Revising an Introductory Computer Science Course: Exploratory Labs, Interactive Lectures, and Just-in-Time Teaching

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Learning Goals: Pre-Class

By the start of class, you should be able to:

- Convert positive numbers from decimal to binary and back.
- Convert positive numbers from hexadecimal to binary and back.
- Take the two's complement of a binary number.
- Convert signed (either positive or negative) numbers to binary and back.
- Add binary numbers.

(Accompanied by assigned readings and recommended problems.)

Pre-Class Quiz: Marked for Correctness

- What is the decimal representation of the unsigned binary number 101110?
- What is the 8-bit unsigned binary representation of the decimal number 218?
- What is the 4-bit binary sum of the two 3-bit binary numbers 011 and 101?
- What is the 6-bit signed binary representation of the decimal number -7?
- What is the two's complement of 6-bit binary number 111010?
- Convert 5E from hexadecimal to binary.

And variants...

At the start of class:

- overview of quiz results
- instruction and exercises where results were poor
- summary of approaches to "completeness" questions

Pre-Class Quiz: Marked for Completeness

Can you be one-third Scottish?

Imagine it’s now 1500h. How could you quickly answer the following with no calculator:

- What time was it 8*21 hours ago?

Learning Goals: In-Class

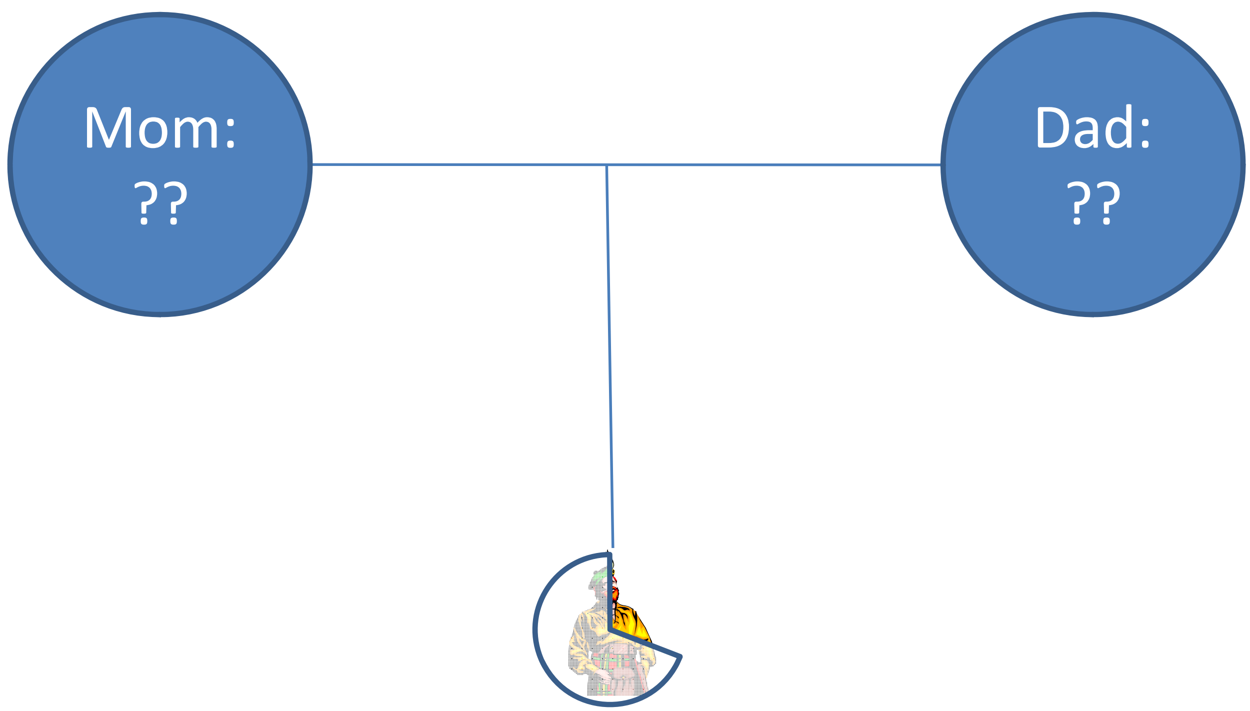
By the end of this unit, you should be able to:

- Critique the choice of a digital representation scheme—including describing its strengths, weaknesses, and flaws (such as imprecise representation or overflow) —for a given type of data and purpose, such as (1) fixed-width binary numbers using a two's complement scheme for signed integer arithmetic in computers or (2) hexadecimal for human inspection of raw binary data.

