

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF CHEMICAL ENGINEERING
CHEG 3013 HEAT, MASS AND MOMENTUM TRANSPORT, FALL 2021**

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Above Average (Graded original work)

Average (Graded original work)

Below Average (Graded original work)

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Above Average (Graded original work)

Average (Graded original work)

Below Average (Graded original work)

Course Description in ABET Format

CHEMICAL ENGINEERING DEPARTMENT CHEG 3301 HEAT, MASS AND MOMENTUM TRANSPORT

1. Course number and name: CHEG 3301: Heat, Mass and Momentum Transport
2. Credits and contact hours: 3 credit hours; 3 contact hours
3. Instructor's or course coordinator's name: Dr. Michael Gyamerah
4. Text book: Title: "Transport Processes and Separation Process Principles"
Author: Christie J. Geankoplis, Allen A. Hersel and Daniel H. Lepek
Publisher, Year & Edition: Prentice Hall-Pearson Education Inc., Boston, 2018, 5th Edition
a. Other Supplemental material
 1. "Transport Phenomena" by Byron R. Bird, Warren E. Stewart and Edwin N. Lightfoot, Revised 2nd Edition (2007), John Wiley & Sons, Inc.
 2. "Fundamentals of Momentum, Heat and Mass Transfer" by James R. Welty, Charles E. Wicks, Robert E. Wilson, and Gregory L. Rorrer, 5th Edition (2008), John Wiley & Sons, Inc.
5. Specific course information
 - a. Brief description of the content of the course (catalog description) CHEG 3301 (3:0) Credit 3 semester hours. Macroscopic and differential balances for heat, mass, and momentum. Energy balances and mechanical energy balances. Ideal and Newtonian and non-Newtonian fluid behavior. Comparison of the transport processes in laminar and turbulent flow. Dimensional analysis.
 - b. Prerequisites CHEG 2333 Material and Energy Balances
MATH 2320 Differential Equations
Required
 - c. *Indicate whether a required, elective, or selected elective (as per definition provided) course in the program
6. Specific goals for the course
 - a. specific outcomes of instruction Students will be able to :
 1. Apply differential and integral calculus and the basic laws of mass and energy to model or quantitatively describe heat, mass and momentum transfer processes.
 2. Identify fundamental engineering problems through ability to sketch the physical situation, identify the subject area and concepts(s) involved, and identify applicable system of units.
 3. Formulate fundamental engineering problems by demonstrating the ability to define known and unknown variables, state relevant laws and applicable equations, and list and apply relevant assumptions to the applicable equations to obtain equations specific to the problem.
 4. Solve fundamental engineering problems by implementing a strategy to solve the problem, show the use of consistent units throughout, and evaluate and interpret the result.

- b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.

This course addresses the following student learning outcome determined by the department:

Outcome D1

Ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics.

7 Brief list of topics to be covered

1. Fluid statics, fluid flow, Newtonian and non-newtonian fluids (3 hours)
2. Control volume, integral approach to fluid flow analysis, continuity equation, equations of motion (6 hours)
3. Equation of mechanical energy, the Bernoulli equation, flow through circular tubes, terminal velocity of a falling sphere, flow of a falling film, friction factors for flow in tubes and applications (9 hours)
4. Differential equations of fluid flow and the differential element (the special type of control volume) and applications (3 hours)
5. Dimensional analysis and similarity (3 hours)
6. Fourier's law of heat conduction, control volume energy balance (3 hours)
7. Conduction through composite walls and cylindrical tubes, and heat transfer coefficients (6 hours)
8. Fick's Law of Diffusion, control volume (shell) mass balance, concentration, mass diffusion through a stagnant film, diffusion with chemical reaction and diffusion into a falling liquid film (6 hours)
9. Inter-phase mass transport in multi-component systems (3 hours)

II ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS

Program Outcomes Assessed in this course

CHEG Department Outcome D1:

An ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics. It involved application of basic knowledge and fundamental concepts of cell and molecular biology to the practical application in engineering processes.

Assessment Summary of Class Semester Averages for Outcomes

CHEG Department Student Outcomes	D1
Semester	Semester Class Average (%)
Fall 2021	71
Fall 2020	67
Fall 2019	72
Comments on Trend of Data (Improving or deteriorating)	The average for the student learning outcome has been around 70 % over the last three assessment periods nearly 5 % points below the expected ideal class average. The fall 2019 class average of 72 % fell to 67 % and a subsequent improvement the following semester back to almost the same level of performance.

*Expected Semester Class Average = 70% (or as defined by the program)
Ideal Semester Class Average = 75% (or as defined by the program)

End of Semester Course Assessment Reports Fall 2021 and Last Two Assessment Periods.

Each summary contains the following Information

1. Performance Statistics

- Total number of students in class
- The class average performance (**stated as %**) in each course outcome assessed in this class and the **two previous times course was assessed**.
- The acceptable class average for the class in each outcome area as set by your Department.
- Percentage of students who scored below the expected average in each outcome.

2. Implementation Summary

- Brief summary of plans implemented during the semester based on last assessment report

3. Perceived Problems

- Instructor's **critical evaluation** of perceived problems that affected students' performance. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

5. Overall Trend over last three assessment periods

- Instructors summary of overall performance trend for each outcome measured over the last three periods.

5. Were Expectations Met?

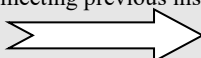
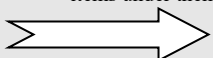
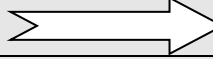
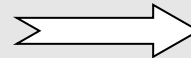
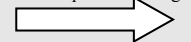
- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer **NO**.

END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT

CHEG 3301-P02 HEAT, MASS AND MOMENTUM TRANSPORT, FALL 2021 SEMESTER

OUTCOME: CHEG Student Learning Outcome D1: Ability to identify, formulate and solve fundamental engineering problems

Report Prepared by: Dr. Michael Gyamerah Report Date: December 17, 2021

Semester	Analysis Type	Number of Students	CHEG Student Learning Outcome D1: Ability to identify, formulate and solve fundamental engineering problems			
			Expected Class Average	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average
Fall 2021	Direct	9	75	70	71	44
Fall 2020	Direct	16	75	70	67	19
Fall 2019	Direct	24	75	70	72	38
Implementation Summary	Items implemented from previous report or after meeting previous instructor 		A diagnostic homework assignment covering DE and MEB (the pre-requisites) was given. Students were provided with handouts detailing an effective approach to problem solving.			
Perceived Problems	Perceived problems are directly related to the PC and the sub items under them 		Students showed difficulty in conceptualizing problems in transport phenomena, identify physical laws, and implement effective problem solving strategies. Students found questions from the AIChE concept inventory very challenging.			
Plans for Addressing Problems	Plans for address specific measures to address PC and their sub areas 		The instructor should: 1. Ascertain the remedies required during the teaching of the course with a diagnostic test 2. Provide tutoring assistance to students 3. Continue with the use of concept tests from the AIChE concept inventory.			
Overall Trend over Periods	Ascertain if there were improvements over previous semesters 		The overall average students' performance in the outcome was 4 % points below the expected class average and only 44 % of the students met the expected class average. The performance was also 4 % points better than the performance of the students during the fall 2020 semester. Although the performance of the students was 1 % point below that of the fall 2019 semester 6 % percentage points more students met the expected average (44 %) compared to 38 % for the fall 2019 semester.			
Were Expectations Met?	Class Average $\geq 75\%$ and $\geq 70\%$ of Students Performed at or Above Expected Average. 		NO			

HEAT, MASS AND MOMENTUM TRANSPORT FALL 2021

Title of Assignment: EXAM 1

TOPICS COVERED IN EXAM 1

EXAM 1 covered the following topics:

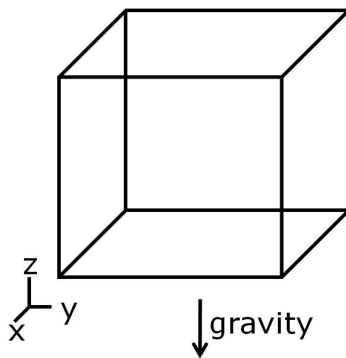
1. Body forces and pressure in a fluid
2. Inviscid, Newtonian and non-Newtonian fluids
3. Flow diagrams or rheograms for Newtonian and non-Newtonian fluids and their differences
4. Application of Newton's law of viscosity

CHEG 3013 P02 HEAT, MASS AND MOMENTUM TRANSPORT FALL 2021

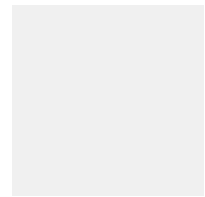
Exam 1: October 11, 2021.

Answer All Questions

1) (10 points)

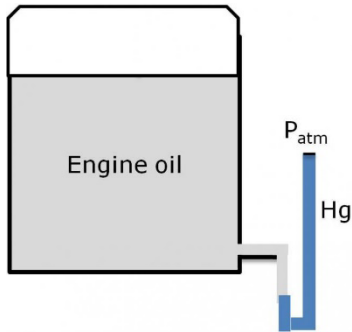


For a fluid volume element, where gravity is acting in the $-z$ direction, the body force is acting in the _____ direction.



Choice	
X	A
-X	B
Z	C
-Z	D

2) (20 points)



A closed tank contains compressed air and engine oil. A U-tube manometer using mercury is attached to the tank. The pressure at the top of the oil is _____ the pressure at the top of the mercury.

Choice	
greater than	A
less than	B
equal to	C
not enough information	D

3) (20 points)

Inviscid flow implies:

Choice	
Bernoulli's equation cannot be used.	A
Shear stresses are negligible.	B
The flow can be thought of as frictionless.	C
A & B	D
B & C	E

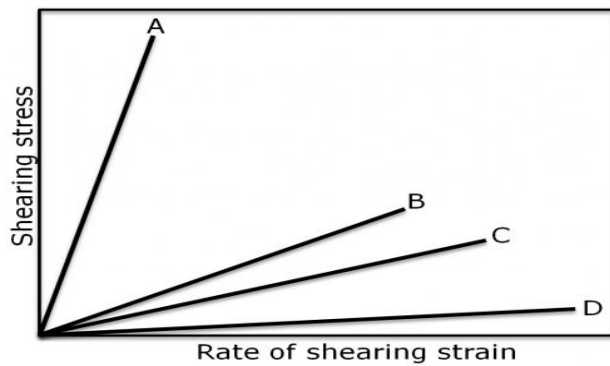
4) (10 points)



Which of the following statements is true of viscosity?

- (A) It is the ratio of inertial to viscous force.
- (B) It always has a large effect on the value of the friction factor.
- (C) It is the ratio of the shear stress to the rate of shear deformation.
- (D) It is usually low when turbulent forces predominate.

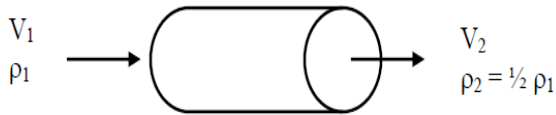
5) (20 points)



Which fluid is most viscous?

Choice	
1	A
2	B
3	C
4	D

6) (20 points)



A fluid flows steadily through a circular pipe of uniform cross-sectional area as shown.

If the outlet density of the fluid decreases to $1/2$ of its inlet value, what happens to the average fluid velocity?

Choice	
The velocity will not change since mass must be conserved and the flow is steady-state.	A
The outlet velocity will be twice the inlet velocity since mass must be conserved in the system.	B
The velocity will increase somewhat but we can't tell how much with the information given.	C
The velocity will decrease somewhat because of friction between fluid and the pipe wall.	D

**CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT
SHEET FOR FALL 2021 SEMESTER**

STUDENT LEARNING OUTCOME D1: Ability to demonstrate mastery of concepts in heat, mass and momentum transport.

Assignments that test mastery of concepts by students and identify misconceptions associated with the course material in heat, mass and momentum transport.

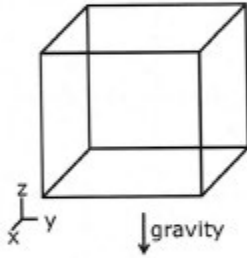
Name: KEY

Title of Assignment: Exam 1 Date: OCT. 11, 2021

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
D1) Ability to demonstrate mastery of concepts in momentum transport. <i>The problem tests the students' mastery of concepts and identify misconceptions associated with course material in momentum transport.</i>		
TOTAL	100	

Answer All Questions

1. (10 points)

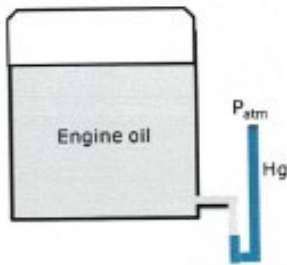


For a fluid volume element, where gravity is acting in the $-z$ direction, the body force is acting in the _____ direction.



Choice	
X	A
-X	B
Z	C
-Z	D

2. (20 points)



A closed tank contains compressed air and engine oil. A U-tube manometer using mercury is attached to the tank. The pressure at the top of the oil is _____ the pressure at the top of the mercury.

Choice	
greater than	☒ A
less than	☐ B
equal to	☐ C
not enough information	☐ D

3. (20 points).

Inviscid flow implies:

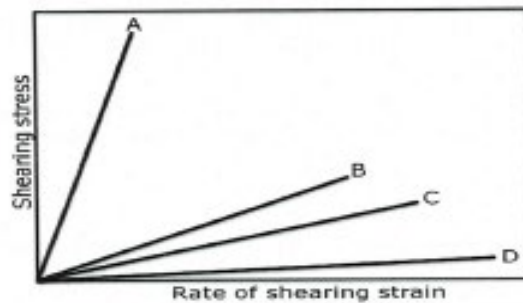
Choice	
Bernoulli's equation cannot be used.	☐ A
Shear stresses are negligible.	☐ B
The flow can be thought of as frictionless.	☐ C
A & B	☐ D
B & C	☒ E

4. (10 points)

Which of the following statements is true of viscosity?

- (A) It is the ratio of inertial to viscous force.
- (B) It always has a large effect on the value of the friction factor.
- (C) It is the ratio of the shear stress to the rate of shear deformation.
- (D) It is usually low when turbulent forces predominate.

5. (20 points)



Which fluid is most viscous?

Choice	
1	A
2	B
3	C
4	D

6. (20 points)



A fluid flows steadily through a circular pipe of uniform cross-sectional area as shown.

If the outlet density of the fluid decreases to $1/2$ of its inlet value, what happens to the average fluid velocity?

Choice	
The velocity will not change since mass must be conserved and the flow is steady-state.	A
The outlet velocity will be twice the inlet velocity since mass must be conserved in the system.	B
The velocity will increase somewhat but we can't tell how much with the information given.	C
The velocity will decrease somewhat because of friction between fluid and the pipe wall.	D

ABOVE AVERAGE

Above Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT
SHEET FOR FALL 2021 SEMESTER**

STUDENT LEARNING OUTCOME D1: Ability to demonstrate mastery of concepts in heat, mass and momentum transport.

Assignments that test mastery of concepts by students and identify misconceptions associated with the course material in heat, mass and momentum transport.

Name: Isis Solomon

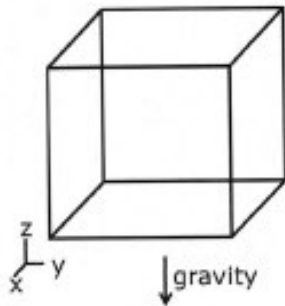
Title of Assignment: Exam 1

Date: 10/11/21

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
D1) Ability to demonstrate mastery of concepts in momentum transport. <i>The problem tests the students' mastery of concepts and identify misconceptions associated with course material in momentum transport.</i>	100	95
TOTAL	100	95

Answer All Questions

1. (10 points)



For a fluid volume element, where gravity is acting in the $-z$ direction, the body force is acting in the _____ direction.

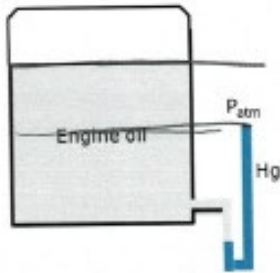
body force
is sum of all
forces

Choice	
X	A
-X	B
Z	C
-Z	☒ D

10

90

2. (20 points)



A closed tank contains compressed air and engine oil. A U-tube manometer using mercury is attached to the tank. The pressure at the top of the oil is _____ the pressure at the top of the mercury.

pressure @ same level is equal

Choice	
greater than	☒ A
less than	☐ B
equal to	☐ C
not enough information	☐ D

20

3. (20 points).

Inviscid flow implies:

Choice	
Bernoulli's equation cannot be used.	☐ A
Shear stresses are negligible.	☐ B
The flow can be thought of as frictionless.	☐ C
A & B	☐ D
B & C	☒ E

20

Q3) INVISCID FLOW - FLUID HAS ZERO VISCOSITY, $\mu = 0$ THEREFORE
NO FRICTION OCCURS

$$\tau = \frac{F}{A}$$

NEWTON'S LAW OF VISCOSITY = $\tau = \mu \frac{dv}{dy}$

μ = CONSTANT, SLOPE
DYNAMIC VISCOSITY

$$\tau = 0 \cdot \frac{dv}{dy}$$

$$\therefore \tau = 0$$

THEREFORE SHEAR STRESS IS NEGLIGIBLE

20

Q4) $\tau = \mu \frac{dv}{dy}$

$$\mu = \frac{\tau}{\frac{dv}{dy}}$$

RATIO OF SHEAR STRESS
TO RATE OF DEFORMATION

μ = VISCOSITY

τ = SHEAR STRESS

$\frac{dv}{dy}$ = RATE OF DEFORMATION,
RATE OF SHEAR
VELOCITY GRADIENT

$$\mu = \frac{\tau}{\frac{dv}{dy}}$$

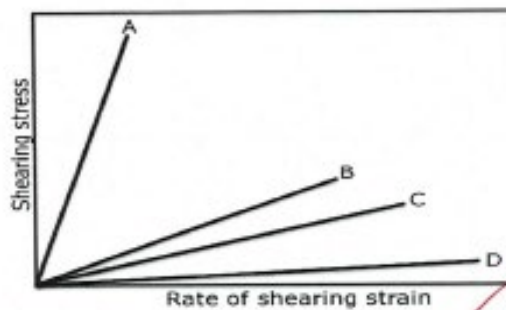
20

4. (10 points)

Which of the following statements is true of viscosity?

- (A) It is the ratio of inertial to viscous force.
- (B) It always has a large effect on the value of the friction factor.
- (C) It is the ratio of the shear stress to the rate of shear deformation.
- (D) It is usually low when turbulent forces predominate.

5. (20 points)



Which fluid is most viscous?

more viscous
if has a
greater slope

Choice	
1	☒ A
2	☐ B
3	☐ C
4	☐ D

20

6. (20 points)



$$A_1 V_1 \rho_1 = A_2 V_2 \rho_2$$

A fluid flows steadily through a circular pipe of uniform cross-sectional area as shown.

If the outlet density of the fluid decreases to 1/2 of its inlet value, what happens to the average fluid velocity?

$$\frac{V_1 + V_2}{2}$$

Choice	
The velocity will not change since mass must be conserved and the flow is steady-state.	A
The outlet velocity will be twice the inlet velocity since mass must be conserved in the system.	B
The velocity will increase somewhat but we can't tell how much with the information given.	C
The velocity will decrease somewhat because of friction between fluid and the pipe wall.	D

20

AVERAGE

Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT
SHEET FOR FALL 2021 SEMESTER

STUDENT LEARNING OUTCOME D1: Ability to demonstrate mastery of concepts in heat, mass and momentum transport.

Assignments that test mastery of concepts by students and identify misconceptions associated with the course material in heat, mass and momentum transport.

Name: CEDRIC SANHOUIN

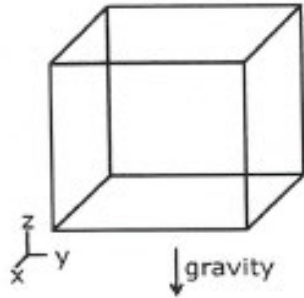
Title of Assignment: Exam 1

Date: _____

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
D1) Ability to demonstrate mastery of concepts in momentum transport. <i>The problem tests the students' mastery of concepts and identify misconceptions associated with course material in momentum transport.</i>	100	84
TOTAL	100	84

Answer All Questions

1. (10 points)

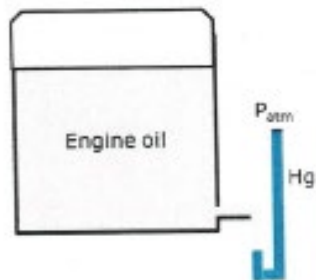


For a fluid volume element, where gravity is acting in the $-z$ direction, the body force is acting in the _____ direction.

Choice	
X	A
-X	☒ B
Z	C
-Z	D

70

2. (20 points)



A closed tank contains compressed air and engine oil. A U-tube manometer using mercury is attached to the tank. The pressure at the top of the oil is _____ the pressure at the top of the mercury.

Choice	
greater than	A
less than	B
equal to	C
not enough information	D

3. (20 points).

Inviscid flow implies:

Choice	
Bernoulli's equation cannot be used.	A
Shear stresses are negligible.	B
The flow can be thought of as frictionless.	C
A & B	D
B & C	E

20

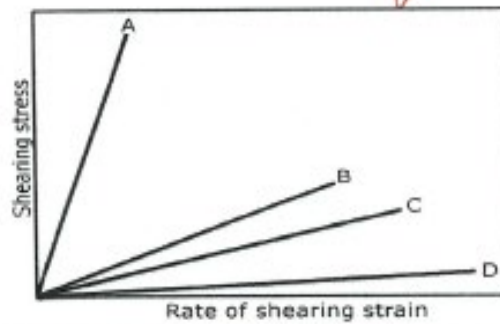
4. (10 points)

Which of the following statements is true of viscosity?

- (A) It is the ratio of inertial to viscous force.
- (B) It always has a large effect on the value of the friction factor.
- (C) It is the ratio of the shear stress to the rate of shear deformation.
- (D) It is usually low when turbulent forces predominate.

10

5. (20 points)



Which fluid is most viscous?

Choice	
1	A
2	B
3	C
4	D

20

6. (20 points)



A fluid flows steadily through a circular pipe of uniform cross-sectional area as shown.

If the outlet density of the fluid decreases to $1/2$ of its inlet value, what happens to the average fluid velocity?



Choice	
The velocity will not change since mass must be conserved and the flow is steady-state.	A
The outlet velocity will be twice the inlet velocity since mass must be conserved in the system.	☒ B
The velocity will increase somewhat but we can't tell how much with the information given.	C
The velocity will decrease somewhat because of friction between fluid and the pipe wall.	D

BELOW AVERAGE

Below Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT
SHEET FOR FALL 2021 SEMESTER**

STUDENT LEARNING OUTCOME D1: Ability to demonstrate mastery of concepts in heat, mass and momentum transport.

Assignments that test mastery of concepts by students and identify misconceptions associated with the course material in heat, mass and momentum transport.

Name: Buel Wrist

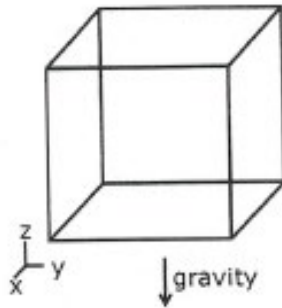
Title of Assignment: Exam 1

Date: 12/11/21

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
D1) Ability to demonstrate mastery of concepts in momentum transport. <i>The problem tests the students' mastery of concepts and identify misconceptions associated with course material in momentum transport.</i>	100	77
TOTAL	100	77

Answer All Questions

1. (10 points)



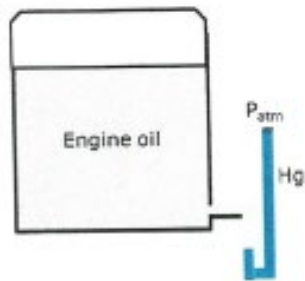
For a fluid volume element, where gravity is acting in the -z direction, the body force is acting in the _____ direction.

✓
D
10

Choice	
X	A
-X	B
Z	C
-Z	D

60

2. (20 points)



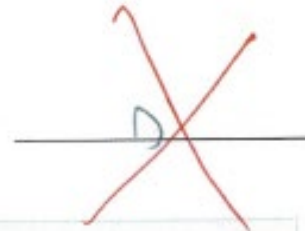
A closed tank contains compressed air and engine oil. A U-tube manometer using mercury is attached to the tank. The pressure at the top of the oil is _____ the pressure at the top of the mercury.



Choice	
greater than	A
less than	B
equal to	C
not enough information	D

3. (20 points).

Inviscid flow implies:



Choice	
Bernoulli's equation cannot be used.	A
Shear stresses are negligible.	B
The flow can be thought of as frictionless.	C
A & B	D
B & C	E

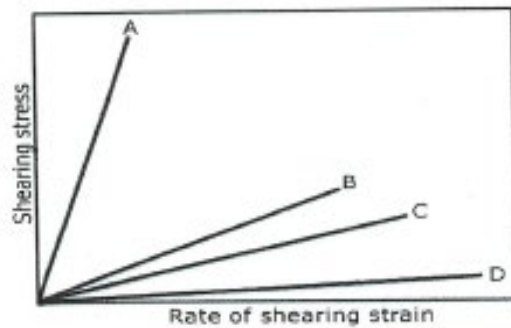
4. (10 points)

Which of the following statements is true of viscosity?

