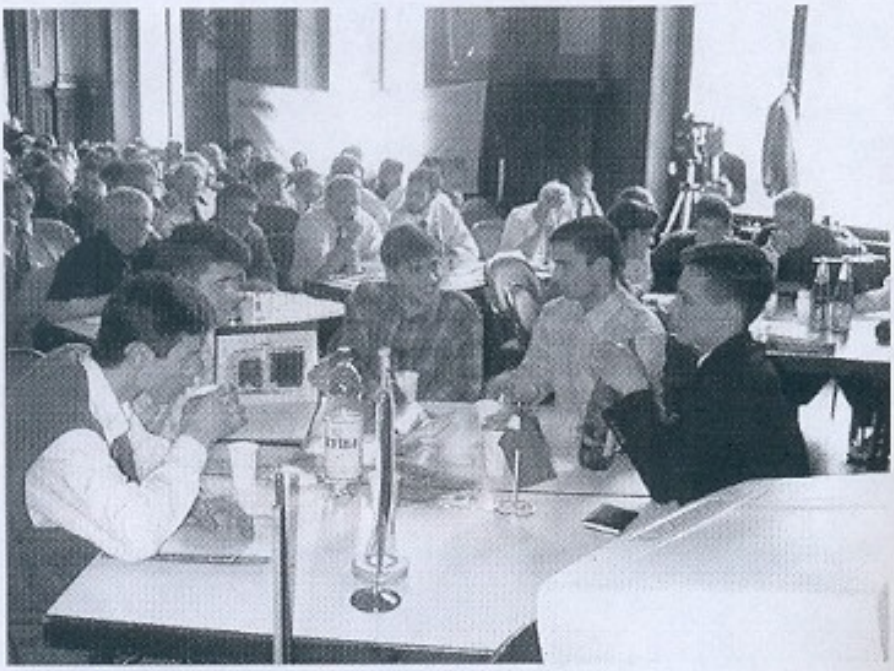
12th International Young Physicists' Tournament

May 23 – 29, 1999

Vienna, Austria

Reports of Georgian Team



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Problems for the International Young Physicists Tournament 1999 in Vienna

1. ROTATION

A long rod, partially and vertically immersed in a liquid, rotates about its axis. For some liquids this will cause an upward motion of the liquid on the rod and for other liquids a downward motion. Explain this phenomenon and determine the essential parameters on which it depends.

2. IONIC MOTOR

An electrolyte (an aqueous solution of $CuSO_4$, NaCl, ...) in a shallow tray is made to rotate in the field of a permanent magnet (a small "pill" placed under the tray). An electric field is applied from a 1.5 V battery in such a way that one electrode is in the form of a conducting ring immersed in the electrolyte - the other is a tip of a wire placed vertically in the center of the ring. Study the phenomenon and find possible relations between the variables.

3. MAGIC MOTOR

Construct a DC motor without a commutator, using a battery, a permanent magnet and a coil. Explain how it functions.

4. SOAP FILM

Explain the appearance and development of colours in a soap film, arranged in different geometries.

5. DROPPED PAPER

If a rectangular piece of paper is dropped from a height of a couple of meters, it will rotate around its long axis whilst sliding down at a certain angle. How does this angle depend on various parameters?

6. SINGING GLASS

When rubbing the rim of a glass containing a liquid a tone can be heard. The same happens if the glass is immersed in a liquid. How does the pitch of the tone depend on different parameters?

7. HEATED NEEDLE

A needle is hanging on a thin wire. When approached by a magnet the needle will be attracted. When heated, the needle will return to its original position. After a while the needle will be attracted again. Investigate this phenomenon, describe the characteristics and determine the relevant parameters.

8. ENERGY CONVERTER

A body of mass 1 kg falls from a height of 1 m. Convert as much as possible of the released potential energy into electric energy and use that to charge a capacitor of 100 µF.

9. AIR DRYER

For 4 minutes collect as much water as possible from the air in the room. The mass of the equipment must not exceed 1 kg. Its initial temperature should be equal to ambient (room) temperature. The water should be collected in a glass test tube, provided by the jury.

10. CHARGED BALLOON

An air-filled balloon rubbed with wool or dry paper may stick to the ceiling and stay there. Investigate this phenomenon and measure the charge distribution on the surface of the balloon.

11. BILLIARD

Before a pool-billiard game starts, 15 balls form an equilateral triangle on the table. Under what conditions will the impact of the white ball (16^{th} ball) produce the largest disorder of the balls?

12. FLOUR CRATERS

If you drop a small object in flour, the impact will produce a surface structure which looks like moon crater. What information about the object can be deduced from the crater?

13. GAS FLOW

Measure the speed distribution of the gas flow in and around the flame of a candle. What conclusions can be drawn from the measurements?

14. WHEAT WAVES

The wind blowing through a wheat field creates waves. Describe the mechanism of the wave formation and discuss the parameters which determine the wavelength.

15. BRIGHT SPOTS

Bright spots can be seen on dew drops if you look at them from different angles. Discuss this phenomenon in terms of the number of spots, their location and angle of observation.

16. LIQUID DIODE

Make an electrochemical diode and investigate its properties, in particular the frequency dependence.

17. SOUND FROM WATER

When you heat water in a kettle you hear a sound from the kettle before the water starts to boil. Investigate and explain this phenomenon.

1.ROTATION

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School № 42 named after I.N. Vekua

First I want to talk about are liquids, which move down. Rod begins to rotate. In cause of viscosity liquid rotates too. Let us consider it's small element, which is situated, on the surface. For it is being at rest it is necessary all the forces, acting on this element be balanced. They are gravitating, centrifugal, and reacting forces. Surface takes such a shape under action of centrifugal force.

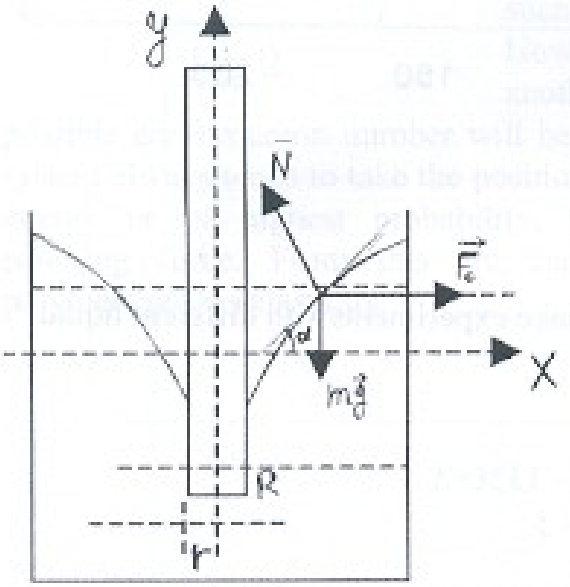


Fig 1.

Tangent of tangent angle inclination in point with coordinate x is :

$$\mathrm{tg}\alpha(x)=\frac{\omega^2(x)x}{g}=y'(x)$$

And how we know it's equal to derivative function. From this I have got function of surface and from equal of initial and final volumes we got that height of falling is:

$$H=\frac{\omega_0^2 r^4 R^4}{4g(R^2-r^2)^3}\left[3+2\left(\frac{R}{r}\right)^2+\left(\frac{r}{R}\right)^4-6\left(\frac{r}{R}\right)^2-12\ln\frac{R}{r}\right]$$

One of idealisations is that w was calculated for the unlimited coaxial cylinders:

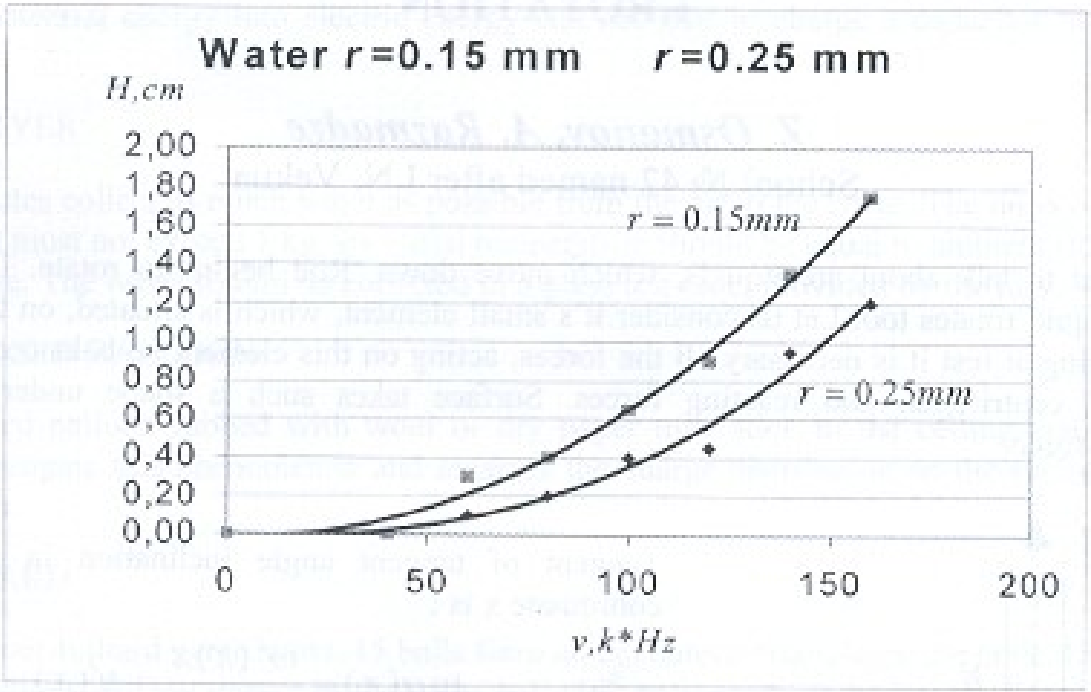
$$\omega(x)=\frac{\omega r^2}{R^2-r^2}\left(\frac{R^2}{x^2}-1\right)\qquad x\in[r,R]$$

From the proposed theory we can find such a tendentious:

1. With increasing of ω (angular velocity) - height of falling increases.
2. With increasing of R (radius of vessel) - height of falling increases.
3. With increasing of r (radius of rod) - height of falling decreases.

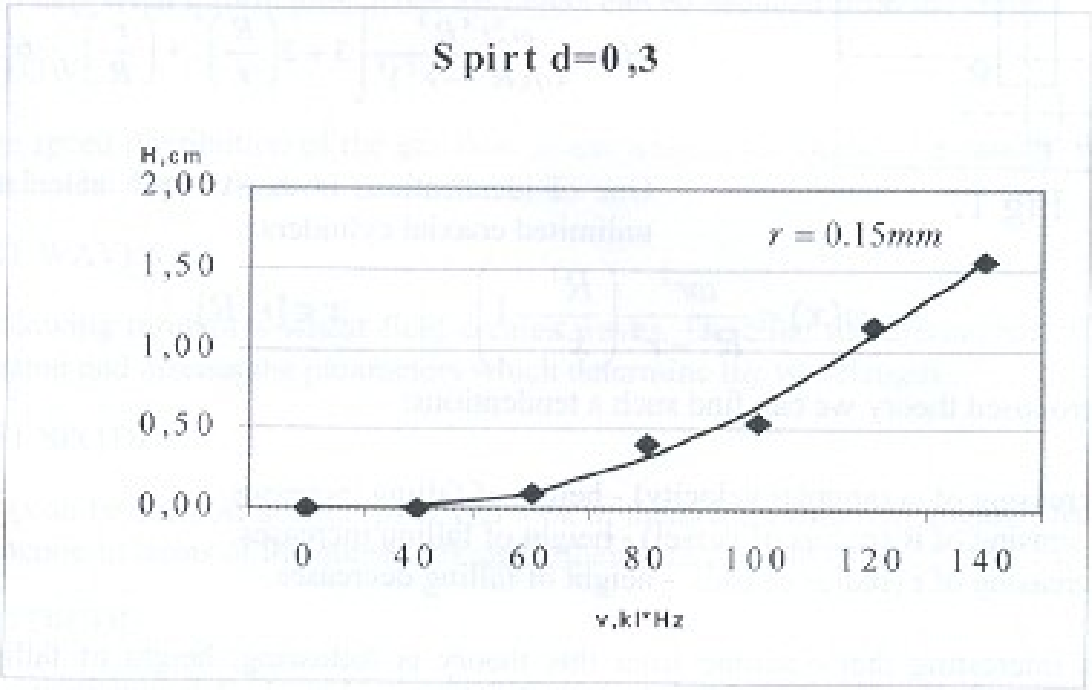
Note: It is interesting that outcome from this theory is following: height of falling does not depend on next liquid parameters: viscosity and density.
Proposed theoretical results are in good agreement with experiments.

To approve theory I want to present some experimental data. Here we can see the detention between height of falling and frequency for water when rod's radiuses are different.



Graph 1.

The next graph shows us that nothing changes when we make experimentswith different liquid.



Graph 2.

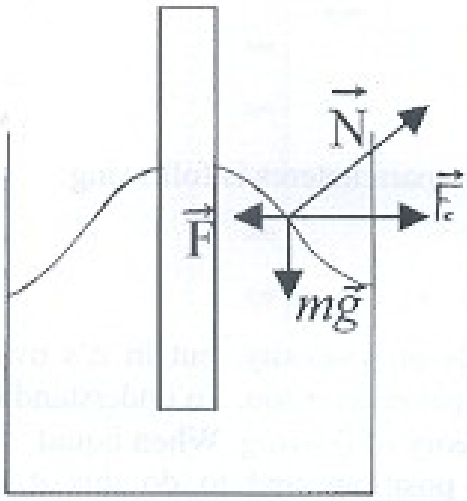


Fig 2.

Next I want to talk about are liquids which make upward motion on the rod. In order to understand difference between these liquids let us again consider small element of the liquid. It is obvious that for being at rest there must be a force, compensating the action of all other forces. Let us understand its origin.

The liquids, which make upward motion on the rod, are polymer liquids and in cause of their structure they posses elasticity. In order to understand the nature of this elasticity let us speak about one molecule. If we leave molecule to its own devices it's one end will freely fluctuate. Generally it will take such a size in which it will be possible to change more forms. Now if we will pull the another end the possible conformation number will be decreased. As the system always tends to take the position with the minimal energy or of highest probability, there appears the restoring force. From this we can understand that polymers posses elasticity.

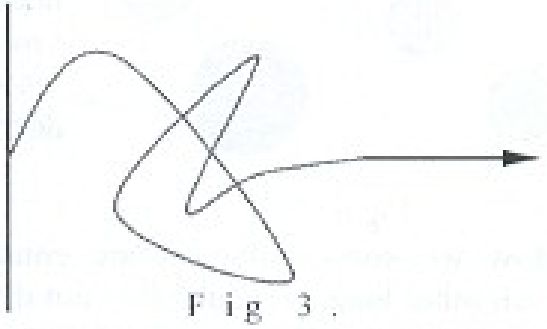


Fig 3.

$E=3\xi KT$ – Jung's module for polymers.

ξ – Number of cohesion.

Let us consider an elementary prism in liquid. In cause of viscosity different layers of liquid moves with different velocities. That's why initial right prism became inclinative. In cause of elasticity increased size will tend to become initial. That's why liquid makes upward motion.

More qualitatively we can represent this phenomenon in the following way: we have a rod and stretched along the whole length elastic. It is not difficult to understand that it tries to contract the rod and makes itself to climb on it. To get quantitative dependence of climbing height on some parameters, we are interested in normal component of this stretch. In cause prism is elastic it is obeyed on Hook's law.

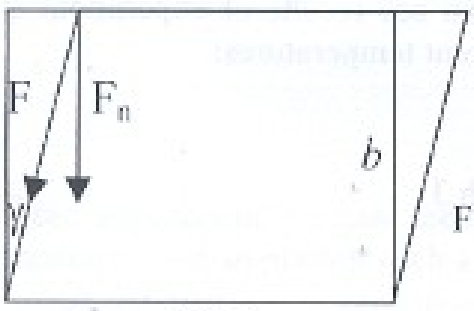


Fig 5.

The projection of tension on normal axis is following:

$$dF_n = \frac{EdS\Delta b}{b}\cos\gamma$$

For displacement we have:

$$dF_\tau = GdS_1\gamma$$

On the other hand force that makes prism to change its form is difference between viscosity forces:

$$dF_\tau \sim dS_1 \eta b V''(x)$$

Pressure acting on rod is following:

$$p = \frac{dF_n}{dS} \approx \rho g H$$

from this we can judje about height of rising.The dependance from parameteres is following:

$$H \sim \frac{\eta^2}{\rho g} \frac{1}{\sqrt{R^2 + 9r^2}} \frac{\omega^2}{E} \frac{R}{r}$$

We can see that height depends on viscosity, but in it's own turn viscosity depends on some parameters too. To understand it qualitatively let us talk about theory of flowing. When liquid flows molecules change their positions and to do this it is necessary to posses definite energy.

From this theory we have that with temperatures increasing viscosity decreases and with angular velocities increasing it decreases too.

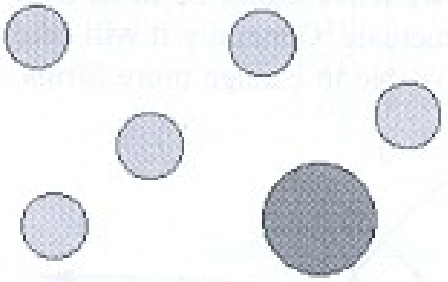


Fig 6.

How we know polymers are entangled to each other long molecule. It is not difficult to understand that if one molecule's end moves in to one place, another can move to another. From this consideration we can get following tendentious:

1.With T increasing viscosity decreases.

2.With ω increasing viscosity decreases.

3 with increasing of concentration viscosity increases.

4.With increasing of molecule's length viscosity increases.

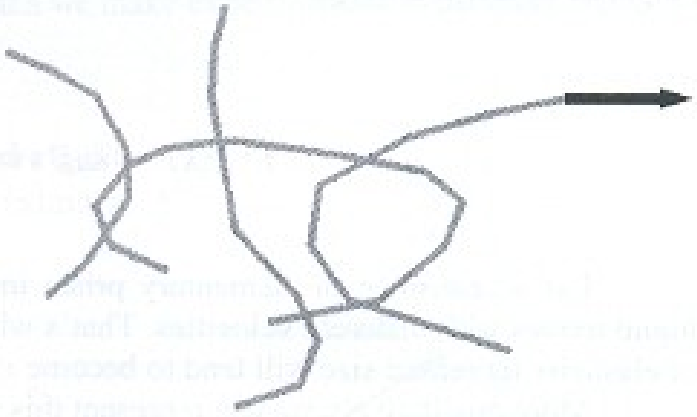
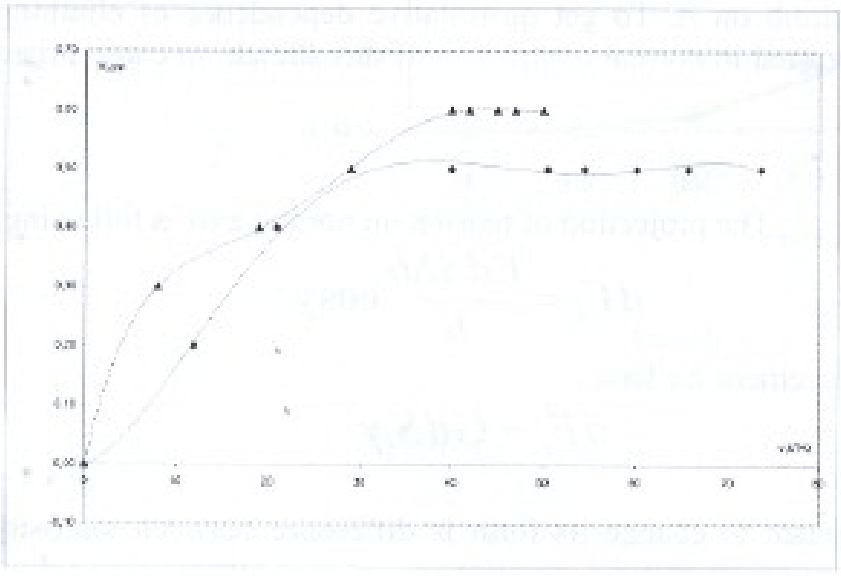


Fig 7.

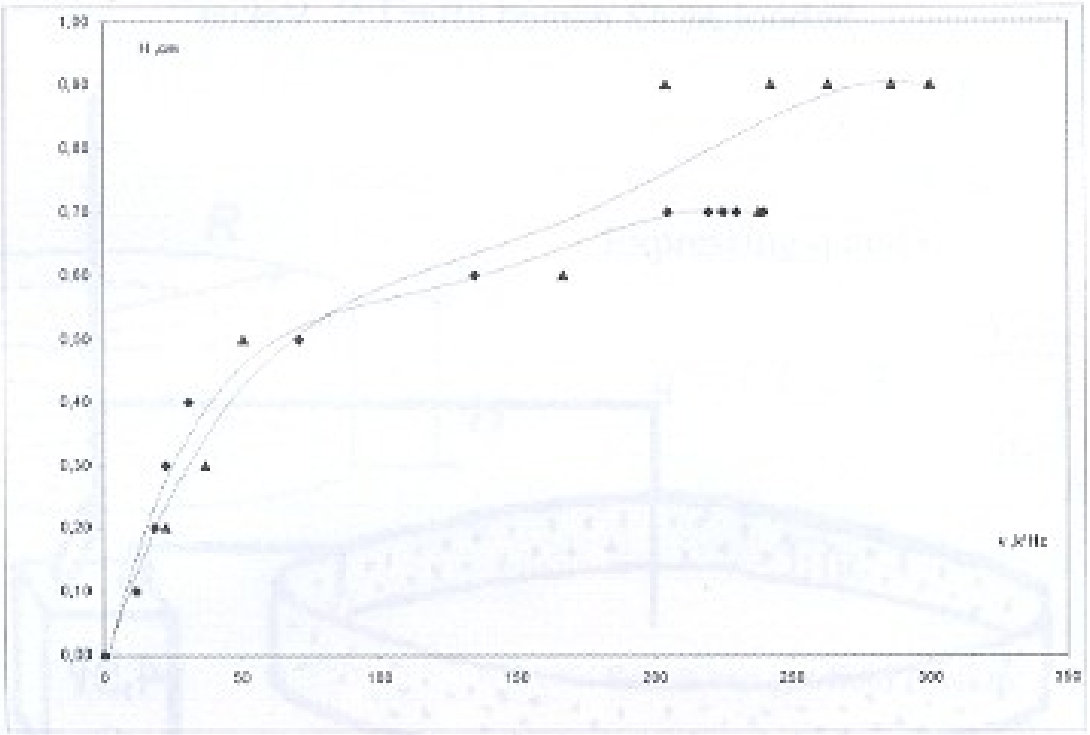
5.With increasing of molecule's mass viscosity increases.

To approve getting dependence here we can see results of experiment at different temperatures:



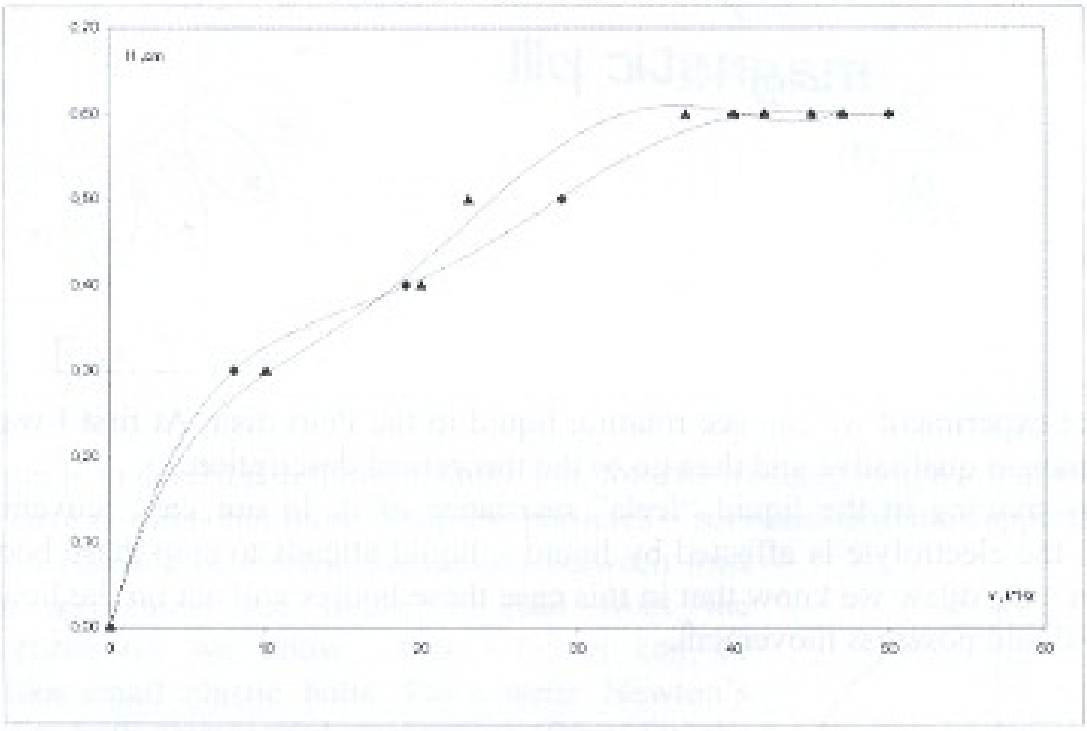
Graph 3.

Different rod's radii:



Graph 4.

Different concentrations:



Graph 5.

From experiment we can see that the height either of downward or upward motion goes on constant. I can explain it such a way: at this time when H goes on constant we can see splash and waves. At definite w centrifugal force is more than elastic. The energy decreases in cause of making waves and on splash. The flow transforms from laminar into turbulent.

2. IONIC MOTOR

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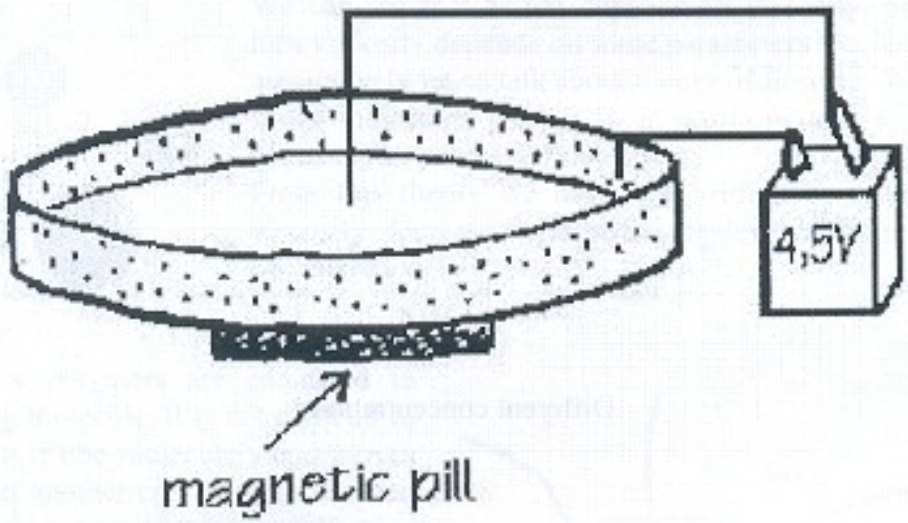
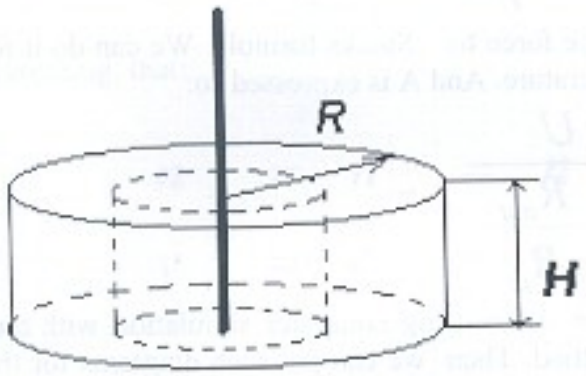


If we make experiment we can see rotating liquid in the Petri dish. At first I want to explain this phenomenon qualitative and then go to the theoretical description.
Every body moving in the liquid "feels" resistance of it. In our case movement of small particles in the electrolyte is affected by liquid – liquid attends to stop these bodies but from the Newton's third law we know that in this case these bodies will act on the liquid with same force. And liquid posesess movement.

Now let us try to describe this phenomenon by some mathematics.
Before we start I want to say, that I assume electric and magnetic field uniform.

To calculate field in our system we can consider it like cylindrical condenser (fig. 1) and write Gauss theorem for the cylindrical surface:



$$ES = \frac{q}{\varepsilon\varepsilon_0}$$

Expressing q and C:

$$q = CU; \quad C = \frac{2\pi\varepsilon\varepsilon_0 H}{\ln\frac{R_{out}}{R_{in}}}$$

Fig. 1

So we can get field tension:

$$E(r) = \frac{U}{\ln\frac{R_{out}}{R_{in}}}\frac{1}{r}$$

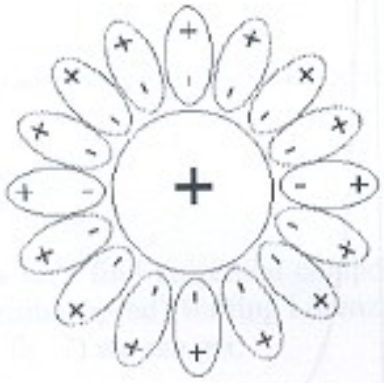


Fig. 2.

