1. Heat engine

\[ Q_{\text{in}} = 500 \text{ kJ} \quad Q_{\text{out}} = 200 - 500 \text{ kJ} = [\boxed{-300 \text{ kJ}}] \]

\[ W_{\text{net}} = 200 \text{ kJ} \]

2. Automobile heat engine

\[ V_{\text{fuel}} = 28 \text{ L/hr} \quad \rho_{\text{fuel}} = 0.8 \text{ kg/L} \]

\[ \rho_{\text{fuel}} V = M_{\text{fuel}} = 28 \text{ L} \times (0.8 \text{ kg/L}) = 22.4 \text{ kg} \quad \frac{1 \text{ hr}}{3600 \text{ s}} \]

\[ M = 0.0062 \text{ kg/s} \quad \quad W_{\text{net}} = 60 \text{ kW} \]

\[ Q_{\text{in}} = 0.0062 \text{ kg} \times (44000 \text{ kJ/kg}) = 273.8 \text{ kW} \]

\[ \eta = \frac{60}{273.8} = 0.219 = (21.9\%) \]

3. Air conditioner

\[ Q = m C_v (T_2 - T_1) = 800 \text{ kg} \times (0.718 \text{ kJ/kg} \cdot \text{min}) \times (20 - 32) \]

\[ Q = -7.66 \text{ kW} \]

\[ \text{AC COP} = 2.5 = \frac{7.66 \text{ kW}}{W_{\text{in}}} \]

\[ W_{\text{in}} = \frac{7.66}{2.5} = \boxed{3.06 \text{ kW}} \]
4. Resistance heater consumed 1,200 kWh to heat.

Heat pump: COP = 2.3

\[ Q_{\text{out}} = 1200 \, \text{kWh} \times 3600 \, \text{kJ/kWh} = 4,320,000 \, \text{kJ/month} \]

\[ W_{\text{in}} = \frac{4,320,000 \, \text{kJ}}{2.3} = 1,878,261 \, \text{kJ/month} \]

Compare $\$

Resistance heat = 1200 kWh \times 0.085 $\text{/kWh} = $102.00/mo

Heat pump = 521.7 kWh \times 0.085 = $44.35/mo

Savings = $57.65/mo.

5. Refrigerator evaporator (Heat exchanger)

P = 120 kPa

\[ W_{\text{in}} = 0.45 \, \text{kW} \]

\[ X_1 = 0.2 \]

\[ T_2 = -20^\circ \text{C} \]

\[ \text{a. } \dot{m} : \quad \text{COP} = \frac{\dot{m} g_{\text{in}}}{W_{\text{in}}} \]

\[ \dot{m}_{\text{in}} = 1.2 \times 0.45 \, \text{kw} = 0.54 \, \text{kw} \]

\[ g_{\text{in}} = h_2 - h_1 \]
5. a) \( h_1 = 0.2 \frac{h_{fg}}{kg} + h_f = 100 \frac{kJ}{kg} = 0.2 (214.8) + 22.49 \frac{kJ}{kg} \) 
\( h_1 = 65.45 \frac{kJ}{kg} \)
\( h_2 = 239 \frac{kJ}{kg} \)
\( g = 239 - 65.45 = 173.55 \frac{kJ}{kg} \)
\( m = \frac{0.54 \text{ kW}}{173.55 \frac{kJ}{kg}} = \frac{0.0031 \text{ kg}}{s} \)

b) \( \dot{Q}_{out} = -0.45 \text{ kW} - 0.54 \text{ kW} \)
\( \dot{Q}_{out} = -0.99 \text{ kW} \)

6.
\( \eta = \frac{3.7 \text{ kW}}{\dot{Q}_{in}} \) 
\( \dot{Q}_{in} = 3.7 \text{ kW} - \left( \frac{15800 \text{ kW}}{3600} \right) \) 
\( \dot{Q}_{in} = 8.09 \text{ kW} \)
\( \eta = \frac{3.7}{8.09} = 0.457 \) claimed

