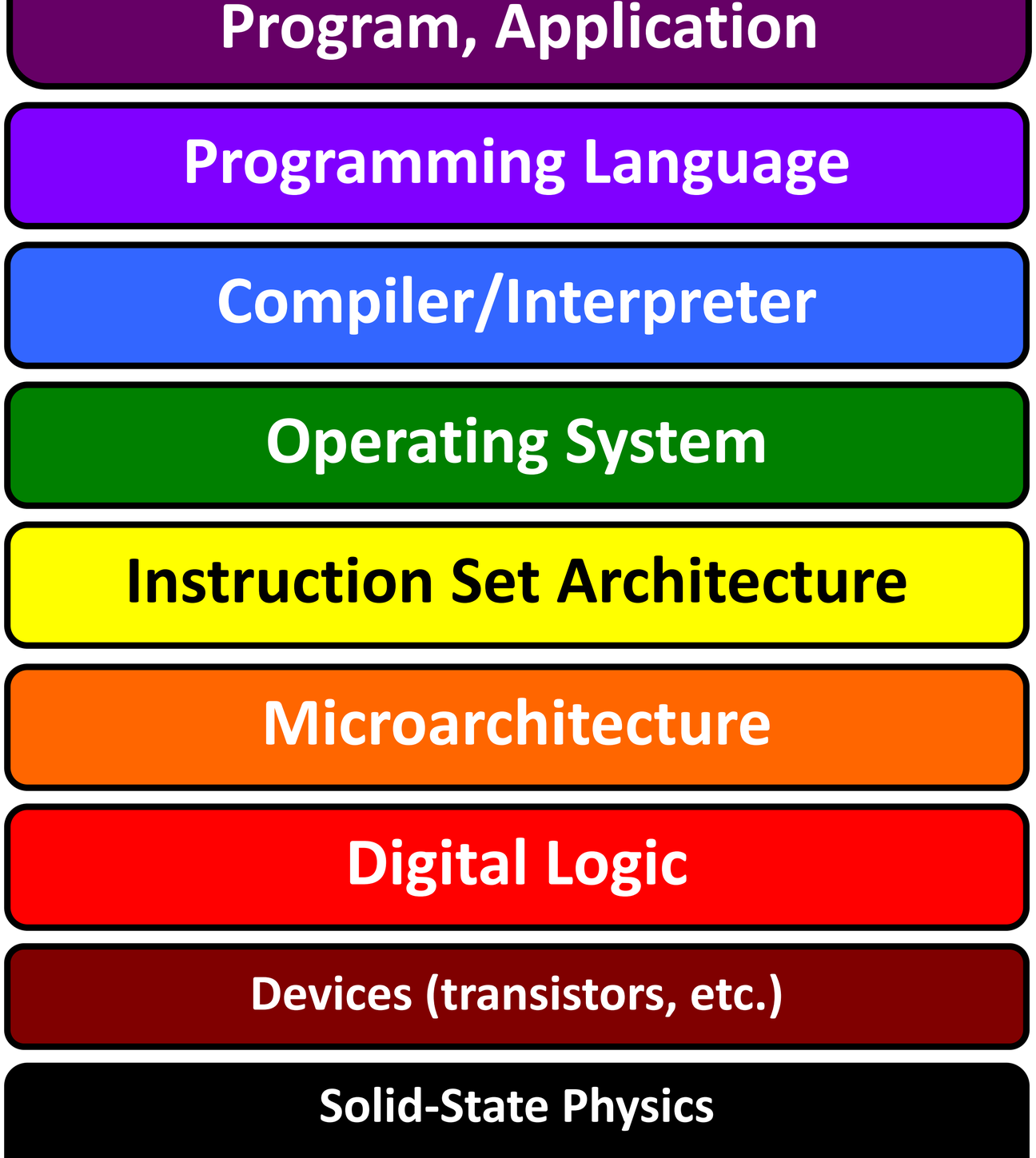
# The Plan

Welcome to

# CS 240:

Foundations of

# Computer Systems!



# Today

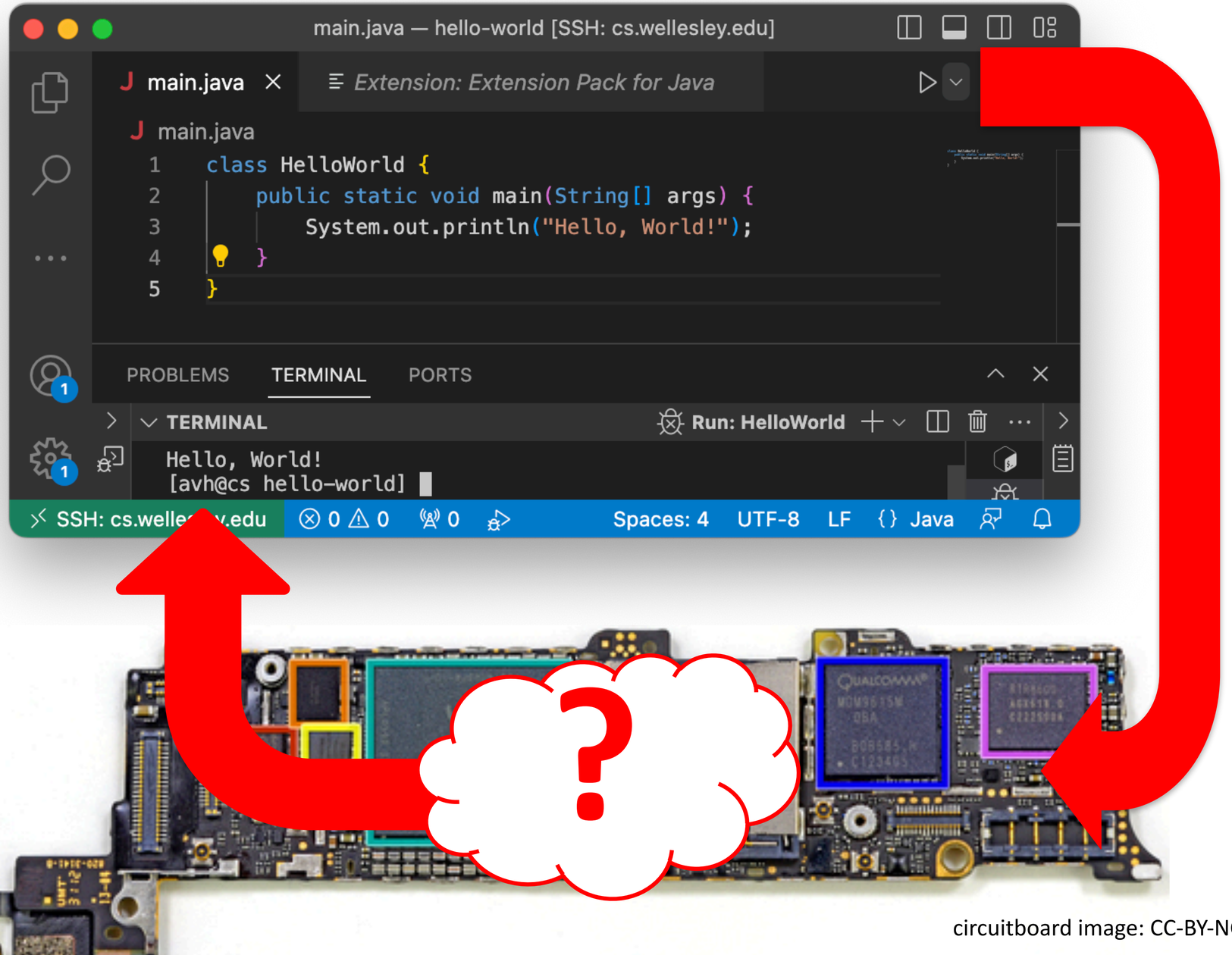
1. **What is CS 240?**
2. Why take CS 240?
3. How does CS 240 work?
4. Start diving into digital logic

