

Mike Holt's Electrical Inspector Video Program

Table of Contents

This document includes the Table of Contents from each book that is included in your library. Click on the title to view details of the contents of that book.



Title	page #
Understanding Electrical Theory	2
Understanding the NEC Volume 1 (Art 90-480).....	6
Bonding and Grounding	16
Understanding the NEC Volume 2 (Art 500-810).....	21
Solar PV & Energy Storage Systems.....	28
Electrical Exam Preparation	37

2023
NEC®

UNDERSTANDING ELECTRICAL THEORY

About This Textbook	ix	4.7	Secondary Distribution Voltage.....	23
Additional Products to Help You Learn	xii	4.8	Service Drop and Service Lateral.....	23
CHAPTER 1—ELECTRICAL FUNDAMENTALS	1	Chapter 1—Practice Questions		25
Unit 1—Atomic Structure	3	CHAPTER 2—USES AND DANGERS OF ELECTRICITY		33
1.1 Introduction.....	3	Unit 5—Uses of Electricity		35
1.2 Atomic Theory.....	3	5.1 Introduction.....		35
1.3 Electrostatic Field.....	4	5.2 Uses of Electricity.....		35
1.4 Atomic Charge of an Atom.....	5	5.3 Electrochemical Processes.....		35
1.5 Electrostatic Charge and Discharge.....	6	5.4 Electromagnetism.....		35
1.6 Lightning.....	7	5.5 Photoelectricity.....		36
1.7 Lightning Protection System.....	8	5.6 Electric Heating.....		37
Unit 2—Electron Theory and Chemical Bonding	9	5.7 Lighting.....		39
2.1 Introduction.....	9	Unit 6—Dangers of Electricity		41
2.2 Electron Orbitals.....	9	6.1 Introduction.....		41
2.3 Valence Electrons.....	9	6.2 <i>National Electrical Code (NEC)</i>		41
2.4 Freeing Valence Electron(s) from an Atom.....	10	6.3 Electrical Fire.....		41
2.5 Conductance.....	10	6.4 Electric Shock and Electrocutation.....		42
2.6 Insulators.....	12	6.5 Electric Arc Flash and Arc Blast.....		43
2.7 Semiconductors.....	12	6.6 Arc Flash Incident Energy.....		44
2.8 Chemical Bonding.....	13	6.7 Electrically Safe Work Condition.....		45
Unit 3—Electrical Circuits and Power Sources	15	6.8 Personal Protective Equipment (PPE).....		46
3.1 Introduction.....	15	Chapter 2—Practice Questions		49
3.2 The Electrical Circuit.....	15	CHAPTER 3—MAGNETISM AND ELECTROMAGNETISM		55
3.3 Electric Current Flow (Electricity).....	15	Unit 7—Basics of Magnetism		57
3.4 Electrical Power Sources.....	16	7.1 Introduction.....		57
Unit 4—The Electrical System	21	7.2 The Natural Magnet.....		57
4.1 Introduction.....	21	7.3 Magnetic Polarities.....		57
4.2 Source of Electrical Generation.....	21	7.4 Theory of Magnetism.....		58
4.3 Step-Up Transmission Voltage.....	21	7.5 Permanent and Temporary Magnets.....		58
4.4 High-Voltage Transmission Lines.....	22	7.6 Magnetizing and Demagnetizing Magnets.....		58
4.5 Primary Distribution Voltage.....	22			
4.6 Primary Distribution Wires.....	22			

7.7	Magnetic Lines of Force.....	59
7.8	Law of Attraction and Repulsion of Magnets.....	59

Unit 8—Electromagnetism 61

8.1	Introduction	61
8.2	Electromagnetism in a Wire.....	61
8.3	Electromagnet Field Interaction	62
8.4	Electromagnetic Field Interaction of Wire Loops.....	62
8.5	Electromagnetic Core	63

Unit 9—Uses of Electromagnetism 65

9.1	Introduction	65
9.2	Motors	65
9.3	Generators	66
9.4	Relays.....	66
9.5	Transformers.....	66

Chapter 3—Practice Questions..... 67

CHAPTER 4—MATHEMATICS 71

Unit 10—Basic Math 73

10.1	Introduction	73
10.2	Whole Numbers.....	73
10.3	Fractional Numbers	73
10.4	Decimal Numbers.....	73
10.5	Percentages.....	74
10.6	Parentheses.....	75
10.7	Squaring a Number	75
10.8	Square Root.....	75
10.9	Kilo.....	76
10.10	Rounding	76
10.11	Surface Area of a Rectangle or Square	76
10.12	Surface Area of a Circle.....	77
10.13	Volume	79
10.14	Reciprocal.....	79
10.15	Testing Your Answer.....	79

Unit 11—Trigonometry 81

11.1	Introduction	81
11.2	Triangles.....	81
11.3	Right Triangle	81
11.4	Pythagorean Theorem.....	82
11.5	Practical Use of Trigonometry	83

Chapter 4—Practice Questions..... 85

CHAPTER 5—OHM’S LAW AND WATT’S LAW 91

Unit 12—Ohm’s Law..... 93

12.1	Introduction	93
12.2	The Electrical Circuit.....	93
12.3	Electromotive Force (Pressure).....	93
12.4	Circuit Resistance	94
12.5	Circuit Intensity	95
12.6	Ohm’s Law	95
12.7	Ohm’s Law Formula Circle	96

Unit 13—Watt’s Law 99

13.1	Introduction	99
13.2	Watt’s Law	99
13.3	Power Formula Circle.....	100
13.4	Power Changes with the Square of the Voltage.....	101

Chapter 5—Practice Questions..... 103

CHAPTER 6—ELECTRICAL CIRCUIT TYPES 107

Unit 14—Series Circuits..... 109

14.1	Introduction	109
14.2	Series Circuits.....	109
14.3	Understanding Series Circuits.....	109
14.4	Series Circuit Summary.....	113
14.5	Series-Connected Power Supplies	113
14.6	Applications of Series Circuits.....	114

Unit 15—Parallel Circuits..... 117

15.1	Introduction	117
15.2	Understanding Parallel Circuits.....	117
15.3	Parallel Circuit Resistance Calculations	119
15.4	Parallel Circuit Summary.....	122
15.5	Parallel-Connected Power Supplies	122
15.6	Practical Uses of Parallel Circuits.....	123

Unit 16—Series-Parallel Circuits..... 125

16.1	Introduction	125
16.2	Understanding Series-Parallel Circuits	125
16.3	Calculating Resistance in Series-Parallel Circuits	126

Chapter 6—Practice Questions..... 129

CHAPTER 7—ALTERNATING CURRENT	137	CHAPTER 8—MOTORS, GENERATORS, RELAYS, AND TRANSFORMERS	177
Unit 17—Alternating Current Fundamentals	139	Unit 21—Motors	179
17.1 Introduction	139	21.1 Introduction	179
17.2 How Alternating Current is Produced	139	21.2 Alternating-Current Motor Principles	179
17.3 Waveforms	140	21.3 Motor Horsepower Rating	180
17.4 Frequency	143	21.4 Motor Amperes	181
17.5 In-Phase Waveforms	143	21.5 Motor Nameplate Amperes	182
17.6 Out-of-Phase Waveforms	143	21.6 Dual-Voltage Motors	184
17.7 Alternating-Current Waveform Values	144	21.7 Reversing the Rotation of Alternating-Current Motors	185
Unit 18—Inductance	147	21.8 Alternating-Current Motor Types	186
18.1 Introduction	147	Unit 22—Generators	187
18.2 How Inductance Works	147	22.1 Introduction	187
18.3 Self-Inductance	147	22.2 Generator Prime Mover	187
18.4 Mutual Inductance	148	22.3 Alternating-Current Generators	187
18.5 Inductive Reactance	149	22.4 Generator Output Current	188
18.6 Uses of Induction	150	22.5 Single-Phase and Three-Phase Generator Voltages	189
Unit 19—Capacitance	151	22.6 Electrical Industry Voltages	189
19.1 Introduction	151	Unit 23—Relays	191
19.2 Capacitance in Capacitors	151	23.1 Introduction	191
19.3 Capacitor Charge and Discharge	152	23.2 How Relays Operate	191
19.4 Capacitive Reactance	152	23.3 Relay Contacts	192
19.5 Uses of Capacitors	153	Unit 24—Transformers	193
Unit 20—True Power, Power Factor, and Apparent Power	155	24.1 Introduction	193
20.1 Introduction	155	24.2 Types of Transformers	193
20.2 True Power	155	24.3 Primary versus Secondary	193
20.3 Power Losses of Wires	156	24.4 Transformer Mutual Induction	194
20.4 Power Losses at Terminals	156	24.5 Secondary Induced Voltage	194
20.5 Equipment Efficiency	157	24.6 Transformer Turns Ratios	194
20.6 Cost of Power	158	24.7 Isolation Transformer (1:1)	196
20.7 Power Factor	159	24.8 Autotransformers	197
20.8 Apparent Power	160	24.9 Transformer kVA Rating	197
20.9 Apparent Power versus True Power	161	24.10 Transformer Current Flow	197
20.10 Effects of Power Factor on Circuits	162	24.11 Transformer Current Rating	197
Chapter 7—Practice Questions	165	24.12 Transformer Configurations	200
		24.13 Delta/Wye Transformers	201
		24.14 Delta/Delta (High-Leg) Transformers	203
		Chapter 8—Practice Questions	205

CHAPTER 9—PROTECTIVE DEVICES	215	Unit 28—Multiwire Circuits	249
Unit 25—Overcurrent Protection	217	28.1 Introduction.....	249
25.1 Introduction.....	217	28.2 Neutral Wire.....	249
25.2 Overcurrent Protection.....	217	28.3 Grounded Wire.....	250
25.3 Fuses.....	219	28.4 Current Flow on the Neutral Wire.....	250
25.4 Circuit Breakers.....	221	28.5 Multiwire Branch Circuits.....	251
25.5 Overcurrent Protective Devices, Time-Current Curves.....	222	28.6 Dangers of Multiwire Circuits.....	253
25.6 Available Short-Circuit Current.....	223	28.7 <i>NEC</i> Requirements.....	254
25.7 Overcurrent Protective Devices, Interrupting Rating.....	225	Unit 29—The Formula Wheel	255
25.8 Equipment Short-Circuit Current Rating (SCCR).....	225	29.1 Introduction.....	255
25.9 Coordination of Overcurrent Protective Devices.....	226	29.2 Formula Wheel Quadrants.....	255
UNIT 26—GFCIs, GFPEs, AFCIs, AND SPDs	229	29.3 Using the Formula Wheel.....	256
26.1 Introduction.....	229	Chapter 10—Practice Questions	259
26.2 Ground-Fault Circuit Interrupters (GFCIs).....	229	FINAL EXAM	267
26.3 Special Purpose Ground-Fault Circuit Interrupters (SPGFCIs).....	231	INDEX	279
26.4 Ground-Fault Protection of Equipment (GFPEs).....	231	About the Author	283
26.5 Arc-Fault Circuit Interrupters (AFCIs).....	232	About the Illustrator	284
26.6 Clearing Arcing Faults.....	232	About the Mike Holt Team	285
26.7 Surge Protective Devices (SPDs).....	233		
26.8 How Surge Protective Devices Function.....	234		
Chapter 9—Practice Questions	235		
CHAPTER 10—GENERAL KNOWLEDGE	241		
Unit 27—Wire Resistance and Voltage Drop	243		
27.1 Introduction.....	243		
27.2 Wire Sizes.....	243		
27.3 Direct-Current Wire Resistance.....	243		
27.4 <i>NEC</i> Wire Direct-Current Resistance.....	244		
27.5 Alternating-Current Wire Resistance.....	245		
27.6 Alternating-Current Resistance versus Direct-Current Resistance.....	246		
27.7 Wire Voltage Drop—Ohm’s Law Method.....	246		

UNDERSTANDING THE 2023 NATIONAL ELECTRICAL CODE, VOLUME 1

About This Textbook	xv	110.17	Servicing and Maintenance of Equipment	81
Additional Products to Help You Learn	xviii	110.20	Reconditioned Equipment	82
How to Use the <i>National Electrical Code</i>	1	110.21	Hazard Markings	82
Article 90—Introduction to the <i>National Electrical Code</i>	7	110.22	Identification of Disconnecting Means	83
90.1 Scope.....	7	110.24	Available Fault Current Marking	83
90.2 Use and Application of the <i>NEC</i>	7	110.25	Lockable Disconnecting Means	84
90.3 Code Arrangement.....	11	Part II. 1000V, Nominal, or Less		84
90.4 <i>NEC</i> Enforcement.....	12	110.26	Spaces Around Electrical Equipment	84
90.5 Mandatory Requirements and Explanatory Material.....	13	110.27	Protection Against Physical Damage	95
90.7 Examination of Equipment for Safety.....	14	110.28	NEMA Enclosure Types	95
Article 90—Review Questions	15	Chapter 1—Review Questions		97
CHAPTER 1—GENERAL RULES	17	CHAPTER 2—WIRING AND PROTECTION		101
Article 100—Definitions	19	Article 200—Use and Identification of Grounded Conductors		103
Article 110—General Requirements for Electrical Installations	63	200.1 Scope.....		104
Part I. General Requirements	63	200.2 General.....		104
110.1 Scope.....	63	200.4 Neutral Conductor.....		104
110.2 Approval of Conductors and Equipment.....	64	200.6 Identification of Neutral and Grounded Conductors.....		105
110.3 Use of Equipment.....	64	200.7 Use of White or Gray Color.....		107
110.5 Conductor Material.....	66	200.10 Receptacle and Screw Shell Terminal.....		108
110.6 Conductor Sizes.....	66	Article 210—Branch Circuits		109
110.7 Wiring Integrity.....	66	Part I. General Provisions		109
110.8 Suitable Wiring Methods.....	66	210.1 Scope.....		109
110.9 Interrupting Rating of Overcurrent Protective Devices.....	67	210.3 Other Articles.....		109
110.10 Equipment Short-Circuit Current Rating.....	68	210.4 Multiwire Branch Circuits.....		109
Available Fault Current	69	210.5 Conductor Identification.....		113
110.11 Deteriorating Agents.....	70	210.6 Branch-Circuit Voltage.....		114
110.12 Mechanical Execution of Work.....	70	210.7 Multiple Branch Circuits.....		114
110.13 Mounting and Cooling of Equipment.....	72	210.8 GFCI Protection.....		114
110.14 Conductor Termination and Splicing.....	72	210.11 Branch Circuits Required.....		125
110.15 High-Leg Conductor Identification.....	79	210.12 Arc-Fault Circuit-Interrupter Protection.....		128
110.16 Arc-Flash Hazard Warning Label, Other Than Dwelling Units.....	79	210.17 Guest Rooms and Guest Suites.....		131
		Part II. Branch-Circuit Ratings		131
		210.19 Conductor Sizing.....		131
		210.20 Overcurrent Protection.....		135

