TBSI course introduction-detail

Update June 2020

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Mandatory course

Track 1

1. **Course Name**: Introduction of physics chemistry disciplines 物理化学学科介绍

Credits: 1, 16 teaching hour

Instructors: Wei Guodan

Text Book (or other supplemental materials): Lecturer will list the references list during the teaching Instructors will provide the electric files.

Specific course information: Combine with their own research achievements, Track one (physics chemistry) will host about eight PIs to present individual frontier research areas. In the meantime, open and dynamic discussion with students will be carried out. It will be divided into five themes: nano energy materials (new energy development、thermal management and battery for energy storage), low dimension materials and devices(two dimension materials、functional devices and growth optimization), optoelectronic materials and devices (solar cells, LEDs and photodetectors), water environment (nano-environment engineering、environment bio engineering and waterwaster management) and photon electronics(silicon photonics、photonic fiber based sensors and photonic crystals)。 Throughout vivid examples and close interaction among professors and students, graduate students will mask science advances and increase their research interests.

Specific goals for the course: We are inviting about eight professors to give lectures focusing on concepts and frontier research trends of low carbon economics and low carbon technologies, such as new energy, nano materials and electronics, environment engineering. Each professor will give 2 hour lecture by means of introduction and discussion about the frontier technologies in the related field. Lectures will encourage students to discuss with professors during the class and let them understand real demand by research and industry.

2. **Course Name**: Nano-energy Materials 纳米能源材料

Credits: 2; 32 teaching hour

Instructors: Kang Feiyu, Yang Quanhong, Junqiao Wu

Text Book (or other supplemental materials): Michio Inagaki and Feiyu Kang, Fundamental of Carbon Materials， Tsinghua Press, 2012

Specific course information: Three professors from the Lab. of Nano Energy Materials, will give lectures focusing on nano-materials, carbon materials, energy application and thermal management, other applications. Lecturers will discuss with students about the concepts and frontier research trends in the related research areas.

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Brief list of topics to be covered:

New energy (4hr) (Kang)

Energy materials (including carbon for battery use) (4hr) (Kang)

Nano materials and (2hr) (Yang)

New Carbon Materials (2hr) (Yang)

Graphene and nano carbon (4hr) (Yang)

Carbon fiber and composite (2hr) (Yang)

Porous carbon (2hr) (Yang)

Thermal management (4hr) (Wu)

High conductive materials (2hr) (Wu)

Carbon with high thermal conductivity (2hr) (Wu)

Phase change materials (2 hr) (Kang)

Nuclear materials (2hr) (Kang)

3. **Course Name**: Dynamics of Environmental Systems: Principles of Mass Transformation and Energy Flow 环境系统与过程原理

Credits: 2; 32 teaching hour

Instructors: Zhang Xihui, Wu Guangxue, Li Bing

Text Book (or other supplemental materials): Introduction to Operations Research by Frederick S. Hillier • Gerald J. Lieberman, 10th or newer editions.

Specific course information: The course will introduce common knowledge of mass transformation and energy flow in environmental systems, especially for the latest development in the fields of separation and purification, chemical treatment processes and biological treatment processes. Its inter-relations with natural environment, massive energy production and dissipation. In addition, the control and management of environmental processes will be presented through the viewpoints of sustainability and low carbon concept.

Specific goals for the course: There is no general courses designed specifically for students from energy and environment. Therefore, this new course will cover knowledge for students from both fields. The course would help students from different disciplines to master key environmental processes in terms of mass transformation and energy flow, and would advance development of innovation ideas. The students with background of materials and energy will be familiar with the environmental problems and know how to solve them with their background knowledge, which would facilitate the creation of new ideas and concepts.

Brief list of topics to be covered:

Environmental Processes

Environmental System

Mass Balance and Energy Flow

Carbon Cycle and Nitrogen Cycle

Mass transformation and Energy in Natural Environment

Structure of Natural Ecology

Functions of Natural Ecology in Environment

Mass Transformation Dynamics

Energy Dynamics

3 Mass Transformation and Energy in Industrialized Society

3.1 Evolution of Industrialized Society

3.2 Characterization of Artificial Compounds and Energy

3.3 Mass Transformation Dynamics

Energy Dynamics

4 Mass transport processes

Flocculation, Sedimentation and Filtration

Membrane Technologies

Chemical Adsorption

Chemical Processes

Chemical Thermodynamics

Advanced Oxidation and Reduction

Disinfection

Biological Processes

Biochemical Kinetics

Microbial Ecology in Engineering Systems

Advanced Biological Processes

Environmental Sustainability and Low-carbon Technologies

Environmental Sustainability

Low-carbon Technologies

Life Cycle Assessment

Practical activities (4 h): Novel materials for enhanced pollutant removal and degradation

Seminar (2 h): Presenting applications of novel technologies or materials for solving environmental problems.

4. **Course Name**: Sustainable Development: Ethics, Physics and Technology 可持续发展：伦理，机理和应用技术

Credits: 1; 16 teaching hour

Instructors: Slav hermanowicz

Text Book (or other supplemental materials): none

Specific course information: Although sustainability and sustainable development have become common themes in public discourse there is little consensus on how to translate these concepts into decisions and actions in the realms of policy, technology, economics, environment. This course will examine the focal issue underlying sustainable development, change and its limits, from different perspectives: ethics, dynamics, physics, technology. Selected applications in various disciplines and economic sectors will be discussed. The course will introduce several mathematical and physical concepts in a rigorous way but with emphasis on understanding these concepts rather than on technical details. Basic college physics and calculus classes would be beneficial for the student.

Specific goals for the course: The objective of this course is to examine critically the concepts of sustainability and sustainable development that have become important in public discourse. Engineers are focused commonly on technology while neglecting social, political and philosophical aspects. The course will bring these subjects into the technological realm to translate them concepts into decisions and actions. Selected applications in various disciplines and economic sectors will be discussed.

Brief list of topics to be covered:

Course Outline

Meetings 1-2
Concept of sustainability and sustainable development
The course will start examining the basic question: what to sustain and what to develop? This question will be discussed initially from the philosophical and moral perspective addressing the following issues:
- How to reconcile changes in natural and social environment with expectations and desires of stability and predictability?
- Revolution and creative disruption *versus* evolution
- Aspects of sustainability and development: social, economic and environmental
- Physical sustainability: living within the laws of nature
- Intragenerational and intergenerational equity: validity and applicability of long-term discount rates
- Example of a specific “sustainability case”

Meeting 3
Sustainability and Water Resources
Concepts of sustainability and their historical evolution in water resources. Sphere and time horizon of sustainability. Possible metrics. Water cycle, virtual water, economic and social aspects of water management. Nutrients recycling.

Meeting 4
Change and Dynamics
This part of the course will be devoted to examination of system dynamics with a goal to

develop an understanding of generic patterns of change such as cycles, equilibria and chaotic behavior. These ideas and related dynamic characteristics will be applied to real ecological systems to recognize their dynamic properties in the phase-space such as stability, periodicity, characteristic times, etc. Specifically, some of the following topics will be addressed:

- System description: intrinsic and extrinsic properties, state variables, degrees of freedom
- Phase space and representation of system dynamics as trajectories in phase space
- Generic dynamic behavior: equilibrium (fixed points), cycles (limit cycles), quasiperiodicity, strange attractors
- Reconstruction of system dynamics from observables: Fourier analysis, Taken's theorem, applications to real-world problems: Earth climate, California water system, Aral Sea
- Characterization of dynamics: dissipative and conservative systems, Lyapunov exponents
- Entropy: system-theoretical approach and connection to limit behaviors of dynamical systems

Meetings 5-6

Energy, Entropy and Materials: Global and Local Views

The third part of the course will attempt to examine sustainability through the lens of well-established physical properties: energy and entropy. This approach is based on the first and second laws of thermodynamics that can provide a scientific and quantitative basis for the discussion of technical, social and policy options. Use and cycling of natural resources will be also addressed. The topics will include:

- Earth as a closed-mass energy-driven system
- Sources of energy: renewables, non-renewables, dynamics of energy transformations
- Quality of energy: exergy
- Sources of high-quality energy (high exergy): oil, coal, natural gas, nuclear, solar, hydro, bio
- Energy and exergy balance: historical perspective, current picture and possible future.
- Material resources: availability and balances
- Energy input and economic output
- Entropy as a measure of system or process performance, reversibility of entropy increases
- Entropy: thermodynamic, system-theoretic, and information-theoretic approaches
- Entropy in economics: Nicholas Georgescu-Roegen, Herman Daly, Robert Costanza and ecological economics
- Applications of energy and entropy to characterize physical sustainability: examples in water treatment, resource recovery and recycling

Meetings 6 - 8

Real World Applications

The last section of the course will deal with selected attempts to apply the concepts of sustainability in the real world. Actual selection of case studies and example will depend on student interests. This section will provide students with opportunities to

present results of their term projects to the class. Some possibilities are listed as follows:
- Green buildings: LEED
- Efficient lightning
- Sustainable agriculture and forestry
- Ecological footprint: concept and critique
- Ecological rucksack: dematerialization
- Factor 10
- Ethanol as fuel
- Life Cycle Assessment
- Water resources management, water reclamation and reuse, desalination
- Nutrient recovery from wastewater
- Sustainable transportation
- other topics depending on the students' interests

5. **Course Name**: Chaos and Complexity – System Dynamics Approach 混沌和复杂性--系统动力学方法

Credits: 1; 16 teaching hour

Instructors: Slav hermanowicz

Text Book (or other supplemental materials): Strogatz, S.H. (2015). Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering (Studies in Nonlinearity), CRC Press; 2 edition Carmona, V. et al. (2018). Nonlinear Systems; Vol. 1: Mathematical Theory and Computational Methods (Understanding Complex Systems) 1st ed. Springer Thompson, J. M. T. Stewart H.B. (2002) Nonlinear Dynamics and Chaos, Wiley 2nd Edition Cambel., A.B. (1993). Applied Chaos Theory. Academic Press, San Diego Addison, Paul S. (1997). Fractals and Chaos: An Illustrated Course, IoP, Bristol and Philadelphia

Specific course information: Exploration of diverse concepts in fractal geometry, nonlinear phenomena and their dynamics leading to chaos and complexity. We will try to look at a variety of natural objects and processes, and their mathematical counterparts to see if we can characterize such features as ruggedness, structure, contingency, "butterfly effect". The focus will be on the development of intuition and on applications rather than rigorous mathematical derivations. I hope that you will acquire a new Weltanschauung and start thinking about scaling laws, sensitivity to initial conditions, small changes and large effects.

Specific goals for the course: This course covers introductory material on complex systems that are applicable to may disciplines. Outcomes: understanding and fundamental analysis of system dynamics – reconstruction and characterization of strange attractors, fractal dimension calculations, understanding of phase space and system trajectories

Brief list of topics to be covered:

1. Introduction

2. Percolation

    2.1. Percolation on regular lattices

    2.2. Threshold estimates – analytical and numerical

    2.3. Cluster properties – size distribution and connectivity

    2.4. Random percolation – stick and Swiss cheese models

3. Percolation – applications

    3.1. Flow through fractured media

    3.2. Oil in rocks

    3.3. Settling of filaments

    3.4. Dielectric discharges

4. Fractals

    4.1. Concept of non-integer dimension

    4.2. Fractals in nature – coastline length, plants, rocks,

5. Geometric fractals

    5.1. Peano curve

    5.2. Sierpinski carpet

    5.3. Rigorous definitions of fractal dimensions

    5.4. Minkowski sausage, correlation dimension, information dimension

6. Real and virtual fractals

    6.1. Aggregates

    6.2. Physiology

6.3. Real and virtual landscapes

7. Nonlinear dynamics

7.1. Dynamics – discrete: logistic equation

7.2. Dynamics – continuous: phase space

7.3. Dynamics - double pendulum, electric circuits

7.4. Lorentz equation - strange attractors

7.5. Stock market

7.6. Characterization of strange attractors

7.7. R/S analysis, Lyapunov exponents

7.8. Attractor reconstruction – Ruelle and Takens theorem

8. Routes to chaos

8.1. Period doubling

8.2. Quasi-periodic- Hopf Bifurcation

8.3. Intermitency

9. Real life examples

9.1. B-Z reaction

9.2. Colorado River ecosystem

10. Wrap-up

6. **Course Name**: Computational materials and materials genome initiative 计算材料学与材料基因组工程

Credits: 3; 48 teaching hour

Instructors: Zou Xiaolong

Text Book (or other supplemental materials): [1] Instructor's slides [2] K. ohno et al., Computational materials science (Springer, 1999) [2] Tao Pang, An introduction to Computational Physics (Cambridge University Press, 1997)

Specific course information: This course will cover fundamentals of computational materials, theory of bandstructures, the conventional applications of computational methods, including Molecular Dynamics, Monte Carlo. Meanwhile, topics from research frontiers will be selected as projects. The newly development of computational materials—materials genome initiative and its various applications including lithium batteries, catalysts design, thermoelectricity, and topological insulators will be introduced.

Specific goals for the course: The objectives of teaching this course are: (1) to expose students to the basic work flow of first-principles simulations, to understand various approximations and the limitation of such methods, and to learn other advanced or alternative methods(2) to teach students to use the softwares and analyze the results, and (3) to train students to discuss research results and present their innovative ideas. During the teaching process.

Brief list of topics to be covered:

Ch1. Fundamentals of computational materials

1.1 Born-Oppenheimer Approx.;

1.2 Hartree-Fork approx.;

1.3 Density functional theory (DFT):

HK theorem; KS equation; LDA, GGA, GW

Ch2. Theory of band structures

2.1 Free electron gas (FES);

2.2 FES under external fields;

2.3 Electrons under periodic fields;

Bloch wave function; (space, transitional, time reversal) symmetry;

Nearly free electron gas; Wannier functions; k·p perturbation;

Different methods for solving band structures;

Ch3. Monte Carlo (MC)

3.1 History and introduction to probability;

3.2 Random number generator; Numerical integration;

3.3 Quasi- Monte Carlo method

3.4 Markov chain

3.5 Metropolis and other algorithms

3.6 Quantum Monte Carlo method

3.7 Kinetic Monte Carlo method

Ch4. Molecular dynamics (MD)

4.1 History and various applications; comparison with MC

4.2 Basic equations;

Forces and potentials; Boundary conditions;

Numerical approaches: Verlet; the leap-frog;

Velocity-verlet; Beeman; Predictor-corrector

4.3 Material properties and analysis from MD

Static and dynamic (time average) properties

Different ensembles:

NVT (velocity rescaling; Nose-Hoover; Anderson)

NPT (Anderson; Parrinello and Rahman)

Ch5. Various examples using computational methods

5.1 Transitional state theory, NEB simulation

5.2 STM, TEM simulations

5.3 Computational hydrogen models

5.4 Phase diagram, Cluster expansion

5.5 Structural prediction methods

Ch6. Materials genome initiative

6.1 Introduction to materials genome initiative

6.2 Application to Lithium batteries;

cathode materials & Solid state electrolytes

6.3 Application to other areas: catalysts design, thermoelectricity, and topological insulators

7. **Course Name**: Materials Physics 材料物理

Credits: 3; 48 teaching hour

Instructors: Zou Xiaolong

Text Book (or other supplemental materials): [1] Instructor's slides [2] W. D. Callister and D. G. Rethwisch, Materials Science and Engineering: An introduction (Wiley, 2013) [3] Zhengfei Hu et. al., An introduction to Materials Physics (Chemical Industry Press, 2009)

Specific course information: This course will cover basic materials physics, including defects, alloy phase diagram, thermodynamic properties, vibration and thermal transport, energy band theory, electronic properties of defects and transport behaviors, dielectric and magnetic properties. We will also incorporate closely-related research on low-dimensional materials in our group study.

Specific goals for the course: (1) to teach students the basic physic principles governing various materials properties, and (2) to train students to discuss research results and present their innovative ideas. The latter will be accomplished through the introduction of active research topics, especially in low-dimensional materials. I will select some prototype systems and problems from research as projects for investigative study, to make the connection between teaching and research, to cultivate their research interest and to develop their understanding on how we do research.

Brief list of topics to be covered:

Ch1. Introduction

Ch2. Point Physics

2.1 defect equilibrium

2.2 defect diffusion

2.2.1 Fick's 1st and 2nd laws; Random-walk diffusion

2.2.2 Diffusion mechanisms: Vacancy, interstitial, interstitialcy diffusion; impurity and cluster diffusion;

2.2.3 Dependence on concentrations, temperature, and pressure

2.2.4 Ionic conductivity

2.3.5 Diffusion of dislocations and grain boundaries

Ch3. Extended defects

3.1 Physical basis of dislocations;

3.2 Elasticity theory, energy, and forces;

3.3 Movement and generation of dislocations;

3.4 Grain boundaries and their physical consequences

Ch4. Phase diagram

4.1 Single component systems;

4.2 Thermodynamics of binary solutions;

4.3 Equilibrium in heterogeneous systems;

4.4 Phase diagram;

Ch5. Crystal vibration and thermal properties

5.1 Phonon dispersion

5.2 Models for calculating phonon dispersion

5.3 Electron-phonon interactions

5.4 Advanced methods

Ch6. Electronic properties

6.1. Theory of band structures

6.1.1 Free electron gas (FES);

6.1.2 FES under external fields;

6.1.3 Electrons under periodic fields;

Bloch wave function; (space, transitional, time reversal) symmetry;

Nearly free electron gas; Wannier functions; k·p perturbation;

Different methods for solving band structures;

6.1.4 Limitation of band theory

6.2 Shallow impurities

6.3 Deep Centers

6.4 transport behaviors

Ch7. Dielectric properties

7.1 Macroscopic electrodynamics

7.2 The dielectric functions

7.3 Excitons

7.4 Emission Spectroscopies

Ch8. Magnetic properties

8. **Course Name**: Materials Chemistry 材料化学

Credits: 3; 48 teaching hour

Instructors: Liu Bilu

Text Book (or other supplemental materials): [1] The instructor's slides [2] Chemistry of New Materials, David E. Newton [3] Chemistry of Advanced Materials, An Overview, Leonard V. Interrante, Mark J. Hampden-Smith, Wiley-VCH

Specific course information: This course will start from elements, and will talk about how elements can form molecules and solids via different kinds of chemical bonding. The crystal structures, electronic properties, and solid chemistry of these molecules and solid state materials will be discussed. Later, the course will introduce most commonly used methods to prepare nanometerials, and use carbon nanotubes and graphene as examples to deepen students' understanding about nanomaterials synthesis. There will also be a lab visit or practice and student seminar sessions at the end of the course

Specific goals for the course: Materials Chemistry will deliver knowledge about how to understand basic properties of various materials, as well as how to synthesize materials with an emphasis on nanomaterials. This course is important but currently missing in TBSI. Via this course, the students are expected to gain a good understanding on materials design, basic property understanding, and materials preparation. The students will also have chance to practice on the synthesis of novel low dimensional materials including carbon nanotubes, graphene, and other two dimensional crystals.

Brief list of topics to be covered:

Lecture #	Name	Core Knowledge
Lecture 1	Elements, molecules, solids	Atomic and electron structure, chemical bonding
Lecture 2	Crystal structure of solids I	Bravais lattice, Reciprocal lattice, symmetry, diffraction
Lecture 3	Crystal structure of solids II	Phase diagram
Lecture 4	Solid state physics I: Free electron model	From atom to molecules and solids, Band diagram
Lecture 5	Solid state physics II: Nearly free electron model	Fermi surface, effective mass, exciton
Lecture 6	Solid state chemistry I:	Chemical bonding, hybridization, covalent bond, ionic bond
Lecture 7	Solid state chemistry II:	MO Theory, Tight Binding model
Lecture #	Name	Core knowledge
Lecture 8	Nanomaterial synthesis I	Gas phase, CVD, PVD, MBE

Lecture 9	Nanomaterial synthesis II	Solid state, diffusion, self-propagating combustion
Lecture 10	Nanomaterial synthesis III	Wet chemistry, sol-gel, solvent thermal, co-precipitation
Lecture 11	Selected topic I	Carbon nanotubes (Practice of Lecture 8)
Lecture 12	Selected topic II	Two-dimensional materials (Practice of Lectures 4,6)
Lecture 13	Student presentation on selected topics	Students will have different topics (Perovskite materials)
Lecture 14	Lab tour	Optional (Metal-free scratching growth)
Lecture 15	Final exam	

9. **Course Name**: Principle of Environmental Behavior 环境行为学原理

Credits: 2; 32 teaching hour

Instructors: Zhang Xihui

Text Book (or other supplemental materials): [1] Wayne L. Winston. Operations Research Applications and Algorithms, 4th edition. [2] Axsäter Sven. Inventory Control. Springer, New York, 2006. [3] Cormen Thomas H., Leiserson Charles E., Rivest Ronald L. and Stein Clifford. Introduction to Algorithms, Second Edition, The MIT Press

Specific course information: Environmental behavior of pollutants at molecular level;Methodological tools: energy metabolism, life cycle assessment, environmental risk assessment, CO_2 emission analysis; Environmental behavior of bio-unit at individual level: algae, bacteria, plant, animal, humankind body; Environmental behavior of natural eco-system: forest, farming land, wetland, river and lake; Environmental behavior of social eco-system: prelim society, agricultural society, industrial society, postmodern society, city society and village society; Typical case studis: CO_2 emission

Specific goals for the course: To let the students understand the principles of global environmental change closely linked with both micro- and macro- behaviors; To help the students realize the environmental consequence of their own academic area; To provide analytic tools (including low carbon analysis, risk assessment, energy metabolism, life cycle assessment) to the students; To provide leadership thinking in their own professional area on the basis of global vision.

Brief list of topics to be covered:

1. Introduction

   1.1 Global occurrence of environmental pollutants

   1.2 Evolution history of natural system on the Earth

   1.3 Evolution history of human kind on the Earth

2. Basic principles

   2.1 Environmental dissipation and self-organization

   2.2 Environmental risk and assessment

   2.3 Energy transformation

   2.4 Life cycle assessment of materials

   2.5 Carbon dioxide emission analysis

3. Dissipation process behavior of environmental pollutants

   3.1 Digitalization of pollutants molecules

   3.2 Physical and physicochemical dissipation

3.3 Biological dissipation

3.4 Collective dissipation

4. Self-organization and environmental behavior of individual organism

   4.1 Self-organization and environmental behavior of autotrophic organism

   4.2 Self-organization and environmental behavior of heterotrophic organism

   4.3 Self-organization and environmental of plants and animals

   4.4 Self-organization and environmental of human body

5. Self-organizing structure and environmental behavior of natural ecosystems

   5.1 Natural forest system

   5.2 Agricultural farming land

   5.3 Wetland

   5.4 waterbody: river and lake

6. Self-organization and environmental behavior of social systems

   6.1 Prelim society

   6.2 Agricultural society

   6.3 Industrial society

   6.4 Post-modern Society

7. Carbon emission behavior: Case Study

8. Short Capstone project

10. **Course Name**: Advanced Materials Characterization: Principles and New Developments 先进材料表征：原理和最新进展

Credits: 3; 48 teaching hour

Instructors: Liu Bilu

Text Book (or other supplemental materials): [1] The instructor's slides [2] Literature assigned during lecturing.

Specific course information: This course will cover materials characterization techniques including both imaging methods and spectroscopy methods. The emphasis will be basic principles of these techniques, examples of applications in scientific research, as well as new developments of the techniques. In addition, the course will offer seminar and hands on experiment practice for students.

Specific goals for the course: Advanced Materials Characterization: Principles and New Developments will deliver knowledge about how to characterize structures and chemistry of various advanced materials, and pay special attention to the cutting-edge research and developments of new characterization techniques. This course will not only talk about fundamental knowledge of materials characterization techniques, but also their applications in cutting-edge research as well as new developments of the technique themselves. This course is important but currently missing in TBSI.

Brief list of topics to be covered:

Part I: Imaging techniques, including Lectures 1-5.

Part II: Spectroscopy techniques, including Lectures 7-12.

Note: Each lecture will be 4*45 minutes

Lecture 1: Overview of imaging techniques and Optical Microscopy

1.1: Overview of materials imaging techniques, from macro- to micro-level.

1.2: History of optical microscopy

1.3: New developments of optical microscopy

1.4: Some examples of using optical microscopy to observe and manipulate advanced nanomaterials.

Lecture 2: Scanning electron microscopy

2.1: Principles and history of SEM

2.2: New developments of SEM

2.3: Some examples of using SEM to observe and manipulate advanced nanomaterials.

Lecture 3: Transmission electron microscopy

3.1: Principles and history of TEM

3.2: New developments of TEM

3.3: A comparison between SEM and TEM

3.4: HRTEM and STEM

3.5: Some examples of using TEM to observe and manipulate advanced nanomaterials.

Lecture 4: Atomic force microscopy

4.1: Principles and history of AFM

4.2: New developments of AFM

4.3: AFM-based surface imaging and characterization techniques

4.4: Some examples of using AFM to observe and manipulate advanced nanomaterials.

Lecture 5: Scanning probe microscopy

5.1: Principles and history of SPM

5.2: New developments of SPM

5.3: SPM-based surface imaging and characterization techniques

5.4: STM and STS

5.5: Some examples of using SPM to observe and manipulate advanced nanomaterials.

Lecture 6: Seminar

Students will give seminars on selected topics (combining their research with a specific characterization technique)

Lecture 7: Optical absorption and emission spectroscopy

7.1: Light-matter interaction

7.2: Principles of optical absorption and emission spectroscopy

7.3: Some examples of using Optical absorption and emission spectroscopy to characterize advanced nanomaterials.

Lecture 8: Raman spectroscopy

8.1: Principles of Raman spectroscopy

8.2: Raman versus Rayleigh scattering

8.3: Some examples of using Optical absorption and emission spectroscopy to characterize advanced nanomaterials.

Lecture 9: XPS, AES, and related surface sensitive techniques

9.1: Principles of XPS

9.2: Principles of AES (Auger Electron Spectroscopy)

9.3: Some examples of using XPS and AES to characterize advanced nanomaterials.

Lecture 10: EDS, EDX, and related bulk sample sensitive techniques

10.1: Principles of EDS

10.2: Principles of EDX

10.3: A comparison between EDS and EDX

10.4: Some examples of using EDS and EDX to characterize advanced nanomaterials.

Lecture 11: EELS

11.1: Principles of EEELS

11.2: A comparison of EELS with other techniques like EDS and EDX

11.3: Some examples of using EELS to characterize advanced nanomaterials.

Lecture 12: XRD and 3D XRD

12.1: Principles of XRD

12.2: 3D XRD, GIXRD, and other new advances in XRD-related techniques.

12.3: Some examples of using XRD to characterize advanced nanomaterials.

11. **Course Name**: Materials and Devices of Energy Storage and Conversion 能源储存与转化：材料和器件

Credits: 1; 16 teaching hour

Instructors: Yang Quanhong, Kang Feiyu

Text Book (or other supplemental materials): 《Cynthia G. Zoski. Handbook of Electrochemistry Elsevier》, 《Carbon Materials and Science and Engineering—From Fundamentals to Applications》

Specific course information: This course will cover four topics on energy storage and conversion: (1) fundamental chemistry, (2) advanced power sources, (3) new energy storage techniques, and (4) development of electric vehicles. Materials and devices applied in energy storage and conversion are the focus of this course. We will employ open discussion through this course.

Specific goals for the course: The course objective is to (1) to allow students to understand the fundamental electrochemistry which is the basis of electrochemical energy storage, and (2) to train students to have an overview of modern energy storage and conversion techniques. The objective will be accomplished through open discussions in the courses on different energy storage and conversion topics, especially in electrochemical energy storage.

Brief list of topics to be covered:

1 Fundamental electrochemistry

1.1 Foundations, Definitions and Concepts.

1.1.1 Ions, Electrolytes and the Quantisation of Electrical Charge.

1.1.2 Transition from Electronic to Ionic Conductivity in an Electrochemical Cell.

1.1.3 Electrolysis Cells and Galvanic Cells: The Decomposition Potential and the Concept of EMF.

1.1.4 Faraday's Laws.

1.1.5 Systems of Units.

1.2 Electrical Conductivity and Interionic Interactions.

1.3 Electrode Potentials and Double-Layer Structure at Phase Boundaries.

1.4 Electrical Potentials and Electrical Current.

1.5 Methods for the Study of the Electrode/Electrolyte Interface.

4.1.3 Fuel cell electric vehicles

4.2 Development of power battery

4.2.1 Fuel cell power battery

4.2.2 Li ion power battery

4.3 Perspective of electric vehicles

12. **Course Name**: MEMS and Its Application　MEMS 及其应用

Credits: 3; 48teaching hour

Instructors:　Wang Xiaohao, Liwei Lin, You Zheng, Dong Ying, Zhang Min

Text Book (or other supplemental materials):　none

Specific course information: The class hours will be assigned to lectures, invited talks, seminars and flipped teaching activities. The topics of the lectures and the talks will include the development and the features of MEMS, current research hotspots in the field of MEMS, typical MEMS products and their applications. R&D training will be provided through case studies. Students will present and discuss their ideas in the seminars. In the flipped teaching activities, students will learn by themselves through making use of the abundant resource in Tsinghua, Berkeley and internet.

Specific goals for the course:　MEMS is considered one of the supporting technologies that make the age of Big Data and Internet of Things. Therefore, learning about MEMS is necessary to the graduate students in the related fields. In both Tsinghua and Berkeley, there are courses about the theories, materials, processing, packaging techniques, devices and applications of MEMS. This course is intend to give students insight into MEMS based on a series of invited talks of current research hotspots as well as lectures on typical products and their applications.

Brief list of topics to be covered:

MEMS History	Xiaohao Wang
Basic Processes：Photolithography, etching	Min Zhang
Operation Principles	Ying Dong
Design and Simulation	Ying Dong
Sensors	Xiaohao Wang
Actuators	Xiaohao Wang
MOEMS	Ying Dong
Microfluidic devices	Min Zhang
RF MEMS	Zheng You

Power MEMS	Zheng You
Integrated Microsystems	Zheng You
Lab: Photolithography& silicon wet etching	Min Zhang
Auto Industries	Ying Dong
NEMS	Min Zhang
Residual Stress in MEMS	Liwei Lin
Comb Resonators	Liwei Lin
Test	

13. **Course Name**: Materials Science and Engineering 材料科学与工程

Credits: 3, 48 teaching hour

Instructors: Qiu Ling

Text Book (or other supplemental materials): Fundamentals of Materials Science and Engineering, William D. Callister, Jr., John Wiley & Sons, Inc.

Specific course information: Materials are foundations of human civilization. Materials science involves the investigation on structure-property relationship, and the design and fabrication of a materials with a predetermined set of properties. The ability to understand and manipulate materials and their properties is crucial skill in both of industrial process and scientific research. This course will provide essential knowledge of materials science.

Specific goals for the course: This course aims to: 1. Describe the basics of materials science and engineering 2. Describe the various techniques for fabrication and characterization of materials 3. Describe the structure-property relationship of materials 4. Describe the recent developed advanced materials, including nanomaterials and soft materials. 5. Describe the basics of materials design and selections for different applications.

Brief list of topics to be covered:

Materials Science and Engineering

1. Classification and properties of the materials

1.1 Classification of the materials

1.2 Properties of the materials and the characterization techniques

2. Atomic structure and interatomic bonding

2.1 Atomic structure

2.2 Atomic bonding in solids

3. Structure and property of metals, ceramics and polymers

3.1 Metallic crystal structure

3.2 Ceramic crystal structure

3.3 Polymer structure

3.4 Properties and applications of metal, ceramic and polymer

4. Soft materials

4.1 Basics of soft materials

4.2 Fabrication and soft materials

4.3 Mechanics of soft materials

4.2 Applications of soft materials

5. Nanomaterials

5.1 Basics of nanomaterials

5.2 Fabrication and characterization of nanomaterials

5.3 Applications of nanomaterials

6. Materials selection

6.1 Basics of materials selection

6.2 Case study of materials selection

14. **Course Name**: Micro Sensors 微传感器

Credits: 2; 32 teaching hour

Instructors: Wang Xiaohao, Liwei Lin, Dong Ying

Text Book (or other supplemental materials): none

Specific course information: The class hours will be assigned to lectures, seminars, flipped classrooms and lab experiments. The purpose of this course is to enable the students to fully understand the working principle and realization method of Micro sensors, so as to acquire the basic knowledge and ability to the research, developing and application of Micro sensors. In the beginning, the relative theories of Micro sensors will be introduced in the form of lecture, including the mechanical properties of the micro structures and the principles of signal detection. Then taking several typical micro sensors as examples and through case studies, seminar discussions, flipped classrooms and lab experiments, the complete process of the design, fabrication, packaging and performance testing of Micro sensors can be practiced by the students.

