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Power Generation

Terminal Examination　　*course Instructor: Engr.Sanaullah Ahmad*

Note: Attempt all Questions & Draw diagrams where necessary.

Question No 1 ***20***

A. With the help of a diagram show different Elements of a Hydropower Plant? CLO 1
B. Water for a small hydroelectric station is to be made available from a pondage with a volume of $5 \times 10^5 m^3$ located at a height uphill to provide water at a head of 100m at a hydraulic efficiency of 85% If the electrical efficiency is 94% and the water supply is available for 8 hours daily, determine the capacity of the generator to be installed at the power station. CLO 2

Question No 2 ***20***

A. Classify different hydropower turbines, what are the parameters required for the selection of hydropower turbines? CLO1
B. Select a suitable turbine for a hydropower scheme with available head height of 190m and rated discharge of 2.2 m^2/s with overall efficiency of 85%? Also determine turbine diameter and jet diameter? Specific speed $Ns = 85.49/(h)^{0.243}$. $Diameter = 38.56\sqrt{h}/n$. *Jet Diameter* $q = (\prod dj^2)Vj/4$ *where* $Vj = \sqrt{2gh}$ CLO 2

Question No 3 ***10***

Explain different stages of Nuclear Fuel Cycle? CLO 1

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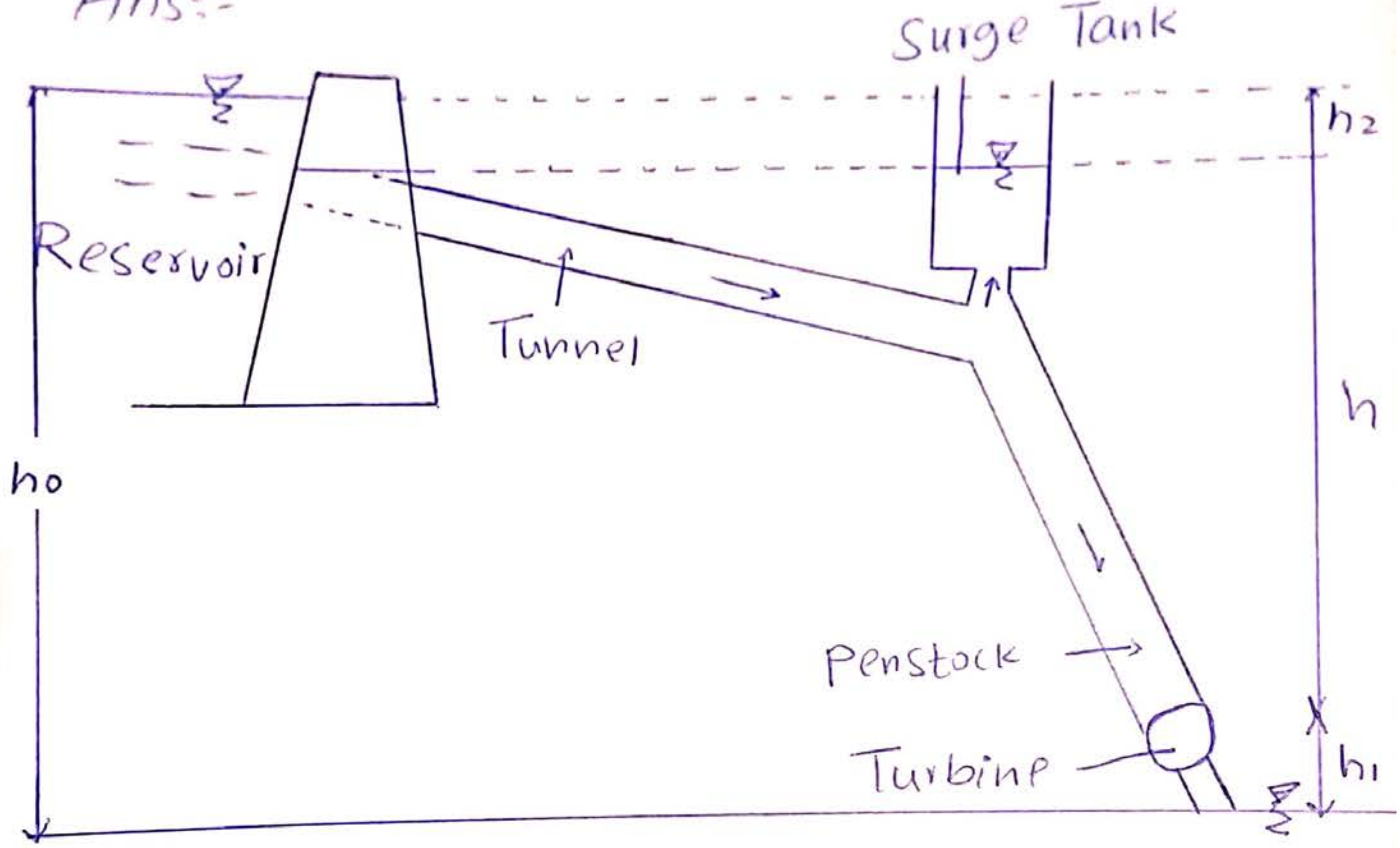
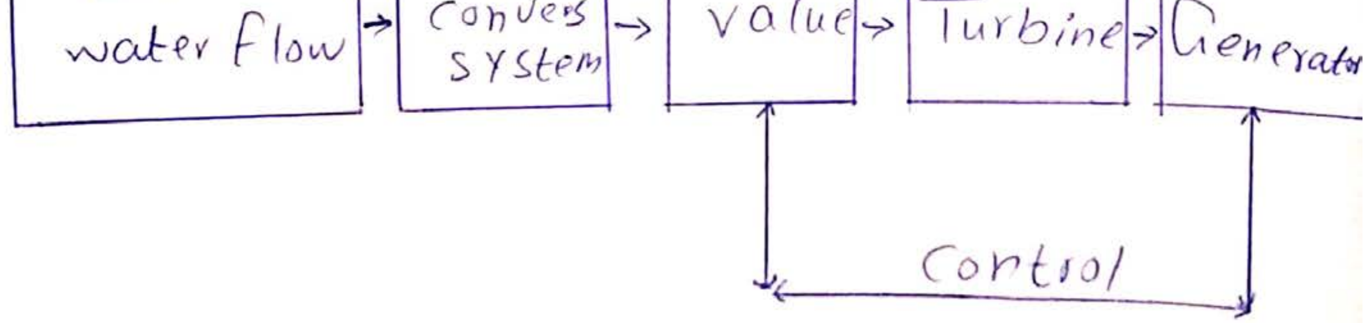
Q 1: (A):-

