Master of Science in Petroleum Engineering

COURSE DESCRIPTION
2016-2017

Imperial College
London

Centre for Petroleum Studies
Department of Earth Science and Engineering
Royal School of Mines Building
Prince Consort Road
London SW7 2AZ
United Kingdom
The Centre for Petroleum Studies is a focus for research, postgraduate teaching and professional development within the framework of petroleum sciences and engineering at Imperial College. Its main objectives are to facilitate multi-disciplinary research between geologists, geophysicists, petroleum engineers and members of other key disciplines in order to advance the state of the art in exploration, appraisal/development and reservoir management, and to plan and implement related post graduate teaching programs which reflect current best practice within the petroleum industry. The Centre has one of the largest concentrations of petroleum scientists and engineers in any UK academic institution with almost 50 members of staff providing research expertise across the complete exploration-production spectrum.

Research is mostly carried out within the Department of Earth Science and Engineering in cooperation with research groups in other science and engineering departments at the College.

Research expertise includes: seismic data processing and imaging; seismic interpretation; sequence stratigraphy; sedimentary petrology; regional tectonics and basin analysis; clastic deposition and reservoir systems; reservoir characterisation, petrophysics; petroleum geomechanics; reservoir physics; well test analysis; stochastic modelling; numerical simulation; reservoir engineering; multiphase flow; process engineering and environment engineering. Funding is largely obtained from industry.

We would like to wish the new students a very happy and successful year in the Department.

Professor Martin Blunt

Course Director

MASTER OF SCIENCE IN PETROLEUM ENGINEERING
The objective of the MSc curriculum is to train petroleum engineering professionals that understand the workflow concepts that are now prevailing in the oil industry and therefore are fully prepared to work in multi-disciplinary teams. The MSc curriculum, organised around five teaching modules, is intended to give students a full understanding of:

1) the fundamental concepts of reservoir characterisation, reservoir modelling, reservoir simulation, and field management;
2) the links between the various types of data; and
3) the processes for integrating and processing all available information.

Details of the curriculum are attached. There are three principal elements to the course:

1) **Formal lectures, problems classes, and computer exercises**

These take place on a full-time, structured basis from October to March in the normal academic terms, for a total of 400 hours:

- Module I provides fundamental knowledge on the reservoir rocks, fluids, production mechanisms and flow equations.
- Module II addresses the reservoir characterisation process and the integration of knowledge from the various types of data into a reservoir model.
- Module III deals with drilling, completion and well performance prediction.
- Module IV is concerned with the simulation of the behaviour of the reservoir model and the prediction of reservoir performance.
- Module V concentrates on surface facilities, safety and environment, and field development.

Lectures are supplemented by field trips, seminars from industry and communication skills. Formal examinations are conducted in January and in April.

2) **Group project work**

This is a 150-hour group exercise involving an integrated study of the evaluation and development of an oil field (currently, the Wytch Farm field). The objective is to inter-relate the separate subjects taught in formal lectures. Each group has to produce a detailed plan covering all aspects of field development beginning with exploration and ending with abandonment.

Data for the project is analysed with prevailing commercial software as part of Modules II to IV, and integrated into a development proposal as part of Module V. For the reservoir characterisation phase (Module II), the groups are multidisciplinary and include petroleum geologists from the MSc in Petroleum Geoscience in addition to petroleum engineers, thus reproducing the environment of an asset team. Time is made available in the timetable but some extra-curricular work is expected. This is assessed initially by presentation to the examiners at the end of the Spring term. After review and discussion, selected groups make further presentations to an invited audience from the industry. The best presentation is awarded the Colin Wall prize.
3) Individual projects

Further, more specific knowledge is developed during a three-and-a-half-month research project after formal examinations at the end of April. Students work on individual research type assignments until public presentation of the project in mid-September. Projects may be selected by the candidate, planned in co-operation with industrial sponsors or allocated by the Department.

Considerable emphasis is placed on communication skills, both written and oral. In the course of the year, all candidates can expect to make a contribution to the group project presentation and give a presentation on their individual project. These two are given to internal and external examiners and an invited audience from industry.

Formal classes are restricted to the conventional College term dates, but students will need to, and are expected to, continue with problems, computer and laboratory work through the vacation when the College is open. The dates for College closures at Christmas and Easter will be available at the start of term. Students are expected to be in attendance from Monday to Friday at all other times. This applies particularly to seminars or lectures held by outside speakers or MSc presentations at all times.
ACADEMIC STAFF
involved with the MSc in Petroleum Engineering 2016/2017

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Lecturer in Petrophysics
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Professor of Reservoir Physics
Ann Muggeridge, PhD
Tel: +44 (0)20 7594 7379  E-mail:  a.muggeridge@imperial.ac.uk

Lecturer in Clean Fossil Fuels
Samuel Krevor, PhD
Tel :: +44 (0)20 7594 2701  E-mail:  s.krevor@imperial.ac.uk

Visiting Professors and Lecturers
Deryck Bond, PhD (Consultant)
John Crawshaw, PhD
Olivier Dubrule, PhD (Total)
Olivier Gosselin (Total)
Gioia Falcone, PhD
Satinder Purewal, BSc, PhD
Sander Suicmez, PhD (Maersk)
David Waldren, BSc, PhD (BP)
Paul F. Worthington, BSc, MSc, PhD, DSc, CEng, CGEOL (GCA)

Industry Lecturers
A.  Baylaucq, (Total)
M.  Dyson (Striatum)
I.  Elliu, MSc, PhD, DIC, C.Eng. (Cisk Ventures, Inc.)
E.  Jankowski (RPS Energy)
Xu Dong Jing, MSc, PhD (Shell)
Carmen Morataya (Consultant)
G.  Simpson (RPS Energy)
P.  Smith (RPS Energy)

plus contributors from Industry.
COURSE CONTENT

1 FUNDAMENTALS

INTEGRATED RESERVOIR MANAGEMENT

COURSES

<table>
<thead>
<tr>
<th>COURSES</th>
<th>Duration, hours</th>
<th>3 hr Units</th>
<th>% Total</th>
<th>By</th>
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<td>INTRODUCTION</td>
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<td>Prof. G. Hampson</td>
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<td>Basic Petroleum Geology</td>
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<td>Dr. P. Fitch</td>
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<tr>
<td>Overview of Unconventional Hydrocarbons</td>
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<td>Prof. A. Fraser &amp; F. Spathhopoulos</td>
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<td>Shale Gas and Hydraulic Fracturing</td>
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<tr>
<td>Field Trip</td>
<td>27</td>
<td>9</td>
<td>4.5%</td>
<td>G.J. Hampson, M.D. Jackson, H.D. Johnson &amp; P. Fitch</td>
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<tr>
<td>Geostatistics</td>
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<td>2.0%</td>
<td>Prof. O. Dubrule</td>
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<td>Uncertainty in Hydrocarbon Reserves</td>
<td>3</td>
<td>1</td>
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<tr>
<td>Production Mechanisms</td>
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<td>Definition of Hydrocarbon Reserves</td>
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<td>Gas Injection</td>
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<td>Fluid Flow in Porous Media</td>
<td>27</td>
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<td>Prof. R.W. Zimmerman</td>
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2. RESERVOIR CHARACTERISATION

### COURSES

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<th>COURSE</th>
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<tr>
<td>Production Logging</td>
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<td>3</td>
<td>1.5%</td>
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<td>Prof. A. Gringarten</td>
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<tr>
<td>Fluid Sampling and Analysis</td>
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<td>Mr. A. Baylaucq (Total)</td>
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<td>2.7. GROUP FIELD PROJECT: 3D</td>
<td>69</td>
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<td>Dr G. J. Hampson and Prof M. Jackson</td>
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<td>Reservoir Model</td>
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<td>(with CPS staff)</td>
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WELL ENGINEERING / WELL PERFORMANCE

COURSES

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<th>% Total</th>
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<tr>
<td>Well Construction (Drilling and Completion)</td>
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<td>3%</td>
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<tr>
<td>Production Engineering / Well Performance</td>
<td>27</td>
<td>9</td>
<td>4.5%</td>
</tr>
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</table>

