



---

## Journey Exam Study Guide and Sample Questions<sup>1</sup>

Based on the 2014 NEC, Michigan Electrical Code Rules-Part 8, and the MRC

The Journey electrician examination will ask questions from the following areas. You will need a basic understanding of electrical fundamentals as well as how to look up information from the current edition of the *National Electrical Code*. You will also need to obtain a copy of the *Part 8* rules to the *Construction Code Act of Michigan (Act 230 of 1972 as amended)*, and a copy of the *Electrical Administrative Act* which governs licensing, permits, and workers conduct on the job (*Public Act 217 of 1956 as amended*). Also be familiar with the current edition of the *Michigan Residential Code (MRC)* and when this Code applies. You can obtain copies of these documents from the Office of the Electrical Division of the Bureau of Construction Codes, Michigan Department of Licensing and Regulatory Affairs or on the web site [www.michigan.gov/lara](http://www.michigan.gov/lara).

### What Subjects to Study?

**Grounding and bonding:** Determination of system and circuit grounding requirements, methods and location of grounding connections. Choosing proper size grounding conductors, bonding of enclosures, equipment and interior metal piping systems.

**Branch circuits, wire connections and devices:** Knowledge of circuit classifications, ratings, design and use requirements. Knowledge and calculation of branch circuit loads. Application of code rules covering electrical outlets and devices, including wiring connectors and methods.

**Conductors:** Determination of ampacity, type of insulation, usage requirements, methods of installation, protection, support and termination including voltage drop and derating.

**General knowledge of electrical trade:** Terminology and practical calculations such as power factor, voltage and current ratings of equipment.

**Motors and control of motors and equipment:** Knowledge of code rules governing installations of motors and controls. Includes calculations for motor feeder and branch circuits, short circuit, ground fault, and overload protection, and disconnecting means. Knowledge of all control circuits and motor types application and usage.

**Services and feeders:** Knowledge of code rules covering services. Calculation of electrical loads and determination of proper size, rating and type of service and feeder conductors.

**General use equipment:** Knowledge of code rules covering appliances, heating and air conditioning equipment, generators, transformers, and similar equipment.

**Overcurrent protection:** Knowledge of application of fuses, circuit breakers and all types of protective devices for conductors and equipment. Includes rules on taps and splices.

**Raceways:** Knowledge of all types of raceways and their uses. Determining proper size, conductor fill, support and methods of installation.

**Special occupancies and equipment:** Knowledge of code rules as they apply to hazardous locations, health care facilities, assembly occupancies, and similar locations including gasoline dispensing stations. Includes code rules on signs, welders, industrial machinery, swimming pools, and other special equipment.

**Boxes, cabinets, panelboards, and non-raceway enclosures:** Application of proper type, use and support of boxes and cabinets, and similar wiring materials. Includes calculation of proper size and rating of boxes and enclosures.

---

<sup>1</sup> This study guide was developed by Truman C. Surbrook, Ph.D., P.E., Master electrician and Professor; and Jonathan R. Althouse, Master electrician and Instructor: Biosystems & Agricultural Engineering Department, Michigan State University, East Lansing, MI 48824-1323. For a copy of this study guide and other educational papers, visit the web site at [www.egr.msu.edu/bae/et](http://www.egr.msu.edu/bae/et)

**Low voltage circuits and equipment:** Knowledge of circuits and equipment characterized by usage and electrical power limitations, which differentiate them from electric light and power circuits. Includes remote-control, signaling, and power limited circuits.

**Lighting and lamps:** Knowledge of all types and applications of lighting fixtures, ratings, requirements for occupancies, special provisions, clearances, and other requirements. Includes load calculations for lighting.

**State laws, rules and code amendments:** Knowledge of *Act 217 of 1956*, as amended (*Electrical Administrative Act*) and *Act 230 of 1972*, as amended (*Construction Code Act*). Includes *Part 8* rules for adoption and amending the *National Electrical Code*. Also be familiar with the current edition of the *Michigan Residential Code*. The MRC will apply to one and two-family dwellings and townhouses not more than three floors in height with individual access directly to the outside.

**Understanding of Basic Electrical Fundamentals and Equations:** The following is a brief review of electrical terms, principles and equations useful in performing the function of a journey electrician.

**Voltage:** The difference in electrical potential between two points. It is measured in volts which is equal to one Joule per Coulomb. Joule is the unit of energy and Coulomb is a quantity of electrical charge. Therefore, voltage is the amount of energy in the charges. It is frequently referred to as electrical pressure. The symbol used for voltage is the letter "E."

**Current:** The flow rate of electrical charges (positive or negative) through a conductor. It is measured in amperes which is equal to one Coulomb per second. The symbol used for current is the letter "I."

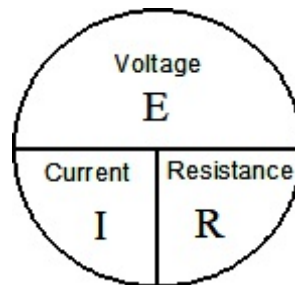
**Resistance:** The opposition to the flow of electrical charges through a conductor. It is measured in ohms. The symbol used for resistance is the letter "R." A similar term used in alternating current circuits which included the resisting effects of circuit capacitance and inductance is **impedance** which also is in units of ohms. The symbol used for impedance is the letter "Z." The value of impedance can be substituted into Ohm's law in place of resistance.

**Ohm's Law:** Voltage, current, and resistance in a circuit are related by an equation called Ohm's law. The voltage of a circuit is equal to the current times the resistance. The higher the resistance of a conductor the more voltage drop that will occur for a given amount of current flow. The following are three different ways to write the equation. Figure 1 is sometimes used as an easy way to remember the Ohm's law equations.

$$\text{Volts} = \text{Amps} \times \text{Ohms}$$

$$\text{Amps} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amps}}$$



**Figure 1** A circle with voltage over amperes and ohms can be used as a handy way to remember the three forms of the Ohm's law equation.

**Example:** A conductor has a resistance of 1.5 ohms and the current flowing on the wire is 5 amperes. The voltage drop along the wire will be the current times the resistance of the conductor or 7.5 volts.

**Example:** A resistance type heating element from an electric water heater operating at 240 volts and has a current flow of 14.6 amperes. The resistance of the heating element will be the voltage divided by the current or 16.4 ohms.

**Transformers:** The most common purpose of a transformer is to change the voltage. A transformer consists of two separate coils of wire wound around a laminated steel core. When an alternating current is passed through one coil of wire the current flow creates a magnetic field around the coil. The second coil of wire, usually wound directly over the first coil, is within the magnetic field created by the current in the first coil. Because the current in the first coil is alternating back and forth, the magnetic field will be in

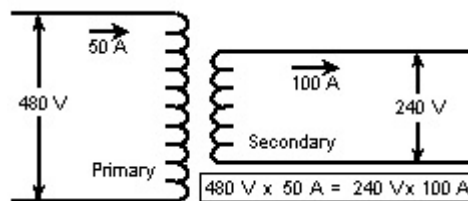
constant motion. The moving magnetic field induces a current flow in the second coil of wire. The relationship between the voltage of the first coil and the voltage of the second coil is directly proportional to the number of turns of wire on the first coil as compared to the number of turns of wire on the second coil. If the first coil (called the primary winding) has twice as many turns as the second coil (called the secondary winding) then the voltage of the secondary winding will be only half that of the primary winding. This is also called the turns ratio.

$$\frac{\text{Voltage}_{\text{Primary Winding}}}{\text{Voltage}_{\text{Secondary Winding}}} = \frac{\text{Number of Turns}_{\text{Primary Winding}}}{\text{Number of Turns}_{\text{Secondary Winding}}} = \text{Turns Ratio}$$

Another important fundamental principle of transformers is that the volts times the amperes of the primary winding is equal to the volts times the amperes of the secondary winding. In an actual transformer there are some losses due to heating and this does not hold exactly true, but for the purpose of installing transformers and the wiring and overcurrent protection for transformers this relationship is assumed to be true because it represents a worst case situation. It is important to note in the following equation that if the secondary voltage is only half the primary voltage, the secondary current will need to be double the primary current to keep both sides of the equation equal.

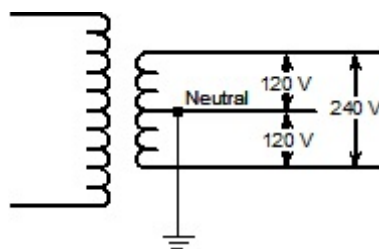
$$\text{Voltage}_{\text{Primary}} \times \text{Current}_{\text{Primary}} = \text{Voltage}_{\text{Secondary}} \times \text{Current}_{\text{Secondary}}$$

**Example:** Assume that 100 amperes of current is flowing through the secondary winding at 240 volts. If the primary winding is energized at 480 volts, half as much current or 50 amperes will be expected to flow in the primary winding as illustrated in Figure 2.



**Figure 2** Volts times amperes on the primary side of a transformer is equal to the volts times the amperes on the secondary side.

**Single-Phase, 3-Wire, Electrical System:** The typical electrical system used for single-phase power has three wires and two voltages available as shown in Figure 3. This is accomplished by connecting an additional wire at the center point of the secondary winding as illustrated in the diagram. Half the voltage of the secondary winding will be between the top and middle wire and the other half of the voltage will be between the middle and the bottom wires. *NEC Section 250.26* requires the middle conductor to be grounded and that wire is called the neutral. Nominal voltages for a 3-wire single-phase electrical system are 120 volts between either (hot conductor) ungrounded wire and the neutral, and 240 volts between the two (hot wires) ungrounded wires. The Code refers to the hot wires as the ungrounded wires.

