Preparation to the Young Physicists' Tournaments' 2014

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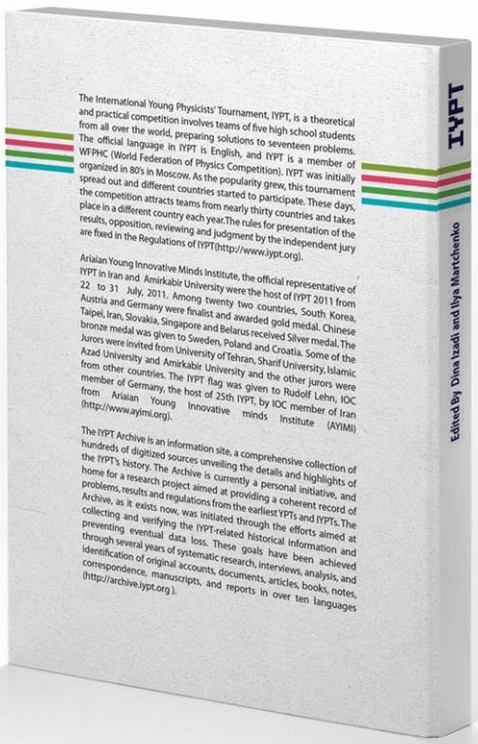
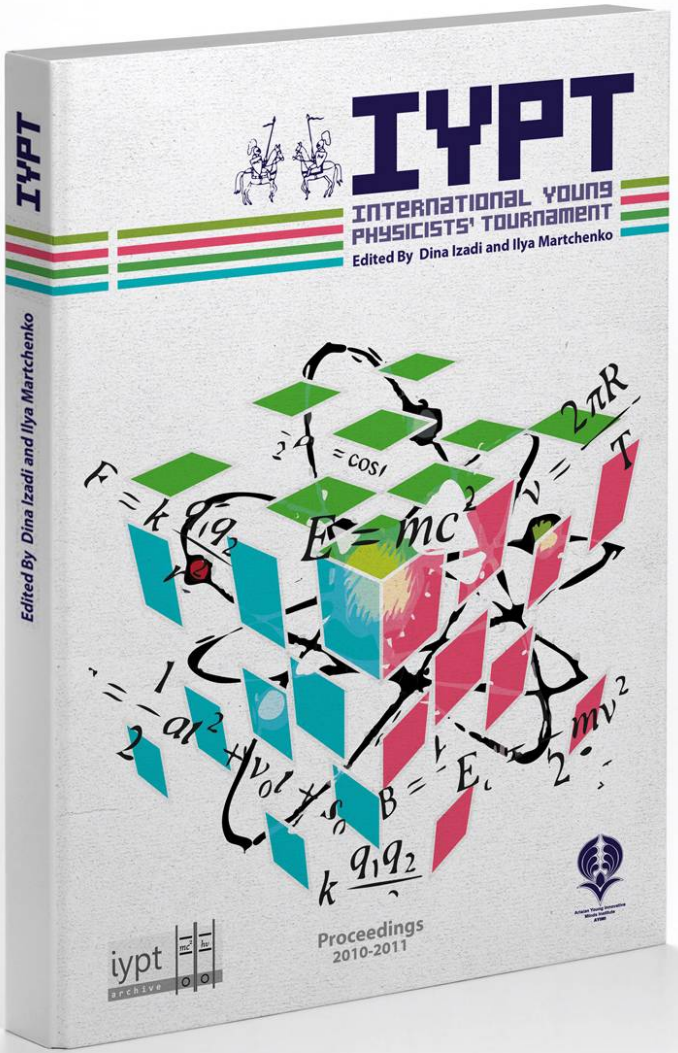




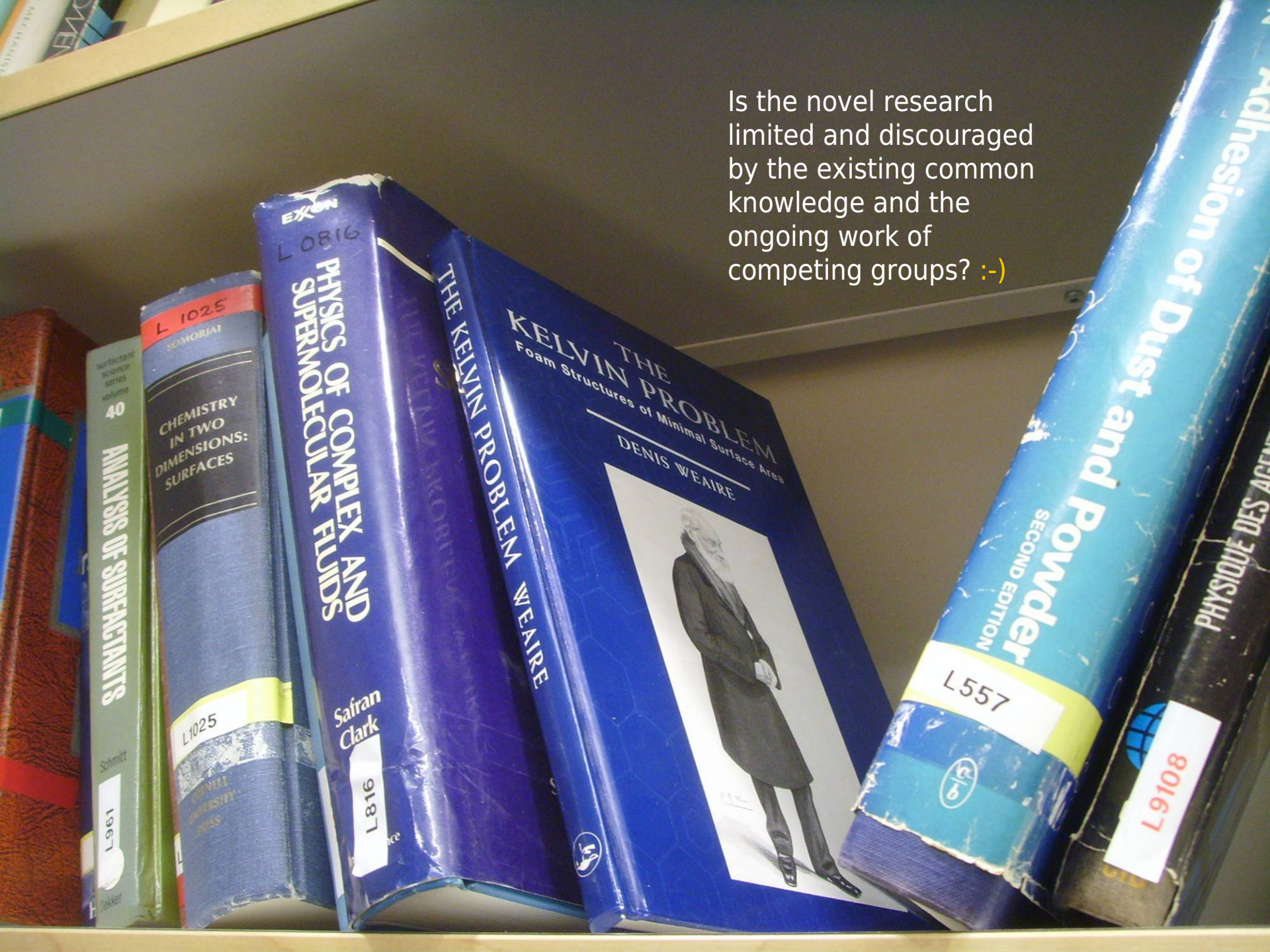
- the first IYPT-themed book where all articles underwent rigorous peer review
- 98 reviews from 25 reviewers
- 32 papers selected
- revisions, resubmissions before getting accepted

Missing!

- The IYPT Archive is missing the names of the UK team members at the IYPT 1991. **Please help!**

- all members were from Hills Road Sixth Form College in Cambridge;
- team leader was Stephen Martin, and one member's first name was Claudia;
- an article might have been published in an HRSFC's magazine or in the Principal's report to the governors;
- some members, including Claudia, are seen on Russian participant Sergey Romanchuk's photos

http://archive.iypt.org/people/#1991


Is the novel research limited and discouraged by the existing common knowledge and the ongoing work of competing groups? :-)
L 0816
PHYSICS OF COMPLEX AND SUPERMOLECULAR FLUIDS
Safran
Clark
L816
THE KELVIN PROBLEM
Foam Structures of Minimal Surface Area
DENIS WEAIRE
THE KELVIN PROBLEM WEAIRE
L 1025
SOMORJAI
CHEMISTRY IN TWO DIMENSIONS: SURFACES
L1025
Surfactant Science Series volume 40
ANALYSIS OF SURFACTANTS
Schmitt
L961
Powder and Dust
SECOND EDITION
L557
L9108

How to tackle the IYPT problems?

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

- Look through the historical solutions in the Archive :-)
  - an opportunity for goal-oriented critical learning
  - examples, not guidelines
  - those solutions were good, but yours should be better!

iypt archive mc^2 hv

Important information

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

Habits and customs

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

These problems have no solution?

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

Arkady Strugatsky and Boris Strugatsky

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

Requirements for a successful IYPT report

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

The jury would like to understand...

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

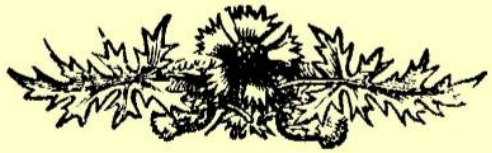
The ultimate response to all "What for?"-questions:

" If we knew what we were doing,
it wouldn't be called research! "

Albert Einstein

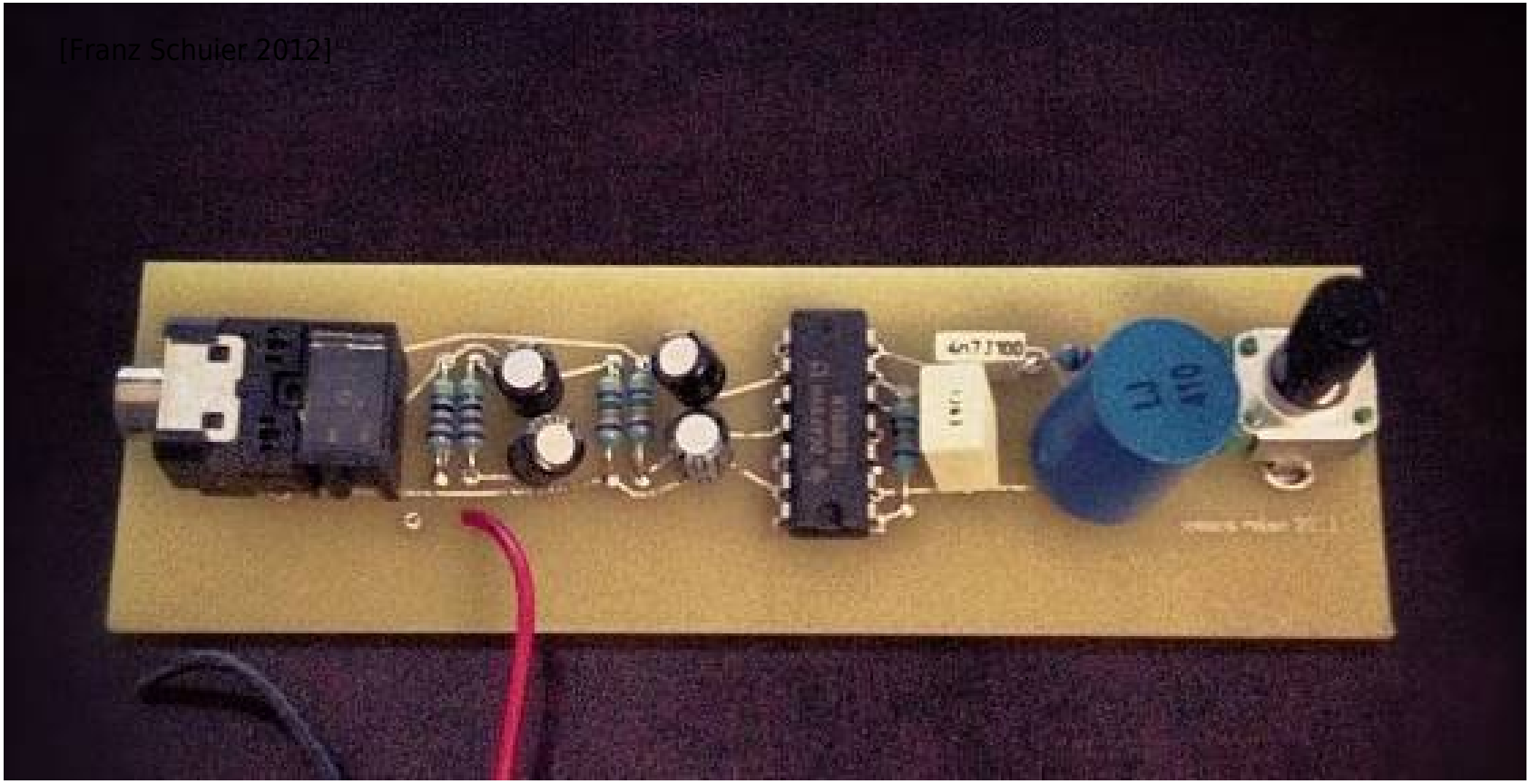
Бросая въ воду камешки, смотри на круги, ими образуемые;
—иначе такое бросаніе будетъ пустою забавою.

