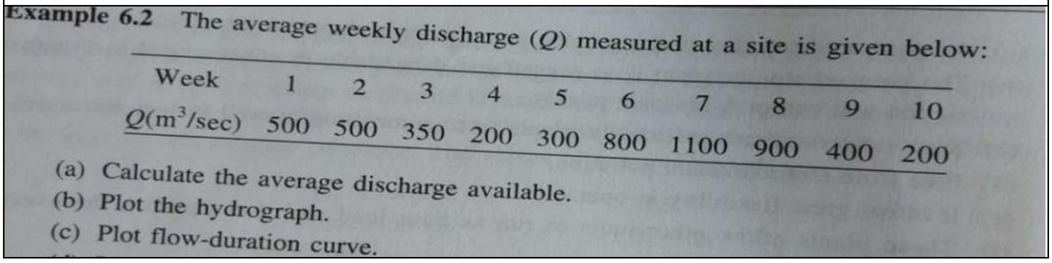
CMR
INSTITUTE OF
TECHNOLOGY

USN

Internal Assesment Test - I

Sub:	Power Generation and Economics							Code:	18EE42
Date:	21/05/2021	Duration:	90 mins	Max Marks:	50	Sem:	4	Branch:	EEE

Answer Any FIVE FULL Questions

		Marks	OBE	
			CO	RBT
1.a	Explain the factors to be considered for the selection of site for a hydroelectric power plant.	[5]	CO2	L1
1.b	A hydroelectric power plant operates under an effective head of 50m and a discharge of 94 m3/sec. Determine the power developed.	[5]	CO1	L5
2.a	Define merits and demerits of hydroelectric power plants?	[5]	CO1	L1
2.b	Explain the characteristics of water turbines.	[5]	CO2	L2
3.	With a neat schematic diagram, explain the essential elements of hydroelectric power plant.	[10]	CO2	L2
4.a	Define Hydrological cycle with neat figure.	[5]	CO1	L1
4.b	With a neat diagram explain the working of turbine governing.	[5]	CO2	L2
5.a	Discuss in detail the factors to be considered for selection of the site for a thermal power plant.	[5]	CO2	L2
5.b	Define (a)hydrograph (b)flow duration curve (c)mass curve	[5]	CO1	L1
6	Explain the working of steam power plant with neat schematic diagram.	[10]	CO2	L2
7.a	Explain how the hydroelectric plants are classified.	[5]	CO1	L2
7.b.		[5]	CO1	L5

Example 6.2 The average weekly discharge (Q) measured at a site is given below:

Week	1	2	3	4	5	6	7	8	9	10
Q(m^3/sec)	500	500	350	200	300	800	1100	900	400	200

(a) Calculate the average discharge available.
(b) Plot the hydrograph.
(c) Plot flow-duration curve.

…………….. ALL THE BEST …………..

Solution

1 a. Explain the factors to be considered for the selection of site for a hydroelectric power plant.

Sol:-

1. **Availability of Water:**

Since in such power stations potential energy of waterfall or kinetic energy of flowing stream is utilized for generation of electric power, therefore such stations should be built where there is adequate water available at good head or huge quantity of water is flowing across a given point.

2. **Water Storage:**

Since storage of water in a suitable reservoir at a height or building of dam across the river is essential in order to have continuous and perennial supply during the dry season, therefore, convenient accommodation for the erection of a dam or reservoir must be available.

3. **Water Head:**

The available water head depends upon the topography of the area. Availability of head of water has considerable effect on the cost and economy of power generation. An increase in effective head reduces the quantity of water to be stored and handled by penstocks, screens and turbines and, therefore, capital cost of the plant is reduced.

4. **Distance from Load Centre:**

Hydroelectric power plant is usually located far away from the load centre. Hence for economical transmission of electric power, the routes and the distances need active considerations.

5. **Accessibility of the Site:**

Adequate transportation facilities must be available or there should be possibility of providing the same so that the necessary equipment and machinery could be easily transported.

6. **Water Pollution:**

Polluted water may cause excessive corrosion and damage to the metallic structures. Hence availability of good quality water is essential.

7. **Sedimentation:**

Gradual deposition of silt may reduce the capacity of the storage reservoir and may also cause damage to the turbine blades. Silting from forest areas is negligible but the regions subject to violent storms and not protected by vegetation contribute lot of silt to the run-off.

8. **Large Catchment Area:**

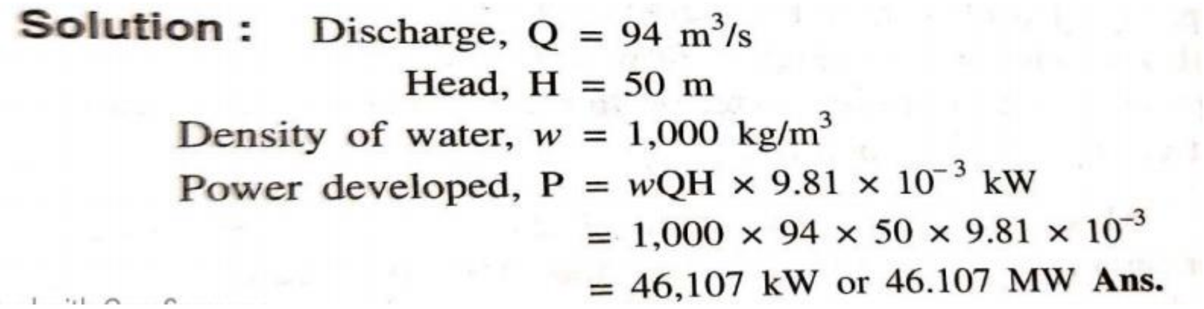
The reservoir must have a large catchment area so that level of water in the reservoir may not fall below the minimum required in dry season.

