

①

The Heat exchanger will only work if the exhaust temperature is higher than the compressor's exit value temperature. Therefore can only flow from hot temperatures to cold temperatures.

$$T_1 = 30^\circ\text{C} + 273 = 303\text{K}$$

$$T_2 = T_1 r_p^{k-1/k}$$

$$r_p = 10$$

$$T_2 = (303)(10)^{\frac{1.4-1}{1.4}}$$

$$k = 1.4$$

$$T_2 = 585\text{K}$$

$$T_3 = 800^\circ\text{C} + 273 = 1073$$

$$T_4 = T_3 r_p^{\frac{k-1}{k}}$$

$$T_4 = (1073)/(10)^{\frac{1.4-1}{1.4}}$$

$$T_4 = 555.76\text{K}$$

Since $T_4 < T_2$ the heat exchanger cannot transfer heat.

①

a) $C_p = 1$ $T_1 = 303$ $T_2 = 585$ $T_4 = 555.76 \text{ K}$
 $T_3 = 1073 \text{ K}$

$W_c = C_p (T_2 - T_1)$

$W_c = (1) (585 - 303) = 282 \frac{\text{kJ}}{\text{kg}}$

$W_t = (1) (1073 - 585) = 488 \frac{\text{kJ}}{\text{kg}}$

$W_{\text{net}} = 488 - 282 = 206 \frac{\text{kJ}}{\text{kg}}$

$Q_{\text{in}} = (1) (1073 - 585) = 488 \frac{\text{kJ}}{\text{kg}}$

$Q_{\text{out}} = (1) (555.75 - 303) = 252.75 \frac{\text{kJ}}{\text{kg}}$

$\eta = \frac{252.75}{488} = 0.52 = 52\%$

Heat Exchanger effectiveness is at zero due to $T_4 < T_2$

b) $W_{\text{net}} = 206$
 $Q_{\text{in}} = 488$
 $Q_{\text{out}} = 252.75$
 $\eta = 50\%$

Same as part A nothing has changed. Heat exchanger effectiveness still zero.

c) $r_p = 8.58$

$T_2 = 303 \cdot 8.58^{\frac{1.4-1}{1.4}} = 560 \text{ K}$

$T_4 = 1073 / 8.58^{\frac{1.4-1}{1.4}} = 580.62 \text{ K}$

$W_c = (1) (560 - 303) = 257 \frac{\text{kJ}}{\text{kg}}$

$W_t = (1) (1073 - 580) = 493 \frac{\text{kJ}}{\text{kg}}$

$W_{\text{net}} = 493 - 257 = 236 \frac{\text{kJ}}{\text{kg}}$

$T_5 = T_4 - 10^\circ \text{C}$

$T_5 = 580.62 - 10 = 570.62 \text{ K}$

$Q_{\text{in}} = (1) (1073 - 570.62) = 502.38 \frac{\text{kJ}}{\text{kg}}$

$Q_{\text{out}} = (1) (580.62 - 303) = 277.62 \frac{\text{kJ}}{\text{kg}}$

$\eta = \frac{236}{502.38} = 0.47 \cdot 100 = 47\%$

$\epsilon = \frac{570.62 - 560}{580.62 - 560} = 0.52$

d) $T_3 = 1168.48$ $T_2 = 585$
 $T_4 = 1168 / 10^{\frac{1.4-1}{1.4}} = 605.2$
 $W_c = 585 - 303 = 282$
 $W_t = (1) (1168.48 - 605.2) = 563.3$

