Fluid Mechanics I
Section 0901-341-03
Spring 2014

INSTRUCTOR: Robert P. Hesketh
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COURSE HOMEPAGE: See BlackBoard

REQUIRED TEXTBOOK AND SUPPLIES:

1. *Fluid Mechanics for Chemical Engineers*, 3rd Ed. By Noel de Nevers, McGraw-Hill, 2005.
2. *Problem Solving in Chemical and Biochemical Engineering with POLYMATH, Excel, and MATLAB* (2nd Edition), Publisher: Prentice Hall PTR; (September 22, 2007) ISBN-10: 0131482041 or ISBN-13: 978-0131482043, by Michael B. Cutlip and Mordechai Shacham. (**C&S2nd**)
3. Engineering Paper for Homework

TOPIC LIST & COURSE SCHEDULE (TENTATIVE)

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Tuesday 09:25 AM - 12:05 PM JAMES 3117
Thursday 09:25 AM - 10:40 PM JAMES 3117
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All Chapter and section references are to the Young et al text unless referenced otherwise.

Date	Topics
January 21 Tuesday	**Introduction to Course, Objectives, Syllabus** Team Problem Solving Inductive Topic Order Chemical Engineers $\rho g = \gamma$ Mechanical Engineers (eqn 2.7) **Fluids Lab 1: Introduction to Fluids Experiments** **Chapter 2** Fluid Statics Sections 2 - 2.2, 2.6, 2.7 and **Chapter 5 Elementary Fluid Dynamics** (Also review Felder & Rousseau Section 3.1-3.4 Fluid Pressure, Hydrostatic Head, Manometers)
23 Thursday	**Fluid Flow without accounting for friction** **Review of Intro to Fluids lab** **Chapter 2 & Chapter 5** – The Bernoulli Equation - Neglecting Friction! Felder & Rouseau 7.7 Mechanical Energy Balances, eqn 7.7-1 3.5 Unsteady-State Mass Balances
28 Tuesday	3.5 Unsteady-State Mass Balances(continued) 3.4.1 Average Velocity Applications of Unsteady-State Mass Balances and Bernoulli's Equation Tank Drainage Problem **Fluids Lab 2: Tank Drainage & Siphon Experiments**
30 Thursday	Applications of Bernoulli's Equation continued: 5.5 Diffusers and Sudden Expansions 5.8.1&5.8.2 Pitot tube 5.8.3 Venturi, Restrictions on the Use of the Bernoulli Equation
February 4 Tuesday	**Fluids Lab 2: Pressure Drop in Pipes** **Computer Lab: Introduction to POLYMATH Laboratory**

6 Thursday	**Chapter 6 Viscous Flow in Pipes** Incompressible Flow in Pipes and Channels Figure 6.10: Friction Factor Chart 6.1 Reynolds Number (*Re)* and viscosity μ Cutlip&Shacham 8.7 Comparison of Friction Factor Correlations for Turbulent Pipe Flow Cutlip&Shacham 8.8 Calculations Involving Friction Factors for Flow in Pipes
11 Tuesday	**Fluids Lab 3: Pressure Drop in Pipeline Elements** **Computer Lab: Problem Solving with Excel**
13 Thursday	6.8 & 6.9 Minor Pressure Losses Frictional Losses in Pipeline Elements Perry's p6-16 (See Table 6-4 for turbulent, Table 6-5 for laminar,)
18 Tuesday	6.5 Pipe Flow Problems – fanning friction factor Standard Steel Pipe Properties: Appendix A.2 page 598, Standard Tube Properties: Cutlip & Shacham p699, Chemical Engineer's Handbook has both **Aspen Computer Lab - Pressure Drop in Pipes**
20 Thursday	**Exam 1: Chapters 2 and 5**
25 Tuesday	6.5 Pipe Flow Problems continued – Example problems: **simple piping** Cutlip&Shacham 8.10 Calculation of the Flow Rate in a Pipeline Cutlip&Shacham 8.14 Optimal Pipe Length for Draining a Cylindrical Tank in Turbulent Flow Cutlip&Shacham 8.14 Optimal Pipe Length for Draining a Cylindrical Tank in Laminar Flow **Computer Lab - POLYMATH/Excel**
27 Thursday	6.10.3 Tubulent Flow in Noncircular Channels 6.10.2 Seal Leaks 6.12 Economic Pipe Diameter, Economic Velocity
March 4 Tuesday	6.2 Laminar and Turbulent flow **Osborne Reynolds' Demonstration** 6.3 Laminar Flow Velocity Profile Entrance Region and Fully Developed Flow Review for Exam 1 **COMSOL Laboratory: Developing Flows**
6 Thursday	**Introduction to Pipe Flow Rate Measurements: orifice, venturi and rotameter** Permanent and Temporary Pressure Loss How to purchase a Flowmeter 5.8: Bernoulli Equation Perry's 10-6 to 10-20 Measurement of Flow
11 Tuesday	**Fluids Lab 3: Rotameter – Variable Area Flowmeter**
13 Thursday	**Chapter 7: Mass, Energy, and Momentum Balances** 7.2 Momentum Balance Typical Forces: gravity, Pressure and Wall Shear Stress
17-21	**Spring Break**
25 Tuesday	Momentum Balances Applications: 7.3.1 Jet-Surface 7.3.2 Pipes 7.3.3 Rockets and Jets. Review for Exam 2 **Momentum Demonstrations**
27 Thursday	**Exam 2: Chapter 6**

