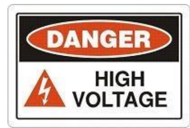
1) Capacitor provides 300V of discharge; careful with disassembling camera
2) Capacitor remains charged even with no battery
3) Capacitor may still hold a charge even after discharging



Say "Cheese" for Capacitor

Subject Area(s): Physics, Science, and Technology

Associated Unit: Circuits and electrostatics

Lesson Title: The function of a capacitor in flash camera

Header

Figure 1-The circuit board shown is the internal part of a disposable camera that operates the flash. The capacitor, shown in black, plays a critical role in charging and discharging the flash for people to say "cheese." No capacitor, no cheese.

http://web.mit.edu/hchin/Public/activlab/d-camera.html

Grade Level 11-12

Time Required **100 min. (two 50 min. periods)**

Summary

The students will explore the purpose and function of capacitors in flash cameras through hands-on design on the first day: The students will make their own parallel-plate capacitor using conductive materials (aluminum foil, copper tape foil, etc.) separated by an insulating material (writing paper, wax paper, or other insulated materials). The activity will engage students through inquiry exploration of capacitors and their important function in electric circuits. The second day will give students more structure and reinforcement of additional characteristics of parallel-plate capacitors through computer simulation. The lesson is meant to give an application and conceptual overview of capacitors, which are usually difficult to conceptualize in high school courses.

Engineering Connection

Many of us take for granted the technology that we depend on today. By looking and examining a single electric component (capacitor), one can appreciate the development of such device in its current function. Insulators, conductive, and semi-conductive materials are widely used together to create a specific function. A "sandwich" of insulating material enclosed by two conductive layers can produce a functional capacitor, while other combinations can produce an antenna or diode (to name a few) which are also critical. Furthermore, each material can be further improved through the use of additional materials (sometime referred as functional materials) which offer different properties desired in electronic applications.

Engineering Category =

Choose the category that best describes this lesson's amount/depth of engineering content:

1. Engineering analysis or partial design

Keywords

Capacitor, capacitance, dielectric, camera, circuit

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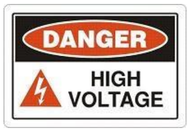

Educational Standards

State STEM Standard Math 2010:

Create equations that describe numbers or relationships *(Grades 9 - 12)*

> 2. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
> *(Grades 9 - 12)*
>
> 4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm\'s law V = IR to highlight resistance R.
> *(Grades 9 - 12)*

ITEEA Standard 2000 Technology K-12 Design:

As part of learning how to apply design processes, students should learn that:
(Grades K - 12)

> N. Identify criteria and constraints and determine how these will affect the design process.
> *(Grades 9 - 12)*
>
> P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
> *(Grades 9 - 12)*
>
> Q. Develop and produce a product or system using a design process.
> *(Grades 9 – 12*

NGSS Standard 2013 Science 9-12:

Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
(Grades 9 – 12)

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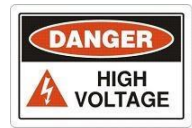

Pre-Requisite Knowledge

Students should have knowledge of safety in dealing with electronics and hazards to avoid injury

Know general circuits (open, closed, and short circuits)

General knowledge of electric conducing and insulating materials

Know general idea of charging and discharging

Learning Objectives

After this lesson, students should be able to:

- **Know the purpose and function of a capacitor in real world applications**
- **Construct a capacitor using different types of materials**
- **Know physical factors that affect the capacitance of a capacitor and how to charge/discharge**
- **Synthesize a general formula for the capacitance of a capacitor based on quantitative data**

Introduction / Motivation (5E – Engage)

Start with a short Back to the Future movie (1:00) in which professor Doc points out the reason why time travel is possible (the flux capacitor). After watching the video, engage students in open ended questions about what it is: some students will know what it's called and what it does. Some might bring into question whether it is possible or not. Entertain the possibility by showing the infomercial of the flux capacitor. Lead on to clarify what a capacitor is and what it does (EXPLAIN). If students are engaged you may want them to generate a list of truth and fact.

