ART AN AMAZING FACT IN SCIENCE

Editor
Dina Izadi

THE IYPT PPTS

COLLECTED FROM SEVERAL YEARS

A BOOK IN PHYSICS PROBLEMS BY
AYIMI & ADIB

ART AN AMAZING FACT IN SCIENCE

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**The IYPT POWER POINTS
COLLECTED FROM SEVERAL YEARS**

A BOOK IN PHYSICS PROBLEMS BY
AYIMI & ADIB

Autumn 2024

Ariaian Young Innovative Minds Institute,
AYIMI
International Center for Research in Education

ADIB Science and Technology,
Cultural and Artistic Institute

ART AN AMAZING FACT IN SCIENCE

The IYPT PPTs Collected from several years

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Dina Izadi

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INTRODUCTION

This book includes a selection of the presented problems solutions (PPTs) in International Young Physicists' Tournament, IYPT , during several years . Division of Education in different countries has recognized this tournament as a way to offer the participants an opportunity to discuss in depth the problems they have solved which may enhance understanding of their concepts.

These challenges not only make learning fun but also promote critical thinking, problem - solving and collaboration among students. For example investigating the physics of *liquid stains,* particularly coffee drops on a smooth surface can be fascinating. In this problem the spreading mechanisms on a asymmetric microstructure and wetting situations are illustrated. Newton cradle as a popular toy which shows fundamental physics concepts demonstrates the principles of conservation of momentum and energy through a series of swinging spheres or metal balls suspended by strings. By challenging existing assumptions, it allows opening up new perspectives and solutions that others might not consider and imagining different scenarios helps us understand the problem from multiple angles.

Imagination strengthens our ability to think critically and adapt to changing circumstances which generate a wide range of ideas, some of which may be truly groundbreaking. By embracing imagination as a tool for problem-solving, we can unlock our full creative potential and contribute to a more innovative and dynamic world.

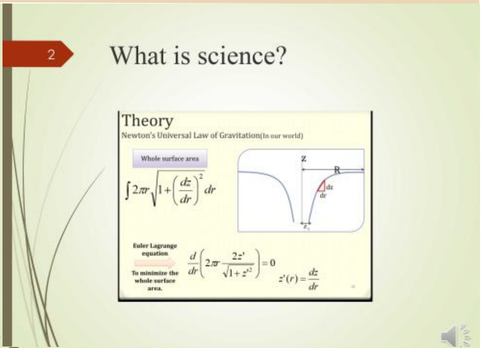
The linking meaningful physics and meaningful learning is a challenge to prepare students to cope with a world of increasing complexity. Students by giving a definition of the model in solving problems, show it is a human construction with a creation of the mind. Most of the model's functions emphasize description and predictions but a distinction is made between real data in experiments and theory which should be analyzed carefully. For an effective information processing to assess whether the data supports or contradicts the theory and the theoretical frameworks against empirical data, the critical factors such as task evaluation and simulation should be considered. But as an essential part of achieving success it is suggested the art and science combine together. Art and science, while seemingly distinct, share a deep connection that can lead to innovative and inspiring collaborations.

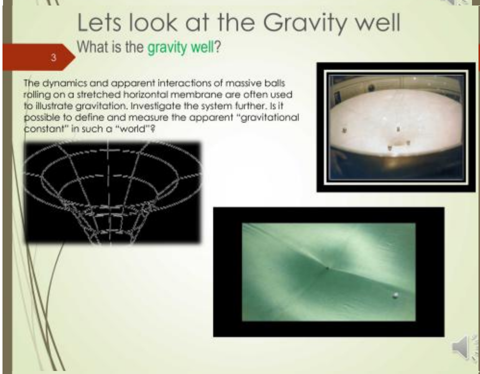
Artists can create stunning visuals to represent complex scientific data and reveal hidden patterns and insights that might not be apparent through traditional analysis . Cross-Disciplinary Collaboration between Artists and scientists causes inspiring innovation and fostering creativity to generate new ideas and approaches to problem-solving. Art can inspire scientific thinking, while science can provide new materials and techniques for artistic expression. By combining their unique strengths, this interdisciplinary approach has the potential to revolutionize different fields in science education.

Art in Science Education (ASE) offers a new model for 21st century teaching to help the shift from human labour to mechanical labour based on human imagination and novelties.

Dina Izadi

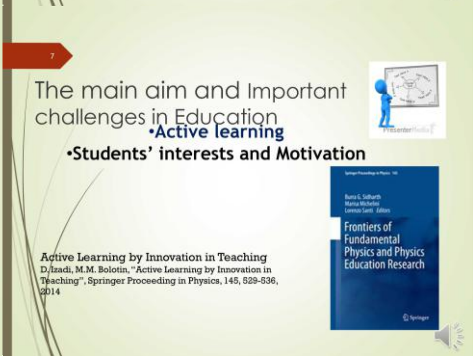

ART an amazing fact in Science
Dr. Dina Izadi
Researcher & President
AYIMI & ADIB International Research and Artistic Institutes
www.ayimi.org
info@ayimi.org
1


2
What is science?
Theory
Newton's Universal Law of Gravitation(In our world)
Whole surface area
Euler Lagrange equation
To minimize the whole surface area.


Lets look at the Gravity well
What is the gravity well?
3
The dynamics and apparent interactions of massive balls rolling on a stretched horizontal membrane are often used to illustrate gravitation. Investigate the system further. Is it possible to define and measure the apparent "gravitational constant" in such a "world"?


4
What is ART ?


6
Sundial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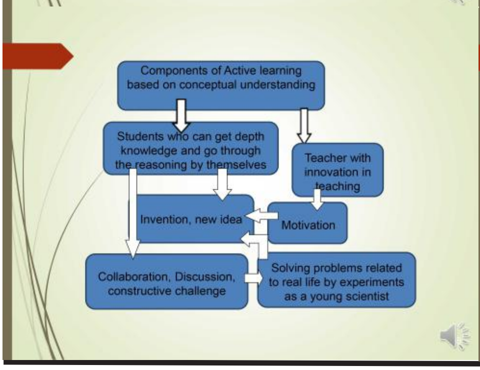
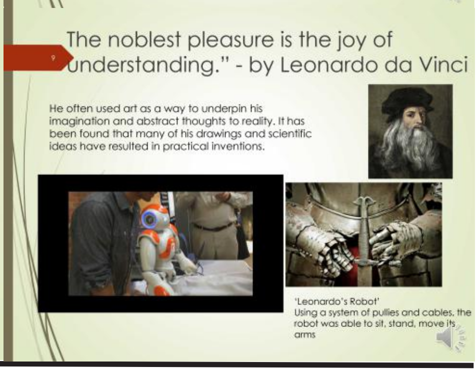
The main aim and Important challenges in Education
•Active learning
•Students' interests and Motivation
Active Learning by Innovation in Teaching
D. Izadi, M.M. Bolotin, "Active Learning by Innovation in Teaching", Springer Proceeding in Physics, 145, 529-536, 2014
Frontiers of Fundamental Physics and Physics Education Research


Components of Active learning based on conceptual understanding
Students who can get depth knowledge and go through the reasoning by themselves
Teacher with innovation in teaching
Invention, new idea
Motivation
Collaboration, Discussion, constructive challenge
Solving problems related to real life by experiments as a young scientist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The noblest pleasure is the joy of understanding." - by Leonardo da Vinci
He often used art as a way to underpin his imagination and abstract thoughts to reality. It has been found that many of his drawings and scientific ideas have resulted in practical inventions.
'Leonardo's Robot'
Using a system of pullies and cables, the robot was able to sit, stand, move its arms

10

So :The reason why art is necessary to science

- Because things we are able to **imagine** in our mind are the things we can also **create**

11

Art and imagination

Imagination is a key which by mixing with scientific ideas can be used in a research projects

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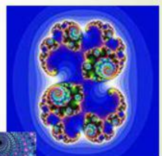
What are the Fractals?

Fractal is a self-similar geometrical object with a fractal dimension.



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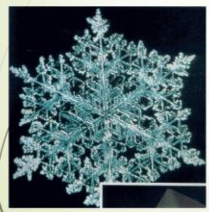
FRACTALS IN PHYSICS

Snowflake



From: Tipler, Physics for Scientists and Engineers, 4th Edition

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Fractals in Biology

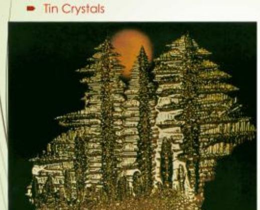
The arterial system of a kidney

Broccoli

15

FRACTALS IN ART

- Tin Crystals



From: Tipler, Physics for Scientists and Engineers, 4th Edition

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"The Greatest Scientists are Artists as well"

Einstein

17

How to develop high level skills in solving problems

- Think about the problem
- Suggest a typical idea and make hypothesis
- Build an apparatus with your imagination
- Do the experiments with try and error
- Show all art are used in solving scientific problems
- Finally analyze and interpret the results

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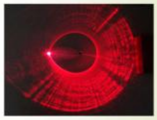
When a laser beam is aimed at a wire, a circle of light can be observed on a screen perpendicular to the wire



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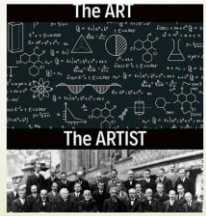
Experimental setups and artistic photos and Videos

some of the greatest discoveries in science have used some form of art



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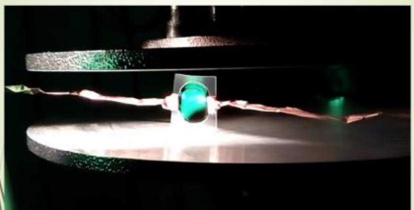
- A soap film in an electric field rotates in its plane



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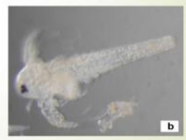
Determination of the Safe Dose of Euphorbia rigida Plant Extract to be used as Biopesticide, Antimicrobial and Antioxidant with Brine shrimp lethality assay
(IMSEF 2020 Gold Medalist, TURKEY)



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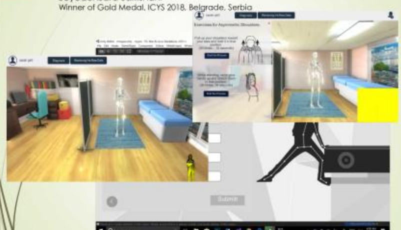
The Intelligent Diagnosis and Treatment of Postural Deformities by Analyzing the Given Data from Kinect Camera
SeyedehSara Jalilishani
Winner of Gold Medal, ICYS 2018, Belgrade, Serbia



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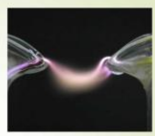
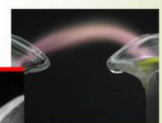
Problem:

If a high voltage is applied to a fluid (e.g. deionized water) in two beakers which are in contact, a fluid bridge may be formed. Investigate the phenomenon.

(Team Iran , Gold Medalist, IYPT 2012 in Germany)





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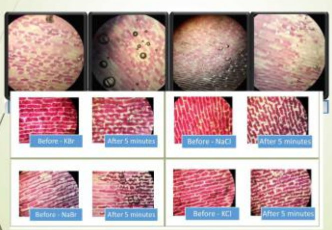
The effect of different salts on onion cell structure



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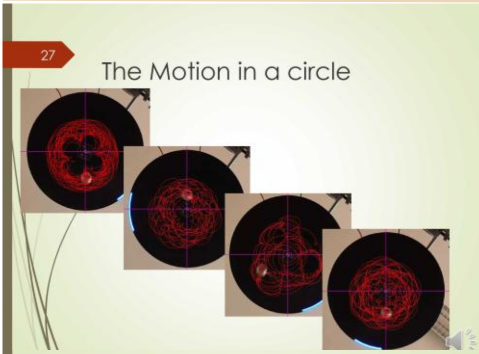
Experimental setup

A pendulum consists of a strong thread and a bob. When the pivot of the pendulum starts moving along a horizontal circumference, the bob starts tracing a circle which can have a smaller radius, under certain conditions. Investigate the motion and stable trajectories of the bob.
IYPT 2016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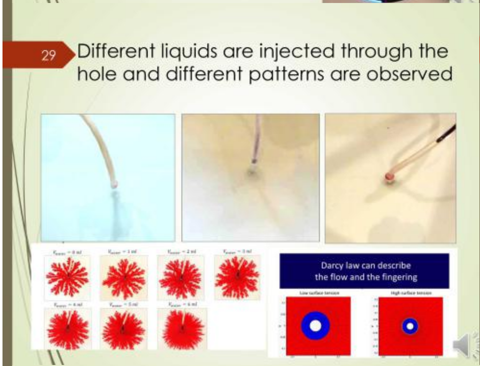
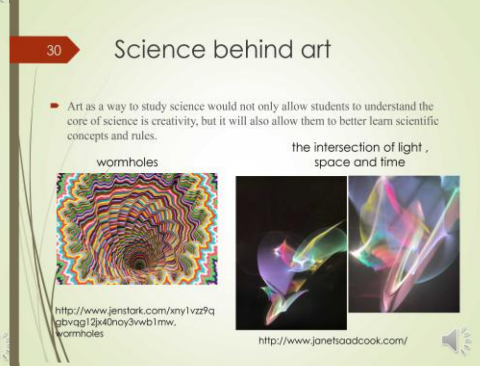
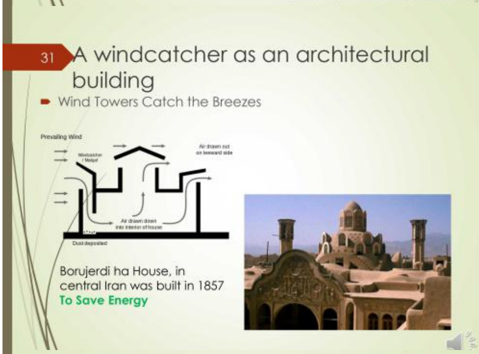
The Motion in a circle


Interesting waves
28
A long string of beads is released from a beaker

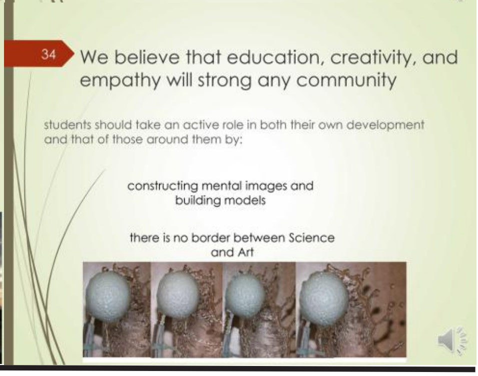

29
Different liquids are injected through the hole and different patterns are observed
Darcy law can describe the flow and the fingering


30
Science behind art
Art as a way to study science would not only allow students to understand the core of science is creativity, but it will also allow them to better learn scientific concepts and rules.
wormholes
the intersection of light , space and time
http://www.jenstark.com/xny1vzz9qgbvqg12jx40noy3vwb1mw, wormholes
http://www.janetsaadcook.com/

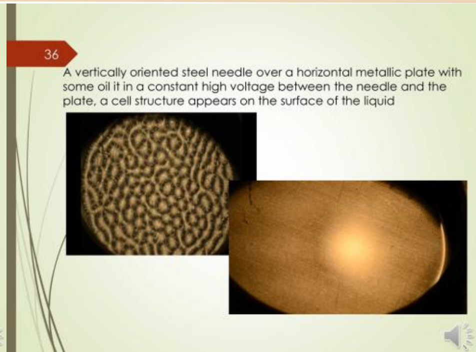

31
A windcatcher as an architectural building
Wind Towers Catch the Breezes
Prevailing Wind
Borujerdi ha House, in central Iran was built in 1857
To Save Energy

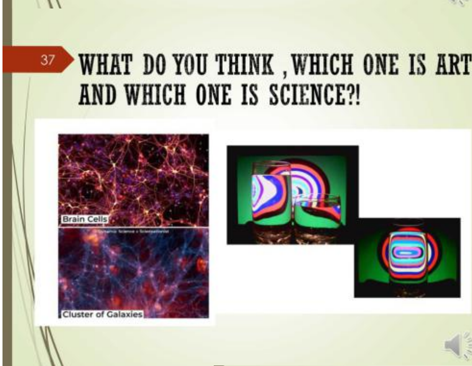

32
Choga Zanbil Temple in Zigorat
height of 62m and a length of 105.20m for each side of the first floor


33
Pasargad Palace in Shiraz


34
We believe that education, creativity, and empathy will strong any community
students should take an active role in both their own development and that of those around them by:
constructing mental images and building models
there is no border between Science and Art


35
Tippe Top as a toy was a physics puzzle that fascinated at least two Nobel Prize Winners
Wolfgang Pauli and Niels Bohr observe the Tippe Top (www.aip.org/history/esva).


36
A vertically oriented steel needle over a horizontal metallic plate with some oil it in a constant high voltage between the needle and the plate, a cell structure appears on the surface of the liquid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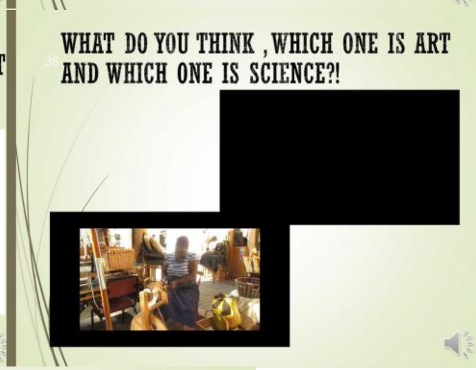
WHAT DO YOU THINK ,WHICH ONE IS ART AND WHICH ONE IS SCIENCE?!
Brain Cells
Cluster of Galaxies


WHAT DO YOU THINK ,WHICH ONE IS ART AND WHICH ONE IS SCIENCE?!


Now it is the time for you ,
Ring the bell,
change your mind,
and think more curiosity about
ART in your Science Projects

International Young Physicists' Tournament (IYPT)

Andrzej Nadolny

History and development of the International Young Physicists' Tournament

History of the IYPT

Young Physicists' Tournament was founded at the Physics Faculty of Moscow State University in 1979 as a competition for secondary school students from Moscow and its vicinity.

Since 1988 *International Young Physicists' Tournaments* are organised. They took place

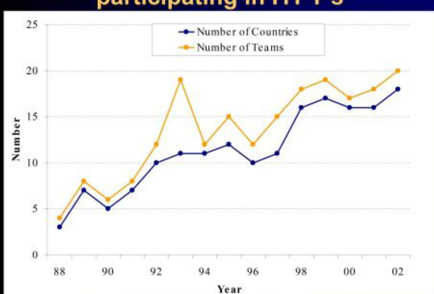
- until 1993 in Russia,
- since 1994 in other countries (every year in a different country).

Countries participating in the IYPT

YEAR	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Armenia	-	-	-	+	-	-	-	-	-	-
Australia	-	-	-	-	-	+	+	+	+	+
Austria	-	-	-	-	-	+	H	+	+	+
Belarus	+	+	+	+	+	+	+	+	+	+
Bulgaria	-	-	-	-	-	-	-	+	+	+
Croatia	-	-	-	-	-	-	-	-	O	+
Czech Republic	+	+	+	+	H	+	+	+	+	+
Finland	-	-	+	-	O	+	+	+	H	+
Georgia	+	+	+	H	+	+	+	+	+	+
Germany	-	-	+	+	+	H	+	+	+	+
Hungary	+	+	+	+	+	+	+	H	+	+
Moldavia	+	-	-	-	-	-	-	-	-	-
Mexico	-	-	-	-	-	+	+	+	-	+
The Netherlands	+	H	+	-	-	+	+	+	+	+
Poland	+	+	H	+	+	+	+	+	+	+
Republic of Korea	-	-	-	-	-	-	-	O	O	+
Russia	H	+	+	+	+	+	+	+	+	+
Slovakia	+	+	+	-	+	+	+	+	+	+
Sweden	-	+	O	-	+	+	+	+	+	O
Switzerland	-	-	-	-	O	-	-	O	O	+
USA	-	-	-	-	-	-	+	-	+	O
Ukraine	+	+	+	+	+	+	+	+	+	H
Uzbekistan	+	+	+	+	+	+	+	-	-	-

H host country + participating team O observer

Number of Countries and Teams participating in IYPT's



"Definition" of the IYPT

The International Young Physicists' Tournament (IYPT) is a competition among teams of secondary school students in their ability to solve complicated scientific problems, to present solutions to these problems in a convincing form and to defend them in scientific discussions, called Physics Fights (PF)

[from *the Regulations of the International Young Physicists' Tournament*]

Description of the competition

- 17 problems, to be solved by participants, are chosen half a year before the IYPT and published, e.g., on the World Wide Web.
- Teams, consisting of 5 students, work out solutions of the problems and prepare their presentations - reports
- During the Tournament teams present their solutions as ***Reporter***. The problems are however not chosen by themselves, but *challenged* by the ***Opponent.***

Structure of the IYPT

- The main element of the IYPT is a scientific discussion called ***Physics Fight (PF)***
- 3 or 4 teams participate in a PF
- There are 3 or 4 ***Stages*** in one PF (the number of stages equals the number of teams).
- The official language is ***English.*** (Russian is still allowed in the following discussion)

Rôles of teams in each stage

- REPORTER - presents the solution to the problem
- OPPONENT - puts questions and criticises the report
- REVIEWER - evaluates the presentations of Reporter and Opponent
- In subsequent Stages teams play all of these rôles according to a special scheme

Scheme of the Physics Fight (PF)

Three teams PF

Team \ Stage	1	2	3
1	Reporter	Reviewer	Opponent
2	Opponent	Reporter	Reviewer
3	Reviewer	Opponent	Reporter

Scheme of the Physics Fight (PF)

Four teams PF

Team \ Stage	1	2	3	4
1	Reporter	Observer	Reviewer	Opponent
2	Opponent	Reporter	Observer	Reviewer
3	Reviewer	Opponent	Reporter	Observer
4	Observer	Reviewer	Opponent	Reporter

The performance order in the Stage

Reserved time in minutes

- The Opponent challenges the Reporter for the problem 1
- The Reporter accepts or rejects the challenge 1
- Preparation of the Reporter 5
- Presentation of the report 12
- Questions of the Opponent to the Reporter
- and answers of the Reporter 2
- Preparation of the Opponent 3
- The Opponent takes the floor (maximum 5 min.)
- and discussion between the Reporter and the Opponent 15
- Questions of the Reviewer to the Reporter
- and the Opponent and answers to the questions 2
- Preparation of the Reviewer 2
- The Reviewer takes the floor 3
- Concluding remarks of the Reporter 2
- Questions of the Jury and grading 2

Grading

Teams (their performances) are graded by a Jury, which is composed of members from different countries. The Jury takes into account all presentations of the members of the team, questions and answers to the questions, and participation in the discussion

Agenda of the IYPT

- All teams participate in 5 **Selective PFs**. Selective PFs are carried out according to a special schedule, following the rule that, if possible, no team meets another team more than once.
- The best 3 teams participate in the **Final PF**.

Features of the IYPT

- Problems of complex character
- Team work
- Long-term work
- Public presentation of the results
- Interpersonal discussion (defending of own solution, immediate satisfaction)
- Equal achievements of boys and girls

Participation in the IYPT develops following *skills*

- Ability to use scientific methods and tools for solving complex problems
- Ability to work in a team
- Communication skills (human interactions)
- Adaptation to an international environment
- Leadership skills (every team is headed by a captain)


International Organizing Committee (IOC)
• formulates the problems for the IYPT
• establishes and changes the Regulations
• elects
• the President
• the Secretary General
• 2 Members of the Executive Committe
• accepts host country for the next IYPT


Executive Committe (2002/03)
• President of the IYPT - Gunnar Tibell (Sweden)
• Secretary General - Andrzej Nadolny (Poland)
• Chairpersons of the LOC:
– Valery Koleboshin (Ukraine) - last IYPT
– Sven Liungfelt (Sweden) - next IYPT
• 2 Members elected by the IOC
– Rudolf Lehn (Germany)
– Valentin Lobyshev (Russia)

Boiled Egg

Republic of Korea
Superheated
Lee Sang kyu

Contents

1. Experimental setup
   1. Torsion viscometer
2. Theoretical Explanation
   1. Force induced by viscosity
   2. Energy loss in one period
   3. Inertia of moment
   4. Solidification of egg
3. Experiment
4. Analysis
5. Result
6. Conclusion

1. Problem

- Construct a torsion viscometer. Use it to investigate the differences in the 'viscous' properties of hens' egg that have been boiled to different extents.

2. Basic Idea

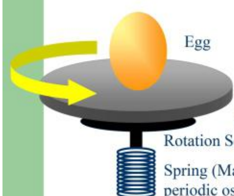
- Torsion viscometer
  - Device to measure viscosity using the fact that viscosity of liquid intervenes rotation of torsion pendulum.
  - Using this principle, it is possible to know the egg's viscous properties without breaking it.
- Viscosity

$$\tau = \mu \frac{dv}{dy}$$

τ : Shear stress $\quad \mu$: viscosity

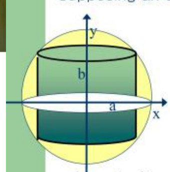
v : Velocity $\quad y$: depth

3. Experimental Setup



4. Theoretical Explanation

Liquid in the egg will make the oscillation damping.
Supposing an egg as an ellipsoid :



ω : angular velocity

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}=1 \qquad y=b\sqrt{1-\frac{x^2}{a^2}}$$

$$A_{cylinder} = 4\pi xy$$

$$F_{viscosity}(x) = A\mu\frac{dv}{dy} = 4\pi xy\mu\omega$$

$$\int_0^a F dx = \frac{4}{3}\pi a^2 b\mu\omega$$

Theoretical Explanation cont.

Equation of damping oscillation of torsion device is :

$$I\ddot{\theta}+k\theta+b\dot{\theta}=0$$

Resisting force in the damping oscillation is :

$$F_r = b\dot{\theta} = b\omega = \frac{4}{3}\mu\omega\pi a^2 b$$

$$\therefore b = \frac{4}{3}\mu\pi a^2 b$$

Energy loss in one period
(Energy damping)

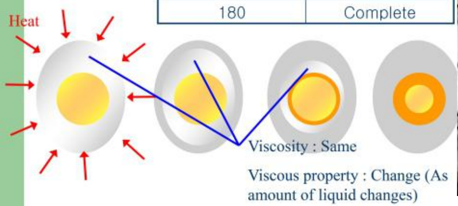
- Energy damping
  - From the device
    - Device has toothed wheels, making the loss of energy proportional to its rotating amount = angular position change
  - From the egg
    - Expected to be proportional to (angular velocity)^2, as is any damping oscillation.

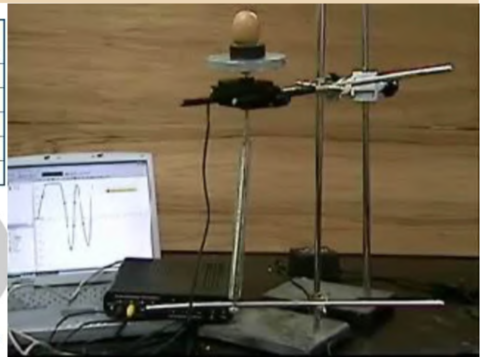
$$-\frac{dE}{dt} = b\dot{\theta}^2$$

Solidificati

- Supposed b

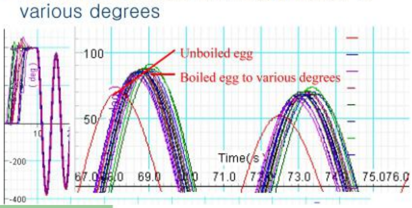
Boiling time (sec. In 100℃ water)	Thickness of solidified albumen
30	1.9mm
60	2.4mm
90	3.35mm
120	4.4mm
180	Complete





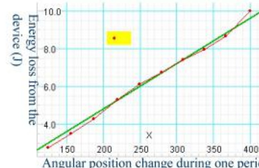
All the damping oscillation

- Damping Oscillation with eggs boiled to various degrees



Analysis

- Energy loss from the device is proportional to the angular position change, as the toothed wheel in the sensor is the main friction source.



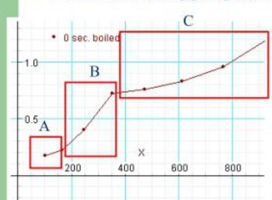
$$\Delta E = 0.23980\theta$$

Analysis cont.

- Leaving out energy loss from the device, the one from egg remains to be proportional to (angular velocity)^2 (Everything in 15℃)

Why not proportional?

- 0 sec. Boiled egg's graph is :



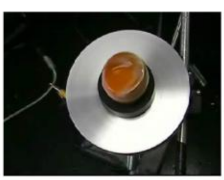
A region : Too slow : Less energy loss from the device

B region : Almost same as expected

C region : Too fast : Albumen can't follow the solid part : less viscous property than expected.

Why less viscous than expected?

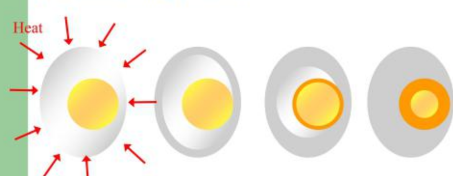
Unboiled egg



30 sec. Boiled egg

Why less viscous than expected? Cont.

- Actual boiling process



“Viscous effect” of an egg when boiled to different extent

- Result

Boiled time(s)	b	Viscosity, (relative viscous property)
0	4.88e−5	1.457 Pa·s (1)
30	2.58e−5	(0.529)
90	1.90e−5	(0.389)
120	1.22e−5	(0.250)
150	7.32e−6	(0.150)
180	7.27e−6	(0.149)

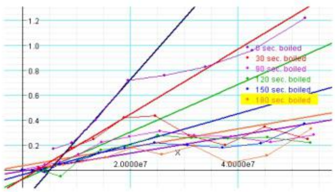
Liquid	Viscosity (Pa·s)
Glycerin	1.17
Lubricating oil	0.1~1
Water	0.00114

Conclusion

- A torsion viscometer can be made using damping effect of viscous liquid.
- Measured viscosity
  - 1.457 Pa·s
- Egg is to solidify when boiled, making its viscous effect less.
  - Egg liquid is so sticky that some expectations are wrong about the egg
  - And as its solidification fixes yolk at particular position, make the egg much less viscous.