210.21	Receptacle Rating.....	136	220.55	Cooking Appliances in Dwelling Units	175
210.23	Multiple-Outlet Branch Circuits.....	137	220.56	Kitchen Equipment Load, Commercial	178
Part III. Required Outlets		137	220.57	Electric Vehicle Supply Equipment Load	179
210.50	Receptacle Outlets.....	137	220.60	Noncoincident Loads.....	179
210.52	Dwelling Unit Receptacle Outlet Requirements.....	138	220.61	Neutral Calculated Load.....	180
210.60	Receptacles in Guest Rooms, Guest Suites, Dormitory Units, and Similar Occupancies.....	145	220.70	Energy Management Systems.....	181
210.62	Show-Window Receptacles	146	Part IV. Optional Method—Feeder/Service Load Calculations	182	
210.63	Equipment Requiring Servicing.....	146	220.82	Optional Load Calculations, Dwellings.....	182
210.65	Meeting Rooms	147	220.84	Optional Load Calculations, Multifamily	183
210.70	Lighting Outlet Requirements.....	148	220.85	Optional Load Calculations, Two-Family Dwelling Units.....	184
			220.87	Determining Existing Loads	184
Article 215—Feeders		153	Part VII. Marinas, Boatyards, and Docking Facilities	185	
215.1	Scope	153	220.120	Shore Power Receptacle Loads	185
215.2	Conductor Sizing.....	154	Article 225—Outside Branch Circuits and Feeders	187	
215.3	Overcurrent Protection Sizing.....	158	Part I. General	187	
215.6	Feeder Equipment Grounding Conductor.....	159	225.1	Scope	187
215.10	Ground-Fault Protection of Equipment	159	225.6	Minimum Conductor Size and Support.....	187
215.12	Conductor Identification.....	159	225.17	Masts as Supports.....	189
215.15	Barriers	161	225.18	Clearance for Overhead Conductors.....	189
215.18	Surge Protection	161	225.19	Clearances from Buildings	190
Article 220—Branch-Circuit, Feeder, and Service Load Calculations		163	225.22	Raceways on Exterior Surfaces of Buildings	191
Part I. General		164	225.26	Trees for Conductor Support	191
220.1	Scope	164	225.27	Raceway Seals	192
220.3	Application of Other Articles.....	164	Part II. Buildings or Other Structures Supplied by a Feeder	192	
220.5	Calculations	164	225.30	Number of Supplies	192
Part II. Branch-Circuit Load Calculations		165	225.31	Disconnecting Means	193
220.11	Maximum Load	165	225.33	Maximum Number of Disconnects.....	194
220.14	Other Loads—Occupancies	166	225.34	Grouping of Disconnects.....	194
Part III. Standard Method—Feeder/Service Load Calculations		168	225.37	Identification of Multiple Supplies.....	194
220.40	General.....	168	225.39	Rating of Disconnecting Means.....	194
220.41	Dwelling Unit(s), Load Calculation	168	225.41	Emergency (Shutoff) Disconnects	194
220.42	Lighting Load for Non-Dwelling Occupancies	169	225.42	Surge Protection	195
220.43	Office Buildings	171	Article 230—Services	197	
220.44	Hotel and Motel Occupancies	171	230.1	Scope	198
220.45	General Lighting Demand Factors	171	Part I. General	199	
220.46	Show-Window and Track Lighting Loads, Commercial	172	230.2	Number of Services	199
220.47	Receptacle Demand Load, Commercial	172	230.3	Not to Pass Through a Building.....	200
220.50	Motor and Air-Conditioning Loads.....	173	230.6	Conductors Considered Outside a Building or Structure.....	200
220.51	Fixed Electric Space-Heating Load	173	230.7	Service Conductors Separate from Other Conductors	201
220.52	Small-Appliance and Laundry Loads, Dwelling	173	230.8	Raceway Seals	201
220.53	Appliance Demand Load, Dwelling	173	230.9	Clearances on Buildings.....	202
220.54	Clothes Dryer Demand Load, Dwelling	174	230.10	Vegetation as Support.....	202

Part II. Overhead Service Conductors	202	240.13	Ground-Fault Protection of Equipment	232
230.23	Overhead Service Conductor Size and Rating	240.15	Overcurrent Protective Device, Handle Ties.....	232
230.24	Vertical Clearance for Overhead Service Conductors.....	Part II. Location of Overcurrent Protective Device		233
230.26	Point of Attachment.....	240.21	Location of Overcurrent Protective Device in Circuit.....	233
230.27	Means of Attachment	240.22	Grounded-Phase Conductor on Overcurrent Device	240
230.28	Service Masts as Support.....	240.24	Location of Overcurrent Protective Devices.....	240
Part III. Underground Service Conductors	205	Part III. Enclosures Containing Overcurrent Protective Devices		241
230.30	Installation	240.33	Vertical Position, Enclosures.....	241
230.31	Underground Service Conductor Ampacity	Part V. Plug Fuses, Fuseholders, and Adapters		242
230.32	Protection Against Damage	240.51	Edison-Base Fuses.....	242
Part IV. Service-Entrance Conductors	207	Part VI. Cartridge Fuses and Fuseholders		242
230.40	Number of Service-Entrance Conductor Sets.....	240.67	Arc-Energy Reduction—Fuses.....	242
230.42	Conductor Sizing	Part VII. Circuit Breakers		242
230.43	Wiring Methods	240.81	Indicating	243
230.46	Spliced and Tapped Connections.....	240.83	Markings	243
230.50	Protection Against Physical Damage.....	240.85	Applications	243
230.51	Cable Supports.....	240.86	Series Ratings	244
230.53	Raceways to Drain	240.87	Arc-Energy Reduction—Circuit Breakers	244
230.54	Overhead Service Locations.....	Article 242—Overvoltage Protection		247
230.56	High-Leg Conductor Identification.....	Part I. General		248
Part V. Service Disconnect—General	213	242.1	Scope	248
230.62	Service Equipment—Barriers	Part II. Surge-Protective Devices (SPDs), 1000V or Less		248
230.66	Marking for Service Equipment.....	242.6	Listing.....	248
230.67	Surge Protection	242.8	Short-Circuit Current Rating.....	248
Part VI. Service Disconnect—Disconnecting Means	215	242.9	Indicating	248
230.70	Service Disconnect Requirements.....	242.12	Uses Not Permitted.....	249
230.71	Number of Service Disconnects.....	242.13	Type 1 SPDs—Supply Side of Service Equipment.....	249
230.72	Grouping of Service Disconnects.....	242.14	Type 2 SPDs—Feeder Circuits	250
230.79	Rating of Disconnect	242.20	Number Required.....	251
230.82	Connected on Supply Side of the Service Disconnect.....	242.24	Routing of Surge-Protective Device Conductors	251
230.85	Emergency (Shutoff) Disconnect	Article 250—Grounding and Bonding		253
Part VII. Service Conductor Overcurrent Protection	221	Part I. General		254
230.90	Overload Protection—Where Required.....	250.1	Scope	254
230.91	Location	250.4	Performance Requirements for Grounding and Bonding	255
230.95	Ground-Fault Protection of Equipment	Earth Shells		259
Article 240—Overcurrent Protection	223	250.6	Objectionable Current.....	260
Part I. General	224	Objectionable Current		260
240.1	Scope	Dangers of Objectionable Current		262
240.3	Other Articles (Overcurrent Protection of Equipment).....	250.8	Connection of Grounding and Bonding Conductors.....	263
240.4	Overcurrent Protection of Conductors.....	250.10	Protection of Ground Clamps and Fittings	263
240.5	Overcurrent Protection of Flexible Cords, Flexible Cables, and Fixture Wires	250.12	Clean Surfaces	263
240.6	Standard Ampere Ratings.....			
240.10	Supplementary Conductor Overcurrent Protection.....			

Part II. System Grounding and Bonding	264	Part VII. Equipment Grounding Conductor Connections	322
250.20 Systems Required to be Grounded	264	250.134 Equipment Connected by Permanent Wiring Methods.....	322
250.21 Ungrounded Systems	264	250.138 Cord-and-Plug-Connected	323
250.24 Service Grounding	265	250.140 Frames of Ranges, Ovens, and Clothes Dryers.....	323
250.28 Main Bonding Jumper and System Bonding Jumper.....	269	250.146 Connecting Receptacle Grounding Terminal to an Equipment Grounding Conductor.....	323
250.30 Transformer Separately Derived Systems.....	271	250.148 Continuity and Attachment of Equipment Grounding Conductors in Boxes.....	326
250.30 Generator Separately Derived Systems	277	Chapter 2—Review Questions	329
250.32 Buildings Supplied by a Feeder	278	CHAPTER 3—WIRING METHODS AND MATERIALS	335
250.36 Impedance Grounded Systems—480V to 1000V.....	279	Article 300—General Requirements for Wiring Methods and Materials	339
Part III. Grounding Electrode System and Grounding Electrode Conductor	281	Part I. General Requirements	339
250.50 Grounding Electrode System	281	300.1 Scope	339
250.52 Grounding Electrode Types	281	300.3 Conductors	340
250.53 Grounding Electrode Installation	285	300.4 Protection Against Physical Damage.....	342
Soil Resistivity	288	300.5 Underground Installations.....	345
250.54 Auxiliary Grounding Electrodes	288	300.6 Protection Against Corrosion.....	348
250.60 Lightning Protection Electrode	290	300.7 Raceways Exposed to Different Temperatures.....	349
250.62 Grounding Electrode Conductor	290	300.9 Raceways in Wet Locations Above Grade	350
250.64 Grounding Electrode Conductor Installation	290	300.10 Electrical Continuity.....	351
250.66 Sizing Grounding Electrode Conductors.....	295	300.11 Securing and Supporting	351
250.68 Grounding Electrode Conductor Connection to Grounding Electrodes	296	300.12 Mechanical Continuity.....	353
250.70 Grounding Electrode Conductor Termination Fittings.....	298	300.13 Mechanical and Electrical Continuity of Conductors— Splices and Pigtails.....	353
Part IV. Enclosure and Raceway	299	300.14 Conductor Length at Boxes	355
250.80 Service Raceways and Enclosures	299	300.15 Boxes or Fittings, Splices and Terminations	355
250.86 Other than Service Enclosures and Raceways	300	300.17 Number and Size of Conductors in a Raceway.....	357
Part V. Bonding	300	300.18 Raceway Installations.....	358
250.92 Bonding Metal Service Raceways and Enclosures	300	300.19 Supporting Conductors in Vertical Raceways.....	359
250.94 Bonding for Communications Systems	303	300.20 Reducing Inductive Heating.....	359
250.97 Bonding Metal Raceways and Metal Cables Containing 277V and 480V Circuits.....	304	300.21 Spread of Fire or Products of Combustion	361
250.98 Bonding Loosely Jointed Metal Raceways.....	305	300.22 Wiring in Ducts and Plenum Spaces.....	362
250.100 Bonding in Hazardous (Classified) Locations	305	300.23 Panels Designed to Allow Access	365
250.102 Bonding Jumper Sizing.....	305	300.25 Exit Stair Towers	365
250.104 Bonding of Piping Systems and Exposed Structural Metal.....	309	Article 310—Conductors for General Wiring	367
250.106 Lightning Protection Systems.....	312	Part I. General	367
Part VI. Equipment Grounding Conductors	312	310.1 Scope	367
250.109 Metal Enclosures, Effective Ground-Fault Current Path.....	312	310.3 Conductors, Minimum Size and Material.....	367
250.114 Equipment Connected by Cord and Plug.....	313	Part II. Construction Specifications	369
250.118 Types of Equipment Grounding Conductors.....	313	310.4 Conductor Construction and Application	369
250.119 Identification of Wire-Type Equipment Grounding Conductors	318	310.6 Conductor Identification.....	371
250.120 Equipment Grounding Conductor Installation.....	319		
250.122 Sizing Wire-Type Equipment Grounding Conductors.....	319		