April 1 Tuesday	Momentum Balances Applications: 7.3.4 Sudden Expansion 7.3.5 Eductors, Ejects etc. **Aspirator laboratory**
3 Thursday	Examples of the Momentum Balances: Impinging jet, Force on a Reducing Pipe Bend, Orifice Plate, Rotameter (also see Chapter 6 in Denn, M.M.)
8 Tuesday	Examples of the Momentum Balance Continued Jet Ejector, Flow and Pressure Distribution in a Manifold (also see Chapter 6 in Denn, M. M.) **Feel the Force or Fun with Water Lab**
10 Thursday	Examples of the Momentum Balance Continued
15 Tuesday	**Fluids Lab 4: Flowmeters:** F1-15 Bernoulli's Theorem Demonstration - **venturi** F1-21 Flowmeter Demonstration – venturi and **orifice plate** Hampden Circuit Demonstrator – flow measurement – **orifice plate**
17 Thursday	6.13: Terminal Velocities: Solid Objects and Spheres
22 Tuesday	6.13 Terminal Velocities (continued) **Lab: Measurement of Terminal Velocities**
24 Thursday	**Chapter 9: Dimensionless Numbers and Dimensional Analysis**
29 Tuesday	**Chapter 9 continued** **ASPEN computer laboratory**
May **1 Thursday**	Review for Comprehensive Final Exam
May 6, Tuesday	**Finals Week 6-10 May** Comprehensive Final Exam Tentative Date: **Tuesday, May 6, 2014** 10:15am - 12:15pm http://www.rowan.edu/provost/registrar/RIG/Spring%202014%20RIG.pdf page 19/23
	Go out and design a fluid transport system for your parent's fountain and pond

Absolute Grading Scale

In this course we would like to create an atmosphere of positive cooperation between students. In your freshman year you were given a task by the Dean to make sure that the person sitting to your right and left graduates with you. In addition, most of the exercises in this course will require you to work in teams and you will be expected to help each other learn the material. By teaching others, studies show that you will have a better understanding of the material. To encourage and support cooperative learning you will be graded on an absolute grading scale as given below.

Letter Grade	University Point System	Percentage	Additional Requirements
A	4.0	93	and achieving a score of 85% on at least 2 Challenge Homework Problems
A-	3.7	90	and achieving a score of 80% on at least 1 Challenge Homework Problems
B+	3.3	87	
B	3.0	83	
B-	2.7	80	
C+	2.3	77	
C	2.0	73	
C-	1.7	70	
D+	1.3	67	
D	1.0	63	
D-	0.7	60	
F	0.0	< 60	

Your final numerical grade in the course will be determined as follows:

Quizzes	10%
Exam 1	25%
Exam 2	25%
Final Exam	25%
Homework	15%

Explanation of Grading System:

Homework: All Homework will be done and handed in by teams unless specified by the professor. Teams of 3 or 4 will be assigned by professors teaching the junior courses. One team member will be designated the leader for each assignment and only one homework assignment per team will be accepted unless specified otherwise.

On the top right hand corner of the first page of the homework specify the team leader and all *participating* team members names. The Rowan Engineering homework format must be followed. The team leader will be responsible for coordinating the work and making sure ***everyone*** in the team ***understands all the problem solutions*** before they are submitted to the professor. After being a team leader, an individual may not be a leader again until everyone else in the team has held the position. If a student's name appears on a solution set, it certifies that he/she has participated in solving some of the problems and ***understands all the solutions***.