9. **Availability of Land:**

The land available should be cheap in cost and rocky in order to withstand the weight of the large building and heavy machinery.

10. There should be possibility of stream diversion during period of construction.

1b. A hydroelectric power plant operates under an effective head of 50m and a discharge of 94 m3/sec. Determine the power developed.



Solution : Discharge, $Q = 94\ \text{m}^3/\text{s}$

Head, $H = 50\ \text{m}$

Density of water, $w = 1{,}000\ \text{kg/m}^3$

Power developed, $P = wQH \times 9.81 \times 10^{-3}\ \text{kW}$

$= 1{,}000 \times 94 \times 50 \times 9.81 \times 10^{-3}$

$= 46{,}107\ \text{kW}$ or $46.107\ \text{MW}$ **Ans.**

2.a. Define merits and demerits of hydroelectric power plants?

Hydroelectric power plants offer many distinct advantages over other power plants.

These advantages can be summarized as under:
(i) No fuel is required by such plants as water is the source of energy. Hence operating costs are low and there are no problems of handling and storage of fuel and disposal of ash.
(ii) The plant is highly reliable and it is cheapest in operation and maintenance.
(iii) The plant can be run up and synchronized in a few minutes.

(iv) The load can be varied quickly and the rapidly chang-ing load demands can be met without any difficulty.
(v) Very accurate governing is possible with water tur-bines so such power plants have constant speed and hence constant frequency.
(vi) There are no standby losses in such plants.
(vi) Such plants are robust and have got longer life (around 50 years).
(viii) The efficiency of such plants does not fall with the age.
(ix) It is very neat and clean plant because no smoke or ash is produced.
(x) Highly skilled engineers are required only at the time of construction but later on only a few experi-enced persons will be required.
(xi) Such plants, in addition to generation of electric power, also serve other purposes such as irrigation, flood control and navigation.
(xii) Hydroelectric plants are usually located in remote areas where land is available at cheaper rates.
However, **the hydroelectric power plants have the following disadvantages also:**
(i) It requires large area.
(ii) Its construction cost is enormously high and takes a long time for erection (owing to involvement of huge civil engineering works).
(iii) Long transmission lines are required as the plants are located in hilly areas which are quite away from the load centre.

(iv) The output of such plants is never constant owing to vagaries of monsoons and their dependence on the rate of water flow in a river. Long dry season may affect the power supply.
(v) The firm capacity of hydroelectric plants is low and so backup by steam plants is essential.
(vi) Hydroelectric power plant reservoir submerges huge areas, uproots large population and creates social and other problems.

2b. Explain the characteristics of water turbines.

Characteristics of Water Turbines:

1. Head:

Reaction turbines of various types can be used for operating heads up to 500 m and Peltonturbines are used for operating heads above 500 m.

2. Specific Speed.

3. Turbine Setting:

A Pelton wheel is always set at a higher level than the highest tailrace level (usually 2 m above) while a Francis turbine runner is placed at a level very near or below the lowest tailrace level.

4. Runaway Speed:

This is the maximum speed at which a turbine wheel would run under the worst operating conditions with all gates open so as to allow all possible water inflow under maximum head. The generator coupled to the turbine must be capable of withstanding the full runaway speed of turbine under permissible head.

5. Constant Speed Curves:

In hydroelectric power plants, the turbines operate at constant speed and, therefore, variables are operating head H and discharge Q. As the discharge and head vary so as to keep the speed constant, the turbine output P_t is measured by brake arrangement. The turbine efficiency η is then calculated for various values of Q and H. Now the output discharge (P_t– Q), efficiency-discharge (η – Q) curves, as shown in Fig. 2.19 and efficiency-percentage full load curves are drawn as shown in Figs. 2 20 and 2.21. From the curves drawn, it can be concluded that the Kaplan and Pelton turbines perform well at part loads but Francis and Propeller turbines do not.

