Electrical Tech Note — 105

Journey Exam Study Guide and Sample Questions[1]
Based on the *2020 NEC*, *Michigan Electrical Code,* Part 8 Rules, 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 form 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 *Skilled Trades Regulation Act* which governs licensing, permits, and workers conduct on the job (*Public Act 407 of 2016* as amended). Also be familiar with the current edition of the *Michigan Residential Code* (*MRC*) and when this copy applies. You can obtain copies of these documents from the Office of the Electrical Division of the Bureau of Construction Codes and Fire Safety, Michigan Department of Licensing and Regulatory Affairs or on the web site 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 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, places of assembly, 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.

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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 407 of 2016*, as amended (*Skilled Trades Regulation 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.

Understanding of Basic Electrical Fundamentals and Formulas: The following is a brief review of electrical terms, principles and formulas 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. Voltage is the amount of energy in the charges. It is frequently referred to as electrical pressure.

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.

Resistance: Opposition to flow of electrical charges through a conductor. It is measured in ohms.

Ohm's Law: Voltage, current, and resistance in a circuit are related by a formula 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 Ohm's law equation. Figure 1 is sometimes used as an easy way to remember the Ohm's law equations.

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

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

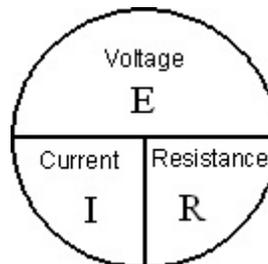$$\text{Ohms} = \frac{\text{Volts}}{\text{Amps}}$$

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 conductor wound around a laminated steel core. When an alternating current is passed through one coil of conductor the current flow creates a magnetic field about the coil. The second coil of conductor, 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 conductor. The relationship between the voltage of the first coil and the voltage of the second coil is directly proportional to the number of turns on the first coil as compared to the number of turns 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 turn, but for the purpose of installing transformers and the wiring and overcurrent protection for transformers this relationship is assumed to be turn because it represents a worst case situation. It is important to note in the following formula 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 coil at 240 volts. If the primary coil 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.
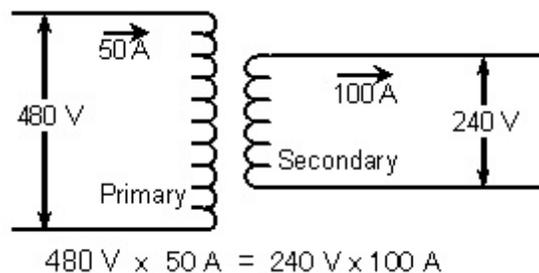

$$480 \text{ V} \times 50 \text{ A} = 240 \text{ V} \times 100 \text{ A}$$

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 conductor 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 conductors and the other half of the voltage will be between the middle and the bottom conductor. *NEC Section 250.26* requires the middle conductor to be grounded and that conductor is called the neutral. Nominal voltages for a 3-wire single-phase electrical system are 120 volts between either (hot conductor) ungrounded conductor and the neutral, and 240 volts between the two (hot conductors) ungrounded conductors. The Code refers to the hot conductors as the <u>ungrounded conductors</u>.
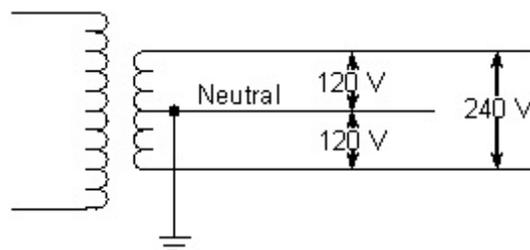

Figure 3 *A single-phase, 3-wire electrical system provides power at 120/240 volts.*

Neutral current for a single-phase, 3-wire electrical system is the difference between the current flowing in the ungrounded conductors as shown in Figure 4. The following diagram shows 120 volt loads connected to each ungrounded conductor 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 travels 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 conductors. If the current flowing in the two ungrounded conductors 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 affect the current in the neutral because this load only draws current using the ungrounded conductors. One ungrounded conductor is often referred to as leg A and the other leg B.

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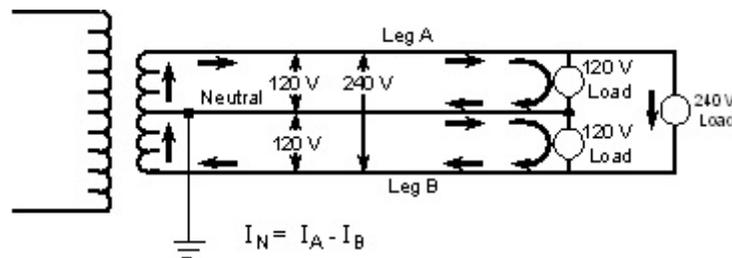

Figure 4 *The current flowing in the neutral of a 120/240 volt 3-wire single-phase system is the difference between the current flowing on the two ungrounded legs.*

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 four-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.
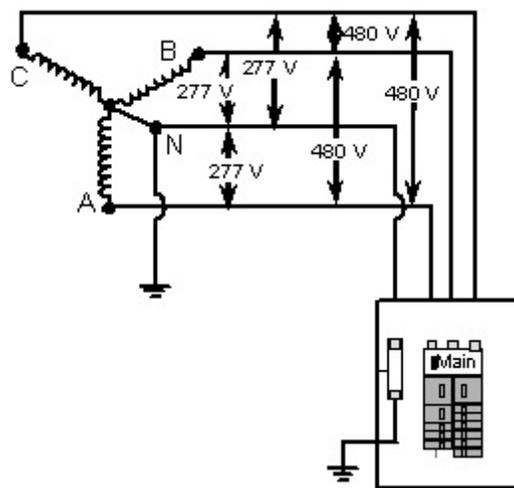

Figure 5 Common wye 3-phase electrical systems available are 4-wire and may provide power at 208/120 volts or at 480/277 volts.