## CS 111, 230, 231, 235, 251:

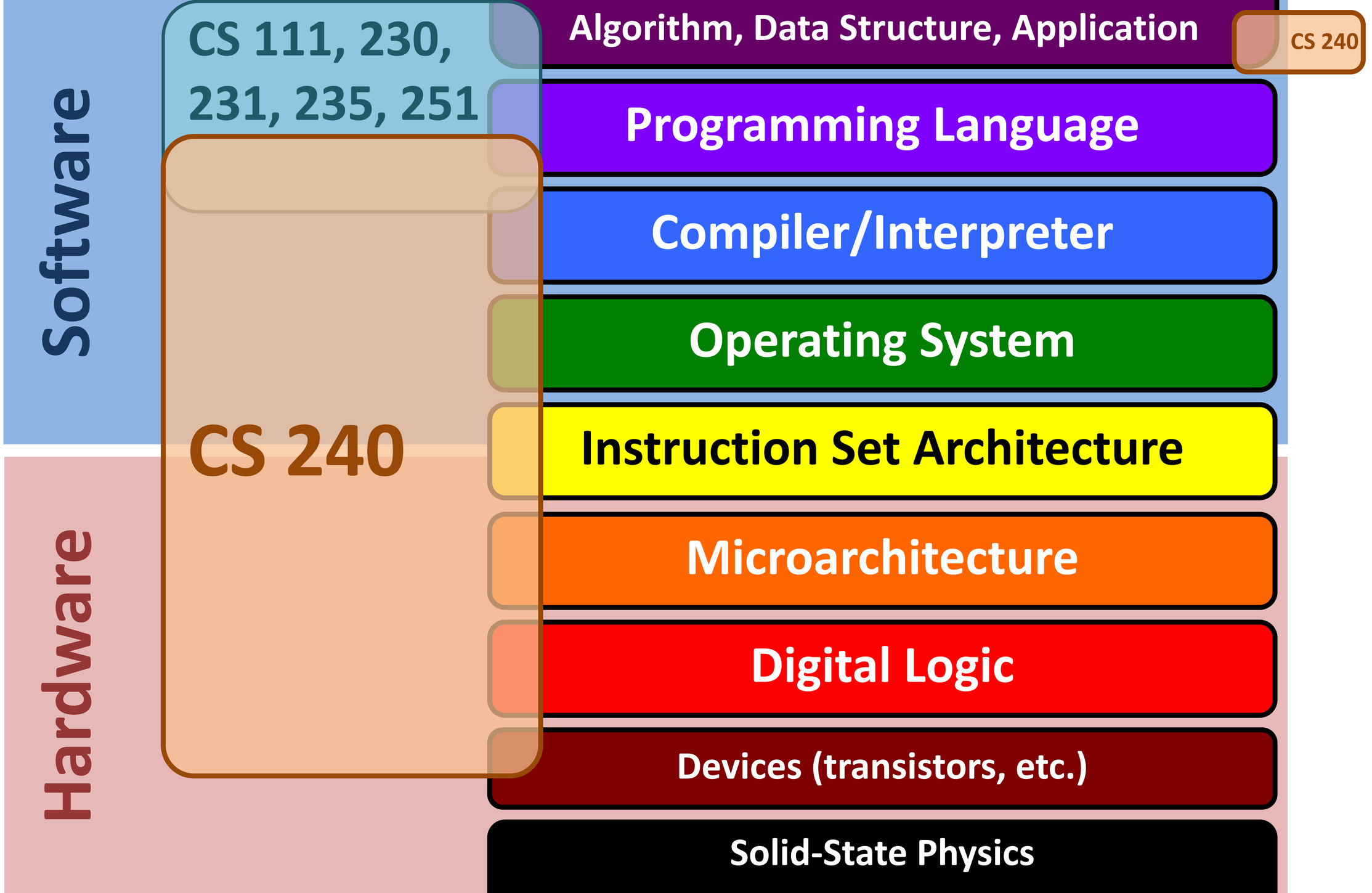
- How do you use programming to solve a problem?
- How do you structure a program?
- How do you know it is correct or efficient?
- How hard is it to solve a problem?
- How is computation expressed?
- What does a program mean?
- …

