Preparation to the Young Physicists' Tournaments' 2010

Ilya Martchenko, Université de Fribourg

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 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 achievements of others?
- Is IYPT all about competing, or about developing professional personal standards?

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 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
- 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?

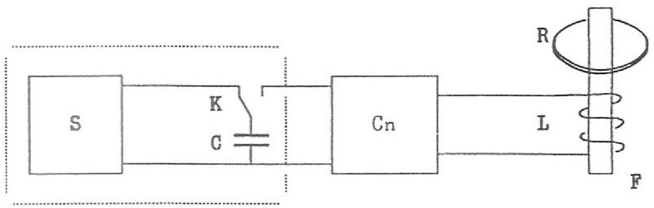

PHYSIK
3.3.3. - 3.2.5.
E
F
1893 - 1968
Systems and Transforms with Applications in Optics
PAPOULIS
VOLUME 1
A GUIDE TO OPTICAL SYSTEM DESIGN
SPIE
3.2.6
36
Is the novel research limited and
discouraged by existing common
knowledge and the ongoing work
of competing groups? :-)

Problem No. 1 “Electromagnetic cannon”

A solenoid can be used to fire a small ball. A capacitor is used to energize the solenoid coil. Build a device with a capacitor charged to a maximum 50 V. Investigate the relevant parameters and maximize the speed of the ball.

IYPT history

- **9-10.** Gun (6th IYPT, 1993)
  - The picture shows an electromagnetic gun circuit. It can launch metal rings.
    - (S, C, K) — power supply consisting of
    - S — the source of constant voltage in the range *10-300 V*,
    - C — capacitor with $C=1000\ \mu F$,
    - K — switch;
    - L — induction coil;
    - F — ferromagnetic core;
    - R — metal ring projectile with mass from *1* to *100 g*.
    - C_n — converter (some device that converts the energy passing from the capacitor to inductance *L* in a way you need.) This element does not contain energy sources. It may be completely absent from your gun.



  - You are to construct, make and demonstrate the electromagnetic gun. It is worth mentioning that the demonstration of your gun will take place with the power supply (elements S, C and K) presented by the Organizing Committee of the YPT. Develop two variants of cannon:
  - 9. Long-range gun is to be constructed to shoot ring at a maximum altitude. The control parameter is the quantity $H=kh/U^2$, where $k=10000\ v^2$, *h* is the height of the projectile, *U* is the voltage to which the capacitor is charged.
  - 10. Gun-lift is to be constructed to achieve the maximum work of lifting a weight (ring). Control parameter is $W=mgh$, where *m* is the mass of the ring, $g=10\ m/s^2$.

Background reading

- Wikipedia: Coilgun, http://en.wikipedia.org/wiki/Coilgun
- Википедия: Пушка Гаусса, http://ru.wikipedia.org/wiki/Пушка_Гаусса
- 700 joule coilgun demo (from JusticeGuy216, Feb. 16, 2009, youtube), http://www.youtube.com/watch?v=XGsp5fxmOIg
- Coilgun Systems, http://www.coilgun.eclipse.co.uk/, http://www.coilgun.eclipse.co.uk/coilgun_basics_1.html
- С. Апресов, С. Коноплев. Выстрел в будущее: Пушка Гаусса своими руками // Популярная механика, авг. 2008 г., http://www.popmech.ru/article/3629-vyistrel-v-buduschee/
- Canon électromagnétique, vidéo de démonstration (Cégep de l'Abitibi-Témiscamingue), http://www.cegepat.qc.ca/tphysique/sebas/page%20accueil/Int%E9gration/2003/canon%E9lectromagn%E9tique.mov
- E. Levi, J. L. He, Z. Zabar, and L. Birenbaum. Guidelines for the design of synchronous-type coilguns. IEEE Trans. on Magnetics 27, 1, 628-633 (1991)
- G. Hainsworth and D. Rodger. Design optimisation of coilguns. IEEE Trans. on Magnetics 31, 1, part 1, 473-477 (1995)
- M. S. Aubuchon, T. R. Lockner, R. J. Kaye, and B. N. Turman. Study of coilgun performance and comments on powered armatures. 26th Int'l Power Modulator Symp., 141-144 (2004)
- D. A. Bresie and J. A. Andrews. Design of a reluctance accelerator. IEEE Trans. on Magnetics 27, 1 (Jan. 1991)

Background reading

- E. A. Mendrela and Z. J. Pudlowski. Transients and dynamics in a reluctance self-oscillating motor. IEEE Trans. on Enegry Conversion 7, 1 (March 1992)
- B. N. Turman. Coilgun launcher for nanosatellites. 2nd Int'l Conf. on Integrated Micro/Nanotechnology for Space App. (April 1999)
- R. A. Marshall. Railgunnery: Where have we been? Where are we going? IEEE Trans. on Magnetics 37, 1 (Jan. 2001)
- A. Egeland. Birkeland's electromagnetic gun: a historical overview. IEEE Trans. on Plasma Science 17, 2 (Apr. 1989)
- I. R. McNab. Early electric gun research. IEEE Trans. on Magnetics 35, 1 (Jan. 1999)
- Another Coilgun Site, http://www.anothercoilgunsite.com/
- Coil gun (4hv.org), http://wiki.4hv.org/index.php/Coil_gun
- Barry's Coilgun Design Site, http://www.coilgun.info/about/home.htm
- Электромагнитное оружие (Gauss2k.narod.ru), http://www.gauss2k.narod.ru/
- Hacked Gadgets Forum: Top 5 Coil Guns (Jan. 27, 2007), http://hackedgadgets.com/2007/01/27/top-5-coil-guns/
- Wirbelstrom Beschleuniger (Rapp Instruments), http://www.rapp-instruments.de/accelerator/gaussgun/gauss.htm
- Spulen Beschleuniger - Coil Gun (Rapp Instruments), http://www.rapp-instruments.de/accelerator/Coilgun/coilgun.htm
- Experiments with electromagnets (coolmagnetman.com), http://www.coolmagnetman.com/magsolen.htm

Background reading

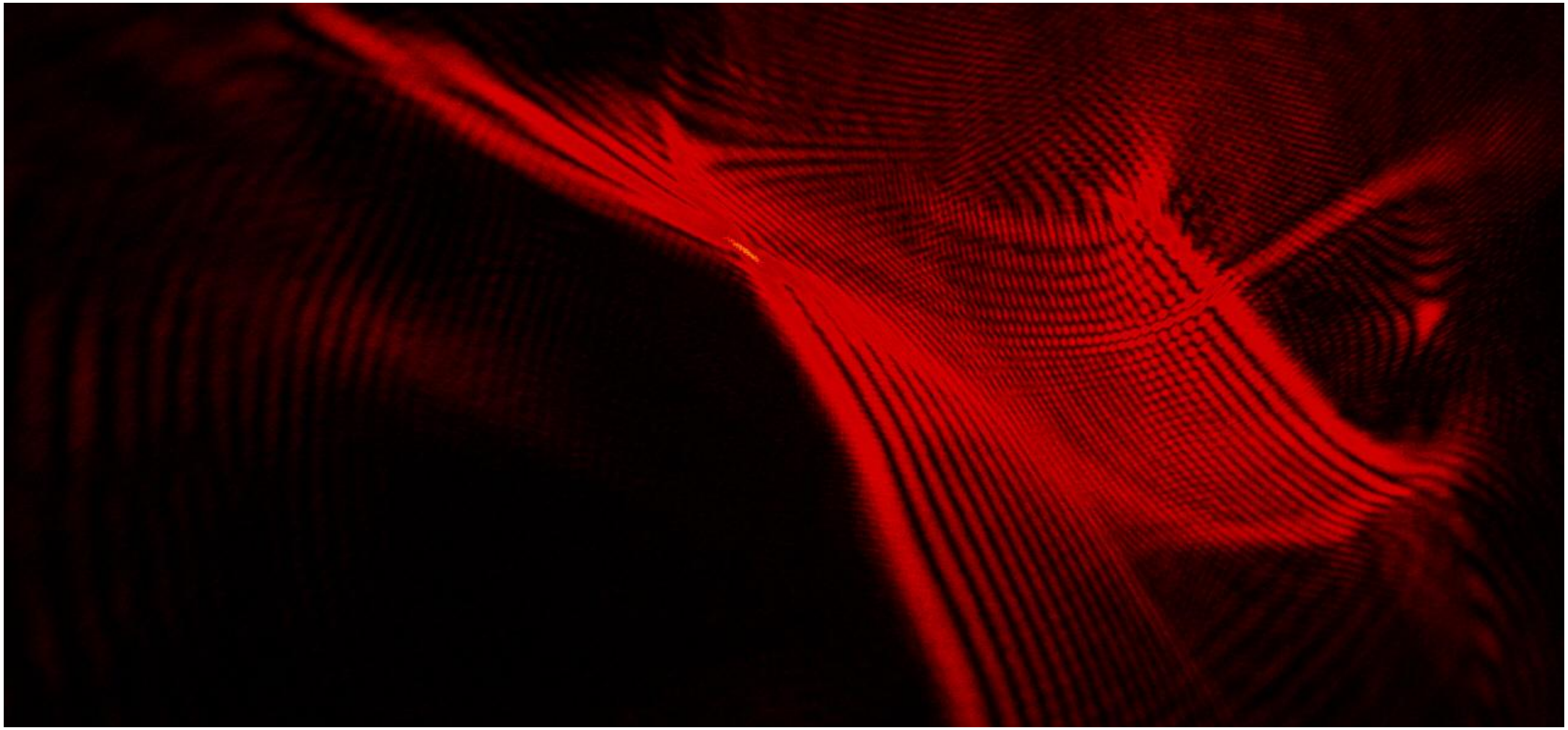
- С. Варламов. Электромагнитная пушка (из архива) // Физика — Перв. сент., 13 (2002), http://fiz.1september.ru/2002/13/no13_1.htm
- Комментарий редактора к статье С.Варламова «Электромагнитная пушка» // Физика — Перв. сент., 13 (2002), http://fiz.1september.ru/2002/13/no13_2.htm
- Electromagnetic Force Gun (Ask A Scientist, Physics Archive, 1999), http://www.newton.dep.anl.gov/askasci/phy99/phy99282.htm
- Railgun with 20kJ 6shots No,4 (from Kisaragieml, Sept. 24, 2006, youtube), http://www.youtube.com/watch?v=4CNldTbYy5A, http://www.youtube.com/watch?v=TkZlfuD7_wk
- 8 Capacitor Coil Gun (from bobdavis321, July 17, 2007, youtube), http://www.youtube.com/watch?v=-gboHGYsHzY
- Rapid Fire Coilgun - Featured on Hacked Gadgets (from abbtech, July 07, 2006, youtube), http://www.youtube.com/watch?v=eHv33mH6Nq0
- My Second Coil Gun (from jspeasrus, Feb. 18, 2008, youtube), http://www.youtube.com/watch?v=6mobpTrl7cA
- Coilgun - Featured on Hacked Gadgets (from abbtech, June 14, 2006, youtube), http://www.youtube.com/watch?v=m86gK-EOEsQ
- My Coilgun @ 2,65 kJ (from FunkenStreckenBrater, Nov, 27, 2006, youtube), http://www.youtube.com/watch?v=yzUAtltT2lY

Background reading

- Homemade Coil Gun Pistol (from FrigginSmift, May 22, 2008, youtube), http://www.youtube.com/watch?v=_BdwxiZX6Is
- Coil Gun 2 (from bobdavis321, March 03, 2007, youtube), http://www.youtube.com/watch?v=NNxfD2hAvpE
- Najnowszy film o naszym dziale elektromagnetycznym, Coil gun version 1.4 (from matys4877, Feb. 14, 2009, youtube), http://www.youtube.com/watch?v=jfeh4vn_l-I
- MV CoilMaster Mark1 coilgun - Featured on Hacked Gadgets (from TeslaCommander, May 09, 2009, youtube), http://www.youtube.com/watch?v=In6PM6OtHQc
- Coil Gun (from gilbondfac, Aug. 28, 2007, youtube), http://www.youtube.com/watch?v=quIgbMkE2gE
- [Tuto]Coilgun Mark II (from realyoyoweb, Aug. 26, 2009), http://www.youtube.com/watch?v=aTkXwW-MVqA
- P. J. Leonard, H. C. Lai, G. Hainsworth, D. Roger, and J. F. Eastham. Analysis of the performance of tubular pulsed coil induction launchers. IEEE Trans. on Magnetics 29, 1, 686-690 (Jan. 1993)
- D. A. Bresie, J. A. Andrews, and S. W. Ingram. Parametric approach to linear induction accelerator design. IEEE trans. on Magnetics 27, 1, 390-393 (Jan. 1991)
- G. Hainsworth, P. J. Leonard, D. Roger, and H. C. Lai. A comparison between finite-element and mutual inductance models of coilguns. Proc. 4th Europ. Symp. on EML Technology (1993)
- S.T.A.L.K.E.R., Fallout 2 Gauss Gun and Reality (from MickeyMutant, July 04, 2007, youtube), http://www.youtube.com/watch?v=D5atTwuPPVg

Key questions

- What interactions cause the ball to accelerate? How to describe these interactions quantitatively?
- At what moment the capacitor should be fully discharged to avoid backward force to projectile?
- What parameters of current surge determine the optimum acceleration of the ball (pulse profile? maximum intensity?)
- What parameters of the coil (inductance? energy losses?) may be controlled?
- What parameters of the capacitor (capacitance? stored energy? minimum discharge time?) may be controlled?
- What parameters of the ball (mass? radius? shape?) may be controlled? What material is best for projectiles, and what magnetic permeability should it have? Does it have to possess ferromagnetic, or other properties?
- What is the role of the friction between the ball and the tube surface, and the air resistance? Do the flux always pass through the ball? Is there a leakage flux?
- What are the optimum time dependences for the ball's speed and acceleration? Is there a lag time between current surge and the shot?
- How to best measure the speed of the ball (with a ballistic pendulum? a high-speed camera?) At what degree the speed is reproduced, if the experiment is repeated?
- Would it be difficult to develop a theory including all relevant parameters as tunable variables? Is it worth modeling the system numerically?
- What safety measures need to be implemented during your experiments?
- Overall, what is your conclusion on the problem? What parameters need to be tuned to maximize the speed of the ball?



Problem No. 2 “Brilliant pattern”

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.


What is the shape of a pendant droplet?

IYPT history

- **6.** Rainbow (2nd IYPT, 1989)
  - Is it possible that three or more rainbows appear on the sky simultaneously?
- **14.** Laser (5th IYPT, 1992)
  - A laser beam is directed horizontally at a flat transparent basin (aquarium) with water, perpendicularly to the walls of the basin. When the beam passes above or under the water surface, a spot of the laser beam can be seen on a screen behind the basin. However, if the laser beam passes along the water surface, a vertical stripe is seen on the screen. Explain the origin of the stripe and study its parameters.
- **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.

Background reading

- P.-G. de Gennes, F. Brochard-Wyart, D. Quéré. Gouttes, bulles, perles et ondes (Paris, éd. Belin, 2002)
- J. A. Lock, C. L. Adler, and R. W. Fleet. Rainbows in the grass. I. External-reflection rainbows from pendant droplets. Applied Optics 47, 34, H203-H213 (2008)
- C. L. Adler, J. A. Lock, and R. W. Fleet. Rainbows in the grass. II. Arbitrary diagonal incidence. Applied Optics 47, 34, H214-H219 (2008)
- J. A. Lock and J. H. Andrews. Optical caustics in natural phenomena. Am. J. Phys. 60, 5, 397-407 (May 1992)
- J. A. Lock and E. A. Hovenac. Internal caustic structure of illuminated liquid droplets. J. Opt. Soc. Am. A – Opt. Image Sci. and Vision 8, 10, 1541-1553 (1991)
- V. R. Daria, C. Saloma, and S. Kawata. Excitation with a focused, pulsed optical beam in scattering media: diffraction effects. Applied Optics 39, 28, 5244-5255 (2000)
- C. L. Adler, J. A. Lock, B. R. Stone et al. High-order interior caustics produced in scattering of a diagonally incident plane wave by a circular cylinder. J. Opt. Soc. Am. A – Opt. Image Sci. and Vision 14, 6, 1305-1315 (1997)

Background reading

- J. A. Lock. Contribution of high-order rainbows to the scattering of a Gaussian laser-beam by a spherical particle. J. Opt. Soc. Am. A – Opt. Image Sci. and Vision 10, 4, 693-706 (1993)
- S. Fordham. On the calculation of surface tension from measurements of pendant drops. Proc. Royal Soc. London A 194, 1 (1948)
- M. V. Berry. Elliptic umbilic diffraction catastrophe. Phil. Trans. Royal Soc. London A 291, 453 (1979)
- G. Dagosta. Time evolution of the caustics of a laser heated liquid-film. Applied Optics 29, 1023 (1990)
- J. A. Lock. Using refraction caustics to monitor evaporation of liquid-drop lenses. Applied Optics 29, 4599 (1990)
- P. L. Marston. Hyperbolic umbilic diffraction catastrophe and rainbow scattering from spheroidal drops. Nature 312, 529 (1984)
- V. Khare. Theory of rainbow. Phys. Rev. Lett. 33, 976 (1974)
- Y. Ji. Analysis of electromagnetic-waves refracted by a spherical dielectric interface. J. Opt. Soc. Am. A – Opt. Image Sci. and Vision 8, 541 (1991)

Key questions

- Can possible patterns on the screen be classified into types? Do such types correspond to similar or different physical phenomena?
- How to best record the pattern on the screen for further analysis? (with a CCD camera? with a flatbed scanner?)
- What shape has a droplet pendant on the tube? How to describe this shape mathematically?
- What is a caustic and a catastrophe in optics? Are they relevant to the problem? Does the system allow approaching wave effects, such as interference or diffraction? Can you re-formulate your explanation using such concepts?
- Is it possible to describe theoretically the light refraction in the droplet, using the information on shape and the Snell's law? What are the optical parameters of the droplet? Is it correct to speak e.g. of a focus distance?
- How does the optical pattern depend on the distance between the screen and the droplet?
- Can the shape of the droplet be tuned? (with diameter or material of the tube? with volume controlled by pressure in the tube?) How does the shape influence on the optical pattern?
- What parameters of the light beam are relevant? (diameter? radiant intensity distribution? spatial angle with respect to droplet?)
- Is it difficult to compile a program to imitate the pattern on the screen? Input data may include parameters of the beam, of the droplet, as well as relevant distances in the system.
- Above all, what is your conclusion on the problem?

Problem No. 3 “Steel balls”

Colliding two large steel balls with a thin sheet of material (e.g. paper) in between may "burn" a hole in the sheet. Investigate this effect for various materials.