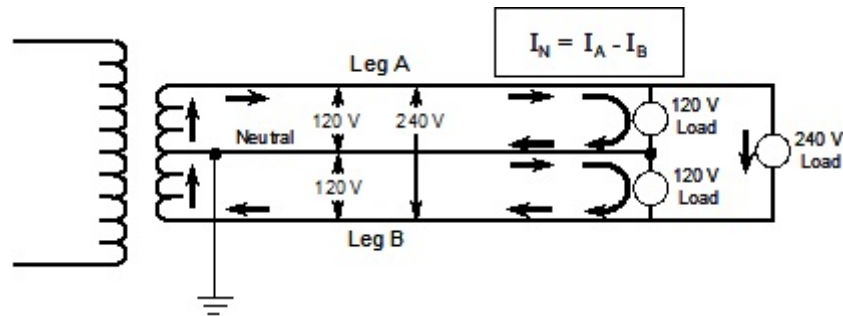


**Figure 3** A single-phase, 3-wire electrical system provides power at 120/240 volts.

Neutral current for a single-phase, 3-wire electrical system is the difference between the current flowing in the ungrounded wires as shown in Figure 4. The following diagram shows 120 volt loads connected to each ungrounded wire and the neutral for a single-phase, 3-wire electrical system. Note that

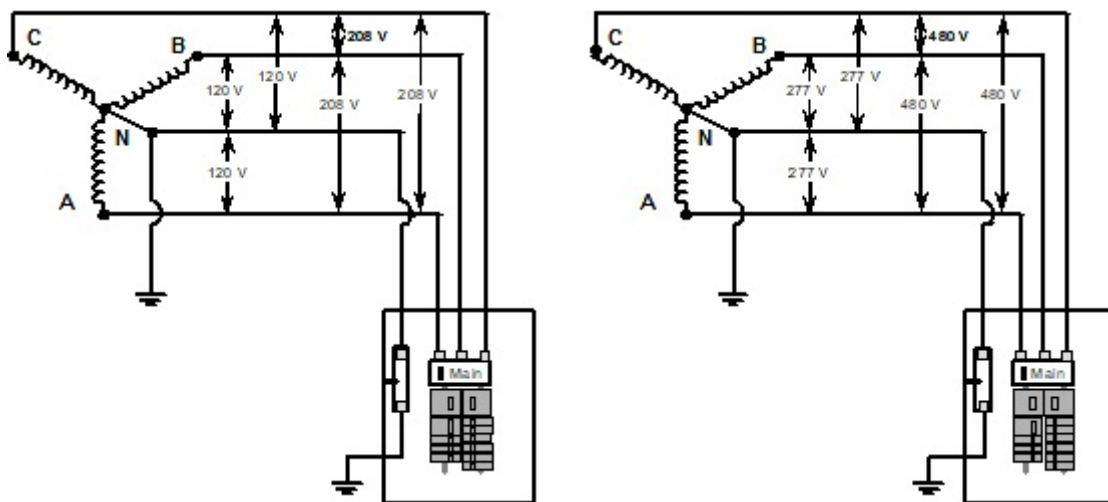
the current flowing in the top circuit and in the bottom circuit travel in opposite directions (180° out-of-phase) when it flows in the same neutral. This is why the current flowing in the neutral is the difference between the current flowing in the ungrounded wires. If the current flowing in the two ungrounded wires is exactly the same, the current flowing in the neutral will be zero, and the 120 volt loads are considered to be balanced. If 240 volt loads are connected, it will not effect the current in the neutral because this load only draws current using the ungrounded wires. One ungrounded wire is often referred to as leg A and the other leg B.

$$\text{Current}_{\text{Neutral}} = \text{Current}_{\text{Leg A}} - \text{Current}_{\text{Leg B}}$$



**Figure 4** The current flowing in the neutral of a 120/240 volt 3-wire single-phase system is the difference between the current flowing on the two ungrounded legs.

**3-Phase Electrical Systems:** Electrical power commercially is generated as 3-phase with three windings on the generator stator connected together with three ungrounded output conductors. Single-phase power is obtained by using any two of the conductors, and 3-phase is obtained by using all three conductors. When 3-phase electrical power is provided to a customer, there are usually three separate windings on the transformer. Those windings can be connected together radially with one end of each winding connected together at a common point. This produces a 4-wire system with three ungrounded conductors and a common conductor which is generally grounded and becomes the neutral conductor. This system is called a **wye system** and is shown in Figure 5 as a 208/120 volt 4-wire system and as a 480/277 volt 4-wire system.

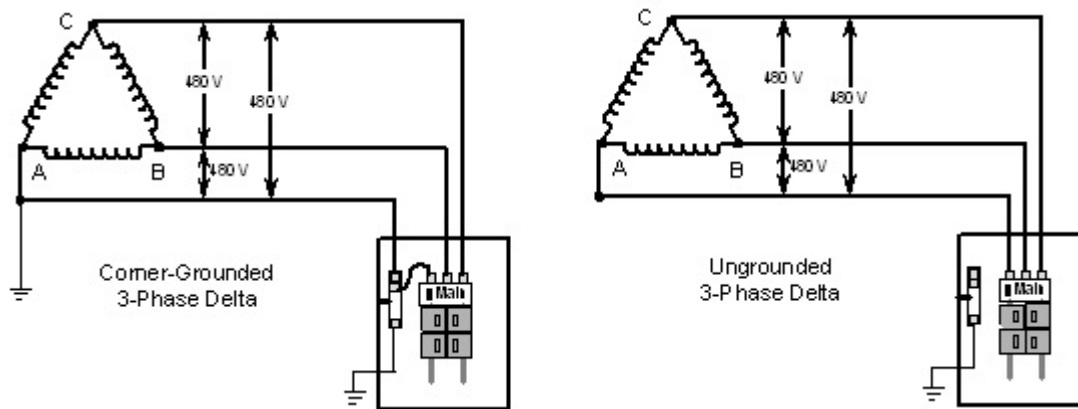


**Figure 5** Common wye 3-phase electrical systems available are 4-wire and may provide power at 208/120 volts or at 480/277 volts.

The three transformer windings can be connected in a loop which forms what is called a **delta system**. A wire is connected to each corner of the delta. This is a 3-wire system and may be grounded or it can be operated as an ungrounded system. If a delta is operated as a grounded system, one of the

phase wires is grounded to the earth as illustrated in Figure 6. This is known as a corner-grounded, 3-wire delta system. The voltages are typically either 240 volts phase-to-phase, or they are 480 volts phase-to-phase. It is important to note the grounded phase wire is not an equipment grounding wire. A separate equipment grounding wire is run to all equipment requiring grounding just like any other circuit.

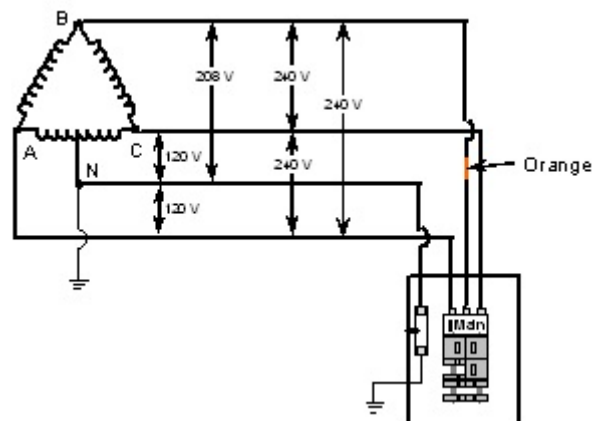
The 3-wire delta system may be operated as an ungrounded system. In this case none of the conductors is connected to earth. The conductors are coupled to the earth by means of capacitance, therefore, a voltage will generally be measured from the ungrounded conductors to the earth. Even though this latter system is not intentionally grounded, a grounding point is required to be established at the main disconnect and a grounding electrode provided as shown in Figure 6. Equipment grounding conductors are run to all equipment requiring grounding just like any other electrical system.



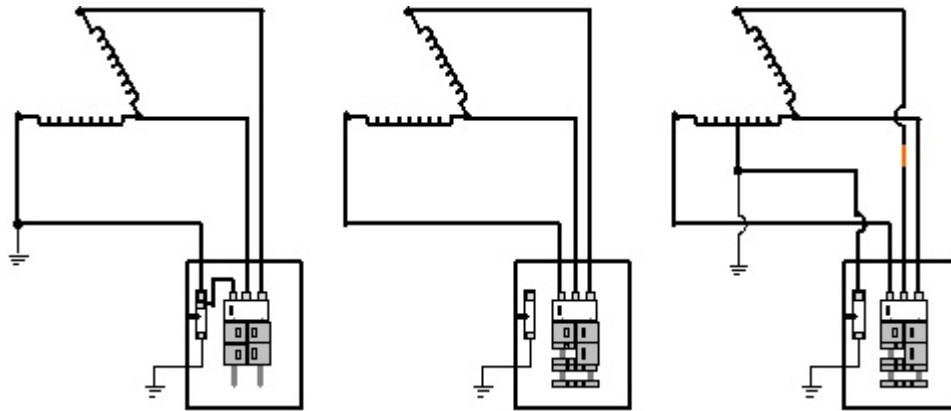
**Figure 6** A 3-wire delta electrical system is typically available at 240 volts or at 480 volts. One phase conductor may be grounded to form a corner-grounded system, or it may be operated as an ungrounded system.

There is a **4-wire delta system** where one of the transformers has a center tap to provide a grounded neutral conductor as illustrated in Figure 7. This system provides single-phase power at 120/240 volts, and it also provides 3-phase power at 240 volts. It is called a 240/120 volt, 4-wire, delta 3-phase system. From two of the phase conductors to neutral is 120 volts, but from the other phase conductor to neutral is 208 volts. In the *NEC* this is referred to as the phase conductor with the higher voltage to ground or as the high leg. *Section 408.3(E)(1)* requires the high leg to be the “B” phase, and the “B” phase is required to be the center of the three phase terminals. Therefore, the high leg is placed in the middle lug. *Sections 110.15 and 230.56*, require the high leg to be labeled orange.

A unique characteristic of the delta electrical system is that it can sometimes be used to provide 3-phase power even when the supply system does not have all three phase conductors available. In this case one of the transformers is omitted to form what is known as an open-delta system. The three basic types of open-delta systems are shown in Figure 8.



**Figure 7** A 240/120 volt 3-phase, 4-wire system can provide single-phase power at 120/240 volts, or it can provide 3-phase power at 240 volts.



**Figure 8** Open-delta systems can provide 3-wire 3-phase power at 240 volts or at 480 volts corner-grounded or ungrounded. An open-delta 4-wire system can provide single-phase power at 120/240 volts or 3-phase power at 240 volts.

