Petroleum Engineering 311 — Reservoir Petrophysics
Syllabus and Administrative Procedures
Fall 2007

Instructor(s):
Instructor: Tom Blasingame
Office: RICH 815
Office Hours: If office door is open, instructor is available.
Phone: +1.979.845.2292
e-mail: t-blasingame@tamu.edu
Lecture: MWF 09:10-10:00 — RICH 313
Lab: R 08:00-10:50 — RICH 212L

Texts:

Reference Materials:
1. Course materials for this semester are located at:
   http://www.pe.tamu.edu/blasingame/data/P311_07C/
2. A compilation of reference materials for this course are located at:
   http://www.pe.tamu.edu/blasingame/data/P311_reference/
   Note: The most materials are in given in .pdf files and some of these files are quite large — you should not open these files on the server, but rather, you should DOWNLOAD the .pdf (or other format file(s)) to your local computer.
3. Journal articles (to be made available in electronic formats)
4. Other text materials:
   ● (N) Von Gonten, W.D., McCain, W.D., Jr., Wu, C.H.: Petroleum Engineering 311 Course Notes (available on web)

Basis for Grade:
Homework(s)/Project(s)................................................................................................................................................................25%
Weekly Quizzes ............................................................................................................................................................................20%
Lab..........................................................................................................................................................................................25%
Final Exam/Final Project ..............................................................................................................................................................25%
Class Participation ..................................................................................................................................................................... 05%
total = 100%

Grade Cutoffs: (Percentages)
A: < 90    B: 89.99 to 80    C: 79.99 to 70    D: 69.99 to 60   F: < 59.99

Policies and Procedures:
1. Students are expected to attend class every session.
2. Policy on Grading
   a. It shall be the general policy for this course that homework, quizzes, and exams shall be graded on the basis of answers only — partial credit, if given, is given solely at the discretion of the instructor.
   b. All work requiring calculations shall be properly and completely documented for credit.
   c. All grading shall be done by the instructor, or under his direction and supervision, and the decision of the instructor is final.
3. Policy on Regrading
   a. Only in very rare cases will exams be considered for regrading; e.g., when the total number of points deducted is not consistent with the assigned grade. Partial credit (if any) is not subject to appeal.
   b. Work which, while possibly correct, but cannot be followed, will be considered incorrect — and will not be considered for a grade change.
   c. Grades assigned to homework problems will not be considered for regrading.
   d. If regrading is necessary, the student is to submit a letter to the instructor explaining the situation that requires consideration for regrading, the material to be regraded must be attached to this letter. The letter and attached material must be received within one week from the date returned by the instructor.
4. The grade for a late assignment is zero. Homework will be considered late if it is not turned in at the start of class on the due date.
   If a student comes to class after homework has been turned in and after class has begun, the student's homework will be considered late and given a grade of zero. Late or not, all assignments must be turned in. A course grade of Incomplete will be given if any assignment is missing, and this grade will be changed only after all required work has been submitted.
5. Each student should review the University Regulations concerning attendance, grades, and scholastic dishonesty. In particular, anyone caught cheating on an examination or collaborating on an assignment where collaboration is not specifically authorized by the instructor will be removed from the class roster and given an F (failure grade) in the course.
Course Description

Systematic theoretical and laboratory study of physical properties of petroleum reservoir rocks; lithology, porosity, relative and effective permeability, fluid saturations, capillary characteristics, compressibility, rock strength, and rock-fluid interaction.

