课程大纲
COURSE SYLLABUS

1.	**课程代码/名称** **Course Code/Title**	PHY5039/现代物理实验 B (Modern signal analysis and data processing）
2.	**课程性质** **Compulsory/Elective**	专业必修课
3.	**课程学分/学时** **Course Credit/Hours**	3/48
4.	**授课语言** **Teaching Language**	中文
5.	**授课教师 Instructor(s)**	韩鹏 (Han, Peng)
6.	**先修要求** **Pre-requisites**	本课程需要有积分变换、概率论与数理统计基础并具备基本的编程能力（主要基于 matlab）。 Prerequisites: Integral Transform, Probability Theory & Mathematical Statistics, and basic programming skills. MATLAB will be used extensively throughout the course.

7. 教学目标 Course Objectives

本课程为地球物理学、力学、地质学、通信工程等相关专业研究生的选修课。本课程主要讲述数字信号采集、处理的基本理论、方法以及在实际观测数据中的应用。修完本课程后，应具有以下能力：

（1） 掌握离散时间信号与系统的基本理论
（2） 掌握 Fourier-变换，Z-变换，Laplace-变换以及三者之间的区别与联系
（3） 了解滤波器（维纳滤波、卡尔曼滤波、自适应滤波）的原理及特征
（4） 掌握功率谱估计方法，能够对给定信号的功率谱进行估计
（5） 掌握时频分析方法（短时傅里叶变换，Gabor 变换，小波变换，希尔伯特-黄变换等），能够对已知信号的时频特征进行分析
（6） 了解信息冗余，压缩感知，大数据分析等信号处理前沿问题

This is a specialized course for students in Geophysics, Mechanics, Geology, Communication Engineering or other related areas. Upon completing the course, students should be able to:

(1) Understand the fundamental theory of discrete time signals and systems.
(2) Perform Fourier transforms, z-transforms, and Laplace transforms, and know the differences and connections.
(3) Understand the principle and characteristics of digital filters such as Wiener filter, Kalman filter, adaptive filter, etc.
(4) Conduct power spectrum estimation.
(5) Apply time-frequency analysis method (STFT, Gabor transform, Wavelet transform, HHT) to analyze the characteristics of given signals.
(6) Know about frontier issues of signal processing such as information redundancy, compressed sensing, and big data analysis.

8. 教学方法 Teaching Methods

本课程前半部分主要侧重于信号处理的理论知识讲解，后半部分则侧重于信号处理方法的运用，通过理论讲解结合编程处理实际观测数据来加深学生对理论知识的理解,并在此基础上培养学生解决实际信号处理问题的能力。修完本课程后学生将对信号处理基础理论有深入了解并能够解决地球物理，力学，以及其它领域中观测信号处理的实际问题，尤其是掌握如何运用时频分析工具提升实际观测信号的信噪比。

The first-half of this course will focus on the fundamental theory of signal processing, and the last-half will mainly discuss how to apply signal analysis. By combining direct instruction and programming exercises for

practical data processing, this course will enhance students' understanding of speculative knowledge and develop their problem solving skills. On completion of this course, students are expected to gain insights into the theory of signal processing, and abilities to apply them to specific problems in Geophysical, Mechanical, or other related areas, particularly know how to conduct time-frequency analysis and filtering to improve SNR.

9. 教学内容 Course Contents

Section 1	离散时间信号和系统 (Discrete time signals and systems) week: 1-2 内容：信号的分类，线性时不变系统，卷积, 离散时间序列变换 Contents: Classification of Signals， Linear Time-invariant System， Convolution, Discrete time series transformation (Fourier transforms, Z-transforms, Laplace transforms)
Section 2	系统响应与滤波器原理（System response & Principles of filter）week: 3-4 内容：系统响应函数，差分方程，IIR 和 FIR 数字滤波器。 Contents: System response function, Difference equation, IIR & FIR digital filters
Section 3	常用滤波器及其应用 (Common filters and applications) week: 5-7 内容: 随机过程、维纳滤波、卡尔曼滤波、自适应滤波。 Contents: Stochastic process, Wiener filter, Kalman filter, Adaptive filter
Section 4	弱信号提取与功率谱估计（Power spectrum estimation）week: 8-9 内容：自回归，相关性分析，信号相干性，自功率谱，互功率谱, Contents: Auto regression, Correlation analysis, Coherence, Auto-power spectrum, Cross-power spectrum
Section 5	时频分析（Time-frequency analysis）week: 10-12 内容：短时傅里叶变换，Gabor 变换，小波变换，希尔伯特-黄变换 Contents: STFT, Gabor transform, Wavelet transform, HHT, and their implementation in practical signal processing
Section 6	大数据分析简介（Introduction to Big data analysis）week: 13-14 内容：神经元网络，深度学习, 参数优化 Contents: Neural network, Deep Learning, Parameter optimization
Section 7	压缩感知（Compressed sensing）week: 15-16 内容：信息冗余，特征分析，压缩采样，信号重构 Contents: Information redundancy, Feature analysis, Compressive sampling, Signal reconstruction

10. 课程考核 Course Assessment

课程最终成绩根据五次作业和期末报告综合评定（课程作业 50%+期末报告 50%）。作业内容为运用课程中所学习到的信号处理方法，编写程序处理实际数据（主要基于 Matlab）。

Assessment will be based on five assignments (50%) and final report (50%). The assignments are compiling programs (mostly based on Matlab) to analyze practical signals.

11. 教材及其它参考资料 Textbook and Supplementary Readings

1) Oppenheim, Alan V., Ronald W. Schafer, and John R. Buck. Discrete-Time Signal Processing. 2nd ed. Upper Saddle River, NJ: Prentice Hall, 1999. ISBN: 9780137549207.
2) Proakis, John G., and Dmitris K. Manolakis. Digital Signal Processing. 4th ed. Upper Saddle River, NJ: Prentice Hall, 2006. ISBN: 9780131873742.
3) 程佩青. 《数字信号处理教程》. 第三版. 北京：清华大学出版社，2007
4) 王艳芬 王刚 张晓光 刘卫东. 《数字信号处理原理及实现》. 清华大学出版社，2008