Problem 1: Steam (dry and saturated) is supplied by the boiler at 15 bar and the condenser pressure is 0.4 bar. Calculate the Rankine efficiencies of the cycle. Neglect the pump work. Use the same numbering for Rankine cycles used in the lecture notes, and for this problem assume $h_4 = h_{f2}$.

Problem 2: Water is the working fluid in an ideal Rankine cycle. Dry saturated vapour enters the turbine at 16 MPa, and the condenser pressure is 8 kPa. The mass flow rate of steam entering in the turbine is 120 kg/s. Calculate:

(a) the net power developed (in MW);

(b) rate of heat transfer to the steam passing through the boiler (in MW);

(c) thermal efficiency;

(d) mass flow rate of the condenser cooling water (in kg/s), if the cooling water undergoes a temperature increase of 18^{o}C with negligible pressure change in passing through the condenser. Assume that the heat capacity at constant pressure $\left(C_p\right)$ of the cooling water is 4.18 $\frac{kJ}{kg.^{\circ}C}$.

Problem 3: The table below represents the steps of an idealised steam power plant:

Step	**Location**	**Pressure (bar)**	**Temperature (°C)**	**Quality / State**	**Velocity m/s**
1	Inlet to turbine	60	380	–	–
2	Exit from turbine and inlet to condenser	0.1	–	0.9	200
3	Exit from condenser and inlet to pump	0.09	–	Saturated Liquid	– –
4	Exit from pump and inlet to boiler	100	–	–	–
5	Exit from boiler	80	440	–	–

Assume that the steam mass flow rate leaving the boiler is 10^4 kg.h^{-1}. Sketch the cycle numbering each stage. Calculate:

(a) Specific enthalpies of all streams;

(b) Power output of the turbine;

(c) Heat transfer per hour in the boiler and condenser;

(d) Mass rate of cooling water circulated (kg/h) in the condenser assuming inlet and outlet fluid temperatures from the condenser of 20°C and 30°C. Assume the heat capacity at constant pressure of the cooling water (C_p) is 4.18 $\dfrac{\text{kJ}}{\text{kg.}^{\circ}\text{C}}$;

(e) Diameter of the pipe connecting the turbine with the condenser;

(f) Sketch the Ts diagram, indicating each step of the cycle.

Problem 4: In the secondary cooling circuit of a nuclear power plant, the steam generator (boiler / reheater) produces superheated steam (SHS, Fig. 1) and is connected to two turbines operating as a reheat Rankine cycle. Isentropic efficiencies of the first (η_{T1}) and second (η_{T2}) turbines are 84%, 80%, respectively. The mass flow rate of water in the system is 1000 kg.s^{-1}.

Stage	P (bar)	T (°C)	State	Quality	h (kJ.kg^{-1})	s (kJ.(kg.K)$^{-1}$)
1	40	320	SHS	–	**(a)**	**(b)**
2	–	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**
3	7	370	SHS	–	**(h)**	**(i)**
4	0.10	**(j)**	**(k)**	**(l)**	**(m)**	**(n)**
5	0.10	**(o)**	**(p)**	–	**(q)**	**(r)**
6	40	–	**(s)**	–	**(t)**	–

Table 1: **Problem 4:**.

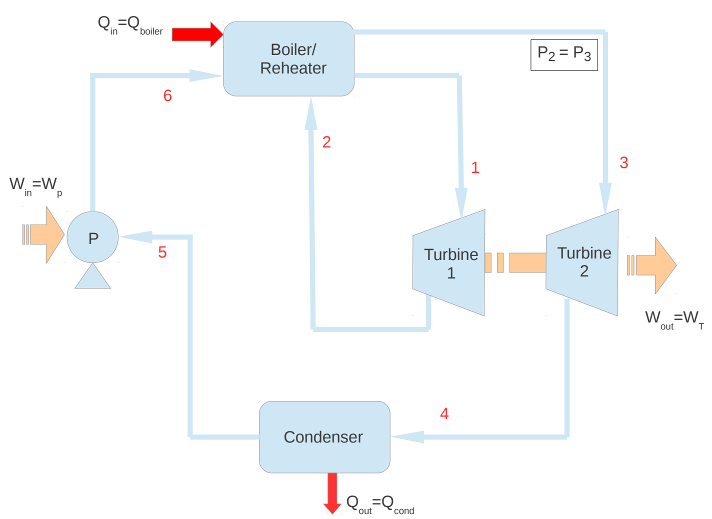

Figure 1: **Problem 4:**

- Determine *(a)-(t)* in Table 1;
- Calculate the power produced by the turbines;
- Calculate the heat supplied by the boiler;

- Calculate the heat extracted from the condenser. Assume that the heat capacity at constant pressure $(\mathrm{C_p})$ is 4.18 $\frac{\mathrm{kJ}}{\mathrm{kg.^\circ C}}$;
- Sketch the Ts diagram of the cycle.

Problem 5: R-22 is the refrigerant fluid in a geothermal heat pump system for a house (Fig. 2). The heat pump uses underground water from a well $\left(T_{\mathrm{w}}^{\mathrm{in}} = 13^\mathrm{o}\mathrm{C}; T_{\mathrm{w}}^{\mathrm{out}} = 7^\mathrm{o}\mathrm{C}\right)$ to produce a heating capacity of 4.2 tons. Determine:

(a) Volumetric flow rate of heated air to the house $\left(m^3/s\right)$;

(b) Isentropic efficiency (η_c) and power $\left(\dot{W}_c\right)$ of the compressor;

(c) Coefficient of Performance;

(d) Volumetric flow rate of water from the geothermal well (l/h);

(e) Sketch the TS diagram.

Given the heat capacity $\left(C_p^{\mathrm{air}} = 1.004\frac{kJ}{kg.K}\right)$ and molecular weight $\left(MW^{\mathrm{air}} = 28.97\frac{kg}{kgmol}\right)$ of air and heat capacity of water $\left(C_p^{\mathrm{water}} = 4.1813\frac{kJ}{kg.K}\right)$.

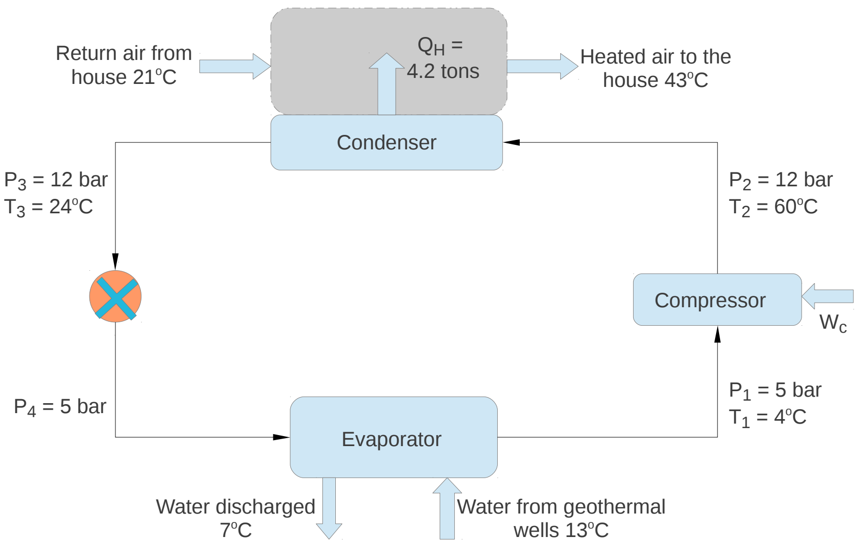

Figure 2: Heat pump cycle: Problem **Problem 5:**.