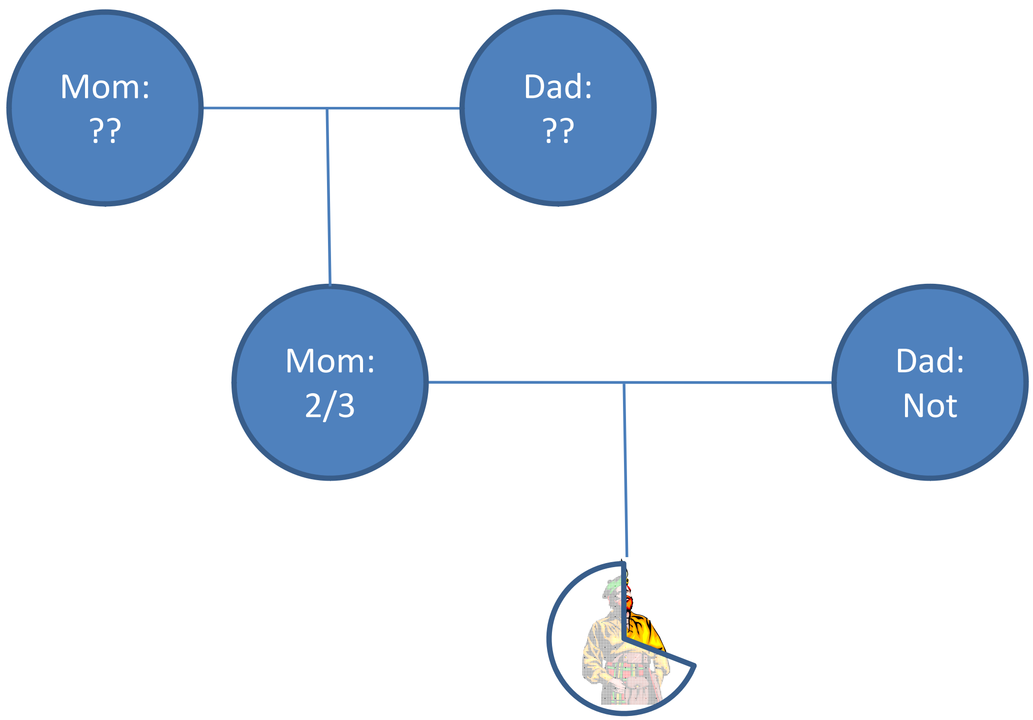
Can you be one-third Scottish?

Can you be one-third Scottish?

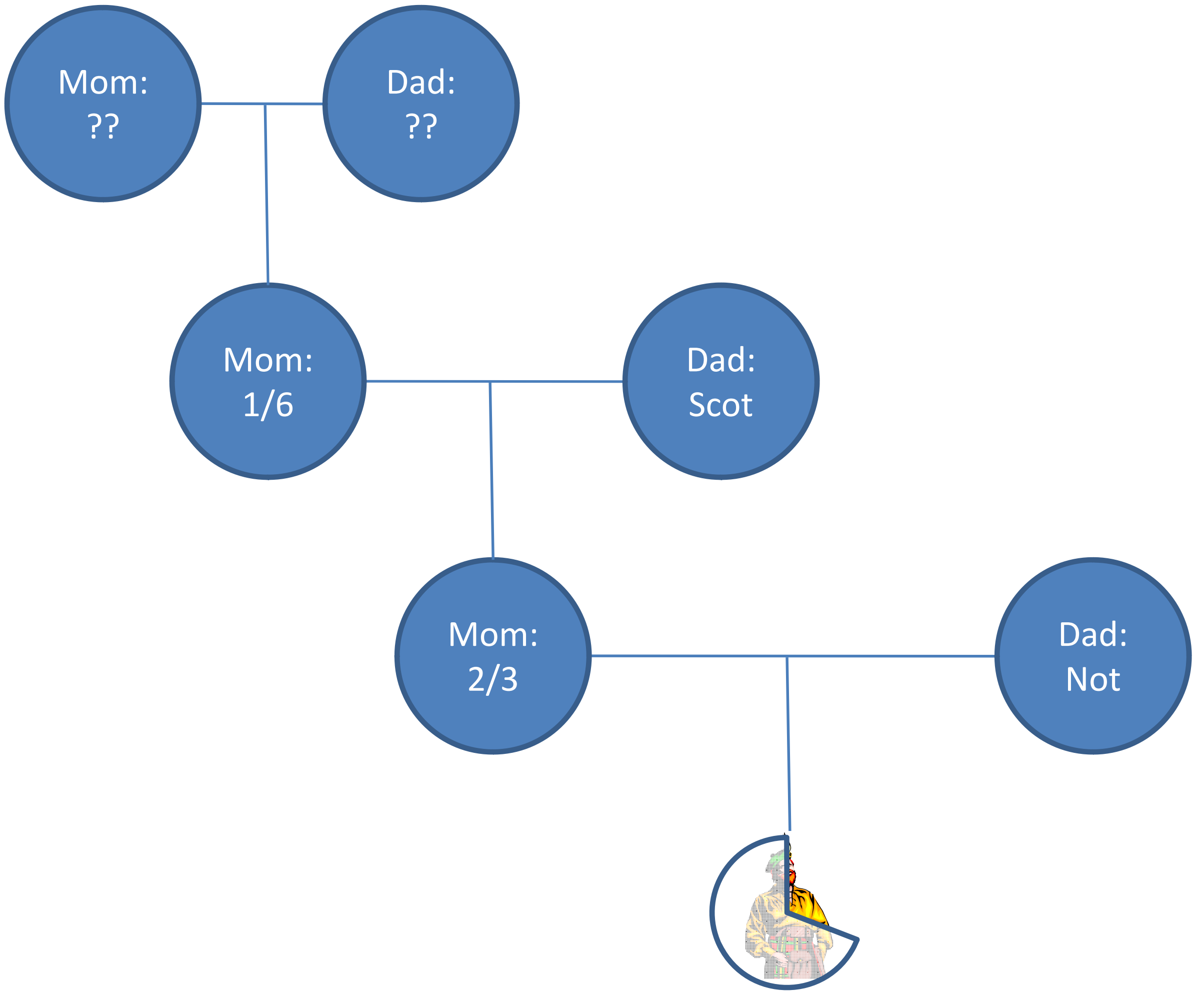
Focus on Mom (and Mom's Mom and so on).
We'll just make Dad "Scot" or "Not" as needed at each step.