What actually happens?
Fracture or plastic deformation?
A sign of exposure to heat?
Crêpe paper tissue

IYPT history

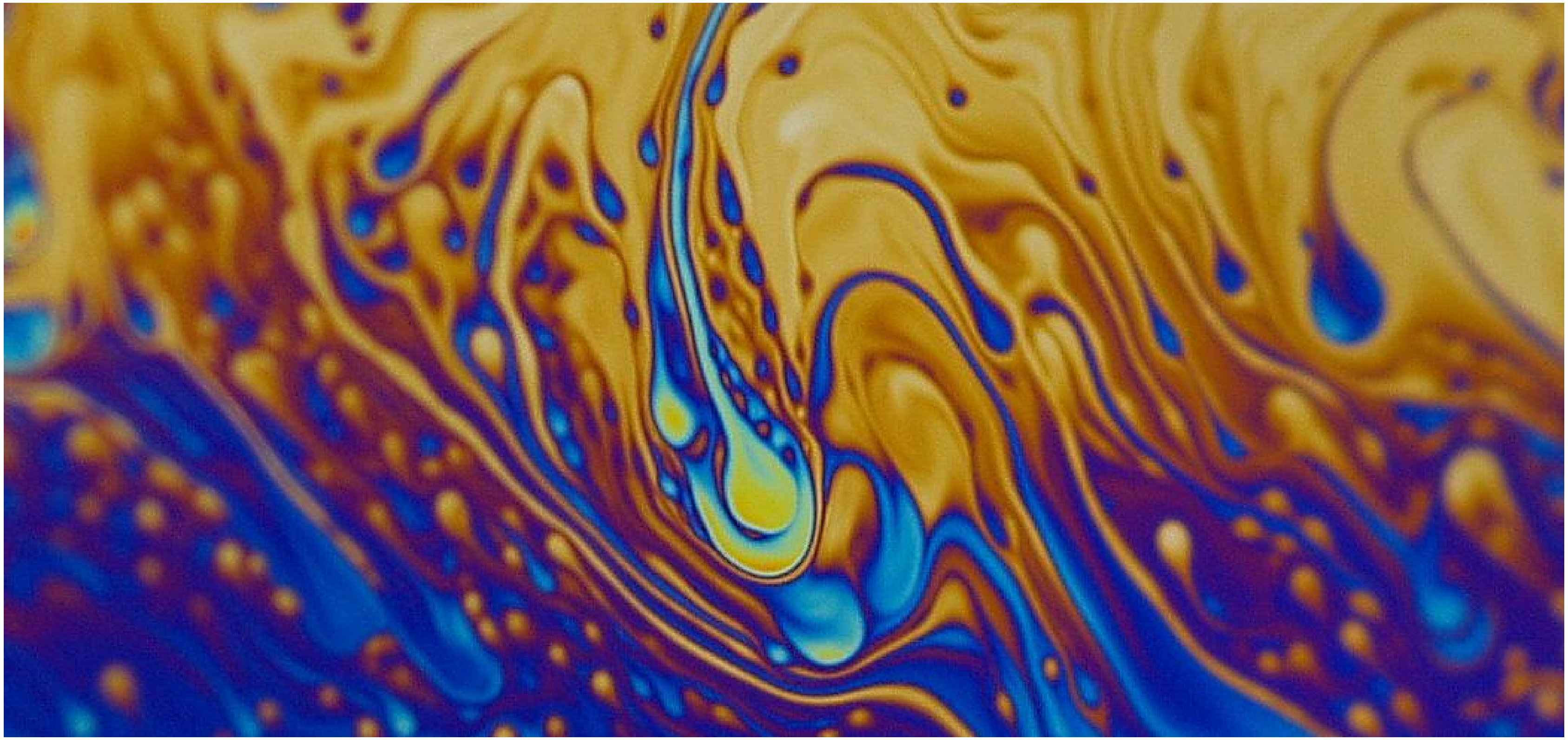
- **11.** Rolling balls (14th IYPT, 2001)
  - Place two equal balls in a horizontal, V-shaped channel, with the walls at 90 degrees to each other, and let the balls roll towards each other. Investigate and explain the motion of the balls after the collision. Make experiments with several different kinds of ball pairs and explain the results.
- **2.** The two ball problem (18th IYPT, 2005)
  - Two balls placed in contact on a tilted groove sometimes do not roll down. Explain the phenomenon and find the conditions, under which it occurs.
- **16.** Hardness (19th IYPT, 2006)
  - A steel ball falls onto a horizontal surface. If one places a sheet of paper onto the surface with a sheet of carbon paper on top of it, a round trace will be produced after the impact. Propose a hardness scale based on this method.

Background reading

- A. Rusinek, J. A. Rodríguez-Martínez, R. Zaera, J. R. Klepaczko, A. Arias, and C. Sauvelet. Experimental and numerical study on the perforation process of mild steel sheets subjected to perpendicular impact by hemispherical projectiles. Int. J. Impact Eng. 36, 4, 565-587 (April 2009)
- D. M. S. Wannigaratne, W. J. Barchelor, A. B. Conn, and I. A. Parker. Image analysis of plastic deformation in the fracture of paper. Appita J., 53, 6, 471-482 (2000), http://users.monash.edu.au/~batchelo/Downloads/Image%20analysis%20of%20plastic%20deformation.pdf
- D. M. S. Wanigaratne, W. J. Batchelor, and I. H. Parker. Comparison of fracture toughness of paper with tensile properties, Appita J., 55, 5, 369-385 (2002), http://users.monash.edu.au/~batchelo/Downloads/Comparison%20of%20fracture%20toughness%20paper.pdf
- G. S. Pisarenko, V. P. Naumenko, and E. E. Onlshchenko. A method of investigating the fracture of sheet materials in biaxial loading. Strength of Materials 14, 3, 275-282 (1982)
- A. F. Liu. Mechanics and mechanisms of fracture: an introduction (ASM International, 2005)
- M. K. Oladimeji. Plane-stress fracture testing of finite sheets under biaxial loads. Exp. Mechanics 23, 2, 217-227 (1983)
- В. В. Соколовский. Теория пластичности. — М.: Высшая школа, 1969
- А. Г. Горшков, Э. И. Старовойтов, Д. В. Тарлаковский. Теория упругости и пластичности. — М.: Физматлит, 2002
- R. S. Seth and D. H. Page. Fracture resistance of paper. J. Mat. Science 9, 1745-1753 (1974). http://www.nd.edu/~rroeder/ame60646/slides/paper.pdf
- R. S. Seth and D. H. Page. Fracture resistance of paper: a failure criterion for paper. Tappi 58, 9, 112 (1975)

Key questions

- Above all, what stresses are applied to the paper sheet during the collision, what processes they initiate, and how exactly the hole is “burned”?
- Paper may be visibly shifted to the edges of the hole, but the edges may appear black and smell like a burned paper. How significant are these and other effects? How to validate or invalidate their presence?
- What theoretical approaches may be used to describe the process of fracture or smoldering?
- Is there a temperature surge at the collision point? How can it be detected and measured? Can evaporating, smoldering or burning the hole be an important aspect? Is there enough oxygen for a complete combustion?
- Is it possible to detect a change of sheet’s mass after fracture, and to what conclusions it can lead?
- What parameters of the steel balls are relevant to the process of fracture:
  - impact speed? impact angular frequency?
  - mechanical properties of the balls? radii and surface roughness of the balls?
- What parameters of the paper sheet are relevant:
  - mechanical strength parameters with respect to different magnitudes and directions of shear stresses?
  - combustion or smoldering temperatures? specific heat?
- What are the possible shapes and sizes of the holes? Is there a way to approach their distribution parameters statistically?
- What conditions need to be fulfilled to control sizes of holes, or protect paper from fracture, in the given range of parameters?
- Above all, what is your conclusion on the problem?



Problem No. 4 “Soap film”

Create a soap film in a circular wire loop. The soap film deforms when a charged body is placed next to it. Investigate how the shape of the soap film depends on the position and nature of the charge.

IYPT history

- **10.** Soap bubbles (9th IYPT, 1996)
  - Dip the ring of a children's toy for blowing out soap bubbles into a soap solution and blow on the film formed in the ring. At what velocity of the air flux blown into the ring will the bubbles form ? How must the velocity of the air flux be adjusted to produce the bubble of maximum size ?
- **4.** Soap film (12th IYPT, 1999)
  - Explain the appearance and development of colours in a soap film, arranged in different geometrical ways.
- **1.** Invent for yourself (13th IYPT, 2000)
  - Suggest a contact-free method for the measurement of the surface tension coefficient of water. Make an estimate of the accuracy of the method.
- **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.

Background reading

- E. Hilton and A. van der Net. Dynamics of charged hemispherical soap bubbles. Eur. Phys. Lett. 86, 24003 (April 2009)
- C. T. R. Wilson and G. I. Taylor. The bursting of soap-bubbles in a uniform electric field. Proc. Cambridge Philos. Soc. 22, 728 (1925)
- O. A. Basaran and E. L. Scriven. Axisymmetrical shapes and stability of pendant and sessile drops in an electric field. J. Colloid Interface Sci. 140, 10-30 (1990)
- N. Dubash and A. J. Mestel. Behaviour of a conducting drop in a highly viscous fluid subject to an electric field. J. Fluid Mech. 581, 469-493 (June 2007)
- D. E. Moulton and J. A. Pelesko. Theory and experiment for soap-film bridge in an electric field. J. Colloid Interface Sci. 322, 1, 252-262 (June 2008)
- D. S. Dean and R. R. Horgan. Electrostatic fluctuations in soap films. Phys. Rev. E 65, 061603 (2002), arXiv:cond-mat/0202124v1 [cond-mat.stat-mech]
- V. Bergeron. Forces and structure in thin liquid soap films. J. Phys.: Condens. Matter 11, R215–R238 (1999)
- E. I. Kats. Physics of soap films. Mol. Cryst. and Liquid Cryst. 292, 199-212 (Jan. 1997)
- W. Frey and E. Sackmann. Dynamic Stabilization of Asymmetric Soap Films. J. Colloid Interface Sci. 174, 2, 378-391 (Sept. 15, 1995)
- Z. Gamba. Macroscopic electrostatic potentials and interactions in self-assembled molecular bilayers: The case of Newton black films. J. Chem. Phys. 129, 164901 (2008)
- W. R. McEntee and K. J. Mysels. Bursting of soap films. I. An experimental study. J. Phys. Chem. 73, 9, 3018-3028 (1969)
- H. K. Yeoh and O. A. Basaran. Equilibrium shapes and stability of a liquid film subjected to a nonuniform electric field. Phys. Fluids 19, 11, 114111 (Nov. 2007)

Background reading

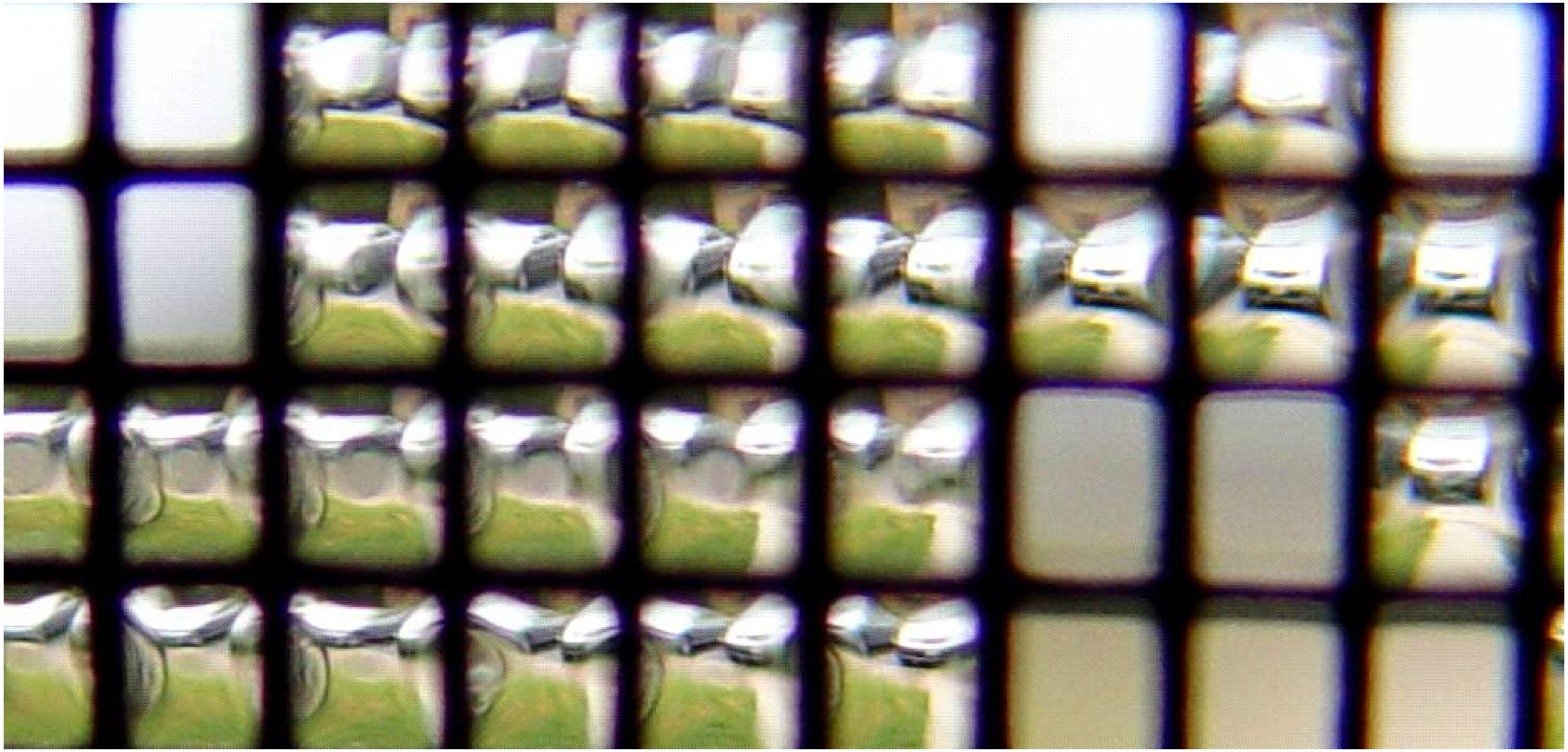
- P. R. Chiarot, S. I. Gubarenko, R. Ben Mrad, and P. E. Sullivan. On the pulsed and transitional behavior of an electrified fluid interface. J. Fluids Eng. - Trans. of the ASME 131, 9, 091202 (Sept. 2009)
- S. I. Gubarenko, P. Chiarot, R. Ben Mrad, and P. E. Sullivana. Plane model of fluid interface rupture in an electric field. Phys. Fluids 20, 4, 043601 (Apr. 2008)
- E. V. Shiryaeva, V. A. Vladimirov, and M. Y. Zhukov. Theory of rotating electrohydrodynamic flows in a liquid film. Phys. Rev. E 80, 4, 041603 (Oct. 2009)
- A. Bateni, A. Ababneh, J. A. W. Elliott, A. W. Neumann, and A. Amirfazli. Effect of gravity and electric field on shape and surface tension of drops. In: Low gravity phenomena and cond. matter experiments in space. Advances in space research 36, 1, 64-69, Sp. Iss. 2005,
- A. Bateni, S. Laughton, H. Tavana, S. S. Susnar, A. Amirfazli, and A. W. Neumann. Effect of electric fields on contact angle and surface tension of drops. J. Colloid Interface Sci. 283, 1, 215-222 (2005)
- A. Bateni, S. S. Susnar, A. Amirfazli, and A. W. Neumann. Development of a new methodology to study drop shape and surface tension in electric fields. Langmuir 20, 18, 7589-7597 (2004)
- M. J. Miksis. Shape of a drop in an electric-field. Phys. Fluids 24, 1967 (1981)
- A. A. Shutov. The shape of a drop in a constant electric field. Technical Physics 47, 12, 1501-1508 (Dec. 2002)
- Research overview by Derek E. Moulton (University of Arizona, 2008), http://math.arizona.edu/~moulton/Research/Research_statement%2011-08.pdf
- F. Graner. Film de savon géant (2005), http://www-lsp.ujf-grenoble.fr/vie_scientifique/annee_mondiale_de_la_physique/films_savon/index.htm
- P.-G. de Gennes, F. Brochard-Wyart, D. Quéré. Gouttes, bulles, perles et ondes (Paris, éd. Belin, 2002), pp. 38 – 67

Background reading

- The shape of a soap film in an electric field (Department of Mathematical Sciences, New Jersey Institute of Technology, 2009), http://m.njit.edu/Undergraduate/Capstone/Spring2009_booty/tagb.html, http://m.njit.edu/Undergraduate/Capstone/Spring2009_booty/pict0253.asf, http://m.njit.edu/Undergraduate/Capstone/Spring2009_booty/0428burst2.avi
- C. V. Boys. Soap bubbles, their colours and the forces which mould them (Dover, New York, 1959)
- A. G. Cook. Tough soap films and bubbles. J. Chem. Educ. 15, 161 (1938)
- A. L. Kuehner. Long lived soap bubbles. J. Chem. Educ. 35, 337 (1958)
- C. L. Stong. How to blow soap bubbles that last for months or even years. Sci. Amer. 220 (5), 128 (1969)
- C. L. Stong. How to blow bubbles that survive for years. Sci. Amer. 229 (1), 110 (1973)
- H. Gonzalez. Stabilization of dielectric liquid bridges by electric-fields in the absence of gravity. J. Fluid Mech. 206, 545 (1989)
- N. A. Pelekasis. Linear oscillations and stability of a liquid bridge in an axial electric field. Phys. Fluids 13, 3564 (2001)
- A. Ramos. Experiments on dielectric liquid bridges subjected to axial electric-fields. Phys. Fluids 6, 3206 (1994)
- N. D. Robinson. Observations of singularity formation during the capillary collapse and bubble pinch-off of a soap film bridge. J. Colloid Interface Sci. 241, 448 (2001)
- Пузырь в электрическом поле // http://www.school.edu.ru/projects/physicexp/bubbles/htmls/text.htm
- Magnetic and Electric Effects on Water (Martin Chaplin, London South Bank University, 2006), http://www1.lsbu.ac.uk/water/magnetic.html

Key questions

- Above all, what is the cause for the film deformation?
- How to best prepare and stabilize the film? How to determine its thickness, expected lifetime, surface energy and elasticity? How do they depend on the surfactant concentration and presence of stabilizers, such as glycerol? What ambient physical conditions may directly influence on film stability? (humidity of the air? temperature of the air?)
- What is the influence on the film shape of the spatial position (vertical? horizontal? inclined?) and size of the film?
- What is the influence on the shape of the spatial position, size, shape, charge distribution and total charge of the charged body? How to best charge a body (with a Wimshurst machine?) Are there boundary conditions for electric field near the (dielectric) film?
- How to best measure the shape of a deformed film (with a camera from a relevant angle? with a laser beam?)
- Is it possible to describe mathematically the shape of the deformed film? Is the math describing the deformations for the film similar to that of elastic circular membrane? Does the film oscillate when the charged body is removed? Is it worth modeling the system numerically?
- Under what conditions the film may burst?



Problem No. 5 “Grid”

A plastic grid covers the open end of a cylindrical vessel containing water. The grid is covered and the vessel is turned upside down. What is the maximal size of holes in the grid so that water does not flow out when the cover is removed?

