SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLGY
DEPARTMENT OF METALLURGICAL ENGINEERING

MET 422	**HQ 1**	**Sept 21, 1987**
MI 223	(closed book)	Noon

1. Write Newton's Law of Viscosity and give the units of each quantity in the equation. Use the CGS system of units.

2. Derive the equation showing the velocity profile for flow in a vertical tube. Only gravity causes the fluid to flow.

3. Derive an equation showing the laminar velocity distribution between two vertical flat plates. One plate (the one at $x = 0$) is stationary while the second plate (the one at $x = \delta$) is moving upward at velocity U. Assume the z direction is down.

4. Fluid Velocity down a plane inclined angle β from the vertical
   where p = density
   g = gravitational constant
   d = layer thickness
   x = distance from the fluid surface towards the inclined plane
   n = viscosity

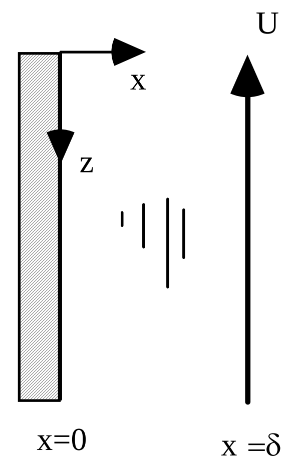
5. Derive an equation for the volume rate of flow along an plane inclined downward from the horizontal by angle β.

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
DEPARTMENT OF METALLURGICAL ENGINEERING

MET 422	HQ 1	October 10,1997
MI 220	(closed book)	2:00 PM

1. Write Newton's Law of Viscosity and give the units of each quantity in the equation. Use the CGS system of units.

2. Derive an equation showing the laminar velocity distribution between two vertical flat plates. One plate (the one at x=0) is stationary while the second plate (the one at x=∂) is moving upward at velocity U. Assume the z direction is down. Gravity acts on the fluid in the z direction. There is no pressure gradient.



3. The Hagen-Poiseuille Equation describes the laminar flow of water through a tube. Derive an equation showing the **volume** flow rate through a tube.
$$v_z = \left[\frac{P_o - P_L}{L} + \rho g\right]\left(\frac{R^2}{4\eta}\right)\left[1 - \frac{r^2}{R^2}\right]$$

4. Find the drag force in dynes for a tethered sphere pulled through water. The room-temperature water is flowing past the 1 cm. diameter sphere at 1000 cm/sec. The viscosity of water is 1 cP.

5. The time required to mix reagents in a reaction vessel is a function of

   L = length of the vessel
   D = diameter of the vessel
   η = viscosity
   ρ = fluid density
   V_o= mixer speed, cm/sec

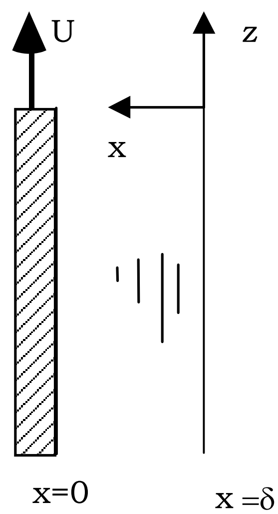
   Reduce the number of independent variables in the function by the use of dimensionless variables. Be sure to make time dimensionless.

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
DEPARTMENT OF MATERIALS & METALLURGICAL ENGINEERING

MET 422	HQ 1	October 3, 2000
MI 222	(closed book)	11:00 AM

1. Write Newton's Law of Viscosity and give the units of each quantity in the equation. Use the CGS system of units.

2. A vertical sheet is moving upward at velocity U with a fluid film as shown below. Derive an equation showing the laminar velocity distribution in the film. Assume the z direction is up. Gravity acts on the fluid in the -z direction. There is no pressure gradient.



3. The natural convection of fluids is caused by fluid density differences arising from temperature differences. For two horizontal plates a distance L apart and with a temperature difference of ΔT, the velocity depends on the following parameters:

$$V = f(L, \rho, \eta, k, C_p, g, \beta, \Delta T)$$

where:

L [=] cm
ρ [=] $g\text{-}cm^{-3}$
η [=] $g\text{-}sec^{-1}\text{-}cm^{-1}$
k [=] $g\text{–}K^{-1}\text{-}sec^{-3}$ (thermal conductivity)
C_p [=] $cm^2\text{-}sec^{-2}\text{-}K^{-1}$
g [=] $cm\text{-}sec^{-2}$
β [=] K^{-1} (thermal coefficient of expansion)
ΔT [=] K

By dimensional analysis, reduce the above parameters to dimensionless groups.
Note: Buoyant force considerations require that g, β, and ΔT all appear in one group. That, is

$$V = f(L, \rho, \eta, k, C_p, g\beta\,\Delta T)$$

4. Using the attached sheet giving the Equations of Change, reduce equations A, B, and C to a simple laminar flow in a cylinder with axial (z) flow direction only. (Cross out the zero terms on the sheet and submit the sheet for your answer.)