The three transformer windings can be connected in a loop which forms what is called a **delta system**. A conductor 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 conductor is <u>not</u> an equipment grounding conductor. A separate equipment grounding conductor 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.
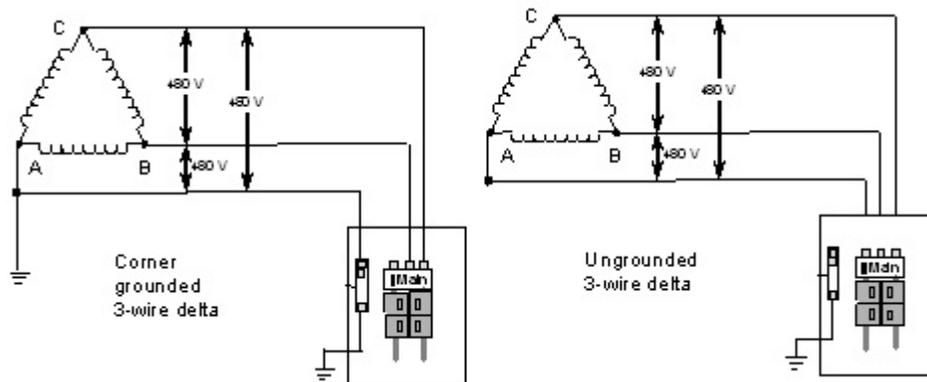

Figure 6 *A 3-wire delta electrical system is available at 240 volts or at 480 volts. One phase conductor may be grounded to form a corner-grounded system.*

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)* 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, 215.8, and 230.56,* require the high leg to be labeled orange.
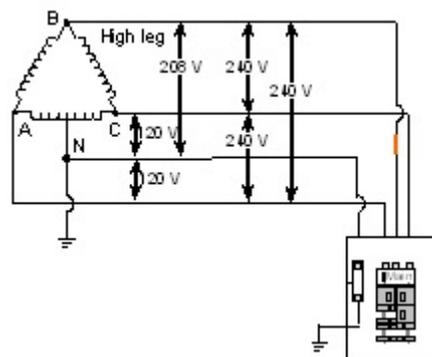

Figure 7 *A 240/120 volt 3-phase, 4-wire system can provide single-phase power at 120/240 volts, or it can provide 3-phase power at 240 volts.*

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.
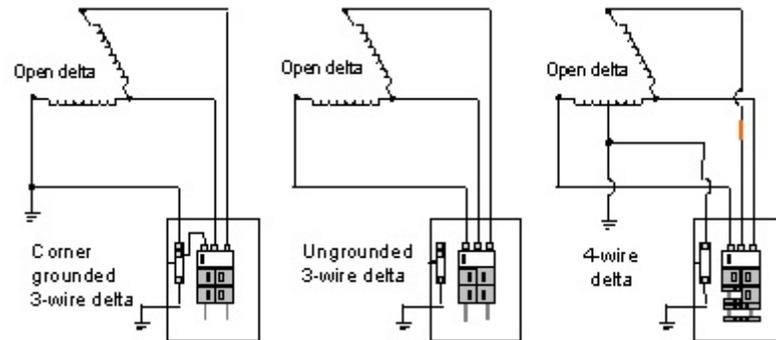

Figure 8 *Open-delta systems can provide 3-wire 3-phase power at 240 volts or at 480 volts corner-grounded or ungrounded. An open-delta 4-wire system can provide single-phase power at 120/240 volts or 3-phase power at 240 volts.*

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 formulas are as follows for single-phase power and for three-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 formula.

Single-phase power:

Power = Volts × Amps × power factor

3-phase power:

Power = 1.73 × Volts × Amps × power factor
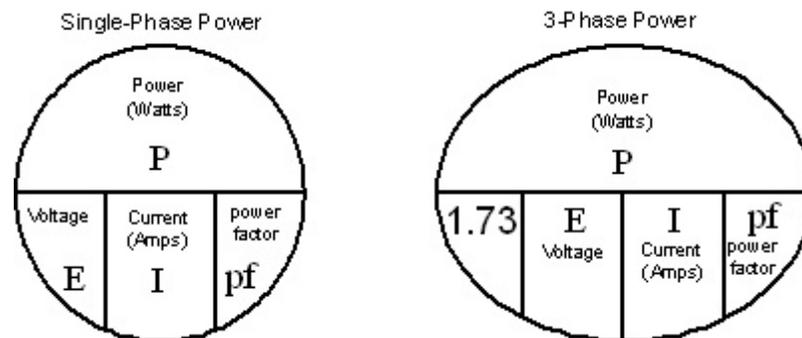
Figure 9 *A circle with watts over volts, amperes, and power factor is a convenient way to remember the different forms of the power formula.*

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 a 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 formulas 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 430.148*) with a 3-phase motor of the same horsepower and voltage (*Table 430.150*).

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.

Conductor diameter in mils   =   conductor diameter in inches   ×   1000

Area in circular mils   =   [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 conductor is higher than the resistance of a copper conductor. Conductor resistance for 1000 ft lengths is given in *Table 8, Chapter 9* of the Code.

Conductor resistance increases as the temperature increases, and decreases as the temperature decreases.   As a rough approximation, the resistance of a conductor will change about 10% 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 conductors is closer to 50°C. Therefore, much of the time, resistance values given in *Table 8* are about 9% too high.

