Harvard University

Physics 167: CONDENSED MATTER PHYSICS

OF MODERN TECHNOLOGIES

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Office hours: Tuesday 2:00-3:30 pm

Course Meetings: MW, 12:00 - 1:30 in Jefferson 256

Homework: Problem sets (every 2-3 weeks), 1/3 of grade

Final Presentation: 2/3 of grade

Tentative Course Outline

Introduction

Condensed matter physics and modern technologies.

Electronic properties of solids.

Periodic crystal lattices and their electronic bandstructure.

Fermi statistics in metals and semiconductors.

Semiclassical electron dynamics. The Drude theory of electrical conductivity.

Beyond Ohm's law. Nonlinear effects in semiconductors.

Logic devices

Homogeneous semiconductors.

Inhomogeneous semiconductors. PN junctions. Bipolar transistors.

Metal-Oxide-Semiconductor Field Effect Transistors (MOSFET).

Complimentary Metal Oxide Semiconductor (CMOS) logic.

Scaling of MOSFET devices. Moore's law.

Physical limits to MOSFET based logic devices. Fundamental limits to information processing.

Novel devices and alternative concepts for information processing.

Single electron transistors (quantum dots). Coulomb blockade effects.

Physical properties of carbon nanotubes. Ballistic transport. Carbon nanotubes for data processing

Spintronics.

Random Access Memories

Random Access Memory (RAM) devices.

Static RAM (SRAM) cells. Dynamic RAM (DRAM) cells.

Read Only Memory (ROM). Flash memory.

Ferroelectric RAM (FRAM) cells.

Ferroelectrics. Landau theory of ferroelectric phase transitions.

Magnetic Hard Disk Drives

Mass storage devices. Magnetic recording.

Magnetism. Magnetic exchange interactions. Itinerant ferromagnetism.

Magnetic recording media. Magnetic read heads. Magneto-resistive technologies.

Giant magnetoresistance and its applications for memory devices.

Magnetoresistive RAMS.

Microwave and Optoelectronic devices

Microwave devices. Solid state microwave sources.

Solid state lighting devices. Light Emitting Diode (LED) devices. Organic LEDs. Full spectrum light emitters.

Laser diodes. Photodetectors

Telecommunications. Transmission media and applications.

Optical communications. Low loss glass fibers. All-optical amplifiers.

Next generation of blue LEDs and LED lasers.

Superconductors

Applications of superconductivity. Cables for electric power transmission. Magnets for MRI and NMR systems. Microwave filters for wireless communications.

General properties of superconductors. Origin and mechanism of superconductivity.

Josephson effect. Superconducting Quantum Interference Devices (SQUID). Applications of SQUIDs. Applications of the Josephson effect to voltage metrology.

Scanning Probe Microscopes *

Basic principles behind scanning probe microscopes, including tunneling microscope, the atomic force microscope, and the magnetic force microscope. Piezoelectric manipulators and feedback mechanisms

Quantum computing*

The main principles underlying quantum information processing (entanglement, quantum superposition, and probabilistic measurement). Current experimental realizations of quantum computers, including trapped ions, nuclear magnetic resonance, cavity quantum electrodynamics, and quantum dots. The basics of quantum cryptography.

*This material may be skipped depending on the pace of the class

Primary references

N. Ashcroft and D. Mermin. *Solid state physics.*

S. Blundell. *Magnetism in condensed matter.*

L. Comstock. *Magnetism and magnetic recording.*

J. Downing. *Fiber optic communications.*

H. Dutton. *Understanding optical communications.*

N. Gershenfeld. *The physics of information technology.*

M. Marder. *Condensed matter physics.*

R. Miller and M. Miller. *Barron's electronics the easy way.*

D. Neamen. *Semiconductor physics and devices. Basic principles.*

D. Pozer. *Microwave engineering.*

M. Shur. *Physics of semiconductor devices*

S. Sze. *Physics of semiconductor devices.*

S. Vonsovskii. *Magnetism.*

R. Waser. *Nanoelectronics and information technology.*

W. Wright and D. Rynders. *Telecommunications and wireless communications.*