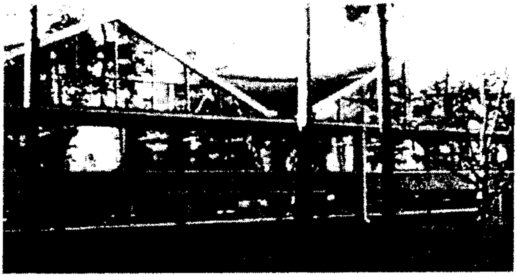
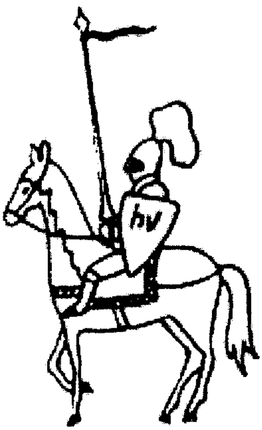


14th International Young Physicists' Tournament

May 22 – 29, 2001

Espoo, Finland

Reports of Georgian Team



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G. Laskhishvili – Team Leader
G. Dalakishvili – Team Coach
T. Bibilashvili – Joury Member

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E. Kiziria (Institute of Physics of the Georgian Academy of Sciences)
L. Koyava (Tbilisi Technical University)
I. Lomidze (I. Javakhishvili Tbilisi State University)
G. Machabeli (Abastumani Astrophysical Observatory of the Georgian Academy of Sciences)
Yu. Mamaladze (Institute of Physics of the Georgian Academy of Sciences)
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CONTENTS

Problems for the 14th IYPT

1. Electrostatic motor

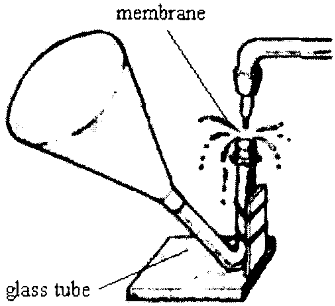
Is it possible to create a motor which works by means of an electrostatic field? If yes, suggest how it may be constructed and estimate its parameters.

2. Singing saw

Some people can play music on a handsaw. How do they get different pitches? Give a quantitative description of the phenomenon.

3. Tuning dropper

Make the music resonator shown in the picture. Investigate the conditions that affect the pitch. Can you observe amplification of external sounds? If yes, how can you explain this?



4. Dancing sand clock

Investigate the trickling of sand when a sand clock (egg-timer) is placed on a vibrating base.

5. Rubber heat machine

Investigate the conversion of energy in the process of deformation of rubber. Construct a heat machine, which uses rubber as the working element and demonstrate how it works.

6. Fractal diffraction

Produce, demonstrate and analyse diffraction pictures of fractal structures of different orders.

7. Cracks

When drying a starch solution, you will see cracks forming. Investigate and explain this phenomenon.

8. Speedometer

Two electrodes of different metal are immersed in an electrolyte solution. Investigate the dependence of the measured potential difference on the relative motion of electrodes and their shapes.

9. Pouring out

Investigate how to empty a bottle filled with a liquid as fast as possible, without external technical devices.

10. Water stream pump

Construct and demonstrate a water stream vacuum pump. What is your record value for the minimum pressure?

11. Rolling balls

Place two equal balls in a horizontal, V-shaped channel, with the walls at 90 degrees to each other, and let the balls roll towards each other. Investigate and explain the motion of the balls after the collision. Make experiments with several different kinds of ball pairs and explain the results.

12. Reaction

Make an aqueous solution of gelatine (10g gelatine in 90ml of water), heat it to 80 degrees C in a water bath and mix it with a solution of potassium iodide. Pour the solution in a test tube and cool it. Pour a solution of copper sulphate on the surface of the gel. Find a physical explanation to the observed phenomena.

13. Membrane electrolyser

In an electrolyser, containing a membrane which completely divides the space between two inert electrodes, the pH-value of the diluted salt solution will change substantially after electrolysis. Investigate how this difference depends on the pore size of the membrane.

14. Thread dropper

One end of a thread is immersed in a vessel filled with water. The other end hangs down outside without contact with the outer wall of the vessel. Under certain conditions, one can observe drops on that end of the thread. What are those conditions? Determine how the time of appearance of the first drop depends on relevant parameters.

15. Bubbles in magnetic field

Observe the influence of an alternating magnetic field (50 or 60 Hz) on the kinetics of gas bubbles in a vessel filled with water. The bubbles can be generated by blowing air into the water.

16. Adhesive tape

Investigate and explain the light produced, when adhesive tape is ripped from a smooth surface.

17. Seiches

Seiching is a phenomenon shown by long and narrow deep lakes. Due to changes in atmospheric pressure, the water of the lake can start moving in such a way that its level at both ends of the lake makes periodic motions, which are identical, but out of phase. Make a model that predicts the period of seiching (depending on appropriate parameters) and test its validity.

1. ELECTROSTATIC MOTOR

Grisha Lutsenko
Georgian Lyceum of Science and Technology,
Tbilisi Gymnasium №7 Named After A.Razmadze

What is electrostatic field? This is a potential electric field caused by a unmovable electric charge, work in which on closed circuit is equal to zero. But if all charges are unmovable the motor will work without taking energy from source, but makes some work. So it is impossible to make such motor, because the energy's conservation law. But as known Coulombs law for moving charges:

$$F = \frac{q_1 q_2}{R^2\left(1-\frac{v^2}{c^2}\right)} \qquad (1)$$

As we can see the process is static if charge's speed is much less than speed of light.

Then motor, which works by mean of electrostatic field, is a device which converts potential energy of electrostatic field to the mechanic energy. There is possible to create many models of such motors. We made three working models of such motors. We called them rotor, ion and pendulum motor.

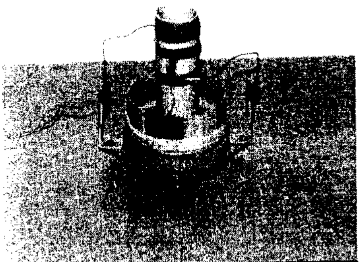


Fig1.Photo of Rotor Motor

Rotor motor consist of internal and external parts. Internal part consist of two plastic tubes with four contacts on each. Each contact on internal tube is connected with each external. The internal part can rotate with low friction. External part consist of two metal plates, to which is connected high voltage source, and two contacts, which are during the rotation of internal part are connecting to different contacts on internal tube. There happens attraction of external plates to the plates on the external tube. We don't explained parameters of this motor because low output power.

Let's look on ion motor. This is most difficult for understanding motor. It is founded on the phenomenon of ion wind. It's construction is very simple. There is metal axe in the center with cooper nails on it, directed perpendicularly, as shown on the picture. Also as you can see there is external tube to which is all this placed. To exclude influence of the current's magnetic field the tube and nails are made from cooper. The

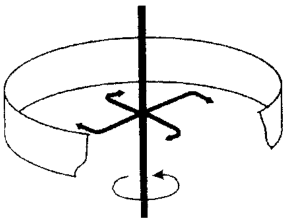
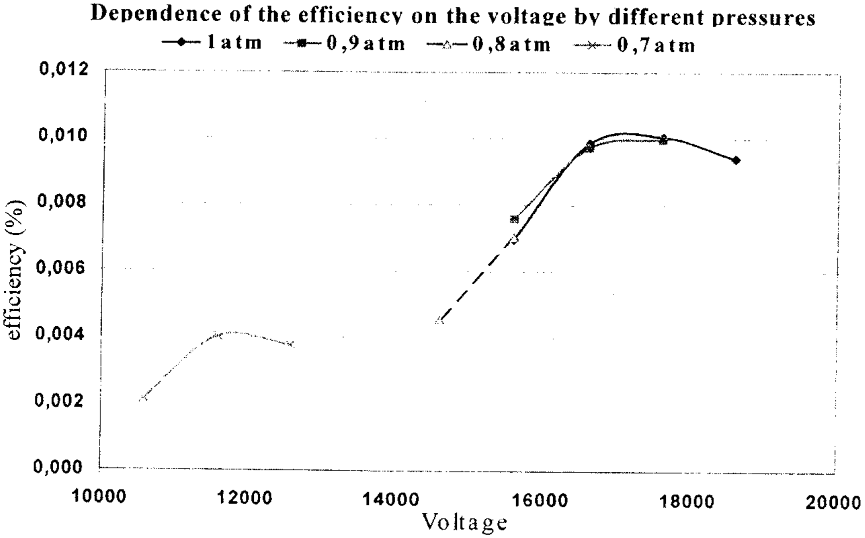


Fig3.Scheme of Ion Motor

Fig2.Photo of Ion Motor

source of high voltage must be connected to metal axe and tube. On the ends of the nails happens crown discharge, by which happens appearing of ions. The ions begin motion by the electrostatic field between nails and tube, and ions are giving impulse to the internal part, by which happens the rotation of the internal part.

We think that the parameters , which are necessary for explaining are output power and efficiency, and their dependence on the external parameters. Useful power is power which we can use, for example work which goes on the lifting of the weight. Placing this motor to the vacuum camera we measured these parameters by different voltages and pressures. Maximum efficiency of ion motor in the air is 0,01%, in CO_2 – 0,02%. Difference of the efficiency in different gazes because masses of molecules are different, so by increasing of the mass causes increasing of the impulse. Also you can see dependence and power on voltage on the graphs.



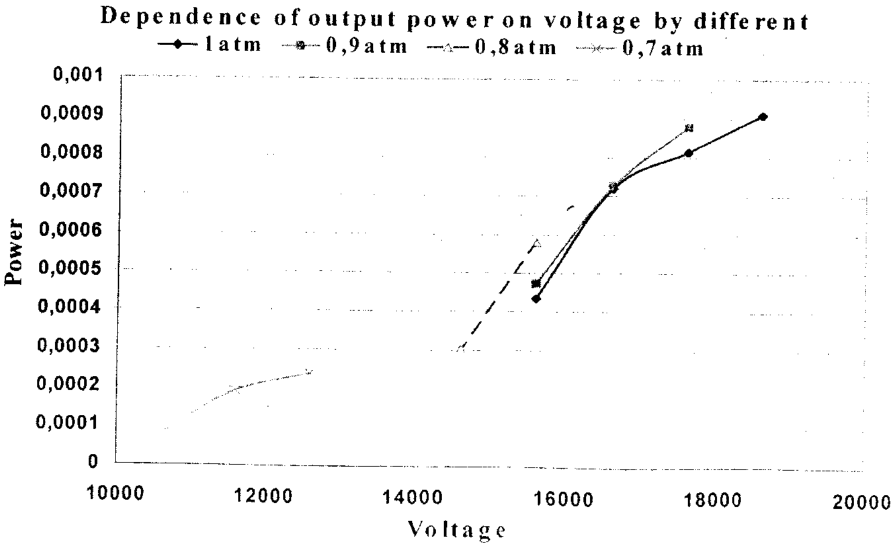


Fig4.Photo of Pendulum Motor

Pendulum motor – is the simplest of our motors and the most efficiency. It is a plane capacitor with metal plate fixed on the stick, flexibly fixed. To make it work is necessary to connect the source to the internal plates of the capacitor. By the gravity force the internal plate connects to the external one. On first look the power, the work, which is made by displacement of the internal plate can be calculated by the formula (2).

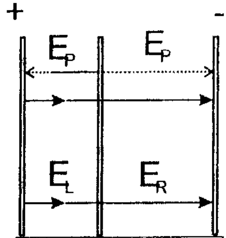


Fig5.Scheme of Pendulum Motor

$$A = eEd \quad (2)$$

But the charge of internal plate is comparable with charge of external plate, and there is EMF connected to the internal plates, the field caused by external plates changes in time. After some calculations, we got next formulas(3,4,5,6)where E– is strain of field caused by external plates, E_P – strain of field caused by internal plate, E_L and E_R – strains of fields between middle plate and left one, and between middle and right one, $\mathcal{E}$ – EMF, x – coordinate of internal plate, d – distance between external plates.

$$E_p = \frac{\sigma}{2\varepsilon_0} = \frac{\mathcal{E}}{2d} \quad (3) \qquad E_L = E - \frac{E}{2d} \quad (4)$$

$$E_R = E + \frac{\mathcal{E}}{2d} \quad (5) \qquad E = \frac{\mathcal{E}}{2d} + \frac{\mathcal{E}x}{d^2} \quad (6)$$

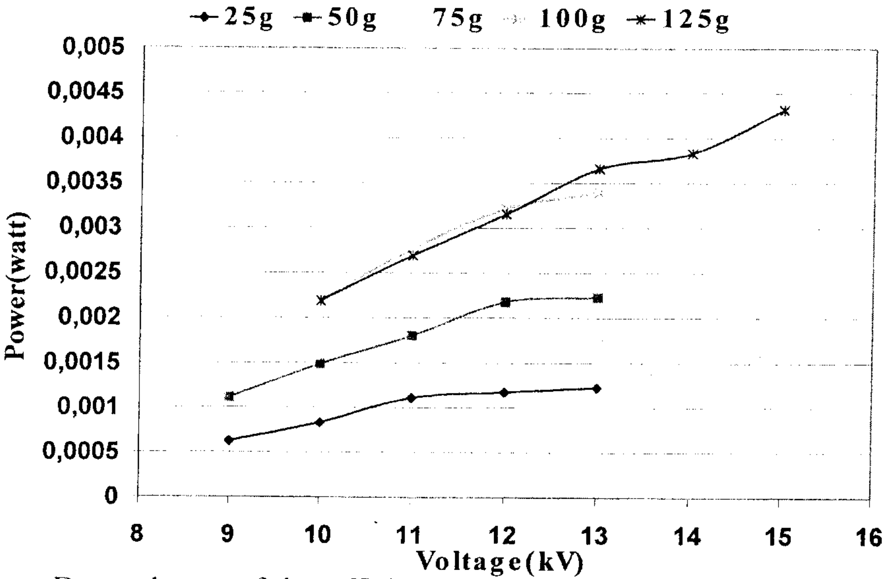
So the work made by field by moving the internal plate is equal to the integral (7), where C – is capacity of capacitor. For our motor C is 5,6 pF.

$$A = \int_0^d Eqdx = C\mathcal{E}^2 \quad (7)$$

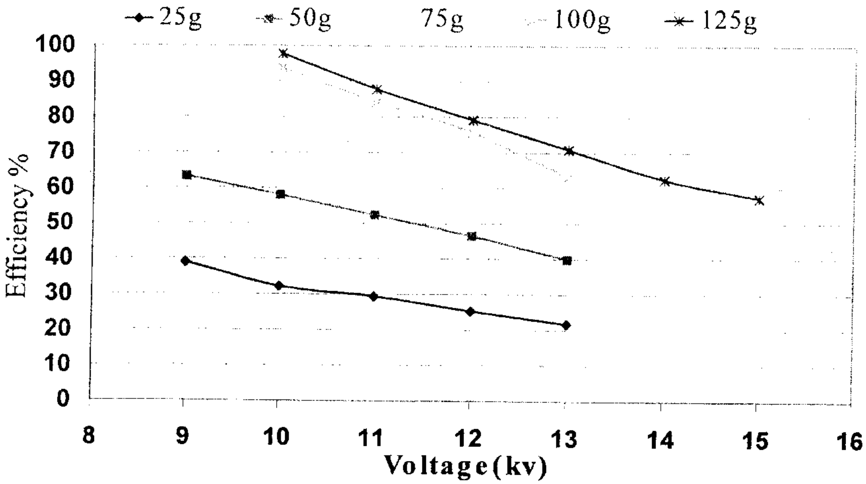
In the moment when internal plate comes near to the opposite charged plate, then on this external plate inducts charge, twice big than charge of internal one. So there all charge from external plate goes on the internal plate, by which don't happens losing of energy.

During the experiments we used some known weight on a thread to measure useful work, and measured number of pendulum's oscillations during the lifting of this weight on height 10 sm. So the efficiency of our motor can be calculated by next formula. Where m – is mass, N – number of oscillations, these parameters are measured experimentally. Efficiency of this motor depends on the lifting mass. This happens because if the mass is small the plate takes more kinetic energy, which cannot be used. For lifting small weights with big efficiency is necessary to make transmission to get the same load on the pendulum. Efficiency of this motor is very high – by mass 125 g it is 97%. Other parameters you can see on the graphs.

Dependence of the power on the voltage by different loads



Dependence of the efficiency on the voltage by different



Summary.

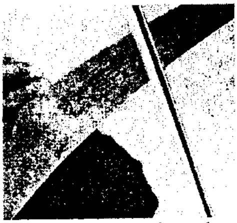
So, the target of our report was to show the possibility of creation of electrostatic motor and to show it's parameters. And we can say, that it possible, and as you saw they have rather good characteristics.

I would like to acknowledge Dr E. Kiziria for the very fruitful consultations.

