Bouncing flame

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Lyceum № 130

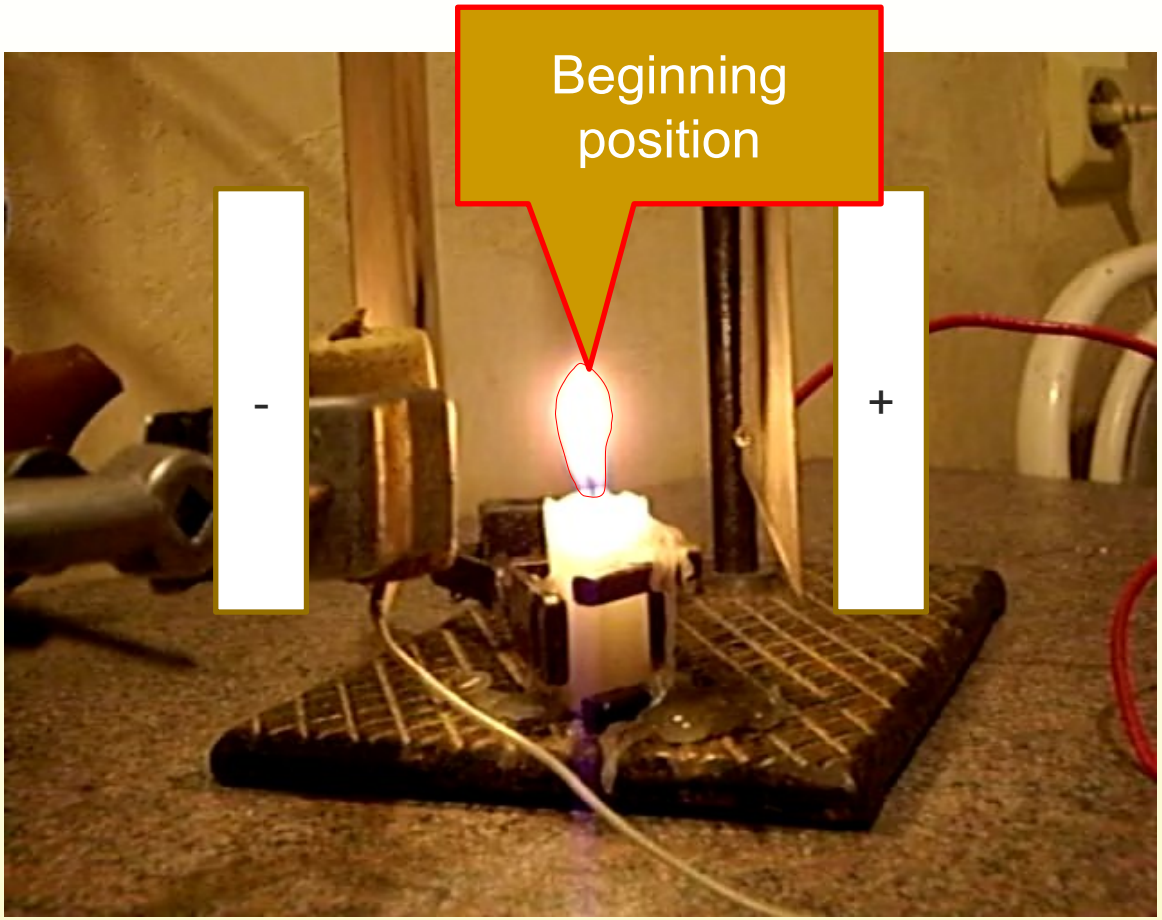
Problem

- Place a flame (e.g. from a Bunsen burner) between two charged parallel metal plates. Investigate the motion of the flame.