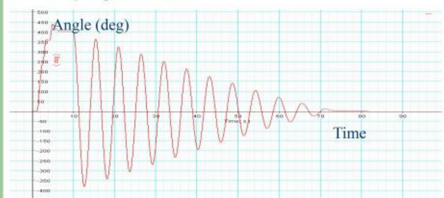
Energy loss fitting in B part

- Fitting proportionally



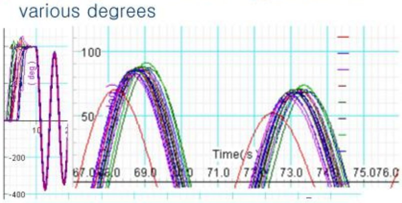
General damping oscillation

- Damping Oscillation



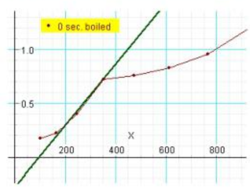
All the damping oscillation

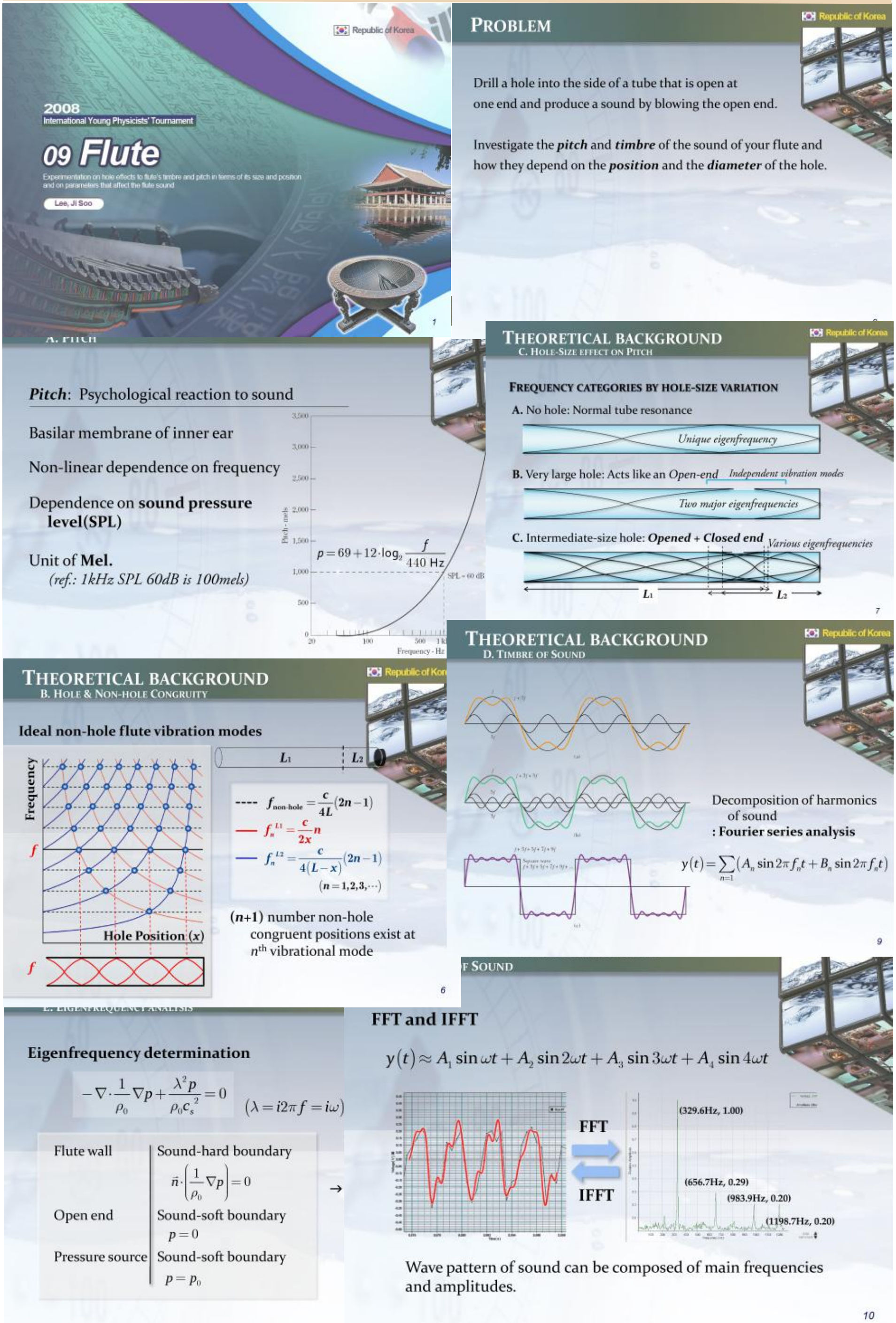
- Damping Oscillation with eggs boiled to various degrees

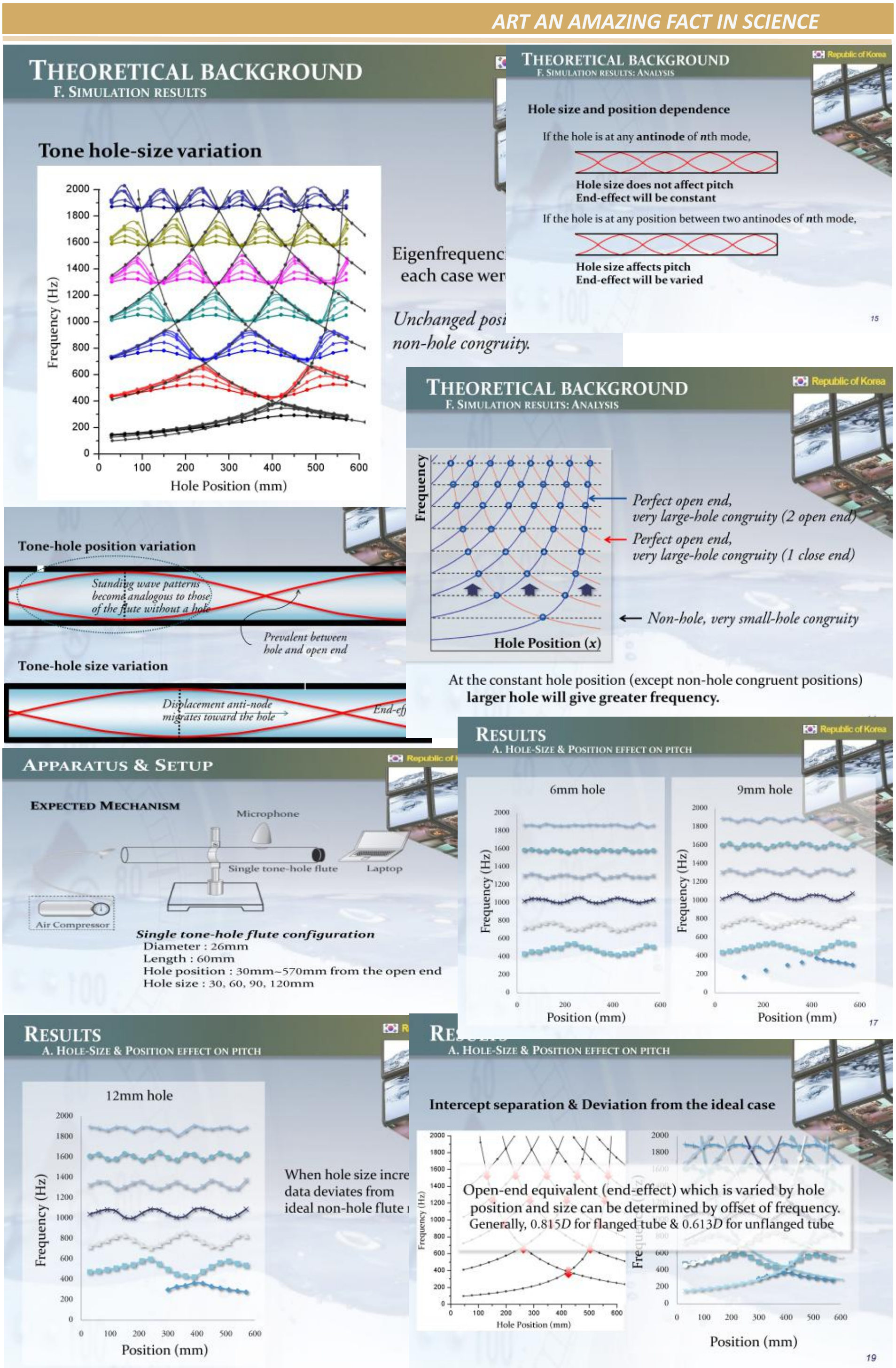


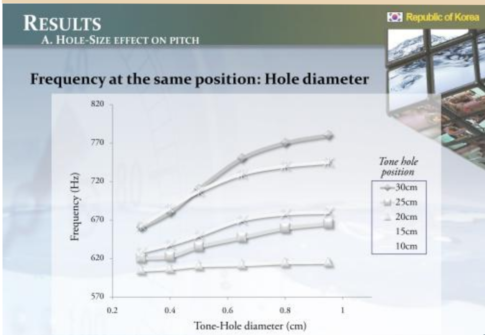
How to fit

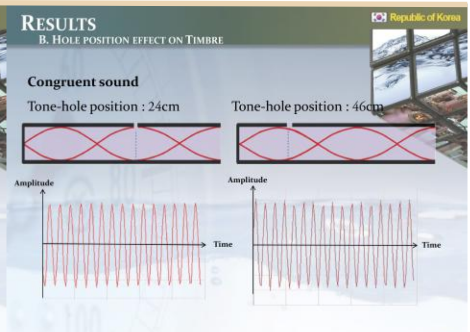
- Fitting the graphs as following :

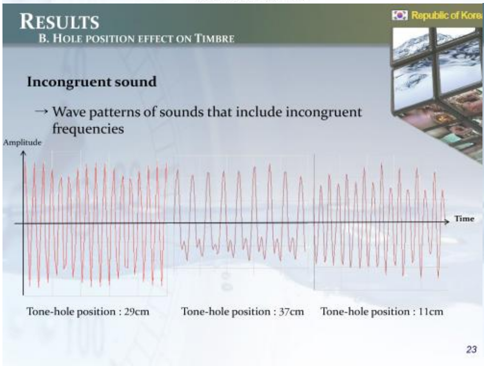


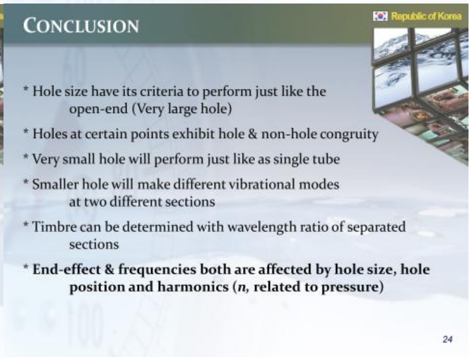

Republic of Korea
2008
International Young Physicists' Tournament
09 Flute
Experimentation on hole effects to flute's timbre and pitch in terms of its size and position and on parameters that affect the flute sound
Lee, Ji Soo
PROBLEM
Drill a hole into the side of a tube that is open at one end and produce a sound by blowing the open end.
Investigate the pitch and timbre of the sound of your flute and how they depend on the position and the diameter of the hole.
Pitch: Psychological reaction to sound
Basilar membrane of inner ear
Non-linear dependence on frequency
Dependence on sound pressure level(SPL)
Unit of Mel.
(ref.: 1kHz SPL 60dB is 100mels)
$p = 69 + 12\cdot\log_2 \frac{f}{440\ \text{Hz}}$
SPL = 60 dB
Pitch - mels
Frequency - Hz
THEORETICAL BACKGROUND
C. HOLE-SIZE EFFECT ON PITCH
FREQUENCY CATEGORIES BY HOLE-SIZE VARIATION
A. No hole: Normal tube resonance
Unique eigenfrequency
B. Very large hole: Acts like an Open-end
Independent vibration modes
Two major eigenfrequencies
C. Intermediate-size hole: Opened + Closed end
Various eigenfrequencies
L1
L2
THEORETICAL BACKGROUND
B. HOLE & NON-HOLE CONGRUITY
Ideal non-hole flute vibration modes
Frequency
Hole Position (x)
$f_{\text{non-hole}} = \frac{c}{4L}(2n-1)$
$f_n^{L1} = \frac{c}{2x}n$
$f_n^{L2} = \frac{c}{4(L-x)}(2n-1)$
$(n = 1,2,3,\cdots)$
(n+1) number non-hole congruent positions exist at n^{th} vibrational mode
THEORETICAL BACKGROUND
D. TIMBRE OF SOUND
Decomposition of harmonics of sound
: Fourier series analysis
$y(t) = \sum_{n=1} (A_n \sin 2\pi f_n t + B_n \sin 2\pi f_n t)$
Eigenfrequency determination
$-\nabla\cdot\frac{1}{\rho_0}\nabla p + \frac{\lambda^2 p}{\rho_0 c_s^2} = 0$
$(\lambda = i2\pi f = i\omega)$
Flute wall — Sound-hard boundary — $\vec{n}\cdot\left(\frac{1}{\rho_0}\nabla p\right) = 0$
Open end — Sound-soft boundary — $p = 0$
Pressure source — Sound-soft boundary — $p = p_0$
FFT and IFFT
$y(t) \approx A_1 \sin\omega t + A_2 \sin 2\omega t + A_3 \sin 3\omega t + A_4 \sin 4\omega t$
FFT
IFFT
(329.6Hz, 1.00)
(656.7Hz, 0.29)
(983.9Hz, 0.20)
(1198.7Hz, 0.20)
Wave pattern of sound can be composed of main frequencies and amplitudes.

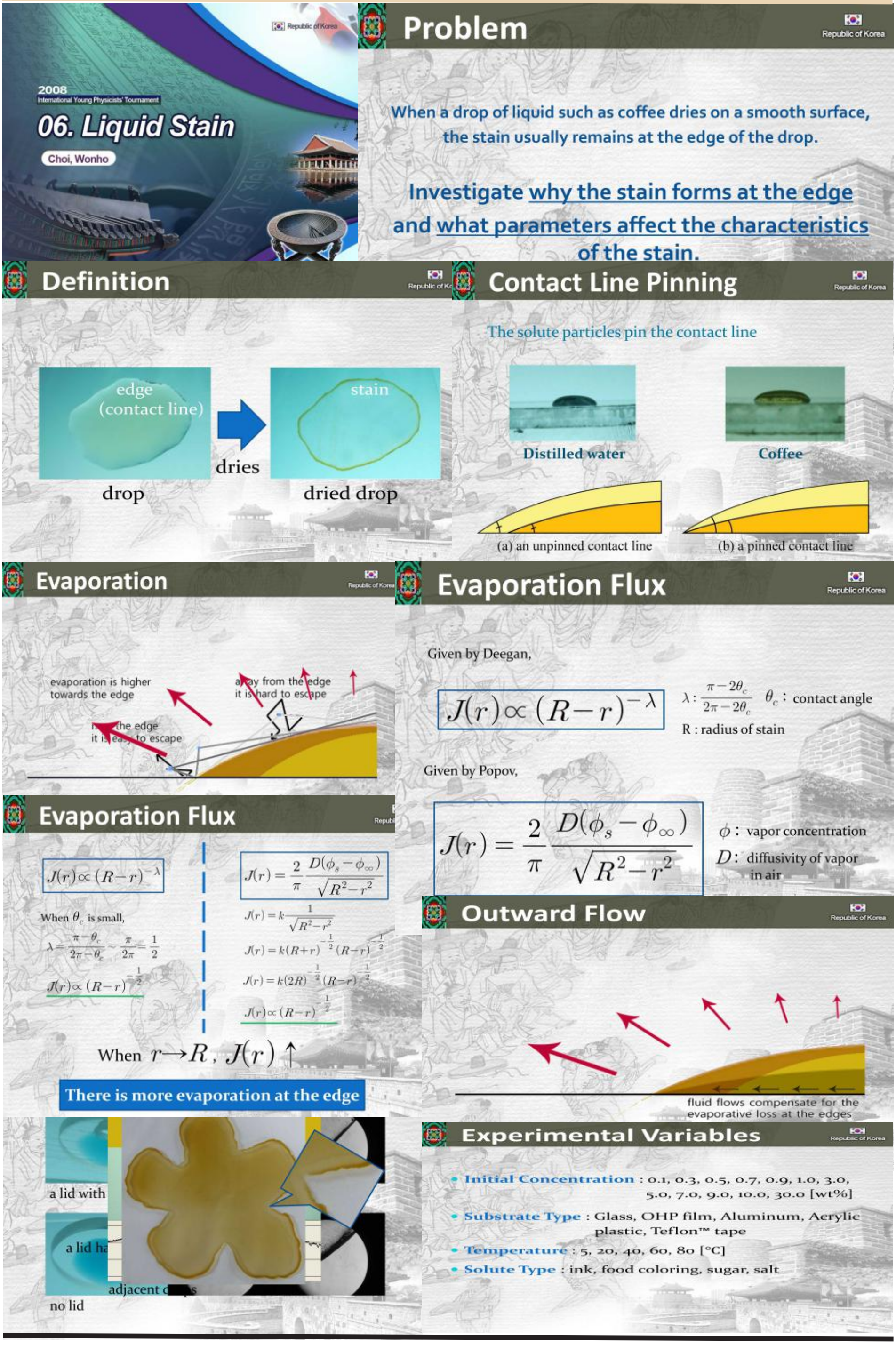

ART AN AMAZING FACT IN SCIENCE
THEORETICAL BACKGROUND
F. SIMULATION RESULTS
Tone hole-size variation
Frequency (Hz)
Hole Position (mm)
Eigenfrequenc
each case wer
Unchanged posi
non-hole congruity.
THEORETICAL BACKGROUND
F. SIMULATION RESULTS: ANALYSIS
Republic of Korea
Hole size and position dependence
If the hole is at any antinode of nth mode,
Hole size does not affect pitch
End-effect will be constant
If the hole is at any position between two antinodes of nth mode,
Hole size affects pitch
End-effect will be varied
15
THEORETICAL BACKGROUND
F. SIMULATION RESULTS: ANALYSIS
Republic of Korea
Frequency
Perfect open end,
very large-hole congruity (2 open end)
Perfect open end,
very large-hole congruity (1 close end)
Non-hole, very small-hole congruity
Hole Position (x)
At the constant hole position (except non-hole congruent positions)
larger hole will give greater frequency.
Tone-hole position variation
Standing wave patterns become analogous to those of the flute without a hole
Prevalent between hole and open end
Tone-hole size variation
Displacement anti-node migrates toward the hole
End-ef
APPARATUS & SETUP
EXPECTED MECHANISM
Microphone
Single tone-hole flute
Laptop
Air Compressor
Single tone-hole flute configuration
Diameter : 26mm
Length : 60mm
Hole position : 30mm~570mm from the open end
Hole size : 30, 60, 90, 120mm
RESULTS
A. HOLE-SIZE & POSITION EFFECT ON PITCH
Republic of Korea
6mm hole
9mm hole
Frequency (Hz)
Position (mm)
17
RESULTS
A. HOLE-SIZE & POSITION EFFECT ON PITCH
12mm hole
Frequency (Hz)
Position (mm)
When hole size incre
data deviates from
ideal non-hole flute
RESULTS
A. HOLE-SIZE & POSITION EFFECT ON PITCH
Intercept separation & Deviation from the ideal case
Open-end equivalent (end-effect) which is varied by hole position and size can be determined by offset of frequency.
Generally, 0.815D for flanged tube & 0.613D for unflanged tube
Hole Position (mm)
Position (mm)
19

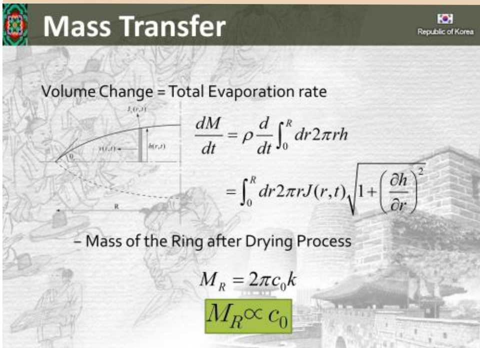

RESULTS
A. HOLE-SIZE EFFECT ON PITCH
Republic of Korea
Frequency at the same position: Hole diameter
Frequency (Hz)
820
770
720
670
620
570
0.2
0.4
0.6
0.8
1
Tone-Hole diameter (cm)
Tone hole position
30cm
25cm
20cm
15cm
10cm


RESULTS
B. HOLE POSITION EFFECT ON TIMBRE
Republic of Korea
Congruent sound
Tone-hole position : 24cm
Tone-hole position : 46cm
Amplitude
Time
Amplitude
Time

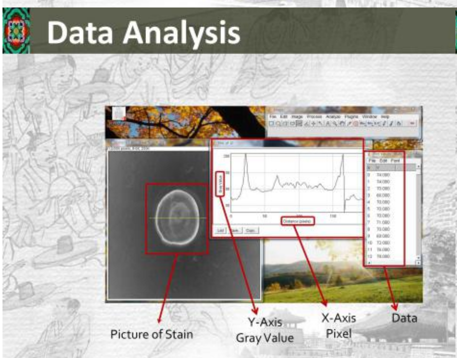

RESULTS
B. HOLE POSITION EFFECT ON TIMBRE
Incongruent sound
→ Wave patterns of sounds that include incongruent frequencies
Amplitude
Time
Tone-hole position : 29cm
Tone-hole position : 37cm
Tone-hole position : 11cm
23

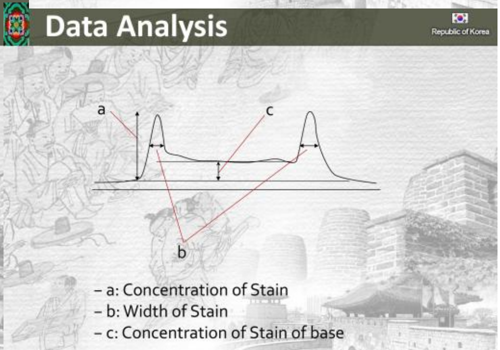

CONCLUSION
Republic of Korea
* Hole size have its criteria to perform just like the open-end (Very large hole)
* Holes at certain points exhibit hole & non-hole congruity
* Very small hole will perform just like as single tube
* Smaller hole will make different vibrational modes at two different sections
* Timbre can be determined with wavelength ratio of separated sections
* End-effect & frequencies both are affected by hole size, hole position and harmonics (n, related to pressure)
24

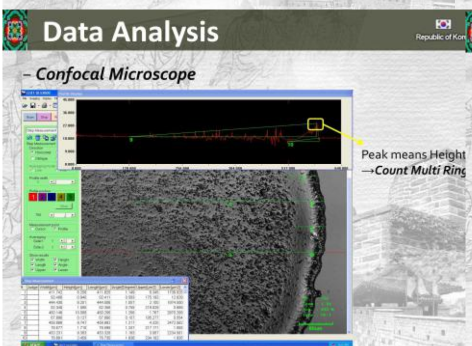

2008
International Young Physicists' Tournament
06. Liquid Stain
Choi, Wonho
Republic of Korea
Problem
When a drop of liquid such as coffee dries on a smooth surface, the stain usually remains at the edge of the drop.
Investigate why the stain forms at the edge and what parameters affect the characteristics of the stain.
Definition
edge (contact line)
dries
stain
drop
dried drop
Contact Line Pinning
The solute particles pin the contact line
Distilled water
Coffee
(a) an unpinned contact line
(b) a pinned contact line
Evaporation
evaporation is higher towards the edge
it is easy to escape
it is hard to escape
Evaporation Flux
Given by Deegan,
$J(r) \propto (R-r)^{-\lambda}$
$\lambda : \frac{\pi - 2\theta_c}{2\pi - 2\theta_c}$ θ_c : contact angle
R : radius of stain
Given by Popov,
$J(r) = \frac{2}{\pi}\frac{D(\phi_s - \phi_\infty)}{\sqrt{R^2 - r^2}}$
ϕ : vapor concentration
D : diffusivity of vapor in air
Evaporation Flux
When θ_c is small,
$\lambda = \frac{\pi - \theta_c}{2\pi - \theta_c} \sim \frac{\pi}{2\pi} = \frac{1}{2}$
$J(r) \propto (R-r)^{-\frac{1}{2}}$
$J(r) = k\frac{1}{\sqrt{R^2 - r^2}}$
$J(r) = k(R+r)^{-\frac{1}{2}}(R-r)^{-\frac{1}{2}}$
$J(r) = k(2R)^{-\frac{1}{2}}(R-r)^{-\frac{1}{2}}$
$J(r) \propto (R-r)^{-\frac{1}{2}}$
When $r \to R$, $J(r) \uparrow$
There is more evaporation at the edge
Outward Flow
fluid flows compensate for the evaporative loss at the edges
a lid with
a lid ha
adjacent d
no lid
Experimental Variables
Initial Concentration : 0.1, 0.3, 0.5, 0.7, 0.9, 1.0, 3.0, 5.0, 7.0, 9.0, 10.0, 30.0 [wt%]
Substrate Type : Glass, OHP film, Aluminum, Acrylic plastic, Teflon™ tape
Temperature : 5, 20, 40, 60, 80 [°C]
Solute Type : ink, food coloring, sugar, salt

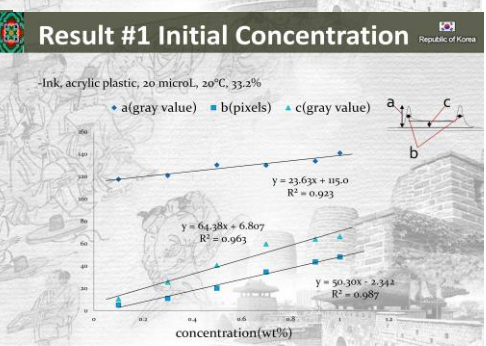

Mass Transfer
Republic of Korea
Volume Change = Total Evaporation rate
$\frac{dM}{dt} = \rho \frac{d}{dt}\int_0^R dr 2\pi r h$
$= \int_0^R dr 2\pi r J(r,t)\sqrt{1+\left(\frac{\partial h}{\partial r}\right)^2}$
– Mass of the Ring after Drying Process
$M_R = 2\pi c_0 k$
$M_R \propto c_0$

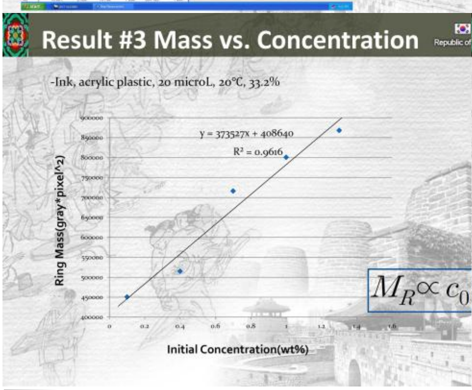

Experiment Apparatus
Republic of Korea
Micro Pipet
Water Bath
Microscope Slide Glass
UF-80 Samsung Presenter

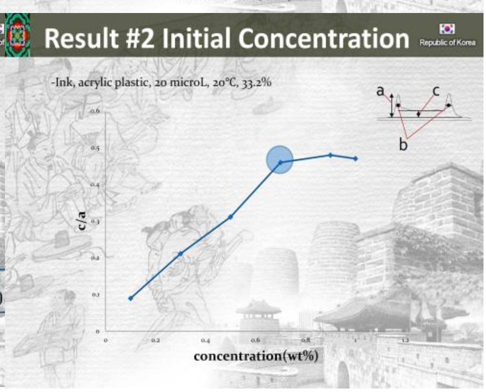

Data Analysis
Picture of Stain
Y-Axis
Gray Value
X-Axis
Pixel
Data

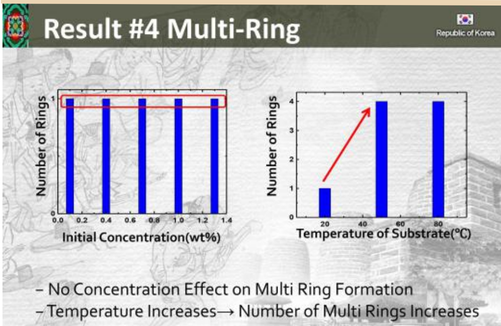

Data Analysis
Republic of Korea
a
c
b
– a: Concentration of Stain
– b: Width of Stain
– c: Concentration of Stain of base

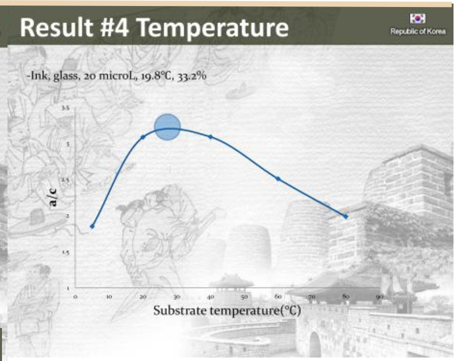

Data Analysis
Republic of Korea
– Confocal Microscope
Peak means Height
→Count Multi Ring


Result #1 Initial Concentration
Republic of Korea
-Ink, acrylic plastic, 20 microL, 20°C, 33.2%
a(gray value)
b(pixels)
c(gray value)
y = 23.63x + 115.0
R² = 0.923
y = 64.38x + 6.807
R² = 0.963
y = 50.30x - 2.342
R² = 0.987
concentration(wt%)
a
c
b


Result #3 Mass vs. Concentration
-Ink, acrylic plastic, 20 microL, 20°C, 33.2%
y = 373527x + 408640
R² = 0.9616
Ring Mass(gray*pixel^2)
Initial Concentration(wt%)
$M_R \propto c_0$


Result #2 Initial Concentration
Republic of Korea
-Ink, acrylic plastic, 20 microL, 20°C, 33.2%
c/a
concentration(wt%)
a
c
b






References

[1] R. D. Deegan, O. Bakajin, T. F. Dupont, G. Huber, S. R. Nagel, and T. A. Witten, Nature (London) 389, 827 (1997).

[2] R. D. Deegan, O. Bakajin, T. F. Dupont, G. Huber, S. R. Nagel, and T. A. Witten, Physical Review E 62, 756 (2000).

[3] R. D. Deegan, Physical Review E 61, 475 (2000).

[4] Y. O. Popov, Physical Review E 71, 036313 (2005).

[5] Y. Y. Tarasevich, Physical Review E 71, 027301 (2005).

ART AN AMAZING FACT IN SCIENCE

Problem#15
Newton's Cradle

The oscillations of a Newton's cradle will gradually decay until the spheres come to rest. Investigate how the rate of decay of a Newton's cradle depends on relevant parameters such as the number, material, and alignment of the spheres.

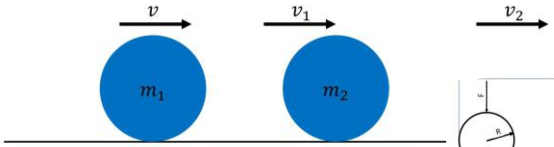
Reporter: Amirmehdi Jafari Fesharaki

Approach

- Initial Observation
- The collision between two balls
- Theory of decay
- Number of the balls
- Material of the balls
- Middle ball and side ball
- Number of the released balls
- Conclusion

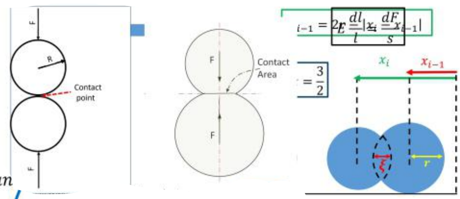
Collision between two balls

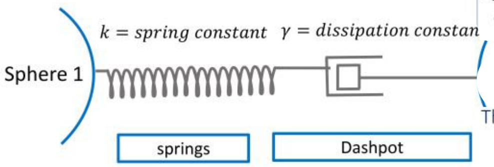
$$\left.\begin{array}{l}\varepsilon\frac{m_1 v^2}{2} = \frac{m_1 {v_1}^2}{2} + \frac{m_2 {v_2}^2}{2} \\ m_1 v = m_1 v_1 + m_2 v_2\end{array}\right\} \xrightarrow{\alpha = \frac{m_2}{m_1},\ \varepsilon = 1} \left\{\begin{array}{l} v_1 = 0 \\ v_2 = v\end{array}\right.$$



Collision between different number of balls

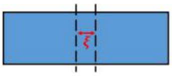
Modeling the collision between two sphere





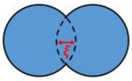
The effects of dissipation

Viscoelastic dissipation force for cylinder :
$F_{diss} = -\gamma' \frac{d}{dt}(\xi)$



Viscoelastic dissipation force for spheres :
$F_{diss} = -\gamma \frac{d}{dt}(\xi^{\frac{3}{2}})$

Hertz-kuwabara-kono equation
https://en.m.Wikipedia.org/wiki/contact_mechanics



The gravitational force acting upon a ball

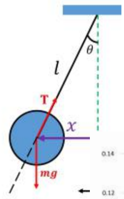
$\sin(\theta) = \frac{x}{l}$

$\cos(\theta) = \frac{\sqrt{l^2 - x^2}}{l} \approx 1$

$T - mg\cos(\theta) = \frac{m(\dot{x}^2 + \dot{y}^2)}{l} \longrightarrow T = mg$

$m\ddot{x} = -T\sin(\theta) \longrightarrow m\ddot{x} \approx -\frac{mgx}{l}$

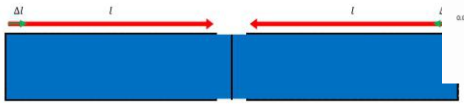
$\longrightarrow F_g = -\frac{mgx}{l}$

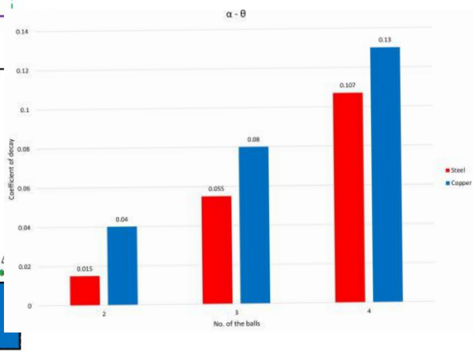


Compression between two cylinders

$stress - strain\ relation \longrightarrow E \frac{\Delta l}{l} = \frac{F}{S} \longrightarrow k\Delta l = F$

E: Young's modulus; F: The force; S: Effective area

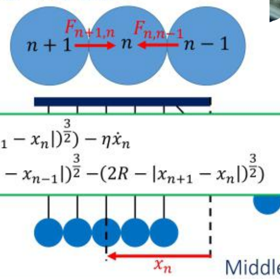




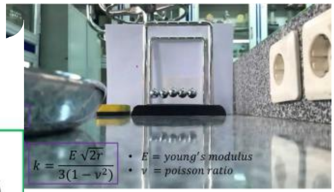
The equation of the motion for the balls

$F_{i,i-1} = k\xi_{i,i-1}^{\alpha}$ $\quad F_{fr} = -\eta v$

$F_{diss} = -\gamma\left(\dot{\xi^{\frac{3}{2}}}\right)$ $\quad F_g = -\frac{mgx}{l}$



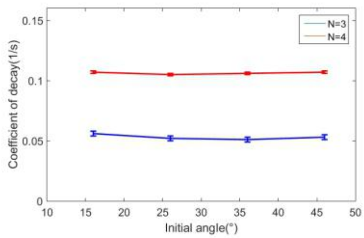
$$m\ddot{x}_n = k((2R - |x_n - x_{n-1}|)^{\frac{3}{2}} - (2R - |x_{n+1} - x_n|)^{\frac{3}{2}}) - \eta\dot{x}_n - \frac{mg(x_n - (n-1)*2R)}{l} + \gamma\frac{d}{dt}((2R - |x_n - x_{n-1}|)^{\frac{3}{2}} - (2R - |x_{n+1} - x_n|)^{\frac{3}{2}})$$



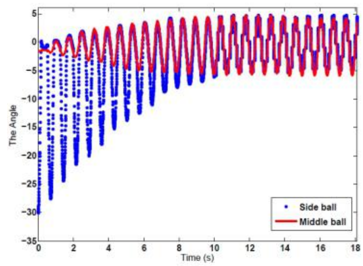
Initial angle

$\alpha_3 = 0.55\ s^{-1}$

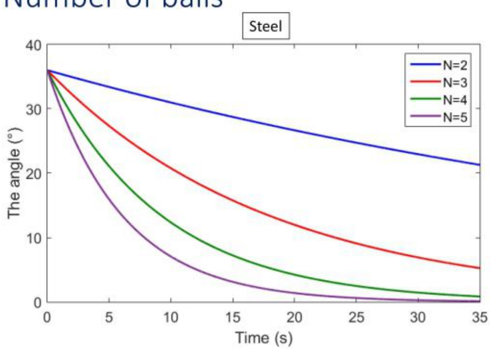
$\alpha_4 = 0.107\ s^{-1}$

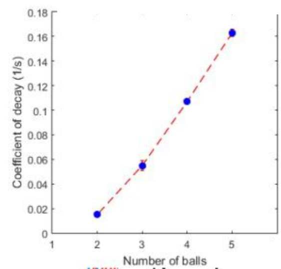


Middle ball and side ball comparison



Number of balls



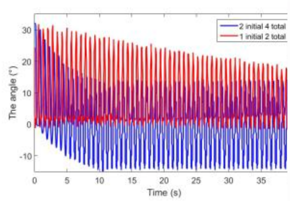


N	α	δα
2	0.015	0.001
3	0.055	0.004
4	0.107	0.0008
5	0.163	0.003

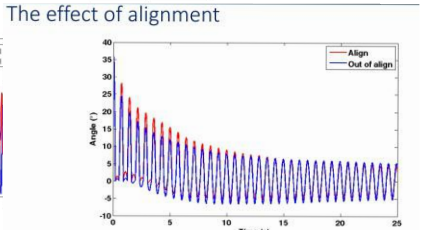
Number of releasing balls

Red line
- Number of releasing balls = 1
- Number Total balls = 2
- Ratio of number of balls = 0.5

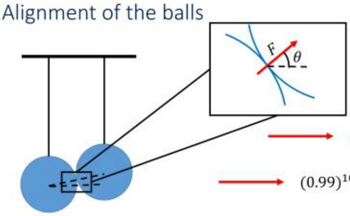
Blue line
- Number of releasing balls = 2
- Number Total balls = 4
- Ratio of number of balls = 0.5



The effect of alignment



Alignment of the balls



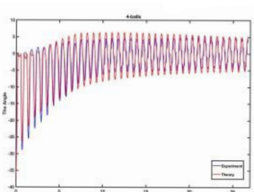
$F_x = F\cos(\theta)$

$\cos(\theta) = 0.99$

$(0.99)^{10} = 0.9$

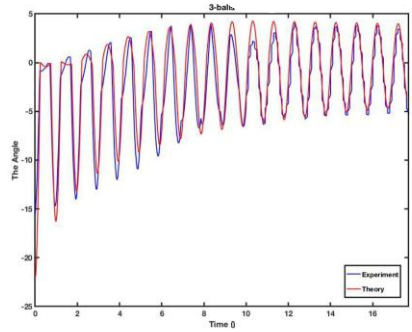
4-balls comparison

$\gamma =$
$\eta =$
$l =$
$k =$



3-balls comparison

$\gamma =$
$\eta =$
$l =$
$k =$

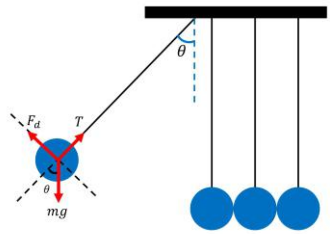


$$T = m\left(g\cos(\theta) + \frac{v^2}{l}\right)$$

$$m\dot{v} = mg\sin(\theta) - F_d$$

$$F_d \sim v$$

$$\frac{F_d}{mg\sin(\theta)} \ll 1$$



$\tau \approx 9.49$

$\tau \approx 9.38$

$\tau \approx 7.44$

$\tau \approx 9.38$

11. Flat Flow

Rojin Anbarafshan

IYPT 2012
BAD SAULGAU - GERMANY

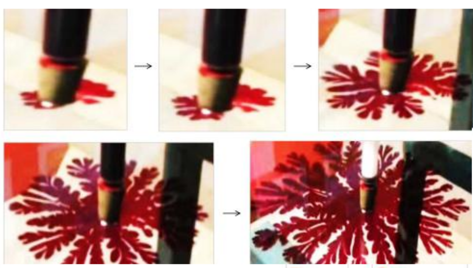
Problem

- Fill a thin gap between two large transparent horizontal parallel plates with a liquid and make a little hole in the center of one of the plates.

