Electricity

Electrostatics

PHYSICS EXPERIMENT

Electric Field in a Plate Capacitor

MEASURE THE ELECTRIC FIELD IN A PLATE CAPACITOR USING THE ELECTRIC FIELD METER.

- **Measuring the electric field within a plate capacitor as a function of the distance between the plates.**
- **Measuring the electric field within a plate capacitor as a function of the applied voltage**

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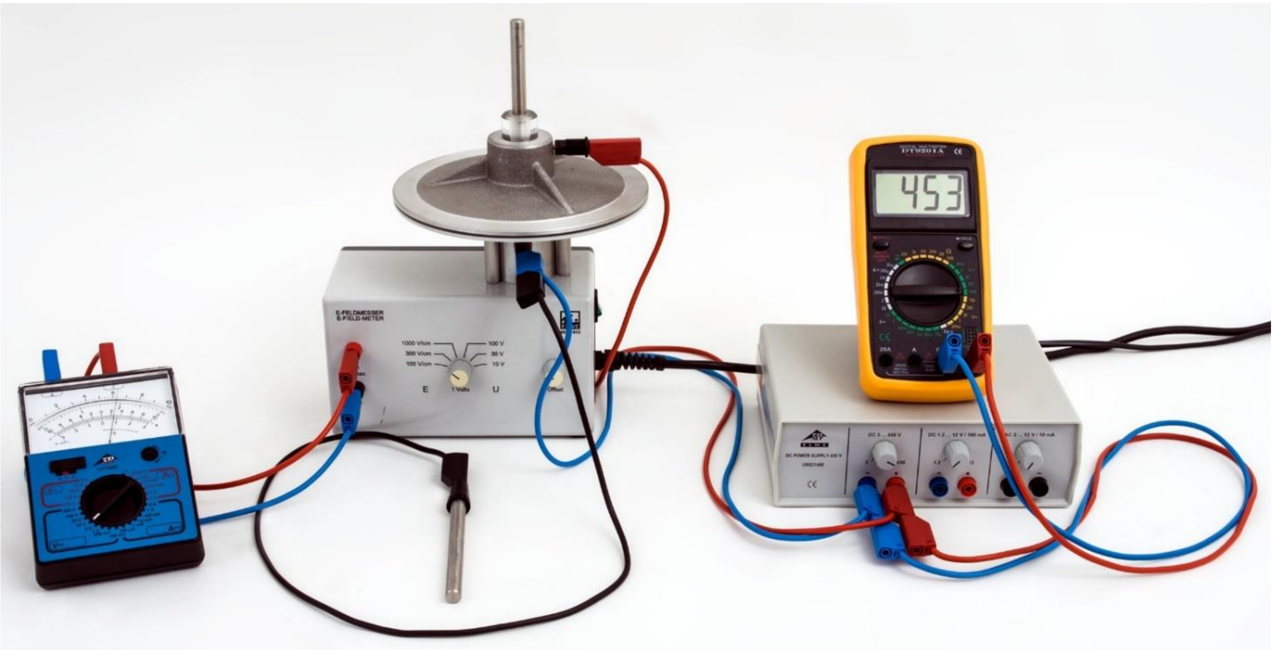

Fig. 1: Measurement set-up

BASIC PRINCIPLES

The electric field meter can be used to measure electric fields directly. In front of an induction plate with four sectors in a star-shaped arrangement, a fan-like disc of similar shape is rotated. It continually interrupts the electrostatic flux, and thereby causes periodic induced charges, which are allowed to dissipate through a large resistance. The voltage pulses that are thereby generated are amplified to give an output voltage, which is then rectified to give a DC voltage that is proportional to the electric field *E* acting on the induction plate.

In the experiment, the electric field strength

$$(1)\quad E = \frac{U}{d}$$

in a plate capacitor is measured using the electric field meter. The applied voltage U and the distance d between the plates are varied in separate experimental runs.

