ECE 340
Solid State Electronic Devices

M,W,F 12:00-12:50 (X), 2015 ECEB
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Office Hours: Wednesday 13:00 – 14:00
Today’s Discussion

- Historical Commentary – Illinois Influence
- Motivation
- Course Purpose & Objectives
- Schedule & Policies
- General Introduction to Semiconductor Electronics
- Assignments
- Topics for Next Lecture
Historical Commentary
Bardeen and Brattain
Electron Tube Shortcomings

• Vacuum Tube Triode
  – Hot cathode needs 5 minutes to warm-up
  – 15 minutes to turn on Radio, TV & radar
  – 120 minutes to turn computer-on
  – Bad Reliability
  – Not amenable to complex systems or integration
  – With ~2,000,000 transistors on modern microprocessors, a “chip” made out of vacuum tubes would be about 300’ X 300’
    – Assuming a 1”X1” tube on a 3” pitch to allow for routing traces, etc
Discovery of Transistor by Bardeen and Brattain (1947)

Identification of minority carrier injection, recombination in the base and collection: underlying bipolar transistor operation
Major Milestones in Semiconductor Devices and Integrated Circuits (Illinois ECE Connection)

1947: First Bipolar Transistor (Bardeen & Brattain)
1958: Invention of Integrated Circuits (Kilby & Noyce)
1960: First MOSFET (Kahng and Atalla)
1962: First LED and Semiconductor Laser (Hall, Holonyak)
1963: Invention of CMOS (Wanlass and Sah)
1968: Invention of DRAM (Dennard)
1971: First Microprocessor (Intel)
First Practical LED: 1962
Will anyone living, live to see our little light
burn out?

After 100 years of constant use, it may lose
only half its brightness.
That's because we don't use a bulb, a filament
or a vacuum.

We use a tiny crystal chip called a light-emitting
diode. It works something like a transistor, but let's not
get into all that.

Our diodes are already in use on computer
panels, freeing the man who used to look for burned-out
bulbs among all those hundreds of winking lights.

That's a good market. But let's look at markets to come.

How about a flat head-light as wide as your car, to evenly light
the road?

Or an inch-deep color TV set?
Or a wrist watch without a dial,
that shows the time in numbers at
the instant you push a button?

That's part of the future we see in our crystal chips.
And just a small part of the future we see in Monsanto: the science company.
The Future Realized: 2013
Motivation

Why is this course important?
Semiconductors Are Everywhere

2017 Worldwide Semiconductor Sales: $408.7 Billion

Larger Than Most Countries’ GDP (Only ~27 Larger), Global Software $406.6 Billion
The Cloud

- Hardware
- Optical Datalinks
- Materials
- Devices
- Lasers
- Modulators
- Photodiodes
- Transistors
- Rack-to-Rack
- Intra-Rack
- Chip to Chip
- On Chip
- ICs
- III-Vs
- Silicon
Behind the Cloud

Supercomputer Optical Interconnects

Server Room

Data Center
The Internet Runs on Hardware

The hardware doesn’t run without semiconductors
The Scale of “Big Data”

