Second draft // October 9, 2011

Preparation to the Young Physicists' Tournaments' 2012

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Call for cooperation

- If you are interested in the idea behind the kit — to structure some earlier knowledge about the physics behind the problems and to encourage students to contrast their personal contribution from this knowledge — your cooperation is welcome
- If more contributors join the work on the kit for 2012, or plan bringing together the kit for 2013, good editions may be completed earlier
- It would be of benefit for everybody,
  - students and team leaders, who would have an early reference (providing a first impetus to the work) and a strong warning that IYPT is all about appropriate, novel research, and not about “re-inventing the wheel”
  - jurors, who would have a brief, informal supporting material, possibly making them more skeptical and objective about the presentations
  - the audience outside the IYPT, who benefits from the structured references in e.g. physics popularization activities and physics teaching
  - the IYPT, as a community and a center of competence, that generates vibrant, state-of-the-art research problems, widely used in other activities and at other events
  - and also the author(s) of the kit, who could rapidly acquire a competence for the future activities and have a great learning experience

How to tackle the IYPT problems?

- How to structure a report?
- What level is competitive?
- How to set goals, decide on the priorities, and set the direction of the work?
- How were people accessing particular issues in the past?

- Look through the historical solutions in the Archive :-)

  - an opportunity for goal-oriented critical learning
  - examples, not guidelines
  - those solutions were good, but yours should become better!

Habits and customs

- Originality and independence of your work is always considered as of a first priority
- There is no “correct answer” to any of the IYPT problems
- Having a deep background knowledge about earlier work in a given field may certainly be a plus
- Taking ideas without citing will seemingly be a serious misconduct
- Critically distinguishing between personal contribution and common knowledge is likely to be appreciated
- Reading more in a non-native language may be very helpful
- Local libraries and institutions can always help in getting access to paid articles in journals, books and databases
- Is IYPT all about reinventing the wheel, or innovating, creating, discovering, and being able to contrast own work with earlier knowledge and the achievements of others?
- Is IYPT all about competing, or about developing professional personal standards?

Important information

- The basic goal of this kit is not in providing students with a start-to-finish manual or in limiting their creativity, but in encouraging them to
  - regard their work critically,
  - look deeper,
  - have a better background knowledge,
  - be skeptical in embedding their projects into the standards of professional research,
  - and, as of a first priority, be attentive in not “re-inventing the wheel”
- An early exposure to the culture of scientific citations, and developing a responsible attitude toward making own work truly novel and original, is assumed to be a helpful learning experience in developing necessary standards and attitudes
- Good examples are known when the kit has been used as a concise supporting material for jurors and the external community; the benefits were in having the common knowledge structured and better visible
- Even if linked from iypt.org, this file is not an official, binding release of the IYPT, and should under no circumstances be considered as a collection of authoritative “musts” or “instructions” for whatever competition
- Serious conclusions will be drawn, up to discontinuing the project in its current form, if systematic misuse of the kit is detected, such as explicit failure of citing properly, replacing own research with a compilation, or interpreting the kit itself as a binding “user guide”
- All suggestions, feedback, and criticism about the kit are warmly appreciated :-)

These problems have no solution?

- “But, my dear fellows,” said Feodor Simeonovich, having deciphered the handwriting. “This is Ben Beczalel’s problem! Didn’t Cagliostro prove that it had no solution?”
- “We know that it has no solution, too,” said Junta. “But we wish to learn how to solve it.”
- “How strangely you reason, Cristo… How can you look for a solution, where it does not exist? It’s some sort of nonsense.”
- “Excuse me, Feodor, but it’s you who are reasoning strangely. It’s nonsense to look for a solution if it already exists. We are talking about how to deal with a problem that has no solution. This is a question of profound principle…”

Arkady Strugatsky and Boris Strugatsky

Quote from: Arkady Strugatsky and Boris Strugatsky. Monday Begins on Saturday. Translated from the Russian. (The Young Guard Publishing House, Moscow, 1966)

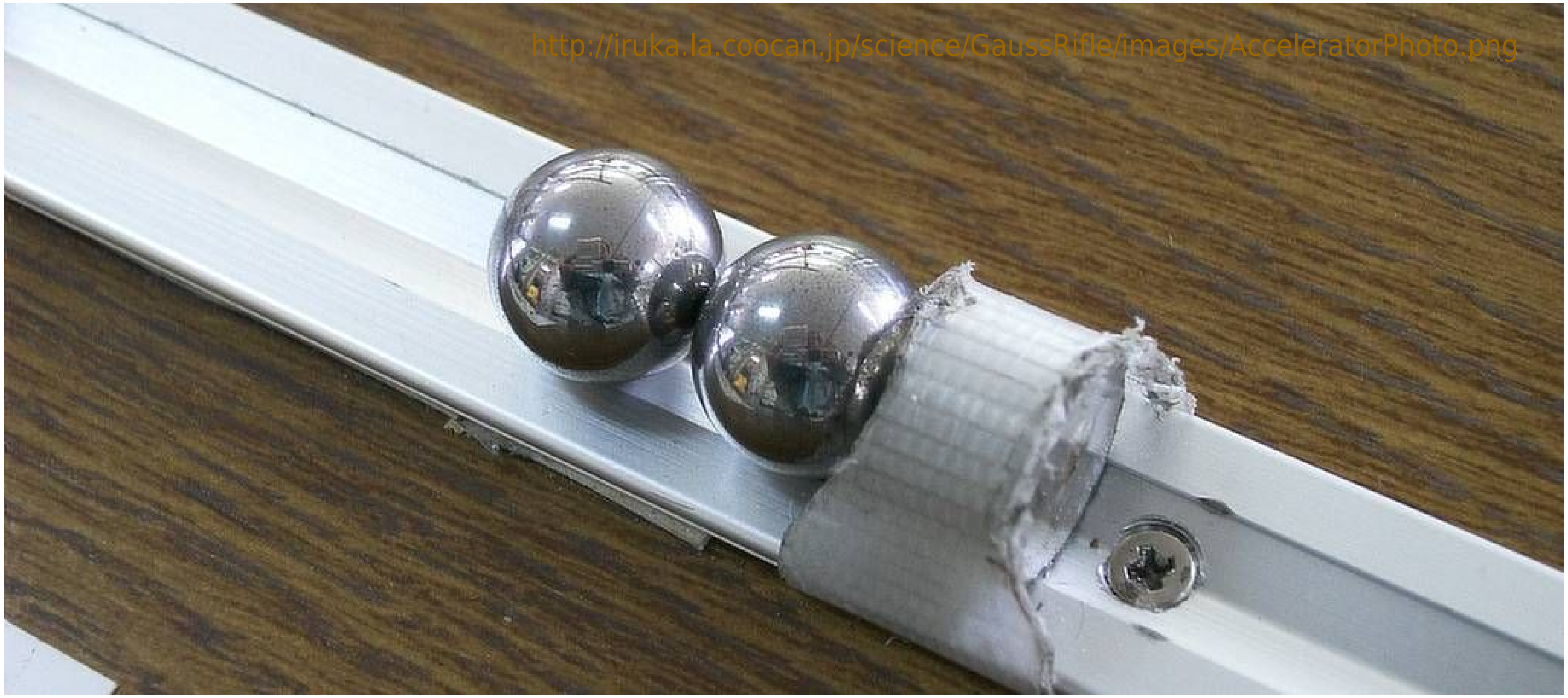
Requirements for a successful IYPT report

- A novel research, not a survey or a compilation of known facts
- A balance between experimental investigation and theoretical analysis
- A comprehensible, logical and interesting presentation, not a detailed description of everything-you-have-performed-and-thought-about
- A clear understanding of the validity of your experiments, and how exactly you analyzed the obtained data
- A clear understanding of what physical model is used, and why it is considered appropriate
- A clear understanding of what your theory relies upon, and in what limits it may be applied
- Comparison of your theory with your experiments
- Clear conclusions and clear answers to the raised questions, especially those in the task
- A clear understanding of what is your novel contribution, in comparison to previous studies
- Solid knowledge of relevant physics
- Proofread nice-looking slides
- An unexpected trick, such as a demonstration *in situ*, will always be a plus

The jury would like to understand…

- What did you actually do?
- Why did you do it?
- How well did you do it?
- Were you able to voice important questions and provide grounded answers?
- What was your major contribution to the understanding of the phenomenon?
- Can you judge the achievements and limits of your work in an objective, skeptical and self-confident manner?
- Are you proficient in relevant physics concepts?
- Were you a self starter?
- Could you be left unsupervised?

Is the novel research limited and discouraged by the existing common knowledge and the ongoing work of competing groups? :-)



Problem No. 1 “Gaussian cannon”

A sequence of identical steel balls includes a strong magnet and lies in a nonmagnetic channel. Another steel ball is rolled towards them and collides with the end ball. The ball at the opposite end of the sequence is ejected at a surprisingly high velocity. Optimize the magnet's position for the greatest effect.

IYPT history

- **2.** Impact (2nd YPT, Correspondence Rounds, 1980)
  - A rod with a speed *v* impacts with its end an absolutely elastic wall. What fraction of the kinetic energy of the rod will go into sound upon the collision? Estimate the volume of a sound that a nearby observer may hear. Perform an experimental verification of your conclusions.
- **1 (18.)** Superball (2nd YPT, Problems for the Finalists, 1980)
  - Estimate the collision time of a superball (a caoutchouc ball) with floor as it falls from a height of 1 *m*.
- **4 (27.)** Steel and lead (3rd YPT, Problems for the Finalists, 1981)
  - A steel ball (r_1=1 *mm*) falls freely on a glass plate from a small height (h_1=20 *cm*) and bounces up to almost the same height. A lead ball (a pellet) of the same size bounces up to much lower height ($r_2=r_1$, $h_2=h_1/10$). How will these balls bounce from a wooden board?
- **8.** Superball (4th YPT, Correspondence Rounds, 1982)
  - A superball falls from a height of 30 *cm* onto a horizontal surface of a steel plate. How many collisions will take place? What is the duration of each collision? For how long will the superball continue “jumping”? Consider that 20% of superball’s kinetic energy goes into heat upon each bounce.
- **9.** Impact (4th YPT, Correspondence Rounds, 1982)
  - Two identical elastic cubes are placed on a smooth table in tight contact to each other. How will they bounce after a central impact by a smooth elastic ball of a same mass? Consider the following cases:
    - a. the facets of the cubes are dry;
    - b. those facets that are in contact are moistened with water;
    - c. the same facets are moistened with machine oil.

Background reading

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Key questions

- How does the device work? Is the phenomenon entirely magnetism-related, or involves also mechanical interactions?
- What is the ‘largest effect’? What parameters need to be tuned to achieve the largest kinetic energy? largest momentum? largest speed?
- How should the balls be placed with respect to the magnet? How to ensure the best momentum transmission? What is the optimum number and size of the steel balls?
- If the number of balls is taken fixed, how should they be placed for the largest effect?
- What are the optimum sizes in the system? Should the diameter of the ball be smaller, larger or equal to the diameter of the magnet?
- What parameters of magnets are relevant? magnetic moment? length? diameter?
- What are the main sources of energy loss in the system? How applicable are the energy and the momentum conservation laws? Of what relevance are the elastic properties of the materials and friction acting on the steel balls? Is it possible to define and determine the efficiency of the system?
- Is it worth studying the system of multiple magnets and steel balls placed in a row one after another? What is the optimum spacing? Is there any limit on the speed of the final ball? (in other words: is it always good to increase the number of magnets?)
- Is the initial speed of the first ball relevant? Is there any hysteresis in the system observed?
- Is there any possible application of such a cannon?
- Is it worth modeling the system numerically? How to analytically describe the relevant interactions between the magnet and the steel balls?

Problem No. 2 “Cutting the air”

When a piece of thread (e.g., nylon) is whirled around with a small mass attached to its free end, a distinct noise is emitted. Study the origin of this noise and the relevant parameters.

bekannt, jedoch einer Untersuchung bis jetzt nicht unterzogen wurde. Es ist bekannt, dass durch rasches Schwingen eines Stabes, einer Klinge, einer Peitsche u. a. in der Luft ein Ton entsteht; nicht weniger bekannt sind auch die hieher gehörigen Töne, die durch Luftströmungen an ausgespannten Drähten, scharfen Kanten, Spalten u. dergl. entstehen. Töne dieser Art, die aus später anzuführenden Gründen am passendsten als R e i b u n g s t ö n e zu bezeichnen sind, bilden den Gegenstand vorliegender Untersuchungen.

When the apparatus is set in motion, we hear the whistling due to the rapid movement of the wire through the air. When we change the wire for a thicker one, the note is not so high for the same speed.

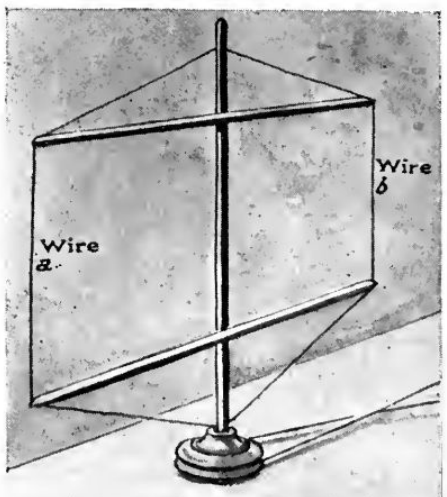


FIG. 61.—Strouhal's apparatus for showing the whistling of the wind. The wires (*a*) and (*b*) may be of different diameters, in which case they will give different notes.

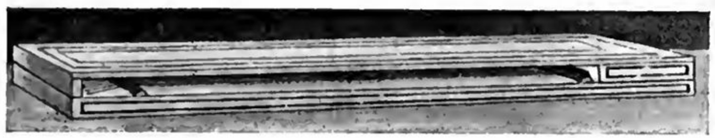
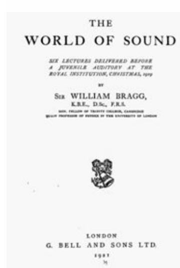


FIG. 59.—Æolian Harp.

IV. ***Ueber eine besondere Art der Tonerregung; von Dr. V. Strouhal.***

(Vorgetragen in der physikalisch-medicinischen Gesellschaft in Würzburg, am 16. Februar 1878.[1])



THE

WORLD OF SOUND

SIX LECTURES DELIVERED BEFORE A JUVENILE AUDITORY AT THE ROYAL INSTITUTION, CHRISTMAS, 1919

BY

SIR WILLIAM BRAGG,

K.B.E., D.Sc., F.R.S.

LONDON

G. BELL AND SONS LTD

1921

The Æolian Harp.

MARCH 1879.

XXVII. *Acoustical Observations.* II. *By* LORD RAYLEIGH, *F.R.S.**

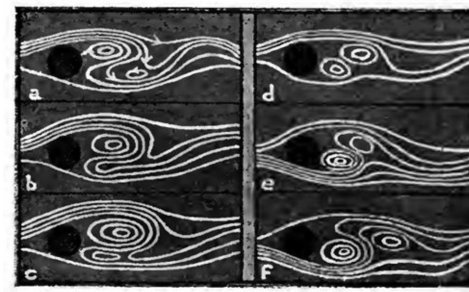


FIG. 58.—Six successive drawings, *a* to *f*, showing how air-whirls are formed, first on one side of a wire, then on the other, as the wind blows past it. The black circle is a section of the wire.

The source of sound…?

- The string itself…?
  - is there anything in common to the Aeolian harp?
  - air drag growing with distance to the center of revolution?
  - a test to alter the size and shape of the attached bob? (that should be of no relevance?)
- The attached bob…?
  - should a rapidly moving body emit a sound?
  - tests with a similar motion but no string? (only rotational motion, or simply throwing the mass…?)
- Both…?
  - if true, should there be any signs of superposition of elementary contributions by each of the sources?
- Another source…?
  - how to identify it?

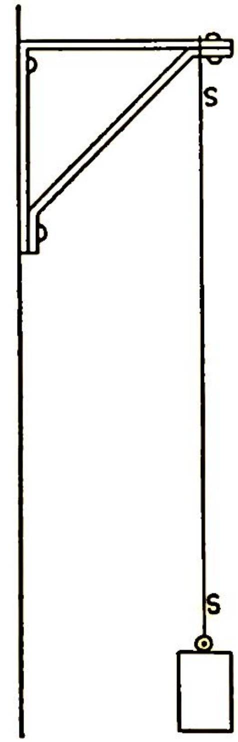


FIG. 21.—This string when made to vibrate does not give out much sound: it is not mounted on a "sounding-board."


