How does a capacitor act in an alternating current circuit? | EEP 5.3 | S

Problem

Prove that a capacitor does not interrupt an alternating current circuit and investigate what determines the current when a capacitor is included in an alternating current circuit.

Equipment

Plug-in board	06033.00	1
On/off switch	39139.00	1
Changeover switch	39169.00	1
Lamp holder E10	17049.00	1
Filament lamp, 6 V/0.5 A, E10, 1 pc.	35673.03	(1)
Filament lamp, 4 V/0.04 A, E10, 1 pc.	06154.03	(1)
Electrolytic capacitor, 47 µF, bipolar	39105.45	1
Electrolytic capacitor, 470 µF, bipolar	39105.47	1
Wire building block	39120.00	4
Connecting cables, 25 cm, red	07360.01	1
Connecting cables, 25 cm, blue	07360.04	1
Connecting cables, 50 cm, red	07361.01	1
Connecting cables, 50 cm, blue	07361.04	1
Multi-range meter	07028.01	1
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1

Set-Up and Procedure

First Experiment

— Set up experiment as shown in Fig. 1. Set on/off switch to off position initially. Connect to alternating current source of 6 V~ and select measurement range of 300 mA~.

— Turn alternating current circuit on, measure current and observe brightness of filament lamp. Enter observation under (1) and measurement in Table 1.

— Set measurement range to 3 A~.

— Replace 47 µF capacitor with 470 µF capacitor. Measure current and note results.

— Replace capacitor with a short-circuit plug. Measure current and note results.

— Switch power supply unit off.

Second Experiment

— Set up experiment as shown in Fig. 2. Set on/off switch to off position initially. Flip changeover switch to position 1 and set direct voltage on power supply unit to 10 V. Discharge capacitor by short circuiting before adding it to the circuit.

— Switch on power supply unit. Turn circuit on and observe filament lamp. Note observation under (2).

— Replace 470 µF capacitor with 47 µF capacitor. Toggle changeover switch back and forth slowly at first, and then more and more quickly (with increasing switching frequency). While doing this, observe filament lamp and note observations under (3).

— Switch power supply unit off.

Fig. 1

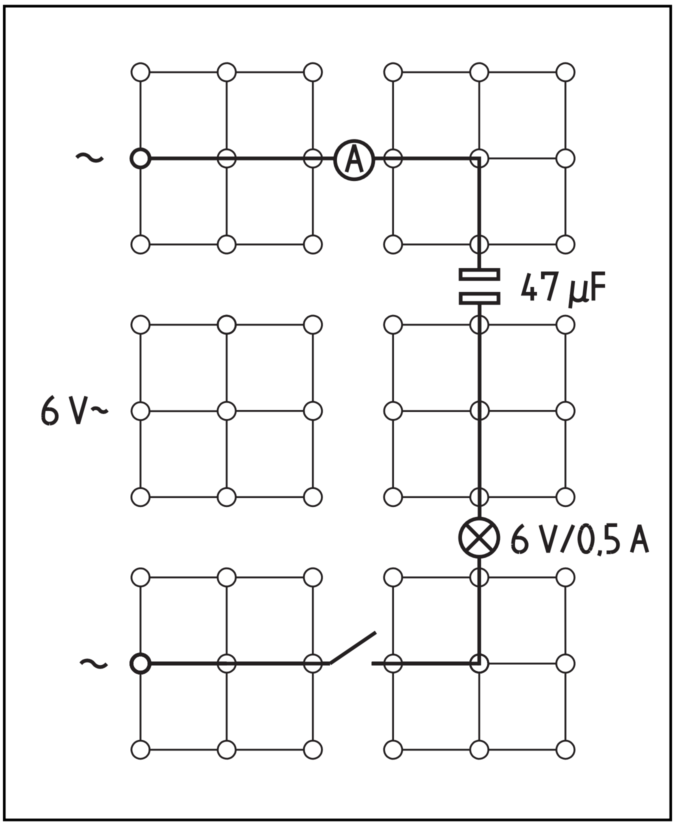
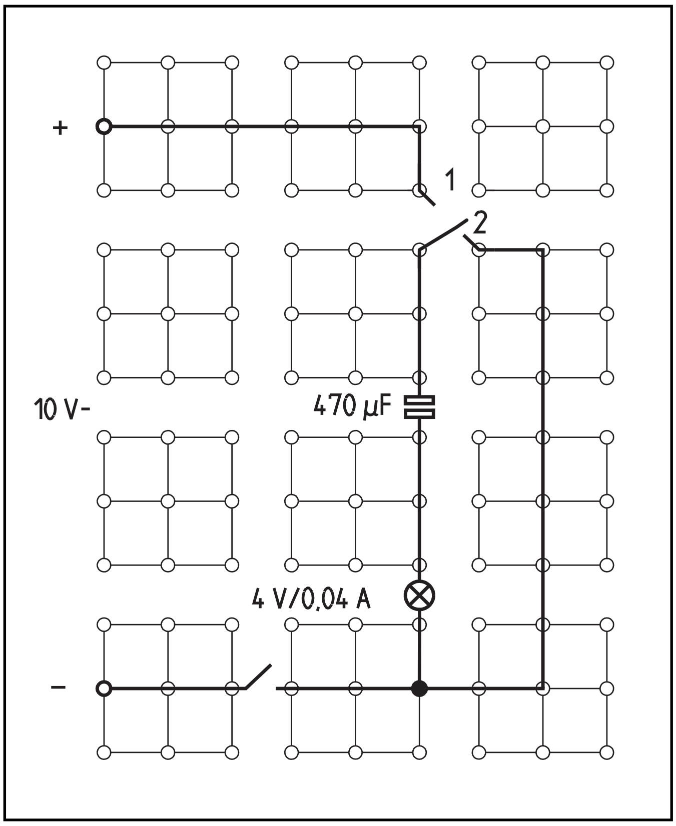


