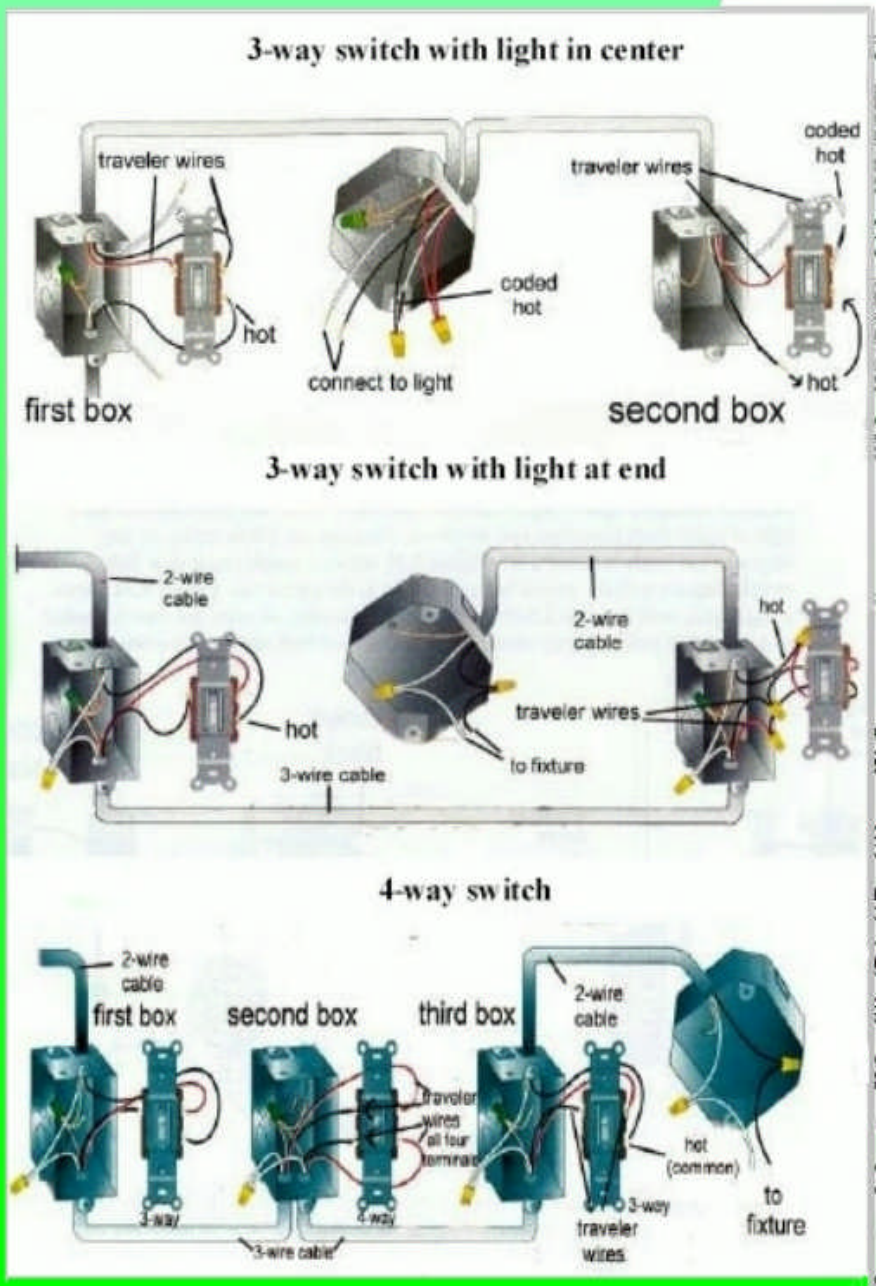
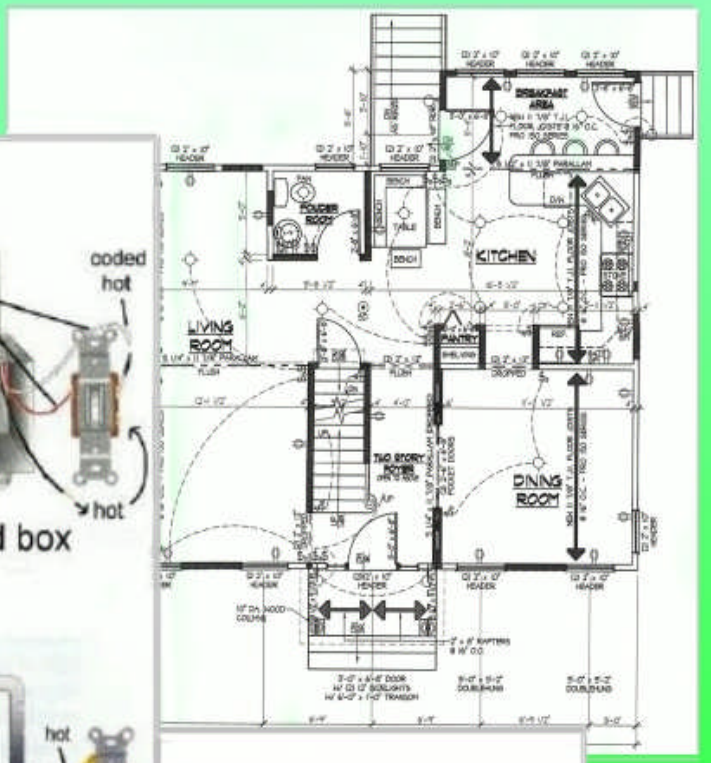
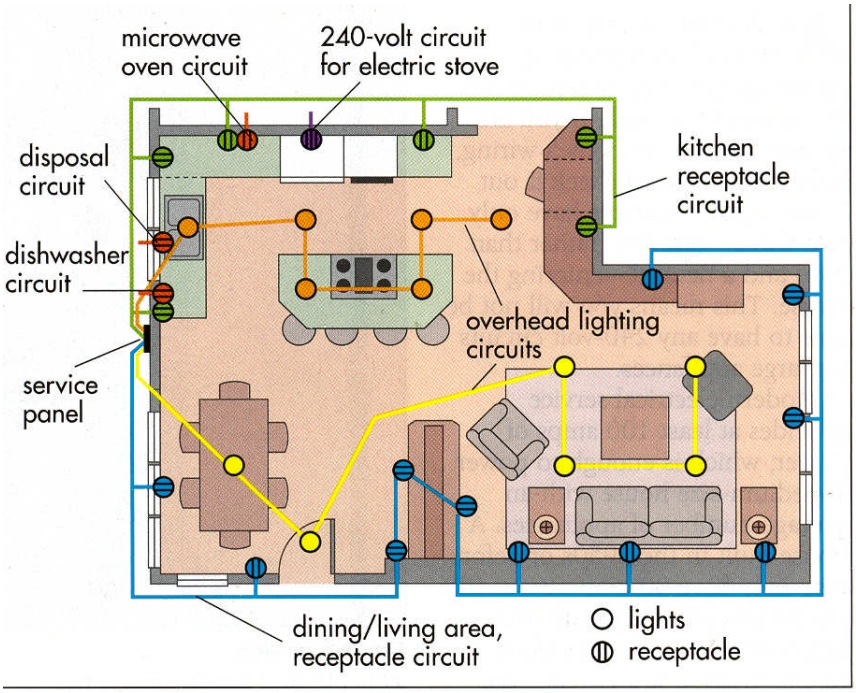
Quick guide

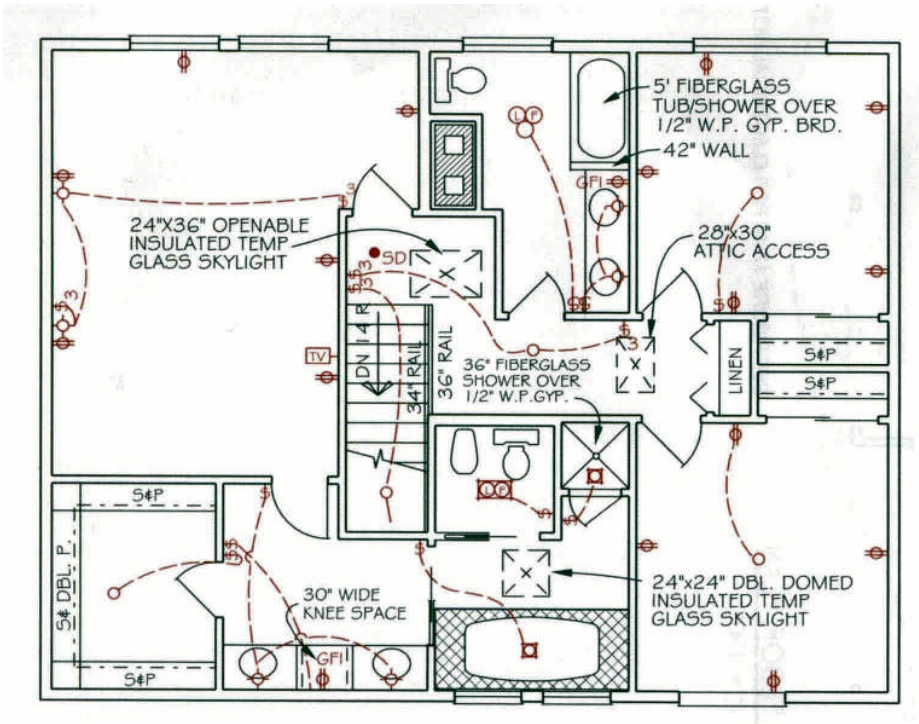
Residential Wiring Diagrams, Codes, And Symbols



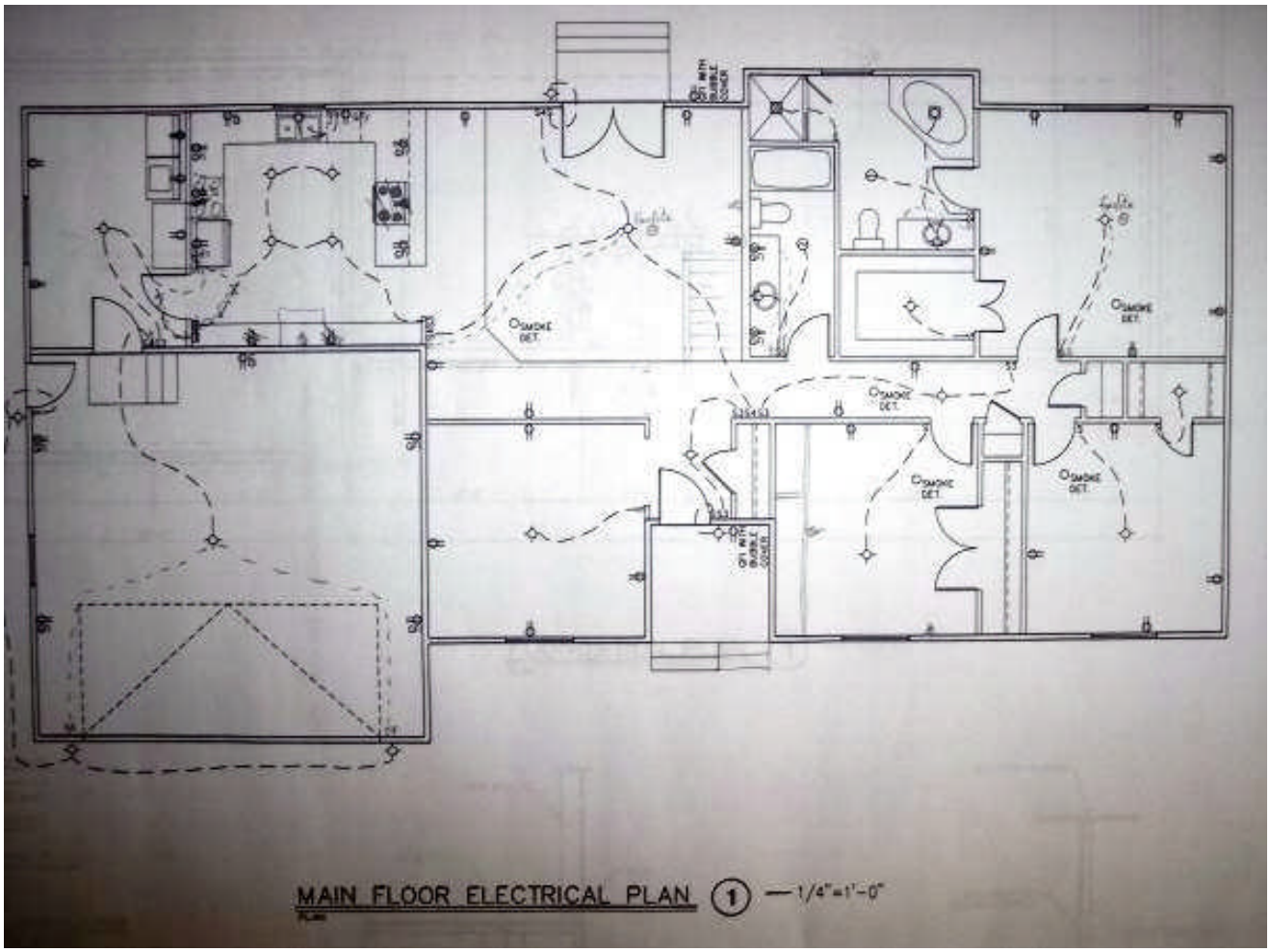


Electrical circuits





Electrical blueprints

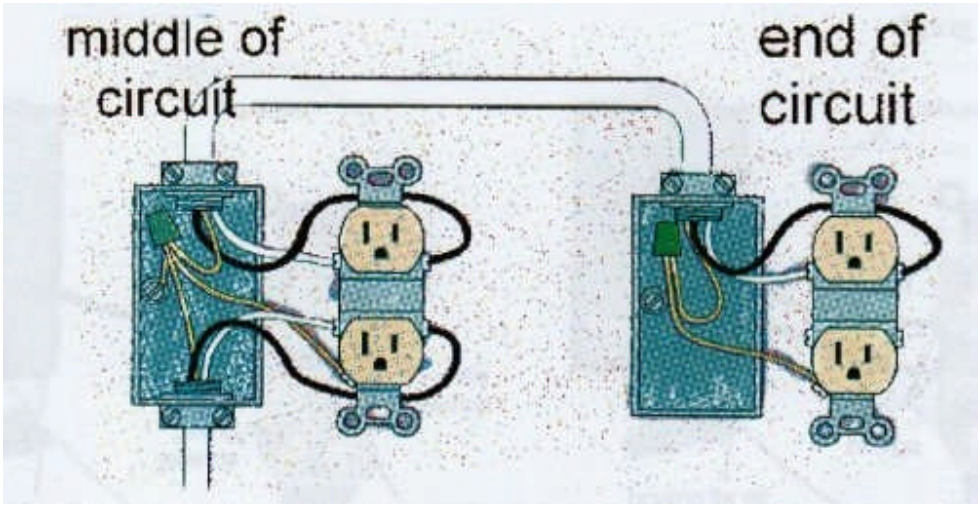


WALL	CEILING		SWITCH OUTLETS	
○	○	OUTLET	S	SINGLE POLE SWITCH
(D)	(D)	DROP CORD	S_2	DOUBLE POLE SWITCH
(F)	(F)	FAN OUTLET	S_3	THREE WAY SWITCH
(J)	(J)	JUNCTION BOX	S_4	FOUR WAY SWITCH
(L)	(L)	LAMP HOLDER	S_D	AUTOMATIC DOOR SWITCH
$(L)_{PS}$	$(L)_{PS}$	LAMP HOLDER WITH PULL SWITCH	S_E	ELECTROLIER SWITCH
(S)	(S)	PULL SWITCH	S_P	SWITCH AND PILOT LAMP
(V)	(V)	VAPOR DISCHARGE SWITCH	S_K	KEY OPERATED SWITCH
(X)	(X)	EXIT OUTLET	S_{CB}	CIRCUIT BREAKER

