Electronics Engineering

Basic Electrical Engineering

Comprehensive Theory

with Solved Examples and Practice Questions

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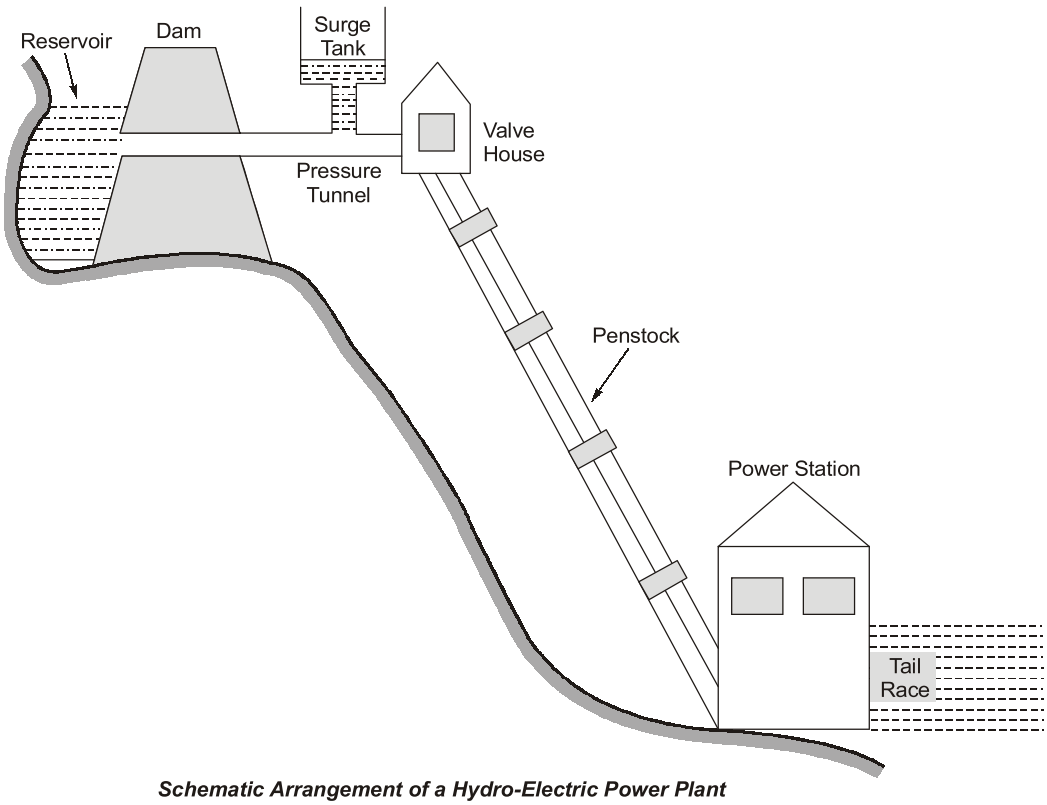
CHAPTER 6

Basics of Power Plant and Batteries

6.1 Hydro Electric Power Plant

Hydroelectric power is the power obtained from the energy of falling water whereas hydroelectric power plant is the power plant utilising the potential energy of water at a high level for the generation of electrical energy.

6.2 Construction



Schematic Arrangement of a Hydro-Electric Power Plant

1. Storage Reservoir

- Its purpose is to store water during excess flow periods (i.e. rainy season) and supply the same during lean flow periods (i.e. dry season).

