



# Electrical Tech Note — 106

Biosystems & Agricultural Engineering Department  
Michigan State University

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

Based on the 2014 NEC, Part 8 of PA 230, PA 407, and the MRC

The Master 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 407 of 2016 as amended*). You should obtain a copy of a permit application, and be familiar with the process of submitting a permit application. 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 at the web site [www.michigan.gov/lara](http://www.michigan.gov/lara).

### What Subjects to Study?

**Grounding and bonding:** Determination of electrical 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. Bonding and grounding at service disconnect where service conductors are run in parallel. Equipment grounding where conductors are run in parallel in separate raceways. Grounding where two or more buildings are supplied from a common service.

**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. Determination of minimum number of general illumination branch circuits for dwellings. Determination of minimum number of lighting and receptacle branch circuits for commercial buildings.

**Conductors:** Determination of ampacity, type of insulation, usage requirements, methods of installation, protection, support and termination. Includes calculation of voltage drop and derating. Be able to size conductors for a circuit where the calculated load and rating of overcurrent device is known and where there are more than three conductors in the raceway. Be able to determine the number of current carrying conductors in a raceway for derating purposes. Determination of minimum conductor size for a service or feeder when the conductors are run as parallel sets.

**General knowledge of electrical trade:** Terminology and practical calculations such as power factor, voltage and current ratings of equipment. Be able to calculate the power drawn by an electric motor as well as the efficiency of the motor.

**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. Be able to read a basic control ladder diagram including the controls for a two-speed motor control or a reversing motor control. Determination of proper size of primary conductors and overcurrent device, and proper size secondary conductors for a wound-rotor motor.

**General use equipment:** Knowledge of code rules covering appliances, heating and air-conditioning equipment, generators, transformers, and similar equipment. Be able to determine the primary and secondary full load current of a transformer. Be able to size the overcurrent protection for a transformer. Determination of minimum demand load for an electric range.

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**Services and feeders:** Knowledge of code rules covering services. Calculation of demand load for dwelling service and small commercial building service. Determination of proper size of conductors and overcurrent device for a service or feeder given the calculated load. Determination of the maximum unbalance load for a service or feeder. Knowledge of the determination of the demand load for a multifamily dwelling including ranges and other electric appliances.

**Overcurrent protection:** Knowledge of application of fuses, circuit breakers and all types of protective devices for conductors and equipment. Determination of minimum size conductor tapped from a feeder for a specific load.

**Raceways:** Knowledge of all types of raceways and their uses. Determining proper size, conductor fill, support and methods of installation. Determine the minimum size conduit or tubing required when the conductors are of different types and sizes. Know the basic rules of installation of cable trays. Determine the amount of expansion or contraction of rigid nonmetallic conduit with a change in temperature.

**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 for installation of signs, welders, industrial machinery, swimming pools, and other special equipment. Determination of conductor size and overcurrent protection for capacitors.

**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. Be able to determine cubic inch capacity of box containing conductors size 6 AWG and smaller. Determination of minimum dimensions of pull boxes for straight and angle pulls for conductors 4 AWG and larger.

**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 luminaires, ratings, requirements for occupancies, special provisions, clearances, and other requirements. Includes load calculations for lighting.

**State laws, rules and code amendments:** Knowledge of *Public Act 407 of 2016*, as amended (*Electrical Administrative Act*) and *Public Act 230 of 1972*, as amended (*Construction Code Act*) which 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 single-family townhouses not over three floors with direct access to the outside. A copy of the *MRC* can be obtained directly from the Bureau of Construction Codes. At this time the *MRC* is not required for the exam.

**Advanced Electrical Fundamentals and Equations:** The following is a brief review of electrical terms, principles and equations useful in performing the function of a master electrician. All master electricians should know the following equations. Applications of these equations will be discussed in the following pages. Also refer to the *Journey Electrician Study Guide* for additional discussion of fundamentals that should be known prior to taking a master electrician examination.

**Ohm's Law:** Voltage = Current × Resistance       $E = I \times R$

**Voltage Drop:** If the objective is to figure voltage drop for a circuit there are two wires for a single-phase circuit and three wires for a 3-phase circuit. If the total voltage drop for the circuit is needed, use the following equations where the resistance of the conductor is looked-up in *Table 8* of the Code. The letter **R** is the resistance of one wire supplying the load, and **I** is the current in one wire supplying the load.

Single-phase: Voltage Drop =  $2 \times I \times R$

Three-phase: Voltage Drop =  $1.73 \times I \times R$

The resistance of a conductor is simply the resistivity (K) times the length of conductor (L) divided by the cross-sectional area (A) of the conductor where cross-sectional area is in circular mils (cmil) and can be found in *Table 8* of the Code. Recommended values of K to use in a calculation of resistance of a conductor at typical operating temperatures are as follows:

K = 12 for copper      K = 19 for aluminum. (At approximately 50°C)

$$\text{Single-phase: Voltage Drop} = \frac{2 \times K \times I \times L}{A}$$

$$\text{Three-phase: Voltage Drop} = \frac{1.73 \times K \times I \times L}{A}$$

If the purpose is to size the conductor given the type of conductor, length of circuit (L), current flow (I), and allowable voltage drop (%), the following equations can be used to determine the minimum size of conductor. The voltage drop is actually the percentage drop to be allowed times the circuit voltage. Convert % to a decimal before using in the equation. Go to *Table 8* in the Code to look up the minimum wire size. (Use value of K from bottom of previous page)

$$\text{Single-phase: } A = \frac{2 \times K \times I \times L}{\%_{\text{Decimal}} \times E_{\text{Circuit}}}$$

$$\text{Three-phase: } A = \frac{1.73 \times K \times I \times L}{\%_{\text{Decimal}} \times E_{\text{Circuit}}}$$

**Power Equation:** This equation is useful to determine the power draw by a load such as an electric motor. If the voltage, current, and power factor of a load is measured, it is easy to calculate the power factor of the load.

$$\text{Watts} = \text{Amps} \times \text{Voltage} \times \text{power factor}$$

$$\text{Single-phase: } P = I \times E \times \text{pf}$$

$$\text{Three-phase: } P = 1.73 \times I \times E \times \text{pf}$$

$$\text{Power factor} = \frac{\text{Watts}}{\text{Volts} \times \text{Amps}} \quad (\text{Single-phase})$$

$$\text{Power factor} = \frac{\text{Watts}}{1.73 \times \text{Volts} \times \text{Amps}} \quad (\text{3-phase})$$

**Efficiency:** The efficiency of a device is the output divided by the input. In the case of an electrical load this is the power produced divided by the power drawn. In the case of an electric motor the power developed is likely in horsepower, while the power drawn is found by measuring the volts, amps, and power factor, then determining the power drawn. Or the power drawn could be measured directly. In any event it will be necessary to either convert watts to horsepower or vice versa. Memorize the horsepower to watts conversion which is 746 watts per horsepower.

$$\text{Efficiency} = \frac{\text{Horsepower} \times 746}{I \times E \times \text{pf}} \quad (\text{Single-phase})$$

$$\text{Efficiency} = \frac{\text{Horsepower} \times 746}{1.73 \times I \times E \times \text{pf}} \quad (\text{3-phase})$$

**Current from Watts or kVA:** The load in watts may be given such as the rating of a water heater, range, or resistance heater. If the current is not given it is simply calculated by use of the power equation. For resistance type loads, power factor is assumed to be 1.0 and the current is the wattage divided by the voltage for single-phase equipment. The following equations can be used to determine the current drawn by resistance loads.

$$\text{Amps} = \frac{\text{Watts}}{\text{Volts}} \quad (\text{Single-phase}) \quad \text{Amps} = \frac{\text{Watts}}{1.73 \times \text{Volts}} \quad (\text{3-phase})$$

Equipment such as transformers are rated in kVA and it is necessary to determine the full-load current before sizing conductors and overcurrent devices. The same previous two equations are used except the kVA is multiplied by one thousand to convert to volt-amperes.

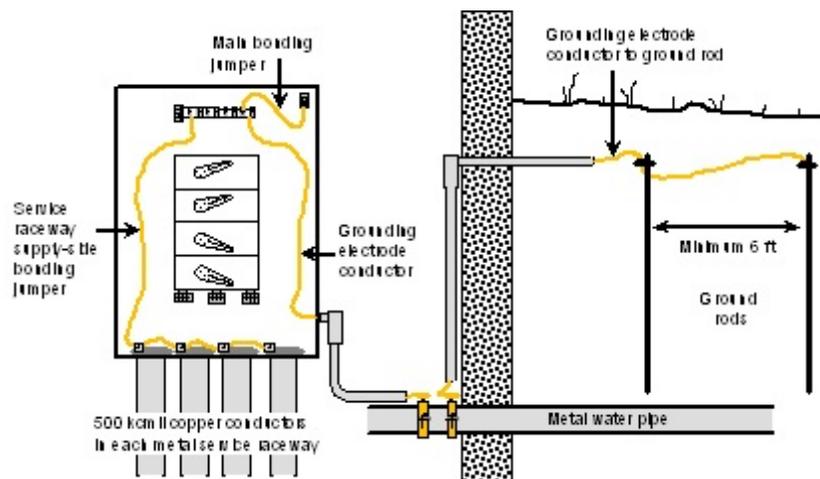
$$\text{Amps} = \frac{\text{kVA} \times 1000}{\text{Volts}} \quad (\text{Single-phase}) \quad \text{Amps} = \frac{\text{kVA} \times 1000}{1.73 \times \text{Volts}} \quad (\text{3-phase})$$

**Grounding and Bonding:** System grounding and equipment grounding serve different purposes and are both covered in *Article 250* of the *NEC*. When sizing the conductors for system grounding and for equipment grounding make sure you use the correct tables in the Code.

**Service Grounding and Bonding:** The master electrician must be able to determine the minimum permitted size of grounding and bonding conductors for a service disconnecting means even when the service conductors are run to the disconnect as parallel sets as illustrated in the following example:

**Example:** A 1600 ampere service is supplied with four sets of 500 kcmil copper conductors. The grounding electrode is an underground metal water pipe and a set of driven ground rods. The service conductors are run in separate rigid metal conduits. The grounded conductor is bonded to the disconnect enclosure with a copper conductor as illustrated in Figure 1. Determine the following for the service:

- (1) Minimum size copper grounding electrode conductor to the water pipe.
- (2) Minimum size copper grounding electrode conductor to the ground rods.
- (3) Minimum size copper main bonding jumper permitted in the disconnect enclosure.
- (4) Minimum size of a single copper supply-side bonding jumper to the metal service raceways.



**Figure 1** The service consists of four parallel sets of 500 kcmil copper service entrance conductors, and the common service conductor is grounded to a metal underground water pipe and a set of driven ground rods.

**Answer:** (1) The size of copper grounding electrode conductor from the neutral terminal to the water pipe according to the rule in 250.66 sets the minimum size at the value found in *Table 250.66*. *Note 1* of *Table 250.66*, in the case of multiple sets of service conductors, specifies the total cross-sectional area of each phase as 4 times 500 kcmil or 2000 kcmil. From *Table 250.66*, the minimum size grounding electrode conductor to the water pipe is size 3/0 AWG copper.

(2) The conductor to the set of ground rods is not required to be larger than size 6 AWG copper as stated in 250.66(A). It is permitted to run the conductor from the grounding point in the disconnect, or simply continue on from the metal water pipe to the set of ground rods.

