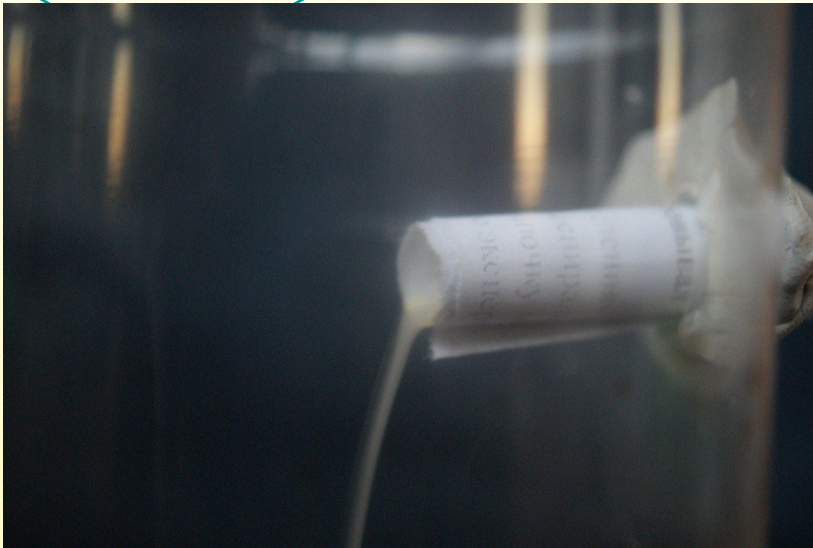


Smoke stream



Dudin Maxim
Lyceum №130

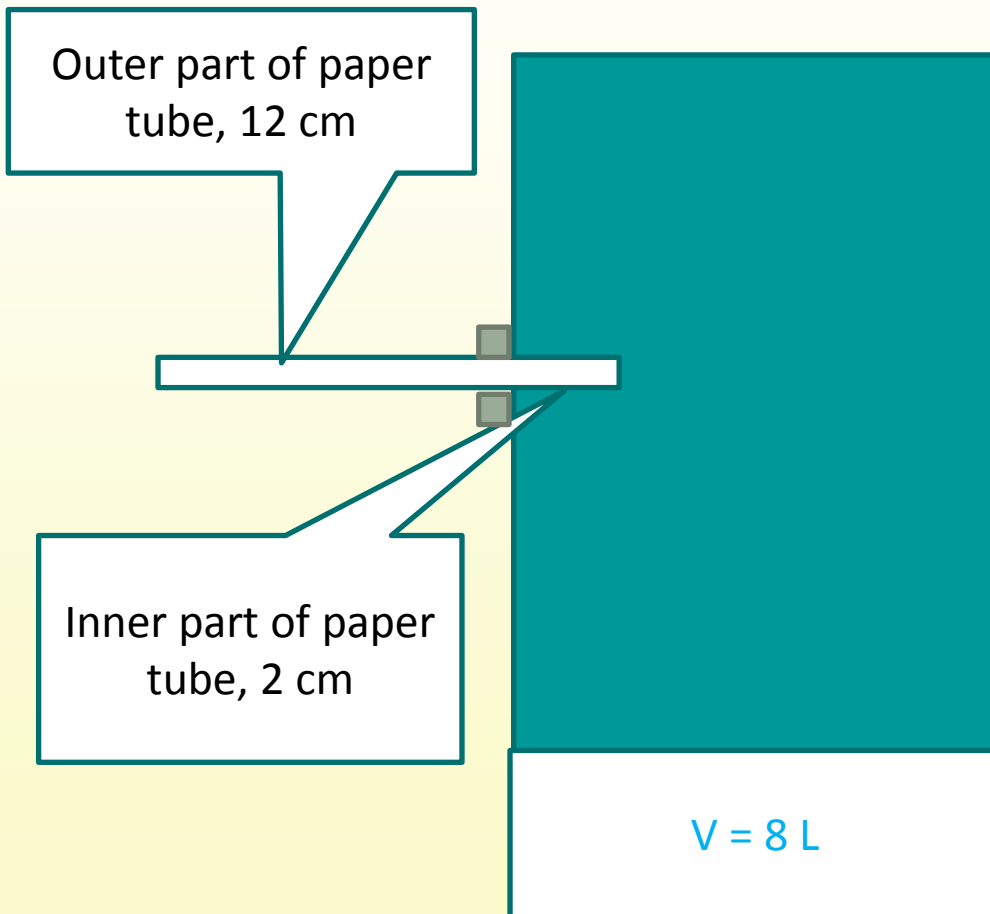
[Problem]

- A glass jar is covered with cellophane. A tightly folded paper tube of length 4-5 cm is inserted hermetically into the jar through the cellophane cover. The tube is oriented horizontally. If one burns the outside end of the tube the dense smoke flows into the jar. Explore this phenomenon.

