# COMP9020

Foundations of Computer Science

## Lecture 1: Course Introduction

Lecturers: Katie Clinch (LIC)
Paul Hunter
Simon Mackenzie

Course admin: ???

Course email: `cs9020@cse.unsw.edu.au`

# Pre-course polls

Pre-course questionnaire

Pre-course poll

# Acknowledgement of Country

We would like to acknowledge and pay our respects to the Bedegal people who are the Traditional Custodians of the land on which UNSW is built, and of Elders past and present.

# Outline

Course introduction

- Who are we?
- Why are we here?
- How will you be assessed?
- What do we expect from you?

How to write mathematics

- Examples
- Proofs
- Proofs - common mistakes
- Proof strategies

# Outline

# COMP9020 23T2 Staff

**Lectures**

| | |
|---|---|
| Lecturers: | Katie Clinch (LIC), Paul Hunter, Simon Mackenzie |
| Times: | Thursday 11-1pm and Friday 12-2pm |

**Online consultations** (anyone is welcome to attend)

| | |
|---|---|
| Tutors: | Mark Raya, Malhar Patel |
| Times: | Tuesday 7-8pm, Wednesday 7-8pm |

**In-person help sessions** (anyone is welcome to attend)

| | |
|---|---|
| Tutors: | Different tutors each session |
| Times: | Thursday 2-4pm, Friday 2-4pm |
| Location: | OShane 105 |

# Links

Course webpages:

- webCMS
- Moodle

Lectures:

- Recordings available on echo360 (through Moodle)

Consultations:

- Microsoft Teams

Other points of contact:

- Course forums (edforum)
- Email: `cs9020@cse.unsw`

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# Pre-course questionnaire - results

Pre-course questionnaire

# What is this course about?

**What is Computer Science?**

> *"Computer science is no more about computers than astronomy is about telescopes"*
>
> – E. Dijkstra

## Course Aims

Computer Science is about exploring the ability, and limitation, of computers to solve problems. It covers:

- **What** are computers capable of solving?
- **How** can we get computers to solve problems?
- **Why** do these approaches work?

This course aims to increase your level of mathematical maturity to assist with the fundamental problem of **finding, formulating, and proving** properties of programs.

Key skills you will learn:

- Working with abstract concepts
- Giving logical (and rigorous) justifications
- Formulating problems so they can be solved computationally

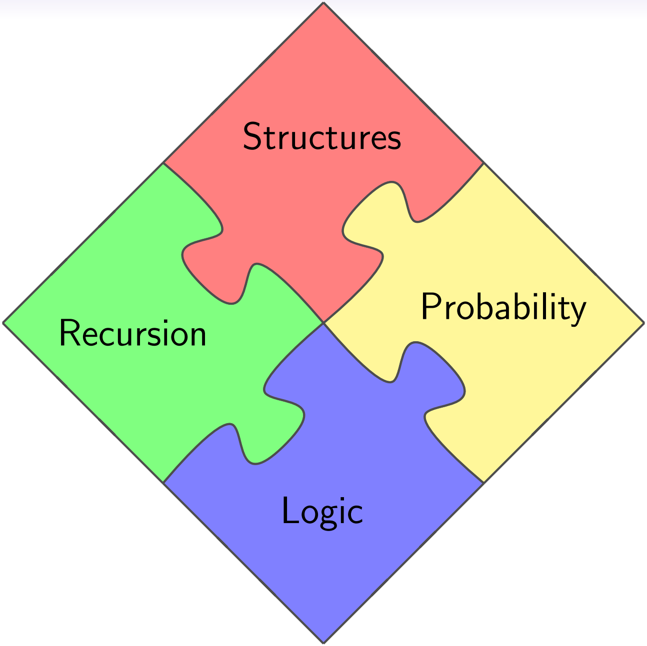
# Course Goals

By the end of the course, you should know enough to **understand** the answers to questions like:

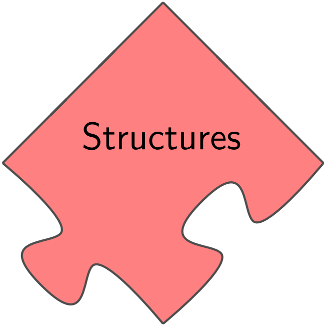
- How does RSA encryption work?
- Why do we use Relational Databases?
- How does Deep Learning work?
- Can computers think?
- How do Quantum Computers work?