THE
WORLD OF SOUND
SIR WILLIAM BRAGG,
LONDON
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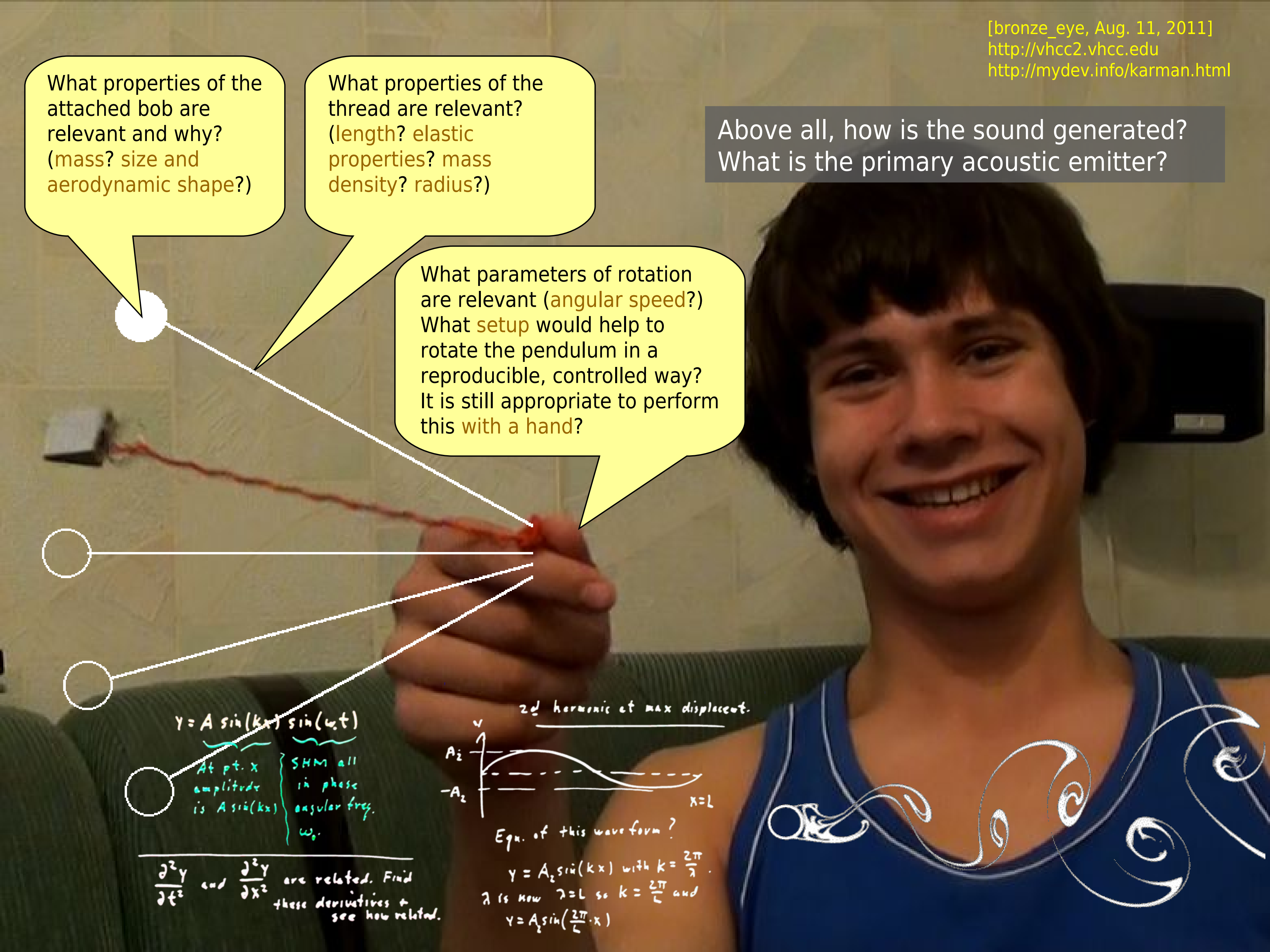

[bronze_eye, Aug. 11, 2011]
http://vhcc2.vhcc.edu
http://mydev.info/karman.html
Above all, how is the sound generated? What is the primary acoustic emitter?
What properties of the attached bob are relevant and why? (mass? size and aerodynamic shape?)
What properties of the thread are relevant? (length? elastic properties? mass density? radius?)
What parameters of rotation are relevant (angular speed?) What setup would help to rotate the pendulum in a reproducible, controlled way? It is still appropriate to perform this with a hand?
$y = A \sin(kx) \sin(\omega_0 t)$
At pt. x amplitude is $A \sin(kx)$
SHM all in phase angular freq. ω_0.
$\frac{\partial^2 y}{\partial t^2}$ and $\frac{\partial^2 y}{\partial x^2}$ are related. Find these derivatives + see how related.
2d harmonic at max displacement.
A_2
$-A_2$
$x=L$
Eqn. of this waveform?
$y = A_2 \sin(kx)$ with $k = \frac{2\pi}{\lambda}$.
λ is now $\lambda = L$ so $k = \frac{2\pi}{L}$ and
$y = A_2 \sin(\frac{2\pi}{L} \cdot x)$

http://apm.iitm.ac.in/fmlab/research.html

[Montauk Beach 2010]

Aeolian Harp...?

Kármán vortex sheet...?

Is an analogy between a revolving “pendulum” and an Aeolian Harp appropriate?

How does the velocity field around the thread look like and what friction-driven interactions does it cause? How do they determine the the effective spectrum of the sound?

What is the basic physics behind the effect?

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Key questions

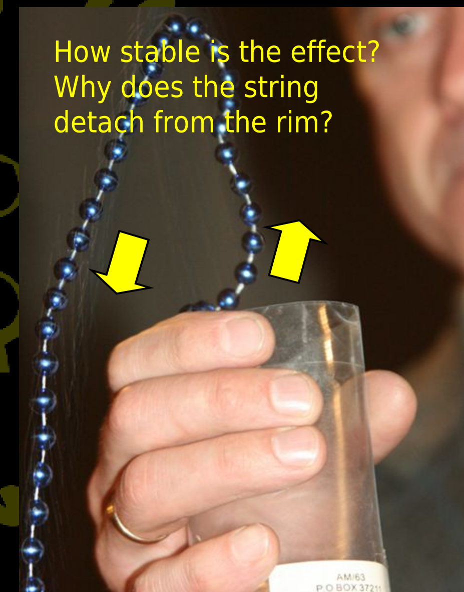
- What is the basic physics behind the generated sound?
- What are the spectra of the produced sounds? The sound may change depending on the position of the string relatively to the observer. How? Why?
- What do the amplitudes and frequencies of the waves depend on?
- How is the energy re-distributed among various oscillatory modes?
- Are any resonance effects relevant to this phenomenon? What is the natural frequency of the mass on the string for different modes, and is this parameter relevant? What is an acoustic impedance and what is its influence on the produced sound?
- What waves (transverse? longitudinal?) may appear in the thread? Are they only due to the air drag? Is it possible to define the oscillations as of a particular nature, e.g. a fluttering or parametric resonance? Is the primary acoustic source the thread, the mass, or anything else?
- What is the distribution of tensions inside the thread and what forces act on a small piece of thread, during the revolution?
- Is Doppler effect important to the phenomenon? How to measure it?
- What parameters describe the sound produced by the thread? Which of them are “physical” and which are “subjective”? (timber? tone color? volume? pitch?)
- It seems to be reasonable to record the sound. What should be the requirements for the sound-recording equipment? Where to place the microphone?
- What total acoustic energy is produced by the system? How does it correspond to the overall mechanical energy in the system?

Problem No. 3 “String of beads”

A long string of beads is released from a beaker by pulling a sufficiently long part of the chain over the edge of the beaker. Due to gravity the speed of the string increases. At a certain moment the string no longer touches the edge of the beaker (see picture). Investigate and explain the phenomenon.

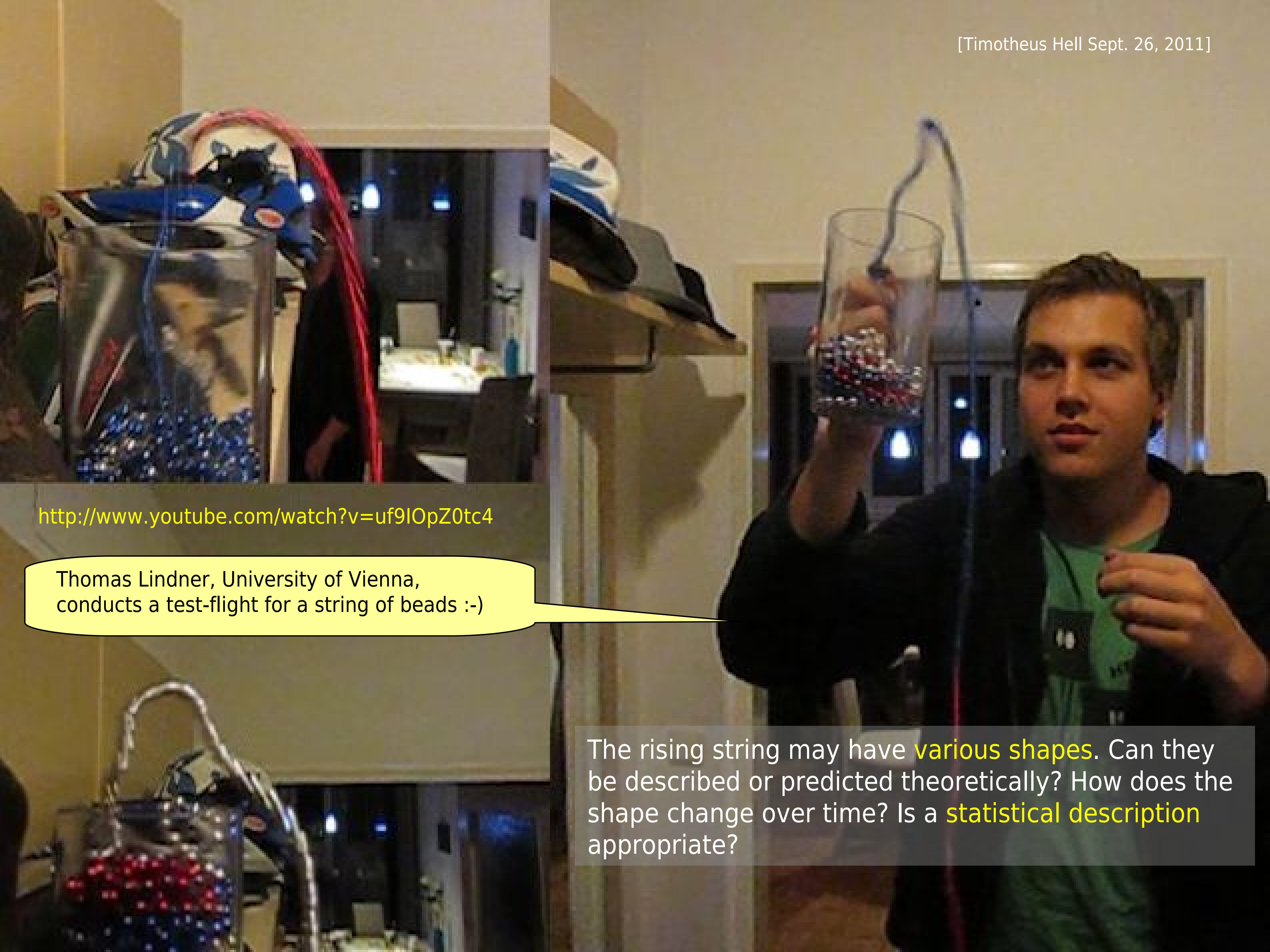
First observations

[Leonid Markovich, Hans Jordens Nov. 4, 2010]



Although the Newton’s Beads is a popular toy, the systematic investigation into the phenomena appears to be limited :-)

Are the basic concepts and the laws of motion sufficient to describe the phenomenon?


[Timotheus Hell Sept. 26, 2011]
http://www.youtube.com/watch?v=uf9IOpZ0tc4
Thomas Lindner, University of Vienna, conducts a test-flight for a string of beads :-)
The rising string may have various shapes. Can they be described or predicted theoretically? How does the shape change over time? Is a statistical description appropriate?

Background reading

- IYPT 2012 - Problem 3: String of beads (Newton's Beads) (youtube.com, from timotheushell, Sept. 26, 2011), http://www.youtube.com/watch?v=uf9IOpZ0tc4
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Key questions

- Above all, what is the basic physics behind the effect?
- What extra potential and kinetic energy does a string need to take off? How does these values correspond to the total energy in the system and the laws of energy conservation?
- What is the structure of the string of beads? What are its relevant properties? (elastic and other mechanical properties? average mass density or mass per unit length? sizes and masses of the beads? spacing between the beads? surface properties of the beads, e.g. the friction coefficients?)
- If the chain is infinitely long, is there a stable, reproducible regime of the motion?
- How to describe the relevant interactions between the beads? What are the important properties of the thread connecting the beads?
- Where is the center of masses of a falling chain, if this concept is applicable? How does the density distribution and the shape influence over the dynamics?
- How does the speed of the string change over time? How does it correspond to the moment of detachment?
- What initial conditions may influence on the results? (position and orientation of the beaker? length of the protruding end? the exact technique of pulling out the end of the chain?)

Key questions

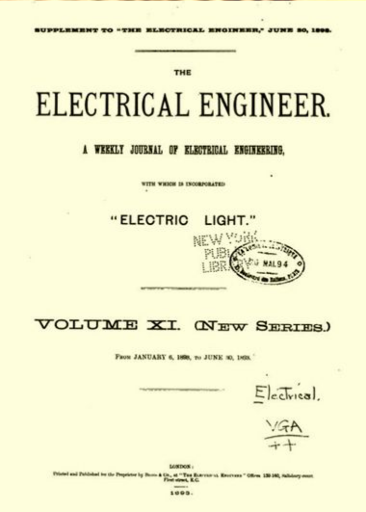
- What is the maximum horizontal displacement for a chain, or for its segments? Does the sliding end fall with a free-fall-dynamics?
- Is the phenomenon possible for a chain of a uniform mass distribution, i.e. a thread?
- How long should be a “long” chain to observe the phenomenon?
- How relevant are the properties of the beaker rim? How to describe their influence, if any?
- What are the relevant interactions between the beads and the confining beaker (collisions? sliding friction?)
- Is there a way to optimize the initial conditions to control the average speed of discharge? stabilize the shape of the string?
- Is it important that the string of beads impacts and interacts with the floor? Does this influence over the phenomenon?
- It might be reasonable to photograph the string from different angles or with different exposures. Where to place the camera and how to treat the obtained images or videos? Would a slow-motion recording be helpful?
- Is it worth modeling the system numerically?

Problem No. 4 “Fluid bridge”

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. (High voltages must only be used under appropriate supervision — check local rules.)

very short time in my hands after its completion, and I made the best use of my time in trying experiments with it in the open air. Amongst other experiments I hit upon a very remarkable one. Taking two wine-glasses filled to the brim with chemically pure water, I connected the two glasses by a cotton thread coiled up in one glass, and having its shorter end dipped into the other glass. On turning on the current, the coiled thread was rapidly drawn out of the glass containing it, and the whole thread deposited in the other, leaving, for a few seconds, a rope of water suspended between the lips of the two glasses. This effect I attributed at the time to the existence of two water currents flowing in opposite directions, and representing opposite electric currents, of which the one flowed within the other and carried the cotton with it. It required the full power of the machine to produce this effect, but, unfortunately, when it went to London, and was fitted up in the lecture-room, I could not get the full power on account of the difficulty of effecting as good insulation i…
the outside air. I therefore failed in getting this resu…
nouncing that I could do it, and I daresay I got th…
romancing. It has ever since been my desire to e…
veracity in this matter, and with the powerful appara…
my command, I speedily succeeded in reproducing the…
in a modified form. In fact, I have done it in different…
the o… …rik…
and can be performed with the single induction coil w…
upon the table. The conditions of the experiment are…
I take a glass bulb having a long neck on one side and a short

The effect seems to be first reported in 1893...


