Massachusetts Institute of Technology
Department of Aeronautics and Astronautics
Cambridge, MA 02139

16.003/16.004 Unified Engineering III, IV
Spring 2007

Problem Set 1

Name: ________________________

Due Date: 02/13/2007

	Time Spent (min)
F1	
T1	
T2	
Study Time	

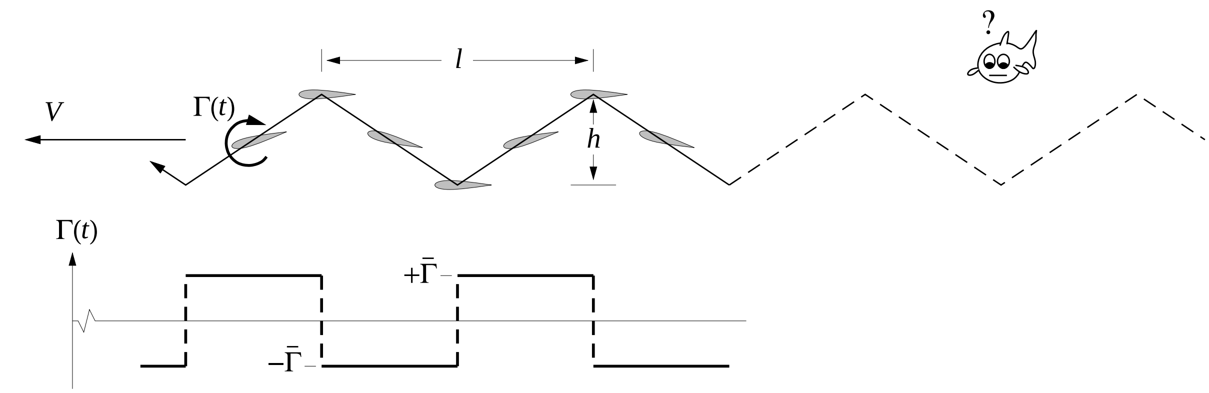
Announcements:

Unified Engineering Spring 2007
Fluids Problem 1

A dolphin tail is in effect an oscillating wing, with an oscillating circulation $\Gamma(t)$. Consider an idealized 2D version of the tail, which moves in the zigzag pattern shown, with the circulation assumed to be piecewise constant in time:

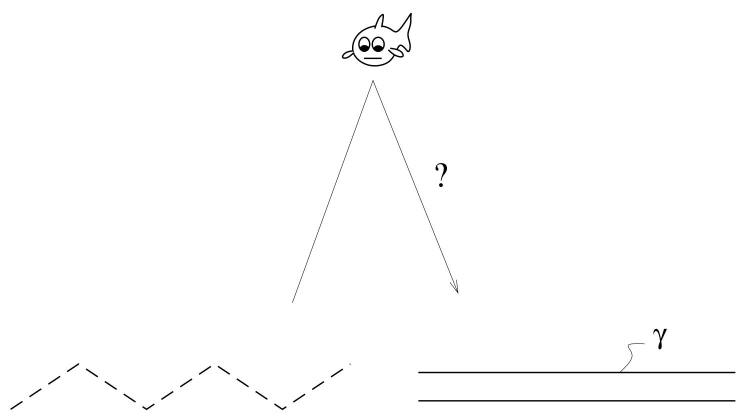
$$\Gamma(t) \;=\; \pm\bar{\Gamma}$$

1) Determine the location and strength of the vortices left by the tail of a dolphin traveling at some speed V, as seen by an observer stationary in the water. Indicate also the direction of the circulation of each vortex.



We now wish to examine the velocity field of the vortices left behind by the dolphin. To do this, we will "smear" the discrete vortices into two continuous vortex sheets parallel to the dolphin's path, with constant strengths $\gamma = +\gamma_s$ and $\gamma = -\gamma_s$.

2) First consider all the positive (clockwise) vortices, which constitute one sheet of strength $+\gamma_s$. Then consider the negative vortices which constitute the other sheet of strength $-\gamma_s$. Determine γ_s and the separation distance of the two sheets. Your answer should be in terms of $\bar{\Gamma}$, ℓ, h of the dolphin tail motion.