Козьма Прутковъ *



* “When throwing pebbles into water, watch the ripples;
otherwise throwing the pebbles becomes a futile pastime.”
Kozma Prutkov

// The epigraph for the problems selected
by the IYPT Founder Evgeny Yunosov on July 5, 2013
// Translated from the Russian



Problem No. 1 “Invent yourself”

It is known that some electrical circuits exhibit chaotic behaviour. Build a simple circuit with such a property, and investigate its behaviour.

Background reading

- Wikipedia: Chua's circuit, http://en.wikipedia.org/wiki/Chua%27s_circuit
- H. G. Schuster and Wolfram Just. Deterministic Chaos: An Introduction (Wiley, 2006), http://books.google.com/books?id=9y2qSGpQR7QC, ftp://84.237.21.152/pub_archive/kolhoz/P_Physics/PNc_Nonlinear%20chaos/Schuster%20H.G.%20Deterministic%20Chaos..%20An%20Introduction%20(Wiley-VCH,2004)(ISBN%203527404155)(299s)_PNc_.pdf
- Bifurcation of Chua's Circuit (youtube.com, from wushuohao, 10.09.2009), http://youtu.be/9RPfuoVRakM
- 電子回路（Chua 回路）で観測される分岐現象（youtube.com, from IkeguchiLab, 04.11.2010), http://youtu.be/B4Zl1llJ5RA
- E. R. Hunt and G. Johnson. Keeping chaos at bay. IEEE Spectrum 30, 11, 32-36 (1993)
- Steven M. Anlage, Vassili Demergis, Ed Ott, Tom Antonsen. RF Upset and Chaos in Circuits: Basic Investigations (University of Mariland), http://www.ireap.umd.edu/MURI-2001/AFOSRvisit-021706/Anlage%20Circuit%20Chaos%20AFOSR%20Feb%202006.pdf
- T. L. Carroll and L. M. Pecora. Nonlinear Dynamics in Circuits (World Scientific, 1995), http://www.google.pl/books?id=WQclcII0c2kC
- G. Chen and T. Ueta. Chaos in Circuits and Systems (World Scientific, 2002), http://books.google.pl/books?id=kzdb6pOK1HAC
- G. Q. Zhong and F. Ayrom. Periodicity and Chaos in Chua's Circuit. IEEE Trans. Circuits Syst. 32, 5, 501-503 (1985)
- L. O. Chua. Chua's Circuit: Ten Years Later. Int. J. Circuit Theory and App. 22, 4, 279–305 (1994)
- L. O. Chua. Chua's Circuit: Ten Years Later. IEICE trans. fundam. electronics, communic., computer sci. 77, 11, 1811-1822 (1994), http://www.eecs.berkeley.edu/~chua/papers/Chua94.pdf
- L. O. Chua, L. Kocarev, K. Eckert, and M. Itoh. Experimental Chaos Synchronization in Chua's Circuit. Int J. Bifurcation Chaos 2, 3, 705-708 (1992)

Background reading

- R. N. Madan. Chua's Circuit: a paradigm for chaos (World Scientific, 1993)
- L. O. Chua, C. W. Wu, A. Huang, and G. Q. Zhong. A universal circuit for studying and generating chaos. I. Routes to chaos. IEEE Trans. Circuits Syst. 40, 10, 732-744 (1993)
- Leon O. Chua, Makoto Itoh, Ljupco Kocarev, and Kevin Eckert. Choas synchronization in Chua's circuit. J. Circuit Syst. Comp. 3, 1, 93-108 (1993)
- J. C. Sprott. A new class of chaotic circuit. Phys. Lett. A 266, 1, 19-23 (2000)
- A. Namajunas and A. Tamasevicius. Modified Wien-bridge oscillator for chaos. Electronics Lett. 31, 5, 335-336 (1995)
- L. Flegar, D. Fischer, and D. Pelin. Identification of chaos in a ferroresonant circuit. Proc. Int'l Conf. on Electr. Power Eng. (Budapest, 1999)
- M. P. Kennedy. Chaos in the Colpitts oscillator. IEEE Trans. Circuits Syst. I: Fundam. Theory Appl. 41, 11, 771-774 (1994)
- T. L. Carroll and L. M. Pecora. Synchronizing chaotic circuits. IEEE Trans. Circuits Syst. 38, 4, 453-456 (1991)
- T. L. Carroll and L. M.Pecora. Synchronization in Chaotic Systems. Phys. Rev. Lett. 64, 8, 821-825 (1990), http://www.csee.wvu.edu/~xinl/library/papers/physics/pecora1990.pdf
- K. M. Cuomo and A. V. Oppenheim. Circuit Implementation of Synchronized Chaos with Applications to Communications. Phys. Rev. Lett. 71, 1, 65-68 (1993), http://www.rle.mit.edu/dspg/documents/CircuitImplementation.pdf
- L. O. Chua, Y. Yao, and Q. Yang. Generating randomness from chaos and constructing chaos with desired randomness. Int. J. Circuit Theory App. 18, 3, 215-240 (1990)
- F. Salam and S. S. Sastry. Dynamics of the forced Josephson junction circuit: The regions of chaos. IEEE Trans. Circuits Syst. 32, 8, 784-796 (1985)
- L. O. Chua. The Genesis of Chua's Circuit. AEUe 46, 4, 250-257 (1992), https://www-inst.cs.berkeley.edu/~ee129/sp10/handouts/GenesisChuasCircuit.pdf

Problem No. 2 “Hologram”

It is argued that a hologram can be hand made by scratching a piece of plastic. Produce such a ‘hologram’ with the letters ‘IYPT’ and investigate how it works.

Background reading

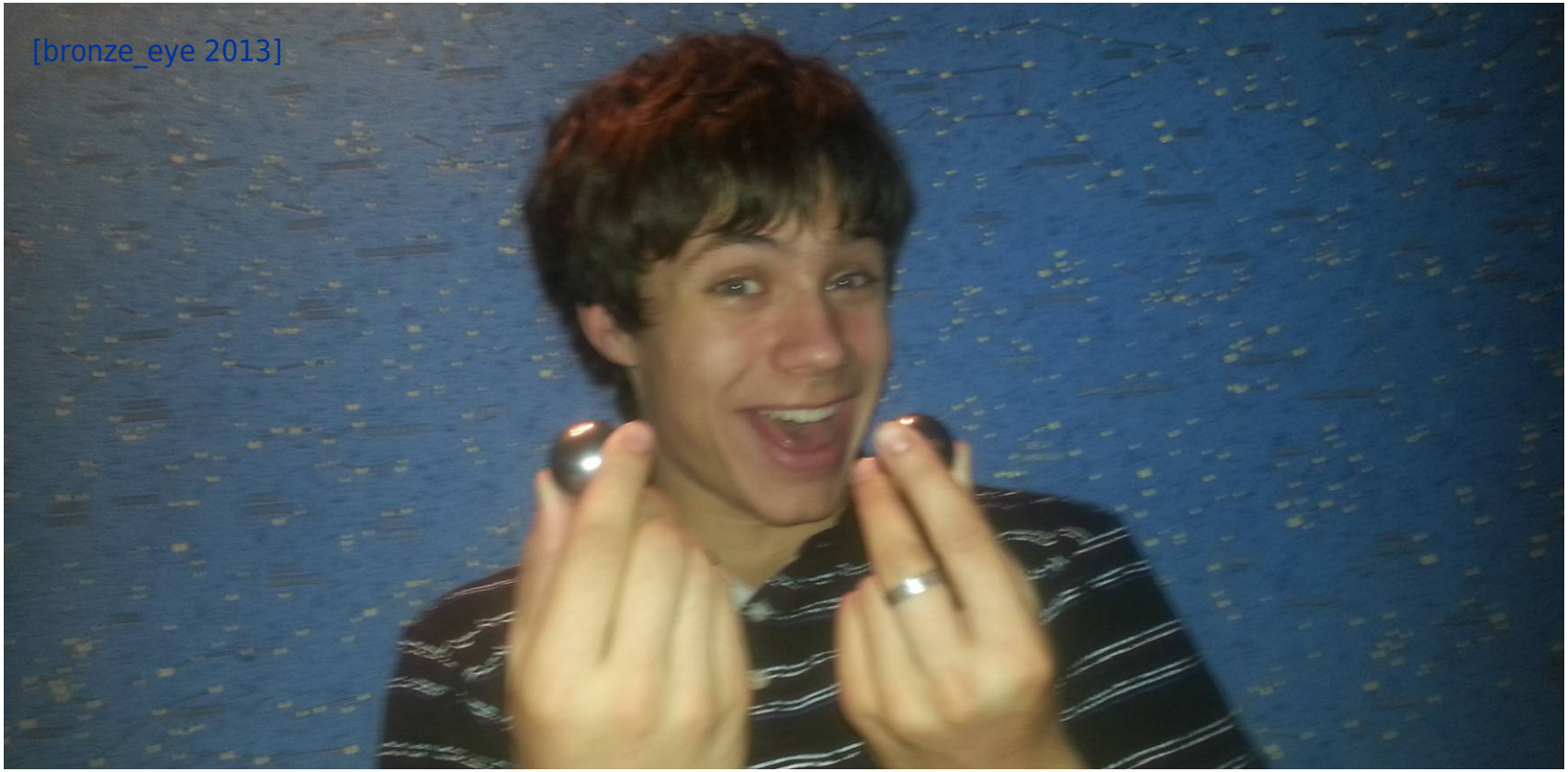
- William J. Beaty. "Abrasion holography": hand-drawn holograms (1995), http://www.amasci.com/amateur/holo1.html.save, http://playpen.icomtek.csir.co.za/~acdc/club%20ideas/pseudo%20holograms/holo1.html
- hand-drawn holograms (youtube.com, from wbeaty, 06.04.2008), http://youtu.be/XUy8lELWhJg
- Scratch Holograms (youtube.com, from fortworthmuseum, 07.01.2009), http://youtu.be/0uko9oixijg
- Wikipedia: Specular holography, http://en.wikipedia.org/wiki/Specular_holography
- Martin E. Horn, Helmut F. Mikelskis. Problems When Studying Holography (2000), http://arxiv.org/ftp/physics/papers/0310/0310132.pdf
- Angel G. Augier and Raúl. B. Sánchez. Making computer –generated scratch holograms from threedimensional virtual models. Photon. Lett. Pol. 2, 4, 153-155 (2010), http://photonics.pl/PLP/index.php/letters/article/viewFile/2-53/125
- Scratch Holograms! (gibbon, instructables.com), http://www.instructables.com/id/Make-a-Tool-to-Draw-Scratch-Holograms!/
- Christian Regg, Szymon Rusinkiewicz, Wojciech Matusik, and Markus Gross. Computational Highlight Holography, http://gfx.cs.princeton.edu/pubs/Regg_2010_CHH/highlight-holography.pdf
- William Beaty. Re: streaked windows and lights (2001), http://www.phys-l.org/archives/2001/01_2001/msg00176.html
- William T. Plummer and Leo R. Gardner. A mechanically generated hologram? Applied Optics 31, 31, 6585-6588 (1992)

Problem No. 3 “Twisted rope”

Hold a rope and twist one end of it. At some point the rope will form a helix or a loop. Investigate and explain the phenomenon.

