9. Flow

Using a DC source, investigate how the resistance between two metallic wires dipped into flowing water (or water solution) depends upon the speed and direction of the flow.
9.1. Introduction

- George Simon Ohm (1787-1854)
  - In 1925, he applied for a job as a post in the Jesuit Gymnasium Cologne.
  - As he was asked to make an unpublished work, he decided to study electricity.
    - \[ U = R \cdot i \]
    - \[ R = \rho \cdot \frac{L}{A} \]
  - However, his work was refused, because of the analogy between the electricity conduction and the heat conduction.
9.1. Introduction

- Important definition

- Electrical resistance is basically the difficulty imposed by a certain conductor to the passage of electricity. It can be measured with a multimeter and its unit is the ohm (\(\Omega\)).
9.2. Methodology

- First Experience:
  - Influence of different ions

- Second Experience:
  - Influence of the speed of the flow
  - Influence of the direction of the flow
9.3. Material used

- Digital Multimeter
- Plastic basin (40cm x 26cm x 10cm)
- 2 liter water jar
- Salts: NaCl, Na$_2$SO$_4$
- Small synthetic sponge
- String
- Flowing water
- Scales
9.4. First Experience

Procedure

- In two different recipients, a wide variety of amounts of salt was dissolved in the water in order to verify the influence of both the number of ions per molecule and the salt dissociation.

- Salts used: NaCl ($\alpha=90\%$), Na$_2$SO$_4$ ($\alpha=30\%$)
9.4. First Experience

Results

<table>
<thead>
<tr>
<th>Concentration (mol/L)</th>
<th>Resistance (kilo ohm)</th>
<th>NaCl (90%)</th>
<th>Na$_2$SO$_4$ (30%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.015</td>
<td>430</td>
<td>640</td>
<td></td>
</tr>
<tr>
<td>0.03</td>
<td>300</td>
<td>510</td>
<td></td>
</tr>
<tr>
<td>0.06</td>
<td>250</td>
<td>470</td>
<td></td>
</tr>
<tr>
<td>0.09</td>
<td>210</td>
<td>440</td>
<td></td>
</tr>
</tbody>
</table>
9.4. First Experience

**Results**

![Graph showing the relationship between concentration (mol/L) and resistance (kilo ohm) for NaCl (90%) and Na2SO4 (30%).]
9.5. Second Experience

Procedure

- In order to verify how the resistance between the wires depends on the speed of the flow, electrodes were dipped into four different situations.

- Besides, this experience was repeated in different flow directions, as it is shown in Pictures 2 and 3.
Picture 3
9.5. Second Experience

## Results

<table>
<thead>
<tr>
<th></th>
<th>0º (parallel)</th>
<th>45º</th>
<th>90º (perpendicular)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.083 L/s</td>
<td>1150 kΩ</td>
<td>940 kΩ</td>
<td>750 kΩ</td>
</tr>
<tr>
<td>0.133 L/s</td>
<td>910 kΩ</td>
<td>830 kΩ</td>
<td>720 kΩ</td>
</tr>
<tr>
<td>0.166 L/s</td>
<td>845 kΩ</td>
<td>780 kΩ</td>
<td>700 kΩ</td>
</tr>
<tr>
<td>0.222 L/s</td>
<td>780 kΩ</td>
<td>730 kΩ</td>
<td>650 kΩ</td>
</tr>
</tbody>
</table>

0.083 L/s = 1L/12s  
0.133 L/s = 1L/7.5s  
0.166 L/s = 1L/6s  
0.222 L/s = 1L/4.5s
9.5. Second Experience

Results

<table>
<thead>
<tr>
<th>Flow (L/s)</th>
<th>Resistance (kΩ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.083 L/s</td>
<td>1L/12s</td>
</tr>
<tr>
<td>0.133 L/s</td>
<td>1L/7.5s</td>
</tr>
<tr>
<td>0.166 L/s</td>
<td>1L/6s</td>
</tr>
<tr>
<td>0.222 L/s</td>
<td>1L/4.5s</td>
</tr>
</tbody>
</table>

- 0° (parallel)
- 45°
- 90° (perpendicular)
9.6. Error Analyses

- Multimeter precision
- Multimeter battery
- Salt dissociation (NaCl, Na₂SO₄)
- Material and sizes of the recipient
- Metallic wires length
9.7. Conclusions

- Salt concentration

- It is possible to conclude that the salt concentration on the water solution dramatically reduces the resistance between the electrodes.

- However, the latter tends to stabilize due to water’s saturation point.
9.7. Conclusions

- Different salts
  - The resistances measured in the first experience confirmed that the bigger is the number of ions dissociated in the solution, the lower is the resistance.
  - Therefore, a good electricity conductor solution should be made with a salt with a big number of ions per molecule and a great dissociation in the liquid.
9.7. Conclusions

- We can also infer that the increase on the water outflow reduces the resistivity between the electrodes.

- This happens because the free ions in the water move faster when the outflow is increased. As a result, more ions conduct electricity between the electrodes per interval of time, reducing the resistance.
9.7. Conclusions

- According to the results, the resistance is lower when the water flows perpendicularly through the electrodes.

- This must occur because the water flows naturally from the top electrode to the bottom one.

- Meanwhile, when the electrodes are parallel to the water flow, the ions are pushed down, increasing the resistance.