Ans:-



General layout of Hydro-Electric:-



Element of a Hydropower Plant:-

(1) Dam and Reservoir:- The dam is constructed on a large river in hilly areas to ensure sufficient water storage at height. The height of water level (called as water head) in the reservoir determine how much of potential energy is stored in it.

(2) Control Gate:- Water from the reservoir is allowed to flow through the Penstock

to the turbine. When the control gate is fully opened maximum amount of water is released through the penstock.

(3) Penstock:-

A penstock is a huge steel pipe which carries water from the reservoir to the turbine. Potential energy of the water is converted into kinetic energy as it flow down through the penstock due to gravity.

(4) Water Turbine:- water from the Penstock is taken into the water turbine. The turbine is mechanically coupled to an electric generator.

Two main type of water turbine

(i) Impulse Turbine.

(ii) Reaction Turbine.

Impulse Turbine are used for large heads and reaction turbine are used for low medium heads.

(5) Generator:-

A generator is mounted in the power house and it is mechanically coupled to the turbine shaft. when the turbine blades are rotated it drives generator and electricity is generated which is then stepped up with the help of a transformer for the transmission purpose.

(6) Surge Tank:-

Surge tanks are usualey Providded in high or medium head power plants when considerably long penstock is requiled. A surge tank is a small reservoir or tank which is open at the top. It is fitted between the reservoir and the power house. This is prevented by using a surge tank in which the water level rises to reduce the pressure. On the other hand the surge tank provide excess water needed when the gates are suddenly opened to meet the increased load demand.

Q 1: (B)

Given data:-

Available volume at pondage

$V = 5 \times 10^5 m^3$

Available head = $h = 100m$

Hydraulic efficiency : 85% 0.85

Electrical efficiency : 0.94

Therefore, overall efficiency 0.85×0.94

Sol:- using formula $= 0.80$

$E = \eta \rho g h v$

$= 0.8 \times 1000 \times 9.81 \times 100 \times 5 \times 10^5$

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

Q 2:-(A)

Ans:- Turbine:-

Turbine is a rotary ~~meta~~ mechanical device that extracts energy from a "fluid flow" and converts it into usefol work.

