Electrical Level 1

Residential Electrical Services 26111-14

Objectives

When trainees have completed this session, they should be able to do the following:

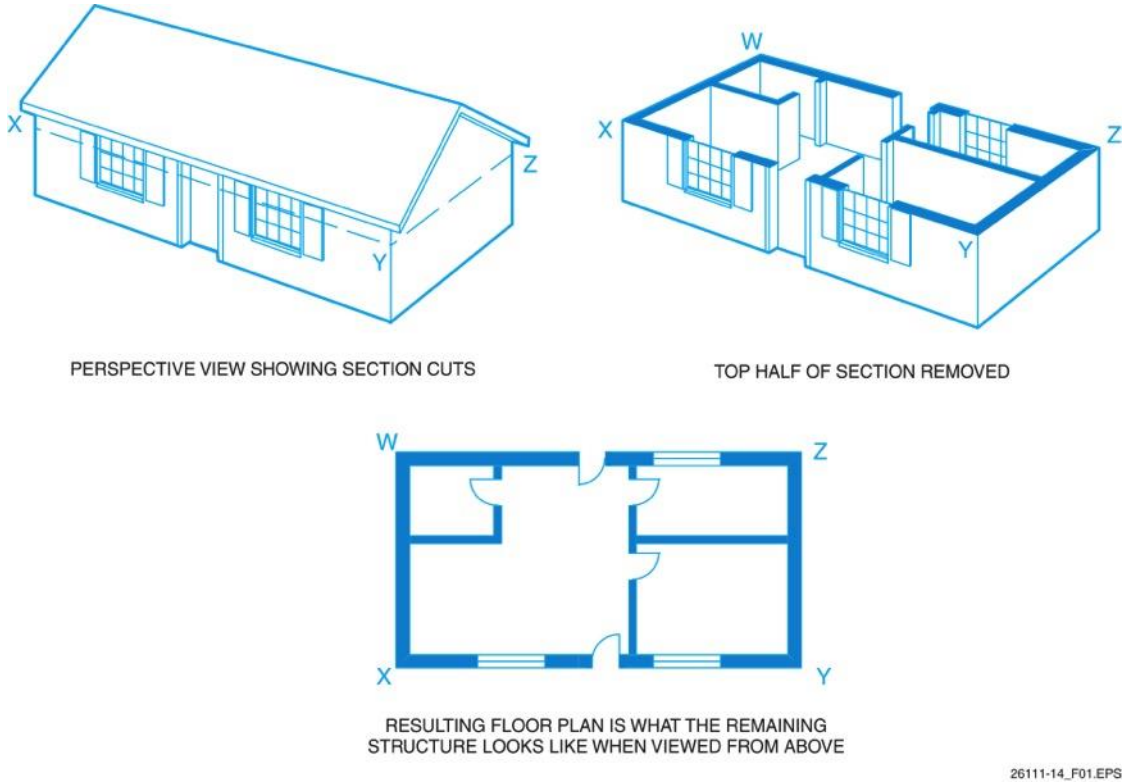
1. Explain the role of the *National Electrical Code*® in residential wiring and describe how to determine electric service requirements for dwellings.
2. Explain the grounding requirements of a residential electric service.
3. Calculate and select service-entrance equipment.
4. Select the proper wiring methods for various types of residences.
5. Compute branch circuit loads and explain their installation requirements.
6. Explain the types and purposes of equipment grounding conductors.
7. Explain the purpose of ground fault circuit interrupters and tell where they must be installed.
8. Size outlet boxes and select the proper type for different wiring methods.
9. Describe rules for installing electric space heating and HVAC equipment.
10. Describe the installation rules for electrical systems around swimming pools, spas, and hot tubs.
11. Explain how wiring devices are selected and installed.
12. Describe the installation and control of lighting fixtures.

Performance Tasks

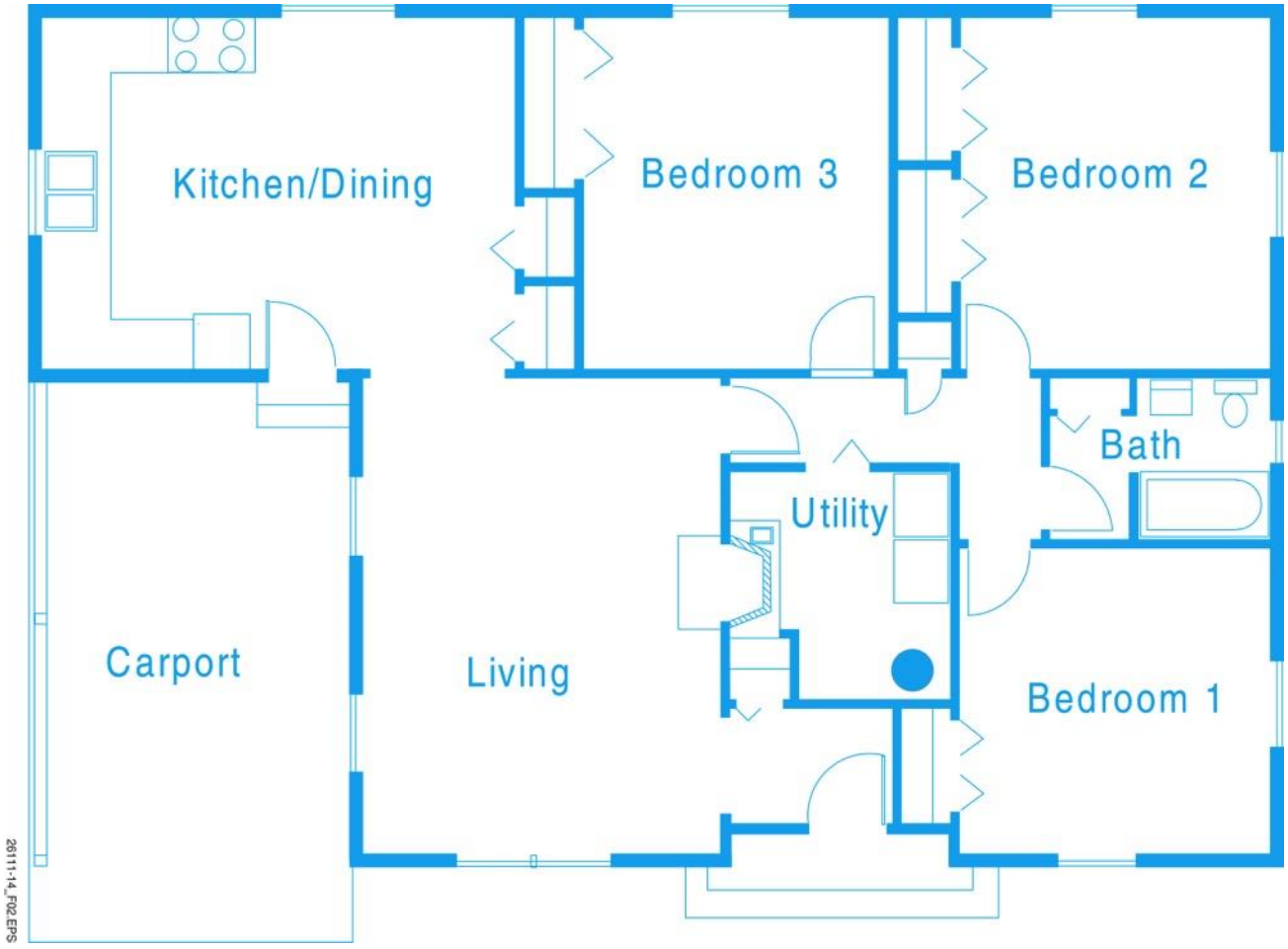
1. For a residential dwelling of a given size, and equipped with a given list of major appliances, demonstrate or explain how to:
   - Compute lighting, small appliance, and laundry loads.
   - Compute the loads for large appliances.
   - Determine the number of branch circuits required.
   - Size and select the service-entrance equipment (conductors, panelboard, and protective devices).
2. Using an unlabeled diagram of a panelboard (Performance Profile Sheet 3), label the lettered components.
3. Select the proper type and size outlet box needed for a given set of wiring conditions.

Introduction; Sizing the Electrical Service

Sizing an electrical service begins with a study of the floor plans to determine where the service and entrance and panelboard(s) will be located.



Floor Plan of Typical Residence



Calculating the Electric Service Load

General Lighting Load						Phase	Neutral
Square footage of the dwelling	[1] 1350	× 3VA =	[2] 4050	*NEC Table 220.12*			
Kitchen small appliance circuits	[3] 2	× 1500 =	[4] 3000	*NEC Section 220.52(A)*			
Laundry branch circuit	[5] 1	× 1500 =	[6] 1500	*NEC Section 220.52(B)*			
Subtotal of gen. lighting loads			[7] 8550				
Subtract 1st 3000VA per *NEC Table 220.42*			[8] 3000	× 100% =	[9] 3000		
Remaining VA times 35% per *NEC Table 220.42*			[10] 5550	× 35% =	[11] 1943		
Total demand for general lighting loads =					[12] 4943	[13]	
Fixed Appliance Loads (Nameplate or NEC FLA of motors) per *NEC Section 220.14*							
Hot water tank, 4.5kVA, 240V			[14] 4500				
Dishwasher 1.5kVA, 120V			[15] 1500				
Disposal 1/2HP, 120V per *NEC Table 430.248* = 9.8A			[16] 1176				
Blower 1/3HP, 120V per *NEC Table 430.248* = 7.2A			[17] 864				
			[18]				
			[19]				
Subtotal of fixed appliances			[20] 8040				
NEC Section 220.53 — If 3 or less fixed appliances take @ 100% =						[21]	[22]
NEC Section 220.53 — If 4 or more fixed appliances take @ 75% =						[23] 6030	[24]
Other Loads per *NEC Section 220.14*							
Electric Range per *NEC Section 220.55* [neutral @ 70% per *NEC Section 220.61(B)*]						[25] 8000	[26]
Electric Dryer per *NEC Section 220.54* [neutral @ 70% per *NEC Section 220.61(B)*]						[27] 5500	[28]
Electric Heat per *NEC Section 220.51* / Air Conditioning *NEC Section 220.82(C)*		omit smaller load per *NEC Section 220.60*				[29]	[30]
Largest Motor = 1176		× 25% (per *NEC Section 430.24*) =				[31] 294	[32]
Total VA Demand =						[33] 24767	[34]
(VA divided by 240 volts) **Amps** =						[35] **103**	[36]
Service OCD and minimum size grounding electrode conductor						[37] 125	[38]
AWG per *NEC Section 310.15(B)(7); NEC Section 220.61 and Table 310.15(B)(16)* for neutral						[39]	[40]

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Sizing Residential Neutral Conductors

General Lighting Load							Phase		Neutral	
Square footage of the dwelling	[1]	1350	× 3VA =	[2]	4050	*NEC Table 220.12*				
Kitchen small appliance circuits	[3]	2	× 1500 =	[4]	3000	*NEC Section 220.52(A)*				
Laundry branch circuit	[5]	1	× 1500 =	[6]	1500	*NEC Section 220.52(B)*				
Subtotal of gen. lighting loads				[7]	8550					
Subtract 1st 3000VA per *NEC Table 220.42*				[8]	3000	× 100% =	[9]	3000		
Remaining VA times 35% per *NEC Table 220.42*				[10]	5550	× 35% =	[11]	1943		
Total demand for general lighting loads =							[12]	4943	[13]	4943
Fixed Appliance Loads (Nameplate or NEC FLA of motors) per *NEC Section 220.14*										
Hot water tank, 4.5kVA, 240V				[14]	4500					
Dishwasher 1.5kVA, 120V				[15]	1500					
Disposal 1/2HP, 120V per *NEC Table 430.248* = 9.8A				[16]	1176					
Blower 1/3HP, 120V per *NEC Table 430.248* = 7.2A				[17]	864					
				[18]						
				[19]						
Subtotal of fixed appliances				[20]	8040					
NEC Section 220.53 — If 3 or less fixed appliances take @ 100% =							[21]		[22]	3540
NEC Section 220.53 — If 4 or more fixed appliances take @ 75% =							[23]	6030	[24]	
Other Loads per *NEC Section 220.14*										
Electric Range per *NEC Section 220.55* [neutral @ 70% per *NEC Section 220.61(B)]*							[25]	8000	[26]	5600
Electric Dryer per *NEC Section 220.5* [neutral @ 70% per *NEC Section 220.61(B)]*							[27]	5500	[28]	3850
Electric Heat per *NEC Section 220.51* / Air Conditioning *NEC Section 220.82(C)*			omit smaller load per *NEC Section 220.60*				[29]		[30]	
Largest Motor = 1176			× 25% (per *NEC Section 430.24*) =				[31]	294	[32]	294
Total VA Demand =							[33]	24767	[34]	18227
(VA divided by 240 volts) **Amps** =							[35]	**103**	[36]	**76**
Service OCD and minimum size grounding electrode conductor							[37]	125	[38]	8 AWG
AWG per *NEC Section 310.15(B)(7); NEC Section 220.61 and Table 310.15(B)(16)* for neutral							[39]	2 AWG	[40]	4 AWG

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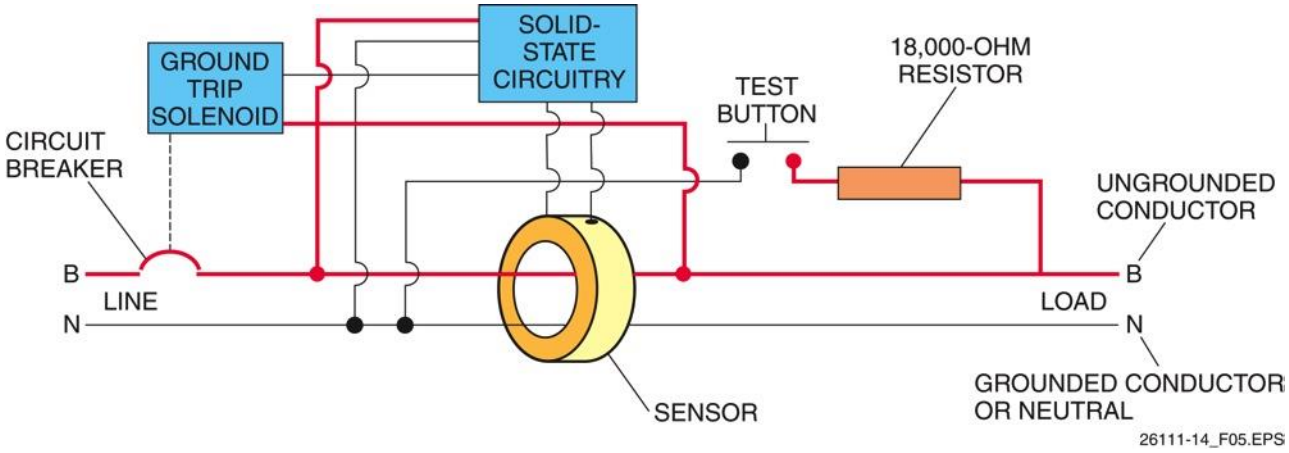
Sizing the Load Center

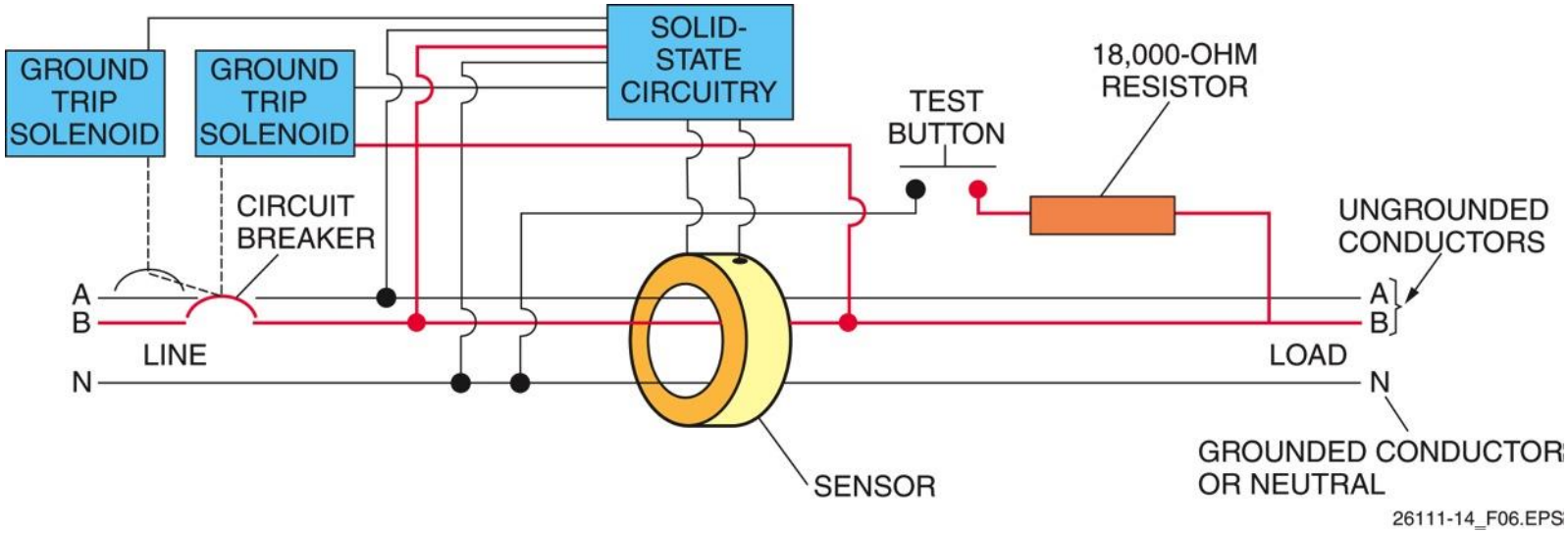
- Each ungrounded conductor in all circuits must be provided with overcurrent protection in the form of fuses or circuit breakers.
- Fuses and circuit breakers are designed to protect the conductors and equipment. People are protected by ground fault circuit interrupters (GFCIs).



Performance Task

Have the trainees calculate various branch loads.

