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Power generation

①

Q1:-

A.

Ans:- Hydro-power or water power is power derived from the energy of falling water or running water.

-> First used by Greeks for grinding wheat.

-> Earlier waterwheels were used to turn machinery.

-> These waterwheels powered textile and industrial mills.

-> Hydro power is conventional but renewable energy source.

Hydro-Electricity:-

Hydroelectricity is the term referring to electricity generated by hydropower, the production of electrical power through the use of the gravitational force of falling or flowing water.

-> About 16-18% of global electricity generation.

-> Total installed hydropower capacity is about 630 GW.

-> China is largest hydroelectricity producer. (721 terawatt/hours).

Hydro power Types :-

-> Conventional hydroelectric refering to hydroelectric dams. (Potential Energy).

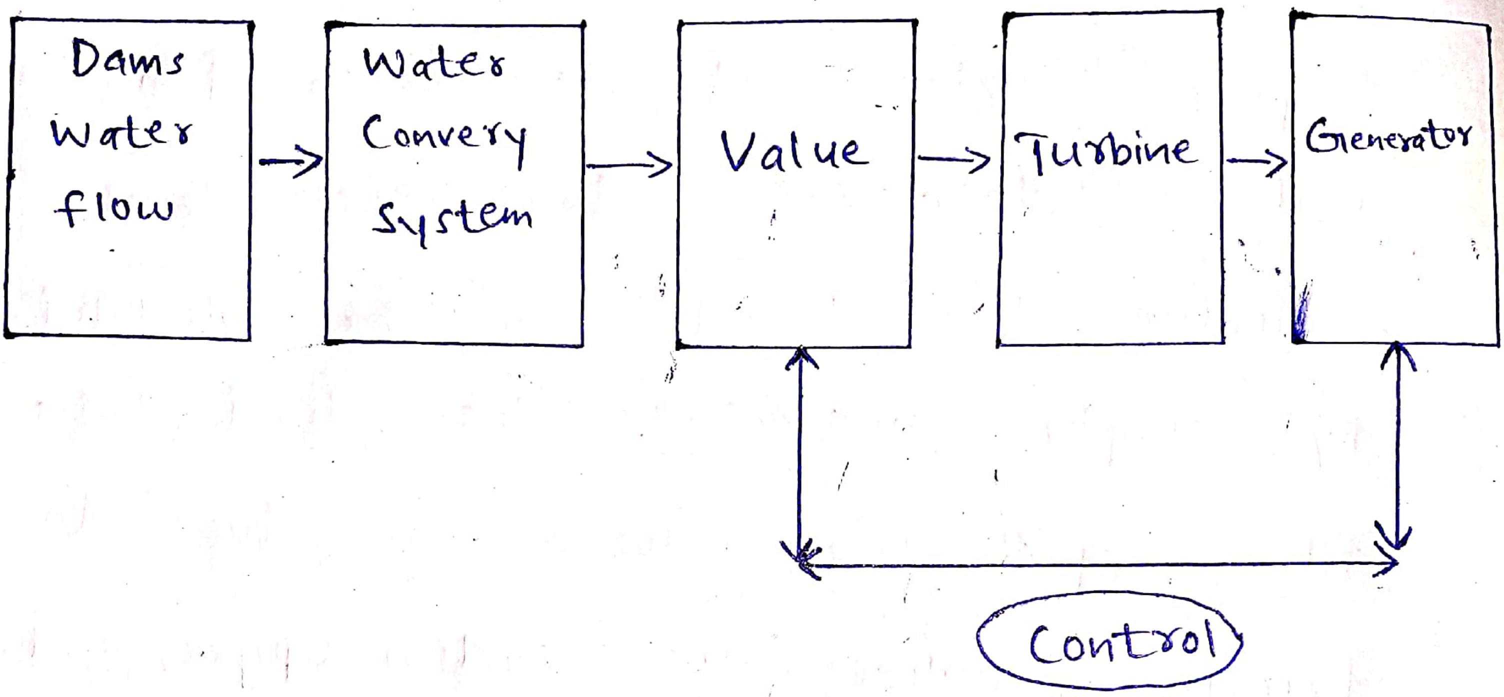
-> Run-of-the-river hydroelectricty which captures the (kinetic energy) in rivers or streams, without the use of dams.

-> Small hydro projects are 10 megawatts or less and often have no artificial reservoirs.

-> Micro hydro projects provide a few kilowatts to a few 100 kilowatts to isolated homes, villages, or small industries.

-> Pumped-storage hydroelectricity stores water pumped during periods of low demand to be released for generation when demand is high.