Types of hydropower turbines:

(1) Impulse Turbine.
(2) Reaction Turbine.

* Impulse:-

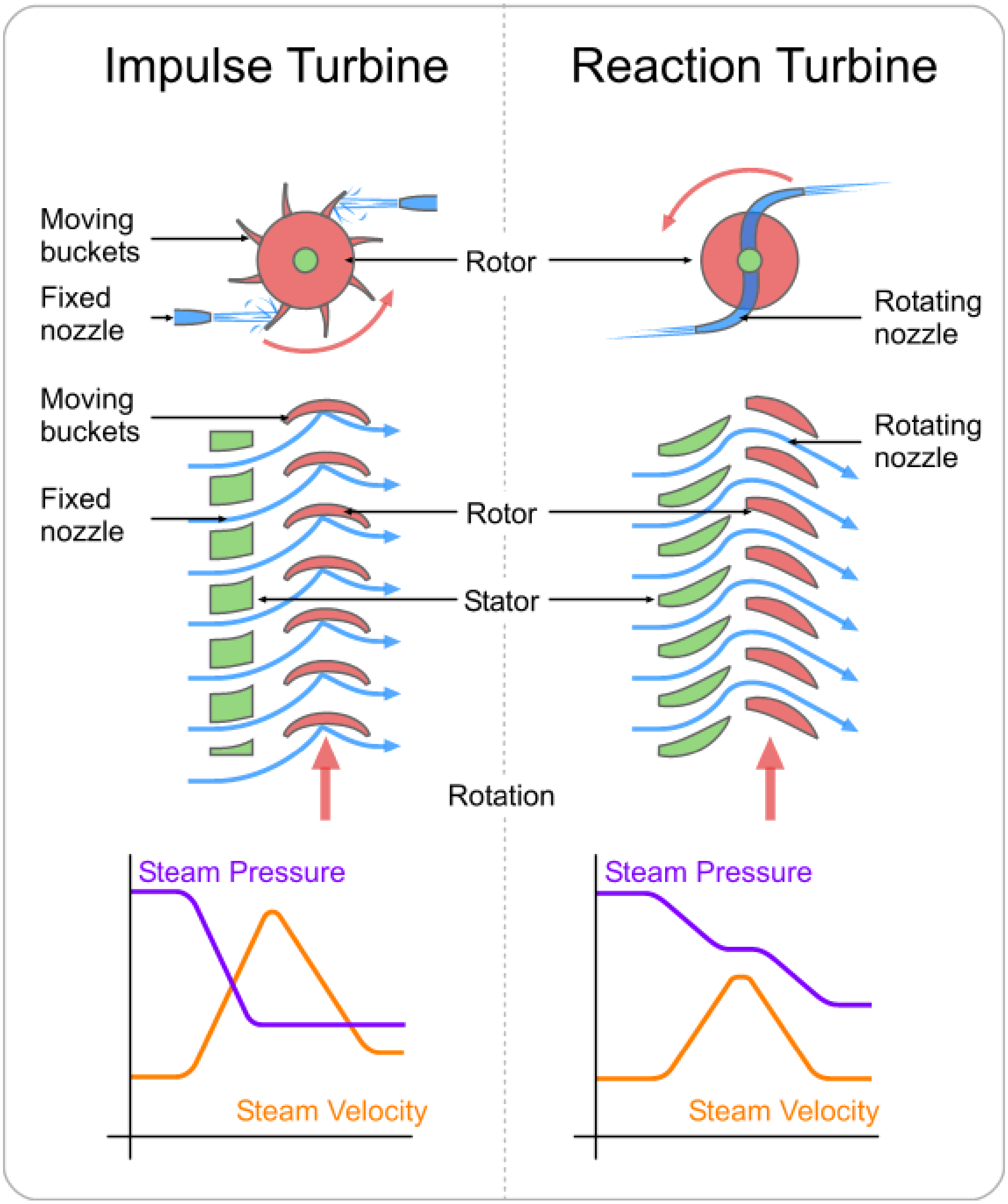
The Steam velocity is very high and therefore turbine speed is very high.

* Reaction:-

The Steam velocity as well as pressure is utilized.

Type of turbine selected for Project is based on:

- Height of standing water "head"
- Flow of water.
- volume of water.
- How deep the turbine must be Set.