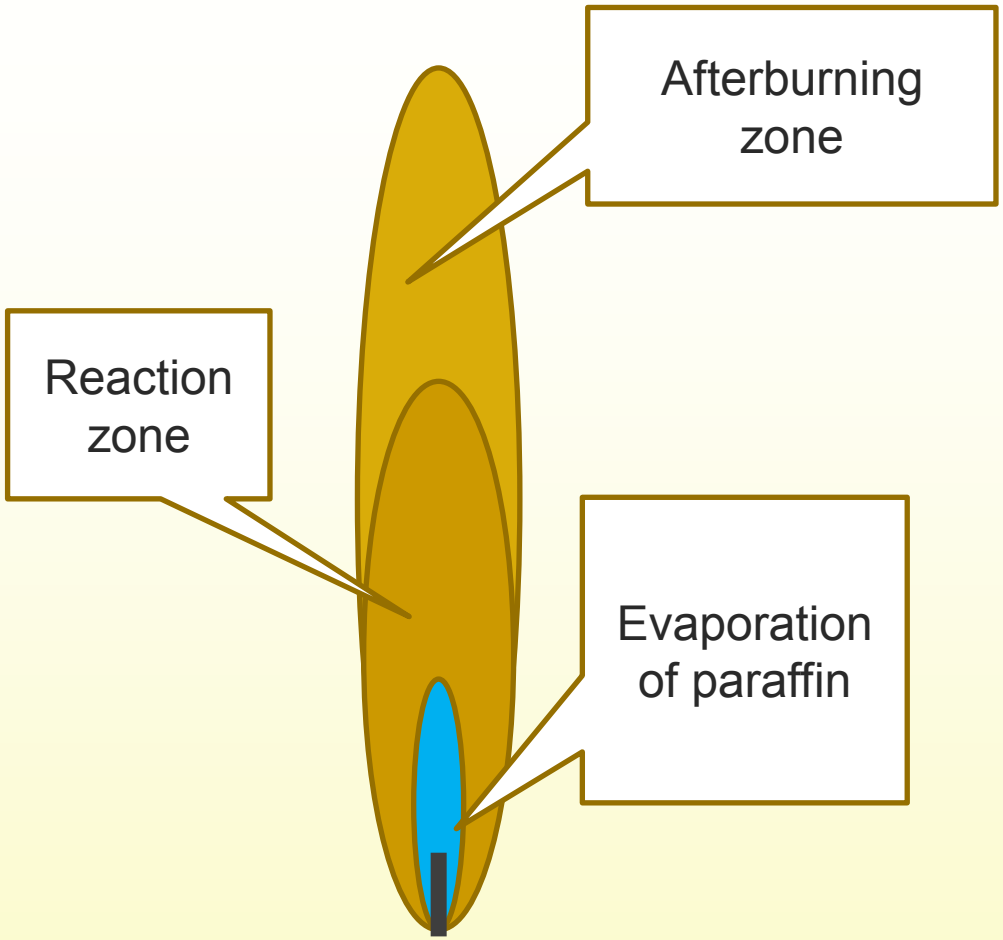
The investigation plan

- To observe the phenomenon
- To study the causes of the phenomenon
- To rate the deviation angle of the flame theoretically
- To build the setup and rate deviation angle of the flame experimentally
- To compare the theory with experiments