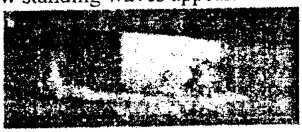
2. SINGING SAW

Nona Karalashvili,
School №42 named after Ilia Vekua
Maxim Matosov
Georgian Lyceum of Science and Technology,
School №42 named after Ilia Vekua

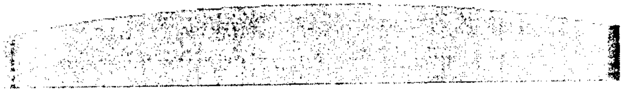
In order to receive sound we must have oscillating body. So to play on saw we must make him oscillate. We can do this with bow or mallet.



After beating saw with mallet or playing with bow in saw standing waves appear. If we will strew sugar or other dust on the surface of saw, and then will play, sugar will accumulate on point, which don't take place in oscillations. These points are called nodal points. Oscillations of saw make air oscillate and sound propagates. Loudness of sound is defined by amplitude of oscillations, so we can control on loudness of saw sound by controlling amplitude of oscillations of saw. Pitch of sound is defined by frequency of oscillations.



Let us define natural frequency of rectangle plate:



$$\zeta = \zeta_0(x, y)\cos(\omega t + \alpha)$$

$$\Delta(\zeta_0 - \zeta) - \chi^4 \zeta_0 = 0, \text{ where } \chi^4 = \omega^2 \frac{12\rho(1-\sigma^2)}{h^2 E}$$

σ -is Puason's coefficient
E -is Eung's modulus
Δ -is Laplas's operator

By help of Relay-Ritz's method, we can define frequency of oscillations of plate with supported ends:

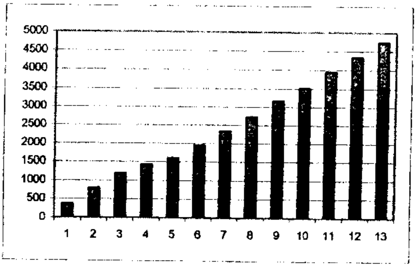
$$\zeta_0 = A\sin\frac{m\pi x}{b}\sin\frac{n\pi y}{a}$$

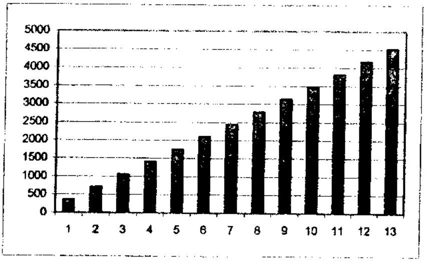
m and n are number of nodes along length and width
a -is length of the saw
b -is width of the saw

$$\omega = \frac{\pi^2 h}{2}\sqrt{\frac{E}{3\rho(1-\sigma^2)}}\left[\frac{n}{a^2}+\frac{m}{b^2}\right]$$

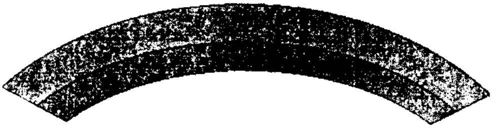
h -is thickness of saw

For iron: $\sigma = 0.25 - 0.3$ $E = (195-205)\cdot 10^9\, pa$ $\rho = (7.7-7.9)\cdot 10^3\, \frac{kg}{m^3}$

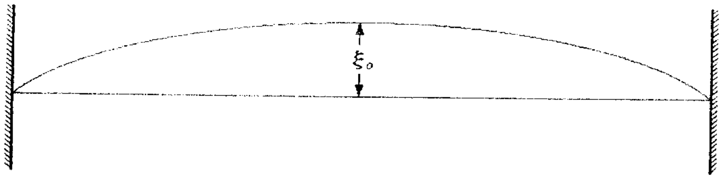




Experiments show that frequency of oscillations changes by deformation of saw.

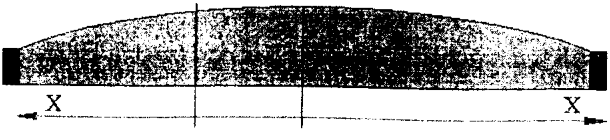


By deformation narrowed and expanded layers appear and stiffness of saw: $K = \frac{ES}{b}$ changes because, that quantities S and b change. That is the reason of change of frequency.

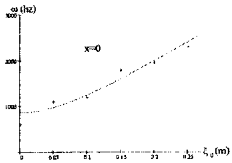


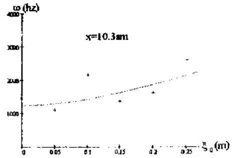
Potential energy of deformed saw: $U = U_0 + \frac{1}{2}K_0 \cdot \xi_0^{\,2} + \frac{1}{12}G\cdot \xi_0^{\,4}$

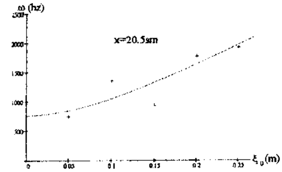
$$\omega^2(\xi_0) = \frac{U''}{m} = \frac{K_0}{m} + \frac{G}{m}\xi_0^{\,2}$$



Comparison of Theory with Experiment
Saw No.1

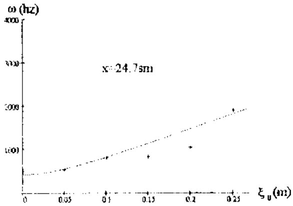






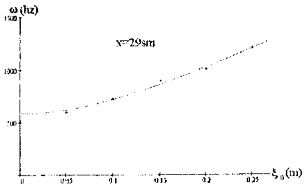
$\frac{K_0}{m} = 8.124 \cdot 10^7 \sec^{-2}$ $\frac{K_0}{m} = 4.889 \cdot 10^7 \sec^{-2}$ $\frac{K_0}{m} = 4.34 \cdot 10^7 \sec^{-2}$ $\frac{K_0}{m} = 5.303 \cdot 10^7 \sec^{-2}$

$\frac{G}{m} = 7.389 \cdot 10^5 (m \cdot \sec)^{-2}$ $\frac{G}{m} = 1.534 \cdot 10^6 (m \cdot \sec)^{-2}$ $\frac{G}{m} = 1.291 \cdot 10^6 (m \cdot \sec)^{-2}$ $\frac{G}{m} = 5.814 \cdot 10^6 (m \cdot \sec)^{-2}$



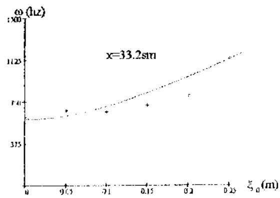
$\frac{K_0}{m} = 5.039 \cdot 10^7 \sec^{-2}$

$\frac{G}{m} = 1.789 \cdot 10^5 (m \cdot \sec)^{-2}$



$\frac{K_0}{m} = 1.789 \cdot 10^7 \sec^{-2}$

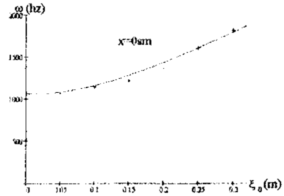
$\frac{G}{m} = 3.415 \cdot 10^5 (m \cdot \sec)^{-2}$



$\frac{K_0}{m} = 1.495 \cdot 10^7 \sec^{-2}$

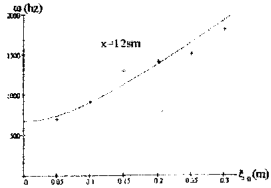
$\frac{G}{m} = 3.541 \cdot 10^6 (m \cdot \sec)^{-2}$

Saw No.2



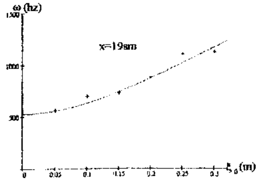
$\frac{K_0}{m} = 1.331 \cdot 10^7 \sec^{-2}$

$\frac{G}{m} = 1.119 \cdot 10^6 (m \cdot \sec)^{-2}$



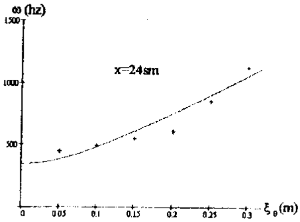
$\frac{K_0}{m} = 3.671 \cdot 10^7 \sec^{-2}$

$\frac{G}{m} = 4.531 \cdot 10^6 (m \cdot \sec)^{-2}$



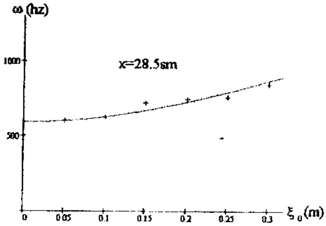
$\frac{K_0}{m} = 1.222 \cdot 10^7 \sec^{-2}$

$\frac{G}{m} = 2.786 \cdot 10^6 (m \cdot \sec)^{-2}$



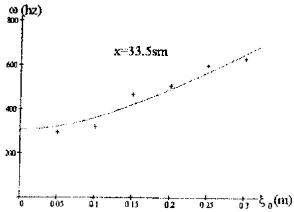
$$\frac{K_0}{m} = 1.120 \cdot 10^7 \sec^{-2}$$

$$\frac{G}{m} = 1.195 \cdot 10^6 (m \cdot \sec)^{-2}$$



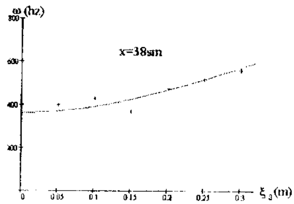
$$\frac{K_0}{m} = 4.481 \cdot 10^6 \sec^{-2}$$

$$\frac{G}{m} = 3.488 \cdot 10^6 (m \cdot \sec)^{-2}$$



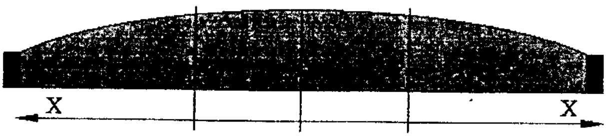
$$\frac{K_0}{m} = 3.611 \cdot 10^6 \sec^{-2}$$

$$\frac{G}{m} = 9.48 \cdot 10^4 (m \cdot \sec)^{-2}$$



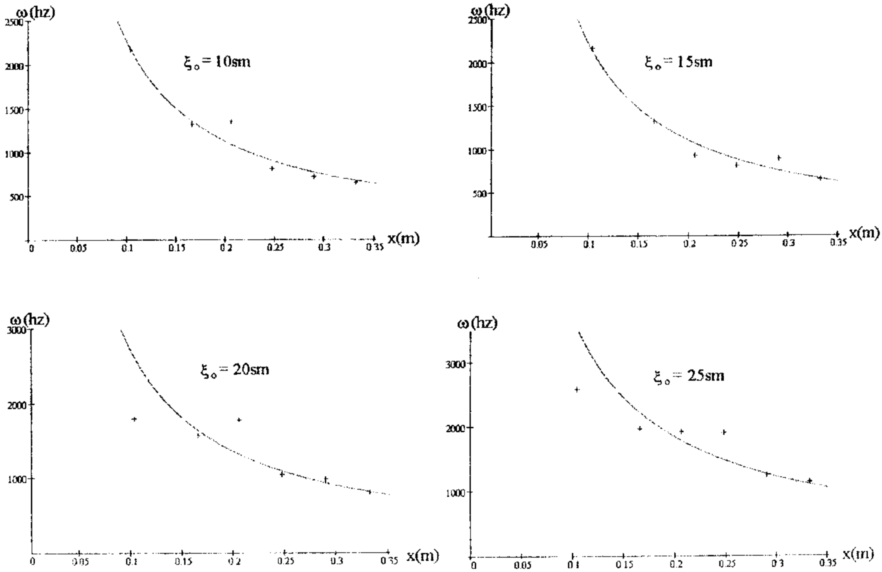
$$\frac{K_0}{m} = 2.169 \cdot 10^6 \sec^{-2}$$

$$\frac{G}{m} = 1.308 \cdot 10^5 (m \cdot \sec)^{-2}$$

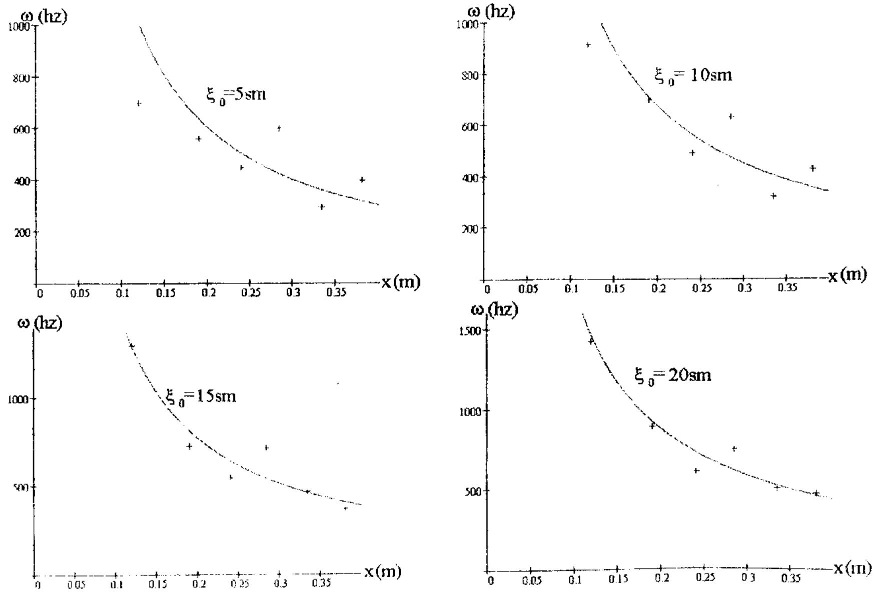


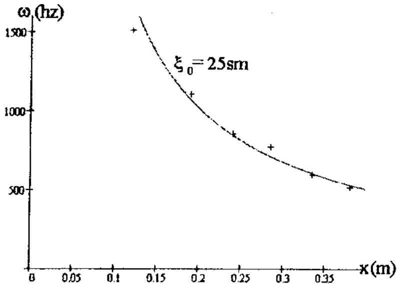
Quantity $\omega \cdot \lambda$ is velocity of propagation of wave on saw and is constant by given deformation. So we can find dependence of frequency of oscillations on the coordinate of point, on which we are playing.

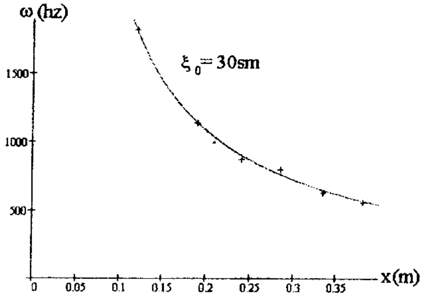
Saw No.1



Saw No.2







On figures experimental points and theoretical curves are shown.

1069.2hz	1228.8hz	1405.8hz	1417.4hz	1749hz	1798.1hz
C#6-9	C#6+31	F6+10	F6+25	A6-10	A6+37

1955.2hz.	2268.8hz	2334.6hz
B6-17	C#7+39	D7-10

Conclusion

We have made number of experiments, investigated oscillations of saw, showed method of discovering of nodal points, gave dependence of frequency of oscillations on deformation of saw and on coordinate of point, on which we are playing and showed which note correspond to given frequencies.

Acknowledgements

I want to express exceptional thanks to Mr. Nodar Mamisashvili and to Vasil Kevlishvili for advices.

3. TUNING DROPPER

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First let us discuss origin of sound we hear. There are some waves on surface of a jet. Velocity of these waves is equal by modulus to velocity of a jet. It is directed opposite to it, so these waves are at rest in reference frame of earth. Amplitude of these waves grows and when its value reaches radius of a jet r jet breaks up to drops. Periodic fall of drops on a membrane causes its vibrations. As a result we hear sound. So we will not hear sound if we put membrane in place where a jet is whole. Theoretical results, which will be presented later, are true if $\nu << \frac{2\pi\rho c^2}{\eta} \sim 10^7\,\text{Hz}$ which means that loose of energy caused by viscosity is negligible. If $\nu >> \frac{c}{2\pi}\sqrt{\frac{\rho g}{\sigma}} \sim 100\,\text{Hz}$ then waves are capillary.

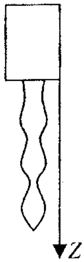

Fig.2

$$x(z,t) = ae^{\alpha t}\cos\frac{2\pi z}{\lambda}$$

Here x is radius of a jet. Dependence of α on frequency of a wave is given on the figure 1. You see that there are waves, which grow at fastest, and waves, which do not grow at all (α<0). We often have a certain constant frequency of drops if there are no external sounds.

Frequencies of oscillations of a membrane are determined from next equation:

$$\nu_{s,n} = \mu_s^{(n)}\frac{1}{r_m}\sqrt{\frac{T}{\sigma_m}}.$$

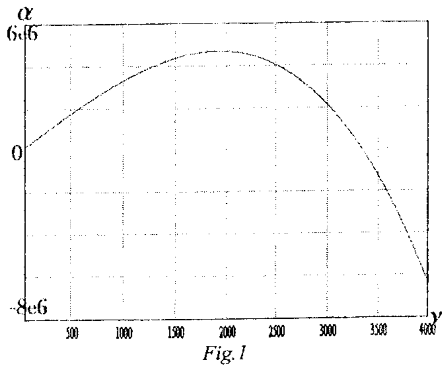

Fig.1

Strong sound can cause oscillations of a tube and a cone. Main frequency of a cone is proportional to $\frac{c\cdot\cos\alpha}{r}$. Here c is speed of sound in the material of which the cone is made, α is the angle of disclosing of the cone and r is radius of the cone. This is confirmed experimentally. A cone concentrates sound with wavelength less then length of the cone so intensity of sound is bigger than in case no cone is used. In fact a cone absorbs part of the energy. Frequency of vertical oscillations of a tube decreases with growth of its height. Frequency of horizontal oscillations of a tube decreases with growth of its radius. A membrane on the top of a tube oscillates with bigger amplitude then a membrane fixed on a ring.