The investigation plan

- To build the experimental setup and observe phenomenon
- To fix some parameters of paper tube and burning of this tube
- To study the influence of different parameters on smoke stream
- To make theoretical explanation and check it

Experimental setup



Section of the tube has 6 mm diameter, we always use quarter of A4 list to build a tube

Edge of the tube was fixed with small layer of glue

Lit using the gas burner

Observation of the effect



Smoke starts to drop when flame is 7.5 cm to the edge of bottle

Smoke starts to drop after 8 sec

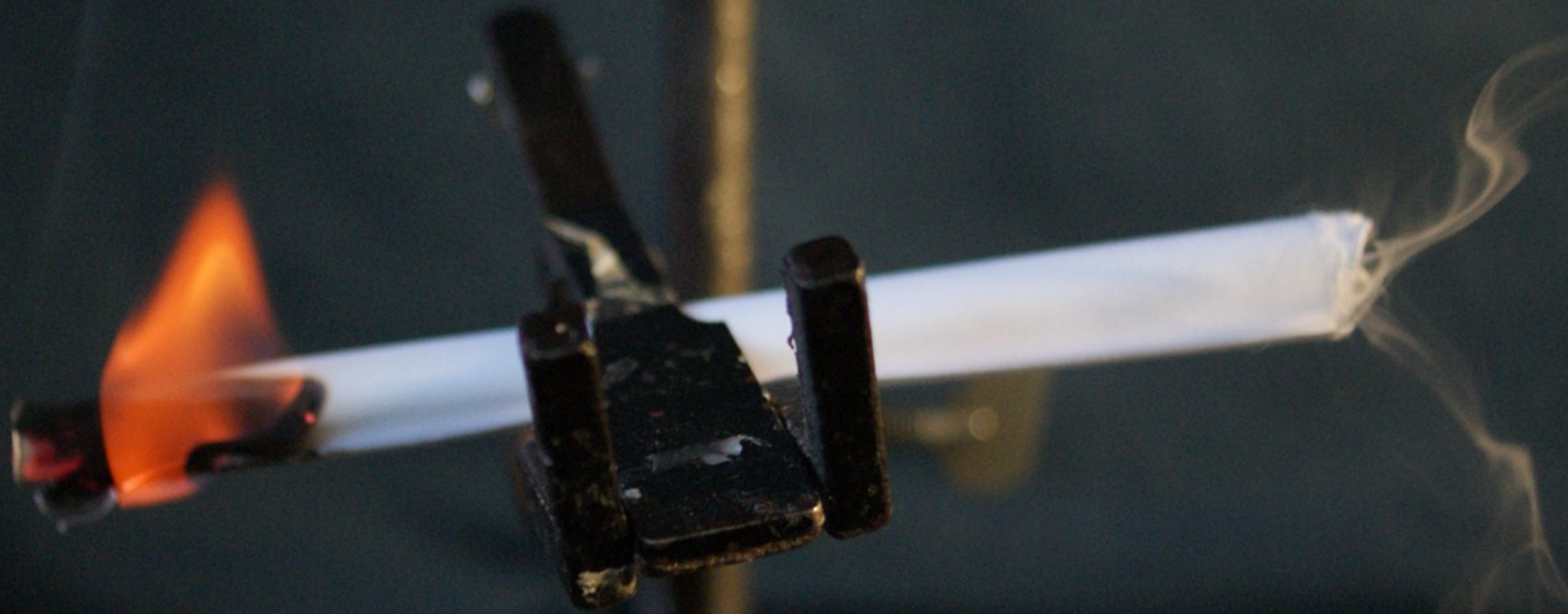
After 36 sec smoke starts to flow up

Investigation of «burning errors»

	Burning time of outer part of tube, sec	Time to up-going flow, sec	The length of the burned area at the time of smoke drop, cm	The length of the burned area at the time of up-going flow, cm
Middle value	36	3.3	33	8
Middle error, %	18%	12%	19%	13%

	Middle value	Middle error
Time to smoke drop, sec	7.5	<u>37%</u>

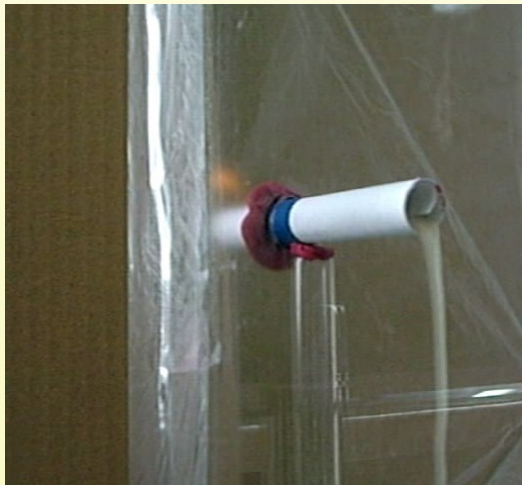
Burning of the tube without bottle



Smoke stream is under influence of outer air streams

Parameters to rate the stream

- Density (HSB parameter - brightness)
- Diameter of the smoke stream
- Velocity of the streams is almost equal in equal moment of the burning