Unless otherwise stated, each team member must submit their initial attempt at the homework. Place name on page and staple each team member's attempts to the back of the homework.

Team homework should be done following this outline for a typical week:

- 5 minute - Initial meeting after class. In this meeting major homework responsibilities are assigned. - **Assign**
- Students attempt **all** homework problems individually. **Define, Generate**
- 2nd Meeting – 1 hr: Discuss homework problems and **Decide** on solution strategy.
- Solve assigned homework problem plus any additional if time permits. **Implement**
- 3rd Meeting 1 hr: Discuss and **Evaluate** all solutions. It is the team leaders responsibility to make sure all team members are able to complete all assigned homework problems.

(Hint: Cooperative learning is not students sitting around a table and doing homework together.)

Individual Effort Assessments for Team Homework: All students will periodically be asked to submit evaluations of how well they and their teammates performed as team members. These evaluations will be incorporated into the assignment of homework grades. If repeated efforts to improve team functioning (including faculty intervention) fail, a nonparticipant may be fired by unanimous consent of the rest of the team. In addition a team member doing essentially all the work may quit. Individuals who quit or are fired *must* find a team of two or three that are unanimously willing to accept them; otherwise they will receive zeros for the remainder of their homework. Homework will be assigned randomly throughout the semester and must be submitted to the professor at the beginning of each class on the day it is due. Late homework will be penalized according to the following system:

• 15 minutes late - 5 PM on due date:	Maximum grade: 80% of total points
• After 5 PM and before 5 PM on day following due date	Maximum grade: 50% of total points
• After 5 PM on the day following the due date.	Maximum grade: 0% of total points

Exceptions will be made in case of illness or other emergency. Homework solutions will be posted on the course website.

Challenge Homework Problems: A minimum of 4 challenge homework problems will be given. Each of these problems will be worth 0.5% of the absolute grading scale. These challenge problems may be worked individually, in pairs or with your assigned team.

Quizzes: *Unannounced* quizzes will be given through out the semester. These quizzes will begin at the start of the class period and have a duration of approximately 5-10 minutes. No make-up quizzes will be given for unexcused absences. (See Attendance Policy section.) Unless announced otherwise, all quizzes are closed book and notes. Bonus points worth 5 quiz points will be given on quizzes if all team members have a score above the criterion announced in class before the quiz. This extra credit is designed to encourage team interaction and increase overall student achievement. The default quiz score for all members to receive the bonus points is 80%.

Exams: Two exams and a comprehensive final examination will be given. Exams will be closed-book and notes unless otherwise announced. Absence at examination time is excusable only in case of illness of the student or similar emergency. An unexcused absence from an exam will result in a zero grade on that exam. If an error has been made in grading your exam, you must resubmit your entire exam for regrading.

Bonus points worth 5 exam points will be given on exams if all team members have a score above the criterion announced in class before the exam. This extra credit is designed to encourage team interaction and increase overall student achievement. The default exam score for all members to receive the bonus points is 80%.

ATTENDANCE POLICY: In keeping with published policy (see p. 40 in the Student Information Guide http://www.rowan.edu/studentaffairs/infoguide/ or the latest *Rowan University Undergraduate Catalog*), attendance is required because substantial in-class material is presented and because attendance is needed to develop teamwork and cooperative learning skills, and accomplish project work. The instructor must be notified of an excused absence in advance of the class.

ACADEMIC CONDUCT: The policy in this class in matters of academic misconduct will follow that stated in "Rowan University Student Information Guide" Any student cheating in this class will receive a grade of F for the course. If another student is involved in the offense knowingly, he or she will receive the same penalty. This guide is located on the web at http://www.rowan.edu/studentaffairs/infoguide/

Course Withdraw Schedule

Dates	Designations on Transcript	Signature(s) Required
28 January to 3 March	**W**	**Student, Professor**
4 March to 4 April	**WP/WF**	**Professor, Dept. Chair**
5 April to 9 May	**WP/WF**	**Professor, Dept. Chair, Dean**

OVERALL COURSE OBJECTIVES:

The following is a partial list of objectives that you are expected to master by the end of this course.

