

ECE 305: Spring 2018

Semiconductor Device Fundamentals: Course Introduction

Professor Peter Bermel
Electrical and Computer Engineering
Purdue University, West Lafayette, IN USA
pbermel@purdue.edu

electron devices

vacuum tube



Edison effect, 1880
J.J. Thompson, 1897
diode (Fleming, 1904)
triode (De Forest, 1905)

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transistor



Bardeen, Brattain,
Shockley, 1947

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integrated circuit



Kilby /Noyce, 1958

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electron devices

modern solar cell



Chapin, Pearson, Fuller,
1954

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LED



Holonyak, 1962

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semiconductor
laser



Hall, 1962

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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>

transistors

"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."

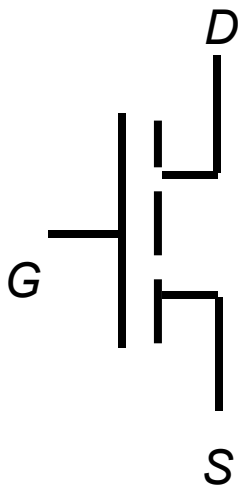
- Ira Flatow, Transistorized!

<http://www.pbs.org/transistor/>

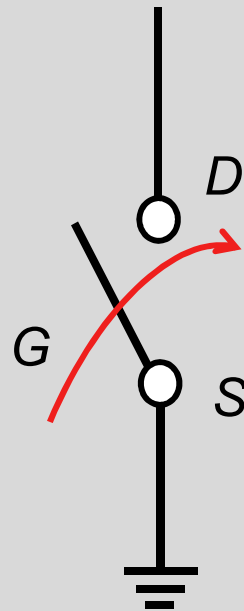
<https://www.youtube.com/watch?v=U4XknGqr3Bo>

transistors

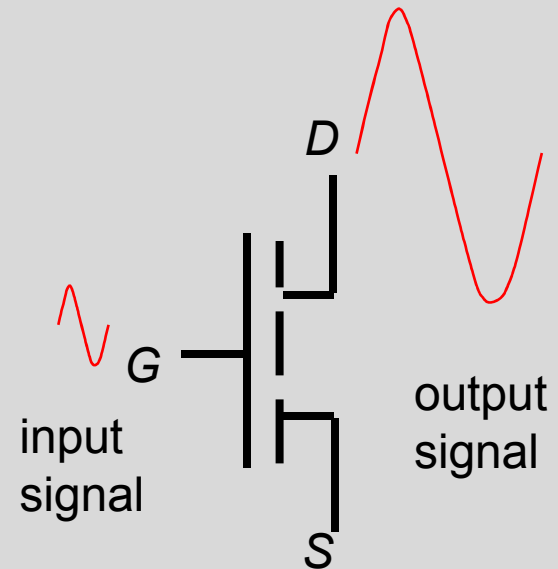
symbol



switch

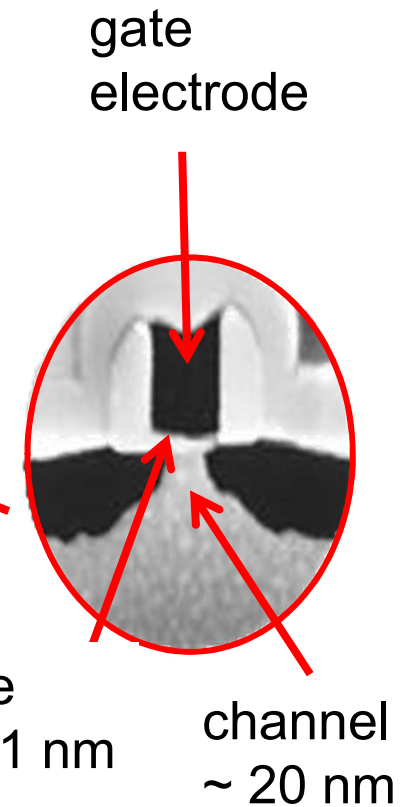
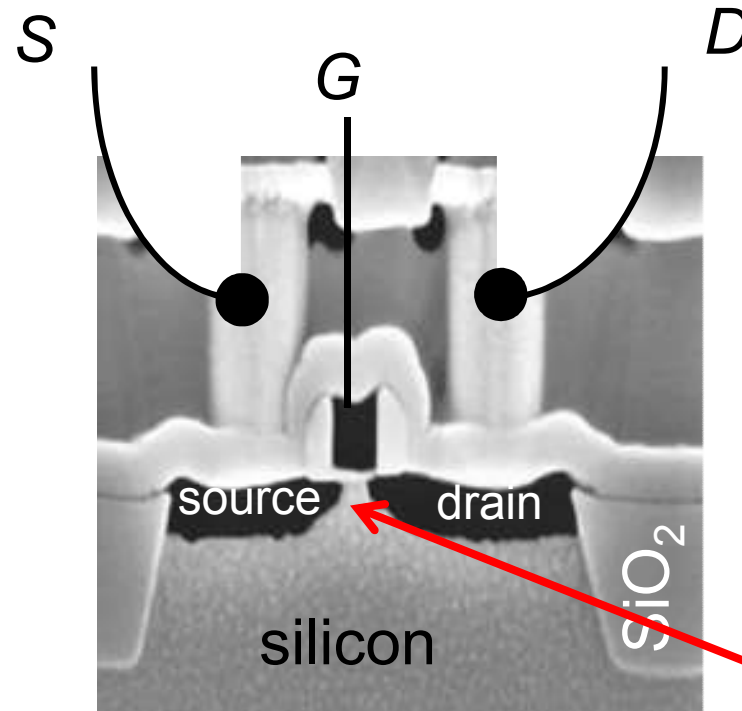
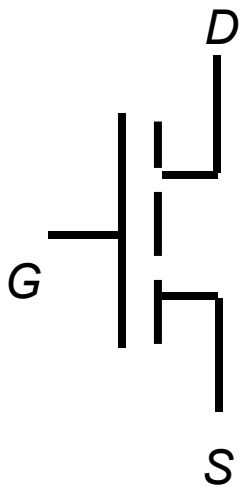