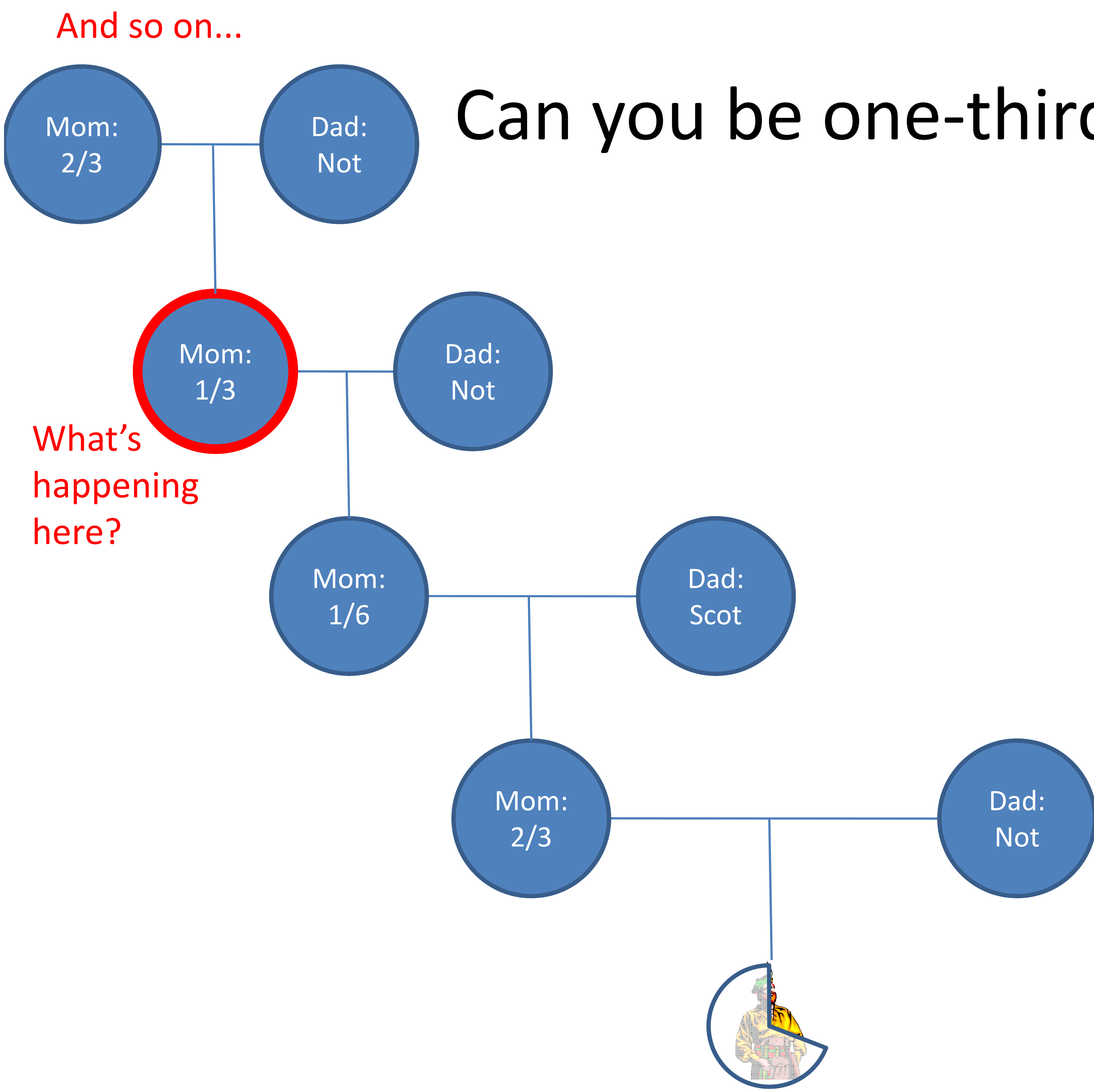
Can you be one-third Scottish?