Observation of the effect



Scheme of burning

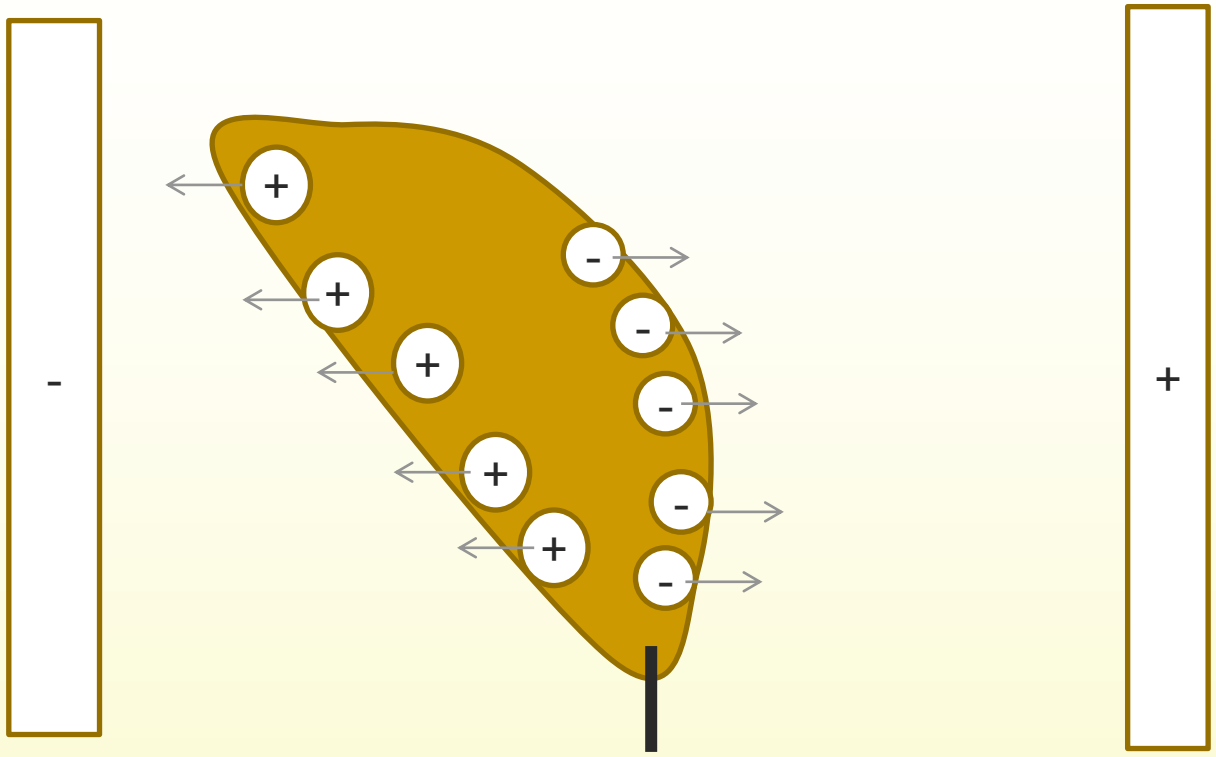


$$C_{32}H_{68}+49O_2 \rightarrow 32CO_2+34H_2O$$

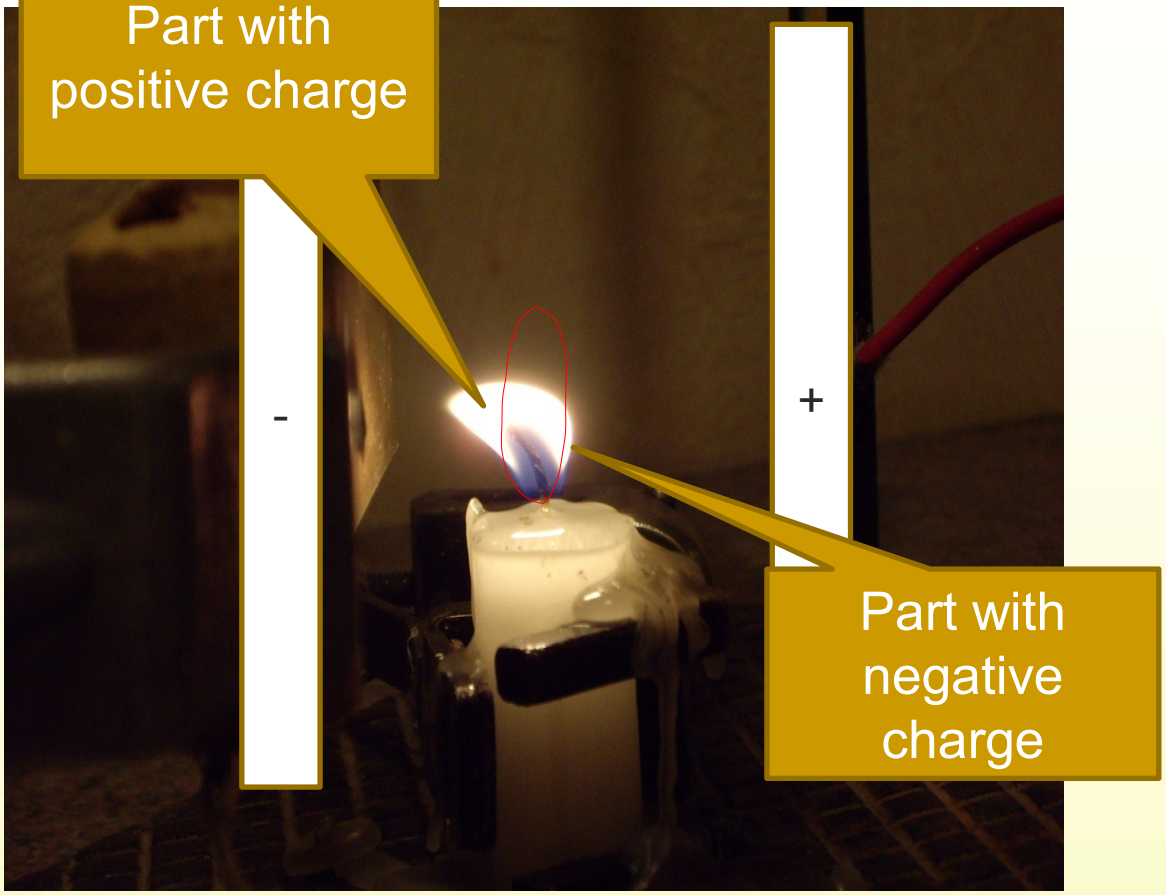
Ionization

- $CH+O \rightarrow CHO^{+}+e^{-}$
- Maximum ionization is in the flame front, where chemical processes take place