If the main frequency of a membrane is much bigger than the drop frequency then we hear frequency of the membrane but not the drop frequency. We usually do not hear cone and tube frequencies because their oscillations have small amplitude.

When we put a membrane in the place of decay of a jet we do not hear sound. External vibrations can cause lifting up of decay level. That means that we got a system, which generates sound only when external vibrations are applied. Any external sound can cause vibrations of a membrane, which can cause stronger sound than initial sound was. If the frequency of the external sound belongs to the interval of possible drop frequencies ($\alpha > 0$) then frequency is conserved. Interval of conservable frequencies can be regulated by change of jet velocity, jet radius and membrane. System can be used as an amplifier of a tuning fork sound, human voice or other vibrations.

Acknowledgements:

I would like to thank Zaza Osmanov and Professor Yu. Mamaladze for consultations and Maxim Matosov for supply in experimental work.

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5. RUBBER HEAT MACHINE.

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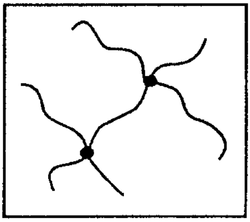


Fig1.Scheme of polymer's net

As known, matter which we call rubber, which became widespread because it's property of highelasticity, is a highmolecular polymer, molecules of which are connected by atoms of sulphur. By this elastic net happens, which has ability for big deformations without destruction of connections.

Experimentally determined, that rubber warms up during stretching, and decreases length by the heating. This phenomenon is called effect of Goule-Hooke. But why this happens? And why rubber has stiffness? For answering on these questions is better to look this on one polymer chain, which consist of big numbers of molecules. If on this chain do not acts any external force, the R can take any values from -L to L, where L – is length of the chain, <R> will be equal to zero. But to stretch the rubber we need to use some force f. Then of course R again will be possible to take any values from -L to L but <R> will not be zero. If to move <R> we used some force means this chain has some kind of stiffness. In case of solid body all is simple: stretching the body we are increasing distance between molecules, by this happens increasing of molecules attraction's potential energy. But rubber has no such potential energy like solid bodies.

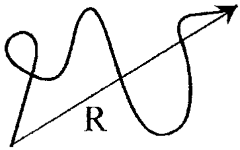


Fig2.Scheme of polymer's chain

If process is isothermic, our work goes on the heating up of the external medium, and potential energy of rubber dont changes. This phenomenon can be described with the entropy, like the ideal gaze.

$$dU = \delta Q + \delta A \quad (1) \qquad dU = TdS + \delta A \quad (2) \qquad T = const \quad (3)$$

So if we know probability of rubber's condition we can calculate entropy thought well known formula(5), where P – is probability.

$$S = k\ln P \quad (4) \qquad \delta A = -TdS \quad (5) \qquad P = Ce^{\left(-\frac{3R^2}{2Nl^2}\right)} \quad (6)$$

If entropy decreases means that work was done on the rubber, if it increases means that work was done by rubber. For comparing the tendentious of the theoretical rubber with experiment is better to determine formula for force, because it is rather simple to measure force, but not energy. According to the formula of potential energy we can get equation for force(7).

$$\vec{F} = \frac{3kT}{Nl^2}\vec{R} \qquad (7)$$

As we can see force is directly proportional to the R and T. On first look this formula looks like Hook's law, but this is incorrect, because in this formula there is no relative length.

We made experiment as shown on the picture. The rubber was

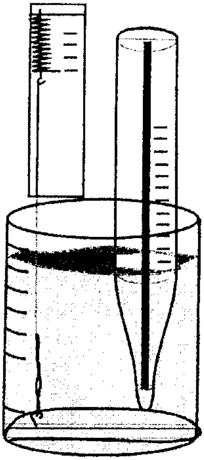
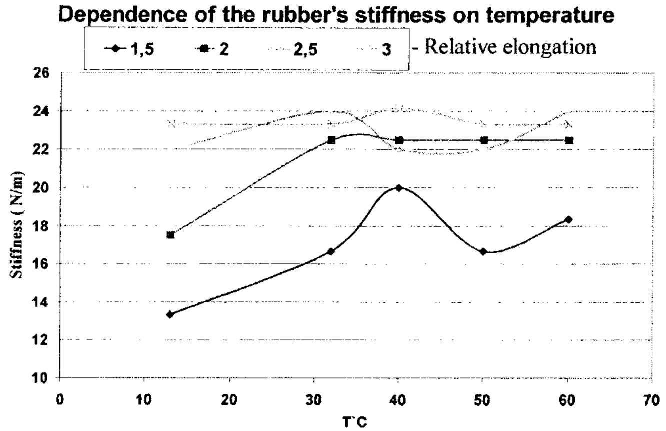
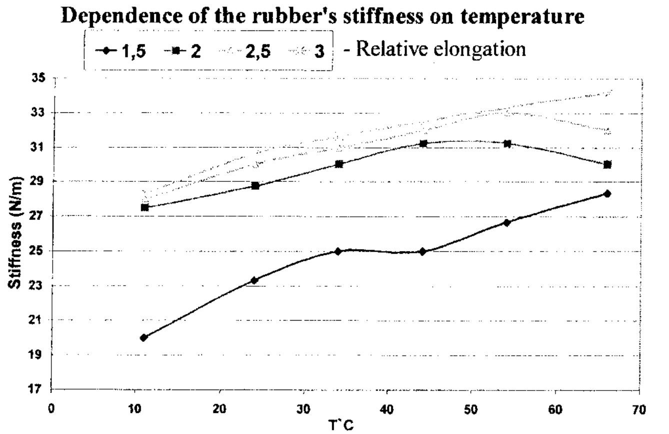


Fig3.Picture of the experiment





placed into the water. Warming up the water we got different temperatures of rubber. On these graphs you can see depending of the stiffness of rubber on temperature by different lengths. The rubber is not ideal linear because the rubber is not clear and chains are displaced random. And also you can see that after some temperatureby the big lengths happens decreasing of the stiffness. This happens because happens destruction of the rubber.

We made rubber heat machine ,which consist of external ring, internal wheel on the axe and 32 rubbers tented between these two wheels. Also there is lamp which works as the heater. Principle of it's work is very simple : Rubbers which are near the lamp are heating up, and by this happens increasing of it's force, by this happens displacement the mass center of the wheel relatively to the rotation axe and by the force of gravity happens the rotation of the wheel. After some turns the rotation

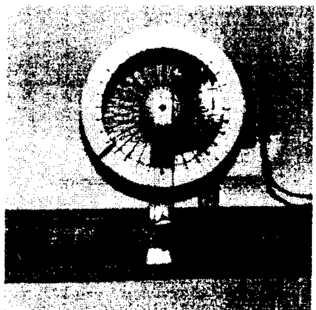


Fig4.Photo of rubber heat machine

becomes uniform. So there we have friction force's moment and gravity force moment. Sum of the moments most be zero. The moment of friction can be measured experimentally. So there left to determine the moment of gravity force.

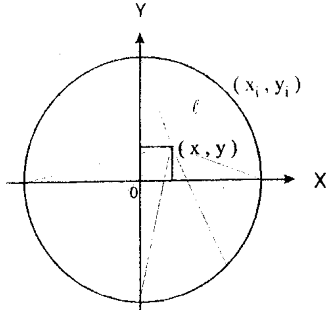


Fig5.Scheme used by calculating of displacement

$$\omega = \varepsilon t \qquad M = \varepsilon I \qquad \ell_i^2 = (x_i - x)^2 + (y_i - y)^2$$

$$\Pi = \sum_i \frac{k_i \ell_i^2}{2}$$

$$x = \frac{\sum_i k_i x_i}{\sum_i k_i}$$

ω - Angle speed
ε - Angle acceleration
t - Time
M - Force moment
I - Moment of inertia
ℓ - Length of rubber
k - Stiffness
Π - Potential energy

Lets find the laws of heating and cooling. The heating happens in lamp by the adsorbtion of the light energy. The cooling happens by the transmiting energy to the external medium. According to this we wrote formulas for rubber which is in the lamp(8), and outside(9).

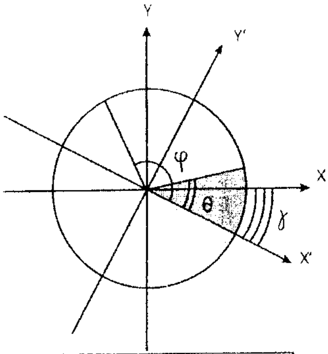


Fig5.Scheme used by calculating of temperatures

Parameters alpha and beta can be also measured experimentally. From this temperatures we can calculate stiffness of every rubber. We drawn graphs of the dependence of center's displacement on the angle speed by different lamp position. Rotation continues even when the lamp is already in the other side. Also is very interesting

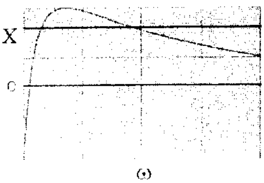
$$\frac{\delta Q}{dt} = \alpha(T - T_0)$$

$$P = \frac{\delta Q}{dt}$$

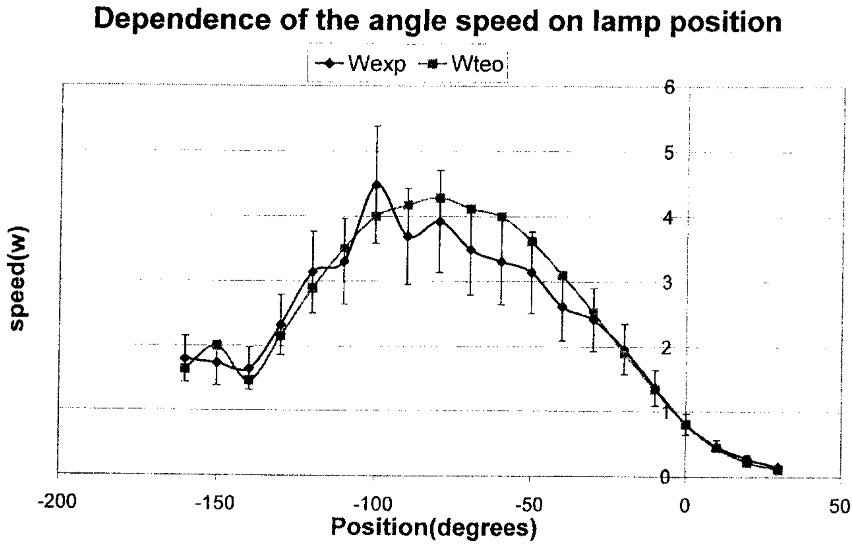
T_0 - External temperature
α - Coefficient of cooling
β - Coefficient of heating
φ - Rubber coordinate
θ - Lamp size
ω - Angle speed
P - Absorbted power
t - Time

$$T_2 = T_0 + \frac{\beta\Theta e^{-\frac{\alpha}{w}(2\pi-\Theta)}}{w\left(1 - e^{-\frac{\alpha}{w}(2\pi-\Theta)}\right)} + \frac{\beta\varphi}{w} \quad (8) \qquad T_1 = T_0 + \frac{\beta\Theta e^{-\frac{\alpha\varphi}{w}}}{w\left(1 - e^{\frac{\alpha(2\pi-\Theta)}{w}}\right)} \quad (9)$$

graph of displacement on angle speed when the lamp is on the other side.



There are two angle speeds in which displacement is equal to necessary. The first angle speed shows critic value of speed which is necessary to make this rotation. If the angle speed is smaller machine will stop and will begin rear rotation. And second shows the stable speed of rotation. We detected from these graph dependence of the angle speed on the lamp position. You can see the graphs of the angle speed on the angle coordinate of the center of the lamp. The difference between theory and experiment is less than 20%.



This theory has list of admissions, such as : this theory cannot show the dynamic of rotation, was not took into account cooling of the rubber when it is in the section of the lamp, also was token contrast size of the lamp.

But not looking on that this theory gives rather good results, and with it can be found dependence of its work on parameters.

So as the result of my report I want to say, that as you already saw, trivial rubber heat machine, which can be found in any book about polymers, is very interesting for researching, and shows very interesting theory of it's uniform rotation. Of course this theory is not ideal, but I think no one is, but in future I think will be possible to delete some errors from it, maybe to make a theory which determinates also dynamic.

6. FRACTAL DIFFRACTION

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Let's at first determine what is fractal and diffraction? It's well known that waves have ability to go around impediment, size of which is comparable with waves length. This phenomenon was called diffraction. It can be viewed on a simple experiment. If we will light on a thin cleft we will get alternation of light lines and dark ones. The diffraction can be described like interferention of secondary wave sources. So in the points where sum all waves we will be maximum we see light line. Also, if we take a thin ware in the monochromatic light on some distances we will not see geometric shadow, because the wave will go around the ware and will be also on the shadow.

Fig1.Example of the diffraction picture

For calculations, is very useful to use Fraungofer's diffraction. The main idea of it is to endlessness far screen. On practice this can get with lens, if we will look diffraction on the focal plane of the lens. In the calculations it is very simple to calculate phase difference between two points. And because the property of lens all waves, which are going by the same angle are going to the same point on the screen.

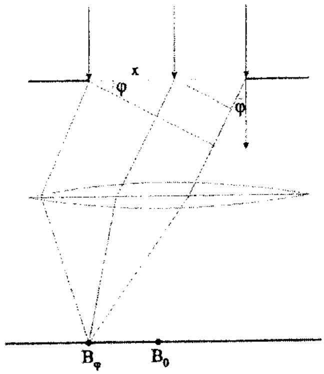

Fig2.Diffraction of the Frangoupher

Diffraction is used for investigating structure or size of matters, for example: diffraction of Roentgen's beam, with known wave length, is used for detecting of crystal's structure and measuring of this structure's size. Also such particles like quarks can be detected only by diffraction.

Let's think now what is fractal? In math fractal is variety with fractal dimension. Ideal fractals has property of self homo, this means that fractal consist of end or endless quantity of self homo structures, which are only dislarged copy of full picture. The dimension of line is 1, of area is 2, and fractal can has any value. It's dimension can be calculated by equation(1).

$$d = \dim A = \lim_{\varepsilon \to 0} \frac{\ln N(\varepsilon)}{\ln \frac{1}{\varepsilon}} \quad (1)$$

Fig3.Cantor's fractal(bars)

For example math fractal: Cantor fractal -- is a fractal which can be got by deleting middle part of line, as shown on the picture. Number of such operations is called fractal's power. The area of this fractal decreases like $(2/3)^N$. The dimension of this fractal can be calculated by formula (2).

$$d = \lim_{n \to \infty} \frac{\ln 2^n}{\ln 3^n} = \frac{\ln 2}{\ln 3} \approx 0{,}630929 \qquad (2)$$

Now, when we said what is diffraction and fractal, we can ask now: what is diffraction on fractals? This is only diffraction on special diffraction grate: fractal. As I said diffraction is very useful for investigating the matters properties. Maybe some crystals have fractal structure. Then knowledge of the pictures, got by the diffraction on fractals can help to learn such crystals and their properties. Also this knowledge can help with learning some properties of fractals.

I already mentioned about Cantor's fractal. Let us at first look on the diffraction on it. For calculation of diffraction picture is better to use complex numbers, then calculations became more simple. Amplitude in any point of the screen can be calculated by the formula (3).

$$A_N = \frac{A_0}{b} \int_{-\infty}^{\infty} dx e^{ikx \sin\varphi} G(x) \qquad (3)$$

$$A_N = \frac{2 \sin\left(\frac{kb \sin\varphi}{3^N} \right)}{k \sin\varphi} \sum_{j=1}^{2N} e^{ikx_j \sin\varphi} \qquad (4)$$

Function G(x) is equal to 1 if in current place is hole, and 0 if there is screen. After some transformations we can get (4). As known, coordinates of Cantor bars can be got by next formulas by changing sign before every number.

$$\begin{aligned}
x_1 &= 2b\left(\frac{-1}{3} + \frac{-1}{3^2} + \ldots + \frac{-1}{3^{N-1}} + \frac{-1}{3^N} \right) \\
x_2 &= 2b\left(\frac{-1}{3} + \frac{-1}{3^2} + \ldots + \frac{-1}{3^{N-1}} + \frac{+1}{3^N} \right) \\
x_3 &= 2b\left(\frac{-1}{3} + \frac{-1}{3^2} + \ldots + \frac{+1}{3^{N-1}} + \frac{-1}{3^N} \right) \qquad (5) \\
x_{2N} &= 2b\left(\frac{+1}{3} + \frac{+1}{3^2} + \ldots + \frac{+1}{3^{N-1}} + \frac{+1}{3^N} \right)
\end{aligned}$$

$$\sum_{j=1}^{2N} e^{ikx_j \sin\varphi} = \prod_{m=1}^{N} 2\cos\left(\frac{2kb \sin\varphi}{3^m} \right)$$

$$(6)$$

$$A_N = A_0 \left(\frac{2}{3} \right)^N \frac{\sin\left(\frac{kb \sin\varphi}{3^N} \right)}{\frac{kb \sin\varphi}{3^N}} \prod_{m=1}^{N} \cos\left(\frac{2kb \sin\varphi}{3^m} \right)$$

So according to this we can transform second part of this formula (6). With this formula we can calculate amplitude in any point of the screen. We made photo-tape, printed on the special printer with 4000 DPI with picture of the Cantor fractal with powers 4 and 5. You can see on the photos got by the laser on this tape, and near you can see theoretical results got by that formula on the computer (See color appendix). There are some interesting properties. 1st property – If wave's length is bigger than the smallest hole of the fractal, but smaller than distance between who holes, then wave goes through some holes like through one. 2nd property is that got picture is also fractal with the same power.

