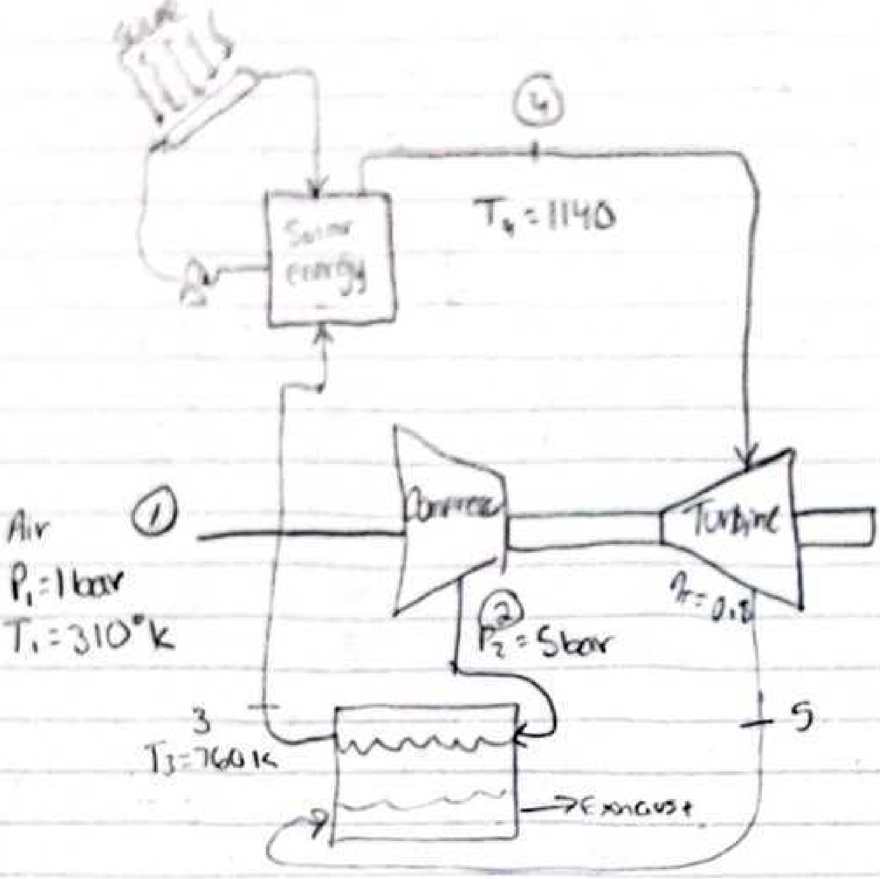
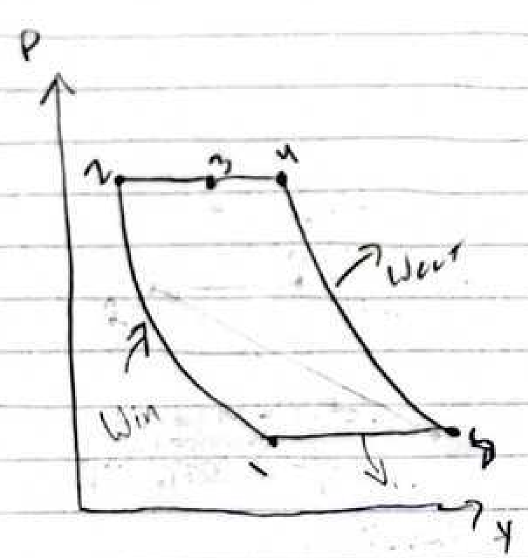
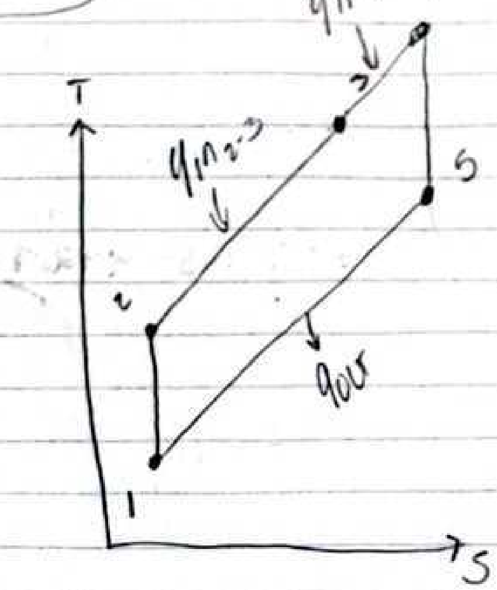
TEST 1

