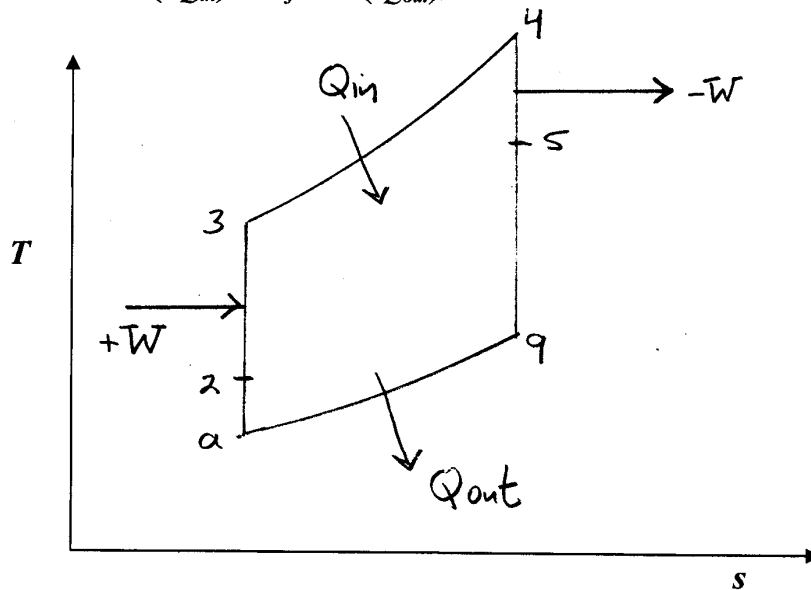


20 minutes. Closed book, closed notes, closed homework and homework solutions.

1. (18 pts.) Using the axes provided below, draw *carefully* the variation in the static temperature,  $T$ , and the entropy,  $s$ , over one complete, *ideal* turbojet engine cycle. Consider the entire cycle, from the oncoming freestream air (condition "a") to the engine nozzle exhaust (condition "9").

Clearly indicate all key points along the cycle, including the compressor inlet and exit (points "2" and "3"), and the turbine inlet and exit (points "4" and "5").

Lastly, indicate over which "legs" of the cycle work is added ( $+W$ ) or extracted ( $-W$ ), and where heat is added ( $+Q_{in}$ ) or rejected ( $-Q_{out}$ ).



2. (16 pts.) In terms of the turbojet nozzle exit velocity,  $V_9$ , the flight velocity,  $V_0$ , the fuel/air mass flow ratio  $f$ , and the fuel heating value,  $h_{pr} = Q_R$ , what are the expressions for the:

a) engine thermal efficiency, 
$$\eta_T = \frac{\dot{m}_a \frac{1}{2} (V_9^2 - V_0^2)}{\dot{m}_f h_{pr}} = \frac{1}{2f h_{pr}} (V_9^2 - V_0^2)$$

b) engine propulsive efficiency, 
$$\eta_p = \frac{\dot{m}_a (V_9 - V_0) V_0}{\dot{m}_a \frac{1}{2} (V_9^2 - V_0^2)} = \frac{2}{\frac{V_9}{V_0} + 1}$$

(continued on back)

3. (16 pts.) Across each of the following turbojet components, indicate whether the stagnation pressure ( $p_t$ ), the static pressure ( $p$ ), the gas velocity ( $u$ ), and the entropy ( $s$ ) increases, decreases, or remains constant. Assume that all components are ideal (loss-free).

a) DIFFUSER/INLET	$p_t$	increases	decreases	<u>remains constant</u>	} isentropic
flow slows down <	$p$	<u>increases</u>	decreases	remains constant	
	$u$	increases	<u>decreases</u>	remains constant	
	$s$	increases	decreases	<u>remains constant</u>	

b) NOZZLE	$p_t$	increases	decreases	<u>remains constant</u>	} isentropic
flow accelerates <	$p$	increases	<u>decreases</u>	remains constant	
	$u$	<u>increases</u>	decreases	remains constant	
	$s$	increases	decreases	<u>remains constant</u>	

4. (12 pts.) Consider a turbine with mass flowrate  $\dot{m}$ , inlet total temperature and total pressure  $T_{t4}$  and  $p_{t4}$ , respectively, outlet total temperature and total pressure  $T_{t5}$  and  $p_{t5}$ , gas constant  $R$ , specific heat  $c_p$ , and specific heat ratio  $\gamma$ . The turbine is not necessarily ideal in its performance.

a) Suppose in this particular turbine, heat is input at a rate  $\dot{Q}$  in an attempt to increase the work/power output. What is the expression for the power output from the turbine in terms of the variables listed?

$$\dot{W}_t = \dot{m} c_p (T_{t4} - T_{t5}) + \dot{Q}$$

b) Suppose the addition of heat does not change the turbine exit conditions  $T_{t5}$  and  $p_{t5}$ . Does the addition of heat result in the generation of more power by the turbine? Give a *physical reason* for your answer.

Exit conditions unchanged  $\Rightarrow$  enthalpy drop across turbine unchanged  $\Rightarrow$  adding heat must give more work output

(end)