- Investigate the flow in such a cell, if a different liquid is injected through the hole.

Literature review

- Viscous fingering of a miscible high viscosity slice of fluid displaced by a lower viscosity fluid is studied in porous media (A. De Wit, Y. Bertho, M. Martin "Viscous fingering of miscible slices" PHYSICS OF FLUIDS 2005)
- Viscous fingering is an ubiquitous hydrodynamic instability that occurs as soon as a fluid of given viscosity displaces another more viscous one in a porous medium (G. M. Homsy, "Viscous fingering in porous media," Annu. Rev. Fluid Mech. 1987)
- Since the physical properties of a fluid depend on both its composition and temperature, one should expect the viscosity to change across both fronts.(M. N. Islam, B. B. Maini and J. Azaiez " Nonlinear Simulation of Thermo-viscous Fingering in Miscible Displacements in Porous Media" 21st International Symposium on High Performance Computing Systems and Applications.2007)
- Recently there has occurred an explosive burst of activity focused on the wide range of physical phenomena that occur when a low-viscosity liquid is forced into a high viscosity liquid.(Gerard Daccord and johann nittmann "Radial viscous fingering and diffusion limited aggregation)



Introduction

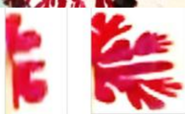
- Initial prediction: Circular pattern (Symmetric)
- Observation: Fingering (Asymmetric)

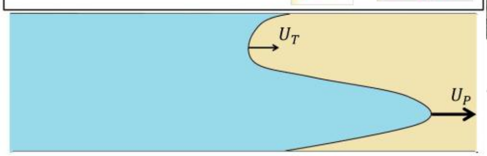
The reason of this incompatibility is the initial disturbances

The initial disturbance is a probability phenomenon:

A function of inhomogeneities on the surface of the plates, irregularities in the gap thickness , or even from thermal or pressure fluctuations [1]

Small protrusions of the interface grow much faster than do the troughs [1]

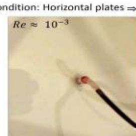




[1]"Soft Matter Physics" , Maurice Kleman ,Oleg D. Lavrentovich

Assumptions

1. Thin gap : The gap is smaller than any other length scale in the problem ⇒ 2D flow
2. Low Reynolds number : $Re = \frac{inertial\ force}{viscous\ force}$ ⇒ Viscous forces are dominant compared to inertia forces
3. Body force : Problem condition: Horizontal plates ⇒ Gravity = 0 ⇒ No body force

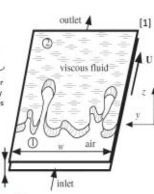


Governing Equations

$$\rho\left(\frac{\partial v}{\partial t} + v\,.\,\nabla v\right) = -\nabla p + \mu\nabla^2 v + f$$

Inertia (per volume): Unsteady acceleration, Convective acceleration; Divergence of stress: Pressure gradient, Viscosity; Other body forces

Assumptions: $\mu\frac{\partial^2 v_i}{\partial z^2} = \nabla_i p\ , i = x, y$



No slip boundary condition : $Darcy\ law: U = -\frac{b^2}{12\mu}\nabla p$ [1]

For flows in porous media

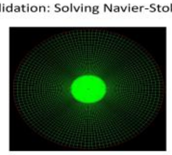
[1]"Soft Matter Physics" , Maurice Kleman ,Oleg D. Lavrentovich

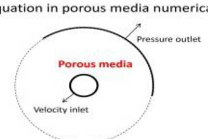
Numerical Solution

Theory Validation

Prediction: Darcy law(equation for porous media) can cause fingering

Validation: Solving Navier-Stokes equation in porous media numerically

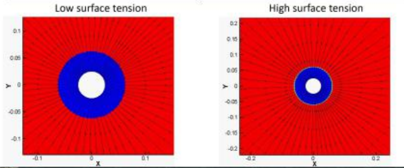




Fluent solve Navier-Stokes equations in each cell

Numerical Results

Darcy law can describe the flow and the fingering

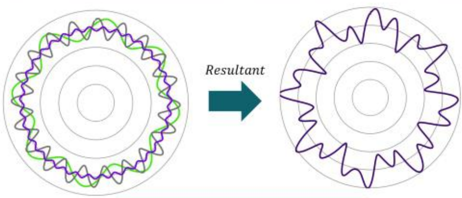


Modeling
Based on Fourier series

We assume the perturbations in the interface as a summation of sinusoids

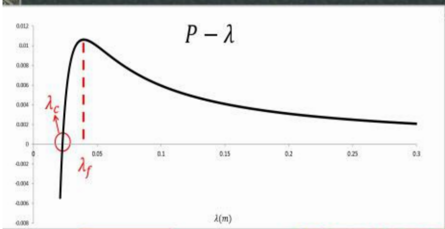
$r_1 = r_0 + A_1\sin(q_1\vartheta + \varphi_1)$ $r_2 = r_0 + A_2\sin(q_2\vartheta + \varphi_2)$ $r_3 = r_0 + A_3\sin(q_3\vartheta + \varphi_3)$

Modeling
Based on Fourier series



$$R = R_0 + \sum_{i=1}^{n} A_i \sin(q_i\vartheta + \varphi_i)$$

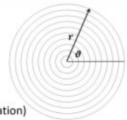
Modeling
Discussion

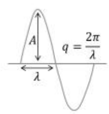


$$\lambda_f = \pi b\sqrt{\frac{\sigma}{U(\eta_B - \eta_A)}} = \sqrt{3}\lambda_c$$ [1]

Modeling
Governing Equations

1. $r(\vartheta, t) = Ut + \sum_{i=1}^{n} A(t)\sin(q_i\vartheta)$
2. Incompressibility : $\nabla . U = 0 \Rightarrow \nabla^2 p = 0$ (Laplace equation)
3. Darcy law : $U(x,y) = -\frac{b^2}{12\eta}\nabla p(x,y)$
4. At the interface: $\Delta P = \sigma\left(\frac{2}{b} + \frac{1}{R_{xy}}\right)$





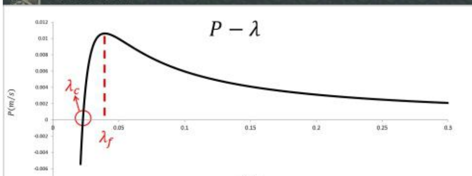
Modeling
Evolution of a Perturbation

Darcy law → Incompressibility → Pressure gradient in horizontal plane → Supposing the perturbation as a sinusoid wave → Using assumptions due to boundary conditions → Conditions of continuity → Pressure jump in the interface due to surface tension → Conditions at the interface

$$\frac{\partial A}{\partial t} = A\frac{12Uq(\eta_B - \eta_A) - \sigma q^3 b^2}{12(\eta_A + \eta_B)}$$

[1]"Soft Matter Physics" , Maurice Kleman ,Oleg D. Lavrentovich

Modeling
Discussion



$$\lambda_f = \pi b\sqrt{\frac{\sigma}{U(\eta_B - \eta_A)}} = \sqrt{3}\lambda_c$$ [1]

[1]"Soft Matter Physics" , Maurice Kleman ,Oleg D. Lavrentovich

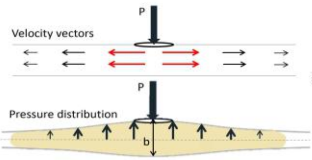
Theory Revision
Parameters

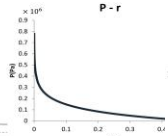
$$\left.\begin{aligned} F(r) &= \frac{3\eta Q r^2}{b^3} \\ y_{max} &= \frac{FD^2}{4\pi h^3 E} \end{aligned}\right\} \Rightarrow b^4 = \frac{3\eta Q r^2 D^2}{2\pi h^3 E} \Rightarrow \lambda_f = \sqrt[4]{\frac{3r^3 D^2 \sigma^2}{h^3 E U \eta}}$$

	1/2	−3/4	−1/4	−1/4	−1/4	3/4	1/2
λ ∝	D^	h^	E^	U^	η^	r^	σ^

Surface tension is very effective on finger width

Theory Development
Plate Deflection



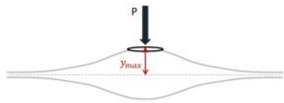


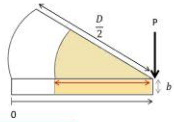
$$U=\frac{Q}{2\pi r b}$$

Darcy: $\frac{\partial P}{\partial r}=\frac{-12\eta}{b^2}U$

$$\Rightarrow P(r)=\frac{6\eta Q}{\pi b^3}\ln\frac{R}{r}\Rightarrow F(r)=\frac{3\eta Q r^2}{b^3}$$

Plate Deflection





$$\frac{d^2y}{dr^2}=\frac{M}{EI}\ [1]\ \xrightarrow{\text{Boundary Conditions}}\ y_{max}=\frac{FD^2}{4\pi h^3 E}$$

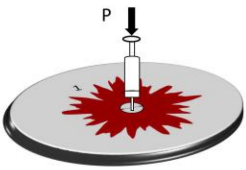
E: Glass elastic young's modulus

$I=\frac{1}{12}bh^3$ (h = diameter of plate)

Experimental Setup

- Placing two large transparent horizontal parallel plates

  Plates diameter: 56 cm
  Hole diameter : 0.5 cm



- Fixing a tube in the hole for conducting the fluid path

Liquid 1 : Glycerin

$\eta_1 = 1.2\ Pa.s$

$\gamma_1 = 0.064\ N/m$

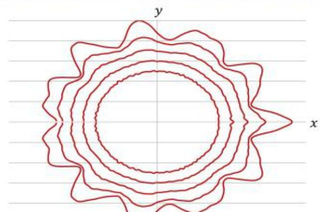
Liquid 2 : Colored Water

$\eta_2 = 8.94\times10^{-4}\ Pa.s$

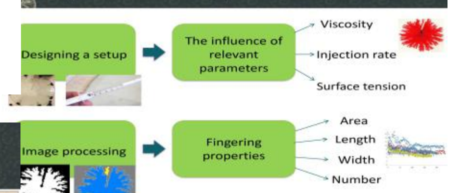
$\gamma_2 = 0.0728\ N/m$

- Injecting the first fluid between the plates by the syringe attached to the tube
- Injecting the second fluid immediately for prevention of injecting air bubbles between plates
- Capturing a video of the phenomenon from above

Theoretical results
Based On Fourier Modeling



Experimental Approach



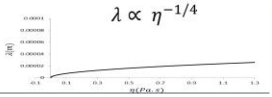
Experiments
Viscosity

Experimental Result

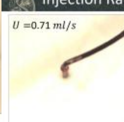
$\eta\uparrow\Rightarrow\lambda\approx cte.$

Theoretical Prediction

$\lambda\propto\eta^{-1/4}$

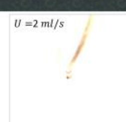


Experiments
Injection Rate



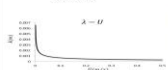
Experimental Result

$U\uparrow\Rightarrow\lambda\approx cte$



Theoretical Prediction

$\lambda\propto U^{-1/4}$



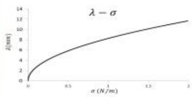
Experiments
Surface Tension

Experimental Result

$\sigma \uparrow \Rightarrow \lambda \uparrow$

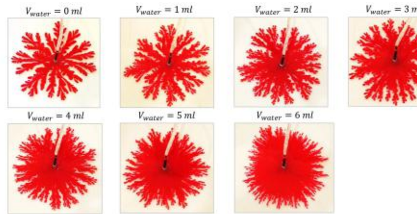
Theoretical Prediction

$\lambda \propto \sigma^{1/2}$



Quantitative Experiments
Surface Tension

- Changing the Surface tension by adding specific amount of water to glycerin (Glycerin Solutions)



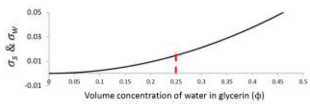
Quantitative Experiments
Surface Tension and Viscosity Calculation

$$\sigma = \sigma_w + \sigma_G - 2K(\sigma_w \sigma_G)^{1/2} \quad [1]$$

$$\sigma_s = \sigma\, \phi^2 \quad [2]$$

K is a constant depending on the nature of the system [1]

$$S^* \propto \int_{-x}^{x} \left(\frac{\partial \phi}{\partial x}\right)^2 dx$$



Experiment: $\phi_{Max} = 0.25$

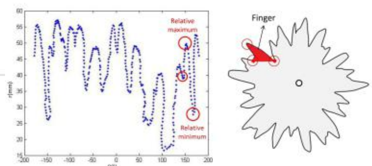
σ Change percentage : 100 %

$\lambda \propto \sigma^{\frac{1}{2}}$ $\Rightarrow$ **λ Change percentage : 10 %**

[1]"Theory of Interfacial Tension of Partially Miscible Liquids" , M.-E. BOUDH-HIR and G.A. MANSOORI

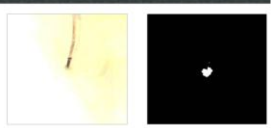
Video Processing
Detecting the Fingers

- Plotting r vs. θ on boundary line

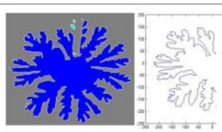


Video Processing
Detecting the Pattern

- Detecting the red points and change the video to a black and white video

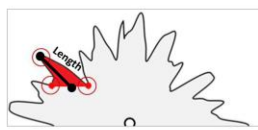


- Detecting the boundary line of the pattern in each frame



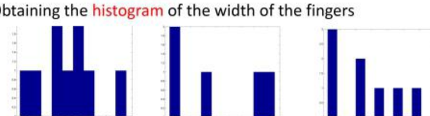
Video Processing
Fingers Properties

- Determining the area of each finger (number of white pixels)
- Determining the effective length of each finger

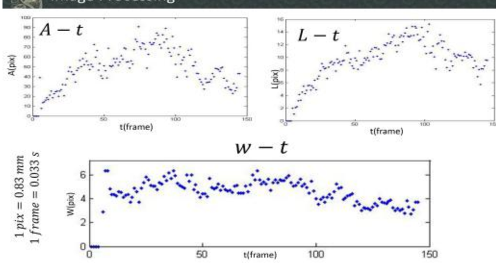


$$Width = \frac{Area}{Lenght}$$

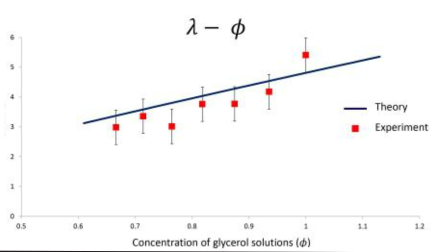
- Determining the effective width of each finger
- Obtaining the histogram of the width of the fingers

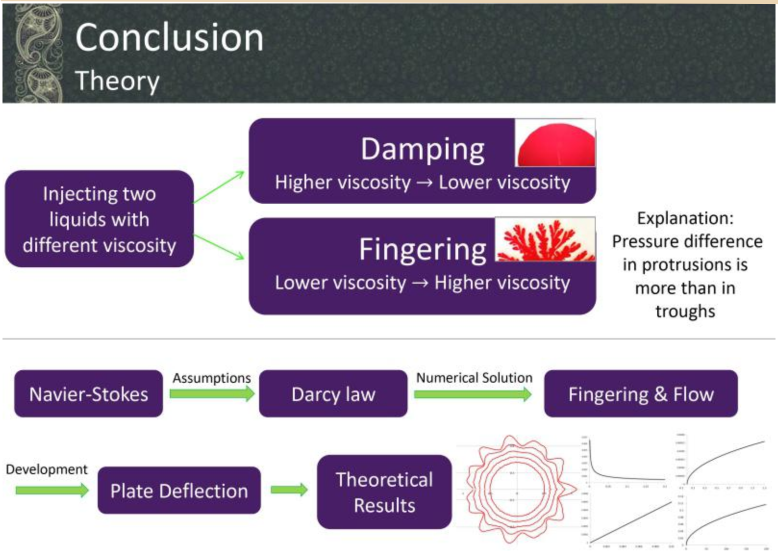


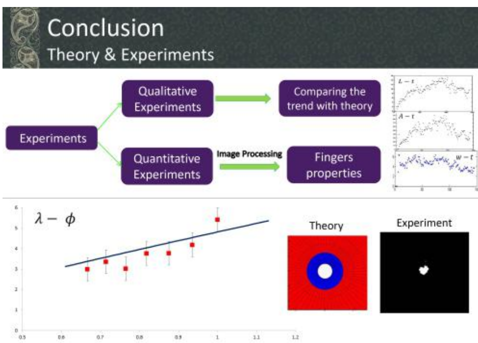
Experimental Results
Image Processing

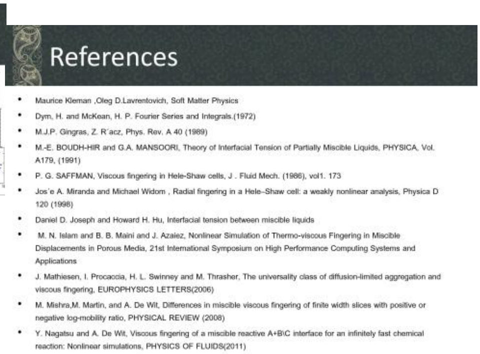


Theory vs. Experiment




Conclusion
Theory
Injecting two liquids with different viscosity
Damping
Higher viscosity → Lower viscosity
Fingering
Lower viscosity → Higher viscosity
Explanation: Pressure difference in protrusions is more than in troughs
Navier-Stokes
Assumptions
Darcy law
Numerical Solution
Fingering & Flow
Development
Plate Deflection
Theoretical Results


Conclusion
Theory & Experiments
Experiments
Qualitative Experiments
Comparing the trend with theory
Quantitative Experiments
Image Processing
Fingers properties
$\lambda - \phi$
Theory
Experiment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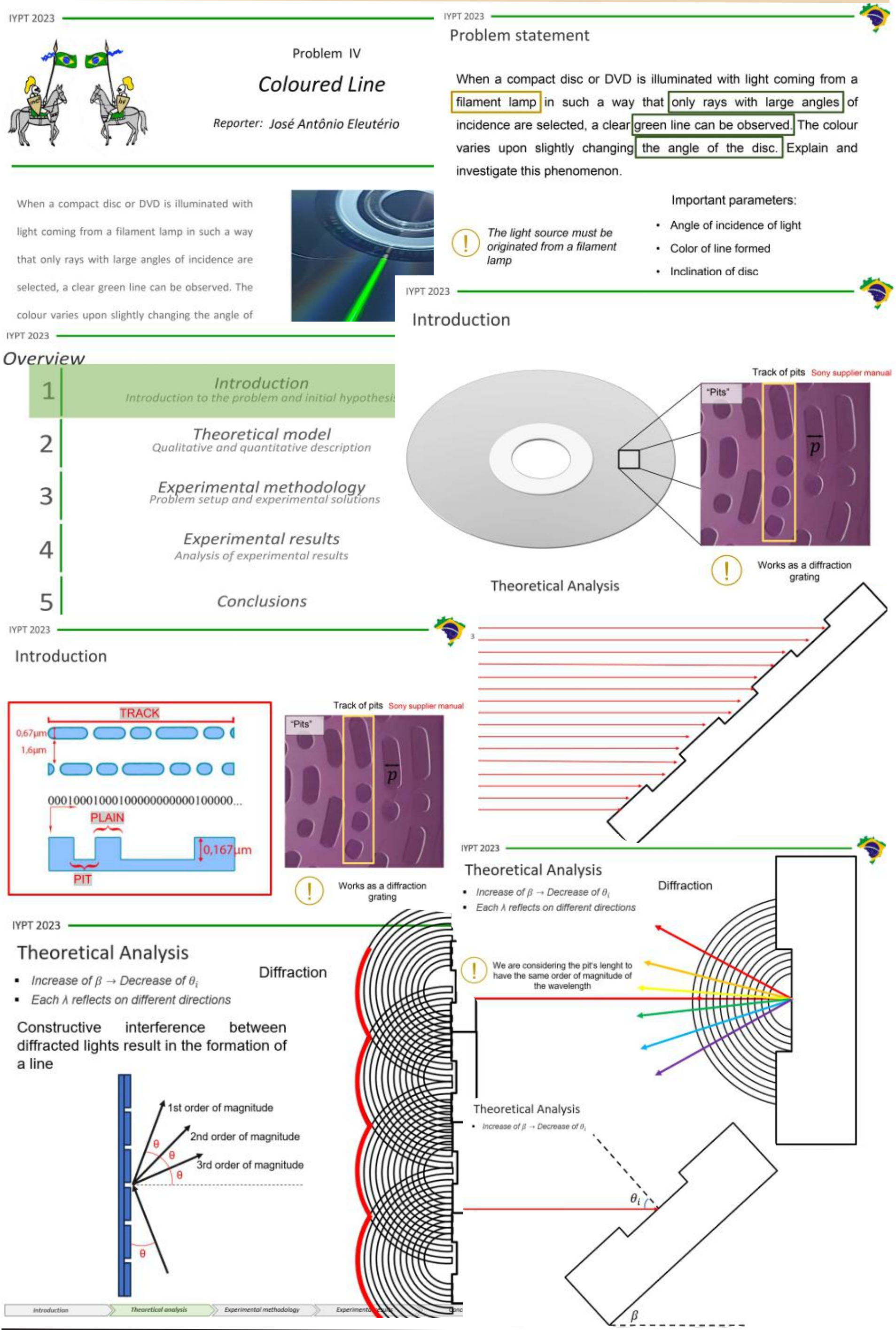

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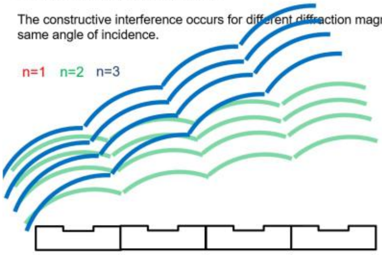
Theoretical Analysis

- *Increase of $\beta \rightarrow$ Decrease of θ_i*
- *Each λ reflects on different directions*

The constructive interference occurs for different diffraction magnitudes at same angle of incidence.



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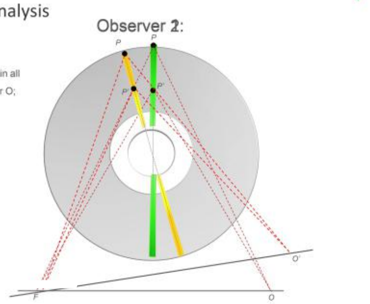
Theoretical Analysis

Disk geometry

PP' line segments contain all observable light rays for O;



Theoretical Analysis

Optics of horizontal disk

$$r = \frac{r_0 + d + mp}{\cos\alpha}$$

r_0: Inner radius of CD

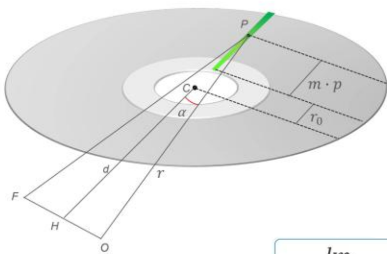
m: Quantity of tracks

d: HC

O: Observer

F: Light source

P: lenght of pit

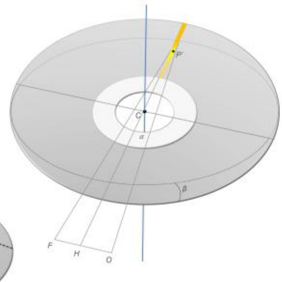


Theoretical Analysis

Optics of inclined disk

An inclination β is added using C as a paramater

Distance $\overline{HC}$ is fixed



$$\frac{kp}{2\cos\alpha} = n\pi \Rightarrow \lambda_n = \frac{p}{n\cos\alpha}$$

Theoretical Analysis

Optics of horizontal disk

Calculation for determining wavelength ⟶ Maximum intensity ⟶ Electrical field Medium of Poynting vector

$$\vec{E}_m = \vec{E}_m \exp(ikr) = \vec{E}_m \exp(ik\frac{r_0 + d + mp}{\cos\alpha})$$

$$\vec{E} = \vec{E}_0 \exp\left(ik\left(\frac{r_0 + d}{\cos\alpha}\right)\right)\exp(\frac{iNkp}{2\cos\alpha})\frac{\mathrm{sen}\left(\frac{(N+1)kp}{2\cos\alpha}\right)}{\mathrm{sen}\left(\frac{kp}{2\cos\alpha}\right)}$$

Using the vector of poynting:

$$I = S_m = \frac{|E|^2}{\mu c}$$

$$I = \frac{1}{\mu c}|E_0|^2 = \frac{1}{\mu c}\exp\left(2ik\left(\frac{r_0 + d}{\cos\alpha}\right)\right)\exp(\frac{iNkp}{\cos\alpha})\frac{\mathrm{sen}^2\left(\frac{(N+1)kp}{2\cos\alpha}\right)}{\mathrm{sen}^2\left(\frac{kp}{2\cos\alpha}\right)}$$

⟵ Maximize

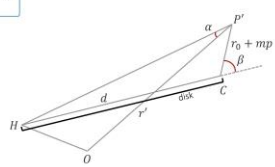
Does not depend on r

Calculating 'new' distance r': $\overline{P'H} = \sqrt{d^2 + (r_0 + pm)^2 + 2d(r_0 + pm)\cos(\beta)}$

Being $\overline{P'H}\cos(\alpha) = r'$: $r' = \frac{\sqrt{d^2 + (r_0 + pm)^2 + 2d(r_0 + pm)\cos(\beta)}}{\cos(\alpha)}$

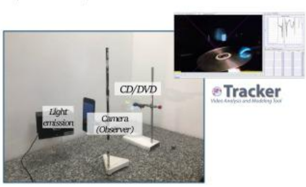
New point of maximum: $\frac{k' p\cos(\beta)}{2\cos(\alpha)} = n\pi$

New λ: $\lambda'_n = \frac{p\cos(\beta)}{n\cos(\alpha)}$



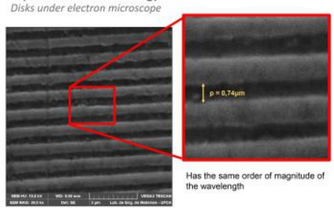
Experimental methodology

Experimental setup



Experimental methodology

Disks under electron microscope



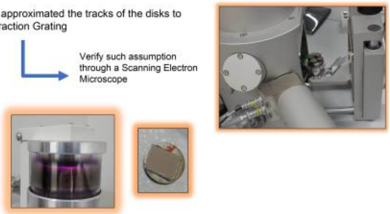
Has the same order of magnitude of the wavelength

Experimental methodology

Disks under scanning electron microscope (SEM)

We approximated the tracks of the disks to Diffraction Grating

Verify such assumption through a Scanning Electron Microscope



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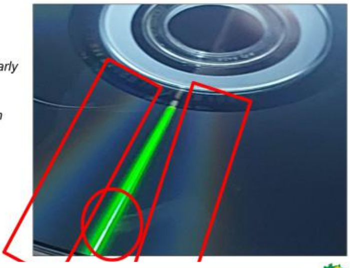
Experimental results

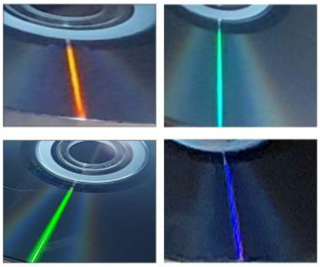
Inaccuracies and possible flaws

- *Boder effects are clearly visible*
- *Incident white light on câmera may cause instability*



Experimental results

Observation of different colours



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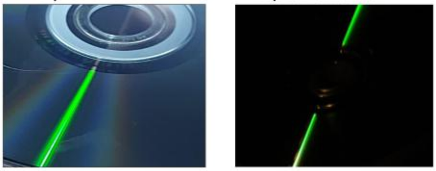
Experimental results

Observation of different colours corrections after improvement

Before experimental improvements | *After experimental improvements*



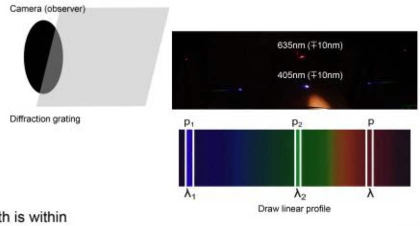
Experimental results

Inaccuracies and possible flaws

How to solve it:
- Isolation of light emitter (reduces interference of white light on camera);
- Focus light emission (reduce border effects);

How to analyze the colored line?

We made our own spectrometer using a diffraction grating of 500 lines/mm.



Experimental results

Color analysis

$$\beta = 130^\circ \qquad \alpha = 9^\circ \qquad p = 1600nm$$

$$\lambda'_n = \frac{p\cos(\beta)}{n\cos(\alpha)}$$

$$\lambda'_1 = 1028nm$$
$$\lambda'_2 = 514nm$$
$$\lambda'_3 = 343nm$$
$$\lambda'_4 = 257nm$$

Only one wavelength is within the observable range.

$$\lambda'_{exp} = 521nm \pm 11.09nm$$

Color	Wavelength (λ)
Red	~ 625-740 nm
Orange	~ 590-625 nm
Yellow	~ 565-590 nm
Green	~ 500-565 nm
Cyan	~ 485-500 nm
Blue	~ 440-485 nm
Violet	~ 390-440 nm

How to analyze the colored line?

$$\lambda'_n = \frac{p\cos(\beta)}{n\cos(\alpha)}$$

How can we extract a wavelength from the experiments without a spectrometer?

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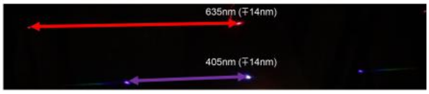
How to analyze the colored line?

We made our own spectrometer using a diffraction grating of 500 lines/mm.



Draw a linear profile between diffraction maxima → Discover any wavelength by proportionality

Experimental results

Color analysis

$\beta = 115°$

$\alpha = 9°$

$p = 1600nm$

$$\lambda'_n = \frac{p\cos(\beta)}{n\cos(\alpha)}$$

$\lambda'_1 = 676nm$

$\lambda'_2 = 338nm$

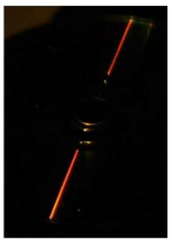
$\lambda'_3 = 225nm$

$\lambda'_4 = 169nm$

Color	Wavelength (λ)
Red	~ 625-740 nm
Orange	~ 590-625 nm
Yellow	~ 565-590 nm
Green	~ 500-565 nm
Cyan	~ 485-500 nm
Blue	~ 440-485 nm
Violet	~ 390-440 nm

The only observable wavelength is in the red spectrum.

$$\lambda'_{exp} = 681nm \pm 11.6nm$$



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Experimental results

Color analysis

$\beta = 150°$

$\alpha = 9°$

$p = 1600nm$

$$\lambda'_n = \frac{p\cos(\beta)}{n\cos(\alpha)}$$

$\lambda'_1 = 1386nm$

$\lambda'_2 = 693nm$

$\lambda'_3 = 462nm$

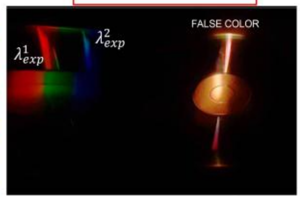
$\lambda'_4 = 363nm$

Two values within the observable range

$$\lambda^1_{exp} = 706nm \pm 11.7nm$$

$$\lambda^2_{exp} = 441nm \pm 10.8nm$$

Color	Wavelength (λ)
Red	~ 625-740 nm
Orange	~ 590-625 nm
Yellow	~ 565-590 nm
Green	~ 500-565 nm
Cyan	~ 485-500 nm
Blue	~ 440-485 nm
Violet	~ 390-440 nm



Experimental results

Color analysis

$\beta = 130°$, $\alpha = 9°$, $p = 740nm$

$$\lambda_{exp} = 472nm \pm 10.9nm$$

$\beta = 130°$, $\alpha = 9°$, $p = 1600nm$

$$\lambda'_{exp} = 521nm \pm 11.09nm$$

Experimental results

Color analysis

$\beta = 130°$

$\alpha = 9°$

$p = 740nm$

$$\lambda'_n = \frac{p\cos(\beta)}{n\cos(\alpha)}$$

$\lambda'_1 = 476nm$

$\lambda'_2 = 238nm$

$\lambda'_3 = 159nm$

$\lambda'_4 = 119nm$

CD → DVD

Two values within the observable range

$$\lambda_{exp} = 472nm \pm 10.9nm$$

Color	Wavelength (λ)
Red	~ 625-740 nm
Orange	~ 590-625 nm
Yellow	~ 565-590 nm
Green	~ 500-565 nm
Cyan	~ 485-500 nm
Blue	~ 440-485 nm
Violet	~ 390-440 nm

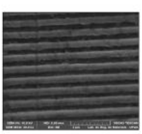
Conclusions

When a compact disc or DVD is ***illuminated*** with light coming from a filament lamp in such a way that ***only rays with large angles of incidence*** are selected, ***a clear green line*** can be observed. The colour varies upon slightly changing the ***angle of the disc***. Explain and investigate this phenomenon.

