COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY

ASSESSMENT REPORT COVER PAGE

MCEG 3063 FLUID MECHANICS

FALL 2005 SEMESTER

NAME OF INSTRUCTOR: Dr. Paul O. Biney

NOTE:
IT IS HIGHLY RECOMMENDED TO USE THIS FILE AS A TEMPLATE WHEN PREPARING YOUR ASSESSMENT REPORT, THEN REPLACE INFORMATION WITH THOSE FROM YOUR COURSE. THIS WAY, THE FORMAT AND ORDER OF ARRANGEMENT CAN BE MAINTAINED.
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2. Detailed Course Syllabus
4. Grade Sheet Showing Student and Class Performance in Outcomes
5. Supporting Outcomes Specific Assignments (Minimum of 2 per outcome)
   6.1 Assignments assessing students’ ability to apply the knowledge of mathematics, science and engineering
   6.2 Assignments assessing students’ ability to identify, formulate, and solve engineering problems
   6.3 Assignments assessing students’ ability to conduct experiments as well as analyze and interpret data.
Detailed Course Syllabus
(Distributed to Students at the beginning of the Semester)
ABET Outcomes measured using course should be
explicitly listed in the syllabus
COURSE FLUID MECHANICS
COURSE NO. MCEG 3063-001 --3063-081 CREDIT: 3 HRS.
COREQUISITE MATH 2043 (DIFFERENTIAL EQUATIONS I)
PREREQUISITE MCEG 2013 (THERMODYNAMICS I)
CO-REQUISITE MCEG 3063 Lab (FLUID MECH. LAB)
CLASS HOURS 8:00 - 8:50 AM T R, Lab: 2:00-4:50 T
CLASS ROOM ROOM 109 Gilchrist (ROOM 0704 - 109G LAB)
INSTRUCTOR DR. PAUL O. BINEY 936-857-4499
OFFICE COLLINS BLDG. ROOM 326
OFFICE HOURS 09:00 a.m. – 12:00 Noon Tuesdays and Thursdays
All others by Appointment

MCEG 3063. Fluid Mechanics. (3-0) Credit 3 semester hours. The fundamental conservation laws in fluid statics and dynamics are derived and solved analytically and numerically. Other topics include analysis of viscous and inviscid flow; laminar and turbulent flows in pipes and on external surfaces; open channel flow; hydraulic machinery; and introduction to compressible flow. Direct applications to problems encountered in practice will be covered. Problem solving will be emphasized.


Each of the references listed below treat all topics to be covered in Fluid Mechanics. However, different authors use different approach to present the various topics, and the student is encouraged to consult some of these references to obtain different approach of presentation of a topic he finds difficult to understand.

REFERENCES

COURSE CONTENT
The fundamental conservation laws, equations in fluid statics and dynamics are derived and solved (analytically and numerically). Viscous and inviscid flow, and laminar and turbulent flow in open and closed conduits. Direct application to the problem encountered in practice and in engineering design will be covered. Introduction to compressible fluid flow. Emphasis on problem solving applications.

Course Objectives and Performance Criteria for MCEG 3063 and How they meet the Mechanical Engineering Department Objectives and ABET Criterion 3

COURSE OBJECTIVES
The objectives of this course are:

1. To train students on the analysis of hydrostatic pressure distribution in fluids, and the effects of these forces on surfaces [a,e], [1,4]
2. To train students on the application of the fundamental conservation equations in fluid mechanics, and to apply these laws to solve practical fluid statics and fluid flow problems in engineering. [a,e], [1,4]
3. To train to be proficient in the methodology for solving fluid mechanics problems using their knowledge in mathematics, science, and the conservation laws. [a,e], [1,4]
4. To prepare students for thefluid mechanics portion of the FE exam. [a,e], [1,4]
5. To train the student on how to represent the physical model by appropriate mathematical equations and how to solve these equations to arrive at a solution based on the model and its assumptions. [a,e], [1,4]
6. To relate what is learned in Fluid Mechanics to the human dimension and to the social implications of the Engineering profession. [h], [3]
7. To conduct experiments for an in-depth understanding of fluid mechanics concepts and devices, and to present results and analysis in a formal technical report. [b,g], [1,2]
CLASS PUNCTUALITY
The class roll will be checked within the first five minutes of the class period. Any one who comes in after the roll is checked will be considered late.

UNEXCUSED ABSENCES
After the first week of the semester, any student who makes more than 4 (4) unexcused absences, will be advised to drop the course.

CHEATING AND PLAGIARISM
Students are referred to the University Policy about cheating and plagiarism. It shall be the policy in this course to discourage cheating to the extent possible, rather than to try to trap and to punish. On the other hand, in fairness to all concerned, cheating and plagiarism will be treated severely wherever it is found. Because a large part of the learning experience comes from interaction with your peers, students are encouraged to discuss assignments with each other. The material submitted for grading must, however, be the product of individual or assigned group effort; anything else constitutes cheating.

GRADING SYSTEM HOMEWORK
The course will be based on a 100 point system. The Homework Assignments are to help you prepare for the Exams and be included in the grading system. Independent work is required of everyone. Due dates will be stated on each assignment.

ALL ASSIGNMENTS MUST BE HANDED IN AT THE BEGINNING OF CLASS ON THE DUE DATE. HOME-WORK ASSIGNMENT NOT TURNED IN AT THE BEGINNING OF CLASS WILL BE ACCEPTED AT 10% LOSS IF TURNED IN ON THE NEXT CLASS AFTER THE DUE DATE. NO ASSIGNMENT WILL BE ACCEPTED AFTER THAT TIME. IF THE DUE DATE IS EXTENDED, THEN NO ASSIGNMENT WILL BE ACCEPTED AFTER THE EXTENDED DUE DATE.

Lab Reports
Laboratory reports should be prepared in accord with the specifications in the laboratory manual.

How Mechanical Engineering Courses Meet Department Objectives & ABET Criterion 3
Specific Objectives of the Mechanical Engineering Program are to produce graduates who will

1. have successful careers in engineering and related fields, thereby, fulfilling the special purpose mission of the university in serving a diverse ethnic and socioeconomic population;
2. be capable of advancing their careers by moving into other lucrative professions and leadership positions;
3. successfully obtain admissions to pursue graduate degrees, and
4. understand and maintain professional ethics and the need to safeguard the public, the environment, and the natural resources.

Mechanical Engineering program Outcomes
Program Outcomes and Assessment: The mechanical Engineering Program must demonstrate that its graduates have:

a. an ability to apply knowledge of mathematics, science, and engineering.
b. an ability to design and conduct experiments, as well as to analyze and interpret data.
c. an ability to design a system, component, or process to meet desired needs.
d. an ability to function on multi-disciplinary teams.
e. an ability to identify, formulate, and solve engineering problems.
f. an understanding of professional and ethical responsibility.
g. an ability to communicate effectively.
h. the broad education necessary to understand the impact of engineering solutions in a global and societal context.
i. a recognition of the need for, and an ability to engage in life-long learning.
j. a recognition of contemporary issues.
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The table below shows how Mechanical Engineering required courses contribute to the students’ knowledge and ability to meet the department’s program objectives and the program outcomes above.
<table>
<thead>
<tr>
<th>MCEG Courses</th>
<th>MCEG Objectives</th>
<th>ABET PROGRAM OUTCOMES</th>
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</thead>
<tbody>
<tr>
<td>1213 Creative Engr. I</td>
<td>x x x</td>
<td>x 5 x x 15 x 20</td>
</tr>
<tr>
<td>2013 Thermodynamics I</td>
<td>x</td>
<td>10 10</td>
</tr>
<tr>
<td>2023 Materials Sci/Engr.</td>
<td>x</td>
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<tr>
<td>3011 Measurement Lab</td>
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<td>3013 Heat Transfer</td>
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<td>x 30 10 x 10 15 x</td>
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<td>3033 Manufacturing Proc</td>
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<td>4063 Dynamic Systems</td>
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<td>4093 Finite Element</td>
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<td>x 5 x</td>
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<tr>
<td>4123 Energy System</td>
<td>x x x x</td>
<td>x 10 10 x 15 x 30 x</td>
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<tr>
<td>4473 Senior Project I</td>
<td>x x x</td>
<td>x x 20 45</td>
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<tr>
<td>4483 Senior Project II</td>
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<td>x x 30 45</td>
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<td>CHEG 3003 Engr. Economy</td>
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<tr>
<td>Total of “Contribution Factor”</td>
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<td>100 100 100 100 100 100 100 100 100 100 100 100 100 100</td>
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</tbody>
</table>