\( \eta_c = 1 - \left( \frac{300}{500} \right) = 0.455 < \text{ claimed } \eta \) 
\( \text{ NOT VALID } \)

7.
\[ \text{NO} \text{ Max efficiency (CARNOT) of HE's (regardless of type) is equal (BEST CASE)} \]
8. Cannot heat pump, R-134a

\[ \dot{m} = 0.265 \text{ kg/s} \]

\[ T_H = 1.25 T_L \]

\[ \dot{W}_{in} = 7 \text{ kW} \]

\[ \text{COP}_{CHP} = \frac{1}{1 - \frac{T_L}{T_H}} = \frac{1}{1 - \frac{1}{1.25}} = 5.0 \]

\[ 5.0 = \frac{Q_{out}}{7 \text{ kW}} \]

\[ Q_{out} = 35 \text{ kW} = \dot{m} \theta \]

\[ \theta = \frac{35 \text{ kW}}{0.265 \text{ kg/s}} = 132.1 \frac{\text{kJ}}{\text{kg}} = -h_{fg} \]

\[ T_H = 65^\circ C = 338 K \]

\[ P_H = 1891 \text{ kPa} \]

\[ T_L = \frac{338 K}{1.25} = 270.4 K = -2.6^\circ C \]

\[ P_L = \frac{252.85}{272.36 - 252.85} = \frac{-2.6 - (-4)}{-2 - (-4)} = 0.7 \]

\[ P_L = 0.7(272.36 - 252.85) + 252.85 \]

\[ P_L = 266.5 \text{ kPa} \]

\[ \frac{P_H}{P_L}_{\text{MAX}} = \frac{1891}{266.5} = 7.1 \]
Homework 8: Due Friday, April 2, 6 PM

1. A heat engine receives 500 kJ of heat from a geothermal reservoir and produces 200 kJ work. How much heat must be rejected?

2. An automobile engine consumes fuel at a rate of 28 L/hr and delivers 60 kw of power to the wheels. If the fuel heating value is 44,000 kJ/kg and density is 800 kg/m³, what is the efficiency of the engine?

3. A man returns to his well-sealed house on a summer day and finds that the house is 32 °C. He turns on the air conditioner which cools the house to 20 °C in 15 minutes. The COP of the air conditioner is 2.5. What is the power drawn by the air conditioner if the mass of air in the house is 800 kg?

4. A house heated by an electric resistance heaters (electricity converted to heat) consumed 1,200 kwh of electric energy during a winter month. If the house were heated by a heat pump that has an average COP of 2.3, how much money would the homeowner have saved if the cost of electricity is $0.085/kwh?

5. Refrigerant (R-134a) enters the evaporator coils in the back of the freezer of a household refrigerator at 120 kPa with a quality of 0.20 and leaves at 120 kPa and -20 °C. The compressor consumes 450 w of power and the COP of the refrigerator is 1.2. (Assume the enthalpy of the R-134a at the outlet = 239 kJ/kg.) Find:
   a. Mass flow rate of refrigerant
   b. Rate of heat rejection to the house air.

6. An inventor claims to have devised a cyclical engine for use in space vehicles that operates using a nuclear fission heat source at 550K and rejects heat to a sink at 300K while producing 3.7 kw power. The heat rejection rate is 15,800 kJ/hr. Is his claim valid?

7. It is well known that the thermal efficiency of a heat engine increases as the temperature of the high temperature reservoir (source) increases. In an attempt to improve the efficiency of a power plant, somebody suggests transferring the heat first to a higher temperature medium by a heat pump which would then supply heat to the power plant. Do you think this will result in improved efficiency? Why/why not?

8. Consider a Carnot heat pump cycle operating under steady flow conditions using R-134a with a mass flow rate of 0.265 kg/s. The maximum absolute temperature (of the high temperature reservoir) in the cycle is 1.25 times the minimum absolute temperature (of the low temperature reservoir). The power input to the heat pump is 7 kw. If the R-134a changes from saturated vapor to saturated liquid during the heat rejection process determine the ratio of maximum to minimum pressures in the Carnot heat pump cycle.