Autumn 2015

**Lecture 1: Propositional Logic**

Overload Request Link: [http://tinyurl.com/p5ys5xb](http://tinyurl.com/p5ys5xb)
We will study the **theory** needed for CSE.

**Logic:**
How can we describe ideas and arguments **precisely**?

**Formal proofs:**
Can we prove that we’re right? [to ourselves? to others?]

**Number theory:**
How do we keep data **secure**? [really? we need to justify numbers?]

**Relations/Relational Algebra:**
How do we store information?
How do we reason about the effects of connectivity?

**Finite state machines:**
How do we design hardware and software? [state!]

**Turing machines:**
What is computation?
Are there problems computers **can’t** solve? [the universe? superheroes?]
The computational perspective.

Example: Sudoku
Given *one*, solve by hand.
Given *most*, solve with a program.
Given *any*, solve with computer science.

- Tools for reasoning about difficult problems
- Tools for communicating ideas, methods, objectives
- Fundamental structures for computer science

[like, uhh, smart stuff]
Prof. Oveis Gharan
CSE 636

Section A
MWF 9:30-10:20 in CMU 120
Office hours MW 10:30-11:30

Prof. Lee
CSE 640

Section B
MWF 1:30-2:20 in MGH 241
Office hours MW 2:30-3:30

We will each sometimes teach both sections.
The person who teaches is the one holding office hours after class.
You can go to any office hours any time.
Teaching assistants:
[office hours TBD soon]
Sam Castle     Jiechen Chen
Rebecca Leslie Evan McCarty
Tim Oleskiw   Spencer Peters
Robert Weber   Ian Zhu

cse311-staff@cs

Quiz Sections:
Thursdays

(Optional) Book:
Rosen
Discrete Mathematics
6\textsuperscript{th} or 7\textsuperscript{th} edition
Can buy online for ~$50

Homework:
Due Fridays on Gradescope
Write up individually
First homework out this Friday (Oct 2)

Exams:
Midterm: Monday, Nov. 9, in class
Final: Monday, Dec. 14

Grading (roughly):
50\% homework
35\% final exam
15\% midterm

All course information at http://www.cs.washington.edu/311.
# CSE 311: Foundations of Computing I

**Autumn, 2015**

- **James R. Lee**  
  *Section B: MWF 1:30-2:20, MGH 241*  
  *Office hours: MW 2:30-3:30, CSE 640*

- **Shayan Oveis Gharan**  
  *Section A: MWF 9:30-10:20, CMU 120*  
  *Office hours: MW 10:30-11:30, CSE 596*

**Email and discussion:**

- Class email list: multi_cse311a_se15  
  Please send any email about the course to cse311-staff@cs.

**Discussion board** (moderated by TBA)

Use this board to discuss the content of the course. This includes everything except the solutions to current homework problems. Feel free to discuss homeworks and exams from past incarnations of the course, and any confusion over topics discussed in class. It is also acceptable to ask for clarifications about the statement of homework problems, but not about their solutions.

**Textbook:**

There is no required text for the course. Some lectures will have associated reading material linked below. Over the first 8 weeks or so, the following textbook can be a useful companion:

(The 6th or 7th editions of the text are equally useful. Used or rental copies of either edition are available for vastly less than the ridiculously high new copy prices.)

### Lectures

<table>
<thead>
<tr>
<th>date</th>
<th>topic</th>
<th>slides</th>
<th>inked (A)</th>
<th>inked (B)</th>
<th>reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>09-Sep</td>
<td>Propositional logic</td>
<td>1.1-1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-Sep</td>
<td>Digital circuits, more logic</td>
<td>1.1-1.3</td>
<td>1.1-1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-Sep</td>
<td>Boolean algebra, combinatorial logic</td>
<td>12.1-12.3</td>
<td>11.1-11.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-Sep</td>
<td>Boolean algebra and circuits</td>
<td>12.1-12.3</td>
<td>11.1-11.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-Sep</td>
<td>Canonical forms, predicate logic</td>
<td>1.4-1.5</td>
<td>1.3-1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28-Sep</td>
<td>Predicate logic, logical inference</td>
<td>1.5-1.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01-Oct</td>
<td>Proofs I</td>
<td>1.6-1.7</td>
<td>1.5-1.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>08-Oct</td>
<td>Proofs II</td>
<td>1.6-17</td>
<td>1.5-1.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-Oct</td>
<td>Set theory</td>
<td>2.1-3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-Oct</td>
<td>Functions, modular arithmetic</td>
<td>4.1-4.2</td>
<td>3.4-3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-Oct</td>
<td>Modular arithmetic and applications</td>
<td>4.1-4.4</td>
<td>3.4-3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-Oct</td>
<td>Primes, GCD</td>
<td>4.3-4.4</td>
<td>3.5-3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26-Oct</td>
<td>Primes, GCD, fewer tangents</td>
<td>4.3-4.4</td>
<td>3.5-3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28-Oct</td>
<td>Solving modular equations</td>
<td>4.4-4.4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TA