Table 1. Global IP traffic, 2016-2021

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<td>Fixed Internet</td>
<td>65,942</td>
<td>83,371</td>
<td>102,960</td>
<td>127,008</td>
<td>155,121</td>
<td>187,386</td>
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<td>Managed IP</td>
<td>22,911</td>
<td>27,140</td>
<td>31,304</td>
<td>35,226</td>
<td>38,908</td>
<td>42,452</td>
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<td>Mobile data</td>
<td>7,201</td>
<td>11,183</td>
<td>16,646</td>
<td>24,220</td>
<td>34,382</td>
<td>48,270</td>
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<td>By Segment (PB per Month)</td>
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<tr>
<td>Consumer</td>
<td>78,250</td>
<td>99,777</td>
<td>124,689</td>
<td>154,935</td>
<td>190,474</td>
<td>232,855</td>
<td>24%</td>
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<td>Business</td>
<td>17,804</td>
<td>21,917</td>
<td>26,220</td>
<td>31,518</td>
<td>37,937</td>
<td>45,452</td>
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<td>By Geography (PB per Month)</td>
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<td>Asia Pacific</td>
<td>33,505</td>
<td>43,169</td>
<td>54,402</td>
<td>88,784</td>
<td>88,088</td>
<td>107,855</td>
<td>26%</td>
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<td>North America</td>
<td>33,848</td>
<td>42,267</td>
<td>51,722</td>
<td>62,330</td>
<td>73,741</td>
<td>85,047</td>
<td>20%</td>
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<td>Western Europe</td>
<td>14,014</td>
<td>17,396</td>
<td>21,167</td>
<td>25,710</td>
<td>30,971</td>
<td>37,393</td>
<td>22%</td>
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<td>Central and Eastern Europe</td>
<td>6,210</td>
<td>7,451</td>
<td>8,940</td>
<td>11,016</td>
<td>13,781</td>
<td>17,059</td>
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<td>Middle East and Africa</td>
<td>2,679</td>
<td>3,910</td>
<td>5,538</td>
<td>7,773</td>
<td>10,941</td>
<td>15,490</td>
<td>42%</td>
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<td>Latin America</td>
<td>5,999</td>
<td>7,502</td>
<td>9,141</td>
<td>10,881</td>
<td>12,909</td>
<td>15,484</td>
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<td>Total (PB per Month)</td>
<td>96,054</td>
<td>121,694</td>
<td>150,910</td>
<td>186,453</td>
<td>228,411</td>
<td>278,108</td>
<td>24%</td>
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Source: Cisco 2017 VNI (Visual Networking Index)
Elements of an Optical Network

Electronics
- CDR
- SERDES
- Protocol Conversion
- Framers
- Switching/Routing

Optics
- Lasers (Fixed $\lambda$ and Tunable $\lambda$)
- Modulators
- Optical Mux / DeMux
- Switches (Cross Connect, ROADM, etc.)
- Amplifiers/Attenuators
- Dispersion Compensation Modules
- Detectors
LEDs – Why Are They Important?

Nighttime Satellite Images of the U.S. and Europe

- Electricity represents approximately 1/3 of the total energy use worldwide (Source: Infineon Technologies)
- In industrialized countries, national lighting electricity ranges from 5% to 15% of total electricity use
- In developing countries, the percentage of total electricity use employed in lighting is as high as 86%
- Approximately 1/3 of the world’s population depends upon fuel-base lighting
  - The cost in $/lumen-hours of kerosene lighting is 325X the cost of incandescent lighting
  - Households in developing spend a significantly higher percentage of their household income on lighting, but receive significantly less service due to the inefficiency of fuel-based lighting
- Moving to high-efficiency lighting can have a significant impact on global energy use and greenhouse gas emissions, and would improve the quality of service in geographies that still heavily depend upon fuel-based lighting
- Source: Evan Mills, Lawrence Berkeley National Laboratory