Part III. Installation	372	Part II. Installation	417
310.10 Uses Permitted.....	372	320.10 Uses Permitted.....	417
310.12 Dwelling Services and Feeders	374	320.12 Uses Not Permitted.....	418
310.14 Ampacities for Conductors Rated 0V to 2000V	377	320.15 Exposed Work.....	418
310.15 Ampacity Tables.....	378	320.17 Through or Parallel to Framing Members.....	418
310.16 Ampacities of Insulated Conductors	385	320.23 In Roof Spaces	419
Article 312—Cabinets, Cutout Boxes, and Meter Socket Enclosures	387	320.24 Bending Radius	419
Part I. General	387	320.30 Securing and Supporting	419
312.1 Scope	387	320.40 Boxes and Fittings.....	420
312.2 Damp or Wet Locations	388	320.80 Conductor Ampacity.....	421
312.3 Position in Walls	389	Part III. Construction Specifications	422
312.4 Repairing Gaps in Noncombustible Surfaces	389	320.100 Construction	422
312.5 Cable Termination to Enclosures.....	389	320.108 Equipment Grounding Conductor.....	422
312.6 Deflection of Conductors.....	390	Article 330—Metal-Clad Cable (Type MC)	423
312.8 Overcurrent Device Enclosures	391	Part I. General	424
312.10 Screws or Other Fasteners	392	330.1 Scope	424
Part II. Construction Specifications	393	330.6 Listing Requirements	424
312.100 Enclosure Material	393	Part II. Installation	424
Article 314—Boxes, Conduit Bodies, and Handhole Enclosures	395	330.10 Uses Permitted.....	424
Part I. General	396	330.12 Uses Not Permitted.....	425
314.1 Scope	396	330.15 Exposed Work.....	425
314.3 Nonmetallic Boxes	396	330.17 Through or Parallel to Framing Members.....	425
314.4 Metal Boxes	396	330.23 In Roof Spaces	426
314.5 Screws or Other Fasteners	396	330.24 Bending Radius	426
Part II. Installation	397	330.30 Securing and Supporting	426
314.15 Wet Locations.....	397	330.80 Conductor Ampacities.....	427
314.16 Outlet Box Sizing	397	Part III. Construction Specifications	428
314.17 Cables That Enter Boxes	404	330.108 Equipment Grounding Conductor.....	428
314.20 Flush-Mounted Boxes	405	Article 334—Nonmetallic-Sheathed Cable (Type NM)	431
314.21 Repairing Noncombustible Surfaces.....	405	Part I. General	432
314.22 Surface Extensions	406	334.1 Scope	432
314.23 Securing Boxes.....	406	334.6 Listing Requirements	432
314.27 Box Requirements.....	409	Part II. Installation	432
314.28 Pull Boxes, Junction Boxes, and Conduit Bodies.....	411	334.10 Type NM Cable, Uses Permitted	432
314.29 Wiring to be Accessible	414	334.12 Uses Not Permitted.....	433
314.30 Handhole Enclosures.....	414	334.15 Exposed Work.....	434
Article 320—Armored Cable (Type AC)	417	334.17 Through or Parallel to Framing Members.....	435
Part I. General	417	334.19 Cables Entering Enclosures	436
320.1 Scope	417	334.23 Accessible Roof Spaces	436
320.6 Listing Requirements	417	334.24 Bending Radius	436
		334.30 Securing and Supporting	436
		334.40 Boxes and Fittings.....	437
		334.80 Conductor Ampacity.....	437

Part III. Construction Specifications	439	342.24	Bends	455	
334.108	Equipment Grounding Conductor.....	439	342.28	Reaming.....	455
Article 336—Power and Control Tray Cable (Type TC) ...	441	342.30	Securing and Supporting	456	
Part I. General	441	342.42	Couplings and Connectors.....	457	
336.1	Scope	441	342.46	Bushings	458
336.6	Listing Requirements	442	342.60	Equipment Grounding Conductor.....	459
Part II. Installation	442	Article 344—Rigid Metal Conduit (RMC)	461		
336.10	Uses Permitted.....	442	Part I. General	462	
336.12	Uses Not Permitted.....	443	344.1	Scope	462
336.24	Bending Radius	443	344.6	Listing Requirements	462
Article 338—Service-Entrance Cable (Types SE and USE)	445	Part II. Installation	462		
Part I. General	445	344.10	Uses Permitted.....	462	
338.1	Scope	445	344.14	Dissimilar Metals.....	463
338.6	Listing Requirements	446	344.20	Trade Size	463
Part II. Installation	446	344.22	Number of Conductors	463	
338.10	Uses Permitted.....	446	344.24	Bends	463
338.12	Uses Not Permitted.....	447	344.28	Reaming and Threading.....	463
338.24	Bending Radius	447	344.30	Securing and Supporting	464
Article 340—Underground Feeder and Branch-Circuit Cable (Type UF)	449	344.42	Couplings and Connectors.....	465	
Part I. General	449	344.46	Bushings	465	
340.1	Scope	449	344.60	Equipment Grounding Conductor.....	466
340.6	Listing Requirements	450	Article 348—Flexible Metal Conduit (FMC)	467	
Part II. Installation	450	Part I. General	467		
340.10	Uses Permitted.....	450	348.1	Scope	467
340.12	Uses Not Permitted.....	450	348.6	Listing Requirements	468
340.24	Bends	450	Part II. Installation	468	
340.80	Ampacity.....	450	348.10	Uses Permitted.....	468
Part III. Construction Specifications	451	348.12	Uses Not Permitted.....	468	
340.108	Equipment Grounding Conductor.....	451	348.20	Trade Size	468
340.112	Insulation	451	348.22	Number of Conductors	469
Article 342—Intermediate Metal Conduit (IMC)	453	348.24	Bends	469	
Part I. General	454	348.28	Trimming.....	469	
342.1	Scope	454	348.30	Securing and Supporting	470
342.6	Listing Requirements	454	348.42	Couplings and Connectors.....	471
Part II. Installation	454	348.60	Equipment Grounding and Bonding Conductors.....	471	
342.10	Uses Permitted.....	454	Article 350—Liquidtight Flexible Metal Conduit (LFMC) ... 473		
342.14	Dissimilar Metals.....	455	Part I. General	474	
342.20	Trade Size	455	350.1	Scope	474
342.22	Number of Conductors	455	350.6	Listing Requirements	474
Part III. Construction Specifications	459	Part II. Installation	474		
342.24	Bends	455	350.10	Uses Permitted.....	474
342.28	Reaming.....	455	350.12	Uses Not Permitted.....	474
342.30	Securing and Supporting	456	350.20	Trade Size	475
342.42	Couplings and Connectors.....	457			
342.46	Bushings	458			
342.60	Equipment Grounding Conductor.....	459			

350.22	Number of Conductors	475
350.24	Bends	476
350.28	Trimming	476
350.30	Securing and Supporting	476
350.60	Equipment Grounding and Bonding Conductors	477

Article 352—Rigid Polyvinyl Chloride Conduit (PVC).....479

Part I. General	480
352.1 Scope	480
352.6 Listing.....	480
Part II. Installation	480
352.10 Uses Permitted.....	480
352.12 Uses Not Permitted.....	481
352.20 Trade Size	482
352.22 Number of Conductors	482
352.24 Bends	482
352.28 Trimming.....	483
352.30 Securing and Supporting	483
352.44 Expansion Fittings.....	484
352.46 Bushings	485
352.48 Joints.....	485
352.60 Equipment Grounding Conductor.....	485

Article 356—Liquidtight Flexible Nonmetallic Conduit (LFNC).....487

Part I. General	488
356.1 Scope	488
356.6 Listing Requirements	488
Part II. Installation	488
356.10 Uses Permitted.....	488
356.12 Uses Not Permitted.....	489
356.20 Trade Size	489
356.22 Number of Conductors	489
356.24 Bends	489
356.30 Securing and Supporting	489
356.42 Fittings	490
356.60 Equipment Grounding Conductor.....	490

Article 358—Electrical Metallic Tubing (EMT).....493

Part I. General	494
358.1 Scope	494
358.6 Listing Requirements	494
Part II. Installation	494
358.10 Uses Permitted.....	494
358.12 Uses Not Permitted.....	495

358.20 Trade Size	495
358.22 Number of Conductors	495
358.24 Bends	496
358.28 Reaming.....	496
358.30 Securing and Supporting	497
358.42 Couplings and Connectors.....	497
358.60 Equipment Grounding Conductor.....	498

Article 362—Electrical Nonmetallic Tubing (ENT).....499

Part I. General	500
362.1 Scope	500
362.6 Listing.....	500
Part II. Installation	500
362.10 Uses Permitted.....	500
362.12 Uses Not Permitted.....	502
362.20 Trade Sizes.....	502
362.22 Number of Conductors	502
362.24 Bends	503
362.28 Trimming.....	503
362.30 Securing and Supporting	503
362.46 Bushings	504
362.48 Joints.....	504
362.60 Equipment Grounding Conductor.....	504

Article 376—Metal Wireways.....505

Part I. General	506
376.1 Scope	506
Part II. Installation	506
376.10 Uses Permitted.....	506
376.12 Uses Not Permitted.....	506
376.20 Conductors Connected in Parallel.....	506
376.21 Size of Conductors.....	507
376.22 Number of Conductors and Ampacity	507
376.23 Wireway Sizing	509
376.30 Supports	509
376.56 Splices, Taps, and Power Distribution Blocks.....	510
376.60 Equipment Grounding Conductor.....	511

Article 380—Multioutlet Assemblies.....513

Part I. General	514
380.1 Scope	514
Part II. Installation	514
380.10 Uses Permitted.....	514
380.12 Uses Not Permitted.....	514
380.76 Through Partitions	514

Article 386—Surface Metal Raceways	515	402.5	Ampacity of Fixture Wires.....	539
Part I. General	515	402.6	Minimum Size.....	540
386.1 Scope	515	402.7	Raceway Size.....	540
386.6 Listing Requirements	516	402.8	Neutral Conductor.....	540
Part II. Installation	516	402.10	Uses Permitted.....	540
386.10 Uses Permitted.....	516	402.12	Uses Not Permitted.....	540
386.12 Uses Not Permitted.....	516	Article 404—Switches		543
386.21 Size of Conductors.....	516	Part I. Installation		543
386.22 Number of Conductors	516	404.1 Scope		543
386.30 Securing and Supporting	517	404.2 Switch Connections		544
386.56 Splices and Taps	517	404.3 Circuit Breaker Enclosures.....		546
386.60 Equipment Grounding Conductor.....	517	404.4 Damp or Wet Locations.....		546
Article 392—Cable Trays	519	404.7 Indicating		547
Part I. General	520	404.8 Accessibility and Grouping		547
392.1 Scope	520	404.9 General-Use Snap Switches, Dimmers, and Control Switches		549
Part II. Installation	520	404.10 Mounting of Snap Switches, Dimmers, and Control Switches		550
392.10 Uses Permitted.....	520	404.12 Bonding of Enclosures.....		551
392.12 Uses Not Permitted.....	521	404.14 Rating and Use of Snap Switches		551
392.18 Cable Tray Installations	522	Part II. Construction Specifications		552
392.20 Cable and Conductor Installation	522	404.20 Switch Marking		552
392.30 Securing and Supporting	523	Article 406—Receptacles, Attachment Plugs, and Flanged Inlets		553
392.44 Expansion Splice Plates	523	406.1 Scope		554
392.46 Bushed Conduit and Tubing.....	523	406.3 Receptacle Rating and Type		554
392.56 Cable Splices.....	523	406.4 General Installation Requirements.....		555
392.60 Equipment Grounding Conductor.....	524	406.5 Receptacle Mounting.....		557
Chapter 3—Review Questions	525	406.6 Receptacle Faceplates		560
CHAPTER 4—EQUIPMENT FOR GENERAL USE	531	406.7 Attachment Plugs and Flanged Surface Inlets		560
Article 400—Flexible Cords	533	406.9 Receptacles in Damp or Wet Locations.....		561
400.1 Scope	534	406.11 Connecting Receptacle Grounding Terminal to Equipment Grounding Conductor		563
400.3 Suitability	534	406.12 Tamper-Resistant Receptacles.....		563
400.4 Types of Flexible Cords.....	534	Article 408—Switchboards and Panelboards		565
400.5 Ampacity of Flexible Cords.....	534	Part I. General		566
400.10 Uses Permitted.....	534	408.1 Scope		566
400.12 Uses Not Permitted.....	536	408.3 Arrangement of Busbars and Conductors.....		566
400.13 Splices.....	537	408.4 Circuit Directory and Description		567
400.14 Pull at Joints and Terminals.....	537	408.5 Clearance for Conductors Entering Bus Enclosures		569
400.17 Protection from Damage	537	408.6 Short-Circuit Current Rating.....		569
Article 402—Fixture Wires	539	408.7 Unused Openings		569
402.1 Scope	539	408.9 Replacement Panelboards.....		569
402.2 Other Articles.....	539			
402.3 Types	539			

