1. Annotation

Course Description

The course will provide a graduate level overview of geophysical methods of hydrocarbon (HC) exploration; including classification, applications, integration; physical properties of rocks (density, susceptibility, resistivity, and seismic wave velocities). All types of geophysical methods will be thoroughly reviewed from a comprehensive geophysical applications but also from the standpoint of fundamental mathematical and physical principles.

The course will study passive geophysical methods using the natural fields of the Earth, e.g. gravity and magnetic; but also, active geophysical methods that requires the input of artificially generated energy, e.g. seismic reflection.

The objective of geophysics is to locate or detect the presence of subsurface structures or bodies and determine their size, shape, depth, and physical properties (density, velocity, porosity...) but also the fluid content (oil, gas, water) contained in the porous media.

The course will introduce also modern techniques of geophysical interpretation based on modeling and inversion.
2. Structure and Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Summary of Topic</th>
<th>Lectures (# of hours)</th>
<th>Seminars (# of hours)</th>
<th>Labs (# of hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geophysical methods of hydrocarbon exploration: Potential Methods</td>
<td>Gravity and magnetic methods, including gravity and magnetic anomalies; ground and airborne gravity, gravity gradiometry, and magnetic surveys; principles of using gravity and magnetic data in exploration for energy resources</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Electrical and electromagnetic (EM) methods</td>
<td>Electrical and electromagnetic (EM) methods, including resistivity method, time-domain and frequency-domain EM surveys, magnetotelluric methods; methods of quantitative interpretation of EM data; application of the electrical and EM methods for on-shore and off-shore HC explorations.</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Seismic methods</td>
<td>Seismic methods, including elastic wave propagation in rocks; principles of seismic refraction method; principles of seismic reflection method. The methods of seismic data acquisition on land and sea, seismic sources (e.g., air guns, etc.);</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Introduction to modern techniques of modeling</td>
<td>Introduction to geophysical numerical modeling. Review of the different numerical methods. Modeling of seismic wave propagation by the finite difference method</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Introduction to modern techniques of interpretation</td>
<td>Introduction to geophysical inverse problems. Local (linear and non-linear gradient methods) and global optimization (Monte-carlo approach).</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

3. Assignments
### Assignment Summary

<table>
<thead>
<tr>
<th>Assignment Type</th>
<th>Assignment Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>Methods of measurement and observation technique (for methods of gravity prospecting, magnetic prospecting, seismic prospecting): including analytical solution, numerical modeling and interpretation</td>
</tr>
<tr>
<td>Test/Quiz</td>
<td>Practical problems including knowledge of the different instruments (their associated measurements and limitations) with quantitative geophysical interpretation</td>
</tr>
<tr>
<td>Team Project</td>
<td>Definition of a geological problem to study. Choice and relevance of the different geophysical measurements in order to solve the geological problem. Feasibility study based on numerical modeling. Quantitative Interpretation based on the generated measurements.</td>
</tr>
</tbody>
</table>

### 4. Grading

<table>
<thead>
<tr>
<th>Type of Assessment</th>
<th>Graded</th>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Grade Structure</th>
<th>Activity Type</th>
<th>Activity weight, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Homework Assignments</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Final Exam</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Team Project</td>
<td>36</td>
</tr>
</tbody>
</table>

### Grading Scale

- **A:** 86
- **B:** 76
- **C:** 66
- **D:** 56
- **E:** 46
- **F:** 0

**Attendance Requirements:** Mandatory

### 5. Basic Information
Course Stream: Science, Technology and Engineering (STE)

Course Term (in context of Academic Year): Term 2

Students of Which Programs do You Recommend to Consider this Course as an Elective?

<table>
<thead>
<tr>
<th>Masters Programs</th>
<th>PhD Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum Engineering</td>
<td>Petroleum Engineering</td>
</tr>
</tbody>
</table>

Course Tags: Engineering

6. Textbooks and Internet Resources

<table>
<thead>
<tr>
<th>Required Textbooks</th>
<th>ISBN-13 (or ISBN-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Geophysics by John Milsom and Asger Eriksen; Wiley; 4 edition (2011)</td>
<td>9780470749845</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended Textbooks</th>
<th>ISBN-13 (or ISBN-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration Seismology by R. E. Sheriff and L. P. Geldart; Cambridge University Press; 2 edition</td>
<td>9780521468268</td>
</tr>
<tr>
<td>Well Logging for Earth Scientists by Darwin V. Ellis and Julian M. Singer ;Springer; 2nd edition (2008)</td>
<td>9781402037382</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Web-resources (links)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.scopus.com/">http://www.scopus.com/</a></td>
<td>Scopus</td>
</tr>
<tr>
<td><a href="http://www.springer.com">www.springer.com</a></td>
<td>Springer</td>
</tr>
<tr>
<td><a href="http://www.sciencedirect.com/">http://www.sciencedirect.com/</a></td>
<td>ScienceDirect</td>
</tr>
<tr>
<td>State Public Scientific and Technical Library of Russia <a href="http://www.gpntb.ru">http://www.gpntb.ru</a></td>
<td>Seismic resources</td>
</tr>
<tr>
<td><a href="http://sepwww.stanford.edu/sep/prof/">http://sepwww.stanford.edu/sep/prof/</a></td>
<td>Jon Claerbout's Classroom</td>
</tr>
<tr>
<td><a href="http://sepwww.stanford.edu/sep/prof/">http://sepwww.stanford.edu/sep/prof/</a></td>
<td></td>
</tr>
</tbody>
</table>

