### Related topics

Capacitor, electric field, potential, voltage, equipotential lines.

### Principle and task

A uniform electric field $\vec{E}$ is produced between the charged plates of a plate capacitor. The strength of the field is determined with the electric field strength meter, as a function of the plate spacing *d* and the voltage *U*. The potential $\phi$ within the field is measured with a potential measuring probe.

### Equipment

| | | |
|---|---|---|
| Plate capacitor, 283×283 mm | 06233.02 | 2 |
| Capacitor plate w. hole d 55 mm | 11500.01 | 1 |
| Spacer plates, 1 set | 06228.01 | 1 |
| Electric field meter | 11500.10 | 1 |
| Potential probe | 11501.00 | 1 |
| Power supply, 0...600 VDC | 13672.93 | 1 |
| Blow lamp, butan cartridge, X2000 | 46930.00 | 1 |
| Butane cartridge | 47535.00 | 2 |
| Rubber tubing, i.d. 7 mm | 39282.00 | 1 |
| Digital multimeter | 07134.00 | 2 |
| Connecting cord, 100 mm, green-yell | 07359.15 | 1 |
| Connecting cord, 750 mm, red | 07362.01 | 5 |
| Connecting cord, 750 mm, blue | 07362.04 | 5 |
| Optical profile bench l = 60 cm | 08283.00 | 1 |
| Base f. opt. profile-bench, adjust. | 08284.00 | 2 |
| Slide mount f. opt. pr.-bench, h 80 mm | 08286.02 | 2 |
| Slide mount f. opt. pr.-bench, h 30 mm | 08286.01 | 1 |
| Support rod, stainl.steel, 250 mm | 02031.00 | 1 |
| Support rod -PASS-, square, l 250 mm | 02025.55 | 1 |
| Right angle clamp -PASS- | 02040.55 | 4 |
| Rule, plastic, 200 mm | 09937.01 | 1 |

### Problems

1. The relationship between voltage and electric field strength is investigated, with constant plate spacing.
2. The relationship between electric field strength and plate spacing is investigated, with constant voltage.
3. In the plate capacitor, the potential is measured with a probe, as a function of position.

### Set-up and procedure

1. The experimental set up is as shown in Fig. 1. The electric field meter should first be zero-balanced with a voltage of 0 V. The electric field strength is now measured at various voltages at any plate spacing (approx. 10 cm).

2. The electric field strength is now measured as a function of the distance between the two capacitor plates, in a range of

Fig. 1: Arrangement for measuring the electric field strength as a function of the voltage and the plate spacing.