Specific goals for the course: Micro sensors are volume producible, low cost information source, which makes the internet of things possible. It is necessary for the students in the related fields to learn the basic concepts and techniques of Micro sensors. This course is designed to provide the students with the relative theories, the approaches to the design, fabrication, package, test and application of Micro sensors. Through lectures, seminars, flipped classrooms and lab experiments, the students can acquire the knowledge and ability to the research, developing and application of Micro sensors.

Brief list of topics to be covered:

No.	Topic	Lecturer
1	History of sensing and sensors	Xiaohao Wang
2	sensing material	Min Zhang
3	Thermo sensor(plus solid state device physics)	Min Zhang
4	Pressure sensors (plus packaging)	Liwei Lin
5	Acoustic sensors (plus piezoelectric effect)	Liwei Lin
6	SiC based sensors (plus harsh environment application)	Liwei Lin
7	Bio and chemical sensing(including gas sensor)	Liwei Lin
8	Inertial Sensors (plus integration)	Xiaohao Wang
9	Magnetic sensors	Xiaohao Wang
10	Flow sensors (plus fluidic simulation)	Ying Dong
11	Optical and photonic sensing	Ying Dong
12	Course excursion	Min Zhang& TA
13	Pressure sensor experiment	Min Zhang & TA
14	Inertial sensor experiment	Ying Dong&TA

15	Sensor design(Intellisuite) and practicing	Ying Dong &TA
16	Discussion: Trend of microsensors	Xiaohao Wang

15. **Course Name:** Introduction of Photonics 光电子概论

Credits: 3; 48 teaching hour

Instructors: Fu Hongyan

Text Book (or other supplemental materials): 1. Ammon Yariv, Pochi Yeh, Photonics: Optical Electronics in Modern Communications, 6th Edition, Oxford University, 2006 2. 朱京平，光电子技术基础(第二版)，科学出版社, 2009 3. 刘旭，葛剑虹，李海峰，沈永行，何建军，光电子学，浙江大学出版社，2014

Specific course information: Photonics is the physical science of light (photon) generation, detection, and manipulation through emission, transmission, modulation, signal processing, switching, amplification, and detection/sensing, etc. This course mainly covers basic optics, interactions between light and materials, laser fundamentals, waveguide theory, semiconductor devices, optical modulation & detection, as well as nonlinear optics. Photonics advances together with other information technologies, making it one of the fundamentals of today's modern information technology.

Specific goals for the course: Photonics is one of the key technologies for today's information ages which contributes lots of research fields, especially, close relate to classical optics, modern optics as well as emerging science likes quantum information, etc. Applications of photonics are ubiquitous. Equipped with fundamental photonic knowledge is important for students at TBSI and it is also the main objective of this course to achieve. From this course, the student can acquire not only basic photonic principle but also some advanced research scopes related to photonics.

Brief list of topics to be covered:

Chapter 1 Introduction

§1-1 Introduction of photonics, including history, research area and applications

§1-2 Introduction of Photonics course

Chapter 2 Electromagnetic fields and waves

§2-1 Introduction

Chapter 6 Guide-wave optics

§6-1 Planar dielectric waveguides

§6-2 Optical coupling in waveguides

§6-3 Step-index fibers

§6-4 Graded-index fibers

Chapter 7 Optical modulation

§7-1 Principles of electro-optics

§7-2 Electro-optics of anisortropic media

§7-3 Interactions of light and sound

§7-4 Acousto-optics devices

Chapter 8 Optical detection

§8-1 Detection of optical radiation

§8-2 Photomultipliers

§8-3 Semiconductor photodiodes

§8-4 Avalanche photodiodes

Chapter 9 Nonlinear optics

§9-1 Nonlinear optical media

§9-2 The nolinear wave equation

§9-3 Second-order nonlinear effect

§9-4 Second-harmonic generation

16. **Course Name**: Nanomaterials and Nanotechnology 纳米材料与技术

Credits: 3; 48 teaching hour

Instructors: Qiu Ling

Text Book (or other supplemental materials): [1] Introduction to Nanoscience and Nanotechnology (by Hornyak, Gabor L. Tibbals, H.F. Dutta, Joydeep , CRC Press, 2008)

Specific course information: This course aims to: 1. Describe the basics of nanomaterials 2. Describe the various techniques for fabrication and characterization of nanomaterials and appraise the advantages and limitation of these techniques. 3. Describe the various assembling techniques for nanomaterial-based bulk structure and appraise the advantages and limitation of these techniques. 4. Describe the structure-property relationship of nanomaterials-based bulk structure and their applications

Specific goals for the course: The objective of this course is to introduce the basic knowledge of nanotechnology to the postgraduate students. On completion of this course, the students should understand the concept of nanotechnology; have a thorough knowledge of fabrication and characterization of nanomaterials; understand the principles of assembly techniques for nanomaterial-based bulk structure; develop a deep understanding on the sophisticated structure-property-application relationship of nanomaterial-based bulk structure.

Brief list of topics to be covered:

1. Introduction of nanomaterials
    a. Overview on nanoscience and nanotechnology
    b. Natural nanomaterials
    c. Zero-dimensional nanoparticles, one-dimensional nanostructures and two-dimensional thin films and nanocomposites.
2. Characterization techniques
    a. General classification of characterization techniques
    b. Atomic force microscopy
    c. Scanning electron microscopy
    d. Transmission electron microscopy
3. Fabrication methods for nanomaterials
    a. Top-down fabrication
    b. Bottom-up fabrication
    c. Fabrication of graphene-based nanomaterials
4. Assembling techniques for nanomaterials-based bulk structure
    a. Self-assembling
    b. Template-directed assembling
    c. 3D printing
    d. Filtration
5. Applications of nanomaterials
    a. Energy storage
    b. Flexible electronics
    c. Commercial challenges and economic viability of nanomaterials

17. **Course Name**: Optical Fiber Communications 光纤通信

Credits: 3, 48 teaching hour

Instructors: Fu Hongyan

Text Book (or other supplemental materials): 1. G. Keiser, Optical Fiber Communications, 4th ed, McGraw-Hill, 2010 2. 原荣，光纤通信，第三版，电子工业出版社, 2012 3. 袁国良，李元元，光纤通信简明教程，清华大学出版社, 2006

Specific course information: Optical fiber technology has brought great technological revolution to the field of communications. With its unique advantages, optical fiber has become one of the main directions of modern communications, and has been widely used. This course focuses on the basis of optical fiber communication, optical fiber cable, optical passive / active devices, photodetector and laser light receiving / transmitting technologies, and several kinds of optical amplifiers; and includes several optical fiber transmission systems, such as electrical frequency division multiplexing system, electrical time-division multiplexing system, optical time-division / wavelength-division multiplexing and optical code division multiplexing systems, as well as recent coherent lightwave communication systems and optical soliton communication system. It will also introduces several problems to be considered in design of optical fiber transmission system, such as the fiber dispersion on the performance of the system and the dispersion compensation method of compensation limit management. The goal of this course is to enable students to understand the latest developments and applications in optical fiber communications.

Specific goals for the course: Applications of fiber optic communication are ubiquitous. Equipped with fundamental fiber optic communication knowledge is important for students at TBSI and it is also the main objective of this course to achieve. From this course, the student can acquire not only basic fiber optic communication principles but also some advanced research scopes related to fiber optics.

Brief list of topics to be covered:

Chapter 1 Overview of optical fiber communication

§1-1 Introduction of optical fiber communications and systems

§1-2 Introduction of optical fiber communications course

Chapter 2 Fundamental physics of optical fiber communication

§2-1 The essence of light

§2-2 Light waves in a homogeneous medium

§5-2 Semiconductor laser

§5-3 Wavelength tunable semiconductor laser

§5-4 Vertical cavity surface emitting lasers

§5-5 High speed optical transmitter

Chapter 6 Optical detection and optical receiver

§6-1 Light detection principle

§6-2 Photoelectric detector

§6-3 Digital optical receiver

§6-4 Signal to noise ratio of receiver

§6-5 Receiver bit error rate and sensitivity

§6-6 Mechanism of sensitivity decrease

§6-7 Types and structures of optical receivers

Chapter 7 Optical amplifier

§7-1 General concepts

§7-2 Semiconductor optical amplifier

§7-3 Fiber Raman amplifier

§7-4 Erbium doped fiber amplifier

§7-5 Application of optical amplifier system

Chapter 8 Optical fiber transmission system

§8-1 Overview

§8-2 Light modulation

§8-3 Multiplexing optical fiber transmission system

§8-4 Optical fiber transmission system for optical recovery

§8-5 Coherent lightwave communication system

§8-6 Experimental system of soliton communication

§8.7 High speed optical fiber transmission system

Chapter 9 System design (3 hours)

§9.1 system architecture and limitations

§9.2 Power budget

§9.3 Functional cost factors

§9.4 Bandwidth design

§9-5 Design of single channel optical fiber communication system

§9.6 DWDM system engineering design

Chapter 10 Dispersion limit, compensation and management

§10-1 Pulse broadening caused by dispersion

§10-2 The limitation of dispersion on system performance

§10-3 Electron dispersion compensation

§10-4 Front compensation technology

§10-5 Negative dispersion fiber compensation

§10-6 Optical filter compensation

§10-7 Phase conjugate compensation

§10-8 Dispersion compensation of wideband system

§10-9 Dispersion management

18. **Course Name**: Nanoscale Fabrication and Optoelectronic Devices 纳米加工和光电子器件导论

Credits: 2; 32 teaching hour

Instructors: Connie Chang-Hasnain, Huang Yidong, Luo Yi, Ning Cunzheng

Text Book (or other supplemental materials): (1) Photonic Crystals Princeton, NJ, Princeton Univ. Press, 1995. (2) Near-field photonics ISBN4-900474-83-5 C3055 (3) Reference paper

Specific course information: Two hours of lecture and one hour of discussion per week. This course discusses various top-down and bottom-up approaches to synthesizing and processing nanostructured materials. The topics include fundamentals of self assembly, nano-imprint lithography, electron beam lithography, nanowire and nanotube synthesis, quantum dot synthesis (strain patterned and colloidal), postsynthesis modification (oxidation, doping, diffusion, surface interactions, and etching techniques). In addition, techniques to bridging length scales such as heterogeneous integration will be discussed. We will discuss new electronic, optical, thermal, mechanical, and chemical properties brought forth by the very small sizes.

Specific goals for the course: This course involves the introduction of novel nano-structure fabrication techniques, the special features of nano- material and structure, and optoelectronics devices with nano-structure.

Brief list of topics to be covered:

I. Optoelectronic devices, in particular integrated devices, based on compound semiconductors. Related material and device physics.

Chapter 1.Basic Characteristics of Devices and Materials

Direct bandgap and indirect bandgapsemicoductors

Double Heterojuction, quantum well structure, diodes.

Lattice matching and strained materials

Some common materials systems (GaAlAs/GaAs Materials, InGaAsP/InP Materials,GaN、AlN、InN Materials)

Quantum Cascade Laser and Quantum Cascade Detector

Chapter 2.Application

Photonic and Optoelectronic Devices in Optical Fiber Communications(OFC)systems

Active devices (LED, LD, SOA, semiconductor optical modulator, semiconductor photodetector)

Passive devices (optical coupler, multiplexer/demultiplexer, optical switch)

Monolithic Integrated photonic devices (OEIC, PIC)\

TE and TM Modes

Semiconductor Lighting and Display

LED

LD

Chapter 3.Some Typical Laser Diodes

F-P

VCSEL

DFB

DBR

II. Optical Waveguide and Its Applications

Chapter 1.Fundamental Theory of Optical Waveguide

1.1 Light Propagation in Isotropic Media

1.2 Wave Propagation in Lossy Media: Lorentz Oscillator Model

1.3 Matrix Optics

1.4 Propagation Matrix Approach for Plane WaveReflection from

a Multilayered Medium

1.5 Symmetric Dielectric Slab Waveguides

1.6 Coupled-Mode Theory

Chapter 2.Wave Propagtion in Periodic MediaPhotonic Crystal Waveguide

2.1 Wave Propagation in Periodic Media

2.2 Calculation of Photonic Band Structure

2.3 Novel Characteristics of Photonic Crystal

2.4 Two Dimensional Photonic Crystal Waveguide

2.5 Mini-Stop-Band in Photonic Crystal Waveguide

2.6 Active Photonic Crystal Waveguide

Chapter 3.Surface Plasmon Polariton Waveguide

3.1 Conducting Media

3.2 SPP Mode of a Single Interface

3.3 Long Range and Short Range SPP Waveguide

3.4 Application of SPP Waveguides

III. Nano Materials, Characterization and Physics

Chapter 1.Light-semiconductor Interactions

Basic relations: absorption coefficient, complex dielectric constant, wave-vectors, Q-factor

Slowly Varying Amplitude Appromixation

Basic materials properties (bandstructures of typical semiconductors, semiconductor alloys

Dipole interactions and 3 basic optical processes

Einstein relations, absorption and optical gain

Carrier population, quasi-Fermi level, transparency density, and transparency frequency, occurrence of optical gain

Carrier lifetimes in semiconductors

Chapter 2.Nano-structures

Schrödinger equation in 1D

Quantum wells, wires, and dots: concepts and the making of them

Densities of states and why are they important

Various examples

Chapter 3.Optical Characterization Techniquesfor Semiconductors, Semiconductor Heterostructures, Nanophotonic Materials, and Related Phenomena

PL (Photoluminescence)

Absorption spectrum

PLE (Photoluminescence Excitation Spectrum)

Concurrent PL and absorption

Various experimental examples

Chapter 4.Semiconductor Nanowires

Basics: motivation, advantages, growth, varieties, characterization

Photonic Applications: nanowire lasers and LEDs, understanding based on modeling results

IV. Fundamental of Semiconductor Lasers, Detectors and Optical Interconnects

Chapter 1.Fundamentals of Semiconductor Lasers

Basics of PN junctions and PIN junctions

Basic characteristics of laser light

Chapter 2.Vertical Cavity Surface Emission Laser

Structures, designs, and applications

Chapter 3.InPNanopillars

Growth and applications

Chapter 4.High Contrast Grating

Mechanisms

Design and fabrication

Applications

19. **Course Name**: Semiconductor Physics and Devices 半导体物理与器件

Credits: 3; 48 teaching hour

Instructors: Wei Guodan

Text Book (or other supplemental materials): 1.Fundamentals of Semiconductor devices, Betty Lise Anderson and Richard L. Anderson 2.Elementary Solid State Physics: Principles and Applications, M. A. Omar

Specific course information: Since the 1st transistor was invented in 1947, human beings are experiencing an era based on microelectronics, in the meantime, semiconductor physics and devices are the basis of microelectronics. This course contains two parts: semiconductor physics and devices. Semiconductor physics includes the fundamental semiconductor materials, carrier models and transportation, and band gap theory; semiconductor devices contains PN junction, bipolar transistor, MOS capacitors and FET.

Specific goals for the course: Semiconductors form the basis of most modern systems and electronic devices.The course objective will to understand the operation and design of semiconductor devices begins with an understanding of the fundamental semiconductor materials and the behavior of electrons in crystalline materials. This course will also teach students basic operation principles of devices: PN-junction diode, the bipolar junction transistor, the metal-oxide-semiconductor capacitor and filed-effect transistor. Other semiconductor devices (solar cells, LEDs) are also introduced.

Brief list of topics to be covered:

1. Introduction
    - 1.1 Crystals and Semiconductor Materials
    - 1.2 Introduction to Quantum Mechanics
    - 1.3 Application to Semiconductor Crystals-Energy Band Gap theory
2. Homogeneous Junction
    - 2.1 Carriers and Statistics
    - 2.2 Recombination-Generation Processes
    - 2.3 Carrier Transport Mechanisms
    - 2.4 Steady State Carrier Diffusion
3. P-N Junctions
    - 3.1 Equilibrium properties of PN junctions
    - 3.2 Space Charge Layer
    - 3.3 I-V Characteristics of PN junctions and its mathematical description
4. Device Applications of PN junctions
    - 4.1 Rectifiers
    - 4.2 Photodiode
    - 4.3 Light Emitting Diodes
    - 4.4 Solar Cells
    - 4.5 Carrier injection in lasers

5. Metal-Oxide-Semiconductor Transistor (MOSFET)

    5.1 Device Structure

    5.2 Formation of Accumulation and Inversion Layer

    5.3 Current Control Mechanisms

    5.4 I-V Characteristics

    5.5 Application Examples

20. **Course Name**: Sustainable Nanotechnology: Environmental Applications and Implications 可持续纳米技术：环境应用及其影响

Credits: 3; 48 teaching hour

Instructors: Huang Yuxiong

Text Book (or other supplemental materials): 1.Wiesner, Mark, and Jean-Yves Bottero. Environmental nanotechnology. New York: McGraw-Hill Professional Publishing, 2007.

Specific course information: Topics include the synthesis and characterization of nanomaterials, environmental application of nanotechnology, nanoparticle dispersion and colloidal chemistry, environmental fate and transport of nanomaterials, the nano-bio interface and mechanistic nanotoxicology, predictive toxicological profiling, the nanomaterial ecosystems interface, in vivo and inhalation toxicity, societal implications of nanotechnology, and nanotechnology regulation.

Specific goals for the course: This course will discuss the positives and negatives of nanotechnology: the benefits to use in environmental applications, as well as considering nanoparticles as an emerging environmental contaminant. It would provide an overview of environmental, societal, and regulatory issues related to synthesis, use, and disposal of nanomaterials. The goal is to better understand the environmental interactions between nanomaterials/nanotechnology with the ecosystem, as well as to develop sustainable nanotechnology-based solutions to environmental challenges.

Brief list of topics to be covered:

Introduction to nanotechnology and nanoscience
- The basic concepts in nanoscience
- The physicochemical properties of nanomaterials
- The function of the size

Week 1.

Manufacturing of nanomaterials

- Natural and engineered nanomaterial
- Overview of the different production route and synthesis methods of engineered nanomaterials

Week 2.

Characterization of nanomaterials

- The structure, morphology, and chemistry
- The colloidal state and surface properties

Week 3.

Environmental application of nanotechnology (I)

- Fundamental in wastewater treatment
- Application of nanotechnology in wastewater treatment

Week 4.

Environmental application of nanotechnology (II)

- Fundamental in groundwater remediation
- Case study of nano-zero valent iron for groundwater remediation

Week 5.

Environmental application of nanotechnology (III)

- Fundamental in biosensing and disinfection
- Application of nanotechnology for biosensing and disinfection

Week 6.

Environmental application of nanotechnology (IV)

- Fundamental in environmental catalysis
- Application of nanotechnology as adsorbents and catalysis

Week 7.

Review and Midterm

Week 8.

The fate and transport of nanomaterials in the environment (I)

- Fundamental in environmental fate and transport
- Water chemistry

Week 9.

The fate and transport of nanomaterials in the environment (II)

- Stability, aggregation, and deposition of nanomaterials
- Transformation of nanomaterials

Week 10.

The toxicity of nanomaterials in the environment (I)

- Fundamental in ecotoxicology

- The microbial toxicity of nanomaterials

Week 11.

The toxicity of nanomaterials in the environment (II)

- Fundamental in the bio-nano interface
- The environmental risks of nanomaterials to public health

Week 12.

The sustainable nanotechnology (I)

- Fundamental in life cycle assessment (LCA)
- The LCA of nanomaterials

Week 13.

The sustainable nanotechnology (II)

- The societal impacts of nanotechnology
- The regulation and policy

Week 14.

The student term paper and presentations

Week 15.

The review and final

21. **Course Name**: Introduction to Statistical Mechanics and Molecular Simulation
统计力学与分子模拟简介

Credits: 3; 48 teaching hour

Instructors: Yu Kuang

Text Book (or other supplemental materials): "Statistical Mechanics" by Donald A. McQuarrie [2] "Understanding Molecular Simulation: From Algorithms to Applications" by Berend Smit & Daan Frenkel

Specific course information: Statistical mechanics is one of the most important cornerstones of materials physics. It is critical to understand statistical mechanics before we understand most phenomenon in materials science, as it is the most important theory that bridges microscopic structures and macroscopic properties. As a direct application of stat mech, molecular simulation is also widely used in modern materials science researches. This course will introduce these two subjects, the main topics include: ensemble theory, ideal gas models, polyatomic molecule and crystal vibrations, Ising model and phase transition, stochastic dynamics, liquid structure, Monte Carlo and molecular dynamics etc.

Specific goals for the course: Statistical mechanics is the fundaments behind almost all research areas in materials science. It is utmost important for our students to have basic knowledge about statistical mechanics, if they want to do any serious scientific work at all in materials science. The course objective is the student should have basic knowledge about statistical mechanics when the class is done. For those already knew stat mech from their undergraduate courses, they can also learn how to apply stat mech to do molecular simulation.

Brief list of topics to be covered:

1. Review of Thermodynamics

Thermodynamic laws

Thermodynamic functions (energy, enthalpy, entropy, free energy): definitions and why

Derivative relationships: temperature, pressure, chemical potential, heat capacity, compressibility, ... (intensive properties)

Maxwell relationship Spontaneous processes, condition of equilibrium and stability

2. Statistical Mechanics

2.1 Basic Laws

Connection between stat mech and thermodynamics: from microscopic to macroscopic.

How to find out long-time, large-space properties from equation of motion of individual particles?

Thermodynamic phase space

Liouville's theorem Ergodicity hypothesis

Equal a priori probability hypothesis.

2.2 Microcanonical Ensemble

Microcanonical (NVE) ensemble

Boltzmann entropy equation, counting states

Probability in macroscopic scale, Stirling approximation

Lagrange Multipliers

2.3 Canonical Ensemble

Canonical ensemble, Boltzmann distribution, and thermodynamic temperature

Canonical partition function and free energy, other thermodynamic properties

Probability expression of entropy in canonical ensemble

2.4 Grand Canonical Ensemble and NPT Ensemble

Grand canonical (VT) ensemble, grand canonical partition function
Thermodynamic functions in grand canonical ensemble

NPT ensemble, partition function and thermodynamic functions

2.5 Fluctuations and Equivalence of Ensembles in Macroscopic Limit
Variance of a random variable, fluctuations of thermodynamic quantities and , how it scales with increasing system size

Density of states, shape of distribution

Particle number fluctuations in grand canonical ensemble, equivalence with canonical ensemble

Legendre transform in thermodynamic functions & Laplace transform in partition function

3. Application of Stat Mech

3.1 Non-interacting Single Atomic Gas

Distinguishable ideal gas, translational partition function, idea gas equation of states

Indistinguishable particles: Fermions and Bosons in Quantum Mechanics, exchange symmetry

Fermi-Dirac statistics, 3d free electron gas

Boson-Einstein statistics

Boltzmann limit, thermal de Broglie wave length, equipartition theorem

Bose-Einstein condensation (can be skipped if no time)

3.2 Diatomic Gas

Partition function of heteronuclear diatomic molecule

Vibration partition function

Rotation partition function

Characteristic temperatures for rotation and vibration, equipartition theorem in diatomic gas.

3.3 Polyatomic molecules and Solid

Polyatomic molecules: normal mode analysis

Phonons in crystal, the band structure of phonons

Solid heat capacity: Einstein model / Debye model, Debye temperature, low temperature behavior

3.4 Phase Transitions and Ising Model

Basic phenomenon in phase transition

Classification of phase transition: 1st order & 2nd order ...

Ising model, magnetic solid materials

Solving 1d Ising model exactly

Solving 2d Ising model, mean field theory, 2nd order phase transition

Critical components and critical phenomena, correlation function and correlation length

Order parameter and Landau theory

3.5 Brownian Dynamics

Brownian motion, the nature of random walk

Einstein relationship, fluctuation-dissipation theorem

Linear response theory, derivation of Einstein relationship

Langevin equation of motion

3.6 Liquid Structure (can be skipped if no time)

Radial distribution function (RDF)

Properties of RDF: normalization and asymptotic behavior

Neutron diffraction intensity and RDF

Kirkwood integral

4. Brief Introduction to Molecular Simulation

4.1 Metropolis Monte Carlo

Markovian chain and detailed balance

Metropolis scheme

Solving 2d Ising model using MC

Lennard-Jones liquid - sample in continuous space

4.2 Molecular Dynamics

Velocity Verlet integrator, energy conservation

Langevin thermostat, stochastic dynamics

Nose-hoover thermostat, extended Lagrangian method

Barostats: Berendsen, Parrinello-Rahman, etc.

Lennard-Jones liquid, case study

4.3 Force Field

Short-range interaction, dispersion interaction, Lennard-Jones/Buckingham potential

Long-range electrostatics, Ewald summation

Cutoff radius, long range correction

Introduction to neighbor list search

Other terms (polarization, many-body term, charge penetration, charge transfer, beyond point charge etc.)

4.4 Free Energy Calculation (can be skipped if no time)

Thermodynamic integration

Thermodynamic perturbation: test particle insertion/deletion 4.5 Enhance Sampling Technique (can be skipped if no time)

Importance sampling, umbrella sampling Replica exchange

22. **Course Name**: Partial Differential Equations for Practical Applications in Engineering 数理方程在工程科学中的实践应用

Credits: 3; 48 teaching hour

Instructors: Wei Guodan

Text Book (or other supplemental materials): Advanced Calculus for Applications, Francis B. Hildebrand, Prentice Hall

Specific course information: Based on the analysis of the application of advanced mathematics calculus in practice, this course starts with the importance of the application of advanced mathematics calculus in practice, and then makes an effective analysis of the application of advanced mathematics calculus in practical engineering application such as in materials science,optical electronics and communication. For example, The partial differential equation will be introduced to simulate the carrier transport in PN junction with external electrical field, to analyze the statistical data and exciton life time in semiconductors. Therefore, complicated problems will be simplified with appropriate mathematical equation, resulting more efficient productivity for researchers with basic transport, wave equation, heat equation and harmonic equation.

Specific goals for the course: Based on the analysis of the application of Partial Differential Equations (PDE) in practice, this course starts with the importance of the application of basic concepts and mathematical models in PDE such as the modelling for four classical types of equations (Transport, wave equation, heat equation and harmonic equation), and then makes an effective analysis of the application of advanced mathematics in practical engineering application such as in materials science,optical electronics and communication.

Brief list of topics to be covered:

1. Ordinary Differential Equations

1.1 Introduction

1.2 Linear Dependence

1.3 Complete Solutions of Linear Equations

1.4 The Linear Differential Equation of First Order

1.5 Linear Differential Equations with Constant Coefficients

2. Numerical Methods for Solvent Ordinary Differential Equations

2.1 Introduction

2.2 Use of Taylor Series

2.3 The Adams Method

2.4 The Modified Adams Method

2.5 Real Examples

3. Series Solutions of Differential Equations: Special Functions

3.1 Properties of Power Series

3.2 Bessel Functions

3.3 Legendre Functions

3.4 Real Examples

4. Boundary-Value Problems and Characteristic-Functional Representations

4.1 Introduction

4.2 The Rotation String

4.3 Boundary-value Problems Involving Nonhomogeneous Differential Equations

4.4 Fourier Sine Series and Cosine Series

4.5 Fourier-Bessel Series

4.6 Legendre Series

4.7 The Fourier Integral

4.8 Real Examples

23. **Course Name**: Opto-electronic Materials & Devices 光电子材料与器件

Credits: 2; 32 teaching hour

Instructors: Ghulam Hasnain, Jie Yao

Text Book (or other supplemental materials): 1. Device Electronics for Integrated Circuits – Muller and Kamins 2. Physics of Semiconductor Devices – Sze 3. Physics of Optoelectronic Devices – Chuang 4. Diode Lasers and Photonic Integrated Circuits – Coldren and Corzine 5.InP-Based Materials and Devices – Ed. by Wada and Hasegawa6. Fundamentals of Semiconductor Theory and Device Physics – Wang 7. Long Wavelength Semiconductor Lasers – Agarwal and Dutta 8. Claus F. Klingshirn, Semiconductor optics, 4th edition, (Springer, 2012) 9. Stefan A. Maier, Plasmonics: Fundamentals and Applications (Springer, 2007) 10. Wenshan Cai, Vladimir Shalaev, Optical Metamaterials: Fundamentals and Applications. (Springer, 2010)

Specific course information: While silicon ICs have become ubiquitous in many smart appliances, optoelectronic devices such as solar cells, LED lighting, LED displays, and 3D sensors that use VCSELs and other lasers are becoming increasingly visible, besides being the backbone of fiber-optic communications. This course will teach students already familiar with semiconductor devices about developing optoelectronic devices such as leds, lasers and photodiodes made from compound semiconductor materials. This course will also discuss topics at the frontier of photonic materials research, including metamaterials, plasmonics and related characterization tools.

Specific goals for the course: The purpose of this course is to discuss issues peculiar to the manufacturing of semiconductor opto-electronic devices such as LEDs, laser diodes and photodetectors. These devices are key to fiber-optics communications, LED Displays, Solar energy, 3D Sensing, and solid-state (LED) lighting. The course will cover several topics including device design and fabrication process needed to meet reliability standards, device characterization both cw and high-frequency; die fabrication and basic packaging issues; and reliability testing. While basic device physics will be reviewed as needed, case studies of some specific devices will be examined in detail.

Material part taught by Prof. Yao will give graduate students an introduction of the recent developments in the research fields of optical materials and nanophotonics. Topics covered include: Basic concepts on light-matter interactions. Polaritons: plasmons, phonons and magnons. Plasmonic materials and their applications. Near field optics and its application in plasmonics. Metamaterials: negative refraction, super-resolution imaging and optical invisibility.

Brief list of topics to be covered:

1. Overview of OE devices

1.1 III-V compounds and their alloys

1.2 Review of PN junction diode

1.3 Heterostuructures and QuantumWells

2. Case Study I : Photodiodes

2.1 Optical absorption

2.2 Design trade-offs for high-speed (50 GHz)

2.3 Waveguide PIN device design & characterization

2.4 Review of Avalanche gain physics

2.5 Fabrication & Characterization of a buried-mesa SAM APD

3. Case Study II : Light Emitting Devices

3.1 Spontaneous & Stimulated Emission

3.2 Blue/Green InGaN LED design issues

3.3 Fab process challenges

3.4 Violet LD design and device characterization

4. Case Study III : Solar Cells and VCSELs

4.1 Compare Si crystalline vs Thin-film vs III-V Multi-junction cell

4.2 Review the development of VCSELs -> to dense 2D arrays for 3D sensing

5.1: Maxwell's Equations; Electromagnetic waves in matter; Dispersion relations

5.2: Drude Model and Lorentz model; Kramers-Kronig Relations.

5.3: Polaritons as quasiparticles; Coupled oscillators and polaritons with spatial dispersion

5.4: Surface plasmon polaritons: propagating modes and localized modes;

5.5: Near-field optics and plasmonics.

5.6: Applications of plasmonics. Recent developments in plasmonic materials.

5.7: Phonon polaritons; Magnons and magnetic polarons.

6.1: Metamaterials: design principles and early demonstrations

6.2: Applications of metamaterials: Negative refractions, super-resolution imaging and invisible cloaks.

6.3: Hyperbolic metamaterials and optical density of states.