We use a frame from video to rate brightness and diameter of smoke stream

Method to rate the density of particles in the stream

- **Color tone (Hue)**

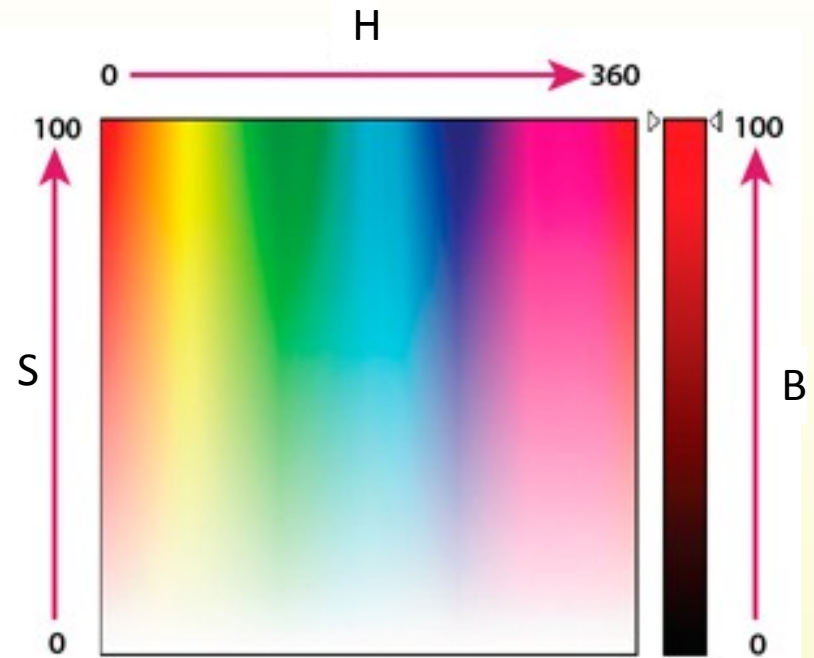
- Color reflected from or transmitted through an object