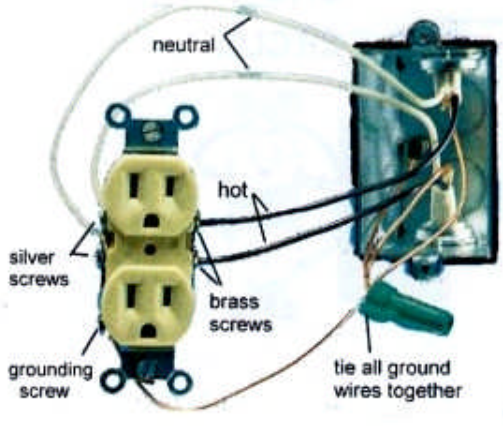
(C)	CLOCK OUTLET	S_{WCB} WEATHER PROOF CIRCUIT BREAKER
(B)	BLANKED OUTLET	S_{MC} MOMENTARY CONTACT SWITCH
	DUPLEX CONVENIENCE OUTLET	S_{RC} REMOTE CONTROL SWITCH
1,3	SINGLE, TRIPLEX, ETC.	S_{WP} WEATHER PROOF SWITCH
	RANGE OUTLET	S_F FUSED SWITCH
S	SWITCH AND CONVENIENCE OUTLET	S_{WPF} WEATHER PROOF FUSED SWITCH
	SPECIAL PURPOSE OUTLET	LIGHTING PANEL
	FLOOR OUTLET	POWER PANEL