Hydroelectric General Layout :-

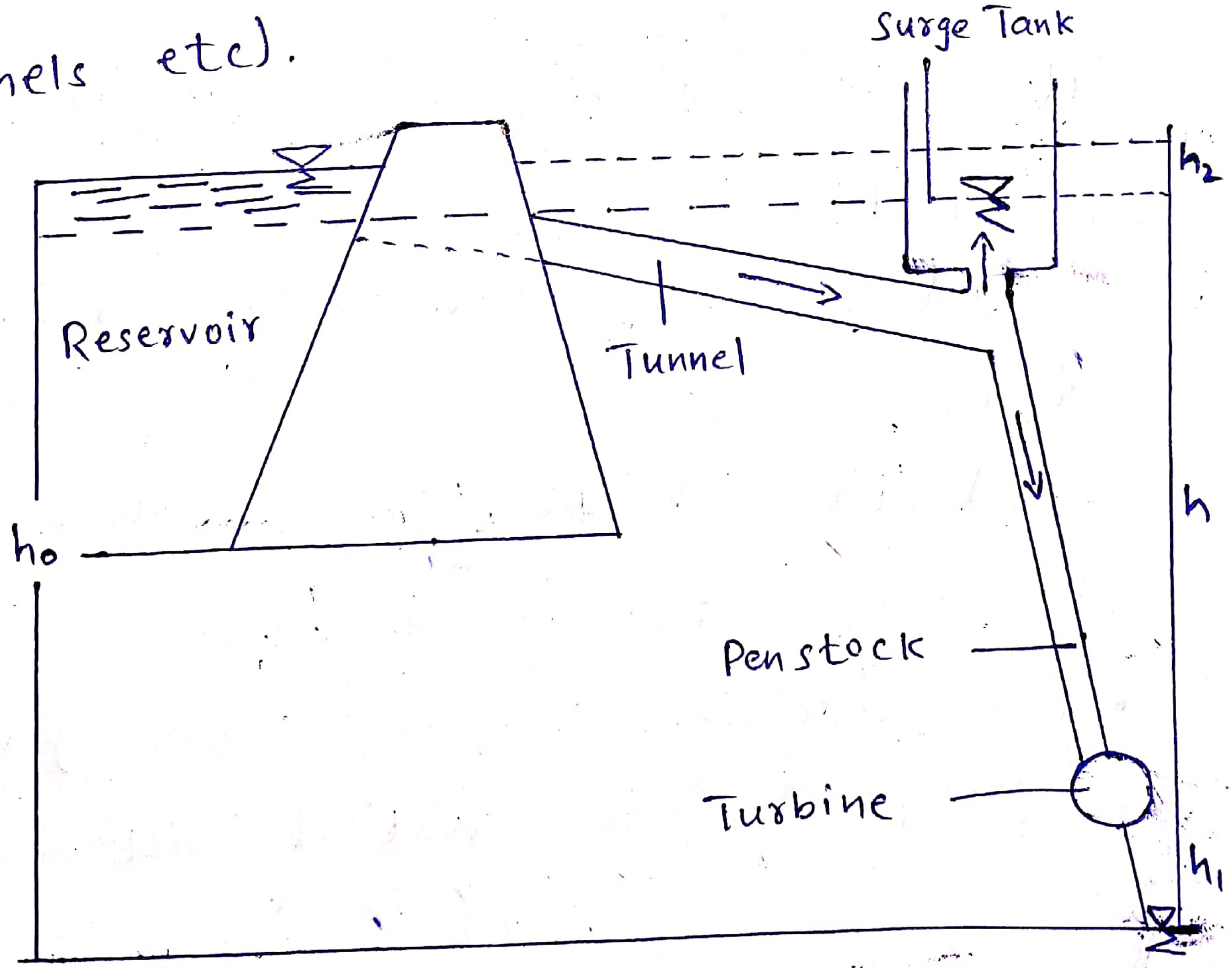


Site Consideration for Hydropower Plants :-

- Two Factor
  → Amount of water flow per unit time.
  → Vertical height that water can be made fall (head).
- For reaction turbines the gross head h_o is the vertical distance between

the water surface level at the intake and the tailrace. While for impulse turbine it is taken from water intake level to nozzle level.

- Effective head height can be calculated by simply subtracting the head losses along path. Head losses are due to frictions within the system (pipes, penstock tunnels etc).



Q1:-

B.