- **Brightness**

- The relative value of light and dark

- **Saturation**

- Saturation presents level of gray in proportion to the hue

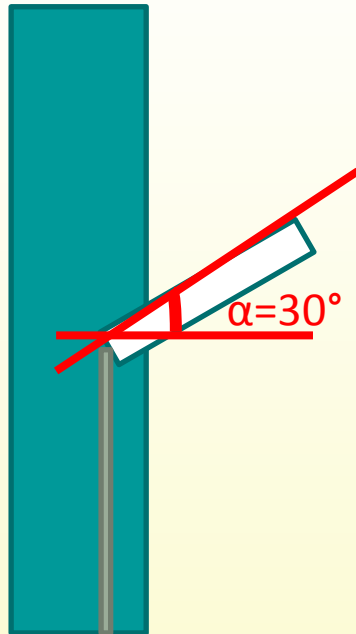


H. Color tone (Hue)

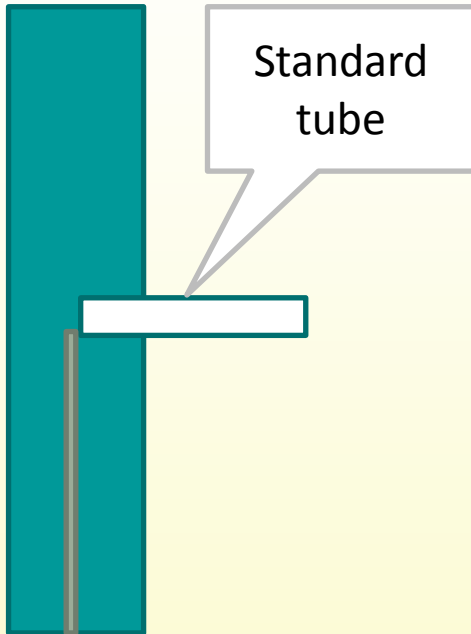
B. Brightness

S. Saturation

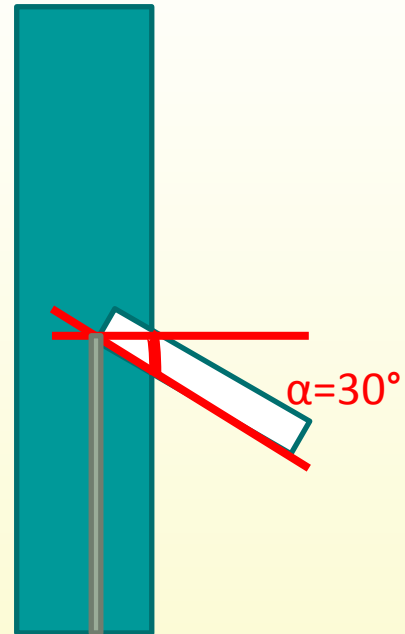
Angle slope of the tube



Diameter of flow is 4.4mm
Brightness 86

