Capacitors, Capacitance, Series & Parallel Circuit

Universiti Teknologi MARA
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PHY407: A Physical Science Activity

Name:______________________________ HP: _____________________ Lab # 4:

Goal

Today, you will determine how the capacitance depends on the plate separation. In addition, you will also determine how to find the effective capacitance when capacitances are connected in series and in parallel, respectively.

Learning Outcomes

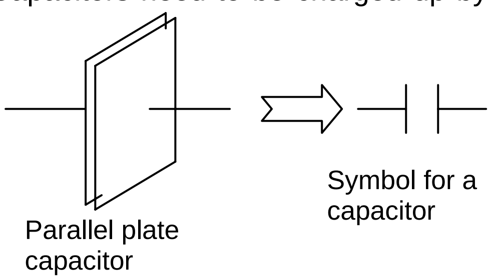
At the end of today's activity, students will be able to

- Use a multimeter to measure capacitance of a variety of capacitors.
- Use a multimeter to measure, the effective capacitance for 2 capacitors connected in series,
- Use a multimeter to measure 2 capacitors connected in parallel
- Use a multimeter to measure 4 capacitors connected in series-parallel combination.
- Obtain a simple relationship to determine effective capacitances in a series or in a parallel configuration.
- Determine the relationship between capacitance of a parallel plate capacitor and the plate separation.

Background Information

Background:

Electrostatics involved the study of excess charges on conductors and nonconductors and is usually explained by the presence of electric field which gives rise to coulomb forces and acceleration or displacement of charges. Charges that are in motion constitutes flowing current. One way of making charges to move is by using a battery or a direct current (DC) power supply which can maintain a constant electromotive force (EMF) or potential difference across its terminals. In addition to batteries as sources of charges, in electronic circuits, a device known as capacitors are used to store charges. The difference between batteries and capacitors is that capacitors are not constant source of charges. Capacitors need to be charged up by batteries or power supplies and once charged, it will hold the charges by maintaining a potential difference across its ends. Once used, it will be depleted of charges and will need to be charged again. The most common and easiest capacitor to analyze is the parallel plate capacitor. This type of capacitor is easy to construct and use simple mathematical calculations and basic physical reasoning. A parallel plate capacitor is commonly represented as shown in the figure to the left.



The amount of charges that capacitors can store, have been shown to be directly proportional to the potential difference applied across its plates, $q \propto V$. When the proportionality is replaced by an equality, a constant is placed in front of the variable and that constant has been determined to be the capacitance C and so the relationship can now be written as $q = CV$ where C is known as the capacitance of the capacitor. Hence, the capacitance is $C = \frac{q}{V}$ and measured in units of Farad where *1 Farad* = $\frac{\textit{1 Coulomb}}{\textit{Volts}}$. The normal strength of capacitors are in the range of picofarad (1 pF = 10^{-12} F) to microfarad (1 µF = 10^{-6} F) to millifarad (1 mF = 10^{-6} F). Hence the higher the emf of a battery used to charge up the plates, the more charges that will be stored. In fact, when a capacitor stores charges it actually stores electrical energy and it can be shown that the average energy stored is, $E = \frac{1}{2}CV^2$ or can also be written in terms of the charge as $E = \frac{1}{2}CV^2 = \frac{1}{2}\frac{q}{V}V^2 = \frac{1}{2}qV$.

The capacitance of capacitors is just a constant value which depends on the area of the plates, the separation of the plates and the nonconducting material inserted between the plates. It has been shown before that the capacitance is directly proportional to the plate's area and the relative permittivity of the material of the medium between the plates, $C \propto \varepsilon A$. If the medium is just air, the relative permittivity is just $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2 / Nm^2$, the relative permittivity for free space. Today, you will determine how the capacitance depends on the plate separation. In addition, you will also determine how to find the effective capacitance when capacitances are connected in series and in parallel, respectively.

Student Activity

Investigation 1-Capacitors & Capacitances

Prediction 1.1: Given 5 different capacitors, predict if a multimeter set to the capacitance mode, will read the same or different capacitance values compared to the values written on the capacitor.

Activity 1.1:

Read the capacitance printed on the capacitors. For each of the capacitors, use a multimeter in the capacitance mode to measure the capacitances by touching the ends of the probes to the ends of the capacitors. Record your reading. Then reverse the polarity of the probe used to touch the ends of the capacitor and observe the reading again. Record the reading and compare with the reading printed on the capacitor. Tabulate the data.

