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

16.03/16.04 Unified Engineering III, IV
Spring 2004

Problem Set 7

Name: ________________________

Due Date: 3/30/04

	Time Spent (min)
F20	
CP2-4	
S1	
S2	
S3	
Study Time	

Announcements: Q3M is on Wednesday, 3/17 at 9am in 35-225.

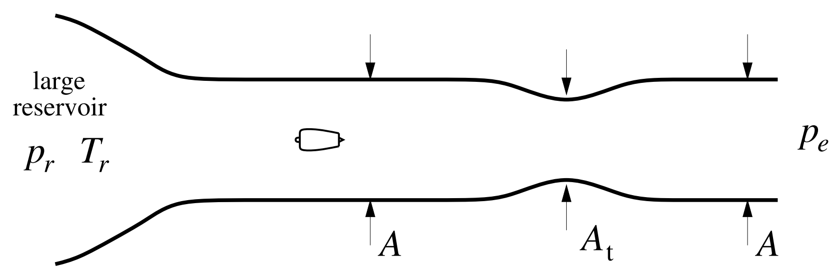
Q4F is on Wednesday, 3/31 at 9am in WALKER.

F20.
A small jet engine is to operate in a test facility which consists of a large air reservoir, exhausting through a duct of area A holding the engine. A throat of area A_t is behind the engine.

a) The engine is to be tested at $M = 0.6$. What must be the ratio A_t/A so that this test Mach number is achieved even if p_e is near vacuum? Will this test Mach number change as the tank gradually empties?

b) If $p_r = 5 \times 10^5$ Pa and $T_r = 300\text{K}^\circ$, what is the minimum p_e needed to ensure proper operation at $M = 0.6$ in a) above?

c) The throat is now set at $A_t = 0.9A$, and we still have $p_r = 5 \times 10^5$ Pa and $T_r = 300\text{K}^\circ$. What must p_e be set to so that a normal shock appears in the straight section downstream of the throat? What is the static temperature just behind the shock?



CP2-4

The problems in this problem set cover lectures C2, C3, and C4.

1.

Part a. Write an algorithm to check if a user entered string is a palindrome.

Assume:

i. Maximum string length is 80 characters
ii. The actual string length is input dependent

Part b. Implement your algorithm as an Ada95 program.

Turn in a hard copy of your algorithm and code listing; and an electronic copy of your code.

2. Modify the program above to read inputs from a text file and store the reversed string in an output text file. The program should:

a. If the line of text is a palindrome, store it in the output file.
b. If it is not a palindrome, reverse the line of text and store the reversed line of text in the output file.
c. Repeat the above steps until there are no more inputs to be processed from the input file.

Assume:

i. Input file name is my_program_input.txt
ii. Output file name is my_program_output.txt

Turn in a hard copy of your algorithm and code listing and an electronic copy of your code.

3.
a. Compare and contrast stacks and queues.

Hint: Summarize the operations on stacks and queues using a table and use a diagram to show the difference between basic operations.

b. Modify the expression conversion algorithm shown in class to include unary operators.

Hint:

i. Unary operators operate on only one argument. -5, +9 etc
ii. How do you distinguish between a unary and binary operator? (Think about the number of arguments)

iii. Use the following test expression -5 + 9 + -6 + 2 to see if the conversion works.

Assume:

i. The unary operators are only ‘+’ and ‘-’.
ii. Inputs are user input strings of maximum length 80.

c. Implement your algorithm as an Ada95 program.

Turn in a hard copy of your algorithm and code listing, and an electronic copy of your code.

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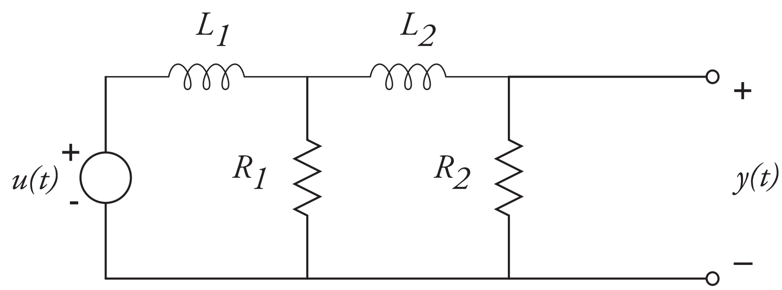
Problem S1 (Signals and Systems)

1. Find and plot the step response of the system



where $L_1 = L_2 = 2$ H, $R_1 = 2$ Ω, and $R_2 = 3$ Ω.

2. For the input signal

$$u(t) = \begin{cases} 0, & t < 0 \\ 2, & 0 \leq t < 1 \\ -1, & t \geq 1 \end{cases}$$

find and plot the output $y(t)$, using superposition.

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Problem S2 (Signals and Systems)

A system has step response given by

$$g_s(t) = \begin{cases} 0, & t < 0 \\ e^{-t} + e^{-3t}, & t \geq 0 \end{cases}$$

Find and plot the response of the system to the input

$$u(t) = \begin{cases} 0, & t < 0 \\ 1 - e^{-2t}, & t \geq 0 \end{cases}$$

using Duhamel's integral.

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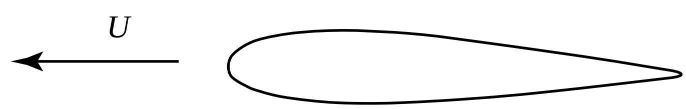
Problem S3 (Signals and Systems)

Note: Please do not use official or unofficial bibles for this problem.

An airfoil with chord c is moving at velocity U with zero angle of incidence through the air, as shown in the figure below:



The air is not motionless, but rather has variations in the vertical velocity, w. As the airfoil flies through this gust field, the leading edge of the airfoil "sees" a variation in the angle of attack. If w is small compared to U, then the angle of attack change seen by the airfoil is $\alpha = w/U$. Since the velocity profile varies in space, the angle of attack seen by the airfoil is a function of time, $\alpha(t)$.

One might expect that the lift coefficient of the airfoil is just

$$C_L(t) = 2\pi\alpha(t)$$

However, the airfoil does not respond instantaneously as the airfoil encounters the gust. If the airfoil encounters a "sharp-edged gust," so that the apparent change in the angle of attack is a step function in time,

$$\alpha(t) = \alpha_0\sigma(t)$$

then the change in lift is given by

$$C_L(t) = 2\pi\alpha_0\psi(\bar{t})$$

where $\bar{t} = 2Ut/c$ is the dimensionless time. $\psi(\bar{t})$ is the *Küssner function*, and is the step response of the airfoil (neglecting multiplicative constants), if the input is considered to be the vertical gust at the leading edge as a function of time, and the output is considered to be the lift as a function of time. The Küssner function can be approximated as

$$\psi(\bar{t}) = \begin{cases} 0, & \bar{t} < 0 \\ 1 - \frac{1}{2}e^{-0.13\bar{t}} - \frac{1}{2}e^{-\bar{t}}, & \bar{t} \geq 0 \end{cases}$$

Assuming that the airfoil acts as an LTI system, determine and plot the lift coefficient, $C_L(t)$, and the gust velocity, $w(t)$, for the following conditions:

$$\begin{aligned} c &= 1 \text{ m} \\ U &= 1 \text{ m/s} \\ w(t) &= \begin{cases} 0 \text{ m/s}, & t < 0 \text{ s} \\ 0.1 \cdot (1 - e^{-2t}) \text{ m/s}, & t \geq 0 \text{ s} \end{cases} \end{aligned}$$