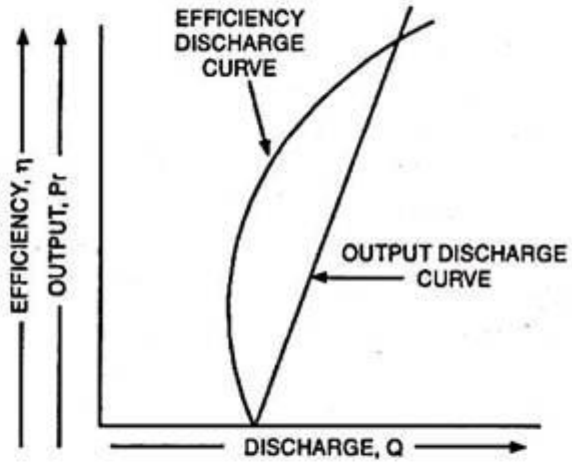


Fig. 2.19. ***Efficiency-Discharge Curve***

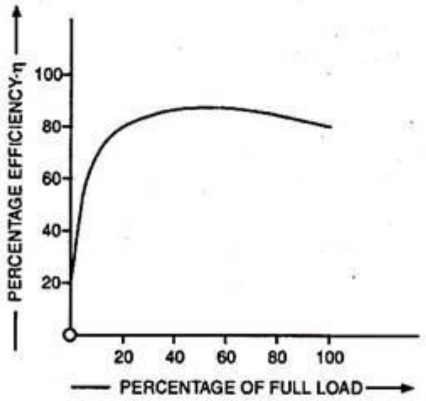


Fig. 2.20. ***Efficiency Curve of Impulse Turbine***

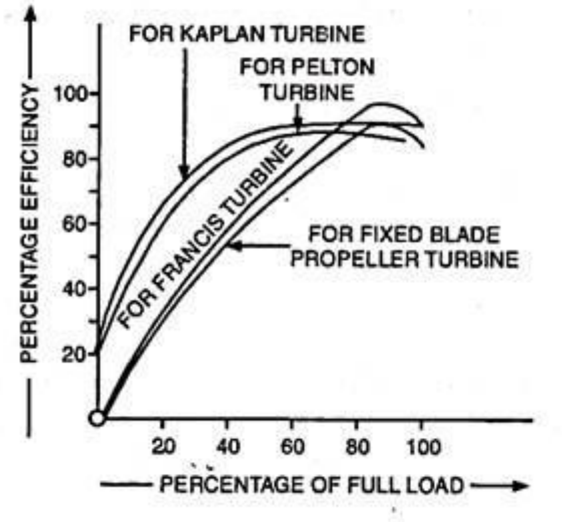
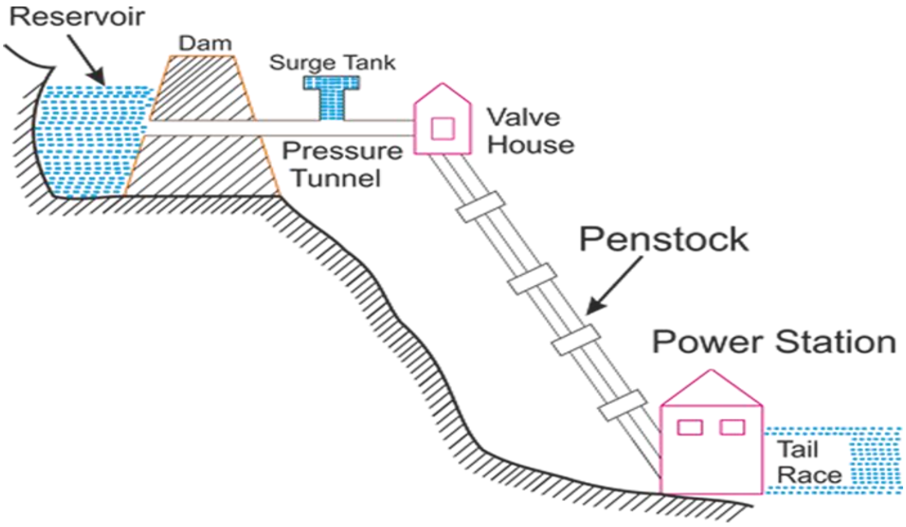


Fig. 2.21. ***Efficiency Curve of Reaction Turbines***

3. With a neat schematic diagram, explain the essential elements of hydroelectric power plant.

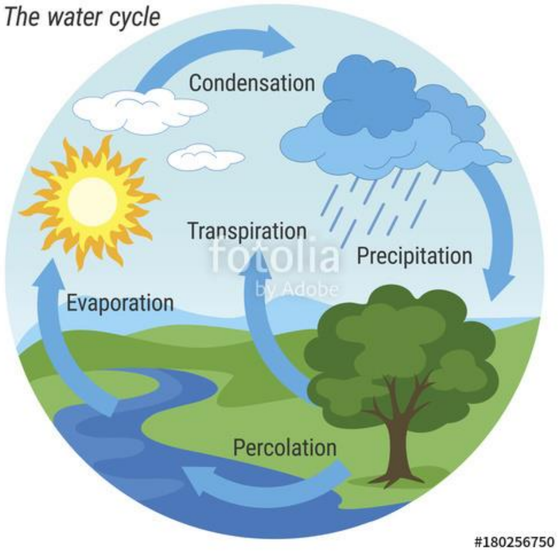
Working principle of hydroelectric power plant depends on the conversion of hydraulic energy into electrical energy. To get this hydroelectricity, hydroelectric power plant needs some arrangements for proper working and efficiency. The block diagram of hydroelectric power plant is shown below:

Hydroelectric power station needs huge amount of water at sufficient head all the time. So a hydroelectric dam is constructed across the river or lake.an artificial storage reservoir where water is stored, is placed back side of the dam. This reservoir creates sufficient water head. A pressure tunnel is placed in between the reservoir to valve house and water is coming from reservoir to penstock via this tunnel. An automatic controlling sluice valve is placed in valve house and it controls water flow to the power station and the letter cuts off supply of water in case the penstock bursts. Penstock is a huge steel pipe in which water is taken from valve house to turbine. A surge tank is also provided just before the valve house for better regulation of water pressure in the system. Now water turbine converts hydraulic energy into mechanical energy and an alternator which is couple to the water turbine converts this mechanical energy into electrical energy.



4 a.Define Hydrological cycle with neat figure.

The Hydrologic Cycle (also called the Water Cycle) is the continuous movement of water in the air, on the surface of and below the Earth. This cycle is the exchange of energy which influences climate. When water condenses, it releases energy and warms the environment. When water evaporates it takes energy from the surrounding environment, dropping temperatures.



4.b. With a neat diagram explain the working of turbine governing.