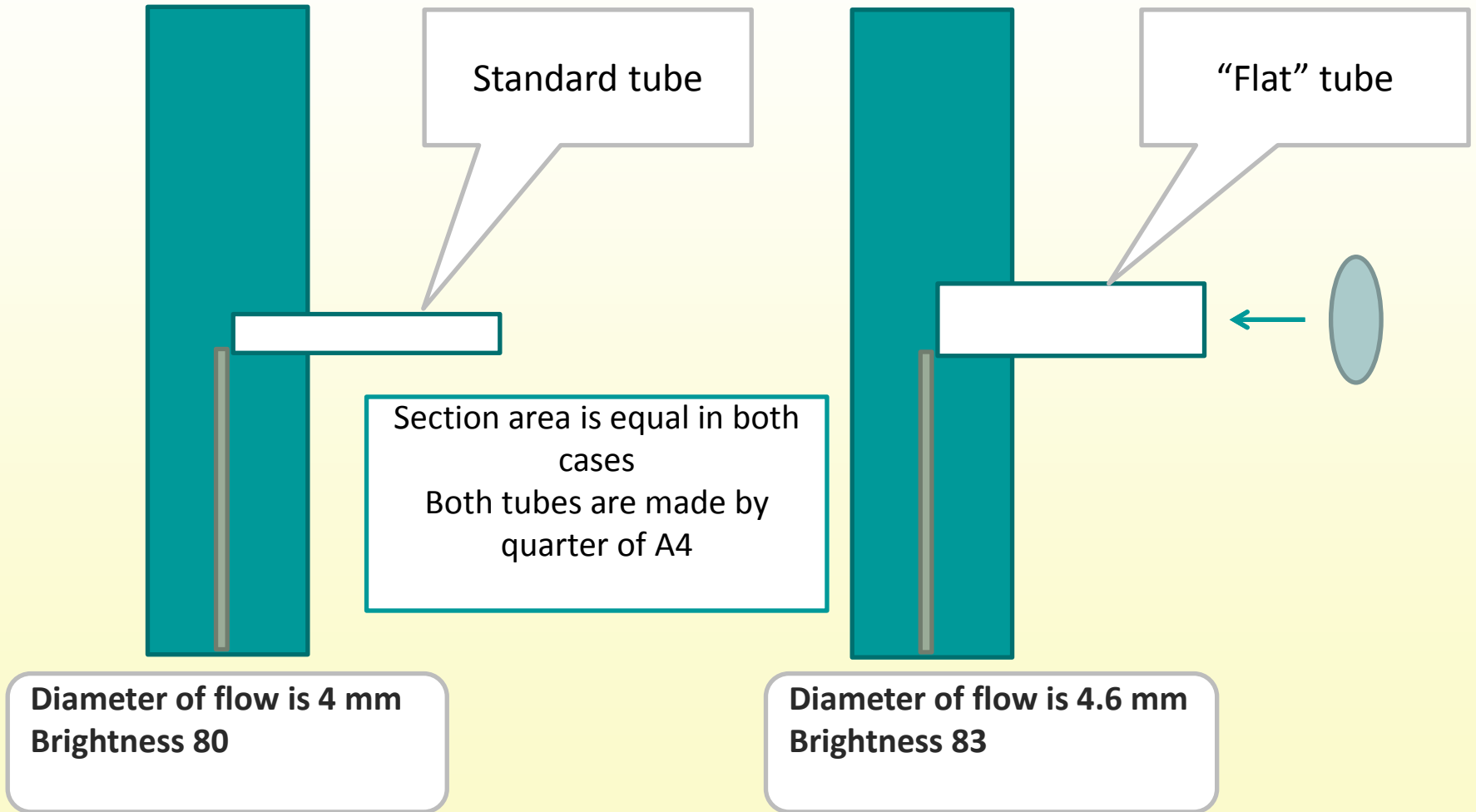


Diameter of flow is 4mm
Brightness 80

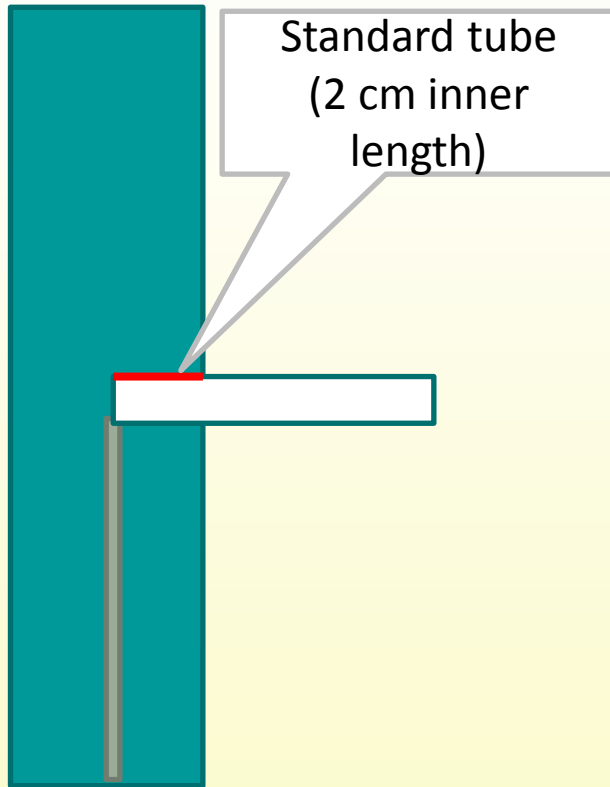


Diameter of flow is 3.3mm
Brightness 68

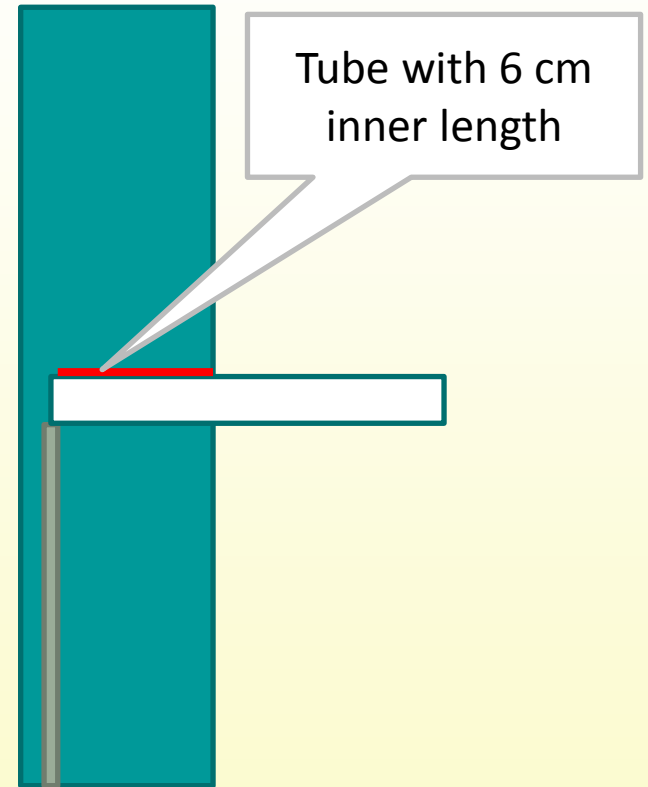
«Flat» tube



Inner length of the tube



**Diameter of flow is 4 mm
Brightness 80**



**Diameter of flow is 2.3 mm
Brightness 74**

Diameter of the tube

Standard tube (6 mm diameter)

