Mike Holt's Illustrated Guide to

ELECTRICAL EXAM PREPARATION

Theory • Calculations • Code **Based on the 2017 NEC®**

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CHAPTER

1 ELECTRICAL THEORY

ESSENTIAL FOR JOURNEYMAN AND MASTER/CONTRACTOR LICENSING EXAMS

Note: This chapter is a practice review of theory as it relates to basic electrical formulas and calculations. Most state electrical exams include questions on general electrical theory and you need a solid foundation to pass your exam. If, after working through this chapter, you feel like you need additional in-depth training on theory, then Mike Holt's Theory DVD Training Program (textbook and DVDs) will give you a comprehensive understanding of this topic.

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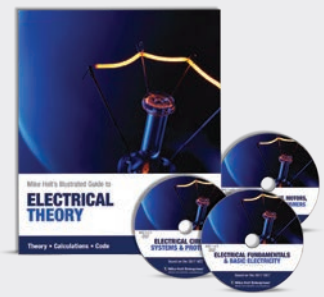


UNIT 1

ELECTRICIAN'S MATH AND BASIC ELECTRICAL FORMULAS

Introduction to Unit 1—Electrician's Math and Basic Electrical Formulas

In order to construct a building that will last into the future, a strong foundation is a prerequisite. The foundation is a part of the building that isn't visible in the finished structure, but is essential in erecting one that will have the necessary strength to endure.

The math and basic electrical concepts of this unit are very similar to the foundation of a building. The concepts presented here are the essential basics that you must understand, because you'll build upon them as you study electrical circuits and systems. As your studies continue, you'll find that a good foundation in electrical theory and math will help you understand why the *NEC* contains certain provisions.

This unit includes math and electrical fundamentals. You'll be amazed at how often your electrical studies return to the basics of this unit. Ohm's law and the electrical formulas related to it are the foundation of all electrical circuits.

Every student begins at a different level of understanding, and you may find this unit an easy review, or you may find it requires a high level of concentration. In any case, be certain that you fully understand these concepts and are able to successfully complete the questions at the end of this unit before going on. A solid foundation will help in your successful study of the rest of this textbook.

Part A—Electrician's Math

Introduction

Numbers can take different forms:

Whole numbers: 1, 20, 300, 4,000, 5,000
Decimals: 0.75, 0.80, 1.15, 1.25
Fractions: ½, ¼, ⅝, ⅓
Percentages: 80%, 125%, 250%, 500%

You'll need to be able to convert these numbers from one form to another and back again, because all of these number forms are part of electrical work and electrical calculations.

You'll also need to be able to do some basic algebra. Many people are apprehensive of algebra, but as you work through the material here you'll see there's nothing to fear.

1.1 Whole Numbers

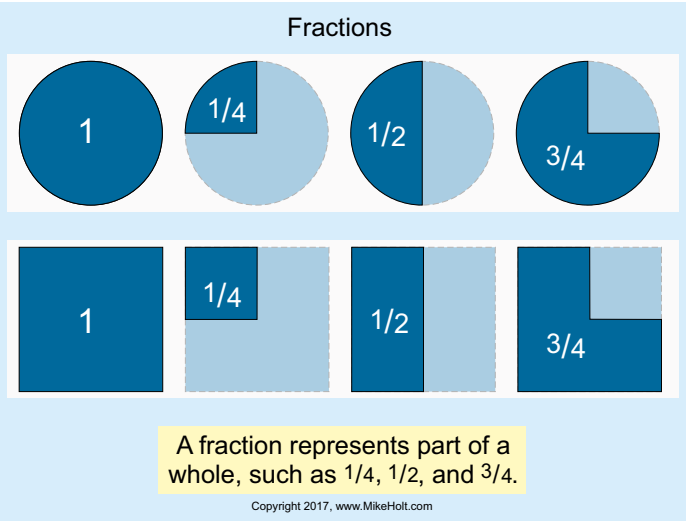
Whole numbers are exactly what the term implies. These numbers don't contain any fractions, decimals, or percentages. Another name for whole numbers is "integers."

1.2 Decimals

The decimal method is used to display numbers other than whole numbers, fractions, or percentages such as, 0.80, 1.25, 1.732, and so on.

1.3 Fractions

A fraction represents part of a whole number. If you use a calculator for adding, subtracting, multiplying, or dividing, you'll need to convert the fraction to a decimal or whole number. To do so, divide the numerator (the top number) by the denominator (the bottom number). ▶Figure 1–1



▶Figure 1–1

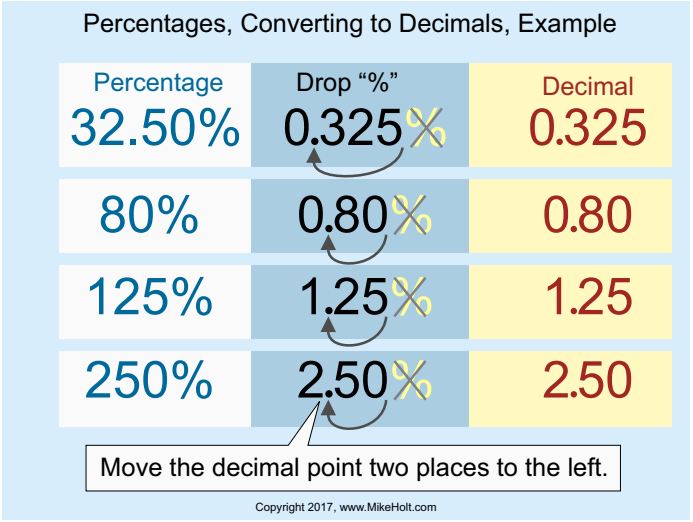
▶ **Examples**

1/6 = one divided by six = 0.166
2/5 = two divided by five = 0.40
3/6 = three divided by six = 0.50
5/4 = five divided by four = 1.25
7/2 = seven divided by two = 3.50

1.4 Percentages

A percentage is another method used to display a value. One hundred percent (100%) means all of a value, fifty percent (50%) means one-half of a value, and twenty-five percent (25%) means one-fourth of a value.

For convenience in multiplying or dividing by a percentage, convert the percentage value to a whole number or decimal, and then use the result for the calculation. When changing a percent value to a decimal or whole number, drop the percentage symbol and move the decimal point two places to the left. ▶Figure 1–2



▶Figure 1–2

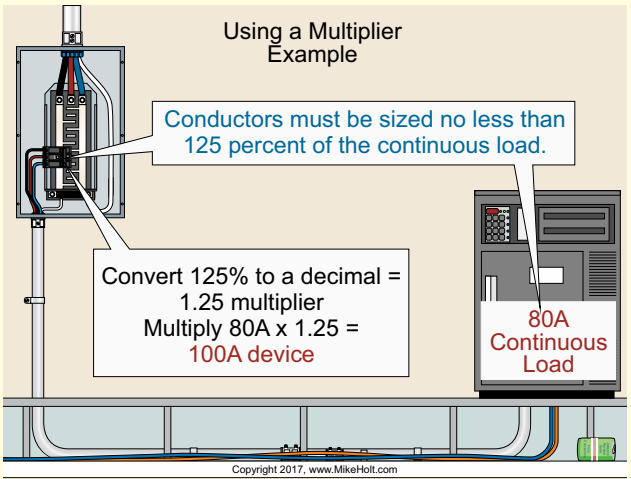
1.5 Multiplier

When a number needs to be changed by multiplying it by a percentage, the percentage is called a multiplier. The first step is to convert the percentage to a decimal, then multiply the original number by the decimal value.

▶ **Example 1**

Question: *An overcurrent protection device (circuit breaker or fuse) must be sized no less than 125 percent of the continuous load. If the load is 80A, the overcurrent protection device will have to be sized no smaller than _____.* ▶Figure 1–3

(a) 75A (b) 80A (c) 100A (d) 125A



▶Figure 1–3

Answer: *(c) 100A*

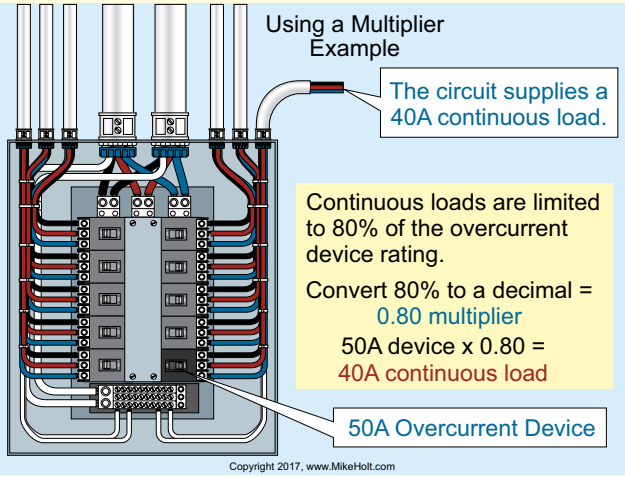
Step 1: *Convert 125 percent to a decimal: 1.25*

Step 2: *Multiply the value of the 80A load by 1.25 = 100A*

▶ Example 2

Question: *The maximum continuous load on an overcurrent protection device is limited to 80 percent of the device rating. If it's rated 50A, what's the maximum continuous load permitted on the overcurrent protection device?* ▶Figure 1–4

(a) 40A (b) 50A (c) 75A (d) 100A



▶Figure 1–4

Answer: *(a) 40A*

Step 1: *Convert 80 percent to a decimal: 0.80*

Step 2: *Multiply the value of the 50A device rating by 0.80 = 40A*

1.6 Percent Increase

Use the following steps to increase a number by a specific percentage:

Step 1: Convert the percentage to a decimal value.

Step 2: Add one to the decimal value to create the multiplier.

Step 3: Multiply the original number by the multiplier found in Step 2.

▶ Example 1

How do you increase the whole number 16 by 25 percent?

Step 1: *Convert 25 percent to decimal form: 0.25*

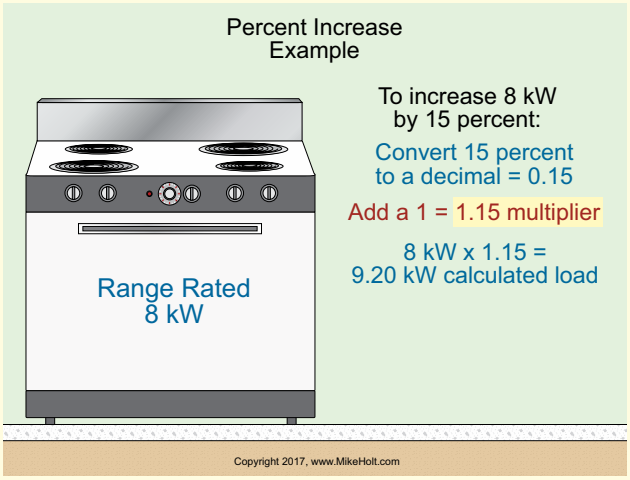
Step 2: *Add one to the decimal value to obtain the multiplier: 1 + 0.25 = 1.25*

Step 3: *Multiply 16 by the multiplier 1.25: 16 × 1.25 = 20*

▶ Example 2

Question: *If the feeder demand load for a range is 8 kW and it's required to be increased by 15 percent, the total calculated load will be _____.* ▶Figure 1–5

(a) 6.80 kW (b) 8 kW (c) 9.20 kW (d) 15 kW



▶Figure 1–5

Answer: *(c) 9.20 kW*

Step 1: *Convert the percentage increase required to decimal form: 15 percent = 0.15*

Step 2: *Add one to the decimal: 1 + 0.15 = 1.15*

Step 3: *Multiply 8 by the multiplier 1.15: 8 kW × 1.15 = 9.20 kW*

1.7 Reciprocals

To obtain the reciprocal of a number, convert it into a fraction with the number one as the numerator (the top number). It's also possible to calculate the reciprocal of a percentage number. Determine the reciprocal of a percentage number by following these steps:

Step 1: Convert the number to a decimal value.

Step 2: Divide the value into the number one.

▶ Example 1

Question: *What's the reciprocal of 80 percent?*

(a) 0.80 (b) 100% (c) 125% (d) 150%

Answer: *(c) 125%*

Step 1: *Convert 80 percent into a decimal (move the decimal two places to the left): 80 percent = 0.80*

Step 2: *Divide 0.80 into the number one: 1/0.80 = 1.25 or 125 percent*

▶ Example 2

Question: *What's the reciprocal of 125 percent?*

(a) 75% (b) 0.80 (c) 100% (d) 125%

Answer: *(b) 0.80*

Step 1: *Convert 125 percent into a decimal: 125 percent = 1.25*

Step 2: *Divide 1.25 into the number one: 1/1.25 = 0.80 or 80 percent*

1.8 Squaring a Number

Squaring a number means multiplying the number by itself.

