CHME420 **Name (Print):** _____
Winter 2016
Exam 1
1/28/16
Time Limit: 125 Minutes

This exam contains 7 pages and 5 problems. Check for missing pages. Put your initials on the top of every page in case the pages become separated.

The exam contains closed book and open book sections. Complete the closed book section and exchange it with your instructor for the open book section. No cell phone use allowed during the exam.

You are required to show your work on each problem. The following rules apply:

- **Read the problem statements carefully**. Do what is requested in each problem. Show your work at every step to communicate your knowledge and thinking process.
- **Organize your work** neatly and coherently in the space provided. Scattered work without a clear order and difficult to understand will receive very little credit.
- **Mysterious or unsupported answers will not receive full credit**. A correct answer that is unsupported by calculations or explanation, will receive no credit; an incorrect answer supported by substantially correct calculations and explanations might still receive substantial partial credit. A correct answer accompanied randomly by an incorrect one will undergo a deduction.
- If you need more space, request extra blank pages from the instructor. Label each additional blank page with your name, the problem number, and the page number for that particular problem. Place your additional pages in the right order and staple them together.

Do not write in this table:

Question	Points	Bonus Points	Score
1	30	0	
2	20	0	
3	10	3	
4	20	0	
5	20	3	
Total:	100	6	

Closed book

1. (30 points) Answer the following questions using words and equations if necessary:
   (a) (5 points) Give two interpretations for the quantity $\tau_{r\phi}$ in spherical coordinates.

   (b) (5 points) What is Fourier's law of heat conduction? Describe it in words. Include in your description its parameters and variables.

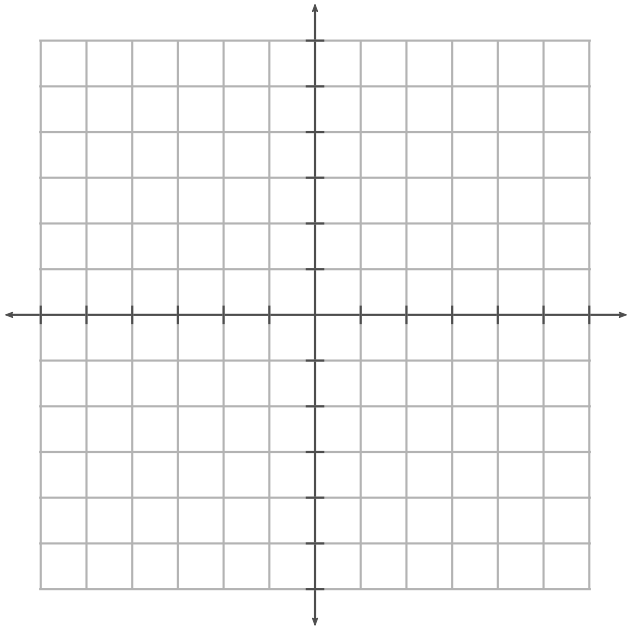
   (c) (5 points) Say that $\underline{q} = \langle q_x, q_y, q_z \rangle$ is the heat flux by conduction and $\underline{n} = \langle n_x, n_y, n_z \rangle$ is the unit normal vector for some surface. What is $\underline{n} \cdot \underline{q}$? Your answer should be both mathematical ($\underline{n} \cdot \underline{q} =$?) and a physical interpretation.

(d) (5 points) What is $\underline{e}$? If it is defined as $\underline{e} = \underline{q} + \left(\frac{1}{2}\rho v^2 + \rho\hat{H}\right)\underline{v} + \left[\underline{\underline{\tau}} \cdot \underline{v}\right]$, what is the physical meaning of each one of the three terms?

(e) (5 points) In the kinetic theory of gases, how do the gas particles interact with each other (in essence, what kind of particles do we assume)? How do they interact in the Chapman-Enskog theory? Can you describe in words what is the main difference between the two approaches?

(f) (5 points) For Newton's law of viscous flow, Fourier's law of heat conduction, and Fisk's law of binary diffusion, give one example for each of a situation in your everyday life in which they are relevant.

Open Book



x	y	z	vx	vy	vz
2	0	0			
-2	0	0			
0	2	0			
0	-2	0			
4	4	0			
-4	4	0			
4	-4	0			
-4	-4	0			

Figure 1: Cartesian axes for Question 1.

2. (20 points) Fill out the table in Figure 1 and sketch the following flow field in the coordinate axis provided (make sure to label your axes) at the $z = 0$ plane:

$$v_x = -\frac{1}{2}x$$
$$v_y = -\frac{1}{2}y$$
$$v_z = z$$

This is called uniaxial elongational flow. Given this flow field, obtain the total momentum flux tensor $\underline{\underline{\phi}}$. You may assume the pressure is constant in the entire flow field. Show your work.

3. (10 points) The viscosity of ethylene (C_2H_2=C_2H_2) is $1.01 \times 10^{-5}\,\mathrm{Pa \cdot s}$ at 293 K and 1 atm.
   (a) (10 points) Use this value to calculate the viscosity of ethylene at $T = 1080\,\mathrm{K}$ by the most accurate method you know.
   (b) (3 points (bonus)) Given your answer to this question, how would you use it to estimate the viscosity at $T = 1080\,\mathrm{K}$ and 150 atm?

4. (20 points) A key process stream has a composition of 0.2 mol/mol ethane (C_2H_6) and the balance propane (C_3H_8). The stream is at 357 K and 432 atm. Estimating the viscosity of this stream is key to determining the suitability of a heat exchanger in the process. Estimate the viscosity using the information in your textbook.

5. (20 points) A key process stream has a composition of 0.2 mol/mol ethane ($\mu_E = 9.40 \times 10^{-5}$ poise) and the balance propane ($\mu_P = 8.31 \times 10^{-5}$ poise). The stream is at 300 K and at low pressure.

   (a) (20 points) Estimating the thermal conductivity of this stream is key to determining the overall heat transfer coefficient of a heat exchanger. Estimate the thermal conductivity using the information in your textbook. The following values for heat capacities in kj/(mol · K) are also available:

$$C_{p,ethane} = .04937$$
$$C_{p,propane} = .06803$$

   (b) (3 points (bonus)) If the viscosity and heat capacity of the substances were not provided in the problem statement, how or where can you calculate, estimate, or find them?