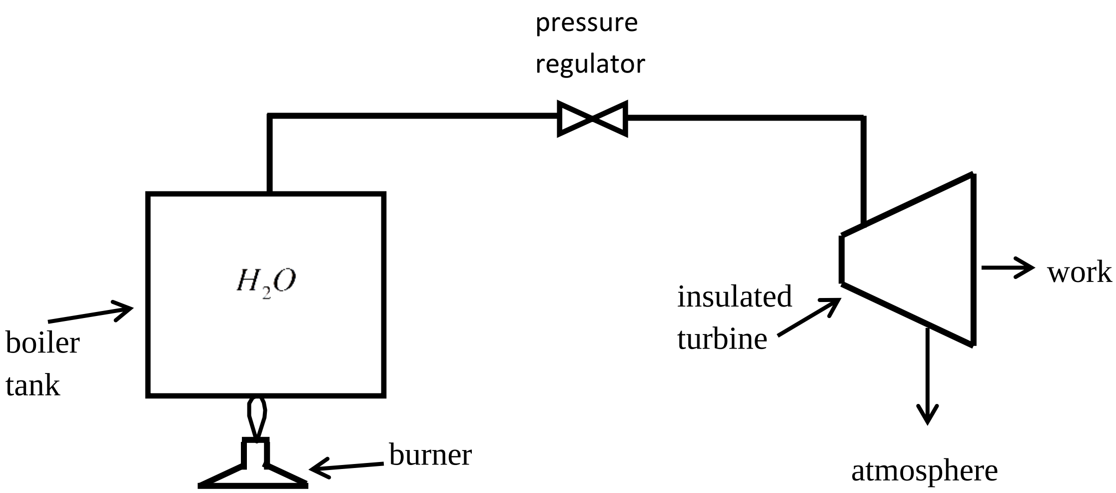
Problem 1



A steam engine based on a turbine is shown above. The boiler tank has a volume of $0.1\ m^3$ and initially contains saturated liquid at 100 kPa. Heat is now added by the burner. The pressure regulator, which keeps the pressure constant, does not open before the boiler pressure reaches 700 kPa. Saturated vapor at 700 kPa enters the turbine and saturated vapor at 100 kPa is discharged to the atmosphere. The burner is turned off when no liquid remains in the boiler.

Find:

i. The total turbine work.
ii. The total heat transfer to the boiler

Assume the mass of H_2O in the piping and turbine is negligible, and only vapor leaves the boiler tank.

Problem 2

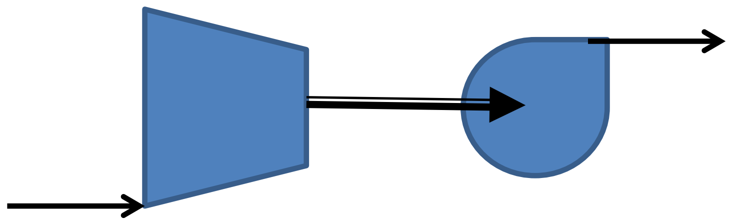
A metal casting of mass *m* is quenched in a large barrel of oil at a constant temperature of T_{oil}. The temperature of the metal (which is assumed to be uniform except very close to the boundary) varies over time according to the following equation, where T_i is the initial temperature of the metal casting as it is immersed in the barrel of oil:

$$T_m(t) = (T_i - T_{oil})\exp(-t/\tau) + T_{oil}$$

a) Derive an expression that describes the total amount of entropy generated *in the metal casting* from the initial immersion, t=0, to an arbitrary time (t_a), prior to the equilibrium state.
b) Determine the instantaneous rate of entropy generation in the metal casting at time t_a.
c) Justify, on physical grounds, the sign of your answer to Part (b).

Problem 3

An **adiabatic** gas turbine with efficiency of 70% drives an **isothermal** pump, which has an efficiency of 80%. The turbine is supplied with air (molar mass = 28.97) at 450 C and 8 bar and exhausts at 1 bar. Assume the air has **constant** specific heat (c_p = 1.004 kJ/kg-K) and constant specific heat ratio of 1.40. The pump shaft power input is 100 kW. Water at **ambient temperature** of 25 C and 1 bar enters the pump suction, and the pump discharge is at 10 bar. Assume the water is an incompressible liquid with specific volume of .001 m^3/kg and specific heat of 4.2 kJ/kg-K. Refer to the following incomplete schematic and add to it as necessary to illustrate this system:



(a) Note the pump efficiency = ________; the turbine efficiency = ___________
(b) Find the work per unit mass of the turbine = _______________ kJ/kg
(c) Find the work per unit mass of the pump =_______________kJ/kg
(d) Find the mass flow of the turbine =_______________kg/s
(e) Find the mass flow of the pump =_______________kg/s
(f) Find the outlet temp of the air = ____________ C
(g) Find the outlet temp of the water (note specs) = ____________ C
(h) Find the rate of entropy generation in the turbine =_______________ kW/K
(i) Find the rate of entropy generation in the pump =_______________ kW/K
(j) Find the rate heat is rejected from the pump = ____________kW
(k) What is the exergy destruction in the turbine = ____________ kW