

# Table of contents provided by Syndetics

- **Preface** (p. xi)
- **Acknowledgments** (p. xv)
- **1.2 Set Operations** (p. 9)
- **Authors** (p. xvii)
- **1 Set Theory and Functions** (p. 1)
- **1.1 Basic Set Definitions** (p. 1)
- **1.2.1 Union** (p. 9)
- **1.2.2 Intersection** (p. 11)
- **1.2.3 Set Difference** (p. 13)
- **1.5 Functions** (p. 24)
- **1.5.1 Partial Functions** (p. 26)
- **1.2.4 Power Set** (p. 19)
- **1.3 Ordered Pairs** (p. 20)
- **1.4 Relations** (p. 21)
- **1.5.2 Into/Onto** (p. 27)
- **1.5.3 Composition** (p. 28)
- **Exercises** (p. 30)
- **2 Finite State Machine** (p. 33)
- **2.1 Key Concepts of Finite State Machines** (p. 34)
- **2.2 Accepting States** (p. 37)
- **2.3 State Machines with Output** (p. 44)
- **2.3.1 Mealy** (p. 45)
- **2.3.2 Moore** (p. 46)
- **2.3.3 Harel (UML)** (p. 46)
- **Exercises** (p. 51)
- **3 Regular Expressions and Languages** (p. 55)
- **3.1 Strings and Languages** (p. 55)
- **3.2 Regular Expressions** (p. 58)
- **3.3 Lex** (p. 63)
- **3.4 Grammar** (p. 65)
- **3.4.1 Productions** (p. 66)
- **3.4.2 Derivations** (p. 69)
- **3.4.3 Parse Trees** (p. 71)
- **3.4.4 Removing Left Recursion** (p. 74)
- **3.4.5 Left Factoring** (p. 77)
- **3.5 Regular Expressions versus Grammars** (p. 78)
- **Exercises** (p. 79)
- **4 Propositional Logic** (p. 83)
- **4.1 Propositional Statements** (p. 83)
- **4.2 Logic Operators and Truth Tables** (p. 84)
- **4.2.1 Well-Formed Formulas** (p. 85)
- **4.2.2 Truth Values** (p. 89)
- **4.2.3 Evaluation of Propositional Formulas** (p. 90)
- **4.3 Logic Equivalencies** (p. 92)

- **4.4 Logic Arguments** (p. 95)
- **4.4.1 Validity and Soundness** (p. 96)
- **4.4.2 Validity Test through Truth Tables** (p. 97)
- **4.4.3 Inference Rules** (p. 98)
  - **4.4.3.1 Or-Introduction ( $\vee$ i)** (p. 98)
  - **4.4.3.2 And-Elimination ( $\wedge$ e)** (p. 98)
  - **4.4.3.3 And-Introduction ( $\wedge$ i)** (p. 98)
  - **4.4.3.4 Modus Ponens (MP)** (p. 98)
  - **4.4.3.5 Modus Tollens (MT)** (p. 99)
  - **4.4.3.6 Implication-Introduction ( $\rightarrow$ i)** (p. 100)
  - **4.4.3.7 Or-Elimination ( $\vee$ e)** (p. 101)
  - **4.4.3.8 Proof by Contradiction (PBC)** (p. 102)
  - **4.4.3.9 Law of the Excluded Middle (LEM)** (p. 103)
- **4.5 Satisfiability of Formulas** (p. 104)
  - **4.5.1 Conjunctive Normal Forms** (p. 105)
  - **4.5.2 Horn Clauses** (p. 108)
- **Exercises** (p. 111)
- **5 Predicate Logic** (p. 115)
  - **5.1 Predicates** (p. 116)
  - **5.2 Quantifiers** (p. 117)
    - **5.2.1 Universal Quantifier** (p. 117)
    - **5.2.2 Existential Quantifier** (p. 118)
    - **5.2.3 Properties of Quantifiers** (p. 120)
  - **5.3 Syntax of Predicate Logic** (p. 122)
    - **5.3.1 Terms** (p. 122)
    - **5.3.2 Formulas** (p. 123)
    - **5.3.3 Parse Trees** (p. 125)
    - **5.3.4 Free and Bound Variables** (p. 126)
    - **5.3.5 Substitution** (p. 128)
  - **5.4 Natural Deduction Rules** (p. 130)
    - **5.4.1 Rules for Equality** (p. 131)
    - **5.4.2 Rules for Universal Quantifier** (p. 132)
    - **5.4.3 Rules for the Existential Quantifier** (p. 134)
  - **5.5 Semantics of Predicate Logic** (p. 138)
    - **5.5.1 Interpretation and Models** (p. 138)
    - **5.5.2 Evaluation of Truth Values** (p. 142)
    - **5.5.3 Satisfiability and Validity** (p. 145)
- **Exercises** (p. 145)
- **6 Temporal Logic** (p. 151)
  - **6.1 Temporal Logic** (p. 151)
    - **6.1.1 Kripke Structures** (p. 151)
    - **6.1.2 Modeling of Time** (p. 153)
  - **6.2 Linear Temporal Logic** (p. 155)
    - **6.2.1 Syntax of LTL** (p. 155)
    - **6.2.2 Parse Trees of LTL Formulas** (p. 156)
    - **6.2.3 Semantics of LTL** (p. 157)

