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

16.001/16.002 Unified Engineering I, II
Fall 2006

Problem Set 4

Name: ________________________

Due Date: 10/03/2006

	Time Spent (min)
F8	
F9	
F10	
M4.1	
M4.2	
Study Time	

Announcements:

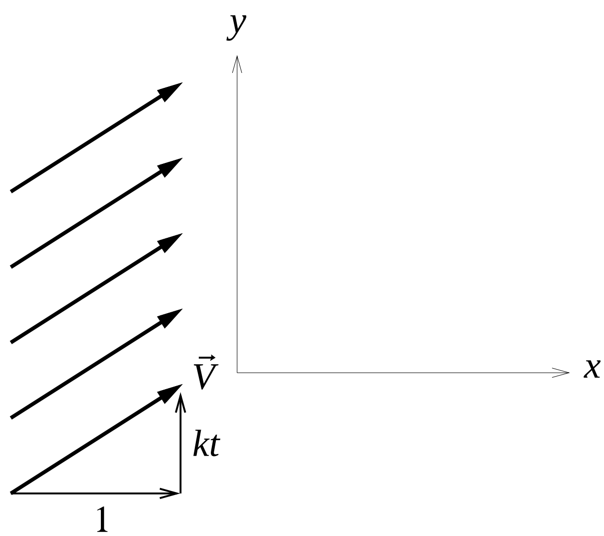
a) A spatially-uniform velocity field has a constant unit x component, and a y component increasing linearly in time at rate k:

$$\vec{V}(t) \;=\; 1\,\hat{\imath} \,+\, kt\,\hat{\jmath}$$

a) Determine the pathline of a particle emitted at the origin $x, y = (0, 0)$ at time $t = 0$.

b) For the time interval $t = 0 \ldots 1$, sketch the three pathlines corresponding to $k = 0$, $k = 1$, and $k = 2$

c) For the case $k = 2$, consider how a streakline emanating from $x, y = (0, 0)$, and starting at $t = 0$, develops in time for $t > 0$. Specifically, sketch this streakline as it appears at the four time snapshots $t = 1/4$, $t = 1/2$, $t = 3/4$, $t = 1$ (all on the same plot).



Unified Engineering Fall 2006
Fluids Problem F9

A 2D airfoil is operating inside a channel of height A as shown. The upstream velocity and pressure are some known V_1, p_1. The airfoil has known lift/span and drag/span L' and D'. The density ρ can be assumed to be constant everywhere (low speed flow). Assume the channel walls are effectively frictionless, with $\tau = 0$.

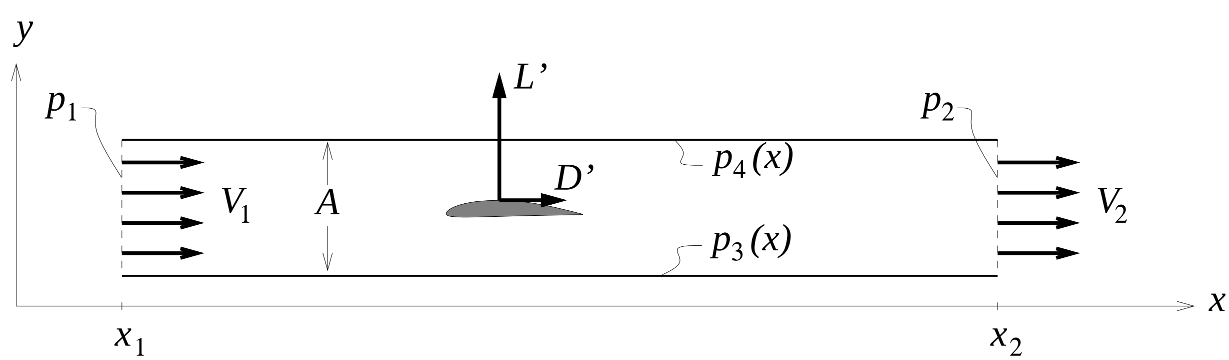
a) The exit station 2 is sufficiently far behind the airfoil so that the airfoil's wake can mix out, making the exit velocity V_2 effectively uniform. Determine this V_2.

b) Determine the pressure difference $p_2 - p_1$, and also the total pressure difference $p_{o_2} - p_{o_1}$. What physical mechanism is responsible for changing p_o between stations 1 and 2?

c) The top and bottom wall pressures $p_4(x)$ and $p_3(x)$ have some unknown x distributions, but their averages can be related. Determine $p_{4_{\rm avg}} - p_{3_{\rm avg}}$, where

$$p_{3_{\rm avg}} \equiv \frac{1}{x_2 - x_1} \int_{x_1}^{x_2} p_3(x)\, dx \qquad\qquad p_{4_{\rm avg}} \equiv \frac{1}{x_2 - x_1} \int_{x_1}^{x_2} p_4(x)\, dx$$

and the length of the channel $x_2 - x_1$ is known.



