Massachusetts Institute of Technology
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Unified Engineering
Spring 2005

Problem Set #5

Due Date: Tuesday, March 8, 2005 at 5pm

	Time Spent (minutes)
P4	
P5	
P6	
F13	
F14/15	
F19	
Study Time	

Name: ________________

Problem P4. (Propulsion) **L.O.'s C & D**

In this problem you are to use the experimental 12 mph drag polar $C_D(C_L)$ that you measured for the Dragonfly wing in Lab 2.

Your Lab 2 data represents the drag of the wing alone: $C_{D\_lab2} = c_d + C_{Di}$
To get the overall aircraft drag, you must add the constant drag coefficient ~ 0.013 of the Dragonfly fuselage, as formulated in the Lab 1 notes:

$$C_D = CDA_o/S + c_d + C_{Di}$$
$$C_D = 0.013 + C_{D\_lab2}$$

This is the $C_D(C_L)$ relation that you will use for the following questions.
The wing loading of the stock Dragonfly is approximately W/S = 5 Pa .

a) Assuming the overall propulsive efficiency is independent of speed, use your $C_D(C_L)$ data to graphically determine the C_L and corresponding speed V that you would fly the Dragonfly to maximize range.

b) Same as a), but find the C_L and V for maximum endurance.

c) Repeat a) and b) for the case of the Dragonfly flying in a circle at a constant 20 degree bank angle.

Problem P5. (Propulsion) **L.O.'s C & D**

A future high performance military fighter is being designed with a wing loading (W/S) of 3200 N/m^2. At a mass of 20,000 kg it must be able to:

1) fly a 6g combat turn at M=0.7,
2) accelerate from M=0.8 to M=2.0 in 15 seconds and
3) fly straight up at M=0.5.

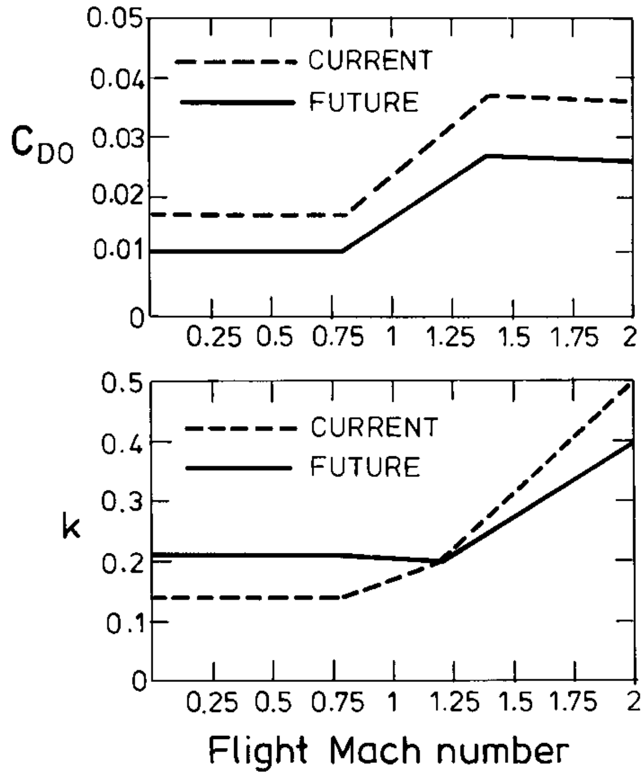
<u>Estimate the maximum design thrust for the engine.</u>

Note, for a 6g turn the load factor, n=6, is the acceleration perpendicular to the wing. For n=1, L=W. Also, assume all maneuvers occur at an altitude of 11km where the pressure is 22.6 kPa, the temperature is 217 K, the density is 0.34 kg/m^3, and the speed of sound is 295 m/s.

Assume the coefficient of lift takes the form

$$C_D = kC_L^2 + C_{Do}$$

Where



0.05
0.04
0.03
0.02
0.01
0
CURRENT
FUTURE
C_{DO}
0.25 0.5 0.75 1 1.25 1.5 1.75 2
0.5
0.4
0.3
0.2
0.1
0
CURRENT
FUTURE
k
0.25 0.5 0.75 1 1.25 1.5 1.75 2
Flight Mach number

Problem P6. (Propulsion) **L.O.'s D & E**

Evaluate the performance of a single stage sounding rocket to be used for atmospheric research. You are given the following design parameters:

Combustion chamber temperature = 3500 K
Combustion chamber pressure = 5 MPa
Nozzle exit area = 0.008 m^2
Nozzle throat area = 0.0006 m^2
Propellant mass = 30 kg
Total mass at takeoff = 40 kg
Gas constant = 300 J/kg-K
Ratio of specific heats = 1.35

a) What are the take-off thrust and take-off Isp for this rocket?
b) What is the Isp when the nozzle is ideally expanded?
c) Assuming the rocket is launched vertically and that the nozzle is ideally expanded, and neglecting drag, how high will it go?
d) If you increase the exit area 10% at a cost of1 kg in total mass at take-off (still 30 kg fuel mass) does the rocket go higher? Why?

[Note: To solve this problem you will have to use relationships from thermodynamics (steady flow energy equation) and fluid mechanics (compressible flow relations). These can all be found in the Unified Propulsion notes (Chapters V and VI). Most of the relations are written in terms of the exit Mach number, Me. To find this you will have to try several values of Me in the relationship for A*/Ae until the equation gives you the same ratio as given in the problem statement. I also recommend doing this with Matlab or a spreadsheet. Once you have it coded in, you can do all the design trades--like part (d).]

You are flying a Dragonfly at 6 m/s inside Johnson, where the air has the following conditions:

$c_p = 1000\,\mathrm{J/kg\,K}$
$T = 290\,\mathrm{K}$
$\rho = 1.2\,\mathrm{kg/m^3}$
$p = 10^5\,\mathrm{Pa}$

The flight speed is 6 m/s, and the 7 in diameter propeller is turning at 6000 rpm.

Determine the velocity of the propeller tip through the air, and the air conditions at the stagnation point of the propeller tip's airfoil.

A rocket motor explodes during a ground test, sending a spherical shock wave traveling away from the explosion into still ambient air which has the following conditions:
$T = 300\,\mathrm{K}$, $p = 10^5\,\mathrm{Pa}$.

When the shock reaches an observer safely far away from the explosion point, the observer sees the shock to be speeding past at 450 m/s. Determine the following quantities at this instant:

a) Mach number of the flow into the shock, in the shock's frame.

b) The air temperature behind the shock

c) The air pressure behind the shock.

d) The air velocity seen by the observer after the shock passes.

e) The observer yells "ouch!" a split second after the shock passes him. Will the sound waves carrying his yell ever reach the shock? Hint: Sound moves with speed a relative to the fluid.

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Fluids Problem F19

One of the Space Station modules is a cylinder 8 m long and 3 m in diameter, and holds air at sea level conditions:
$T = 300\,\mathrm{K}$, $p = 10^5\,\mathrm{Pa}$.

A micrometeorite punches a 1 cm diameter hole through a wall of the module, and the air starts to leak out. The air is not replaced, although it is held at a constant 300 K by the environmental system.

a) Determine the intial mass flow $\dot{m}$ out when the hole is first made, assuming the air flowing out is choked at the hole.

b) Determine the rate of pressure decrease $\dot{p}$ inside the tank when the hole is first made.

c) The astronauts have a limited amount of time to plug the hole before the air density drops too low to sustain consciousness. To reduce the magnitude of the density decrease rate $\dot{\rho}$, should they increase or decrease the air temperature inside the module?