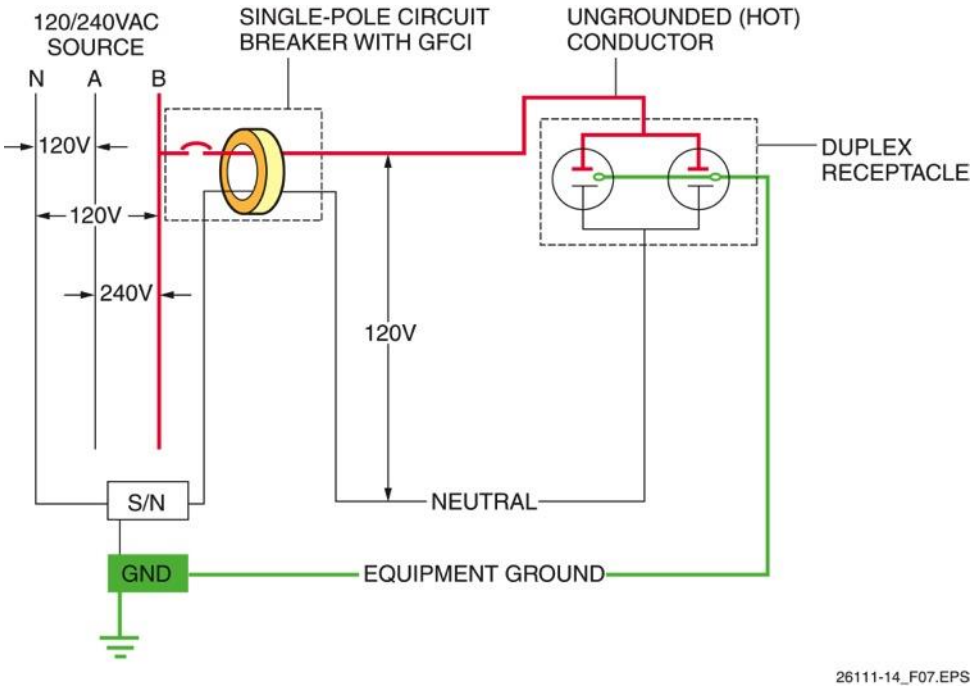
Operating Characteristics of a Two-Pole GFCI



- A two-pole GFCI continuously monitors the balance between two hot conductors and the neutral conductor.
- Any current imbalance above 4mA will trip the device.

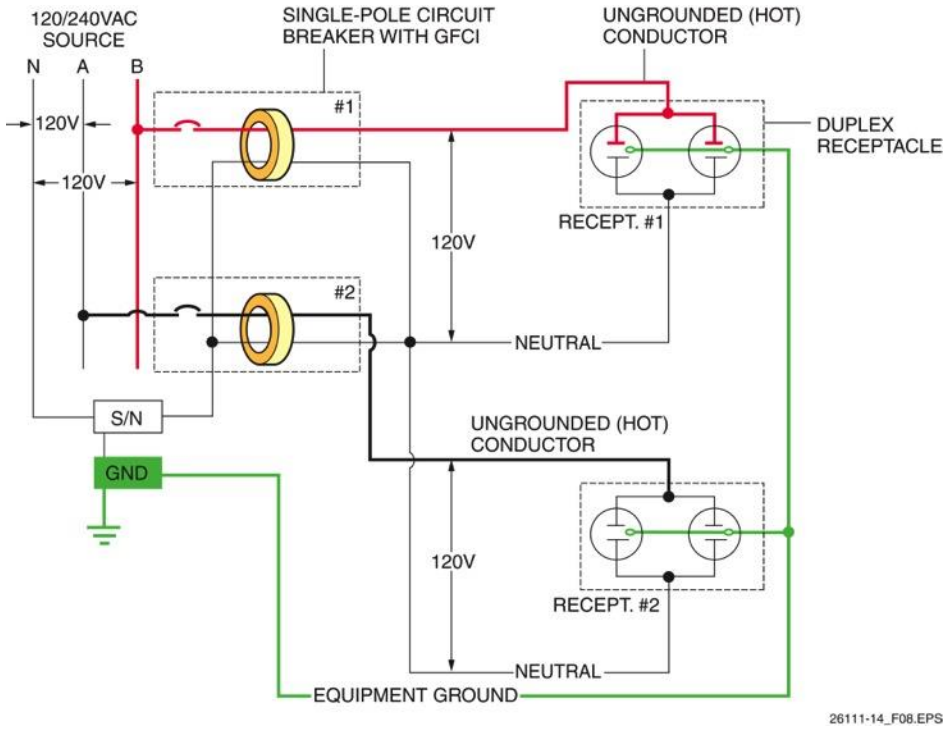
Single-Pole GFCI Circuit Breakers

- A GFCI breaker is installed in the panel like any other breaker, except the white wire pigtail is attached to the panel neutral assembly.
- The neutral and ungrounded conductors are both terminated in the breaker.



Two-Pole GFCI Circuit Breakers

- If two GFCI breakers are used with a common neutral, one of the breakers will trip when a load is applied to the second receptacle.
- A two-pole GFCI breaker eliminates this problem by passing the currents through the same sensor.



Next Session…

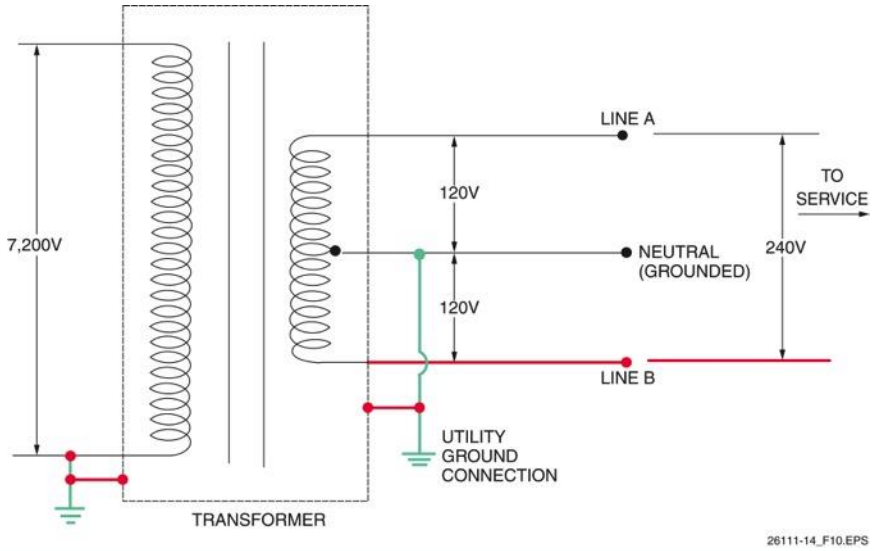
Direct-Wired GFCI Receptacles; Arc Fault Circuit Interrupters

- Direct-wired GFCI receptacles provide ground fault protection on 120V circuits.
- GFCI receptacles also provide downstream protection to other outlets on the same circuit.

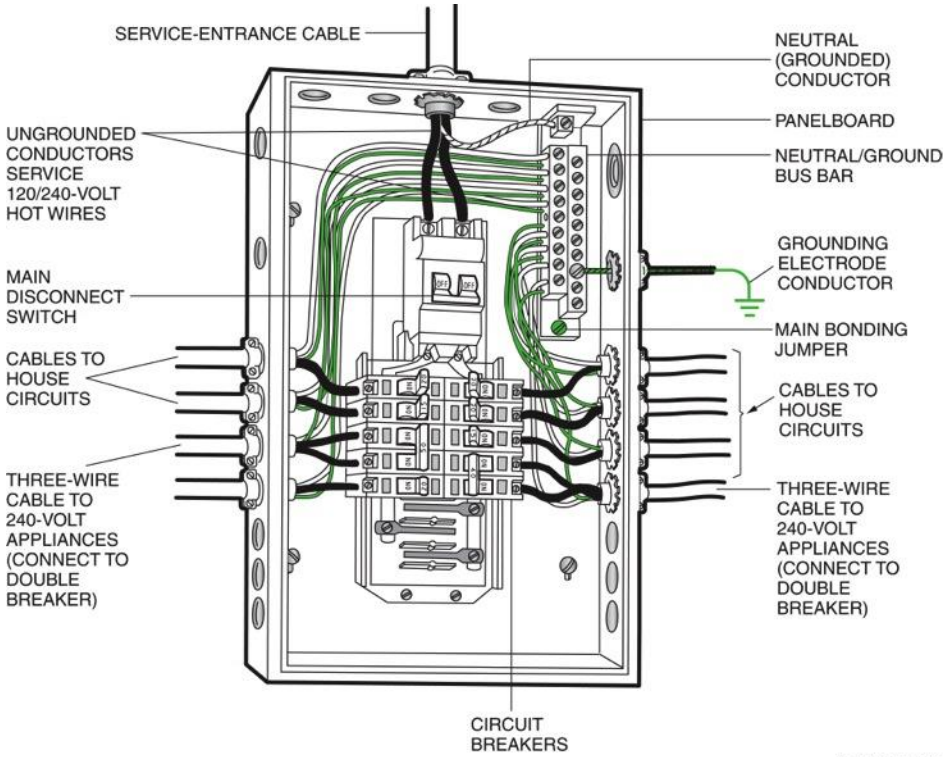
Grounding

Grounding

- There are two classifications of grounding, system grounding and equipment grounding.
- System grounding includes the service entrance and all circuit conductors connected to form an effective ground fault path and connected to system grounding electrodes as listed in ***NEC Section 250.52(A)***.



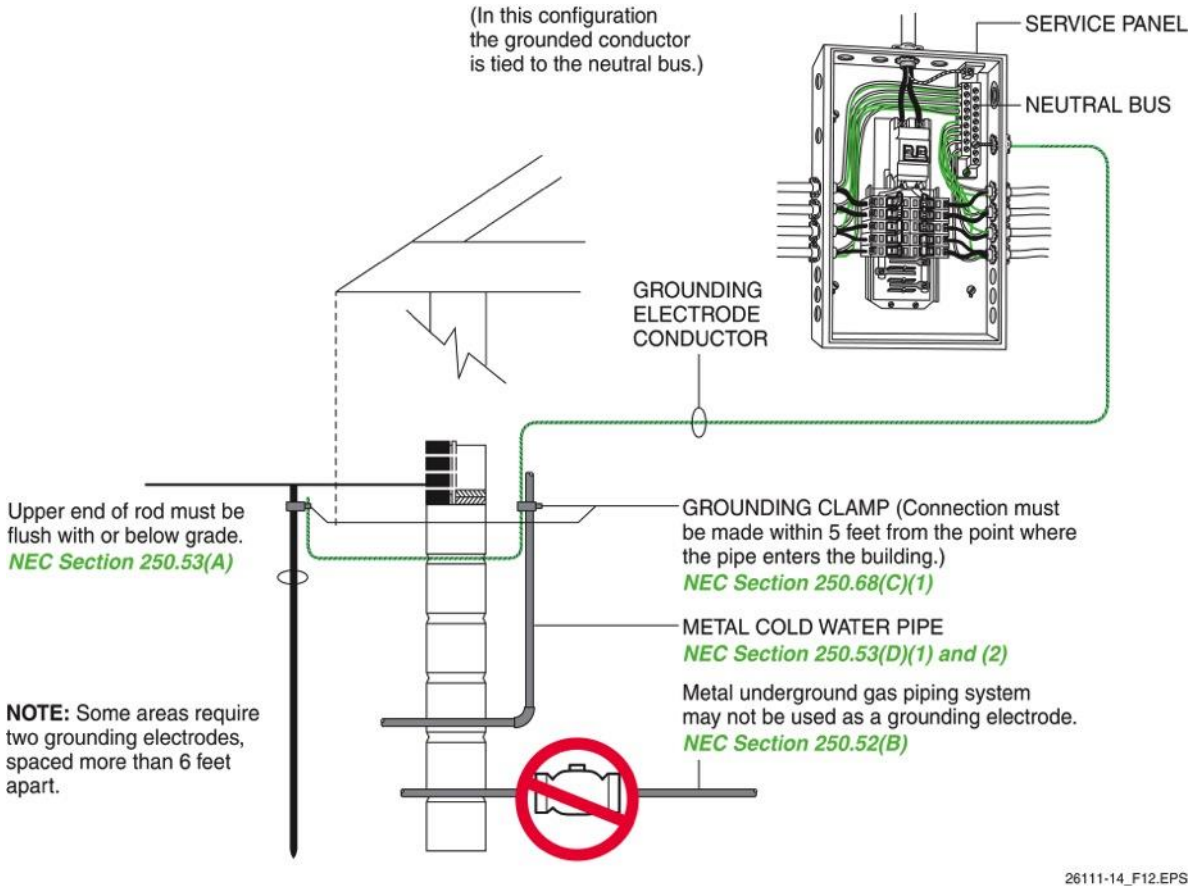
Interior View of Panelboard Showing Connections



Performance Task

Have the trainees identify the components of a panelboard.

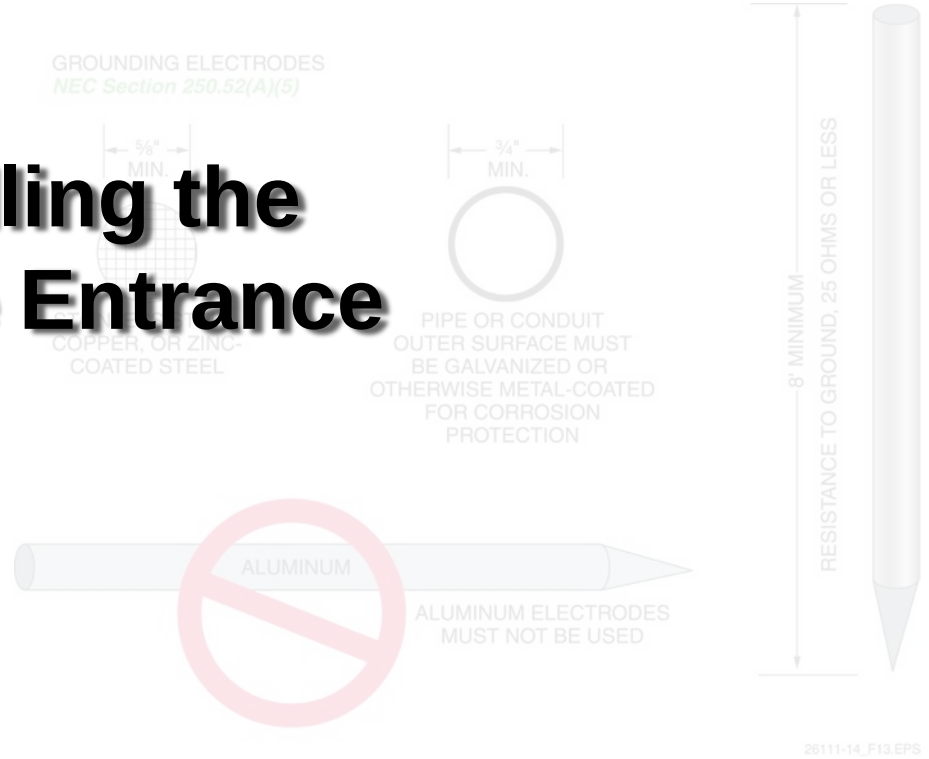
Components of a Residential Grounding System



Next Session…

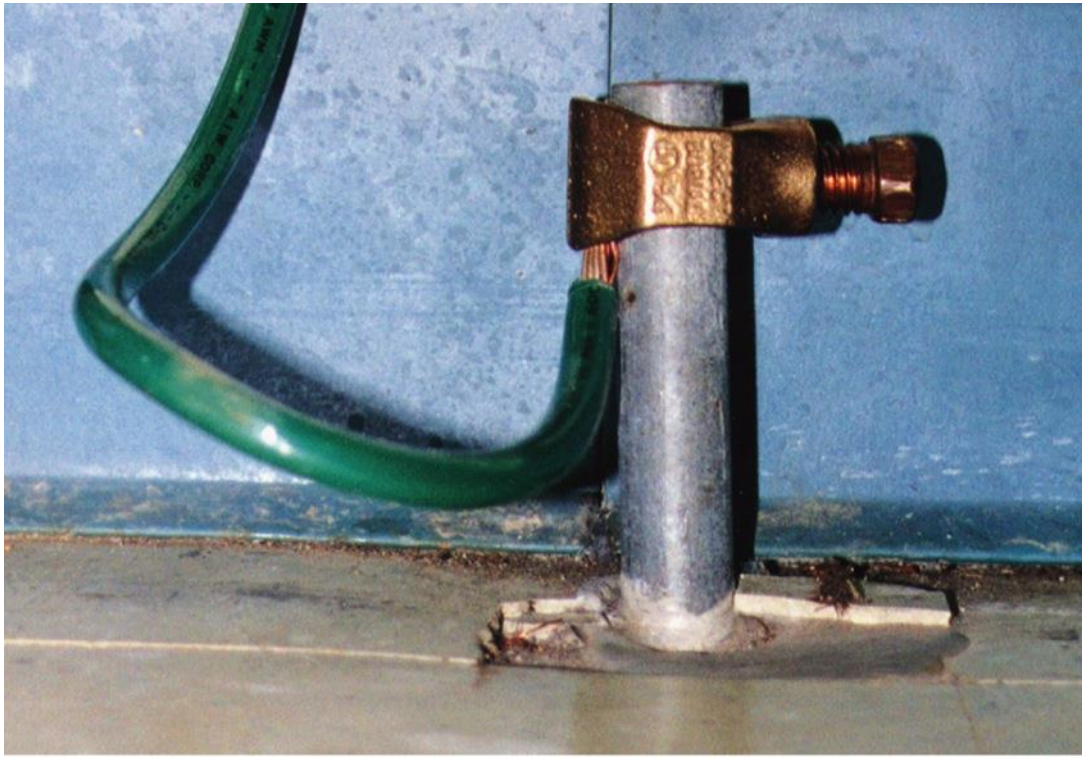
Specifications for Rod and Pipe Grounding Electrodes

- Rod, pipe, and plate electrodes must be buried below the permanent moisture level and free of nonconductive coatings such as paint or enamel.
- Pipe may be driven at an angle if the presence of a rock substrate prevents the rod or pipe from being driven vertically to a minimum depth of 8'.



Installing the Service Entrance

Grounding Conductors



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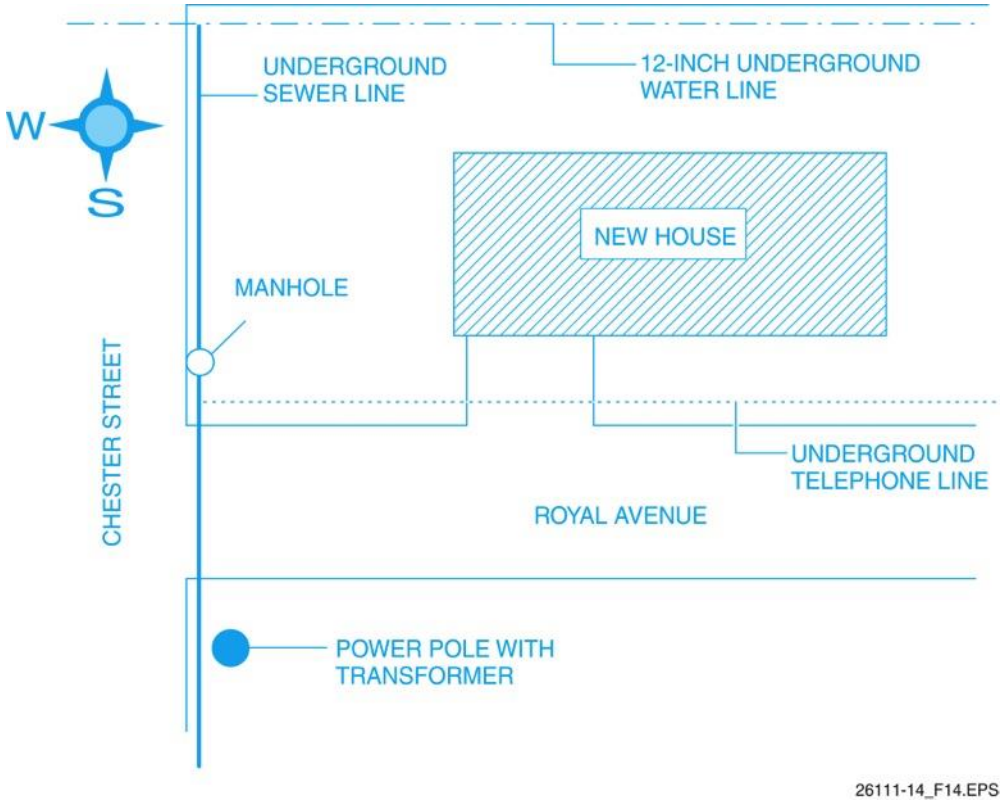
A grounding electrode should be connected to a rod that travels through the floor and at least 8' into the ground.