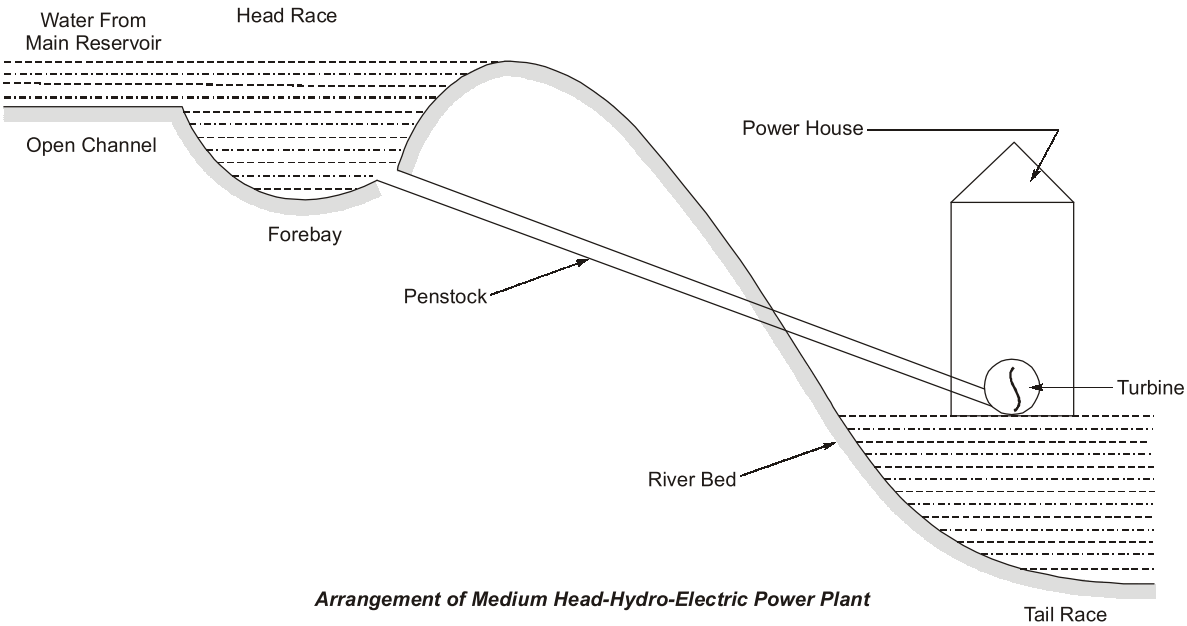
- A reservoir can be natural or artificial. A natural reservoir is a **lake** in high mountains and an artificial reservoir is made by constructing a **dam** across the river.
- Low head plants require very large storage reservoir.

2. DAM

- A dam is the most expensive and important part of hydro-project.
- The function of dam is not only to raise the water surface of the stream to create an artificial head but also to provide the **storage**.

3. Forebay

- Serves as a regulating space, storing water temporarily during light load period and providing the same for initial increase on account of increasing load during which water in the canal is being accelerated.
- This may be a **pond** behind the diversion dam.
- Where the hydroelectric plants are located just at the base of the dam, no fore bay is required because the reservoir itself serves the purpose of the forebay. However where the plants are situated away from the storage reservoir a forebay is provided.



Arrangement of Medium Head-Hydro-Electric Power Plant

4. Spillway

This is constructed to act as a **safety valve**. It discharges the overflow water to the down stream side when the reservoir is full, a condition mainly arising during flood periods. These are generally constructed of concrete and provided with water discharge opening shut off by metal control gates. By changing the degree to which the gates are opened, the discharge of the head water to the tail race can be regulated in order to maintain the water level in the reservoir.

5. Surge Tank

A reduction in load on the generator causes the governor to close the turbine gates and thus create an increased pressure in the penstock. This may result in water hammer phenomenon and may need pipe of extraordinary strength to withstand it otherwise the penstock may burst.

To avoid this positive water hammer pressure, some mean are required to be provided for taking rejected flow. This may be accomplished by providing a small storage reservoir or tank (open at the top) for receiving the rejected flow and thus relieving the pipe of excessive water hammer pressure. This storage reservoir is called surge tank.

NOTE : A forebay also serves the function of a surge tank.

6. Penstock

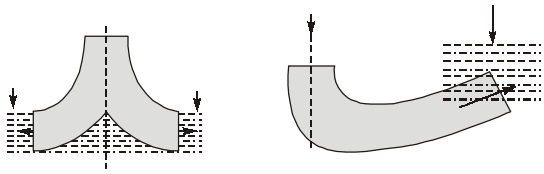
It is closed conduit which conducts the forebay or surge tank to the scroll case of the turbine. Penstocks are built of steel or reinforced concrete.

7. Tail Race

The water after having done its useful work in the turbine is discharged to the tail race which may lead it to the same stream or to another one.