6.4: Optical antennas and metasurfaces; Metalens and flat optics

24. **Course Name**: Environmental Monitoring and Analysis 环境污染物监测与分析

Credits: 3; 48 teaching hour

Instructors: Huang Yuxiong

Text Book (or other supplemental materials): [1] Hazardous Wastes: Sources, Pathways, Receptors, by RichardWatts [2] Environmental Chemical Analysis by B.B.Kebbekus and S.Mitra

Specific course information: This course will cover water quality parameters (with a focus on toxic pollutants), pollutants properties, measurement techniques, and control technologies. We will also review strategies to monitor complex environments for established and emerging contaminants, with comprehensive theories and principles to use particular technologies and/or methods to monitor water, soil/sediments, and flora/fauna for anthropogenic contamination.

Specific goals for the course: The objective of "Environmental Monitoring and Analysis" is to provide an understanding of fate and transport of pollutants in environment as well as environmental measurement principles, including physical, chemical and biological processes that govern the distribution, transformation or degradation of a contaminant through the environment, the field and laboratory sample collection and analysis in the areas of water chemistry, air chemistry, soil chemistry and environmental exposure assessment/biological monitoring. We will also discuss the technical details in gravimetric analysis, volumetric analysis, spectrophotometric analysis employing uv-vis, atomic absorption, ICP-MS technology, and GC-MS techniques and etc

Brief list of topics to be covered:

Week 1.

Course introduction

The basic concepts of environmental monitoring and analysis

Contaminants in the environment and their sources

Week 2.

Properties of contaminants

Pollutant classification

Chemical structures, properties and toxicity of pollutant

Week 3.

Equilibrium distribution of contaminants

Distribution of contaminants in air, water and soil

The mass balances at equilibrium

Week 4.

Transport of contaminants in environment

Advection and dispersion of contaminants

Retardation of contaminants

Week 5.

Transformation of contaminants

Physical and chemical transformation of contaminants

Biological degradation

Week 6.

Fate and transport of contaminants

Fate and transport in open or closed system

Multiphase flow

Week 7.

General water physical and chemical parameters

General water chemistry

Water quality parameters

Week 8.

Review and Midterm

Week 9.

Water Quality Analysis (I)

Physical parameter measurement

Titrimetric and colorimetric procedures

Week 10.

Water Quality Analysis (II)

Beers law and spectroscopic methods

Analysis of common anions

Chemical and biochemical oxygen demand

Week 11.

Gas chromatography

Principles of chromatography

GC columns and detectors

Week 12.

High performance liquid chromatography

HPLC instrumentation and detectors

Ion chromatography

Week 13.

Mass spectrometry

Interpretation of mass spectra

Ion sources, mass analyzers, ion detectors

Week 14.

Atomic spectroscopy

Flame and furnace atomic absorption spectroscopy

Inductively coupled plasma emission spectroscopy

Week 15.

Sample preparation

Sample extraction techniques

Quality control and quality assurance

Week 16.

The review and final

25. **Course Name**: Nanoscale energy transfer 微纳尺度能量输运

Credits: 3; 48 teaching hour

Instructors: Sun Bo

Text Book (or other supplemental materials): None

Specific course information: This course discusses energy carriers (phonons, electrons, etc.) transport process in nanomaterials.

Specific goals for the course: There is no course in TBSI and SIGS instructing on nanoscale energy transfer process, which is very important for research in nano energy materials. The course will provide students detailed analysis of different energy transport processes. From this course, the students should learn how energy is transferred from different transfer mechanisms.

Brief list of topics to be covered:

1.Introduction to energy transfer in materials

a. Macroscopic theory of heat transfer

b. Microscopic theory of heat carriers and their transport

c. Nanoscale transport phenomena

2. Material waves and energy quantization

a. Wave nature of matter

b. Solutions of the Schrödinger Equation

c. Harmonic oscillator

3. Energy states in solids

a. Crystal structure

b. Electrons and phonons

c. Density of states

4. Statistical thermodynamics

a. Internal energy and specific heat

b. Size Effects on internal energy and specific heat

5. Energy transfer by waves

a.Interface reflection and refraction of a plane wave

b. Wave propagation in thin films

c. Energy transfer in nanostructures

6. Particle description of energy transport process

a. Carrier scattering

26. **Course Name**: Introduction to Quantum Chemistry: Theory and Application 量子化学简介：理论与应用

Credits: 3; 48 teaching hour

Instructors: Yu Kuang

Text Book (or other supplemental materials): [1]. Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, by Attila Szabo and Neil Ostlund

Specific course information: Quantum Chemistry has become a quite common tool in the study of chemical mechanisms and molecular properties. Considering its wide application (and how frequently it is used in modern literatures), we need an introduction course to teach students its core ideas and fundamental principles. The objective of the new course is to let student understand the basic ideas behind quantum chemistry and what problems they can solve using quantum chemistry tools. Meanwhile, the students are also supposed to learn how to use modern HPC systems to run a computation job in general

Specific goals for the course: The primary goal of this course is to introduce the most widely used methods to solve many-body electronic Schrodinger equation. With these methods, we can obtain useful information such as: molecular structure, inter-molecular interactions, molecular response properties etc. Via computing these properties, we can study many important problems such as: chemical stability, reaction mechanisms and kinetics, thus predicting experimental results. The course will cover various electronic structure theories including HF, MP, CI, CC, and hybrid methods such as QM/MM and embedding theories. Meanwhile, through several computational labs, we will also teach student how to set up a typical calculation in the linux environment of modern HPC in general. With these skills, the student will be able to conduct Ab intio calculations independently after the course.

Brief list of topics to be covered:

1. Mathematical Preparation (week 1)

1. Vectors and Matrices
2. Determinants
3. Change of Basis
4. Eigen Problems
5. Matrix Functions

6. Orthogonality
7. Variational Methods

2. Electronic Structure Problem and Single Particle Basis Set (week 2)
1. Atomic Unit
2. Bohn-Oppenheimer Approximation
3. Symmetry and Paul Exclusion Principles
4. Spin Orbitals, Many-Body and Single-Particle Wavefunctions
5. Basis Set

3. Slater Determinant (week 3)
1. Hartree Products
2. Slater Determinant
3. Hartree-Fock Approximation
4. Excited Slater Determinant
5. Form of Exact Wavefunction and Full Configuration Interactions (FCI)
6. Example: Minimal Basis H2 Molecule

4. Properties of Slater Determinant and Second Quantization (week 4)
1. Matrix Elements, one and two electron integrals
2. General Rules for Computing Matrix Elements
3. Coulomb and Exchange Integrals
4. Spin Configurations of Slater Determinant
5. Second Quantization
6. Second Quantized Operators

5. Hartree-Fock (HF) Method (week 5)

1. Hartree-Fock (HF) Equations

2. Interpretation of HF results: Orbital Energies, Koopman's Theorem

3. Spin Restricted and Unrestricted HF

4. Population Analysis

5. Orbital Localization

6. Post Hartree-Fock Method - 1 (week 6)

1. Truncated Configuration Interaction (CI)

2. Multireference Methods: Complete Active Space (CAS) Methods, Restricted Active Space (RAS) Methods

3. Density Matrix

4. GVB Methods

5. Size Consistency Problem

7. Post Hartree-Fock Method - 2: Moller-Plesset Perturbation Theory (week 7)

1. MP2

2. Higher order MP theories

3. Resolution of Identity Technique

8. (VERY) Brief Introduction to Other Post-HF Methods (week 8)

1. Coupled Cluster Theory

2. CASPT Methods

3. Symmetry-Adapted Perturbation Theory (SAPT)

4. Localized CI and CC Methods

9. Introduction to Density Functional Theory (DFT) in Quantum Chemistry (week 9)

1. Hohenberg-Kohn Theorem

2. Kohn-Sham Equation

3. Introduction to Density Functional Approximations: LDA, GGA, meta-GGA, hybrid functionals, double hybrid functional etc.

4. Orbital Free DFT

5. Pseudo Potential (USPP, NCPP, PAW etc)

6. Brief Introduction to TDDFT

10. Stochastic Methods in Quantum Chemistry (week 10)

1. Quantum Monte Carlo (including VMC and DMC)

2. Stochastic CI

3. Stochastic DFT

11. Geometry Optimization and Reaction Rate Calculation (week 11)

1. Line Optimization Methods

2. Multi-Dimensional Optimization Methods: Steepest Decent, Conjugate Gradient, Newton Raphson...

3. Transition State Optimization, NEB Method

4. Common Procedure for Reaction Rate Calculations, Zero-Point Energy Correction

5. Anharmonicity Problem

12. Interpreting Interaction Energies from Quantum Calculations (week 12)

1. Charge Susceptibility of Molecules

2. Multipole Expansions, Distribution of Charges

3. Induction, Distributed Polarizability

4. Dispersion

5. Short Range Interactions

6. Energy Decomposition Analysis (EDA)

13. Hybrid Methods: QM/MM, Embedding Theories (week 13)

1. Motivation of QM/MM
2. Embedding Methods
3. Semi-Empirical QM Methods
4. Embedding Theories

14. Running A Real QM Calculation: Computation Lab (week 14, 15)

1. Basic Commands in Linux
2. Vim Text Editor
3. Basic Structure of HPC
4. Job Scheduler System
5. Environmental Variables
6. Shell Scripts
7. Settings in NWChem
8. Examples (single point, geometry optimization, pupulation analysis)

15 Final Exam (week 16)cs to be covered:

27. **Course Name**: Thermal Physics and Engineering 热物理学与工程

Credits: 3; 48 teaching hour

Instructors: Wu Junqiao, Sun Bo

Text Book (or other supplemental materials): [1] Principles of Electronic Materials and Devices, by S. O. Kasap.The 1-2 Chapters.[2] Nanoscale thermal transport. II. 2003–2012, by David G. Cahill et al., Applied Physics Reviews 1, 011305 (2014)

Specific course information: This course will focus on thermal physics (phonons, electrons and their physics), thermal measurement techniques and research progress in thermal sciences.

Specific goals for the course: This course is an extension of the existing course 86000021. When Professor Junqiao Wu first opened course 86000021, there was only 1 or 2 students in TBSI working on thermal sciences. So course 86000021 served as an introduction. Now we have expanded our research strength and capability in thermal sciences and engineering, with 4-5 new PhD students joining in, and this course seems to be not enough for them. The new course will provide students with knowledge on thermal sciences, nanoscale heat transfer, thermal measurement techniques and the research progress in thermal sciences. Students should have a general picture of heat transfer in solid state matter after taking this course.

Brief list of topics to be covered:

1. THERMAL DYNAMICS

a. Laws of thermal dynamics

b. Statistical thermodynamics

2. HEAT TRANSFER

a. Steady state heat transfer problem

b. Transit heat transfer problem

3. THERMAL MEASUREMENT TECHNIQUES

a. Fourier Law and its application in thermal measurements

b. Steady state thermal measurement techniques

c. Micro-Raman thermometry

d. TDTR

e. Laser flash thermometry

4.RADIATION

a. Stefan-Boltzmann Law

b. Far-field thermal radiation

c. Near-field thermal radiation

d. Applications

5. SOLID STATE PHYSICS BASICS

a. General trends, k-space, band structure, density of states and Fermi distribution

b. effective mass approximation

6. ELECTROSTATICS AND ELECTRODYNAMICS

a. Maxwell equations and Poisson's equation

b. Band bending and carrier equilibration

7. Drude's model

d. Boltzmann transport theory

8. PHONONS AND THERMAL EFFECTS

a. Phonons

b. Heat capacity

c. Heat conduction and dissipation

9. THERMOELECTRICS

a. Seebeck and Peltier effects

b. Thermoelectricity

28. **Course Name**: Organic Electronics: Materials and Emerging Technologies 有机电子：材料与新兴技术

Credits: 3; 48 teaching hour

Instructors: Xiaomin Xu

Text Book (or other supplemental materials): [1] Handbook of Organic Materials for Electronic and Photonic Devices, O. Ostroverkhova, 2019 Elsevier Ltd. [2] Electronic processes in Organic Electronics: Bridging Nanostructure, Electronic States and Device Properties, T. Nakayama, K. Kudo, H. Ishii, N. Ueno, 2015 Springer Japan [3] Organic Electronics: Emerging concepts and Technologies, F. Cicoira, C. Santato, 2013 Wiley-VCH

Specific course information: This course will introduce the development of cutting-edge technologies in organic electronics and the emerging applications. Chapter 1 introduces the basics of organic semiconductor materials, including the principles of structural design, microstructure engineering, electronic structure, and the band theory. Chapter 2 describes the fabrication and performance of organic elemental devices. Starting from the thin film deposition methods, this chapter focuses on the structure and working principle of organic field effect transistors (OFETs), organic light emitting diodes (OLEDs), and organic photovoltaics (OPVs), etc. On the basis of the fundamentals introduced above, Chapter 3 and 4 further introduce novel materials and the cutting-edge design of organic electronic and optoelectronic devices. The topics include interfaces, electrodes, single-molecule devices, low-dimensional devices, organic imaging and sensing systems, etc. Chapter 5 talks about organic bioelectronics. The emerging biocompatible organic materials, and the application in biomolecular sensing, biological diagnosis and treatment will be addressed. Chapter 6 introduces flexible and stretchable organic electronics. The concept and development of “electronic skin” will be thoroughly overviewed. The prototype of wearable circuits, textiles, and other flexible (opto)electronics will be demonstrated. The potential of organic electronics in driving the Internet of Things (IoT), and the technical challenges for future development are expected to trigger an open discussion in the class.

The grading of the course is based on four parts: Participation (10%), 6 Assignments (30%, 5% each), Discussion During Class (10%), and Seminar Presentation (50% = 25% students + 10% TA + 15% Instructor).

Specific goals for the course: The objective of this highly interdisciplinary course is to provide a comprehensive overview of organic electronics, from the fundamentals to the latest innovation and technologies. After taking this course, the student should be able to demonstrate theoretical knowledge on the following subjects: concept of organic semiconductors, charge carrier transport in polymeric and molecular semiconductors, optical properties of organic semiconductors, operating mode of the elemental devices including organic light-emitting diodes (OLEDs), organic field-effect transistors (OFETs), and organic photovoltaic cells (OPVs), etc. Further, latest developments in bioelectronic technology, wearable electronics, and implications for health-care applications will be thoroughly introduced at the latter part. In this way, students are invited to join the conversation about the future of human-machine interfaces and body-centric technologies enabled by organic flexible electronics.

Brief list of topics to be covered:

Unit 1. Organic semiconductors: structure, microstructure, and the electronic structure

- Fundamental aspects and the nature of organic semiconductors
- Engineering organic single crystals and polycrystalline films
- Electronic process in organic solids
- Carrier transport regimes and mobility limiting factors

Unit 2. Organic electronics and optoelectronics: the fabrication and properties

- Thin film deposition: mechanisms and technologies
- Characterization techniques for organic thin films
- Elemental organic electronic devices

- Fabrication and characterization of organic optoelectronics

Unit 3. Engineering advanced materials

- Advanced organic materials for the transport layers
- Photophysical and photoconductive properties of novel organic semiconductors
- Designed interfaces in organic electronics
- New materials for transparent electrodes

Unit 4. Engineering novel device structure and functionalities

- Single-molecule organic (opto)electronics and organic circuits
- Organic low-dimensional materials and devices
- Organic light-emitting field-effect transistors
- Photodetectors, imaging and sensing systems

Unit 5. Organic bioelectronics: the principle and applications

- Emerging green and biocompatible materials for transient electronics
- From proton transport in ion channels to bioprotonic devices
- Organic electronics in biomolecular sensing and diagnostic applications
- Organic optoelectronic interfaces for vision restoration

Unit 6. Toward the wearables: flexible and stretchable organic electronics

- The concept of "Electronic skin (E-skin)"
- Smart and self-healing materials for stretchable organic electronics
- Ultraflexible circuits and sensor sheets for human-machine interfacing
- Electronic textiles: smart fabrics and wearable technologies

29. **Course Name**: Materials and Devices for Energy Storage and Conversion 能源储存与转化：材料与器件

Credits: 3; 48 teaching hour

Instructors: Yidan Cao

Text Book (or other supplemental materials): [1] Jung-Ki Park. Principles and Applications of Lithium Secondary Batteries, 2012[2] Michio Inagaki, Feiyu Kang. Materials Science and Engineering of Carbon: Fundamentals, 2014.

Specific course information: This course is designed for first-year graduate students who have interests on technology and research about materials and devices for energy storage and conversion. In the classroom lecture sessions, lectures on basics and state-of-the-art of materials and devices for energy storage and conversion will be delivered. This course will cover four areas on energy storage and conversion: (1) fundamental chemistry and electrochemistry in typical energy storage and conversion systems, (2) advanced power sources, (3) advanced energy storage and conversion techniques, and (4) development of characterization techniques. Materials and devices applied in energy storage and conversion are the focus of this course. Open discussion will be encouraged during this course. This is a 3-credit course with 48 teaching hours (3 hours per week). Upon completion of this course, students should be able to comprehend and summarize the primary categories of energy storage and conversion devices, integrate knowledge about energy storage and conversion from chemistry and physics, critically evaluate research progress in academic and popular media, and effectively present information about research project and proposal, etc.

The grading of the course is based on four parts: Participation (10%), 6 Assignments (30%, 5% each), Discussion During Class (10%), and Seminar Presentation (50% = 25% students + 10% TA + 15% Instructor).

Specific goals for the course: This course is for first-year graduate students who have interests on technology and research about materials and devices for energy storage and conversion. In the classroom lecture sessions, lectures on basics and state-of-the-art of materials and devices for energy storage and conversion will be delivered. Upon completion of this course, students should be able to:

- Comprehend and summarize the primary categories of energy storage and conversion devices.
- Calculate the energy storage efficiency of different battery technology.
- Integrate knowledge about energy storage and conversion from chemistry and physics.

- Identify and synthesize sources of information on research about energy storage and conversion.
- Critically evaluate research progress in academic and popular media.
- Interact with others regarding to the most recent advancement in energy storage and conversion science.
- Effectively present information about research project and proposal.

Brief list of topics to be covered:

Week	Focus Topic	Activities	Readings
1	Introduction, Overview of Energy Storage and Conversion Devices	Lecture 1 Assignment 1	Book 1: Chapter 1 [1] "Progress in electrical energy storage system: A critical review." Progress in Natural Science 19.3 (2009): 291. [2] "Electrical energy storage for the grid: a battery of choices." Science 334.6058 (2011): 928.
2	Lithium Ion Battery: Electrode Materials-Cathode	Lecture 2	Book 1: Chapter 2
3	Lithium Ion Battery: Electrode Materials-Anode	Lecture 3 Assignment 2	Book 1: Chapter 3 Book 2: Chapter 1
4	Lithium Ion Battery: Electrolyte	Lecture 4	Book 1: Chapter 4
5	Lithium Ion Battery: Safety & Battery Design	Lecture 5 Assignment 3	Book 1: Chapter 6
6	All Solid State Lithium Battery	Lecture 6	[1] "Electrolytes for solid-state lithium rechargeable batteries: recent advances and perspectives." Chemical Society Reviews 40.5 (2011): 2525.

Week	Focus Topic	Activities	Readings
7	Other Lithium Battery Systems and Perspectives	Lecture 7 Assignment 4	[1] “Review on High-Loading and High-Energy Lithium-Sulfur Batteries.” Advanced Energy Materials, 2017, 7(24). [2] “The Lithium/Air Battery: Still an Emerging System or a Practical Reality?” Advanced Materials, 2014, 27(5):784-800.
8	Sodium Batteries, Pottasium Batteries and other Secondary Batteries	Lecture 8	[1] “Sodium-based batteries: from critical materials to battery systems”. Journal of Materials Chemistry A, 2019, 7, 9406. [2] “Recent Advances in Aqueous Zinc-ion Batteries”. ACS Energy Letters, 2018, 3(10), 2480.
9	Fuel Cells Devolopment	Lecture 9	[1] "Fuel cells–fundamentals and applications." Fuel cells 1.1 (2001): 5.
10	Solar Cells Development	Lecture 10 Assignment 5	[1] “A Review on Solar Cells from Si-single Crystals to Porous Materials and Quantum Dots” Journal of Advanced Research, 2013, 6(2):123.
11	Hybrid Wind-Photovoltaic Energy System	Lecture 11	[1] “Hybrid wind/photovoltaic energy system developments: Critical review and findings”. Renewable & Sustainable Energy Reviews, 2015, 52:1135-1147.
12	Light-emitting Diodes for Energy Conversion	Lecture 12	[1] “Flexible graphene devices related to energy conversion and storage” Energy & Environmental Science, 8(3):790.
13	Redox Flow Batteries	Lecture 13	[1] "Redox flow batteries: a review." Journal of Applied Electrochemistry 41.10 (2011): 1137.
14	Supercapacitors for Energy Storage	Lecture 14 Assignment 6: Proposal of	[1] "Where do batteries end and supercapacitors begin?" Science 343.6176 (2014): 1210-1211. [2] "A review of electrode materials for

Week	Focus Topic	Activities	Readings
		Presentations	electrochemical supercapacitors." Chemical Society Reviews 41.2 (2012): 797.
15	Electrochemical Analysis and Materials Characterization Techniques	Lecture 15	Book 1: chapter 5
16	Seminar 1	Seminar 1 Presentations	Students' presentations

30. **Course Name**: Techniques in Computational Materials Science 材料学计算技术入门

Credits: 3; 48 teaching hour

Instructors: Kuang Yu

Text Book (or other supplemental materials): [1] Manuals of VASP, Lammps, OpenMM[2] Manual of SLURM[3] Manual of Python3[4] Manual of Linux

Specific course information: In this course we will introduce a variety of techniques commonly used in computational materials science, including: basics of linux and vim, software compilation and installation, parallel computing, HPC structure, job scheduler system etc. Also, we will introduce some common DFT and MD programs in materials science. Through this training, the students are expected to master an efficient tool chain to do the work ranging from environment configuration, system construction, running calculation, to data processing. We hope the students could perform a variety of computations in a modern HPC independently after this course.

Specific goals for the course: Computer simulations have become a standard part of modern materials science research. However, after a simple survey, I found a lot of students (in both computational and experimental directions) are having difficulties in getting started. This course provides the students with the basic technical trainings to run various types of scientific computations in a modern HPC (high performance computing) platform. The objective is to train the experimental students to conduct simple calculations on their own, while also to prepare the theoretical students for more serious computational research in future.

Brief list of topics to be covered:

1. Basics of Linux (2 weeks)
a. Setup of local linux system
b. Basic commands
c. Vim text editor
d. Environmental variables, modules
e. Conda environments
f. Mount point and file system
g. Bash script and workflow control
h. Processes and threads
i. Basic concepts about parallelization (MPI and OpenMP)
2. Basics of job scheduling system (2 weeks)
a. Structure of HPC
b. Slurm and PBS torque, basic job handling (submission/cancellation/checking status)
c. Queues priority
d. Key environmental variables in slurm
e. Resource allocation
f. Interactive jobs submission
g. Cross-node communication, efficiency of parallelization
3. Basics of software installation in linux (2 weeks)
a. Compile and link, library files
b. Dynamic link and static link
c. Head files and include path
d. Environmental variables in compiling process
e. Makefile
f. Configure and CMake/CCMake
4. Basic programming (python) (2 weeks)
a. Concepts in python

b. Loop and if statement

c. Data structure (numpy array, matrix, dictionary, list, …)

d. Objects in python, attributes, functions

e. Modules

f. Application of python: building structures, plotting figures, workflow control

5. VASP & quantum espresso (3 weeks)

a. Basic concepts about planewave DFT

b. Basic examples, how to run locally and in slurm

c. File format (POSCAR, INCAR, POTCAR, KPOINTS)

d. K-space sampling

e. Energy cutoff

f. Smearing

g. Geometry optimization, Pulay stress

h. Transition state search (nudged elastic band)

i. Dispersion correction

j. Band structure calculation

k. Python interface with Atomic simulation environment (ASE)

l. Training projects

6. MD programs (Lammps, OpenMM) (3 weeks)

a. Basic concepts in MD

b. Key parameters: timestep, thermostat, barostat

c. Force field setup

d. Trajectory analysis, basic statistics

e. Python tools for trajectory analysis

f. Python interfaces with lammps and OpenMM

g. Parallelization GPU acceleration

h. Training projects

7. Ab initio simulation tool I-Pi (1 week)

a. Ab initio MD and ab initio path integral MD

b. Host-client system

c. How to run i-PI, tutorial

31. **Course Name**: Lectures on frontier research about low-dimensional materials 低维材料前沿研究讲座

Credits: 3; 48 teaching hour

Instructors: Xiaolong Zou

Text Book (or other supplemental materials): [1] Instructor's slides

Specific course information: The objectives of teaching this course are: (1) to teach students the basic physic principles governing various materials properties, and (2) to train students to discuss research results and present their innovative ideas. The latter will be accomplished through the introduction of active research topics. I will select some prototype systems (for examples, graphene, two-dimensional transition metal dichalcogenides) and problems fitted with current research in TBSI as projects for investigative study, to make the connection between teaching and research, to cultivate their research interest and to develop their understanding on how we do research.

Specific goals for the course: This Couse will cover frontier research on low-dimensional materials in recent years, including defects in LD materials, mechanical, electronic, photoelectronic, magnetic, thermal transport properties, prediction of new LD materials, growth mechanism of representative LD materials, as well as their applications in energy storage, catalysts, and thermoelectricity.

Brief list of topics to be covered:

Ch1. Defects in low-dimensional (LD) materials
- 1.1 Basic structures of various LD materials
  - 1.1.1 Alloy
  - 1.1.2 Structural transition
- 1.2 Point defects
- 1.3 Edges and interfaces
  - 1.3.1 Graphene, h-BN, and their in-plane heterojunctions
  - 1.3.2 Edges and homojunction in 2D transition metal dichalcogenides (TMDs)
- 1.4 Topological defects

Ch2. Mechanical properties of LD materials
- 2.1 Intrinsic mechanical properties of various LD materials
  - 2.1.1 Graphene
  - 2.1.2 2D TMDs
  - 2.1.3 Single-layer black phosphorous
  - 2.1.4 Auxetic (negative Poisson's ratio) materials
  - 2.1.5 Fracture in Graphene
- 2.2 Influences of dislocations and grain boundaries (GBs)

- 2.2.1 CNTs
- 2.2.2 Graphene
- 2.2.3 2D TMDs

Ch3 Electronic and photoelectronic properties of LD materials

- 3.1 Basic electronic structures of various LD materials
  - 3.1.1 Graphene
  - 3.1.2 2D TMDs
  - 3.1.3 Single-layer phosphorous
  - 3.1.4 Other 2D materials
- 3.2 Photoelectronic properties
  - 3.2.1 Basic photoelectronic properties of various LD materials
  - 3.2.2 Excitonic effects
  - 3.2.3 Modulation of photoelectronic properties
- 3.3 Influences of various defects
  - 3.3.1 Point defects
  - 3.3.2 Topological defects
- 3.4 Heterojunctions
  - 3.4.1 Band alignment and different types of heterojunctions
  - 3.4.2 Vertical heterojunctions
  - 3.4.3 Lateral heterojunctions

Ch4 Magnetic properties of LD materials

- 4.1 Basic concepts
- 4.2 Magnetism in graphene
  - 4.2.1 Edges
  - 4.2.2 Defects
- 4.3 Magnetism in TMDs
  - 4.3.1 Edges
  - 4.3.2 Defects
- 4.4 Magnetism in other LD materials
  - 4.4.1 Magnetism introduced by defects
  - 4.4.2 2D materials with intrinsic magnetism
  - 4.4.3 Carrier doping

Ch5 Thermal transport of LD materials

- 5.1 Basic concepts in thermal transport
- 5.2 Methods to obtain thermal conductivity
- 5.3 Modulation by structures and defects
- 5.4 Applications

Ch6 Other novel LD materials

- 6.1 LD ferroelectric materials
  - 6.1.1 Ferroelectric polarization and phase transition
  - 6.1.2 Curie temperature and phase transition
  - 6.1.3 Ferroelectric domain
  - 6.1.4 Other LD ferroelectric materials
- 6.2 LD ferroelastic materials
- 6.3 LD piezoelectric materials
- 6.4 Applications of 2D ferroelectric, ferroelastic and piezoelectric materials

32. **Course Name**: Principles and Applications of Electrochemistry 电化学原理及应用

Credits: 3; 48 teaching hour

Instructors: Guangmin Zhou

Text Book (or other supplemental materials): [1] Allen J. Bard, Larry R.Faulkner, Electrochemical Methods Fundamentals and Applications, John Wiley & Sons, 2001.[2] Robert Huggins, Advanced Batteries, Springer, 2009.

Specific course information: On successful completion of this course, students will:

(1) understand the basic principles of electrochemistry;

(2) understand thermodynamics and kinetics of electrochemistry;

(3) be familiar with different electrochemical measurement techniques for electrochemistry and explain which type of information that can be obtained with these techniques;

(4) know different electrode materials, electrolytes, separators, and energy storage systems;

(5) understand basic structure and the working principles of different energy storage devices.

Specific goals for the course: This course aims to:

1. Introduce electrochemistry and electrode processes

2. Describe the thermodynamics and kinetics of electrochemistry

3. Describe the different measurement techniques for electrochemistry

4. Describe the recent developed electrode materials, electrolytes, separators, and energy storage systems

5. Describe the basic structure and the working principles of different energy storage devices.

Brief list of topics to be covered:

- Part I. Thermodynamics and Kinetics of Electrochemistry
- Lecture 1: Introduction of electrochemistry
- Lecture 2: Electrode processes

- Lecture 3: Galvanic and electrolytic cells
- Lecture 4: Potentials and thermodynamics of electrochemical cells
- Lecture 5: Kinetics of electrode reactions
- Part II. Measurement Techniques for Electrochemistry
- Lecture 6: Cyclic voltammetry and linear sweep voltammetry
- Lecture 7: Electrochemical impedance spectroscopy
- Lecture 8: Potentiostatic and galvanostatic tests
- Lecture 9: Rotating ring-disk electrodes
- Part III. Applications of Electrochemistry
- Lecture 10: Overview of lithium-ion batteries
- Lecture 11: Novel battery systems: lithium-sulfur, lithium-air batteries
- Lecture 12: Electrolytes and separators: liquid, polymer, solid.
- Lecture 13: Solid-electrolyte interfaces and additives
- Lecture 14: Battery safety
- Lecture 15: Other energy storage devices: supercapacitors, lead acid, redox flow, Na-S batteries, sodium ion batteries
- Part IV. Lab Tour
- Lecture 16: Lab tour or workshop tour (Group report)

Track 2

33. **Course Name**: Energy-Environment and Data-Information 100 level course 能源环境与数据信息概论

Credits: 1, 16 teaching hour

Instructors: Zhan Xuan

Text Book (or other supplemental materials): Instructors will provide the electric files.

Specific course information: This course consists of seminars regarding Energy-Environment and Data-Information. The topics include: Smart grid and renewable energy, Intelligent transportation and logistic systems, Low carbon economy and financial risk analysis, Internet of things and social cyber physical systems, Big data and future Internet, Smart image, etc.

Specific goals for the course: The seminars focus on the background knowledge of energy, environment, data and information technology from device to system perspective, and from the infrastructure to algorithm perspective. The applications and future trends will also be covered. Lectures will encourage students to discuss with professors during the class and let them understand real demand by research and industry.

Brief list of topics to be covered:

34. **Course Name**: Fundamentals of applied information theory 应用信息论基础

Credits: 2; 32 teaching hour

Instructors: Zhang Lin

Text Book (or other supplemental materials): [1] T. Cover, J. Thomas. Elements of Information Theory, 2nd Edition. [2] R.G. Gallager, Information Theory and Reliable Communication [3] I. Csizar, J. Korner, Informaion Theory: Coding Theorem for Discrete Memoryless Systems

Specific course information: This course is based on three Shannon theorems in information theory and introduces the statistical method, information processing and theoretical issues involved in the information measurement. The course will help students to master the basic concept of information theory, and understand the theory and method of information processing, transmission, storage and compression. It is helpful for the in-depth understanding of some essential issues in information and communication engineering and improvement of the innovative thinking and analysis in practical problems.

Specific goals for the course: Information theory is a classic and powerful tool in the analytics of communication and data systems. It not only has provided the theoretical bounds and insightful assistance for the communication and network systems design in the past 68 years, but also reaches a renaissance at dawn of the Big Data era. I think it would be crucial to build the theoretical framework for future data scientist and enable to think problems conversely, i.e., to pay attention to the bound of algorithmic capacity and avoid blind-minded and try-error-style system design.