**Course Outcomes**
At the end of the course, students who pass the course will possess the following skills:

1. The ability to apply the knowledge of mathematics, science and engineering in solving fluid mechanics problems.
2. Ability to identify, formulate and solve problems in fluid mechanics using the conservation laws and well-accepted systematic procedure.
3. Ability to conduct experiments, as well as to analyze and interpret data.
4. Ability to write reports to communicate the procedure, analysis and presentation of experimental results.
5. A recognition of the need for, and an ability to engage in life-long learning.

**GRADING SUMMARY:**
Grading will be strictly in accord with participation, the formal written lab reports, and proven understanding of the underlying theoretical principles their relationships to the experimental results. The breakdown of the major parts of the grades are given below:

**A. Laboratory Component**

1. *Ability to conduct experiments, as well as to analyze and interpret data.*
   - Laboratory Participation 3%
   - Procedure/measured results 3%
   - Analysis and Presentation of derived results 8%
2. *Ability to engage in lifelong learning* 3%
   - Use of reference materials for report and to support Conclusions. Ability to identify trend of results

2. *Ability to communicate effectively.*
   - Report format, technical & grammatical quality
     Of report, soundness of discussions and conclusions 3%
   - Subtotal for Lab Component 20%

**B. All other Course Components**

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
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<tr>
<td>HOMEWORK</td>
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<tr>
<td>QUIZZES</td>
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<tr>
<td>TEST 1</td>
<td>10</td>
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<td>TEST 2</td>
<td>10</td>
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<td>TEST 3</td>
<td>10</td>
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<tr>
<td>FINAL EXAM</td>
<td>30</td>
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</tbody>
</table>

All the items listed under (B) will be used to test students,
3. Ability to apply knowledge of mathematics, science, and engineering in fluid mechanics
4. Ability to identify, formulate, and solve fluid mechanics problems systematically

Subtotal for all other components 80%

TOTAL 100%

<table>
<thead>
<tr>
<th>POINTS</th>
<th>GRADE</th>
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<tr>
<td>90 - 100%</td>
<td>A</td>
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<td>80 - 89.9%</td>
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<tr>
<td>65 - 79.9%</td>
<td>C</td>
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<tr>
<td>55 - 64.9%</td>
<td>D</td>
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<tr>
<td>0 - 54.9%</td>
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</table>

The sequencing of topics to be covered in this course has been carefully done to provide a logical transition from one topic to another. Each topic builds on the previous topics and students are encouraged to ensure thorough understanding of earlier topics to aid them to understand the new ones being introduced. The plan of course described below was designed with the above objectives in mind.

PLAN OF COURSE

The topics to be covered in Thermodynamics I and the approximate number of 1 hour periods assigned are as follows:

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>NUMBER OF HOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) History of Fluid Mechanics</td>
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<tr>
<td>Introduction, Fluid Properties</td>
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<tr>
<td>(ii) Fluid Statics</td>
<td>5</td>
</tr>
<tr>
<td>(iii) Fluid Flow Concepts, Integral Equations, and Applications</td>
<td>7</td>
</tr>
<tr>
<td>(iv) Analysis of Fluid Flow Using Differential Formulation and Applications</td>
<td>2</td>
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<tr>
<td>(v) Dimensional Analysis and Dynamic Similitude</td>
<td>3</td>
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<td>(vi) Analysis of Viscous Flow in Ducts</td>
<td>8</td>
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<tr>
<td>(vii) External Flow of Fluid Over Bodies</td>
<td>3</td>
</tr>
<tr>
<td>(viii) Compressible Fluid Flow</td>
<td>4</td>
</tr>
<tr>
<td>(ix) Open Channel Flow</td>
<td>3</td>
</tr>
<tr>
<td>(x) Turbomachines: Pumps and Turbines</td>
<td>3</td>
</tr>
<tr>
<td>Classifications, Performance, Selection, and Matching to system</td>
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</table>

Class Attendance Policy
Prairie View A&M University requires regular class attendance. Attending all classes supports full academic development of each learner whether classes are taught with the instructor physically present or via distance learning technologies such as interactive video. Excessive absenteeism, whether excused or unexcused, may result in a student’s course grade being reduced or in assignment of a grade of “F”. Absences are accumulated beginning with the first day of class during regular semesters and summer terms.

NOTE: For this class, attendance will be taken at the beginning of class. After the first week of class, students will be marked present, absent, late or excused absence. Absent, late, and excessive excused absence will count negatively towards your grade by reducing your class percentage according to the formula below:

Absent = -1% per each class student is absent.
Late = -0.5% per each class student is late
Excused absence = -0.25% for each excused absence above 3 class periods (No penalty for first three excused absences). An excused absent will be given when accompanied by verifying records and approved by the course instructor.
# FLUID MECHANICS
## FALL 2005
### TENTATIVE CLASS SCHEDULE

<table>
<thead>
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<th>MEETING NUMBER</th>
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<th>ASSIGNMENT</th>
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<tr>
<td>1</td>
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<td>Introduction 1. Section 1.1-1.3</td>
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<td>Sections 1.6 – 1.7</td>
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<td>Problem Review</td>
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<td>3</td>
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### CHAPTER 1 INTRODUCTION

<table>
<thead>
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<tr>
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<td>Sections 2. 1 - 2.3</td>
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<td>5</td>
<td>08/30/05</td>
<td>Sections 2. 3 - 2.4</td>
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<td>Section 2.5</td>
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<td>Sections 2.6 – 2.7</td>
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<td>6</td>
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<td>Section 2.8, Problem Session</td>
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### CHAPTER 2 FLUID STATICS

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### CHAPTER 3 FLUID FLOW CONCEPTS AND BASIC EQUATION

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<td>9</td>
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### CHAPTER 4 DIFFERENTIAL RELATIONS

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### CHAPTER 5 DIMENSIONAL ANALYSIS AND SIMILITUDE

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### CHAPTER 6 VISCOUS FLOW IN DUCTS

<table>
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<td><strong>CHAPTER 7 BOUNDARY LAYER FLOWS</strong></td>
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<td><strong>CHAPTER 10 OPEN CHANNEL FLOW</strong></td>
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<td>11/29/05</td>
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<td>Grades for Graduating Seniors</td>
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<tr>
<td></td>
<td>12/14/05</td>
<td>All other Grades Ready</td>
</tr>
</tbody>
</table>
POLICY, SCHEDULE, AND COVERAGE FOR TESTS AND QUIZZES

1. All tests will be closed book closed notes unless otherwise stated.

2. One 8 ½ X 11 sheet containing ONLY FORMULATE will be allowed during each test. Note the sheet should not contain any definitions or worked problems. This sheet may be provided by the instructor.

