Voltage on a Plate Capacitor

MEASURE THE ELECTROSTATIC VOLTAGE AS A FUNCTION OF THE DISTANCE BETWEEN THE PLATES

- Measuring the electrostatic voltage on a plate capacitor as a function of the distance between the plates.
- Confirming the proportionality between the voltage and the distance between the plates for small plate distances.

UE3010800

09/15 UD

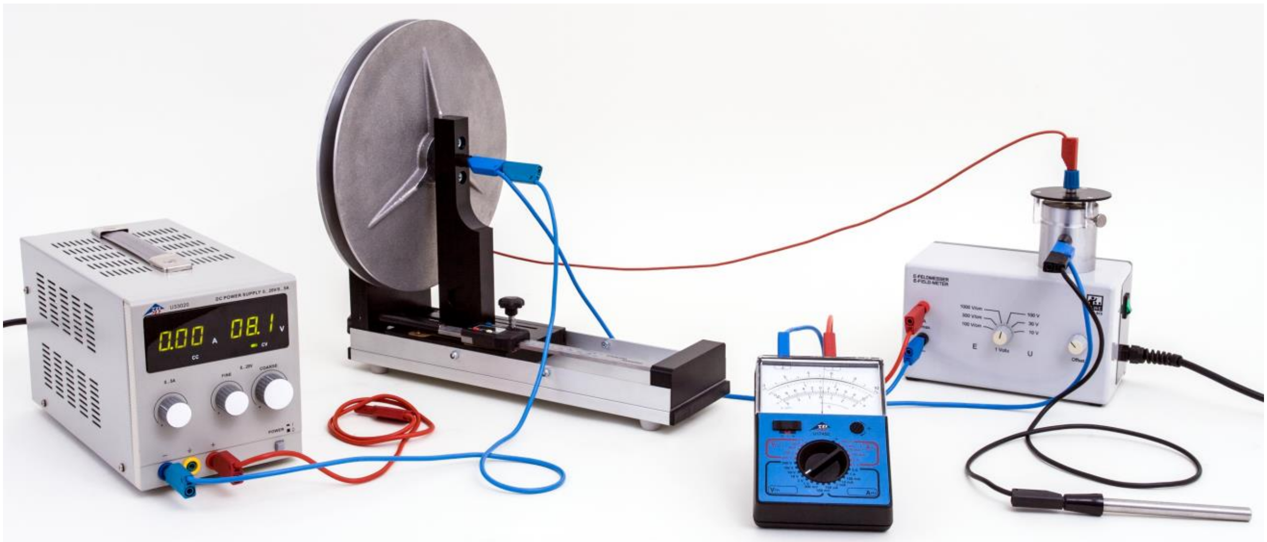

Fig. 1: Measurement set-up.

BASIC PRINCIPLES

The charged plates of a plate capacitor exert an attractive force on each other. Therefore, to increase the distance between the plates of a capacitor that has been charged and its external connections removed, mechanical work must be performed. The additional energy supplied to the capacitor in this way can be measured as an increase of the voltage between the plates, provided that no current flows between the plates during the measurement.

A more precise description of this relation is obtained by considering the homogeneous electric field *E* between the plates of the capacitor, which carry the charges *Q* und –*Q*. The electric field strength is:

(1) $E = \frac{1}{\varepsilon_0} \cdot \frac{Q}{A}$,

where *A*: area of each plate and,

$\varepsilon_0 = 8.85 \cdot 10^{-12} \frac{\mathrm{V \cdot s}}{\mathrm{A \cdot m}}$: the permittivity of free space (dielectric constant). (A is the unit ampere, not to be confused with area *A*).

If no current can flow if the plate distance *d* is changed, the charge *Q* and thus also the electric field *E* remain unchanged.

For small distances, for which the electric field can be assumed to be homogeneous, the voltage *U* on the capacitor and the electric field *E* are given by:

(2) $U = E \cdot d$,

where *d*: distance between the plates.

Thus, the voltage *U* is proportional to the distance between the plates *d*.

In the experiment, this relationship is tested by using the electric field meter as an electrostatic voltmeter. This method ensures that no current can flow through the voltmeter between the capacitor plates and the charge *Q* on the plates remains unchanged.

LIST OF EQUIPMENT

1 Electric Field Meter E U8533015 1001029/30

1 Plate Capacitor D U8492355 1006798

1 DC Power Supply 0-20 V, 0-5 A U33020 1003311/2

1 Analogue Multimeter Escola 100 U8557380 1013527

1 Set of 15 Experiment Leads 2.5 mm² U13801 1002841

SET-UP

- Set up the experiment as shown in Fig. 2.