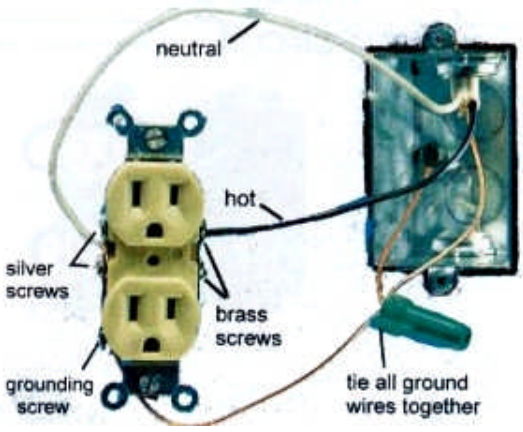
Electrical Wiring Diagrams

Simple outlet circuit

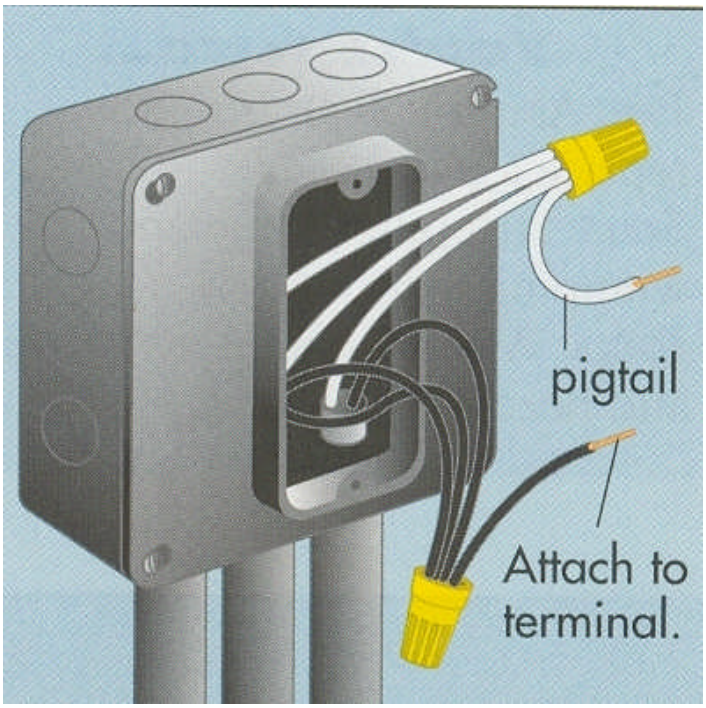


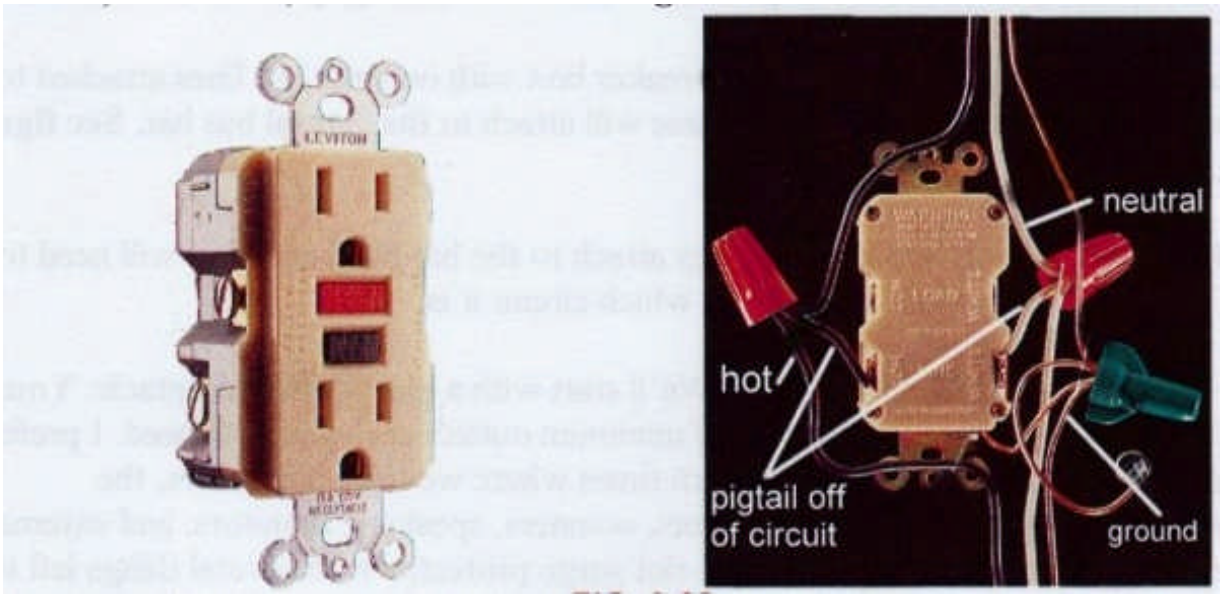
To end of circuit



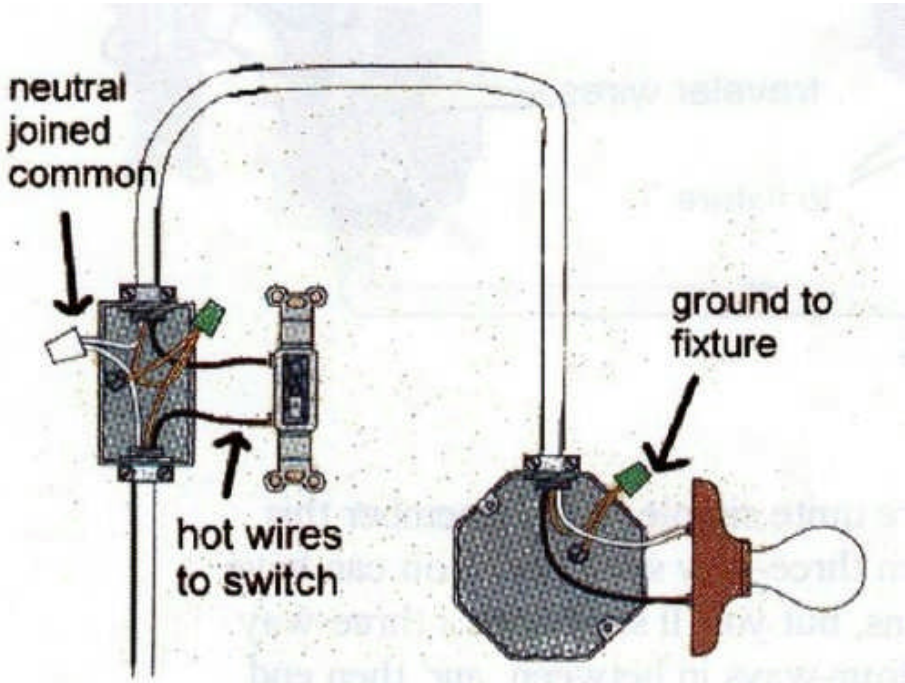


Pigtail GFCI Outlets

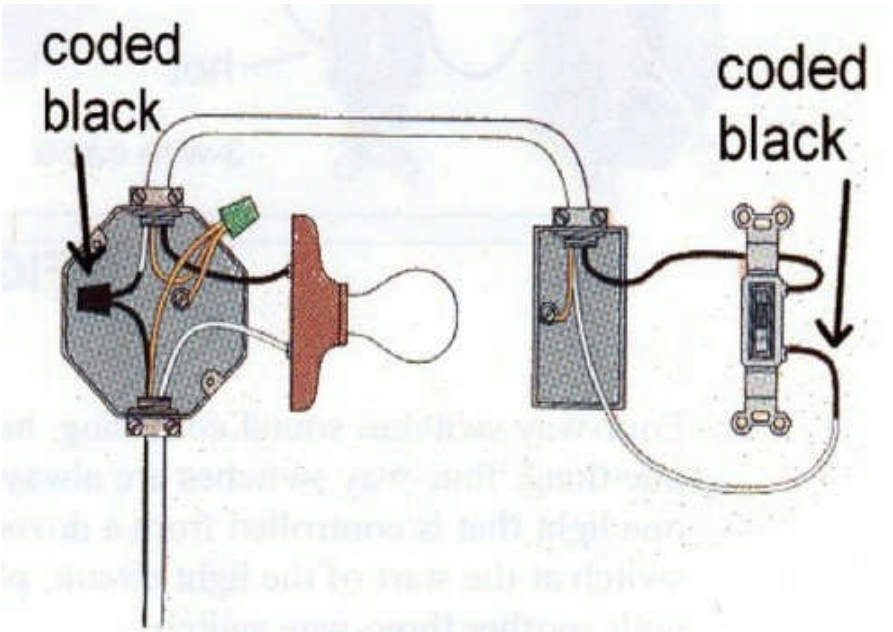




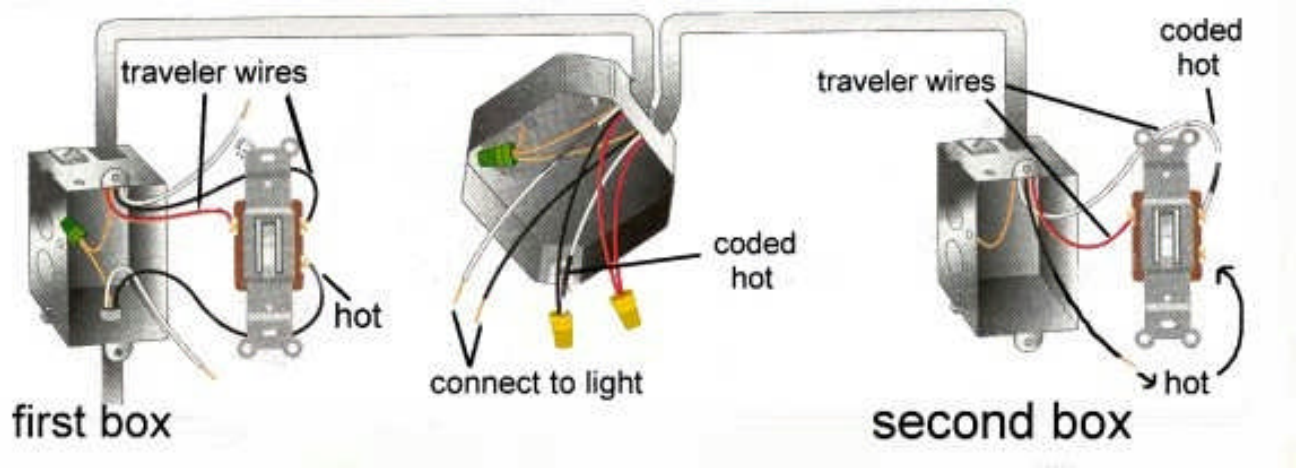
Single switch before light



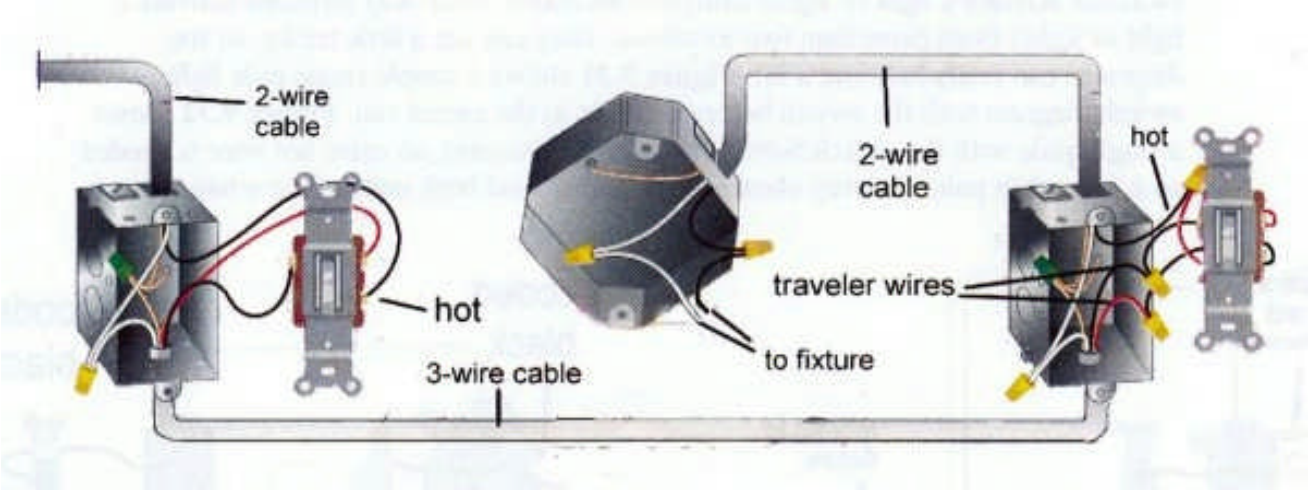
Single switch after light



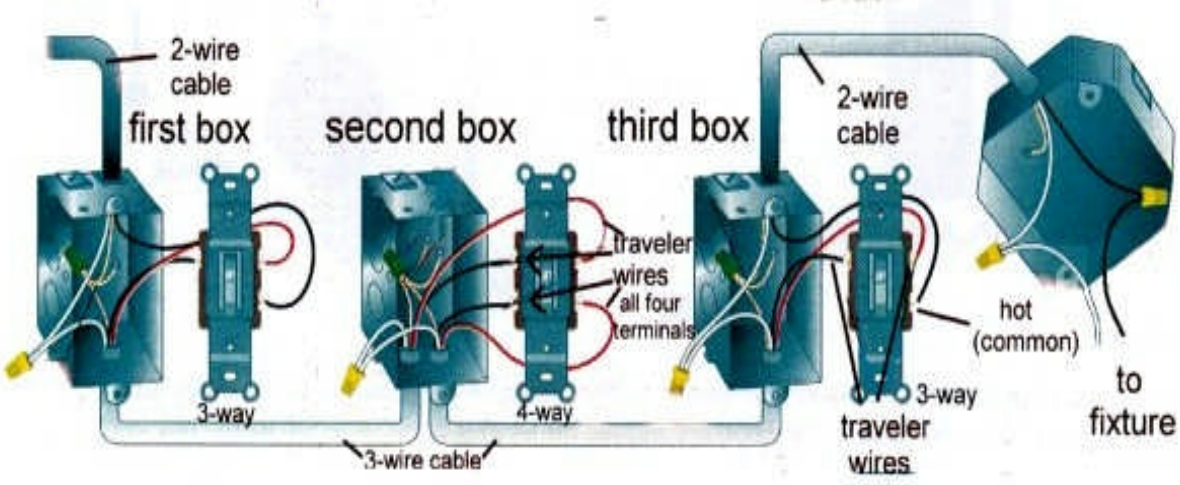
3-way switch with light in center



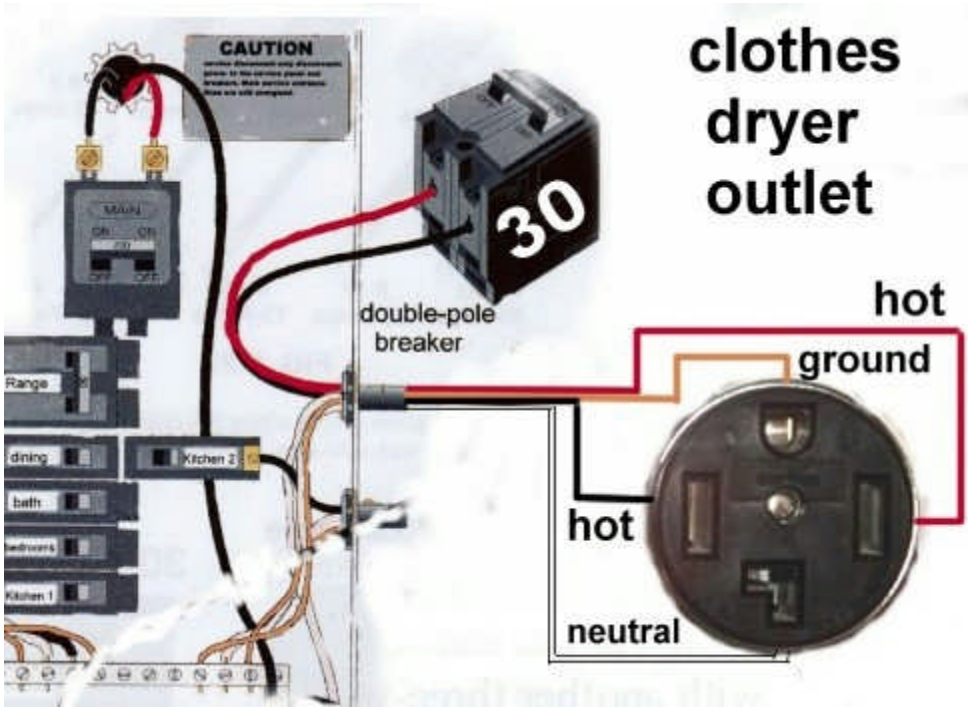
3-way switch with light at end



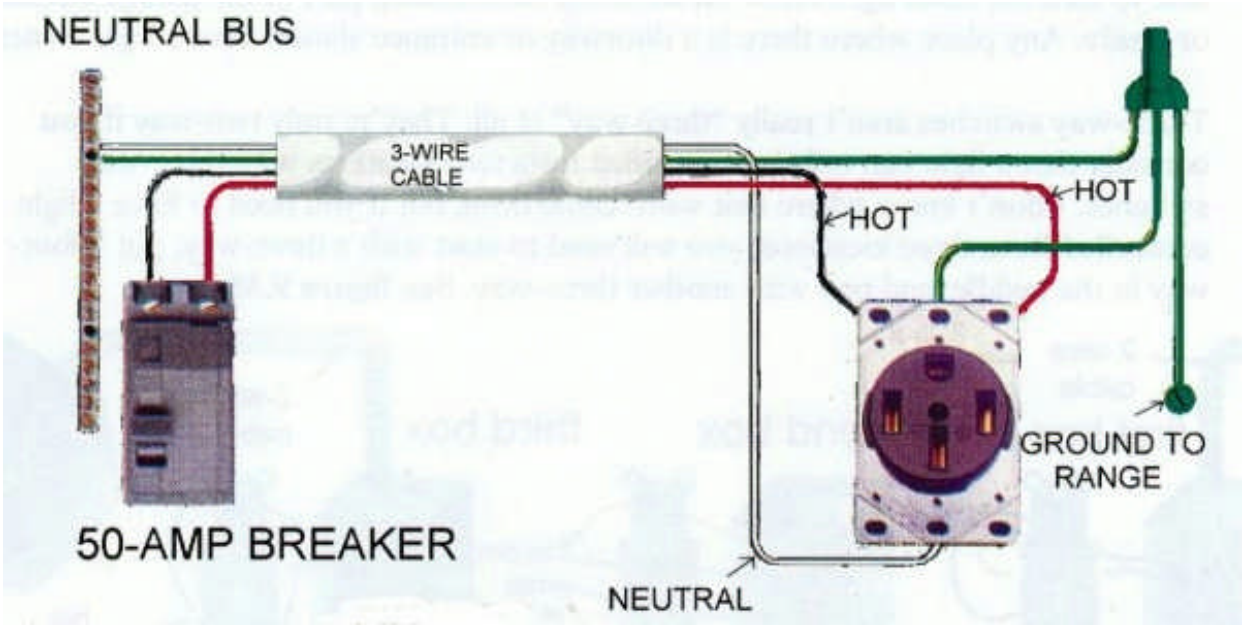
4-way switch



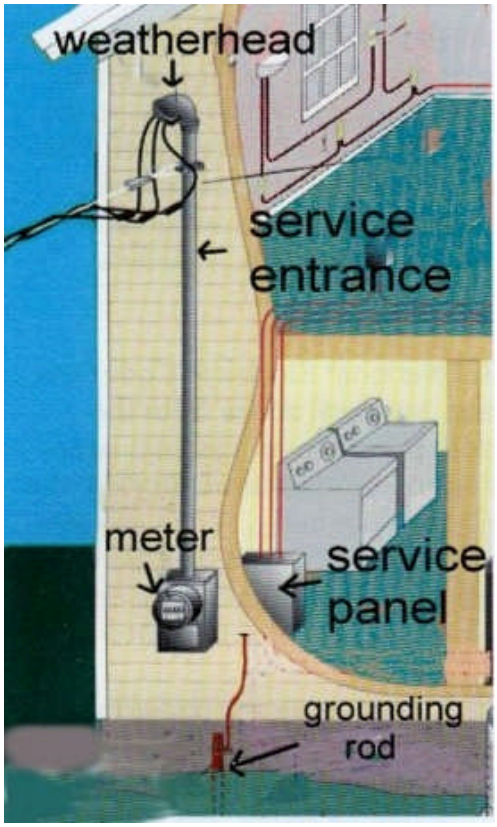
Dedicated circuits

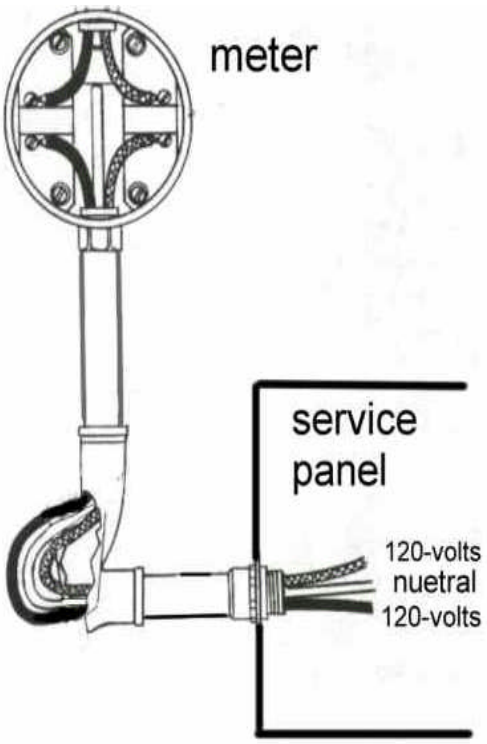


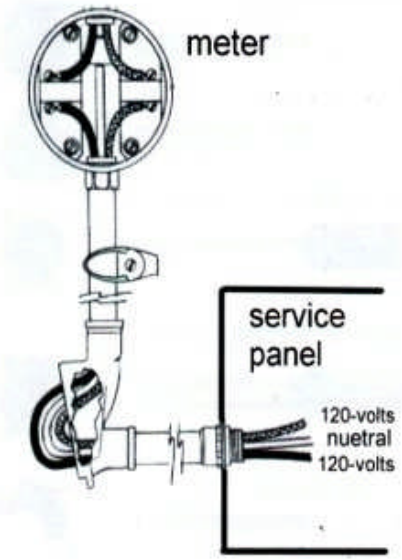
Oven/range

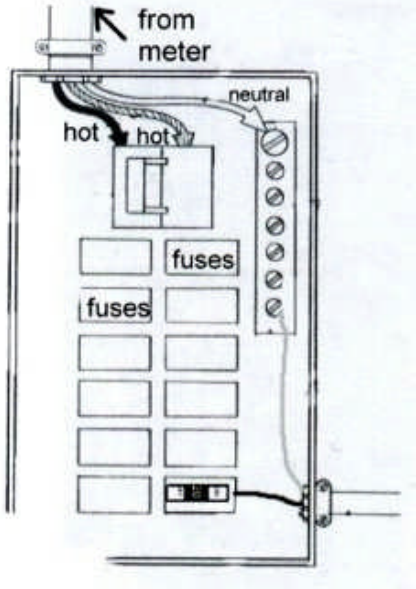


Service entrance to breaker box

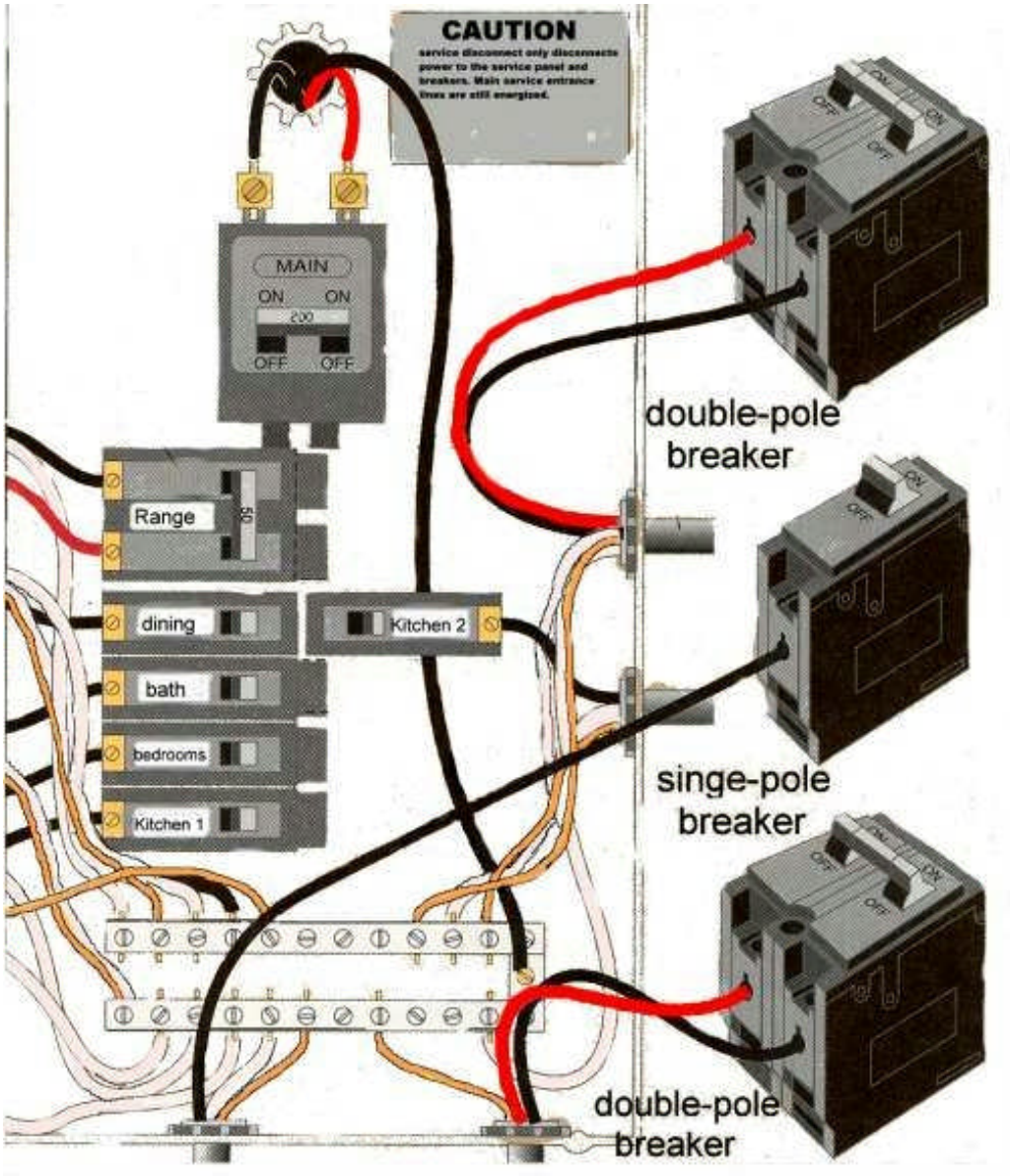




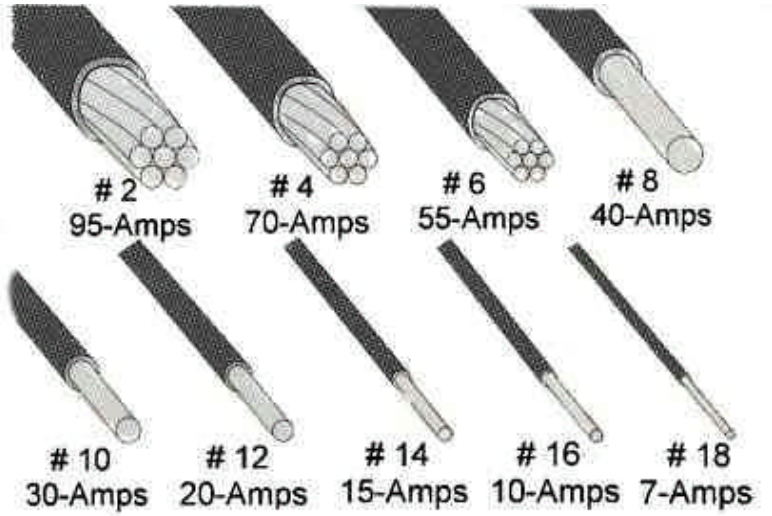


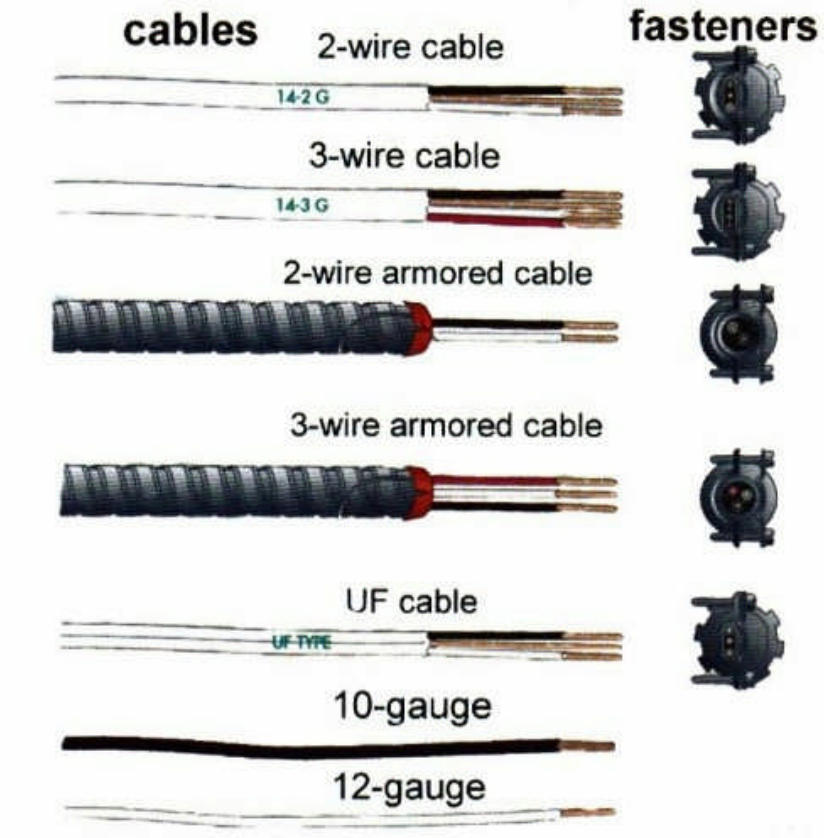


Breaker box

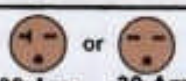
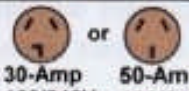
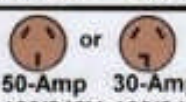

CAUTION
service disconnect only disconnects power to the service panel and breakers. Main service entrance lines are still energized.
MAIN
ON ON
200
OFF OFF
Range
50
dining
Kitchen 2
bath
bedrooms
Kitchen 1
double-pole breaker
singe-pole breaker
double-pole breaker

Cable Sizes


2
95-Amps
4
70-Amps
6
55-Amps
8
40-Amps
10
30-Amps
12
20-Amps
14
15-Amps
16
10-Amps
18
7-Amps


cables
fasteners
2-wire cable
14-2 G
3-wire cable
14-3 G
2-wire armored cable
3-wire armored cable
UF cable
UF TYPE
10-gauge
12-gauge

Outlet Receptacles

Appliance	Voltage	Wire size	Receptacle
Electric dryer	120/240V 20 to 30 amps	#10	 30-Amp 120/240V
Electric water heater	240V 20 to 30 amps	#10	 30-Amp 120/240V or 30-Amp 240V
Electric range	120/240V 50 amps	Two #6 hot wires and a #8 neutral wire	 30-Amp 120/240V or 50-Amp 120/240V
Separate oven and cooktop	120/240V 30 amps separate 50 amps together	seperate 30-Amp circuits use #10 wire	 50-Amp 120/240V or 30-Amp 120/240V
Refrigerator	120V 20 amps	#12	 20-Amp 120V

GFCI Residential Location Requirements **06 IRC** **08 NEC**

The following rules apply to 15A & 20A receptacles on 120V circuits. They do not apply to 240V receptacles or to 30A 120V receptacles.