In order to have electrical output of constant frequency it is necessary to maintain speed of the alternator driven by the turbine constant. This is achieved by controlling the flow of water entering the turbine by the automatic adjustment of guide vanes in case of reaction turbines and of the nozzle needle in the case of impulse turbines. Such an operation of speed regulation is called the governing, and it is attained automatically by means of a governor. In case of impulse turbine the governor also operates the auxiliary relief valves or jet deflectors.

For the regulation of water below the penstock connection, at the time of decrease in load on the impulse turbines, the governor reduces the water flow from the power nozzle and the surplus water is diverted with the help of auxiliary relief nozzles. In the case of multi-nozzle turbines, a deflector plate deflects some water from the runner buckets by swinging into the water jet from each nozzle. With the movement of deflector plate out of the path of water jets, the needles slowly reduces the flow of water so as to keep the output of the turbine constant at the level of new load.

In the case of Francis turbine, there are pressure regulators for discharging the water from the casing to the tailrace at the time of drop in load. The regulators close as fast as the guide vanes open and vice versa.

The governor should be quite sensitive to variations in the shaft speed and should be rapid in action but not so rapid as to cause water hammer in the penstock. The governing systems for the modern hydraulic turbines have a regulating time of 3-5 seconds.

Simplified arrangement of a water turbine governor is illustrated in Fig. 2.22. The principal elements of the governor are:

1. The speed-responsive element—usually flyball mechanism or speed (centrifugal) governor.

2. Control valve or relay valve to supply fluid under pressure to the power cylinder (servomotor) in order to actuate the turbine control mechanism. The use of control valve and servomotor is to amplify the small force created by the flyballs.

3. The restoring mechanism or follow-up linkage to hold the servomotor in required fixed position when the turbine output and load demand are equalised.

4. The fluid pressure supply required for the action of servomotor.

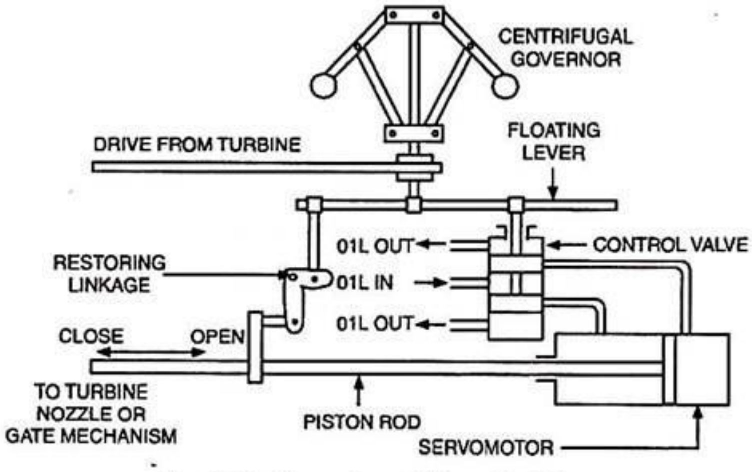


Fig. 2.22. *Governing of Water Turbines*

The flyballs may be belt driven, as shown in Fig. 2.22 or driven by a small electric motor fed from a separate generator operated in synchronism with the turbine. When the load on the turbine decreases, the speed of the turbine increases, consequently, the flyballs also rotate at high speed and move outwards. The floating lever gets lifted up, control valve is displaced upwards from its central or dead beat position, the upper port is uncovered and the oil flows from a pressure tank through the port into the right hand end of the servomotor cylinder.

The piston moves to the left and closes the nozzle with the help of a spear in the case of Pelton wheels and adjusts the guide vanes in the case of reaction turbines. In case of increase of load on the generator, the speed of the turbine will decrease and the reverse action would take place. The restoring or follow up linkage resets the relay; pilot or control valve after the servomotor piston has adjusted the water control mechanism.

In case of Pelton wheel a combined spear and deflector regulation is employed in order to avoid water hammer in the penstock. In case of decrease of load on turbine, the deflector, which is usually a plate connected to the servomotor by means of levers, is brought in between the nozzle and buckets, thereby, diverting water away from the runner and directing into the tailrace. In the mean time, the spear has been adjusted to the new position of equilibrium and the deflector plate is moved out of the path of water nozzle.

5.a. Discuss in detail the factors to be considered for selection of the site for a thermal power plant.

- ***Supply of fuel-*** Thermal power station as close as possible to the coal mine, economy consideration , considering transmission & transportation charges.
- ***Ash disposal facility-*** Ash content of the coal should be as low as possible, Indian coal has ash content 20-40% & sufficient space is required for storing ash.
- ***Availability of water-*** Feed water for the boiler, Huge quantity of water is required for condenser & disposal of ash.
- ***Land requirement-*** Average land requirement is 3 to 4 acres per MW capacity. Land should be available cheap rate & good bearing capacity.
- ***Transportation facility-*** Huge quantity of coal is required, rail & road facility should be available very near.
- ***Distance from the populated area-***As huge amount of coal is burnt in steam power station, therefore smoke & fumes pollute the surrounding area. This necessitates that the plant should be located at a considerable distance from the populated area.
- ***Labour supplies-*** Skilled labours should be available at reasonable rates near the site of the plant.

5.b. Define (a)hydrograph (b)flow duration curve (c)mass curve.

