Wire types and sizes

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Resources and methods for learning about these subjects (list a few here, in preparation for your research):

Questions

Question 1

In the Unites States of America, an organization known as the *National Fire Protection Association*, or NFPA, publishes an important set of standards called the *National Electrical Code*. What type of information is contained in this set of standards?

file 00278

Question 2

Most electrical wire is covered in a rubber or plastic coating called *insulation*. What is the purpose of having this "insulation" covering the metal wire?

file 00018

Question 3

In the early days of electrical wiring, wires used to be insulated with *cotton*. This is no longer accepted practice. Explain why.

file 00019

Question 4

Describe the difference between *solid* and *stranded* wire types.

file 00275

Question 5

Electrical wire is often rated according to its cross-sectional diameter by a *gauge* scale. Which is the larger-diameter wire size, 14 gauge or 8 gauge?

file 00164

Question 6

Suppose you pick up a piece of electrical wire and notice this label printed on the insulation:

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14 AWG MTW
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What does this label tell you about the wire?

file 00277

Question 7

What is meant by the *ampacity* rating of a wire? What criteria establish the ampacity rating of any given wire?

file 00276

Question 8

Examine the following American Wire Gauge table. Please note that most of the odd-numbered gauges have been omitted, because the even-numbered gauges tend to be more common:

Gauge #	Diameter (inches)	Area (circular mils)
4/0	0.4600	211,600
3/0	0.4100	168,100
2/0	0.3650	133,225
1/0	0.3250	105,625
1	0.2890	83,521
2	0.2580	66,564
4	0.2040	41,616
6	0.1620	26,244
8	0.1280	16,384
10	0.1020	10,404
12	0.0810	6,561
14	0.0640	4,096
16	0.0510	2,601
18	0.0400	1,600
20	0.0320	1,024
22	0.0253	640.1

How many gauge numbers must you increase to (approximately) double the diameter of any given wire gauge? What effect does the doubling of diameter have on the cross-sectional *area* of the wire?

file 03380

Question 9

How many gauge American Wire Gauge sizes must you increase to (approximately) double the ampacity of any given wire gauge?

file 01956

Question 10

Describe what *electrical conduit* is, and what applications it is commonly used in. Contrast "conduit" against *raceways* and *wire trays*.

file 00281

Question 11

What is a *busbar*?

file 00279

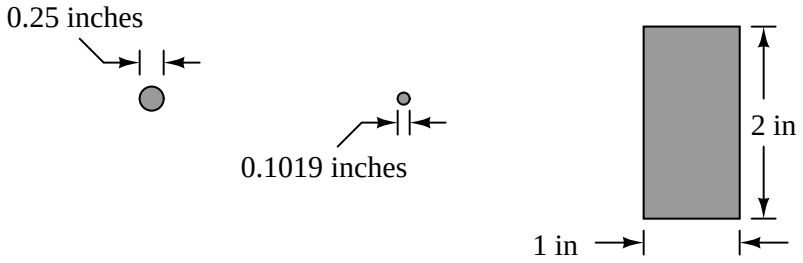
Question 12

The cross-sectional area of wires is often measured in units of *circular mils* rather than square inches or other common area units. Explain how the "circular mil" is defined, and how it is calculated for round wires.

file 01954

Question 13

Determine the cross-sectional area of these conductors (viewed from one end), in units of "square inches" as well as "circular mils":



file 00280

Question 14

Small electrical wires are almost always sized by *gauge* rather than by *circular mils* (cmils). So, if you had to calculate the resistance of a length of 22-gauge copper wire and did not have the proper tools to measure the wire's diameter, how could you find the equivalent cross-sectional area in circular mils so as to use the equation $R = \frac{\rho l}{A}$?

file 01955

Question 15

If an electric drill is plugged into a very long extension cord instead of being plugged directly into a power receptacle, what will happen to the drill's performance? Explain your answer, with reference to Ohm's Law.

file 00386

Question 16

Find a piece of wire or electrical cable and bring it with you to class for discussion. Identify as much information as you can about your conductor prior to discussion:

- Gauge
- Ampacity
- Voltage rating of insulation
- Temperature rating of insulation
- Insulation type (plastic, Teflon, silicone, etc.)
- Insulation service (conduit, wireway, direct burial, etc.)

file 01154

Answers

Answer 1

The NEC contains standards regarding the installation of electrical power circuits (primarily), but also communications and control circuitry. It is the predominant reference for construction electrical work of all types.

Answer 2

The purpose of *insulation* covering the metal part of an electrical wire is to prevent accidental contact with other conductors of electricity, which might result in an unintentional electric current through those other conductors.

Answer 3

Cotton, like many natural fibers, is an electrical insulator . . . until it becomes wet!

Answer 4

"Solid" wire is formed from a single strand of metal. "Stranded" wire is formed from multiple strands, wound together.

Answer 5

8 gauge is the larger diameter.

Answer 6

This label indicates the gauge of the wire (`14 AWG`) and the type of insulation (`MTW`) it has. You didn't think I would just tell you what "MTW" meant, did you?