Brief list of topics to be covered:

0. Introduction

0.1 Concept of information

0.2 Background of information theory

0.3 Shannon and his contribution

0.4 References

1. Basic Concepts

1.1 Entropy

1.2 Mutual information and discrimination information

1.3 Convexity

1.4 Fano inequality and data estimation

1.5 Entropy and mutual information for continuous random variables

2. Information Source and Lossless Coding

2.1 AEP

2.2 Fix length coding theorem

2.3 Entropy rate of discrete source

2.4 Coding types

6. Maximum Entropy and Minimum Discrimination Information Principle

6.1 Ill posed problem

6.2 Maximum entropy principle

6.3 Minimum discrimination information principle

6.4 Relationship

6.5 Rationality

6.6 Applications

7. Network Information Theory

7.1 Introduction

7.2 Multi-user information theory

7.3 Capacity region of wireless networks

7.4 Network coding

35. **Course Name**: Introduction of smart grid 智能电网导论

Credits: 2; 32 teaching hour

Instructors: Sun Hongbin, Wang Liming, Wu Wenchuan, Guo Qinglai

Text Book (or other supplemental materials): [1]. Fereidoon P. Sioshansi. Smart Grid: Integrating Renewable, Distributed & Efficient Energy

Specific course information: Smart grid is an emerging and developing concept. The course Introduction of Smart Grid is for the graduate students of Low-carbon Economics and New Energy Technology Center at Tsinghua-Berkeley joint institute in Shenzhen. In this course, with well-designed seminars and discussions, the students will understand the motivation, definition, features, key technologies and typical cases of smart grid. It will cover the important elements in smart grid, including the source side (such as renewable energy sources and distributed generations), the grid side (such as advanced transmission grid, active distribution grid, micro grid), the demand side (such as electric vehicles, demand response, smart buildings), and information & communication technologies (such as energy management and cyber physical systems). With this course, the students are expected to get an overview about smart grid, and have fundamental knowledge for future further research.

Specific goals for the course: Smart grid is an emerging concept, whose definitions, features and typical cases are still developing. An introduction course of smart grid would be necessary to help the students (especially those without electrical engineering backgrounds) to well understand what is smart grid and what is happening in smart grid. With this course, we hope to help the students get appropriate knowledge on the most significant characteristics of smart grid, and improve their abilities of innovation and critical thinking on this field.

Brief list of topics to be covered:

1. Basics of Power Systems

1.1 Load and Generation

1.2 Power Flow Analysis

1.3 Economic Dispatch and Unit Commitment Problems

1.4 Voltage Control Problems

2. Overview of Smart Grid

2.1 Definition

2.2 New Technologies for the Electric Grid

2.2.1 Renewable Resources: Wind and Solar

2.2.1 Energy Storage

Batteries, Flywheels, Hydro pumper, Compressed Air, Thermal

2.2.2 Micro-grids

2.2.4 Demand-Response

2.2.5 Customer Equipment

2.2.5 Multiple Energy Flow

2.3 Standardization

2.4 Government and Industry

3. Smart Grid Communications:

3.1 Two-way Digital Communications Paradigm

3.2 Network Architectures

3.2 IP-based Systems

3.2 Power Line Communications

3.2 Advanced Metering Infrastructure

4. Wide Area Measurement

4.1 Sensor Networks

4.2 Phasor Measurement Units

4.3 Communications Infrastructure

4.4 Applications and Challenges

5. Active distribution network

5.1 Definition, Applications, and State-of-the Art

5.2 Active distribution network automation

5.3 Active distribution network voltage/var control

5.4 Active distribution network reconfiguration and restoration

5.5 Autonomous operation and control of DERs

6. Demand Response

6.1 Definition, Applications, and State-of-the Art

6.2 Pricing and Energy Consumption Scheduling

6.3 Controllable Load Models, Dynamics, and Challenges

6.4 Electric Vehicles and Vehicle-to-Grid Systems

6.5 Smart Home/Community energy management

6.6 Demand Side Ancillary Services

7. Security and Privacy:

7.1 Cyber Security Challenges in Smart Grid

7.2 Load Altering Attacks

7.3 False Data Injection Attacks

7.4 Defense Mechanisms

7.5 Privacy Challenges

36. **Course Name**: Supply Chain Design and Management 供应链设计与管理

Credits: 4; 64 teaching hour

Instructors: Xiao Li, Max Shen

Text Book (or other supplemental materials): Fundamentals of supply chain theory (2011). Lawrence V. Snyder, Zuo-Jun Max Shen.

Specific course information: This course covers a wide range of topics in supply chain management, including facility locations models, uncertainty in facility locations, deterministic inventory models, stochastic inventory model, multi-echelon inventory models and uncertainty in inventory optimization. The objective of this course is to help students to gain some perspectives on supply chain management, its classical models and emerging developments. The students are expected to gain the understanding of the methods to model and analyze supply chain models. More importantly, these tools they learned can also be applied to other fields, such as health care, energy, finance and service management.

Specific goals for the course: The objective of this course is to help students to gain some perspectives on supply chain management, its classical models and emerging developments. The students are expected to gain the understanding of the methods to model and analyze supply chain models. More importantly, these tools they learned can also be applied to other fields, such as health care, energy, finance and service management.

Brief list of topics to be covered:

Lecture 1. Classical facility location models

Set-covering, Max-Covering;

P-Center, P-dispersion, P-median;

Un-capacitated and Capacitated Fixed-Charge Models;

Hub-Spoke problems and Solution algorithms.

Lecture 2. Supply chain network design and Disruption models

Supply chain network design models;

Disruption problems in Location problems;

Supply uncertainty and Reverse bullwhip effect.

Lecture 3. Integrated supply chain models

Location-inventory problems;

EOQ model with market choice flexibility;

Lecture 4. Process flexibility and Modern warehouse systems

Process flexibility: Models and Applications;

Introduction to modern warehouse systems

37. **Course Name**: Computational Photography 计算摄像学

Credits: 3; 48 teaching hour

Instructors: Fang Lu

Text Book (or other supplemental materials): [1] self-editing course notes 《Hot Topics in Computational Photography》

Specific course information: Computational Photography is an emerging new field created by the convergence of computer graphics, computer vision and photography. Its role is to overcome the limitations of the traditional camera by using computational techniques to produce a richer, more vivid, perhaps more perceptually meaningful representation of our visual world. The aim of this advanced course is to study ways in which samples from the real world (images and video) can be used to generate compelling computer graphics imagery. We will learn how to acquire, represent, and render scenes from digitized photographs. Several popular image-based algorithms will be presented, with an emphasis on using these techniques to build practical systems. This hands-on emphasis will be reflected in the programming assignments, in which students will have the opportunity to acquire their own images of indoor and outdoor scenes and develop the image analysis and synthesis tools needed to render and view the scenes on the computer.

Specific goals for the course: Study ways in which samples from the real world (images and video) can be used to generate compelling computer graphics imagery. Learn how to acquire, represent, and render scenes from digitized photographs. Several popular image-based algorithms will be presented, with an emphasis on using these techniques to build practical systems. This will be reflected in the programming assignments, in which students will have the opportunity to acquire their own images of indoor and outdoor scenes and develop the image analysis and synthesis tools needed to render and view the scenes on the computer.

Brief list of topics to be covered:

Chapter 0: Introduction

0.1 Background

0.2 Relationship to other disciplines

0.3 State-of-the-art

0.4 Teaching arrangements and requirements

Chapter 1: Digital Camera

1.1 History of camera

1.2 Principle of camera

1.3 Single-lens reflex camera

Chapter 2: From Traditional Photography to Computational Photography

2.1 History of computational photography

2.2 Research contents of computational photography

2.3 Design of plenoptic camera

Chapter 3: Light Field

3.1 Concept and variations of light field

3.2 Parametric description of light field

3.3 Light field camera

3.4 Application of light field theory

Chapter 4: High-Quality 2D Information Acquisition

4.1 Image acquisition with large depth of field

4.2 Image acquisition with large field of view

4.3 Image acquisition with high resolution

4.4 Image acquisition with high dynamic range

Chapter 5: Depth Information Acquisition

5.1 Depth estimation

5.2 Stereo camera

5.3 Depth camera

Chapter 6: Multispectral Imaging

6.1 Wave properties of light

6.2 Spectral image acquisition

6.3 Spectral image fusion

Chapter 7: High-Speed Motion Acquisition

7.1 High-speed camera

7.2 Capture high-speed motion from low-speed cameras

Chapter 8: Research Frontier

8.1 Computational camera

8.2 Computational light

8.3 Research trends

38. **Course Name**: Introduction to Probability theory 概率论

Credits: 3; 48 teaching hour

Instructors: Huang Shaolun

Text Book (or other supplemental materials): [1] Grimmett, Geoffrey, and David Stirzaker. Probability and Random Processes. 3rd ed. Oxford University Press, 2001. ISBN: 9780198572220

Specific course information: This is a course on the fundamentals of probability geared towards first- or second-year graduate students who are interested in a rigorous development of the subject. The course covers most of the topics in probability theory (sample space, random variables, expectations, transforms, Bernoulli and Poisson processes, limit theorems) in more depth. There are also a number of additional topics, such as language, terminology, and key results from measure theory; interchange of limits and expectations; multivariate Gaussian distributions; deeper understanding of conditional distributions and expectations.

Specific goals for the course: The probability theory is an important foundation to numerous scientific fields, and is a necessary fundamental course to engineering students. This kind of courses are necessary to boost TBSI to outstanding international school, hence the one given here is definitely a core course for students to build up their international competitiveness

Brief list of topics to be covered:

1. Fundamentals of Measure Theory
   a. Sample space
   b. Conditional probability
   c. Independence
2. Random Variables and Their Distributions
   a. Discrete random variables
   b. Expectation and variance
   c. Continuous random variables
3. Generating Functions and Their Applications
   a. Generating functions
   b. Random walk
   c. Branching processes
4. Markov Chains
   a. Markov processes
   b. Stationary distribution and the limit theorem
   c. Reversibility
5. Convergence of Random Variables
   a. Modes of convergence
   b. Law of large number
   c. The strong law
6. The Application s of Probability Theory to Data Inference
   a. Data inference
   b. The local information geometry
   c. Feature selection

39. **Course Name**: Optimization methods for power systems 电力系统优化方法论

Credits: 1; 16 teaching hour

Instructors: Javad Lavaei

Text Book (or other supplemental materials): 1- "Linear and Nonlinear Optimization" by Igor Griva, Stephen G. Nash, Ariela Sofer, SIAM, second edition, 2009 2- "Electrical Transmission System Cascades and Vulnerability: An Operations Research Viewpoint" by Daniel Bienstock 3- "Analytic Research Foundations for the Next-Generation Electric Grid", The National Academies Press

Specific course information: The course will cover several topics on optimization theory and its application in power systems, including: - Nonlinear optimization - Numerical algorithms - Power optimization problems such as state estimation, unit commitment, optimal power flow, and transmission planning - Efficient optimization and numerical algorithms for mixed-integer nonlinear problems - Control and optimization for renewable energy

Specific goals for the course: This course helps students understand several topics about optimization theory and its application in the operation of power systems..

Brief list of topics to be covered:

- Nonlinear optimization
    - Optimality conditions
    - Convex optimization
    - Conic optimization
    - Convex relaxation
- Numerical algorithms
    - First- and second-order methods
    - Algorithms for big data
- Optimization for energy systems
    - Optimal power flow

    - State estimation
    - Security analysis
    - Unit commitment
- Control for energy systems
    - Stability analysis
    - Distributed control
    - Robustness
    - Control of renewable resources

40. **Course Name**: Markov Chains: Theory and Applications 马尔科夫链：理论与应用

Credits: 1; 16 teaching hour

Instructors: Xin Guo

Text Book (or other supplemental materials): 1- Adventures in stochastic processes, by S. Resnick 2- A first course in stochastic processes, by S. Karlin and H. Taylor

Specific course information: The course will cover basic concepts and results in the theory of stochastic processes, with applications, - Review of conditional probability and expectations - Markov chains and examples - Chapman-Kolmogorov equations and classification of states - Irreducibility, recurrence and periodicity of Markov chains - Stationary distributions and limiting distribution - Applications in Google search algorithms.

Specific goals for the course: This course helps students build fundamental knowledge in one of the most important concepts and theories in stochastic processes. Critical skills for any engineering major.

Brief list of topics to be covered:

1. Review of basic probability
    d. Random variables, expectations and variance
    e. Independence
    f. Conditional probability and expectations
1. Markov Chains
    d. Definitions and examples

   e. Champman-Kolmogorov equations
   f. Classification of states
   g. Irreducibility, recurrence, periodicity
   h. Invariance measure and the stationary distribution
   i. limiting distribution, coupling, and ergodicity
2. Applications of Markov chains
   d. Google search algorithm
   e. MCMC

41. **Course Name**: Discrete-Event Simulation 离散事件系统仿慎

Credits: 3; 48 teaching hour

Instructors: Chan Wai Kin

Text Book (or other supplemental materials): [1]. Event Graph Modeling Using SIGMA, D.L. Schruben and L.W. Schruben, 1995 (http://sigmawiki.com) [2]: Simulation with Arena, 6th ed. W. David Kelton, Randall P. Sadowski, and Nancy B. Zupick, McGraw-Hill Higher Education, 2015, ISBN: 0073401315. （http://highered.mheducation.com/sites/0073401315/student_view0/arena_software_download.html） [3]. Simulation Modeling and Analysis, 5th ed., A. M. Law

Specific course information: The primary objective is to introduce discrete-event simulation modeling and analysis techniques at a level that will enable students to correctly use simulation experimental methodologies in practice and research. Students will 1. learn the strengths and weaknesses of different approaches, giving them a foundation for selecting methodologies and software appropriate for different types of engineering problems, 2. become familiar with the fundamental similarities among simulation packages (mainly Sigma and Arena), 3. learn how to model random processes and experiment with simulated systems, and 4. develop interactive simulation-based decision-support systems.

Specific goals for the course: Many common systems are discrete-event systems, including production, manufacturing, healthcare, communication, transportation, and queueing. These systems are often very complex. Discrete-event simulation is an efficient way of analyzing and optimizing these systems.

Brief list of topics to be covered:

1. Introduction and EGM

   1.1 Course Introduction

   1.2 Introduction to Event Graph Models

2. Event Graph Modeling

    2.1 Basic Event Graph Models

    2.2 Advanced Event Graph Models

3. Event Graph Modeling

    3.1 Parametric Event Graphs

    3.2 Event Graph Models for Large-scale Systems

4. Arena

    4.1 Arena Basic

    4.2 Arena Advanced

5. Arena

    5.1 Arena Animation

    5.2 Hold and Signal

6. Arena

    6.1 Flexible Batching

    6.2 Optimization Using OptQuest

7. Monte-Carlo Simulation and Petri Nets

    7.1 Monte-Carlo Simulation

    7.2 Introduction to Petri Nets

8. Random Number and Variate Generation

    8.1 Random Number Generation

    8.2 Boolean Expression

9. Random Variate Generation

    9.1 Inverse Transformation

    9.2 Composition, Convolution, Acceptance and Rejection

10. Input Modeling

10.1 Data Collection

10.2 Tests of Input Models

11. Input Modeling

11.1 Input Analyzer

11.2 Output to and Read from External Files

12. Output Analysis

12.1 Initial and Termination Bias, Correlation

12.2 Variance Reduction Techniques

13. Output Analysis

13.1 Output Analysis Methods

13.2 Output Analyzer and Process Analyzer

14. Simulation Examples and Design of Experiments

14.1 Job-Shop Simulation Example

14.2 Factorial Design

15. Validation; Sensitivity Analysis and Other Topics

15.1 Model Validation and Sensitivity Analysis

15.2 Other Topics and Summary

16. Final Project Presentation

16.1 Project Presentation I

16.2 Project Presentation II

42. **Course Name**: Inference and Information 信息推论

Credits: 3; 48 teaching hour

Instructors: Huang Shaolun

Text Book (or other supplemental materials): [1] T. M. Cover and J. A. Thomas, Elementary of Information Theory, Wiley Interscience, 1991. [2] MacKay, David. Information Theory, Inference, and Learning Algorithms. Cambridge, UK: Cambridge University Press, 2003.

Specific course information: This is a course on the intersection of information theory and machine learning geared towards first or second-year graduate students who are interested in the fundamental aspects and the state-of-art developments of these subjects. The course is geared towards students who are interested in understanding machine learning, data mining, and information theory at a fairly sophisticated level, and to carry out research involving the applications of the mathematical frameworks to machine learning problems. One of the objectives of the course is to understand the fundamental perspectives and develop solid connections between mathematical theory and learning systems.

Specific goals for the course: The course is geared towards students who are interested in understanding machine learning, data mining, and information theory at a fairly sophisticated level, and to carry out research involving the applications of the mathematical frameworks to machine learning problems. One of the objectives of the course is to understand the fundamental perspectives and develop solid connections between mathematical theory and learning systems.

Brief list of topics to be covered:

1. Decision theory
    a. Bayesian hypothesis testing
    b. NonBayesian decision theory
    c. Bayesian parameter estimation
2. Inference and statistics
    a. Exponential families
    b. Sufficient statistics
    c. The EM algorithm
    d. Inference as decision
3. Information theory and learning
    a. Information geometry
    b. Modeling as inference
    c. Extensions to continuous parameters
    d. Approximations: deterministic
    e. Approximations: stochastic
4. Machine Learning
    a. Introduction to parametric modeling

b. Model selection
c. Universal Compression

43. **Course Name**: Learning from Data 数据学习

Credits: 3; 48 teaching hour

Instructors: Huang Shaolun

Text Book (or other supplemental materials): [1] Hastie, T., R. Tibshirani, and J. H. Friedman. The Elements of Statistical Learning: Data Mining, Inference and Prediction. New York, NY: Springer, 2001. [2] Bishop, Christopher. Neural Networks for Pattern Recognition. New York, NY: Oxford University Press, 1995.

Specific course information: This is a course on the intersection of mathematical theory and machine learning geared towards first or second-year graduate students who are interested in the fundamental aspects and the state-of-art developments of these subjects. The course is geared towards students who are interested in understanding machine learning, data mining, and information theory at a fairly sophisticated level, and to carry out research involving the applications of the mathematical frameworks to machine learning problems. One of the objectives of the course is to understand the fundamental perspectives and develop solid connections between mathematical theory and learning systems.

Specific goals for the course: The course is geared towards students who are interested in understanding machine learning, and data mining at a fairly sophisticated level, and to carry out research involving the applications of the mathematical frameworks to machine learning problems. One of the objectives of the course is to understand the fundamental perspectives and develop solid connections between mathematical theory and learning systems.

Brief list of topics to be covered:

1. Supervised Learning
   d. Linear regression
   e. Logistic regression
   f. Generalizaed linear model
   g. Naïve Bayesian model
   h. Support Vector Machine
   i. Deep neural networks
1. Unsupervised Learning
   e. Principal component analysis

f. K-mean clustering
g. Independent component analysis
h. Mixture Gaussian and EM algorithm
2. Model selection
a. Regularization
b. Empirical risk and hypothesis testing
c. VC dimension
3. Reinforcement learning
f. Markov decision process
g. Value iteration and policy iteration

44. **Course Name**: Distributed Control and Optimization of Power Systems 电力系统分布式控制与优化

Credits: 3; 48 teaching hour

Instructors: Xu Yinliang

Text Book (or other supplemental materials): [1]. Ali Bidram, etc, Cooperative Synchronization in Distributed Microgrid Control, Springer, 2017. [2]. Computational Methods for Electric Power Systems, 2nd ed. by M. L. Crow, Boca Raton, FL: CRC, 2009 [3]. Optimal Control, 3rd ed., by F.L. Lewis, D. Vrabie, and V. L. Syrmos, Wiley, 2012.

Specific course information: This course focus on the control and optimization of renewable energy generation. The trend of developing lower-carbon generation technology and higher efficiency devices in energy systems has resulted in more distributed generation resources and more diverse distributed energy storage systems. A short introduction into power systems with high renewable energy generation penetration and smart grid will be provided. Microgrid is a promising concept to meet the challenges of integrating various distributed generations and energy storage systems into power systems. Applications of advanced distributed control and optimization techniques to microgrid are presented.

Specific goals for the course: Considering the importance and foreseeable large deployment of distributed renewable generation in electric power systems, a comprehensive technical course is needed for academia. This course will be providing an in-depth analysis and discussion of distributed control and optimization approaches and their applications for electric power systems. This course aims to guide the students how to identify and model practical engineering problems and solve with the appropriate methods taught in class.

Brief list of topics to be covered:

1. Introduction to electrical power systems
   1.1 Energy diversity
   1.2 Renewable energy generation
   1.3 Microgrid
2. Introduction to optimization methods
   2.1 KKT conditions
   2.2 Convergence speed analysis
   2.3 Least Square Method
   2.4 Heuristic optimization methods
3. Advanced control theory
   3.1 Optimal control
   3.2 Consensus
   3.3 distributed control
4. Applications in Microgrid
   4.1 Economic dispatch
   4.2 Demand Response
   4.3 Social welfare Optimization
   4.4 Microgrid dynamics
   4.4 Hierarchical control structure
   4.5 Primary and secondary control
   4.6 Fuzzy logic systems control
5. Course Project
   5.1 Presentation
   5.2 Report

45. **Course Name**: Mathematical Statistics and Application in R 数理统计与 R 语言应用

Credits: 3; 48 teaching hour

Instructors: Chan Wai Kin

Text Book (or other supplemental materials): 1) Recommended: Introduction to Probability and Mathematical Statistics 2nd Ed., Lee F. Bain and Max Engelhandt, Duxbury Classic (Thomson Learning), ISBN: 0534380204 (BE) 2) Recommended: Mathematical Statistics with Applications in R, 2nd Ed., Kandethody M. Ramachandran and Chris P. Tsokos, Academics Press, ISBN 978-0124171138. (RT) 3) Reference: Introduction to Mathematical Statistics, 6th Ed., Robert V. Hogg, Joseph McKean, Allen T. Craig, Prentice Hall, 2004, ISBN 0130085073. (HMC)

Specific course information: This course is a 3-unit graduate-level course in the theory of mathematical statistics. The primary objective of this course is to provide students with a basic foundation in statistics and prepare them for future specialized statistical courses. It will introduce students with statistical theory at a level that will enable students to correctly use statistical mythologies both in practice and research. Another component of this course is the introduction to R. Students will learn not only applications of mathematical statistics but also solving problems using R. Topics covered in this class include statistics and sampling distributions, overview of limit theorems; point estimation—methods and criteria, sufficiency, interval estimation, hypothesis tests, and goodness-of-fit tests.

Specific goals for the course: This course is designed to help students reach the following learning outcomes:

1. An ability to apply knowledge of mathematics, science and engineering.
2. An ability to design and conduct experiments, as well as to analyze and interpret data.
3. An ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental social, political, ethical, health and safety, manufacturability, and sustainability.
4. An ability to identify, formulate and solve engineering problems.
5. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

Brief list of topics to be covered:

Lecture	Topics	Reading: Chapter(s)		Assignments (Due dates s.t. change)
		BE	RT	
1	Review of Probability 1. Independence 2. Moment Generating Function	1-6	2	
2	Review of Probability & Statistics and Sampling Distributions 1. Gamma Distribution 2. Transformation 3. Order Statistics	8	2, 3, 4	In-Class Exercise 1
3	Statistics and Sampling Distributions 1. Basic Statistics 2. Normal Distribution 3. Chi-Square Distribution	8	4	Hw1
4	Sampling Distributions 1. Snedecor's *F* Distribution 2. Students' *t* distribution 3. Beta Distribution	9	4	In-Class Exercise 2
5	Point Estimation 1. Maximum Likelihood Estimation 2. Invariance Property	9	5	Hw2

6	Point Estimation 1. Methods of Moments Estimators 2. Criteria for Evaluating Estimators	9	5	
7	Mid-Term Exam & Point Estimation 1. Mid-Term Exam 2. Minimax Estimator 3. Bayes Estimator	9, 7	5	In-Class Exercise 3 Quiz 1 Mid-Term
8	Sufficiency & Completeness 1. Sufficient Statistics 2. Completeness	10	5	Hw3
9	Sufficiency & Completeness 1. Completeness 2. Regular Exponential Class			
10	Sufficiency & Completeness 1. Regular Exponential Class 2. UMVUE	10	5	
11	Interval Estimation 1. Confidence Interval 2. Pivotal Quantity 3. Tow-Sample Problems	11	6	In-Class Exercise 4 Quiz 2 Hw4
12	Interval Estimation 1. Consistency 2. Approximated Confidence Interval 3. Paired Sample Confidence Interval 4. Bootstrap Confidence Interval	11	6	
13	Hypothesis Tests 1. Type-I and Type-II Errors 2. Power Function 3. *p*-value 4. Test for Variance 5. Paired Sample *t*-test	12	7	In-Class Exercise 5 Hw5
14	Hypothesis Tests 1. Most Powerful Test 2. Randomized Test 3. Uniformly Most Powerful Test	12	7	
15	Hypothesis Tests and Goodness-Of-Fit Tests 1. Generalized Likelihood Ratio Test 2. Conditional Test 3. Goodness-of-Fit Test	13	7	In-Class Exercise 6 Quiz 3 Hw6
16	Other Topics and Review 1. Contingency Table	15	8, 10, 12	

	2. Test for Independence 3. Non-Parametric Method			
17	Final Exam (TBA)			Final Exam

46. **Course Name**: Introduction to Queuing Theory and its Applications 排队论及其应用

Credits: 3; 48 teaching hour

Instructors: Xiao Li

Text Book (or other supplemental materials): [1] Fundamentals of Queueing Theory, 4th Edition (2008). Donald Gross, John F. Shortle, James M. Thompson, Carl M. Harris

Specific course information: Queueing theory is one very important subject in operations management. The objective of this course is to help students learn about the basic mathematical models and analysis techniques in queueing theory, as well as its various applications in practice. From this course, students will have an understanding about what kinds of problems can be modeled as a queueing model, how to derive various performance measures, such as customer waiting time and queue length, and how to optimize a queueing model, in terms of minimizing the cost or waiting time.

Specific goals for the course: Queueing theory is one very important subject in operations management, however, currently TBSI does not provide this course. The objective of this course is to help students learn about the basic mathematical models and analysis techniques in queueing theory, as well as its various applications in practice. From this course, students will have an understanding about what problems can be modeled as a queueing model, and how to derive various performance measures.

Brief list of topics to be covered:

1. Introduction:

   Describe a queueing problem

   Measure system performance

   Little's Law

   Poisson process, exponential distribution and its markovian property

Review of markov chains

2. Simple markovian queueing models:
   Birth death process

   Single-server queue (M/M/1)

   Multi-server queue (M/M/c)

   Queues with truncation (M/M/c/K)

   Erlang loss formula (M/M/c/c)

   State-dependent service

   Queues with impatience

3. Series and networks:
   Series queues

   Open Jackson networks

   Close Jackson networks

   Extensions of Jackson networks

4. General arrival or service
   General service (M/G/1)

   General arrival (G/M/1)

   General arrival and service (G/G/1)

   Constant service (M/D/c)

5. Bounds and approximation
   Bounds

   Approximations

   Network approximations

6. Simulation
   Numerical techniques

   Discrete event stochastic simulation

47. **Course Name**: Seminar in Data Science and Information Technology 数据科学与信息技术讨论课

Credits: 2; 32 teaching hour

Instructors: Huang Shaolun

Text Book (or other supplemental materials): [1] T. M. Cover and J. A. Thomas, Elementary of Information Theory, Wiley Interscience, 1991. [2] Mitchell, Tom. Machine Learning. New York, NY: McGraw-Hill, 1997.

Specific course information: This is a seminar course on the intersection of information theory and machine learning geared towards first or second-year graduate students who are interested in the fundamental aspects and the state-of-art developments of these subjects. In this course, classical literatures in different topics in information theory and machine learning will be selected and discussed every week. In addition, each student will be asked to select a topic and present their reflection about the selected literatures. The presentation will be conducted in the manner of interactive discussions, so students can share their opinions with each other. Finally, some celebrated scholars around the world will be invited as guest speakers to present the up-to-date research results in information theory and machine learning. Finally, some celebrated scholars around the world will be invited as guest speakers to present the up-to-date research results in information theory and machine learning.

Specific goals for the course: The course is geared towards students who are interested in understanding information theory and machine learning at a fairly sophisticated level, and to carry out research involving the applications of the mathematical frameworks to machine learning problems. One of the objectives of the course is to understand the fundamental perspectives and develop solid connections between mathematical theory and learning systems.

Brief list of topics to be covered:

1. Fundamentals of Information Theory and Machine Learning
    a. Introduction to entropy, Kullback-Leibler divergence, mutual information, and their operational meaning
    b. An overview of the main topics and objectives in machine learning
2. Applications of Information Theory to Machine Learning
    a. Feature Extraction through Information Decomposition in Distribution Spaces
    b. Community detection in general stochastic block models: fundamental limits and efficient recovery algorithms
    c. Clustering of Random Variables by Multivariate Mutual Information
    d. Information Theory of DNA Shotgun Sequencing
3. Statistical Learning
    a. An Overview of Statistical Learning Theory
    b. Vapnik-Chervonenkis Dimension and Model Selection
    c. Statistical Theory in Dimensional Reduction

    d. High Dimensional Statistics
    e. Efficiently learning Ising models on arbitrary graphs
4. Mathematical Theory in Deep Learning
    a. Deep Learning in Restricted Boltzmann machine
    b. Universal Approximation Theorem
    c. A Mathematical Theory of Deep Convolutional Neural Networks for Feature Extraction

48. **Course Name**: Fundamentals of Digital Image and Video Processing 数字图像与视频处理

Credits: 3; 48 teaching hour

Instructors: Fang Lu

Text Book (or other supplemental materials): "Digital Image Processing", Book by Rafael C. Gonzalez and Richard Eugene Woods. [2] "Digital Video Processing", book by A. Murat Tekalp.

Specific course information: Signal, image and video processing continues to enable the multimedia technology revolution we are experiencing today. The course is an interdisciplinary course presenting the theory and practice of Signal, Image and Video Processing. We will learn the science behind how digital images and video are made, altered, stored, and used. Meanwhile, we will look at the vast world of digital imaging, from how computers and digital cameras form images to how digital special effects are used in various areas. The course starts with the fundamentals of how the human visual system works, followed by the engineering, mathematics, and computer science that makes digital images work. We will show the basic algorithms used for adjusting images, explore JPEG and MPEG standards for encoding and compressing video images, and go on to learn about image segmentation, noise removal and filtering. Finally, we will end with state-of-the-art image and video processing techniques used in various areas. In all cases, example images and videos pertaining to specific application domains will be utilized.

Specific goals for the course: Digital images and videos are everywhere these days, covering scientific (e.g., astronomical, bio-medical), consumer, industrial, artistic applications etc. Moreover, they come in a wide range of the electromagnetic spectrum - from visible light and infrared to gamma rays and beyond. The ability to process image and video signals is therefore an incredibly important skill to master for engineering/science students, software developers, and practicing scientists.