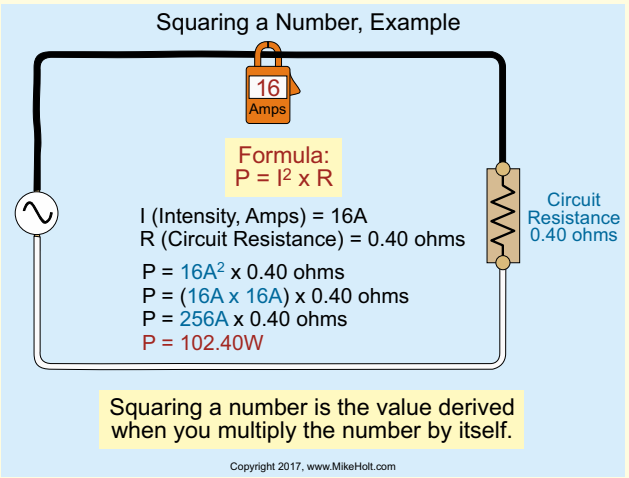
$10^2 = 10 \times 10 = 100$ or $23^2 = 23 \times 23 = 529$

▶ Example 1

Question: *What's the power consumed in watts by a 12 AWG conductor that's 200 ft long, and has a total resistance (R) of 0.40 ohms, if the current (I) in the circuit conductors is 16A? (Answers are rounded to the nearest 50).* ▶Figure 1–6

Power(P) = $I^2 \times R$

(a) 50W (b) 100W (c) 150W (d) 200W



▶Figure 1–6

Answer: *(b) 100W*

$P = I^2 \times R$

I = 16A

R = 0.40 ohms

$P = 16A^2 \times 0.40$ ohms

P = (16A × 16A) × 0.40 ohms

P = 102.40W

▶ Example 2

Question: *What's the area in square inches (sq in.) of a trade size 1 raceway with an inside diameter of 1.049 in.?*

$Area = \pi \times r^2$

$\pi = 3.14$

r = radius (equal to 0.50 of the diameter)

(a) 0.34 sq in. (b) 0.50 sq in. (c) 0.86 sq in. (d) 1 sq in.

Answer: *(c) 0.86 sq in.*

$Area = \pi \times r^2$

$Area = 3.14 \times (0.50 \times 1.049)^2$

$Area = 3.14 \times 0.5245^2$

$Area = 3.14 \times (0.5245 \times 0.5245)$

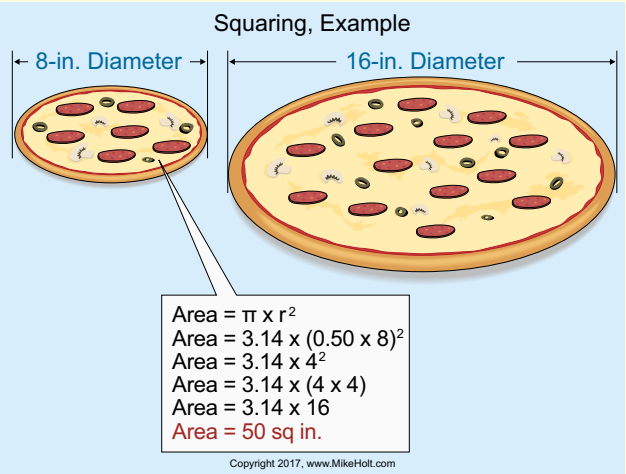
$Area = 3.14 \times 0.2751$

$Area = 0.86$ sq in.

▶ Example 3

Question: *What's the sq in. area of an 8-in. pizza?* ▶Figure 1–7

(a) 25 sq in. (b) 50 sq in. (c) 64 sq in. (d) 75 sq in.



▶Figure 1–7

Answer: *(b) 50 sq in.*

$Area = \pi \times r^2$

$Area = 3.14 \times (0.50 \times 8)^2$

$Area = 3.14 \times 4^2$

$Area = 3.14 \times (4 \times 4)$

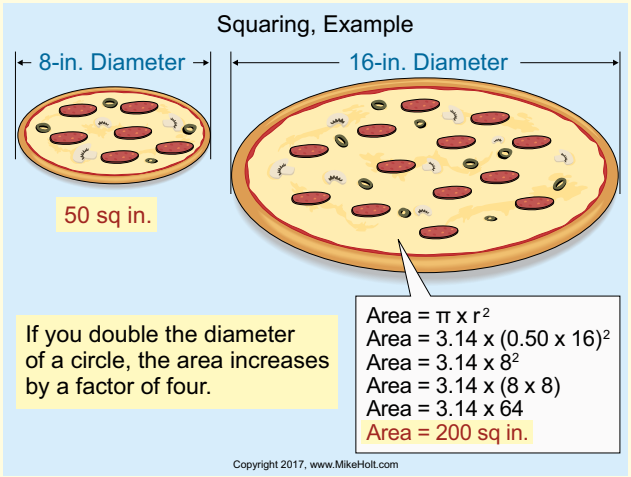
$Area = 3.14 \times 16$

$Area = 50$ sq in.

▶ Example 4

Question: *What's the sq in. area of a 16-in. pizza?* ▶Figure 1–8

(a) 100 sq in. (b) 150 sq in. (c) 200 sq in. (d) 256 sq in.



▶Figure 1–8

Answer: *(c) 200 sq in.*

$Area = \pi \times r^2$

$Area = 3.14 \times (0.50 \times 16)^2$

$Area = 3.14 \times 8^2$

$Area = 3.14 \times (8 \times 8)$

$Area = 3.14 \times 64$

$Area = 200$ sq in.

Author's Comment:

- As you see in Examples 3 and 4, if you double the diameter of the circle, the area contained within it is increased by a factor of four! By the way, a large pizza is always cheaper per sq in. than a small one.

1.9 Parentheses

Whenever numbers are in parentheses, complete the mathematical function within the parentheses before proceeding with the rest of the problem.

Parentheses are used to group steps of a process into the correct order. For instance, adding the sum of 3 and 15 to the product of 4 and 2 equals 26.

$(3 + 15) + (4 \times 2) = 18 + 8 = 26$

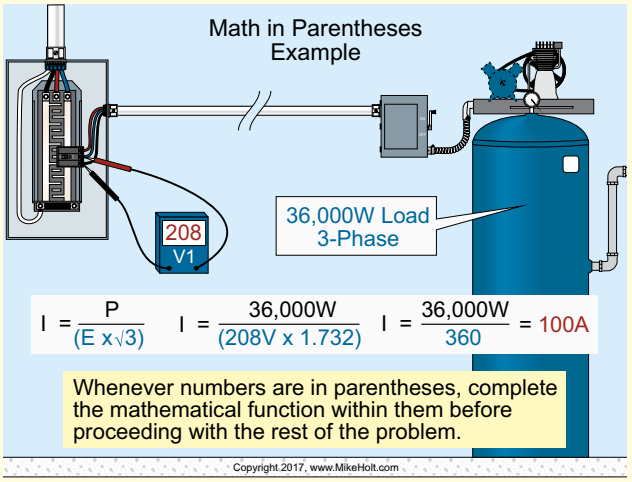
▶ **Example**

Question: *What's the current of a 36,000W, 208V, three-phase load?* ▶Figure 1–9

Amperes = Watts /(Volts × 1.732)

Amperes = (I), Watts = (P), Volts = (E)

(a) 50A (b) 100A (c) 150A (d) 360A



▶Figure 1–9

Answer: *(b) 100A*

Step 1: *Perform the operation inside the parentheses first—determine the product of: 208V × 1.732 = 360V*

Step 2: *Divide 36,000W by 360V = 100A*

1.10 Square Root

Deriving the square root of a number ($\sqrt{n}$) is the opposite of squaring a number. The square root of 36 is a number that, when multiplied by itself, gives the product 36. The $\sqrt{36}$ equals six, because six, multiplied by itself (which can be written as 6^2) equals the number 36.

Because it's difficult to do this manually, just use the square root key of your calculator.

$\sqrt{3}$: Following your calculator's instructions, enter the number 3, then press the square root key = 1.732.

$\sqrt{1{,}000}$: Enter the number 1,000, then press the square root key = 31.62.

If your calculator doesn't have a square root key, don't worry about it. For all practical purposes in using this textbook, the only number you need to know the square root of is 3. The square root of 3 equals approximately 1.732.

To add, subtract, multiply, or divide a number by a square root value, determine the decimal value and then perform the math function.

▶ **Example 1**

Question: *36,000W/(208V × $\sqrt{3}$) is equal to _____.*

(a) 100A (b) 120A (c) 208A (d) 360A

Answer: *(a) 100A*

Step 1: *Determine the decimal value for the $\sqrt{3}$ = 1.732*

Step 2: *Divide 36,000W by (208V × 1.732) = 100A*

▶ **Example 2**

Question: *The phase voltage of a 120/208V system is equal to 208V/$\sqrt{3}$, which is _____.*

(a) 120V (b) 208V (c) 360V (d)480V

Answer: *(a) 120V*

Step 1: *Determine the decimal value for the $\sqrt{3}$ = 1.732*

Step 2: *Divide 208V by 1.732 = 120V*

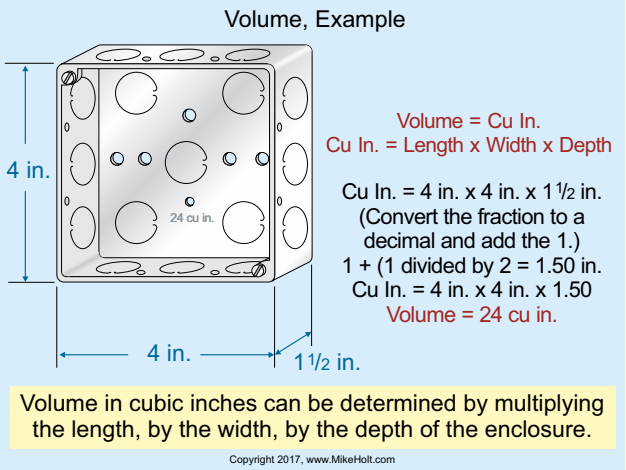
1.11 Volume

The volume of an enclosure is expressed in cubic inches (cu in.). It's determined by multiplying the length, by the width, by the depth of the enclosure.

▶ Example

Question: *What's the volume of a box that has the dimensions of 4 in. × 4 in. × 1½ in.?* ▶Figure 1–10

(a) 12 cu in. *(b) 20 cu in.* *(c) 24 cu in.* *(d) 30 cu in.*



▶Figure 1–10

Answer: *(c) 24 cu in.*

1½ = 1.50
4 × 4 × 1.50 = 24 cu in.

Author's Comment:

- The actual volume of a 4 in. square electrical box is less than 24 cu in. because the interior dimensions may be less than the nominal size and corners are often rounded, so the allowable volume is given in the *NEC*, Table 314.16(A).

1.12 Kilo

The letter "k" is used in the electrical trade to abbreviate the metric prefix "kilo," which represents a value of 1,000.

To convert a number which includes the "k" prefix into units, multiply the number preceding the "k" by 1,000.

▶ Example 1

Question: *What's the wattage value for an 8 kW rated range?*

(a) 8W *(b) 800W* *(c) 4,000W* *(d) 8,000W*

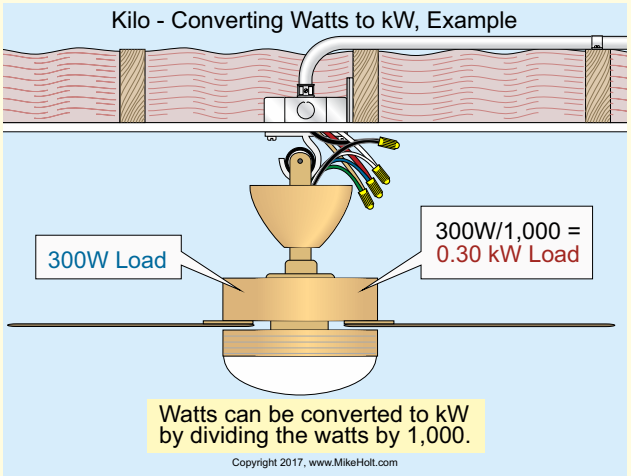
Answer: *(d) 8,000W*

To convert a unit value to a "k" value, divide the number by 1,000 and add the "k" suffix.

▶ Example 2

Question: *What's the kW rating of a 300W load?* ▶Figure 1–11

(a) 0.30 kW *(b) 30 kW* *(c) 300 kW* *(d) 3,000 kW*



▶Figure 1–11

Answer: *(a) 0.30 kW*

kW = Watts/1,000
kW = 300W/1,000 = 0.30 kW

Author's Comment:

- The use of the letter "k" isn't limited to "kW." It's also used for kVA (1,000 volt-amperes), kcmil (1,000 circular mils) and other units such as kft (1,000 feet).

