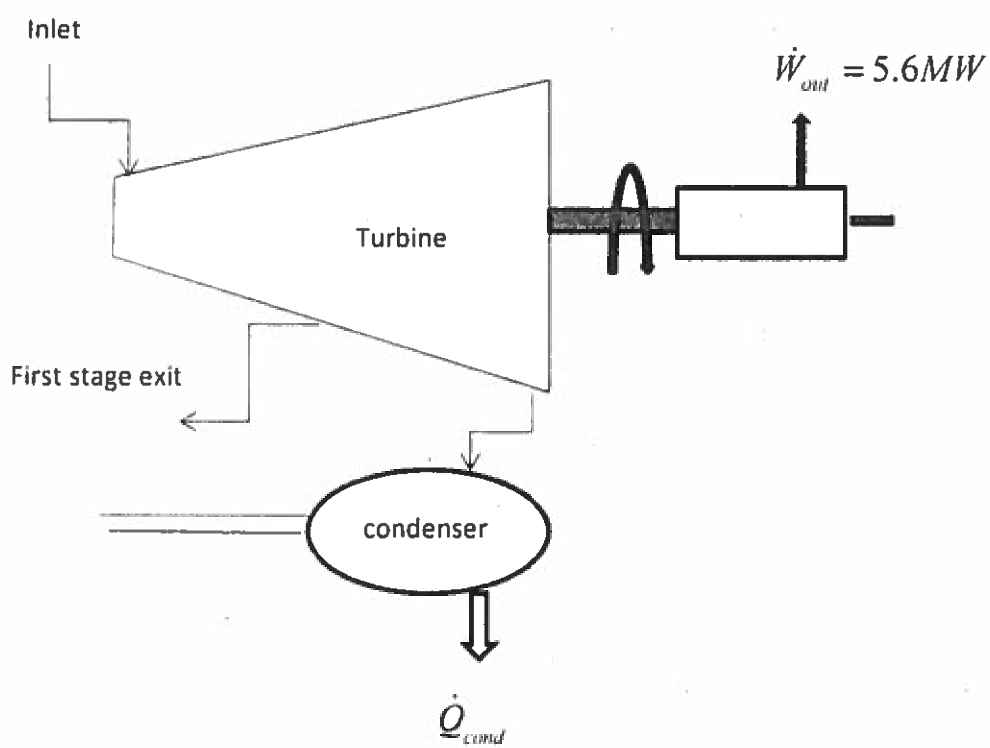
Problem 1

A two-stage steam turbine operates in steady state. At inlet to the turbine the pressure is 2 MPa, the flow rate is 15 kg/s, the temperature is 360°C, and the velocity is 80 m/s. At exit from the first stage of the turbine the pressure is 1 MPa and the temperature is 280°C, the flow rate is 1.5 kg/s, and velocity is 20 m/s. At exit from the second stage, saturated steam at 0.1 bar flows with a velocity of 40 m/s. The inlet is at an elevation of 4 m with respect to the exit from the first and second stages of the turbine. The first and second stage exits are at the same elevation. The steam leaving the second stage flows through a condenser, and leaves the condenser as a saturated liquid-vapor mixture with a quality of 0.01. The turbine's rotational speed is 100 revolutions per second. The turbine drives a generator that has an efficiency of 80% and generates electric power at the rate of 5.6 MW.

a) Find the flow area at inlet to the turbine, in m^2.
b) Find the rate of heat transfer between the turbine and surroundings, in kW.
c) Find the cooling power of the condenser (i.e., heat transfer rate between the condenser and surroundings), neglecting kinetic energy of the mixture that leaves the condenser.
d) Find the magnitude of the torque that the turbine imposes on the generator.

For gravitational acceleration use $g=9.81\ m/s^2$.



Problem 2

A perfectly-insulated, rigid closed cylinder having a volume of 1.0 liter (0.001 m^3) contains 0.5 kg of water. (The cylinder itself is of negligible mass.) Initially the temperature of the water is 20.0°C. The container is repeatedly thrown straight upward and caught. During each throw the container achieves an elevation of 4 meters above the release point (which is also the catch point). After all of the throws and the container is allowed to sit still.

a) How many throws would be required to achieve a final temperature of 22.0°C?
b) Considering the interior of the cylinder as the control volume, state whether the process is internally reversible and justify your answer.
c) Prove that there is no way to return the temperature to its original state so long as it resides within the given container.

Problem 3

The figure shows a solar power plant operating on a Rankine cycle and using R134a as the working fluid. Saturated vapor (point 1) at 60 °C enters the turbine and exits (point 2) at 6 bar. Saturated liquid exits the condenser (point 3). The rate of energy input from the sun to the solar collector is K = 0.4 kW per m^2 of collector surface area. Neglect heat transfer from the turbine and pump to their surroundings and the pressure drop in the heat exchangers. Determine the minimum possible solar collector area per kW of net power produced by the plant, the cycle efficiency, and the back work ratio. Sketch this cycle on a T-s diagram.