Sol:- Given data

Available volume at pondage $V = 5 \times 10^5 m^3$

Available head $h = 100m$

Hydraulic efficiency $= 85\% = 0.85$

Electrical efficiency $= 94\% = 0.94$

Overall efficiency $= 0.85 \times 0.94 = 0.80$

Using,

$$E = \eta \rho g h V = 0.8 \times 1000 \times 9.81 \times 100 \times 5 \times 10^5$$

$$E = 3.92 \times 10^{11} \text{ W/s}$$

x ——————————— x

Q3:-

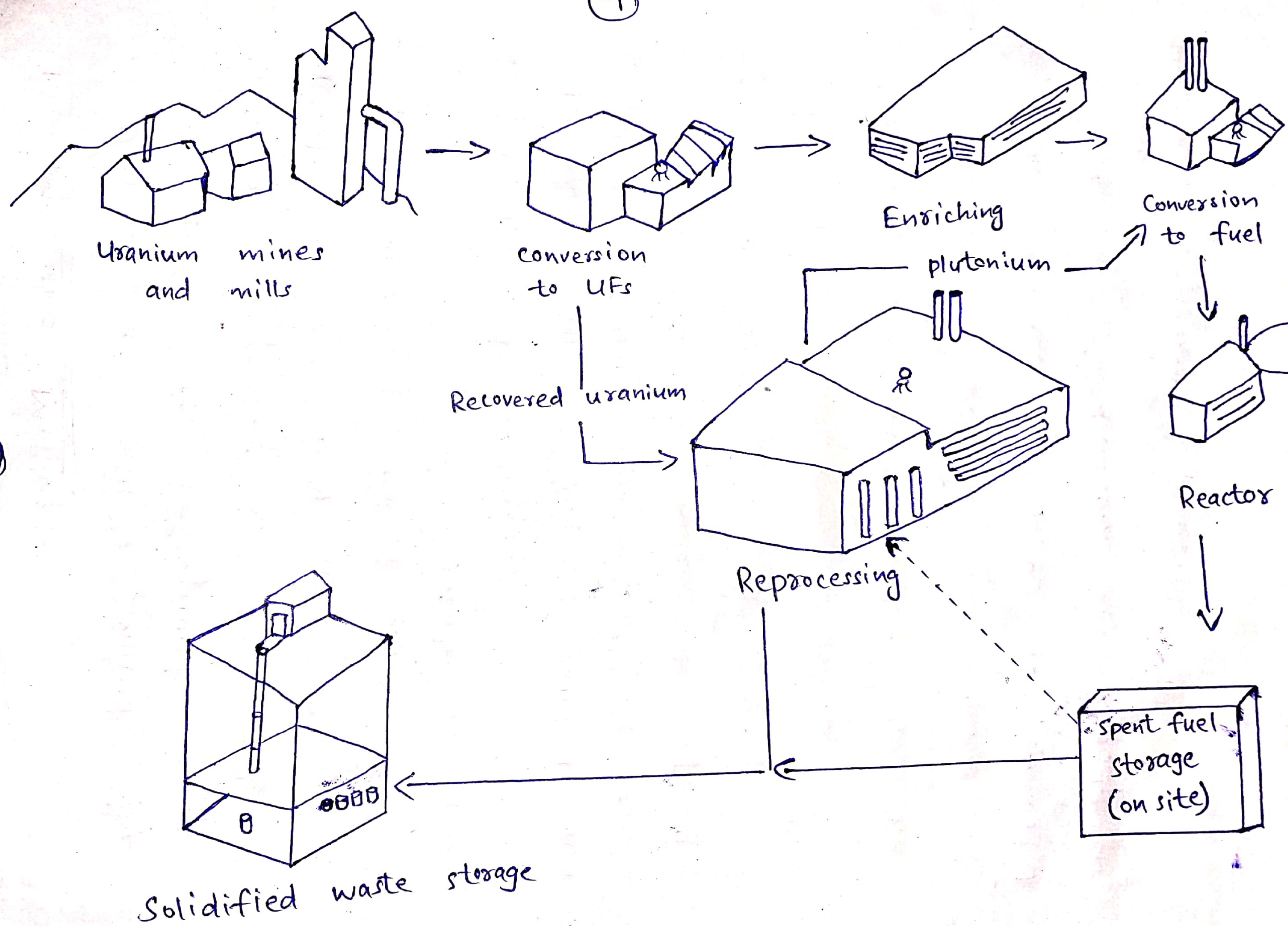
Ans:- **Nuclear Fuel Cycle:-**

→ The nuclear fuel cycle is the series of indurtrial processes which involve the production of electricity from uranium in nuclear power reactorss.