$W_{\text{net}} = 563.3 - 282 = 281.28 \frac{\text{kJ}}{\text{kg}}$

$T_5 = T_4 - 10 = 605.2 - 10 = 595.2$

$T_5 = 595.2 \text{ K}$

$Q_{\text{in}} = (1) (1168.48 - 595.2) = 573.28 \frac{\text{kJ}}{\text{kg}}$

$Q_{\text{out}} = (1) (605.2 - 303) = 302.2 \frac{\text{kJ}}{\text{kg}}$

$\eta = \frac{281.28}{573.28} = 0.49 \cdot 100 = 49\%$

$\epsilon = \frac{595.2 \text{ K} - 585}{605.2 - 585} = 0.5$

e) $T_1 = 303 \text{ K}$ $r_p = 10 \rightarrow 2 \text{ stages}$ $r_p = \sqrt{10}$
 $T_{\text{max}} = 1073 \text{ K}$ $r_p = 3.2$

$T_2 = T_1 r_p^{\frac{\gamma-1}{\gamma}} = 303 \text{ K} (3.2)^{\frac{1.4-1}{1.4}} = 422.5 \text{ K}$

$T_2' = 303 \text{ K}$

$T_3 = 303 \text{ K} (3.2)^{\frac{1.4-1}{1.4}} = 422.5 \text{ K}$

$W_c \leq (1) (422.5 - 303) + (422.5 - 303) = 239 \frac{\text{kJ}}{\text{kg}}$

$T_4 = 1073 \text{ K} / 10^{\frac{1.4-1}{1.4}} = 555.76 \text{ K}$

$W_t = (1) (1073 - 555.76) = 517.24 \frac{\text{kJ}}{\text{kg}}$

$W_{\text{net}} = 517.25 - 239 = 278.25 \frac{\text{kJ}}{\text{kg}}$

$T_5 = T_4 - 10 = 555.76 - 10 = 545.76 \text{ K}$

$Q_{\text{in}} = C_p (T_{\text{max}} - T_5) = (1) (1073 - 545.76)$

$Q_{\text{in}} = 527.24 \frac{\text{kJ}}{\text{kg}}$

$Q_{\text{out}} = C_p (T_4 - T_1) = (1) (555.76 - 303)$

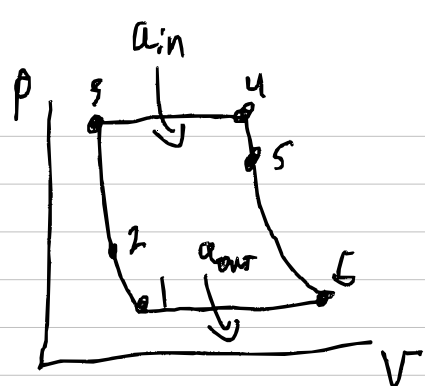
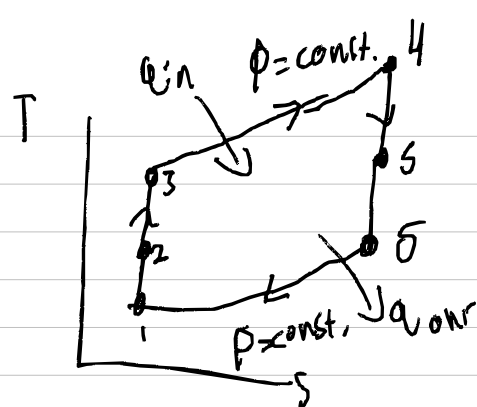
$Q_{\text{out}} = 252.76 \frac{\text{kJ}}{\text{kg}}$

$\eta = \frac{W_{\text{net}}}{Q_{\text{in}}} = \frac{278.25}{527.25} = 0.53 \cdot 100 = 53\%$

$\epsilon = \frac{T_5 - T_3}{T_4 - T_3} = \frac{545.76 - 422.5}{555.76 - 422.5} = 0.92$

c is probably the best option out of all of them. A and B their Heat exchanger is useless so those are out. C is OK. It's not the best due to low thermal eff. but it's not the worst. d is the best option if you want less complexity and reduce cost but in the long run it out shines d. e is more complex and expensive but its thermal eff. and heat exchanger effectiveness is way better than the other options. It has the highest thermal eff. (53%) and the highest heat exchanger effectiveness which I think outweighs the complexity and price.