- ☐ All bathroom receptacles [3802.1] {210.8A1}
- ☐ All garage & accessory building receptacles [3802.2] {210.8A2}[21]
- ☐ All receptacles in unfinished basements EXC [3802.5] {210.8A5}[21]
  Permanently installed fire or burglar alarm system [3802.5X3] {210.8A5X}

The 2005 NEC and the 2006 IRC have exceptions for receptacles in garages and unfinished basements that are not readily accessible or that serve appliances not easily moved from one place to another, such as freezers. A receptacle for a single appliance under that exception must be a single receptacle, and for two such appliances a duplex receptacle can be used.

- ☐ All outdoor receptacles EXC [3802.3] {210.8A3}
  Receptacles for snow melting & deicing equipment on dedicated branch circuit if located so they are not readily accessible [3802.3X] {210.8A3X}
- ☐ Equipment plugged into receptacles installed under above exception req's GFPE protection in plug cap [4001.7] {426.28}
- ☐ All receptacles in crawlspaces at or below grade level [3802.4] {210.8A4}
- ☐ All receptacles serving kitchen counters **F30** [3802.6] {210.8A6}
- ☐ Receptacles within 6ft of outside edge of laundry, utility, or wet bar sinks [3802.7][22] {210.8A7}
- ☐ Receptacles in boathouses [3802.8] {210.8A8}

Residential Electrical Guidelines

GENERAL RESIDENTIAL GUIDELINES

Here are a few typical guidelines that apply to residential work. These are NOT legal interpretations of any one code, so check with your local authority before starting work.

Kitchens

- All kitchen, breakfast room, pantry, and dining room outlets must be supplied by at least two 20-amp small appliance circuits.
- Outlets above the kitchen counter (used by countertop appliances) normally are fed by both circuits -- they all cannot be wired to just one circuit. The circuits should not supply any lights or other outlets in the house.

Appliances

- Separate circuits are needed for built-in appliances (i.e. oven, range, disposer, dishwasher, central air conditioner, furnace).
- One 20-amp circuit is needed for the laundry outlet within 6' of the machines. An electric dryer requires an additional 240-volt circuit.

Outlets

- One lighting/convenience outlet circuit should be provided for every 575 square feet of floor space in a house.
- Any bathroom or garage outlet within 6' of a sink must be Ground-Fault Circuit Interrupter (GFCI) protected. All kitchen outlets for countertop must be GFCI protected. Bedroom outlets should be Arc-Fault Circuit Interrupter (AFCI) protected.
- At least one GFCI outlet is required in an unfinished basement, as well as most outdoor outlets. Exceptions include inaccessible outlets like those in a garage ceiling or behind a refrigerator.
- Any point along the bottom of a wall (which is 2' or wider) must be within 6' of an outlet. The 6' distance cannot be measured across a doorway or fireplace. And the outlet must be within 5 1/2' of the floor. (This cuts down on extension cord use, especially across doorways, fireplaces and similar openings.)

Switches

- Every habitable room, hallway, stairway or garage must have a light switch that controls lighting in that area. In kitchens and bathrooms, the light switch must control a permanently installed light fixture. In other rooms, the switch can control either a light fixture (in the ceiling, for example) or a receptacle into which a lamp may be plugged.

	240-volt outlet, wall mounted
	240-volt outlet, clothes dryer, wall mounted
	240-volt outlet, range, wall mounted
	Clothes washer outlet, wall mounted
	Dishwasher outlet, wall mounted
	Duplex receptacle outlet, ceiling mounted
	Duplex receptacle outlet, floor mounted
	Duplex receptacle outlet, wall mounted
	Duplex receptacle outlet with GFI/GFCI device, wall mounted
	Duplex special purpose outlet, key letter or abbrev., or indicate NEMA config.
	Emergency outlet, wall mounted
	Garbage disposal outlet, wall mounted
	General outlet, ceiling mounted
	General outlet, wall mounted
	Junction box, ceiling mounted
	Junction box, wall mounted

Rough-in Electrical

In a new house, addition or major remodeling project, cable and boxes are "roughed-in" before the walls are insulated and drywalled.

NOTE: Insulation can be put up then removed for an inspection, but inspection must be done before the walls are sealed by a vapor barrier and wallboard.

- Locate/place/attach all device and junction boxes for outlets, lights and switches.

  Make sure wall switches are located with proper respect to door swing, and wall outlets will not conflict with tile, cabinets, lockers, casework, or baseboard heating.

  Each box should stick out a little past the framing so its front will be flush with – or set back just a fraction from – the drywall.

  You can use a scrap piece of drywall to set boxes out the right distance. Some boxes even have a pre-formed ½" reference line for quick installation.
- Drill or notch the framing to allow for the cable/wiring to run between boxes, down into the under-floor crawl spaces, up into the ceiling, as well as through studs. (Most rooms have either an attic above or a basement/crawlspace below. Drill holes so cable runs horizontally through joists.)

  A heavy-duty right-angle drill with a 1" bit is the tool for this job. Wall holes drilled at about knee-height will be just right for outlets. Holes through ceiling joists and wall plates will be a bit harder; that's where the right-angle drill comes in really handy.
- Run wire/cable/conduit from the service panel to each box and between boxes. (See "Pulling Cable," inside.)
- Pull wire/cable into each box; clip, clamp and cap.
- Use metal reinforcing plates (nailing plates) at all points where the drilled hole is less than 1½" from either outside edge of a stud or joist. Nailing plates are required over all notches.

Notching walls and drilling holes

Nominal Dimensions	Actual Dimensions	STUDS			
		NOTCHED		DRILLED	
		25%	40%	40%	60%
2 x 4	1½ x 3½	7/8"	1 25/64	1 25/64	2 3/32
2 x 6	1½ x 5½	1 3/8	2 13/64	2 13/64	3 19/64

STUDS

Load-Bearing Walls	Holes should represent less than 40% of the joist depth (see Drilled / 40% above) Notches should represent less than 25% of the joist depth (see Notched / 25% above)
Non-Load-Bearing Walls	Holes should represent less than 60% of the joist depth (see Drilled / 60% above) Notches should represent less than 40% of the joist depth (see Notched / 40% above)

JOISTS

- Notches must represent less than 1/6th of the depth of the joist
- Notches are not allowed in the middle third of the joist length (only allowed toward the ends)
- Drilled holes in joists must not be within 2 inches of an outside edge of the joist
- Drilled holes must represent less than 1/3rd of the overall depth of the joist

Cable Checklist

Cabling must be installed and supported properly. It also must be protected from physical damage and from electrical damage.
Bends in Romex must not be made too sharply. Bending cable incorrectly can weaken the outer sheathing as well as the insulation on the individual conductors. The radius of the curve of the inner edge of any bend must not be less than five times the diameter of the cable. A correct installation will result in a "jug handle."
Cable must be fastened to the framing every 4-1/2 feet, using staples, cable ties, straps, hangers, or similar fittings.
Flat cables (e.g., 14/2 Romex or 12/2 Romex) must not be stapled on edge.
Flat cables may be installed on top of one another and fastened with one staple, so long as one flat side of one cable is against the framing member and the other flat side is against the flat side of the next cable. (Two cables should not be placed side-by-side and fastened with one staple; this can damage the cable insulation.)
Check that staples or fasteners do not cut through a cable's insulation.
Where cable runs through wood framing members, it must be no closer than 1-1/4 inches to the nearest edge of the framing member. When this clearance cannot be maintained, a nailing plate must be added for protection. In cases where a framing member is notched to accommodate electrical cabling, a nailing plate is always required.
Where cable runs through metal studs, plastic grommets must be inserted in all holes, whether those holes are manufactured or field-drilled. The plastic grommet must cover all metal edges of the hole, to provide physical protection as the cables are pulled through the metal studs.
Openings around penetrations through walls, floors, and ceilings must be filled with an approved fire-stopping material. (Some locales require fire-stopping measures in both non-fire-rated and fire-rated building components.)
Check for draft-stopping measures where cabling penetrates framing members.
Cabling must be secured within 8" of every nonmetallic box that's smaller than 2¼" x 4".
Cabling must be secured within 12" of every nonmetallic box that's larger than 2¼" x 4".
Cabling for recessed lights should be fastened to the nearest framing, providing a jug handle.
All cables that run into metal or plastic boxes must be protected from abrasion. This can be accomplished by using connectors that have smooth openings for the cabling to go through or by simply making sure a short section of the cable sheathing extends past the clamping mechanism of a cable clamp.
All cables that run into metal or plastic boxes must be secured to the boxes. Commonly, this is done using internal or external clamps.
Account for the voltage drop that can be caused by long runs of cable. Try to limit drop to less than 3%. (See Voltage Drop table.)
Separate runs of cable/wire are required for bedroom outlets (so they can be provided with Arc-Failure Circuit Interrupter (AFCI) protection. The same is true for any other circuits requiring AFCI or GFCI protection.

PULLING CABLE

"Running cable" or "pulling cable" is a bit more involved than it sounds. Getting cable to cooperate can be frustrating and time consuming. So it helps to be patient... and a bit creative.

Double-check your circuit diagrams before running any cable. Also make a note where you can double-up runs anywhere by pulling two cables at once.

When pulling wire through conduit, or even when pulling nonmetallic-sheathed cable through holes in studs, joists, etc., "fish tape" can be fed through holes, hooked to the cable or wire, and pulled back to retrieve it.

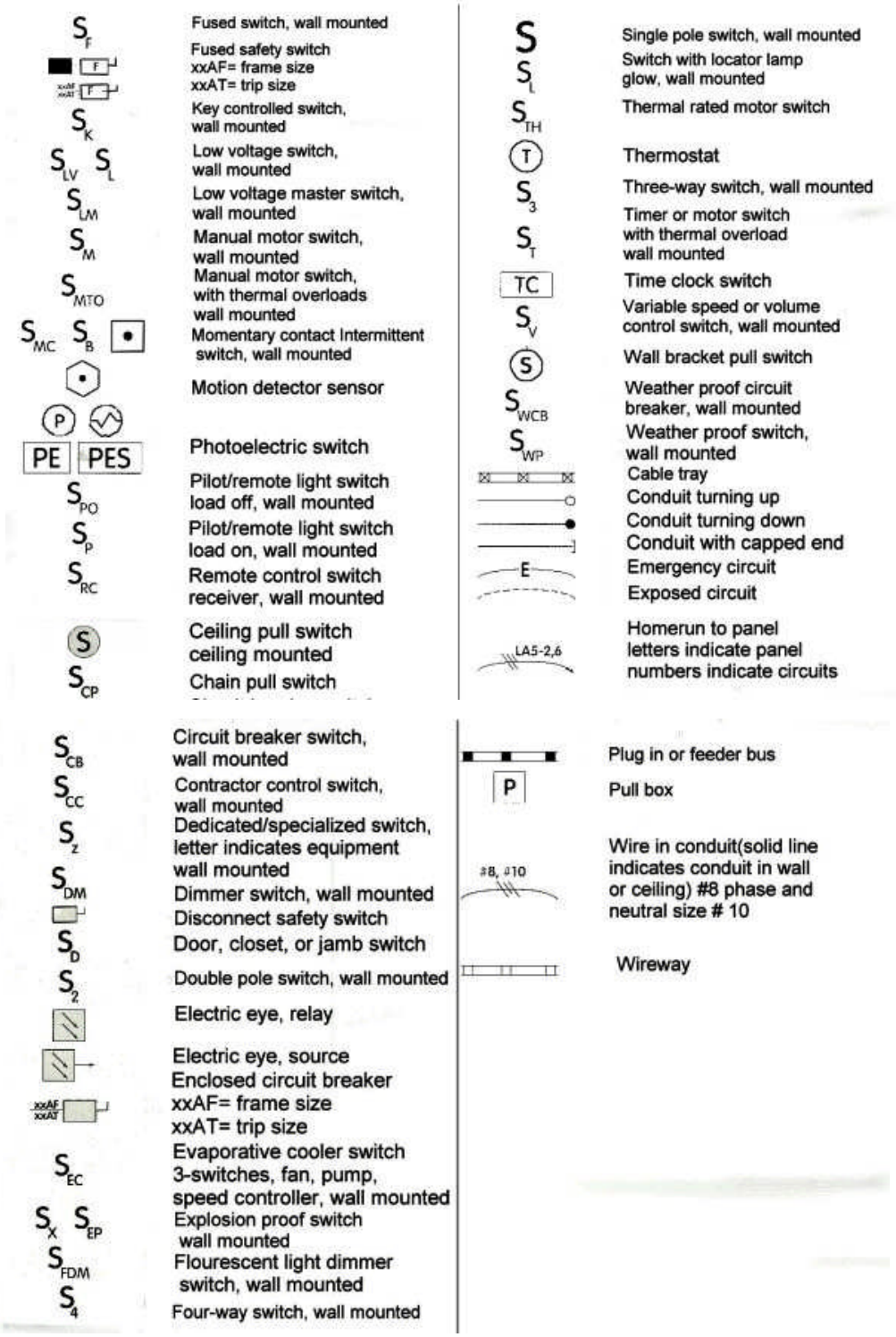
A typical way to pull cable is to start at the last fixture in the run, pull cable to each fixture in the circuit, and continue all the way back to the service panel:

- ☐ Leave the box/spool of cable at the fixture you are cabling, unwind enough cable to complete the run, and then start pulling it through the holes. On long runs, you may need to return to the box or spool a few times to feed more cable through. Two people can really save time: one feeding cable and one pulling cable.
- ☐ Nonmetallic-sheathed cable can tangle or bind. If you feel resistance while pulling, the cable is probably kinked somewhere along the run and should be straightened out.
- ☐ Each time you reach a junction box, pull a few extra feet of cable through for making connections later.
- ☐ Once the cable reaches the service panel, leave a foot or so of extra length on both the service end and the box/spool end for connecting.
- ☐ After the cable is in place, fasten it to framing with staples every 4'-6", at turns, and within 12" of where cable enters a box. At turns, provide a jug handle.
- ☐ Label each cable at the panel end with a felt pen or piece of tape to keep them organized.