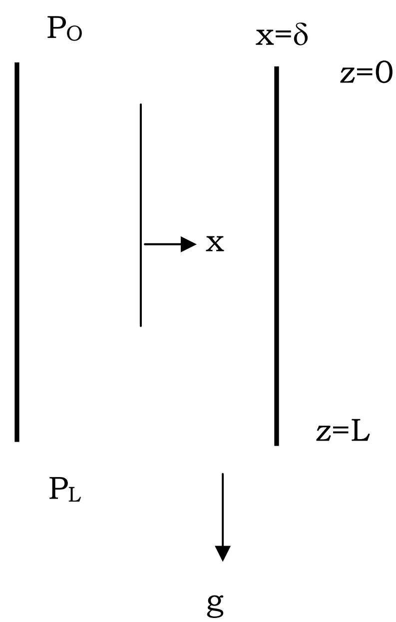
South Dakota School of Mines and Technology
Department of Materials Metallurgical Engineering

Met 422	HQ 1	October 5, 2002
MI 222	(closed book)	11:00 AM

1. Find the drag force on a sphere 1 m in diameter tethered in a 40 m/sec wind.

2. a) Derive an equation showing the laminar velocity distribution between two vertical flat plates both fixed. Assume the z direction is positive downward. Gravity acts on the fluid in the z direction. There is a pressure gradient.

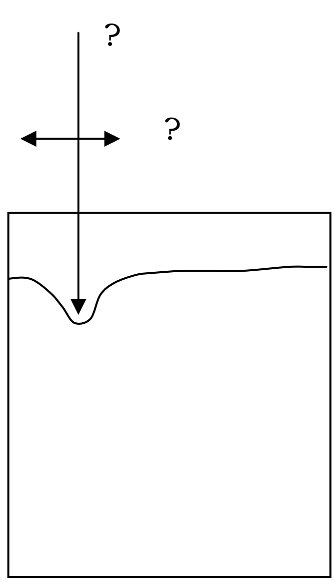
   b) Show how to find the pressure gradient required to keep the net cup mixing flow at zero. That is, there is a pressure up that should counteract the gravity down. Show how to find it.



3. A study is to be done to determine the mixing occurring as a stream of molten slag is poured from a distance into a ladle as shown. Discuss the pertinent factors needed to model the slag system with water. Address the relative sizes of the systems, the dimensionless variables Involved, the relationship between times in the two systems, etc. The goal is to find the optimal location of the stream relative to the centerline and the optimal height. Ask yourself, " How could I get meaningful results for the slag system using a water model"? What are the important variables?

   Use:
   D = diameter of the vessel
   η = viscosity
   ρ = fluid density
   h = Height of stream

   Add more, if needed
   Would you keep some dimensions in the same ratio?
   What is geometric similarity?
   Use the next page.



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

Met 422	HQ 1_Makeup	October 8, 2002
MI 222	(closed book)	3:00 PM

1. A smooth horizontal cylindrical tube 0.10 m in diameter and 12 meters long has water flowing through it of Re = 100,000?
   a) Find the drag force in N
   b) Average velocity in m/sec
   c) The pressure drop need to sustain the flow in N/m^2 (Pascals).

2. Derive an equation showing the laminar velocity distribution in a vertical cylinder with a rod of diameter kR moving upward with a velocity of Vo. Assume the z direction is positive downward. Gravity acts on the fluid in the z direction. There is a pressure gradient.