(3) In many cases the manufacturer of the equipment provides a means of bonding the disconnect enclosure to the grounded service conductor. In this case it will be assumed that a copper conductor will be used as the main bonding jumper. *Section 250.28(D)(1)* requires the minimum size to be determined using *Table 250.102(C)(1)* unless the conductor size exceeds the size listed in the table. In this case *Note 1* requires the minimum size to be determined by multiplying the largest service conductor cross-sectional area by 0.125 (12½%). For this example the main bonding jumper will be 0.125 times 2000 kcmil which is 250 kcmil.

(4) It is required to bond the metal service raceways to the grounded service conductor. This is called a supply-side bonding jumper. The minimum size conductor, according to the last sentence of 250.102(C)(2), is required to be not smaller than specified in *Table 250.102(C)(1)* and *Note 1* based upon the combined area of the parallel sets of service conductors. If the conductors are larger than the maximum size listed in *Table 250.102(C)(1)*, the minimum size is based upon 0.125 times (12½%) the cross-sectional area of the largest equivalent area of the parallel service conductors of one phase. For this example the minimum size single copper supply-side bonding jumper to bond all four service conductor raceways, as shown in Figure 1, is 250 kcmil copper.

**Equipment Grounding:** When equipment grounding is accomplished by means of an equipment grounding conductor, the size is determined from *Table 250.122*. For a branch circuit or a feeder, the conductor is protected by fuses or a circuit breaker. The size of equipment grounding conductor is based upon the rating of the fuse or circuit breaker. For the following example, look up 150 amperes in *Table 250.122*. It will be necessary to go to 200 amperes because 100 amperes is too small.

**Example:** A set of size 1/0 AWG copper feeder conductors with 75°C insulation and terminations is protected with a 150 ampere circuit breaker. The conductors are run in nonmetallic raceway and an equipment grounding conductor is required. The minimum size copper equipment grounding conductor for this circuit is determined from *Table 250.122* and is:

- |    |                |    |                      |
|----|----------------|----|----------------------|
| A. | 12 AWG copper. | D. | <u>6 AWG copper.</u> |
| B. | 10 AWG copper. | E. | 6 AWG aluminum.      |
| C. | 8 AWG copper.  |    |                      |

When branch circuit or feeder conductors are run in parallel as permitted by 310.10(H) with each set of conductors in a separate nonmetallic raceway, an equipment grounding conductor is required to be run with the circuit conductors in each raceway, 250.122(F). The equipment grounding conductor in each raceway is required to be sized based upon the rating of the circuit or feeder overcurrent device as stated in the last sentence of 250.122(F). For the following example, look up the 300 ampere overcurrent device in *Table 250.122*. A size 4 AWG equipment grounding conductor is required to be run in each of the parallel raceways.

**Example:** A feeder is run from one panel to another as two parallel sets of size 1/0 AWG copper conductors with 75°C insulation and terminations in separate rigid nonmetallic raceways. The feeder is protected by a set of 300 ampere fuses. If the equipment grounding conductor run with each parallel set of conductors is copper, the minimum size permitted is:

- |    |               |    |        |
|----|---------------|----|--------|
| A. | 8 AWG.        | D. | 3 AWG. |
| B. | 6 AWG.        | E. | 2 AWG. |
| C. | <u>4 AWG.</u> |    |        |

**Voltage Drop Adjustment:** The size of a circuit conductor will affect the amount of current that will flow if there is a short circuit or a ground fault. Therefore, if the conductor size is increased to compensate for voltage drop or oversized for any reason more than the minimum required, it will be necessary according to 250.122(B) to make a proportional increase in size of equipment grounding conductor, if one is required

to be run with the circuit conductors. Examine the following example where the feeder conductor size is increased from size 3 AWG to size 2 AWG.

**Example:** A feeder requires size 3 AWG copper conductors run in rigid nonmetallic conduit if protected with a 100 ampere circuit breaker. The length of run is long, and to prevent excessive voltage drop, the circuit conductor is increased to size 2 AWG rather than using size 3 AWG which is the minimum size permitted. If a copper equipment grounding conductor is installed in the rigid nonmetallic conduit, the minimum size permitted is:

- |                  |           |           |
|------------------|-----------|-----------|
| A. 8 AWG.        | C. 4 AWG. | E. 2 AWG. |
| <b>B. 6 AWG.</b> | D. 3 AWG. |           |

**Answer:** First look up the minimum size equipment grounding conductor required for the circuit using *Table 250.122*. The minimum size required is 8 AWG copper. Look up the circular mil area of the ungrounded conductors from *Table 8, Chapter 9* and divide the largest by the smallest. (size 3 AWG is 52,620 circular mils and size 2 AWG is 66,360 cmil) Divide 66,360 by 52,620 to get 1.26. This is the multiplier you will use to adjust the size of equipment grounding conductor. Next look up the minimum size of equipment grounding conductor required for the circuit. Assuming copper, the minimum is size 8 AWG for a 100 ampere circuit which from *Table 8, Chapter 9* has an area of 16,510 cmil. Now multiply 16,510 by 1.26 to get 20,803 cmil. The adjusted size of equipment grounding conductor must not have an area less than this value. Finally look up the new minimum size equipment grounding conductor in *Table 8, Chapter 9* which is a 6 AWG with an area of 26,240 cmil. (From a practical standpoint, in most cases just choose the next size larger equipment grounding conductor.)

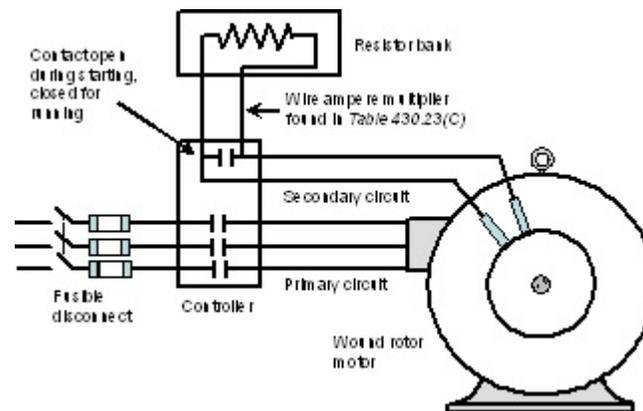
**Grounding When Supplying Two or More Buildings:** This is a change that started with the *2008 Code*. When supplying power from an electrical system with a grounded conductor out of one building and into another building on the same property, it is required by *250.32(B)* to run a separate equipment grounding conductor in addition to an insulated neutral for all new construction. There is an exception that permits the neutral to also serve as the equipment grounding conductor when feeding an existing building. Take the time to study this section. There may be a question on the exam about this subject. Also read *250.32(A)* which specifies a grounding electrode to be installed at the main disconnect for a building supplied from elsewhere on the premises.

**Motor Circuits:** The Master exam will test understanding of a single-motor circuit as well as a feeder supplying multiple motors. It is also important to understand some basic motor controls.

**Single Motor Circuit:** The rules for specifying the size of components of a motor branch circuit are found in *Article 430*. The conductor is sized according to the rule in *430.22*. Look up the full-load current of the motor in either *Table 430.248* or *Table 430.250*, and multiply that current by 1.25. This is the minimum allowable ampacity of the conductors. Generally circuit breakers and terminals in motor circuits are rated at 75°C, therefore, the 75°C column of *Table 310.15(B)(16)* can be used. Common 3-phase motors are generally design B, design C, or design D and thus according to *110.14(C)(1)(a)(4)* it is permitted to use the 75°C column of *Table 310.15(B)(16)* provided the conductors have 75°C rated insulation. Look up the conductor size directly from the table. For example, if the motor draws 15.2 amperes, multiply by 1.25 to get 19 amperes. This is a size 14 AWG copper conductor. When sizing the branch-circuit short-circuit and ground fault device, (fuse or circuit breaker), look up the multiplier from *Table 430.52*. Then multiply the full-load current by this multiplier and look up the next standard rating overcurrent device in *240.6(A)* that is equal to or higher than the ampere value determined. For example, assume time-delay fuses are used and the motor draws 15.2 amperes. Find the multiplier of 1.75 from *Table 430.52*. The maximum rating overcurrent device permitted for a normal starting motor is 15.2 amperes times 1.75 equals 26.6 amperes. Round up to a 30 ampere overcurrent device, *430.52(C)(1) Ex 1*. Also know the rules for sizing running overcurrent protection from *430.32*.

**Wound-Rotor Motor:** A wound-rotor motor is a 3-phase induction motor with windings on the rotor instead of an aluminum squirrel cage. There are slip rings so the rotor circuit can be run to a remote set of resistors. The rotor circuit is called the secondary of the wound-rotor motor. When the stator field winding is energized with 3-phase power, current is induced into the windings in the rotor. By placing resistance in series with the rotor windings, the inrush current of the motor and speed of acceleration can

be controlled to some extent. A typical wound-rotor motor circuit has supply conductors running to a controller then to the motor. This part of the circuit is sized just like any other single-motor branch circuit. There is often a set of secondary wires running from the motor back to the controller. The full-load secondary current must be shown on the motor nameplate and given in the problem. The conductors from the motor back to the controller are sized at 1.25 times the full-load secondary current,  $430.23(A)$ . The resistors may be located in an enclosure separate from the controller. If that is the case, those conductors will not be carrying the full-load secondary current. The secondary full-load current would then be multiplied by the appropriate factor found in *Table 430.23(C)*. Any question would have to give the information necessary to use the table. Figure 2 shows a wound-rotor motor circuit.

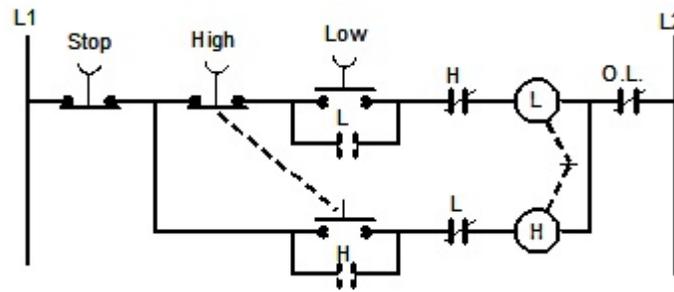


**Figure 2.** A wound-rotor motor supply circuit is treated like any other single motor branch circuit, but the secondary circuit conductors are sized according to the rules in 430.23.

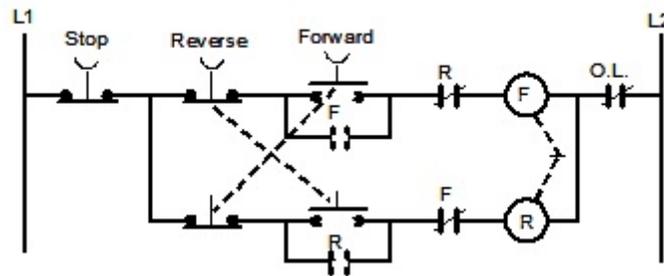
**Feeder Supplying Several Motors:** If a feeder conductor supplies several motors, the feeder can be sized for that specific motor load. The conductor is not permitted to be smaller than 1.25 times the full-load current of the largest motor plus the full-load current of all other motors according to 430.24. The maximum permitted rating of motor feeder fuse or circuit breaker is determined using the rule in 430.62. Be careful here. You must first find out which motor circuit supplied by the feeder has the highest rated fuse or circuit breaker. Take that rating and add to it the full-load current of all other motors. For example, assume a feeder supplies three 460 volt, 3-phase motors; one draws 52 amperes, one draws 40 amperes and the last draws 34 amperes. Assume each motor circuit is protected by time-delay fuses and the rating of fuses for the circuits are 100 amperes, 70 amperes, and 45 amperes. The maximum rating time-delay fuse permitted for the feeder is 150 amperes. (100 ampere fuse rating plus 40 amperes plus 34 amperes equals 174 amperes.) This is a maximum that cannot be exceeded, therefore, it is required to round down to 150 amperes. Incidentally the minimum permitted conductor size for these motors is 1.25 times 52 amperes plus 40 amperes plus 34 amperes which gives 139 amperes which is a size 1/0 AWG copper wire.