One thing they should point out is that it provides a source of electrical energy through electrical discharge. Other discussions might lead to lightning discharge, starting an AC compressor, and eventually a flash in photography.

The student will then be introduce to the task of building a capacitor to replace the capacitor on a disposable flash camera. These circuits should be disassembled, capacitor clipped and discharged before the students have access to them by you, the teacher (safely). May also choose to solder wires where the capacitor was removed for ease of charging and discharging the self-made capacitor.

Lesson Background & Concepts for Teachers (5E – Explain)

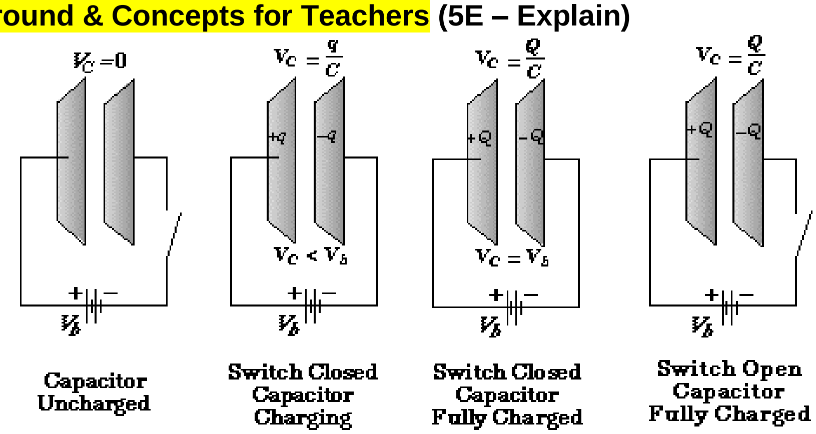

Figure 1: Charging a capacitor using a potential difference (battery).[8]

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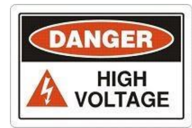

Fig. 1 above shows the way a capacitor charges by a potential difference (battery): The parallel plates are conductive material (aluminum) and electrons can move about easily. When connected to a battery, electrons are attracted to the (+) side of the battery due to an electric field; leaving the left plate (+). The electrons are driven around to the right conductive plate; making it negative. The capacitor plates stop charging when they reach the potential difference of the battery. The capacitor will continue to hold the charge even if the battery was removed.

The capacitor is now charged and electrons on the right plate are strongly attracted to the left plate but there is no closed path to return. Simply closing the gap between the plates will create a short circuit and can be harmful, Figure 2.

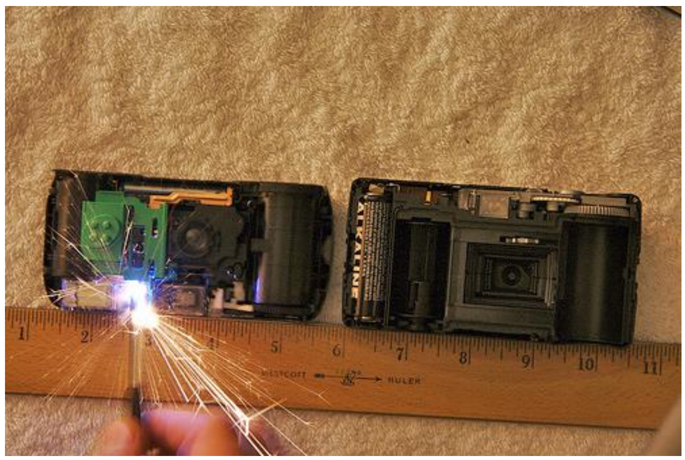

Figure 2: Capacitor discharged with screwdriver (unsafe)[9]

However, placing an electronic element such as a flasher allows the charge to flow through and provides a useful purpose. Figure 3 is a schematic diagram of the circuit for a Jufi Film disposable camera.