1.13 Rounding Off

There's no specific rule for rounding off, but rounding to two or three "significant digits" should be sufficient for most electrical calculations. Numbers below five are rounded down, while numbers five and above are rounded up.

0.1245—the fourth number is five or above = 0.125 rounded up

1.674—the fourth number is below five = 1.67 rounded down

21.99—the fourth number is five or above = 22 rounded up

367.20—the fourth number is below five = 367 rounded down

Rounding Answers for Multiple Choice Questions

You should round your answers in the same manner as the multiple choice selections given in the question.

▶ **Example**

Question: *The sum* of 12, 17, 28, and 40 is equal to _____.*

(a) 70 (b) 80 (c) 90 (d) 100

Answer: *(d) 100*

**A sum is the result of adding numbers.*

The sum of these values equals 97, but that answer isn't listed as one of the choices. The multiple choice selections in this case are rounded off to the closest "tens."

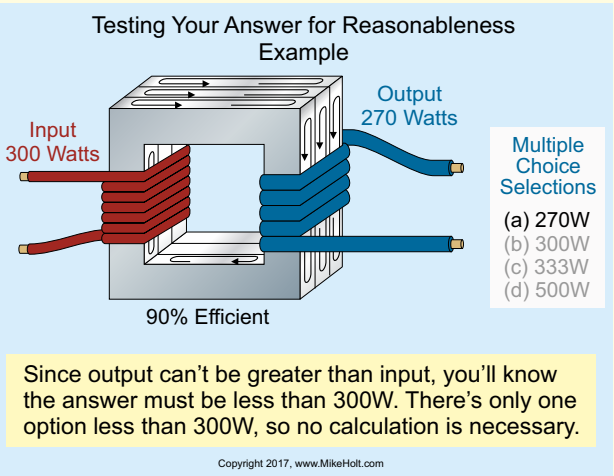
1.14 Testing Your Answer for Reasonableness

When working with any mathematical calculation, don't just blindly do the calculation and assume it's correct. When you perform a mathematical calculation, you need to know if the answer is greater than or less than the values given in the problem. Always do a "reality check" to be certain your answer isn't nonsense. Even the best of us make mistakes at times, so always examine your answer to be sure it makes sense!

▶ **Example**

Question: *The input of a transformer is 300W; the transformer efficiency is 90 percent. What's the transformer output?* ▶Figure 1–12

(a) 270W (b) 300W (c) 333W (d) 500W



▶Figure 1–12

Answer: *(a) 270W*

Since the output must be less than the input (300W), you won't have to perform any mathematical calculation because the only multiple choice selection that's less than 300W is (a) 270W.

The math to work out the answer is:
300W × 0.90 = 270W

To check your multiplication, use division:
270W/0.90 = 300W

Author's Comment:

- One of the nice things about mathematical equations is that you can usually test to see if your answer is correct. To do this test, substitute your answer back into the equation with which you're working and verify that it indeed equals out correctly. This method of checking your math will become easier once you know more of the formulas and how they relate to each other.

Part B—Basic Electrical Circuits and Formulas

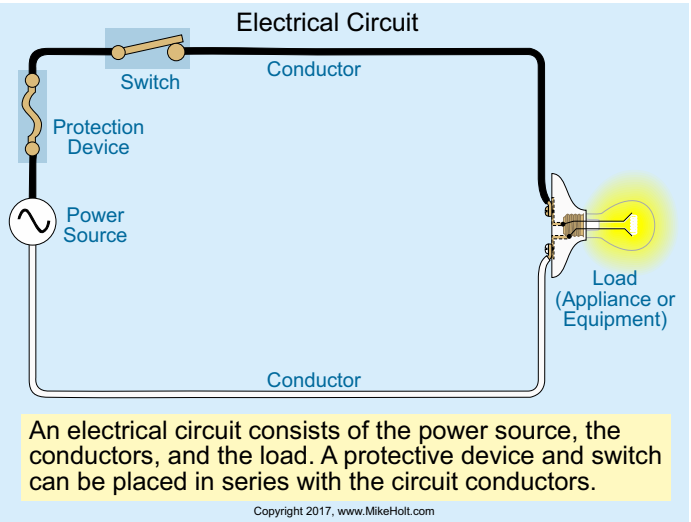
Introduction

Many false notions about the application of Article 250—Grounding and Bonding, and Chapter 3—Wiring Methods and Materials (both in the *NEC*) arise when people only use Ohm's Law to solve practice problems on paper but lack a real understanding of how that law works and how it should be applied. After completing this unit, you'll have that understanding, and won't be subject to those false notions—or the unsafe conditions to which they lead.

But we won't stop with Ohm's Law. You're also going to have a high level of proficiency with the power equation. One of the tools for handling the power equation with ease—and Ohm's Law—is the power wheel. With it, you'll be able to solve all kinds of problems.

1.15 Electrical Circuit

A basic electrical circuit consists of the power source, the conductors, and the load. A switch can be placed in series with the circuit conductors to control the operation of the load (turning it on or off). ▶Figure 1–13



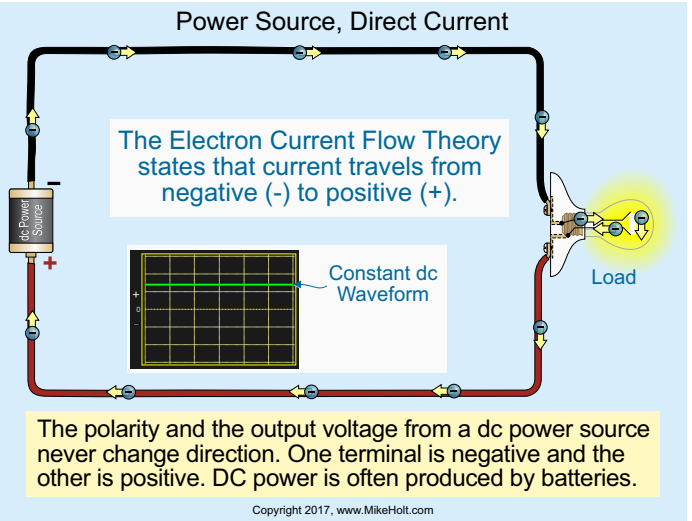
▶Figure 1–13

1.16 Power Source

The power necessary to move electrons out of their orbit around the nucleus of an atom can be produced by chemical, magnetic, photovoltaic, and other means. The two categories of power sources are direct current (dc) and alternating current (ac).

Direct Current

The polarity and the output voltage from a direct-current power source never change direction. One terminal is negative and the other is positive, relative to each other. Direct-current power is often produced by batteries, direct-current generators, and electronic power supplies. ▶Figure 1–14



▶Figure 1–14

Direct current is used for electroplating, street trolley and railway systems, or where a smooth and wide range of speed control is required for a motor-driven application. Direct current is also used for control circuits and electronic instruments.

Alternating Current

Alternating-current power sources produce a voltage that changes polarity and magnitude. Alternating current is produced by an alternating-current power source such as an alternating-current generator. The major advantage of alternating current over direct current is that voltage can be changed through the use of a transformer. ▶Figure 1–15

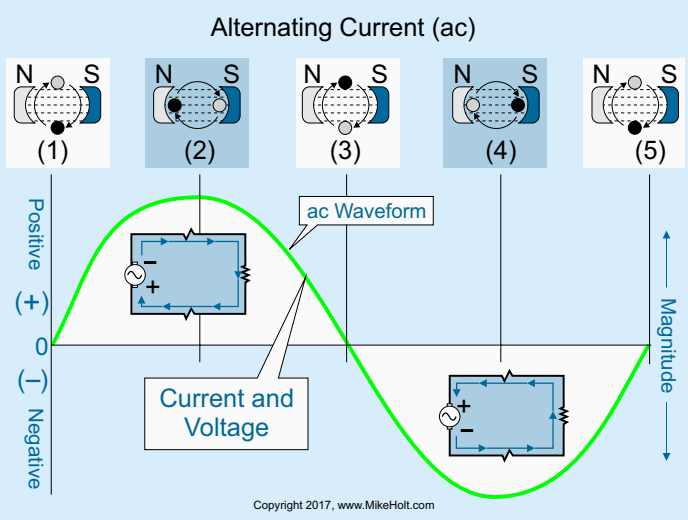


Figure 1–15

Author's Comment:

- Alternating current accounts for more than 90 percent of all electric power used throughout the world.

1.17 Conductance

Conductance, or conductivity, is the property of a metal that permits current to flow. The best conductors in order of their conductivity are silver, copper, gold, and aluminum. Copper is most often used for electrical applications. Figure 1–16

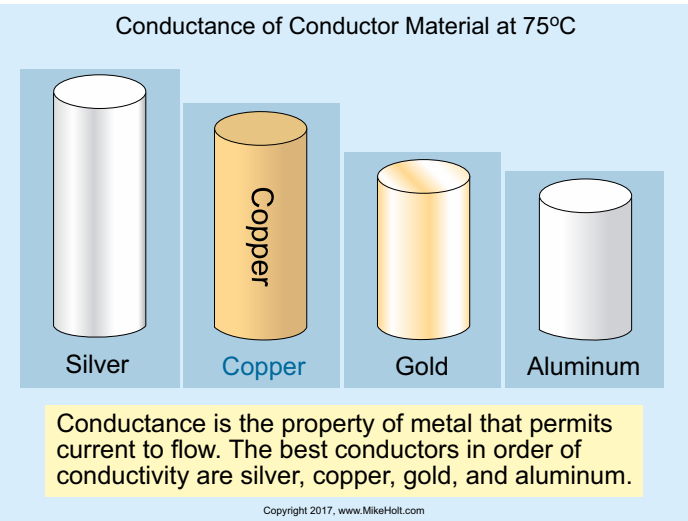


Figure 1–16

1.18 Circuit Resistance

The total resistance of a circuit includes the resistance of the power supply, the circuit wiring, and the load. Appliances such as heaters and toasters use high-resistance conductors to produce the heat needed for the application. Because the resistances of the power source and conductor are so much smaller than that of the load, they're generally ignored in circuit calculations. Figure 1–17

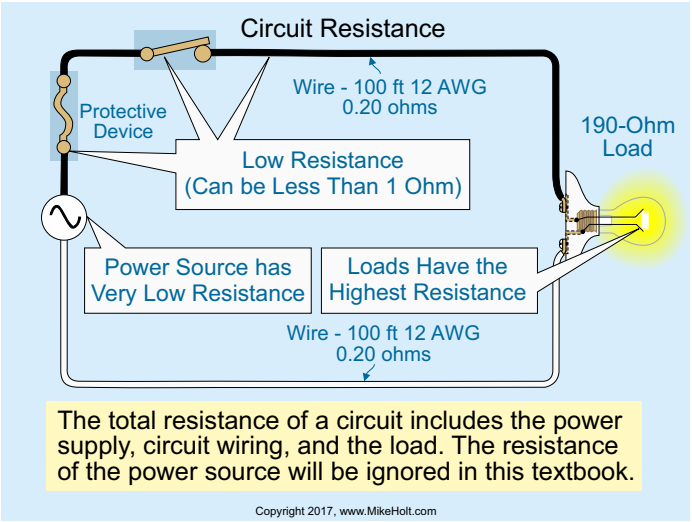


Figure 1–17

1.19 Ohm's Law

Ohm's Law expresses the relationship between a direct-current circuit's current intensity (I), electromotive force (E), and its resistance (R). This is expressed by the formula: $I = E/R$

Author's Comment:

- The symbol Ω represents "ohms."
- The German physicist Georg Simon Ohm (1787–1854) stated that current is directly proportional to voltage, and inversely proportional to resistance.

Direct proportion means that changing one factor results in a direct change to another factor in the same direction and by the same magnitude.

If the voltage increases 25 percent, the current increases 25 percent—in direct proportion (for a given resistance). If the voltage decreases 25 percent, the current decreases 25 percent—in direct proportion (for a given resistance). Figure 1–18

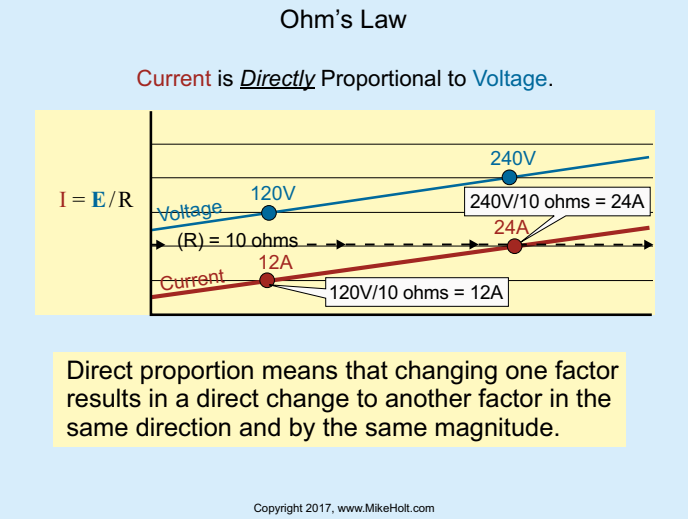


Figure 1–18

Inverse proportion means that increasing one factor results in a decrease in another factor by the same magnitude, or a decrease in one factor will result in an increase of the same magnitude in another factor.