If circuit breakers were used for branch-circuit and ground-fault protection for the motors of the previous example the values would be 150 amperes, 100 amperes, and 90 amperes. The feeder conductor would remain size 1/0 AWG copper, however, the feeder short-circuit and ground-fault protective device would have a rating limit of 200 amperes ( $150\text{ A} + 40\text{ A} + 34\text{ A} = 224\text{ A}$ , round down to 200 A).

**Motor Control Circuits:** It is important to be able to read and understand motor control ladder diagrams. See the *Journey Exam Study Guide* for the basics of reading ladder diagrams. In addition to the basics, be able to recognize a properly connected two-speed motor control circuit and a reversing motor control circuit. A diagram of each is shown in Figure 3 and Figure 4. The primary difference between the two diagrams is that in Figure 3 it is necessary to push the stop button before the motor will go from high speed to low speed. Examine the diagram of the control circuit of Figure 3 and Figure 4. Just ahead of the solenoid coil note the normally closed set of contacts. These contacts prevent both solenoids from being energized at the same time.



**Figure 3.** There are three push buttons, one marked stop, one marked high speed, and one marked low speed. The other high push button is internal. The dotted lines mean the components are mechanically interlocked so they operate at the same time. The two coils are interlocked so one will not close unless the other is open.



**Figure 4.** There are three push buttons, one marked stop, one marked forward, and one marked reverse. The dotted lines mean the components are mechanically interlocked so they operate at the same time. The two coils are interlocked so one will not close unless the other is open.

**Capacitor Conductor Sizing and Overcurrent Protection:** Capacitors are frequently a part of equipment such as a motor variable frequency drive. Unless the drive is opened for maintenance, an electrician is generally not required to size and install circuit components such as conductors and overcurrent protection. Where these tasks may be necessary is in the case of power factor correction.

**Capacitor Full-Load Current:** Capacitors may be added to a wiring system sometimes for power factor correction. The capacitors used for this purpose are generally selected for the proper voltage, and rated in kilo-VARs (kVARs). It may be necessary to size the conductors for a bank of capacitors as well as the overcurrent protection. For this purpose, treat the problem just like it was a power problem as described earlier. To determine the full-load current, multiply the kVAR rating of the capacitor by 1000 and divide by the voltage. If it is a 3-phase capacitor bank, also divide by 1.73. The following equation is for a 3-phase capacitor bank. For a single-phase capacitor bank omit the 1.73 in the denominator.

$$\text{Full-load current} = \frac{\text{kVAR} \times 1000}{1.73 \times \text{Volts}}$$

**Capacitor Conductor Size:** Conductors connected to a capacitor bank are sized at 135% of the capacitor full-load current rather than the typical 125% for other types of circuits, 460.8(A). After determining the capacitor full-load current, multiply by 1.35 and look up the minimum size in *Table 310.15(B)(16)*. Make sure the termination temperature rating and the conductor insulation is known in order to use the correct column of *Table 310.15(B)(16)*.

**Example:** Determine the size of conductors for a 50 kVAR, 460 volt, 3-phase capacitor bank.

**Answer:** First determine the full-load current of the capacitor bank. In this case it is a 3-phase bank and the 1.73 must be in the denominator as shown in the above equation.

$$\text{Full-load current} = \frac{50 \text{ kVAR} \times 1000}{1.73 \times 460 \text{ V}} = 63 \text{ amperes}$$

Next, size the conductor by multiplying the full-load current by 1.35 and look up the conductor size in *Table 310.15(B)(16)*. The minimum permitted conductor ampacity is 1.35 times 63 amperes which is 85 amperes. If conductor insulation and termination temperature are not specified in the problem, then use the 60°C column and find size 3 AWG copper. If the conductors are size 1/0 AWG or larger, use the 75°C column of *Table 310.15(B)(16)*. There is no specific rule for determining the minimum or maximum rating of the overcurrent device except that it is to be as low as practical. It is a complex process that is performed by qualified personnel.

**Conductor Sizing for Branch Circuits and Feeders:** Conductors for a branch-circuit or a feeder depend upon the load to be served and the overcurrent device chosen for the circuit. Here is a suggested set of steps that can be used to determine the minimum size of conductor for a branch circuit or a feeder where the actual load to be served is known. In many cases the branch circuit or feeder is sized much larger than the actual load to be served in order to allow extra capacity for future loads. In this case the rules of *240.4* must be followed to make sure the conductor is properly protected from overcurrent.

- (1) If the overcurrent device rating is not known, then determine the minimum permitted rating for the load before proceeding. (See the procedure below)
- (2) Determine the minimum size of conductor permitted for the load. The procedure is described in *210.19(A)(a)* and *215.2(A)(1)(a)*. If there are no adjustment factors that are required to be applied, then this is the minimum wire size permitted. Review termination temperature ratings and wire insulation type. Use the lowest of these temperatures to find the correct column to use in the ampacity table. (See the procedure below)
- (3) If adjustment factors are required for the circuit then determine the factors that must apply. Multiply these adjustment factors times the conductor ampacity found in the table. It may be permitted to start with column temperature rating higher than used in the previous step. The final adjusted ampacity must not be less than the actual circuit or feeder load and it must also meet the overcurrent protection rules of *240.4*. Keep selecting a larger wire until these rules are satisfied. (See example on next page)

**Overcurrent Device Selection:** (1) The rule for determining the minimum size overcurrent device permitted for a branch-circuit is found in *210.20(A)*. In the case of a feeder the minimum overcurrent device rating is determined according to *215.3*. In either case the rule is the same. The overcurrent device must have a rating not less than the noncontinuous load plus 1.25 times the continuous load. *Section 240.6(A)* lists the standard ratings of overcurrent devices. Choose a rating that is larger than the calculated load. The following example will illustrate the procedure.

**Example:** A feeder supplies 92 amperes of continuous load and 70 amperes of noncontinuous load. Determine the minimum rating of overcurrent device permitted to protect this feeder.

**Answer:** The feeder consists of three type THHN copper current-carrying conductors in raceway. The minimum rating of overcurrent device is required to be not smaller than 125% of the continuous load plus the noncontinuous load. The calculation for this feeder is as follows:

$$\begin{array}{rcll} 92 \text{ A} \times 1.25 & = & 115 \text{ A} & \text{continuous load} \\ 70 \text{ A} \times 1.00 & = & \underline{70 \text{ A}} & \text{noncontinuous load} \\ & & 185 \text{ A} & \text{minimum overcurrent device rating} \end{array}$$

The overcurrent device is required to be at least 185 amperes. From *240.6(A)*, the next higher standard rating is 200 amperes.

**Minimum Conductor Size for a Load:** (2) The method to determine the minimum size conductor for a specific load for a feeder is found in *215.2(A)(1)(a)* and for a branch circuit in *210.19(A)(1)(a)*. The rule is the same in both cases. The minimum conductor size is not permitted to be smaller than the noncontinuous load plus 1.25 times the continuous load. This minimum size is determined without any consideration of adjustment or correction factors. If the wiring method is conductors in raceway or cable,

*Table 310.15(B)(16)* will be used to determine conductor ampacity. In most cases conductor terminations are rated at 75°C. It is important to understand the rules of *110.14(C)* in order to know whether the termination rating is 60°C or 75°C in cases where the termination rating is not known. If the conductor insulation is 90°C rated, but the terminations are 75°C rated, it is necessary to use the 75°C column of *Table 310.15(B)(16)*. If the overcurrent device is rated greater than 100 amperes or the conductor is size 1/0 AWG or larger, the terminations are rated 75°C unless otherwise specified. For overcurrent devices 100 amperes and smaller or conductor sizes 1 AWG and smaller, the terminations are rated at 60°C unless otherwise specified.

**Example:** Consider the previous example where a feeder supplies a 92 ampere continuous load and a 70 ampere noncontinuous load. The wire is THHW copper run in EMT and the termination ratings are 75°C. Determine the minimum wire size assuming no adjustment factors apply to the feeder.

**Answer:** The wire is required to have an ampacity not less than 125% of the continuous load plus the noncontinuous load which was determined in the previous example to be 185 amperes. Since we must look at the complete circuit, the 75°C rated terminations will determine the column to use in *Table 310.15(B)(16)*. The minimum conductor size in this case is 3/0 AWG. Check to make sure the overcurrent rule of *240.4* is satisfied. In the previous example a 200 ampere overcurrent device was selected.

**Adjustment Factors Applied to Wire Ampacity:** (3) According to *Table 310.15(B)(2)(a)*, the ampacity values given in *Table 310.15(B)(16)* must be reduced to 80% of their value if more than three but not more than six wires are in conduit or cable. If there are more current carrying conductors in the conduit or cable, other adjustment factors must apply. *Table 310.15(B)(16)* is based upon the wires placed in an ambient temperature of 30°C. If the branch circuit or feeder run passes through an area where the surrounding temperature is much higher than 30°C, then an adjustment in the ampacity shown in *Table 310.15(B)(16)* is required. The temperature adjustment factors are given in *Table 310.15(B)(2)(a)*. When applying the adjustment factors to a portion of a circuit, often the only limitation in that portion of the circuit is the conductor insulation. Terminations are often not a factor when applying adjustment factors to the ampacity found in *Table 310.15(B)(16)*. If the wires have 90°C insulation, it is frequently permitted to start the adjustment using the ampacity for the size of wire in the 90°C column of the ampacity table. Also, when finished applying the adjustment factors, the wire ampacity is not permitted to be less than the actual load. For this comparison it is not necessary to multiply the continuous load by 1.25.

**Example:** Consider the same feeder as the previous example, except in this case assume the feeder shares the raceway with three other current-carrying conductors for a total of six current carrying conductors. Determine the minimum size wire required for the feeder.

**Answer:** The ampacity given in *Table 310.15(B)(16)* must be multiplied by the adjustment factors. In the raceway there are no terminations, and the only temperature limitation is the insulation on the wires which is rated at 90°C. For the purpose of determining the ampacity of the THHN copper conductors in the raceway, the 90°C column of *Table 310.15(B)(16)* can be used. In this case, the size 3/0 AWG copper conductor is rated at 225 amperes. The adjustment factor for six current carrying conductors is found in *Table 310.15(B)(3)(a)* and has a value of 0.80. This current must be reduced to 80% of the value found in *Table 310.15(B)(16)* which is 180 amperes.

$$225 \text{ A} \times 0.8 = 180 \text{ A}$$

*Section 215.2(A)(1)(b)* requires the conductor to have an ampacity not less than the load to be served. It does not require the continuous load to be multiplied by 1.25 except for the overcurrent device and determination of the minimum conductor size. In this case the noncontinuous load is 70 amperes plus the continuous load of 92 amperes which gives a total of 162 amperes. The size 3/0 AWG copper THHN conductor is rated at 180 amperes after applying the adjustment factor, which is greater than the load. But the conductor is protected with a 200 ampere overcurrent device. *Section 240.4(B)* permits a conductor to be protected from overcurrent at a rating higher than the conductor ampacity provided the conductor is adequate to supply the load, and the conductor is protected by the next higher standard rated overcurrent device as listed in *240.6(A)*. The conclusion is that the

size 3/0 AWG copper THHN conductor is permitted for this feeder with six conductors in the raceway.

**Ambient Temperature Adjustment:** Making conductor ampacity adjustments for a high ambient temperature is done in a manner similar to the previous example. If the conductor ampacity is being determined using *Table 310.15(B)(16)*, the temperature adjustment factors are found in *Table 310.15(B)(2)(a)*. If there are also more than three current carrying conductors in the raceway, then both of these factors must be used to adjust the current of the conductors. The following is a continuation of the previous example where the conductors are also exposed to a high ambient temperature.