## A BIG question is missing…

1



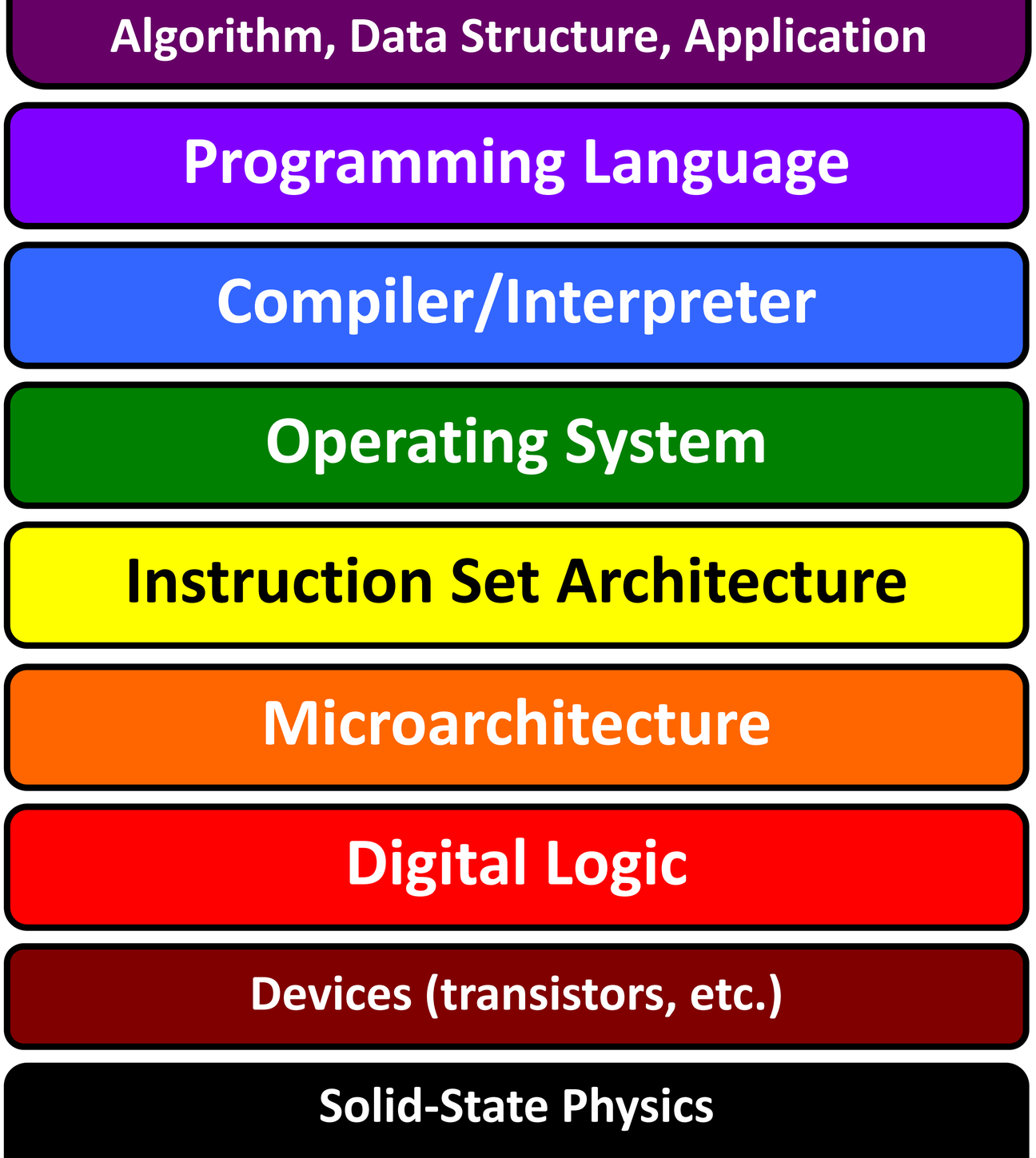

circuitboard image: CC-BY-NC-SA ifixit.com


Software
Hardware
CS 111, 230, 231, 235, 251
CS 240
Algorithm, Data Structure, Application
CS 240
Programming Language
Compiler/Interpreter
Operating System
Instruction Set Architecture
Microarchitecture
Digital Logic
Devices (transistors, etc.)
Solid-State Physics

Big Idea:

# Abstraction


*Layers manage complexity.*



# Big Idea: Abstraction

***with a few recurring subplots***

**Simple, general interfaces:**

Hide complexity of efficient implementation.

Make higher-level systems easy to build.

**Representation** of data and programs

0s and 1s, electricity

**Translation** of data and programs

compilers, assemblers, decoders

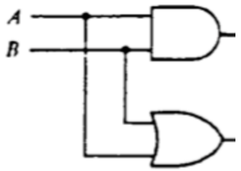
**Control flow** within/across programs

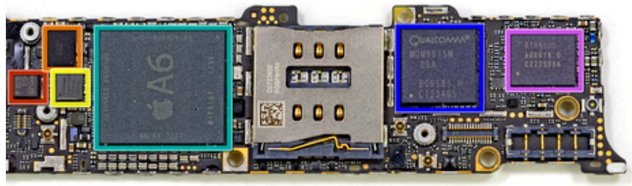
branches, procedures, operating system

# CS 240 in 3 acts (4-5 weeks each)

## 1. Hardware *implementation*

From transistors to a simple computer



## 2. Hardware-software *interface*

From instruction set architecture to programming in C

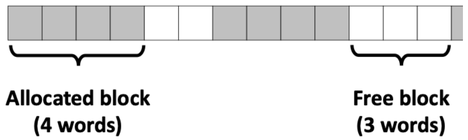
```
MOV x9, x10
ADD x12, x12, #1

*x = malloc(…);
```