1) Given the pressure of water in a pipe of known diameter estimate the velocity
2) Given a detailed description of a chemical process, the students will be able to determine the pressure drop for each component.
3) Apply the momentum balance to flow measurement devices to obtain an equation for flowrate.
4) Describe the devices that can be used for fluid flow measurement to a high school freshman.
5) Derive the Bernoulli Equation.
6) Show which pressure is static and dynamic in a pitot tube.
7) Predict the resultant force on a nozzle given the dimensions and flowrate.
8) Using a momentum balance calculate the force on a car that is propelled with a jet of water.
9) Define the term fluid to a freshman in high school.
10) Define viscosity, surface tension, Reynolds Number, turbulent and laminar flow.
11) Define shear stress, strain, and momentum.
12) Given the fluid properties and desired flowrate, specify a flowmeter for the system.
13) Demonstrate the use of the Bernoulli equation in fluid flow using an experiment.
14) Using POLYMATH, predict the length of time required to drain a tank given the tank dimensions and fluid properties.
15) Determine the inlet pressure required in a piping system given the dimensions and configuration of the pipe, fluid flowrate, and fluid properties.
16) Use AspenPlus to predict the fluid flowrate in a pipeline given the pipe diameter and pressure drop per unit length.

Rowan Engineering Homework Format

All homework problems, unless otherwise directed by your instructor, should follow the Rowan Engineering Format. This format is used for most professional engineering work. Unless otherwise directed by your instructor, you should use engineering paper or the equivalent for all homework assignments.

1) **Headers:** The five boxes at the top of each sheet of engineering paper that you use for a homework assignment should contain the following information from left to right:
   a) put the staple (which is the required homework binder) in the first (small) box
   b) print the team leaders name in the 2nd box and the names of each *participating* team member below this box
   c) print the course name in the third (large) box
   d) print the date that the assignment was completed in the fourth box.
   e) print the page number / total number of pages in the fifth (small) box
2) **Writing Mechanics**: All homework should be:
   a) carefully printed and not written in cursive
   b) printed in pencil and not in ink
   c) neat and clean, i.e. printed on the lines with no smudges or cross-outs
3) **Calculations:** All homework calculations should:
   a) include at least one complete sample for every type of calculation presented
   b) include all units for each term in each equation and the units must balance
   c) use the appropriate number of significant figures (usually three) for all numbers
   d) clearly indicate the final solution by boxing it in with a rectangle
4) **Problem Order:** Problems should be presented
   a) in the order assigned (one, two, three, etc.)
   b) with a new problem starting on a new page of engineering paper
   c) with the designated problem number, from textbook or professor, under box 2.
   d) using only the front side of each sheet of engineering paper
5) **Problem Essentials:** Problem solutions should include the following items in order:
   a) homework problem number listed at beginning of problem
   b) the given information - the information that will be used to solve the problem
   c) the required information - the information or solution that we are looking for
   d) a straight-edge diagram or diagrams that clearly illustrate the problem
   e) the solution of the problem including all required steps and calculations
6) **Evaluation:** Double-check all of your calculations to make sure that:
   a) all of your math is correct, i.e. you made no errors in using the calculator or computer
   b) all of your equations are correct, i.e. you made no errors in manipulating equations
   c) all of your units balance, i.e. you derived the correct units for the desired solution
   d) your final answer is reasonable. (e.g. is your reactor bigger than the empire state building, is the temperature of any liquids much higher than the mixture boiling point. Is the pressure drop greater than 10% of the total pressure.
7) **Computers**: Homework Assignments using Computers
   a) Show how the problem was set up for the computer program using engineering paper. This includes a diagram of the physical dimensions of the problem and the equations and known values that will be input into the program.
   b) Show sample calculations (with units) for each spreadsheet or POLYMATH calculation on engineering paper.
   c) Do not printout raw data from data acquisition experiments. A summary of the data in the form of a table and/or a graphical presentation of this data is sufficient unless otherwise requested from the professor.
   d) For homework requiring **POLYMATH**, the following additional printouts are required:
      i) A printout or an electronic version of the summary page titled **POLYMATH Report**. To reduce the number of printouts, you must paste this output into a word document containing all tables and graphs required for a particular homework.
      ii) A summary table of the iterations required for a solution and any trials required for the solution. The solution should be identified on the green engineering paper and boxed. It should not just be a number on the printout. If requested the program file may need to be uploaded on blackboard.
      iii) Do not use an analytical solution as an aid to obtain a numerical solution to an identical problem. The goal in this class is to compare the analytical solution to a numerical solution to gain an understanding of the capabilities of numerical solutions.
   e) For homework requiring ASPEN: i) A summary table of the solution ii) a process flow diagram iii) electronic file uploaded on blackboard or otherwise instructed by professor.
   f) For homework requiring COMSOL: i) handwritten setup of the problem showing geometry and equations ii) required graphs and tables iii) electronic *.mph file uploaded on blackboard or otherwise instructed by professor
8) **Electronic Submissions**

   All answers submitted electronically (e.g. Blackboard) must be in a single word document for the entire assignment. For example if there are 3 problems, then there will be 3 problem answers in the one word document. Beyond the initial electronic word document, points will be subtracted for each electronic file that is required to be opened to see the work of the student.