IYPT history

- **14.** Bottle (7th YPT, Correspondence Competition, 1985)
  - A bottle with volume of 0.5 L is filled with water and tightly closed with a tap that has a long tube in it. The inner diameter of the tube is 2—4 mm, the length of the tube is from 10 cm to 1 m. If the bottle is turned upside down, the water will either flow out completely, either will be flowing in portions. Investigate the phenomenon. (The length of the tube should be considered the key parameter.)

- **8.** Trick (11th IYPT, 1998)
  - It is known that a glass filled with water and covered with a sheet of paper may be turned upside down without any loss of water. Find the minimum amount of water to perform the trick successfully.

Background reading

- R. Subramaniam and Y. K. Hoh. ‘Magic’ cup illustrates surface tension. Phys. Educ. 43, 251-252 (May 2008)
- R. Subramaniam and T. K. Aun. ‘Magic’ cup defies the laws of physics. Phys. Educ. 39, 334 (2004)
- Н. А. Козырева. Вода в решете // Потенциал, №8, 2005, http://ru.wikibooks.org/wiki/Вода_в_решете
- А. Дозоров. Можно ли носить воду в решете? // Квант, №10, 1979, http://kvant.mirror1.mccme.ru/1979/10/mozhno_li_nosit_vodu_v_reshete.htm
- М. А.Старшов. Вода в решете — без решета // Физика — Первое сентября. http://fiz.1september.ru/articlef.php?ID=200600813
- Л. Я. Гальперштейн. Здравствуй, физика! — М.: Детская литература, 1967. — с. 122
- Я. И. Перельман. Занимательная физика, книга 1. — М.: Наука, 1972. — с. 89
- В. А. Саранин. Равновесие жидкостей и его устойчивость. — М.: Институт Компьютерных Исследований, 2002
- P.-G. de Gennes, F. Brochard-Wyart, D. Quéré. Gouttes, bulles, perles et ondes (Paris, éd. Belin, 2002)
- P. Brunet, F. Lapierre, F. Zoueshtiagh, V. Thomy, A. Merlen. To grate a liquid into tiny droplets by its impact on a hydrophobic micro-grid. arXiv:0912.0035v1 [physics.flu-dyn]
- М. А. Лаврентьев, Б. В. Шабат. Проблемы гидродинамики и их математические модели. — М.: Наука, 1973
- Л.Д. Ландау, Е.М. Лифшиц. Теоретическая физика, т. 6: Гидродинамика. — М.: Наука, 1986
- Вода в решете // Обсуждение на Prepody.ru (2007 г.), http://www.prepody.ru/topic50.html?pid=285&mode=threaded&show=&st=&#entry285

Key questions

- What is the Raleigh-Taylor instability and is the effect relevant to it?
- What physical parameters of the grid influence on the effect? (size and shape of the grid holes? properties of the surface, such as the contact angle between grid plastic and water?)
- What physical parameters of water influence on the effect (density? surface tension? viscosity?)
- What other parameters are relevant (height of water column? amount of air left above the water surface inside the vessel? shape of the vessel?)
- What forces, besides capillary, may oppose water to leave the vessel?
- If water starts to flow out of the vessel, will it pour out completely, or until a certain level?
- Is the phenomenon reproducible? Is it worth speaking of a probability that the water starts pouring out under certain conditions? Of a probability that a certain amount of water pours out?
- What is the shape of water surface in the holes of the grid, if no water pours out?
- How does the surface energy increase with increasing curvature? In terms of energy balance, what is the relation between total surface energy, the potential energy of water column and the potential energy of the decompressed air column?
- What would change if the vessel open from the top is used?

Problem No. 6 “Ice”

A wire with weights attached to each end is placed across a block of ice. The wire may pass through the ice without cutting it. Investigate the phenomenon.

XXIV. *On Regelation, and on the Conservation of Force.* *By* Professor FARADAY.

[The volume of reprinted 'Experimental Researches in Chemistry and Physics,' by Prof. Faraday, which has just been published, contains the following new matter in relation to the above subjects. We think it expedient to transfer it to our pages.]

On Regelation.

THE subject of regelation has of late years acquired very great interest through the experimental investigations of Tyndall, J. Thomson, Forbes and others, and in its present state will perhaps justify a few additional remarks on my p
cause. On the first observation of the effect eigh
I attributed it to the greater tendency which a part
water had to assume the solid state, when in cont
on two or more sides, above that it had when in co
side only. Since then Mr. Thomson has shown t
lowers the freezing-point of water*, and has point
such an effect occurring at the places where two m
press against each other, may lead first to fusion
union of the ice at those places, and so he explains the fact of

THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

CONDUCTED BY
SIR DAVID BREWSTER, K.H. LL.D. F.R.S.L. & E. &c.
SIR ROBERT KANE, M.D., F.R.S., M.R.I.A.
WILLIAM FRANCIS, PH.D. F.L.S. F.R.A.S. F.C.S.
JOHN TYNDALL, F.R.S. &c.

"Nec aranearum sane textus ideo melior quia ex se fila gignunt, nec noster vilior quia ex alienis libamus ut apes." JUST. LIPS. *Polit.* lib. i. cap. 1. Not.

VOL. XVII.—FOURTH SERIES.
JANUARY—JUNE, 1859.

What actually happens?

Background reading

- Wikipedia: Regelation, http://en.wikipedia.org/wiki/Regelation
- Faraday. On regelation, and on the conservation of force. Phil. Mag. 17, 113, 162-169 (1859)
- J. T. Bottomley. Melting and regelation of ice. Nature (London) 5, 185 (January 4, 1872)
- M. W. Zemansky. The regelation of ice is a complicated phenomenon. Phys. Teacher, 3, 7, 301-302 (Oct. 1965)
- E. Hahne and U. Grigull. Some experiments on the regelation of ice. Physics of Ice (Plenum Press, 1969), pp. 320-328, http://www.td.mw.tum.de/tum-td/de/forschung/pub/CD_Grigull/047.pdf
- L. D. Drake and R. L. Shreve. Melting and regelation of ice by round wires. Proc. R. Soc. London A 332, 1588, 51-83 (1973)
- R. R. Giplin. Wire regelation at low temperatures. J. Colloid Interface Sci., 77, 2, 435-448 (Oct. 1980)
- E. W. P. Hahne and U Grigull. The regelation of ice — a problem of heat conduction. Int. J. Heat Mass Transfer, 15, 5, 1057-1058, IN1, 1059-1066 (May 1972)
- P. D. Dunn, J. D. Burton, X. Xu, and A. G. Atkins. Paths swept out by initially slack flexible wires when cutting soft solids; when passing through a very viscous medium; and during regelation. Proc. R. Soc. London A 463, 2077, 1-20 (2007)
- Doctor Campbell's Science Demo – Regelation (by Jambell, March 09, 2008, youtube), http://www.youtube.com/watch?v=bRKAECWdVhY

Background reading

- Slicing ice (Pennsylvania State University, 2005), http://www.ipse.psu.edu/activities/nitinol/Slicing%20Ice.pdf
- Cutting Ice into One (Exploratorium, media release, Nov. 1, 2009), http://press.exploratorium.edu/cutting-ice-into-one-november-2009/
- R. Hipschman. Ice under pressure. Exploratorium Quarterly, “Ice,” 13, 2, 11-15 (Summer 1989), http://www.exploratorium.edu/ronh/cool_experiments/
- W. W. Locke. Pressure melting of ice: While-U-Wait (Department of Earth Sciences, Montana State University, 2005), http://serc.carleton.edu/sp/compadre/demonstrations/examples/pressure_melt.html
- R. Rosenberg. Why is ice slippery? Physics Today, 50-55 (Dec. 2005), http://people.virginia.edu/~lz2n/mse305/ice-skating-PhysicsToday05.pdf
- J. W. Telford and J. S. Turner. The motion of a wire through ice. Phil. Mag. 8, 87, 527-531 (June 1963)
- L. Makkonen. Surface melting of ice. J. Phys. Chem. B 101, 32, 6196–6200 (1997)

Key questions

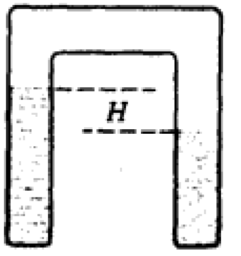
- Above all, what is the cause for this profoundly researched effect?
- Is there a direct dependence of the melting temperature and specific melting heat on pressure, or other parameters?
- What is the influence of the ambient temperature? What is the temperature range at which the effect is still possible for a given wire, loads and size of ice brick?
- Is there a crucial physical difference between performing the experiment at temperatures below and above 0 °C? Is such a phenomenon possible if a large brick at a low temperature is brought to warm environment?
- Is it possible to measure the temperature at the wire to detect possible heating? Can the ice block be cut with a thermocouple wire, with junction inside the block?
- How is the pressure distributed under and around the wire? Is there a way to measure or model the pressure distribution?
- What is the influence of the wire (heat conductivity? diameter? metal or polymer?), masses of loads, size and temperature of the block on the speed of wire? Is the speed constant over time?
- Many rumors on the validity and invalidity of earlier explanations circulate on the web. Is there indeed a temperature increase? Is there something common with ice skating?
- Above all, what is your conclusion on the problem?

Problem No. 7 “Two flasks”

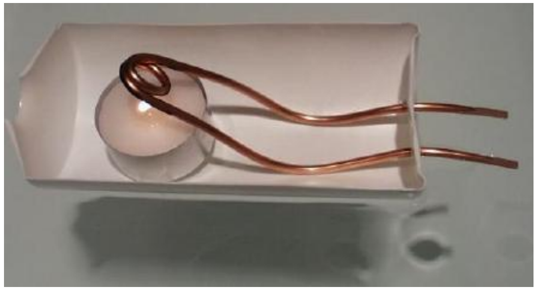
Two similar flasks (one is empty, one contains water) are each connected by flexible pipes to a lower water reservoir. The flasks are heated to 100°C and this temperature is held for some time. Heating is stopped and as the flasks cool down, water is drawn up the tubes. Investigate and describe in which tube the water goes up faster and in which the final height is greater. How does this effect depend on the time of heating?

IYPT history

- **6.** Evaporation-condensation (3rd IYPT, 1990)
  - A П-shaped soldered glass tube contains some water (Fig.). If there is an initial difference of water levels *H*, then after some time water levels will become equal. Estimate the rate of this equalization for a given *H* and *T=const*,
    - a. if there is no air in the tube
    - b. if there is some air in the tube, at normal atmospheric pressure.



- **8.** Boiling (5th IYPT, 1992)
  - A tall cylindrical vessel partially filled with water is immersed with its opened end into a wide vessel with water. When heating to the boiling temperature and consequently cooling, the water level in the cylinder changes. Investigate experimentally the dependence of the water column height in cylinder on temperature at repeated heatings and coolings. Explain the observed phenomena.
- **15.** Heat and temperature (19th IYPT, 2006)
  - A tube passes steam from a container of boiling water into a saturated aqueous salt solution. Can it be heated by the steam to a temperature greater than 100°C? Investigate the phenomenon.
- **10.** Steam Boat (20th IYPT, 2007)
  - A boat can be propelled by means of a candle and metal tubing with two open ends (an example is shown in the picture). Explain how such a boat is propelled and optimize your design for maximum velocity.

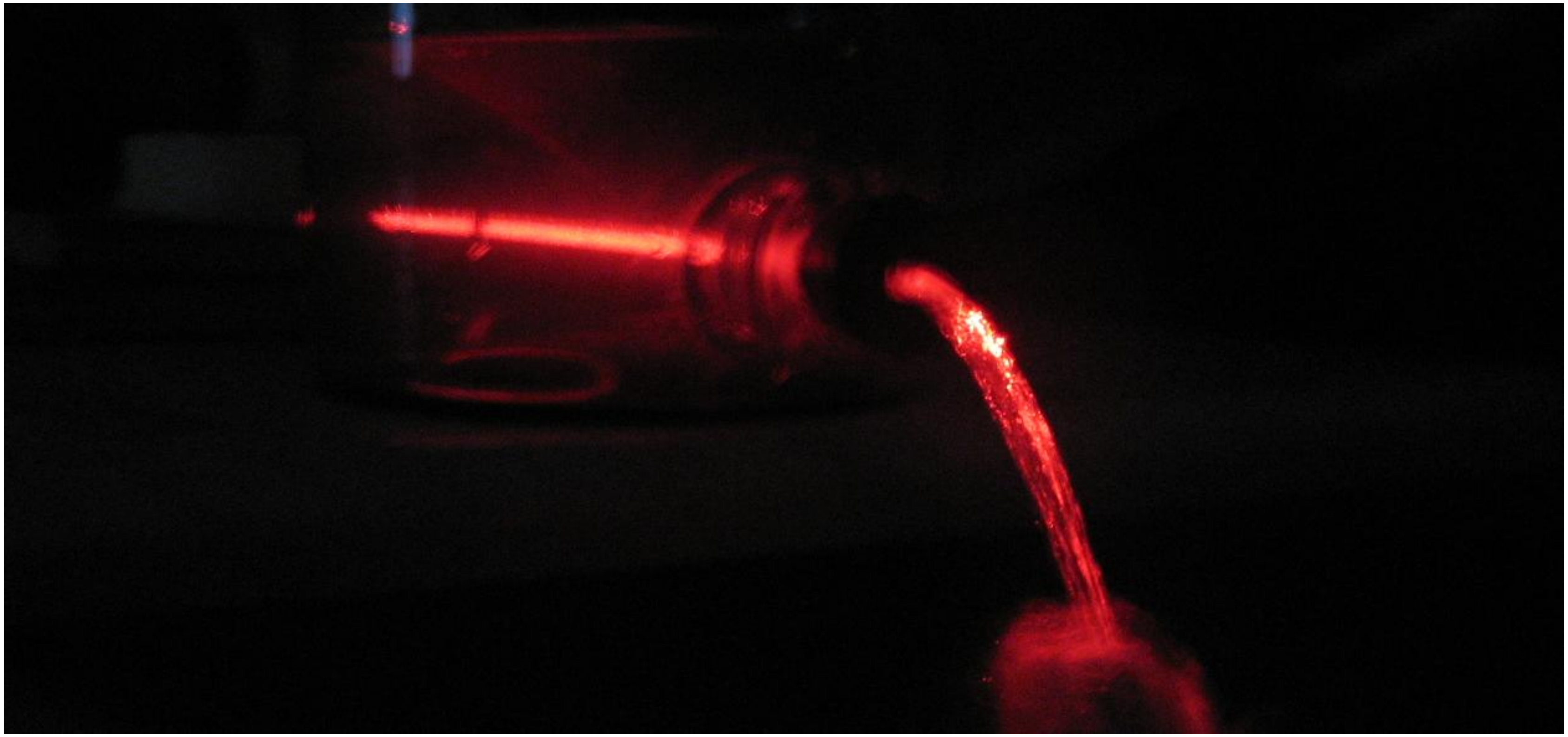


Background reading

- J. G. Baker. Self-induced vibrations. Trans. Am. Soc. Mechanical Engineers 55, APM-55-2, 5-13 (1933)
- Wikipedia: Thermal efficiency, http://en.wikipedia.org/wiki/Thermal_efficiency
- Wikipedia: Heat engine, http://en.wikipedia.org/wiki/Heat_engine
- Wikipedia: Heat engine classifications, http://en.wikipedia.org/wiki/Heat_engine_classifications
- Wikipedia: Carnot cycle, http://en.wikipedia.org/wiki/Carnot_cycle
- Wikipedia: Carnot heat engine, http://en.wikipedia.org/wiki/Carnot_heat_engine
- H. Joachim Schlichting, B. Rodewald. Physicalische Phänomene am Dampf-Jet-Boot. Praxis der Naturwissenschaften, Physik 39/8, 19 (1990)
- I. Finnie, R. L. Curl. Physics in a toy boat. Am. J. Phys. 31, 289 (1963)
- Pop-pop pages. How to build a pop-pop boat, http://www.nmia.com/~vrbass/pop-pop/
- Wikipedia: Knatterboot, http://de.wikipedia.org/wiki/Knatterboot
- Wikipedia: Moteur pop-pop, http://fr.wikipedia.org/wiki/Moteur_pop-pop
- J. S. Miller. Physics in a toy boat. Am. J. Phys. 26, 199 (1958)
- R. S. Mackay. Boat driven by thermal oscillations. Am. J. Phys. 26, 583 (1958)

Key questions

- Finally, what is the dynamics of water lift in both tubes? How does the lift speed of water column in tubes depend on time?
- What physical parameters may be controlled in a certain experiment:
  - temperatures in different points, including both flasks, lower vessel and the ambient air?
  - pressures in different points, including both flasks?
  - time dependences for altitude of water levels in tubes?
- What other properties are proposed to be determined and what methods might be used to measure them?
- What is the heat-induced expansion for air? for saturated water vapor at given temperature? for water? How do they influence on the effect?
- What physical parameters of tubes influence the effect? (length of the tubes? diameter of the tubes?) Can vertically aligned tubes improve measurements of altitudes and pressures?
- How fast the system is cooled down? How to describe it quantitatively? What is the Fourier law?
- Is it possible to observe oscillations of water column? In what of the tubes? How they may be explained?
- Are the observed dependences reproducible, if the experiment is repeated? Are they reproducible, if just one flask, not both of them, is connected to lower vessel?
- Many approaches and concepts may emerge at discussions (thermodynamic cycles? entropy? enthalpy? irreversible processes? energy dissipation? feedback?) How relevant they are to your explanation and can you discuss their role and re-formulate your model with such concepts?
- If you propose an explanation, does it look as a subject to direct experimental proof or disproof?
- Above all, what is your conclusion on the problem?



Problem No. 8 “Liquid light guide”

A transparent vessel is filled with a liquid (e.g. water). A jet flows out of the vessel. A light source is placed so that a horizontal beam enters the liquid jet (see picture). Under what conditions does the jet operate like a light guide?

PHYSIQUE. — *Sur les réflexions d'un rayon de lumière à l'intérieur d'une veine liquide parabolique;* Lettre de M. Colladon.

« J'ai souvent cherché dans mes cours à rendre visibles pour tous les élèves les différentes formes que prend une veine fluide en sortant par des orifices variés. C'est pour y parvenir que j'ai été conduit à éclairer intérieurement une veine placée dans un espace obscur. J'ai reconnu que cette disposition est très-convenable pour le but que je m'étais proposé, et que de plus elle offre dans ses résultats une des plus belles et des plus curieuses expériences que l'on puisse faire dans un cours d'optique.

» L'appareil que j'emploie pour ces essais se compose d'un vase parallélipédique de 1 mètre de hauteur; sur une des faces, un peu au-dessus du fond, est une ouverture où s'adaptent à vis différents diaphragmes pour varier la grosseur du jet. Cette veine s'échap
horizontale : pour l'éclairer intérieurement o
opposée sur la même direction, et on adapte
On ajoute en dehors du vase un tube horizo
tiné à empêcher les rayons obliques à l'axe d
L'appareil est ensuite placé dans une cha
de cette chambre est percé d'un trou auque
l'on renvoie par un miroir un faisceau de l
l'axe du tube.

