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

Unified Engineering
Spring 2005

Problem Set #4

Due Date: Tuesday, March 1 , 2005 at 5pm

	Time Spent (minutes)
P1	
P2	
P3	
F11	
F12	
M8	
M9	
Study Time	

Name: __________________

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Fluids Problem F11

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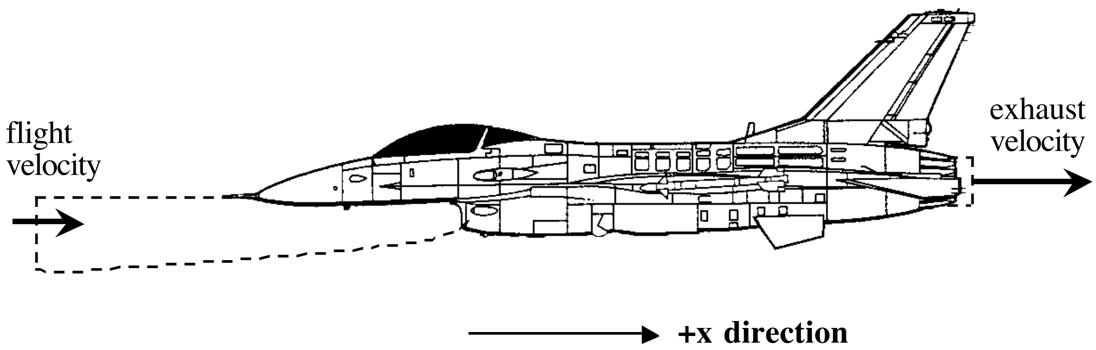
a) Anderson Problem 7.9 (p 463)

b) Anderson Problem 7.10 (p 463)

Problem P1. (Unified Propulsion) L.O.'s A & B
A single engine airplane is traveling in steady level flight at 400 m/s. The mass flow through the engine is 50 kg/s and the exhaust velocity is 700 m/s. A control volume is shown for the flow that passes through the engine. There is no flow across the boundaries of the control volume except as shown. The pressure around the engine control volume is 30 kPa except at the exhaust plane where the pressure is 25 kPa. The area of the exhaust plane is $1m^2$.



a) What is the momentum flux into the engine?

b) What is the momentum flux out of the engine?

c) What is the net momentum flux?

d) What is the net pressure force on the control volume?

e) What is the net force on the mass in the control volume?

f) In what direction does this force act?

g) What is the sum of all other forces on the aircraft?

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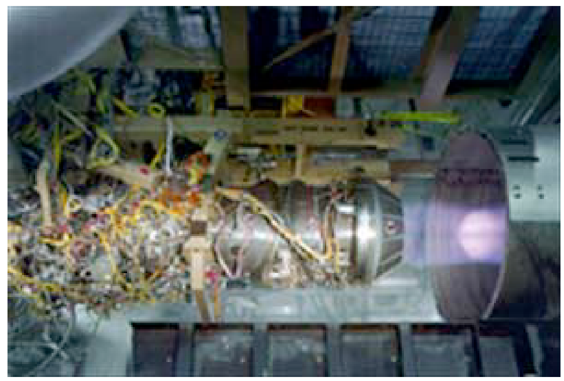
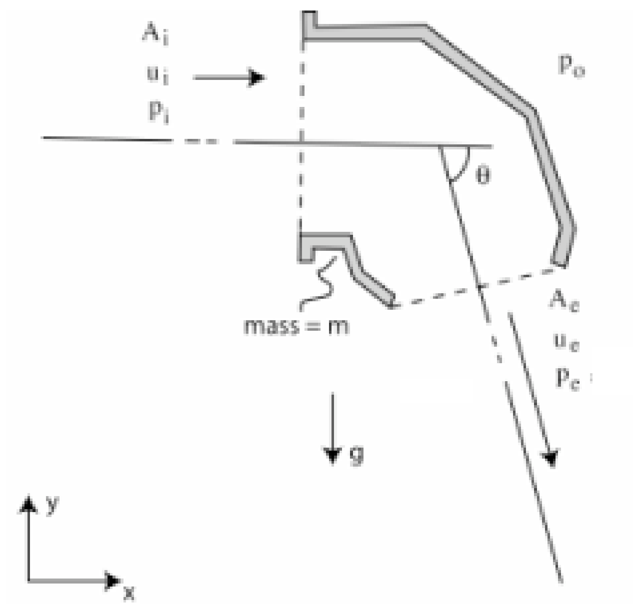
Problem P2. (Unified Propulsion) L.O.'s A & B

Below is a schematic of the main exhaust nozzle for the F-35 Joint Strike Fighter. The exhaust nozzle can vector thrust to angles greater than 90 degrees. Assume that the pressure on the control volume is equal to p_o except at the inlet and the exit to the nozzle.