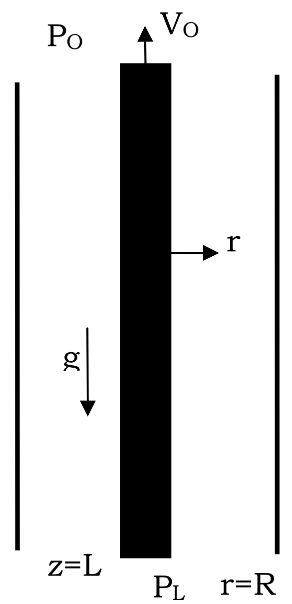


Figure for Problem #2

3. A study is to be done to determine the mixing occurring as a stream of molten slag is poured from a distance into a ladle as shown. Discuss the pertinent factors needed to model the slag system with water. Address the relative sizes of the systems, the dimensionless variables Involved, the relationship between times in the two systems, etc. The goal is to find the optimal location of the stream relative to the centerline and the optimal height. Ask yourself, “ How could I get meaningful results for the slag system using a water model”? What are the important variables?

   Use:
   D = diameter of the vessel
   η = viscosity
   ρ = fluid density
   h = Height of stream

   Add more, if needed
   Would you keep some dimensions in the same ratio?

   What is geometric similarity?
   Use the next page.

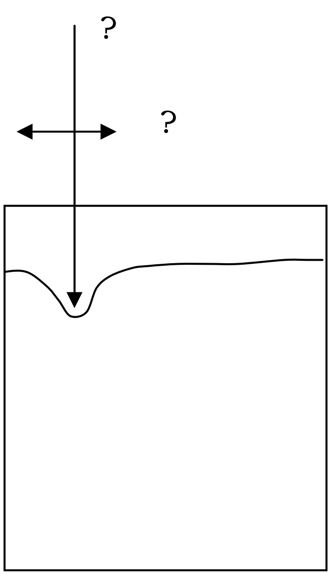


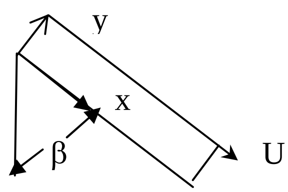
Figure for Problem #3

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
DEPARTMENT OF MATERIALS & METALLURGICAL ENGINEERING

OPEN BOOK

MET 422 HQ 1 Oct 1, 2004

1. Derive an equation for fully developed laminar and Newtonian fluid flow between two parallel plates on an incline having an angle β from the vertical as shown below. Assume the bottom plate is stationary and the top plate has a velocity U down the plate. The plates are separated by a distance of δ.



2 Start with the General Momentum Equation in Cylindrical Coordinates and reduce the equation to the differential equation for flow in a cylindrical tube. Assume there is no flow in the radial or angular directions. Use velocity rather than momentum terms and assume the fluid is incompressible (i.e. – constant density).

3. Consider the SDSM&T flagpole. To find the load at the base of the pole on a windy day, one must know the force exerted on it by the wind. Compute the force for each meter-long segment, assuming there are no end effects, that it is 10 cm in diameter, and that the wind is blowing at 44 m/s. Assume the atmospheric pressure is 0.95 atm and the temperature is 280 K. R=0.08205 L*atm/(gmole*K) and the molecular weight of air is 28.8. The Pr# for air is 0.7.

4 One of your classmates suggested that it would be fun to model a hurricane hitting palm trees. The idea was that the class could set up a variable speed fan and make 1/20th of actual size scale models of palm trees and then film their gyrations. Once filmed, the real event could be mimicked by playing back the video providing, of course, it was slowed down or up just right.

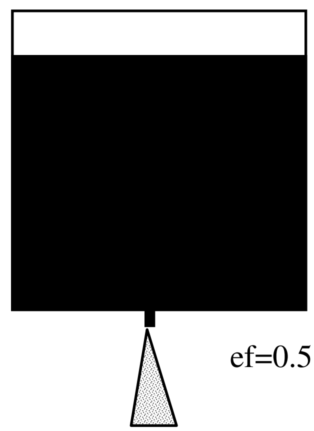
Flexure of the palms depends on Young's Modulus ([=]Newtons/m^2 [=] Kg/(m*s)) and the forces exerted by the wind, which depend on the air's ρ, η, V_∞ , and some characteristic dimension, say D. For the time being, it is decided to skip the effect of gravity on the swaying motion of the palms, because it is likely to be a secondary effect compared to the effect of the gale force winds. Assume that the above five independent variables determine everything about the movement of the palms.

a) How many independent, dimensionless groups would be needed to model this situation?
b) If air is also used for the small model, what might you change, to make the models behave in a similar fashion?
c) Do you think you are able to predetermine that the model is 1/20th scale or must that remain something computed so as to make the model work and why?
d) Suggest how would one compute just how much to speed up (or slow down) the video to make everything look realistic?