COMPTE RENDU

DES SÉANCES

DE L'ACADÉMIE DES SCIENCES.

SÉANCE DU LUNDI 4 JUILLET 1842.

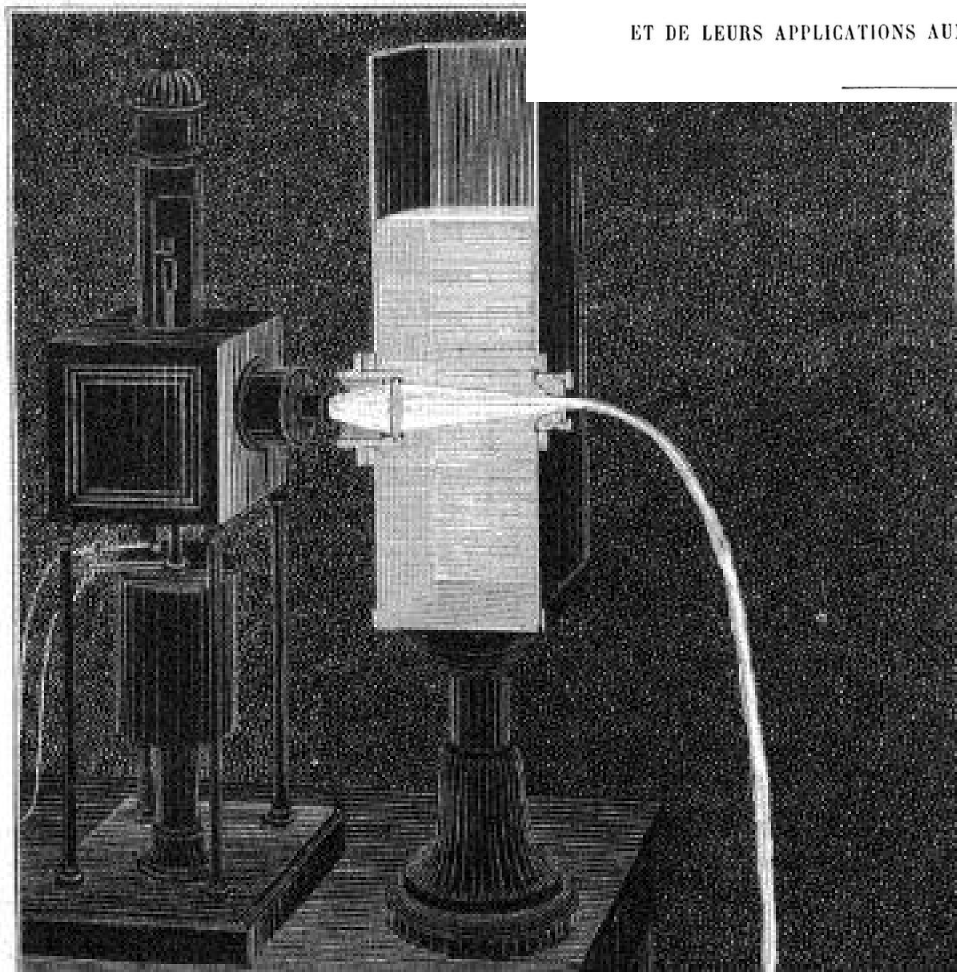
PRÉSIDENCE DE M. PONCELET.

LA FONTAINE COLLADON

RÉFLEXION D'UN RAYON DE LUMIÈRE A L'INTÉRIEUR D'UNE VEINE LIQUIDE PARABOLIQUE

Nous avons récemment publié la description de la remarquable cloche d'eau imaginée par le regretté M. Eugène Bourdon[1]. A cette occasion nous avons parlé de l'appareil de M. Colladon pour faire circuler la lumière en ligne courbe à l'intérieur d'une veine liquide, appareil désigné dans les cabinets de physique sous le nom de fontaine Colladon.

Cet appareil qui a été expérimenté dans bien des pays et même dans des pièces de théâtre, notamment dans *Faust*, à l'Opéra, n'a jamais été représenté, et nous avons pensé que nos lecteurs accueilleraient avec intérêt des documents précis à ce sujet ; nous en avons demandé



des plus belles et des plus curieuses expériences que l'on puisse faire dans un cours d'optique.

12e ANNÉE. — N° 575. 7 JUIN 1884.

LA NATURE

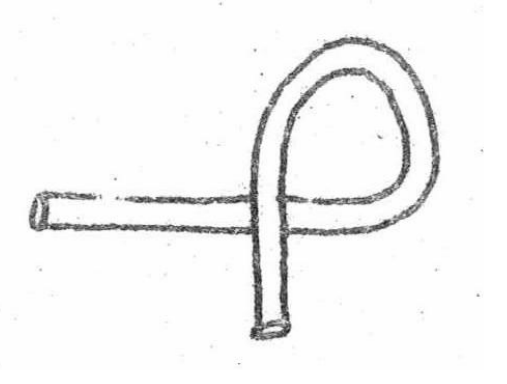
REVUE DES SCIENCES

ET DE LEURS APPLICATIONS AUX ARTS ET A L'INDUSTRIE

intérieurement on perce un trou dans la paroi opposée sur la même direction, on adapte à ce trou une lentille convexe et on ajoute en dehors du vase un tube court, horizontal, noirci à l'intérieur, destiné à empêcher les rayons obliques à l'axe du jet de pénétrer dans le vase. L'appareil est ensuite placé dans une chambre obscure ; un des volets de cette cham-

IYPT history

- **2.** Light guide (3rd YPT, Correspondence Competition, 1981)
  - The properties of light guides are well illustrated by a glass or a plexiglas rod, bent e.g. as shown in the picture. Study the properties of a similar, or a more interesting, light guide made in the school laboratory. Construct a device illustrating or using the properties of a light guide.



Background reading

- Daniel Colladon. Sur les réflections d'un rayon de lumière à l'intérieur d'une veine liquide parabolique. Compte rendu des séances de l'Académie des Sciences (Paris, le 4 juillet 1842), pp. 800-802
- Daniel Colladon. La fontaine Colladon. Réflection d'un rayon de lumière à l'intérieur d'une veine liquide parabolique. La Nature, voy. n° 584 du 9 août 1884, pp. 159-160
- Guiding light and famous fountains (1841-1890.) In: Jeff Hecht. City of Light: The Story of Fiber Optics (New York: Oxford University Press, 1999), pp. 12-27
- Jeff Hecht. Colladon's 'light jet' predates Tyndall's 'light pipe'. Laser Focus World http://www.laserfocusworld.com/articles/258026
- Tyndall's historical experiment. Industrial Laser Optics (2002), http://www.i-fiberoptics.com/educ/Tyndall.pdf
- Jearl Walker. The Amateur Scientist. Scientific American, 254, 120-125 (January 1986)
- D. K. Cohen and J. E. Potts. Light transmission through reflecting cylindrical tubes. Am. J. Phys., 46, 727-728 (1978), http://books.google.com/books?id=_G8B_lU_UHEC

Key questions

- What phenomena may worsen the behavior of the jet as a light guide (jet splitting into droplets? light scattering? absorption? imperfection of the shape where total internal reflection may be locally impossible?) How do they evolve over time? How to describe them quantitatively?
- Why the jet may seem glowing? (internal light scattering? surface light scattering? evanescent radiation? non-scattered rays passing through the surface?)
- Is it worth visualizing possible rays leaving the jet with some smoke? Does the point where it happens really correspond to the limit angle of total internal reflection for the air-water interface?
- What parameters of the liquid may influence the effect (percentage of light scattering particles? refractive index? viscosity and surface tension responsible for the stability of the jet?) Is the jet laminar or turbulent and what are the typical Reynolds numbers?
- What geometrical parameters are relevant? (horizontal and vertical alignment of the beam? radius and position of the outlet? altitude of the vessel?)
- How to compare the input and output light intensity? What further optical properties may be proposed to be determined and what methods might be used to measure them?
- Is it possible to use the system for digital data transmission?
- To what degree the effect is reproducible, if the experiment is repeated? Can important parameters be approached statistically?
- How to arrange the vessel where the jet falls? If any information is transferred via the jet, how to receive it?
- Is it worth modeling the system numerically?
- Above all, what are the physical parameters of your light guide (maximum transmission distance? life time? energy losses? maximum data transfer rate?)

Problem No. 9 “Sticky water”

When a horizontal cylinder is placed in a vertical stream of water, the stream can follow the cylinders circumference along the bottom and continue up the other side before it detaches. Explain this phenomenon and investigate the relevant parameters.

IYPT history

- **10.** Water dome (7th IYPT, 1994)
  - A vertical water jet falls on the butt-end of a cylindrical bar and creates a bell-like water dome. Explain this phenomenon and evaluate the parameters of the dome.

Background reading

- Wikipedia: Coandă effect, http://en.wikipedia.org/wiki/Coandă_effect
- Jean-Louis Naudin. The Coandă effect (JLN Labs, Sept. 26, 1999), http://jnaudin.free.fr/html/coanda.htm
- Video of Coandă efftect by Jean-Louis Naudin (Sept. 26, 1999), http://jnaudin.free.fr/videos/coandvid.rm
- The Coandă effect (from psidot, June 17, 2007, youtube), http://www.youtube.com/watch?v=AvLwqRCbGKY
- Coandă effect (from yutewang, April 27, 2007, youtube), http://www.youtube.com/watch?v=o_-Eph9w6_A
- I. Reba. Applications of the Coandă effect. Scientific American, 214, 84-92 (June 1966)
- J.-M. Vanden-Broeck and J. B. Keller. Pouring flows with separation. Phys. Fluids A 1, 156 (1989)
- M. Reiner. A tea-pot effect. Bulletin of the Res. Council of Israel, 2, 265-266 (Sept. 1952)
- M. Reiner. The teapot effect. . . a problem. Phys. Today, 9, 16-20 (Sept. 1956)
- J. B. Keller. Teapot effect. J. Appl. Phys., 28, 8, 859-864 (1957)
- J. Walker. The troublesome teapot effect, or why a poured liquid clings to the container. The Amateur Scientist. Scientific American, 251, 4, 144-152 (Oct. 1984)
- A. Triboix and D. Marchal. Stability analysis of the mechanism of jet attachment to walls. Int. J. Heat and Mass Transfer, 45, 2769-2775 (2002)
- C. Duez, C. Ybert, C. Clanet, L. Bocquet. Beating the teapot effect. arXiv:0910.3306v1 [cond-mat.soft] 17 Oct 2009

Background reading

- S. F. Kistler and L. E. Scriven. The teapot effect: Sheet-forming flows with deflection, wetting and hysteresis. J. Fluid Mech. 263, 19 (1994)
- Yu. A. Lashkov, I. N. Sokolova and E. A. Shumilkina. Jet flow over ribbed curved surfaces. Fluid Dynamics 27, 1, 1, 135-137 (1992)
- R. Wille and H. Fernholz. Report on the first European Mechanics Colloquium, on the Coandă effect. J. Fluid Mech. 23, 4, 801-819 (1965)
- S. Matsuo, T. Setoguchi, T. Kudo, and Sh. Yu. Study on the characteristics of supersonic Coandă jet. J. Thermal Sci. 7, 3, 165-175 (1998)
- Coandă Effect with a balloon (from PeregrineTCC, March 27, 2007, youtube), http://www.youtube.com/watch?v=oXm7oSdh_X8
- Coandă Effect demonstration of working principle (from bluelightning77 Apr. 11, 2007, youtube), http://www.youtube.com/watch?v=S-SAQtODAQw
- K. Weltner and M. Ingelman-Sundberg. Misinterpretations of Bernoulli's Law (Dpt of Phys., University Frankfurt; Stockholm), http://user.uni-frankfurt.de/~weltner/Mis6/mis6.html
- 7.1 Répartition de pression. Effet Coandă. Dans: Chapitre 7, Ecoulements où la viscosité est négligeable. Laboratoire Hydrodynamique et Mécanique Physique de l'ESPCI, http://www.pmmh.espci.fr/fr/Enseignement/Archives/Cours/Grand_reynolds.pdf
- Joseph Slomski and Tom Marino. Navy successfully simulates effect that may improve low-speed maneuverability. JA Fluent 153 (2002), http://www.fluent.com/solutions/articles/ja153.pdf
- M. M. Alam and Y. Zhou. Fluid dynamics around an inclined cylinder with running water rivulets. Proc. ASME Fluid Eng. Division Summer Conf. 1, 395-405 (2006)

Background reading

- Г. Майер. Липкая струя // Квант, №11, 1977, http://kvant.mirror1.mccme.ru/1977/11/lipkaya_struya.htm
- J.-M. Vanden-Broeck and J. B. Keller. Pouring flows. Phys. Fluids 29, 3958 (1986)
- E. J. Covington. The flow from the spout of a teapot. http://home.frognet.net/~ejcov/teapot.html
- M.-M. Tanasescu. Governing equations, Coandă effect: Fluid dynamics. (Texas Tech University, Dec. 2004), http://www.phys.ttu.edu/~cmyles/Phys5306/Talks/2004/Fluid%20Dynamics.ppt
- Professor spills secret of the dripping teapot. BBC, December 3, 1998. http://news.bbc.co.uk/2/hi/science/nature/227572.stm
- S. Shetty and R. L. Cerro. Spreading of a liquid point source over a complex surface. Ind. Eng. Chem. Res., 37 (2), 626–635 (1998)
- D. J. Long Benney. Waves on liquid films. J. Math. Phys., 45, 150 (1966)
- Sanat A. Shetty and Ramon L. Cerro. Spreading of liquid point sources over inclined solid surfaces. Ind. Eng. Chem. Res., 34, No. 11, 4078 (1995)
- H. S. Kheshgi. The motion of viscous liquid films. PhD thesis at the University of Minnesota, Minneapolis (1984)
- K. Sashaki, M. Iguchi, T. Ishii, and S. Yukoya. The Coandă effect on bubbling jet behind a horizontally placed circular cylinder. Iron Steel Inst Jpn 42, 11, 1196-1202 (2002)
- Flying cylinder (from blindbrick, Dec. 30, 2007, youtube), http://www.youtube.com/watch?v=B8edpSPhMx0
- R. A. Churchill. Coandă effect jet around a cylinder with an interacting adjacent surface. PhD thesis, West Virginia University, Morgantown, VA (1992)

Key questions

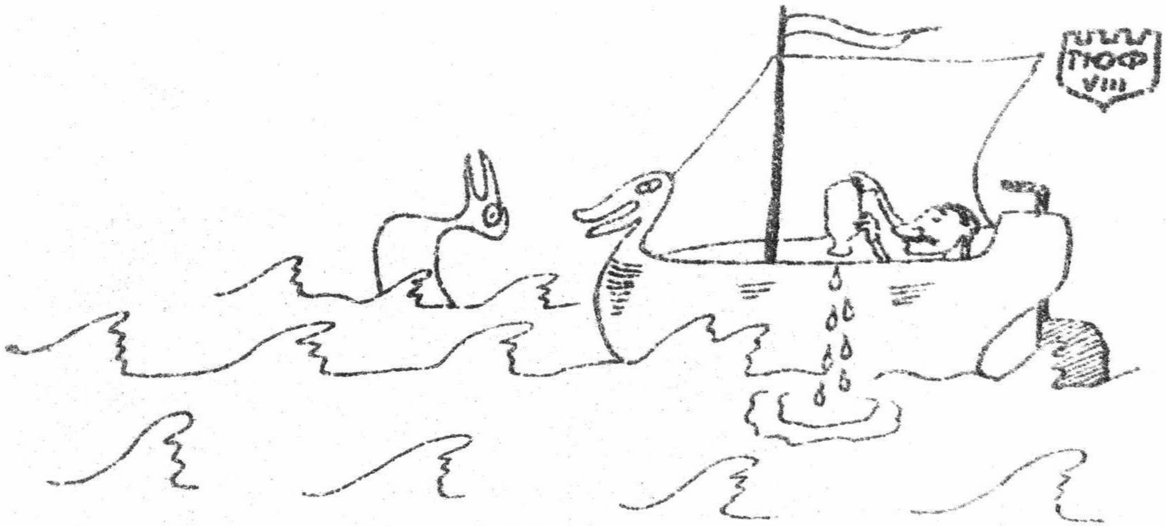
- What is the primary cause of the flow at the other side of the cylinder? Is it due to surface tension, adhesion, or pressure difference at different points due to Bernoulli principle? What points in the flow experience higher pressure due to Bernoulli effect?
- What energy does the jet need to follow the cylinder surface and to separate? On what parameters does this energy depend? Are we interested in increasing or decreasing these energies?
- What part of the cylinder the jet can take off from? Under what conditions the it detaches? At what point the jet is likely to split into droplets? What forces influence the detachment process (capillary? gravitational? viscous? inertial?)
- What is the role of the cylinder material and curvature?
- What is the role of the properties of the liquid (viscosity? density? surface tension?)
- What physical parameters may influence the flow (horizontal displacement of the jet? initial speed or discharge rate for water? diameter of the jet?)
- How to describe the effective trajectory of the liquid and its evolution in time? Is the effect stable? How to describe its stability (statistically? dynamically?) Is it worth taking a long exposure photo of the flow to estimate where the flow becomes time unstable?
- What determines the direction of flow (clockwise/counter-clockwise) if the jet is incident just on the top of the cylinder?
- What are the magnitudes of the Reynolds number for the jet? Is the laminar-turbulent transition relevant? Are any aerodynamic forces relevant to the problem? How significant is air resistance?
- Is it worth modeling the system numerically?
- What new we can add to this profoundly researched problem?