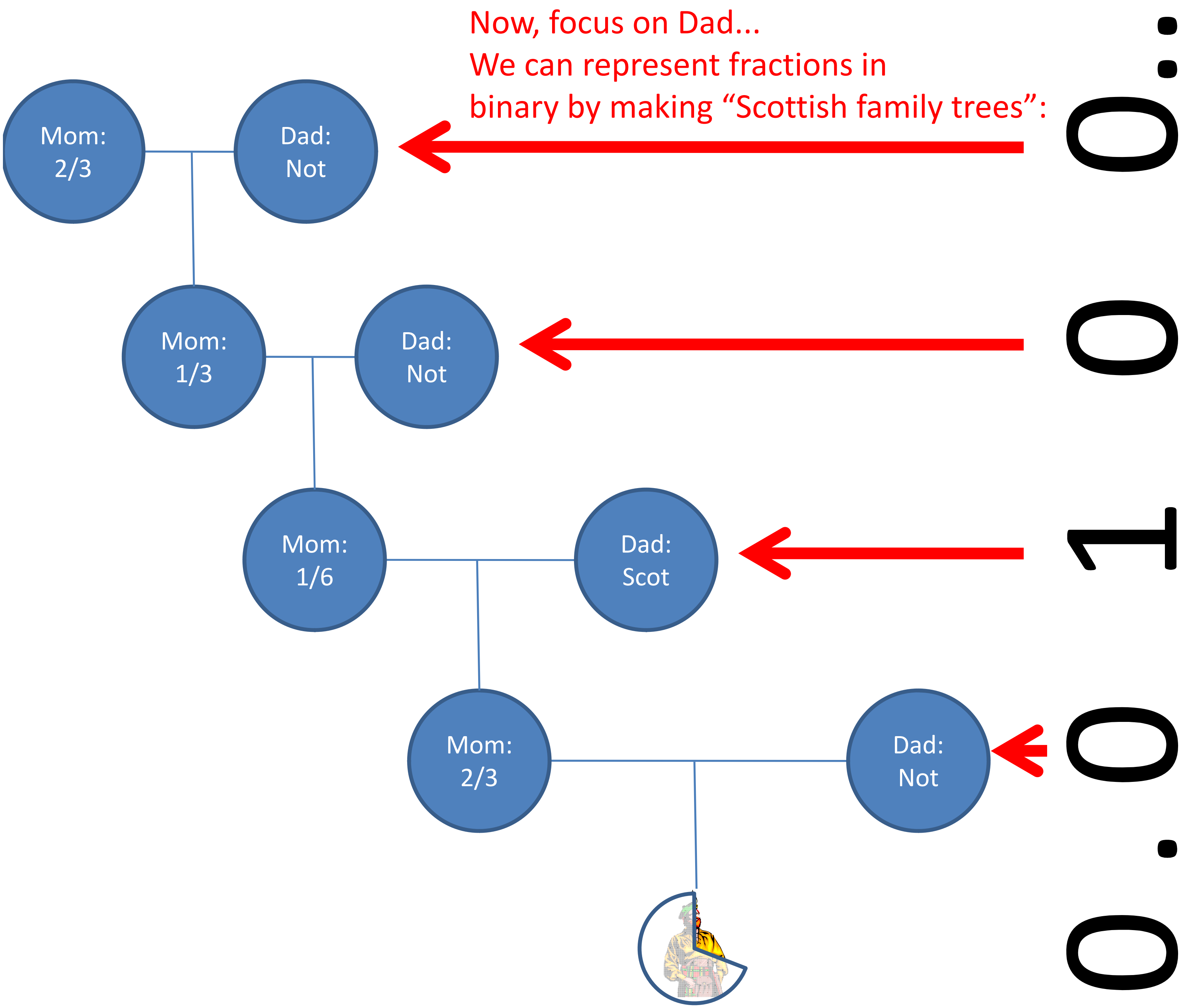


Can you be one-third Scottish?