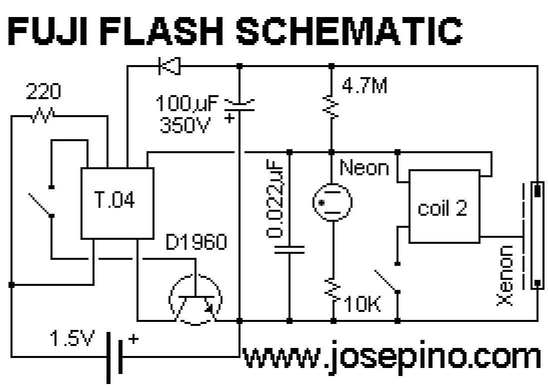

Figure 3: Schematic diagram of camera[4]

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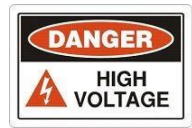

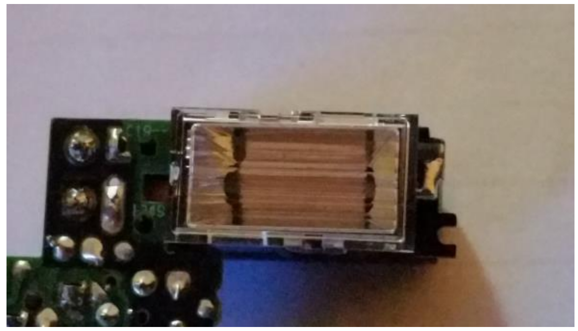

Vocabulary / Definitions

Word	Definition
Parallel plate capacitor	Most basic form of capacitor in which two parallel-conductive plates are separated by an insulating layer of dielectric material
Capacitance	Defined as the measure of the ratio of charge (Q) to potential difference (V), $C=Q/V$. In making a capacitor, the area (A), distance between plates (d), and dielectric constant (ε), determine the capacitance (C), $C=\varepsilon A/d$.
Conductive material	Materials where charges (electrons) can move about easily. Here used are aluminum foil and copper foil tape.
Insulating material	Materials where charges (electrons) cannot move easily. Here used are different types of papers (PDMS coating is also insulating material).
Dielectric	Insulating materials are classified by different dielectric constants (e.g., air=1, paper=2, wood=2-3.5, ABS 1.5-2.5, and diamond 5.5-10). [1]

Associated Activities (5E – Explore)

Day 1: Have students make a capacitor in groups: Each group will use the same insulating material (paper) but each group will make different size capacitors.

Materials and cost per group.

Disposable camera $7.00

6"x6" aluminum foil $0.10

Copper foil or tape maybe substitute $1.00

12"x12" paper sheets $0.25

Notebook, wax, construction, etc.

Gluestick $0.10

6" insulated wire $0.50

Students will test the capacitance of each capacitor to compare which gave the most brightness. Make assumptions about what affects the brightness. NOTE: The teacher should connect and discharge the capacitor due to the potential danger. Instructions for building capacitor here.[3]

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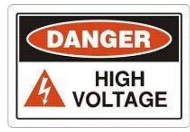

Day 2: Students will explore the properties of a capacitor following a guided worksheet and computer simulated lab. Each student will collect data to derive a potential equation for the capacitance of a capacitor based on its area, distance between plates, and dielectric constant (**C= εA/d).** Simulation and worksheet can be found here. [5]

Lesson Closure

Assessment (5E – Evaluate)

Pre-Lesson Assessment: Throw open ended discussion about "flux capacitors"

What is the purpose of a capacitor?

What type of energy is supplied by a capacitor?

How is this generated?

Where does the energy come from?

Post-Introduction Assessment: Throw Day 1 activity as you walk about

Which capacitor might provide the most energy?

What would happen if the plates were farther/closer?

How does the dielectric material affect the capacitance?

Lesson Summary Assessment:

During day 1 discharging of capacitor

Which capacitor was the brightest?