- (A) It is the ratio of inertial to viscous force.
- (B) It always has a large effect on the value of the friction factor.
- ☒ (C) It is the ratio of the shear stress to the rate of shear deformation.
- (D) It is usually low when turbulent forces predominate.

10

5. (20 points)



Which fluid is most viscous?

20



Choice	
1	☒ A
2	☐ B
3	☐ C
4	☐ D

6. (20 points)



A fluid flows steadily through a circular pipe of uniform cross-sectional area as shown.

If the outlet density of the fluid decreases to $1/2$ of its inlet value, what happens to the average fluid velocity?

20

Choice	
The velocity will not change since mass must be conserved and the flow is steady-state.	A
The outlet velocity will be twice the inlet velocity since mass must be conserved in the system.	☒ B
The velocity will increase somewhat but we can't tell how much with the information given.	C
The velocity will decrease somewhat because of friction between fluid and the pipe wall.	D

HEAT, MASS AND MOMENTUM TRANSPORT FALL 2021

Title of Assignment: EXAM 2

TOPICS COVERED IN EXAM 2

1. Fourier's law of heat conduction and heat loss from a furnace without and with insulation
2. Calculation of the rate diffusion of ethanol in the vapor phase above an ethanol-water solution into the atmosphere and the amount of ethanol lost from the container in a day.

CHEG 3301-P02 Heat, Mass and Momentum Transport (Fall 2021): Exam II
December1, 2021

You will be graded based on your ability to identify, formulate and solve fundamental engineering problems. Show clearly each step of your calculation. Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

1. A furnace constructed of 1 cm-thick steel operates at 800 °C. The outside of the furnace is maintained at 25 °C and the heat loss per m² of the furnace was calculated. The outside of the furnace was then insulated with 10 cm of fiberglass and the outside temperature maintained at 25 °C. The heat loss per m² was again calculated.

You may assume that the thermal conductivities of steel and fiberglass are 16 W/m.K and 0.03 W/m.K respectively.

- (i) Calculate the heat loss per m² of furnace before the insulation;
- (ii) Calculate the heat loss per m² of furnace after insulation of the furnace;
- (iii) Was there an increase or decrease in the heat flux? Explain.
- (iv) Calculate the percentage increase or decrease reduction of the heat flux

2. A fan is blowing 32 °F air over a container open to the atmosphere and filled to within 1 in. of the top with a solution of ethyl alcohol in water. The partial pressure of the ethyl alcohol at the interface is 0.5 atm and the air flowing across the container does not contain ethyl alcohol.

Assume the mouth of the container is narrow enough to ensure that the 1 in. of the top of the solution constitutes stagnant gas.

- (i) Calculate the rate of diffusion of ethyl alcohol.
- (ii) If the diameter of the tank is 2 ft., how much ethyl alcohol will be lost in one day by diffusion if the ethyl alcohol level is maintained constant?

Data and relevant equations:

The diffusivity of ethyl alcohol for this system is 0.4 ft²/h

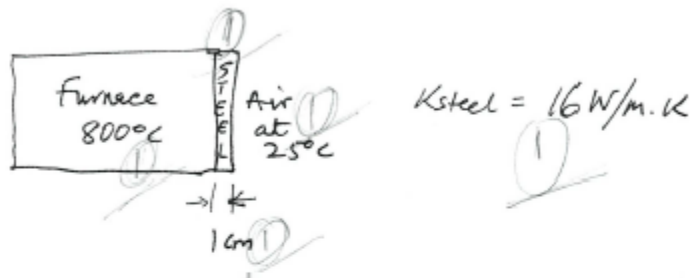
$$^{\circ}\text{F} = 32 + 1.8(^{\circ}\text{C}) \text{ and } ^{\circ}\text{R} = ^{\circ}\text{F} + 459.67$$

$P = CRT$, where P = total pressure, C = total concentration, and $R = 0.7302 \text{ ft}^3 \cdot \text{atm} / \text{lb-mol} \cdot ^{\circ}\text{R}$

$$N_A = -D_{AB} \frac{dC_A}{dy} + \frac{C_A}{C} (N_A + N_B)$$

Heat, Mass & Momentum Transport 1 of 6

EXAM 2



$$q = -k \frac{dT}{dx}$$

$$q = -k \frac{\Delta T}{\Delta x}$$

$$\Delta T = (25 - 800) \text{ K}$$

$$= -775 \text{ K}$$

$$\Delta x = 1 \text{ cm} \left| \frac{1 \text{ m}}{100 \text{ cm}} \right| = 0.01 \text{ m}$$

$$q = -16 \frac{\text{W}}{\text{m.K}} (-775 \text{ K}) \left(\frac{1}{0.01 \text{ m}} \right)$$

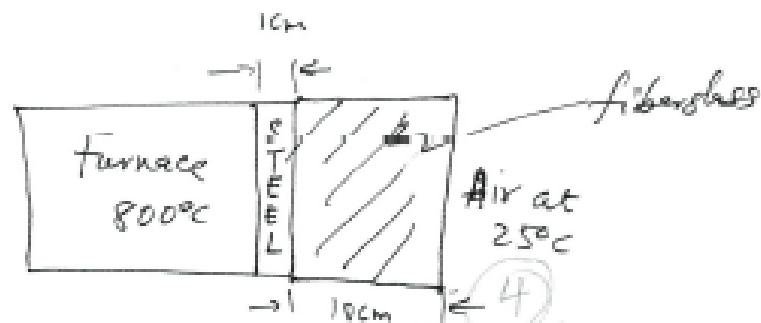
$$= \frac{1.6 \times 7.75 \times 10^3 \text{ W}}{1.0 \times 10^{-2} \text{ m}^2}$$

$$= \frac{1.24 \times 10^4 \text{ W}}{1.0 \times 10^{-2} \text{ m}^2} = 1.24 \times 10^6 \text{ W/m}^2$$

e.1-5

e.2-5

e.2 $\frac{10}{20}$



$$K_{\text{fiberglass}} = 0.03 \text{ W/mK} \text{ and } K_{\text{steel}} = 16 \text{ W/mK}$$

$$q = - \frac{\Delta T}{\frac{\Delta x_{\text{steel}}}{K_{\text{steel}}} + \frac{\Delta x_{\text{fiberglass}}}{K_{\text{fiberglass}}}}$$

$$\Delta T = (25 - 800) \text{ K} = -775 \text{ K}$$

$$\frac{\Delta x_{\text{steel}}}{K_{\text{steel}}} = \frac{0.01 \text{ m}}{16 \text{ W/mK}} = \frac{0.01 \text{ m}^2 \text{ K}}{16 \text{ W}}$$

$$\frac{\Delta x_{\text{fiberglass}}}{K_{\text{fiberglass}}} = \frac{0.10 \text{ m}}{0.03 \text{ W/mK}} = \frac{0.10 \text{ m}^2 \text{ K}}{0.03 \text{ W}}$$

$$\begin{aligned} q &= - \frac{(-775 \text{ K})}{\left(\frac{0.01}{16} + \frac{0.10}{0.03} \right) \frac{\text{m}^2 \text{ K}}{\text{W}}} = \frac{775 \text{ W} \cdot \text{K}}{\left(\frac{0.01}{16} + \frac{0.10}{0.03} \right) \text{m}^2 \text{ K}} \\ &= \frac{775 \text{ W} \cdot \text{K}}{(6.25 \times 10^{-4} + 3.333) \text{m}^2 \text{ K}} = \frac{775 \text{ W} \cdot \text{K}}{3.3339 \text{m}^2 \text{ K}} \\ &= 232.46 \text{ W/m}^2 \text{ K} = 232.46 \text{ W/m}^2 \end{aligned}$$

(iii) There is a reduction in the heat flux. The ~~3076~~
heat flux decreased from $1240 \times 10^3 \text{ W/m}^2$ to
 232 W/m^2

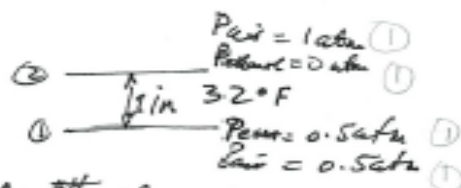
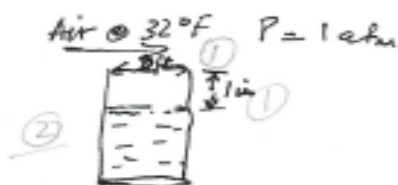
(iv) % reduction in the heat flux is given by:

$$\frac{(1240 \times 10^3 - 0.232 \times 10^3) \frac{\text{W}}{\text{m}^2} \times 100}{1240 \times 10^3 \text{ W/m}^2}$$

$$= 99.98\%$$

5

2.



$$P_{A1} = 0.5 \text{ atm}$$

Let A = ethanol and B = Air

$$P_{A2} = 0.0 \text{ atm}$$

$$D_{AB} = 0.4 \text{ ft}^2/\text{h}$$

Dia Diameter of container = 2 ft

$$T = 32^\circ\text{F}$$

$$(i) \quad N_A = -D_{AB} \frac{dC_A}{dy} + \frac{C_A}{C} (N_A + N_B)$$

For stagnant air, $N_B = 0$

$$\therefore N_A = -D_{AB} \frac{dC_A}{dy} + \frac{C_A}{C} N_A$$

$$P = CRT \Rightarrow C = \frac{P}{RT}$$

$$P_A = C_A RT \Rightarrow C_A = \frac{P_A}{RT}$$

$$\therefore N_A = -D_{AB} \frac{d\left(\frac{P_A}{RT}\right)}{dy} + \frac{\frac{P_A}{RT}}{\frac{P}{RT}} N_A$$

$$= -\frac{D_{AB}}{RT} \frac{dP_A}{dy} + \frac{P_A}{P} N_A$$

$$N_A - \frac{P_A}{P} N_A = -\frac{D_{AB}}{RT} \frac{dP_A}{dy}$$

$$N_A \left(1 - \frac{P_A}{P}\right) = -\frac{D_{AB}}{RT} \frac{dP_A}{dy}$$

$$N_A dy = - \frac{D_{AB}}{RT} \frac{dP_A}{1 - \frac{P_A}{P}}$$

$$N_A dy = - \frac{D_{AB} P}{RT} \frac{dP_A}{P - P_A}$$

$$N_A \int_0^y dy = - \frac{D_{AB} P}{RT} \int_{P_{A1}}^{P_{A2}} \frac{dP_A}{P - P_A} \quad (4)$$

$$P = 1 \text{ atm}$$

$$P_{A1} = 0.5 \text{ atm}$$

$$P_{A2} = 0$$

$$R = 0.7302 \text{ ft}^3 \cdot \text{atm} / (\text{lbmol} \cdot \text{R}) \quad (1)$$

$$T = 32^\circ \text{F} = 32 + 459.67 = 491.67^\circ \text{F} \quad (1)$$

$$y = \frac{1}{12} \text{ in} = \frac{1}{96} \text{ ft} \quad (1)$$

$$\therefore N_A \int_0^y dy = - \frac{D_{AB} P}{RT} \int_{0.5}^0 \frac{dP}{P - P_A}$$

$$N_A \left(\frac{1}{12} - 0 \right) = \frac{D_{AB} P}{RT} \ln(P - P_A) \Big|_{0.5}^0 \quad (4)$$

$$N_A \left(\frac{1}{12} \right) = \frac{D_{AB} P}{RT} \left[\ln P - \ln(P - 0.5) \right] \\ = \frac{D_{AB} P}{RT} \left[\ln \frac{1}{0.5} \right] = \frac{D_{AB} P}{RT} \ln 2 \quad (2)$$

$$N_A = 0.4 \frac{\text{ft}^3}{\text{h}} \cdot \frac{1 \text{ atm} \cdot \text{lbmol} \cdot \text{R}}{0.7302 \text{ ft}^3 \cdot \text{atm}} \times \frac{1}{491.67^\circ \text{R}} \times \ln 2 \quad (5)$$

$$= 0.4 \frac{\text{ft}^3}{\text{h}} \cdot \frac{1 \text{ atm} \cdot \text{lbmol} \cdot \text{R}}{0.7302 \text{ ft}^3 \cdot \text{atm}} \times \frac{1}{491.67^\circ \text{R}} \times \ln 2$$

$$= \frac{0.4 \ln 2 \times 12}{0.7302 \times 491.67} \frac{\text{lbmol}}{\text{h}} = \frac{4.8 \ln 2}{7.302 \times 4.9167 \times 10} \frac{\text{lbmol}}{\text{h}} \quad (5)$$

$$N_A = \frac{4.8 \times 0.69315}{7.302 \times 49.167} \frac{\text{lbmol}}{\text{h}} = \frac{3.32712}{7.302 \times 49.167} \frac{\text{lbmol}}{\text{h}} = 9.27 \times 10^{-3} \frac{\text{lbmol}}{\text{h}}$$

$$N_A = 9.27 \times 10^{-3} \text{ lbmol/ft}^2 \cdot \text{h} \quad (5)$$

(ii) Diameter of the container $D = 2 \text{ ft}$

$$\text{Cross-sectional Area of Container} = \frac{\pi D^2}{4} \quad (1)$$

$$= \frac{\pi (2)^2 \text{ ft}^2}{4}$$

$$= \pi \text{ ft}^2$$

$$= 3.142 \text{ ft}^2 \quad (1)$$

$$\text{Loss of ethanol by evaporation} = \frac{\pi D^2}{4} N_A \quad (2)$$

$$= 3.142 \text{ ft}^2 \times 9.27 \times 10^{-3} \text{ lbmol/ft}^2 \cdot \text{h}$$

$$= 3.142 \times 9.27 \times 10^{-3} \text{ lbmol/h} \quad (5)$$

$$\text{Loss of ethanol by evaporation per day} = 3.142 \times 9.27 \times 10^{-3} \text{ lbmol/h} \times \frac{24 \text{ h}}{\text{day}}$$

$$= 3.142 \times 9.27 \times 10^{-3} \times 24 \text{ lbmol/day}$$

$$= 0.699 \text{ lbmol/day} \quad (5)$$

ABOVE AVERAGE

Above Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME
ASSESSMENT SHEET FOR FALL 2021 SEMESTER

ABET OUTCOME D1: Ability to identify, formulate, and solve engineering problems.

Assignments that test competency in this area will include problems that test a student's ability to (1) apply systematic problem solving methodology that includes identifying all known and unknown variables, (2) construction of reasonable schematic representation of the problem, listing appropriate assumptions, determining appropriate property values, (3) applying the appropriate conservation laws, physical and chemical laws, and mathematics to solve the problem, and (4) evaluating the reasonableness of the computed results.

Name: Najam Din

Title of Assignment: Exam II Date: 12/1/21

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
D1) Ability to identify engineering problems. <i>The problem tests the students' ability to (i) understand the given problem, identify the subject area and concept(s) involved, (ii) draw a labeled sketch of system, and (iii) identify the applicable system of units.</i>	26	18
D1) Ability to formulate engineering problems. <i>The problem tests the students' ability to (i) define the known and unknown variables, (ii) state relevant laws and equations needed to solve the problem, and (iii) list and apply any assumptions to the relevant laws and equations to obtain equation specific to the problem.</i>	35	30
D1) Ability to solve engineering problems. <i>The problem tests the students' ability to (i) implement a strategy to solve the engineering problem, (ii) solve the problem showing consistent units throughout, and (iii) evaluating and interpreting the result.</i>	45	42
TOTAL	100	90



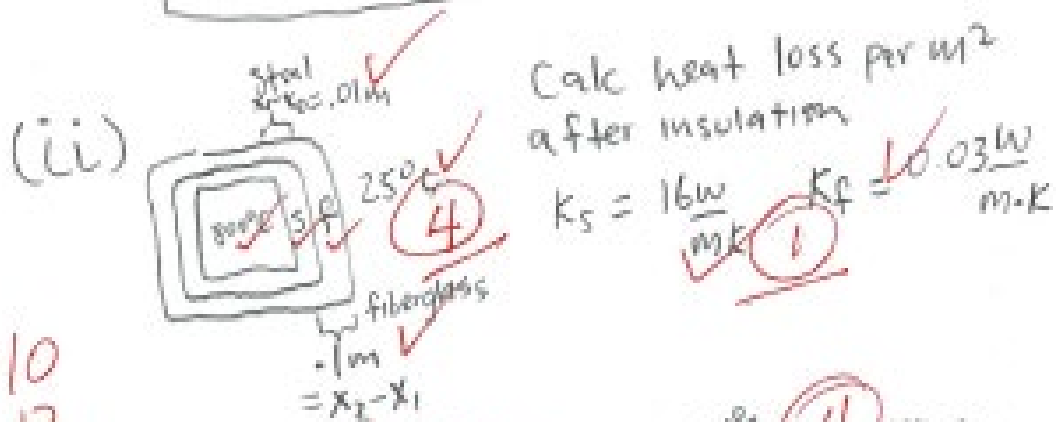
$k_{\text{steel}} = 16 \frac{\text{W}}{\text{m}\cdot\text{K}}$ $1\text{cm} = .01\text{m}$

①

e.1-17 (i) calc heat loss per m^2 before insulation
 e.2-22 $q = \frac{Q}{A} = -k \frac{dT}{dx} = -16 \frac{\text{W}}{\text{m}\cdot\text{K}} \cdot \frac{(800-25)^\circ\text{C}}{.01\text{m}} = -1,240,000 \frac{\text{W}}{\text{m}^2}$
 e.3-42 ⑤
 81

$q = 1.24 \times 10^6 \frac{\text{W}}{\text{m}^2}$

⑨



Calc heat loss per m^2 after insulation

$k_s = 16 \frac{\text{W}}{\text{m}\cdot\text{K}}$ $k_f = .03 \frac{\text{W}}{\text{m}\cdot\text{K}}$

①

e.1-10
 e.2-13
 e.3-23
 46

$q = \frac{T_2 - T_1}{\frac{x_1 \cdot k_s}{k_s} + \frac{x_2 \cdot k_f}{k_f}} = \frac{-(800-25)^\circ\text{C}}{\frac{.01\text{m}}{16 \frac{\text{W}}{\text{m}\cdot\text{K}}} + \frac{.1\text{m}}{.03 \frac{\text{W}}{\text{m}\cdot\text{K}}}} = 232.7 \frac{\text{W}}{\text{m}^2}$

④

⑤

$q = 232.7 \frac{\text{W}}{\text{m}^2}$

(iii) There was a decrease in heat flux as the additional material insulated the furnace and decreased heat transfer.

(iv) % change = $\frac{q_f - q_i}{q_i} \cdot 100\% = \frac{232.7 - 1.24 \times 10^6}{1.24 \times 10^6} \cdot 100\%$

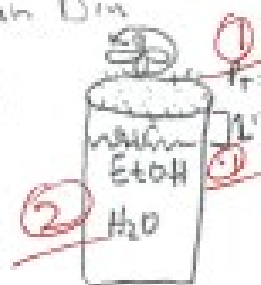
⑤

99.98%
 heat reduction.

Nayan Din

Transport Exam 2 pg 2

(2)



$$P_{\text{EtOH}} = .59 \text{ atm} = P_{\text{sat EtOH}}$$

$$P_{\text{air}} = 1 \text{ atm @ } 32^\circ\text{F}$$

$$32^\circ\text{F} = 491.67^\circ\text{R}$$

$$32^\circ\text{F} = 491.67^\circ\text{R}$$

$$D = 0.4 \text{ ft}^2$$

$$R = 0.7302 \text{ ft}^3 \cdot \text{atm} / (\text{lbmol} \cdot ^\circ\text{R})$$

(i) cal NA of EtOH:

e.1-7

e.2-9

e.3-19
35

$$P = CRT$$

$$P_{\text{EtOH}} = C_{\text{EtOH}} \cdot RT \therefore C_{\text{EtOH}} = \frac{P_{\text{EtOH}}}{RT} = \frac{.59 \text{ atm}}{0.7302 \text{ ft}^3 \cdot \text{atm} / (\text{lbmol} \cdot ^\circ\text{R}) \cdot 491.67^\circ\text{R}}$$

$$C_{\text{EtOH}} = .00139 \text{ lbmol} / \text{ft}^3$$

$$N_A = \frac{P \cdot D}{R \cdot T \cdot L} \cdot \ln \frac{P_{B_2}}{P_{B_1}} = \frac{1 \text{ atm} \cdot 0.4 \text{ ft}^2}{0.7302 \text{ ft}^3 \cdot \text{atm} / (\text{lbmol} \cdot ^\circ\text{R}) \cdot 491.67^\circ\text{R} \cdot .083 \text{ ft}} \cdot \ln \left(\frac{1 \text{ atm}}{.59 \text{ atm}} \right)$$

$$N_A = .0093 \text{ lbmol} / \text{hr} \cdot \text{ft}^2$$

(ii) if $D = 2 \text{ ft}$ ($R = 1 \text{ ft}$) how much EtOH will be lost in 1 day (24h)?

$$A = \pi R^2$$

$$N_A = \frac{\text{lbmol}}{\text{hr} \cdot \text{ft}^2} \therefore N_A \cdot A = \text{total lbmol per hour}$$

$$\text{total lbmol in 1 day} = \frac{24 \text{ hr}}{1 \text{ day}} \cdot (.0093 \text{ lbmol} / \text{hr} \cdot \text{ft}^2) \cdot \pi \cdot 1 \text{ ft}^2$$

$$\text{total EtOH loss} = 0.701 \text{ lbmol} / \text{day}$$

AVERAGE

Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME
ASSESSMENT SHEET FOR FALL 2021 SEMESTER

ABET OUTCOME D1: Ability to identify, formulate, and solve engineering problems.

Assignments that test competency in this area will include problems that test a student's ability to (1) apply systematic problem solving methodology that includes identifying all known and unknown variables, (2) construction of reasonable schematic representation of the problem, listing appropriate assumptions, determining appropriate property values, (3) applying the appropriate conservation laws, physical and chemical laws, and mathematics to solve the problem, and (4) evaluating the reasonableness of the completed results.