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

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

The resistance of a conductor decreases as the cross-sectional area of the conductor 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 formula can be used to determine the resistance of a conductor with a different cross-sectional area.

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

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.
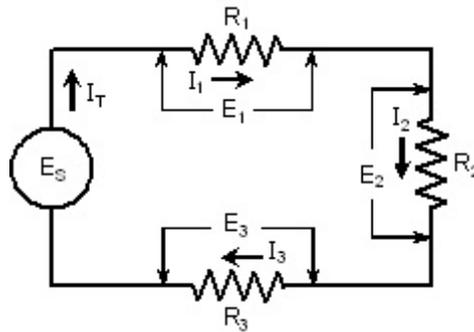

Figure 10 A series circuit has only one path for current to flow so that the same current flows through every resistor in the circuit.

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 the 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.
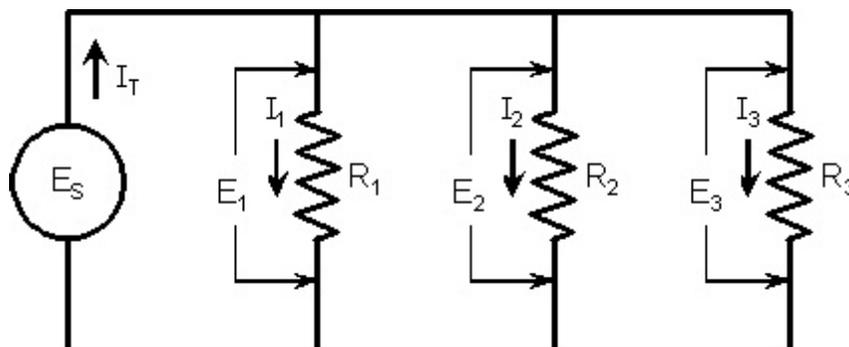

Figure 11 A parallel circuit is one where current can divide and flow through each element with the total current being the sum of the currents through each resistor.

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 th normally closed (NC) control devices in Figure 12.
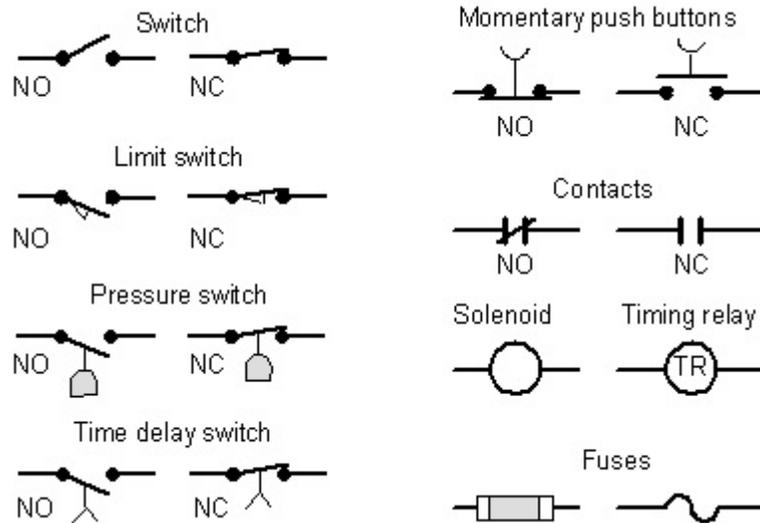
Figure 12 *Common control devices found in a motor control ladder diagram.*

For the journey exam the electrician should understand how to control a magnetic motor starter with a 2-wire control circuit or a 3-wire control circuit. Figure 13 shows a simple 2-wire control circuit where a pressure switch operates the motor starter. In this case a holding contact in the motor starter is not needed. Compare the ladder diagram with the actual wiring of the control circuit.

Figure 13 *A pressure switch controls a motor using a two-wire control circuit.*

The 3-wire control circuit is used where a motor is operated using a momentary contact start-stop station. One push button starts the motor and a separate push button stops the motor as shown in Figure 14. It is also important to at 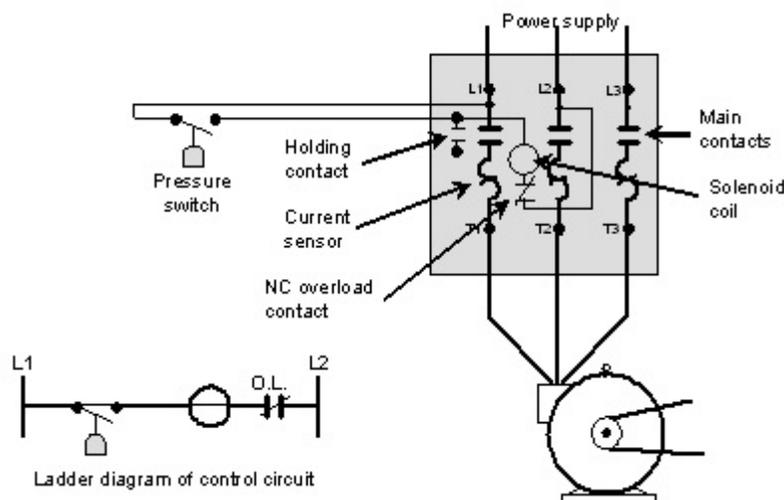least know how to control a motor from more than one location. To accomplish this two stop push buttons are connected in series and two start push buttons are connected in parallel.
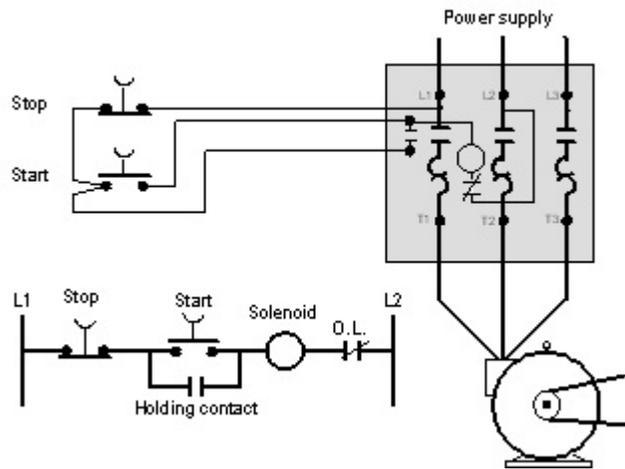