3. Cheating during exams will result in an automatic grade of “F” and possible suspension from the University.

4. Students should bring blank sheets or paper, the text book, pens and scientific calculator to all test and quiz sessions. The number of significant digits in final answers should be at least equal to that in the problem or in the tables used.

5. Sharing of text book, calculators, formula sheet and other form of communication will not be allowed during a test or quiz.

6. There will be no make up test and quizzes in this course. For death in the family or serious illness requiring admission to a hospital, the student should inform the instructor as soon as possible, preferably before the day of the test or quiz. Each case will be considered on an individual basis.

7. All computer assignments would include, the statement of the problem, the analysis, the flow chart and listing of the computer program, and the results all presented on 8 ½ X 11 sheets of paper properly stapled together.

NOTE:
1. Please read the UNIVERSITY CLASS ATTENDANCE POLICY (undergraduate catalog, 2005-2007, pp. 111).

DISABILITY REQUIREMENTS:

Do you have any special needs in this class related to a disability? If yes, please contact your instructor as soon as possible.
(Undergraduate Catalog, 2005-2007, p. 61) Any student who has, or believes they may have a disability that requires accommodations is advised to contact the Office of Students with Disabilities at 936-857-2610 in Evans Hall Room 315.)
Title of Experiment: ____________________________________________

Name:_____________________

Date Lab was Performed: _______________ Report Due Date:_______________

<table>
<thead>
<tr>
<th>Competency Area</th>
<th>Max</th>
<th>Your Score</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>b) Ability to design and conduct experiments, as well as to analyze and interpret data.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active participation in Lab Experiments</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedure, Measured Results</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample Analysis and Presentation of derived results (Tables, Graphs)</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soundness of discussions &amp; conclusions.</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-Total</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) A recognition of the need for, and an ability to engage in life-long learning.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of reference materials for report and to support conclusion. Identify expected trend of results. Additional reading on lab topic</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g) Ability to communicate effectively</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report format, Technical and grammatical quality of lab report.</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-Total</td>
<td>10</td>
<td></td>
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</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
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</table>
ASSIGNMENT TITLE: ____________________________________________________________

DUE DATE: ____________________    DATE SUBMITTED: _______________

Name of Student: __________________________

Title of Assignment: __________________________________________________________

<table>
<thead>
<tr>
<th>Competency Area</th>
<th>Max for this Assignment</th>
<th>Student’s Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Ability to apply the knowledge of mathematics, science, and engineering.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assignments that test competency in this area will include problems that test a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>students ability to (1) solve algebraic, integral, and differential equations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(that are encountered in fluid Mechanics) analytically or numerically, and (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>apply appropriate conservation principles to solve fluid mechanics problems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e) Ability to identify, formulate, and solve engineering problems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assignments that test competency in this area will include problems that test a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>students ability to (1) apply systematic problem solving methodology that</td>
<td></td>
<td></td>
</tr>
<tr>
<td>includes identifying all known variables, unknown variables, construction of</td>
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<td></td>
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<tr>
<td>reasonable schematic for realistic visual representation of the problem, listing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>appropriate assumptions, determining appropriate property values, and using</td>
<td></td>
<td></td>
</tr>
<tr>
<td>appropriate conservation principles, laws, and mathematic to solve the problem,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and evaluating the reasonableness of the computed results.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g) Ability to communicate effectively (written and Oral)</td>
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<tr>
<td>Assignments that test competency in written and communication will include</td>
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<tr>
<td>problems that test the students ability to logically arrange information, use</td>
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<td></td>
</tr>
<tr>
<td>correct grammar, use appropriate report format, use discipline specific</td>
<td></td>
<td></td>
</tr>
<tr>
<td>conventions including citations, use appropriate visual aids and presentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>techniques to engage audience, modulate voice and speak clearly without</td>
<td></td>
<td></td>
</tr>
<tr>
<td>distractions, use acceptable graphical conventions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) A recognition of the need for, and the ability to engage in life-long</td>
<td></td>
<td></td>
</tr>
<tr>
<td>learning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assignments that test competency in this area will include problems that test a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>students ability to (1) identify, retrieve, and organize information needed for</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a particular new task even if the task is outside of his/her area of expertise,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) apply facts, formulas, theories, to everyday life, and (3) develop a study</td>
<td></td>
<td></td>
</tr>
<tr>
<td>plan and follow the plan.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOTAL                                                                                   100
Problem Statement
A rod 180 mm in diameter moves along its axis at 0.18 m/s inside a concentric cylinder 180.5 mm in diameter and 1.5 m long. The space between them is filled with an oil of specific gravity 0.85 and kinematic viscosity \( \nu = 10^{-4} \text{ m}^2/\text{s} \).

a) What is the shear stress at the rod surface?
b) What is the viscous force resisting the motion?
c) What is the power required to move the shaft at the specified velocity?

**KNOWN:**
- A rod of diameter \( D_1 = 180 \text{ mm} \)
- Rod moves axially with a velocity \( U = 0.18 \text{ m/s} \)
- Rod moves in a concentric cylinder of diameter \( D_2 = 180.5 \text{ mm} \), and of length \( L = 1.5 \text{ m} \)
- Space between filled with fluid of \( SG = 0.85 \), and kinematic viscosity \( \nu = 10^{-4} \text{ m}^2/\text{s} \)

**FIND:**
- Viscous force, \( F_{\text{visc}} \), resisting the motion
- The shear stress, \( \tau_{\text{shear}} \) at the rod surface
- The power, \( P \), required to move the shaft

**ASSUMPTIONS:**
- Oil behaves as a Newtonian fluid

**PROPERTIES:**
- \( S_g_{\text{oil}} = 0.85 \), \( \rho_{\text{water}} = 1000 \text{ kg/m}^3 \), \( \nu_{\text{oil}} = 10^{-4} \text{ m}^2/\text{s} \), \( U = 0.18 \text{ m/s} \)

**ANALYSIS:**

Basic Laws/Equations:

\[
\tau = \mu_{\text{oil}} \frac{U}{\delta}, \text{ where } \delta = \frac{D_2 - D_1}{2}, \text{ and } \mu_{\text{oil}} = \rho_{\text{oil}} \nu_{\text{oil}}
\]

\[
\rho_{\text{oil}} = \rho_{\text{water}} S_g_{\text{oil}}
\]

\[
F = \tau A \text{ where } A = \pi D_1 L
\]

\[
P = FU
\]

Solution Plan
Calculate \( \mu_{\text{oil}} \) and then \( \tau \) and \( A \) using the appropriate equations above
Calculate $F$ from the values of $\tau$ and $A$
Calculate $P$ from the last equation after calculating $F$

Solution:

$$\rho_{oil} = \rho_{water} S g_{oil} = (1000 \text{kg/m}^3)(0.85) = 850 \text{kg/m}^3$$

$$\mu_{oil} = \rho_{oil} \nu_{oil} = (850 \text{kg/m}^3)(10^{-4} \text{m}^2/\text{s}) = 0.085 \text{kg/(m.s)}$$

$$\delta = \frac{D_2 - D_1}{2} = \frac{(180.5 - 180) \text{mm}}{2} = 0.25 \text{mm} = 0.00025 \text{m}$$

(a) \hspace{1cm} \tau = \mu_{oil} \frac{U}{\delta} = 0.085 \text{kg/(m.s)} \frac{0.18 \text{m/s}}{0.00025 \text{m}} = 61.2 \text{ N/m}^2$

