Resistivity of conducting putty

Theory

The electrical resistance of an object depends on its dimensions and the resistivity of the material of which it is made. The relationship between these parameters is:

$$R = \frac{\rho l}{A}$$

Where R = resistance (Ω)
ρ = resistivity (Ωm)
l = length of object (m)
and A = cross-sectional area (m^2)

If you measure the resistance of several different specimens of putty of the same cross-sectional area and plot a graph of R against l you should be able to find the resistivity of the material if the cross-section is known.

Alternatively, if you measure the resistance of specimens of the same length but of different cross-sectional areas and plot a graph of R against 1/A, again the resistivity of the putty can be determined from the gradient of the graph if the fixed length is known.

Apparatus

Conducting putty
Knife
Digital multimeter (DMM)
Copper strips with connecting wires
Rolling boards
Plastic gloves
Half-metre rule

Method

a) Firstly, knead the putty (with gloves on) to soften it. Roll the putty out between the boards into an even cylindrical shape approximately 1.0 – 1.5 cm in diameter. Measure the diameter in several places and calculate the average cross-sectional area of the cylinder.

Using the digital multimeter on a direct resistance reading range, measure the resistance of the putty for various lengths. Embed the copper strips into the putty 'sausage' to ensure consistent pressure of contact. Begin with the two strips as far apart as possible, and move one end towards the other to reduce the length of the putty under test.

b) Roll the putty into a shorter, but larger diameter cylinder and take measurements to enable you to calculate the average cross-sectional area. Again, embed the copper strips into the putty 'sausage' with sufficient putty outside of the strips to ensure a consistent pressure of contact. Record the length between the copper contacts and measure the resistance. Now remove the contacts and roll out **the same** 'sausage' to reduce its diameter. Replace the copper contacts keeping the length between them constant and repeat the measurements. Continue this process until the sausage becomes too thin to use.

Results

For the variation with length, record a table of resistance and corresponding length of the putty 'sausage'. Also record several values of the diameter of the 'sausage' so that you can calculate an average cross-sectional area.

For the variation with area, you need to record a table with columns for resistance and diameter of the 'sausage'. You should also record the length between the connectors.

Analysis

For the variation with length, the equation in the theory can be rearranged as:

$$R = \frac{\rho}{A} l \ (+0)$$

Comparing with $y = mx + c$ it can be seen that if you plot a graph of R against l it would be a straight line of gradient $\frac{\rho}{A}$ which passes through the origin.

- Plot a graph of R *v* *l* and measure the gradient. Don't forget to include a unit.
- Use this gradient and the calculated value of A in m^2 (πr^2 or $\pi d^2/4$) to calculate ρ, again quoting an appropriate unit.

For the variation with area, we can rearrange the equation to give

$$R = \rho l \frac{1}{A} (+0)$$

Again comparing with $y = mx + c$ you can see that a graph of R against $\frac{1}{A}$ should be a straight line of gradient ρl passing through the origin.

- Tabulate values of cross-sectional area, *A* and $\frac{1}{A}$ for each diameter 'sausage'.
- Plot a graph of R *v* 1/A and measure the gradient. Don't forget to include a unit.
- Use this gradient and the length of the putty 'sausage' to calculate a second value for ρ.
- Calculate the percentage difference between your 2 values of resistivity, using the average value in the denominator.

Discussion and Conclusion

It is difficult to specify a precise value for the resistivity of the putty; however the two values you obtain should be the same. Compare the percentage difference between the two results with the percentage uncertainties in your measurements and decide if there is reasonable agreement. Which of the measurements would you expect to introduce the greatest error? You may also want to look at the 'scatter' on your best fit straight lines.

If both of your results are reasonable, then quote an average value for the resistivity of the putty. Alternatively, you may want to quote the value that you consider to be most reliable.