Background reading

- V. G. A. Goss, G. H. M. van der Heijden, J. M. T. Thompson, and S. Neukirch. Experiments on Snap Buckling, Hysteresis and Loop Formation in Twisted Rods. Exp. Mech. 45, 101-111 (2005), http://www.lmm.jussieu.fr/~neukirch/articles/goss_experiments_snap_buckling_and_loop_formation_in_twisted_rods_ExpMech_2005.pdf
- R. E. Hobbs, M. S. Overington, J. W. S. Hearle, and S. J. Banfield. Buckling of fibres and yarns within ropes and other fibre assemblies (tensiontech.com), http://www.tensiontech.com/papers/papers/buckling_fibres_yarns/buckling_fibres_yarns.pdf
- Ning Pan and David Brookstein. Physical Properties of Twisted Structures. II. Industrial Yarns, Cords, and Ropes. ING PAN, http://ningpan.net/Publications/51-100/72.pdf
- S. Przybyl and P. Pieranski. Helical close packings of ideal ropes. Eur. Phys. J. E 4, 4, 445-449 (2001), arXiv:physics/0101080v1
- Wikipedia: Wire rope, http://en.wikipedia.org/wiki/Wire_rope
- Roland Vereet and Isabel Ridge. Damage from rotation. In: Wire rope forensics (casar.de), p. 33, http://www.seile.com/bro_engl/wire_rope_forensics_a4.pdf
- Philip T. Gibson. Operational characteristics of ropes and cables (unols.org), http://www.unols.org/publications/winch_wire_handbook__3rd_ed/08_oper_char_ropes_cables.PDF
- Anchoring Technology (yalecordage.com), http://www.yalecordage.com/pdf/anchoring_tech.pdf
- Closely Packed Helix (youtube.com, from pieranski, 20.01.2009), http://youtu.be/7NqhDyzzG7Y
- J. Michael and T. Thompson. Single-molecule magnetic tweezer tests on DNA: bounds on topoisomerase relaxation. Proc. R. Soc. Lond. A 464, 2811-2829 (2008)
- A. Goriely and M. Tabor. Nonlinear dynamics of filaments. IV Spontaneous looping of twisted elastic rods. Proc. R. Soc. Lond. A 454, 3183-3202 (1998), http://math.arizona.edu/~goriely/Papers/1998-PRSA-(Kirchhoff-fil4).pdf



Problem No. 4 “Ball sound”

When two hard steel balls, or similar, are brought gently into contact with each other, an unusual ‘chirping’ sound may be produced. Investigate and explain the nature of the sound.

Background reading

- Lord Rayleigh. The Theory of Sound. (London, Macmillan, 1877, Courier Dover Publications, 1945), http://books.google.com/books?id=v4NSAlsTwnQC, http://books.google.com/books?id=Frvgu1wSFfUC
- Поющие магниты. Singing Magnets (youtube.com, from QQQ3118, 06.02.2013), http://youtu.be/XjqJ208Z5GM
- Cool Magnets (youtube.com, from minnesotavikingsnf, 03.05.2010), http://youtu.be/ARmmdjGa1mE
- Eulers Disc (youtube.com, from Hendrik Ball, 05.02.2011), http://youtu.be/rFtYzVJcWyA
- David Auerbach. Colliding rods: Dynamics and relevance to colliding balls. Am. J. Phys. 62, 6, 522-525 (1994), http://www.physics.umd.edu/deptinfo/facilities/lecdem/services/refs_scanned_WIP/3%20-%20Vinit's%20LECDEM/C711/6/GetPDFServlet.pdf
- C. Zheng and D. L. James. Toward high-quality modal contact sound. ACM Trans. on Graphics 30, 4 (2011), http://www.cs.cornell.edu/projects/Sound/mc/ModalContactSound2011.pdf
- Wang Yufang and Tong Zhongfang. Sound radiated from the impact of two cylinders. J. Sound Vibration 159, 2, 295-303 (1992)
- K. Mehraby, H. Khademhosseini Beheshti, and M. Pursina. Impact noise radiated by collision of two spheres: Comparison between numerical simulations, experiments and analytical results. J. Mech. Sci. Technol. 25, 7, 1675-1685 (2011)
- A. W. Crook. A Study of Some Impacts between Metal Bodies by a Piezo-Electric Method. Proc. R. Soc. Lond. A 212, 1110, 377-390 (1952)
- M. Endo, S. Nishi, M. Nakagawa, and M. Sakata. Sound radiation from a circular cylinder subjected to elastic collision by a sphere. J. Sound. Vibr. 75, 2, 285-302 (1981)

Background reading

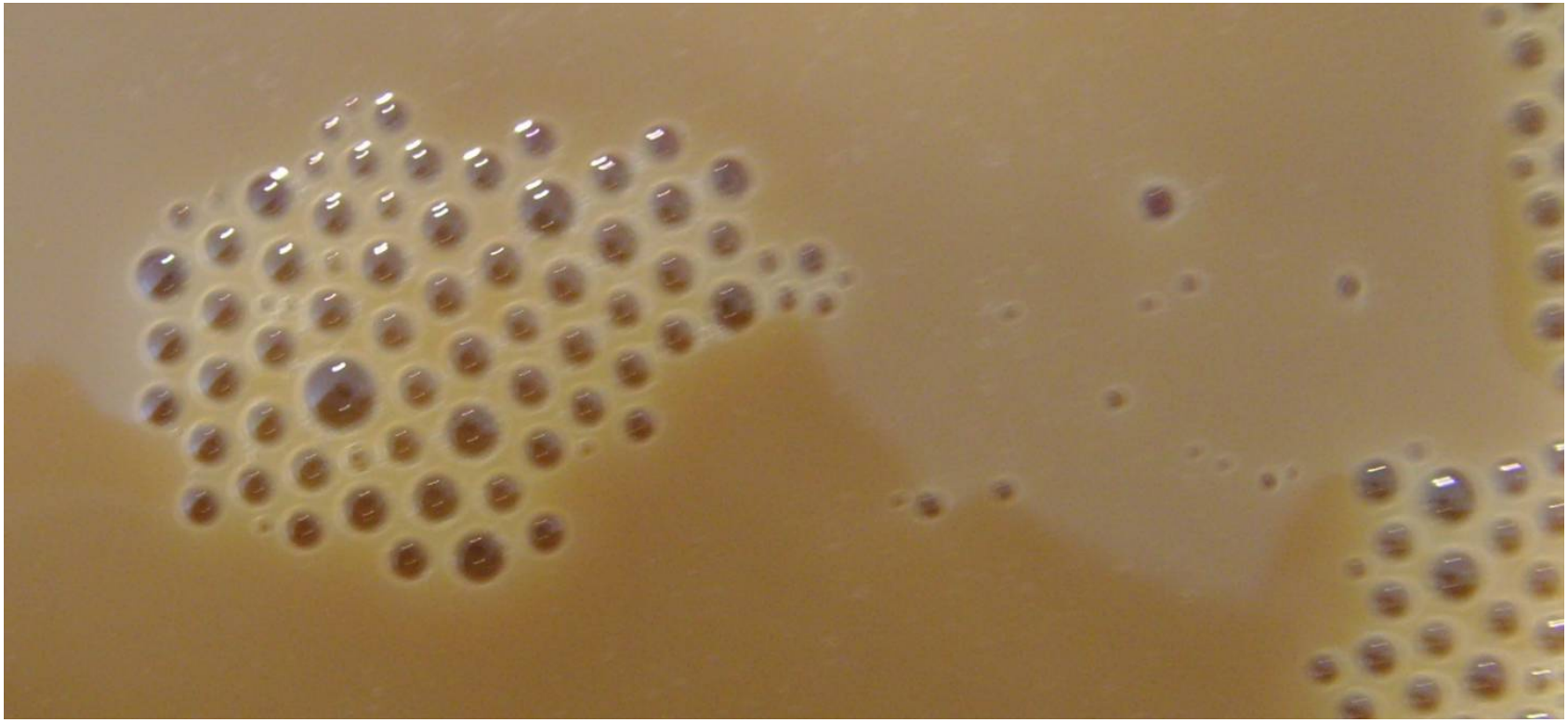
- K. Mehraby, H. Khademhosseini Beheshti, and M. Poursina. Impact noise radiated by collision of two spheres: Comparison between numerical simulations, experiments and analytical results. J. Mech. Sci., Technol. 25, 7, 1675-1685 (2011), http://www.j-mst.org/On_line/admin/files/06-J2010-597_1675-1685_.pdf
- G. Nishimura and K. Takahashi. Impact sound by mutual collision of two steel balls. Bull. Jap. Soc. Precision Engineers 1, 47-51 (1965)
- L. L. Koss and R. J. Alfredson, Transient sound radiated by spheres undergoing an elastic collision, J. Sound Vibr. 27 (I), 59-75, (1973)
- Hiroyuki Ohta and Takumi Nakagawa. Using Ceramic Balls to Reduce Noise in a Linear Guideway Type Recirculating Linear Ball Bearing, http://eportfolio.lib.ksu.edu.tw/~T093000103/repository/fetch/Using%20Ceramic%20Balls%20to%20Reduce%20Noise%20in%20a%20Linear%20Guideway%20Type%20Recirculating%20Linear%20Ball%20Bearing.pdf
- Rod Cross. Differences between bouncing balls, springs, and rods. Am. J. Phys. 76, 10, 908-915 (2008), http://www.physics.usyd.edu.au/~cross/PUBLICATIONS/42.%20SpringBounce.pdf

Problem No. 5 “Loaded hoop”

Fasten a small weight to the inside of a hoop and set the hoop in motion by giving it an initial push. Investigate the hoop’s motion.

Background reading

- W. F. D. Theron and M. F. Maritz. The amazing variety of motions of a loaded hoop. Math. Comp. Modelling 47, 9-10, 1077-1088 (2008)
- W. F. D. Theron and N. M du Plessis. The dynamics of a massless hoop. Am. J. Phys. 69, 3, 354-359 (2001)
- W. F. D. Theron. The rolling motion of an eccentrically loaded wheel. Am. J. Phys. 68, 9, 812-820 (2000)
- M. F. Maritz and W. F. D Theron. Experimental verification of the motion of a loaded hoop. Am. J. Phys. 80, 7, 594-598 (2012)
- A. Taylor and M. Fehrs. The dynamics of an eccentrically loaded hoop. Am. J. Phys. 78, 5, 496-498 (2010)
- W.F.D Theron. Analysis of the rolling motion of loaded hoops (PhD thesis, Stellenbosch, 2008), https://ir1.sun.ac.za/bitstream/handle/10019.1/1206/theron_analysis_2008.pdf
- P. E. Wellstead. The ball and hoop system. Automatica 19, 4, 401-406 (1983)
- V. A. Lubarda. Dynamics of a light hoop with an attached heavy disk: inside an interaction pulse. J. Mech. of Mat. and Struct. 4, 6, 1027-1040 (2009)



Problem No. 6 “Bubble crystal”

A large number of very small, similar air bubbles float on the surface of a soapy liquid. The bubbles will arrange themselves into a regular pattern similar to a crystalline lattice. Propose a method to obtain bubbles of a consistent size, and investigate the formation of such a bubble crystal.

Background reading

- Wikipedia: Bubble Rafts, http://en.wikipedia.org/wiki/Bubble_rafts
- Lawrence Bragg and J. F. Nye. A Dynamical Model of a Crystal Structure. Proc. R. Soc. Lon. A 190, 1023, 474-481 (1947), http://web.mit.edu/mikejd/previously_online/aices_mit_2009/Bragg-bubble_raft.pdf
- L. Bragg and W. M. Lomer, A Dynamical Model of a Crystal Structure II. Proc. R. Soc. Lond. A 196, 1045, 171-181 (1949)
- W. M. Lomer. A Dynamical Model of a Crystal Structure. III. Proc. R. Soc. Lond. 196, 1045, 182-194 (1949)
- W. M. Lomer and J. F. Nye. A Dynamical Model of a Crystal Structure. IV. Grain Boundaries. Proc. R. Soc. Lon. A 212, 1111, 576-584 (1952)
- Wikipedia: Weaire-Phelan structure, http://en.wikipedia.org/wiki/Weaire-Phelan_structure
- Wikipedia: Plateau's laws, http://en.wikipedia.org/wiki/Plateau's_laws
- Bragg Bubble Raft (with vacancy) (youtube.com, from Christie Gilliland, 16.09.2012), http://youtu.be/AM86z7cTqi0
- Practical 1P5: Bubble Raft (youtube.com, from Suraj Bhattacharjee, 24.01.2013), http://youtu.be/efxrO2OBIqY
- Bubble raft sintering model .m4v (youtube.com, from Bob Morris, 08.01.2012), http://youtu.be/ah1Q6yqTdpA
- Animating bubble interactions in a liquid foam (youtube.com, from Huamin Wang, 05.04.2013), http://youtu.be/GPbFp50ZGUE
- O. Busaryev, T. K. Dey, H. Wang, and R. Zhong. Animating bubble interactions in a liquid foam. ACM Trans. Graphics 31, 4 (2012), http://www.cse.ohio-state.edu/~tamaldey/paper/foam/bubble.pdf