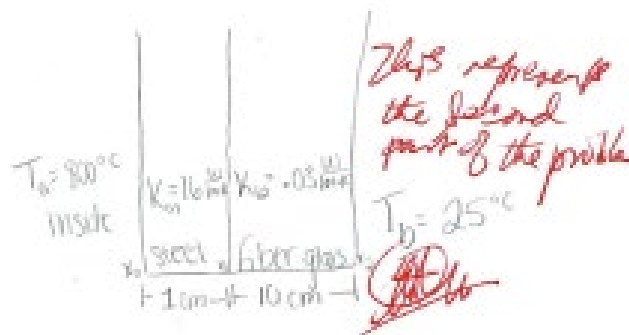
Name: Jasmine Davenport

Title of Assignment: Exam II

Date: December 1st, 2021

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
D1) Ability to identify engineering problems. <i>The problem tests the students' ability to (i) understand the given problem, identify the subject area and concept(s) involved, (ii) draw a labeled sketch of system, and (iii) identify the applicable system of units.</i>	20	15
D1) Ability to formulate engineering problems. <i>The problem tests the students' ability to (i) define the known and unknown variables, (ii) state relevant laws and equations needed to solve the problem, and (iii) list and apply any assumptions to the relevant laws and equations to obtain equation specific to the problem.</i>	35	29
D1) Ability to solve engineering problems. <i>The problem tests the students' ability to (i) implement a strategy to solve the engineering problem, (ii) solve the problem showing consistent units throughout, and (iii) evaluating and interpreting the result.</i>	45	36
TOTAL	100	80

Problem 1:



$$T_a = 800^\circ\text{C} + 273\text{K} = 1073\text{K} \quad (1)$$

$$T_b = 25^\circ\text{C} + 273\text{K} = 298\text{K} \quad (1)$$

$$L_{\text{steel}} = 1\text{ cm} = 0.01\text{ m} \quad (1)$$

$$L_{\text{fiber}} = 10\text{ cm} = 0.1\text{ m} \quad (1)$$

$$x_1 - x_0 = 0.01\text{ m} \quad (1)$$

$$x_2 - x_1 = 0.1\text{ m} \quad (1)$$

$$K_{s1} = 16 \frac{\text{W}}{\text{m}\cdot\text{K}} \quad (1)$$

$$K_{s2} = 0.03 \frac{\text{W}}{\text{m}\cdot\text{K}} \quad (1)$$

i.) $q_0 = K \frac{\Delta T}{dx}$ - heat loss before insulation

$$q_0 = -K \frac{T_a - T_b}{x_1 - x_0} \rightarrow q_0 = -16 \frac{\text{W}}{\text{m}\cdot\text{K}} \frac{1073\text{K} - 298\text{K}}{0.01\text{ m}} \quad (5)$$

$$q_0 = -1.24 \times 10^6 \frac{\text{W}}{\text{m}^2} \quad (4) \quad (3)$$

$$h = \frac{q_0}{T_a - T_b} \rightarrow h = \frac{-1.24 \times 10^6}{1073 - 298} = -417.2 \text{ W/m}^2\cdot\text{K}$$

e.1-14
e.2-22
e.3-28
64

$$\text{ii.) } q_1 = - \frac{(T_a - T_b)}{\frac{x_1 - x_0}{K_{s1}} + \frac{x_2 - x_1}{K_{s2}}} \quad (5)$$

$$q_1 = \frac{1073\text{K} - 298\text{K}}{\frac{0.01\text{ m}}{16 \frac{\text{W}}{\text{m}\cdot\text{K}}} + \frac{0.1\text{ m}}{0.03 \frac{\text{W}}{\text{m}\cdot\text{K}}}} \quad (4) \quad (5)$$

$$h = \frac{q_1}{T_a - T_b} = \frac{232.73 \frac{\text{W}}{\text{m}^2}}{1073 - 298} = 0.33 \frac{\text{W}}{\text{m}^2\cdot\text{K}}$$

e.1-8
e.2-14
e.3-16
38

iii.) There was a decrease in heat flux because there is more area to take account for, since heat flux is $\frac{\text{W}}{\text{m}^2\cdot\text{s}}$.

$$\text{iv.) } \% \text{ decrease} = \frac{q_0 - q_1}{q_0} \times 100 \rightarrow 43\%$$

e.1-8
e.2-14
e.3-16
38

Problem 2:



$$dL = L_2 - L_1 = 1 \text{ m} \rightarrow .08 \text{ ft} \quad \textcircled{1}$$

$$T = 32^\circ\text{F} + 460^\circ\text{R} = 492^\circ\text{R} \quad \textcircled{1}$$

$$P_{\text{atm}} = 1 \text{ atm} \quad \textcircled{1}$$

$$P_{a1} = .5 \text{ atm} \quad \textcircled{1}$$

$$D_{AB} = 0.4 \frac{\text{ft}^2}{\text{h}} \quad \textcircled{1}$$

$$R = 0.73 \frac{\text{ft}^3 \cdot \text{atm}}{\text{lbmol} \cdot ^\circ\text{R}} \quad \textcircled{1}$$

$$i.) \quad N_A = \frac{D_{AB}(P_T)}{RT dL} \ln \left(\frac{P_{B2}}{P_{B1}} \right) \quad \textcircled{8}$$

$-P_{B2} = P_{\text{atm}}$ since the container is open to the atmosphere

$$P_{\text{atm}} = P_{A1} + P_{B1}$$

after rearranging to find P_{B1} $\textcircled{1}$

$$P_{B1} = P_{\text{atm}} - P_{A1} \rightarrow P_{B1} = 1 \text{ atm} - .5 \text{ atm} \rightarrow P_{B1} = 0.5 \text{ atm}$$

$$N_A = \frac{(0.4 \frac{\text{ft}^2}{\text{h}})(1 \text{ atm})}{(0.73 \frac{\text{ft}^3 \cdot \text{atm}}{\text{lbmol} \cdot ^\circ\text{R}})(492^\circ\text{R})(.08 \text{ ft})} \ln \left(\frac{1 \text{ atm}}{0.5 \text{ atm}} \right) \quad \textcircled{10}$$

$$N_A = 9.61 \times 10^{-3} \frac{\text{lbmol}}{\text{ft}^2 \cdot \text{h}}$$

ii.)

$$N_A = \frac{9.61 \times 10^{-3} \text{ lbmol}}{\text{ft}^2 \cdot \text{hr}} \left| \frac{24 \text{ hr}}{1 \text{ day}} \right| = 2.31 \times 10^{-1} \frac{\text{lbmol}}{\text{ft}^2 \cdot \text{day}} \quad \textcircled{2}$$

e.1-6

e.2-8

e.3-12
26

BELOW AVERAGE

Below Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME
ASSESSMENT SHEET FOR FALL 2021 SEMESTER**

ABET OUTCOME D1: Ability to identify, formulate, and solve engineering problems.

Assignments that test competency in this area will include problems that test a student's ability to (1) apply systematic problem solving methodology that includes identifying all known and unknown variables, (2) construction of reasonable schematic representation of the problem, listing appropriate assumptions, determining appropriate property values, (3) applying the appropriate conservation laws, physical and chemical laws, and mathematics to solve the problem, and (4) evaluating the reasonableness of the computed results.

Name: Caridanan Gaultoby

Title of Assignment: Exam II

Date: _____

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
D1) Ability to identify engineering problems. <i>The problem tests the students' ability to (i) understand the given problem, identify the subject area and concept(s) involved, (ii) draw a labeled sketch of system, and (iii) identify the applicable system of units.</i>	20	13
D1) Ability to formulate engineering problems. <i>The problem tests the students' ability to (i) define the known and unknown variables, (ii) state relevant laws and equations needed to solve the problem, and (iii) list and apply any assumptions to the relevant laws and equations to obtain equation specific to the problem.</i>	35	29
D1) Ability to solve engineering problems. <i>The problem tests the students' ability to (i) implement a strategy to solve the engineering problem, (ii) solve the problem showing consistent units throughout, and (iii) evaluating and interpreting the result.</i>	45	21
TOTAL	100	63

Problem I.

$$T_0 = 800^\circ\text{C} = 1073\text{K}$$

$$T_1 = 298\text{K}$$

$$x_1 = 0.1\text{m}$$

$$K_1 = 16\text{ W/m.K}$$

$$x_2 = 1\text{m}$$

$$K_2 = 0.03\text{ W/m.K}$$

i. Heat loss before insulation

$$\frac{Q}{A} = -K \frac{dt}{dx} \Rightarrow \frac{Q}{A} dx = -K dt$$

$$\frac{Q}{A} \int_{x_0}^{x_1} dx = -K \int_{T_0}^{T_1} dt$$

$$\frac{Q}{A} (x_1 - x_0) = -K [T_1 - T_0]$$

$$\frac{Q}{A} = \frac{-K_1 (T_1 - T_0)}{x_1 - x_0}$$

$$\frac{Q}{A} = \frac{K_1 (T_0 - T_1)}{x_1 - x_0} = \frac{(16 \frac{\text{W}}{\text{m.K}}) (1073 - 298)\text{K}}{(0.1 - 0)\text{m}}$$

$$\frac{Q}{A} = 1.24 \times 10^5 \text{ W/m}^2$$

e.1-11

e.2-16

e.3-12
39

ii. Heat loss after insulation

e.1-6

e.2-5

e.3-7
18

Problem 2.

$$T_{air} = 32^{\circ}F = 491.67^{\circ}R$$

$$P_A = 0.5 \text{ atm} \text{ (1)}$$

$$P_{at} = 1 \text{ atm} \text{ (1)}$$



i) rate of diffusion of ethyl alcohol

$$N_A = -D_{AB} \frac{dc_A}{dy} + \frac{C_A}{C} (N_A + N_B) \text{ (1)}$$

$$N_A = \text{ethyl alcohol gas} \quad N_B = \text{Air}$$

since the gas at the top of the solution constitutes stagnant gas which is air then $N_B = 0 \text{ (2)}$

Hence,

$$N_A = -D_{AB} \frac{dc_A}{dy} + \frac{C_A}{C} N_A \text{ (2)}$$

$$\text{with } \frac{C_A}{C} = x_A \Rightarrow \frac{N_A}{C_A} = x_A \cdot C$$

$$= -D_{AB} \frac{d(x_A \cdot C)}{dy} + x_A N_A$$

$$N_A - x_A N_A = -D_{AB} \cdot C \frac{dx_A}{dy}$$

$$N_A (1 - x_A) = -D_{AB} \cdot C \frac{dx_A}{dy}$$

Assuming N_A is a constant and doing change of variables and applying integration we have

$$e.1-5$$

$$e.2-11$$

$$e.3-5$$

$$21$$

$$N_A \int_{z_1}^{z_2} dy = -D_{AB} \cdot C \int_{x_{A1}}^{x_{A2}} \frac{1}{1-x_A} dx_A \quad (4)$$

let's take $u = 1 - x_A \Rightarrow du = -dx_A$

$$N_A (z_2 - z_1) = -D_{AB} \cdot C \int_{x_{A1}}^{x_{A2}} \frac{-du}{u}$$

$$N_A (z_2 - z_1) = -D_{AB} \cdot C \left[\ln(1 - x_A) \right]_{x_{A1}}^{x_{A2}}$$

$$N_A = \frac{-D_{AB} \cdot C \left[\ln(1 - x_A) \right]_{x_{A1}}^{x_{A2}}}{z_2 - z_1}$$

At $z_1 = 0 \Rightarrow x_{A1} = \frac{P_{A1}}{P_T} = \frac{0.5 \text{ atm}}{1 \text{ atm}} = 0.5$

At $z_2 = 1 \text{ in} \quad x_{A2} = 0$

$P = CRT \Rightarrow C = \frac{P}{RT} = \frac{1}{(0.7302)(491.67)} = 2.78 \times 10^{-3} \text{ lbmol}$

$$N_A = \frac{(0.4)(2.78 \times 10^{-3}) [\ln(1-0) - \ln(1-0.5)]}{1} \quad (5)$$

**HEAT, MASS AND MOMENTUM TRANSPORT
FALL 2021**

Title of Assignment: MIDTERM EXAM

TOPICS COVERED IN MIDTERM EXAM

MIDTERM EXAM covered the following topics:

- - 1. Pressure due to a column of fluid**
 - 2. Viscosity of fluids, shear rates and apparent viscosities**
 - 3. Pressure drops in pipes and Newtonian flow of fluids in pipes**
 - 4. Momentum balance on a horizontal jet of water**
 - 5. Differential form of the continuity equation an incompressible fluid**

**CHEG 3301 P02 HEAT, MASS AND MOMENTUM TRANSPORT
FALL 2021**

Midterm Exam: October 13, 2021
Answer All Questions

You will be graded based on your ability to identify, formulate and solve engineering problems. Show clearly each step of your calculation. Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

1. (10 points)

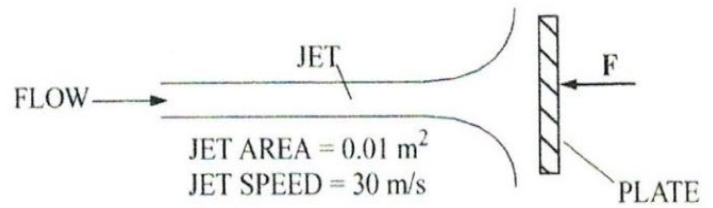
The density of a fluid is 70 lb/ft^3 . The barometric pressure is 14.6 psia, and the local acceleration due to gravity is 32.15 ft/s^2 . The absolute static pressure at the bottom of a column of fluid of height 20 ft., open to the atmosphere is closest to:

- A. 20 psia
- B. 24 psia
- C. 28 psia
- D. 32 psia

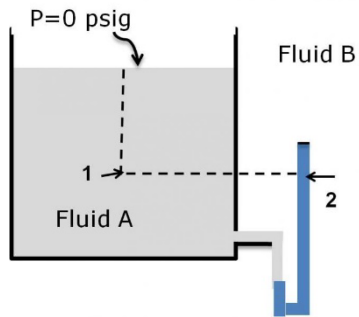
2. (20 points)

A horizontal jet of water (density = $1,000 \text{ kg/m}^3$) is deflected perpendicularly to the original jet stream by a plate as shown below. The magnitude of force F (kN) required to hold the plate in place is most nearly:

- (A) 4.5
- (B) 9.0
- (C) 45.0
- (D) 90.0



3. (5 points)



Fluid A is contained in a tank open to the atmosphere. At the height indicated, what can be said about the pressure at point 1 with respect to the pressure at point 2?

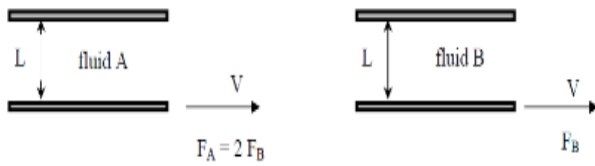
Choice	
$P_1 > P_2$	A
$P_2 > P_1$	B
$P_2 = P_1$	C
not enough information	D

4. (5 points)

The correct statement about fluid viscosity is:

- A. Viscosity is not a property of the fluid.
- B. Viscous forces are unimportant for air flows.
- C. Viscous forces act normal to a surface.
- D. Viscosity is a measure of a fluid's resistance to flow.
- E. Viscous forces are much smaller than pressure forces.

5. (10 points)



Two different Newtonian fluids (A & B) are placed between identical sets of parallel plates as shown below. Each pair of plates is separated by the same distance L . Both bottom plates are pulled to the right at a constant velocity V and both top plates are held stationary. The force required to pull the bottom plate in contact with fluid A (F_A) is twice the force required to pull the bottom plate in contact with fluid B (F_B). The only motion occurring in each fluid is caused by the movement of the bottom plate. Based on this observation and ignoring edge effects, how are viscosities of the two fluids (μ_A and μ_B) related?

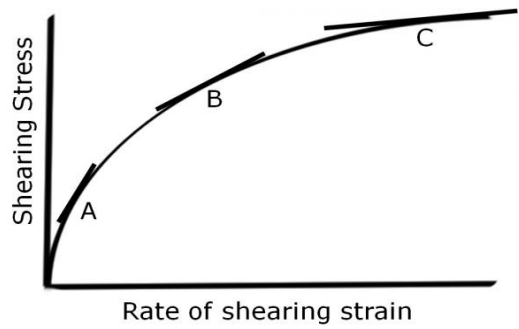
Choice	
$\mu_A = \mu_B$ because the force required to move the plate is a function of V and L but not fluid properties	A
μ_A and μ_B are unrelated because the force required to move the plate is only a function of fluid density	B
$\mu_A > \mu_B$ but the exact relationship cannot be determined from the information given	C
$\mu_A = 2\mu_B$ because the force required to move the plate is directly proportional to viscosity	D

6. (10 points)

A Newtonian fluid is flowing in a pipe at a Reynolds number of 1500. The viscosity is lowered to 50 % and the density to 60 % of their original values by heating with the volumetric flow rate and the pipe dimensions remaining the same.

- A. The new Reynolds number is greater than 2100 and the flow is turbulent
- B. The new Reynolds number is less than 2100 and the flow is laminar
- C. The Reynolds number remains the same and the flow regime is unchanged
- D. Not enough information to determine the flow regime

7. (5 points)



The viscosity is highest at which rate of shearing strain?

Choice	
A	A
B	B
C	C
Viscosity is independent of rate of shearing strain	D

8. (5 points)

$$\left(\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \right) = 0$$

If the continuity equation reduces to what is shown below, this implies _____.

Choice	
the flow is incompressible	A
the flow is steady-state	B
the volume dilatation rate (the rate of change of the volume per unit volume) equals zero	C
A & B	D
A & C	E

9. (30 points)

Using a differential mass balance for fluid flow where $\mathbf{v}$ is the velocity vector of motion:

- (i) Show that the continuity equation may be written as:

$$\frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho \mathbf{v}), \text{ where the quantity } \nabla \cdot \rho \mathbf{v}, \text{ is the divergence of the mass velocity vector } \rho \mathbf{v}.$$

- (ii) Also show that the continuity equation $\frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho \mathbf{v})$ for an incompressible fluid flow at steady-state may be written as $\frac{\partial \rho}{\partial t} + v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} + \rho \nabla \cdot \mathbf{v} = 0$, and that under these conditions it reduces to:

$$\nabla \cdot \mathbf{v} = 0$$

CHEG 3301 P02 HEAT, MASS AND MOMENTUM TRANSPORT: FALL 2021

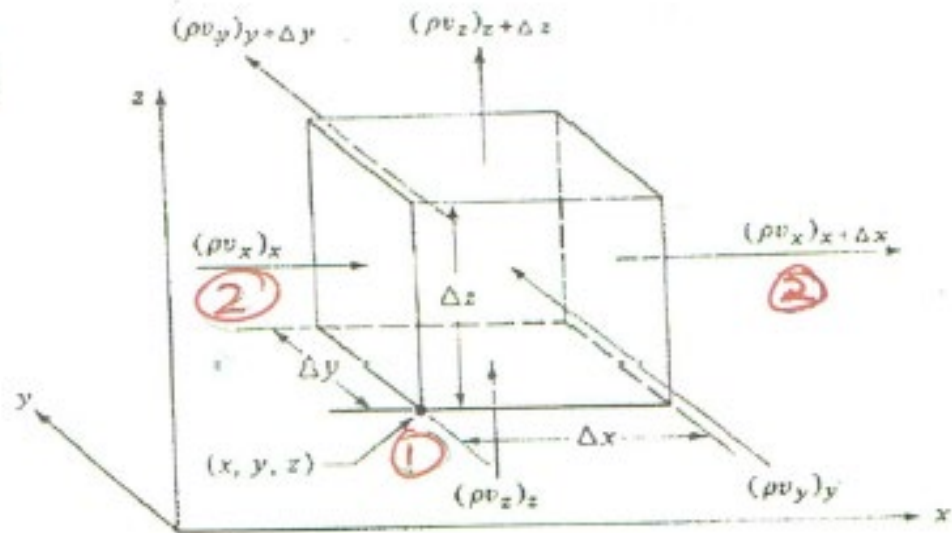
Midterm Exam: October 13, 2021

KEY

1. B
2. B
3. D
4. D
5. D
6. B
7. A
8. D

9.

Let fluid flow through a stationary volume element (differential volume element) $\Delta x \Delta y \Delta z$ which is fixed in space



Mass balance for a pure fluid flowing through a fixed volume $\Delta x \Delta y \Delta z$ in space.

The mass balance over the volume element $\Delta x \Delta y \Delta z$ for a fluid of density $\rho \text{ kg/m}^3$ is given by:

$$(\text{rate of mass in}) - (\text{rate of mass out}) = \text{rate of mass accumulation or rate of increase of mass} \quad \textcircled{2}$$

In the x-direction, we consider the faces perpendicular to it

The rate of mass entering the face at x with area $\Delta y \Delta z \text{ m}^2$ is given by:

$$\text{The mass entering the face is } (\rho v_x)_x \Delta y \Delta z \frac{\text{kg}}{\text{s}} \quad \textcircled{1}$$

$$\text{The mass leaving the face at } x + \Delta x \text{ is } (\rho v_x)_{x+\Delta x} \Delta y \Delta z \frac{\text{kg}}{\text{s}} \quad \textcircled{1}$$

In the y direction rate of mass entering the face at y with area $\Delta x \Delta z \text{ m}^2$ is given by:

$$(\rho v_y)_y \Delta x \Delta z \frac{\text{kg}}{\text{s}} \quad \textcircled{1}$$

$$\text{The mass leaving the face at } y + \Delta y \text{ is } (\rho v_y)_{y+\Delta y} \Delta x \Delta z \frac{\text{kg}}{\text{s}} \quad \textcircled{1}$$

The rate of mass entering the face at z with area $\Delta x \Delta y m^2$ is given by:

$$(\rho v_z) \Big|_z \Delta x \Delta y \frac{kg}{s} \quad (1)$$

The mass leaving the face at $z + \Delta z$ is $(\rho v_z) \Big|_{z + \Delta z} \Delta x \Delta y \frac{kg}{s} \quad (1)$

The rate of mass accumulation within the differential volume element $\Delta x \Delta y \Delta z =$

$$\Delta x \Delta y \Delta z \frac{\partial \rho}{\partial t} \quad (2)$$

Substituting the expressions into the mass balance equation gives:

$$\Delta y \Delta z (\rho v_x) \Big|_x - \Delta y \Delta z (\rho v_x) \Big|_{x + \Delta x} + \Delta x \Delta z (\rho v_y) \Big|_y - \Delta x \Delta z (\rho v_y) \Big|_{y + \Delta y} + \Delta x \Delta y (\rho v_z) \Big|_z - \Delta x \Delta y (\rho v_z) \Big|_{z + \Delta z} = \Delta x \Delta y \Delta z \frac{\partial \rho}{\partial t} \quad (5)$$

Dividing both sides of the equation by $\Delta x \Delta y \Delta z$, we obtain:

$$\frac{[(\rho v_x) \Big|_x - (\rho v_x) \Big|_{x + \Delta x}]}{\Delta x} + \frac{[(\rho v_y) \Big|_y - (\rho v_y) \Big|_{y + \Delta y}]}{\Delta y} + \frac{[(\rho v_z) \Big|_z - (\rho v_z) \Big|_{z + \Delta z}]}{\Delta z} = \frac{\partial \rho}{\partial t} \quad (3)$$

The limit as Δx , Δy and Δz approach zero may be written as

$$\lim_{\Delta x \rightarrow 0} \frac{[(\rho v_x) \Big|_x - (\rho v_x) \Big|_{x + \Delta x}]}{\Delta x} + \lim_{\Delta y \rightarrow 0} \frac{[(\rho v_y) \Big|_y - (\rho v_y) \Big|_{y + \Delta y}]}{\Delta y} + \lim_{\Delta z \rightarrow 0} \frac{[(\rho v_z) \Big|_z - (\rho v_z) \Big|_{z + \Delta z}]}{\Delta z} = \frac{\partial \rho}{\partial t} \quad (5)$$

and noting that $\frac{\lim_{\Delta x \rightarrow 0} \frac{[(\rho v_x) \Big|_x - (\rho v_x) \Big|_{x + \Delta x}]}{\Delta x}}{\Delta x} = - \lim_{\Delta x \rightarrow 0} \frac{[(\rho v_x) \Big|_{x + \Delta x} - (\rho v_x) \Big|_x]}{\Delta x} \quad (1)$

the definition of the partial derivative gives:

$$\frac{- \lim_{\Delta x \rightarrow 0} \frac{[(\rho v_x) \Big|_{x + \Delta x} - (\rho v_x) \Big|_x]}{\Delta x}}{\Delta x} = - \frac{\partial (\rho v_x)}{\partial x} \quad (1)$$

Hence,

$$\lim_{\Delta x \rightarrow 0} \frac{[(\rho v_x)_x - (\rho v_x)_{x-\Delta x}]}{\Delta x} + \lim_{\Delta y \rightarrow 0} \frac{[(\rho v_y)_y - (\rho v_y)_{y-\Delta y}]}{\Delta y} + \lim_{\Delta z \rightarrow 0} \frac{[(\rho v_z)_z - (\rho v_z)_{z-\Delta z}]}{\Delta z} = \frac{\partial \rho}{\partial t}$$

becomes $-\frac{\partial \rho v_x}{\partial x} - \frac{\partial \rho v_y}{\partial y} - \frac{\partial \rho v_z}{\partial z} = \frac{\partial \rho}{\partial t}$ (5)

This is the equation of continuity or conservation of mass of a pure liquid

Now the differential operator nabla or del is given by:

$$\nabla = \frac{\partial}{\partial x} \vec{i} + \frac{\partial}{\partial y} \vec{j} + \frac{\partial}{\partial z} \vec{k} \quad (1)$$

The mass velocity $\rho \vec{v}$ is a vector and may be written in the Cartesian coordinate system in terms of its components as

$$\rho \vec{v} = \rho v_x \vec{i} + \rho v_y \vec{j} + \rho v_z \vec{k} \quad (1)$$

The divergence of the mass velocity vector $\rho \vec{v}$, is given: (5)

$$\nabla \cdot \rho \vec{v} = \left(\frac{\partial}{\partial x} \vec{i} + \frac{\partial}{\partial y} \vec{j} + \frac{\partial}{\partial z} \vec{k} \right) \cdot (\rho v_x \vec{i} + \rho v_y \vec{j} + \rho v_z \vec{k}), \text{ which}$$

reduces to

$$\nabla \cdot \rho \vec{v} = \frac{\partial \rho v_x}{\partial x} + \frac{\partial \rho v_y}{\partial y} + \frac{\partial \rho v_z}{\partial z} \quad (5)$$

$$\therefore -\frac{\partial \rho v_x}{\partial x} - \frac{\partial \rho v_y}{\partial y} - \frac{\partial \rho v_z}{\partial z} = -\nabla \cdot \rho \vec{v}, \text{ and } (3)$$

$$\frac{\partial \rho}{\partial t} = -\left[\frac{\partial}{\partial x} (\rho v_x) + \frac{\partial}{\partial y} (\rho v_y) + \frac{\partial}{\partial z} (\rho v_z) \right]$$

reduces to:

$$\frac{\partial \rho}{\partial t} = -\nabla \cdot \rho \vec{v} \quad (5)$$

(ii) From ^{the} continuity equation $\frac{\partial \rho}{\partial t} = - \left[\frac{\partial}{\partial x}(\rho v_x) + \frac{\partial}{\partial y}(\rho v_y) + \frac{\partial}{\partial z}(\rho v_z) \right]$ the product rule

may be used to rewrite $\left[\frac{\partial}{\partial x}(\rho v_x) + \frac{\partial}{\partial y}(\rho v_y) + \frac{\partial}{\partial z}(\rho v_z) \right]$ as

$$\rho \frac{\partial v_x}{\partial x} + v_x \frac{\partial \rho}{\partial x} + \rho \frac{\partial v_y}{\partial y} + v_y \frac{\partial \rho}{\partial y} + \rho \frac{\partial v_z}{\partial z} + v_z \frac{\partial \rho}{\partial z}, \text{ or}$$

$$v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} + \rho \left(\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \right) \quad (5)$$

Hence the continuity equation may be rewritten as:

$$\frac{\partial \rho}{\partial t} = - \rho \left(\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \right) - \left(v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} \right) \quad (5)$$

The divergence of the velocity vector $\vec{v}$ is given by

$$\nabla \cdot \vec{v} = \left(\frac{\partial}{\partial x} \vec{i} + \frac{\partial}{\partial y} \vec{j} + \frac{\partial}{\partial z} \vec{k} \right) \cdot (v_x \vec{i} + v_y \vec{j} + v_z \vec{k}) = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \quad (5)$$

Substituting $\nabla \cdot \vec{v}$ for $\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}$ in the equation

$$\frac{\partial \rho}{\partial t} = - \rho \left(\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \right) - \left(v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} \right) \quad \text{gives}$$

$$\frac{\partial \rho}{\partial t} = - \rho \nabla \cdot \vec{v} - \left(v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} \right), \text{ which may be re-written as:}$$

$$\frac{\partial \rho}{\partial t} + v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} + \rho \nabla \cdot \vec{v} = 0 \quad (5)$$

(iii) At steady-state $\frac{\partial \rho}{\partial t} = 0$ and the continuity equation

$$\frac{\partial \rho}{\partial t} + v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} + \rho \nabla \cdot \vec{v} = 0$$

reduces to:

$$v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} + \rho \nabla \cdot \vec{v} = 0$$

For an incompressible fluid ρ is constant, and

$$\frac{\partial \rho}{\partial x} = 0, \quad \frac{\partial \rho}{\partial y} = 0 \quad \text{and} \quad \frac{\partial \rho}{\partial z} = 0$$

The continuity equation then reduces to:

$$v_x \times 0 + v_y \times 0 + v_z \times 0 + \rho (\nabla \cdot \vec{v}) = 0$$

Since the density ρ constant,

$$(\nabla \cdot \vec{v}) = 0$$

ABOVE AVERAGE

Above Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT
SHEET FOR FALL 2021 SEMESTER

STUDENT LEARNING OUTCOME D1: Ability to apply the knowledge of mathematics, science, and engineering.

