Millikan Oil Drop Experiment

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Outline

• Brief History
• Millikan's Experiment
• Method
• Data and Analysis
• Discussion
• Conclusion
Electric Charge

- 600 BC Greeks observe amber rubbed with fur can attract small, light particles.
- 18th Century, Benjamin Franklin and others argue in favor of “one-fluid” theory of electricity.
- 1909 Millikan's oil drop experiment provides strong evidence in favor of electricity being quantized.
Millikan's Experiment

- Drops sprayed into chamber with constant electric field.
- Oil drops ionized by X-rays.
- Entire chamber submerged in diesel oil to stabilize temperature.
- Rising and falling velocities determined.

http://millikan.nbaoh.com/1.htm
Method

- Measure pressure, temperature.
- Insert the focusing wire into the chamber and focus on it.
- Set voltage, spray oil drops through the lid.
- Pick a drop that falls freely with no voltage and rises with voltage.
- Measure time it takes to fall and rise a specific distance.
Method

\[ a = \sqrt{\left(\frac{b}{2p}\right)^2 + \frac{9n\nu_f}{2g \rho}} - \frac{b}{2p} \]

- To find the velocities, time the oil drop as it passes a certain number of lines to measure rising and falling velocities.

\[ q = \left(\frac{4}{3} \pi d \left(\frac{1}{g \rho} \left(\frac{9n}{2}\right)^3\right) \left(1 + \frac{b}{pa}\right) \right)^{\frac{3}{2}} \left(\frac{\nu_f + \nu_r}{V}\right)^{\frac{3}{2}} \]
Data

Q1 ave \((1.7486 \pm 0.13) \times 10^{-19}\) C
Q2 ave \((3.0710 \pm 0.1) \times 10^{-19}\) C
Q3 ave \((4.7374 \pm 0.16) \times 10^{-19}\) C
Q4 ave \((6.1980 \pm 0.24) \times 10^{-19}\) C
Q6 \((9.769 \pm 0.4) \times 10^{-19}\) C

- 30 values for the charge were calculated.
- Uncertainties came from averaging, except for Q6.
- Most of the variables had negligible uncertainty.
Accepted value of $e$

<table>
<thead>
<tr>
<th>Value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chisq: 4.1359</td>
<td>NA</td>
</tr>
<tr>
<td>$\gamma$: 0.99653</td>
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</tbody>
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Residual for accepted
Data

Value of $e$ from data

<table>
<thead>
<tr>
<th>Value</th>
<th>Error</th>
</tr>
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<tbody>
<tr>
<td>m1</td>
<td>1.5744</td>
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<tr>
<td>Chisq</td>
<td>3.1438</td>
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<tr>
<td>R</td>
<td>0.99736</td>
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</tbody>
</table>

Residual for fit from data

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Discussion

$(1.57 \pm 0.03) \times 10^{-19} \text{ C}$

Reduced Chi-square: .79
P-value: about 50%

For the fit to standard value:

Reduced Chi-square: .8
P-value about 50%
Conclusion

- The results are accurate, within one standard deviation of accepted value.
- The data are not precise, 2% uncertainty.
- The data are not statistically significant.
- Many more measurements are needed for a statistically significant outcome.
- If the eyepiece could be connected to a monitor and camera it would make the experiment much easier and faster.
Resources

- http://millikan.nbaoh.com/1.htm
- http://store.pasco.com/pascostore/showdetl.cfm?&DID=9&Product_ID=51874&Detail=1