(b) \hspace{1cm} A = \pi D_1 L = \pi (0.18 \text{m})(1.5 \text{m}) = 0.8482 \text{m}^2

$$F = \tau A = (61.2 \text{ N/m}^2)(0.8482 \text{m}^2) = 51.91 \text{ N}$$

(c) \hspace{1cm} P = FU = (51.91 \text{N})(0.18 \text{ m/s}) = 9.34 \text{ W}$$

**COMMENTS:** The shear stress and the force are not very large. A system like this can be used to measure the viscosity of a fluid if the force needed to move the shaft can be measured experimentally.
End of Semester
Course Assessment Report

This 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. You cannot use any number of your choice
   - 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.
## END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
### MCEG3063-001 FLUID MECHANICS
#### FALL 2005 SEMESTER

Report Prepared by: Dr. Paul O. Biney  
Report Date: December 21, 2005

<table>
<thead>
<tr>
<th>Semester</th>
<th>Analys is Type</th>
<th>Numbe r of Student s</th>
<th>Outcome a: Ability to apply knowledge of mathematics, science, &amp; engineering</th>
<th>Outcome b: Conduct experiments, analyze &amp; Interpret data</th>
<th>Outcome e: Ability to identify, formulate, and solve engineering problems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Expected Average</td>
<td>Class Average</td>
<td>% Students Meeting Expected Average</td>
</tr>
<tr>
<td>Fall 2005</td>
<td>Direct</td>
<td>11</td>
<td>75</td>
<td>59.4</td>
<td>82</td>
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<tr>
<td>Spring 2005</td>
<td>Direct</td>
<td>12</td>
<td>75</td>
<td>57.1</td>
<td>92</td>
</tr>
<tr>
<td>Fall 2004</td>
<td>Direct</td>
<td>10</td>
<td>75</td>
<td>46.8</td>
<td>90</td>
</tr>
</tbody>
</table>

### Implementation Summary

Students were made aware of the importance of differential & integral calculus as well as DE in the beginning of the course. Summary notes on differentiation, integration, and differential equation provided, and assignment on these given. Practice sessions in class on how to rephrase procedure, sample analyses done in lab and answers compared to that obtained by instructor at lab, and where time was a constrain, instructor performed analysis using first data point and provided the correct answers to students to use to check their analysis data.

### Perceived Problems

Students mathematical abilities not good in simple differentiation, integration, and differential equations and unable to apply pre-requisite subjects in fluid mechanics. Students perform analysis without regard to units, thus making them unable to get the correct results, but they were able to determine their answers were wrong and tried to resolve difficulty with instructor. “Dry analysis” procedure discussed in class. Informal problems given that concentrated in formulation of problems.

### Plans for Addressing Problems

The following is recommended for implementation:
1. Recommendation is being made for the department to develop a plan with Math department to determine the root cause of the poor mathematical ability and to address it.
2. Instructor should continue and prepare basic materials for calculus review and a few assignments on differentiation, integration and algebraic manipulations.
3. Instructor should prepare a summary of pre-requisite topics to be reviewed by students with some homework in those areas.

The following is recommended for implementation the next time the course is offered.
1. Continue the practice of requiring students to perform one sample calculation during the lab period. The results will be checked by instructor to ensure the analyses are correct before writing the lab report.

The instructor should:
1. Even though the instructor reduce the time spent on giving notes on the board by making copies of notes for students, it is recommended that this be continued in subsequent semesters. However, instructor should use some of the Lab time to assist students in analyzing homework problems.
2. Need to continue providing tutoring assistance to interested students.
3. Instructor should introduce students to EES so students can concentrate initially in identifying and formulating the problem and solve using EES.

The instructor should make an assignment requiring students to:
1. Indicate expected trend of results based on theoretical analyses.
2. Request students to incorporate these in the lab reports and comment on the expected trend and the experimentally obtained trend.
3. There should be a limit on the number of times a student can repeat a course to weed out those students with no potential to be successful in engineering.

### Overall Trend over Periods

Students performed better than in the Spring 05 semester but still the expected average was not achieved. There is a slow improvement trend. Even though the class average was above the expected average, the average was below that of the Spring 05 and Fall 04 averages. There was improvement during last two semesters, and a slight decline in Fall 05 semester. Students performance improved by about 10% over the Spring 05 semester, but was still shy of the expected average. There is minimal improvement trend. Students performance decreased compared to Spring 05. There were a number of repeaters who still performed below average. Students performance was disappointing this semester since the average was lower than that of Spring 05. No consistent trend.

Note: A blank copy of this table is provided below for you to modify and use.
## END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT

**MCEG3063-001 FLUID MECHANICS**  
**SPRING 2006 SEMESTER**

Report Prepared by: **Dr. Paul O. Biney**  
Report Date: **May 13, 2005**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Analysis Type</th>
<th>Number of Students</th>
<th>Outcome a: Ability to apply knowledge of mathematics, science, &amp; engineering</th>
<th>Outcome b: Design &amp; conduct experiments, analyze &amp; Interpret data</th>
<th>Outcome e: Ability to identify, formulate, and solve engineering problems</th>
<th>Outcome g: Oral &amp; Written Communication</th>
<th>Outcome (i): Life-long learning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Expected Average</td>
<td>Class Average</td>
<td>% Students Meeting Expected Average</td>
<td>Expected Average</td>
<td>Class Average</td>
</tr>
<tr>
<td>Spring 2005</td>
<td>Direct</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Fall 2004</td>
<td>Direct</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Spring 2003</td>
<td>Direct</td>
<td>75</td>
<td>75</td>
<td>75</td>
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<td>75</td>
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</table>

### Implementation Summary

<table>
<thead>
<tr>
<th>Perceived Problems</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Plans for Addressing Problems</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Overall Trend over Periods</th>
</tr>
</thead>
</table>

Note: Blue Text need to be changed; Red numbers are set by the Department not by Instructor, use number for your Department.
Grade Sheet Showing
Student and Class Performance in Outcomes
The computed semester average in each outcome
as stated in the Assessment report are
highlighted in boldface
# Grade Sheet Showing Student and Class Performance in Course Outcomes

## MCEG 3063 Fluid Mechanics

**Fall 2005 Semester**

### Grade Summary for MCEG 3063 Fluid Mechanics

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Weight</th>
<th>TOTALS</th>
<th>Home Assignment TOTALS</th>
<th>Lab Report TOTALS</th>
<th>Bonus Assignment TOTALS</th>
<th>Overall TOTALS</th>
<th>CURRENT GRADE</th>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>A</td>
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<tr>
<td></td>
<td>0.20</td>
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<td>A</td>
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<td></td>
<td>0.00</td>
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</table>

### Sample Grade Sheet

**TEST**

<table>
<thead>
<tr>
<th>Weight</th>
<th>TOTALS</th>
<th>HOMEWORK</th>
<th>LAB REPORT</th>
<th>Bonus Assignment</th>
<th>OVERALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0.10</td>
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<td>0.10</td>
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<td></td>
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<tr>
<td>0.20</td>
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<td></td>
<td></td>
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<tr>
<td>0.00</td>
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<td></td>
<td></td>
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</table>

### Class Average for All Passing Students

<table>
<thead>
<tr>
<th>Weight</th>
<th>TOTALS</th>
<th>HOMEWORK</th>
<th>LAB REPORT</th>
<th>Bonus Assignment</th>
<th>OVERALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.10</td>
<td></td>
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<tr>
<td>0.10</td>
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<td></td>
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<tr>
<td>0.20</td>
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<td></td>
<td></td>
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<tr>
<td>0.00</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

The Class averages for the outcomes shown here should match those listed for the outcomes in the End of Semester assessment Report.
OUTCOME SPECIFIC ASSIGNMENTS
USED TO ASSESS OUTCOMES
FACULTY, PLEASE NOTE:

THIS SECTION OF THE REPORT IS VERY IMPORTANT AND SHOULD BE DONE EXACTLY AS SHOWN IN THIS REPORT

EACH ASSIGNMENT SHOULD HAVE THE BLUE JUSTIFICATION PAGE FOLLOWED BY THE PROBLEM STATEMENT AND THEN EITHER A SAMPLE GRADED STUDENT WORK OR YOUR MASTER SOLUTION USED TO GRADE THE ASSIGNMENT.

