CSE 20
DISCRETE MATH

Winter 2017

http://cseweb.ucsd.edu/classes/wi17/cse20-ab/

Final exam

The final exam is **Saturday March 18 8am-11am**.

- Lecture A will take the exam in GH 242
- Lecture B will take the exam in SOLIS 107

Practice questions +seat maps for the final exam are now available on Piazza.

- Solutions will not be posted for these questions. However, the TAs will discuss them in the review session **Thursday 03/16/2017 8:00p-10:50p PETER 108.**

1. Algorithms
2. Number systems and integer operations
3. Propositional Logic
4. Predicates & Quantifiers
5. Proof strategies
6. Sets
7. Induction & Recursion
8. Functions & Cardinalities of sets
9. Binary relations & Modular arithmetic

Algorithms

- Trace pseudocode given input.
- Explain the higher-level function of an algorithm expressed with pseudocode.
- Identify and explain (informally) whether and why an algorithm expressed in pseudocode terminates for all input.
- Describe and use classical algorithms:
  - Addition and multiplication of integers expressed in some base
- Define the greedy approach for an optimization problem.
- Write pseudocode to implement the greedy approach for a given optimization problem.

Pseudocode

Prove that after the code snippet

$$\textbf{if } x + 2 > 3 \textbf{ then}$$
$$x := x + 1$$

executes, the value stored in *x* is not equal to 2.

What proof technique will you try?

A. Direct proof
B. Contrapositive proof
C. Proof by contradiction
D. Exhaustive proof (proof by cases)
E. Find an example

Pseudocode

Prove that after the code snippet

$$\textbf{if } x + 2 > 3 \textbf{ then}$$
$$\quad x := x + 1$$

executes, the value stored in *x* is not equal to 2.

Do you want to go through the proof together?

A. Yes
B. No

Number systems and integer representations

- Convert between positive integers written in any base b, where b >1.
- Define the decimal, binary, hexadecimal, and octal expansions of a positive integer.
- Describe and use algorithms for integer operations based on their expansions
- Relate algorithms for integer operations to bitwise boolean operations.
- Correctly use XOR and bit shifts.
- Define and use the DIV and MOD operators.

Arithmetic + Representations *Rosen p. 251*

What is the sum of $(2A)_{16}$ and $(13)_{16}$?

What is the product of $(2A)_{16}$ and $(13)_{16}$?

A. Do you want to work through both together?
B. Just work through sum.
C. Just work through product.
D. Neither.

Hexadecimal digits

0	8
1	9
2	A
3	B
4	C
5	D
6	E
7	F

Propositional Logic

- Describe the uses of logical connectives in formalizing natural language statements, bit operations, guiding proofs and rules of inference.
- Translate sentences from English to propositional logic using appropriate propositional variables and boolean operators.
- List the truth tables and meanings for negation, conjunction, disjunction, exclusive or, conditional, biconditional operators.
- Evaluate the truth value of a compound proposition given truth values of its constituent variables.
- Form the converse, contrapositive, and inverse of a given conditional statement.
- Relate boolean operations to applications: Complex searches, Logic puzzles, Set operations and spreadsheet queries, Combinatorial circuits
- Prove propositional equivalences using truth tables
- Prove propositional equivalences using other known equivalences, e.g. DeMorgan's laws, Double negation laws, Distributive laws, etc.
- Identify when and prove that a statement is a tautology or contradiction
- Identify when and prove that a statement is satisfiable or unsatisfiable, and when a set of statements is consistent or inconsistent.
- Compute the CNF and DNF of a given compound proposition.

Conditionals

Rosen p. 6-10

Which of these compound propositions **is** logically equivalent to

$$\neg((p \to \neg q) \to r)$$

A. $(p \to \neg q) \to \neg r$

B. $\neg r \to \neg(p \to \neg q)$

C. $(q \vee r) \to (\neg p \wedge \neg r)$

D. $\neg(p \to \neg q) \vee r$

E. None of the above.

p	q	p → q
T	T	T
T	F	F
F	T	T
F	F	T

Conditionals

Rosen p. 6-10

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C. $(q \vee r) \to (\neg p \wedge \neg r)$

D. $\neg(p \to \neg q) \vee r$

E. None of the above.

Normal forms:

A. Do you want to find equivalent CNF and DNF?
B. Just find DNF?
C. Just find CNF?
D. Neither.

Predicates & Quantifiers

- Determine the truth value of predicates for specific values of their arguments
- Define the universal and existential quantifiers
- Translate sentences from English to predicate logic using appropriate predicates and quantifiers
- Use appropriate Boolean operators to restrict the domain of a quantified statement
- Negate quantified expressions
- Translate quantified statements to English, even in the presence of nested quantifiers
- Evaluate the truth value of a quantified statement with nested quantifiers

Evaluating quantified statements *Rosen p. 64 #1*

$$\forall x \forall y (x < y \rightarrow \exists z (x < z < y))$$

In which domain(s) is this statement true?

A. All positive real numbers.
B. All positive integers.
C. All real numbers in closed interval [0,1].
D. The integers 1,2,3.
E. The power set of {1,2,3}

Proof strategies

- Distinguish between a theorem, an axiom, lemma, a corollary, and a conjecture.
- Recognize direct proofs
- Recognize proofs by contraposition
- Recognize proofs by contradiction
- Recognize fallacious “proofs”
- Evaluate which proof technique(s) is appropriate for a given proposition: Direct proof, Proofs by contraposition, Proofs by contradiction, Proof by cases, Constructive existence proofs, induction
- Correctly prove statements using appropriate style conventions, guiding text, notation, and terminology

A sample proof by contradiction

- Theorem: There are infinitely many prime numbers.