Disk acts like a diffraction grating → White light is emitted to the disk → Each wavelenght suffers diffraction into a different angle → ...oured lines are ...n on the disk

Conclusions

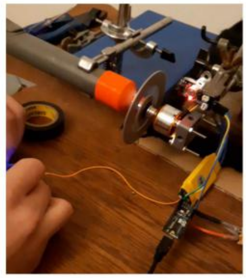
When a compact disc or DVD is ***illuminated*** with light coming from a filament lamp in such a way that ***only rays with large angles of incidence*** are selected, ***a clear green line*** can be observed. The colour varies upon slightly changing the ***angle of the disc***. Explain and investigate this phenomenon.



3 - Siren

Team Czechia

Maksymilian Yurchenko
36th IYPT in Murree
July 23, 2023



Assignment

If you direct an **air flow** onto a **rotating disk with holes**, a so
heard. Explain this phenomenon and investigate how the **sou**
characteristics depend on the **relevant parameters.**

Disk = cylinder of the height much shorter than its radius

Sound characteristics:
- Frequencies present & their intensities
- Loudness

Relevant parameters:
- Geometrical parameters
- Parameters of the flow

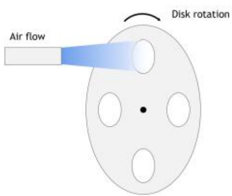
Phen. Explanation & Simple Theory

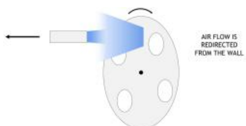
Frequencies Investigation

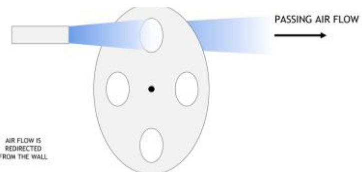
Signal Theory

Loudness Measurements

Phenomenon Explanation



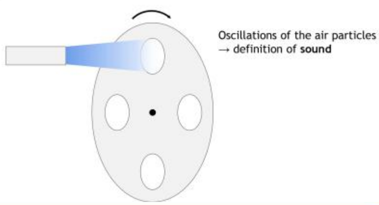




Simple Theory

f - sound frequency
N - number of holes
f_m - frequency of the disk rotation

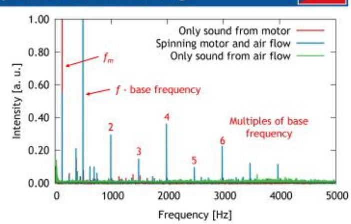
$$f = N f_m$$



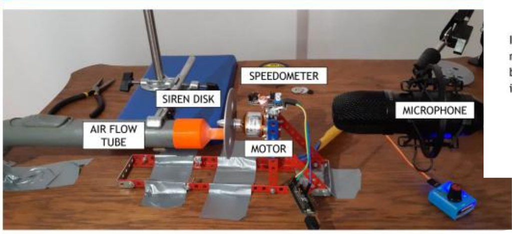
Drawbacks:
- Does not predict intensity of sound
- Does not account asymmetric disks

Spectra Of Recordings

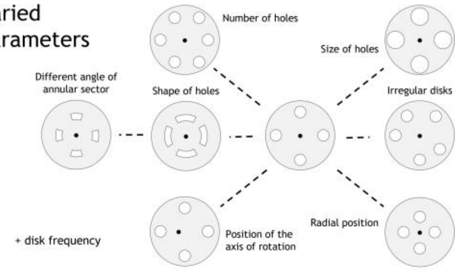
Intensities normalized by base frequency intensity



Used Setup



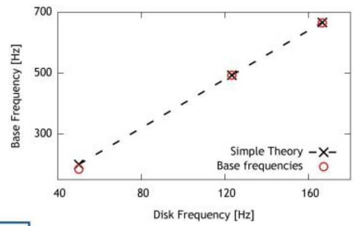
Varied Parameters



Disk Frequency

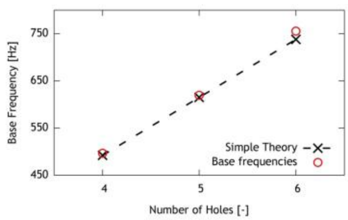
N = 4, D = 1 cm, r = 2 cm, α = 45°, sector shape

$$f = N f_m$$

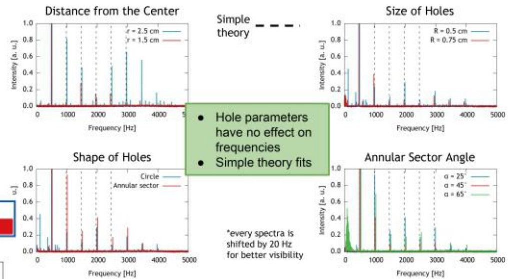


Number of Holes

f_m = 123 Hz, R = 0.5 cm, r = 2 cm, circular shape

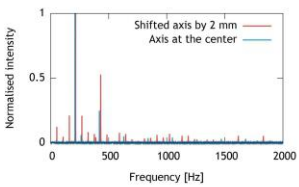


$$f = N f_m$$

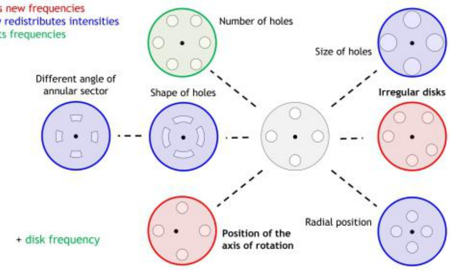


Shifted Axis of Rotation

N = 4, f_m = 53 Hz, R = 0.5 cm, r = 2 cm, circular shape

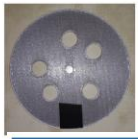


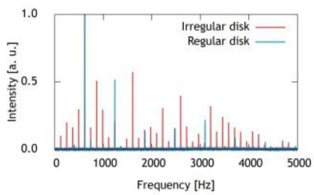
Adds new frequencies
Only redistributes intensities
Shifts frequencies



Disk Irregularity

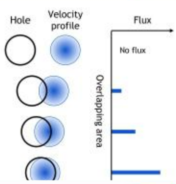
N = 5, f_m = 123.3 Hz, R = 0.5 cm, r = 2 cm, circular shape





Signal Theory

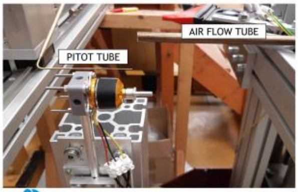
- Reproduction of air flux behind the disk
- FFT of the signal
  → sound characteristics
- Approximation - sound pressure is proportional to air flux
- Oscillations depends on:
  - Hole shape
  - Velocity profile



Measurement of Pressure Profile

- Measurement of dynamic pressure (by Pitot tube) at end of the tube

→ Obtaining of velocity profile



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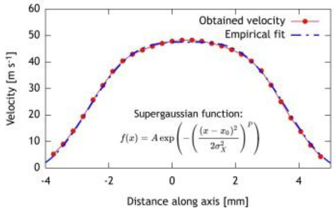
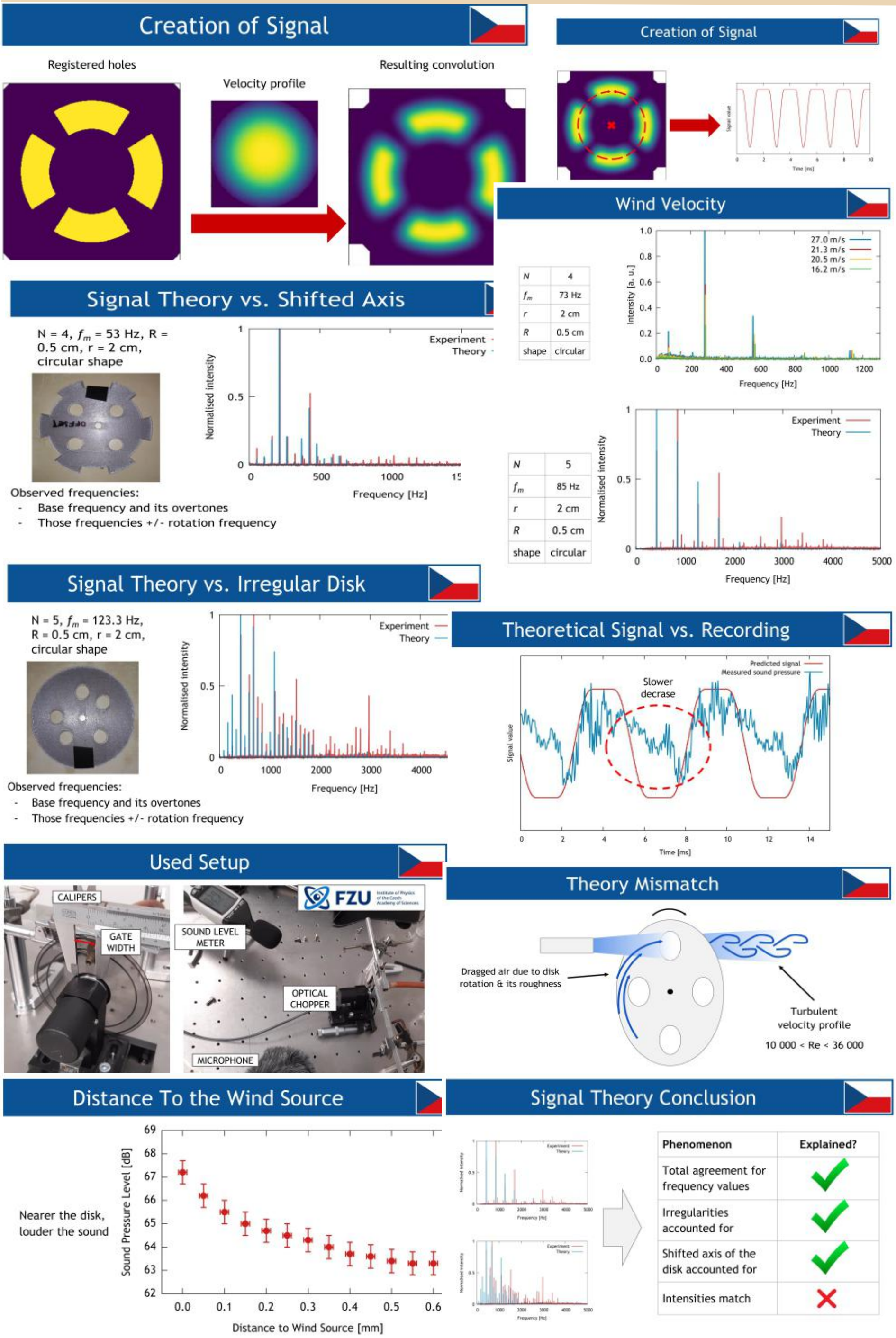
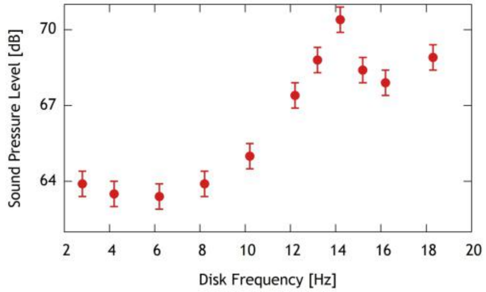
Velocity Profile



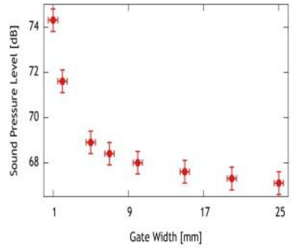

Creation of Signal
Registered holes
Velocity profile
Resulting convolution
Creation of Signal
Wind Velocity
N 4
f_m 73 Hz
r 2 cm
R 0.5 cm
shape circular
27.0 m/s
21.3 m/s
20.5 m/s
16.2 m/s
Intensity [a. u.]
Frequency [Hz]
Signal Theory vs. Shifted Axis
N = 4, f_m = 53 Hz, R = 0.5 cm, r = 2 cm, circular shape
Experiment
Theory
Normalised intensity
Frequency [Hz]
Observed frequencies:
- Base frequency and its overtones
- Those frequencies +/- rotation frequency
N 5
f_m 85 Hz
r 2 cm
R 0.5 cm
shape circular
Signal Theory vs. Irregular Disk
N = 5, f_m = 123.3 Hz, R = 0.5 cm, r = 2 cm, circular shape
Observed frequencies:
- Base frequency and its overtones
- Those frequencies +/- rotation frequency
Theoretical Signal vs. Recording
Predicted signal
Measured sound pressure
Slower decrase
Signal value
Time [ms]
Used Setup
CALIPERS
GATE WIDTH
SOUND LEVEL METER
OPTICAL CHOPPER
MICROPHONE
FZU
Theory Mismatch
Dragged air due to disk rotation & its roughness
Turbulent velocity profile
10 000 < Re < 36 000
Distance To the Wind Source
Nearer the disk, louder the sound
Sound Pressure Level [dB]
Distance to Wind Source [mm]
Signal Theory Conclusion
Phenomenon | Explained?
Total agreement for frequency values | ✓
Irregularities accounted for | ✓
Shifted axis of the disk accounted for | ✓
Intensities match | ✗

Base Frequency

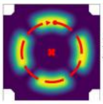


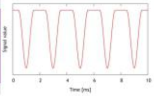
Gate Width

Thinner the gate, louder the sound

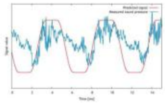


Conclusion

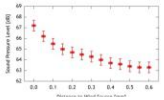




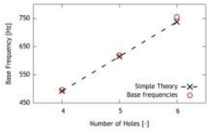
- **Created signal theory** to predict frequency spectrum & account for **asymetrical disks**
  - **Total agreement for frequencies**
  - Difference in recorded signal due to turbulencies



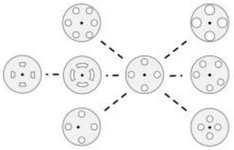
- Overall loudness investigation
  - Surrounding may amplify sound



- Phenomenon **observed** and **explained** by simple theory



- **Systematically** investigated all reasonable **geometrical** parameters
  - Shifted axis, number of holes, angular velocity, radial position, shape of holes, angle of holes, size of holes



ART AN AMAZING FACT IN SCIENCE

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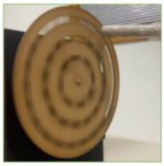
Problem 3

Siren

Reporter: José Antônio Eleutério

If you direct an air flow onto a rotating disk with holes, a sound may be heard. Explain this phenomenon and investigate how the sound characteristics depend on the relevant parameters.



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Problem statement

If you direct an air flow onto a rotating disk with holes, a sound may be heard. Explain this phenomenon[1] and investigate how the sound characteristics depend on the relevant parameters[2].

Tasks:

1. Explain the phenomenon
2. Investigate relevant parameters

Parameters:

- Air flow characteristics
- Rotation speed
- Distribution of holes
- Sound characteristics

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Overview

1. *Introduction* — *Introduction to the problem and initial hypothesis*
2. *Theoretical model* — *Qualitative and quantitative description*
3. *Experimental methodology* — *Problem setup and experimental solutions*
4. *Experimental results* — *Analysis of experimental results*
5. *Conclusions*

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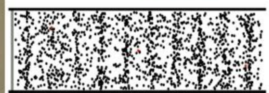
Let's take a look at history...

Wikimedia Commons (2018)

Means of studying *pure tones*



Dan Russell (2011)

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Introduction

Production of sound

- Is formed a pattern of compression-expansion when the flow pass through the hole;

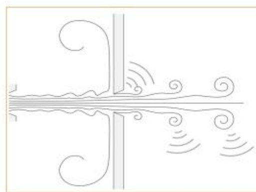

Fig. 2(a): Air flux through hole.

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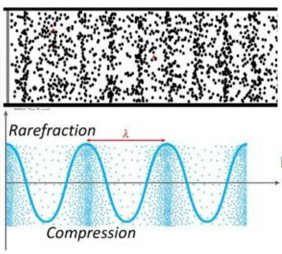
Let's take a look at history...

Means of studying *pure tones*

Wikimedia Commons (2018)



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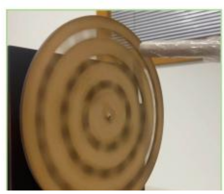
Introduction

Observation of the phenomenon



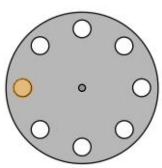


Fig. 3(a): Air flux through hole.

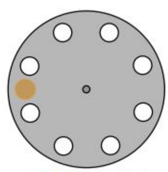


Fig. 3(b): Air collision with wall.

- Air flux through hole;
- **Sound** production.

- Air flux collides with wall;
- **Noise** production.

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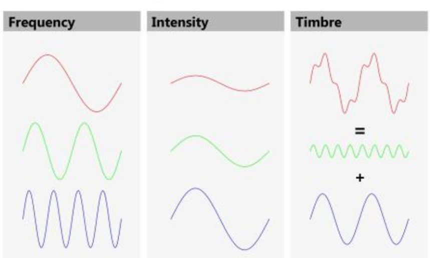
Introduction

Characteristics of the sound produced



ART AN AMAZING FACT IN SCIENCE

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Introduction
Production of sound

Fig. 2(a): Air flux through hole.

Fig. 2(b): Air collision with wall.

Production of sound | Production of noise

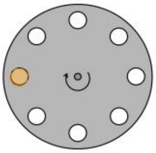

Fig. 3: Air collision with wall.

- Periodic alternance between the flow passage and collision;
- Periodic alternance betwenn sound and noise;

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Introduction
Production of noise

- The flow is blocked for the disc, however some kind of "noise" will be produced;

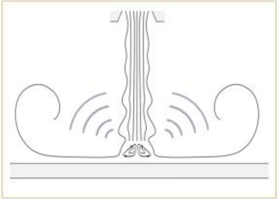

Fig. 3: Air collision with wall.
[1] "The aerocoustics of steam kettle", R. H. Henrywood e A. Agarwal – Physics of Fluids 25, 107101 (2013)."

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Initial Hypothesis
Sound intensity and area of intersection

Air flux intersects completely with the hole	Air flux intersects partially with the wall and the hole	Air flux intersects completely with the wall
Production of compression wave with full intensity	Production of compression wave with partial intensity	Production of noise, absence of compression wave production

Hypothesis:
The intensity of the sound produced we hear is proportional to the area of ...

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Initial Hypothesis
Sound intensity and area of intersection

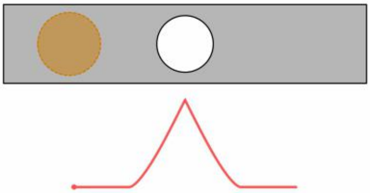

Fig. 6: Area of intersection with time.

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Initial Hypothesis
Alternancy between sound production and noise production

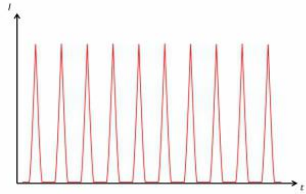
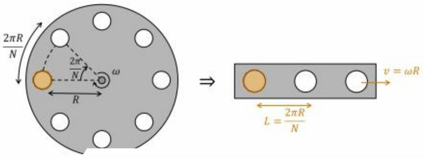
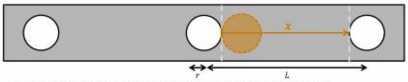


Fig. 7: Intensity of sound in function to time

Quantitative description
Definition of system



Quantitative description
Alternancy between sound production and noise production



- The area of intersection between flow and hole is a periodical:
- If $2r \leq x \leq L - 2r$, so $S(x) = 0$

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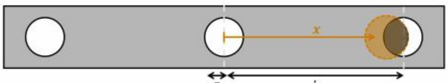
Quantitative description
Alternancy between sound production and noise production



- The area of intersection between flow and hole is a periodical:
- If $2r \leq x \leq L - 2r$, so $S(x) = 0$
- If $0 \leq x \leq 2r$ or $L - 2r \leq x \leq L$, we have:

$$S(x) = 2r^2 \cos^{-1}\left(\frac{|x|}{2r}\right) - \frac{|x|}{2}\sqrt{4r^2 - xr^2}$$

$$I(x) \propto S(x)$$

Introduction > Theoretical analysis > Experimental methodology > Experimental results > Conclusions

Quantitative description:
Fourier series and coefficient

- The area of the intersection is a piecewise periodic:
- The Fourier Series is given by:

$$S(x) = a_0 + \sum_{n=1}^{\infty}\left[a_n \cos\left(\frac{2\pi n x}{L}\right) + b_n \sin\left(\frac{2\pi n x}{L}\right)\right]$$

- In which the coefficients are:

$$a_0 = \frac{1}{L}\int_{-L/2}^{L/2} S(x)dx \longrightarrow a_0 = \frac{32r^3}{6L}$$

$$a_n = \frac{2}{L}\int_{-L/2}^{L/2} S(x)\cos\left(\frac{2\pi n x}{L}\right)dx \longrightarrow a_n = \frac{32r^3}{L}\frac{1}{k}\int_0^1 \sqrt{1-u^2}\sin(ku)\,du,$$

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Quantitative description:

Fourier series and coefficient

- The area of the intersection is a piecewise periodic:
- The Fourier Series is given by:

$$S(x) = a_0 + \sum_{n=1}^{\infty}\left[a_n \cos\left(\frac{2\pi n x}{L}\right) + b_n \sin\left(\frac{2\pi n x}{L}\right)\right]$$

- In which the coefficients are:

$$a_n = \frac{2}{L}\int_{-L/2}^{L/2} S(x)\cos\left(\frac{2\pi n x}{L}\right)dx \rightarrow a_n = \frac{32r^3}{L}\frac{1}{k}\int_0^1 \sqrt{1-u^2}\sin(ku)\,du\,,$$

$$B(k) = \frac{\pi}{8}\sum_{j=0}^{\infty}\frac{(-1)^j\left(\frac{k}{2}\right)^{2j}}{\Gamma\left(j+\frac{3}{2}\right)\Gamma\left(j+\frac{5}{2}\right)} \qquad a_n = \frac{32r^3}{L}B\left(\frac{4\pi n r}{L}\right)$$

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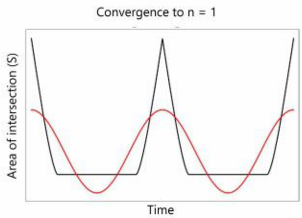
Quantitative description:

Fourier Convergences



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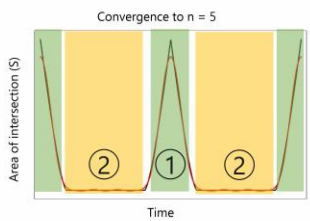
Quantitative description:

Fourier Convergences



① *Production of sound* ② *Production of noise*

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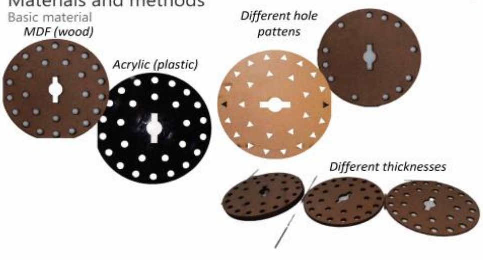
Materials and methods

Basic material



We used CNC machines to make the disks to reduce humane flaws

- So, the Fourier Series of $S(x)$ is:

$$S(x) = \frac{32r^3}{L}\left[\frac{1}{6} + \sum_{n=1}^{\infty} B\left(\frac{4\pi n r}{L}\right)\cos\left(\frac{2\pi n x}{L}\right)\right]$$

- Where in green are all the terms related to amplitude and in yellow are the terms related to frequency

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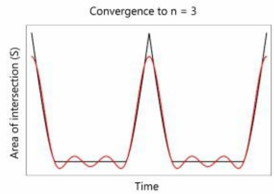
Quantitative description:

Fourier Convergences



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Quantitative description:

Fourier Convergences

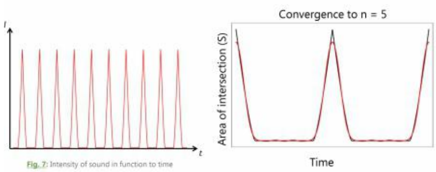

Fig. 7: Intensity of sound in function to time

Qualitative description of the phenomenon

$$S(x) = \frac{32r^3}{L}\left[\frac{1}{6} + \sum_{n=1}^{\infty} B\left(\frac{4\pi n r}{L}\right)\cos\left(\frac{2\pi n x}{L}\right)\right]$$

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Quantitative description:

Fourier series and coefficient

- Knowing that $I(x) \propto S(x)$, we have:

$$I(x) = C\,S(x) = \frac{32Cr^3}{L}\left[\frac{1}{6} + \sum_{n=1}^{\infty} B\left(\frac{4\pi n r}{L}\right)\cos\left(\frac{2\pi n x}{L}\right)\right]$$

- The relative intensity of a fundamental harmonic of a wave is:

$$\frac{I_n}{I_1} = \left[B\left(\frac{4\pi r}{L}n\right)\right]^2 / \left[B\left(\frac{4\pi r}{L}\right)\right]^2$$

- The relative intensity of the n-th harmonic with respect to the fundamental harmonic of the wave is defined by:

$$f_n = \frac{\omega N}{2\pi}n \qquad N - \textit{number of holes}$$

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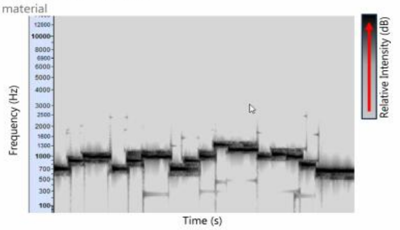
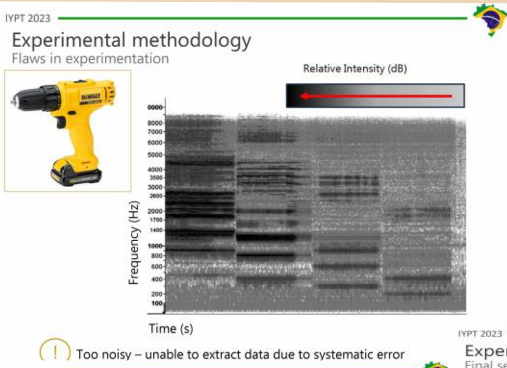
Materials and methods

Basic material



Spectrogram analyses the intensity of the sound at different frequencies over time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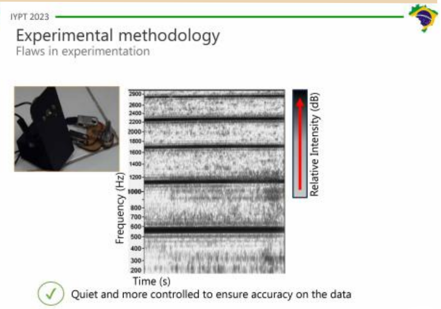
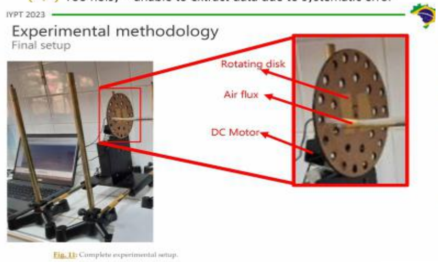
Experimental methodology
Flaws in experimentation
Relative Intensity (dB)
Frequency (Hz)
Time (s)
Too noisy – unable to extract data due to systematic error


IYPT 2023
Experimental methodology
Flaws in experimentation
Frequency (Hz)
Relative Intensity (dB)
Time (s)
Quiet and more controlled to ensure accuracy on the data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Experimental methodology
Final setup
Rotating disk
Air flux
DC Motor
Fig. 11: Complete experimental setup.


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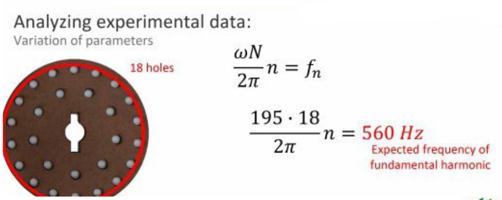
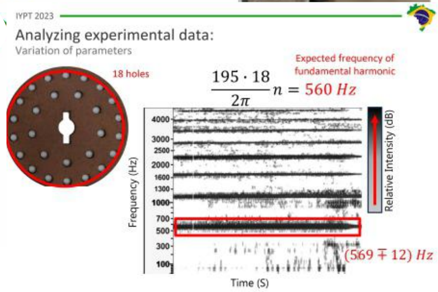
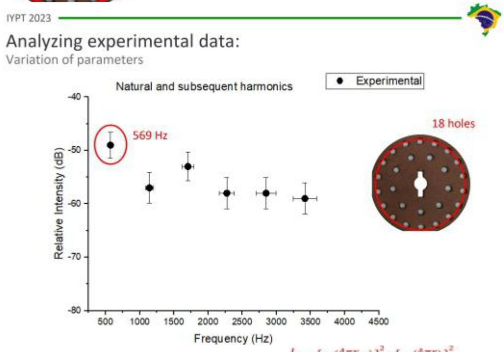
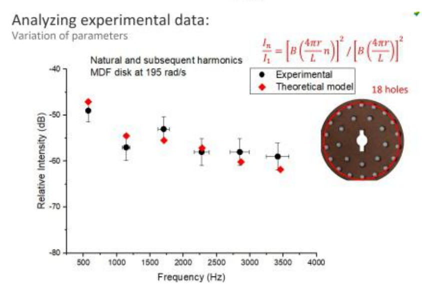
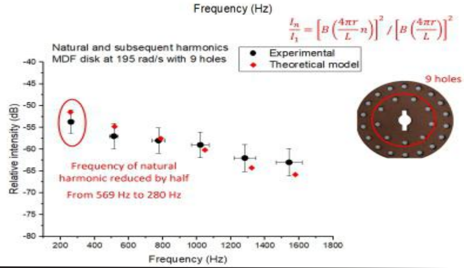
Experimental methodology
Final setup
Fig. 11: Complete experimental setup.

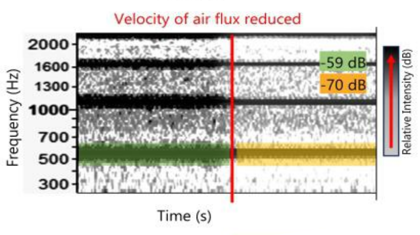

Analyzing experimental data:
Variation of parameters
18 holes
$\frac{\omega N}{2\pi} n = f_n$
$\frac{195 \cdot 18}{2\pi} n = 560\ Hz$
Expected frequency of fundamental harmonic


IYPT 2023
Analyzing experimental data:
Variation of parameters
18 holes
$\frac{195 \cdot 18}{2\pi} n = 560\ Hz$
Expected frequency of fundamental harmonic
Frequency (Hz)
Relative Intensity (dB)
$(569 \mp 12)\ Hz$
Time (S)


IYPT 2023
Analyzing experimental data:
Variation of parameters
Natural and subsequent harmonics
Experimental
569 Hz
18 holes
Relative Intensity (dB)
Frequency (Hz)

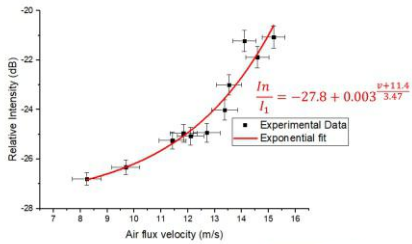

Analyzing experimental data:
Variation of parameters
$\frac{I_n}{I_1} = \left[B\left(\frac{4\pi r}{L}n\right)\right]^2 / \left[B\left(\frac{4\pi r}{L}\right)\right]^2$
Natural and subsequent harmonics
MDF disk at 195 rad/s
Experimental
Theoretical model
18 holes
Relative Intensity (dB)
Frequency (Hz)


$\frac{I_n}{I_1} = \left[B\left(\frac{4\pi r}{L}n\right)\right]^2 / \left[B\left(\frac{4\pi r}{L}\right)\right]^2$
Natural and subsequent harmonics
MDF disk at 195 rad/s with 9 holes
Experimental
Theoretical model
9 holes
Frequency of natural harmonic reduced by half
From 569 Hz to 280 Hz
Relative intensity (dB)
Frequency (Hz)

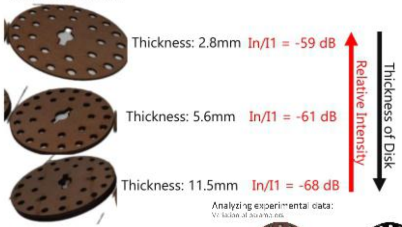

Velocity of air flux reduced
-59 dB
-70 dB
Frequency (Hz)
Relative Intensity (dB)
Time (s)

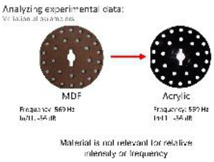
Analyzing experimental data:
Variation of parameters

What happens if we alter the speed of the air flux?

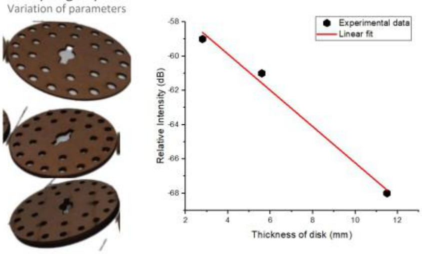


Analyzing experimental data:
Variation of parameters



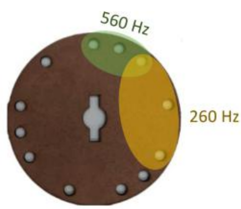


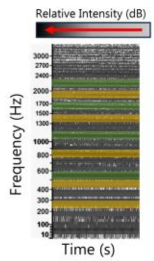
Analyzing experimental data:
Variation of parameters



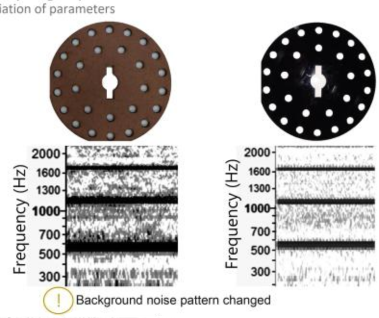
Analyzing experimental data:
Variation of parameters

Combination of different frequencies

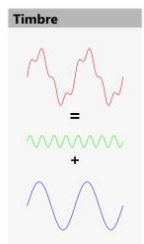




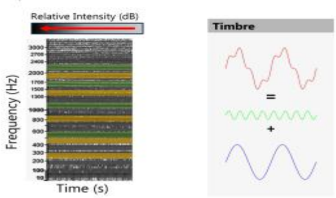
Analyzing experimental data:
Variation of parameters



Analyzing experimental data:
Variation of parameters

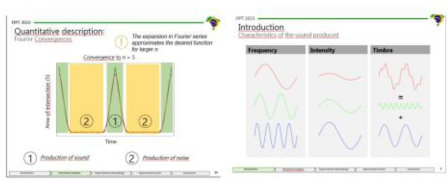


Analyzing experimental data:
Variation of parameters



Conclusion
Resume about the tasks

Explain this phenomenon



Conclusion
Resume about the tasks

on the relevant parameters[2].