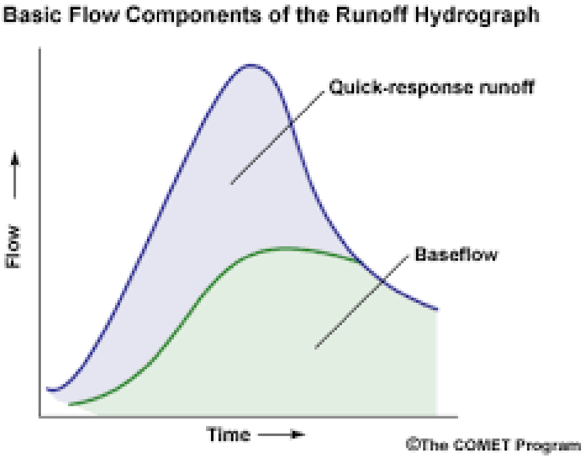
(a)hydrograph

A hydrograph is a graph or plot that shows the rate of water flow in relation to time, given a specific point or cross section. These graphs are often used to evaluate stormwater runoff on a particular site considering a development project.

A natural landscape with no development or impervious surfaces will have high levels of rainfall abstraction and produce less runoff due to the vegetation and infiltration capacity of the soils, which produces a gradually sloped hydrograph (1). In this scenario, rainwater will meet multiple obstacles while flowing towards a stream in the form of rainfall interception by vegetation, transpiration by plants, evaporation from land surfaces, infiltration into soils, and ponding of water in surface depressions.

When the natural landscape is altered by development, trees and other vegetation are replaced by impervious surfaces such as roofs, driveways, gutters, and parking lots. These impervious areas curtail the landscape’s ability to filter and infiltrate water, and results in higher peak flows and greater runoff volumes as seen in hydrograph (2).

Stripping the landscape’s ability to naturally manage stormwater results in increased erosion, sedimentation, and nutrients entering our waterways.

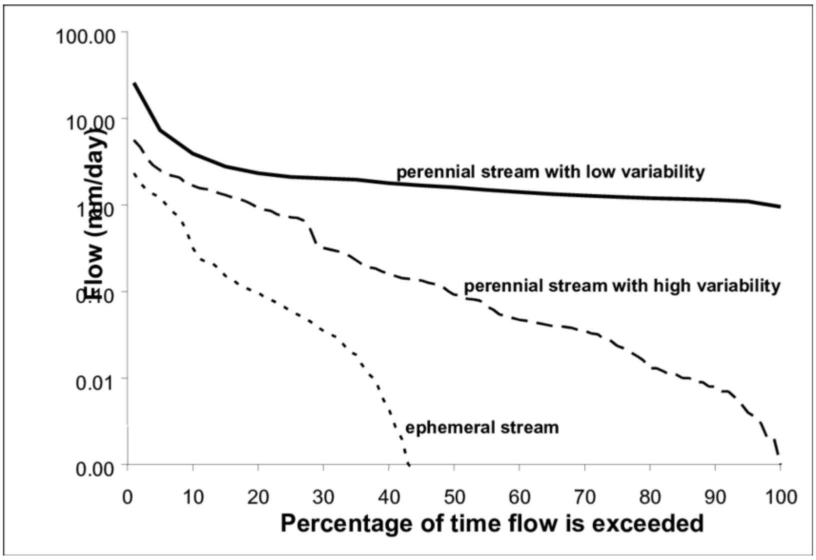


(b)flow duration curve

The flow duration curve is a plot that shows the percentage of time that flow in a stream is likely to equal or exceed some specified value of interest. For example, it can be used to show the percentage of time river flow can be expected to exceed a design flow of some specified value (e.g., 20 cfs), or to show the discharge of the stream that occurs or is exceeded some percent of the time (e.g., 80% of the time).

How is it calculated?

The basic time unit used in preparing a flow-duration curve will greatly affect its appearance. For most studies, mean daily discharges are used. These will give a steep curve. When the mean flow over a long period is used (such as mean monthly flow), the resulting curve will be flatter due to averaging of short-term peaks with intervening smaller flows during a month. Extreme values are averaged out more and more, as the time period gets larger (e.g., for a flow duration curve based on annual flows at a long-record station).

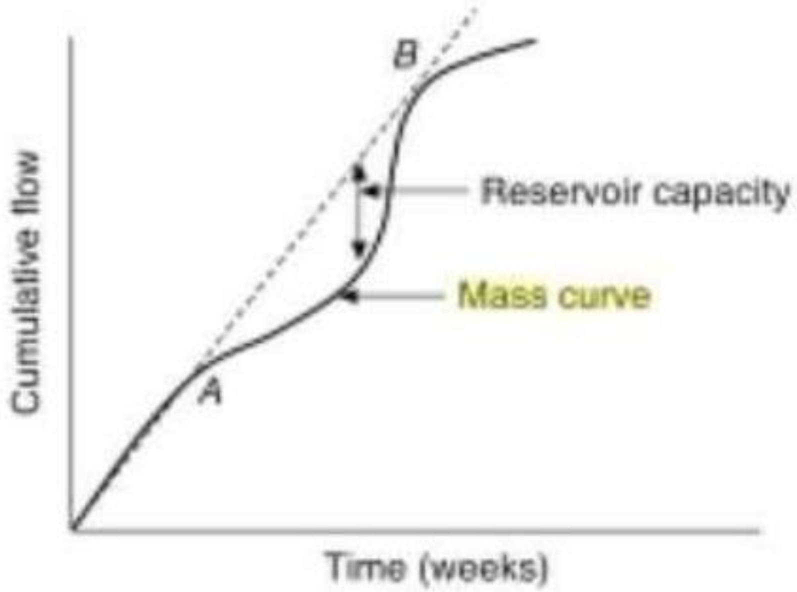


c) Mass curve:

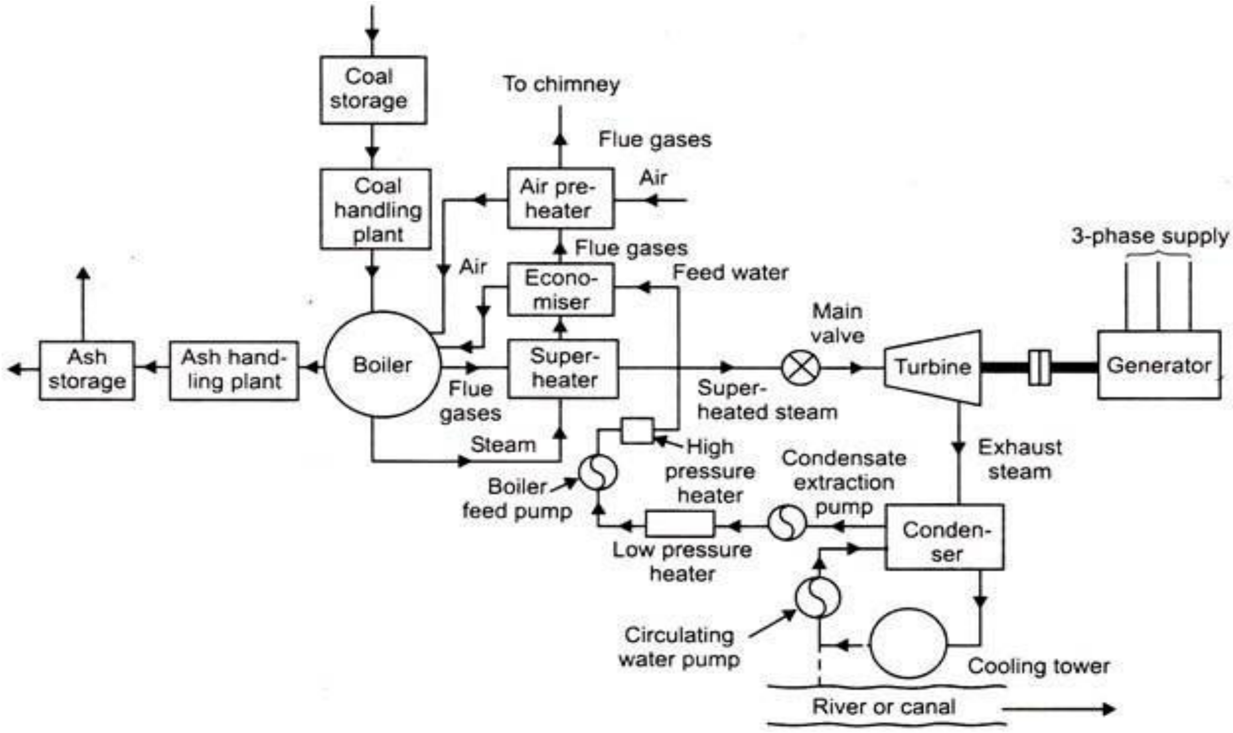
A plotting of the cumulative values of a variable as a function of time.

This is applied especially to mass curves of rainfall in storm studies, to departures of various weather elements from normal, and to streamflow data for reservoir studies.

Mass curve



6. Explain the working of steam power plant with neat schematic diagram.



The schematic arrangement of a modern steam power station can be divided into the following stages:

- *Coal and ash handling plant*
- *Steam generating plant*
- *Steam turbine*
- *Alternator*
- *Feed water*
- *Cooling arrangement*

COAL AND ASH HANDLING PLANT

- Coal is transported to power station by rail or road and stored in coal storage plant and then pulverised
- Pulverised coal is fed to fed to the boiler by belt conveyers
- Coal gets burned in the boiler and ash produced is removed to the ash handling plant and then delivered to ash storage plant for disposal
- A 100MW station operating at 50% LF may burn about 20000 tons of coal per month and produce 3000 tons of ash

The Ash from the boiler is collected in two forms:

1. **Bottom Ash(Slurry):It's a waste which is dumped into a Ash Pond**
2. **Fly ash: Fly ash is separated from Flue Gases in ESP(Electro static Precipitator).**

STEAM GENERATING PLANT

The steam generating plant consists of a boiler for the production of steam and other auxiliary equipment for the utilization of flue gases

1) ***Boiler:*** The heat of combustion in the boiler is utilized to convert water into steam at high temperature and pressure
2) ***Superheater:*** The steam produced in boiler is wet and is passed through a superheater where it is dried and superheated. Increases efficiency
3) ***Economiser:*** It's essentially a feed water heater and derives heat from the flue gases
4) ***Air Preheater:*** Increases the temperature of the air supplied for coal burning by deriving heat from flue gases. Air is drawn from the atmosphere by a forced drought fan and is passed through air preheater before supplying to the boiler furnace.

STEAM TURBINE

- Dry and superheated steam from superheater is fed to the steam turbine.
- The heat energy of steam when passing over the blades of turbine is converted into mechanical energy.
- After giving energy to the turbine, the steam is exhausted to the condenser which condenses the exhausted steam by means of cold water circulation

ALTERNATOR

- Steam turbine is coupled to an alternator which converts the mechanical energy to electrical energy
- The electrical output of the alternator is delivered to the bus bars through transformer, circuit breakers and isolators.