Course Objectives: (These are minimum skills to be achieved/demonstrated)

The student should be able to:

- Define porosity, discuss the factors which effect porosity, and describe the methods of determining values of porosity.
- Define the coefficient of isothermal compressibility of reservoir rock and describe methods for determining values of formation compressibility.
- Reproduce the Darcy equation in differential form, explain its meaning, integrate the equation for typical reservoir system, discuss and calculate the effect of fractures and channels, and describe methods for determining values of absolute permeability.
- Explain boundary tension and wettability and their effect on capillary pressure, describe methods of determining values of capillary pressure, and convert laboratory capillary pressure values to reservoir conditions.
- Describe method of determining fluid saturations in reservoir rock and show relationship between fluid saturation and capillary pressure.
- Define resistivity, electrical formation resistivity factor, resistivity index, saturation exponent, and cementation factor and show their relationship and uses; discuss laboratory measurement of electrical properties of reservoir rocks; and demonstrate the calculations necessary in analyzing laboratory measurements.
- Define effective permeability, relative permeability, permeability ratio; reproduce typical relative permeability curves and show effect of saturation history on relative permeability; illustrate the measurement of relative permeability; and demonstrate some uses of relative permeability data.
- Describe three-phase flow in reservoir rock and explain methods of displaying three-phase effective permeabilities.
- Demonstrate the techniques of averaging porosity, permeability, and reservoir pressure data.
- Demonstrate capability to perform calculations relating to all concepts above.
# Petroleum Engineering 311 — Reservoir Petrophysics

