Electrician's Math and Basic Electrical Formulas

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Introduction

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About the Author

Mike Holt worked his way up through the electrical trade-from an apprentice electrician to become one of the most recognized experts in the world as it relates to electrical power installation. He was a Journeyman Electrician, Master Electrician, and Electrical Contractor. Mike came from the real world, and his dedication to electrical training is the result of his own struggles as an electrician looking for a program that would help him succeed in this challenging industry.

It is for reasons like this that Mike continues to help the industry by providing free resources such as this document. It is the goal of Mike Holt and everyone on the Mike Holt Team to do everything in our power to aid in your pursuit of excellence.

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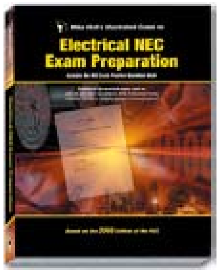
About this Free PDF



This Free Unit was extracted from Mike's *Electrical NEC Exam Preparation* textbook which is why you will notice that this pdf starts with page 3. To fully prepare for your *National Electrical Code* exam you need to study the entire *Electrical NEC Exam Preparation* textbook.

Most electrical exams contain questions on electrical theory, basic electrical calculations, the *Code*, and important and difficult *National Electrical Code* Calculations. The *Electrical NEC Exam Preparation* textbook contains hundreds of illustrations, examples, almost 3,200 practice questions covering all of these subjects and 36 practice quizzes. This book is intended to be used with the 2008 *National Electrical Code*.

UNIT 1

Electrician's Math and Basic Electrical Formulas

Introduction

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 is not visible in the finished structure, but is extremely essential in erecting a building 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 in this unit are the essential basics that you must understand, because you will 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, electrical fundamentals, and an explanation of the operation of electrical meters to help you visualize some practical applications. 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 the concepts of this unit and are able to successfully complete the questions at the end of the unit before going on. A solid foundation will help in your successful study of the rest of this book.

PART A—ELECTRICIAN'S MATH

1.0 Introduction

Numbers can take different forms:

Whole numbers: 1, 20, 300, 4,000, 5,000
Decimals: 0.80, 1.25, 0.75, 1.15
Fractions: 1/2, 1/4, 5/8, 4/3
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 have a fear of algebra, but as you work through the material here you will see there is nothing to fear but fear itself.

1.1 Whole Numbers

Whole numbers are exactly what the term implies. These numbers do not 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, etc.

1.3 Fractions

A fraction represents part of a whole number. If you use a calculator for adding, dividing, subtracting, or multiplying, you need to convert the fraction to a decimal or whole number.

To change a fraction to a decimal or whole number, divide the numerator (top number) by the denominator (bottom number).

► **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 the 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 this value 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 1–1

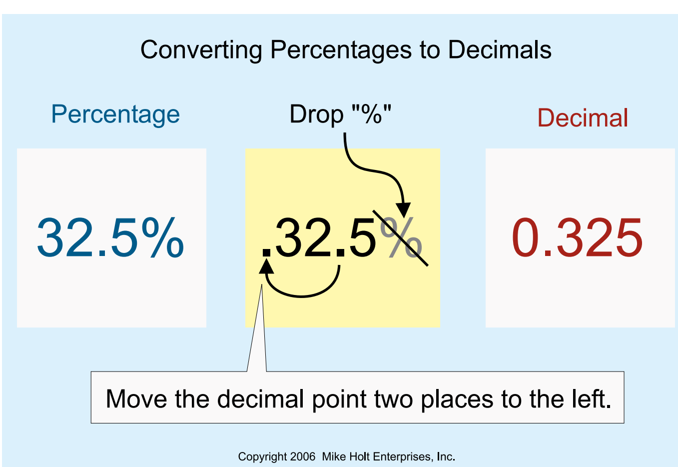


Figure 1–1

► **Examples**

Percentage	**Number**
32.50%	0.325
80%	0.80
125%	1.25
250%	2.50

1.5 Multiplier

When a number needs to be changed by multiplying it by a percentage, this 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 A**

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 1–2

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

• Answer: (b) 100A

Step 1: Convert 125 percent to a decimal: 1.25

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

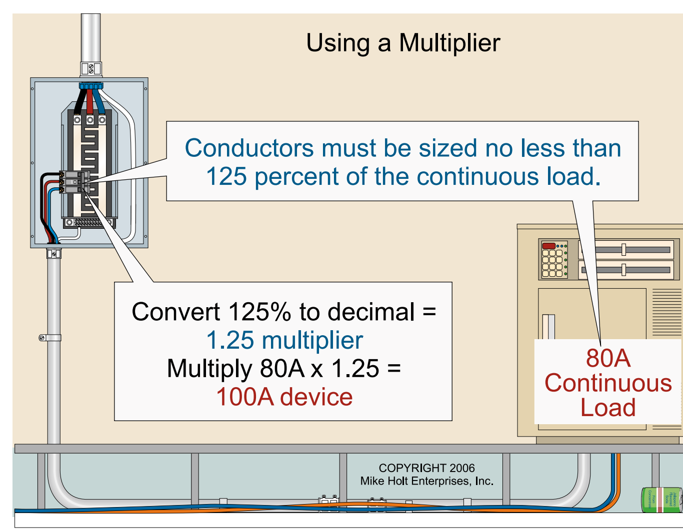


Figure 1–2

► **Example B**

The maximum continuous load on an overcurrent protection device is limited to 80 percent of the device rating. If the protective device is rated 50A, what is the maximum continuous load permitted on the protective device? Figure 1–3

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

• Answer: (a) 40A

Step 1: Convert 80 percent to a decimal: 0.80

Step 2: Multiply the value 50A by 0.80 = 40A

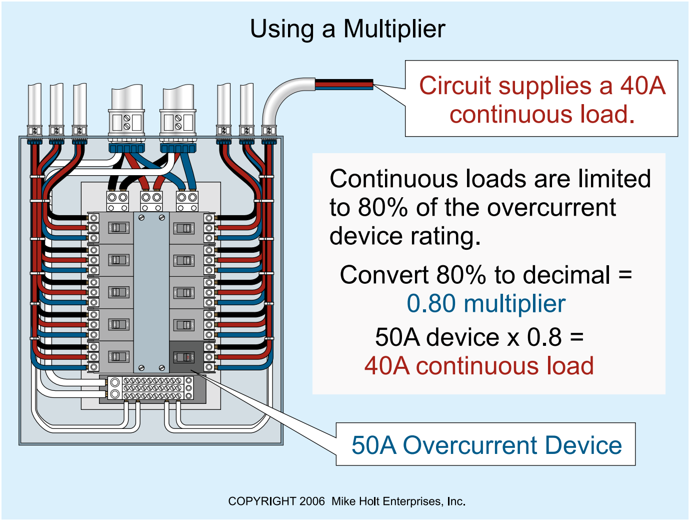


Figure 1–3

1.6 Percent Increase

The following steps accomplish increasing a number by a specific percentage:

Step 1: Convert the percent 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 A

Increase the whole number 45 by 35 percent.

Step 1: Convert 35 percent to decimal form: 0.35

Step 2: Add one to the decimal value: 1 + 0.35 = 1.35

Step 3: Multiply 45 by the multiplier: 1.35: 45 x 1.35 = 60.75

► Example B

If the feeder demand load for a range is 8 kW and it is required to be increased by 15 percent, the total calculated load will be _____. Figure 1–4

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

• Answer: (d) 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 x 1.15 = 9.20 kW

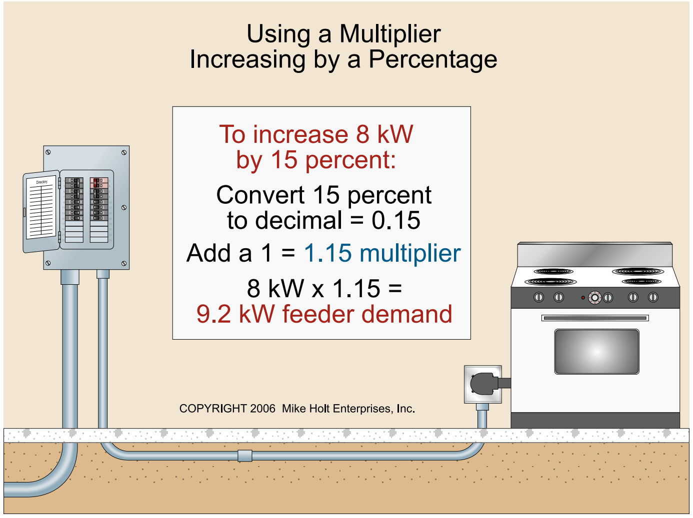


Figure 1–4

1.7 Reciprocals

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

Step 1: Convert the number to a decimal value.

Step 2: Divide the value into the number one.

► Example A

What is 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 B

What is the reciprocal of 125 percent?

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

• Answer: (a) 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 x 10 = 100
23^2 = 23 x 23 = 529

▶ Example A

What is the power consumed in watts by a 12 AWG conductor that is 200 ft long, and has a total resistance of 0.40 ohms, if the current (I) in the circuit conductors is 16A?

Formula: Power = I^2 x R
(Answers are rounded to the nearest 50).