Problem No. 10 “Calm surface”

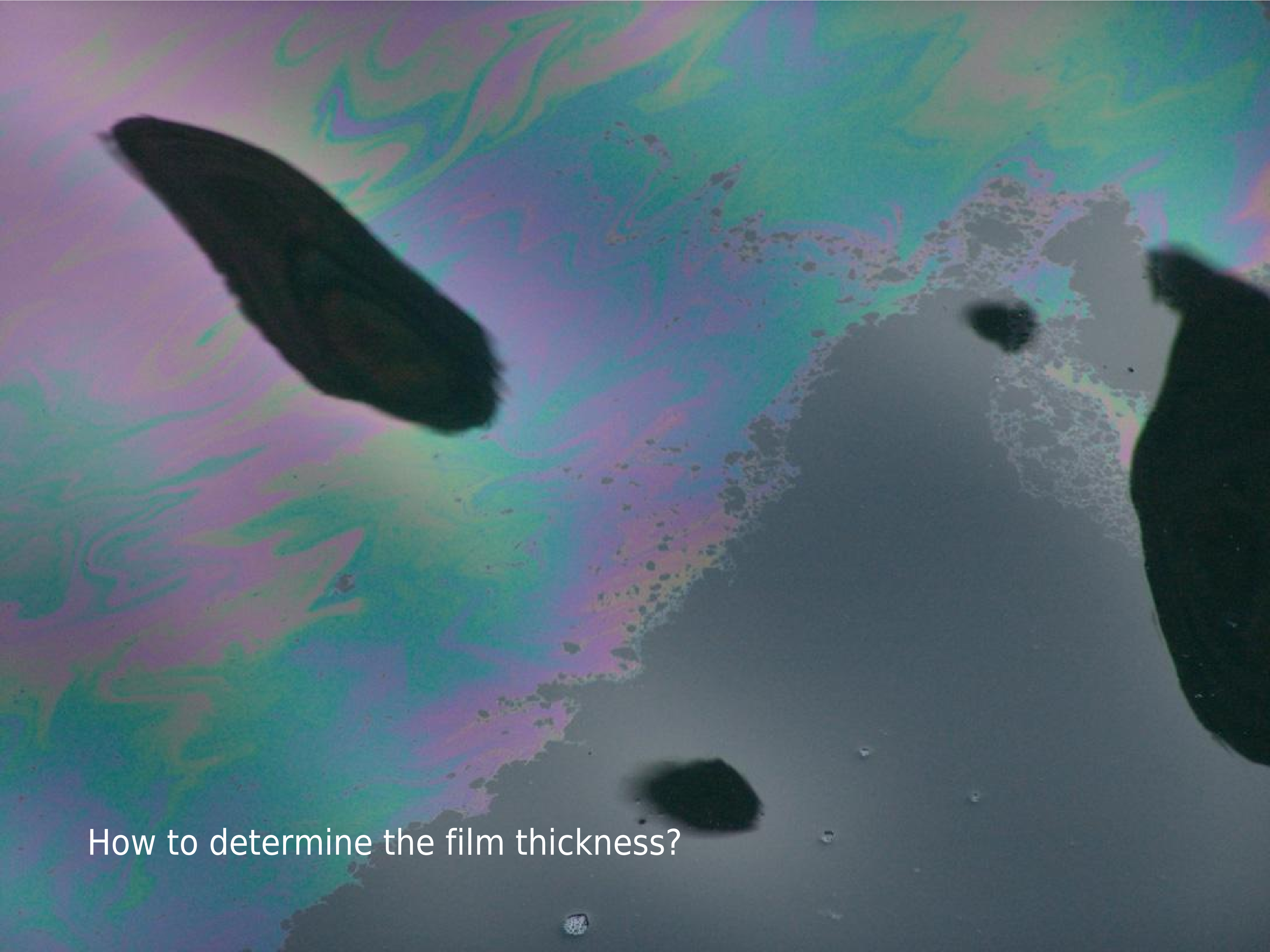
When wind blows across a water surface, waves can be observed. If the water is covered by an oil layer, the waves on the water surface will diminish. Investigate the phenomenon.

IYPT history

- **6.** Oil film (8th YPT, Correspondence Competition, 1986)
  - “In 1757, being at sea in a fleet of ninety-six sail bound against Louisbourg, I observed the wakes of two of the ships to be remarkably smooth, while all the others were ruffled by the wind, which blew fresh. Being puzzled with the differing appearance, I at last pointed it out to our captain and asked him the meaning of it. “ The cooks,” said he, “have I suppose been just emptying their greasy water through the scuppers, which has greased the sides of those ships a little.” And this answer he gave me with an air of some little contempt, as to a person ignorant of what everybody else knew. ” *Benjamin Franklin.*
  - Explain the phenomenon that the scientist noticed. Perform experiments in pouring oil on a troubled water surface.




How to avoid oil droplet aggregation?


How to determine the film thickness?

Background reading

- A. Marcelin. Solutions superficielles: fluides à deux dimensions et stratifications monomoleculaires (Les presses universitaires de France, 1933)
- Baron T. de Wogan. Manuel de l'homme de la mer (Paris, 1894)
- Vizeadmiral G. Cloué. Le filage d'huile sur la mer (Paris, 1887), pp. 34-35, 85
- J. Mertens. The honour of Dutch seamen: Benjamin Franklin's theory of oil on troubled waters and its epistemological aftermath (Feb. 20, 2005), http://www.benfranklin300.org/_etc_pdf/Dutch_Joost_Mertens.pdf
- Oil-on-Water Calming Effect (from psidot, July 21, 2007, youtube), http://www.youtube.com/watch?v=00PPPt7EJqo
- A. Pockels. Surface tension. Nature 43, 437-439 (1891), http://cwp.library.ucla.edu/articles/pockels/pockels.html
- I. Langmuir. The constitution and fundamental properties of solids and liquid. II. Liquids. J. Am. Chem. Soc. 39, 9, 1848-1906 (1917)
- J. C. Scott. The influence of surface-active contamination on the initiation of wind waves. J. Fluid Mech. 56, 3, 591-606 (1972)
- T. Takoshima and A. Masuda. Investigation of fatty acid monolayers at the air-water interface using a reflectance-measuring technique and a phase contrast microscope. Thin Solid Films 210-211, 1, 51-56 (1992)
- L. F. Voss, C. M. Hadad, and H. C. Allen. Competition between atmospherically relevant fatty acid monolayers at the air/water interface. J. Phys. Chem. B 110, 39, 19487–19490 (2006)
- Oil on the Waters (A letter from Benjamin Franklin to William Brownrigg, 1773), http://jcbmac.chem.brown.edu/scissorsHtml/chem/Avogadro/BenFranklin.html
- G. Richmond. From Franklin's Oil-Drop Experiment to Self-Assembled Monolayer Structures (University of Oregon, 2006), http://www2.avs.org/benjaminfranklin/richmond.pdf
- B. R. Rus. Comparative Study of Monolayer Fatty Acids at the Air/Water Interface (Technical University of Cluj-Napoca), http://lejpt.utcluj.ro/A03/111_117.htm

Key questions

- What is a Langmuir layer and can the oil film be considered a Langmuir layer?
- What oil is most promising for forming a stable film? What nanoscale interactions may be responsible for the stability and properties of layer?
- What physical parameters determine that the waves indeed diminished? (maximum or average amplitude? decay rate for the amplitude when the wind stops?)
- How is the surface tension changed after the oil film is placed onto the water? What other parameters beside surface tension are altered? What parameters of the film are relevant? (thickness? surface area?)
- What is the nature of wind-driven waves on water? Are they gravitational or capillary? What forces oppose the waves with and without film? (capillary? gravitational? viscous? inertial?) What physical properties of a water basin influence the waves? (depth in a given point? proximity of walls? shape of a vessel?)
- How do the average wavelengths, amplitudes and surface profiles depend on speed, direction, and stability of airflow?
- What is the primary cause for the changes when the film is formed? Do the presence of film influence on the dynamic damping of waves (decreased amplitude) or on the relaxation behavior (decay rate for the amplitude?) Are any aerodynamic forces relevant to the problem and can the air drag force be smaller due to smoother surface?
- In terms of energy balance, what is the surface energy increase due to Langmuir film in comparison to the decrease of total energy of waves?
- What new we can add to this profoundly researched problem?

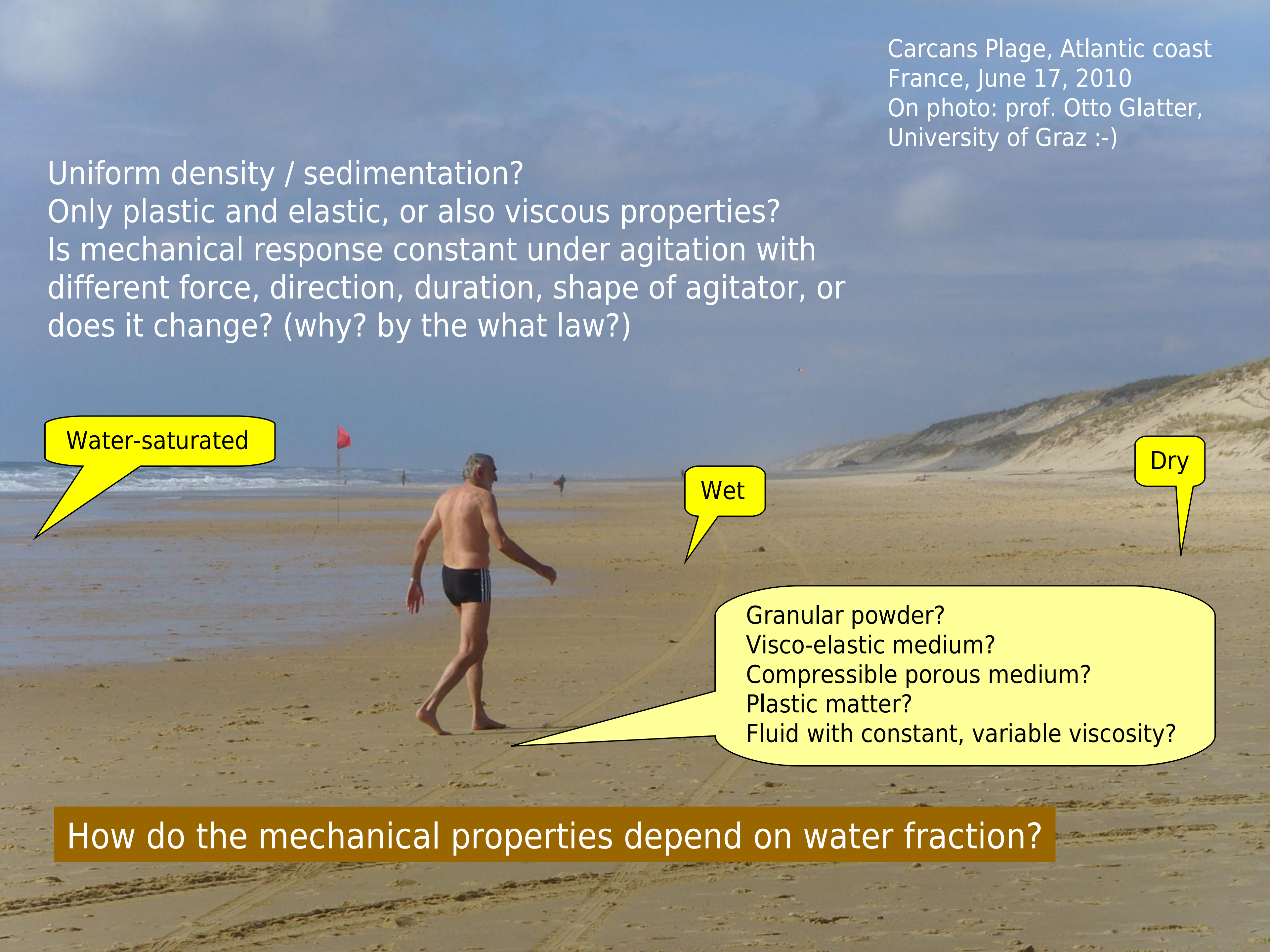
Problem No. 11 “Sand”

Dry sand is rather ‘soft’ to walk on when compared to damp sand. However sand containing a significant amount of water becomes soft again. Investigate the parameters that affect the softness of sand.


Fully dry sand: very soft? very dispersed?


Wet sand: retains deformation? any solid properties?


Water saturated sand: fluid? rapidly sedimenting suspension?


Carcans Plage, Atlantic coast
France, June 17, 2010
On photo: prof. Otto Glatter,
University of Graz :-)
Uniform density / sedimentation?
Only plastic and elastic, or also viscous properties?
Is mechanical response constant under agitation with different force, direction, duration, shape of agitator, or does it change? (why? by the what law?)
Water-saturated
Wet
Dry
Granular powder?
Visco-elastic medium?
Compressible porous medium?
Plastic matter?
Fluid with constant, variable viscosity?
How do the mechanical properties depend on water fraction?

IYPT history

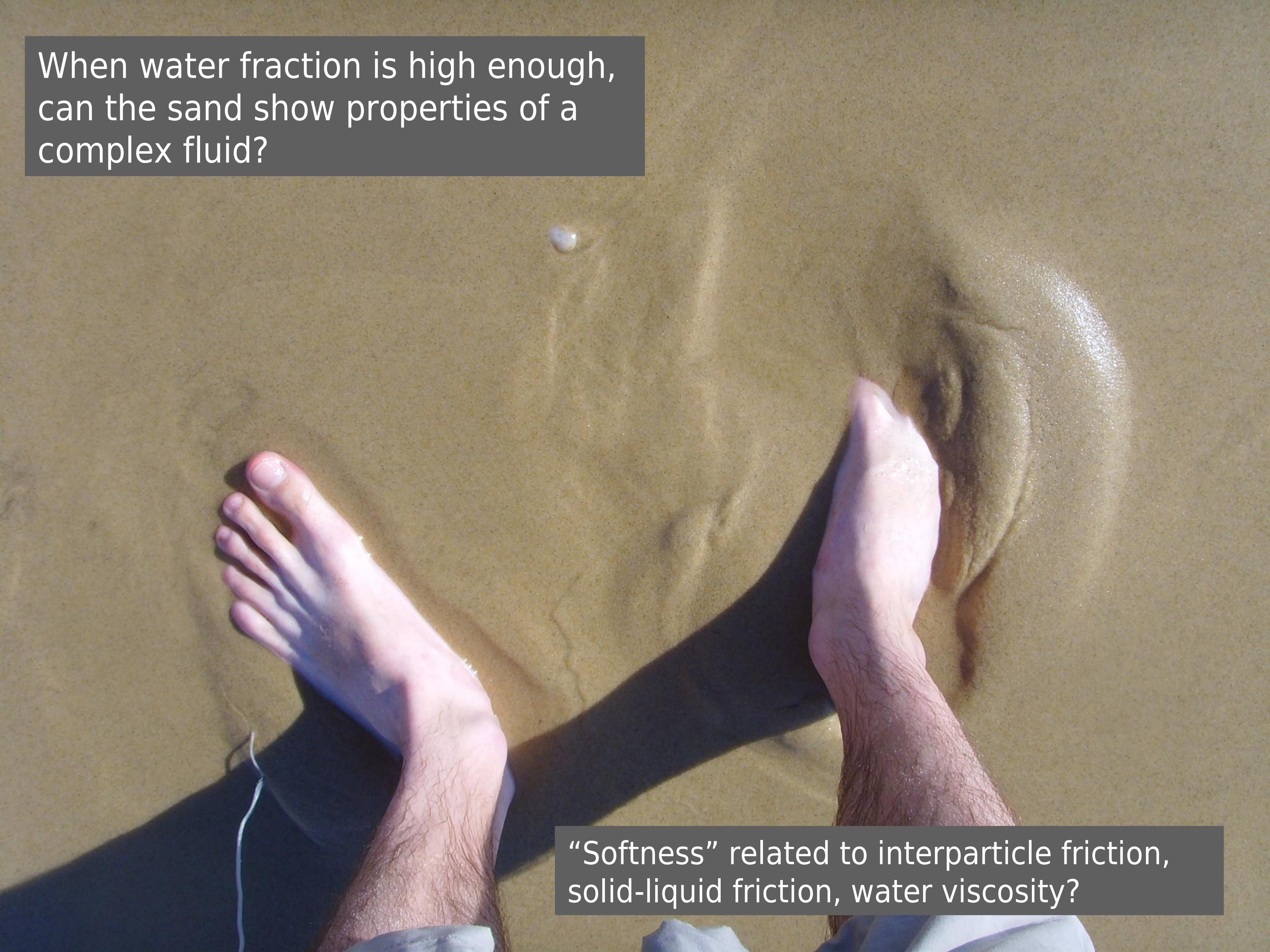
- **8.** Ball and sand (2nd YPT, Correspondence Competition, 1980)
  - Sand is poured onto soil in a thick smooth layer. A steel ball with diameter of *5 cm* falls freely from the height of *1 m*. To what depth the ball will plunge into sand?
- **12.** Sand in a tube (2nd IYPT, 1989)
  - A glass tube is installed vertically and its lower end is tightly closed with a tap. The tube is filled with some sand. In what time *T* the sand will flow out of the tube, when the tap is opened? Study the dependence of the duration *T* on the following parameters: size of sand grains *d*, length of the tube *L*, diameter of the tube *D*. Accept that the sand grains are pressed together at a constant degree — specify and validate this parameter on your own. Don't use an excessively high degree of pressing for being able to compare the results. It is advised to take $10\ cm<L<1\ m$.
- **3.** Dam (5th IYPT, 1992)
  - There is an expression, "money leaks out like water leaks through sand". However, sand dams hold water. What should be the thickness of a dam to hold water if the water level beyond dam is *10 m*.
- **13.** Hard starch (18th IYPT, 2005)
  - A mixture of starch (e.g. cornflour or cornstarch) and a little water has some interesting properties. Investigate how its viscosity changes when stirred and account for this effect. Do any other common substances demonstrate this effect?
- **6.** Rheology (20th IYPT, 2007)
  - It has been said that if you are sinking in soft mud, you should not move vigourously to try to get out. Make a model of the phenomenon and study its properties.

Some mechanical properties of a media

- Plasticity is a property of a material to undergo a non-reversible change of shape in response to an applied force
- Viscosity is a measure of the resistance of a fluid to deform under shear stress
- Elasticity is a property of material to deform under stress and to return to its original shape when the stress is removed
- Creep limit is the maximal stress under which the velocity or the creep deformation doesn’t exceed the fixed value
- Ultimate stress is the maximal stress a material can withstand without fraction
- Yield point is the characteristic of plastic material durability. It’s the stress at which the flowing deformation
- Elasticity limit is stress at which the permanent strain reaches the fixed value


When water fraction tends to zero, can the sand flow until compactization as a soft, dispersed granular powder?
“Softness” related to dispersity, interparticle friction?


When water fraction is low, can the sand show plastic behavior?
“Softness” related to surface tension effects, interparticle friction?


When water fraction is high enough, can the sand show properties of a complex fluid?
“Softness” related to interparticle friction, solid-liquid friction, water viscosity?

