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

16.03/16.04 Unified Engineering III, IV
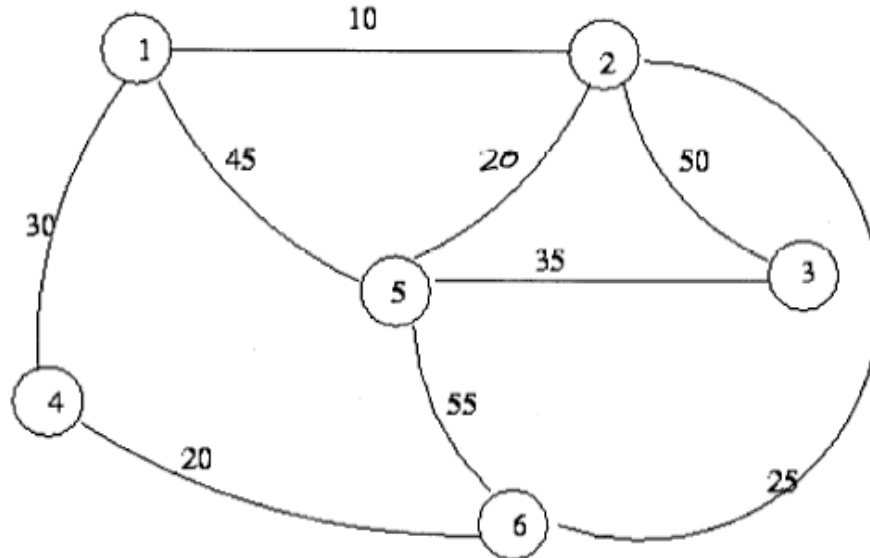### Spring 2004

Problem Set 9

Name: _____

Due Date: 4/13/04

	Time Spent (min)
CP7_9	
P1	
P2	
S8	
S9	
Study Time	

Announcements:

CP7_9

The problems in this problem set cover lectures C7, C8 and C9

1. What is the Minimum Spanning Tree of the graph shown below using both Prim's and Kruskal's algorithm. Show all the steps in the computation of the MST (not just the final MST).

2. Compute the computation complexity of the bubble sort algorithm. Show all the steps in the computation based on the algorithm.

3. What are the best case and worst case computation complexity of:

a.   Inserting a node into an unsorted singly linked list
b.   Inserting a node into a sorted singly linked list

Show the steps in the complexity computation based on the algorithm and justify your answer by using a diagram of the insertion operation.

4.
a. Design an Ada95 Package to:
      i.   Read in N integers from an input file into an array. (N is user defined <=50)
      ii. Sort the array in ascending order
      iii. Perform binary search on the array.

b. Write a program to test your package that will
      - Prompt the user for a number to search for.
      - If the number is found using the binary search algorithm

                - Display the location (index)
                - Display the number
         - If the number is not found using the binary search algorithm
                - Display "Number not in array" to the user

Turn in an electronic copy of your Package and test program and a hard copy of your algorithm and code listing.
Assume: Input file name is my_input.txt

5. Implement the merge sort algorithm as an Ada95 program. Your program should
         - Read in N integers from an input file. (N is user defined <=50)
         - Sort using your merge sort implementation.
         - Display the sorted and unsorted inputs to the user

Turn in an electronic copy of your code and a hard copy of your algorithm and code listing.
Assume: Input file name is my_input.txt

Problem P1. (Propulsion)

a. Consider a turbojet powered aircraft during landing with the throttles set to some
    fraction of that required to achieve take-off thrust. As the aircraft is rolling down the
    runway at 60m/s, the engine consumes 150kg/s of air and produces an exhaust jet
    velocity of 200m/s.

    What is the thrust of the engine? (Assume that the exhaust jet is ideally expanded and
    that the mass flow rate of fuel is small compared to the mass flow rate of the air.)

b. Now suppose that the pilot engages the thrust reversers which deflect the engine
    exhaust normal to the direction of travel (say half up and half down) without affecting
    the operating condition of the engine.

    What is the magnitude and direction (i.e. forward or reverse) of the thrust produced
    by the engine?

c. With the thrust reversers still engaged, the aircraft comes to a stop on the taxiway.
    The engine is now consuming 80 kg/s of air and producing an exhaust velocity of 150
   m/s.