If the resistance increases by 25 percent, the current decreases by 25 percent—in inverse proportion (for a given voltage), or if the resistance decreases by 25 percent, the current increases by 25 percent—in inverse proportion (for a given voltage). Figure 1–19

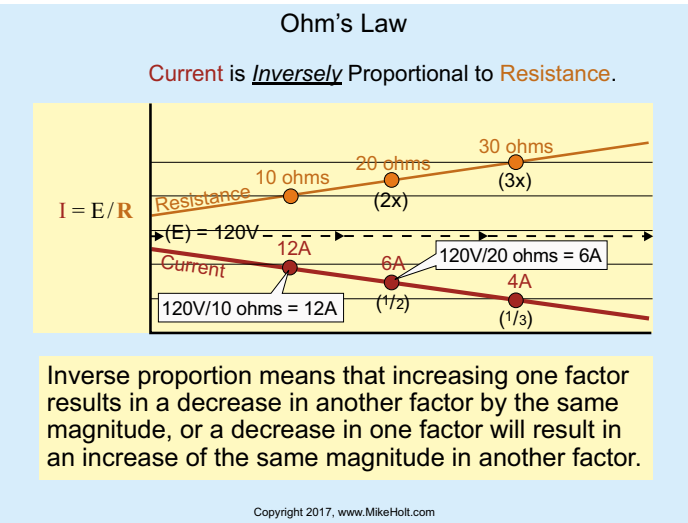


Figure 1–19

1.20 Ohm's Law and Alternating Current

Direct Current

In a direct-current circuit, the only opposition to current flow is the physical resistance of the material through which it flows. This opposition is called "resistance" and is measured in ohms.

Alternating Current

In an alternating-current circuit, there are three factors that oppose current flow: the resistance of the material; the inductive reactance of the circuit; and the capacitive reactance of the circuit.

Author's Comment:

- For now, we'll assume that the effects of inductance and capacitance on the circuit are insignificant and they'll be ignored.

1.21 Ohm's Law Formula Circle

Ohm's Law, the relationship between current, voltage, and resistance expressed in the formula, $E = I \times R$, can be transposed to $I = E/R$ or $R = E/I$. In order to use these formulas, two of the values must be known.

Author's Comment:

- Place your thumb on the unknown value in Figure 1–20, and the two remaining variables will "show" you the correct formula.

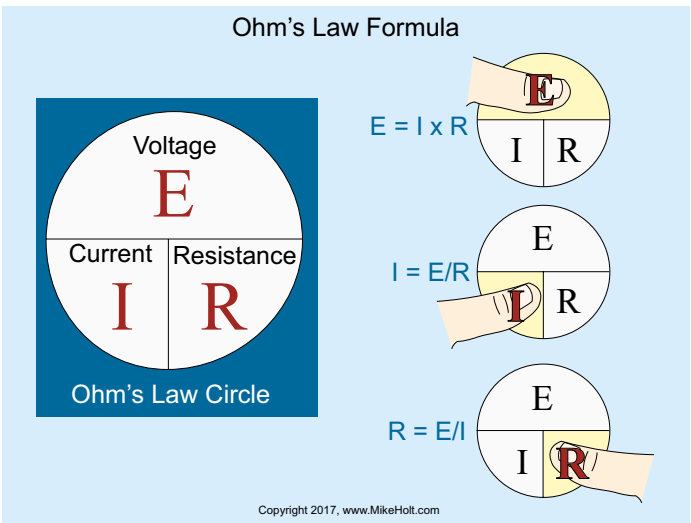
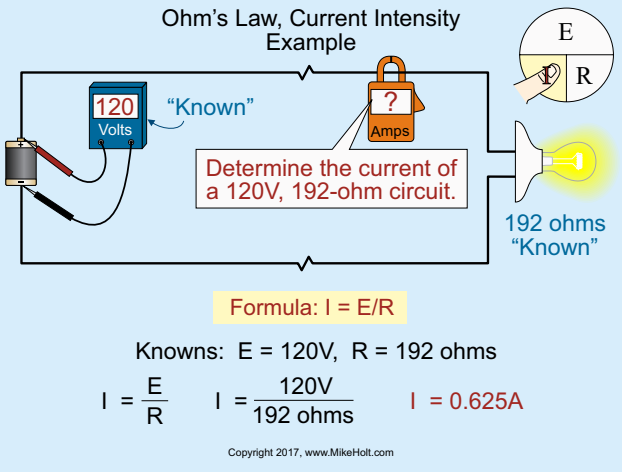


Figure 1–20

▶ Current Example

Question: *120V supplies a lamp that has a resistance of 192 ohms. What's the current flow in the circuit?* ▶Figure 1–21

(a) 0.50A (b) 0.60A (c) 1.30A (d) 2.50A



▶Figure 1–21

Answer: *(b) 0.60A*

Step 1: *What's the question? What's "I"?*

Step 2: *What do you know? E = 120V, R = 192 ohms*

Step 3: *The formula is* ***I = E/R***

Step 4: *The answer is I = 120V/192 ohms*

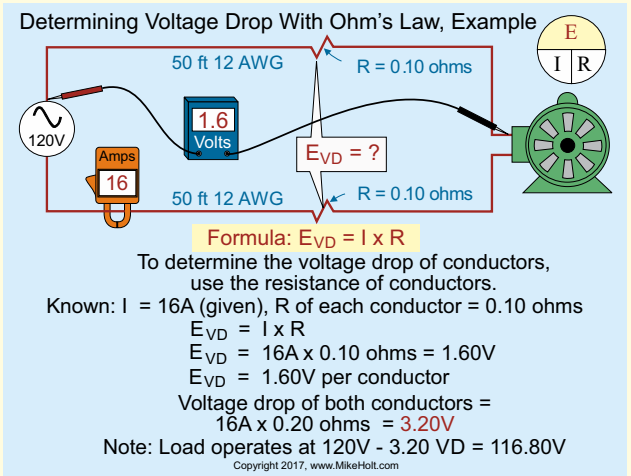
Step 5: *The answer is I = 0.625A*

▶ Voltage-Drop Example

Question: *What's the voltage drop (E_{VD}) of two 12 AWG conductors (resistance of 0.20 ohms per 100 ft) supplying a 16A load located 50 ft from the power supply?* ▶Figure 1–22

(a) 1.60V (b) 3.20V (c) 16V (d) 32V

Answer: *(b) 3.20V*

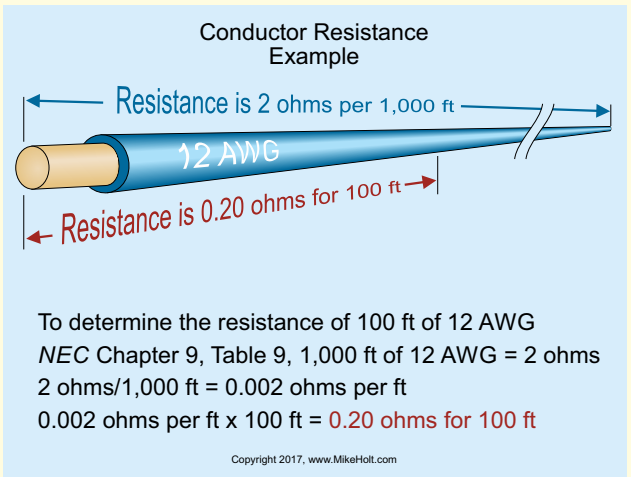


▶Figure 1–22

Step 1: *What's the question? What's "E_{VD}"?*

Step 2: *What do you know about the conductors?*

I = 16A and R = 0.20 ohms. The NEC *lists the alternating-current resistance of 1,000 ft of 12 AWG as 2 ohms [Chapter 9, Table 9]. The resistance of 100 ft is equal to 0.20 ohms.* ▶Figure 1–23



▶Figure 1–23

Step 3: *The formula is* ***$E_{VD} = I \times R$***.

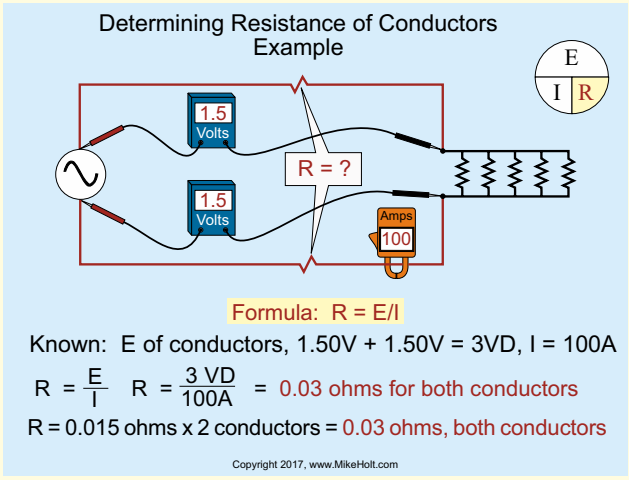
Step 4: *The answer is $E_{VD} = 16A \times 0.20$ ohms*

Step 5: *The answer is $E_{VD} = 3.20V$*

▶ Resistance Example

Question: *What's the resistance of two circuit conductors when the conductor voltage drop is 3V and the current flowing in the circuit is 100A?* ▶Figure 1–24

(a) 0.03 ohms (b) 2 ohms (c) 30 ohms (d) 300 ohms



▶Figure 1–24

Answer: *(a) 0.03 ohms*

Step 1: *What's the question? What's "R"?*

Step 2: *What do you know about the conductors?*
E_{VD} *= 3V dropped and I = 100A.*

Step 3: *The formula is* ***R = E/I****.*

Step 4: *The answer is R = 3V/100A*

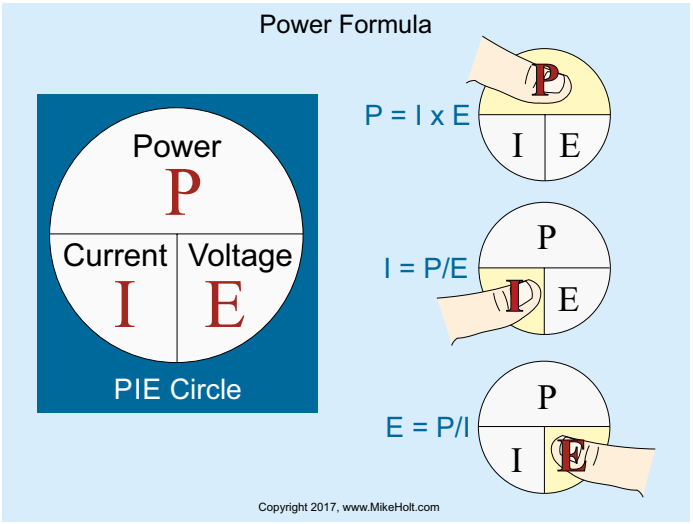
Step 5: *The answer is R = 0.03 ohms*

1.22 PIE Formula Circle

The PIE formula circle demonstrates the relationship between power, current, and voltage, and is expressed in the formula **P = I × E**. This formula can be transposed to **I = P/E** or **E = P/I**. In order to use these formulas, two of the values must be known.

Author's Comment:

- Place your thumb on the unknown value in ▶Figure 1–25 and the two remaining variables will "show" you the correct formula.