**Example:** Consider the previous example where there are six current carrying conductors in the raceway which passes through an area where the ambient temperature typically runs at 130°F. Determine the minimum size copper, THHN conductors for the circuit.

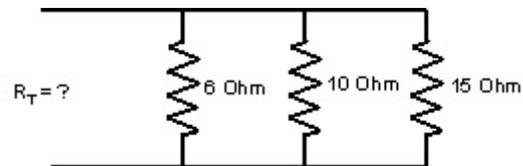
**Answer:** From the previous example it was determined that 225 amperes could be used for the size 3/0 AWG, THHN copper conductors for the purpose of adjustment of ampacity rating. For six conductors in the raceway the adjustment factor was 0.80. Now go to *Table 310.15(B)(2)(a)* and go down the 90°C column and find the row for 130°F ambient temperature. The adjustment factor is 0.76. Applying both of these adjustment factors, the size 3/0 AWG, THHN copper conductor ampere rating is now 137 amperes. This is too small both for the 162 ampere load and to satisfy *240.4(B)*. A larger size wire is required. Size 4/0 AWG, THHN copper wire also fails to meet the requirements. Now try 250 kcmil, THHN copper which is rated for 290 amperes before adjustment. After adjustment it has a maximum current rating of 176 amperes which is higher than the load of 162 amperes and also meets the requirement of *240.4(B)*.

Size 3/0 AWG, THHN copper	$225 \text{ A} \times 0.80 \times 0.76 = 137 \text{ A}$
Size 4/0 AWG, THHN copper	$260 \text{ A} \times 0.80 \times 0.76 = 158 \text{ A}$
Size 250kcmil, THHN copper	$290 \text{ A} \times 0.80 \times 0.76 = 176 \text{ A}$

### Sample Master Exam Questions:

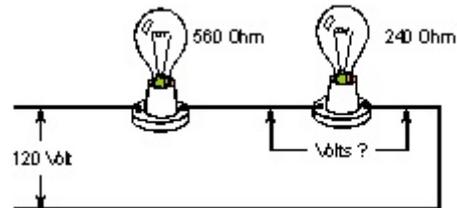
The following are sample questions typical of what is found on a master electrician examination. This study guide is not complete relative to all the questions that can be asked on an exam. Look up each Code section and read the indicated section to gain the most benefit from this study guide. Questions will also be asked from the *Construction Code Act, Part 8 (PA 230)* and the *Skilled Trades Regulation Act (PA 407)*. You should be able to complete the following questions in 1 hour, 45 minutes without using any notes. You are permitted to use a Code that has commercially produced tabs. You are also permitted to have several sheets of blank paper and a calculator. You are also permitted to refer to *Part 8* of the *Construction Code Act*, and the *Skilled Trades Regulation Act*. At the end of these questions are the answers.

- Three electric devices are connected in parallel on a circuit with the first device having a resistance of 6 ohms, the second having a resistance of 10 ohms, and the third having a resistance of 15 ohms, shown in Figure 5. The total resistance of the circuit is:
  - 3 ohm.
  - 5 ohm.
  - 12 ohm.
  - 15 ohm.
  - 31 ohm.



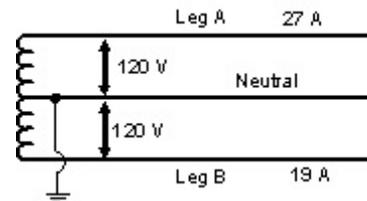
**Figure 5** A 6 ohm, 10 ohm, and a 15 ohm resistor are connected in parallel. Determine the total resistance.

2. A single-phase electric motor draws 28 amperes and is supplied by a size 10 AWG stranded uncoated copper conductor. The length of the circuit from the panel to the motor is 200 feet. The approximate voltage drop caused by the circuit conductors when the motor is running is:
  - A. 6.9 volts.
  - B. 10.0 volts.
  - C. 13.9 volts.
  - D. 21.6 volts.
  - E. 34.7 volts.
  
3. Two incandescent lamps are connected in series and supplied at 120 volts. One lamp has a resistance of 560 ohms and the other has a resistance of 240 ohms, shown in Figure 6. The voltage across the lamp with the 240 ohm resistance is:
  - A. zero volts.
  - B. 36 volts.
  - C. 60 volts.
  - D. 84 volts.
  - E. 120 volts.



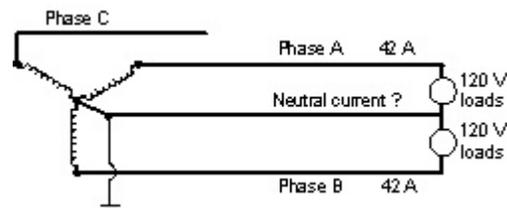
**Figure 6** Two incandescent lamps are connected in series, one with a resistance of 560 ohms and the other with a resistance of 240 ohms. If the circuit is energized at 120 volts, determine the voltage across the 240 ohm resistance.

4. If a single-phase resistance type strip heater is energized at 120 volts and has a rating of 4500 watts, the strip heater will draw approximately:
  - A. 4.3 amperes.
  - B. 11.4 amperes.
  - C. 18.8 amperes.
  - D. 32.7 amperes.
  - E. 37.5 amperes.
  
5. A clamp-around ammeter is used to measure the current flowing in each ungrounded leg of a 3-wire, 120/240 volt electrical service. The current flowing on leg A is 27 amperes, and the current flowing on leg B is 19 amperes, shown in Figure 7. The current flowing on the neutral is:
  - A. 8 amperes.
  - B. 19 amperes.
  - C. 23 amperes.
  - D. 27 amperes.
  - E. 46 amperes.



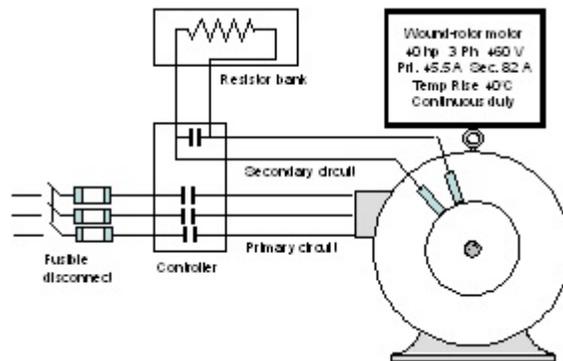
**Figure 7** For this single-phase, 3-wire service, the current on leg A is 27 amperes and the current on leg B is 19 amperes. Determine the current flowing on the neutral.

6. An apartment building is supplied power from a 3-phase, 4-wire 208/120 volt electrical system with a 3-wire, 208/120 volt feeder with two ungrounded conductors and a neutral to each living unit as shown in Figure 8. With only 120 volt loads operating, the current flowing on each ungrounded conductor is measured at 42 amperes. The neutral current is approximately:
  - A. 0 amperes.
  - B. 21 amperes.
  - C. 36 amperes.
  - D. 42 amperes.
  - E. 84 amperes.



**Figure 8** A 3-wire feeder originating from a 208/120 volt 3-phase electrical system has 42 amperes of 120 volt load flowing on both phase A and phase B. Determine the neutral current.

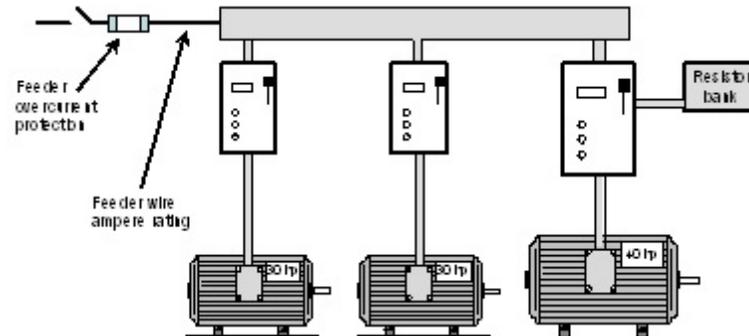
7. An electrical conductor is made up of 19 strands each with a diameter of 0.0837 inches. The approximate circular mil area of the conductor is approximately:
- A. 105,600 cmil.                      C. 167,800 cmil.                      E. 211,600 cmil.  
 B. 133,100 cmil.                      D. 184,200 cmil.
8. A 3-phase, 460 volt, 40 horsepower continuous duty wound-rotor induction motor has a nameplate primary full-load current of 45.5 amperes, a nameplate secondary full-load current of 82 amperes, and a temperature rise of 40°C. The circuit is illustrated in Figure 9. The resistor bank classification is “medium intermittent duty” and is located separate form the controller. The minimum primary conductor current rating permitted is:
- A. 46 amperes.                      C. 65 amperes.                      E. 82 amperes.  
 B. 57 amperes.                      D. 74 amperes.



**Figure 9** The 40 horsepower wound-rotor motor has a primary full-load current of 45.5 amperes, a secondary full-load current of 82 amperes, a temperature rise of 40°C, and a resistor bank located separate from the controller. The resistor bank classification for this installation is “medium intermittent duty”.

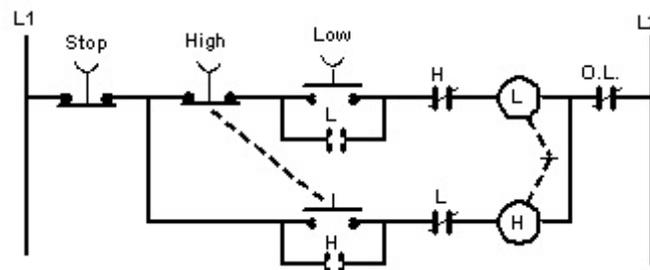
9. Refer to Figure 9 showing a 3-phase, 460 volt, 40 horsepower continuous duty wound-rotor induction motor with a nameplate primary full-load current of 45.5 amperes, a nameplate secondary full-load current of 82 amperes, and a temperature rise of 40°C. The resistor bank classification is “medium intermittent duty” and is located separate from the controller. The minimum secondary conductor current rating permitted between the motor and the controller is:
- A. 82 amperes.                      C. 125 amperes.                      E. 175 amperes.  
 B. 103 amperes.                      D. 146 amperes
10. Refer to Figure 9 showing a 3-phase, 460 volt, 40 horsepower continuous duty wound-rotor induction motor with a nameplate primary full-load current of 45.5 amperes, a nameplate secondary full-load current of 82 amperes, and a temperature rise of 40°C. The circuit is protected from short-circuits and ground-faults with time-delay fuses. The maximum time-delay fuse rating permitted for this circuit is:
- A. 50 amperes.                      C. 70 amperes.                      E. 90 amperes.  
 B. 60 amperes.                      D. 80 amperes.

11. A feeder supplies two 30 horsepower 3-phase, 460 volt, design B induction motors with a service factor of 1.15, and a 3-phase 460 volt, 40 horsepower wound-rotor induction motor with a primary full-load current of 45.5 amperes, and a temperature rise of 40°C. The feeder is illustrated in Figure 10, and all motors operate independent of each other. The minimum feeder conductor current rating permitted to supply this specific motor load is:
- A. 102 amperes.
  - B. 145 amperes.
  - C. 165 amperes.
  - D. 174 amperes.
  - E. 188 amperes.



**Figure 10** A 3-phase, 460 volt feeder supplies two 30 horsepower induction motors with a service factor of 1.15 and a 40 horsepower wound-rotor motor with a primary full-load current of 45.5 amperes and a temperature rise of 40°C.