amplifier



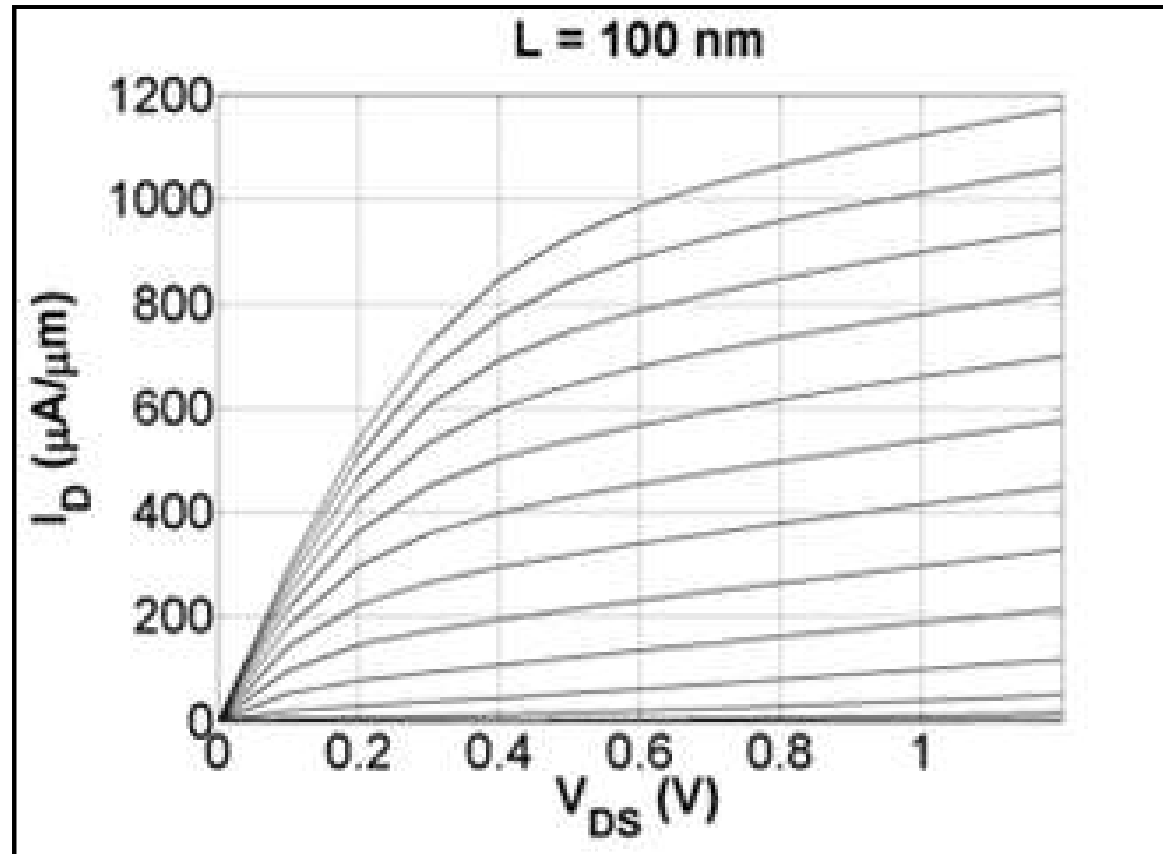
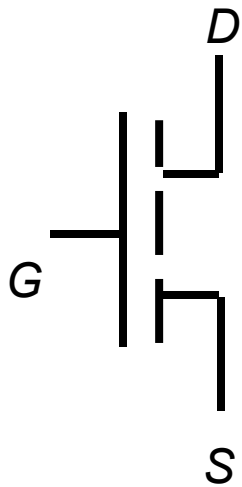
real transistors

symbol



transistor IV

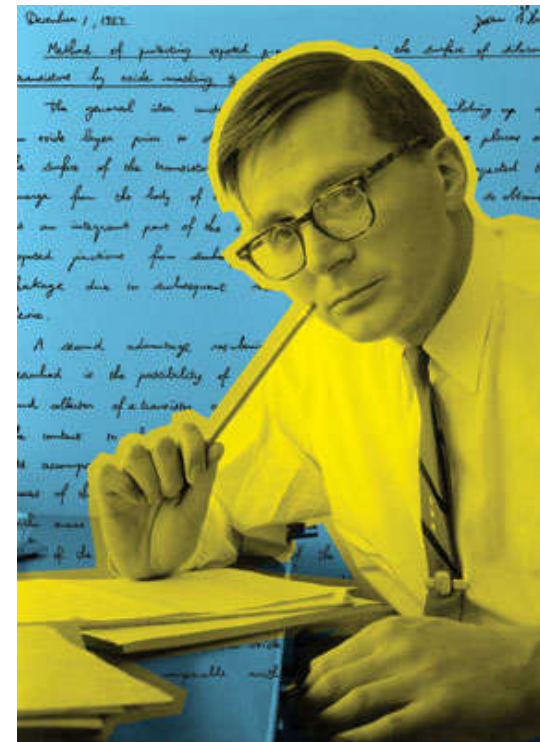
symbol



“The most important moment since humankind emerged as a life form.”

