TO: The Faculty of the College of Engineering

FROM: Elmore Family School of Electrical and Computer Engineering

RE: New Graduate Course, ECE 50631 Fundamentals of Current Flow

The faculty of the School of Electrical and Computer Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ECE 50631 Fundamentals of Current Flow
Sem. 1, 2and 3, Lecture 1, Cr. 1.
Prerequisite by Topic:

Description: Traditional description of electronic motion through a solid is based on diffusive transport which means that the electron takes a random walk from the source to the drain. However, modern nanoelectronic devices often have channel lengths comparable to a mean free path so that electrons travel ballistically, or "like a bullet." This course provides a unified conceptual framework for ballistic and diffusive transport of both electrons and phonons, that is very different from what is taught in standard courses, but indispensable to understanding nanolectronic devices.

Reason: This course presents a new perspective that has emerged in the last two decades provides a powerful approach to new questions at the frontier of modern nanoelectronics. To our knowledge, there is no other course at any level addressing these topics. We believe this new perspective is of general interest, not just for electrical engineers, but for anyone interested in an atomic level understanding of everyday processes, like the flow of heat and electrical current. With this in mind, we have developed this course, assuming very little background beyond linear algebra and differential equations. But we discuss very advanced concepts involving non-equilibrium statistical mechanics, and that is why graduate level maturity is necessary.

Milind Kulkarni,
Associate Head for Teaching and Learning
Elmore Family School of Electrical and Computer Engineering

PURDUE UNIVERSITY

FCF: FUNDAMENTALS OF CURRENT FLOW

NANOSCIENCE AND TECHNOLOGY MICROMASTERS®

Course Run

Fundamentals of Current Flow (2T2020a)

Instructors

- Supriyo Datta, *Professor of Electrical and Computer Engineering, Purdue University*
- Shuvro Chowdhury, *PhD student, Purdue University*

Audience

This course is intended to be broadly accessible to students in any branch of science or engineering who would like to learn about the modern conceptual framework for describing the flow of electrons in solid-state electronic devices.

Estimated Effort

- 5 - 6 hours/week
- 5 weeks total

Prerequisites

This course is designed for students pursuing an undergraduate degree in engineering or the physical sciences, having a familiarity with differential equations, and linear algebra.

Languages

- Content: English | Videos: English | Transcripts: English

Course Difficulty

- Advanced

Course Learning Outcomes

After completing this course, you will be able to:

- Explain the new perspective on conductivity and its relation to the standard Drude formula
- Evaluate quantities like the density of states, number of modes, electron density and conductivity for a given energy-momentum relation
- Explain concepts like the minimum interface resistance and the two Landauer formulas

Required Text and Materials

- S.Datta, *Lessons from Nanoelectronics, Part A: Basic Concepts*, Second Edition, World Scientific (2017).
- Course textbook is provided to enrolled students as a free download on the *Textbook* tab

Course Structure

- All lectures are available immediately.
- Multiple-choice self-assessments will follow each lecture to assess your understanding of the material. These questions are not graded.
- This course contains "Bonus Material" that is not covered in the exams. These materials are for students who wish to learn more at their leisure, depending on their interests.
- There are three (3) Practice Exams included in the course. These questions are not graded.

Course Schedule

Week	Dates	Topic	Tasks	Exams
1	Jan.18 – Jan.24	The New Perspective	• Review Syllabus & Schedule • Complete Pre-Course survey • View Lectures 1.1 – 1.5 • Read: Chapters 1 – 4	Course begins **Monday, Jan.18, 8:00 AM ET** (12:00 UTC) **Proctortrack Onboarding due by: Thursday, Jan.21 8:00 AM ET** (12:00 UTC)
2	Jan.25– Jan.31	The New Perspective (continued)	• View Lectures 1.6 – 1.10 • Read: Chapters 1- 4 • Complete practice exam 1 • Complete Motivation survey	**Exam 1:** • Opens: **Thursday, Jan.28, 8:00 AM ET** (12:00 UTC) • Due: Sunday, Jan.31, 8:00 AM ET (12:00 UTC) • Timed: 50 minutes
3	Feb.1– Feb.7	Energy Band Model	• View Lectures 2.1 – 2.5 • Read: Chapter 6	
4	Feb.8– Feb.14	Energy Band Model (continued)	• View Lectures 2.6, 2.7, 2.10 • Read: Chapter 6	**Exam 2:** • Opens: Thursday, Feb.11, 8:00 AM ET (12:00 UTC) • Due: Sunday, Feb.14 8:00 AM ET (12:00 UTC) • Timed: 50 minutes
5	Feb.15– Feb.21	What and Where is the Voltage	• View Lectures 3.1 – 3.5 • Read: Chapter 8, 10.1-10.2 • Complete practice exam 2 • Complete Post-course survey	**Exam 3:** • Opens: Thursday, Feb.18, 8:00 AM ET (12:00 UTC) • Due: Sunday, Feb.21, 8:00 AM ET (12:00 UTC) • Timed: 50 minutes
	Feb.21	Course closes		
	Feb.23	Certificates available		