STUDENT LEARNING OUTCOME D1: Ability to demonstrate mastery of concepts in heat, mass and momentum transport.

Assignments in this area (i) test mastery of concepts by students and identify misconceptions associated with the course material in heat, mass and momentum transport; (ii) test students ability to (a) apply knowledge of mathematics, science (chemistry and physics) and engineering (2) solve algebraic, integral and differential equations analytically or numerically, and (b) apply appropriate conservation laws to solve transport phenomena problems.

Name: Najam Din

Title of Assignment: Midterm Exam Due Date: 10/13/21

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Student Outcome 1: Ability to apply the knowledge of intermediate mathematics <i>This assignment tests students' knowledge and application of (1) physics and engineering (2) vector algebra and differential calculus, and (3) appropriate conservation laws transport phenomena problems.</i>	70	60
D1) Ability to demonstrate mastery of concepts in momentum transport. <i>The problem tests the students' mastery of concepts and identify misconceptions associated with course material in momentum transport.</i>	30	25
TOTAL	100	85

92

Heat, Mass and Momentum Transport (Fall 2021): Midterm Exam

October 13, 2021

You will be graded based on your ability to apply knowledge of (1) mathematics, science (chemistry and physics) and engineering (2) intermediate mathematics involving differential and integral calculus, partial differentials and vector algebra. Show clearly each step of your calculation. Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

$$P_a - P_b = R(P_a - P_b)g$$

1. (10 points)

The density of a fluid is 70 lb/ft^3 . The barometric pressure is 14.6 psia , and the local acceleration due to gravity is 32.15 ft/s^2 . The absolute static pressure at the bottom of a column of fluid of height 20 ft. , open to the atmosphere is closest to:

A. 20 psia

☒ B. 24 psia

C. 28 psia

D. 32 psia

$$P = \rho g h + P_0$$

$$P = 70 \frac{\text{lb}}{\text{ft}^3} \cdot \frac{32.15 \text{ ft}}{32.15 \frac{\text{ft}}{\text{s}^2}} \cdot 20 \text{ ft} + 14 \frac{\text{lb}}{\text{in}^2} \cdot \frac{(12 \text{ in})^2}{\text{ft}^2}$$

$$P = 1400 \frac{\text{lb}}{\text{ft}^2} + 2016 \frac{\text{lb}}{\text{ft}^2}$$

$$P = 3416 \frac{\text{lb}}{\text{ft}^2}$$

$$P = 3416 \frac{\text{lb}}{\text{ft}^2} \cdot \frac{(1 \text{ ft})^2}{(12 \text{ in})^2} = 23.7 \frac{\text{lb}}{\text{in}^2}$$

$$\approx 24 \text{ psia}$$

$$1 - 10 + 20 + 10 + 20 = 60$$

$$2 - 5 + 10 + 5 + 5 = 25$$

2. (20 points)

$$\frac{kg}{s} = \frac{kg}{m^3} \cdot \frac{m^3}{s}$$

$$\rho, A, V_1$$

$$\dot{m} = \rho A V$$

A horizontal jet of water (density = 1,000 kg/m³) is deflected perpendicularly to the original jet stream by a plate as shown below. The magnitude of force F (kN) required to hold the plate in place is most nearly:

- (A) 4.5
- (B) 9.0
- (C) 45.0
- (D) 90.0



$$\sum F_x = F_{xg} + F_{xp} + F_{xs} + R_x = m_2 V_2 - m_1 V_1$$

$$R_x = m_2 V_2 - m_1 V_1$$

$$\dot{m} = \rho A V$$

$$V_2 = 0$$

$$F_{xg} = 0$$

$$F_{xs} = 0$$

$$R_x = m_2 V_2$$

$$R_x = \rho_2 A_2 \cdot V_2^2$$

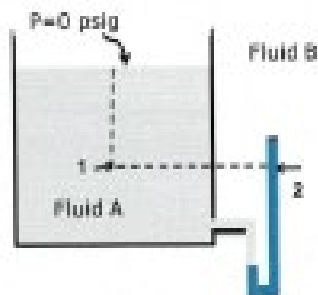
$$R_x = (1000 \frac{kg}{m^3}) (0.01 m^2) (30 \frac{m}{s})^2$$

$$R_x = 9000 N$$

$$= 9 kN$$

20

3. (5 points)



Fluid A is contained in a tank open to the atmosphere. At the height indicated, what can be said about the pressure at point 1 with respect to the pressure at point 2?

Choice	
$P_1 > P_2$	A
$P_2 > P_1$	B
$P_2 = P_1$	☒ C
not enough information	D

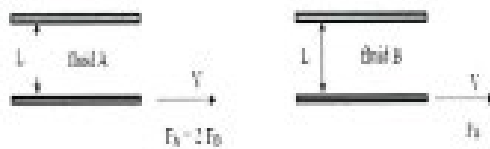
4. (5 points)

The correct statement about fluid viscosity is:

- ~~A.~~ Viscosity is not a property of the fluid.
- ~~B.~~ Viscous forces are unimportant for air flows.
- ~~C.~~ Viscous forces act normal to a surface.
- ☒ D. Viscosity is a measure of a fluid's resistance to flow.
- ~~E.~~ Viscous forces are much smaller than pressure forces.

5

5. (10 points)



$$F_A = 2F_B$$

$$V_A = V_B$$

$$\Delta y_A = \Delta y_B$$

$$F_A = \mu_A \frac{\partial v}{\partial y}$$

$$F_B = \mu_B \frac{\partial v}{\partial y}$$

Two different Newtonian fluids (A & B) are placed between identical sets of parallel plates as shown below. Each pair of plates is separated by the same distance L . Both bottom plates are pulled to the right at a constant velocity V and both top plates are held stationary. The force required to pull the bottom plate in contact with fluid A (F_A) is twice the force required to pull the bottom plate in contact with fluid B (F_B). The only motion occurring in each fluid is caused by the movement of the bottom plate. Based on this observation and ignoring edge effects, how are viscosities of the two fluids (μ_A and μ_B) related?

Choice	
$\mu_A = \mu_B$ because the force required to move the plate is a function of V and L but not fluid properties	☒
μ_A and μ_B are unrelated because the force required to move the plate is only a function of fluid density	☒
$\mu_A > \mu_B$ but the exact relationship cannot be determined from the information given	☒
$\mu_A = 2\mu_B$ because the force required to move the plate is directly proportional to viscosity	☒

$$\frac{F_A}{F_B} = \frac{\mu_A}{\mu_B}$$

$$\frac{2F_B}{F_B} = \frac{\mu_A}{\mu_B}$$

$$2\mu_B = \mu_A$$

10

$$\dot{V} = \frac{m^3}{s} \cdot \frac{1}{m^2} = \frac{m}{s} \quad \therefore \frac{\dot{V}}{A} = V$$

6. (10 points)

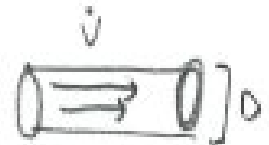
A Newtonian fluid is flowing in a pipe at a Reynolds number of 1500. The viscosity is lowered to 50 % and the density to 60 % of their original values by heating with the volumetric flow rate and the pipe dimensions remaining the same.

A. The new Reynolds number is greater than 2100 and the flow is turbulent

☒ B. The new Reynolds number is less than 2100 and the flow is laminar

C. The Reynolds number remains the same and the flow regime is unchanged

D. Not enough information to determine the flow regime



$$N_{RE} = \frac{D \cdot V \cdot \rho}{\mu}$$

$$N_{RE_A} = 1500 = \frac{D \cdot V \cdot \rho}{\mu}$$

$$1500 = \frac{D \cdot V \cdot (.6 \rho)}{.5 \mu}$$

$$\frac{1500 \cdot (.5)}{.6} = N_{RE_B}$$

$$N_{RE_B} = 1250$$

LAMINAR

$$\mu_B = .5 \mu_A$$

$$\rho_B = .6 \rho_A$$

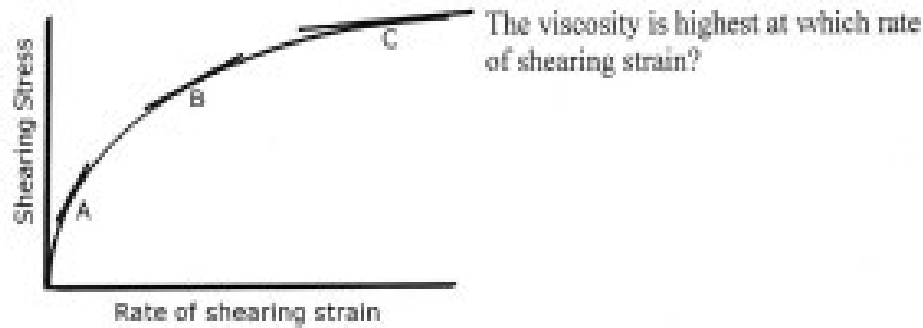
$$D_A = D_B$$

$$\dot{V}_A = \dot{V}_B, A_A = A_B$$

$$\therefore V_A = V_B$$

10

7. (3 points)



Choice	
A	(A) ✓
B	B
C	C
Viscosity is independent of rate of shearing strain	D

A has highest slope ✓

$$\tau = \mu \frac{dv}{dy}$$

Shear Stress ← τ μ ← Viscosity $\frac{dv}{dy}$ ← Rate of Shear ✓

8. (5 points)

$$\left(\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \right) = 0$$

If the continuity equation reduces to what is shown below, this implies _____.

$$\nabla \cdot \mathbf{V} = 0$$

ρ is constant
Steady state

Choice	
the flow is incompressible ✓	A
the flow is steady-state ✓	B
the volume dilatation rate (the rate of change of the volume per unit volume) equals zero	C
A & B	☒ D
A & C	E



9. (30 points)

Using a differential mass balance for fluid flow where v is the velocity vector of motion:

- (i) Show that the continuity equation may be written as:

$$\frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho v), \text{ where the quantity } \nabla \cdot \rho v, \text{ is the divergence of the mass velocity vector } \rho v.$$

- (ii) Also show that the continuity equation $\frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho v)$ for an incompressible fluid flow at steady-state may be written as $\frac{\partial \rho}{\partial t} + v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} + \rho \nabla \cdot v = 0$, and that under these conditions it reduces to:

(i)

$\nabla \cdot v = 0$

— Mass in — Mass out = Mass accumulated

$$\rho v_x \Delta y \Delta z - \rho v_x \Delta y \Delta z + \rho v_y \Delta x \Delta z - \rho v_y \Delta x \Delta z + \rho v_z \Delta x \Delta y - \rho v_z \Delta x \Delta y = \frac{\partial \rho}{\partial t} \Delta x \Delta y \Delta z$$

You should have clearly shown the terms for mass in and the terms for mass out.

$\rho v_x \Delta y \Delta z - \rho v_x \Delta y \Delta z + \rho v_y \Delta x \Delta z - \rho v_y \Delta x \Delta z + \rho v_z \Delta x \Delta y - \rho v_z \Delta x \Delta y = \frac{\partial \rho}{\partial t} \Delta x \Delta y \Delta z$ (10)

— Rearranging:

$$(\rho v_x \Delta y \Delta z - \rho v_x \Delta y \Delta z) + (\rho v_y \Delta x \Delta z - \rho v_y \Delta x \Delta z) + (\rho v_z \Delta x \Delta y - \rho v_z \Delta x \Delta y) = \frac{\partial \rho}{\partial t} \Delta x \Delta y \Delta z$$

64 = 20

— Dividing Both sides by $\Delta x \Delta y \Delta z$ we get:

$$\frac{\rho V_x|_x - \rho V_x|_{x+\Delta x}}{\Delta x} + \frac{\rho V_y|_y - \rho V_y|_{y+\Delta y}}{\Delta y} + \frac{\rho V_z|_z - \rho V_z|_{z+\Delta z}}{\Delta z} = \frac{\partial \rho}{\partial t} \quad (3)$$

— Taking the limit as $\Delta x, \Delta y$ and $\Delta z \rightarrow 0$
 $x, y, z \rightarrow 0$

$$\lim_{\substack{\Delta x \rightarrow 0 \\ x \rightarrow 0}} \frac{\rho V_x|_x - \rho V_x|_{x+\Delta x}}{\Delta x} + \lim_{\substack{\Delta y \rightarrow 0 \\ y \rightarrow 0}} \frac{\rho V_y|_y - \rho V_y|_{y+\Delta y}}{\Delta y} + \lim_{\substack{\Delta z \rightarrow 0 \\ z \rightarrow 0}} \frac{\rho V_z|_z - \rho V_z|_{z+\Delta z}}{\Delta z} = \frac{\partial \rho}{\partial t}$$

— Using the definition of derivative we get: (3)

$$-\frac{\partial \rho V_x}{\partial x} - \frac{\partial \rho V_y}{\partial y} - \frac{\partial \rho V_z}{\partial z} = \frac{\partial \rho}{\partial t} \quad (5)$$

differential operator nabla or del

— The ~~Divergence~~ vector, $\nabla = \frac{\partial}{\partial x} \hat{i} + \frac{\partial}{\partial y} \hat{j} + \frac{\partial}{\partial z} \hat{k}$ (1) can be used w/
 the continuity eq using the dot product

$$-(\nabla \cdot \rho \vec{V}) = \left(\frac{\partial}{\partial x} \hat{i} + \frac{\partial}{\partial y} \hat{j} + \frac{\partial}{\partial z} \hat{k} \right) \cdot (\rho V_x \hat{i} + \rho V_y \hat{j} + \rho V_z \hat{k}) = ? \quad (5)$$

You have not performed the dot product.

$$\therefore \frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho \vec{V}) \quad (5)$$

(i) — If fluid is incompressible $\rho = \text{constant}$

— If fluid is steady state $\frac{\partial \rho}{\partial t} = 0$

— Rearranging continuity eq.

$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho V_x}{\partial x} + \frac{\partial \rho V_y}{\partial y} + \frac{\partial \rho V_z}{\partial z} = 0 \quad (5)$$

- Using product rule and pulling out ρ

$$\frac{\partial \rho}{\partial t} + \rho \left(\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \right) + \cancel{v_x \frac{\partial \rho}{\partial x}} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} = 0$$

- If incompressible $\partial \rho = 0$ what happens to the equation?

- If steady state $\checkmark \frac{\partial \rho}{\partial t} = 0$ (5) You need to show!

$$\therefore \rho \left(\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \right) = 0$$

- Using nabla, ∇ , we get

$$\rho (\nabla \cdot \vec{v}) = 0$$

where is $\vec{v}$? You need to

$$\text{show } \nabla \cdot \vec{v} = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}$$

$$\text{where } \vec{v} = v_x \vec{i} + v_y \vec{j} + v_z \vec{k}$$

ρ is constant $\checkmark$

$$\nabla \cdot \vec{v} = 0$$

(5)

AVERAGE

Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT
SHEET FOR FALL 2021 SEMESTER

STUDENT LEARNING OUTCOME D1: Ability to apply the knowledge of mathematics, science, and engineering.

STUDENT LEARNING OUTCOME D1: Ability to demonstrate mastery of concepts in heat, mass and momentum transport.

Assignments in this area (i) test mastery of concepts by students and identify misconceptions associated with the course material in heat, mass and momentum transport; (ii) test students ability to (a) apply knowledge of mathematics, science (chemistry and physics) and engineering (2) solve algebraic, integral and differential equations analytically or numerically, and (b) apply appropriate conservation laws to solve transport phenomena problems.

Name: Britton Andrews

Title of Assignment: Midterm Exam Due Date: 11/13/21

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Student Outcome 1: Ability to apply the knowledge of intermediate mathematics <i>This assignment tests students' knowledge and application of (1) physics and engineering (2) vector algebra and differential calculus, and (3) appropriate conservation laws transport phenomena problems.</i>	70	48
D1) Ability to demonstrate mastery of concepts in momentum transport. <i>The problem tests the students' mastery of concepts and identify misconceptions associated with course material in momentum transport.</i>	30	25
TOTAL	100	73

85

Heat, Mass and Momentum Transport (Fall 2021): Midterm Exam

October 13, 2021

You will be graded based on your ability to apply knowledge of (1) mathematics, science (chemistry and physics) and engineering (2) intermediate mathematics involving differential and integral calculus, partial differentials and vector algebra. Show clearly each step of your calculation. Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

1. (10 points)

The density of a fluid is 70 lb/ft^3 . The barometric pressure is 14.6 psia , and the local acceleration due to gravity is 32.15 ft/s^2 . The absolute static pressure at the bottom of a column of fluid of height 20 ft. , open to the atmosphere is closest to:

A. 20 psia

B. 24 psia

C. 28 psia

~~D. 32 psia~~

$$P_0 + \rho \frac{g}{g_c} h$$

2

$$14.6 \text{ psia} + \left[\frac{70 \text{ lb}}{\text{ft}^3} \cdot \frac{32.15 \text{ ft}}{\text{s}^2} \cdot 20 \text{ ft} \right]$$

$$14.6 \text{ psia} + [45010 \text{ lb/ft}^2]$$

$$1 - 2 + 20 + 10 + 16 = 48$$

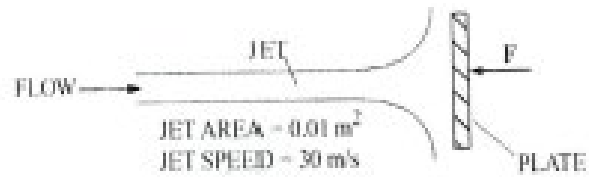
$$2 - 5 + 10 + 5 + 5 = 25$$

2. (20 points)

A horizontal jet of water (density = $1,000 \text{ kg/m}^3$) is deflected perpendicularly to the original jet stream by a plate as shown below. The magnitude of force F (kN) required to hold the plate in place is most nearly:

- (A) 4.5
- (B) 9.0
- (C) 45.0
- (D) 90.0

20



$$\Sigma F_x = \cancel{F_{xg}} + F_{xp} + \cancel{F_{xs}} + R_x = m_2 v_2 - m_1 v_1$$

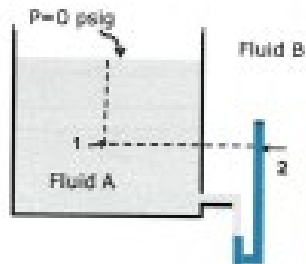
$\uparrow$
 only in
 the x-direction

$m = \rho A$

$$(1000 \text{ kg/m}^3 \cdot A_2) v_2 - \underline{1000 \text{ kg/m}^3 \cdot 0.01 \cdot 30}$$

$$1000 \text{ kg/m}^3 \cdot A_2 v_2 = 300$$

3. (5 points)



Fluid A is contained in a tank open to the atmosphere. At the height indicated, what can be said about the pressure at point 1 with respect to the pressure at point 2?

Choice	
$P_1 > P_2$	 A B C D
$P_2 > P_1$	
$P_2 = P_1$	
not enough information	

4. (5 points)

The correct statement about fluid viscosity is:

- A. Viscosity is not a property of the fluid.
- B. Viscous forces are unimportant for air flows.
- C. Viscous forces act normal to a surface.
- ☒ D. Viscosity is a measure of a fluid's resistance to flow.
- E. Viscous forces are much smaller than pressure forces.

5. (10 points)



Two different Newtonian fluids (A & B) are placed between identical sets of parallel plates as shown below. Each pair of plates is separated by the same distance L . Both bottom plates are pulled to the right at a constant velocity V and both top plates are held stationary. The force required to pull the bottom plate in contact with fluid A (F_A) is twice the force required to pull the bottom plate in contact with fluid B (F_B). The only motion occurring in each fluid is caused by the movement of the bottom plate. Based on this observation and ignoring edge effects, how are viscosities of the two fluids (μ_A and μ_B) related?

Choice	
$\mu_A = \mu_B$ because the force required to move the plate is a function of V and L but not fluid properties	A
μ_A and μ_B are unrelated because the force required to move the plate is only a function of fluid density	B
$\mu_A > \mu_B$ but the exact relationship cannot be determined from the information given	C
$\mu_A = 2\mu_B$ because the force required to move the plate is directly proportional to viscosity	D

10

$Re < 2100$
laminar

6. (10 points)

A Newtonian fluid is flowing in a pipe at a Reynolds number of 1500. The viscosity is lowered to 50 % and the density to 60 % of their original values by heating with the volumetric flow rate and the pipe dimensions remaining the same.

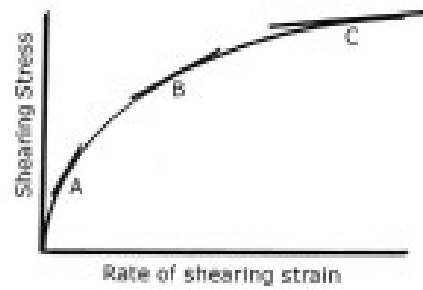
- ☒ A. The new Reynolds number is greater than 2100 and the flow is turbulent
- ☒ B. The new Reynolds number is less than 2100 and the flow is laminar
- ☐ C. The Reynolds number remains the same and the flow regime is unchanged
- ☐ D. Not enough information to determine the flow regime

10

$$1500 = \frac{\rho \cdot v \cdot D}{\mu}$$

$$1500 = \frac{0.60 \rho \cdot v \cdot D}{0.5 \mu}$$

7. (5 points)



The viscosity is highest at which rate of shearing strain?

Choice	
A	☒ A
B	☐ B
C	☐ C
Viscosity is independent of rate of shearing strain	☐ D

5

8. (5 points)

$$\left(\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \right) = 0$$

If the continuity equation reduces to what is shown below, this implies _____.