Isaac Asimov

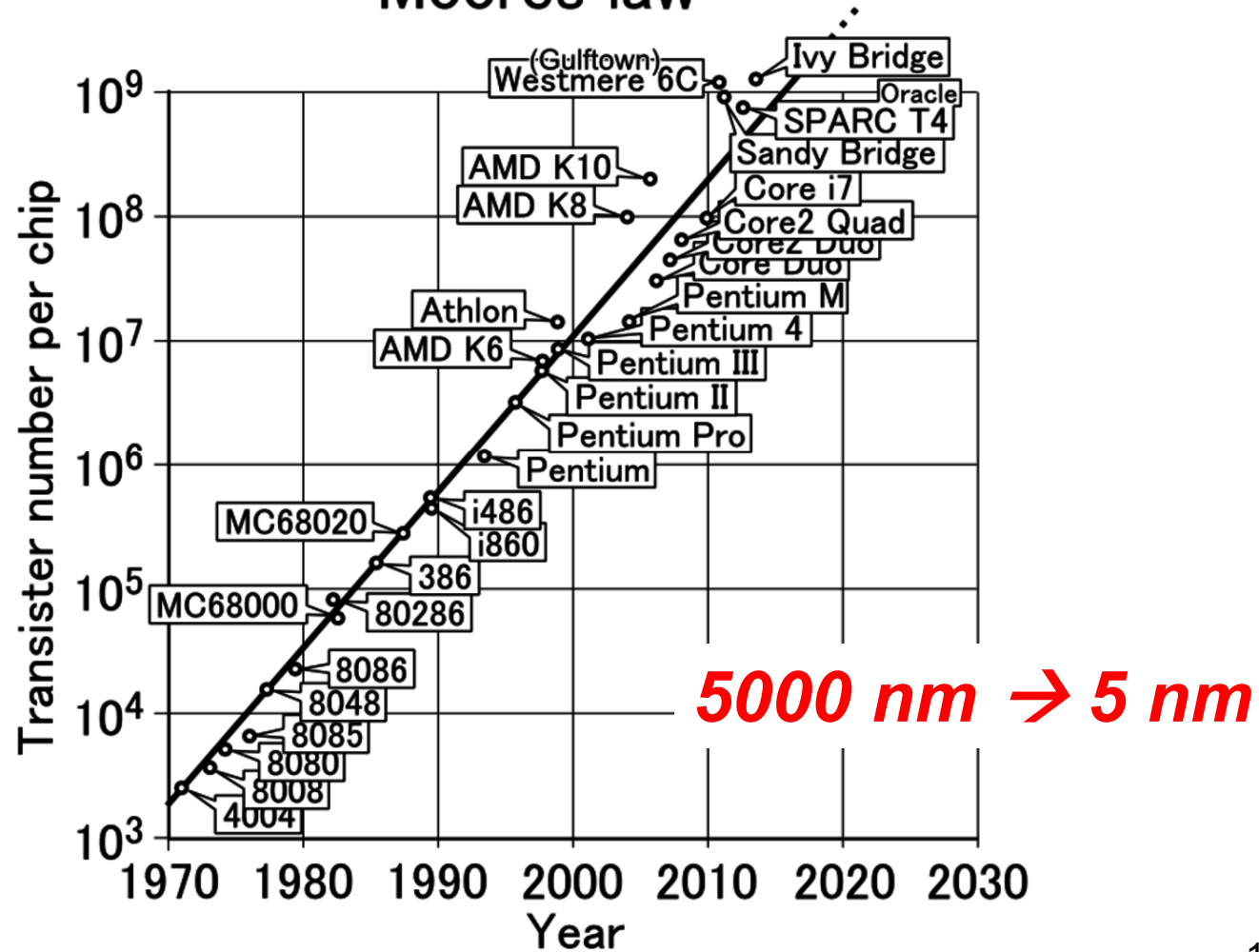
(speaking about the “planar process” used to manufacture ICs -
- invented by Jean Hoerni,
Fairchild Semiconductor, 1959).



IEEE Spectrum Dec. 2007

exponential growth

Moore's law



21st Century electronics

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

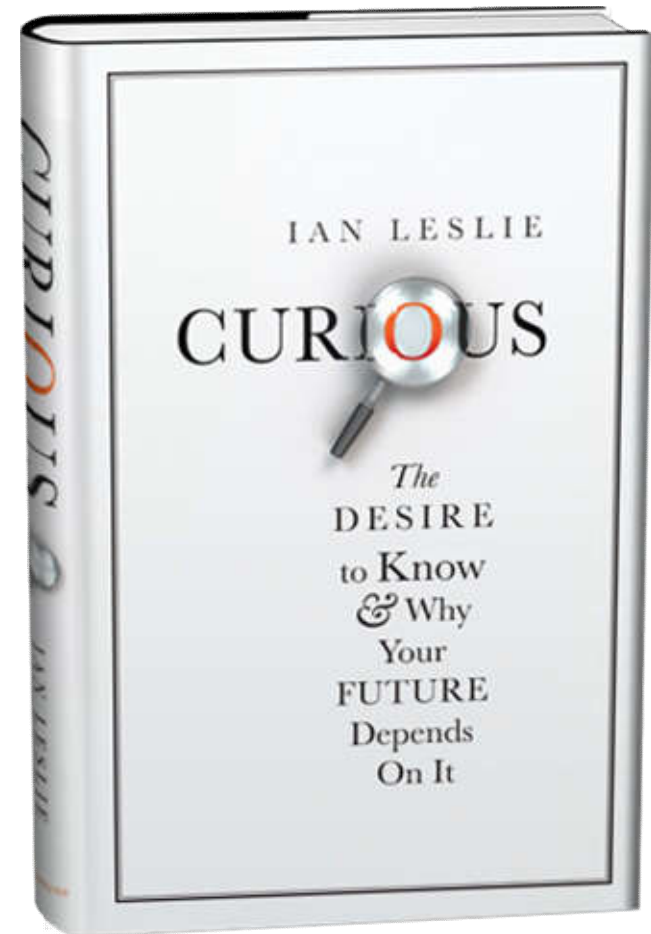


www.apple.com

CMOS imager
Gyroscope
MEMS devices
Magnetometer
Microphone, speaker
LCD display and touch screen

what engineers have done

“If someone from the 1950’s suddenly appeared today, what would be the most difficult thing to explain to them about today?”