LED Applications

LED Traffic Signals
Source: gelightingsolutions.com

LED Backlit TV
Source: digitaltrends.com

Architectural Lighting
Source: vividleds.us

LED General Lighting
Source: led-resource.com

Automotive
Source: spie.org
Global Energy Consumption

<table>
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<tr>
<th>Region and energy source</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
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<tr>
<td></td>
<td>(Quadrillion British Thermal Units)</td>
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<td>World, total</td>
<td>472.7</td>
<td>483.1</td>
<td>495.2</td>
<td>543.5</td>
<td>590.5</td>
<td>638.7</td>
<td>686.5</td>
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<td>OECD, total</td>
<td>243.8</td>
<td>244.1</td>
<td>245.7</td>
<td>246.0</td>
<td>254.2</td>
<td>263.2</td>
<td>271.4</td>
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<td>OECD North America</td>
<td>122.4</td>
<td>121.8</td>
<td>123.7</td>
<td>124.3</td>
<td>129.4</td>
<td>134.9</td>
<td>140.2</td>
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<tr>
<td>United States \1</td>
<td>100.5</td>
<td>99.8</td>
<td>101.7</td>
<td>101.6</td>
<td>105.0</td>
<td>108.3</td>
<td>111.2</td>
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<td>Canada</td>
<td>14.8</td>
<td>14.5</td>
<td>14.3</td>
<td>14.6</td>
<td>15.4</td>
<td>16.3</td>
<td>17.2</td>
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<td>Mexico</td>
<td>7.1</td>
<td>7.4</td>
<td>7.7</td>
<td>8.1</td>
<td>9.0</td>
<td>10.4</td>
<td>11.8</td>
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<tr>
<td>OECD Europe</td>
<td>82.4</td>
<td>82.9</td>
<td>82.3</td>
<td>82.0</td>
<td>83.0</td>
<td>85.0</td>
<td>86.5</td>
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<td>OECD Asia</td>
<td>39.0</td>
<td>39.5</td>
<td>39.7</td>
<td>39.7</td>
<td>41.8</td>
<td>43.3</td>
<td>44.8</td>
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<td>Japan</td>
<td>23.1</td>
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<td>21.1</td>
<td>21.9</td>
<td>22.1</td>
<td>22.1</td>
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<td>South Korea</td>
<td>9.3</td>
<td>9.4</td>
<td>9.7</td>
<td>10.6</td>
<td>11.7</td>
<td>12.7</td>
<td>13.8</td>
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<tr>
<td>Australia/New Zealand</td>
<td>6.6</td>
<td>6.7</td>
<td>7.2</td>
<td>8.0</td>
<td>8.2</td>
<td>8.5</td>
<td>8.9</td>
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<tr>
<td>Non-OECD, total</td>
<td>229.0</td>
<td>239.0</td>
<td>249.5</td>
<td>297.5</td>
<td>336.3</td>
<td>375.5</td>
<td>415.2</td>
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<td>Non-OECD Europe and Eurasia</td>
<td>50.4</td>
<td>51.0</td>
<td>51.5</td>
<td>52.4</td>
<td>54.2</td>
<td>56.2</td>
<td>57.8</td>
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<td>Russia</td>
<td>29.7</td>
<td>30.5</td>
<td>30.5</td>
<td>30.7</td>
<td>31.6</td>
<td>32.8</td>
<td>33.9</td>
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<tr>
<td>Other</td>
<td>20.7</td>
<td>20.6</td>
<td>21.0</td>
<td>21.7</td>
<td>22.5</td>
<td>23.3</td>
<td>23.9</td>
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<tr>
<td>Non-OECD Asia</td>
<td>112.6</td>
<td>119.6</td>
<td>127.1</td>
<td>159.3</td>
<td>187.8</td>
<td>217.0</td>
<td>246.9</td>
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<tr>
<td>China</td>
<td>68.4</td>
<td>73.0</td>
<td>78.0</td>
<td>101.4</td>
<td>121.4</td>
<td>142.4</td>
<td>162.7</td>
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<td>India</td>
<td>17.5</td>
<td>18.8</td>
<td>20.3</td>
<td>24.3</td>
<td>28.2</td>
<td>31.1</td>
<td>34.1</td>
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<tr>
<td>Other Non-OECD Asia</td>
<td>26.7</td>
<td>27.8</td>
<td>28.8</td>
<td>33.7</td>
<td>38.2</td>
<td>43.5</td>
<td>50.2</td>
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<tr>
<td>Middle East</td>
<td>22.8</td>
<td>23.9</td>
<td>25.1</td>
<td>32.9</td>
<td>36.5</td>
<td>39.1</td>
<td>41.8</td>
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<tr>
<td>Africa</td>
<td>17.2</td>
<td>17.3</td>
<td>17.8</td>
<td>20.8</td>
<td>22.5</td>
<td>24.6</td>
<td>26.5</td>
</tr>
<tr>
<td>Central and South America</td>
<td>26.0</td>
<td>27.1</td>
<td>28.0</td>
<td>32.1</td>
<td>35.5</td>
<td>38.7</td>
<td>42.2</td>
</tr>
<tr>
<td>Brazil</td>
<td>11.2</td>
<td>11.7</td>
<td>12.3</td>
<td>14.9</td>
<td>16.9</td>
<td>19.3</td>
<td>21.9</td>
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<tr>
<td>Other Central and South America</td>
<td>14.8</td>
<td>15.4</td>
<td>15.7</td>
<td>17.2</td>
<td>18.6</td>
<td>19.3</td>
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<td>Liquids</td>
<td>170.4</td>
<td>172.8</td>
<td>174.7</td>
<td>179.3</td>
<td>186.0</td>
<td>197.2</td>
<td>210.0</td>
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<td>Natural gas</td>
<td>106.3</td>
<td>108.3</td>
<td>112.1</td>
<td>129.1</td>
<td>141.2</td>
<td>150.2</td>
<td>155.8</td>
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<td>Coal</td>
<td>122.3</td>
<td>126.4</td>
<td>132.4</td>
<td>139.1</td>
<td>152.4</td>
<td>167.8</td>
<td>185.6</td>
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<td>Nuclear</td>
<td>27.5</td>
<td>27.8</td>
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<td>32.2</td>
<td>37.4</td>
<td>41.1</td>
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<td>Other</td>
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<td>47.9</td>
<td>48.8</td>
<td>63.8</td>
<td>73.4</td>
<td>82.4</td>
<td>91.2</td>
</tr>
</tbody>
</table>