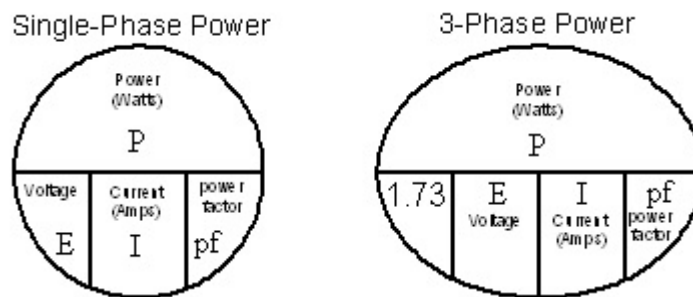
**Power:** Power is the rate of doing work or the rate at which energy is expended. The unit of measure is the watt or kilowatt. One watt is equal to one joule per second. Power can be determined if the voltage, current, and power factor of a circuit are known. The equations are as follows for single-phase power and for 3-phase power. The circle in Figure 9 with watts over volts, amperes, and power factor is a handy way to remember the different forms of the equation. The symbol for power is the letter “P.”

**Single-phase power:**

$$\text{Power} = \text{Volts} \times \text{Amps} \times \text{power factor}$$

**3-phase power:**

$$\text{Power} = 1.73 \times \text{Volts} \times \text{Amps} \times \text{power factor}$$



**Figure 9** A circle with watts over volts, amperes, and power factor is a convenient way to remember the different forms of the power equation.

**Power factor** of a circuit is a number that can range from zero to one and it only occurs in an alternating current circuit. Inductance or capacitance in a circuit can cause the voltage sine wave and the current sine wave to not be lined up so they do not reach a peak or zero at exactly the same time. When that happens, the power factor drops below one. The more out of alignment the current and voltage become, the lower will be the power factor of the circuit. Electric motors have high inductance and, therefore, they generally have a power factor that is less than 1.0. For an incandescent light bulb or a resistance type electric heater the voltage and current will be in alignment and the power factor will be 1.0. That is why the current drawn by an incandescent light bulb can be simply determined by dividing the wattage by the voltage.

In the case of a 3-phase circuit, there are three conductors supplying the load rather than only two wires as in the case of a single-phase load. The current in one conductor supplying the 3-phase load is

120° shifted in phase from the current flowing in each of the other wires. A factor that takes all of this into account is the number 1.73 which is the square root of three. You can see by comparing the previous two equations that if the power, voltage, and power factor are the same, less current will be flowing to a three-phase load as to a single-phase load of the same wattage. Compare the current drawn by a single-phase motor (*Table 430.248*) with a 3-phase motor of the same horsepower and voltage (*Table 430.250*).

**Conductor sizes:** Electrical conductors are given sizes in AWG or American Wire Gauge up to a size of 0000 or 4/0. The smaller the number the larger the wire cross-sectional area. For the purpose of sizing conductor raceways, conductor cross-sectional area is given in square inches. Cross-sectional area of common conductors is found in *Table 5 in Chapter 9*, and for bare conductors *Table 8 in Chapter 9*. For the purpose of sizing conductors for a particular current capacity, the area is given in circular mils which is the diameter of the wire converted from inches to mils and then squared.

$$\text{Conductor diameter in mils} = \text{conductor diameter in inches} \times 1000$$

$$\text{Area in circular mils} = [\text{conductor diameter in mils}]^2$$

Conductor sizes larger than 4/0 AWG are listed in thousands of circular mils and given the abbreviation **kcmil**. For example 250 kcmil means 250,000 circular mils. The old designation for thousands of circular mils was in the Roman numbering system with “M” meaning 1000. The old designation was MCM such as 250 MCM. Many conductors in use today still have this older designation, and the electrician must know what that designation means.

**Conductor Resistance:** The resistance of a conductor depends upon the type of material. For example, copper is a better conductor than aluminum, therefore, the resistance of an aluminum wire is higher than the resistance of a copper wire of the same size and length. Wire resistance for 1000 ft lengths is given in *Table 8, Chapter 9* of the Code.

Wire resistance increases as the temperature increases, and decreases as the temperature decreases. As a rough approximation, the resistance of a wire will change about 8% for every 25°C change in conductor temperature. *Table 8* in the Code gives conductor resistance at 75°C. Most of the time the operating temperature of wires is closer to 50°C. Therefore, much of the time, resistance values for wires is only 0.92 times the value given in *Table 8*.

The resistance of a wire is proportional to the length of the wire. If a wire is only 500 ft in length, its resistance will be only half that found in *Table 8*. The following equation can be used to determine the resistance of a wire of a particular length.

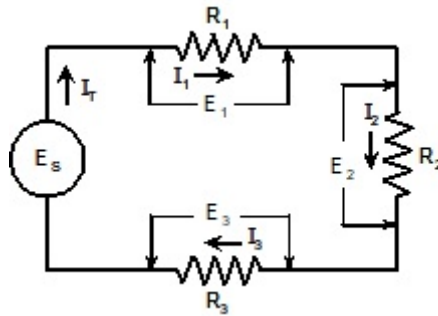
$$\text{Resistance of Wire} = \text{Resistance of 1000 ft} \times \frac{\text{Length, ft}}{1000 \text{ ft}}$$

The resistance of a wire decreases as the cross-sectional area of the wire increases. For example a size 10 AWG wire has about four times the cross-sectional area of a size 16 AWG wire. Note from *Table 8* that the size 10 AWG wire has about one-quarter the resistance of a size 16 AWG wire. The following equation can be used to determine the resistance of a wire with a different cross-sectional area.

$$\text{Resistance of Wire} = \text{Resistance of known size} \times \frac{\text{Old circular mil area}}{\text{New circular mil area}}$$

**Electrical Current flow:** Electrical current starts at a source such as a battery or transformer, travels through the conductors and equipment and returns to the source from which it originated. This is different than a liquid flowing through pipes. If there is a leak, the liquid usually does not return to the source. If electrical charge leaks out of a conductor it always returns to its source. It is important for an electrician to understand the concept of series and parallel paths. If the current in one part of a circuit is less than it is in another part of the circuit, then the difference in current is somehow taking an alternate or parallel path back to the source. Remembering this concept of current flow is very useful in tracing out electrical circuit problems. Following is a basic review of the basic concepts of series and parallel circuits, and you will be tested on them when you take the journey electrician examination.

**Series Circuit:** A series circuit is one where there is only one path for current to flow through the circuit. A typical series circuit is shown in Figure 10. The current flowing through one element in the circuit must flow through every element in the circuit. Here are the basic rules of a series circuit.



**Figure 10** A series circuit has only one path for current to flow so that the same current flows through every resistor in the circuit.

**Current:** In a series circuit the current ( I ) in amperes is the same everywhere in the circuit.

$$I_T = I_1 = I_2 = I_3$$

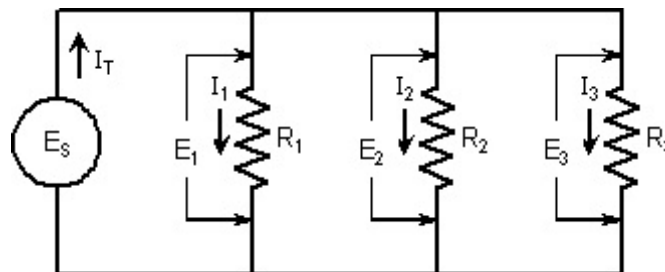
**Voltage:** The total voltage of the circuit will be the sum of the voltages across each of the resistors in the circuit.

$$E_T = E_1 + E_2 + E_3$$

**Resistance:** The total resistance of the circuit will be the sum of the individual resistors in the circuit.

$$R_T = R_1 + R_2 + R_3$$

**Parallel Circuit:** A parallel circuit has multiple paths for the current to follow as shown in Figure 11. It is important to note that the voltage will be the same across each of the resistors of the circuit. If the total resistance of the parallel circuit is desired, first examine the individual resistors and determine the lowest value. The total resistance of the circuit will be smaller than the value of the smallest resistor.



**Figure 11** A parallel circuit is one where current can divide and flow through each element with the total current being the sum of the currents through each resistor.

**Voltage:** The voltage will be the same across all resistors in the circuit and it will be equal to the supply voltage.

$$E_T = E_1 = E_2 = E_3$$



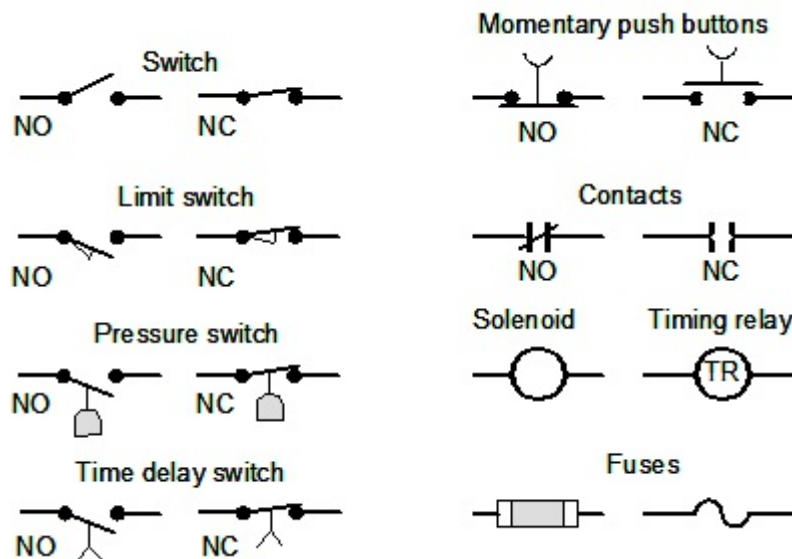
**Current:** The total current ( I ) in amperes flowing in the circuit will be the sum of the currents through each parallel branch of the circuit.

$$I_T = I_1 + I_2 + I_3$$

**Resistance:** The total resistance of a circuit where all resistors are in parallel is a little difficult to determine. The reciprocal of the total resistance is the sum of the reciprocals of each resistance. It is very important to note that the total resistance will be smaller than the smallest resistance in the circuit. If all the resistors are of the same value, then just divide the resistance by the total number of resistors. A good way to solve for the total resistance is to assign a voltage to the circuit and then determine the total current flow. Then divide the voltage by the total current flow using Ohm's law to get the total resistance.