Part II. Switchboards	569	Article 411—Low-Voltage Lighting	585
408.18 Clearances.....	569	411.1 Scope.....	585
Part III. Panelboards	570	411.2 Listing Required.....	585
408.30 Panelboard Rating.....	570	411.3 Voltage Limitations.....	586
408.36 Overcurrent Protection.....	570	411.4 Low-Voltage Lighting Systems.....	586
408.37 Panelboards in Damp or Wet Locations.....	571	411.6 Specific Location Requirements.....	586
408.38 Enclosure.....	571	411.8 Branch Circuit.....	587
408.40 Equipment Grounding Conductor.....	571	Article 422—Appliances	589
408.41 Neutral Conductor Terminations.....	572	Part I. General	589
408.43 Panelboard Orientation.....	572	422.1 Scope.....	589
Article 410—Luminaires	573	422.6 Listing Required.....	589
Part I. General	574	Part II. Branch-Circuit Requirements	590
410.1 Scope.....	574	422.10 Branch Circuits.....	590
410.6 Listing Required.....	574	422.11 Overcurrent Protection.....	590
Part II. Luminaire Locations	574	422.12 Central Heating Equipment.....	591
410.10 Luminaires in Specific Locations.....	574	422.13 Storage Water Heaters.....	591
410.16 Luminaires in Clothes Closets.....	576	422.16 Flexible Cords.....	591
Part III. Luminaire Outlet Boxes and Covers	577	422.18 Support of Ceiling-Suspended (Paddle) Fans.....	594
410.22 Outlet Boxes to be Covered.....	577	422.20 Outlet Boxes to be Covered.....	594
410.24 Connection of Electric-Discharge and LED Luminaires.....	578	Part III. Disconnecting Means	594
Part IV. Luminaire Supports	578	422.30 Disconnect—General.....	594
410.30 Supports.....	578	422.31 Permanently Connected Appliance Disconnects.....	594
410.36 Means of Support.....	579	422.33 Cord-and-Plug-Connected Appliances.....	595
Part V. Grounding (Bonding)	580	Article 424—Fixed Electric Space-Heating Equipment	597
410.44 Connection to the Equipment Grounding Conductor.....	580	Part I. General	597
Part VI. Wiring of Luminaires	581	424.1 Scope.....	597
410.62 Cord-Connected Luminaires.....	581	424.3 Other Articles.....	597
410.71 Disconnecting Means for Fluorescent or LED Luminaires that Utilize Double-Ended Lamps.....	581	424.4 Branch Circuits.....	598
Part X. Special Provisions for Flush and Recessed Luminaires	582	Part III. Electric Space-Heating Equipment	599
410.115 Temperature.....	582	424.19 Disconnecting Means.....	599
410.116 Clearance and Installation.....	582	Part VI. Duct Heaters	599
Part XIV. Track Lighting	583	424.65 Location of Disconnecting Means for Electric Duct Heater.....	599
410.150 Installation.....	583	Article 430—Motor Circuits, Controllers, and Adjustable-Speed Drives	601
410.154 Fastening.....	583	Part I. General	602
Part XVI. Special Provisions for Horticultural Lighting Equipment	583	430.1 Scope.....	602
410.170 General.....	583	430.6 Motor Table FLC versus Motor Nameplate Current Rating.....	602
410.172 Listing.....	583	430.14 Location of Motors.....	603
410.174 Installation and Use.....	583	430.17 Highest Rated Motor.....	603
410.176 Locations Not Permitted.....	583	Part II. Conductor Ampacity	604
410.178 Flexible Cord.....	583	430.22 Motor Conductor Ampacity.....	604
410.180 Fittings and Connectors.....	584	430.24 Several Motors—Conductor Ampacity.....	606
410.182 Equipment Grounding Conductor.....	584		
410.184 GFCI and Special Purpose GFCI Protection.....	584		
410.186 Support.....	584		

Part III. Motor and Branch-Circuit Overload Protection607	Article 445—Generators629
430.31 Overload Protection607	445.1 Scope629
430.32 Overload Protection for Continuous-Duty Motors.....608	445.6 Listing.....630
Part IV. Branch-Circuit Short-Circuit and Ground-Fault Protection609	445.11 Marking.....630
430.51 General.....609	445.13 Conductor Ampacity.....630
430.52 Branch-Circuit Short-Circuit and Ground-Fault Protection.....610	445.19 Emergency Shutdown of Prime Mover631
430.55 Combined Overcurrent Protective Device613	
Part V. Feeder Short-Circuit and Ground-Fault Protection613	Article 450—Transformers633
430.62 Motor Feeder Protection613	450.1 Scope633
Part VI. Motor Control Circuits615	450.3 Primary Overcurrent Protection.....634
430.72 Overcurrent Protection for Control Circuits.....615	450.9 Ventilation636
430.75 Disconnect for Control Circuits.....615	450.10 Grounding and Bonding.....636
Part VII. Motor Controllers616	450.13 Transformer Accessibility.....636
430.83 Motor Controller Horsepower Rating.....616	450.14 Disconnecting Means637
Part IX. Disconnecting Means616	
430.102 Disconnect Location.....616	Article 480—Stationary Standby Batteries639
430.107 Motor or Controller Disconnect, Readily Accessible.....617	480.1 Scope639
430.109 Type of Disconnecting Means.....618	480.4 Battery and Cell Terminations640
Part X. Adjustable-Speed Drive Systems619	480.9 Battery Support Systems.....640
430.120 General.....619	480.10 Battery Locations.....640
430.122 Conductor Ampacity.....619	480.12 Battery Interconnections.....641
430.124 Overload Protection620	Chapter 4—Review Questions643
430.128 Disconnecting Means.....620	
430.130 Branch-Circuit Short-Circuit and Ground-Fault Protection.....620	FINAL EXAM A—STRAIGHT ORDER649
Part XIV. Tables620	FINAL EXAM B—RANDOM ORDER659
Table 430.248 Full-Load Current, Single-Phase Motors.....620	
Table 430.250 Full-Load Current, Three-Phase Motors621	INDEX669
Article 440—Air-Conditioning Equipment623	About the Author678
Part I. General624	About the Illustrator679
440.1 Scope624	About the Mike Holt Team680
440.4 Marking on Hermetic Motor-Compressors and Equipment...624	
440.8 Bathtub and Shower Space625	
440.9 Equipment Grounding Conductor.....625	
Part II. Disconnecting Means626	
440.11 General.....626	
440.14 Location626	
Part III. Overcurrent Protection626	
440.22 Short-Circuit and Ground-Fault Protective Device Size.....626	
Part IV. Conductor Ampacity627	
440.33 Conductor Ampacity.....627	

2023 *NEC* REQUIREMENTS FOR BONDING AND GROUNDING

About This Textbook	x	4.4 High-Voltage Transmission Lines.....	34
Additional Products to Help You Learn	xiii	4.5 Primary Distribution Voltage.....	34
How to Use the <i>National Electrical Code</i>	1	4.6 Primary Distribution Wires.....	34
		4.7 Secondary Distribution Voltage.....	34
		4.8 Service Drop and Service Lateral.....	35
		Unit 4—Review Questions	36
SECTION I—ELECTRICAL THEORY	7	Unit 6—Dangers of Electricity	39
Unit 1—Atomic Structure	9	6.1 Introduction.....	39
1.1 Introduction.....	9	6.2 <i>National Electrical Code (NEC)</i>	39
1.2 Atomic Theory.....	9	6.3 Electrical Fire.....	39
1.3 Electrostatic Field.....	10	6.4 Electric Shock.....	40
1.4 Atomic Charge of an Atom.....	11	6.5 Electric Arc Flash and Arc Blast.....	41
1.5 Electrostatic Charge and Discharge.....	12	6.6 Arc Flash Incident Energy.....	42
1.6 Lightning.....	13	6.7 Electrically Safe Work Condition.....	43
1.7 Lightning Protection System.....	14	6.8 Personal Protective Equipment (PPE).....	43
Unit 1—Review Questions	15	Unit 6—Review Questions	45
Unit 2—Electron Theory and Chemical Bonding	19	Unit 25—Overcurrent Protection	49
2.1 Introduction.....	19	25.1 Introduction.....	49
2.2 Electron Orbitals.....	19	25.2 Overcurrent Protection.....	49
2.3 Valence Electrons.....	19	25.3 Fuses.....	50
2.4 Freeing Valence Electron(s) from an Atom.....	20	25.4 Circuit Breakers.....	52
2.5 Conductance.....	20	25.5 Overcurrent Protective Devices, Time-Current Curves.....	53
2.6 Insulators.....	22	Unit 25—Review Questions	56
Unit 2—Review Questions	23	SECTION II—<i>NEC</i> RULES FOR BONDING AND GROUNDING	59
Unit 3—Electrical Circuits and Power Sources	25	Article 90—Introduction to the <i>National Electrical Code</i>	61
3.1 Introduction.....	25	90.1 Scope.....	61
3.2 The Electrical Circuit.....	25	90.2 Use and Application of the <i>NEC</i>	61
3.3 Electric Current Flow (Electricity).....	25	90.3 <i>Code</i> Arrangement.....	65
3.4 Electrical Power Sources.....	26	90.4 <i>NEC</i> Enforcement.....	66
Unit 3—Review Questions	30	90.5 Mandatory Requirements and Explanatory Material.....	67
Unit 4—The Electrical System	33	90.7 Examination of Equipment for Safety.....	68
4.1 Introduction.....	33	Article 90—Review Questions	69
4.2 Source of Electrical Generation.....	33		
4.3 Step-Up Transmission Voltage.....	33		

CHAPTER 1—GENERAL RULES	73	Part III. Grounding Electrode System and Grounding Electrode Conductor	154
Article 100—Definitions	75	250.50 Grounding Electrode System	154
Article 110—General Requirements for Electrical Installations	101	250.52 Grounding Electrode Types	155
Part I. General Requirements	101	250.53 Grounding Electrode Installation	159
110.1 Scope	101	Soil Resistivity	162
110.2 Approval of Conductors and Equipment	102	250.54 Auxiliary Grounding Electrodes	162
110.3 Use of Equipment	102	250.60 Lightning Protection Electrode	164
110.5 Conductor Material	104	250.62 Grounding Electrode Conductor	164
110.6 Conductor Sizes	104	250.64 Grounding Electrode Conductor Installation	164
110.7 Wiring Integrity	104	250.66 Sizing Grounding Electrode Conductors	169
110.8 Suitable Wiring Methods	104	250.68 Grounding Electrode Conductor Connection to Grounding Electrodes	170
110.11 Deteriorating Agents	105	250.70 Grounding Electrode Conductor Termination Fittings	172
110.12 Mechanical Execution of Work	106	Part IV. Enclosure and Raceway	173
110.14 Conductor Termination and Splicing	107	250.80 Service Raceways and Enclosures	173
Chapter 1—Review Questions	113	250.86 Other than Service Raceways and Enclosures	174
CHAPTER 2—WIRING AND PROTECTION	123	Part V. Bonding	174
Article 215—Feeders	125	250.92 Bonding Metal Service Raceways and Enclosures	174
215.1 Scope	125	250.94 Bonding for Communications Systems	177
215.6 Feeder Equipment Grounding Conductor	126	250.97 Bonding Metal Raceways and Metal Cables Containing 277V and 480V Circuits	178
Article 250—Grounding and Bonding	127	250.98 Bonding Loosely Jointed Metal Raceways	179
Part I. General	128	250.100 Bonding in Hazardous (Classified) Locations	179
250.1 Scope	128	250.102 Bonding Jumper Sizing	179
250.4 Performance Requirements for Grounding and Bonding	129	250.104 Bonding of Piping Systems and Exposed Structural Metal ...	183
Earth Shells	133	250.106 Lightning Protection Systems	186
250.6 Objectionable Current	134	Part VI. Equipment Grounding Conductors	186
Objectionable Current	134	250.109 Metal Enclosures, Effective Ground-Fault Current Path	186
Dangers of Objectionable Current	136	250.114 Equipment Connected by Cord and Plug	186
250.8 Connection of Grounding and Bonding Conductors	137	250.118 Types of Equipment Grounding Conductors	187
250.10 Protection of Ground Clamps and Fittings	137	250.119 Identification of Wire-Type Equipment Grounding Conductors	191
250.12 Clean Surfaces	137	250.120 Equipment Grounding Conductor Installation	193
Part II. System Grounding and Bonding	138	250.122 Sizing Wire-Type Equipment Grounding Conductors	193
250.20 Systems Required to be Grounded	138	Part VII. Equipment Grounding Conductor Connections	196
250.21 Ungrounded Systems	138	250.134 Equipment Connected by Permanent Wiring Methods	196
250.24 Service Grounding	139	250.138 Cord-and-Plug-Connected	197
250.28 Main Bonding Jumper and System Bonding Jumper	143	250.140 Frames of Ranges, Ovens, and Clothes Dryers	197
250.30 Transformer Separately Derived Systems	145	250.146 Connecting Receptacle Grounding Terminal to an Equipment Grounding Conductor	197
Generator Separately Derived Systems	151	250.148 Continuity and Attachment of Equipment Grounding Conductors in Boxes	200
250.32 Buildings Supplied by a Feeder	152	Chapter 2—Review Questions	202
250.36 Impedance Grounded Systems—480V to 1000V	153		