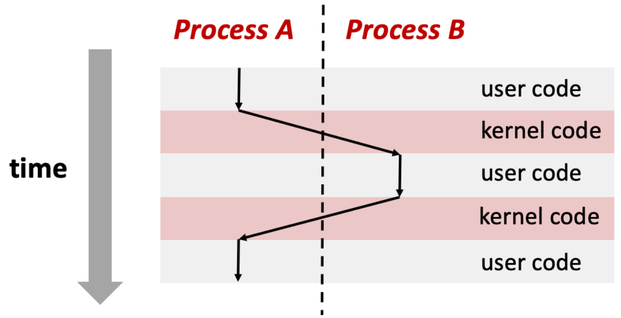
## 3. Abstraction for practical systems

Memory hierarchy

Operating system basics

Higher-level languages and tools



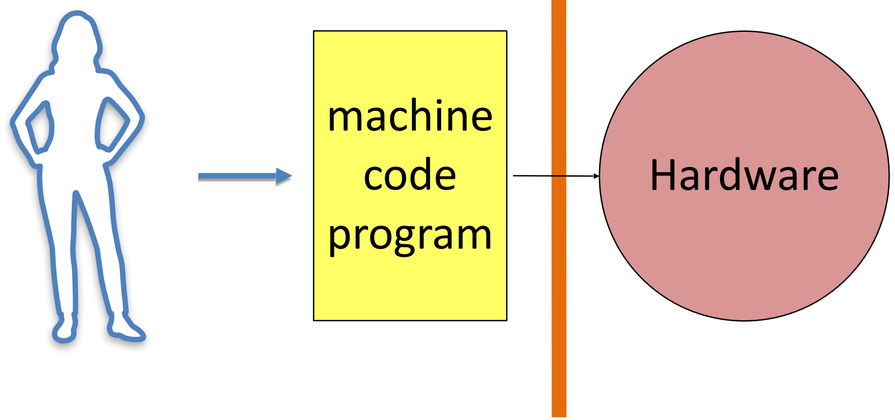



# Machine Instructions

(adds two values and stores the result)

00000010100010101100100000010000

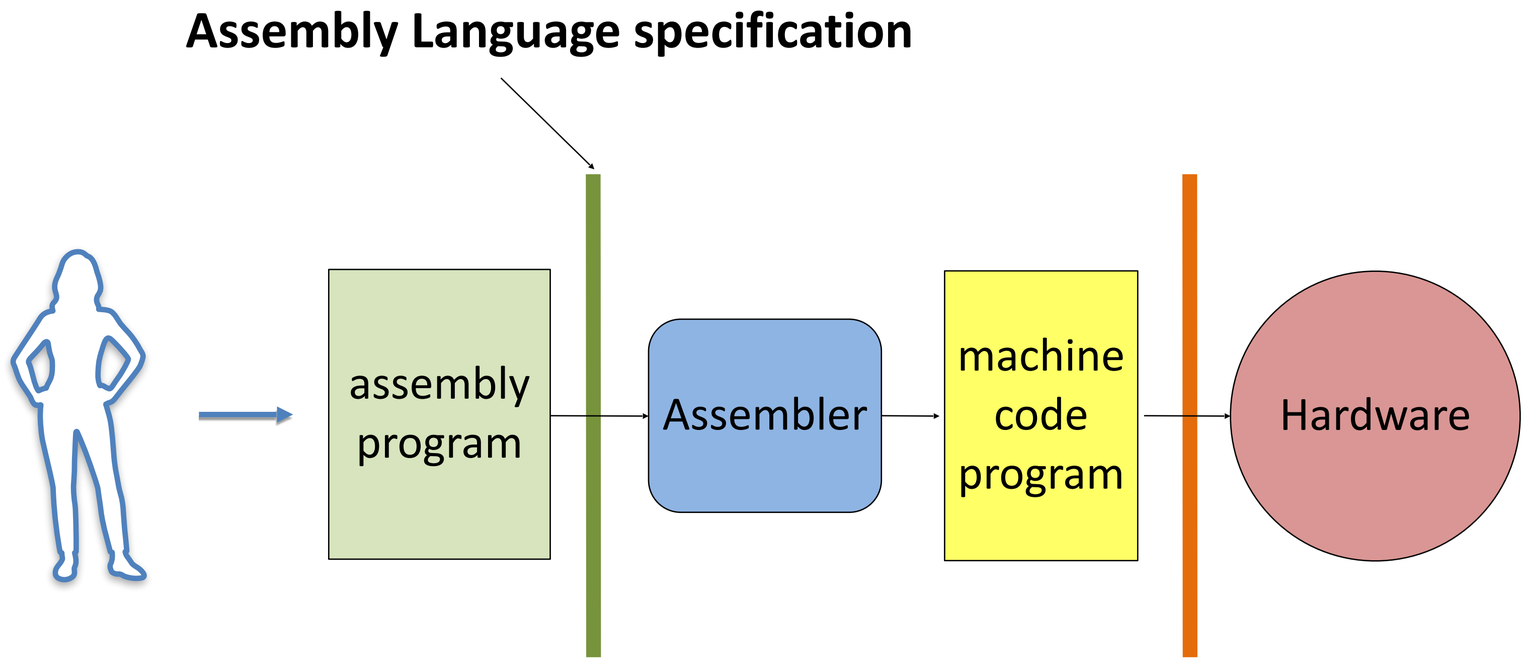
**Instruction Set Architecture specification**



# Assemblers and Assembly Languages

```
addl %eax, %ecx
```

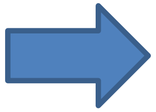
```
00000001010001010110010000010000
```