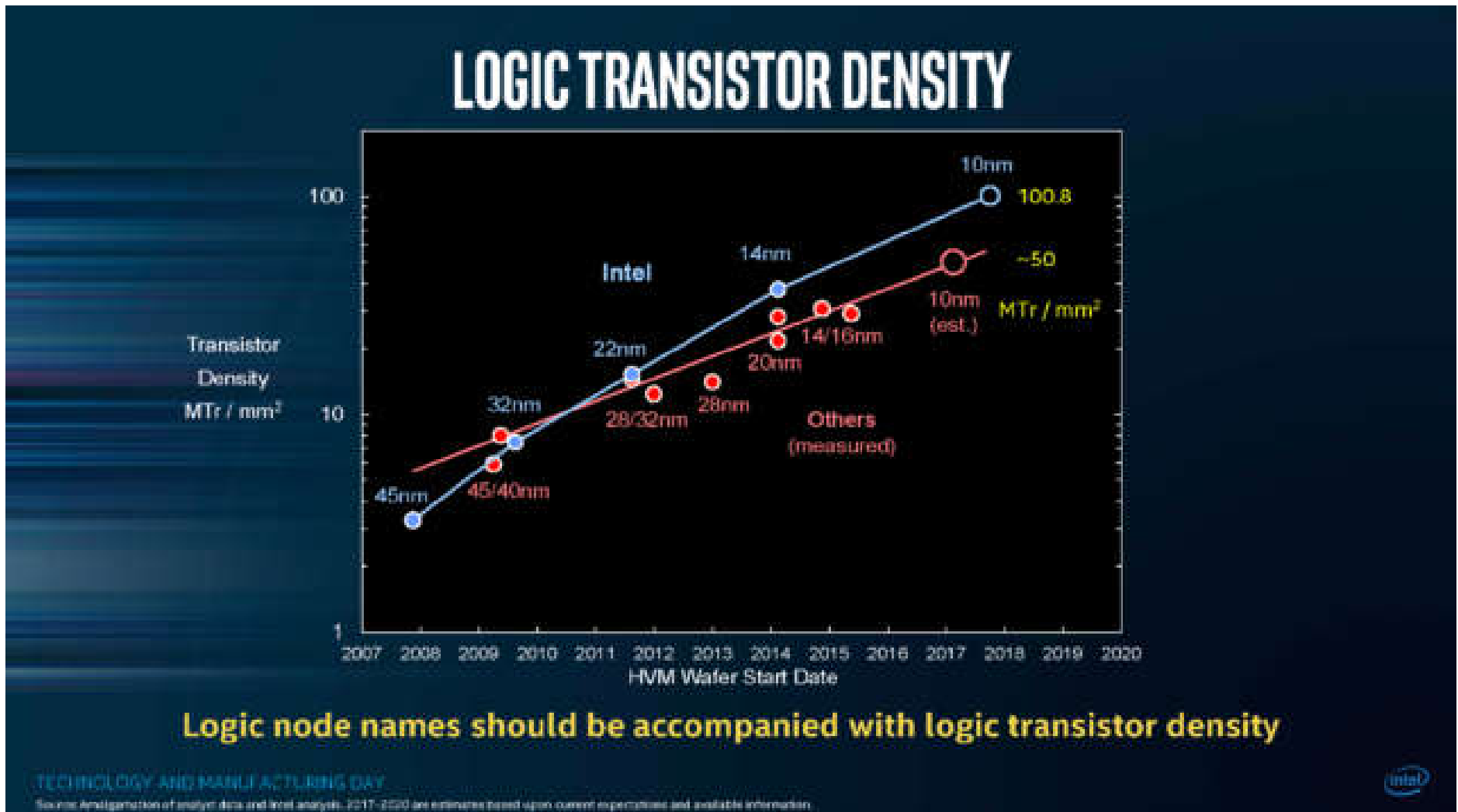


most popular answer

“I possess a device in my pocket that is capable of assessing the entirety of information known to humankind.

I use it to look at pictures of cats and get into arguments with strangers.”

“The end of Moore’s Law?”



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<http://www.extremetech.com/extreme/199636-intel-at-isscc-14nm-in-the-bag-full-steam-ahead-on-10nm>

Intel: January 2018

14 nm technology (in production)

10 nm (demo'd last month, following TSMC + Samsung)

7 nm (productizing)