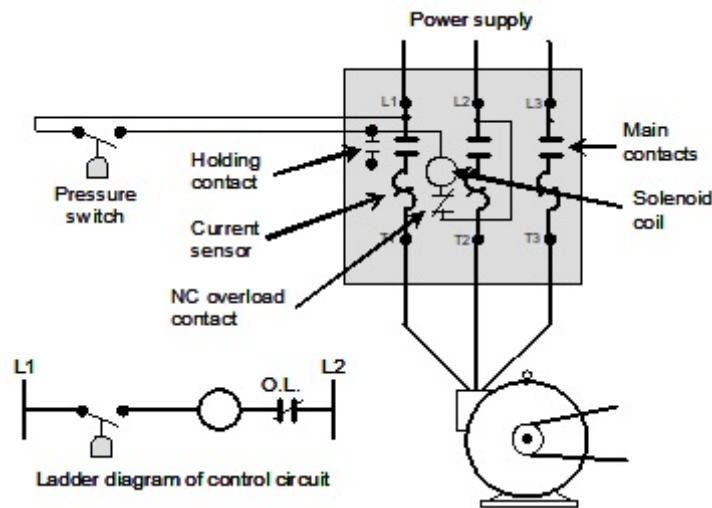
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

**Motor Control Circuits:** It is important for the journey exam to understand the basics of motor control symbols and ladder diagrams. A ladder diagram is a logical way to show how all of the elements of a motor control system operate. The confusing part is that the different control contacts in a device may be spread out in different places on the control diagram. They will be identified by a number or a letter. Figure 12 shows several common types of control devices that may be found in a ladder diagram. There are basically two types of control devices. One is normally open (NO) and requires an action to close and complete the circuit. The other is normally closed (NC) and requires an action to open the circuit. Look for the normally open (NO) and the normally closed (NC) control devices in Figure 12.



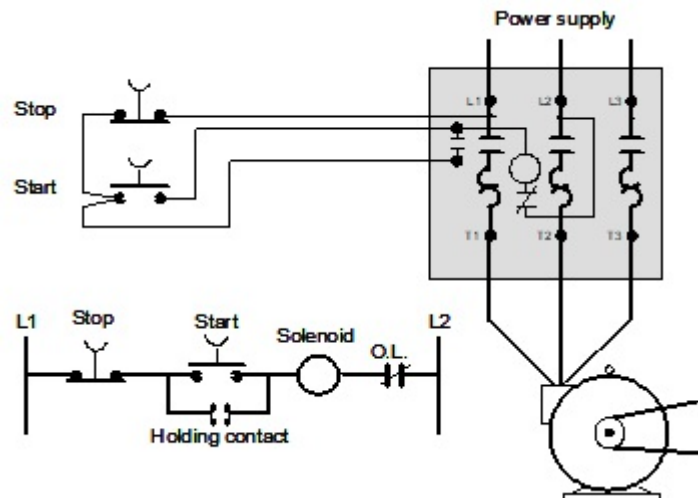
**Figure 12** Common control devices found in a motor control ladder diagram.

For the journey exam the electrician should understand how to control a magnetic motor starter with a 2-wire control circuit and a 3-wire control circuit. Figure 13 shows a simple 2-wire control circuit where a pressure switch operates a magnetic motor starter. The main contacts supplying power to the motor are closed when the control system supplies power to a solenoid coil inside the motor starter. The solenoid coil is usually represented by a circle as shown in Figure 13. One or more normally closed contacts (NC) are installed in the control circuit to interrupt power to the solenoid in the case of a motor overload. Usually some type of device senses current to the motor and operates these overload (O.L.) contacts. In this case of a 2-wire control circuit, a holding contact in the motor starter is not needed. Compare the ladder diagram in Figure 13 with the actual wiring of the control circuit.



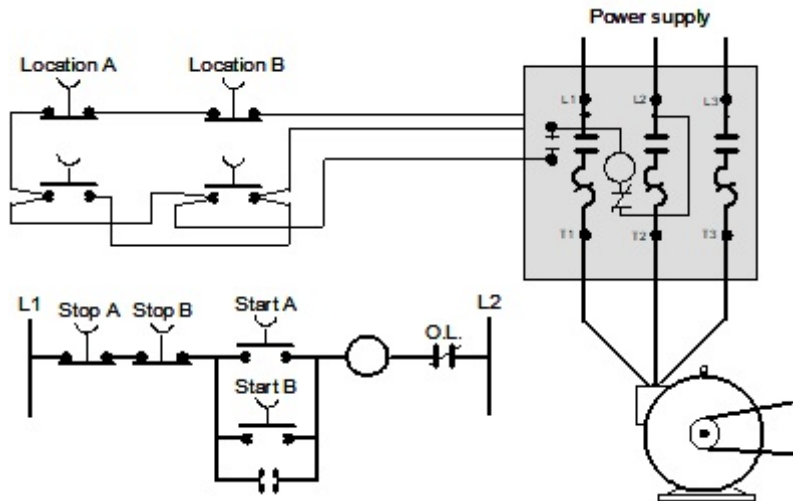
**Figure 13** A pressure switch controls a motor using a two-wire control circuit. A holding contact is not needed in this type of control circuit.

The 3-wire control circuit is used where a motor is operated using a momentary contact start-stop station. It is necessary to at least know how to control a motor with several momentary control devices. The stop push button is normally closed (NC) as shown in Figure 14. Pushing this button opens the control circuit and cuts power to the solenoid in the motor starter. The start push button is normally open (NO) and must be pressed to send power to the solenoid coil. This causes the open main contacts (NO) in the motor starter to close. The holding contact in the motor starter provides a path around the start push button when it is released. Any temporary interruption of power to the solenoid opens the holding contact and the motor shuts down. In the case of this 3-wire control circuit it is necessary for an operator to reactivate the circuit. For the 2-wire control circuit of Figure 13, the motor will start immediately when power is restored to the control circuit.



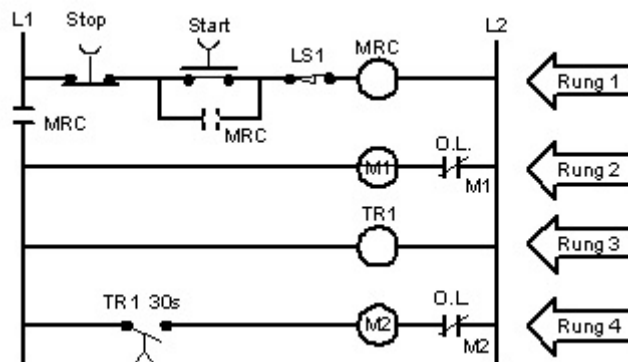
**Figure 14** A start-stop push button station is an example of a 3-wire control circuit where a holding contact is needed in the motor starter to provide a by-pass around the start push button to keep the motor running once the motor has been started.

Figure 15 shows a motor that can be started or stopped from two different locations. The stop push buttons are connected in series and the start push buttons are connected in parallel. The holding contact in the motor starter must be connected in parallel with the start push buttons. Study the actual wiring diagram and compare it to the ladder diagram. In this case the motor can be started from each location and it can be stopped from either location.



**Figure 15** This control circuit permits the motor to be started or stopped from either of two separate location.

The person taking the journey exam must also be able to interpret a ladder diagram that contains several control devices. Examine the ladder diagram of Figure 16. The top rung of the ladder contains a normally closed momentary stop push button and a normally open momentary start push button with a holding contact in parallel with the momentary start push button. There is also a normally closed limit switch and a solenoid for a master control relay. The holding contact is activated by the master control relay as well as the master control contact in the left side of the control diagram. When the master control contact closes, power is applied to the lower three rungs of the ladder. According to the second rung of the ladder, motor M1 will start immediately. In rung three of the diagram a time delay relay (TR1) is activated, and after the preset time expires all devices operated by the relay will move to the alternate position. In rung four a normally open contact will closed after 30 seconds. A ladder control diagram may be shown on the exam and several questions may be asked about what will happen if certain actions are taken. Note in the first rung of the ladder diagram is a normally closed (NC) limit switch with the address (LS1). When the material sensed opens this limit switch, power is interrupted to the master control solenoid and the entire control system shuts down.

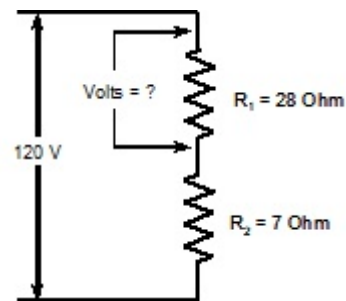


**Figure 16** The four rung ladder control diagram operates two motors using a master control relay, a momentary start-stop push button station, and a time delay relay

**Sample Questions:**

The following are sample questions of the type typical of what is found on a journey electrician examination. This study guide is not complete relative to all the questions that can be asked on an exam. Look up each Code section and read the indicated section. Questions will also be asked based upon the *Part 8 Electrical Code Rules, Public Act 230 and Public Act 217*. You should be able to complete the following questions in 2 hours without using any notes, and using a copy of the Code (commercial tabs are permitted) that does not have any hand written notes or any highlighting. At the end of these questions are the answers, solutions to problems, and related Code sections. Answer all Code questions using the 2014 NEC and the Part 8 rules. At this time the Michigan Residential Code is not required for the examination.

