

TAP 126- 4: Charging capacitors

What to do

Answer the questions. They develop a line of thought, so answering them in order is likely to help.

Questions

In an experiment a capacitor is charged from a constant current supply by a 100 mA current pulse which lasts 25 s.

1. Calculate the charge on the capacitor after this time.
2. The pd across the capacitor is 6 V when it has been charged. Calculate the capacitance of the capacitor.

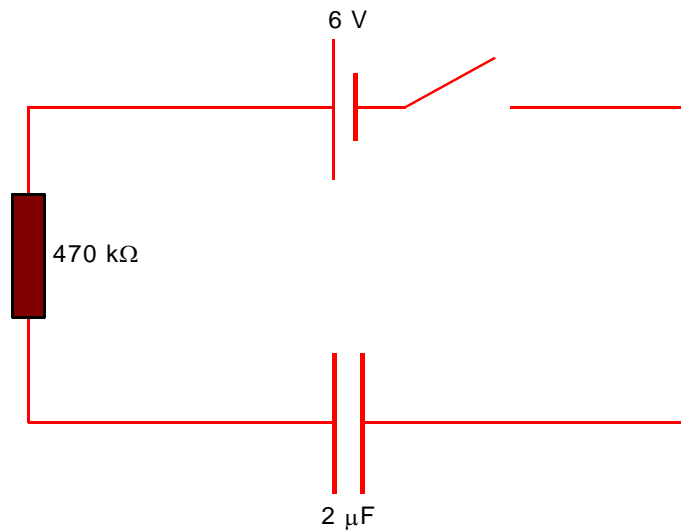
A capacitor is charged at a constant current of 2.0 mA until the charge on the capacitor is

0.010 C.

3. How long did it take the capacitor to charge to this value?
4. The capacitance of the capacitor is 100 microfarad (μF). To what pd had it been charged?
5. This question allows you to practise using the equation $Q = C V$. Fill in the gaps in the table.

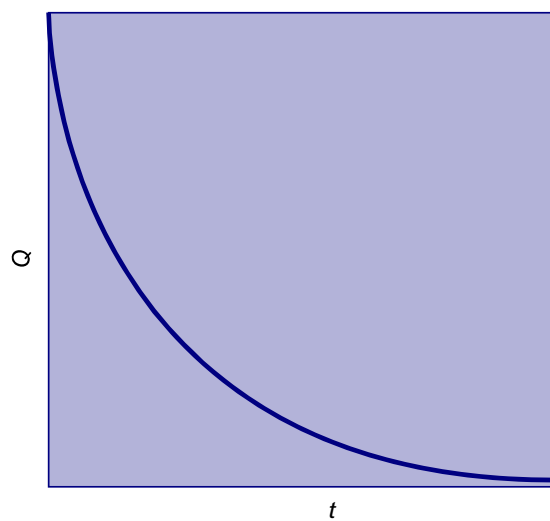
C	Q	V
1000 μF		12 V
	2 mC	250 V
32 μF	0.64 mC	
33 mF		6 V
	1.25 C	25 kV
10 mF	2.5 C	

In this circuit the capacitor is initially uncharged.



6. Calculate the current through the resistor when the switch is first closed.
7. What is the current after the switch has been closed for a long time? Explain your answer.
8. Calculate the current through the resistor when the pd across the capacitor is 2.0 V .

When this capacitor is charged through the fixed resistor, the graph shows how the charge on the capacitor varies with time.



9. What is the significance of the gradient of the graph?

10. Explain why the gradient of the graph gradually falls?

11. Calculate the maximum charge on the capacitor.

12. Use the same axes to sketch the curve you would expect if the resistor were replaced by one with a smaller resistance.

Practical advice

Students are expected to have met the equation $Q = CV$ and to understand the definition of capacitance as the ratio of charge to potential difference. They should also be familiar with the farad as the unit of capacitance but also the submultiples of 'milli' and 'micro' as more common variants since the farad is such a large unit.