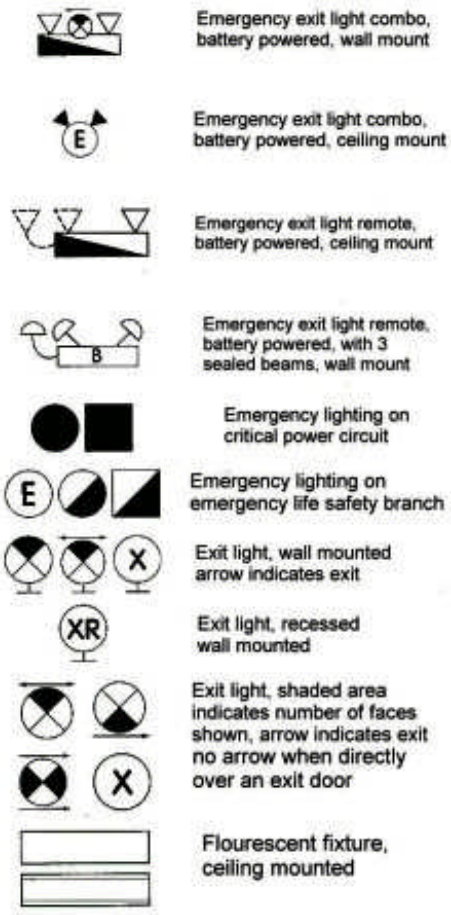
Next Steps: Attach the cable to the framing (see diagrams on following pages for maximum distances between fasteners) and securing the cable to junction/device boxes with clamps provided within the boxes.

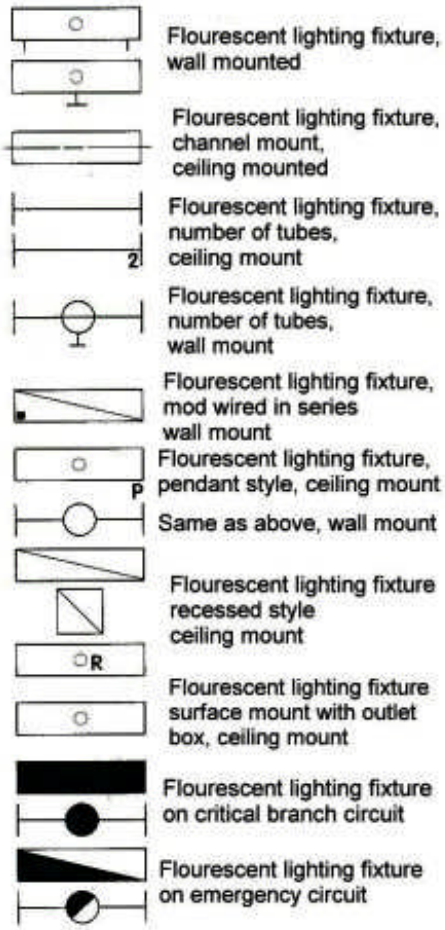
WIRE COLOR	CIRCUIT TYPE
BLACK	"Hot" wire. In an outlet, it is always wired to the narrow spade or brass-colored terminal.
GREEN	"Ground" or "grounding" wire. In an outlet, it is always wired to the green terminal.
RED	"Second hot" wire in a 3-way outlet. Often called the "traveler."
WHITE OR GRAY	"Neutral" wire. In an outlet, it is always wired to the wide spade or silver-colored terminal.

Electrical Switch Symbols



Fixture Symbols





Fixture Symbols

Flourescent fixtures continuous row

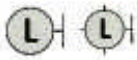
Illuminated house number, wall mount

Incandescent lighting fixture, ceiling mounted

Incandescent lighting fixture, blank, unused ceiling mounted

Incandescent lighting fixture, blank, unused wall mounted

Incandescent lighting fixture, chandelier, ceiling mounted



Incandescent lighting fixture, controlled by low voltage switch relay in box, wall mounted

Incandescent lighting fixture, letter in triangle is reference to key, ceiling mounted

Incandescent lighting fixture, mirror lights, ceiling mounted

Incandescent lighting fixture, mirror/vanity lights, wall mounted

Incandescent lighting fixture, multiple flood lights, wall mounted

Incandescent lighting fixture, recessed, ceiling mounted

Incandescent lighting fixture, recessed directional light fixture, ceiling mounted

Incandescent lighting fixture, rough-in only, ceiling mounted

Incandescent lighting fixture, spot light, ceiling mounted

Incandescent lighting fixture, heat lamp, ceiling mounted

Incandescent lighting standard uppercase = key, number= circuit number, switch control

Incandescent lighting fixture surface directional light wall mounted

Incandescent lighting fixture, track lighting

Incandescent lighting fixture underwater recessed, bottom fixture

Incandescent lighting fixture underwater recessed, wall mounted

Incandescent lighting fixture underwater up beam bottom mounted

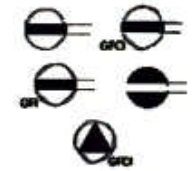
Incandescent lighting fixture fan ceiling mounted

Wall fan

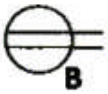
Incandescent lighting with pull switch, wall mounted

Outlet Symbols

Outlet symbols



Duplex receptacle outlet
with GFI or GFCI device,
wall mounted



Duplex receptacle outlet,
isolated ground, wall mounted

Duplex receptacle outlet,
split wired, wall mounted

Duplex special purpose outlet

Emergency outlet,
wall mounted

Garbage disposal outlet,
wall mounted

General outlet,
ceiling mounted

General outlet,
wall mounted

Junction box,
ceiling mounted

Junction box,
wall mounted

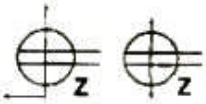
Lamp holder,
ceiling mounted

Outlet Symbols

Lampholder, wall mounted

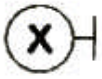
Lampholder, with pull switch, ceiling mounted

Lampholder, with pull switch, wall mounted



Multi-outlet assembly or power strip

Outlet for exit lamp, ceiling mounted



Outlet for exit lamp, wall mounted

Poke-through with electrical outlets, floor mounted

Poke-through (abandoned)

Polarized plug receptacle outlet, wall mounted

Pull switch, ceiling mounted

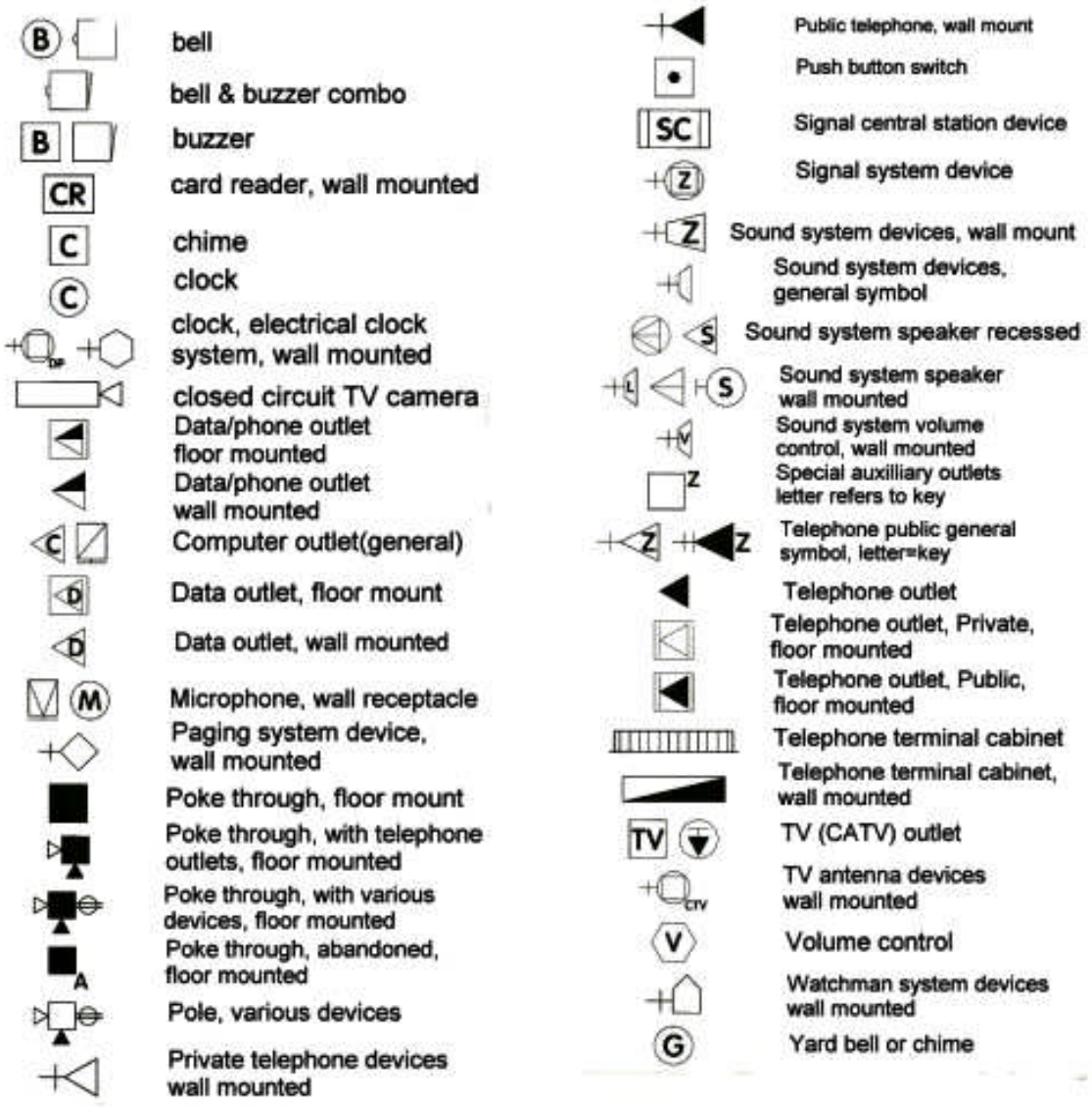
Pull switch, wall mounted

Quadraplex (double duplex) receptacle outlet, ceiling mounted

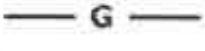
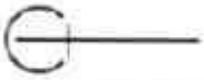
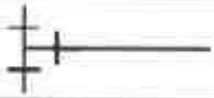
Quadraplex (double duplex) receptacle outlet, floor mounted

Outlet Symbols

Communication Symbols



Plumbing Symbols

 Water Meter	Cold Water
Hot Water	Vent Line
Sanitary Waste	 Gas Pipe
 Gate Valve	 Water Heater Shut Off
 Water Closet	 Lavatory
 Water Heater	 Dishwasher
 Clothes Washer	 Floor Drain
 Clean Out	 Vent Thru Roof
 90 degree Elbow	 Pipe Turns Up
 Pipe turns Down	 Tee
 Union	 Cap

WC Toilet, floor outlet

WC Toilet, wall hung

WC Toilet, tank type

Bidet

UR Urinal, wall hung

S Sink, general

FS Sink, floor

KS Sink, kitchen

MS Sink, mop

SS Sink, utility

LAV Lavatory

Bathtub, recessed type

DF Drinking fountain, floor mounted

Drinking fountain, wall hung

SHWR Shower, stall type

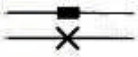
Shower, handicapped

HWT Hot Water Tank

WH Water Heater

Equipment, insulation (indicate thickness)

Equipment, pipe hanger, alignment guide



Equipment, pipe hanger, clevis type

CSH Equipment, pipe hanger, constant support type

RH Equipment, pipe hanger, roller type

SS Equipment, pipe hanger, sliding support type

SCH Equipment, pipe hanger, spring cushion type

Equipment, pipe hanger, spring type

TH Equipment, pipe hanger, trapeze type

PS Equipment, pipe stand (floor supported)

Equipment, pump (arrowhead shows flow)

RC Equipment, riser clamp

Equipment, sediment strainer

Equipment, strainer basket type

Equipment, strainer blow off type (with valve)

Equipment, strainer, cone type

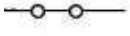
Equipment, strainer, continuous type

Equipment, strainer, T type

Equipment, strainer, temporary

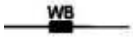
Equipment, trap, generic

Equipment, trap, float



Equipment, trap, running

Equipment, trap, vacuum



WB Equipment, wall

Fitting, bell & spigot

Fitting, bulkhead flange

Fitting, bull plug, bell and spigot

Fitting, bull plug, flanged

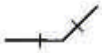
Fitting, bull plug, screwed

Fitting, bushing

Fitting, choke nipple

FCO Fitting, clean out, floor

CO Fitting, clean out, exposed



Fitting, elbow, 45-degree

Fitting, elbow, 45-degree dropping

Fitting, elbow, 45-degree rising

Fitting, elbow, 90-degree

Fitting, elbow, 90-degree turned down

Fitting, elbow, 90-degree turned down

Fitting, elbow, 90-degree turned up

Fitting, elbow outlets: side and down

Fitting, elbow, outlets: side and up

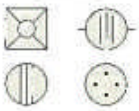
Fitting, elbow, reducing

Fitting, expansion joint, bellows

Fitting, expansion joint, sliding

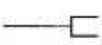
Fitting, flanged

Fitting, flexible connection

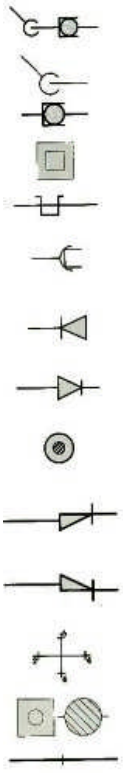


FD Fitting, floor drain

Fitting, flow straightener (flanged fitting shown)



Fitting, hose connector, quick-couple



Fitting, joint, double plane swing type

Fitting, joint, swing type or ball joint

Fitting, overflow

Fitting, Pete's plug

Fitting, pipe or cleanout plug, bell & spigot

Fitting, pipe or cleanout plug, screwed

Fitting, reducer, concentric

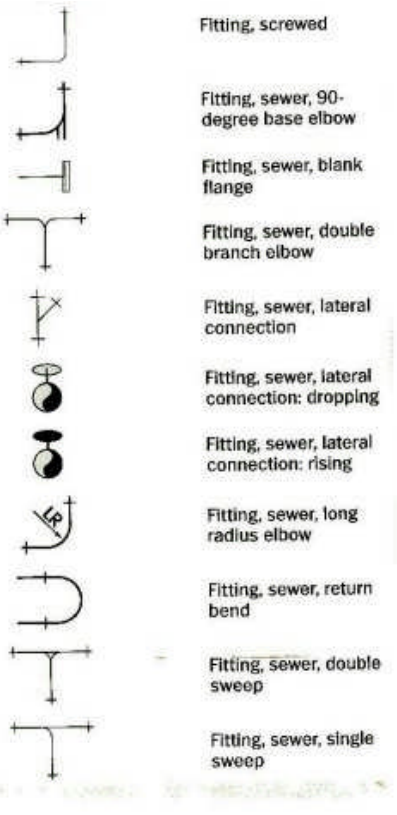
Fitting, reducer, concentric, rising or descending

Fitting, reducer, eccentric, straight crown

Fitting, reducer, eccentric, straight invert

Fitting, reducing cross

RD Fitting, roof drain



Fitting, screwed

Fitting, sewer, 90-degree base elbow

Fitting, sewer, blank flange

Fitting, sewer, double branch elbow

Fitting, sewer, lateral connection

Fitting, sewer, lateral connection: dropping

Fitting, sewer, lateral connection: rising

Fitting, sewer, long radius elbow

Fitting, sewer, return bend

Fitting, sewer, double sweep

Fitting, sewer, single sweep

Fitting, sewer, street elbow

Fitting, sewer, tee (side outlet/outlet up)

Fitting, sewer, through double T-Y

Fitting, sewer, through double Y

WYE Y Fitting, sewer, true Y

Fitting, sleeve

Fitting, soldered

Fitting, solvent cement

Fitting, straight size cross

Fitting, straight size tee

Fitting, tee down

Fitting, tee up

Fitting, tee, outlets: side and down

Fitting, tee, outlets: side and up

Fitting, tee, reducing

Fitting, union, flanged

Fitting, union, screwed

W.H. Fitting, wall hydrant (2 connections shown)