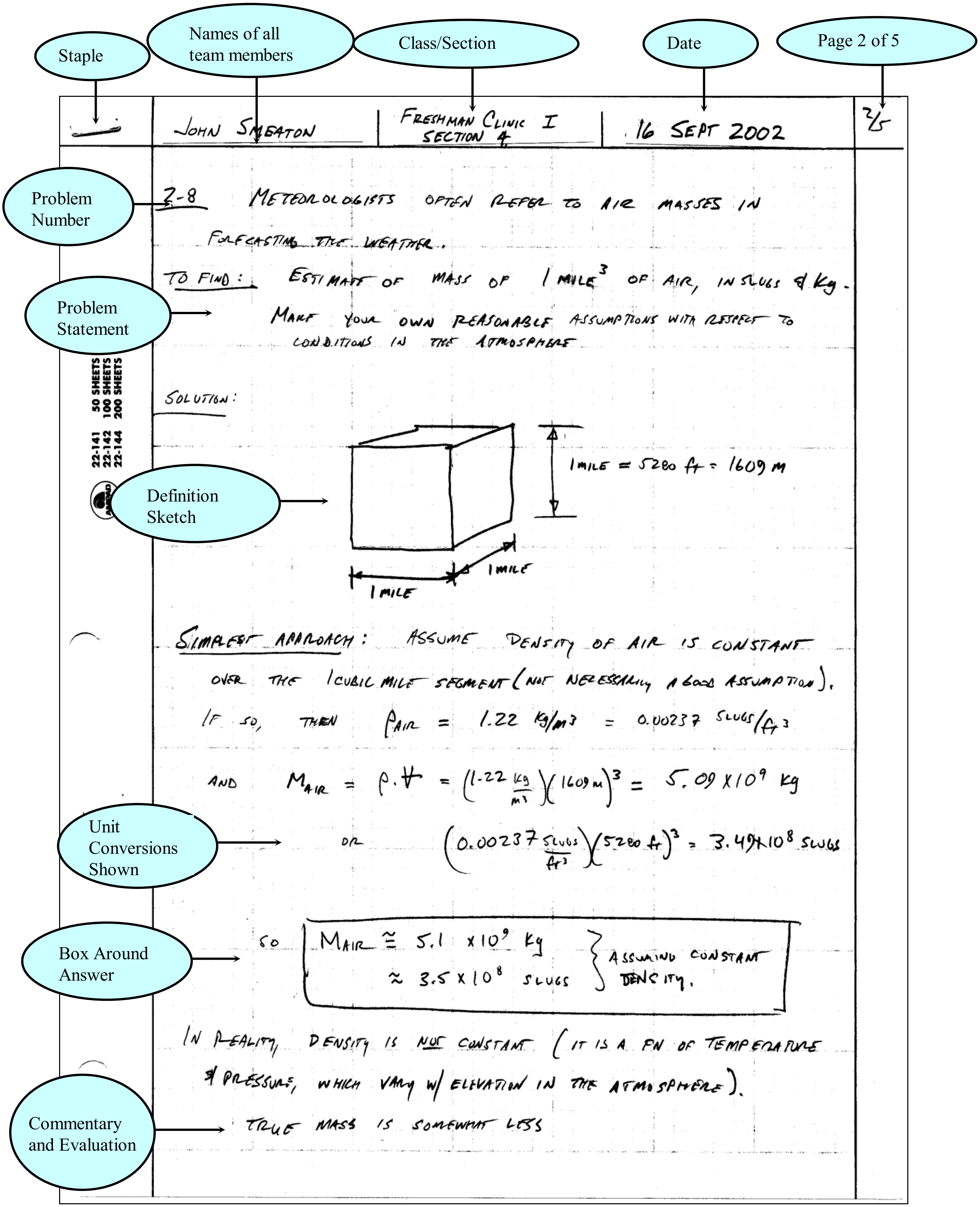

Figure 1: Sample homework on engineering paper in proper format.