8. Draft Tubes

An air tight pipe of suitable diameter attached to the runner outlet and conducting water down from the wheel and discharging it under the surface of the water in the tail race is known as draft tube. This creates a negative pressure head at the runner exit.



Draft Tubes

9. Prime Movers or Water Turbine

Water turbines are used as prime movers and their function is to convert the kinetic energy of water into mechanical energy which is further utilised to drive the alternators generating electrical energy.

Axial Flow ← Kaplan turbine → propeller turbines → low head and high flow (Head < 30 M)

Mixed Flow ← Francis turbine → reaction turbine → medium head and medium flow (30 < Head < 200 m)

Tangential Flow ← Pelton wheel → impulse turbine → high head and low flow (Head > 200 m)

Note: The electrical power given by,

$P = WQH\eta \times 9.81 \times 10^{-3}$ kW

W = specific weight of water in kg/m^3

Q = rate of flow of water in m^3/s

H = height of water fall in meter (head)

η = over all efficiency of operation

6.3 Classification of Hydroelectric Power Plant

(1) According to water flow regulation available

(i) Run-off power plants without Pondage: Water is taken from the river directly and no pondage or storage is possible.

(ii) Run-off river power plants with pondage

(iii) Reservoir power plants: When water is stored in a big reservoir behind a dam, it is possible to control the flow of water and use it most effectively. This type of plant can be used as base load or as a peak load plant.

(2) According to availability of water head

(a) Low head : Less than 30 m

(b) Medium head : 30–300 m

(c) High head : > 300 m

(3) According to type of load supplied:

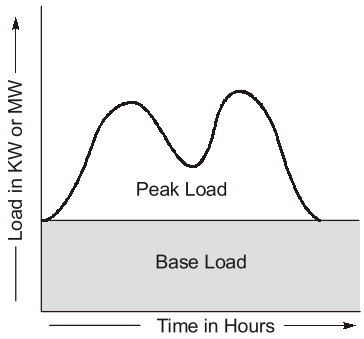
(a) **Base Load Plant:** take up load on the base portion of the load curve of the power system. **Large capacity**, **high load factor** i.e. unit cost of energy generation by plant should be low. ex: run off river plant without pondage.

(b) **Peak Load Plant:** Top portion of the load curve, **load factor is low,** ex: run-off river with pondage. (They store water during off-peak periods).

(c) **Pumped storage plants** for the peak load.

6.4 Base Load and Peak Load

As already mentioned, the load on the power plant is seldom constant rather it varies from time to time, as shown in figure. The load on any power plant can be conveniently considered into two parts namely (i) base load and (ii) peak load. The unvarying load, which occurs almost the whole day on the power plant is called the base load whereas the various peak demands of the load over and above the base load of the power plant is called the peak load.

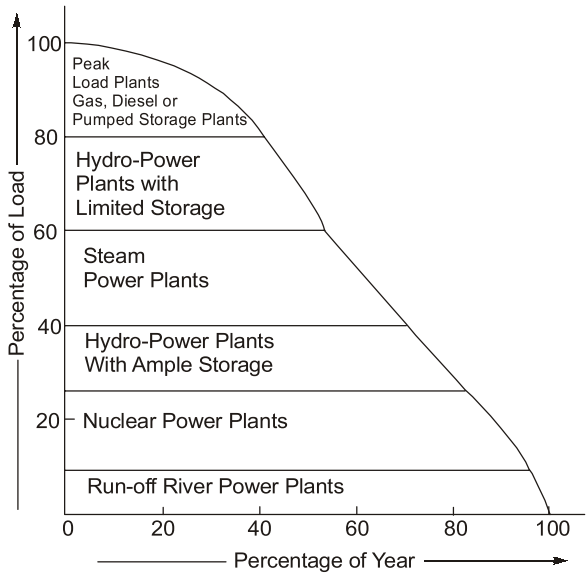


Coordination of Base Load and Peak Load Power Plants: If the load represented by figure is to be supplied from one power plant only, then the installed capacity of the plant should be equal to the peak load or more. Such a power plant would be uneconomical since the peak load occurs only for a short period in a year and therefore the capacity equal to the difference of the peak load and base load would remain idle for the major portion of the year. Hence such a power load should not be supplied from a single power plant. There would be some power stations supplying the base load and others, possibly of different types, supplying the peak load. Thus the coordination of operation of different power stations is essentials.