**What other questions would you like to know the answer to?**

# Course Topics

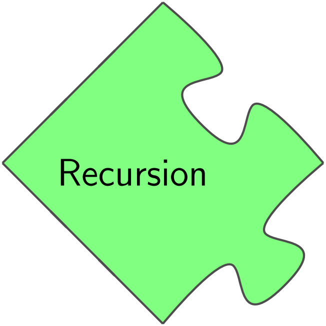


# Course Topics



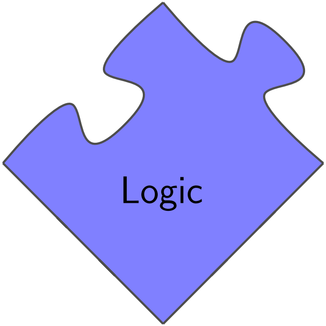

- Week 1: Number theory
- Week 2: Set Theory
- Week 2: Formal Languages
- Week 3: Graph Theory
- Week 4: Relations
- Week 5: Functions

# Course Topics



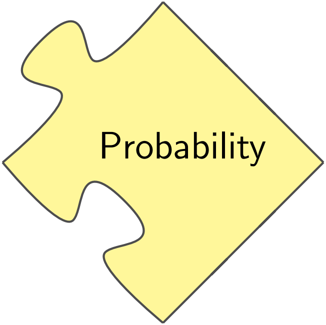

- Week 5: Recursion
- Week 7: Induction
- Week 8: Algorithmic Analysis

# Course Topics




- Week 8: Boolean Logic
- Week 9: Propositional Logic

# Course Topics




- Week 9: Combinatorics
- Week 10: Probability
- Week 10: Statistics

# Course Material

All course information is placed on the course website

www.cse.unsw.edu.au/~cs9020/

Content includes:

- Lecture slides and recordings
- Quizzes and Assignments
- Course Forums
- Practice questions

# Course Material

Textbooks:

- KA Ross and CR Wright: Discrete Mathematics
- E Lehman, FT Leighton, A Meyer:
  Mathematics for Computer Science

Alternatives:

- K Rosen: Discrete Mathematics and its Applications

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# Assessment Philosophy

What is the purpose of assessment?

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Types of assessment:

- Quizzes,
- Assignments,
- Final exam

# Assessment Summary

60% exam, 30% assignments, 10% quizzes.

**Quizzes**

- 9 weekly quizzes
- only your best 7 quiz marks will count towards your final grade
- Each quiz contains: 4-6 threshold questions and 4-6 mastery questions on the week's material
- Released on Wednesday of weeks: 1,2,3,4,5,7,8,9,10.
- Due on Wednesday of weeks: 2,3,4,5,6,8,9,10,11.

**Assignments**

- 4 assignments, worth up to 7.5 marks each
- Each covers two weeks of material
- Released: weeks 1,3,5 and 8.
- Due on Thursdays of weeks: 3,5,8,10.

**Final exam**

- **You must achieve 40% on the final exam to pass**

# Late policy and Special Consideration

All assessments are submitted through the course website

**Lateness policy**

- Assignments: 5% of total grade off raw mark per 24 hours or part thereof
- Quizzes: Late submissions not accepted
- Exam: Late submissions not accepted

If you cannot meet a deadline through illness or misadventure you need to apply for Special Consideration.

# More information

View the course outline here:

https://webcms3.cse.unsw.edu.au/COMP9020/24T1/outline

Particularly the sections on **Student conduct** and **Plagiarism**.

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# Learning Objectives

We want you to demonstrate:

- Your understanding of the material
- Your ability to work with the material

**NB**

*How you get an answer is as, if not more important than what the answer is.*

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Why?

# Pre-course poll - results

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## Guidelines for good mathematical writing

Mathematical writing should be:

- Clear
- Logical
- Convincing

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- Clear
- Logical
- Convincing

**NB**

*All submitted work must be typeset. Diagrams may be hand drawn.*

# How can you do well?

The best way to improve is to **practice**.