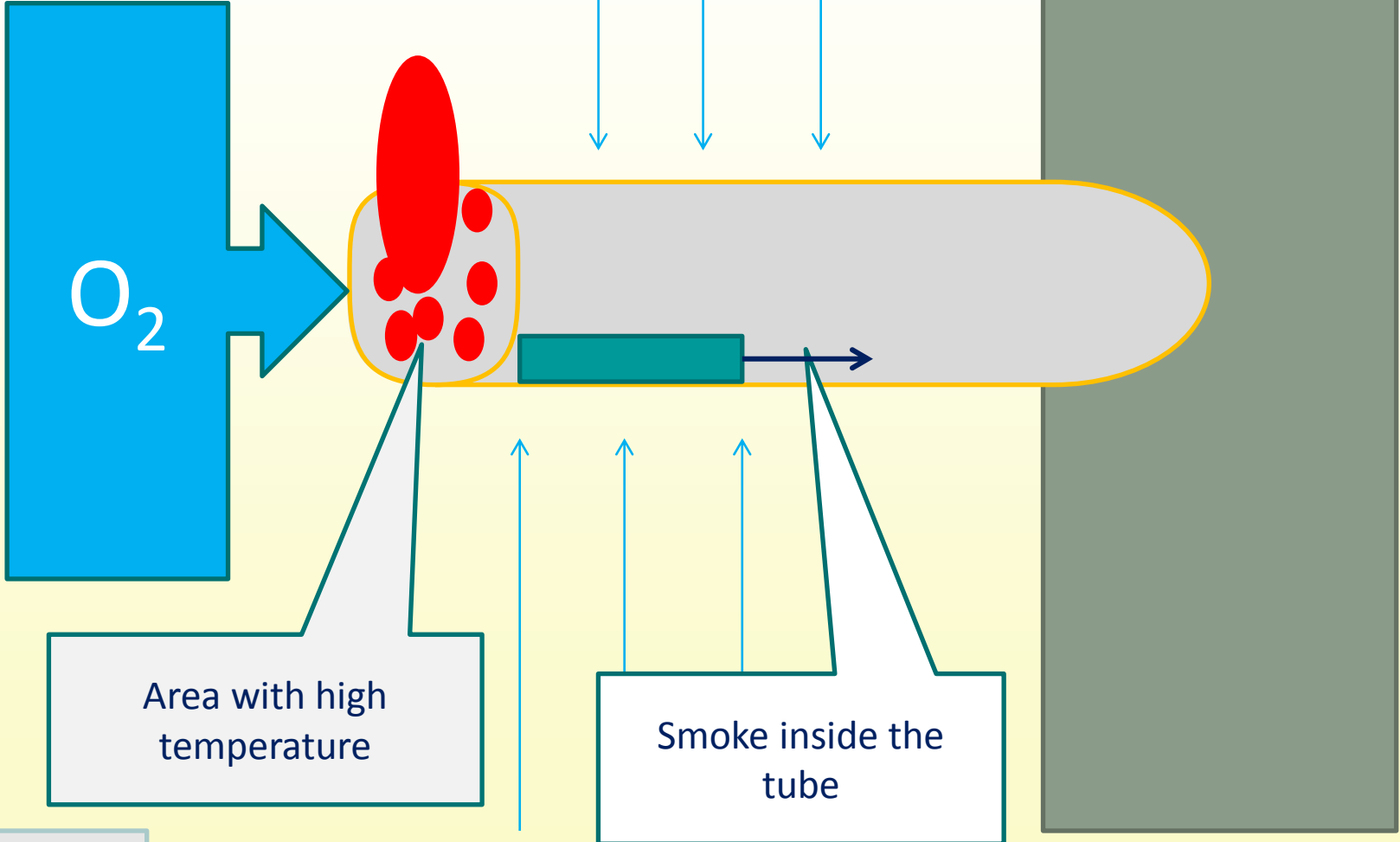
Tube with 9 mm diameter

Both tubes are made by quarter of A4

Diameter of flow is 4 mm
Brightness 80

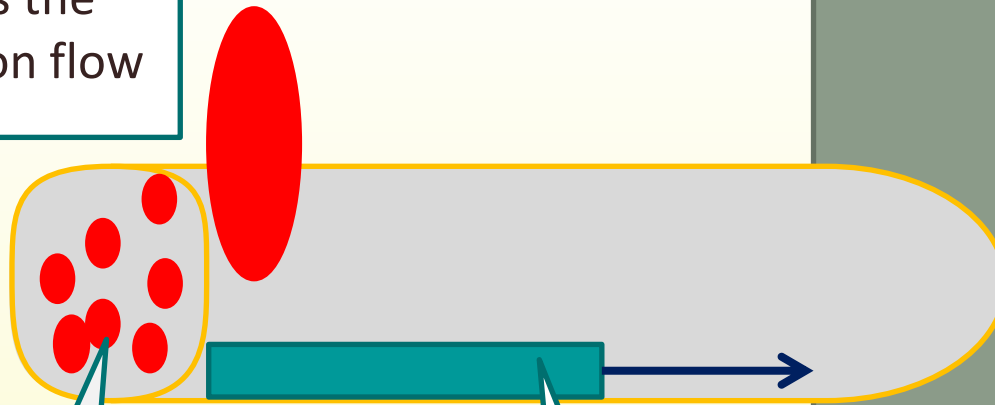
Diameter of flow is 4.4 mm
Brightness 77

[First stage]



Second stage

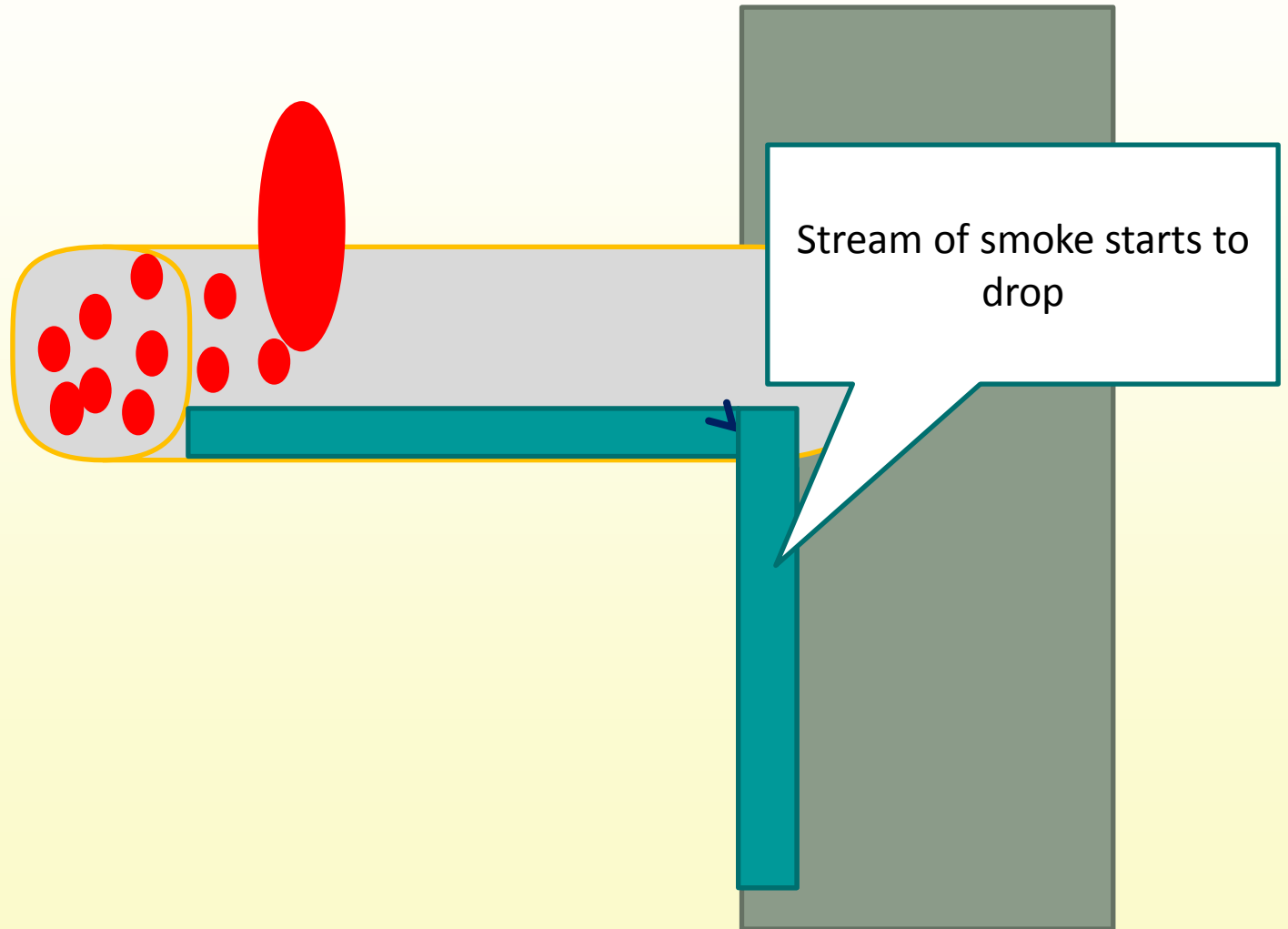
Smoke stream is the result of convection flow



