IQRA National University, Peshawar
Department of Electrical Engineering
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Power Generation

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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* $= 38.56\ \overline{h}/n$. *Jet Diameter* $q = (\prod dj^2)Vj/4$ *where* $Vj = 2gh$ CLO 2

Question No 3 — *10*

Explain different stages of Nuclear Fuel Cycle? CLO 1

GOOD LUCK

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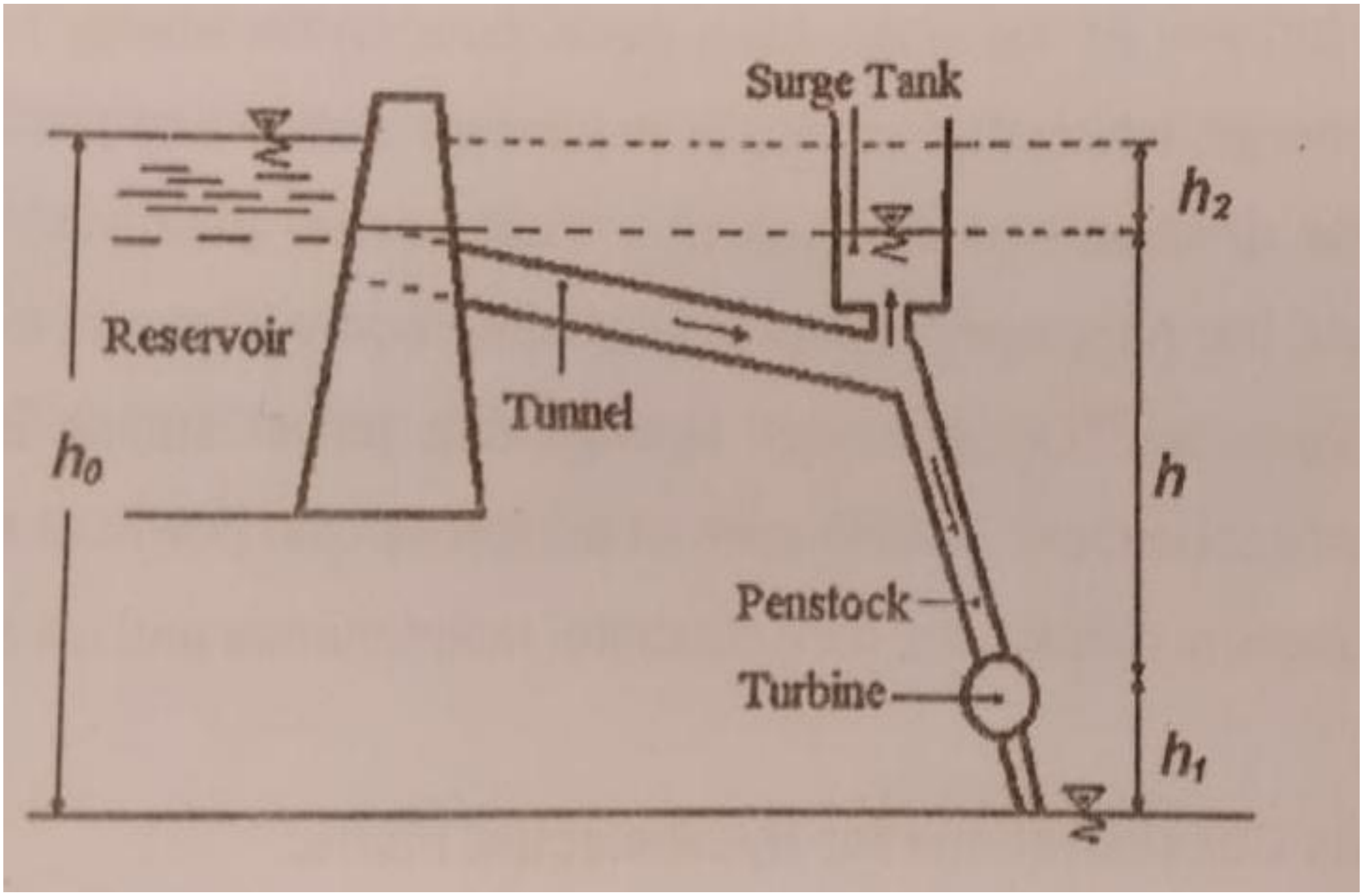
Question No 1
Part (A)



A hydroelectric plant consists of a reservoir for storage of water, a diversion dam, an intake structure for controlling and regulating the flow of water, a conduit system to carry the water from the intake to the waterwheel, the turbines coupled with generators, the draft tube for conveying water from waterwheel to the tailrace, the tailrace and a power house i.e., the building to contain the turbines, generators, the accessories and other miscellaneous items.