In applying Equation 1, one must take into account the fact that the induction plate is about 1 mm below the lower capacitor plate. Therefore, Equation 1 must be replaced by:

$$(2)\quad E = \frac{U}{d_{\mathrm{eff}}} = \frac{U}{d + 1\,\mathrm{mm}}\,.$$

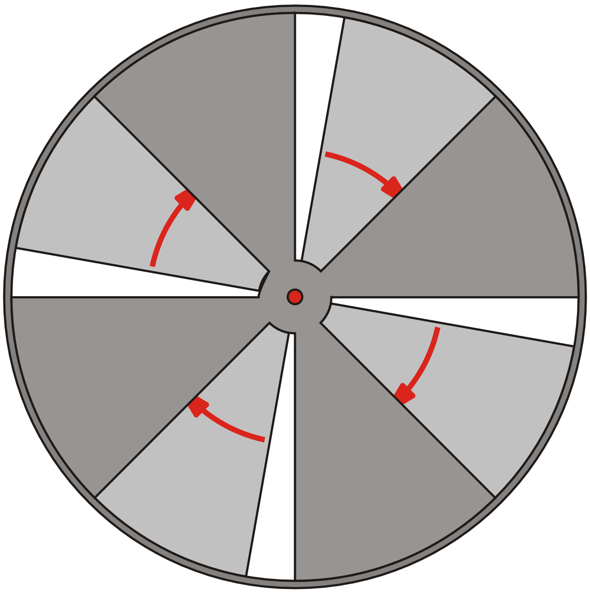

Fig. 2: Rotating disc of electric field meter.

LIST OF EQUIPMENT

1 Electric Field Meter @230V 1001030 (U8533015-230)
or
1 Electric Field Meter @115V 1001029 (U8533015-115)
1 DC Power Supply 450 V@230V 1008535 (U8521400-230)
or
1 DC Power Supply 450 V@115V 1008534 (U8521400-115)
1 Digital Multimeter E 1018832 (U8531051)
1 Analogue Multimeter Escola 30 1013526 (U8557330)
1 Set of 15 Safety Experiment Leads, 75 cm 1002843 (U138021)

SET UP AND PROCEDURE

General instructions

- Whenever possible, conduct the experiments using voltages that are not dangerous to the touch.
- When using mains-connected instruments that generate a voltage that would be dangerous to touch, use a 300 kΩ resistor (1000690) to limit the current.
- For all measurements, connect the contact rod to the earth socket on the screening cylinder and hold it in your hand, so that you are also at the same potential.
- Before each set of measurements, the zero-point of the electric field meter should be calibrated for all the measurement ranges.
- After plugging into the mains, wait a few minutes for the instrument to reach normal working temperature.
- To avoid damage to the electric field meter, do not touch the rotating vaned wheel.
- The insulating parts of the instrument and the measurement plates must be kept clean and dry (avoid touching them). When the air is very humid, it may be necessary to dry them in a current of warm air (use a hair-dryer).

Zero-point calibration

- Set up the experiment as shown in Fig. 1. Do not turn on the DC power supply yet.
- Put the voltage measurement plate for measuring range 1x (with 4-mm socket) on the screening cylinder, secure it with the help of the knurled screw and connect it to the earth socket of the screening cylinder.
- First calibrate the zero-point for the indicating instrument (Analogue Multimeter Escola 30) (see relevant instruction sheet).
- Turn the measurement range switch to the “U” position and set to the highest range.
- Switch on the electric field meter and set the zero point using offset adjustment.
- Calibrate the zero-point for the two lower measurement ranges by the same procedure.

Tab. 1: Adjustment of plate separations d = 1 – 15 mm by combinations of spacers.

	d / mm														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Knurled screw from below		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spacer, 2 mm with thread		X	X	X	X	X	X								
Spacer, 8 mm with thread								X	X	X	X	X	X	X	X
Spacer, 1 mm	X		X		X		X		X		X		X		X
Spacer, 2 mm				X	X					X	X			X	X
Spacer, 4 mm						X	X					X	X	X	X

- Replace the voltage measurement plate, putting the capacitance measuring plate on the screening cylinder instead. Secure it in place with its fastening screw.

Adjustment of plate separation

- To adjust plate separation to d = 1 mm, place the three 1 mm spacer discs about 120° apart on the edge of the capacitance measuring disc and then put the capacitor plate on top of them.
- To adjust plate separation to d = 2 – 7 mm, screw the three 2 mm spacers with internal thread about 120° apart on the edge of the capacitance measuring disc by means of the knurled screws. Then also slot the three 1, 2 and 4 mm spacers onto the knurled screws as shown in Table 1 and place the capacitor plate on top of these spacers.
- To adjust plate separation to d = 8 – 15 mm, use the three 8 mm spacers with internal thread instead of the 2 mm ones.

Electric field as a function of plate separation

- Set the plate separation to d = 2 mm and enter the corresponding effective plate separation d_{eff} = 3 mm into Table 2.
- Turn on the DC power supply and set the voltage to U = 100 V.
- Select a measuring range of 100 V/cm on the electric field meter.

A voltage of 1 V read off from the analogue multimeter corresponds to an electric field of 100 V/cm = 1 V/m.