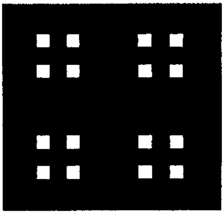

Fig3.Cantor's fractal(dust) 2th power

Let us try detect formula for another fractal. It can be simple done for fractal, called Cantor's dust. It looks like Cantor's fractal, but it is on the plane. Then formula for it is (7). From this formula we can see that max. Amplitude decreases like (2/3)2N, like the open part of fractal. Second multiplier is diffraction picture from one hole, and last is result of interferention from all fractal's holes. We made computer model for this fractal too. Now you can see experimental and theoretical pictures(See color insertion). On them is can be viewed better fractal structure of diffraction picture.

$$A_N = A_0\left(\frac{2}{3}\right)^{2N} \frac{\sin\left(\frac{kb\sin\varphi}{3^N}\right)}{\frac{kb\sin\varphi}{3^N}} \frac{\sin\left(\frac{kb\sin\gamma}{3^N}\right)}{\frac{kb\sin\gamma}{3^N}} \prod_{m=1}^{N} 2\cos\left(\frac{2kb\sin\varphi}{3^m}\right) \prod_{m=1}^{N} 2\cos\left(\frac{2kb\sin\gamma}{3^m}\right) \quad (7)$$

Summary

So in our researches we got formula for intensity for two different fractals, and made program which gives ability to calculate diffraction picture for fractals with different generations and different wave lengths. We got theoretical and experimental results, which are convergent. The next step is to spread of theory on other fractals, but problem happens when we are trying with not indent holes, then disfactorization is impossible, and it can be calculated by quantity methods.

7. CRACKS

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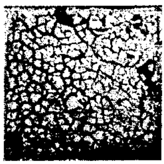
Starch can not be dissolved in water at room temperature. Its polymeric molecules are packed into granules, which collapse in water at 50-70 degrees. Some molecules of water join polymeric chains of starch by hydrogen connections. Molecules of starch break up to shorter glucose chains at temperatures close to 200 degrees. We do not assume obtained glucose solution to be starch solution.

Elastic properties of polymeric materials strongly differ from elastic properties of metals. Big zone of convertible nonlinear deformations and critical relative lengthening about 10 is characteristic for them. Polymeric molecules are characterized by entropy elasticity. The most probable distance between the ends of a chain is equal to 0. In a starch solution forces of interaction of polymeric chains are rather weak. Critical relative lengthening is about 1. In a solution with high concentration of starch so called glassing process occurs and the solution becomes non-extensible. Critical tension decreases with growth of time of load. There exists a minimal time in which a non-liquid piece of starch solution can be collapsed. Also a minimal constant loading which can force such body to collapse exists.

Only solutions with concentrations lower then 10% are liquid and can be poured. Maximal possible concentration of starch is about 50%.

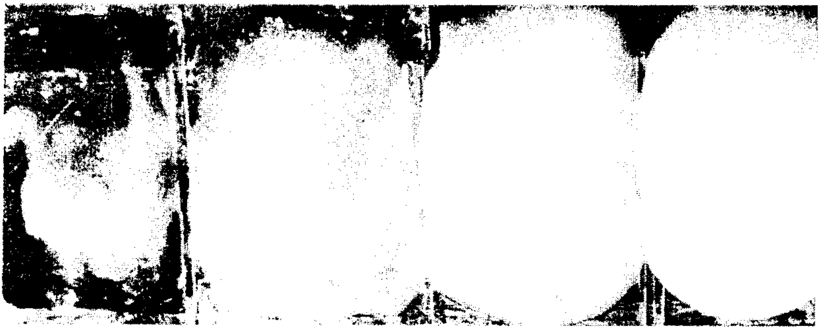
Evaporation from surface layers happens after placing starch solution on a surface. Oozing of some water from lower layers is also possible. Concentration of starch in surface layers increases. This causes fast growth of forces of interaction of polymeric molecules in surface layers. Surface layers tend to decrease their volume. Lower layers and surface on which starch solution is placed hold them. Tension appears in surface layers as a result. This tension is not big. First visible cracks form after several hours. For a solution with initial concentration higher then 30% concentration changes very slowly. In this case no tensions able to form a crack appear.

First cracks often appear in places where starch is not well dissolved or external bodies are immersed. First cracks appear on the perimeter of a starch layer if starch interacts weakly with the material from which the vessel is made. They appear in the center of the surface of a starch layer if interaction of starch with vessel is strong. In both cases first cracks appear earlier then if no interaction with vessel exists. In all cases we have a very complex mechanical system and it is hard to make a good model of it.



Time of appearance of the first visible crack varies from 1 hour up to several days. The concentration by which cracks usually appear at fastest is about 15 percents. Distance between cracks increases with growth of concentration. Such shape and size of cracks and distance between cracks exist which is most favorable energetically. That is why are cracks identical in a uniform system. Second crack is usually perpendicular to first one because line of biggest tension is perpendicular to first crack.

Starch interacts strongly with surface of this vessel



Artificial cut preserves the surface from the further crack formation in the direction of the cut

Acknowledgements

I would like to acknowledge Professor G. Chirakadze for the consultations and Goga Ayrapetov for discussions.

8. SPEEDOMETER

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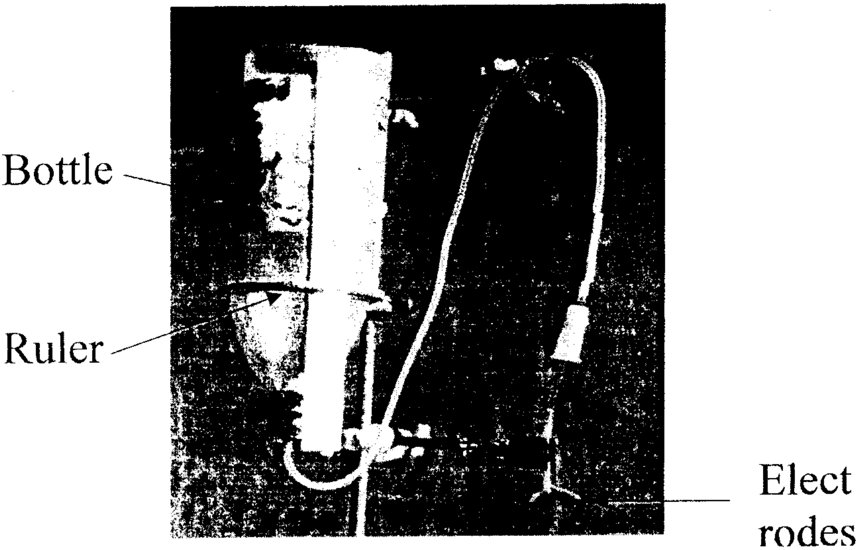
If we have two electrodes in electrolyte, than the potential difference appear.

To investigate dependents of potential difference on relative motion of electrodes the following experiment was made. It consists in following:

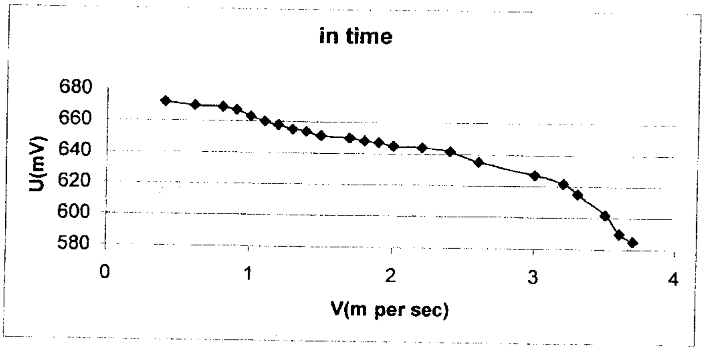


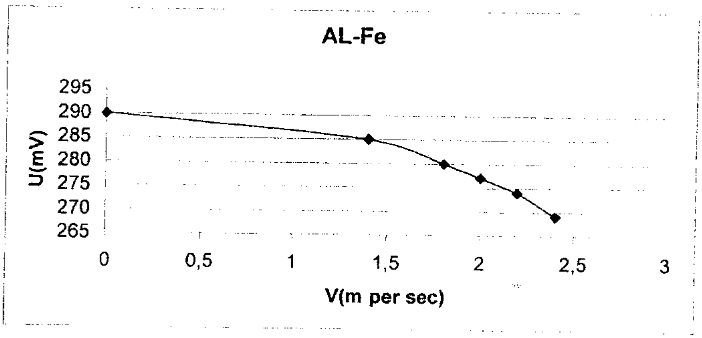
Bottle without bottom is fixed in turn over position on the stand. The thin hose which is raised up is fixed with it is one end to the neck of the bottle. Ruler is fixed on the side of bottle, such as the zero of ruler coincides with the neck of the bottle. Electrolyte is poured into the bottle up to the definite level which is maintained constant. We can change the speed of electrolyte's leak from the second end of the hose, in which electrodes are put. The change of speed is fulfilled with the help of raising up and lowering down of the second end of the hose. Potential difference is measured during the leak of electrolyte.

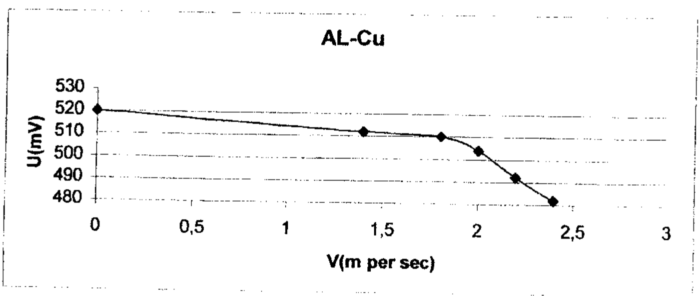
This experiment is notable because relative speed of electrodes is equal to zero,

But we can observe change of potential difference. In this case the potential difference is created by motion of electrolyte. If we pass into the reference frame relatively to electrolyte than electrodes will be in motion.

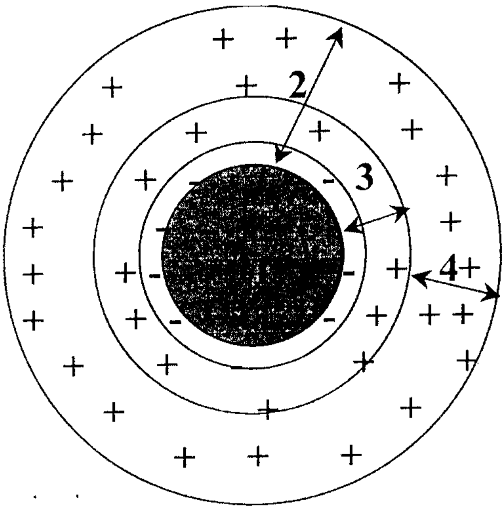
On this graph you can see how a potential difference for couple of any metals decreases by increase of speed.







By relative motion of electrodes or electrolyte the electrokinetic phenomenon appear. That is potential difference by displacement of one phase relatively to another appear. There is electric double layer on the boundary of two phases. It is a thin surface layer which consist of electric charges with opposite sign. Electric double layer is subdivided on dense and diffusive parts. Dense part consist of positive ions and negative ions. And diffusive part consist of the other positive ions. Washing of the electric double layer takes place in our experiment. The diffusive part of the electric double layer is mostly changeable, and this part is washed off in this case, and thickness of electric double layer decreases.



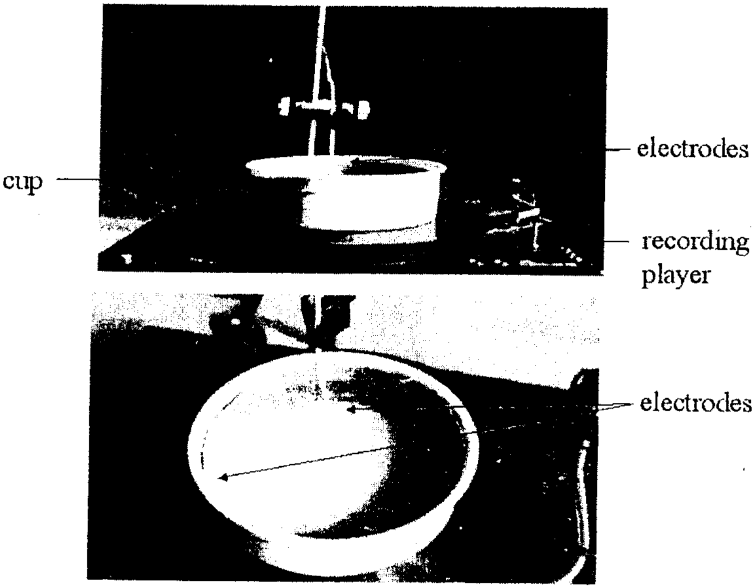
1 - electric

2 – electric double layer

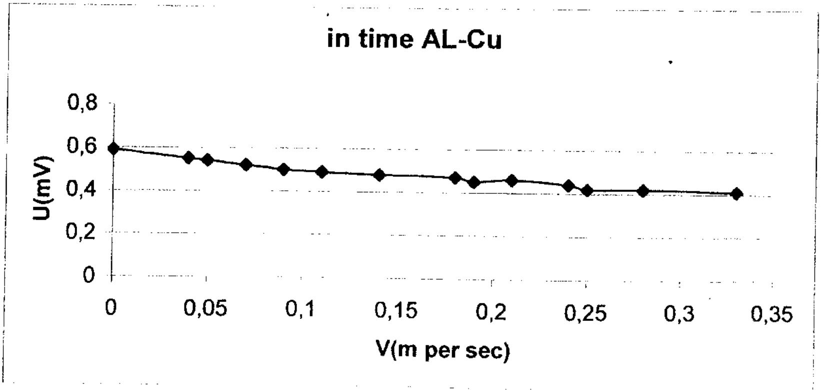
3 – dense part

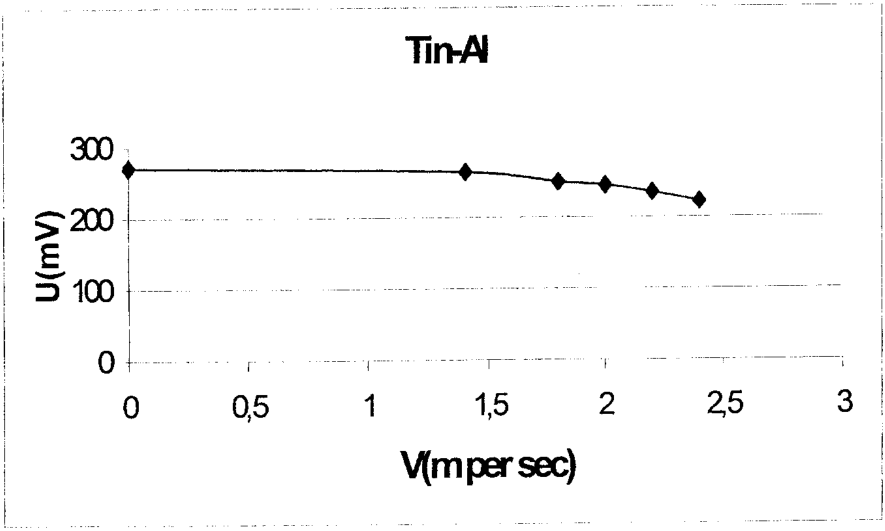
4 – diffusive part

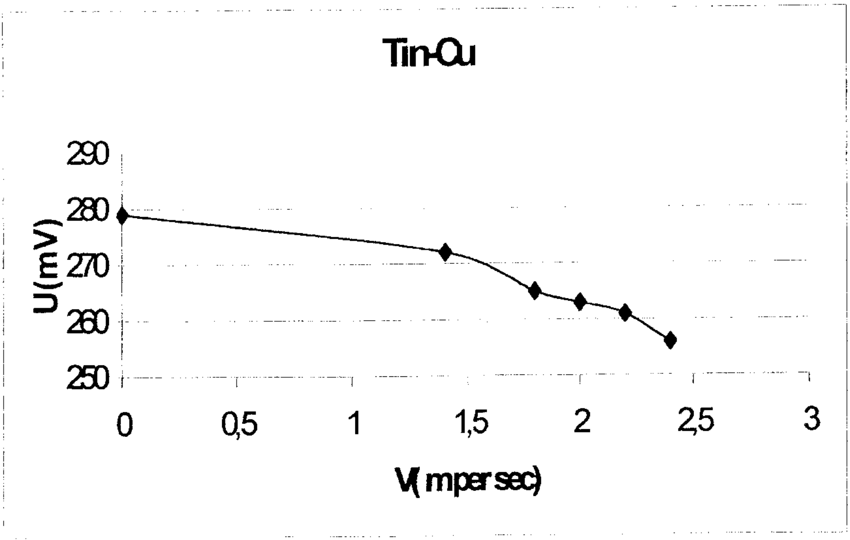
To investigate dependence of potential difference on the speed of relative motion of the electrodes and on their shapes the following experiment was made. It consists in following:



We have rotating platform on which the round plastic cup is placed. The copper plate, which is also electrode, is stuck by the perimeter of whole cup. The second electrode can be put into the cup with the help of the stand. During the experiment we can change speed of electrodes' motion. We can fulfilled it with help of cups with different radiuses. You can see the graphs of dependence of potential difference on the speed by different metals.