Figure 14 *This control circuit permits the motor to be started or stopped from one location with one push button to start and another push button to stop.*

The person taking the journey exam must also be able to interpret a ladder diagram that contains several control deices. Examine the ladder diagram of Figure 15. 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.
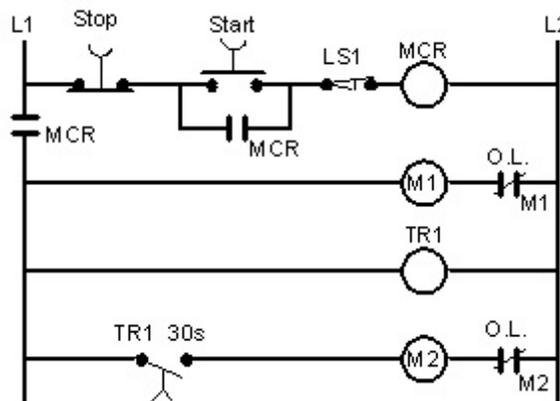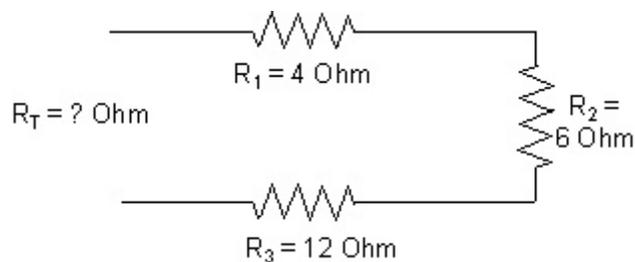

Figure 15 *The four rung ladder control diagram operates two motors using a master control relay, a momentary start-stop push button station, and a time delay relay.*

Sample Questions:

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The following are sample questions similar those 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 407*.   You should be able to complete the following questions in 1 hour, 20 minutes without using any notes, and using a copy of the Code that does not contain any personal notes.   At the end of the questions are the answers.

1.   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:
    A.   4600 watts.
    B.   5200 watts.
    C.   5800 watts.
    D.   6200 watts.
    E.   7400 watts.

2.   If an electrical clothing iron having a resistance of 24 ohms is plugged into a 120 volt outlet, the current flow will be:
    A.   2 amperes.
    B.   3 amperes.
    C.   5 amperes.
    D.   0 amperes.
    E.   15 amperes.

3.   A 3-phase electrical heater drawing 10 amperes at 240 volts, line-to-line, with a power factor of 1.0 produces:
    A.   2101 watts of heat.
    B.   2400 watts of heat.
    C.   2985 watts of heat.
    D.   4152 watts of heat.
    E.   4315 watts of heat.

4.   An electric frypan in a dwelling kitchen rated at 1440 watts that is plugged into a 120 volt receptacle will draw:
    A.   4 amperes.
    B.   7 amperes.
    C.   8 amperes.
    D.   10 amperes.
    E.   12 amperes.

5.   If three resistors are connected in series across a 120 volt source, the first 4 ohms, the second 6 ohms and the third resistor 12 ohms. The total resistance of the circuit will be:
    A.   11 ohm.
    B.   18 ohm.
    C.   22 ohm.
    D.   24 ohm.
    E.   20 ohm.

$R_1 = 4$ Ohm
$R_T = ?$ Ohm
$R_2 = 6$ Ohm
$R_3 = 12$ Ohm

6. If a 4 ohm resistor, a 6 ohm resistor, and a 12 ohm resistor are all connected in parallel, the total resistance in the circuit will be:
   A. 22 ohms
   B. 12 ohms
   C. 7.3 ohms
   D. 3 ohms
   E. 2 ohms

R_T = ? Ohm R_1 = 4 Ohm R_2 = 6 Ohm R_3 = 12 Ohm
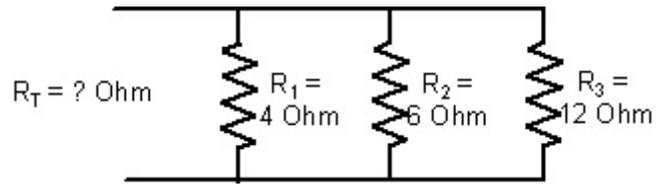
7. Wherever practical, electrical motors with the highest voltage rating are used to:
   A. obtain higher motor rpm.
   B. get more power from the motor.
   C. reduce the size of supply conductors required.
   D. improve electrical safety.
   E. lower the cost of operation.

8. Five 200 watt incandescent lamps operating for 18 hours where the average cost of electrical energy is 15 cents per kWh ($0.15 / kWh). Total cost of operating these lamps will be:
   A. $0.11.
   B. $0.40.
   C. $1.28.
   D. $2.70.
   E. $5.62.

9. If the primary to secondary turns ratio of a dry-type transformer 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.