$A_i = 1\text{m}^2$
$u_i = 500$ m/s
$p_i = 1.85$MPa
$A_e = 1\text{m}^2$
$u_e = 1500$ m/s
$p_e = 0.095$MPa
mass flow = 100 kg/s
nozzle mass = 400 kg
$p_o = 0.1$MPa
$\theta = 80$ degrees



a) What are the x and y components of the net pressure force on the mass in the control volume?

b) Does the net pressure force in the x-direction act to put the flange in tension or compression?

c) What are the x and y components of the net momentum flux for the control volume?

d) Does this net momentum flux in the x-direction act to put the flange in tension or compression?

e) Including the weight of the nozzle, what are the x and y components of the net force that must be applied at the flange to hold the nozzle in place?

f) How is the force transmitted from the fluid to the nozzle structure?

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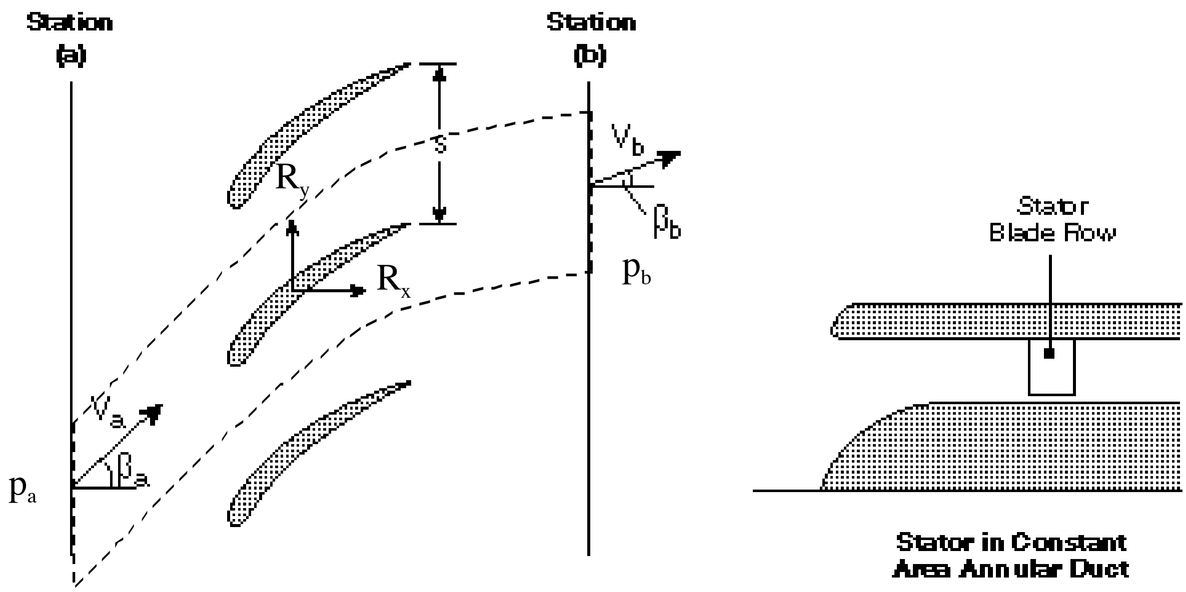
Problem P3. (Unified Propulsion) L.O.'s A, B & G

An incompressible fluid flows steadily through a two-dimensional infinite row of fixed airfoils (*e.g.* a stator blade row). The blade row is contained in a constant area annulus, as shown on the right side of the figure below. The spacing between the airfoils is *s*.