Can you be one-third Scottish?

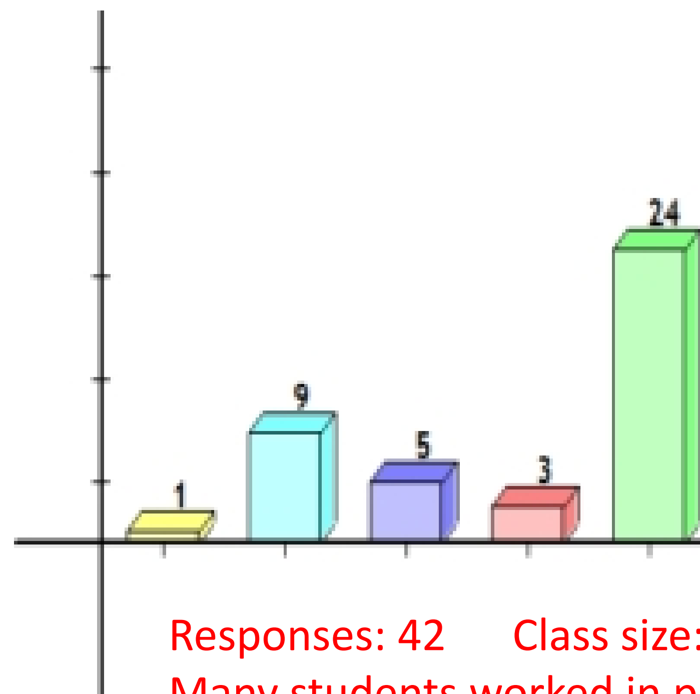



Now, focus on Dad...
We can represent fractions in
binary by making “Scottish family trees”:
Mom: 2/3
Dad: Not
Mom: 1/3
Dad: Not
Mom: 1/6
Dad: Scot
Mom: 2/3
Dad: Not
0.0100..

Follow-up Concept Q

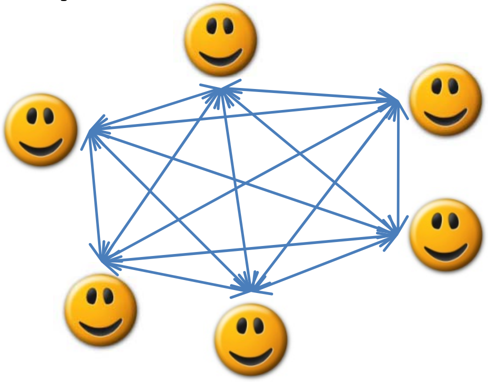
Which of the following numbers can be precisely represented with a finite number of digits/bits using a “decimal point”-style representation in base 10 but **not** base 2?

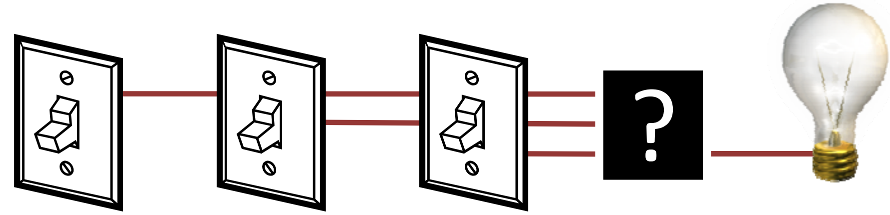
a. 1/9
b. 1/8
c. 1/7
d. 1/6
e. None of these.



Responses: 42 Class size: 89
Many students worked in pairs

How many introductions does a group of people need to meet each other? Prove it!

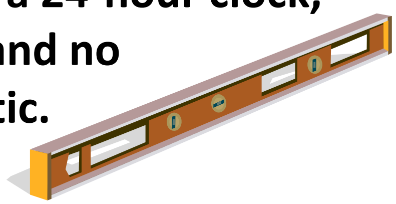




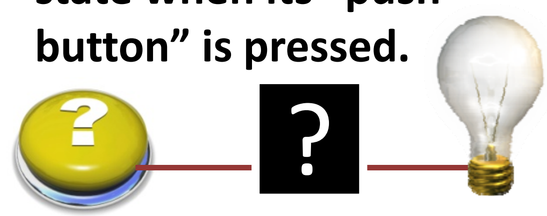
Design a light that changes state whenever any of the switches that control it is flipped.