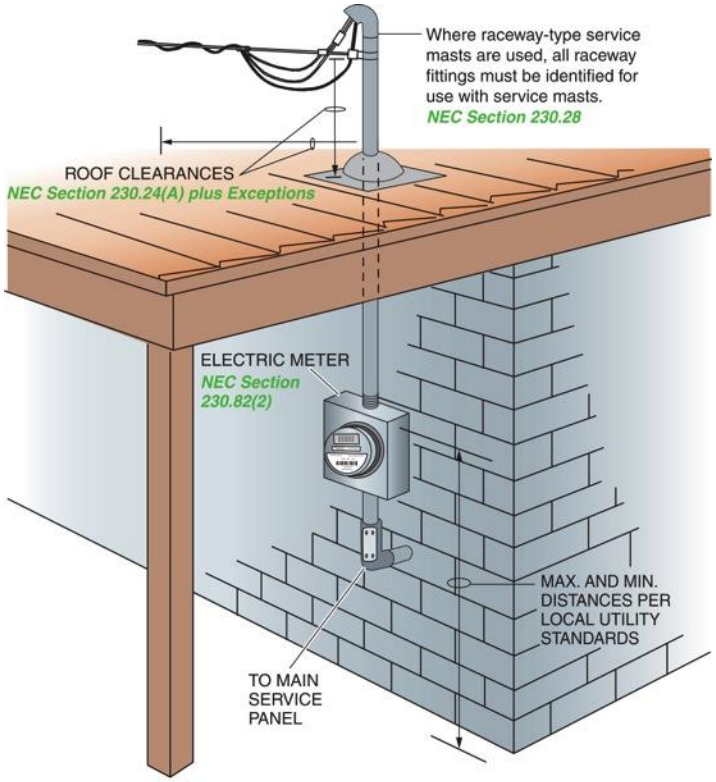
Installing the Service Entrance



- The plot plan is used to determine the location of the nearest power pole when selecting a location for the service entrance.
- All service installations must be coordinated with the local power company.

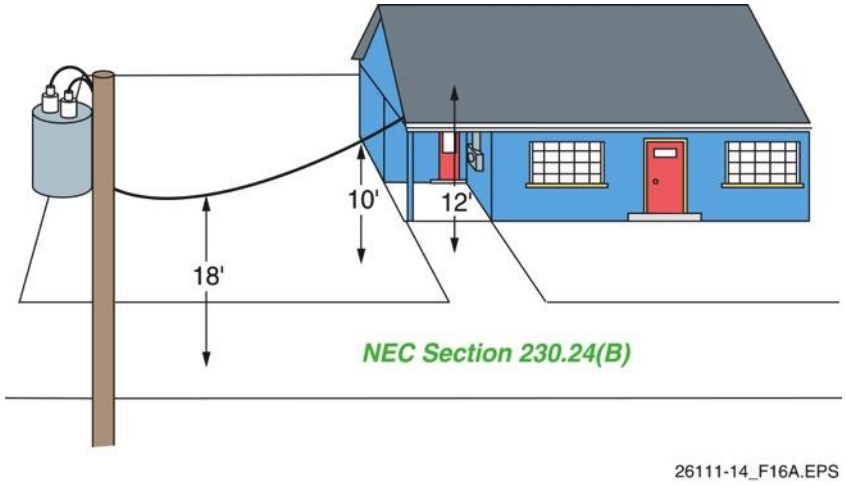
NEC® Sections Governing Service Mast Installations

Follow the *NEC*® clearance requirements when installing the service mast.



Vertical Clearances of Service Drop Conductors

- Service conductors must be a minimum of 10' above the ground at all times and no less than 15' when passing over residential driveways.
- The minimum clearance is 18' when conductors pass over public roadways.



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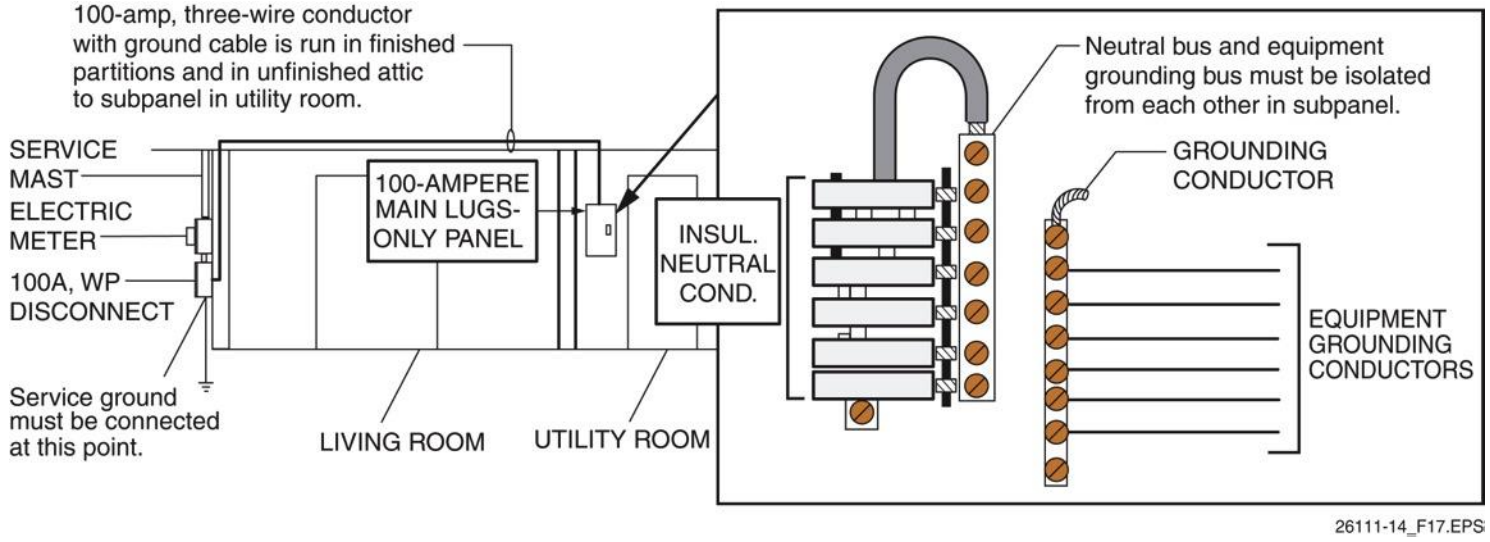
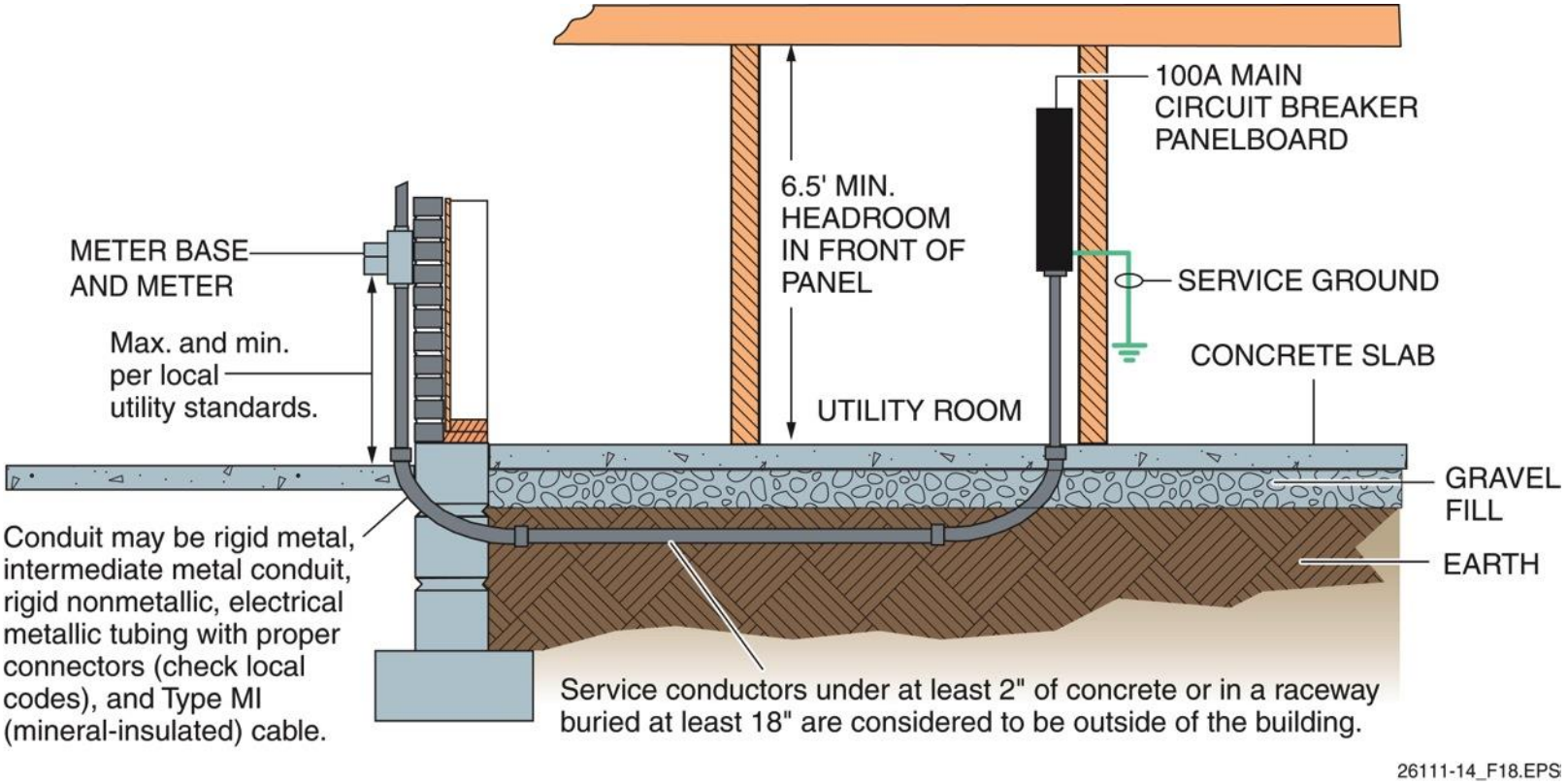
Panelboard Location

- The main service disconnect is normally located in a basement or utility area on an outside wall.
- The *NEC*® requires that the main service disconnect be located in a readily accessible area, and if indoors, located nearest the point of entry of the service conductors.



Alternate Method of Service Installation for the Sample Residence

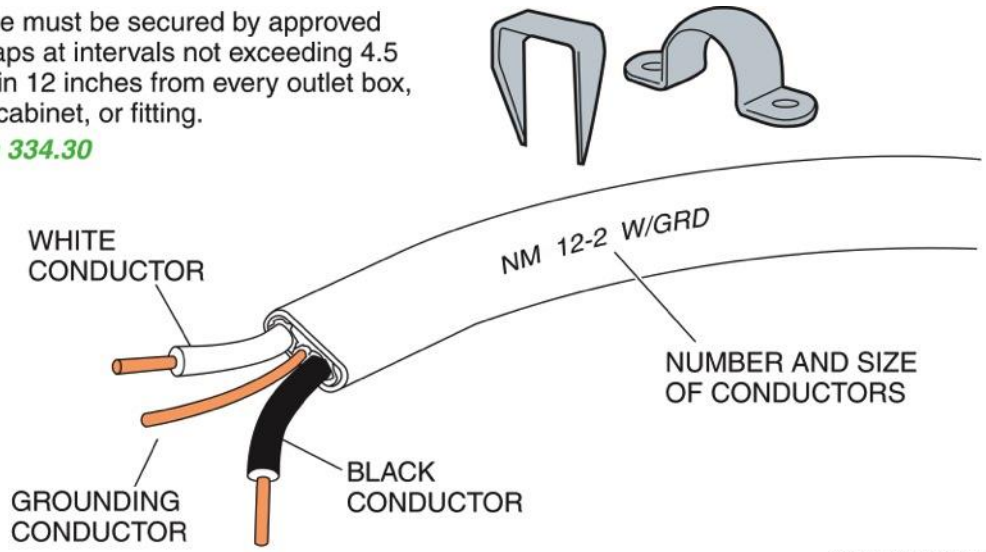


Wiring Methods

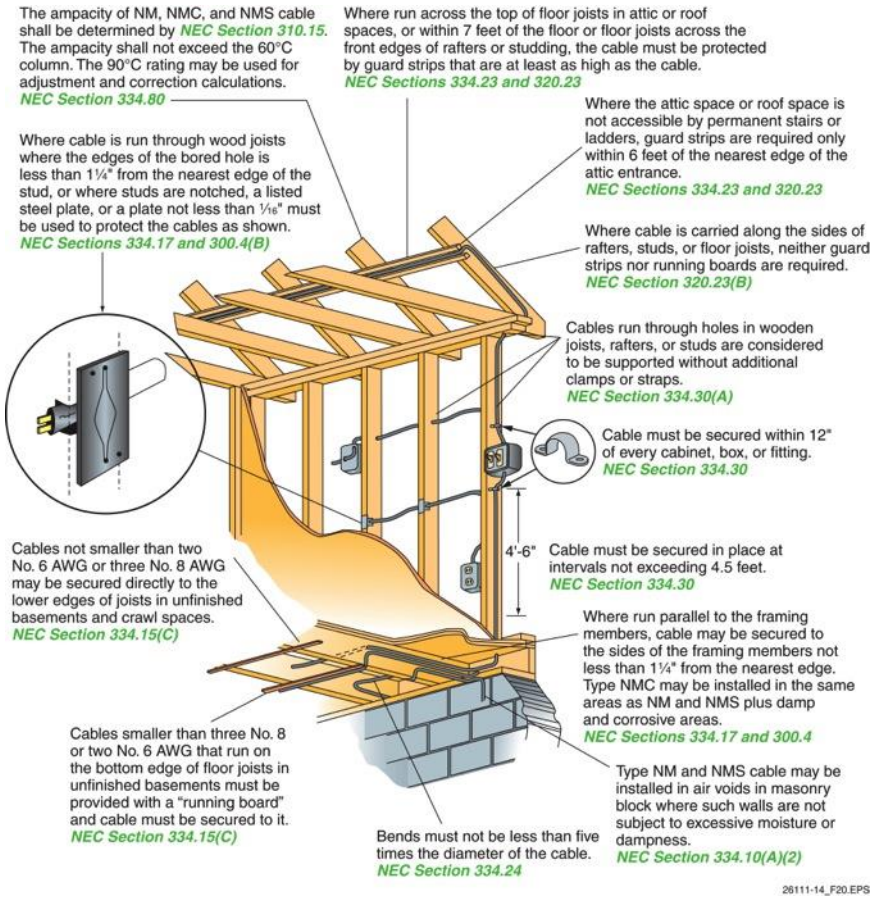
- Most residences are wired using sheathed cable (Type NM) and/or raceway systems.
- The method selected depends on the local codes, type of building construction, and location of the wiring in the building.

Type NM cable must be secured by approved staples or straps at intervals not exceeding 4.5 feet, and within 12 inches from every outlet box, junction box, cabinet, or fitting.

NEC Section 334.30



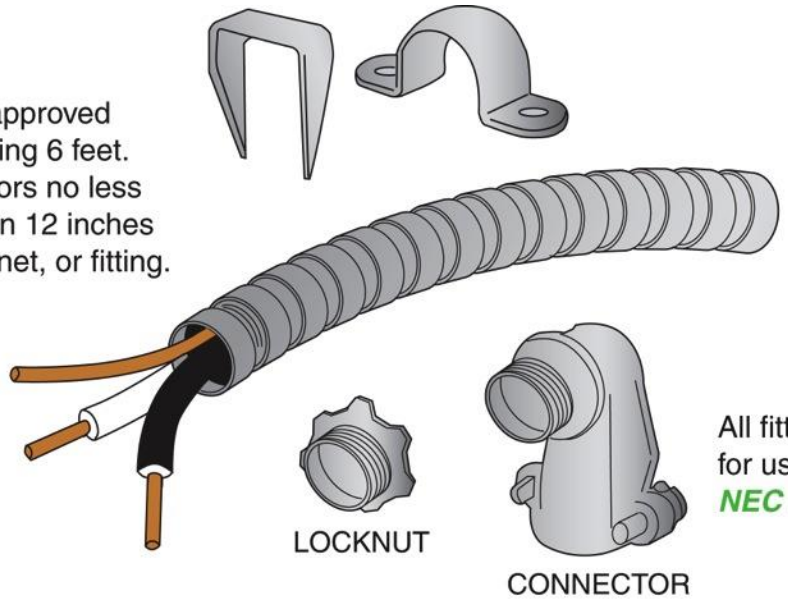
NEC® Sections Governing the Installation of Type NM Cable



Metal-Clad Cable

Metal-clad (MC) cable offers both mechanical protection and a continuous grounding bond without the need for additional grounding conductors.