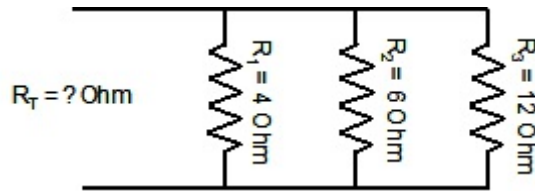
- The total connected load in watts of the following electric heaters rated 1200 watts at 120 volts, 1600 watts at 120 volts, and 1800 watts at 240 volts is:
  - 4600 watts.
  - 5200 watts.
  - 5800 watts.
  - 6200 watts.
  - 7400 watts.
- If an electrical clothing iron having a resistance of 24 ohms is plugged into a 120 volt outlet, the current flow will be:
  - 2 amperes.
  - 3 amperes.
  - 5 amperes.
  - 0 amperes.
  - 15 amperes.
- A 3-phase electrical resistance heater drawing 10 amperes at 240 volts, line-to-line, with a power factor of 1.0 has an output of:
  - 2101 watts.
  - 2400 watts.
  - 2985 watts.
  - 4152 watts.
  - 4315 watts.
- An electric frypan in a dwelling kitchen is a resistance load and is rated at 1440 watts. If plugged into a 120 volt receptacle it will draw:
  - 4 amperes.
  - 7 amperes.
  - 8 amperes.
  - 10 amperes.
  - 12 amperes.
- If two resistors are connected in series across a 120 volt source, the first with 28 ohms of resistance and the second with 7 ohms of resistance, as shown in Figure 17, the voltage drop across the first resistor (28 ohms) will be:
  - 96 volts.
  - 75 volts.
  - 60 volts.
  - 24 volts.
  - 120 volts.



**Figure 17** A 28 ohm and a 7 ohm resistor are connected in series and energized at 120 volts. Determine the voltage across the 28 ohm resistor.

6. If a 4 ohm resistor, a 6 ohm resistor, and a 12 ohm resistor are all connected in parallel, as shown in Figure 18, the total resistance of the circuit will be:

- A. 22 ohms
- B. 12 ohms
- C. 7.3 ohms
- D. 3 ohms
- E. 2 ohms

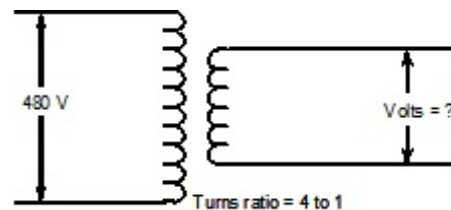


**Figure 18** A 4 ohm, 6 ohm, and 12 ohm resistor are connected in parallel. Determine the total resistance of the circuit.

7. Wherever practical, dual voltage electrical motors are connected to operate at the highest voltage rating to:
- A. obtain higher motor rpm.
  - B. get more power from the motor.
  - C. minimize the size of supply conductors required.
  - D. improve electrical safety.
  - E. lower the cost of operation.
8. Two 100 watt incandescent lamps operating for 18 hours where the average cost of electrical energy is 11 cents per kWh (\$0.11/kWh) will have a total energy cost of:
- A. \$0.11.
  - B. \$0.40.
  - C. \$1.28.
  - D. \$2.34.
  - E. \$5.62.

9. If the primary to secondary turns ratio of the transformer, shown in Figure 19, is 4:1 and the primary is rated at 480 volts, the secondary voltage will be:

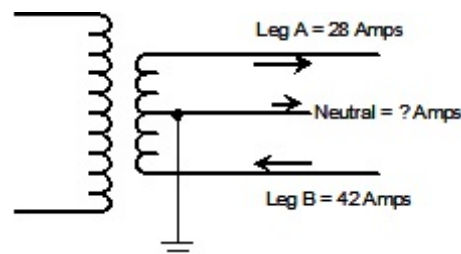
- A. 1920 volts.
- B. 240 volts.
- C. 960 volts.
- D. 120 volts.
- E. 480 volts.



**Figure 19** A transformer with a 4 to 1 turns ratio has the primary winding connected to 480 volts. Determine the secondary output voltage.

10. If the current flowing in each ungrounded conductor of a single-phase, 120/240 volt, 3-wire service entrance is 28 amperes on leg A and 42 amperes on leg B, shown in Figure 20, the current flowing in the neutral will be:

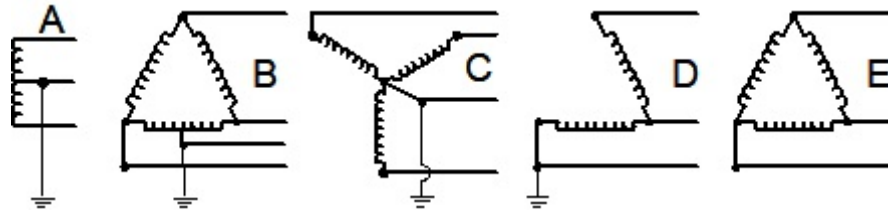
- A. 28 amperes.
- B. 42 amperes.
- C. 14 amperes.
- D. 35 amperes.
- E. 0 amperes.



**Figure 20** For this single-phase, 120/240 volt, 3-wire electrical service if there is 28 amperes flowing in leg A and 42 amperes flowing in leg B, determine the current flowing in the neutral.

11. The type of 3-phase electrical system, shown in Figure 21, in the diagram that has one ungrounded conductor with a higher voltage to ground than the other ungrounded conductors is:

- A.
- B.
- C.
- D.
- E.



**Figure 21** Of these common types of single-phase and 3-phase electrical systems, which one has an ungrounded conductor with a higher voltage to ground than the other ungrounded conductors?

12. If the resistance of a copper wire is 0.410 ohms/k ft, the total resistance of the circuit wires for a single-phase load located 125 feet from the current supply is:

- A. 0.0514 ohms.
- B. 0.1025 ohms.
- C. 0.1135 ohms.
- D. 0.5125 ohms.
- E. 1.0250 ohms.

13. If the diameter of a solid copper wire is 0.125 inch, the cross-sectional area of the wire is:

- A. 12,265 cmil.
- B. 15,625 cmil.
- C. 25,000 cmil.
- D. 37,500 cmil.
- E. 49,063 cmil.

14. The wire from the following list that has the largest cross-sectional area is size:

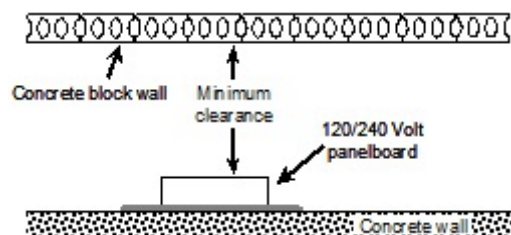
- A. 4 AWG.
- B. 12 AWG.
- C. 6 AWG.
- D. 14 AWG.
- E. 2 AWG.

15. Wiring which is installed to meet minimum requirements of the *National Electric Code* is:

- A. adequate to meet future needs.
- B. adequate for present needs.
- C. always the most efficient wiring.
- D. essentially free from hazards.
- E. always the most convenient wiring.

16. A 120/240 volt 100 ampere panelboard is installed for a single-family dwelling service. The panelboard has a removable front cover and the opposite wall in front of the panelboard is concrete block as shown in Figure 22. The minimum clearance permitted from the front of the panelboard to the concrete block wall is:

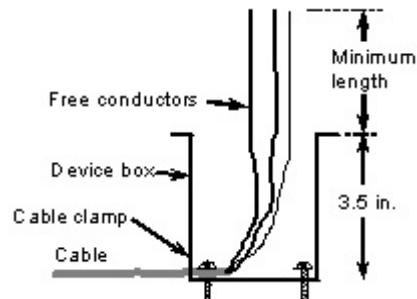
- A. 24 inch.
- B. 30 feet.
- C. 3 feet.
- D. 3.5 feet.
- E. 6 feet.



**Figure 22** A panelboard supplied at 120/240 volts is mounted on a surface opposite to a concrete block wall. Determine the minimum distance required from the front of the panelboard to the concrete block wall.

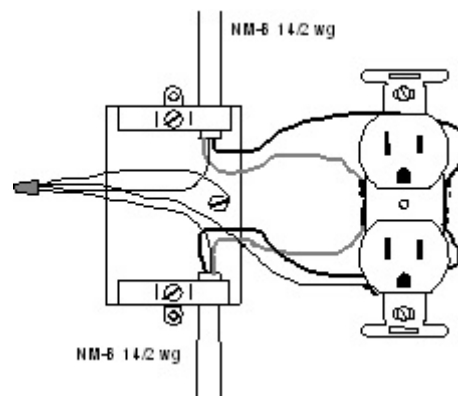
17. The receptacle outlets on 125-volt, 20-ampere circuits on the walls and above the counters of the kitchen, pantry, breakfast room, dining room, and similar rooms of a dwelling are required to be supplied by a minimum of:
- one circuit.
  - two circuits.
  - three circuits.
  - one circuit for each room and no other room.
  - as many circuits as required to limit the circuit to four receptacles per circuit.
18. Assuming clearance requirements are met, a type of lighting luminaire not permitted to be installed in a clothes closet is a:
- surface mounted incandescent luminaire with a completely enclosed lamp.
  - surface mounted fluorescent luminaire with a completely enclosed lamp.
  - surface mounted fluorescent luminaire with an exposed lamp.
  - recessed incandescent luminaire with a completely enclosed lamp.
  - surface mounted porcelain incandescent lamp receptacle.
19. A single-family living unit in an apartment building has a laundry area and only one bathroom. There is no direct access to the outside. Assuming that only one ground-fault circuit-interrupter device is used to protect all receptacles on a circuit required to be GFCI protected, the minimum number of 125 volt rated GFCI devices required for this dwelling living unit is:
- one.
  - two.
  - three.
  - four.
  - five.
20. All 120-volt, 15- and 20-ampere circuits serving the kitchen, dining room, bedrooms, closets, hallways, laundry, and similar areas of a living unit of a multi-family dwelling are required to be protected by a:
- receptacle type arc-fault circuit interrupter of the branch/feeder or combination type.
  - branch/feeder type arc-fault circuit interrupter circuit breaker at the source of the circuit.
  - combination type arc-fault circuit interrupter circuit breaker at the source of the circuit.
  - receptacle type GFCI/AFCI arc-fault circuit interrupter.
  - GFCI or an arc-fault circuit interrupter at the source of the circuit.
21. The receptacles serving a single-family dwelling kitchen counter are to be located such that the distance from any point along the wall line to a receptacle is not more than:
- 12 inch.
  - 24 inch.
  - 4 feet.
  - 6 feet.
  - 12 feet.
22. The demand load permitted to be used to determine the minimum rating of branch circuit for a dwelling electric range with a rating of 17.6 kW is:
- 8 kVA.
  - 10.4 kVA.
  - 14.1 kVA.
  - 17.6 kVA.
  - 22 kVA.
23. An overhead single-phase feeder operating at 120/240 volts and consisting of multiplex cable passes over an area accessible only to pedestrians. The minimum clearance permitted from grade level to the lowest point of the open conductors is :
- 10 feet.
  - 12 feet.
  - 15 feet.
  - 18 feet.
  - 22 feet.