What does it mean (precisely!) for a list to be sorted?

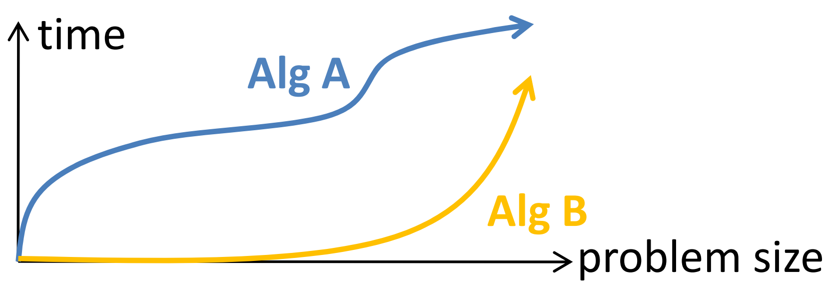
It’s 0500h. How many hours until midnight? Give an algorithm that requires a 24-hour clock, a level, and no arithmetic.

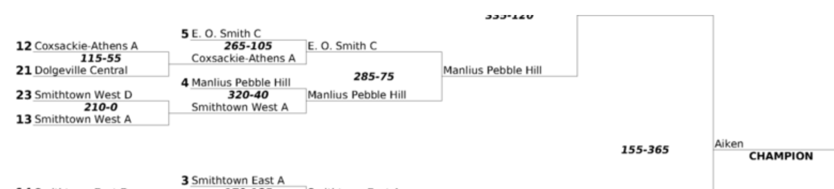


Design a light that changes state when its “push-button” is pressed.



What might it mean (precisely!) for one algorithm to be “generally faster” than another?





How many teams can play in an *n* round single-elimination tournament? Prove it!

Lessons Learned: Lecture

- **Have help (TAs!)** for in-class discussion
- **Quizzes need “little questions”**
- Explicitly **discuss the quiz results**
- **Scaffold problems** and **provide worked examples**, yet **encourage diverse solutions**
- **Structure** lectures carefully
- Work on culture of **participation and pair work**
- Plan for both **slow and quick finishers**
- Use **clickers optionally and anonymously**

Course revision takes **lots of time**!

Revising Labs

- More exploration

  Lab #2: verify known behaviour →
  use behaviour to discover identity

- Shorter instructions

  Lab #2: 2400 words → 1800 words, still 6 pages

- Move to lab supplied equipment

  Better logistics, better student experience

- Lab coordinator (TA) runs weekly TA training
- Early release of labs
- More lab-like problems in lecture

CPSC 121: Models of Computation, Spring 2008
Lab #2: Implementing circuits using the Magic Box (Excerpt)

1 Experimenting with an Unknown Chip

Your TA will provide you with two ICs. The label on both ICs is covered, but the notch is visible (so you know the orientation to place them on your breadboard!). One of these chips is a hex inverter, a chip with six inverters. The other is one of: a quad 2-input NAND gate, a quad 2-input AND gate, a quad 2-input OR gate, or a quad 2-input XOR gate. Your job is:

1. First, figure out which one is the hex inverter.

2. Second, figure out which of the four possible “quad” chips you have.

TODO: Report on your experiment by answering the following questions. The first few are prelab exercises:

1. **Prelab:** How will you determine which of the two chips is the hex inverter? Sketch your wiring plan and the steps you’ll take.

2. **Prelab:** Once you’ve done that, how will you determine which one of the “quad” chips you have? Again, sketch your wiring plan and your steps.

3. **Prelab:** If you could reveal the chips’ labels, how would you verify your answers? (We’re looking for a straightforward answer here; no tricks.)

4. According to your circuit, which chip is the inverter? (Which colour indicated the inverter?)

5. According to your circuit, which “quad” chip did you have?

6. Why *didn’t* we include the quad 2-input NOR gate as one of the possible “quad” chips? (It is possible to answer this prelab.)

CPSC 121: Models of Computation, Fall 2008
Lab #2: Implementing circuits using the Magic Box (Excerpt)

1 Getting started

Test a two-input gate: Now, you are ready to try a simple circuit on the breadboard. You will connect *The Magic Box* to your choice of a two-input-AND, two-input-OR, two-input-NAND, or two-input-XOR. You will use the switches to apply all four input patterns of the truth table and record the output for each input combination as displayed on the LED.

1. Choose the gate you want to use according to the table below:

AND	74ALS08
OR	74ALS32
NAND	74ALS00
XOR	74ALS86

   and find the chip in your tube of chips.