→ Uranium is relatively common element that is found throughout the world. It is mined in a number of countries and must be processed before it can be used as fuel for a nuclear reactor.

→ Fuel removed from a reactor, after it has reached the end of its useful life, can be reprocessed so that most is recycled for new fuel.

9


Uranium mines and mills
conversion to UFs
Enriching
Conversion to fuel
plutonium
Recovered uranium
Reactor
Reprocessing
spent fuel storage (on site)
Solidified waste storage

Mining and Milling :-

-> Uranium is usually mined by either surface or underground mining techniques depending on the depth at which the ore body is found.

-> From these, the mined uranium ore is sent to a mill which is usually located close to mine.

-> At the mill the ore is crushed and ground to a fine slurry which is leached is sulfuric acid to allow the separation, of uranium from the waste rock.

Conversion :-

-> Because uranium needs to be in the form of a gas before it can be enriched, the U_3O_8 is converted into the gas uranium hexafluriode (UF_6) at a conversion plant.

Enriching :-

→ Need to enrich uranium to at least 3% for a power plant.

→ Two Methods of Enriching

→ Gaseous Diffusion Method :-

→ UF_6 (hexafluoride) gas heated.

→ U-238 is heavier than U-235

→ Hexafluoride gas can be separated into two streams.

→ Low velocity U-238

→ High velocity U-235

Centrifuge Method :-

→ Gas spun in centrifuge

→ Lighter U-235 will separate from heavier U-238.

Fuel Conversion :-

→ Enriched uranium transported to a

fuel fabrication plant where it is converted to uranium dioxide (UO_2) powder and pressed into small pellets.

-> These pellets are inserted into thin tubes, usually of a zirconium alloy or stainless steel, to form fuel rods.

-> The rods are then sealed and assembled in clusters to form fuel assemblies for use in the core of the nuclear reactor.

Fuel Packaging in the core :-

-> Rods contain uranium enriched

-> Needs roughly 100 tons per year for a 1000 MW plant.

The Reactor Core :-

-> The reactor core consists of fuel rods and control rods.

-> Fuel rods contain enriched uranium.

→ Control rods are inserted between the fuel rods to absorb neutrons and slow the chain reaction

→ Control rods are made of cadmium which absorb neutron effectively

Moderator :-

→ Neutrons produced during fission in the core are moving too fast to cause a chain reaction

→ A moderator is required to slow down the neutrons.

→ In Nuclear power plants water or graphite acts as the moderator.

Uranium Reprocessing :-

→ Spent fuel still contains approximately 96% of its origin uranium, of which the fissionable U-235 content has been reduced to less than 1%

-> Spent fuel comprises waste products and the remain 1% is plutonium produced while the fuel was in the reactor.

-> Reprocessing extracts useable fissile U-238.

-> Most of the spent fuel can be reprocessed.

-> Federal law prohibits commercial reprocessing because it will produce plutonium (which can be used both as a fuel and in constructing bombs)

Q2:-

Ans:- **Turbine:-**

Turbine is a rotary mechanical device that extract energy from a "fluid flow" and converts into useful work.

Types of hydropower turbines:-

1. Impulse Turbine
2. Reaction Turbine

Impulse:- The steam velocity is very high and therefore turbine speed is very high.

Reaction:- The steam velocity as well as pressure is utilized.

1. Impulse turbine :-

The impulse turbine generally uses the velocity of the water to move the runner. The water stream hits each bucket on the runner.

-> An impulse turbine is generally suitable for high head, low flow applications.

-> In impulse turbine, at inlet, only Kinetic energy available. But in reaction turbine both are available.

Types of Impulse Turbine :-

1. Pelton Turbine
2. Cross-flow Turbine

1. Pelton Turbine :- A pelton turbine wheel

has one or more free jets, discharging water on the buckets of a runner. Draft tubes are not required for impulse turbine since the runner must be located above the maximum tail water to permit operation at at atomspheric pressure.

→ A Turgo wheel, resemble a fan blade that is closed on the outer edges. The water stream is applied on one side, goes across the blades and exists on the other side.

2. <u>Cross-flow Turbines</u> :- It resembles a "squirrel cage" blower. The cross-flow turbine allows the water to flow through the blades twice. The first pass is when the water flows from the outsides of the blades to the inside, the second pass is from the inside back out. A guide vane

at the entrance to the turbines directs the flow to the limited portion of the runner. The cross flow was developed to accommodate larger water flows and lower heads than the pelton.

2. Reaction turbine :- A reaction turbine develops power from the combined action of pressure and moving water. The runner is placed directly in the water steam flowing over the blades rather than striking each individually.