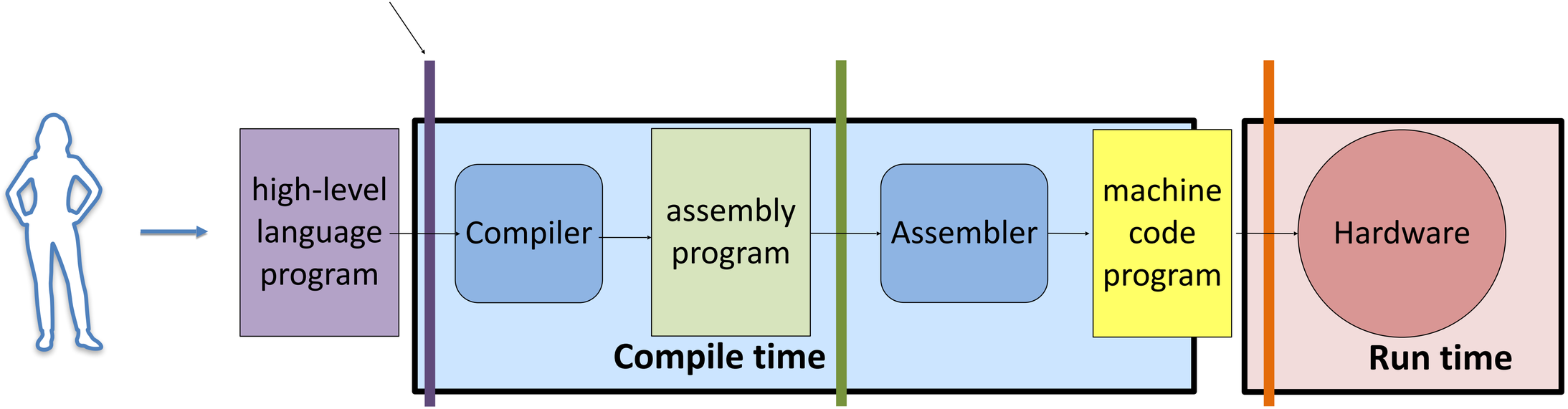
# Higher-Level Programming Languages

```
x = x + y;
```

```
addl %eax, %ecx
```



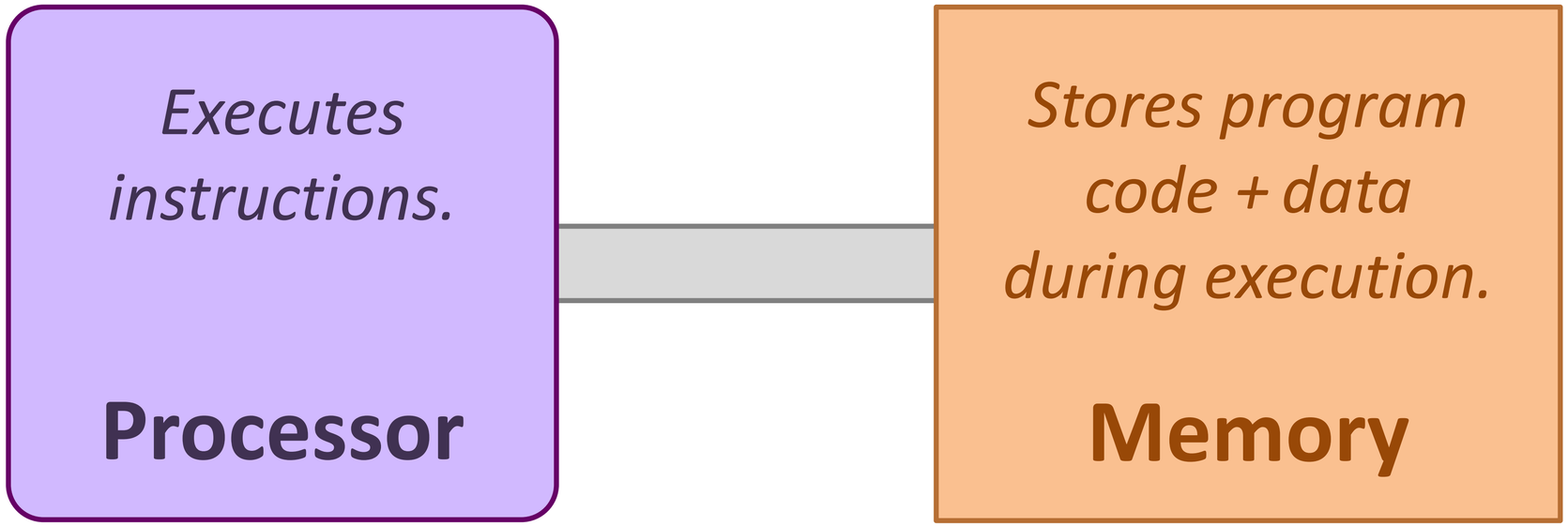
```
00000010100010101100100000010000
```



