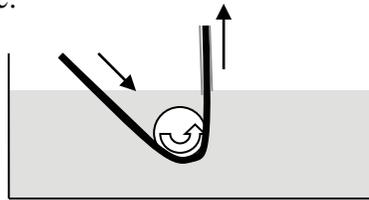


Department of Materials Science and Engineering
Massachusetts Institute of Technology
3.044 Materials Processing – Spring 2013
Problem Set #4

Problem 1

Hot-dip galvanizing is a process in which a continuous sheet of steel passes through a bath of molten zinc:



The zinc coating provides corrosion protection by corroding preferentially to steel, and thus avoiding rust. Consider the sheet to be moving at a velocity v_0 , and write down an equation for the flow of the molten zinc as a function of distance from the sheet.

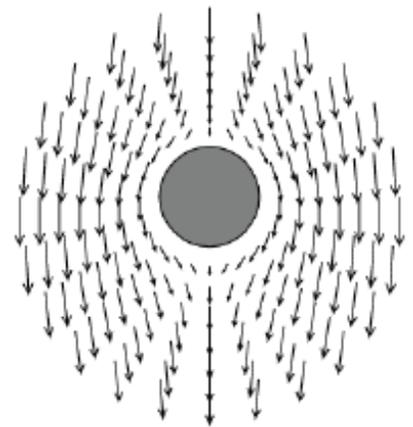
Problem 2

For the same process of hot-dip galvanizing, imagine that as the sheet leaves the bath, it is coated with 50 microns of molten zinc at the melting temperature of zinc. The sheet remains at room temperature, and is 2 mm thick. Derive an equation that would describe the solidification of the zinc coating, and determine the time required to do so. Look up any values you need, and provide a numerical answer.

Problem 3

In class we discussed the flow of a liquid past a solid spherical particle. For laminar flow, the flow field in this situation is shown at the right, straight from the class notes.

Explain briefly how the flow field in this picture can be determined mathematically. First, explain the coordinate system that would be most appropriate for this problem. Then, write down the equation to be solved, and the boundary conditions necessary. DO NOT try to solve the problem; just lay it out through the above series of steps.



Problem 4

Following on from Problem 3, what if we were dealing not with a solid sphere, but with a vapor bubble of the same size, fixed in the same location. Indicate what elements of the solution method would change as compared with Problem 3.

In a plane that cuts through the equator of the sphere, draw a schematic of what you think the flow field would look like around the bubble. As an example, this is done for you here for the solid sphere case. Complete the drawing for the case of the bubble at the right. Write one sentence of explanation for your drawing.



Problem 5

Shear mixers essentially work by having a long, thin, solid inner cylinder concentric with a larger outer shell cylinder, with a gap in between. The inner cylinder spins relative to the outer cylinder. Solve for the fluid flow profile inside the shear mixer by writing down the appropriate form of the Navier-Stokes equation and the appropriate boundary conditions.

Now find the analogous heat transfer problem solution and translate each variable into the language of fluid flow. Also write down the heat transfer problem boundary conditions and translate those to fluid flow.

Problem 6

(a) Find the terminal velocity of a settling spherical particle, including buoyancy. Assume that the fluid is stationary, and that flow will be laminar.

(b) Is it possible that the flow around the particle could become turbulent due to it sinking through otherwise stationary fluid? What properties of the particle promote turbulence?

Problem 7

Red blood cells (RBCs) are separated from blood plasma by centrifuging. The average human RBC is about 7 microns in diameter and has a density of 1125 kg/m^3 . Assuming that the RBC is a sphere and the individual RBCs do not interact, estimate how fast a centrifuge with radius 5cm must spin so that the RBCs can be separated in 1 minute. Assume that the test tubes are oriented at 45 degrees, and that they are 10 cm tall. Also, take the density of plasma to be 1025 kg/m^3 and the viscosity of blood plasma to be 0.004 Pa s . Is your answer reasonable? Hint: begin by drawing a force diagram.

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