480 V   Volts = ?   Turns ratio = 4 to 1
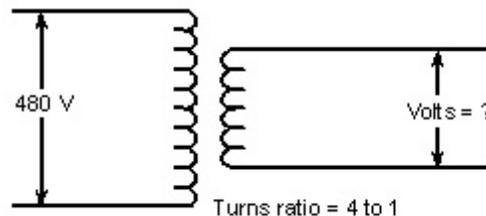
10. If the current flowing in each "hot" conductor of a single-phase, 120/240 volt, 3-wire service entrance is 28 amperes on leg A and 42 amperes on leg B, the current flowing in the neutral will be:
    A. 28 amperes.
    B. 42 amperes.
    C. 14 amperes.
    D. 35 amperes.
    E. 0 amperes.

11. The type of 3-phase electrical system 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.

A   B   C   D   E
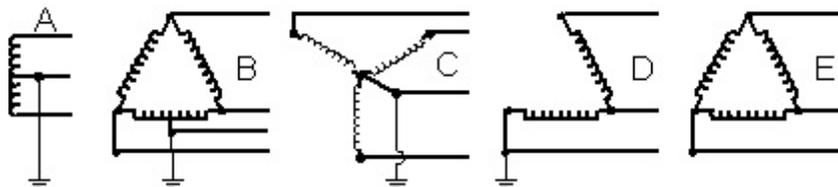
12. If the resistance of a copper conductor is 0.410 ohms/k ft, the total resistance of the circuit conductors for a single-phase load 125 ft from the current supply is:
    A.   0.0514 ohms.
    B.   0.1025 ohms.
    C.   0.1135 ohms.
    D.   0.5125 ohms.
    E.   1.0250 ohms.

13. If the diameter of a solid copper conductor is 0.125 in., the area of the conductor is:
    A.   12,265 cmil.
    B.   15,625 cmil.
    C.   25,000 cmil.
    D.   37,500 cmil.
    E.   49,063 cmil.

14. The conductor 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.   for all practical purposes safe and free from hazards.
    E.   always the most convenient wiring.

16. A 120/240 volt 100 ampere panelboard is installed for a dwelling service. The panelboard has a removable front cover and the opposite wall in front of the panelboard is concrete block. The minimum clearance permitted from the front of the panelboard to the concrete block wall is:
    A.   24   in.
    B.   30   ft.
    C.   3   ft.
    D.   3.5 ft.
    E.   6   ft.
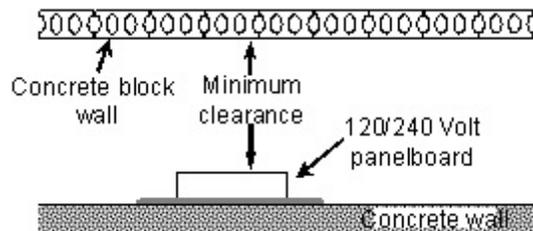
17. The receptacles serving a dwelling kitchen counter are to be located such that the distance from any point along the wall line to a receptacle is not more than:
    A.   12 in.
    B.   24 in.
    C.   4 ft.
    D.   6 ft.
    E.   12 ft.

18. 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:
    A.   8   kVA.
    B.   10.4 kVA.
    C.   14.1 kVA.
    D.   17.6 kVA.
    E.   22   kVA.

19. A grade level single-family dwelling has one bathroom, an attached garage, and an unfinished basement where the sump pump, laundry, furnace and electrical service panel are located. 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 is:
    A. one.
    B. two.
    C. three.
    D. four.
    E. five.

20. 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 ft.
    B. 12 ft.
    C. 15 ft.
    D. 18 ft.
    E. 22 ft.

21. A standard rating of overcurrent device is:
    A. 110 amperes.
    B. 275 amperes.
    C. 550 amperes
    D. 900 amperes
    E. 1500 amperes

22. Size 2/0 AWG, THWN, aluminum conductors are installed for a 150 ampere service. The minimum size copper grounding electrode conductor run to the water pipe for the service is:
    A. 8 AWG.
    B. 6 AWG.
    C. 4 AWG.
    D. 3 AWG.
    E. 1 AWG.

23. 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:
    A. 10 AWG.
    B. 8 AWG.
    C. 6 AWG.
    D. 4 AWG.
    E. 2 AWG.

24. 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 a ground rod as the supplemental electrode. The minimum size copper grounding electrode conductor permitted to be run to the ground rod is:
    A. 10 AWG.
    B. 8 AWG.
    C. 6 AWG.
    D. 4 AWG.
    E. 2 AWG.

25. A wiring method <u>not</u> permitted to serve as an equipment grounding conductor is:
    A. a combination metallic sheath and grounding conductor of type MC cable.
    B. electrical metallic tubing.
    C. a bare solid copper conductor in nonmetallic sheathed cable sized in accordance with *Table 250.122*.
    D. ½ in. trade diameter flexible metal conduit not over 6 ft long and containing circuit wires protected at 20 amperes.
    E. ½ in. trade diameter flexible metallic tubing not over 6 ft long and containing circuit wires protected at 20 amperes and terminated in fittings listed for grounding.

26. A nonmetallic sheathed cable, type NM-B, 12/2 with ground, is installed in a 3½ in. deep device box as shown in the diagram 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 conductor required to extend out of the box is:
    A. 3 in.
    B. 4 in.
    C. 6 in.
    D. 8 in.
    E. 12 in.
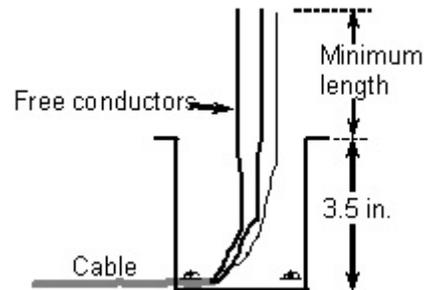
27. Electrical conductors run within rigid metal conduit and installed under a parking lot with a cover equivalent to a 4 in. thick slab of concrete are to be at a depth from the finished grade level to the top of the conduit of not less than:
    A. 4 in.
    B. 6 in.
    C. 12 in.
    D. 18 in.
    E. 24 in.