Now our target is to describe motion of single ion, for this we have to know that in electrolytic solvates we have not ions but more complex particles – solvions. Solvions appearance can be explained by existence of electric interaction between ions and solvent molecules, see figure 2. And from the solvatation chemistry we know that solvions can be considered like small elastic balls. Let's write Newton's second law in both vector and projections form for the moving solvion:

$$m\,\vec{a} = \vec{F}_s + \vec{F}_e + \vec{F}_l$$

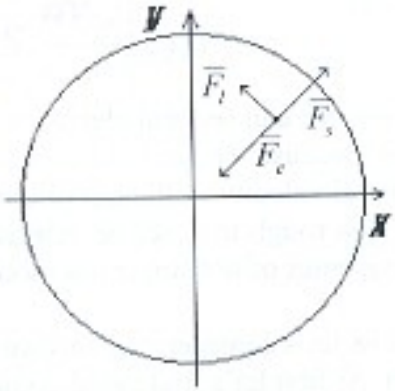


Fig. 3.

On the figure 3 you can see choused coordinate system and forces vectors. And in projections one can write:

$$m\ddot{x} = -6\pi r_s \eta \dot{x} - \frac{Aq}{r^2} x - q\dot{y}B$$

$$m\ddot{y} = -6\pi r_s \eta \dot{y} - \frac{Aq}{r^2} y + q\dot{x}B$$

Here you can see that we've expressed resistance force by Stocks formula. We can do it for this case ("microworld") it's known from the literature. And A is expressed so:

$$A = \frac{U}{\ln \frac{R_{out}}{R_{in}}}$$

So we get differential equations, which we can solve using computer simulation with any numerical method, for example Runge-Kutt method. Then we can get such diagrams for the solvion trajectory (fig. 4) and velocity (fig. 5):

Fig. 4.

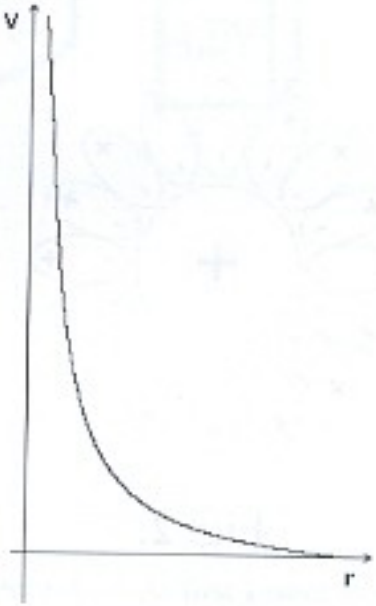


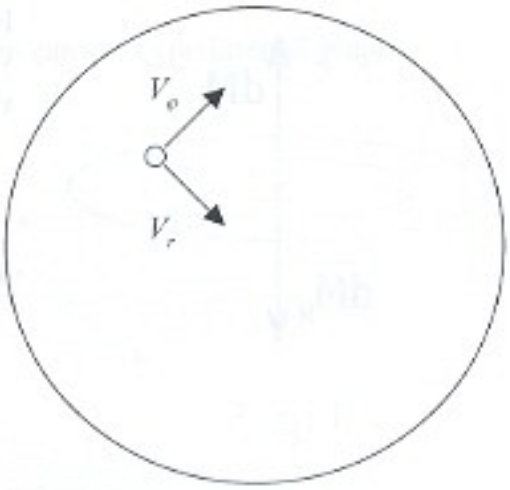
Fig. 5.

Now we can see that character of the trajectory is right but velocity dependence doesn't satisfy us, because we know from the hydrodynamics that near the surface of body immersed in the liquid velocity of the liquid flow is zero, but we didn't get this from our model. So this model is too rough to describe velocity of the ion. Let's go to our second model – in it we describe dynamics of not single ion motion but of the whole water.

Now let's consider that solvion velocity consists of two components: tangential and radial (fig. 6). At first let's find radial component.

One can write expression for the current flow:

$$j = n_+ q v_+ + n_- q v_-$$



Assuming, that:

$$n_+ = n_- = n$$

$$v_+ = v_- = v_r$$

and

$$I = jS \; ; S = 2\pi rh \; ; n = \frac{N}{V}$$

Fig. 6.

So, radial velocity is expressed as follows:

$$v_r = \frac{MIR}{8emN_A}$$

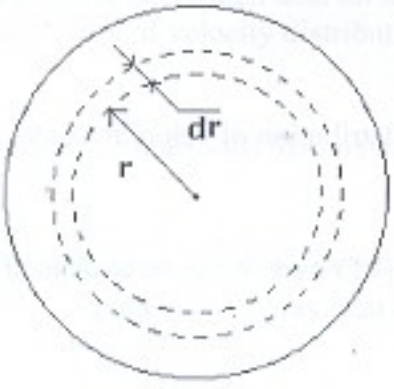
Now let's find tangential component of solvion velocity(this will be equal to water rotatio tangential speed).Writing Lorenz force moment for the thin layer of the liquid(with a thickne dr – fig. 7) we can get:

$$\left.\begin{aligned} dM_l &= dqBv_r r \\ dq &= nq_0 dV \end{aligned}\right) \Rightarrow dM_l = \frac{BI}{R} r^2 dr$$

For the moment of the viscous resistance force we have:

$$dM_R = ((-\eta S \left.\frac{dv_\varphi}{dr}\right|_{r+dr}) - (-\eta S \left.\frac{dv_\varphi}{dr}\right|_r))r =$$

$$= -2\pi h \eta \frac{d}{dr}\left(r^2 \frac{dv_\varphi}{dr}\right) dr$$



Because we are observing established rotation, one can equate these two moments (figure 8.):

Fig. 7.

$$dM_{\ell} = dM_{R} \Rightarrow$$

Here we've got expression for the solvion tangential velocity which is equal to water rotation tangential velocity.

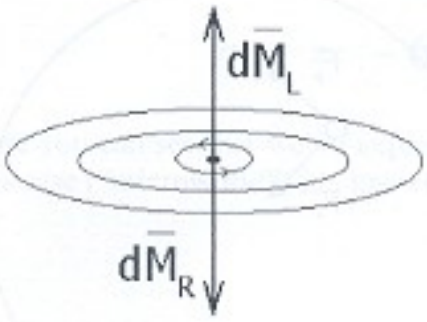


Fig. 5.

$$v_{\varphi} = \frac{C}{6}(R^2 - x^2) + \frac{Cr}{6x}(R - r)(R - x)$$

where

$$C = \frac{BI}{2\pi\eta\ Rh}$$

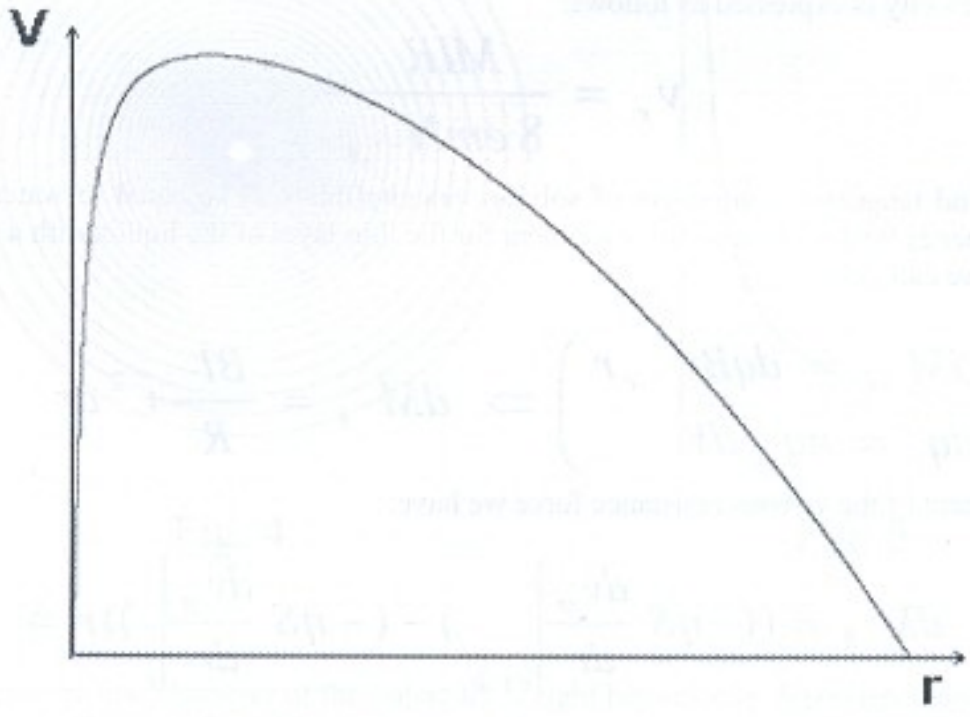
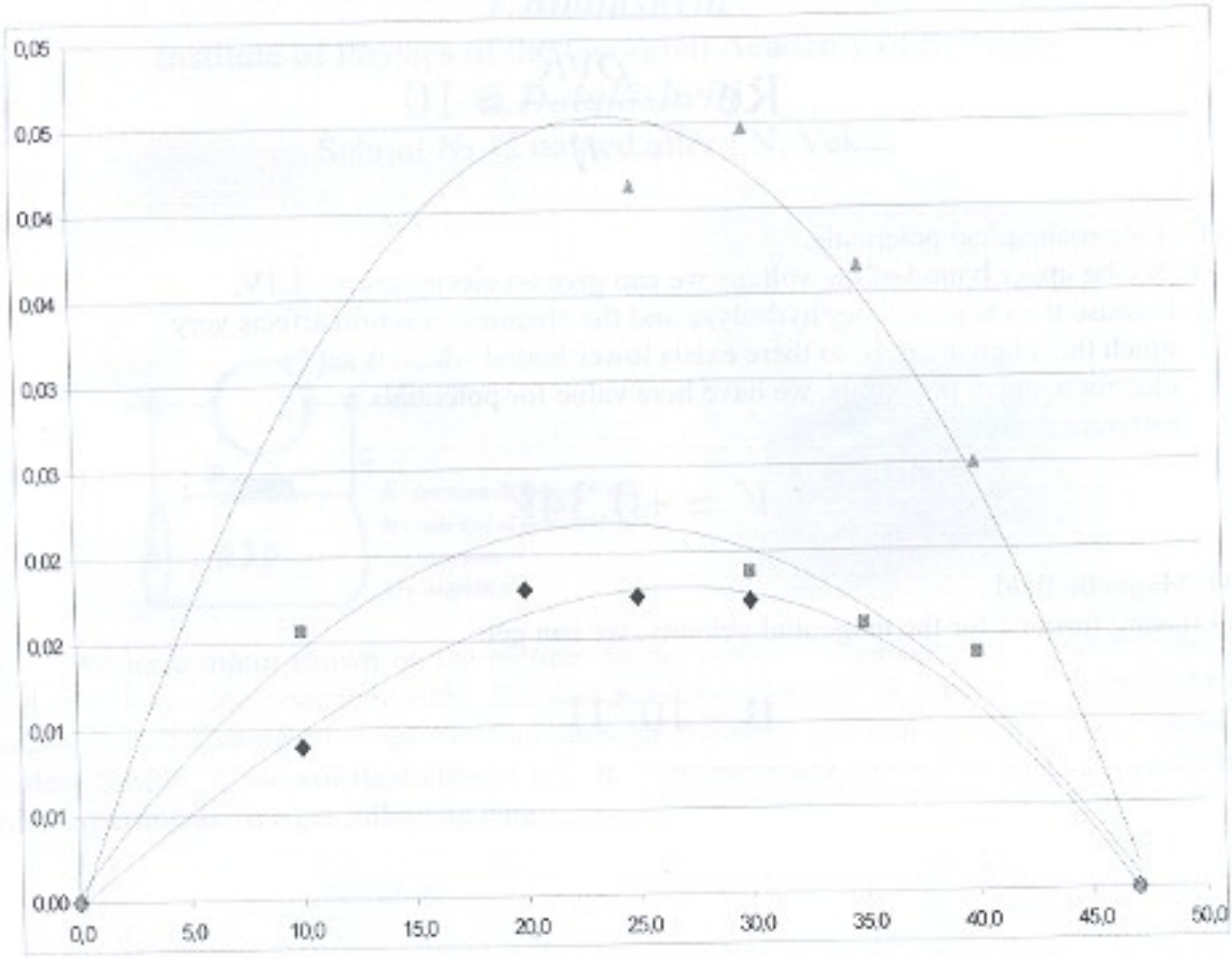


Fig. 9.

Tangential velocity dependence on distance from center – distribution of velocities onto radius.

Here we can see that our graph is more "compressed" near zero of r axis, it can be explained if we remember that viscous force depends on surface square and near zero of r we have relatively small surface of inner electrode.

Now let's see some experimental data. Here you can see experimental graphs.



I want to clarify some unclear moments in this problem. At first about radial component of water velocity – does the liquid in our system poses radial velocity? The answer is "no" and it's because the both types of ions move along radius but in opposite directions, when one ion "tries" to move water in one direction , other "tries" to move water in opposite direction so the water stays stationary. But if we throw in electrolyte small bodies (chalk dust for ex.) they doesn't stay on fixed distance from inner electrode. It can be explained by existence of velocity, and correspondingly pressure gradient. And because of pressure gradient there appears force (which acts on our small body) and this force makes small body moving to the peak point of velocity distribution.

Additional questions that may appear in this problem.

Q1: Lifetime of this system.
A1: We know Faradays formula :

$$M = KIt$$

And if we put in I=1A, M=10g we can get that time after which all electrolyte will exhaust is t ~ 3 hours.

Q2: Reynolds number.
A2: R here is Petri dish radius.

$$\mathrm{Re} = \frac{\rho v R}{\eta} \approx 10$$

Q3: Electrochemical potentials.
A3: So the upper bound of the voltage we can give on electrodes is ~1,1V, because then begins water hydrolyze and the chemical reaction affects very much this phenomenon, so there exists lower bound which is set by electrochemical potentials, we have here value for potentials difference V :

$$V \approx +0.34V$$

Q4: Magnetic field.
A4: Using formula for the tangential velocity, we can get:

$$B \sim 10^{-5}\mathrm{Tl}$$

3. MAGIC MOTOR

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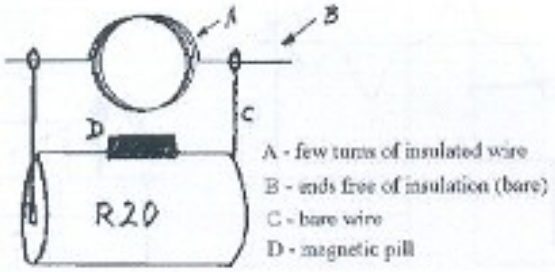
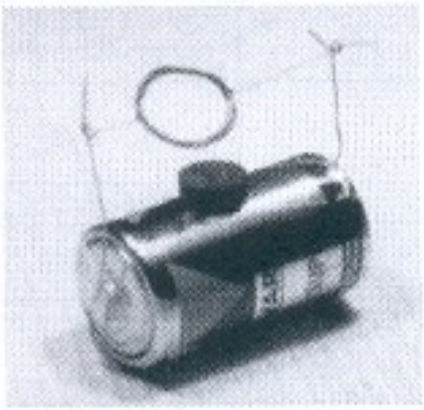
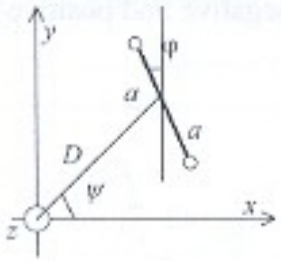


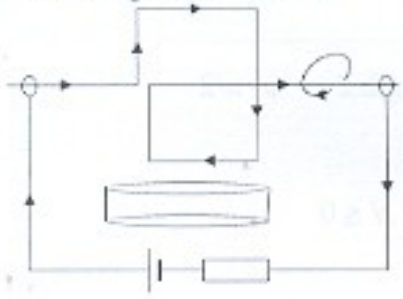


We have motor shown on the picture. In our model we consider rectangular frame as coil and take dipol magnetic field. Because inductivity of coil is small $L\sim10^{-6}$ and E.M.F. caused by alternating of magnetic flux thruogh frame is negligable $\sim10^{-5}$v. We consider buttery E.M.F. ξ and constant current $I=\xi/R$. The proposed aprouch is in good agreement with experiments. We get following data:



$\xi = 9$ V
$R_0 \approx 20\,\Omega$
$2a = 2$ cm
d = 0.2 mm
$A = 0.001\,\mathrm{T}\cdot\mathrm{m}^3$
$k = 0.5$
$g = 9.8\,\mathrm{m/s}^2$
$D = 6$ cm

where R_0 is resistance of buttary, d - diameter of wire, k – index of friction between wires, g is free falling acceleration.



$$\vec{B} = A\frac{(\vec{\mu}\cdot\vec{r})\cdot\vec{r} - r^2\cdot\vec{\mu}}{r^5}$$

$\vec{r}(x,y,z)$
$\vec{\mu}(0,1,0)$
$\vec{F}_1 = I\cdot\vec{a}_1\times\vec{B}_1 \qquad \vec{a}_1(0,0,2a)$
$\vec{F}_2 = I\cdot\vec{a}_2\times\vec{B}_2 \qquad \vec{a}_2(0,0,-2a)$

where μ is dipole moment

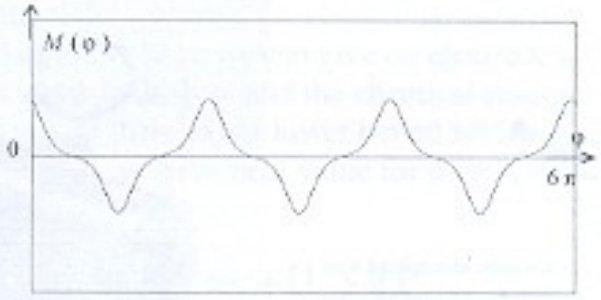
From magnetic field on frame with current act forces F_1 and F_2 they make moments M_1 and M_2 with respect to c.m. of frame and it begins to rotate.

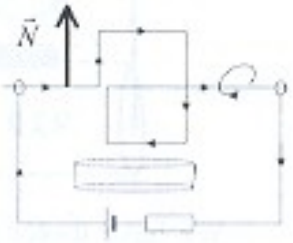
$$\vec{M}_1 = \vec{a}_1' \times \vec{F}_1 \qquad \vec{a}_1'(-a\sin\varphi, a\cos\varphi, 0)$$

$$\vec{M}_2 = \vec{a}_2' \times \vec{F}_2 \qquad \vec{a}_2'(a\sin\varphi, a\cos\varphi, 0)$$

$$\vec{M} = \vec{M}_1 + \vec{M}_2$$

From graph one can see that work of moment per one period is zero, it means that we have not source of energy but we have a friction, loosing of energy and rotating must fade.





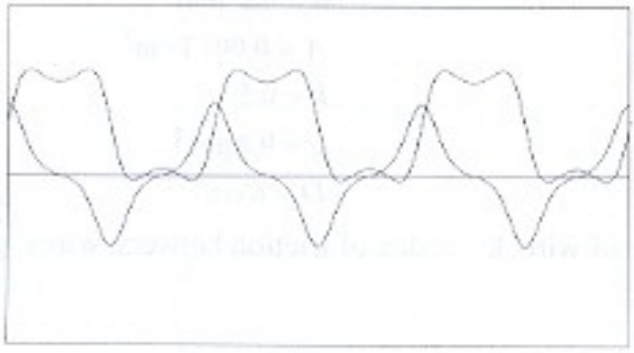
$$N_y = mg + F_{1y} + F_{2y}$$

where N_y is a reaction force between wires

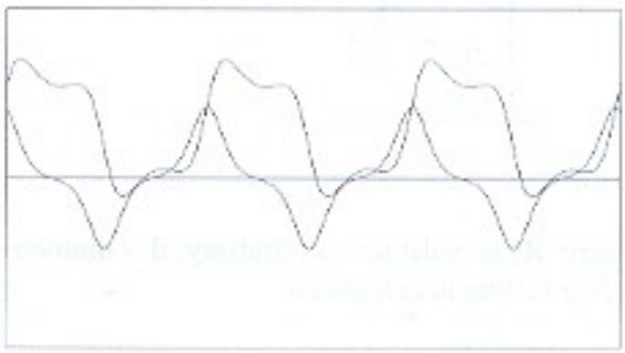
When $0 \geq N_y$, the coil jumps. Graph (1) shows us a picture when the magnet is shifted with respect to the symmetric axe of frame, graph (2) shows a picture when the magnetic pill is exactly under frame axe.

From graph (1) is clear that during disconnection is cut negative part of moment so we have positive work

From graph (2) is clear that with disconnection is cut equal negative and positive parts of moment so work is zero



graph.1 $\psi \neq \pi/2$



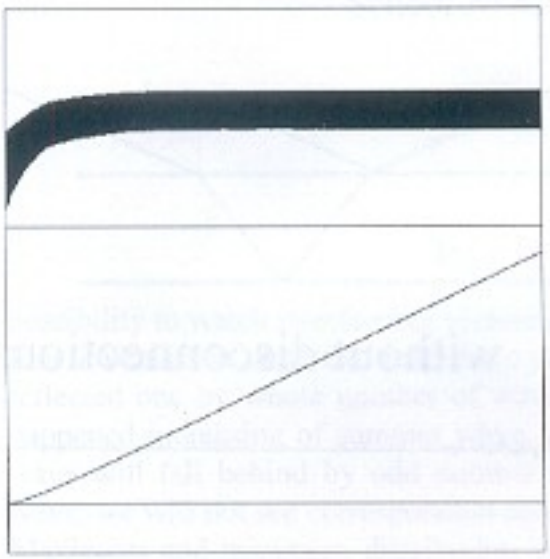
graph.2 $\psi = \pi/2$

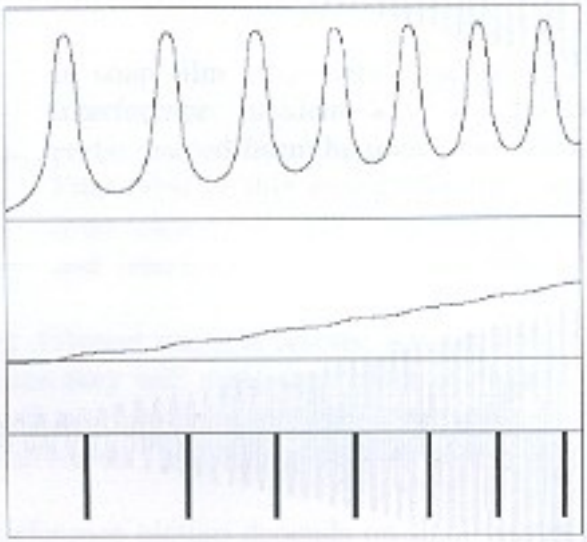
$$M_f = \begin{cases} kNd/2 & \dot{\varphi} \leq 0 \\ 0 & \dot{\varphi} = 0 \quad \text{or} \quad N \leq 0 \\ -kNd/2 & \dot{\varphi} \geq 0 \end{cases}$$

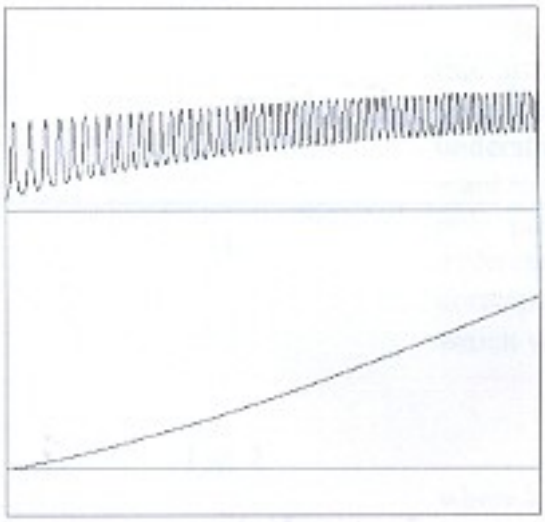
$$M_{af} = -\alpha\dot{\varphi}$$

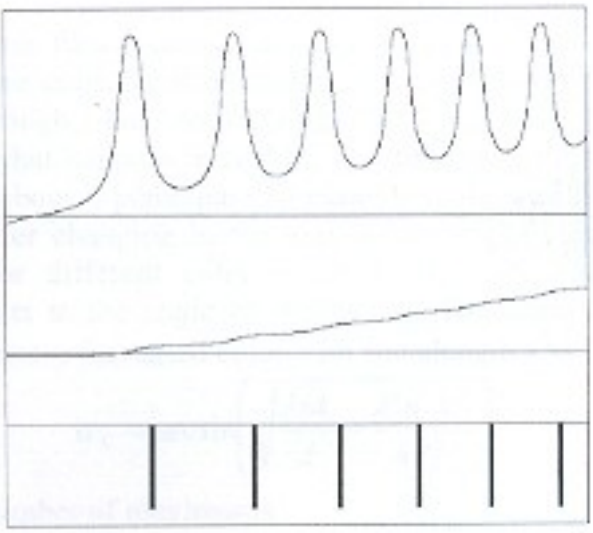
$$J\ddot{\vec{\varphi}} = \vec{M}_1 + \vec{M}_2 + \vec{M}_f + \vec{M}_{af}$$

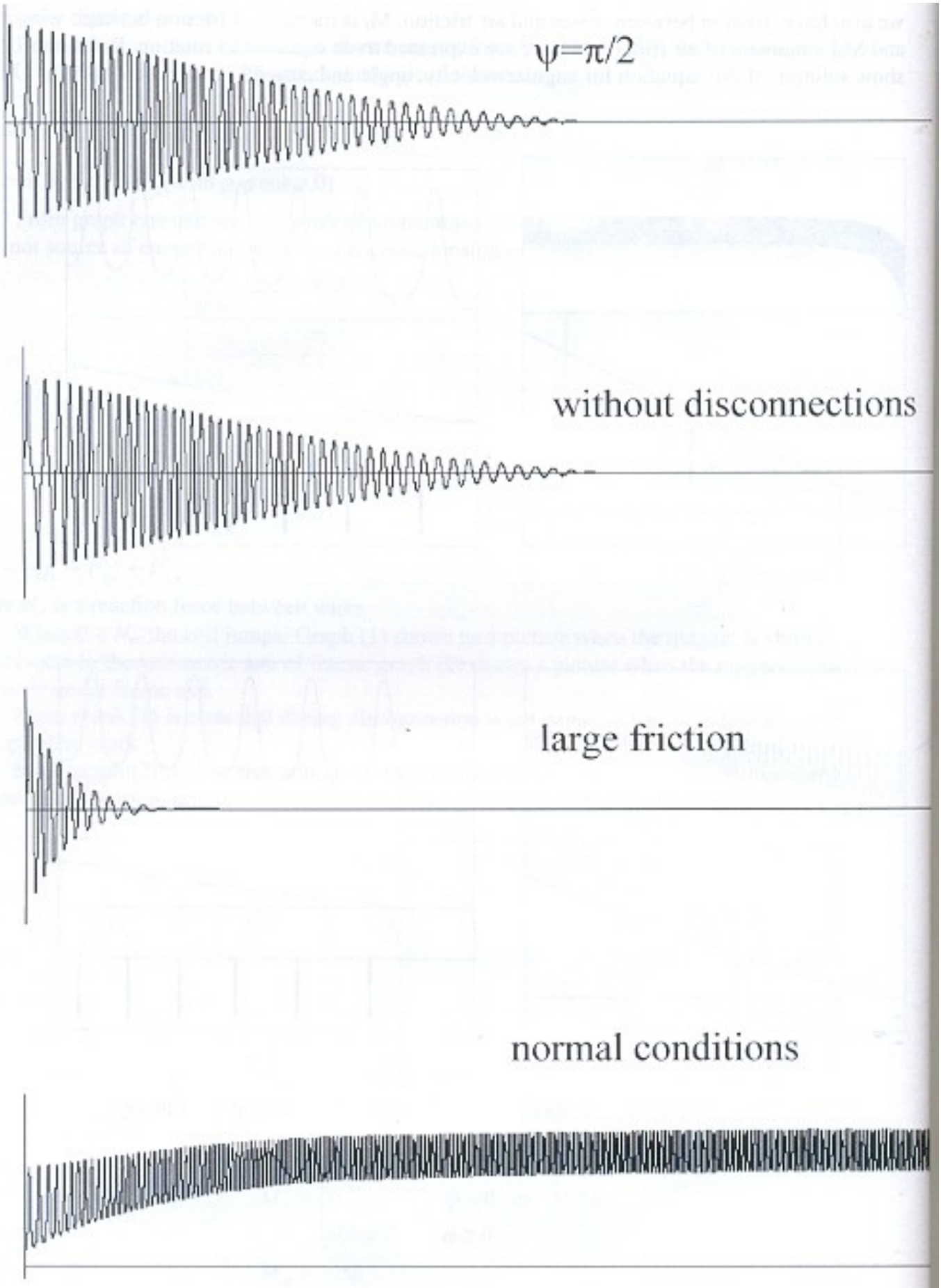
we also have friction between wires and air friction. M_f is moment of friction between wires and M_{af} – moment of air friction. Above are expressed main equation of rotation. Below we show solution of this equation for angular velocity, angle and current.










ψ=π/2
without disconnections
large friction
normal conditions

4. SOAP FILM

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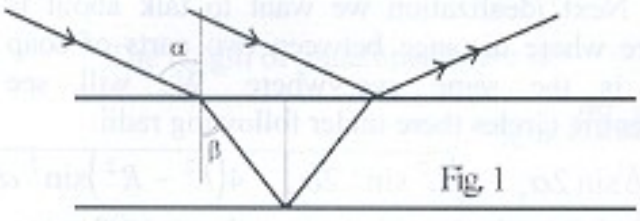

Fig. 1

In soap film color appearance is caused by interference. Incident wave divides on two parts: reacted from the upper and lower sides. Film must be thin enough for these waves to meet each other. They are brought together and interfered to each other. This gives us possibility to watch interference picture.

