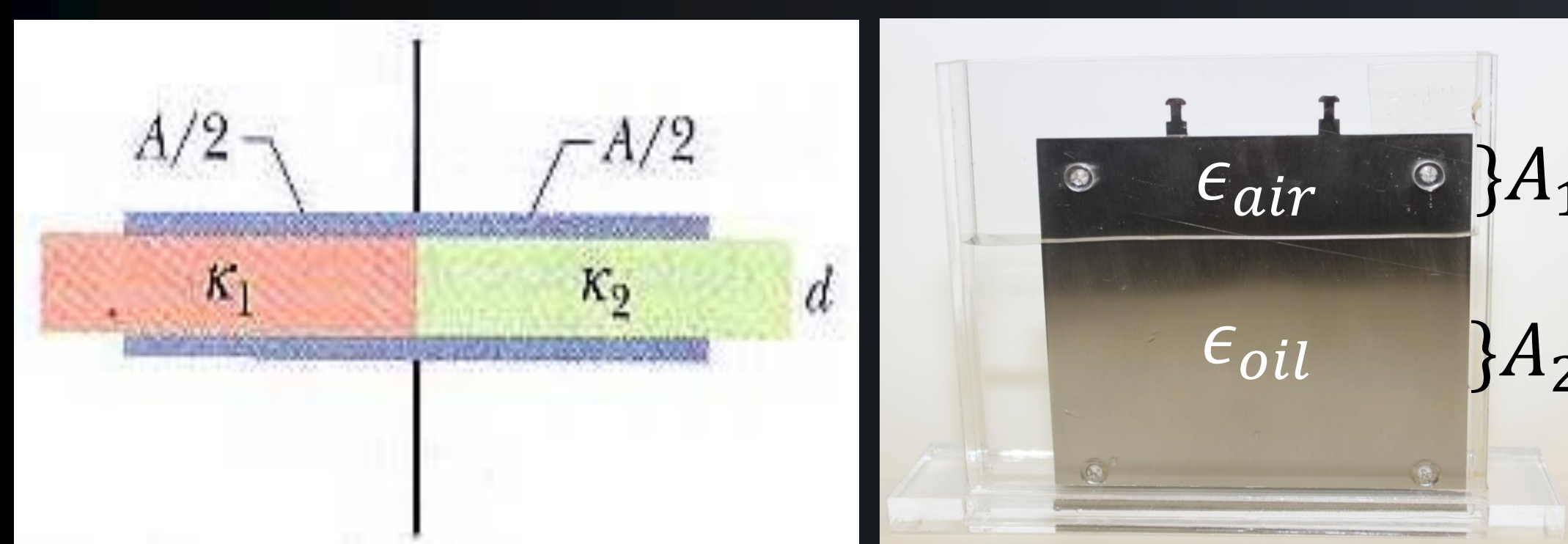# EQUIVALENCE OF A FIXED PARALLEL PLATE CAPACITOR INSTRUMENT AND CAPACITORS IN PARALLEL

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Introduction

- Fixed separation parallel-plate capacitor
- Gauss's Law $\rightarrow$ $C = \frac{\epsilon_0 \epsilon_r A}{d} \rightarrow C_{total} = C_1 + C_2 + \cdots \rightarrow$

$$\frac{\epsilon_0 \epsilon_r A_{total}}{d} = \frac{\epsilon_0 \epsilon_{r_1} A_1}{d} + \frac{\epsilon_0 \epsilon_{r_2} A_2}{d} + \cdots$$

- Using oils as dielectrics – oil with air
- Dielectrics stacked side by side act like separate capacitors in parallel