Impulse Turbine
Reaction Turbine
Moving buckets
Fixed nozzle
Rotor
Rotating nozzle
Moving buckets
Fixed nozzle
Rotor
Rotating nozzle
Stator
Rotation
Steam Pressure
Steam Velocity
Steam Pressure
Steam Velocity

- Efficiency.
- Cost.

(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 application.
- In impulse turbine, at inlet, only kinetic energy available. But in reaction turbine, at inlet kinetic energy as well as pressure energy both are available.

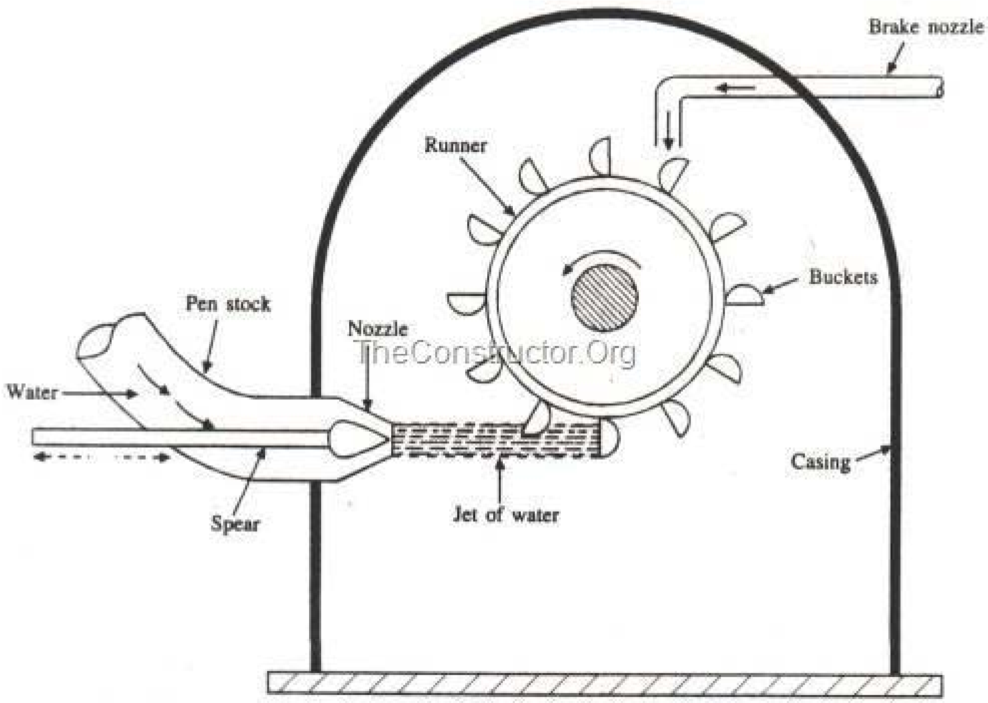
Types of Impulse Turbines:

1. Pelton Turbine.
2. Cross-flow Turbine.

(1) Pelton Turbines:-

A Pelton wheel has one or more free jets, discharging water on ~~turbine~~ 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 atmospheric pressure.

Pictures of Pelton Turbines and Turgo

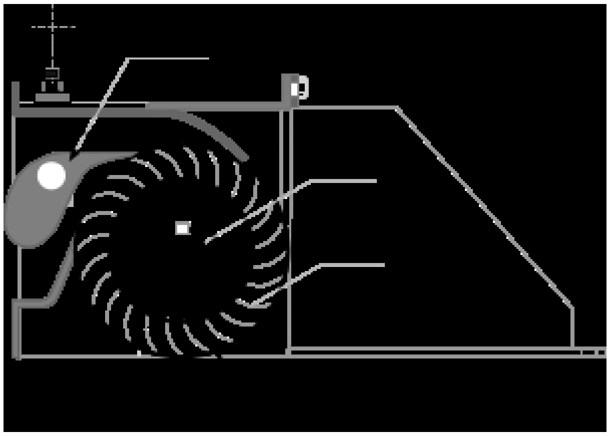


- A Turgo wheel, resembles a fan blade that is closed on the outer edges. The water stream is applied on one side, goes across the blades and exits on the other side.

(11) Cross-flow Turbines:

it resemble a "squirrel cage" blower. The cross-flow Turbines allows the water to flow through the blades twice. The first Pass is when the water flow from the outside of the blades to the inside; the second pass is from the inside back out.