Fitting, welded

Piping, crossover (no junction)

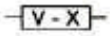
Piping, pipe

Piping, point of connection (old to new work)

D 3:12 Piping, sloped pipe, drop (indicated e.g. 1:24)

R 3:12 Piping, sloped pipe, rise (indicated e.g. 2:12)

VTR Piping, vent through roof



Valve (designated by key or abbreviations)

Valve in pit or valve box

Valve in riser

Valve in wall box

Valve, 3-way (shading indicates closed side)

Valve, 4-way

Valve, air- or gas-line

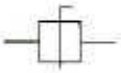
Valve, angled gate type

Valve, angled globe type

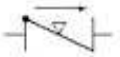
Valve, ball type

Valve, butterfly

HB Valve, hose bibb



Valve, hot water balance



Valve, lift check type

Valve, listed indicating

Valve, lockable

Valve, needle type

Valve, petcock or cock

Valve, pig ball type

Valve, plug type

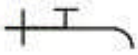
PIV Valve, post-indicator

Valve, pressure reducing

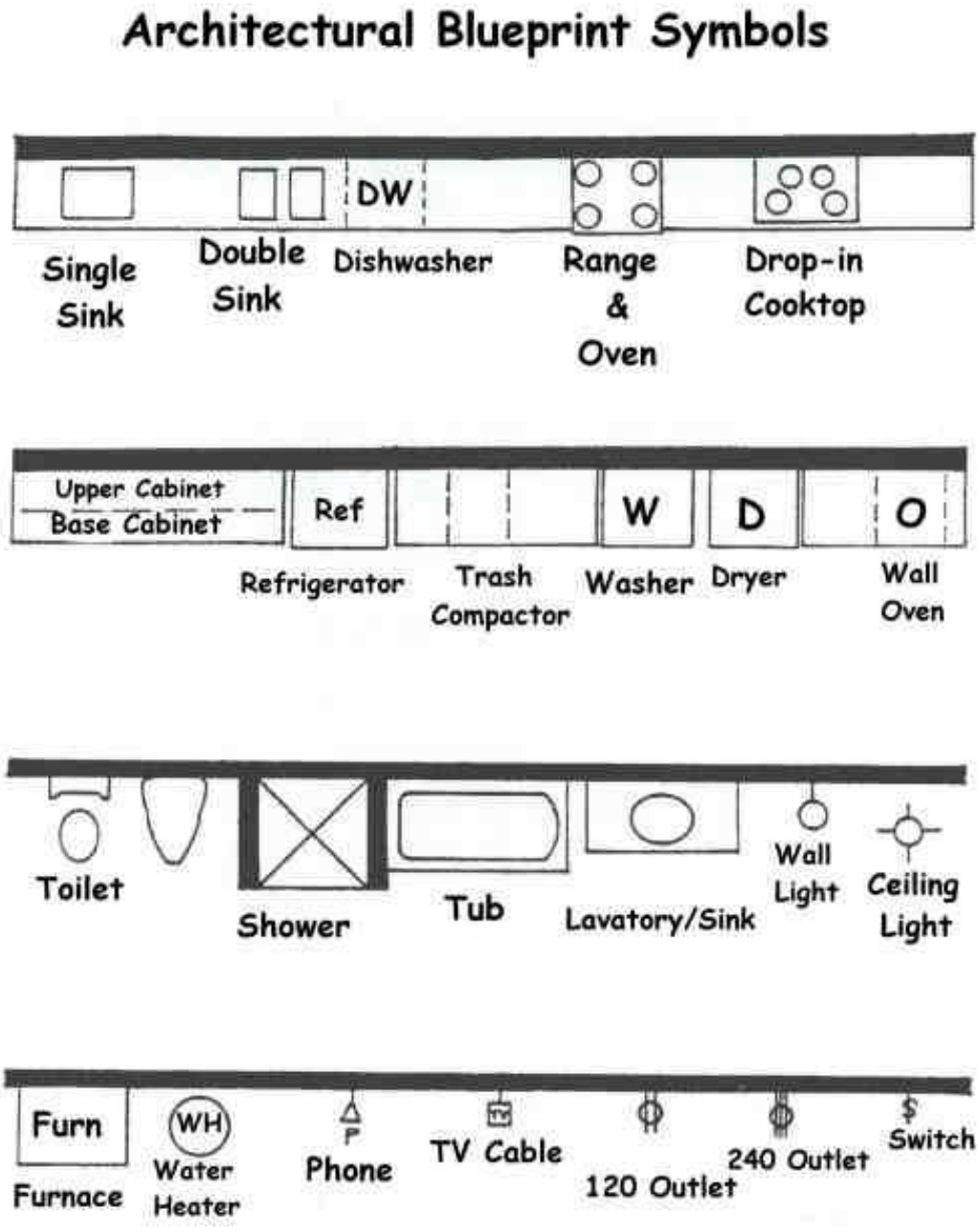
Valve, pressure relief

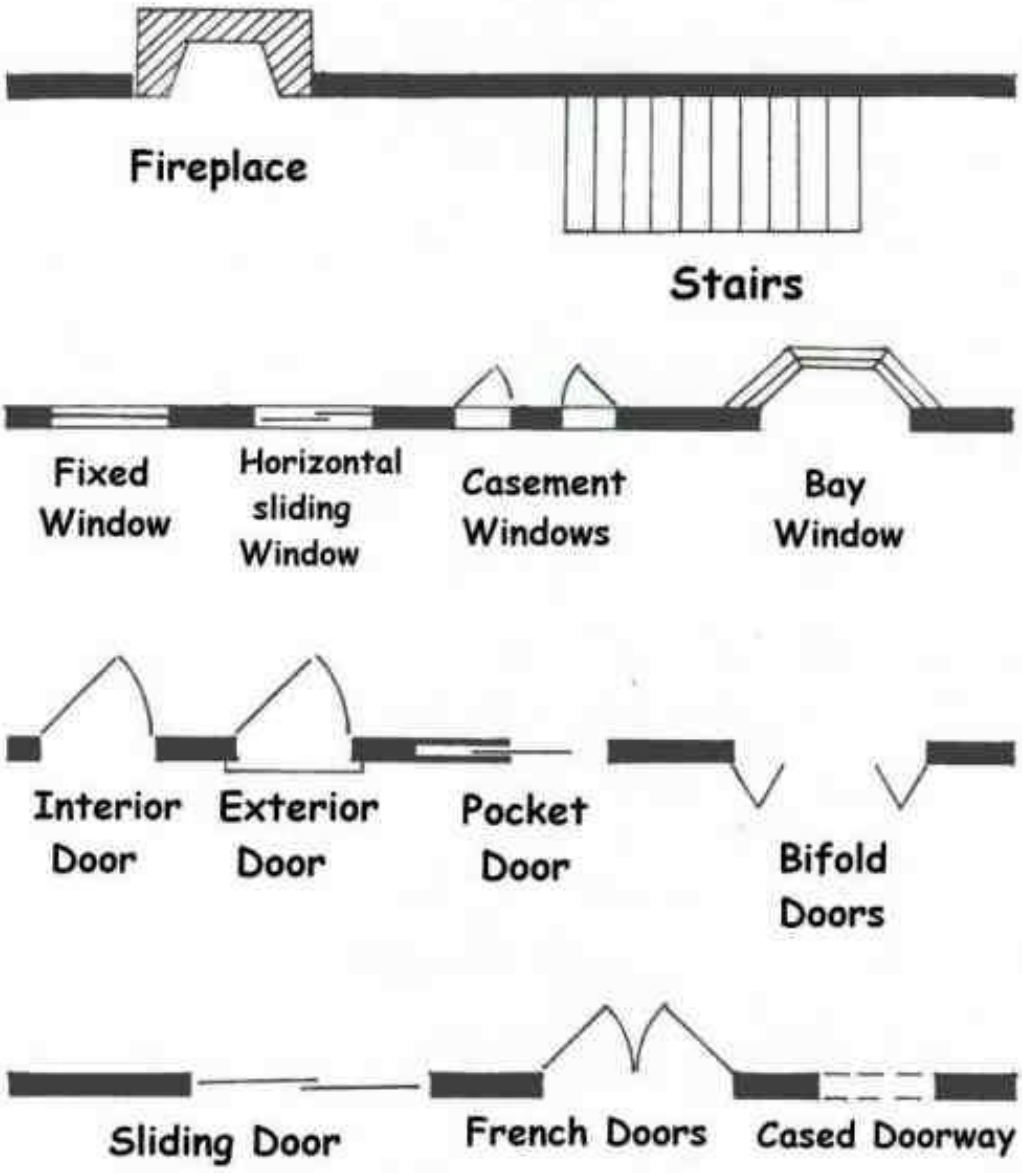
Valve, rotary plug type

Valve, safety type

	**BFP**	Valve, check (also called swing check or backflow preventer)
		Valve, control, diaphragm actuator
		Valve, control, hand actuator
		Valve, control, motor operated
		Valve, control, rotary actuated
		Valve, control, solenoid operated
		Valve, diaphragm type
		Valve, faucet
		Valve, float type
		Valve, flush valve
	**GV**	Valve, gate type, normally closed
	**GV**	Valve, gate type, normally opened (abbrev. or letter refers to key)
		Valve, globe type
		Valve, spring check type
		Valve, stop check type
		Valve, stop cock plug or cylinder type, 2-way
		Valve, stop cock plug or cylinder type, 3-way/2-port
		Valve, stop cock plug or cylinder type, 3-way/3-port
		Valve, stop cock plug or cylinder type, 4-way/4-port
		Valve, triple duty (flow, flow balance, backflow prevention)
		Valve, V-ball type

Architectural symbols




Fireplace
Stairs
Fixed Window
Horizontal sliding Window
Casement Windows
Bay Window
Interior Door
Exterior Door
Pocket Door
Bifold Doors
Sliding Door
French Doors
Cased Doorway

Electrical boxes

BOXES

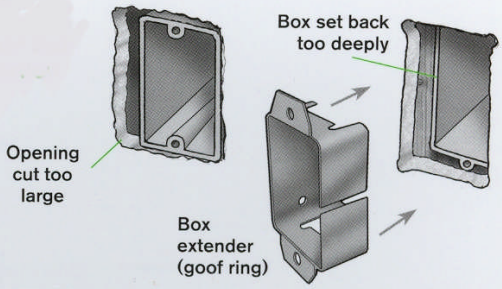
Boxes are necessary to safely enclose and protect wiring splices and to support devices and luminaires (fixtures). In raceways, they provide a pull point for the wiring. Boxes must be large enough to contain all the conductors and devices inside them, and sufficient wire must be brought into the box to safely make up connections. Luminaires that are supported from boxes are generally designed so their connections will be made inside the box, rather than inside the fixture canopy. Device boxes with 6/32 threaded holes are designed to mount switches and receptacles and are not generally used to mount luminaires.

General	06 IRC	08 NEC
☐ Metal boxes must be grounded	[3805.2]	{314.4}
☐ Box & conduit body covers must remain accessible	[3805.10]	{314.29}
☐ Max 1/4in setback from noncombustible surface **F19**	[3806.5]	{314.20}
☐ Box extenders OK to correct excess setback	[3806.5]	{l314.20}
☐ Boxes flush w/ combustible surface **F19**	[3806.5]	{314.20}
☐ Plaster gap max 1/8in for flush cover boxes **F19**	[3806.6]	{314.21}
☐ Min 6in free conductor & 3in past box face	[3306.10.3]	{300.14}
☐ Ceiling lighting boxes rated min 50lb	[3805.6]	{314.27A}[20]
☐ Wall boxes marked w/ max weight if not 50lb EXC	[n/a]	{314.27A}[20]
Wall sconces ≤6lb OK mounted on device boxes	[3805.6X]	{314.27AX}
☐ Smoke alarms OK mounted to device boxes	[n/a]	{314.27EX}
☐ Boxes must be rigidly supported	[3806.8]	{314.23}
☐ PVC & EMT not OK for box support	[3806.8.5]	{314.23E&F}
☐ PVC & EMT OK for conduit body support	[3806.8.5]	{314.23E&F}

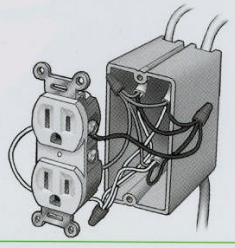
Also see NEC sections 352.12B & 358.12.

☐ Wet location boxes & conduit bodies listed for wet	[3805.11]	{314.15}
☐ Damp or wet location boxes must keep out water	[3805.11]	{314.15}

Box Fill	06 IRC	08 NEC
☐ Size sufficient to provide free space for conductors	[3805.12]	{314.16}
☐ Standard metal boxes per code tables	[3805.12.1.1]	{314.16A1}
☐ Include volume of marked mud rings & extensions	[3805.12.1]	{314.16A}
☐ Plastic boxes have volume marking	[3805.12.1.2]	{314.16A2}
☐ No splices in pancake boxes EXC **F21**	[3805.12.2]	{314.16B}
4in (6cu in) pancake OK at end of 14/2 run **F21**	[3805.12.2]	{314.16B}
☐ 18cu in box too small for 3 12/2 Romex **T8,F20**	[3805.12.2]	{314.16B}



Box Fill Factors **T7,T8**	06 IRC	08 NEC
☐ Count each conductor exiting box EXC	[3805.12.2.1]	{314.16B1}
EGCs from luminaires or up to 4 conductors <14AWG from luminaires w/ domed canopies	[3805.12.2.1X]	{314.16B1X}
☐ Unbroken conductors passing through box count as only 1 conductor EXC	[3805.12.2.1]	{314.16B1}
Looped unbroken conductors >12in count as 2	[3805.12.2.1]	{314.16B1}
☐ Do not count pigtailed conductors to devices	[3805.12.2.1]	{314.16B1}
☐ All internal clamps count as 1, based on largest conductor in box	[3805.12.2.2]	{314.16B2}
☐ Support fittings count as 1 conductor for each fitting type based on largest conductor in box	[3805.12.2.3]	{314.16B3}
☐ Count devices as 2 conductors based on the connected wire size	[3805.12.2.4]	{314.16B4}
☐ All EGCs count as only 1 based on largest	[3805.12.2.5]	{314.16B5}



Pancake Boxes

4 cu. in. 6 cu. in.

Branch circuits and outlets

Receptacle Outlets–General Purpose F27&28	06 IRC	08 NEC
☐ Walls ≥2ft wide req receptacle	[3801.2.2]	{210.52A2}
☐ Partitions & bar-type counters count as walls F30	[3801.2.2]	{210.52A2}
☐ Doorways & fireplaces not counted as walls	[3801.2.2]	{210.52A2}
☐ Receptacle req'd within 6ft horizontally of any point along wall	[3801.2.1]	{210.52A1}
☐ Receptacle req'd for hallways ≥10ft in length F28	[3801.10]	{210.52H}
☐ Receptacles that are part of electric baseboard heaters OK as req'd outlets	[3801.1]	{210.52}
☐ Receptacles >5½ft high not OK as req'd outlets	[3801.1]	{210.52}
☐ Floor receptacles >18in from wall not OK as req'd outlets	[3801.2.3]	{210.52A3}
☐ Switched receptacles installed as req'd lighting do not count as part of req'd receptacle outlets unless "half hot"	[n/a]	{210.52}[25]

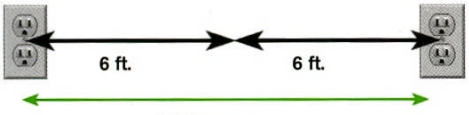
FIG. 27

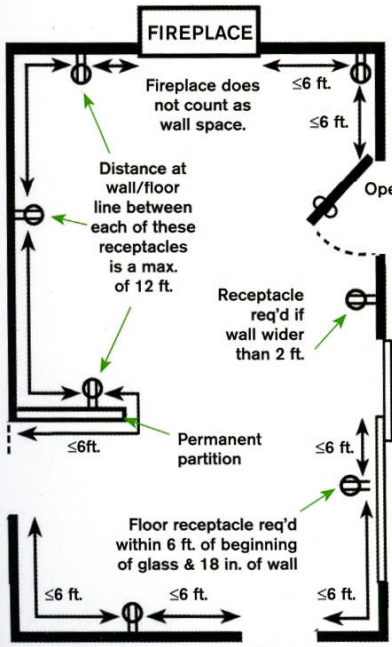
6 ft. & 12 ft. Rule

FIG. 28

6 ft. & 12 ft. Rule Explained

Wall receptacles serve the spaces for 6 ft. on each side of the receptacle. Therefore, the maximum spacing between wall receptacles is 12 ft.





