**Global Learning Initiatives Program Course Syllabus**

Please complete the following form in English. The information will be updated to the Global Learning Initiatives Program website for students’ reference. If you will be offering more than one course, please fill out one form per course offered. Examples in grey.

**Course Information**

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| --- | --- |
| Course Name  \*provide the **English** course name of the course. | Introduction to two-dimensional materials and systems |
| Lecturer(s)  \*provide the lecturers’ **English** name. If there are more than one lecturer, please indicate all lecturers in the column. | Prof. Sheng-Shiuan Yeh |
| Course Description  \*briefly describe the contents covered in the courses. | The dimension of semiconductor devices is continuously shrinking to prolong Moore's law. In the foreseeable future, quantum phenomena will become more and more profound, which may seriously affect the characteristics of future electronic devices and impede the further downsizing. Development of novel semiconductor materials such as two-dimensional (2D) materials may solve this problem. Thus, understanding the physics in such low-dimensional materials and systems is demanded. In this course, we will introduce several fundamental topics in low-dimensional material and systems, including nanowires and 2D materials. First, we will briefly review the quantum mechanics and apply these principles to develop the basic concepts of solid state physics, including band theory and charge transport properties in metals and semiconductors. Then, in terms of these knowledge, we will discuss electrical transport properties in low-dimensional electron systems such as quasi-1D nanostructures and 2D materials. Finally, we will learn the low-frequency (1/f) noise properties in metallic nanowires and 2D semiconductors. |
| Course Objectives  \*list out knowledge or skills students should acquire upon completion of course. | Students will learn several fundamental topics in low-dimensional electronic devices, including electrical transport properties in quasi-1D nanostructures and 2D materials, and the low-frequency (1/f) noise properties in metallic nanowires and 2D semiconductors. |
| Suggested Proficiencies  (if any)  \*list preferred knowledge or skills students should have before taking the course. |  |
| Reading List  (if any)  \*list out the textbooks, references, or other reading materials. | [1] D. K. Ferry and J. P. Bird, Electronic Materials and Devices (Academic Press, 2001).  [2] J. P. Colinge, J. C. Greer, and Jim Greer, Nanowire Transistors: Physics of Devices and Materials in One Dimension (Cambridge University Press, 2016).  [3] T. Grasser (ed.), Noise in Nanoscale Semiconductor Devices (Springer Nature Switzerland AG., 2020). |
| Grading Criteria  \*how would the students be assessed during the course. | Homework: 30% Midterm Exam: 30% Final exam (or report): 40% |

**Course Schedule**

Please complete the following table with the dates and expected course topics. If there are more than one lecturers instructing the course, please also indicate the lecturer for each class.

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| Class | Date (YYYY/MM/DD) | Course Topic | Lecturer |
| 1 |  | Course introduction. The wave mechanics of electrons: The Schrödinger equation. Particles in a box. Atomic energy levels. Covalent bonding, ionic bonding, and metallic crystals. | Prof. Sheng-Shiuan Yeh |
| 2 |  | Electrons in metals (free-electron model): Quantum free-electron gas. The free-electron gas at absolute zero. Density of states. The free-electron gas at non-zero temperature. Dynamics of the free-electron gas. | Prof. Sheng-Shiuan Yeh |
| 3 |  | Electrons in crystals (I): Bloch’s theorem. Energy gaps. | Prof. Sheng-Shiuan Yeh |
| 4 |  | Electrons in crystals (II): Electron dynamics in energy bands. Effective mass. Metals, semiconductors, and insulators. Holes. | Prof. Sheng-Shiuan Yeh |
| 5 |  | Semiconductors (I): Intrinsic semiconductors. Extrinsic semiconductors. Carriers in extrinsic semiconductors. | Prof. Sheng-Shiuan Yeh |
| 6 |  | Semiconductors (II): Carrier drift in semiconductors. Semiconductor band structures. Experimental determination of electronic structures. | Prof. Sheng-Shiuan Yeh |
| 7 |  | Electronic transport in quasi-1D nanostructures (I): Semi-classical descriptions. Conductance quantization. Landauer conductance formula. Charge mobility. | Prof. Sheng-Shiuan Yeh |
| 8 |  | Midterm exam. | Prof. Sheng-Shiuan Yeh |
| 9 |  | Electronic transport in quasi-1D nanostructures (II): Scattering mechanism. Scattering length. Quasi-ballistic transport in nanowire transistors. | Prof. Sheng-Shiuan Yeh |
| 10 |  | Electronic transport in 2D materials (I): Introduction to 2D materials. Tunable band structure. Electronic transport. | Prof. Sheng-Shiuan Yeh |
| 11 |  | Electronic transport in 2D materials (II): Van der Waals heterojunctions. Composite films. Future outlooks. | Prof. Sheng-Shiuan Yeh |
| 12 |  | 1/f noise in metallic nanowires (I). | Prof. Sheng-Shiuan Yeh |
| 13 |  | 1/f noise in metallic nanowires (II). | Prof. Sheng-Shiuan Yeh |
| 14 |  | 1/f noise in semiconductors (I). | Prof. Sheng-Shiuan Yeh |
| 15 |  | 1/f noise in semiconductors (II). | Prof. Sheng-Shiuan Yeh |
| 16 |  | Final exam (or report). | Prof. Sheng-Shiuan Yeh |