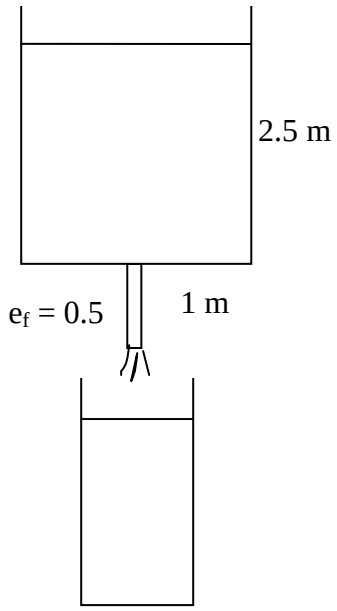
South Dakota School of Mines and Technology
Department of Materials and Metallurgical Engineering

MET 422 Final Exam - Open Book Dec 13, 2008

All needed physical constants are to be obtained from the text. Estimations are permissible if a needed constant is not available in the text.

1. A 2-cm diameter spherical pellet of NiO is being reduced to form Ni in a stream of hydrogen gas at 773 K. Its weight is being recorded over time to determine the reaction rate. Determine the magnitude of the drag force on the pellet if the gas is moving past the pellet at 20 cm/sec.

2. A ladle of liquid aluminum at 700 ^{o}C with 1-m radius is feeding a billet caster through a tube with a 1-cm radius as shown below. Calculate the mass flow rate of Al to the billet caster.



3. A 2-cm diameter by 1-meter long stainless steel rod is pulled from a furnace at 1020 ^{o}C into air at 20 ^{o}C continuously blown at 10 m/s over the cylinder transverse to its long axis. How long will it take for the center to cool to 320 ^{o}C?

   Use for stainless steel: $k = 28\ W*m^{-1}*K^{-1}$ $\rho = 7860\ kg/m^3$ $C_p = 1.16\ J/kg\text{-}K$

4. A 6-cm diameter thin-walled tungsten tube is to be used to heat samples in a vacuum furnace by passing 5,000 Watts through its 20 cm length. Heat shields of Ta will be placed around the outside of the tungsten element to reduce heat loss. How many heat shields will be needed to allow the furnace to operate at 1800 K inside the tungsten tube? Assume there is no heat loss at the ends and that the emissivity of all material is ⅓.

5. A 2-cm pellet of FeO is being reduced by the reaction $CO_{(g)} + FeO_{(s)} = CO_{2\,(g)} + Fe_{(s)}$.
   As the reduction proceeds a layer of porous Fe forms on the outside of the pellet leaving a core of yet-to-be-reduced FeO. Derive an equation showing the concentration profile of CO in the Fe layer as a function of radius under the following conditions:
   a) The CO and CO_2 are diluted with N_2 and combined consist of only 1% of the total gas surrounding the pellet.
   b) The CO and CO_2 are the only gases present.

   Note #1: You may assume that the radius of the Fe-FeO interface changes so slowly that the concentration profile at any time is essentially at steady state.

   Note #2: The diffusivity of CO through the porous layer of Fe is the diffusivity of CO through the gases present with some reduction made for i) the reduced area available for diffusion and ii) a further reduction for the less-than-straight-line diffusion from the outside surface to the Fe-FeO layer. This is called the *effective diffusivity* $\mathcal{D}_{\text{eff}}$, which you can use in your derivation without giving a value. (It is typically 40% of the unimpeded diffusivity.)

6. An open ladle has just been filled with 200 tons of molten steel. Show how to calculate the initial cooling rate of the steel. Provide a heat balance and show the terms needed to compute dT/dt. This problem concerns mechanisms and concepts ***NOT*** numbers (numerical values) or specific correlations.