7. Facilities
### Equipment

- Class room, equipped with projector
- Computer room
- Access to the Internet through a computer class and Wi-Fi network of the institute
- Smart board or a similar technology
- Tablet - electronic board
- The library, including electronic publications
- Syllabus documents and materials on the topics of discipline

### Software

- Wolfram Mathematica
- Python (Anaconda)

### 8. Learning Outcomes

#### Knowledge

- Understanding of Potential methods (Gravity and Magnetic)
- Understanding of Electromagnetic methods
- Understanding of seismic methods
- Understanding of seismic processing and migration
- Understanding of geophysical modeling
- Understanding of geophysical inversion

#### Skill

- Process different geophysical measurements in order to determine the subsurface physical properties
- Forecast which type of geophysical measurements is more adequate for reservoir exploration
- Perform a geophysical survey design
- Perform modern interpretation modern techniques based on modeling & inversion
### Experience

- Abstract thinking, analysis, synthesis;
- Readiness for acting under non-standard circumstances, bearing social and ethical responsibility for the decisions made;
- Readiness for pursuing personal development, talent-tapping and unlocking creative potential;
- Ability to formulate and solve tasks arising from academic research and practical activities;
- Ability to convert into a different academic and scientific and industrial focus of one’s professional activity;
- Ability to assess prospects and possibilities for the use of scientific and technological progress achievements in the innovative development of the sector, come up with ways of their implementation;
- Ability to perform calculations on projects, technical and economic and functional cost analysis to assess performance of the designed equipment, hardware, and technological processes;
- Ability to use scientific research methodology in professional activities;
- Mathematical and scientific knowledge;
- Knowledge of applied sciences and engineering;
- Interdisciplinary thinking, knowledge structure and their inter-action;
- Knowledge and use of modern methods and tools;
- Knowledge and methods of reasoning;
- Communication;
- Communication in international environment;
- Understanding the global public, environmental and business context;

### 9. Assessment Criteria

**Input or Upload Example(s) of Assignment 1:**

<table>
<thead>
<tr>
<th>Select Assignment 1 Type</th>
<th>Homework Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Example(s) of Assignment 1 (preferable)</td>
<td></td>
</tr>
</tbody>
</table>
Explain the measurement principles and the petrophysical properties derived from the measurements for the following well logging tools:

1. Caliper
2. Spontaneous potential (SP)
3. Gamma ray
4. Density (Nuclear)
5. Neutron
6. Resistivity (Dual Laterolog)

Assessment Criteria for Assignment 1
The assessment is based on how much the student answers correctly to the questions that are covered during the course but also on how much he incorporates extra knowledge based on his readings from books.

Input or Upload Example(s) of Assignment 2:

Select Assignment 2 Type
Test/Quiz

Input Example(s) of Assignment 2 (preferable)
We logged a thick sand reservoir with the previous logging measurements

- How can I check the quality of the interpreted measurements?
- How can I differentiate a clean sand reservoir from a shaly sand reservoir?
- Is it possible to locate the aquifer, the oil and gas zones in the sand reservoir? Do we need more measurements?
- If the sand reservoir is clean and homogeneous with a porosity of 20%, the aquifer zone has a resistivity of 10 Ohm.m and the hydrocarbon zone has a resistivity of 100 Ohm.m. Is it possible to estimate the water and oil saturation in the oil zone? If not, why?

Or Upload Example(s) of Assignment 2
https://ucarecdn.com/cc77a1e7-8410-404b-8bba-de3079d4d827/

Assessment Criteria for Assignment 2
The assessment is based on
1) the acquired knowledge
2) the reasoning
3) Answering correctly the quantitative questions

Input or Upload Example(s) of Assignment 3:

Select Assignment 3 Type
Team Project

Input Example(s) of Assignment 3 (preferable)
A) We would like to promote the interpretation method of combined Surface electrical and seismic refraction methods for a 3 layers problem
1) Applicable for common acquisition systems
2) Applicable for the geology of Moscow region

B) Build a numerical experiment for illustration
1) Derive & write numerical simulation for seismic refraction and for electrical problems
2) Generate synthetic data
3) Add noise to the data
4) Analyze the data

C) Inversion
1) Refracted data (with & without constraints)
2) Derive the posterior model parameters and their uncertainties
3) Electrical data (with & without constraints)
4) Derive the posterior model parameters and their uncertainties

D) Joint Inversion
Derive the posterior model parameters and their uncertainties

**Assessment Criteria for Assignment 3**

Each team member will do a presentation covering part of the project with Q&A from the committee.

The assessment will be based (half) for each team member with the following criteria:
- a) Technical understanding
- b) Presentation
- c) Innovation

and half on the evaluation of the full team project based on the same criteria