Brief list of topics to be covered:

1. Introduction to Signal, Image and Video Processing
1.1. Digital images definition & formation
1.2. Human visual system

2. Signals and Systems
2.1 Discrete-Time (DT) Systems
2.2 Convolution

3. Fourier Transform
3.1 Discrete-time Fourier series
3.2 Discrete-time Fourier transform
3.3 Discrete-time modulation

4. Image Enhancement
4.1 Sampling and Interpolation
4.2 Image Filtering

5. Image Restoration
5.1 Image Denoising
5.2 Image Deblurring
5.3 Image Dehazing

6. Image Compression
6.1 Lossless Compression
6.2 Lossy Compression

7. Motion Estimation
7.1 Video Representation
7.2 Optical Flow

8. Video Compression
8.1 Color Space
8.2 Motion Compensation

8.3 HEVC Standard

9. Image and Video Segmentation
9.1 Superpixel Representation
9.2 Object Boundary
9.3 Semantic Segmentation

10. Advanced Algorithms on Image and Video Processing
10.1 Applications in various areas

49. **Course Name**: Operations Research 运筹学

Credits: 3; 48 teaching hour

Instructors: Xiao Li, Chan Wai Kin

Text Book (or other supplemental materials): [1] Introduction to Operations Research, 10 th ed. F. S. Hillier and G. J. Lieberman

Specific course information: This course introduces commonly used methods of deterministic and stochastic operations research. Topics that can be taught include linear programming, simplex algorithms, duality, network flow, integer programming, dynamic programming, convex optimization, Markov chains, Markov process, queuing theory, and decision analysis. However, based on the need of each class, some of the topics may be skipped or new topics could be added.

Specific goals for the course: Operations research is one of the fundamental courses for students who want to use mathematical models to solve real-world problems. This course introduces commonly used methods of deterministic and stochastic operations research. Students will learn to build mathematical models and develop algorithms to solve these problems. Moreover, students will also study ways of explaining and communicating solutions as well as applying the solutions to real-world problems. Commonly used software for optimization will be introduced and used to solve problems in class.

Brief list of topics to be covered:

1 Linear programming

Basic and Examples

Geometry of linear programming.

2 Simplex algorithms

3 Duality

4 Integer programming

5 Network Optimization

6 Convex optimization

Convex set

Convex function

Convex optimization

7 Markov chains

8 Markov process,

9 Queueing theory.

M/M/1, M/M/c

M/G/1, G/M/1

Queueing network

50. **Course Name**: Estimation and Control of Dynamical Systems 动力系统的评价与控制

Credits: 3; 48 teaching hour

Instructors: Zhang Xuan

Text Book (or other supplemental materials): [1] J. P. Hespanha, Linear Systems Theory, Princeton University Press, 2009 [2] C. T. Chen, Linear Systems Theory and Design. Oxford University Press, 3rd Edition, 1999 [3] 吴麒，自动控制原理（第二版），2006

Specific course information: This graduate level course studies dynamical systems in time domain with inputs and outputs. We will learn how to design the estimator and controller for a system to ensure desirable properties (e.g., stability, performance, robustness) of the dynamical system. In particular, we will focus on systems that can be modeled by linear Ordinary Differential Equations (ODEs) and that satisfy time-invariance conditions. The course will introduce the fundamental mathematics of linear spaces, linear operator theory, and then proceeds with the analysis of the response of linear time-variant systems.

Specific goals for the course: In TBSI, there is no control course yet. But for all centers, control theory and related applications are necessary for students to conduct interdisciplinary research. This graduate level course studies dynamical systems in time domain with inputs and outputs. We will learn how to design the estimator and controller for a system to ensure desirable properties (e.g., stability, performance, robustness) of the dynamical system. In particular, we will focus on systems that can be modeled by linear Ordinary Differential Equations (ODEs) and that satisfy time-invariance conditions.

Brief list of topics to be covered:

1. Introduction

2. A review of linear algebra and matrix theory, e.g. least squares approximation, singular value decomposition and matrix norm

   2.1 Linear algebra review

   2.2 Matrix theory review

3. Linear ordinary differential equations: existence and uniqueness of solutions, the state transition matrix and matrix exponential

   3.1 Linear state-space form

   3.2 Impulse response transfer function

   3.3 Elementary realization theory

   3.4 Solution to Linear Time-Varying (LTV) and Linear Time-Invariant (LTI) systems

4. Input-output and internal (Lyapunov) stability

   4.1 Internal stability

   4.2 Input-output stability

   4.3 Stability of nonlinear systems

5. Controllability and state feedback

   5.1 Controllable and reachable

   5.2 Controllable system

   5.3 Controllable decomposition

   5.4 Stabilizability

6. Observability and output feedback

6.1 Observability

6.2 Output feedback

7. Linear quadratic optimal control: Riccati Equation, properties of the Linear Quadratic Regulator (LQR) and Kalman filtering

7.1 LQR

7.2 Riccati Equation

7.3 Linear Quadratic Gaussian control (LQG)

8. Advanced topics such as robust control, model predictive control, linear quadratic games and distributed control will be presented based on allowable time and interest from the class

8.1 Performance limit and Robustness

8.2 Robust control

8.3 Some advanced topics

51. **Course Name**: Advanced Managerial Economics 高级管理经济学

Credits: 2; 32 teaching hour

Instructors: Kong Ying

Text Book (or other supplemental materials): [1] Managerial Economics and Business Strategy, Michael Baye, Irwin McGraw-Hill, 2010 [2] Industrial Organization—Theory and Applications, Oz Shy, The MIT Press, 1995 [3] Intermediate Microeconomics with Calculus: A Modern Approach，Hal R. Varian, W.W. Norton, 2014

Specific course information: Managerial economics is a branch of economics, managerial economics for business decision-making provides a systematic and logical analysis method, the management decision not only affects the day-to-day decisions, also affect the economic force of the long-term planning and decision-making, microeconomics in the practice of management, is the bridge of communication theory of economics and business management decision-making for enterprise decision-making and management to provide analysis tools and methods, the theory is mainly around demand, proposed several production, cost, market and other factors. How to analyze and compare the alternatives of the management economics, and find out the most likely solutions to the enterprise target. In this decision process, the function of management economics is to provide the related analysis tools and analysis method.

Specific goals for the course: Students who successfully complete the course will have a good understanding of economic concepts and tools that have direct managerial applications. The course will sharpen their analytical skills through integrating their knowledge of the economic theory with decision making techniques. Students will learn to use economic models to isolate the relevant elements of a managerial problem, identify their relationships, and formulate them into a managerial model to which decision making tools can be applied.

Brief list of topics to be covered:

Week 1

The Fundamentals of Managerial Economics

Market Forces: Demand and Supply

Quantitative Demand Analysis

The Theory of Individual Behavior

Week 2

The Production Process and Costs

The Organization of the Firm

The Nature of Industry

Week 3

Midterm Exam

Managing in Competitive, Monopolistic,

Monopolistically Competitive Market

Week 4

Basic Oligopoly Models

Game Theory: Inside Oligopoly

Pricing Strategies for Firms with Market Power

Week 5

The Economics of Information

Advanced Topics in Business Strategy

Week 6

A Manager’s Guide to Government in the Marketplace

Project Proposal Hand In

Week 7

Project Presentation and Discussion

Week 8

Final exam

52. **Course Name**: Foundations for Big Data Analytics 大数据分析基础

Credits: 2; 32 teaching hour

Instructors: Zhu Wenwu, Wang Zhi

Text Book (or other supplemental materials): 《Mahout in Action》《MapReduce Design Patterns: Building Effective Algorithms and Analytics for Hadoop and Other Systems》

Specific course information: Commerce and research are being transformed by data-driven discovery and prediction. Skills required for data analytics at massive levels – scalable data management on and off the cloud, parallel algorithms, statistical modeling, and proficiency with a complex ecosystem of tools and platforms – span a variety of disciplines and are not easy to obtain through conventional curricula. The course will be focused on basis of statistics, data analytics, big-data systems and big-data applications.

Specific goals for the course: This course serves as a foundation for big data analytics, and students will master basical skills for data science.

Brief list of topics to be covered:

Part1: Basic Statistics

Overview: Descriptive, Predictive, and Prescriptive Data Analytics

Probability: Events, Probability, Bayes’ Rule

Discrete Random Variables: Examples, Expectation

Continuous Random Variables: Examples, Expectation

Linear Regression: Offline and online

Clustering; Hard and Soft Expectation Maximization

Hypothesis Testing

Analysis of Variance

Part 2: Analytics (Wenwu Zhu)

Introduction to Data Mining

Matrix Factorization

Hashing

Recommendation

Introduction to Machine Learning

Deep learning

Part 3 System (Zhi Wang)

Infrastructure and Resource Management

Storage (e.g., HDFS, GFS)

Computing (e.g., MapReduce, Spark)

Database (e.g., HBase)

Graph DB (e.g., GraphLab)

Streaming (e.g., Storm)

Integrated Tools (e.g., R)

Part 4 Big Data Application (Wenwu Zhu)

Social media analysis and Behavioral Implication

53. **Course Name**: ITS and High-accuracy Positioning Technologies 智能交通高精度定位

Credits: 2; 32 teaching hour

Instructors: Miao Lixin, Zhang Kai

Text Book (or other supplemental materials): [1] R.R. Brooks, S.S. Iyengar, Multi-sensor fusion: fundamentals and applications with software, Prentice Hall. [2] Dan Simon, Optimal State Estimation: Kalman, H-infinity, and Nonlinear Approaches, John Wiley & Sons. [3] Mohinder S. Grewal, Lawrence R. Weill, Angus P. Andrews, Global Positioning Systems, Inertial Navigation, and Integration, John Wiley & Sons, Inc.

Specific course information: The course will introduce common knowledge and the latest development of high-accuracy positioning in ITS. The course will cover the architecture and technologies of highly accurate positioning, including Global Navigation Satellite System, Inertial Navigation, Map Matching, and Optimal State Estimation Theories. During the course, students will practice programming robot positioning to help them master the theories, as well as they will make literature survey and present the results.

Specific goals for the course: High-accuracy positioning techniques are the base of many ITS services, such as distance based electronic road pricing, driving assistance, LBS services.The class teaches the architecture and technologies of highly accurate positioning, including Global Navigation Satellite System， Inertial Navigation, Map Matching, and Optimal State Estimation Theories. The students with different background will be familiar with the high-accuracy positioning problems and state of art techniques, which would facilitate the creation of new ideas and concepts.

Brief list of topics to be covered:

Overview

1. Introduction

Application in ITS

Positioning Sensors

2. Introduction

Global Navigation Satellite System

Inertial Navigation System

Other Sensors

Integrated Positioning

Introduction

Kalman Filter

Unscented Filter

Particle Filter

3 Map Matching

3.1 Introduction

3.2 Global Max-Weight Algorithm

3.3 Global Geometric Algorithms Based on Frechet Distance

Practical activities (2 h): Programming robot positioning based on particle filter

Seminar (2 h): Presenting novel technologies of positioning technologies.

54. **Course Name**: Mobile and Pervasive Computing 移动设备和普适计算

Credits: 1; 16 teaching hour

Instructors: Zhang Pei

Text Book (or other supplemental materials): none

Specific course information: This is a course exploring research issues in the newly emerging field of mobile computing. Many traditional areas of computer science and computer engineering are impacted by the constraints and demands of mobility. Examples include network protocols, power management, user interfaces, file access, ergonomics, and security. This will be an "advanced" course in the truest sense--most, if not all, the topics discussed will be ones where there is little consensus in the research community on the best approaches. The course will also offer significant "hand-on" experience in this area. Each student will have to present and lead the discussion on a number of papers. Each student will also be required to write one of two documents: (a) a research proposal (similar in spirit to an NSF proposal) on an idea in mobile computing or (b) a short business plan for a commercial opportunity in mobile computing. Grading will be based on the quality of the presentations, and the proposal or business plan.

Specific goals for the course: This is a course exploring research issues in mobile computing and its close relative, pervasive computing.

Brief list of topics to be covered:

Topics

Introduction and Background

Ubiquitous Data Access

Exploiting Virtual Machines

Resource-Driven Dynamic Adaptation

Sensing and Actuation

Mobile Hardware Technologies

Location and Context Awareness

Security and Privacy

Design Methodologies and Infrastructure

55. **Course Name**: Energy Systems and Control 能源系统与控制

Credits: 1; 16 teaching hour

Instructors: Scott Moura

Text Book (or other supplemental materials): none

Specific course information: Introduction to control system tools for students interested in energy system applications. Applications of interest include batteries, electric vehicles, renewable energy, power systems, and smart buildings/homes. Technical tools include system modeling, state-space representations, stability, parameter identification, state observers, feedback control, and optimization. Prerequisites: Graduate student standing, multivariable calculus, linear algebra, programming, physics-mechanics, physics-electromagnetism, thermodynamics.

Specific goals for the course: This course provides students in the Smart Grid and Renewable Energy Lab with the fundamental tools to design energy management systems (EMS). Objectives 1. To encourage the development of a "systems and control perspective" necessary for the design and management of energy systems. 2. To provide students with an introduction to energy systems across multiple infrastructures, including transportation, buildings, and power systems. 3. To strengthen students' programming and mathematical analysis skills.

Brief list of topics to be covered:

This course provides control system tools for the analysis and management of energy systems. The

homework assignments facilitate motivation and application of these tools.

HW System & Control Tool Energy Application

1 Dynamic system modeling Batteries

2 Parameter Identification Building heating

3 State Estimation Offshore Oil Drilling

4 Optimization Power Systems

5 Optimal Control Hybrid vehicles

56. **Course Name**: Analysis and Optimization on Logistics System 物流系统分析及优化

Credits: 2; 32 teaching hour

Instructors: Miao Lixin, Zhang Canrong

Text Book (or other supplemental materials): [1] Wayne L. Winston. Operations Research Applications and Algorithms, 4th edition. [2] Axsäter Sven. Inventory Control. Springer, New York, 2006. [3] Cormen Thomas H., Leiserson Charles E., Rivest Ronald L. and Stein Clifford. Introduction to Algorithms, Second Edition, The MIT Press

Specific course information: This course is aimed at introducing the basic models and algorithms, latest developments and practical applications associated with some typical logistics systems, such as seaborne transportation, regional distribution, logistics within factory, and so on. In the course, location and allocation problem, routing problem, lot-sizing problem, operation management in hub nodes and other topics of interest and relevance will be covered. Focuses will be concentrated on both theoretic research and practical application. Through the course, the students will have an in-depth understanding on the basic problems related to logistics systems and its latest developments in the literature and industrial application, and most importantly, the students will be able to utilize the proper mathematical tools, such as mixed integer programming, dynamic programming, heuristic algorithm, and so on, to solve the real-life problems. Therefore, this course will help enhance the following competences for the students: problem analysis, mathematical modeling, algorithm design and computer programming.

Specific goals for the course: This course is aimed at introducing the basic models and algorithms, latest developments and practical applications associated with some typical logistics systems, such as seaborne transportation, regional distribution, logistics within factory, and so on.

Brief list of topics to be covered:

Introduction

Introduction to logistics systems

Quantitative analysis methods

Location and allocation

Covering problem

Clustering methods

Transportation problem

Hub and spoke mode

Seminar 1: Regional distribution network (Huawei global logistics network)

Seminar 2: Cargo flight planning (Shun Feng case)

Experiment 1: Invoking CPLEX on JAVA platform to solve MIP models

Routing

Shortest paths

Traveling salesman problem (TSP)

Vehicle routing problem (VRP)

Seminar 3: Container drayage problem under separable truck mode

Lot-sizing

Economic order quantity (EOQ) and its extensions

Wagner-Whitin model and algorithm

Experiment 2: Coding W-W algorithm using JAVA language

(s, S) policy

(r, Q) policy

Seminar 4: Advanced Planning System (APS) (Huawei case)

Operation management in hub nodes and other topics of interest and relevance

Seminar 5: Berth and quay crane scheduling in container terminals (FICT case)

Seminar 6: Container location assignment (FICT case)

Seminar 7: Stochastic logistics system modeling

Seminar 8: Robust logistics system modelingEnd-to-End Application Drivers

57. **Course Name**: Introduction to Advanced ITS 现代智能交通系统导论

Credits: 2; 32 teaching hour

Instructors: Zhang Yi

Text Book (or other supplemental materials): none

Specific course information: The course will focus on the newly development of intelligent transportation systems in the world. The most advanced techniques will be explored to provide solutions to meet the global challenges of safety, efficiency and pollution. Beside the introduction of the theory for traffic flow, planning and design, the most advanced techniques will be explored to provide solutions to meet the global challenges of safety, efficiency and pollution, including data fusion, status perception, GPS, big data, smart city, intelligent vehicle-infrastructure cooperative systems, autopilot and information security, etc.

Specific goals for the course: The course will focus on the newly development of intelligent transportation systems in the world. The most advanced techniques will be explored to provide solutions to meet the global challenges of safety, efficiency and pollution. Beside the introduction of the theory for traffic flow, planning and design, the most advanced techniques will be explored to provide solutions to meet the global challenges of safety, efficiency and pollution, including data fusion, status perception, big data, smart city and information security, etc.

Brief list of topics to be covered:

Lecture 1. Introduction to ITS Development (2)

1) ITS Development
2) Latest Typical Application Systems
3) Advanced IT Impacts on ITS
4) Challenging Issues on Future ITS

Lecture 2. Intelligent Vehicle-Infrastructure Cooperation Technology (4)

1) i-VICS Framework
2) Key Technology
3) Analysis and Simulation

4) Typical Application

Lecture 3. Traffic Status Acquisition and Data Fusion (4)

1) Spatial-Temporal Status Acquisition
2) Data Fusion
3) Big Data Based Traffic Analysis
4) i-VICS Based Traffic Status Analysis

Lecture 4: Traffic Control Theory and Application (4)

1) Urban Traffic Parameters
2) Fundamental Knowledge for Traffic Control
3) Traffic Control Theory
4) i-VICS Based Traffic Control

Lecture 5. Traffic Allocation Theory and Application (4)

1) Traffic Allocation Principle
2) Traffic Allocation Theory and Approach
3) OD Based Urban Travelling Demand Analysis
4) i-VICS Based En-route Dynamic Guidance

Lecture 6. Global Positioning Technology and Systems (4)

1) Introduction to Main Positioning Systems
2) Principle of Global Positioning
3) Combined Positioning and Navigation
4) i-VICS Based Positioning and Application

Lecture 7. Crowded Decision-Making for Connected Vehicles (4)

1) Connected Vehicles and Its Development
2) Autopilot Development
3) i-VICS Based Intelligent Vehicles
4) Crowded Decision-Making and Control

Lecture 8. ITS Architecture and Specifications (4)

1) ITS Architecture
2) Structure and Analysis for Different ITS Architectures
3) ITS Architecture in China
4) i-VICS Based Proposed ITS Architecture in China

58. **Course Name**: Traffic Modeling and Simulation 交通建模与仿真

Credits: 2; 32 teaching hour

Instructors: Miao Lixin, Zhang Kai

Text Book (or other supplemental materials): Multi-Agent Transportation Simulation，K. Nagel，pre-print，2004.

Specific course information: The course will cover various modeling and simulation approaches used in studying traffic dynamics and control in a transportation network. The model-based simulation tools discussed include dynamic macroscopic and microscopic traffic flow simulation and assignment models. Models will be analyzed for their performance in handling traffic dynamics, route choice behavior, and network representation.

Specific goals for the course: The model-based simulation techniques are important and effective approaches in studying traffic dynamics and control in transportation research. However, there is no general courses designed specifically for models and simulation of traffic network. The students with different background will be familiar with the fundamentals of traffic flow and state of art techniques of transportation systems modeling and simulation.

Brief list of topics to be covered:

1. Introduction
2. Car following models
2.1. Microscopic traffic flow models
2.2. Mesoscopic traffic flow models
3. Solution methods using waves
3.1. LWR models
3.2. Macroscopic traffic flow models
4. Fundamental relationship between flow, speed, and density
5. Traffic control for two interacting traffic streams
5.1. Miller’s model
5.2. Gazis’s models
6. Traffic control for serial systems
6.1. Spatial queues
6.2. Point queues
7. User-Equilibrium vs. System Optimum
7.1. User-Equilibrium
7.2. System Optimum
8. Paradoxical phenomenon in system control
9. Time-dependent models
9.1. Time-dependent models for bottlenecks

9.2. Time-dependent models for lane-blockage incidents
The state-of-the-art commercial traffic simulation models

59. **Course Name**: Hybrid System Design for Smart City 智慧城市混合系统设计

Credits: 2; 32 teaching hour

Instructors: Khalid M.Mosalam

Text Book (or other supplemental materials): [1] A.K. Chopra. Dynamics of Structures: Theory and Applications to Earthquake Engineering, 5th Edition, 2016 [2] K-J. Bathe. Finite Element Procedures, 1996 [3] C. R. Farrar and K. Worden. Structural health monitoring: a machine learning perspective, 2012

Specific course information: This course consists of three major sections: 1. System modeling and analysis, which includes basic structural dynamics, finite element method and experimental methods; 2. Data collection, processing and interpretation, including mobile sensor net, machine learning techniques and their applications on structural health monitoring; 3. Sustainability and resiliency that covers performance-based engineering, risk and reliability analysis, especially under extreme events, and their corresponding decision making for integrated/holistic design.

Specific goals for the course: The intent of this course is to encourage the multidisciplinary fusion such that students can develop comprehensive understanding of the theory and its application, leading to novel research collaborations. Students are expected to get a holistic view and deep understanding of examples about the system design of hybrid systems in smart cities, from electrical and civil engineering perspective.

Brief list of topics to be covered:

1. Hands-on Sensor Node Development using IoT Technologies (Dr. Clement Barthes) (workshop on how to use the latest IoT technologies for SHM)
   1.1 Javascript for IoT (Beginners – 2 hrs)
      1.1.1 Interaction with sensors
      1.1.2 Introduction to web development with HTML5 features
      1.1.3 Live data streaming over the web
   1.2 Embedded Linux for IoT (Advanced – 2 hrs)
      1.2.1 Basic Linux commands and presentation of the sysfs folder system
      1.2.2 C++ programming on a Linux virtual machine with all the tools required to compile and employ the code on the IoT kit as shown below
2. System Modeling & Analysis
   2.1 Dynamics of Structural Systems (**1-4**)
      2.1.1 Structural dynamics basics (2)

2.1.2 Numerical algorithms (2)

2.2 Finite Element Method (**5-10**)

2.2.1 FEM basics (2)

2.2.2 Modeling with different types of elements (hands-on using FEDEASlab) (2)

2.2.3 Application to a variety of engineering fields (civil/mechanical/electrical…) (2)

2.3 Experimental Methods (**11-16**)

2.3.1 Dimensional analysis & similitude requirements (1)

2.3.2 Sensors, data acquisition and control (1)

2.3.3 Hybrid simulation basics (2)

2.3.4 Hybrid simulation applications (OpenFrescoExpress) (2)

3. Data Collection, Processing & Interpretation

3.1 Mobile Sensor Net (Prof. Pei Zhang) (**17-20**) (**July 11 Tuesday afternoon**)

3.2 Signal Processing & Data Mining (Prof. Hae Young Noh) (**21-24**) (**July 14 Friday morning**)

3.3 Structural Health Monitoring (**25-28**)

3.3.1 SHM basics (2)

3.3.2 Data-driven SHM (1)

3.3.3 Hands-on session using SHM interface (1)

3.4 Case study: Deep Learning in Image Classification (**29-30**)

4. Sustainability & Resiliency

4.1 Performance-Based Engineering (**31-32**)

4.1.1 Performance-based earthquake engineering (1)

4.1.2 Extension to other engineering fields (1)

4.2 Risk and Reliability Analysis in Engineering (**33-37**)

4.2.1 Uncertainty Quantification (2)

4.2.1.1 Probability Theory

4.2.1.2 Statistics and extreme values

4.2.1.3 Modelling of the uncertainties

4.2.2 Structural Reliability (2)

4.2.2.1 Methods of structural reliability (FORM, MCS, …)

4.2.2.2 System Reliability

4.2.2.3 Time dependent Reliability Analysis and Stochastic Dynamic

4.2.3 Risk Analysis and Decision under Risk (1)

4.2.3.1 Bayesian Analysis

4.2.3.2 Bayesian Probabilistic Networks

4.3 Decision Making for Integrated/Holistic Design (**38-40**)

4.3.1 Decision philosophy (0.5)

4.3.2 Multi-criteria decision making (1)

4.3.3 PBE with MAUT (1)

4.3.4 Integrated design and lifecycle holistic analyses (0.5)

60. **Course Name**: Introduction to Nonlinear Optimization 非线性优化概述

Credits: 1; 16 teaching hour

Instructors: Shmuel Oren

Text Book (or other supplemental materials): "Linear and Nonlinear Programming" by Luenberger and Ye Chapters 7,8,11,12.

Specific course information: The course cover theory and algorithms for nonlinear continuous optimization. We start with some examples of applications of nonlinear programming. Then we proceed with characterization of necessary and sufficient conditions for and optimum of unconstrained and constrained optimization problems, the KKT conditions, and specific results that hold under convexity assumptions. We then study local and global convergence theory with application to specific algorithms and explore the impact of structural properties of the objective function on algorithms' performance.

Specific goals for the course: The course covers fundamental material of Operations Research that is underlying energy modeling, power systems Logistics and financial engineering

Brief list of topics to be covered:

1. Introduction
    a. Basic mathematical concepts
    b. Examples of Nonlinear Optimizatin Probems
2. Basic Properties of Solutions
    a. First Order Necessary Conditions
    b. Second Order Conditions
    c. Convex and Concave Functions and generalizations
    d. Optimization of Convex functions
    e. Constrained Optimization
    f. Tangent Plane
    g. First Order Necessary Conditions for Equality Constrained Problems
    h. Second Order Conditions
    i. Eigenvalues in Tangent Subspace
    j. Lagrange Multipliers and Sensitivity
    k. Inequality Constrained Problems
3. Basic Properties of Algorithms
    a. Global Convergence of Descent Algorithms
    b. Speed of convergence
4. One Dimensional Optimization
    a. Fibonacci and Golden Section Search

    b. Line Search by curve Fitting
    c. Global and local convergence of line search algorithms
    d. Closedness of Line Search algorithms and inexact searches
5. Multidimensional Descent Algorithms
    a. Steepest Descent
    b. Deflected Steepest Descent and scaling
    c. Newton Method.
6. Linear Constrained Algorithms
    a. Reduced Gradient Method
    b. Gradient Projection Method.

61. **Course Name**: Introduction to Quantitative Investment 量化投资概论

Credits: 2; 32 teaching hour

Instructors: Lin Jianwu

Text Book (or other supplemental materials): Options, Futures, and Other Derivatives, John Hull, Prentice-Hall, 9th Edition Measuring Market Risk, Kevin Dowd, Wiley Finance, 2nd Edition Quantitative Equity Portfolio Management: Modern Techniques and Applications, Edward E. Qian, Ronald H. Hua, Eric H. Sorensen, Chapman Hall CRC, 2007

Specific course information: The emphasis in this course is basic theories and applications of Financial Engineering. The main topic areas (in order covered) are: (1) Introduction of financial markets (2) Time value and financial return (3) Volatility and financial risk (4) Financial Stochastic processes (5) Traditional and behavioral finance theories (6) Portfolio management (7) Pricing of financial instruments. At the end, an experiment will be held in financial engineering lab to introduce a computer software for practicing all knowledge in this course by several case studies.

Specific goals for the course: To cultivate students' financial engineering research and application ability, to enhance students' understanding toward the nature of financial engineering. This course will mainly focus on theory introduction, case discussing, coding on computer, after-class homework to improve students' solving ability in financial engineering problems. This course is not only aiming at financial engineering theory and model constructing but also real-world investment strategy exploiting and practical application ability.

Brief list of topics to be covered:

Introduction of financial markets

Development of global financial markets

Development of asset management

Development of financial engineering

Traditional and behavioral finance theories

- Traditional finance and efficient market hypothesis
- Behavioral finance and prospect theory

Time value and financial return

- Time value and discount rate
- Characteristics of financial return, CAPM and APT
- Financial data processing

Volatility and financial risk

- Volatility and risk measurement
- Volatility and correlation modeling
- Value at risk

Financial stochastic processes

- Brownian motion
- Ornstein-Uhlenbeck process
- Market Microstructure models

Portfolio management

- Mean-variance framework
- Black-litterman model
- Almgran-Chriss model

Pricing of financial instruments

- Fixed income pricing
- Options pricing

Experiments and case studies

Statistics arbitrage

Multifactor risk model

Options trading strategies

62. **Course Name**: Optimization Theory and Machine Learning 优化理论和机器学习

Credits: 1; 16 teaching hour

Instructors: Somayeh Sojoudi

Text Book (or other supplemental materials):none

Specific course information: The course covers several topics on optimization theory, numerical algorithms, machine learning, and different applications. It provides a basic understanding of the area and yet identifies important challenging problems for research. In particular, the students learn about the role of convex and conic optimization in machine learning and data science (such as lasso type algorithms) and how to apply these techniques to real-world data for human brain, transportation, power systems and many others. The course also discusses the design of efficient algorithms for solving large-scale learning problems.

Specific goals for the course: This course helps students understand several topics about optimization theory that are essential in machine learning. The course also discusses different important applications.

Brief list of topics to be covered:

- Convex optimization theory:
    - Optimality conditions
    - Lagrangian
    - Duality
    - Convexification
- Conic optimization
    - Mathematics of conic problems (e.g., semidefinite programs)
    - Low-rank optimization
    - Sparse conic programming
- First- and second-order algorithms
    - Descent algorithms
    - Primal-dual algorithms

- Interior-point methods
- Distributed computation techniques (ADMM, etc.)

- Sparsity-promoting techniques
  - Regularized conic optimization
  - Case studies in compressive sensing, low-rank optimization and learning
- Statistical learning
  - Supervised learning
  - Unsupervised learning
  - Reinforcement learning
  - Deep learning

- Graphical models
  - Bayesian networks
  - Structure learning
  - Clique trees
  - Graphical lasso
- Applications
  - Neuroscience
  - Transportation
  - Energy
  - Signal processing

63. **Course Name**: Compressive Sensing with Sparse Models:Theory, Algorithms, and Applications 压缩感知与稀疏模型：理论、算法与应用

Credits: 1; 16 teaching hour

Instructors: Ma Yi

Text Book (or other supplemental materials): High-Dim Data Analysis with Sparse and Low-Dim Models: Theory, Algorithms, and Applications, by John Wright, Yi Ma, and Allen Yang, draft by summer 2018.

Specific course information: This graduate level course introduces basic concepts and results in low-dimensional models for high-dimensional signal processing and data analysis, spanning basic theory, efficient algorithms, and diverse applications. We will discuss recovery theory mainly for sparse models. We will introduce principles and methods for developing efficient optimization algorithms, with an emphasis on simple and scalable first-order methods, covering state of the art convex and greedy algorithms. We will illustrate the theory and algorithms with numerous application examples, drawn from computer vision, image processing, communications. The course will provide ample mathematical and programming exercises with supporting algorithms, codes, and data. Throughout the course, we will discuss strong conceptual, algorithmic, and likely theoretical connections between low-dimensional models with other popular data-driven methods such as deep neural networks (DNN), providing some new perspectives to understand deep learning.

Specific goals for the course: This course introduces the state of the art theory, algorithms, and applications of compressive sensing.

Brief list of topics to be covered:

Course introduction, motivating Examples, linear algebra review.

Sparse Solutions, l^0 minimization, l^0 uniqueness, NP-hardness.

l^1 relaxation, l^1 recovery under incoherence.

Recovery under RIP, random matrices.

Noise and inexact sparsity.

Optimization I: review of first order methods, proximal gradient, acceleration.

Optimization II: constraints, Augmented Lagrangian, ADMM.

Applications: face recognition, communications, MRI and others.

Advanced topics: dictionary learning, blind deconvolution, neural networks etc.

64. **Course Name**: Computational Methods for Electric Power Systems 电力系统计算方法

Credits: 2; 32 teaching hour

Instructors: Xu Yinliang

Text Book (or other supplemental materials): [1] Computational Methods for Electric Power Systems, 2nd ed. by M. L. Crow, Boca Raton, FL: CRC, 2009.

Specific course information: This course introduces various computational methods for power flow calculation and their convergence analysis. Students should be able to use Matlab to accomplish power flow calculation satisfying the requirements of computation speed and accuracy. Those are the common and practical problems in electrical power systems, which must be mastered by the students majoring in electrical power system and understood by students in other majors who are interested in power systems and numerical methods.

Specific goals for the course: Computer simulation plays a large role in control and security assessment. Commercial packages routinely fail or give erroneous results when used to simulate stressed systems. This course will be providing an in-depth analysis and discussion of computation methods for electric power systems. This course aims to understand the analytical background of the algorithms used in numerous commercial packages to better understand the results and identify potential errors and anomalies and solve with the appropriate methods.