It is obvious that these two parts have passed different ways. If reacted wave falls behind the reflected one by whole number of waves, then they will meet each other in phase and will happened increasing of summer wave, we will see increased correspondent color. If reacted wave will fall behind by odd number of halfwaves will happened decreasing of summer wave, we will not see correspondent color.

Maximum and minimum distribution in interference picture depends on light waves length, on reflection index, angle of incidence and films thickness. Dependence of interference from these parameters is given by path length's difference:

$$\Delta r = 2d\sqrt{n^2 - \sin^2\alpha} + \frac{\lambda}{2}$$

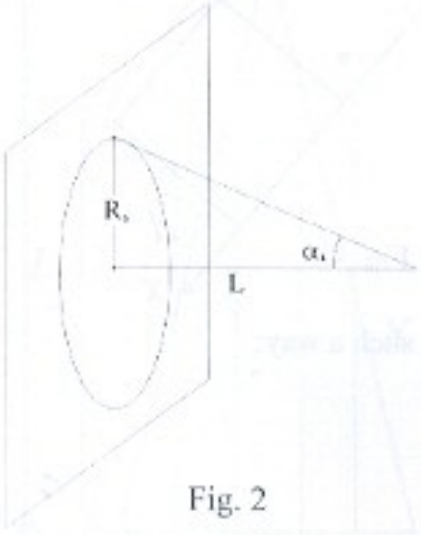

Fig. 2

Real soap film is quit difficult object of observation. In this article we consider it as totality of some idealizations. They are rough, but considering them we can better understand what happens in reality. The first idealization we want to talk about is plane-parallel plate. It is obvious that the only parameter changing in the expression of path length's difference for different color is angle of observation (it correspondents to the angle of incidence). The angle under which we observe increased color with wavelength λ is:

$$\alpha_K = \arcsin\left(\sqrt{\frac{\lambda nk}{d} - \frac{\lambda^2 n^2 k^2}{4d^2}}\right),$$

where k is number of maximums.

It is not difficult to understand that passing from plane picture (Fig. 1) to space one (Fig. 2) we will see concentric circles of different colors. These circles are with following radii:

$$R_s = L\,tg\ \alpha_k,$$

where L is distance between eye and plate.

Speaking about colors we must mention about intensities with which we see them. This is the expression for intensity at interference:

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\left(\frac{2\pi\Delta r}{\lambda}\right)$$

The intensity of the wave that was reflected from the lower and upper sides is respectively:

$$I_1 = I_0(1-R)R(1-R) \qquad I_2 = I_0 R$$

We got them from Frenel's formulas. In them reflection number is following:

$$R = \frac{1}{2}\left[\frac{\sin^2(\alpha-\beta)}{\sin^2(\alpha-\beta)} + \frac{tg^2(\alpha-\beta)}{tg^2(\alpha+\beta)}\right]$$

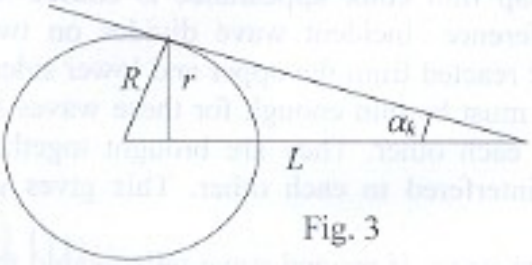

Fig. 3

Next idealization we want to talk about is sphere where distance between two parts of soap film is the same everywhere. We will see concentric circles there under following radii:

$$r = L\sin 2\alpha_k - \sqrt{L^2\sin^2 2\alpha_k - 4(L^2-R^2)\sin^2\alpha_k}$$

L is distance between our eye end center of soap bubble.

How we know under the action of gravitating force soap film changes its thickness (liquid in it flows). To bring in proposed solution times factor we consider liquids flowing. For small element of liquid we write Newton's II law:

$$0 = ma = mg_x - \eta S\frac{\Delta V}{\Delta z}, \text{ (flow has settled).}$$

Having made some transformations we have:

$$Sd\rho g_x \sim \eta S\frac{V}{d}$$

From this we get middle velocity of flowing:

$$V \sim \frac{\rho g}{\eta}d^2$$

After this from Law of mass conservation we have:

$$-Vd\Delta t = l\Delta db$$

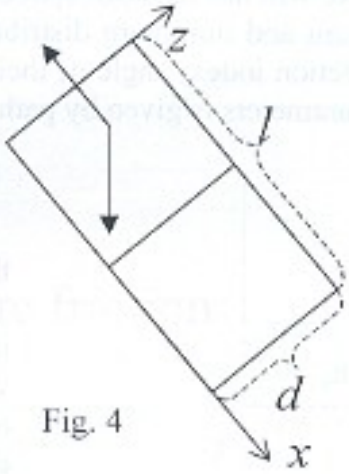

Fig. 4

From this we can get, that film thickness depends on time such a way:

$$d(t) = \frac{1}{\sqrt{\frac{2\rho g_x t}{\eta l} + \frac{1}{d_0^2}}}$$

(We assumed that thickness decreases uniformly everywhere.)

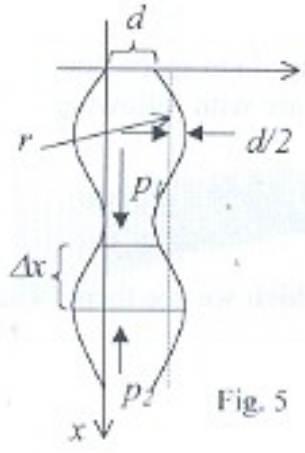

Fig. 5

Flow is laminar when $\mathrm{Re} \in [20;30]$

When $\mathrm{Re} \in [30;50]$ appears regime of waviness flow. Under this regime surface tension forces became comparable with others. In cause of it appears capillary wave, which is undamped in time.

Newton's II law in this case is:

$$\Delta ma = -\eta \Delta SV' + \Delta mg_x - \frac{\Delta p}{\Delta x}\Delta x S_1$$

Middle velocities in both regimes are approximately equal:

$$\langle V_W \rangle \approx \langle V_L \rangle \sim \frac{\rho g}{\eta} d^2$$

The length of undamped wave is:

$$\lambda \approx \frac{\rho g_x d^2}{\eta}\sqrt{\frac{2\sigma d}{\rho}}$$

This wave moves with velocity $c \approx 3V$

The frequency of given wave is:

$$f = \frac{1}{v^2}\sqrt{\frac{2\sigma d}{\rho}}$$

For the function, which expresses thickness of the film we have:

$$z(t) = d\left(\frac{1}{2}\cos(\omega t - kx) + 1\right)$$

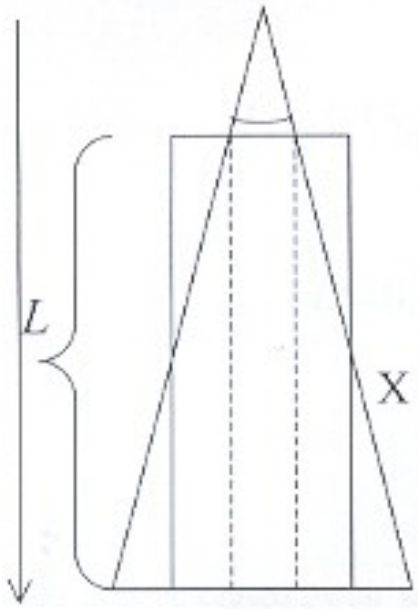

Fig. 6

In cause of flowing film takes wedgeble shape. During Δt time soap film's upper part decreases by Δd:

$$\Delta d = \frac{\rho g d^3}{\eta l}\Delta t$$

For the angle of opening we have:

$$\gamma(t) = \frac{1}{l}\left[d - \left(\frac{2\rho g t}{\eta l} + \frac{1}{d_0^2}\right)^{-\frac{1}{2}}\right]$$

It's the thickness along x-axis $d(x) = d(t) + 2\gamma(t)x$

$$\psi = \beta + \gamma$$

The path length difference for wedge is:

$$\Delta r = 2d(x)n\cos\psi + \frac{\lambda}{2}$$

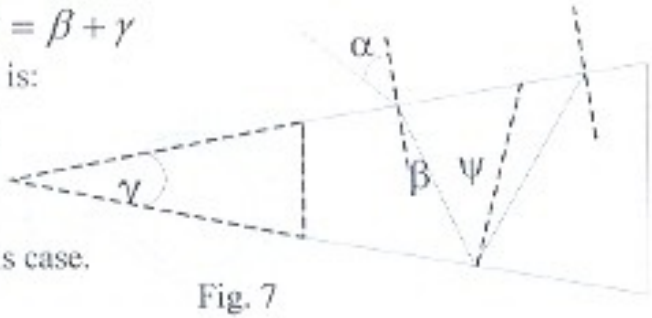

Fig. 7

Now we can judge about interference in this case.

On the other hand the film is membrane, it joins into resonance with frequencies, coinciding with its natural frequency.

The rough estimation of soap film's natural frequency is:

$$\nu \sim \sqrt{\frac{\sigma}{m}}$$

The soap film mass is:

$$m \approx 4\pi R^2 \rho d$$

$$d \in \left(10^{-7};10^{-5}\right)m$$

Theoretical frequencies which we got are following:

$$\nu \in (100;1000)Hz$$

It is in good agreement with experiment.

5. DROPED PAPER

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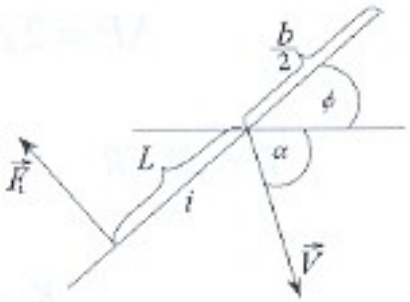
pic.1



pic.2

Re~10^3

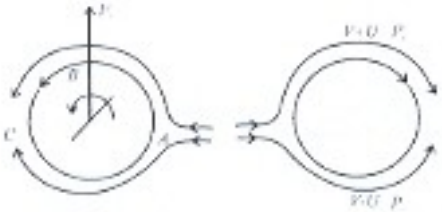
$$F_1 = 0{,}13\rho V^2 S \sin i \qquad \sin i = \sin(\alpha - \varphi)$$

$$L = 0{,}3b(1 - \sin i) \qquad tg\alpha = \frac{\dot{y}}{\dot{x}}$$

$$M_o = F_1 L$$

$$M_o = I\ddot{\varphi} \qquad I = \frac{mb^2}{12}$$

F_1 is force caused by air when paper moves with velocity V. F_1 makes moment M_0 with respect to c.m. of paper and paper begins rotation. ρ - density of air, S-square of paper, I - inertial moment with respect to longest axis, m is mass of paper and b-width of paper. L,φ,α are shown on pic.2



When paper rotates because of air friction air rotates around paper and as a result of this event we have two flows: rotating and blowing ones.

At the ABC airflow intensive each other at the AC break each other ABC is longer than AC so rotation conserves Because of velocity difference according the Bernoulli rule appears difference of pressure U is velocity of rotating Forces caused by difference of pressure are expressed below
In simple model we have:

$$P_1 = P_0 - \frac{\rho(U-V)^2}{2} \qquad P_2 = P_0 - \frac{\rho(U+V)^2}{2}$$

$$\Delta P = 2\rho UV \qquad F = \Delta PS$$

$$F = \rho KVR \qquad \text{where} \qquad K = 2\pi RU$$

$$K = \sum_{ACA} \Delta\vec{r}\vec{V} = \oint_{ACA} \vec{V}d\vec{r}$$

force caused by rotation is following:

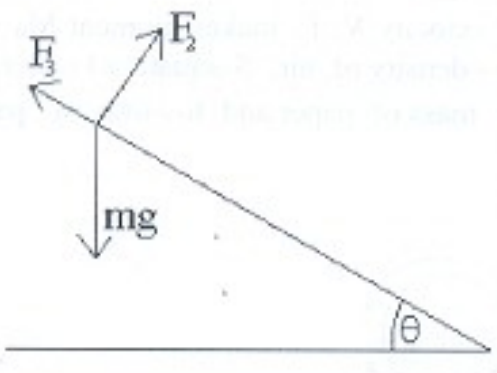
$F_2 = \rho KVl$ $K = \mu\pi b^2 \omega$ ω- an angular velocity of paper

$F_3 = \eta l_1 V$ viscosity force η-viscosity of air

$m\vec{a} = m\vec{g} + \vec{F}_1 + \vec{F}_2 + \vec{F}_3$ Newton's second law

When air surrounds paper F_1 disappears and we have no moment.

Steady motion



Steady motion trajectory of a paper is line which makes angle θ with respect to the horizontal. Steady condition means balance of all forces Condition of balance is expressed below and we get dependence of steady angle on different parameters.

$$F_3 = mg\sin\theta$$

$$F_2 = mg\cos\theta$$

$$tg\theta = \frac{F_3}{F_2} = \frac{\eta l_1}{\mu\pi b^2 \omega l \rho}$$

6. Singing Glass

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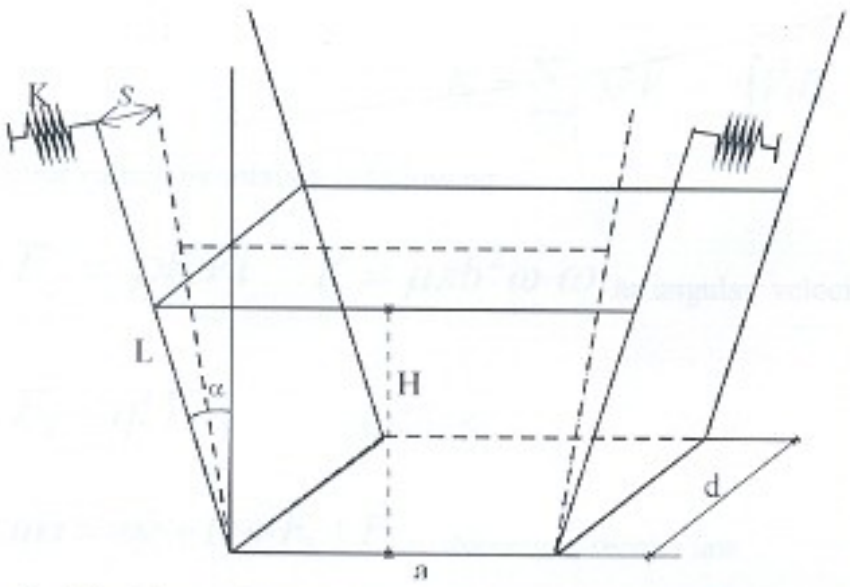
The main part of the problem is to find how depends frequency of the sound on some parameters. To find this dependence we must find a frequency, but the glass has very difficult form and we'll get too difficult mathematical equations. Therefore, we can solve this problem for a model of the glass. In this paper, I'll consider three model of the glass.

First model is the truncated pyramid, which you can see on the picture.



This model gave me best results because of this it's main model and I'll consider it more exact than others.

Now some comments about variables that are present here. Some of them are clear I think, but I want to talk about S and K. S is the little shift of the glass wall in some moment of the time. In real case(I mean in the glass) we have oscillations because of there is elasticity of the glass, so in model instead of glass elasticity I brought in spring with elasticity K.

So to find a frequency we must write the Low of Energy Conservation and after deriving it we'll get formula like formula (1). All energies which are present in this system:

Kinetic energy of the inner water

$$E_{Kw\_in}=\frac{\rho d\dot{S}^2H^3}{12L^2\cos^4\alpha}\times\left(\frac{4a+3H\tan\alpha}{3}+\frac{4aH^2+3H^3\tan\alpha}{(a+2H\tan\alpha)^2}\right)$$

Kinetic energy of the outer water

$$E_{Kw\_out}=\frac{\rho dH^3}{12L^2\cos^4\alpha}\cdot\frac{(4D-3h\tan\alpha)}{6}\left(\frac{h^2}{4(D-h\tan\alpha)^2}+\frac{1}{36}\left(1+\frac{h\tan\alpha}{2(D-h\tan\alpha)}\right)^2\right)$$

Kinetic Energy of glass wall

$$E_{Kwall} = \frac{M\dot{S}^2}{3}$$

Potential energy of the spring

$$E_{Pspring} = KS^2 - S\left(\frac{Hgd}{2\cos^2\alpha L}\left(\rho_{in}H^2 - \rho_{out}h^2\right) + \frac{Mg}{\sin\alpha}\right) + C_1$$

Potential energy of the inner water

$$E_{Pw\_in} = \frac{\rho dgH^2 S}{2L} \cdot \frac{a + H\tan\alpha}{a + 2H\tan\alpha}$$

Potential energy of the outer water

$$E_{Pw\_out} = C_2 S$$

Potential energy of the glass wall

$$E_{Pwall} = \frac{1}{2}\frac{MHSg}{L\sin 2\alpha}$$

$$E_{Kw\_in} + E_{Kw\_out} + E_{Kwall} + E_{Pspring} + E_{Pw\_in} + E_{Pw\_out} + E_{Pwall} = const$$

$$\ddot{x} + \omega^2 x + C = 0 \quad (1)$$

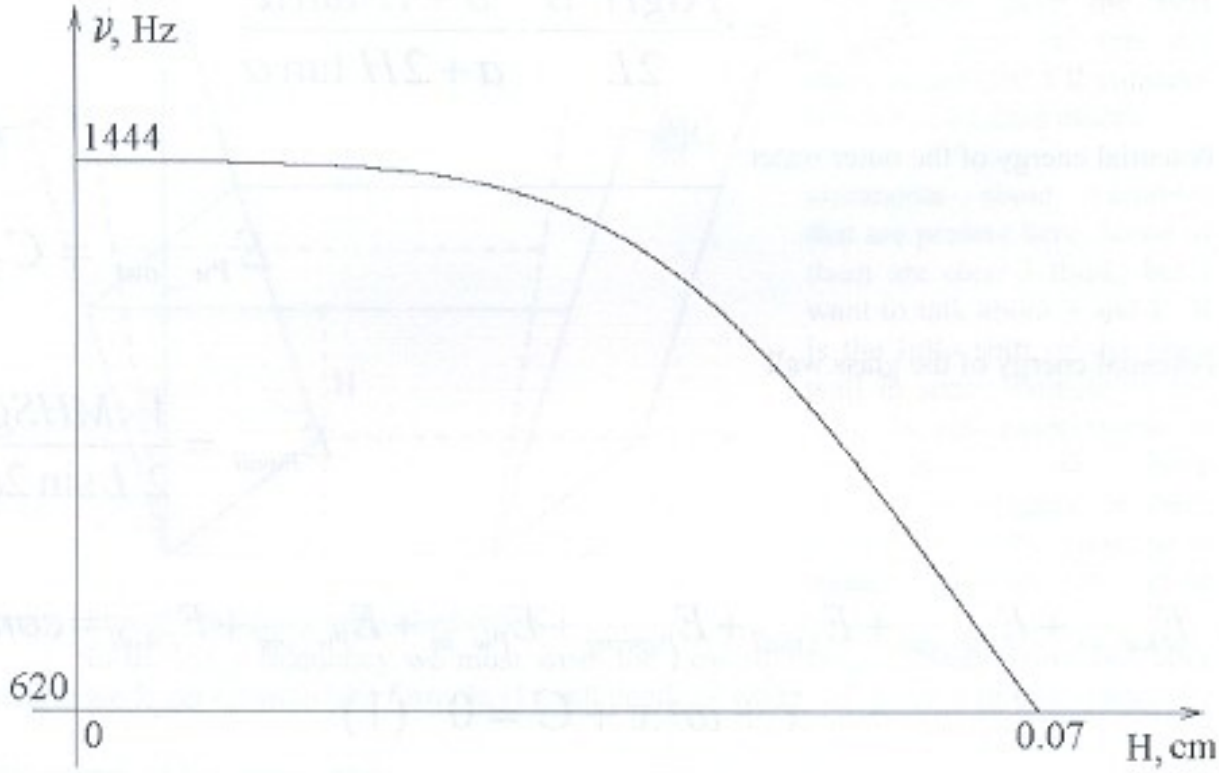
So here you can see frequency dependence on some water and glass parameters

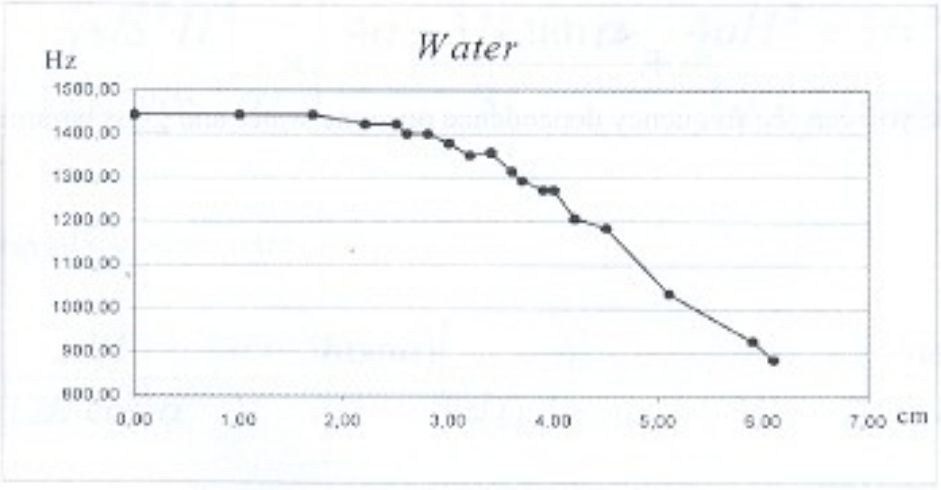
$$A = \frac{K}{\frac{\rho d h^3}{L^2 \cos^4 \alpha}\left(\frac{4D - 3h\tan\alpha}{6}\right)\left(\frac{h^2}{4(D - h\tan\alpha)^2} + \frac{1}{36}\left(1 + \frac{h\tan\alpha}{2(D - h\tan\alpha)}\right)^2\right) + \frac{M}{3}}$$

$$B = \frac{K}{\frac{H^3 \rho d}{12 L^2 \cos^4 \alpha}\left(\frac{4a + 3H\tan\alpha}{3} + \frac{4aH^2 + 3H^3\tan\alpha}{(a + 2H\tan\alpha)^2}\right)}$$

$$\omega = \sqrt{A + B}$$

Graph of the Sound frequency dependence on the inner water's height

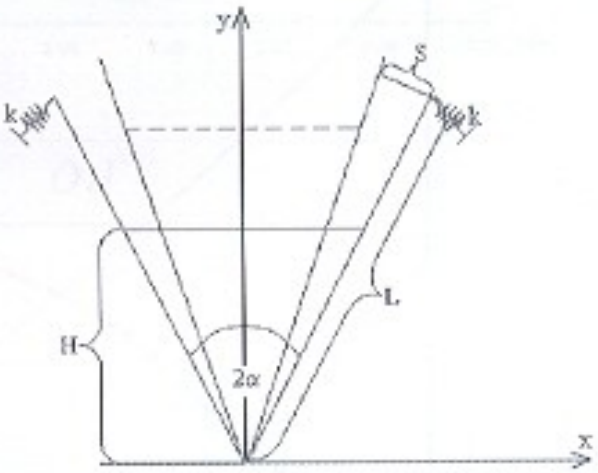


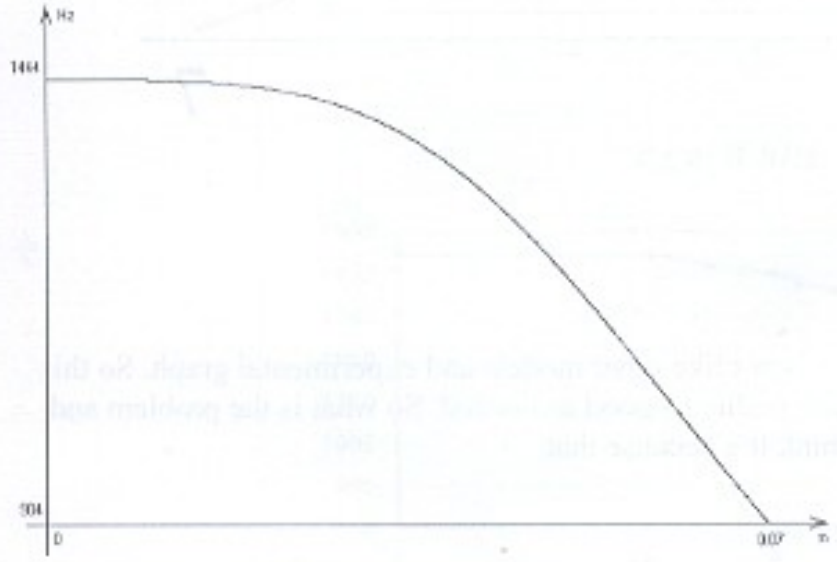


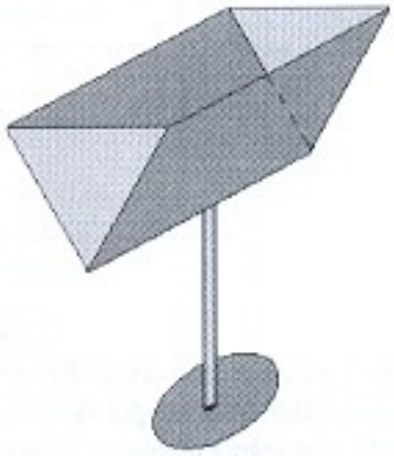
How you can see from these theoretical and experimental graphs they are close to each other, so we can say that this theory explains reality good enough.

Now lets talk about other models which I had considered. Second model is full pyramid you can see it on the picture and also here are formula of frequency for this model and graph of this formula.

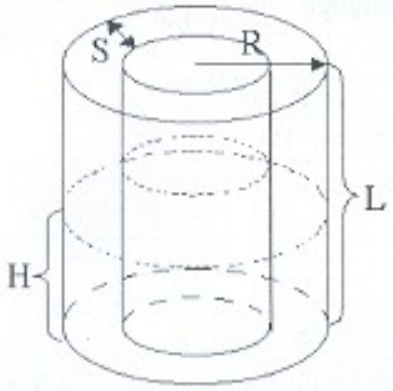
$$\omega = \sqrt{\frac{2K}{\frac{\rho d t g \alpha H^4}{2L^2 \sin^2 2\alpha}\left(\frac{tg^2\alpha}{3}+1\right)+\frac{2M}{3}}}$$



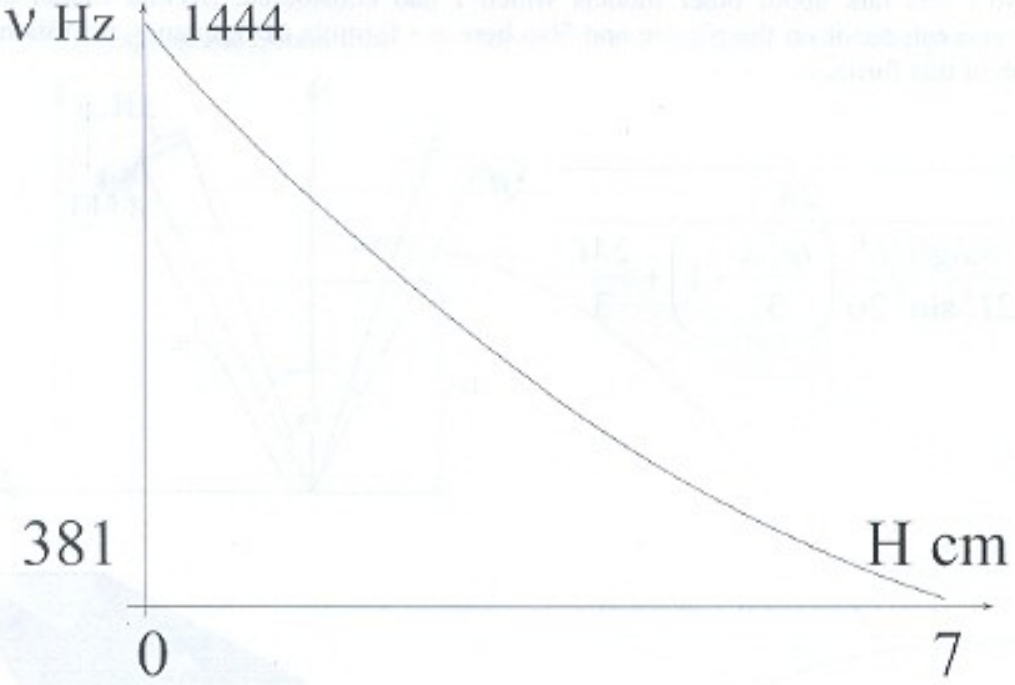




Here you can see third cylindrical model of the glass. You also can see dependence and graph of this dependence.