Choice	
the flow is incompressible	A
the flow is steady-state	B
the volume dilatation rate (the rate of change of the volume per unit volume) equals zero	C
A & B	☒ D
A & C	E

5

9. (30 points)

Using a differential mass balance for fluid flow where $\mathbf{v}$ is the velocity vector of motion:

- (i) Show that the continuity equation may be written as:

$$\frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho \mathbf{v}), \text{ where the quantity } \nabla \cdot \rho \mathbf{v}, \text{ is the divergence of the mass velocity vector } \rho \mathbf{v}.$$

- (ii) Also show that the continuity equation $\frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho \mathbf{v})$ for an incompressible fluid flow at steady-state may be written as $\frac{\partial \rho}{\partial t} + v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} + \rho \nabla \cdot \mathbf{v} = 0$, and that under these conditions it reduces to:

$$\nabla \cdot \mathbf{v} = 0$$



$\rho \mathbf{v}$ can be written the same way in the y and z directions.

mass of rate in - mass of rate out = rate of accumulation

X-direction

mass in: $\rho v_x|_x \Delta y \Delta z$ (1)

mass out: $\rho v_x|_{x+\Delta x} \Delta y \Delta z$ (1)

accumulation

$$\frac{\partial \rho \Delta x \Delta y \Delta z}{\partial t} \quad (2)$$

y-direction

mass in: $\rho v_y|_y \Delta x \Delta z$ (1)

mass out: $\rho v_y|_{y+\Delta y} \Delta x \Delta z$ (1)

z-direction

mass in: $\rho v_z|_z \Delta x \Delta y$ (1)

mass out: $\rho v_z|_{z+\Delta z} \Delta x \Delta y$ (1)

$$51 \equiv 16$$

$$i) \quad PV_x|_x \Delta y \Delta z - PV_x|_{x+\Delta x} \Delta y \Delta z + PV_y|_y \Delta x \Delta z - PV_y|_{y+\Delta y} \Delta x \Delta z + \\ PV_z|_z \Delta x \Delta y - PV_z|_{z+\Delta z} \Delta x \Delta y \quad \text{---} \quad \Delta x \Delta y \Delta z \quad \frac{\partial P}{\partial t}$$

* $\Delta x \Delta y \Delta z$ is a constant therefore it can be taken out of the partial derivative

the next step is to divide both sides by $\Delta x \Delta y \Delta z$:

$$\frac{\Delta y \Delta z [PV_x|_x - PV_x|_{x+\Delta x}]}{\Delta x \Delta y \Delta z} + \frac{\Delta x \Delta z [PV_y|_y - PV_y|_{y+\Delta y}]}{\Delta x \Delta y \Delta z} + \frac{\Delta x \Delta y [PV_z|_z - PV_z|_{z+\Delta z}]}{\Delta x \Delta y \Delta z} = \frac{\partial P}{\partial t}$$

$$\frac{PV_x|_x - PV_x|_{x+\Delta x}}{\Delta x} + \frac{PV_y|_y - PV_y|_{y+\Delta y}}{\Delta y} + \frac{PV_z|_z - PV_z|_{z+\Delta z}}{\Delta z} = \frac{\partial P}{\partial t}$$

$$\lim_{\Delta x \rightarrow 0} \frac{PV_x|_x - PV_x|_{x+\Delta x}}{\Delta x} + \lim_{\Delta y \rightarrow 0} \frac{PV_y|_y - PV_y|_{y+\Delta y}}{\Delta y} + \lim_{\Delta z \rightarrow 0} \frac{PV_z|_z - PV_z|_{z+\Delta z}}{\Delta z} = \frac{\partial P}{\partial t}$$

$$= -\frac{\partial PV_x}{\partial x} - \frac{\partial PV_y}{\partial y} - \frac{\partial PV_z}{\partial z} = \frac{\partial P}{\partial t}$$

$$- \left[\frac{\rho \partial V_x}{\partial x} + \frac{V_x \partial \rho}{\partial x} \right] - \left[\frac{\rho \partial V_y}{\partial y} + \frac{V_y \partial \rho}{\partial y} \right] - \left[\frac{\rho \partial V_z}{\partial z} + \frac{V_z \partial \rho}{\partial z} \right] = \frac{\partial P}{\partial t}$$

$$-\rho \left[\frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y} + \frac{\partial V_z}{\partial z} \right] - \frac{V_x \partial \rho}{\partial x} - \frac{V_y \partial \rho}{\partial y} - \frac{V_z \partial \rho}{\partial z} = \frac{\partial P}{\partial t}$$

$$-\rho \left[\frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y} + \frac{\partial V_z}{\partial z} \right] = \frac{\partial P}{\partial t}$$

This is not how to show that $\frac{\partial P}{\partial t} = -\nabla \cdot \vec{p}$

$$\nabla \cdot \vec{V} = \frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y} + \frac{\partial V_z}{\partial z} \quad \nabla = \frac{\partial}{\partial x} \vec{i} + \frac{\partial}{\partial y} \vec{j} + \frac{\partial}{\partial z} \vec{k} \quad \text{---} \quad \textcircled{1}$$

therefore the continuity equation can be written as

$$\frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho \mathbf{v})$$

(ii) When a fluid is incompressible that means that the density of the fluid has little to no effect and can be assumed to be constant. When a system is in steady-state that means what comes in the system must come out

$$\rho_{in} = \rho_{out}$$

You were to show that $\frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho \mathbf{v})$ may be written

$$\text{as } \frac{\partial \rho}{\partial t} = -v_x \frac{\partial \rho}{\partial x} - v_y \frac{\partial \rho}{\partial y} - v_z \frac{\partial \rho}{\partial z} - (\nabla \cdot \rho \mathbf{v})$$

$$\frac{\partial \rho}{\partial t} + v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} + \cancel{(\nabla \cdot \rho \mathbf{v})} = 0$$

③ steady-state the accumulation term = 0

$$\frac{\partial \rho}{\partial t} = 0$$

$$0 + v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} + \nabla \cdot \rho \mathbf{v} = 0$$

when incompressible ρ is constant and derivative of a constant = 0

$$\text{hence } \frac{\partial \rho}{\partial x} = \frac{\partial \rho}{\partial y} = \frac{\partial \rho}{\partial z} = 0$$

$$0 + 0 v_x + v_y 0 + v_z 0 + \rho \nabla \cdot \mathbf{v} = 0$$

$$\frac{\rho \nabla \cdot \mathbf{v}}{\rho} = 0$$

$$\nabla \cdot \mathbf{v} = 0 \checkmark$$

BELOW AVERAGE

Below Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT
SHEET FOR FALL 2021 SEMESTER

STUDENT LEARNING OUTCOME D1: Ability to apply the knowledge of mathematics, science, and engineering.

STUDENT LEARNING OUTCOME D1: Ability to demonstrate mastery of concepts in heat, mass and momentum transport.

Assignments in this area (i) test mastery of concepts by students and identify misconceptions associated with the course material in heat, mass and momentum transport; (ii) test students ability to (a) apply knowledge of mathematics, science (chemistry and physics) and engineering (2) solve algebraic, integral and differential equations analytically or numerically; and b3) apply appropriate conservation laws to solve transport phenomena problems.

Name:

WILFRIED ZAGRE

Title of Assignment: Midterm Exam

Due Date: 10/15/2021

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Student Outcome 1: Ability to apply the knowledge of intermediate mathematics <i>This assignment tests students' knowledge and application of (1) physics and engineering (2) vector algebra and differential calculus, and (3) appropriate conservation laws transport phenomena problems.</i>	70	31
D1) Ability to demonstrate mastery of concepts in momentum transport. <i>The problem tests the students' mastery of concepts and identify misconceptions associated with course material in momentum transport.</i>	30	20
TOTAL	100	51

(71)

Heat, Mass and Momentum Transport (Fall 2021): Midterm Exam

October 13, 2021

You will be graded based on your ability to apply knowledge of (1) mathematics, science (chemistry and physics) and engineering (2) intermediate mathematics involving differential and integral calculus, partial differentials and vector algebra. Show clearly each step of your calculation. Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

1. (10 points)

The density of a fluid is 70 lb/ft^3 . The barometric pressure is 14.6 psia , and the local acceleration due to gravity is 32.15 ft/s^2 . The absolute static pressure at the bottom of a column of fluid of height 20 ft , open to the atmosphere is closest to:

- A. 20 psia
- B. 24 psia
- C. 28 psia
- D. 32 psia

find low

$$F = m \cdot a$$

$$\rho = 70 \text{ lb/ft}^3$$

$$P = 14.6 \text{ psia}$$

$$a = 32.15 \text{ ft/s}^2$$

$$h = 20 \text{ ft}$$

$$F = \rho g h$$

$$\frac{P}{\rho} = g h$$

$$1 - 10 + 2 + 10 + 9 = 31$$

$$2 - 5 + 10 + 5 = 20$$

2. (20 points)

A horizontal jet of water (density = $1,000 \text{ kg/m}^3$) is deflected perpendicularly to the original jet stream by a plate as shown below. The magnitude of force F (kN) required to hold the plate in place is most nearly:

- (A) 4.5
- (B) 9.0
- (C) ~~45.0~~
- (D) ~~90.0~~



$$\rho = 1000 \text{ kg/m}^3$$

$$V = 30 \text{ m/s}, \quad Q = ?$$

$$A = 0.01 \text{ m}^2$$

$$V = 1 \text{ m}^3$$

$$m = 1000 \text{ kg}$$

$$F_1 = F_2$$

(2)

$$V = 1 \text{ m}^3$$

$$\frac{Q}{A} = V \quad Q = 0.03 \text{ m}^3/\text{s}$$

$$\Rightarrow Q = V \cdot A = 0.01 \text{ m}^2 \times 30 \text{ m/s} = 0.03 \text{ m}^3/\text{s}$$

$$F = \frac{p}{A} = \rho \cdot V$$

$$\rho = \frac{m}{V}$$

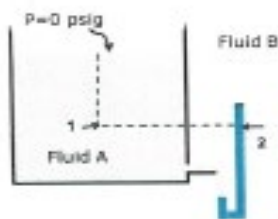
$$m = 100$$

$$\rho = \rho \cdot V \cdot A = 1000 \text{ kg} \times 0.03 = 30$$

9.)

$$\begin{aligned} \sum F_x &= F_{xg} + F_{xp} + F_{xv} + F_{xv} = m_2 V_2 - m_1 V_1 \\ &= P_1 A_1 - P_2 A_2 + R_x = m_2 V_2 - m_1 V_1 \\ &= P_1 A_1 - 0 + R_x = 1000 (g) - 1000 (g) \\ &= P_1 A_1 + m_2 V_2 \end{aligned}$$

3. (5 points)



Fluid A is contained in a tank open to the atmosphere. At the height indicated, what can be said about the pressure at point 1 with respect to the pressure at point 2?

$$P = \frac{F}{A}$$

Choice	
$P_1 > P_2$	☒
$P_2 > P_1$	☐
$P_2 = P_1$	☐
not enough information	☐

4. (5 points)

The correct statement about fluid viscosity is:

- A. Viscosity is not a property of the fluid.
- B. Viscous forces are unimportant for air flows.
- C. Viscous forces act normal to a surface.
- ☒ D. Viscosity is a measure of a fluid's resistance to flow.
- E. Viscous forces are much smaller than pressure forces.

5

5. (10 points)



Two different Newtonian fluids (A & B) are placed between identical sets of parallel plates as shown below. Each pair of plates is separated by the same distance L . Both bottom plates are pulled to the right at a constant velocity V and both top plates are held stationary. The force required to pull the bottom plate in contact with fluid A (F_A) is twice the force required to pull the bottom plate in contact with fluid B (F_B). The only motion occurring in each fluid is caused by the movement of the bottom plate. Based on this observation and ignoring edge effects, how are viscosities of the two fluids (μ_A and μ_B) related?

Choice	
$\mu_A = \mu_B$ because the force required to move the plate is a function of V and L , but not fluid properties	A
μ_A and μ_B are unrelated because the force required to move the plate is only a function of fluid density	B
$\mu_A > \mu_B$ but the exact relationship cannot be determined from the information given	C
$\mu_A = 2\mu_B$ because the force required to move the plate is directly proportional to viscosity	D

10

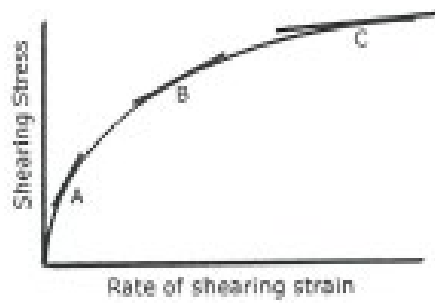
6. (10 points)

A Newtonian fluid is flowing in a pipe at a Reynolds number of 1500. The viscosity is lowered to 50 % and the density to 60 % of their original values by heating with the volumetric flow rate and the pipe dimensions remaining the same.

- A. The new Reynolds number is greater than 2100 and the flow is turbulent
- ✓ B. The new Reynolds number is less than 2100 and the flow is laminar
- C. The Reynolds number remains the same and the flow regime is unchanged
- D. Not enough information to determine the flow regime

10

7. (5 points)



The viscosity is highest at which rate of shearing strain?



Choice	
A	A
B	B
C	C
Viscosity is independent of rate of shearing strain	D

8. (5 points)

$$\left(\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} \right) = 0$$

If the continuity equation reduces to what is shown below, this implies _____.

D ✓

Choice	
the flow is incompressible	A
the flow is steady-state	B
the volume dilatation rate (the rate of change of the volume per unit volume) equals zero	C
A & B	D
A & C	E

5 ✓

9. (30 points)

Using a differential mass balance for fluid flow where v is the velocity vector of motion:

- (i) Show that the continuity equation may be written as:

$$\frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho v), \text{ where the quantity } \nabla \cdot \rho v, \text{ is the divergence of the mass velocity vector } \rho v.$$

- (ii) Also show that the continuity equation $\frac{\partial \rho}{\partial t} = -(\nabla \cdot \rho v)$ for an incompressible fluid flow at steady-state may be written as

$$\frac{\partial \rho}{\partial t} + v_x \frac{\partial \rho}{\partial x} + v_y \frac{\partial \rho}{\partial y} + v_z \frac{\partial \rho}{\partial z} + \rho \nabla \cdot v = 0, \text{ and that under these conditions it reduces to:}$$

$$\nabla \cdot v = 0$$

i) Continuity equation

Mass in - Mass out = Mass accumulated

For mass In: $\rho \cdot V$

$$x_{\text{direct}} = \rho V_x|_x \text{ (1)}, y_{\text{direct}} = \rho V_y|_y \text{ (1)}, z_{\text{direct}} = \rho V_z|_z \text{ (1)}$$

For mass out:

$$x_{\text{direct}} = \rho V_x|_{x+\Delta x} \text{ (1)}, y_{\text{direct}} = \rho V_y|_{y+\Delta y} \text{ (1)}, z_{\text{direct}} = \rho V_z|_{z+\Delta z} \text{ (1)}$$

mass accumulated: $\frac{\partial \rho}{\partial t} \Delta x \Delta y \Delta z$

$$\frac{\partial (\rho \Delta x \Delta y \Delta z)}{\partial t}$$

$$\frac{\partial}{\partial t} (\rho V_x|_x - \rho V_x|_{x+\Delta x}) \Delta y \Delta z + (\rho V_y|_y - \rho V_y|_{y+\Delta y}) \Delta x \Delta z + (\rho V_z|_z - \rho V_z|_{z+\Delta z}) \Delta x \Delta y$$

(2)

Divide by $\Delta x \Delta y \Delta z$ and take limit $\Delta \rightarrow 0$

$$\Delta x \Delta y \Delta z \frac{\partial \rho}{\partial t} = (\rho V_x|_x - \rho V_x|_{x+\Delta x}) \frac{\Delta y \Delta z}{\Delta x \Delta y \Delta z} - (\rho V_y|_y - \rho V_y|_{y+\Delta y}) \frac{\Delta x \Delta z}{\Delta x \Delta y \Delta z} - (\rho V_z|_z - \rho V_z|_{z+\Delta z}) \frac{\Delta x \Delta y}{\Delta x \Delta y \Delta z} \quad (1)$$

$$\Rightarrow \lim_{\Delta x \rightarrow 0} \left(\frac{\rho V_x|_x - \rho V_x|_{x+\Delta x}}{\Delta x} \right) + \lim_{\Delta y \rightarrow 0} \left(\frac{\rho V_y|_y - \rho V_y|_{y+\Delta y}}{\Delta y} \right) + \lim_{\Delta z \rightarrow 0} \left(\frac{\rho V_z|_z - \rho V_z|_{z+\Delta z}}{\Delta z} \right) = - \frac{\partial \rho}{\partial t} \quad (2)$$

$$\nabla \cdot (\vec{\rho} \vec{V}) = \left(\frac{\partial}{\partial x} \rho V_x + \frac{\partial}{\partial y} \rho V_y + \frac{\partial}{\partial z} \rho V_z \right) = \frac{\partial \rho}{\partial t} + \rho \nabla \cdot \vec{V} \quad (3)$$

$$\rho \nabla \cdot \vec{V} = - \frac{\partial \rho}{\partial t} - \rho \nabla \cdot \vec{V} = \rho \nabla \cdot \vec{V} \quad (4)$$

$$\nabla \cdot \rho \vec{V} = \left(\frac{\partial}{\partial x} \rho V_x + \frac{\partial}{\partial y} \rho V_y + \frac{\partial}{\partial z} \rho V_z \right) = \frac{\partial \rho}{\partial t} + \rho \nabla \cdot \vec{V} \quad (5)$$

$$\frac{\partial \rho}{\partial t} = - \rho \nabla \cdot \vec{V} \quad \text{and} \quad \nabla \cdot \rho \vec{V} = \frac{\partial \rho}{\partial t} + \rho \nabla \cdot \vec{V}$$

$$\frac{\partial \rho}{\partial t} = - \nabla \cdot \rho \vec{V} \quad (6)$$

$$29 \equiv 9 \quad (7)$$

ii) Incompressible fluid $\rho = \text{const}$ steady state $\frac{\partial}{\partial t} = 0$
 from $\nabla \cdot \rho \mathbf{V}$

$$\nabla \cdot \rho \mathbf{V} = \frac{\partial \rho V_x}{\partial x} + \frac{\partial \rho V_y}{\partial y} + \frac{\partial \rho V_z}{\partial z}$$

Product Rule:

$$\rho \left(\frac{\partial V_x}{\partial x} + V_x \frac{\partial \rho}{\partial x} \right) + \rho \left(\frac{\partial V_y}{\partial y} + V_y \frac{\partial \rho}{\partial y} \right) + \rho \left(\frac{\partial V_z}{\partial z} + V_z \frac{\partial \rho}{\partial z} \right) = 0$$

$$\left(\frac{\partial \rho V_x}{\partial x} + \frac{\partial \rho V_y}{\partial y} + \frac{\partial \rho V_z}{\partial z} \right) = \left(\frac{\partial \rho}{\partial t} \right) (V_x + V_y + V_z) = 0$$

at steady state $\frac{\partial}{\partial t} = 0$

$$\nabla \cdot \mathbf{V} = \left(\frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y} + \frac{\partial V_z}{\partial z} \right) = 0$$

$$\frac{\partial \rho}{\partial t} + V_x \frac{\partial \rho}{\partial x} + V_y \frac{\partial \rho}{\partial y} + V_z \frac{\partial \rho}{\partial z} = 0 \Rightarrow \rho \nabla \cdot \mathbf{V} = 0$$

HEAT, MASS AND MOMENTUM TRANSPORT FALL 2021

Title of Assignment: FINAL EXAM

TOPICS COVERED IN FINAL EXAM

FINAL EXAM covered the following topics:

1. Fourier's law of heat conduction and heat transfer through multi-layers of cylinders with an insulated pipe
2. Fluid behavior in turbulent and laminar flow and pressure drops during flow in pipes
3. Fourier's law of heat conduction and heat transfer through insulated pipes
4. Fick's law of molecular diffusion through stagnant air in a vent and calculation of loss of material due to evaporation

Heat, Mass and Momentum Transport: Final Exam (Fall 2021)

December 1, 2021

Answer all questions. You will be graded based on your ability to formulate, and solve engineering problems. Show clearly each step of your calculation. Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

1. (a) Water is flowing at 50 °F through a long horizontal smooth 3-in Schedule 40 steel pipe at a velocity of 8 ft/s. Calculate the pressure drop in lb_f/in² per 50 ft of pipe. Assume the fluid density $\rho = 62.42 \text{ lb}_m\text{ft}^{-3}$, and the viscosity $\mu = 8.80 \times 10^{-4} \text{ lb}_m\text{ft}^{-1}\text{s}^{-1}$.

2. A steel pipe carrying steam has an outside diameter of 89 mm. It is lagged with 76 mm of insulation having an average $k = 0.043 \text{ W/m.K}$. Two thermocouples, one located at the interface between the pipe wall and the insulation and the other at the surface of the insulation, give temperatures of 115°C and 32°C, respectively. Calculate the heat loss in W per meter of pipe.

3. A condenser for the overhead methanol vapor from a distillation column has a small cooler with a vent. The temperature in the cooler and the vent is 21 °C and the partial pressure of methanol in the cooler is 100 mm Hg. The inner diameter of the vent is 38 mm and the length of the vent is 0.4 m. Atmospheric pressure is 10^5 Pa . The diffusivity of methanol in air D_{AB} is given by the relationship $PD_{AB} = 1.526 \text{ Pa.m}^2/\text{s}$ for the air-methanol system at 294 K where P is the total pressure is 10^5 Pa , and D_{AB} is the diffusivity. The total pressure $P = CRT$ where C is the total concentration, the partial pressure of A is $P_A = C_A RT$ where C_A is the concentration of A, R is the gas constant (8.314 J/mol.K) and T the temperature.

For a two-component methanol-air (A-B) system, the molar flux of A is given by:

$$N_A = -D_{AB} \frac{dC_A}{dy} + \frac{C_A}{C} (N_A + N_B)$$

Calculate the loss of methanol due to molecular diffusion in a day through the vent at steady-state, assuming stagnant air and the partial pressure of methanol at the outlet of the vent to be zero. The molar mass of methanol may be taken as 32.04 g/mol.

Heat, Mass and Momentum Transport.

Final Exam

1. Given:

3-in Schedule 40 Steel pipe ①

50 ft of pipe ①

Flow rate of water $V = 8 \text{ ft/s}$ ①

$\rho_{\text{water}} = 62.42 \text{ lbm/ft}^3$ ①

$\mu_{\text{water}} = 8.80 \times 10^{-4} \text{ lbm/ft.s}$ ①

Pipe roughness = smooth pipe ②

ID 3-in Schedule 40 Steel pipe = 3.068 in ③

2.1-10

2.2-10

2.3-20
40

$$\Delta P = \frac{2 \rho f L V^2}{D} \quad \underline{\underline{8}}$$

$$N_{Re} = \frac{\rho V D}{\mu} \quad \underline{\underline{2}}$$

$$N_{Re} = \frac{62.42 \times 8 \times 3.068}{12 \times 8.80 \times 10^{-4}} = 1.451 \times 10^5 \quad \underline{\underline{5}}$$

From the plot for a smooth pipe, $f = 0.0041$ for $N_{Re} = 1.451 \times 10^5$ ⑤

$$\therefore \Delta P = \frac{2 \times 62.42 \times 0.0041 \times 50 \times 64}{3.068} \times \frac{\text{lbm} \cdot \text{ft} \cdot \text{ft}^2}{\text{ft}^2 \cdot \text{s}^2} \times \frac{1}{\text{ft}} \times \frac{1 \text{ lbm} \cdot \text{s}^2}{32.174 \text{ ft} \cdot \text{lbm}} \times \frac{1 \text{ ft}^2}{144 \text{ in}^2}$$

$$\Delta P = \frac{2 \times 62.42 \times 0.0041 \times 50 \times 64 \times 12}{3.068 \times 32.174 \times 144} \frac{\text{lbm}}{\text{in}^2} = 1.383 \frac{\text{lbm}}{\text{in}^2} \quad \underline{\underline{5}}$$

Heat, Mass & Momentum Transport Final Exam

2.