Tin-Al
300
200
100
0
U(mV)
0
0,5
1
1,5
2
2,5
3
V(m per sec)


Tin-Cu
290
280
270
260
250
U(mV)
0
0,5
1
1,5
2
2,5
3
V(mper sec)

Also I will show you what we got when we have different shape of electrodes.

		U(mV)	
AL	Cu	V=0.25(m per sec)	V1=0.35(m per sec)
w	plate	0,52	0,49
plate	plate	0,52	0,53
L	plate	0,54	0,51
U	plate	0,5	0,5
circle	plate		
R=6	plate	0,62	0,61
R=5	plate	0,57	0,56
R=4	plate	0,54	0,53
R=3	plate	0,52	0,51

At the conclusion I want to talk about electrolyte concentration. Positive ions transformed from the diffusive part to the dense part when the concentration of the solution increases and thickness of the electric double layer decreases. That is why the potential also decreases. At some concentrations of electrolyte all positive ions transformed to the dense part. And then we get that the potential is equal to 0. It is very difficult to fulfill it by the experiment.

Acknowledgement:

I would like to acknowledge Dr. T.Barnaveli for the very fruitful discussions of this problem.

9. POURING OUT

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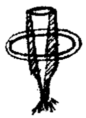
It's very important in this problem how we define technical device. We assume that all devices, which human uses, are technical devices and human himself isn't technical device.

Shape of bottle is significant in pouring out process. We have made number of experiments with champagne bottle filled with water. We choose champagne bottle because, it has good shape in comparison with others. Its neck is like cone-shape, which makes easier motion of liquid in this part of bottle. In made experiments bottle moved on different interesting trajectories. $\Delta t = 0.3$ sec–is inaccuracy of measurements, which consists of man's reaction time and inaccuracy of stopwatch.

1) In turned over position

$t = (11.2 \pm 0.3)$ sec

2) Rotating



In this experiment we have vortex of water, that's why crater appears and air enters intensivly.
$t = (5.1 \pm 0.3)$ sec

3) Declined in such way, when gurgling doesn't begin

$t = (10.4 \pm 0.3)$ sec

4) Motion of bottle up and down

$t = (10.4 \pm 0.3)$ sec

5) Period of gurgling is connected with motion of bottle up and down

$t = (8.5 \pm 0.3)$ sec

6) To empty beating on the bottom bottle by hand

$t = (8.3 \pm 0.3)$ sec

7) Rotation of bottle around its vertical axis left right by hand

$t = (5.9 \pm 0.3)$ sec

8) Motion of turned over bottle

$t = (5.9 \pm 0.3)$ sec

9) Motion of bottle in horizontal plane left and right (top view is shown on figure)

$t = (8.1 \pm 0.3)$ sec

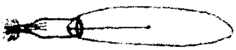
10) Motion of bottle up and down in vertical plane (side view is shown on figure)

$t = (6.8 \pm 0.3)$ sec

11) Motion of turned over bottle in circle

$t = (6.7 \pm 0.3)$ sec

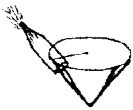
12) Motion of bottle in circle in horizontal position
In this experiment we have pressure, caused by rotation in circle.
$t = (4.7 \pm 0.3)$ sec



13) Motion of declined bottle in circle

$t = (4.3 \pm 0.3)$ sec

14) Motion of bottle above head in circle

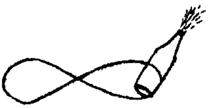


$t = (4.9 \pm 0.3)$ sec

15) Motion in circle with small rotation of bottle

$t = (5.1 \pm 0.3)$ sec

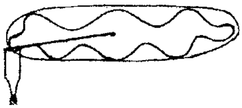
16) Motion of bottle on trajectory shown on figure



$t = (3.7 \pm 0.3)$ sec

17) Motion of bottle on trajectory shown on figure

1) In turned over position

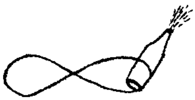


$t = (6.5 \pm 0.3)$ sec

2) In horizontal plane

$t = (3.9 \pm 0.3)$ sec

The shortest period of pouring out of bottle in our experiments is 3.5 sec, which was fixed in the following experiment:



The explanation of shortest time of pouring out of bottle is the fact, that in this case besides vortex we also have pressure, caused by rotation.

We have made experiments on liquids, with different viscosity and saw that bottles filled with liquids with big viscosity get empty faster by different methods. For example bottle filled with honey, oil and other liquids with big viscosity pours out by the methods

"To empty bottle beating on the bottom by hand "

"Rotation of bottle around its vertical axis by hand"

During pouring out of turned over bottle, we will see phenomenon of gurgling.

Lowering down of water level is accompanied by extension of air in bottle, that's why air pressure decreases. As a result of the fact, that this pressure is less then atmosphere pressure the last one pushes the water. On the surface of water Relay-Tailors disturbances appear and air goes into bottle, and this is the reason of gurgling.

fig.1

We can determine that all devices which are putting into the bottle aren't external devices. For example, there exist external and internal modems.

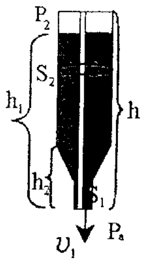
Let us consider bottle with tube shown on fig.2.

This method is convenient because, more air goes in tube and we don't have phenomenon of gurgling, which hinders pouring out of bottle. As I sad, vortex makes that we don't have gurgling, and tube plays the same role in this case.

Tube wholly is inside bottle and its the second end finishes with neck. In the tube air moves freely.

fig.2

Cross-section areas of bottle $S_1 < S_2$, and cross-section areas of tube $S_3 < S_4$



We wrote down Bernoulli's equation for water

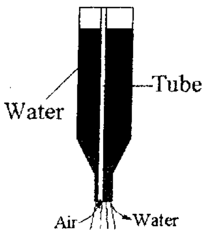
$$p_2 + \rho g h + \frac{\rho \upsilon_2^2}{2} = p_a + \frac{\rho \upsilon_1^2}{2} \quad (1)$$

and continuity condition

$$\upsilon_2 S_2 = \upsilon_1 (S_1 - S_4) \quad (2)$$

$$\Delta p = p_a - p_2$$

$$(1),(2) \Rightarrow \Delta p = \rho g h + \frac{\rho \upsilon_2^2}{2}\left(1 - \frac{S_2^2}{(S_1 - S_4)^2}\right) \quad (3)$$



The volume of air, entering the bottle equals to the volume of water, coming out of the bottle. that's why

$$\upsilon_2 S_2 = \upsilon_3 S_3 \quad (4)$$

Let us write down Poiseuille's equation for air

$$\upsilon_3 S_3 = \frac{\pi \Delta p}{8 \mu_1 l} R_3^4 \quad (5)$$

$$S_3 = \pi R_3^2 \quad (6)$$

where l is length of tube

$$(4),(5),(6) \Rightarrow \qquad \Delta p = \frac{8\mu_1 h \pi S_2 \upsilon_2}{S_3^2} \qquad (7)$$

Let us take designates

$$a = \frac{S_2^2}{(S_1 - S_4)^2} - 1 \, , \qquad b = \frac{8\mu_1 h \pi S_2}{S_3^2}$$

$A = \dfrac{b}{a\rho_w}$, $B = \dfrac{2g}{a}$ find υ_2 from Bernoulli's and Poiseuille's equations

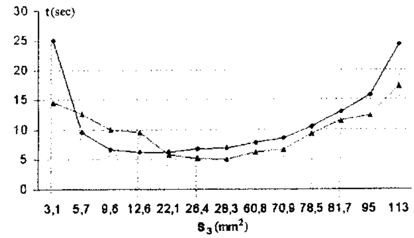
$$\upsilon_2 = -A + \sqrt{A^2 + Bh}$$

$$\upsilon_2 = -\frac{dh}{dt}$$

From these equations we can calculate time, which is needed by water to lower down from h_1 to h_2 in cylinder-shape part.

$$t_c = \frac{2A}{B}\left[\sqrt{1+\frac{Bh_1}{A^2}} - \sqrt{1+\frac{Bh_2}{A^2}} + \ln\left(\frac{\sqrt{1+\frac{Bh_1}{A^2}}-1}{\sqrt{1+\frac{Bh_2}{A^2}}-1}\right)\right]$$

We have made experiments on big coca-cola bottle filled with water with tubes, with different cross-section areas. In made experiments we have measured time of pouring out of bottle with different tubes, thickness of them was the same. By this way we choose tube with optimal cross-section area, by which bottle is pouring out faster. Here theoretical and experimental graphs are shown. On these graphs we can see how time of pouring out of bottle depends on internal cross-section area of tube. Thickness of tubes is equal to 1.5mm.



Periods of time, during which coca-cola bottle with optimal tube pours out:

Theoretical $t = (6.9 \pm 0.2)\,\text{sec}$

Experimental $t = (5.0 \pm 0.3)\,\text{sec}$

Cross-section areas of optimal tube are

Internal $S_3 = 36.0mm^2$

External $S_4 = 90.3mm^2$

Experimental quantities:

$\eta_1(20^0) = 1.8 \cdot 10^{-7}\, pa \cdot \sec$

$\eta_w(20^0) = 1.0 \cdot 10^{-3}\, pa \cdot \sec$

$l = 32 sm$

$d_1 = 2.1 sm$

$d_2 = 8.0 sm$

$h_1 = 28.8 sm$

$h_2 = 8.5 sm$

Champagne bottle pours out:

With optimal tube $t = (2.7 \pm 0.3)\sec$

With vortex $t = (5.1 \pm 0.3)\sec$

We also have considered pouring out of bottle without bottom. In this case $\Delta p = 0$,

$$a_1 = \left(\frac{S_2}{S_1}\right)^2 - 1$$

$$\upsilon_2 = -h'$$

and write Bernoulli's equation for this case

$$\rho g h = a_1 \frac{\rho \upsilon_2^2}{2}, \quad \upsilon_2 = \sqrt{\frac{2gh}{a_1}}$$

$$t_{open} = \sqrt{\frac{2a_1}{g}}\left(\sqrt{h_1} - \sqrt{h_2}\right)$$

For coca-cola bottle

Theoretical $t_{open} = 1.6 \sec$

Experimental $t_{open} = (1.5 \pm 0.3)\sec$

Besides that, we have made experiments on pouring out of different bottle with and without optimal tube.

Experimental Data

Bottle	Volume (liter)	Time with tube (sec)	Time without tube (sec)
Coca-cola (big)	1.5	5.3 ± 0.3	21.0 ± 0.3
Wine	0.75	3.2 ± 0.3	11.9 ± 0.3
Champagne	0.75	2.7 ± 0.3	11.2 ± 0.3
Oil	0.6	2.6 ± 0.3	10.3 ± 0.3
Lemonade	0.5	2.6 ± 0.3	10.2 ± 0.3
Borjomi	0.35	1.2 ± 0.3	5.3 ± 0.3
Beer	0.35	1.2 ± 0.3	5.0 ± 0.3
Coca-cola (small)	0.25	1.1 ± 0.3	6.1 ± 0.3

You see how tube makes faster pouring out of bottle.

Experiments show, that the higher temperature of liquid the faster pouring out of bottle.

Time of pouring out of champagne bottle at different temperature of liquid

Temperature $[^0C]$	Time (sec)
92	7.6 ± 0.3
80	7.8 ± 0.3
50	9.6 ± 0.3
40	10.0 ± 0.3

Reynolds's number (with the best tube)

1) Flow of water in cylinder-shape part

$$\upsilon_2 = 0.1 m/\sec\ , d_2 = 8sm$$

$$\mathrm{Re} = \frac{\upsilon_2 d_2 \rho}{\eta_w} = 8000 > 1000$$

2) Flow of water in neck of bottle

$$\upsilon_1 = 1.8 m/\sec, d_1 = 2.1 sm$$

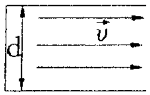
$$\mathrm{Re} = \frac{\upsilon_1 d_1 \rho}{\eta_w} = 37800 > 1000$$

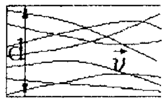
Because of fact, that we have turbulent regimes, let's refine how useful is Bernoulli's equation.

1) $\eta_w(20^0) = 10^{-3} pa \cdot \sec$, that's why work of viscosity is small;

2) We have fluctuations of velocity and pressure. But we can find mean velocity and pressure by diameter d and write conservation low of energy like Bernoulli's equation.

υ, P $\bar{\upsilon}, \bar{P}$





Lacks: We haven't taken into account work of viscosity in Bernoulli's equation, but we estimated it and maximal inaccuracy, which it gives is $0.2\sec$. Our Lack is the fact, that we haven't considered unsteady of water flows and haven't estimated acceleration of water in this case.

Conclusions: 1) We have made number of experiments on pouring out of champagne bottle, which moved on different trajectories.
2) We have discovered those methods by which bottle filled with big viscosity liquid is pouring out maximally fast.
3) We have made experiments on liquids by different temperature.
4) We have used tube method and received coincidence of theoretical and experimental results.
5) We have investigated how to pour out bottle maximally fast in different conditions.

I want to express exceptional thanks to Professor Yu. Mamaladze for useful advices.

10. WATER STREAM PUMP

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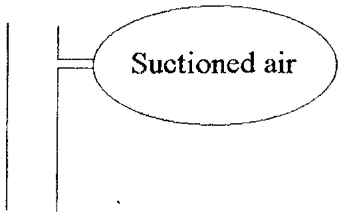
School №42 named after Ilia Vekua
Alex Bidjamov,
Georgian Lyceum of Science and Technology,
Tbilisi Gymnasium №7 Named After A.Razmadze

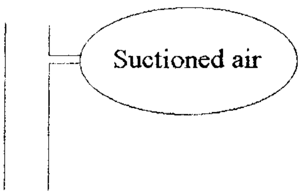
Simple Pump

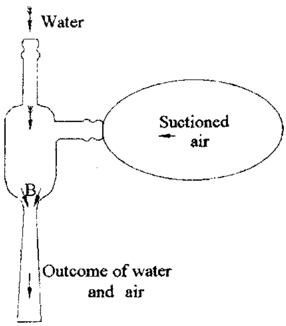


Water flows in hose, there exist pressure difference, that is why air comes out from vessel. We have made experiments on this pump and got minimal result: $P_{min} = (31.6 \pm 2.5) \cdot 10^3 \, pa$.

Because of fact, that we have free surface of water, pressure of suctioned air can't be less then pressure of saturated vapor at temperature of water. Temperature of water in our experiment was $9^0 C$, so absolute minimum (pressure of saturated vapor) in this case is: $P_{min} = (1 \pm 0.2) \cdot 10^3 \, pa$

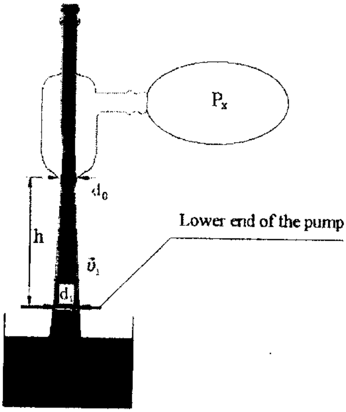
Let us consider arrangement and method of working of improved pump:





Method of working is the same: there exist pressure difference, that is why air leaks from vessel. Cone-shape narrowing makes water to slow down and because of that point of minimal pressure is at B.

In order to investigate the dependence of pressure of suctioned air on parameters of pump, let us make idealization and assume that we have no fluctuations of water by diameter. In this model we can write down Bernoulli's equation.