SUPPLEMENT TO "THE ELECTRICAL ENGINEER," JUNE 30, 1893.

THE

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A WEEKLY JOURNAL OF ELECTRICAL ENGINEERING,

WITH WHICH IS INCORPORATED

"ELECTRIC LIGHT."

VOLUME XI. (NEW SERIES.)

FROM JANUARY 6, 1893, TO JUNE 30, 1893.

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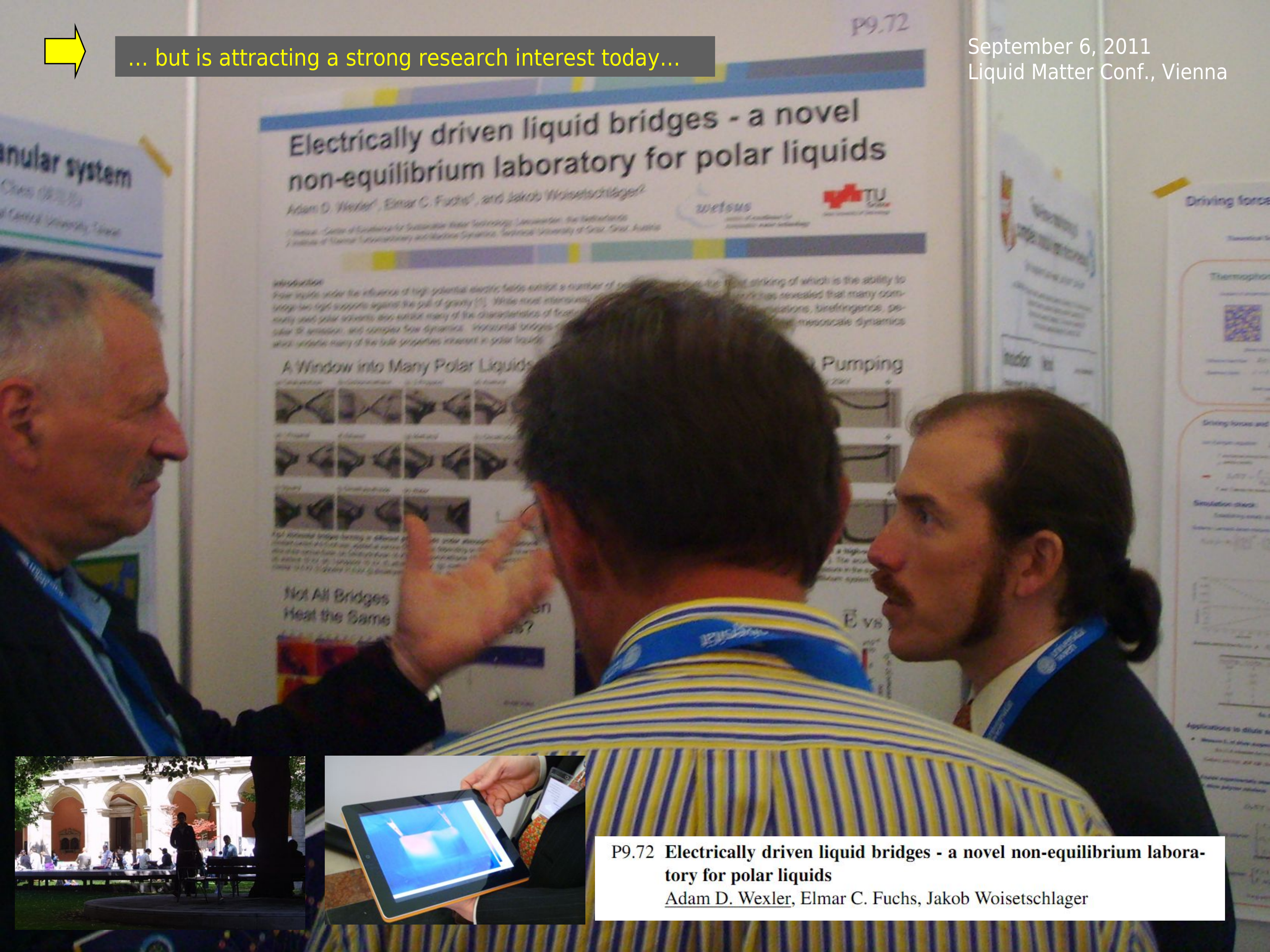
1893.

... but is attracting a strong research interest today...

September 6, 2011
Liquid Matter Conf., Vienna



P9.72 **Electrically driven liquid bridges - a novel non-equilibrium laboratory for polar liquids**
Adam D. Wexler, Elmar C. Fuchs, Jakob Woisetschlager

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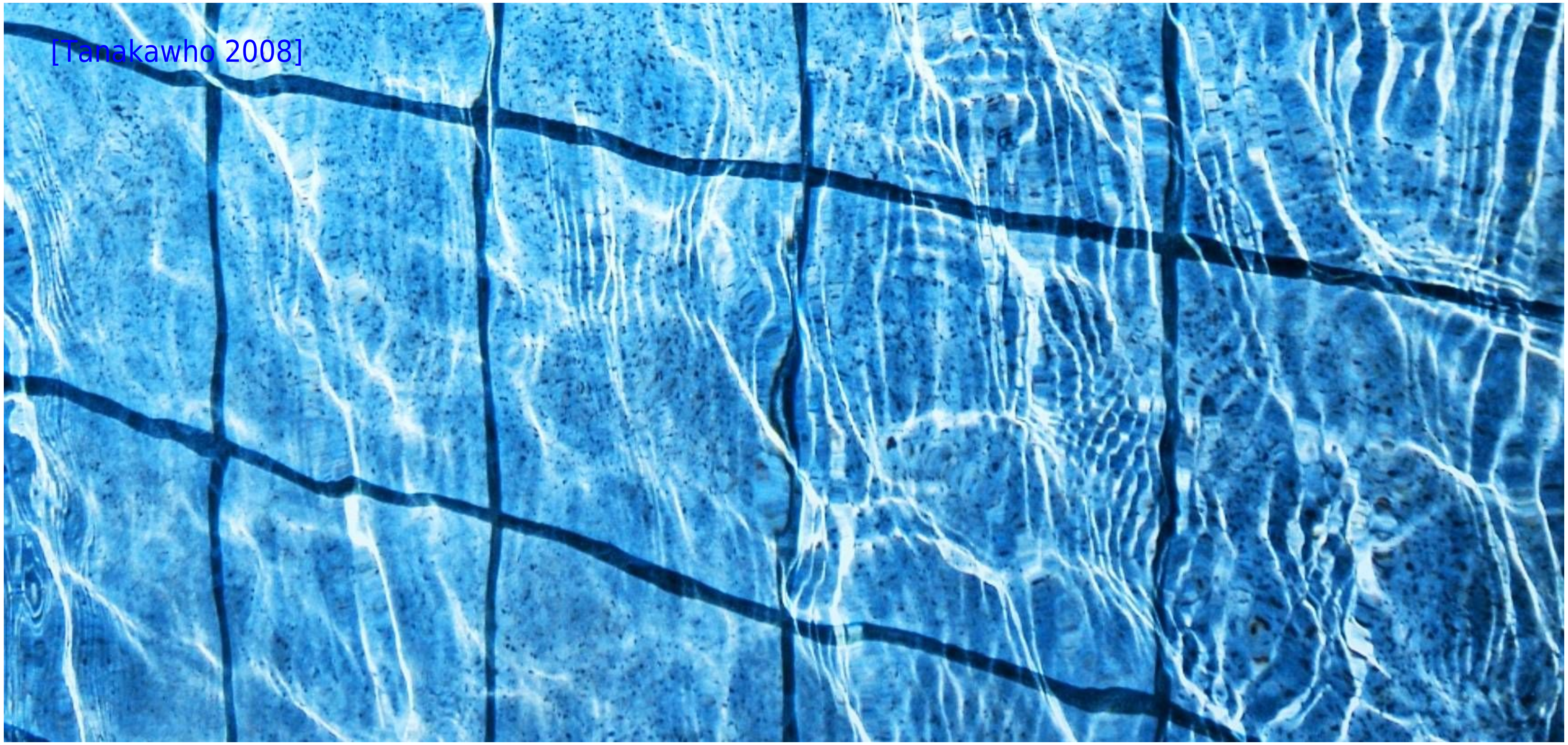
Key questions

- Above all, why does the phenomenon occur? How important is using deionized water only? What are the necessary properties of the fluid for a bridge to be appear?
- What does it mean for the beakers to be “in contact”?
- How to describe the stability of the bridge? What forces keep the bridge together as the beakers are moved away? (surface tension? electrostatic?) Does the bridge respond to the presence of a charged body?
- Is there any fluid flow in the bridge? How to prove or rule out such a flow? Is the flow of the fluid dependant on the initial level in the beakers? Are there any current carriers and an electric current through the bridge?
- Can the laws of energy conservation by applied? Is there a relation between the electric potential and e.g. extra surface energy?
- What is the dynamics of the formation of a bridge? How large is the time lag before the bridge is formed? Is it possible that, under certain conditions, the lime lag is sufficiently long?
- Is there a difference in the effect if the voltage is increased gradually or instantly?

Key questions

- What are the key differences between an ongoing stability of an already existing bridge and formation of a new bridge?
- What are the key parameters of the bridge? (maximum stable length? temperature gradient? diameter? stability? shape?) How do they depend on the voltage applied? geometry and position of the electrodes? parameters of the fluid (conductivity? surface tension? density?) parameters of the ambient air? (humidity?)
- Is there a room for quantitative predictions and measurements?
- What would happen if there are two different liquids in the two beakers? Do they need to possess any additional properties? What if the liquids are non-Newtonian? What if an AC voltage is applied?
- If there is a raw of beakers, is it possible to have many bridges? one extended bridge?
- What new we can add to this profoundly researched problem?



Problem No. 5 “Bright waves”

Illuminate a water tank. When there are waves on the water surface, you can see bright and dark patterns on the bottom of the tank. Study the relation between the waves and the pattern.

IYPT history

- **14.** Laser (5th IYPT, 1992)
  - A laser beam is directed perpendicularly to the wall of a transparent glass tank filled with water. If the beam passes through the tank above or below the level of the water in the tank, we can observe a spot on the screen behind the tank. If the beam passes along the level of the water we observe a vertical line. Explain the origin of the line and calculate its parameters.
- **8.** Surface information (9th IYPT, 1996)
  - Develop a method for transferring information by the waves on the surface of water. Investigate the angular characteristics of the emitter and the receiver (the antennas) which you constructed.
- **15.** Bright spots (12th IYPT, 1999)
  - Bright spots can be seen on dew drops if you look at them from different angles. Discuss this phenomenon in terms of the number of spots, their location and angle of observation.
- **12.** Fluid lens (20th IYPT, 2007)
  - Develop a fluid lens system with adjustable focus. Investigate the quality and possible applications of your system.
- **2.** Brilliant pattern (23rd IYPT, 2010)
  - Suspend a water drop at the lower end of a vertical pipe. Illuminate the drop using a laser pointer and observe the pattern created on a screen. Study and explain the structure of the pattern.
- **10.** Calm surface (23rd IYPT, 2010)
  - When wind blows across a water surface, waves can be observed. If the water is covered by an oil layer, the waves on the water surface will diminish. Investigate the phenomenon.

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Theory vs life?

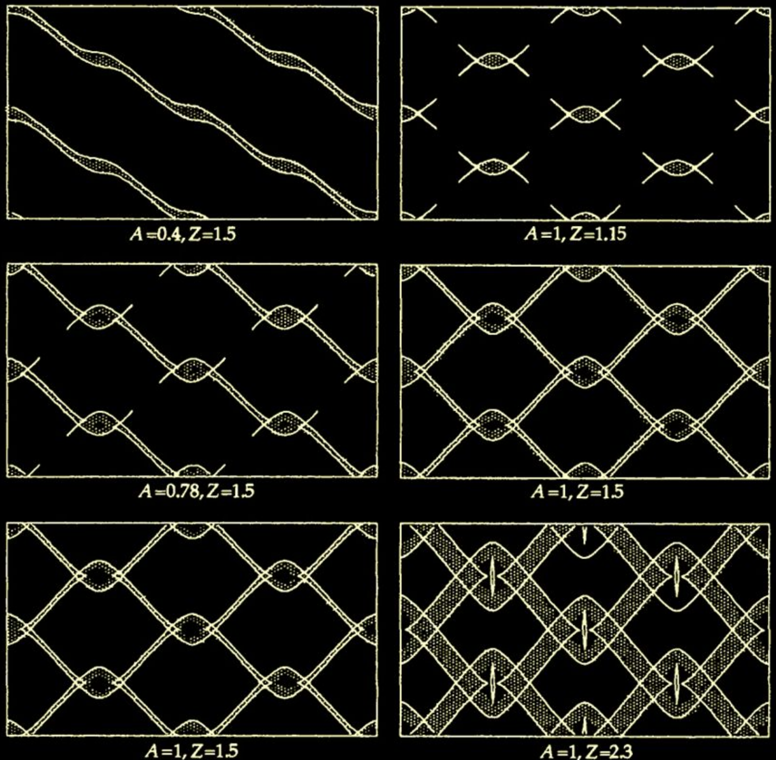
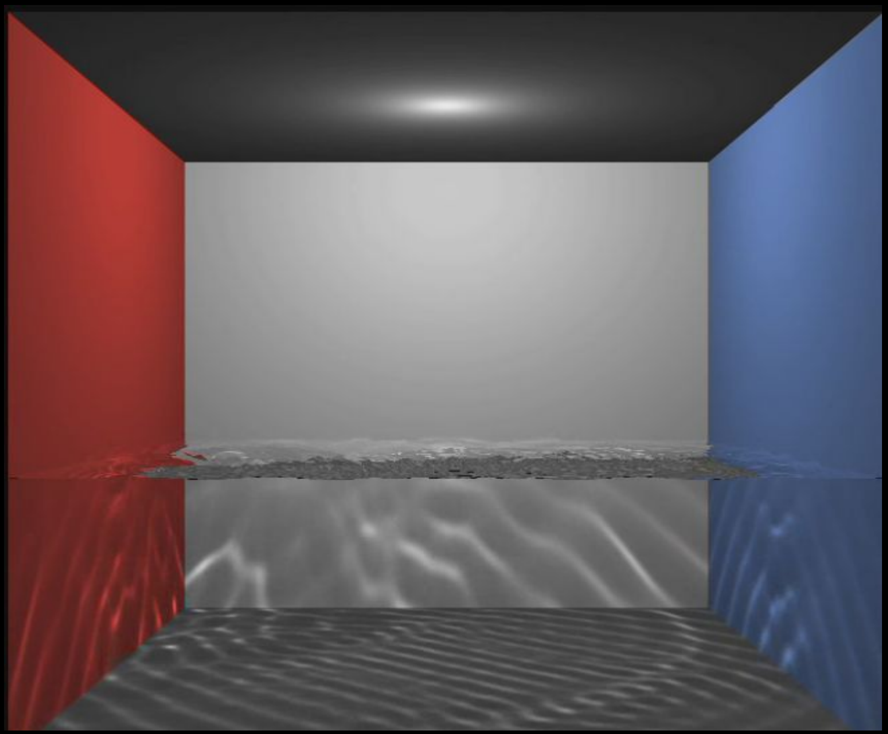


Figure 9.2. Computed fold lines for two sinusoids intersecting at $\theta = 60°$.



Is it possible to describe the caustic pattern analitycally?

Are the algorithms involved in CGI physically correct? Is proffesional CGI software capable of correctly predicting the patterns?

J. F. Nye. Natural Focusing and Fine Structure of Light (IOP Pub., 1999)

http://graphics.cs.ucf.edu/caustics/

Key questions

- What types of patterns can appear on the bottom? Can they be classified into distinct categories? Are they macroscopic only, or a microscopic, fine structure might exist? (a fractal-like pattern?)
- What is a caustic and how relevant this concept is to the problem?
- How exactly do the patterns change over time? What features are not time-dependant? Can these changes be described quantitatively?
- Can the effects be explained in terms of geometrical optics only? Is there room for wave phenomena, such as diffraction? Is there any light scattering involved?
- How to describe the waves on water? Are they capillary or gravitational? What of their properties are the most relevant? (amplitude? wavelength? speed of propagation? modes of oscillations? frequency? overall, the time-dependant 3D profile of the water surface?) How relevant are the parameters of the waves and on the parameters of the container (depth? size? shape?)
- Are there any essential effects not related to the 3D surface shape, e.g. changes in the optical path length? How does the phenomenon depend on the optical parameters of the fluid? optical properties of the container?
- Are there threshold values for the amplitude of the waves and the depth of the container for the bright patterns to be visible?