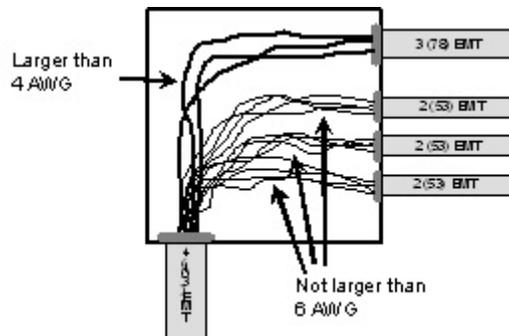
12. Refer to the feeder illustrated in Figure 10 supplying two 30 horsepower 3-phase, 460 volt, design B induction motors with a service factor of 1.15, and a 3-phase 460 volt, 40 horsepower wound-rotor induction motor with a primary full-load current of 45.5 amperes, and a temperature rise of 40°C. Each motor operates independent of the others, and each motor circuit, as well as the feeder, is protected from short-circuits and ground-faults with time-delay fuses. The maximum time-delay fuse rating permitted for the feeder is:
- A. 100 amperes.
  - B. 110 amperes.
  - C. 125 amperes.
  - D. 150 amperes.
  - E. 175 amperes.
13. The control system in Figure 11 operates a two-speed motor. When the motor is:
- A. running at high speed, pressing the low button will change the motor to low speed.
  - B. not running, it is necessary to start at low speed before the motor will run at high speed.
  - C. running at high speed, care must be taken not to press the low speed button or a short circuit will occur.
  - D. not running, it will remain off by pressing both high and low buttons at the same time.
  - E. running at high speed, the stop button must be pressed to switch from high to low speed.



**Figure 11** The ladder diagram represents a control circuit for a two-speed magnetic motor controller.



20. A 4 inch trade size EMT enters one side of a pull box, and a 3 inch along with three 2 inch trade size EMT runs enter the adjacent side as shown in Figure 13. Only the 4 inch and 3 inch trade size EMT contain wires of size 4 AWG or larger. The minimum size pull box from the following list is:
- A. 12 in. by 18 in.      C. 18 in. by 24 in.      E. 24 in. by 30 in.  
 B. 18 in. by 18 in.      D. 24 in. by 24 in.



**Figure 13** A pull box has a 4 inch trade size EMT entering one side, and a 3 inch along with three 2 inch trade size EMT runs entering the adjacent size. Determine the minimum dimensions of the pull box.

21. An existing building on the same property is supplied 120/240 volt single-phase power from another building. There is no metallic water pipe or other metal equipment connecting the two buildings that would form a parallel path for neutral current. If the second existing building is supplied from a 3-wire feeder (two ungrounded conductors and a neutral), the neutral conductor is:
- A. required to be bonded to the disconnect enclosure in the second building and connected to a grounding electrode.  
 B. not permitted to be bonded to the disconnect enclosure or be connected to a grounding electrode in the second building.  
 C. only permitted to be connected to a grounding electrode at the supply end of the feeder in the first building.  
 D. only permitted to be connected to a grounding electrode and bonded to the disconnect enclosure at the second building.  
 E. not permitted to be connected to a grounding electrode and bonded to the disconnect enclosure at either building.
22. A new building on the same property is supplied 120/240 volt single-phase power from another building. The second new building is supplied from a 4-wire feeder (two ungrounded conductors, an insulated neutral conductor, and an equipment grounding conductor), where the neutral conductor is:
- A. required to be connected to a grounding electrode and bonded to the disconnect enclosure at both buildings.  
 B. not permitted to be connected to a grounding electrode or bonded to the disconnect enclosure at either building.  
 C. required to be bonded to the disconnect enclosure in the second building and connected to a grounding electrode, but not at the first building.  
 D. permitted to be bonded to the disconnect enclosure in the second building and connected to a grounding electrode.  
 E. not permitted to be connected to a grounding electrode or the disconnect enclosure at the second building.
23. A feeder protected by 800 ampere fuses is run from one part of a building to another under the floor in two parallel sets of rigid nonmetallic conduit with size 500 kcmil copper RHW wires. The minimum size copper equipment grounding conductor permitted to be run in each conduit is:
- A. 4 AWG.      C. 2 AWG.      E. 1/0 AWG.  
 B. 3 AWG.      D. 1 AWG.

24. A service entrance with a 1000 ampere main circuit breaker is supplied with three parallel sets of size 400 kcmil copper THWN wires. A metal underground water pipe entering the building is used as a grounding electrode for the service. The minimum size copper grounding electrode conductor permitted to be run to the water pipe is:
- A. 6 AWG.
  - B. 1/0 AWG.
  - C. 3/0 AWG.
  - D. 250 kcmil.
  - E. 400 kcmil.
25. The copper THWN wires for a 480 volt, 3-phase feeder protected by 150 ampere time-delay fuses are increased in size from the minimum required 1/0 AWG to size 3/0 AWG to compensate for voltage drop. If the feeder is run in rigid nonmetallic conduit (PVC), the minimum size copper equipment grounding conductor permitted to be run for this feeder is:
- A. 8 AWG.
  - B. 6 AWG.
  - C. 4 AWG.
  - D. 3 AWG.
  - E. 2 AWG.
26. A transformer supplies a 200 ampere panelboard with 120/240 volt single-phase power. The secondary conductors from the transformer to the panelboard are size 3/0 AWG copper. This transformer is near the service disconnect for the building, and it is grounded to the same metal underground water pipe as the service. The minimum size copper grounding electrode conductor permitted for this transformer installation is:
- A. 10 AWG.
  - B. 8 AWG.
  - C. 6 AWG.
  - D. 4 AWG.
  - E. 2 AWG.
27. An equipotential bonding grid for a permanent swimming pool is formed by connecting together with a bonding wire all metal parts associated with the pool such as metallic parts of the pool structure, forming shells, mounting brackets of lighting fixtures, metal ladders, and other metal attached to the pool, metal equipment associated with the water circulating system, pool covers, reinforcing steel in the pool shell and paved walkway around the pool, and similar metal parts. The conductor used for this bonding is:
- A. required to be solid copper insulated, covered, or bare, not smaller than size 8 AWG.
  - B. permitted to be solid aluminum if insulated and not smaller than size 8 AWG.
  - C. required to be insulated copper, stranded, and not smaller than size 8 AWG.
  - D. permitted to be bare, insulated, or covered copper not smaller than size 6 AWG.
  - E. required to be copper not smaller than size 2 AWG.
28. A feeder supplies a load that does not contain general use receptacles and consists of 40 amperes of continuous load and 36 amperes of noncontinuous load. All terminations for the feeder are rated at 75°C. The feeder conductor is copper with THHN insulation and there are only three current-carrying conductors in raceway. The minimum standard rating overcurrent device permitted for this feeder is:
- A. 60 ampere.
  - B. 70 ampere.
  - C. 80 amperes.
  - D. 90 amperes.
  - E. 100 amperes.
29. A building served with a 208/120 volt, 3-phase electrical system has a demand load of 750 amperes. The service consists of a single 1000 ampere main circuit breaker supplied with three parallel sets of service conductors each in a separate rigid metal conduit. The neutral does not count as a current carrying conductor. The minimum size copper THWN ungrounded wire permitted for this service is:
- A. 250 kcmil.
  - B. 300 kcmil.
  - C. 350 kcmil.
  - D. 400 kcmil.
  - E. 500 kcmil.



35. A dwelling has an electric range with a nameplate rating of 18.4 kW. The minimum demand load permitted for this 120/240 volt range circuit is:
- A. 33 amperes.
  - B. 43 amperes.
  - C. 44 amperes.
  - D. 61 amperes.
  - E. 77 amperes.
36. An apartment building consists of 36 living units. Twenty of the living units are supplied with 10 kW electric ranges, eight living units are supplied with 12 kW electric ranges and the remaining eight living units are supplied with 17 kW electric ranges. When figuring the minimum demand load to be included for the electric ranges for determining the size of service conductors, it is first necessary to determine the average size of electric range for the building. For this apartment building, the average electric range size is:
- A. 12 kW.
  - B. 13.1 kW.
  - C. 13.8 kW.
  - D. 14 kW.
  - E. 14.4 kW.
37. In an apartment building there are 8 living units each with a 3.5 kW, 240 volt electric water heater. When figuring the demand load for the service to the apartment building, the minimum demand load that is permitted to be included for the water heaters is:
- A. 14 kVA.
  - B. 16.8 kVA.
  - C. 18.5 kVA.
  - D. 21 kVA.
  - E. 28 kVA.
38. An apartment building is served with single-phase, 120/240 volt, 3-wire power, and has 12 living units each with a 13.5 kW electric range. Using the rules of 220.55, the minimum load that is required to be included in the service calculation for the electric ranges is:
- A. 28.4 kVA.
  - B. 29 kVA.
  - C. 29.7 kVA.
  - D. 129.6 kVA.
  - E. 162 kVA.
39. A commercial building is served with a single-phase, 3-wire, 120/240 volt service with a 150 ampere main circuit breaker, and size 1/0 AWG copper ungrounded service conductors. The calculated unbalanced demand load for the building is 32 amperes. If all service wires are copper with 75°C insulation and terminations, the minimum size neutral permitted is:
- A. 6 AWG.
  - B. 4 AWG.
  - C. 3 AWG.
  - D. 2 AWG.
  - E. 1 AWG.
40. A commercial building has 96 general purpose, 120 volt duplex receptacles supplied by 20 ampere branch circuits. The minimum number of circuits permitted for this load is:
- A. six.
  - B. seven.
  - C. eight.
  - D. nine.
  - E. ten.
41. An electrician installs two 20 ampere, 120 volt circuits to supply 16 fluorescent luminaires. Each luminaire draws 1.4 amperes. In addition there are two 120 volt fans on individual circuits each drawing 5.6 amperes. If the building is served by a 120/240 volt, single-phase, 3-wire service, the minimum neutral current to serve these loads is:
- A. 0 amperes.
  - B. 2.8 amperes.
  - C. 5.6 amperes.
  - D. 16.8 amperes.
  - E. 33.6 amperes.
42. A 3-phase 75 kVA transformer is connected 480 volts on the primary and 208/120 volts on the secondary. The full-load current of the transformer secondary is:
- A. 90 amperes.
  - B. 156 amperes.
  - C. 184 amperes.
  - D. 208 amperes.
  - E. 361 amperes.