Apparatus Design

- Parallel plate capacitor (Fig. 1)
  - Two 10 cm x 10 cm metal plates
  - Approximately 1.0 mm fixed separation, maintained by a nylon washer in between the plates
- Plates are held by an open acrylic container (12.5 cm x 2.5 cm x 12.5 cm)
- Acrylic base plate to balance the apparatus
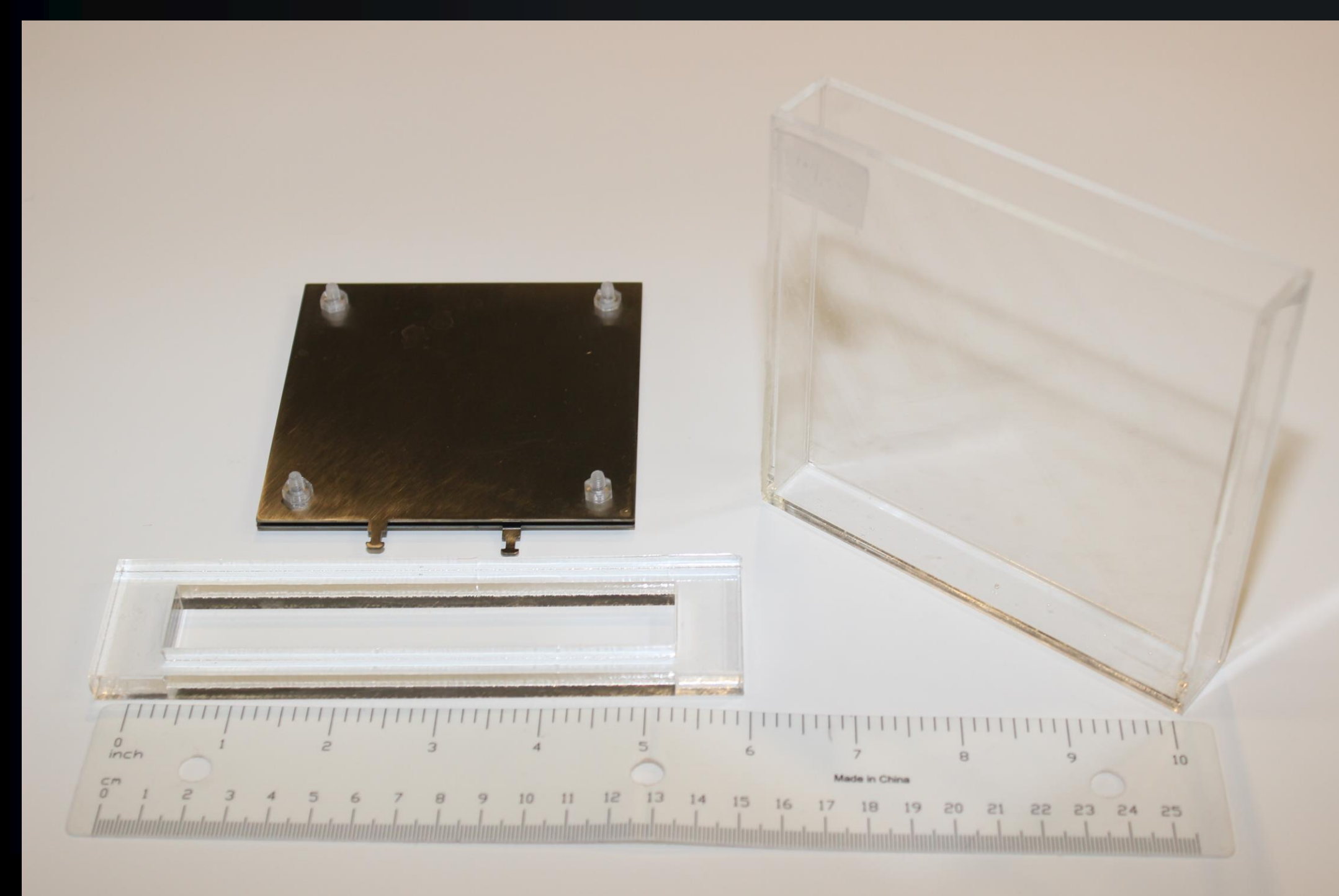
Procedure

