

Flux, Gauss's law and continuous charge

AP Physics C (Mechanics and E&M, calculus-based) · Lab

Name: _____ Date: _____ Class: _____

A charged ball hangs between two parallel plates and swings away from vertical when the voltage is turned on. How does the sideways force depend on the field, and what charge does the ball carry? This lab measures the deflection against voltage and links it to Gauss's law for the plates.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:E&M Unit 8

Aim

To show that the force on a charged ball between parallel plates is proportional to the field $E = V/d$, and to estimate the charge on the ball and the surface charge density on the plates.

Equipment

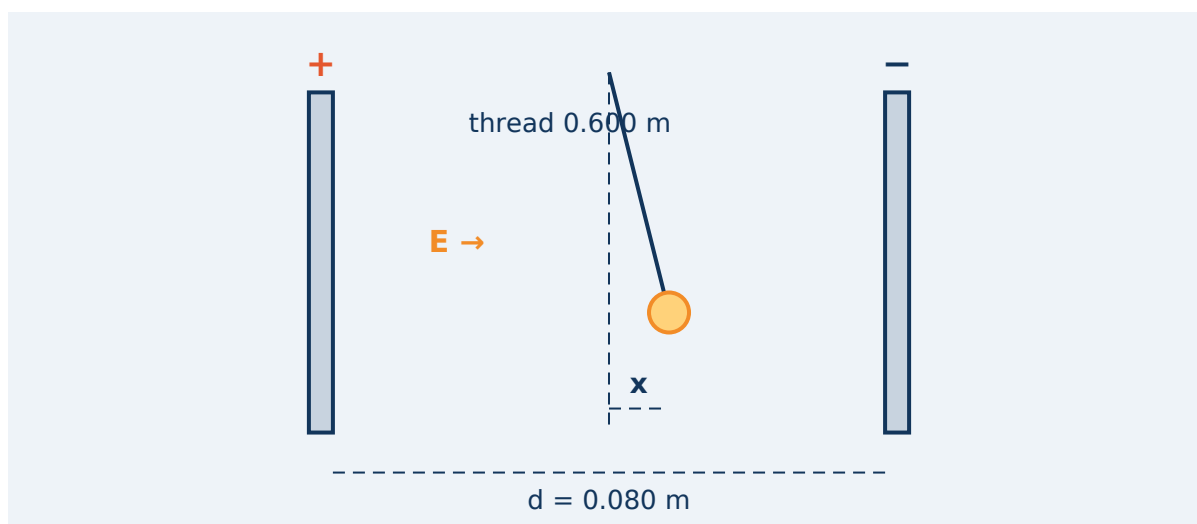
- Two parallel metal plates 0.080 m apart on insulating stands
- A variable high-voltage supply (0 to 5 kV) with a protective 5 M Ω resistor
- A foil-coated polystyrene ball of mass 0.12 g on a thin nylon thread 0.600 m long
- A ruler and a plain background card

Safety

Safety

Use only a supply designed for school use with a built-in 5 M Ω safety resistor. Switch off and discharge the plates with an insulated lead before touching anything. Teacher supervision is required. Keep away from anyone with a pacemaker.

Method



Set-up: the deflection x of a charged ball measures the horizontal force qE between the plates.

1. Charge the ball once by touching it to the positive terminal, then hang it midway between the plates with no voltage applied.
2. Set the supply to 1.0 kV and measure the sideways displacement x of the ball with the ruler.
3. Increase V in steps of 1.0 kV up to 5.0 kV, measuring x each time.
4. Calculate $E = V/d$ and $\tan\theta = x / \sqrt{L^2 - x^2}$ with $L = 0.600$ m.
5. Plot $\tan\theta$ against E and find the gradient.

Results

Sample measurements:

V (kV)	$E = V/d$ (10^4 N/C)	x (mm)	$\tan\theta$
1.0	1.25	25	0.042
2.0	2.50	51	0.085
3.0	3.75	76	0.128
4.0	5.00	100	0.169
5.0	6.25	125	0.213

Analysis questions

Question 1 Check the table

Verify the value of $\tan\theta$ for $V = 4.0$ kV.

Question 2 Why $E = V/d$

Explain why the field between large parallel plates is uniform and equal to σ/ϵ_0 , and why this gives V/d .

Question 3 Equilibrium condition

Show that $\tan\theta = qE/(mg)$ for the ball in equilibrium.

Question 4 Charge on the ball

Find the gradient of the $\tan\theta$ -E graph using the first and last points, and calculate the charge on the ball.

Question 5 Surface charge density

Calculate the surface charge density on the plates at 5.0 kV.

Question 6 Uncertainty

The displacement is read to ± 2 mm. Calculate the percentage uncertainty in x at 5.0 kV and in the charge.

Question 7 Improving the experiment

Suggest two sources of error and two improvements.