## Course Outline

### Fall 2007 (Spring Break: 12-16 March 2007)

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>ABW Text</th>
<th>Course Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Module 1 Introductory Materials</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>August</strong></td>
<td></td>
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<tr>
<td>27 M</td>
<td>Course Introduction—Review of the Syllabus</td>
<td>Chapter 1</td>
<td>...</td>
</tr>
<tr>
<td>29 W</td>
<td>Course Introduction—Review of the Syllabus</td>
<td>Chapter 1</td>
<td>...</td>
</tr>
<tr>
<td>31 F</td>
<td>Definition of Porosity</td>
<td>36-43</td>
<td>I-1 to I-4</td>
</tr>
<tr>
<td><strong>September</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>03 M</td>
<td>Laboratory Determination of Porosity</td>
<td>43-57</td>
<td>I-5 to I-13</td>
</tr>
<tr>
<td>05 W</td>
<td>Subsurface Measurement of Porosity</td>
<td>...</td>
<td>I-13 to I-24</td>
</tr>
<tr>
<td>07 F</td>
<td>Compressibility of Porous Rocks</td>
<td>57-64</td>
<td>I-25 to I-39</td>
</tr>
<tr>
<td>10 M</td>
<td>Introduction to Permeability</td>
<td>64-71</td>
<td>II-1 to II-4</td>
</tr>
<tr>
<td>12 W</td>
<td>Flow of Liquids in Porous Media</td>
<td>71-78</td>
<td>II-5 to II-13</td>
</tr>
<tr>
<td>14 F</td>
<td>Flow of Gases in Porous Media</td>
<td>71-78</td>
<td>II-13 to II-18</td>
</tr>
<tr>
<td><strong>Lab:</strong></td>
<td></td>
<td></td>
<td>Porosity Measurement and Sieve Analysis, Porosity Models</td>
</tr>
<tr>
<td>17 M</td>
<td>Conversion Factors for Oilfield Units</td>
<td>78-79</td>
<td>II-19 to II-23</td>
</tr>
<tr>
<td>19 W</td>
<td>Flow in Layered Systems</td>
<td>79-83</td>
<td>II-24 to II-28</td>
</tr>
<tr>
<td>21 F</td>
<td>Flow in Channels and Fractures, Analogies of Darcy's Law</td>
<td>83-86</td>
<td>II-29 to II-32</td>
</tr>
<tr>
<td>24 M</td>
<td>Laboratory Measurement of Permeability and Factors which affect Permeability Measurements</td>
<td>86-96</td>
<td>II-33 to II-39</td>
</tr>
<tr>
<td>26 W</td>
<td>Factors which affect Permeability Measurements</td>
<td>91-96</td>
<td>II-33 to II-39</td>
</tr>
<tr>
<td>28 F</td>
<td>Boundary Tension and Wettability</td>
<td>133-135</td>
<td>III-1 to III-4</td>
</tr>
<tr>
<td><strong>Lab:</strong></td>
<td></td>
<td></td>
<td>Gas Permeability</td>
</tr>
<tr>
<td><strong>October</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01 M</td>
<td>Introduction to Capillary Pressure</td>
<td>135-140</td>
<td>III-5 to III-12</td>
</tr>
<tr>
<td>03 W</td>
<td>Capillary Pressure and Saturation History and Capillary Pressure in Reservoir Rock</td>
<td>141-142</td>
<td>III-13 to III-18</td>
</tr>
<tr>
<td>05 F</td>
<td>Laboratory Measurement of Capillary Pressure</td>
<td>142-155</td>
<td>III-19 to III-25</td>
</tr>
<tr>
<td>08 M</td>
<td>Capillary Pressure/Saturation Relations</td>
<td>150-155</td>
<td>III-26 to III-30</td>
</tr>
<tr>
<td>10 W</td>
<td>Capillary Pressure Averaging and Correlations</td>
<td>155-161</td>
<td>III-31 to III-38</td>
</tr>
<tr>
<td>12 F</td>
<td>Capillary Pressure/Permeability Relations</td>
<td>167-174</td>
<td>handout</td>
</tr>
<tr>
<td><strong>Lab:</strong></td>
<td></td>
<td></td>
<td>Liquid Permeability</td>
</tr>
<tr>
<td>15 M</td>
<td>Introduction to Determination of Fluid Saturations</td>
<td>100-110</td>
<td>IV-1 to IV-4</td>
</tr>
<tr>
<td>17 W</td>
<td>Laboratory Determination of Fluid Saturations</td>
<td>100-110</td>
<td>IV-4 to IV-20</td>
</tr>
<tr>
<td>19 F</td>
<td>Laboratory Determination of Fluid Saturations</td>
<td>100-110</td>
<td>IV-4 to IV-20</td>
</tr>
<tr>
<td>22 M</td>
<td>Electrical Properties of Reservoir Rocks</td>
<td>111-117</td>
<td>V-1 to V-8</td>
</tr>
<tr>
<td>24 W</td>
<td>Measurement of Electrical Properties of Reservoir Rocks</td>
<td>117-120</td>
<td>V-9 to V-17</td>
</tr>
<tr>
<td>26 F</td>
<td>Effect of Clay on Electrical Properties</td>
<td>121-124</td>
<td>V-18 to V-21</td>
</tr>
<tr>
<td><strong>Lab:</strong></td>
<td></td>
<td></td>
<td>Capillary Pressure</td>
</tr>
<tr>
<td>29 M</td>
<td>Effective and Relative Permeability</td>
<td>174-181</td>
<td>VI-1 to VI-6</td>
</tr>
<tr>
<td>31 W</td>
<td>Three Phase Relative Permeability</td>
<td>181-184</td>
<td>VI-7 to VI-14</td>
</tr>
<tr>
<td><strong>November</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>02 F</td>
<td>Laboratory Measurement of Relative Permeability</td>
<td>184-203</td>
<td>VI-14 to VI-30</td>
</tr>
<tr>
<td>05 M</td>
<td>Laboratory Measurement of Relative Permeability</td>
<td>184-203</td>
<td>VI-14 to VI-30</td>
</tr>
<tr>
<td>07 W</td>
<td>Field Determination of Relative Permeability Ratios and Correlations of Relative Permeability Ratios</td>
<td>203-209</td>
<td>VI-31 to VI-32</td>
</tr>
<tr>
<td>09 F</td>
<td>Use of Relative Permeability Data</td>
<td>203-209</td>
<td>VI-33 to VI-39</td>
</tr>
<tr>
<td><strong>Lab:</strong></td>
<td></td>
<td></td>
<td>Fluid Saturations and Electrical Properties</td>
</tr>
<tr>
<td>12 M</td>
<td>Use of Relative Permeability Data</td>
<td>203-209</td>
<td>VI-33 to VI-39</td>
</tr>
<tr>
<td>14 W</td>
<td>Relative Permeability from Capillary Pressure Data</td>
<td>195-199</td>
<td>handout</td>
</tr>
<tr>
<td>16 F</td>
<td>Relative Permeability from Capillary Pressure Data</td>
<td>195-199</td>
<td>handout</td>
</tr>
<tr>
<td>19 M</td>
<td>Relative Permeability Correlations</td>
<td>...</td>
<td>handout</td>
</tr>
<tr>
<td>21 W</td>
<td>Relative Permeability Correlations</td>
<td>...</td>
<td>handout</td>
</tr>
<tr>
<td>23 F</td>
<td>Thanksgiving Holiday (No Classes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 M</td>
<td>Statistical Analysis of Reservoir Data</td>
<td>...</td>
<td>VII-1 to VII-17</td>
</tr>
<tr>
<td>28 W</td>
<td>Statistical Analysis of Reservoir Data</td>
<td>...</td>
<td>handout</td>
</tr>
<tr>
<td>29 F</td>
<td>Special Topics</td>
<td>...</td>
<td>handout</td>
</tr>
<tr>
<td><strong>Lab:</strong></td>
<td></td>
<td></td>
<td>Relative Permeability</td>
</tr>
<tr>
<td><strong>December</strong></td>
<td></td>
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</tr>
<tr>
<td>03 M</td>
<td>(Redefined day) Special Topics/Course Review/Closure</td>
<td>...</td>
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</tr>
<tr>
<td>10 M</td>
<td>Final Exam/Project (University Registrar — Monday, 10 December, 8-10 a.m. for classes held MWF 9:10-10 a.m.)</td>
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Homework Format Guidelines