Source: U.S. Energy Information Administration

495 peta-BTU (E15), Includes All Sectors – Commercial, Residential, Transportation, etc.
• In 60W Increments, ~ 2.76E11 - 60W Units, or 40 - 60W Units Per Person
• For US Per Capita Energy Consumption, Equivalent to 181 60W Units Per Person
Energy Units

- **British Thermal Unit (Btu)**, 1 Btu = 251.9958 cal
  - The amount of energy needed to cool or heat one pound of water by 1° F
  - Another imprecise unit that is still in use
  - Thermochemical Btu \(1\) Btu = 1054.35 J
  - 15 °C Btu \(1\) Btu = 1054.80 J
  - IT Btu \(1\) Btu = 1055.06 J
  - Mean Btu \(1\) Btu = 1055.87 J
- **Kilowatt-hour (kWh)**, 1 kWh = 3.6E6 J (exact)
- **Commonly Used Large Scale Units:**
  - Exajoule (\(10^{18}\) J), Quadrillion Btu (\(10^{15}\) BTU), Terawatt-year (\(10^{12}\) W•year)
- **Commonly Used Energy Equivalents**
  - 1 barrel of oil = ~5.80 MBtu (typically ranges from 5.6 to 6.3), 1 MBtu=1000 Btu
  - 1 tonne (metric ton) of coal = ~27.8 Mbtu
  - 1 cubic foot natural gas = ~900-1100 Btu, 1 therm = 100,000 Btu \(\approx\) 100 ft\(^3\)
- **As a rough estimate, if all lighting were LED based we would reduce global energy use by the equivalent of 2.3 trillion barrels of oil annually**

High Efficiency Solar Cells

Terrestrial Power

UAV

Military

Solar Systems

Wireless

Amonix

Space
Course Purpose and Objectives
Course Purpose & Objectives

• Introduce key concepts in semiconductor materials
• Provide a basic understanding of p-n junctions
• Provide a basic understanding of light-emitting diodes and photodetectors
• Provide a basic understanding of field effect transistors
• Provide a basic understanding of bipolar junction transistors
Schedule & Policies
Instructional Objectives (1)

By the time of exam No. 1 (after 17 lectures), the students should be able to do the following:

1. Outline the classification of solids as metals, semiconductors, and insulators and distinguish direct and indirect semiconductors.
2. Determine relative magnitudes of the effective mass of electrons and holes from an E(k) diagram.
3. Calculate the carrier concentration in intrinsic semiconductors.
4. Apply the Fermi-Dirac distribution function to determine the occupation of electron and hole states in a semiconductor.
5. Calculate the electron and hole concentrations if the Fermi level is given; determine the Fermi level in a semiconductor if the carrier concentration is given.
6. Determine the variation of electron and hole mobility in a semiconductor with temperature, impurity concentration, and electrical field.
7. Apply the concept of compensation and space charge neutrality to calculate the electron and hole concentrations in compensated semiconductor samples.
8. Determine the current density and resistivity from given carrier densities and mobilities.
9. Calculate the recombination characteristics and excess carrier concentrations as a function of time for both low level and high level injection conditions in a semiconductor.
10. Use quasi-Fermi levels to calculate the non-equilibrium concentrations of electrons and holes in a semiconductor under uniform photoexcitation.
11. Calculate the drift and diffusion components of electron and hole currents.
12. Calculate the diffusion coefficients from given values of carrier mobility through the Einstein’s relationship and determine the built-in field in a non-uniformly doped sample.

https://my.ece.illinois.edu/courses/description.asp?ECE340
Instructional Objectives (2)

By the time of Exam No.2 (after 32 lectures), the students should be able to do all of the items listed under A, plus the following:

13. Calculate the contact potential of a p-n junction.
14. Estimate the actual carrier concentration in the depletion region of a p-n junction in equilibrium.
15. Calculate the maximum electrical field in a p-n junction in equilibrium.
16. Distinguish between the current conduction mechanisms in forward and reverse biased diodes.
17. Calculate the minority and majority carrier currents in a forward or reverse biased p-n junction diode.
18. Predict the breakdown voltage of a p+-n junction and distinguish whether it is due to avalanche breakdown or Zener tunneling.
19. Calculate the charge storage delay time in switching p-n junction diodes.
20. Calculate the capacitance of a reverse biased p-n junction diode.
21. Calculate the capacitance of a forward biased p-n junction diode.
22. Predict whether a metal-semiconductor contact will be a rectifying contact or an ohmic contact based on the metal work function and the semiconductor electron affinity and doping.
23. Calculate the electrical field and potential drop across the neutral regions of wide base, forward biased p+-n junction diode.
24. Calculate the voltage drop across the quasi-neutral base of a forward biased narrow base p+-n junction diode.
25. Calculate the excess carrier concentrations at the boundaries between the space-charge region and the neutral n- and p-type regions of a p-n junction for either forward or reverse bias.
Instructional Objectives (3)

By the time of the Final Exam, after 44 class periods, the students should be able to do all of the items listed under A and B, plus the following:

26. Calculate the terminal parameters of a BJT in terms of the material properties and device structure.
27. Estimate the base transport factor “B” of a BJT and rank-order the internal currents which limit the gain of the transistor.
28. Determine the rank order of the electrical fields in the different regions of a BJT in forward active bias.
29. Calculate the threshold voltage of an ideal MOS capacitor.
30. Predict the C-V characteristics of an MOS capacitor.
31. Calculate the inversion charge in an MOS capacitor as a function of gate and drain bias voltage.
32. Estimate the drain current of an MOS transistor above threshold for low drain voltage.
33. Estimate the drain current of an MOS transistor at pinch-off.
34. Distinguish whether a MOSFET with a particular structure will operate as an enhancement or depletion mode device.
35. Determine the short-circuit current and open-circuit voltage for an illuminated p/n junction solar cell.
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<th>JAN 19</th>
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<tr>
<td></td>
<td>Course overview</td>
<td>Intro to semiconductor electronics</td>
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<td>JAN 22</td>
<td>Materials and crystal structures</td>
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<td>JAN 24</td>
<td>Bonding forces and energy bands in solids</td>
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<td>JAN 26</td>
<td>Metals, semiconductors, insulators, electrons, holes</td>
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<td>JAN 29</td>
<td>Intrinsic and extrinsic material</td>
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<td>FEB 2</td>
<td>Distribution functions and carrier concentrations</td>
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<td>FEB 7</td>
<td>Conductivity and mobility</td>
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<td>FEB 9</td>
<td>Resistance, temperature, impurity concentration</td>
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<td>FEB 12</td>
<td>Invariance of Fermi level at equilibrium</td>
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<td>FEB 14</td>
<td>Optical absorption and luminescence</td>
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<td>FEB 16</td>
<td>Generation and recombination</td>
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**Subject to Change**
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<tr>
<td>FEB 19</td>
<td>Quasi-Fermi levels and photoconductive devices</td>
<td>FEB 21</td>
<td>Carrier diffusion</td>
<td>FEB 23</td>
<td>Built-in fields, diffusion and recombination</td>
</tr>
<tr>
<td>Feb 26</td>
<td>Review, discussion, problems (2/27 exam)</td>
<td>FEB 28</td>
<td>Steady state carrier injection, diffusion length</td>
<td>MAR 2</td>
<td>p-n junctions in equilibrium &amp; contact potential</td>
</tr>
<tr>
<td>MAR 5</td>
<td>p-n junction Fermi levels and space charge</td>
<td>MAR 7</td>
<td>Continue p-n junction space charge</td>
<td>MAR 9</td>
<td>NO CLASS (EOH)</td>
</tr>
<tr>
<td>MAR 12</td>
<td>p-n junction current flow</td>
<td>MAR 14</td>
<td>Carrier injection and the diode equation</td>
<td>MAR 16</td>
<td>Minority and majority carrier currents</td>
</tr>
<tr>
<td>3/19-3/23 Spring Break</td>
<td>Reverse-bias breakdown</td>
<td>MAR 28</td>
<td>Stored charge, diffusion and junction capacitance</td>
<td>MAR 30</td>
<td>Photodiodes, I-V under illumination</td>
</tr>
</tbody>
</table>

