Lesson Title	Capacitors Introduction
Length of Lesson	2 Hours
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Subject	Physics
Grade Level	11-12
State Standards	Physics: 1g, 5
DOK Level	DOK 4
DOK Application	Analyze, Draw Conclusions, and Develop a Logical Argument
National Standards	Physics B
Graduate Research Element	Data analysis, electric circuits.

Student Learning Goal:

Mississippi Standards:
Physics: 1g. Collect, analyze, and draw conclusions from data to create a formal presentation using available technology (e.g., computers, calculators, SmartBoard, CBL's, etc.).
Physics: 5. Apply an understanding of magnetism, electric fields, and electricity.

National Standards:
Physics:

- In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons.

Materials Needed (supplies, hand-outs, resources):
Part 1 of this lab uses:

- 1 Pasco current and voltage probe
- 1 1kOhm resistor
- Several jumper cables
- 1 capacitor

Part 2 of this lab uses:

- 1 function generator
- 1 oscilloscope

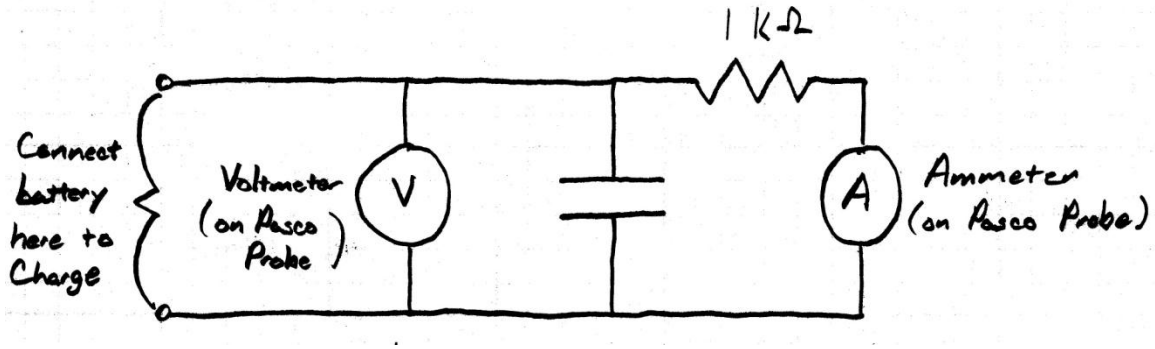
Part 3 of this lab uses:

- 1 oscilloscope
- 1 operational amplifier in a duel inline pin package
- 2 approximately 1kOhm resistors

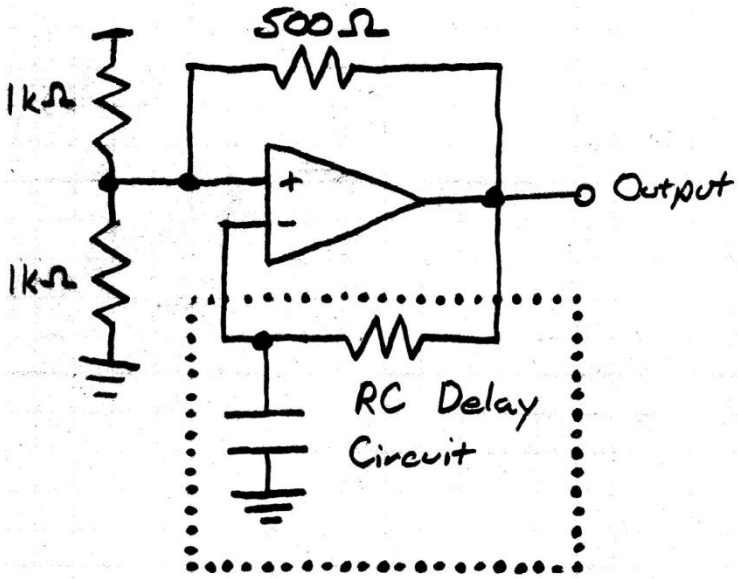
- 1 approximately 500 Ohm resistor
- 1 capacitor and 1 resistor to create an RC time delay circuit
- various wires
- 1 prototyping breadboard (or circuit board if you don't want to be able to change the RC delay circuit)
- 1 diode (optional)

Circuit Diagrams:

I suggest you build the circuit in part 3 and test it for the students before class to save time. However, if you have time and want to teach the students how to build circuits, this would be good practice.



Part 1 Circuit



Part 2 Circuit

Lesson Performance Task/Assessment:
We ask the students to turn in a formal report on what they observe. They will be measuring the capacitance of an unknown capacitor in part 1. In part 2, the students learn how to use an oscilloscope. In part 3, we give them a circuit which generates a square wave where the frequency is dependent on the resistance and capacitance in the delay circuit, and they will report how resistance and capacitance are related to frequency. This also gives them experience working with oscilloscopes, which will help in later labs.

Lesson Relevance to Performance Task and Students:
The students learn how to measure capacitance in part 1. In part two, they learn how to use their oscilloscopes. In part 3, they learn how a capacitor is used in a common circuit.

Anticipatory Set/Capture Interest:
We gave them a short talk about capacitance and described how to use the lab equipment.

Guided Practice:
First talk about what capacitors do, and how they work. I used several water containers to talk about how they compare to capacitors, and what the value of capacitance means. The value of capacitance is similar to the area on the bottom of a cylindrical container in that a larger value means that more charge per volt can be stored in the capacitor just as more water per unit of height can be stored in the water container. From then, we talked about how to use the lab equipment. Finally, we talked about the procedures. In part 1, they will use the equations

$$C = \frac{q}{V} \tag{1}$$

and

$$q = \int I dt \tag{2}$$

to estimate the capacitance of a capacitor. Their Pasco probes measure voltage (V) and current (I), and they can regress a exponential function to the current, which they can integrate to get charge (q). The students were able to get very accurate estimates of the capacitance. In parts 2 and 3, the students will use their oscilloscopes to make measurements.

Independent Practice:
Part 1

- The students build the part 1 circuit, and measure the capacitance of the capacitor.
- The students will report the capacitance and describe the circuit they built.

Part 2

- Each student will select a frequency on the function generator and measure the output with the oscilloscope. They need to report the frequency displayed on the function generator, and the measured frequency and amplitude.

Part 3

- Give the students the oscillator circuit (part 3 circuit).
- They will measure the frequency using the oscilloscope for 4 combinations of resistance and capacitance in the delay circuit.
- If the oscilloscope has 2 channels, they can measure the voltage at the inverting input of the opamp to see the exponential decay of the delay circuit.
- The students will report what the frequency was for each of the 4 combinations.

Remediation and/or Enrichment:
Remediation: individual IEP; partner help throughout the lesson; the teacher can observe the students and intervene during the independent practice.

Check(s) for Understanding:
During the lab, the teacher can walk around and observe the students. If some of the students appear to not understand how the equipment works or what they are expected to do, ask them some leading questions.

Closure:
Answer questions about analyzing the data and ask them what they observed.

Possible Alternate Subject Integrations:
Math

Teacher Notes:
This is a difficult lab to pull off if the students have no experience with circuits before, so expect some a lot of questions if you don't describe it very well.