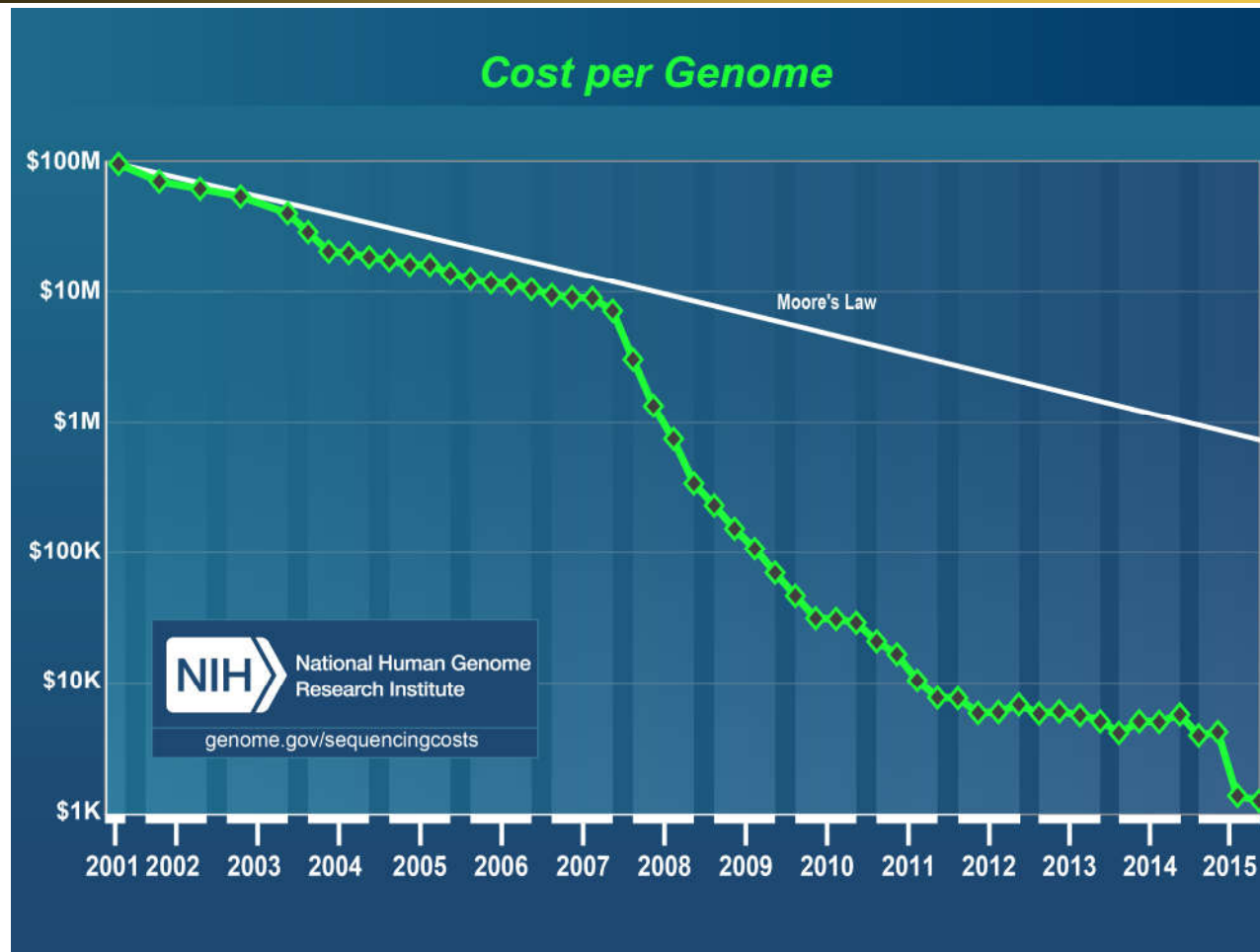
5 nm (research)

Biggest concern: energy dissipation.

Biggest source of energy dissipation: moving data in and out of memory.

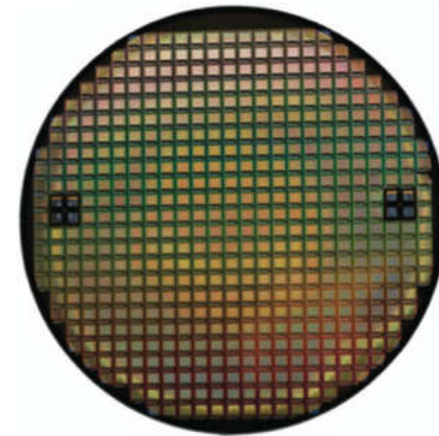
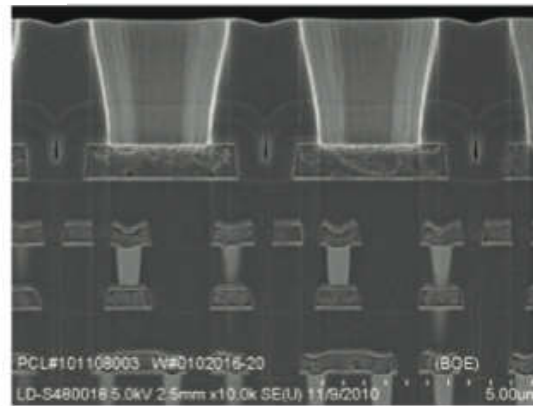
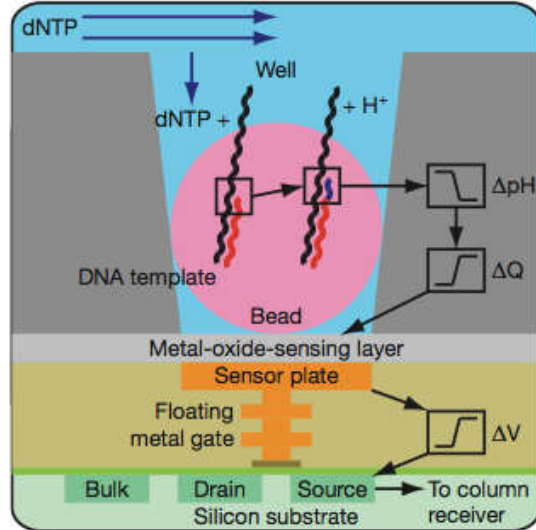
Need a fundamentally better transistor, but it is really hard to find one.

More-than-Moore: Gene sequencing



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

Electronics beyond Moore's Law



Ion Torrent (*Nature*, **475**, 349, 21 July, 2011)

Tricorder X Prize Winner: Final Frontier Medical Devices



<https://www.space.com/37681-star-trek-tricorder-explore-space.html>

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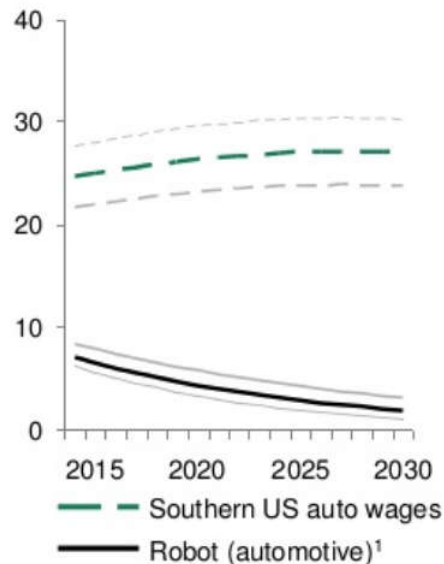
robotic manufacturing