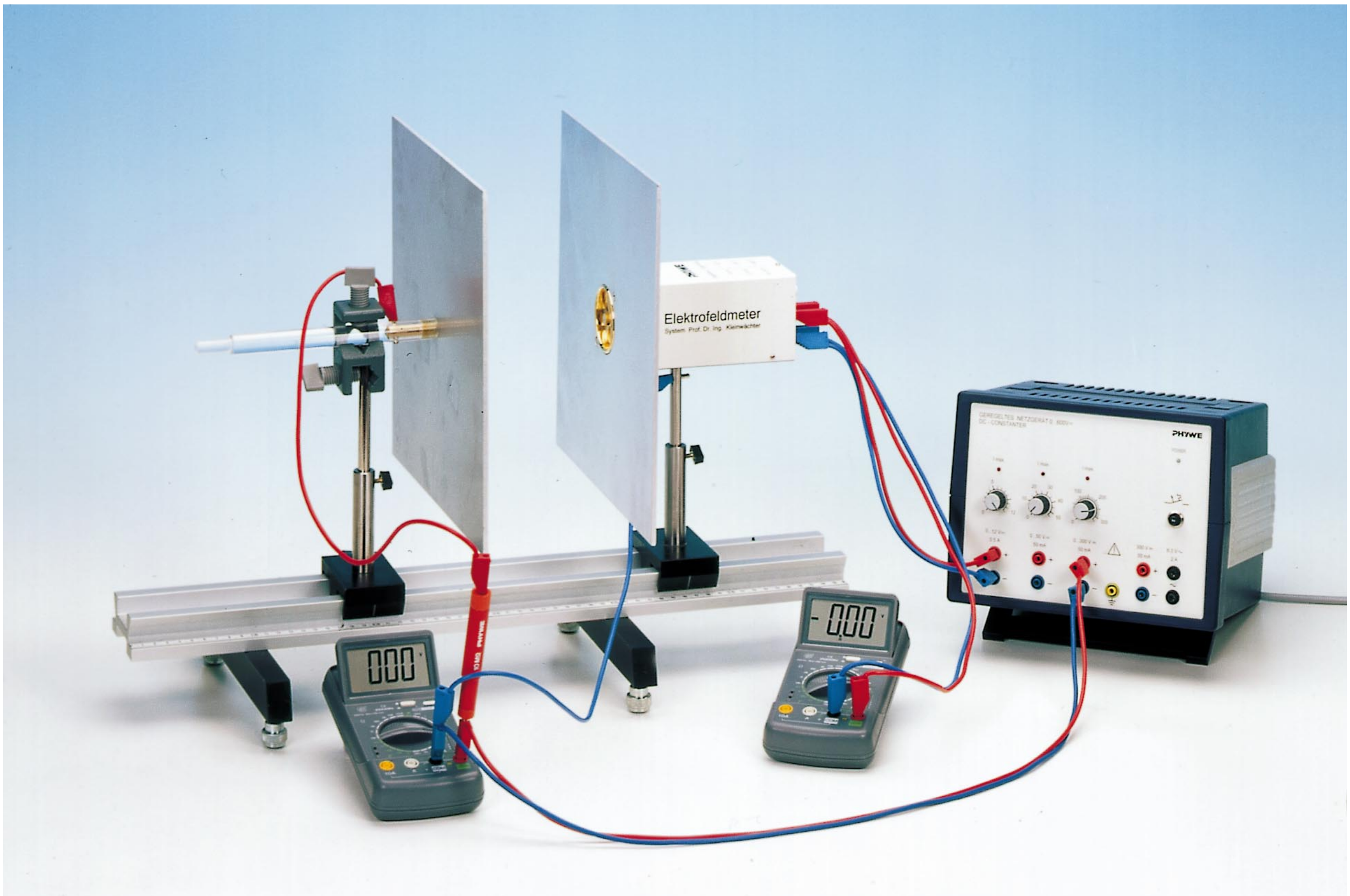


Fig. 2: Arrangement for measuring the potential in the plate capacitor as a function of the position.


approx. 2 to 12 cm, with an unchanged set up, but with a constant voltage of 200 V.

3. The experimental set up is as shown in Fig. 2. The plates have a spacing of 10 cm; the applied voltage is 250 V.

The potential between the plates is measured with the potential measuring probe. In order to avoid interference from surface charges, the air at the tip of the probe is ionised, using a flame 3 to 5 mm long. The probe should always be moved parallel to the capacitor plates.

**Theory and evaluation**

$$\text{rot } \vec{E} = -\dot{\vec{B}}$$

$$\text{div } \vec{D} = \rho$$

follow from Maxwell's equations for the electric field $\vec{E}$ in the plate capacitor.

For the steady-state case in the charge-free space between the plates,

$$\text{rot } \vec{E} = 0 \qquad (1)$$

$$\text{div } \vec{D} = 0 \,. \qquad (2)$$

If one plate is placed in the *y-z* plane and the other parallel to it at a distance *d,* and if boundary disturbances due to the finite extent of the plates are disregarded, it follows from (2) that $\vec{E}$ lies in the *x*-direction and is uniform. Since the field is irrotational (rot $\vec{E}$ = 0) it can be represented as the gradient of a scalar field $\phi$:

$$\vec{E} = -\text{grad } \phi = -\frac{\partial \phi}{\partial x} \,,$$

while $\vec{E}$, because of its uniformity, may also be expressed as the quotient of differences

$$E = \frac{\phi_1 - \phi_0}{x_1 - x_2} = \frac{U}{d} \,, \qquad (3)$$

where the potential difference is equal to the applied voltage *U* and *d* is the distance between the plates.

From the regression line to the measured values of Fig. 3, with the exponential statement

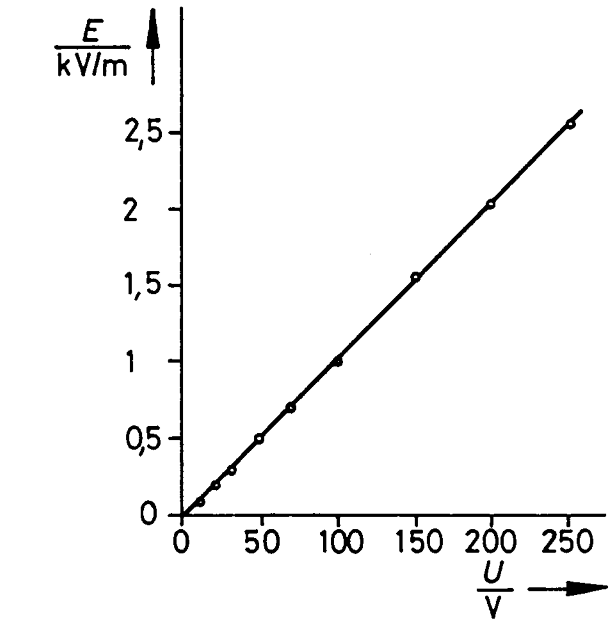
$$E = A \cdot U^B$$

the exponent follows as

$$B = 1.005 \pm 0.003.$$

With constant spacing *d, E* is thus proportional to the voltage.

Fig. 3: Electric field strength as a function of the plate voltage.