Given:

OD of steel pipe = 89 mm ①

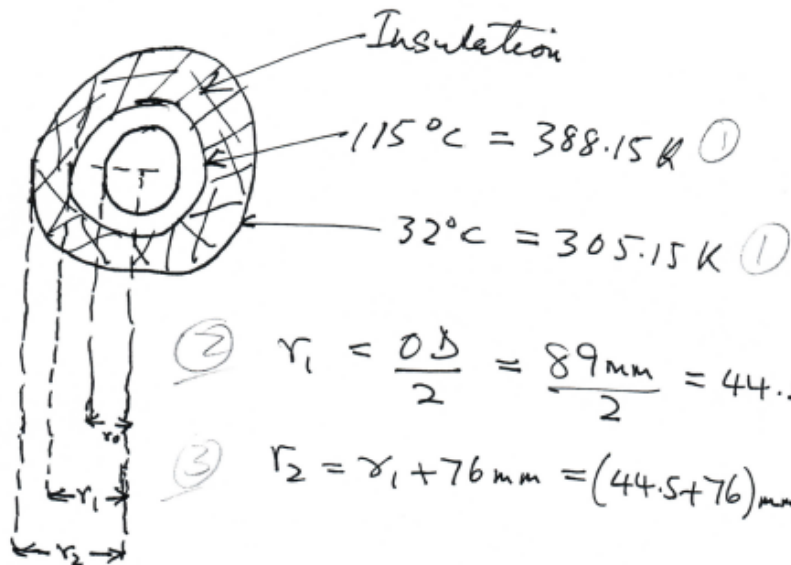
Thickness of insulation = 76 mm ①

k of insulation = $0.043 \text{ W/m}\cdot\text{K}$ ①

e.1-10

e.2-10

e.3-10
30



② $r_1 = \frac{\text{OD}}{2} = \frac{89 \text{ mm}}{2} = 44.5 \text{ mm}$

③ $r_2 = r_1 + 76 \text{ mm} = (44.5 + 76) \text{ mm} = 120.5 \text{ mm}$

$T_1 - T_2 = \frac{r_2 q_2 \ln\left(\frac{r_2}{r_1}\right)}{k_{\text{insulation}}}$

where $T_1 = 388.15 \text{ K}$ and
 $T_2 = 305.15 \text{ K}$

⑥ $q_2 = \frac{T_1 - T_2}{\frac{\ln\left(\frac{r_2}{r_1}\right)}{k_{\text{insulation}}}} = \frac{(388.15 - 305.15) \text{ K}}{\frac{\ln\left(\frac{120.5}{44.5}\right)}{0.043 \text{ W/m}\cdot\text{K}}}$

$= \frac{83 \text{ K} (0.043 \text{ W/m}\cdot\text{K})}{\ln\left(\frac{120.5}{44.5}\right)}$ ②

Heat, Mass & Momentum Transport Final Exam

$$r_o q_o = \frac{83 \text{ K} (0.043 \text{ W/m} \cdot \text{K})}{\ln 2.708} = \frac{3.569 \text{ W/m}}{0.9962}$$

$$r_o q_o = \frac{3.569}{0.9962} \text{ W/m} = 3.583 \text{ W/m} \quad (3)$$

$Q = 2\pi L r_o q_o = 2\pi L r_i q_i$, where Q is the heat loss in W for pipe of length L

$\therefore$ For 1m of pipe length,

$$Q = 2\pi L r_o q_o = 2\pi (1\text{m}) (3.583 \text{ W/m}) \quad (2)$$

$$Q = 2\pi (3.583 \text{ W})$$

$$Q = 22.51 \text{ W} \quad (3)$$

3. $T_{\text{vent}} = 21^\circ\text{C} = 294.15\text{ K}$ ⑤
 Diameter of vent $= 10 = 38\text{ mm}$ ①
 Length of vent $= 0.4\text{ m}$ ①

e.1-5
 e.2-15
 e.3-10

$$P_{DAB} = 1.526\text{ Pa}\cdot\text{m}^2/\text{s}$$
 ①

$$P_{A1} = 100\text{ mm Hg}$$
 ⑤

$$P_{A2} = 0\text{ mm Hg}$$
 ⑤

$$\text{Atmospheric pressure} = 10^5\text{ Pa}$$
 ⑤

$$N_{A2} = -D_{AB} \frac{dC_A}{dz} + \frac{C_A}{C} (N_{A2} + N_{B2})$$
 ①

where N_{A2} = flux of A and N_{B2} = flux of B represent
 molar flux and air respectively
 For stagnant air, $N_B = 0$ ①

$$\therefore N_{A2} = -D_{AB} \frac{dC_A}{dz} + \frac{C_A}{C} N_{A2}$$
 ②

$$N_{A2} \left(1 - \frac{C_A}{C}\right) = -D_{AB} \frac{dC_A}{dz}$$

$$N_{A2} dz = - \frac{D_{AB} dC_A}{1 - \frac{C_A}{C}}$$

$$N_{A2} \int_{z_1}^{z_2} dz = - D_{AB} \int_{C_{A1}}^{C_{A2}} \frac{dC_A}{1 - \frac{C_A}{C}}$$
 ③

$$N_{Az}(z_2 - z_1) = -D_{AB} \left[-C \ln \left(1 - \frac{C_A}{C} \right) \right]_{C_{A1}}^{C_{A2}}$$

$$N_{Az}(z_2 - z_1) = D_{AB} \left[C \ln \left(1 - \frac{C_A}{C} \right) \right]_{C_{A1}}^{C_{A2}}$$

$$N_{Az}(z_2 - z_1) = D_{AB} C \ln \left[\frac{C - C_{A2}}{C - C_{A1}} \right]$$

$$\therefore N_{Az} = \frac{D_{AB}}{z_2 - z_1} C \ln \left[\frac{C - C_{A2}}{C - C_{A1}} \right] \quad (4)$$

$$P = CRT \text{ and } P_A = C_A RT \quad (1/2)$$

$$\text{Hence } N_{Az} = \frac{D_{AB} P}{(z_2 - z_1) RT} \ln \left[\frac{\frac{P}{RT} - \frac{P_{A2}}{RT}}{\frac{P}{RT} - \frac{P_{A1}}{RT}} \right]$$

$$N_{Az} = \frac{D_{AB} P}{(z_2 - z_1) RT} \ln \left(\frac{P - P_{A2}}{P - P_{A1}} \right) \quad (2)$$

$$z_2 - z_1 = \text{length of vent} = 0.4 \text{ m} \quad (1)$$

$$P_{A2} = 0 \quad (1/2)$$

$$P_{A1} = \frac{100 \text{ mmHg}}{760 \text{ mmHg}} \times 1.013 \times 10^5 P_a = 0.1329 \times 10^5 P_a \quad (1/2)$$

$$\therefore N_{Az} = \frac{1.526}{8.314 \times 294 \times 0.4} \ln \frac{10^5}{10^5 - 0.1329 \times 10^5} = \frac{1.526}{8.314 \times 294 \times 0.4} \ln \frac{10^5}{0.8671 \times 10^5}$$

$$\begin{aligned}
 N_{A2} &= \frac{1.526 \times 0.1426 \left(\frac{N}{m^2} \cdot \frac{m^2}{s} \right)}{8.314 \times 294 \times 0.4 \left(\frac{J}{mol \cdot K} \right) K \cdot m} \\
 &= \frac{0.2182 \left(\frac{N}{s} \right)}{977.7264 \left(\frac{J \cdot m}{mol} \right)} = \frac{0.2182 \left(\frac{N}{s} \right)}{977.7264 \left(\frac{N \cdot m}{mol} \right) m} \\
 &= \frac{2.2315 \times 10^{-4} \left(\frac{1}{s} \right)}{m^2/mol}
 \end{aligned}$$

$$N_{A2} = 2.2315 \times 10^{-4} \frac{mol}{m^2 s} \quad \textcircled{2}$$

In a day of 24 hours, the loss of methanol

$$= N_{A2} \times A \times \frac{24 \text{ hours}}{\text{day}} \cdot \frac{1 \text{ day}}{3600 s} \quad \textcircled{1}$$

Where $A = \pi \frac{D^2}{4}$ and $D = \text{diameter of the vent}$

$$\begin{aligned}
 \text{Methanol loss/day} &= 2.2315 \times 10^{-4} \frac{mol}{m^2 \cdot s} \cdot \left| \frac{24 h}{\text{day}} \right| \cdot \left| \frac{1 \text{ day}}{3600 s} \right| \cdot \frac{\pi}{4} (0.038)^2 \\
 &= 2.2315 \times 10^{-4} \times 24 \times 3600 \times \frac{\pi}{4} \times (0.038)^2 \text{ mol} \\
 &= 2.187 \times 10^{-2} \text{ mol} \\
 &= 0.6992 g \\
 &= 0.70 g
 \end{aligned}$$

ABOVE AVERAGE

Above Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME
ASSESSMENT SHEET FOR FALL 2021 SEMESTER

ABET OUTCOME D1: Ability to identify, formulate, and solve engineering problems.

Assignments that test competency in this area will include problems that test a student's ability to (1) apply systematic problem solving methodology that includes identifying all known and unknown variables, (2) construction of reasonable schematic representation of the problem, listing appropriate assumptions, determining appropriate property values, (3) applying the appropriate conservation laws, physical and chemical laws, and mathematics to solve the problem, and (4) evaluating the reasonableness of the computed results.

Name: Canidanan Coulibaly

Title of Assignment: Final Exam

Date: 12/06/21

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
D1) Ability to identify engineering problems. <i>The problem tests the students' ability to (i) understand the given problem, identify the subject area and concept(s) involved, (ii) draw a labeled sketch of system, and (iii) identify the applicable system of units.</i>	25	22
D1) Ability to formulate engineering problems. <i>The problem tests the students' ability to (i) define the known and unknown variables, (ii) state relevant laws and equations needed to solve the problem, and (iii) list and apply any assumptions to the relevant laws and equations to obtain equation specific to the problem.</i>	35	33
D1) Ability to solve engineering problems. <i>The problem tests the students' ability to (i) implement a strategy to solve the engineering problem, (ii) solve the problem showing consistent units throughout, and (iii) evaluating and interpreting the result.</i>	40	34
TOTAL	100	89

Exercise 1

$$\rho = 62.42 \text{ lbm/ft}^3 \quad (1)$$

$$\mu = 8.80 \times 10^{-4} \text{ lbm/ft.s} \quad (1)$$

$$D = 3 \text{ in each } 40 = 3.068 \text{ in} = 0.25 \text{ ft} \quad (3)$$

$$L = 50 \text{ ft} \quad (1) \quad ; \quad V = 8 \text{ ft/s} \quad (1)$$

$$\Delta P_f = \frac{2 f \Delta L \rho V^2}{D} \quad (8)$$

+ Let's find f first

$$N_{Re} = \frac{\rho V D}{\mu} = \frac{(62.42 \text{ lbm/ft}^3)(8 \text{ ft/s})(0.25 \text{ ft})}{8.80 \times 10^{-4} \text{ lbm/ft.s}} = 1.42 \times 10^5 \quad (5)$$

From the Moody chart, the friction factor for $N_{Re} = 1.42 \times 10^5$ and smooth pipe is $f = 0.007$ ~~(2)~~
 $f = 0.004$ ~~(2)~~

Hence:

$$\Delta P_f = \frac{2 (0.007) (50 \text{ ft}) (62.42 \text{ lbm/ft}^3) (8 \text{ ft/s})^2}{(0.25 \text{ ft})}$$

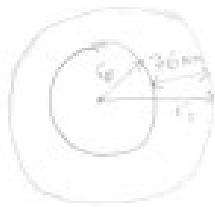
$$= (11186 \frac{\text{lbm}}{\text{ft.s}^2}) \left(\frac{\text{lb.f.s}^2}{32.17 \text{ lbm.ft}} \right) \left(\frac{\text{ft}^2}{144 \text{ in}^2} \right) \quad (3 \frac{1}{2})$$

$$\Delta P_f = 2.41 \text{ lb.f/in}^2 \quad (4)$$

$$\begin{aligned} e.1 - 10 + 9 + 3 &= 22 \\ e.2 - 10 + 9 + 9 \frac{1}{2} &= 28 \frac{1}{2} \\ e.3 - 15 + 10 + 4 &= 29 \\ &79 \frac{1}{2} \end{aligned}$$

$$\begin{aligned} e.1 - 10 \\ e.2 - 10 \\ e.3 - 15 \\ \hline 35 \end{aligned}$$

Exercise 2



$$OD = 89 \text{ mm} = 0.089 \text{ m} \quad (1)$$

$$r_0 = 0.044 \text{ m} \quad (2)$$

$$x_{ins} = 76 \text{ mm} = 0.076 \text{ m} \quad (1)$$

$$r_1 = r_0 + x_{ins} = 0.12 \text{ m} \quad (2) \quad = 0.1205$$

$$T_{in} = 388 \text{ K} \quad (1) \quad T_o = 305 \text{ K} \quad (1)$$

$$L = 1 \text{ m}$$

$$(1) \quad k_{av} = 0.043 \text{ W/m.K}$$

$$(4) \quad R = \frac{\ln(r_1/r_0)}{2\pi k L} = \frac{\ln(0.12/0.044)}{2\pi (0.043 \text{ W/m.K}) \times 1 \text{ m}} = 3.71 \frac{\text{K}}{\text{W}} \quad (5)$$

$$\text{Thus } Q = \frac{T_{in} - T_o}{R} = \frac{(388 - 305) \text{ K}}{3.71 \frac{\text{K}}{\text{W}}} = 22.4 \text{ W} \quad (5)$$

$$e.1 - 9$$

$$e.2 - 9$$

$$e.3 - 10$$

$$\underline{28}$$

Exercise 3

$$P_{A1} = \frac{760 \text{ mmHg}}{760 \text{ mmHg}} = 0.13 \text{ atm}$$

$$y_2 = 0.4 \text{ m}$$

$$N_B = 0$$

$$P_{\text{atm}} = 10^5 \text{ Pa}$$

$$D_{AB} = 1.526 \text{ Pa} \cdot \text{m}^2/\text{s}$$

$$R = 8.314 \text{ J/mol} \cdot \text{K}$$

$$N_A = -D_{AB} \frac{dC_A}{dy} + \frac{C_A}{C} (N_A + N_B)$$

$$N_A = -D_{AB} \frac{dC_A}{dy} + \frac{C_A}{C} N_A$$

since $N_B = 0$ assuming stagnant air

$$\frac{C_A}{C} = \frac{P_A}{P} \quad C_A = \frac{P_A}{RT}$$

$$\text{Thus, } N_A = -\frac{D_{AB}}{RT} \frac{dP_A}{dy} + \frac{P_A}{P} N_A$$

$$N_A \left(1 - \frac{P_A}{P}\right) = -\frac{D_{AB}}{RT} \frac{dP_A}{dy}$$

$$N_A \int_{y_1}^{y_2} dy = -\frac{D_{AB}}{RT} \int_{P_{A1}}^{P_{A2}} \frac{dP_A}{1 - \frac{P_A}{P}}$$

$$N_A (y_2 - y_1) = \frac{D_{AB} P}{RT} \ln \left[\frac{P - P_{A2}}{P - P_{A1}} \right]$$

$$\Delta y = 0.4 \text{ m} \quad P = 10^5 \quad P_{A2} = 0 \quad P_{A1} = 13400 \text{ Pa} \quad D_{AB} = 1.526 \times 10^{-5} \text{ m}^2/\text{s}$$

$$N_A = \frac{D_{AB} P}{RT \Delta y} \ln \left[\frac{P - P_{A2}}{P - P_{A1}} \right]$$

$$N_A = \frac{(1.526 \times 10^{-5} \text{ m}^2/\text{s}) \ln \left(\frac{10^5}{10^5 - 13400} \right)}{(8.314 \text{ J/mol} \cdot \text{K})(294 \text{ K})(0.4 \text{ m})} = 2.17 \times 10^{-4} \text{ mol/s}$$

$$2.23 \times 10^{-4} \text{ mol/s}$$

$$e.1 - 3$$

$$e.2 - 9\frac{1}{2}$$

$$e.3 - 4$$

$$16\frac{1}{2}$$

AVERAGE

Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME
ASSESSMENT SHEET FOR FALL 2021 SEMESTER

ABET OUTCOME D1: Ability to identify, formulate, and solve engineering problems.

Assignments that test competency in this area will include problems that test a student's ability to (1) apply systematic problem solving methodology that includes identifying all known and unknown variables, (2) construction of reasonable schematic representation of the problem, listing appropriate assumptions, determining appropriate property values, (3) applying the appropriate conservation laws, physical and chemical laws, and mathematics to solve the problem, and (4) evaluating the reasonableness of the computed results.

Name: Bruce Wright

Title of Assignment: Final Exam

Date: 12/06/21

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
D1) Ability to identify engineering problems. <i>The problem tests the students' ability to (i) understand the given problem, identify the subject area and concept(s) involved, (ii) draw a labeled sketch of system, and (iii) identify the applicable system of units.</i>	25	18
D1) Ability to formulate engineering problems. <i>The problem tests the students' ability to (i) define the known and unknown variables, (ii) state relevant laws and equations needed to solve the problem, and (iii) list and apply any assumptions to the relevant laws and equations to obtain equation specific to the problem.</i>	35	28
D1) Ability to solve engineering problems. <i>The problem tests the students' ability to (i) implement a strategy to solve the engineering problem, (ii) solve the problem showing constant units throughout, and (iii) evaluating and interpreting the result.</i>	40	28
TOTAL	100	74

1) Given

$$T = 50^\circ F$$

$$D = 3 \text{ in} = 0.25 \text{ ft}$$

$$T = 8 \text{ ft/s}$$

$$L = 50 \text{ ft}$$

$$P = 62.42 \text{ lb/ft}^3$$

$$\mu = 8.1 \times 10^{-4} \text{ lb/ft}^2 \cdot \text{s}$$



Formulas:

$$Re = \frac{P V D}{\mu}$$

$$\Delta P_f = 4f \left(\frac{L}{D} \right) \rho \frac{V^2}{2 \cdot g_c}$$

$$\Delta P_f = 4f \left(\frac{L}{D} \right) \rho \frac{V^2}{2 \cdot g_c}$$

$$Re = \frac{P V D}{\mu}$$

$$= \frac{62.42 \text{ lb/ft}^3 \cdot 8 \text{ ft/s} \cdot 0.25 \text{ ft}}{8.1 \times 10^{-4} \text{ lb/ft}^2 \cdot \text{s}}$$

$$= 141863.63 > 2100 \Rightarrow \text{Turbulent}$$

- from graph

$$f = 0.004$$

$$\Delta P_f = 4f \left(\frac{L}{D} \right) \rho \frac{V^2}{2 \cdot g_c}$$

$$\Delta P_f = 4f \left(\frac{L}{D} \right) \rho \frac{V^2}{2 \cdot g_c}$$

$$= 4 \cdot 0.004 \cdot \frac{50 \text{ ft}}{0.25 \text{ ft}} \cdot \frac{62.42 \text{ lb/ft}^3}{2 \cdot 32.174 \text{ ft/s}^2}$$

$$= 0.016 \cdot 200 \cdot 0.9942$$

$$= 3.183 \text{ lb/ft}^2$$

$$\frac{3.183 \text{ lb/ft}^2 \cdot 144 \text{ in}^2}{1 \text{ ft}^2} = 458.36 \text{ lb/in}^2$$

$$e. 1 - 4 + 5 + 4 = 13$$

$$e. 2 - 4 + 6 + 11 = 21$$

$$e. 3 - 11\frac{1}{2} + 5 + 4 = 20\frac{1}{2}$$

$$e. 1 - 4$$

$$e. 2 - 4$$

$$e. 3 - 11\frac{1}{2}$$

2) Given:

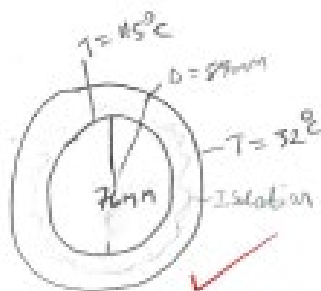
$$OD = 89 \text{ mm} = 0.089 \text{ m} \quad (1)$$

$$ID = 76 \text{ mm} = 0.076 \text{ m} \quad (2)$$

$$k_{ins} = 0.043 \text{ W/m}\cdot\text{K} \quad (3)$$

$$T_{is} = 115^\circ\text{C} = 388 \text{ K} \quad (4)$$

$$T_{os} = 32^\circ\text{C} = 305 \text{ K} \quad (5)$$



Formulas:

$$Q_p = \frac{T_a - T_b}{\left(\frac{1}{h_o} + \frac{r_o}{k_o} + \frac{r_i}{k_i} + \frac{1}{h_i} \right)}$$

$$A = 2\pi r$$

$$Q_p = \frac{T_a - T_b}{\left(\frac{1}{h_o} + \frac{r_o}{k_o} + \frac{r_i}{k_i} + \frac{1}{h_i} \right)} \quad (6)$$

$$e.1 - 5$$

$$e.2 - 6$$

$$e.3 - \frac{5}{16}$$

$$T = 388 \text{ K} - 305 \text{ K}$$

$$Q = \frac{0.089 \text{ m} + 0.076 \text{ m}}{0.043 \text{ W/m}\cdot\text{K}} + 0$$

$$= \frac{83 \text{ K}}{5.14 \text{ W/m}\cdot\text{K}}$$

$$= 21.63 \text{ W/m}$$

$$r_{ins} = 21.63 \text{ W/m} \cdot A$$

$$A = 2\pi r$$

$$= 2\pi (0.039)$$

$$= 0.238 \text{ m}$$

$$21.63 \text{ W/m} \cdot 0.238 \text{ m} = 5.14 \text{ W/m}^2$$

$$r_o Q_o = \frac{T_1 - T_2}{\frac{1}{k} \left(\frac{r_2}{r_1} \right)}$$

$$T_1 = 388 \text{ K}$$

$$T_2 = 305 \text{ K}$$

$$r_2 = \frac{(0.089 + 0.076)}{2} \text{ m}$$

$$r_1 = \frac{(0.089)}{2} \text{ m}$$

$$k_{insulation} = 0.043 \text{ W/m}\cdot\text{K}$$

3) 6.4m:

$$T_{cr} = 21^{\circ}C = 294.15K$$

$$P_n = 10^5 Pa \div 760 = 0.1315 atm$$

$$ID = 38mm = 0.038m$$

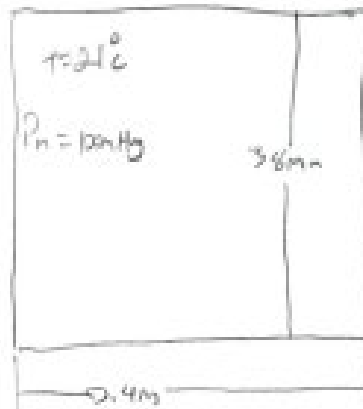
$$L = 0.4m$$

$$P = 10^5 Pa$$

$$D_{AB} = 1.526 \text{ Pa} \cdot m^2/s$$

$$R = 8.314 \text{ J/mol} \cdot K$$

$$M_M = 32.04 \text{ g/mol}$$



Assume:

- Steady state

- Constant density

- Stream Air - $N_2 = 0$

Formula:

$$N_A = \frac{D_{AB} P}{R T Z} \ln \left(\frac{P_{A2}}{P_{A1}} \right)$$

$$1 - P_A = P_B$$

$$D_{AB} \propto \frac{T^{1.5}}{P}$$

e.1-4

e.2-11

e.3-4
19

$$N_A = \frac{D_{AB} P}{R T Z} \ln \left(\frac{P_{A2}}{P_{A1}} \right)$$

$$= D_{AB} \cdot \frac{T^{1.5}}{P} \ln \left(\frac{P_{A2}}{P_{A1}} \right)$$

$$= 0.050$$

$$N_A = \frac{0.0504 \cdot 10^5}{8.314 \text{ J/mol} \cdot K \cdot 294.15 K \cdot 0.4m} \ln \left(\frac{1.526 \text{ Pa} \cdot m^2/s}{0.526} \right)$$

$$= \frac{5040}{977.4264} \cdot 1.065$$

$$= 5.49 \text{ Pa} \cdot m^2/s$$

1 min	1 hr	1 day
$60s$	$3600s$	$24hr$

~~$6.55 \times 10^5 \text{ Pa} \cdot m^2/s$~~

BELOW AVERAGE

Below Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME
ASSESSMENT SHEET FOR FALL 2021 SEMESTER**

ABET OUTCOME D1: Ability to identify, formulate, and solve engineering problems.

Assignments that test competency in this area will include problems that test a student's ability to (1) apply systematic problem solving methodology that includes identifying all known and unknown variables (2) construction of reasonable schematic representation of the problem, listing appropriate assumptions, determining appropriate property values, (3) applying the appropriate conservation laws, physical and chemical laws, and mathematics to solve the problem, and (4) evaluating the reasonableness of the computed results.

Name: Irene Atatan

Title of Assignment: Final Exam

Date: 12/6/21

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
D1) Ability to identify engineering problems. <i>The problem tests the students' ability to (i) understand the given problem, identify the subject area and concepts involved, (ii) draw a labeled sketch of system, and (iii) identify the applicable system of units.</i>	25	14
D1) Ability to formulate engineering problems. <i>The problem tests the students' ability to (i) define the known and unknown variables, (ii) state relevant laws and equations needed to solve the problem, and (iii) list and apply any assumptions to the relevant laws and equations to obtain equation specific to the problem.</i>	35	21
D1) Ability to solve engineering problems. <i>The problem tests the students' ability to (i) implement a strategy to solve the engineering problem, (ii) solve the problem showing consistent units throughout, and (iii) evaluating and interpreting the result.</i>	40	26
TOTAL	100	61

Given: 50°F Horizontal pipe

3 in ~~40~~ Steel pipe ⁽²⁾ calculate pressure drop

Velocity 8 ft/s ⁽⁵⁾ Equation used Reynolds #

$P = 62.42 \text{ lbm/ft}^3$ ⁽¹²⁾ $\mu = 1.5 \times 10^{-4} \text{ lbm/ft-s}$ ⁽²⁾ Equation: $f = \frac{K}{Re}$ ⁽⁴⁾ $f = \frac{K}{Re}$ ⁽⁴⁾

$U = 8.80 \times 10^{-4} \text{ lbm/ft-s}$ ⁽¹⁾ Friction factor =

$U = 8 \text{ ft/s}$ ⁽³⁾ How can $U = 8 \text{ ft/s}$?