CHAPTER 3—WIRING METHODS AND MATERIALS.....221

Article 300—General Requirements for Wiring Methods and Materials.....225

Part I. General Requirements.....225

300.1 Scope225

300.3 Conductors226

300.6 Protection Against Corrosion.....227

300.10 Electrical Continuity.....228

300.12 Mechanical Continuity.....229

300.20 Reducing Inductive Heating.....230

Article 314—Boxes, Conduit Bodies, and Handhole Enclosures.....233

Part I. General233

314.1 Scope233

314.3 Nonmetallic Boxes234

314.4 Metal Boxes234

314.30 Handhole Enclosures.....234

Article 320—Armored Cable (Type AC).....237

320.1 Scope237

320.108 Equipment Grounding Conductor.....238

Article 330—Metal-Clad Cable (Type MC).....239

330.1 Scope240

330.108 Equipment Grounding Conductor.....240

Article 334—Nonmetallic-Sheathed Cable (Type NM).....243

334.1 Scope243

334.108 Equipment Grounding Conductor.....243

Article 340—Underground Feeder and Branch-Circuit Cable (Type UF).....245

340.1 Scope245

340.108 Equipment Grounding Conductor.....246

Article 342—Intermediate Metal Conduit (IMC).....247

342.1 Scope247

342.60 Equipment Grounding Conductor.....247

Article 344—Rigid Metal Conduit (RMC).....249

344.1 Scope249

344.60 Equipment Grounding Conductor.....250

Article 348—Flexible Metal Conduit (FMC).....251

348.1 Scope251

348.60 Equipment Grounding and Bonding Conductors.....252

Article 350—Liquidtight Flexible Metal Conduit (LFMC).....253

350.1 Scope253

350.60 Equipment Grounding and Bonding Conductors.....254

Article 352—Rigid Polyvinyl Chloride Conduit (PVC).....255

352.1 Scope255

352.60 Equipment Grounding Conductor.....256

Article 356—Liquidtight Flexible Nonmetallic Conduit (LFNC).....257

356.1 Scope257

356.60 Equipment Grounding Conductor.....258

Article 358—Electrical Metallic Tubing (EMT).....259

358.1 Scope259

358.60 Equipment Grounding Conductor.....260

Article 362—Electrical Nonmetallic Tubing (ENT).....261

362.1 Scope261

362.60 Equipment Grounding Conductor.....262

Article 376—Metal Wireways.....263

376.1 Scope263

376.60 Equipment Grounding Conductor.....264

Article 386—Surface Metal Raceways.....265

386.1 Scope265

386.60 Equipment Grounding Conductor.....266

Article 392—Cable Trays.....267

392.1 Scope267

392.60 Equipment Grounding Conductor.....268

Chapter 3—Review Questions.....270

CHAPTER 4—EQUIPMENT FOR GENERAL USE	275	Article 517—Health Care Facilities	307
Article 404—Switches	277	517.1 Scope	307
404.1 Scope	277	517.13 Equipment Grounding Conductor for Receptacles and Fixed Electrical Equipment in Patient Care Spaces.....	308
404.9 General-Use Snap Switches, Dimmers, and Control Switches	278	517.16 Isolated Ground Receptacles.....	310
404.12 Bonding of Enclosures.....	279	Article 547—Agricultural Buildings	313
Article 406—Receptacles, Attachment Plugs, and Flanged Inlets	281	547.1 Scope	313
406.1 Scope	282	547.44 Equipotential Planes	314
406.3 Receptacle Rating and Type	282	Article 555—Marinas, Boatyards, and Docking Facilities	317
406.4 General Installation Requirements.....	282	555.1 Scope	317
406.11 Connecting Receptacle Grounding Terminal to Equipment Grounding Conductor	284	555.37 Equipment Grounding Conductor.....	317
Article 408—Switchboards and Panelboards	285	Chapter 5—Review Questions	319
408.1 Scope	285	CHAPTER 6—SPECIAL EQUIPMENT	323
408.40 Equipment Grounding Conductor.....	285	Article 600—Electric Signs	325
Article 410—Luminaires	287	600.1 Scope	325
410.1 Scope	287	600.7 Grounding and Bonding.....	326
410.30 Supports	288	Article 645—Information Technology Equipment (ITE)	329
410.44 Connection to the Equipment Grounding Conductor	289	645.1 Scope	329
410.182 Equipment Grounding Conductor.....	290	645.15 Equipment Grounding and Bonding.....	329
Article 440—Air-Conditioning Equipment	291	Article 680—Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations	331
440.1 Scope	291	Part I. General Requirements for Pools, Spas, Hot Tubs, and Fountains	332
440.9 Equipment Grounding Conductor.....	292	680.1 Scope	332
Article 450—Transformers	293	680.7 Grounding and Bonding.....	332
450.1 Scope	293	Part II. Permanently Installed Pools	333
450.10 Grounding and Bonding.....	294	680.23 Underwater Pool Luminaires	333
Chapter 4—Review Questions	295	680.24 Junction Box, Transformer, or GFCI Enclosure	336
CHAPTER 5—SPECIAL OCCUPANCIES	299	680.26 Equipotential Bonding	337
Article 501—Class I Hazardous (Classified) Locations	301	Part IV. Hot Tubs	342
501.1 Scope	301	680.40 General.....	342
501.30 Grounding and Bonding.....	301	680.42 Outdoor Installations.....	342
Article 502—Class II Hazardous (Classified) Locations	305	Part V. Fountains	343
502.1 Scope	305	680.50 General.....	343
502.30 Grounding and Bonding.....	306	680.54 Connection to an Equipment Grounding Conductor.....	343
		680.55 Methods of Equipment Grounding	344
		680.56 Cord-and-Plug-Connected Equipment.....	344

Part VII. Hydromassage Bathtubs.....344
680.70 General.....344
680.74 Equipotential Bonding344

Article 690—Solar Photovoltaic (PV) Systems.....347

Part I. General347

690.1 Scope347
690.43 Equipment Grounding Conductor.....348
690.45 Size of Equipment Grounding Conductors349
690.47 Grounding Electrode System349

Chapter 6—Review Questions.....351

CHAPTER 8—COMMUNICATIONS SYSTEMS357

Article 810—Antenna Systems359

Part I. General359

810.1 Scope359

Part II. Receiving Equipment—Antenna Systems.....360

810.15 Metal Antenna Supports—Bonding360
810.20 Antenna Discharge Unit.....360
810.21 Bonding Conductors and Grounding Electrode Conductors ..360

Chapter 8—Review Questions.....363

NEC FINAL EXAM A—STRAIGHT ORDER.....365

NEC FINAL EXAM B—RANDOM ORDER377

INDEX.....389

About the Author395

About the Illustrator396

About the Mike Holt Team397

UNDERSTANDING THE 2023 NATIONAL ELECTRICAL CODE, VOLUME 2

About This Textbook	xii	110.17	Servicing and Maintenance of Equipment	89
Additional Products to Help You Learn	xvi	110.20	Reconditioned Equipment.....	90
How to Use the <i>National Electrical Code</i>	1	110.21	Hazard Markings.....	90
Article 90—Introduction to the <i>National Electrical Code</i>	7	110.22	Identification of Disconnecting Means	91
90.1 Scope	7	110.24	Available Fault Current Marking.....	92
90.2 Use and Application of the <i>NEC</i>	7	110.25	Lockable Disconnecting Means	92
90.3 <i>Code</i> Arrangement.....	11	Part II. 1000V, Nominal, or Less		92
90.4 <i>NEC</i> Enforcement.....	12	110.26	Spaces Around Electrical Equipment	92
90.5 Mandatory Requirements and Explanatory Material	13	110.27	Protection Against Physical Damage.....	103
90.7 Examination of Equipment for Safety	14	110.28	NEMA Enclosure Types.....	104
Article 90—Review Questions	15	Chapter 1—Review Questions		105
CHAPTER 1—GENERAL RULES	19	CHAPTER 5—SPECIAL OCCUPANCIES		125
Article 100—Definitions	21	Article 500—Hazardous (Classified) Locations		127
Article 110—General Requirements for Electrical Installations	71	500.1	Scope—Articles 500 Through 503	128
Part I. General Requirements	71	500.4	Documentation.....	128
110.1 Scope	71	500.5	Classifications of Hazardous (Classified) Locations.....	129
110.2 Approval of Conductors and Equipment.....	72	500.6	Material Groups.....	131
110.3 Use of Equipment.....	72	500.7	Protection Techniques.....	132
110.5 Conductor Material	74	500.8	Equipment.....	134
110.6 Conductor Sizes	74	Article 501—Class I Hazardous (Classified) Locations		137
110.7 Wiring Integrity.....	74	Part I. General		137
110.8 Suitable Wiring Methods.....	74	501.1	Scope	137
110.9 Interrupting Rating of Overcurrent Protective Devices	75	Part II. Wiring		137
110.10 Equipment Short-Circuit Current Rating	76	501.10	Wiring Methods.....	137
Available Fault Current	77	501.15	Conduit and Cable Seals	140
110.11 Deteriorating Agents.....	78	501.20	Conductor Insulation.....	146
110.12 Mechanical Execution of Work	78	501.30	Grounding and Bonding.....	146
110.13 Mounting and Cooling of Equipment.....	80	Part III. Equipment		148
110.14 Conductor Termination and Splicing.....	80	501.115	Enclosures Containing Make-and-Break Contact Devices	148
110.15 High-Leg Conductor Identification.....	87	501.125	Motors and Generators	148
110.16 Arc-Flash Hazard Warning Label, Other Than Dwelling Units	88	501.130	Luminaires	149
		501.135	Utilization Equipment.....	149
		501.140	Flexible Cords, Class I, Divisions 1 and 2.....	150
		501.145	Receptacles	150

Article 502—Class II Hazardous (Classified)

Locations..... 153

Part I. General 153

502.1 Scope 153

502.5 Explosionproof Equipment 154

Part II. Wiring..... 154

502.10 Wiring Methods 154

502.15 Sealing..... 155

502.30 Grounding and Bonding..... 156

Part III. Equipment..... 157

502.115 Enclosures Containing Make-and-Break Contacts 157

502.125 Motors and Generators 158

502.130 Luminaires 158

502.135 Utilization Equipment..... 159

502.140 Flexible Cords 159

502.145 Receptacles and Attachment Plugs..... 160

Article 511—Commercial Repair and Storage

Garages..... 161

511.1 Scope 161

511.3 Classification of Hazardous Areas..... 161

511.7 Wiring and Equipment Above Hazardous (Classified)
Locations 164

511.8 Wiring Below Hazardous (Classified) Locations 165

511.9 Seals 165

511.10 Special Equipment 165

511.12 GFCI-Protected Receptacles 166

Article 514—Motor Fuel Dispensing Facilities 167

514.1 Scope 167

514.3 Classification of Locations 167

514.4 Wiring and Equipment Within Hazardous (Classified)
Locations 168

514.7 Wiring and Equipment Above Hazardous (Classified)
Locations 168

514.8 Underground Wiring..... 169

514.9 Conduit Seal 169

514.11 Circuit Disconnects 170

514.16 Bonding Requirements..... 170

Article 517—Health Care Facilities..... 171

Part I. General 171

517.1 Scope 171

Part II. Wiring and Protection..... 173

517.10 Applicability 173

517.12 Wiring Methods 174

517.13 Equipment Grounding Conductor for Receptacles and
Fixed Electrical Equipment in Patient Care Spaces..... 174

517.16 Isolated Ground Receptacles..... 177

517.18 Category 2 Spaces..... 177

Article 518—Assembly Occupancies 179

518.1 Scope 179

518.2 General Classifications 179

518.3 Temporary Wiring..... 180

518.4 Wiring Methods 180

518.6 Illumination 181

Article 525—Carnivals, Circuses, Fairs, and Similar Events..... 183

Part I. General 183

525.1 Scope 183

525.5 Overhead Conductor Clearances..... 183

525.6 Protection of Electrical Equipment..... 184

Part III. Wiring Methods..... 184

525.20 Wiring Methods 184

525.21 Rides, Tents, and Concessions 185

525.22 Outdoor Portable Distribution or Termination Boxes 185

525.23 GFCI-Protected Receptacles and Equipment 185

Part IV. Grounding and Bonding..... 186

525.32 Portable Equipment Grounding Conductor Continuity..... 186

Article 547—Agricultural Buildings..... 187

Part I. General 187

547.1 Scope 187

Part II. Installations 188

547.20 Wiring Methods 188

547.22 Equipment Enclosures, Boxes, Conduit Bodies, and Fittings.... 188

547.23 Damp or Wet Locations 188

547.24 Corrosive Atmosphere..... 188

547.25 Flexible Connections..... 188

547.26 Physical Protection 189

547.27 Equipment Grounding Conductor 189

547.28 GFCI Protection of Receptacles..... 189

547.31 Luminaires 190

547.44 Equipotential Planes 190

Article 555—Marinas, Boatyards, and Docking Facilities 193

Part I. General 193

555.1 Scope 193

555.3 Electrical Datum Plane Distances 194

555.4	Location of Service Equipment	194	Article 620—Elevators	241	
555.7	Transformers	195	Part I. General	241	
555.10	Electric Shock Hazard Sign.....	195	620.1	Scope	241
555.11	Motor Fuel Dispensing Stations—Hazardous (Classified)		620.6	GFCI Protection for Receptacles.....	242
	Locations	195	Part III. Wiring	243	
555.12	Repair Facilities—Hazardous (Classified) Locations.....	195	620.22	Branch Circuits for Elevator Car(s).....	243
555.15	Replacement of Equipment.....	196	620.23	Branch Circuits for Machine Room/Machinery Space	243
Part II. Marinas, Boatyards, and Docking Facilities		196	620.24	Branch Circuit for Hoistway Pit Lighting and Receptacles	244
555.30	Electrical Equipment and Connections.....	196	Part IV. Installation of Conductors	244	
555.33	Receptacles	197	620.37	Wiring in Elevator Hoistways, Control, and Machine	
555.34	Wiring Methods and Installation.....	198		Rooms/Spaces.....	244
555.35	Ground-Fault Protection (GFPE and GFCI).....	199	Part VI. Disconnecting Means and Control	244	
555.36	Shore Power Receptacle Disconnecting Means.....	200	620.51	Disconnecting Means	244
555.37	Equipment Grounding Conductor.....	201	Article 625—Electric Vehicle Power Transfer		
555.38	Luminaires	201	System	247	
Article 590—Temporary Installations		203	Part I. General	247	
590.1	Scope	203	625.1	Scope	247
590.2	All Wiring Installations.....	203	625.6	Listed.....	247
590.3	Time Constraints.....	204	Part III. Installation	248	
590.4	General.....	204	625.40	Electric Vehicle Branch Circuit.....	248
590.5	Listing of Decorative Lighting.....	207	625.41	Overcurrent Protection	249
590.6	GFCI Protection for Personnel.....	207	625.42	Load.....	249
590.8	Overcurrent Protective Devices.....	208	625.43	Disconnecting Means	251
Chapter 5—Review Questions		209	625.48	Interactive Equipment	251
CHAPTER 6—SPECIAL EQUIPMENT		229	625.49	Island Mode	251
Article 600—Electric Signs		231	625.52	Ventilation	252
Part I. General		231	625.54	GFCI	252
600.1	Scope	231	Part IV. Wireless Power Transfer Equipment	252	
600.3	Listing.....	232	625.101	Grounding	252
600.4	Markings.....	232	625.102	Installation	252
600.5	Branch Circuits.....	232	Article 630—Electric Welders	255	
600.6	Disconnecting Means	233	Part I. General	255	
600.7	Grounding and Bonding.....	235	630.1	Scope	255
600.9	Location	237	630.6	Listing.....	255
600.21	Ballasts, Transformers, Class 2 Power-Limited Power		630.8	Receptacle, GFCI Protection	255
	Sources, and Electronic Power Supplies.....	237	Part II. Arc Welders	256	
600.24	Class 2 Power-Limited Power Sources	238	630.11	Ampacity of Supply Conductors.....	256
Article 604—Manufactured Wiring Systems		239	630.12	Overcurrent Protection	259
604.1	Scope	239	630.13	Disconnecting Means	259
604.6	Listing Requirements	239	630.15	Grounding of Welder Secondary Circuit	259
604.7	Installation—Securing and Supporting	239	Part III. Resistance Welders	259	
604.10	Uses Permitted.....	240	630.31	Ampacity of Supply Conductor	259
			630.32	Overcurrent Protection	261
			630.33	Disconnecting Means	261