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The size, location, and type of each of these essential elements depend upon the topography and geological conditions and the amount of water to be used. The height to which the dam may be built is usually limited by the extent of flowage damage. Pondage may have great value, particularly for peak load power plants, warranting the purchase of extensive flowage rights. The spillway section of the dam must be long enough to pass safely the maximum amount of water to be expected.

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Part (B)

Given that:

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:

$85 \times 0.94 = 0.80$

Using $E = \eta \rho g h V$

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

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

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Question No 2
Part (A)

Classification of Turbines:
1: Impulse Turbine
2: Reaction Turbine

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, at inlet kinetic energy as well as pressure energy both are available.

Types of Impulse Turbines:

1: Pelton Turbine
2: Cross-flow Turbine

Reaction Turbines:

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

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Types of Reaction Turbines:

1: Propeller Turbine
2: Francis Turbine
3: Kinetic Turbine

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Part (B)

(1)

Given that:

Head $= h = 190m$

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

Overall efficiency: $\eta = 85\%$ or 0.85

Solution:

$$N_s = 85.49 / (h)^{0.243}$$

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

$$N_s = \frac{85.49}{(190)^{0.243}}$$

$$\boxed{N_s = 23.88 \, rpm}$$

At 250 rpm at 50 Hz

$$D = 38.56 \sqrt{h} / n$$

$$= 38.56 \times \frac{\sqrt{190}}{250}$$

$$\boxed{D = 2.12m}$$

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OR,
we take the value of

$N_s = 23.88 rpm$

$D = 38.56 \times \frac{\sqrt{190}}{23.88}$

$D = 38.56 \times \frac{13.78}{23.88}$

$D = 38.56 \times 0.577$

$\boxed{D = 22.25 m}$

<u>Jet Diameter:</u>

$q = (\pi d_j^2) v_j / 4$

$d_j = \sqrt{\frac{4q}{\pi v_j}}$

where,

$V_j = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 190}$

$V_j = 61.05 m/s$

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

$\boxed{d_j = 0.214 m \text{ OR } 21.4 cm}$

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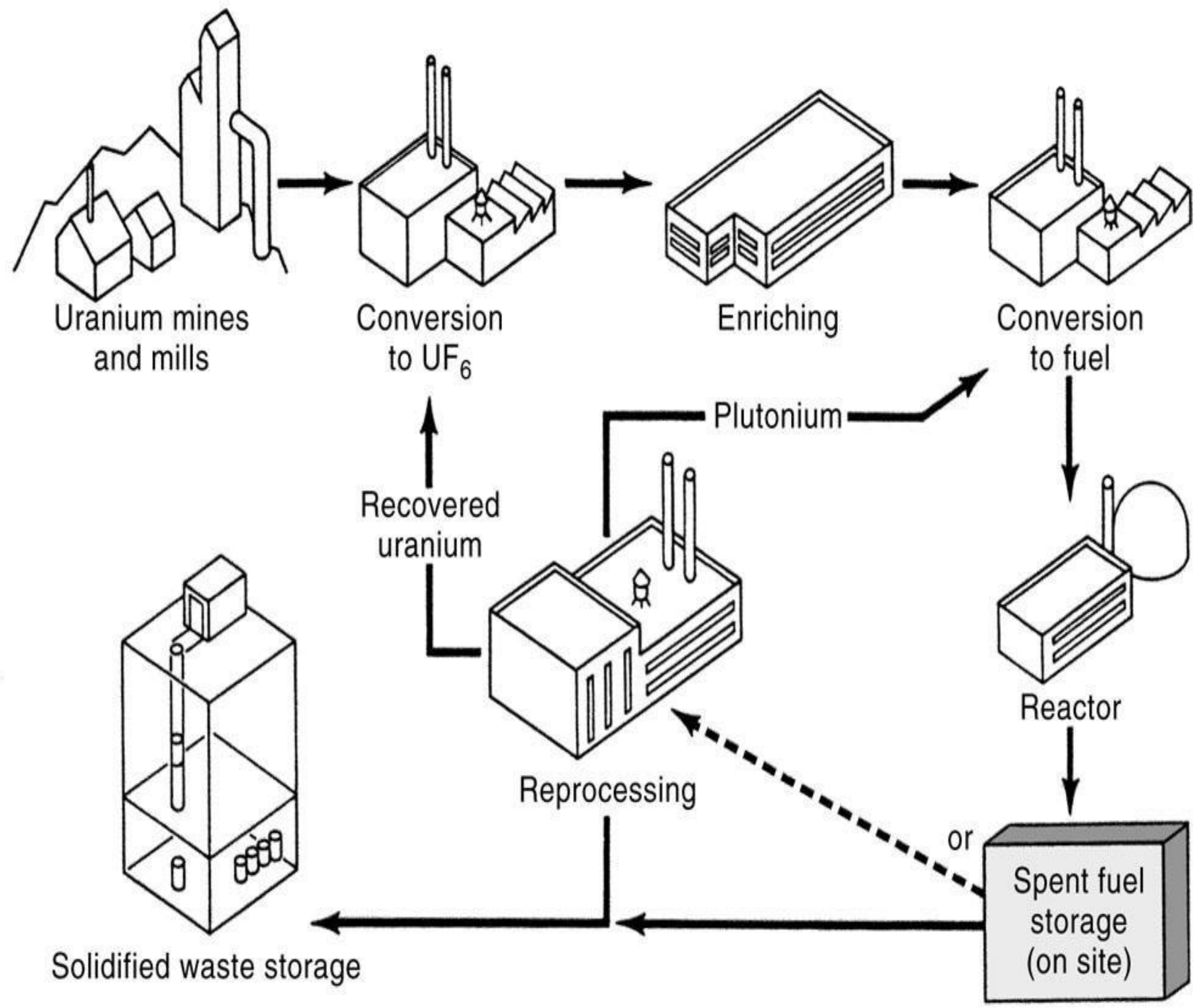
Question 3



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Uranium Mining:

Both “conventional” open pit, underground mining, and in situ techniques are used to recover uranium ore. In general, open pit mining is used where deposits are close to the surface and underground mining is used for deeper deposits. Open pit mining involves a large pit where stripping out and removal of much overburden (overlying rock) is required. Underground mines have relatively small surface disturbance and the quantity of material that must be removed to access the ore is considerably less than in the case of an open pit mine. Special precautions, consisting primarily of increased ventilation, are required in underground mines to protect against airborne radon exposure.

Uranium Milling and Processing:

Uranium oxide concentrate (often known as “yellowcake”) is produced from naturally occurring uranium minerals through milling uranium ore extracted through conventional mining or processing uranium-bearing solution from ISR operations. Most mining facilities include a mill, although where mines are close together, one mill may process the ore from several mines. Milling produces a uranium oxide concentrate, which is shipped from the mill. In the milling process, uranium is extracted from the crushed and ground-up ore by leaching, in which either a strong acid or a strong alkaline solution is used to dissolve the uranium oxide. The uranium oxide is then precipitated and removed from the solution. After drying and usually heating, it is packed in drums as a concentrate.

Conversion:

For most types of reactors, the concentration of the fissile ^{235}U isotope in natural uranium must be enriched typically to between 3 percent and 5 percent. Natural uranium oxide from mines and processing plants is chemically converted into uranium hexafluoride (UF_6), a compound that when heated forms a gas that can be fed into enrichment plants.

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Honeywell International Inc. operates the only uranium conversion facility in the U.S., in Metropolis, Illinois

Enrichment:

The enrichment process separates gaseous uranium hexafluoride into two streams, one being enriched to the required level known as low-enriched uranium (LEU); the other stream is progressively depleted in ^{235}U and is called “tails," or simply depleted uranium.

There are two types of enrichment technologies in large-scale commercial use, each of which uses uranium hexafluoride gas as feed: gaseous diffusion and gas centrifuge. These processes both use the physical properties of molecules, specifically the 1 percent mass difference between the two uranium isotopes, to separate them. A third technology that can be used to enrich uranium is called laser enrichment. This technology has not been utilized at the commercial level as of today.

