GEOL 20160: Quantitative Geosciences

MODULE COORDINATOR: Dr Ivan Lokmer

CREDITS: 5	**MODULE LEVEL**: 2	**SEMESTER**: I

PRE-REQUISITES/PRIOR LEARNING:

Passes in Level 1 Calculus and Linear Algebra modules are strongly recommended. Laptops are used in practical classes. Students using their own laptop should pre-install Microsoft Excel (including data analysis module) and Matlab or Octave.

OVERVIEW OF MODULE:

This module covers the applications and understanding of basic mathematical tools required in different topics of Earth Sciences. It is aimed at undergraduates who want to understand the Earth and its evolution but do not have necessary quantitative skills to move beyond qualitative concepts. The module consists of applying different mathematical concepts (power law and scaling exponents, curve fit and parameter uncertainties, basic statistics, vectors and matrices, basic differential equations used in Geosciences, ...) to real world problems and datasets. Apart from obvious benefits in introducing the students to quantitative skills required in geosciences, the module should also help them to deepen their understanding of scientific problems related to the Earth.

LEARNING OUTCOMES:

On completion of this module students should be able to:

1. Recap basic mathematical topics and relate them to practical Earth science problems;
2. Learn how to examine the statistics of a dataset and visualise important relationships between parameters;
3. Understand the importance of the power law in different natural processes;
4. Learn how to construct a simple mathematical model of a descriptive geoscience problem and solve it using a suitable software package;
   Ability to produce plots and graphical images of datasets and results using appropriate software.

ASSESSMENT:

Practical Examination: 25%
(Practical examination on first half of course)

Practical Examination: 25%
(Practical examination on second half of course)

Written Examination: 50%
(2 hr end of semester examination covering entire module)

LECTURES:

Lecture 1: Introduction. *(Dr I. Lokmer)*
Introducing the module content, learning outcomes, recommended literature and required software. Outlining general scientific workflow in identifying and testing hypotheses through data analysis. Significant figures and rounding numbers. Units and dimensions of physical quantities.

Lecture 2: Why do geoscientists need mathematics? *(Dr I. Lokmer)*
An introductory lecture given by a guest lecturer.

Lecture 3: Rearranging equations. *(Dr I. Lokmer)*
Recap. Introducing the rules and techniques for rearranging equations.

Lectures 4&5: Logarithms, exponentials & power-law relationships in geosciuences. *(Dr I. Lokmer)*
Explaining the importance of understanding the nature of a process. Examples.

Lecture 6: Gutenberg-Richter relationship for the earthquake size distribution. *(Dr I. Lokmer)*
Analysing global earthquake catalogues using Excel. Intoduction to Excel.

Lecture 7 & 8: Linear, quadratic and higher-order equations in geosciences. *(Dr I. Lokmer)*
Recognising and plotting different types of relationships. Examples from sedimentation, temperature distribution inside the Earth, sea-floor spreading. Use of polynomials for approximation of Earth processes.

Lecture 9 & 10: Introduction to data analysis: probability and statistics. *(Dr I. Lokmer)*
Introducing the concept of probability and statistics through a simple example of the size and weight distribution of the pebbles on a beach. Mean, standard deviation, normal distribution, central limit theorem.

Lecture 11: Errors and uncertainties. *(Dr I. Lokmer)*
Difference between an error and uncertainty. Calculating the errors of measurements. Examples

Lecture 12: Error propagation. *(Dr I. Lokmer)*
Measured values are often used to calculate other quantities of interest. How the error of a measurement propagates through the calculation? What is the uncertainty of the calculated final value?

Lecture 13 : Mathematical formulation of verbally described problems. *(Dr I. Lokmer)*
How to solve a verbally expressed problems using maths? Where to start? Problem parametrization.

Lecture 14: Recap through examples. *(Dr I. Lokmer)*
Solving different types of geoscience-related problems using statistics, probability and algebraic equations. Analysing graphs and diagrams. Using Excel.

Lecture 15: Trigonometry. *(Dr I. Lokmer)*
Applications of trigonometric functions in (geo)science. Basic trigonometric rules. Relationships between apparent and true fault dip. Geology examples of using trigonometry.

Lecture 16: Vectors. *(Dr I. Lokmer)*
Basic operations with vectors. Decomposing and averaging vectors. Vector applications in geoscientific problems.

Lecture 17: Differentiation. *(Dr I. Lokmer)*
Basic of differentiation. Applications to geoscientific problems.

Lecture 18: Integration. *(Dr I. Lokmer)*
Applications of integration in geosciences. Examples

Lecture 19: Introduction to time-series analysis. *(Dr I. Lokmer)*
Importance and application of time-series analysis. Sepctral analysis. Fourer series and transform in analysing datasets.

Lecture 20: Questions and answers. *(Dr I. Lokmer)*
Recap and examples. Preparation for the final exam.

PRACTICAL CLASSES:

Practical 1: Recap. *(Dr I. Lokmer)*
Assessment of the previous knowledge

Practical 2: Algebraic equations. *(Dr I. Lokmer)*
Solving and plotting algebraic equations. Earth science examples (radioactive decay, temperature distribution inside the Earth, population growth, sedimentation rate, solar radiation, etc.)

Practical 3: Polynomials, exponential and logarithmic expressions. *(Dr I. Lokmer)*
Use of polynomials, exponential and logarithmic expressions in describing and solving Earth related problems (hand-written + Excel).

Practical 4: Power-law, logarithmc and exponential relationships. *(Dr I. Lokmer)*
Plotting and analyzing power-law, logarithmic and exponential relationships in Earth related problems (tsunami wave speed, radioactive decay, earthquake size distribution etc.)

Practical 5: Basic statistics and datasets. *(Dr I. Lokmer)*
Distribution of the mass of the pebbles on a beach. Normal distribution. Analysing basic statistics of a dataset using Excel.

Practical 6: Comparison of two means: t-test. *(Dr I. Lokmer)*
Calculating confidence intervals for the gas measurement datasets for different volcanoes. Comparison of two means – t-test.

Practical 7: Error propagation. *(Dr I. Lokmer)*
Error propagation from the measurement of the volcanic plume height to the estimation of the mass eruption rate. Examples of the error propagation in geoscience problems.

Practical 8: Vectors. *(Dr I. Lokmer)*
Averaging vectors' length and direction. Calculating average wind speed. Estimating the final throw of several faults within the fault zone.

Practical 9: Trigonometry. *(Dr I. Lokmer)*
Trigonometry. Apparent vs real dip. Estimating real dip from outcrops.