Charge distribution



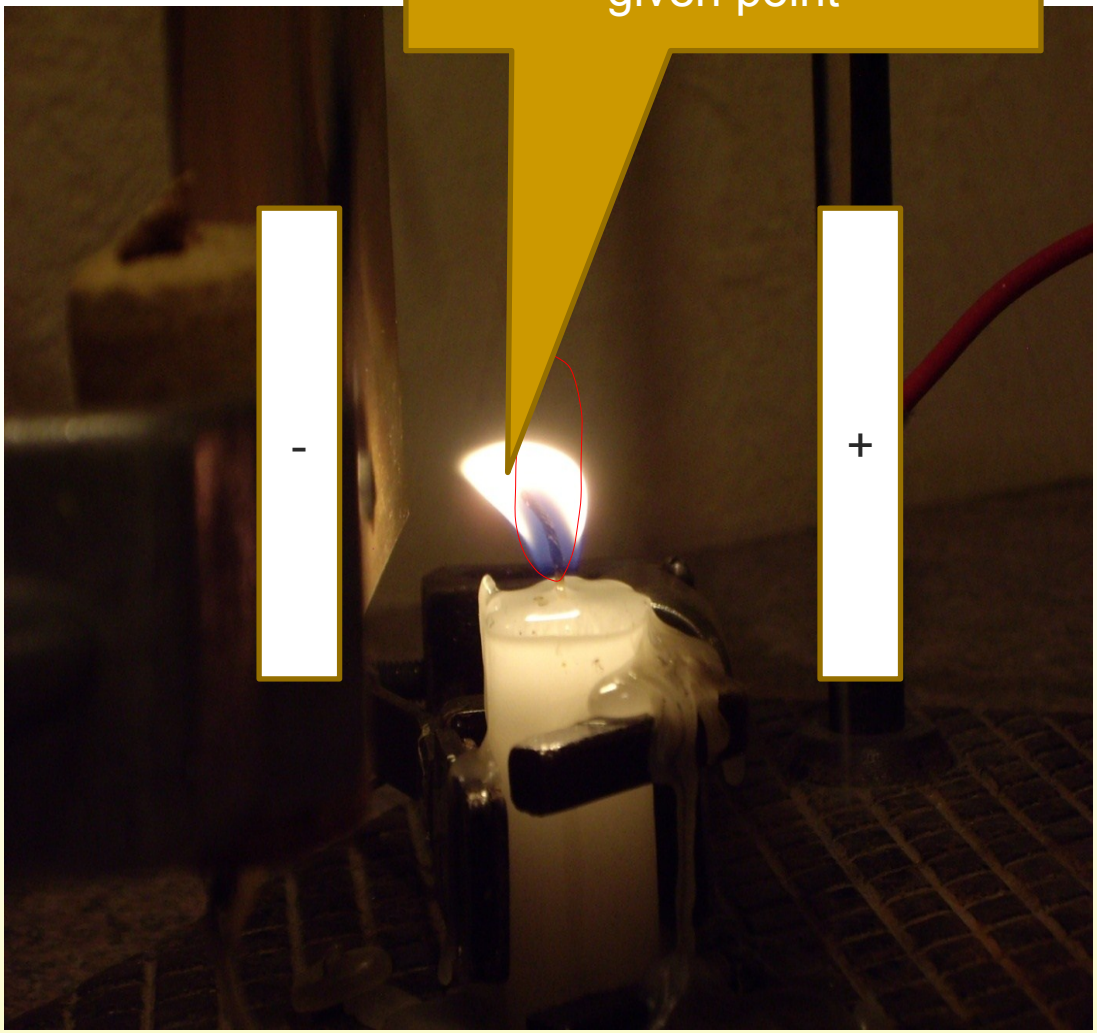
Theoretical explanation of deviation and bounces