Key questions

- The observed pattern changes rapidly. How to build an experimental setup to study the dynamic system in a reproducible, reliable manner?
- How to record the visible patterns?
- What information about the system can be extracted from the observed patterns?
- How relevant is an approach involving a model system, e.g. by creating a stationary meniscus? Is such an approach applicable and appropriate?
- How does the pattern depend on the illumination and the position of the light sources? What changes if we illuminate the largest possible area or the smallest possible area?
- Is it possible to describe the patterns in case of a randomly ondulating surface?
- The phenomenon would be typically observed from above of the surface. Can this disturb the measurements?
- Is every pattern unique for a particular physical system, so that a reverse problem can be solved: restoring the 3D surface shape from the intensity distribution on the bottom?
- Above all, what is your conclusion on the problem?

Problem No. 6 “Woodpecker toy”

A woodpecker toy (see picture) exhibits an oscillatory motion. Investigate and explain the motion of the toy.

[Leine *et al.* 2003]

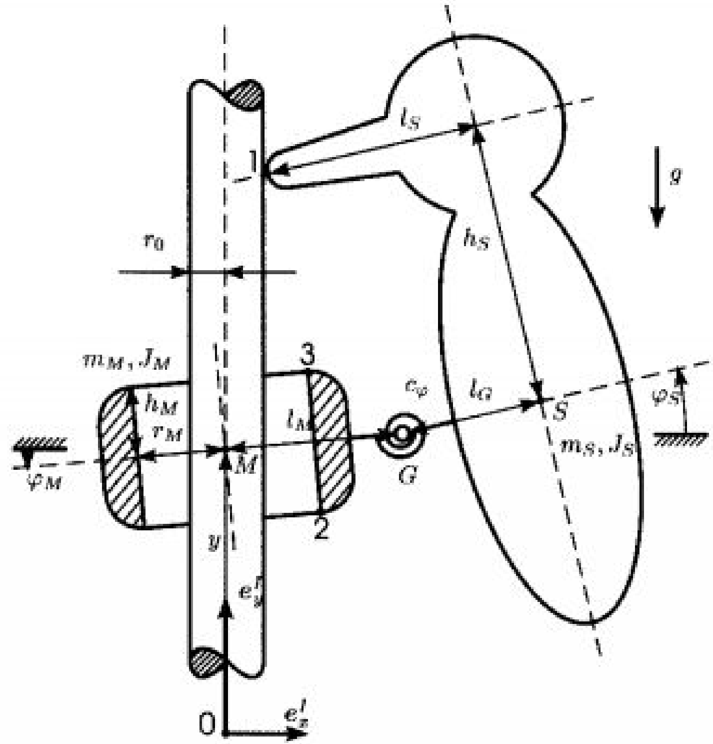


Figure 4. Model of the woodpecker toy (not to scale).

The hole in the sleeve is slightly larger than the diameter of the pole, thus allowing a kind of pitching motion interrupted by impacts with friction.

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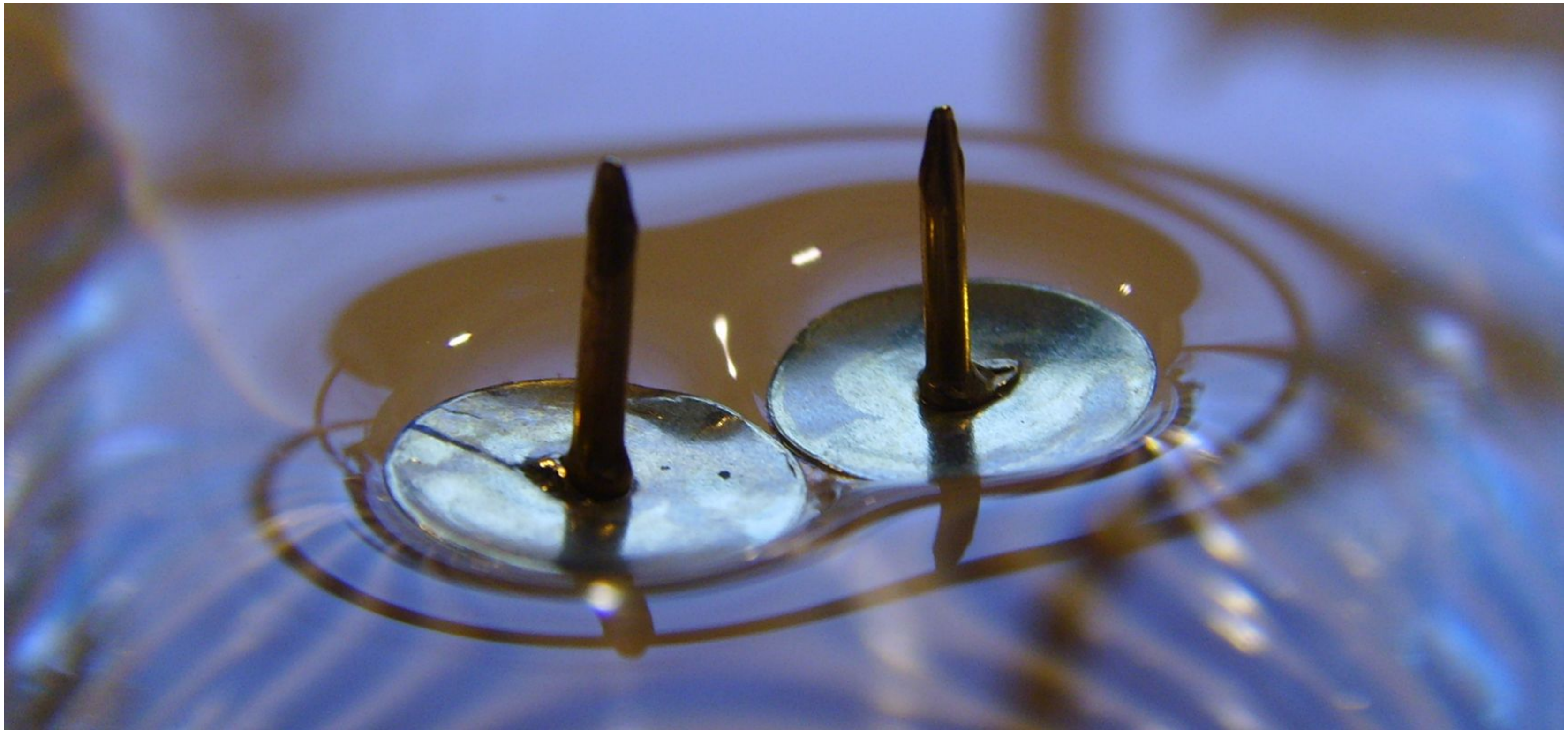
Key questions

- How to easily describe the physics behind the motion? What are the phases of motion? What are the most relevant parameters involved?
- What is the role of impact dynamics and friction in the descent of the toy? What are the most relevant parameters of impact (time of contact? velocity before collision?)
- What are the possible types of oscillatory motion?
- Is the motion of the woodpecker always 2D? Is a stable rotation about the central axis possible?
- The toy has been studied theoretically before. How can we seriously contribute to the problem? Are there any theoretical gaps to fill in? Any new approaches to study the system? (a simplified quantitative theory? the role of parameters not studied earlier?) Is there a way to perform new experiments to verify the existing models, or check the parameters not yet sufficiently investigated?
- How relevant in the initial deflection? Is it necessary to control it experimentally? Does the system forget initial conditions? If so, after what number of collisions?
- Is it more logical to test a single toy or to construct and study toys that differ by particular parameters? There may be an endless number parameters to study. Which of them are the most relevant to the problem?
- Is it worth studying a woodpecker placed at an inclined central pole?



Problem No. 7 “Drawing pins”

A drawing pin (thumbtack) floating on the surface of water near another floating object is subject to an attractive force. Investigate and explain the phenomenon. Is it possible to achieve a repulsive force by a similar mechanism?

IYPT history

- **4.** Dusty blot (17th IYPT, 2004)
  - Describe and explain the dynamics of the patterns you observe when some dry dust (e.g. coffee powder or flour) is poured onto a water surface. Study the dependence of the observed phenomena on the relevant parameters.
- **5.** Razor blade (20th IYPT, 2007)
  - A razor blade is placed gently on a water surface. A charged body brought near the razor makes it move away. Describe the motion of the razor if an external electric field is applied.
- **9.** Ink droplet (20th IYPT, 2007)
  - Place a droplet of ball pen ink on a water surface. The droplet begins to move. Explain the phenomenon.
- **9.** Escaping powder (24th IYPT, 2011)
  - When a hot wire is plunged into a beaker of water with powder (e.g. lycopodium) floating on the surface, the powder moves rapidly. Investigate the parameters that alter the speed of movement of the powder.

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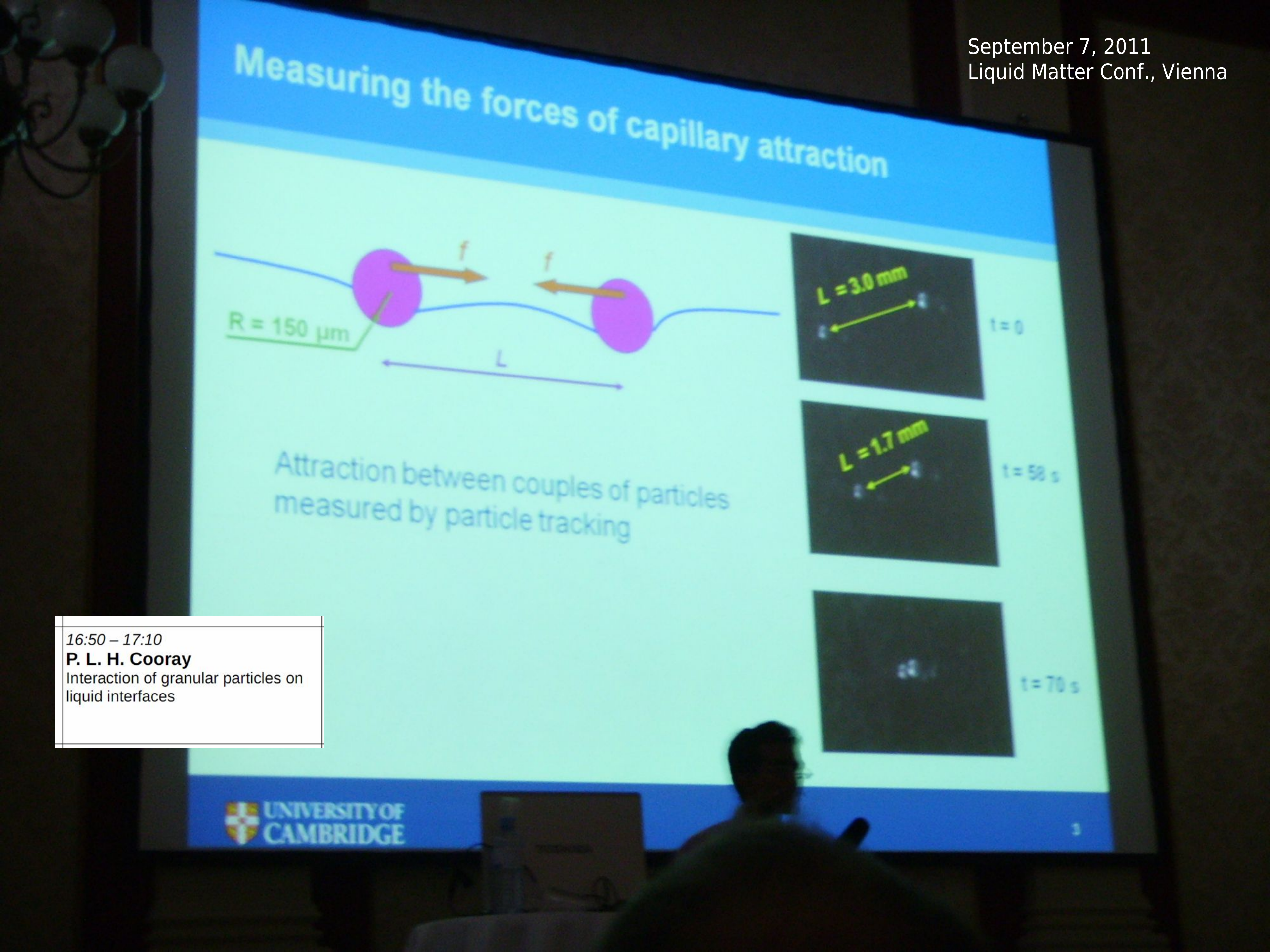
Key questions

- Above all, what types of motion can be observed? Can all of them be linked to unbalanced capillary forces due to unequal contact angles?
- Is there a way to provide a visual and straightforward experimental evidence for what happens?
- Why do the heavy metal pins not sink in the water?
- Are pins hydrophilic or hydrophobic? Is this feature relevant as for the direction of the force between two pins?
- What determines if the floating objects attract or repulse, and how does the direction and value of the effective force depend on their geometry, contact angles with liquid and other parameters?
- Is it possible to measure and accurately describe theoretically the 3D shape of the meniscus near a drawing pin?
- How is the phenomenon dependant on the liquid's parameters? (surface tension, viscosity?) What conclusions can be drawn from tuning the surface tension, or other parameters of water? Is it possible to obtain a repulsive force by changing the fluid only?
- Is the fluid flow relevant? Is there any convective flow observed? Any surface flow?
- How to describe quantitatively the forces between the pins? How appropriate is a steady-state approximation where the forces are calculated as if the pins were immobile?

Key questions

- How relevant is the viscous drag? the vertical oscillations of the drawing pins?
- Is it possible to measure the lateral forces acting on the drawing pins?
- What are the speeds and accelerations of the drawing pins? How to record and analyze them? How do they depend on the multiple relevant parameters, and how do they evolve over time?
- What is the ultimate state of the system? Is there only a single scenario with all pins clustered together?
- What physical information can be retrieved if more than two drawing pins are considered? Is the observed motion consistent with the (assumed) superposition of interactions? Are the observed accelerations indeed the vector sums only?
- What replacement (a model system) may be appropriate? What parameters need to be kept under control? (wettability? mass? size and shape of the bodies?)
- Is the depth of the container relevant? How relevant are the walls of the vessel: do they repel or attract particles? What is the relative importance of particle-to-particle interactions and particle-to-wall interactions?
- The phenomenon is well known and has been extensively studied theoretically and experimentally in the literature. How to come up with a novel research in the area?
- Does your explanation permit a direct experimental proof or disproof? Above all, what is the conclusion on the problem?