Article 640—Audio Signal Amplification and Reproduction Equipment.....263

Part I. General263

640.1 Scope263

640.3 Locations and Other Articles264

640.4 Protection of Electrical Equipment.....264

640.5 Access to Electrical Equipment Behind Panels Designed to Allow Access264

640.6 Mechanical Execution of Work264

640.9 Wiring Methods265

640.10 Audio Systems Near Bodies of Water265

Part II. Permanent Audio System Installations265

640.21 Use of Flexible Cords and Flexible Cables265

640.23 Conduit or Tubing.....266

Article 645—Information Technology Equipment (ITE)267

645.1 Scope267

645.3 Other Articles.....267

645.4 Special Requirements268

645.5 Supply Circuits and Interconnecting Cables268

645.10 Disconnecting Means269

645.15 Equipment Grounding and Bonding270

Article 680—Swimming Pools, Hot Tubs, and Fountains271

Part I. General Requirements for Pools, Spas, Hot Tubs, and Fountains.....272

680.1 Scope272

680.4 Inspections After Installation.....273

680.5 GFCI and SPGFCI Protection273

680.6 Listing Requirements274

680.7 Grounding and Bonding.....274

680.9 Overhead Conductor Clearance275

680.10 Electric Pool Water Heaters and Heat Pumps.....276

680.11 Underground Wiring.....276

680.12 Equipment Rooms, Vaults, and Pits277

680.13 Equipment Disconnecting Means.....277

680.14 Corrosive Environment277

Part II. Permanently Installed Pools.....278

680.20 General.....278

680.21 Pool Pump Motors.....279

680.22 Receptacles, Luminaires, and Switches.....279

680.23 Underwater Pool Luminaires282

680.24 Junction Box, Transformer, or GFCI Enclosure285

680.26 Equipotential Bonding286

680.27 Specialized Equipment291

680.28 Gas-Fired Water Heaters291

Part III. Storable Pools292

680.30 General292

680.31 Pumps292

680.32 GFCI Protection.....292

680.34 Receptacle Locations293

680.35 Storable Pools293

Part IV. Hot Tubs293

680.40 General.....293

680.41 Emergency Shutoff Equipment.....294

680.42 Outdoor Installations.....294

680.43 Indoor Installations295

680.44 GFCI or SPGFCI Protection296

680.45 Permanently Installed Immersion Pools296

Part V. Fountains.....296

680.50 General.....296

680.51 Luminaires and Submersible Equipment297

680.54 Connection to an Equipment Grounding Conductor.....298

680.55 Methods of Equipment Grounding298

680.56 Cord-and-Plug-Connected Equipment.....299

680.57 Electric Signs in or Adjacent to Fountains.....299

680.58 GFCI Protection of Receptacles.....299

680.59 GFCI or SPGFCI Protection for Permanently Installed Nonsubmersible Pumps299

Part VII. Hydromassage Bathtubs.....299

680.70 General.....299

680.71 GFCI Protection.....300

680.73 Accessibility.....300

680.74 Equipotential Bonding300

Article 690—Solar Photovoltaic (PV) Systems.....303

Part I. General304

690.1 Scope304

690.4 General Requirements.....304

690.6 Alternating-Current Modules307

Part II. Circuit Requirements308

690.7 Maximum PV System Direct-Current Circuit Voltage308

690.8 Circuit Current and Conductor Sizing.....313

690.9 Overcurrent Protection322

690.11 Arc-Fault Circuit Protection324

690.12 Rapid Shutdown—PV Circuits on Building324

Part III. Disconnect329

690.13 PV System Disconnect329

690.15 PV Equipment Disconnect/Isolating Device.....331

Part IV. Wiring Methods	333	700.4	Capacity and Rating.....	389	
690.31	Wiring Methods and Materials.....	333	700.5	Transfer Switch.....	389
690.32	Component Interconnections.....	338	700.6	Signals.....	390
690.33	Connectors (Mating).....	338	700.7	Signs.....	390
690.34	Access to Boxes.....	339	700.8	Surge Protection.....	390
Part V. Grounding and Bonding	339	Part II. Circuit Wiring		391	
690.41	PV System DC Circuit Grounding and Protection.....	339	700.10	Wiring to Emergency Loads.....	391
690.43	Equipment Grounding Conductor.....	340	700.11	Wiring, Class 2-Powered Emergency Lighting Systems.....	393
690.45	Size of Equipment Grounding Conductors.....	341	Part III. Sources of Power	393	
690.47	Grounding Electrode System.....	342	700.12	General Requirements.....	393
Part VI. Source Connections	343	Part IV. Emergency System Circuits for Lighting and Power		395	
690.56	Identification of Power Sources.....	343	700.15	Loads on Emergency Branch Circuits.....	395
690.59	Connection to Other Power Sources.....	343	700.16	Emergency Illumination.....	395
			700.19	Multewire Branch Circuits.....	396
			700.27	Class 2 Powered Emergency Lighting Systems.....	396
Article 691—Large-Scale Photovoltaic (PV) Electric Supply Stations	345	Part VI. Overcurrent Protection		396	
691.1	Scope.....	345	700.30	Accessibility.....	396
691.4	Special Requirements for Large-Scale PV Electric Supply Stations.....	345	700.32	Selective Coordination.....	396
691.5	Equipment.....	346	Article 701—Legally Required Standby Systems	399	
691.6	Engineered Design.....	346	Part I. General	400	
691.7	Conformance of Construction to Engineered Design.....	346	701.1	Scope.....	400
691.8	Direct-Current Operating Voltage.....	346	701.3	Commissioning and Maintenance.....	400
691.9	Disconnect for Isolating Photovoltaic Equipment.....	346	701.4	Capacity and Rating.....	401
691.10	Fire Mitigation.....	347	701.5	Transfer Switches.....	401
691.11	Fence Bonding and Grounding.....	347	701.6	Signals.....	401
			701.7	Signs.....	401
Article 695—Fire Pumps	349	Part II. Circuit Wiring		401	
695.1	Scope.....	349	701.10	Wiring.....	401
695.3	Electric Power Source(s).....	350	Part III. Sources of Power	402	
695.4	Continuity of Power.....	351	701.12	General Requirements.....	402
695.5	Transformers.....	352	Part IV. Overcurrent Protection	402	
695.6	Power Wiring.....	352	701.30	Accessibility.....	402
695.7	Fire Pump Controller Voltage Drop.....	354	701.32	Selective Coordination.....	403
695.10	Listed Equipment.....	355	Article 702—Optional Standby Systems	405	
695.12	Equipment Location.....	355	Part I. General	405	
695.14	Control Wiring.....	355	702.1	Scope.....	405
695.15	Surge Protection.....	355	702.4	Capacity and Rating.....	406
Chapter 6—Review Questions	357	702.5	Interconnection Equipment or Transfer Equipment.....	407	
		702.7	Signs.....	408	
CHAPTER 7—SPECIAL CONDITIONS	385	Part II. Circuit Wiring		409	
Article 700—Emergency Systems	387	702.10	Wiring.....	409	
Part I. General	388	702.12	Outdoor Generators.....	409	
700.1	Scope.....	388			
700.3	Tests and Maintenance.....	389			

Article 705—Interconnected Electric Power	
Production Sources	411
Part I. General	411
705.1 Scope	411
705.6 Equipment Approval	412
705.8 System Installation	414
705.10 Identification of Parallel Power Production Sources	414
705.11 Service Connection	415
705.12 Load-Side Source Connection	417
705.13 Energy Management Systems	423
705.20 Power Production Source Disconnect	423
705.25 Wiring Methods	424
705.28 Output Current and Circuit Sizing	425
705.30 Overcurrent Protection	426
705.32 Ground-Fault Protection	428
705.40 Loss of Primary Source	429
705.45 Unbalanced Interconnections	429
Part II. Microgrid Systems	430
705.50 Microgrid System Operation	430
705.60 Connections to the Primary Source	431
705.70 Microgrid Interconnect Devices (MID)	432
705.76 Microgrid Control System (MCS)	432
Article 706—Energy Storage Systems	433
Part I. General	433
706.1 Scope	433
706.3 Qualified Personnel	433
706.4 System Nameplate Requirements	434
706.5 Listing	435
706.6 Multiple Systems	435
706.7 Commissioning and Maintenance	435
Part II. Disconnect	436
706.15 Disconnect	436
706.16 ESS in Parallel with Other Sources of Power	439
Part III. Installation Requirements	439
706.20 General Installation Requirements	439
Part IV. Energy Storage System Circuit Requirements	440
706.30 Circuit Current Rating	440
706.31 Overcurrent Protection	441
Article 710—Stand-Alone Systems	443
710.1 Scope	443
710.6 Equipment Approval	444
710.10 Identification of Power Sources	444
710.12 Stand-Alone Inverter Input Circuit Current	444
710.15 Wiring	444
Article 722—Cables for Power-Limited Circuits	445
Part I. General	445
722.1 Scope	445
722.3 Other Articles	446
722.21 Electrical Equipment Behind Access Panels	448
722.24 Mechanical Execution of Work	448
722.25 Abandoned Cable	451
722.135 Installation of Power-Limited Cables	451
Part II. Listing Requirements	454
722.179 Listing and Marking of Power-Limited Cables	454
Article 724—Class 1 Power-Limited Circuits	457
Part I. General	457
724.1 Scope	457
724.30 Class 1 Circuit Identification	457
724.40 Class 1 Power Source	458
724.43 Class 1 Circuit Overcurrent Protection	458
724.45 Class 1 Circuit Overcurrent Protective Device Location	458
724.46 Class 1 Circuit Wiring Methods	459
724.48 Conductors of Different Circuits in Same Cable, Cable Tray, Enclosure, or Raceway	459
724.49 Class 1 Circuit Conductors	459
724.51 Number of Conductors in a Raceway	459
Article 725—Class 2 Power-Limited Circuits	461
Part I. General	461
725.1 Scope	461
725.31 Safety-Control Equipment	462
Part II. Class 2 Circuit Requirements	462
725.60 Power Sources for Class 2 Circuits	462
725.127 Wiring Methods on Supply Side of the Class 2 Power Source	463
725.130 Wiring Methods on Load Side of the Class 2 Power Source	463
725.136 Separation from Power Conductors	463
725.139 Conductors of Different Circuits in Same Cable, Enclosure, Cable Tray, and Raceway	465
725.144 Bundling Cables Transmitting Power and Data	466
Article 760—Fire Alarm Systems	469
Part I. General	469
760.1 Scope	469
760.3 Other Articles	470
760.21 Access to Electrical Equipment Behind Panels Designed to Allow Access	472
760.24 Mechanical Execution of Work	472