24. A building is served with a 208/120 volt, 3-phase, 4-wire, wye electrical system. The lowest point of the drip loop of the building electric entrance shall have a clearance above a pedestrian sidewalk of not less than:
- A. 10 feet.
  - B. 12 feet.
  - C. 15 feet.
  - D. 18 feet.
  - E. 22 feet.
25. A standard rating of overcurrent device is:
- A. 110 amperes.
  - B. 275 amperes.
  - C. 500 amperes.
  - D. 900 amperes.
  - E. 1,500 amperes.
26. A nonmetallic sheathed cable, type NM-B, 12/2 with ground, is installed in a 3½ in. deep device box as shown in Figure 23 with the cable entering the bottom of the box and free conductors exposed from the point where they emerge from the cable clamp. The minimum length of free conductor required to extend outside of the box is:
- A. 3 inch.
  - B. 4 inch.
  - C. 6 inch.
  - D. 8 inch.
  - E. 12 inch.



**Figure 23** What is the minimum length of free conductor required to extent outside of a device box?

27. In the case of nonmetallic single-gang device boxes installed in walls and ceilings, clamping of type NM-B cables to the box is not required if the cable is supported as measured along the cable a distance of not more than:
- A. 18 inch. of the box.
  - B. 14 inch. of the box.
  - C. 12 inch. of the box.
  - D. 10 inch. of the box.
  - E. 8 inch. of the box.
28. The minimum size metallic device box with cable clamps which is permitted to be used to contain a duplex receptacle with a type NM-B 14-2 w.g. cable entering and leaving, as shown in Figure 24, is:
- A. 3 × 2 × 1½ inch.
  - B. 3 × 2 × 2½ inch.
  - C. 3 × 2 × 2¾ inch.
  - D. 3 × 2 × 3½ inch.
  - E. 3 × 2 × 2 inch.



**Figure 24** A metal device box with cable clamps contains a duplex receptacle and has a Type NM-B size 14, 2-wire cable with ground entering each end of the box. Determine the minimum depth of box required.



29. Size 2/0 AWG, THWN, aluminum conductors are installed for a 150 ampere service. An underground metal water pipe entering the building is used as a grounding electrode. The minimum size copper grounding electrode conductor run to the water pipe for the service is:
- 8 AWG.
  - 6 AWG.
  - 4 AWG.
  - 3 AWG.
  - 1 AWG.
30. A 60 ampere rated circuit is run in rigid nonmetallic conduit using size 4 AWG, THHN, copper conductors. The minimum size copper equipment grounding conductor permitted to be run in the conduit with the circuit conductors is:
- 10 AWG.
  - 8 AWG.
  - 6 AWG.
  - 4 AWG.
  - 2 AWG.
31. A wiring method not permitted to serve as an equipment grounding conductor is:
- a combination metallic sheath and grounding conductor of type MC cable.
  - electrical metallic tubing.
  - a bare solid copper wire in nonmetallic sheathed cable sized in accordance with *Table 250.122*.
  - ½ inch trade diameter flexible metal conduit not over 6 feet long and containing circuit wires protected at 20 amperes.
  - ½ inch trade diameter flexible metallic tubing not over 6 feet long and containing circuit wires protected at 20 amperes and terminated in fittings listed for grounding.
32. A commercial service entrance with a 200 ampere main circuit breaker has size 3/0 AWG, THWN, copper service entrance conductors, and the service is grounded to a metal underground water pipe and also to a set of ground rods as the supplemental electrode. The maximum size copper grounding electrode conductor required to be run to the ground rods is:
- 10 AWG.
  - 8 AWG.
  - 6 AWG.
  - 4 AWG.
  - 2 AWG.
33. When boring holes through wood members such as studs and joists for the installation of nonmetallic sheathed cable (Type NM-B) it is not required to install metal plates or sleeves to protect the cable from damage by nails and screws provided the distance from the edge of the wood member to the closest edge of the bored hole is not less than:
- ½ inch.
  - ¾ inch.
  - 1 inch.
  - 1¼ inch.
  - 1½ inch.
34. Electrical conductors run within rigid metal conduit and installed under a commercial parking lot as shown in Figure 25 with a cover equivalent to a 4 inch thick slab of concrete are to be at a depth from the finished grade level to the top of the conduit of not less than:
- 4 inch.
  - 6 inch.
  - 12 inch.
  - 18 inch.
  - 24 inch.

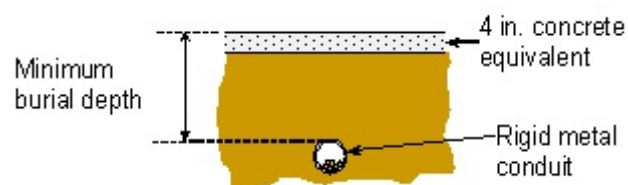


Figure 25 Determine the minimum depth of burial below finish grade for a rigid metal conduit installed under a paved vehicle parking area equivalent to 4 in. thick concrete.

35. A set of feeder conductors is protected by 400 ampere fuses and the calculated load on the feeder is 340 amperes. If the feeder conductors are copper with 75°C insulation and terminations, and no derating factors apply, the minimum size conductor permitted for this feeder is:
- A. 300 kcmil.
  - B. 350 kcmil.
  - C. 400 kcmil.
  - D. 500 kcmil.
  - E. 600 kcmil.
36. The minimum size type THWN aluminum conductors which are permitted to be installed for a 120/240 volt single-phase single-family dwelling service entrance that has a calculated demand load of 150 amperes and terminates at a 200 ampere main circuit breaker is:
- A. 250 kcmil.
  - B. 1/0 AWG.
  - C. 2/0 AWG.
  - D. 3/0 AWG.
  - E. 4/0 AWG.
37. A size 3/0 AWG, THWN, copper conductor if run in a conduit where there are a total of 8 current carrying conductors has an allowable ampacity of:
- A. 100 amperes.
  - B. 125 amperes.
  - C. 140 amperes.
  - D. 160 amperes.
  - E. 200 amperes.
38. The main overcurrent device for a 3-phase, 4-wire, 208/120 volt commercial service, as shown in Figure 26, is rated at 1200 amperes. There are three sets of service entrance wires run in separate service conduits. For this service the neutral wires are not required to be counted as current-carrying conductors. If the calculated demand load for the service is 930 amperes, the minimum size copper Type THWN conductors permitted is:
- A. 350 kcmil.
  - B. 400 kcmil.
  - C. 500 kcmil.
  - D. 600 kcmil.
  - E. 750 kcmil.

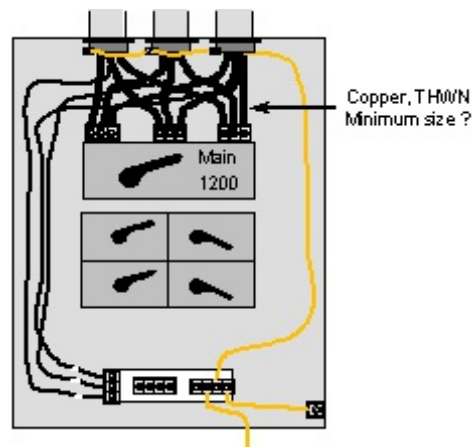
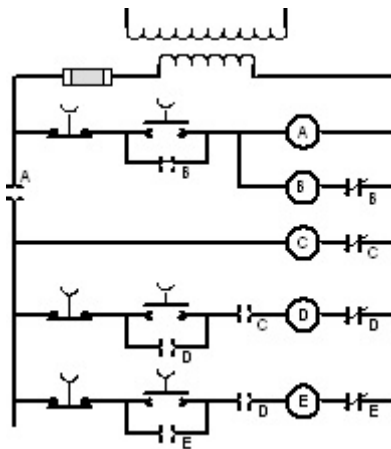


Figure 26 Determine the minimum size copper, THWN ungrounded conductors when run in three separate raceways assuming the neutral does not count as a current carrying conductor for this 1200 ampere service.

39. A horizontal straight run of 2 inch diameter rigid metal conduit with threaded couplings shall be supported at intervals of not to exceed:
- A. 10 feet.
  - B. 12 feet.
  - C. 14 feet.
  - D. 16 feet.
  - E. 20 feet.

40. Nonmetallic sheathed cable is required to be secured within 12 inch from every cabinet, box, or fitting, and at intervals along the cable of not more than:
- A. 3 feet.
  - B. 4½ feet.
  - C. 6 feet.
  - D. 10 feet.
  - E. 12 feet.
41. The minimum trade diameter of rigid metal conduit permitted for eight size 10 AWG THWN conductors is:
- A. 3/8 inch.
  - B. ½ inch.
  - C. ¾ inch.
  - D. 1 inch.
  - E. 1¼ inch.
42. A recessed lighting fixture that is not marked as Type IC is required to be installed such that all parts of the luminaire are spaced a minimum distance of ½ inch from combustible material except the mounting points of the luminaire, and thermal insulation is not permitted to be installed above the luminaire and must be kept a minimum distance from the luminaire enclosure of:
- A. ½ inch.
  - B. 3 inch.
  - C. 6 inch.
  - D. 8 inch.
  - E. 12 inch.
43. The power supply to central heating equipment such as a gas furnace is:
- A. permitted to be installed on a circuit with other equipment.
  - B. permitted to be connected to a general purpose branch circuit.
  - C. not permitted to be connected to the same circuit with a central air-conditioner.
  - D. required to be on an individual circuit rated not less than 20 amperes.
  - E. required to be on an individual branch circuit.
44. The minimum branch circuit conductor size, THHN, copper with 75°C terminations permitted to supply a 7½ horsepower 3-phase, 240 volt electric motor is:
- A. 14 AWG.
  - B. 12 AWG.
  - C. 10 AWG.
  - D. 8 AWG.
  - E. 6 AWG.
45. A design B, 3-phase, 15 horsepower, 460 volt electric motor has a service factor of 1.15, and a nameplate full-load current of 19 amperes. The maximum rating of time-delay fuse permitted for branch-circuit short-circuit and ground-fault protection assuming the motor does not start with difficulty is:
- A. 20 amperes.
  - B. 25 amperes.
  - C. 30 amperes.
  - D. 35 amperes.
  - E. 40 amperes.
46. A 120 volt, cord and plug supplied window air-conditioner is permitted to be supplied by a general-purpose 20 ampere branch circuit provided the addition of the air-conditioner does not overload the circuit, and provided the full-load current of the air-conditioner does not exceed:
- A. 10 amperes.
  - B. 12 amperes.
  - C. 15 amperes.
  - D. 16 amperes.
  - E. 20 amperes.