**Subject to Change**
# Tentative Schedule [3]

<table>
<thead>
<tr>
<th>APR 2</th>
<th>APR 4</th>
<th>APR 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEDs and Diode Lasers</td>
<td>Metal-semiconductor junctions</td>
<td>MIS-FETs: Basic operation, ideal MOS capacitor</td>
</tr>
<tr>
<td>APR 9</td>
<td>APR 11</td>
<td>APR 13</td>
</tr>
<tr>
<td>MOS capacitors: flatband &amp; threshold voltage</td>
<td>Review, discussion, problems (4/12 exam)</td>
<td>MOS capacitors: C-V analysis</td>
</tr>
<tr>
<td>APR 16</td>
<td>APR 18</td>
<td>APR 20</td>
</tr>
<tr>
<td>MOSFETs: Output &amp; transfer characteristics</td>
<td>MOSFETs: small signal analysis, amps, inverters</td>
<td>Narrow-base diode</td>
</tr>
<tr>
<td>APR 23</td>
<td>APR 25</td>
<td>APR 27</td>
</tr>
<tr>
<td>BJT fundamentals</td>
<td>BJT specifics</td>
<td>BJT normal mode operation</td>
</tr>
<tr>
<td>APR 30</td>
<td>MAY 2 (LAST LECTURE)</td>
<td>FINAL EXAM</td>
</tr>
<tr>
<td>BJT common emitter amplifier and current gain</td>
<td>Review, discussion, problem solving</td>
<td><strong>Date &amp; time to be announced</strong></td>
</tr>
</tbody>
</table>

**Subject to Change**
Important Information

• Course Website:
  – [http://courses.engr.illinois.edu/ece340/](http://courses.engr.illinois.edu/ece340/)

• Download and Review Syllabus / Course Information from Website!

• Course Coordinator: Prof. John Dallesasse
  – [jdallesa@illinois.edu](mailto:jdallesa@illinois.edu)
  – Coordinates schedule, policies, absence issues, homework, quizzes, exams, etc.

• Contact Information and Office Hours for All ECE340 Professors & TAs in Syllabus

• Lecture Slides: Click on “(Sec. X)” next to my name in instructor list

• DRES Students: Contact Prof. Dallesasse ASAP

• Textbook:
  – Additional reference texts listed in syllabus
Key Points

• Attend Class!
  – 3 unannounced quizzes, each worth 5% of your grade
  – You must take the quiz in your section
  – Excused absences must be pre-arranged with the course director
  – Absences for illness, etc. need a note from the Dean
    • See policy on absences in the syllabus

• No Late Homework
  – Homework due on the date of an excused absence must be turned in ahead of time
  – You must turn in homework in your section
  – No excused absences for homework assignments
  – Top 10 of 11 homework assignments used in calculation of course grade
    • Do all of them to best prepare for the exams!