Charged parts of the flame are under influence of Coulomb force

↓

Flame starts to deviate



Charge concentration is changing

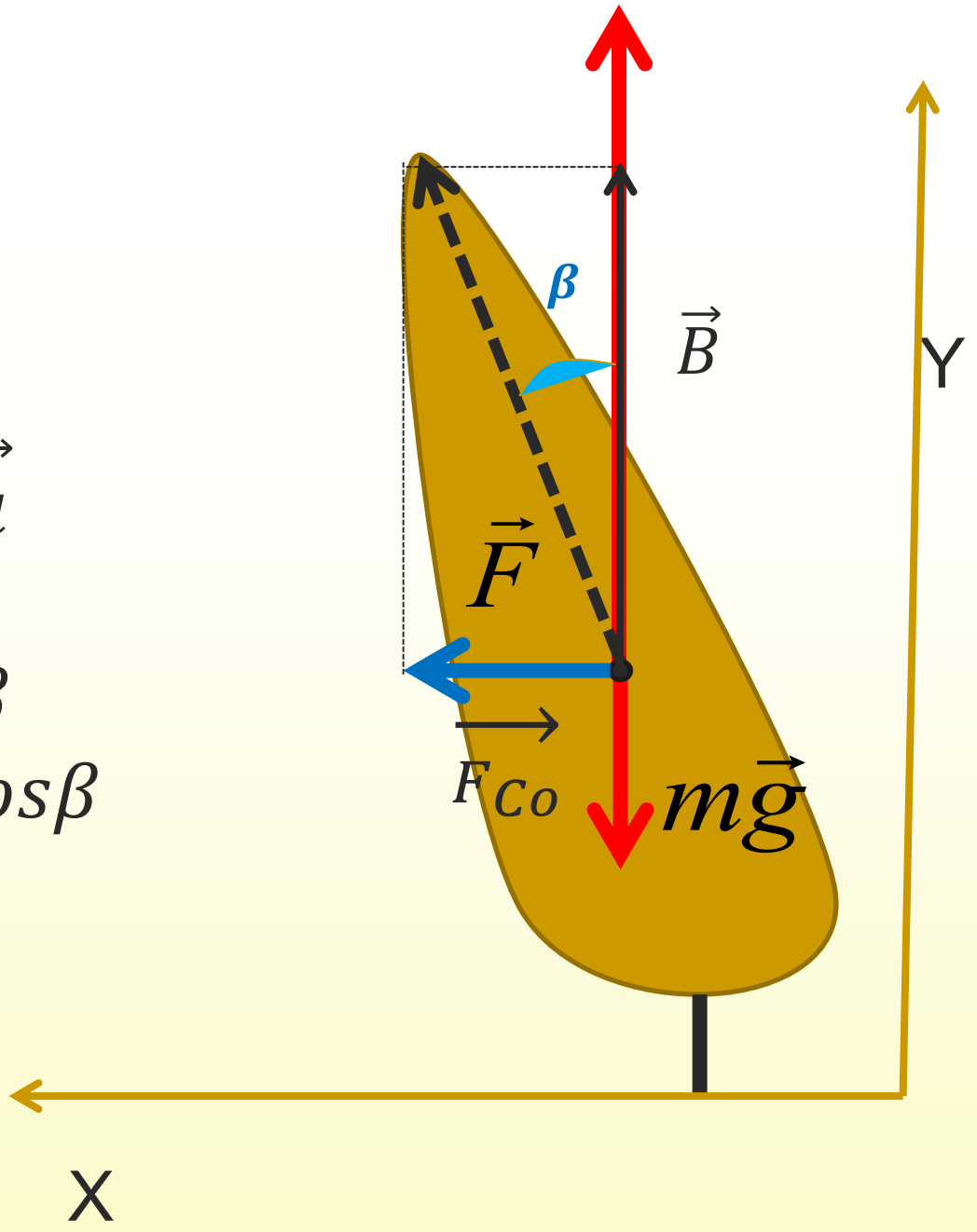
$$U = E * d$$
$$d = const$$
$$U = const$$
$$E = \frac{F_{Co}}{q}$$
q varies, therefore F_{Co} varies too