1. Place the plates inside the plastic container so that the two tabs are situated in an upward position.
2. Measure the capacitance of the setup without any oil, i.e. using only air as a dielectric.
3. Fill the container with a food grade oil (e.g. corn oil, mineral oil), using a syringe to slowly place oil into the bottom of the container until the oil reaches 2 cm on a ruler parallel to the container.
4. Using a multimeter with a capacitance setting, measure the capacitance across the two plates partially submerged in the oil.
5. Using the depth-measuring probe on Vernier calipers, measure the height of the oil between the plates as the oil will have risen up the inside of the plates due to capillary action.
6. Record the measured capacitance and corresponding height of the oil inside the plates. Plot capacitance as a function of height.
7. Repeat steps 1-6, adding 1 cm of oil until the oil between the plates reaches the top of the capacitor.
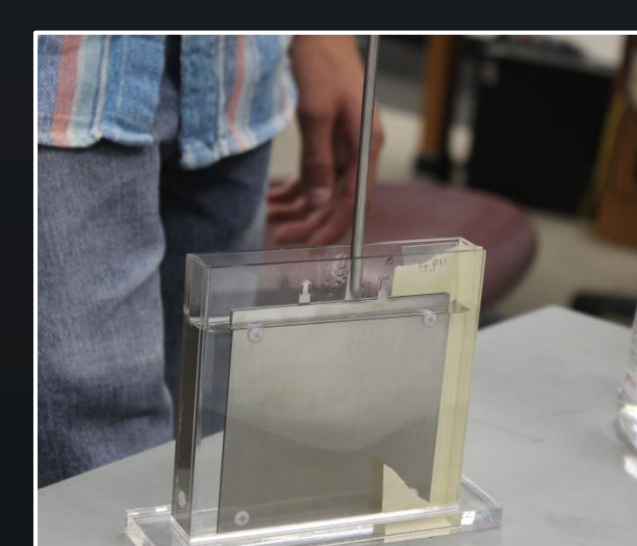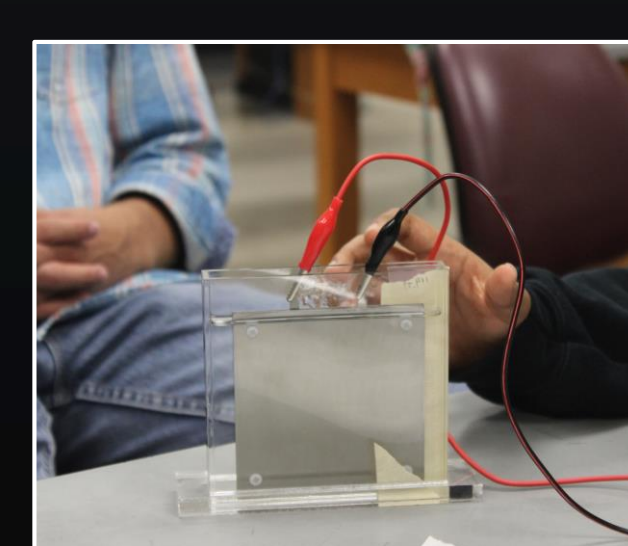

Using a syringe to place oil into the acrylic container
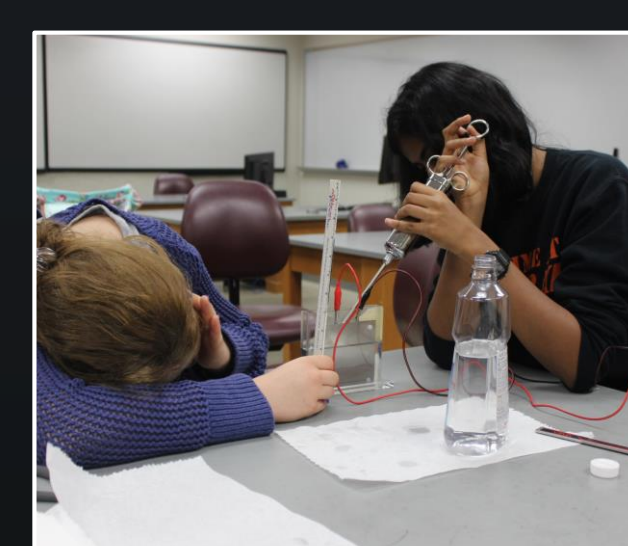
Estimating the height of the oil between the plates