43. A 3-phase 480 volt capacitor bank rated 90 kVARs is connected near the main service of a building to correct the power factor. The minimum permitted ampere rating of the conductors to the capacitor bank is:
- A. 115 amperes.                      C. 146 amperes.                      E. 260 amperes.  
B. 130 amperes.                      D. 198 amperes.
44. A single-family dwelling is served by a single-phase, 120/240 volt 3-wire service. The living area of the dwelling is 2400 sq. ft, and the dwelling contains a 12 kW electric range, a 3.5 kW, 240 volt electric water heater, a ½ horsepower, 120 volt garbage disposer, a 1.2 kVA, 120 volt dishwasher, a 5 kW clothes dryer, a 1½ horsepower, 240 volt central air-conditioner, and a ⅓ horsepower, 120 volt furnace blower motor. The minimum load that is required to be included for general illumination, small appliances, and laundry, before applying demand factors, is:
- A. 1,500 VA.                              C. 4,500 VA.                              E. 11,700 VA.  
B. 3,000 VA.                              D. 7,200 VA.
45. A single-family dwelling is served by a single-phase, 120/240 volt 3-wire service. The living area of the dwelling is 2400 sq. ft, and the dwelling contains a 12 kW electric range, a 3.5 kW, 240 volt electric water heater, a ½ horsepower, 120 volt garbage disposer, a 1.2 kVA, 120 volt dishwasher, a 5 kW clothes dryer, a 1½ horsepower, 240 volt central air-conditioner, and a ⅓ horsepower, 120 volt furnace blower motor. The minimum load that is permitted to be included in the calculation to determine the maximum unbalanced load for the electric range is:
- A. zero because the range operates at 240 volts.  
B. 5,600 VA  
C. 8,000 VA.  
D. 8,400 VA.  
E. 12,000 VA.
46. A difference between a mobile home and a manufactured home is that a manufactured home:
- A. is only permitted to be mounted on a permanent foundation.  
B. is required to have the service mounted adjacent to the manufactured home.  
C. is required to be constructed with at least two separate sections.  
D. Is not permitted to be more than 40 feet in length.  
E. is designed to be used with or without a permanent foundation, and is permitted to have the service equipment mounted in or on the structure.
47. In a hospital, the exit sign circuit is a part of the:
- A. equipment system.  
B. critical branch of the essential electrical system.  
C. normal power system.  
D. alternate power branch of the normal power system.  
E. life safety branch of the essential electrical system.
48. The minimum number of branch circuits serving the patient bed location of a general care area of a hospital is:
- A. one.                                      C. three.                                      E. not specified.  
B. two.                                      D. four.
49. The circuit conductors from an emergency panelboard to exit signs in a building are:
- A. required to be run only as metal sheathed cable.  
B. required to be run in rigid metal conduit.  
C. permitted to be run in the same electrical metallic tubing with normal power conductors provided all conductors have 600 volt insulation.  
D. required to be run only in metallic raceway.  
E. not permitted to be run in the same raceway with other power or lighting circuit conductors.

50. A wiring method not permitted to serve as an equipment grounding conductor in a commercial building is:
- A. a combination metallic sheath and grounding conductor of type MC cable.
  - B. electrical metallic tubing.
  - C. a bare solid copper wire in nonmetallic sheathed cable sized in accordance with *Table 250.122*.
  - D. ½ inch trade diameter flexible metal conduit not over 6 feet long and containing circuit wires protected at 20 amperes.
  - E. intermediate metal conduit.
51. An assembly occupancy is considered a building or portion of a building or structure designed or intended for the assembly of:
- A. 50 persons or more.
  - B. 100 persons or more.
  - C. 200 persons or more.
  - D. 500 persons or more.
  - E. more than 1000 persons.
52. A 15- or 20-ampere receptacle on a general purpose branch circuit is not permitted to be located from the inside wall of an outside installed hot tub a distance closer than:
- A. 6 feet.
  - B. 10 feet.
  - C. 12 feet.
  - D. 20 feet.
  - E. 25 feet.
53. All 125-volt, 15- and 20-ampere receptacles installed on the outside of a commercial building are required to be:
- A. arc-fault circuit interrupter protected and listed as combination type.
  - B. ground-fault circuit interrupter (GFCI) protected.
  - C. only of a grounding type.
  - D. of the isolated grounding type.
  - E. listed as both ground-fault circuit-interrupter and arc-fault circuit-interrupter protected.
54. For the service area of a commercial garage where self-propelled vehicles powered by volatile flammable liquids are maintained and repaired (cars and trucks), the minimum requirement for receptacles used to service the vehicles is that they be:
- A. located not less than 18 inches above the floor.
  - B. ground-fault circuit-interrupter protected.
  - C. of the insulated grounding type.
  - D. arc-fault circuit-interrupter protected.
  - E. listed as commercial grade.
55. Current-interrupting contacts of a motor starter for an installation are not enclosed within a hermetically sealed chamber or immersed in oil. In a Class I, Division 1 hazardous location, conduit seals are required to be installed in each conduit within a distance from the motor starter of not more than:
- A. 6 inches.
  - B. 10 inches.
  - C. 12 inches.
  - D. 18 inches.
  - E. 24 inches.
56. Wiring run underground to a vehicle gasoline dispensing unit at a commercial service station:
- A. shall be in rigid metal conduit or steel intermediate metallic conduit with threaded connectors.
  - B. is permitted to be run in Type MC cable listed for direct burial.
  - C. is permitted for any portion of the run that is a minimum of 24 inches below grade to be run in PVC conduit with RMC or steel IMC used for emergence to above grade wiring.
  - D. is permitted for any portion of the run that is a minimum of 24 inches below grade to be run in PVC conduit provided it is encased in a minimum of 2 inches of concrete with RMC or steel IMC used for emergence to above grade wiring.
  - E. shall to be run in stainless steel rigid metal conduit.

57. Electrical installations in or on a single-family dwelling and accessory structures are required to:
  - A. comply with all provisions of the National Electrical Code.
  - B. comply with all provisions of the current Michigan Electrical Code.
  - C. comply with the current Michigan Residential Code.
  - D. be exactly the same as electrical installations of a dwelling unit of a multi-family dwelling (apartment building).
  - E. be different for a single-family townhouse that is not more than three floors in height and has separate means of egress.
  
58. A set of plans and specifications is required to be submitted with an application for permit if the installation involves a:
  - A. service or feeder of more than 400 amperes and the building floor area is more than 3,500 square feet.
  - B. cost for the installation of \$25,000 or more.
  - C. cost for the installation of \$10,000 or more.
  - C. voltage greater than 150 volts to ground and 1000 amperes or more.
  - D. building or structure other than a one-family or two-family dwelling.
  
59. A permit or copy of the permit to perform an electrical installation is:
  - A. required to be kept at the site of the work.
  - B. only required to be kept on file at the office of the electrical contracting firm.
  - C. not required to be kept at the job site.
  - D. required to be carried by the supervising person at the job site.
  - E. not required for existing dwelling electrical installations.
  
60. An electrical contracting firm shall have not less than one master electrician on record with the State. The master electrician shall be:
  - A. designated as responsible for code compliance for the firm but is not required to be full-time employed by the firm.
  - B. responsible for code compliance for a firm, but not required to be employed by the firm.
  - C. permitted to serve as the master electrician of record for other electrical contracting firms.
  - D. full-time employed by the firm, responsible for code compliance, and serves as master of record for no other firm.
  - E. permitted to serve as master of record for only one firm, yet work part time for another firm.

**Solutions to Sample Master Exam Questions:**

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1. **A 3 ohms.** The easiest method for determining the total resistance when several resistances are in parallel is to assume the circuit is energized at a voltage into which every resistor will easily divide. Then add up the total current and divide into the voltage you chose. The other method is to add the reciprocals of the resistances. Remember that the total resistance will be smaller than the smallest resistor of the group. That means the answer without even doing any calculations in this case will be either A or B.

Choose 30 volts and find the current through each resistor:

$$I_6 = 5 \text{ A}, I_{10} = 3 \text{ A}, I_{15} = 2 \text{ A} \quad I_T = 5 \text{ A} + 3 \text{ A} + 2 \text{ A} = 10 \text{ A}$$

$$R_T = \frac{E}{I_T} = \frac{30 \text{ V}}{10 \text{ A}} = 3 \text{ ohm} \quad \text{or:}$$

$$\frac{1}{R_T} = \frac{1}{6} + \frac{1}{10} + \frac{1}{15} = \frac{10}{30} \quad R_T = \frac{30}{10} = 3 \text{ ohm}$$

2. **C 13.9 Volts.** Look up the resistance of a size 10 AWG stranded copper wire in *Table 8*. One way length of circuit is 200 feet so total circuit wire length is 400 feet.

$$R = 1.24 \text{ ohm} \times 0.4 = 0.496 \text{ ohm}$$

$$E_{\text{DROP}} = I \times R = 28 \text{ A} \times 0.496 \text{ ohm} = 13.9 \text{ Volts}$$

This can also be solved using the equation for voltage drop where the value of conductor resistivity (K) is used. The answer may be off by a little because the value of (K) and the resistance of a conductor varies with temperature.

$$E_{\text{DROP}} = \frac{2 \times K \times I \times L}{\text{Area}} = \frac{2 \times 12 \times 28 \text{ A} \times 200 \text{ ft.}}{10,380 \text{ cmil}} = 12.9 \text{ Volts}$$

3. **B 36 Volts.** This problem can be solved in several ways. The voltage drop across any one resistor will be the proportion of that resistance to the total resistance.

$$E_{240} = E_{\text{TOTAL}} \times \frac{R_{240}}{R_{\text{TOTAL}}} = 120 \text{ V} \times \frac{240 \text{ ohm}}{800 \text{ ohm}} = 36 \text{ Volts}$$

Another method is to determine the total resistance (800 ohm) and then determine the current using Ohn's law ( $120 \text{ V} / 800 \text{ ohm} = 0.15 \text{ A}$ ). Then multiply the current times the value of the resistor ( $0.15 \text{ A} \times 240 \text{ ohm} = 36 \text{ V}$ ).

4. **E 37.5 Amperes** Power factor for a resistance type load is 1.0.

$$\text{Amperes} = \frac{\text{Power}}{\text{Volts}} = \frac{4500 \text{ W}}{120 \text{ V}} = 37.5 \text{ A}$$

5. **A 8 Amperes.** The current flowing on the neutral of a 120/240 volt, 3-wire, single-phase system will be the difference of current flowing on the two ungrounded legs.

$$I_{\text{NEUTRAL}} = I_A - I_B = 27 \text{ A} - 19 \text{ A} = 8 \text{ A}$$

6. **D 42 Amperes.** This is a 3-phase system and the currents flowing in line A to neutral and in line B to neutral are  $120^\circ$  out of phase with each other. In a single-phase 120/240 volt, 3-wire system the currents are  $180^\circ$  out of phase and they subtract from each other. In the 3-wire system derived from the 3-phase system, the currents on the neutral must add as vectors and, therefore, the current will never be lower than the smallest phase current and never higher than the highest phase current. A good estimate of the neutral current is the average of the two currents which in this case is 42 amperes, *310.15(B)(5)(b)*.

7. **B 133,100 cmil.** First convert the inches to mils and then square the mils to get circular mils of one strand. Multiply that number by 19 strands.

$$0.0837 \text{ inch} = 83.7 \text{ mils} \quad (\text{one strand})$$

$$83.7 \text{ mils} \times 83.7 \text{ mils} = 7005.7 \text{ cmils for one strand}$$

$$19 \text{ strands} \times 7005.7 \text{ cmils} = 133,108 \text{ cmils}$$

An alternate method is to look up a 19 strand conductor in *Table 8, Chapter 9* which has an individual strand diameter of 0.0837 inch. A size 2/0 AWG wire has 19 strands each with a diameter of 0.084 inch. The circular mil area of that conductor is 133,100 cmil.

8. **C 65 Amperes.** Use the full load current listed in *Table 430.250* and not the current of the nameplate as stated in *430.6(A)(1)*. Then multiply that value by 1.25 as required by *430.22*.

$$52 \text{ A} \times 1.25 = 65 \text{ Amperes}$$

9. **B 103 Amperes.** The wound-rotor motor has windings on the rotor and they come out of the motor through slip rings and connects first to the controller, then to a resistor bank. Generally resistance is applied to the rotor windings during starting and then lowered or eliminated after the motor has started. The rotor circuit is often called a secondary circuit. The full load secondary current must be given on the motor nameplate. The secondary conductor ampacity between the motor and controller is determined according to *430.23(A)*. The secondary current is multiplied by 1.25.

$$82 \text{ A} \times 1.25 = 102.5 \text{ Amperes} \quad (\text{Round up to } 103 \text{ A})$$

10. **D 80 Amperes.** Rules for sizing the time-delay fuses for a wound-rotor motor are found in *430.52*. That section specifies the multiplier factor found in *Table 430.52* to be used with the full-load current found in *Table 430.250*, *430.6(A)(1)*.

$$52 \text{ A} \times 1.5 = 78 \text{ Amperes}$$

*Section 430.52(C)(1) Exception 1* permits the ampere rating determined to be rounded up to the next standard rating of fuse as given in *240.6(A)* which in this case would be 80 amperes.