47. A receptacle outlet installed on the outside of a gasoline service station building wall is not considered to be located within a Class I, Division 2 area as long as it is not less than 18 inch above grade level or located from the edge of a dispensing device a distance of not less than:
- 10 ft.
  - 12 ft.
  - 20 ft.
  - 25 ft.
  - 50 ft.
48. A branch circuit serving receptacles at the patient care areas of a hospital are run in metal raceway. The receptacles are required to be:
- installed in nonmetallic boxes.
  - of the insulated grounding type.
  - protected by a ground-fault circuit-interrupter.
  - also grounded with an insulated copper equipment grounding wire in addition to the metal raceway.
  - also grounded with a copper equipment grounding wire, permitted to be bare, in addition to the metal raceway.
49. Refer to the ladder control diagram of Figure 27 where each solenoid coil operates a motor starter and one solenoid operates a master control relay. If solenoid coil "D" is de-energized:
- only the motor controlled by "D" will stop operating.
  - both motors "C" and "D" will stop operating.
  - motor "D" will stop and motor "C" will start.
  - all motors will stop operating.
  - motors "D" and "E" will stop operating.



**Figure 27** The ladder diagram of the control system for a set of electric motors.

50. Refer to the ladder control diagram of Figure 27 where each solenoid coil operates an electric motor starter. The solenoid that operates the master control relay (MCR) is coil:
- A.
  - B.
  - C.
  - D.
  - E.
51. Refer to the ladder control diagram of Figure 27 where each solenoid coil operates an electric motor starter. If the overload in the control circuit of solenoid "B" opens:
- all of the motors will stop.
  - only motor "B" will stop.
  - motors "A" and "B" will stop.
  - motors "B", "C", "D", and "E" will stop.
  - motors "A", "B", "D", and "E" will stop.

52. Type MC cable used for branch circuit wiring in a restaurant is required to contain an equipment grounding conductor or be listed and identified as an equipment grounding conductor if the restaurant is designed for the assembly of:
- 75 or more people.
  - 100 or more people.
  - 150 or more people.
  - 200 or more people.
  - 500 or more people.
53. General purpose 125 volt, 15 or 20 ampere receptacles are not permitted to be located closer than 6 feet to the inside wall of a permanent swimming pool at a dwelling. At least one receptacle served by a general purpose branch circuit, and GFCI protected, is required to be installed such that it is not located from the inside wall of the pool a distance of more than:
- 12 feet.
  - 15 feet.
  - 20 feet.
  - 25 feet.
  - 50 feet.
54. The wiring supplying a permanent swimming pool water circulating pump motor is run in PVC conduit with two circuit wires and an equipment grounding wire. The equipment grounding wire run inside the PVC conduit is required to be:
- covered or insulated copper not smaller than 12 AWG.
  - bare, covered, or insulated copper not smaller than 12 AWG.
  - insulated copper not smaller than 12 AWG.
  - solid bare copper not smaller than 12 AWG.
  - solid bare copper not smaller than 8 AWG.
55. For an inside permanent pool installation, any lighting fixtures mounted above the pool or above the area extending outward 5 feet from the edge of the pool is required to be mounted a minimum distance above the maximum water level a distance of not less than:
- 8 feet.
  - 10 feet.
  - 12 feet.
  - 15 feet.
  - 18 feet.
56. Of these class 2 power-limited circuit cables listed, the type permitted to be run exposed through a commercial building ceiling used as an environmental air handling space is marked with the letters:
- CL2.
  - CL3.
  - CL2R.
  - CL2P.
  - CL2X.
57. Nonmetallic-sheathed cable (NM-B) is permitted to be run:
- concealed within non-fire rated walls of a multi-floor commercial building.
  - in commercial buildings only if run within metal conduit or tubing.
  - as surface wiring in a single-floor commercial building.
  - only within walls, floors, and ceilings with a 15-minute finish fire rating even for a single-floor commercial building.
  - as direct burial cable in the earth.
58. Electrical permits are issued to:
- an apprentice electrician.
  - a licensed journey electrician.
  - any licensed master electrician.
  - a homeowner who does electrical work on a neighbors property.
  - a licensed electrical contractor.

59. To qualify to take the Michigan master electrician examination an applicant licensed in Michigan as a journey electrician must show by a notarized statement from a present or former employer the accumulation of practical electrical wiring experience under the supervision of a master electrician of not less than:
  - A. two years of full-time employment.
  - B. 12,000 hours over a period of not less than six years, and held a journey electrician license for not less than two years.
  - C. 20,000 hours.
  - D. 15,000 hours over a period of not less than two years.
  - E. 2,000 hours over any period of time.
  
60. After July 4<sup>th</sup>, 2016, a journey electrician performing a dwelling electrical installation is permitted to supervise on that same job site not more than:
  - A. one apprentice.
  - B. two apprentices.
  - C. three apprentices.
  - D. four apprentices.
  - E. six apprentices.

**Solutions to Sample Questions:**

Please take the time to look up and read the Code sections where the answers are found. Only through practice looking up Code sections will you get proficient at finding information in the Code. Also take the time to work all of the problems.

1. **A 4600 watts.** The voltage makes no difference. Just add the wattage of each heater.  

$$1200\text{ W} + 1600\text{ W} + 1800\text{ W} = 4600\text{ W}$$
  
2. **C 5 amperes.** The iron is a resistance load and the power factor is 1.0.  

$$\text{Amperes} = \frac{\text{volts}}{\text{Resistance}} = \frac{120\text{ V}}{24\text{ ohm}} = 5\text{ A}$$
  
3. **D 4152 watts.** Power = 1.73 x Volts x Amperes x power factor  

$$\text{Power} = 1.73 \times 240\text{ V} \times 10\text{ A} \times 1.0 = 4152\text{ W}$$
  
4. **E 12 amperes.**  

$$\text{Amperes} = \frac{\text{Power}}{\text{Volts}} = \frac{1440\text{ W}}{120\text{ V}} = 12\text{ A}$$
  
5. **A 96 volts.** The voltage drop will be in the same proportion as each resistance in series is to the total circuit resistance. The 28 ohm resistor is 80% of the total resistance (35 ohms) so 80% of the voltage will be across the 28 ohms resistor.  

$$\frac{28\text{ ohm}}{35\text{ ohm}} \times 120\text{ V} = 96\text{ V}$$

$$\frac{\text{Resistor}}{\text{Total Resistance}} \times \text{Total Voltage} = \text{Resistor voltage}$$
  
6. **E 2 ohms.**  

$$\frac{1}{R_T} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12} = \frac{3+2+1}{12} = \frac{6}{12}$$

$$R_T = \frac{12}{6} = 2\text{ ohms}$$
  
7. **C minimize the size of supply conductors required.** Check current of a motor of a certain horsepower at two different voltages in *Table 430.248* or *Table 430.250*.
  
8. **B \$0.40.**  $200\text{ W} = 0.2\text{ kW}$        $0.2\text{ kW} \times 18\text{ hrs.} \times \$0.11 = \$0.40$

9. **D 120 volts.**

$$\frac{\text{Primary voltage}}{\text{Turns ratio}} = \text{Secondary voltage} = \frac{480 \text{ V}}{4} = 120 \text{ V}$$

10. **C 14 amperes.** This is a single-phase, 3-wire, 120/240 volt electrical system and the current on the common neutral will be the difference in the current flowing on each ungrounded leg. (42 A – 28 A = 14 A)

11. **B 4-wire delta.** The voltage from the neutral which is connected to the center of one of the transformers is 208 volts to the phase at the top of the delta. See also Figure 7.

12. **B 0.1025 ohms.** There are two wires in the 125 feet run so the total length of wire is 250 feet. 250 feet is 25% of 1000 feet so the resistance will be 0.1025 ohm.

$$\frac{2 \times 125 \text{ ft}}{1000 \text{ ft}} \times 0.410 \text{ ohm} = 0.1025 \text{ ohm}$$

13. **B 15,625 cmil.** 0.125 in. = 125 mils      125 mils × 125 mils = 15,625 cmil

14. **E 2 AWG.** Examine *Table 310.15(B)(16)* or *Table 8, Chapter 9.*

15. **D essentially free from hazards.** Read *Section 90.1(B)*

16. **C 3 ft.** *Table 110.26(A)(1) column 2*, 150 volts to ground.

17. **B two circuits.** It states in *210.11(C)(1)* and *210.52(B)(1)* that two small appliance branch circuits are required as a minimum to serve the kitchen and similar rooms and that two circuits must serve the counter spaces in the kitchen.

18. **E surface mounted porcelain incandescent lamp receptacle.** It states in *410.16(B)* that incandescent lampholders are not permitted to be installed in a clothes closet. Luminaires that are permitted are listed in *410.16(C)*.

19. **D four.** It states in *210.8(A)* that two circuits are required for the kitchen counters. Circuits required are listed in *210.11(C)*. One circuit is needed for bathroom receptacle. One circuit is required for the laundry. One GFCI will be needed for each circuit. For this apartment unit the minimum count is four circuits.

20. **C a combination type arc-fault circuit interrupter circuit breaker at the source of the circuit.** There are other acceptable means of providing arc-fault protection for these circuits, but this is the only acceptable method listed in the question, *210.12(A)(1)*.