Frequency
- Angular velocity
- Amount of holes

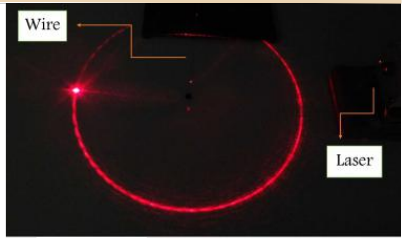
Intensity
- Air flow velocity
- Thickness
- Area of air flow intersection

Timbre
- Combination of different frequenci
- Material of disk

Circle of light

Problem #5

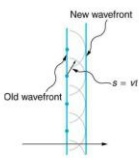
AmirHossein Ebadi



When a laser beam is aimed at a wire, a circle of light can be observed on a screen perpendicular to the wire. Explain this phenomenon and investigate how it depends on the relevant parameters.

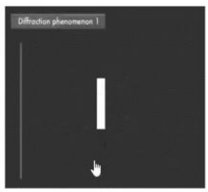
Huygens–Fresnel principle

The **Huygens Principle** as modified by **Fresnel** states that every unobstructed point on a wave front acts, at a given instant, as a source of outgoing secondary spherical waves.[1]



[1]:http://www.atoptics.co.uk/droplets/huygens.htm

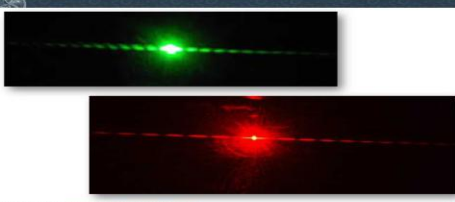
- **Diffraction** refers to various phenomena which occur when a wave encounters an obstacle or a slit.
- In classical physics, the **diffraction** phenomenon is described as the interference of waves according to the Huygens Fresnel principle.



Diffraction from an obstacle

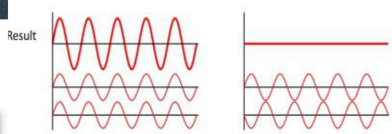
Diffraction from a slit

Diffraction of a wire



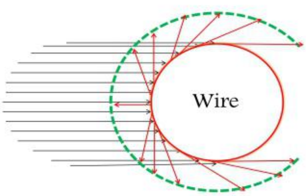
Photos from. groups.physics.umn.edu

Interference of waves is a phenomenon in which two waves superpose to form a resultant wave of greater or lower amplitude.



Constructive interference

Destructive interference



A schematic figure of the wire from above showing the effect of reflection

Babinet's principle

The principle:
Is a theorem concerning diffraction that states that the diffraction pattern from an opaque body is identical to that from a hole of the same size and shape except for the overall forward beam intensity.

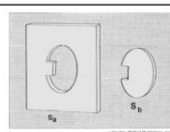
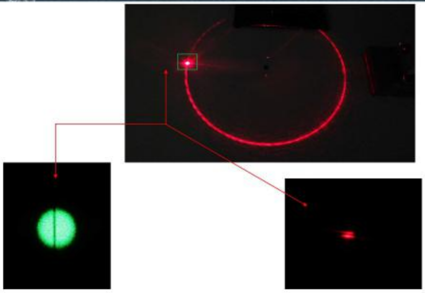


Figure 6.3: According to Babinet's principle, these two screens produce the same diffraction pattern in all regions that are not colinear with the incident beam.

[1]:Yusuf Ziya Umul - Babinet's principle in the Fraunhofer diffraction by a finite thin wire

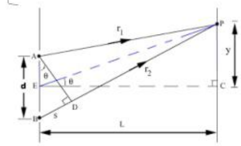
ART AN AMAZING FACT IN SCIENCE

Transmission isn't true



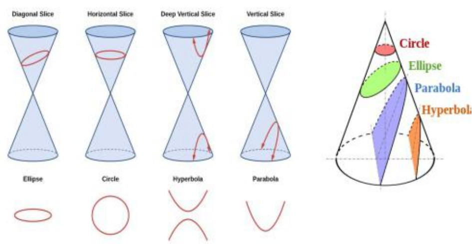
Diffraction equation

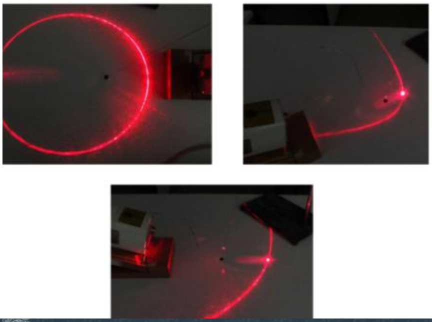
$$d\sin\theta = \begin{cases} n\lambda \quad (n \in W) & \text{Bright fringes} \\ (n-0.5)\lambda \quad (n \in N) & \text{Dark fringes} \end{cases}$$

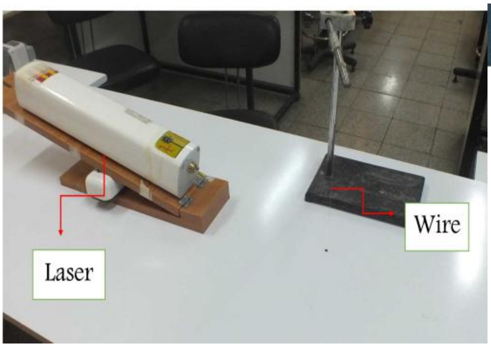


[1]:Bradly W. Carroll – An introduction to modern astrophysics

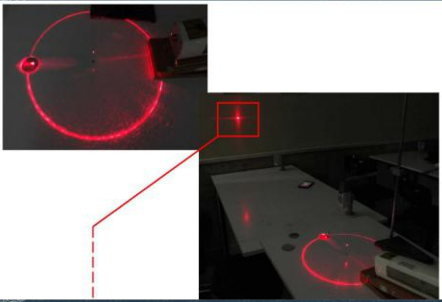
Orientation of the surface



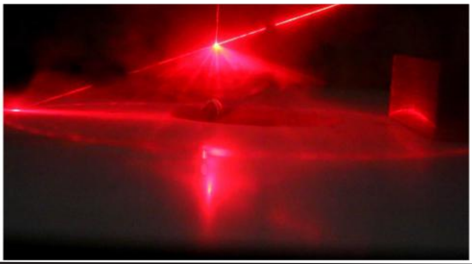




Diffraction pattern

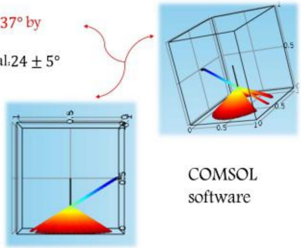


Conic



Diffraction & Simulation

Diffraction: 37° by simulation
Experimental:24 ± 5°

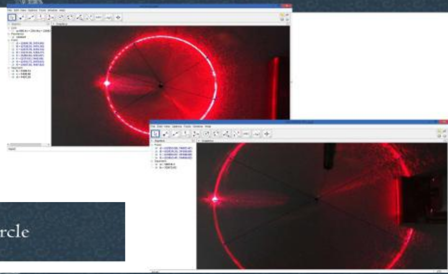


COMSOL software

Effective parameter

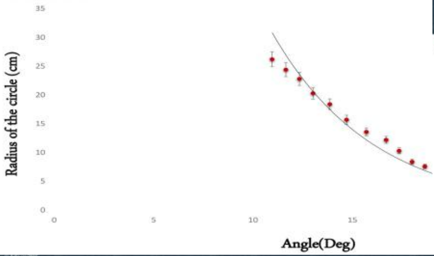
- Distance between laser and wire
- Angle of laser
- Thickness of wire
- Wavelength of laser
- Type of wire

Circle



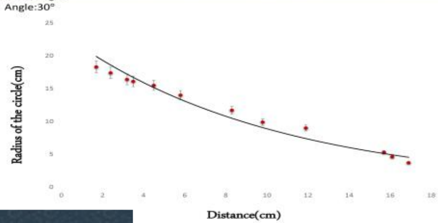
Angle of the laser – Radius of the circle

Same distances
Distance:20 cm



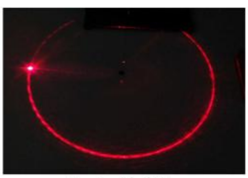
Distance– Radius of the circle

Same angle
Angle:30°

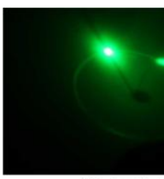


Wavelength of laser

We experimented with different wave length but because the difference between the wave length were less than 300 nm we cant see something different.

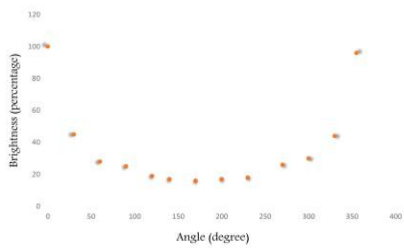


Wavelength : 632 nm

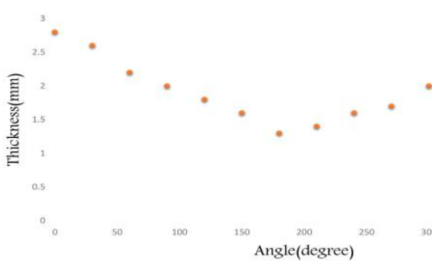


Wavelength : :

Brightness vs. Angle



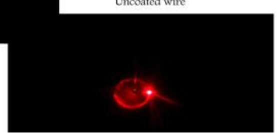
Thickness of the circle Vs. Angle

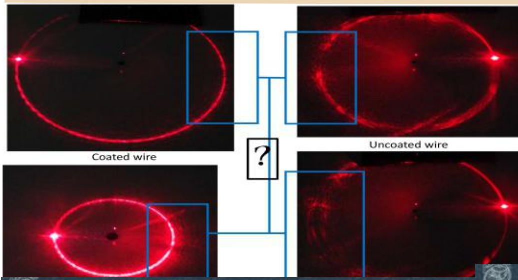


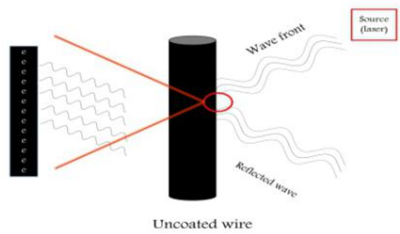
Type of wire

Coated wire

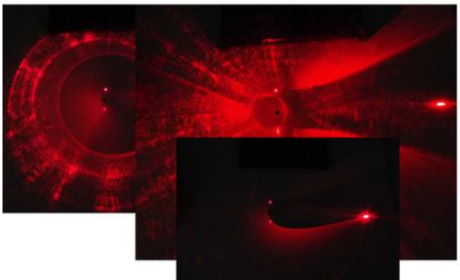
Uncoated wire



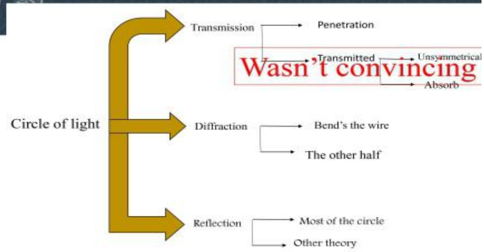




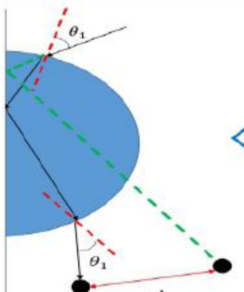
Another layer(using oil and uncoated wire)

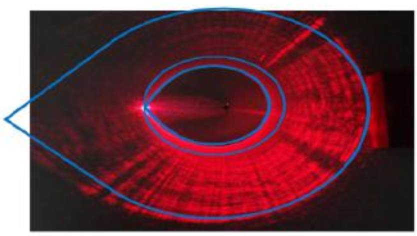


Conclusion



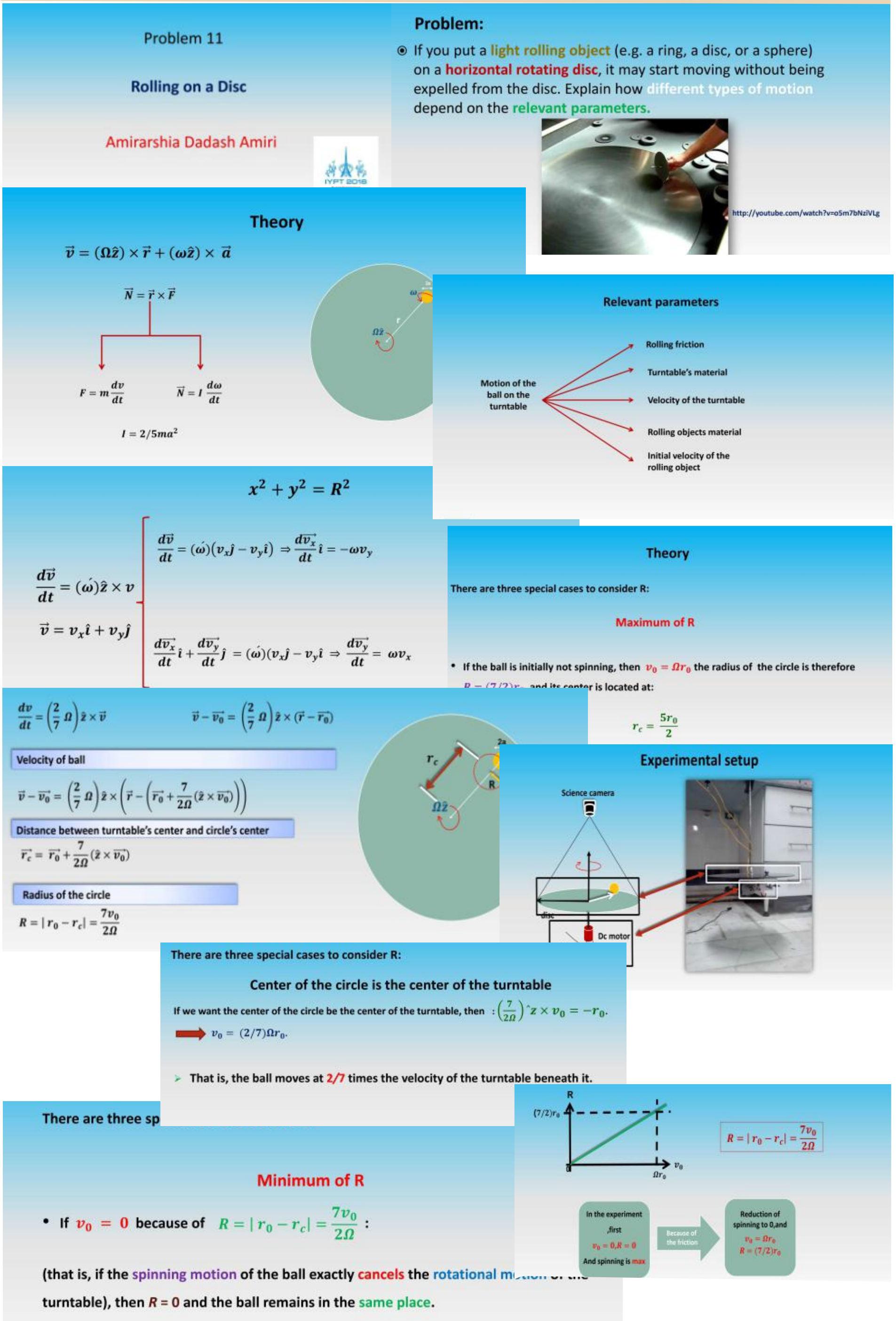
Schematic picture of what is happening

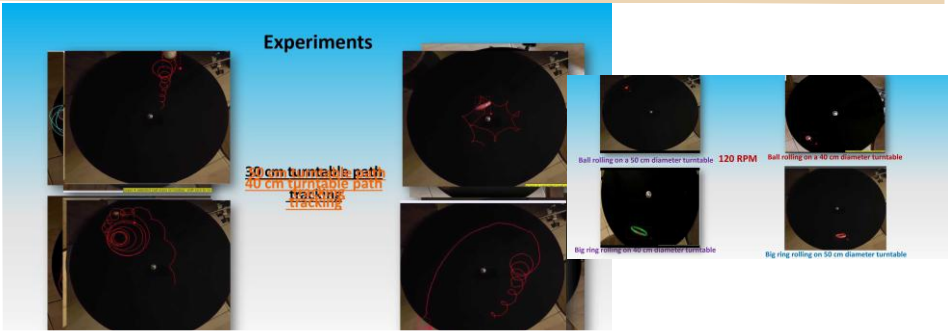


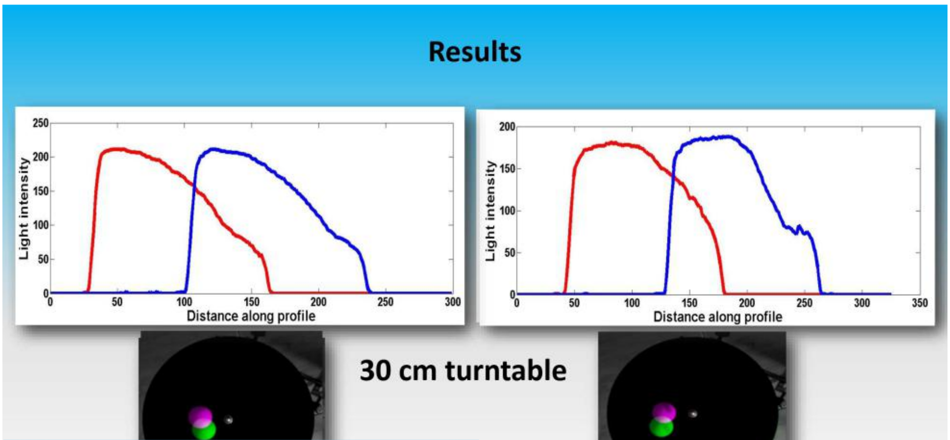


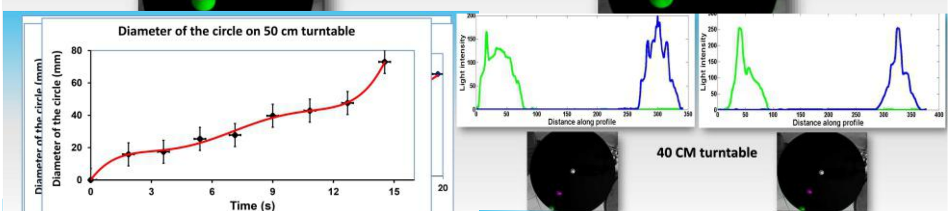
References

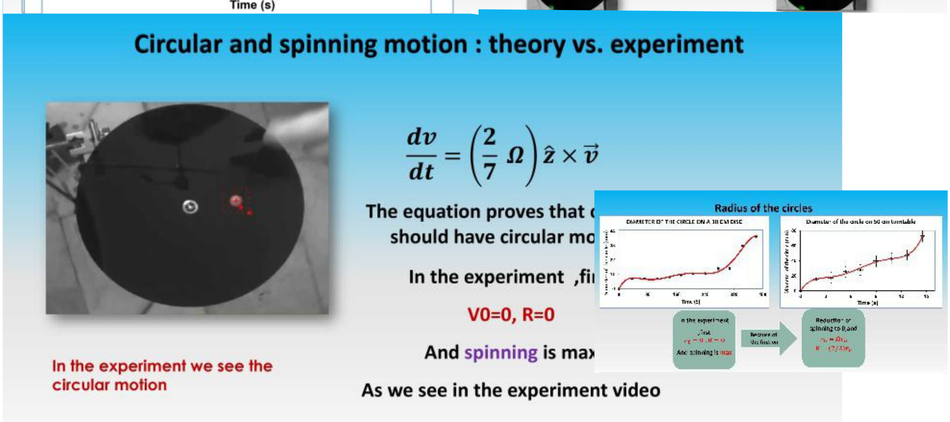
1. A. Ike Mowete1 and A. Ogunsola - Plane Wave Scattering by a Coated Thin Wire
2. L.A. Haverkate; L.F. Feiner - Optical properties of cylindrical nanowires
3. Yusuf Ziya Umul - Babinet's principle in the Fraunhofer diffraction by a finite thin wire
4. H. J. Kong - Hollow conic beam generator using a cylindrical rod and its performances


Problem 11
Rolling on a Disc
Amirarshia Dadash Amiri
IYPT 2016
Problem:
If you put a light rolling object (e.g. a ring, a disc, or a sphere) on a horizontal rotating disc, it may start moving without being expelled from the disc. Explain how different types of motion depend on the relevant parameters.
http://youtube.com/watch?v=o5m7bNziVLg
Theory
$\vec{v} = (\Omega\hat{z}) \times \vec{r} + (\omega\hat{z}) \times \vec{a}$
$\vec{N} = \vec{r} \times \vec{F}$
$F = m\frac{dv}{dt}$
$\vec{N} = I\frac{d\omega}{dt}$
$I = 2/5ma^2$
Relevant parameters
Motion of the ball on the turntable
Rolling friction
Turntable's material
Velocity of the turntable
Rolling objects material
Initial velocity of the rolling object
$x^2 + y^2 = R^2$
$\frac{d\vec{v}}{dt} = (\acute{\omega})\hat{z} \times v$
$\vec{v} = v_x\hat{\imath} + v_y\hat{\jmath}$
$\frac{d\vec{v}}{dt} = (\acute{\omega})(v_x\hat{\jmath} - v_y\hat{\imath}) \Rightarrow \frac{d\vec{v_x}}{dt}\hat{\imath} = -\omega v_y$
$\frac{d\vec{v_x}}{dt}\hat{\imath} + \frac{d\vec{v_y}}{dt}\hat{\jmath} = (\acute{\omega})(v_x\hat{\jmath} - v_y\hat{\imath}) \Rightarrow \frac{d\vec{v_y}}{dt} = \omega v_x$
Theory
There are three special cases to consider R:
Maximum of R
If the ball is initially not spinning, then $v_0 = \Omega r_0$ the radius of the circle is therefore
and its center is located at:
$r_c = \frac{5r_0}{2}$
$\frac{dv}{dt} = \left(\frac{2}{7}\Omega\right)\hat{z} \times \vec{v}$
$\vec{v} - \vec{v_0} = \left(\frac{2}{7}\Omega\right)\hat{z} \times (\vec{r} - \vec{r_0})$
Velocity of ball
$\vec{v} - \vec{v_0} = \left(\frac{2}{7}\Omega\right)\hat{z} \times \left(\vec{r} - \left(\vec{r_0} + \frac{7}{2\Omega}(\hat{z} \times \vec{v_0})\right)\right)$
Distance between turntable's center and circle's center
$\vec{r_c} = \vec{r_0} + \frac{7}{2\Omega}(\hat{z} \times \vec{v_0})$
Radius of the circle
$R = |r_0 - r_c| = \frac{7v_0}{2\Omega}$
Experimental setup
Science camera
disc
Dc motor
There are three special cases to consider R:
Center of the circle is the center of the turntable
If we want the center of the circle be the center of the turntable, then : $\left(\frac{7}{2\Omega}\right)\hat{z} \times v_0 = -r_0$.
$v_0 = (2/7)\Omega r_0$.
That is, the ball moves at 2/7 times the velocity of the turntable beneath it.
There are three sp
Minimum of R
If $v_0 = 0$ because of $R = |r_0 - r_c| = \frac{7v_0}{2\Omega}$:
(that is, if the spinning motion of the ball exactly cancels the rotational m
turntable), then $R = 0$ and the ball remains in the same place.
$(7/2)r_0$
Ωr_0
v_0
$R = |r_0 - r_c| = \frac{7v_0}{2\Omega}$
In the experiment ,first $v_0 = 0, R = 0$ And spinning is max
Because of the friction
Reduction of spinning to 0,and $v_0 = \Omega r_0$ $R = (7/2)r_0$


Experiments
30 cm turntable path tracking
40 cm turntable path tracking
Ball rolling on a 50 cm diameter turntable
120 RPM
Ball rolling on a 40 cm diameter turntable
Big ring rolling on 40 cm diameter turntable
Big ring rolling on 50 cm diameter turntable

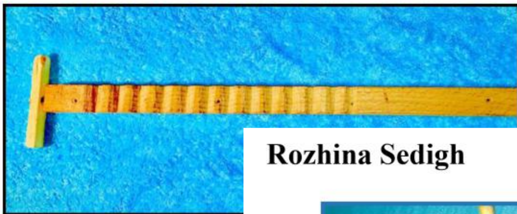

Results
Light intensity
Distance along profile
30 cm turntable


Diameter of the circle on 50 cm turntable
Diameter of the circle (mm)
Time (s)
Light intensity
Distance along profile
40 CM turntable

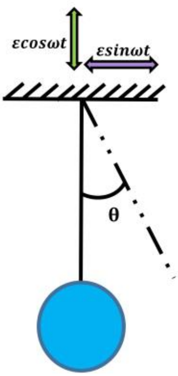

Circular and spinning motion : theory vs. experiment
$$\frac{dv}{dt} = \left(\frac{2}{7}\,\Omega\right)\hat{z} \times \vec{v}$$
The equation proves that c
should have circular mo
In the experiment ,fi
V0=0, R=0
And spinning is max
As we see in the experiment video
In the experiment we see the
circular motion
Radius of the circles

14. Gee haw whammy diddle

A gee-haw whammy diddle is a **mechanical toy** consisting of a simple **wooden stick** and a second stick that is made up of a **series of notches** with a **propeller** at its end. When the wooden stick is pulled over the notches, the propeller starts to **rotate**. Explain this phenomenon and investigate the relevant parameters.



Rozhina Sedigh

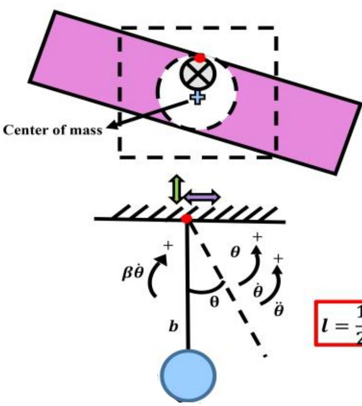


Horizontal motion in the support

1) $$\ddot{\theta} + \varepsilon \sin\omega t \cos\theta = 0$$

Vertical motion in the support

2) $$\ddot{\theta} + \varepsilon \cos\omega t \sin\theta = 0$$



$$v^{\rightarrow} = v^{\rightarrow}_{center\ of\ mass} + v^{\rightarrow}_{motion\ of\ support}$$

$$l = \frac{1}{2}mv^2 + I\dot{\theta}^2$$

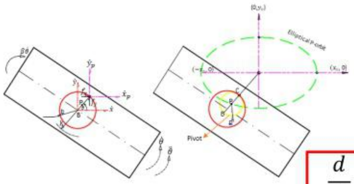
$$v_{center\ of\ mass} = \dot{x}i + \dot{y}j$$

$$v_{motion\ of\ support} = b\dot{\theta}\cos\theta i - b\dot{\theta}\sin\theta j$$

$$v^{\rightarrow} = (\dot{x} + b\dot{\theta}\cos\theta)i + (\dot{y} - b\dot{\theta}\sin\theta)j$$

$$I = \frac{1}{2}mk^2$$

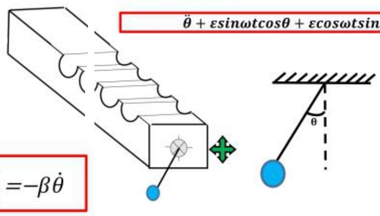
$$l = \frac{1}{2}m\left[(\dot{x} + b\dot{\theta}\cos\theta)^2 + (\dot{y} - b\dot{\theta}\sin\theta)^2\right] + \frac{1}{2}mk^2\dot{\theta}^2$$



$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot\theta}\right) - \frac{\partial L}{\partial \theta} = -\beta\dot\theta$$

Sum of equations 1 and 2

$$\ddot\theta + \varepsilon sin\omega t cos\theta + \varepsilon cos\omega t sin\theta = 0$$



$$\underbrace{\frac{d}{dt}}_{2}\left(\underbrace{\frac{\partial L}{\partial \dot\theta}}_{1}\right) - \underbrace{\frac{\partial L}{\partial \theta}}_{3} = -\beta\dot\theta$$

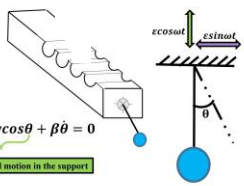
$$l = \frac{1}{2}m\left[(\dot x + b\dot\theta cos\theta)^2 + (\dot y - b\dot\theta sin\theta)^2\right] + I\dot\theta^2$$

1) $$\frac{\partial L}{\partial \dot\theta} = 2I\dot\theta + \frac{1}{2}m[2(\dot\theta + b\dot\theta cos\theta)(bcos\theta) + 2(\dot\theta - b\dot\theta sin\theta)(-bsin\theta)]$$

2) $$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot\theta}\right) = 2I\ddot\theta + \frac{1}{2}m[2(\ddot\theta + b\ddot\theta cos\theta + b\dot\theta\dot\theta sin\theta)(bcos\theta) + 2(\dot\theta + b\dot\theta cos\theta)(-b\dot\theta sin\theta) + 2(\ddot\theta - b\ddot\theta sin\theta - b\dot\theta\dot\theta cos\theta)(-bsin\theta) + 2(\dot\theta - b\dot\theta sin\theta)(-bcos\theta\dot\theta)]$$

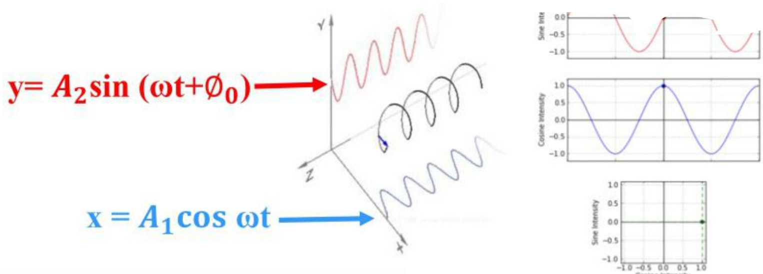
3) $$\frac{\partial L}{\partial \theta} = \frac{1}{2}m[2(\dot\theta + b\dot\theta cos\theta)(-bsin\theta) - 2(\dot\theta - b\dot\theta sin\theta)(-b\dot\theta cos\theta)]$$

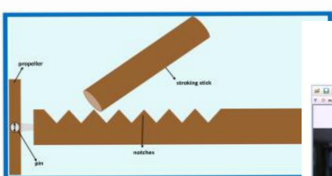
$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot\theta}\right) - \frac{\partial L}{\partial \theta} = 2I\dot\theta + mb^2\ddot\theta + mb\ddot x sin\theta - mbycos\theta = \beta\dot\theta$$

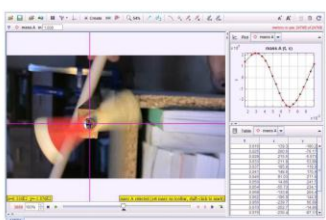


$$2I\dot\theta + mb^2\ddot\theta + \underbrace{mb\ddot x sin\theta}_{\text{Horizontal motion in the support}} - \underbrace{mbycos\theta}_{\text{Vertical motion in the support}} + \beta\dot\theta = 0$$

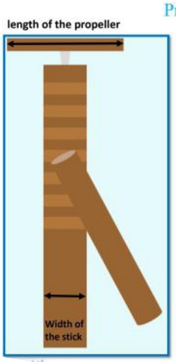
Horizontal motion in the support | Vertical motion in the support





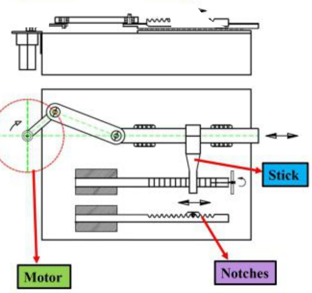


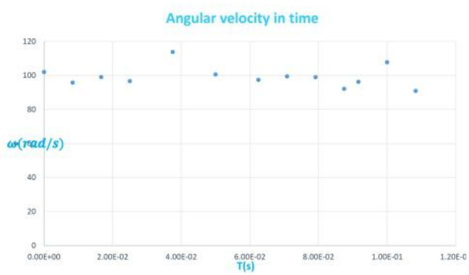
Prediction of Relevant Parameters



- Length of the propeller
- Width of the stick
- Diameter of the hole
- material of the stick
- place of the pin
- Depth of the notches
- Shape of the notches
- Distance between notches
- Frequency of the stick

Experimental setup



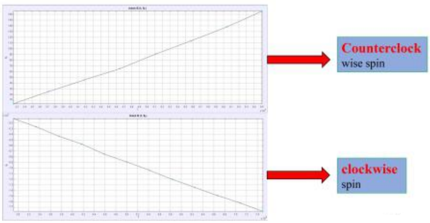


Distance between the notches

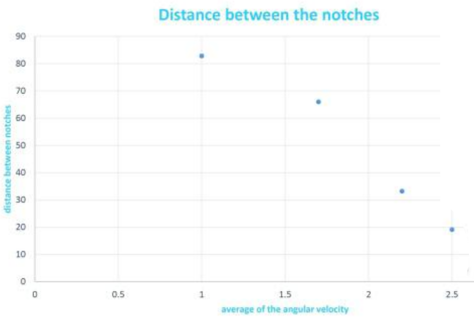
Average of the angular velocity	The number of rotation
19.14	3.048
33.15	5.27
65.97	10.5
82.78	13.18

Material of the stick	Average of the angular velocity	The number of rotation
laminated gypsum stick	48.25	7.68
Wooden stick	65.97	10.5

Width of the stick	Average of the angular velocity	Number of rotation
4 cm	83.26	13.25
3.2 cm	70.25	11.18
2.4 cm	65.97	10.5
1.7 cm	31.91	5.08



Length of the propeller	Average of the angular velocity	The number of rotation
6cm	98.49	15.68
7cm	65.97	10.5
9cm	48.25	7.68



By **increasing** :

❖1) The distance notches

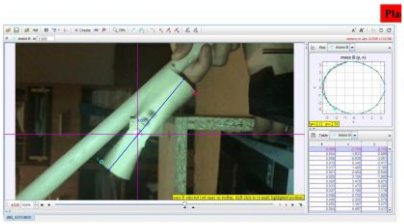
❖2) The width stick

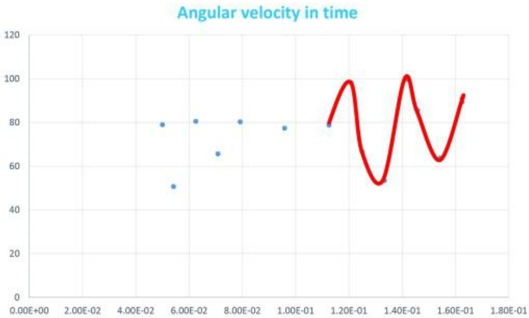
❖3) The length propeller

❖4) The diameter of the hole

❖5) The frequency of the stick

❖Average of the angular velocity is higher in a wooden stick





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2. Geiger, J. D., J. Newsted, R. A. Drongowski, and Lelli, J. L., Jr., "Car surfing: an underreported mechanism of serious injury in children and adolescents," Journal of Pediatric Surgery, 36, No. 1, 232-234 (January 2001)
3. Carey, J., M. C. McCarthy, A. P. Ekeh, L. Patterson, and R. Woods, "Car-surfing in southwest Ohio: Incidence and injuries," Journal of Trauma. Injury, Infection, and Critical Care, 59, No. 3, 734-736 (September 2005)
4. Peterson, T., G. Timberlake, A. Yeager, M. Jadali, and K. Royer, "Car surfing: an uncommon cause of traumatic injury," Annals of Emergency Medicine, 33, No. 2, 192-194 (February 1999)
5. Allan, R. S., P. J. Spittaler, and J. G. Christie, "'Ute surfing': a novel cause of severe head injury," Medical Journal of Australia, 171, Nos. 11-12, 681-682 (6 December 1999)

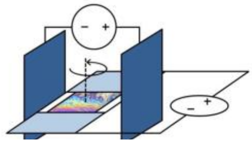
No.4 Liquid Film Motc

Team of Iran
Anahita Abdollahi

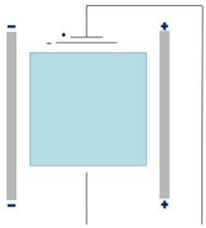
Problem Statement

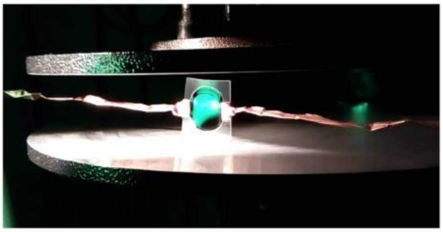
Form a soap film on a flat frame. Put the film in an electric field parallel to the film surface and pass an electric current through the film. The film rotates in its plane.

