

TABLE OF CONTENTS

About This Textbook	ix
Passing Your Exam	xiii
Additional Products to Help You Learn	xix
How to Use the <i>National Electrical Code</i>	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