Brief list of topics to be covered:

1. The solution to linear systems 8 hours

1.1 Gaussian Elimination

1.2 LU factorization

2. The solution to nonlinear systems 8 hours

2.1 Various numerical methods

2.2 Stability and convergence speed analysis

3. Numerical Integration Methods 8 hours

3.1 One-step method

3.2 Multi-step method

3.3 Truncation Error Analysis

4. Power System Applications 8 hours

4.1 Optimal Power Flow

4.2 State Estimation

4.3 Economic Dispatch

65. **Course Name**: Resilience-based Engineering of Smart Infrastructure Systems 基于弹性工程学的智慧建筑系统

Credits: 1; 16 teaching hour

Instructors: Khalid M.Mosalam

Text Book (or other supplemental materials): None

Specific course information: This course consists of three major sections: 1. System modeling and analysis, which includes basic structural dynamics, finite element method and experimental methods; 2. Data-driven Structural Health Monitoring, including machine learning techniques and their applications on structural health monitoring; 3. Sustainability and resiliency that covers performance-based engineering, risk and reliability analysis, especially under extreme events, and their corresponding decision making for integrated/holistic design.

Specific goals for the course: None

Brief list of topics to be covered:

1. System Modeling & Analysis [7 hrs]

1.1 Basics of Finite Element Method and Hybrid Simulation (3)

1.2 Experimental Methods (4)

1.2.1 Dimensional analysis & similitude requirements (1)

1.2.2 Sensors, data acquisition and control (2)

1.2.3 Basics of Structural Health Monitoring (SHM) (1)

2. Machine learning in SHM [4 hrs]

2.1 Basics (2)

2.2 Deep learning in SHM (2)

3. Sustainability & Resiliency [5 hrs]

3.1 Performance-Based Engineering (1)

3.2 Risk and Reliability Analysis in Engineering (2)

3.2.1 Uncertainty Quantification (1)

3.2.2 Structural Reliability (1)

3.3 Decision Making for Integrated/Holistic Design (2)

66. **Course Name**: System Miscellanies 系统杂论

Credits: 2; 32 teaching hour

Instructors: Zhang Xuan

Text Book (or other supplemental materials): [1] P. Glendinning, “Stability, Instability and Chaos: an introduction to the theory of nonlinear differential equations”, Cambridge Texts in Applied Mathematics, 1994. [2] R. Srikant, “The Mathematics of Internet Congestion Control”, Birkhauser, 2003. [3] A. Pikovsky, M. Rosenblum, J. Kurths, “Synchronization: A universal concept in nonlinear sciences”, CUP, 2003. [4] J. J. Slotine and W. Li, “Applied Nonlinear Control”, Prentice-Hall 1991.

Specific course information: This graduate level course studies different types of systems from different viewpoints, mainly including dynamical systems, networked systems, and nonlinear systems. First on dynamical systems, students will learn several aspects of dynamical systems theory (e.g., equilibria, stability, bifurcation, chaos) and how it is applied in a range of examples. Second on networked systems, students will learn some of the best-studied networked systems and their properties (e.g., Internet congestion control schemes, synchronization in oscillator networks, consensus in multi-agent systems). Third on nonlinear systems, students will learn some techniques for analysis and control design for nonlinear systems (e.g., stability theory, passive systems).

Specific goals for the course: This graduate level course studies different types of systems from different viewpoints, mainly including dynamical systems, networked systems, and nonlinear systems. First on dynamical systems, students will learn several aspects of dynamical systems theory and how it is applied in a range of examples. Second on networked systems, students will learn some of the best-studied networked systems and their properties.Third on nonlinear systems, students will learn some techniques for analysis and control design for nonlinear systems.

Brief list of topics to be covered:

1. Couse Overview

2. Introduction to Dynamical Systems

   2.1 Examples of dynamical systems

   2.2 Terminology, notation and relevant background

   2.3 Different types of dynamical systems

3. Equilibria and Stability

   3.1 Equilibrium solutions

3.2 Stability

3.3 Linear systems

3.4 Nonlinear systems

4. Invariant Manifolds

4.1 Linear systems: Stable, unstable and centre subspaces

4.2 Nonlinear systems: Local theory and invariance

4.3 Non-hyperbolic equilibria

5. Lyapunov Functions

5.1 Lyapunov functions

5.2 Vector fields possessing an integral

5.3 Hamiltonian systems

5.4 Gradient systems

5.5 A relationship between Gradient and Hamiltonian systems

6. Asymptotic Behaviour

6.1 LaSalle's invariance principle

6.2 The Poincare Bendixson theorem

7. Limit Cycles and Index Theory

7.1 Non-existence of periodic orbits for 2-D systems

7.2 Gradient systems

7.3 Index theory

7.4 Limit cycles

7.5 The Poincare map

8. Bifurcations

8.1 One-dimensional bifurcations

8.2 Hopf bifurcations

9. Chaos

 9.1 Chaos in maps

 9.2 Chaos in flows

 9.3 Back to maps: Mandelbrot set

10. Introduction to Networked Systems

 10.1 Examples

 10.2 Preliminaries

11. Matrices and Graphs

 11.1 An introduction to graph theory

 11.2 Properties of the graph Laplacian

 11.3 Weighted graphs

 11.4 Special graph structures

 11.5 Large graphs for large networks

 11.6 Writing dynamics on graphs

12. Optimization and Dual Decomposition Methods

 12.1 Unconstrained optimization

 12.2 Constrained optimization

 12.3 Network flow problems

13. Internet Congestion Control I

 13.1 Introduction

 13.2 Resource allocation

 13.3 Resource allocation as an optimization programme

 13.4 A dual decomposition scheme for solving the resource allocation programme

14. Internet Congestion Control II

 14.1 A primal congestion control scheme

14.2 Current Internet protocols

14.3 Jacobson's algorithm

14.4 Fairness, unmodelled dynamics and outlook

15. Synchronization in Oscillator Networks

15.1 Introduction

15.2 Coupled oscillators

15.3 Complete oscillator networks

15.4 General oscillator networks

16. Coordination in Multi-Agent Systems

16.1 Alignment/consensus algorithms

16.2 Flocking

16.3 Convergence properties of alignment algorithms

16.4 Equilibrium properties

17. Nonlinear systems

17.1 Introduction

17.2 Lyapunov stability

17.3 convergence analysis

17.4 Passive systems

67. **Course Name**: Power Systems and Market Operations 电力系统与市场运行

Credits: 3; 48 teaching hour

Instructors: Guo Ye

Text Book (or other supplemental materials): 1. Antonio Conejo and Luis Baringo, Power Systems Operations, Springer, 2018. A non-ideal but free (online) alternative is Optimization of power system operation, IEEE-Wiley, 2015. 2. D. Kirschen and G. Strabac, Fundamentals of power system economics, Wiley, 2004. 3. Class notes posted after lectures.

Specific course information: Currently, the first provincial electricity market in China is under construction here in Guangdong. This course will focus on power system operations and electricity markets, providing students who are interested in penitent areas with necessary basic knowledge. Namely, the content of this course includes but not limited to: (i) power system modeling and power flow analysis, (ii) energy management system, (iii) basic structure and design of electricity markets, (iv) market equilibrium and market power, (v) interregional market, retail market, and comprehensive energy market.

Specific goals for the course: A solid basis for the future research revolving around smart grid is forged. Moreover, China is current undergoing a remarkable electricity market reform. It is crucial for students to understand what is going on right here right now, so they can participant in such a progress as much as possible in the future. This is the main incentive for me to apply for the opening of this new course. Students will fortify their knowledge of power systems and markets, which are indispensable basis for their future research and career development.

Brief list of topics to be covered:

1. Introduction to power system operations

2. System operations

• Key concepts and tools in convex optimization.

• Power system models and power flow analysis.

• Economic dispatch, optimal power flow, unit commitment.

• Energy management system and state estimation.

3. Market operations

• Elements of microeconomics.

• Wholesale electricity market and locational marginal price.

• Strategic behavior of market participants and market power.

• Retail market.

4. Advanced topics

• Virtual transactions.

• Interface bidding.

• Financial transmission rights.

• Comprehensive energy market

68. **Course Name**: Quantitative Method for Business and Policy Analysis 商业和政策分析的定量方法

Credits: 3; 48 teaching hour

Instructors: Kong Ying

Text Book (or other supplemental materials): [1] Basic Econometrics, (5th Edition) Damodar N. Gujarati, McGraw-Hill Education, 2009. [2] Introductory Econometrics: A Modern Approach, (sixth edition) Jeffrey M. Wooldridge, 2015. [3] Burfisher M E. Introduction to Computable General Equilibrium Models[M]. Cambridge University Press, 2011.

Specific course information: This course is a methodology disciplines for integration economics, mathematics, statistics and computer application. From the application point of view, the econometric approach is to establish an econometric model. Econometric model is a mathematical simulation of the real economic environment. With one or a set of simultaneous equations to reflect the link between economic variables. The main content includes model design, estimation, testing, the econometric problems of basic assumptions contrary, model analysis and applies, use of econometrics package description.

Specific goals for the course: The course objective is to introduce the basic concepts, research contents and modeling steps of econometrics and CGE model, so that students can preliminarily grasp the basic theory and methods of econometrics, acquire the preliminary ability of using econometric methods to analyze real economic problems, proficient in Stata and other quantitative analysis software.

Brief list of topics to be covered:

1. Introduction

1.1 What is Econometrics?

1.2 Steps in empirical economic analysis

1.3 Types of economic data

2. Simple linear regression model

2.1 Regression analysis and regression function

2.2 Derivation of ordinary least square method

2.3 Statistical test of one linear regression model

3. Multiple linear regression model

3.1 Basic assumptions of multiple linear regression models

3.2 Parameter estimation of multiple linear regression models

3.3 Statistical test of multiple linear regression models

3.4 Practical prediction of multiple linear regression models

4. Further discussion of classical linear regression models: relaxing the basic assumptions

4.1 Heteroskedasticity

4.2 Sequence auto-correlation

4.3 Multicollinearity

4.4 Virtual variable

5. Regression analysis of time series data

5.1 Stationarity test of time series data

5.2 Stochastic time series analysis model

5.3 Co-integration and error correction model

5.4 Case analysis

6. CGE models for simulation analysis of economic development policy

6.1 Policy simulation and general equilibrium model

6.2 Basic concept of CGE models

6.3 Implementation of CGE models: Database, SAM, NIPA, IO

6.4 Application of CGE models in Energy-Environment

6.5 Extended application -- dynamic CCE model and its application

69. **Course Name**: Large Network Steady-State Analysis 大型网络稳态分析方法

Credits: 3; 48 teaching hour

Instructors: Guo Ye

Text Book (or other supplemental materials): [1]. Boming Zhang and Zheng Yan, Advanced Electric Power Network Analysis, CENGAGE Learning Asia, Jul 26, 2010

Specific course information: This course focuses on basic mathematical tools to study large scale networks under steady-state assumptions, such as the sparse matrix technique, the Woodbury matrix identity, update of factor tables after small disturbance, network partition and equivalence, and parallel and distributed computations. Power networks will be used as examples in many cases but methodologies presented in this course are applicable to a variety of engineering problems.

Specific goals for the course: Multiple labs at TBSI are interested in large network analysis. However, there is hitherto no course focusing on special techniques for large networks. Many classical optimization methods or computational approaches may not scale well when the network is large, and this will be the main theme of this new course. The students are expected to learn several key approaches for large networks, such as the graphical description of a large system, sparse matrix technique, fast update of solutions with minor changes in the network and so on.

Brief list of topics to be covered:

1. Introduction

2. Sparse matrix technique

• Basic concept

• LU decomposition and linear equation solution

• Sparse vector technique

• Optimal indexing of variables

3. Large network analysis

• Woodbury matrix identity

• Updating linear equation solutions with minor disruptions

• State estimation and N-1 analysis

• Brief review on nonlinear networks

4. Multi-agent networks

• Network equivalence

• Network splitting and computation

• Parallel computation and distributed computation

• Privacy concerns and cyber-security

• Possible strategic behaviors and their impacts

70. **Course Name**: Information Theory and Statistical Learning 信息论与统计学习

Credits: 3; 48 teaching hour

Instructors: Huang Shaolun, Zhang Lin

Text Book (or other supplemental materials): [1] T. M. Cover and J. A. Thomas, Elementary of Information Theory, Wiley Interscience, 1991. [2] MacKay, David. Information Theory, Inference, and Learning Algorithms. Cambridge, UK: Cambridge University Press, 2003.

Specific course information: This is a course on the intersection of information theory and machine learning geared towards first or second-year graduate students who are interested in the fundamental aspects and the state-of-art developments of these subjects. The course is geared towards students who are interested in understanding machine learning, data mining, and information theory at a fairly sophisticated level, and to carry out research involving the applications of the mathematical frameworks to machine learning problems. One of the objectives of the course is to understand the fundamental perspectives and develop solid connections between mathematical theory and learning systems.

Specific goals for the course: The course is geared towards students who are interested in understanding machine learning, data mining, and information theory at a fairly sophisticated level, and to carry out research involving the applications of the mathematical frameworks to machine learning problems. One of the objectives of the course is to understand the fundamental perspectives and develop solid connections between mathematical theory and learning systems.

Brief list of topics to be covered:

1. Fundamental of Information Theory

a. Entropy, mutual information, K-L divergence

b. Asymptotic equipartition property

c. The method of type

d. Large deviation theory

2. Decision theory

a. Bayesian hypothesis testing

b. NonBayesian decision theory

c. Bayesian parameter estimation

3. Inference and statistics

a. Exponential families

b. Sufficient statistics

c. The EM algorithm

d. Inference as decision

4. Information theory and learning

a. Information geometry

b. Modeling as inference

c. Extensions to continuous parameters

d. Approximations: deterministic

e. Approximations: stochastic

5. Machine Learning

a. Introduction to parametric modeling

b. Model selection

c. Universal Compression

71. **Course Name**: SPECIAL ISSUES IN SEMICONDUCTOR OPTO-ELECTRONIC DEVICE MANUF 半导体光电器件制造中的特殊问题

Credits: 2; 32 teaching hour

Instructors: Ghulam Hasnain, Guo Haozhong

Text Book (or other supplemental materials): 1.Device Electronics for Integrated Circuits – Muller and Kamins 2.Physics of Semiconductor Devices – Sze 3.Physics of Optoelectronic Devices – Chuang 4.Diode Lasers and Photonic Integrated Circuits – Coldren and Corzine 5.InP-Based Materials and Devices – Ed. by Wada and Hasegawa 6.Fundamentals of Semiconductor Theory and Device Physics – Wang 7.Long Wavelength Semiconductor Lasers – Agarwal and Dutta 8.3D TCAD Simulation for Semiconductor Processes, Devices and Optoelectronics –Simon Li, Yue Fu

Specific course information: While silicon ICs have become ubiquitous in many smart appliances, optoelectronic devices such as solar cells, LED lighting, LED displays, and 3D sensors that use VCSELs and other lasers are becoming increasingly visible, besides being the backbone of fiber-optic communications. This course will teach students already familiar with semiconductor devices about developing opto-electronic devices such as leds, lasers and photodiodes made from compound semiconductor materials.

Specific goals for the course: The purpose of this course is to address and discuss issues peculiar to the manufacturing of semiconductor opto-electronic devices such as LEDs, laser diodes and photodetectors. These devices are key to fiber-optics communications, LED Displays, solar cells, laser printers, and solid-state (LED) lighting. The course will cover several topics including the device design modifications needed to meet reliability standards, design of mask sets and fabrication process, device characterization both dc and high-frequency, die fabrication and basic packaging issues, reliability testing and failure analysis. Case studies of some specific devices will be examined in detail.

Brief list of topics to be covered:

1.Overview of OE devices

1.1III-V,

1.2alloy,

1.3heterostructures,…

2.Case Study I : PIN/APD

2.1Absorption,

2.2avalanche gain,

2.3device design,

2.4mask,

2.5fab process

3.Crosslight Device Simulation: PN junction

3.1PIN/APD modeling,

4.Case Study II : Blue LED/LD

4.1spontaneous/stimulated emission,

4.2device design,

4.3mask,

4.4fab process,

5.Crosslight Device Simulation LED/LD

5.1LED modeling,

6.Case Study III : Solar Cells

6.1Compare Si vs III-V MJ cells,

7.Crosslight Device Simulation VCSEL/LD

7.1laser modeling,

8.Crosslight Device Simulation -present and report

8.1 results by student- LED/LD/Detector,

72. **Course Name**: Reinforcement Learning for Energy Systems 能源系统的强化学习

Credits: 1; 16 teaching hour

Instructors: Scott Moura

Text Book (or other supplemental materials): [1]D. P. Bertsekas and J. Tsitsiklis, Neuro-dynamic Programming, Athena Scientific, 1996. [2]R. S. Sutton and A. G. Barto, Introduction to reinforcement learning, Cambridge: MIT press, 1998 [3]W. B.

Powell, Approximate Dynamic Programming: Solving the curses of dimensionality, John Wiley & Sons, 2007.

Specific course information: Introduction to reinforcement learning for students interested in energy system applications, in addition to transportation, robotics, economics, and more. The objective is to provide students with the fundamental concepts to understand and apply reinforcement learning algorithms. Students will strengthen both their theoretical understanding, and experience applications of reinforcement learning through a course project.

Specific goals for the course: This course introduces reinforcement learning to students interested in solving problems in energy systems, transportation, robotics, economics, and more. The objective is to provide students with the fundamental concepts to understand and apply reinforcement learning algorithms. Students will strengthen both their theoretical understanding, and experience applications of reinforcement learning through a course project.

Brief list of topics to be covered:

1. Model-based RL
1.1. Dynamic programming
1.2. Linear Quadratic Regulator
1.3. Markov decision processes
2. Model-free RL
2.1. Tabular Q-learning
2.2. Deep Q-learning
2.3. Policy gradient methods
3. Applications in energy systems
3.1. Solar + storage
3.2. Batteries
3.3.Hybrid vehicles

73. **Course Name**: Machine learning, with application to medical and financial data
机器学习及其在医疗和金融数据上的应用

Credits: 1; 16 teaching hour

Instructors: Xin Guo

Text Book (or other supplemental materials): None.

Specific course information: This seminar style course will cover the most recent research topics on theory and applications of machine learning, includinf some most recent research progress with respect to applications in the areas of medical diagnosis and financial risk management.

Specific goals for the course: This seminar style course will cover the most recent research topics on theory and applications of machine learning, includinf some most recent research progress with respect to applications in the areas of medical diagnosis and financial risk management.

Brief list of topics to be covered:

1. Review in theory of Machine Learning and Statistics

1a, Regression analysis

1b, Neural Networks

1c, GANs and Autoencoder

1d, SVM

1e, Simulation

2. Applications

2a. Early cancer detection with SVM

2b. NN for eye disease detection

2c. Autoencoder for discovery of new super microorganism

2d. Simulation for blockchian systems

74. **Course Name**: Bayesian Learning and Data Analysis 贝叶斯学习与数据分析

Credits: 2; 32 teaching hour

Instructors: Ercan Engin KURUOGLU

Text Book (or other supplemental materials): 1. Data Analysis, a Bayesian Tutorial, D.S. Sivia and J. Skilling, Oxford University Press, 2006. 2. Andrew Gelman, John Carlin, Hal Stern, David Dunson, Aki Vehtari, and Donald Rubin, Bayesian Data Analysis, CRC Press

Specific course information: The course introduces Bayesian statistics and its application to learning. It starts with the philosophical foundations of Bayesian theory.

It gives a historical perspective and it proceeds to the development of the mathematical framework both analytically and numerically. It introduces Monte Carlo methods for the calculation of Bayesian estimation, starting from basic sampling methods progressing to Markov chain Monte Carlo methods including Gibbs sampling. The course also studies model selection problem and discusses Reversible Jump MCMC method and shows its extension to beyond selection of model dimension. The course than presents Sequential Monte Carlo methods, namely Particle filtering for the solution of time-varying estimation problems

Specific goals for the course: Bayesian learning is an important branch of statistical learning which is not covered in classical machine learning courses. It provides a strong mathematical framework for including the a-priori information about the problem into the formulation hence reducing search space and time. Bayesian learning is an efficient model for human learning and can give important insights into design of machine learning methods. The students can use Bayesian formulation in their research in any application area of data analysis, machine learning, artificial intelligence and operations research.

Brief list of topics to be covered:

1. Introduction to Bayesian Estimation Theory 2 hours

a. History,

b. Bayes theorem,

c. Classical versus Bayesian interpretation of probability,

d. Bayesian philosophy

2. Posterior distribution 2 hours

a. Point estimation based on posterior

3. Prior distribution 2 hours 2 hours

a. Non-informative priors

b. Jeffrey's prior

c. Conjugate priors

4. Analytical solutions 4 hours

a. Single parameter models,

b. multiparameter model,

c. hierarchical models 2 hours

5. Sampling 4 hours

a. Why sampling?

b. Reverse sampling

c. Rejection sampling

d. Importance sampling

e. Monte Carlo sampling

6. A review of Markov chain theory 4 hours

a. Markov processes

b. Stationary distribution

c. Ergodicity

d. Irreducibility

7. Markov chain Monte Carlo 4 hours

a. Relation with statistical mechanics

b. Metropolis method

c. Metropolis-Hastings

d. Gibbs sampling

e. Relation with simulated annealing

8. Bayesian Model Selection 2 hours

a. Reversible jump MCMC

9. Advanced topics: convergence, multiple MCMC, etc 1 hours

10. Sequential Monte Carlo 2 hours

a. Filtering non-stationary signals (Kalman filter and its extensions)

b. Unscented Kalman filter

c. Particle filter

11. Seminars on Applications 6 hours

a. Computer vision,

b. Telecommunications ,

c. Image Processing,

d. Computational biology

e. …

75. **Course Name**: Random Processes 随机过程

Credits: 3; 48 teaching hour

Instructors: Ercan Engin KURUOGLU

Text Book (or other supplemental materials):

Specific course information: The course starts with probability theory fundamentals, starting from a single random variable and its probabilistic description, then moving to two random variables and a random vector and then generalizing this discussion to a multiple random variables in a sequence hence a random or stochastic process. We will provide a characterization of random processes also in the transform domain and present spectrum analysis. Random walks such as Brownian Motion will be presented and its applications in various contemporary topics will be mentioned. The discussion will also be extended to Levy flights. This will lead to the discussion on normality of Gaussian processes and its extension to Levy-stable processes.

Specific goals for the course: Random Processes is a fundamental course that needs to be taken by any engineering graduate student. It provides a mathematical framework for most real world or man-created non-deterministic processes the student would encounter in his research and later in his career. It is an indispensable course that Data Analysis, Signal and Image Processing, Telecommunications, Machine Learning, Artificial Intelligence, Operations Research depends on. The students at the end of this course will have the capability of modelling any real life process as a random process and will have mathematical means to solving this random process to obtain parameters that describe it.

Brief list of topics to be covered:

1 The Meaning of Probability

1-1 The Definitions / 1-2 Probability and Induction / 1-3 Causality Versus Randomness

2 The Axioms of Probability

2-1 Set Theory / 2-2 Probability Space / 2-3 Conditional Probability

3 Repeated Trials

3-1 Combined Experiments / 3-2 Bernoulli Trials / 3-3 Bernoulli's Theorem and Games of Chance

4 The Concept of a Random Variable

4-1 Distribution and Density Functions / 4-2 Specific Random Variables / 4-3 Conditional Distributions / 4-4 Asymptotic Approximations for Binomial Random Variable

5 Functions of One Random Variable

5-1 The Random Variable g(x) / 5-2 The Distribution of g(x) / 5-3 Mean and Variance / 5-4 Moments / 5-5 Characteristic Functions

6 Two Random Variables

6-1 Bivariate Distributions / 6-2 One Function of Two Random Variables / 6-3 Two Functions of Two Random Variables / 6-4 Joint Moments / 6-5 Joint Characteristic Functions / 6-6 Conditional Distributions / 6-7 Conditional Expected Values

7 Sequences of Random Variables

7-1 General Concepts / 7-2 Conditional Densities, Characteristic Functions, and Normality / 7-3 Mean Square Estimation / 7-4 Stochastic Convergence and Limit Theorems / 7-5 Random Numbers: Meaning and Generation

8 General Concepts

8-1 Definitions / 8-2 Systems with Stochastic Inputs / 8-3 The Power Spectrum / 8-4 Discrete-Time Processes

9 Random Walks

9-1 Random Walks / 9-2 Poisson Points and Shot Noise / 9-3 Autoregressive Processes / 9-4 Moving Average Processes / 9-5 Cyclostationary Processes / 9-6 Brownian Motion / 9-7 Levy Flights / 9-8 Gaussian Processes / 9-10 Levy Processes

10 Spectral Representation

10-1 Factorization and Innovations / 10-2 Finite-Order Systems and State Variables / 10-3 Fourier Series and Karhunen–Löeve Expansions / 10-4 Spectral Representation of Random Processes

11 Spectrum Estimation

11-1 Ergodicity / 11-2 Spectrum Estimation / 11-3 Extrapolation and System Identification / 11-4 The General Class of Extrapolating Spectra and Youla's Parametrization

12 Markov Chains

12-1 Introduction / 12-2 Higher Transition Probabilities and the Chapman–Kolmogorov Equation / 12-3 Classification of States / 12-4 Stationary Distributions and Limiting Probabilities / 12-5 Transient States and Absorption Probabilities / 12-6 Branching Processes

13 Markov Processes

14 Poisson Processes

15 Renewal Processes

76. **Course Name**: Advanced Signal Processing: Methods and Practice 高级信号处理：方法与实践

Credits: 3; 48 teaching hour

Instructors: Huang Shaolun

Text Book (or other supplemental materials): A.V.Oppenheim and R.W. Schafer "Digital Signal Processing", Prentice Hall, 1975.A.V.Oppenheim, A.S.Willsky and L.T.Young, "Signals and Systems", Prentice Hall 1983, 1997

Specific course information: This course covers the signal representation/analysis, especially how to represent the complex signals in simple format either in time or frequency domain. Based on that, it also covers how signals behave after passing through various linear, time-invariant systems. It consists of following individual yet highly related sessions including Introduction, time-domain analysis on the linear, time-invariant systems, signal representation in frequency domain (Fourier analysis & Fourier transform), Laplace Transform, Discrete time-domain signals, Z-Transform, Discrete & Fast Fourier transform, the state space analysis of the linear systems, and etc. This course focuses on the basic theory and analytical method from time-domain to transform domain, from continuous to discrete, from the description of single-input-single-output to the state variables. It will lay down a solid foundation for the further study for courses including Digital Signal Processing, Stochastic Process, Communication Circuit, Principle of Communication.

Specific goals for the course: The signals and systems are the fundamental core courses for the students in EE, which could provide the whole picture in the field of communications systems and signal processing as well as the basic skills for research. It covers the application areas for both communications and control system from signal analysis point of view, with a separate short semester (separate credit) focusing on how to use matlab/Labview/Python to perform the data acquisition, signal processing, optimization etc. at the fundamental level.

Brief list of topics to be covered:

1. A revisit to signals and systems

a. Signal representation and operation

b. Signal transform (Fourier, Laplace, FFT)

2. Advanced signal processing methods

a. Estimation theory, Modern spectral estimation

b. Adaptive filtering

c. Matrix operation and analysis

d. Introduction to convex optimization

3. Modern signal processing methods and practice

a. Sparse signal processing

b. High-dimensional signal processing

c. Blind signal processing

d. Deep learning enabled signal processing

e. Artificial intelligence and its applications in smart systems

4. Implementation and Simulation Platform

a. Matlab, Labview or Python

77. **Course Name**: Nanogenerators and Self-powered Systems 纳米发电机与自驱动系统

Credits: 3, 48 teaching hour

Instructors: Ding Wenbo

Text Book (or other supplemental materials): Zhong Lin Wang, “Nanogenerators for self-powered devices and systems”, Link, https://smartech.gatech.edu/handle/1853/39262; Zhong Lin Wang et al, “Triboelectric Nanogenerators”, Springer, 2016.; Zhong Lin Wang, “Piezotronics and Piezo-Phototronics”, Springer, 2013.

Specific course information: Nanogenerators are the emerging frontier research in the field of nanotechnology and will enable the applications for IoT, human-machine interfacing and etc. This course will introduce the basic principles, structural construction, performance analysis of nanogenerators and self-powered sensing systems based on nanogenerators. The purpose is to enable graduate students to understand the physical mechanism of triboelectric charging and how nanotechnology can convert triboelectric charging into useful currents, expand students' knowledge of physics, enhance their knowledge of cutting-edge nanomaterials and sensor design, and lay the foundation for their subsequent research work.

Specific goals for the course: Nanogenerators are the emerging frontier research in the field of nanotechnology and will enable the applications for IoT, human-machine interfacing and etc. This course will expand students' knowledge of physics, enhance their knowledge of cutting-edge nanomaterials and sensor design, and lay the foundation for their subsequent research work.

Brief list of topics to be covered:

1. Introduction

a. Nanogenrators vs Traditional Generators

b. Self-powered Systems

2. Triboelectric Nanogenrators (TENG)

a. Charge transfer mechanism on Friction Interface based on AFM

b. Contact-separation mode and sliding mode TENG

c. Single-electrode mode and free-standing mode TENG

d. Theoretical model and simulation tools of TENG

e. TENG figure of merit

f. Micro and nano fabrication for TENG

g. 3D printing and fiber based TENG

h. High-performance TENG and power management

i. Ambient energy harvesting for IoT and wearable devices

j. Human-machine interfacing based on TENG and Tribotronics

3. Piezoelectric Nanogenerators (PENG)

a. Working mechanism of PENG

b. Nano-wire array based PENG

c. Brief introduction to Piezotronics and Piezo-Phototronics

b. 2D materials and PENG

e. 3rd Generation Semiconductor

78. **Course Name**: Time series analysis 时间序列分析

Credits: 3, 48 teaching hour

Instructors: KURUOGLU, Ercan Engin

Text Book (or other supplemental materials): [1] Brockwell and Davis, Introduction to Time Series and Forecasting, Springer, Second Edition, 2002. [2] Nielsen, Practical Time Series Analysis: Prediction with Statistics and Machine Learning, O`Reilly, 2019.

Specific course information: This course aims to compensate a missing dimension in Data Science/Machine Learning studies addressing the analysis of data which changes over time, that is time-series. It will provide students with the tools for analyzing time-series data. The course start by building a background on random/stochastic processes and frequency transforms. We will then discuss parametric process models for time-series such as AR, ARMA, etc and provide classical estimation methods. We will then extend the discussion to prediction and forecasting. Unlike classical courses on Time-Series Analysis we will cover also non-stationary time series, introducing methods and transforms. We will also extend multivariate analysis to graph time series. We aim to present also implementations using R or Python.

Specific goals for the course: The new course addressed the time dimension of data analysis and hence provides a missing feature in TBSI curriculum. The students will learn analyzing time-series data using various methods from statistics, signal processing and machine learning, this will give them an edge over other machine learning/data science practitioners.