-> Reaction turbine are generally used for sites with lower head and higher flows than compared with the impulse turbines.

Types of Reaction Turbines :-

-> Propeller Turbine
-> Francis Turbine

→ Kinetic Turbine

1. **Propeller Turbine** :- A propeller turbine generally has a runner with three to six blades in which the water contacts all of the blades constantly.

→ The pitch of the blades may be fixed or adjustable.

Types of Propeller Turbines :-

i. Bulb Turbine
ii. Straflo Turbine
iii. Tube Turbine
iv. Kaplan Turbine

i. **Bulb Turbine** :- The turbine and generator are a sealed unit placed directly in the water stream.

ii. **Straflo Turbine** :- The generator is attached directly to the perimeters of the turbine.

iii. Tube Turbine :- The penstock bends just before or after the runner.

iv. Kaplan Turbine :- Both the blades and the wicket gates are adjustable, allowing for a wider range of operations.

2. Francis Turbine :- A francis turbine has a runner with fixed buckets usually nine or more. Water is introduced just above the runner and all around it and then falls through, causing it to spin. Besides the runner, the other major components are the scroll case, wicket gates, and draft tube.

3. Kinetic Turbine :- Kinetic turbine also called free flow turbines, generate electricity from the kinetic energy present in the flowing water. The system may operate in

rivers, man-made channels, tidal waters, or ocean currents. Kinetic system utilize the water streams natural pathway. Kinetic system do not require large civil works however they can existing structures such as bridges and channels.

Turbine Properties and Selection :-

Head classification	Turbine types	
	Impulse	Reaction
High (>50m)	• Pelton • Turgo	
Medium (10-50m)	• Cross-flow • Turgo • Multi-jet pelton	• Francis (spiral case)
Low (<10m)	• Cross flow • Undershot water wheel	• Propeller • Kaplan • Francis (open flume)

Selection of Turbines:-

- Net Head
- Range of Discharge through turbine
- Rotational Speed
- Cost

→ Francis is slow runner will be used in high head schemes, where Kaplan, Propeller and bulb as used in low head schemes with high speeds.

→ The available energy therefore depends on the head of the water above the turbine and volume of water flowing through it.

→ Turbines can also be selected on the basis of their output power and rated discharge.

Kaplan :-

-> Smoth operation to low flow.

-> Higher efficiency over a wide range.

-> May result in a single unit instead of two Francis

-> Higher specific speed and rotational speed (smaller generator).

Francis :-

-> Less expansive.

Pelton :-

-> Less excavation cost.

-> Better for erosive water.

-> Better part load efficiency.

-> Less sensitive to head variation.

-> Wide operation range.

-> Lower maintenance cost.

Francis :-

-> Higher specific speed and rotational speed.

-> Higher peak efficiency

Q2:-

(b) Given data

Head $h = 190m$

Discharge $q = 2.2 \, m^2/s$

Overall Efficiency $\eta = 85\% = 0.85$

$$n_s = \frac{85.49}{(h)^{0.243}}$$

$$n_s = \frac{85.49}{(190)^{0.243}} = 23.88 \text{ Rpm}$$

Using,

$P = \eta \rho q g h$ to obtain power output

$P = 0.85 \times 1000 \times 2.2 \times 9.81 \times 190$

$= 348.5 \text{ kw}$

$$n = n_s = 23.88 \times \frac{(190)^{3/4}}{\sqrt{3485.5}} \qquad \because n = n_s \times \frac{h^{3/4}}{\sqrt{P}}$$

$= 285.32 \text{ rpm}$

The number of poles required are computed by

$$N_s = \frac{120f}{P}$$

$$P = \frac{120 \times 50}{285.32}$$

$$P = 21.02 \text{ poles}$$

We will select 24 poles which will rotat at 250 rpm at 50 Hz. So the turbine will all have diameter. which can be calculated by

$$D = 38.567 \frac{\sqrt{4}}{n} = 38.567 \frac{\sqrt{190}}{250} = 2.12\,m$$

For calculating Jet diameter

$$q = \pi d_g^2 \left(\frac{v_g}{4}\right)$$

$$\text{Jet velocity} = v_j' = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 190}$$

$$= 61.05 \text{ m/sec}$$

Therefore jet diameter will be

$$d_j = \sqrt{\frac{4q}{\pi v_j}} = \sqrt{\frac{4 \times 2.2}{3.14 \times 61.05}}$$

$$= 0.214\,m \text{ or } 21.4\,cm.$$