The first questions refer to a capacitor having being charged at constant current and it will be useful if they have either seen this demonstrated or, if possible, done the experiment themselves. It offers a good way to see how charge accumulates on a capacitor with the corresponding build-up of pd across it.

Question 5 is designed to give practice in using $Q = CV$ and, in particular to sort out their 'millis' from their 'micros'.

The third group of questions concentrates on charging a capacitor through a fixed resistance with the corresponding fall in current as the pd across the capacitor rises. They must relate the gradient of the graph to the current flowing. In your teaching, you may wish to direct some students towards the differential equation which describes the curve mathematically, but this is not appropriate for all.

Solutions and worked examples

1. 2.5 C
2. 0.42 F
3. 5 s
4. 100 V
- 5.

C	Q	V
1000 μ F	0.012C	12 V
8 μ F	2 mC	250 V
32 μ F	0.64 mC	20V

33 mF	0.02C	6 V
50 μ F	1.25 C	25 kV
10 mF	2.5 C	250V

6. 13 mA
7. Zero
8. 8.5 mA
9. The gradient is the current at that time.
10. As the capacitor charges up, the pd across it rises and the pd across the resistor falls. The current through the resistor is equal to the pd across it divided by the resistance, so the current, and therefore the gradient, gradually decreases.
11. 12 mC
12. The graph is steeper; it reaches maximum charge in a shorter time.

Worked solutions

1. $Q = It = 100 \times 10^{-3} \text{ A} \times 25 \text{ s} = 2.5 \text{ C}$

2.

$$C = \frac{Q}{V} = \frac{2.5 \text{ C}}{6.0 \text{ V}} = 0.42 \text{ F}$$

3.

$$t = \frac{Q}{I} = \frac{0.010 \text{ C}}{2.0 \times 10^{-3} \text{ A}} = 5 \text{ s}$$

4.

$$V = \frac{Q}{C} = \frac{0.010 \text{ C}}{100 \times 10^{-6} \text{ F}} = 100 \text{ V}$$

5.

$$Q = CV = 1000 \times 10^{-6} \text{ F} \times 12 \text{ V} = 0.012 \text{ C}$$

$$C = \frac{Q}{V} = \frac{2 \times 10^{-3} \text{ C}}{250 \text{ V}} = 8 \times 10^{-6} \text{ F}$$

$$V = \frac{Q}{C} = \frac{0.64 \times 10^{-3} \text{ C}}{32 \times 10^{-6} \text{ F}} = 20 \text{ V}$$

$$Q = CV = 33 \times 10^{-3} \text{ C} \times 6.0 \text{ V} = 0.20 \text{ C}$$

$$C = \frac{Q}{V} = \frac{1.25 \text{ C}}{25 \times 10^3 \text{ V}} = 50 \times 10^{-6} \text{ F}$$

$$V = \frac{Q}{C} = \frac{2.5 \text{ C}}{10 \times 10^{-3} \text{ F}} = 250 \text{ V}$$

$$I = \frac{V}{R} = \frac{6.0 \text{ V}}{470 \times 10^3 \Omega} = 1.3 \times 10^{-5} \text{ A}$$

6.

7. Zero, because when capacitor is fully charged, the pd across the resistor is zero and so no current flows through it.

8. The pd across the resistor is 4.0 V, therefore

$$I = \frac{4.0 \text{ V}}{470 \times 10^3 \Omega} = 8.5 \times 10^{-6} \text{ A.}$$

9. The gradient is the current at that time.

10. As the capacitor charges up, the pd across it rises and the pd across the resistor falls. The current through the resistor is equal to the pd across it divided by the resistance, so the current, and therefore the gradient, gradually decreases.

11.

$$Q = CV = 2 \times 10^{-6} \text{ F} \times 6.0 \text{ V} = 12 \times 10^{-6} \text{ C}$$

12. With smaller resistance the initial current is greater so the graph is initially steeper. The pd across the capacitor rises more quickly and so the capacitor takes less time to charge.

External references

This activity is taken from Advancing Physics Chapter 10, 60S