Mike Holt's 2023 Electrical Exam Preparation

TABLE OF CONTENTS

About This Textbook ix

Passing Your Exam xiii

Additional Products to Help You Learn xix

How to Use the *National Electrical Code* 1

THEORY

MODULE I—ELECTRICAL FUNDAMENTALS 7

Unit 10—Basic Math 9
10.1 Introduction 9
10.2 Whole Numbers 9
10.3 Fractional Numbers 9
10.4 Decimal Numbers 9
10.5 Percentages 10
10.6 Parentheses 11
10.7 Squaring a Number 11
10.8 Square Root 11
10.9 Kilo 11
10.10 Rounding 12
10.11 Surface Area of a Rectangle or Square 12
10.12 Surface Area of a Circle 13
10.13 Volume 14
10.14 Reciprocal 15
10.15 Testing Your Answer 15
Unit 10—Review Questions 16

Unit 12—Ohm's Law 19
12.1 Introduction 19
12.2 The Electrical Circuit 19
12.3 Electromotive Force (Pressure) 19
12.4 Circuit Resistance 20
12.5 Circuit Intensity 21
12.6 Ohm's Law 21
Unit 12—Review Questions 23

Unit 13—Watt's Law 25
13.1 Introduction 25
13.2 Watt's Law 25
13.3 Power Formula Circle 26
13.4 Power Changes with the Square of the Voltage 27
Unit 13—Review Questions 28

Unit 14—Series Circuits 31
14.1 Introduction 31
14.2 Series Circuits 31
14.3 Understanding Series Circuits 31
14.4 Series Circuit Summary 34
14.5 Series-Connected Power Supplies 35
14.6 Applications of Series Circuits 36
Unit 14—Review Questions 37

Unit 15—Parallel Circuits 39
15.1 Introduction 39
15.2 Understanding Parallel Circuits 39
15.3 Parallel Circuit Resistance Calculations 41
15.4 Parallel Circuit Summary 44
15.5 Parallel-Connected Power Supplies 44
15.6 Practical Uses of Parallel Circuits 45
Unit 15—Review Questions 47

Unit 16—Series-Parallel Circuits 51
16.1 Introduction 51
16.2 Understanding Series-Parallel Circuits 51
16.3 Calculating Resistance in Series-Parallel Circuits 51
Unit 16—Review Questions 53

Unit 17—Alternating Current Fundamentals 55
17.1 Introduction 55
17.2 How Alternating Current is Produced 55
17.3 Waveforms 56
17.4 Frequency 58
17.5 In-Phase Waveforms 59
17.6 Out-of-Phase Waveforms 59
17.7 Alternating-Current Waveform Values 60
Unit 17—Review Questions 63

Unit 20—True Power, Power Factor, and Apparent Power 67
20.1 Introduction 67
20.2 True Power 67
20.3 Power Losses of Wires 67
20.4 Power Losses at Terminals 68
20.5 Equipment Efficiency 69
20.6 Cost of Power 69
20.7 Power Factor 70
20.8 Apparent Power 72
20.9 Apparent Power versus True Power 73
Unit 20—Review Questions 74

Unit 21—Motors 77
21.1 Introduction 77
21.3 Motor Horsepower Rating 77
21.5 Motor Nameplate Amperes 78
21.7 Reversing the Rotation of Alternating-Current Motors 79
21.8 Alternating-Current Motor Types 80
Unit 21—Review Questions 81

Unit 22—Generators 83
22.1 Introduction 83
22.4 Generator Output Current 83
22.5 Single-Phase and Three-Phase Generator Voltages 84
Unit 22—Review Questions 85

Unit 23—Relays 87
23.1 Introduction 87
23.2 How Relays Operate 87
23.3 Relay Contacts 88
Unit 23—Review Questions 89

Unit 24—Transformers 91
24.1 Introduction 91
24.6 Transformer Turns Ratios 91
24.8 Autotransformers 93
24.11 Transformer Current Rating 93
Unit 24—Review Questions 97

Unit 25—Overcurrent Protection 101
25.1 Introduction 101
25.6 Available Short-Circuit Current 101
25.7 Overcurrent Protective Devices, Interrupting Rating 103
Unit 25—Review Questions 104

Unit 29—The Formula Wheel 105
29.1 Introduction 105
29.2 Formula Wheel Quadrants 105
29.3 Using the Formula Wheel 106
Unit 29—Review Questions 108
Module I—Electrical Fundamentals—Practice Exam 111
Module I—Electrical Fundamentals Section Reference Index 117