Opportunities for you:

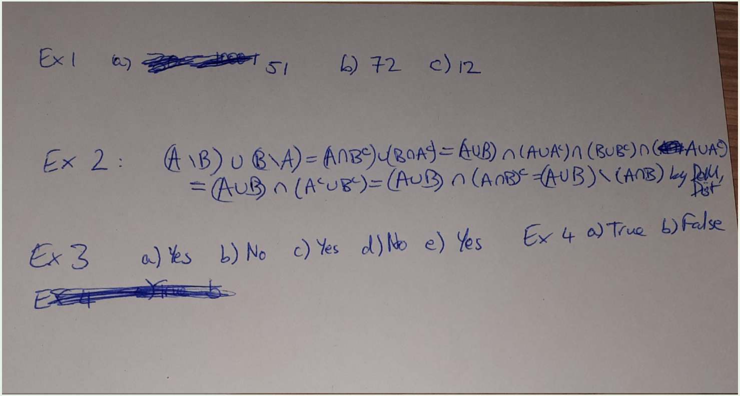
- Weekly quizzes
- Four assignments of longer questions
- Practice questions – including past exam questions
  - Looking for solutions! (Post to forum)
- Textbook and other questions (links on the course website)

Support:
If you get stuck, you can get one-on-one support from our tutors by

- attending face-to-face **help sessions**
- attending **online consultations**
- posting questions on **edforum**.

# Examples

## Example (Bad)


Ex 1 a) 51 b) 72 c) 12

Ex 2: $(A \setminus B) \cup (B \setminus A) = (A \cap B^c) \cup (B \cap A^c) = (A \cup B) \cap (A \cup A^c) \cap (B \cup B^c) \cap (A \cup A^c)$
$= (A \cup B) \cap (A^c \cup B^c) = (A \cup B) \cap (A \cap B)^c = (A \cup B) \setminus (A \cap B)$ by DeM, Dist

Ex 3 a) Yes b) No c) Yes d) No e) Yes

Ex 4 a) True b) False

# Examples

## Example (Good)

Ex. 2

$$
\begin{aligned}
(A \setminus B) \cup (B \setminus A) &= (A \cap B^c) \cup (B \cap A^c) && \text{(Def.)} \\
&= ((A \cap B^c) \cup B) \cap ((A \cap B^c) \cup A^c) && \text{(Dist.)} \\
&= (A \cup B) \cap (B^c \cup B) \\
&\qquad \cap (A \cup A^c) \cap (B^c \cup A^c) && \text{(Dist.)} \\
&= (A \cup B) \cap (A^c \cup B^c) && \text{(Ident.)} \\
&= (A \cup B) \cap (A \cap B)^c && \text{(DeM.)} \\
&= (A \cup B) \setminus (A \cap B) && \text{(Def.)}
\end{aligned}
$$

# Examples

**Example (Good)**

Ex. 4a

We will show that if $R_1$ and $R_2$ are symmetric, then $R_1 \cap R_2$ is symmetric.

Suppose $(a, b) \in R_1 \cap R_2$.

Then $(a, b) \in R_1$ and $(a, b) \in R_2$.

Because $R_1$ is symmetric, $(b, a) \in R_1$; and because $R_2$ is symmetric, $(b, a) \in R_2$.

Therefore $(b, a) \in R_1 \cap R_2$.

Therefore $R_1 \cap R_2$ is symmetric.

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# Proofs

A large component of your work in this course is giving **proofs** of **propositions.**

A **proposition** is a statement that is either true or false.

**Example**

Propositions:

- $3 + 5 = 8$
- All integers are either even or odd
- There exist $a, b, c$ such that $1/a + 1/b + 1/c = 4$

Not propositions:

- $3 + 5$
- $x$ is even or $x$ is odd
- $1/a + 1/b + 1/c = 4$

# Proposition structure

Common proposition structures include:

| | |
|---|---|
| If A then B | $(A \Rightarrow B)$ |
| A if and only if B | $(A \Leftrightarrow B)$ |
| For all x, A | $(\forall x.A)$ |
| There exists x such that A | $(\exists x.A)$ |

$\forall$ and $\exists$ are known as **quantifiers**.

# Proofs

A large component of your work in this course is giving **proofs** of **propositions.**

A proof of a proposition is an argument to convince the reader/marker that the proposition is true.

A **proof** of a proposition is a finite sequence of logical steps, starting from base assumptions (**axioms** and **hypotheses**), leading to the proposition in question.