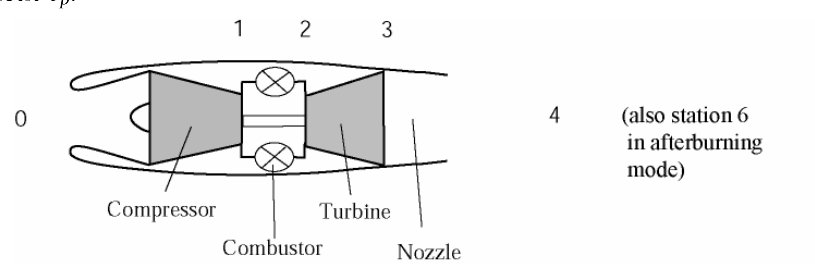
3) Now determine and sketch the velocity field of the two vortex sheets. Explain how this velocity field, which is set up by the tail, is consistent with the tail acting as a propulsor. Hint: If it helps, qualitatively compare the velocity field of the sheets to the velocity field behind a jet engine.

Unified Engineering Spring 2007
Thermodynamics & Propulsion Z. S. Spakovszky

(Add a short summary of the concepts you are using to solve the problem)

Problem T1

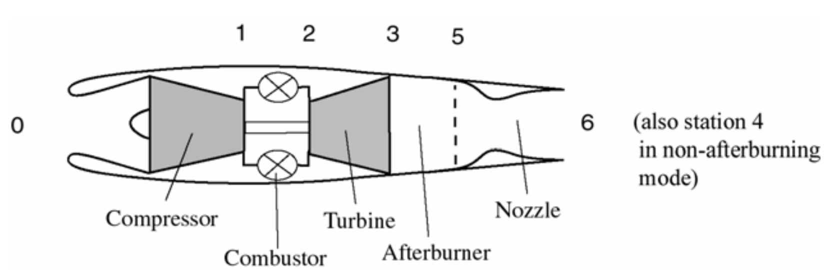
An ideal turbojet engine can be operated with or without afterburning. The cycle is shown in the figure below. Operated without an afterburner, it consists of reversible, adiabatic compression from 0 to 1, constant pressure burning from 1 to 2, then reversible adiabatic expansion through the turbine and the nozzle from 2 to 4, where the pressure at state 4 is atmospheric. The cycle pressure ratio is *PR* and the temperature ratio (T_1/T_0 where T_1 is the temperature at the compressor exit and T_0 is the atmospheric temperature) is *TR*, which is equal to 2. The ratio of maximum temperature in the cycle to atmospheric temperature is 10. The kinetic energy changes across the turbine and compressor can be neglected, as can any temperature rise produced in the inlet and diffuser ahead of the compressor. If necessary, express your answers in terms of T_0 and the specific heat c_p.



a) Sketch the non-afterburning cycle 0-1-2-4 in a *p*-*v* diagram.
b) What is the thermal efficiency of the non-afterburning cycle?
c) What is the net cycle work produced per unit mass flow?

In the afterburning mode, expansion takes place in the turbine from state 2 to state 3, and then the flow is passed through an afterburner where it undergoes constant pressure combustion from state 3 to state 5. The maximum temperature at the afterburner is the same as the maximum temperature at the combustor exit. On leaving the afterburner, the flow expands through a nozzle to atmospheric pressure at state 6.

d) Sketch states 3, 5 and 6 in the same *p*-*v* diagram.
e) The afterburner entrance is at the turbine exit. What is the afterburner inlet temperature T_3?
f) The afterburner exit temperature, T_5, is the nozzle inlet temperature. What is the nozzle exit temperature, T_6?



Unified Engineering Spring 2007
Thermodynamics & Propulsion Z. S. Spakovszky

(Add a short summary of the concepts you are using to solve the problem)

Problem T2

A closed system consists of an ideal gas with constant specific heat ratio γ. In the first case, the gas undergoes a process in which the temperature increases from T_1 to T_2.

a) Show that the entropy change for the process is greater if the change in state occurs at constant pressure than if it occurs at constant volume.
b) Sketch the processes in a *p-v* diagram and indicate lines of constant entropy (how are *p* and *v* related for an isentropic process?).

In the second case, the gas undergoes a process in which pressure increases from p_1 to p_2.

a) Show that the ratio of the entropy change for an isothermal process to the entropy change for a constant-volume process is $(1-\gamma)$.
b) Sketch the processes in a *p-v* diagram and indicate lines of constant entropy.