Homework #6

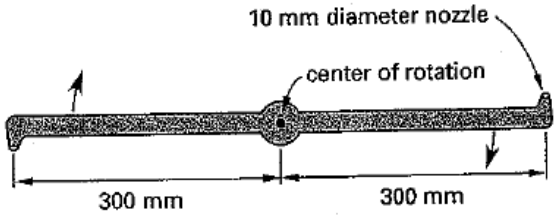
Due: Friday 10/11/2013
(5 problems worth 20 points)

1*. [2 points] What horizontal force is required to hold the plate stationary against the water jet? (All of the water leaves parallel to the plate.)

(A) 17.7 N
(B) 35.4 N
(C) 42.2 N
(D) 67.5 N

2. [3 points] A lawn sprinkler consists of a rotating runner with two nozzles. The nozzles are oriented at right angles to the runner. The diameter of the runner is 20 mm; the diameter of the sprinkler nozzles is 10 mm. Water is supplied by the attached hose (not shown) at a rate of 14 m3/h. What single force must be placed on one sider of the runner at a distance of 100 mm from the center of rotation in order to stop the sprinkler from rotating?

(A) 12 N
(B) 50 N
(C) 75 N
(D) 290 N



3.[5 points] You are designing a new rocket spacecraft and decided to test a small model. The total initial mass of the rocket model is *M(0)* = 10 kg and 90% of the mass is fuel and oxidizer, which will be exhausted out of the nozzle. The rocket exhaust has a density ρ_e = 1.1 kg/m^3, and leaves with a constant velocity V_j= 340m/s relative to the rocket. The exit diameter of the nozzle is D_e=7cm. The rocket starts from rest and accelerates upward.

a) Neglect the aerodynamic forces acting on the outside of the rocket ship. Use the global conservation of mass and momentum equations to obtain a system of differential equations for the mass and momentum of the rocket ship. Solve the system of equations and determine the rocket's mass and velocity as a function of time. The rocket reaches its maximum velocity when it runs out of fuel. Determine the maximum velocity of the rocket.

b) Now assume that the rocket has a drag coefficient C_d=0.2 the wetted area of the rocket is 120 cm^2, and the density of the air is (assumed constant) ρ_a= 1.22 kg/m^3. Repeat part a). In this case, solve the system of ODEs numerically. If you wish, you may write your own program using a different language or you may use the MATLAB function ODE23 or ODE45. You should make sure your numerical solution is accurate enough by reducing the time step Δt to the point that the velocity does not change significantly. Along with your results, turn in the formulation of the equations you are solving and a listing of your M-file (or program).

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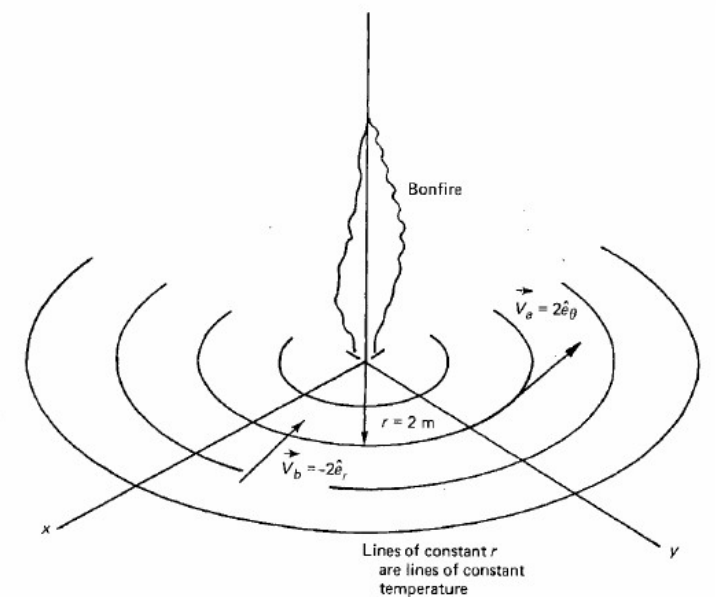
* Problems 1 and 2 are from Fundamentals of Engineering Exam, Fluids Section, 2004.

Plot and compare the results obtained in parts a) and b). Comment on the difference drag makes.

4. [5 points] You are attending the bonfire before the homecoming football game. The temperature of the air varies inversely with distance from the fire, so any circle centered at the fire is a constant temperature contour. However, the fire increases in intensity with time, so the temperature of the air at a given point increases with time. Assume that the temperature (K) of the air is given by T= 277 + 4t/r. Two students are following different paths as shown below. Path ***a*** moves tangentially to a circle whose radius is 2 m. Path ***b*** moves directly toward the fire.



What is the rate of change in temperature the two students are experiencing in degrees per sec at r=2m and t=10s ?

5.[5 points] For the velocity field:

$$u = x^2 + y^2 + z^2$$
$$v = xy + yz + z^2$$
$$w = -3xz - z^2/2 + 4$$

Write the strain rate tensor and the rotation rate tensor. Find the dilation rate (divergence of velocity) and vorticity. Is this flow rotational or irrotational?

Quote of the week:

"If I had eight hours to chop down a tree, I'd spend six hours sharpening my axe." - Abraham Lincoln, 1809 – 1865.