# Proofs

**Example**

Prove: $3 \times 2 = 2 \times 3$

$$3 \times 2 = (2 + 1) \times 2$$

# Proofs

**Example**

Prove: $3 \times 2 = 2 \times 3$

$$\begin{aligned} 3 \times 2 &= (2+1) \times 2 \\ &= (2 \times 2) + (1 \times 2) \end{aligned}$$

# Proofs

## Example

Prove: $3 \times 2 = 2 \times 3$

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# Proofs

## Example

Prove: $3 \times 2 = 2 \times 3$

$$
\begin{aligned}
3 \times 2 &= (2+1) \times 2 \\
&= (2 \times 2) + (1 \times 2) \\
&= (1 \times 2) + (2 \times 2) \\
&= 2 + (2 \times 2)
\end{aligned}
$$

# Proofs

**Example**

Prove: $3 \times 2 = 2 \times 3$

$$\begin{aligned} 3 \times 2 &= (2+1) \times 2 \\ &= (2 \times 2) + (1 \times 2) \\ &= (1 \times 2) + (2 \times 2) \\ &= 2 + (2 \times 2) \\ &= (2 \times 1) + (2 \times 2) \end{aligned}$$

# Proofs

**Example**

Prove: $3 \times 2 = 2 \times 3$

$$\begin{aligned}
3 \times 2 &= (2+1) \times 2 \\
&= (2 \times 2) + (1 \times 2) \\
&= (1 \times 2) + (2 \times 2) \\
&= 2 + (2 \times 2) \\
&= (2 \times 1) + (2 \times 2) \\
&= 2 \times (1 + 2)
\end{aligned}$$

# Proofs

## Example

Prove: $3 \times 2 = 2 \times 3$

$$
\begin{aligned}
3 \times 2 &= (2+1) \times 2 \\
&= (2 \times 2) + (1 \times 2) \\
&= (1 \times 2) + (2 \times 2) \\
&= 2 + (2 \times 2) \\
&= (2 \times 1) + (2 \times 2) \\
&= 2 \times (1+2) \\
&= 2 \times 3.
\end{aligned}
$$

# Proofs: How much detail?

- Depends on the context (question, expectation, audience, etc)
- Each **step** should be justified (excluding basic algebra and arithmetic)

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- Depends on the context (question, expectation, audience, etc)
- Each **step** should be justified (excluding basic algebra and arithmetic)

**Guiding principle**

Proofs should demonstrate your **ability** and your **understanding**.

# Outline

# Proofs: pitfalls

Starting from the proposition and deriving true **is not valid**.

**Example**

Prove: $0 = 1$

$$\begin{array}{lrcll}
 & 0 & = & 1 & \\
\text{So (mult. by 2)} & 0 & = & 2 & \\
\text{So (subtract 1)} & -1 & = & 1 & \\
\text{So} & (-1)^2 & = & (1)^2 & \\
\text{So} & 1 & = & 1 & \text{which is true.}
\end{array}$$

Does this mean that $0 = 1$?

# Proofs: pitfalls

Make sure each step is logically valid

**Example**

$$-20 = -20$$

# Proofs: pitfalls

Make sure each step is logically valid

**Example**

$$\begin{aligned} -20 &= -20 \\ \text{So} \quad 25 - 45 &= 16 - 36 \end{aligned}$$

# Proofs: pitfalls

Make sure each step is logically valid

**Example**

$$
\begin{array}{lrcl}
 & -20 & = & -20 \\
\text{So} & 25 - 45 & = & 16 - 36 \\
\text{So} & 5^2 - 2 \cdot 5 \cdot \frac{9}{2} & = & 4^2 - 2 \cdot 4 \cdot \frac{9}{2}
\end{array}
$$

# Proofs: pitfalls

Make sure each step is logically valid

**Example**

$$
\begin{array}{lrcl}
 & -20 & = & -20 \\
\text{So} & 25-45 & = & 16-36 \\
\text{So} & 5^2 - 2\cdot 5\cdot \frac{9}{2} & = & 4^2 - 2\cdot 4\cdot \frac{9}{2} \\
\text{So} & 5^2 - 2\cdot 5\cdot \frac{9}{2} + \left(\frac{9}{2}\right)^2 & = & 4^2 - 2\cdot 4\cdot \frac{9}{2} + \left(\frac{9}{2}\right)^2
\end{array}
$$

# Proofs: pitfalls

Make sure each step is logically valid

**Example**

$$\begin{array}{lrcl} & -20 & = & -20 \\ \text{So} & 25-45 & = & 16-36 \\ \text{So} & 5^2-2\cdot 5\cdot \frac{9}{2} & = & 4^2-2\cdot 4\cdot \frac{9}{2} \\ \text{So} & 5^2-2\cdot 5\cdot \frac{9}{2}+\left(\frac{9}{2}\right)^2 & = & 4^2-2\cdot 4\cdot \frac{9}{2}+\left(\frac{9}{2}\right)^2 \\ \text{So} & (5-\frac{9}{2})^2 & = & (4-\frac{9}{2})^2 \end{array}$$