- **6.2.4 Equivalencies of LTL Formulas** (p. 160)
- **6.2.5 System Property Specification** (p. 161)
- **6.3 Computation Tree Logic** (p. 163)
- **6.3.1 Syntax of CTL** (p. 163)
- **6.3.2 Semantics of CTL** (p. 165)
- **6.3.3 Equivalencies of CTL Formulas** (p. 168)
- **6.3.4 System Property Specification** (p. 169)
- **6.3.5 LTL versus CTL** (p. 170)
- **6.4 CTL\*** (p. 171)
- **Exercises** (p. 173)
- **7 Formal Verification by Model Checking** (p. 177)
- **7.1 Introduction to Model Checking** (p. 177)
- **7.2 CTL Model Checking Algorithm** (p. 178)
- **7.2.1 The Labeling Algorithm** (p. 178)
- **7.2.2 State Explosion Issues in Model Checking** (p. 181)
- **7.3 The NuSMV Model Checking Tool** (p. 181)
- **7.3.1 Description Language** (p. 182)
- **7.3.1.1 Data Types and Operators** (p. 182)
- **7.3.1.2 Single-Module SMV Program** (p. 182)
- **7.3.1.3 Multi-Module SMV Program** (p. 184)
- **7.3.1.4 Asynchronous Systems** (p. 185)
- **7.3.2 Specifications** (p. 186)
- **7.3.3 Running NuSMV** (p. 188)
- **7.4 Example: The Ferryman Puzzle** (p. 191)
- **Exercises** (p. 195)
- **8 Petri Nets** (p. 201)
- **8.1 Petri Nets** (p. 201)
- **8.1.1 Multiplicity of Arcs** (p. 204)
- **8.2 Common Petri Net Structures and Substructures** (p. 206)
- **8.2.1 Sequential Execution** (p. 207)
- **8.2.2 Concurrent Execution** (p. 207)
- **8.2.3 Synchronization** (p. 208)
- **8.2.4 Nondeterminism** (p. 208)
- **8.2.5 Loop** (p. 209)
- **8.2.6 Source** (p. 209)
- **8.2.7 Consumer** (p. 210)
- **8.2.8 Control** (p. 210)
- **8.2.9 Accumulator** (p. 211)
- **8.3 Reduction Rules** (p. 212)
- **8.3.1 Fusion of Series Places** (p. 212)
- **8.3.2 Fusion of Series Transitions** (p. 213)
- **8.3.3 Fusion of Parallel Places** (p. 213)
- **8.3.4 Fusion of Parallel Transitions** (p. 214)
- **8.3.5 Elimination of Self-Loop Places** (p. 214)
- **8.3.6 Elimination of Self-Loop Transitions** (p. 214)
- **8.4 Modeling** (p. 216)

- **8.5 Mathematical Description of Petri Nets** (p. 221)
- **8.6 Petri Net Behavior** (p. 224)
  - **8.6.1 Reachability** (p. 224)
    - **8.6.1.1 The Reachability Tree** (p. 224)
    - **8.6.1.2 Reachability Graph** (p. 226)
  - **8.6.2 Boundedness** (p. 229)
  - **8.6.3 Liveness** (p. 229)
  - **8.6.4 Reversibility** (p. 232)
  - **8.6.5 Fairness** (p. 232)
  - **8.6.6 Incidence Matrix** (p. 232)
  - **8.6.7 T-Invariants** (p. 234)
  - **8.6.8 S-Invariants** (p. 236)
  - **8.6.9 Siphons and Traps** (p. 237)
- **Exercises** (p. 238)
- **9 Timed Petri Nets** (p. 245)
  - **9.1 Introducing Time to Petri Nets** (p. 245)
  - **9.2 Deterministic Timed Petri Nets** (p. 247)
    - **9.2.1 States in DTPNs** (p. 248)
    - **9.2.2 Transition Firing Rules** (p. 249)
    - **9.2.3 Performance Evaluation Based on DTPNs** (p. 252)
- **9.3 Probability and Stochastic Process** (p. 254)
  - **9.3.1 Probability** (p. 254)
  - **9.3.2 Stochastic Process** (p. 257)
  - **9.3.3 Continuous-Time Markov Chains** (p. 258)
- **10.2 Colored Petri Nets** (p. 279)
  - **9.4 Stochastic Petri Nets** (p. 262)
    - **9.4.1 Definition** (p. 262)
  - **10 Colored Petri Nets** (p. 271)
    - **10.1 Introductory Examples** (p. 271)
    - **9.4.2 Performance Evaluation** (p. 265)
      - **Exercises** (p. 268)
        - **10.2.1 Multi-Set** (p. 279)
      - **Exercises** (p. 286)
    - **Index** (p. 291)
    - **10.2.3 Evaluation of an Expression** (p. 280)
    - **10.2.2 Variable Set of an Expression** (p. 280)
    - **10.3 Analysis of Colored Petri Nets** (p. 285)