2)



$$D = 1.6 \text{ m}$$

$$V_1 = 400 \text{ km/h} \rightarrow 250 \text{ m/s}$$

$$\eta_c = 0.9$$

$$T_1 = -35^\circ \text{C} \rightarrow 238 \text{ K}$$

$$\eta_c = 0.8$$

$$p_1 = 40 \text{ kPa}$$

$$T_3 = 990^\circ \text{C} = 1223 \text{ K}$$

$$W_c = W_t = W = 500 \frac{\text{kJ}}{\text{kg}}$$

$$c_p = 1 \frac{\text{kJ}}{\text{kg} \cdot \text{K}} = 1000 \frac{\text{J}}{\text{kg} \cdot \text{K}}$$

a)

$$T_2 = T_1 + \frac{V_1^2}{2c_p}$$

$$T_2 = 238 + \frac{250^2}{2(1000)} = 289.25 \text{ K}$$

$$\frac{p_2}{p_1} = \left(\frac{T_2}{T_1} \right)^{\frac{\gamma}{\gamma-1}} \rightarrow p_2 = (40) \left(\frac{289.25}{238} \right)^{\frac{1.4}{1.4-1}}$$

$$p_2 = 61.61 \text{ kPa}$$

$$W_c = c_p (T_3 - T_2)$$

$$500 = 1 (T_3 - 289.25)$$

$$500 = T_3 - 289.25$$

$$789.25 = T_3$$

$$\eta_c = \frac{T_{3s} - T_2}{T_3 - T_2} \rightarrow 0.8 = \frac{T_{3s} - 289.25}{789.25 - 289.25}$$

$$T_{3s} = 669.25$$

$$\frac{p_3}{p_2} = \left(\frac{T_3}{T_2} \right)^{\frac{1.4}{1.4-1}} \rightarrow p_3 = (61.6) \left(\frac{669.25}{289.25} \right)^{\frac{1.4}{1.4-1}}$$

$$p_3 = 1491.4 \text{ kPa}$$

$$500 = W_t = c_p (T_3 - T_4) = (1)(1223 - T_4)$$

$$T_4 = 723 \text{ K}$$

$$\eta_c = \frac{T_3 - T_4}{T_3 - T_{4s}} \rightarrow 0.9 = \frac{1223 - 723}{1223 - T_{4s}}$$

$$T_{4s} = 667 \text{ K}$$

$$\frac{p_4}{p_3} = \left(\frac{T_{4s}}{T_3} \right)^{\frac{1.4}{1.4-1}} = (1491.4) \left(\frac{667}{1223} \right)^{\frac{1.4}{1.4-1}}$$

$$p_4 = 173.65 \text{ kPa}$$

$$b) T_6 = T_5 \left(\frac{p_6}{p_5} \right)^{\frac{\gamma-1}{\gamma}}$$

$$T_6 = (723) \left(\frac{40}{173.65} \right)^{\frac{1.4-1}{1.4}} = 475 \text{ K}$$

$$V_6 = \sqrt{2c_p (T_5 - T_6)} = \sqrt{2(1000)(723 - 475)}$$

$$b) V_6 = 704 \text{ m/s}$$

$$c) A = \frac{\pi D^2}{4} = \frac{\pi (1.6)^2}{4} = 2.01 \text{ m}^2$$

$$\rho = \frac{p}{RT} = \frac{40000 \text{ Pa}}{(287 \text{ J/kg} \cdot \text{K})(238 \text{ K})} = 0.59 \frac{\text{kg}}{\text{m}^3}$$

$$\dot{m} = \rho A V = (0.59)(2.01)(250)$$

$$\dot{m} = 296.475$$

$$F = \dot{m} (V_6 - V_1) = (296.475)(704 - 250)$$

$$F = 134,145.7 \text{ N}$$

I labeled the wrong numbers shifted down on A