Sets

- Define and differentiate between important sets: **N, Z, Z+, Q**, **R**, **R+**, **C**, empty set, {0,1}*
- Use correct notation when describing sets: {...}, intervals, set builder
- Define and prove properties of: subset relation, power set, Cartesian products of sets, union of sets, intersection of sets, disjoint sets, set differences, complement of a set
- Describe computer representation of sets with bitstrings

Power set example

Power set: For a set S, its power set is the set of all subsets of S.

$$\mathcal{P}(S) = \{A \mid A \subseteq S\}$$

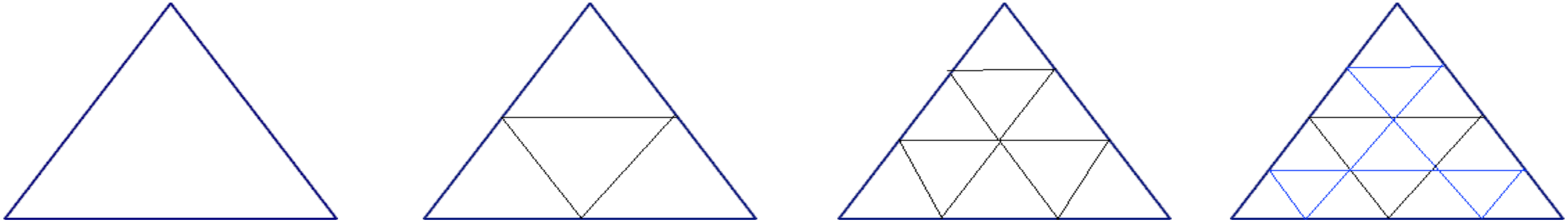
Which of the following is **not** true (in general)?

A. $S \in \mathcal{P}(S)$
B. $\emptyset \in \mathcal{P}(S)$
C. $S \subseteq \mathcal{P}(S)$
D. $\emptyset \in S$
E. None of the above

Induction and recursion

- Explain the steps in a proof by mathematical induction
- Explain the steps in a proof by strong mathematical induction
- Use (strong) mathematical induction to prove correctness of identities and inequalities
- Use (strong) mathematical induction to prove properties of algorithms
- Use (strong) mathematical induction to prove properties of geometric constructions
- Apply recursive definitions of sets to determine membership in the set
- Use structural induction to prove properties of recursively defined sets

Triangles



Theorem: If start with an equilateral triangle and divide each side into n equal segments, then connect the division points with all possible line segments parallel to sides of original triangle, then _______ many small triangles will be contained in the original triangle.

Triangles

Theorem: At stage n, n^2 triangles are formed.

Proof: by Mathematical Induction.

1. Basis step WTS that when side lengths undivided, 1^2 triangles are formed.
2. Inductive hypothesis Let k be a nonnegative integer. Assume that when divide sides into k pieces, k^2 triangles are formed.

3. Induction step WTS when divide sides into k+1 pieces, $(k+1)^2$ triangles are formed.

Structural induction

Theorem: For any bit strings w, ones(w) ≤ l(w).

A. What does this mean? How to prove it?
B. Just talk about what it means.
C. How does structural induction apply?
D. Neither.

Postage

What postage can you make using just 3c and 5c stamps?

Functions & Cardinality of sets

- Represent functions in multiple ways
- Define and prove properties of domain of a function, image of a function, composition of functions
- Determine and prove whether a function is one-to-one
- Determine and prove whether a function is onto
- Determine and prove whether a function is bijective
- Apply the definition and properties of floor function, ceiling function, factorial function
- Define and compute the cardinality of a set
    - Finite sets
    - countable sets
    - uncountable sets
- Use functions to compare the sizes of sets
- Use functions to define sequences: arithmetic progressions. geometric progressions
- Use and prove properties of recursively defined functions and recurrence relations (using induction)
- Use and interpret Sigma notation

Cardinality and subsets

Suppose A and B are sets and $A \subseteq B$.

A. If A is infinite then B is finite.
B. If A is countable then B is countable.
C. If B is infinite then A is finite.
D. If B is uncountable then A is uncountable.
E. None of the above.

Binary relations

- Determine and prove whether a given binary relation is
  - symmetric
  - antisymmetric
  - reflexive
  - transitive
- Represent equivalence relations as partitions and vice versa
- Define and use the congruence modulo m equivalence relation

Properties of binary relations

Over the set $\mathbf{Z}^+$

A. Define an equivalence relation with exactly three equivalence classes.
B. Define an equivalence relation with infinitely many equivalence classes, each of finite size.
C. Define a binary relation that is reflexive but not symmetric and not antisymmetric.
D. Define a binary relation that is reflexive, symmetric, antisymmetric, and transitive.
E. Define a binary relation that is not reflexive, not symmetric, not antisymmetric, and not transitive.

Modular arithmetic

Rosen p. 288

Solve the congruences

$$x \equiv 3 \pmod{4} \qquad \text{i.e.} \qquad x \mathbin{\mathbf{mod}} 4 = 3$$

$$5 + x \equiv 3 \pmod{7} \qquad \text{i.e.} \qquad 5 + x \mathbin{\mathbf{mod}} 7 = 3$$

$$5x \equiv 3 \pmod{7} \qquad \text{i.e.} \qquad 5x \mathbin{\mathbf{mod}} 7 = 3$$

Reminders

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2. Number systems and integer operations
3. Propositional Logic
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6. Sets
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