The assignment should be clearly related to the outcome being measured

Information in this section will be used to prepare the all important OUTCOMES BINDER for your program.

ASSIGNMENTS FOR OUTCOME “a”

Ability to apply knowledge of mathematics, science, & engineering

(As it relates to Fluid mechanics)
Title of Assignment

TEST 1

Outcome Measured Using this Assignment

Outcome a
Ability to apply knowledge of mathematics, science, & engineering

Brief justification of the suitability of this assignment for the outcome

The questions on this section of Test 1 tests the students ability in differential and integral calculus and their application in solving fluid mechanics problems.

The questions in this section of the test also test the students ability in the pre-requisite thermodynamics course.
3. Which of the following must be satisfied by the flow of any fluid, such as air?
   1. Mass conservation of mass
   2. Conservation of momentum
   3. Energy conservation
   4. Conservation of angular momentum

   Choose the correct answer from the list below:
   a. 1, 2, and 4
   b. 1, 3, and 4
   c. 2, 3, and 4
   d. 1, 2, and 3

4. A heavy object is thrown upward in a vertical direction. Which of the following is the correct statement about the motion of the object?
   a. It accelerates upward.
   b. It rises to a maximum height, then falls back to the ground.
   c. It falls to the ground immediately.
   d. It reaches a maximum height and then returns to the ground.

5. Problem statement for questions 9 and 10
   Two parallel plates, one moving with a velocity of 10 m/s, and the other fixed, are separated by a thin layer of oil of negligible gravity. Calculate the velocity of the oil.

   a. 0 m/s
   b. 5 m/s
   c. 10 m/s
   d. 20 m/s

6. Problem statement for questions 11 to 13
   Determine the density of water if the density of water in 20°C is 1.000 g/mL.

   a. 0.999 g/mL
   b. 1.000 g/mL
   c. 1.001 g/mL
   d. 1.002 g/mL

7. Problem statement for question 14
   The wall of a pipe is subjected to a force F. Find the stress in the pipe wall.

   a. \( \sigma = \frac{F}{A} \)
   b. \( \sigma = \frac{F}{2A} \)
   c. \( \sigma = \frac{F}{3A} \)
   d. \( \sigma = \frac{F}{4A} \)

8. Problem statement for question 15
   A stream of air flows over a surface. The velocity of the air is given by
   \( v = v_0 \left( 1 - \frac{x}{L} \right) \)

   a. \( v = v_0 \frac{x}{L} \)
   b. \( v = v_0 \left( 1 + \frac{x}{L} \right) \)
   c. \( v = v_0 \left( 1 - \frac{L}{x} \right) \)
   d. \( v = v_0 \left( 1 + \frac{L}{x} \right) \)

9. Problem statement for question 16
   The velocity of a fluid is given by
   \( u = u_0 \left( 1 + \frac{x}{L} \right) \)

   a. \( u = u_0 \left( 1 + \frac{x}{L} \right) \)
   b. \( u = u_0 \left( 1 - \frac{x}{L} \right) \)
   c. \( u = u_0 \left( 1 + \frac{L}{x} \right) \)
   d. \( u = u_0 \left( 1 - \frac{L}{x} \right) \)
Title of Assignment

TEST 2

Outcome Measured Using this Assignment

Outcome a
Ability to apply knowledge of mathematics, science, & engineering

Brief justification of the suitability of this assignment for the outcome

The questions on this section of Test 2 tests the students ability in differential and integral calculus and their application in solving fluid mechanics problems.
QUESTION 1

(c) For flow of viscous fluid through a parallel gap h between two fixed parallel plates shown in Figure 1, the pressure and the velocity distribution are of the form

\[ u = u(y) \]

\[ p = p(x) \]

1. Gravity can completely be neglected in this type of flow. Hence the Navier-Stokes equations take the form of a single differential equation for each.

\[ \rho \frac{D \mathbf{u}}{D t} = -\nabla p + \mu \nabla^2 \mathbf{u} \]

\[ \nabla \cdot \mathbf{u} = 0 \]

2. In the equations for this flow, what are the proper boundary conditions for the given problem?

At \( y = 0 \), \( u = 0 \)
At \( y = h \), \( u = 0 \)

3. Integrate and find the argument for why computing the pressure gradient is required in any case.

\[ \frac{\partial u}{\partial y} = \frac{1}{\mu} \frac{\partial p}{\partial x} \]

\[ u = \frac{1}{\mu} \int (\frac{\partial p}{\partial x}) \frac{1}{2} y + C_1 \]

\[ v = \frac{1}{\mu} \int (\frac{\partial p}{\partial x}) \frac{1}{2} y + C_2 \]

At \( y = 0 \), \( u = 0 \) \( \Rightarrow 0 = C_1 \) \( \frac{1}{2} y + C_1 \)
At \( y = h \), \( u = 0 \) \( \Rightarrow 0 = C_1 \) \( \frac{1}{2} y + C_1 \)

\[ C_1 = -\frac{1}{\mu} \int (\frac{\partial p}{\partial x}) \frac{1}{2} \]

\[ u = \frac{1}{\mu} \int (\frac{\partial p}{\partial x}) \frac{1}{2} y + \frac{1}{\mu} \int (\frac{\partial p}{\partial x}) \frac{1}{2} y \]

\[ = \frac{1}{\mu} \int (\frac{\partial p}{\partial x}) \int (\frac{y - h}{2}) \]

\[ = \frac{1}{\mu} \int (\frac{\partial p}{\partial x}) \int (y - h) \]
Title of Assignment

Final Examination

Outcome Measured Using this Assignment

Outcome a
Ability to apply knowledge of mathematics, science, & engineering

Brief justification of the suitability of this assignment for the outcome

The questions on this section of the final examination tests the students ability in differential and integral calculus and their application in solving fluid mechanics problems.
Problem statement for questions 3 to 6

1. Identify the $x$ and $y$ components of the velocity and find an expression for the flow around a circular cylinder.

2. Find an expression for the effective momentum in water

3. The pressure on the fluid is the wall for the flow in the circular pipe is given by

4. From the given velocity distribution and pipe diameter, determine the pressure at the wall of the pipe in a circular plane section. The velocity of the fluid is $V_c = 7.5$ m/s, $R = 0.25$ m.

5. The continuity equation for a flow through a circular pipe is given by

6. The continuity equation

Continuity Equation

From given velocity distribution

Therefore, the momentum is not possible under the given conditions.
ASSIGNMENTS FOR OUTCOME “e”

Ability to identify, formulate, and solve engineering problems. (As it relates to Fluid Mechanics)
Title of Assignment

TEST 1

Outcome Measured Using this Assignment

Outcome e
Ability to identify, formulate, and solve engineering problems.