Within the US automotive and electrical equipment industries, robotic price/performance is better than or near parity with manual labor costs

US automotive industry

2013 industrial robot shipments (units) 10,320

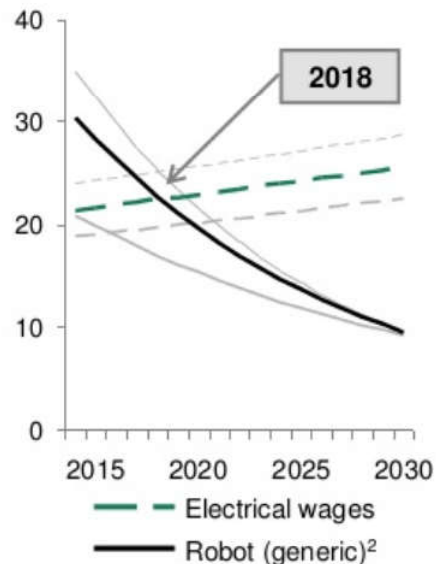
Price/performance-adjusted nominal wages and operating cost (\$/hour)



US electrical equipment industry

2013 industrial robot shipments (units) 3,328

Price/performance-adjusted nominal wages and operating cost (\$/hour)

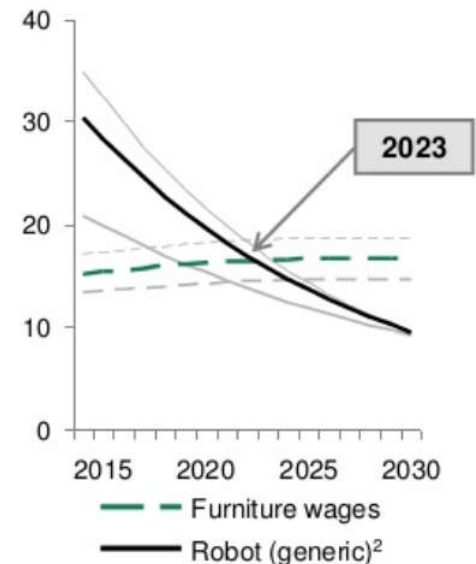


In other industries, robotic systems may surpass manual labor in the next 10 years

US furniture industry

2013 industrial robot shipments³ (units) 23

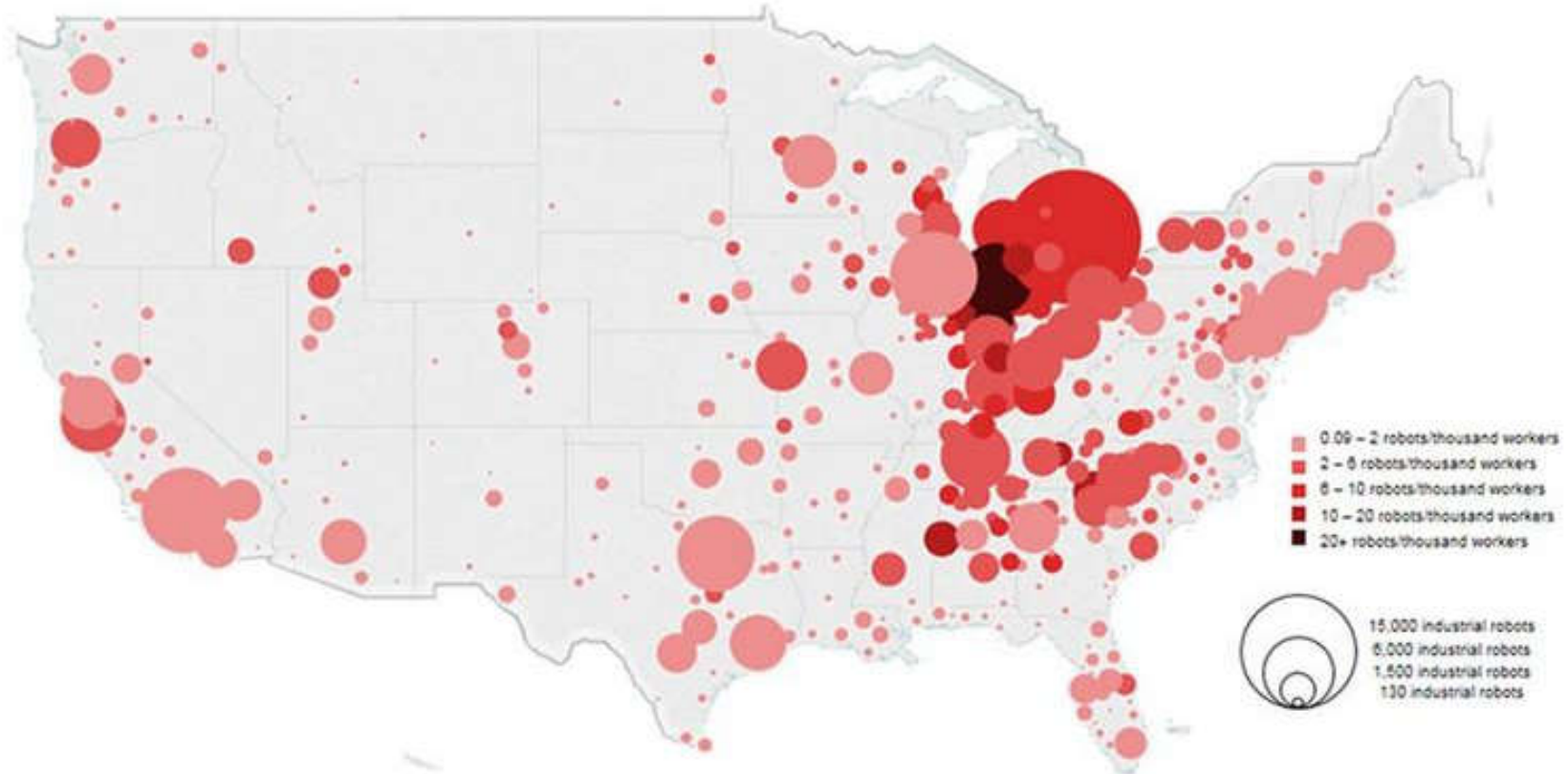
Price/performance-adjusted nominal wages and operating cost (\$/hour)