Gaseous Diffusion:

The gas diffusion process involves forcing uranium hexafluoride gas under pressure through a series of porous membranes or diaphragms. As ^{235}U molecules are lighter than the ^{238}U molecules they move faster and have a slightly better chance of passing through the pores in the membrane. The UF_6 that diffuses through the membrane is thus slightly enriched, while the gas that did not pass through is depleted in ^{235}U.

This process is repeated many times in a series of diffusion stages called a cascade. Each stage consists of a compressor, a diffuser and a heat exchanger to remove the heat of compression. The enriched UF_6 product is withdrawn from one end of the cascade and the depleted UF_6 is removed at the other end. The gas must be processed through some 1,400 stages to obtain a product with a concentration of 3 to 5 percent ^{235}U.

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Gas Centrifuge:

The gas centrifuge like the diffusion process uses UF_6 gas as its feed and makes use of the slight difference in mass between ^{235}U and ^{238}U. The gas is fed into a series of vacuum tubes rotated at very high speeds to obtain efficient separation of the two isotopes. The slightly heavier ^{238}U isotope is concentrated closer to the cylinder wall with the lighter ^{235}U increasing toward the center of the cylinder where it can be drawn off. Although the capacity of a single centrifuge is much smaller than that of a single diffusion stage, its separative capability is significantly greater. In the centrifuge process, the number of stages may only be 10 to 20, instead of a thousand or more for diffusion. Centrifuge stages are arranged in parallel into cascades. The gas centrifuge technology consumes only about 5 percent as much electricity as the gaseous diffusion technology to produce a given amount of product.

Laser Separation:

Laser separation uses laser technology to selectively excite ^{235}U, the fissile isotope, from the much more abundant ^{238}U isotope. This technology promises to provide improved enrichment method as compared to first generation gaseous diffusion and second generation gaseous centrifugation methods.

Fuel Fabrication:

Reactor fuel is generally in the form of ceramic pellets. These are formed from pressed uranium oxide (UO_2), which is sintered (baked) at a high temperature (over 2550°F). The pellets are then encased in metal tubes to form fuel rods, which are arranged into a fuel assembly ready for introduction into a reactor. The dimensions of the fuel pellets and other components of the fuel assembly are precisely controlled to ensure consistency in the characteristics of the fuel. Nuclear fuel assemblies are specifically designed for particular types of reactors and are made to quality assurance specifications. The most common reactor, the pressurized-water reactor (PWR), contains 150-200 fuel assemblies, whereas the boiling-water reactor, the second most common reactor, contains 370-800 fuel assemblies.

Power Reactor:

Generation of electricity in a nuclear reactor is similar to a coal-fired steam station. The difference is the source of heat. Fissioning, or splitting, of uranium atoms produces energy in the same way burning coal, gas, or oil is used as a source of heat in fossil fuel power plants. The fuel used in nuclear generation is ^{235}U and/or ^{239}Pu. The process of producing electricity begins when uranium atoms are split (i.e., fission) by particles known as neutrons. ^{235}U has a unique quality that causes it to break apart when it collides with a neutron. Once an atom of ^{235}U is split, neutrons from the uranium atom collide with other atoms of the ^{235}U. A chain reaction begins that produces heat. This heat is used to heat water and turn it into steam. The steam is used to drive a turbine connected to a generator that produces electricity. Some of the ^{238}U in the nuclear fuel is turned into plutonium in the reactor core during the fission process. The plutonium isotope is also fissile and yields about one third of the energy in a typical nuclear reactor. Typically, some 44 million kilowatt-hours of electricity are produced from one ton of natural uranium.

Moderators:

Neutrons produced during fission in the core are moving too fast to cause a chain reaction
– Note: This is not an issue with a bomb, where fissile uranium is so tightly packed that fast moving neutrons can still do the job.

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

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Pressurized Water Reactor (PWR):

Water in the core heated top 315°C but is not turned into steam due to high pressure in the primary loop. Heat exchanger used to transfer heat into secondary loop where water is turned to steam to power turbine. Steam used to power turbine never comes directly in contact with radioactive materials.

Uranium Reprocessing:

Spent fuel still contains approximately 96% of its original uranium, of which the fissionable U235 content has been reduced to less than 1%. Spent fuel comprises waste products and the remaining 1% is plutonium produced while the fuel was in the reactor. Reprocessing extracts useable fissile U-238.

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. Spent nuclear fuel must be isolated for thousands of years. After 10,000 years of radioactive decay, according to EPA standards, the spent nuclear fuel will no longer pose a threat to public health.

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