By

M. Dyson (Striatum)

Prof. G. Falcone
RESERVOIR ENGINEERING / RESERVOIR PERFORMANCE

RESERVOIR PERFORMANCE

COURSES

<table>
<thead>
<tr>
<th>COURSES</th>
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<th>By</th>
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<td>Prof. M. Blunt</td>
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<tr>
<td>EOR</td>
<td>12</td>
<td>4</td>
<td>2%</td>
<td>Dr. S. Krevor</td>
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<tr>
<td>Numerical Simulators</td>
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<td>Prof. D. Waldren (BP)</td>
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<td>Upscaling</td>
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<td>Olivier Gosselin (Total)</td>
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<td>Practical Use of Simulators</td>
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<td>8</td>
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<td>Schlumberger</td>
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<td>Economics</td>
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<tr>
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<td>G. Scotton</td>
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<tr>
<td>GROUP FIELD PROJECT: Simulation Model / Production optimisation</td>
<td>66</td>
<td>22</td>
<td>11%</td>
<td>O. Gosselin (with CPS staff)</td>
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FIELD DEVELOPMENT

COURSES

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<thead>
<tr>
<th>Module</th>
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<tr>
<td>Process Engineering and Surface Facilities</td>
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<td>Dr. I. Ellul (CISK Ventures.)</td>
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<td>T. Ingram (SEC)</td>
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<td>GROUP FIELD PROJECT: Field development Plan</td>
<td>57</td>
<td>19</td>
<td>9.5%</td>
<td>O. Gosselin &amp; Dr S. Purewal (with CPS staff)</td>
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</table>
6 COMMUNICATION SKILLS AND VISITING LECTURERS
Objective: To enable students to communicate with industrial colleagues and to be aware of the latest developments in the industry. All students will give a talk as part of the Group Project in the Autumn term.
A number of lectures will be given by visitors from the Industry and Government Institutions on aspects of Petroleum Engineering covering current industrial problems and practice, within each teaching module.

7 RESEARCH (450 hours, CPS staff)
Three-and-a-half month individual research project, usually on location with an oil producing or service company.
COURSE OUTLINES
COURSE OUTLINE: INTRODUCTION TO PETROLEUM GEOLOGY

Dr Peter Fitch

Aims

1. To present an overview of the fundamentals of Earth Science
2. To outline the geological parameters and processes controlling oil and gas accumulations
3. To introduce the topic of Petroleum System Analysis
4. To demonstrate the role of Earth Sciences in petroleum exploration: acquisition and interpretation of data
5. To show the types and global distribution of “conventional reserves”
6. To review the definitions of conventional reserves and reserve estimation methods
7. To introduce the concept of uncertainty, risk and risk analysis in exploration projects
8. To review “unconventional resources”
9. To provide an overview of the petroleum systems of the North Sea Basin

Objectives

On completion of this module students should be able to:

(a) Identify and apply the principles of geology to controls on hydrocarbon generation, migration, and accumulation.
(b) Identify and characterise the main petroleum rock types (sandstone, mudstone, limestone and dolomite)
(c) Use and interpret key data relating the role of geology to petroleum exploration and in the quantification of conventional resources.
(d) Understand the potential unconventional hydrocarbon resources and their likely impact on future hydrocarbon supplies.
(e) Appreciate the impact of geology on reservoir thickness, quality, continuity, distribution, subdivisions and established “flow units”.
(f) Understand how geological features influence effective appraisal, development and managements of hydrocarbon fields.
(g) Recognise the importance of a multidisciplinary approach and integration of geological, geophysical and petroleum engineering data in field development and production – leading to an increased awareness of the relationships between the two MSc courses.

Prerequisites

No prior knowledge of geology is required.

Duration

18 hours of lectures and practical sessions during the Autumn term.

Assessment

The material presented in this module provides a foundation for the subsequent modules studied throughout the MSc Petroleum Engineering degree. It is not assessed directly but will feed into assessed assignments such as the Wessex basin field trip and the Field Development Project.

Lecture syllabus (session plan)

1) Module Introduction
2) Earth Science 101
3) Concepts: Rock types
4) Clastics: Sandstones
5) Clastics: Mudstones
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6) Unconventional Reservoirs
7) Carbonates and evaporates
8) Hydrocarbon: generation, maturation and migration
9) Concepts: Stratigraphy and structures
10) Exploration methods & Petroleum Systems
11) Play concepts, conventional reservoir classification & controls
12) Reserves – estimation, risk and uncertainty
13) North Sea Basin Case Study
14) Global perspectives

To make the most of classroom contact hours suggested reading and short tasks will be set in advance and for 30-60 minutes during non-contact hours. Blackboard will be used to support independent study and revision.

Texts (direction to relevant sections will be made during the module)

Fitch, P, (2016), Introduction to Petroleum Geology – course notes. Imperial College London


Aims

(1) To introduce the fundamental concepts and methods of geostatistical heterogeneity modelling.
(2) To present the basics of reservoir uncertainty quantification.

Objectives

At the end of the course students should:

(1) Understand the meaning of a variogram and the differences between kriging and simulation. Be able to make an informed choice of variogram model in practical situations.
(2) Know about the main approaches for modelling the distribution of reservoir facies in 3D and be able to choose the right one in practical situations.
(3) Understand the basic Monte-Carlo and geostatistical simulation tools for quantifying volumetric uncertainties and avoid the most common mistakes.

Timing

15 hours

Prerequisites

It is preferable that the students have a basic knowledge of probability and statistics. This includes discrete and continuous random variables, correlation versus independence between variables, and the impact of summing and multiplying random variables together. Some previous experience of Monte-Carlo simulation may be useful too. However all these concepts will be re-defined during the course.

Texts (from simplest to more complex)

http://www.mathsrevision.net/advanced-level-maths-revision/advanced-level-level-statistics

Pyrcz, M.J. and Deutsch, C.V., Geostatistical Reservoir Modelling, Oxford University Press, 2014


Chilès, J.P. and Delfiner, P, Geostatistics: Modeling Spatial Uncertainty, Wiley, 2012,
2. Reminders on Continuous Random Variables.
3. Geostatistics for Continuous Variables (Variogram, Kriging, Conditional Simulation…).
4. Reminders on Discrete Random Variables.
5. Facies Simulation (Indicator Simulation, Object-Based Models, Pluri-Gaussians, Multi-Point Statistics, Markov Transiograms…)
6. Uncertainties (Quantifying their Magnitude and Evaluating their Impact with Monte-Carlo and Geostatistics).

COURSE OUTLINE: FIELD PROJECT

G.J. Hampson, M.D. Jackson, P. Fitch, O. Gosselin and All CPS Staff

Description
This is a computer-aided field development training exercise which illustrates the integration required for field development. The project covers selected activities from drilling and reservoir characterisation to the design of the surface facilities, from economic forecasting of pre-performance to application to regulatory authorities. The field group project is carried out by groups of about five/six students.

**Aims**

1. To serve as tutorial for taught courses
2. To form a firm basis for integrating topics learned in formal lectures
3. To encourage interdisciplinary (“lateral”) thinking
4. To train students to be team players in multi-disciplinary field management groups (asset management teams, business units etc.)
5. To expose students to the most up-to-date reservoir management tools
6. To familiarise students with all aspects of a field development process

**Objectives**

At the end of the field project, the student should

1. be able to make provisional risk-weighted estimates of the hydrocarbon reserves
2. provide technically acceptable development options for the field
3. produce an economic evaluation of the project for the preferred development option
4. be able to summarise all the studies conducted into a submission for development approval to regulatory authorities
5. analyse the initial performance of the reservoir under the proposed development plan.

**Timing**

150 hours + extra time to be allocated for presentations by the project groups.

**Texts**

The recommended reading and reference list include:

- Wood Mackenzie Upstream Oil and Gas Publications for UK North Sea,
- ROBERTSON GROUP, *Oil and Gas Fields of the North Sea*. In 3 Volumes, Robertson Group, 1990

**Assessment**

Assessment will be based on:

1. the overall technical quality of the work produced
2. the deliverables during the routine presentations to Centre for Petroleum Studies (CPS) staff
3. the contributions of individuals to Group work
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Project Implementation

The following working practices are expectations from each project group:

1. each group must develop its own working procedures
2. responsibilities are individual as well as common
3. all members of each group must be familiar with all aspects of the project
4. groups should maintain certain professional working discipline. If for any reason, a Group underperforms, the reasons should timely be identified and cured in co-operation with the CPS staff as appropriate.