Source: Boston Consulting Group, "The Shifting Economics of Global Manufacturing" (February 2015)

robotic manufacturing

Number and incidence of industrial robots (per thousand workers) by metropolitan statistical area, 2015



Note: Robot incidence reflects private employment only

D | Metropolitan Policy Program

Source: Brookings Institution Report (2017)

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21st Century electronics



Bell Labs 1947

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Apple 2007

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21st Century
electronics

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course outline

Course objectives: *To introduce students to the fundamentals of semiconductors and semiconductor devices.*

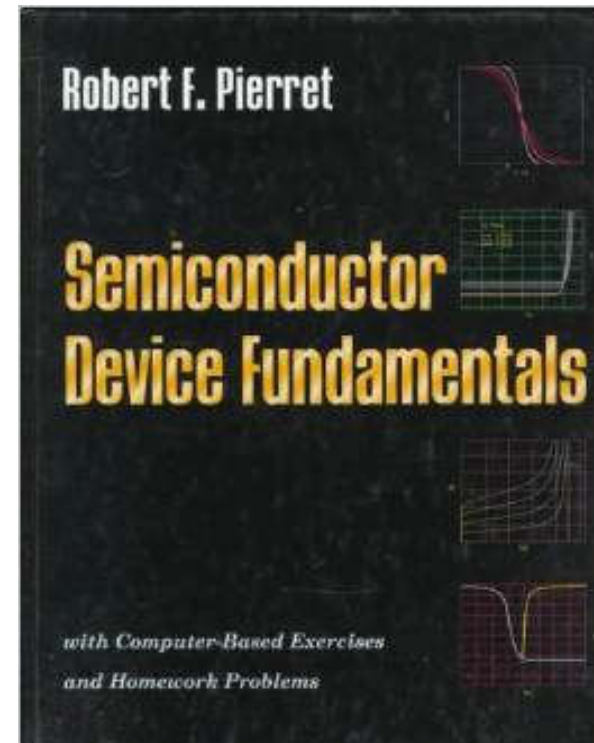
Part 1: Semiconductor Materials:	3 weeks
Part 2: PN diodes and Photovoltaics	3 weeks
Part 3: MS / Schottky diodes	3 weeks
Part 4: MOS / MOSFET devices	3 weeks
Part 5: Bipolar Junction Transistors	3 weeks

course objectives

- i. To predict the observable properties of semiconductors as a function of various parameters
- ii. To design pn diodes suitable for current rectification and solar power production
- iii. To predict the behavior and limitations of Schottky diodes
- iv. To evaluate the design and performance of metal-oxide-semiconductor field effect transistors (MOSFETs)
- v. To describe, predict, and improve the behavior of bipolar junction transistors (BJTs)

course text

Semiconductor Device Fundamentals, 2nd Edition (SDF)
R.F. Pierret, Addison-Wesley Publishing Co, 1996.
ISBN-0-201-54393-1



grading

550 total course points

**Homework assigned Monday. Due next Tuesday.
Solutions posted Friday** (maximum of 100 points)

In-class quizzes (maximum of 50 points)

5 exams (4 in class + “final”, maximum of 100 points each)

Total score: The sum of the highest 4 of exams 1-5 plus your HW plus your quiz total. **You must take Exam 5**, or it counts as a zero in your average.

Letter grade: Will divide total score by 500, and assign letter grades on a 10-point scale

frequent exams

- 1) Multiple choice (5 questions) 40 points
- 2) Problem 1 (usually 30 points)
- 3) Problem 2 (usually 30 points)

SUNDAYREVIEW

How Tests Make Us Smarter

JULY 18, 2014

Gray Matter

By HENRY L. ROEDIGER III

TESTS have a bad reputation in education circles these days: They take time, the critics say, put students under pressure and, in the case of standardized testing, crowd out other educational priorities. But the truth is that, used properly, testing as part of an educational routine provides an important tool not just to measure learning, but to promote it.

In one study I published with Jeffrey D. Karpicke, a psychologist at Purdue, we assessed how well students remembered material they had read. After an initial reading, students were tested on some passages by being given a blank sheet of paper and asked to recall as much as possible. They recalled about 70

getting help

Instructor Office Hours: TR, 1:15-2:15 pm, EE 332

TA (Mohammad Sadi, msadi). Office Hours held in EE 209

- All Wednesdays, starting Jan. 10: 2-6 pm
- All Mondays, starting on Jan. 15: 12-2 pm

Help from Piazza: <http://piazza.com/purdue/spring2018/ece305>

course web page

All course information is posted on the class home page

<http://nanohub.org/groups/ece305bermel>

Class announcements will supersede prior written information and will be posted on the course homepage

Campus Emergency Policies: In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. Information about changes will be posted on the course web page and available from pbermel@purdue.edu

EMERGENCY PREPAREDNESS

To report an emergency, **call 911**. To obtain updates regarding an ongoing emergency, sign up for Purdue Alert text messages, view www.purdue.edu/ea.

There are nearly 300 **Emergency Telephones** outdoors across campus and in parking garages that connect directly to the PUPD. If you feel threatened or need help, push the button and you will be connected immediately.

If we hear a **fire alarm** during class we will immediately suspend class, evacuate the building, and proceed outdoors. Do not use the elevator.