Investigate and explain the phenomenon.

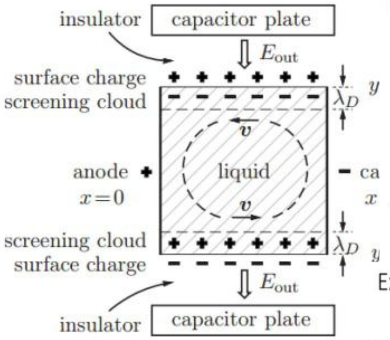


The System





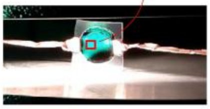
Theory :



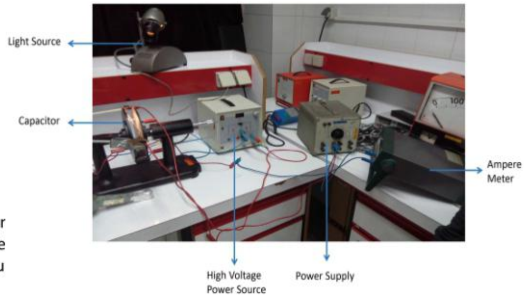
Euler's Equation:

$$\vec{v}(\vec{r} + \vec{v}dt, t + dt) = \vec{v}(\vec{r}, t) + \frac{\vec{f}}{\rho} dt$$

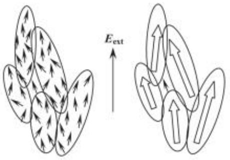
f →
- Electric Force
- Pressure Difference
- Dissipative Forces (Viscoity)



Experiment Setup:



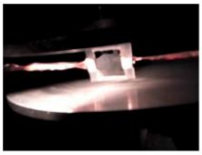
Dipole Theory :

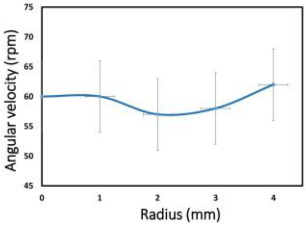


Continuous destruction ar reestablishme dipole structu

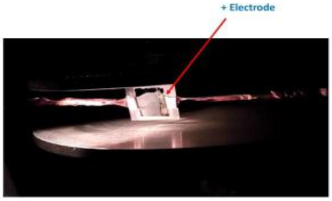
Angular Velocity:

$v = r\,\omega$

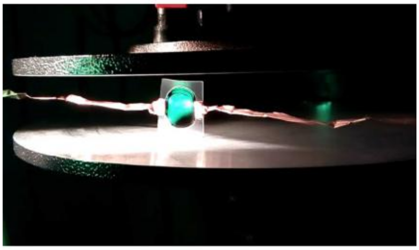




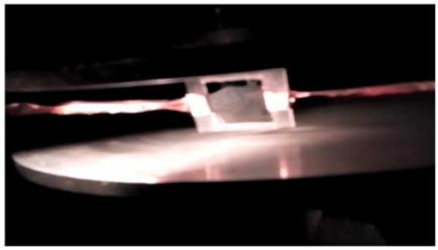
tation Starting Point:



Thinner Layer



Thicker Layer



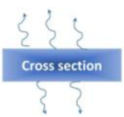
- Starting Point
- Rotation of Non-Polar Liquids
- Uniform Velocity In The System

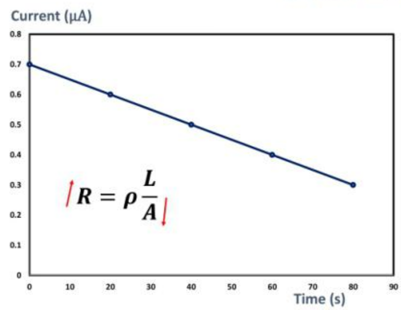
Parameters Overall:

- Conductivity
- Thickness
- Viscosity
- Electric Field & Current Strength

Resistance:
15-20 MΩ

- Surface Evaporation
- Electrolysis





References:

A Liquid Film Motor
A. Amjadi, R. Shirsavar, N. Hamedani Radja, M. R. Ejtehadi Sharif
University of Technology, Department of Physics

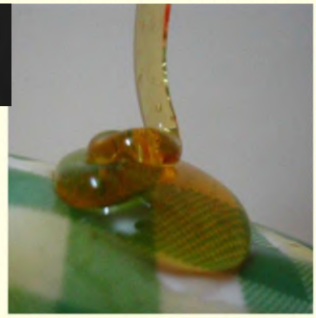
Theory of rotating electrohydrodynamic flows in a liquid film
E. V. Shiryaeva, PHYSICAL REVIEW 2009

Dynamical mechanism of the liquid film motor
Zhong-Qiang Liu

Question

A thin, downward flow of viscous liquid, such as honey, often turns itself into circular coils.

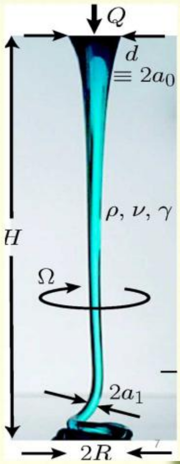
Study and explain this phenomenon.

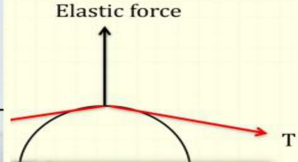


Theory

Coiling is determined by the balance of 3 forces in the coil portion of the viscous fluid :

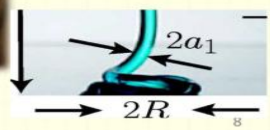
- viscous forces
- Gravitational forces
- inertial forces





$$F_G \approx \rho g a_1^2 \rightarrow mg$$

$$F_I \approx \rho a_1^2 U_1^{\,2} R^{-1} \rightarrow m\frac{v^2}{R}$$



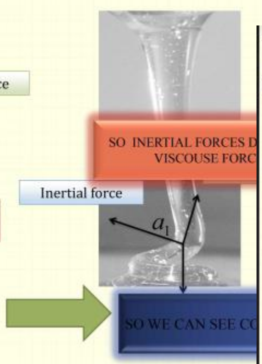
Theory

Force diagram

$$F_V \approx \rho \upsilon a_1^4 U_1^{1} R^{-4}$$

$$F_I \approx \rho a_1^2 U_1^{2} R^{-1}$$

$$F_G \approx \rho g a_1^2$$



Theory

Gravitational regime

According to some experiments

$$0.08 < H\left(\frac{g}{\upsilon^2}\right)^{\frac{1}{3}} < 0.4 \Rightarrow F_G \approx F_V >> F_I$$

So the scaling law gives us :

$$F_G \approx \rho g a_1^2 \approx \rho \upsilon a_1^4 U_1 R^{-4} \approx F_V$$

$$R \approx g^{\frac{-1}{4}} \upsilon^{\frac{1}{4}} Q^{\frac{1}{4}} \equiv R_G$$

$$\Omega \approx g^{\frac{1}{4}} \upsilon^{\frac{-1}{4}} a_1^{-2} Q^{\frac{3}{4}} \equiv \Omega_G$$

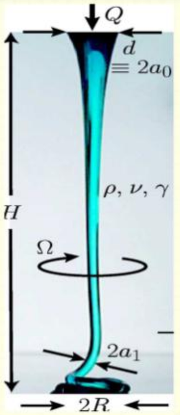
Theory

Viscous regime

$$F_V >> F_G$$
$$F_V >> F_I$$

$$\Omega = \frac{U}{R} = \frac{\frac{Q}{\pi a_1^2}}{H} \quad \Rightarrow \quad R = \frac{Q}{a_1^2 \Omega}$$
$$Q = \pi \Omega R a_1^2$$

R~H



nertial regime

According to the experiments $H\left(\frac{g}{\upsilon^2}\right)^{\frac{1}{3}} > 1.2 \Rightarrow F_I \approx F_V >> F_G$

So the scaling law gives us :

$$F_I \approx \rho a_1^2 U_1^2 R^{-1} \approx \rho \upsilon a_1^4 U_1 R^{-4} \approx F_V$$
$$R \approx \upsilon^{\frac{1}{3}} a_1^{\frac{4}{3}} Q^{\frac{-1}{3}} \equiv R_I$$
$$\Omega \approx \upsilon^{\frac{-1}{3}} a_1^{\frac{-10}{3}} Q^{\frac{4}{3}} \equiv \Omega_I$$

Experiments

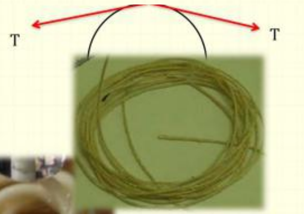
Experimental setup...

regime is a transition between the gravitational and inertial regimes.

in the IG regime, the coiling frequency for a given height is multi-valued.

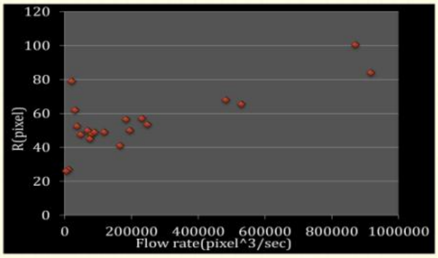
A figure of eight.

with high flow rates and low viscosity liquids.



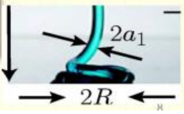
Experiments

Obtaining different regimes

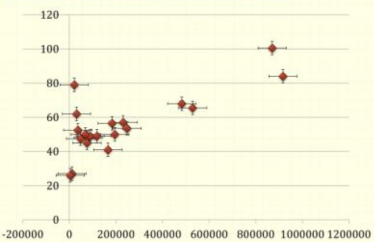


1 pixel =0.13mm

Q	R
11640.08	27
4035.227	26
870590.3	100.5
916816.3	84
529036.6	65.5
482615.5	68
183376	56.5
247557.6	53.5
230875.5	57
194996.2	50
165611.5	41
80704.54	48
75785.86	45
89395.8	49
68766	50
118366.7	49
36802.54	52.5
48422.73	47.5
30944.7	62
21078	79



Experiment (error bar)



13. Misty Glass

Reporter: Shiva Azizpour

IYPT 2012

Question

- Breathe on a cold glass surface so that water vapour condenses on it. Look at a white lamp through the misted glass and you will see colored rings appear outside a central fuzzy white spot. Explain the phenomenon.

Background &Theory
- Possible conditions
- Diffraction
- Explanation
- division
  - Part 1:outside light
  - Part2:inside light
- summation of inside & outside lights
- Final Pattern

Experiments
- *Droplet experiment*
  - Image processing
  - Drop size histogram
- *Optical experiment*
  - Image processing (R,G,B vs. θ)
  - Bright angles - time
  - Intensity -θ

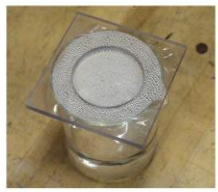
Discussion
- Ratio of bright angles
- Droplet size estimatio
- Bright angle-time
  - (theory vs. exp)
- Intensity – θ
  - (theory vs. exp)
- Revised Theory
- Different temperature

Main Approach

conclusion
- Phenomena Explanation
- Fuzzy white spot
- Why shifting

What is mist?

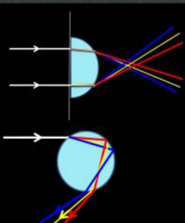
[1]



[1]

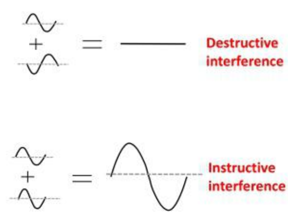
Possible Explanations

- Refraction
- Reflection

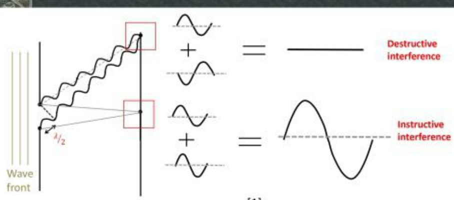


- Diffraction

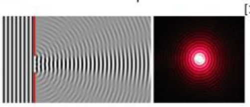
Electric field of the light interference



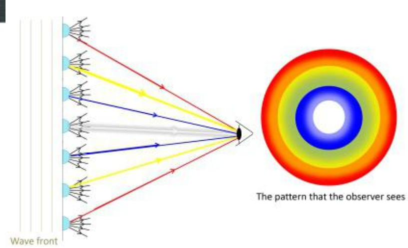
Diffraction



[1]

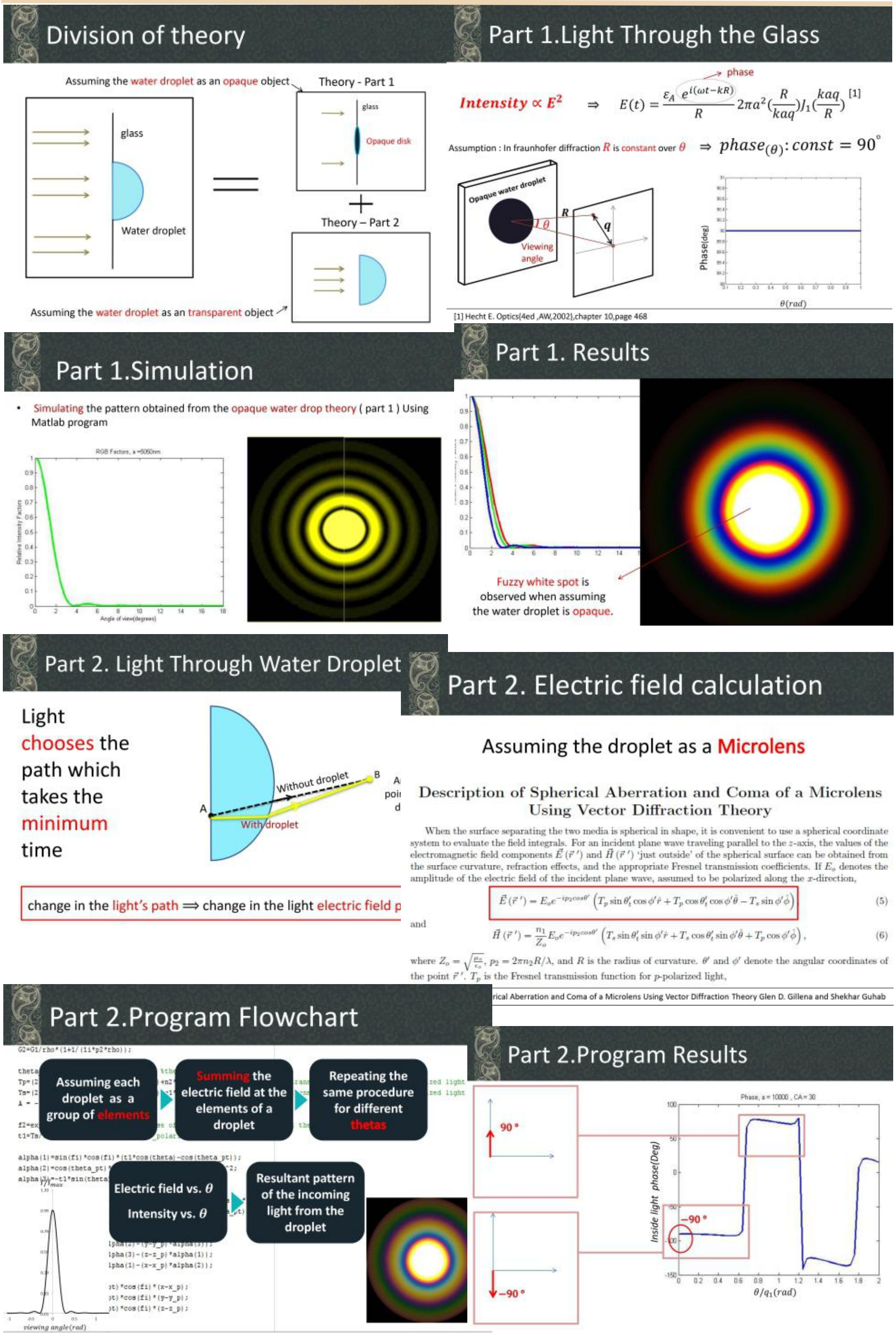


Fraunhofer diffraction is when the diffraction pattern is viewed at a long distance from the diffracting object.

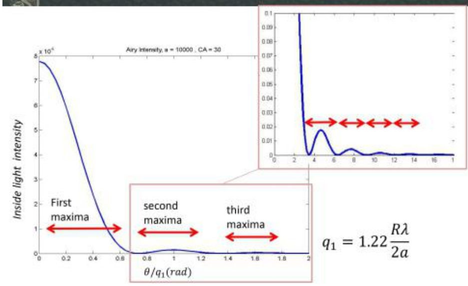


The pattern that the observer sees

[1] Andrew Norton "Dynamic fields and waves of physics. p. 102. (2000)

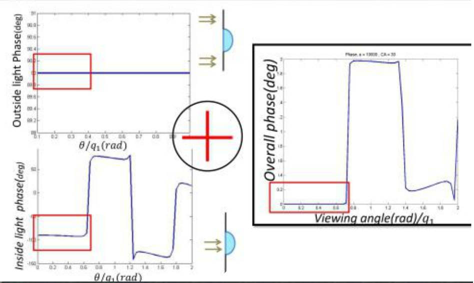

Division of theory
Assuming the water droplet as an opaque object
Theory - Part 1
glass
Opaque disk
Water droplet
Theory – Part 2
Assuming the water droplet as an transparent object
Part 1.Light Through the Glass
phase
Intensity ∝ E²
Assumption : In fraunhofer diffraction R is constant over θ
phase(θ): const = 90°
Opaque water droplet
Viewing angle
Phase(deg)
θ(rad)
[1] Hecht E. Optics(4ed ,AW,2002),chapter 10,page 468
Part 1.Simulation
Simulating the pattern obtained from the opaque water drop theory (part 1) Using Matlab program
Part 1. Results
Fuzzy white spot is observed when assuming the water droplet is opaque.
Part 2. Light Through Water Droplet
Light chooses the path which takes the minimum time
Without droplet
With droplet
change in the light's path ⟹ change in the light electric field p
Part 2. Electric field calculation
Assuming the droplet as a Microlens
Description of Spherical Aberration and Coma of a Microlens Using Vector Diffraction Theory
When the surface separating the two media is spherical in shape, it is convenient to use a spherical coordinate system to evaluate the field integrals. For an incident plane wave traveling parallel to the z-axis, the values of the electromagnetic field components E(r′) and H(r′) 'just outside' of the spherical surface can be obtained from the surface curvature, refraction effects, and the appropriate Fresnel transmission coefficients. If E₀ denotes the amplitude of the electric field of the incident plane wave, assumed to be polarized along the x-direction,
where R is the radius of curvature. θ′ and φ′ denote the angular coordinates of the point r′. Tp is the Fresnel transmission function for p-polarized light.
rical Aberration and Coma of a Microlens Using Vector Diffraction Theory Glen D. Gillena and Shekhar Guhab
Part 2.Program Flowchart
Assuming each droplet as a group of elements
Summing the electric field at the elements of a droplet
Repeating the same procedure for different thetas
Electric field vs. θ
Intensity vs. θ
Resultant pattern of the incoming light from the droplet
viewing angle(rad)
Part 2.Program Results
90°
−90°
Inside light phase(Deg)
θ/q₁(rad)

Part 2.Program Results

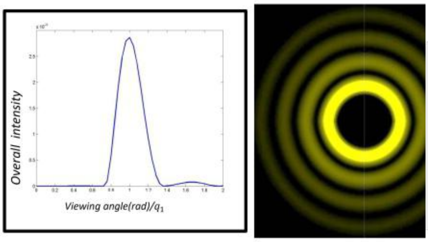


$$q_1 = 1.22\frac{R\lambda}{2a}$$

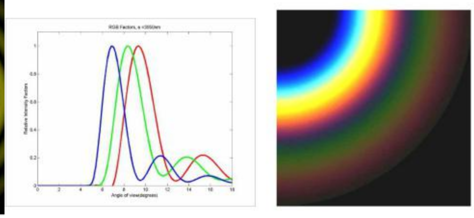
Combination of part 1. & 2. phase



Combination of Part 1.&2. Intensity



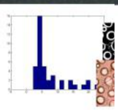
Overall Pattern the light within & outside



Experiment Overview

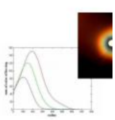
Droplet Experiment

- Set up
- Experiments with microscope
- Image processing
- Histogram (number of drops vs. radius)

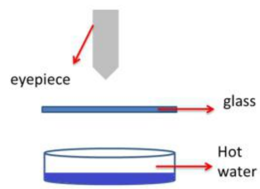


Optical Experiment

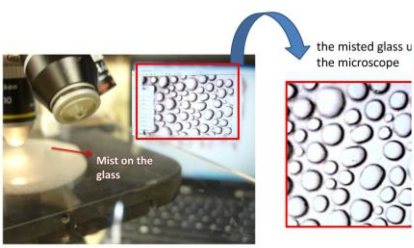
- set up
- Experiments-time lapse
- Image processing
- Intensity vs. θ diagrams(R,G,B and total intensity)
- Maximum R,G,B angles vs. time



Droplet experiment setup



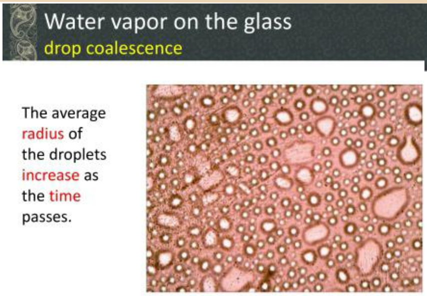
Droplet experiment setup

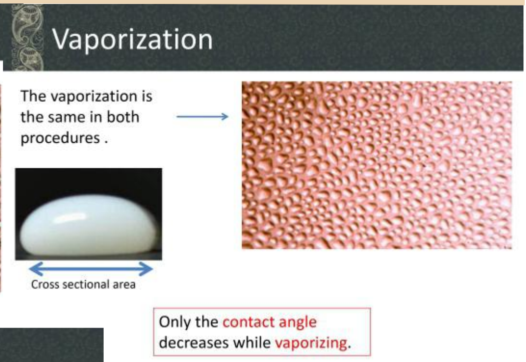


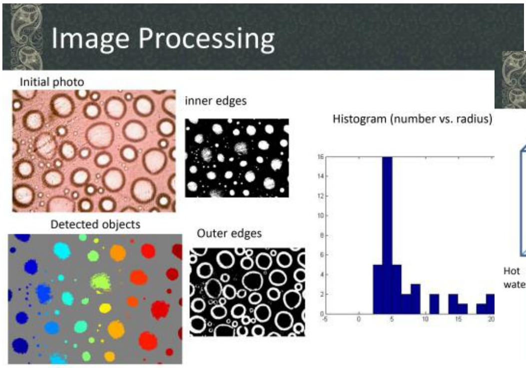
Breath on glass(Hhaaw)

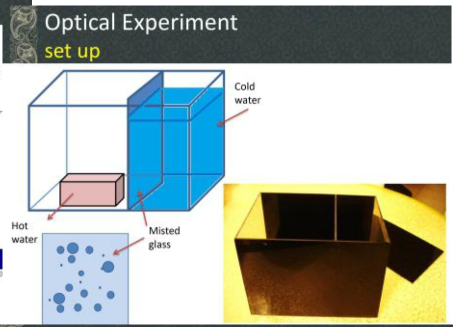
Start of breathing
Drop growth
Coalescence
End of the breath
vaporization

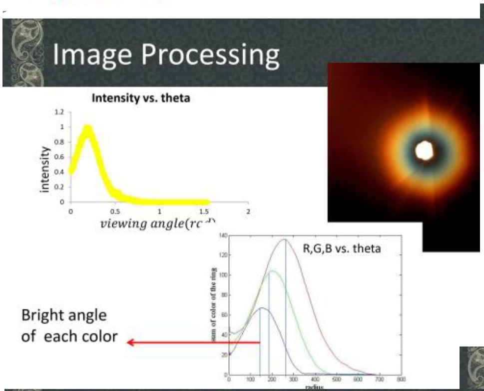
ART AN AMAZING FACT IN SCIENCE

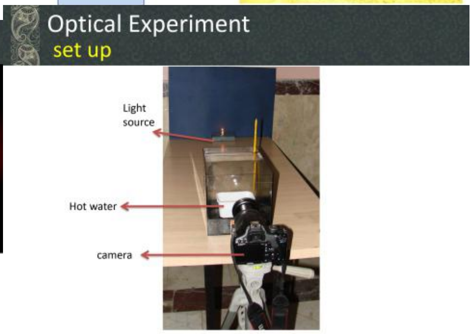


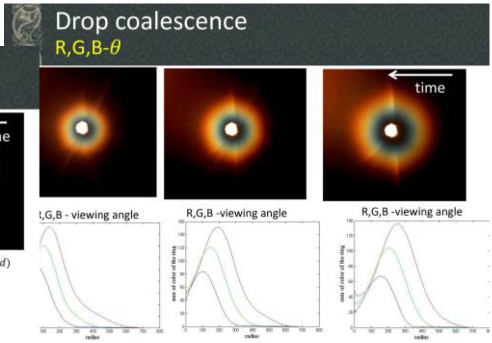


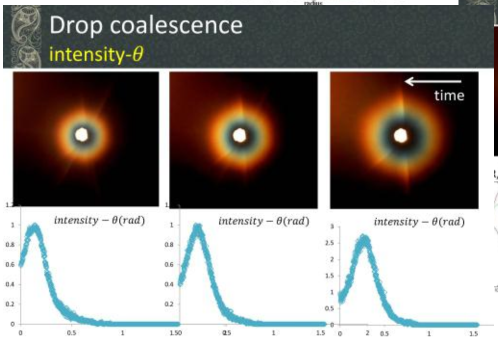




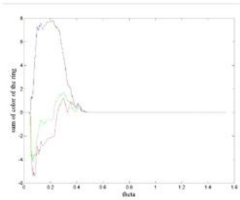




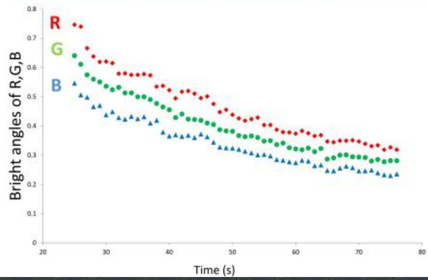




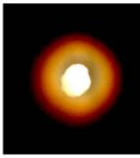
Drop Growth



Results
condensation



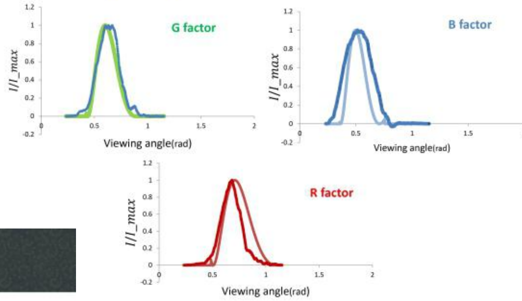
How the pattern change while vaporization?



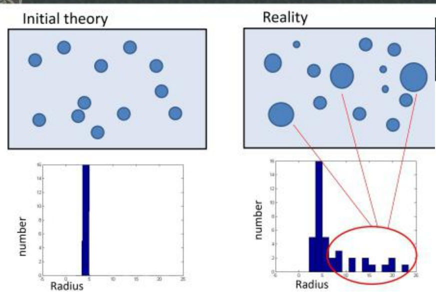
The pattern almost doesn't change while vaporizing .

The pattern disappears when the contact angle becomes zero.

Intensity - θ
Theory vs. Experiment



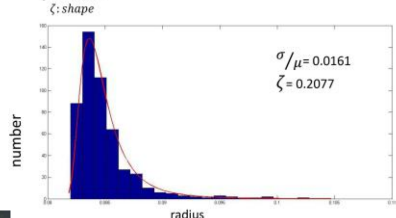
Revised Theory



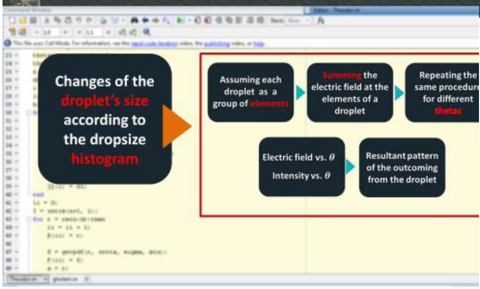
Drop size distribution

the GEV function :

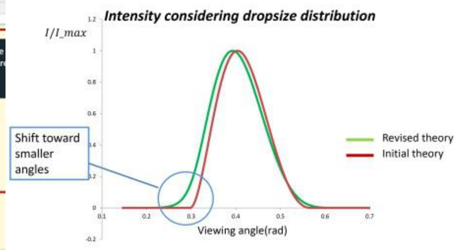
σ: scale
μ: location
ζ: shape



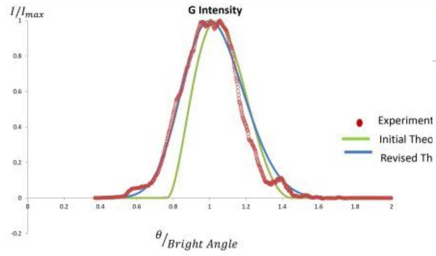
Programming



Comparison
Revised and Initial Theories

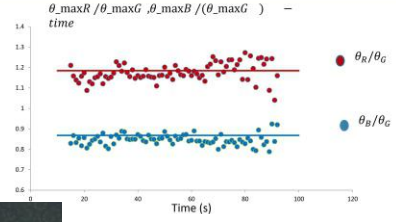


Theory vs. Experiment
initial and revised theories

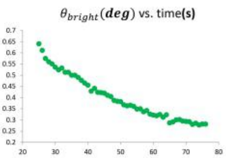


Theory vs. Experiment
ratio between bright angles

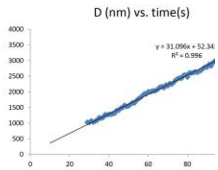
$$\theta_{bright\ \lambda} = 1.73\frac{\lambda}{D} \longrightarrow \frac{\theta_{\max R}}{\theta_{\max G}} = \frac{\lambda_R}{\lambda_G} = const.$$



Radius Calibration

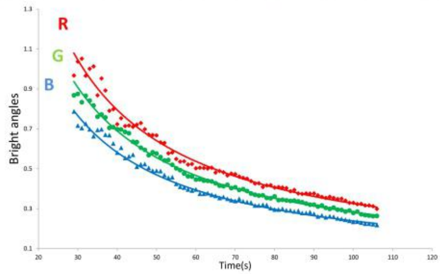


$$D = \frac{1.73\ \lambda}{\theta_{bright(\lambda)}}$$

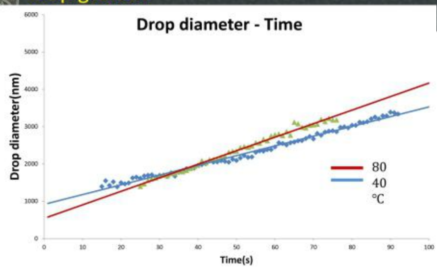


D as a function of time is a linear function as predicted.