$Re = \frac{(62.42 \text{ lbm/ft}^3) (8 \text{ ft/s})}{8.80 \times 10^{-4} \text{ lbm/ft-s}} =$

$= \frac{24960}{8.80 \times 10^{-4}} = 0.28372 \text{ ft/s}^{-1}$

(4) $\frac{2(0.034) 3 \ln(8 \text{ ft/s})^2}{62.42} = 0.02614$

$\frac{P}{D} = \frac{f U^2}{2}$

$\frac{P}{D} = \frac{62.42 \times 8^2}{2} = 2017.28$

e.1 - $2\frac{1}{2}$

e.2 - 4

e.3 - $\frac{4}{10\frac{1}{2}}$

e.1 - $2\frac{1}{2} + 5 + 3\frac{1}{2} = 11$

e.2 - $4 + 6 + 2 = 12$

e.3 - $4 + 5 + 5 = 14$

37

2) GIVEN:

outside: 89 mm

insulated: 76 mm
thickness

temperatures: 115°C 32°C

$$\begin{array}{r} 115 + 273 \\ \hline 388 \text{ K} \\ \text{Ta} \end{array} \quad \begin{array}{r} 32 + 273 \\ \hline 305 \text{ K} \\ \text{Tb} \end{array}$$

AVG: 0.043 W/m.K

Equations: Temp Difference
Used SUM OF RESISTANCE

Heat loss equation:

$$\frac{T_a - T_b}{\frac{x_0}{k_0} + \frac{x_1}{k_1} + \frac{x_2}{k_2} \dots}$$

$$R_{09} = \frac{T_a - T_b}{\frac{\ln R_1}{k_0} + \frac{\ln R_2}{k_1} + \frac{\ln R_3}{k_2}}$$

$$388 - 305 \text{ K} = 83$$

3 resistance



turbulent
flow

$$\frac{83}{\frac{89}{0.043} + \frac{44.5}{0.043} + 76} = \frac{83}{2069 R_1 + 1034.88 + 76}$$

$$\frac{89}{2} = 44.5$$

R3: insulated
thickness t_{R2}

$$115 - 32 = 83$$

$$\ln \frac{2069}{89} + \ln \frac{1034.88}{2069} + \ln \frac{110.85}{1034.88}$$

$$3.146 - 0.692 - 2.234 = 0.22$$

$$\begin{array}{r} e.1 - 5 \\ e.2 - 6 \\ e.3 - 5 \\ \hline 16 \end{array}$$

$$= 397.272$$

3) Given:
 temperature in cooler: 24°C ⁽¹⁾
 partial pressure 100 mmHg ⁽²⁾
 inner diameter 38 mm ⁽¹⁾
 length: 0.4 m ⁽¹⁾
 molar mass: 32.04 ⁽²⁾
 $P_{\text{DAB}} = 1.526\text{ Pa m}^2/\text{s}$ ⁽²⁾
 $P_{\text{total}} = 10^5\text{ Pa}$ ⁽²⁾

Equation $N_A = -D_{AB} \frac{dC_A}{dy} + \frac{C_A}{C} (N_A + N_B)$ ⁽²⁾
 assumptions: ^{used} stagnant air = constant zero ⁽²⁾

$$N_A + N_B \frac{P_A}{P} = \frac{-D_{AB}}{Rt} \frac{C_{PA}}{C_{PA}}$$

$$10000 - 1332.23 = 8667.77$$

(5)

$$1.524 \times 10^{-5}$$

$$\frac{8.314 \times 2.34 \times 0.4}{1.71 \times 10^{-6}}$$

$$e.1 - 3\frac{1}{2}$$

$$e.2 - 2$$

$$e.3 - 5$$

$$\underline{10\frac{1}{2}}$$

HEAT, MASS AND MOMENTUM TRANSPORT

FALL 2021

Title of Assignment: HOMEWORK 1

TOPICS COVERED IN HOMEWORK 1

1. Introduction to chemical engineering analysis, essential in the study of transport phenomena, using mass balances to mathematically model a simple non-reacting system
2. Solving the resulting differential equations obtained to determine the dynamic behavior of the system

HEAT, MASS AND MOMENTUM TRANSPORT FALL 2021

SAMPLE QUESTIONS, SOLUTION, AND GRADING SCHEME FOR HOMEWORK 1

Heat, Mass and Momentum Transport (Fall 2021): Home Work 1

August 30, 2021

Due: September 6, 2021

Answer all questions. You will be graded based on (1) your ability to apply knowledge of intermediate mathematics involving differential and integral calculus, and (2) your ability to apply your knowledge of Material and Energy Balances. Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

Water is being pumped at a rate of 10 ft³/min into a 10-ft-diameter tank initially empty. Water leaves the tank at a rate that is dependent on the height of liquid in the tank described by the following relationship:

$Q_{\text{out}} = 2h$ where,

Q_{out} is in ft³/min and h is the height of liquid in feet in the tank.

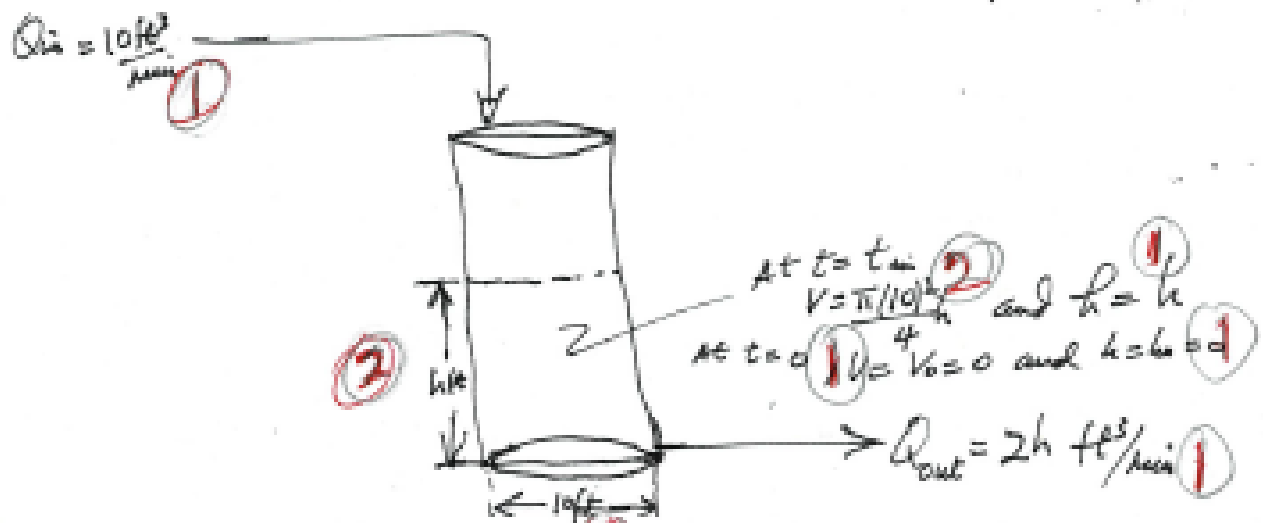
A. Using the above information:

- (1) Draw a simple sketch of the system (*10 points*)
- (2) Write down the conservation rate equations and all equation applicable to the system (*10 points*)

B. From the final forms of the applicable rate equations obtained in A(2) above set up the appropriate differential equations and:

- (1) Find the height of liquid in the tank as a function of time (*40 points*)
- (2) At what height of liquid in the tank does the water level stabilize or become constant? (*40 points*)

Homework 1 Heat, Mass & Momentum Transport



Let the density of the water = ρ and the temperature taken as constant.

Hence ρ is constant and the mass balance is given as:

mass of water in - mass of water out = mass of water accumulated in the tank

$$\text{mass of water in} = Q_{in} \rho = 10 \frac{\text{ft}^3}{\text{min}} \left(\frac{\rho \text{ lbm}}{\text{ft}^3} \right) = 10 \rho \frac{\text{lbm}}{\text{min}}$$

$$\text{mass of water out} = Q_{out} \rho = 2h \frac{\text{ft}^3}{\text{min}} \left(\frac{\rho \text{ lbm}}{\text{ft}^3} \right) = 2h \rho \frac{\text{lbm}}{\text{min}}$$

$$\text{mass of water accumulated in the tank} = \frac{d(PV)}{dt} = \frac{d\left(\rho \frac{\pi(10^2)}{4} h\right)}{dt}$$

$$\therefore 10\rho - 2h\rho = 25\rho\pi \frac{dh}{dt}$$

$$5 - h = 12.5\pi \frac{dh}{dt}$$

$$\frac{dh}{dt} = \frac{5-h}{12.5\pi}$$

$$\therefore \frac{dh}{5-h} = \frac{1}{12.5\pi} dt$$

Home work 1

Heat, Mass & Momentum 292
Transport

$$\frac{dh}{5-h} = \frac{dt}{12.5\pi}$$

When $t=0$, $V=V_0=0$ and $h=h_0=0$ (2)

When $t=t$, $V=V=25\pi h$ and $h=h$ (2)

$$\therefore \int_0^h \frac{dh}{5-h} = \frac{1}{12.5\pi} \int_0^t dt$$
 (4)

$$-\ln(5-h) \Big|_0^h = \frac{1}{12.5\pi} t \Big|_0^t$$
 (4)

$$-\ln(5-h) + \ln 5 = \frac{1}{12.5\pi} t$$

$$\ln \frac{5}{5-h} = \frac{1}{12.5\pi} t$$
 (4)

$$-\ln \left(\frac{5-h}{5} \right) = \frac{1}{12.5\pi} t$$

$$\ln \frac{5-h}{5} = -\frac{1}{12.5\pi} t$$
 (2)

$$\frac{5-h}{5} = e^{-\frac{t}{12.5\pi}}$$
 (2)

$$5-h = 5e^{-t/12.5\pi}$$

$$h = 5 - 5e^{-t/12.5\pi}$$
 (10)

$$\therefore h = 5(1 - e^{-t/12.5\pi})$$

When $t \rightarrow \infty$, $e^{-t/12.5\pi} \rightarrow 0$ and $h = 5(1 - e^{-t/12.5\pi}) \rightarrow$

$$h = 5(1 - 0) = 5$$

$\therefore$ Height of liquid in the tank when the level has stabilized is 5 ft. (15)

ABOVE AVERAGE

Above Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3013
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR FALL 2021 SEMESTER**

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of and (1) solve integral and differential equations analytically or numerically, and (2) apply appropriate conservation laws, chemical and physical principles to solve problems in transport phenomena.

Name: CANIDANAN COULIBALY

Title of Assignment: _____ Homework 1 _____ Due Date: September 6, 2021

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply the knowledge of intermediate mathematics <i>This assignment tests students' knowledge and application of intermediate mathematics and involves their competency in applying and solving problems involving differential and integral calculus as applied to Material Balances</i>	80	74
Knowledge and application of material Balances <i>The problem tests the student's knowledge and ability to apply Material Balances in an unsteady-state process</i>	20	15
TOTAL	100	89

Canadian Coulibely

Homework #1

Given information:

$$Q_{in} = 10 \text{ ft}^3/\text{min}, \quad Q_{out} = 2 \text{ h}$$

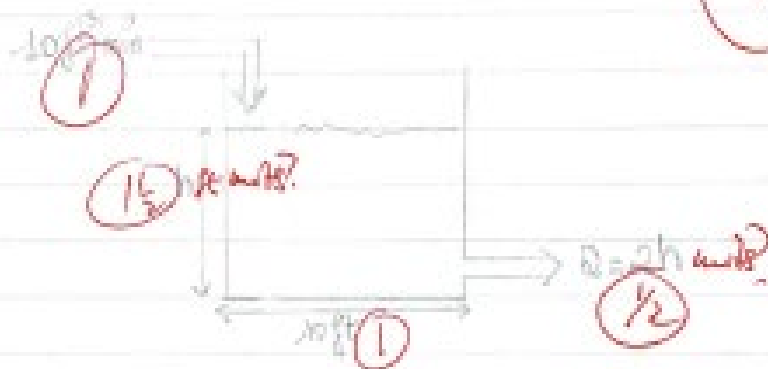
$$B = 10 \text{ ft}, \quad h_i = 0 \text{ ft}$$

89

A-

(1) Sketch the system

79



(2) Equations.

$$\text{At } t = t, \quad V = V, \quad \text{At } t = t + \Delta t, \quad V = V + \Delta V$$

Amount of water at $t = t$ is $\rho_w V$ where $\rho_w = ?$
at $t = t + \Delta t \Rightarrow \rho_w (V + \Delta V)$ you should define all variables.
where $V = ?$

* Conservation rate equation

rate of water in - rate of water out = rate of accumulation of water

(4)

$$\rho Q_{in} - \rho Q_{out} = \frac{\rho(V + \Delta V) - \rho V}{\Delta t} \quad \text{where } \rho = ?$$

$$\rho Q_{in} - \rho Q_{out} = \rho \frac{\Delta V}{\Delta t}$$

$$\rho Q_{in} - \rho Q_{out} = \lim_{\Delta t \rightarrow 0} \rho \frac{\Delta V}{\Delta t}$$

$$\rho Q_{in} - \rho Q_{out} = \rho \frac{dv}{dt}$$

(6)

$$\boxed{Q_{in} - Q_{out} = \frac{dv}{dt}}$$

B)

(i) Find height of liquid

$$Q_{in} - Q_{out} = \frac{d(A \cdot h)}{dt}$$

$$10 \frac{ft^3}{min} - 2h = A \frac{dh}{dt}$$

(4)

Where did the h come from?

You should have clearly stated how

$$Q_{in} - Q_{out} = \frac{dv}{dt}$$

$$\text{became } Q_{in} - Q_{out} = \frac{d(A \cdot h)}{dt}$$

$$2(5-h) = \pi r^2 \frac{dh}{dt}$$

$$2(5-h) = \frac{\pi d^2}{4} \frac{dh}{dt}$$

$$5-h = \left(\frac{\pi 10^2}{8}\right) \frac{dh}{dt}$$

$$5-h = 39.3 \frac{dh}{dt}$$

$$\int_0^t dt = 39.3 \int_0^h \frac{dh}{5-h}$$

4

$$t = -39.3 [\ln(5-h)]_0^h$$

4

$$= -39.3 [\ln(5-h) - \ln 5]$$

$$t = -39.3 \ln \left[\frac{5-h}{5} \right]$$

8

$$e^{-t/39.3} = e^{\ln \left(\frac{5-h}{5} \right)}$$

$$e^{-t/39.3} = \frac{5-h}{5}$$

$$h = 5 - 5e^{-t/39.3}$$

$$h = 5[1 - e^{-t/39.3}] \text{ ft}$$

10

2) height of liquid does the water stabilize

Let's calculate the limit of h when t approaches infinity

$$\lim_{t \rightarrow \infty} h = \lim_{t \rightarrow \infty} [5(1 - e^{-t/39.3})]$$

$$10 = \lim_{t \rightarrow \infty} 5[1 - e^{-\infty/39.3}]$$

$$= \lim_{t \rightarrow \infty} 5[1 - e^{\cancel{\infty}}]$$

$$= \lim_{t \rightarrow \infty} 5[1 - 0]$$

$$\boxed{\lim_{t \rightarrow \infty} h = 5}$$

5

Therefore, the water level in the tank stabilizes at 5 ft.

15

AVERAGE

Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR FALL 2021 SEMESTER

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of and (1) solve integral and differential equations analytically or numerically, and (2) apply appropriate conservation laws, chemical and physical principles to solve problems in transport phenomena.

Name: Britton Andrews

Title of Assignment: HWK#1 Due Date: September 6, 2021

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply the knowledge of intermediate mathematics <i>This assignment tests students' knowledge and application of intermediate mathematics and involves their competency in applying and solving problems involving differential and integral calculus as applied to Material Balances</i>	80	63
Knowledge and application of material Balances <i>The problem tests the student's knowledge and ability to apply Material Balances in an unsteady-state process</i>	20	14
TOTAL	100	77

Britton Andrews

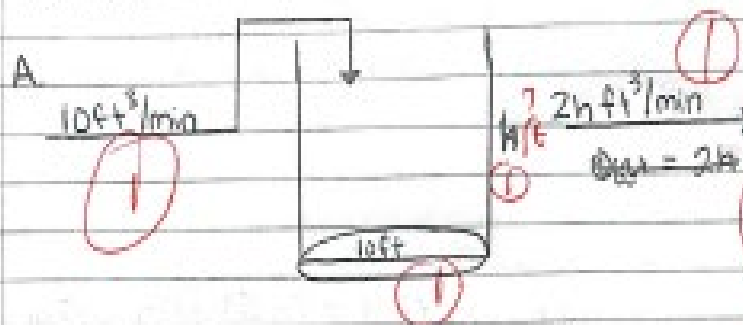
9/03/21

77

HW#1

Water is being pumped @ a rate of $10 \text{ ft}^3/\text{min}$ into a 10-diameter tank initially empty. Water leaves the tank at a rate that is dependent on the height of liquid in the tank described by the following relationship:

$Q_{\text{out}} = 2h$ where Q_{out} is in ft^3/min and h is the height of liquid in feet in the tank.



Accumulation = input - output

$$\text{Accumulation} = 10 \text{ ft}^3/\text{min} - 2h \text{ ft}^3/\text{min}$$

What does $\frac{dh}{dt} \cdot A$ represent?

$$\frac{dh}{dt} \cdot A = 10 \text{ ft}^3/\text{min} - 2h \text{ ft}^3/\text{min}$$

$$\text{Area of the base (A)} = \frac{\pi}{4} D^2 = \frac{\pi}{4} (10)^2 = 78.53 \text{ ft}^2$$

Why are you doing a mass balance and not a flow rate balance? What assumptions did you make?

$$B. \frac{dh}{dt} \cdot A = \frac{10t^3}{\text{min}} - \frac{2ht^3}{\text{min}}$$

$$\frac{dh}{dt} \cdot 78.53 \text{ ft}^2 = \frac{10t^3}{\text{min}} - \frac{2ht^3}{\text{min}} \quad (4)$$

$$\frac{dh}{dt} = 0.1273 - 0.0254h \quad \frac{dt}{dh} \cdot \frac{dh}{dt} = \frac{1}{0.1273 - 0.0254h} \quad (4)$$

$$(4) \int dt = \int \frac{1}{0.1273 - 0.0254h} dh \quad \int \frac{1}{a+b} dx = \frac{1}{a} \ln|a+bx|$$

where are your limits of integration?

$$-0.0254 \cdot t = \frac{-1}{0.0254} \ln|0.1273 - 0.0254h| \cdot -0.0254$$

How did you get this without limits of integration?

$$-0.0254t = \ln|0.1273 - 0.0254h|$$

$$e^{-0.0254t} = \frac{0.1273 - 0.0254h}{-0.1273} \quad (10)$$

$$\frac{e^{-0.0254t} - 0.1273}{-0.0254} = \frac{-0.0254h}{-0.0254}$$

$$5.0118 - \frac{e^{-0.0254t}}{0.0254} = h \quad (5)$$

Where is t in this expression?

(2) At what height of liquid in the tank does the water stabilize or become constant?

$$\lim_{t \rightarrow \infty} 5.0118 - \frac{e^{-0.0254t}}{0.0254} = 5.0118 - \frac{0}{0.0254} = 5.0118 \text{ ft} \quad (10)$$

There is no t in this expression

BELOW AVERAGE

Below Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR FALL 2021 SEMESTER**

CHEG STUDENT OUTCOME D1: an ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include problems that test a student's ability to apply knowledge of and (1) solve integral and differential equations analytically or numerically, and (2) apply appropriate conservation laws, chemical and physical principles to solve problems in transport phenomena.

Name: _____ Irene atatah _____

Title of Assignment: _____ Homework 1 _____ Due Date: September 10, 2021

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
Ability to apply the knowledge of intermediate mathematics <i>This assignment tests students' knowledge and application of intermediate mathematics and involves their competency in applying and solving problems involving differential and integral calculus as applied to Material Balances</i>	80	56
Knowledge and application of material Balances <i>The problem tests the student's knowledge and ability to apply Material Balances in an unsteady-state process</i>	20	10
TOTAL	100	66

Water Accumulation Homework 1

66

Given

Equation Used (2)

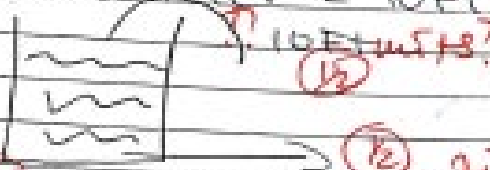
$$\text{mass in} - \text{mass out} = \text{acc}$$

Rate of water 10 ft 3/min

$Q_{in} = 10 \text{ ft diameter}$

$Q_{out} = 2 \text{ in}$

Diameter = 10 ft



(1) 10 ft $Q_{out} = 2 \text{ in}$

$$Q_{in} - Q_{out} = \frac{d(A)h}{dt}$$

What type of balance are you doing? Is it a mass balance? What is the mass in, out and accumulation?

Rate of water in - Rate of water out = water accumulation

$$A \frac{dh}{dt} = Q_{in} - Q_{out} \quad (2)$$

$$\frac{dh}{dt} = \left(\frac{10}{A} - \frac{2 \text{ in}}{A} \right) \quad (4)$$

$$\begin{array}{r} a. - 10 \\ e. - 34 \\ \hline 44 \end{array}$$

$$\frac{dh}{dt} + \frac{2 \text{ in}}{A} = \frac{10}{A} \quad (4)$$

$$\frac{dV}{dt} + 2V = 10^2 \quad A = \frac{\pi D^2}{4} = \frac{\pi (10)^2}{4} = \frac{\pi (100)}{4} = 25\pi \text{ ft}^2$$

$$2/25\pi = 2/5\pi \text{ what does this mean?}$$

AVPDX

PVPdE

e f 2/25\pi dt

e ^{2t}/_{25\pi}

What does this mean?

It is not clear what you are doing. No explanation has been given for the steps and what the terms represent.

10

1 f 0 dt + C

$$\int \frac{2}{25\pi} x^2 / 5\pi dt + C$$

$$e^{2t} / 25\pi \times h = \frac{2}{5\pi} \times 25\pi / 2 + e^{2t} / 25\pi + C$$

$$e^{2t} / 25 \times h = 5 \times \frac{2t}{25\pi} + C$$

10

$$h = 5 \times \frac{e^{2t} / 25\pi}{e^{2t} / 25\pi} + C \cdot e^{-2t} / 25\pi$$

Where did C come from and what does it represent?

16

$$h = 5 + C \cdot e^{-2t} / 25\pi$$

$$h_{\text{equiv}} = 5 \text{ mps}$$

HEAT, MASS AND MOMENTUM TRANSPORT

FALL 2021

Title of Assignment: HOMEWORK 2

TOPIC COVERED IN HOMEWORK 2

Application of the mechanical energy balance equation to calculate the lost work in a pipeline

HEAT, MASS AND MOMENTUM TRANSPORT FALL 2021

SAMPLE QUESTIONS, SOLUTION, AND GRADING SCHEME FOR HOMEWORK 2

Heat, Mass and Momentum Transport (Fall 2021): Homework 2 -Taskstream Assignment

Due: November 21, 2021

Answer all questions. You will be graded based on (1) your ability to apply knowledge of intermediate mathematics involving differential and integral calculus, (2) your ability to formulate and solve engineering problems, and (3) your ability to apply appropriate conservation laws, chemical and physical principles to solve transport phenomena problems. Clarity of presentation would ensure that you do not lose all the points for a calculation if you should make a mistake.

Water is flowing through a fouled 500 ft length of 3-in schedule 40 pipe at a rate of 230 gal/min. The pipe expands to a 4-in schedule 40 pipe. The 500 ft pipe length is the distance between point A and point B on the pipe where point A is on the 3-in schedule 40 pipe and point B is a couple of feet downstream the start of the 4-in schedule 40 pipe. Point B on the pipe is at an elevation 100 ft above point A. The gage pressures at points A and B are 120 psig and 15 psig respectively.

