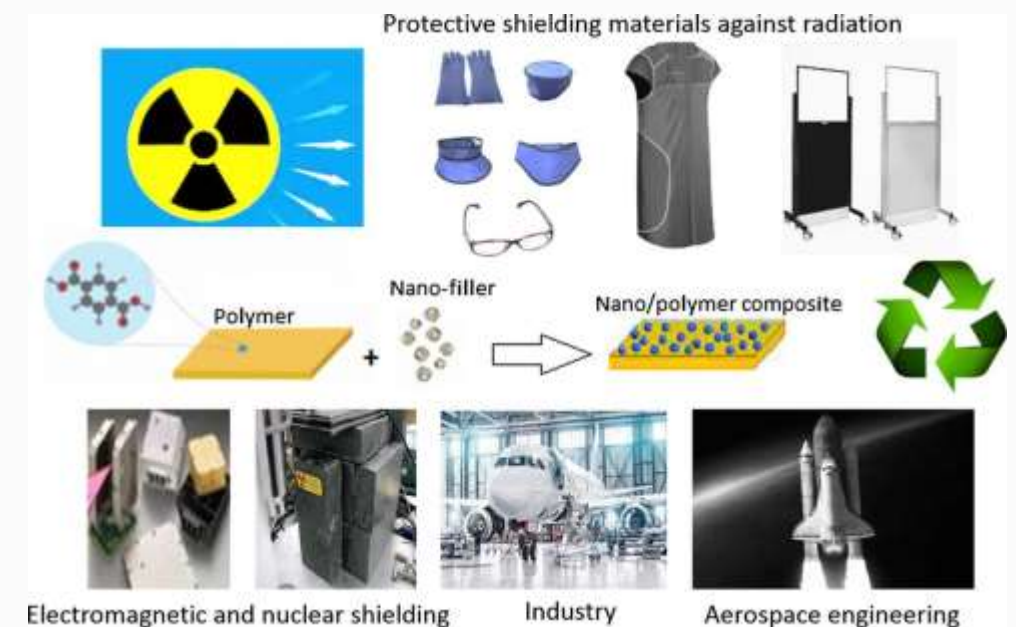


2. The Safety Shield Puzzle Question:

Which component protects the environment and personnel from radiation, and what materials is it made of?

Answer: ✓ Biological Shield, made of thick concrete or lead.

Explanation: It absorbs harmful radiation emitted from the reactor core, ensuring operational safety.



References



<https://www.youtube.com/watch?v=1U6Nzcv9Vws&t=83s>

https://www.youtube.com/watch?v=K9F8-Tz6lzc&list=PLSGws_74K01-ZTnC-LoJ0brEzy_a6DBMf&index=26

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