Project Milestones/Deliverables

The project follows the MSc course modular structure. Some of the group project deliverables will be integral parts of the lecture tutorials, others will be developed during dedicated sessions. Steps and milestones are as follows:

Phase 1: Reservoir Characterisation (during the “Reservoir Characterisation” Module)

General description of the Project
Academic objectives of the Project
Project working procedures and expected deliverables
Assessment Procedures. Work schedule and structures
Prospect Evaluation:
Study the map.
Study the allocated location in the North Sea ( Regional Settings/Tectonic History, Depositional Environment, Source and Reservoir Rocks, Expected Stratigraphic Column, Porosity and Water Saturation estimates, recovery factors in the region, simple risk assessment by using regional risk factors as a guideline).
Processing of Hard Data
Identify correlatable and uncorrelatable data
Establish deterministic relationships between the correlatable data - this includes core permeability to core porosity; core porosity to log porosity; core permeability to well test permeability; Leverett J-Function for special core analysis
Establish statistical relationships by generating statistical distribution function including PDFs
Generation of Soft Data
Complete missing information for wells
Generate interwell data : the followings may be used
Fence Diagrams
Interpretative contouring
Stochastic techniques - totally random processes ( Monte Carlo Approach, sampling from PDFs )
Statistical techniques - Geostatistics ( Use of Semi-Variograms and Kriging )
Deliverables: Processed Well Data
Maps for parameters at desired scale: these should include maps for permeability, porosity, irreducible and residual saturation, relative permeability end points, net-to-gross ratio, isopach, top surface.
STOIIP. 3D Reservoir model.

Phase 2 (during the “Reservoir Engineering/Reservoir Performance” Module)

Generation of hydraulic tables for the optimal technical scenario and other alternative scenarios for use in integrated simulation application (approximate desired surface pressures, compressor requirements etc. will be selected, to be improved during Field Development Module).

Upscaling of data for use in simulation - Realisations based on different upscaling techniques (this will later be one of the parametric studies of performance prediction).
Basic reservoir engineering studies using upscaled parameters and estimation of recovery factors (also to be used for the control of simulation). Well performance data will be used to identify the required number of wells, and initial estimates of well spacing (patterns). The uncertainty in the performance of the reservoir under the optimal production scenario will also be studied.

Prediction studies to identify possible integrated solutions with surface facilities and economics to be assessed later.

Prepare
- Identification of well locations and objectives.
- Rate and total volume of fluids produced
- Associated uncertainty analysis with range of possible outcomes

Drilling timing
- Data Acquisition Programme (Coring, Mud Logging, Well logging, RFT, DST, Routine and Special Core Analysis Results and Others Planned)

Phase 3: Field Development
- Design the surface facilities and if necessary iterate using the simulator.
- Identify the best platform options for offshore applications.
- Prepare plans of the activities - Project bar charts etc.;
- Prepare abandonment plans.
- Apply economics to find out the optimal CAPEX and OPEX; Assess project economics.
- Perform a number of iterations until a feasible development scenario is established.
- Summarise lessons learned

COURSE OUTLINE: Shale Gas: Drilling, Hydraulic Fracturing and Global Warming

Dr J. Crawshaw

Aims
(1) to present information on shale gas as a new and clean (?) resource of fossil fuels
(2) to explain the oilfield process of “fracking” shale gas reservoirs, including
Objectives
At the end of the course, students should:

(1) understand the importance of conventional and unconventional gas resources
(2) understand the pros and cons of shale gas recovery, in comparison with conventional resources, in terms of Economics, Politics and Environment
(3) understand the fundamentals of the fracking process,
(4) understand the importance of Darcy’s law for flow in porous media
(5) realise the limitations of Darcy’s law regarding shale gas production
(6) understand calculation of GWP of fugitive methane emissions in comparison with coal

Prerequisites
Basic knowledge of physics / chemistry is recommended.

Duration
3 hours of lectures during the Autumn term.

Assessment
This course will not be formally examined.

Lecture notes
Crawshaw J.P., 2015. Shale gas, Imperial College course notes (slides)

Texts:
Valko, P. and Economides, M.J. Hydraulic Fracture Mechanics, John Wiley and Sons Ltd (1995)

Additional literature on pore scale imaging and modelling (optional):
J. Crawshaw and E.S.Boek, Reviews in Mineralogy & Geochemistry 77, 431-458 (2013)
(2014)

COURSE OUTLINE: Production Mechanisms

M. J. Blunt

Aims

(1) to introduce the fundamentals concepts of reservoir behaviour
Objectives

At the end of the course students should:

(1) understand concepts of primary, secondary and tertiary recovery
(2) appreciate the changes in reservoir behaviour as reservoir pressure drops

Timing

3 hours of lectures

Prerequisites

Courses 1.3 and 1.5

Texts


Assessment

There will be related homework in the ‘Reservoir Performance Predictors’ course in the Spring Term and it will be examined in the ‘Reservoir Engineering and Secondary Recovery’ exam in April.

Syllabus

1 Primary and improved/enhanced oil recovery.
2 Primary oil production; reservoir drives and production mechanisms; solution gas, gas cap, aquifer, gravity drainage, compaction. Recovery factors.
3 Secondary recovery; waterdrive, gas injection
4 IOR/EOR. Life of field recovery processes.
5 Gas reservoirs; water influx effects on gas reservoir production.
6 Concepts of depletion planning from reservoir mechanistic point of view.
7 Composition and how it affects reservoir behaviour.

COURSE OUTLINE: RESOURCES and RESERVES CATEGORISATION (PRMS)

Dr. Satinder Purewal

Aims

(1) To outline the basic principles of resources/reserves categorisation (PRMS).
(2) To show the difference between resources and reserves
Objectives

At the end of the course, students should:

(1) Understand the different categories of reserves and resources.
(2) Appreciate the reasons for uncertainty and the need to address it.
(3) Be able to differentiate between deterministic and probabilistic methods.
(4) Be aware of the limitations of reserve assessment methods.
(5) Appreciate the relationship between reserves, development plan and economics.

Prerequisites

Firstly, a desire to understand the resources and reserves categorisation as outlined in the Petroleum Resource Management System (PRMS), including the treatment of uncertainty. Secondly, an open mind with regard to the pros and cons of various methods used for reserves assessment. Finally, an ability to recognise the potential for improvement.

Timing

3 hours of lectures during autumn term.

Assessment

This material will be assessed as part of Phase 1 of the Group Field Project.

Texts

- “SPE/WPC Reserves Definitions Approved”, JPT (May 1997) 527.
- “Classification of Petroleum Resources on the Norwegian Continental Shelf”, The Norwegian Petroleum Directorate (July 1997).

Lecture syllabus

1 Reserves and resources definitions and guidelines.
2 Petroleum Resource Management System (PRMS)
3 Other Categorisation Systems.
COURSE OUTLINE: GAS INJECTION

Dr V. S. Suicmez
Maersk Oil

Aims
The main aims of this course are:

(1) To familiarise the students with the practical aspects of the gas injection process.
(2) To discuss the reasons and best practices of the gas-based enhanced oil recovery (EOR).
(3) To identify the key enablers and disablers of the gas injection projects.

Objectives
At the end of the course, students should:
Master of Science in Petroleum Engineering

(1) Understand the requirements of the implementation of a gas injection project.
(2) Gain a clear understanding on dynamic PVT experiments such as the swelling test, slim tube and multi contact experiments.
(3) Understand the concept of miscibility and the estimation of the minimum miscibility pressure (MMP).
(4) Be familiar with the issues associated with the simulation of gas injection processes.

Prerequisites
Basic knowledge of phase behaviour, flow in porous media and reservoir simulation is recommended.

Timing
9 hours of lectures

Assessment
Work will be assessed by means of course work and via the in-class exercises.