Type MC cable must be secured using approved staples or straps at intervals not exceeding 6 feet. Cables containing four or fewer conductors no less than No. 10 AWG must be secured within 12 inches from every outlet box, junction box, cabinet, or fitting. ***NEC Section 330.30(B)***



All fittings must be listed for use with Type MC cable. ***NEC Section 330.40***

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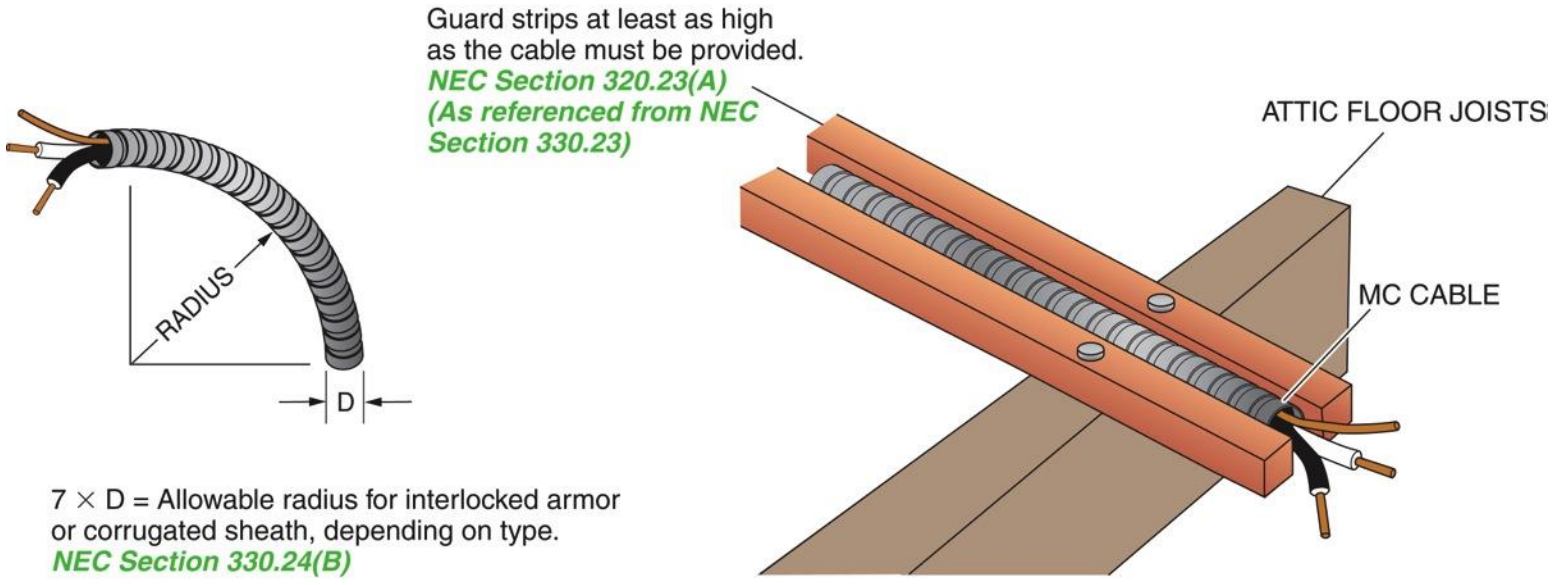
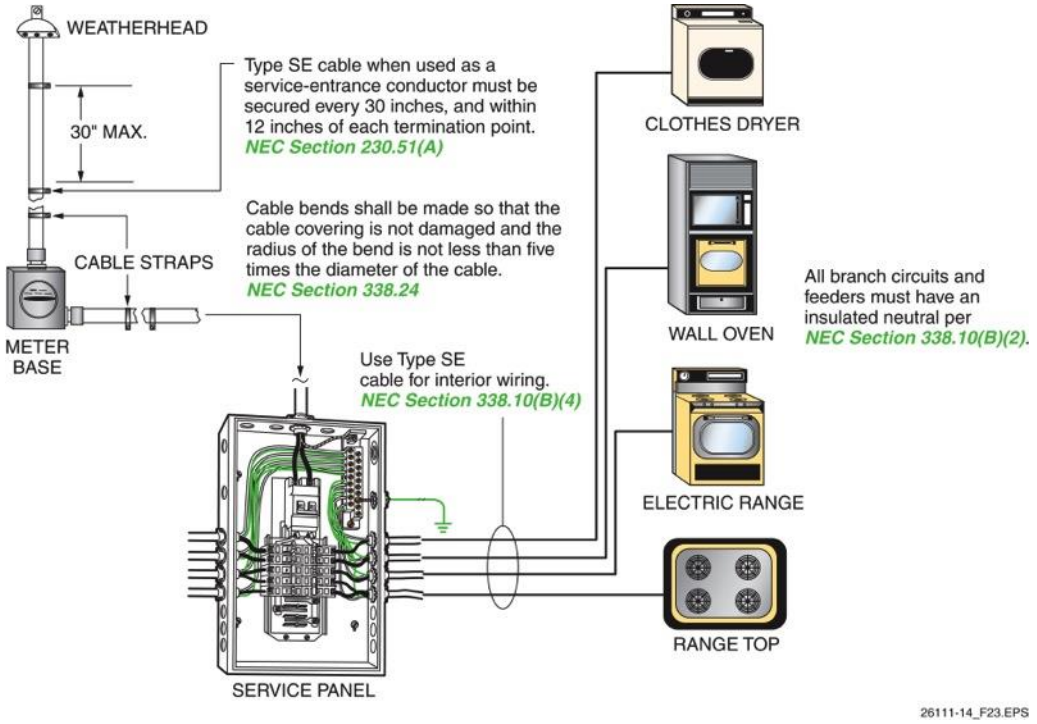
NEC® Sections Governing the Installation of Type MC Cable

- MC must be installed and protected per *NEC*® requirements.
- Type UF cable is similar to NM but includes a weather-resistant jacket for direct burial.

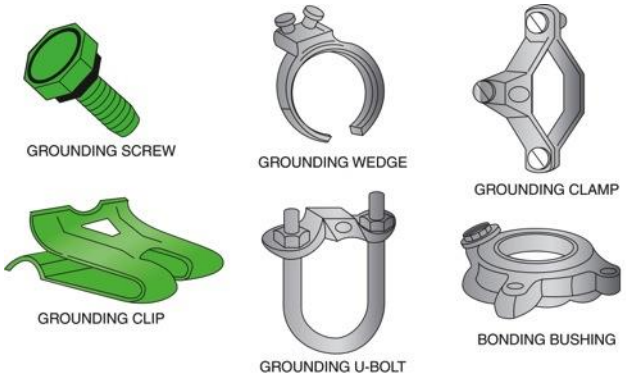


NEC® Sections Governing Type SE Cable

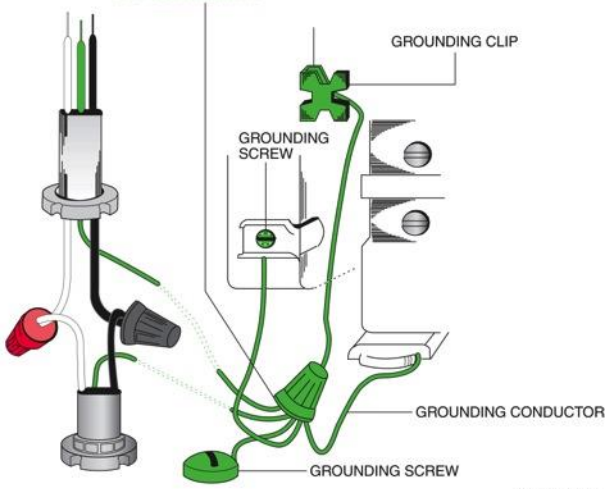
- Service-entrance (Type SE) and underground service-entrance (Type USE) are used to route power for electrical services.
- Type SE is available with an insulated grounded conductor for interior wiring systems.
- Various types of raceways are used to protect conduit in residential applications.



Equipment Grounding System

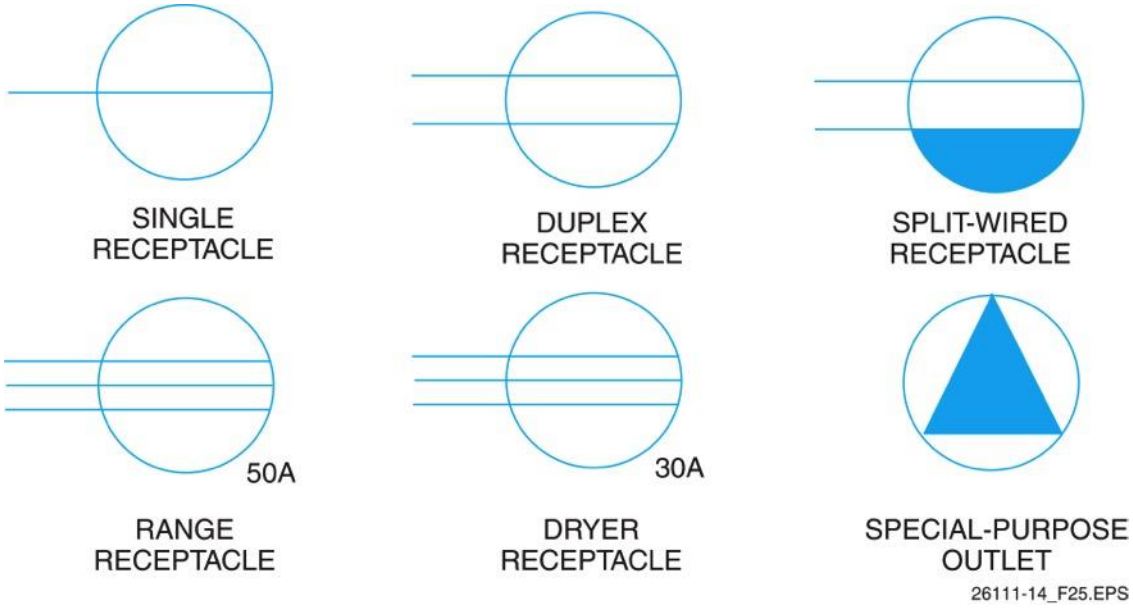


Where splices are made in a junction box, the grounding conductors must be spliced to the metal junction box.
NEC Section 250.148



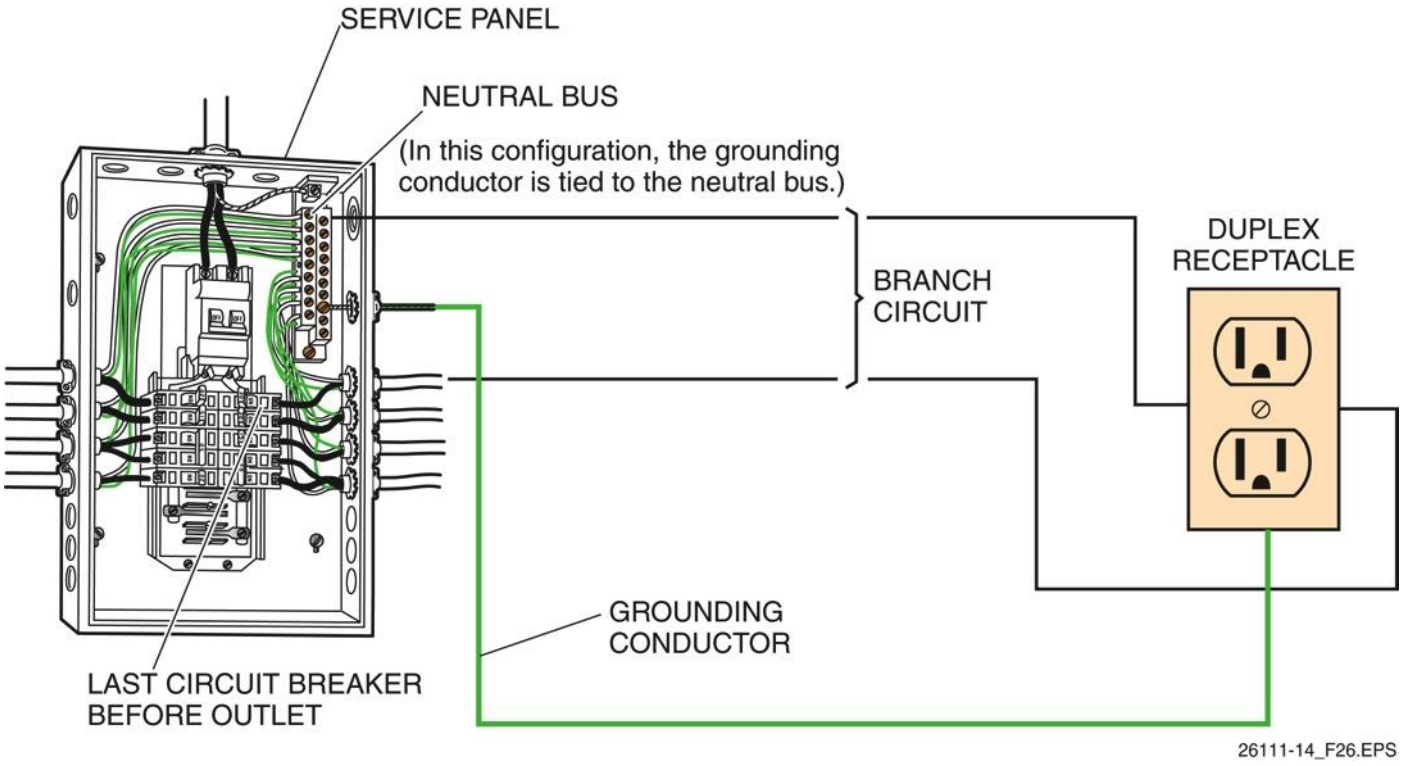
Branch Circuit Layout for Power

- Residences typically include several types of receptacle symbols on the electrical plan.
- Special receptacles such as ranges and clothes dryers may also be marked with their amperage requirements.

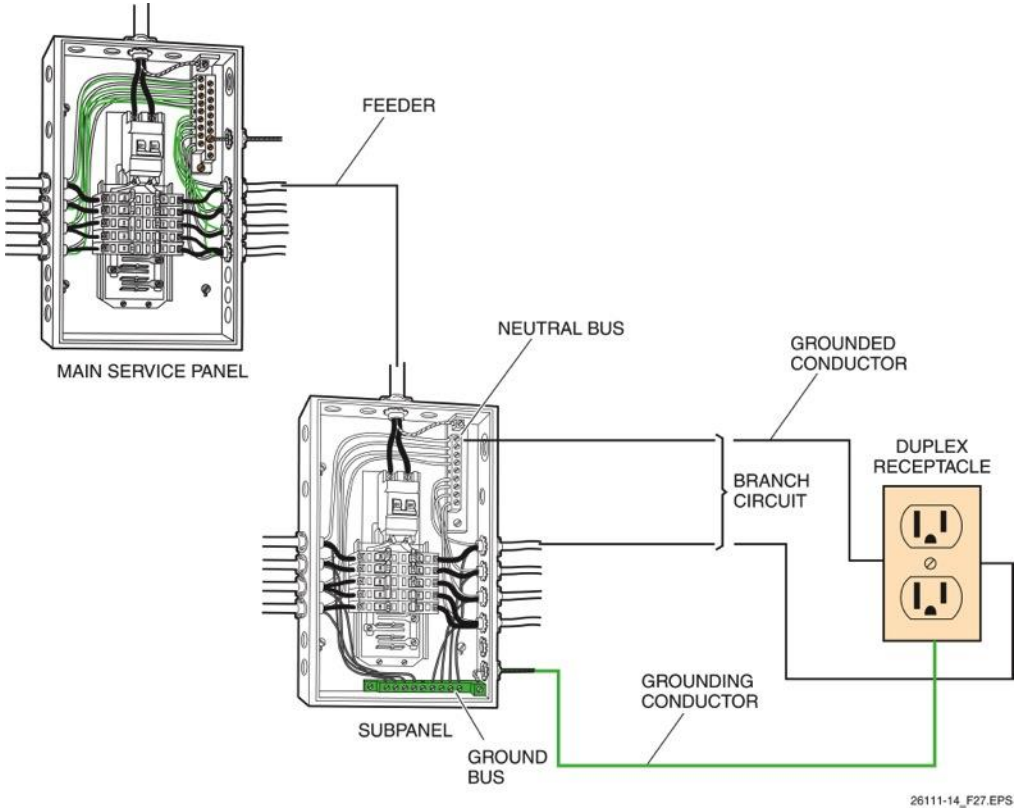


Branch Circuits and Feeders

The conductors that extend from the panelboard to the various outlets are known as branch circuits.

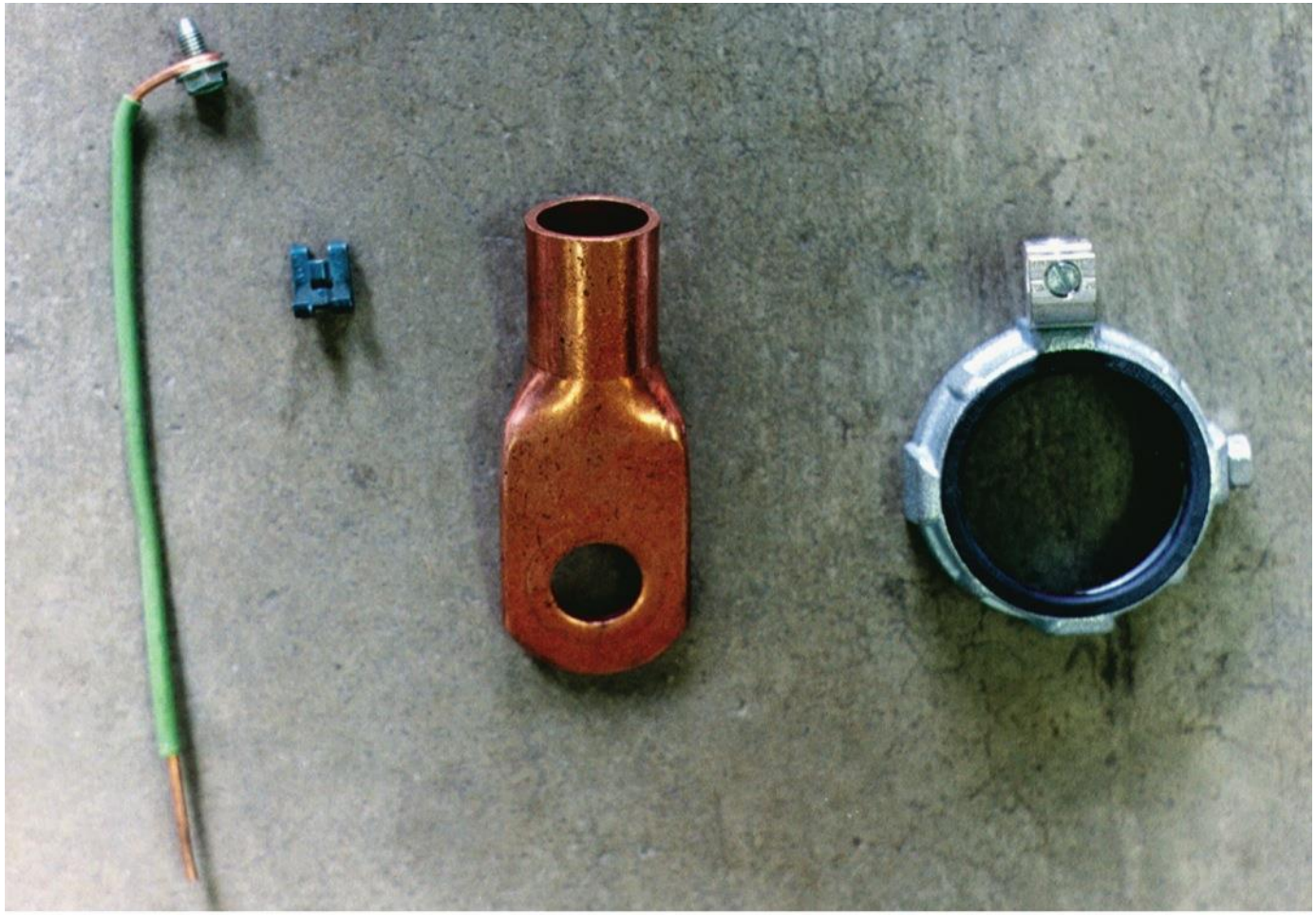


A Feeder Being Used to Feed a Subpanel from the Main Service Panel



A feeder consists of all conductors between the service equipment and the final overcurrent device.