Brief justification of the suitability of this assignment for the outcome

The questions on this section of Test 1 tests the students' ability to identify relevant laws and equations, formulate the solution methodology, and solve the resulting engineering equations in fluid mechanics.
11. Calculate the pressure at point A in the fluid shown in the pipe in Figure 1. The quantity of the fluid in the pipe, i.e., the pipe’s diameter, is not shown.

\[ P_A = \sigma h_A - P_g = 2\sigma h_A \]

10. What is the effective pressure in a pipe when the pipe’s diameter is 3.1 inches, and the pressure is 60 ksi? The pressure is 450 psi.

\[ P_{\text{effective}} = \frac{P_s + P_g}{2} \]

9. What will be the vacuum pressure in a pipe if the pipe’s diameter is 1/2 inch if the water pressure in the pipe is 300 psi?

\[ P_{\text{vacuum}} = \frac{P_s - P_g}{2} \]

8. With 1 inch of water head, how much pressure is there in a pipe if the pipe’s diameter is 1/2 inch if the water pressure in the pipe is 300 psi?

\[ P_{\text{water}} = \frac{P_s + P_g}{2} \]

7. Determine the hydraulic pressure on the base of the tank, shown in Figure 2, if the fluid level is 2 feet high. Assume the fluid is 10% higher than the tank's height.

\[ F_h = \frac{1}{2} \rho g h^2 \]

6. Determine the pressure at point A in the fluid shown in the pipe in Figure 1. The quantity of the fluid in the pipe, i.e., the pipe’s diameter, is not shown.

\[ P_A = \sigma h_A - P_g = 2\sigma h_A \]

5. Determine the pressure at point A in the fluid shown in the pipe in Figure 1. The quantity of the fluid in the pipe, i.e., the pipe’s diameter, is not shown.

\[ P_A = \sigma h_A - P_g = 2\sigma h_A \]

4. Determine the pressure at point A in the fluid shown in the pipe in Figure 1. The quantity of the fluid in the pipe, i.e., the pipe’s diameter, is not shown.

\[ P_A = \sigma h_A - P_g = 2\sigma h_A \]

3. Determine the pressure at point A in the fluid shown in the pipe in Figure 1. The quantity of the fluid in the pipe, i.e., the pipe’s diameter, is not shown.

\[ P_A = \sigma h_A - P_g = 2\sigma h_A \]

2. Determine the pressure at point A in the fluid shown in the pipe in Figure 1. The quantity of the fluid in the pipe, i.e., the pipe’s diameter, is not shown.

\[ P_A = \sigma h_A - P_g = 2\sigma h_A \]

1. Determine the pressure at point A in the fluid shown in the pipe in Figure 1. The quantity of the fluid in the pipe, i.e., the pipe’s diameter, is not shown.

\[ P_A = \sigma h_A - P_g = 2\sigma h_A \]
24. Determine the distance MB between the water surface and the center of gravity of the water column. Note whether the center of gravity is above or below the water surface.

\[ MB = \frac{C_G - V}{\rho g} \]

\[ MB = \frac{300 - 0}{9810} = 0.003 \text{ m} \]

25. The specific weight of the water is 9.81 kN/m³. The tank is suspended in the air in a high velocity wind of 20 m/s in the direction shown in the figure. (Problem 4)

**Statement for question 27 & 28**

The tank of water in Figure 6 is to be used as a pump. The specific weight of the water is 9.81 kN/m³. The tank is suspended in the air in a high velocity wind of 20 m/s in the direction shown in the figure. (Problem 4)

\[ F = \frac{mg}{sin \theta} \]

\[ F = \frac{9810 \times 300}{sin 30°} = 196200 \text{ N} \]

**Statement for question 29 & 30**

The tank of water in Figure 6 is to be used as a pump. The specific weight of the water is 9.81 kN/m³. The tank is suspended in the air in a high velocity wind of 20 m/s in the direction shown in the figure. (Problem 4)

\[ F = \frac{mg}{sin \theta} \]

\[ F = \frac{9810 \times 200}{sin 30°} = 396300 \text{ N} \]

27. Determine the position of the center of gravity of the water column shown in Figure 6. Assume the weight of the water is 0.0001 N/m³. The tank is suspended in the air in a high velocity wind of 20 m/s in the direction shown in the figure. (Problem 4)

\[ y_c = \frac{\int y \rho dV}{\int \rho dV} \]

\[ y_c = \frac{18 \times 200 \times 400}{1000 \times 200} = 18 \text{ m} \]

28. Determine the position of the center of gravity of the water column shown in Figure 6. Assume the weight of the water is 0.0001 N/m³. The tank is suspended in the air in a high velocity wind of 20 m/s in the direction shown in the figure. (Problem 4)

\[ y_c = \frac{\int y \rho dV}{\int \rho dV} \]

\[ y_c = \frac{18 \times 200 \times 400}{1000 \times 200} = 18 \text{ m} \]

29. Using a mathematical model for the water tank, determine the position of the center of gravity. (Problem 4)

\[ y_c = \frac{\int y \rho dV}{\int \rho dV} \]

\[ y_c = \frac{18 \times 200 \times 400}{1000 \times 200} = 18 \text{ m} \]

30. Calculate the pressure at point D using the equation for the fluid column.

\[ P = \rho gh \]

\[ P = 9810 \times 1.0 \times 20 \times 9.81 = 196200 \text{ N} \]

**Statement for question 31 & 32**

The tank of water in Figure 6 is to be used as a pump. The specific weight of the water is 9.81 kN/m³. The tank is suspended in the air in a high velocity wind of 20 m/s in the direction shown in the figure. (Problem 4)

\[ P = \rho gh \]

\[ P = 9810 \times 1.0 \times 20 \times 9.81 = 196200 \text{ N} \]
MECHANICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
FLUID MECHANICS
FALL 2005
Instructor: Dr. Paul O. Biney

Title of Assignment

TEST 2

Outcome Measured Using this Assignment

Outcome e
Ability to identify, formulate, and solve engineering problems.

Brief justification of the suitability of this assignment for the outcome

The questions on this section of Test 2 tests the students ability to identify relevant laws and equations, formulate the solution methodology, and solve the resulting engineering equations in fluid mechanics.
**QUESTION 2**

The water tank in Figure 2 stands on a frictionless table and emits a jet of diameter 3 cm and velocity 15 m/s, which is accelerated by a vane as shown.

(a) Determine the x and y components of the force on the flat:

\[
F = \left[ F_x, F_y \right] = \left[ F_x, F_y \right] = \left[ F_x, F_y \right] = \left[ F_x, F_y \right] = \left[ F_x, F_y \right]
\]

\[
F_x = \frac{m_i}{2} \cdot \frac{V_x^2}{g} = \frac{1}{2} \cdot \frac{V_x^2}{g}
\]

\[
F_y = \frac{m_i}{2} \cdot \frac{V_y^2}{g} = \frac{1}{2} \cdot \frac{V_y^2}{g}
\]

\[
F_x = m_i \cdot V_x - m_i \cdot V_{in}
\]

\[
F_y = m_i \cdot V_y - m_i \cdot V_{in}
\]

\[
\begin{align*}
F_x &= \frac{1}{2} \cdot \frac{(15^2)}{g} \\
F_y &= \frac{1}{2} \cdot \frac{(15^2)}{g}
\end{align*}
\]

\[
F_x = \frac{1}{2} \cdot \frac{(15^2)}{g} = \frac{225}{g} = 22.5 \text{ kg} / \text{s}
\]

\[
F_y = \frac{1}{2} \cdot \frac{(15^2)}{g} = \frac{225}{g} = 22.5 \text{ kg} / \text{s}
\]

\[
V_{in} = 15 \text{ m/s} \quad V_{ex} = 15 \text{ m/s}
\]

\[
F_x = \left[ 22.5 \right] \left[ (15 \text{ m/s}^2) - 15 \text{ m/s} \right] = 337.5 \text{ N}
\]

\[
F_y = 0
\]

(b) Determine the tension in the cable:

\[
\text{Tension in cable} = -F_x = -337.5 \text{ N}
\]
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OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
FLUID MECHANICS
FALL 2005
Instructor: Dr. Paul O. Biney

Title of Assignment
Final Examination

Outcome Measured Using this Assignment
Outcome e
Ability to identify, formulate, and solve engineering problems.