1. Solar energy proposed solution as heat source in an ideal cold air standard cycle







Assuming Cp, Cv CONSTANT

① $\xrightarrow{\text{Isentropic Compression}}$ ② $\xrightarrow{P = \text{const}}$ ③ $\xrightarrow{P = \text{const}}$ ④ $\xrightarrow{\text{Isentropic exp}}$ ⑤ $\xrightarrow{P = \text{const}}$

①	②	③	④	⑤
$P_1 = 1\text{bar}$	$P_2 = 5\text{bar}$	$P_3 = 5\text{bar}$	$P_4 = 5\text{bar}$	$P_5 = 1\text{bar}$
$T_1 = 310\text{ K}$	$T_2 = 490\text{K}$	$T_3 = 760\text{K}$	$T_4 = 1140\text{ K}$	$T_5 = 719.78$
	$h_2 = 492.74$	$h_3 = 778.18$	$h_4 = 1207.57$	

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \qquad \frac{T_5}{T_4} = \left(\frac{P_5}{P_4}\right)^{\frac{k-1}{k}}$$

$$T_2 = 310\text{K}\left(\frac{5}{1}\right)^{\frac{1.4-1}{1.4}} \qquad T_5 = 1140\left(\frac{1}{5}\right)^{\frac{1.4-1}{1.4}}$$

$$T_2 = 490.98\text{ K} \qquad T_5 = 719.78\text{K}$$

a) Thermal Efficiency and Heat exchanger effectiveness

$$\eta_T = \frac{W_{net}}{q_{in}}$$

$$W_{net} = W_{out} - W_{in} = W_{out_{4-5}} - W_{in_{1-2}} = 337.84 - 181.88 = 155.96$$

$$W_{out_{4-5}} = h_5 - h_4 = C_p(T_4 - T_5) = 1.005(1140 - 719.78)$$
$$= 422.3 \cdot 0.8 = 337.84$$

$$W_{in_{1-2}} = h_2 - h_1 = C_p(T_2 - T_1) = 1.005(490.98 - 310)$$
$$= 181.88$$

$$q_{in} = q_{in_{2-3}} + q_{in_{3-4}}$$
$$(h_3 - h_2) + (h_4 - h_3)$$
$$(778.18 - 492.74) + (1207.57 - 778.18)$$
$$= 714.83$$

$$\eta_T = \frac{155.96}{714.83}$$
$$= 21.8\%$$

$$\varepsilon = \frac{h_3 - h_2}{h_4 - h_2} = \frac{\text{actual}}{\text{max}}$$
$$= \frac{778.18 - 492.74}{1207.57 - 492.74}$$
$$0.3993 = 39.93\%$$

effective

b) The air mass flow rate, in kg/s, for a net power output of 500 kW

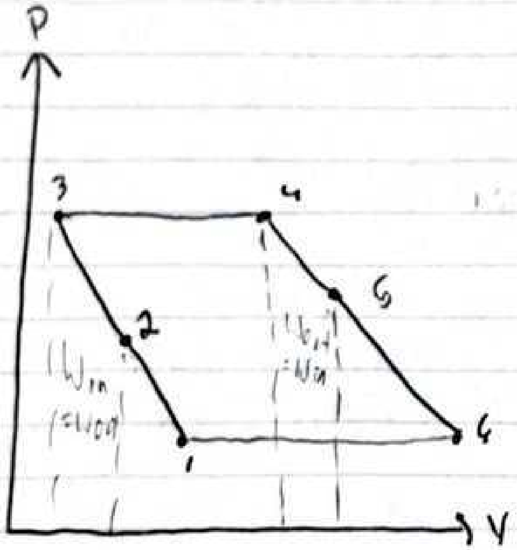
$$\dot{m} = \frac{\dot{W}_{given}}{W_{net}} = \frac{500\ kW}{155.96} = 3.20\ \frac{kg}{s}$$

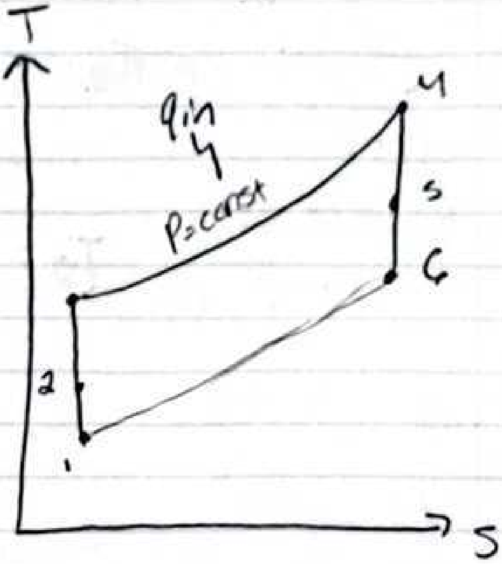
c) What would be the thermal efficiency if the heat exchanger were operating at 100% effectiveness