FEED WATER

- The condensate from the condenser is used as feed water to the boiler.
- The water that may be lost in the cycle is made up from the external source
- The feed water on its way to boiler gets heated up by water heaters and economiser.
- This helps to improve the overall efficiency of the plant

COOLING ARRANGEMENT

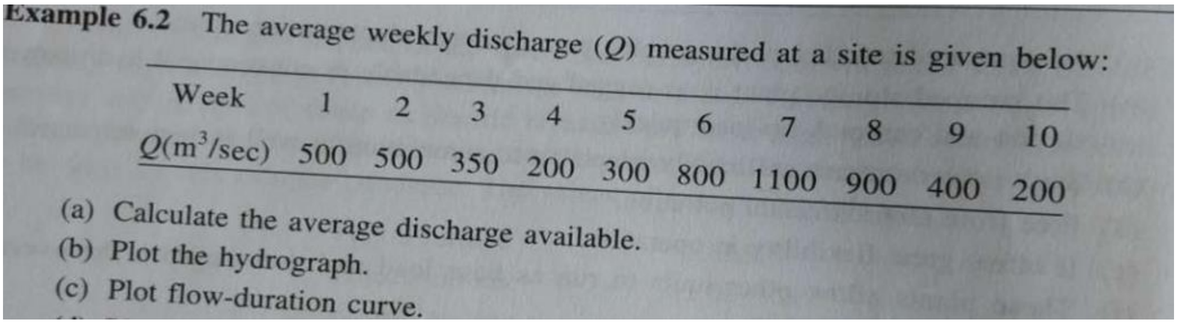
- Condenser condenses the steam exhausted from the turbine
- Water is drawn from natural sources like river, lake, canals…
- Circulating water takes up the heat and itself gets heated up
- This hot water can be discharged away or used again by using a cooling tower

---

7.**a.Explain how the hydroelectric plants are classified.**

According to Head of water,
a) Low head plant
b) Medium head plant
c) High head plant
According to Nature of load,
a) Base load plant
b) Peak load plant
According to Capacity of plant,
a) Low capacity plant (100-999 kW)
b) Medium capacity plant (1 MW-10 MW)
c) High capacity plant (above 10 MW)
According to Quantity of water available,
a) Run-off river plants without pondage
b) Run-off river plants with pondage
c) Pumped storage plant

7.b.

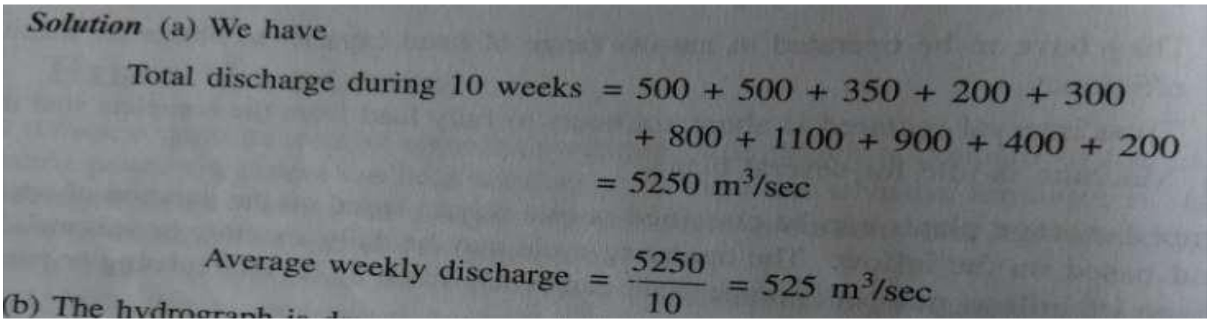


Example 6.2 The average weekly discharge (Q) measured at a site is given below:

Week	1	2	3	4	5	6	7	8	9	10
Q(m^3/sec)	500	500	350	200	300	800	1100	900	400	200

(a) Calculate the average discharge available.
(b) Plot the hydrograph.
(c) Plot flow-duration curve.

Sol:

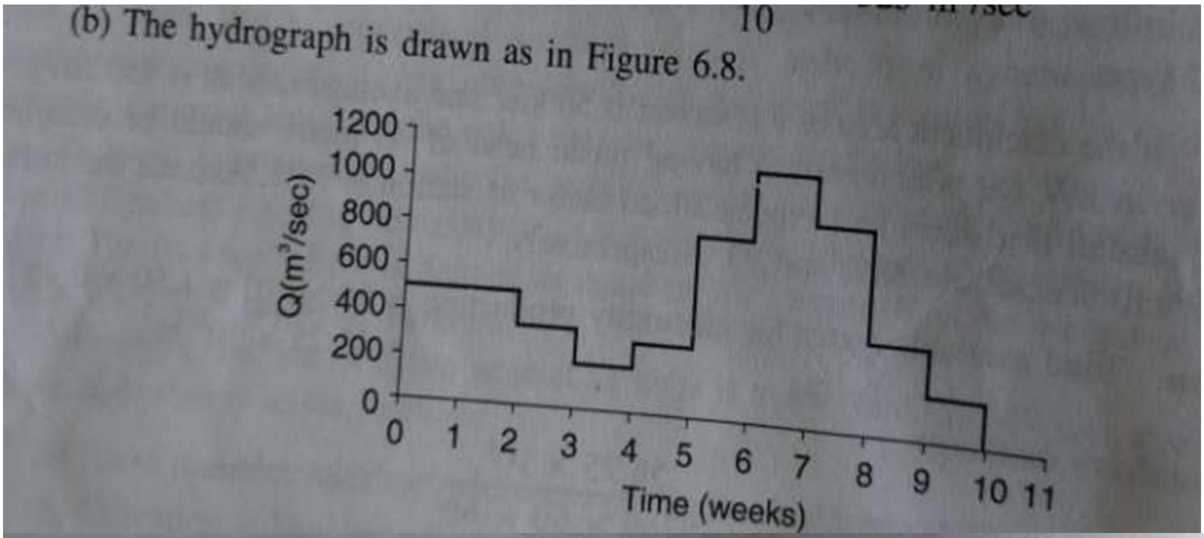


Solution (a) We have

$$\text{Total discharge during 10 weeks} = 500 + 500 + 350 + 200 + 300 + 800 + 1100 + 900 + 400 + 200 = 5250 \text{ m}^3\text{/sec}$$