Let us write Bernoulli's equation:

$$P_x + \rho g h + \frac{\rho \upsilon_0^2}{2} = P_a + \frac{\rho \upsilon_1^2}{2}$$

and continuity condition:

$$\upsilon_0 S_0 = \upsilon_1 S_1$$

From these equations it follows, that:

$$P_x = P_a - \rho g h - \frac{\rho \upsilon_1^2}{2}\left(\frac{d_1^4}{d_0^4} - 1\right)$$

where ρ -is density of water

P_a -is atmosphere pressure

υ_1 is velocity of water at lower exit of the pump and can be measured experimentally: we can fill vessel of known volume V and measure interval of time t, after which this vessel will be filled: $\upsilon_1 = \frac{4V}{\pi d^2 t}$. By this way we find mean velocity of water.

Let us thoroughly consider arrangement of the pump. Because of sudden reduce of cross-section area , continuity condition in this case will have following shape:

$\upsilon_1 \rho_1 S_1 = \rho S \upsilon$ where υ_1 -is velocity of water at the lower exit of pump

υ -is velocity of water at entrance of the pump

ρ, ρ_1 -are densities of water at the neck and at the lower exit of the pump

$\frac{\rho}{\rho_1} \equiv \alpha$ α depends on the ratio of cross-section areas and on Reynolds's number.

To compare theory with experiment, let us put experimental quantities into received formula and get corresponding theoretical result:

$$\upsilon_1 = 3.01 \frac{m}{\sec}$$

$$h = 10sm$$

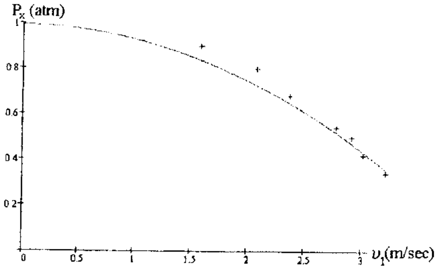
$$\frac{d_1}{d_0} = 1.909$$

$$P_{ex} = 0.42atm$$

$$P_{th} = 0.43atm$$

$$\text{Difference} \approx 2\%$$

Comparisons of Theory with Experiment



On figure experimental points and theoretical curve are shown.

υ_1 -is velocity of water at the lower exit of the pump

Coincidence of theoretical curve with experimental data proofs validity of our idealization.

We have made experiments on this pump too and got minimal result of pressure: $P_x = (4 \pm 0.15) \cdot 10^3 pa$, by putting corresponding experimental data into formula we get corresponding theoretical result: $P_x = 2.8 \cdot 10^3 pa$. Difference between theoretical and experimental results is $\approx 30\%$. Absolute minimum of pressure, i.e. pressure of saturated vapor at $9^0 C$ is: $P_{min} = (1 \pm 0.2) \cdot 10^3 pa$.

So experimental minimum is 4 times bigger then absolute minimum, but there exist ways of improvement of result. To improve result we must increase velocity of water flow.

Conclusions

We have made experiments with the simple pump, and improved pump, observed existence of coefficient α. We investigated motion of water in pump and described it. We received $P_x = (4 \pm 0.15) \cdot 10^3 pa$ minimal pressure, which is 4 times bigger then absolute minimum, show ways of improvement of result.

I want to express exceptional thanks to Professor Yu. Mamaladze and to Dr. Zurab Tsaqadze for advices.

11. ROLLING BALLS

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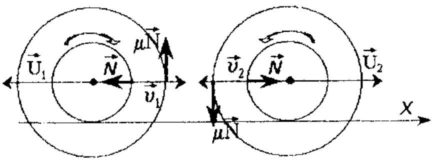
We have made experiments on kernels and spheres and investigated phenomena after their collision.

Experiments showed that hollow balls after first collision always collide secondly too, and in case of kernels second collision happens or not. During experiments we saw that it is possible one ball to change direction of its translational velocity after first collision and to overtake another one, which didn't change the direction of its translational velocity. This phenomenon is observed on kernels.

Let's consider what happens during collision generally.



If collision is inelastic and k is coefficient of restore, velocities of balls after collision are equal to:

$$U_1 = \upsilon_1 + \frac{(k+1)m_2}{m_1 + m_2}(\upsilon_2 - \upsilon_1) \qquad 0 \le k \le 1$$

$$U_2 = \upsilon_2 + \frac{(k+1)m_2}{m_1 + m_2}(\upsilon_1 - \upsilon_2) \qquad (U_1 < 0, \upsilon_2 < 0)$$

Because balls are the same $m_1 = m_2 = m$, so

$$U_1 = \frac{1}{2}(\upsilon_1 + \upsilon_2 + k(\upsilon_2 - \upsilon_1))$$

$$U_2 = \frac{1}{2}(\upsilon_1 + \upsilon_2 + k(\upsilon_1 - \upsilon_2))$$

Let us assume that $\omega_1 > \omega_2$

$$\frac{m\Delta\vec{\upsilon}_1}{\tau} = -<\vec{N}> \qquad \frac{m\Delta\vec{\upsilon}_2}{\tau} = <\vec{N}>$$

$<\vec{N}>$-is mean reaction force

τ -is time of collision

Let's write moments of forces:

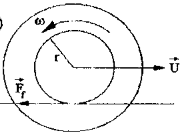
$$I\frac{\Delta\vec{\omega}_1}{\tau} = -\mu_1 <\vec{N}> r \qquad \text{where } r = \frac{\sqrt{2}}{2}R \text{ is radius of balls rotation}$$

$$I\frac{\Delta\vec{\omega}_2}{\tau}=\mu_1<\vec{N}>r$$ μ_1 -is coefficient of friction between balls

From these equations we can calculate final angular velocities of balls.

After collision we can have following picture:

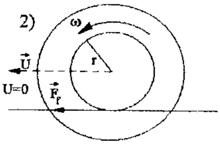
1)



As friction force reduces translational velocity and slows down rotation, so we can observe the second collision of balls.

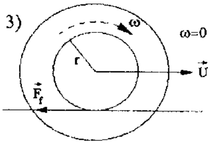
It is possible translational or angular velocity to become zero.

2)



Force of friction is directed in this way, so it will change direction of translational velocity of ball.

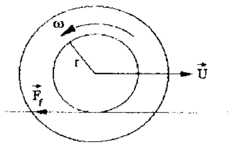
3)



In this case friction force changes direction of ω angular velocity of ball and the second collision of ball isn't possible.

In order second collision to happen the condition $\frac{t_\omega}{t_u}>1$ must fulfill.

It is interesting, why the second collision of balls happens. Let's consider experiment, when both balls change their direction of translational velocities after first collision.



As friction force reduces translational velocity and slows down rotation, so equations of motion are:

$$U=U_0-at \qquad F_{fr}r=I\xi$$

$$\omega=\omega_0-\xi t \qquad F_{fr}=ma$$

U_0-is velocity of ball after collision

ω_0-is angular velocity of ball after collision

In order to return ball U translational velocity must become zero sooner then ω angular velocity.

As we know equations of motion, we can define in which conditions translational velocity will become zero sooner, then angular velocity.

$$\frac{t_{\omega_1}}{t_{u_1}}=\frac{\frac{4I}{mR^2}\upsilon_1-\mu_1(\upsilon_1+\upsilon_2)(k+1)}{k(\upsilon_1+\upsilon_2)+\upsilon_2-\upsilon_1}>1 \qquad \frac{t_{\omega_2}}{t_{u_2}}=\frac{\frac{4I}{mR^2}\upsilon_2+\mu_1(\upsilon_1+\upsilon_2)(k+1)}{k(\upsilon_1+\upsilon_2)+\upsilon_1-\upsilon_2}>1$$

Let us consider simple case when initial velocities of balls are equal to each other: $\upsilon_1=\upsilon_2=\upsilon$. In this case, we don't have friction between balls. That's why condition of balls' return can be rewrite in the following shape:

$$k<\frac{2I}{mR^2}$$

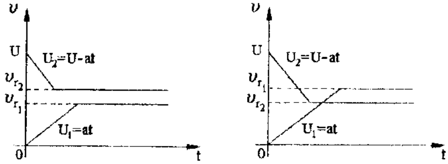
Inertial moment of sphere is: $I_s=\frac{2}{3}mR^2$

In order the second collision of spheres to take place, condition $k<\frac{4}{3}$ must fulfill, which always is carried out according to definition of k $(0\le k\le 1)$

$I_f=\frac{2}{5}mR^2$ ball will return when $k<0.8$, in the opposite case ball won't return and continues motion with terminal velocity $\frac{\upsilon_0}{9}$. In our case $k_1=0.88$ and $k_2=0.6$

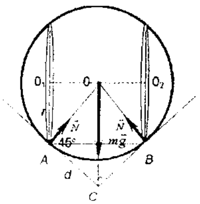
As I said, such phenomenon was also observed during experiment: After first collision one kernal will return, overtake another and collide. The second collision will happen when velocity of ball, which overtakes another, will bigger then translational velocity of another one.

Graphs of translational velocities of balls are:



On these graphs zero-level of time coincides with moment when translational velocity have become zero.

In order one ball to overtake another it is necessary to fulfill the following condition $\upsilon_{r_1}>\upsilon_{r_2}$ where υ_{r_1} and υ_{r_2} are terminal rolling velocities of balls.



As we know equations of motion we can define condition of overtaking.

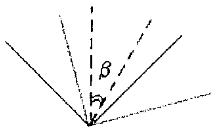
$$k<\frac{2I}{mR^2}$$

Let us project forces acting on ball on Y-axis

$$mg - 2N\cos\alpha = 0$$
$$2N = \sqrt{2}mg$$

That's why the force of friction is equal to: $F_f = \sqrt{2}\mu mg$, where μ-is friction coefficient between channel and balls.

We also considered such channel, where friction coefficients of sides were different $(\mu_1 \neq \mu_2)$ and estimated modulus of horizontal torque: $M_1 = \frac{|\mu_1 - \mu_2|}{2} mgR$.



We estimated declined channel case

In this case torque is equal to: $M_2 = 4\frac{\sin\beta}{\cos^2 2\beta}\mu mgR$

We also estimated friction of rolling: $F_r = k'\frac{N}{r}$, where k'-is coefficient of rolling friction, r-is radius of rotation.

We didn't take into account air friction because its magnitude is much less, than force of gravity: In our case: $\rho = 1kg/m^3$, $R = 4\cdot10^{-2}m$, $\upsilon = 0.5m/\sec$, $m = 5\cdot10^{-2}kg$, so condition $\rho S\upsilon^2 << mg$ fulfills, so we can neglect air friction. Lack of our solution is that we haven't taken into account friction of balls with channel during collision of balls.

Conclusion

We have made experiments and saw different kinds of second collision and explained this phenomenon.

Acknowledgements

I am thankful to Z.Osmanov for the interesting and fruitful discussions of the problem. I am grateful also to Dito Shugliashvili for the assistance during computer simulation of the problem.

12. Reaction

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The mostly evident process in this problem is the change of color during reaction.

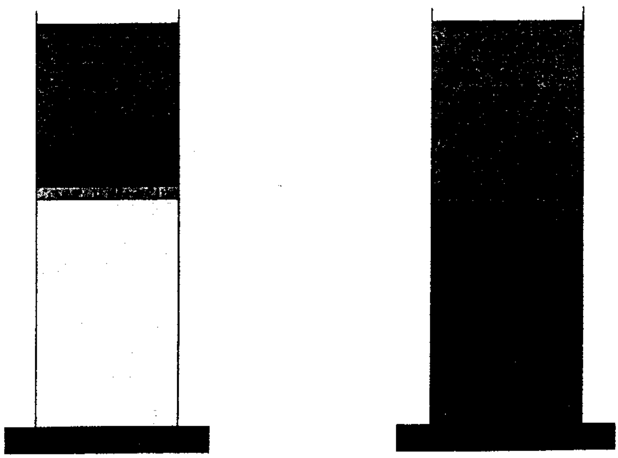
At the beginning of the reaction we have gelatin of yellow color in which there is a iodide of potassium and above it there is copper vitriol of blue color.

Now let us consider which products we will get at the end of reaction.

$$2CuSO_4 + 4KJ = 2K_2SO_4 + Cu_2J_2 \downarrow + J_2 \uparrow$$

As we can see we got precipitation Cu_2I_2 at the surface of gelatin. That is why we see brown color on the surface of the gelatin. During reaction we observe the change of copper vitriol from blue to green. It is caused by separation of iodine. At the and of reaction we see that the color of copper vitriol has changed into dark red, which also caused by active separation of iodine. At the end of reaction gelatin, in it's turn, changes color from yellow to brown. It is caused by precipitation which has brown color and by existence of K_2SO_4 in gelatin and by the rest of iodine.

during reaction end of reaction



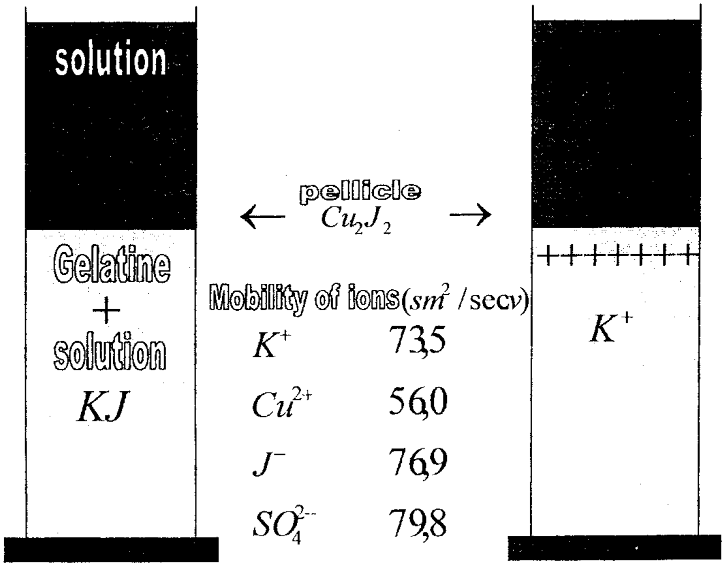
One more process, which we can observe in this problem, is formation of periodical layers, which have different colors. These layers are called rings of Lisegung. This rings are formed because of periodical precipitation. Periodical precipitation proceeds by the following principle: solution of copper vitriol lowers down and reacts with solution of potassium iodide and solution of supersaturated concentration is formed. And this solution precipitates. Then copper vitriol passes to the next layer of potassium iodide, but this layer is already poor. Then copper vitriol passes to the next layer of potassium iodide, where it reacts against and solution of supersaturated concentration is formed again and precipitation takes place too. Such process take place periodically and layers of different color , which are called Lisegung's rings are formed.

Lisegung's rings.

Rings of Lisegung

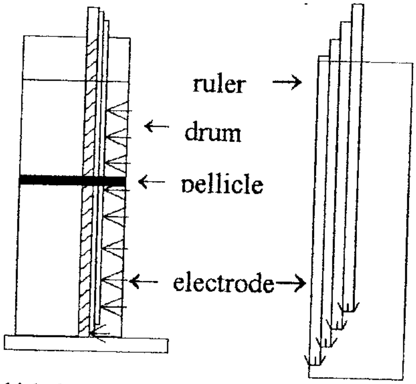
Let us consider once more what products we will get at the end of reaction.

$$2CuSO_4 + 4KJ = 2K_2SO_4 + Cu_2J_2 \downarrow + J_2 \uparrow$$

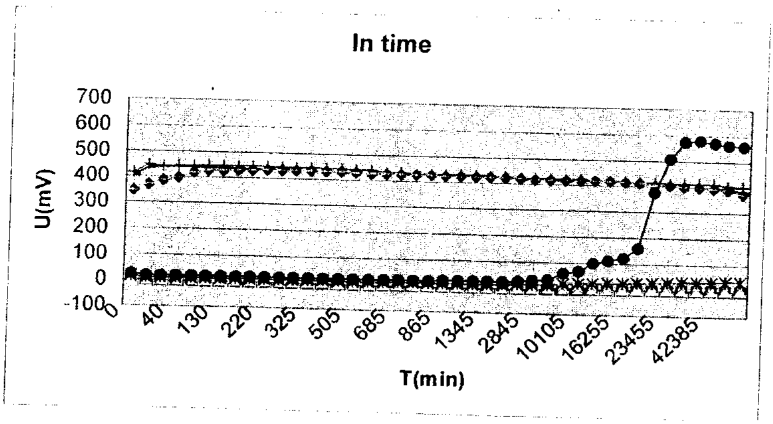


As we can see instantaneous formation of precipitation Cu_2I_2 and volatilization of I_2 happens. Precipitation Cu_2I_2 with the surface of gelatin forms hard passable pellicle for ions K^+ in gelatin and ions of SO_4^{2-} solution of copper vitriol. That why accumulation of ions of opposite sign is formed on the both sides of pellicle. Big potential jump is formed on the boundary of two mediums. Nevertheless ions of SO_4^{2-} pass down through this pellicle due to its mobility and it is confirmed by experiment.