Lecture List:

Week 1: The New Perspective

1.1 Introduction
1.2 Two Key Concepts
1.3 Why Electrons Flow
1.4 Conductance Formula
1.5 Ballistic (B) Conductance

Week 2: The New Perspective (Continued)

1.6 Diffusive (D) Conductance
1.7 Connecting B to D
1.8 Angular Averaging
1.9 Drude Formula
1.10 Summing Up

Week 3: Energy Band Model

2.1. Introduction
2.2. E(p) or E(k) Relation
2.3. Counting States
2.4. Density of States
2.5. Number of Modes

Week 4: Energy Band Model (Continued)

2.6. Electron Density (n)
2.7. Conductivity vs. n
* 2.8 - 2.9 *Bonus Lectures*; *NOT covered on exams*
2.10 Summing Up

Week 5: What and Where is the Voltage

3.1 Introduction
3.2 A New Boundary Condition
3.3 Quasi-Fermi Levels (QFL's)
3.4 Current from QFL's
3.5 Landauer formulas
* 3.6 - 3.10 *Bonus Lectures; NOT covered on exams*

* Epilogue: Looking Forward-From Semiclassical to Quantum *Bonus Lecture; NOT covered on exams*

Exams

- To submit exams in this course, every Verified/Master's track learner must have successfully completed an Onboarding session with Proctortrack.
    - See Taking Exams in **Fundamentals of Current Flow** (link to be inserted) for more details
- Exam Availability:
    - Each exam is available for 60 hours. You must complete the exam within the scheduled dates and times.
    - Each exam is timed. Once you open the exam, the timer will begin. The timer cannot be paused.
    - See *Schedule* tab for dates and times.
- Exams are open notes, but online tools not allowed.
- No calculators allowed.
- Blank scratch paper is allowed.

Grading

This course will be graded based on the following criteria:

Assessment Type	Description	% of Final Grade
Exam 1	Proctored, multiple-choice exam	40%
Exam 2	Proctored, multiple-choice exam	40%
Exam 3	Proctored, multiple-choice exam	20%

- Course grade will be based on three (3) proctored exams.
    - See the *Progress* tab for grade ranges (A, B, C, D, F)
- **Verified learners:** To receive an edX course certificate, you must have a passing grade.
- **Purdue University transfer credit:** Only edX Purdue MicroMasters® courses with a grade "B" or higher may be eligible for transfer to Purdue.
- **Purdue University students:** To use this course toward your MS ECE degree, you must have a grade of "C- "or higher and maintain a plan of study of 3.0.

Getting Help

- **Technical difficulties:** If you experience technical difficulties with the edX platform, contact edX Support using the **Contact Us** form in the Connect section at the bottom of your screen.
- **Course content issues:** If you experience any issues with course content, post your concern or question to the discussion forum.
- **For general questions** about using the edX platform, we recommend viewing the **edX Demo course**.
- **Other edX Resources**
    - Technical Help
    - Learner Help Center
- If you wish to discuss any questions with the instructor personally or in group, please send an email including times you are available. Instructor will set up a Zoom meeting, typically within 24 hours
- Professor Datta's email: datta@purdue.edu
- Teaching Assistant, Shuvro Chowdhury's email: chowdhu7@purdue.edu

Discussion Guidelines

- Do not use offensive language. Present ideas appropriately.
- Be cautious in using Internet language. For example, do not capitalize all letters since this suggests shouting.
- Avoid using vernacular and/or slang language. This could possibly lead to misinterpretation.
- Keep an "open-mind" and be willing to express even your minority opinion.
- Do not hesitate to ask for feedback.
- Be concise and to the point. Give other students the opportunity to join in the discussion.
- Think and edit before you push the "Post" button.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern.