Unified Engineering Fall 2006
Fluids Problem F10

A water rocket nozzle has an area distribution given by

$$\begin{aligned} A(x) &= A_0 + (A_1 - A_0)\frac{x}{\ell} \\ A_0 &= 0.0100\,\mathrm{m}^2 \\ A_1 &= 0.0005\,\mathrm{m}^2 \\ \ell &= 0.2\,\mathrm{m} \end{aligned}$$

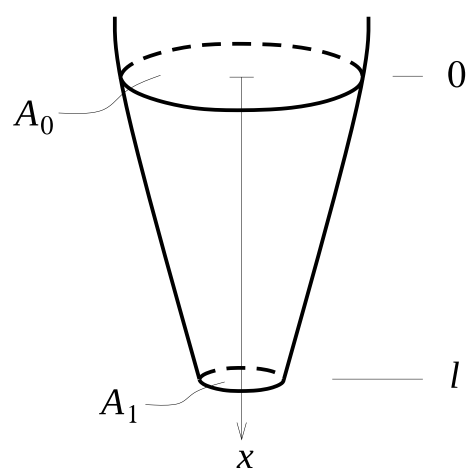
The rocket is partially filled with water ($\rho = 1000\,\mathrm{kg/m^3}$), and the air above the water is pressurized to a gauge pressure of $\Delta p \equiv p_0 - p_1 = 4.0 \times 10^5\,\mathrm{Pa}$ (60 psi).

a) Using the Bernoulli relation, determine the exit velocity V_1.
For this calculation, it's appropriate to neglect the water's dynamic pressure at $x = 0$.

b) Using the mass continuity equation for a channel, determine and plot the water's velocity distribution $V(x)$ along the nozzle, for $x = 0 \ldots \ell$.

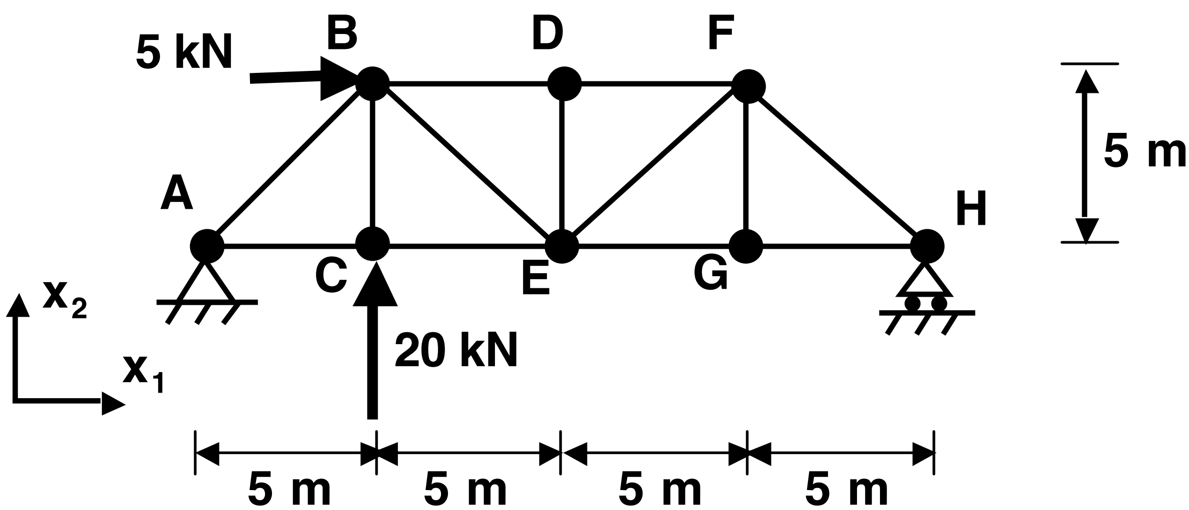
c) Determine and plot the water's acceleration $a(x)$ along the nozzle. Specify your units.

d) Is the gravitational acceleration significant here?



