Homework 1
CM3110 Morrison

Numbered problems are from the Morrison text (Understanding Fluid Mechanics, 2013, Cambridge University Press); Lettered problems are on the pages that follow.

Module	Number	Topics	Assigned Problems in **Morrison**	Stretch Problems
1	1	simple mass balances	J	
1	2	fluid statics/manometer	4.13	
1	3	fluid statics	C	
1	4	flow rate <v>=Q/A irregular container	1.10	
1	5	flow rate; Moody 2100 for laminar		1.19
1	6	flow rate <v>=Q/A	A	
1	7	sensible heat to calculate Q	K	
1	8	fluid statics	1.26	
1	9	math - curvilinear coords	1.41	
1	10	math - matrix multiply	1.44	
1	11	math - curvilinear coords	1.45	
1	12	math matrices dot product, mag vec, compon	B	
1	13	math - cyl coords		1.48
1	14	math - plot profile		1.58
1	15	math-integration to Q	D	
1	16	Identify the boundary lami/turbulent, calc <v>	2.21	
1	17	2 fluid manometer	F	
1	18	MEB discharge closed tank	1.36	
1	19	data fitting		3.11
1	20	define limits double integral	H	
1	21	closed-end manometer	4.14	
1	22	fluid statics tilted vessel		4.20
1	23	friction in straight pipes; Moody chart		1.8
1	24	latent heat of vaporization	E1	
1	25	latent heat of vap; state function		E2

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Problem A:

Water (25^oC) flows steadily in a horizontal smooth pipe (inner pipe diameter is $1.22\ inches$; pipe length is $38 feet$). If the average fluid velocity is $2.9 \times 10^{-1}\ ft/s$, what is the volumetric flow rate (in gallons per minute, gpm) for the flow? The water's density and viscosity are given on the formula sheet.

Problem B:

Evaluate the following four quantities for the vectors and matrix given below. Show supporting work.

$$\underline{\underline{A}} = \begin{pmatrix} 1 & 1 & 2 \\ 1 & 0 & 0 \\ 2 & -1 & 3 \end{pmatrix}_{xyz}$$

$$\underline{w} = \begin{pmatrix} 1 \\ 0 \\ 2 \end{pmatrix}_{xyz}$$

$$\underline{u} = \begin{pmatrix} 1 \\ 2 \\ 2 \end{pmatrix}_{xyz}$$

a. $\underline{u} \cdot \underline{w} = ?$
b. $\underline{\underline{A}} \cdot \underline{w}$=?
c. What is $|\underline{u}|$? (the magnitude of $\underline{u}$)
d. What is the component of $\underline{w}$ in the direction of $\underline{u}$?

Problem C:

What is the fluid pressure (in units of $Pascals$) a distance 3.2 $meters$ below the surface of Lake Superior? Indicate your assumptions.

Problem D:

For the steady, downward, laminar flow of water in a pipe, the fluid velocity varies with radial distance from the centerline, r. With the methods of this course, we calculate the velocity as a function of position in cylindrical coordinates to be:

$$\underline{v} = \begin{pmatrix} v_r \\ v_\theta \\ v_z \end{pmatrix}_{r\theta z} = \begin{pmatrix} 0 \\ 0 \\ v_z(r) \end{pmatrix}_{r\theta z} = v_z \hat{e}_z = v_z \hat{k}$$

$$v_z(r) = \frac{\Delta p R^2}{4\mu L}\left(1 - \frac{r^2}{R^2}\right)$$

All symbols are defined below. The following quantities are constants:

$\Delta p =$ fluid pressure drop across pipe length
$L =$ pipe length
$\mu =$ fluid viscosity
$R =$ pipe inner radius

Calculate the flow rate Q from the velocity profile $v_z(r)$ above, using the integral given below:

$$Q = \int_0^{2\pi} \int_0^R (v_z) \quad r dr d\theta$$

where r, θ, z are cylindrical coordinate variables (see formula sheet for the geometry of cylindrical coordinates. Please show your work and box your answer.