September 7, 2011
Liquid Matter Conf., Vienna



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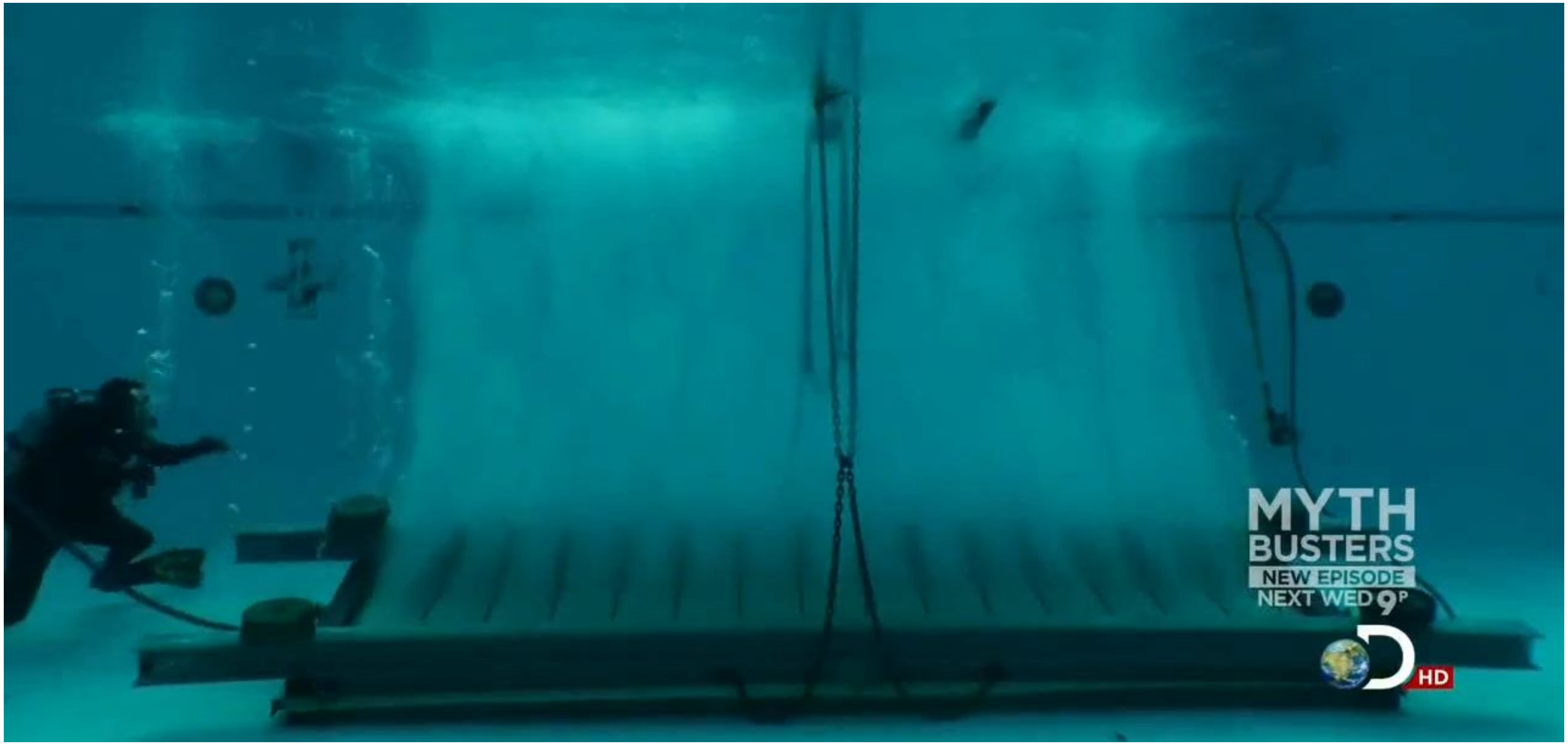
P. L. H. Cooray
Interaction of granular particles on liquid interfaces



Problem No. 8 “Bubbles”

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.

Bermuda Triangle mystery solved? It's a load of gas

By Jason Dowling
October 23, 2003

Melbourne honours student David May at Monash University yesterday.
Picture: Andrew De La Rue

Massive gas bubbles rising from the sea floor may be capable of sinking ships and could explain the disappearance of a vessel in a North Sea "Bermuda Triangle", Melbourne researchers have concluded.

In a report published in the September issue of the *American Journal of Physics*, Monash University's Professor Joseph Monaghan and honours student David May said that a trawler discovered resting in a large methane crater off the east coast of Scotland may have been sunk by a huge gas bubble. The possibly lethal gas bubbles are created by underwater deposits of methane that have built up over thousands of years.

"It's long been known that there are pockets of methane gas, known as methane gas hydrates, beneath the ocean floor that could erupt if they're disturbed or if their internal pressure becomes too large," Professor Monaghan said.

The massive gas bubbles had the potential to cause aircraft to crash, Mr May said yesterday. "In the Bermuda Triangle, methane gas is known to be present and the release of that gas could cause not only boats to sink, as shown in our study, but also aeroplanes to crash," he said. The gas could cause an explosion if it came in contact with the hot engine of a plane.

Oil-drilling platforms are aware of the dangers of ocean floor gas bubbles and have safety procedures to follow if they hit a methane pocket. But the discovery of the fishing trawler in the North Sea suggests that not all vessels were as well prepared. Sonar surveys of the ocean floor 150 kilometres east of Scotland have revealed high levels of methane and gas eruption sites. At a site known as the Witch's Hole, a documentary film crew in 2000 discovered a wreck resting in the centre of an underwater crater, likely caused by a huge methane gas release. The wreck was a 22-metre, steel-hulled fishing trawler, built between 1890 and 1930. The trawler was relatively undamaged and was horizontal on the sea bed.

From laboratory experiments, the Monash University researchers were able to conclude that large gas bubbles, theoretically, had the ability to sink ships. "It is quite possible that the trawler languishing in Witch's Hole was sunk by a bubble with a radius equal to or bigger than the trawler's hull," Professor Monaghan said.

Bubbling seas can sink ships

› 19:00 26 September 2001 by **Joanna Marchant**

Lab tests have proved that bubbles can sink floating objects. The findings add weight to suggestions that methane bubbles escaping from methane reserves in the seabed might have been to blame for vessels disappearing in the Bermuda Triangle and the North Sea.

The Greek mathematician Archimedes realised that for something to float, the density of the liquid has to be greater than the density of the object. So a simple argument is that if you mix enough bubbles into a liquid to lower its average density, an object floating on its surface should sink. People have suggested that this process is behind the mysterious demise of many ships that sank for no obvious reason.

However, Bruce Denardo at the Naval Postgraduate School in Monterey, California, was sceptical. He points out that rising bubbles often carry currents of water up with them, exerting an upwards force on the floating object. For all but the most violent bubbles, this upward drag might be enough to keep an object afloat.

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Key questions

- Rumors of gas bubbles causing the Bermuda Triangle disappearances circulate on the web and in sensationalist media. What earlier research was undergone to validate or invalidate these rumors? Are there reasonable arguments if the effect if strong enough to cause ships to sink?
- Do the bubbles influence on the average density of the fluid? How strong is this effect? Do the bubbles create an upward motion of water, causing a pressure on the floating body? How strong is this effect?
- The bubbles are not solid bodies moving in vacuum. How to correctly describe the momentum or the induced hydrodynamic pressure, if any? Are collisions of the bubbles with the body important? If so, what happens if we change surface properties of the body?
- What is the key difference between a confined (a tank) and an unconfined (an ocean) system? Does this parameter influence significantly? What is the importance of the ratio between the sizes of bubbles and of the floating object? What happens if the size of a body is comparable to the size of a bubble?
- What parameters of the gas-liquid mixture are the most important (average density? effective viscosity? size of the bubbles? volume fraction of the bubbles? number density of the bubbles? nature and density of the gas?)
- What parameters of the floating body are the most relevant (mean density? shape? volume? mass distribution?)
- How do the bubbles influence on the upper surface of the water? Is the flow under the floating body turbulent or laminar, at various length scales? Is it important for the resultant buoyancy?
- How to effectively produce bubbles with desired sizes and occupying a desired volume fraction? How large should be the experimental task to fulfill the goals?
- What experiments can give quantitative description for the changes in the effective buoyancy? How to conduct them in a controlled way?
- Is it reasonable to introduce dimensionless parameters (like size ratios or Reynolds or Bond numbers)?

Problem No. 9 “Magnet and coin”

Place a coin vertically on a magnet. Incline the coin relative to the magnet and then release it. The coin may fall down onto the magnet or revert to its vertical position. Study and explain the coin’s motion.

IYPT history

- **2.** Rolling magnets (19th IYPT, 2006)
  - Investigate the motion of a magnet as it rolls down an inclined plane.
- **12.** Levitating spinner (24th IYPT, 2011)
  - A toy consists of a magnetic spinning top and a plate containing magnets (e.g. "Levitron"). The top may levitate above the magnetic plate. Under what conditions can one observe the phenomenon?

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- :-)

Key questions

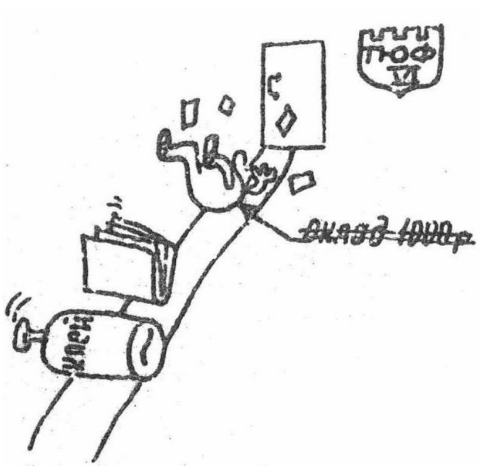
- What interactions affect on the initial stability of the coin? How to describe them theoretically? How important are the magnetic properties of the coin (ferromagnetic? paramagnetic? diamagnetic?)
- What is the proper model for coin’s interaction with the magnetic field? (dipole or something more complex?)
- When the coin stands vertically, or lays horizontally on the magnet, are these the only stable equilibrium positions? Is the threshold angle a position of an unstable equilibrium?
- Does the coin oscillate upon an upwelling motion? Are the oscillations harmonic? How to quantitatively describe the oscillations? Is it possible that, under certain conditions, the coin flips upside-down?
- What parameters of the coin are relevant (mass? moment of inertia? (about what axis?) magnetic properties?)
- What parameters of the magnet are relevant? Are eddy currents that occur during the movement of the coin relevant?
- How does the effect depend on the position of the coin relatively to the poles of the magnet? On the friction between the coin and the magnet? Is the air drag of any importance?
- Is it possible to alter direction of the resulting magnetization by keeping the coin close to the magnet?
- What is the dynamics of the coin during the falling (is it a free fall?) or during the upward motion? How to measure and theoretically describe the time-dependant angular speeds, and other relevant parameters?
- Above all, what is the final conclusion? Is there only a single threshold value for the inclination angle? What are the parameters that determine the exact value of this angle for a given system?

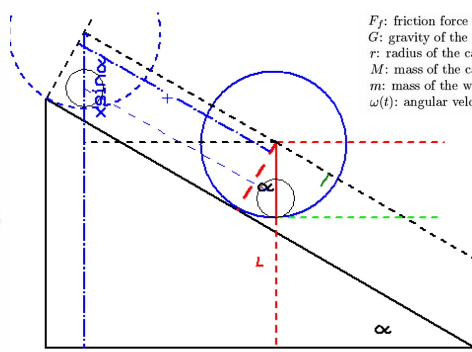
Problem No. 10 “Rocking bottle”

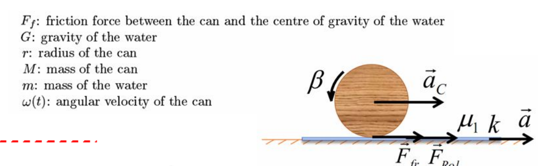
Fill a bottle with some liquid. Place it on a horizontal surface and give it a push. The bottle may first move forward and then oscillate before it comes to rest. Investigate the bottle’s motion.

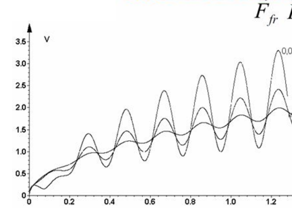
IYPT history

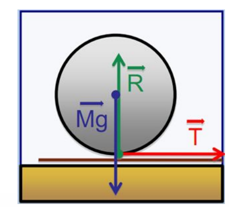
- **5.** Glue (6th YPT, Correspondence Rounds, 1984)
  - A little bottle partly filled with a liquid glue (a fresh silicate glue) rolls down an inclined plane without slipping. An experimenter can set almost any initial speed to the bottle. What will be the stable speed of rolling of the bottle down a very long inclined plane in dependence of the initial conditions?
- **13.** Rolling can (13th IYPT, 2000)
  - A can partially filled with water rolls down an inclined plane. Investigate its motion.
- **14.** Moving cylinder (24th IYPT, 2011)
  - Place a sheet of paper on a horizontal table and put a cylindrical object (e.g. a pencil) on the paper. Pull the paper out. Observe and investigate the motion of the cylinder until it comes to rest.











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Key questions

- How does the fluid interact with the bottle? Does it cause an oscillatory motion?
- What types of motion can the bottle perform? Can one draw an analogy to a damped pendulum?
- Is the problem all about the rolling? Should we also investigate other rotational modes, such as the revolution around an axis normal to the principal axis of the bottle (if the push was not centered)?
- How relevant if the actual shape of the bottle? What simplifying assumptions may be made as for its geometry?
- How does the motion depend on the initial push? (its duration? strength? direction? position of the contact point?)
- Besides the amount of the liquid in the bottle, what are the other important parameters of the liquid (density? viscosity? rheological behavior?) Is it worth studying non-Newtonian fluids in the bottle, such as yoghurt?
- How to describe the fluid flow inside the bottle? Is there a possibility for an analytical model under certain assumptions? How to describe the oscillations, the total distance traveled, the total time of motion?
- Is it possible to describe or measure the relative motion of the center-of-the-masses, and the effective moment of inertia of the bottle?
- How do the momentum, translational and angular speeds, orientation of the bottle change over time?
- Can the bottle show the hula hooping effect? Is there a possibility of slipping?
- What are the main sources of energy losses? What is the kinetics of the bottle before the final rest, and what additional forces or interactions may influence on it?
- To what degree the motion is reproducible, if the experiment is repeated? Above all, what are your conclusions on the problem?

Problem No. 11 “Flat flow”

Fill a thin gap between two large transparent horizontal parallel plates with a liquid and make a little hole in the centre of one of the plates. Investigate the flow in such a cell, if a different liquid is injected through the hole.

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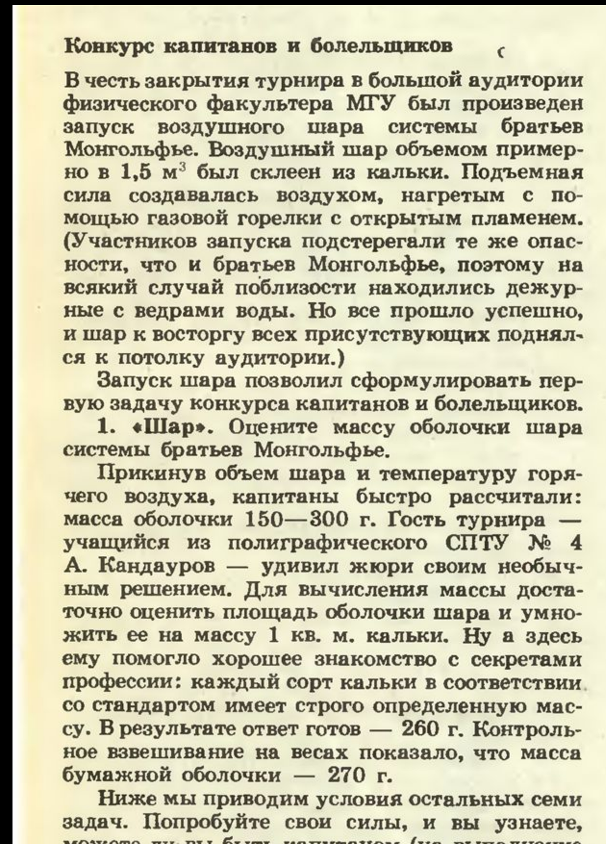
Key questions

- Is it correct to suggest that the system in question is a Hele-Shaw cell? How to characterize the flow? Under what conditions the flow between the plates can be treated as effectively 2D?
- What is the basic mechanism behind the observed flows? Can they be classified into distinct, physically different types?
- Many approaches and concepts may emerge at discussions (Saffman-Taylor instability, viscous fingering, Darcy law, Laplace growth…) Can you re-formulate your explanation with different basic concepts?
- What is the role of boundary conditions in the phenomenon? (fixed pressure difference? fixed inflow rate?)
- Are there any dimensionless criteria (like a Reynolds number) providing an insight into the behavior of the system?
- What might mean a “different liquid”? Which parameters of the liquids are the most important (density? viscosity? surface or interface tension?)
- What is Darcy equation and how appropriate is it to describing the system?
- Is the shape, the surface roughness or other parameters of the plates relevant? What is the role of the size of a little hole?
- How to conduct reliable, reproducible experiments? How to control small volumetric flows?
- What changes if the liquids are miscible?
- What is the role of the roughness of the plates?

Problem No. 12 “Lanterns”

Paper lanterns float using a candle. Design and make a lantern powered by a single tea-light that takes the shortest time (from lighting the candle) to float up a vertical height of 2.5 m. Investigate the influence of the relevant parameters. (Please take care not to create a risk of fire!)