Background reading

- Andrew de Laix and Tanmay Vachaspati. On Random Bubble Lattices, Phys. Rev. D 59, 045017 (1999), arXiv:hep-ph/9802423
- Wikipedia: Cheerios Effect, http://en.wikipedia.org/wiki/Cheerios_effect
- J. M. Georges, G. Meille, J. L. Loubet and A. M. Tolen. Bubble raft model for indentation with adhesion. Nature 320, 342-344 (1986)
- L. T. Shi and A. S. Argon. The potential and force law between different-sizebubbles in soap bubble rafts. Phil. Mag. A 46, 2, 255-274 (1982)
- A. van der Net, W. Drenckhan, D. Weaire and S. Hutzler. The crystal structure of bubbles in the wet foam limit. Soft Matter 2, 129-134 (2006)
- Mark J. Bowick, Luca Giomi, Homin Shin, and Creighton K. Thomas. Bubble-raft model for a paraboloidal crystal. Phys. Rev. E, 77, 2 (2008)
- V. I. Dubinko, V. V. Slezov, A. V. Tur and V. V. Yanovsky. The theory of gas bubble lattice. Radiation Effects 100, 1-2, 85-104 (1986)
- Y. Ishida. Order structures and dislocations in bubble raft grain boundary. J. Mat. Sci. 7, 1, 75-83 (1972)
- Dominic Vella and L. Mahadevan. The “Cheerios effect”, Am. J. Phys. 73, 9, 817-825 (2005)
- Goran Bezjak. The “Cheerios effect” (University of Ljubljana, 2010), http://mafija.fmf.uni-lj.si/seminar/files/2009_2010/The_Cheerios_Effect.pdfC. Korner, M. Thies, T. Hofmann, N. Thurey, and U. Rude. Lattice Boltzmann Model for Free Surface Flow for Modeling Foaming. J. Stat. Phys. 121, 1/2, 179-196 (2005), http://www10.informatik.uni-erlangen.de/Publications/Papers/2005/Koerner_etal_J.Statist.Phys.121_2005.pdf
- M. F. Ashby. The properties of foams and lattices. Phil. Trans. R. Soc. A 364, 1838, 15-30 (2006), http://rsta.royalsocietypublishing.org/content/364/1838/15.full.pdf

Background reading

- Carolin Koerner. Lattice Boltzmann Model for Foam Evolution. In: Integral Foam Molding of Light Metals (Springer, 2008), pp. 171-183, http://link.springer.com/content/pdf/10.1007%2F978-3-540-68839-6_9.pdf
- Andy Kraynik, Doug Reinelt, Frank van Swol, Sascha Hilgenfeldt. Foam Structure and Rheology: The shape and feel of random soap froth “Foam Microrheology", http://www.ima.umn.edu/2009-2010/W10.12-16.09/activities/Kraynik-Andrew/IMA_Kraynik.pdf
- Andrew M. Kraynik and Douglas A. Reinelt. Foam microrheology: from honeycombs to random foams (1999), http://faculty.smu.edu/reinelt/foam_rheology.pdf
- Christopher Breward. The Mathematics of Foam (Oxford, 1999), http://eprints.maths.ox.ac.uk/34/1/breward.pdf
- Marc Durand and Howard A. Stone. Relaxation time of the topological T1 process in a two-dimensional foam. Phys. Rev. Lett. 97, 226101 (2006), arXiv:cond-mat/0608426 [cond-mat.soft]
- V. I. Dubinko , V. V. Slezov , A. V. Tur, and V. V. Yanovsky. The theory of gas bubble lattice, Radiation Effects: Incorporating Plasma Science and Plasma Technology, 100, 1-2, 85-104 (1986)
- Claudia Lautensack. Random Laguerre Tesselations, 113-126 (PhD thesis, University of Karlsruhe, 2007), http://www.itwm.fraunhofer.de/fileadmin/ITWM-Media/Abteilungen/BV/Pdf/Dissertation_CRedenbach.pdf
- P.-G. de Gennes, F. Brochard-Wyart, D. Quéré. Gouttes, bulles, perles et ondes (Paris, éd. Belin, 2002)

Problem No. 7 “Pot-in-pot refrigerator”

The ‘pot-in-pot refrigerator’ is a device that keeps food cool using the principle of evaporative cooling. It consists of a pot placed inside a bigger pot with the space between them filled with a wet porous material, e.g. sand. How might one achieve the best cooling effect?

Background reading

- Clay Pot Refrigerator Test (youtube.com, from tjar12, 04.07.2012), http://youtu.be/ATWEIKE_nLw
- Wikipedia: Pot-in-pot refrigerator, http://en.wikipedia.org/wiki/Pot-in-pot_refrigerator
- J. R. Mihelcic, J. B. Zimmerman, A. Ramaswami. Integrating Developed and Developing World Knowledge into Global Discussions and Strategies for Sustainability. 1. Science and Technology. Environm. Sci. Tech. 41, 10, 3415-3421 (2007)
- Wikipedia: Wet-bulb temperature, http://en.wikipedia.org/wiki/Wet-bulb_temperature
- Wikipedia: Evaporative cooler, http://en.wikipedia.org/wiki/Evaporative_cooler
- Wikipedia: Evaporation, http://en.wikipedia.org/wiki/Evaporation
- Wikipedia: Porous medium, http://en.wikipedia.org/wiki/Porous_medium
- Evaporative Cooling - The Clay Refrigerator (practicalaction.org), http://practicalaction.org/evaporative-cooling-the-clay-refrigerator
- Pot-in-pot cooler (solarcooking.wikia.com), http://solarcooking.wikia.com/wiki/Pot-in-pot_cooler
- Methods of Alternative Refrigeration (provident-living-today.com), http://www.provident-living-today.com/Alternative-Refrigeration.html
- Passive Cooling (permaculturetokyo, 2006), http://permaculturetokyo.blogspot.com/2006/11/passive-cooling.html
- Understanding Wet Bulb Temperature And Other Aspects That Affect Evaporative Cooling Tower Performance (advantageengineering.com), http://www.advantageengineering.com/fyi/273/advantageFYI273.php
- Dry-Bulb? Wet-Bulb? What's the Difference? (buildinggreen.com, 2012), http://www.buildinggreen.com/auth/article.cfm/2012/6/29/Dry-Bulb-Wet-Bulb-What-s-the-Difference/

Background reading

- Michael Brian Schiffer, James M. Skibo, Tamara C. Boelke, Mark A. Neupert, and Meredith Aronson. New perspectives on experimental archaeology: Surface treatments and thermal response of the clay cooking pot. American Antiquity 59, 2, 197-217 (1994)
- S. W. Peng and K. Mizukami. A general mathematical modelling for heat and mass transfer in unsaturated porous media: an application to free evaporative cooling. Heat and mass transfer 31, 1-2, 49-55 (1995)
- Rosa Schiano-Phan. The development of passive downdraught evaporative cooling systems using porous ceramic evaporators and their application in residential buildings (PhD thesis, Open University, 2004), http://www.plea-arch.org/PLEA/ConferenceResources/PLEA2004/Proceedings/p1152final.pdf
- A. Almusaed. Cooling by Direct Evaporative Systems. In: Biophilic and Bioclimatic Architecture (Springer, 2011), pp. 353-361
- A. S. Naik and V. K. Dhir. Forced flow evaporative cooling of a volumetrically heated porous layer. Int. J. Heat Mass Tranfer 25, 4, 541–552 (1982)
- A. lal Basediya, D. V. K. Samuel, and V. Beera. Evaporative cooling system for storage of fruits and vegetables-a review. J. Food Sci. Tech. 50, 3, 429-442 (2013)
- I. F. Odesola and O. Onyebuchi. A review of porous evaporative cooling for the preservation of fruits and vegetables. Pacific J. Sci. Technol. 10, 2, 935-941 (2009), http://www.akamaiuniversity.us/PJST10_2_935.pdf
- A. W. Date. Heat and mass transfer analysis of a clay-pot refrigerator. Int. J. Heat Mass Transfer 55, 15-16, 3977–3983 (2012)

Problem No. 8 “Freezing droplets”

Place a water droplet on a plate cooled down to around -20 °C. As it freezes, the shape of the droplet may become cone-like with a sharp top. Investigate this effect.

Background reading

- Freezing water drops (youtube.com, from Oscar Enríquez, 18.10.2011), http://youtu.be/9VIRtyKSNVI
- Freezing singularities in water drops (youtube.com, from dj Busby, 29.10.2011), http://youtu.be/RFvY6uYvWgg
- Oscar R. Enríquez, Álvaro G. Marín, Koen G. Winkels, and Jacco H. Snoeijer. Freezing singularities in water drops. Phys. Fluids 24, 091102 (2012), arXiv:1110.3698 [physics.flu-dyn], http://stilton.tnw.utwente.nl/people/snoeijer/Papers/2012/EnriquezPOF12.pdf
- D. M. Anderson, M. G. Worster, and S. H. Davis. The case for a dynamic contact angle in containerless solidification. J. Cryst. Growth 163, 329 (1996)
- Herbert Grove Dorsey. Peculiar ice formations. Phys. Rev. 18, 2, 162-164 (1921)
- V. S. Ajaev and S. H. Davis. Boundary-integral simulations of containerless solidification. J. Comp. Phys. 187, 492 (2003)
- Jacco H. Snoeijer and Philippe Brunet. Pointy ice-drops: How water freezes into a singular shape. Am. J. Phys. 80, 764 (2012), http://stilton.tnw.utwente.nl/people/snoeijer/Papers/2012/SnoeijerAJP12.pdf
- Michael Nauenberg. Comment on “Pointy ice-drops: How water freezes into a singular shape” [Am. J. Phys. 80, 764–771 (2012)] Am. J. Phys. 81, 2, 150 (2013)
- Lingyan Huang, Zhongliang Liu, Yaomin Liu, Yujun Gou, Li Wang. Effect of contact angle on water droplet freezing process on a cold flat surface. Exp. Thermal Fluid Sci. 40, 74-80 (2012)
- Freezing water droplets form sharp ice peaks (phys.org, Oct 05, 2012), http://phys.org/news/2012-10-droplets-sharp-ice-peaks.html