Fig. 2



Observations and Measurement Results

(1) Table 1

Component in alternating current circuit	Filament lamp shines	Current I /mA
47 μF capacitor		
470 μF capacitor		
No capacitor		

(2)

(3)

Evaluation

1. Capacitors in direct current circuits represent an infinitely large resistance since they interrupt the circuit. What conclusions can you draw from the results noted in Table 1 for the first experiment?

2. Based on your observations under (3), what can you say about the relationship between the resistance of a capacitor in an alternating current circuit and the frequency?

3. Summarize the results of both experiments and explain

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Problem
The students should recognize that capacitors in alternating current circuits represent an infinitely large resistance factor. Both of the experiments in this section should demonstrate capacitive resistance through qualitative and/or semi-quantitative analysis.

Notes on Set-Up and Procedure
In the second experiment, toggling the changeover switch back and forth creates an alternating current in spite of the direct voltage in the circuit branch with the capacitor and filament lamp. The students should understand the theoretical basis of this concept before carrying out this experiment.

Observations and Measurement Results
(1) Table 1

Component in alternating current circuit	Filament lamp shines	Current I /mA
47 μF capacitor	not at all	106
470 μF capacitor	brightly	450
No capacitor	more brightly	500

(2) The filament lamp shines briefly when the circuit is switched on.

(3) The filament lamp shines more brightly as the switching frequency is increased.

Evaluation
1. A capacitors does not interrupt an alternating current circuit. It represents a(n) (additional) resistance factor. The smaller the capacity of the capacitor, the larger the resistance it represents.
2. The smaller the frequency of the alternating current, the larger the resistance of the capacitor.
3. The smaller the capacity of the capacitor and the smaller the frequency of the alternating current, the greater the resistance factor of the capacitor in the alternating current.
   Explanation: The smaller the capacity, the less the charge taken on by the capacitor when charging (and/or released by the capacitor when discharging). A smaller frequency means the charge flows less frequently, meaning the capacitor takes on and/or releases the charge less frequently per unit of time through one section of the conductor. In both cases, that means even less current and, thus, greater resistance.

Notes
The filament lamp shines very weakly in the first experiment if the 470 μF capacitor is replaced with a short-circuit plug. However, in order to demonstrate the difference clearly, it is recommended that the plug be used to short circuit the capacitor repeatedly.
The resistance a capacitor produces in an alternating current circuit is referred to as capacitive resistance X_c.
The following equation applies:

$$X_c = 1/(\omega \cdot C) = 1/(2\pi \cdot f \cdot C).$$

If there is only one capacitive resistance present in an alternating current, aside from the ohmic resistance R, then the impedance associated with a sinusoidal alternating current is:

$$Z = \sqrt{R^2 + X_c^2} = \sqrt{R^2 + (1/(\omega C))^2}.$$

Capacitors in Alternating Current Circuits

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Room for notes