Pictures of Cross-flow turbines



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 stream 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:

(1) Propeller turbine.

(2) Francis Turbine.

(3) 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:

(1) Bulb Turbines:

The turbine and generator are a sealed unit placed directly in the water stream.

(2) Straflo Turbine:
The generator is attached directly to the perimeters of the turbine.

(3) Tube Turbines:
The pen stock bends just before or after the runner.

(4) Kaplan Turbines:
Both the blades and the wicket gates are adjustable, allowing for a wider range of operation.

(2) Francis Turbines:
A Francis turbine has a runner with fixed buckets (vanes) usually nine or more. Besides the runner, the other major components are the

Scroll case, wicket gates, and draft tube.

(3) Kinetic Turbines:

Kinetic turbines, also called free-flow turbine, generate electricity from the kinetic energy present in flowing water. Kinetic System utilize the water stream's natural pathway. Kinetic systems do not require large civil work; however they can use existing Structures such as bridges, and channels.

Kaplan/Francis Decision

Kaplan: Smooth operation to low flow

- Higher efficiency over a wide range.
- May result in a single unit

instead of two Francis.

Francis:-

Less expansive

Francis / Pelton decision

- Pelton:-

Less excavation cost.

Better for erosive water.

Better Part load efficiency.

Lower maintenance cost.

- Francis:-

Higher specific speed and rotational speed (Smaller generator)

- Higher peak efficiency.

Specific Speed for Different Turbines

Type of Turbine	Specific Speed (rpm)	Reference (source)
Pelton Wheel (single jet)	$n_S = \frac{85.49}{(h)^{0.243}}$	Siervo and Lugaresi, 1978
Francis	$n_S = \frac{3763}{(h)^{0.854}}$	Schweiger and Gregory, 1989
Kaplan	$n_S = \frac{2283}{(h)^{0.486}}$	Schweiger and Gregory, 1989
Cross-flow	$n_S = \frac{513.25}{(h)^{0.505}}$	Kpordze and Warnick, 1983
Bulb	$n_S = \frac{1520.6}{(h)^{0.2837}}$	Kpordze and Warnick, 1983

Q 2: (b)

Given data:-

Head $h = 190m$

Discharge $q = 2.2 \, m^3/s$

Overall efficiency $= \eta = 85\% \; 0.85$

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

$$n_s = \frac{85.49}{(190)^{0.243}} = 23.88 \, rpm$$

The output power can be obtained using

$P = \eta \rho q g h$ watts

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

$$= 3485.5 \text{ KW}$$

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

$$= 285.32 \text{ rpm}$$

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

$$P = \frac{120 \times 50}{285.32} = 21.02 \text{ Poles.}$$

24 pole alternator at 250 rpm

$$D = 38.567 \frac{\sqrt{H}}{n} = 38.567 \times \frac{\sqrt{190}}{250} = 2.12 \text{ m}$$

page (20)

using (eq)