# Proofs: pitfalls

Make sure each step is logically valid

**Example**

$$\begin{array}{lrcl} & -20 & = & -20 \\ \text{So} & 25 - 45 & = & 16 - 36 \\ \text{So} & 5^2 - 2 \cdot 5 \cdot \frac{9}{2} & = & 4^2 - 2 \cdot 4 \cdot \frac{9}{2} \\ \text{So} & 5^2 - 2 \cdot 5 \cdot \frac{9}{2} + \left(\frac{9}{2}\right)^2 & = & 4^2 - 2 \cdot 4 \cdot \frac{9}{2} + \left(\frac{9}{2}\right)^2 \\ \text{So} & (5 - \frac{9}{2})^2 & = & (4 - \frac{9}{2})^2 \\ \text{So} & 5 - \frac{9}{2} & = & 4 - \frac{9}{2} \end{array}$$

Does this mean that $5 = 4$?

# Proofs: pitfalls

Make sure each step is logically valid

**Example**

Suppose $a = b$. Then,

$$\begin{array}{lrcl} & a^2 & = & ab \\ \text{So} & a^2 - b^2 & = & ab - b^2 \\ \text{So} & (a-b)(a+b) & = & (a-b)b \\ \text{So} & a+b & = & b \\ \text{So} & a & = & 0 \end{array}$$

This is true no matter what value $a$ is given at the start, so does that mean everything is equal to $0$?

# Proofs: pitfalls

For propositions of the form $\forall x.A$ where $x$ can have infinitely many values:

- You cannot enumerate infinitely many cases in a proof.
- Only considering a finite number of cases is not sufficient.

**Example**

For all $n$, $n^2 + n + 41$ is prime

True for $n = 0, 1, 2, \ldots, 39$. Not true for $n = 40$.

# Proofs: pitfalls

The order of quantifiers matters when it comes to propositions:

**Example**

- For every number $x$, there is a number $y$ such that $y$ is larger than $x$
- There is a number $y$ such that for every number $x$, $y$ is larger than $x$

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# Proof strategies: direct proof

| Proposition form | You need to do this |
|---|---|
| $A \Rightarrow B$ | Assume A and prove B |
| $A \Leftrightarrow B$ | Prove “If A then B” and “If B then A” |
| $\forall x.A$ | Show A holds for every possible value of x |
| $\exists x.A$ | Find a value of x that makes A true |

# Proof strategies: contradiction

To prove A is true, assume A is false and derive a contradiction.
That is, start from the negation of the proposition and derive false.

**Example**

Prove: $\sqrt{2}$ is irrational
Proof: Assume $\sqrt{2}$ is rational ...

# Negating propositions

| Proposition form | Its negation |
| --- | --- |
| $A$ and $B$ | |
| $A$ or $B$ | |
| $A \Rightarrow B$ | |
| $A \Leftrightarrow B$ | |
| $\forall x.A$ | |
| $\exists x.A$ | |

# Negating propositions

| Proposition form | Its negation |
|---|---|
| $A$ and $B$ | not $A$ or not $B$ |
| $A$ or $B$ | |
| $A \Rightarrow B$ | |
| $A \Leftrightarrow B$ | |
| $\forall x.A$ | |
| $\exists x.A$ | |

# Negating propositions

| Proposition form | Its negation |
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| $A$ and $B$ | not $A$ or not $B$ |
| $A$ or $B$ | not $A$ and not $B$ |
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# Negating propositions

| Proposition form | Its negation |
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# Negating propositions

| Proposition form | Its negation |
|---|---|
| $A$ and $B$ | not $A$ or not $B$ |
| $A$ or $B$ | not $A$ and not $B$ |
| $A \Rightarrow B$ | $A$ and not $B$ |
| $A \Leftrightarrow B$ | $A$ and not $B$, or $B$ and not $A$ |
| $\forall x.A$ | |
| $\exists x.A$ | |

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| $\forall x.A$ | $\exists x.$ not $A$ |
| $\exists x.A$ | |

# Negating propositions

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| $\forall x.A$ | $\exists x.$ not $A$ |
| $\exists x.A$ | $\forall x.$ not $A$ |

# Proof strategies: contrapositive

To prove a proposition of the form “If A then B” you can prove “If not B then not A”

**Example**

Prove: If $m + n \geq 73$ then $m \geq 37$ or $n \geq 37$.

# That's it!

See you in tomorrow's lecture