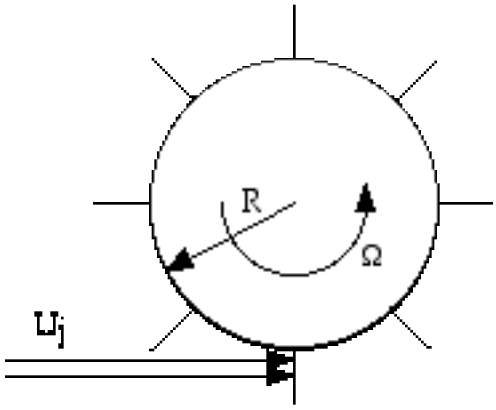
CHEG 355 TRANSPORT PHENOMENA I

First Hour Exam
10/5/04

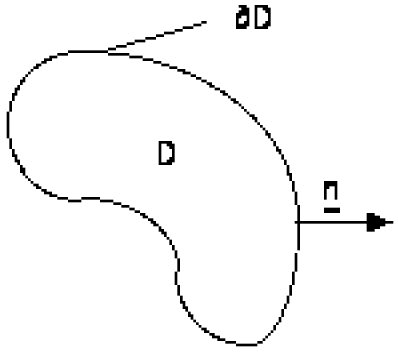
This test is closed books and closed notes

Problem 1. (20 pts) Consider the Pelton wheel, the simple turbine discussed in class, depicted below. A water jet moving with velocity U_j and volumetric flow rate Q impinges on the vanes of a wheel of radius R turning with angular velocity Ω. If the collision of the water with the vane is completely inelastic (e.g., it leaves with a velocity equal to the velocity of the vane, rather than bouncing off) determine the conditions under which the rate of work done on the wheel is a maximum. What is the efficiency of mechanical energy utilization under these conditions? What happens to the lost mechanical energy?

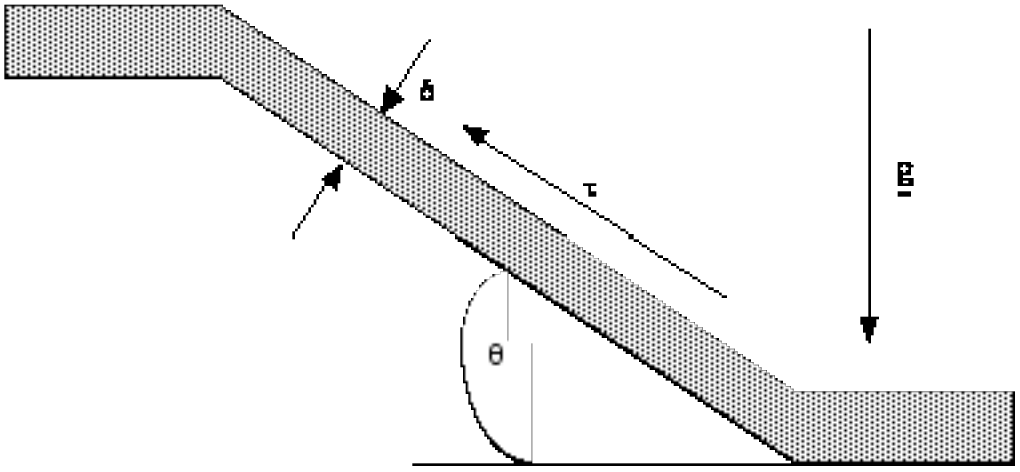


Hint: This problem is very easy if you draw a control volume surrounding the wheel, and properly account for convection of momentum in and out!

Problem 2. (20 pts) Starting from the arbitrary stationary control volume depicted below, derive the Cauchy stress equations (the momentum equations left in terms of the stress tensor $\underline{\underline{\sigma}}$). Hint: the momentum per unit volume of a fluid is given by $\rho\underline{u}$, the volumetric source of momentum (e.g., the body force) is $\rho\underline{g}$, and the surface stress is $\underline{\underline{\sigma}} \cdot \underline{n}$.



Problem 3. (20 pts) Consider the velocity distribution acquired by the slow flow of a very viscous fluid down an incline, as is depicted below. In contrast to the problem considered in class, here we have a breeze trying to blow the fluid back up the incline, in addition to the gravity trying to draw the fluid down. We model the effect of the breeze with a constant shear stress τ at the upper surface of the fluid (note: τ will be negative). For some film depth δ, angle θ, density ρ and viscosity μ, how large does this shear stress have to be for the surface velocity (e.g., the velocity at $y = \delta$) to be zero? Solve the problem assuming unidirectional flow.



Problem 4. (20 pts) Index notation / Additional Readings / Multimedia CD questions

1. Flow visualization using the time-lapsed photography of a tracer particle technique reveals which of the below for **steady** flows?
   A. Pathlines
   B. Streaklines
   C. Streamlines
   D. All of the above

2. Order according to their date of death (oldest -> most recent):
   A. James Clerk Maxwell
   B. Hero of Alexandria
   C. Osbourne Reynolds
   D. G. I. Taylor

3. Small variations in initial conditions sometimes result in huge, dynamic transformations in concluding events. This statement summarizes the idea behind:
   A. The Peanut Butter Effect
   B. The Butterfly Effect
   C. Poiseuille flow
   D. The Prandtl Number

4. Crooke's Radiometer works because of:
   A. The momentum of light
   B. Thermal transpiration
   C. Maxwell said it should
   D. Hot gas on the black face of the vane

5. The most deadly aspect of volcanism is:
   A. Sediment flows
   B. Lava flows
   C. Pyroclastic flows
   D. Mudslides

6. Write down the continuity equation for an incompressible fluid using index notation.

7. Write down the index notation representation of the rate of strain tensor for a velocity field u_i.

8. The symmetric part of the rate of strain tensor is usually given the symbol e_{ij}. What is its representation in terms of u_i? (Index notation, please!)

9. The vorticity is defined as the curl of the velocity. Write down this defining relation using index notation.

10. What is the most general isotropic second order tensor?