CODE

MODULE II—*NEC* REVIEW QUESTIONS 119
NEC Article 90—Introduction to the *National Electrical Code* Review Questions 121
NEC Chapter 1—General Rules Review Questions 123
NEC Chapter 2—Wiring and Protection Review Questions 130
NEC Chapter 3—Wiring Methods and Materials Review Questions 155
NEC Chapter 4—Equipment for General Use Review Questions 172
NEC Chapter 5—Special Occupancies Review Questions 185
NEC Chapter 6—Special Equipment Review Questions 192
NEC Chapter 7—Special Conditions Review Questions 199
NEC Chapter 8—Communications Systems Review Questions 219
Module II—*NEC* Review Questions—Practice Exam 225
Module II—*NEC* Review Questions *Code* Rule Index 235

CALCULATIONS

MODULE III—*NEC* CALCULATIONS 239
Unit 1—Raceway Calculations 241
1.1 Conductor Cross-Sectional Area—Chapter 9, Tables 5 and 8 241
1.2 Raceway Properties 245
1.3 Sizing Raceways, Conductors all the Same Size—Annex C 247
1.4 Raceways Sizing with Different Size Conductors 251
1.5 Multiconductor and Optical Fiber Cables—Chapter 9, Note (5) and Note (9) 253
1.6 Wireways and Cable Tray Systems 254
1.7 Tips for Raceway Calculations 258
Unit 1—Review Questions 259

Unit 2—Box Calculations 265
Part A—Outlet Box Sizing 265
Introduction 265
2.1 Box Sizing—Conductors All the Same Size [Table 314.16(A)] 266
2.2 Outlet Box Fill Calculations [314.16(B)] 267
2.3 Outlet Box Sizing, Examples [314.16(B)] 271
2.4 Tips for Outlet Box Sizing 272
Part B—Pull and Junction Boxes 273
Introduction 273
2.5 Pull/Junction Box Sizing Requirements 273
2.6 How to Size Pull/Junction Boxes 275
2.7 Pull Box Sizing Examples 275
2.8 Tips for Pull Box Sizing 277
Unit 2—Review Questions 279

Unit 3—Conductor Sizing and Protection Calculations 283
Part A—Conductor Insulation, Terminals, and Overcurrent Protection 283
Introduction 283
3.1 Conductor Insulation [Table 310.4(1)] 283
3.2 Conductor Sizes 284
3.3 Conductor Size—Equipment Terminal Rating [110.14(C)] 285
3.4 Overcurrent Protection of Conductors [240.4] 288
Part B—Conductor Ampacity and Protection 290
Introduction 290
3.5 Conductor Ampacity Table [310.15(A)] 290
3.6 Conductor Ampacity Correction [310.15(B)(1)] 290
3.7 Conductor Ampacity Adjustment [310.15(C)(1)] 292
3.8 Ampacity Correction and Adjustment [310.15] 294
3.9 Neutral Current-Carrying Conductor [310.15(E)] 295
3.10 Branch Circuit Conductor Sizing [210.19(A)(1)] 297
3.11 Branch Circuit Conductor Sizing—Loads 298
3.12 Branch Circuit Overcurrent Protection Sizing [210.20(A)] 299
3.13 Feeder Conductor Sizing [215.2(A)(1)] 300
3.14 Feeder Neutral Conductor Size [215.2(A)(1) Ex 3] 301
3.15 Feeder Overcurrent Protection Sizing [215.3] 302
3.16 Feeder Tap Rules [240.21(B)] 302
Unit 3—Review Questions 307

Unit 4—Motor, Air-Conditioning, and Transformer Calculations 315
Part A—Motor Calculations 315
Introduction 315
4.1 Motor Full-Load Current (FLC) 315
4.2 Motor Full-Load Current and Motor Nameplate Current Rating [430.6(A)] 317
4.3 Branch-Circuit Conductor Sizing Continuous Duty Application [430.22] 318
4.4 Branch-Circuit Conductor Sizing for Duty-Cycle Application [430.22(E)] 321
4.5 Overcurrent Protection 322
4.6 Motor Overload Protection 323
4.7 Branch-Circuit Short-Circuit and Ground-Fault Protection [430.52] 327
4.8 Branch-Circuit Summary 331
4.9 Motor Circuit Equipment Grounding Conductor Size [250.122(D(1)] 332
4.10 Feeder Conductor Sizing [430.24] 332
4.11 Feeder Short-Circuit and Ground-Fault Protection [430.62(A)] 334
Part B—Air-Conditioning Calculations 336
Introduction 336
4.12 Air-Conditioning Equipment Nameplate [440.4(B)] 336
4.13 Air-Conditioning Equipment, Short-Circuit and Ground-Fault Protection [440.22] 337
4.14 Air-Conditioning Equipment, Conductor Ampacity [440.33] 338
Part C—Transformers 339
Introduction 339
4.15 Transformer Primary Only Overcurrent Protection [450.3(B)] 339
4.16 Transformer Secondary Conductor Sizing [240.21(C)] 342
Unit 4—Review Questions 345