Using a depth-measuring probe to measure the height of the oil

Using a multimeter to measure the capacitance

Results

- Trial 1: corn oil as a dielectric
- Trial 2: mineral oil and air as a dielectric
- The two oils have different relative permittivities calculated by using the ideal capacitance equation
- Capacitance is plotted against the height of the oil (blue data points)
- Second line is plotted using calculated permittivities (red data points), treating the oil and air as two separate capacitors in parallel
- The lines largely overlap $\rightarrow$ adjacent dielectrics (oil and air) behave like separate capacitors in parallel
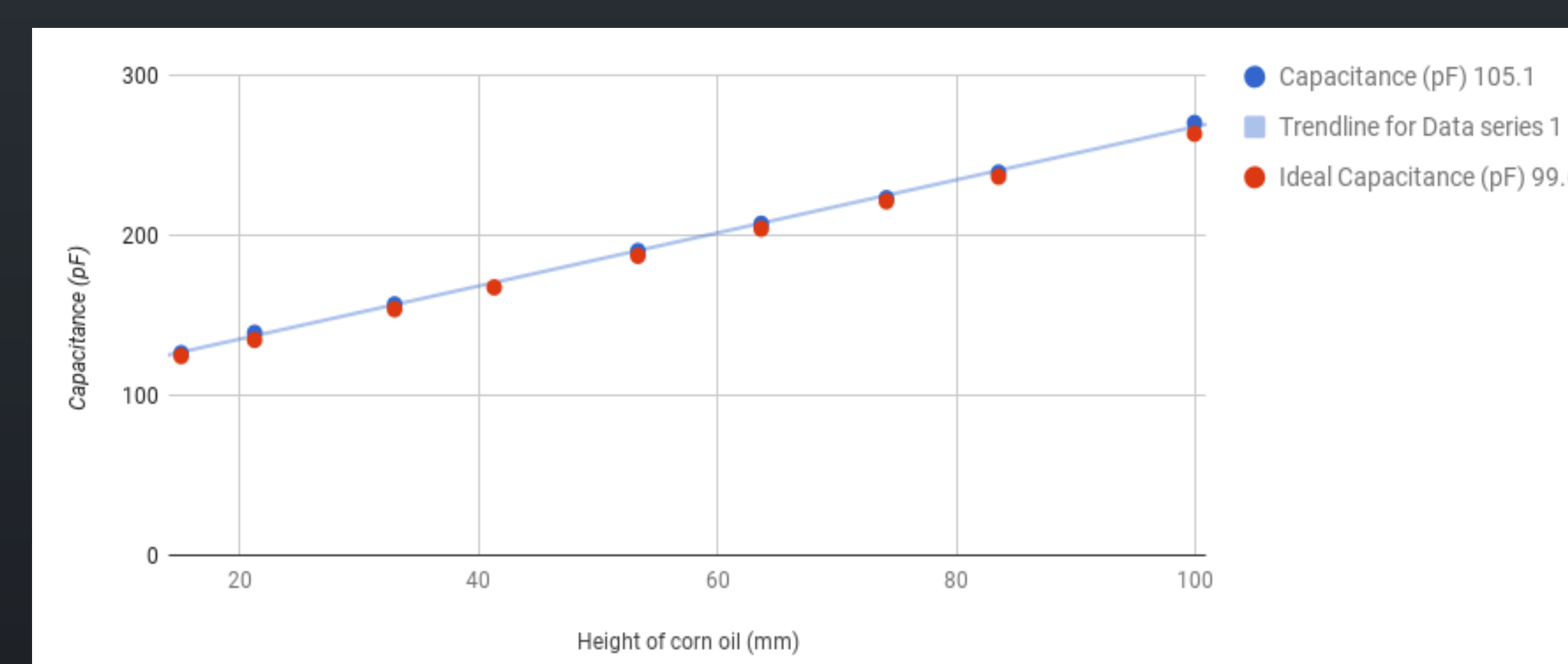

