

# IS 2150 / TEL 2810

## Information Security & Privacy



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A Quick Review of Some Maths  
For IS 2150/TEL 2810



# Objective

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- Review some mathematical concepts
  - Propositional logic
  - Predicate logic
  - Mathematical induction
  - Lattice



# Propositional logic/calculus

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- Atomic, declarative statements (propositions)
  - that can be shown to be either TRUE or FALSE but not both; E.g., “Sky is blue”; “3 is less than 4”
- Propositions can be composed into compound sentences using connectives
  - Negation  $\neg p$  (NOT) highest precedence
  - Disjunction  $p \vee q$  (OR) second precedence
  - Conjunction  $p \wedge q$  (AND) second precedence
  - Implication  $p \rightarrow q$   $q$  logical consequence of  $p$
- Exercise: Truth tables?



# Propositional logic/calculus

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- Contradiction:
  - Formula that is always false :  $p \wedge \neg p$
  - What about:  $\neg(p \wedge \neg p)$ ?
- Tautology:
  - Formula that is always True :  $p \vee \neg p$ 
    - What about:  $\neg(p \vee \neg p)$ ?
- Others
  - Exclusive OR:  $p \oplus q$ ; p or q but not both
  - Bi-condition:  $p \leftrightarrow q$  [*p if and only if q* (p iff q)]
  - Logical equivalence:  $p \Leftrightarrow q$  [p is logically equivalent to q]
- Some exercises...



# Some Laws of Logic

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- Double negation
- DeMorgan's law
  - $\neg(p \wedge q) \Leftrightarrow (\neg p \vee \neg q)$
  - $\neg(p \vee q) \Leftrightarrow (\neg p \wedge \neg q)$
- Commutative
  - $(p \vee q) \Leftrightarrow (q \vee p)$
- Associative law
  - $p \vee (q \vee r) \Leftrightarrow (p \vee q) \vee r$
- Distributive law
  - $p \vee (q \wedge r) \Leftrightarrow (p \vee q) \wedge (p \vee r)$
  - $p \wedge (q \vee r) \Leftrightarrow (p \wedge q) \vee (p \wedge r)$



# Predicate/first order logic

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- Propositional logic
- Variable, quantifiers, constants and functions
- Consider sentence: *Every directory contains some files*
- Need to capture “every” “some”
  - $F(x)$ : x is a file
  - $D(y)$ : y is a directory
  - $C(x, y)$ : x is a file in directory y



# Predicate/first order logic

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- Existential quantifiers  $\exists$  (There exists)
  - E.g.,  $\exists x$  is read as There exists  $x$
- Universal quantifiers  $\forall$  (For all)
- $\forall y D(y) \rightarrow (\exists x (F(x) \wedge C(x, y)))$
- read as
  - for every  $y$ , *if*  $y$  is a directory, *then* there exists a  $x$  such that  $x$  *is a file* and  $x$  *is in directory*  $y$
- What about  $\forall x F(x) \rightarrow (\exists y (D(y) \wedge C(x, y)))$ ?



# Mathematical Induction

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- Proof technique - to prove some mathematical property
  - E.g. want to prove that  $M(n)$  holds for all natural numbers
- **Base case OR Basis:**
  - Prove that  $M(1)$  holds
- **Induction Hypothesis:**
  - Assert that  $M(n)$  holds for  $n = 1, \dots, k$
- **Induction Step:**
  - Prove that if  $M(k)$  holds then  $M(k+1)$  holds





# Mathematical Induction

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- Exercise: prove that sum of first  $n$  natural numbers is
  - $S(n): 1 + \dots + n = n(n + 1)/2$
- Prove
  - $S(n): 1^2 + \dots + n^2 = n(n + 1)(2n + 1)/6$



# Lattice

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- Sets
  - Collection of unique elements
  - Let  $S, T$  be sets
    - Cartesian product:  $S \times T = \{(a, b) \mid a \in A, b \in B\}$
    - A set of order pairs
- Binary relation  $R$  from  $S$  to  $T$  is a subset of  $S \times T$
- Binary relation  $R$  on  $S$  is a subset of  $S \times S$



# Lattice

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- If  $(a, b) \in R$  we write  $aRb$ 
  - Example:
    - $R$  is “less than equal to” ( $\leq$ )
    - For  $S = \{1, 2, 3\}$ 
      - Example of  $R$  on  $S$  is  $\{(1, 1), (1, 2), (1, 3), \text{????}\}$
  - $(1, 2) \in R$  is another way of writing  $1 \leq 2$



# Lattice

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- Properties of relations
  - Reflexive:
    - if  $aRa$  for all  $a \in S$
  - Anti-symmetric:
    - if  $aRb$  and  $bRa$  implies  $a = b$  for all  $a, b \in S$
  - Transitive:
    - if  $aRb$  and  $bRc$  imply that  $aRc$  for all  $a, b, c \in S$
  - Which properties hold for “less than equal to” ( $\leq$ )?
  - Draw the Hasse diagram
    - Captures all the relations



# Lattice

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- Total ordering:
  - when the relation orders all elements
  - E.g., “less than equal to” ( $\leq$ ) on natural numbers
- Partial ordering (poset):
  - the relation orders only some elements not all
  - E.g. “less than equal to” ( $\leq$ ) on complex numbers; Consider  $(2 + 4i)$  and  $(3 + 2i)$



# Lattice

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- Upper bound ( $u, a, b \in S$ )
  - $u$  is an upper bound of  $a$  and  $b$  means  $aRu$  and  $bRu$
  - Least upper bound :  $lub(a, b)$  *closest upper bound*
- Lower bound ( $l, a, b \in S$ )
  - $l$  is a lower bound of  $a$  and  $b$  means  $lRa$  and  $lRb$
  - Greatest lower bound :  $glb(a, b)$  *closest lower bound*



# Lattice

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- A lattice is the combination of a set of elements  $S$  and a relation  $R$  meeting the following criteria
  - $R$  is reflexive, antisymmetric, and transitive on the elements of  $S$
  - For every  $s, t \in S$ , there exists a **greatest lower bound**
  - For every  $s, t \in S$ , there exists a **lowest upper bound**
- Some examples
  - $S = \{1, 2, 3\}$  and  $R = \leq?$
  - $S = \{2+4i; 1+2i; 3+2i, 3+4i\}$  and  $R = \leq?$



# Overview of Lattice Based Models

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- Confidentiality
  - Bell LaPadula Model
    - First rigorously developed model for high assurance - for military
    - Objects are classified
    - Objects may belong to Compartments
    - Subjects are given clearance
    - Classification/clearance levels form a lattice
    - Two rules
      - No read-up
      - No write-down





# Summary

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- Basics of Logic
- Induction technique
- Lattice