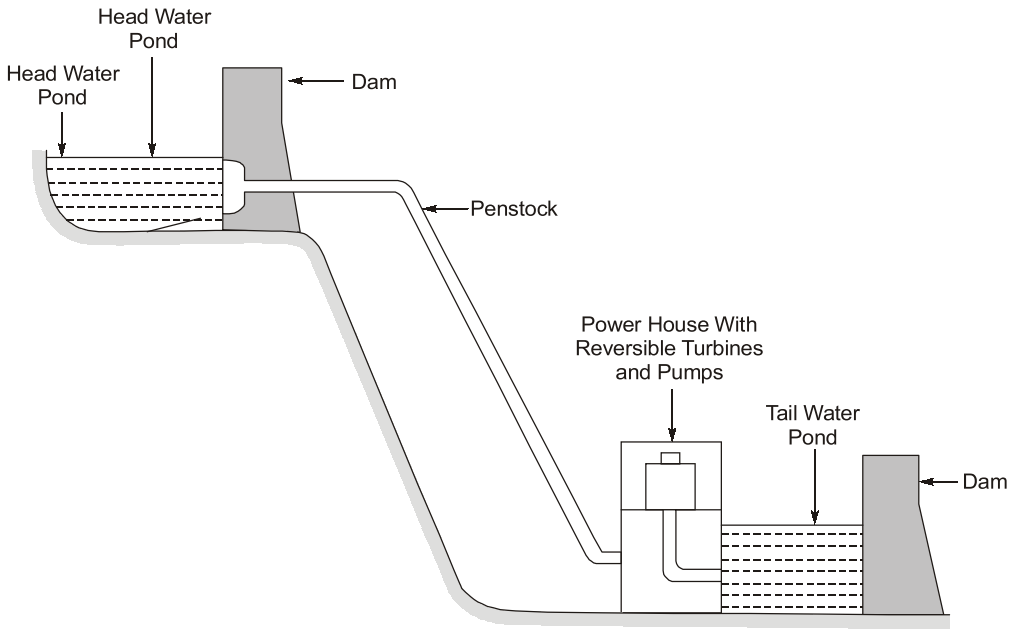
The power plants to be employed as base power plants should have (i) low operating cost (ii) capability of working continuously for the long periods (iii) requirement of few operating personnel and their repair should be economical and speedy. The power plants to be employed as peak power plants should have the capability of quick start, synchronisation and taking up of system load and quick response to load variations.

The hydropower plants are well suited for both base load and peak load operations. The hydropower plants should be employed for base load operation as far as possible because of their higher capital cost. However, during the periods of drought, the hydropower plants may be used as peak load plants.

A steam power plant gives minimum cost of generation per unit when employed as base load plant. However, in order to save fuel it may be used as peak load plant. Nuclear power plants are suitable only for base load operation at high load factors of over 0.8. Gas turbine power plants are suitable for supplying peak loads. Diesel engine power plants are playing a very little role in bulk power generation because of their uneconomical operating costs.



6.5 Pumped Storage Plant



Pumped Storage Power Plant

- Pump and turbine on the same shaft with electrical element acting on either generator or motor.
- Francis turbine is used, which is just the reverse of centrifugal pump. During peak hours the turbine drives the generator and the plant generates electrical energy while during off peak hours the generator operates as a motor and drives the turbine which now works as a pump raising the water from the tail water pumps to the head water ponds.

Advantages:

1. Peak load can be supplied at a lower cost than that when supplied by steam and nuclear power plant.
2. Steam and nuclear power plants can be operated at almost unity load factor which ensures their most efficient and economic operation.
3. 2-3 seconds starting time, and in 15 seconds loaded fully.
4. Can be employed for load frequency control.

6.6 Advantages and Disadvantages of Hydroelectric Power Plant

Advantages:

(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 synchronised in a few minutes.

(iv) The load can be varied quickly and the rapidly changing load demands can be met without any difficulty.

(v) Very acute governing is possible with water turbines so such power plants have constant speed and hence constant frequency.

(vi) There are no standby losses in such plants.