28. A set of feeder conductors is protected by a set of 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.

29. The minimum size type THWN aluminum conductor which is permitted to be installed for a 200 ampere, 120/240 volt single-phase single-family dwelling service entrance that has a calculated demand load of 150 amperes is:
    A. 250 kcmil.
    B. 1/0 AWG.
    C. 2/0 AWG.
    D. 3/0 AWG.
    E. 4/0 AWG.

30. A horizontal straight run of 2 in. diameter rigid metal conduit with threaded couplings shall be supported at intervals of not more than:
    A.   10 ft.
    B.   12 ft.
    C.   14 ft.
    D.   16 ft.
    E.   20 ft.

31. Nonmetallic sheathed cable is required to be secured within 12 in. from every cabinet, box, or fitting, and at intervals along the cable of not more than:
    A.   3   ft.
    B.   4½ ft.
    C.   6   ft.
    D.   10   ft.
    E.   12   ft.

32. The minimum trade diameter of rigid metal conduit permitted for eight size 10 AWG THWN conductors is:
   A.   ⅜ in.
    B.   ½ in.
    C.   ¾ in.
    D.   1   in.
    E.   1¼ in.

33. 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 in. of the box.
    B.   14 in. of the box.
    C.   12 in. of the box.
    D.   10 in. of the box.
    E.   8 in. of the box.

34. 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 is:
    A.   3 × 2 × 1½ in.
    B.   3 × 2 × 2½ in.
    C.   3 × 2 × 2¾ in.
    D.   3 × 2 × 3½ in.
    E.   3 × 2 × 4   in.
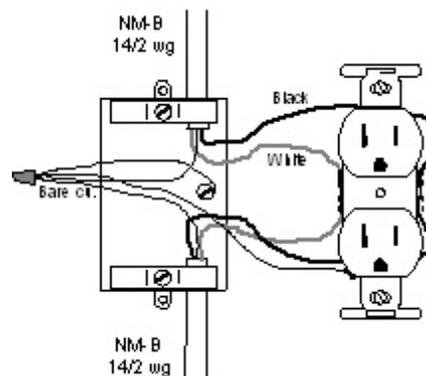
35. Assuming clearance requirements are met, a type of lighting fixture <u>not</u> permitted to be installed in a clothes closet is a:
    A.   surface mounted incandescent fixture with a completely enclosed lamp.
    B.   surface mounted fluorescent fixture with a completely enclosed lamp.
    C.   surface mounted fluorescent fixture with an exposed lamp.
    D.   recessed incandescent fixture with a completely enclosed lamp.
    E.   surface mounted porcelain incandescent lamp receptacle.

36. 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.

37. A design B, 3-phase, 15 horsepower, 480 volt electric motor has a service factor of 1.15, and a nameplate full-load current of 19 amperes. The maximum rating time-delay fuses permitted to provide 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.

38. 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.

39. 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 location as long as it is not less than 18 in. above grade level or located a distance from the edge of a dispensing device less than:
    A.   10 ft.
    B.   12 ft.
    C.   20 ft.
    D.   25 ft.
    E.   50 ft.

40. A branch circuit serving receptacles at the patient care area of a hospital is run in metal raceway. The receptacles are required to be:
    A.   installed in nonmetallic boxes.
    B.   of the insulated grounding type.
    C.   protected by a ground-fault circuit-interrupter.
    D.   grounded with an insulated copper equipment grounding wire in addition to the metal raceway.
    E.   grounded with a bare copper equipment grounding wire in addition to the metal raceway.

45. General purpose 125 volt, 15 or 20 ampere receptacles are not permitted to be located closer than 6 ft to the inside wall of a permanent swimming pool at a dwelling where space is not restricted. At least one receptacle served by a general purpose branch circuit is required to be installed such that it is not located from the inside wall of the pool more than:
    A.   12 ft.
    B.   15 ft.
    C.   20 ft.
    D.   25 ft.
    E.   50 ft.

41. Refer to the ladder control diagram where each relay controls an electric motor. If coil "D" is de-energized:
    A. only the motor controlled by "D" will stop operating.
    B. both motors "C" and "D" will stop operating.
    C. motor "D" will stop and motor "C" will start.
    D. all motors will stop operating.
    E. motors "D" and "E" will stop operating.
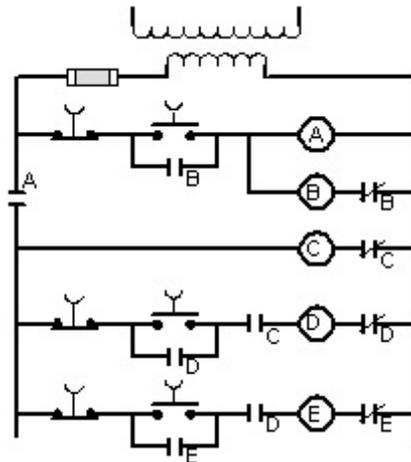
42. Refer to the ladder control diagram where each relay controls an electric motor. If the overload in the circuit of coil "B" opens:
    A. all of the motors will stop.
    B. only motor "B" will stop.
    C. motors "A" and "B" will stop.
    D. motors "B", "C", "D", and "E" will stop.
    E. motors "A", "B", "D", and "E" will stop.