Problem E1:

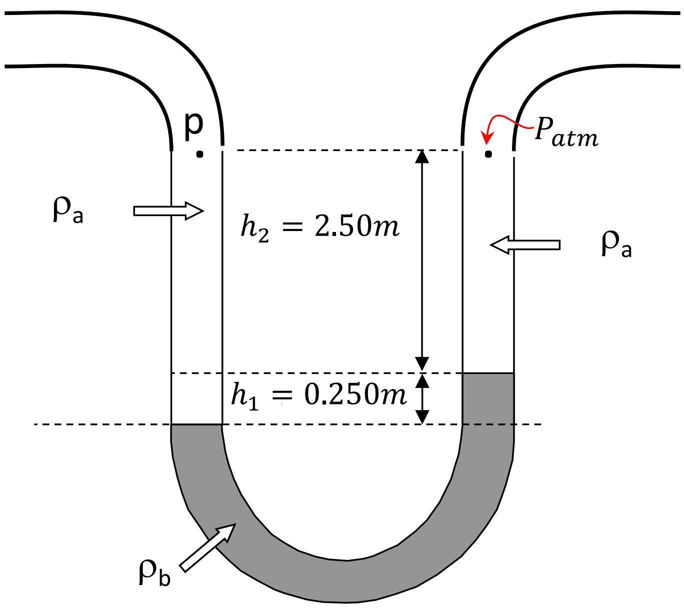
How much heat do we need to add (kW) to a liquid stream of methanol at its normal boiling point to generate 1500 g/min of saturated methanol vapor? Answer: 28kW. Note that Felder and Rousseau have a table of boiling points in the back. Based on FR Example 8.4-1

Problem E2:

One hundred moles per hour of liquid n-hexane at 25^oC and $7.0\ bar$ is vaporized and heated to 300^oC at constant pressure. How much heat $\dot{Q}$ must be supplied? You may neglect the effect of pressure on enthalpy in your calculations. Based on FR Example 8.4-2

Problem F:

Fluid (a) and fluid (b) are used in a manometer as shown below; the pressure on the top of the right side is $p_{atm} = 1.00atm$. The density of fluid (a) is 1.000 g/cm^3 and the density of fluid b is 13.60 g/cm^3. What is the pressure p? Please give your answer in *atm*.

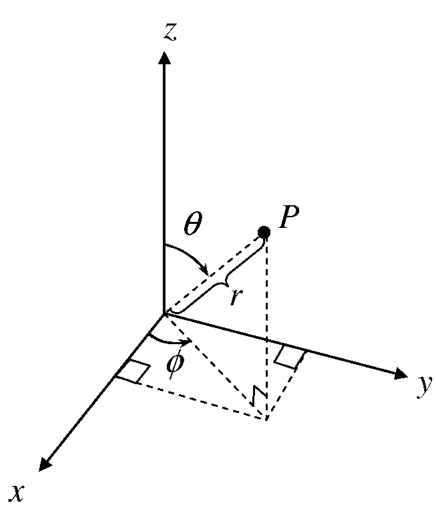


Note: the inner diameter of the manometer tube is $11.2\ mm$.

Problem H

The surface area of a sphere (sphere radius = R) may be calculated from the integral below, carried out in spherical coordinates. What are the correct limits to use in the integrals? Carry out the integration and obtain the surface area of a sphere. The spherical coordinate system is shown below and is also discussed in the formula sheets provided.

$$\text{surface area} = \int_?^? \int_?^? R^2 \sin\theta d\theta d\phi$$



Problem J

One hundred kmoles/hr of a mixture of A and B is divided into two streams by a separator. The feed is $60\ mole\%\ A$ and the balance is B. Half of the flow exits in the top stream, which is $95\ mole\%\ A$. What is the composition of the bottom stream?

Problem K

Fifteen kmol/minute of air is cooled from 260^oC to 0^oC. Calculate the amount of heat that must be removed from the stream to affect this temperature change. You may use approximate physical properties from the Exam 1 handout. Answer: $1900\ kW$.