Background reading

- The Wet-Sand Effect (from psidot, July 19, 2007, youtube), http://www.youtube.com/watch?v=B_qRh5Y-hO8
- Wikipedia: Sand, http://en.wikipedia.org/wiki/Sand
- I. Peterson. Dry sand, wet sand. Digging into the physics of sandpiles and sand castles. Science News, 152, 12, 186 (Sept. 20, 1997), http://www.sciencenews.org/pages/pdfs/data/1997/152-12/15212-16.pdf
- A. L. Barabási, R. Albert, P. Schiffer. The physics of sand castles: maximum angle of stability in wet and dry granular media. Physica A 266, 366-371 (1999)
- M. D. Dianov, N. A. Zlatin, S. M. Mochalov, G. S. Pugachev, L. K. Rosomakho. Shock compressibility of dry and water-saturated sand. Sov. Tech. Phys. Lett., 2, 207-208 (1976)
- A. D. Resnyansky, N. K. Bourne. Shock compression of dry and hydrated sand. In: M. D. Furnish et al. (eds.) Shock compression of condensed matter. Am. Inst. Phys., Portland (2004), p. 1474–1477
- M. Arlery, M. Gardou, J.M. Fleureau, and C. Mariotti. Dynamic behaviour of dry and water-saturated sand under planar shock conditions. Int. J. Impact Eng., 37, 1, 1-10 (Jan. 2010)
- Daniel Bonn. Les sables mouvants. La conférence organisée par l'École normale supérieure (3 déc. 2005), http://www.savoirs.ens.fr/diffusion/video/2005_12_03_bonn_adsl.zip
- S. Imhoff, A. Pires Da Silva, and D. Fallow. Susceptibility to compactation, load support capacity, and soil compressibility. Soil. Sci. Soc. Am. 68, 17-24 (2004)
- P. L. Barry. The physics of sandcastles (NASA, July 11, 2002), http://science.nasa.gov/headlines/y2002/11jul_mgm.htm

Background reading

- A. Khaldoun, G. Wegdam, E. Eiser and D. Bonn. Quicksand! Europhys. News 37, 4, 18-19 (2006)
- D. C.-H. Cheng. Viscosity-concentration equations and flow curves for suspensions. Chem. and Industry 17, 403-406 (1980)
- B. Clarke. Rheology of coarse settling suspensions. Trans. Inst. Chem. Engrs. 45, 251–256 (1967)
- J. M. F. Fereira and S. M. Olhero. Influence of particle size distribution on rheology and particle packing of silica-based suspensions. Powder Tech. 139, 69–75 (2003)
- S. K. Kawatra and T. C. Eisele. Rheological effects in grinding circuits. Int. J. Miner. Process 22, 251–259 (1988)
- S. Nowak, A. Samadani, and A. Kudrolli. Maximum angle of stability of a wet granular pile. Nature Physics 1, 50-52 (2005), arXiv:cond-mat/0508352v1 [cond-mat.other]
- S. Morrel and I. Stephenson. Slurry discharge capacity of autogenous and semi-autogenous mills and the effect of grate design. Int. J. Miner. Process. 46, 52-72 (1995)
- R. Rutgers. Relative viscosity and concentration. Rheologica Acta, 2, 305-348 (1962)
- F. Shi. Slurry rheology and its effects on grinding. PhD thesis at Julius Kruttschnitt Mineral Research Centre, University of Queensland (1994)
- D. G. Thomas. Transport characteristic of suspension: VIII. A note on the viscosity of Newtonian suspensions of uniform spherical particles. J. Colloid. Sci., 20, 267-277 (1965)
- J. Duran, A. Reisinger. Sands, powders, and grains: An introduction to the physics of granular materials (Springer-Verlag New York, 1999)
- P. Schiffer. A bridge to the sandpile stability. Nature Physics 1, 21-22 (2005), http://physics.clarku.edu/~akudrolli/preprints/newsandviews.pdf

Key questions

- What parameters of sand grains influence on the overall mechanical behavior of the water-sand mixture? (mean size, shape of sand grains? distribution of grains in water suspension? friction coefficient on solid-solid, solid-liquid interfaces? density?)
- What parameters of water (or supernate) influence on the behavior of mixture? (viscosity, surface tension, density?)
- How to take into account possible interactions between grains and water (adherence? interface friction?) and energy losses needed to translate and rotate the grains?
- How to describe the dependence of the mechanical behavior on the liquid/solid fraction? Can observed behavior patterns be classified into various types? Is it relevant to speak of viscous, plastic, elastic, or more complicated properties of the wet sand? What are the stress limits and when transitions between regimes may take place?
- How to characterize sedimentation of the wet sand? Under what conditions the density is uniformly distributed over the volume?
- How does mechanical response depend on intensity, velocity, direction, and time of agitation? Are shear stresses and shear rates the only relevant parameters?
- How does the wet sand interact with the leg (or the agitating body)? Is molecular adherence of supernate to this body relevant? What is the role of the shape of the body?
- What experimental approaches to study wet sand can be developed? Do the parameters that you measure sufficiently characterize the behavior? What ranges for important parameters need to be studied?
- What theoretical models could describe the observed mechanical behaviors?
- Above all, what are your conclusions on the problem?

Problem No. 12 “Wet towels”

When a wet towel is flicked, it may create a cracking sound like a whip. Investigate the effect. Why does a wet towel crack louder than a dry one?

IYPT history

- **1.** Invent yourself — a physical photo contest (3rd IYPT, 1990)
  - Submit to a contest the photographs of a rapidly occurring physical phenomenon. Explain in your commentaries the physical value of these photographs.
- **3.** Paper (10th IYPT, 1997)
  - How does the tensile strength of paper depend on its humidity?

Background reading

- N. Lee, S. Allen, E. Smith, and L.W. Winters. Does the tip of a snapped towel travel faster than sound? Phys. Teach. 31, 376-377 (1993)
- Does the tip of a snapped towel travel faster than sound? (HiViz.com), http://www.hiviz.com/PROJECTS/towel/towel.htm, http://www.hiviz.com/PROJECTS/towel/towel_design.htm, http://www.hiviz.com/PROJECTS/towel/towel_exp1.htm, http://www.hiviz.com/PROJECTS/towel/verify.htm, http://www.hiviz.com/PROJECTS/towel/towel_exp2.htm, http://www.hiviz.com/projects/towel/towel_exp2.htm
- Is the sound of a snapping towel a sonic boom? (Straightdope.com, June 20, 2001), http://www.straightdope.com/columns/read/1930/is-the-sound-of-a-snapping-towel-a-sonic-boom
- Discussion at Physicsforums.com (June 2003), http://www.physicsforums.com/showthread.php?t=2822
- Wikipedia: Whipcracking, http://en.wikipedia.org/wiki/Whipcracking
- Whip cracking mystery explained (Hypography.com, Am. Phys. Soc., May 26, 2002), http://hypography.com/news/physical-sciences/32479.html
- T. McMillen and A. Goriely. Whip waves. Physica D: Natural Phenomena 184, 1-4, 192-225 (2003), http://math.arizona.edu/~goriely/Papers/2003-PhysD(whip-waves).pdf
- A. Goriely and T. McMillen. The shape of a cracking whip. Phys. Rev. Lett. 88, 24, 244301 (2002), http://math.arizona.edu/~goriely/papers/whip.pdf
- Editorial, Why a whip “cracks”. Sci. Am. (April 3, 1915)

Background reading

- M. May. Crackin' Good Mathematics. Am. Scientist 90, 5 (2002)
- J. M. Jones. The crack of a whip. Sci. Am. (July 10, 1915)
- E. E. Larson. Why a whip cracks. Sci. Am. (July 24, 1915)
- У. Брэгг. Мир света, мир звука. — М.: Наука, 1967
- Z. Carrière. Le claquement du fouet. J. Phys. Radium Ser. VI 8, 9, 365-384 (1927)
- Z. Carrière. Exploration par le fouet des deux faces du mur du son. Cahiers de Physique 63, 1-17 (1955)
- Wikipedia: Sonic boom, http://en.wikipedia.org/wiki/Sonic_boom
- B. Bernstein. D. A. Hall, and H. M. Trent. On the dynamics of a bull whip. J. Acoust. Soc. Am. 30, 1112-1115 (1958)
- R. Grammel, K. Zoller. Zur Mechanik der Peitsche und des Peitschenknalles. Z. Phys. 127, 11-15 (1949)
- J&B Whips (France), http://www.jbwhips.com
- P. Krehl, S. Engemann, and D. Schwenkel. The puzzle of whip cracking – uncovered by a correlation of whip-tip kinematics with shock wave emission. Shock Waves 8, 1, 1-9 (1998)
- R. Lehoucq, J. M. Courty et E. Kierlik. Le claquement du fouet. Pour la Science N°285 (Juillet 2001)

Key questions

- Lee *et al*. have demonstrated that dry towels seemingly produce a sonic boom, but their evidence was not exhaustive. What qualitative or quantitative experiments may provide further grounds to validate or invalidate this or other possible explanations?
- What technique of snapping the towel is optimal? What conditions of snapping must be fulfilled to obtain a cracking sound? How does the sound depend of the chosen technique? At what degree the sound is reproducible?
- What are the accelerations of different parts of the towel, and especially its tip? What is the shape of the towel during snapping? How to describe the evolution of the shape? Is there a way to record the these parameters during snapping? At what precise moment the sound is heard?
- How significant is air resistance? Does it influence on the motion of towel? How to describe its influence?
- What is the dependence of the intensity, duration and spectrum of the sound on
  - sizes, aspect ratio, material, surface density of the towel?
  - amount of water in the towel? distribution of moisture across towel?
- How to record the sound and analyze its parameters? What total acoustic energy is produced by the snapping towel? How does it correspond to the mechanical energy of moving towel?
- Do all your conclusions look as a subject to direct experimental proof or disproof? What is a “confirmability” and a “falsifiability” or a physical theory?
- Above all, do wet towels better click than dry towels, and if so, why? What are your practical recommendations for reliably producing a slick?

Problem No. 13 “Shrieking rod”

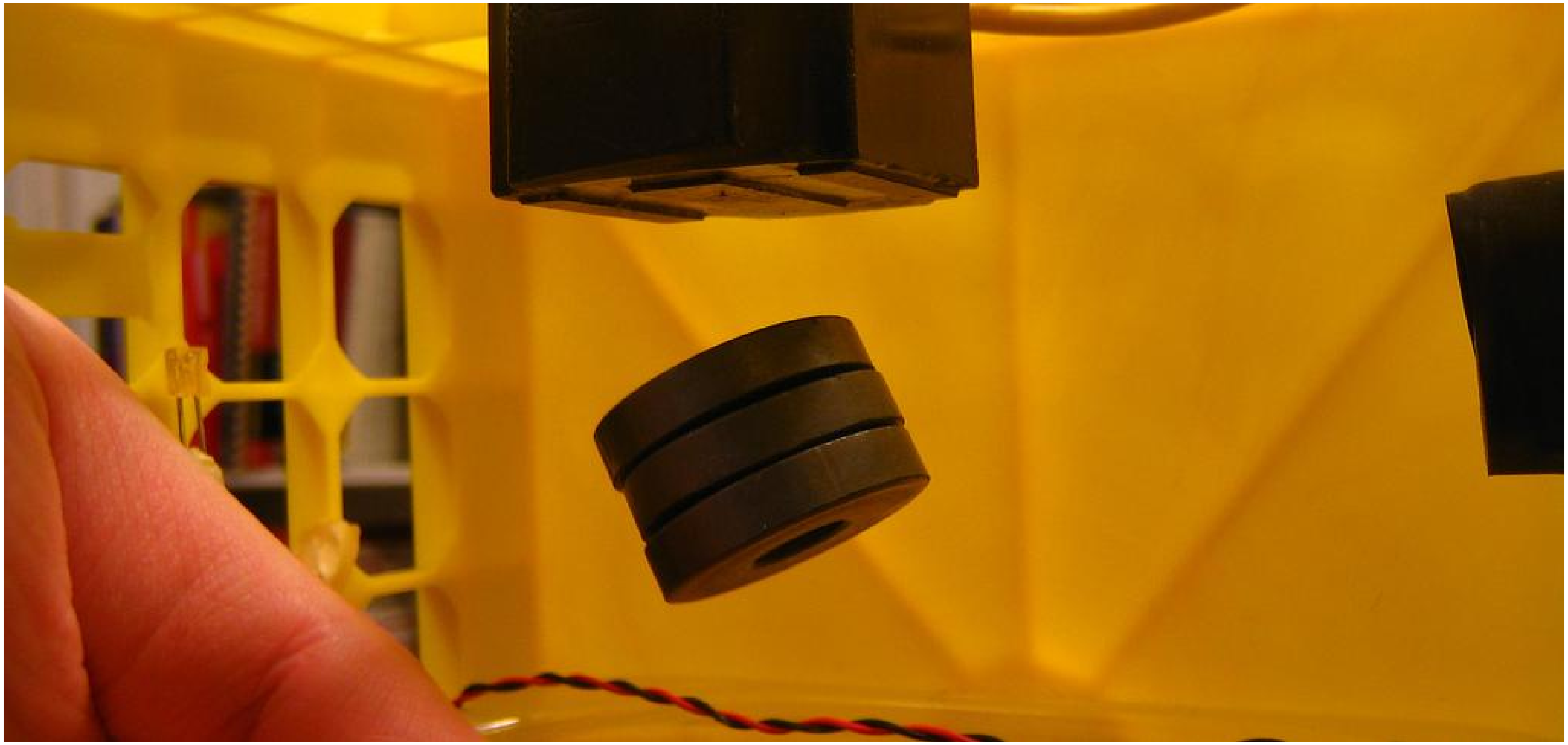
A metal rod is held between two fingers and hit. Investigate how the sound produced depends on the position of holding and hitting the rod?

Background reading

- Lord Rayleigh. The Theory of Sound (London, Macmillan, 1877)
- S. Kumar, H. M. Forster, P. Bailey, and T. D. Griffiths. Mapping unpleasantness of sounds to their auditory representation. J. Acoust. Soc. Am. 124, 6, 3810-3817 (Dec. 2008), http://www.staff.ncl.ac.uk/t.d.griffiths/Kumar_JASA_2008.pdf
- K. Popp. Modelling and control of friction-induced vibrations. Math. Comp. Modelling of Dyn. Syst. 11, 3, 345-369 (Sept. 2005)
- C. M. Jung and B. F. Feeny. Friction-induced vibration in periodic linear elastic media. J. Sound Vibr. 252, 5, 945-954 (16 May 2002)
- C. M. Jung and B. F. Feeny. On the discretization of an elastic rod with distributed sliding friction. J. Sound Vibr. 252, 3, 409-428 (2 May 2002), http://www.egr.msu.edu/~feeny/jsv252junga.ps
- S. V. Belokobyl'skii and V. K. Prokopov. Friction-induced self-excited vibrations of drill rig with exponential drag law. J. Int. Appl. Mech. 18, 12 (Dec. 1982)
- A. Steindl. Stability and bifurcations of rotating stick-slip-separation waves. Proc. 6th Eur. Solid Mech. Conf. 2006, Budapest, Hungary, http://esmc2006.mm.bme.hu/cdproc/S33/250_250.pdf
- Q.-S. Nguyen, A. Oueslati, and A. Lorang. Brake squeal: a problem of dynamic instability and stick-slip-separation waves? Proc. EUROMECH 457 (eds S. Bellizzi et al., Press of the ENTPE, Lyon, 2004), 99-102
- M. Neubauer, C.-C. Neuber, and K. Popp. Control of stick-slip vibrations. IUTAM Symp. on Vibr. Control of Nonlin. Mechanisms and Structures, 130 (2005)
- S. Chatterjee. Non-linear control of friction-induced self-excited vibration. Int. J. Non-Lin. Mech. 42, 3, 459-469 (April 2007)
- The squeal of chalk (experiments on sound made by chalk on blackboard.) Science News (May 11, 1985), http://findarticles.com/p/articles/mi_m1200/is_v127/ai_3769479/?tag=content;col1
- Vibration frequency, 'slip-stick' effect makes wine glasses sing (Ask A Scientist! June 21, 2006), http://www.ccmr.cornell.edu/education/ask/index.html?quid=1143

Key questions

- Above all, what is the cause of the sound? Are the oscillations due to friction of rod with fingers, or a different cause? How are the oscillations generated? What are the stick-slip vibrations?
- What modes of oscillations (torsion? longitudinal? transverse?) of the rod can be observed? What are the fundamental frequencies? Is there a room for theoretical description?
- What determines the positions of nodes and antinodes on the oscillating rod? Are the fingers holding the rod in certain points relevant?
- What parameters describe the sound produced by the rod? Which of them are "physical" and which are "subjective"? (timber? pleasantness? tone color? volume? pitch?) How do they correspond to the fundamental frequency and the upper harmonics?
- What is the spectrum of the produced sound? Is there a possibility for damping of certain harmonics?
- What is the source for the energy of oscillations? Is there a possibility of feedback? Does the rod works as a resonator?
- What parameters of fingers are relevant? (contact area? wet or dry fingers? friction factor?)
- What parameters of the rod are relevant? (elastic properties? density? length? diameter?)
- What is the acoustic impedance and does it influence on the produced sound?
- It seems to be reasonable to record the rod's sound. What should be the requirements for the sound-recording equipment?
- Above all, how the position of holding and hitting the rod influences the sound?



Problem No. 14 “Magnetic spring”

Two magnets are arranged on top of each other such that one of them is fixed and the other one can move vertically. Investigate oscillations of the magnet.

IYPT history

- **1.** Invent yourself (5th IYPT, 1992)
  - The design of future rapid trains includes a “magnetic suspender”. Develop and construct an experimental model of such a suspender.

- **12.** Rolling magnets (19th IYPT, 2006)
  - Investigate the motion of a magnet as it rolls down an inclined plane.