Unified Engineering Problem Set **Lectures: M7, M8**
Week 4 Fall, 2006 **Units: (M1.3), M1.4**

M4.1 ***(15 points)*** A 5-meter high truss has a 20-meter span and is made up of thirteen individual bars of various lengths in four bays as shown in the accompanying illustration. Each bay of the truss is 5 meters long. The truss is simply-supported being pinned at the left end and attached via a roller support at the other. Loads are applied at various joints as noted.



(a) Draw the free body diagram for this situation.

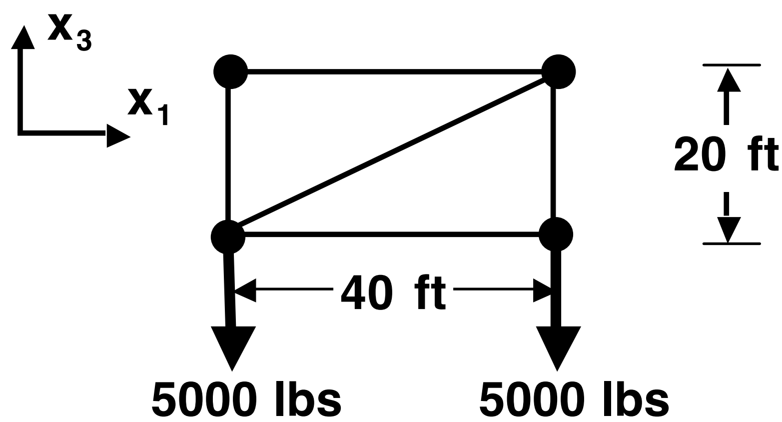
(b) Determine the reaction forces.

(c) Without performing any calculations, can you determine if there are any bars in the truss that carry no load? Which are they? Explain clearly.

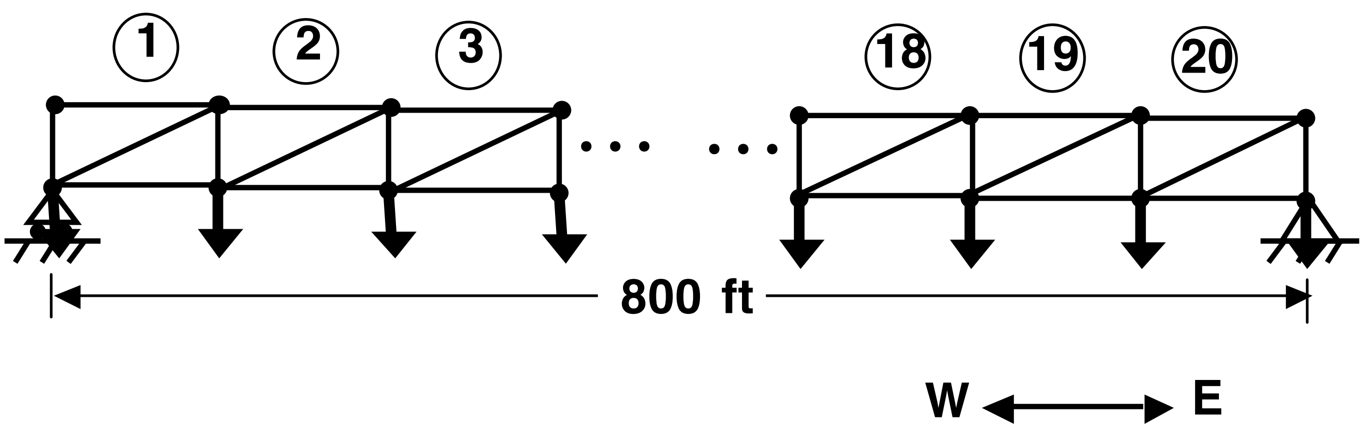
(d) Determine the load in all the bars using the *method of joints*. Draw a clear diagram showing the entire configuration and the manner in which loads are carried.

(e) Check the result for the load in bar EG by the *method of sections*.

M4.2 ***(5 points)*** A bridge spanning an 800-foot length is modeled as a two-dimensional truss comprising 20 identical bays each 40 feet in length and 20 feet high. The structural configuration of the bay unit is shown below.



For design purposes, loading is represented as a downward load of 5000 pounds at each lower node. The bridge is simply-supported with a roller support at the west end and a pin support at the east end. This overall configuration can be partially represented as follows



(a) Determine the reaction forces for this overall structural configuration.

(b) Determine the bar loads in the horizontal and diagonal bars in the 10th bay (counting from the west end).