Texts

Lecture syllabus

1. Introduction to EOR and Gas Injection
2. A recap on Phase Behaviour
3. Concept of Miscibility and the Estimation of the MMP
4. Simulation of Gas Flooding
5. Practical Case Studies

COURSE OUTLINE: FLUID FLOW IN POROUS MEDIA

Professor R.W. Zimmerman

Aims:

(1) To present the diffusion equation that governs single-phase flow of a fluid through a porous medium.
(2) To present the mathematical solutions to basic problems relevant to well-test analysis.
(3) To introduce advanced mathematical methods used to analyse flow through porous media such as Laplace transforms, eigenfunction expansions, and convolution.
(4) To present the fundamental equations governing the flow of multi-phase fluids and gases in porous media.
Objectives:

At the end of the course, students should:

1. Understand the derivation of the pressure diffusion equation, and understand the significance of the parameters that appear in it, such as permeability and storativity.
2. Understand the assumptions underlying the line-source solution to the diffusivity equation, and the logarithmic approximation to this solution.
3. Understand the concepts of dimensionless time and dimensionless pressure.
4. Understand, and be able to utilise, the concept of superposition, in both time and space.
5. Understand the effects of skin, wellbore storage, and outer boundaries on well-test behaviour.
6. Understand the use of Laplace transforms and convolution in solving diffusion-type problems.

Prerequisites:

In order to be able to follow the course, students would need the following preliminary knowledge:

1. Good understanding of differential and integral calculus.
2. Some familiarity with ordinary differential equations.

Timing:

27 hours of lectures and tutorials during the Autumn term

Texts:

Course notes will be distributed. Other relevant texts are:


Assessment:

Work will be assessed as part of the Flow in Porous Media and Well Test Analysis examination in January.

Lecture syllabus:

1. Diffusivity Equation: Darcy’s law and definition of permeability; Potential, datum levels, and corrected pressures; Concept of Representative Elementary Volume; Conservation of mass equation; Diffusivity equation in Cartesian coordinates; Diffusivity equation in cylindrical coordinates; Steady-state Thiem-Dupuit solution for radial flow; Equations governing multi-phase flow.

2. Line-Source solution: Derivation of line-source solution via the Boltzmann transformation; Dimensionless pressure and dimensionless time; Criterion for applicability of line-source solution; Logarithmic approximation to line-source solution; Solution for instantaneous pulse of injected/produced fluid.
3. Pressure build-up tests and superposition: Buildup-test in infinite reservoir; Buildup-test in bounded reservoir; Multi-rate flow tests; Convolution integral for variable flow-rate tests.

4. Effect of linear boundaries: Principle of superposition of sources/sinks in space; Well near an impermeable linear fault; Well near intersecting impermeable linear faults; Well near a constant-pressure linear boundary.

5. Inner (wellbore) boundary conditions: Wellbore skin concept - steady-state model; Effect of wellbore skin on pressure tests; Wellbore-storage phenomena and wellbore-storage coefficient; Effect of wellbore storage on pressure tests.

6. Outer boundary conditions: Well in a circular reservoir: method of eigenvalue expansions; van Everdingen-Hurst solution for well in circular reservoir; Flow regimes in terms of dimensionless time; Dietz shape factors for non-circular reservoirs.

7. Laplace transform methods in well-test analysis: Introduction to Laplace transforms; Convolution principle in Laplace space; Numerical inversion of Laplace-space solutions using Stehfest algorithm; Solution for flow to a hydraulically-fractured well.

8. Naturally-fractured reservoirs: Warren-Root dual-porosity model; Dimensionless parameters for Warren-Root model; Flow to a well in dual-porosity reservoir; Dual-permeability model and other extensions.

9. Flow of gases in porous media: Derivation of governing equations for gas flow; Pseudo-pressure, p-squared method, etc.; Forchheimer equation and non-Darcy effects; Klinkenberg effect for gas flow.

COURSE OUTLINE: RESERVOIR FLUIDS

Prof. V. Vesovic

Aims

(1) To introduce the fundamental description of thermophysical properties and behavior of reservoir fluids.

Objectives
At the end of the course students should:

1. understand the fundamental concepts of hydrocarbon thermodynamics;
2. understand the use of equation-of-state;
3. be able to carry out simple phase-equilibria calculations;

Timing

18 hours.

Prerequisite

A basic understanding of thermodynamics, as covered in the first year of an engineering course.

Texts


Assessment

The course is assessed by one question in the Rock and Fluid Properties exam in January.

Syllabus

*Phase Behavior*

Pure substance: PT-diagram, PV-diagram, critical point, quality lines; Binary mixtures: PT-diagram, dew and bubble point lines, sub-critical and supercritical behavior, retrograde condensation; Multicomponent mixtures: black oil, volatile oil, retrograde gas, wet and dry gas; behavior of fluids in the reservoirs.

*Equation of State*

Fluid Characterization
Heavy end definition, characterizing heavy end, True Boiling Point distillation, Single Carbon Number groups, Whitson gamma distribution, Riazi and Daubert critical properties correlation, Watson K-factor, Lumping, pseudo components mixing rules, tuning.

Modelling Phase Equilibria
VLE flash calculation, Rachford-Rice equation, K-values, ideal case, correlations, fugacity, EOS approach to VLE, calculating bubble and dew point pressure, sensitivity to tuning parameters.

Thermophysical properties
Formation volume factors, viscosity, isothermal compressibility; behavior for different reservoir fluids.

COURSE OUTLINE: PETROPHYSICS – LOG AND CORE ANALYSIS

Dr. P Fitch & Prof. M Jackson

Aims
(1) To introduce the theory and practice of open hole log interpretation and core analysis.
(2) To present the limitations of current practices and describe the emerging technologies.

Objectives
At the end of the course, students should:
(1) Have a clear understanding of the fundamental physics involved in various petrophysical measurements from borehole logs and cores.
(2) Be able to conduct basic log interpretation to determine lithology and petrophysical parameters such as porosity, saturation for clean and shaly formations, and permeability prediction.
(3) Be aware of the current industry practices in formation evaluation and future trends.

Prerequisites
In order to follow the course, students should understand the fundamentals of reservoir geology and rock properties as outlined in section 1.1 and 1.3

Duration
36 hours of lectures and practical sessions in the autumn term (18 hours P Fitch, 18 hours M Jackson)

Assessment
Short questions and quantitative interpretation included in the Petrophysics & Seismic Techniques exam in May

Texts
(1) Module 2, Petrophysics (Well log analysis), P Fitch, Imperial College course notes, 2014.
(2) Module 2, Petrophysics (Core analysis), M Jackson, Imperial College course notes, 2014.
(7) J.S. Archer & C.G. Wall 1982: Petroleum Engineering
(8) R.P. Monicard : Properties of Reservoir Rocks – Core Analysis

Lecture syllabus
1. Introduction.
2. Acquisition and recording of basic well logs
   - Passive logs: gamma ray and spontaneous potential logs
   - Porosity logs: density, neutron, and sonic logs
   - Resistivity logs
3. Qualitative and quantitative log analysis
4. Advanced well logs
   - Nuclear magnetic resonance logs
   - Borehole image logs
5. Log analysis in shaly sand and carbonate formations
7. Relative permeability, irreducible saturation.
8. Electrical resistivity, formation factor, Archie’s law.

COURSE OUTLINE: PRODUCTION LOGGING

N. Kotlar
Kappa Engineering

Aims

(1) To review the applications of production logging (PL) and the factors affecting the PL measurements.
(2) To review the most common PL tools.
(3) To cover the basics of PL interpretation in single and multi-phase flow.
(4) To highlight the potential limitations of the measurements and/or the interpretation models.
(5) To review the most recent tools for complex environments.

Objectives

At the end of the course, students should:

(1) Be familiar with the typical response of the most common PL tools.
(2) Understand the steps involved in PL interpretation and the underlying assumptions.
(3) Be able to perform single phase or 2-phase interpretations by hand.
(4) Have hands on experience on more complex situations using a PL interpretation software.

Prerequisite

In order to follow the course, students should understand the fundamentals of electric wireline data acquisition, reservoir fluid behaviour in the wellbore region, and completions.

Timing

9 hours of lectures in November.

Assessment

Course work will be given during the lecture.

Texts


Lecture Syllabus

1. Overview of the PL applications, and review of the many factors affecting the PL measurements
2. Presentation of the most common PL sensors
3. In-situ spinner calibration.
5. Multi-phase interpretation principles and models.
8. Special applications: Selective Inflow Performance, Temperature.

