Activity 3: Soil Resistance

Introduction: Archaeologists use the electrical properties of the ground beneath them to search for evidence (as seen on "Time Team"!). In this activity, you will find out some of the variables which affect electrical currents, and then apply your knowledge to finding a buried object.

Key Stage: Physics KS4

National Curriculum Ref: Sc4 1c, d, p

Time: 15 minutes

Pupil learning outcomes: Be able to measure resistance, showing an appreciation of the Earth context.

Context: The electrical resistance of soil can be measured using electrical methods. This is particularly important for archaeological and mineral investigations – looking for buried artefacts, underground water courses or rock features (faults for example) and mineral deposits.

Common misconceptions: It is often not appreciated that: the Earth can transmit electrical currents; the potential difference may vary locally; natural water (containing ions from dissolved minerals) has a low resistance to an electric current, i.e. it readily conducts electricity.

Resource list:

- 3 sand samples (400 cm^3 dry) in three 500 ml beakers
- 150ml distilled water
- 150ml saturated brine (salt water)
- power pack
- ammeter
- voltmeter
- 5 connecting leads and crocodile clips
- 2 steel electrodes (mounted 3cm apart) with volt and amp meters
- iron bar that will fit horizontally inside a beaker

Lead-in: Re-cap Ohms' Law (V=IR).

Activity: Carry out the activity as shown on the pupil sheets.

Since local conditions vary, use a voltage across sand soaked in salt water to get a current of approximately 100 mA: 2-4 volts should be fine. Once the voltage has been measured, leave it set. Measure the current on a suitable meter.

The table below shows figures obtained during a pilot run.

Sample	Voltage (v)	Current (I)	Resistance (R)
Dry sand	4.76	0	Infinity
Sand soaked in deionised water	3.16	0.01	316
Sand soaked in salt water	2,86	0.45	6.3

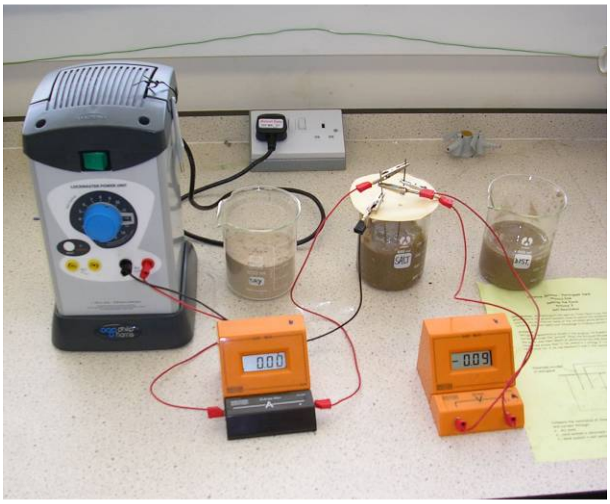
The results show that dry sand has infinite resistance. It cannot conduct electricity because there are no free electrons or ions to carry the current. The lowest resistance is found in the brine-soaked sand where the ion-rich water is able to conduct electricity well.

Thus, the resistance of soil decreases after rain. Since porous sand will contain more water than low porosity sand, it will have lower resistance – and this would help archaeologists find a buried ditch, since the ditch fill is likely to be more porous than the surrounding area.
An important element of the geophysical exploration of boreholes by 'downhole logging' techniques uses electrical measurements to distinguish more porous rocks (low resistance) from less porous ones (higher resistance).

Buried conducting materials, such as the iron bar, greatly reduce resistance, allowing these methods to be effective in prospecting for metal deposits such as copper, iron and zinc ores, but not for non-conducting materials such as limestones, diamonds and china clay.

Note that you have been using the concept of resistance, which is familiar to students in dealing with electrical circuits. Comparisons may be made between the resistance of the different soil samples only if the spacing between the electrodes, their composition and their depth in the soil are kept constant.

In field surveying, the separation of the electrodes is deliberately varied. In this case, the resistivity is calculated (measured in ohm metres). Resistivity is the opposite of conductivity, so a low resistivity value indicates a high conductivity, such as over the buried iron bar.
We can equate the lab experiment with the field situation by saying that, so long as the variables above are kept constant, then resistivity is directly proportional to the resistance, as measured by the students.



Measuring soil resistance *(Activity 3)*

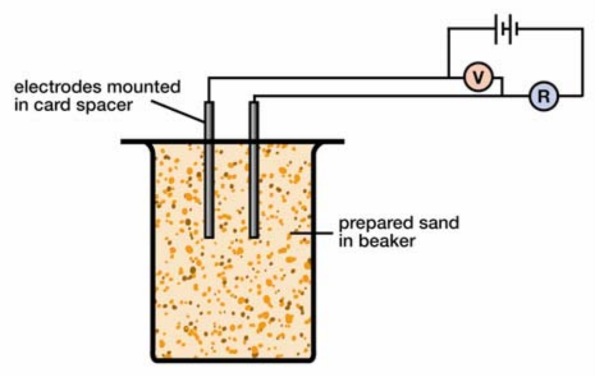
An electrical survey in the field *(Activity 3)*

All photographs can be found in colour on the Earth Science Education Unit website.

Activity 3: Soil Resistance

Introduction:
Archaeologists (as seen on "Time Team"!) use the electrical properties of the ground beneath them to search for evidence. In this activity, you will find out some of the variables, which affect electrical currents, and then apply your knowledge to finding a buried object.

Activity:
Set up the apparatus, using a 500ml beaker, and card spacers with electrodes, which are 3cm apart as shown in the diagram, to enable you to pass a current through the "ground". Keep the distance between the electrodes the same: also their depth of penetration into the sand.
Ohm's Law states that V= IR, where V = voltage; I = current and R = resistance. So, if we can measure V and I, the resistance is given by R= V/I.



Compare the resistance of three sand samples by measuring the voltage and current through:

- 400ml dry sand
- 400ml sand soaked in 150ml deionised water
- 400ml sand soaked in 150ml salt water

Copy the following table, fill in your results and calculate the resistance.

Sample	Voltage (V)	Current (I)	Resistance (R)
Dry sand			
Sand soaked in deionised water			
Sand soaked in salt water			

- Switch off when you have finished.
- Which of the three has the greatest resistance?
- Which of the three has the least resistance?
- How would you expect the resistance of dry soil to change after rain?
- Which would have higher resistance, damp sand with lots of connected pore spaces (high porosity) or damp sand with connected few pore spaces (low porosity).
- How might geophysicists help archaeologists to find a buried ditch?
- How could measuring the resistance be used to indicate the porosity of water-filled sandstones in boreholes?

Follow-up:

Investigate the salt water sample again, but bury a steel bar low down in the beaker. What effect does it have on the resistance?

Copy and complete the following table:

Sample	**P.D. (V)**	**Current (A)**	**Resistance (R)**
Sand soaked in salt water			

- Does the iron bar reduce or increase the resistance?
- How could this method be used in geophysical prospecting?
- Which raw materials might best be prospected for by this method: copper ores; iron ores; zinc ores; limestone; diamonds; china clay?