IYPT history



Конкурс капитанов и болельщиков

В честь закрытия турнира в большой аудитории физического факультера МГУ был произведен запуск воздушного шара системы братьев Монгольфье. Воздушный шар объемом примерно в 1,5 м³ был склеен из кальки. Подъемная сила создавалась воздухом, нагретым с помощью газовой горелки с открытым пламенем. (Участников запуска подстерегали те же опасности, что и братьев Монгольфье, поэтому на всякий случай поблизости находились дежурные с ведрами воды. Но все прошло успешно, и шар к восторгу всех присутствующих поднялся к потолку аудитории.)

Запуск шара позволил сформулировать первую задачу конкурса капитанов и болельщиков.

1. «Шар». Оцените массу оболочки шара системы братьев Монгольфье.

Прикинув объем шара и температуру горячего воздуха, капитаны быстро рассчитали: масса оболочки 150—300 г. Гость турнира — учащийся из полиграфического СПТУ № 4 А. Кандауров — удивил жюри своим необычным решением. Для вычисления массы достаточно оценить площадь оболочки шара и умножить ее на массу 1 кв. м. кальки. Ну а здесь ему помогло хорошее знакомство с секретами профессии: каждый сорт кальки в соответствии со стандартом имеет строго определенную массу. В результате ответ готов — 260 г. Контрольное взвешивание на весах показало, что масса бумажной оболочки — 270 г.

Ниже мы приводим условия остальных семи задач. Попробуйте свои силы, и вы узнаете, можете ли вы быть капитаном (на выполнение

Montgolfière hot air balloon

Closing Ceremony of the 8th YPT

February 16, 1986

VIII Турнир юных физиков

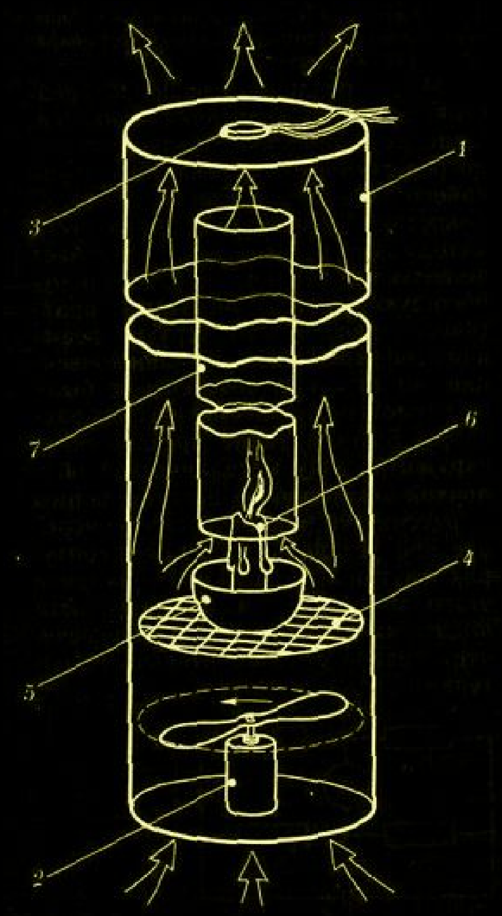
Быть может, эти электроны — миры...
В. Брюсов

Восьмой турнир юных физиков был проведен физическим факультетом МГУ с сентября 1985 г. по февраль 1986 г. Впервые в заочном конкурсе турнира приняли участие не только

Shell made out of tracing paper
Volume reported as 1.5 m³
Gas burner with an open flame
Safety team on standby with water

- Problem No. 1: To estimate the mass of the shell
- Teams: volumes, temperatures → 150…300 g?
- Guest student A. Kandaurov: surface of the shell, standard density of industrial Soviet tracing paper → 260 g
- Control measurement of the real value: 270 g

IYPT history

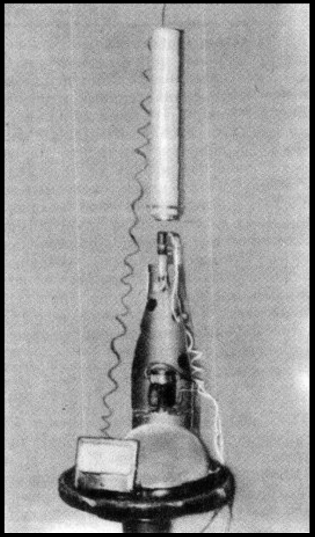


И. Алексеев, Д. Свирида

И светит и греет

В заочном конкурсе III Московского турнира юных физиков была такая задача:

Свеча при горении светит и греет. Определите теплотворную способность парафиновой свечи.



1: tube; 2: rotating fan; 3: thermosensor; 4: grid; 5: plate to collect molten paraffin; 6: candle; 7: long metal cylinder covered by soot

3. Candle (3rd YPT, Correspondence Rounds, 1981)
A candle shines and warms up as it burns.
Determine the calorific value of a paraffin candle.

- Solution published by I. Alexeyev and D. Svirida in *Kvant*, no. 3, 17-19, 1982

- Heating up a certain object at open air is not precise as the surrounding air is also heated
- Placing a candle into closed metal capsule requires an artificial oxygen supply

- A comparative method is suggested: candle vs an electric heater of known, tunable power
- If outflows of warm air are same, thermal powers may be considered equal too

- 550 Ohm heater at 50...120 W power
- Mass of the candle measured over time
- Mass ratio between burned paraffin, produced CO_2:

$$2C_nH_{2n} + 3nO_2 \rightarrow 2nCO_2 + 2nH_2O,$$

- Precision of the method: ca. 5%

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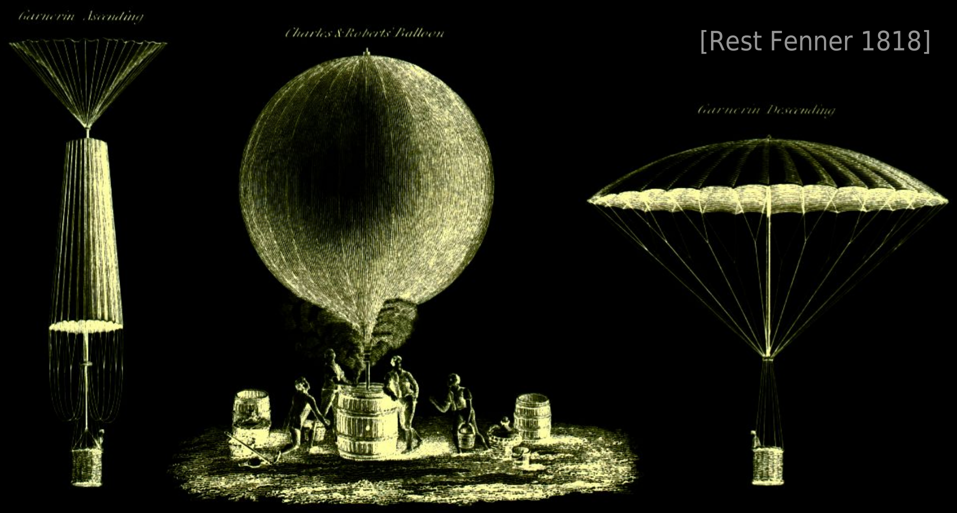
- William G. Phillips. The Forces and Pressures of Balloon Flight (Balloon Life, Feb. 1987), https://www.brisbanehotairballooning.com.au/media/BalloonFlightForcesPressures.pdf
- Hot Air Balloon Physics (real-world-physics-problems.com), http://www.real-world-physics-problems.com/hot-air-balloon-physics.html
- How to Make a Mini Flyable Hot Air Balloon with Candles (wikihow.com), http://www.wikihow.com/Make-a-Mini-Flyable-Hot-Air-Balloon-with-Candles

(Very) basic ideas

- Each design can be described by an infinite number of parameters, each influencing the ascent time
- What parameters are the most influential?
- Among them, what parameters should be altered and studied, and what should be kept constant?



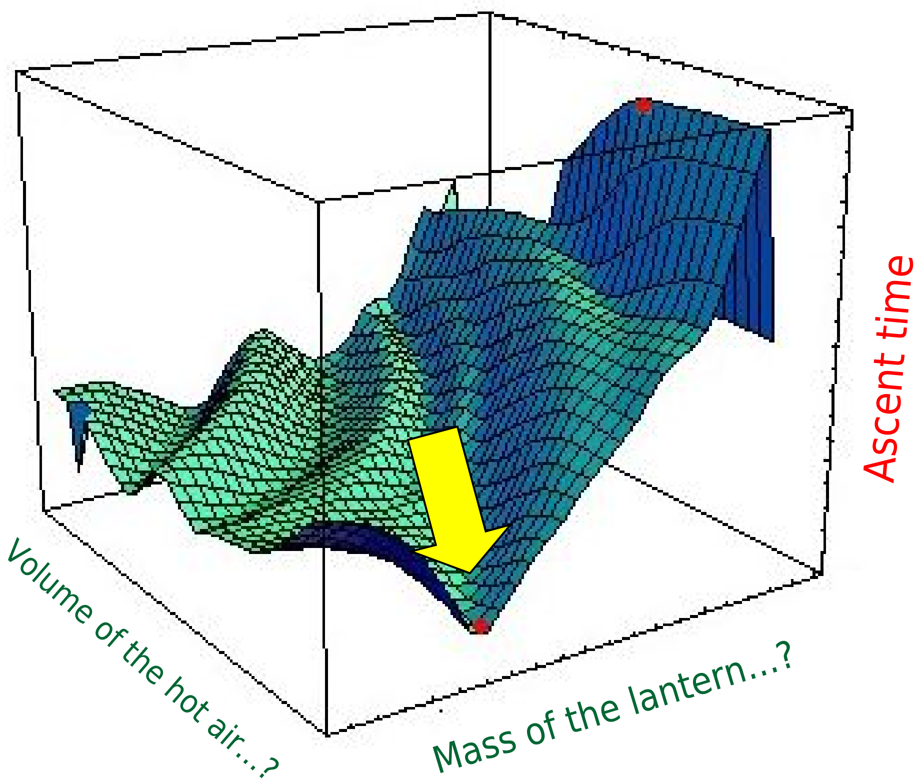
[Rest Fenner 1818]

- What are the designs outlined and/or permitted in the task? (what is a lantern? what is a tea-light?)
- What is the basic physics behind the chosen design?

- A clear statement of the parameters to optimise?
- Is it the mean ascent time? How relevant is the distribution of results?

[Ovi G 2011] [Alexandre Dulaunoy 2011]

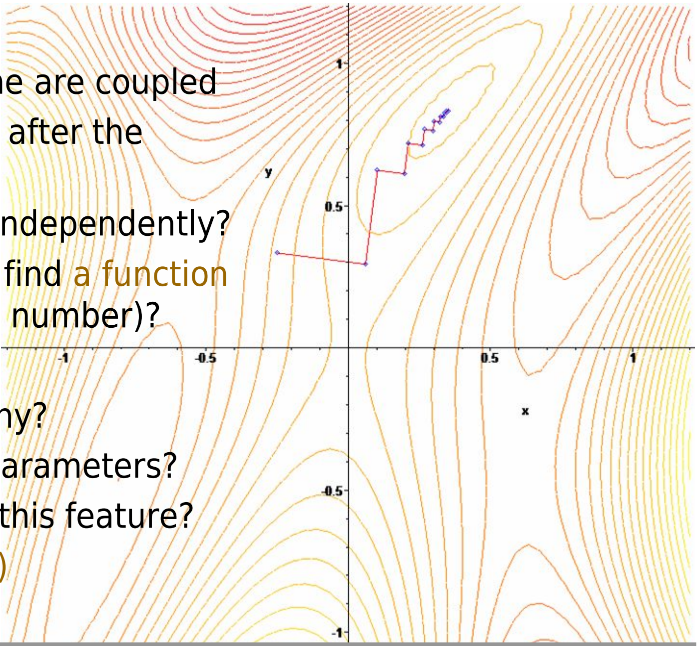
Minimizing the ascent time?



- We are looking for a global extremum of a function with multiple variables
- Some are rather fixed, some are not

- Heat energy of combustion released per unit time? (fixed?)
- Mass of the tea-light? (fixed?)
- Air density and viscosity? (fixed?)
- Ambient airflows (wind), not induced by the devise itself? (fixed as zero?)
- Mass of the apparatus? (not fixed?)
- Shell volume? (not fixed?)
- Aerodynamic shape? (not fixed?)

Decoupling the parameters?



- Although the ascent time is a function of many variables, some are coupled
- Some parameters can be altered directly, while some can not after the design concept is fixed
- Which parameters are coupled weakly and can be optimized independently?
- When a few parameters are strongly coupled, is it possible to find a function of these parameters that describes the system (e.g. Reynolds number)?

- Should a single parameter only be altered in experiments? Why?
- What is the reproducibility of the ascent time? Sensitivity to parameters?
- Is there a lag between ignition and take-off? How to optimize this feature?
- It is way too trivial to play only with the mass of the lantern :-)

- It is possible to find the global, fundamental, and absolute minimum of the ascent time?
- What parameters are studied and how do you justify your choice? Remember that the tournament is not about studying all the possible design concepts
- Comment on the coupling between your parameters
- Present the final conclusions and compare your solution with the rivals, where particular parameters are not optimized

- Other teams will probably present a radically different design approach, so a good insight into the relevant physics (flow dynamics, hot air ballooning, stability…) seems to be helpful
- An understanding of a methodology to optimize a set of parameters would help to avoid a long and pointless discussion :-)

BUNDESGESETZBLATT
FÜR DIE REPUBLIK ÖSTERREICH

Jahrgang 2009 **Ausgegeben am 9. Dezember 2009** **Teil II**

423. Verordnung: Wunschlaternenverordnung

423. Verordnung des Bundesministers für Arbeit, Soziales und Konsumentenschutz, mit der das In-Verkehr-Bringen von Miniatur-Heißluftballonen verboten wird (Wunschlaternenverordnung)

Auf Grund des § 11 Abs. 1 und 2 des Produktsicherheitsgesetzes 2004, BGBl. I Nr. 16/2005, wird verordnet:

Begriffsbestimmungen

§ 1. Gegenstand dieser Verordnung sind Miniatur-Heißluftballone, die mit einem Brenner (offene Flamme) zur Erzeugung von Heißluft betrieben werden. Sie werden unter Anderem auch als Wunschlaternen, Skylaternen, Himmelslaternen oder Glücksballone bezeichnet.

Verbot des In-Verkehr-Bringens

§ 2. Das In-Verkehr-Bringen von Miniatur-Heißluftballonen gemäß § 1 ist verboten.

Schlussbestimmungen

§ 3. Diese Verordnung wurde unter Einhaltung der Bestimmungen der Richtlinie 98/34/EG über ein Informationsverfahren auf dem Gebiet der Normen und technischen Vorschriften, ABl. Nr. L 204 vom 21. Juli 1998, in der Fassung der Richtlinie 2006/96/EG, ABl. Nr. L 363 vom 20. Dezember 2006, notifiziert (Notifikationsnummer 2009/0345/A).

Hundstorfer

http://www.ris.bka.gv.at/Dokumente/BgblAuth/BGBLA_2009_II_423/BGBLA_2009_II_423.pdf

Key questions

- What forces do act on a lantern? Are buoyancy and gravity the dominant forces? How important is the air drag?
- Although the tissue of the actual Asian lanterns is very thin and lightweight and the volume occupied by the hot air is large, such lanterns are generally powered by a cotton ball and ethanol, or a similar burner. Does a tea-light has a small enough mass and a strong enough "thermal power" for an ascend?
- What are the relevant parameters of the "balloon" (mass? volume? shape? type of the paper used?) What are the relevant parameters of the candle? (mass? "heat released per unit time"?)
- Is there a time lag between ignition and take-off?
- Is it preferred to prevent hot air from escaping from the lantern? Is there a convection inside the lantern, and how to characterize it? Where should the holes be located and what should be their size and shape?
- How to optimize the position of a tea-light inside the lantern? Is it important? Should the lantern be "open" all the time? Can one increase the speed of ascent by appropriately opening or closing the holes in the balloon?
- How to stabilize the lantern so that it does not topple? How relevant for the stability is the density distribution inside a lantern? What is the optimum shape of the paper shell? Is it worth investigating it theoretically?