(vii) 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 experienced 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.

Disadvantages:

(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.

Example 6.1 A generating station which has a high investment cost and low operating cost is usually operated as a

(a) peak load station
(b) base load station
(c) medium load station
(d) None of the above

Answer: **(b)**

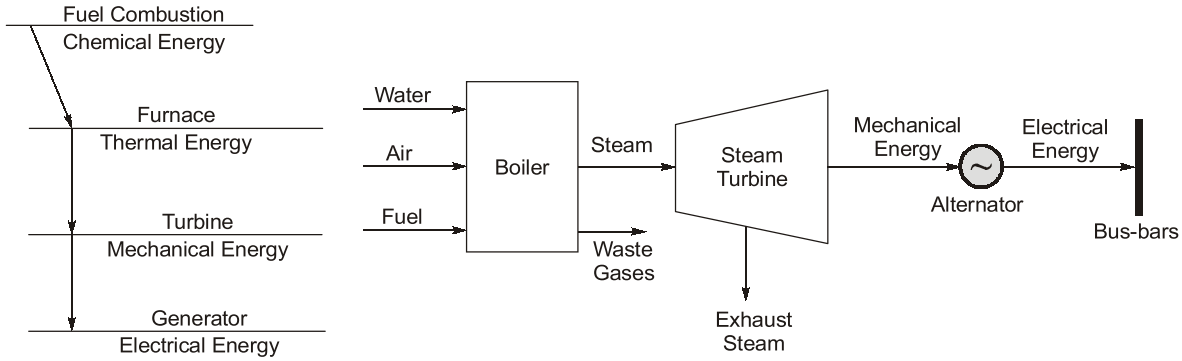
Example 6.2 Which of the plants is suitable for peak load?

(a) Diesel engine plant
(b) Steam power plant
(c) Nuclear power plant
(d) Hydroelectric plant
(d) All of them