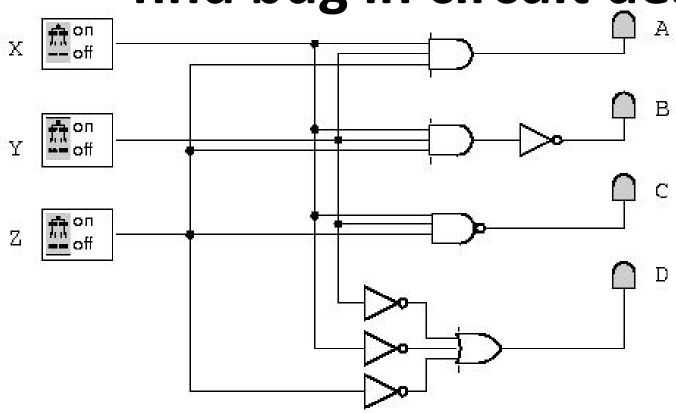
2. Now that you have your gate wired up, turn the power back on to *The Magic Box*. Try all four combinations of switch values and fill-in the following table. Hopefully, your circuit will work right away. If not, take a look at the debugging hints provided in the *Magic Box Debugging Guide* that is available in the “Handouts” section of the course Web page.

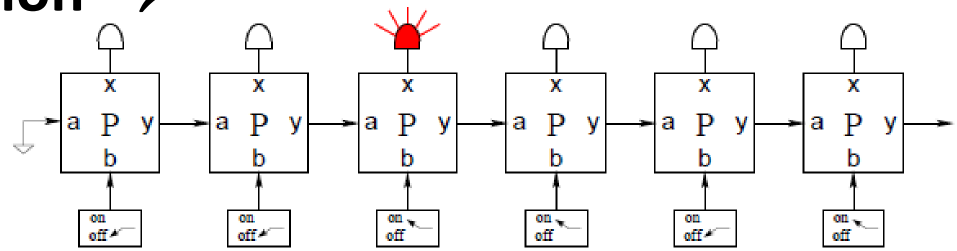
in1	in2	out
F	F	
F	T	
T	F	
T	T	

Type of gate (AND, OR, NAND, XOR): __________

Chip number: 74ALS______

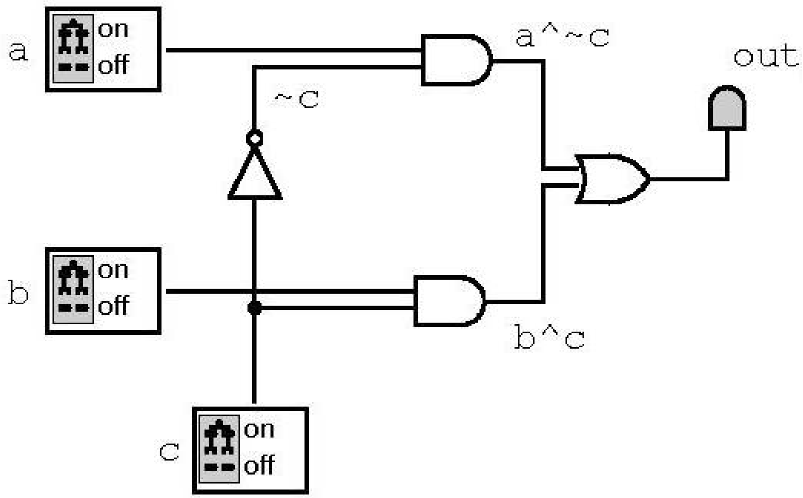
verify known behaviour of simulation → find bug in circuit design

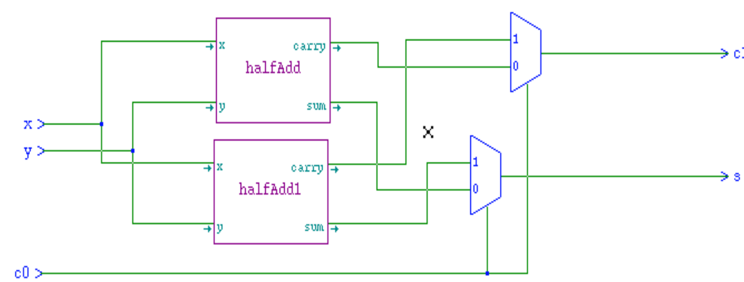




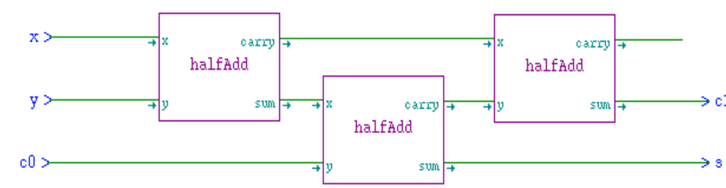
design arbitrary circuit → design meaningful circuit

discover why modeled, simulated, and actual behaviour of a circuit differ





vs.



discover when and why circuits whose models are identical behave differently

Lessons Learned: Lab

- Establish exploratory style and collaborative nature of labs **on day one**
- Require completed pre-lab **for marks**
- Post labs early
- Run TA training **before** posting labs publicly
- Challenge students!