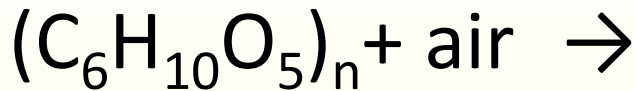
Area with high temperature

Smoke inside the tube

[Third stage]



Chemistry of paper burning



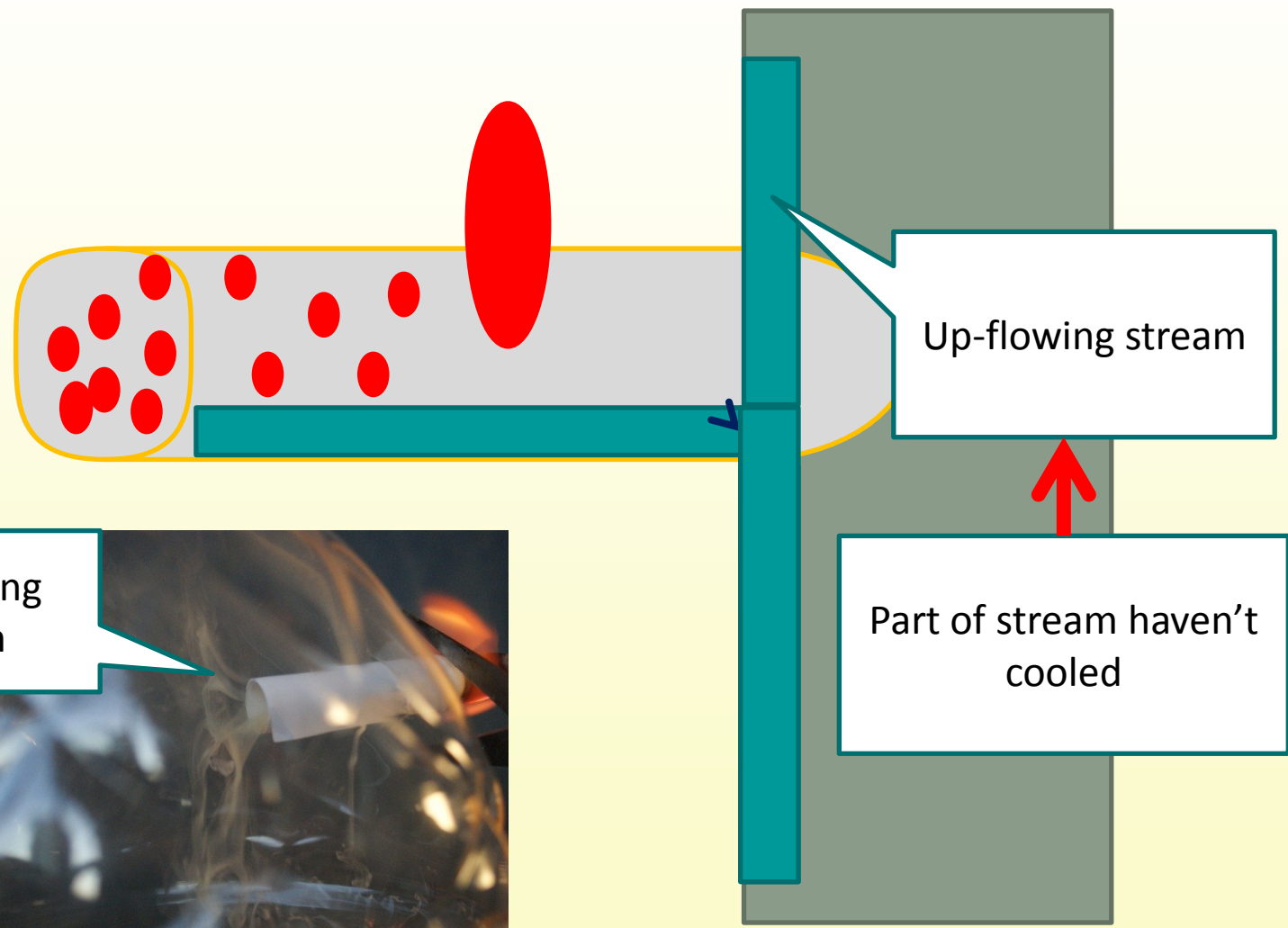
- CO (M = 28 g/mole)
- H₂O (M = 18 g/mole)
- CO₂ (M = 44 g/mole)
- N₂O (M = 44 g/mole)
- C (M = 12 g/mole)
- Other gases and particles + soot