Homework Topics: (These are intended topics, addition and/or deletion of certain problems may occur as other problems become available. Multiple assignments from each topic are possible.)

- Porosity (fundamentals and laboratory measurements).
- Permeability (fundamentals and laboratory measurements).
- Compressibility of reservoir rocks (derivations/applications).
- Steady-state flow of liquids and gases in porous media (derivations/applications).
- Flow in channels and layered reservoir systems (derivations/applications).
- Capillary pressure (fundamentals, laboratory measurements, and correlations)
- Electrical properties (fundamentals and laboratory measurements).
- Relative permeability (fundamentals, laboratory measurements, and correlations)
- Statistical analysis and correlation of reservoir data.

Computing Topics: In general, some programming (spreadsheet/Visual Basic) assignments may be required. Students must develop their own codes unless otherwise instructed.

Homework/Project Format Guidelines:

General Instructions:

0. Coversheet: You must use the required coversheet — such a coversheet will be provided by the instructor for EVERY assignment.
1. Paper: You must use engineering analysis paper or lined notebook paper (8.5 inches in width by 11 inches in height).
2. Writing: You are to ONLY write (or print) on the FRONT of any particular page (and you must write as neatly as possible).
3. Numbering: Number the pages of your work in the upper right corner of each page as follows:
   Problem #/page #/total pages (for a particular problem)
4. Binding: Use a SINGLE staple (or binder clip) in the upper left hand corner (do not use a notebook or spiral bind).

Homework/Project Format:

1. Given: (Statement of Problem and Problem Data)
2. Required: (Problem Objectives)
3. Solution: (Methodology)
   a. Sketches and Diagrams
   b. Assumptions, Working Hypotheses, References
   c. Formulas and Definitions of Symbols (Including Units)
   d. Calculations (Including Units)
4. Results:
   a. Use properly-scaled plots — the data should be identified with symbols and the model (if used) should be presented using lines.
   b. Do NOT submit numerous pages of data/computer output — a single (example) page is sufficient.
5. Conclusions: Provide a short summary that discusses the problem results.
6. References: Any/all references used in the solution of the problem MUST be cited.
7. Appendices: Data, plots, computer codes, etc. which are not necessary for the body of the submission.

In all of your work, full detail (calculations, data, units, etc.) must be shown for credit — penalties will be assessed for incomplete work.