Background reading

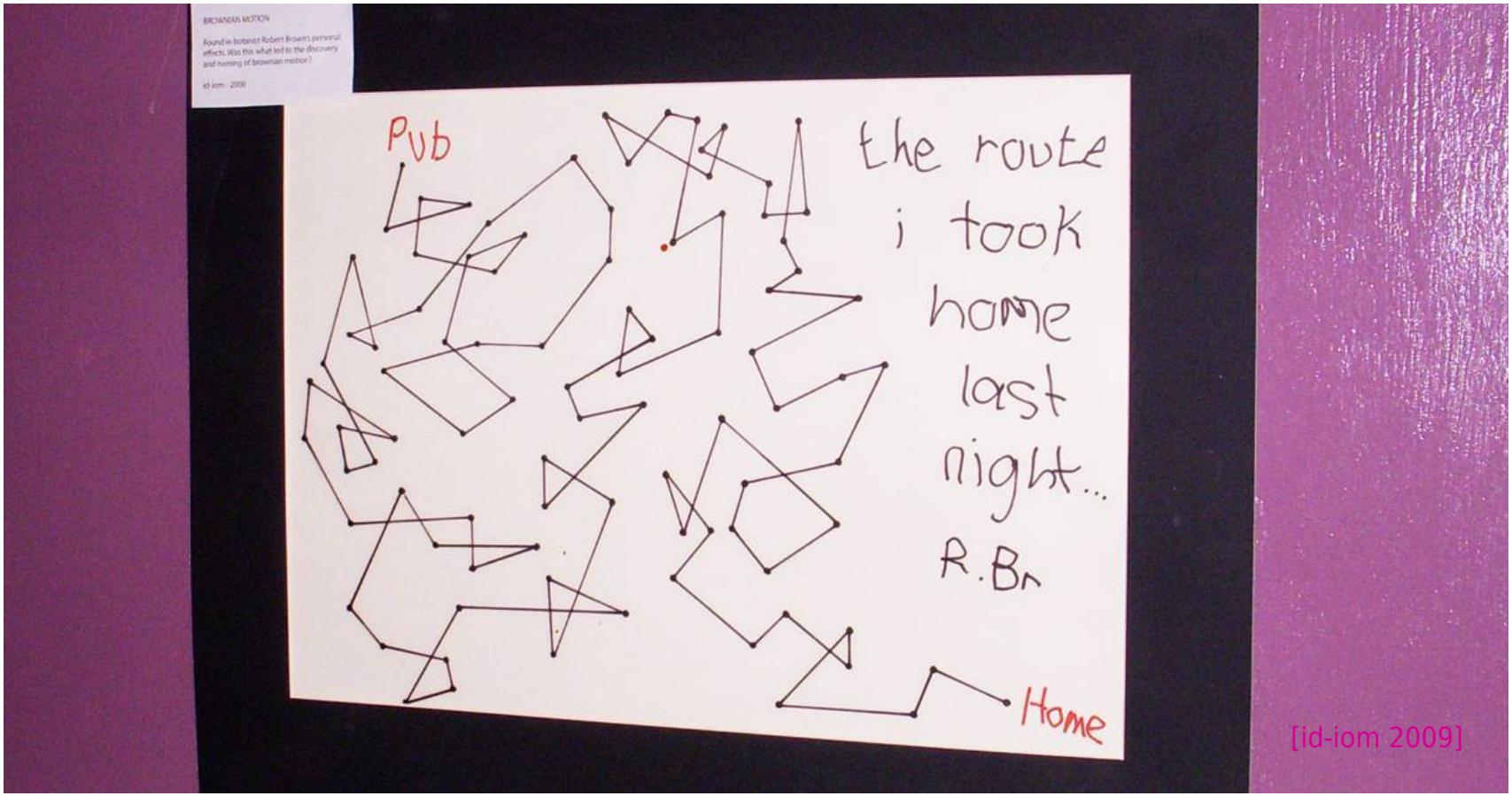
- John Hallet. Crystal growth and the formation of spikes in the surface of supercooled water. Journal of Glaciology 3, 28, 698-704 (1960), http://www.igsoc.org/journal/3/28/igs_journal_vol03_issue028_pg698-704.pdf
- K. G. Libbrecht and K. Lui. An investigation of laboratory-grown “ice spikes”. J. Glaciology 50, 170, 371-374 (2004), arXiv:cond-mat/0310267v1 [cond-mat.mtrl-sci], http://www.its.caltech.edu/~atomic/snowcrystals/icespikes/icespikes.pdf
- Helene F. Perry. Ice spikes — can you explain them. Phys. Teach. 31, 112 (1993); 31, 264 (1993)
- Helene F. Perry. A ‘last word’ on ice spikes. Phys. Teach. 33, 148 (1995)
- Giuseppi Abrusci and Joe Pifer. Question #65. What conditions determine crystal growth? Am. J. Phys. 65, 10, 941 (1997)
- Charles A. Knight. Answer to Question #65. What conditions determine crystal growth? The triangular ice spike. Am. J. Phys. 66, 12, 1041-1042 (1998)
- H. F. Perry. Answer to Question #65. What conditions determine crystal growth?” Am. J. Phys. 69, 2, 106 (2001)
- B. J. Mason and J. Maybank. The fragmentation and electrification of freezing water drops. Quart. J. Royal Meteor. Soc. 86, 368, 176-185 (1960)
- James R. Carter. Other unusual formations of ice // Ice formations with daily (diurnal) freeze/thaw cycles (Illinois State University), http://my.ilstu.edu/~jrcarter/ice/diurnal/
- G. Bjorbaek. Unusual ice formations. Weather 49, 188-189 (1994)
- K. P. Trout. Homemade ice spike. Phys. Teach. 39, 190 (2001)
- L. Hill, E. Lozowski, and R. D. Sampson. Experiments on ice spikes and a simple growth model. J. Glaciology 50, 170, 375-381 (2004)

Problem No. 9 “Water bombs”

Some students are ineffective in water balloon fights as the balloons they throw rebound without bursting. Investigate the motion, deformation, and rebound of a balloon filled with fluid. Under what circumstances does the balloon burst?

Background reading

- Wikipedia: Water balloon, http://en.wikipedia.org/wiki/Water_balloon
- Slow Motion: Water Balloons Free Falling (youtube.com, from hackability, 13.08.2012), http://youtu.be/VlUNevsIgE4
- Martino Reclari, Matthieu Dreyer, Stephanie Tissot, Danail Obreschkow, Florian Wurm, Mohamed Farhat. "Oenodynamic": Hydrodynamic of wine swirling (2011), arXiv:1110.3369 [physics.flu-dyn]
- Hydrodynamics: Wine Swirling and Bursting Water Balloons, http://astronasty.blogspot.se/2011/11/hydrodynamics-wine-swirling-and.html
- The Science Behind Bursting Water Balloons (youtube.com, from dj Busby, 02.11.2011), http://youtu.be/1qYyVPjsb5k
- Alex Santoso. Physics of Water Balloons (neatorama.com, 2012), http://www.neatorama.com/2012/01/17/physics-of-water-balloons/
- Hugh Lund and Stuart B. Dalziel. Tension-driven Richtmyer-Meshkov instability, http://iwpctm12.imamod.ru/files/user_files/dalziel_abs.pdf
- A water balloon not exploding in high-speed (youtube.com, from LucidMovement, 15.02.2007), http://youtu.be/XngQJzAmVm8
- Wikipedia: Richtmyer-Meshkov instability, http://en.wikipedia.org/wiki/Richtmyer–Meshkov_instability
- Hugh M. Lund and Stuart B. Dalzie. Bursting water balloons (2011), arXiv:1110.3320 [physics.flu-dyn]
- T. A. Peyser, S. D. Murray et al. Review of Experiments and Calculations of the Compressible Richtmyer-Meshkov Instability from a Single-mode, Nonlinear Initial Perturbation. Proc. 6th Int'l Conf. on Phys. of Turbulent Compressible Mixing (Marseille, 1997), https://www.etde.org/etdeweb/servlets/purl/301929-E8UDuc/webviewable/301929.pdf



Problem No. 10 “Coefficient of diffusion”

Using a microscope, observe the Brownian motion of a particle of the order of micrometre in size. Investigate how the coefficient of diffusion depends on the size and shape of the particle.

Background reading

- Wikipedia: Diffusion, http://en.wikipedia.org/wiki/Diffusion
- Wikipedia: Brownian motion, http://en.wikipedia.org/wiki/Brownian_motion
- Wikipedia: Einstein relation, http://en.wikipedia.org/wiki/Einstein_relation_(kinetic_theory)
- Wikipedia: Stokes' law, http://en.wikipedia.org/wiki/Stokes'_law
- Wikipedia: Kinetic theory, http://en.wikipedia.org/wiki/Kinetic_theory
- Wikipedia: Random walk, http://en.wikipedia.org/wiki/Random_walk
- Wikipedia: Perrin friction factors, http://en.wikipedia.org/wiki/Perrin_friction_factors
- Brownian Motion (youtube.com, from Stephen Curry, 25.09.2012), http://youtu.be/ernnQJwaKTs
- Robert Brown. A brief account of microscopical observations made in the months of June, July and August, 1827, on the particles contained in the pollen of plants; and on the general existence of active molecules in organic and inorganic bodies. Phil. Mag. 4, 161-173 (1828), http://sciweb.nybg.org/science2/pdfs/dws/Brownian.pdf
- Marian von Smoluchowski. Zur kinetischen Theorie der Brownschen Molekularbewegung und der Suspensionen. Ann. Phys. 326, 14, 756–780 (1906)
- A. Einstein, A. Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen. Ann. Phys. 17, 549-560 (1905)
- Jean Perrin. Mouvement brownien et réalité moléculaire. Annales de Chimie et de Physique, 8e série 18, 1–114 (1909)
- Don S. Lemons and Anthony Gythiel.Paul Langevin's 1908 paper ''On the Theory of Brownian Motion'' ['Sur la théorie du mouvement brownien,'' C. R. Acad. Sci. (Paris) 146, 530–533 (1908)]. Am. J. Phys. 65, 11, 1079-1081 (1997(, http://www.physik.uni-augsburg.de/theo1/hanggi/History/Langevin1908.pdf

Problem No. 11 “Candle Power Plant”

Design a device that converts the heat of a candle flame into electrical energy. Investigate how different aspects of the device affect its efficiency.

Background reading

- Wikipedia: Energy harvesting, http://en.wikipedia.org/wiki/Energy_harvesting
- Wikipedia: Thermogenerator, http://en.wikipedia.org/wiki/Thermogenerator
- Wikipedia: Stirling engine, http://en.wikipedia.org/wiki/Stirling_engine
- Wikipedia: Thermomechanical generator, http://en.wikipedia.org/wiki/Thermomechanical_generator
- Wikipedia: Electric generator, http://en.wikipedia.org/wiki/Electric_generator
- Wikipedia: Turbine, http://en.wikipedia.org/wiki/Turbine
- Thermoelectric Lamp, Electric Generator Plans (scraptopower.co.uk), http://www.scraptopower.co.uk/thermoelectric/Thermoelectric-lamp-seebeck-generator
- Electricity from a Candle (http://light.sci-toys.com), http://light.sci-toys.com/candle_electricity
- Jaymi Heimbuch. A Single Tea Light Candle Powers This Portable Electricity Generator (treehugger.com, 2012), http://www.treehugger.com/gadgets/single-tea-light-powers-portable-electricity-generator.html
- DIY Peltier Candle Powered Electric Generator (youtube.com, from filear, 17.01.2011), http://youtu.be/SvBeCCjb9ds
- Thermoelectric Generator Lamp (x2jiggy.com, 2013), http://x2jiggy.com/blog/2013/4/3/thermoelectric-generator-lamp.html
- Joseph T. Kummer et al. Thermo-Electric Generator. US Patent No. 3458356 (1969), http://www.google.com/patents/US3458356

Background reading

- Lewis M. Fraas, James E. Avery, and John E. Samaras. Hydrocarbon fired room heater with thermophotovoltaic electric generator. U.S. Patent No. 5,651,838 (1997), http://www.google.com/patents/US5651838
- Crispin L. DeBellis et al. Thermophotovoltaic electric generator. U.S. Patent No. 5,932,885 (1999), http://www.google.com/patents/US5932885
- Donald Spector. Candle-powered aroma generator. U.S. Patent No. 4,781,895 (1988), http://www.google.com/patents/US4781895
- Lewis M. Fraas, Douglas J. Williams, and John E. Samaras. Thermophotovoltaic electric generator using low bandgap photovoltaic cells with a hydrocarbon burner and enhanced catalytic infrared emitter. U.S. Patent No. 5,616,186 (1997), http://www.google.com/patents/US5616186
- C. A. Gould, N. Y. A. Shammas, S. Grainger, and I. Taylor. A comprehensive review of thermoelectric technology, micro-electrical and power generation properties. Proc. 26th Int'l Conf. on Microelectronics (MIEL, 2008), http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=4559288
- Tristan Caroff, Emmanuelle Rouvière, and Jérôme Willemin. Thermal Energy Harvesting. In: Energy Autonomous Micro and Nano Systems (eds M. Belleville and C. Condemine, Wiley, 2012), pp. 153-184
- A. Cuadras, M. Gasulla, and Vittorio Ferrari. Thermal energy harvesting through pyroelectricity. Sensors and Actuators A: Physical 158, 1, 132-139 (2010)
- M. Ujihara, G. P. Carman, and D. G. Lee. Thermal energy harvesting device using ferromagnetic materials. App. Phys. Lett. 91, 9, 093508-093508 (2007)
- Y. Apertet, H. Ouerdane, O. Glavatskaya, C. Goupil, and P. Lecoeur. Optimal working conditions for thermoelectric generators with realistic thermal coupling. Europhys. Lett. 97, 2, 28001 (2012)

Background reading

- Energy harvesting technologies (eds Shashank Priya and Daniel J. Inman, Springer, 2008)
- D. M.Rowe. Thermoelectrics, an environmentally-friendly source of electrical power. Renewable Energy 16, 1-4, 1251-1256 (1999)
- A. Hoshi, N. Tezuka, S. Sasaki, I. Fujimoto, and N. Yamada. Development of Practical Stirling Engine for Co-Generation System Using Woody Biomass Fuels. Proc. ISES World Congress 2007 (Vol. I- V, Springer, 2009), p. 2453-2457
- Peter L. Tailer. Thermal Lag Machine. U.S. Patent No. 5414997 (1995), http://www.google.com/patents/US5414997
- B. Whitaker, G. Araujo, J. I. Beasley, N. Payne, and V. Camara. Lamina Flow Heat Engine, http://www.nathantpayne.com/app/download/476784504/ME4444+Final+Report.pdf
- C. Fernandez-Aballi Altamirano, M. De Paepe, S. Verhelst, and J. J. Gonzales Bayon. Control Volume Energy Based Model for a Thermal Lag Engine (Proc. CIER 2009, Havana), https://archive.ugent.be/input/download?func=downloadFile&fileOId=851101&recordOId=851098
- candles make electricity (youtube.com, from suburbanjeff4x4, 31.05.2010), http://youtu.be/-VDVJy9p83U
- Electricity From Candles (youtube.com, from levent sakar, 01.03.2009), http://youtu.be/cAijFoFlz0k
- Mike Szczys. Generate electricity with a candle (hackaday.com, 2010), http://hackaday.com/2010/01/05/generate-electricity-with-a-candle/
- Pt.3 Candle Powered Peltier Charger / Lamp / Defroster / Warming Plate (youtube.com, from KyleCarrington, 08.03.2012), http://youtu.be/zopX9NH0Gzs
- Thermoelectric Peltier Generator passive candle powered. HD (youtube.com, from Elwyn Harris, 19.12.2010), http://youtu.be/lEj1fcrI0tk

Problem No. 12 “Cold balloon”

As air escapes from an inflated rubber balloon, its surface becomes cooler to the touch. Investigate the parameters that affect this cooling. What is the temperature of various parts of the balloon as a function of relevant parameters?