Background reading

- Wikipedia: Magnetic levitation, http://en.wikipedia.org/wiki/Magnetic_levitation
- S. Earnshaw. On the nature of the molecular forces which regulate the constitution of the luminiferous ether. Trans. Cambridge Philos. Soc., 7, 97-112 (1842)
- Calibrating an oscillating magnet in the field of a current carrying coil (Bowling Green State University), http://feynman.bgsu.edu/physics/rm137/expt.2.10-mag.fld/Expt.2.10-intro.html
- R. Edge. Levitation using only permanent magnets. Phys. Teach. 33, 252-253 (1995)
- E. H. Brandt. Levitation in Physics. Science 243, 349-355 (1989)
- M. J. Moloney. Coupled oscillations in suspended magnets. Am. J. Phys., 76, No. 2, 125-128 (February 2008), http://newton.phys.uaic.ro/data/pdf/Oscilatii_cuplate.pdf
- O. I. Gorskii and E. A. Zel'dina. The stability of the vertical oscillations of a body in a dynamic potential well. Int. App. Mech. 36, 10, 1393-1397 (Oct. 2000)
- B. P. Mann and N. D. Sims. Energy harvesting from the nonlinear oscillations of magnetic levitation. J. Sound Vibr. 319, 1-2, 515-530 (Jan. 2009)
- P. Doherty. Magnetic Oscillators. http://www.exo.net/~pauld/summer_institute/summer_day16magnetism/MagneticOscillators/MagneticOscillators.html
- How can you magnetically levitate objects? http://my.execpc.com/~rhoadley/maglev.htm
- A. K. Geim, M. D. Simon, M. I. Boamfa, and L. O. Heflinger. Magnet levitation at your fingertips. Nature 400, 323-324 (1999)
- Y. Kraftmakher. Pendulums are magnetically coupled. Phys. Educ., 43, 248-251 (2008)

Background reading

- B. P. Mann and N. D. Sims. Energy harvesting from the nonlinear oscillations of magnetic levitation. J. Sound Vibr. 319, 1-2, 515-530 (Jan. 2009)
- Magnetic levitation (from Eltimple, April 30, 2007, youtube), http://www.youtube.com/watch?v=icpGonZljvA
- Magnetic levitation (from Wushu17, July 02, 2006, youtube), http://www.youtube.com/watch?v=nWTSzBWEsms
- Magnetic levitation Ferromagnetic diamagnatism (from Eltimple, March 09, 2007, youtube), http://www.youtube.com/watch?v=lsDTSUfH6UI
- Levitation: Glass of Wine (from simerlab, Dec. 23, 2006, youtube), http://www.youtube.com/watch?v=tEu5Qkqw7Tg
- Tori Johnson and Jenna Wilson. Magnetic Levitation (2007), http://www.chem.orst.edu/courses/ch224-6/ch226/2007/Magnetic%20Levitation%20PowerPoint.ppt
- T. Ohji, S. Ichiyama, K. Amei, M. Sakui, and S. Yamada. A new conveyor system based on a passive magnetic levitation unit having repulsive-type magnetic bearings. J. Mag. Magnetic Mat. 272-276, 1, E1731-E1733 (May 2004)
- C. Elbuken, M. B. Khamesee, and M. Yavuz. Eddy current damping for magnetic levitation: downscaling from macro- to micro-levitation. J. Phys. D: Appl. Phys. 39, 3932-3938 (2006)
- G. Genta, C. Delprete, and D. Rondano. Gyroscopic stabilization of passive magnetic levitation. Meccanica 34, 6, 411-424 (Dec. 1999)
- Magnetic Levitation (Georgia State University), http://hyperphysics.phy-astr.gsu.edu/Hbase/solids/maglev.html

Background reading

- Damping of Levitated Magnet Motion (Georgia State University), http://hyperphysics.phy-astr.gsu.edu/hbase/Solids/maglev5.html
- R. F. Post and D. D. Ryutov. The Inductrack: A Simpler Approach to Magnetic Levitation, http://www.askmar.com/Inductrack/1999-9%20Simpler%20Approach.pdf
- M. D. Simon, L. O. Heflinger, and S. L. Ridgway. Spin stabilized magnetic levitation. Am. J. Phys. 65, 286-282 (1997), http://www.physics.princeton.edu/~mcdonald/examples/mechanics/simon_ajp_65_286_97.pdf
- M. D. Simon, L. O. Heflinger, and A. K. Geim. Diamagnetically stabilized magnetic levitation. Am. J. Phys. 69, 6, 702-713 (2001), http://www.physics.ucla.edu/marty/diamag/ajp601.pdf
- M. D. Simon and A. K. Geim. Diamagnetic levitation: Flying frogs and floating magnets (invited). J. App. Phys. 87, 9, 6200-6204 (2000), http://www.physics.ucla.edu/marty/diamag/diajap00.pdf
- T. B. Jones, M. Washizu, and R. Gans. Simple theory for the Levitron. J. Appl. Phys., 82, 883-888 (1997), http://heligone.free.fr/levitron/Levitron_rochester.simple.pdf
- R. F. Gans, T. B. Jonesm and M. Washizu. Dynamics of the Levitron. J. Phys. D. 31, 671 (1998)
- Magnetic Levitation - Science is Fun. http://www.levitationfun.com
- Magnetic Toys. The physics display case in the East Bridge hallway at Caltech, http://www.its.caltech.edu/~atomic/display/displaycase.htm
- M. V. Berry. The Levitron: an adiabatic trap for spins. Proc. Roy. Soc. London, 452 1207-1220 (1996)
- Levitron. http://www.levitron.com/

Background reading

- J. M. McBride. A Toy Story: The Chemical Relevance of Earnshaw's Theorem, and How the Levitron® Circumvents It (Gordon Research Conference on Physical-Organic Chemistry June 29-July 4, 1997), http://www.chem.yale.edu/~chem125/levitron/levitron.html
- Michael V. Berry. Frequently Asked Questions About the Levitron. http://www.lauralee.com/physics.htm
- Mike and Karen Sherlock. The hidden history of the Levitron. http://www.amasci.com/maglev/lev/expose1.html
- Oscillation period of a bar magnet suspended? Yahoo answers (2009), http://answers.yahoo.com/question/index?qid=20091026084159AAhOVYC
- J. Bransky. Superconductivity - A New Demonstration. Phys. Teach. 28, 392 (1990)
- A. M. Wolsky, R. F. Giese and E. J. Daniels. The new superconductors: prospects for applications. Sci. Am. 260, 60 (Feb 1989)
- Mark T. Thompson. Eddy current magnetic levitation: models and experiment. IEEE Potentails 40-46 (2000), http://www.classictesla.com/download/ieee_potentials_2000.pdf
- Donald W. Kerst . Levitated ball. In: Magnetism, Physics Demonstrations (University of Wisconsin-Madison), http://sprott.physics.wisc.edu/demobook/chapter5.htm
- T. Hikihara, F. C. Moon. Chaotic levitated motion of a magnet supported by semiconductor. Phys. Lett. A 191, 3-4, 279-284 (Aug. 1994)
- K. Halbach. Application of permanent magnets in accelerators and electron storage rings. J. App. Phys. 57, 3605 (1985)

Key questions

- What interactions cause the upper magnet to oscillate? How to describe these interactions quantitatively? The task does not specify if permanent or electric magnets are required. What are the opportunities in studying each of these magnets?
- A sight displacement of the upper magnet causes its rotational instability and further attraction to lower magnet due to re-orientation of poles. How to stabilize the system? Can ring-type magnets be helpful?
- Are we violating the task if using a diamagnetic or a ferromagnetic body, or a superconductor? If spinning the upper magnet? If making a potential well to remove horizontal instability of the magnets?
- What are the roles of friction force in suspension, air resistance, or induction heating? What torques experience the magnets and how they influence the friction at suspension? How fast the oscillations decay and how would they look like at minimized energy losses?
- How to measure the magnetic field in the vicinity of the magnets without influencing the system itself?
- What parameters of magnets are relevant? (magnetic moment? mass? moment of inertia?) What other interactions, besides magnetic and gravitational, are relevant?
- What possible oscillatory modes may be observed? How to classify them? What is the potential energy due to gravity in comparison to the potential energy due to magnetic interaction at every moment? How to best record the oscillations? (video?) At what degree the oscillations of both magnets may be reproduced, if the experiment is repeated?
- Is it worth modeling the system numerically?

Problem No. 15 “Paper anemometer”

When thin strips of paper are placed in an air flow, a noise may be heard. Investigate how the velocity of the air flow can be deduced from this noise?

IYPT history

- **11.** Flying colours (15th IYPT, 2002)
  - Why do flags flutter in the wind? Investigate experimentally the airflow pattern around a flag. Describe this behaviour.

Background reading

- C. Eloy, R. Lagrange, C. Souilliez, and L. Schoveiller. Aeroelastic instability of cantilevered flexible plates in uniform flow. J. Fluid Mech., 611, 97-106 (2008)
- B. S. H. Connel and D. K. P. Yue. Flapping dynamics of a flag in a uniform stream. J. Fluid Mech., 581, 33-67 (2007)
- L. Tang and M. P. Païdoussis. The dynamics of two-dimensional cantilevered plates with an additional spring support in axial flow. Nonlin. Dyn., 51, 3, 429-438 (2008)
- J. Zhang, S. Childress, A. Libchaber, and M. Shelley. Flexible filaments in a flowing soap film as a model for one-dimensional flags in a two-dimensional wind. Nature, 408, 835–839 (2000)
- C. Eloy. Instablité multipolaire de tourbillons. Thèse de Doctorat, a l'Université Aix-Marseille II (2000)
- V. V. Vedeneev. High-frequency flutter of a rectangular plate. Fluid Dynamics, 41, 4, 641-648 (2006)
- V. V. Vedeneev. Flutter of a wide strip plate in a supersonic gas flow. Fluid Dynamics, 40, 5, 805–817 (2005)
- A. D. Fitt and M.P. Pope. The unsteady motion of two-dimensional flags with bending stiffness. J. Eng. Math., 40, 227-248 (2001)
- M. T. Morris-Thomas and S. Steen. Experiments on the stability and drag of a flexible sheet under in-plane tension in uniform flow. J. Fluids Structures, 25, 5, 815-830 (July 2009)

Background reading

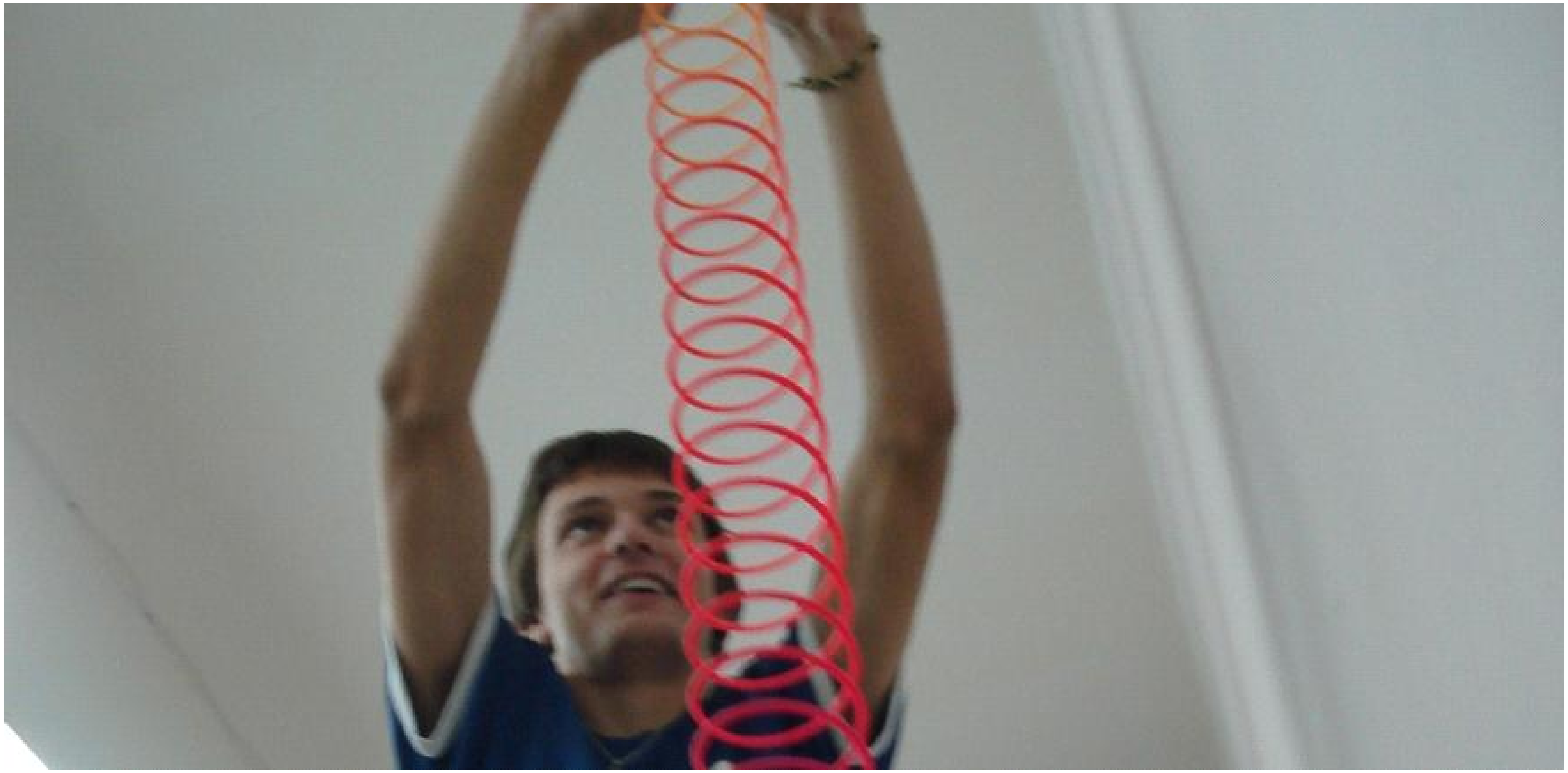
- M. Argentina and L. Mahadevan. Fluid-flow-induced flutter of a flag. Proc. Natl. Acad. Sci., 102, 6, 1829-1834 (2005)
- C. Lemaitre, P. Hémon, and E. de Langre. Instability of a long ribbon hanging in axial air flow. J. Fluids Structures, 20, 913 (2005)
- L. Schouveiler, C. Eloy, and P. Le Gal. Flow-induced vibrations of high mass ratio flexible filaments freely hanging in a flow. Phys. Fluids, 17, 4, 047104.1-047104.8 (2005)
- L. Schouveiler and C. Eloy. Coupled flutter of parallel plates. Phys. Fluids, 21, 081703 (2009)
- C. Eloy, C. Souilliez, and L. Schouveiler. Flutter of a rectangular plate. J. Fluids Struct., 23, 904-919 (2007)
- C. Souilliez, L. Schouveiler, and C. Eloy. Flutter modes of a flexible plate in an air flow. J. Visualization, 9, 242 (2006)
- S. Taneda. Waving motions of flags. J. Phys. Soc. Jpn., 24, 392–401 (1968)
- S.K. Datta. Instability of an elastic strip hanging in an airstream. ASME J. App. Mech., 42, 195 (1975)
- A.C. Carruthers. Aerodynamic drag of streamers and flags. J. Aircraft, 42, 976 (2005)
- S. Alben. The flapping-flag instability as a nonlinear eigenvalue problem. Phys. Fluids, 20, 104106 (2008)
- Y. Watanabe, S. Suzuki, M. Sugihara, and Y. Sueoka. An experimental study of paper flutter. J. Fluids Structures, 16, 4, 529-542 (2002)

Background reading

- L. Tang and M. P. Païdoussis. The influence of the wake on the stability of cantilevered flexible plates in axial flow. J. Sound Vibration, 310, 3, 512-526 (2008)
- N. Yamaguchi, K. Ito, and M. Ogata. Flutter limits and behaviors of flexible webs having a simplified basic configuration in high-speed flow. ASME J. Fluids Eng., 125, 2, 345-353 (2003)
- S. Taneda. Waving motions of flags. J. Phys. Soc. Jpn., 24, 392–401 (1968)
- S. Taneda. Experiment on flow around a waving plate. J. Phys. Soc. Jpn., 36, 1683-1689 (1974)
- L. Huang. Flutter of cantilevered plates in axial flow. J. Fluids Struct., 9, 2, 127-147 (1995)
- D. M. tang, H. Yamamoto, and E. H. Dowell. Flutter and limit cycle oscillations of two-dimensional panels in three-dimensional axial flow. J. Fluids Struct., 17, 2, 225-242 (2003)
- R. Coene. Flutter of slender bodies under axial stress. App. Sci. Res., 49, 2, 175-187 (1992)
- D. G. Crighton and J. E. Oswell. Fluid loading with mean flow. I. Response of an elastic plate to localized excitation. Phil. Trans. R. Soc. A., 335, 557–592 (1991)
- V. V. Vedeneev. High-frequency plate flutter. Fluid Dynamics, 41, 2, 313–321 (2006)
- L. D. Zhu and C. S. Peskin. Simulation of a flapping flexible filament in a flowing soap film by the immersed boundary method. J. Comp. Phys., 179, 2, 452-468 (2002)

Key questions

- Is the problem all about strips fixed at a single end (like a fluttering flag), or at both ends (like a string)?
- What interactions cause the paper strips to flutter? How to describe them?
- What are the oscillatory modes of the strips? What are the expected wavelengths and shapes of strips during fluttering? Are torsion oscillations possible? Are the oscillations stable?
- What are the flow lines for air around paper strips? Can they be visualized in experiments? Is the flow laminar or turbulent and what is the Reynolds number? How do the strips themselves influence on the air flow? Are any vortices induced?
- What additional parameters may be relevant in describing the system? (acoustic pressure? shear stresses?)
- How does the acoustic spectrum depend on
  - lengths, widths, and mechanical properties of the strips?
  - speed, direction and stability of air flow? vector field of velocities in all relevant points?
- Is there a critical air speed so that no fluttering is possible at slower flows? How does the critical speed depend on parameters of the stripes? How and when does the transition between the initial motion and the fluttering take place?
- How to best record the sound of fluttering? Would it be correct to numerically subtract the background noise with no paper strips? What should be the requirements for the sound-recording equipment?
- What aspects of spectrum are most dependant on the speed of flow? Why? Can the sound be classified as ‘noise’ and, if yes, of what type (white? pink? more complicated one?)
- How to deduce the speed of air flow from a given spectrum? What other parameters (such as of stripes) could be also deduced?
- Above all, what are your conclusions on the problem?

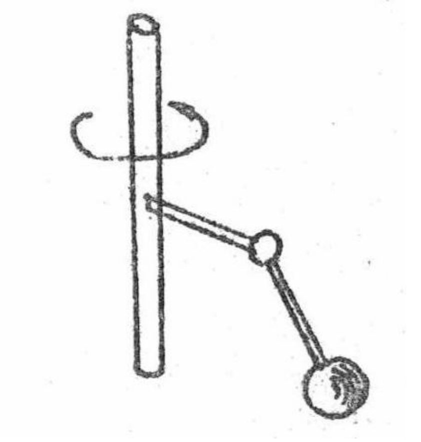


Problem No. 16 “Rotating spring”

A helical spring is rotated about one of its ends around a vertical axis. Investigate the expansion of the spring with and without an additional mass attached to its free end.

IYPT history

- **6.** Centrifugal pendulum (3rd YPT, Correspondence Competition, 1981)
  - An arm of length *l* is started to rotate in horizontal plane up to angular speed ω about the vertical axis passing through its end. A heavy ball is attached to the arm on a thread of length *L*. Find the “equilibrium positions” of the ball and study their stability. Consider the cases of slow and fast rotational acceleration.



- **16.** Elastic pendulum (15th IYPT, 2002)
  - Study and describe the behaviour of a pendulum where the bob is connected to a spring or an elastic cord rather than to a stiff rod.
- **2.** Slinky (20th IYPT, 2007)
  - Suspend a Slinky vertically and let it fall freely. Investigate the characteristics of the Slinky's free-fall motion.