A. Using the above information:

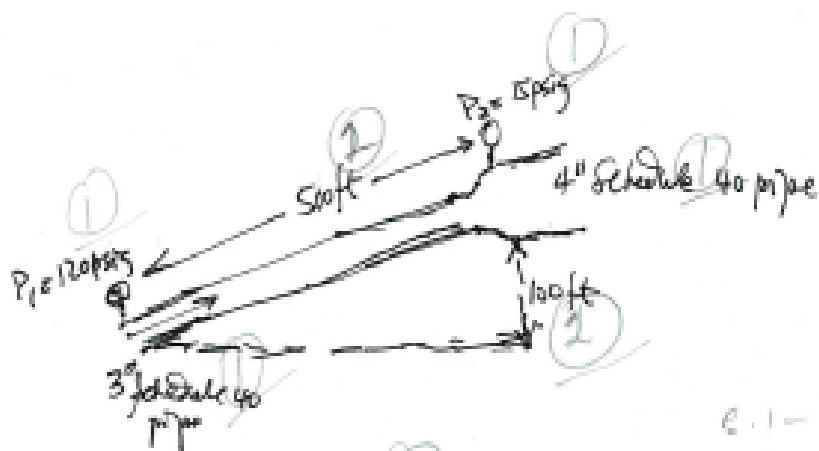
- (1) Draw a simple sketch of the system**
- (2) Write down the conservation equation applicable to the system**
- (3) List and justify any simplifying assumptions**
- (4) Using the simplifying assumptions write down the final form of the applicable conservation equation**

**B. From the final form of the applicable conservation equation obtained in A(4) above calculate:
the lost work in the 500 ft pipeline.**

Heat, Mass and Momentum Transport: Homework 2 Taskstream- Solution and Grading Scheme

Heat, Mass & Momentum Transport ^{1 of 3}

Taskstream Assignment



$$Q = 230 \text{ gal/min} \quad (2)$$

$$D_1 = 3 \text{ inch Schedule 40 pipe} = 3.068 \text{ inch} \quad (3)$$

$$D_2 = 4 \text{ inch Schedule 40 pipe} = 4.026 \text{ inch} \quad (3.5)$$

$$P_1 = 120 \text{ psig} \equiv 120 \frac{\text{lb}}{\text{in}^2} + 14.73 \frac{\text{lb}}{\text{in}^2} \quad (1.5)$$

$$P_2 = 15 \text{ psig} \equiv 15 \frac{\text{lb}}{\text{in}^2} + 14.73 \frac{\text{lb}}{\text{in}^2} \quad (1.5)$$

C.1 - 20

C.2 - 30

C.3 - 50
100

Mechanical Energy balance

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + Z_1 g + W_s = \frac{P_2}{\rho} + \frac{V_2^2}{2} + Z_2 g + \sum F \quad (15)$$

Since there is ~~not~~ shaft work, $W_s = 0$ (3)

$$\therefore \frac{P_1 - P_2}{\rho} + \frac{V_1^2 - V_2^2}{2} + (Z_1 - Z_2)g = \sum F \quad (5) \text{ for incompressible fluid (H}_2\text{O)}$$

Heat, Mass & Momentum Transport

Talkstream Assignment

$$A_1 = \frac{\pi D_1^2}{4} = \frac{\pi}{4} \left(\frac{3.068}{12} \right)^2 = 0.05134 \text{ ft}^2 \quad (2)$$

$$A_2 = \frac{\pi D_2^2}{4} = \frac{\pi}{4} \left(\frac{4.026}{12} \right)^2 = 0.08842 \text{ ft}^2 \quad (2)$$

$$\rho_{H_2O} = 8.33 \frac{\text{lbm}}{\text{gal}} \quad (1) \text{ and } 1 \text{ ft}^3 = 7.48 \text{ gal} \quad (1)$$

$$V_1 = \frac{Q}{A_1} = \left(\frac{230 \text{ gal}}{\text{min}} \right) \left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}} \right) \left(\frac{1 \text{ min}}{60 \text{ s}} \right) \left(\frac{1}{0.05134 \text{ ft}^2} \right) = 10 \text{ ft/s} \quad (4)$$

$$V_2 = \frac{Q}{A_2} = \frac{Q}{A_1} \cdot \frac{A_1}{A_2} = 10 \frac{\text{ft}}{\text{s}} \left(\frac{0.05134 \text{ ft}^2}{0.08842 \text{ ft}^2} \right) = 5.82 \text{ ft/s} \quad (4)$$

$$\frac{V_1^2}{2} - \frac{V_2^2}{2} = \left(50 - 33.8724 \right) \frac{\text{ft}^2}{\text{s}^2} = \left(50 - 16.9362 \right) \frac{\text{ft}^2}{\text{s}^2} = 33.064 \frac{\text{ft}^2}{\text{s}^2} \quad (5)$$

$$P_1 - P_2 = (120 - 15) \frac{\text{lbf}}{\text{in}^2} = 105 \frac{\text{lbf}}{\text{in}^2} = 105 \frac{\text{lbf}}{\text{in}^2} \left| \frac{12 \text{ in}}{1 \text{ ft}} \right|^2 = 105 \times 144 \frac{\text{lbf}}{\text{ft}^2} \quad (2)$$

$$\frac{P_1 - P_2}{\rho} = 105 \times 144 \frac{\text{lbf}}{\text{ft}^2} \left| \frac{1 \text{ gal}}{8.33 \text{ lbm}} \right| \left| \frac{1 \text{ ft}^3}{7.48 \text{ gal}} \right| = \frac{105 \times 144 \text{ lbf} \cdot \text{ft}}{8.33 \times 7.48 \text{ lbm}} \quad (3)$$

$$\frac{P_1 - P_2}{\rho} = 242.664 \frac{\text{lbf} \cdot \text{ft}}{\text{lbm}} \quad (6)$$

$$\frac{V_1^2}{2} - \frac{V_2^2}{2} = 33.064 \frac{\text{ft}^2}{\text{s}^2} = 33.064 \frac{\text{ft}^2}{\text{s}^2} \left| \frac{1 \text{ lbf}}{1 \text{ lbm} \times 32.174 \text{ ft/s}^2} \right| = 33.064 \frac{\text{ft}^2}{\text{s}^2} \left| \frac{1 \text{ lbf} \times \text{s}^2}{1 \text{ lbm} \times 32.174 \text{ ft}} \right| \quad (3)$$

$$\frac{V_1^2}{2} - \frac{V_2^2}{2} = \frac{33.064 \text{ lbf} \cdot \text{ft}}{32.174 \text{ lbm}} = 1.028 \frac{\text{lbf} \cdot \text{ft}}{\text{lbm}} \quad (3)$$

$$(Z_1 - Z_2)g = (0 - 100) \text{ ft} \times 32.2 \frac{\text{ft}}{\text{s}^2} = -3220 \frac{\text{ft}^2}{\text{s}^2} = \frac{-3220 \text{ lbf} \cdot \text{ft}}{32.174 \text{ lbm}} \quad (4)$$

$$(Z_1 - Z_2)g = -100.08 \frac{\text{lbf} \cdot \text{ft}}{\text{lbm}} \quad (4)$$

$$\frac{P_1 - P_2}{\rho} = 242.664 \frac{\text{lb} \cdot \text{ft}}{\text{lbm}}$$

$$\frac{V_1^2}{2} - \frac{V_2^2}{2} = 1.028 \frac{\text{lb} \cdot \text{ft}}{\text{lbm}}$$

$$(Z_1 - Z_2)g = -100.08 \frac{\text{lb} \cdot \text{ft}}{\text{lbm}}$$

Substitution in $\frac{P_1 - P_2}{\rho} + \frac{V_1^2}{2} - \frac{V_2^2}{2} + (Z_1 - Z_2)g = \Sigma F$

$$\Sigma F = (242.664 + 1.028 - 100.08) \frac{\text{lb} \cdot \text{ft}}{\text{lbm}} \quad (4)$$

$$\Sigma F = 143.612 \frac{\text{lb} \cdot \text{ft}}{\text{lbm}}$$

The lost work in the pipe line $\Sigma F = 143.6 \frac{\text{lb} \cdot \text{ft}}{\text{lbm}} \quad (10)$

ABOVE AVERAGE

Above Average Student Original Graded Assignment

CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR FALL 2021 SEMESTER

OUTCOME 8: Ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include ability to (1) apply knowledge of mathematics, science (chemistry and physics) and engineering; (2) solve algebraic, integral and differential equations analytically or numerically; and (3) apply appropriate conservation laws, chemical and physical principles to solve transport phenomena problems.

Name: Canidaman

Title of Assignment: Coulibaly Due Date: 11/23/2021

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
1. Identify and Formulate engineering problems using principles of engineering/mathematics/science The student is able to: (a) Understand the given problem and identify the subject area and concepts involved. (b) Convert the problem into a well-labeled sketch (such as free body diagram, flow chart, functional block diagram, schematic diagram).	20	18
2. Identify and Formulate engineering problems using principles of engineering/mathematics/science The student is able to: (i) Formulate the engineering problem into a mathematical model (using basic, intermediate and advanced mathematics ranging from algebra & trigonometry, calculus, probability & statics, analysis to Fourier transforms & Laplace transforms) or experimental framework stating all relevant assumptions. (iv) Formulate the engineering problem into an engineering model (using relevant laws and equations from engineering and science areas) stating all relevant assumptions.	30	26
3. Solve engineering problems The student is able to: (i) Solve the resulting engineering/mathematical/science formulations analytically, numerically, experimentally or through the use of appropriate software or computer program. (ii) Evaluate and interpret the results.	50	40
TOTAL	100	84

Assignment 8

$$\begin{aligned}
 L &= 500 \text{ ft} & D_1 &= 3 \text{ in sch 40} & D_2 &= 4 \text{ in sch 40} \\
 \rho_w &= 62.4 \frac{\text{lbm}}{\text{ft}^3} & D_1 &= 3.068 \text{ in} & D_2 &= 4.026 \text{ in} \\
 V_1 &= 230 \text{ gal/min} & Z_0 &= 100 \text{ ft} & P_1 &= 120 \text{ psig} \\
 & & & & P_0 &= 15 \text{ psig}
 \end{aligned}$$

1°)

1) sketch of the system

e.1-16
e.2-24
e.3-30

70

1



$D_2 = 4.026 \text{ in}$
 $V_2 = 16 \text{ ft/s}$
 $V_0 = ?$

2

2°) Using the conservation of mechanical energy balance:

84

2

rate of energy in - rate of energy out = rate of energy accumulation

$$\dot{m} \left(\Delta H + \frac{\Delta V^2}{2} + g \Delta Z \right) = Q + W_s + \dot{m} \frac{d}{dt} (U + KE + PE)_{cv}$$

$$\Delta H + \frac{\Delta V^2}{2} + g\Delta z = \frac{Q}{\dot{m}} + \frac{W_s}{\dot{m}} + \frac{d}{dt}(U+KE+PE)\rho V$$

$$\left[Q + \int_{P_1}^{P_2} \frac{dP}{\rho} \right] \frac{\Delta V^2}{2} + \Delta z g = \frac{Q}{\dot{m}} + \frac{W_s}{\dot{m}} + \frac{d}{dt}(U+KE+PE)\rho$$

3) List of simplifying assumptions

* Steady state $\Rightarrow \frac{d}{dt}(U+PE+KE)\rho V = 0$

* Incompressible fluids $\Rightarrow \rho = \text{const} \Rightarrow \int_{P_1}^{P_2} \frac{dP}{\rho} = \frac{P_2 - P_1}{\rho}$

* no shaft work $\Rightarrow W_s = 0$ 3

4) Final form of equation

$$\frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + \Delta z g + \Sigma F = 0$$
 15

B) Find lost work in pipe.

$$* V_1 = \frac{\cancel{Q}^{(2)}}{\cancel{A_1}^{(1)}} = \frac{230 \text{ gal/min}}{\frac{\pi}{4} (5.068)^2} = \frac{230 \left(\frac{\text{gal}}{\text{min}} \right) \left(\frac{35.3145 \text{ ft}^3}{248.17 \text{ gal}} \right) \left(\frac{\text{min}}{60 \text{ s}} \right)}{(7.39 \text{ in}^2) \left(\frac{\text{ft}^2}{144 \text{ in}^2} \right)}$$

$$V_1 = \frac{0.51 \text{ ft}^3/\text{s}}{0.051 \cancel{\text{ft}^2}^{(2)}} = 9.93 \text{ ft/s} \quad \underline{\underline{(4)}}$$

$$* V_2 = \frac{\cancel{Q}^{(2)}}{\cancel{A_2}^{(1)}} = \frac{0.51 \text{ ft}^3/\text{s}}{\frac{\pi}{4} (4.026 \text{ in})^2 \left(\frac{\text{ft}^2}{144 \text{ in}^2} \right)} = 6.77 \text{ ft/s} \quad \underline{\underline{(4)}}$$

Hence,

$$\frac{(15-120) \frac{\text{lb}_f}{144 \text{ in}^2}}{62.43 \frac{\text{lb}_m}{\text{ft}^3}} + \left(\frac{5.77^2 - 9.93^2}{2} \right) \frac{\text{ft}^2}{\text{s}^2} + (100 \text{ ft} - 0 \text{ ft}) \left(32.17 \frac{\text{ft}}{\text{s}^2} \right) + \Sigma F = 0$$

$$\Rightarrow \Sigma F = +0.01 \frac{\text{ft} \cdot \text{lb}_f}{\text{lb}_m} + 32.66 \frac{\text{ft}^2}{\text{s}^2} - 3217 \frac{\text{ft}^2}{\text{s}^2}$$

$$\boxed{\Sigma F = -3184.33 \frac{\text{ft} \cdot \text{lb}_f}{\text{lb}_m}}$$

units? 17 units? 20

You cannot add terms with different units.

AVERAGE

Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR FALL 2021 SEMESTER**

OUTCOME 8: Ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Engage in the engineering activities with such depth of applied knowledge in mathematics, science, chemistry and physical and engineering (1) solve algebraic, integral and differential equations analytically or numerically, and (2) apply engineering conservation laws, chemical principles and principles of heat transport to determine effects.

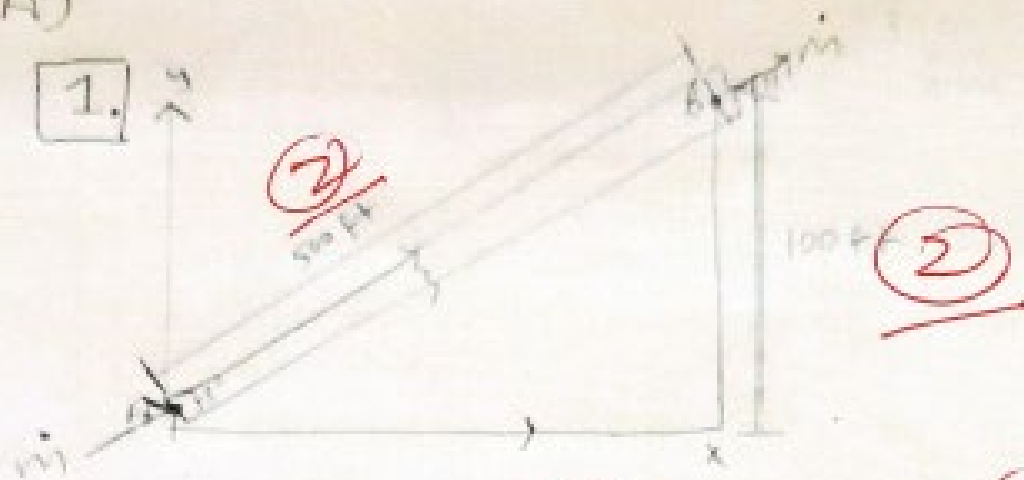
Amir Najam Din

Title of Assignment: Task 5 from 4 assignments† Due Date: 11/21/21

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
1. Identify and formulate engineering problems using principles of engineering and the natural sciences The student is able to: (i) Understand the given problem and identify the subject area and concepts involved (ii) Convert the problem into a well-labeled sketch (such as free body diagram, flow chart, functional block diagram, schematic diagram)	20	19
2. Identify and formulate engineering problems using principles of engineering mathematics/science The student is able to: (i) Formulate the engineering problem into a mathematical model (using basic, intermediate and advanced mathematics ranging from algebra & trigonometry, calculus, probability & statistics, analysis to Fourier transforms & Laplace transforms) or a computational framework stating all rules and assumptions (ii) Formulate the engineering problem into an engineering model (using relevant laws and equations from engineering and science areas) stating all rules and assumptions	30	22
3. Solve engineering problems The student is able to: (i) Solve the resulting engineering/mathematical/science formulations analytically, numerically, or experimentally or through the use of appropriate software or computer program (ii) Evaluate and interpret the result	50	35
TOTAL	100	76

A)

1.



From Appendix:

3 in Schedule 40: $D_o = 3.50$ in

$$A_o = 0.0513 \text{ ft}^2$$

4 in Schedule 40: $D_o = 4.50$ in

$$A_o = 0.0854 \text{ ft}^2$$

Known:

$$\dot{Q}_A = \dot{Q}_B = 230 \text{ gal/min}$$

$$P_A = 120 \text{ psig} = 17280 \frac{\text{lb}}{\text{ft}^2}$$

$$P_B = 15 \text{ psig} = 2160 \frac{\text{lb}}{\text{ft}^2}$$

$$Z_A = 0$$

$$Z_B = 100 \text{ ft}$$

2.

Mass:

In mass - Out mass = Accumulated Mass

There is no accumulation $\therefore$

In mass = Out mass

$$\dot{m}_A = \dot{m}_B$$

Energy

In energy = Out energy + Work lost + $\dot{W}_s$

$$\frac{P_A}{\rho_A} + \frac{V_A^2}{2} + gZ_A + \dot{W}_s = \frac{P_B}{\rho_B} + \frac{V_B^2}{2} + gZ_B + \dot{W}_{\text{lost}}$$

E.1 - 19

E.2 - 17

E.3 - 22

58

76

Assumptions

1. Density is constant @ STP

$$P_A = P_B = 62.4 \frac{\text{lb}}{\text{ft}^3}$$

2. No change in temperature

3. No shaft work

$$\dot{W}_s = 0$$

$$[4] \left(\frac{P_B}{\rho} + \frac{V_B^2}{2} + g z_B \right) \dot{m} = \left(\frac{P_A}{\rho} + \frac{V_A^2}{2} + g z_A \right) \dot{m} + \dot{W}_{lost}$$

Dividing both sides by $\dot{m}$:

$$\frac{P_B}{\rho} + \frac{V_B^2}{2} + g z_B = \frac{P_A}{\rho} + \frac{V_A^2}{2} + \frac{\dot{W}_{lost}}{\dot{m}}$$

B) Find $\dot{W}_{lost}$:

finding $\dot{m}$:

$$\dot{m} = \rho V_A A_A = 32.0 \frac{\text{lb}}{\text{s}}$$

$$V_A A_A = V_B A_B$$

$$V_B A_B = V_A A_A = Q$$

$$V_A = \frac{Q}{A_A} = \frac{230 \frac{\text{gal}}{\text{min}}}{0.014 \text{ ft}^2} \cdot \frac{1}{1.94} \cdot \frac{0.1337 \text{ ft}^3}{1 \text{ gal}} \cdot \frac{1 \text{ min}}{60 \text{ s}} = 9.99 \frac{\text{ft}}{\text{s}}$$

$$V_B = \frac{Q}{A_B} = \frac{230 \frac{\text{gal}}{\text{min}}}{0.0094 \text{ ft}^2} \cdot \frac{1}{1.94} \cdot \frac{0.1337 \text{ ft}^3}{1 \text{ gal}} \cdot \frac{1 \text{ min}}{60 \text{ s}} = 5.79 \frac{\text{ft}}{\text{s}}$$

plugging values of $V_B, V_A, \rho, P_A, P_B, g$ into eq (4)

$$\dot{m} \left(\frac{P_B}{\rho} + \frac{V_B^2}{2} + g z_B - \frac{P_A}{\rho} - \frac{V_A^2}{2} \right) = \dot{W}_{lost}$$

$$32 \left(\frac{2160}{62.4} + \frac{5.79^2}{2} + 32.17 \cdot 100 - \frac{17280}{62.4} - \frac{9.99^2}{2} \right) = \dot{W}_{lost}$$

$$\dot{W}_{lost} = 94,130 \frac{\text{ft} \cdot \text{lb}}{\text{s}}$$

BELOW AVERAGE

Below Average Student Original Graded Assignment

**CHEMICAL ENGINEERING DEPARTMENT
HEAT, MASS AND MOMENTUM TRANSPORT CHEG 3301
COURSE ASSIGNMENT GRADING AND OUTCOME ASSESSMENT SHEET
FOR FALL 2021 SEMESTER**

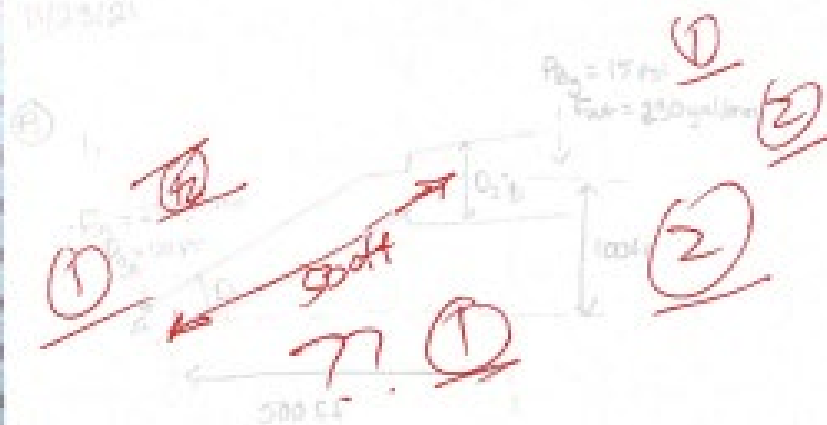
OUTCOME 8: Ability to identify, formulate, and solve fundamental engineering problems by applying principles of engineering, science, and mathematics

Assignments that test competency in this area will include ability to (1) apply knowledge of mathematics, science (chemistry and physics) and engineering (2) solve algebraic, integral and differential equations analytically or numerically, and (3) apply appropriate conservation laws, chemical and physical principles to solve transport phenomena problems.

Name: **Britten Andrews**

Title of Assignment: **Taskstream Assignment** Due Date: **December 1, 2021**

Description of Performance Criteria Being Assessed	Max for this Assignment	Your Score
1. Identify and Formulate engineering problems using principles of engineering/mathematics/science The student is able to: (i) Understand the given problem and identify the subject area and concepts involved. (ii) Convert the problem into a well-labeled sketch (such as free body diagram, flow chart, functional block diagram, schematic diagram)	20	12
2. Identify and Formulate engineering problems using principles of engineering/mathematics/science The student is able to: (i) Formulate the engineering problem into a mathematical model (using basic, intermediate and advanced mathematics ranging from algebra & trigonometry, calculus, probability & statics, analysis to Fourier transform & Laplace transforms) or experimental framework stating all relevant assumptions. (iv) Formulate the engineering problem into an engineering model (using relevant laws and equations from engineering and science areas) stating all relevant assumptions.	30	18
3. Solve engineering problems The student is able to: (i) Solve the resulting engineering/mathematical/science formulations analytically, numerically, experimentally or through the use of appropriate software or computer program. (ii) Evaluate and interpret the results.	50	35
TOTAL	100	65



e.1 - 7
e.2 - 10
e.3 - $\frac{25}{42}$

2. Use the Navier-Stokes equation in the x-direction for this system

$$\rho \left(\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} \right) = \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right) - \frac{\partial P}{\partial x} + \rho g_x$$

3. Assumptions:

- constant density
- negligible friction loss
- zero viscosity
- uniform flow
- steady-state

4. w/ zero viscosity $\mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right) \rightarrow 0$

③ steady-state $\frac{\partial u}{\partial t} = 0$

③ uniform flow $\frac{\partial u}{\partial x} = 0$ and $\frac{\partial u}{\partial y} = 0$

Where is the friction loss in the equation?

$$\rho \left[v \frac{\partial u}{\partial x} \right] = -\frac{\partial P}{\partial x} + \rho g_x \rightarrow \frac{\partial (v^2/2)}{\partial x} + \frac{\partial P}{\partial x} - \rho g_x = 0$$

$$\int \rho \frac{\partial (v^2/2)}{\partial x} + \frac{\partial P}{\partial x} - \rho g_x \cdot dx$$

$$\frac{P}{\rho} + \frac{v^2}{2} + g z = C \rightarrow \boxed{\frac{P}{\rho} + \frac{v^2}{2} + g z = C}$$

$$\text{work} = \left[\frac{p}{\rho g} + \frac{V^2}{2g} + z \right]_A - \left[\frac{p}{\rho g} + \frac{V^2}{2g} + z \right]_B$$

$$Q_A = \frac{23 \text{ gal}}{1 \text{ min}} \therefore Q_A = 230 \text{ gal/min}$$

$$= 0.8706 \text{ m}^3/\text{min}$$

$$A_A = \frac{\pi D^2}{4}$$

$$D_A = \text{X}$$

$$D_A = \text{X} \quad 0.0760 \text{ m}$$

$$V_A = \frac{0.8706}{(\pi/4)(0.0760)^2}$$

$$V_A = 191.0123 \text{ m/min}$$

$$= 3.1835 \text{ m/sec}$$

② steady state and constant density

$$Q_A = Q_B \quad \textcircled{2}$$

$$V_A A_A = V_B A_B$$

$$\textcircled{1} \quad V_A D_A^2 = V_B D_B^2 \rightarrow (3.1835)(0.076)^2 = V_B (0.076)^2$$

$$V_B = 1.79 \text{ m/s}$$

e.1-7

e.2-10

e.3-25

42

65

$$z_A - z_B = -10 \text{ ft} = -3.05 \text{ m}$$

$$p_A - p_B = 10 \text{ psig}$$

$$= 725.95 \text{ lbf/ft}^2$$

$$\rho = 79.7 \text{ lb/ft}^3 \text{ @ } 25^\circ\text{C}$$

You were not asked to work in SI units.

→ work with

$$= \frac{p_A - p_B}{\rho g} + \frac{1}{2g} (V_A^2 - V_B^2) + (z_A - z_B)$$

$$= \frac{725.95 \text{ (lb)}}{79.7 \text{ (lb/ft}^3)} + \frac{1}{2(32.2)} (3.1835^2 - 1.79^2) + (-30.1 \text{ ft})$$

20

$$= 14.072 - (0.0534) = 14.019$$

$$= 45.3924 \text{ m}$$

$$\text{Egh} = \text{lost work in ghd}$$

$$= (270)(9.81)(45.3924)$$

$$= 429,293.3 \text{ or } \boxed{429,943}$$