Background reading

- Wikipedia: Adiabatic process, http://en.wikipedia.org/wiki/Adiabatic_process
- Wikipedia: Ideal gas law, http://en.wikipedia.org/wiki/Ideal_gas_law
- D. R. Merrit and F. Weinhaus. The pressure curve for a rubber balloon. Am. J. Phys. 49, 10, 976 (1978)
- R. S. Stein. On the inflating of balloons. J. Chem. Educ. 35, 4, p. 203 (1958)
- L. R. G. Treloar. The Physics of Rubber Elasticity (Oxford University Press, 2005)
- Rubber and Rubber Balloons: Paradigms of Thermodynamics (eds Ingo Müller, Peter Strehlow, Springer, 2004)
- W. B. Wiegand and J. W. Snyder. The Rubber Pendulum, the Joule Effect, and the Dynamic Stress-Strain Curve. Rubber Chem. Tech. 8, 2, 151-173 (1935)
- S. L. Dart, R. L. Anthony, and E. Guth. Rise of Temperature on Fast Stretching of Synthetics and Natural Rubbers. Ind. Eng. Chem. 34, 11, 1340-1342 (1942)
- S. L. Dart and E. Guth. Rise of Temperature on Fast Stretching of Butyl Rubber. Rubber Chem. Tech. 18, 4, 803-816 (1945)
- R. J. Farris. Rubber Heat Engines, Analyses and Theory. Rubber Chem. Tech. 52, 1, 159-172 (1979)
- F. Rodriguez. Demonstrating rubber elasticity. J. Chem. Educ. 50, 11, p. 764 (1973)

Problem No. 13 “Rotating saddle”

A ball is placed in the middle of a rotating saddle. Investigate its dynamics and explain the conditions under which the ball does not fall off the saddle.

Background reading

- Rotating Saddle (youtube.com, from NatSciDemos, 24.01.2013), http://youtu.be/XTJznUkAmIY
- Wikipedia: Mechanical Equilibrium, http://en.wikipedia.org/wiki/Mechanical_equilibrium
- Wikipedia: Stability Theory, http://en.wikipedia.org/wiki/Stability_theory
- Wikipedia: Quadrapole Ion Trap, http://en.wikipedia.org/wiki/Quadrupole_ion_trap
- Wikipedia: Penning Trap, http://en.wikipedia.org/wiki/Penning_trap
- Wikipedia: Inverted Pendulum, http://en.wikipedia.org/wiki/Inverted_pendulum
- Scholarpedia: Equilibrium, http://www.scholarpedia.org/article/Equilibrium
- Inverted Pendulum (youtube.com, from NatSciDemos, 20.12.2012), http://youtu.be/5oGYCxkgnHQ
- Upside-down pendulum (Franz-Josef Elmer, University of Basel, 1998), http://www.elmer.unibas.ch/pendulum/upside.htm
- Parametric Resonance (Franz-Josef Elmer, University of Basel, 1998), http://www.elmer.unibas.ch/pendulum/parres.htm
- Rotating Saddle Shape (Harvard Natural Sciences Lecture Demonstrations), http://www.fas.harvard.edu/~scidemos/OscillationsWaves/SaddleShape/SaddleShape.html
- Stability and Instability (Alan A. Berryman, Washington State University, 1997), http://classes.entom.wsu.edu/529/Stability.htm
- Ion Trap Research Group (Jessie Petricka, Gustavus Adolphus College), http://physics.gac.edu/~petricka/research.html
- Wolfgang Rueckner. Rotating Saddle Paul Trap. Am. J. Phys. 63, 2, 186-187 (1995)

Background reading

- R. I. Thompson, T. J. Harmon, and M. G. Ball. The rotating-saddle trap: a mechanical analogy to RF-electric-quadrupole ion trapping? Can. J. Phys. 80, 12. 1433-1448 (2002)
- T. Hasegawa and John J. Bollinger. Rotating-radio-frequency ion traps. Phys. Rev. A. 72, 4, 043403 (2005), http://tf.nist.gov/general/pdf/2072.pdf
- T. Hasegawa, M. J. Jensen, and John J. Bollinger. Stability of a Penning trap with a quadrupole rotating electric field. Phys. Rev. A 71, 2, 023406 (2005), http://tf.boulder.nist.gov/general/pdf/2016.pdf
- A. K. Johnson and J. A. Rabchuk. A bead on a hoop rotating about a horizontal axis: A one-dimensional ponderomotive trap. Am. J. Phys. 77, 11, 1039–1048 (2009)
- Timothy Jones. Mathieu's equations and the ideal RF-Paul trap (Drexel University), http://www.physics.drexel.edu/~tim/open/mat/mat.pdf
- Andrew Johnson and James Rabchuk. Demonstrating the Principle of an rf Paul Ion Trap. Bull. Am. Phys. Soc. 53 (2008), http://meetings.aps.org/Meeting/MAR08/Event/75663
- Rotating saddle (thekidshouldseethis.com), http://thekidshouldseethis.com/post/41457034607
- Wikipedia: Quadrupole ion trap, http://en.wikipedia.org/wiki/Quadrupole_ion_trap
- Wolfgang Rueckner, Justin Georgi, Douglass Goodale, Daniel Rosenberg, and David Tavilla. Rotating saddle Paul trap. Am. J. Phys. 63, 2, 186-187 (1995), http://www.physics.umd.edu/lecdem/services/refs_scanned_WIP/1%20-%20Krishna's%20LECDEM/A216/Rotating%20saddle%20Paul%20trap.pdf

Problem No. 14 “Rubber motor”

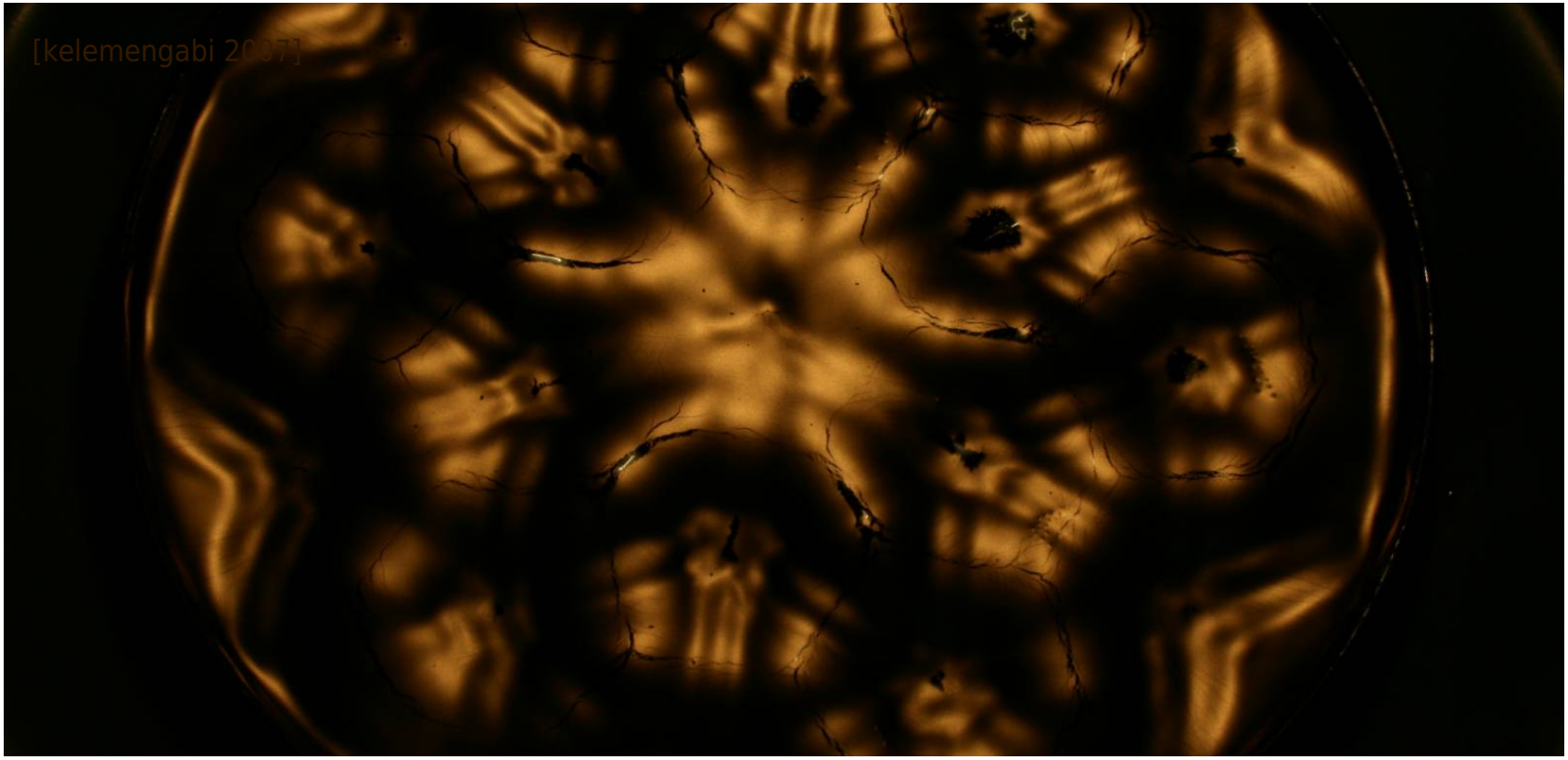
A twisted rubber band stores energy and can be used to power a model aircraft for example. Investigate the properties of such an energy source and how its power output changes with time.

Background reading

- Wikipedia: Rubber band, http://en.wikipedia.org/wiki/Rubber_band
- Rubber band airplane (youtube.com, from rmfoco, 08.08.2009), http://youtu.be/-WVrPgG0y9U
- rubber band powered biplane conversion (youtube.com, from MPHWORLD, 25.02.2009), http://youtu.be/Y8xhKghukgc
- Wikipedia: Rubber Elasticity, http://en.wikipedia.org/wiki/Rubber_elasticity
- Wikipedia: Hyperelastic Material, http://en.wikipedia.org/wiki/Hyperelastic_material
- Wikipedia: Mullins Effect, http://en.wikipedia.org/wiki/Mullins_effect
- Wikipedia: Elastometer, http://en.wikipedia.org/wiki/Elastomer
- Hysteresis and Rubber Bands (madphysics.com), http://www.madphysics.com/exp/hysteresis_and_rubber_bands.htm
- Elastomers and entropic springs (Aparna Baskaran, Syracuse University), http://physics.syr.edu/~abaskara/rubber_popular.html
- GCSE Physics Notes: Stretching Rubber (astarmathsandphysics.com), http://www.astarmathsandphysics.com/gcse_physics_notes/gcse_physics_notes_stretching_rubber.html
- Stretching a Rubber Band (schoolphysics.co.uk), http://www.schoolphysics.co.uk/age14-16/Matter/text/Rubber_band/index.html
- L. G. McAneny. Rubber band powered motor for model airplane. U.S. Patent No. 4,629,438 (1986), http://www.google.com/patents/US4629438
- R. Liedtke. Winding mechanism for rubber band motor. U.S. Patent No. 5,390,763 (1995), http://www.google.com/patents/US5390763
- I. M. Ward and J. Sweeney. An introduction to the mechanical properties of solid polymers (Wiley, 2005)