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

• Answer: (c) 100

P = I^2 x R
I = 16A
R = 0.40 ohms

P = $16A^2$ x 0.40 ohms
P = 16A x 16A x 0.40 ohms
P = 102.40W

▶ Example B

What is the area in square inches (sq in.) of a trade size 1 raceway with an inside diameter of 1.049 in.?

Formula: Area = ^{1} x r^2
^{1} = 3.14
r = radius (is equal to 0.50 of the diameter)

(a) 1 (b) 0.86 (c) 0.34 (d) 0.50

• Answer: (b) 0.86

Area = π x r^2
Area = 3.14 x $(0.50 \times 1.049)^2$
Area = 3.14 x 0.5245^2
Area = 3.14 x (0.5245 x 0.5245)
Area = 3.14 x 0.2751
Area = 0.86 sq in.

▶ Example C

What is the sq in. area of an 8 in. pizza? Figure 1–5A

(a) 50 (b) 75 (c) 25 (d) 64

• Answer: (a) 50

Area = π x r^2
Area = 3.14 x $(0.50 \times 8)^2$
Area = 3.14 x 4^2
Area = 3.14 x 4 x 4
Area = 3.14 x 16
Area = 50 sq in.

▶ Example D

What is the sq in. area of a 16 in. pizza? Figure 1–5B

(a) 100 (b) 200 (c) 150 (d) 256

• Answer: (b) 200

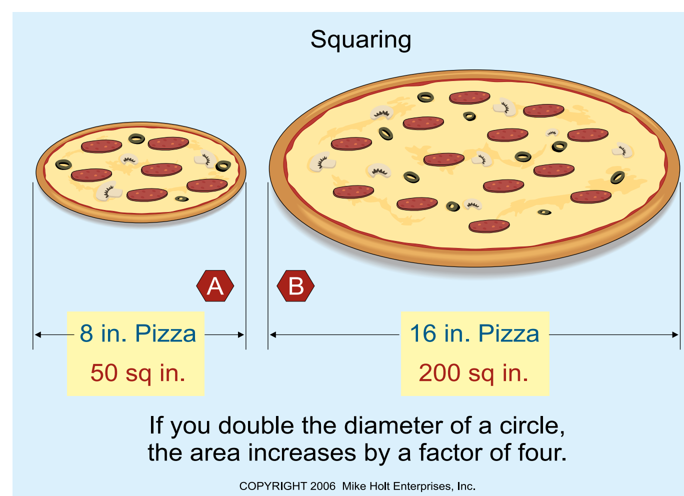


Figure 1–5

Area = π x r^2
Area = 3.14 x $(0.50 \times 16)^2$
Area = 3.14 x 8^2
Area = 3.14 x 8 x 8
Area = 3.14 x 64
Area = 200 sq in.

AUTHOR'S COMMENT: As you see in Examples C and D, if you double the diameter of the circle, the area contained in the circle is increased by a factor of four! By the way, a large pizza is always cheaper per sq in. than a small pizza.

1.9 Parentheses

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

What is the current of a 36,000W, 208V, three-phase load? Figure 1–6

Formula: Ampere (I) = Watts/(E x 1.732)

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

• Answer: (b) 100A

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

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

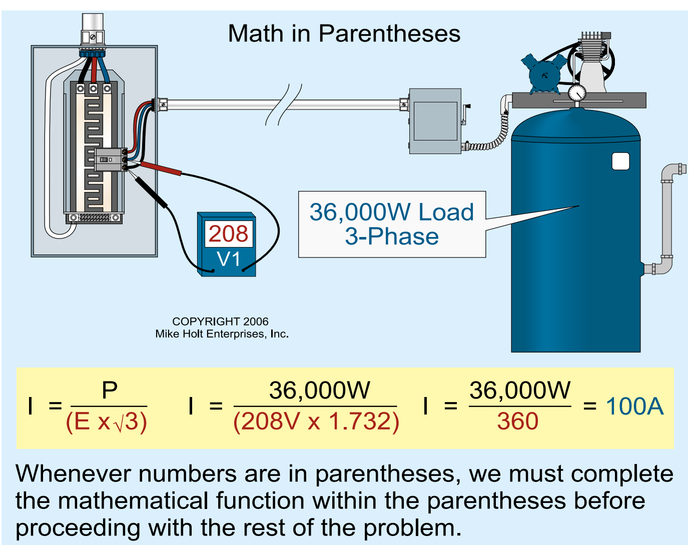


Figure 1–6

► Example

Parenthesis are used to group steps of a process in the correct order. For instance, the sum of 3 and 15 added to the product of 4 and 2.

(3 + 15) + (4 x 2) = 18 + 8 = 26

1.10 Square Root

Deriving the square root (√n) of a number 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 √36 equals six (6), because six, multiplied by itself (6^2) equals the number 36.

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

► Example

√3: Following your calculator's instructions, enter the number 3, then press the square root key = 1.732.

√1,000: enter the number 1,000, then press the square root key = 31.62.

If your calculator does not have a square root key, don't worry about it. For all practical purposes of 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 multiply, divide, add, or subtract a number by a square root value, determine the decimal value, then perform the math function.

► Example A

36,000W/(208V x √3) is equal to _____.

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

• Answer: (d) 100A

Step 1: Determine the decimal value for the √3 = 1.732

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

► Example B

The phase voltage of a 120/208V system is equal to 208V/√3 which is _____.

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

• Answer: (a) 120V

Step 1: Determine the decimal value for the √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 is determined by multiplying the length, by the width, by the depth of the enclosure.

Example

What is the volume of a box that has the dimensions of 4 x 4 x 1½ in.? Figure 1–7

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

• Answer: (b) 24 cu in.
1½ = 1.50
4 x 4 x 1.50 = 24 cu in.

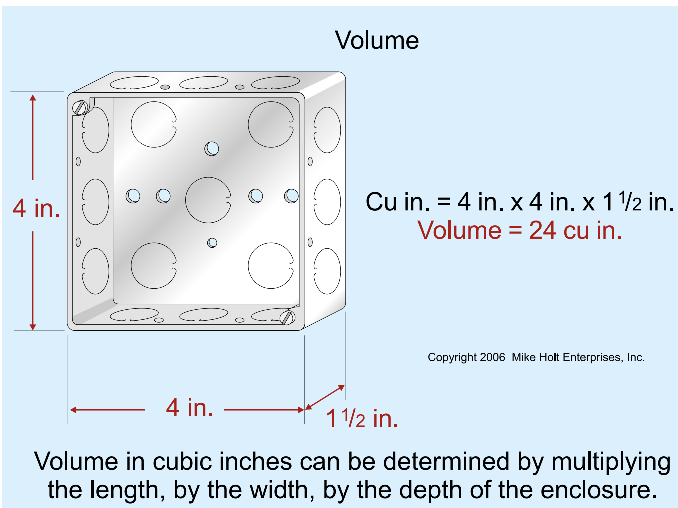


Figure 1–7

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 often corners are rounded, so the allowable volume is given in *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 to units, multiply the number preceding the "k" by 1,000.

Example A

What is the wattage value for an 8 kW rated range?

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

• Answer: (b) 8,000W

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

Example B

A 300W load will have a _____ kW rating. Figure 1–8

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

• Answer: (d) 0.30 kW
kW = Watts/1,000
kW = 300W/1,000 = 0.30 kW

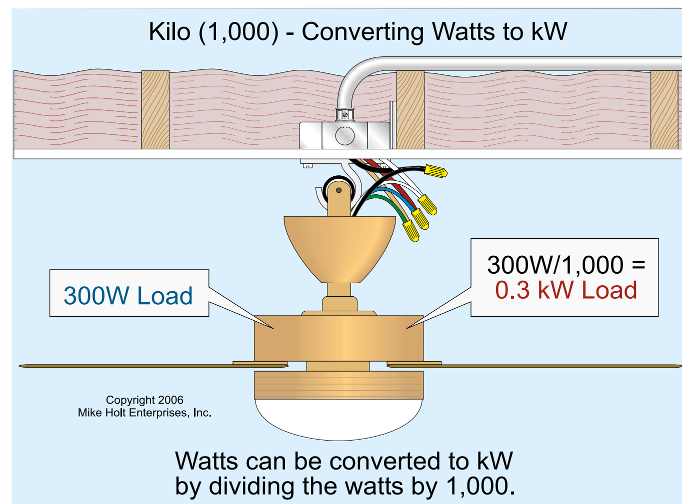


Figure 1–8

AUTHOR'S COMMENT: The use of the letter "k" is not limited to "kW." It is also used for kVA (1,000 volt-amps), and kcmil (1,000 circular mils) and other units such as kft (1,000 feet).

1.13 Rounding Off

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

Examples

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

1.674—fourth number is below five =
1.67 rounded down

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

367.20—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**

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 this is not 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. 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 that your answer is not nonsense. Even the best of us make mistakes at times, so always examine your answer to make sure it makes sense!