Is it possible to make a smaller capacitor brighter than a large one? Explain

During day 2 simulation of capacitor

Are the questions to the Post-Introduction assessment being confirmed? Explain

Homework

Using your data from the simulation, propose a formula for the capacitance of a capacitor

Lesson Extension Activities (5E – Extension)

Find other real-world applications of capacitors

Research how capacitors are being improved

Additional Multimedia Support

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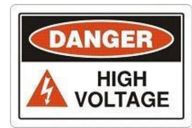

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Attachments

Worksheet (last page) for simulation from https://phet.colorado.edu/en/simulation/capacitor-lab

Contributors

Artemio Perez, Dr. Jing Wang, and Juan Castro

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Acknowledgements

Thank you for the experience as a research assistant at the USF. The experience of engineering research will enable me to promote more engineering fields to my physics students at Plant City High School within Hillsborough County.

Classroom Testing Information

None

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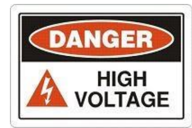

Attachments

Dielectrics and Capacitance

Today we will be exploring the behavior of capacitors with and without dielectrics. You will complete the virtual lab using the Capacitor Lab from Phet, data analysis software (Logger Pro or Excel) and this document. Each member of the lab group must complete and submit a copy of the assignment.

Pre-Lab Questions

1. Draw a diagram of a simple capacitor in a circuit with one battery (1.5 V).

2. What is a dielectric?

3. What does a capacitor store?

Basic Characteristics of a Capacitor

Open the [Capacitor Lab](https://phet.colorado.edu/en/simulation/capacitor-lab) (https://phet.colorado.edu/en/simulation/capacitor-lab)

Set the plates to the minimum area (100.0 mm^2), maximum separation (10.0 mm) and maximum positive battery voltage (1.5 V) to begin.

Using the provided meters in the simulation complete the following data table:

Trial	Separation (mm)	Plate Area (mm^2)	Capacitance (μF)	Stored Energy (J)	Plate Charge (C)	Electric Field between plates (V/m)
1	10	300				
2	9	300				
3	8	300				
4	7	300				
5	6	300				
6	5	400				
7	5	350				
8	5	300				
9	5	250				
10	5	200				

Dielectrics and Capacitance

Analyze the data above and answer the following questions. You may want to create graphs to better explain relationships between variables. Attach any graphs or figures you create with the data to explain your responses.

1. Which variables increase as the plates are moved further apart? What is the pattern of increase?

2. As the plate separation decreases which variables increase? What is the pattern of increase?

3. Which variables increase as the plate area is decreased? What is the pattern of increase?

4. As the plate area increases which variables increase? What is the pattern of increase?

Dielectrics and Capacitance

Dielectrics

Click on the "Dielectrics" tab in the Capacitor Lab.

Set the plates to the area (200.0 mm^2), separation (8.0 mm), maximum positive battery voltage (1.5 V) and minimum dielectric constant (1) with zero offset to begin.

Using the provided meters in the simulation complete the following data table (keep the plate separation and area constant through all trials):

Trial	Dielectric Constant	Capacitance (μF)	Stored Energy (J)	Plate Charge (C)	Sum Electric Field between (V/m)	Electric Field in Dielectric (V/m)	Electric Field between the plates (V/m)
1	1						
2	1.5						
3	2						
4	2.5						
5	3						
6	3.5						
7	4						
8	4.5						
9	5						

Analyze the data above and answer the following questions. You may want to create graphs to better explain relationships between variables. Attach any graphs or figures you create with the data to explain your responses.

5. How does the dielectric constant affect capacitance?

6. As the dielectric constant increases how does the total stored energy change?

7. Does the dielectric constant affect the amount of charge stored on the plate? If so, what is the relationship?

Dielectrics and Capacitance

8. Based on the data from your two experiments and any further experimentation you wish to carry out, what do you think the dielectric constant of air (which is what separates the plates in the first experiment) would be?

Conclusion

Explain how you would construct the ideal capacitor. In your explanation include the basic physical dimensions as well as any specific materials you feel would work. While you might not be able to give specific numbers, you should be able to relate general trends and magnitudes of the figures.