Background reading

- G. Savarino and M. R. Fisch. A general physics laboratory investigation of the thermodynamics of a rubber band. Am. J. Phys. 59, 2, 141-145 (1991)
- J. Pellicer, J. A. Manzanares, J. Zúñiga, and P. Utrillas. Thermodynamics of rubber elasticity. J. Chem. Educ. 78, 2, 263 (2001)
- J. Diani, B. Fayolle, and P. Gilormini. A review on the Mullins effect. Eur. Polymer J. 45, 3, 601-612 (2009)
- C. M. Roland. The Mullins effect in crosslinked rubber. J. Rheology 33, 4, 659-670 (1989)
- P. G. Santangelo and C. M. Roland. Chain ends and the Mullins effect in rubber. Rubber Chem. Technol. 65, 5, 965-972 (1992)
- L. Mullins. Effect of stretching on the properties of rubber. Rubber Chem. Technol. 21, 2, 281-300 (1948)
- L. R. G. Treloar. The physics of rubber elasticity (Oxford University Press, 1975)
- R. T. Deam and S. F. Edwards. The theory of rubber elasticity. Phil. Trans. R. Soc. Lon. A 280, 1296, 317-353 (1976)
- R. W. Ogden and D. G. Roxburgh. A pseudo–elastic model for the Mullins effect in filled rubber. Proc. R. Soc. Lon. A 455, 1988, 2861-2877 (1999)
- A. N. Gent. Rubber Elasticity: Basic Concepts and Behavior. In: Science and Technology of Rubber (Elsevier, 2005), pp. 1-27, http://v5.books.elsevier.com/bookscat/samples/9780124647862/9780124647862.PDF
- Harry L. Roderick. Spring motor. US Patent No. 1936072 (1929), http://www.google.com/patents/US1936072
- William H. Miller. Flying model airplane. US Patent No. 4895541 (1990), http://www.google.com/patents/US4895541
- Wikipedia: Rubber band motor, http://en.wikipedia.org/wiki/Rubber_band_motor
- Rubber band car engine (youtube.com, from TheKunsthammer, 06.10.2012), http://youtu.be/gju3SNMnwY4
- NC Science Olympiad: How to Wind and Fly your Helicopter (youtube.com, from kellstuh, 18.10.2010), http://youtu.be/H7HqkcE1oO4



Problem No. 15 “Oil stars”

If a thick layer of a viscous fluid (e.g. silicone oil) is vibrated vertically in a circular reservoir, symmetrical standing waves can be observed. How many lines of symmetry are there in such wave patterns? Investigate and explain the shape and behaviour of the patterns.

Background reading

- Jean Rajchenbach, Didier Clamond, and Alphonse Leroux. Observation of star-shaped surface gravity waves. Physical Review Letters 110, 9, 094502 (2013), http://math.unice.fr/~didierc/DidPublis/prl_starwave_2013.pdf
- Michael Faraday. On a peculiar class of acoustical figures; and on certain forms assumed by groups of particles upon vibrating elastic surfaces. Phil. Trans. R. Soc. Lon. 121, 299-340 (1831), http://www.jstor.org/stable/107936
- Wikipedia: Waves, http://en.wikipedia.org/wiki/Waves
- Wikipedia: Dispersion, http://en.wikipedia.org/wiki/Dispersion_(water_waves)
- Wikipedia: Capillary Waves, http://en.wikipedia.org/wiki/Capillary_wave
- Wikipedia: Gravity Waves, http://en.wikipedia.org/wiki/Gravity_wave
- Wikipedia: Rogue Waves, http://en.wikipedia.org/wiki/Rogue_wave
- Wikipedia: Solitary Wave, http://en.wikipedia.org/wiki/Solitary_wave_(water_waves)
- Wikipedia: Soliton, http://en.wikipedia.org/wiki/Soliton
- Wikipedia: Cnoidal Waves, http://en.wikipedia.org/wiki/Cnoidal_wave
- Wikipedia: Faraday Waves, http://en.wikipedia.org/wiki/Faraday_wave
- Mark J. Ablowitz and Douglas E. Baldwin. Nonlinear shallow ocean-wave soliton interactions on flat beaches. Phys. Rev. E 86, 3, 036305 (2012)
- W. S. Edwards and S. Fauve. Patterns and quasi-patterns in the Faraday experiment. J. Fluid Mech. 278, 123-148 (1994)
- Doung Binks and Willem van de Water. Nonlinear pattern formation of Faraday waves. Phys. Rev. Lett. 78, 21, 4043-4046 (1997), http://alexandria.tue.nl/openaccess/Metis132530.pdf

Background reading

- Peilong Chen and Jorge Viñals. Pattern selection in Faraday waves. Phys. Rev. Lett. 79, 14, 2670–2673 (1997)
- John Miles. On Faraday waves. J. Fluid Mech. 248, 671-683 (1993)
- Wenbin Zhang and Jorge Vinals. Square patterns and quasipatterns in weakly damped Faraday waves. Phys. Rev. E 53, 5, R4283–R4286 (1996)
- Peilong Chen and Jorge Vinals. Amplitude equation and pattern selection in Faraday waves. Phys. Rev. E 60, 1, 559–570 (1999)
- Mark-Tiele Westra, Doug J. Binks, and Willem Van De Water. Patterns of Faraday waves. J. Fluid Mech. 496, 1-32 (2003)
- John W. Miles. Parametrically excited solitary waves. J. Fluid Mech. 148, 451-460 (1984)
- M. J. Lighthill. Waves in fluids. Comm. Pure and App. Math. 20, 2, 267–293 (1967)
- G. S. Guthart and T. Yao-Tsu Wu. On the stability of standing solitons in Faraday resonance. In: Nonlinear instability of nonparallel flows (Springer, 1994), pp. 397-406
- Jean Marc Vanden-Broeck. Water waves and related free-surface flows. IUTAM Symp. on Free Surface Flows (Springer, 2001)

Problem No. 16 “Magnetic brakes”

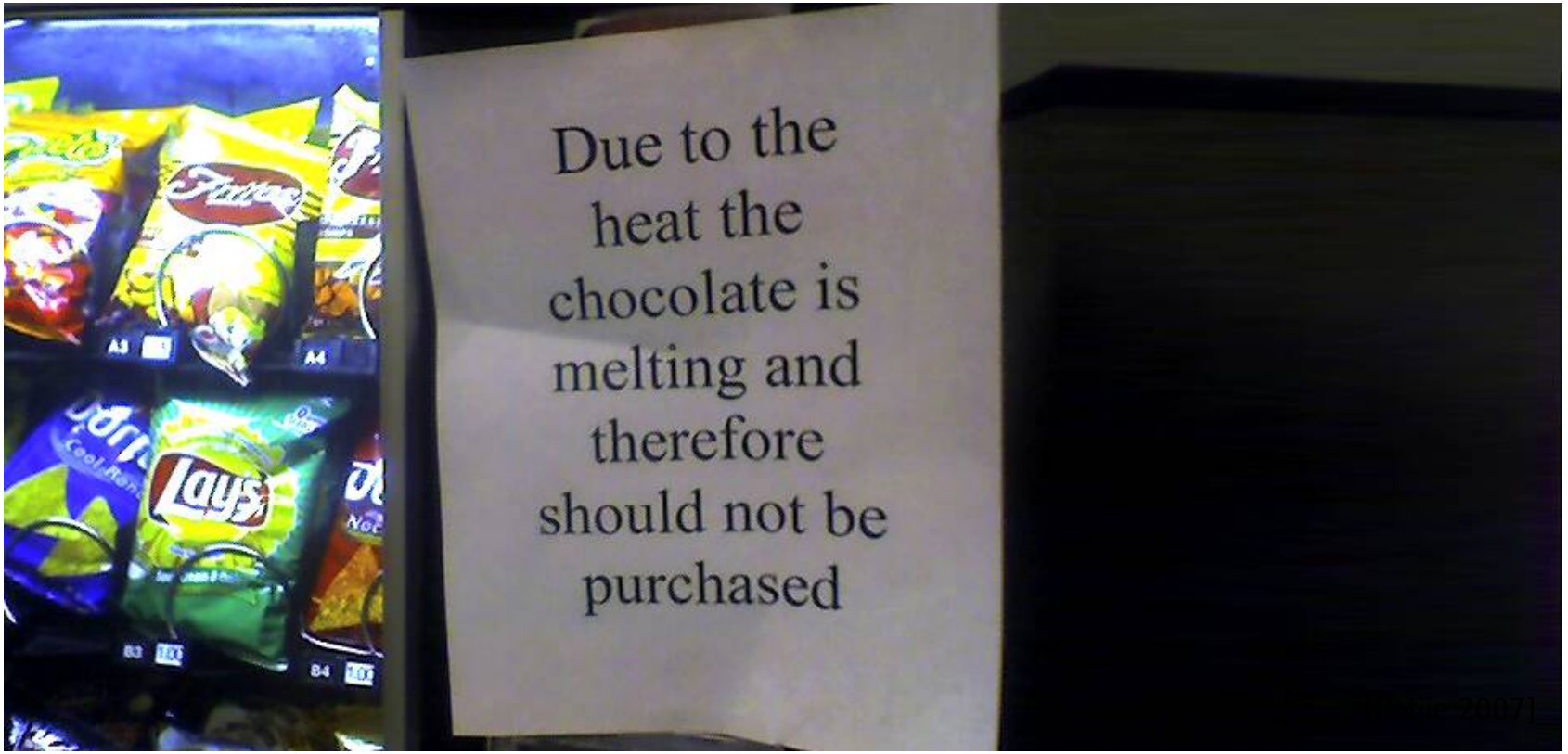
When a strong magnet falls down a non-ferromagnetic metal tube, it will experience a retarding force. Investigate the phenomenon.

Background reading

- Neodymium magnet falling through a copper tube (youtube.com, from Les Garwood, 11.10.2010), http://youtu.be/kCq1u_x07S8
- Gravity Machine (youtube.com, from RayBamBay, 08.08.2011), http://youtu.be/mS0Y5nTfoqc
- Eddy Current Tubes (Extra Large) (youtube.com, from EducateInnovate, 23.03.2010), http://youtu.be/MT16pLWqvXo
- Wikipedia: Eddy current brake, http://en.wikipedia.org/wiki/Eddy_current_brake
- Wikipedia: Eddy current, http://en.wikipedia.org/wiki/Eddy_current
- MIT Physics Demo - Lenz's Law with Copper Pipe (MIT), http://video.mit.edu/watch/physics-demo-lenzs-law-with-copper-pipe-10268/
- M. H. Partori and E.J. Morris. Electrodynamics of a magnet moving through a conducting pipe. Canad. J. Phys. 84, 253–271 (2006)
- C. S. Maclatchy, P, Backman, and L. Bogan. A quantitative magnetic braking experiment. Am. J. Phys. 61, 1096 (1993)
- G. Ireson and J. Twidle. Magnetic braking revisited: Activities for the undergraduate laboratory. Eur. J. Phys. 29, 745–751 (2008)
- K. D. Hahn, E. M. Johnson, A. Brokken, and S. Baldwin. Eddy current damping of a magnet moving through a pipe. Am. J. Phys. 66, 1066 (1998)
- M. A. Heald. Magnetic braking: Improved theory. Am. J. Phys. 56, 521–522 (1988)
- Y. Levin, S. L. Da Silveira, and F.B. Rizzato. Electromagnetic braking: A simple quantitative model. Am. J. Phys. 74, 815–817 (2006)
- Magnet in a copper pipe, http://www.wimp.com/copperpipe/
- H. D. Wiederick, N. Gauthier, D. A. Campbell, and P. Rochan. Magnetic braking: Simple theory and experiment. Am. J. Phys. 55, 500–503 (1987)
- Wikipedia: Eddy current testing, http://en.wikipedia.org/wiki/Eddy-current_testing

Background reading

- Eddy Current Tubes (youtube.com, from ybelfort, 29.05.2008), http://youtu.be/nrw-i5Ku0mI
- Eddy Currents, Magnetic Braking and Lenz's Law (youtube.com, from Fiona Meade, 21.06.2011), http://youtu.be/otu-KV3iH_I
- Magnet Brakes its own fall (youtube.com, from George Mizzell, 04.09.2007), http://youtu.be/iABmUEH5s0k
- Copper Pipe Magnet (youtube.com, from JamesRB1995, 19.05.2010), http://youtu.be/G7ysnXH53Wo
- S. Butterworth. Eddy-Current Losses in Cylindrical Conductors, with Special Applications to the Alternating Current Resistances of Short Coils. Phil. Trans. R. Soc. Lon. A 222, 57-100 (1922), http://www.jstor.org/stable/pdfplus/91202.pdf, http://archive.org/stream/philtrans05342880/05342880#page/n0/mode/2up
- Hugo Rosman. Eddy currents in a straight cylindrical conductor, having a circular section, in periodical non-harmonic steady-state (May 16, 2012), http://www.bulipi-eee.tuiasi.ro/archive/2012/fasc.2/p1_f2_2012.pdf
- The Principles of Eddy Current Testing (Nat'l Cheng Kung Univ), http://ndewww.ee.ncku.edu.tw/Course/NondestructiveTesting/NDE_ch2.pdf
- E. E. Kriezis, T. D. Tsiboukis, S. M. Panas, and J. A. Tegopoulos. Eddy currents: theory and applications. Proc. IEEE, 80, 10, 1559-1589 (Oct 1992)
- G. Moritz. Eddy currents in accelerator magnets, (CAS Magnets, Bruges, June 16-25, 2009), http://cas.web.cern.ch/CAS/Belgium-2009/Lectures/PDFs/Moritz-New.pdf
- Ana Alonso Rodriguez and Alberto Valli. Eddy Current Approximation of Maxwell Equations: Theory, Algorithms and Applications (Springer, 2010), http://books.google.com/books?id=qcq2bubYY4sC
- George Birnbaum and George Free. Eddy-Current Characterization of Materials and Structures : A symposium (Am. Soc. for Testing and Materials, 1981), http://books.google.com/books?id=Xm7QUkm_E9QC
- Johannes Marius Bartholomeus Kroot. Analysis of Eddy Currents in a Gradient Coil (Technische Universiteit Eindhoven, 2005), http://alexandria.tue.nl/extra2/200511789.pdf



Problem No. 17 “Chocolate hysteresis”

Chocolate appears to be a solid material at room temperature but melts when heated to around body temperature. When cooled down again, it often stays melted even at room temperature. Investigate the temperature range over which chocolate can exist in both melted and ‘solid’ states and its dependence on relevant parameters.