# More and more layers…

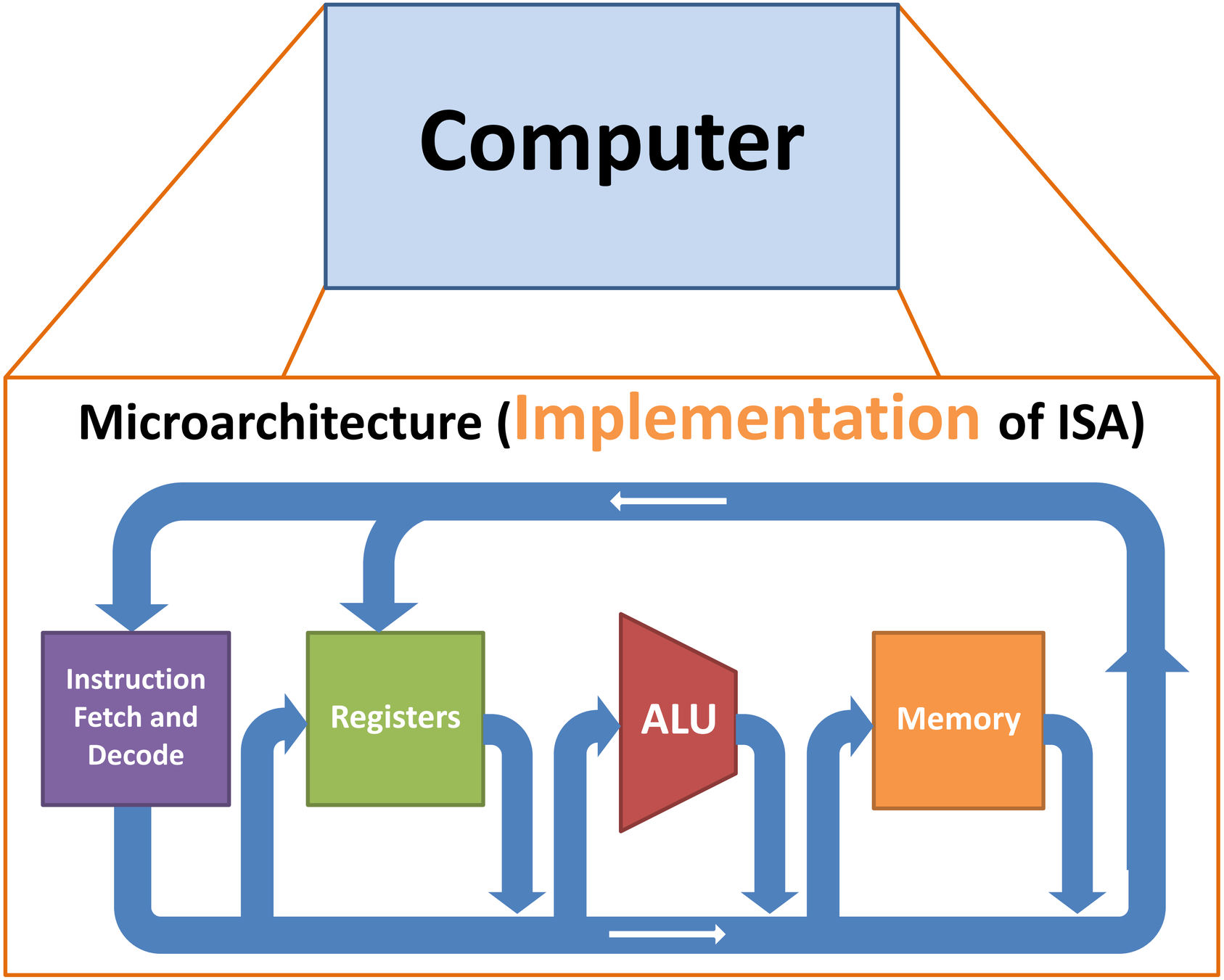
- Operating systems
- Virtual machines
- Hypervisors
- Web browsers
- …

# Modern Computer Organization




**Processor repeats:**

1. fetch instruction
2. fetch data used by instruction
3. execute instruction on data
4. store result or choose next instruction


Computer
Microarchitecture (Implementation of ISA)
Instruction Fetch and Decode
Registers
ALU
Memory

