202: Principles of electrical science  
**Handout 7: Resistivity**

**Learning outcome**

The learner will:

1. Understand the relationship between resistance, resistivity, voltage, current and power.

**Assessment criteria**

The learner can:

4.3 describe what is meant by resistance and resistivity in relation to electrical circuits.

4.7 state what is meant by the term voltage drop in relation to electrical circuits.

**Resistivity**

Up until now we have assumed that the conductors that form part of the circuit have no resistance. However, every conductor possesses resistance, the value of which depends on four factors:

1. the length of the conductor (L metres)
2. the cross-sectional area of the conductors (CSA mm2)
3. the type of conducting material (ρ Rho)
4. the temperature (t °C).

**Length of conductor**

The conductor length can be considered as being made up of a lot of resistors all in series. If the length of short conductors is L1, L2, L3, etc then the total length LM is made up of short lengths as shown:

|  |
| --- |
| resistivity 01.png |

|  |
| --- |
| resistivity 01.PNG |

Also, if the short conductors have resistances R1, R2, R3 and R4 then the total resistance of the length LM is:

It therefore follows that the resistance of a conductor is proportional to its length:

|  |
| --- |
| (resistance is proportional to length) |

**Example 1**

If a cable has a resistance of 0.15Ω/m what will be the resistance of 320m of the same cable?

Since resistance is proportional length:

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

**Example 2**

If 50m of a conductor have a resistance of 0.01Ω what would be the resistance of 500m of the same cable?

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

**Example 3**

If 750m of a conductor have a resistance of 0.013Ω what will be the resistance of 150m of the same conductor?

Since resistance is proportional to length:

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

**Cross sectional area (CSA) of conductors**

A conductor of cross sectional area (a) can be regarded as being made up of a number of smaller conductors joined together in parallel, as shown.

If the areas of the small conductors are a1, a2, a3, a4, etc then the total area a, made up of small conductors, is calculated by:

|  |
| --- |
| resistivity 02.png |

If the resistances of the small conductors are R1, R2, R3 and R4 then the total resistance RT is given by:

Therefore, the resistance of a conductor is inversely proportional to its CSA.

|  |
| --- |
| (resistance is inversely proportional to area) |

**Example 4**

If the resistance of 100m of a certain conductor is 0.076Ω, calculate the resistance of 100m of the same conductor but with:

1. twice the CSA
2. four times the CSA
3. half the CSA
4. one quarter of the CSA.
5. Since , then:

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |

1. Since , then:

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |

1. Since , then:

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |

1. Since , then:

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |

**Example 5**

If the resistance of 100m of a certain conductor is 1.24Ω, calculate the resistance of 500m of the same conductor but with twice the CSA.

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

But:

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

**Type of conducting material**

Since different materials have a different number of electrons in their structure, it must follow that they will not all have the same resistance to current flow. This resistance to current flow in a material is known as its **resistivity** (symbol ρ ‑ RHO). A material that is a good conductor has a low resistivity, while a poorer conductor will have a higher value. The table below gives the resistivity of some commonly used materials in the electrical industry.

|  |  |
| --- | --- |
| **Material** | **Resistivity at 20°C** |
| Copper | 17.2 x 10-9 ohm metre |
| Aluminium | 26.5 x 10-9 ohm metre |
| Silver | 15.9 x 10-9 ohm metre |
| Gold | 22.4 x 10-9 ohm metre |
| Brass (58% copper) | 59.0 x 10-9 ohm metre |
| Brass (63% copper) | 71.0 x 10-9 ohm metre |

The table lists copper as 17.2 x 10-9 ohm metre at a temperature of 20°C. This means that the resistance of a cubic metre of copper – 1m long by 1m high and 1m deep – has a resistance of 0.0000000172Ω or 17.2 x 10-9Ω when measured across two opposite faces.

|  |
| --- |
| resistivity 03.png |

|  |
| --- |
|  |

but it will be written as 17.2E‑9 for convenience.

Since the resistance of any conductor is directly proportional to length and inversely proportional to its CSA, the formula for calculating the resistance of any conductor is:

|  |  |  |
| --- | --- | --- |
|  | **or** |  |

where:

R = conductor resistance in ohms

ρ = cable resistivity in Ω m

 = cable length in metres

a = cross sectional area (CSA) in metre2.

Cable CSA is usually quoted in mm2 and this will need to be converted to m2. In order to convert:

**Example 6**

Calculate the resistance of 1,000m of 16mm2 (CSA) single copper conductor. Take ρ to be 17.2 x 10-9 ohm metre.

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

**Example 7**

Calculate the resistance of an aluminium wire 100m long and CSA of 25mm2. Take the resistivity of aluminium to be 26.5 x 10-9 ohm metre.

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

**Example 8**

Calculate the resistance of 100m of copper conductor if ρ = 17.2 x 10-9 ohm metre for the material and the CSA is 2.5mm2.

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

**Example 9**

Calculate the resistance of 100m of silver conductor if ρ = 15.9 x 10-9 ohm metre for the material and the CSA is 2.5mm2.

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

**Voltage drop**

As we have demonstrated in this lesson, the conductors themselves will have resistance and, like any resistance will affect the current flow and voltage drop in the circuit. The magnitude of the volt drop will not only depend on the resistance of the cable but also the amount of current being drawn by the load. An example will help to demonstrate this:

**Example 10**

A load with a resistance of 23Ω is connected to 230V supply with a cable that has a total resistance of 0.7Ω. Calculate:

1. The voltage drop in the cable,
2. The voltage that will appear across the load.

|  |  |  |  |
| --- | --- | --- | --- |
|  | R |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
| a) |  |  |  |
|  |  |  |  |
|  |  |  |  |
| b) |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  | As a check, according to Kirchoff’s voltage law: | | |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  | Although not exactly 230 volts, the slight discrepancy can be explained because we rounded the answer for the total current. Kirchoff’s voltage law is proved. | | |