Background reading

- Savina Radosavljevic and Anna Schlunk. Melting Chocolate (The University of Sydney, 2000), http://web.aeromech.usyd.edu.au/rheology/snasseri/images/chocolate.pdf
- How to melt and temper chocolate (youtube.com, from Howdiniguru, 24.02.2009), http://youtu.be/bDcF7nJbF04
- Wikipedia: Chocolate, http://en.wikipedia.org/wiki/Chocolate
- Wikipedia: Types of chocolate, http://en.wikipedia.org/wiki/Types_of_chocolate
- Wikipedia: Rheology, http://en.wikipedia.org/wiki/Rheology
- Wikipedia: Chocolate bloom, http://en.wikipedia.org/wiki/Chocolate_bloom
- Stephen T. Beckett. The Science of Chocolate (R. Soc. of Chemistry, 2008), www.google.com/books?id=ny9oVf4usz8C
- H. Schenk and R. Peschar. Understanding the structure of chocolate. Radiation Phys. and Chem. 71, 3-4, 829-835 (2004)
- J. Chevalley, Rheology of chocolate, J. Text. Stud. 6, 2, 177-196 (1995)
- E. O. Afoakwa, A. Pareson, M. Fowler, and J. Vieira. Relationship between rheological, textural and melting properties of dark chocolate as influenced by particle size distribution and composition, Eur. Food Res. Technol. 227, 4, 1215-1223 (2008)
- E. O. Afoakwa, A. Paterson, and M. Fowler. Factors influencing rheological and textural qualties in chocolate - a review. Trends in Food Sci. Technol. 18, 6, 290-298 (2007)
- D. Gabriele, M. Migliori, N. Baldino, and B. de Cindio. Influence of Fat Content on Chocolate Rheology. AIP Conf. Proc. 1027, pp. 1265-1267 (2008)

Background reading

- A. G. Marangoni and R. W. Lencki. Ternary Phase Bahaviour of Milka Fat Fractions. J. Agric. Food Chem. 46, 10, 3879-3884 (1998)
- K. van Malssen, A. van Langevelde, R. Peschar, and H. Schenk. Phase behavior and extended phase scheme of static cocoa butter investigated with real-time X-ray powder diffraction. J. Am. Oil Chem. Soc. 76, 6, 669-676 (1999)
- G. Mazzanti, S. E. Guthrie, E. B. Sirota, A. G. Marangoni, and S. H. J. Idziak. Orientation and Phase Transitions of Fat Crystals under Shear. Crystal Growth & Design, 3, 5, 721-725 (2003)
- G. Talbot. Chocolate Temper. In: Industrial Chocolate Manufacture and Use (Springer, 1994), pp. 156-166
- C. Loisel, G. Keller, G. Lecq, C. Bourgaux, and M. Ollivon. Phase transitions and polymorphism of cocoa butter. J. Am. Oil Scientists' Soc. 75, 4, 425-439 (1998)
- K. Sato. Crystallization behaviour of fats and lipids - a review. Chem. Eng. Sci. 55, 7, 2255-2265 (2001)
- J. Bricknell and R. W. Hartel. Relation of fat bloom in chocolate to polymorphic transition of cocoa butter. J. Am. Oil Chemists' Soc. 75, 11, 1609-1615 (1998)
- Y. Kinta and T. Hatta. Morphology of fat bloom in chocolate. J. Am. Oil Scientists' Soc. 82, 9, 685 (2005)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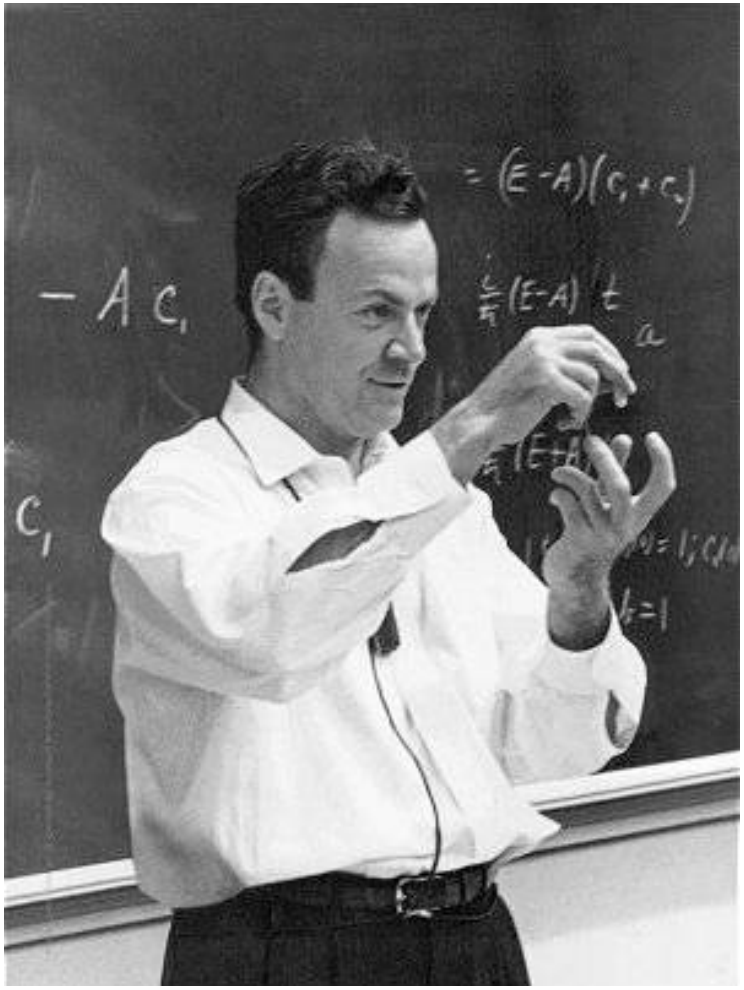
To work towards results?

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

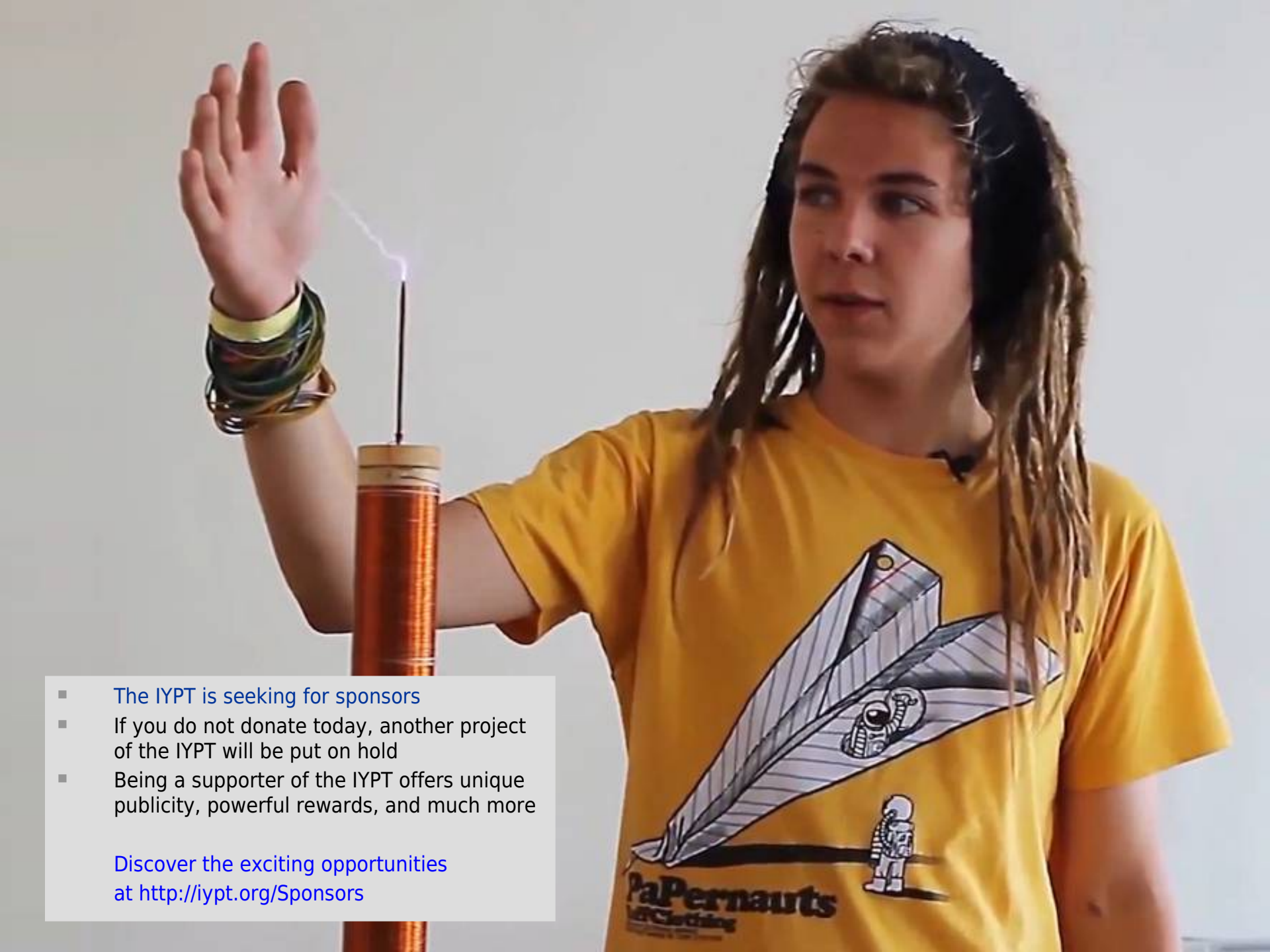
- If you cannot solve the entire problem, decide what is really necessary and solve a partial problem
- If you can solve the entire problem, nevertheless decide what partial case is sufficient, and your solution will be much better
- Be brave in what you do, but always reserve a great degree of scientific 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)



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August 1, 2013

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Call for cooperation

- If you are interested in the idea behind the Kit — to structure some earlier knowledge about the physics behind the problems and to encourage students to contrast their personal contribution from this knowledge — your cooperation is welcome
- If more contributors join the work on the Kit for 2014, or plan bringing together the Kit for 2015, good editions may be completed earlier
- It would be of benefit for everybody,
  - students and team leaders, who would have an early reference (providing a first impetus to the work) and a strong warning that IYPT is all about appropriate, novel research, and not about “re-inventing the wheel”
  - jurors, who would have a brief, informal supporting material, possibly making them more skeptical and objective about the presentations
  - the audience outside the IYPT, who benefits from the structured references in e.g. physics popularization activities and physics teaching
  - the IYPT, as a community and a center of competence, that generates vibrant, state-of-the-art research problems, widely used in other activities and at other events
  - and also the author (-s) of the Kit, who could rapidly acquire a competence for the future activities and have a great learning experience