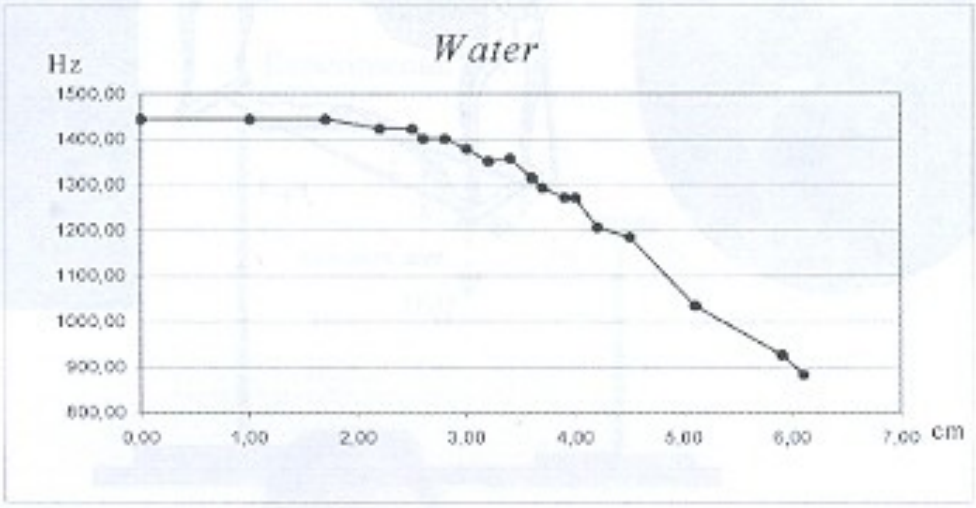


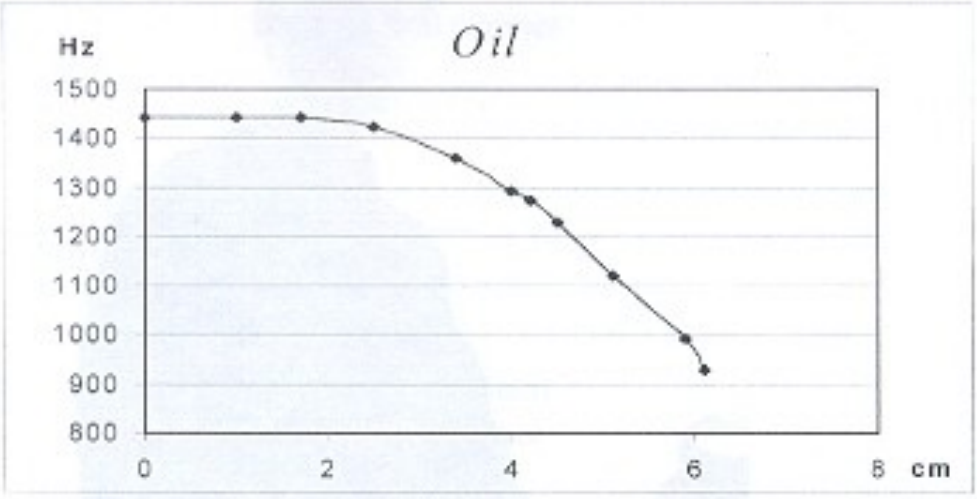
$$\omega = \sqrt{\frac{24k}{12\rho_k RLd + \rho H(3R^2 + 8H^2)}}$$

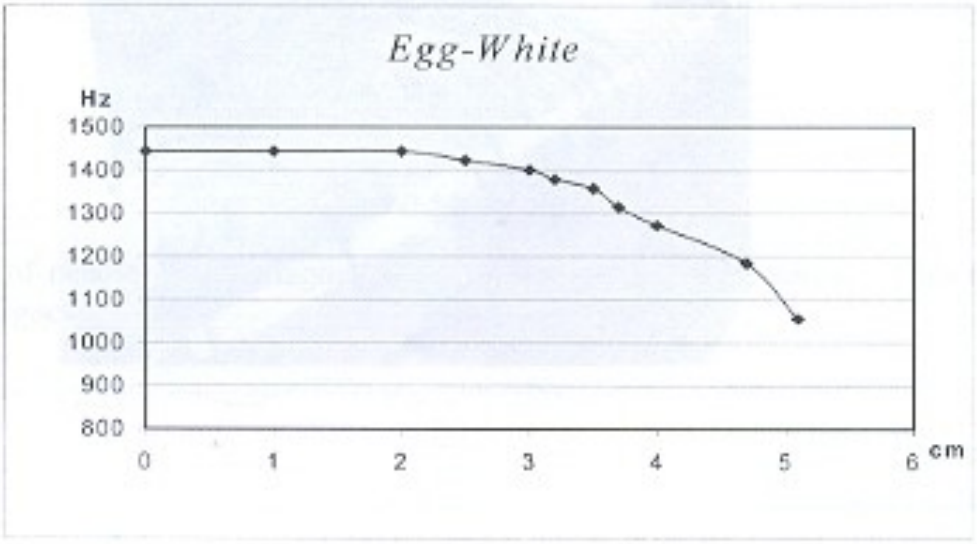


How you can see from this graph it is not like other models and experimental graph. So this means that this model don't explains reality as good as needed. So what is the problem and why it doesn't explains reality. I think it's because that

Experimental Data







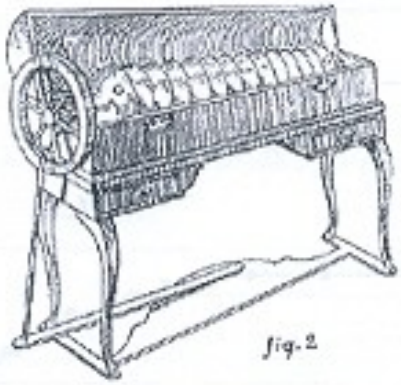


fig. 2

THE ARMONICA

7. HEATED NEEDLE

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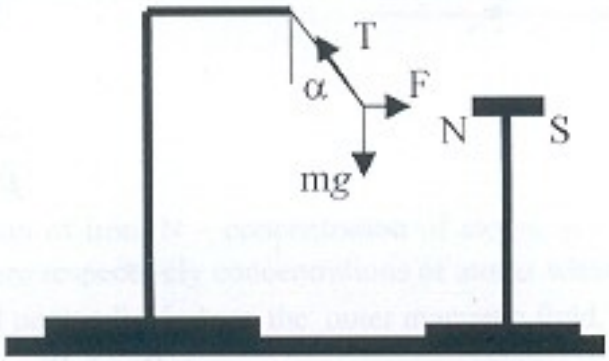
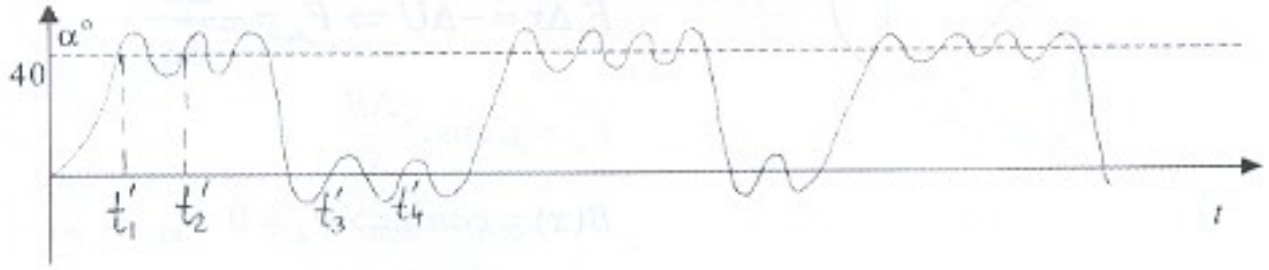
School № 42 named after I.N. Vekua

Experimental device



Experimental regimes



$\alpha_0=40^0$ $l_n=40$ mm
$\tau_1=t'_2-t'_1\approx 0{,}43$ sec
$\tau_2=t'_4-t'_3\approx 1$ sec

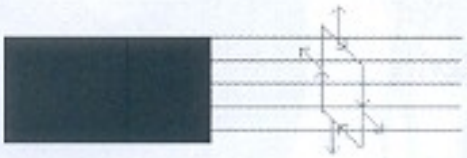
$$F = mg\operatorname{tg}\alpha_0$$

$$\omega = \sqrt{\frac{\sqrt{F^2+(mg)^2}}{ml}}$$

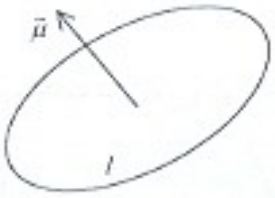
$$\tau = \frac{2\pi}{\omega} \approx 0{,}53$$

where l_n is length of needle, F is a magnet force, m is mass of needle and ω - frequency of oscilations near magnet.

$\alpha_0=37^0$ $\alpha_1=25^0$ $l_n=40$ mm



$$\vec{\mu} = I\vec{s}$$



$$u = -\mu B\cos\vartheta \qquad \vartheta = (\vec{\mu}, \vec{B})$$

$$F_x\Delta x = -\Delta U \Rightarrow F_x = -\frac{\Delta U}{\Delta x}$$

$$F_x = \mu\cos\vartheta\frac{\Delta B}{\Delta x}$$

$$B(x) = const \Rightarrow F_x = 0$$

where μ is a magnet moment of circuit, I – current in the circuit, F_x – interaction force between circuit and magnet and S is square of the circuit.

From pictures and expression for F_x is clear that we have repulsion or attraction when magnetic field is not uniform

$$\begin{cases} M = N < \mu > \\ N_{\uparrow\uparrow} = ae^{+\mu\cdot B/kT} \\ N_{\perp} = a \\ N_{\uparrow\downarrow} = ae^{-\mu B/kT} \\ N = N_{\uparrow\uparrow} + N_{\uparrow\downarrow} + N_{\perp} \\ < \mu >= \dfrac{N_{\uparrow\downarrow}(+\mu) + N_{\uparrow\uparrow}(-\mu) + 0 \cdot N_{\perp}}{N} \end{cases}$$

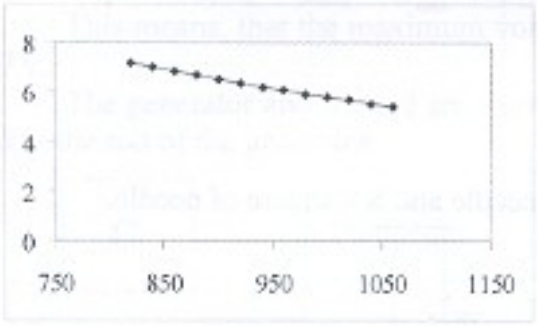
Probability is following:

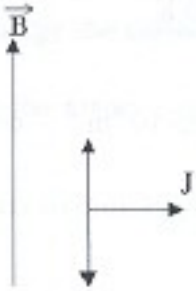
$$p \sim e^{-(\text{State energy})/kT}$$

$$B = \mu_0 \cdot (H_{out} + \omega \cdot M)$$

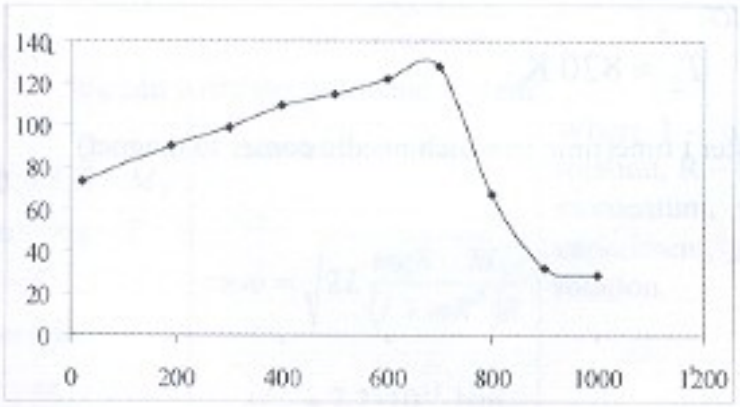
$$M = \mu N \frac{e^{-\mu B/kT} - e^{\mu B/kT}}{e^{-\mu B/kT} + e^{\mu B/kT} + 1}$$

where M is magnetization of iron, N – concentration of atoms, μ - magnetic moment of an atom, $N_{\uparrow\uparrow}$, $N_{\uparrow\downarrow}$, $N_{\perp}$ - are respectively concentrations of atoms whose magnetic moments are directed to, opposite and perpendicularly to the outer magnetic field,



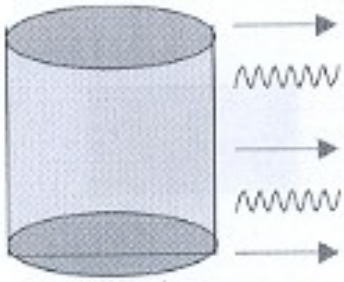


Dependence of magnetization on temperature



Dependence of coil inductivity on temperature of an iron core.

Thermodynamical calculations



For balance law we will get following expression:

$$-cmdT = \xi S(T - T_0)dt + \varepsilon\sigma S T^4 dt$$

$\xi \approx 20\ J/Ksm^2$ $\varepsilon \approx 0{,}5$

$T_0 \approx 290\ K$ $m \approx 0{,}15\ g$

$S \approx 1{,}25 \cdot 10^{-6} m^2$ $c=460\ J/kg \cdot K$

where T_0 is temperature of environment, m – mass of needle and S – square of needle.

$$-t\frac{S\varepsilon\sigma}{cm} = \int_{T_2}^{T_1} \frac{dT}{T^4 + \frac{\xi}{\varepsilon\sigma}T - \frac{\xi T_0}{\varepsilon\sigma}} \qquad t = 3s$$

$T_1 \approx 990\ K$ $T_2 \approx 820\ K$

T_1 and T_2 are respectively initial and after t time(time in which needle comes to magnet) temperatures.

8. ENERGY CONVERTER

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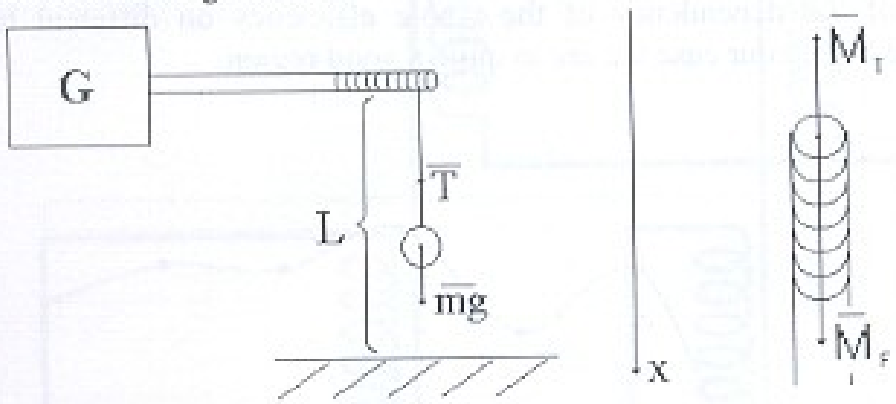
The main aim of our problem is to charge a capacitor, which we reach by converting the potential energy of falling body into electric energy. We tie the body of 1 kg. to rope of 1 m, which is winded round the rod of the generator. The fall of body makes the rod of the generator to rotate.

At first let's consider the ideal case, when the potential energy of falling body is converted into the electric energy without any loses, so:

$\eta^{id} = 100\%$ then $U^{id}_{max} \approx 447$v

This means, that the maximum voltage, to which we can charge the capacitor to equals to 447 v.

The generator and the rod are shown on the picture 1, with the forces applied to the body and to the rod of the generator.



Pic. 1

We can write the following system:

$$\begin{cases} I\dot{\omega} = T_1 R - M_f \\ ma = mg - T \\ T = T_1 \\ a = R\dot{\omega} \\ L = \dfrac{at^2}{2} \end{cases} \quad \omega = at \qquad a = const$$

$$\Rightarrow \omega = \sqrt{2L\frac{mgR - M_f}{(I + mR^2)R}}$$

$M_f \approx 7{,}7 \cdot 10^{-3}$ Nm.

Where I – is the inertia momentum of rod rotation, R – the rod radius, M_F – the friction momentum, which we measured from our experiment, ω - the angular velocity of rod rotation.

We can consider our problem in two stages: In first stage the potential energy of falling body converts into the kinetic energy of rod rotation. In the second stage the kinetic energy of rod rotation converts into the electric energy. At first let's consider the first stage.

Let's find the efficiency of converting potential energy into kinetic one:

$$\eta_1 = \frac{1 - \frac{M_F}{mgR}}{1 + \frac{mR^2}{I}} \approx 0{,}69$$

From the formula we see that with the decrease of M_F, η_1 is increased.

Now let's consider the ideal case, when the kinetic energy of rod rotation converts into the electric energy, than we'll have:

$$E_K = E_{El}^{id} \qquad U_{max} \approx 371\,\text{V}$$

Now we sea that the maximum voltage we can charge the capacitor to equals to 371 v.

Now let's consider the real case, and find out the efficiency of converting kinetic energy into electric. From the experiment we saw that the value of voltage to which we could charge the capacitor equals to 220 v. then we'll have:

$$\eta_2 = \frac{E_{El}^{R}}{E_K} \approx 0{,}35$$

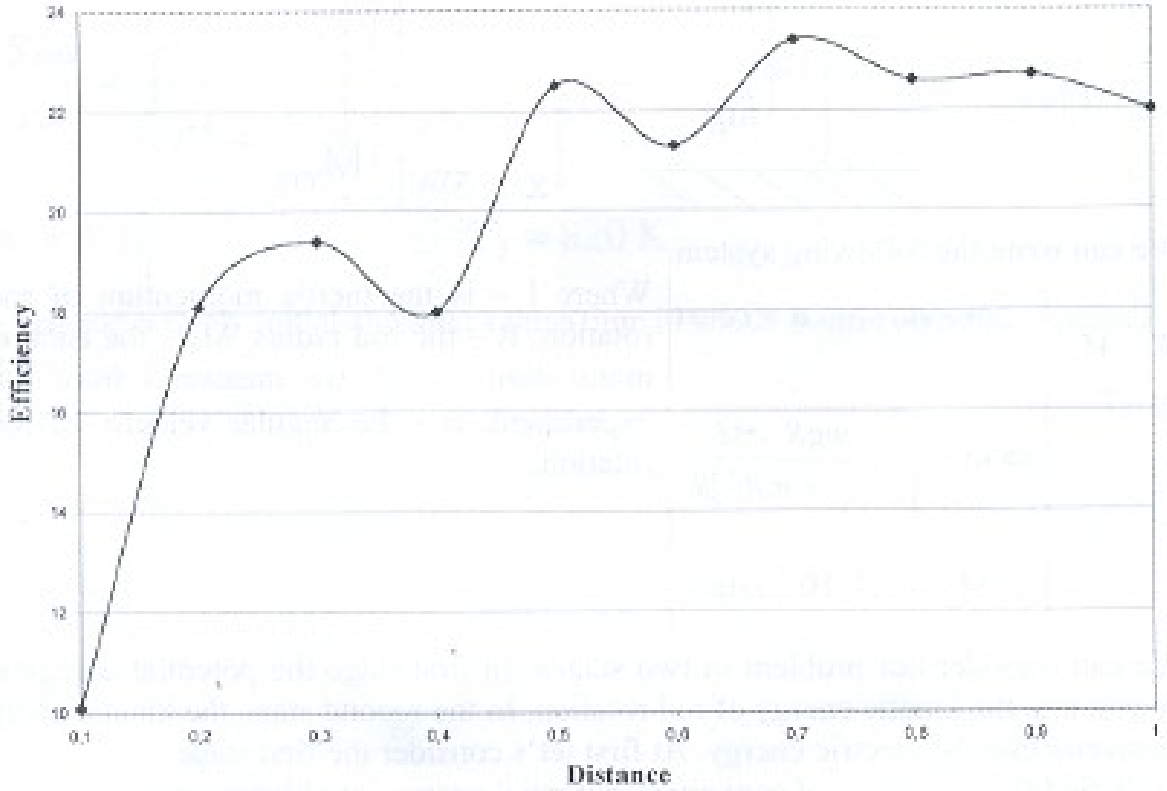
The whole efficiency, or the efficiency of converting the potential energy into electric will be:

$$\eta = \eta_1 \eta_2 \approx 0{,}24$$

This means, that we use 24% of released potential energy to charge the capacitor.

We built the graph of the dependency of the whole efficiency on different heights, (picture 2) from which we see that in our case we are in quite a good region.

Pic. 2

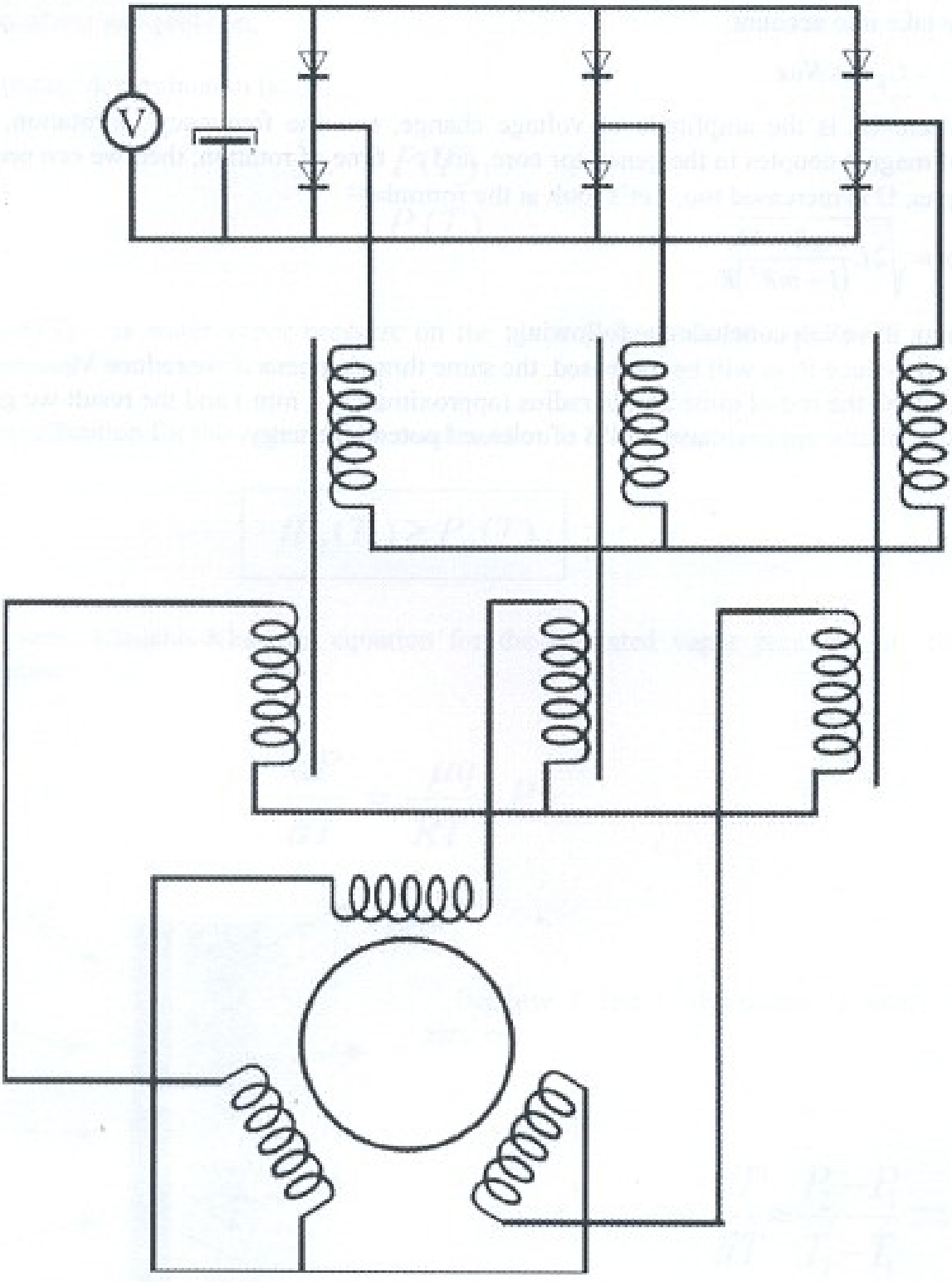


Now about the way we charge the capacitor:

We took 3-phase generator (picture 3), in order to have the minimum lose of voltage. The position of coils is shown on the picture 3. This position of coils is optimal in our case. They are shifted from each other by the angle 120°. Then we took 3-phase step-up transformer and connected each of the coils to the appropriate winding. The generator produces approximately 6 v. and then transformer steps it up.

The transformer in its way is connected to the special rectifiable diode system (chosen by us), by help of which we charge the capacitor and voltmeter shows the voltage it's charged to.

Pic.3



Now let's consider in details the principle of work of our rectifiable diode system.

The rotation of core in the generator emerges the maximum and minimum value of voltage on the coils. This changes in time. As the coils are connected to the appropriate transformer windings, and they in their way are connected to the proper diode couple, so work only those diode couples, which are proper to the maximum and minimum voltage value. For the maximum voltage lower diodes work (picture 3), for the minimum voltage – higher, and the current goes always by the same direction.

In the end let's speak about the way to improve achieved result. One of the ways is to increase the number of transformer windings, but we can't increase it infinitely. Another way is that, if we take into account:

$$U = U_0 \cos N\omega t$$

Where U_0 is the amplitude of voltage change, ω - the frequency of rotation, N - the number of magnet couples in the generator core, and t – time of rotation, then we can see, that by increasing ω, U is increased too. Let's look at the formula:

$$\omega = \sqrt{2L\frac{mgR - M_F}{\left(I + mR^2\right)R}}$$

From it we can conclude the following:

If we reduce R, ω will be increased, the same thing happens if we reduce M_F.

We took the rod of quite a little radius (approximately 3 mm.) and the result we got in this case is 220 v. that's approximately 24% of released potential energy.

9. AIR DRYER

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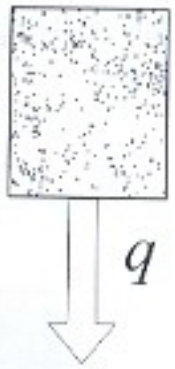
To solve this problem, let's at first solve such a sub-problem. We have vessel with water vapor at given humidity and on given temperature, and the question will be: how much shell we decrease temperature for water vapor to condense? This problem has direct connection with our one, because we also get water from atmosphere air by condensing it and we need low temperatures of condensing surface. So let's go directly to solution of our sub-problem.



Humidity determination is:

$$f = \frac{P(T)}{P_s(T)}$$

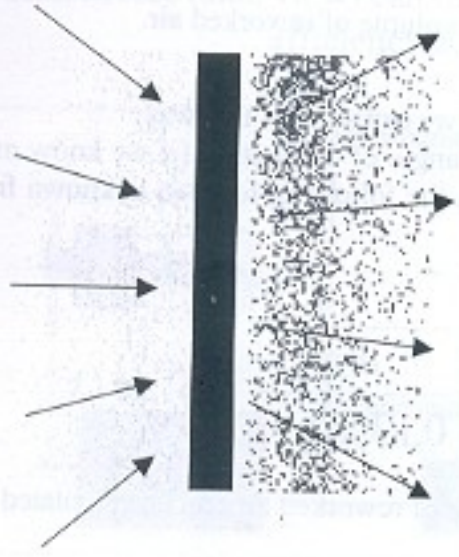
Where P(T) – is water vapor pressure on the given T temperature and P_s (T) – saturated vapor pressure on the given temperature.

So, the condition for the water vapor condensation is following:

$$fP_H(T_0) \geq P_H(T)$$

Let's write Klausius-Klaperon equation for the saturated vapor pressure on the given temperature:

$$\frac{dP}{dT} = \frac{\mu q}{RT^2} P$$



Because T and P alternation is small, one can assume:

$$\frac{dP}{dT} \approx \frac{P_2 - P_1}{T_2 - T_1} \Rightarrow$$

And get, that:

$$\frac{T_2 - T_1}{P_2 - P_1} = \frac{RT_1^2}{\mu q P_1}$$

Finally applying following conditions:

$$P(T_1) = fP_H(T_1) = fP_1$$

$$P_2 = \frac{T_2}{T_1} fP_1$$

One can get:

$$T_2 - T_1 = -3{,}3K$$

So, it's enough for temperature to change on 3,3K for dew to fall, but really in experiment we have much bigger temperature alterantion: about 20-25K.

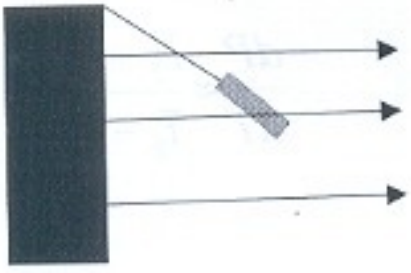
After these calculations we can choose the way of cooling condensing surface: it can be ether vaporisation or solution of ammonium nitrate. We've constructed both type of devices and it was very interesting to estimate their efficiencies. So we input such definition of efficiency: since we can get hov much air we've "refined" we can calculate how much water potentially we could get (on given humidity) and from experiment we know how much water we've got so let's call ratio of experimentally got water to potentially "refined" water efficiency:

$$\boxed{\eta = \frac{m_e}{m_p}}$$

$$m_p = v\mu$$

where μ — mass of a water per volume unit. v — volume of reworked air.