215.12	Conductor Identification.....	125	230.43	Wiring Methods.....	151
215.15	Barriers.....	127	230.46	Spliced and Tapped Connections.....	152
215.18	Surge Protection.....	127	230.50	Protection Against Physical Damage.....	152
Article 225—Outside Branch Circuits and Feeders.....			230.51	Cable Supports.....	153
Part I. General.....			230.53	Raceways to Drain.....	153
225.1	Scope.....	129	230.54	Overhead Service Locations.....	153
225.6	Minimum Conductor Size and Support.....	129	230.56	High-Leg Conductor Identification.....	154
225.17	Masts as Supports.....	131	Part V. Service Disconnect—General.....		
225.18	Clearance for Overhead Conductors.....	131	230.62	Service Equipment—Barriers.....	155
225.19	Clearances from Buildings.....	132	230.66	Marking for Service Equipment.....	155
225.22	Raceways on Exterior Surfaces of Buildings.....	133	230.67	Surge Protection.....	156
225.26	Trees for Conductor Support.....	133	Part VI. Service Disconnect—Disconnecting Means.....		
225.27	Raceway Seals.....	134	230.70	Service Disconnect Requirements.....	157
Part II. Buildings or Other Structures Supplied by a Feeder.....			230.71	Number of Service Disconnects.....	158
225.30	Number of Supplies.....	134	230.72	Grouping of Service Disconnects.....	159
225.31	Disconnecting Means.....	135	230.79	Rating of Disconnect.....	159
225.33	Maximum Number of Disconnects.....	136	230.82	Connected on Supply Side of the Service Disconnect.....	160
225.34	Grouping of Disconnects.....	136	230.85	Emergency (Shutoff) Disconnect.....	161
225.37	Identification of Multiple Supplies.....	136	Part VII. Service Conductor Overcurrent Protection.....		
225.39	Rating of Disconnecting Means.....	136	230.90	Overload Protection—Where Required.....	163
225.41	Emergency (Shutoff) Disconnects.....	136	230.91	Location.....	164
225.42	Surge Protection.....	137	230.95	Ground-Fault Protection of Equipment.....	164
Article 230—Services.....			Article 240—Overcurrent Protection.....		
230.1	Scope.....	139	Part I. General.....		
Part I. General.....			240.1	Scope.....	166
230.2	Number of Services.....	141	240.3	Other Articles (Overcurrent Protection of Equipment).....	167
230.3	Not to Pass Through a Building.....	142	240.4	Overcurrent Protection of Conductors.....	167
230.6	Conductors Considered Outside a Building or Structure.....	142	240.5	Overcurrent Protection of Flexible Cords, Flexible Cables, and Fixture Wires.....	172
230.7	Service Conductors Separate from Other Conductors.....	142	240.6	Standard Ampere Ratings.....	172
230.8	Raceway Seals.....	143	240.10	Supplementary Conductor Overcurrent Protection.....	173
230.9	Clearances on Buildings.....	144	240.13	Ground-Fault Protection of Equipment.....	174
230.10	Vegetation as Support.....	144	240.15	Overcurrent Protective Device, Handle Ties.....	174
Part II. Overhead Service Conductors.....			Part II. Location of Overcurrent Protective Device.....		
230.23	Overhead Service Conductor Size and Rating.....	145	240.21	Location of Overcurrent Protective Device in Circuit.....	175
230.24	Vertical Clearance for Overhead Service Conductors.....	145	240.22	Grounded-Phase Conductor on Overcurrent Device.....	182
230.26	Point of Attachment.....	146	240.24	Location of Overcurrent Protective Devices.....	182
230.27	Means of Attachment.....	147	Part III. Enclosures Containing Overcurrent Protective Devices.....		
230.28	Service Masts as Support.....	147	240.33	Vertical Position, Enclosures.....	183
Part III. Underground Service Conductors.....			Part V. Plug Fuses, Fuseholders, and Adapters.....		
230.30	Installation.....	148	240.51	Edison-Base Fuses.....	183
230.31	Underground Service Conductor Ampacity.....	148	Part VI. Cartridge Fuses and Fuseholders.....		
230.32	Protection Against Damage.....	149	240.67	Arc-Energy Reduction—Fuses.....	184
Part IV. Service-Entrance Conductors.....			Part VII. Circuit Breakers.....		
230.40	Number of Service-Entrance Conductor Sets.....	149	240.81	Indicating.....	184
230.42	Conductor Sizing.....	149	240.83	Markings.....	184

300.11	Securing and Supporting	287	314.3	Nonmetallic Boxes	331
300.12	Mechanical Continuity	288	314.4	Metal Boxes	332
300.13	Mechanical and Electrical Continuity of Conductors— Splices and Pigtails	289	314.5	Screws or Other Fasteners	332
300.14	Conductor Length at Boxes	291	Part II. Installation	332	
300.15	Boxes or Fittings, Splices and Terminations	291	314.15	Wet Locations	332
300.17	Number and Size of Conductors in a Raceway	292	314.16	Outlet Box Sizing	332
300.18	Raceway Installations	294	314.17	Cables That Enter Boxes	340
300.19	Supporting Conductors in Vertical Raceways	295	314.20	Flush-Mounted Boxes	340
300.20	Reducing Inductive Heating	295	314.21	Repairing Noncombustible Surfaces	341
300.21	Spread of Fire or Products of Combustion	297	314.22	Surface Extensions	341
300.22	Wiring in Ducts and Plenum Spaces	298	314.23	Securing Boxes	342
300.23	Panels Designed to Allow Access	301	314.27	Box Requirements	345
300.25	Exit Stair Towers	301	314.28	Pull Boxes, Junction Boxes, and Conduit Bodies	346
			314.29	Wiring to be Accessible	349
			314.30	Handhole Enclosures	349
Article 310—Conductors for General Wiring	303		Article 320—Armored Cable (Type AC)	353	
Part I. General	303		Part I. General	353	
310.1	Scope	303	320.1	Scope	353
310.3	Conductors, Minimum Size and Material	303	320.6	Listing Requirements	353
Part II. Construction Specifications	305		Part II. Installation	353	
310.4	Conductor Construction and Application	305	320.10	Uses Permitted	353
310.6	Conductor Identification	307	320.12	Uses Not Permitted	354
Part III. Installation	308		320.15	Exposed Work	354
310.10	Uses Permitted	308	320.17	Through or Parallel to Framing Members	354
310.12	Dwelling Services and Feeders	310	320.23	In Roof Spaces	355
310.14	Ampacities for Conductors Rated 0V to 2000V	313	320.24	Bending Radius	355
310.15	Ampacity Tables	314	320.30	Securing and Supporting	355
310.16	Ampacities of Insulated Conductors	321	320.40	Boxes and Fittings	356
			320.80	Conductor Ampacity	357
Article 312—Cabinets, Cutout Boxes, and Meter Socket Enclosures	323		Part III. Construction Specifications	358	
Part I. General	323		320.100	Construction	358
312.1	Scope	323	320.108	Equipment Grounding Conductor	358
312.2	Damp or Wet Locations	324			
312.3	Position in Walls	324	Article 330—Metal-Clad Cable (Type MC)	359	
312.4	Repairing Gaps in Noncombustible Surfaces	325	Part I. General	359	
312.5	Cable Termination to Enclosures	325	330.1	Scope	359
312.6	Deflection of Conductors	326	330.6	Listing Requirements	359
312.8	Overcurrent Device Enclosures	327	Part II. Installation	360	
312.10	Screws or Other Fasteners	328	330.10	Uses Permitted	360
Part II. Construction Specifications	328		330.12	Uses Not Permitted	361
312.100	Enclosure Material	328	330.15	Exposed Work	361
			330.17	Through or Parallel to Framing Members	361
Article 314—Boxes, Conduit Bodies, and Handhole Enclosures	331		330.23	In Roof Spaces	361
Part I. General	331		330.24	Bending Radius	362
314.1	Scope	331	330.30	Securing and Supporting	362
			330.80	Conductor Ampacities	363

Part III. Construction Specifications	364	340.10	Uses Permitted.....	383
330.108 Equipment Grounding Conductor.....	364	340.12	Uses Not Permitted.....	384
Article 334—Nonmetallic-Sheathed Cable (Type NM)	365	340.24	Bends	384
Part I. General	365	340.80	Ampacity.....	384
334.1 Scope	365	Part III. Construction Specifications		385
334.6 Listing Requirements	366	340.108 Equipment Grounding Conductor.....		385
Part II. Installation	366	340.112 Insulation		385
334.10 Type NM Cable, Uses Permitted	366	Article 342—Intermediate Metal Conduit (IMC)		387
334.12 Uses Not Permitted.....	367	Part I. General		387
334.15 Exposed Work.....	368	342.1 Scope		387
334.17 Through or Parallel to Framing Members.....	369	342.6 Listing Requirements		387
334.19 Cables Entering Enclosures	370	Part II. Installation		388
334.23 Accessible Roof Spaces	370	342.10 Uses Permitted.....		388
334.24 Bending Radius	370	342.14 Dissimilar Metals.....		388
334.30 Securing and Supporting	370	342.20 Trade Size		388
334.40 Boxes and Fittings.....	371	342.22 Number of Conductors		388
334.80 Conductor Ampacity.....	371	342.24 Bends		389
Part III. Construction Specifications	373	342.28 Reaming		389
334.108 Equipment Grounding Conductor.....	373	342.30 Securing and Supporting		389
Article 336—Power and Control Tray Cable (Type TC)	375	342.42 Couplings and Connectors.....		391
Part I. General	375	342.46 Bushings		392
336.1 Scope	375	342.60 Equipment Grounding Conductor.....		392
336.6 Listing Requirements	376	Article 344—Rigid Metal Conduit (RMC)		393
Part II. Installation	376	Part I. General		393
336.10 Uses Permitted.....	376	344.1 Scope		393
336.12 Uses Not Permitted.....	377	344.6 Listing Requirements		393
336.24 Bending Radius	377	Part II. Installation		394
Article 338—Service-Entrance Cable (Types SE and USE)	379	344.10 Uses Permitted.....		394
Part I. General	379	344.14 Dissimilar Metals.....		394
338.1 Scope	379	344.20 Trade Size		395
338.6 Listing Requirements	379	344.22 Number of Conductors		395
Part II. Installation	380	344.24 Bends		395
338.10 Uses Permitted.....	380	344.28 Reaming and Threading.....		395
338.12 Uses Not Permitted.....	381	344.30 Securing and Supporting		395
338.24 Bending Radius	381	344.42 Couplings and Connectors.....		397
Article 340—Underground Feeder and Branch-Circuit Cable (Type UF)	383	344.46 Bushings		398
Part I. General	383	344.60 Equipment Grounding Conductor.....		398
340.1 Scope	383	Article 348—Flexible Metal Conduit (FMC)		399
340.6 Listing Requirements	383	Part I. General		399
Part II. Installation	383	348.1 Scope		399
		348.6 Listing Requirements		399
		Part II. Installation		399
		348.10 Uses Permitted.....		399
		348.12 Uses Not Permitted.....		400

348.20	Trade Size	400
348.22	Number of Conductors	401
348.24	Bends	401
348.28	Trimming	401
348.30	Securing and Supporting	402
348.42	Couplings and Connectors	403
348.60	Equipment Grounding and Bonding Conductors	403

Article 350—Liquidtight Flexible Metal Conduit (LFMC).....405

Part I. General	405
350.1 Scope	405
350.6 Listing Requirements	406
Part II. Installation	406
350.10 Uses Permitted.....	406
350.12 Uses Not Permitted.....	406
350.20 Trade Size	406
350.22 Number of Conductors	407
350.24 Bends	407
350.28 Trimming	407
350.30 Securing and Supporting	407
350.60 Equipment Grounding and Bonding Conductors	409

Article 352—Rigid Polyvinyl Chloride Conduit (PVC).....411

Part I. General	412
352.1 Scope	412
352.6 Listing.....	412
Part II. Installation	412
352.10 Uses Permitted.....	412
352.12 Uses Not Permitted.....	413
352.20 Trade Size	414
352.22 Number of Conductors	414
352.24 Bends	414
352.28 Trimming	415
352.30 Securing and Supporting	415
352.44 Expansion Fittings.....	416
352.46 Bushings	416
352.48 Joints.....	417
352.60 Equipment Grounding Conductor.....	417

Article 356—Liquidtight Flexible Nonmetallic Conduit (LFNC).....419

Part I. General	419
356.1 Scope	419
356.6 Listing Requirements	419
Part II. Installation	420
356.10 Uses Permitted.....	420
356.12 Uses Not Permitted.....	420

356.20	Trade Size	421
356.22	Number of Conductors	421
356.24	Bends	421
356.30	Securing and Supporting	421
356.42	Fittings	422
356.60	Equipment Grounding Conductor.....	422

Article 358—Electrical Metallic Tubing (EMT).....423

Part I. General	423
358.1 Scope	423
358.6 Listing Requirements	423
Part II. Installation	424
358.10 Uses Permitted.....	424
358.12 Uses Not Permitted.....	425
358.20 Trade Size	425
358.22 Number of Conductors	425
358.24 Bends	426
358.28 Reaming.....	426
358.30 Securing and Supporting	426
358.42 Couplings and Connectors.....	427
358.60 Equipment Grounding Conductor.....	428

Article 362—Electrical Nonmetallic Tubing (ENT).....429

Part I. General	429
362.1 Scope	429
362.6 Listing.....	430
Part II. Installation	430
362.10 Uses Permitted.....	430
362.12 Uses Not Permitted.....	431
362.20 Trade Sizes.....	432
362.22 Number of Conductors	432
362.24 Bends	432
362.28 Trimming	433
362.30 Securing and Supporting	433
362.46 Bushings	433
362.48 Joints.....	434
362.60 Equipment Grounding Conductor.....	434

Article 376—Metal Wireways.....435

Part I. General	435
376.1 Scope	435
Part II. Installation	435
376.10 Uses Permitted.....	435
376.12 Uses Not Permitted.....	436
376.20 Conductors Connected in Parallel.....	436
376.21 Size of Conductors.....	436
376.22 Number of Conductors and Ampacity	437