    What is the magnitude and direction (i.e. forward or reverse) of the thrust produced
    by the engine?

d. You are asked to design some of the vanes used in the thrust reverser. Estimate the
    vertical forces (y-direction) on the turning vanes as a function of the variables shown.
    (Assume steady flow and no acceleration of the vehicle.)

Engine

P_{atm}

Nozzle

U_e, ρ_e

A_e

α

A_e

P_{atm}

U_e, ρ_e

y

x
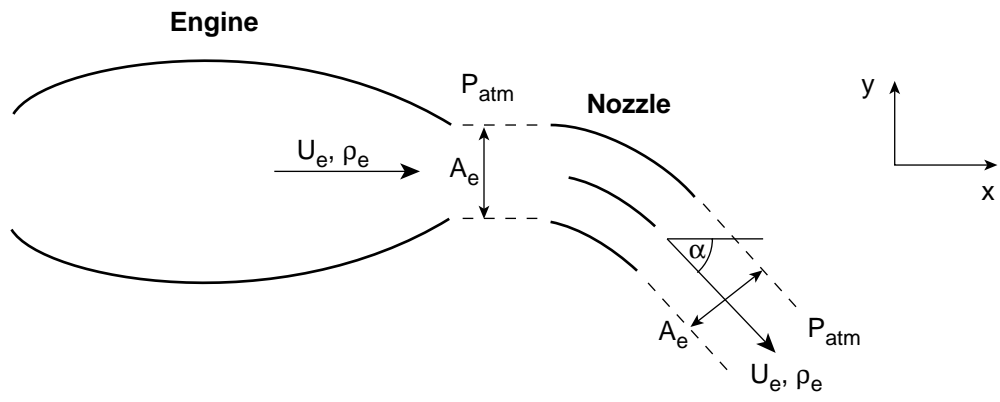
Problem P2. (Propulsion)

There is a test facility at NASA Langley Research Center where a hydraulic catapult is used to accelerate vehicles. It provides an instructive illustration of the integral momentum theorem.
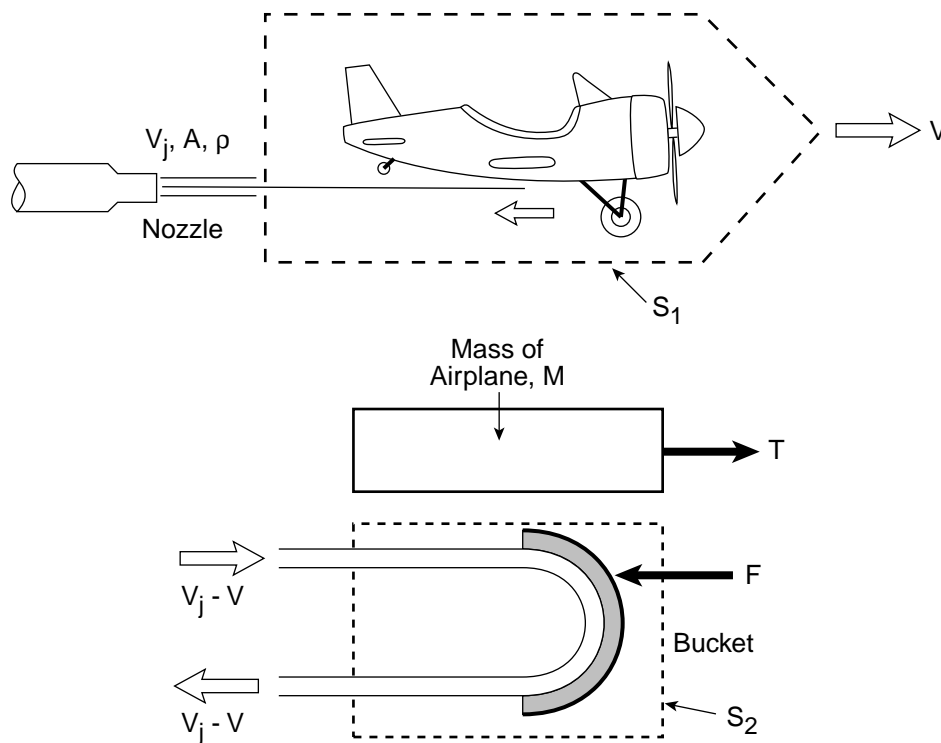
a) Explain what each term in the equation of motion represents.

b) Derive an equation of motion for the airplane acceleration ($dV(t)/dt$) as a function of the velocity, area, and density of the water jet (V_j, A_j and ρ_j respectively), and the mass (m) and velocity (V) of the airplane. Neglect the effects of gravity and assume the forces associated with the air around the vehicle and launcher are small compared to those associated with the water jet. Assume the mass of water in contact with and accelerating the bucket is negligible relative to M so you can neglect any change with time of the momentum of the jet within the control volume.

c) What is the thrust, T, on the airplane?