• No Cheating
  – Penalties are severe and will be enforced

• Turn Off Your Phone
  – No video recording, audio recording, or photography
Homework

• Assigned Friday, Due Following Friday
  – Due dates shown in syllabus
• Due at Start of Class
• Follow Guidelines in Syllabus
• Peer Discussions Related to Homework are Acceptable and Encouraged
• Directly Copying Someone Else’s Homework is Not Acceptable
  – Graders have been instructed to watch for evidence of plagiarism
  – Both parties will receive a “0” on the problem or assignment
Absences

• The absence policy in the syllabus will be strictly enforced
• To receive an excused absence (quiz), you must:
  – Pre-arrange the absence with the course director (valid reason and proof required)
  – Complete an Excused Absence Form at the Undergraduate College Office, Room 207 Engineering Hall (333-0050)
    • The form must be signed by a physician, medical official, or the Emergency Dean (Office of the Dean of Students)
    • The Dean’s Office has recently put a strict policy in place (3 documented days of illness)
  – Excused quiz score will be prorated based upon average of completed scores
  – No excused absences are given for homework, but only the best 10 of 11 are used to calculate your final grade
  – Excused absences are not given for exams, except in accordance with the UIUC Student Code
    – Unexcused work will receive a “0”
• Failure to take the final will result in an “incomplete” grade (if excused) or a “0” (if unexcused)
Exams

• Exam I: Tuesday February 27th, 7:30-8:30 pm
• Exam II: Thursday April 12th, 7:30-8:30 pm
• Final Exam: Date/Time To Be Announced
  – Determined by University F&S
## Grading

<table>
<thead>
<tr>
<th>Grading Criterion</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>10 %</td>
</tr>
<tr>
<td>Quizzes</td>
<td>15 %</td>
</tr>
<tr>
<td>Hour Exam I</td>
<td>20 %</td>
</tr>
<tr>
<td>Hour Exam II</td>
<td>20 %</td>
</tr>
<tr>
<td>Final Exam</td>
<td>35 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100 %</strong></td>
</tr>
</tbody>
</table>

### Historical Grade Trends*

<table>
<thead>
<tr>
<th>Grade</th>
<th>Spring 2016</th>
<th>Fall 2016</th>
<th>Spring 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>A’s</td>
<td>27 %</td>
<td>28 %</td>
<td>27 %</td>
</tr>
<tr>
<td>B’s</td>
<td>37 %</td>
<td>26 %</td>
<td>38 %</td>
</tr>
<tr>
<td>C’s</td>
<td>27 %</td>
<td>25 %</td>
<td>27%</td>
</tr>
<tr>
<td>D’s</td>
<td>6 %</td>
<td>16 %</td>
<td>4 %</td>
</tr>
<tr>
<td>F’s</td>
<td>3 %</td>
<td>5 %</td>
<td>16 %</td>
</tr>
</tbody>
</table>

*Past performance is not necessarily indicative of future results.
Assignments
Assignments

• Read info packet – key course policies and schedule are outlined here, including hourly exam dates
• Homework assigned every Friday, due following Friday
• Begin to read Chapter 1 of Streetman’s book
  – Sections 1.1, 1.2, 1.3.1, 1.4
  – I suggest reading all of Chapter 1, but only the above sections are assigned
• Chapter 1 in Pierret covers similar material, and complements Streetman for another perspective
Topics for Next Lecture
Outline, 1/19/17

• Introduction to semiconductor electronics
• Semiconductor materials
• Common semiconductor crystal structures
• Lattice constants
• Miller indices
• Examples:
  – Determining Miller indices for various crystal planes
  – Density calculations
• Epitaxial growth technologies
Thank You for Listening!