- **Sam Castle**  
  *Office hours: MW 11:30-12:30, CSE 596*
- **Jiechen Chen**  
  *Office hours: MW 1:30-2:30, CSE 640*
- **Rebecca Leslie**  
  *Office hours: Th 3:30-4:30, CMU 111*
- **Evan McCarty**  
  *Office hours: Th 2:30-3:30, CSE 596*
- **Tim Oleskiew**  
  *Office hours: Th 12:30-1:30, CSE 596*
- **Spencer Peters**  
  *Office hours: Th 4:30-5:30, CSE 596*
- **Robert Weber**  
  *Office hours: Th 1:30-2:30, CSE 596*
- **Ian Zhu**  
  *Office hours: Th 12:30-1:30, CSE 596*

### Section Day/Time Room

- **AA**  
  *Th 8:30-9:20*  
  *MGH 242*
- **AE**  
  *Th 9:30-10:20*  
  *MGH 242*
- **AC**  
  *Th 10:10-11:20*  
  *JHN 675*
- **BA**  
  *Th 1:30-2:20*  
  *MGH 242*
- **BB**  
  *Th 10:10-11:20*  
  *MGH 242*
- **BC**  
  *Th 2:30-3:20*  
  *MSE 242*

### Homeworks

Assignments will be submitted via Gradescope. An

---

**administrivia**
• Why not use English?
  • Turn right here...
  • Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo.

[The sentence means "Bison from Buffalo, that bison from Buffalo bully, themselves bully bison from Buffalo."]

• We saw her duck.

• "Language of Reasoning" like Java or English
  • Words, sentences, paragraphs, arguments...
  • Today is about **words** and **sentences**.
why learn a new language?

Logic as the “language of reasoning”, will help us...

- Be more **precise**
- Be more **concise**
- Figure out what a statement means more **quickly**

[ please stop ]
A proposition is a statement that
• has a truth value, and
• is “well-formed”

[“If I were to ask you out, would your answer to that question be the same as your answer to this one?”]
Consider these statements:

• $2 + 2 = 5$
• The home page renders correctly in IE.
• This is the song that never ends.
• Turn in your homework on Wednesday.
• This statement is false.
• Akjsdf? [hey, I akjsdf you a question]
• The Washington State flag is red.
• Every positive even integer can be written as the sum of two primes.
• A **proposition** is a statement that
  • has a truth value, and
  • is “well-formed”

• Propositional variables: $p, q, r, s, ...$
• Truth values: $T$ for *true*, $F$ for *false*
“Roger is an orange elephant who has toenails if he has tusks, and has toenails, tusks, or both.”

• What does this proposition mean?
• It seems to be built out of other, more basic propositions that are sitting inside it! What are they?
“Roger is an orange elephant who has toenails if he has tusks, and has toenails, tusks, or both.”

RElephant : “Roger is an orange elephant”
RTusks : “Roger has tusks”
RToenails : “Roger has toenails”
logical connectives

- Negation (not) \( \neg p \)
- Conjunction (and) \( p \land q \)
- Disjunction (or) \( p \lor q \)
- Exclusive or \( p \oplus q \)
- Implication \( p \rightarrow q \)
- Biconditional \( p \leftrightarrow q \)

“Roger is an orange elephant who has toenails if he has tusks, and has toenails, tusks, or both.”