Assume that the velocities and pressures V_a, V_b, p_a, p_b, are constant at stations (a) and (b), and that the flow angles are given by β_a and β_b.

a) Do the tangential (swirl) and axial components of velocity increase , stay the same, or decrease across the blade row?

b) Write an expression for the axial flux of tangential momentum. Does this increase, stay the same or decrease across the blade row?

c) Does the pressure increase , stay the same, or decrease across the blade row?

d) Using the control volume shown above (the upper and lower surfaces are streamlines), apply conservation of mass and momentum to determine the forces R_x and R_y that must be applied to the fluid (these are equal and opposite to the forces needed to keep each vane in place).

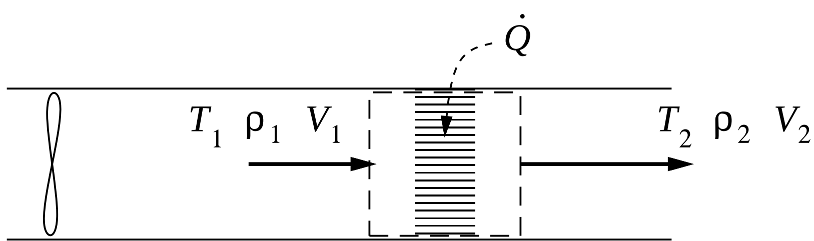
A small room heater consists of a fan and a heating coil inside a duct of cross-sectional area $A = 0.01\,\mathrm{m}^2$. The electric heating coil delivers $\dot{Q} = 1000\,\mathrm{W}$ to the airflow. The room conditions are

$c_p = 1000\,\mathrm{J/kg\,K}$
$T_1 = 290\,\mathrm{K}$
$\rho_1 = 1.2\,\mathrm{kg/m^3}$
$p_1 = 10^5\,\mathrm{Pa} \simeq p_2$

The flow is low speed, which justifies the assumption of nearly constant pressures.

a) Apply the integral enthalpy equation to the dashed control volume. For safety, the exit temperature T_2 must not exceed 340 K (150 F). What is the minimum velocity V_1 which the fan must provide?

b) Assuming the fan is providing the minimum velocity, determine the exit density ρ_2 and the exit velocity V_2.



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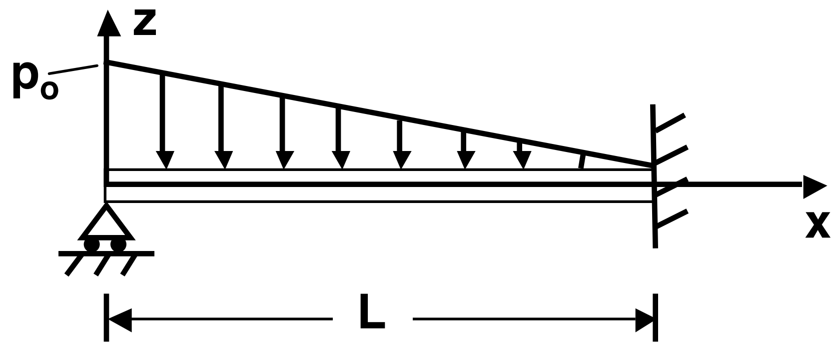
M8 A beam of length L is clamped at one end and supported by a roller at the other. The beam has a constant cross-section with area A and moment of inertia I, and is made of a material with modulus E and Poisson's ratio □. The beam is loaded by a linearly-varying downward load of intensity equal to zero at the clamped end and p_o at the other end.



(a) Determine the maximum deflection of this beam and its location.

(b) Determine the maximum axial stress magnitude, $\square_{xx}$, and its location in the x-direction.

(c) Determine the maximum shear stress magnitude, $\square_{xz}$, and its location in the x-direction.

M9 An aluminum rod has a solid circular cross-section with a 5-inch diameter and is 4 feet in length. The rod is clamped to a solid wall at one end and is subjected to a concentrated negative torque of 200 ft-lbs at the other end. In addition, there is a distributed positive torque of 50 ft-lbs/ft along the first half of the rod. The configuration is shown below. The modulus of aluminum is 10.3 Msi and the Poisson's ratio is 0.3.

(a) Determine the torque distribution in the rod structural configuration and sketch this as a function of x_1.

(b) Determine the twist at the tip of the rod.

(c) Determine the maximum shear stress in the rod and its location.

(d) If the rod were a hollow tube with the same outer radius and a wall with a thickness of 1 inch, how would these answers change?