course objectives

To introduce students to the fundamentals of semiconductors and semiconductor devices.
**electron devices**

- **vacuum tube**
  - Edison effect, 1880
  - J.J. Thompson, 1897
- **transistor**
  - diode (Fleming, 1904)
  - triode (De Forest, 1905)
  - Bardeen, Brattain, Shockley, 1947
- **integrated circuit**
  - Kilby /Noyce, 1958

**modern solar cell**
- Chapin, Pearson, Fuller, 1954

**LED**
- Holonyak, 1962

**semiconductor laser**
- Hall, 1962
Purdue’s semiconductor history

“Karl Lark-Horovitz is best known for turning the physics department of Purdue University, then a backwater school, into a research powerhouse. His personal research was in germanium and solid state science -- and if anyone had had a chance of inventing the transistor before Bell, it was Lark-Horovitz. As it was, the Purdue physics lab was probably only six to twelve months behind.”

http://www.pbs.org/transistor/album1/addlbios/lark.html

1941: WWII: Semiconductor diode rectifiers
http://www.computerhistory.org

electronics in the 21st Century

CMOS transistors for logic
III-V transistors for RF
A/D and D/A convertors
Digital Signal processor
Microprocessor
ROM and FLASH memory

www.apple.com

CMOS imager
Gyroscope
MEMS devices
Magnetometer
Microphone, speaker
LCD display and touch screen
"The transistor was probably the most important invention of the 20th Century, and the story behind the invention is one of clashing egos and top secret research."

- Ira Flatow, Transistorized!

http://www.pbs.org/transistor/
uses for transistors

symbol

| S | D | G |

switch

input signal

amplifier

output signal

source

drain

SiO$_2$
silicon

channel ~ 22 nm

gate oxide

SiON ~ 1.1 nm

gate electrode

real transistors

symbol

Si

G

D

S

input signal

output signal

S

D

G

source

drain

gate electrode

channel ~ 22 nm

gate oxide

SiON ~ 1.1 nm
transistor IV

symbol

\[ I_V = I_D = I_{GS} \]

integrated circuits

IBM Power7 (45nm, 1.2B transistors)

Moore’s Law

$L = 5000 \text{ nm}$
Micro-electronics

$L = 5 \text{ nm}$
Nano-electronics

exponential growth

transistors per cpu chip

Year

Billions of transistors

1974


Lundstrom ECE-606 S13
“The most important moment since man emerged as a life form.”

Isaac Asimov

(about the “planar process” used to manufacture ICs (invented by Jean Hoerni, Fairchild Semiconductor, 1959).

“converging technologies”

multidisciplinary

nano  bio  info  cog
example: gene sequencing

http://www.genome.gov/sequencingcosts/

Electronics beyond Moore’s Law

Ion Torrent (Nature, 475, 349, 21 July, 2011)
NBIC convergence

Electronics and healthcare

http://www.qualcommtricorderxprize.org

Electronics and:
- Energy
- Environment
- Cognition
- Security
- Personalized learning
- ...

transdisciplinary R&D

multidisciplinary

nano bio info cog
course outline

Part 1: Semiconductor Fundamentals:  7 weeks
Part 2:  PN diodes, MS diodes, and LEDs  2 weeks
Part 3:  Transistors  6 weeks

course texts

Advanced Semiconductor Fundamentals, 2nd Edition (ASF)

Semiconductor Device Fundamentals, 2nd Edition (SDF)
ISBN-0-201-54393-1
course format: “flipped”

http://nanohub.org/groups/ece606lundstrom

Lecture quizzes and questions: 25%

Exams (5 at 15% each) 75%

Quiz score = x/total times 25%, where x is the number of quizzes you turned in and passed and total is the total number of lectures in the course.

Exam score = average of the percentage scores of the 5/6 best exams scores including any retake.

Approximate curve:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Score Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>91 – 100%</td>
</tr>
<tr>
<td>B</td>
<td>81 – 90%</td>
</tr>
<tr>
<td>C</td>
<td>71 – 80%</td>
</tr>
<tr>
<td>D</td>
<td>61 – 70%</td>
</tr>
<tr>
<td>F</td>
<td>60% or less</td>
</tr>
</tbody>
</table>
Steven Chu:

“Learning science and thinking about science or reading a paper in science is not about learning what a person did. You have to do that, but **to really absorb it, you have to turn it around** and cast it in a form as if you invented it yourself. You have to look and be able to see things that other people looked at and didn't see before.

How do you do that? There are two ways. Either you make a new instrument, and it gives you better eyes, … Or you try to internalize it in such a way that it really becomes intuitive.