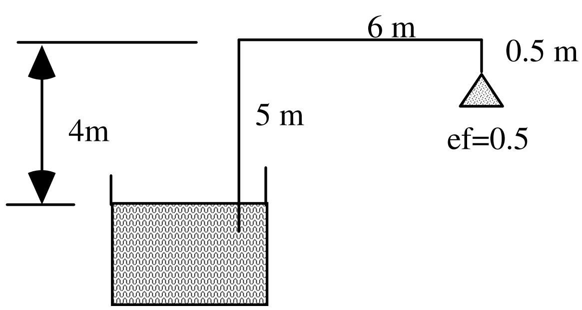
SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
DEPARTMENT OF METALLURGICAL ENGINEERING

MET 422	HQ 2	November 10,1994
MI 220	(closed book)	2:00 PM

1. How long would it take to empty a molten steel-filled ladle 3 meters in diameter and 2 meters deep if the tap hole is 5 cm in diameter?



2. How many watts of power would be required to pump 100 tons/hr of liquid Pb through the following network? The pipe diameter is 2 cm and is smooth.



DATA:

$\eta_{Pb}=2x10^{-3}$ Nsm-2 ρ_{Pb}= 11,400Kg/m^3

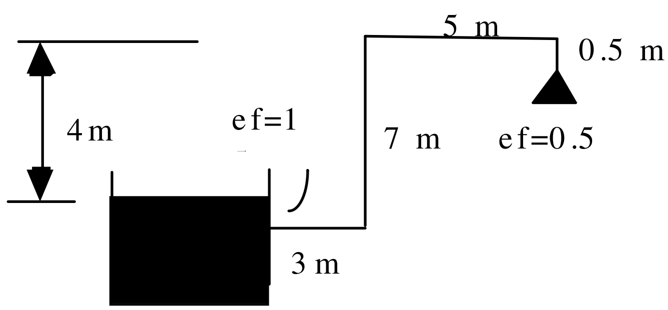
η_{Fe}= 5x10^{-3} Nsm-2 ρ_{Fe}= 7,530Kg/m^3

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
DEPARTMENT OF METALLURGICAL ENGINEERING

Met 422	HQ 2	Nov 19, 1997
MI 222	(open book)	2:00 PM

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. How many watts of power would be required to pump 100 tons/hr of liquid Pb through the following network? The pipe diameter is 1 inch and a surface roughness of $\varepsilon/D=0.01$. **Assume f=0.095 but describe how to check this assumption**.



DATA: $\eta_{Pb}=2x10^{-2}\ gs^{-1}cm^{-1}$ $\rho_{Pb}= 11.4 g/cm^3$

2. Calculate the pressure drop required to move 30 liters of room-temperature water per minute through an ion resin bed with a cross sectional area of 100 cm^2. The resin beads are 0.2 cm diameter. The bed has a void fraction of 0.4 and is 100 cm deep. The resin density is 1.1 g/cm^3.

3. If the bed in Problem #2 were fluidized to a 0.6 void fraction, find the
   a) superficial velocity
   b) pressure drop across the bed

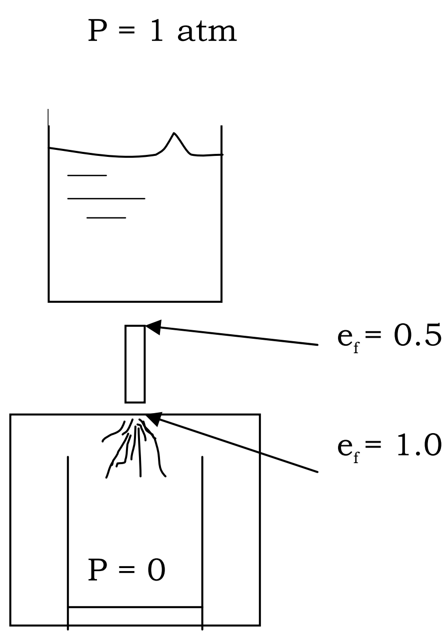
SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY
DEPARTMENT OF MATERIALS & METALLURGICAL ENGINEERING

MET 422	HQ 2	Nov 7, 2000
MI 222	(open book)	11:00 AM

1. A packed bed of ion exchange resin beads 0.1 mm in diameter are in a column 4 cm in diameter and 100 cm long. What pressure would be needed to drive 3 liters of water per minute through the bed? The void fraction is 0.3.