Grounding Devices



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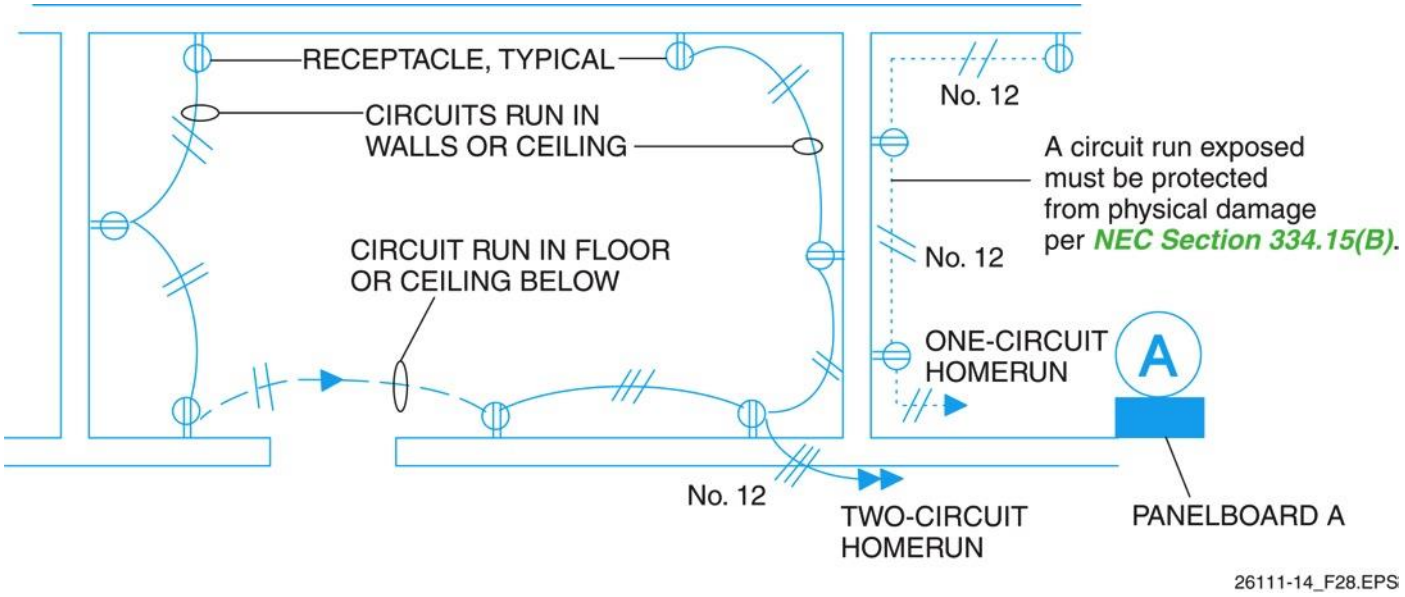
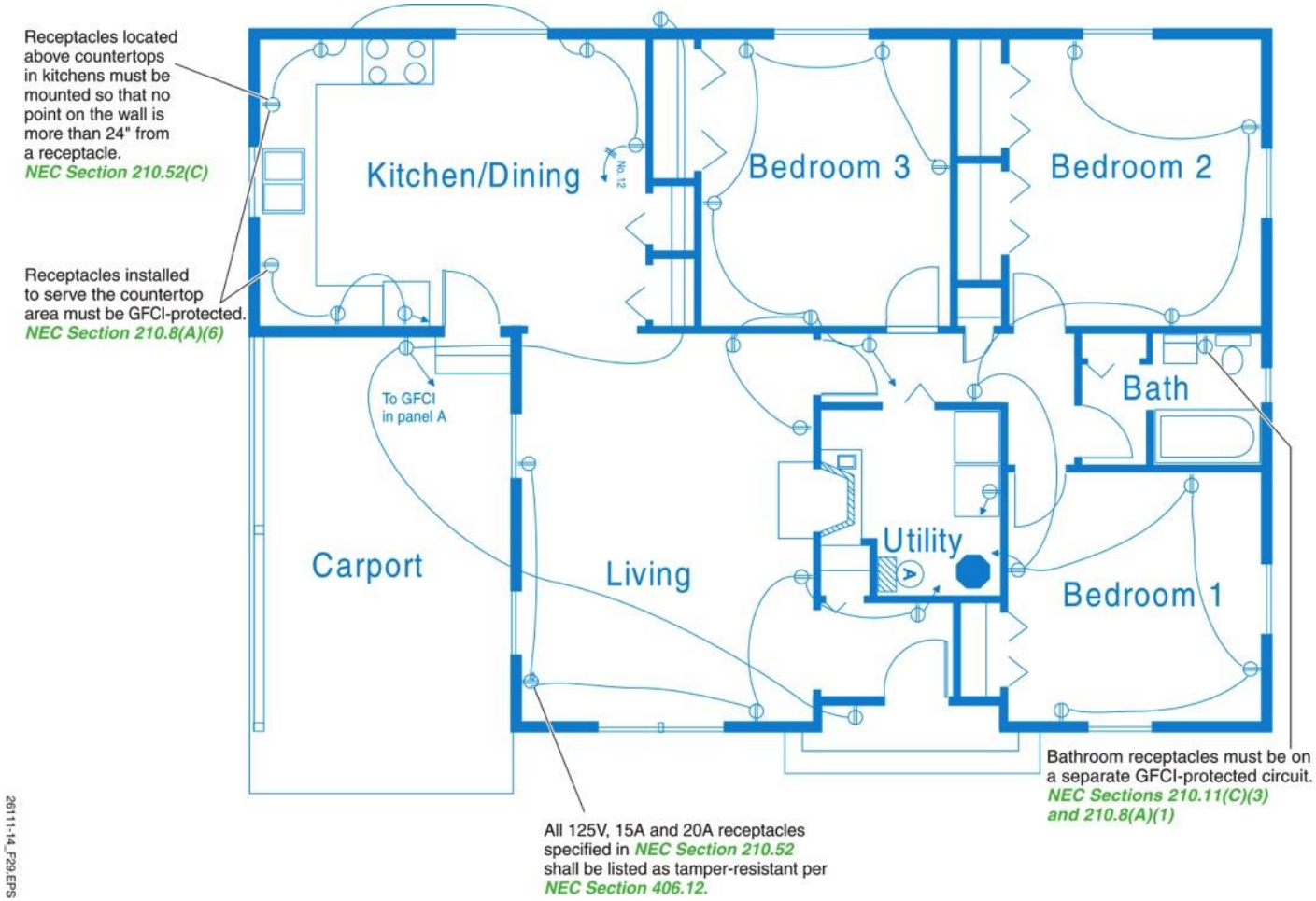
Types of Branch Circuit Lines Shown on Electrical Working Drawings

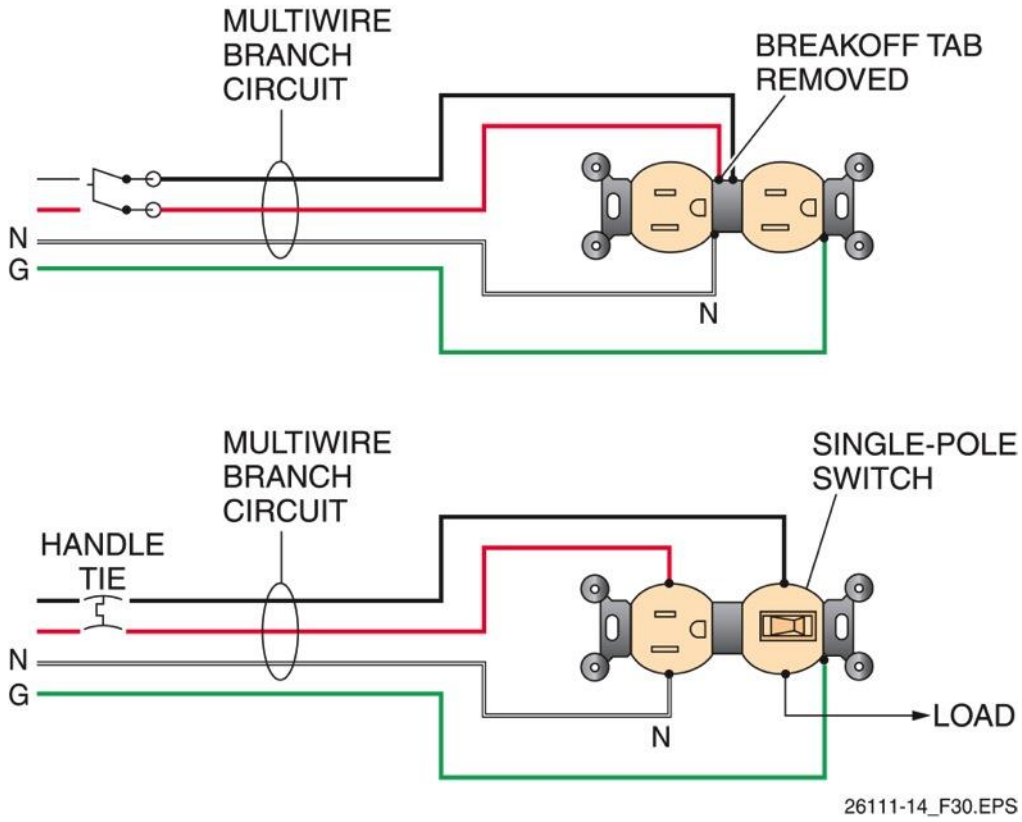
A basic branch circuit requires two wires or conductors to provide a continuous path for the flow of electric current, plus a third wire for equipment grounding.



Locating Receptacles



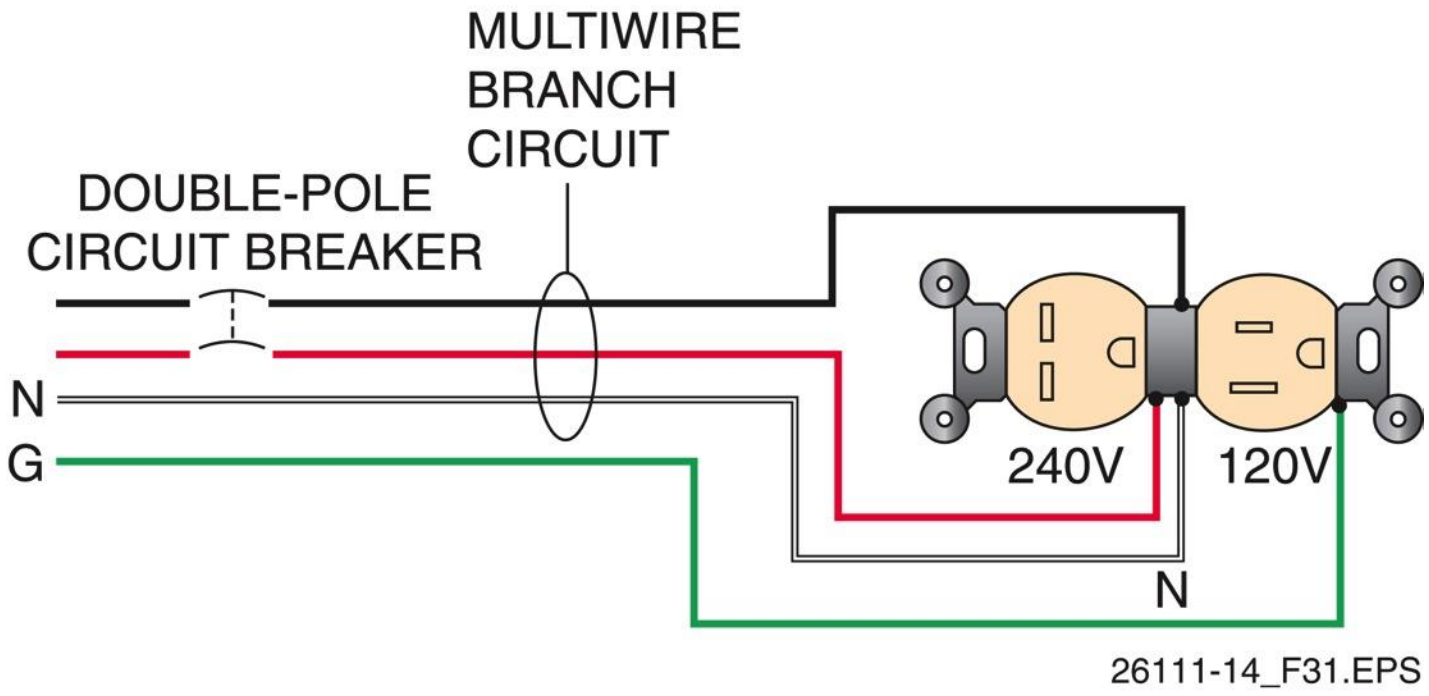
Split-Wired Duplex Receptacles; Multiwire Branch Circuits



A split-wired receptacle allows a lamp to be controlled by a switch and leaves the other outlet open for other devices to be plugged in.

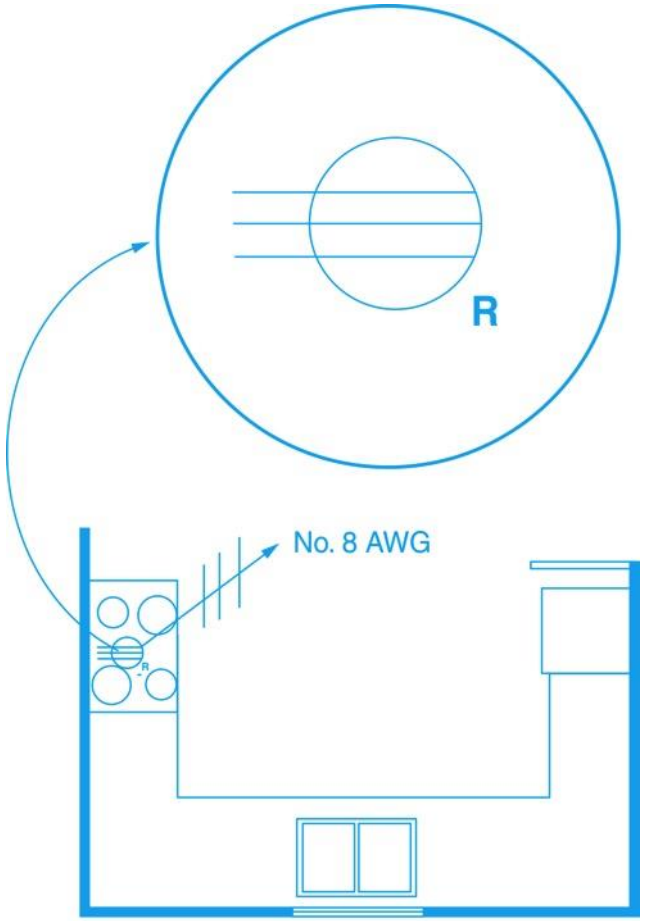
Combination Receptacle

Combination receptacles can supply two voltages in a multiwire branch circuit.



240-Volt Circuits

- Large appliances such as electric ranges, clothes dryers, and water heaters operate on 240V and are each fed by their own circuit connected to a two-pole breaker in the panelboard.
- The conductor size and overcurrent protection for 240V loads must be calculated per the *NEC*®.



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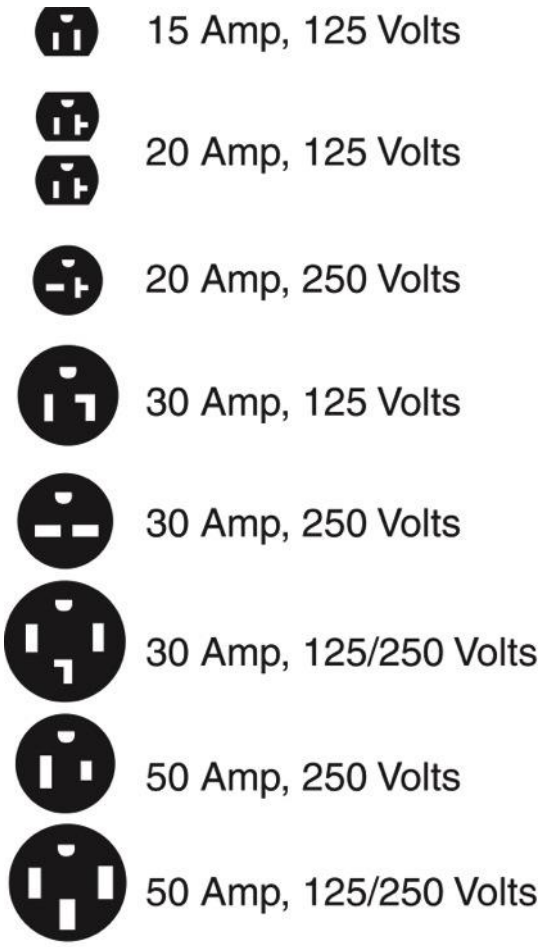
Residential Receptacle Configurations

Receptacles are supplied in unique configurations to match specific voltage and amperage combinations.