Garages & Unfinished Basements	06 IRC	08 NEC
☐ Min 1 wall-switched lighting outlet in garage	[3803.3]	{210.70A2a}
☐ Min 1 receptacle not dedicated to fixed equipment	[3801.9]	{210.52G}[26]

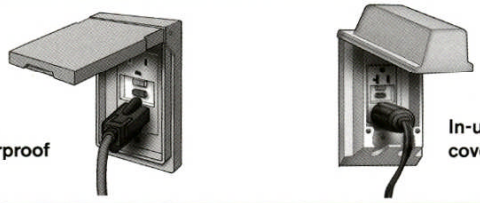
Bathrooms	06 IRC	08 NEC
☐ Receptacle req'd on wall within 3ft of each basin OR	[3801.6]	{210.52D}
May be in cabinet side or face ≤12in below countertop	[3801.6X]	{210.52D}
☐ No face-up outlets on vanity countertop	[3801.6]	{406.4E}
☐ No receptacles within or directly over tub or shower	[3902.11]	{406.8C}
☐ Separate 20A circuit for bath receptacles only OR	[3603.4]	{210.11C3}
Dedicated 20A circuit to each bathroom	[3603.4X]	{210.11C3X}
☐ Max rating of fixed space heater on general lighting circuit 15A circuit: 900W; 20A circuit: 1,200W	[3602.5]	{210.23A2}

Laundry	06 IRC	08 NEC
☐ Min 1 20A circuit to laundry receptacles	[3603.3]	{210.11C2}
☐ No other outlets on laundry receptacle circuit	[3603.3]	{210.11C2}
☐ Receptacle within 6ft of intended appliance location	[3801.5]	{210.50C}
☐ Electric dryer min 30A circuit (10AWG Cu, 8AWG Al)	[T3604.2(1)]	{220.54}
☐ Electric dryer req's 4-conductor branch circuit EXC	[3808.7]	{250.140}
Existing 3-wire circuits allowed to remain in use	[n/a]	{250.140X}

Outdoors	06 IRC	08 NEC
☐ Receptacle accessible from grade req'd at front & rear of dwelling max 6½ft above grade	[3801.7]	{210.52E1}
☐ Receptacle req'd for balconies w/ interior access & ≥20sq ft	[n/a]	{210.52E3}[27]
☐ Receptacles in damp or wet locations req'd to be listed weather-resistant type	[n/a]	{406.8A&B}[28]
☐ Outdoor damp location receptacle (e.g., protected porch) req's weatherproof cover F29	[3902.8]	{406.8A}
☐ Wet location 15A & 20A receptacles req in-use covers F29	[3902.9]	{406.8B1}

FIG. 29

Outdoor Receptacle Covers



Lighting Outlets (also see p.19)	06 IRC	08 NEC
☐ Wall-switch controlled lighting outlets req'd in all habitable rooms & bathrooms	[3803.2]	{210.70A1}
☐ Habitable room lighting outlets may be switched receptacle except in kitchen & bathroom	[3803.2X1]	{210.70A1X1}
☐ Occupancy-sensor wall switches OK	[3803.2X2]	{210.70A1X2}
☐ Wall-switch controlled lighting outlets req'd in hallways, stairways, attached garages, & detached garages w/ power	[3803.3]	{210.70A2}
☐ Interior stair req's switch at each entrance if ≥6 risers	[3803.3]	{210.70A2c}
☐ Lighting outlet req'd on exterior side grade-level doors	[3803.3]	{210.70A2b}
☐ Lighting outlet req'd at garage egress doors	[3803.3]	{210.70A2b}
☐ Lighting outlet not req'd at garage vehicle doors	[3803.3]	{210.70A2b}

KITCHENS

A minimum of two small-appliance branch circuits are required for portable appliances that are used in kitchens and dining areas. These circuits are in addition to those that supply lighting or permanently installed appliances. Portable kitchen appliances have short cords so they are not as likely to be run across cooktops or sinks or to hang down in the reach of children. A receptacle is needed to serve every countertop 1ft. or more in width.

Branch Circuits

	06 IRC	08 NEC
☐ Min 2 20A small-appliance circuits req'd	[3603.2]	{210.11C}
☐ Small-appliance circuits must serve refrigerator & all countertop & exposed wall receptacles in kitchen, dining room, & pantry EXC Refrigerator OK on individual branch circuit ≥15A	[3603.2] [3603.2X]	{210.52B1} {210.52B1X2}
☐ Switched receptacle for dining room light OK on non-small-appliance circuit	[n/a]	{210.52B1X1}
☐ No other outlets (including lights) on small appliance branch circuits EXC Receptacles for clock or gas range ignition OK	[3801.3.1] [3801.3.1X]	{210.52B2} {210.52B2X}
☐ Dishwasher & disposer req separate circuits if combined rating exceeds branch circuit rating	[3601.2]	{210.19A1}
☐ Circuits for ranges ≥8.75kW min 40A 240V	[3602.9.1]	{210.19A3}

Receptacles for Countertop Spaces

	06 IRC	08 NEC
☐ Receptacles req'd for wall counter spaces ≥12in wide	[3801.4.1]	{210.52C1}
☐ Countertop spaces separated by sinks or ranges considered separate countertop spaces **F30**	[3801.4.4]	{210.52C4}
☐ Spacing so no point >24in from receptacle **F31**	[3801.4.1]	{210.52C1}
☐ Area behind sink or range not considered countertop space if <12in for straight wall **F32** or <18in for corner appliance **F33**	[3801.4.1X][29]	{210.52C1X}
☐ Max 20in above countertop	[3801.4.5]	{210.52C5}
☐ Peninsula countertop spaces req receptacle if long dimension >24in & short dimension >12in, measured from connecting edge **F30**	[3801.4.3]	{210.52C3}
☐ Island & peninsula countertop spaces min 1 receptacle per space–no 24in rule **F30**	[3801.4.2&3]	{210.52C2&3}
☐ Island & peninsula receptacles may be mounted no more than 12in below counter if max 6in counter overhang & no backsplash or means of installing receptacle in an overhead cabinet **F30**	[3801.4.5X]	{210.52C5X}
☐ No face-up countertop receptacles	[3801.4.5]	{406.4E}
☐ GFCI protection for all receptacles serving countertops	[3802.6]	{210.8A6}

FIG. 30

Kitchen Receptacles

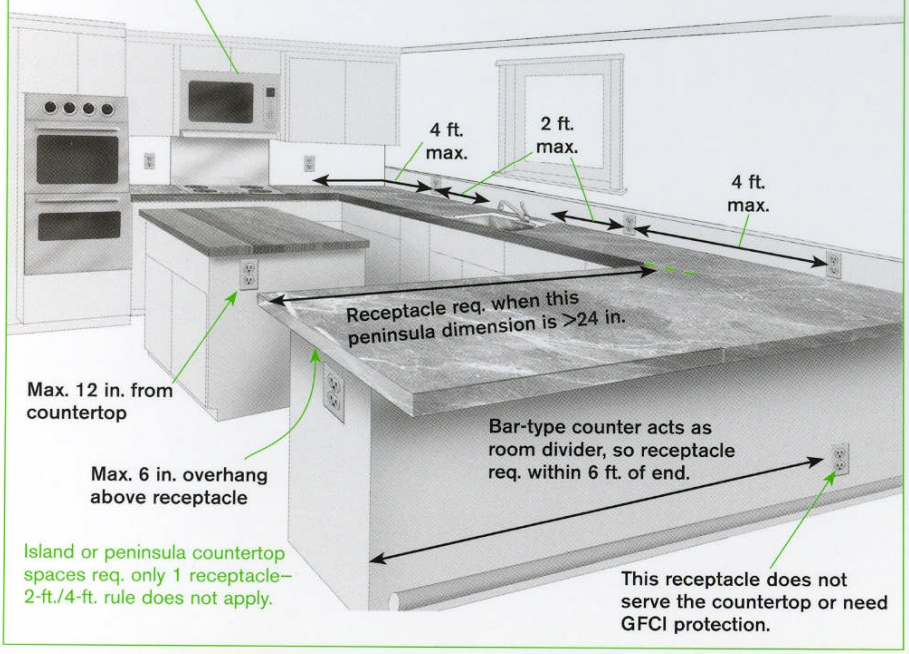


FIG. 31

2-ft./4-ft. Rule

Wall countertop receptacles serve the spaces for 2 ft. on each side of the receptacle. Therefore, the maximum spacing between receptacles on the same countertop space is 4 ft.

FIG. 32

Extended Range or Sink

If **X** ≥ 12 in., countertops not considered separate spaces & the 2-ft./4-ft. rule applies to the entire countertop.

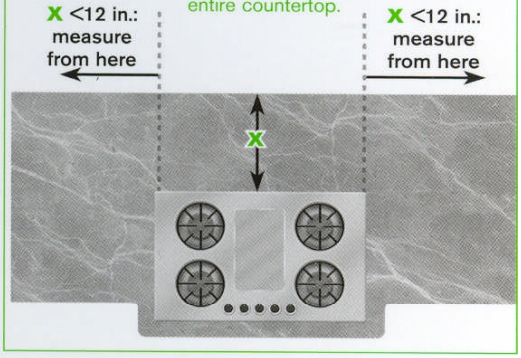
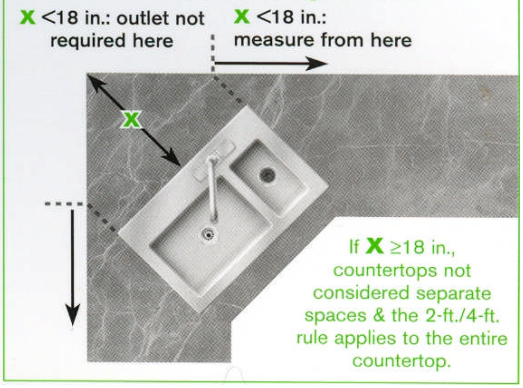


FIG. 33

Corner Range or Sink



SWITCHES

Switch installations must ensure that an equal load is going in and out on each wiring method. Some modern occupancy sensors require a neutral conductor, and old-style switch loops are not sufficient for these sensors.

Switches	06 IRC	08 NEC
☐ All switching in ungrounded conductors **F34,35**	[3901.8&9]	{404.2A&B}
☐ Snap switches & dimmers req grounding EXC	[3901.11.1]	{404.9B}
Replacement switches OK w/ GFCI or plastic faceplate	[3901.11.1X]	{404.9BX}
☐ Grounding OK by screws to grounded metal box	[3901.11.1]	{404.9B1}
☐ Metal faceplates must be grounded to switch	[3901.11.1]	{404.9B}
☐ Faceplate must completely cover wall opening	[3901.11]	{404.9A}
☐ 3-way switches req'd at stairs w/ 6 or more risers	[3803.3]	{210.70A2c}
☐ Dimmers OK for incandescent lights not receptacles	[3901.12]	{404.14E}
☐ Current-carrying conductors of circuit grouped **F34**	[3306.7]	{300.3B}
☐ Re-identify ungrounded white or gray wires **F34**	[3307.3X]	{200.7C}
☐ "CO/ALR" switch req'd if direct Al wire connection	[3901.2]	{404.14C}

FIG. 34

3-Way Switch

3-way switching takes place from a common terminal to one or the other traveler terminals.

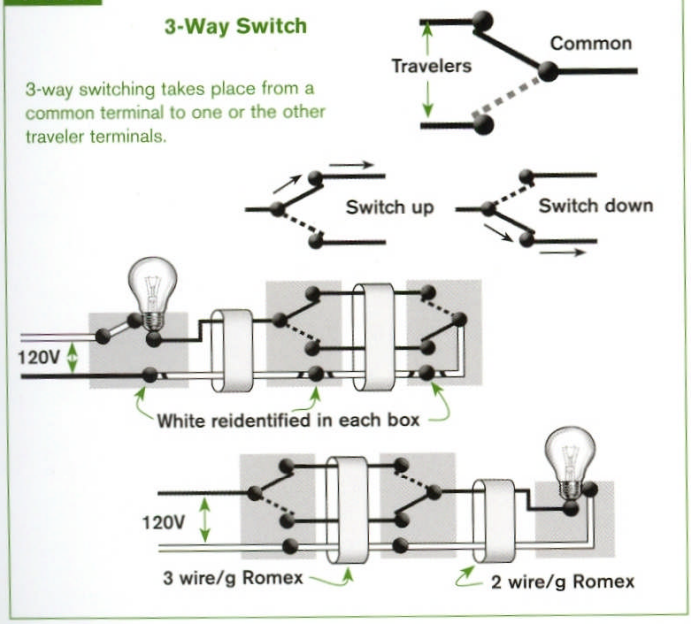
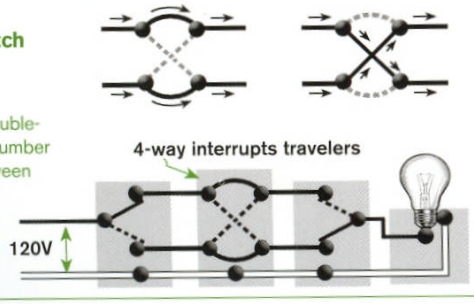


FIG. 35

4-Way Switch

A 4-way switch is a double-pole, double-throw switch. Any number can be placed between the two 3-ways.



LIGHTING

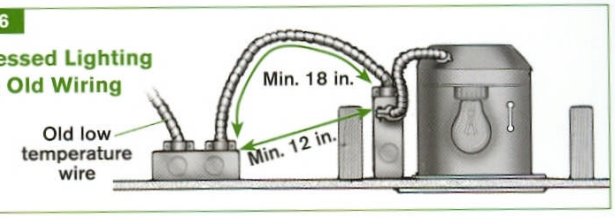
Lighting outlets and luminaires must be installed with no exposed live parts that could pose a shock hazard. The heating effect of luminaires must be considered, especially around thermal insulation. Lights rated "type IC" are suitable for insulated ceilings. See **p.17** for required locations.

General	06 IRC	08 NEC
☐ All luminaires & lampholders listed	[3303.3]	{410.6}[30]
☐ Exposed metal parts grounded EXC	[3903.3]	{410.42A}
Incidental metal parts such as mounting screws	[3903.3]	{410.42A}
☐ Wet location luminaires L&L for wet location	[3903.8]	{410.10A}
☐ Damp location luminaires L&L for damp or wet location	[3903.8]	{410.10A}
☐ Screw shells for lampholders only–no adapters	[3903.4]	{410.90}

Recessed Lights	06 IRC	08 NEC
☐ Non-Type IC min 1/2in from combustibles	[3904.8]	{410.116A1}
☐ Non-Type IC min 3in from insulation	[3904.9]	{410.116B}
☐ Type IC OK in contact w/ combustible material	[3904.8]	{410.116A2}
☐ Type IC OK in contact w/ insulation	[3904.9]	{410.116B}
☐ Luminaires that req >60°C wire must be marked	[n/a]	{410.74}
☐ Connect proper temp-rated wire to luminaire	[n/a]	{410.117A}
☐ Tap conductors to 60°C wire min 18in max 6ft **F36**	[n/a]	{410.117C}

FIG. 36

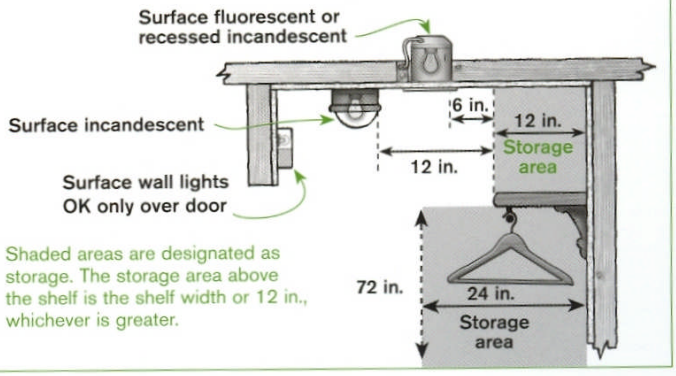
Recessed Lighting with Old Wiring



Closet Lights **F37**	06 IRC	08 NEC
☐ Incandescent bulbs req'd to be fully enclosed	[3903.11]	{410.16A1}
☐ Partially enclosed incandescent bulbs prohibited	[3903.11]	{410.16B}
☐ Surface-mounted only on ceiling or wall above door	[3903.11]	{410.16C1&2}
☐ Surface incandescents min 12in from storage	[3903.11]	{410.16C1}
☐ Surface fluorescents min 6in from storage	[3903.11]	{410.16C2}
☐ Recessed (wall or ceiling) min 6in from storage	[3903.11]	{410.16C3&4}
☐ Surface fluorescent or LED (light-emitting diode) OK in storage area if listed for same	[n/a]	{410.16C5}[31]

FIG. 37

Closet Lights



Shaded areas are designated as storage. The storage area above the shelf is the shelf width or 12 in., whichever is greater.