► **Example**

The input of a transformer is 300W; the transformer efficiency is 90 percent. Since output is always less than input because of efficiency, what is the transformer output? Figure 1–9

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

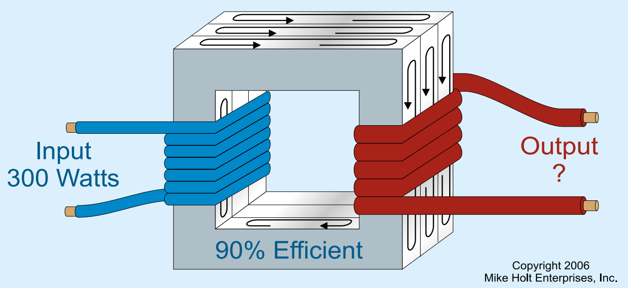
• Answer: (b) 270W

Since the output has to be less than the input (300W), you would not have to perform any mathematical calculation; the only multiple choice selection that is less than 300W is (b) 270W.

The math to get the answer was:
300W x 0.90 = 270W

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

Testing Your Answer for Reasonableness



If you know the output must be less than the input where efficiency is involved, you will know the answer must be less than 300. The only multiple choice selection less than 300 is (b) 270. No calculation is necessary.

Figure 1–9

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 the answer you arrived at back into the equation you are working with, and verify that it is indeed an equality. 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 FORMULAS

Introduction

Now that you've mastered the math and understand some basics about electrical circuits, you are ready to take your knowledge of electrical formulas to the next level. One of the things we are going to do here is strengthen your proficiency with Ohm's Law.

Many false notions about the application of *NEC* Article 250 and *NEC* Chapter 3 wiring methods arise when people use Ohm's Law only to solve practice problems on paper but lack a real understanding of how it works and how to apply it. You will have that understanding, and won't be subject to those false notions—or the unsafe conditions they lead to.

But we won't stop with Ohm's Law. You are also going to have a high level of proficiency with the power equation. One of the tools for handling the power equation—and Ohm's Law—with ease is the power wheel. You will be able to use that to solve all kinds of problems.

1.15 Electrical Circuit

An 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 (on or off). Figure 1–10

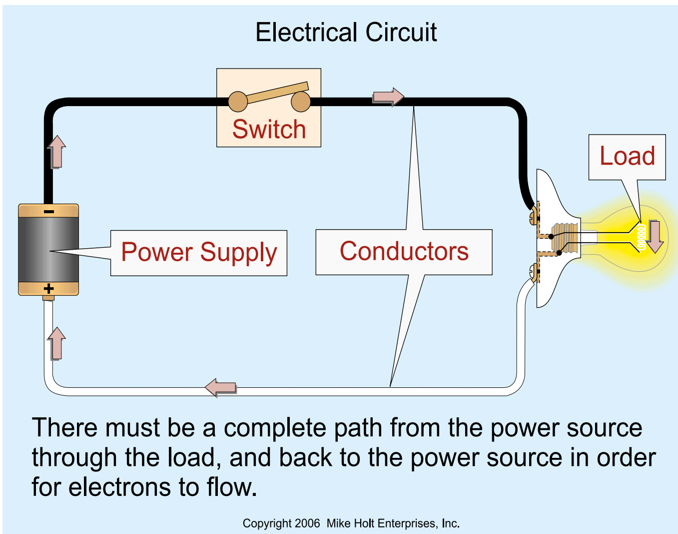


Figure 1–10

AUTHOR'S COMMENT: According to the "electron current flow theory," current always flows from the negative terminal of the source, through the circuit and load, to the positive terminal of the source.

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 dc 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, dc generators, and electronic power supplies. Figure 1–11

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.

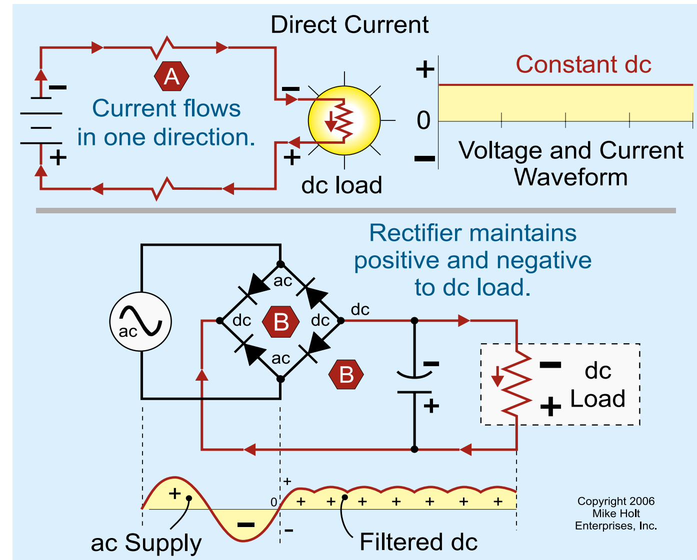


Figure 1–11

Alternating Current

Alternating-current power sources produce a voltage that changes polarity and magnitude. Alternating current is produced by an ac power source such as an ac generator. The major advantage of ac over dc is that voltage can be changed through the use of a transformer. Figure 1–12

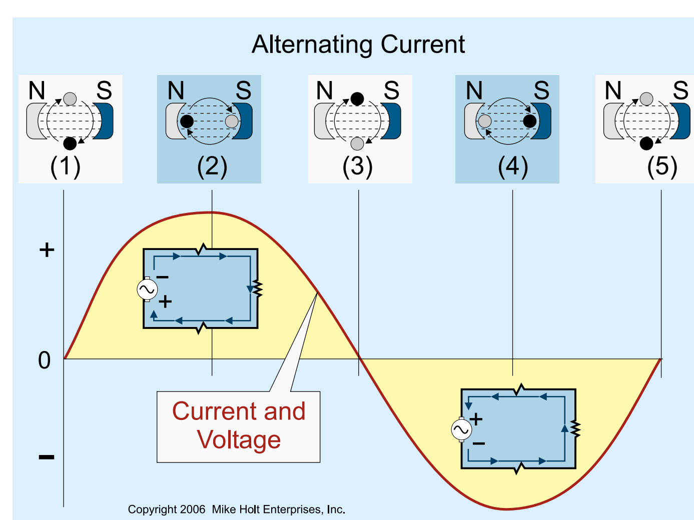


Figure 1–12

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 1–13

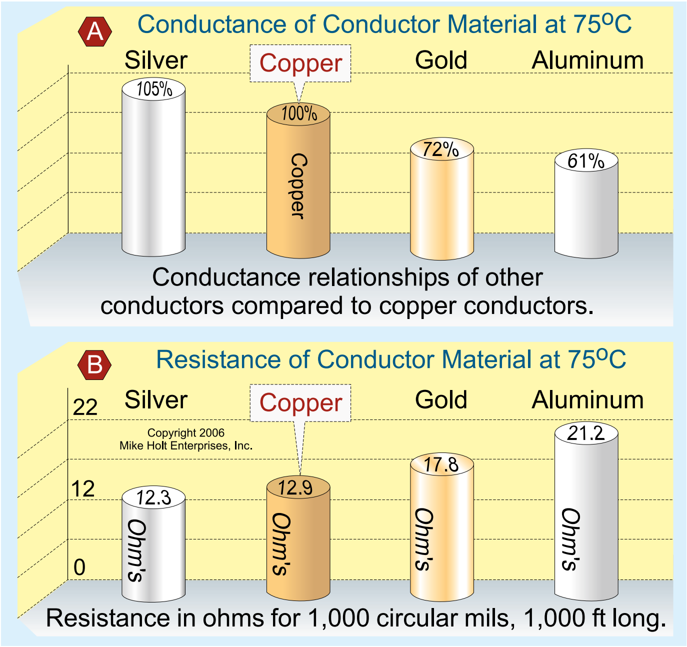


Figure 1–13

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 resistance of the power source and conductor are so much smaller than that of the load, they are generally ignored in circuit calculations. Figure 1–14

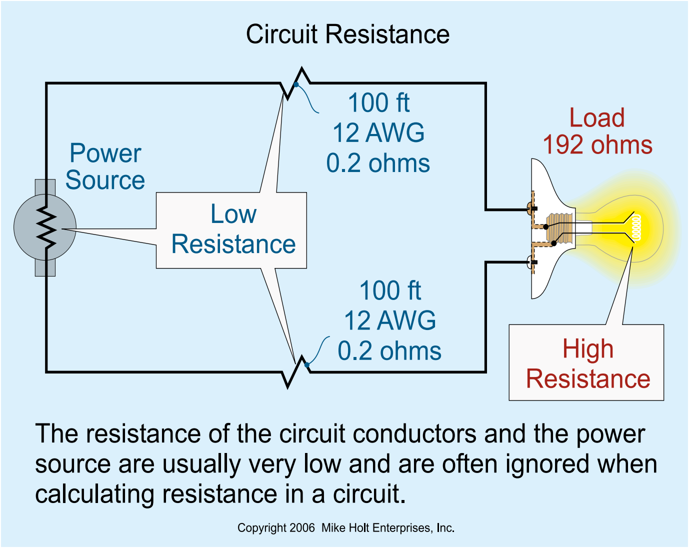


Figure 1–14

1.19 Ohm's Law

Ohm's Law expresses the relationship between a dc 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 German physicist Georg Simon Ohm (1787-1854) stated that current is directly proportional to voltage, and inversely proportional to resistance. Figure 1–15

Direct proportion means that changing one factor results in a direct change to another factor in the same direction and by the same magnitude. Figure 1–15A

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).

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. Figure 1–15B

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).