The visible part of the flame start to bounce

Force applying

$$\vec{F} = m\vec{g} + \vec{B} + \overrightarrow{F_{cl}}$$

$$Ox: F_{cl} = F * sin\beta$$
$$Oy: B - mg = F * cos\beta$$



Calculation of buoyancy and gravitation force

$$B = \rho_{air} g V$$

$$mg = \rho g V$$

Using Mendeleev-Clapeyron equation we can calculate the density of subsistence in the flame (ρ)

$$PV = \mu RT = \frac{m}{M} RT$$

$$\rho = \frac{PM}{RT}$$

Value of the flame is 1,3 cm^2 , temperature is 1567 K

$$F * cos\beta = B - mg = gV\left(\rho_{air} - \frac{PM}{RT}\right) = 1{,}09 * 10^{-2} N$$

Calculation of Coulomb force

$\alpha = \frac{n_i}{N}$ - Ionization degree (the ratio of ionized molecules n_i to the whole number of molecules N)

$q = \alpha N e$ - Positive charge

$F_{cl} = qE \qquad E = \frac{U}{d} \longrightarrow F_{cl} = \alpha N e \frac{U}{d}$

Using Mendeleev-Clapeyron equation we can calculate N:

$N = \mu N_A \qquad \mu = \frac{PV}{RT} \qquad N = \frac{PV}{RT} N_A$

$$F_{cl} = \alpha \frac{PV}{RT} N_A e \frac{U}{d}$$

Calculation of ionization degree

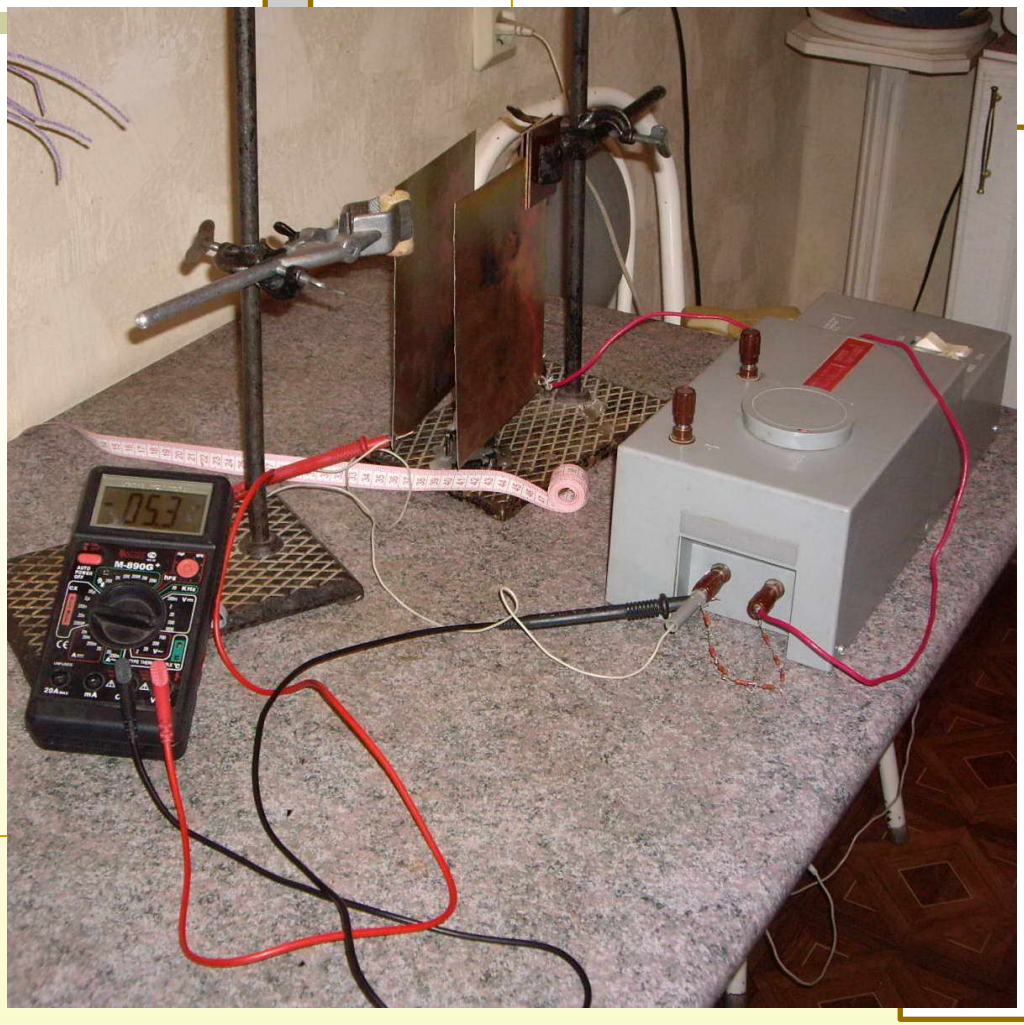
Saha's formula was used to calculate the degree of heat ionization in gas:

$$\frac{\alpha^2}{(1-\alpha^2)} = \left(\frac{2\pi m}{h^2}\right)^{\frac{3}{2}} * \frac{(KT)^{\frac{5}{2}}}{P} * e^{-\frac{W_i}{KT}}$$