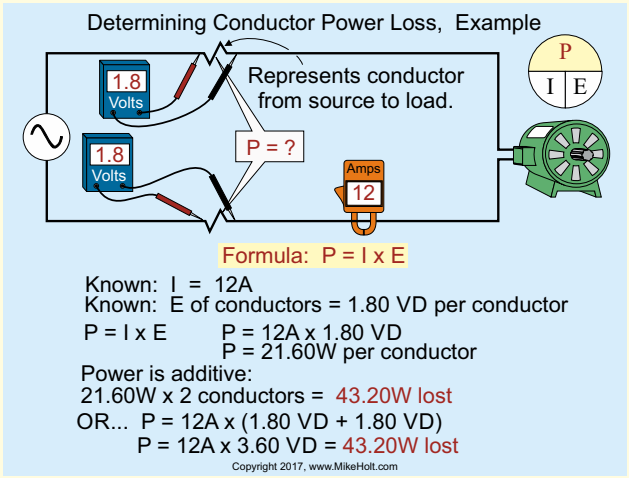


▶Figure 1–25

▶ Power Loss Example

Question: *What's the power loss in watts for two conductors that carry 12A and have a voltage drop of 3.60V?* ▶Figure 1–26

(a) 4.30W (b) 24W (c) 43.20W (d) 432W



▶Figure 1–26

• • •

Answer: *(c) 43.20W*

Step 1: *What's the question? What's "P"?*

Step 2: *What do you know? I = 12A and E = 3.60V.*

Step 3: *The formula is* ***P = I × E****.*

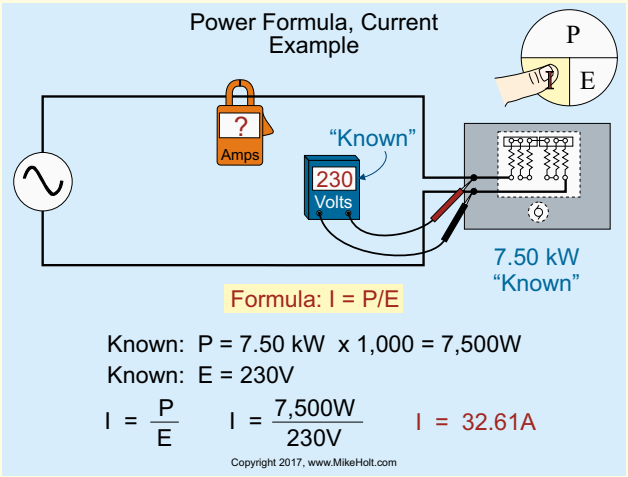
Step 4: *The answer is P = 12A × 3.60V.*

Step 5: *The answer is 43.20W.*

▶ Current Example

Question: *What's the current flow in amperes through a 7.50 kW heat strip rated 230V when connected to a 230V power supply?* ▶Figure 1–27

(a) 25A *(b) 33A* *(c) 39A* *(d) 230A*



▶Figure 1–27

Answer: *(b) 33A*

Step 1: *What's the question? What's "I"?*

Step 2: *What do you know? P = 7,500W and E = 230V.*

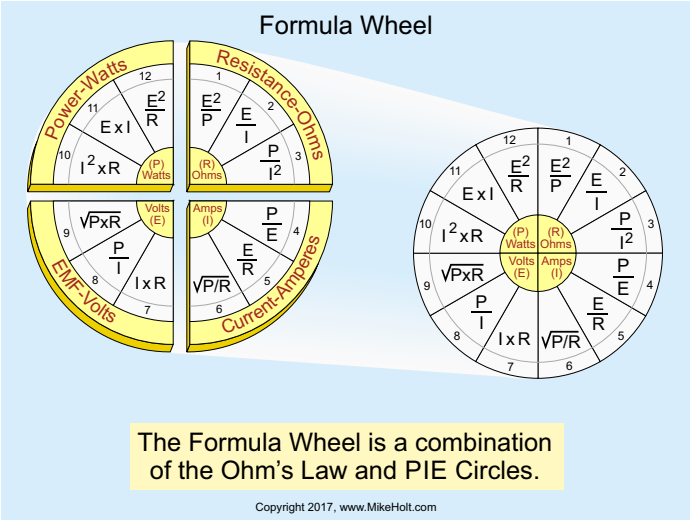
Step 3: *The formula is* ***I = P/E****.*

Step 4: *The answer is I = 7,500W/230V.*

Step 5: *The answer is 32.60A.*

1.23 Formula Wheel

The formula wheel is a combination of the Ohm's Law and the PIE formula wheels. The formulas in the formula wheel can be used for direct-current circuits or alternating-current circuits with unity power factor. ▶Figure 1–28



▶Figure 1–28

Author's Comment:

- Unity power factor is explained in Unit 3. For the purpose of this unit, we'll assume a power factor of 1.00 for all alternating-current circuits.

1.24 Using the Formula Wheel

The formula wheel is divided into four sections with three formulas in each. ▶Figure 1–29 When working the formula wheel, the key to calculating the correct answer is to follow these steps:

Step 1: Know what the question is asking for: I, E, R, or P.

Step 2: Determine the knowns: I, E, R, or P.

Step 3: Determine which section of the formula wheel applies: I, E, R, or P and select the formula from that section based on what you know.

Step 4: Work out the calculation.

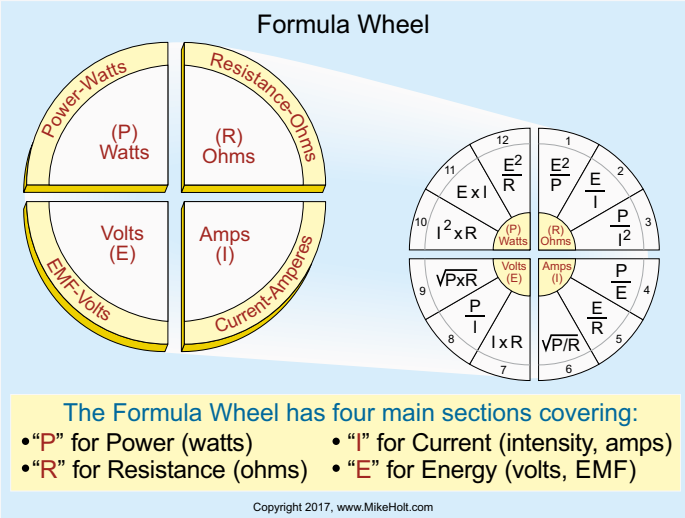


Figure 1–29

Example

Question: *The total resistance of two 12 AWG conductors, 75 ft long is 0.30 ohms, and the current through the circuit is 16A. What's the power loss of the conductors?* Figure 1–30

(a) 20W (b) 75W (c) 150W (d) 300W

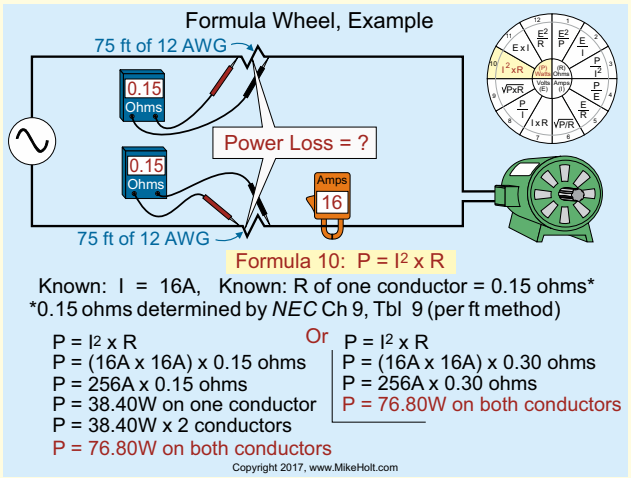


Figure 1–30

Answer: *(b) 75W*

Step 1: *What's the question? What's the power loss of the conductors "P"?*

Step 2: *What do you know about the conductors? I = 16A and R = 0.30 ohms.*

Step 3: *What's the formula?* $P = I^2 \times R$

Step 4: *Calculate the answer:* $P = 16A^2 \times 0.30 \text{ ohms} = 76.80W$. *The answer is 76.80W.*

1.25 Power Losses of Conductors

Power in a circuit can be either "useful" or "wasted." Most of the power used by loads such as fluorescent lighting, motors, or stove elements is consumed in useful work. However, the heating of conductors, transformers, and motor windings is wasted work. Wasted work is still energy used; therefore, it must be paid for, so we call wasted work "power loss."

Example

Question: *What's the conductor power loss in watts for a 10 AWG conductor that has a voltage drop of 3 percent in a 240V circuit, and carries a current flow of 24A?* Figure 1–31

(a) 17W (b) 173W (c) 350W (d) 450W

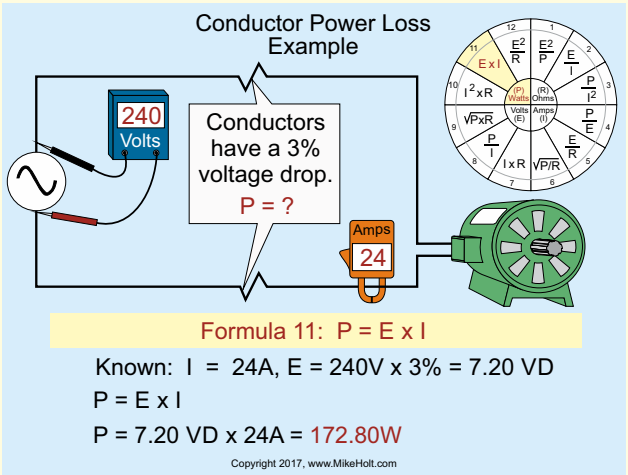


Figure 1–31

Answer: *(b) 173W*

• • •

Step 1: *What's the problem asking you to find? What's wasted "P"?*

Step 2: *What do you know about the conductors?*
I = 24A
E = 240V × 3%
E = 240V × 0.03
E = 7.20V

Step 3: *The formula is* $P = E \times I$.

Step 4: *Calculate the answer: P = 24A × 7.20V = 172.80W. The answer is 172.80W.*

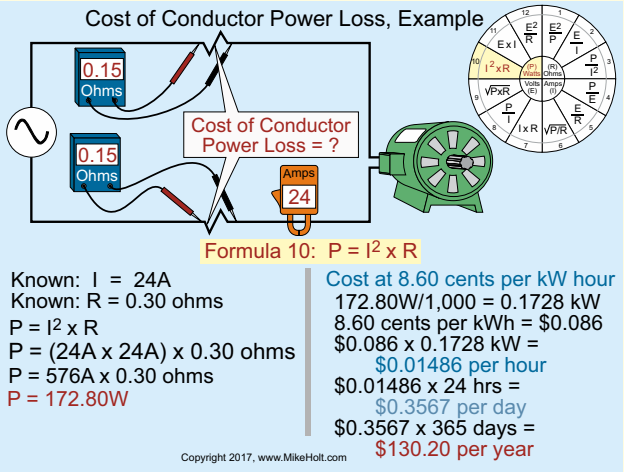
1.26 Cost of Power

Since electric bills are based on power consumed in watts, we should understand how to determine the cost of power.

▶ Example

Question: *What does it cost per year (at 8.60 cents per kWh) for the power loss of two 10 AWG circuit conductors that have a total resistance of 0.30 ohms with a current flow of 24A?* ▶Figure 1–32

(a) $1.30 *(b) $13* *(c) $130* *(d) $1,300*



▶Figure 1–32

Answer: *(c) $130*

Step 1: *Determine the amount of power consumed:*

$P = I^2 \times R$

P = 24A² × 0.30 ohms
P = 172.80W

Step 2: *Convert the answer in Step 1 to kW:*
P = 172.80W/1,000W
P = 0.1728 kW

Step 3: *Determine the cost per hour:*
(0.086 dollars per kWh) × 0.17280 kW = 0.01486 dollars per hr

Step 4: *Determine the dollars per day:*
0.01486 dollars per hr × (24 hrs per day) = 0.3567 dollars per day

Step 5: *Determine the dollars per year:*
0.3567 dollars per day × (365 days per year) = $130.20 per year

Author's Comment:

- That's a lot of money just to heat up two 10 AWG conductors for one circuit. Imagine how much it costs to heat up the conductors for an entire building!

Conclusion to Unit 1—Electrician's Math and Basic Electrical Formulas

You've gained skill in working with Ohm's Law and the power equation, and can use the power wheel to solve a wide variety of electrical problems. You also know how to calculate voltage drop and power loss, and can relate the costs in real dollars.

As you work through the practice questions, you'll see how well you've mastered the mathematical concepts and how ready you are to put them to use in electrical formulas. Always remember to check your answer when you're done—then you'll know you have the correct answer every time. As useful as these skills are, there's still more to learn. But, your mastery of these basic electrical formulas means you're well prepared. Work through the questions that follow, and go back over the instructional material if you have any difficulty. When you believe you know the material here in Unit 1, you'll be ready to tackle the electrical circuits covered in Unit 2.

UNIT 1

UNIT REVIEW QUESTIONS

The questions in this section are based on the content you have just reviewed. If you struggle with any of the answers, go back and review that section of Unit 1 one more time.

PART A—ELECTRICIAN'S MATH

1. The decimal equivalent for the fraction "½" is _____.

   (a) 0.50
   (b) 0.70
   (c) 2
   (d) 5

2. The approximate decimal equivalent for the fraction "$\frac{1}{18}$" is _____.

   (a) 0.20
   (b) 2.50
   (c) 3.50
   (d) 4.50

1.4 Percentages

3. To change a percent value to a decimal or whole number, drop the percentage sign and move the decimal point two places to the _____.