Figure 2. Capacitance of corn oil as a dielectric compared with the ideal equation using corn oil as a dielectric in parallel.
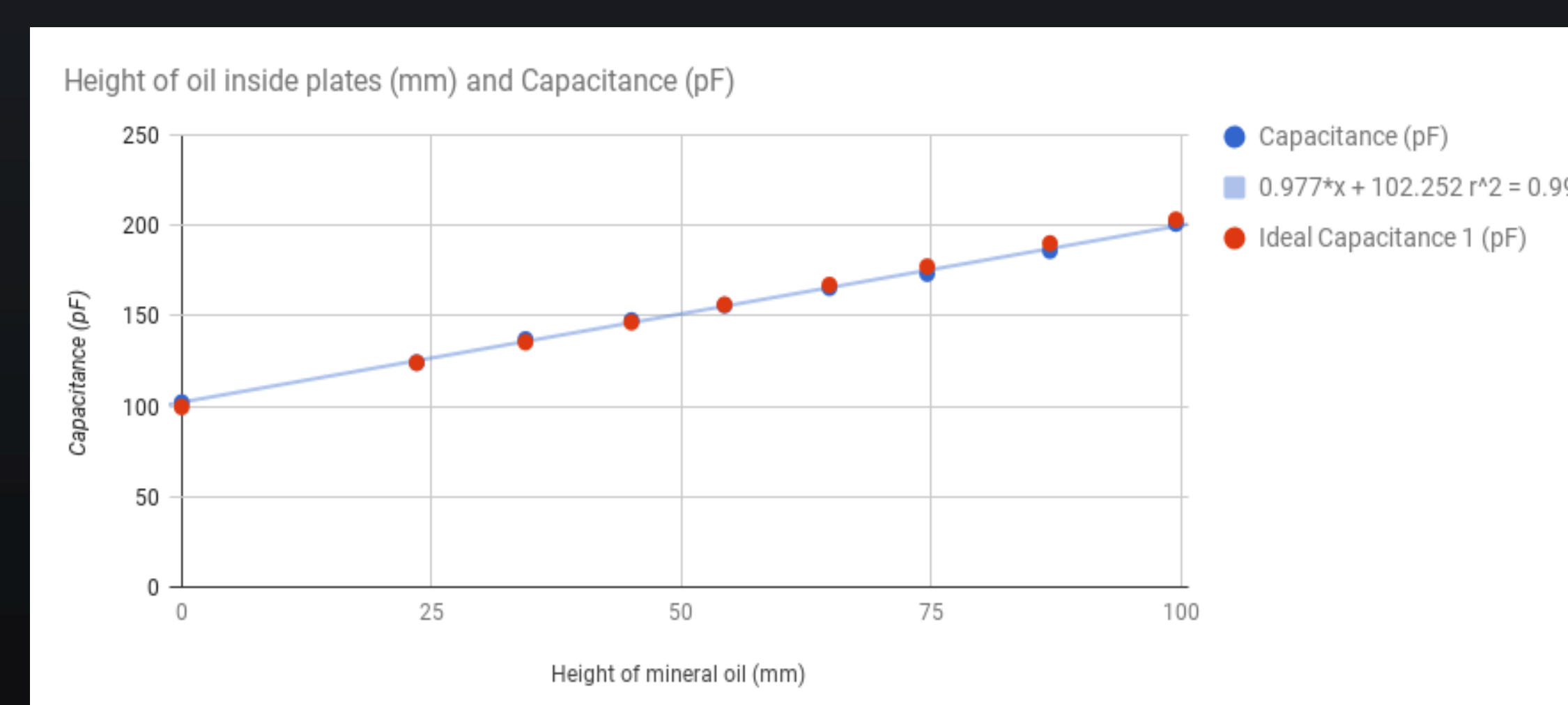

Figure 3. Capacitance of mineral oil as a dielectric compared with the ideal equation using mineral oil as a dielectric in parallel.

Conclusion

- Equipment is accessible to high school and undergraduate laboratories
- Experiment compared measured values from a fixed parallel-plate capacitor instrument with dielectrics adjacent to each other and theoretical values for capacitors in parallel
- Experiments enrich a basic understanding of the comparison between theoretical versus experimental capacitance

References

Baker, E., Farwell, A., Foster, H., Gao, X., Gruber, B., Jones, E., . . . Xu, S. (2016). *QuarkNet 2015 Summer Research at SMU*[PPT]. Dallas: Southern Methodist University.

Camarota, L. (2004, August). *APC Resource Lesson: A Guide to Gauss' Law.* Retrieved July 12, 2017, from http://online.cctt.org/physicslab/content/phyapc/lessonnotes/GaussLaw/lesson.asp

LECTURE 3: Fluid Statics[PDF]. (n.d.). Boston: Massachusetts Institute of Technology.

Liao, S., Dourmashkin, P., & Belcher, J. (2004). *Capacitance and Dielectrics*[PDF]. Boston: Massachusetts Institute of Technology.

Perlman, H. (2016, December 2). *Capillary action.* Retrieved July 12, 2017, from https://water.usgs.gov/edu/capillaryaction.html

Ye, J. (2017, July 8). QuarkNet Capacitor Paper Question [E-mail to the author].