Now our problem is to get, how much air we reworked, we can solve it this way:
If we hang small plate over the air flow we can get by angle of inclination (if we know mass and surface square of the plate) velocity of the air flow, the following formula is known from Jukowski's SOCHINENIYA.



$$v = \sqrt{\frac{mg}{0{,}135 S tg\alpha}} \approx 6 \quad m/s$$

Then volume of reworked air can be calculated so:

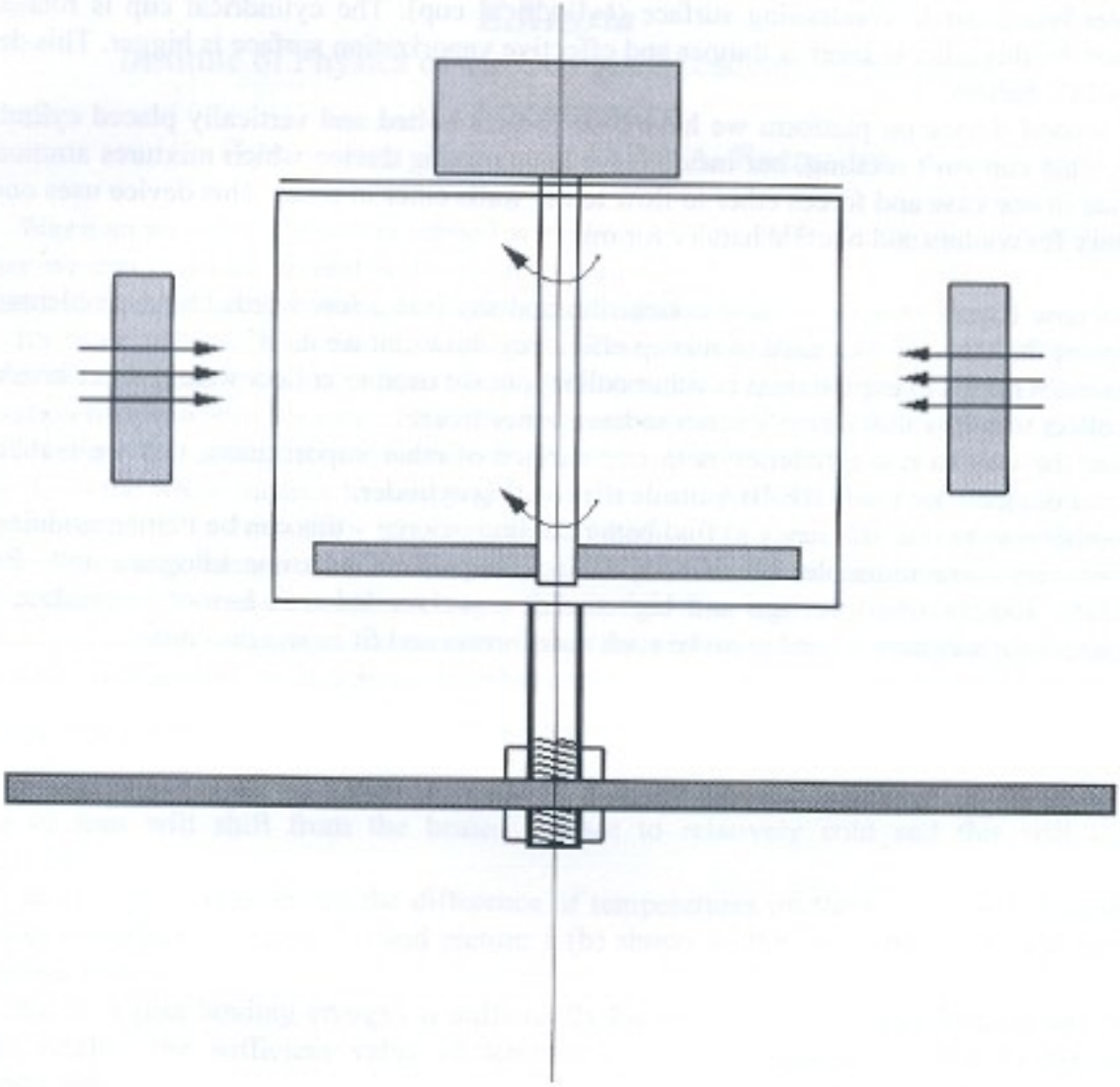
$$V = NSvt$$

where t is 4 mins and N – number of air emitting coolers.

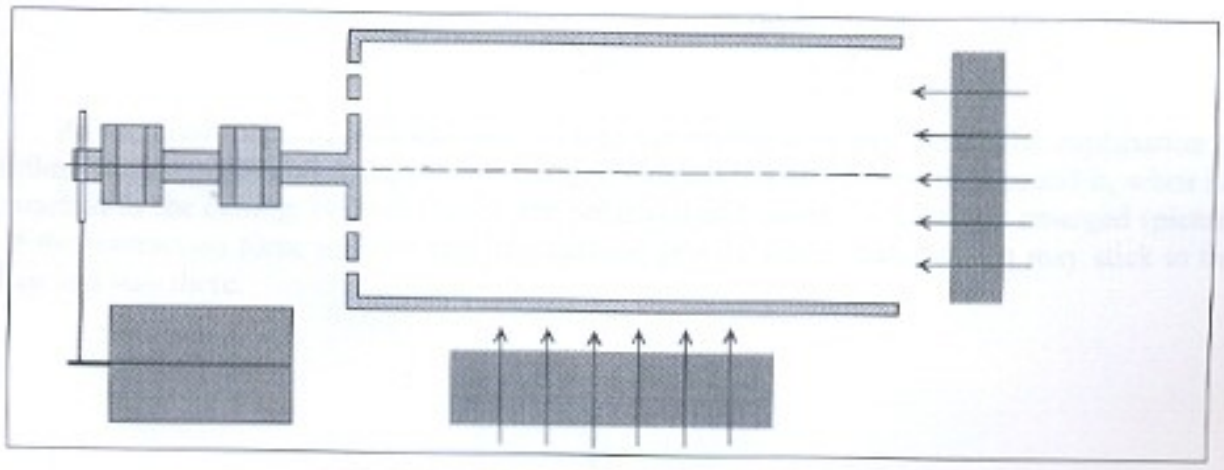
So, efficiencies for both two devices are:

Here are schemes of our devices.

$$\eta_1 \approx 6\% \quad \eta_2 \approx 3\%$$



This device (side view) can be used both with ammonium nitrate and ether, efficiency coefficient before is for ether.



And this device (top view) can be used only with ether.

Now I want to describe our devices.

In first we have a platform where are bolted: motor, two coolers and cylindrical cup in horizontal position (due to its symmetry axis). This cup has holes in bottom – it's for vaporized ether to flow out. Job of one of the coolers is to make ether flowing out and other cooler brings air to condensing surface (cylindrical cup). The cylindrical cup is rotated by motor, by this ether is layer is thinner and effective vaporization surface is bigger. This device uses 18V battery.

In second device on platform we have four coolers bolted and vertically placed cylindrical cup. This cup isn't rotating, but inside it we have mixing device which mixtures ammonium nitrate in one case and forces ether to flow to the walls ether in other. This device uses one 9V battery for coolers and one 3V battery for mixer.

And now I want to make a short conclusion and say just a few words about problems with usage of this devices. We need to rise up efficiency: how can we do it?

The main minus in exploitation is water collection, we used to collect water rubber brush and to collect water by this way it's better to have water freeze.

Also the way to rise efficiency is to rise surface of ether vaporization, this we realized in second device – we made REZBA inside the rotating cylinder.

Another way to rise efficiency to find better cooling source – this can be Peltier modules, but for us they were unusable, because the device mass limit was one kilogram and Peltier modules require small voltage and big current – we needed transformer to produce such output, but it's extremly hard to make such transformer and fit in weight limit.

10 CHARGED BALLOON

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When an air filled balloon is rubbed with wool or dry paper electrization takes place. In this case we can consider several ways of electrization. One of the ways is the ruin of balloon structure and electron loses. In this case balloon is charged in positive charge.

It's more realistic to consider electrization case, which depends only on friction. In this case we assume that there is neither dust nor humidity layer on the balloon surface, so electrization happens only because of friction, in another words triboelecrization takes place.

It's clear that some definite surface is heated by friction. Here we consider two cases of heating: I - is the whole surface heating and II - is the heating of some surface inequalities. Both cases are depended on the surface structure characteristics. It's clear that for some solid bodies, which can have high temperature for inequalities, it's possible thermo emission, after which the heated surface is charged in positive charge. Albeit this case isn't inevitable. If both structures have freely connected ions, than we can determine the number of those ions that can shift from one structure into another by Boltzman distribution:

$$N = N_0 e^{-A/kT}$$

Where N_0 is the initial number of ions and A is the ion binding energy. In this case a big number of ions will shift from the heated surface to relatively cold and this will lead to electrization.

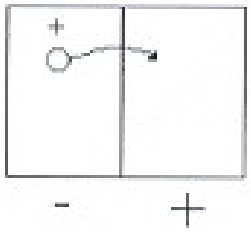
On picture 1 (a) is shown the difference of temperatures on the surface with inequalities (that leads to surface electrization) and picture 1 (b) shows us the electrization process between two rubbing bodies.

But if A (ion binding energy) is sufficiently big, than by the surface heating one of the surfaces reaches the sufficient value of temperature for the charge to shift by the above mentioned way.

Pic. 1

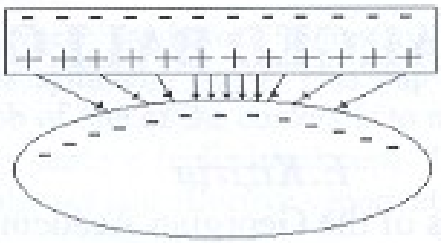
(a)

$T_1 > T_2$



(b)

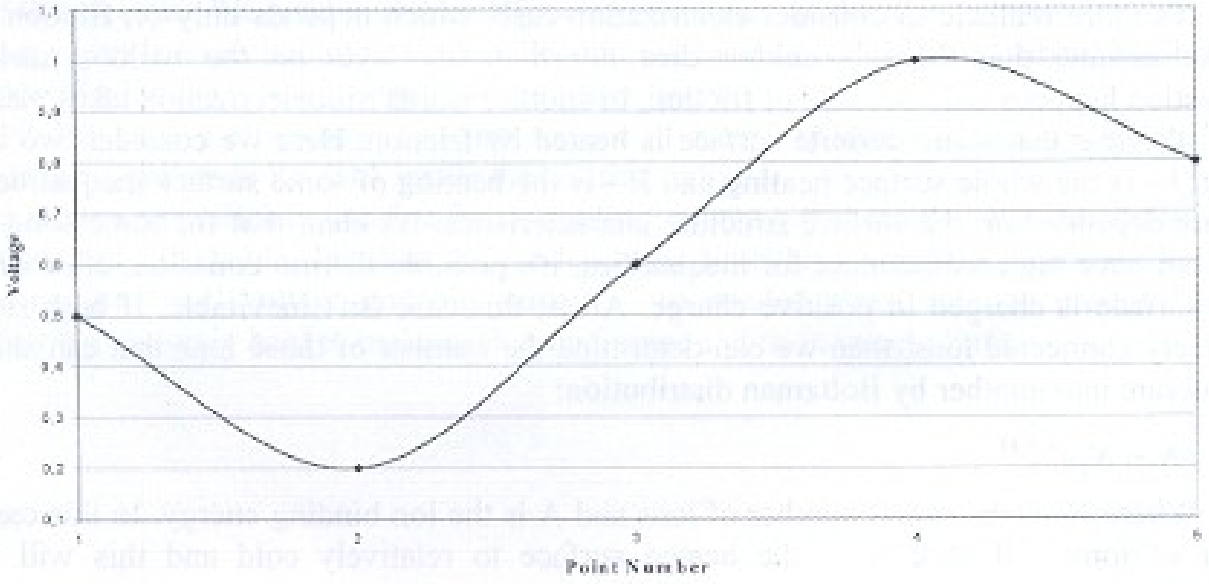
As we know charged balloon may stick to the ceiling and stay there. The explanation of this phenomenon is the following: as the charged balloon has an electric field round it, when it's approached to the ceiling, ceiling dipoles are polarized and interaction force is emerged (picture 2). If the interaction force is more than the balloon gravity force, than balloon may stick to the ceiling and stay there.



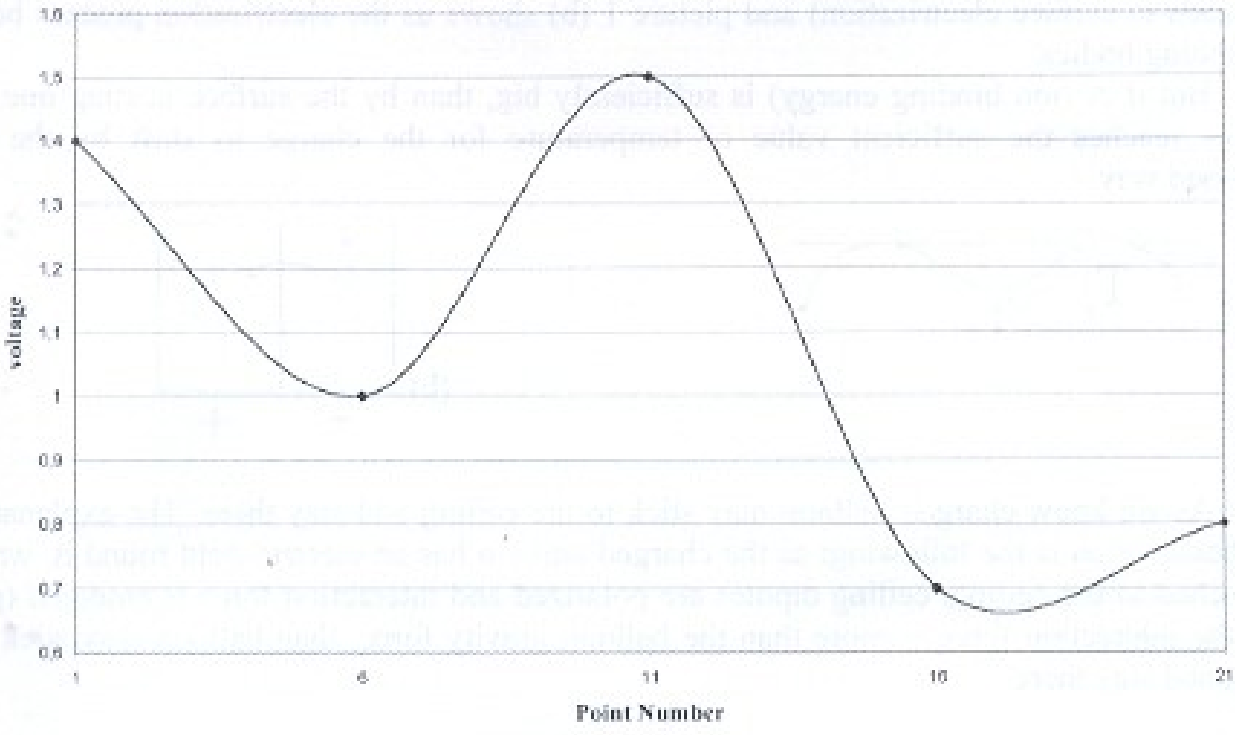
Pic. 2

The charge of the balloon and its ability to stick to the ceiling is greatly influenced by air humidity. We constructed several graphs of charge distribution on the surface for different air humilities, here are some of them:

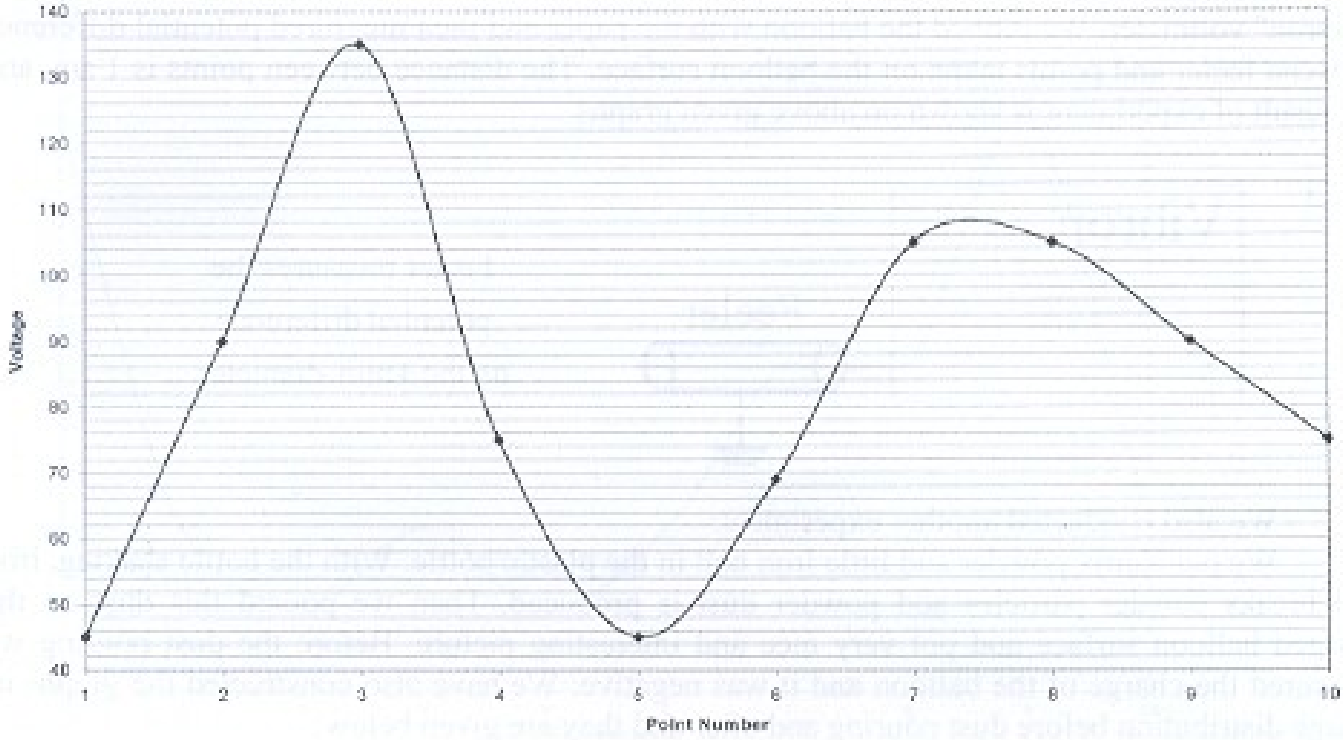
Charge distribution for φ=78%



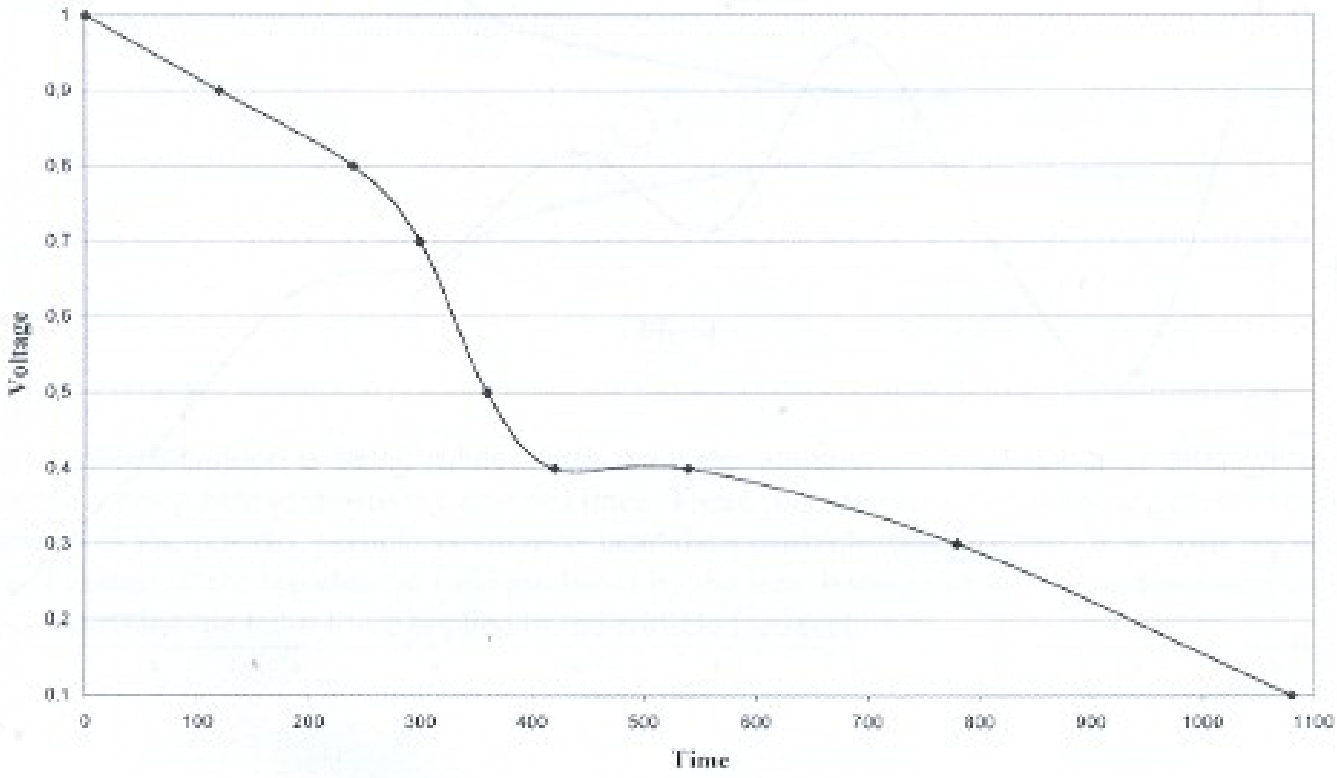
Charge distribution for φ=78%



Charge distribution for φ=83%



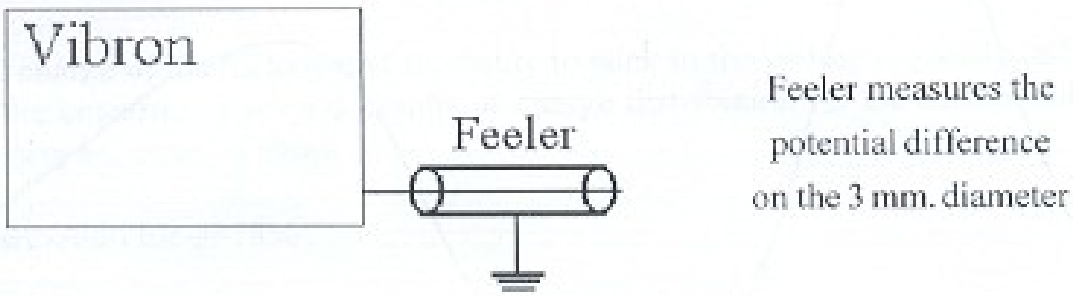
Charge lose in time for φ=83%



These graphs are made from the following experiment:

We constructed "feeler" (see picture 3) that is a conductor, which is connected to special "Vibron" voltmeter. We rubbed the balloon with the paper and then measured potential difference between feeler and points taken on the balloon surface. The distance between points is 1 sm. and the result of experiment is shown on above given graphs.

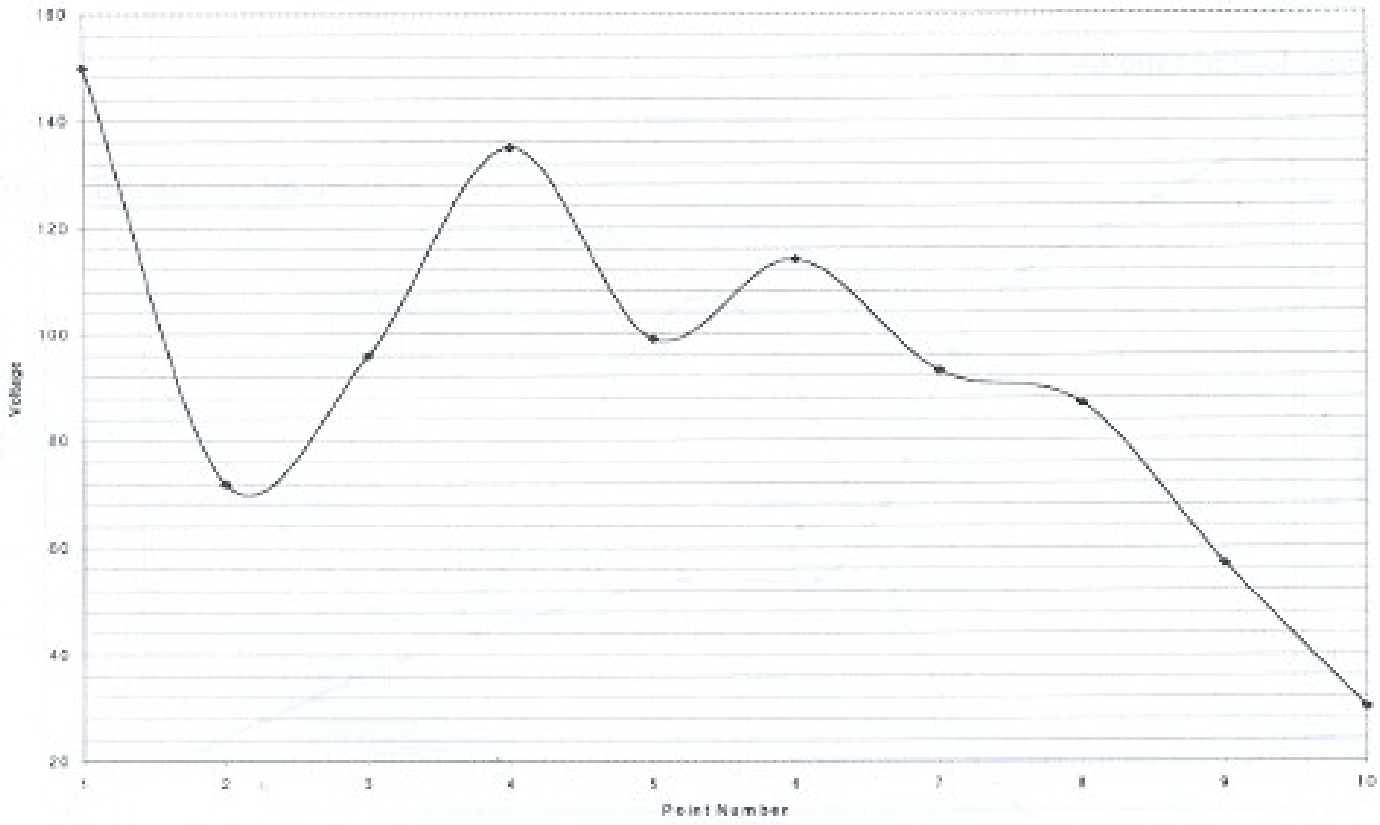
Pic. 3



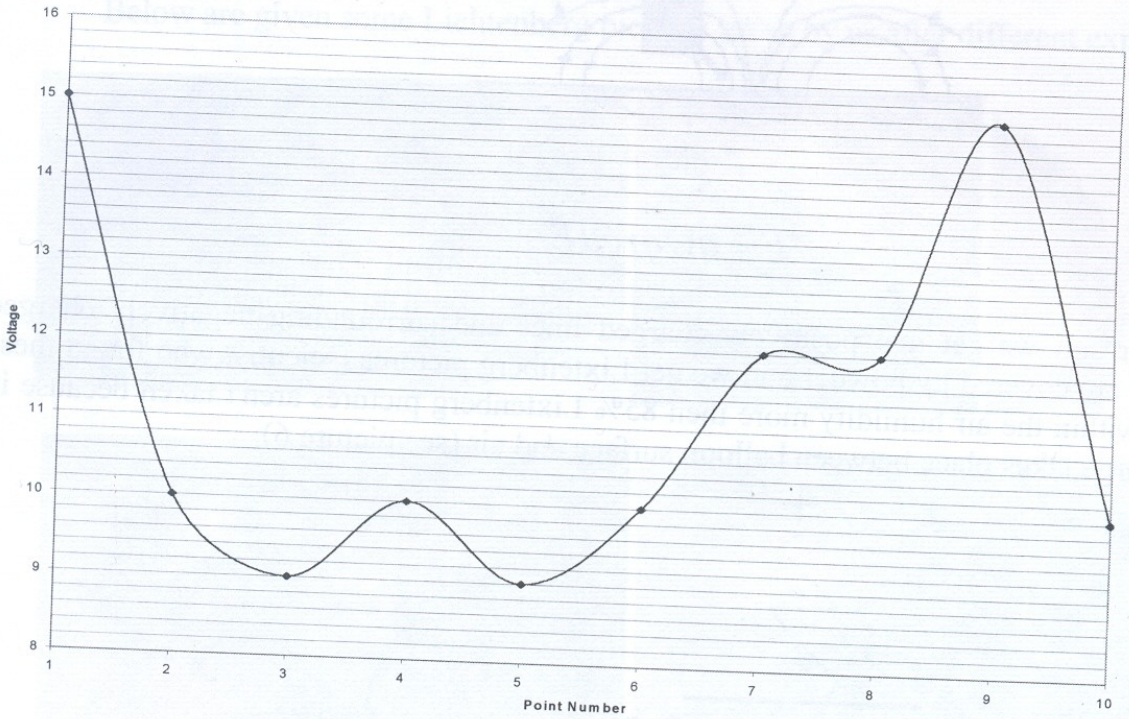
We also conducted another experiment:

We put Xerox powder and little iron ball in the plastic bottle. With the bottle shaking, iron ball breaks powder particles and powder dust is produced. Then we poured this dust on the charged balloon surface and got very nice and interesting picture. Before the dust pouring we measured the charge of the balloon and it was negative. We have also constructed the graphs of charge distribution before dust pouring and after and they are given below:

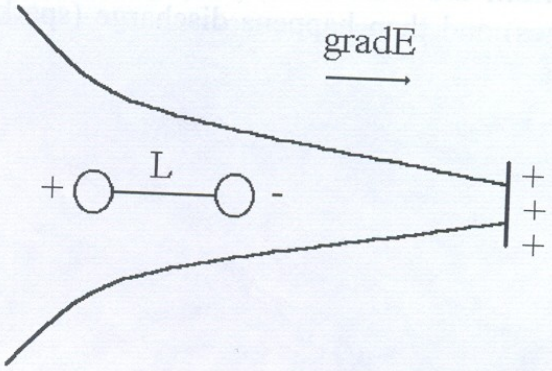
Charge distribution before pouring for φ=83%



Charge distribution after pouring for φ=83%

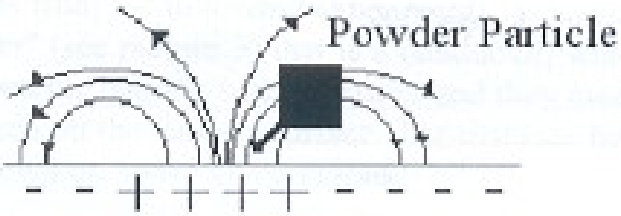


Now let's consider what happens when we pour powder on the charged (in our experiment negatively charged) balloon surface. Powder particles are dielectrics and they are polarized (see picture 4).