Unit 5—Voltage-Drop Calculations 351
Part A—Conductor Resistance Calculations 351
Introduction 351
5.1 Conductor Cross-Sectional Area in Circular Mills [Chapter 9, Table 8] 351
5.2 Conductor Resistance 353
5.3 Conductor Resistance [Chapter 9, Table 8] 354
Part B—Voltage-Drop Calculations 356
Introduction 356
5.4 Conductors' Voltage Drop—Ohm's Law Method 356
5.5 Single-Phase Circuit Voltage Drop—Formula Method 357
5.6 Three-Phase Circuit Voltage Drop—Formula Method 359
5.7 Sizing Conductor Single-Phase Circuit Voltage Drop—Formula Method 360
5.8 Sizing Conductor Three-Phase Circuit Voltage Drop—Formula Method 362
Unit 5—Review Questions 365

Unit 6—Dwelling Unit Calculations 369
Part A—Optional Method Load Calculations [Article 220, Part IV] 369
Introduction 369
6.1 Dwelling Unit Optional Load Calculations [220.82] 369
6.2 Dwelling Unit Optional Load Calculation [220.82], Example 371
Part B—Standard Method Load Calculations [Article 220, Part III] 372
Introduction 372
6.3 Dwelling Unit Standard Load Calculation 372
6.4 General Lighting and General-Use Receptacle Demand Load [220.41 and Table 220.45] 372
6.5 Fixed Appliance Demand Load [220.53] 375
6.6 Dryer Demand Load [220.54] 376
6.8 Electric Cooking Equipment Demand Load [220.55] 376
6.10 Electric Vehicle [220.57] 378
6.11 Air-Conditioning Versus Heating [220.50, 220.51, and 220.60] 379
6.12 Service Conductor Size [Table 310.12(A)] 380
6.13 Standard Method Load Calculations, Example [Article 220, Part III] 381
6.14 Number of General Lighting and General-Purpose Receptacle Circuits [210.11(A)] 382
Part C—Neutral Load Calculations 383
Introduction 383
6.15 Neutral Calculations—Dryers and Ranges [220.61] 383
6.16 Service Neutral Calculation [220.61] 384
Unit 6—Review Questions 387
Module III—*NEC* Calculations Practice Exam 393

MODULE IV—ADVANCED *NEC* CALCULATIONS 401

Unit 7—Multifamily Dwelling Calculations 403
Part A—Optional Method Load Calculations [Article 220, Part IV] 403
Introduction 403
7.1 Multifamily Dwelling Optional Load Calculations [220.84] 403
7.2 Multifamily Dwelling Optional Method, Example [220.84] 404
Part B—Standard Method Load Calculations [Article 220, Part III] 405
Introduction 405
7.3 General Lighting and General-Use Receptacle Demand Load [220.41 and 220.45] 406
7.4 Appliance Demand Load [220.53] 407
7.5 Dryer Demand Load [220.54] 408
7.6 Single-Phase Dryers on Three-Phase Service [220.54] 410
7.7 Electric Cooking Equipment [220.55] 412
7.8 Single-Phase Ranges on Three-Phase Service [220.55] 414
7.9 Air-Conditioning and Heating Demand Load 416
7.10 Service Conductor Sizing [Table 310.16] 417
7.11 Multifamily Dwelling Calculations—Standard Method, Examples 418
7.12 Two-Family (Duplex) Dwelling Units Load Calculations [220.85] 420
Part C—Neutral Load Calculations 423
Introduction 423
7.13 Neutral Demand Load—Dryers and Ranges [220.61] 423
7.14 Service Neutral Demand Load [220.61(B)] 424
Unit 7—Review Questions 427

Unit 8—Commercial Calculations 435
Part A—General Commercial Demand Loads 435
Introduction 435
8.1 General Lighting Load [Table 220.42(A)] 435
8.2 General Lighting Load, Examples [Table 220.42(A)] 436
8.3 General Lighting Load Demand Factors [Table 220.45] 437
8.4 Number of General Lighting Circuits 438
8.5 Sign Circuit [220.14(F)] 439
8.6 Multioutlet Assemblies [220.14(H)] 439
8.7 Receptacle Demand Load [220.14(I) and 220.47] 440
8.8 Air-Conditioning versus Heating Demand Load [220.60] 442
Part B—Office, Mobile Home, Kitchen, Restaurants, and School Examples 442
Introduction 442
8.9 Office Building, Example 443
8.10 Mobile Home Parks [550.31] 444
8.11 Kitchen Equipment and Restaurants 444
8.12 School Optional Method Load Calculations [220.86] 447
Part C—Welder Calculations 448
Introduction 448
8.13 Arc Welders 448
8.14 Resistance Welders 450
Part D—Light Industrial Calculations 452
Introduction 452
8.15 Light Industrial Calculations 452
Unit 8—Review Questions 455
Module IV—Advanced *NEC* Calculations—Practice Exam 461
Modules III and IV—*NEC* Calculations *Code* and Section Index 465

About the Author 469
About the Illustrator 470
About the Mike Holt Team 471