COURSE OUTLINE: WELL TEST ANALYSIS

Professor A. C. Gringarten

Aims

(1) To explain the contribution of well test analysis to reservoir characterisation and to the prediction of well performance
(2) To teach the practical aspects of well test analysis

Objectives

At the end of the course, students should:

(1) understand the fundamental concepts of well test analysis
(2) understand what results can be obtained from well test analysis
(3) be able to interpret any well test using a well defined, state-of-the-art methodology
(4) have a clear idea of the state-of-the-art in well test analysis
(5) know how to use and judge some of the prevailing commercial well test analysis software products

Prerequisites

In order to take full benefit from the course, students should understand the following concepts:

1. nature and characteristics of reservoir rocks
2. nature, characteristics and behaviours of reservoir fluids
3. diffusivity equation and equations for the various flow regimes that dominate during a test
4. superposition in time and space

Timing

36 hours during the Autumn term: 27 hours of lectures, 3 hours of tool presentations, and 6 hours of presentation by software vendors (Interpret/2, Pie, Pan Oil/Gas, Saphir)

Texts

Course notes will be distributed.
List of milestone technical publications will be provided.

Assessment

Work will be assessed by means of course work and as part of Phase 1 of the Group Project, and as part of the Flow in Porous Media and Well test Analysis exam in January.

Lecture syllabus

1. Introduction: Well testing as part of the integrated reservoir management process: well performance, reservoir performance and reservoir characterisation.
2. Well testing as a signal analysis problem. Concept of interpretation model. Interpretation and reservoir models. Identification and verification of the interpretation model.
3. Mathematical representations of the well test interpretation model
4-6. Well test interpretation techniques: Use of straight-line analyses, pressure log-log analysis and pressure derivatives and deconvolution. Tutorials 1 and 2. Use of well test analysis software.
13. Test design.
14. Practical considerations in well test measurements and analysis. Research areas.
COURSE OUTLINE: FLUID SAMPLING AND ANALYSIS

A. Baylaucq
   Total

Aims

(1) to introduce the essentials of how reservoir fluid samples are obtained and analysed
(2) to define the proper use of fluid analyses

Objectives

At the end of the course students should:

(1) appreciate the difficulties of obtaining valid reservoir samples
(2) know the different laboratory procedures for obtaining the needed PVT data
(3) know the methods of obtaining a PVT analysis for gas and oil
(4) know how to use the PVT analysis

Timing

6 hours of lectures

Prerequisite

Basic Fluid properties and well test analysis
Master of Science
in Petroleum Engineering

2016-2017

Texts


Assessment

This will be assessed as part of Phase 1 of the Group project.

Syllabus

1. Laboratory measurement of PVT, gas and liquid PVT properties and viscosity.
2. Problems of getting correct sample. Good sampling procedures. Downhole and surface preferences. Rate of production and drawdown effects.
3. Thermodynamic path problems. Problems of gas-oil ratio; flash, differential separation, separator tests.
4. Analysis - gas chromatography and other methods. Volatile oils and gas condensates
5. Other properties - pour point, wax, asphaltenes, hydrates.
6. Fluid representations
7. Extension of fluid data at the reservoir scale

COURSE OUTLINE: WELL PLANNING, ENGINEERING & CONSTRUCTION

Mr M.J. Dyson
Striatum Limited

Aims

1. Introduce the basic principles of well planning, design and construction.
2. Demonstrate how well design and construction contributes to optimal field development
3. Describe the practical stages of drilling and completing wells, and typical equipment used
4. Explain alternative completion designs and techniques for optimising production and well integrity
5. Raise awareness of safety, costs and operations management

Objectives

At the end of the course, students should:

1. Be able to articulate the basic principles of well planning, design and construction.
2. Understand how well design and construction contributes to optimal field development
3. Recognise the basic drilling and completion stages and equipment used
4. Possess a basic understanding of alternative completion designs
5. Appreciate well operations safety, costs and operations management

Prerequisites

No prior knowledge of well engineering or drilling is required or assumed
Timing

18 hours of lectures during Spring term.

Assessment

This material will be assessed as part of Phase 2 of the Group Field Project

Texts

1. *A Primer of Oilwell Drilling*, 6th edition, Ron Baker, Published by The University of Texas at Austin
2. *Applied Drilling Engineering*, Bourgoyne, Chenevert, Millheim and Young, Published by SPE

Lecture syllabus

1. Purpose of wells. Well planning.
2. Onshore and offshore drilling and well engineering
4. Casing and cementing.
7. Well control. Well control using mud; Casing selection & design. Primary cementing. BOPs. Drilling problems & control
8. Completion designs, well testing, sand control, selectivity, smart wells
9. Stimulation operations
10. Well maintenance
12. Safety
COURSE OUTLINE: RESERVOIR PERFORMANCE PREDICTION

M. J. Blunt

Aims

This course will describe how different, analytical methods can be used
(1) to assess the development potential of oil and gas reservoirs and
(2) to identify the principal mechanisms controlling the performance of producing reservoirs.
(3) to validate the predictions of numerical simulators

Objectives

On completion of this course students will be able to:

(1) Use material balance methods to identify the principal drive mechanisms in a reservoir.
(2) Estimate recovery efficiencies for a water-drive using the Buckley-Leverett method and extensions.
(3) Determine the best overall recovery strategy for a reservoir.
(4) Understand displacement processes.

Prerequisite

(1) Water and hydrocarbon PVT behaviour (formation volume factors, solution gas oil ratio etc.)
(2) Principal recovery mechanisms (primary: gas cap drive, aquifer, compaction etc., secondary: waterflood, tertiary: miscible, WAG etc.).
(3) Darcy’s Law, relative permeabilities, definition of fractional flow
Timing

The course will consist of 24 hours of lectures.

Tutorial question sheets will be handed out at intervals during the course. These are an integral part of the course. Some will revise the material learnt in lectures, others will supplement it. Material that is learnt through tutorial questions rather than lectures is still examinable.

Texts


Assessment

This material will be assessed in the Reservoir Mechanics and Secondary Recovery exam in May.

Syllabus

1. **Review of links with rest of course**
   Reservoir engineering overview: oil vocabulary and definitions, data sources and reliability, fluid distribution and flow in reservoirs, concepts of the recovery factor. Recovery mechanisms. Meaning of average reservoir pressure, fluid types.

2. **Material Balance**
   Conservation of mass/conservation of volume.
   Classification of reservoirs (gas/oil/condensate)
   Gas reservoirs. Gas production, P/Z plots, effects of water influx on gas production, uncertainties.
   Oil reservoirs. Primary oil production, natural drive mechanisms including solution gas drive, gas cap, aquifer, gravity drainage. Implications for planning field development. Complete material balance in oil reservoirs including material balance calculations for fields below the bubble point and the significance of compressibility, effects of gas expansion, aquifer influx effects, combination drive.

3. **Displacement Mechanisms**
   Review concepts in immiscible displacement calculations - relative permeabilities, mobility ratio, fractional flow, saturation distribution, imbibition, drainage, residual saturation, capillary pressure.
   Microscopic sweep efficiency: Buckley-Leverett analysis to give post-breakthrough recovery calculations.

4. **Decline curve analysis**
   Review when used. Different curves: exponential, hyperbolic, etc.
COURSE OUTLINE: Enhanced Oil Recovery

Sam Krevor

Aims

(1) To introduce students to the main technologies and underlying physical concepts used for enhanced oil recovery

Objectives

At the end of the course students should:

(1) Understand the role of enhanced oil recovery in global oil production today
(2) Understand the main technologies that have been used, or are in use, for enhanced oil recovery
(3) Understand the physical principles behind technologies used for enhanced oil recovery

Timing

12 hours of lecture

Prerequisites

Reservoir performance prediction

Texts

Lake, L.W., 2010 Enhanced Oil Recovery Society of Petroleum Engineers

Assessment
There will be no marked assessment

Syllabus

1 Definition of EOR
2 Overview of prevalent technologies
3 The role of EOR in current and future oil production
4 Enhancing the recovery factor
5 Principles of gas injection
6 Principles of chemical EOR including low salinity flooding
7 Practical considerations
COURSE OUTLINE: PRODUCTION ENGINEERING /WELL PERFORMANCE

G. Falcone

Aim

(1) Present the very basic concepts in oil and gas well production and completion engineering to enable the students to understand the mechanism of production from wells.
(2) After attending this course, students should be able to design and troubleshoot oil and gas wells at least at very basic level.
(3) Students should understand why wells flow with the rates they flow and if that flow can be improved and how

Objectives

At the end of this course, students should be able to:

(1) perform necessary calculations on productivity of wells
(2) establish the Inflow Performance Relationship for oil and gas wells
(3) evaluate the well deliverability under different GOR’s and reservoir conditions
(4) understand the principle of single-phase and multi-phase flow in oil and gas wells and determine the optimum size of the flow string to be used in well completion
(5) establish the IPR and evaluate the future well deliverability with depletion
(6) determine the economic production rate and the time when artificial lift system is required
(7) understand the principles of artificial lift systems, and be able to design gas lift and electric submersible pump systems
(8) perform nodal system analysis on oil and gas wells for the optimised production system design and troubleshooting.