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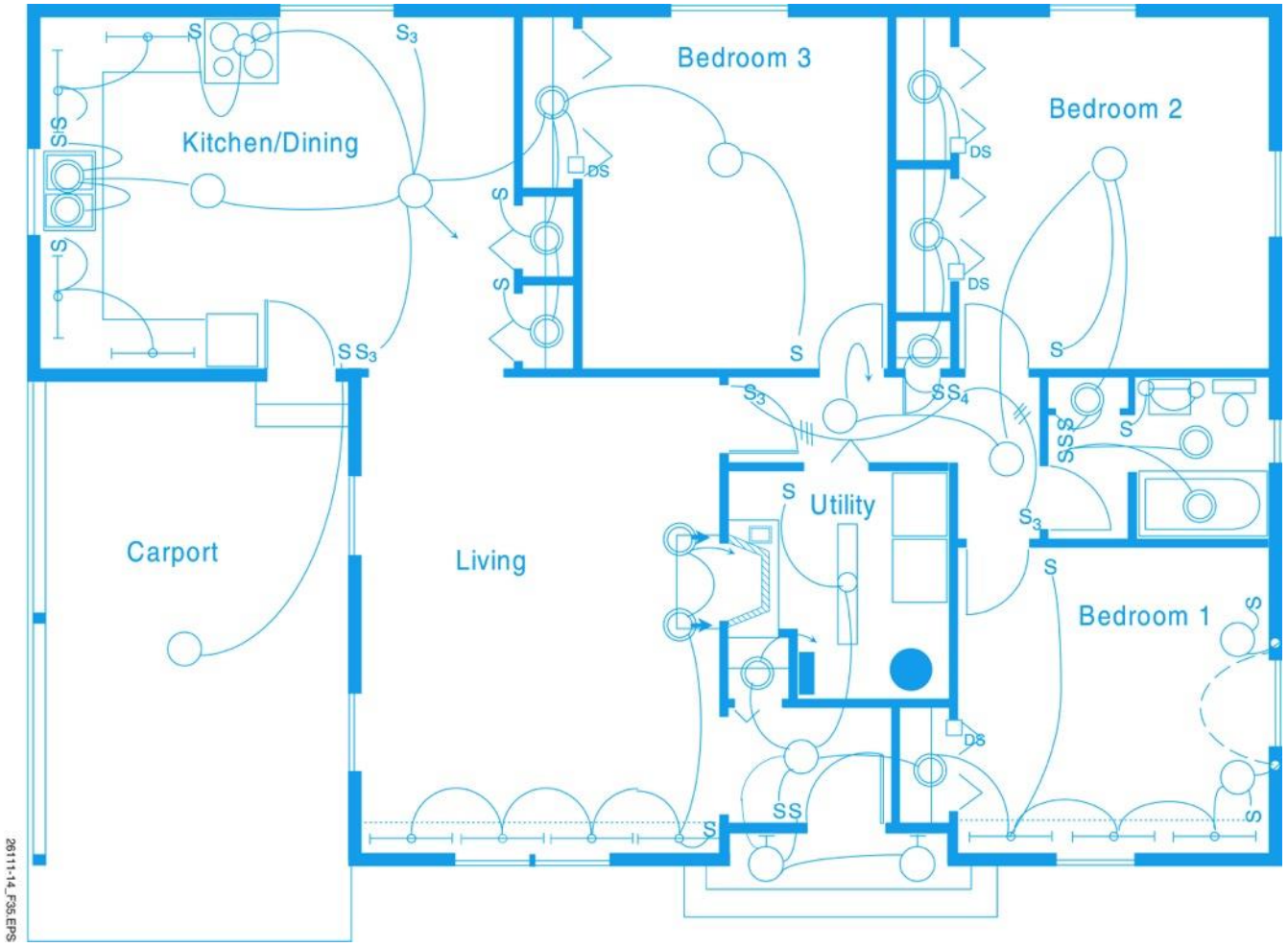
Next Session…

Branch Circuit Layout for Lighting

Branch Circuit Layout for Lighting



Symbols

SURFACE-MOUNTED CEILING LIGHTING FIXTURE WITH INCANDESCENT LAMP

SURFACE-MOUNTED WALL LIGHTING FIXTURE WITH INCANDESCENT LAMP

RECESSED CEILING LIGHTING FIXTURE WITH INCANDESCENT LAMP

DIRECTIONAL RECESSED CEILING LIGHTING FIXTURE WITH INCANDESCENT LAMP
ARROW INDICATES DIRECTION THAT LAMP IS POINTED

SURFACE-MOUNTED CEILING LIGHTING FIXTURE WITH FLUORESCENT LAMP

SINGLE-POLE SWITCH

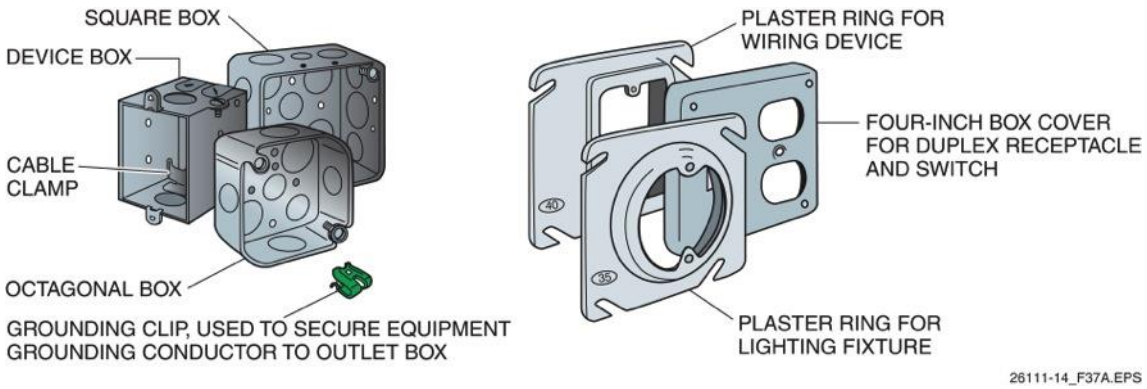
THREE-WAY SWITCH

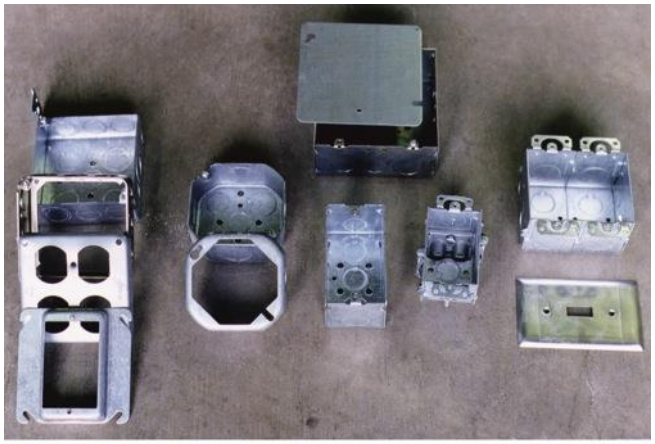
DOOR-ACTUATED SWITCH

26111-14_F36.EPS

Outlet Boxes

Outlet boxes are selected for the application and type of construction, and sized using ***NEC Section 314.16***.



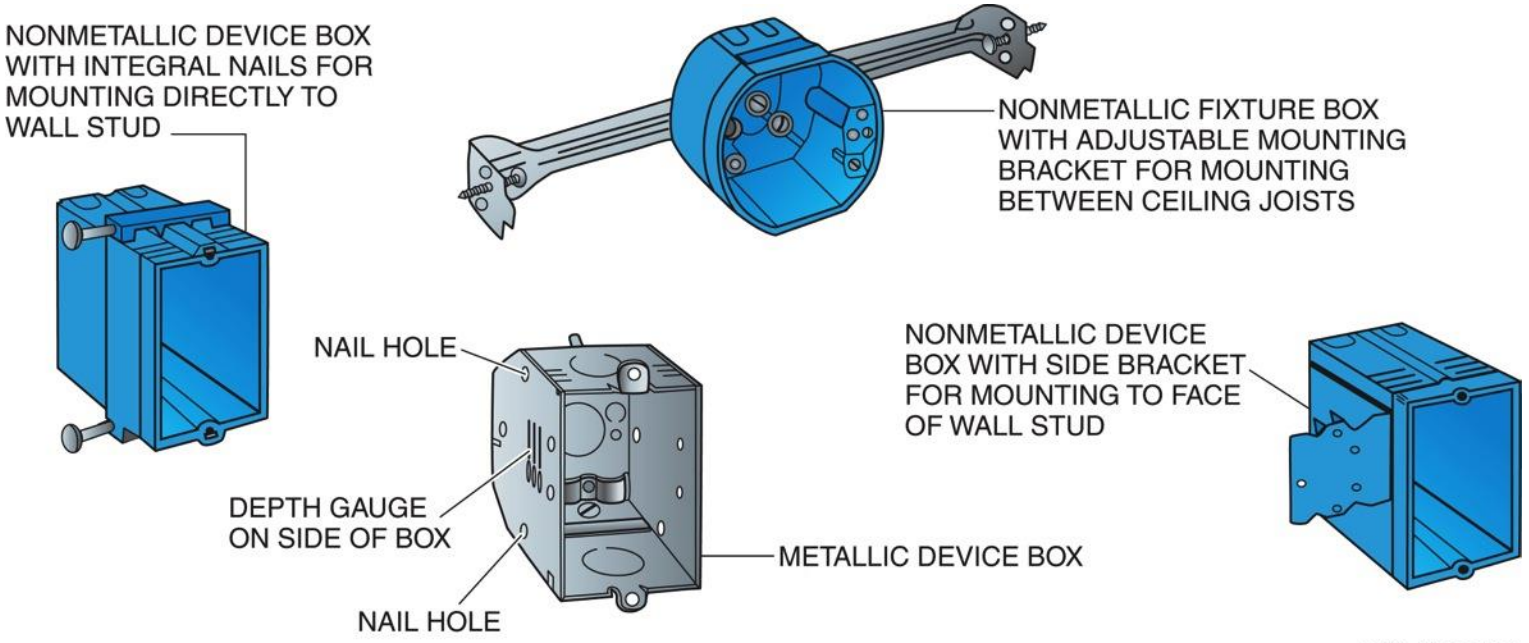


Performance Task

Have the trainees select the proper type and size outlet box needed for a given set of wiring conditions.

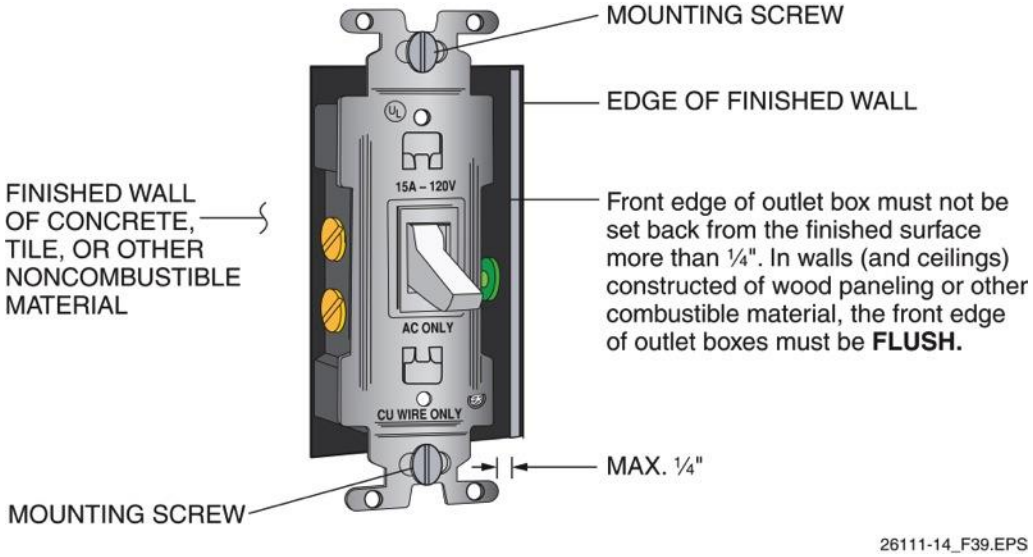
Mounting Outlet Boxes

- A wide variety of metallic and nonmetallic outlet boxes are available.
- Nonmetallic outlet boxes may include integral nails for mounting.



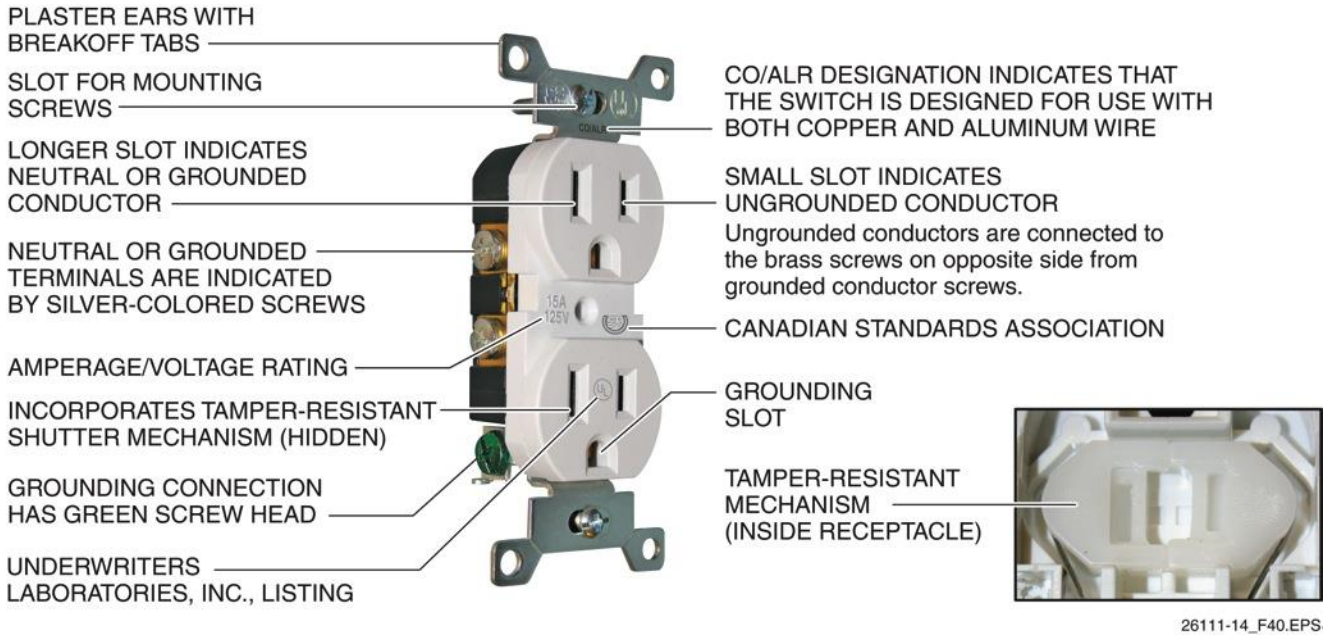
Outlet Box Installation

- Boxes must be installed level and plumb, and mounted flush with the surface of walls and ceilings having a combustible finish.
- ***NEC Sections 314.17 and 314.20*** include requirements for mounting outlet boxes.



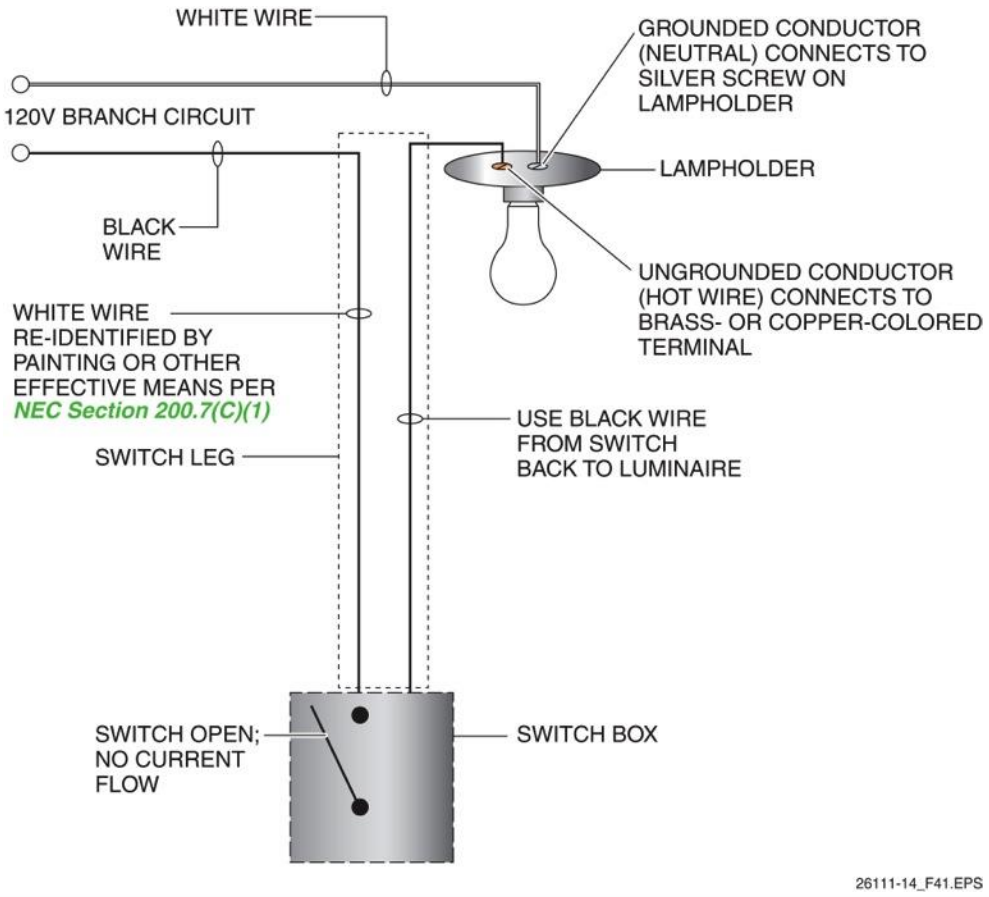
Wiring Devices

- The requirements for wiring devices can be found in ***NEC Article 406***.
- All 15A and 20A, 125V receptacles must be tamper-resistant per ***NEC Section 406.12***.

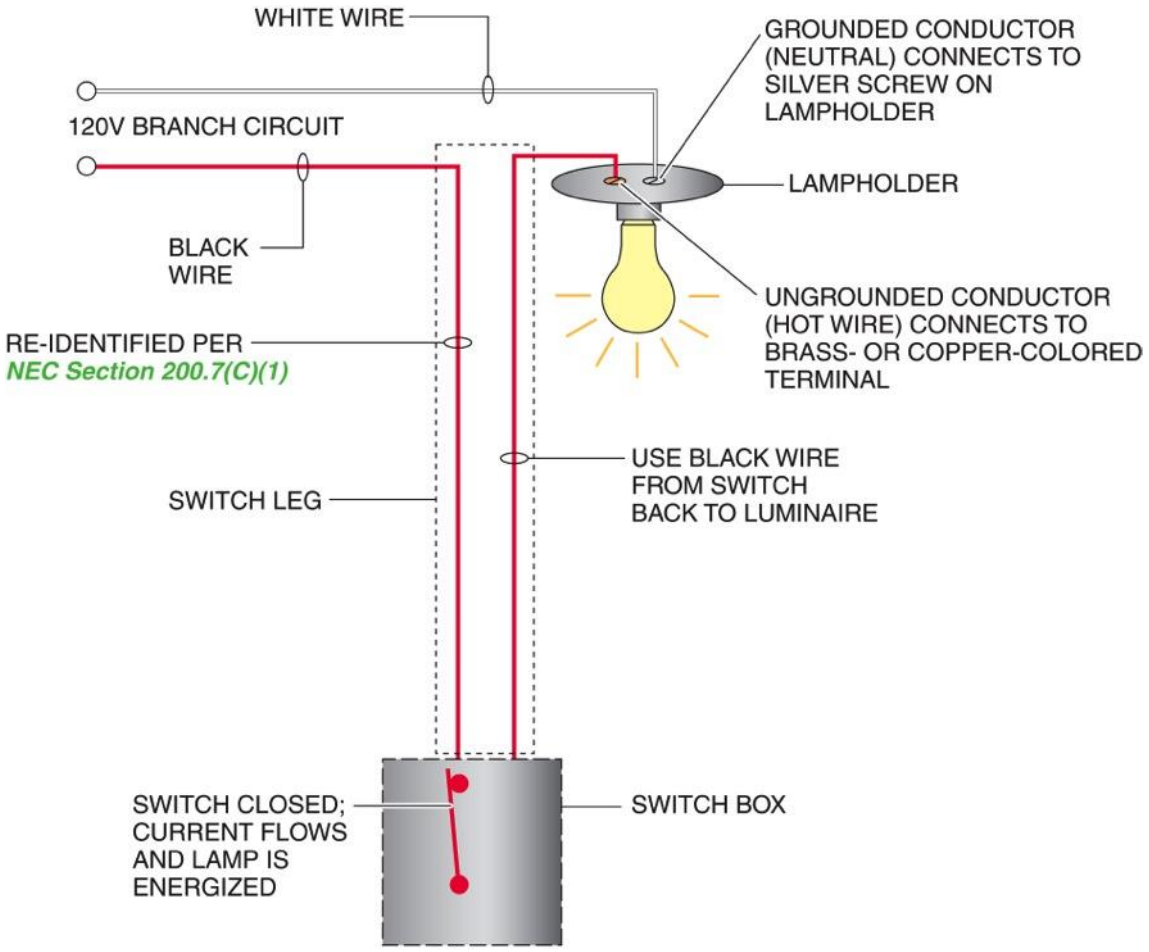


Lighting Control

A standard lighting circuit is controlled by a simple toggle switch.