21. **B 24 in.** *210.52(C)(1)*

22. **B 10.4 kW.** *Table 220.55, Note 1* deals with the case where the range is rated greater than 12 kW. The value in column C is increased by 0.05 for each kW the actual range size is greater than 12 kW. It is necessary to round the nameplate kW to the nearest whole number. In this case round 17.6 up to 18 kW. The first 12 kW is taken at a demand of 8 kVA. Next increase the 8 kVA by 0.05 for each kW larger than 12 as follows:

$$[(\text{kW} - 12) \times 0.05 \times 8\text{kVA}] + 8\text{kVA} = \text{Range Demand Load}$$

$$[(18 - 12) \times 0.05 \times 8\text{kVA}] + 8\text{kVA} = 2.4\text{kVA} + 8\text{kVA} = 10.4\text{kVA}$$

23. **A 10 feet.** This is a feeder not a service cable so the answer is found in *Section 225.18(B)(1)*.

- 24. **A 10 feet.** The voltage from an ungrounded service conductor is not over 150 volts to ground, so the lowest point of the drip loop need only have a clearance above grade of 10 ft., 230.24(B)(1).
- 25. **A 110 amperes.** 240.6(A)
- 26. **A 3 inch.** 300.14 requires a minimum of 6 inch of free conductor, but there must be 3 inch of conductor outside of the box.
- 27. **E 8 inch of the box.** 314.17(C) *Exception*
- 28. **D 3 × 2 × 3½ inch.** The method for figuring the count for conductors in the box is found in 314.16(B). Using the size 14 AWG conductor count of 8, look up the minimum device box depth in *Table 314.16(A)*.

conductors	4
equipment grounds	1
duplex receptacle	2
cable clamps	1
Total count 14 AWG	8

- 29. **B 6 AWG.** Select the size of the grounding electrode conductor based on the size and type of ungrounded service conductors using *Table 250.66*.
- 30. **A 10 AWG.** There is an overcurrent device at the supply end of the conductor so the equipment grounding conductor is sized from *Table 250.122* based upon the rating of the overcurrent device which in this case is 60 amperes.
- 31. **D ½ inch trade diameter flexible metal conduit not over 6 feet long and containing circuit wires protected at 20 amperes.** Flexible metal conduit is not permitted for grounding. The *Part 8 Rule 408.30869* revises 250.118, and *Rule 408.30867* revises 348.60. These revised sections are what applies in Michigan, not what is printed in the NEC.
- 32. **C 6 AWG.** 250.66(A) only requires the grounding electrode conductor to a ground rod or set of ground rods to be as large as size 6 AWG copper where it only connects to the ground rod.
- 33. **D 1¼ inch.** 300.4(A)(1).
- 34. **E 24 inch.** *Table 300.5* required a depth of burial of 24 inch under a parking lot no matter if there is a concrete cover or not.
- 35. **D 500 kcmil.** The conductor is rated at 380 amperes but it is permitted to be protected at 400 amperes because the load is only 340 amperes. This is according to *Section 240.4(B)*. Other Code sections are 240.6(A) and *Table 310.15(B)(16)*.
- 36. **E 4/0 AWG.** The key here is single-phase, 120/240 volt, 3-wire supplying entire dwelling load. The conductor size is permitted to be determined using 310.15(B)(7)(1) which allows the dwelling service conductors to be sized at 83% of the rating of the service, which in this case would be 166 amperes. Then look up the minimum size aluminum wire in the 75°C column of *Table 310.15(B)(16)*.

$$200 \text{ A} \times 0.83 = 166 \text{ A}$$

- 37. **C 140 amperes.** The allowable ampacity values given in *Table 310.15(B)(16)* are only valid if there are no more than three current carrying conductors in a raceway or cable and if the ambient temperature does not exceed 30°C. In this case there are 8 current carrying conductors in the raceway so it is necessary to adjust the ampere rating of the conductors by a factor of 0.7 which is found in *Table 310.15(B)(3)(a)*.

$$200 \text{ A} \times 0.7 = 140 \text{ A}$$



38. **D 600 kcmil.** Divide the 1200 ampere main overcurrent device rating by three. In this case 240.4( C) applies which means the conductors must have a current rating of 400 amperes. Find the minimum size wire in the 75°C column of *Table 310.15(B)(16)*. Ampacity adjustment factors are not required for this example.

$$\text{Minimum Conductor Ampacity} = \frac{1,200 \text{ A}}{3 \text{ sets}} = 400 \text{ A}$$

39. **D 16 feet.** When threaded couplings are used with RMC and IMC, the maximum spacing between supports is permitted to be determined using *Table 344.30(B)(2)*.
40. **B 4½ feet.** The maximum support spacing for nonmetallic-sheathed cable is found in *334.30*.
41. **C ¾ inch.** When all of the conductors in a raceway are of the same type and size, the minimum trade diameter raceway permitted is to be determined using one of the tables in *Informative Annex C*, according to *344.22* and *Table 1 Note 1 Chapter 9*. Rigid metal conduit minimum trade size is found in *Table C8*.
42. **A ½ inch.** A recessed luminaire that is not marked Type IC can be a fire hazard if not installed with proper spacing from potentially combustible materials and must meet the spacing requirement of *410.116(A)(1)*.
43. **E required to be on an individual branch circuit.** Found in *422.12*. There are exceptions.
44. **C 10 AWG.** *430.6(A)(1)* requires the motor full-load current of 22 amperes to be looked up in *Table 430.250* not taken from the nameplate. *430.22(A)* required full-load current to be multiplied by 1.25 and then look up the minimum wire size in the 75°C column of *Table 310.15(B)(16)*.
- $$(22 \text{ A} \times 1.25 = 27.5 \text{ A}) \text{ Round up to 28 amperes.}$$
45. **E 40 amperes.** *430.6(A)(1)* requires the motor full-load current of 21 amperes to be looked up in *Table 430.250* not taken from the nameplate. *430.52( C)(1)* sets the maximum rating time-delay fuse at a value determined by multiplying the full-load current of 21 amperes by a multiplier found in *Table 430.52*. Find the multiplier of 1.75 by using the motor design letter B. Next multiply 21 amperes by 1.75 to get 36.75 amperes. *Exception 1* of *430.52* permits rounding up to a standard size 40 ampere overcurrent device. The standard sizes of overcurrent devices are listed in *240.6(A)*. *Exception 2* does not apply because it was stated in the question that the motor did not start with difficulty.
46. **A 10 amperes.** When a cord and plug connected window air-conditioner is supplied from a general-purpose branch circuit, it is not permitted to have a rating in excess of 50% of the rating of the circuit. This is stated in *Section 440.62(C)* and *Section 210.23(A)(2)*.
- $$20 \text{ A} \times 0.5 = 10 \text{ amperes}$$
47. **C 20 feet.** The space within 20 feet horizontally in all directions and up to a height of 18 inches above grade is considered a Class I, Division 2 location and a standard receptacle installation within that space is not permitted. The extent of the classified areas is found in *Table 514.3(B)(2)* or *Figure 514.3*
48. **D also grounded with an insulated copper equipment grounding conductor in addition to the metal raceway.** *517.13* requires receptacles within reach of a patient bed location to be grounded with an insulated copper equipment grounding conductor in addition to the grounding provided by the metal raceway system. This insulated copper equipment grounding wire is required to be connected both to the receptacle as well as to the metal box.
49. **E motors D and E will stop operating.** When motor D stops, the auxiliary contact to motor E will also open and motor E will stop. All other motors will remain running.

50. **A** Relay A is a master control relay because it controls power to a group of motor control circuits.
51. **A** **all of the motors will stop.** When motor B stops, the holding contact to motor B will open and master control relay A opens. When master control A opens, all motors will stop.
52. **B** **100 or more people.** 518.1 states that the rules of this article apply in cases where the building will have 100 or more people. 518.2 specifically states that a restaurant is considered to be an assembly occupancy, and 518.4(A) gives the requirements for cable construction when type MC cable is installed in an assembly occupancy. It may also be helpful to examine the requirements for Type MC cable being listed as an equipment grounding conductor in 250.122(10).
53. **C** **20 feet.** Section 680.22(A)(1) requires that a 15 or 20 ampere rated 125 volt receptacle on a general-purpose branch circuit be installed not closer than 6 feet but not more than 20 feet from the inside edge of a permanent swimming pool.
54. **C** **insulated copper not smaller than 12 AWG.** The equipment grounding conductor for equipment associated with a swimming pool is required to be insulated copper and not smaller than 12 AWG, according to 680.21(A)(1) for permanent wiring, and 680.21(A)(5) for cord connections to equipment.
55. **C** **12 feet.** Except for certain luminaires that are GFCI protected, according to 680.22(B)(1) & (2) the luminaire mounting height for an inside installation is the same as for an outside installation.
56. **D** **CL2P.** This type of cable is permitted to be installed as an exposed cable within an environmental air handling space according to Figure 725.154(A), Table 725.154, Table 725.179(K), or 725.179(A). Other types not approved as exposed cable are permitted as long as they are installed inside metal raceway.
57. **C** **as surface wiring in a single-floor commercial building.** Part 8 Rule 408.30873 modifies the uses permitted, 334.10(3). Section 334.10 in the NEC does not apply in Michigan.
58. **E** **a licensed electrical contractor.** Part 8, 80.19.1 explains to whom an electrical permit can be issued.
59. **B** **12,000 hours over a period of not less than six years, and held a journey electrician license for not less than two years.** This involves doing wiring related to electrical construction, maintenance of buildings, or electrical wiring of equipment under the supervision of a master electrician. Public Act 217 of 1956, R338.883(c).
60. **C** **Three apprentices.** Public Act 217 of 1956, R338.883e(4). This Public Act was amended by Public Act 73 of 2016 that changed the licensed electrician to registered apprentice ratio for all locations to three to one.

Michigan State University offers a 100% on-line Journey Electrical Exam study course. The course covers electrical fundamentals, journey electrician level Code material, and associated materials such as the Construction Code Act Part 8 Rules, P.A. 230, and the Electrical Administrative Act, P.A. 217 concerning licensing. Details are at [www.egr.msu.edu/bae/electricaltraining](http://www.egr.msu.edu/bae/electricaltraining)