Brief list of topics to be covered:

1. Time series versus timeless data

a. Examples of applications

b. Inadequacy of classical Machine Learning methods for analysing time-series data

2. Basics of stochastic processes

a. Random variables, random vectors, functions of random vectors

b. Stationarity, wide-sense-stationarity, ergodicity

3. Fourier transform methods

a. Fourier series

b. Continuous-time Fourier transform

c. Discrete-time Fourier transform

d. Discrete Fourier Transform

e. Z-Transform

4. Spectral characterization of stochastic processes

5. Parametric stochastic models for stationary processes

a. Linear regressions

b. Autoregressive (AR) processes

c. Autoregressive-Moving Average (ARMA) processes

d. Polynomial AR (PAR), Polynomial ARMA (PARMA) processes

e. ARIMA processes

f. Fractional ARIMA (FARIMA)processes

6. Estimation methods

a. Least squares estimation

b. Maximum likelihood estimation

c. Yule-Walker equations

d. Wiener filter

e. Box-Jenkins method

f. Bayesian methods

7. Forecasting/prediction

a. Durbin-Levinson algorithm

b. Bayesian prediction

8. Multi-variate time series analysis

a. Vector AR/MA/ARMA Models

b. Forecasting for VAR/VMA/VARMA models

c. Graph time-series

d. Graphs in transform domain

9. Non-stationary processes

a. Time-frequency analysis

b. Wavelet transform

c. State-space models

d. Kalman filtering

e. Extended Kalman Filter (EKF)

f. Unscented Kalman Filter (UKF)

g. Particle Filter

h. Time varying graphs

10. Machine learning for time-series

a. Classification

b. Clustering

11. Deep learning for time-series

a. Deep learning architectures

b. Back propagation

c. adaptive learning

12. Implementation issues

a. Time-series databases

b. Preprocessing data

c. Time-series simulations

Track 3

79. **Course Name**: Design of Precision Medicine Platforms for Disease Diagnosis and Therapeutics 精准医疗平台的设计及其疾病诊断和治疗应用

Credits: 1; 16 teaching hour

Instructors: Ma ShaoHua

Text Book (or other supplemental materials): There is no reference book. It's an introductory course to multiple fields under the concept of precision medicine

Specific course information: This course provides fundamental understandings and introductory advances on the development of precision medicine. The course covers the topics in cancer biology and therapeutics, point-of-care diagnosis, biomarkers, biomicrofluidics and microreactors, biomaterials and biofabrication, organoids, personalised therapeutics, stem cell biology and therapy, molecular genetics and gene therapy, etc.

Specific goals for the course: Students will learn the technologies and fundamental advances in the different fields of precision medicine. The course is an introductory course to different advances, and students are expected to be self-motivated to explore more after the course on specific topics attracting their attention. They are also expected to Understand the practical barriers to clinical implementation of precision medicine and develop strategies to overcome the barriers to allow scalability in a medically responsible manner.

Brief list of topics to be covered:

80. **Course Name**: Translational Research(C) 转化研究（C)

Credits: 1; 16 teaching hour

Instructors: Ma Lan

Text Book (or other supplemental materials): none

Specific course information: For the part I, introduce students to the general and technical aspects of noninvasive cancer markers. It covers imaging, cutting-edge molecular technologies for biomarker development, and noninvasive or minimally invasive sources of molecular markers, as well as quality control and ethical issues in cancer biomarker discovery. For the part II, introduce students to the use of nanotechnology in diagnostics ranging from single molecule diagnostics to cell based systems.

Specific goals for the course: For the part I, introduce students to the general and technical aspects of noninvasive cancer markers. It covers imaging, cutting-edge molecular technologies for biomarker development, and noninvasive or minimally invasive sources of molecular markers, as well as quality control and ethical issues in cancer biomarker discovery. For the part II, introduce students to the use of nanotechnology in diagnostics ranging from single molecule diagnostics to cell based systems.

Brief list of topics to be covered:

Chapter 1 General and Technical Aspects for cancer diagnostics（6 class hours）

1.1 Cancer Biomarker Discovery（3 class hours）

1.1.1 Introduction of Cancer Biomarkers and their applications（0.5 class hour）

1.1.2 Types of Cancer Biomarkers（0.5 class hour）

1.1.3 Technologies for discovery of Cancer Biomarkers（1 class hour）

1.1.4 Quality Specifications for Caner Biomarker Assays（0.25 class hour）

1.1.5 FDA Critical Path Initiative and Biomarker R&D（0.25 class hour）

1.1.6 From Validated Biomarker Assay to a Clinical Laboratory Diagnostic（0.5 class hour）

1.2 Innovative Technologies for Early Detection of Cancer（3 class hours）

1.2.1 Molecular Fingerprinting of Cancer（0.25 class hour）

1.2.2 Biomarkers of Inflammation in Cancer（0.25 class hour）

1.2.3 Omics for the Early Detection of Cancer（1 class hour）

1.2.4 Mitochondrial DNA in Early Cancer Diagnosis and Screening（0.25 class hour）

1.2.5 Circulating miRNA Biomarkers in Various Solid Cancers（0.25 class hour）

1.2.6 Salivary Biomarkers in Early Diagnosis and Monitoring of Cancer（0.5 class hour）

1.2.7 Stem Cell Biomarkers in Early Diagnosis, Prognosis, and Therapy of Cancer（0.5 class hour）

Chapter 2　Nanomedicine in Diagnostics（10 class hours）

2.1　Nanobiotechnology　（3 class hours）

2.1.1 Nanomaterials for Biolabeling　（0.5 class hour）

2.1.2 Nanoproteomics and Biomarkers（0.5 class hour）

2.1.3 Nanoparticles for Molecular Imaging　（0.5 class hour）

2.1.4 Nanoparticles for Discovering Biomarkers　（0.5 class hour）

2.1.5 Nucleoprotein Nanodevices for Detection of Cancer Biomarkers（0.5 class hour）

2.1.6 Future Prospects of Application of Nanobiotechnology for Biomarkers（0.5 class hour）

2.2　Noninvasive Nanodiagnostics for Cancer（7 class hours）

2.2.1 Biotechnology-Utilized Nanopore for Single-Molecule Investigation（1 class hour）

2.2.2 Self-assembled Peptide and Protein Nanostructures in Diagnosis（1 class hour）

2.2.3 Biosensors for Diagnostics（2 class hours）

2.2.4 Electrochemical Sensor Systems for Medicine（1 class hour）

2.2.5 Emerging Nanotechnology for Efficient Capture of Circulating Tumor Cells（1 class hour）

2.2.6 Nanomedicine Technologies for Cell-Based Drug Screening（1 class hour）

81. **Course Name**: Introduction to Mechanobiology　机械生物学介绍

Credits: 2; 32 teaching hour

Instructors: Ma Shaohua

Text Book (or other supplemental materials):　Introduction to Cell Mechanics and Mechanobiology, edited by C. R. Jacobs, H. Huang, R. Y. Kwon, publhed by Garland Science. 2012.

Specific course information: This course provides fundamental understanding in the decisive roles of mechanical forces during development of tissues and organs, during remodelling following injury as well as in normal function. The course covers: mechanical properties of cytoskeletal polymers; mechanical properties of the cell membrane; roles of matrix mechanical properties on cell adhesion and function; effects of mechanical loading on cell cytoskeletal remodelling; mechanical testing of cell-populated matrices; cell migration behaviour in 3D matrices; roles of mechanics in cartilage development; roles of both cellular and external forces on tissue morphogenesis; roles of mechanical forces on tumour growth and cancer metastasis.

Specific goals for the course: This course is to provide perspectives on how cells are regulated by physical cues from their environment. Biological organisms are surrounded by forces like shear stresses, blood pressure, forces generated when you move your arms, stretch your skins, and also gravity of bone and cartilage. These forces work both in the macroscopic and microscopic levels. In recent years, mechanical signals have become widely recognized as being critical to the proper functioning of numerous biological processes.

Brief list of topics to be covered:

Part I. Basic Mechanics

- Introduction – Cell mechanics and human disease
- Solid mechanics
- Fluid mechanics
- Statistical mechanics
- Mechanics at the nanoscale

Part II. Cellular mechanics

- Fundamentals in cell biology
- Cellular micromanipulation and measurement of forces produced by cells
- Mechanics of biopolymers
- Mechanics of cytoskeleton
- Mechanics of the cell membrane
- Adhesion, migration and contraction
- Cellular mechanotransduction

Part III. Tissue Mechanics

- Cell-matrix interactions
- Mechanics of cell-seeded ECM scaffolds
- Cell mobility in 3D matrices

Electromechanical and physicochemical properties of tissues
Connective tissue development
Mechanics of tissue morphogenesis
Continuum physics of tumour growth
Cell force-mediated collagen remodelling in cancer metastasis

82. **Course Name**: Technology Advances for Regenerative Medicine 再生医学技术进展

Credits: 3, 48 teaching hour

Instructors: Ma Shaohua

Text Book (or other supplemental materials): [1] Principles of Tissue Engineering, 4th ed, edited by Robert Lanza, Robert Langer, Joseph P. Vacanti Academic Press. 2013 [2] Yoshiki Sasai, Next-Generation Regenerative Medicine: Organogenesis from Stem Cells in 3D Culture, Cell Stem Cell, 2013, 12, 520. [3] Sean V Murphy, Anthony Atala, 3D bioprinting of tissues and organs, Nature Biotechnol 2014, 32, 773-785.

Specific course information: The science of regenerative medicine and, in particular, the design of intelligent biomimetic materials that are capable of interacting with their biological environment have been evolving rapidly in the last two decades. Regenerative medicine uses a combination of approaches, including biomedical materials science, gene therapy, stem cell transplantation, tissue engineering and mechanical engineering. The overall course is designed to develop key research-based skills and, in particular, prepare students with knowledge of this rapidly evolving science and industry. Various processes on the cellular, tissue and organ levels will be used as illustrative examples to highlight conserved principles governing tissue repair and regeneration. The students will learn about technological breakthroughs in stem cell therapy, biotechnology, bio-inspired materials and genetic studies. This course will introduce the latest methods in regulating and modulating the biological, chemical and mechanical properties in novel bioengineered constructs, obtaining functional organ mimics.

Specific goals for the course: The objective is to provide students with current scientific and technological advances of this exciting field which explores the repair, regeneration, or replacement of damaged tissues and failed organs. The student will examine the underlying principles of the normal processes of repair and regeneration in humans. The student will be able to integrate their prior knowledge of cell and molecular biology, tissue engineering and mechanobiology to rationalize and practice regulation of the repair and regeneration of tissues and organs.

Brief list of topics to be covered:

1. Introduction to regenerative medicine (6 class hours)
    1.1. The basis of growth and differentiation
    1.2. In vitro control of tissue development
    1.3. In vivo synthesis of tissues and organs
2. Introduction to human systems (12 class hours)
    1.1. Breast
    1.2. Liver
    1.3. Cardiovascular system
    1.4. Gastrointestinal system
    1.5. Musculoskeletal system
    1.6. Nervous system
    1.7. Skin
    1.8. Group presentation
3. Technologies developed for regenerative medicine (15 class hours)
    1.1. Stem cell therapy
    1.2. iPSCs and organoids
    1.3. Gene therapy
    1.4. Biomaterials design
    1.5. 3D bioprinting and biofabrication
    1.6. Challenges in regenerative medicine
    1.7. Group presentation
4. Laboratory and clinical imaging (3 class hours)
5. Group presentations (12 class hours)
    1.1. Case study at laboratory levels
    1.2. Case study – pushing laboratory development towards clinical applications

83. **Course Name**: Introduction of biophotonics 生物光子学方法与实践

Credits: 3, 48 teaching hour

Instructors: Ma Hui, Gerard Marriott, Seung-Wuk Lee, He Yonghong

Text Book (or other supplemental materials): none

Specific course information: Introduction of biophotonics is a multidisciplinary course which can serves as a mandatory core course for graduate students of life science major, or an elective course for those from other related majors such information technology and manufacturing. The course includes brief introductions on the basic physics for photon-matter interactions and the corresponding physics observables, on different biophotonics sensing and imaging techniques which retrieve these observables and disentangle the encoded information on the structure and dynamics of the biological system, and on typical applications of these techniques in both biomedical and other related fields. The course includes laboratory practice which allows the students to know the essential hardware modules and the data processing techniques of biophotonics imaging and sensing apparatus, such as light sources, optical components, detectors, data processor and displays. The students will be prepared to incorporate into their own work the latest technological advances in optics and related fields, such as cloud computing and big data..

Specific goals for the course: This course is multidisciplinary and combines lecturing with seminars and discussions. The students will not only learn about the principles, experimental techniques and applications of biophotonics, but also be exposed to the latest progresses in frontier researches by the PIs of TBSI as well as the latest technological advances in optics and related fields, such as GPU, cloud computing and big data technologies.

Brief list of topics to be covered:

课程教学（22 学时）

1. 生物医学光学基础知识（2 学时），

1.1 生物医学光学概念、目标、方法与需求

1.2 生物医学光学实验基本装置与器件

2. 光学相互作用与生物医学光学基本方法（I）（2 学时）

2.1 光的吸收以及后续过程，包括荧光、电离、解离和无辐射弛豫

2.2 基于光吸收的各种测量方法。

3. 光学相互作用与生物医学光学基本方法（II）（2 学时）

3.2 光的散射，非线性光学

3.2 基于光散射和非线性过程的各种测量方法

4. 基于弹性散射的成像方法 （I）（2 学时）

4.1 光学相干层析方法

5. 基于弹性散射的成像方法 （II）（2 学时）

5.1 浑浊介质中光的传播

5.2 扩散光子成像方法，FMT，BLT

6. 基于弹性散射的成像方法 （III）（2 学时）

6.1 光的偏振与表征

6.2 偏振光学成像方法

7. 基于吸收作用的生物医学光学方法与技术（2 学时）

7.1 分子荧光与荧光成像技术

8. 基于吸收作用的生物医学光学方法与技术（2 学时）

8.1 光声成像技术

9. 喇曼光谱技术与成像（2 学时）

9.1 喇曼光谱技术

10. 生物光子学探针（2 学时）

10.1 荧光探针与纳米量子点

10.2 探针生物兼容性与表面改性方法

11. 生物传感技术（2 学时）

11.1 超灵敏传感

11.2 高通量筛选

实验教学（10 学时）：

1. 生物医学光学中光源、探测器的使用与熟悉（2 学时）

自制简易光栅光谱仪

2. 生物医学干涉测量（2 学时）

调试光学相干层析装置

3. 生物医学偏振测量（2 学时）

调试偏振成像装置

4. 生物医学共焦成像实验（2 学时）

调试共焦荧光扫描显微装置

5. 生物医学荧光探针实验（2 学时）

观测纳米材料对荧光检测的影响

84. **Course Name**: Introduction to Computer-Aided Tissue Engineering 计算机辅助组织工程

Credits: 2; 32 teaching hour

Instructors: Sun Wei, Mi Shengli

Text Book (or other supplemental materials): 1)Principles of CAD/CAM/CAE Systems", by Kunwoo Lee, Addison-Wesley, latest edition 2)"Principle of Tissue Engineering", R. Lanza, R. Langer, and W. Chick, R.G. Landes Company and Academic Press, Inc., Latest edition 3) "Biomechanics: Mechanical Properties of Living Tissue", Y.C. Fung, Springer, New York, Latest edition

Specific course information: Introduction to Computer-Aided Tissue Engineering (CATE) is designed for graduate and senior undergraduate students in engineering and bioengineering major who are interested in acquiring the knowledge and skill in utilizing computer-aided technologies for tissue engineering application. The course will introduce: 1) the engineering and bioengineering aspect of tissue regeneration; 2) basics of computer-aided design, computer-aided engineering, and computer-aided manufacturing (CAD/CAM/CAE); 3) knowledge on the use of integrated CAD/CAE/CAM technology in tissue engineering application; and 4) a hand-on experience on using enabling CAD, medical imaging processing and three-dimensional reconstruction software, and 3D Printing technology for tissue scaffold design, modeling, simulation, and freeform fabrication.

Specific goals for the course: Introduction to Computer-Aided Tissue Engineering (CATE) is designed for graduate and senior undergraduate students in engineering and bioengineering major who are interested in acquiring the knowledge and skill in utilizing computer-aided technologies for tissue engineering application..

Brief list of topics to be covered:

讲课（共 22 学时）：

1. Introduction to CAD, CAD/CAM, cellular biology and tissue engineering;
2. Introduction to Computer-Aided Tissue Engineering(CATE);
3. Non-invasive Imaging (CT/MRI) Based 3D Reconstruction;
4. Biomodeling;
5. Biomimetic Design of 3D Tissue Scaffolds;
6. Bio-additive Manufacturing for Tissue Scaffold Fabrication;
7. Cell and Organ Printing;
8. Emerging application of CATE: Biofabrication of in vitro 3D biological model
9. Emerging Application of CATE: other topic

实验（共 6 学时）：

1. Basic cell-scaffold biological study;
2. Tissue scaffold design and fabrication;
3. Biomechanical testing of 3D constructs.

85. **Course Name**: Translational Research (B)）转化研究（B）

Credits: 1; 20 teaching hour

Instructors: Wu Yaojiong

Text Book (or other supplemental materials): [1] Essentials of Stem Cell Biology, Third Edition by Robert Lanza, John Gearhart, Brigid Hogan and Douglas Melton (2013-11) [2] Stem Cells: Scientific Facts and Fiction, Second Editon by C. Mummery, A. van de Stolpe, B. Roelen, H. Clevers (2014)

Specific course information: Stem cells can self-renew and differentiate into a variety of specialized cells. Regenerative medicine studies the function of stem cells in organ formation, tissue repair and methods to use stem cells to create de novo tissues and organs. The format of this course includes lecturing, literature discussion, laboratory experiments and essay writing. The aim of the course is to give students a comprehensive view of the basic knowledge, fundamental methods, milestone discoveries, and challenges in stem cell research and regenerative medicine.

Specific goals for the course: We are entering a new era in which a fundamental understanding of the biology of stem cells and their role in tissue regeneration and organogenesis is of critical significance. In this course, embryonic stem cells, iPS cells and adult stem cells in different organs are examined in terms of their molecular and cellular properties and their therapeutic potentials in particular.

Brief list of topics to be covered:

1. Introduction to stem cells: basic concepts: self-renewal and differentiation, differentiation potential

2. High resolution fluorescence microscope technologies to control the stem cell microenvironment and to image molecular events in stem cell differentiation (Professor Gerard Marriott, Berkeley)

3. iPSC and cell phenotypic conversion: Somatic Cell Nuclear Transfer (SCNT), generation of iPSC in vitro, generation of iPSC in vivo, significance of iPSC, applications of iPSC, challenges in iPSC research, cell phenotypic conversion in regenerative medicine

4. Somatic Stem Cells: concept of adult stem cells, introduction to hematopoietic stem cells, endothelial progenitor cells, mesenchymal stem cells, neural stem cells, cardiac stem cells

5. Stem cell regeneration and therapy in eye development and diseases for now (Professor Xiaohua Gong, Berkeley)

6. Isolation of stem cells from tissues: strategies and basic methods

7. Stem cell niche and rejuvenation

8. Mechanical control of stem cell self-renewal and differentiation (Professor Song Li, Berkeley)

9. Stem cells in tissue regeneration

10. Stem cells in tissue engineering and organogenesis

11. Stem cell transplantation: trafficking, migration and engraftment

12. Cancer stem cells

13. Lab experiments: characterization of stem cells; stem cell differentiation; isolation of stem cells from tissues

86. **Course Name**: Introduction to Advanced Medical Device Design and Fabrication 高端医疗器械设计及制造概论

Credits: 1; 16teaching hour

Instructors: Xu Tao

Text Book (or other supplemental materials): [1] Design of Biomedical Devices and Systems, Third Edition. Paul H. King, Richard C. Fries, Arthur T. Johnson. CRC Press [2] Medical Device Design: Innovation from concept to market, First Edition. Peter J Ogrodnik. Academic Press

Specific course information: Introduction to Advanced Medical Devices Design and Fabrication(AMDDF) is designed for graduate and senior undergraduate students in engineering and bioengineering major who are interested in acquiring the knowledge and skill in advanced medical device technologies and their applications. The course will cover: 1) the engineering and biology aspects and fundamentals of advanced medical devices; 2) basics of design, engineering, and fabrication of In-vitro diagnostics, advanced medical imaging systems, and implants; the development procedures and evaluation methodologies of medical devices; and 4) the quality controls and regulations of medical devices in different countries and regions.

Specific goals for the course: 高端医疗器械为生物制造学科的重要内容和应用。本课程目的在于培养学生在高端医疗器械设计和制造中问题分析和解决的能力，特别是注重开发学生挖掘和运用先进工程技术和方法解决疾病诊断及治疗等有关人类健康问题。通过课程讲授、课程研讨、实践、课程报告等环节，学生能够较为系统了解高端医疗器械设计及制造的基本原理和知识，重点包括体外诊断、高级影像、植入式、穿戴式器械设计和制造。课程也注重对加强学生对本领域高端器械技术转化特别是开发流程及注册法规了解，为后续学生进入医学工程相关产业及临床应用奠定一定知识基础。同时，此课程与采用全英文教学，通过课程设置的各环节，提高学生的英文听说读写能力。

Brief list of topics to be covered:

1. 高端医疗器械简介（2 学时）（Introduction to advanced medical devices）
   a) 医疗器械的发展历史，与药物类产品不同 (History of medical devices, difference from phamacetical drug treatment)
   b) 医疗器械 ISO 定义及各国分类标准 (ISO definition of medical devices and classifications at different countries and regions)
2. 体外诊断医疗器械设计与制造（2 学时）(Design and fabrication of in-vitro diagnostics IVD)
   a) 蛋白诊断器械 (Protein based IVD)

b) 基因诊断器械 (Gene based IVD)

3. 成像医疗器械设计原理（2 学时）(Design of medical imaging systems)
   a) CT 原理及设计基础 (CT fundamentals and design)
   b) MRI 原理及设计基础 (MRI fundaments and design)
4. 植入式医疗器械设计与制造（2 学时）(Design and fabrication of implantable medical devices)
   a) 组织修复及再生基础 (Basis of tissue repair and regeneration)
   b) 植入式设计原理 (Designing factors of implants)
   c) 植入式器械制造 (Fabrication of implants)
5. 医疗器械开发流程（2 学时）(Development procedure and protocol of medical devices)
   a) 设计输入 (Design input)
   b) 设计输出 (Design output)
   c) 设计验证 (Design verification)
6. 医疗器械评价体系（2 学时）(Evaluation of medical devices)
   a) 安全性评价（理化、生物学评价等）(Safety evaluation)
   b) 有效性评价（动物及临床评价等）(Effectiveness evaluation)
7. 质量体系建设和注册法规（2 学时）(Quality control system and regulatory affairs)
   a) ISO 及 GMP 质量体系 (ISO and GMP quality control)
   b) FDA，欧盟及中国注册法规 (Medical Regulations of US FDA, European CE, and Chinese FDA)

实验及实践（共 4 学时）(Practices)

参观相关临床或者产业化单位 (Tour to clinical settings or medical device industry)

87. **Course Name**: Tissue Engineering 组织工程

Credits: 1; 16 teaching hour

Instructors: Song Li

Text Book (or other supplemental materials): none

Specific course information: The goal of tissue engineering is to fabricate substitutes to restore tissue structure and functions. Understanding cell function in response to environmental cues will help us to establish design criteria and develop engineering tools for tissue fabrication. The objectives of this course are: (1) To introduce the basics of tissue engineering, including quantitative cell and tissue characterization, 3D fabrication, extracellular matrix and biomaterials, and immuno-modulation/isolation; (2) To illustrate the cutting-edge research in tissue engineering; (3) To build up the skills in analyzing and designing engineered tissue products.

Lectures will be based on the reference books and recent literature. Students will have opportunities to interact with faculty and learn the basic theory and lab skills, as well as the state-of-the-art in this field.

Specific goals for the course: none

Brief list of topics to be covered:

Day 1. Tissue engineering and tissue regeneration

Day 2. Cell engineering / Cell culture lab

Day 3. Biomaterials / Biomaterials lab

Day 4. Scaffold guided tissue engineering and 3D fabrication / 3D printing lab

Day 5. Class presentation / Design project

88. **Course Name**: Soft Material Module 1: Biological Soft Materials 软质材料模块1：生物软质材料

Credits: 1; 16 teaching hour

Instructors: Seung-Wuk Lee

Text Book (or other supplemental materials): none

Specific course information: This course is designed for students to gain a fundamental understanding in the soft matter, biomaterials and their application toward biomaterials. Beginning with a brief introduction of the principles governing polymer and biomacromolecule's phase behavior in bulk, in thin films and at interfaces, the characterization techniques to assess their behavior under biologically relevant conditions, the course will provide general knowledge critical for students to build fundamental knowledge in how to design, engineering and validate biomaterials relevant to nanotechnology and biotechnology.

Specific goals for the course: none

Brief list of topics to be covered:

Module 1: Biological Soft Materials

-Bio-Inspired Nanotechnology

Bio-inspired nanoscience

Biomineralization of sea shells, diatoms, sponges

-DNA Based Materials

Basic structure of DNA and their properties

DNA based nanostructures

DNA based nanomachines

-Peptide Based Materials

Basic structure of amino acids, peptides, proteins and their properties
Principle of peptide nanostructure assembly
Peptide amphiphiles nanostructure and application

-Protein Based Materials

Basic principle of genetic engineering.
Functional protein nanostructure design and preparation

-Virus/Cell Based Materials

Structure of viruses/ Virus based functional nanostructure
Combinatorial approaches for functional protein development

89. **Course Name**: Soft Material Module 2: Synthetic and Hybrid Soft Materials 软质材料模块 2: 合成、混合软材料

Credits: 1; 16 teaching hour

Instructors: Ting Xu

Text Book (or other supplemental materials): none

Specific course information: This course is designed for students to gain a fundamental understanding in the soft matter, biomaterials and their application toward biomaterials. Beginning with a brief introduction of the principles governing polymer and biomacromolecule's phase behavior in bulk, in thin films and at interfaces, the characterization techniques to assess their behavior under biologically relevant conditions, the course will provide general knowledge critical for students to build fundamental knowledge in how to design, engineering and validate biomaterials relevant to nanotechnology and biotechnology.

Specific goals for the course: none

Brief list of topics to be covered:

Module 2: Synthetic and Hybrid Soft Materials

- Basics of polymer

Polymer basics
Polymer characterization

- Polymer chemistry

Polymerization
Controlled synthesis of polymers

- Polymer physics

Amorphous polymer
Semicrystaline polymer
Polymer of controlled architecture

- Polymeric nanostructures

Block copolymer
Polymer-based nanostructure fabrication
- Polymers for biomedical applications
Polymers for diagonosis
Polymers for therapuetics

90. **Course Name**: Soft Material Module 3: Fabrication of Biomaterials 软质材料模块 3：生物材料制造工程

Credits: 1; 16 teaching hour

Instructors: Xu Tao

Text Book (or other supplemental materials): none

Specific course information: This course is designed for students to gain a fundamental understanding in the soft matter, biomaterials and their application toward biomaterials. Beginning with a brief introduction of the principles governing polymer and biomacromolecule's phase behavior in bulk, in thin films and at interfaces, the characterization techniques to assess their behavior under biologically relevant conditions, the course will provide general knowledge critical for students to build fundamental knowledge in how to design, engineering and validate biomaterials relevant to nanotechnology and biotechnology.

Specific goals for the course: none

Brief list of topics to be covered:

Module 3: Fabrication of Biomaterials

-Fabrication of metallic and ceramic biomaterials
Machining, CAD & CAM
Sintering, coating
Lasing engraving for cardiovascular stent
Additive manufacturing for customized implant

-Fabrication of polymeric biomaterials
Solvent casting
Weaving & knitting
Molding
Nanofabrication

-Fabrication of natural biomaterials
Gelling and crosslinking
Freeze-drying process
Decellularization

-Bio-compatibility, evaluation of medical devices, and clinical trials

Bio-compatibility
Safety and efficacy evaluations for medical devices
Design criteria of clinical trials for medical devices

-Lab work for biomaterial fabrication

-Regulatory affairs, commercialization of biomaterials products,

FDA and CFDA regulations of medical devices
Basic steps of implant commercialization
On-site visit to biomaterial industry

91. **Course Name**: Vision and Imaging Science 视觉及影像科学

Credits: 1; 16 teaching hour

Instructors: Gong Xiaohua

Text Book (or other supplemental materials):none

Specific course information: This is a 1-unit graduate level course about the eye vision research and imaging technology for understanding modern basic and translationalresearch.The course will review current knowledge and technological tools in cell and development biology, genetics, stem cell, tissue engineering and molecular and cellular imaging. Recent progress in biomedical detection and imaging as well as innovative approaches for the future will be explored. The primary goal of the course is to better prepare students for research activitiesin academia or industry. The focus is to promote their ability in research development and creative thinking. The course provides specific information to address students'research interests and assessments.

Specific goals for the course:none

Brief list of topics to be covered:

Total 4 Topics for lecture and discussion:

1) Vision and eye development and diseases

Anatomy and development of the eye

Eye diseases and vision disorders

2) Genetics and imaging research

a) Genetics and animal models

b) Imaging living multicellular tissue

3) Tissue engineering and blindness treatment

a) Ocular surface reconstruction using stem cell and tissue engineering

b)Cell transplantation in blindness treatment

4) Modern biomedical detection and imaging in vision science

a) Quantitative analysis of optical coherence tomography (OCT)

b) Imaging mass spectrometry of the visual system

92. **Course Name**: Current Topics in Cancer Biology 癌症生物学的研究现状

Credits: 3; 48 teaching hour

Instructors: Peter Lobie

Text Book (or other supplemental materials): 1. Weinberg, RA. The Biology of Cancer, Second Edition. Garland Science 2013. 2. Kerr DJ, Haller DG, van de Velde CJ, Baumann M. Oxford Textbook of Oncology. Oxford University Press. Third Edition. 2015 3. As provided by instructor.

Specific course information: Cancer is a heterogeneous multitude of diseases of varying aetiology. It is characterized by aberrant cell proliferation and survival combined with the propensity to invade surrounding tissues and metastasize to distant organs with metastatic complications being the predominant cause of mortality. The science of, and therapeutic approaches in oncology encompass multiple interdisciplinary approaches. These include genomics and proteomics, gene therapy, cell and organ biology, medicine, materials science, pharmaceutical chemistry and bioengineering among others. The aims of this course are multiple: (1) To improve students basic and clinical understanding of the disease; (2) To introduce students to relevant and topical areas of research interest in cancer; (3) To develop the analytic capacity of the students to identify areas of unmet research need in cancer; (4) To train students to confidently present, question and discuss science in both a formal and informal context.

Specific goals for the course: Cancer is one of the most prevalent diseases of contemporary society. The aims of this course are multiple: (1) To improve students basic and clinical understanding of the disease; (2) To introduce students to relevant and topical areas of research interest in cancer; (3) To develop the analytic capacity of the students to identify areas of unmet research need in cancer; (4) To train students to confidently present, question and discuss science in both a formal and informal context.

Brief list of topics to be covered:

1. Introduction to the course and basic oncology (3 class hours)

2. Student seminars and discussion on major cancer systems (6 class hours)

2.1 Breast

2.2 Liver

2.3 Lung

2.4 Gastric

2.5 Colon

2.6 Skin

2.7 Endometrial

2.8 Prostate

3. Presentation and discussion of current topics in Oncology (24 class hours)

Content will be determined annually based on published literature to ensure the course stays updated and relevant.

4. Discussion and presentation of proposals of unmet research needs in Oncology (15 class hours)

93. **Course Name**: fMRI physics and practical data analysis 磁共振成像物理原理与数据分析

Credits: 3; 48 teaching hour

Instructors: Qin Peiwu

Text Book (or other supplemental materials): Huettel, S. A., A. W. Song, and G. McCarthy. Functional Magnetic Resonance Imaging. 1st edition. Sunderland, MA: Sinauer Associates, Inc., 2004. ISBN: 9780878932887. Note: The 2nd edition of this book was published after the Fall 2008 term, and Dr. Gollub recommends its use. Huettel, S. A., A. W. Song, and G. McCarthy. Functional Magnetic Resonance

Imaging. 2nd ed. Sunderland, MA: Sinauer Associates, Inc., 2009. ISBN: 9780878932863. This book will be supplemented by readings in the research literature and other books

Specific course information: fMRI, one of the most developed form of neuroimaging technology, allows noninvasive assessment of brain activity and function. Imaging phenotype is critical for precision medicine in the brain due to the complex nature of brain diseases. In this course, I will introduce the basic physical principle of fMRI imaging, statistical method for data analysis, and the python programming for the implementation to analyze fMRI data.

Specific goals for the course: The goal of this course is to teach fMRI principles and python programing to analyze the fMRI data with linear regression. The students with diverse background come to TBSI and I will assume most students without any background of fMRI. I will try to build up the physics principle and statistical analysis step-by-step and gradually lead them into advanced topic like machine learning for fMRI data analysis.