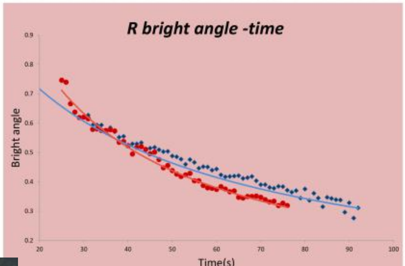
Theory vs. Experiment
bright angles -time



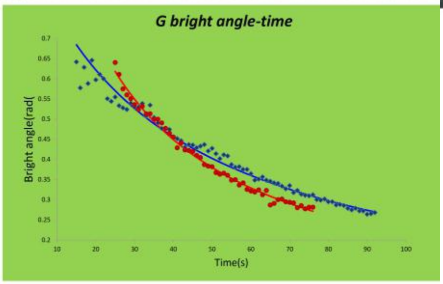
Effect of Temperature
drop growth



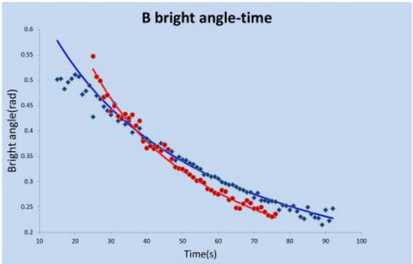
Effect of Temperature
R bright angle-time

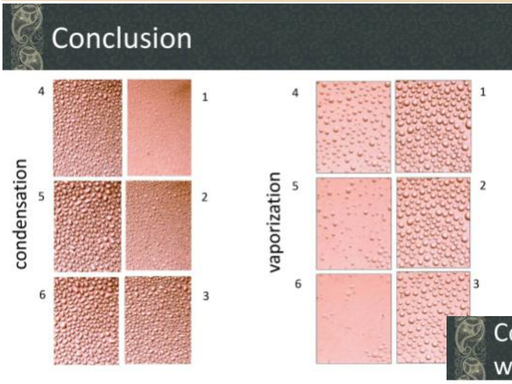


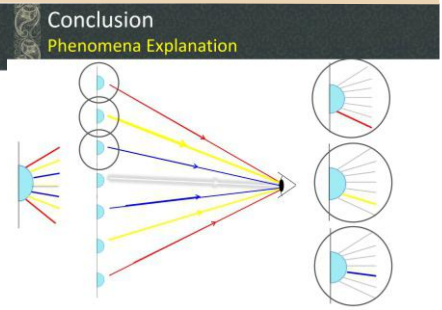
Effect of Temperature
G bright angle-time

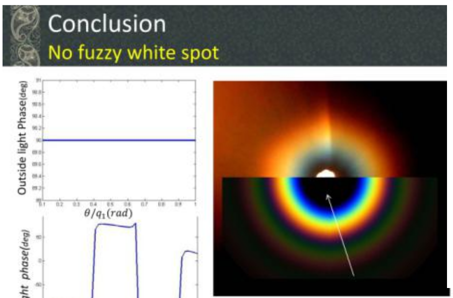


Effect of Temperature
B bright angle-time

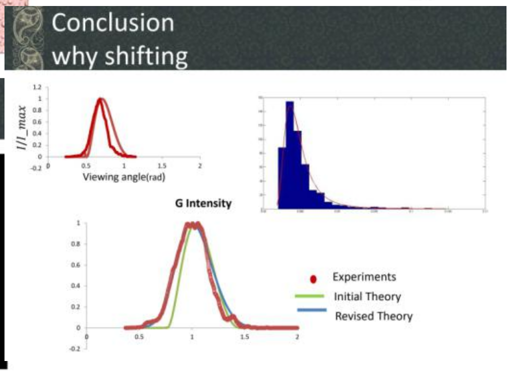


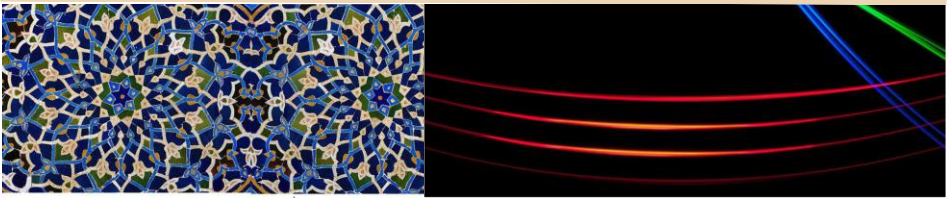






No fuzzy white spot





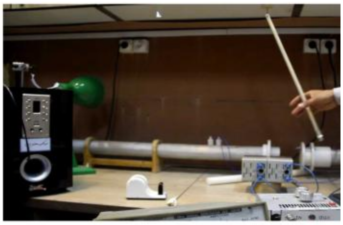
PROBLEM NO.13 Magnetic Pendulum

Yasamin Masoumi

IYPT 2015, Team of Iran

Make a light pendulum with a small magnet at the free end. An adjacent electromagnet connected to an AC power source of a much higher frequency than the natural frequency of the pendulum can lead to undamped oscillations with various amplitudes. Study and Explain this Phenomenon.

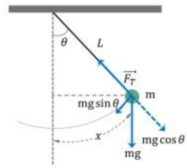
7 Hz



Simple Harmonic Motion

$$\sum \vec{\tau} = I\vec{\alpha}$$

$$\left.\begin{array}{l} -mgL\sin\theta = mL^2\alpha \\ \theta_0 \ll 1 \end{array}\right\} \quad \left.\begin{array}{l} \omega = \sqrt{\frac{g}{L}} \\ T = \frac{2\pi}{\omega} \end{array}\right\} \quad T = 2\pi\sqrt{\frac{L}{g}}$$

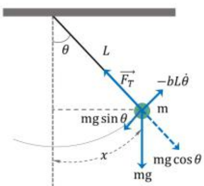


Damped Oscillation

$$\sum \vec{\tau} = I\vec{\alpha}$$

$$\left\{\begin{array}{l} bL^2\dot{\theta} + mgL\sin\theta + mL^2\ddot{\theta} = 0 \\ \theta_0 \ll 1 \end{array}\right.$$

$$\theta_t = \theta_0 e^{-\frac{b}{2m}t}\cos\left(\sqrt{\frac{4g}{L} - \left(\frac{b}{m}\right)^2}\, t\right)$$



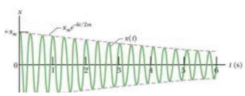
Resonance

$x(t) = x_m\cos(\omega_d t + \phi)$

$\omega_d = \omega$ Condition for Resonance

Our System

$\omega_d \gg \omega$ No Resonance



Halliday, David Fundamentals of physics / David Halliday, Robert Resnick, Jearl Walker —9th ed

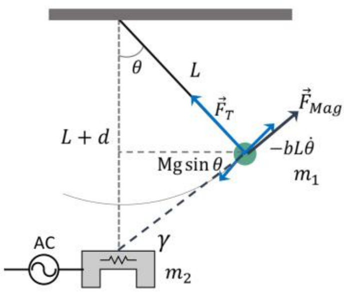
Torque of Our System

$$\sum \tau_i = \tau_{\text{gravity}} + \tau_{\text{damping}} + \tau_{\text{magnetic}}$$

$$\tau_{\text{gravity}} = -LMg\sin\theta$$

$$\tau_{\text{damping}} = -bL^2\dot{\theta}$$

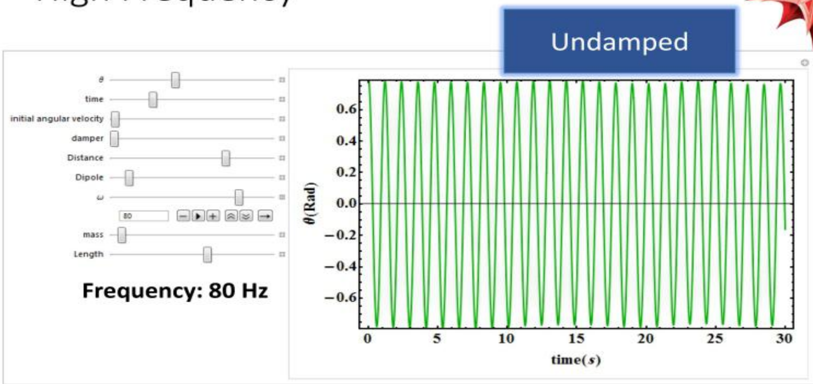
$$\tau_{\text{magnetic}} = \frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^2}L\sin(2\pi f t)\cos(\theta - \gamma)$$



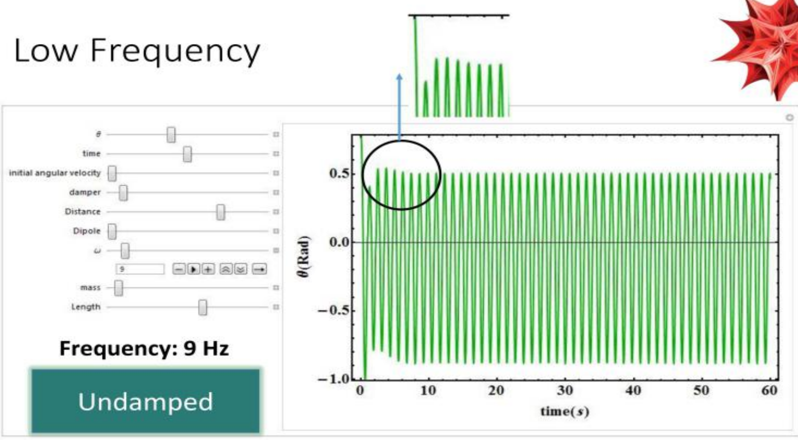
$$\frac{mL^2}{3} + ML^2 = -LMg\sin\theta - bL^2\dot{\theta} + \frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^2}L\sin(2\pi f t)\cos(\theta - \gamma)$$

d :Minimum distance from the magnet m: Mass of Rod b: Damping coefficient m_1, m_2: Magnetic Moment

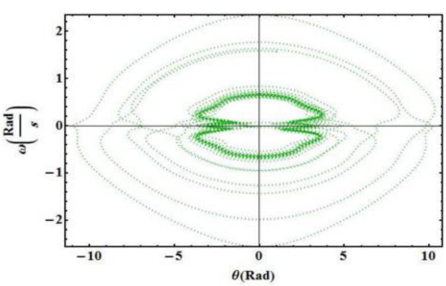
High Frequency



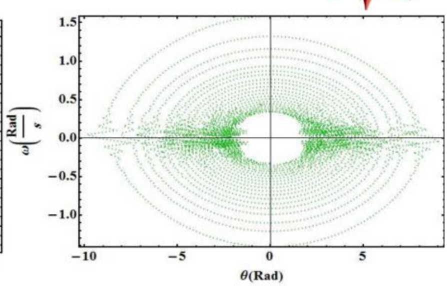
Low Frequency



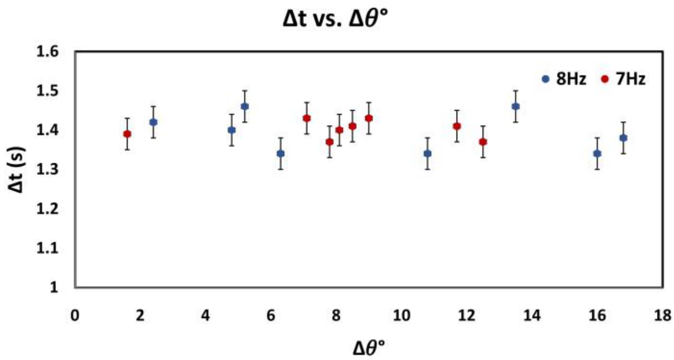
Low Frequency



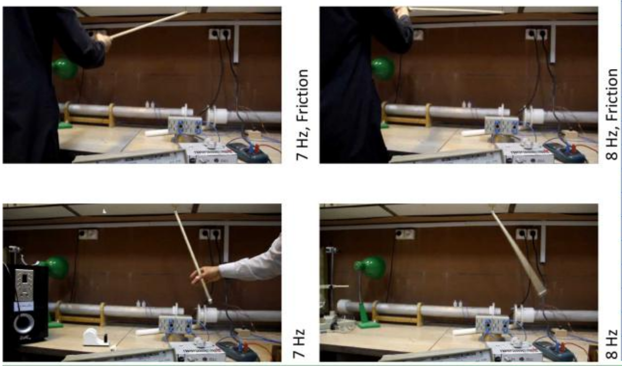
Frequency: 8 Hz



Frequency: 80 Hz

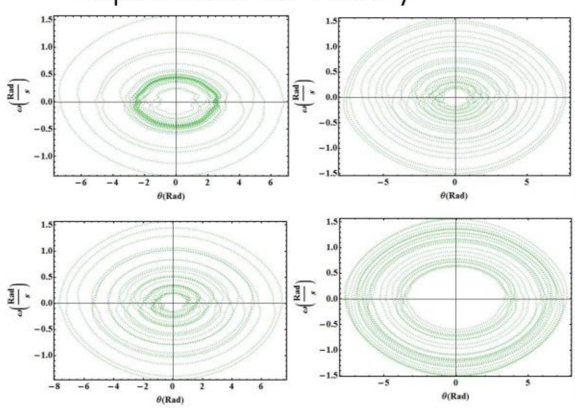


Friction of System



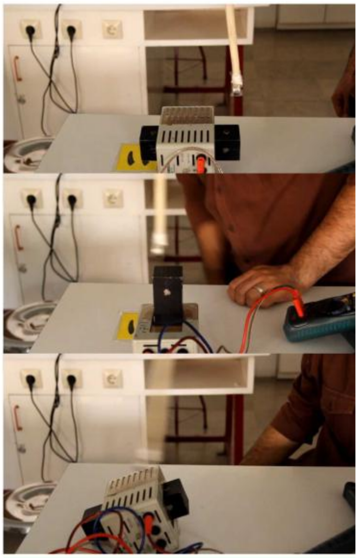
7 Hz	8 Hz	7Hz, Friction	8Hz, Friction
11	21	16	11
17	25	21	16
21	32	25	21
26	37	28	23
30	40	31	25
34	44	34	28
37	49	37	31
40	50	42	32
46	51	55	40
52	53	57	44
55	56	59	45
58	58	60	50
62	67	65	58
68	70	67	65
			70
			77
			82

Experiment vs. Theory

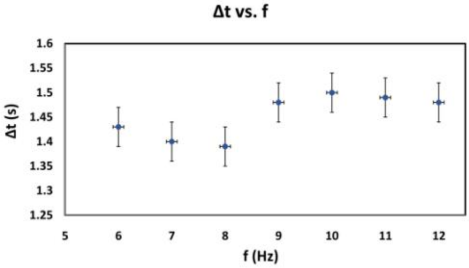


7 Hz	8 Hz	9 Hz	10 Hz
11	21	25	17
17	25	27	20
21	32	28	23
26	37	31	24
30	40	36	25
34	44	41	26
37	49	42	27
40	50	46	28
46	51	51	30
52	53	53	31
55	56	55	35
58	58	61	41
62	67	65	48
68	70	69	51
		76	60
		78	70
		80	79

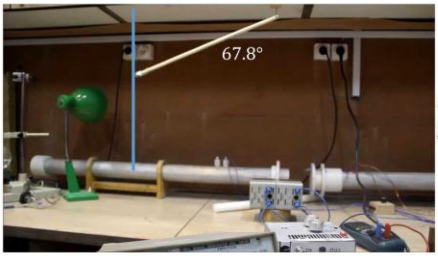
Position of Electromagnet

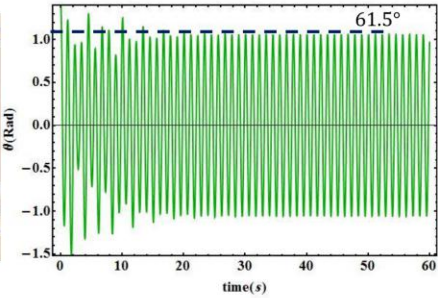


2.4 Hz (horizontal electromagnet)	2.4 Hz (vertical electromagnet)	2.4 Hz (inclined electromagnet)
3.9 degrees	3.7 degrees	8 degrees
4.1 degrees	4 degrees	11.2 degrees
4.4 degrees	5 degrees	13.0 degrees
6.1 degrees		13.8 degrees
7.2 degrees		14.4 degrees
7.8 degrees		20.1 degrees
9.4 degrees		21.1 degrees
		21.4 degrees



Experiment vs. Theory

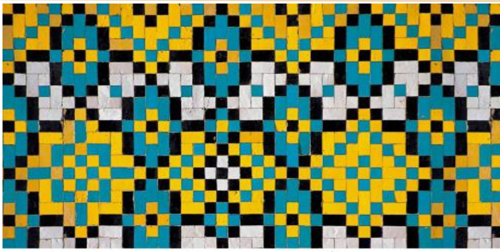


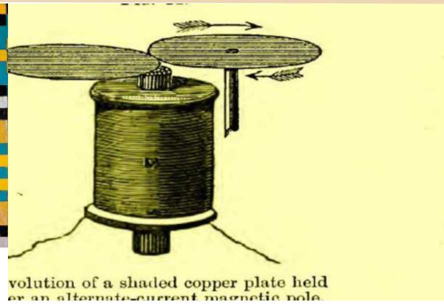


$\Delta\theta^\circ \approx 6^\circ$

References

1. Halliday, David Fundamentals of physics / David Halliday, Robert Resnick, Jearl Walker.—9th ed.
2. Nonlinear dynamics of a sinusoidally driven pendulum in a repulsive magnetic field, Am. J. Phys. 65 (5), May 1997, Azad Siahmakoun etc.
3. Self-oscillatory systems with high-frequency energy sources, American Institute of Physics , Sov. Phys. Usp. 32 (8), August 1989, P.S. Landa and Ya. B. Duboshinskii





PROBLEM NO.7 Shaded Pole

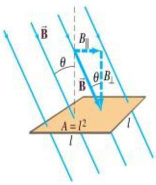
Yasamin Masoumi

Laws of Induction

$\phi = \int \vec{B}.d\vec{a}$ Magnetic Flux

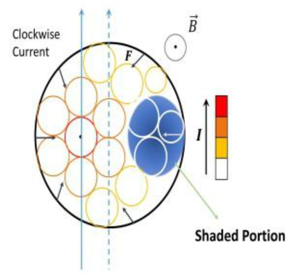
$\mathcal{E} = -\dot{\phi}$ Induced EMF for 1 Loop

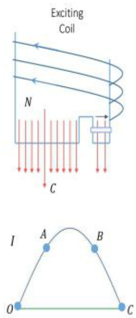
$\mathcal{E} = -N\dot{\phi}$ Induced EMF for N Loops



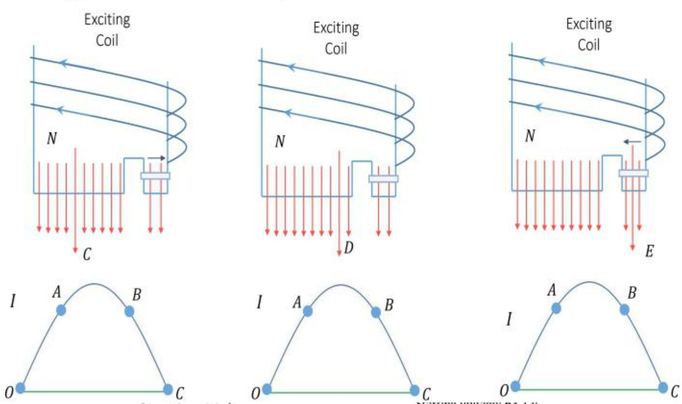
ϕ: Magnetic Flux B: Magnetic Field da: Element of Area $\mathcal{E}$: Induced emf N: Number of Loops

Magnetic Field Analysis





Magnetic Field Analysis



Starting Voltage

Starting voltage: 63.1 V

R: Reluctance of the surface Z_{sc}: Impedance of the shading coil ϕ_{sp}: Flux in the shaded pole

ϕ_m^{sc}: Flux component linking shading coil i_{sc}: Current in the shading coil e_{sc}: emf induced in the shading coil

ϕ_m: Main Winding Flux at the Shaded Portion of Pole ϕ'_m: Flux component passing down the air-gap of the rest of the pol

Shaded Pole Flux Analysis

$$\phi_{sp} = \phi_m^{sc} + \phi_{sc}$$

Main Winding Flux at the Shaded Portion of Pole

$$\phi_m = \phi_{max} \sin \omega t$$

$$\phi_m = \phi_m^{sc} + \phi_m'$$

$$e_{sc} = \frac{d\phi_m^{sc}}{dt} = \phi_{max}^{sc} \omega \cos \omega t$$

Impedance of the shading coil

$$Z_{sc} = R_{sc} + jX_{sc}$$

Phasor Lag

$$\tan \theta_{sc} = \frac{X_{sc}}{R_{sc}}$$

$$i_{sc} = \left[\frac{\phi_{max}^{sc}\ \omega}{Z_{sc}}\right](\cos \omega t - \theta_{sc})$$

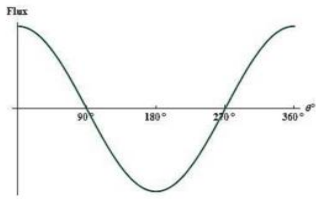
Flux of the current in the shading coil

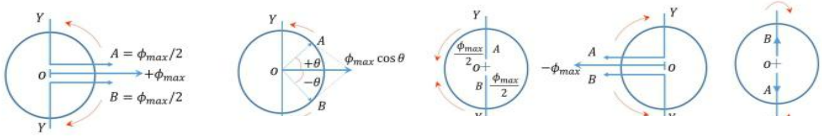
$$\phi_{sc} = \frac{i_{sc}}{R} = \frac{\omega\ \phi_{max}^{sc}}{Z_{sc}\ R}\cos(\omega t - \theta_{sc})$$

Double-field Revolving Theory

$$\cos\theta = \frac{e^{j\theta} + e^{-j\theta}}{2}$$

$$\phi_{max} \cos 2\pi f t = \frac{\phi_{max}}{2}(e^{j2\pi f t} + e^{-j2\pi f t})$$

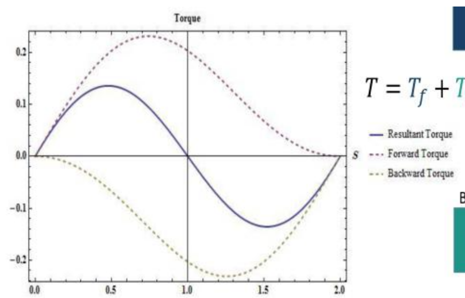




AC Supply　Coil　Cell　Rotor

$N = 500$　　$R = 55\ \Omega$

Torque vs. Slip

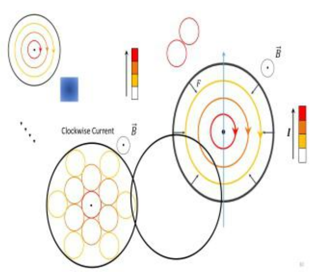


$$T_f = k\frac{I^2R}{s}$$

$$T = T_f + T_b$$

Backward Torque

$$T_b = -k\frac{I^2R}{(2-s)}$$



n_s: Synchronous Speed　n_r: Speed of Rotor　P: Number of Poles　P_g: Power Developed By Rotor (Output)　$n_r = n_s(1-s)$

$$\phi_{sp} = \phi_m^{sc} + \phi_{sc}$$

Torque

Slip

$$s = \frac{n_s - n_r}{n_s}$$

$$n_s = \frac{2f}{P}$$

$$P_g = \left(\frac{1-s}{s}\right) I^2 R$$

$$T_g = \omega P_g$$

$$T_g = \frac{1}{2\pi n_r}\left(\frac{1-s}{s}\right) I^2 R$$

$$T = T_f + T_b$$

Double-field Revolving Theory

Backward Torque

$$T_b = -k\frac{I^2 R}{(2-s)}$$

Forward Torque

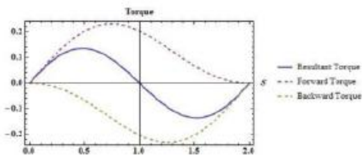
$$T_f = k\frac{I^2 R}{s}$$

n_s: Synchronous Speed n_r: Speed of Rotor P: Number of Poles P_g: Power Developed By Rotor (Output) $n_r = n_s(1-s)$

Single Phase Motors

Single-Phase Motors

- Needs — Initial Torque
- $s = 1$ — Not Self Starting



Shading Coil

- Shaded Pole Motors — Low Efficiency
  - Shading Coil
  - Relative Speed
- Multi-Phase Motors — Controllable
  - Different Phases
  - Relative Speed

Our Way Through the Problem

Observation → Background Knowledge → Magnetic Field → Double-Field Revolving Theory → Shaded Pole Flux → Torque → Setup → Tricks → Slip of Experiment → Single-Phase Motors → Shading Coils → Simply nothing :D

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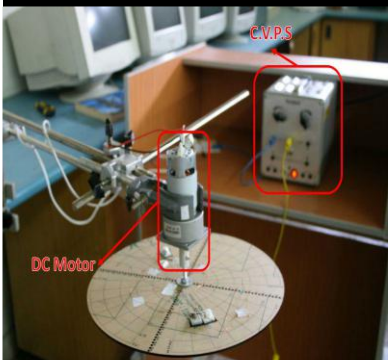
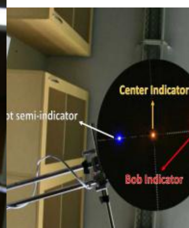
Question

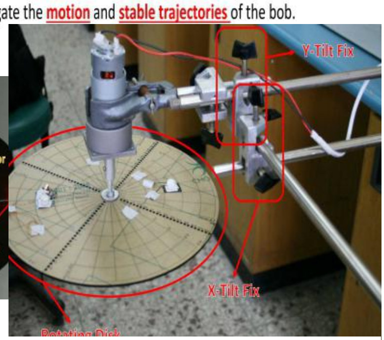
A pendulum consists of a strong thread and a bob.

When the pivot of the pendulum starts moving along a horizontal circumference, the bob starts tracing a circle which can have a smaller radius, under certain conditions.

Investigate the motion and stable trajectories of the bob.







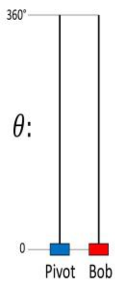
Observation

high α

ω:

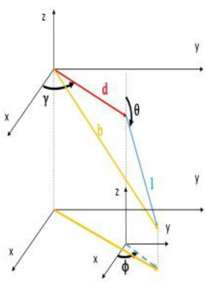
Phenomenon: Lag

θ:

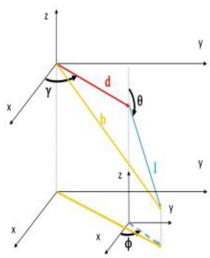


Experiment

Model



Model



$q \equiv q(t)$

$\mathbf{b} = \mathbf{d} + \mathbf{l}$

$x = d\cos\gamma + l\sin\theta\cos\phi$

$y = d\sin\gamma + l\sin\theta\sin\phi$

$z = l\cos\theta$

Theory

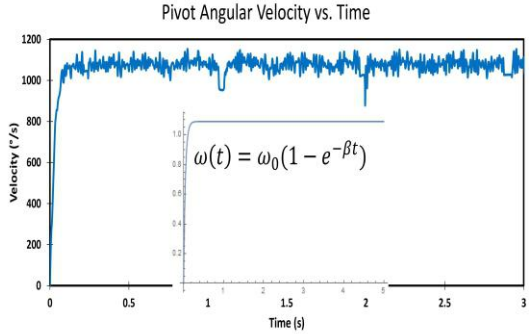
Model: Degrees Of Freedom

γ, θ, ϕ

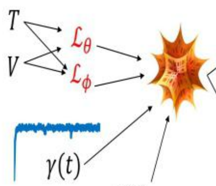
γ >> Motor

θ, ϕ >> Pendulum

$\gamma(t) = ?$



Eqn's of motion



$\theta(0) = \pi$

$\dot{\theta}(0) = 0$

$\phi(0) = 0$

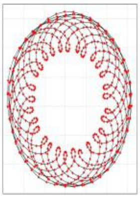
$\dot{\phi}(0) = 0$

Initial Conditions

$$e^{-t\beta} l m \times \left(e^{2t\beta} g \,\mathrm{Sin}[\theta[t]] + d\omega_0 \mathrm{Cos}[\theta[t]] \times \left(\left(-1 + e^{t\beta} + t\beta\right)^2 \omega_0 \mathrm{Cos}[(1 - e^{-t\beta}) t\omega_0 - \phi[t]] - e^{t\beta}\beta(-2 + t\beta)\,\mathrm{Sin}[(1 - e^{-t\beta}) t\omega_0 - \phi[t]] \right) + e^{2t\beta} l \left(\mathrm{Cos}[\theta[t]]\mathrm{Sin}[\theta[t]]\phi'[t]^2 - \theta''[t]\right) \right) = 0$$

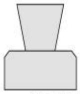
$$e^{-t\beta} l m \,\mathrm{Sin}[\theta[t]] \times \left(d\omega 0 \times \left(-e^{t\beta}\beta(-2 + t\beta)\,\mathrm{Cos}[(1 - e^{-t\beta}) t\omega 0 - \phi[t]] - \left(-1 + e^{t\beta} + t\beta\right)^2 \omega 0 \,\mathrm{Sin}[(1 - e^{-t\beta}) t\omega 0 - \phi[t]] \right) + e^{2t\beta} l \left(2\mathrm{Cos}[\theta[t]]\theta'[t]\phi'[t] + \mathrm{Sin}[\theta[t]]\phi''[t]\right) \right) = 0$$

Relevant Parameters



- Bob Mass
- Pivot Frequency
- Pivot Radius
- Thread Length
- Pendulum Initial Angles

Experiment Data



IPhone® 240 fps
Slow-motion camera

Pivot:

$r(t)$ $\theta(t)$
$v(t)$ $\omega(t)$
$a(t)$ $\alpha(t)$ Bob Mass

Bob:

$r(t)$ $\theta(t)$
$v(t)$ $\omega(t)$
$a(t)$ $\alpha(t)$

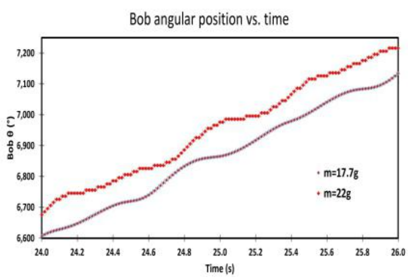
Perspective

Perspective corrector

Bob:

$r(t)$ $\theta(t)$
$v(t)$ $\omega(t)$
$a(t)$ $\alpha(t)$

Corrected



Paradox?

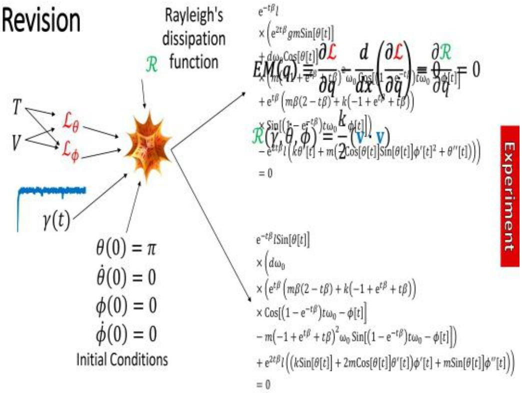
$$\mathcal{L}(\gamma,\theta,\phi,\dot\gamma,\dot\theta,\dot\phi) = T(\dot\gamma,\dot\theta,\dot\phi) - V(\gamma,\theta,\phi)$$
$$= m\,(\ldots..) - m\,(\ldots..) = m\,(\ldots..)$$

m is constant.

$$\frac{\partial\mathcal{L}}{\partial q} - \frac{d}{dx}\left(\frac{\partial\mathcal{L}}{\partial\dot q}\right) = m(\ldots..) = 0 \Rightarrow (\ldots..) = 0$$

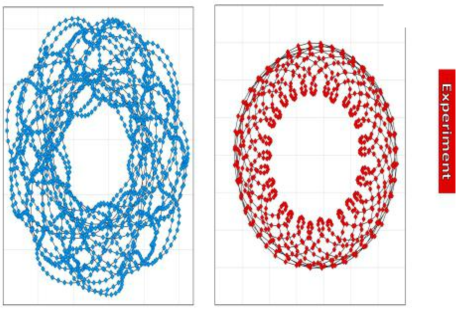
No sign of m. Mass isn't important!

Revision

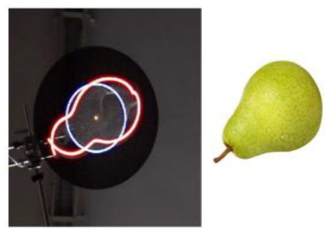


Trajectory Evolution

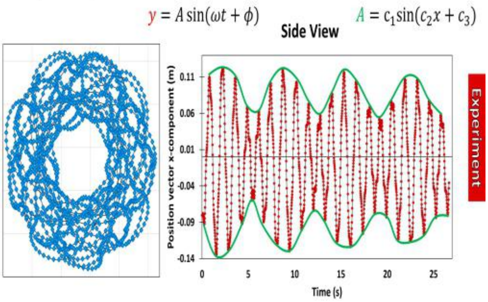
After a long time (~15min



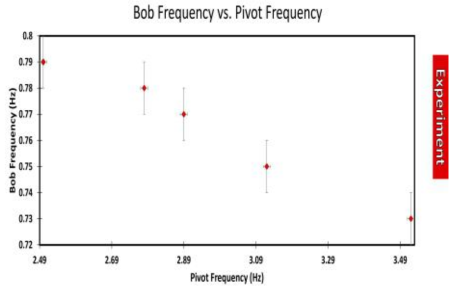
Trajectory



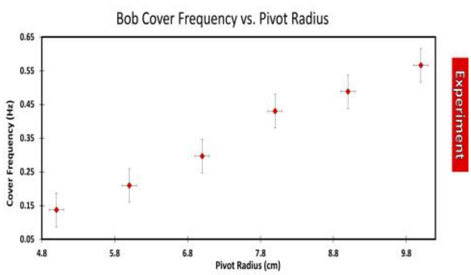
Trajectory



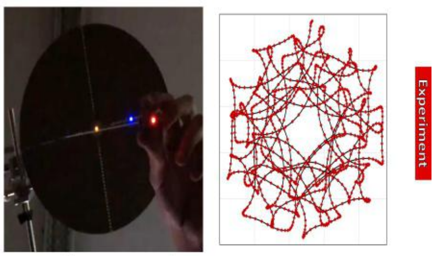
Pivot Frequency



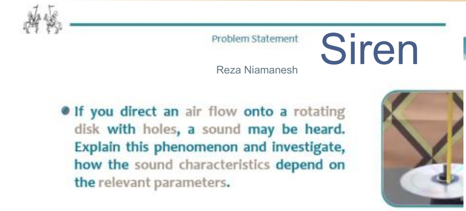
Pivot Radius

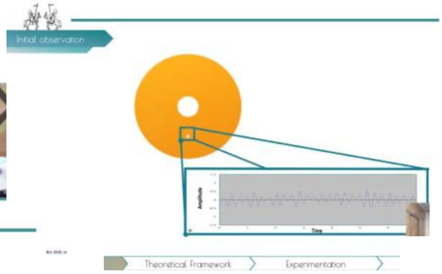


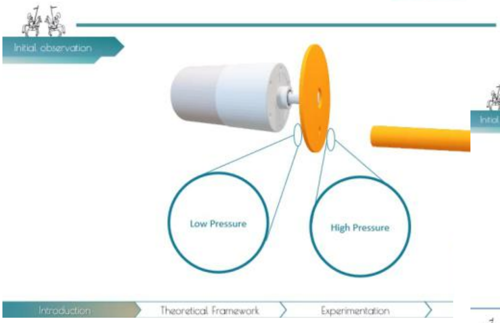
Pendulum Initial Inward Angle

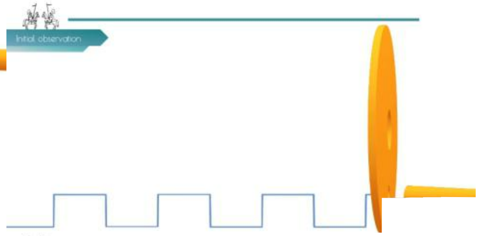


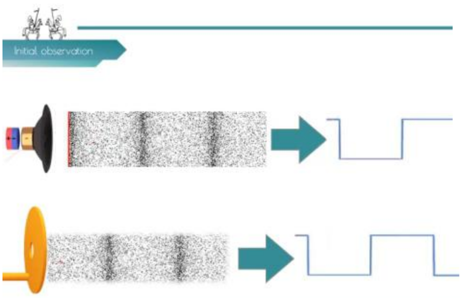
Pendulum Facing Inward

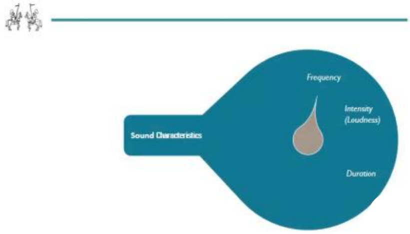

Problem Statement
Siren
Reza Niamanesh
If you direct an air flow onto a rotating disk with holes, a sound may be heard. Explain this phenomenon and investigate, how the sound characteristics depend on the relevant parameters.