Background reading

- W. J. Goodey. On the natural modes and frequencies of a suspended chain. Quarterly J. Mechanics Appl. Math. 14, 1, 118-127 (1961)
- J.-M. Noël, C. Niquette, S. Lockridge, and N. Gauthier. Natural configurations and normal frequencies of a vertically suspended, spinning, loaded cable with both extremities pinned. Eur. J. Phys. 29, N47-N53 (2008), arXiv:physics/0510026v1 [physics.class-ph]
- H. Bailey. Motion of a hanging chain after the free end is given an initial velocity. Am. J. Phys. 68, 764-767 (2000)
- D. A. Levinson. Natural frequencies of a hanging chain. Am. J. Phys. 45, 680-681 (1977)
- J. P. McCreesh, T. J. Goodfellow, and A. H. Seville. Vibrations of a hanging chain of discrete links. Am. J. Phys. 43, 646-648 (1975)
- R. A. Young. Longitudinal standing waves on a vertically suspended slinky. Am. J. Phys. 61, 353-360 (1993)
- A. B. Western. Demonstration for observing on a resonant vertical J_0 (x) on a resonant vertical chain. Am. J. Phys. 48, 54-56 (1980)
- T. J. Allen and J. R. Schmidt. Vibrational modes of a rotating string. Can. J. Phys. 76, 965-975 (1998)
- M. G. Faulkner, A. Mioduchowski, and J. S. Kennedy. The dynamic behaviour of stiffened strings. Archive of Applied Mechanics 46, 2, 97-103 (1977)
- H. Biezeveld. The bungee jumper: A comparison of predicted and measured values. Phys. Teach. 41, 238–241 (April 2003)

Background reading

- W. J. Cunningham. The physics of the tumbling spring. Am. J. Phys. 15, 348-352 (1947)
- M. S. Longuet-Higgins. On Slinky: The dynamics of a loose, heavy spring. Proc. Cam. Phil. Soc. 50, 347-351 (1954)
- R. Newburgh and G. Andes. Galileo redux or, how do nonrigid, extended bodies fall? Phys. Teach. 33, 586–588 (Dec. 1995)
- Wikipedia: Slinky, http://en.wikipedia.org/wiki/Slinky
- Slinky simple physics. http://www.firstpr.com.au/slinky/
- W. J. Cunningham. Slinky: The tumbling spring, in "Marginali," Am. Scientist 75, 289-290 (1987)
- G. N. Webb and W. J. Cunningham. Origins of Slinky (letters), Am. Scientist 75, 457 (1987)
- D. S. Saxon and A. S. Cahn. Modes of vibration of a suspended chain. Quarterly J. Mechanics Appl. Math. 6, 273 (1956)
- A. G. Pugsley. On the natural frequencies of suspension chains. Quarterly J. Mechanics Appl. Math. 2, 412 (1949)
- T. P. Toepker. Center of mass of a suspended slinky: An experiment. Phys. Teach. 42, 1, 16-17 (Jan. 2004)
- Double Spring 2D (MyPhysicsLab.com), http://www.myphysicslab.com/dbl_spring2d.html
- J. Lee and D. J. Thompson. Dynamic stiffness formulation free vibration and wave motion of helical springs. J. Sound Vibr. 239, 2, 297-320 (2001)

Key questions

- What parameters may be controlled in a certain experiment:
  - initial length, stiffness and mass of the spring?
  - mass of the load?
  - angular speed? angular acceleration?
- What parameters may be measured in the experiment:
  - distribution of spring density, or number of loops per unit length, on coordinate? (measured via photographs?)
  - deviation angle for stable rotation? stability of the motion?
  - transition dynamics, such as the dependence of position and shape of the spring on time?
  - curvature of the spring, and possible oscillatory modes?
  - effective elongation of the spring? 3D trajectory of the mass for non-stable rotation?
  - forces and mechanical tensions in different points of the string?
- Does the spring always follow the Hook's law? Is there a dependence of total elastic force on elongation?
- How exactly the spring may be "rotated"? Is it about forced rotation with a motor, or free rotation after acceleration given to the system? What apparatus may help to best rotate the spring? What are possible suspensions for the upper end (permitting spin around the symmetry axis of the spring, or not)?
- Where is the center of masses of the spring and mass? How does the dynamical displacement of the center of masses influences on the moment of inertia and further stability of rotation?
- How and when do possible transitions of rotational and oscillatory modes take place?
- Is it worth modeling the system numerically? Is it difficult to compile a program having all important parameters as input values?

Problem No. 17 “Kelvin’s dropper”

Construct Kelvin’s dropper. Measure the highest voltage it can produce. Investigate its dependence on relevant parameters.

Background reading

- William Thomson (Lord Kelvin). On a self-acting apparatus for multiplying and maintaining electric charges, with applications to illustrate the voltaic theory. Proc. Royal Soc. London, 16, 67-72 (June 20, 1867), http://www.jstor.org/stable/112474
- Wikipedia: Kelvin's dropper, http://en.wikipedia.org/wiki/Kelvin_water_dropper
- M. Fast. Apparatus for teaching physics: Electrostatic lobby display. Phys. Teach. 10, 2, 100-101 (Feb. 1972)
- C. Bettis. The "ting-a-ling" machine. Phys. Teach. 26, 5, 304-306 (May 1988)
- M. Hill and D. J. Jacobs. A novel Kelvin electrostatic generator. Phys. Educ. 32, 60-63 (1997)
- M. Ziaei-Moayyed, E. Goodman, and P. Williams. Electrical deflection of polar liquid streams: a misunderstood demonstration. J. Chem. Educ. 77, 11, 1520-1523 (Nov. 2000)
- G. K. Vemulapalli and S. G. Kukolich. Why does a stream of water deflect in an electric field? J. Chem. Educ. 73, 9, 887-888 (Sept. 1996)
- M. Zahn. Self-excited ac high voltage generation using water droplets. Am. J. Phys. 41, 2, 196-202 (Feb. 1973)
- G. Planinšič and T. Prosen. Conducting rod on the axis of a charged ring: the Kelvin water drop generator. Am. J. Phys. 68, 12, 1084-1089 (Dec. 2000), http://www.fmf.uni-lj.si/~planinsic/articles/dropcharge.pdf

Background reading

- S. Mak. The Kelvin water-drop electrostatic generator - an improved design. Phys. Teach. 35, 9, 549-551 (Dec. 1997)
- P. Chagnon. Animated Displays VI: Electrostatic motors and water dropper. Phys. Teach. 34, 8, 491-494 (Nov. 1996)
- C. Z. Van Doorn. Demonstration of electrostatic generator principles. Am. J. Phys. 37, 2, 225 (Feb. 1969)
- L. Evans and J. T. Stevens. Kelvin water dropper revisited. Phys. Teach. 15, 9, 548-549 (Dec. 1977)
- M. Sady. The Kelvin water dropper: an elementary experience. Phys. Teach. 22, 8, 516 (Nov. 1984)
- W. Blunk. Doing physics: Kelvin electrostatic generator workshop. Phys. Teach. 20, 6, 412-413 (1982)
- A. D. Moore. Electrostatics (Doubleday & Co., New York), pp. 174-179, 204-211
- J. A. Chalmers. Atmospheric Electricity (2nd ed., Pergamon Press, New York, 1967)
- H. Mason. A text-book on static electricity (McGraw Publishing Co., New York, 1904), 52. The Dropping Generator, pp. 135-137
- H. F. Weiners. Physics demonstration experiments, electrostatics (Ronald Press Co., New York, 1970), pp. 847-850

Background reading

- Lego Kelvin water dropper: a water powered electrostatic generator. http://www.splung.com/content/sid/3/page/lego_kelvin_water_dropper
- Kelvin water drop generator (from apuz011, Apr. 18, 2009, youtube), http://www.youtube.com/watch?v=yDun7ILKrUI
- High voltage from water drops (from ykonik, Jan. 15, 2007, youtube), http://www.youtube.com/watch?v=MR2Quj2isIo
- Kelvin-generator (from jackklute, Jan. 12, 2008, youtube), http://www.youtube.com/watch?v=biWUP1uQHeo
- Kelvin Water Dropper (from glanzman500, May 22, 2007, youtube), http://www.youtube.com/watch?v=rVYBmZ0hUSY
- Lord Kelvins thunderstorm (by BrizzyWiz, Apr. 18, 2009, youtube), http://www.youtube.com/watch?v=hQmAIo6JWMU
- Kelvin water drop at Laboratoire de Physique de la Matière Condensée, Université de Nice (from isalbert, Apr. 14, 2007, youtube), http://www.youtube.com/watch?v=3b23umXzPVA
- Water Levitation - Kelvin Generator (from Damanic84, Sept. 1, 2009, youtube), http://www.youtube.com/watch?v=sX-HbFt456U
- Needed help!!! Kelvin's water drop generator doesn't work!!! (from kubawlo, Sept. 16, 2008, youtube), http://www.youtube.com/watch?v=DVNdM89DgTs
- J. Vanderkooy. An electrostatic experiment of Lord Kelvin with running water. Physics News 52 (Jan. 1984)

Background reading

- http://web.cvcaroyals.org/~rheckathorn/documents/KelvinWaterDropGeneratorPhys13News-Mine.doc
- R. G. Harrison The global atmospheric electrical circuit and climate. Surveys in Geophysics 25, 5-6, 441-484 (Nov. 2004), arXiv:physics/0506077v1 [physics.ao-ph]
- B. Beaty. "Kelvin's Thunderstorm“: Lord Kelvin's water-drop electrostatic generator (amasci.com, 1995), http://amasci.com/emotor/kelvin.html, http://www.eskimo.com/~billb/emotor/kelvin.html
- Kelvin water dropper (Swarthmore College), http://www.swarthmore.edu/NatSci/physics/demos/Kelvin_dropper.html
- Wayne Plummer. Sparking Buckets. http://homepage.ntlworld.com/plummer/wayne/sparkingbuckets.html, http://bizarrelabs.com/buckets.htm
- The Kelvin water dropper (Electricity and magnet playwiths), http://members.ozemail.com.au/~macinnis/scifun/elecmag.htm
- William Beaty. An in-line waterdrop electrostatic generator (amasci.com, 1996), http://amasci.com/emotor/ikelv.html
- Product information: Lord Kelvin’s water drop experiment demonstrator (Science Kit), http://sciencekit.com/ig0020117/p/IG0020117/
- Lord Kelvin’s water-drop electrostatic generator (Evergreen State College, Feb. 1, 2005), http://academic.evergreen.edu/curricular/energy0405/students/waterdopr.ppt

Background reading

- Kelvin water dropper induction device (University of Melbourne, 2006), http://lecturedemo.ph.unimelb.edu.au/Electrostatics/El-7-Kelvin-Water-Dropper-Induction-Device
- C. L. Strong. The Amateur Scientist. Sci. Am., 175 (June 1960)
- Walter Lewin. Lecture 10 on Electricity and Magnetism at MIT during Spring 2002 (from MIT, Jan. 7, 2008, youtube), http://youtube.com/watch?v=RQX8I9ZWtPQ
- Kelvin's Thunderstorm - Create lightning from water and gravity! (instructables.com), http://www.instructables.com/id/Kelvin_s-Thunderstorm---Create-lightning-from-wate/
- What is Kelvin's Thunderstorm? http://www.kelvinsthunderstorm.com/what-is-kelvins-thunderstorm/
- Kelvin's Thunderstorm. http://www.mpoweruk.com/homebrew.htm#kelvin
- B. Beaty. Kelvin's thunderstorm or Kelvin's water-drop electrostatic generator (newphys.se), http://www.newphys.se/fnysik/3_1/kelvin/index.html
- Water drop electrostatic generator (linux-host.org), http://www.linux-host.org/energy/bkelv1.htm
- Water drop electrostatic generator (Research Triangle at geocites), http://web.archive.org/web/20021019002345/http://www.geocities.com/ResearchTriangle/Lab/1135/kelv1.htm

Background reading

- What factors affect the voltage produced by a Kelvin's Dropper? Discussion at Naked Scientists (2009), http://www.thenakedscientists.com/forum/index.php?topic=25985.msg278528
- Lord Kelvin electrostatic generator. A Scorpacuda Presentation (July 2007), http://www.scorpacudas.com/2007Files/2007Research_LordKelvin.ppt
- Hagen Schmidt. Quantitative Ladungsmessung am Kelvingenerator (Belegarbeit, Hochschule für Technik, Wirtschaft und Kultur Leipzig, 19.02.2006), http://home.arcor.de/GDN2/Seiten/Publikationen/quant_ladungsm_am_kelvingen.pdf
- D. Göring, S. Peterhänsel, J. Reinhard, C. Scholz, M. Spanner, R. Wiegner. Bau eines Kelvisgenerators (Protokoll, Friedrich-Alexander-Universität Erlangen-Nürnberg, Physikalisches Institut, 2005), http://pp.physik.uni-erlangen.de/groups/ws0506/ppg7/pdf/Kelvingenerator.pdf
- Jan Treiber. Der Kelvingenerator (Technische Universität Ilmenau), http://get-16.e-technik.tu-ilmenau.de/taskweb/daten/kelvin1.rm
- Cała Polska buduje generator Kelvina: Polsko-Ukraiński Konkurs Fizyczny “Lwiątko”, 2007. Artykul Krzysztofa Tabaszewskiego, http://www.lwiatko.org/kelvin/generator_kelvina.pdf, relacje http://www.lwiatko.org/index.php?opt=5&kelv=1
- Ivan Publishuk. Электричество из воды — капельный генератор Кельвина // watta.ru, http://watta.ru/opyityi/elektrichestvo-iz-vodyi-kapelnyiy-generator-kelvina.html

Key questions

- Which of Kelvin generator's variants are optimal to implement in practice? How to best assemble such devices? What conditions are necessary for operation of the dropper? Above all, what is the physical cause for the generated voltage?
- What physical parameters of droplets influence the generated voltage (average droplet size? speed or discharge rate? single droplets or spray? conductivity of liquid? distances between droplets and important parts of the generator?)
- What physical parameters of cans influence the generated voltage? (capacitance determined by radius, length, shape, material? roughness?)
- What ambient physical conditions may directly influence on the physical processes in the generator? (humidity of the air? presence of microparticles that increase conductivity?)
- When and under what conditions the voltage breakdown appears?
- What is the Kelvin generator's efficiency in comparison to more widespread electric generators? What limits its efficiency?
- What is the total energy of air droplets in comparison to output electric energy? Is a reverse effect with accelerating water droplets by electricity possible?
- Would it be difficult to develop a theory for the dropper predicting the output voltage and including all relevant parameters as tunable variables? Is it worth modeling the system numerically? Can such models be directly compared with experiments?
- Does the generator age with time? (leakage currents? air ionization or growing humidity?)
- Kelvin droppers are profoundly researched. What new we can add to this problem?

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

To work towards results?

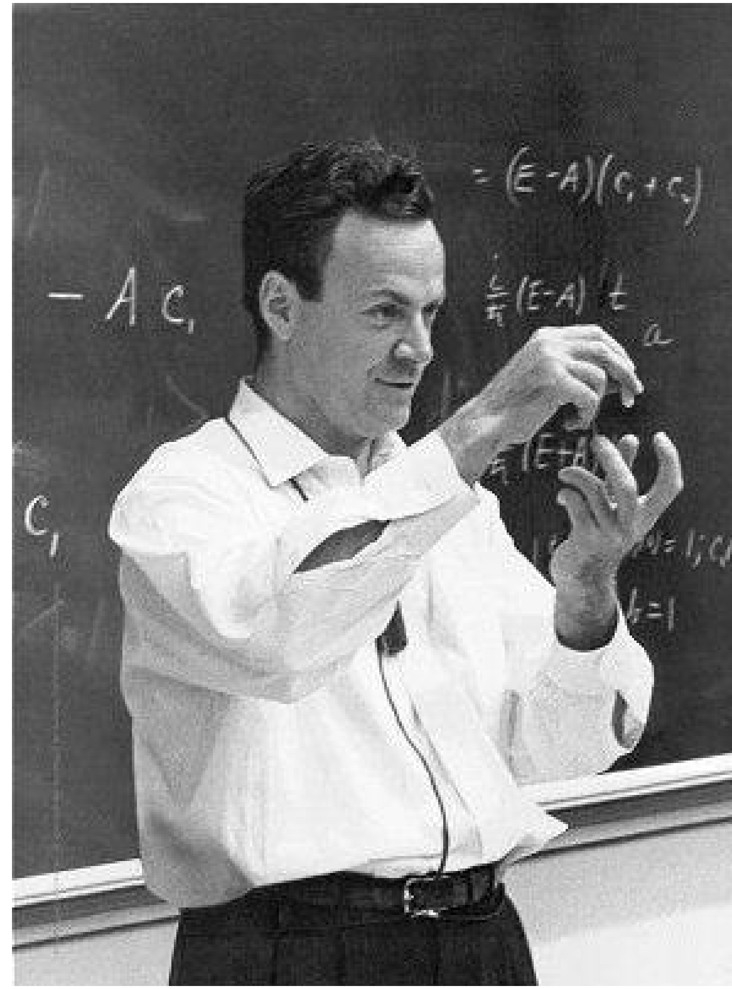
- Nobody needs an infinitely perfect report in an infinite time!

- 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)

Preparation to 23rd IYPT' 2010:

questions, references and advices

Ilya Martchenko,
Université de Fribourg

ilyam.org ilya.martchenko@unifr.ch

July 31, 2009...July 16, 2010

Proceeded in Fribourg, Geneva, Zürich, Villigen (CH), Kraków, Warsaw (PL), Český Těšín (CZ), St Petersburg (RU), Copenhagen (DK), Saint-Genis-Pouilly, Bordeaux, Bombannes (FR), Frankfurt, Munich, Düsseldorf (DE), Minsk (BY), Amsterdam (NL), Leoben (AT), Madrid, Granada, Córdoba (IS) :-)

Gathering the IYPT history: You can help

In the rush of the growth of the competition, the opportunities for maintaining the archives of the earliest YPTs and IYPTs were sometimes neglected.

The considerable interest that the today's IYPT community has in the history of the competition has motivated the author and his colleagues to start investigating the details of early IYPTs and Soviet-based YPTs and locating original documents, proceedings, problems, results, and information on participants. Quite naturally, many of these materials were not written in English or in Russian, but in local languages of participants. (Documents in over ten languages are now on the list.)

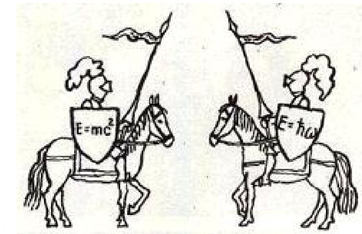
As of 2010, our research priorities are

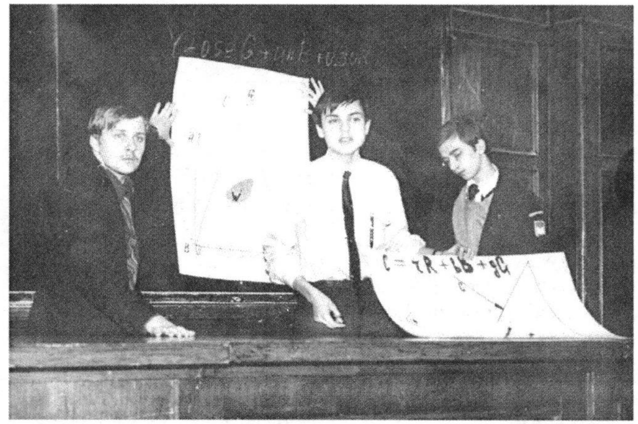
1. to trace, proofread, and translate the problems for 1979 - 1987 and 1988 - 1993 into English,
2. to locate information on teams and results in 1979 - 1987 and 1988 – 1993, and
3. to clarify how the regulations and the typical research projects of the Tournament evolved since 1979.

Plans exist to catalogue the growing archives online. Any contributions from the readers on early IYPTs are warmly welcomed.

The Dutch team at the third IYPT (1990), among the first active Western European participants, having joined in 1989

Evgeny Yunosov and a team captain from the Moscow School 47 during the first IYPT (1988)





Participants from Moscow School 710 make a presentation in 1988 with visual aids typical of the time period

You can help :-)

A discussion-based Physics Fight at the third IYPT (1990)

World Gifted 29, 1, 13-15 (2010)