Prerequisite

Before taking this course the students should have a clear understanding of:

(1) the nature and characteristics of reservoir rocks
(2) the nature, characteristics and behaviour of reservoir fluids – Black Oil and Compositional Models
(3) well Testing and well Logging for acquiring reservoir data
(4) well completion practices.

Timing

27 hours during the spring term.

Texts

Course notes and references given during lectures.

References:


Assessment

This material will be assessed as part of the Production Engineering and Well Performance exam in May. In addition, an important and essential part of the Group Project (Phase 2) is on the materials covered in this course.

PE Course Outline:

1. Production Systems Analysis – definition of Production System, IPR Curves and Tubing Intake curve, System graph, Sensitivity graph

   a. Darcy and Non-Darcy flow with implications and remediation

   b. Skin characterization- completion skin vs time dependent skin

      i. Causes, detection and remedies

   c. Production Optimization: sensitivity analysis

   d. Use of Sensitivity Graph for system design

   e. Loading and unloading of oil and gas wells

   f. Design of Velocity string

   g. Why artificial lift

   h. Design of Injection wells

2. Applications to horizontal, multi-layer & multilateral Wells: Inflow Performance Relationship (IPR)
3. Fluid Phase Properties: Black Oil Model in detail and Compositional Model in short
   (Prerequisite)

   in Well Performance
   a. Use in calculation of Tubing Intake Curve
   b. Design of hilly terrain flow lines

5. Well Completions:
   a. Open hole and Perforated completions: Screening and design (Shot density,
      Entrance Hole diameter, Tunnel Length etc)
      i. Partial penetration
      ii. Perforation for fracturing
   b. Stimulation
      i. Matrix acidization for skin removal- applicability, advantages and
         limitations
      ii. Fracturing for stimulation – applicability, advantages and limitations
   c. Artificial Lift design and evaluation
      i. Plunger Lift – types, applicability, limitations
      ii. Gas Lift – Design, Optimization, screening criteria with other artificial lift
          methods, trouble shooting
      iii. Electrical Submersible Pumps, ESP - Design, Optimization, screening
           criteria with other artificial lift methods, trouble shooting

6. Typical Well Problems: diagnostics or detection and remediation
   a. Un-targeted fluids (gas, water)
   b. Joule-Thompson cooling and its adverse effects on well productivity
i. Use of Temperature Log for detection of source of gas entry

c. Casing leakage

d. Scale: Organic and Inorganic (sublimation of sulphar)

e. Solids: Sand flow and fines or clay deposition

f. Sand fill in wells: Impression block

g. Hydrates (Clathrate)- phase behavior
Aims

The objective of this course is to provide an understanding of the following:

1. The theoretical background.
2. Types of models and their uses.
3. Data sources and treatment in the simulator.
4. Limitations.
5. Practical considerations.

Objectives

At the end of the course, the student should

1. have the sound knowledge of principles of numerical reservoir simulation process, its limitations, uses and abuses,
2. be familiarised with the latest techniques of reservoir simulation,
3. be able to transform important reservoir engineering problems into manageable numerical simulation models,
4. have a sound understanding of the applicability areas and the limitations of the numerical simulators.

Timing

21 Hours during Spring Term.

Text

The main text will be the lecture notes. Recommended reading includes:


Assessment

Work will be assessed by means of course work.

Lecture Syllabus
1. Reservoir models
   - Introduction
   - Physical models: analogue models, comprehensive models, elemental models
   - Mathematical models
   - Numerical models
   - Models as comparative tools

2. Equations and terminology
   - Mass Conservation
   - Darcy’s Law
   - Diffusivity equation
   - Finite difference
   - Implicit and Explicit formulation
   - Dispersion and weighting
   - Non Linearity and outer iterations
   - Linear Solvers

3. Buckley Leverett Displacement

4. Reservoir models
   - Model components: reservoir description, initialisation, model control, production data, output
   - Model types: Cross sectional models, sector models, cylindrical single well models, full field models

5. Grid systems
   - Cartesian systems
   - Cylindrical systems
   - Stream line grids
   - Special connections
   - Corner point representation
   - Local grid refinement
   - Non-orthogonality

6. Rock properties
   - Core data: Routine core analysis, porosity, permeability, special core analysis, compressibility, relative permeability, capillary pressure
   - Log data
   - Test data

7. Model relative permeability
   - Data manipulation
   - Three phase relative permeability
   - Vertical equilibrium
   - Pseudo relative permeability
   - Well pseudo relative permeability
   - Summary

8. Model capillary pressure
   - Manipulation of capillary pressure
   - Vertical equilibrium
   - Summary

9. Fluid properties and experiments
   - Single component properties
   - Properties of mixtures
   - Hydrocarbon types
   - Definitions: Saturation pressure, bubble point pressure, dew point pressure, oil formation volume factor, gas formation volume factor, gas deviation factor, solution gas content, gas gravity, coefficient of thermal expansion, isothermal compressibility
   - Experiments: Constant composition expansion, differential liberation, constant volume depletion, separator tests

10. Model fluid properties
    - Black oil fluid properties: Component, phase, phase mole fraction of a component, phase equilibrium, black oil
    - Data manipulation
    - Spatial variations: variable bubble point, variable api gravity
11. Aquifer treatment
   Hurst - van Everdingen
   Carter Tracy
   Fetkovich
   Numerical aquifer
12. Model well and production data
    Production control data: targets, constraints, actions
    Practical considerations: history match, prediction
13. Tutorials:
    Numerical dispersion
    Mobility weighting
    Time stepping and grid size
    Grid orientation effects
    IMPES versus fully implicit
    Simulator initialisation
    Grid refinement / Coarsening
    Pseudo-Relative permeability
COURSE OUTLINE: UPSCALING

Professor O. Gosselin
Total

Aims

(1) to understand the multi-scale nature of data and recovery processes, and the related modelling/simulation issues
(2) to review the different techniques available to deal with change of scales
(3) to make the students aware of the problems and pitfalls of upscaling techniques, and aware of current trends and future evolution

Objectives

On completion of this course students will be able to:

(1) understand the context of “upscaling” fully
(2) determine when it is required, in relation with its scope
(3) identify the most appropriate methods for a given reservoir/production, a given property
(4) list the assumptions and limitations associated with these techniques
(5) validate the chosen methodology
(6) list the sources of uncertainties

Prerequisite

(1) Darcy’s Law, relative permeabilities, definition of fractional flow, Welge analysis
(2) Reservoir characterisation techniques
(3) Reservoir performance and principal recovery mechanisms
(4) Numerical flow simulation basics

Timing

The course will consist of 9 hours of lectures. Tutorial question sheets will be handed out during the course. These are an integral part of the course. Some will revise the material learnt in lectures, others will supplement it. Material that is learnt through tutorial questions rather than lectures is still be examinable.

Texts

- SPE Compact Disc (upscaling papers)

Assessment

This material will be assessed as part of the Group Field Project (Phase 2)

Lecture Syllabus

1. Review the multiple scale issues of data and processes
2. Review why and how upscaling is a part of the reservoir modelling workflow
3. Analyse and discuss the requirements for performance prediction, anisotropy and key heterogeneity, and which data are concerned
4. Review the required resolution of detailed geological models, simulation flow models, under constraints of computing resources and numerical models.
5. Upscaling of scalar properties: porosity, initial water saturation, net-to-gross, etc.
6 Single phase upscaling (absolute permeability): various means, numerical methods.
7 Two phase upscaling (pseudo rel. perm, Pc): analytical and numerical methods.
8 Limitations of upscaling; validation of upscaled models; best practices; overview of tools available; future prospects and methods.