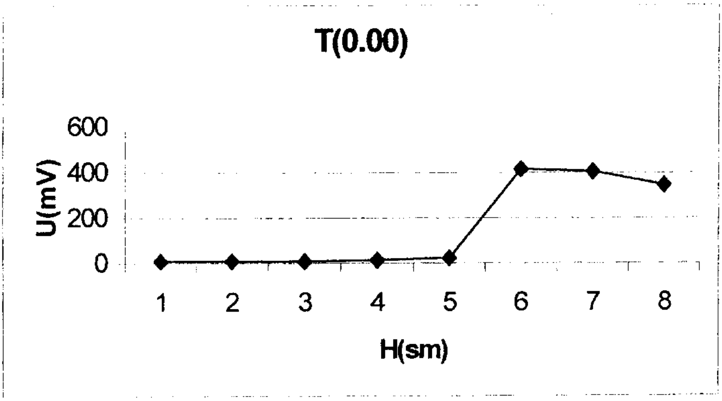
To reveal this jump we constructed the following device.

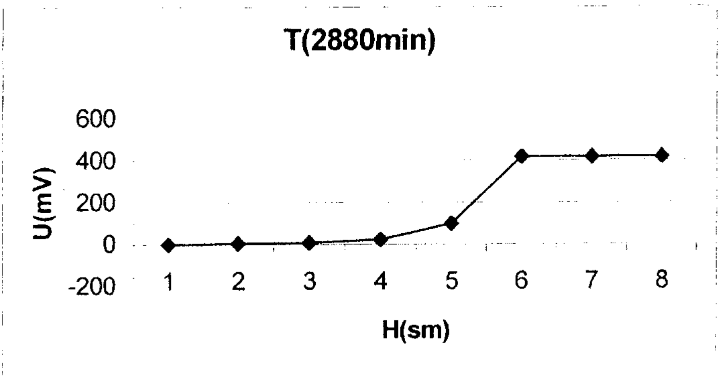


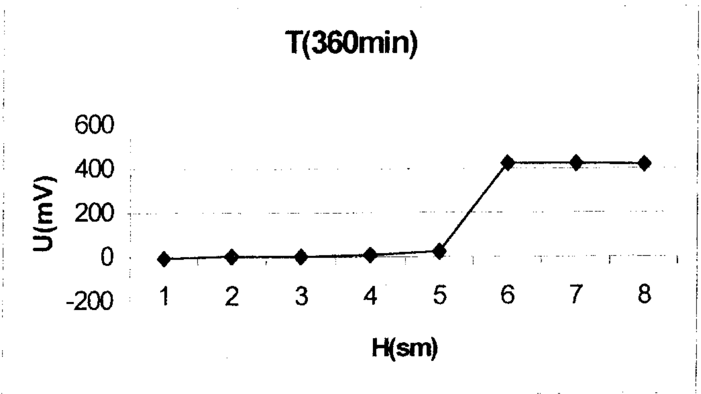
There is a wooden ruler on which the definite number of electrodes is fixed on the definite distance from each other. This ruler with electrodes is put into the cylinder Gelatin with potassium iodide and solution of copper vitriol is pored into this cylinder. After that the potential difference relatively to the first electrode is measured.
On this graph you can see how this jump changes in time.

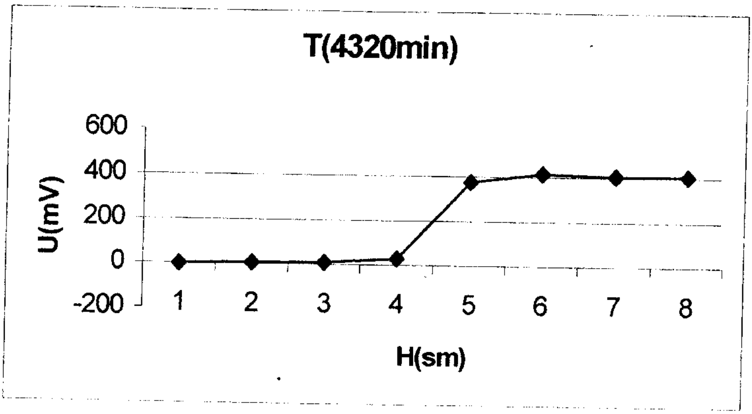


During some time it reaches maximum and then begins to decrease.


T(0.00)
600
400
200
0
U(mV)
1
2
3
4
5
6
7
8
H(sm)


T(2880min)
600
400
200
0
-200
U(mV)
1
2
3
4
5
6
7
8
H(sm)


T(360min)
600
400
200
0
-200
U(mV)
1
2
3
4
5
6
7
8
H(sm)



Acknowledgements

I am thankful to Professor Kokhta Japaridze for the very interesting and stimulating consultations. I am grateful also to Nick Sambelashvili for criticism and many interesting questions and advises.

13.Membrane electrolyzer

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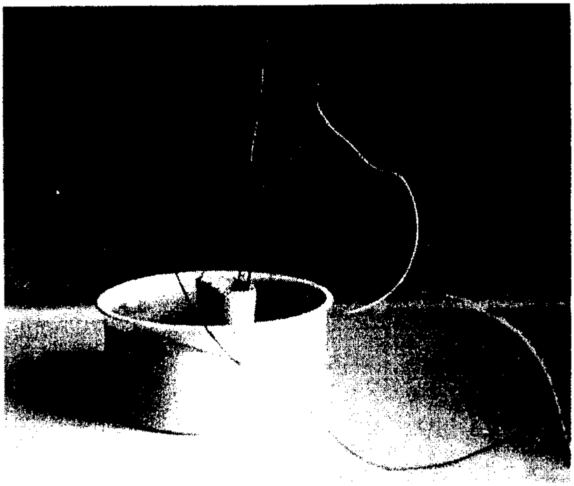
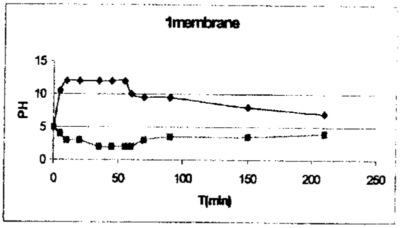
To investigate how a difference of PH-value depends on the pore size of the membrane we have made experiment. It consists in following.

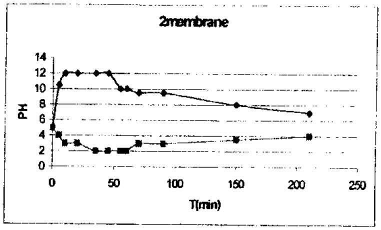


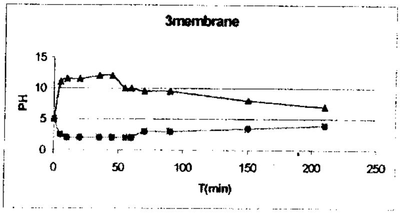
We took a test tube with electrolyte. Electrolyte is sodium sulfate .We placed two inert electrodes (lead and stainless steal) in test tube. There is membrane between them, which has cylinder shape. Membrane is stick by dichlorethane glue to acrylic plastic. Both of them are inert

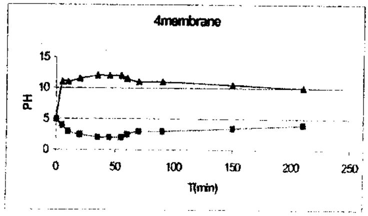
The current flows to system throw rectifier. During given period of time we measure PH-value in anodic and cathodic parts of system. PH-value we measure by litmus paper. We have some membranes with different pore size. Then we take PH-value and compare them. You can see the graphs on which there is dependence PH-value on the time of electrolyze by given diameter of membrane's pore.

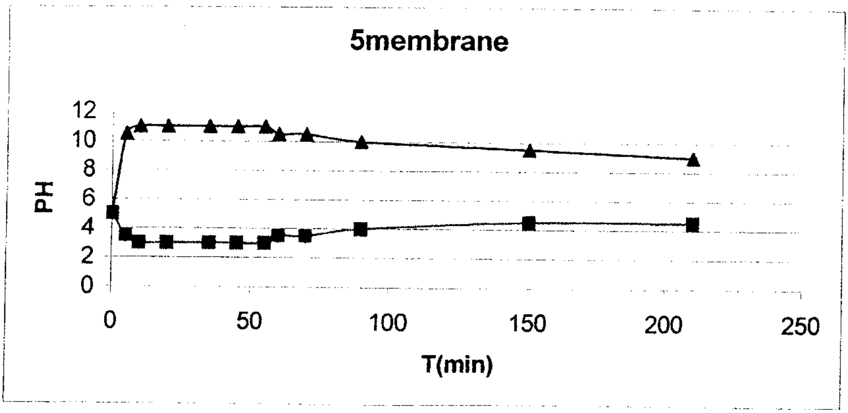
Graphs


1membrane
PH
T(min)


2membrane
PH
T(min)


3membrane
PH
T(min)


4membrane
PH
T(min)


5membrane
PH
T(min)

Now let us consider what we have during electrolyses and why we have difference of PH-value in anode cathode.

$$Na_2SO_4 + 4H_2O \rightarrow 2H_2\uparrow + O_2\uparrow + 2NaOH + H_2SO_4$$

$$NaOH \rightarrow Na^+ + OH^-$$

$$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$$

So we get liberation of oxygen and hydrogen. We can observe this phenomenon visually.

Visual

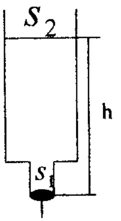
$Na^+ \quad OH^-$	$Na^+ \quad OH^-$
$2H^+ \quad SO_4^{2-}$	$2H^+ \quad SO_4^{2-}$

Also we have ions of sodium, hydrogen and

Ions OH^- and H^+ pass throw membrane to anode and cathode and ions of Na^+ and SO_4^{2-} transfer the charge. So the difference of PH-value is made by OH^- and H^+ ions.

To calculate pore size we have made the second experiment. It consists in following.

We have bottle at one side of which membrane stick. In the bottle we have the same level of electrolyte. And we calculated the hydrostatic pressure and velocity of electrolyte's leak. Then by this quantities we can calculated the coefficient of leak K.



Membrane

$$K = \frac{vl\eta}{pS_1\tau}$$

$$p = gh\rho$$

$$h = const$$

$$v = \sqrt{\frac{2gh}{1 - \frac{s_1}{s_2}}}$$

v – velocity of water

l – thickness of membrane

η – viscosity of water

p – hydrostatic pressure

S_1 – area of membrane

τ – time

h – height of water

s_2 – area of bottle

The following expression is for the pore diameter calculation.

$$D = 0,003\beta\sqrt{k/g}$$

β – coefficient of twisting, g – bulk porosity, k – coefficient of leak

It is very difficult to calculate coefficient of pore twisting, but we know that it varies from 1 to 2.So to reduce the error, we took the coefficient of twisting equal to1.5.

$$\beta \in (1;2)$$

We can calculate bulk porosity by formula

$$g = 1 - \frac{d_{ap}}{d_t}$$

$$d_t = \frac{p_d}{p_d - p_w}$$

$$d_{ap} = \frac{mg}{Vg\rho}$$

d_{ap} -apparent specific gravity

d_t - true specific gravity

V -volume of membrane

p_d -mass of membrane in dry state

p_w -mass of membrane in wet state

All membranes were scaled at the exact electric weight. By this way we can calculate diameters of pore.

You can see diameters of pore by given membranes.

Diameters

$D_1 = 167 \cdot 10^{-6}(m)$ $D_2 = 152 \cdot 10^{-6}(m)$

$D_3 = 115 \cdot 10^{-6}(m)$ $D_4 = 8.1 \cdot 10^{-6}(m)$

$D_5 = 328 \cdot 10^{-6}(m)$

Acknowledgements

I am thankful to the staff of the Cathedra of Electrochemistry and to the head of this cathedra Professor G.Agladze. Thanks to Professor J. Gvelesiani and Dr. N.Koyava.

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Reference Book on Elementary Chemistry.

14. THREAD DROPPER

Alexander Tarkhnishvili
Georgian Lyceum of Science and Technology,
School №42 named after Ilia Vekua

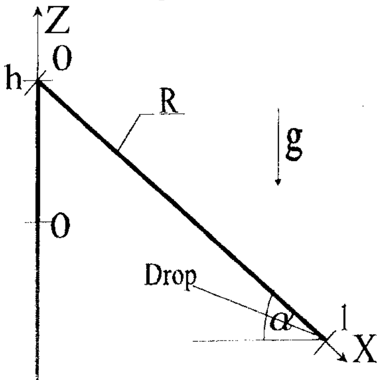
A thread consists of many thin fibers. Average radius of the fibers and average distance between neighbor fibers is of order 10 μm. Fibers are sinuous.

Thread is straight on both sides of the vessel in our model. Length of the underwater part of the thread is much bigger then radius of a fiber. That means that depth of immersion of the thread has no influence on the phenomena observed. Temperature of water is equal to temperature of surrounding air and doesn't change in time. Front surface of water in a thread is assumed to be stationary, because the potential energy change due to the surface shape variation is negligible.

The forces acting on water in a thread are force of gravity(F_G), force of surface tension(F_S) and force of viscous friction(F_V). Water can evaporate from the side surface of a thread. In some conditions this factor can has considerable influence on the motion of water.

Let us list conditions under which a drop will be observed. If H is maximal height on which water can be lifted in a thread by surface tension then h shouldn't be more than H to let water to enter external part of a thread. Also l should not extend$(h + \frac{\pi R \theta \sigma}{\rho S g}) / \sin\alpha$ to let a drop appear (R-radius of a thread, S-area occupied by water in a cross section of a thread, θ – wettability of a thread). In other case force of surface tension will stop water on the end of a thread. Also rate of evaporation shouldn't be more then rate at which water enters a thread.

Angle between drop's surface and horizon increases with growth of its mass. Drop falls when force of surface tension reaches its maximal value. Drop can form also on the way to the end of a thread. It is hardly possible if a thread is uniform. A real thread has some fibers ending out of the thread. They let some water to flow out. If we assume that water flown out of the thread has shape of a half sphere, its radius should extend following value to guarantee further forming of a drop: $\sqrt{\frac{6\theta\sigma}{\rho g}}$



Describing motion of water in a thread lets us find the time when the first drop appears and the time when it falls (Time is equal to zero in the moment of immersion of a thread in water). We write down Newton's second law for variable mass:

$$\frac{d\vec{P}}{dt} = \vec{F}_S + \vec{F}_G + \vec{F}_V$$

A computer solves this equation using Runge method of solving differential equations.

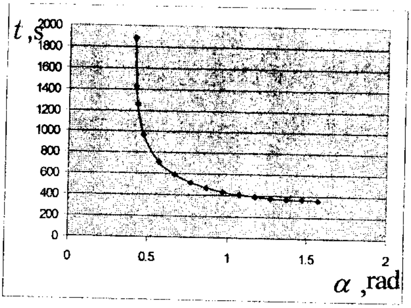


Fig.1 Dependence of time of fall of first drop on the angle α

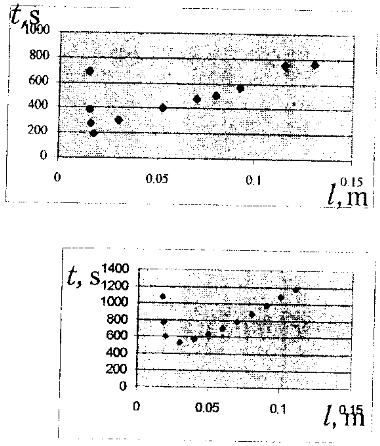


Fig.2 Experimental and theoretical dependence of time of fall of first drop on l

I would like to thank Professor Yu. Mamaladze for consultations. I am thankful to George Dolidze for discussions.

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16. ADHESIVE TAPE

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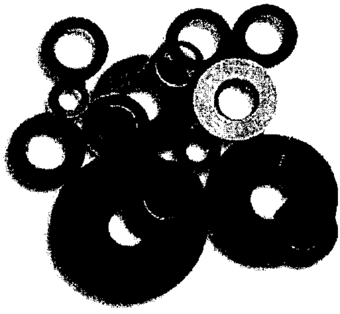

Fig1.Different adhesive tapes

So, let us at first determine what is adhesive tape? Adhesive tape – is tape, which consist of thin dielectric tape, with glue on one or both surfaces of this tape. This glue is non drying and has ability to adhere to a surface by van der Waals's forces. Such adhesive tapes are widespread: for example scotch (diaphanous adhesive tape) or insulation tape.

Fig2.Smooth surface(bottom) and non smooth(top)

Now, when we know, what is adhesive tape, we can consider the main questions of the problem. In the text of the problem there is a remark that surface must be flat. We think that surface must be smooth to get more big area of contact with tape.

Fig3.The ripping

At first we decided to determine, whether is it possible to observe by an eye the light produced by ripping, and by which tape can be got maximum effect. As flat surface we used fiberglass. During the experiment we glued adhesive tape on the fiberglass and after some time ripped it in the dark. By this we determined that the most bright light can by got by ripping of scotch. By this can be observe a weak blue light. This effect is called Deriagin-Krotova's effect and is investigated rather small, but it is known that it has electric nature.

We decided to make photo of this phenomenon. For this we glued scotch directly to the emulsive layer of photo tape Kodak Gold 400 and ripped it. You can now see the result of our experiments (see color appendix). On these photos you can see a blue places –this is the light we were interested. To proof that this is light, and not some another radiation, which could act on the film, we ripped scotch from glass, under which a photo film was placed. Glass passes only light, and adsorbs other kinds of radiation (see color appendix). Blue spots on the photos are darker, because the distance between scotch and film was enlarged. Also we discerned that light's brightness enlarges with the speed of ripping. It is very difficult to measure brightness with some apparatus, because the light is very weak and very transient. To determine approximate dependence on velocity we ripped scotch with different speed from emulsive layer of photo film Konica Centuria 800. On these photos you can see that with increasing of the speed enlarges also brightness (see color appendix).

