Preparation to the Young Physicists' Tournaments' 2009

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Problem No. 1 "Stearin engine"

A candle is balanced on a horizontal needle placed through it near its centre of mass. When the candle is lit at both ends, it may start to oscillate. Investigate the phenomenon. Maximize the output mechanical power of the system.

Background reading

- How to do the candle experiment, a video from Neistat brothers. http://www.youtube.com/watch?v=N15HECk9SGI

- Стеариновый мотор // Том Тит. Научные развлечения. — М., Л.: Детиздат ЦК ВЛКСМ, 1937

- Burning a candle at both ends. In: David Featonby. What happens next? A teaching strategy to get students of all ages talking. Science in School, Issue 7, 24-27 (Winter 2007), http://www.scienceinschool.org/repository/docs/issue7_whathappens.pdf

- Candle Wax Motor, Savaplace. http://savasplace.com/equilibrium/

- Опыт №8: «Парафиновый мотор» // Юлия Лайтнер. Занимательные опыты по физике. http://festival.1september.ru/articles/524485/

- Волшебные качели // http://lmagic.info, fan1990. http://lmagic.info/volshebnie_kacheli.html

- Discussion at Physics Forums. http://www.physicsforums.com/archive/index.php/t-249419.html

Key questions

- Bifurcation state or butterfly effect when a small loss of symmetry causes large-scale oscillations?

- What parameters of the candle may influence the effect (melting temperature, heat capacity, heat conductivity, combustion heat, density of stearin? viscosity of molten stearin? diameters of the pores, thickness of the thread, lengths of overhanging threads? linear dimensions of the candle?) What is the role for each of them?

- What is the role of the friction in needle and of the ambient conditions (such as air temperature?)

- What torques and forces appear in the system when a certain number of stearin droplets take off from the candle? Can we speak of a lag time between a drop drip and a visible acceleration?

- Are the oscillations harmonic? A classical oscillator shows repeated transitions of its kinetic and potential energies. Is that somehow relevant to the problem?

- Besides making the stearin molten, what effects does the excessive combustion heat cause?

- When exactly do stearin droplets take off from the candle? How many droplets take off within a single period of oscillations? Do they fall down regularly? Is there a resonance effect?

- How does the system evolve in time? What are the time dependences for candle's mass and moment of inertia, for the period and amplitude of oscillations?

- Is it worth modeling the system numerically?

- Finally, what parameters need to be tuned to maximize the mechanical power? Is it possible to achieve a higher mechanical power for a given candle by only varying the initial overhanging lengths of threads, best setting both ends on fire, reducing friction, or changing ambient conditions?

Problem No. 2 "Coupled compasses"

Place a compass on a table. Place a similar compass next to the first one and shake it gently to make the needle start oscillating. The original compass' needle will start oscillating. Observe and explain the behavior of these coupled oscillators.

Background reading

- Joseph L. Snider. Simple demonstration of coupled oscillations. Am. J. Phys., Vol. 56, No. 3, 200 (March 1988)

- Yaakov Kraftmakher. Pendulums are magnetically coupled. Phys. Educ., 43, 248-251 (2008)

- Michael 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

- Magnetic field at different locations and times. National Geophisical Data Center. http://www.ngdc.noaa.gov/geomagmodels/IGRFWMM.jsp

- Oscillations of two compass needles couple. Demonstrations of coupled oscillations at Wesleyan University, University of Colorado, http://www.wesleyan.edu/physics/demos/pirabib/3oandw/3A70.html, http://physicslearning.colorado.edu/PIRA/PiraSubTOC.asp?STopic=3A70

Key questions

- What interactions cause the original compass needle to oscillate? How to describe these interactions quantitatively?

- What parameters of needles are relevant? (magnetic moment? moment of inertia?)

- What are the roles of friction force in suspension and air resistance? How fast the oscillations decay and how would they look like at zero friction?