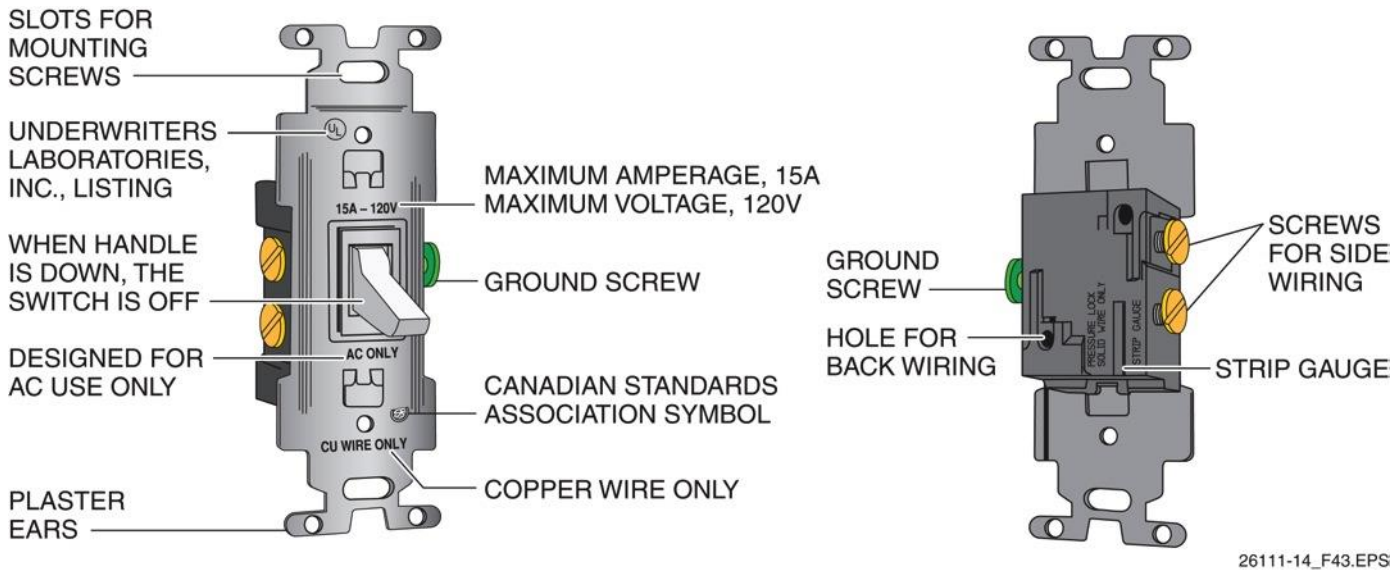


Switch Operation, Contacts Closed



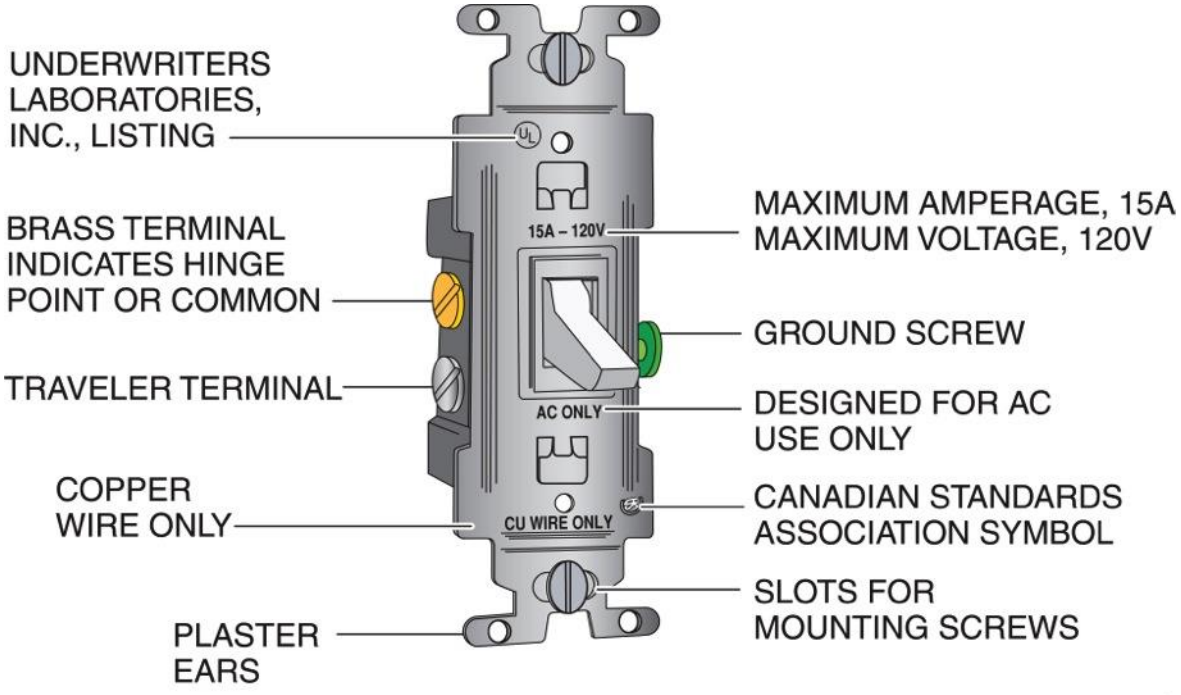
Characteristics of a Single-Pole Quiet Switch

Like receptacles, switches are marked with the maximum voltage and amperage, along with the type of wire to be used and certification.

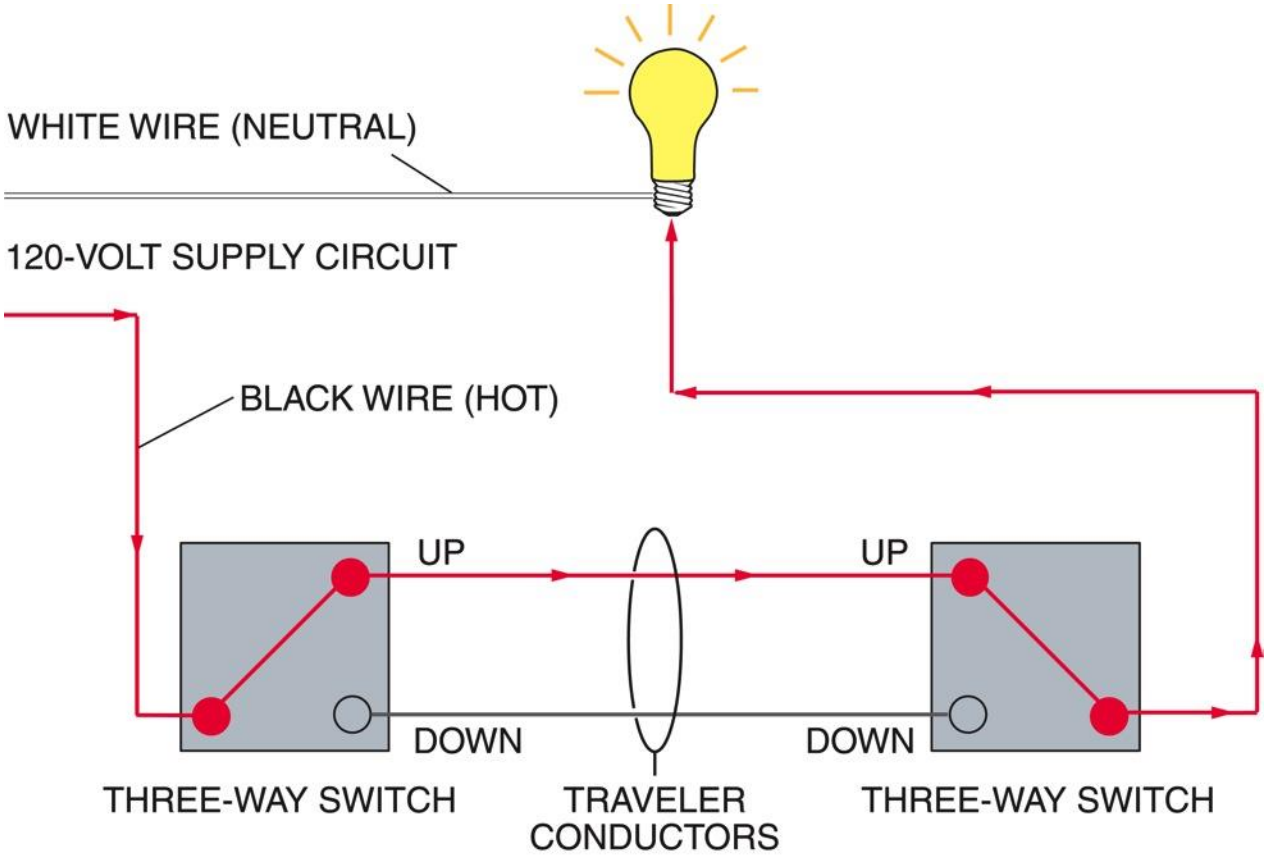


Three-Way Switches

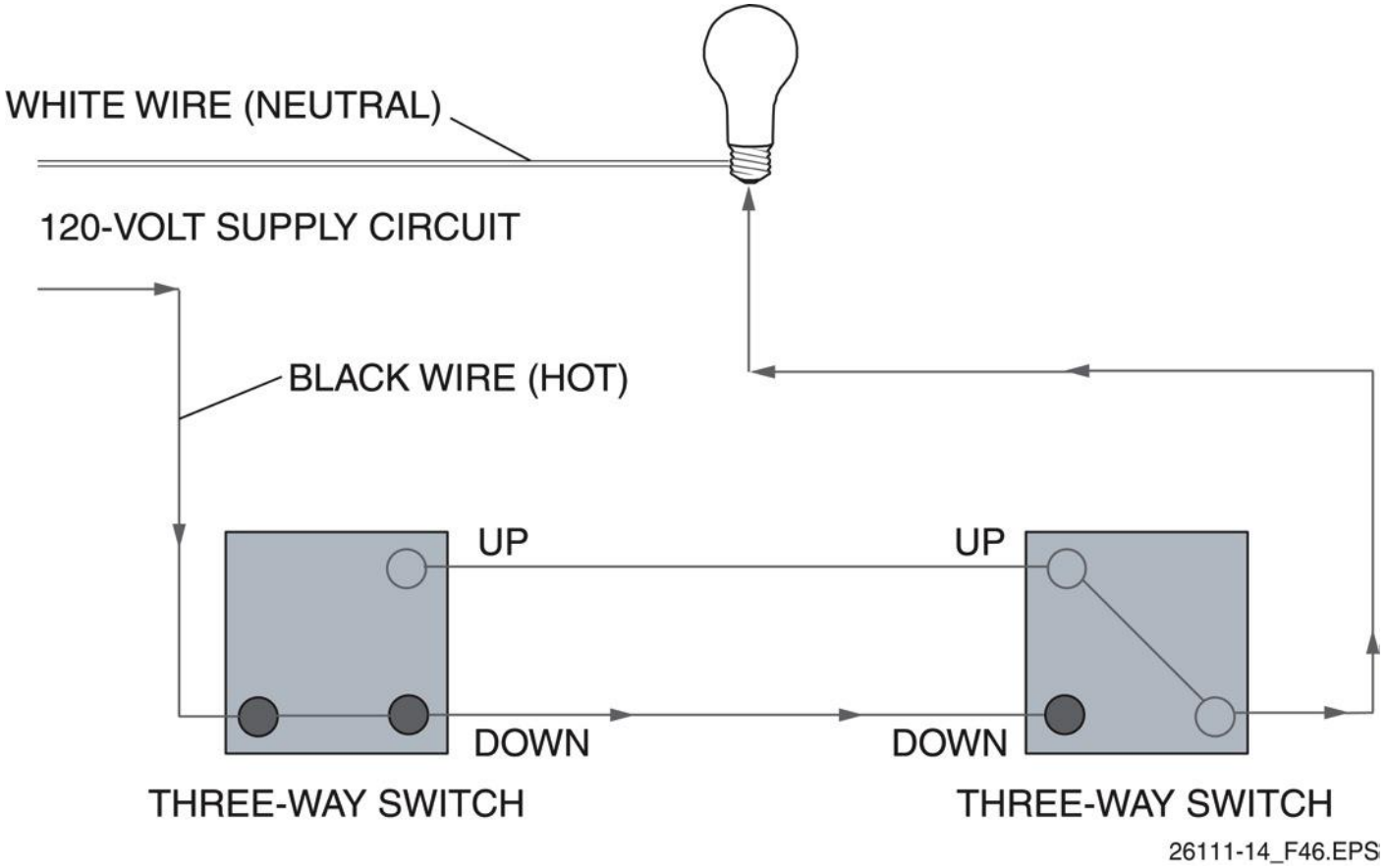
Three-way switches are normally used at the tops and bottoms of stairways to control the light from either location.



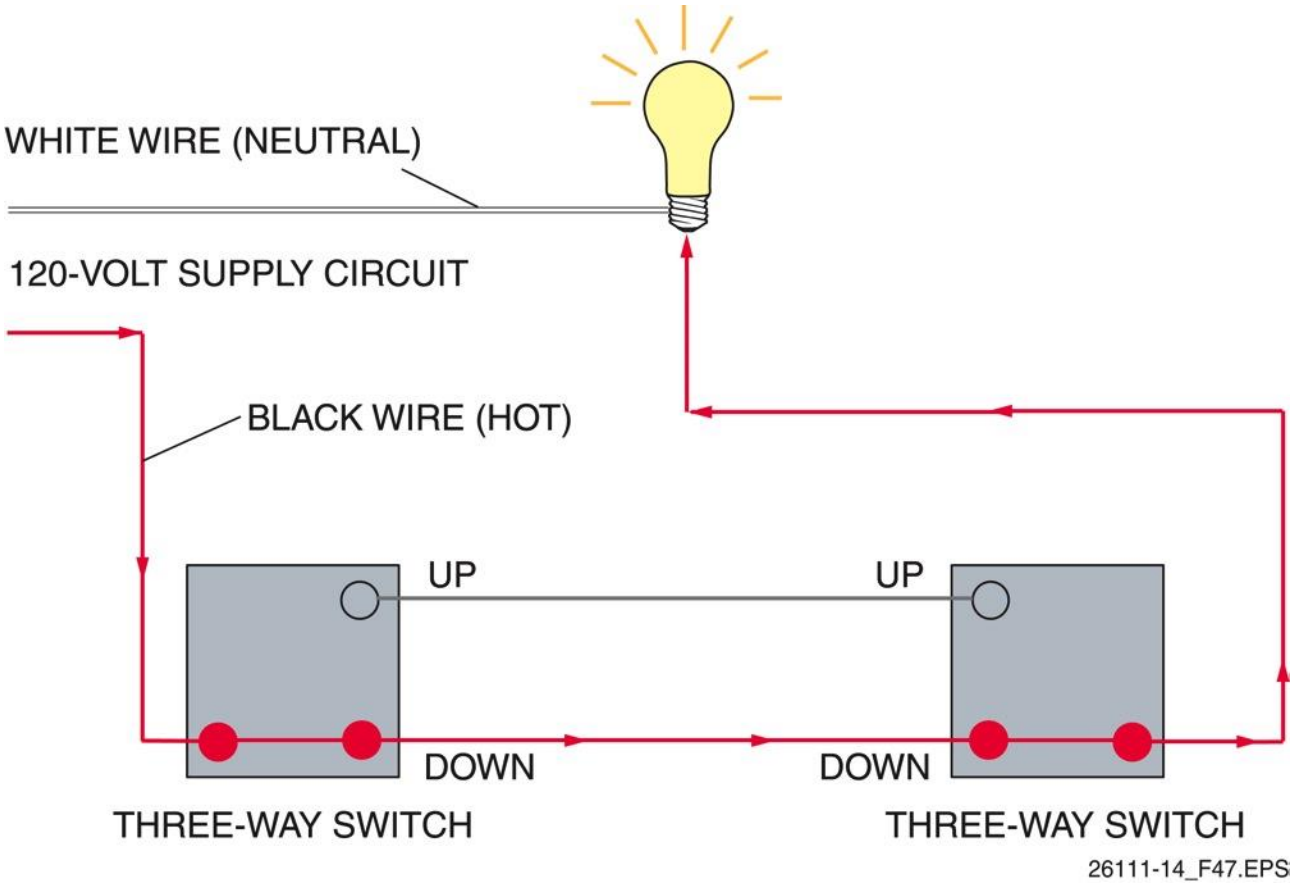
Three-Way Switches in the On Position; Both Handles are Up



Three-Way Switches in the Off Position; One Handle is Down, One Handle is Up

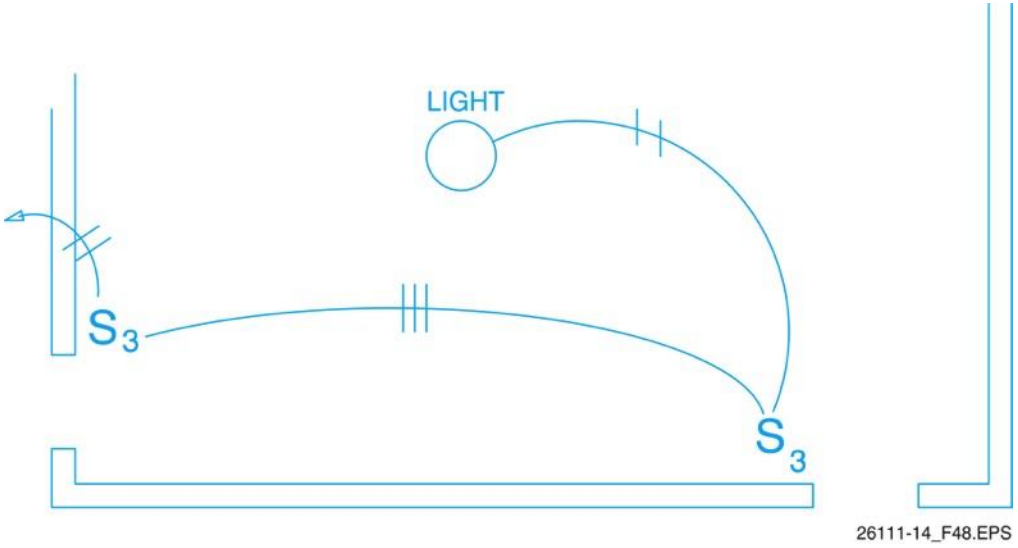


Three-Way Switches with Both Handles Down; the Light is Energized



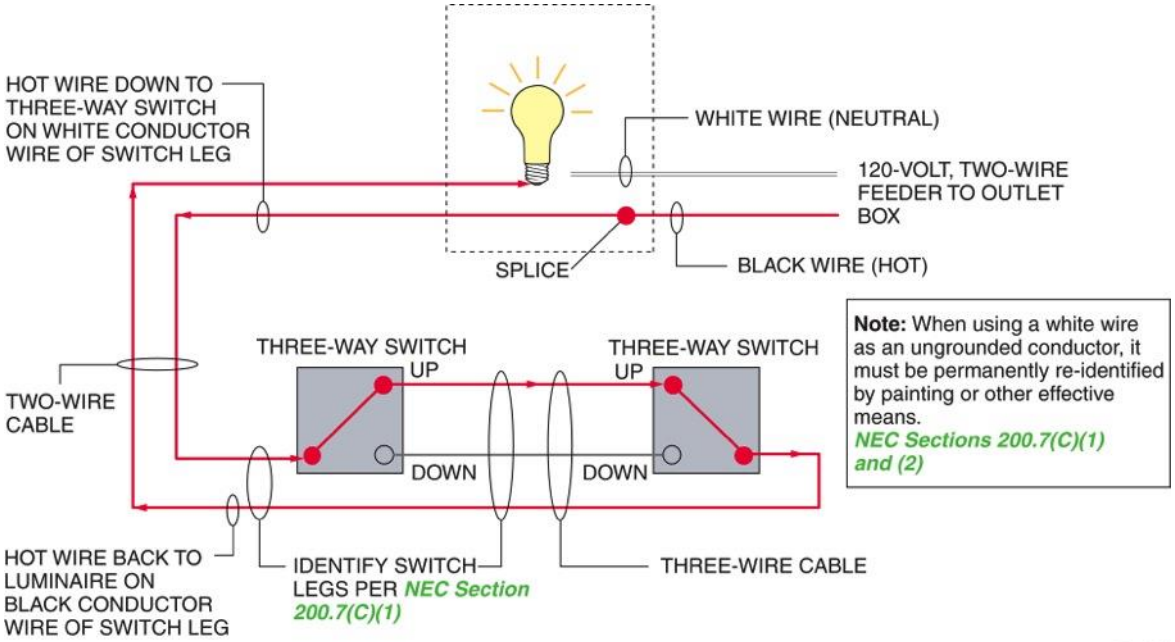
Method of Showing the Wiring Arrangement on a Floor Plan

- A three-way switch is marked with the symbol S_3 on a wiring plan.
- In this case, three-wire cable is used to carry the two travelers and the neutral.