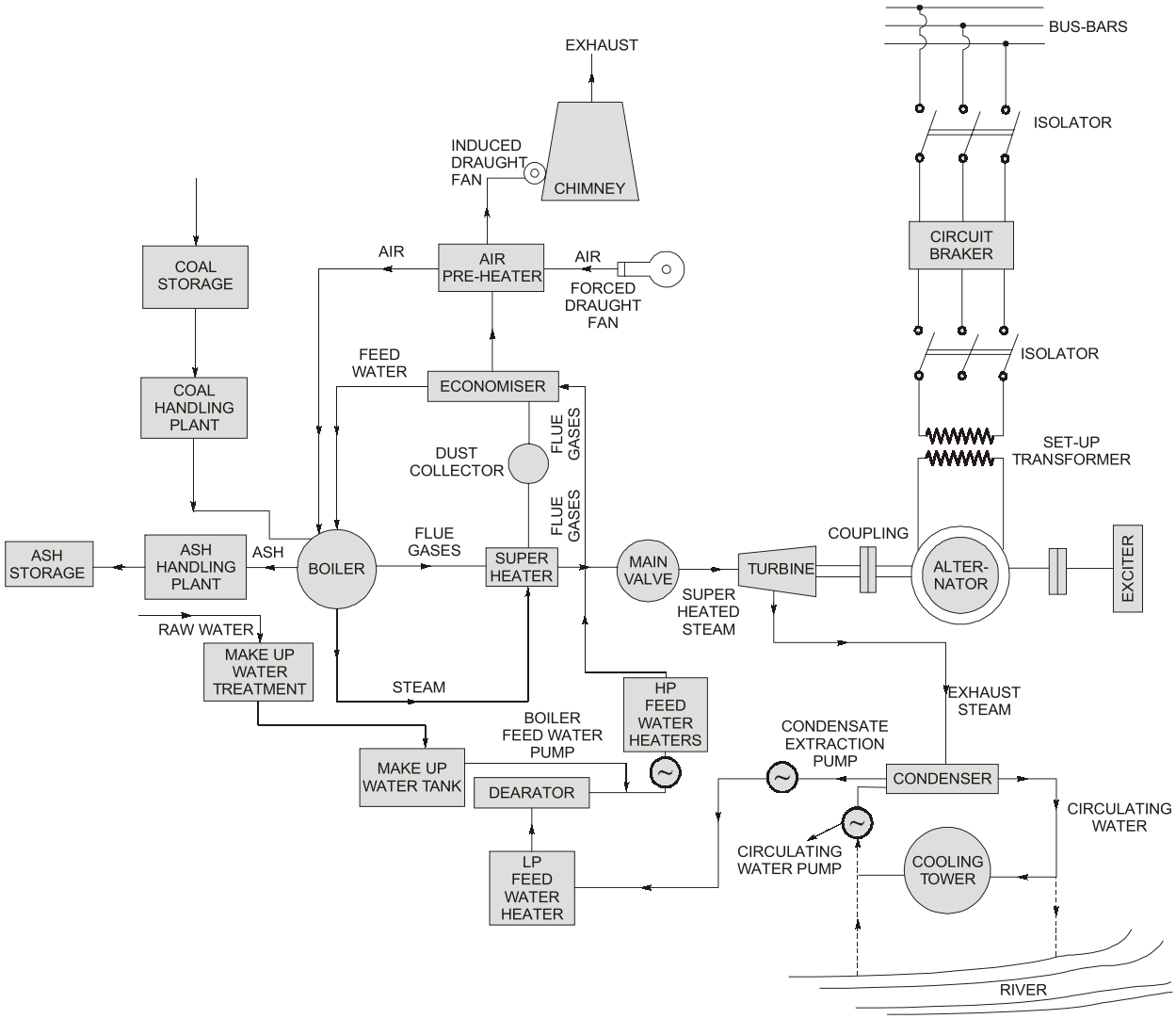
Answer: **(a)**

6.7 Steam Power Plant

- More than 60 Percent of electric power is produced by steam plants in India.
- In steam power plants, the heat of combustion of fossil fuel (coal, oil or gas) is utilised by the boilers and raise steam at high pressure and temperature.
  The steam so produced in used in driving the steam turbines or sometimes steam engines coupled to generators and thus in generating electrical energy.



6.8 Construction



SCHEMATIC ARRANGEMENT OF A MODERN COAL FIRED POWER PLANT

Example 6.29 The fuel cell converts chemical energy

(a) into mechanical energy
(b) directly into electrical energy
(c) into heat energy
(d) electronic energy

Answer: **(b)**

Example 6.30 Fuel cells have conversion efficiencies of about

(a) 25%
(b) 40%
(c) 65%
(d) 85%

Answer: **(c)**

Example 6.31 Fuel cell converts chemical energy into

(a) heat energy
(b) low-voltage direct current electrical energy
(c) low-voltage alternating current electrical energy
(d) mechanical energy

Answer: **(b)**

Student's Assignments 1

Q.1 Sulphation in a lead-acid battery occurs due to:
(a) trickle charging
(b) incomplete charging
(c) heavy discharging
(d) fast charging

Q.2 A dead storage battery can be revived by
(a) a dose of H_2SO_4
(b) adding so-called battery restorer
(c) adding distilled water
(d) none of the above

Q.3 The sediment which accumulates at the bottom of a lead-acid battery consists largely of
(a) lead-proxide
(b) lead-sulphate
(c) antimony-lead alloy
(d) graphite

Q.4 The reduction of battery capacity at high rates of discharge is primarily due to:
(a) increase in its internal resistance
(b) decrease in its terminal voltage
(c) rapid formation of $PbSO_4$ on the plates
(d) non-diffusion of acid to the inside active materials.

Q.5 Any charge given to the battery when taken off the vehicle is called.
(a) bench charge
(b) step charge
(c) float charge
(d) trickle charge

Q.6 List-I (Turbine)
A. Peltol wheel
B. Francis turbine
C. Kaplan turbine

List-II (Type of turbine)
1. Inward radial flow reaction turbine
2. Axial flow reaction turbine
3. Tangential flow impulse turbine

Codes:

	A	B	C
(a)	1	2	3
(b)	2	3	1
(c)	3	1	2
(d)	1	3	2

Q.7 List-I (Type of Fuel)
A. Fertile
B. Fissile

List-II (Nuclear Fuel)
1. U-238
2. Pu-239