With constant voltage *U,* the field strength *E* varies in inverse proportion to the spacing *d.*

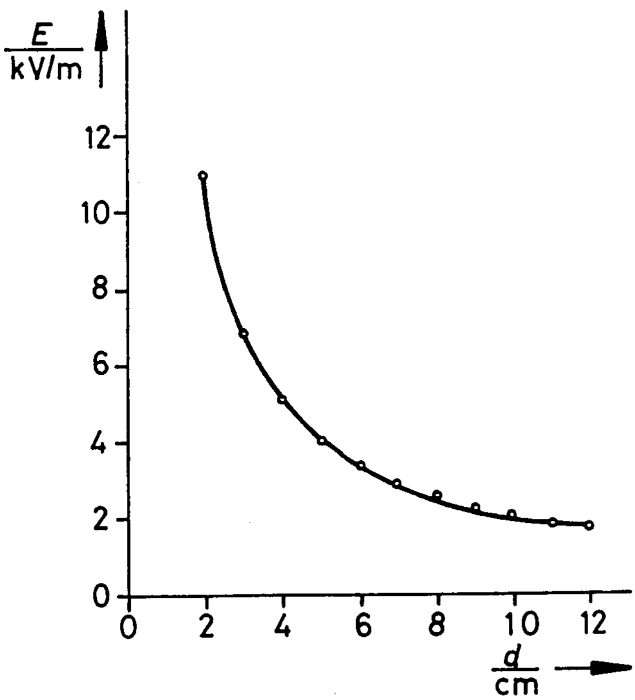
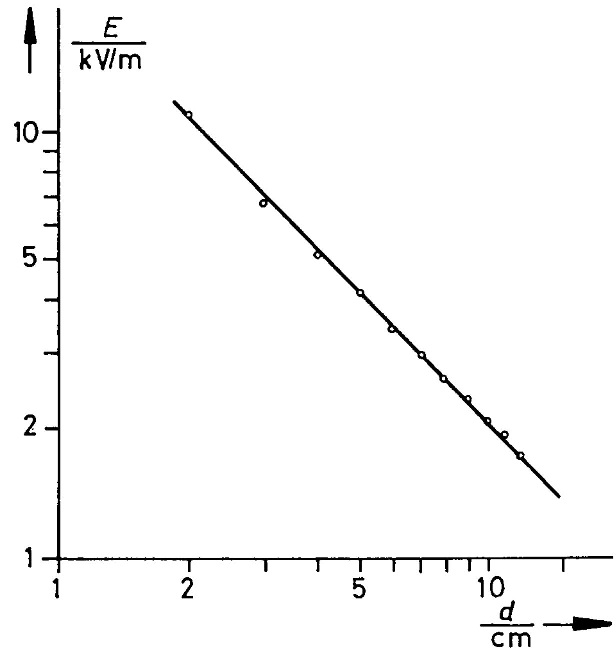



Fig. 4: Electric field strength as a function of the plate spacing.

Fig. 5: The measured values of Fig. 4, plotted on log-log paper.




If the measured values are plotted on log-log paper (Fig. 5) , then because

$$\log E = \log \frac{U}{d} = \log U - \log d \,,$$

a straight line is obtained with slope –1.02 with a standard error 0.02.

Since the potential $\phi$ of an equipotential surface in the plate capacitor is linearly dependent on its distance *x*, e.g. from the plate with potential $\phi_1$, then

$$\phi = \phi_1 - E \cdot x = \phi_1 - \frac{U}{d} \cdot x \,,$$

while $\phi_0$ is set = 0 (Fig. 6).

With a voltage $U$ = 250 V and a plate spacing $d$ = 10 cm, the measured values of Fig. 7 show the linear relationship between position and potential.

With the linear statement

$$\phi = \phi_1 + Ex$$

there follows

$$\phi_1 = 256 \text{ V}$$

and

$$E = -2.68 \pm 0.04 \, \frac{\text{kV}}{m} \,.$$

Fig. 6: Measurement of potential in the plate capacitor.

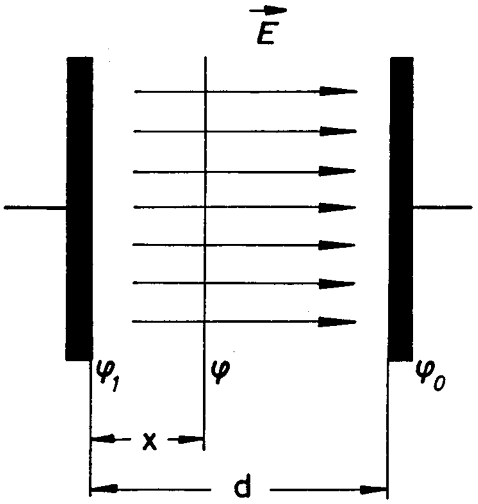



Fig. 7: The potential within the plate capacitor ($U$ = 250 V, $d$ = 10 cm).