Key questions

- How do the external parameters affect the ascent? (ambient temperature? humidity of the air? external air flows?)
- Is it appropriate to optimize the tea-light (by choosing the most effective brand) to improve the heating process?
- How relevant are the energy losses, such as the outflow of hot air, or heat transfer trough the paper?
- What is the temperature field inside the shell? How does it evolve over time? How appropriate is a uniform temperature assumption (when it comes to creating the theory)?
- How to measure experimentally temperatures in different points? What measurement techniques may work best? (thermocouples? IR sensors?)
- How to visualize the flow around the rising lantern?
- If your lantern shows a minimum ascent time up a height of 2.5 m, would it be still showing a best result for smaller or larger heights?
- What is the dependence of ascent rate on time for your lantern?

Problem No. 13 “Misty glass”

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 coloured rings appear outside a central fuzzy white spot. Explain the phenomenon.

« V. *Expérience de M. Quetelet*. — Si l'on ternit une glace ordinaire d'appartement, en soufflant légèrement dessus, ou bien y faisant adhérer un peu de poussière ou de sciure de bois (il faut éviter le lycopode et les poussières à grains égaux, qui donnent d'autres anneaux à cause de cette particularité même), on voit de part et d'autre de l'image de la lumière d'une bougie que l'on regarde dans la glace, en la tenant près de l'œil et un peu de côté, une belle série de franges courbes colorées, dans lesquelles la flamme occupe le milieu d'une bande blanche, escortée de part et d'autr de franges colorées à couleurs récurrentes. Il est aisé de voir que ces franges naissent des rayons qui ont traversé deux fois l'épaisseur de la glace, les uns disséminés en entrant et revenant après la réflexion dans une direction autre que celle de la réflexion principale, et les autres disséminés à leur retour du fond de la glace par la même surface, et coïncidant en direction avec les premiers. La théorie de ces franges courbes ou anneaux est encore plus simple que celle des anneaux des plaques épaisses mises dans la lumière convergente, car l'expression de leur demi-diamètre est linéaire au lieu d'être donnée par un radical.

« Il semble qu'il devrait être facile de reproduire ces franges de M. Quetelet avec une plaque dépolie placée presque perpendiculairement entre une bougie et l'œil ; cependant je n'y ai point encore réussi ; peut-être est-il nécessaire que l'œil et la bougie soient à la même distance de la plaque, pour mieux reproduire les circonstances ordinaires de l'expérience primitive. Ce sera l'objet d'une recherche pratique ultérieure.

6e ANNÉE. L'Institut. N° 252. 25 OCTOBRE 1838.
Journal général des Sociétés et Travaux scientifiques de la France et de l'Étranger.
Ire SECTION.
Sciences Mathématiques, Physiques et Naturelles.

XC. *On Quetelet's Rings and other Allied Phenomena.* By

C. V. Raman, *M.A.*, *Palit Professor of Physics, and* Goverdhan Lal Datta, *M.A.*, *Palit Research Scholar, University of Calcutta* *.

[Plate XXV.]


PHILOSOPHICAL MAGAZINE

JOURNAL OF SCIENCE

Contents.

1. *Introduction.*

WHEN a distant point-source of light is viewed by reflexion from a plane mirror silvered on the back, the scattered light surrounding the reflected image of the source exhibits a system of coloured rings, the brilliancy of which is greatly enhanced by purposely dimming the front surface of the mirror, as, for instance, by breathing upon it. These rings (generally referred to in the literature as Quetelet's Rings) belong to the same class of diffraction phenomena as the well-known " diffusion " rings surrounding the focus of a thick concave mirror discovered by Newton.

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- C. V. Raman and G. L. Datta. On Quételet's rings and other allied phenomena. Phil. Mag., 42, 251, 826-840 (1921)
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- H. Joachim Schlichting. Quételet-Ringe auf Fenstern. Physik in unserer Zeit 36/4, 185-187 (2005), http://www.uni-muenster.de/imperia/md/content/fachbereich_physik/didaktik_physik/publikationen/31_quetelet_korr.pdf
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- Я. Е. Амстиславский. Необычные явления вокруг обычных источников света // Квант, 1982, № 6, с. 15–18, http://kvant.mirror1.mccme.ru/1982/06/neobychnye_yavleniya_vokrug_ob.htm
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- http://paraselene.de/cgi/bin?_SID=xxx&_bereich=artikel&_aktion=detail&_sprache=paraselene_englisch&idartikel=113692

Key questions

- What is the basic mechanism for the rings to appear? There might be different causes for different patterns; how to clarify and confirm what physical phenomenon is responsible for each pattern? Why are the patterns shifted?
- The known explanations involve diffraction and interference. What is the actual difference between these two in this effect? Can one observe the Moiré Fringes in the system?
- Is the condensed water vapor a crucial feature? Do other substances cause a similar effect? Why do we need the water vapor to condense?
- What is the interaction between the particles (e.g. of water) and the light? What scattering is involved? How does this depend on the sizes of particles? distribution of sizes? number density of particles? How to measure and control these parameters?
- What exactly is a 'white lamp'? Is it necessary that it is white? What are the other relevant properties of illumination? (intensity? polarization?) The light generated by an incandescent lamp is generally incoherent. Shouldn't it exclude the possibility of interference?
- There is light scattered in all directions in the system, but does each elementary beam contribute to the pattern? What quantitative predictions can be given for the system? (distances between rings? number of visible rings? maximum and minimum angle of observation?)
- Why are rings colored? What is the order of colors and why? How to explain the granular structure of the patterns? How does the observed pattern change when the point of observation is changed? What changes if we look with one or both eyes?
- What are the relevant properties of the glass? (refractive index? surface roughness? thickness?) Is it possible to say whether the pattern is generated only due to the reflection from the surface, or will it also be observed for diffuse scattering surfaces? From which side should the glass be covered with the vapor?

Problem No. 14 “Granular splash”

If a steel ball is dropped onto a bed of dry sand, a “splash” will be observed that may be followed by the ejection of a vertical column of sand. Reproduce and explain this phenomenon.

IYPT history

- **8.** Ball and sand (2nd YPT, Correspondence Rounds, 1980)
  - Some sand is poured onto the ground in a thick uniform layer. A steel ball 5 *cm* in diameter falls freely from a height of 1 *m*. Onto what depth will the ball penetrate into the sand?
- **12.** Flour craters (12th IYPT, 1999)
  - If you drop a small object in flour, the impact will produce a surface structure which looks like a moon crater. What information about the object can be deduced from the crater?

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- A. Seguin, Y. Bertho, P. Gondret, and J. Crassous. Sphere penetration by impact in a granular medium: A collisional process. Eur. Phys. Lett. 88, 44002 (2009), http://perso.univ-rennes1.fr/jerome.crassous/Publis/EPL.2009.pdf
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Key questions

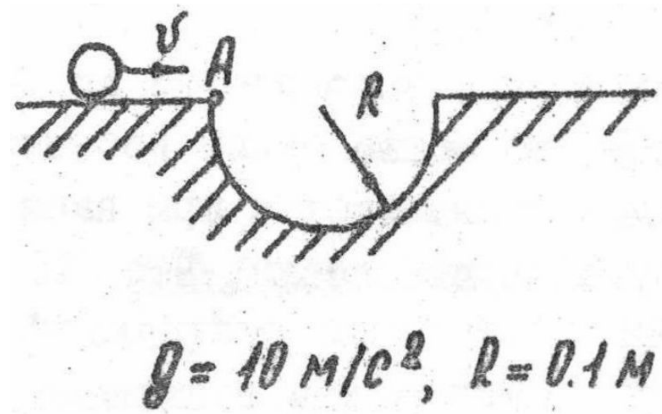
- To what extent is it possible to treat a granular matter as a fluid? What are the advantages and limitations for this approximation? What are the similarities and differences between a liquid splash and a granular splash? Are the jets formed in a similar way in both cases?
- What is the basic physical mechanism for a jet formation?
- What are the pressures or stresses in the system during the various phases of the impact? How to describe the impact dynamics through the stresses in the system?
- Is it possible to model the phenomenon analytically? Is a numerical simulation the only feasible solution? Can the problem be simplified to a 2D case?
- Why has the sand to be dry? What are important parameters (distribution of grain sizes? velocity of a steel ball just prior to the impact? size and mass of the ball? humidity? volume fraction of interparticle air? mass density distribution in the granular bed?)
- Are the walls of the vessel important? Does the jet appear is the sand is unconfined? What is the influence of the depth of the sand? What changes if the layer is very thin?
- What should be the optimum speed of the ball for a splash to occur? What is the speed of the ball for a jet to form?
- How long does the collision last? What is the time scale of the impact? Can the ball produce also the secondary jets? How to investigate the phenomenon without a fast-speed camera? How to record and control the necessary parameters?
- What can be done if particular features of the granular speed are not visible behind non-transparent sand? Can a 2D experimental cell be helpful? Is such a replacement appropriate?
- What features of the granular splash may be measuring experimentally (trajectories and velocities of grains in the splash? maximum altitude of the jet? penetration depth of the ball? the mass of the displaced sand?)

Problem No. 15 “Frustrating golf ball”

It often happens that a golf ball escapes from the hole an instant after it has been putted into it. Explain this phenomenon and investigate the conditions under which it can be observed.

IYPT history

- **1 (18.)** Elastic scattering (9th YPT, Problems for the Finalists, 1987)
  - A material point (for short, let say a ball) slides with no friction on a horizontal plane and gets into a semi-spherical hole. Its interaction with the surface of the hall is absolutely elastic.
    - a. under what conditions would the ball start moving in a reverse direction, after interacting with the hole?
    - b. under what conditions would the ball get into the point A, after one or several collisions with the surface of the hole?
    - c. for what maximum time can the ball get trapped in the hole?
  - Perform a visual calculation of this model with a computer.



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Key questions

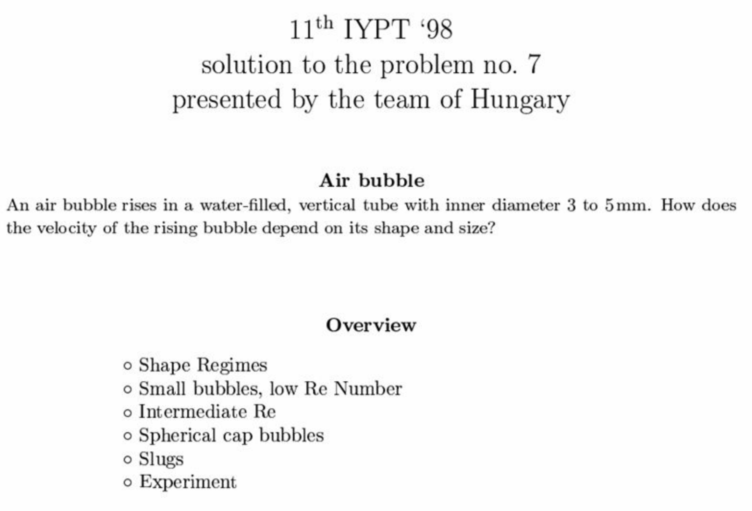
- What is a putt? What are the typical speeds, forces, and distances as a is putted into a hole? Can a ball be putted into the hole while spinning?
- What parameters are relevant to the problem? (radius, mass, elasticity, surface properties of the ball? dimensions of the hole? initial velocity or angular speed? friction?
- What simplifying assumptions should be made when modeling the impact? (instantenous collision? no bouncing? no kinetic friction? no static friction?) Is it correct to study only a 2D system?
- Is it possible to quantitatively describe the system in detail? Can the equations governing the system be solved analytically? Is it worth modeling the system numerically?
- Is there any noteworthy behavior observed for extreme cases: fully elastic / fully inelastic collisions, ball much smaller / comparable to to the size of the hole? Are such considerations physically relevant?
- Is it possible to determine, under given conditions, the probability for the ball to escape out of the hole? Is there a finite number of ways in which a ball can get out of the hole?
- Under what conditions does the influence of the air become relevant? Can there be any new effects associated with the air flows? Is a pressure difference due to Bernoulli effect enough important?
- What assumptions can be made regarding the ball's motion on the surface? (ideal rotation? no rolling friction?) How important are the small irregularities in the system: rounded edges of the hole, a small height difference between the ground and the hole edge?
- In what sports is the phenomenon also observed? Can the same theory be utilized to describe the basketball escaping the basket?
- Can the theoretical considerations be used to outline the parameters of the 'best' hole? How to design the hole to minimize or maximize the chances of such a frustration for a given ball?
- What are the final conclusions? How to present them? (probability distribution for the escape vs initial parameters?)

Problem No. 16 “Rising bubble”

A vertical tube is filled with a viscous fluid. On the bottom of the tube, there is a large air bubble. Study the bubble rising from the bottom to the surface.

IYPT history

- **7.** Air bubble (11th IYPT, 1998)
  - An air bubble rises in a water-filled, vertical tube with inner diameter 3 to 5 mm. How does the velocity of the rising bubble depend on its shape and size?



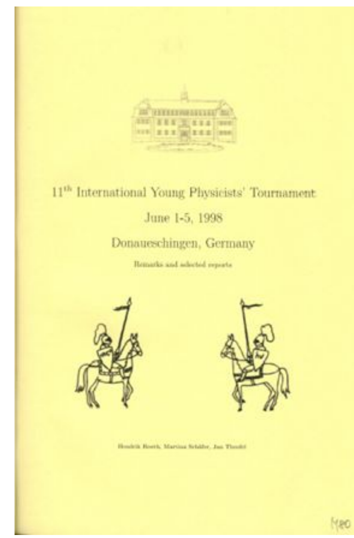
11th IYPT ‘98
solution to the problem no. 7
presented by the team of Hungary

Air bubble

An air bubble rises in a water-filled, vertical tube with inner diameter 3 to 5 mm. How does the velocity of the rising bubble depend on its shape and size?

Overview

- Shape Regimes
- Small bubbles, low Re Number
- Intermediate Re
- Spherical cap bubbles
- Slugs
- Experiment



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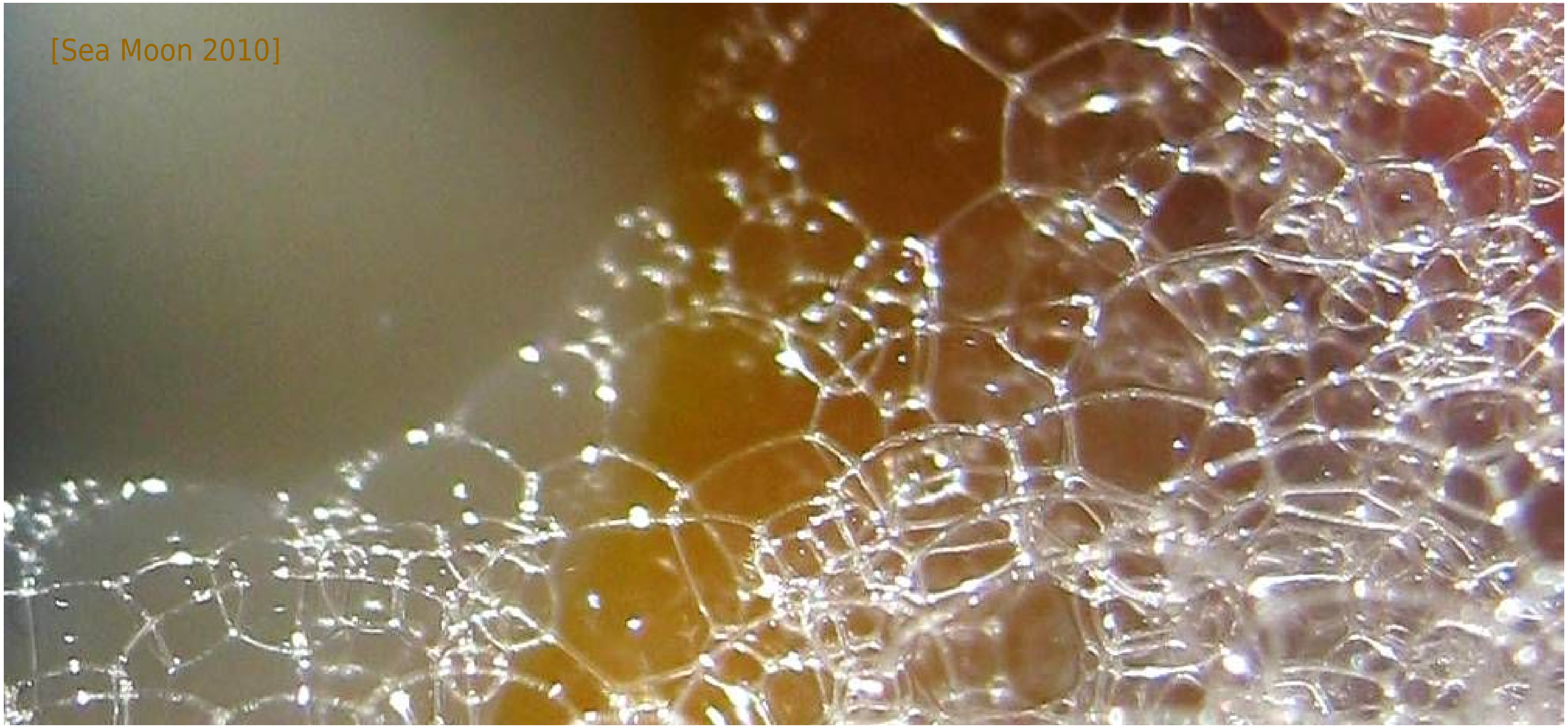
Key questions

- How relevant is the problem to the old and classical hydrodynamic problems, e.g. the flow of a spherical droplet in another fluid in the limit of low Reynolds number and low Capilary number (p. 235 of [Batchelor 1967]), behavior of large bubbles (p. 367) or the behavior of larger "spherical cup" bubbles (p. 474)?
- What does "a large air bubble" actually mean? What determines the relevant length scales (size the cross section of the tube? an interplay between the effects of viscosity, surface tension and gravity?)
- What is a sufficiently "viscous fluid"? Can one treat the flow inside the tube as a Stokes flow?
- What are the forces acting on a bubble? Is the speed of the bubble constant over time? What is the effect of the proximity of the walls?
- What dimensionless criteria may be relevant (Weber? Bond? Froude? Reynolds?)
- How stationary and reproducible is the motion of the bubble? Under what conditions can the bubble spit into smaller bubbles? Under what conditions the bubble may be considered spherical? (or of another well-determined shape?) Is it justifiable to use well known equations for the flow of a spherical bubble (valid in low Re limit)?
- What parameters determine the shape of the bubble? (volume of gas? position in the tube? viscosity and surface tension of the liquid?) How relevant are impurities of the liquid?
- Does the process of initial injection of air into the tube determine the evolution of the system?
- How to visualize the flow in the system without affecting the phenomenon?
- What conclusions may be drawn, in the end?