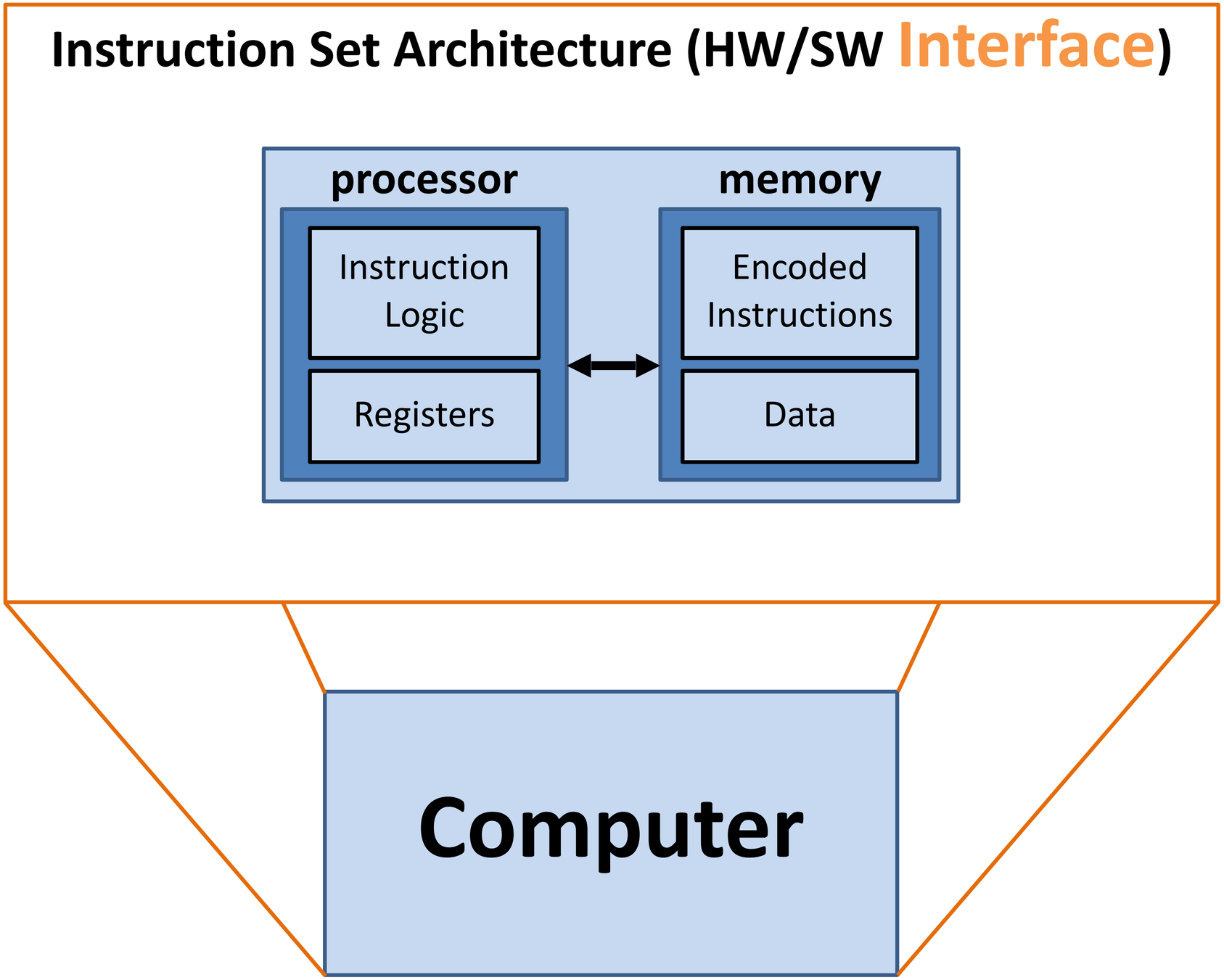
Software

Desired computation
in a programming language


**Hardware/Software Interface**

Hardware

Physical implementation
with circuits and electricity.


Instruction Set Architecture (HW/SW Interface)
processor
memory
Instruction Logic
Registers
Encoded Instructions
Data
Computer

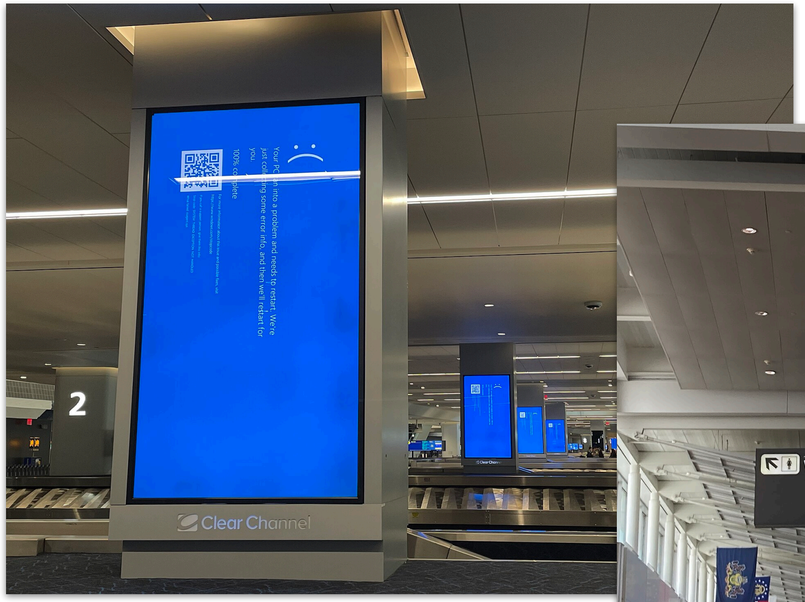

Why take CS 240?

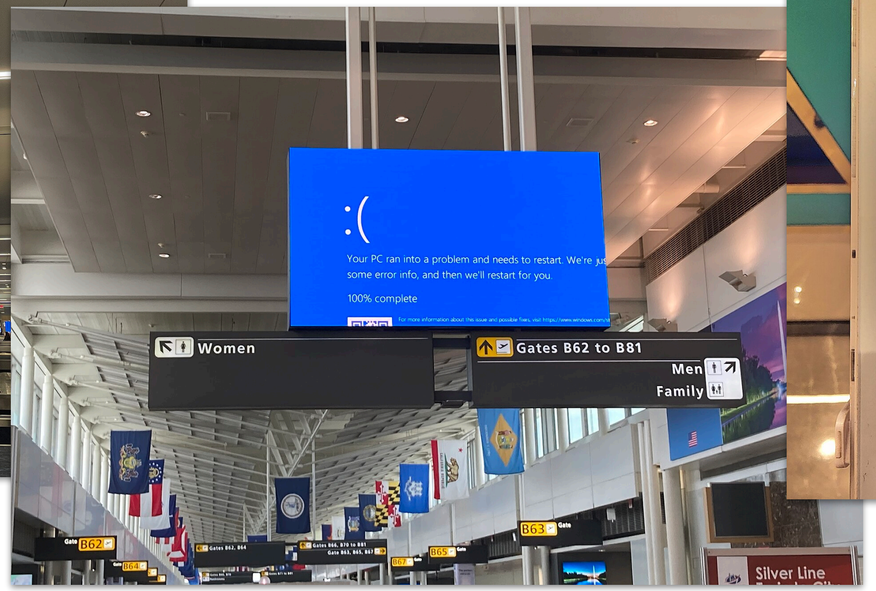
***I just like to program.***

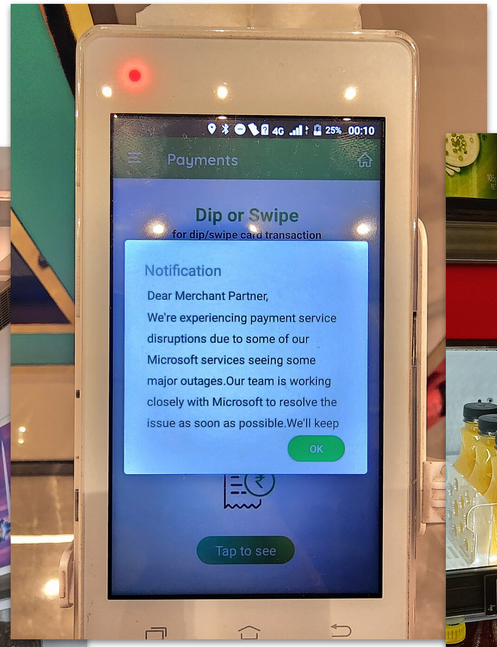
***Why study the implementation?***

Does anyone remember what was noteworthy about July 19, 2024?

…was anyone trying to travel by plane around then?