- m – mass of electron
- h – Planck constant
- K – Boltzmann constant
- T – temperature of flame (1567 K)
- P – pressure of gas (atmospheric)
- W_i - energy of atoms ionization (CH_2)

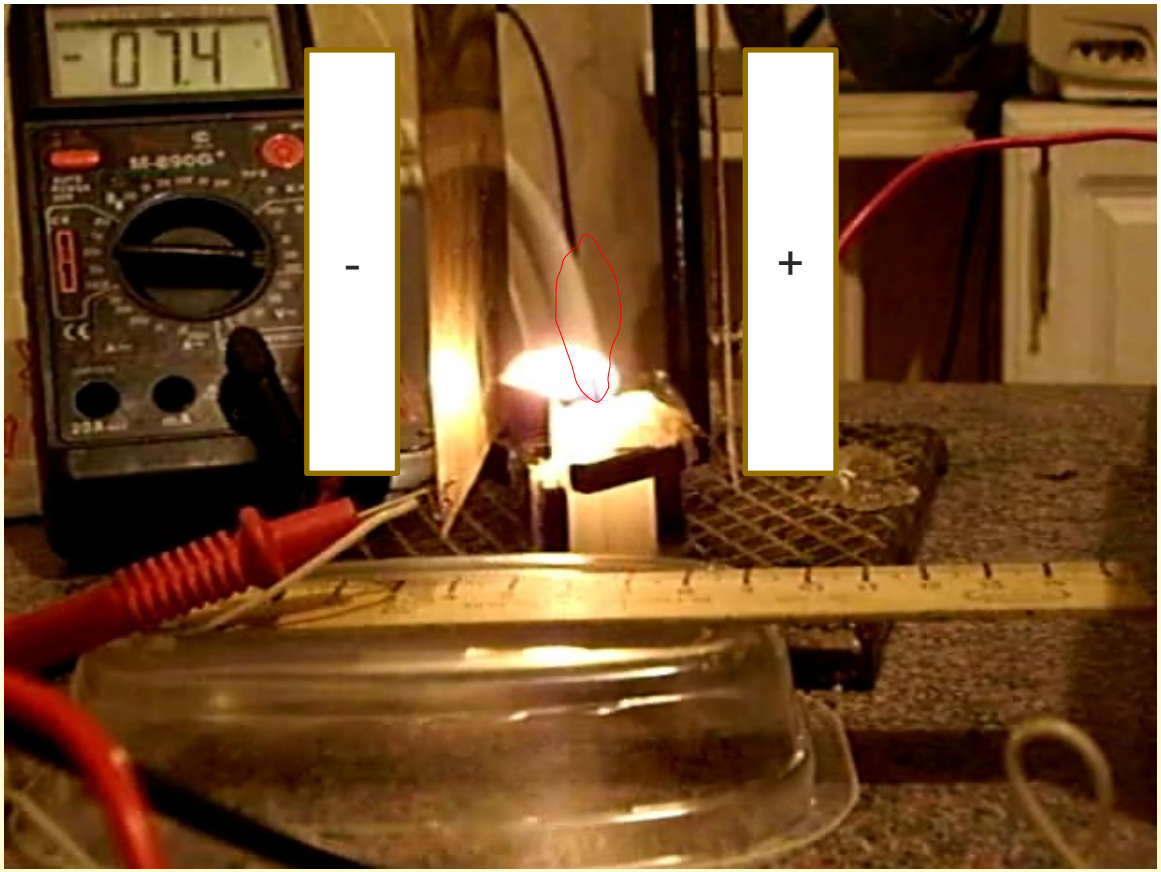
Theoretical dependence

Setup



Current source, 12V

Experiment

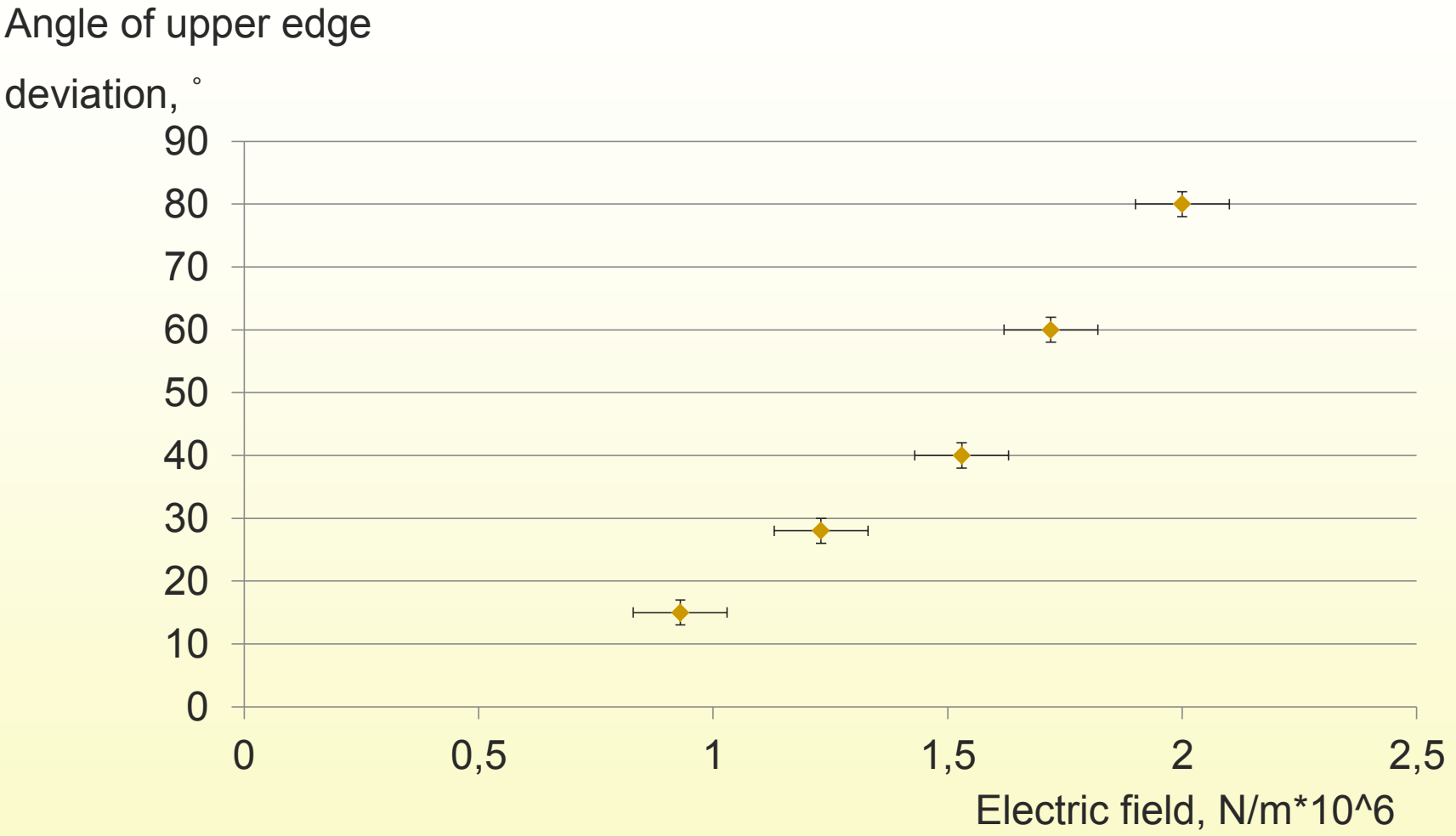


5 cm between plates

Deviation of the upper edge of the flame in the horizontal – 1.9 cm

Deviation angle of the upper edge is about 72°

Dependence of angle of upper edge deviation on the distance between the plates



Results of the research

- Phenomenon was observed
- Theoretical explanation of the effect was suggested:
- Chemical properties and ionization were investigated
- Main reason of deviation – applying of the Coulomb force
- Main reason of bounces – changing of charge at the given point
- Theoretical dependence of deviation angle on electric field was made
- All the forces were calculated
- Experimental dependence of deviation angle on electric field was made
- We've compared theoretical results with experimental results

Thanks for attention