If we are notified during class of a **Shelter in Place requirement for a tornado** warning, we will suspend class and shelter.

If we are notified during class of a **Shelter in Place requirement for a hazardous materials release, or a civil disturbance**, including a shooting or other use of weapons, we will suspend class and shelter in the classroom, shutting the door and turning off the lights.

Please review the Emergency Preparedness website for additional information.
http://www.purdue.edu/ehps/emergency_preparedness/index.html

cheating

It's wrong. I have a zero tolerance policy. Any case of cheating will earn you an F in the course and a report to the Dean of Students.

----- Exam Integrity Statement -----

If I am caught cheating on this exam, I will earn an F for the course and be reported to the Dean of Students. Write out the above statement:

Signature: _____

Google Official: on “ideal recruits”

"There is no single set of discrete skills one can learn that will last an entire career in high-tech," Johnson writes. Instead, **"ideal recruits are creative, adaptable and autonomous, and they have achieved a deep understanding of core subjects such as math, physics and computer science** that make it possible to have a razor-sharp intuition and an ability to assimilate new subjects and technologies quickly, without even the expectation of being trained; they train themselves on the skills du jour as the need arises and with minimum help or structure."

Bruce Johnson, the Atlanta site and engineering director for Google, in the Atlanta Journal-Constitution (12/23/11).

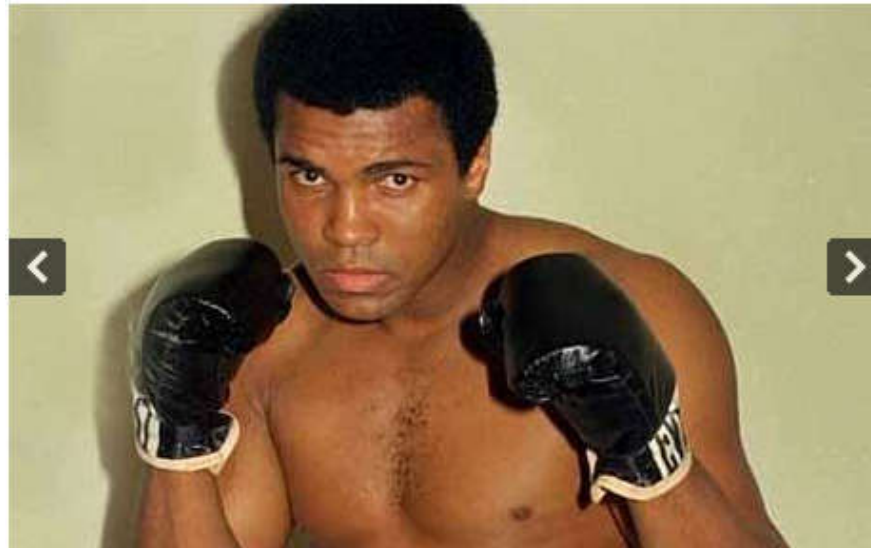
How to study

- 1) Do the assigned reading **before class**
- 2) Attend class and pay attention
- 3) Review the lecture after class
- 4) Do the HW without looking at the solutions
- 5) Review and understand the solutions
- 6) Be sure you understand the quizzes
- 7) Ask questions

ECE Honors

Consider signing an “Honors contract” for ECE 305

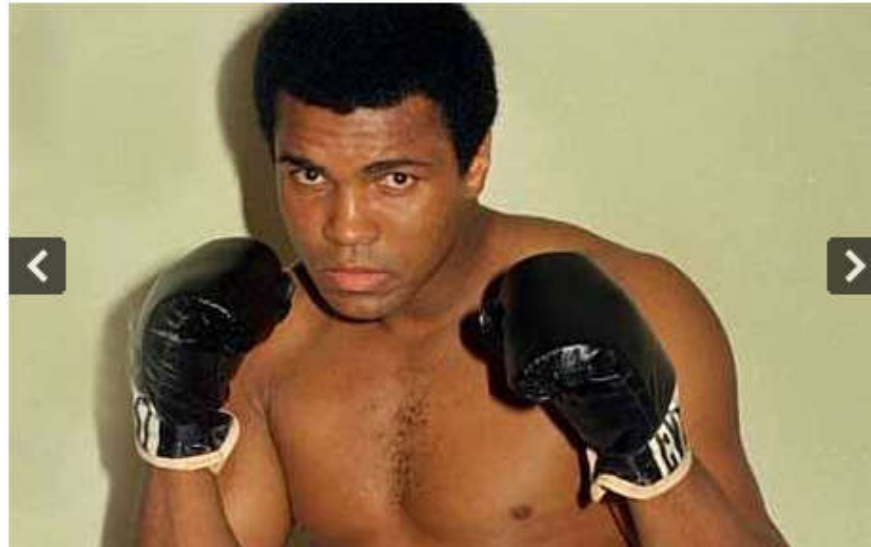
you're in training



“I hated every minute of training, but I said, 'Don't quit. Suffer now and live the rest of your life as a champion.’”
-Muhammad Ali

<http://www.brainyquote.com/quotes/quotes/m/muhammadal148629.html>

Muhammad Ali's advice



"Stay in College, get the knowledge, stay there until you are through. If they can make penicillin out of moldy bread, they can sure make something of you!"

-Muhammad Ali

<http://www.brainyquote.com/quotes/quotes/m/muhammadal148629.html>.

summary

- We're going to learn the fundamental science and engineering behind the modern electronics that underpin our lives today!
- The course will be taught with clear, detailed notes, frequent in-class activities, weekly homework assignments utilizing online tools, and five exams (four in-class, and one during finals week)
- The majority of course points (400) will come from exams; however homework (100) and in-class assignments (50) will be needed to get above a C
- Questions can be addressed through course website, Piazza, TA, or professor office hours

ECE 305

Work hard, have fun, learn something you can use for the rest of your career.

Get started now!

<https://nanohub.org/groups/ece305bermel>