Answer 7

The "ampacity" of a wire is its maximum rated current. I won't tell you what criteria establish the ampacity rating of a wire, but I will say that you will find the characteristics of the insulation coating a wire has as much to do with a wire's ampacity as the physical characteristics of the metal itself!

Answer 8

Wire diameter approximately doubles once for every six wire gauge sizes. Cross-sectional area *quadruples* for the same wire gauge interval.

Answer 9

The "rule of thumb" here is that a change of three gauge sizes will either double or halve the ampacity, depending on which way the gauge size changes.

Answer 10

"Conduit" is large-diameter metal tubing used as pathways for electrical wires and cables.

Answer 11

A "busbar" is a conductor of unusually large cross-sectional area.

Answer 12

The "circular mil" is defined as the area of a circle with a diameter of $\frac{1}{1000}$ inch (a diameter of one *mil*).

Answer 13

From left to right:

0.049 in^2	0.008 in^2	2.0 in^2
62,500 cmil	10,384 cmil	2,546,479 cmil

Answer 14

This information may be found in a *wire gauge table*, where gauge numbers and circular mil values are cross-referenced.

Answer 15

The drill will not perform with as much power as it would if directly plugged into a power receptacle.

Challenge question: draw an equivalent schematic diagram showing the resistance of the extension cord conductors as resistors with the labels R_{wire1} and R_{wire2}.

Answer 16

If possible, find a manufacturer's datasheet for your type of wire to discuss with your classmates.

Notes

Notes 1

NEC code books are rather large, so students may feel inclined to limit their answers to what is included in the "Answer" for this question. However, you should challenge them to look deeper into an NEC book and discover the wealth of information contained therein.

Specifically, ask them to describe some of the "Article" topics typically found in an NEC book.

Notes 2

Not only is this question practical from the standpoint of understanding circuit function, but also from the perspective of electrical safety. Why is it important for wires to be insulated? Are overhead power lines insulated like the wires used in classroom projects? Why or why not? How were electrical wires insulated before the advent of modern plastics technology?

Notes 3

This question affords the opportunity to discuss electrical safety with regard to clothing (often made of cotton). Does dry clothing offer insulation to electricity like the old-style cotton wire insulation? Can cotton clothing be trusted to insulate you safely from hazardous voltage?

Notes 4

A good follow-up question to this would be to ask, "What are some of the advantages and disadvantages of solid versus stranded wire?" Challenge your students to consider such issues as cost, physical flexibility, and ease of connections.

Notes 5

For students familiar with shotguns, the methodology of the wire gauge scale makes sense. For just about everyone else, the gauge scale seems "backward."

Notes 6

It is important that students know where to look for information like this, because they will surely come across unique wire types in their later experience, and will need to know how to identify the wire.

Notes 7

Be sure to ask your students what resource(s) proved helpful in researching the answer to this question. Being essentially a safety issue, there are several industry publications on electrical safety regulations that may prove informative.

This question connects several important principles together: physical ratings of materials, power dissipation in metallic conductors, and electrical safety. Challenge your students to "connect" these principles on their own by probing their knowledge with follow-up questions.

Notes 8

Wire gauge numbers and diameters for this table were taken from table 2-85 of the *American Electrician's Handbook* (eleventh edition) by Terrell Croft and Wilford Summers. Area in circular mils for each AWG size was calculated from the given diameter.

Notes 9

Although this rule is only approximate, it is useful to know!

Notes 10

If you happen to have pieces of conduit available for demonstration, show them to your students during discussion time. Better yet, take them to a place where they can see electrical conduit in use!

Be sure to ask them questions about the other methods (raceways, wire trays) of laying wire, and how these methods compare with rigid conduit.

Notes 11

Ask your students to describe possible applications for busbars. Where would they typically encounter such huge conductors of electricity?

Notes 12

Explain how this is analogous to the "square inch" being defined as the area of a square measuring one inch on a side. If you need to approach the definition in smaller conceptual steps, you might want to first define what a "circular inch" is before you define what a "circular mil" is.

Notes 13

Calculating the cross-sectional area of the 1×2 busbar in units of circular mils may be challenging for some students, because an equation directly relating linear dimensions to circular mil area may not be easy to obtain. However, even in the event that no equation can be found, there is a way to solve for the busbar's area in units of circular mils by observing the answers obtained for the other two conductors' areas.

Notes 14

Show your students a wire gauge table, if their textbooks do not already contain one.

Notes 15

Students who have worked with power tools, especially on construction sites where long extension cords are commonly used, will be familiar with this phenomenon. Ask your students what effect different gauges of wire in the extension cord would have on this degradation of drill motor performance. Also, ask about different lengths of extension cord. What, exactly, is the electrical quantity that varies with these dimensional changes, that causes the drill motor performance to vary?

Notes 16

The purpose of this question is to get students to kinesthetically interact with the subject matter. It may seem silly to have students engage in a "show and tell" exercise, but I have found that activities such as this greatly help some students. For those learners who are kinesthetic in nature, it is a great help to actually *touch* real components while they're learning about their function. Of course, this question also provides an excellent opportunity for them to practice interpreting component markings, use a multimeter, access datasheets, etc.