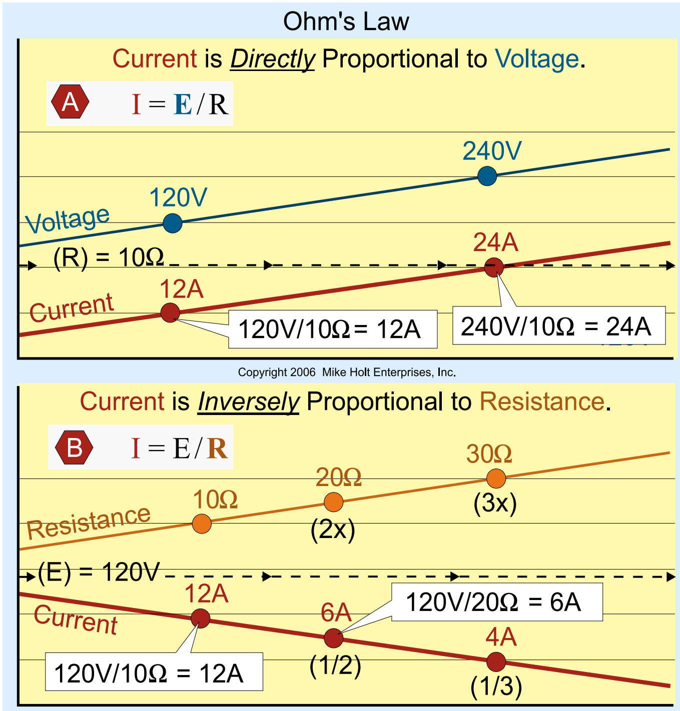


Figure 1–15

AUTHOR'S COMMENT: Place your thumb on the unknown value in Figure 1–16, and the two remaining variables will "show" you the correct formula.

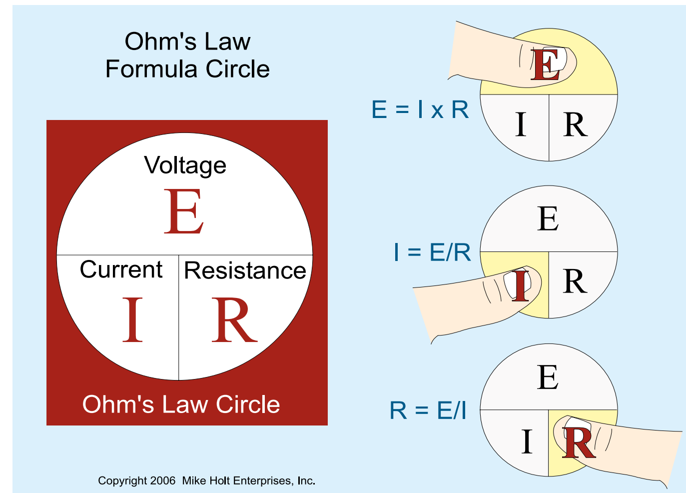


Figure 1–16

1.20 Ohm's Law and Alternating Current

Direct Current

In a dc circuit, the only opposition to current flow is the physical resistance of the material that the current flows through. This opposition is called resistance and is measured in ohms.

Alternating Current

In an ac 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 will assume that the effects of inductance and capacitance on the circuit are insignificant and they will 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 x 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.

► Current Example

120V supplies a lamp that has a resistance of 192 ohms. What is the current flow in the circuit? Figure 1–17

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

• Answer: (a) 0.60A

Step 1: What is the question? What is "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

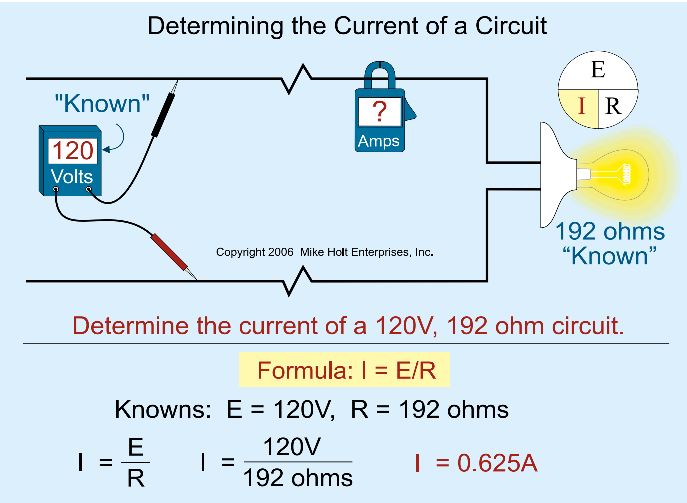


Figure 1–17

► Voltage-Drop Example

What is the voltage drop over two 12 AWG conductors (resistance of 0.20 ohms per 100 ft) supplying a 16A load located 50 ft from the power supply? Figure 1–18

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

• Answer: (d) 3.20V

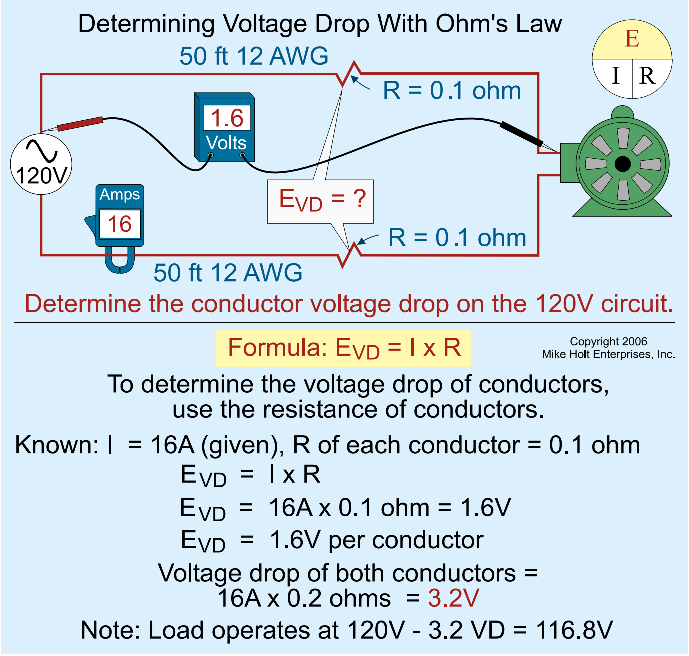


Figure 1–18

Step 1: What is the question? What is "E?"

Step 2: What do you know about the conductors?

I = 16A, R = 0.20 ohms. The *NEC* lists the ac resistance of 1,000 ft of 12 AWG as 2 ohms [Chapter 9, Table 8]. The resistance of 100 ft is equal to 0.20 ohms. Figure 1–19

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

Step 4: The answer is E = 16A x 0.20 ohms

Step 5: The answer is E = 3.20V

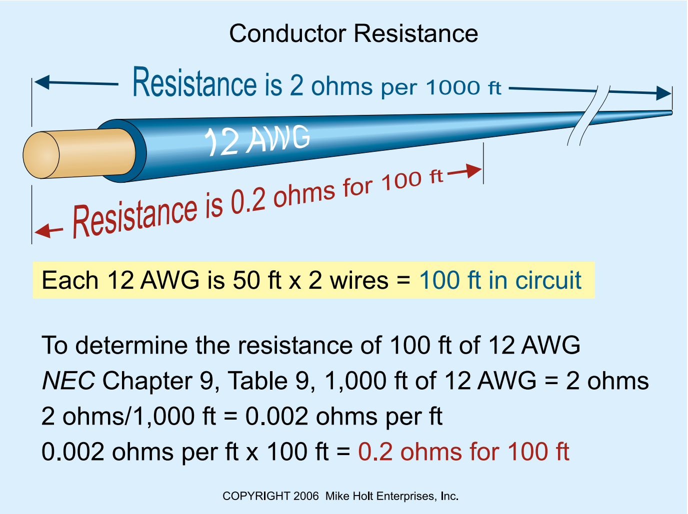


Figure 1–19

► Resistance Example

What is the resistance of the circuit conductors when the conductor voltage drop is 3V and the current flowing in the circuit is 100A? Figure 1–20

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

• Answer: (a) 0.03 ohms

Step 1: What is the question? What is "R?"

Step 2: What do you know about the conductors?

E = 3V dropped, 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

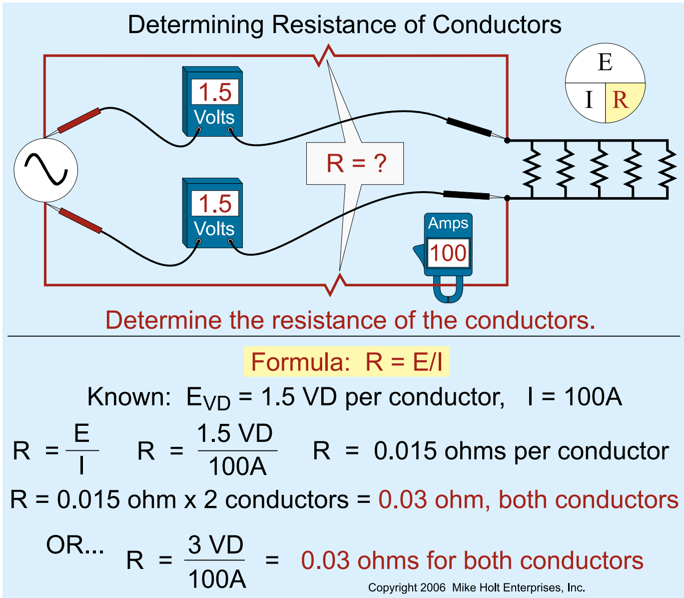


Figure 1–20

1.22 PIE Formula Circle

The PIE formula circle demonstrates the relationship between power, current, and voltage, and it is expressed in the formula P = I x 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 1–21 and the two remaining variables will "show" you the correct formula.