Course revision takes **lots of time**!

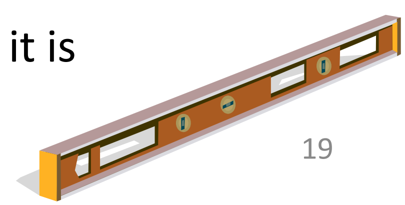
SPARES

Clock Arithmetic

It's 0500h. How many hours until midnight?

Give an algorithm that requires a 24-hour clock, a level, and no arithmetic.

A level is a carpentry tool, essentially a straightedge that indicates when it is either horizontal or vertical.

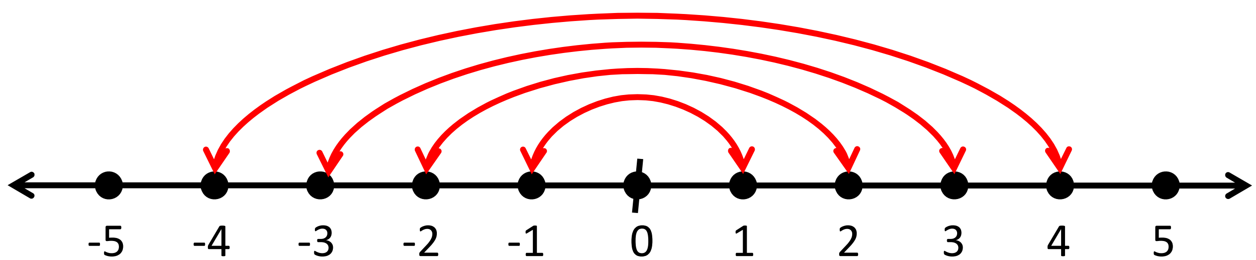


Prelude: Additive Inverse

The "additive inverse" of a number x is another number y such that x + y = 0.

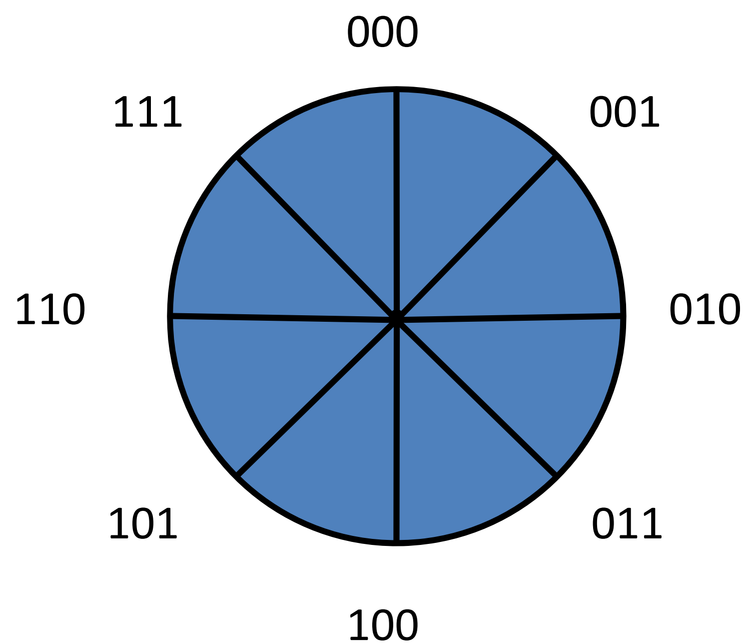
What is the additive inverse of 3?

What is the additive inverse of -7?



We want to be able to add signed binary numbers. We need x + -x to be 0. And, we want addition to be easy to implement.

Clock Arithmetic: Food for Thought



If 111 is the additive inverse of 001 anyway, why not make 111 be -001?

Concept Q: Clock Arithmetic

It’s 1830. Without using any numbers larger than 24 in your calculations, what time will it be 22*7 hours from now? (In other words, **don’t** multiply 22 by 7!)

a. Got it. Easy to calculate.
b. Got it. Took some notes and figuring.
c. Don’t see how to get this without some arithmetic on larger numbers.