The Purdue Honor Pledge

"As a Boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue"

Accessibility Support

Purdue University and edX strive to make learning experiences as accessible as possible.
If you anticipate or experience physical or academic barriers based on disability:

- You are welcome to let your instructor know so that you can discuss options.
- Instructor: Prof. Supriyo Datta at: datta@purdue.edu
- edX Accessibility Policy
- ProctorTrack Web Accessibility Policy

Purdue Student Accessibility Resources

- Purdue students are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.
- Purdue Disability Resource Center Website
- Purdue Web Accessibility Policy
- Purdue Equal Access Frequently Asked Questions (FAQs)

For accessibility concerns beyond this, the **Office of Institutional Equity** is responsible for ensuring Americans with Disability Act compliance, can be contacted with any accessibility concerns at:

- Phone: (765) 494-7253
- Email: equity@purdue.edu
- TTY: (765) 496-1343
- Website

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. Link to Purdue's nondiscrimination policy statement.

Academic Guidance due to Quarantine/Isolation

If you become quarantined or isolated at any point in time during the semester, in addition to support from the Protect Purdue Health Center, you will also have access to an Academic Case Manager who can provide you academic support during this time. Your Academic Case Manager can be reached at acmq@purdue.edu and will provide you with general guidelines/resources around communicating with your instructors, be available for academic support, and offer suggestions for how to be successful when learning remotely. Importantly, if you find yourself too sick to progress in the course, notify your academic case manager and notify me via email: datta@purdue.edu or Brightspace. We will make arrangements based on your particular situation. The Office of the Dean of Students (odos@purdue.edu) is also available to support you should this situation occur.

Attendance Policy during COVID-19

Students should stay home and contact the Protect Purdue Health Center (496-INFO) if they feel ill, have any symptoms associated with COVID-19, or suspect they have been exposed to the virus. In the current context of COVID-19, in-person attendance will not be a factor in the final grades, but the student still needs to inform the instructor of any conflict that can be anticipated and will affect the submission of an assignment or the ability to take an exam. Only the instructor can excuse a student from a course requirement or responsibility. When conflicts can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency conflict, when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email, through Brightspace, or by phone. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases of bereavement, quarantine, or isolation, the student or the student's representative should contact the Office of the Dean of Students via email or phone at 765-494-1747. Our course Brightspace includes a link on Attendance and Grief Absence policies under the University Policies menu.

Classroom Guidance Regarding Protect Purdue

The Protect Purdue Plan, which includes the Protect Purdue Pledge, is campus policy and as such all members of the Purdue community must comply with the required health and safety guidelines. Required behaviors in this class include: staying home and contacting the Protect Purdue Health Center (496-INFO) if you feel ill or know you have been exposed to the virus, wearing a mask in classrooms and campus building, at all times (e.g., no eating/drinking in the classroom), disinfecting desk/workspace prior to and after use, maintaining proper social distancing with peers and instructors (including when entering/exiting classrooms), refraining from moving furniture, avoiding shared use of personal items, maintaining robust hygiene (e.g., handwashing, disposal of tissues) prior to, during and after class, and following all safety directions from the instructor.

Students who are not engaging in these behaviors (e.g., wearing a mask) will be offered the opportunity to comply. If non-compliance continues, possible results include instructors asking the student to leave class and instructors dismissing the whole class. Students who do not comply with the required health behaviors are violating the University Code of Conduct and will be reported to the Dean of Students Office with sanctions ranging from educational requirements to dismissal from the university.

Any student who has substantial reason to believe that another person in a campus room (e.g., classroom) is threatening the safety of others by not complying (e.g., not wearing a mask) may leave the room without consequence. The student is encouraged to report the behavior to and discuss next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights.

Addendum: EFD 10-22

Grade Mapping:

A > 90%

B 80% - 90%

C 70% - 80%

D 60% - 70%

F < 60%

Previous Course Offerings:

ECE 59500 Fundamentals of Current Flow, Spring 21 (18), Fall 20 (47), Sum 20 (3), Spring 20 (2), Fall 19 (8)