   (a) right
   (b) left
   (c) depends
   (d) none of these

4. The decimal equivalent for "75 percent" is _____.

   (a) 0.075
   (b) 0.75
   (c) 7.50
   (d) 75

5. The decimal equivalent for "225 percent" is _____.

   (a) 0.225
   (b) 2.25
   (c) 22.50
   (d) 225

6. The decimal equivalent for "300 percent" is _____.

   (a) 0.03
   (b) 0.30
   (c) 3
   (d) 30.00

1.5 Multiplier

7. The method of increasing a number by another number is done by using a _____.

   (a) percentage
   (b) decimal
   (c) fraction
   (d) multiplier

8. An overcurrent device (circuit breaker or fuse) must be sized no less than 125 percent of the continuous load. If the load is 16A, the overcurrent device will have to be sized at no less than _____.

   (a) 17A
   (b) 20A
   (c) 23A
   (d) 30A

9. The maximum continuous load on an overcurrent device is limited to 80 percent of the device rating. If the overcurrent device is rated 100A, the maximum continuous load is _____.

   (a) 72A
   (b) 80A
   (c) 90A
   (d) 125A

1.6 Percent Increase

10. The feeder calculated load for an 8 kW load, increased by 20 percent is _____.

    (a) 8 kW
    (b) 9.60 kW
    (c) 10 kW
    (d) 12 kW

1.7 Reciprocals

11. What's the reciprocal of 1.25?

    (a) 0.80
    (b) 1.10
    (c) 1.25
    (d) 1.50

12. A continuous load requires an overcurrent device sized no smaller than 125 percent of the load. What's the maximum continuous load permitted on a 100A overcurrent device?

    (a) 75A
    (b) 80A
    (c) 100A
    (d) 125A

1.8 Squaring a Number

13. Squaring a number means multiplying the number by itself.

    (a) True
    (b) False

14. What's the power consumed in watts by a 12 AWG conductor that's 100 ft long and has a resistance (R) of 0.20 ohms, when the current (I) in the circuit is 16A?

    $\text{Power} = I^2 \times R$
    Power = 16A x 0.20 ohms

    (a) 50W
    (b) 75W
    (c) 100W
    (d) 200W

15. What's the approximate area in square inches of a trade size 2 raceway?

    $\text{Area} = \pi \times r^2$, $\pi = 3.14$, r = radius (½ of diameter)
    Area = 3.14×1^2

    (a) 1 sq in.
    (b) 2 sq in.
    (c) 3 sq in.
    (d) 4 sq in.

16. The numeric equivalent of 4^2 is _____.

    (a) 2
    (b) 8
    (c) 16
    (d) 32

17. The numeric equivalent of 12^2 is _____.

    (a) 3.46
    (b) 24
    (c) 144
    (d) 1,728

1.9 Parentheses

18. What's the maximum distance that two 14 AWG copper conductors can be run if they carry 16A and the maximum allowable voltage drop is 10V?

    $D = (\text{Cmil} \times E_{VD})/(2 \times K \times I)$
    D = (4,110 Cmil x 10V)/(2 wires x 12.90 ohms x 16A)

    (a) 50 ft
    (b) 75 ft
    (c) 100 ft
    (d) 150 ft

19. What's the current in amperes of an 18 kW, 208V, three-phase load?

Current: I = VA/(E x √3)
Current: I = 18,000W/(208V x 1.732)

(a) 25A
(b) 50A
(c) 100A
(d) 150A

1.10 Square Root

20. Deriving the square root of a number is almost the same as squaring a number.

(a) True
(b) False

21. What's the approximate square root of 1,000?

(a) 3
(b) 32
(c) 100
(d) 500

22. The square root of 3 is _____.

(a) 1.50
(b) 1.732
(c) 9
(d) 729

1.11 Volume

23. The volume of an enclosure is expressed in _____, and is calculated by multiplying the length, by the width, by the depth of the enclosure.

(a) cubic inches
(b) weight
(c) inch-pounds
(d) none of these

24. What's the volume (in cubic inches) of a 4 x 4 x 1.50 in. box?

(a) 20 cu in.
(b) 24 cu in.
(c) 30 cu in.
(d) 33 cu in.

1.12 Kilo

25. What's the kW of a 75W load?

(a) 0.075 kW
(b) 0.75 kW
(c) 7.50 kW
(d) 75 kW

1.13 Rounding Off

26. The approximate sum of 2, 7, 8, and 9 is equal to _____.

(a) 20
(b) 25
(c) 30
(d) 35

1.14 Testing Your Answer for Reasonableness

27. The output power of a transformer is 100W and the transformer efficiency is 90 percent. What's the transformer input if the output is lower than the input?

Input = Output/Efficiency
Input = 100W/0.90

(a) 90W
(b) 100W
(c) 110W
(d) 125W

PART B—BASIC ELECTRICAL FORMULAS

1.15 Electrical Circuit

28. An electrical circuit consists of the _____.

(a) power source
(b) conductors
(c) load
(d) all of these

29. According to the Electron Flow Theory, electrons leave the _____ terminal of the source, flow through the conductors and load(s), and return to the _____ terminal of the source.

(a) positive, negative
(b) negative, positive
(c) negative, negative
(d) positive, positive

1.16 Power Source

30. The polarity and the output voltage from a direct-current power source changes direction. One terminal will be negative and the other will be positive at one moment, then the terminals switch polarity.

(a) True
(b) False

31. Direct current is used for electroplating, street trolley and railway systems, or where a smooth and wide range of speed control is required for a motor-driven application.

(a) True
(b) False

32. The polarity and the output voltage from an alternating-current power source never change direction.

(a) True
(b) False

33. The major advantage of alternating current over direct current is the ease of voltage regulation by the use of a transformer.

(a) True
(b) False

1.17 Conductance

34. Conductance is the property that permits current to flow.

(a) True
(b) False

35. The best conductors, in order of their conductivity, are gold, silver, copper, and aluminum.

(a) True
(b) False

36. Conductance, or conductivity, is the property of metal that permits current to flow. The best conductors in order of their conductivity are _____.

(a) gold, silver, copper, aluminum
(b) gold, copper, silver, aluminum
(c) silver, gold, copper, aluminum
(d) silver, copper, gold, aluminum

1.18 Circuit Resistance

37. The circuit resistance includes the resistance of the _____.

(a) power source
(b) conductors
(c) load
(d) all of these

38. Often the resistances of the power source and conductor are ignored in circuit calculations.

(a) True
(b) False

1.19 Ohm's Law

39. The Ohm's Law formula, $I = E/R$, states that current is _____ proportional to the voltage, and _____ proportional to the resistance.

(a) indirectly, inversely
(b) inversely, directly
(c) inversely, indirectly
(d) directly, inversely

40. Ohm's Law demonstrates the relationship between circuit _____.

(a) intensity
(b) EMF
(c) resistance
(d) all of these

1.20 Ohm's Law and Alternating Current

41. In a direct-current circuit, the only opposition to current flow is the physical resistance of the material. This opposition is called reactance and is measured in ohms.

    (a) True
    (b) False

42. In an alternating-current circuit, the factor(s) that oppose current flow is(are) _____.

    (a) resistance
    (b) inductive reactance
    (c) capacitive reactance
    (d) all of these

1.21 Ohm's Law Formula Circle

43. What's the voltage drop of two 12 AWG conductors (0.40 ohms) supplying a 16A load, located 100 ft from the power supply?

    $E_{VD} = I \times R$
    E_{VD} = 16A x 0.40 ohms

    (a) 1.60V
    (b) 3.20V
    (c) 6.40V
    (d) 12.80V

44. What's the resistance of the circuit conductors when the conductor voltage drop is 7.20V and the current flow is 50A?

    $R = E/I$
    R = 7.20V/50A

    (a) 0.14 ohms
    (b) 0.30 ohms
    (c) 3 ohms
    (d) 14 ohms

1.22 PIE Formula Circle

45. What's the power loss in watts of a conductor that carries 24A and has a voltage drop of 7.20V?

    $P = I \times E$
    P = 24A x 7.20V

    (a) 175W
    (b) 350W
    (c) 700W
    (d) 2,400W

1.23 Formula Wheel

46. The formulas in the power wheel apply to _____.

    (a) direct-current circuits
    (b) alternating-current circuits with unity power factor
    (c) direct-current circuits or alternating-current circuits
    (d) a and b

1.24 Using the Formula Wheel

47. When working any formula, the key to calculating the correct answer is following these four steps:

    Step 1: Know what the question is asking you to find.
    Step 2: Determine the knowns of the circuit.
    Step 3: Select the formula.
    Step 4: Work out the formula calculation.

    (a) True
    (b) False

1.25 Power Losses of Conductors

48. Power in a circuit can be either "useful" or "wasted." Wasted work is still energy used; therefore it must be paid for, so we call wasted work "_____."

    (a) resistance
    (b) inductive reactance
    (c) capacitive reactance
    (d) power loss

49. The total circuit resistance of two 12 AWG conductors (each 100 ft long) is 0.40 ohms. If the current of the circuit is 16A, what's the power loss of both conductors?

$P = I^2 \times R$

$P = 16A^2 \times 0.40$ ohms

(a) 75W
(b) 100W
(c) 300W
(d) 600W

50. What's the conductor power loss for a 120V circuit that has a 3 percent voltage drop and carries a current flow of 12A?

$P = I \times E$

$P = 12A \times (120V \times 3\%)$

(a) 43W
(b) 86W
(c) 172W
(d) 1,440W

1.27 Power Changes with the Square of the Voltage

51. The voltage applied to a resistor dramatically affects the power consumed by that resistor because power is affected in direct proportion to the voltage.

(a) True
(b) False

UNIT 1

UNIT CHALLENGE QUESTIONS

These questions provide additional work on the content you have just learned. These advanced-level problems allow you to really challenge yourself.

PART A—ELECTRICIAN'S MATH

1.12 Kilo

1. One kVA is equal to _____.

   (a) 100 VA
   (b) 1,000V
   (c) 1,000W
   (d) 1,000 VA

PART B—BASIC ELECTRICAL FORMULAS

1.17 Conductance

2. Which of the following is the most conductive?

   (a) Bakelite.
   (b) Oil.
   (c) Air.
   (d) Salt water.

1.19 Ohm's Law

3. If the contact resistance of a connection increases and the current of the circuit (load) remains the same, then the voltage dropped across the connection will _____.

   (a) increase
   (b) decrease
   (c) remain the same
   (d) can't be determined

4. To double the current of a circuit when the voltage remains constant, the R (resistance) must be _____.

   (a) doubled
   (b) reduced by half
   (c) increased
   (d) none of these

5. An ohmmeter is being used to test a relay coil. The equipment instructions indicate that the resistance of the coil should be between 30 and 33 ohms. The ohmmeter indicates that the actual resistance is less than 22 ohms. This reading most likely indicates _____.

   (a) the coil is okay
   (b) an open coil
   (c) a shorted coil
   (d) a meter problem

1.24 Using the Formula Wheel

6. To calculate the energy consumed in watts by a resistive appliance, you need to know _____ of the circuit.

   (a) the voltage and current
   (b) the current and resistance
   (c) the voltage and resistance
   (d) any of these pairs of variables

7. The power consumed by a resistor can be expressed by the formula $I^2 \times R$. If 120V is applied to a 10-ohm resistor, the power consumed will be _____.

$P = E^2/R$

(a) 510W
(b) 1,050W
(c) 1,230W
(d) 1,440W

8. Power loss in a circuit because of heat can be determined by the formula _____.

(a) P = R x I
(b) P = I x R
(c) $P = I^2 \times R$
(d) none of these

9. The energy consumed by a 5-ohm resistor is _____ than the energy consumed by a 10-ohm resistor, assuming the current in both cases remains the same.

(a) more
(b) less

1.24 Using the Formula Wheel

10. What's the power loss of two 10 AWG conductors when the current through the circuit is 16A and the total resistance is 0.18 ohms?

$P = I^2 \times R$

(a) 2.80W
(b) 3.80W
(c) 46W
(d) 55W

1.27 Power Changes with the Square of the Voltage

11. When a 100W, 115V lamp operates at 230V, the lamp will consume approximately _____ when the total resistance is 132.25 ohms.

$P = E^2/R$

(a) 150W
(b) 300W
(c) 400W
(d) 450W

12. A 1,500W resistive heater is rated 230V and is connected to a 208V supply. The power consumed by this load at 208V will be approximately _____ when the total resistance is 35.27 ohms.

$P = E^2/R$

(a) 1,225W
(b) 1,625W
(c) 1,750W
(d) 1,850W

13. The total resistance of a circuit is 10.20 ohms. The load has a resistance of 10 ohms and the wire has a resistance of 0.20 ohms. If the current of the circuit is 12A, then the power consumed by the circuit conductors (0.20 ohms) is approximately _____.

$P = I^2 \times R$

(a) 8W
(b) 29W
(c) 39W
(d) 45W

NEC PRACTICE QUIZ 1 STRAIGHT ORDER

NEC Practice Quiz—Straight Order [90.1–210.8]

Please use the 2017 *Code* book to answer the following questions.