11. **B 145 Amperes.** The feeder conductor minimum current rating is determined according to *430.24* which takes the sum of all motor full load currents and adds to that 0.25 times the full-load current of the largest motor. Use motor currents from *Table 430.250* not nameplate.

$$40 \text{ A} + 40 \text{ A} + 52 \text{ A} + (0.25 \times 52 \text{ A}) = 145 \text{ Amperes}$$

12. **D 150 Amperes.** The maximum rating of overcurrent device for a feeder supplying two or more motors is not permitted to be greater than the value determined by *430.62(A)*. Before that calculation can be made it is necessary to determine the maximum permitted rating of branch-circuit short-circuit and ground-fault protection for each motor according to *430.52*. In this case all motor circuits are protected with time-delay fuses. In problem 10 the fuse rating for the wound rotor motor was determined to be 80 amperes. For the two 30 horsepower motors, multiply the full-load current in *Table 430.250* by the multiplier factor from *Table 430.52* and round up to the next standard rating ( $40 \text{ A} \times 1.75 = 70 \text{ A}$ ).

*Section 430.62(A)* gives the maximum overcurrent rating as not more than the maximum rating for any motor circuit branch-circuit short-circuit and ground-fault protection rating plus the full-load current of all other motors served by that feeder. For this case the 40 horsepower motor is protected with 80 ampere fuses and the 30 horsepower motors are protected with 70 ampere fuses. The maximum feeder overcurrent device rating is determined by adding the highest rated motor circuit overcurrent device and the full-load currents of all other motors served by that feeder. The calculation is as follows and rounded down to the next standard rating as given in *240.6(A)*.

$$80 \text{ A} + 40 \text{ A} + 40 \text{ A} = 160 \text{ A} \quad (\text{round down to } 150 \text{ Amperes})$$

13. **E Operating at high speed, the stop push button must be pressed before the motor will drop down to low speed.** When the motor is running at high speed, a normally closed contact in the low speed control circuit is open and will not allow the low speed relay to be energized. It is necessary to de-energize the high speed relay to allow the normally closed contact to close again to allow the low speed circuit to operate.

14. **D 85%.** Efficiency is power out divided by power in. The power out is 15 horsepower which must be converted to watts by multiplying by 746 watts per horsepower. Power is the current drawn at the given voltage and power factor.

$$\text{Efficiency} = \frac{\text{Power out}}{\text{Power in}} = \frac{\text{h.p.} \times 746}{1.73 \times E \times I \times \text{pf}} = \frac{15 \text{ hp} \times 746}{1.73 \times 460\text{V} \times 21\text{A} \times 0.79}$$

$$\text{Efficiency} = \frac{11,190 \text{ watts}}{13,202 \text{ watts}} \times 100 = 85\%$$

15. **C 9 inch.** Section 392.10(B)(1)(a) gives maximum rung spacing for ladder type cable tray with single conductor cables.
16. **A Operating with forward rotation, pressing the reverse push button will reverse the motor shaft of 3-phase induction motors.** This will not work on single-phase motors, because they must come to nearly a complete stop before they can be reversed.
17. **E 3 inch.** The cross-sectional area of the conductors must first be determined and then the minimum size of rigid metal conduit can be determined. First look up the cross-sectional area of the two conductors in Table 5 of Chapter 9.

THWN	1	AWG	0.1562 in <sup>2</sup>	×	3	=	0.4686 in <sup>2</sup>	
THW	4/0	AWG	0.3718 in <sup>2</sup>	×	6	=	2.2308 in <sup>2</sup>	
							-----	
Total conductor area							=	2.6994 in <sup>2</sup>

The maximum rigid metal conduit fill is 40% of the internal conduit cross-sectional area according to Table 1 in Chapter 9. Find the part of Table 4 that gives the cross-sectional area of rigid metal conduit and find the 40% column. Go down the column until you find an area that is as large or larger than 2.6994 sq. in. That will be a trade size of 3 inch.

18. **C 27 cu. in.** From Section 314.16(B) determine an equivalent conductor count for each size of conductor and multiply by the required minimum cubic inch capacity per conductor given in Table 314.16(B). The equipment grounding conductors only count as one conductor, but at the maximum size.

	10 AWG	8 AWG	
conductors	6	3	
grounds	0	1	
		-----	
Totals	6	4	
	6 × 2.5 in <sup>3</sup>	= 15 in <sup>3</sup>	
	4 × 3 in <sup>3</sup>	= 12 in <sup>3</sup>	
		-----	
		27 in <sup>3</sup>	

19. **C 60 amperes.** Section 424.22(B) requires that any resistance type heating element is required to be subdivided into loads not exceeding 48 amperes which are permitted to have overcurrent protection rated at not more than 60 amperes. Section 424.3(B) requires an electric heating load to be considered a continuous load which is required to have overcurrent protection rated at 25% greater than the continuous load.

20. **D 24 inch by 24 inch.** The method of determining the minimum dimensions of an angle pull box is found in 314.28(A)(2). The side adjacent must be at least 6 times the diameter of the largest conduit entering the side. If there are other conduits entering that same side in the same row of conduits, then add the diameters of each additional conduit to 6 times the largest conduit.

One side is 24 inch determined as follows:

$$6 \times 4 \text{ in.} = 24 \text{ in.}$$

The other side is 24 inches determined as follows:

$$6 \times 3 \text{ in.} = 18 \text{ in.} + 2 \text{ in.} + 2 \text{ in.} + 2 \text{ in.} = 24 \text{ in.}$$

21. **A required to be bonded to the disconnect enclosure in the second building and connected to a grounding electrode.** This only applies in the case of an existing building. The neutral conductor is required to be bonded to the disconnect enclosure in the second building and connected to a grounding electrode when the grounded conductor acts both as the neutral and the equipment grounding conductor. This rule is covered in 250.32(B)(1) and *Exception 1*.
22. **E not permitted to be connected to a grounding electrode or the disconnect enclosure at the second building.** The neutral conductor is only permitted to be connected to the grounding electrode and bonded to the disconnect enclosure at the supply end of the feeder in the first building. A separate equipment grounding conductor is required to be run to all new buildings. This rule is covered in 250.32(B)(1).
23. **E 1/0 AWG.** Section 250.122(F) requires an equipment grounding conductor to be run in each raceway and each sized using *Table 250.122* based on the rating of the feeder overcurrent device.
24. **C 3/0 AWG.** Note 1 of *Table 250.66* states that the grounding electrode conductor size is to be determined based upon the combined cross-sectional areas of the parallel sets of conductors. *Table 250.66* reaches a maximum size which is 3/0 AWG.

$$3 \times 400 \text{ kcmil} = 1,200 \text{ kcmil}$$

25. **C 4 AWG.** A feeder with overcurrent protection rated 150 amperes would be required to have ungrounded copper conductors size 1/0 AWG. The copper equipment grounding conductor for the circuit would be size 6 AWG but *Section 250.122(B)* requires the size of the equipment grounding conductor to be increased in proportion with the increase in conductor circular mil area from the minimum required to the size used. It is necessary to look up the cross-sectional areas of the conductors in *Table 8* of *Chapter 9*. The calculations are as follows:

3/0 AWG	167,800 cmil	
1/0 AWG	105,600 cmil	Divide 167,800 by 105,600 to get 1.589

$$6 \text{ AWG} \quad 26,240 \text{ cmil} \times 1.589 = 41,696 \text{ cmil} \quad (4 \text{ AWG from } Table 8)$$

26. **D 4 AWG.** *Section 250.30(A)(5)* requires that the grounding electrode conductor be sized according to the maximum size ungrounded conductor supplied by the separately derived system (3/0 AWG copper) using *Table 250.66*.
27. **A required to be solid copper insulated, covered, or bare, not smaller than size 8 AWG.** The conductor used as a part of the equipotential bonding grid is required to be copper, not smaller than 8 AWG, and insulated, covered, or bare, solid conductor, 680.26(B).

28. **D 90 amperes.** *Section 215.3* gives the rule for the minimum size of overcurrent device for a feeder. Then look up the standard ratings of overcurrent devices in *240.6(A)*. The continuous load is multiplied by 1.25 and added to the non-continuous load.

$$\begin{array}{r} 40 \text{ A} \times 1.25 = 50 \text{ A} \\ 36 \text{ A} \times 1.00 = \underline{36 \text{ A}} \\ \hline 86 \text{ A} \quad (\text{round up to } 90 \text{ A}) \end{array}$$

29. **D 400 kcmil.** *Section 240.4(C)* requires the conductors to have an ampacity not less than the rating of the overcurrent device when the overcurrent device is rated in excess of 800 amperes. There are three sets of conductors each in separate raceway and each conductor must have an ampacity of not less than 333 amperes from *Table 310.15(B)(16)*. For this example it is assumed no ampacity adjustment factors apply.

$$\text{Each conductor ampacity} = 1000 \text{ A} / 3 \text{ sets} = 333 \text{ A}$$

30. **B 6 AWG.** The minimum size conductor permitted for a branch circuit is specified in *Section 210.19 (A)(1)(a)* as 125% of the continuous load plus any non-continuous load.

$$44 \text{ A} \times 1.25 = 55 \text{ A}$$

The conductor size is found in *Table 310.15(B)(16)*, but first it must be determined which column to use. *Section 310.15(A)(2)* specifies that when more than one condition for determining ampacity of a conductor exists, the most limiting will apply to the entire circuit. The terminations are rated 75°C and the conductor insulation is rated 90°C. In this case the 75°C column of *Table 310.15(B)(16)* will apply and the minimum conductor size is 6 AWG. The conductor must have an ampacity not less than the minimum calculated value which in this case is 55 amperes, and it must also be protected with an overcurrent device not greater than the ampacity of the conductor which in this case is 60 amperes, *240.4(B)*.

31. **C 6 AWG.** This is the same branch circuit as in the previous question except this time there are six extra conductors in the raceway so the adjustment factors of *Table 310.15(B)(3)(a)* will apply. With nine conductors in the raceway, the values of ampacity in *Table 310.15(B)(16)* must be reduced to 70% of their listed value for this circuit. There are no 75°C terminations in the raceway, and the conductor insulation is rated 90°C, therefore, the 90°C column of *Table 310.15(B)(16)* can be used for the purpose of applying the adjustment factors, which for a size 6 AWG copper conductor is 75 ampere.

$$75 \text{ A} \times 0.7 = 53 \text{ A}$$

The requirement in *210.19(A)(1)(b)* simply states that after adjusting the conductor ampacity, the conductor current rating must not be less than the actual load which for this circuit is 44 amperes. Size 6 AWG THHN copper meets this requirement, as well as *240.4(B)*.