COURSE OUTLINE: PRACTICAL USE OF SIMULATORS
Schlumberger

Aims

(4) Introduce students to the practical use of reservoir numerical simulators

Objectives

The course emphasizes practical use of the software rather than simulation methodology. At the end of the course, students should be able to:

(5) Understand how a simulator initializes and executes

(6) Define the model grid geometry

(7) Describe rock and fluid properties

(8) Allocate initial pressure and saturation distribution

(9) Control wells under history matching and production regimes

(10) Specify and edit input and output data

(11) Build and execute a simulation model

(12) Analyze results through post processing

Prerequisites

English proficiency
Basic Windows and practical computing skills
A reservoir engineering background / completion of first term of lectures for this MSc course

Timing

18 hours of lectures during the Spring term.

Assessment

Part of Phase 2 of the Field Group project

Texts

• ECLIPSE Blackoil Reservoir Simulation Course, Schlumberger

Lecture syllabus

1 ECLIPSE features
2 File organization and structure
3 Grids
4 Fluid properties
5 Rock properties
6 Wells
7 Aquifer modelling
8 History matching
9 Prediction

COURSE OUTLINE: PETROLEUM ECONOMICS
Aims

(1) To introduce the basic concepts and background for the financial and economic assessment of projects within the petroleum industry.

Objectives

At the end of the course students should:

(1) be able to model risk and uncertainty related to projects using probabilistic Resource methodologies such as monte carlo analysis techniques,
(2) have an understanding of different fiscal systems,
(3) be able to calculate the NPV and/or EMV of a project, understand what input data is necessary to undertake such a valuation, carry out Decision Tree Analysis and be able to select the best option from several possibilities,
(4) be able to carry out simple portfolio management decisions under conditions of uncertainty, including economic, technical and political risk,
(5) understand the relationship between economic valuation and the booking of Reserves.

Prerequisite

(1) Familiarity of field development and reservoir life cycle

Timing

18 hours during the Spring term.

Texts

- Wood Mackenzie *Upstream Oil and Gas publications for UK North Sea*

Lecture syllabus

1. Introduction to the Value Chain and the valuation process
2. Fundamentals of economic valuation (time value of money, discounting and NPV)
3. Estimating Resource volumes (volumetric formula, risk and uncertainty, probabilistic methods)
4. Reserves and Resources
5. Project risking (chance of discovery, chance of development, dependency)
6. Volumetric aggregation (consolidation of Reserves and Resources)
7. General framework of hydrocarbon fiscal systems
8. Project cash flow analysis (price forecasts, calculation of future cash flows, cash flow metrics)
<table>
<thead>
<tr>
<th>No.</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Sources of finance</td>
</tr>
<tr>
<td>10</td>
<td>Non technical risk mitigation</td>
</tr>
<tr>
<td>11</td>
<td>Project development (development options, production forecasts, cost estimation and schedule)</td>
</tr>
<tr>
<td>12</td>
<td>Project valuation (unrisked and risked valuation of oil and gas projects, NPV vs. EMV)</td>
</tr>
<tr>
<td>13</td>
<td>Utility Functions</td>
</tr>
<tr>
<td>14</td>
<td>Portfolio valuation</td>
</tr>
<tr>
<td>15</td>
<td>Portfolio management and optimisation</td>
</tr>
<tr>
<td>16</td>
<td>Reserves and Resources – relationship between economic analysis and the booking of hydrocarbons</td>
</tr>
</tbody>
</table>
COURSE OUTLINE: PETROLEUM MANAGEMENT AND LEADERSHIP

G. Scotton

COURSE OUTLINE: PROCESS ENGINEERING /SURFACE FACILITIES
Aims
To provide a working knowledge of the design and operation of crude oil and gas processing and transportation systems including:

(1) The theory behind, and analysis of, the transportation of single and multiphase fluids through flowlines and pipelines
(2) The design and operation of oil and gas processing systems to address:
    a. Gas, oil, water separation
    b. The treatment of produced gas and oil
    c. The handling of emulsions
(3) Flow assurance
(4) Pipeline operations and real-time systems

Objectives
At the end of the course students must:

(1) be able to perform calculations of, and size, single and multiphase oil and gas pipelines in association with pump and compressor systems
(2) understand the necessity, and the principle, of well fluid treatment in field operation
(3) understand the principles of physical separation of liquid/liquid and gas/liquid separation and the function, components and different types of separators
(4) be able to design and work out the sizes of horizontal separation equipment
(5) be able to perform equilibrium flash calculations to determine the GOR, and other fluid properties of the produced oil and gas
(6) be able to optimise the separator operating pressure for maximum hydrocarbon liquid recovery
(7) understand the principle of emulsion treatment
(8) understand the necessity of, and the methods (such as absorption and adsorption processes), with their merits and demerits used in the field for the treatment of natural gas and gas condensates

Prerequisite
Before taking this course the students should have a clear understanding of:

(1) the nature, characteristics and behaviour of reservoir fluids
(2) the principle of well production
(3) fluid flow in pipelines.

Timing
27 hours (21 hours lecturing and 6 hours workshops)

Texts
1. Course notes.
A list of reference technical publications will be provided.

Assessment

This material will be assessed as part of Field Development and Process Engineering exam in May. In addition, an important and essential part of the group project will be based on the materials covered in this course.

Lecture Syllabus

1. Introduction, Workflow, and Single Phase Systems
2. Pipeline Design – the Engineering Approach
3. Multiphase Systems
4. Flow Assurance
5. Surface Production Operations I
6. Surface Production Operations II
7. Pipeline Simulation I
8. Pipeline Simulation II
9. Distribution and Field Project

COURSE OUTLINE: OCCUPATIONAL HEALTH AND SAFETY
T. Ingram (Business Assurance Director – Port of Tyne)

Aim

1. To provide an introduction to occupational health, safety, environment and process safety in the work and major hazard environment.
2. To examine the consequences, influences and causes of a significant health and safety incidents.
3. To outline a basic systematic approach to managing health and safety and understanding the concepts of hazard and risk.

Objectives

By the end of the lecture, students should:

1. Have a broad appreciation of why health and safety at work is important
2. Have an understanding of the potential consequences of a breakdown in health and safety systems.
3. Appreciate what role they have to fulfil in ensuring their own safety and the safety of those round about them at work.

Prerequisites

No prior knowledge of occupational health and safety matters is required

Timing

One lecture of three hours

Assessment

It is anticipated that this material will be essential to the completion of the Group Field Project.

Texts

“Successful health and safety management” Health and Safety Executive ISBN 0 7176 1276 7
“Management of health and safety at work” Health and Safety Commission ISBN 0 7176 2488 9

“Managing for health and safety” (HSG65) – HSE – HSG65 2013

“The Public Inquiry into the Piper Alpha Disaster Report” (Cullen 1992)


A Guide to the Control of Major Accident Hazard (COMAH) Regulations” ISBN: 9780717666058


“The Offshore Installations (Offshore Safety Directive) (Safety Case etc) Regulations 2015”

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Imperial College
Centre for Petroleum Studies
Department of Earth Science and Engineering

London
“Disastrous Decisions – The Human and Organisational Causes of the Gulf of Mexico Blowout”.
Hopkins, A – 2012

Syllabus

1. We will examine the failures that led to a major health and safety incident and the changes this brought about.
2. We will examine the wider operational and legal context within which the company involved in the incident was operating.
3. We will look at an industry framework for developing and maintaining major hazard health and safety systems.
4. We will look at how this system might have been applied to the incident considered.
5. We will look at how the system might be applied to the group project. We will consider the role of individuals in maintaining a safe working environment.
The individual project is one of the two main components of the course and a pass must be obtained in it in order to succeed on the course. It is a demanding task requiring the utmost in commitment and effort over an intensive period of around four months. For the project to be successful, it must meet the academic requirements demanded of MSc calibre work. These are

- Exercise of independent thinking and critical analysis and judgement.
- Technical content of substantial depth and relevance to Petroleum Engineering.
- Substantial volume of work achieved through effort and industry.