Capacitance printed on capacitor, pF	Measured Capacitance; pF	Measured Capacitance (Reversed polarity); pF

Questions

1. Does changing polarity of the meter probes produce different values? Why or why not?
2. Which reading, the printed values or the multimeter reading is more reliable? Explain.

Prediction 1.2: (Series & Parallel Circuit)

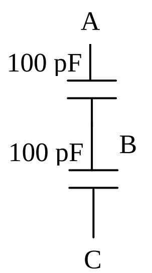
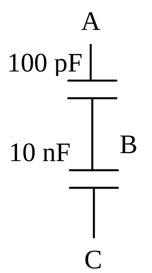
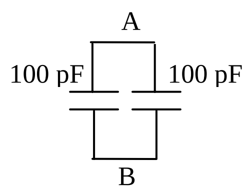
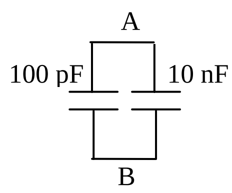
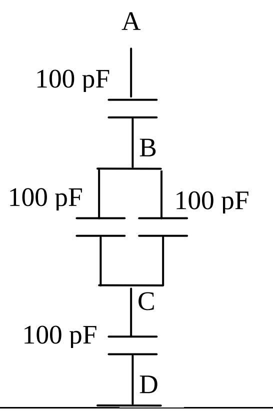
i) What do you physically do when you connect capacitances in series or in parallel?

ii) What happens to the effective or total capacitance when they are added in series and in parallel respectively?

Activity 1.2:

i) Using a multimeter in resistance mode, check which points on the circuit board produce zero reading and the points that produce infinite reading. Ii)`

ii) Connect the capacitors you used in activity 1.1 on the circuit board. These are as shown in the 5 configurations in Figure 1. Then use the multimeter to measure the effective capacitances. Record your reading.

				
C_{AB}= __ pF C_{BC}= __ pF C_{AC}= __ pF	C_{AB}= __ pF C_{BC}= __ nF C_{AC}= __ nF	C_{AB}= ______ pF	C_{AB}= ______ nF	C_{AB}= __ pF C_{BC}= __ pF C_{CD}= __ pF C_{AD}= __ pF

Questions

1. What happens to the effective capacitance when capacitances are connected in series? Does it increase or decrease? Can you write down a possible mathematical relation to determine the effective capacitance? Is it consistent with, $\frac{1}{C_{eq,series}} = \frac{1}{C_1} + \frac{1}{C_2} + ..\frac{1}{C_n}$?
2. What happens to the effective capacitance when capacitances are connected in parallel? Does it increase or decrease? Can you write down a possible mathematical relation to determine the effective capacitance? Is it consistent with, $C_{eq,parallel} = C_1 + C_2 + ..C_n$?
3. What happens to the effective capacitance when capacitances are connected in series-parallel combination?

Investigation 2 – Capacitance

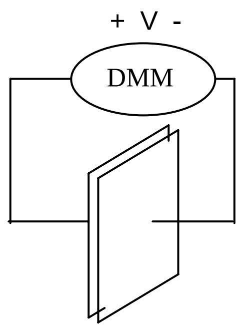
Prediction 2.1 (Refer to the figure below)

i) What type of excess charge will build up on the metal plate that is attached to the negative terminal of the battery? What type of excess charge will build up on the plate that is connected to the positive terminal of the battery? Explain.

ii) Can the excess positive charges on one plate of a charged parallel-plate capacitor exert forces on the excess negative charges on the other plate? Explain.

iv) Once the plates have been charged up and the wires removed from the batteries, how will the capacitance change when the distance between the plates is increased?

iv) Once the plates have been charged up and the wires removed from the batteries, how will the charge, the potential difference between the plates, the electric field and the total energy stored by the capacitor change when the distance between the plates is increased?



Activity 2.1:

i) Connect the circuit as shown in the figure. Be sure the multimeter dial is set to read capacitance.

ii) Beginning with the plate separation of 1 mm, record the value of the capacitance as the separation is increased by 1 mm.

Plate Separation, d mm	Capacitance, C
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	

iii) Graph the capacitance on the y-axis and the plate separation, d, on the x-axis. Then observe and conclude the relationship that you see. Find the slope and identify what physical quantity, the slope or its inverse, represents. Is it consistent with $C = \frac{\varepsilon_0 A}{d}$?

Questions

1. What happens to the capacitance when the separation is changed?
2. What can you conclude about the capacitance-plate separation relationship from the graph that you plotted?
3. How is the slope of the line useful to you?
4. Is the slope or its inverse comparable to the product of $\varepsilon_0 A$? Explain.