- Enter the voltage reading from the analogue multimeter as the value of the electric field in units of V/m into Table 2.
- Turn the voltage down all the way on the DC power supply then turn off the power supply and discharge the capacitor plate by briefly connecting it to the screening cylinder.
- Repeat the measurement with the same applied voltage U = 100 V for plate separations of d = 4, 6, 8, 10 and 12 mm (Table 1) and enter the field strengths you measure next to the corresponding effective separations d_{eff} in Table 2.

Electric field as a function of applied voltage

- Set the plate separation to d = 9 mm (d_{eff} = 10 mm).
- Turn on the DC power supply and set the voltage to U = 50 V.
- Select a measuring range of 100 V/cm on the electric field meter.

A voltage of 1 V read off from the analogue multimeter corresponds to an electric field of 100 V/cm = 1 V/m.

- Enter the voltage reading from the analogue multimeter as the value of the electric field in units of V/m into Table 3.
- Turn the voltage down all the way on the DC power supply then turn off the power supply and discharge the capacitor plate by briefly connecting it to the screening cylinder.
- Repeat the measurement with the same plate separation d = 9 mm for voltages of U = 100, 150, 200, 250, 300, 350, 400 and 450 V and enter the field strengths you measure next to the corresponding effective separations d_{eff} in Table 3.

SAMPLE MEASUREMENT

Tab. 2: Electric field strength as a function of plate separation for U = 100 V.

d_{eff} / mm	E / V/m
3	3.45
5	2.04
7	1.45
9	1.12
11	0.92
13	0.78

Tab. 3: Electric field strength as a function of applied voltage U for d_{eff} = 10 mm.

U / V	E / V/m
50	0.58
100	1.10
150	1.70
200	2.20
250	2.70
300	3.30
350	3.90
400	4.50
450	4.95

EVALUATION

- Plot the electric field strengths E you have measured against the effective plate separations d_{eff} (Table 2) and the applied voltage U (Table 3) (see Figs. 3, 4).
- The hyperbolic relationship between field strength and effective plate separation (Fig. 3) and the linear dependence on applied voltage (Fig. 4) as predicted by equation (2) are verified by these graphs.

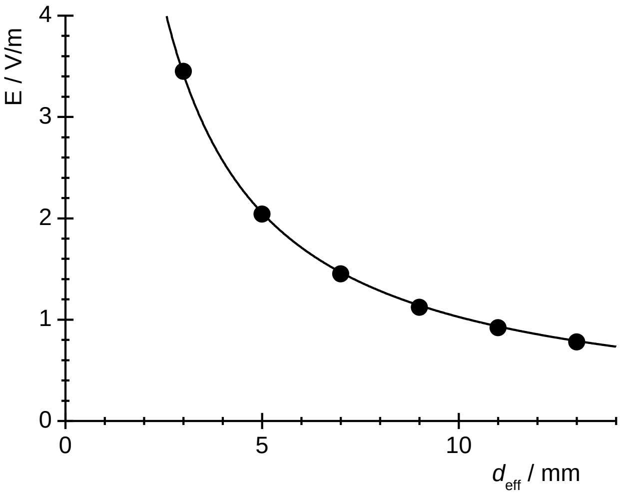

Fig. 3: Electric field within plate capacitor as a function of plate separation for U = 100 V.

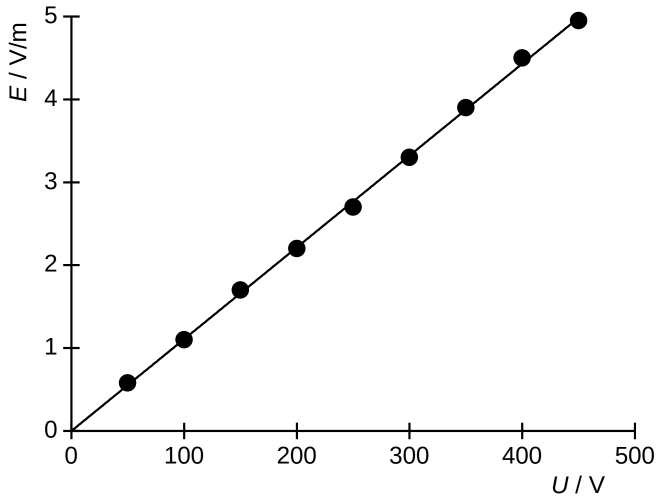

Fig. 4: Electric field within plate capacitor as a function of applied voltage U for d_{eff} = 10 mm.