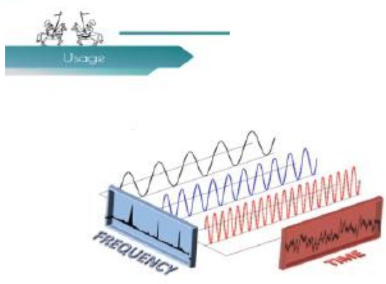

Initial observation
Amplitude
Time
Theoretical Framework
Experimentation

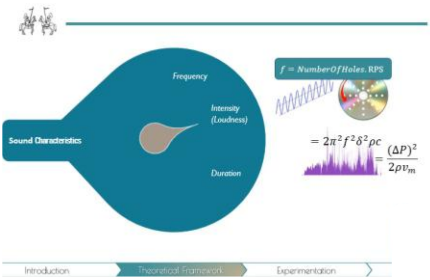

Initial observation
Low Pressure
High Pressure
Introduction
Theoretical Framework
Experimentation

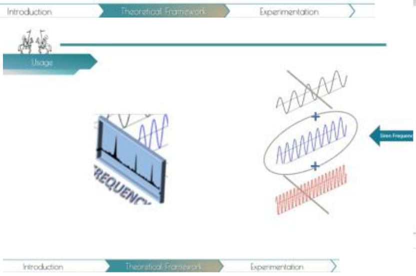

Initial observation

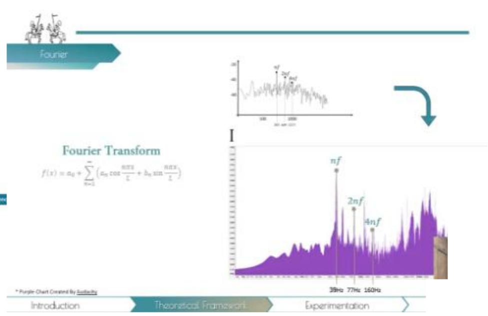

Initial observation


Sound Characteristics
Frequency
Intensity
(Loudness)
Duration

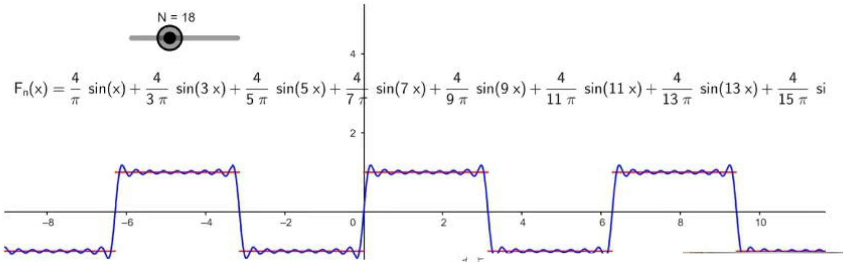

Usage
FREQUENCY
TIME


Sound Characteristics
Frequency
Intensity
(Loudness)
Duration
f = NumberOfHoles.RPS
= 2π²f²δ²ρc = (ΔP)²/2ρv_m
Introduction
Theoretical Framework
Experimentation


Usage
Introduction
Theoretical Framework
Experimentation


Fourier
Fourier Transform
nf
2nf
4nf
39Hz 77Hz 160Hz
Introduction
Theoretical Framework
Experimentation

Fourier



Sound Intensity₁

$$I = 2\pi^2 f^2 \delta^2 \rho c$$

$$\rho_{air} = \frac{PM}{RT}$$

- ρ: air density $\left(\frac{kg}{m^3}\right)$
- P: pressure (Pa)
- R: gas constant $\simeq 8.3\ \left(\frac{J}{K.m}\right)$
- M: molar mass of dry air $\simeq 0.029\ \left(\frac{kg}{mol}\right)$
- T: temperature (K)

Sound Intensity₁

$I \propto$

- f = Frequency of sound wave,
- δ = Amplitude of sound wave
- ρ = Density of medium in which sound is traveling
- c = Speed of sound

Airflow Options

Air Compressor | Balloon | Blowir

Airflow Options

Option\Ability	Controlling	measurement	Stability
Air Compressor	✓	✓	✓
Balloon	✗	✓	✓
Blowing	✓	✗	✗

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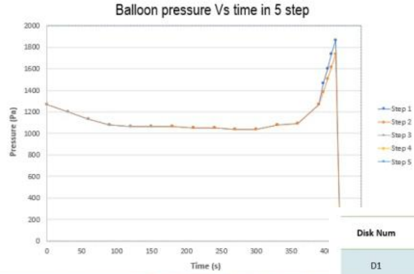
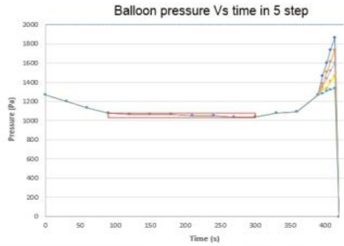
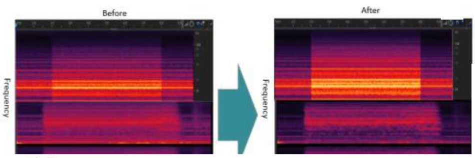
Balloon Pressure



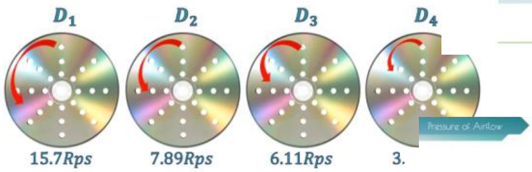




Disk Num	RPS	Frequency	Voices
D1	15.7	252.496 Hz	Voice 1
D2	7.9	126.24 Hz	Voice 2
D3	6.1	97.76 Hz	Voice 3
D4	3.9	62.08	Voice 4

Frequency/RPS		Number of Holes
$\frac{252.496}{15.7}$	16.0825	16
$\frac{126.24}{7.9}$	15.9797	16
$\frac{97.76}{6.1}$	16	16
$\frac{62.08}{3.88}$	16	16

RPS

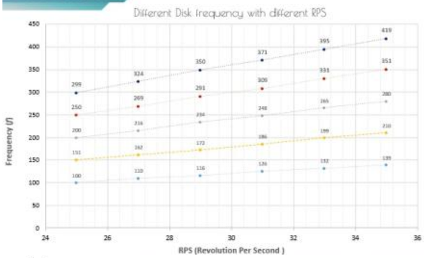


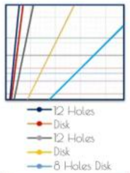
$$f_1 = f_2 = f_3$$
$$I_1 < I_2 < I_3$$

$$\mathrm{I} = \frac{(\Delta P)^2}{2\rho v_m}$$

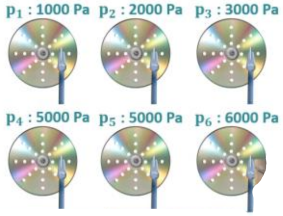
P = change in pressure
ρ = density of the material the sound is traveling through
v_m = speed of observed sound

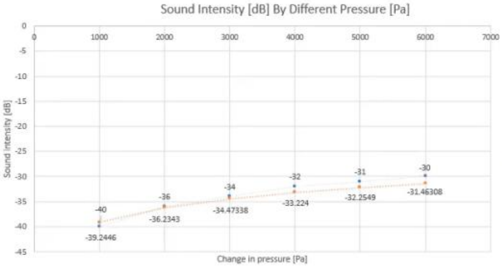
Different Hole Size

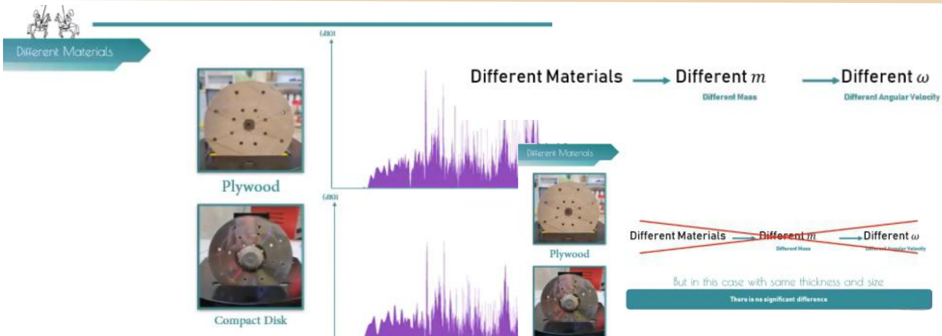




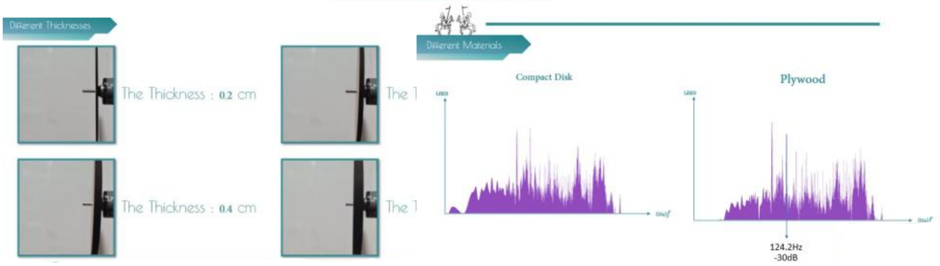
Pressure of Airflow







* Chart By Audacity



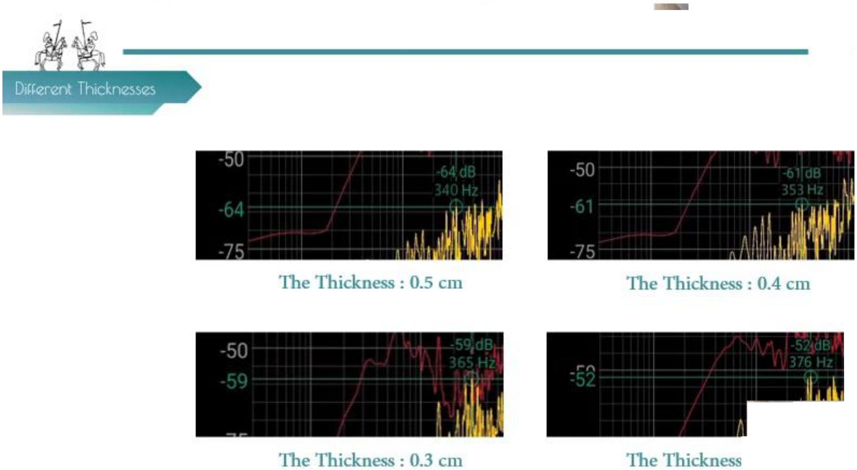
Different Thicknesses → Different m → Different ω

Increasing Thickness — Increasing Mass — Decreasing RPS

$f = NumberOfHoles.\mathrm{RPS}$ → Decreasing Frequency

$I = 2\pi^2 f^2 \delta^2 \rho c$ → Decreasing Intensity

$I \downarrow \quad f \downarrow$



* Chart By Spectroid

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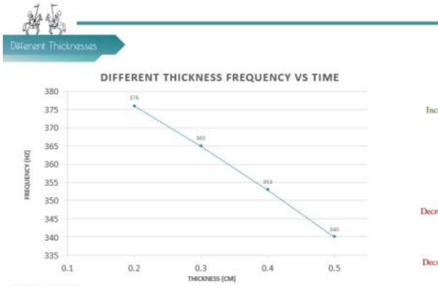
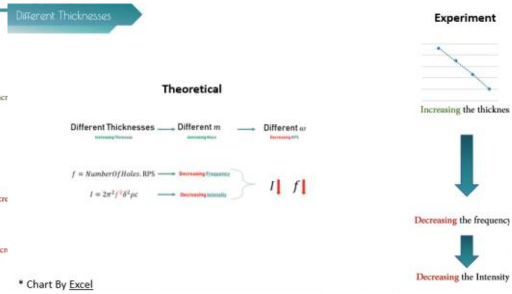
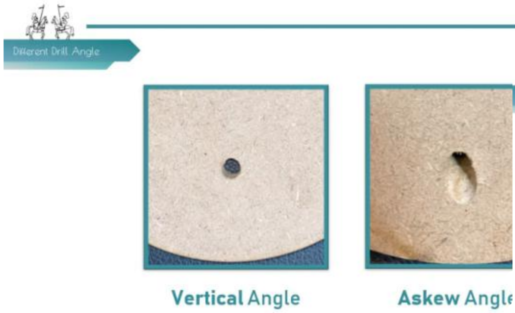
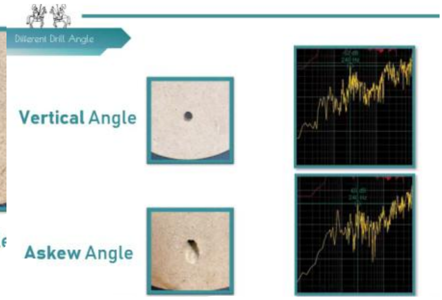


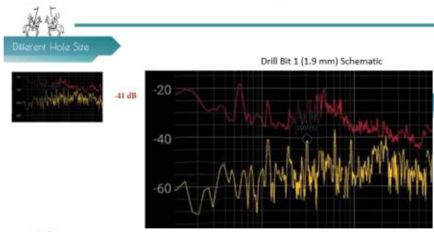
* Chart By Excel

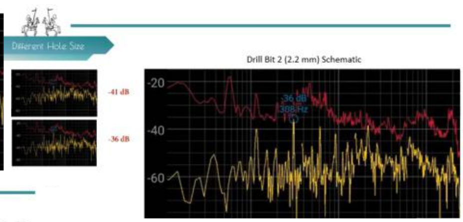


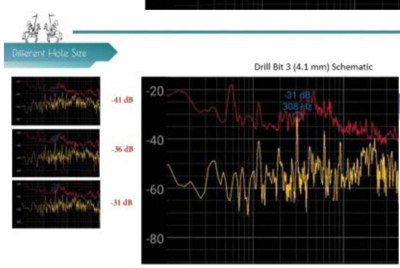
* Chart By Excel

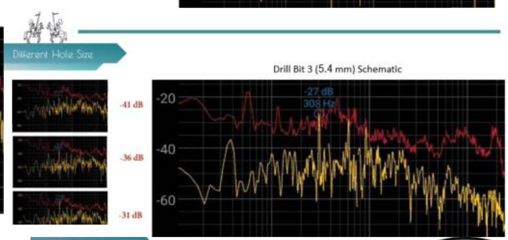


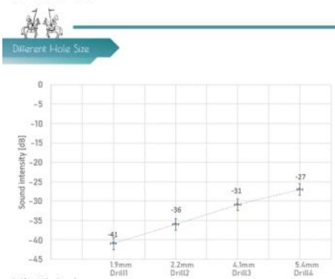




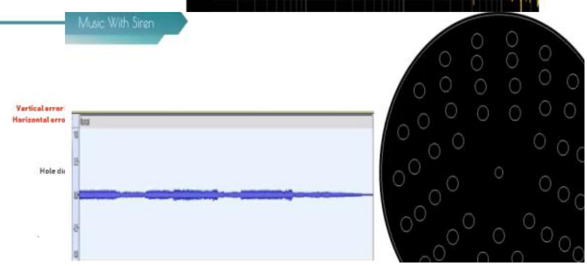


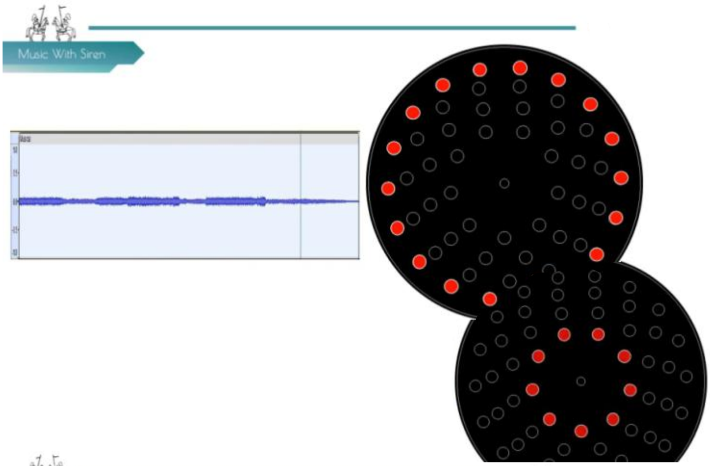


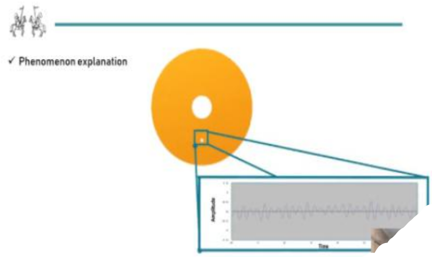


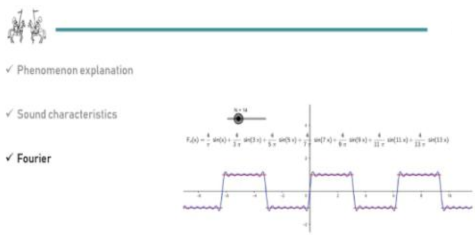


* Chart By Excel









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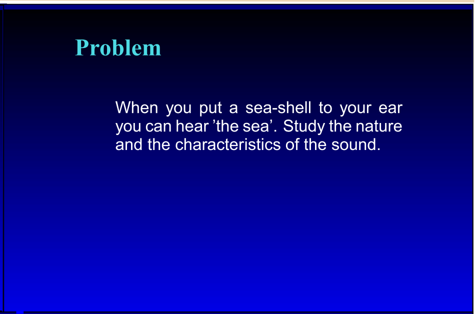
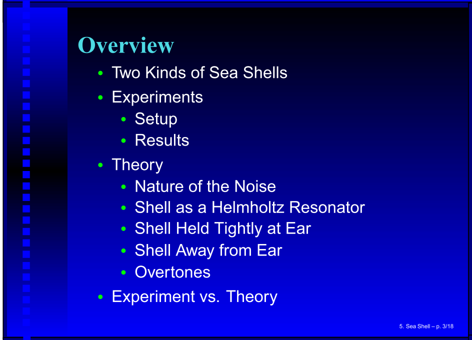
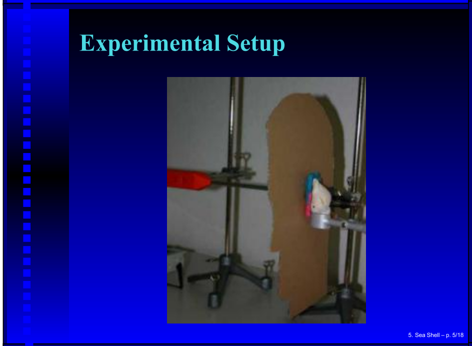
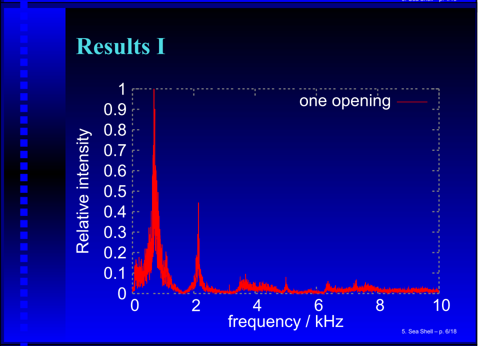
5. Sea Shell
Markus Helmer
German Team

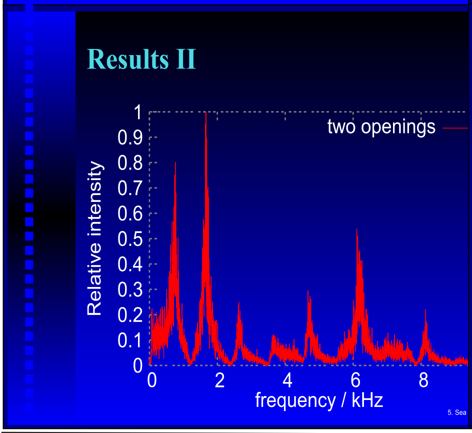

Problem
When you put a sea-shell to your ear you can hear 'the sea'. Study the nature and the characteristics of the sound.

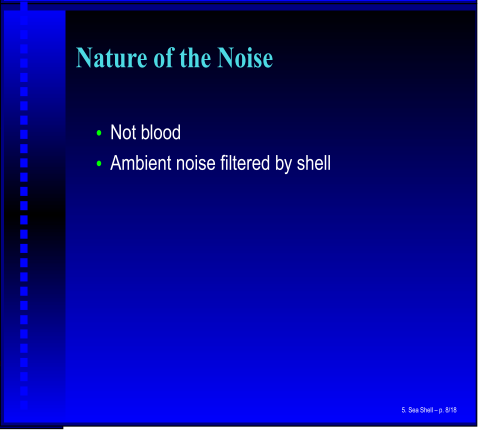

Overview
Two Kinds of Sea Shells
Experiments
Setup
Results
Theory
Nature of the Noise
Shell as a Helmholtz Resonator
Shell Held Tightly at Ear
Shell Away from Ear
Overtones
Experiment vs. Theory
5. Sea Shell – p. 3/18


Two Kinds of Sea Shells
(1) one
(2) two
opening(s)
when held tightly to the ear
(3) shell held away from ear
5. Sea Shell – p. 4/18


Experimental Setup
5. Sea Shell – p. 5/18


Results I
one opening
Relative intensity
frequency / kHz
5. Sea Shell – p. 6/18


Results II
two openings
Relative intensity
frequency / kHz
5. Sea

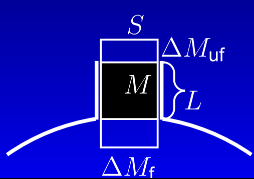

Nature of the Noise
Not blood
Ambient noise filtered by shell
5. Sea Shell – p. 8/18

Shell as Helmholtz Resonator

- Wave entering shell causes pressure-chang
- Reacting force
- Intensities of resonance frequency and overtones magnified by shell

Effective Oscillating Mass

- Mass in neck: $M = \rho_0 \pi a^2 L$
- Additional mass loaded on interface l obtained by integration over all wavel
  $\Delta M_{\text{f}} \approx \frac{8}{3}\rho_0 a^3 \qquad \Delta M_{\text{uf}} \approx 2\rho_0 a^3$
- Effective mass
  $M_{\text{eff}} = M + \Delta M_{\text{uf}} + \Delta M_{\text{f}} = \rho_0 a^3 \left(\frac{14}{3} + \frac{\pi L}{a}\right)$



Shell Held Away from Ear

- Tone pitch increases when pus away from ear:

$$\nu_0' = \frac{c}{2\pi}\sqrt{\frac{S'}{L'_{\text{eff}}V'}}$$

- Intensity decreases with distar

Reactive Force from Shell

- Pressure change in shell is adiabatic:

$$pV^\gamma = \text{const.}$$

- Deriving:
  $\mathrm{d}pV^\gamma + \gamma V^{\gamma-1}p\mathrm{d}V = 0 \quad \Rightarrow \quad \mathrm{d}p = -K\frac{\mathrm{d}V}{V}$
- $\gamma p = K = \rho_0 c^2 \qquad \mathrm{d}V = -S\,\mathrm{d}\xi$
- Reactive pressure force $\mathrm{d}F = -S\,\mathrm{d}p$:

$$F_p(t=)\ -\frac{\rho_0 c^2 S^2}{V}\xi(t=)\ -D\xi(t)$$

Resonance Frequency

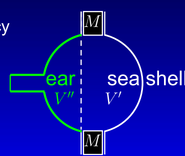
- Helmholtz-Resonator:
  - Air in Cavity → spring
  - Air in Neck → oscillating mass
- Resonance Frequency

$$\nu_0 = \frac{1}{2\pi}\sqrt{\frac{D}{M_{\text{eff}}}} = \frac{c}{2\pi}\sqrt{\frac{S}{L_{\text{eff}}V}}$$

Two Openings

- At both exits two identical masses M_{eff} oscillate
- Two masses connected to a spring
- $D_{\text{eff}} = 2D$
- Resonance frequency

$$\nu_0 = \frac{c}{2\pi}\sqrt{\frac{2S}{L_{\text{eff}}V}}$$



Overtones

- Helmholtz-resonator: mass connected to a spring
- Modified view: wave propagates through cavity
- Nodal plane in cavity
- Position of nodal planes determines overtones

Exemplary Calculation

- Cross-sectional area S of neck not constant
- Difficulty to measure Length L accurately
- Reasonable (exemplary) Values:

$$S = 3\,\text{mm} \qquad L_{\text{eff}} = 1\,\text{cm} \qquad V = 50\,\text{ml}$$

$\Rightarrow$ Resonance frequency: 478.6 Hz

- Same order of magnitude as in experiments

ART AN AMAZING FACT IN SCIENCE

Problem No. 8

Bubbles

Kamran.K.Hedayat

IYPT 2012
BAD SAULGAU - GERMANY

IYPT 2012 Germany, National team of I. R. Iran

Background Knowledge
- Buoyancy
- Drag Force

Theory
- Theory Explanation
- Defining Forces
- Density of mixture
- Summation of the Forces

Experiment
- Experimental Setup
- Confined – Unconfined Plume
- Effect of Height
- Effect of Contact Angle

Main Approach

Conclusion & Discussion
- Theory Vs. Experiments
- Possibility of Floating
- Effect on Buoyancy

Problem

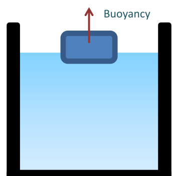
- Is it possible to float on water when there are a large number of bubbles present?
- Study how the buoyancy of an object depends on the presence of bubbles.

Background Knowledge - Buoyancy

- ***Buoyancy** is a force exerted by a fluid, that opposes an object's weight.*

$$F_B = \rho_f V_{disp} g$$

ρ_f: *Density of Fluid*
V_{disp}: *Object's displacment inside water*
g: *Gravitional Acceleration*



Background Knowledge – Drag Force

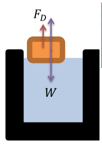
- In fluid dynamics, drag refers to forces which act on a solid object in the direction of the relative fluid flow velocity.
- There are two causes of drag:
  - Viscous Drag
  - Inertial Drag

$$F_D = \frac{1}{2}\rho C_d v^2 A$$

- The drag coefficient is a dimensionless quantity that is used to quantify the drag or resistance of an object in a fluid environment such as air or water.

Theory – Objectives & Base

- Developing an equation:
  - Decreasing of Density
  - Measuring the upward force exerted by bubbles
  - Measuring the upward force exerted by water
  - Effect of water circulation
- Acting forces on the Floater:
  - Buoyancy → F_B
  - Weight → W
  - Water's Upward Force → F_D

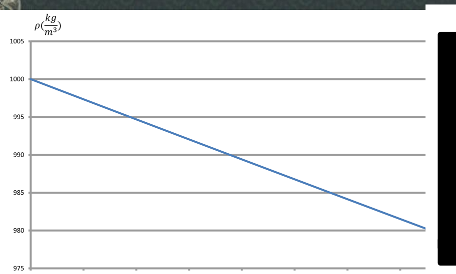


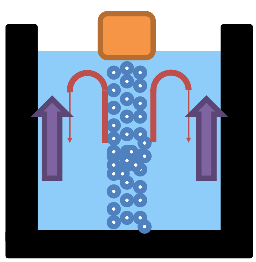
Theory – Developing an Equation (Density of Mix)

- To measure the density of the mix an equation has been developed :

$$\rho_{mix} = \left(\frac{m_w + m_b}{V_T}\right)\left(\frac{n}{t}\right)$$

Theory – Density of the mix





We have water's upwards force & Water's Circulation Force.

Theory – Upwards Force

$$dV_{plume} = \rho R^2 dy$$
$$dV_{bubbles} = Qdt$$

Using the equations above at the depth of (h) the volumetric flow rate of our plume could be measured by :

$$Q(h) = \frac{h_0 Q_0}{h + h_0}$$

Q : Volumetric Flow Rate
h : Height of the bubble

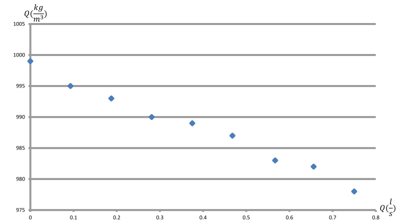
- So the velocity of the water would be

$$u(h) = \frac{dy}{dt} = \frac{h_0 Q_0}{\pi R^2 (h + h_0)} - w$$

- And the force would be measured by:

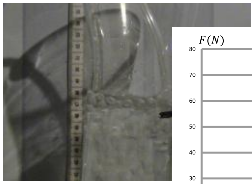
$$F_D = \frac{1}{2} \rho v^2 A C_d$$

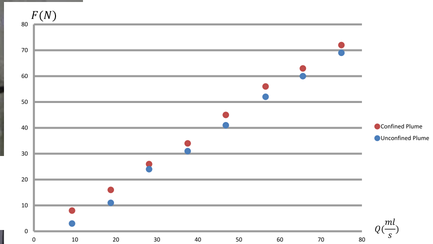
Experiments – Density of Mix

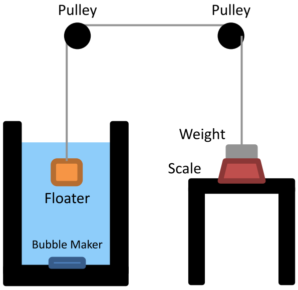


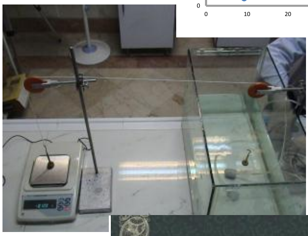
Experiments – Density of Mix (Setup)

- By using a Vertical tube with the capacity of $4750\ cm^3$ and a bubble maker we measured ρ_n terms of different pump coefficients.

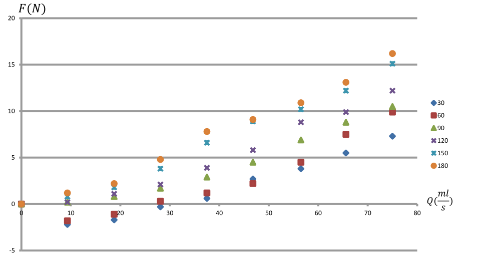




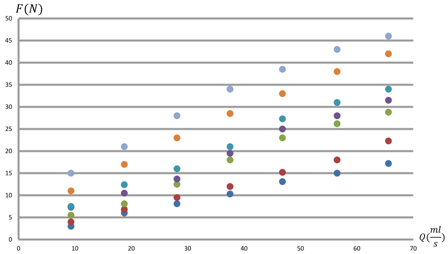




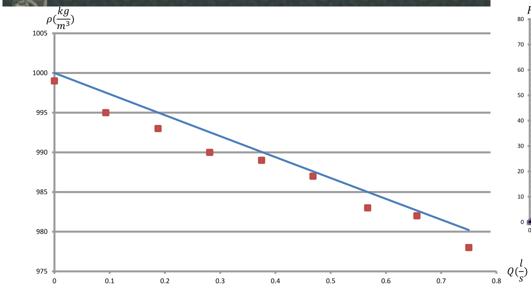
Experiments – Effect of Contact Angle



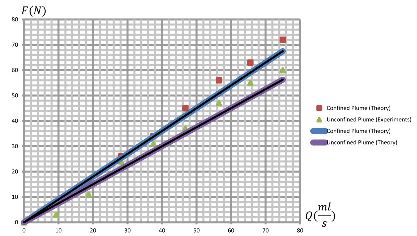
Experiments – Effect of Height

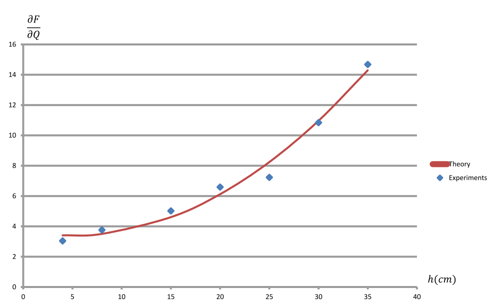


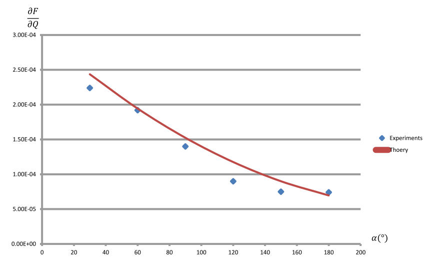
Discussion – Theory Vs. Experiments



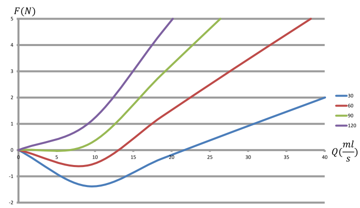
Discussion – Theory Vs. Experiments







Conclusion – Possibility of Floating



Conclusion – Glimpse at the Problem

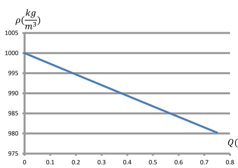
I. Is it possible to float on water whe there are a large number of bubble present?

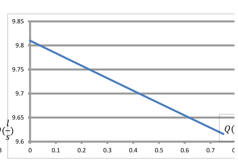
II. Study how the buoyancy of an object depends on the presence of bubbles.

Conclusion – Effect on Buoyancy

- According to this formula :

$$F_B = \rho_f V_{disp} g$$





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