We predict, that molar mass of smoke is about 31 g/mole

Equal proportion of water, carbon oxide and dioxide were taken

Molar mass of the air – 29 g/mole

[Fourth stage]



Condition of down-flowing and up-flowing streams

$$B = mg$$

$$\rho_{air}gV = \rho_{str}gV$$

$$\rho_{air} = \rho_{str}$$

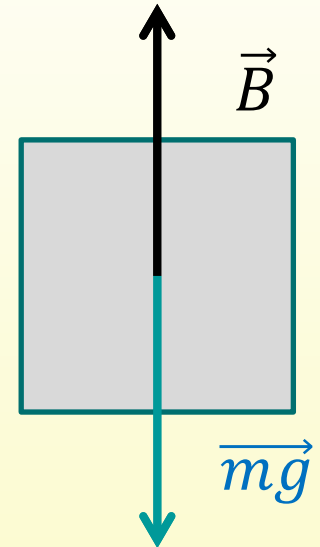
By Mendellev-Clapeyron law:

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

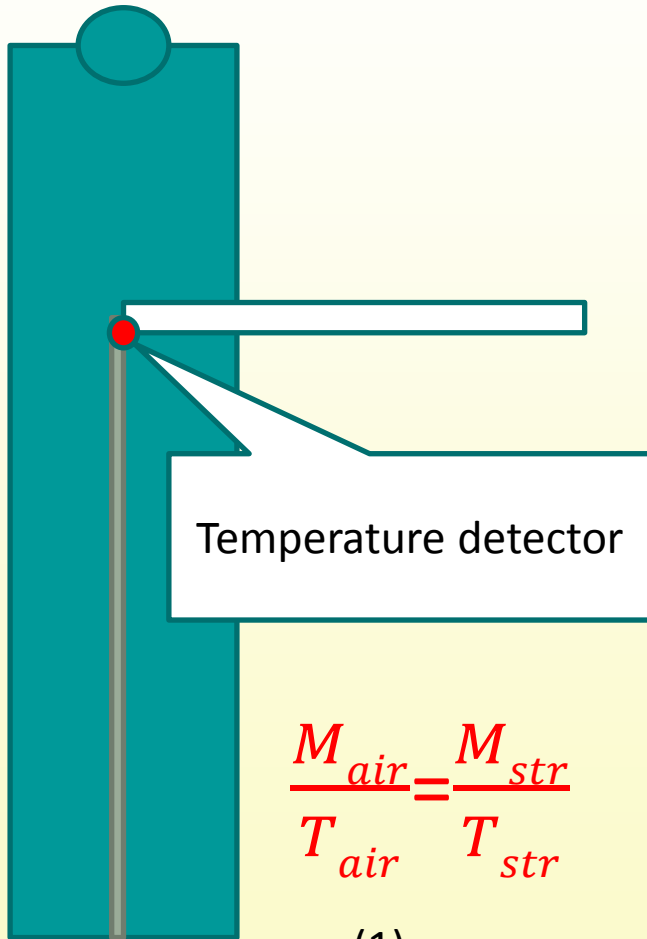
$$\rho = \frac{PM}{RT}$$

- m is a mass of smoke cube
- V is a value of smoke cube
- T is a temperature of the stream
- μ is amount of substance
- ρ_{str} is a density of smoke stream
- ρ_{air} is a density of air

$$\frac{M_{air}}{T_{air}} = \frac{M_{str}}{T_{str}}$$



Checking of suggestion



$$\frac{M_{air}}{T_{air}} = \frac{M_{str}}{T_{str}}$$

(1)

- Using equation (1) and predicted molar mass we can calculate the temperature of the stream, which is necessary to up-flow
- Theoretical temperature is 316 K
- Experimental temperature is 322 K
- Errors might be connected with molar mass prediction

Results of the research

- We have found next parameters, which influence the smoke flow :
 - Angle slope
 - Inner and outer length of the tube
 - Diameter of the tube
 - Form of the tube
- Through the research we have made theoretical explanation of down-going and up-going streams
- This explanation was checked experimentally

[Thanks for attention]