32. **D 4 AWG.** This is the same branch circuit as in the previous question except this time there are six extra conductors in the raceway so the adjustment factors of *Table 310.15(B)(3)(a)* will apply, and the raceway also passes through an area where the ambient temperature is 120°F. Temperature correction factors also apply and for the conductors in *Table 310.15(B)(16)*, the temperature correction factors are found in *Table 310.15(B)(2)(a)*. With nine conductors in the raceway, the values of ampacity in *Table 310.15(B)(16)* must be reduced to 70% of the listed value. There are no 75°C terminations in the raceway, and the conductor insulation is rated 90°C, therefore, the 90°C column of *Table 310.15(B)(16)* can be used for the purpose of applying the adjustment factors. A size 6 AWG copper conductor has a current rating of 75 ampere. Because the 90°C column of *Table 310.15(B)(16)* was used, the temperature correction factor is found in the 90°C column of *Table 310.15(B)(2)(a)* and is 0.82 for an ambient temperature of 120°F ambient temperature. After these corrections, the size 6 AWG copper conductor has a current rating of 43 amperes.

$$75 \text{ A} \times 0.7 \times 0.82 = 43 \text{ A}$$

This adjusted current rating according to 210.19(A)(1)(b) must not be less than the actual load which for this example is 44 ampere. Note in this case the adjusted ampacity is less than the load of 44 amperes, therefore, a larger wire size must be used. Apply the adjustment and correction factors for a size 4 AWG copper THHN conductor to get 55 amperes. The ampacity of this conductor exceeds the circuit load and also it meets the requirement of 240.4(B).

$$95 \text{ A} \times 0.7 \times 0.82 = 55 \text{ A}$$

33. **E 1/0 AWG.** This is the 25 foot tap rule as found in 240.21(B)(2). The 100 ampere overcurrent device supplies only requires a size 1 AWG copper wire, but the tap conductor is ahead of the 100 ampere overcurrent device and is only protected from short circuits and ground faults by the 400 ampere feeder circuit breaker. The tap conductor is required to have an ampacity not less than one-third that of the feeder overcurrent device which in this case is 133 amperes.

$$400 \text{ A} / 3 = 133 \text{ A} \quad \text{Size 1/0 AWG from 75°C column of Table 310.15(B)(16).}$$

34. **B five.** Section 220.12, Table 220.12, 220.14(J), and 210.11(A) specify that the minimum load for general illumination in a dwelling is not to be less than the living area of the dwelling times the volt-ampere value found in Table 220.12. Then divide the load by 120 volts to determine the minimum ampacity. To determine the minimum number of circuits, divide by the rating of the circuit which in this case is 15 amperes.

$$3 \text{ VA/ft}^2 \times 2680 \text{ ft}^2 = 8040 \text{ VA}$$

$$\frac{8040 \text{ VA}}{120 \text{ V} \times 15 \text{ A/circuit}} = 4.5 \text{ circuits (Round up to 5)}$$

35. **B 43 amperes.** The rule for determining the minimum demand load for a dwelling electric range larger than 12 kW is described in Note 1 of Table 220.55. The value in column C is increased by 5% for each kW the range size is larger than 12 kW. The only trick is that the range size is rounded off to the nearest whole number before starting. In this case, 18.4 kW is rounded down to 18 kW.

$$\begin{array}{r} 18 \text{ kW} \\ - 12 \text{ kW} \\ \hline 6 \text{ kW} \end{array} \quad 6 \times 8 \text{ kW} \times 0.05 = 2.4 \text{ kVA}$$

$$\begin{array}{r} 8 \text{ kVA} \\ + 2.4 \text{ kVA} \\ \hline \text{Total demand load} = 10.4 \text{ kVA} \end{array}$$

$$\frac{10.4 \text{ kVA} \times 1000}{240 \text{ V}} = 43 \text{ amperes}$$

36. **B 13.1 kW.** The average range size is determined using the rule in Note 2 of Table 220.55. The trick is that all ranges smaller than 12 kW (in this case there are 20 at 10 kW) are to be figured at 12 kW for the purpose of determining the average range size. The method is as follows:

20 ranges at 10 kW and 8 ranges at 12 kW

$$\begin{array}{r} \text{Take 28 ranges at 12 kW} \quad 28 \times 12 \text{ kW} = 336 \text{ kW} \\ \quad \quad \quad \quad \quad \quad \quad 8 \times 10 \text{ kW} = 136 \text{ kW} \\ \hline 472 \text{ kW} / 36 \text{ ranges} = 13.1 \text{ kW} \end{array}$$

37. **D 21 kVA.** Section 220.53 permits the application of a demand factor of 0.75 if there are four or more appliances.

$$\text{Demand load} = 8 \text{ units} \times 3.5 \text{ kW} \times 0.75 = 21 \text{ kVA}$$

38. **C 29.7 kVA.** There are 12 living units and the value for the electric ranges is found in column C of *Table 220.55*. Because the ranges are rated greater than 12 kW, the value found in column C must be increased by 5% for every kW the actual range size is greater than 12. Read *Note 2* of *Table 220.55*. The ranges are 13.5 kW, therefore, this value is rounded up to 14 before doing the calculation. The following equation can be used to determine the load that must be included for the ranges.

$$[(14 - 12) \times 0.05 \times 27 \text{ kVA}] + 27 \text{ kVA} = 29.7 \text{ kVA}$$

39. **A 6 AWG.** There is a minimum neutral conductor size for a service no matter the calculated unbalanced load. The minimum neutral conductor size is specified in *230.42(C)*. The minimum is never permitted to be smaller than the size of grounding electrode conductor as found in *Table 250.66*. If the calculated unbalanced load is used, the neutral conductor size would be 10 AWG copper. For this service it is not permitted to be that small.
40. **C eight.** The minimum load that is permitted to be applied to general use receptacles with no specific load in other than dwellings is 180 VA per receptacle strap, *220.14(I)*. A duplex receptacle is one receptacle strap and only counts as 180 VA. Simply multiply the 180 VA by the number of receptacles, divide by 120 volts and divide by the rating of the circuit.

$$\text{Minimum circuits} = \frac{96 \text{ receptacles} \times 180 \text{ VA/receptacle}}{120 \text{ V} \times 20 \text{ A/circuit}} = 7.2 \text{ circuits}$$

41. **A 0 amperes.** It is expected the electrician will attempt to balance the loads on the ungrounded conductors and minimize the current on the neutral conductor. In this case, it is possible to balance the loads by placing 8 luminaires on one circuit and 8 luminaires on the other circuit. Do the same with the two fans. The result is a balanced 120 load which means zero amperes on the neutral.

Leg A	Leg B
8 fixtures 11.2 A	8 fixtures 11.2 A
fan 5.6 A	fan 5.6 A
16.8 A	16.8 A

42. **D 208 amperes.** This is a calculation that is required before the rules of overcurrent protection for a transformer can be applied.

$$I_{\text{Secondary}} = \frac{75 \text{ kVA} \times 1000}{1.73 \times 208 \text{ V}} = 208 \text{ A}$$

43. **C 146 Amperes.** First the current must be determined that will flow to the capacitor bank when it is energized. The same equation is used as would be used to determine the full load current of a transformer except in this case kVAR is used instead of kVA. Then multiply full-load current by 1.35, according to *460.8(A)*.

$$I_{\text{CAPACITOR}} = \frac{\text{kVAR} \times 1000}{1.73 \times V} = \frac{90 \times 1000}{1.73 \times 480} = 108.4 \text{ Amperes}$$

$$I_{\text{CONDUCTOR}} = 108.4 \text{ A} \times 1.35 = 146 \text{ Amperes}$$

44. **E 11,700 VA.** What must be included is stated in 220.40. The general illumination load is 3 VA per square foot as found in 220.12 and *Table 220.12*. The small appliance load is 1500 VA for each small appliance circuit according to 220.52(A). *Section 210.11(C)(1)* requires a minimum of two small appliance branch circuits. *Section 220.52(B)* requires 1500 VA for the laundry circuit in the dwelling. *Section 210.11(C)(2)* requires one laundry circuit in a dwelling.

General illumination	$2400 \text{ ft}^2 \times 3 \text{ VA/ft}^2 =$	7,200 VA
Small appliance		3,000 VA
Laundry		1,500 VA
		11,700 VA

45. **B 5600 VA.** For an electric range in a dwelling, a demand factor can be applied according to 220.55. A 12 kW electric range according to *Table 220.55* column C is taken as an 8000 VA load. In 220.61(B), it is permitted to take only 70% of the range demand load as unbalanced load on the neutral which in this case is 5600 VA.
- $$8000 \text{ VA} \times 0.7 = 5600 \text{ VA}$$
46. **E is designed to be used with or without a permanent foundation, and is permitted to have the service equipment mounted in or on the structure.** A manufactured home will have a label and it is designed to be mounted on a foundation, but not required to be mounted on a foundation. In 550.2 compare the definitions of a mobile home and a manufactured home. The service is permitted to be installed in or on the manufactured home according to 550.32(B).
47. **E life safety branch of the essential electrical system.** According to 517.32, 517.42, 517.32(B) and 517.42(B), Exit signs are to be supplied by the life safety branch of the essential electrical system.
48. **B two.** *Section 517.18(A)* requires two separate circuits to supply power to each bed location of a general care area. At least one shall be supplied from the critical branch of the essential power system.
49. **E. not permitted to be run in the same raceway with other power or lighting circuit conductors.** *Section 700.10(B)* requires exit sign circuits to be completely independent of normal power circuits which means they must be kept separated if run in cable and not run in the same raceway. The subject is also covered in 517.30(C)(1) and 517.41(D).
50. **D ½ inch trade diameter flexible metal conduit not over 6 feet long and containing circuit wires protected at 20 ampere.** 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*.
51. **B 100 persons or more.** This is stated in 518.1 where some examples of assembly occupancies are given. Also see 518.2(B).
52. **A 6 feet.** First paragraph of 680.42 requires outside hot tub installations to meet requirements for a permanent outside pool for receptacle installation. The answer is then found in 680.22(A)(1). A receptacle on a general-purpose circuit is required to be not closer than 6 feet nor more than 20 feet from the inside edge of the hot tube same as with a permanent swimming pool.
53. **B ground-fault circuit interrupter (GFCI) protected.** Receptacles on 15- or 20-ampere, 120-volt general purpose circuits installed outdoors for any type of building are required to be GFCI protected, 210.8(B)(4).
54. **B ground-fault circuit-interrupter protected.** GFCI protection on these service bay receptacles is required by 511.12 and 210.8(B)(8). Receptacles are permitted to be installed less than 18 inches of the floor but if so they must be of a type suitable for a Class I, Division 2 location. This is not practical so they are located 18 inches or more above the floor.

55. **D 18 inches.** Unless the arcing contacts are within a separate chamber suitable for a Class I location, the conduit entries must be sealed within 18 inches of the enclosure, *501.15(A)(1)*.
56. **C is permitted for any portion of the run that is a minimum of 24 inches below grade to be run in PVC conduit with RMC or steel IMC used for emergence to above grade wiring.** (*514.8 Ex 2, see also 501.10(A)(1)(a) Ex*)
57. **C comply with the current *Michigan Residential Code*.** *Part 8 Rules to the Construction Code Act (P.A. 230 of 1972). Section 80.1 Exception.*
58. **A service or feeder of more than 400 amperes and the building floor area is more than 3,500 square feet.** *Part 8 Rules to the Construction Code Act (P.A. 230 of 1972). Section 80.21.*
59. **A required to be kept at the site of the work.** *Part 8 Rules to the Construction Code Act (P.A. 230 of 1972). Section 80.19.3.1.*
60. **D full-time employed by the firm, responsible for code compliance, and serves as master of record for no other firm.** The answer is found in *P.A. 407 of 2016*. In ***MCL338.5711*** a person is only permitted to serve as the master for one contracting firm. In ***MCL338.5713*** the person is designated on the license for the firm and must be in full-time employment and be in charge of Code compliance for the contracting firm.

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 *Skilled Trades Regulation Act*, P.A. 407 concerning licensing. Details are at [www.egr.msu.edu/bae/electricaltraining](http://www.egr.msu.edu/bae/electricaltraining)  
The *Journey Exam Study Guide*, Tech Note 105 contains explanations of Code Material and fundamentals not covered in this study guide. For a discussion of recent changes to the Construction Code Act, Part 8 and the electrical Licensing Act, refer to Tech Note 107, also available at no cost at the web site shown above.