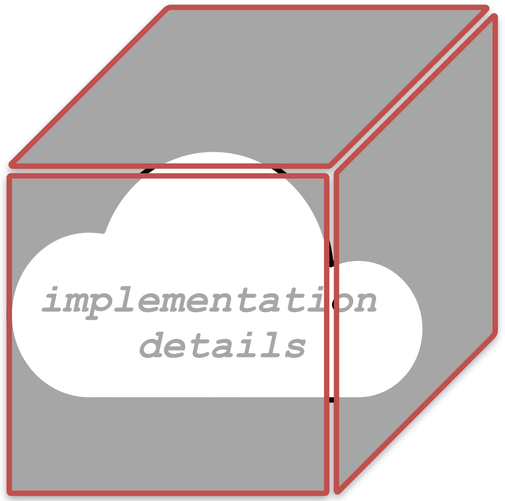
What happened?

*invalid memory access in C* *code running in OS kernel* *insufficient testing & validation*

*unchecked array length* *limitations of processor multithreading*

… all CS240 topics!

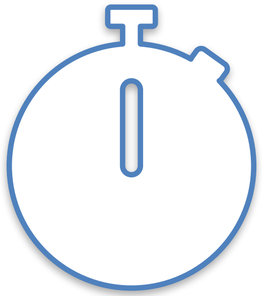
# 2 *I just like to program. Why study the implementation?*


Most system abstractions "leak."

Implementation details affect your programs:

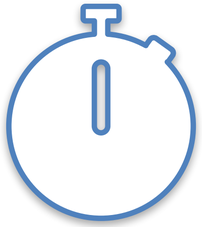
Their performance



Their correctness

Their security

# Performance



**x / 973**

```
void copyji(int src[2048][2048],
            int dst[2048][2048])
{
  int i,j;
  for (j = 0; j < 2048; j++)
    for (i = 0; i < 2048; i++)
      dst[i][j] = src[i][j];
}
```

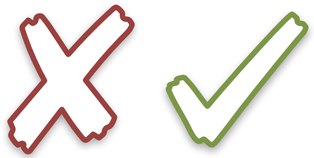
**x / 1024**

```
void copyij(int src[2048][2048],
            int dst[2048][2048])
{
  int i,j;
  for (i = 0; i < 2048; i++)
    for (j = 0; j < 2048; j++)
      dst[i][j] = src[i][j];
}
```

**several times faster**

**due to hardware caches**

# Correctness



**int ≠ integer**
**float ≠ real**

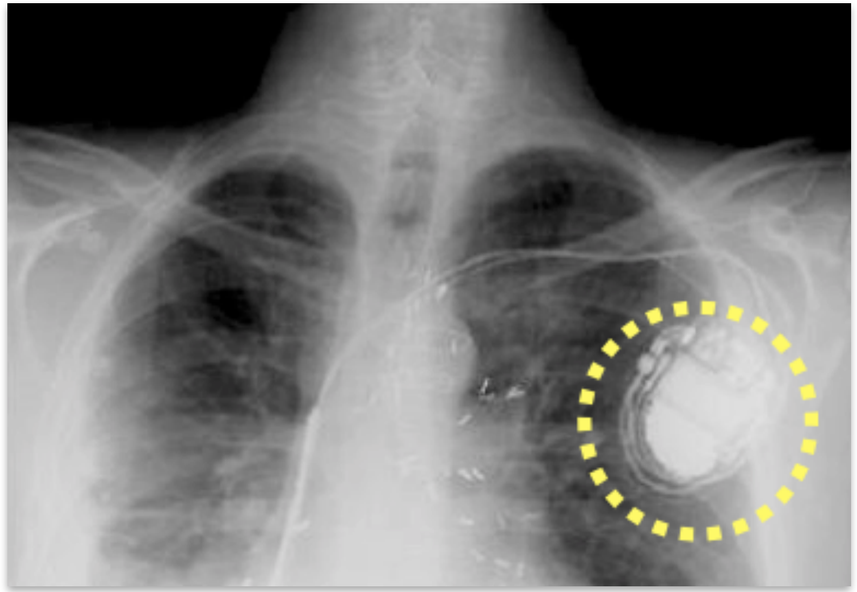
Exploded due to **cast** of 64-bit floating-point number to 16-bit signed number. **Overflow.**

## Boeing 787, 2015

"... a **Model 787 airplane** … can lose all alternating current (AC) electrical power … caused by a **software counter** internal to the GCUs that will **overflow** after **248 days** of continuous power. We are issuing this AD to prevent loss of all AC electrical power, which could result in **loss of control of the airplane**."
--FAA, April 2015

# Security

The ***GHOST vulnerability*** is a buffer overflow condition that can be easily exploited locally and remotely, which makes it extremely dangerous. This vulnerability is named after the *GetHOSTbyname* function involved in the exploit.



Cyber-Safe

All computers are flawed -- and the fix will take years

by Selena Larson @selenalarson

January 26, 2018: 12:07 PM ET

Meltdown and Spectre

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## A Heart Device Is Found Vulnerable to Hacker Attacks

By BARNABY J. FEDER
Published: March 12, 2008

To the long list of objects vulnerable to attack by computer hackers, add the human heart.

The threat seems largely theoretical. But a team of computer security researchers plans to report Wednesday that it had been able to gain wireless access to a combination heart defibrillator and pacemaker.

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# Why take CS 240?

**Learn *how* computers execute programs.**
Deepen your appreciation of **abstraction.**
Improve your **critical thinking** skills.

Become a **better programmer**:
- Think rigorously about execution models.
- Identify limits and impacts of abstractions and representations.
- Learn to use software development tools.

**Foundations** for:
- Compilers, security, computer architecture, operating systems, …

Have fun and feel accomplished!

3

https://cs.wellesley.edu/~cs240/

All details about the course.
Please read syllabus (About link) and schedule (Calendar link) before Friday's lecture and ask questions then.


Let's start learning about Digital Logic!
(separate slide deck)