

Conductors and Insulators

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

Question 1

What is the difference between materials classified as *conductors* versus those classified as *insulators*, in the electrical sense of these words?

file 00072

Answer 1

Electrical "conductors" offer easy passage of electric current through them, while electrical "insulators" do not. The fundamental difference between an electrical "conductor" and an electrical "insulator" is how readily electrons may drift away from their respective atoms.

For an illustration of electron mobility within a metallic substance, research the terms *electron gas* and "*sea of electrons*" in a chemistry reference book.

Notes 1

It is important to realize that electrical "conductors" and "insulators" are not the same as thermal "conductors" and "insulators." Materials that are insulators in the electrical sense may be fair conductors of heat (certain silicone gels used as heat-transfer fluids for heat sinks, for instance). Materials that are conductors in the electrical sense may be fair insulators in the thermal sense (conductive plastics, for example).

Question 2

Identify several substances that are good conductors of electricity, and several substances that are good insulators of electricity.

file 00073

Answer 2

It is very easy to research (and test!) whether or not various substances are either conductors or insulators of electricity. I leave this task in your very capable hands.

Notes 2

If students have access to simple multimeters, they may perform conductivity tests on various substances with them. This is a fun and interesting classroom activity!

Question 3

What naturally occurring substance is the *best* conductor of electricity?
file 00155

Answer 3

Most people think the answer to this question is *gold*. However, there is another type of metal that conducts electricity better than any other type of metal, including gold! Document where you found your answer to this question.

Notes 3

A few of your students may come across *superconductors* in their research, which of course conduct electricity perfectly (with no resistance to electric current whatsoever). However, the answer I'm looking for here is the non-superconducting metal with the lowest electrical resistance of all.

Question 4

Given two lengths of metal wire, which one will have the least electrical resistance: one that is short, or one that is long? Assume all other factors are equal (same metal type, same wire diameter, etc.).

file 00157

Answer 4

The short wire will have less electrical resistance than the long wire.

Notes 4

Many analogies exist to express this concept: water through a pipe, compressed air through a hose, etc. Which pipe or hose is less restrictive: the short one or the long one?

Question 5

Given two lengths of solid metal wire with round cross-sections, which one will have the least electrical resistance: one that is small-diameter, or one that is large-diameter? Assume all other factors are equal (same metal type, same wire length, etc.).

file 00158

Answer 5

The large-diameter wire will have less electrical resistance than the small-diameter wire.

Notes 5

Many analogies exist to express this concept: water through a pipe, compressed air through a hose, etc. Which pipe or hose is less restrictive: the skinny one or the fat one?

Question 6

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

Answer 6

8 gauge is the larger diameter.

Notes 6

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

Question 7

What disadvantages might there be to using undersized wire in an electrical power distribution system, where electricity is transmitted from generators (sources) to "loads" (devices requiring power) far away? What might happen if the wires we choose for this application were to have insufficient cross-sectional area?
[file 00168](#)

Answer 7

An analogy: what would happen if the water pipes in a municipal water supply system were sized too small?

Notes 7

The effects of undersized wiring are multiple: not only is there inefficiency in the system when conductors are too small, but there are safety hazards as well!

Question 8

What disadvantages might there be to using oversized wire in an electrical power distribution system, where electricity is transmitted from generators (sources) to "loads" (devices requiring power) far away? What might be bad about using wires with more than sufficient cross-sectional area for the purpose?

file 00169

Answer 8

An analogy: what would be bad about using oversized water pipes in a municipal water supply system? Nothing, perhaps, once the system was operational. However, what about the cost of building the system?

Notes 8

The bad effects of oversized wiring are more difficult to discern than the bad effects of undersized wiring. With oversized wiring, there is little electrical inefficiency, but this doesn't mean the system is inefficient in other ways! The cost of the wiring itself, of course, is obvious, but there are other costs as well. Brainstorm ideas with your students about the cost-inefficiencies of oversized wiring in an electrical system.

Question 9

What does the *breakdown voltage* (also known as *dielectric strength*) rating for an electrically insulating substance mean?

file 00160

Answer 9

The breakdown voltage, or dielectric strength, rating of an insulator is the maximum amount of applied voltage it may withstand per unit thickness without conducting appreciable current.

Notes 9

This question provides an opportunity for "qualitative" analysis: does the voltage rating of an insulator increase or decrease as its thickness is increased, given a constant dielectric strength?

Question 10

How much voltage can a 50 mm thick piece of mica withstand before breaking down?
file 00161

Answer 10

Approximately 1000 volts, or 1 kV.

Notes 10

Be sure to ask your students where they obtained the dielectric strength rating for mica. Different sources of information may give different figures, which will lead to different answers to this question.

Question 11

Design a circuit to test the breakdown voltage of a material.
file 00167

Answer 11

I won't provide you with a ready-made schematic diagram for such a circuit, but I will give you a hint. If a substance were to be subjected to a voltage in excess of its dielectric strength, what effect(s) would indicate breakdown?

Notes 11

Designs for testing dielectric strength may range from the crude to the sophisticated, but the real point of this question is to challenge students to reason from the effects of high-voltage breakdown to a means of detecting when that takes place, and measuring the voltage needed for it to happen.