TAP 128- 3: Energy stored in a capacitor and the potential difference across the plates.

Introduction

This demonstration is intended to make the link between the energy stored in a capacitor and the potential difference to which it has been charged. It relies on the heating effect of the current which flows when the capacitor is discharged resulting in a measurable rise in temperature. The rise in temperature is assumed to be proportional to the energy stored. It is possible to obtain a series of readings by charging the capacitor to different potential differences and determining the rise in temperature each time.

Requirements

✓ capacitor 10 000 μF, 30 V working

✓ resistance coil (about 1 m of 34 swg insulated eureka wire wound into a small coil which will tightly enclose the temperature probe/thermocouple), or thermally insulated carbon film resistor of a few ohms resistance.

✓ thermocouple, copper–constantan

✓ micro voltmeter

✓ spdt switch

✓ multimeter

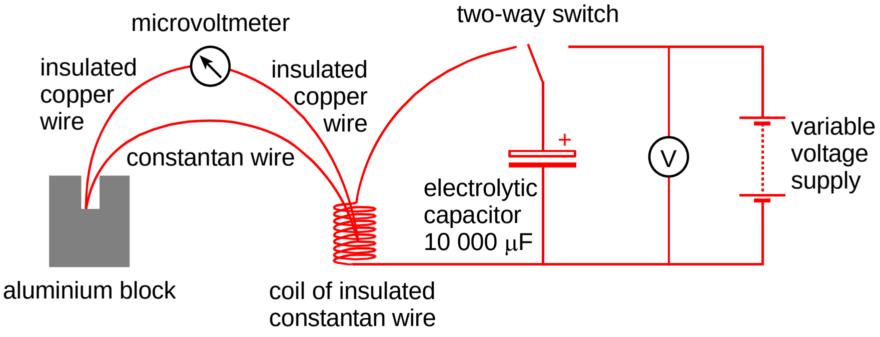
✓ power supply, 0–25 V

✓ aluminium block

✓ leads, 4 mm

Set-up

1. Set up this apparatus.



Make sure that the capacitor is connected to the supply correctly otherwise it may suffer damage. You will need to use the thermocouple connected to a sensitive voltmeter, measuring in mV.

2. Adjust the output of the dc supply to (say) 5.0 V.
3. Connect the capacitor to the supply using the two-way switch so that it becomes charged. Record the reading on the voltmeter.
4. Discharge the capacitor through the resistance coil and record the reading on the sensitive voltmeter, the output from the thermocouple.

5. Charge the capacitor to a different potential difference and repeat the experiment. Obtain a series of values of potential difference V and sensitive voltmeter readings. Do not exceed the safe working voltage of the capacitor (30 V).

6. Plot a graph that will enable you to deduce a relationship between the energy stored in the capacitor and the potential difference across its plates.

You are assuming that the energy stored in the capacitor is equal to the change in internal energy of the resistance coil, which is proportional to the temperature rise of the coil. Note that the reading on the sensitive voltmeter is proportional to the rise in temperature of the thermocouple probe.

What you have learned

1. From the shape of your graph, you should be able to deduce the link between the pd across the capacitor and the energy stored in it, as measured by the temperature rise.

Practical advice

Care should be taken to ensure that electrolytic capacitors are connected with the correct polarity and that the working voltage is not exceeded.

It will be worth spending some time familiarising students with the thermoelectric effect. This provides an essential link to temperature rise and thus the energy stored by the capacitor. It is advisable to discuss in advance how to analyse the data recorded.

Be careful to shield the apparatus from draughts, as they affect the final temperature rise obtained. Ensure the ‘cold junction’ of the thermocouple is in thermal contact with the aluminium block – a few drops of glycerol may help, with a smack rubber bung to hold the wires still.

Try out the experiment first for yourself to decide whether or not it will yield quantitative information about the relationship $W = ½ C V^2$. If there is too much scatter in the points, there will be no justification for plotting a straight line graph. If it is not convincing quantitatively, it may still be worthwhile to carry out the experiment qualitatively.

The use of small bead resistor instead of the coil enables the thermocouple’s hot junction to be taped securely to its surface. As stated, shielding from draughts is important, as the hot junction assembly has small thermal inertia.

The apparatus can be calibrated by delivering short timed pulses of current at a known voltage from the power supply, to calibrate the output, in terms of temperature rise, against a known energy input ItV. As such the exercise has to be treated as an extended experiment, which will be carried out over 2 practical sessions.

Alternative approaches

A preliminary demonstration to show how a discharging capacitor can briefly light a bulb could be useful. Large value capacitors, used as backup power supplies for memory (5 V working, 1.0 F) are also available, and can light LEDs for considerable lengths of time.

You might use a temperature probe for the main experiment if you have a suitable one with a sufficiently small thermal capacity.

External references

This activity is adapted from Advancing Physics, Chapter 10, 130E