RElephant and (RToenails if RTusks) and (RToenails or RTusks or (RToenails and RTusks))
some truth tables

<table>
<thead>
<tr>
<th>p</th>
<th>( \neg p )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>p</th>
<th>q</th>
<th>( p \land q )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>p</th>
<th>q</th>
<th>( p \lor q )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>p</th>
<th>q</th>
<th>( p \oplus q )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
“If $p$, then $q$” is a **promise**:  
- Whenever $p$ is true, then $q$ is true  
- Ask “has the promise been broken?”

<table>
<thead>
<tr>
<th>$p$</th>
<th>$q$</th>
<th>$p \rightarrow q$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*If it’s raining, then I have my umbrella.*  
*Suppose it’s not raining...*
“I am a Pokémon master only if I have collected all 151 Pokémon.”
Can we re-phrase this as “if \( p \), then \( q \)”? 

\[ p \rightarrow q \]
Implication:
- $p$ implies $q$
- whenever $p$ is true $q$ must be true
- if $p$ then $q$
- $q$ if $p$
- $p$ is sufficient for $q$
- $p$ only if $q$
• Implication: $p \rightarrow q$
• Converse: $q \rightarrow p$
• Contrapositive: $\neg q \rightarrow \neg p$
• Inverse: $\neg p \rightarrow \neg q$

How do these relate to each other?
"Roger is an orange elephant who has toenails if he has tusks, and has toenails, tusks, or both."

\[\text{RElephant} \land (\text{RToenails if RTusks}) \land (\text{RToenails} \lor \text{RTusks} \lor (\text{RToenails} \land \text{RTusks}))\]

Define shorthand ...

\[\begin{align*}
\ p & : \text{RElephant} \\
\ q & : \text{RTusks} \\
\ r & : \text{RToenails}
\end{align*}\]
roger’s sentence with a truth table

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>p</td>
<td>q</td>
<td>r</td>
<td>q → r</td>
<td>p ∧ (q → r)</td>
<td>r ∨ q</td>
<td>r ∧ q</td>
<td>(r ∨ q) ∨ (r ∧ q)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Shorthand:

- **p**: RElephant
- **q**: RTusks
- **r**: RToenails
Roger is only orange if whenever he either has tusks or toenails, he doesn't have tusks and he is an orange elephant.”

$p$: “Roger is an orange elephant”
$q$: “Roger has tusks”
$r$: “Roger has toenails”
Roger is only orange if whenever he either has tusks or toenails, he doesn't have tusks and he is an orange elephant.”

\[
\begin{align*}
\text{RElephant} & \iff \text{whenever } (\text{RTusks} \oplus \text{RToenails}) \text{ then not RTusks}) \text{ and RElephant} \\
\text{RElephant} & \rightarrow (\text{whenever } (\text{RTusks} \oplus \text{RToenails}) \text{ then } \neg \text{RTusks}) \text{ and RElephant} \\
\end{align*}
\]

\[
\begin{align*}
p &: \text{RElephant} \\
q &: \text{RTusks} \\
r &: \text{RToenails} \\
\end{align*}
\]
Roger's second sentence with a truth table

<table>
<thead>
<tr>
<th>$p$</th>
<th>$q$</th>
<th>$r$</th>
<th>$q \oplus r$</th>
<th>$\neg q$</th>
<th>$((q \oplus r) \rightarrow \neg q)$</th>
<th>$p \rightarrow ((q \oplus r) \rightarrow \neg q)$</th>
<th>$(p \rightarrow ((q \oplus r) \rightarrow \neg q)) \land p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>F</td>
<td>T</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>T</td>
<td>T</td>
<td>F</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>F</td>
</tr>
<tr>
<td>T</td>
<td>F</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>F</td>
</tr>
<tr>
<td>T</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>F</td>
<td>T</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>T</td>
<td>F</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
<td>T</td>
<td>T</td>
<td>F</td>
<td>T</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>
biconditional: $p \iff q$

- $p$ iff $q$
- $p$ is equivalent to $q$
- $p$ implies $q$ and $q$ implies $p$

<table>
<thead>
<tr>
<th>$p$</th>
<th>$q$</th>
<th>$p \iff q$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>