These questions allow you to test your knowledge of the *Code* and are sequenced in the order in which their content appears in the *NEC*. They provide you with an opportunity to start testing your *Code* knowledge, and give you practice answering the types of *Code* questions you would see on an electrical exam. They'll help you build your core knowledge of the *NEC*.

Article 90. Introduction to the *National Electrical Code*

1. The *NEC* is _____.

   (a) intended to be a design manual
   (b) meant to be used as an instruction guide for untrained persons
   (c) for the practical safeguarding of persons and property
   (d) published by the Bureau of Standards

2. Which of the following systems shall be installed and removed in accordance with the *NEC* requirements?

   (a) Signaling conductors, equipment, and raceways.
   (b) Communications conductors, equipment, and raceways.
   (c) Electrical conductors, equipment, and raceways.
   (d) all of these

3. The *NEC* applies to the installation of _____.

   (a) electrical conductors and equipment within or on public and private buildings
   (b) outside conductors and equipment on the premises
   (c) optical fiber cables and raceways
   (d) all of these

4. Utilities may include entities that are designated or recognized by governmental law or regulation by public service/utility commissions.

   (a) True
   (b) False

5. Chapters 1 through 4 of the *NEC* apply _____.

   (a) generally to all electrical installations
   (b) only to special occupancies and conditions
   (c) only to special equipment and material
   (d) all of these

6. Chapters 5, 6, and 7 apply to special occupancies, special equipment, or other special conditions and may supplement or modify the requirements in Chapters 1 through 7.

   (a) True
   (b) False

7. Communications wiring such as telephone, antenna, and CATV wiring within a building shall not be required to comply with the installation requirements of Chapters 1 through 7, except where specifically referenced in Chapter 8.

   (a) True
   (b) False

8. Factory-installed _____ wiring of listed equipment need not be inspected at the time of installation of the equipment, except to detect alterations or damage.

   (a) external
   (b) associated
   (c) internal
   (d) all of these

CHAPTER 1. GENERAL RULES

Article 100. Definitions

9. Capable of being reached quickly for operation, renewal, or inspections without resorting to portable ladders or the use of tools (other than keys) is known as "_____."

   (a) accessible (as applied to equipment)
   (b) accessible (as applied to wiring methods)
   (c) accessible, readily
   (d) all of these

10. The *NEC* defines a(n) "_____" as a structure that stands alone or that is separated from adjoining structures by fire walls.

   (a) unit
   (b) apartment
   (c) building
   (d) utility

11. A cable routing assembly is composed of single or connected multiple channels as well as associated fittings, forming a structural system to _____ communications wires and cables, optical fiber and data cables; and Class 2, Class 3, and Type PLTC cables; and power-limited fire alarm cables in plenum, riser, and general-purpose applications.

   (a) support
   (b) route
   (c) protect
   (d) a and b

12. Communications equipment includes equipment and conductors used for the transmission of _____.

   (a) audio
   (b) video
   (c) data
   (d) any of these

13. A communications raceway is an enclosed channel of nonmetallic materials designed for holding communications wires and cables; optical fiber cables; data cables associated with information technology and communications equipment; Class 2, Class 3, and Type PLTC cables; and power-limited fire alarm cables in _____ applications.

   (a) plenum
   (b) riser
   (c) general-purpose
   (d) all of these

14. The selection and installation of overcurrent protective devices so that an overcurrent condition will be localized to restrict outages to the circuit or equipment affected, is called "_____."

   (a) overcurrent protection
   (b) interrupting capacity
   (c) selective coordination
   (d) overload protection

15. _____ enclosures are constructed so that dust will not enter under specific test conditions.

   (a) Dust-ignitionproof
   (b) Dusttight
   (c) a or b
   (d) a and b

16. A fixed, stationary, or portable self-contained, electrically operated and/or electrically illuminated utilization equipment with words or symbols designed to convey information or attract attention describes _____.

   (a) an electric sign
   (b) equipment
   (c) appliances
   (d) none of these

17. A(n) _____ that performs field evaluations of electrical or other equipment is known as a "Field Evaluation Body (FEB)."

   (a) part of an organization
   (b) organization
   (c) a or b
   (d) none of these

18. Equipment or materials to which has been attached a(n) _____ of an FEB indicating the equipment or materials were evaluated and found to comply with requirements as described in an accompanying field evaluation report is known as "field labeled (as applied to evaluated products)."

    (a) symbol
    (b) label
    (c) other identifying mark
    (d) any of these

19. An interactive inverter is an inverter intended for use in parallel with a(n) _____ to supply common loads that may deliver power to the utility.

    (a) electric utility
    (b) photovoltaic (PV) system
    (c) battery
    (d) none of these

20. A "_____" is the total components and subsystem that, in combination, converts solar energy into electric energy for connection to a utilization load.

    (a) photovoltaic system
    (b) solar array
    (c) a and b
    (d) none of these

21. A "raceway" is an enclosed channel designed expressly for the holding of wires, cables, or busbars, with additional functions as permitted in the *Code*.

    (a) True
    (b) False

22. A contact device installed at an outlet for the connection of an attachment plug, or for the direct connection of electrical utilization equipment designed to mate with the corresponding contact device, is known as a(n) "_____."

    (a) attachment point
    (b) tap
    (c) receptacle
    (d) wall plug

23. A single receptacle is a single contact device with no other contact device on the same _____.

    (a) circuit
    (b) yoke
    (c) run
    (d) equipment

24. A "structure" is that which is built or constructed, other than equipment.

    (a) True
    (b) False

Article 110. Requirements for Electrical Installations

25. Conductors normally used to carry current shall be _____ unless otherwise provided in this *Code*.

    (a) bare
    (b) stranded
    (c) of copper or aluminum
    (d) none of these

26. Equipment intended to interrupt current at fault levels shall have an interrupting rating at nominal circuit voltage at least equal to the current that is available at the line terminals of the equipment.

    (a) True
    (b) False

27. When protecting equipment against damage from the weather during construction, minimum _____ provisions provided in NFPA 5000 *Building Construction and Safety Code, the International Building Code (IBC)*, and the *International Residential Code for One- and Two-Family Dwellings (IRC)* can be referenced for additional information.

    (a) safety
    (b) flood
    (c) weather
    (d) none of these

28. Where a tightening torque is indicated as a numeric value on equipment or in installation instructions provided by the manufacturer, a(n) _____ torque tool shall be used to achieve the indicated torque value, unless the equipment manufacturer has provided installation instructions for an alternative method of achieving the required torque.

    (a) calibrated
    (b) identified
    (c) adjustable
    (d) listed

29. In other than dwelling units, in addition to requirements for field or factory marking of equipment to warn qualified persons of potential electric arc-flash hazards, a permanent label shall be field or factory applied to service equipment rated _____ or more.

    (a) 600A
    (b) 1,000A
    (c) 1,200A
    (d) 1,600A

30. Service equipment labeling in other than dwelling units shall not be required if an arc-flash label is applied in accordance with _____ industry practice.

    (a) routine
    (b) acceptable
    (c) documented
    (d) none of these

31. NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides guidance, such as determining severity of potential exposure, planning safe work practices, arc-flash labeling, and selecting _____.

    (a) personal protective equipment
    (b) coordinated overcurrent protective devices
    (c) a and b
    (d) none of these

32. Acceptable industry practices for equipment labeling are described in NFPA 70E, *Standard for Electrical Safety in the Workplace*. This standard provides specific criteria for developing arc-flash labels for equipment that provides _____, and so forth.

    (a) nominal system voltage and incident energy levels
    (b) arc-flash boundaries
    (c) minimum required levels of personal protective equipment
    (d) all of these

33. Reconditioned equipment shall be marked with the name, trademark, or other descriptive marking by which the _____ responsible for reconditioning the electrical equipment can be identified, along with the date of the reconditioning.

    (a) name of the individual
    (b) approving authority
    (c) organization
    (d) listing agency

34. Where caution, warning, or danger signs or labels are required by this *Code*, the label marking shall warn of the hazards using effective _____.

    (a) words
    (b) colors
    (c) symbols
    (d) any combination of words, colors, or symbols

35. _____ at other than dwelling units shall be legibly field marked with the maximum available fault current, include the date the fault-current calculation was performed, and be of sufficient durability to withstand the environment involved.

    (a) Service equipment
    (b) Sub panels
    (c) Motor control centers
    (d) all of these

36. NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides guidance for working space about electrical equipment, such as determining severity of potential exposure, planning safe work practices, arc-flash labeling, and selecting personal protective equipment.

    (a) True
    (b) False

37. Where equipment operating at 1,000 volts, nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while energized is required by installation instructions or function to be located in a space with limited access, and where equipment is installed above a lay-in ceiling, there shall be an opening not smaller than _____.

    (a) 6 in. x 6 in.
    (b) 12 in. x 12 in.
    (c) 22 in. x 22 in.
    (d) 22 in. x 30 in.

38. Where equipment operating at 1,000 volts, nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while energized is required by installation instructions or function to be located in a space with limited access, the width of the working space shall be the width of the equipment enclosure or a minimum of _____ in., whichever is greater.

    (a) 12
    (b) 22
    (c) 26
    (d) 30

39. Where equipment operating at 1,000 volts, nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while energized is required by installation instructions or function to be located in a space with limited access, all enclosure doors or hinged panels shall be capable of opening a minimum of _____ degrees.

    (a) 60
    (b) 90
    (c) 120
    (d) 180

40. Where equipment operating at 1,000 volts, nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while energized is required by installation instructions or function to be located in a space with limited access, the space in front of the enclosure shall comply with the depth requirements of Table 110.26(A)(1).

    (a) True
    (b) False

41. Illumination shall be provided for all working spaces about service equipment, switchboards, switchgear, panelboards, or motor control centers _____.

    (a) over 600V
    (b) installed indoors
    (c) rated 1,200A or more
    (d) using automatic means of control

42. All switchboards, switchgear, panelboards, and motor control centers shall be located in dedicated spaces and protected from damage, and outdoor installations shall be _____.

    (a) installed in identified enclosures
    (b) protected from accidental contact by unauthorized personnel or by vehicular traffic
    (c) protected from accidental spillage or leakage from piping systems
    (d) all of these

43. All switchboards, switchgear, panelboards, and motor control centers shall be located in dedicated spaces and protected from damage and the working clearance space for outdoor installations shall include the zone described in _____.

    (a) 110.26(A)
    (b) 110.26(B)
    (c) 110.26(C)
    (d) 110.26(D)

CHAPTER 2. WIRING AND PROTECTION

Article 210. Branch Circuits

44. Article 210 provides the general requirements for _____.

    (a) outside branch circuits
    (b) branch circuits
    (c) ungrounded conductors
    (d) feeder calculations

45. In existing installations where a voltage system(s) already exists and a different voltage system is being added, it shall be permissible to mark only the old system voltage.

    (a) True
    (b) False

46. Where two or more branch circuits supply devices or equipment on the same yoke or mounting strap, a means to disconnect simultaneously the ungrounded supply conductors shall be provided at the _____.

    (a) point where the branch circuits originate
    (b) location of the device or equipment
    (c) point where the feeder originates
    (d) none of these

47. The GFCI protection required by 210.8(A), (B), (C), (D), and (E) shall be _____.

    (a) the circuit breaker type only
    (b) accessible
    (c) readily accessible
    (d) concealed

48. Requirements for branch-circuit GFCI protection for personnel are contained in 210.8 and requirements for _____are contained in 422.5(A).

    (a) feeders
    (b) appliances
    (c) motors
    (d) all of these

49. For the application of GFCI protection for personnel, when determining distance from receptacles for sinks [210.8(A)(7) and 210.8(B)(5)] and bathtubs or shower stalls [210.8(A)(9)], the distance shall be measured as the _____ path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a door, doorway, or window.

    (a) longest
    (b) shortest
    (c) most direct
    (d) none of these

50. GFCI protection shall be provided for all 15A and 20A, 125V, single-phase receptacles in dwelling unit unfinished portions or areas of basements not intended as habitable rooms.

    (a) True
    (b) False

NEC PRACTICE QUIZ 1 RANDOM ORDER

NEC Practice Quiz—Random Order [90.1–210]

Please use the 2017 *Code* book to answer the following questions.

To further improve your ability to use your *Code* book in a testing environment, the following quiz provides 50 *NEC* questions in random order. This randomization allows you to expand your ability to find items in the *NEC* and improve your knowledge of its organization and design. As you progress through this textbook, you'll find additional articles in subsequent randomized quizzes until you've been exposed to questions from the entire *Code* book. If you haven't had in-depth *Code* training and find any of these questions challenging, you may want to explore our Understanding the *National Electrical Code* products which will provide detailed instruction of the *NEC* and give you true confidence in this part of your job and on your exam.