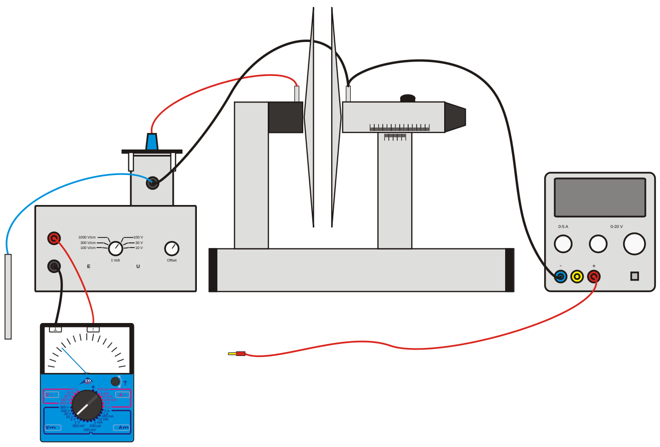

Fig. 2: Experiment set-up

- Place the voltage measurement plate, with its range set to 1x, on the screening cylinder of the electric field meter in such a way that the distance between it and the screening plate is as small as possible. Secure the voltage measurement plate in place with the help of the knurled screw.
- Connect the fixed capacitor plate to the voltage measurement plate.
- Connect the movable capacitor plate to the ground socket of the electric field meter and the negative pole of the power supply.
- Connect the holding rod to the ground socket on the screening cylinder of the electric field meter.
- Connect one end of a lead to the positive pole of the power supply and put the other, loose end on the table without connecting it to anything.
- Connect the multimeter for measuring the voltage to the voltage output of the electric field meter.
- Set the range selector switch of the electric meter to 10 V, turn on the electric field meter and wait about three minutes for it to settle down.
- Turn on the power supply, setting the voltage on it to U_0 = 3 V.

PROCEDURE

- Set the plate separation *d* to 5 mm using the plate capacitor's fine adjustment mechanism.
- To discharge the plate capacitor, touch the fixed capacitor plate with the holding rod. This creates a short circuit between the plates. At the same time, use the offset knob on the electric field meter to calibrate its zero point.
- Remove the holding rod for the fixed capacitor plate and hold it in your own hand for the purpose of providing equipotential bonding.
- Do not let go of the holding rod for the full duration of the measurement.
- In order to charge the plate capacitor with the loose end of the wire connected to the positive terminal of the power supply, touch it to the fixed capacitor plate.
- When the capacitor is charged, take the wire away from the fixed capacitor plate again, thereby disconnecting it from the positive of the power supply.
- Read off the *U* for a plate separation of *d* = 2 mm and enter the value into Table1.

Note:
The voltage reading corresponds to the voltage U_0, with which the plate capacitor was charged. After it has been charged up one time, the plate carries the charge $Q = C \cdot U_0$ and the capacitance is $C \sim 1/d$. Since the plate capacitor will not be discharged during the rest of the measurement, this charge will remain on the plates. As the distance *d* between the capacitor plates is increased, the capacitance of the set-up goes down, which leads to a corresponding increase in the voltage $U > U_0$.

- Quickly increase the separation of the plates up to *d* = 18 mm in steps of 2 mm at a time. For each of these steps, read off the voltage *U* for the plate separation you have set and enter the result into Table 1.

SAMPLE MEASUREMENT

Tab. 1: Measurements of voltage *U* across a plate capacitor as a function of plate separation *d*.

d / mm	*U* / V
2	3.0
4	6.0
6	9.5
8	12.3
10	14.0
12	16.0
14	17.5
16	19.0
18	20.0

EVALUATION

- Plot the measurements of the voltage *U* across the plate capacitor, as entered into Table 1, against the set plate separation values *d* in a graph (Fig. 3).

From Equation 2, a plot of *U* against *d* will give a straight line passing through the origin and through the measurement points, with a gradient corresponding to the constant electric field *E*. Deviations can be attributed to the fact that the electric field can no longer be assumed to be homogeneous with an increasing distance between the plates.

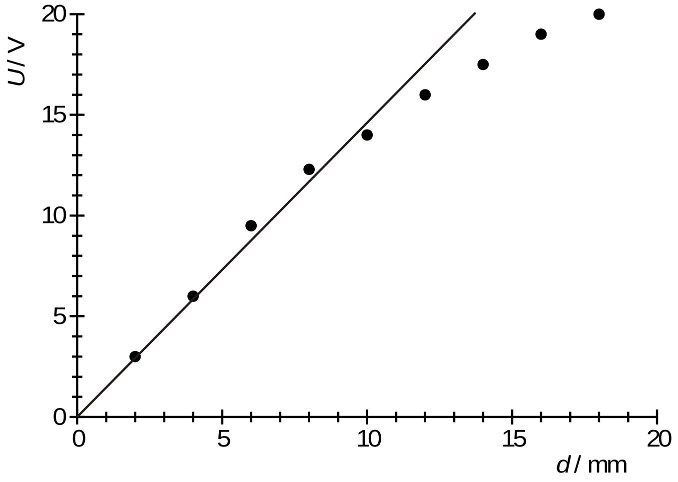

Fig. 3 Voltage *U* on the plate capacitor as a function of distance *d* between the plates