Let us find explanation for this phenomenon. It will be better to begin solving of the problem from scotch glue's composition and it's properties. It is very difficult to determine chemical formula of the scotch's glue, but it is known, that a glue, used in adhesive tapes, is a liquid high-molecular polymer, which molecules are electric dipoles with big dipole moment. By the contact of such a glue with surface an adsorption takes place. Adsorption – is property of surface of solid bodies or liquids to connect molecules of other matter that is in liquid or aeriform condition, which is in contact with surface. In this process molecules of adsorbing matter are orienteering in one direction. As I mentioned molecules of glue are electric dipoles, and when they are polarized the double electric layer with strain about 10^8 V/m appears. Under the action of electrostatic field redistribution happens of electrons between glue and surface in the way to compensate this field.

So what will happen by the ripping? If we pulled glue from the surface, on some distance adsorption will disappear. As the result, the molecules, polarized earlier, are going to random positions, and double electric layer disappears. But there are redistributed electrons, which are also creating electrostatic field. Hereinafter the pulling can be considered like recession of flat capacitor's plates. By the increasing of a distance, potentials difference between glue and surface increases, until discharge happens. The existence of discharges can be proofed by the following experiment. We dust the plexiglass, from which scotch was ripped, by two component powder. Components must have different color and charge. By this we can see well known Lihtemberg's figures. You can see the results of our experiments now. We used mixture of the printer's HP5L toner powder (it is black) with powder of canella (it is yellow). By the mixing, toner takes positive charge and canella – negative (see color appendix). On these pictures we can see zones, in which discharge happened. Now it is possible to determine the reason of light intensity dependence on the speed. During the pulling efflux of charge happens, and as time of ripping is more, then bigger is lose of charge, so energy, which is spend on the discharge, decreases.

Also process of light liberating by the discharge is interesting. By the ripping, as I already mentioned, enlarging of the potential's difference happens. And if potential is enough for discharge, so if

$$A = eEd$$

then electrons, which are flying out from the glue and surface, under action of electrostatic field are taking energy, that is enough for ionization of gases in the air. Air consist of 21% of oxygen and 78% nitrogen. During the discharge oxygen liberates light with wave length 435 nm (12,6 eV), and nitrogen – with wave length 410 nm (13,6 eV) and 415 nm (13,3 eV). All these values of wave length's are in blue sector of visible spectrum, what is corresponding to the light observed.

So as result of my report I want to remind the question of the problem. The is written: investigate and explain the light produced by ripping. Unfortunately, because the light is very weak and very transient, we could not quantitatively measure intensity of light, and also it's dependence on external parameters: such as external pressure, humidity and other, but we investigated the light by the photos and explained using Lihtemberg's pictures and photos.

Acknowledgements:

Special thanks to my friend Goga Ayropetov, who was also worked on the solving of this problem.

Reference:

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17. SEICHE

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School №42 named after Ilia Vekua
Maxim Matosov
Georgian Lyceum of Science and Technology,
School №42 named after Ilia Vekua

Why Do Seiches Appear

Seiches are standing waves that slosh to and fro in deep lakes, from one end to another. Changes in barometric pressure or other disturbances may start such standing waves.

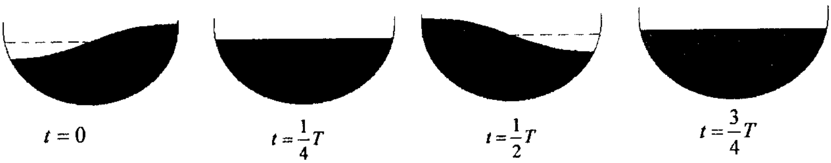


fig.1

On the fig.1 single-nodal point Seiche is shown. Nodal points are points, which don't take part in oscillations.

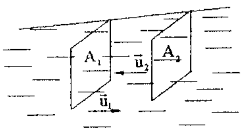


fig.2

We can write equation of motion

$$\begin{cases} h\dfrac{du}{dx} = -\dfrac{d\zeta}{dt} \\ \dfrac{du}{dt} = -g\dfrac{d\zeta}{dx} \end{cases}$$

where u -is velocity of water along axis x

ζ -is amplitude of seiche

h -is depth of lake

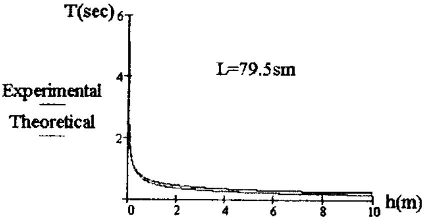
$$\frac{a_x}{a_y} = 10^6$$ a_x -is vertical component of acceleration

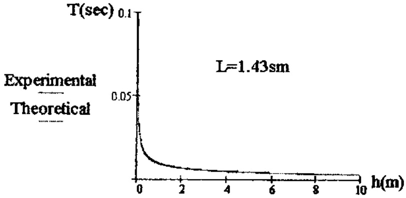
a_y -is horizontal component of acceleration

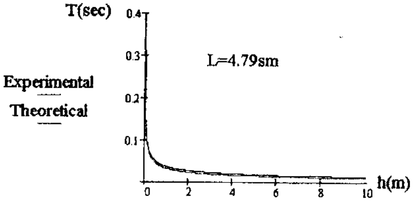
$$T_1 = \frac{2l}{\sqrt{gh}}$$ (Marian's equation)

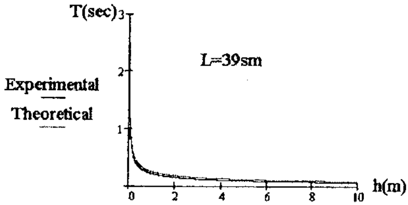
T_1 - is period of seiche
l - is length of lake
g - is free fall acceleration

Comparisons of Theory with Experiment









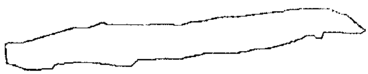


fig.3

Loch Earn lake (Scotland) $l = 10km \;\; h = 60m$

$T_{th} = 14\text{min}$

$T_{ex} = 14.5\text{min}$

Difference 4%

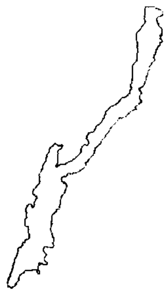


fig.4

Lake George (New Walse) $l = 30\,\text{km}$ $h = 5.5\,\text{m}$

$T_{th} = 136\text{min}$

$T_{ex} = 131\text{min}$

Difference 4%

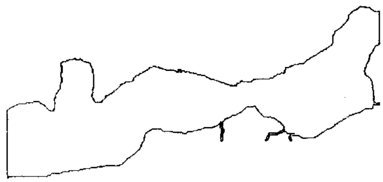


fig.5

Lake Jeneva (Switzerland) $l = 70\,\text{km}$ $h = 160\,\text{m}$

$T_{th} = 59\,\text{min}$

$T_{ex} = 73.5\,\text{min}$

Difference 25%

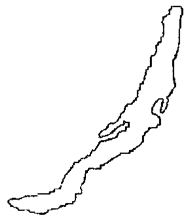


fig.6

Lake Baikal (Russia) $l = 665\text{km}$ $h = 680\,\text{m}$

$T_{th} = 4.5 hours$

$T_{ex} = 4.64 hours$

Difference 3%

Two Nodal Point Seiches

After solution of transport equation we get equation for amplitude of seiche

$$\zeta = \frac{Th}{2l}\cdot C\cdot\cos\frac{\pi x}{l}\cos\frac{2\pi t}{T}$$

From this equation it follows that, coordinates of nodal points are $x = \frac{1}{4}l$ and $x = \frac{3}{4}l$

$T_2 = \frac{1}{2}T_1$ where T_2 -is period of two nodal point seiche

T_1 -is period of single nodal point seiche

For Morge $T_{th2} = 35.1\,\text{min}$

$T_{ex2} = 35.5\,\text{min}$

Difference between theory and experiment $\approx 1\%$

For Loch Earn Lake $T_{th2} = 7\,\text{min}$

$T_{ex2} = 8.1\,\text{min}$

Difference between theory and experiment $\approx 16\%$

Multinode Seiches

After solution of equation of motion we get

$$\begin{cases} u = A\sin\frac{m\pi x}{a}\cos\frac{n\pi y}{b}\sin\frac{2\pi t}{T} \\ \upsilon = B\cos\frac{m\pi x}{a}\sin\frac{n\pi y}{b}\sin\frac{2\pi t}{T} \end{cases}$$

a -is length of lake

b -is width of lake

m -is number of nodal points along length

n -is number of nodal points along width

$$T = \frac{2}{\sqrt{gh}}\left(\frac{m^2}{a^2}+\frac{n^2}{b^2}\right)^{-\frac{1}{2}}$$

Internal Seiches

Internal seiches consist of two or more layers. The reason of appearance of internal seiches is difference in densities. In two layer internal seiche the higher layer is called epilimnion, lower layer is called hypolimnion.

$t=0$ $\quad t=\frac{1}{4}T$ $\quad t=\frac{1}{2}T$ $\quad t=\frac{3}{4}T$

fig.7

We can rewrite equation of motion for internal seiche

$$\begin{cases} h\dfrac{du}{dt}+\dfrac{d}{dt}(\zeta-\zeta')=0 \\ h'\dfrac{du'}{dx}+\dfrac{d\zeta'}{dt}=0 \end{cases}$$

where ζ -is amplitude of epilimnion

ζ' -is amplitude of hypolimnion

h - is height of epilimnion

h' - is height of hypolimnion

After solution we get

$$T=2l\left(\frac{\rho'}{\rho'-\rho}\cdot\frac{1}{g}\left(\frac{1}{h}+\frac{1}{h'}\right)\right)^{\frac{1}{2}}$$

ρ -is density of epilimnion,

ρ' -is density of hypolimnion.

For Loch-Ern Lake

$h=16m$

$h'=44m$

$\rho=0{,}9991\,\frac{g}{sm^3}$

$\rho'=0{,}9999\,\frac{g}{sm^3}$

$T_{th}=18hours$

$T_{ex}=15.2hours$

Difference between theory and experiment $\approx 16\%$

Seiches in Lakes with Nonrectangular Basin

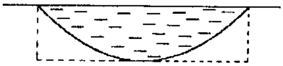


fig.8

$$T_1 = 1.11T_0$$

where T_1 -is period of seiche in lake on the fig.8
T_0 -is period of rectangular lake

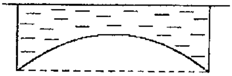


fig.9

$$T_2 = 0.95T_0$$

where T_2 -is period of seiche in lake on fig.9

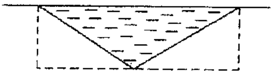


fig.10

$$T_3 = 1.05T_0$$

where T_3 -is period of seiche in lake on fig.10

Conclusions

We have investigated seiches in different lakes, presented theoretical dependencies on different parameters: on length and depth of lake, on numbers of nodal point, on densities of different layers, on shape of basin. We have made experiments and compared with theory. Difference between them, as you saw, is very small. We have, also, compared theory with experimental data for lakes and in this case too theory and reality are in very good agreement with each other.

We have, also, created model of seiche: rectangular aquarium, which characterizes dependence on different parameters with accuracy approximately 5%, which is very good approximation for hydrodynamic problem.

Acknowledgements

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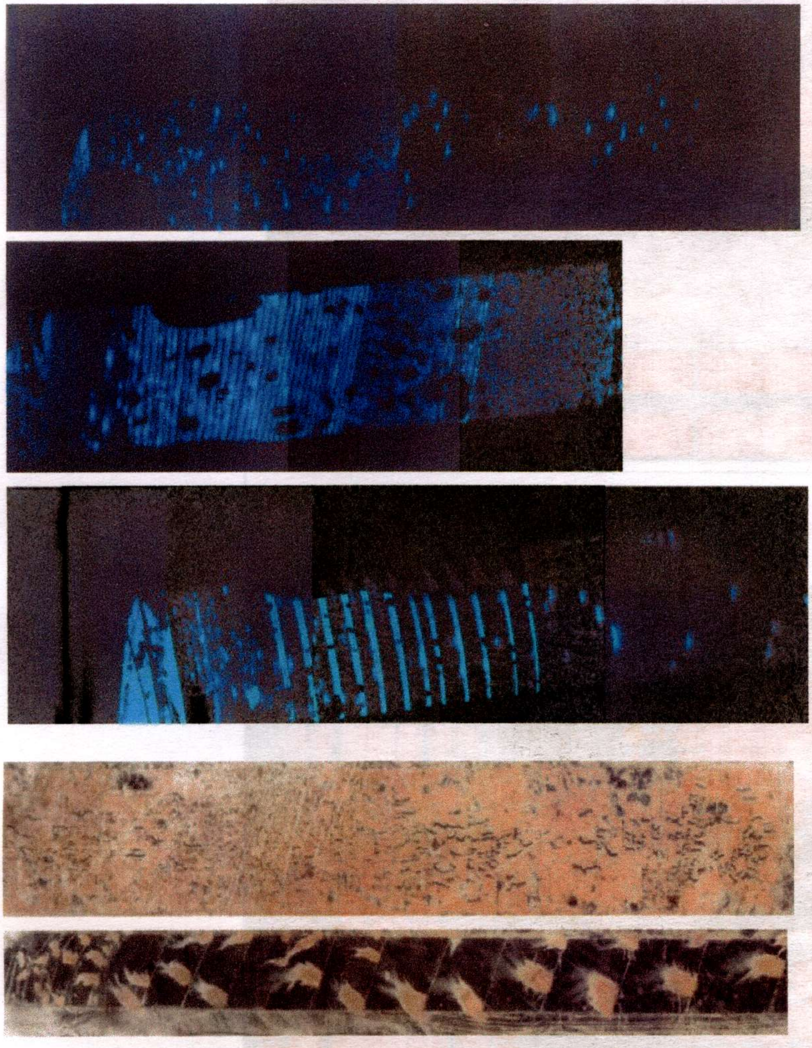
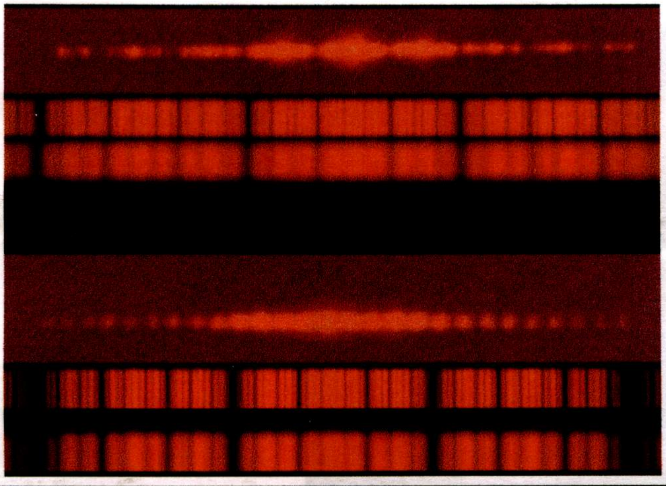
References

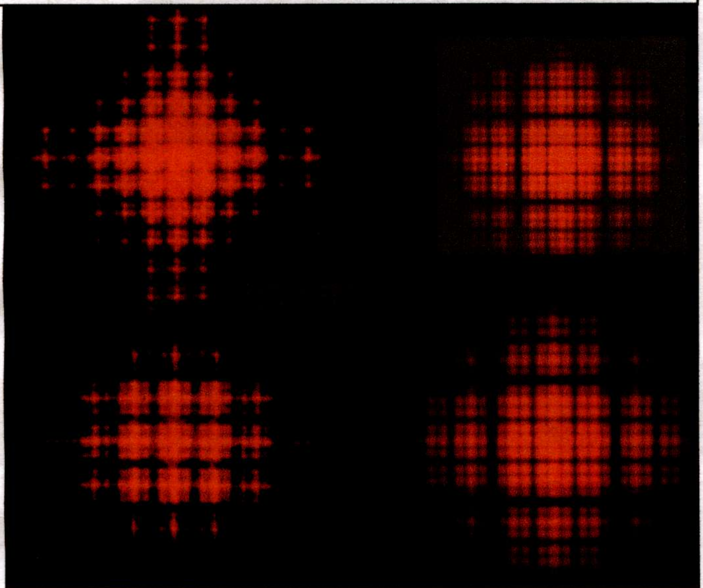
Shulejkin V.V., Physics of Sea, Moscow 1953



Dependence of the light's brightness on the speed(top three photos),
And Lihtemberg's pictures(bottom)



Difraction pictures on Cantor bars with 4 power(top 3 lines) and 5 power (bottom 3 lines). First line is experimental results and under them theoretical.



Difraction pictures on Cantor dust with 4 power(top) and 5 power (bottom). Left pictures are - experimental and right- theoretical.