$$\eta_0 = 1 - \frac{T_1}{T_5}$$

$$= 1 - \frac{310}{719.78} = 56.9\%$$

2) A turbojet aircraft flies w/ a velocity of 900 km/h at an altitude where Temp is -35°C and P is 40 kPa. Combustion gases enter turbine at 950°C. The turbine produces 500 kJ/kg of work, all of which is used to drive the compressor. Assuming an isentropic efficiency of 80% for the compressor, an isentropic efficiency of 90% for the turbine and using variable Specific heats.





Diffuser Compressor Burner Turbine Nozzle

$$① \xrightarrow[\text{Differ}]{\text{ISENT}} ② \xrightarrow{\text{ISENT}} ③ \xrightarrow{\text{Pconst}} ④ \xrightarrow{\text{ISENT}} ⑤ \xrightarrow{\text{ISENT}} ⑥$$

500 kJ/kg

$T_1 = 238k$ $T_2 = 239.45$ $T_4 = 1223K$ $P_6 = 40\,kpa$

$P_1 = 40\,kPA$ $P_2 = 40.85$

$V_1 = 900\,km/h$ $V_2 = 0$

$v_1 = \frac{RT_1}{P_1}$ $v_2 = \frac{RT_2}{P_2} = 1.68$

$= \frac{0.2870 \cdot 238}{40}$

$= 1.708$

$q_{in}\, Cp(T_5 - T_4)$

$T_5 = 1729007.k$ WRONG TOO HIGH

$\frac{V_1^2}{2} + h_1 = \frac{\cancel{V_2^2}}{2} + h_2$

$Cp(T_2 - T_1) = \frac{V_1^2}{2}$

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

$= 238 + \frac{\cancel{400}^2}{2(1.005)}$

$T_2 = 239.45\,K$

$W_C = W_T$

$\cancel{Cp}(T_2 - T_1) = \cancel{Cp}(T_4 - T_5)$

$239.45 - 238 = (1223 - T_5)$

$1.45 = 1223 - T_5$

$T_5 = 1221.55$

$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{\frac{k}{k-1}}$

$P_2 = P_1 \cdot \left(\frac{T_2}{T_1}\right)$

$P_2 = 40.85$

$\eta_T = \frac{h_4 - h_{5a}}{h_4 - h_{5s}}$

$h_4 = 1301$

$h_5 = 1905.93$ interpolation APP

$.90 = \frac{1301 - h_{5a}}{1301 - 1905.93}$

$h_5 = 1845.437$

$T_3 = T_2 + \frac{V_2^2}{2cp}$

$= 239.45 + \frac{1.68^2}{2(1.004)}$

$T_3 = 240.85$

$\left(\frac{T_3}{T_2}\right) = \left(\frac{P_3}{P_2}\right)^{\frac{k-1}{k}}$

$\frac{240.85}{239.45} = \left(\frac{P_3}{40.85}\right)^{\frac{0.4}{1}}$

$P_3 = 41.69$

$\frac{T_5}{T_4} = \left(\frac{P_5}{P_4}\right)^{\frac{k-1}{k}}$

$\frac{1221.007}{1223} = \left(\frac{P_5}{41.69}\right)$

$P_5 = 41.62$

$\frac{T_6}{T_5} = \left(\frac{P_6}{P_5}\right)^{\frac{k-1}{k}}$

$T_6 = 1221.55 = \left(\frac{40}{41.6}\right)^{\frac{1.4-1}{1.4}}$

$T_6 = 1207.9$

a) Pressure of Combustion gases @ Turbine exit

$P_5 = 41.62$ kPA

b) Velocity of the gases at the nozzle exit

$V_6 = \sqrt{2 C_p (T_5 - T_6)}$

$= \sqrt{2(1.005)(1221.55 - 1207.9)}$

$V_6 = 5.237$ km/h

c) The thrust for engine if diffuser inlet diameter is 1.6m

$\dot{m} = \rho_1 V_1 A_1$

$= \frac{1}{v} \cdot V_1 \cdot \pi r^2$

$= \frac{1}{1.708} \cdot 900 \cdot (\pi \cdot 0.8^2)$

$\dot{m} = 1059.46$

$F = \dot{m}(V_{exit} - V_{inlet})$

$= 947965.608$

UH OH