Instructor Responsibilities

The instructor is responsible for

1. A learning environment where students of all skills levels are appropriately challenged.
2. Showing respect and consideration to the students.
3. Being prepared for class and keeping on schedule with the syllabus.
4. Preparing exercises that follow the course objectives.
5. Covering the material that will be tested on exams.

The instructor is not responsible for

1. Work missed by absent students (unless a University-excused absence is provided to the instructor).
2. Poor performance by unattentive or uninterested students. This is a fundamental course in Reservoir Engineering, one that you will use actively in your career as a reservoir or production engineer.
3. Personal issues — if you have personal issues that impair your performance in this course, you are encouraged to discuss these problems with your instructor for possible remedies. However, the instructor is responsible for assigning your grade based solely on your performance and is not at liberty to allow personal appeals to influence your grade.

Student Responsibilities

The student is responsible for

1. Class attendance. Students should attend all scheduled class meetings.
2. Being prepared for class. In-class quizzes will be given. Always bring your books, course notes, and calculator to each class meeting.
3. Being prepared for exams. The instructor or TA may choose to review materials prior to exams, but do not rely on this review as your only exam preparation—nor should you rely on old exams for your exam preparation. The best preparation for exams is to stay current with the class, rework assignments, and get plenty of rest the night before the exam.
4. Showing respect and consideration to his classmates and the instructor. Do not talk excessively with your neighbors during class. Do not take up class time for discussions with the instructor that should be held outside of class. Students who disrupt the class will be asked to leave.
Petroleum Engineering 311 — Reservoir Petrophysics
Assignment Coversheet — Required by University Policy
Fall 2007

Petroleum Engineering Number — Course Title
Assignment Number— Assignment Title
Assignment Date — Due Date

Assignment Coversheet
(This sheet must be included with your work submission)

Required Academic Integrity Statement: (Texas A&M University Policy Statement)

Academic Integrity Statement
All syllabi shall contain a section that states the Aggie Honor Code and refers the student to the Honor Council Rules and Procedures on the web.

Aggie Honor Code
"An Aggie does not lie, cheat, or steal or tolerate those who do."

Upon accepting admission to Texas A&M University, a student immediately assumes a commitment to uphold the Honor Code, to accept responsibility for learning and to follow the philosophy and rules of the Honor System. Students will be required to state their commitment on examinations, research papers, and other academic work. Ignorance of the rules does not exclude any member of the Texas A&M University community from the requirements or the processes of the Honor System. For additional information please visit: www.tamu.edu/aggiehonor/

On all course work, assignments, and examinations at Texas A&M University, the following Honor Pledge shall be preprinted and signed by the student:

"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work."

Aggie Code of Honor:
An Aggie does not lie, cheat, or steal or tolerate those who do.

Required Academic Integrity Statement:
"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work."

_______________________________ (your signature)

Coursework Copyright Statement: (Texas A&M University Policy Statement)
The handouts used in this course are copyrighted. By "handouts," this means all materials generated for this class, which include but are not limited to syllabi, quizzes, exams, lab problems, in-class materials, review sheets, and additional problem sets. Because these materials are copyrighted, you do not have the right to copy them, unless you are expressly granted permission.

As commonly defined, plagiarism consists of passing off as one’s own the ideas, words, writings, etc., that belong to another. In accordance with this definition, you are committing plagiarism if you copy the work of another person and turn it in as your own, even if you should have the permission of that person. Plagiarism is one of the worst academic sins, for the plagiarist destroys the trust among colleagues without which research cannot be safely communicated.

If you have any questions about plagiarism and/or copying, please consult the latest issue of the Texas A&M University Student Rules, under the section "Scholastic Dishonesty."
Faculty-Student Contract: (T. Blasingame)

The most important element of your education is your participation. No matter how hard we as faculty try (or don't try) to prepare you to learn, we cannot force you to work. We can only provide examples of how you should perform and we can only evaluate your performance — not your intentions or your personality, nor can we make allowances for your personal problems or your lack of preparation.