1. Each disconnecting means shall be legibly marked to indicate its purpose unless located and arranged so _____.

   (a) that it can be locked out and tagged
   (b) it is not readily accessible
   (c) the purpose is evident
   (d) that it operates at less than 300 volts-to-ground

2. An "optical fiber cable" is a factory assembly or field assembly of one or more optical fibers having a(n) _____ covering.

   (a) conductive
   (b) nonconductive
   (c) overall
   (d) metallic

3. The term "Luminaire" means a single individual lampholder by itself.

   (a) True
   (b) False

4. The highest current at rated voltage that a device is identified to interrupt under standard test conditions is the "_____."

   (a) interrupting rating
   (b) manufacturer's rating
   (c) interrupting capacity
   (d) withstand rating

5. All 15A and 20A, 125V, single-phase receptacles installed in crawl spaces at or below grade level of dwelling units shall have GFCI protection.

   (a) True
   (b) False

6. "Continuous duty" is defined as _____.

   (a) when the load is expected to continue for five hours or more
   (b) operation at a substantially constant load for an indefinitely long time
   (c) operation at loads and for intervals of time, both of which may be subject to wide variations
   (d) operation at which the load may be subject to maximum current for six hours or more

7. Multiwire branch circuits shall _____.

   (a) supply only line-to-neutral loads
   (b) not be permitted in dwelling units
   (c) have their conductors originate from different panelboards
   (d) none of these

8. When modifications to the electrical installation occur that affect the maximum available fault current at the service, the maximum available fault current shall be verified or _____ as necessary to ensure the service equipment ratings are sufficient for the maximum available fault current at the line terminals of the equipment.

   (a) recalculated
   (b) increased
   (c) decreased
   (d) adjusted

9. On a 4-wire, delta-connected system where the midpoint of one phase winding is grounded, only the conductor or busbar having the higher phase voltage-to-ground shall be durably and permanently marked by an outer finish that is _____ in color.

   (a) black
   (b) red
   (c) blue
   (d) orange

10. A panel, including buses and automatic overcurrent devices, designed to be placed in a cabinet or cutout box and accessible only from the front is known as a "_____."

    (a) switchboard
    (b) disconnect
    (c) panelboard
    (d) switch

11. A "kitchen" is defined as an area with a sink and _____ provisions for food preparation and cooking.

    (a) listed
    (b) labeled
    (c) temporary
    (d) permanent

12. Constructed, protected, or treated so as to prevent rain from interfering with the successful operation of the apparatus under specified test conditions defines the term "_____."

    (a) raintight
    (b) waterproof
    (c) weathertight
    (d) rainproof

13. As applied to wiring methods, "on or attached to the surface, or behind access panels designed to allow access" is known as _____.

    (a) open
    (b) uncovered
    (c) exposed
    (d) bare

14. All single-phase receptacles rated 150V to ground or less, 50A or less and three-phase receptacles rated 150V to ground or less, 100A or less installed indoors, in other than dwelling units, in wet locations shall be GFCI protected.

    (a) True
    (b) False

15. Grounded conductors _____ AWG or larger can be identified by distinctive white or gray markings at their terminations.

    (a) 10
    (b) 8
    (c) 6
    (d) 4

16. Installations of communications equipment that are under the exclusive control of communications utilities, and located outdoors or in building spaces used exclusively for such installations _____ covered by the *NEC*.

    (a) are
    (b) are sometimes
    (c) are not
    (d) may be

17. Where grounded conductors of different systems are installed in the same raceway, cable, or enclosure, the means of identification of the different neutrals shall be documented in a manner that is _____ or be permanently posted where the conductors of different systems originate.

    (a) available to the AHJ
    (b) available through the engineer
    (c) readily available
    (d) included in the as-built drawings

18. A "_____" is an area that includes a basin with a toilet, urinal, tub, shower, bidet, or similar plumbing fixtures.

    (a) bath area
    (b) bathroom
    (c) rest area
    (d) none of these

19. "_____" is a term indicating that there is an intentional delay in the tripping action of the circuit breaker, which decreases as the magnitude of the current increases.

    (a) Adverse time
    (b) Inverse time
    (c) Time delay
    (d) Timed unit

20. Industry standards are available for application of reconditioned and refurbished equipment. _____ servicing of equipment that remains within a facility should not be considered reconditioning or refurbishing.

    (a) Normal
    (b) Incidental
    (c) Emergency
    (d) none of these

21. A(n) "_____" is a point on the wiring system at which current is taken to supply utilization equipment.

    (a) box
    (b) receptacle
    (c) outlet
    (d) device

22. "_____" means acceptable to the authority having jurisdiction.

    (a) Identified
    (b) Listed
    (c) Approved
    (d) Labeled

23. GFCI protection shall be provided for all 15A and 20A, 125V, single-phase receptacles _____ in dwelling unit kitchens.

    (a) installed to serve the countertop surfaces
    (b) within 6 ft from the top inside edge of the bowl of the sink
    (c) for all receptacles
    (d) a and b

24. The authority having jurisdiction has the responsibility for _____.

    (a) making interpretations of rules
    (b) deciding upon the approval of equipment and materials
    (c) waiving specific requirements in the *Code* and permitting alternate methods and material if safety is maintained
    (d) all of these

25. In other than dwelling locations, GFCI protection is required for all single-phase receptacles rated 150V to ground or less, 50A or less and three-phase receptacles rated 150V to ground or less, 100A or less in _____.

    (a) indoor wet locations
    (b) locker rooms with associated showering facilities
    (c) garages, service bays, and similar areas other than vehicle exhibition halls and showrooms
    (d) all of these

26. A "_____" is an accommodation that combines living, sleeping, sanitary, and storage facilities within a compartment.

    (a) guest room
    (b) guest suite
    (c) dwelling unit
    (d) single-family dwelling

27. In other than dwelling units, all single-phase receptacles rated 150 volts-to-ground or less, 50A or less and three-phase receptacles rated 150 volts-to-ground or less, 100A or less installed in(on) _____ shall have GFCI protection for personnel.

    (a) rooftops
    (b) kitchens
    (c) bathrooms
    (d) all of these

28. This *Code* covers the installation of _____ for public and private premises, including buildings, structures, mobile homes, recreational vehicles, and floating buildings.

    (a) optical fiber cables
    (b) electrical equipment
    (c) raceways
    (d) all of these

29. The minimum height of working spaces about electrical equipment, switchboards, panelboards, or motor control centers operating at 1,000V, nominal, or less and likely to require examination, adjustment, servicing, or maintenance while energized shall be 6½ ft or the height of the equipment, whichever is greater, except for service equipment or panelboards in existing dwelling units that do not exceed 200A.

    (a) True
    (b) False

30. Internal parts of electrical equipment, including _____, shall not be damaged or contaminated by foreign materials such as paint, plaster, cleaners, abrasives, or corrosive residues.

    (a) busbars
    (b) wiring terminals
    (c) insulators
    (d) all of these

31. Hazards often occur because of _____.

    (a) overloading of wiring systems by methods or usage not in conformity with the *NEC*
    (b) initial wiring not providing for increases in the use of electricity
    (c) a and b
    (d) none of these

32. As used in the *NEC*, equipment includes _____.

    (a) fittings
    (b) appliances
    (c) machinery
    (d) all of these

33. A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system is called the "_____ conductor."

    (a) main grounding
    (b) common main
    (c) equipment grounding
    (d) grounding electrode

34. Compliance with either the SI or the inch-pound unit of measurement system shall be permitted.

    (a) True
    (b) False

35. Connection by means of wire-binding screws, studs, and nuts having upturned lugs or the equivalent shall be permitted for _____ AWG or smaller conductors.

    (a) 12
    (b) 10
    (c) 8
    (d) 6

36. The *NEC* does not cover electrical installations in ships, watercraft, railway rolling stock, aircraft, or automotive vehicles.

    (a) True
    (b) False

37. GFCI protection shall be provided for all 15A and 20A, 125V, single-phase receptacles installed in a dwelling unit _____.

    (a) attic
    (b) garage
    (c) laundry area
    (d) b and c

38. Service conductors originate at the service point and terminate at the service disconnecting means.

    (a) True
    (b) False

39. Working space shall not be used for _____.

    (a) storage
    (b) raceways
    (c) lighting
    (d) accessibility

40. Conduit installed underground or encased in concrete slabs that are in direct contact with the earth is considered a _____location.

    (a) dry
    (b) damp
    (c) wet
    (d) moist

41. Connected (connecting) to ground or to a conductive body that extends the ground connection is called "_____."

    (a) equipment grounding
    (b) bonded
    (c) grounded
    (d) all of these

42. A switch constructed so that it can be installed in device boxes or on box covers, or otherwise used in conjunction with wiring systems recognized by the *NEC* is called a "_____switch."

    (a) transfer
    (b) motor-circuit
    (c) general-use snap
    (d) bypass isolation

43. A conducting object through which a direct connection to earth is established is a "_____."

    (a) bonding conductor
    (b) grounding conductor
    (c) grounding electrode
    (d) grounded conductor

44. When the *Code* uses "_____," it means the identified actions are allowed but not required, and they may be options or alternative methods.

    (a) shall
    (b) shall not
    (c) shall be permitted
    (d) a or b

45. A Class A GFCI protection device is designed to trip when the current to ground is _____or higher.

    (a) 4 mA
    (b) 5 mA
    (c) 6 mA
    (d) 7 mA

46. A unit of an electrical system, other than a conductor, that carries or controls electric energy as its principal function is a(n) "_____."

    (a) raceway
    (b) fitting
    (c) device
    (d) enclosure

47. All 15A and 20A, 125V, single-phase receptacles installed in _____ of dwelling units shall have GFCI protection.

    (a) unfinished attics
    (b) finished attics
    (c) unfinished portions or areas of basements not intended as habitable rooms and crawl spaces
    (d) finished basements

48. A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class, such as 120/240V, is called "_____voltage."

    (a) root-mean-square
    (b) circuit
    (c) nominal
    (d) source

49. A "stand-alone system" supplies power independently of an electrical production and distribution network.

    (a) True
    (b) False

50. The *NEC* requires that electrical equipment be _____.

    (a) installed in a neat and workmanlike manner
    (b) installed under the supervision of a licensed person
    (c) completed before being inspected
    (d) all of these

NEC CHALLENGE QUIZ **1**

NEC Challenge Quiz [90.1–Chapter 9]

Please use the 2017 *Code* book to answer the following questions.

These questions are based on content in the entire *NEC*. Initially you may find them extremely challenging, but as you work through each quiz of this type, you'll gain more confidence in how your *Code* book is organized and how to find the answers you need.

1. The messenger of messenger-supported wiring shall be supported at dead ends and at intermediate locations so as to eliminate _____ on the circuit conductors.

   (a) static
   (b) magnetism
   (c) tension
   (d) induction

2. All luminaires, lampholders, and any receptacles installed in theater dressing rooms, dressing areas, and makeup areas adjacent to the mirrors and above the dressing table counter(s), shall be controlled by wall switches in the dressing or makeup room(s).

   (a) True
   (b) False

3. A portable electric sign shall not be placed in or within _____ ft from the inside walls of a fountain.

   (a) 5
   (b) 10
   (c) 15
   (d) 20

4. Optical fiber riser cables suitable for use in a vertical run in a shaft or from floor to floor include Types _____.

   (a) OFNP and OFCP
   (b) OFNR and OFCR
   (c) OFNG and OFCG
   (d) OFN and OFC

5. The voltage drop on technical power systems for sensitive electronic equipment shall not exceed _____ percent for feeder and branch-circuit conductors combined.

   (a) 1.50
   (b) 2
   (c) 2.50
   (d) 3

6. Surface nonmetallic raceways and associated fittings shall be supported in accordance with the _____ installation instructions.

   (a) vendor's
   (b) supplier's
   (c) manufacturer's
   (d) engineer's

7. Electrical equipment used in hazardous (classified) locations that is designed for use in the ambient temperature range between _____ requires no ambient temperature marking. For equipment rated for a temperature range other than _____, the marking shall specify the special range of ambient temperatures in degrees Celsius.

   (a) -10ºC and +20ºC
   (b) -10ºC and +30ºC
   (c) -25ºC and +40ºC
   (d) -40ºC and +40ºC

8. Type MI cable shall be supported and secured at intervals not exceeding _____ ft.

   (a) 3
   (b) 3½
   (c) 5
   (d) 6

9. Sprinkler piping shall be permitted to share a cable tray with fire alarm conductors, provided the conductors are supplied by a power-limited source.

   (a) True
   (b) False

10. Dry-type transformers installed indoors rated over _____ shall be installed in a vault.

    (a) 1,000V
    (b) 20,000V
    (c) 35,000V
    (d) 50,000V