$$q = \frac{\pi d g^2 (v g)}{4}$$

velocity $= v_j = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 190}$

$= 61.05$ m/sec

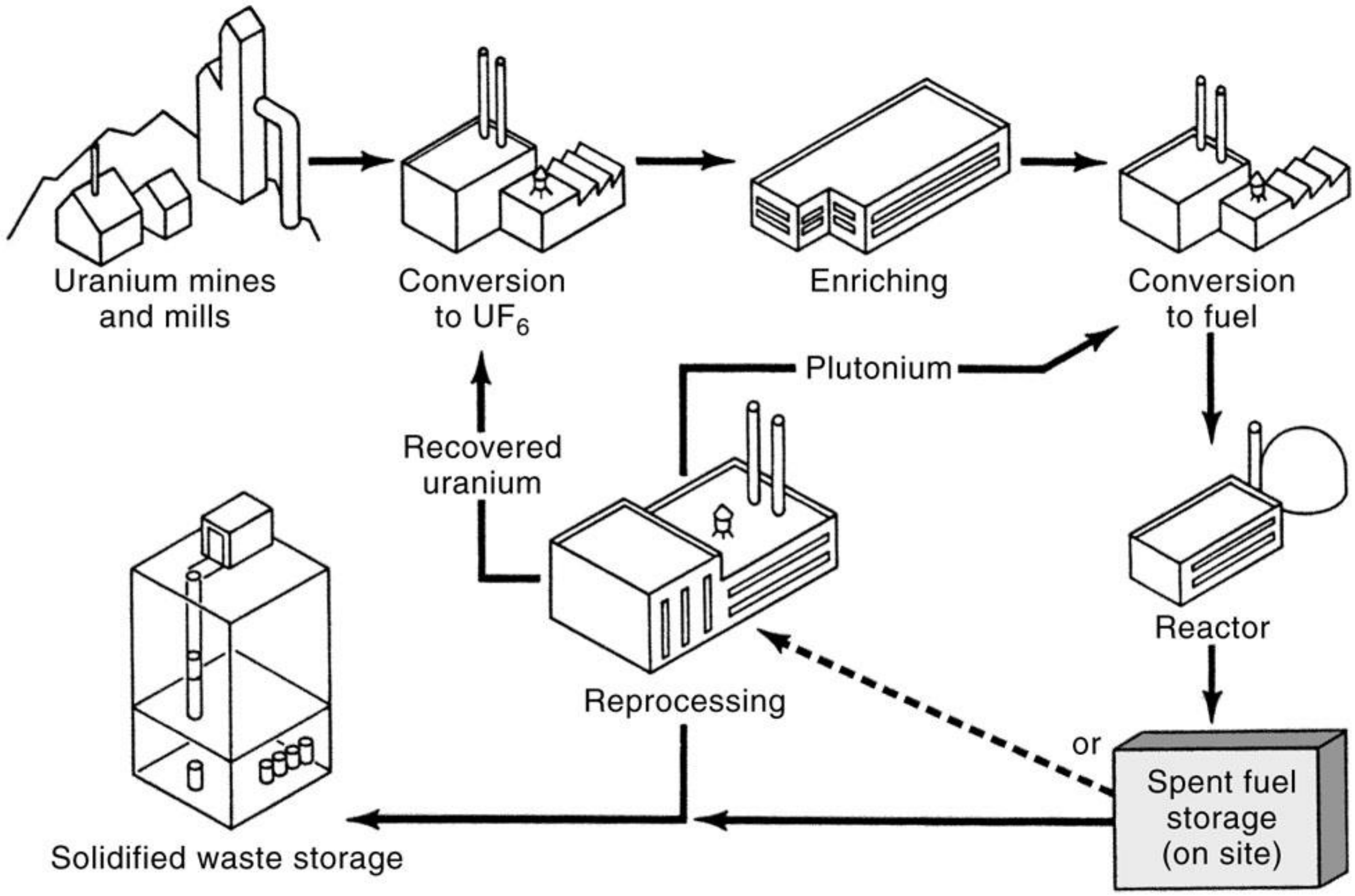
diameter will

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

$= 0.214$ m or 21.4 cm.

$d_j = 21.4$ cm.

Nuclear Fuel Cycle



Q 3:

Ans:- Mining and Milling:-

- Uranium is usually mined by either Surface (open cut) 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 the mine.
- At the mill the ore is crushed and ground to a fine slurry which is leached in sulfuric acid to allow the separation of uramium from the waste rock.

• It is then recovered from solution as uranium oxide (U_3O_8) concentrate.

* 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 hexafluoride (UF_6) at a conversion plant.

* Enriching:-

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

(1) Gaseous Diffusion method:-

* UF_6 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

(2) 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.

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

- Fuel Packaging in the core:-
  - Rods contain uranium enriched
  - Need roughly 100 tons per year for a 1000mw plant.

- The Reactor Core:-

The reactor core consists of fuel rods and control rods.

- Fuel rods contain enriched uranium.

- Control rods are made of cadmium, which absorb neutrons effectively

- Moderators:-

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

- A moderater is required to slow down the neutrons.
- In Nuclear Power plants water or graphite acts as the moderator.

- Boiling Water Reactor:-

- Heat generated in the core is used to generated steam exchanger.

- The steam runs a turbine just like a normal power plant.

* Uranium Reprocessing:-

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

- 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)

- Nuclear waste Disposal:-

In the U.S., no high-level nuclear waste is ever disposed of it sits in specially designed pools resembling large swimming pools (water cools the fuel and acts as a radiation shield) or in specially designed dry storage containers.

- After 10,000 years of radioactive decay, according to EPA standards, the spent nuclear fuel will no longer pose a threat to public health.