43. Refer to the ladder control diagram where each relay controls an electric motor. The coil that acts as a master control relay (MCR) is coil:
    A.
    B.
    C.
    D.
    E.

44. Type MC cable used for branch circuit wiring in a restaurant is required to have an insulated equipment grounding conductor in the cable if the restaurant is designed for the assembly of:
    A. 75 or more people.
    B. 100 or more people.
    C. 150 or more people.
    D. 200 or more people.
    E. 500 or more people.

46. Of the following cables, the type permitted to be run exposed through a commercial building ceiling used as an environmental air handling space for a class 2 power limited circuit is marked:
    A. CL2.
    B. CL3.
    C. CL2R.
    D. CL2P.
    E. CL2X.

47. Electrical permits are issued to:
     A.   an apprentice electrician.
     B.   a licensed journey electrician.
     C.   any licensed master electrician.
     D.   a homeowner who does electrical work on a neighbors property.
     E.   a licensed electrical contractor.

48. When an electrical inspection is required, notice shall be given to the authority having jurisdiction (inspector) prior to the desired time of inspection a period of not less than:
     A.   36 hours.
     B.   24 hours.
     C.   12 hours.
     D.   6 hours
     E.   one working week.

49. 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.

50. 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.   12,000 hours over a period of not less than 6 years.
     B.   2,000 hours as a journey electrician over a period of not less than two years.
     C.   20,000 hours.
     D.   15,000 hours over a period of not less than two years.
     E.   8,000 hours.

51. A service entrance panel with a main circuit breaker on the inside of an existing single-family dwelling is to be replaced with a new service panel with a main circuit breaker:
     A.   An additional service disconnecting means in an accessible location is not required to be installed on the outside of the dwelling.
     B.. In addition to the new service panel, a suitable service disconnecting means is required to be installed on the outside of the dwelling in an accessible location.

52. Ground-fault circuit-interrupter protection of 15- and 20-ampere general use vranch circuits in a single-family dwelling kitchen are:
     A.   Only required for all receptacles serving locations along the kitchen counters.
     B.   Only required for all 125 volt receptacles in the kitchen including at the floor level.
     C.   Required for all kitchen receptacles in the kitchen including, 125- volt and 250-volt receptacles including an electric range that is cord and plug connected.

Solutions to Sample Questions:

References are given where the answer can be found in the Michigan Residential Code even though the questions is not specifically a one-family or a two-family dwelling installation.

1.   A   4600 watts.
                    The voltage makes no difference. Just add the wattage of each heater.
                    1200 + 1600 + 1800 = 4600

2.   C   5 amperes

$$\text{Amperes} = \frac{\text{volts}}{\text{Resistance}} = \frac{120\ V}{24\ \Omega} = 5\ A$$

3.   D   4152 watts of heat

Power = 1.73 × Volts × Amperes × power factor

= 1.73 × 240 V × 10 A × 1.0 = 4152 W

4.   E   12 amperes

$$\text{Amperes} = \frac{\text{Power}}{\text{Volts}} = \frac{1440\ W}{120\ V} = 12\ A$$

5.   A   96 volts

The voltage drop will be in the same proportion as each resistance in series is to the total circuit resistance. 28 ohms is 80% of the total resistance (35 ohms) so 80% of the voltage will be across the 28 ohms resistor.   (0.8 × 120 V = 96 V)

6.   E   2 ohms

$$\frac{1}{R_T} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12} = \frac{6}{12} \qquad\qquad R_T = \frac{12}{6} = 2\ \text{ohms}$$

7.   C   reduce the size of supply conductors required

Check current of a particular motor at two different voltages in *Table 430.148* or *Table 430.150*.

8.   B $0.40

200 W = 0.2 kW   0.2 kW × 18 hrs. = 3.6 kWh

3.6 kWh × $0.11 = $0.40

9.   D   120 volts

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

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 ft run so the total length of wire is 250 ft. 250 ft is 25% of 1000 ft so the resistance will be 0.1025 ohm.   (0.25 × 0.410 ohm = 0.1025 ohm)

13.   B   15,625 cmil

0.125 in. = 125 mils   125 mils × 125 mils = 15,625 cmil

14.   E   2 AWG

Examine *Table 310.16* or *Table 8, Chapter 9*.

15. D   for all practical purposes safe and free from hazards
           Read *Section 90.1(A)*

16. C   3 ft
           Table 110.26(A)(1) column 2 , 150 volts to ground.
           MRC — E3305.1 and *E3305.2*

17. B   24 in.
           210.52(C)(1)   *MRC — E3801.4.1*

18. B   10.4 kW
           Table 220.19, 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 off 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:

           [(kW – 12) × 0.05 × 8kVA] + 8kVA = Range Demand Load

           [(18 – 12) × 0.05 × 8kVA] + 8kVA = 2.4kVA + 8kVA = 10.4kVA
           MRC — E3602.9 and *Table E3604.3(2)*

19. D   four
           It states in *210.8(A)* that two circuits are required for the kitchen counters. One GFCI
           will be needed for each circuit *210.52(B)(2)*. One circuit is needed for bathroom
           receptacles with one GFCI *210.11(C)(1)*. The Garage, basement, and outdoor
           receptacles can be on one circuit with one GFCI.
           MRC — Kitchen is covered in *E3802.6* and *E3603.2.* Bathrooms covered in *E3802.1*
           and *E3603.4*