Pic. 4

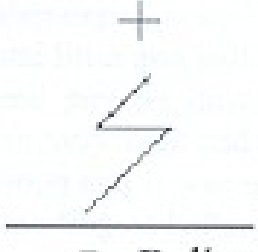
When balloon is being rubbed with the paper some electron groups may shift across the surface leaving behind positively charged lines. These lines are surrounded by negatively charged surface. If the powder particle is situated near the positively charged line, it is attracted to the line, because of the big electric field produced by the line, because of the Kulon force and we can also determine the main force applied to the particle (see picture 5).



Pic. 5

$$F = qL\, grad E$$

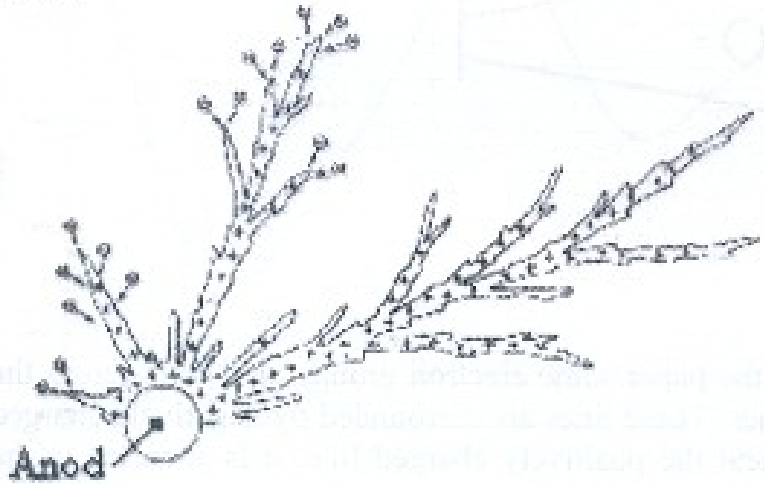
As the result we get that positively charged lines and surrounding negatively charged balloon surface are covered by powder and we get Lixtenberg pictures (scientist who found these pictures). But within the air humidity more then 85% Lixtenberg pictures aren't taken because in this case discharge takes place between balloon surface and air (see picture 6).



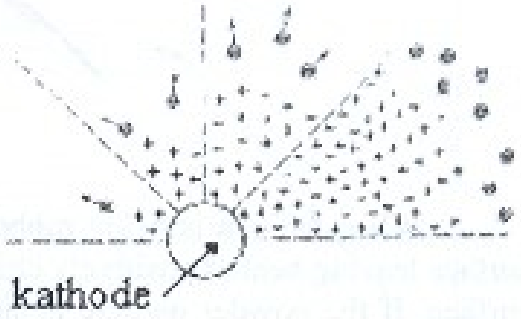
Pic. 6

If anode is approached to the negatively charged balloon surface (in our experiment paper plays anode role) electrons from the whole surface gather in the point under anode (leaving behind positively charged lines) and then happens discharge (sparkle). Picture 7 (a) shows the result we get after this process.

Pic. 7



(a)

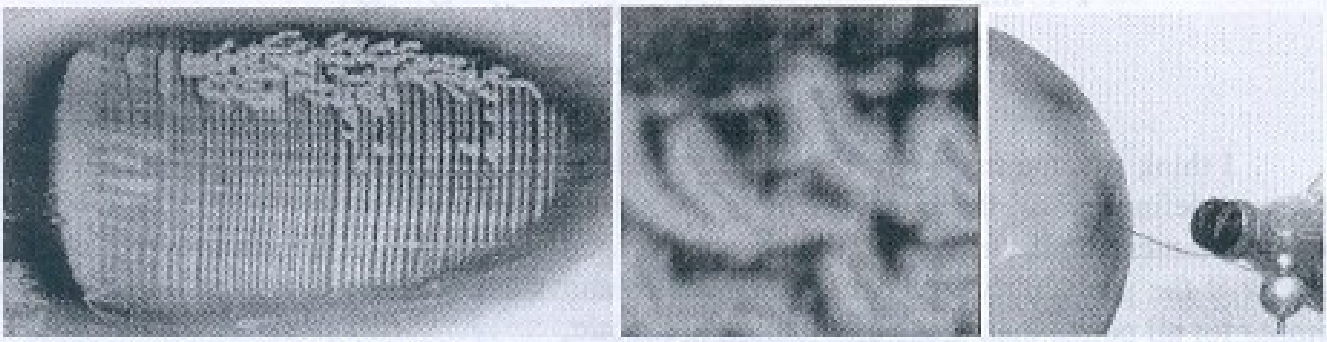


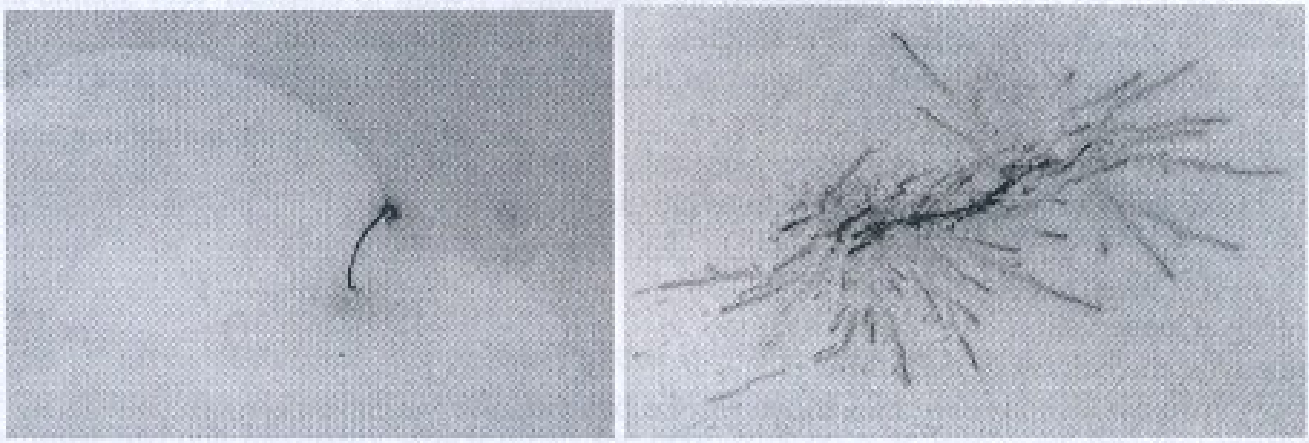
(b)

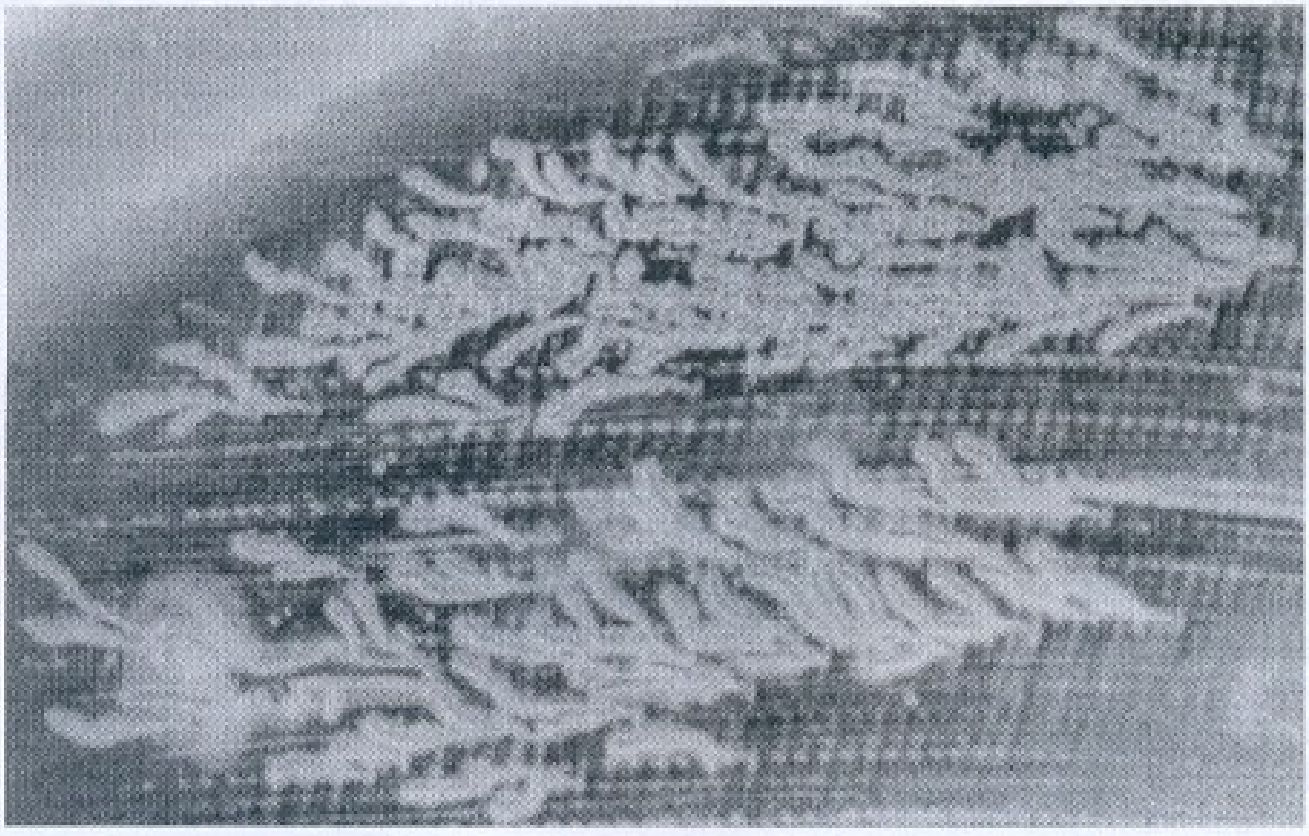
Another picture occurs if cathode is approached to the negatively charged balloon surface. Electrons are repulsed from the place under cathode and leave behind positively charged areas. These areas attract electrons from the cathode and electrons are shifted from the cathode to the

surface. Then the same process happens until cathode is removed from the surface and finally we get the picture 7 (b).

Below are given some Lichtenberg pictures taken by us after different experiments:







11. BILLIARD

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I think that the main part of the problem is to understand what is the chaos therefore we must define it. So I think that we have chaotic distribution of some particles on the plane or in the dimension if we have no priorities in the particle's positions. Or we can say this such a way: if the probability that particle will be in some point of the plane (or dimension) is similar for all points than those distribution is chaotic.

Ok lets go back to the Billiard. At the beginning, I want to consider very simple and very rough model of the Billiard. It is rough so it has some idealizations.

1) After the first collision, the energy of the 16th ball will be distributed uniformly for all balls. So we have no energy losses.
2) We have no more collisions between balls after the first collision.
3) All balls are identical. All collisions are elastic.

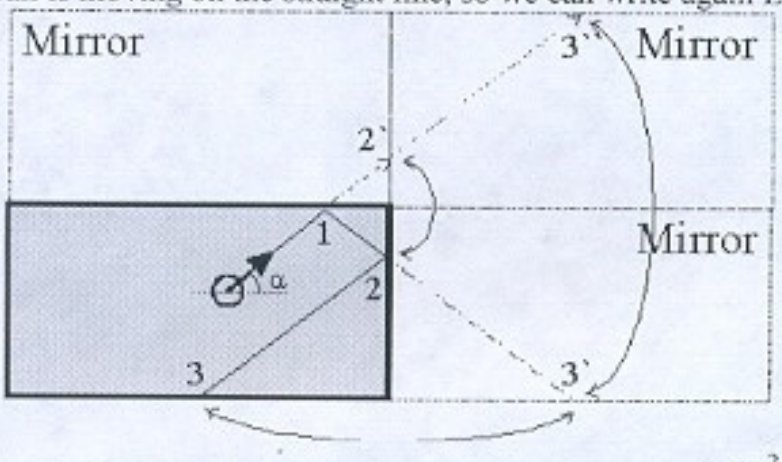
By idealization (1) and Low of Energy Conservation we can calculate velocity of the balls after the collision.

$$V_1 = \frac{7}{20}V$$

Now we can absorve movement of one ball because we have no more collisions between balls.

Let's assume that after the first collision one of the balls was directed by any angle but with known velocity. Our problem is to find coordinates of this ball, when it will be stopped by friction with table. For this we must follow it's way and it's every collision with walls. But I think this too difficult so to do this more easily I want to bring in mirror reflections of the table (pic. 1).

On this picture ball is moving on the straight line, so we can write again Low of Energy



conservation and find full L way which this ball would make. $L = \frac{mV_1^2}{2F_{fr}}$

But we wan to find coordinates of this ball in the table coordinate system so we must convert L to the X and Y of this system. Here you can see formulas by which we can make this convert.

$$X=\begin{cases} a\cdot\left\{\dfrac{X_0+L_x}{a}\right\},\left[\dfrac{X_0+L_x}{a}\right]=2k \\ a-a\cdot\left\{\dfrac{X_0+L_x}{a}\right\},\left[\dfrac{X_0+L_x}{a}\right]=2k+1 \end{cases}$$

$$Y=\begin{cases} b\cdot\left\{\dfrac{Y_0+L_y}{b}\right\},\left[\dfrac{Y_0+L_y}{b}\right]=2k \\ b-b\cdot\left\{\dfrac{Y_0+L_y}{b}\right\},\left[\dfrac{Y_0+L_y}{b}\right]=2k+1 \end{cases}$$

It is very interesting that we get fraction parts in these formulas, because there is the formula that is generating accidental numbers.

$$a_{n+1}=\{a_n k\},\quad a_n\in(0;1),k>1$$

It gives us numbers and probability that it will give us some number is similar for all numbers and this like our definition of chaos. So our ball's final coordinates are chaotic. But we must add one inequality which u can see here. It is because that if we had no collisions with balls than we will have distribution like this on picture and it's not chaotic. So after solving this inequality we will get final answer: To get finally after stopping of the balls chaotic distribution on the table we must impact 16th ball with velocity not less than 17 m/s.

$$\left.\begin{matrix} L_x>a \\ L_y>b \end{matrix}\right\}\Rightarrow L>\sqrt{a^2+b^2}\Rightarrow \qquad V>17\ \text{m/s}$$

Now lets consider more exact model of the Billiard. This model is with the help of the computer. The final answer that this model will give us is the velocity of the first impact, angle by which was made this impact. Idealizations of this model are not too serious but I must say about them.

1) The friction force is constant and we have only rolling friction.
2) All collisions are absolutely elastic and central.
3) Balls are moving only by straight lines and we have no jumps.

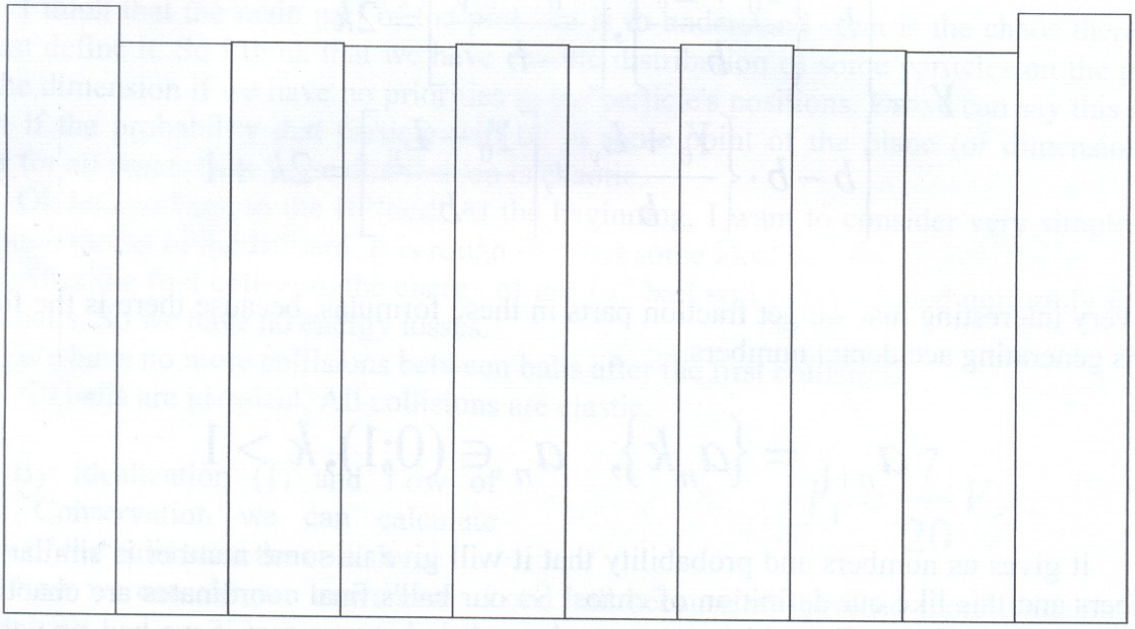
Now lets talk about model and what is doing computer. Computer "knows" initial distribution of the balls (pic.1). We must input angle and velocity of 16th ball and then it will follow each ball movement. Computer is calculating balls position every 0.00001-sec. and I think this is good exactness. So computer "knows" each ball position at any moment of the time.

Now lets go back to the chaos definition. We define chaos for the plane. Yes our Billiard table is a plane, but it is not infinity it has borders. Therefore, these borders must take effect and we must understand what is a real chaos for the Billiard table. For this computer removes friction (to watch balls motion for a long time) and shoots 16th ball with any velocity

and angle. Then after every $\Delta t=0.1$ sec. time it divides the table on the 10×10 cell and looks how many balls are there in each cell, remembers this number.

Computer makes those calculations 400000 times and adds all 400000 tables to each other. I think is sufficient big statistic. Well finally we will get 10×10 table which shows us distribution of the balls during approximately 22 hour of balls moving. Here you can see the histogram of this distribution in 2-D view.

Function of chaotic distribution



I want to say that if in the future I will get that distribution on the table than I'll say that this distribution is chaotic.

To prove this definition I can say that when this distribution is established it is not changing any more.

How you can see from the histogram, balls are more often near the walls than in the other parts of the table. This is very interesting and I think it's because we have more collisions near the walls then in other parts, because here we have not only collisions between balls we have also collisions with the walls.

Well now lets go back to the model. After definition of the chaos computer returns friction to the model and begins loop.

Loop:

1) Get angle in the range $\alpha \in [o; 90)$
2) Get velocity in the range $V \in (0; +\infty)$
3) Shoot the 16^{th} ball with taken velocity and angle.
4) After stopping all balls computer divides table 10×10, then creates table of numbers and writes in this table of numbers how many ball is in each cell of Billiard table.
5) Compare table of numbers with table of chaotic distribution and if these two tables are similar then last distribution is chaotic and computer remembers this velocity and angle and makes everything again for next angle. Back to (1)
   Else if they are not similar computer changes only velocity. Back to (2)
6) Finding minimal velocity from list of all velocities that gave us chaos.

So after this loop we will get a final answer. But at first I want to talk about comparing. Computer makes this comparing by method X^2 (Greek). X^2-is a number and for table 10×10 it must be less than 35 after comparing and in this case we must say that two compared tables are similar with exactness 99%.

Principally by one picture we can not say is it chaotic or no. Therefore for each angle and velocity computer gets $\alpha \pm 1\%\alpha$, $V \pm 1\%V$ regions and makes experiments 10000 times in this range. Then it adds these 10000 tables and compares it with the table of chaotic distribution.

Well it's time to say about final answer on the problem. After all these experiments we got next answer:

Final Results:

$V \approx 10$ m/s $\quad \alpha \approx 2^{\circ} \quad t \approx 7.5$ s

14. WEAT WAVES

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If wind blows an obstacle around it appear vortices. These vortices make wave-like structure. Because one comb behaves as an obstacle appear next vortex which flows on a surface of and makes depth area. (see pictures)

With certain amplitude stabile waves are large ones, because force acting on the wave from wind is proportional to A/λ, where A is amplitude and λ - wavelength. If the force is big the wave is not stabile. For decreasing of above force wavelength must be increased

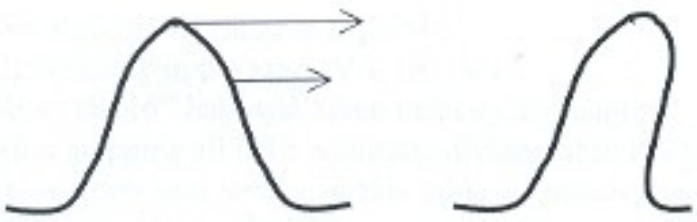
Self organization mechanism

Self organization means that with different elasticity, masses and nonlinear distribution of concentration different wavelengths appear, but the system as a whole one behaves as a large wave. In this case appear areas with high density, which means that spikes are put on each other. This area behaves as a wall and it cuts waves because of which overtones take place.

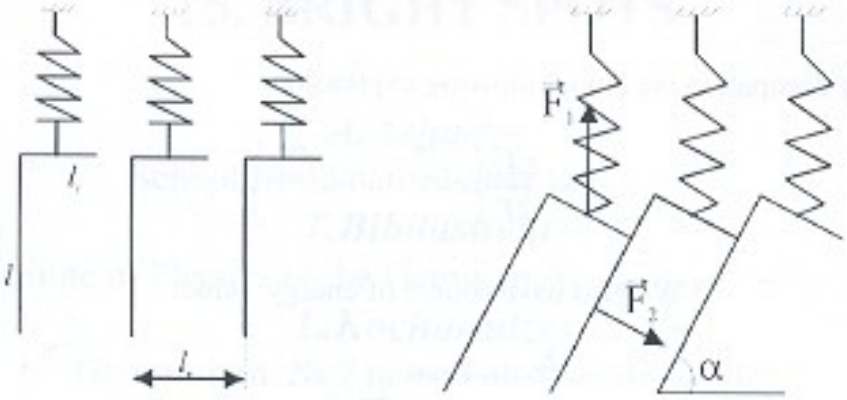
Fourier component of amplitude is following:

$$A(\omega)\sim 1/\omega^2$$

it means that: λ is large.



Theoretical model



We characterize elasticity of spike by spring with elasticity k and this spring is deformed vertically. l_1 is initial deformation of spike caused by own mass. α is angle with which we have correlation among spikes. so we have correlated system were the wave can propagate.

F_1 is force caused by deformation and F_2 is force caused by wind.

$$F_1 = kA \qquad F_2 = \frac{1}{2}\rho S V^2 \sin 2\alpha \qquad A = \frac{(l_0 - l_1)}{l_0} l,$$

were F_1 is force caused by deformation, F_2 is force caused by wind, ρ is density of air, S – square of spike and V – velocity of wind.

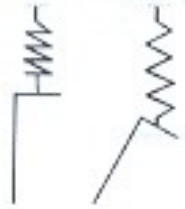
$$l_0 \sim 0.1\ \text{m}$$

$$l \sim 1\ \text{m} \qquad l_1 \sim 0.06\ \text{m} \qquad \sin\alpha = \frac{l}{l_0}$$

$$k \sim 10^{-1}\ \text{N/m}$$

$$F_1 = F_2 \Rightarrow \quad V \sim 3\ \text{m/s}$$

We write down equation of force balance and get result the minimal velocity of wind after which the wave propagates.



$$F_1 = -kx$$
$$F_2 = -\eta l V_x$$

Because of air friction spike looses its energy. Friction is caused by viscosity, F_2 is expression of a viscosity force and F_1 – elasticity one along vertical axe where η is an air viscosity.

Solution of spike motion equation gives us expression of amplitude fading:

$$A = A_0 e^{-\frac{\eta l}{m}t}$$

For energy dissipation we have following expression:

$$\overline{P_1} = \frac{kA^2}{2T}\left(e^{\frac{-2\eta l}{m}(t+T)} - e^{\frac{2\eta l}{m}t}\right)$$

We also have source of energy: wind.

Expression for force coming from wind action on the wave is following:

$$F = 4\gamma\rho(U-C)^2 s\frac{A}{\lambda}\pi^2 \qquad C = \frac{\omega}{\sqrt{n}}$$

$$P_2 = FV \qquad \omega = \sqrt{\frac{k}{m}}$$

$$V = \frac{AC}{\lambda}$$

where C is wave velocity, U – a wind one, n – spike concentration, λ - wavelength and A amplitude.

If we write down the balance equation for all energies we will get the wavelength expression:

$$\left|\overline{P_2}\right| = nS\left|P_1\right| \Rightarrow \lambda = (U-C)\frac{2\pi}{\omega}\sqrt{\frac{\gamma\rho C}{n\eta l}}$$

$$\eta \sim 10^{-5}\text{Pa s} \quad m \sim 10^{-3}\text{kg} \quad \rho \sim 1\text{kg/m}^3$$

15. BRIGHT SPOTS

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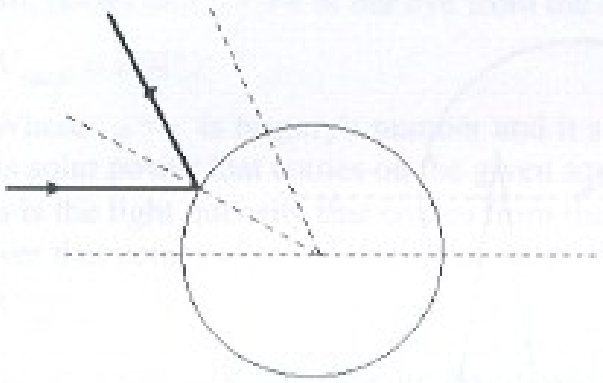
Let us start with the definition of dewdrops:

Dewdrops are little water drops, in which surface tension force is much more than the gravity force and we can consider it as the dominant force applied to the drops. By its influence dewdrop takes the sphere shape, so we will solve the problem for the sphere drops.

At first let us consider the case of direct reflection. A dewdrop is shown on the picture 1, on which a sunbeam falls by an φ angle. In this case our eye is located by the angle θ=2φ and we see the direct reflection spot.

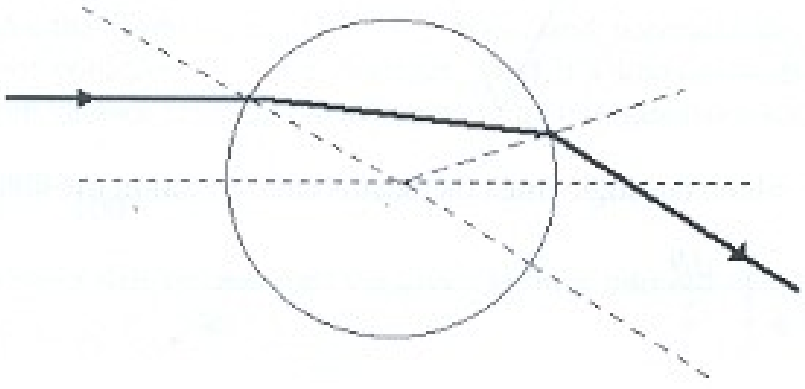
Pic. 1



$$\vartheta(\phi) = 2\phi$$
$$\alpha(\phi) = \phi$$

Now let us talk more generally about other spots. Let us consider the case when the sunbeam enters the drop by the angle φ, is refracted by the angle β and leaves the drop by the angle α. In this case our eye is situated by the angle θ and we see the bright spot (see picture 2).

Pic. 2



If we write refraction rule, from the picture we can see that it is easy to find θ angle:

$$\vartheta(\phi) = 2\phi + \left(\pi - 2\arcsin\left(\frac{\sin\phi}{n}\right)\right)N$$

Where (N-1) is the internal reflection number and n is the refraction coefficient (in our case it approximately equals to 4/3).

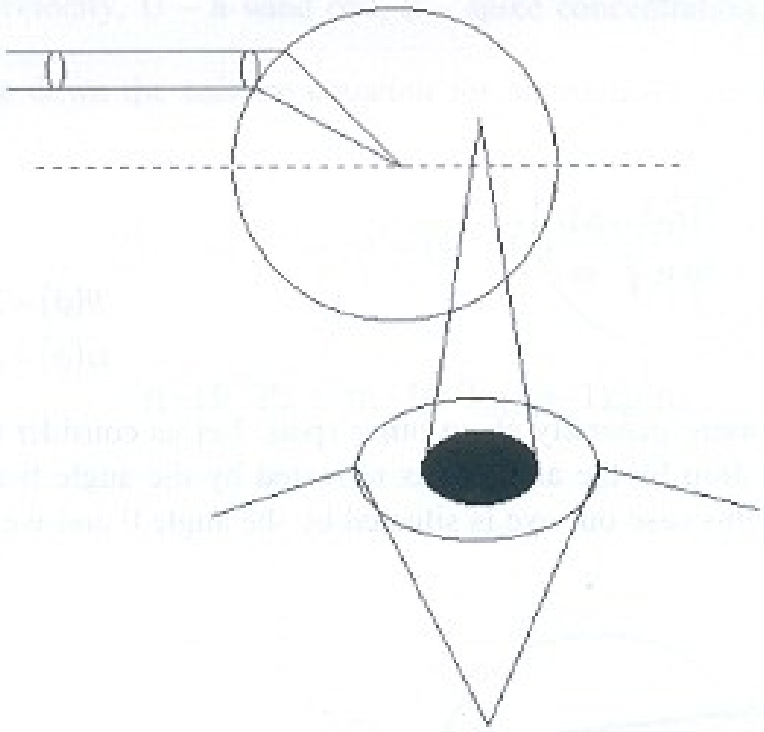
As the problem is about spots' location, so it is important to find α angle. It is clear from the picture that in the case of absence of internal reflections we have $\alpha=0-\varphi$, but the refraction may take place also in points of internal reflection. In this case as we count angle α from horizontal axis, then we will have:

$$\alpha(\phi) = 2\pi\left\{\frac{\phi + \left(\pi - 2\arcsin\left(\frac{\sin\phi}{n}\right)\right)N}{2\pi}\right\}$$

Now let us consider the case, when the bunch of beams with the cross section ΔS falls on the dewdrop. We can define ΔS by the following way: $\Delta S \approx \frac{\pi}{4}(r\cos\phi d\phi)^2$

The bunch enters by the angle φ and an eye sees spots in the angle $d\theta=d_{eye}/L$, where d_{eye} is diameter of eye and L is distance from dewdrop to observer (see picture 3).