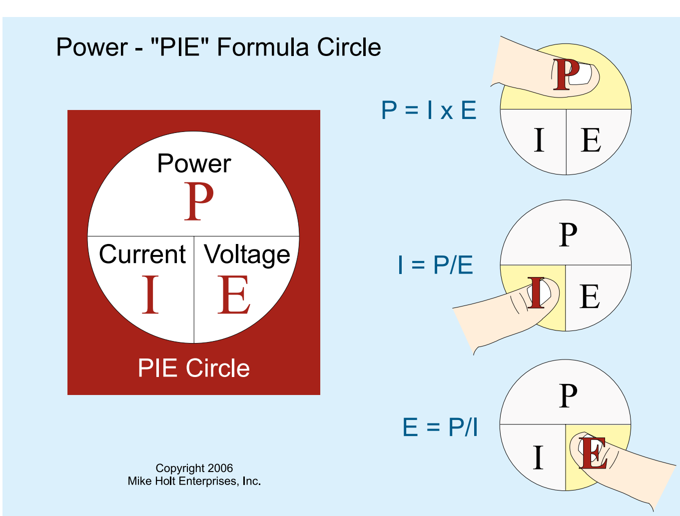


Figure 1–21

▶ Power Loss Example

What is the power loss in watts for two conductors that carry 12A and have a voltage drop of 3.6V? Figure 1–22

(a) 4.3W (b) 43.2W (c) 432W (d) 24W

• Answer: (b) 43.2W

Step 1: What is the question? What is "P?"

Step 2: What do you know? I = 12A, E = 3.60 VD

Step 3: The formula is P = I x E

Step 4: The answer is P = 12A x 3.60V

Step 5: The answer is 43.2W

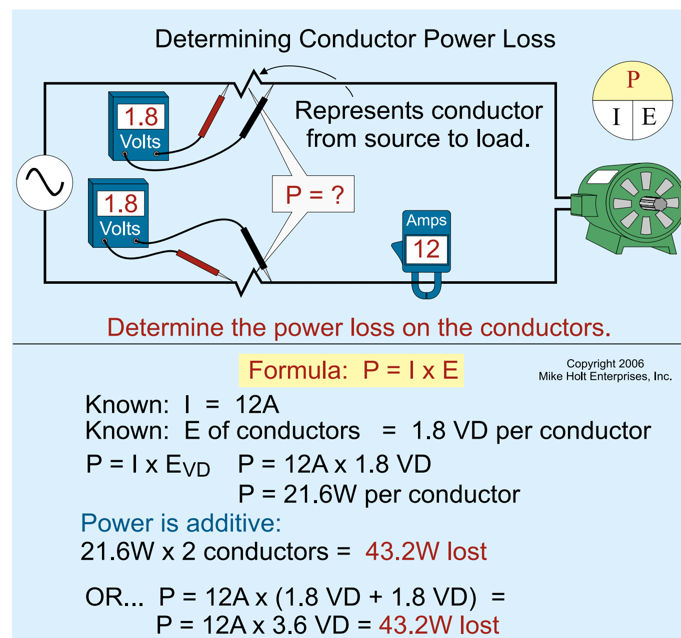


Figure 1–22

▶ Current Example

What is the current flow in amperes through a 7.50 kW heat strip rated 230V when connected to a 230V power supply? Figure 1–23

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

• Answer: (b) 33A

Step 1: What is the question? What is "I?"

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

Step 3: The formula is I = P/E

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

Step 5: The answer is 32.6A

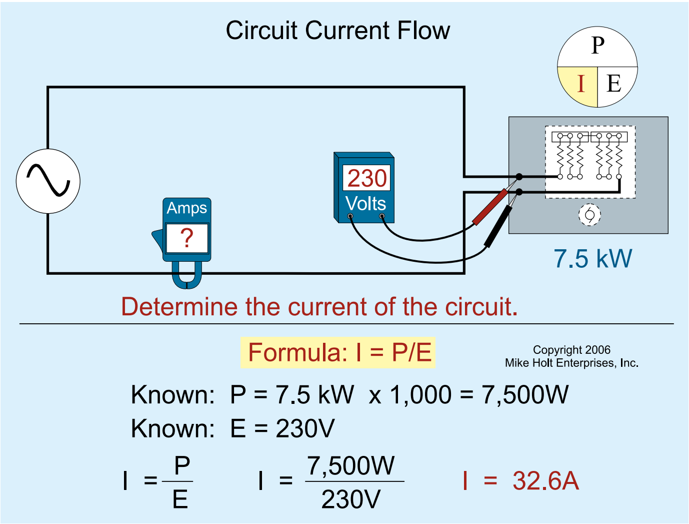


Figure 1–23

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 dc circuits or ac circuits with unity power factor. Figure 1–24

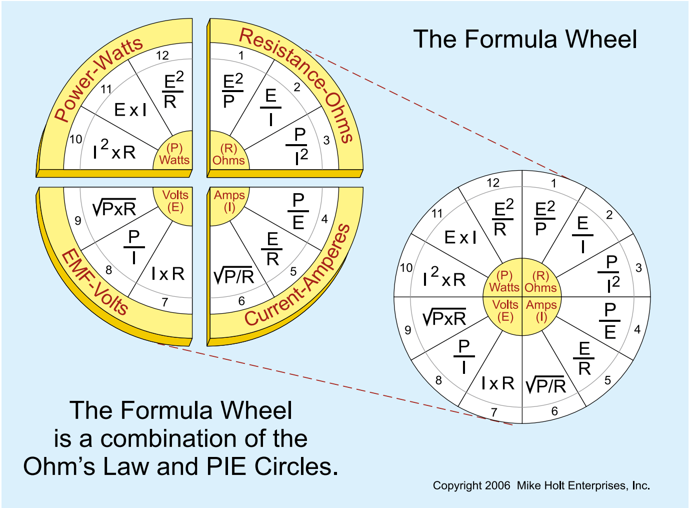


Figure 1–24

AUTHOR'S COMMENT: Unity power factor is explained in Unit 3. For the purpose of this Unit, we will assume a power factor of 1.0 for all ac circuits.

1.24 Using the Formula Wheel

The formula wheel is divided into four sections with three formulas in each section. Figure 1–25. When working the formula wheel, the key to getting 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.

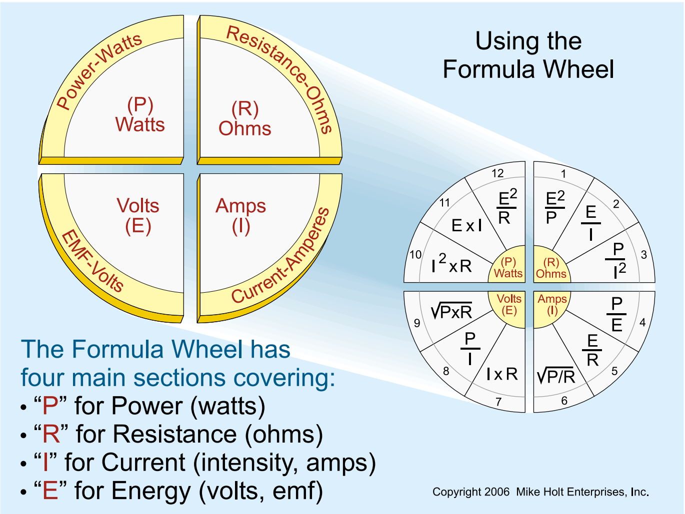


Figure 1–25

► Example

The total resistance of two 12 AWG conductors, 75 ft long is 0.30 ohms, and the current through the circuit is 16A. What is the power loss of the conductors? Figure 1–26

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

• Answer: (b) 75W

Step 1: What is the question? What is the power loss of the conductors "P"?

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

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

Step 4: Calculate the answer: $P = 16A^2 \times 0.30$ ohms = 76.8W
The answer is 76.80W

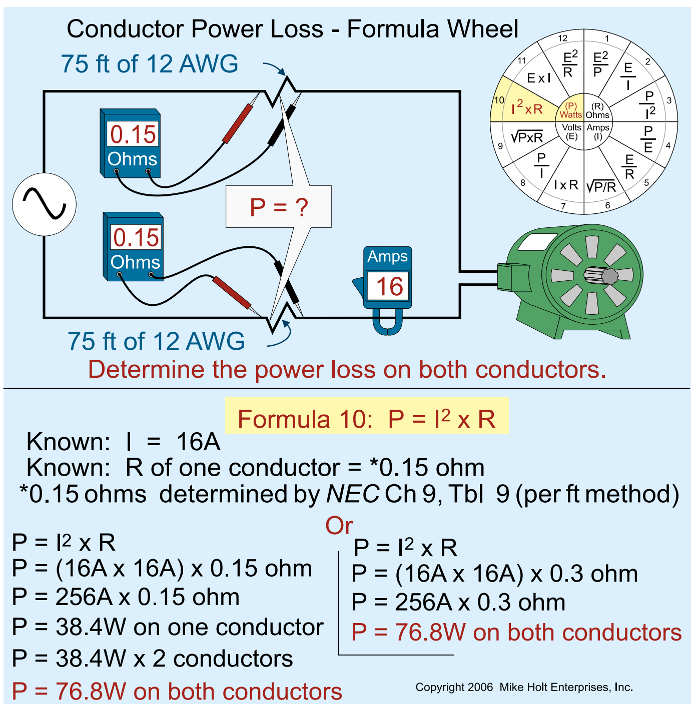


Figure 1–26

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 these power losses.