Students are warned that a project is not of an MSc calibre if it merely involves routine application of their knowledge or skill without demanding a high degree of their own thinking and scholarship. They must therefore make sure when they engage in an Industry-sponsored project, that they exercise their own independent thinking; the Company guides them, but the scholarship is theirs. Students should not act merely as a technical assistant in carrying out the project; they must participate in shaping it.

Assessment of the projects is based on industry and effort; oral presentation; written reports and poster.

Selection of the topic can be made as early as the Autumn term; a full list of the topics is made available around January of each year. These topics may be suggested by either Industry or Academic Staff; students may also choose a topic outside this list. Once a topic is selected, they discuss it with the appropriate Academic Staff to identify the following:

- The objective of the project.
- Deliverables aimed for.
- Where the work is to be conducted.
- Who will be the main supervisor.

This should be done preferably by the end of March and no later than end of April.

The timetable is as follows:

- End of February: area of interest is defined;
- End of March: specific topic and general objectives defined; start project after the end of examinations;
- Mid-May: project review - a 10-minute presentation that highlights objectives, approach and plan for the Project;
- June-July-August: short progress forms sent to College;
- Early September: submission of draft report;
- Mid September: preparation of poster on project, handing in of written dissertation (16 page SPE technical publication format plus figures, diagrams etc.) followed by oral examination in front of Academic Staff and Industry visitors.
- Late September: submission of final report for binding.

The detailed instructions are given to the students at the appropriate time.

In recent years many (usually over 50%) of students carry out their project in the industry, normally in the offices of the companies, with of course academic co-supervision.

Further details, including poster design, are given during the term.
ASSESSMENT

The MSc and DIC Awards:

(1) The MSc of Imperial College is awarded for passes obtained in formal examination and coursework assessments and, separately, in a project report or dissertation. An outstanding performance in one area cannot compensate for failure in the other. A re-sit of one or more examinations is allowed only on the next occasion of the examinations, i.e. after a lapse of one year.

(2) The MSc award is an unclassified award, i.e. the result is 'Pass' or 'Fail'; however, exceptionally, a candidate may be recommended for an award of "Distinction". This requires an overall performance in contributions to group work, in examination results, and in project work of a very high standard. The award of “merit” is also awarded for performance in group work, in examination results, and in project work to a high standard. It should be noted that minimum passes in all subjects will not necessarily be regarded as an examination pass for the MSc.

Any relevant topic is potentially examinable, whether presented by an internal member of staff, an external lecturer, or by a research or other student.

The assessment is in two parts;

- Part A - examination of formal lectures and group project.
- Part B - individual project

Both parts must be passed.

Part A includes the 5 teaching modules, the group project, coursework and examinations with the following weights:

<table>
<thead>
<tr>
<th>Modules</th>
<th>Weighting</th>
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<tbody>
<tr>
<td>COURSE WORK</td>
<td>20%</td>
</tr>
<tr>
<td>EXAMINATIONS</td>
<td>60%</td>
</tr>
<tr>
<td>GROUP FIELD PROJECT</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

The Group Field Project report is assessed with allocations of marks for the oral presentations and effort given to the group by the student (as assessed by the project organiser).

Part B - The individual project assessment is based on the presentation both orally and poster and by a written report of the work, to be submitted in September.

Examinations

Examinations include formal sittings (taking no longer than 18 hours in total) together with coursework assessment which includes the 3 phases of the group project. Fuller details of times and typical information is given during the year.
Take-home assignments and homeworks (Part A)

There are take-home homeworks in most of the lectures. These are assessed and used as evidence of progress and of the student's understanding of the course. They also test elements of numeracy and written communication skills.

Most of these are marked and are part of the MSc assessment. Their purpose is to give students a guide to their own progress, especially for those who have returned to study after a period in industry and for our overseas students to familiarise themselves with our examination procedures. There are also 3 phases of the Wytch Farm Field Development project. These are carried out in teams, phase 1 will be carried out with the MSc Petroleum Geoscience students, and phase 2 and 3 with fellow Petroleum Engineers.

Examinations (Part A)

The students take 5 written examination papers, all of 3 hours, in:

<table>
<thead>
<tr>
<th>Modules</th>
<th>Topics</th>
<th>Papers</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FUNDAMENTAL KNOWLEDGE</td>
<td>Rock Properties and Reservoir Fluids</td>
<td>1</td>
<td>Mid-January</td>
</tr>
<tr>
<td>2. RESERVOIR CHARACTERISATION</td>
<td>Well Testing and Flow in Porous Media</td>
<td>1</td>
<td>Mid-January</td>
</tr>
<tr>
<td>3-4. WELL AND RESERVOIR PERFORMANCE</td>
<td>Process Engineering and Field Development</td>
<td>1</td>
<td>End of April</td>
</tr>
<tr>
<td>5. FIELD DEVELOPMENT</td>
<td>Reservoir Mechanics and Secondary Recovery</td>
<td>1</td>
<td>End of April</td>
</tr>
</tbody>
</table>

All papers are double marked and available for inspection by the external examiner. Individual staff examiners mark initially to their own scheme but the marks are reported to the MSc course Director. The Director collates all the marks. The marks are then totalled according to the current weighting scheme. These ‘averaged’ marks determine the ranking of the student. It is these marks that are reported to the University to be given to the candidates.

The major papers (Fundamental knowledge; Reservoir Characterisation; Well and Reservoir Performance; Field Development) are closed book examinations. The formulae needed that are difficult to remember or correlation graphs are provided when appropriate. The questions are typically the hand calculations carried out in the industry to check computer estimations and many questions are derived from real field data. We believe this method of examining gives the student the proper technical preparation for industry employment. The testing of understanding is demonstrated in the field project.

Students who fail one or two papers maximum, but have an average of 50% or above in the exams, may, after discussion at the examiners’ meeting, be given an oral or further written work or both. Those that fail the oral, or have failed one or more papers and have an average of less than 50% in the exams will have their degree deferred until they re-sit the failed papers the following year. If they then pass, they will be placed in the examination pass list for that year.

The individual projects (Part B) are assessed by a report, a poster and a presentation of 15 minutes (plus 5 minutes for questions) to the examiners and representatives from the oil industry. The reports are read by two examiners and must obtain a mark of 50% or above. Marks received for the presentation and the poster are added to the report marks to determine the project marks. The candidates are awarded a pass for marks at 50% or above and a fail below 50%. Reports with marks below 50% are deferred for a period between one and eleven months, as determined by the Board of Examiners. They must be re-submitted before the end of the period and be found satisfactory to be awarded a PASS.
Master of Science
in Petroleum Engineering

2016-2017

Marking scheme

<table>
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<tr>
<th></th>
<th>Examinations</th>
<th>Individual Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distinction</td>
<td>70% average or above</td>
<td>70% or above</td>
</tr>
<tr>
<td></td>
<td>No exam below 60%</td>
<td></td>
</tr>
<tr>
<td>Merit</td>
<td>60% average or above</td>
<td>60% or above</td>
</tr>
<tr>
<td></td>
<td>No exam below 50%</td>
<td></td>
</tr>
<tr>
<td>Pass</td>
<td>No more than two exams below 50%</td>
<td>50% or above</td>
</tr>
</tbody>
</table>

Candidates are notified of their performance and (if needed) any re-sits needed.

Examiners Meetings

Two Examiners’ meetings are held; a preliminary meeting in late May to consider the Part A performance, and a meeting in September to consider all the results.

Programme Specification

Please visit the link below to find our Programme specification, which provides a concise summary of the main features of the programme and the learning outcomes that our students might reasonably be expected to achieve and demonstrate throughout the course.

https://workspace.imperial.ac.uk/earthscienceandengineering/Public/MSc%20Postgraduate/Programme%20Specification%202012.pdf

Examinations and Religious Obligations

Imperial College takes very seriously the religious obligations many of our students face, which can often clash with examination dates. Please visit the link below to find out more on our advice for students who may face this situation:

https://workspace.imperial.ac.uk/registry/Public/Exams/Exams%20and%20religious%20obligations.pdf