Pic. 3



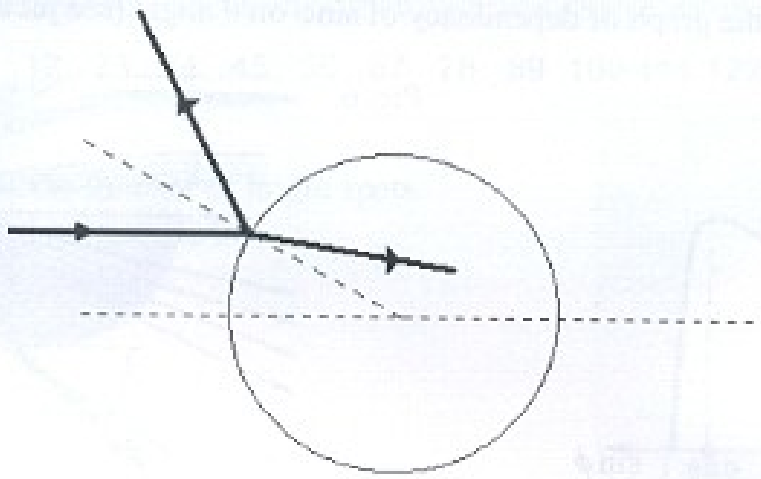
We need to know by which dφ angle must the beams enter to fall in the dθ angle:

$$d\phi = \left(1 - \frac{N\cos\phi}{\sqrt{n^2 - \sin^2\phi}}\right)^{-1}\frac{d\vartheta}{2}$$

Now let us talk about power that comes in our eye:
Picture 4 shows the sunbeam that is reflected from the dewdrop and refracted inside it. The coefficient of reflection is expressed by following formula:

$$R = \frac{1}{2}\left(\frac{\sin^2(\phi-\beta)}{\sin^2(\phi+\beta)} + \frac{tg^2(\phi-\beta)}{tg^2(\phi+\beta)}\right)$$

Pic. 4



So, power that comes in our eye from the direct reflection is equal to:

$$W_{eye,0} = RW_0 e^{-\alpha l}$$

Where $e^{-\alpha l}$ is Napery's number and it shows how the medium absorbs the light and W_0 is solar power that comes on the given square on earth equals to $W_0 = \omega\Delta S$
Where ω is the light intensity that comes from the sun.
And power that comes after (N-1) internal reflection equals to:

$$W_{eye,N} = R^{N-1}(1-R)^2 W_0 e^{-\alpha l}$$

Below some literature data are given, which are important in our case:

$$d_{eye} \approx 0{,}5 \text{ sm.} \quad S_{eye} = \frac{\pi}{4} d_{eye}^2 \quad \omega = 0{,}139 \text{ w/sm}^2$$

It's known that an eye sees the light if the power that comes from the object (in our case dewdrop) is 1,5% or more of the power that comes from the surface on which the object is located.

As the problem is about dewdrops, and naturally dewdrops are on the grass or plants, we considered a green surface. And it's known from literature, that per unit of time green surface reflects 7% of intensity that comes from sun, so:

$$\omega_G \approx \frac{7}{100}\omega$$

Power that comes from the green surface into our eye, equals to:

$$W_G = \omega_G S_{eye} e^{-\alpha l}$$

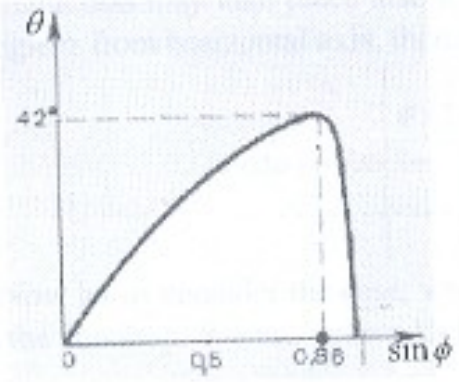
So if the following equation is correct, then we will see the spot:

$$\frac{W_{отр.}}{W_0} > 1{,}5\%$$

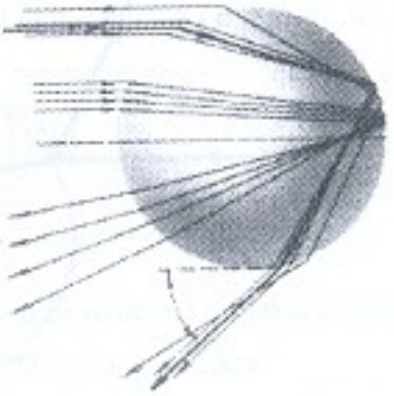
Now let us talk about the kind of spots we are able to see on the dewdrop: it can be direct reflection spots, spots produced by the way shown on picture 3, or spots produced in the extreme point, where sunbeams leave the spot.

We have constructed the graph of dependency of sinφ on θ angle (see picture 5).

Pic. 5



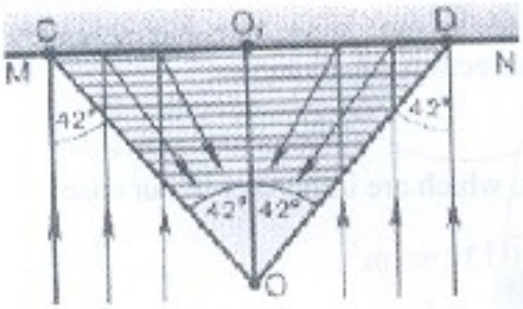
Pic. 6



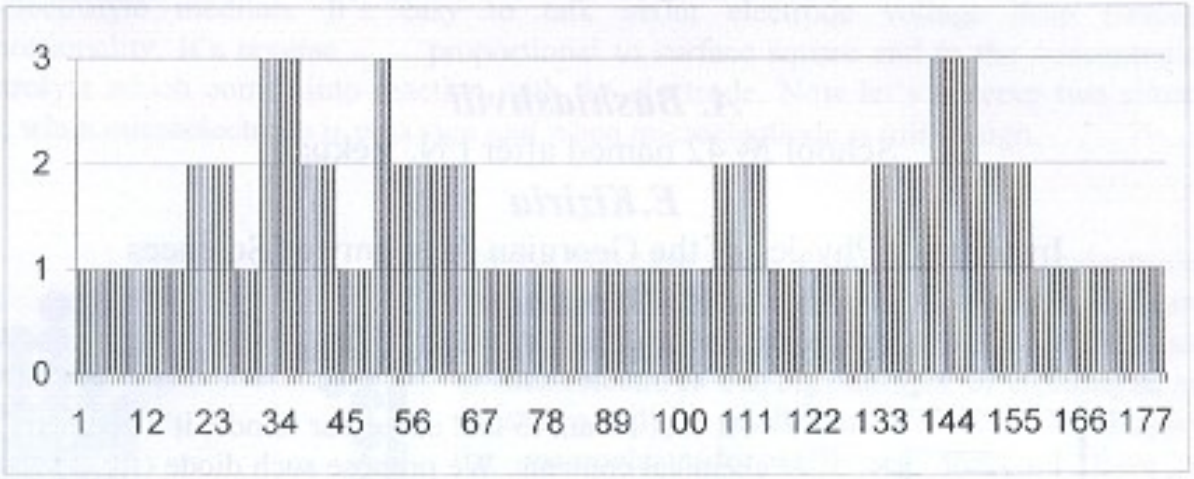
Picture 6 shows the spot produced in the extreme point.

If there are several drops located on the surface we will see the picture something like rainbow. On picture 7 several drops are located on the MN surface, observer is in the point O and he sees the picture on the CD distance. Most intensively he sees the spots located near D and C points.

Pic.7



We have mainly investigated the phenomenon with one dewdrop and wrote a computer program. We give the computer the value of θ angle and it draws all the possible spots that are on the drop when we observe it at the given angle. Below is given the table of dependence of θ angle (θ is from 1° to 90°) on number of spots (there are given all possible spots):



Vertical axis: number of bright spots.
Horizontal axis: angle θ.

16. LIQUID DIODE

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Z. Osmanov
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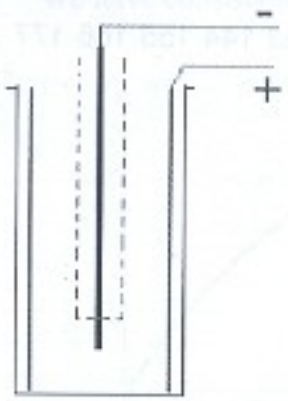


Fig. 1.

At first I want to talk about our diode, it's geometry, and chemical contents. We propose such diode (fig. 1) : vessel with two electrodes put in: one with a big surface square (macroelectrode) and another with a small surface (microelectrode). In the vessel is poured tricky electrolyte which is a mixture of two another electrolytes, they can be:
Ferrocyanide – ferricyanide ,
Kaliumiodum – iodum.

Chemical processes running in the electrolyte:

Ferrocyanide – Ferricyanide:

$$K_4Fe(CN)_6 \xrightarrow{H_2O} 4K^+ + Fe(CN)_6^{4-}$$

$$K_3Fe(CN)_6 \xrightarrow{H_2O} 3K^+ + Fe(CN)_6^{3-}$$

Kaliumiodum - Iodum

$$KI \rightarrow K^+ + I^-$$

$$I^- + I_2 \rightarrow I_3^-$$

When we put voltage on electrodes these processes on the cathode(K) and anode(A) begin:

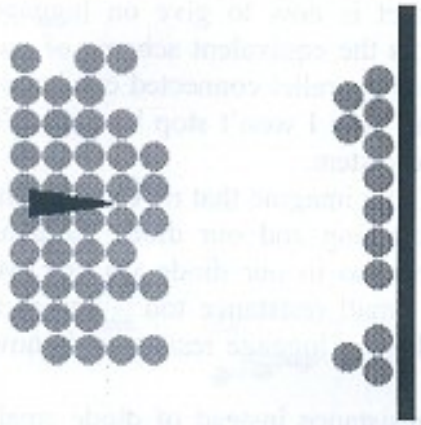
$$K: \quad Fe(CN)_6^{3-} + 1e \rightarrow Fe(CN)_6^{4-}$$

$$I_3^- + 2e \rightarrow 3I^-$$

$$A: \quad Fe(CN)_6^{4-} - 1e \rightarrow Fe(CN)_6^{3-}$$

$$2I^- - 2e \rightarrow I_2$$

Now I'll try to explain why this system poses diode properties. To do this let's understand that voltage drop on the diode consists of voltage drop on microelectrode, macroelectrode and in electrolyte medium. It's easy to talk about electrode voltage drop (resistance) proportionality. It's reverse proportional to surface square and to the concentration of electrolyte which comes into reaction with the electrode. Now let's observe two situations: first, when microelectrode is plus sign and when microelectrode is minus sign.



In the first case (fig. 2) plus sign at microelectrode) we have due to chemical reactions big amount of electrolyte (ferrocyanide or kaliumiodum), so we have small surface of microelectrode but big amount of electrolyte, so the resistance will be small. And if we observe situation on the macroelectrode we'll see that we have small concentration but big surface – voltage drop won't be big here too. And as a result we have good conductivity of our system.

Fig. 2.

Now in second case (fig. 3) on the macro electrode we have small voltage drop but on the microelectrode with the small surface square we have very small concentration of electrolyte, and voltage drop is very big. The system has bad conductivity now.

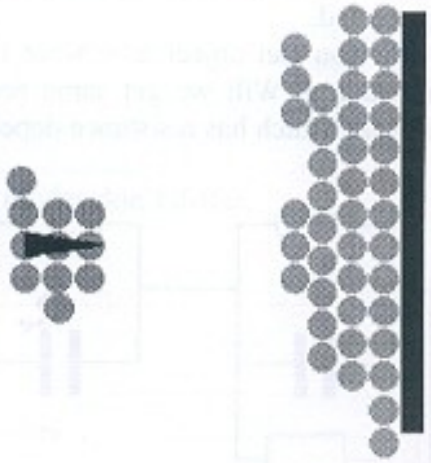
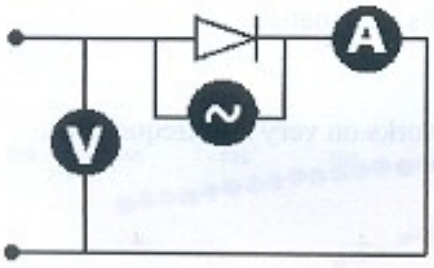


Fig. 3.

Two following schemes we used to take diode's voltamperic characteristics and frequency characteristics:



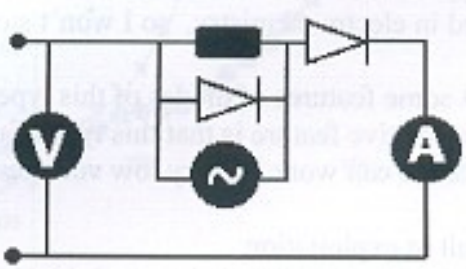


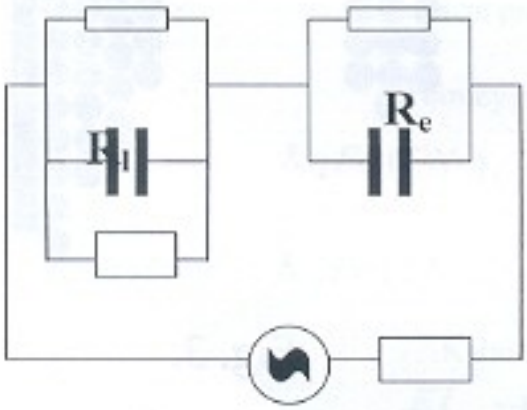
Fig. 4.One diode testing circuit. **Fig. 5.Two-diode system testing circuit.**

You can see that we used also circuit where are two electrochemical diodes used with resistance. Role of this scheme is to extend frequency characteristics of our diode. So whole system constructed from two diodes and resistance we will call diode.

In many electrochemical systems there is such a phenomenon like reverse current, and our system can operate in such a way too (when we give on electrodes alternative current), and one of purposes we use this scheme is to suppress this current. Our resistance is luggage resistance which can be – so commonly in radiotechnicks are called headphones, speakers, devices on which we take modified signal. And our target is now to give on luggage resistance cut in diode-like style signal. Here on the fig. 6 is the equivalent scheme of our two-diode system. You can see that we replaced each diode by parallel connected condenser and resistance, on explanation why we replaced diode in this way I won't stop because it's easy to understand it. Now I'll go to explanation of two-diode system.

As I said the main purpose is to suppress reverse current. Let's imagine that reverse current appeared - what happens? This current is effectively alternating and our diode contains condenser which has small resistance for alternating current, so in our diode we get two resistance parallel connected and this connection produces small resistance too – and as a result the main part of the current will go through the diode, our luggage resistance is now protected.

But you can object now what if we connect to luggage resistance instead of diode small resistance? Will we get same result? No, it's because we need nonlinear elements in our scheme which has resistance dependent on voltage.



Now let's estimate order of resistance and capacity of diode. So, taking experimental results: Voltages on one diode and resistor R_e on the two different frequencies, we can get system of N equations with N variables and find values for R and C order:

$$R \sim 100k\Omega$$

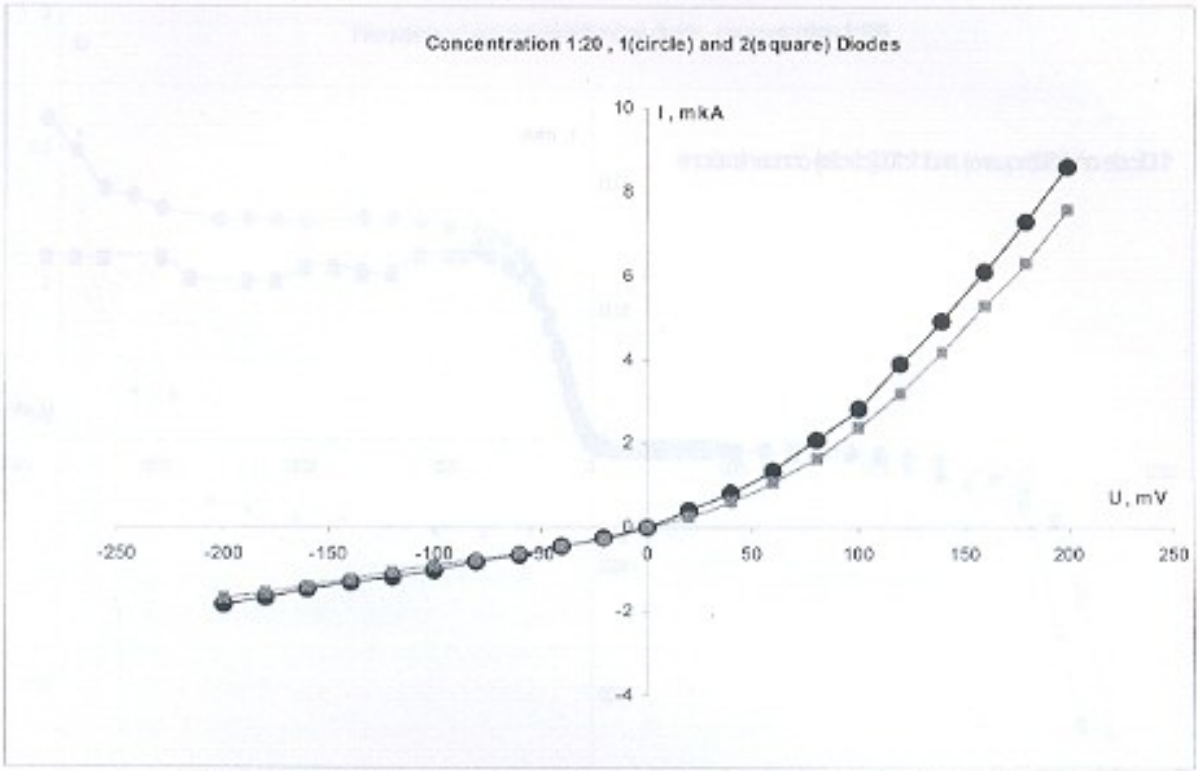
$$C \sim 0.1\mu\Phi$$ Fig. 6.

So, I want to clarify one moment in this problem – why this diode poses capacity. This capacity appears because of existence of double electron layer near the electrodes. This layer is explained in electrochemistry, so I won't stop on it's explanation.

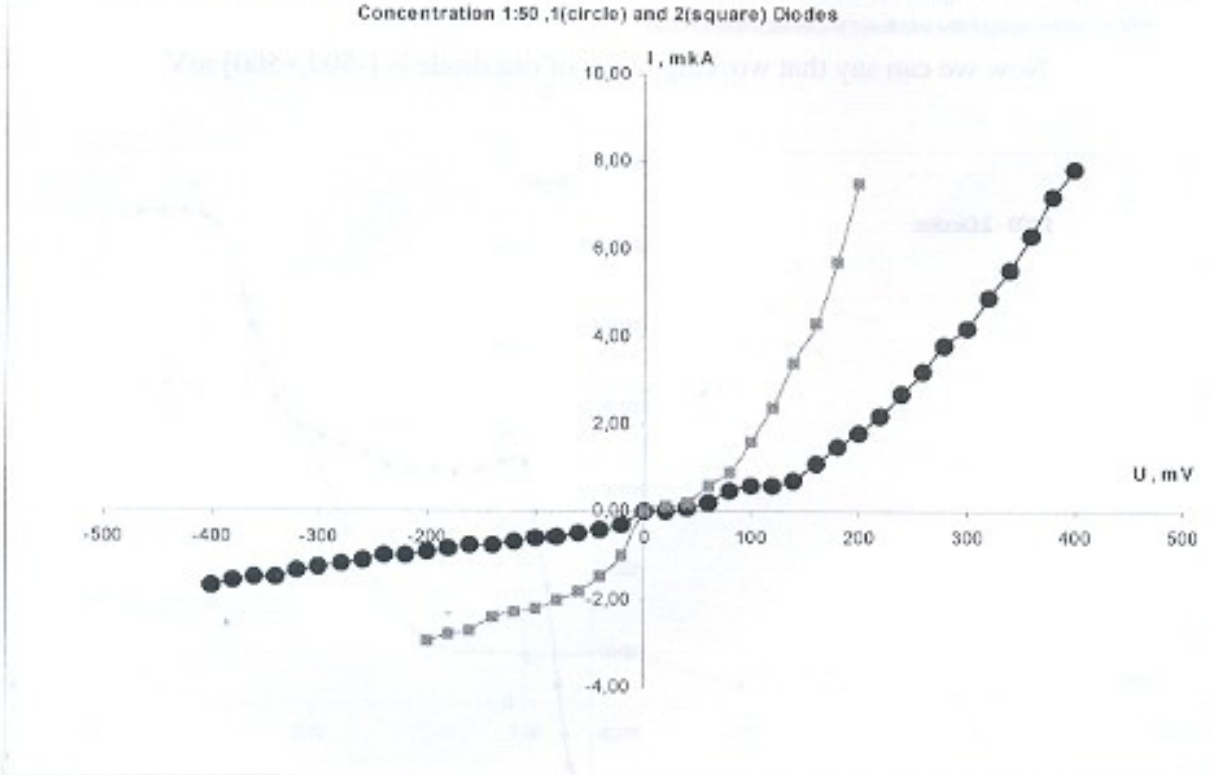
Now about some features of diodes of this type.
One of the positive feature is that this type of diode works on very low frequencies.
Also this diode can work on very low voltages.
But…
It's difficult in exploitation.
It's very sensitive to external electric field, shaking.
And it can't work on high frequencies (higher then ~20kHz).

Now when well prepared in theory let's go directly to experimental data.

Following two graphs made for stainless steel electrodes:

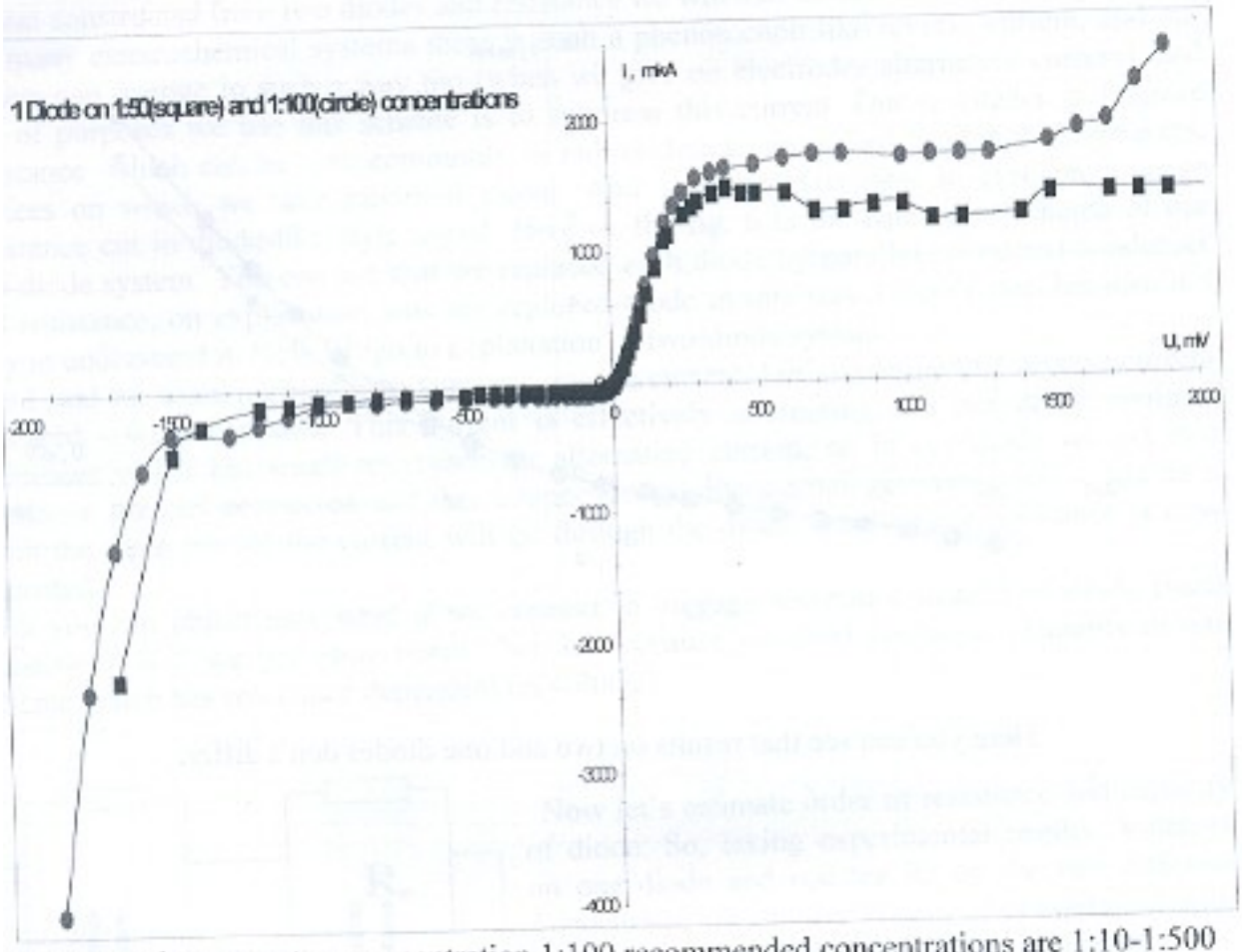


Here you can see that results on two and one diodes don't differ.



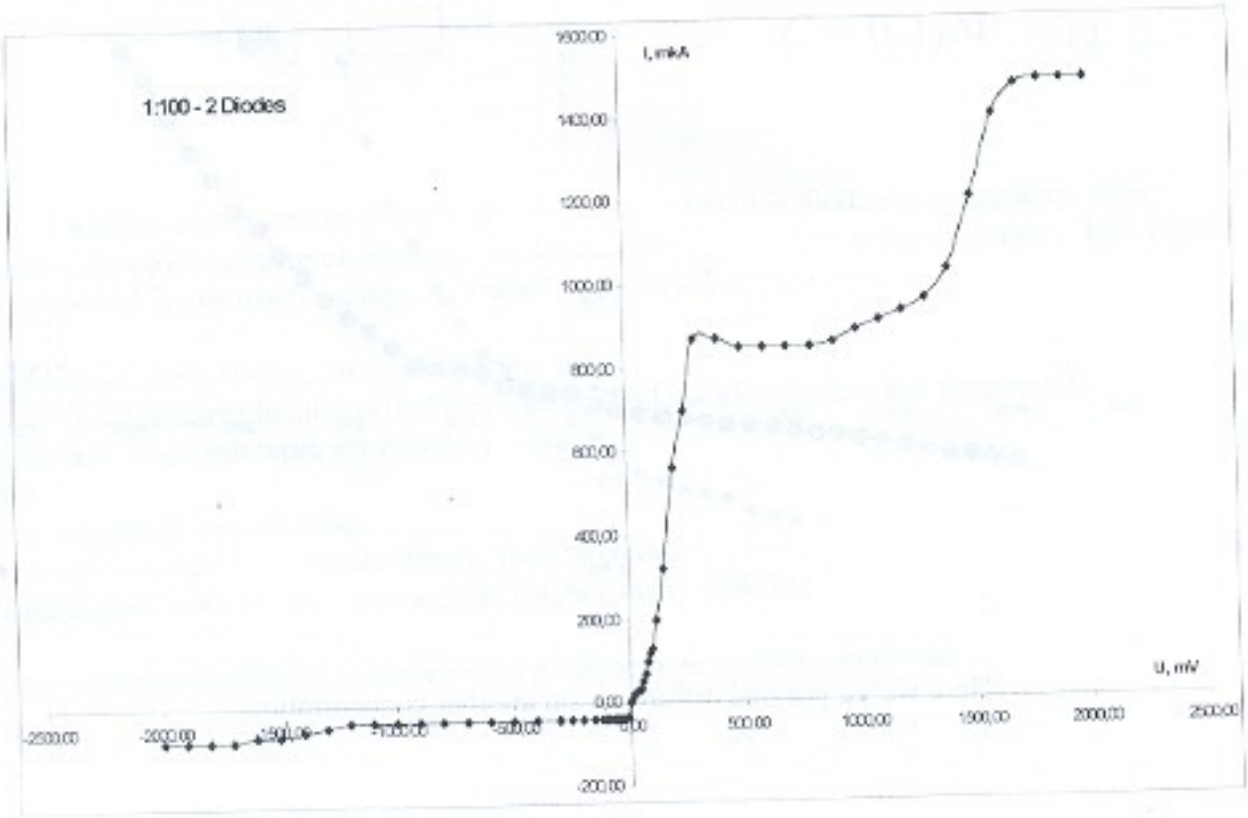
Here we've got real difference on another concentration.