▶ Example

What is the conductor power loss in watts for a 10 AWG conductor that has a voltage drop of 3 percent and carries a current flow of 24A? Figure 1–27

(a) 17W (b) 173W
(c) 350W (d) none of these

• Answer: (b) 173W

Step 1: What is the problem asking you to find? What is wasted "P"?

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

Step 3: The formula is **P = I x E**

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

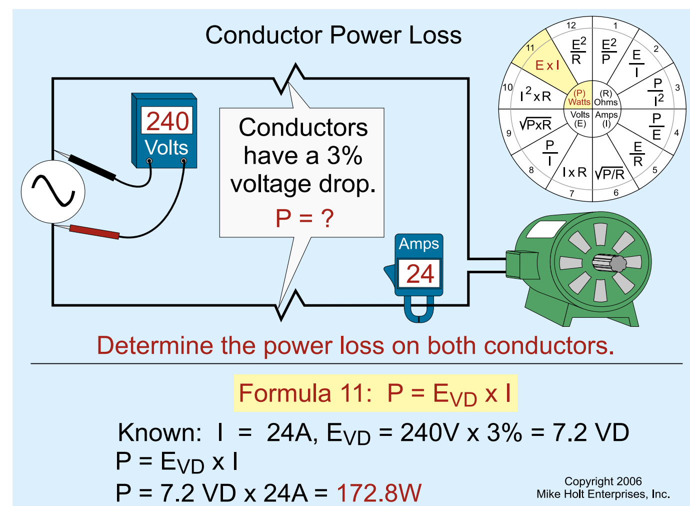


Figure 1–27

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

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 1–28

(a) \$1.30 (b) \$13.00 (c) \$130 (d) \$1,300

• Answer: (c) \$130

Step 1: Determine the power consumed:
$P = I^2 \times R$
$P = 24A^2 \times 0.30$ ohms
P = 172.80W

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

Step 3: Determine cost per hour:
(0.086 dollars per kWh) x 0.172.80 kW =
0.01486 dollars per hr

Step 4: Determine dollars per day:
0.01486 dollars per hr x (24 hrs per day) =
0.3567 dollars per day

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

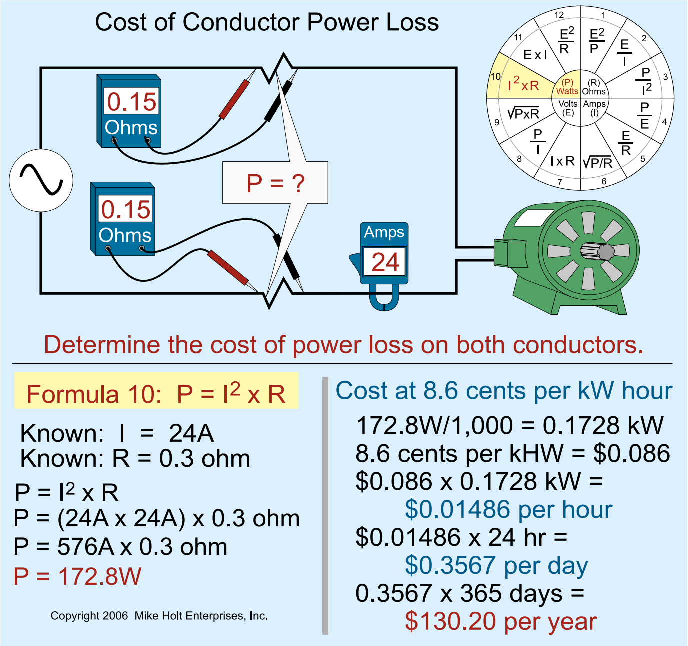


Figure 1–28

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!

1.27 Power Changes with the Square of the Voltage

The voltage applied to a resistor dramatically affects the power consumed by that resistor. Power is determined by the square of the voltage. This means that if the voltage is doubled, the power will increase four times. If the voltage is decreased 50 percent, the power will decrease to 25 percent of its original value. Figure 1–29

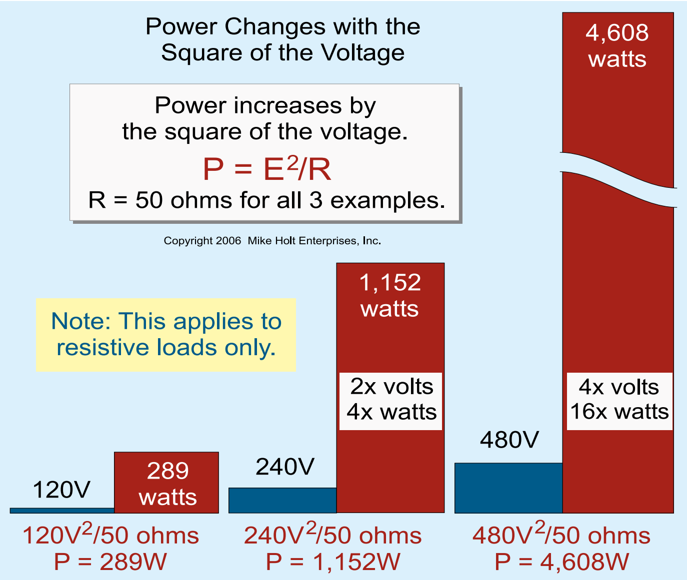


Figure 1–29

► Power Example at 230V

What is the power consumed by a 9.60 kW heat strip rated 230V connected to a 230V circuit? Figure 1–30

(a) 7.85 kW (b) 9.60 kW
(c) 11.57 kW (d) 9.60W

• Answer: (b) 9.60 kW

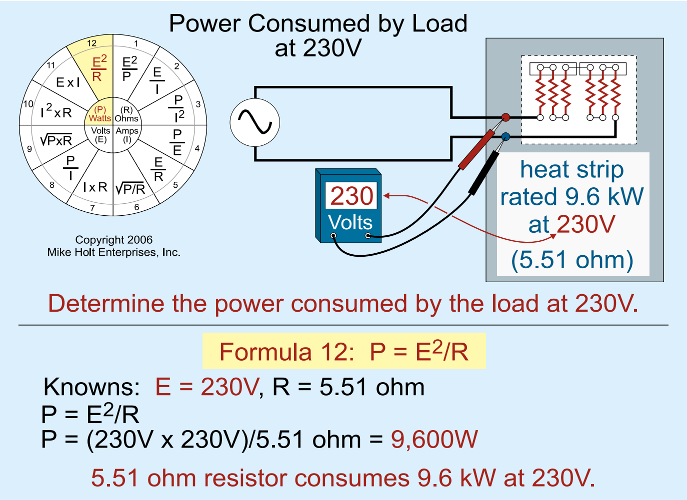


Figure 1–30

Step 1: What is the problem asking you to find?
Power consumed by the resistance.

Step 2: What do you know about the heat strip?
You were given P = 9.60 kW in the statement of the problem.

▶ Power Example at 208V

What is the power consumed by a 9.60 kW heat strip rated 230V connected to a 208V circuit? Figure 1–31

(a) 7.85 kW (b) 9.60 kW
(c) 11.57 kW (d) 208 kW

• Answer: (a) 7.85 kW

Step 1: What is the problem asking you to find?
Power consumed by the resistance.

Step 2: What do you know about the heat strip?
E = 208V, R = E2/P
R = 230V x 230V/9,600W
R = 5.51 ohms

Step 3: The formula to determine power is: $P = E^2/R$

Step 4: The answer is:
$P = 208V^2/5.51$ ohms
P = 7,851W or 7.85 kW

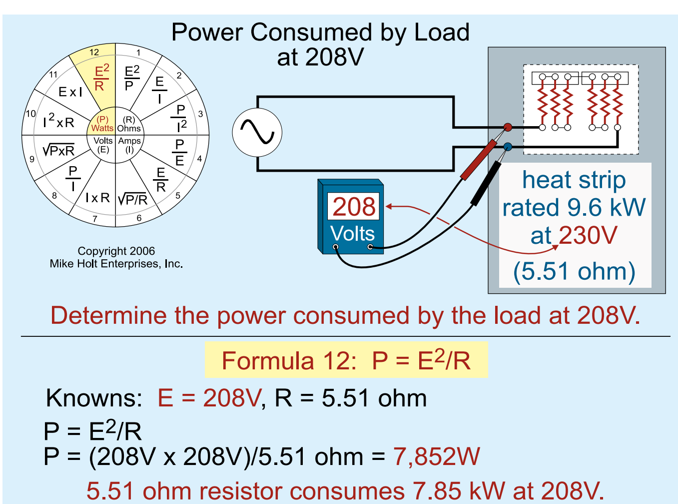


Figure 1–31

AUTHOR'S COMMENT: It is important to realize that the resistance of the heater unit does not change—it is a property of the material that the current flows through and is not dependent on the voltage applied.