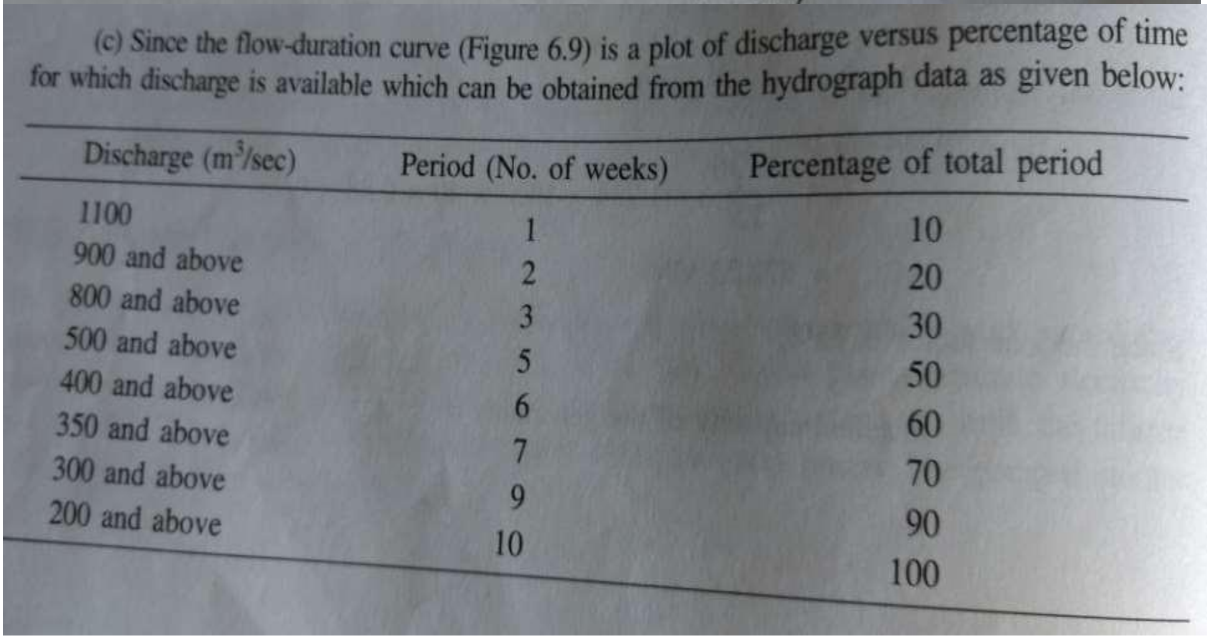
$$\text{Average weekly discharge} = \frac{5250}{10} = 525 \text{ m}^3\text{/sec}$$

(b) The hydrograph



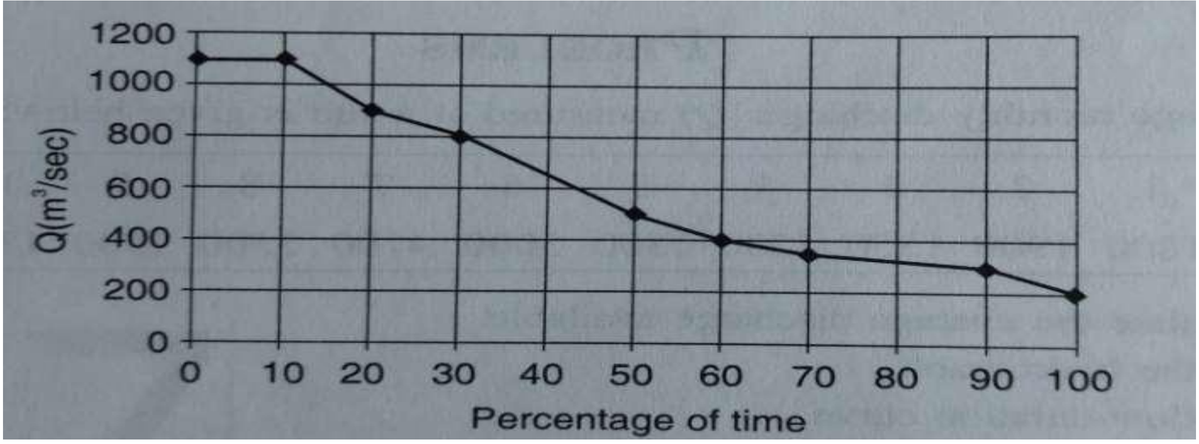
10

(b) The hydrograph is drawn as in Figure 6.8.



(c) Since the flow-duration curve (Figure 6.9) is a plot of discharge versus percentage of time for which discharge is available which can be obtained from the hydrograph data as given below:

Discharge (m^3/sec)	Period (No. of weeks)	Percentage of total period
1100	1	10
900 and above	2	20
800 and above	3	30
500 and above	5	50
400 and above	6	60
350 and above	7	70
300 and above	9	90
200 and above	10	100



Flow duration Curve