2. What void fraction would be achieved in a bed of Al_2O_3 spheres 0.8 cm in diameter in water flowing upward at a rate of 30 cm per second through a column? The density of Al_2O_3 is 2.7 g per cm^3.

3. A ladle of molten steel at 1900 K is to be vacuum degassed as shown below. Note that the pressure above the steel in the ladle is 1 atmosphere while the pressure in the vacuum degasser is essentially 0 atmosphere. If the depth of the steel in the ladle is 3 meters and the length off the 10-cm inside diameter pipe from the ladle to the degasser is 1 meter in length, what is the exit velocity of the steel in the pipe? You may use the friction loss coefficients shown below for the flows into and out of the pipe. (Note: 1 atm = 1.013×10^6 dynes.)



SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY
DEPARTMENT OF MATERIALS & METALLURGICAL ENGINEERING

MET 422	HQ 2	Nov 30, 2002
MI 222	(open book)	11:00 AM

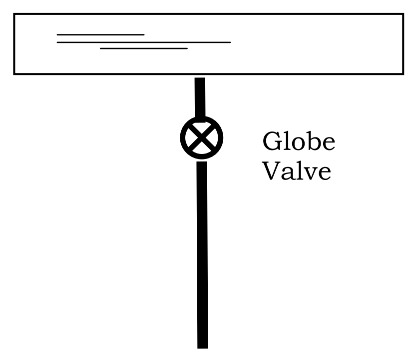
1. Two hundred pounds of Ni shot is to be fluidized in the (for Mond Process) in a 6-inch diameter cylindrical reactor. What pressure drop must there be across the bed in psi?

2. A packed bed of ion exchange resin beads 0.1 mm in diameter are in a column 4 cm in diameter and 100 cm long. Assuming that the water flowing through the column is well within the laminar flow regime, what flow rate through the bed would be expected from a pressure drop of 5 psi? The void fraction is 0.3. (1 atm = 1.013×10^6 dynes.)

3. A tank of water shown below is to be drained as rapidly as possible. Develop an equation that shows the time to drain the tank as a function of the following factors:

   L = length of straight from the tank pipe
   D = Diameter of pipe
   f = friction factor of the pipe (assumed constant at 0.008)
   D_t = Diameter of the tank
   H = Initial height of water in the tank

   Note: H<<L and the entrance and expansion frictional losses are very small compared to the losses in the pipe and valve.

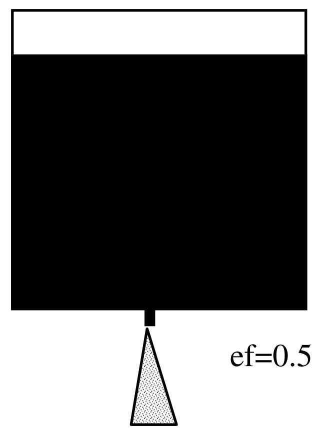


4. What superficial velocity would be required to fluidized the bed in Problem #2 to a void fraction of 0.4?

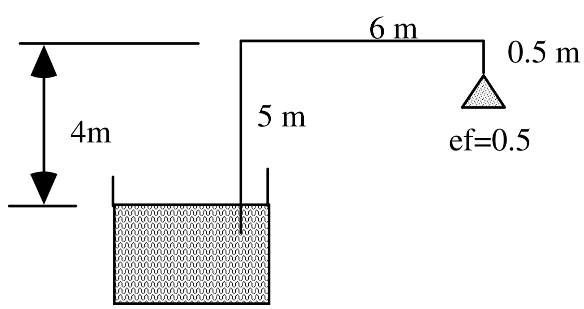
SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
DEPARTMENT OF METALLURGICAL ENGINEERING

MET 422	HQ 2	November 10,1994
MI 220	(closed book)	2:00 PM

1. How long would it take to empty a molten steel-filled ladle 3 meters in diameter and 2 meters deep if the tap hole is 5 cm in diameter?



2. How many watts of power would be required to pump 100 tons/hr of liquid Pb through the following network? The pipe diameter is 2 cm and is smooth.



DATA:

$\eta_{Pb}=2x10^{-3}\ Nsm^{-2}$ $\rho_{Pb}= 11{,}400Kg/m^3$

$\eta_{Fe}= 5x10^{-3}\ Nsm^{-2}$ $\rho_{Fe}= 7{,}530Kg/m^3$