20. A   10 ft
           230.24(B)(1)
           MRC — E3504.2.2

21. A   110 amperes
           240.6(A)
           MRC — E3605.6

22. B   6 AWG
           This is a service entrance conductor and there is no overcurrent device on the supply
           end of the conductors. Base the grounding electrode conductor on the size and type
           of ungrounded conductors using *Table 250.66*.
           MRC — E3503.4 and *Table E3503.1*

23. 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.
           MRC — E3808.12 and *Table E3808.12*

24. C   6 AWG
           250.66(A) only requires the grounding electrode conductor to a ground rod to be as
           large as an size 6 AWG copper where it only connects to the ground rod.
           MRC — E3503.4 and *Table E3503.1 Note d*

25. D   flexible metal conduit is not permitted for grounding
> Refer to *Electrical Code Rules, Part 8*. This is a rule where *250.118(6)* has been amended for use in Michigan.
> *MRC* — No one answer, all are permitted. *E3808.8.1*

26. A   3 in.
> *300.14* requires a minimum of 6 in. of free conductor, but there must be 3 in. of conductor outside of the box.
> *MRC* — *E3306.10.3*

27. E   24 in.
> *Table 300.5* required a depth of burial of 24 in. under a parking lot no matter if there is a concrete cover or not.
> *MRC* — *Table E3703.1*

28. 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 310.16*.
> *MRC* — *Table E3605.1*. The table only goes up to size 4/0 AWG. For there to be an answer from the *MRC* there would have to be a set of two parallel 3/0 AWG.

29. E   4/0 AWG
> The key here is residential, single-phase, 120/240 volt, 3-wire. The conductor size is found in *Table 310.15(B)(6)*.
> *MRC* — *E3603.1* and *Table E3503.1*

30. D   16 ft
> *344.30(B)(2)* and *Table 344-30(B)(2)*
> *MRC* — The answer is A. *Table E3702.1*

31. B   4½ ft
> *334.30*
> *MRC* — *Table E3702.1*

32. C   ¾ in.
> *344.22, Table 1 Note 1 Chapter 9, Table C8, Annex C*
> *MRC* — *Table E3804.6(8)*

33. E   8 in. of the box
> *314.17(C) Exception*
> *MRC* — *Table E3702.1, footnote h*

34. D   3 × 2 × 3½ in.
> 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 |
>
> *MRC* — *E3805.12.2* and *Table E3805.12.1*

35. E   surface mounted porcelain incandescent lamp receptacle
> *410.8(C)*
> *MRC* — *E3903.11*

36. C   10 AWG

430.6(A)(1) requires the motor full-load current of 22 amperes to be looked up in *Table 430.150* 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 *Table 310.16*.
(22 A × 1.25 = 27.5 A)
MRC — E3602.6 The *MRC* does not cover motor circuits other than sizing the wire.

37. E   40 amperes

430.6(A)(1) requires the motor full-load current of 21 amperes to be looked up in *Table 430.150* not taken from the nameplate. *430.52* 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.

38. 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 A × 0.5 = 10 amperes
MRC — E3602.3 and *E3602.12.2*

39. C   20 ft

Table 514.3(B)(1) or *Figure 514.3*

40. D   Grounded with an insulated copper equipment grounding conductor

517.13(A) required receptacles within reach of a patient bed location be grounded with an insulated copper equipment grounding conductor in addition to the grounding provided by the metal raceway system.

41. 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.

42. A   all of the motors will stop

When motor B stops, the holding contact to motor B will open and master control relay coil A will be deenergized. When master control A opens, all motors will stop.

43. A

Relay A is a master control relay because it controls power to a group of motor control circuits.

44. 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 a plate of assembly, and *518.4(A)* gives the requirements for cable construction when type MC cable is installed in a place of assembly.

45. C   20 ft

680.22(A)(3) requires that a 15 or 20 ampere rated 125 volt receptacle be installed not closer than 10 ft but not more than 20 ft from the inside edge of a permanent swimming pool at a dwelling. When space is restricted, *680.22(A)(4)* permits the receptacle to be closer than 10 ft, but not closer than 5 ft.
MRC — E4103.1.2

46. D　CL2P
　　　725.61(A) or *Table 725.61* specifies the type of cable that is permitted to be installed as an exposed cable within an environmental air handling space. Other types not approved as exposed cable are permitted as long as they are installed in metal raceway. Another location where the answer can be found is *725.71(A)* and *Table 725.71*.
　　　MRC — E4203.2.1

47. E　a licensed electrical contractor
　　　Electrical Code Rules, Part 8, 80.19.1

48. B　24 hours
　　　Electrical Code Rules, Part 8, 80.22

49. C　140 amperes
　　　The allowable ampacity values given in *Table 310.16* 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. There are ambient temperature correction factors at the bottom of the table and adjustment factors in *Table 310.15(B)(2)(a)* when there are more than three current carrying conductors in the raceway or cable. In this case, the adjustment factor from *Table 310-15(B)(2)(a)* is 0.7. Multiply the ampacity of a size 3/0 AWG, copper THWN conductor by 0.7 to get the adjusted ampacity of the conductor which is 140 amperes.

　　　200 A　×　0.7　=　140 A

　　　MRC — E3605.3, Table E3605.3, and *Table 3605.1*

50. A　not less than 12,000 hours over a period of not less than 6 years. This involves doing wiring related to electrical construction, maintenance of buildings, or electrical wiring of equipment under the supervision of a master electrician.
　　　General rules to P.A. 217, R338.883(c)

51. B.　　　　　230.85 as amended by State of Michign.

52. C.　　　　　E3601.6,2 and 230.70(A)(1),

Score: Count the number of correct answers. To pass the exam you are required to get 75% of the questions correct. For this 52 question sample exam 75% is 39 correct questions.