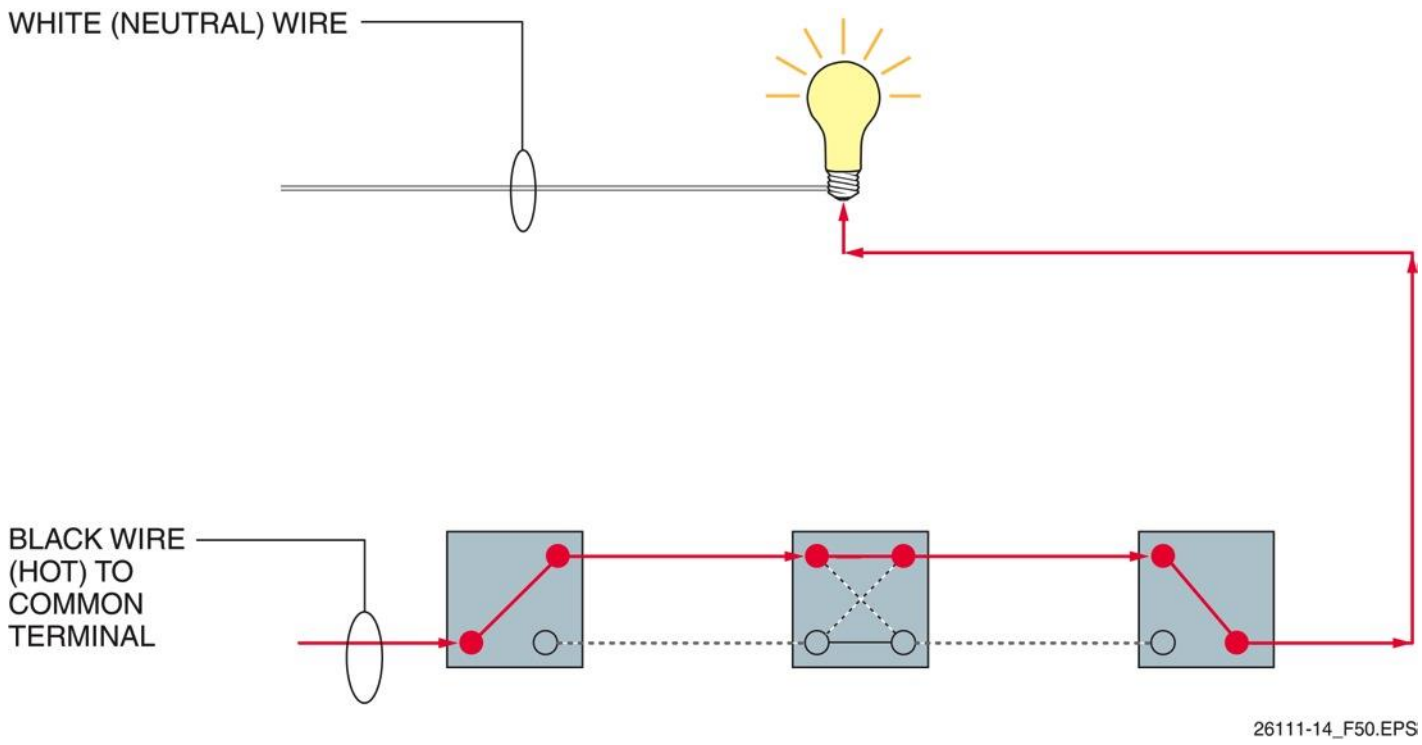
One Way to Connect a Pair of Three-Way Switches to Control One Lighting Fixture

This shortcut method uses one two-wire cable from the lighting outlet to one three-way switch, and then a three-wire cable between the two switches.

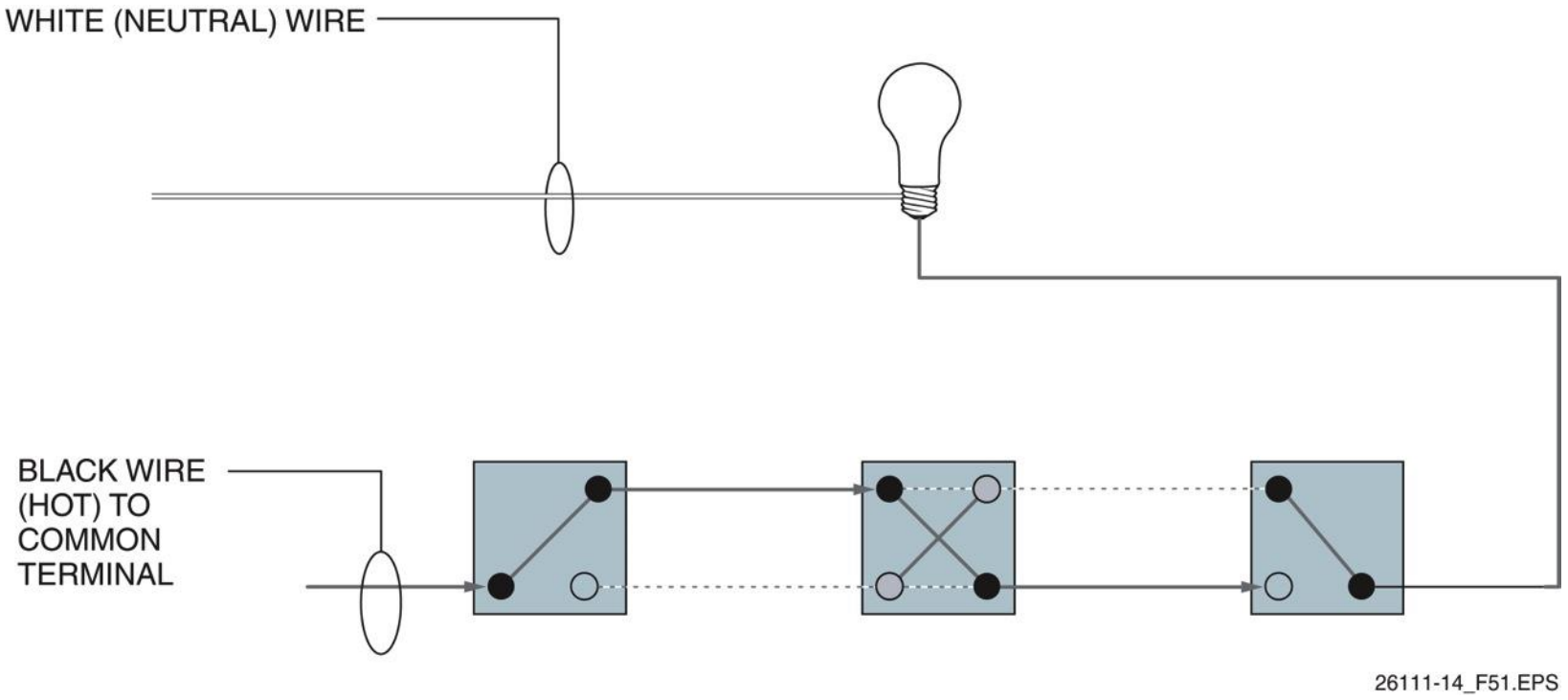


Four-Way Switches

A four-way switch may be used in conjunction with two three-way switches to control a device from three locations.



Three- and Four-Way Switches Used in Combination; the Light is off

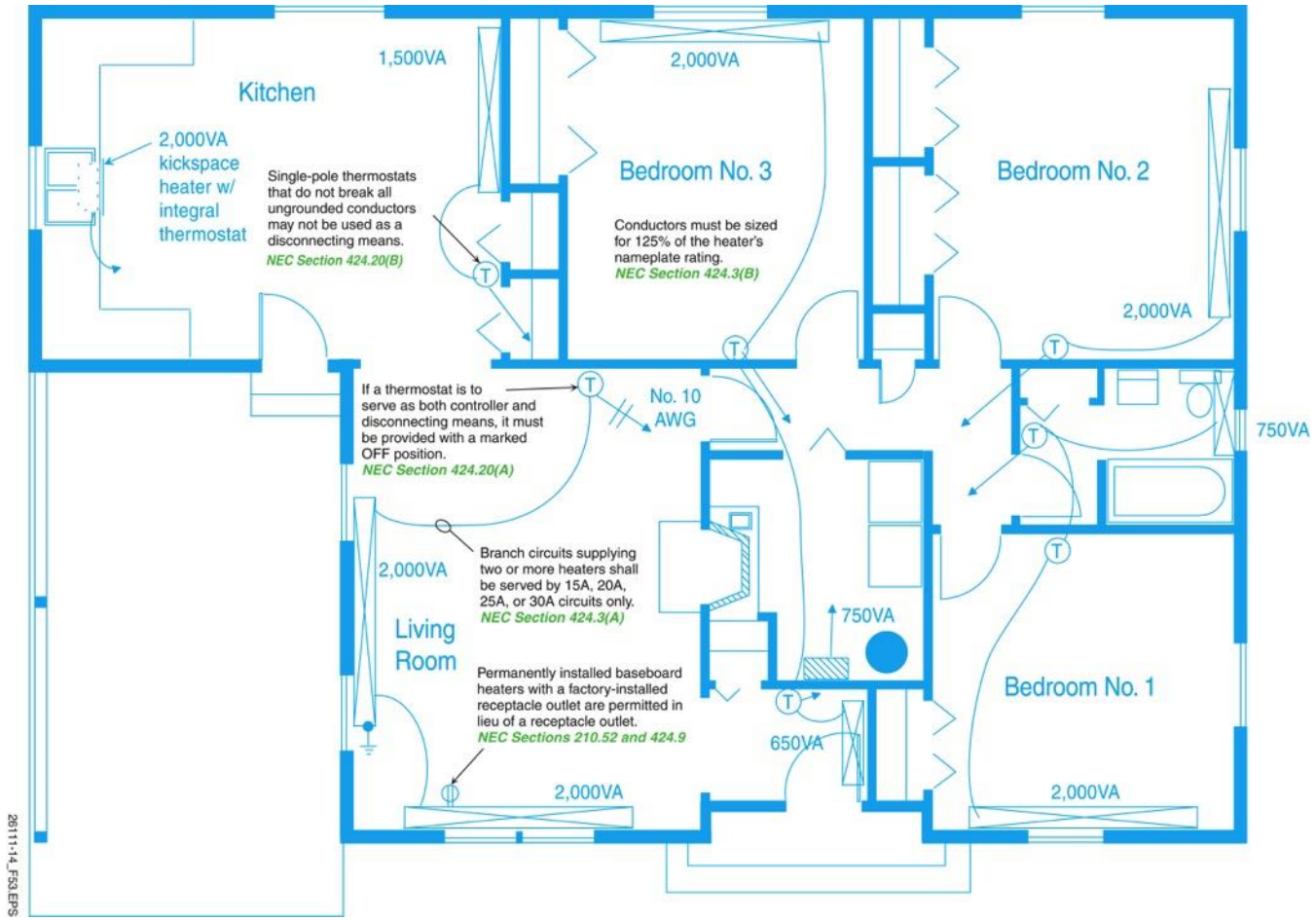


Next Session...

Switches and Relays

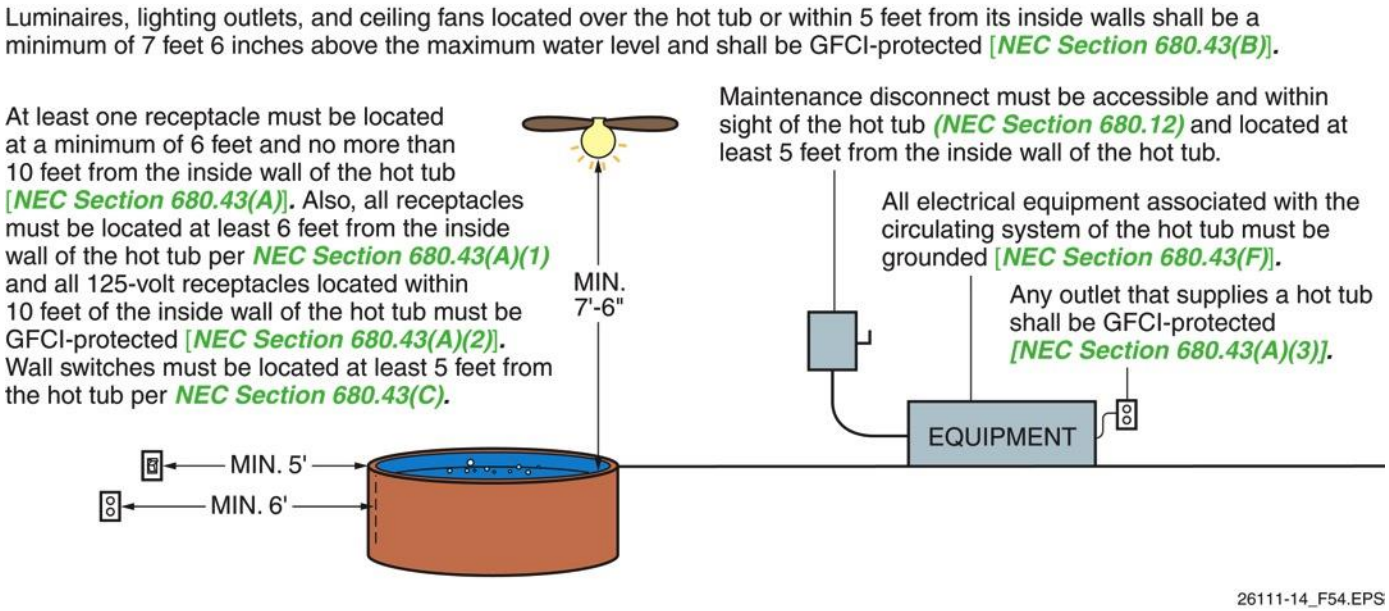
Electric Heating

Electric Heating

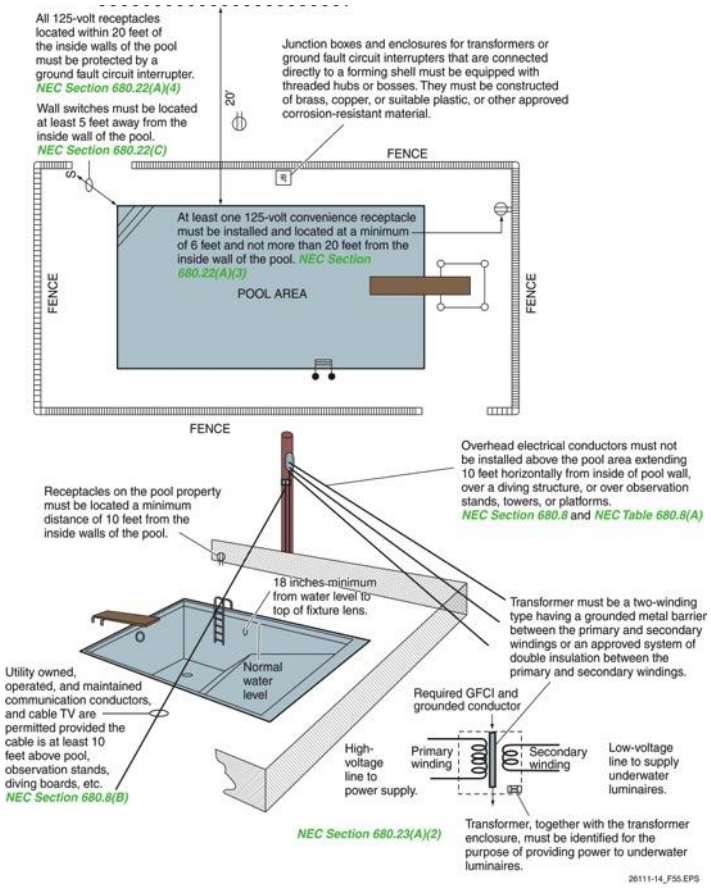


Residential Swimming Pools, Spas, and Hot Tubs

Residential swimming pools, spas, and hot tubs have special requirements due to the increased potential for electric shock in these applications.



NEC® Requirements for Typical Swimming Pool Installations



Wrap Up

3-2-1

3 – Write 3 important things learned during class

2 – Write 2 questions you have about the material

1 – Write 1 thought you had about the material

Next Session…

MODULE EXAM

Review the complete module to prepare for the module exam. Complete the Module Review as a study aid.