Problem No. 17 “Ball in foam”

A small, light ball is placed inside soap foam. The size of the ball should be comparable to the size of the foam bubbles. Investigate the ball’s motion as a function of the relevant parameters.

IYPT history

- **1.** Froth (19th IYPT, 2006)
  - Investigate the nature of the decay in height of the “froth” or “foam” on a liquid. Under what conditions does the froth remain for the longest time?
- **9.** Sound and foam (19th IYPT, 2006)
  - Investigate the propagation of sound in foam.

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Key questions

- What is the 3D structure of a foam? How is it related to the surface energy in the system? What are the most relevant parameters of a foam? (bubble size or distribution of sizes? liquid fraction? surface tension in the walls? macroscopic rheological properties?) How to control and measure them experimentally?
- How do the parameters of the foam change over time? How relevant are the ageing effects, such as coarse graining via gas diffusion or liquid drainage? Is it necessary to control them in experiments?
- What is a "comparable size"? What length scales are of interest in the problem?
- What parameters of the ball motion may be studied? (linear displacement? angular displacement? 3D trajectory? speeds and accelerations?) Is it worth studying the interaction between the ball and a single bubble? How to approach the system with multiple bubbles?
- How do the ball and the foam interact? Is there any analogy to a motion through a Newtonian fluid? How is the initial potential energy re-distributed as the ball starts to move? What is the influence of the walls? Are the parameters of the container (size?) relevant?
- What is the effective drag on a body in a foam? How relevant are the simplest models, such as the Stokes formula? What forces oppose the motion? (capillary? buoyancy? viscous? inertial?)
- What parameters of the foam can be extracted from the parameters of the motion, for a given ball? (rheological properties? average bubble size?)
- A 2D case of the problem seems to be well-investigated. What are the key differences for a 3D case?
- Is it appropriate to study the flow around a fixed ball instead of studying the ball moving in the foam?
- Is it worth modeling the flow numerically?
- How to record and study the motion of the ball when it is not visible through the scattering foam? (radio waves? time-of-flight measurements? magnetic induction? proper illumination of the system?)

what are its x, y, and z compon...

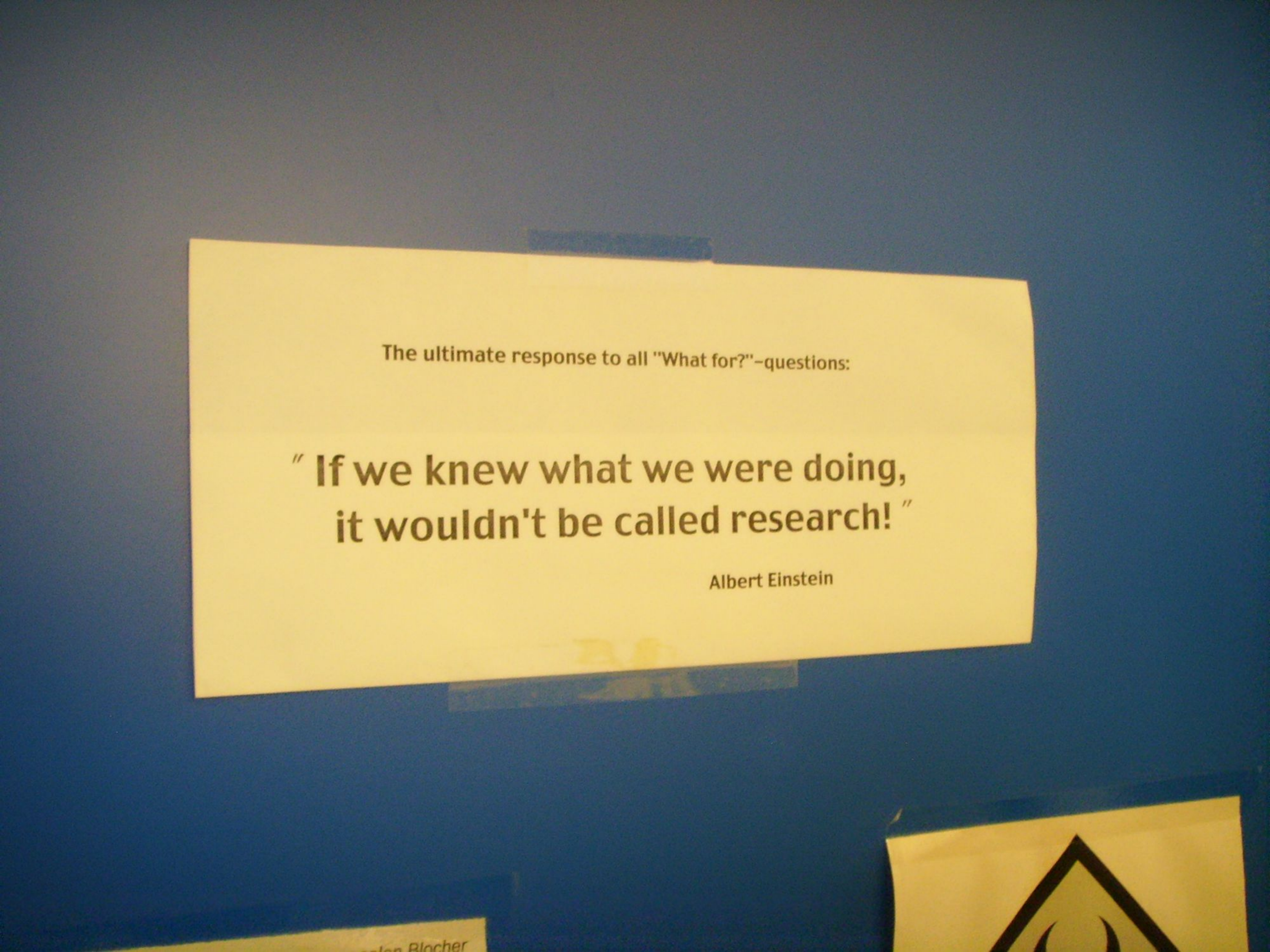
(b) Compute $(\hat{\mathbf{r}} \cdot \nabla)\hat{\mathbf{r}}$, where $\hat{\mathbf{r}}$ is the uni...

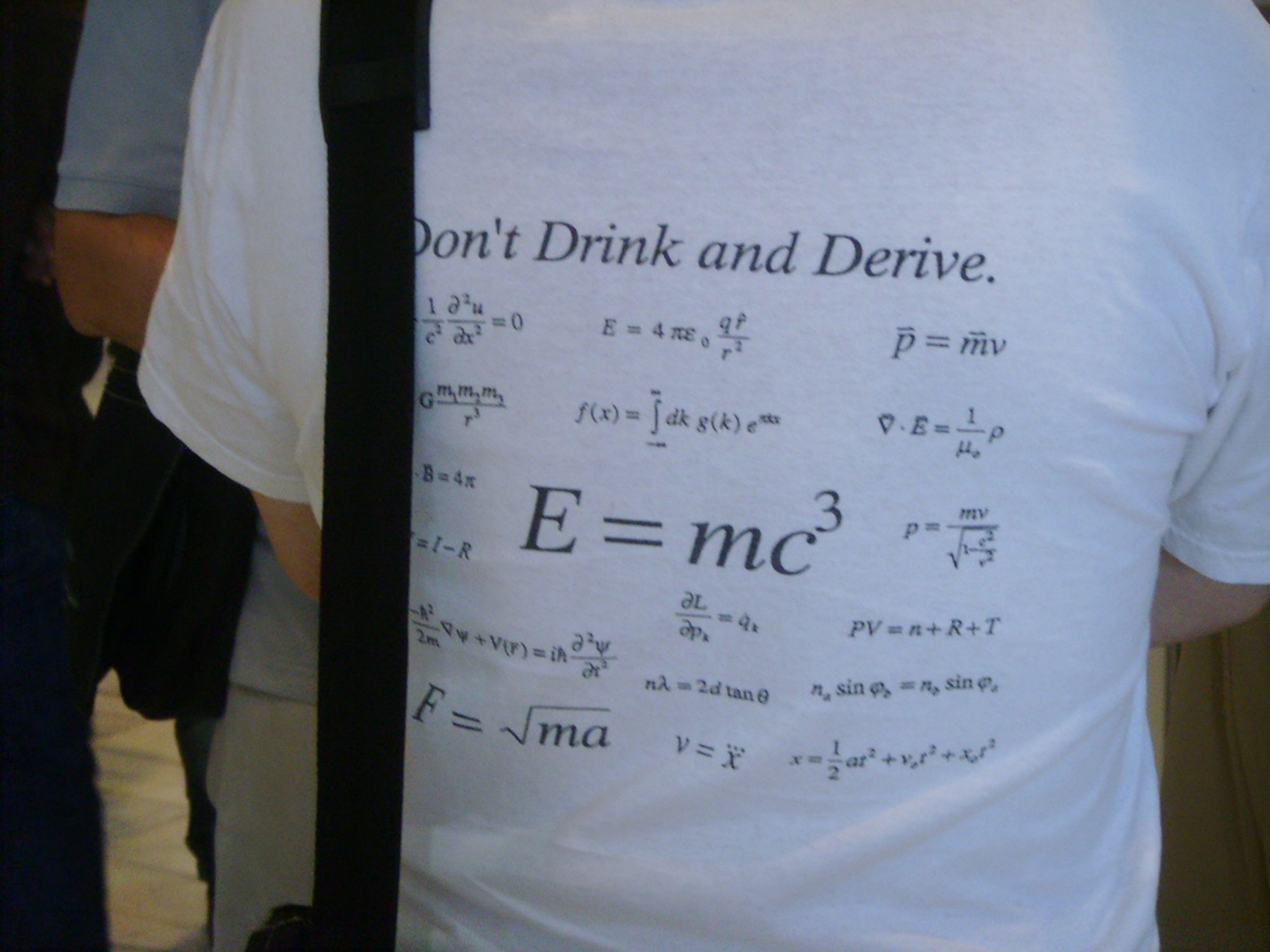
(c) For the functions in Prob. 1.15, evalu...

Problem 1.22 (For masochists only.) P...
the definition of $(\mathbf{A} \cdot \nabla)\mathbf{B}$.

Problem 1.23 Derive the three quotien...

Problem 1.24


The ultimate response to all "What for?"-questions:
" If we knew what we were doing,
it wouldn't be called research! "
Albert Einstein

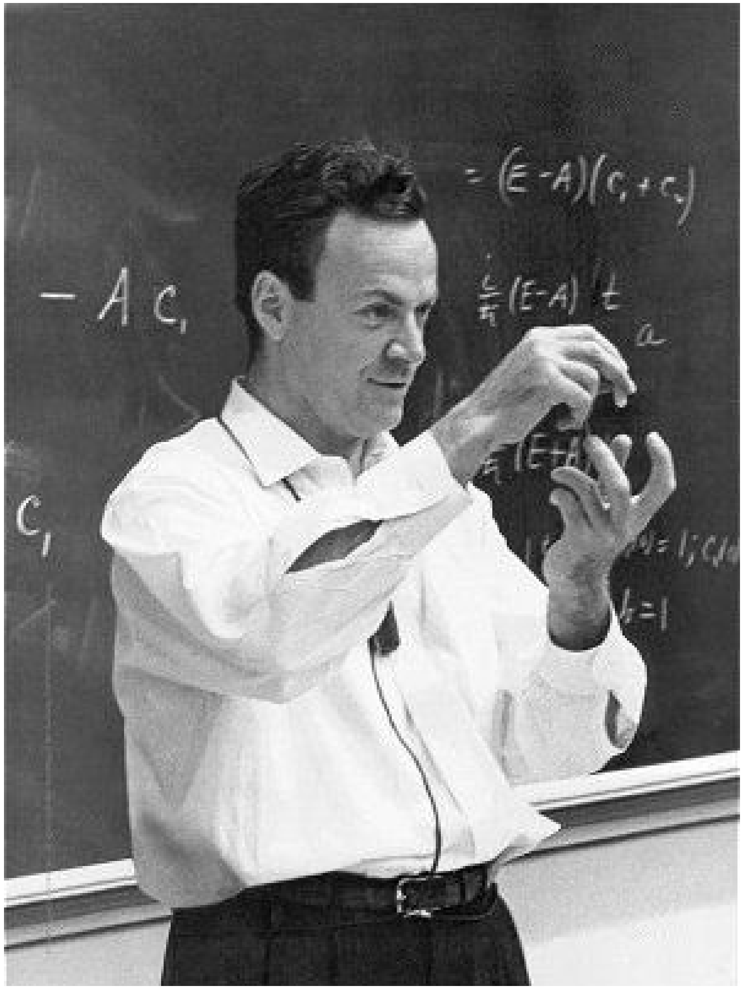

on't Drink and Derive.
$E = 4\pi\varepsilon_0 \frac{q^2}{r^2}$
$\bar{p} = \bar{m}v$
$E = mc^3$
$\frac{\partial L}{\partial p_x} = \dot{q}_x$
$PV = n + R + T$
$n\lambda = 2d \tan\theta$
$F = \sqrt{ma}$
$x = \frac{1}{2}at^2 + v_0t^2 + x_0t^2$

To work towards results?

- Nobody needs an infinitely perfect report in an infinite time!
- If you cannot solve the entire problem, decide what is really necessary and solve a partial problem
- If you can solve the entire problem, nevertheless decide what partial case is sufficient, and your solution will be much better
- Be brave in what you do, but always reserve a great degree of scientific skepticism!
- Procrastination is definitely a risk :-)

Feynman: to be self-confident?

- “I’ve very often made mistakes in my physics by thinking the theory isn’t as good as it really is, thinking that there are lots of complications that are going to spoil it
- — an attitude that anything can happen, in spite of what you’re pretty sure should happen.”



R.P. Feynman. Surely You’re Joking, Mr. Feynman (Norton, New York, NY, 1985)

Second draft // October 9, 2011

Preparation to 25th IYPT' 2012: references, questions and advices

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July 30, 2011…October 9, 2011 :-)

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