Brief justification of the suitability of this assignment for the outcome

The questions on this section of the final examination tests the students ability to identify relevant laws and equations, formulate the solution methodology, and solve the resulting engineering equations in fluid mechanics.
PART B

This section of the Final Examination Tests Your ability to Identify, Formulate and Solve Fluid Machinery Problems. Mechanics Problems

3. An axial flow pump is shown in Figure 2. The unit is used to pump water (ρ = 1000 kg/m³, ν = 10⁻⁶ m²/s).

![Diagram of an axial flow pump](image)

**Figure 2: Schematic of axial flow pump**

Calculate the mass flow rate of the unit and the flow rate, needed to prevent the suction pipe from moving in the axial plane. Also, determine the flow rate of the impeller, and the mass flow rate of the fluid.

- Mass Flow Rate:
  \[ \dot{m} = \rho \dot{V} = \rho \frac{\pi D^2}{4} (\text{rpm}) \text{ m}^3/\text{s} \]

- Flow Rate:
  \[ \dot{Q} = \frac{\pi D^3}{4} \text{ m}^3/\text{s} \]

4. Write down the momentum equation and determine the pressure difference \( \Delta p \), for the momentum flow in the Figure 3. Assume \( \rho = 1000 \text{ kg/m}^3 \) and velocity of water is 1000 m/s.

![Diagram of a fluid machinery system](image)

**Figure 3: Fluid machinery system**

Membrane Equations:

\[ P_a + \gamma \Delta H_a + 1.5 \gamma_b + 1.2 \gamma_a = P_a \]
\[ P_b + \gamma_a (1 + i - 3) + \gamma_b (a - 1 - 3) = P_b \]
\[ \Delta H_b = \gamma_a \]
\[ \Delta H_b - P_b = \gamma_a - 0.9 \gamma_b \]
\[ \gamma_b = 1000 \text{ kg/m}^3 \]
\[ \gamma_a = 1000 \text{ kg/m}^3 \]
\[ \Delta H_b = 120 \text{ m} \]
\[ \Delta H_a = 30 \text{ m} \]

5. What will be the velocity \( V_p \) at the impeller? Use the duct flow model to estimate the velocity. Also, estimate the pressure drop across the impeller, given the impeller diameter and flow rate.

\[ V_p = \frac{2gH}{L} \]
\[ \Delta P = \rho V_p^2 \frac{L}{D} \]

6. What will be the flow rate in m³/s for the prototype under dynamically similar conditions? (Scale: 1/10).

\[ \dot{Q}_p = \frac{A_p}{A} \dot{Q} \]

7. What will be the length \( L_p \) of the pipe for the prototype under dynamically similar conditions? (Scale: 1/10).

\[ L_p = \frac{L}{A} \]

8. What will be the head \( H_p \) for the prototype under dynamically similar conditions? (Scale: 1/10).

\[ H_p = \frac{H}{A} \]

9. What will be the power \( P_p \) for the prototype under dynamically similar conditions? (Scale: 1/10).

\[ P_p = \frac{1}{2} \rho V_p^2 A \]

10. What will be the torque \( T_p \) for the prototype under dynamically similar conditions? (Scale: 1/10).

\[ T_p = \frac{1}{2} \rho V_p^2 A \]

11. What will be the drag force \( F_p \) for the prototype under dynamically similar conditions? (Scale: 1/10).

\[ F_p = \frac{1}{2} \rho V_p^2 A \]

12. What will be the lift force \( L_p \) for the prototype under dynamically similar conditions? (Scale: 1/10).

\[ L_p = \frac{1}{2} \rho V_p^2 A \]

13. What will be the weight \( W_p \) for the prototype under dynamically similar conditions? (Scale: 1/10).

\[ W_p = \frac{1}{2} \rho V_p^2 A \]
12. Determine the total number of work done

\[ \sum W \]

13. Determine the pressure for each variable, and the total number of moments in the problem

\[ P = \frac{M^2}{L} \]

14. Determine the number of momentum groups needed to solve for these variables

\[ \sum \text{Momentum Groups} = V - D = 6 - 3 = 3 \]

15. Select the dependent variables and state any assumptions

\[ \text{Assumptions:} \]

16. Determine the equations where pressures are being

\[ \sum P = \frac{M^2}{L} \]

17. A given tank has a base area of 0.5 m. Determine the force required to drive the tank at 0.5 m/s when it contains 2 m of liquid. The capacity of the tank is shown in the figure 4, with a total weight of 1,000 kg.

\[ \text{Force} = mg \]

\[ F = 1,000 \text{ kg} \times 9.8 \text{ m/s}^2 = 9,800 \text{ N} \]

\[ F = \frac{m_1 v_{1x}}{t} - \frac{m_2 v_{2x}}{t} \]

\[ F = 1,000 \text{ kg} \times 2 \text{ m/s} = 2,000 \text{ N} \]

\[ \text{Total Force} = 9,800 \text{ N} + 2,000 \text{ N} = 11,800 \text{ N} \]
Problems statement for Question 23-25

Water of density 1000 kg/m³ and dynamic viscosity, μ = 1.00 x 10⁻³ kg/(m·s) is pumped from tank A to tank B through the piping system shown in Figure 7. The volumetric flow rate is 0.003 m³/s. The total friction loss coefficient for the system, η = 1.5.

19. Determine the depth of the water in the tank, h:

\[ h = \frac{Q^2}{A} \]

20. Calculate the flow velocity, \( V \), through the pipe:

\[ V = \frac{Q}{A} \]

21. Calculate the Reynolds number and the friction coefficient:

\[ \text{Re} = \frac{V \cdot D}{\mu} \]

22. Calculate the pump head in meters:

\[ h_p = \frac{\Delta p}{\rho g} \]

23. Calculate the total head in meters:

\[ h_t = h_p + h_f \]

24. Determine the total power in kW if the pump efficiency is 70%.

\[ P = \frac{\rho g h_p Q}{\eta} \]

25. Determine the head loss in m:

\[ h_f = h_t - h_p \]
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OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
FLUID MECHANICS
FALL 2005
Instructor: Dr. Paul O. Biney

Title of Assignment

Laboratory Experiment Report

Outcome Measured Using this Assignment

Outcome b
Ability to conduct experiment as well as analyze and interpret data

Brief justification of the suitability of this assignment for the outcome

This section of the Laboratory report shows the procedure students used to conduct the experiment, the raw data recorded, the analysis and presentation of the derived results, and interpretation of the results in the discussions and conclusions.
OBJECTIVES

The objective of this experiment was to determine the loss factors (K) for flow through a range of fittings including bends, a contraction, an enlargement and a gate valve.

THEORY

The equipment consists of a wide variety of pipes and components, commonly used in industrial piping systems, mounted on a frame which, in turn, mounted on casters for high mobility.