Thus, for a small change in voltage, there is a considerable change in power consumption by this heater.

AUTHOR'S COMMENT: The current flow for this heat strip is I = P/E.

P = 7,851W
E = 208V
I = 7,851W/208V
I = 38A

▶ Power Example at 240V

What is the power consumed by a 9.60 kW heat strip rated 230V connected to a 240V circuit? Figure 1–32

(a) 7.85 kW (b) 9.60 kW
(c) 10.45 kW (d) 11.57 kW

• Answer: (c) 10.45 kW

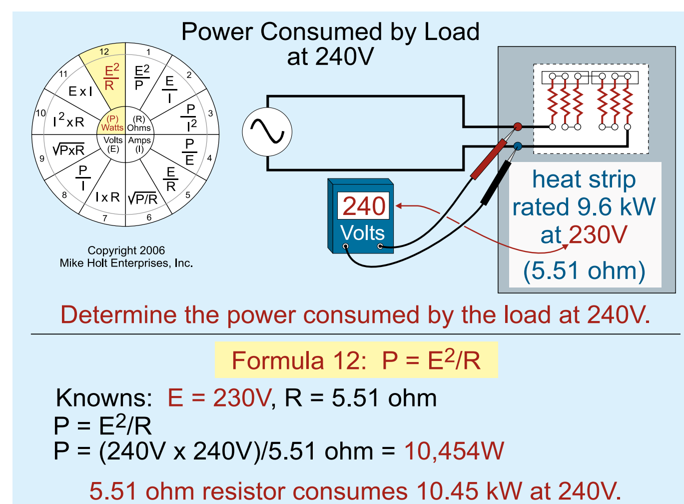


Figure 1–32

Step 1: What is the problem asking you to find?
Power consumed by the resistance.

Step 2: What do you know about the resistance?
R = 5.51 ohms*

*The resistance of the heat strip is determined by the formula $R = E^2/P$.

E = Nameplate voltage rating of the resistance, 230V

P = Nameplate power rating of the resistance, 9,600W

$R = E^2/P$
$R = 230V^2/9{,}600W$
R = 5.51 ohms

Step 3: The formula to determine power is: **$P = E^2/R$**

Step 4: The answer is:
P = 240V x 240V/5.51 ohms
P = 10,454W
P = 10.45 kW

AUTHOR'S COMMENT: The current flow for this heat strip is **I = P/E.**

P = 10,454W
E = 240V
I = 10,454W/240V
I = 44A

As you can see, when the voltage changes, the power changes by the square of the change in the voltage, but the current changes in direct proportion.

UNIT 1 Conclusion

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 have 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 are done—then you'll know you have a right answer every time. As useful as these skills are, there is still more to learn. But, your mastery of the basic electrical formulas means you are 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 in Unit 1, you are ready to tackle the electrical circuits of Unit 2.

UNIT 1 Calculation Practice Questions

PART A—ELECTRICIAN'S MATH

1.3 Fractions

1. The decimal equivalent for the fraction "1/2" is _____.

   (a) 0.50 (b) 5 (c) 2 (d) 0.20

2. The approximate decimal equivalent for the fraction "4/18" is _____.

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

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

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

   (a) 0.03 (b) 0.30 (c) 3 (d) 30.0

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

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

9. The maximum continuous load on an overcurrent protection 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) 6.40 kW (d) 10 kW

1.7 Reciprocals

11. What is the reciprocal of 1.25?

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

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

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

1.8 Squaring a Number

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

    (a) True (b) False

14. What is the power consumed in watts by a 12 AWG conductor that is 100 ft long and has a resistance (R) of 0.20 ohms, when the current (I) in the circuit is 16A? Formula: Power = I^2 x R.

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

15. What is the area in sq in. of a trade size 2 raceway? Formula: Area = Pi x r^2, Pi = 3.14, r = radius (1/2 of the diameter)

    (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 is the maximum distance that two 14 AWG conductors can be run if they carry 16A and the maximum allowable voltage drop is 10V?

    D = (Cmil x VD)/(2 x K x I)
    D = (4,110 cmil x 10V)/(2 x 12.90 ohms x 16A)

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

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

Current: $I = VA/(E \times \sqrt{3})$
Current: $I = 18{,}000W/(208V \times 1.732)$

(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 is the approximate square root of 1,000 ($\sqrt{1{,}000}$)?

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

22. The square root of 3 ($\sqrt{3}$) is _____.

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

1.11 Volume

23. The volume of an enclosure is expressed in _____, and it 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 is 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 is the kW of a 75W load?

(a) 75 kW (b) 7.50 kW (c) 0.75 kW (d) 0.075 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 is the transformer input if the output is lower than the input? Formula: Input = Output/Efficiency

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

PART B—BASIC ELECTRICAL FORMULA

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 dc power source changes direction. One terminal will be negative and the other will be positive.

(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 ac power source never change direction.

(a) True (b) False

33. The major advantage of ac over dc 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 resistance 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 dc 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 ac circuit, the factors that oppose current flow are _____.

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

1.21 Ohm's Law Formula Circle

43. What is the voltage drop of two 12 AWG conductors (0.40 ohms) supplying a 16A load, located 100 ft from the power supply? Formula: $E_{VD} = I \times R$

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

44. What is the resistance of the circuit conductors when the conductor voltage drop is 7.20V and the current flow is 50A? Formula: R = E/I

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

1.22 PIE Formula Circle

45. What is the power loss in watts of a conductor that carries 24A and has a voltage drop of 7.20V? Formula: P = I x E

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

46. What is the approximate power consumed by a 10 kW heat strip rated 230V, when connected to a 208V circuit? Formula: $P = E^2/R$

(a) 8.20 kW (b) 9.3 kW (c) 10.90 kW (d) 11.20 kW

1.23 Formula Wheel

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

(a) dc (b) ac with unity power factor (c) dc or ac circuits (d) a and b

1.24 Using the Formula Wheel

48. When working any formula, the key to getting 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

49. 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 this _____.

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

50. 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 is the power loss of both conductors? Formula: $P = I^2 \times R$

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

51. What is the conductor power loss for a 120V circuit that has a 3 percent voltage drop and carries a current flow of 12A? Formula: $P = I \times E$

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

1.26 Cost of Power

52. What does it cost per year (at 8 cents per kWh) for the power loss of a 12 AWG conductor (100 ft long) that has a total resistance of 0.40 ohms and a current flow of 16A? Formula: Cost per Year = Power for the Year in kWh x $0.08

(a) $33 (b) $54 (c) $72 (d) $89

1.27 Power Changes with the Square of the Voltage

53. 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

54. What is the power consumed by a 10 kW heat strip that's rated 230V, if it's connected to a 115V circuit? Formula: $P = E^2/R$

(a) 2.50 kW (b) 5 kW (c) 7.50 kW (d) 15 kW

UNIT 1 Calculation Challenge Questions

(• Indicates that 75% or fewer of those who took this exam answered the question correctly.)

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, the voltage dropped across the connection will _____.

(a) increase (b) decrease (c) remain the same (d) cannot 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 would most likely indicate _____.

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

1.23 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 of a resistor can be expressed by the formula I^2 x R. If 120V is applied to a 10 ohm resistor, the power consumed will be _____.

(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 x 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

10. When a load is rated 500W at 115V is connected to a 120V power supply, the current of the circuit will be _____. Tip: At 120V, the load consumed more than 500 ohms, but the resistance of the load remains constant.

(a) 3.80A (b) 4.50A (c) 2.70A (d) 5.50A

1.27 Power Changes with the Square of the Voltage

11. A 120V-rated toaster will produce _____ heat when supplied by 115V.

(a) more (b) less (c) the same (d) none of these

12. •When a 100W, 115V lamp operates at 230V, the lamp will consume approximately _____.

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

13. •A 1,500W resistive heater is rated 230V and it is connected to a 208V supply. The power consumed for this load at 208V will be approximately _____.

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

14. •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 _____.

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

UNIT 1 Notes

UNIT 1 CALCULATION PRACTICE QUESTIONS ANSWERS

1. (a) 0.5
2. (d) 0.2
3. (b) left
4. (b) 0.75
5. (c) 2.25
6. (c) 3
7. (d) multiplier
8. (a) 20A

   The overcurrent protection device must be sized 1.25 times larger than the load.
   16A x 1.25 = 20A
9. (b) 80A

   The continuous load must be limited to 80 percent of the rating of the protection device.
   100 x 0.8 = 80A
10. (b) 9.6 kW

    Step 1: -Change the % to its decimal multiplier 20% increase = 1.20

    Step 2: -Multiply the number by the multiplier 8 kW x 1.2 = 9.6 kW
11. (a) 0.8

    Reciprocal of 1.25 = 1/1.25
    Reciprocal of 1.25 = 0.80
12. (c) 80A

    The continuous load must be limited to 80 percent of the rating of the protection device.