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Problem S8 (Signals and Systems)

This problem shows why a radar system sends out a chirp, which has a broad range of frquencies in the signal, and *not* a short sinusoidal pulse, which is at a single frequency. To see why a sinusoidal pulse doesn't work well, let's try a radar signal

$$u(t) = \begin{cases} \sin(2\pi t), & -3 \le t \le 0 \\ 0, & \text{otherwise} \end{cases}$$

The matched filter for this pulse has impulse response

$$g(t) = u(-t) = \begin{cases} \sin(-2\pi t), & 0 \le t \le 3 \\ 0, & \text{otherwise} \end{cases}$$

The radar sends out a signal, $u(t)$, that reflects off the aircraft and returns to the radar system. The time it takes the signal to return is twice the distance to the aircraft, divided by the speed of light. The received signal is $u(t-T)$, where T is the round trip travel time of the signal. For the purposes of this problem, we can ignore the time delay, T, and just look at how the matched filter response to $u(t)$.

1. Find the convolution
$$y(t) = g(t) * u(t)$$
   You will find it helpful to use the flip and slide method to set up the integral. The integral can be evaluated relatively easily in closed form, if you set up the integral properly.

2. Plot $y(t)$.

3. $y(t)$ as plotted above is the signal that results when the round-trip time of the pulse is zero. When the delay time is greater, of course, the signal that results is $y(t-T)$, which is just $y(t)$ shifted right by T. What feature of $y(t-T)$ would you use to identify the time T?

4. Explain why it might be difficult to determine T from a returned radar pulse, especially if there is additional noise added to the signal.

5. The signal $y(t)$ as plotted in Part 2 is called the *ambiguity function*, because it helps determine how ambiguous the delay time T is in the presence of noise. Explain why the ambiguity function corresponding to the chirp signal of Problem S6 is better than the ambiguity function in this problem.
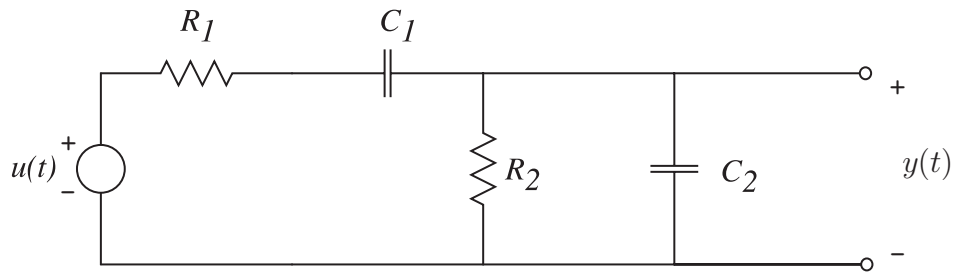
Problem S9 (Signals and Systems)

(a) Find and plot the step response of the circuit below, using Laplace transform
techniques.
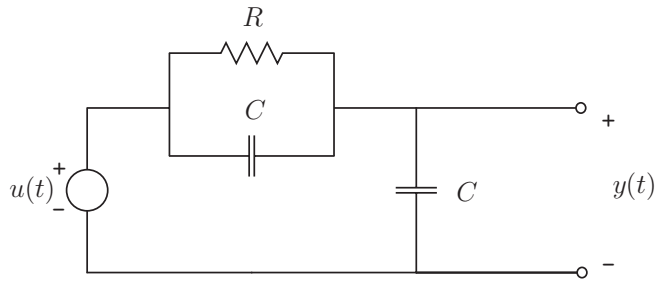
Assume that $R = 2\ \Omega$, and $C = 0.25$ F. Note: This is a problem that's tricky to
do using ordinary differential equation methods — Can you see why?

(b) Find and plot the step response of the circuit below, using Laplace transform
techniques.

Assume that $R_1 = R_2 = 2\ \Omega$, $C_1 = 0.2$ F, and $C_2 = 0.3$ F.