Pressure taps are provided across the pipes and fittings allowing pressure drops due to fluid friction losses to be measured by the B400A Digital Manometer, which is powered by a 9V battery. This measurement system takes the place of the more time-consuming traditional method of U-tube manometers. Not only are various smooth bore pipes supplied, the equipment also includes an artificially roughened pipe for comparison. The equipment is designed primarily for use with the H1 Gravimetric or H1D Volumetric Hydraulics Benches which provide the necessary water supply, drain and flow measurement facilities. Alternatively, the customer may arrange their own water supply and flow measurement facilities, if desired.

The energy loss which occurs in a pipe fitting (so-called secondary loss) is commonly expressed in terms of a head loss (h, meters) in the form:

\[ h = \frac{KV^2}{2g} \]

Where K = the loss coefficient and \( v = \) mean velocity of flow into the fitting.
THEORY

The equipment consists of a wide variety of pipes and components, commonly used in industrial piping systems, mounted on a frame which, in turn, mounted on castors for high mobility.

Pressure tapings are provided across the pipes and fittings allowing pressure drops due to fluid friction losses to be measured by the H408A Digital Manometer, which is powered by a 9V battery. This measurement system takes the place of the more time-consuming traditional method of U-tube manometers. Not only are various smooth bore pipes supplied, the equipment also includes an artificially roughened pipe for comparison. The equipment is designed primarily for use with the HI Gravimetric or HID Volumetric Hydraulics Benches which provides the necessary water supply drain and flow measurement facilities. Alternatively, the customer may arrange their own water supply and flow measurement facilities, if desired.

The energy loss which occurs in a pipe fitting (so-called secondary loss) is commonly expressed in terms of a head loss (h, meters) in the form:

$$\Delta h = \frac{KV^2}{2g}$$

Where $K$ = the loss coefficient and $V$ = mean velocity of flow into the fitting.

Because of the complexity of flow in many fittings, $K$ is usually determined by experiment. For the pipe fitting experiment, the head loss is calculated from two manometer readings, taken before and after each fitting, and $K$ is then determined as

$$K = \frac{\Delta h}{V^2/2g}$$

Due to the change in pipe cross-sectional area through the enlargement and contraction, the system experiences an additional change in static pressure. This change can be calculated as

$$\frac{V_1^2}{2g} - \frac{V_2^2}{2g}$$

To eliminate the effects of this area change on the measured head losses, this value should be added to the head loss reading for the enlargement, and subtracted from the head loss reading for the contraction.
For the gate valve experiment, pressure difference before and after the gate is measured directly using a pressure gauge. This can then be converted to an equivalent head loss using the equation

\[ 1 \text{ bar} = 10.2 \text{ m water} \]

The head loss coefficient may then be calculated as above for the gate valve. Reynolds number is a dimensionless number used to compare flow characteristics. A full investigation of Reynolds number, and typical flow

**APPARATUS**

**HYDRAULIC BENCH**

This is a water re-circulation system consisting of a water sump tank, mono block pump, and top tray with drain, discharge measurement tank, and a bye-pass arrangement for the mono block pump. It allows us to measure flow by timed volume collection.
EXPERIMENTAL PROCEDURES

1) The basic apparatus on the hydraulic bench was set up so that its base was horizontal (this was necessary for accurate height measurements from the manometer).

2) The test rig inlet was connected to the bench flow supply and the outlet extension tube was directed to the volumetric tank.

3) The bench valve, the gate valve and the flow control valve were opened; then the pump was started to fill the test rig with water.

4) A length of small bore tubing was connected from the air valve to the volumetric tank.

5) The bench valve was then opened to allow air to the manometer.

6) The manometer levels were then checked to ensure that they were on scale at the maximum flow rate required (approximately 17 liters/minute).

7) The bases were then measured across all pipe fittings except the gate valve, which was kept fully opened.

8) The flow from the bench control valve was then adjusted at a given flow rate. The height readings from the manometer were taken after all levels have been checked.

9) A time volume collection using the volumetric tank was carried out by a use of a stop watch to determine the volume flow rate.

10) The fluid was collected for at least one minute to minimize timing errors.

11) The procedure was repeated for at least three times over a flow range of approximately 5 liters per minute.
## Experimental Data

<table>
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<tr>
<th>Fitting</th>
<th>Manometer $h_1$</th>
<th>Manometer $h_2$</th>
<th>Head Loss $h_1 - h_2$</th>
<th>Volume $V$</th>
<th>Time (seconds)</th>
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</tr>
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</table>
ANALYSIS

CALCULATIONS FOR DERIVED RESULT

FOR LINE 1 FOR ELBOW:

1) \[ Q_t \text{ (flow rate)} = \frac{\text{Volume (m}^3\text{)}}{\text{Time (seconds)}} \]
Volume = 5 \times 10^{-3} \text{ m}^3, \text{ Time} = 17.03 \text{ secs}
\[ Q_t = 0.000294 \text{ m}^3/\text{s} \]

2) \[ V \text{ (Velocity)} = \frac{Q}{A} \]
\[ Q = 0.000294 \text{ m}^3/\text{s}, A = \pi \text{ m}^2, d = 0.0196 \text{ m} \]
\[ V = 0.00302 \text{ m}^2/\text{s} \]
\[ V = 0.974 \text{ m/s} \]

3) \[ \text{Dynamic Head} = \frac{V^2}{2g} \]
Where \[ V = (0.974 \text{ m/s})^2 = 0.949 \text{ m}^2/\text{s}^2, g = 9.81 \text{ m/s}^2 \]
\[ \text{Dynamic Head} = 0.949 \text{ m}^2/\text{s}^2 \]
\[ (2 \times 9.81 \text{ m/s}^2) \]
\[ \text{Dynamic Head} = 0.0484 \text{ m} \]

4) \[ K = \frac{\Delta h}{\frac{V^2}{2g}} \]
Where \[ \Delta h = 0.107 \text{ m}, \frac{V^2}{2g} = 0.0484 \text{ m} \]
\[ K = 2.21 \]
## RESULTS

<table>
<thead>
<tr>
<th>Fitting</th>
<th>(a_1)</th>
<th>(a_2)</th>
<th>(a_1 - a_2)</th>
<th>Volume</th>
<th>Time</th>
<th>Flow Rate</th>
<th>Velocity</th>
<th>(v^2/2g)</th>
<th>K</th>
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<tbody>
<tr>
<td>Elbow</td>
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<td>0.255</td>
<td>0.000</td>
<td>17.17</td>
<td>0.0002</td>
<td>0.094</td>
<td>0.172</td>
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<td>0.270</td>
<td>0.013</td>
<td>49.03</td>
<td>0.0001</td>
<td>0.358</td>
<td>0.0059</td>
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<tr>
<td></td>
<td>0.347</td>
<td>0.275</td>
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<tr>
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<td>0.252</td>
<td>0.045</td>
<td>49.21</td>
<td>0.0001</td>
<td>0.338</td>
<td>0.0059</td>
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<td>153.31</td>
<td>0.0003</td>
<td>0.109</td>
<td>5.03</td>
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<tr>
<td>Entrance</td>
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<td>0.315</td>
<td>0.005</td>
<td>39.21</td>
<td>0.0001</td>
<td>0.338</td>
<td>0.0059</td>
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</table>
DISCUSSION OF RESULTS

The results of this experiment showed that there might have been something wrong with the manner in which the experiment was carried out or in the manner in which it was analyzed during the raw data collection. The calculated values of $K$ supposed to have been constant for different flow rates for different geometric configurations i.e. for the bends, gate valve, expansion or contraction, but the calculated readings showed that there wasn’t even a relationship between the readings for different flow rates. $K$ is not a function of flow but is a function of geometric form and the internal roughness of the devices it flows through.