We can of course provide some pretty unpleasant alternatives as incentives (e.g., poor grades), but poor grades are a product of only two issues, a lack of subject mastery, or apathy. We as faculty can do much to prepare you for a rewarding career, not only as engineers, but also as productive members of society in whatever capacity you wish to serve. But—we cannot make you care, we cannot make you prepare, and we cannot make you perform — only you can do this.

We have chosen our path in life to help you find yours, we want you to succeed (perhaps sometimes more than you do) and we will do our best to make your education fulfilling and rewarding. As we embark on what will likely be a tedious and challenging experience, we reaffirm our commitment to seeing that you get the most out of your education. When it seems as though we are overbearing taskmasters (and we may well be), remember that we are trying to prepare you for challenges where there is no safety net — and where there may be no second chance.

Our goal is to be your guide — we will treat you with the respect and consideration that you deserve, but you must have the faith to follow, the dedication to prepare, and the determination to succeed — it will be your turn to lead soon enough.

General Procedures for Studying: (Adapted from Arizona State U., 1992)

1. Before each lecture you should read the text carefully, don't just scan topics, but try to resolve sections of the reading into a simple summary of two or three sentences, emphasizing concepts as well as methods.
2. During the lecture take careful notes of what your instructor says and writes, LISTEN to what is being said as well as how it is emphasized. Don't try to be neat, but do try to get every detail you can — think of the lecture as an important story that you will have to tell again later.
3. As soon as possible after the lecture (and certainly the same day), reread the text and your "messy" lecture notes, then rewrite your lecture notes in a clear and neat format — redrawing the figures, filling in missed steps, and reworking examples. You are probably thinking that no one in their right mind would do this—but the secret is that successful students always review and prepare well in advance of exams.
4. Prepare a list of questions or issues that you need clarified, ask your instructor at the start of the next class (so others can benefit) or if you need one-on-one help, see your instructor as soon as possible, do not assume that it will "come to you later."
5. Work one homework problem at a time, without rushing. You are not learning if you are rushing, copying, or scribbling. Spread the problems out in time and write down any questions you have.
6. ASK QUESTIONS. In class, during office hours, ANY chance you get. If you do not understand something you cannot use it to solve problems. It will not come to you by magic. ASK! ASK! ASK!
7. Practice working problems. In addition to assigned problems, work the unassigned ones. Where do you think faculty take exam questions? You should establish a study group and distribute the load — but you should work several of each type of problem that you are assigned.
8. Before a test, you should go over the material covered by preparing an outline of the important material from your notes as well as the text. Then rewrite your outline for the material about which you are not very confident. Review that material, then rewrite the notes for the material about which you are still not confident. Continue until you think that you understand ALL of the material.
9. "Looking over" isn't learning, reading someone else's solution is insufficient to develop your skills, you must prepare in earnest — work lots and lots of problems, old homework, old exams, and study guide questions.
10. Speed on exams is often critical. It is not just a test of what you know, but how well you know it (and how fast you show it). The point is not just to "understand" but to "get it in your bones."
11. Participate in class. The instructor must have feedback to help you. Force the issue if you must, it is your education.
Absence Policy:
Work missed due to absences will only be excused for University-approved activities in accordance with TEXAS A&M UNIVERSITY STUDENT RULES (see http://student-rules.tamu.edu/rule7.htm). Specific arrangements for make-up work in such instances will be handled on a case-by-case basis. In accordance with recent changes to Rule 7, please be aware that in this course, any "injury or illness that is too severe or contagious for the student to attend class" will require "a medical confirmation note from his or her medical provider" even if the absence is for less than 3 days (see 7.1.6.2 Injury or illness less than three days.).

Returned Work Protocol:
In this course, student work will be returned to students in a variety of ways:
- By direct return of work from instructor to student.
- By placing papers in a common box(s) located at the instructor's office for students to pick up personally.