    100A x 0.8 = 80A
13. (a) True
14. (b) 50W

    $P = I^2 \times R$
    $P = 16A^2 \times 0.2$ ohms
    P = (16A x 16a) x 0.2 ohms
    P = 51.2W
15. (c) 3 sq in.

    Area = -Pie x r^2
    Pie = 3.14
    r = radius (1/2 of the diameter)

    Area = 3.14 x $(1/2 \times 2)^2$
    Area = 3.14 sq in.
16. (c) 16

    $4^2 = 4 \times 4 = 16$
17. (c) 144

    $12^2 = 12 \times 12 = 144$
18. (c) 100 ft

    D = (Cmil x VD)/(2 x K x I)
    D = -(4,110 Cmil x 10V)/(2 wires x 12.9 ohms x 16A)
    D = 41,100/4,128
    D = 99 ft
19. (b) 50A

$I = VA/(E \times \sqrt{3})$
$I = 18{,}000W/(208V \times 1.732)$
Current = 18,000W/360
Current = 50A

20. (b) False
21. (b) 32
    Enter the number on your calculator, then push the square root key ( ).
22. (a) 1.732
    Enter the number on your calculator, then push the square root key ( ).
23. (a) cubic inches
24. (b) 24 cu in.
    Volume = 4 in. x 4 in. x 1.5 in.
    Volume = 24 cu in.
25. (d) 0.075 kW
    kW = W/1000
    kW = 0.75W/1000
    kW = 0.075 kW
26. (b) 25
    2 + 7 + 8 + 9 = 26, the multiple choice selections are rounded to the nearest "fives."
27. (b) 110W
    The input must be greater than the output.
    Input = Output/Efficiency
    Input = 100W/0.9
    Input = 111W
28. (d) all of these
29. (b) negative, positive
30. (b) False
31. (a) True
32. (b) False
33. (a) True
34. (a) True
35. (b) False
36. (d) silver, copper, gold, aluminum
37. (d) all of these
38. (a) True
39. (d) directly, inversely
40. (d) all of these
41. (b) False
42. (d) all of these
43. (a) 6.4 ohms
    E_{VD} = I x R
    E_{VD} = 16A x 0.4 ohms
    E_{VD} = 6.4 ohms
44. (a) 0.14 ohms

R = E/I
R = 7.2V/50A
R = 0.14 ohms

45. (a) 175W

P= I x E
P = 24A x 7.2V
P = 172.8W

46. (a) 8.2 kW

The power consumed by this resistor will 10,000W if connected to a 230V source. But, because the applied voltage (208V) is less than the equipment voltage rating (230V), the actual power consumed will be less.

Step 1: -Determine the resistance rating of a 10 kW, 230V load.

$R = E^2/P$
$R = 230V^2/10{,}000W$
R = 5.29 ohms

Step 2: --Determine the power consumed for a 5.29 ohm load connected to a 208V source.

$P = E^2/R$
$P = 208V^2/5.29$ ohms
P = (208V x 208V)/5.29 ohms
P = 43,264/5.29
P = 8,178W or 8.2 kW

47. (d) a and b

48. (a) True

49. (d) power loss

50. (b) 100W

$P = I^2$ x R
$P = 16A^2$ x 0.4 ohms
P = (16A x 16a) x 0.4 ohms
P = 102.4W

51. (a) 43W

P = I x E
P = 12A x (120V x 3%)
P = 12A x 3.6V
P = 43.2W

52. (c) $70

Formula: Cost per Year = Power for the Year in kWh x $0.08

Step 1: Determine the power loss per hour.

$P = I^2$ x R
$P = 16A^2$ x 0.4 ohms
P = (16A x 16a) x 0.4 ohms
P = 102.4W per hour

Step 2: -Determine the power loss in kWh for the year.

Power for the Year in kWh = (Power per hour x 24 hours per day x 365 days)/1,000
Power for the Year in kWh = (102.4W x 24 hours x 365 days)/1,000
Power for the Year in kWh = 897 kWh
(continued)

Step 3: -Determine the cost per year for the conductor power losses.

Formula: Cost per Year = kWh per year x Cost per kWh

Cost per Year = 897 kWh x $0.08
Cost per Year = $71.76

53. (b) False

54. (a) 2.5 kW

The power consumed by this resistor will be 10,000W if connected to a 230V source. But, because the applied voltage (115V) is less than the equipment voltage rating (230V), the actual power consumed will be less.

Step 1: -Determine the resistance rating of a 10 kW, 230V load.

$R = E^2/P$
$R = 230V^2/10{,}000W$
R = (230V x 230V)/10,000W
R = 52,900/10,000
R = 5.29 ohms

Step 2: -Determine the power consumed for a 5.29 ohm load connected to a 115V source.

$P = E^2/R$
$P = 115V^2/5.29$ ohms
P = (115V x 115V)/5.29 ohms
P = 13,225/5.29 ohms
P = 2,500W or 2.5 kW

Note: Power changes with the square of the voltage. If the voltage is reduced to 50%, then the power consumed will be equal to the new voltage $percent^2$ or $50\%^2$, or 10,000 x (0.50 x 0.50 = 0.25 = 25%) = 2,500W.

UNIT 1 CALCULATION CHALLENGE QUESTIONS ANSWERS

1. (d) 1,000 VA

2. (d) Salt water

3. (a) increase

4. (b) reduced by half

According to Ohm's Law, current is inversely proportional to resistance. This means that if the resistance goes down, assuming voltage remains the same, the current will increase. It also works in the opposite direction; if the resistance increases, again assuming the voltage remains the same, the current will decrease.

Example: What is the current of a 120V circuit if the resistance is 5 ohms, 10 ohms or 20 ohms? Formula: I =E/R

Answer: At 5 ohmss the current is equal to 24A, at 10 ohms the current is equal to 12A, and at 20 ohms, the current is only equal to 6A

I = 120V/5 ohms = 24A
I = 120V/10 ohms = 12A
I = 120V/20 ohms = 6A

5. (c) a shorted coil

If the reading is less than 30V, this indicates that the length of the coil's conductor must be shorted.

6. (d) any of these pairs of variables

7. (d) 1,440W

The formula I^2 x R in the question has nothing to do with the actual calculation. If we know the voltage of the circuit and the resistance in ohms of the resistor, the formula we need to use is:

$P = E^2/R$
P = 120V2/10 ohms

$P = (120V \times 120V)/10$ ohms
$P = 1{,}440W$

8. (c) $P = I^2 \times R$

9. (b) Less

If current remains the same and resistance increases, then energy consumed will increase.
Example:
$P = I^2 \times R$
$P = 10A^2 \times 5$ ohms
$P = 500W$
$P = 10A2 \times 10$ ohms
$P = 1{,}000W$

10. (b) 4.5A

The power consumed by this resistor will be 500W if connected to a 115V source. But, because the applied voltage (120V) is greater than the equipment voltage rating (115V), the actual power consumed will be greater than 500W.

Step 1: -Determine the resistance rating of a 500W, 115V load.
$R = E^2/P$
$R = 115V^2/500W$
$R = 13{,}225/500$
$R = 26.45$ ohms

Step 2: -Determine the current of a 26.45 ohm load connected to a 120V source.
$I = E/R$
$P = 120/26.45$ ohms
$P = 4.54A$

11. (b) less

When the resistance is not changed, the power will decrease with decreasing voltage. For example a 144 ohm resistor will consume 144W of power at 120V, but only 132W of power at 115V.

$P = E^2/R$
$P = 120V^2/100$ ohms
$P = 144W$
$P = 115V^2/100$ ohms
$P = 132W$

12. (c) 400W

The power consumed by this resistor will be 100W if connected to a 115V source. But, because the applied voltage (120V) is greater than the equipment voltage rating (115V), the actual power consumed will be greater than 100W.

Step 1: -Determine the resistance rating of a 100W, 115V lamp.
$R = E^2/P$
$R = 115V^2/100W$
$R = (115V \times 115V)/100W$
$R = 13{,}225/100$
$R = 132.25$ ohms

Step 2: -Determine the power consumed for a 132.25 ohm load connected to a 120V source.
$P = E^2/R$
$P = 230V^2/132.25$ ohms
$P = (230V \times 230V)/132.25$ ohms
$P = 52{,}900/132.25$ ohms
$P = 400W$

Note: Power increases with the square of the voltage. This means that if the voltage doubled (from 115V to 230V), the power will increase four times.

13. (d) 1,225W

The power consumed by this resistor will be 1,500W if connected to a 230V source. But, because the applied voltage (208V) is less than the equipment voltage rating (230V), the actual power consumed will be less than 1,500W.

Step 1: -Determine the resistance rating of a 1,500W, 230V load.

$R = E^2/P$
$R = 230V^2/1,500W$
$R = (230V \times 230V)/1,500W$
$R = 52,900/1,500$
$R = 35.27$ ohms

Step 2: -Determine the power consumed for a 25.27 ohm load connected to a 208V source.

$P = E^2/R$
$P = 208V^2/35.27$ ohms
$P = (208V \times 208V)/35.27$ ohms
$P = 43,264/35.27$ ohms
$P = 1,227W$

14. (b) 29W

$P = I^2 \times R$
$P = 12A^2 \times 0.20$ ohms
$P = 29W$