Another data – we used platinum electrodes and got better results.

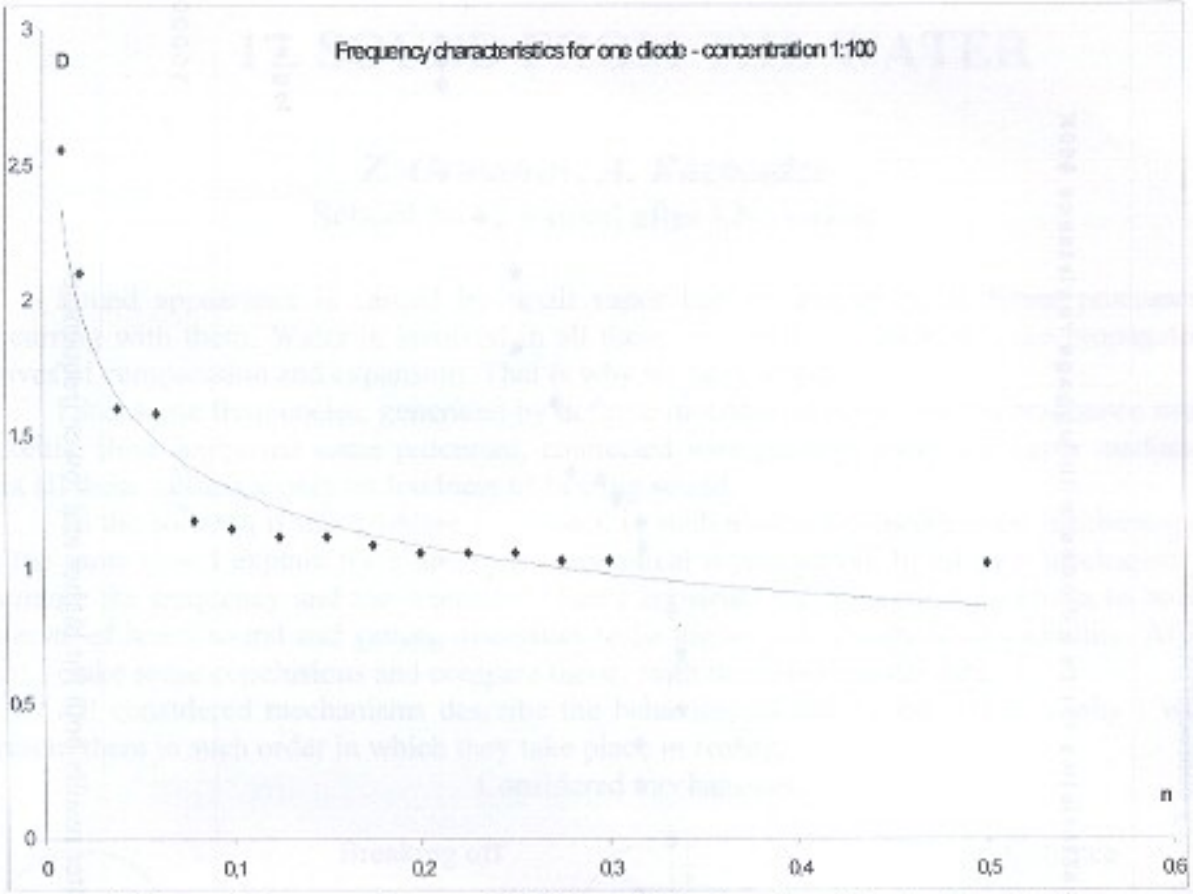


Better result were got on concentration 1:100,recommended concentrations are 1:10-1:500

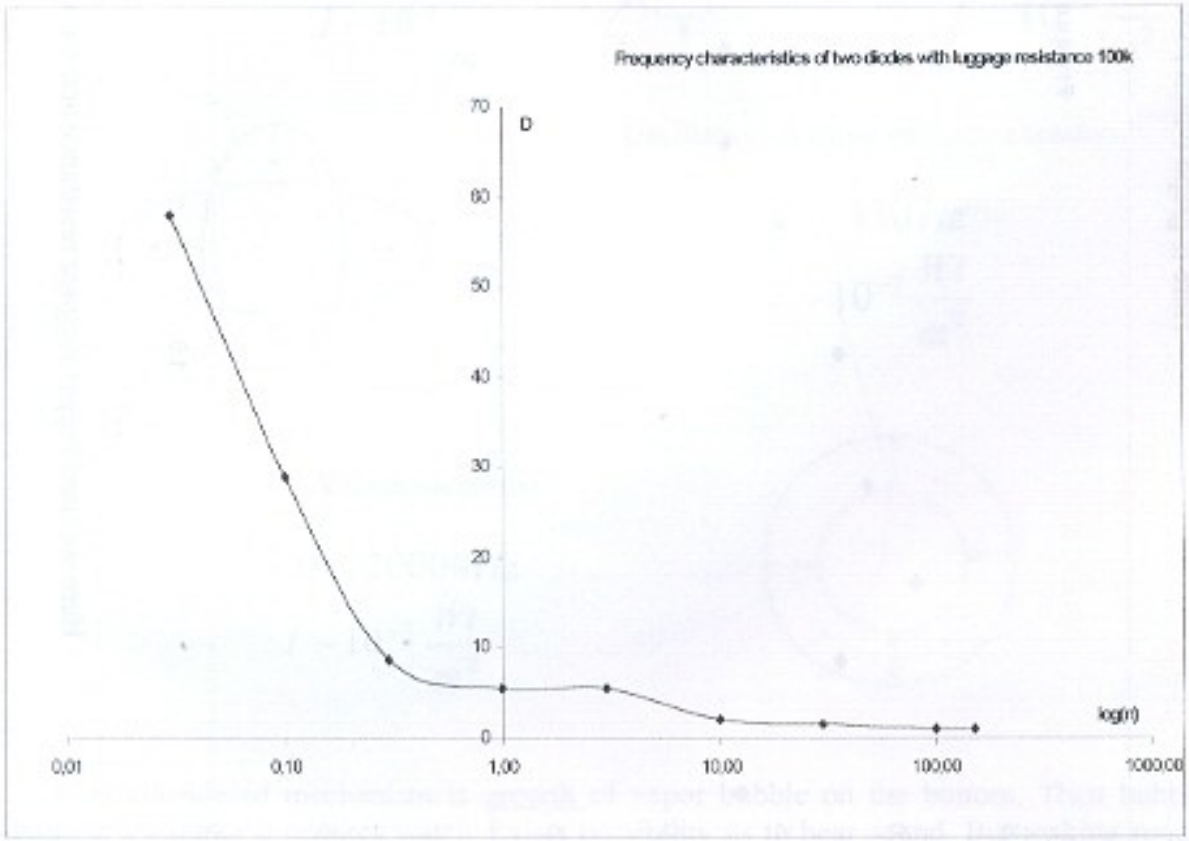
Now we can say that working range of our diode is [-500,+500] mV



Here are frequency characteristics.

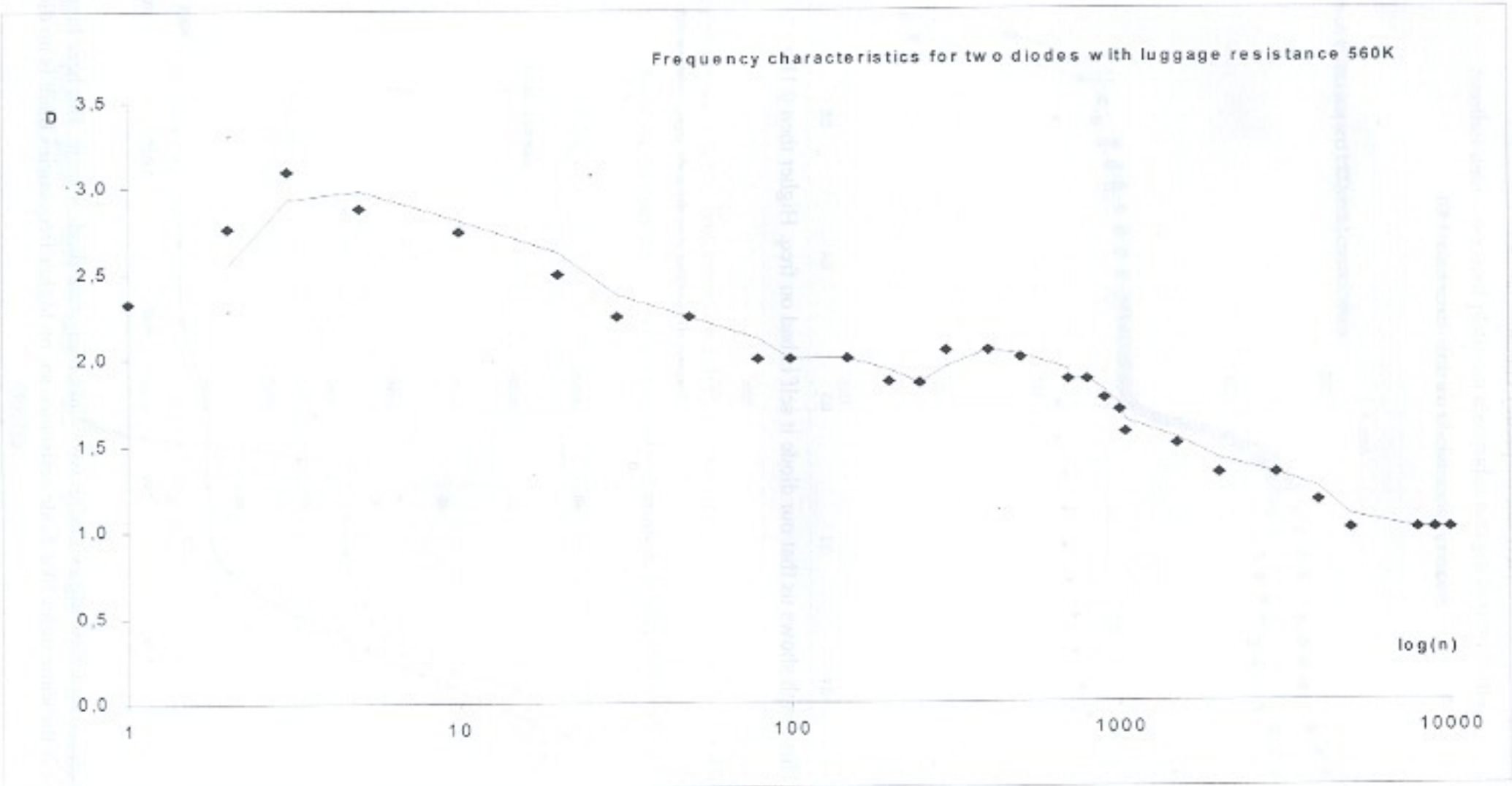


This graph shows us that our diode it self is bad on freq. Higher then 0.1Hz



Here we can see now how big extension we've got using two-diode system. But here luggage resistance is the same order like diode resistance so, on higher frequencies there is no diode effect.

Here is graph which shows us frequency characteristics for



Here we used bigger luggage resistance and we've got better results both for higher and lower frequencies

17. SOUND FROM THE WATER

Z. Osmanov, A. Razmadze
School № 42 named after I.N. Vekua

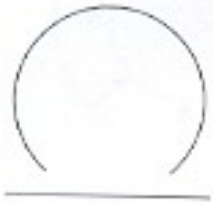
Sound appearance is caused by small vapor bubble, exactly by different processes, occurring with them. Water is involved in all these processes. In cause of it are propagated waves of compression and expansion. That is why we hear sound.

Later some frequencies, generated by definite mechanism come into the resonance with a kettle, there happened some processes, connected with passage throw the vapor medium. But all these influence only on loudness of hearing sound.

To the solution if this problem I approach in such a way: I consider some mechanisms, at the same time I explain them and make theoretical investigation. In all each mechanism I estimate the frequency and the intensity. Then I construct the theoretical spectrum to be in interval of heard sound and getting intensities to be higher then threshold of audibility. After that I make some conclusions and compare theory with the experimental data.

All considered mechanisms describe the behaviors of one bubble. That is why I will present them in such order in which they take place in reality.

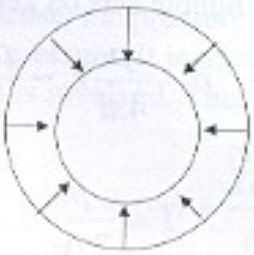
Considered mechanisms:



Breaking off

$\nu \sim 100 Hz$

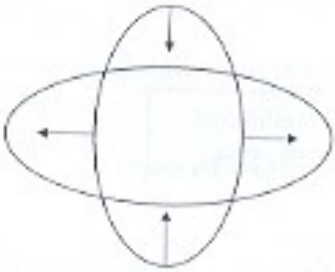
$I \sim 10^{-8} \frac{Wt}{m^2}$



Collapce

$\nu \sim 1800 Hz$

$I \sim 10^{-5} \frac{Wt}{m^2}$



Oscillation in cause of surface tension

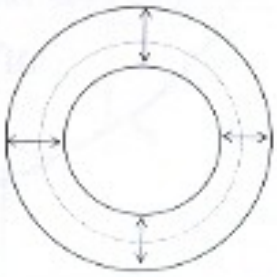
$\nu \sim 350 Hz$

$I \sim 10^{-7} \frac{Wt}{m^2}$

Volum oscilation

$\nu \sim 20000 Hz$

$I \sim 10^{-7} \frac{Wt}{m^2}$



First considered mechanism is growth of vapor bubble on the bottom. Then bubble changes it's volume it occures water. Exists possibility us to hear sound. But making rough

estimation we got $\nu \sim 10^6\, Hz$. Such sound does not lies over hearing range. That is why it is not interesting to discuss this mechanism here.

The next mechanism is bubbles breaking off. When bubble reaches such a size that Archimed force balances the surface tention force bubble begans to break off. In this moment the resistance force begins to act on it. Here we wright Newton's II law:

$$M_0 a = F_A - M_0 g - M_{AB} a - F_\sigma$$

All the forces except Arkhimed and Resistance forces are negligible small. From this we can get the acceleration:

$$a \approx \frac{F_A}{M_{AD}} = 2g$$

During breaking off bubble moves on a distance which is equal to bubble's radius.

$$r = \frac{at^2}{2}$$

The frequency of generated sound is equal to the order of

$$\nu \sim \frac{1}{t} \sim \sqrt{\frac{g}{r}} \sim 100 Hz,$$

t is character time. (in this case time of breaking off.)

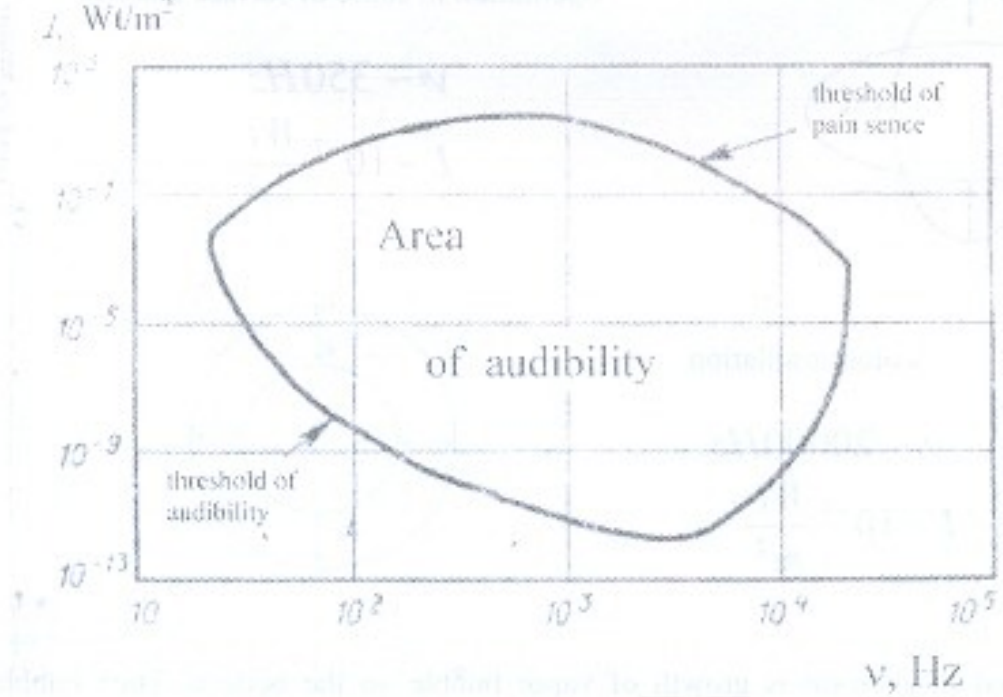
The pressure, with which bubble acts on kettle, is following:

$$p \sim \frac{\rho}{4\pi l}\ddot{V} \sim \frac{\rho r^3}{3l}\nu^2$$

For intensity we will have:

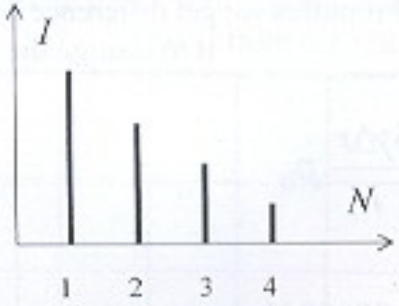
$$I \approx \frac{p}{2\rho c} \sim 10^{-8}\,\frac{Wt}{m^2}$$

When we compare this with threshold of audibility it is clear that we will not hear the sound



of one bubble. But in the kettle several bubbles are breaking off at the same time. That's why it is possible that we will hear them.

After that we use that character of generating sound is not sinusoidal. We decompose given signal into Furies sum. Besides the main sound with frequency ν we will hear sound with frequencies which differ in whole number but with low intensities. Using ready result, taking into account that $I \sim A^2$, we have that n-number harmonic differs from initial at $\frac{1}{n^2}$ times.



The next mechanism that I consider is the collapse of the bubble. After the bubble will break off the bottom it will raise up to the colder layers. Vapor inside it will begin to condense, the pressure will decrease and it will not compensate outside pressure. It is obvious that by the collapse the definite waters mass is involved. This pressure acts on vapoour bubble is:

$$p_0 + \rho g h + \frac{2\sigma}{r} \approx p_0$$

We write Newton's II law for small waters mass Δm :

$$\Delta m a \sim \Delta F$$

I calculate mass Δm and force ΔF .

$$\Delta m \sim R^3 \rho$$

It's mass of water layer , which moves together with bubble

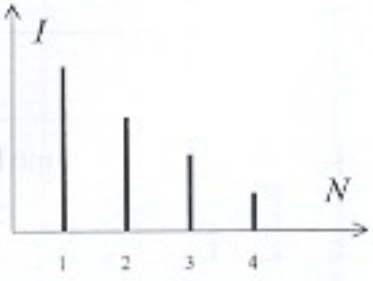
$$\Delta F = \Delta p R^2$$

In the expression for ΔF Δp is the pressure's difference on which decreases pressure inside the bubble by decreasing temperature on 1° C. After that I estimate frequency.

$$\Delta p = p_{100} - p_{99} \approx 10^3 \, Pa$$

Then frequency is following:

$$\nu \sim \frac{1}{r}\sqrt{\frac{\Delta p}{\rho}} \sim 1800 Hz$$

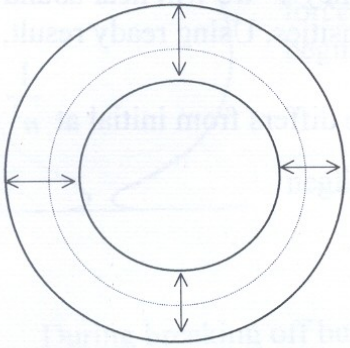


Intensity is:

$$I \sim 10^{-5} \frac{Wt}{m^2}$$

Now let us consider mechanism of volume oscillations. Let us assume that our bubble got into the sound wave. In cause of this it changed its volume. During this it creates sound itself too.

$$\Delta ma \sim \Delta F$$

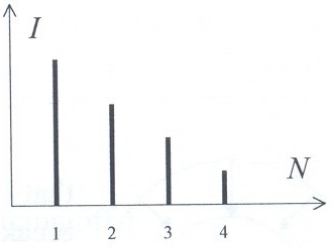


We consider this process adiobatic in cause it occures fastly. That is why we write adiobats equestion.

$$p\left(\frac{4\pi r^3}{3}\right)^{\gamma} = p'\left(\frac{4\pi}{3}(r-\Delta r)^3\right)^{\gamma}$$

From this we get difference between pressures that makes it to change the volume.

$$\Delta p = p' - p \approx \frac{3\gamma\Delta r}{r} p_0$$



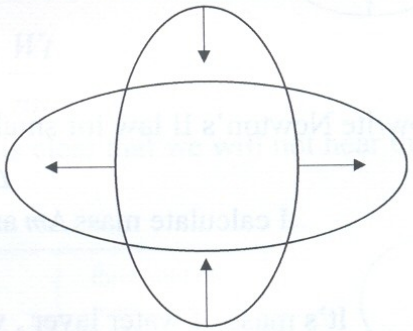
The frequency is following:

$$\nu \sim \frac{1}{r}\sqrt{\frac{3\gamma p_0}{\rho}} \sim 20000 Hz$$

The intensity is:

$$I \sim 10^{-4} \frac{Wt}{m^2}$$

The next mechanism is volumes oscillations in cause of surface tension. Such oscillations cough be caused by breaking off.



$$\Delta ma = \Delta F$$

Here the Laplass pressure plays role of returning pressure.

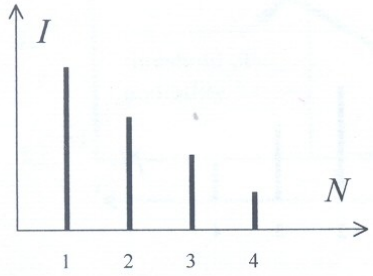
$$\frac{2\sigma}{r} dS \sim a\Delta r R^2 \rho$$

Frequency of this mechanism is:

$$\nu \sim \sqrt{\frac{\sigma}{R^3\rho}} \sim 350 Hz$$

The intensity is:

$$I \sim 10^{-7} \frac{Wt}{m^2}$$



The both lust processes occure in reality in the same time but for simplier I devided them.

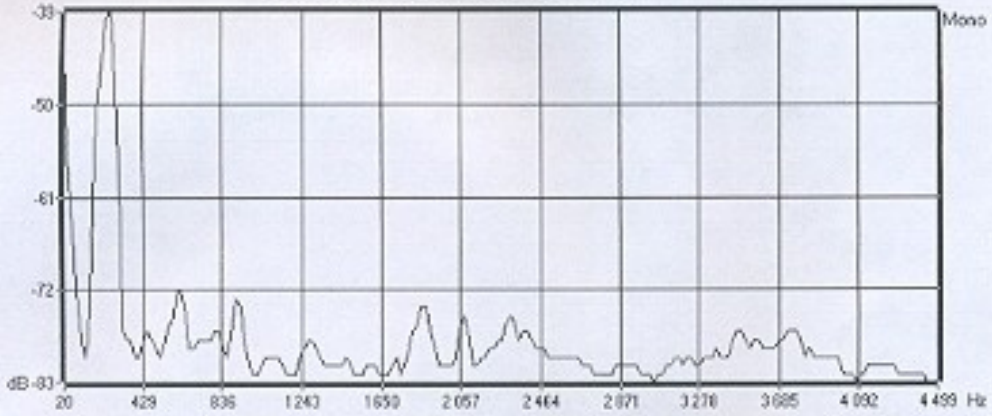
Now let us understand what mechanism plays first role. First mechanism has quit low frequensy and intensity. In two lust mechanisms take place volume oscillations by order equal to radius. That means that our bubble can collapse essidentaly. The main mechanism is collapse. Its frequensy is by order equal to 1000 Hz and how we know our ear is more sensetive to sounds with such frequensies. So it selects this sound too.

Let us speak about experimental part. How we see from it the audibilitable interval is in first quadrant. Other sounds we hear worstly. So how we can see such rough and simply theory can describe difficult processes.

We made some experiments with different water's heights in kettle. We recorded kettles natural frequency and got some peaks with correspondent frequencies.

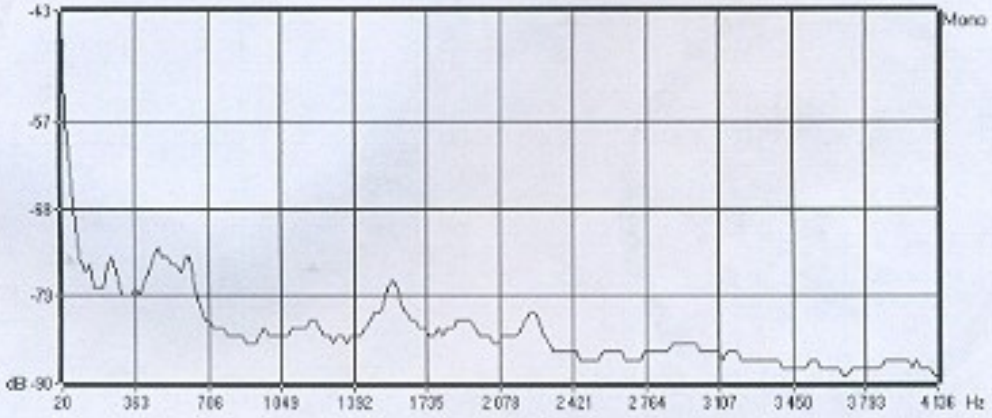
Sound from the water:

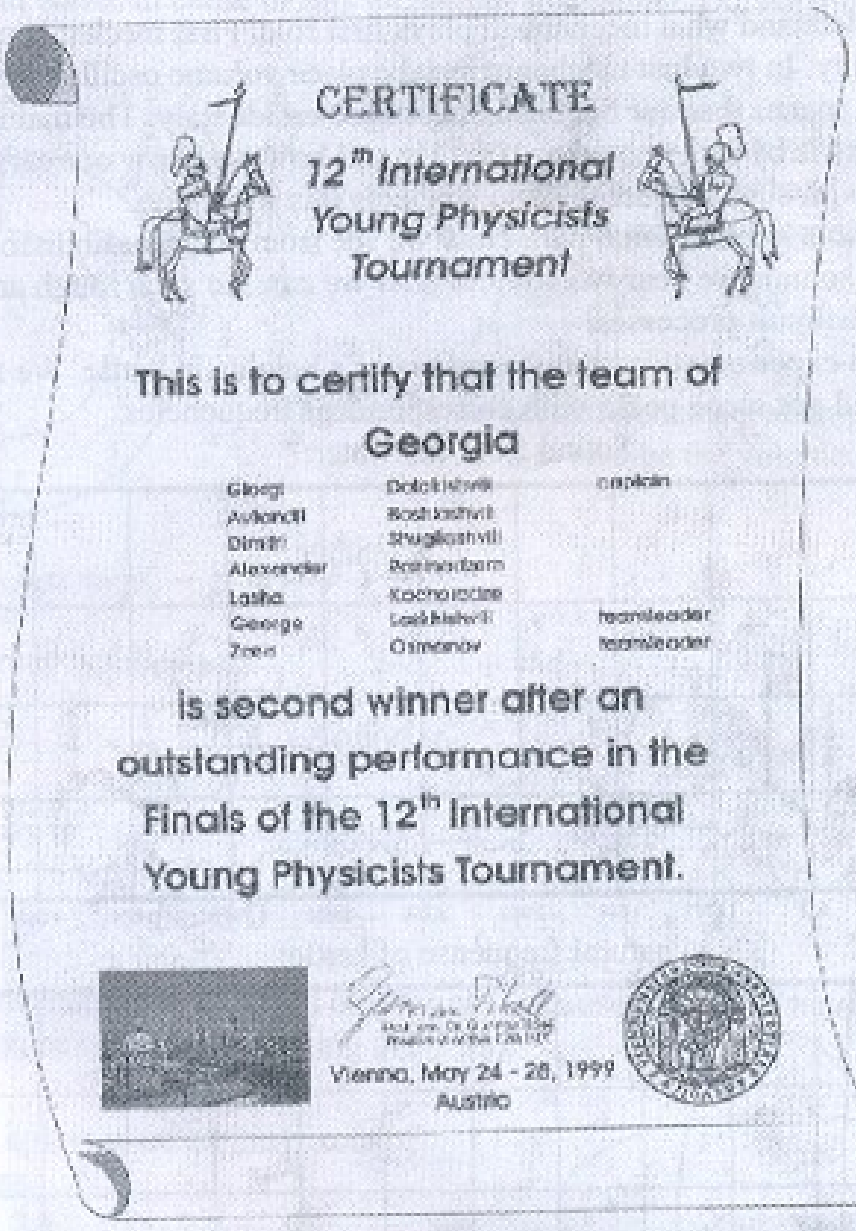
natural frequense of kettle:



Besides it we wrote sound of heated kettle with soda water. We were interested what will change with high gas concentration. How we can see it differs.

sound from soda water:





CERTIFICATE

12th International Young Physicists Tournament

This is to certify that the team of

Georgia

Giorgi	Dolidzetvili	captain
Avtandil	Rodchashvili	
Dimitri	Shugliashvili	
Alexander	Rotenberg	
Lasha	Kochoradze	
George	Lashkashvili	teamleader
Zaza	Osmanov	teamleader

is second winner after an outstanding performance in the Finals of the 12th International Young Physicists Tournament.

Vienna, May 24 - 28, 1999
Austria