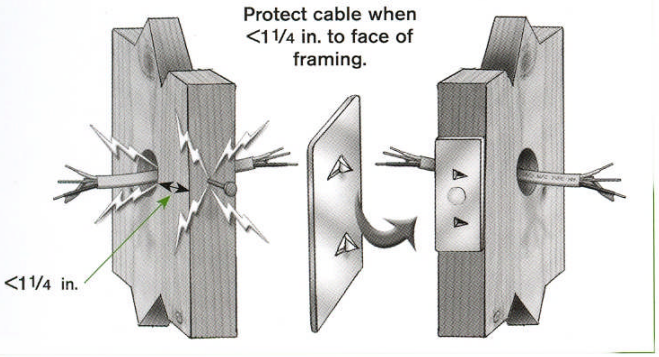
CABLE SYSTEMS

Cable systems are the most common residential wiring methods. Cables contain all conductors of the circuit inside a protective outer sheath of metal or plastic Starting with the 2005 edition, the NEC uses a parallel numbering system for rules pertaining to cables and raceways. See the common numbering system table (**T23**) on the inside back cover.

Cable Protection Indoors (NM, AC, MC, UF, SE)	06 IRC	08 NEC
☐ Bored holes & standoff clamps 1¼in setback **F56**	[3702.1]	{300.4A&D}
☐ Protect cables w/ 1/16in steel plate {or L&L plate} if closer than 1¼in to framing surfaces **F45**	[3702.1]	{300.4A&D}
☐ Provide guard strips within 6ft of attic scuttle **F46**	[3702.2.1]	{334.23}
☐ Provide guard strips up to 7ft high in attic w/ ladder or permanent stairs **F46**	[3702.2.1]	{334.23}

FIG. 45

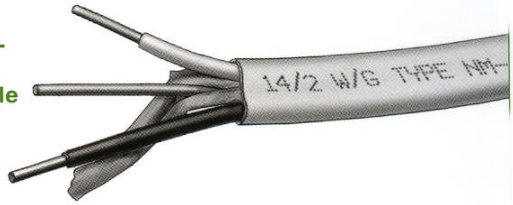
Nail-Plate Protection



NM–Nonmetallic Sheathed Cable (Romex) **F48**	06 IRC	08 NEC
☐ OK in dry locations only	[3701.4]	{334.12B4}
☐ Protect exposed cable from damage where necessary	[3702.3.2]	{334.15B}
☐ Listed grommets for holes through metal framing	[3702.1]	{300.4B1}
☐ OCPD selection based on 60° column **T11**	[3605.4.4]	{334.80}
☐ Derating & temp correction based on 90° rating	[3605.4.4]	{334.80}
☐ Derate >2 NM cables in same caulked (fireblocked) hole	[3605.4.4][36]	{334.80}
☐ Derate >2 NM cables installed w/o spacing in contact w/ thermal insulation	[n/a]	{334.80}[37]
☐ Secure to box w/ approved NM clamp EXC **F49**	[3805.3.2]	{314.17B&C}
Single-gang (2¼×4in) plastic box stapled within 8in	[3805.3.2]	{314.17CX}
☐ Min ¼in sheathing into plastic boxes	[3805.3.1]	{314.17C}
☐ Secure within 12in of box & max 4¼ft intervals	[3702.1]	{334.30}
☐ Do not overdrive staples or staple flat cable on edge	[3702.1]	{334.30}
☐ Bends gradual (min 5× cable diameter)	[3702.5]	{334.24}
☐ Running board for small cable under joists **F47**	[3702.4]	{334.15C}

FIG. 48

NM (Romex)–Nonmetallic-Sheathed Cable



GLOSSARY OF ELECTRICAL TERMS

Accessible: Not permanently concealed or enclosed by building construction.

Accessible, as appplied to equipment: Capable of being removed or exposed without damaging the building finish or structure. A piece of equipment can be considered accessible even if tools must be used or other equipment must be removed to gain access to it.

Accessible, readily: Capable of being reached quickly for operation or inspection without the necessity of using tools to remove covers, resorting to ladders, or removing other obstacles.

Alternating current (AC): Current that flows in one direction and then in the other in regular cycles; referred to as frequency or Hertz.

Apparent power: See *power*.

Approved: Acceptable to the AHJ. The AHJ will usually approve materials that are listed and labeled.

Arc fault: An electric current propagated through air.

AFCI, Arc-Fault Circuit Interrupter: Device intended to provide protection from the effects of arc faults by recognizing certain characteristics unique to arcing and by functioning to de-energize the circuit when an arc fault is detected.

AFCI, branch/feeder type: An AFCI meeting the standard for interrupting parallel arcs if 75A of current are available at the device.

AFCI, combination type: An AFCI meeting the standard for interrupting both series and parallel arcs, and requiring <75A available current to facilitate operation.

Authority Having Jurisdiction (AHJ): The building official or person(s) authorized to act on his or her behalf.

Bonded, bonding: Connected to establish continuity and conductivity.

Branch circuit: The circuit conductors between the final OCPD (breaker or fuse) protecting the circuit and the outlet or outlets.

Branch circuit, general purpose: Branch circuit that supplies two or more receptacles or outlets for lighting and appliances.

Branch circuit, individual: Branch circuit supplying only one piece of equipment.

Branch circuit, multiwire, residential: Branch circuit consisting of two hot conductors having a 240V potential between them and a grounded neutral having a 120V difference between it and each hot conductor **F17**.

Branch circuit, small appliance: Branch circuit supplying portable household appliances in kitchens and related rooms and that has no permanently installed equipment connected to it (see **p. 18** for exceptions).

Clothes closet: A non-habitable room or space intended primarily for storage of garments and apparel **F37**.

Controller: A device to directly open and close power to a load.

Derating: A reduction in the allowable ampacity of conductors because of ambient temperatures >86°F or more than three current-carrying conductors in the same raceway, or cables without spacing between them.

Device: A piece of equipment that carries or controls electrical energy as its primary function, such as a switch, receptacle, or circuit breaker.

Equipment: A general term including materials, fittings, devices, appliances, luminaires (fixtures), apparatus, machinery, and the like used as a part of, or in connection with, an electrical installation.

Equipment Grounding Conductor (EGC): A wire or conductive path that limits voltage on metal surfaces and provides a path for fault currents **F16**.

Flexibility after installation: Anticipated movement after initial installation, such as that caused by motor vibration or equipment repositioning.

Feeders: Conductors supplying panelboards other than service panels.

Gooseneck: A curve at the top of a service entrance cable designed to prevent water from entering the open end of the cable.

Ground: The Earth.

Grounded conductor: A current-carrying conductor that is intentionally connected to earth (a neutral).

Grounding electrode conductor (GEC): A conductor used to connect the service neutral or the equipment to a grounding electrode or to a point on the grounding electrode system **F6**.

Ground fault: An unintentional connection of a current-carrying conductor to equipment or conductors that are not normally intended to carry current.

GFCI: A device to protect against shock hazards by interrupting current when an imbalance of 6 milliamps or more is detected.

GFPE: A device to protect equipment from ground faults and allowing higher levels of leakage current than a GFCI.

Hertz: A measure of the frequency of AC. In North America, the standard frequency is 60 Hertz.

Individual branch circuit: A circuit supplying only one piece of utilization equipment.

In sight: See *within sight.*

Load: The electrical demand of a piece of electrical equipment measured in amps or watts.

Lighting outlet: An outlet intended for the direct connection of a lampholder or a luminaire.

Location, damp: An area protected from weather, yet subject to moderate degrees of moisture, such as a covered porch.

Location, dry: A location not normally subject to dampness or wetness.

Location, wet: All installations underground or in concrete or masonry in direct contact with the earth and areas subject to direct saturation with rain water or other liquids.

Luminaire: (formerly lighting fixture) A complete lighting unit, including parts to connect it to the power supply and possibly parts to protect or distribute the light source. A lampholder, such as a porcelain socket, is not itself a luminaire.

Neutral conductor: The conductor connected to the neutral point of a system that is intended to carry current under normal conditions **F17**.

Open conductors: Individual conductors not contained within a raceway or cable sheathing, such as a typical service drop.

Outlet: The point on a wiring system at which current is taken to supply equipment. A receptacle or a box for a lighting fixture is an outlet; a switch is not an outlet.

Overcurrent: Any current in excess of the rating of equipment or conductor insulation. Overcurrents are produced by overloads, ground faults, or short circuits.

Overfusing: A fuse or breaker that has an overload rating greater than allowed for the conductor it is protecting.

Overload: Equipment drawing current in excess of the equipment or conductor rating and in such a manner that damage would occur if it continued for a sufficient length of time. Short circuits and ground faults are not overloads.

Panelboards: The "guts" of an electrical panel; the assembly of bus bars, terminal bars, etc., designed to be placed in a "cabinet." What is commonly called an electrical panel or load center is, by NEC terms, a panelboard mounted in a cabinet **F16**.

Power: Electrical power is the product of volts times amps and can be expressed as either watts (true power) or VA (apparent power).

Service: The conductors and equipment providing a connection to the utility **F2**.

Service drop: The overhead conductors supplied by the utility **F2**.

Service entrance conductors: The conductors on the customer's premises that convey power to the service equipment.

Service equipment: The equipment at which the power conductors entering the building can be switched off to disconnect the premises' wiring from the utility power source. A meter can be a part of or separate from the service equipment.

Service lateral: Underground service entrance conductors.

Service point: The connection or splice point at which the service drop and service entrance meet—it is the handoff between the utility and the customer.

Short circuit: A direct connection of current-carrying conductors without the interposition of a load, resulting in high levels of current.

Short circuit rating (SCR): The amount of current that a piece of equipment (such as a breaker or switch) is rated to sustain without damage.

Snap switch: A typical wall switch, including 3-way and 4-way switches.

Ufer: A concrete-encased grounding electrode, named after the developer of the system, Herbert Ufer **F6**.

Unit switch: A switch that is an integral part of an appliance.

Within sight: (also written as "in sight") Visible, unobstructed, and not more than 50 ft. away.

OHM'S LAW

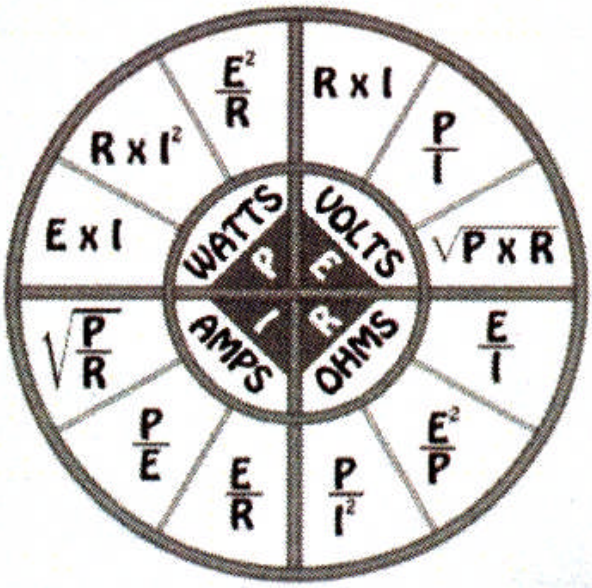
The rate of the flow of the current is equal to electromotive force divided by resistance.

I = Intensity of Current = Amperes
E = Electromotive Force = Volts
R = Resistance = Ohms
P = Power = Watts

The three basic Ohm's law formulas are:

$$I = \frac{E}{R} \qquad R = \frac{E}{I} \qquad E = I \times R$$

Below is a chart containing the formulas related to Ohm's law.
To use the chart, from the center circle, select the value you need to find, I (Amps), R (Ohms), E (Volts) or P (Watts). Then select the formula containing the values you know from the corresponding chart quadrant.



Example:
An electric appliance is rated at 1200 Watts, and is connected to 120 Volts. How much current will it draw?

$$\textbf{Amperes} = \frac{\textbf{Watts}}{\textbf{Volts}} \qquad I = \frac{P}{E} \qquad I = \frac{1200}{120} = 10\ A$$

What is the Resistance of the same appliance?

$$\textbf{Ohms} = \frac{\textbf{Volts}}{\textbf{Amperes}} \qquad R = \frac{E}{I} \qquad R = \frac{120}{10} = 12\ \Omega$$

OHM'S LAW

In the preceding example, we know the following values:

I = amps = 10 R = ohms = 12Ω

E = volts = 120 P = watts = 1200

We can now see how the twelve formulas in the Ohm's Law chart can be applied.

$$\text{AMPS} = \sqrt{\frac{\text{WATTS}}{\text{OHMS}}} \qquad I = \sqrt{\frac{P}{R}} = \sqrt{\frac{1200}{12}} = \sqrt{100} = 10\text{A}$$

$$\text{AMPS} = \frac{\text{WATTS}}{\text{VOLTS}} \qquad I = \frac{P}{E} = \frac{1200}{120} = 10\text{A}$$

$$\text{AMPS} = \frac{\text{VOLTS}}{\text{OHMS}} \qquad I = \frac{E}{R} = \frac{120}{12} = 10\text{A}$$

$$\text{WATTS} = \frac{\text{VOLTS}^2}{\text{OHMS}} \qquad P = \frac{E^2}{R} = \frac{120^2}{12} = \frac{14{,}400}{12} = 1200\text{W}$$

$$\text{WATTS} = \text{VOLTS} \times \text{AMPS} \qquad P = E \times I = 120 \times 10 = 1200\text{W}$$

$$\text{WATTS} = \text{AMPS}^2 \times \text{OHMS} \qquad P = I^2 \times R = 100 \times 12 = 1200\text{W}$$

$$\text{VOLTS} = \sqrt{\text{WATTS} \times \text{OHMS}} \qquad E = \sqrt{P \times R} = \sqrt{1200 \times 12} = \sqrt{14{,}400} = 120\text{V}$$

$$\text{VOLTS} = \text{AMPS} \times \text{OHMS} \qquad E = I \times R = 10 \times 12 = 120\text{V}$$

$$\text{VOLTS} = \frac{\text{WATTS}}{\text{AMPS}} \qquad E = \frac{P}{I} = \frac{1200}{10} = 120\text{V}$$

$$\text{OHMS} = \frac{\text{VOLTS}^2}{\text{WATTS}} \qquad R = \frac{E^2}{P} = \frac{120^2}{1{,}200} = \frac{14{,}400}{1{,}200} = 12\Omega$$

$$\text{OHMS} = \frac{\text{WATTS}}{\text{AMPS}^2} \qquad R = \frac{P}{I^2} = \frac{1200}{100} = 12\Omega$$

$$\text{OHMS} = \frac{\text{VOLTS}}{\text{AMPS}} \qquad R = \frac{E}{I} = \frac{120}{10} = 12\Omega$$