376.23	Wireway Sizing	438	400.10	Uses Permitted.....	458
376.30	Supports	439	400.12	Uses Not Permitted.....	460
376.56	Splices, Taps, and Power Distribution Blocks.....	439	400.13	Splices.....	461
376.60	Equipment Grounding Conductor.....	440	400.14	Pull at Joints and Terminals.....	461
			400.17	Protection from Damage.....	461
Article 380—Multioutlet Assemblies.....		443	Article 402—Fixture Wires.....		
Part I. General		444	402.1	Scope	463
380.1	Scope	444	402.2	Other Articles.....	463
Part II. Installation		444	402.3	Types	463
380.10	Uses Permitted.....	444	402.5	Ampacity of Fixture Wires.....	463
380.12	Uses Not Permitted.....	444	402.6	Minimum Size.....	463
380.76	Through Partitions.....	444	402.7	Raceway Size.....	464
Article 386—Surface Metal Raceways.....		445	402.8	Neutral Conductor.....	464
Part I. General		445	402.10	Uses Permitted.....	464
386.1	Scope	445	402.12	Uses Not Permitted.....	464
386.6	Listing Requirements	446	Article 404—Switches.....		
Part II. Installation		446	Part I. Installation		465
386.10	Uses Permitted.....	446	404.1	Scope	465
386.12	Uses Not Permitted.....	446	404.3	Circuit Breaker Enclosures.....	466
386.21	Size of Conductors.....	446	404.4	Damp or Wet Locations.....	466
386.22	Number of Conductors.....	446	404.7	Indicating	467
386.30	Securing and Supporting	447	404.8	Accessibility and Grouping	467
386.56	Splices and Taps	447	404.9	General-Use Snap Switches, Dimmers, and Control Switches	469
386.60	Equipment Grounding Conductor.....	447	404.10	Mounting of Snap Switches, Dimmers, and Control Switches	470
Article 392—Cable Trays.....		449	404.12	Bonding of Enclosures.....	471
Part I. General		449	404.14	Rating and Use of Snap Switches	471
392.1	Scope	449	Part II. Construction Specifications.....		472
Part II. Installation		449	404.20	Switch Marking	472
392.10	Uses Permitted.....	449	Article 406—Receptacles, Attachment Plugs, and Flanged Inlets.....		
392.12	Uses Not Permitted.....	451	406.1	Scope	474
392.18	Cable Tray Installations	451	406.3	Receptacle Rating and Type	474
392.20	Cable and Conductor Installation.....	452	406.4	General Installation Requirements.....	475
392.30	Securing and Supporting	452	406.5	Receptacle Mounting.....	475
392.44	Expansion Splice Plates	452	406.6	Receptacle Faceplates	478
392.46	Bushed Conduit and Tubing.....	452	406.7	Attachment Plugs and Flanged Surface Inlets	478
392.56	Cable Splices.....	453	406.9	Receptacles in Damp or Wet Locations.....	478
392.60	Equipment Grounding Conductor.....	453	406.11	Connecting Receptacle Grounding Terminal to Equipment Grounding Conductor	481
CHAPTER 4—EQUIPMENT FOR GENERAL USE.....		455	406.12	Tamper-Resistant Receptacles.....	481
Article 400—Flexible Cords.....		457			
400.1	Scope	457			
400.3	Suitability	457			
400.4	Types of Flexible Cords.....	458			
400.5	Ampacity of Flexible Cords.....	458			

Article 408—Switchboards and Panelboards	483
Part I. General	484
408.1 Scope	484
408.3 Arrangement of Busbars and Conductors.....	484
408.4 Circuit Directory and Description	485
408.5 Clearance for Conductors Entering Bus Enclosures	487
408.6 Short-Circuit Current Rating.....	487
408.7 Unused Openings	487
408.9 Replacement Panelboards	487
Part II. Switchboards	487
408.18 Clearances	487
Part III. Panelboards	488
408.30 Panelboard Rating.....	488
408.36 Overcurrent Protection	488
408.37 Panelboards in Damp or Wet Locations	489
408.38 Enclosure	489
408.40 Equipment Grounding Conductor.....	489
408.41 Neutral Conductor Terminations	489
408.43 Panelboard Orientation.....	490
Article 445—Generators	491
445.1 Scope	491
445.6 Listing.....	492
445.11 Marking.....	492
445.13 Conductor Ampacity.....	492
445.18 Disconnecting Means	493
445.19 Emergency Shutdown of Prime Mover	493
Article 450—Transformers	495
450.1 Scope	495
450.3 Primary Overcurrent Protection.....	496
450.9 Ventilation	498
450.10 Grounding and Bonding.....	498
450.13 Transformer Accessibility.....	498
450.14 Disconnecting Means	499
Article 480—Stationary Standby Batteries	501
480.1 Scope	501
480.4 Battery and Cell Terminations	502
480.9 Battery Support Systems.....	503
480.10 Battery Locations.....	503
480.12 Battery Interconnections.....	504
EXAM A	
STRAIGHT ORDER—ARTICLES 90–480	505

CHAPTER 6—SPECIAL EQUIPMENT	515
Article 625—Electric Vehicle Power Transfer System	517
Part I. General	517
625.1 Scope	517
625.6 Listed.....	517
Part III. Installation	518
625.40 Electric Vehicle Branch Circuit.....	518
625.41 Overcurrent Protection	519
625.42 Load.....	520
625.43 Disconnecting Means	521
625.48 Interactive Equipment	521
625.49 Island Mode	521
625.52 Ventilation	522
625.54 GFCI	522
Part IV. Wireless Power Transfer Equipment	522
625.101 Grounding	522
625.102 Installation	523
Article 690—Solar Photovoltaic (PV) Systems	525
Part I. General	525
690.1 Scope	525
690.4 General Requirements.....	526
690.6 Alternating-Current Modules	529
Part II. Circuit Requirements	530
690.7 Maximum PV System Direct-Current Circuit Voltage	530
690.8 Circuit Current and Conductor Sizing.....	535
690.9 Overcurrent Protection	544
690.11 Arc-Fault Circuit Protection.....	546
690.12 Rapid Shutdown—PV Circuits on Building	546
Part III. Disconnect	551
690.13 PV System Disconnect	551
690.15 PV Equipment Disconnect/Isolating Device.....	553
Part IV. Wiring Methods	555
690.31 Wiring Methods and Materials.....	555
690.32 Component Interconnections	559
690.33 Connectors (Mating).....	560
690.34 Access to Boxes	561
Part V. Grounding and Bonding	561
690.41 PV System DC Circuit Grounding and Protection.....	561
690.43 Equipment Grounding Conductor.....	562
690.45 Size of Equipment Grounding Conductors	563
690.47 Grounding Electrode System	564
Part VI. Source Connections	565
690.56 Identification of Power Sources.....	565
690.59 Connection to Other Power Sources.....	565

Article 691—Large-Scale Photovoltaic (PV) Electric Supply Stations567

691.1 Scope567

691.4 Special Requirements for Large-Scale PV Electric Supply Stations567

691.5 Equipment.....568

691.6 Engineered Design.....568

691.7 Conformance of Construction to Engineered Design.....568

691.8 Direct-Current Operating Voltage568

691.9 Disconnect for Isolating Photovoltaic Equipment.....568

691.10 Fire Mitigation.....569

691.11 Fence Bonding and Grounding569

CHAPTER 7—SPECIAL CONDITIONS571

Article 702—Optional Standby Systems573

Part I. General573

702.1 Scope573

702.4 Capacity and Rating.....574

702.5 Interconnection Equipment or Transfer Equipment575

702.7 Signs.....576

Part II. Circuit Wiring.....577

702.10 Wiring577

702.12 Outdoor Generators577

Article 705—Interconnected Electric Power Production Sources579

Part I. General579

705.1 Scope579

705.6 Equipment Approval580

705.8 System Installation581

705.10 Identification of Parallel Power Production Sources.....582

705.11 Service Connection.....583

705.12 Load-Side Source Connection585

705.13 Energy Management Systems.....590

705.20 Power Production Source Disconnect.....591

705.25 Wiring Methods592

705.28 Output Current and Circuit Sizing.....593

705.30 Overcurrent Protection594

705.32 Ground-Fault Protection596

705.40 Loss of Primary Source596

705.45 Unbalanced Interconnections.....597

Part II. Microgrid Systems597

705.50 Microgrid System Operation.....597

705.60 Connections to the Primary Source598

705.70 Microgrid Interconnect Devices (MID).....598

705.76 Microgrid Control System (MCS)599

Article 706—Energy Storage Systems601

Part I. General601

706.1 Scope601

706.3 Qualified Personnel.....602

706.4 System Nameplate Requirements602

706.5 Listing.....603

706.6 Multiple Systems.....603

706.7 Commissioning and Maintenance603

Part II. Disconnect604

706.15 Disconnect604

706.16 ESS in Parallel with Other Sources of Power607

Part III. Installation Requirements.....607

706.20 General Installation Requirements.....607

Part IV. Energy Storage System Circuit Requirements608

706.30 Circuit Current Rating608

706.31 Overcurrent Protection609

Article 710—Stand-Alone Systems.....611

710.1 Scope611

710.6 Equipment Approval611

710.10 Identification of Power Sources.....611

710.12 Stand-Alone Inverter Input Circuit Current612

710.15 Wiring612

Article 750—Energy Management Systems613

750.1 Scope613

750.6 Listing.....613

750.20 Alternate Power Sources614

750.30 Load Management.....614

750.50 Directory615

**EXAM B
STRAIGHT ORDER—ARTICLES 625–750**617

**FINAL EXAM
RANDOM ORDER—ARTICLES 90–750**627

INDEX.....639

About the Author648

About the Illustrator649

About the Mike Holt Team650

2023 ELECTRICAL EXAM PREPARATION

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.....	59
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
<i>NEC Article 90—Introduction to the National Electrical Code Review Questions</i>	121
<i>NEC Chapter 1—General Rules Review Questions</i>	123
<i>NEC Chapter 2—Wiring and Protection Review Questions</i>	130
<i>NEC Chapter 3—Wiring Methods and Materials Review Questions</i>	155
<i>NEC Chapter 4—Equipment for General Use Review Questions</i>	172
<i>NEC Chapter 5—Special Occupancies Review Questions</i>	185
<i>NEC Chapter 6—Special Equipment Review Questions</i>	192
<i>NEC Chapter 7—Special Conditions Review Questions</i>	199
<i>NEC Chapter 8—Communications Systems Review Questions</i>	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(C)(1)].....	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]	339
Part C—Transformers	340
Introduction.....	340
4.15 Transformer Primary Only Overcurrent Protection [450.3(B)]	340
4.16 Transformer Secondary Conductor Sizing [240.21(C)]	343
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	7.11 Multifamily Dwelling Calculations—Standard Method, Examples.....	418
Part A—Optional Method Load Calculations [Article 220, Part IV]	369	7.12 Two-Family (Duplex) Dwelling Units Load Calculations [220.85]	421
Introduction.....	369	Part C—Neutral Load Calculations	423
6.1 Dwelling Unit Optional Load Calculations [220.82].....	369	Introduction.....	423
6.2 Dwelling Unit Optional Load Calculation [220.82].....	371	7.13 Neutral Demand Load—Dryers and Ranges [220.61]	423
Part B—Standard Method Load Calculations [Article 220, Part III]	372	7.14 Service Neutral Demand Load [220.61(B)].....	424
Introduction.....	372	Unit 7—Review Questions	427
6.3 Dwelling Unit Standard Load Calculation	372	Unit 8—Commercial Calculations	435
6.4 General Lighting and General-Use Receptacle Demand Load [220.41 and Table 220.45].....	372	Part A—General Commercial Demand Loads	435
6.5 Fixed Appliance Demand Load [220.53].....	375	Introduction.....	435
6.6 Dryer Demand Load [220.54].....	376	8.1 General Lighting Load [Table 220.42(A)]	435
6.8 Electric Cooking Equipment Demand Load [220.55].....	376	8.2 General Lighting Load, Examples [Table 220.42(A)].....	436
6.10 Electric Vehicle [220.57]	378	8.3 General Lighting Load Demand Factors [Table 220.45].....	437
6.11 Air-Conditioning Versus Heating [220.50, 220.51, and 220.60].....	379	8.4 Number of General Lighting Circuits.....	438
6.12 Service Conductor Size [Table 310.12(A)].....	380	8.5 Sign Circuit [220.14(F)]	439
6.13 Standard Method Load Calculations [Article 220, Part III].....	381	8.6 Multioutlet Assemblies [220.14(H)].....	439
6.14 Number of General Lighting and General-Purpose Receptacle Circuits [210.11(A)]	382	8.7 Receptacle Demand Load [220.14(I) and 220.47].....	440
Part C—Neutral Load Calculations	383	8.8 Air-Conditioning versus Heating Demand Load [220.60]	442
Introduction.....	383	Part B—Office, Mobile Home, Kitchen, Restaurants, and School Examples	442
6.15 Neutral Calculations—Dryers and Ranges [220.61]	383	Introduction.....	442
6.16 Service Neutral Calculation [220.61].....	384	8.9 Office Building, Example.....	443
Unit 6—Review Questions	387	8.10 Mobile Home Parks [550.31]	444
Module III—NEC Calculations Practice Exam	393	8.11 Kitchen Equipment and Restaurants	444
MODULE IV—ADVANCED NEC CALCULATIONS	401	8.12 School Optional Method Load Calculations [220.86].....	447
Unit 7—Multifamily Dwelling Calculations	403	Part C—Welder Calculations	448
Part A—Optional Method Load Calculations [Article 220, Part IV]	403	Introduction.....	448
Introduction.....	403	8.13 Arc Welders	448
7.1 Multifamily Dwelling Optional Load Calculations [220.84].....	403	8.14 Resistance Welders	450
7.2 Multifamily Dwelling Optional Method, Example [220.84].....	404	Part D—Light Industrial Calculations	452
Part B—Standard Method Load Calculations [Article 220, Part III]	405	Introduction.....	452
Introduction.....	405	8.15 Light Industrial Calculations.....	452
7.3 General Lighting and General-Use Receptacle Demand Load [220.41 and 220.45].....	406	Unit 8—Review Questions	455
7.4 Appliance Demand Load [220.53]	407	Module IV—Advanced NEC Calculations—Practice Exam	461
7.5 Dryer Demand Load [220.54].....	408	Modules III and IV—NEC Calculations Questions Code Rule Index	465
7.6 Single-Phase Dryers on Three-Phase Service [220.54].....	410	About the Author	469
7.7 Single-Phase Ranges on Single-Phase Service [220.55].....	412	About the Illustrator	470
7.8 Single-Phase Ranges on Three-Phase Service [220.55]	414	About the Mike Holt Team	471
7.9 Air-Conditioning and Heating Demand Load	416		
7.10 Service Conductor Sizing [Table 310.16]	417		