Brief list of topics to be covered:

1. Introduction to fMRI

1.1 Quantum mechanics basics: operator, Hamiltonia, angular momentum, particle in 3D box

1.2 Fourier transformation, 1D and 2D NMR, coherence, chemical shift.

1.3 Free induction decay, proton relaxation, analysis of basic pulse sequence with angular momentum

2: Pulse Sequences and image Contrast.

2.1 Creating a MR Image

2.2 BOLD fMRI Imaging

2.3 Functional Localization of Activation using BOLD fMRI: Limits on Resolution, Understanding refractory effects

2.4 Spatial and Temporal Properties of BOLD fMRI, Effects of sampling upon functional images

3. python programing and Github.

3.1 Installation of python and Github

3.2 Collaboration with Github

3.3 version control and diagnostics

3.3 Python module：numpy, pandas and nibabel

4 Statistical method for data analysis

4.1 convolution and correlation

4.2 regression and general linear model

4.3 diagnostics using principle component analysis

4.41D interpolation and slice timing

4.5 optimization, 2D interpolation and registration

4.6coordiate systems and cross modality registration

4.7 registration between subjects

4.8 smoothing and modeling

4.9 random effects, choosing models

4.10 statistical inference

94. **Course Name**: Experimental biology 实验生物学

Credits: 3; 48 teaching hour

Instructors: Qin Peiwu

Text Book (or other supplemental materials):

Specific course information: This course is intended to provide a comprehensive and hands-on training on fundamental experimental skills and theoretical background behind. Students will learn the basic biological experimental skills including cell culture, cell storage, virus packing, virus transduction, gene cloning, DNA gel, protein expression, purification, characterization, protein gel, FPLC, et al. Each week's session will be composed of a 2.5-hour lectures and 5-hour laboratory. Students will be arranged into 2-3 groups and perform three independent lab section. After they completed each section, they will switch to next section to learn all the fundamental biology techniques. As this is a graduate course, grades will reflect a certification of training, rather than a competition between students.

Specific goals for the course: Fundamental experimental skills are important for any biomedical research including cell culture, cell line generation, virus packaging, gene cloning, plasmid construction, protein expression, purification, and characterization, protein ligand binding, cell imaging, image analysis. I will cover both theoretical and experimental parts of these fundamental skills, so our students including non-biologists can understand biological questions and techniques better. The objective of this course is to learn fundamental biology and experimental skills.

Brief list of topics to be covered:

1. Cell composition, structure, and function

1.1 History and milestone of cell biology

1.2 Cell structure and function

1.3 Organelle structure and function

1.4 Cell biology techniqes

1.5 Lab section on cell biology techniques

2. Gene expression and chromosome architecture.

2.1 Gene transcription and regulation

2.2 Chromosome structure

2.3 Chromosome architecture and gene transcription and cell lineage

2.4 Introduction to molecular biology techniques

2.5 Lab section of molecular biology

3 Protein translation, structure, function, and posttranslational modification

3.1 Amino acid and protein structure

3.2 Relationship of protein structure and function

3.3 Protein structure techniques

3.4 Protein biochemistry and biophysics method

3.5 Lab on protein biochemistry and biophysics

95. **Course Name**: The molecular basis of cancer 癌症的分子学基础

Credits: 3; 48 teaching hour

Instructors: Vijay K. Pandey

Text Book (or other supplemental materials): In lectures, peer-reviewed research articles, reviews, and supportive material will be suggested for relevant topics

Specific course information: Introduction to the molecular basis of cancer covers current concepts and knowledge of cancer. This course will educate students on various genetic and molecular changes normal cells undergo during the transformation into malignant cancer cells. This course will explore the cellular and molecular mechanisms underlying cancer development with the aim of understanding how changes in the normal growth and division processes lead to the formation of tumors. Topics include the oncogenes, tumor suppressors, cell cycle regulation, DNA repair mechanisms, epigenetic changes, cellular immortalization, tumorigenesis, angiogenesis, metastasis, and current therapeutic approaches to cancer treatment.

Specific goals for the course: Students will gain knowledge of tumorigenesis, learn the molecular and cellular basis of cancer progression, sharpen their critical thinking skills, and gain insight into the cellular and molecular basis of disease. Students will be able to: describe the six hallmarks of cancer, explain the types of gene mutations possible and how these mutations can contribute to cancer formation, describe an oncogene or tumor suppressor and why its function is important in cancer development, learn how cancer cells escape cell death and explain current approaches in cancer treatment.

Brief list of topics to be covered:

Lecture	Date/ time	Topics	Objectives
1		1. Introduction to the course 1.1 Historical perspective 1.2 Overview of the hallmarks of cancer	What types of cellular processes go awry in the transformation of normal cells to cancerous cells? What evidence indicates that tumors arise from normal tissues in a multi-step process?

2		2. Genetic abnormalities 2.1 Alteration in chromosomes 2.2 Mutations	What is a mutation, and what are some of the ways that mutations arise? What evidence indicates that cancer is caused by mutations? Since cancer is not an "infectious" disease, in what ways do viruses contribute to the cause of cancer?
3		3. Role of growth factors and receptors 3.1 Proto-oncogenes and oncogenes 3.2 An altered growth factor signaling 3.3 The Src protein functions as a tyrosine kinase	What is an oncogene, and in what ways can a proto-oncogene be activated? What are the mechanisms of growth factor receptor activation? In what ways do growth factor receptors contribute to cancer?
4		Student-led presentations/discussions/assignments	
5		5. MAPK/ERK signaling in cancer 5.1 The Ras protein 5.2 Tyrosine phosphorylation 5.3 Ras-regulated signaling pathways 5.4 Tumor suppressor genes and proteins function in diverse ways	In what ways can oncogenic activation of RAS contribute to the development of cancer? What is a tumor suppressor gene, and how may one become inactivated? Why do tumor suppressors typically function as recessive alleles, while oncogenes are usually dominant?
6		6. Cell cycle regulation and apoptosis 6.1 Cell cycle regulators 6.2 pRB and control of cell cycle clock 6.3 p53 and program cell death 6.4 DNA damage and deregulated growth signals	What is the role of pRB in the cell cycle, and how does the disruption of the cell cycle contribute to the development of cancer? What is the role of p53 in the regulation of DNA repair and apoptosis? How does the loss of p53 contribute to the development of cancer?

96. **Course Name**: The Immunology of Emerging Infectious Diseases 新兴传染病的免疫学

Credits: 3; 48 teaching hour

Instructors: Edwin Leeansyah

Text Book (or other supplemental materials):

Specific course information: Immunology underpins virtually every aspect of human health and disease, incl. in infectious diseases. This course will provide students with a fundamental understanding in immunology and infectious diseases in the context of modern societies. Students will learn about the immune system and how it can fight infection, and how an immune response can fail and contribute to severe disease outcomes in infectious diseases settings. Students will learn examples of different types of clinically relevant infectious agents and the type of immunity they activate. In addition, students will learn how infectious agents can overcome the natural immune response and cause disease. Importantly, students will learn about recent emerging infectious diseases of human health significance and the immune response toward these novel infectious diseases, exemplified by the novel 2019 coronavirus disease. The course will also illustrate how the immune response against these agents can be manipulated through the use of vaccines, incl. in host-directed immunotherapy which is becoming an increasingly important and relevant component in precision medicine and healthcare.

By the completion of the course, students are expected to have a fundamental knowledge in immunologic processes during the course of infectious diseases incl. those caused by emerging infectious diseases, and in relevant and topical areas of research interest in immunology and emerging infectious diseases. Moreover, students are expected to develop the analytic capacity to identify areas of unmet research need in immunology of emerging infectious diseases, and to confidently present, question, and discuss science in both a formal and informal context among peers.

Specific goals for the course: Immunology underpins virtually every aspect of human health and disease, particularly in infectious diseases. There are multiple emerging infectious diseases of human health significance in recent history, exemplified by the 2019 novel coronavirus disease pandemic. The immunobiology and disease progression of such emerging infectious diseases is currently unclear. However, excessive immune system activation and immunopathology are strongly associated with severe disease outcomes in multiple emerging infectious diseases. On the flip side of the coin, host-directed immunotherapy can potentially be utilised to treat such infections in the near future. Moreover, immunotherapy has increasingly become an important and relevant component in precision medicine and healthcare. The aims of this course are: (1) To improve students basic and clinical understanding of immunologic processes during the course infectious diseases, incl. those caused by emerging infectious diseases; (2) To introduce students to relevant and topical areas of research interest in immunology of emerging infectious diseases; (3) To develop the analytic capacity of the students to identify areas of unmet research need in immunology of emerging infectious diseases; (4) To train students to confidently present, question and discuss science in both a formal and informal context among peers.

Brief list of topics to be covered:

1. Introduction to the course and basic immunology of infectious diseases (3 class hours)

2. Student seminars and discussion on immunology and infectious diseases (6 class hours)

- Fundamental immunology including development, maturation, interactions, and functional regulations of innate and adaptive immune responses.

- Immune evasion strategies and immunopathogenic mechanisms used by pathogens that are important in their interactions with humans

- Principles of vaccination, host-directed immunotherapy, and immunomodulation

- The immune response to emerging infectious diseases of human health significance in recent history

3. Presentation and discussion of current topics in immunology of emerging infectious diseases (24 class hours)

Content will be determined annually based on published literature to ensure the course stays updated and relevant.

4. Discussion and presentation of proposals of unmet research needs in immunology and infectious diseases (15 class hours)

97. **Course Name**: Introduction to traditional chinse medicine 中药基础理论

Credits: 2; 32 teaching hour

Instructors: Qin Peiwu

Text Book (or other supplemental materials):

Specific course information: Traditional Chinese Medicine (TCM), which is the quintessence of the Chinese culture heritage, has a long history of 5000 years as that of the Chinese nation and has made an everlasting contribution to the Chinese Nation survival and producing offspring and prosperity. More and more problems cannot be solved by western medicine in the 21st Century. TCM theory emphasizes on the self-healing power of man for curing diseases and keeping fitness, and many of its therapies are employed for enhancing this power. This course is intended to introduce the fundamental theory of TCM. Students will learn the history, principle, and diagnosis of TCM. Grades is composed of participation in course sessions (10%), completion of in-class exercises (20%) and homework (35%), and two in-class quiz

(25%). Auditors are welcome (and encouraged) to take the course, but regular attendance and participation is required.

Specific goals for the course: We are establishing the TCM research center. In order to attract graduate students, we will design this course to give a comprehensive introduction of TCM. The objective is to internationalize and educate students to engage in the TCM research.

Brief list of topics to be covered:

1. Preface

1.1 Ancient Chinese Philosophy

1.2 A brief history of TCM

1.3 Famous top 10 Chinese doctors in history

2. Philosophical concepts of TCM

2.1 Concept of overall balance

2.2 Qi-Xue

2.3 The five elements

2.4 Causes of diseases: the six external agents and seven internal emotions

3 Diagnosis of TCM

3.1 Four pillars of TCM diagnosis

3.2 Obsevation

3.3 Listening and smell

3.4 Take a history

3.5 Take the pulse

4. Eight syndromes.

4.1 Yang and yin syndrome

4.2 Superficial and deep syndrome

4.3 Cold and heat syndrome

4.4 Deficiency and excess syndrome

5. Current TCM development

5.1 TCM and systems biology

5.2 TCM and big data

Mandatory course

98. **Course Name**: 英语专业写作与表达 English Academic Writing and Communication

Credits: 2; 32 teaching hour

Instructors: Liu Lisha

Text Book (or other supplemental materials): [1] Cai, J. (2016). Academic English for Science and Engineering (2nd Ed.), published by FLTRP. [2] Gillett, A. (2008). Using English for Academic Purpose: A Guide for Students in Higher Education: Academic Writing.

Specific course information: This course is designed for TBSI Chinese postgraduate students who aim to use English in the methods and aims of advanced-level research and scholarship. By the end of this course, participants will be able to achieve the following outcomes: • Provide critical evaluation of research-based, scholarly arguments and academic papers in the subject-related fields; • Write and publish scientific articles in academic English; • Learn to take into consideration the expectations of one's readership with regard to academic writing discourse; • Identify, locate, cite, and evaluate scholarly critical resources at postgraduate level; • Analyze and interpret an academic text with increasing sophistication; • Present and participate at international academic conferences.

Specific goals for the course: Develop students' use of English in the methods and aims of advanced-level research and scholarship. Student learning outcome: participants will learn texts of subject-related genres, various critical evaluation, academic writing and presentation skills over the course of a semester.

Brief list of topics to be covered:

Series 1 – Language in academic settings

1 Genres of academic English

1.1 Differences between general and academic English

1.2 Features of academic English

2 Academic reading strategies

2.1 Reading for scientific studies

2.2 Academic reading skills

2.3 Reading literature critically

3 Academic poster presentation

3.1 Academic layouts and language

3.2 PADS: poster presentation formula

4 Academic oral presentation

4.1 Public speaking skills

4.2 Principles of academic oral presentation

5 Academic Q&A and discussion skills

5.1 How to deal with questions

5.2 Useful discussion expressions

6 Academic lecture: note-taking & summary

6.1 Note-taking skills

6.2 Paraphrasing

6.2 Summarizing and synthesizing

7 Mid-term exam

Series 2 – Academic writing

8 General description & academic integrity

8.1 Deciding on a topic and writing a working title

8.2 Formulating research questions

8.3 Academic integrity: basic moral code in academia

9 Graph descriptive writing

9.1 Using tables and figures effectively

9.2 Graph descriptive language

9.3 Framework for graph description

10 Writing abstracts

10.1 Types of abstracts

10.2 Principles of abstract writing

10.3 Writing a conference abstract

11 Literature search, citation and referencing

11.1 Searching for and evaluating various sources

11.2 Citation and referencing

11.3 How to avoid plagiarism

12 Paper publication & introduction

12.1 Paper publication process

12.2 How to write introduction of a scientific paper

13 Literature review & methodology

13.1 Understanding a literature review

13.2 Writing a good literature review

13.3 Writing a methods section

14 Results, discussion & conclusion

14.1 Writing a results section

14.2 Reporting the statistical result scientifically

14.3 Writing discussion and conclusion sections

15 Editing & proofreading

15.1 Editing your own scientific papers

15.2 Proofreading symbols

16 Final exam

99. **Course Name**: 中国文化概览 A Panoramic View of Chinese Culture

Credits: 2; 32 teaching hour

Instructors: Liu Lisha

Text Book (or other supplemental materials): 《中国文化概览》吴鼎民 凤凰出版传媒集团/译林出版社

Specific course information: This course is designed for postgraduate students, which aims to improve the skills of English expression of Chinese culture.

Specific goals for the course: There are two goals for this course. Firstly, to continue to strengthen the training of English listening, speaking, reading and writing skills based on the students' original foundation. Due to the limitation of teaching hour, this class is mainly based on listening and speaking. Secondly, to cultivate students' ability to express Chinese culture in English. All of the English skills training focuses on the theme of Chinese culture.

Brief list of topics to be covered:

Unit 1 Course introduction & Overview of China

1.1 Course overview

1.2 Symbols of the state

1.3 Geography and outline history

1.4 Population and distribution of the ethnic groups

1.5 Chinese names, language and the 24 seasonal division points

Unit 2 Ancient Chinese philosophy

2.1 Confucius and his conception of Ren

2.2 Confucian thought on Li

2.3 Laozi's thought on Dao and Reversion

2.4 Paradoxical expressions

2.5 Comparison between Laozi and Confucius

Unit 3 Chinese characters

3.1 The origin of Chinese characters

3.2 The six major stages in the development of Chinese characters

3.3 The conformation of Chinese Characters

3.4 The characteristics of Chinese characters

Unit 4 Chinese festivals

4.1 Lunar calendar and solar calendar

4.2 Spring Festival

4.3 Mid-autumn Day

4.4 Contrast and comparison of Chinese and western festivals

Unit 5 Chinese food

5.1 Rich Chinese food culture

5.2 Balance of Yin-Yang

5.3 The Chinese palates

5.4 Eight cuisines

Unit 6 Chinese wedding

6.1 Engagement

6.2 Preparation

6.2 Wedding day

6.3 Post-wedding ceremonies

Mid-term exam

Unit 7 Chinese clothing

7.1 Origin of Chinese Cheongsam (Qipao)

7.2 Evolution of Cheongsam

7.3 Design of Chinese clothing and its cultural connotation and aesthetic thoughts

Unit 8 Chinese crafts

8.1 History of Chinese paper cutting

8.2 Artistic features of Chinese paper cutting

14.1 The principles, schools and techniques of Chinese Kong Fu

14.2 Traditional Chinese music

14.3 Folk music

Final exam

100. **Course Name**: Professional Development and Presentation 职业发展与专业表达

Credits: 2; 32 teaching hour

Instructors: Li Xiangming

Text Book (or other supplemental materials): [1] Day, Robert; Sakaduski, Nancy (30 June 2011). Scientific English: A Guide for Scientists and Other Professionals, Third Edition. ABC-CLIO. ISBN 978-0-313-39173-6. [2] Matthew Duncan, Gustav W. Friedrich, Oral Presentations in the Composition Course: A Brief Guide [3] Robert K. Throop, Marion B. Castellucci, Reaching Your Potential: Personal and Professional Development

Specific course information: This course offers students a variety of experiences that develop basic concepts of the oral and written communication process. The class includes scientific writing as well as speech preparation and delivery. It is the General Education requirements for PhD and Master's students at Tsinghua-Berkeley Shenzhen Institute and is a required course all students. The grade will be based on the work completed in each of three parts, namely writing training, debate, and oral presentation. Each unit consists of a variety of weekly assignments that will introduce students to communication theory and practice, as well as prepare students for the preparation of a formal scientific writing and delivery of a speech. This course requires three mandatory essay assignments from each student in the first parts. Students will also be required to participate the debate over the assigned topics in the second part. In the third part, each student will be couched and deliver a 18-minute TED style talk. Through the above three parts, students will have the opportunity to enhance their ability to sharpen their ideas on scientific research and to present the ideas smoothly, efficiently, and convincingly. In addition to traditional classroom, students are encouraged to interact with each other and the instructor. The course is designed to foster a sense of community among classmates.

Specific goals for the course: Presentation is a critical skill for professional development of our students. The systematic and comprehensive training on professional presentation skills including oral presentation, writing, debate, and discussion is crucial for graduate students. This course is an opportunity for students to create a community in which every member could open their minds to the audience, and become comfortable to present fluently and accurately to the public. The course will also help students to build up solid scientific writing skills by intensive exercise and peer-review style evaluation.。

Brief list of topics to be covered:

PART I Fundamentals of Scientific Writing and presentation (8 units)

Academic and engineering ethics

Technical papers: how to write and where to submit

Writing successful proposals

How to participate a debate

Secret to deliver a successful presentation

PART II Debate Practice (8 units)

In this part, each week's two units will be split into two halves. In the first unit, a guest lecturer will give a speech that will create a topic for debate, and in the second half, students will be separated in two groups to debate over the topics.

Sample seminars are listed as following:

2.1 Guest Lecture: Internet Privacy and Security

Panel Debate: Should we be tracked on the internet?

2.2 Guest Lecture: Data policy in the era of the big data

Panel: Should we store our data in the cloud of big companies, like Google and Apple?

2.3 Guest Lecture: Intellectual Property Rights: Patent, Copyright, Trade-secret

Panel: IPR, protecting inventers, or hindering innovation?

2.4 Guest Lecture: DNA sequencing, analysis, and modification techniques.

Panel: Genetic engineering, changing the world or destroying it?

PART III Delivery of Presentations (16 units)

This part will be the flipped teaching, each students is required to choose one topic out of the following twenty and prepare a seminar to deliver the ideas. He/she will be challenged by the audience.

3.1 What makes CDMA work for my cell phone?

3.2 How does Google sell ad spaces?

3.3 How does Google rank webpages?

3.4 How does Netflix recommend movies?

3.5 When can I trust product ratings on Amazon?

3.6 Why does Wikipedia even work?

3.7 How do I viralize a YouTube video and tip a Groupon deal?

3.8 How do I influence people on Facebook and Twitter?

3.9 Can I really reach anyone in 6 steps?

3.10 Does the Internet have an Achilles' heel?

3.11 Why do AT&T and Verizon Wireless charge me $10 a GB?

3.12 How can I pay less for my Internet connection?

3.13 How does traffic get through the Internet?

3.14 Why doesn't the Internet collapse under congestion?

3.15 How can Skype and BitTorrent be free?

3.16 What's inside the cloud of iCloud?

3.17 Netflix, iTunes, IPTV: Which way to watch video?

3.18 Why is WiFi faster at home than at a hotspot?

3.19 Why am I only getting a few % of advertised 3G/4G speed?

3.20 Is it fair that my neighbors iPhone downloads faster?

101. **Course Name**: Theory and Practice of Socialism with Chinese Characteristics 中国特色社会主义理论与实践研究

Credits: 2; 32 teaching hour

Instructors: Li Ping

Text Book (or other supplemental materials):none

Specific course information: In addition to the basic content of the course recommended by the Ministry of Education "Science socialist theory and practice" teaching the provisions of the To teach, but also appropriate added to the contemporary world situation and the evolution of international political and economic history, causes and trends, the world socialist movement toward the concrete process and other aspects of history, in a bid to the international history of the evolution of social patterns Perspective on the evolution of modern times, the process of the socialist movement of history, achievements and problems of a full range of perspective and analysis, enabling students to a more broad historical background and international perspective on the history of socialism and the inevitable nature of the reasons to have a more profound Awareness

Specific goals for the course: 通过对中国特色的社会主义理论与实践的研究，力图以国际社会格局演变的历史视角，对近代以来的社会主义历史运动演变的过程、成就和问题进行全方位的透视和分析，使学生能够以更宽阔的历史背景和国际视角对社会主义产生的历史原因和必然性质有更深刻的认识。使学生能够在更深的学理层面，对马克思主义理论和科学社会主义理论以及中国特色的社会主义建设有更为深刻的理解.

Brief list of topics to be covered:

导论

一、中国特色社会主义的形成和发展
二、中国特色社会主义理论和实践成果
三、中国特色社会主义需要研究的重大理论和实践问题

第一讲 当代中国的基本国情

一、当代中国的基本特点
二、社会主义初级阶段基本国情和发展的阶段性特征
三、中国特色社会主义的总体布局和战略任务
四、仅仅抓住和用好重要战略机遇期

第二讲 中国特色社会主义经济建设

一、科学发展是当代中国的主题
二、加快转变经济发展方式
三、统筹经济社会发展和区域发展
四、着力构建有利于科学发展的体制机制

第三讲 中国特色社会主义政治建设

一、坚持走中国特色社会主义政治发展道路
二、健全中国特色社会主义民主制度
三、建设社会主义法治国家
四、积极稳妥地推进政治体制改革
第四讲　中国特色社会主义文化建设

一、建设社会主义核心价值体系
二、推进文化创新，深化文化体制改革
三、推动社会主义文化大发展大繁荣
四、提高国家文化软实力
第五讲 中国特色社会主义社会建设

一、加快推进以改善民生为重点的社会建设
二、跪进社会体制改革
三、促进社会公平正义
四、激发社会创造活力、促进社会更加和谐
第六讲 中国特色社会主义生态文明建设

一、当前生态和环境保护面临的重大问题
二、建设资源节约型和欢迎友好型社会
三、实现经济发展与人口资源环境相协调
四、坚持文明发展道路
第七讲　中国特色社会主义执政党建设

一、办好中国的事情关键在党
二、正确应对党执政面临的新可以新考验
三、提高党的建设科学化水平
四、坚决惩治和有效预防腐败
第八讲 当代中国与当代世界

一、当代世界发展的新特点和新趋势
二、当代中国同世界关系发生的历史性变化
三、中国发展道路的广泛影响和重大意义
结束语

当代中国青年的历史责任

102. **Course Name**: Chinese Marxism and Contemporary World 中国马克思主义与当代

Credits: 2; 32 teaching hour

Instructors: Wang Pusheng, Li Ping, He Jun

Text Book (or other supplemental materials): none

Specific course information: 中国马克思主义是马克思主义与发展着的时代和发展着的中国实际相结合的产物，它是马克思主义的中国化，是马克思主义在中国的继承、丰富、创新和发展。中国马克思主义包括着马克思主义中国化两次历史性飞跃所形成的伟大理论成果。马克思主义中国化第一次历史性飞跃所形成的伟大理论成果是毛泽东思想；马克思主义中国化第二次历史性飞跃所形成的伟大理论成果是中国特色社会主义理论体系（邓小平理论、"三个代表"重要思想、科学发展观）。 《中国马克思主义与当代》课程，既不是单纯讲授中国马克思主义，也不是单纯讲授当代和当代问题，而是以中国马克思主义的当代视野、世界视野，以中国马克思主义的立场、观点、方法去透视当代，去分析当代的重大矛盾和问题，把中国马克思主义的立场、观点、方法渗透到对当代的重大矛盾和问题的分析、回答和解决过程中，通过对当代的重大矛盾和问题的分析、回答和解决，使博士生更深刻地掌握中国马克思主义的立场、观点和方法。

Brief list of topics to be covered:

专题一中国的政治文明

1 从"无产阶级专政下继续革命"到"全面深化改革"（4 学时）

1.1 从"历史周期律"说起

1.2 从"改革开放"到"全面深化改革"

2 西方视角下的中国：以中美文化比较为例（4 学时）

2.1 费正清"中国系列"

2.2 基辛格《论中国》

2.3 当代中国与美国比较

专题二 当代中国发展

1 当代中国社会问题解析（4 学时）

1.1 深度城市化与农业转移人口市民化的路径

1.2 全面建成小康社会压力与挑战

2 中国的科技追赶与创新系统转型（4 学时）

2.1 中国的科技政策学习与自主创新战略

2.2 中国的低碳创新与可持续发展

专题三 科研与工程伦理

1 科学活动中的伦理问题（4 学时）

1.1 伦理学基本理论与方法

1.2 科研伦理及其案例分析

2 工程伦理与中国实践（4 学时）

2.1 工程师的伦理与责任

2.2 工程风险与伦理治理

专题四 法律法规建设

1 创新创业与知识产权法（4 学时）

1.1 技术创新与专利

1.2 企业发展与商标

2 可持续发展与环境保护立法（4 学时）

2.1 环境保护法基本原则和制度

2.2 环境保护领域国内外最新立法

103. **Course Name**: Introduction to Dialectics of Nature 自然辩证法概论

Credits: 1; 18 teaching hour

Instructors: Wang Pusheng, Li Ping

Text Book (or other supplemental materials): 曾国屏等主编：《当代自然辩证法教程》，清华大学出版社，2005 年版。

Specific course information: The Outline of Dialectics of Nature The Second Lecture: The Establishment and Development of Dialectical Materialism of nature The Third Lecture: on Science and Technology of Marxism The Fourth Lecture: Scientific Knowledge Production and Innovation-oriented Country The Fifth Lecture:

Science and Technology and The Harmonious Development of Society The Sixth Lecture: Scientific Development and Ecological Civilization

Specific goals for the course:通过本课程教学，使学生了解自然辩证法的基本内容和体系，掌握自然界和科学技术发展的一般规律和人类认识自然和改造自然的一般方法以及研究自然及其规律的方法，了解把握科学技术与社会进步、发展的相互关系，进一步树立辩证唯物主义世界观，掌握科学思维方法，增强辩证思维能力，提高科学创造力，并在理论联系实际的基础上分析和处理科学技术发展中的现实问题。

Brief list of topics to be covered:

绪论（1 学时）

第一部分自然科学发展历程（5 学时）

1 古代自然科学的产生

2 近代自然科学的发展（前期与后期）

3 现代自然科学的突破

4 人类认识自然的观念演变

第二部分科学技术方法论（4 学时）

5 科学问题与科研选题

6 科学事实与观察实验

7 科学思维的逻辑方法与非逻辑方法

8 科学知识增长的机制

第三部分科学技术社会论（5 学时）

9 作为社会建制的科学与技术

10 科学技术的社会功能

11 创新与经济增长

12 科学技术运行的社会治理与人文引导

第四部分阳光课堂（3 学时）

104. **Course Name**: Introduction to Creativity, innovation, startup, makers and venture capitals 创意创新创业与创客创投概论

Credits: 1; 16 teaching hour

Instructors: Ma Yongbin

Text Book (or other supplemental materials): 1.马永斌，《公司治理之道：控制权争夺与股权激励》，清华大学出版社，2013； 2.魏炜，朱武祥，《发现商业模式》，机械工业出版社，2009； 3.亚德里安▪斯莱沃斯基等，《发现利润区》，中信出版社，2014

Specific course information: “Creativity, innovation, startup, makers and venture captals” is a novel course introducing the total process of starting a new startup company, including creative thinking, innovative consciousness, makers, entrepreneurship ability and venture capitals. This course will be practical and invite experts and enterprising men for lectures and discussions. The course has five topics, including creative thinking, innovative consciousness, makers, entrepreneurship ability and venture capitals. Each topic will be hold for 3 hours. Last lesson will be the roadshows of students, and winners will be rewarded with venture fund and startup fields.

Specific goals for the course: 为了更好地让具有创新创业梦想的清华学生能够全面而系统地了解创业的全过程，特此申请开设《创意创新创业创客创投》“五创”课程，让学生不仅仅是出于兴趣来创新创业，或者仅仅是追随创业潮流，而是系统地了解“五创”的基础、目标、方法和资源，从而培育创新思维、培训创新意识、理清创客理念、增强创业能力、接触创投流程，为以后的创业打好基础。

Brief list of topics to be covered:

周	日期	教学内容	教学方法	备注
1		第一讲 创业的梦想与实践 创业的过程 创业的模式 创业的实践	讲授 案例 讨论	**3 学时**

2		**第二讲 创意：品牌战略与创新设计** **创意的来源** **创意的设计** **品牌战略**	**讲授** **案例** **讨论**	**3 学时**
3		**第三讲 技术创新与实践** 第一节 技术创新的基础架构 第二节 新常态下的创新 第三节 企业中的创新实践	讲授 案例 讨论	3 学时
4		**第四讲 创客运动** 第一节 中国创客这一年 第二节 创客空间的力量 第三节 风口上的创客 第四节 创客变革世界的时代	讲授 案例 讨论	3 学时
4		**第五讲 创业融资：创业助推器** 第一节 创业中资本的力量 第二节 风险投资的运作模式 第三节 创业融资的基本过程	讲授 案例 讨论	3 学时
6		**第六讲 课程总结与实战演练** 第一节 创业团队路演 第二节 创业导师项目点评与投融资对接 第三节 课程总结	路演 点评	3 学时

105. **Course Name**: Capstone Project 创新训练营

Credits: 1; 16 teaching hour

Instructors: Zhang Lin

Text Book (or other supplemental materials): none

Specific course information: Capstone Project is an innovation research course open for all TBSI doctoral students. Students will be provided with advisors' guidance and team support so as to conduct research on global major challenges. More importantly, students will learn how to use their initiative and exercise their leadership. All the students are expected to fully utilize their practical knowledge to bring forward a proposal for resolution of the challenge through effective teamwork in innovative research, which will increase their research and innovation capability.

Specific goals for the course: 致力于培养全球科技领袖和未来企业家，为解决区域和全球性重大课题输送高素质人才。希望学生在这门课中能够扮演 Role Model 的角色，通过跨学科创新挑战赛等形式，尝试提出解决区域和全球性重大工程技术和科学研究课题的新思路。

106. **Course Name**: Elementary Chinese 初级汉语

Credits: 2; 32 teaching hour

Instructors: Xie Jian

Text Book (or other supplemental materials): none

Specific course information: The points we will study are emphasize the words and drills used in daily life.

107. **Course Name**: Intermediate Chinese 中级汉语

Credits: 2, 32teaching hour

Instructors: Liu Lisha

Text Book (or other supplemental materials):

Specific course information: mainly focus on special spoken sentence patterns and words, discuss complicated issues related to life, study, social culture, etc.ssuch as the parents-kids relationship, respect life and so on, in order to possess the students with the communication abilities to speak Chinese.