- How does the magnetic field of the Earth influence the effect?

- How to measure the magnetic field in the vicinity of the needles without influencing the results?

- What possible oscillatory modes may be observed? How to classify them? Is there a possibility for interference beat?

- Can we describe this system as an oscillator with feedback?

- At what degree the oscillations of both needles may be reproduced, if the experiment is repeated?

- What is the role of background magnetic fields, such as from CRTs or speakers?

- Is it reasonable to speak of an analogy between coupled compasses and two pendulums connected with an elastic spring? Under what assumptions this analogy may be used?

- Is it worth modeling the system numerically?

Problem No. 3 "Resonating modes"

Place a mobile phone inside a metallic container with a hole in it. Investigate under what conditions the mobile phone starts to ring after calling it.

Background reading

- Wikipedia: Field test mode. http://en.wikipedia.org/wiki/Field_test_mode

- Wikipedia: Timing advance. http://en.wikipedia.org/wiki/Timing_advance

- Wikipedia: Received signal strength indication. http://en.wikipedia.org/wiki/Received_signal_strength_indication

- Wikipedia: Time division multiple access. http://en.wikipedia.org/wiki/Time_division_multiple_access

- Wikipedia: Telecommunications link. http://en.wikipedia.org/wiki/Telecommunications_link

- Frequency hopping on GSM networks. Steve Punter's Southern Ontario Cell Phone Page. http://www.arcx.com/sites/FrequencyHopping.htm

- CDMA vs TDMA. Steve Punter's Southern Ontario Cell Phone Page. http://www.arcx.com/sites/CDMAvsTDMA.htm

- Проект «Нетмонитор». http://www.netmonitor.ru

- Paul Falstad. Java applet demonstrating standing electromagnetic waves in a 3D rectangular box, or cavity resonator. http://www.falstad.com/embox/

Background reading

- Standing waves in a rectangular box. In: William Cronk Elmore, Mark A. Heald. Physics of waves (Courier Dover Publications, 1985), pp. 160-163

- C. Y. Wu. Field distribution inside a box with aperture. A PhD thesis at Syracuse Univ., NY (1977)

- E. Lopez-Martin, J. C. Bregains, F. J. Jorge-Barreiro, J. L. Sebastian-Franco, E. Moreno-Piquero, and F. Ares-Pena. An experimental set-up for measurement of the power absorbed from 900 MHz GSM standing waves by small animals, illustrated by application to picrotoxin-treated rats. Progress in Electromagnetics Research-Pier. Vol. 86, 149-165 (2008)

- Mitsuo Taguchi, Yuta Sanabe, and Yasushi Hamada. Numerical analysis of electromagnetic field distribution in hollow metallic rectangular parallelepiped with poof. Proc. 2007 Korea-Japan Microwave Conference, pp. 29-32. http://naosite.lb.nagasaki-u.ac.jp/dspace/bitstream/10069/19205/1/KJMW%202007_29_TH02-2.pdf

Key questions

- What parameters of the signal (besides intensity) determine if the phone will correctly decode the transmission from the base station? What is RSSI, timeslot, frequency hopping?

- How to record the signal parameters? What is Netmonitor/FieldTest? How to use it?

- How to treat experimental results? Are they reproducible? Is it reasonable to speak of a probability that the phone will or will not ring under given conditions? How to find the conditions under which the phone rings only sometimes and is sensitive to slight changes of all relevant parameters?

- Is that electric or magnetic field that is detected by antennas in common mobile phones? What is the intensity of the signal emitted by the phone in comparison to the signal emitted by the base station?

- What are the operating frequencies for common GSM or CDMA phones? What are the corresponding wave lengths? Does a phone dynamically change operating frequency to ensure best data transfer? Does the base station always provide the signal of uniform intensity?

- How exactly does the container shield the field? What does a hole make? How does the radiation come into the container through the hole? What happens in the area of poor or unstable coverage?

- Is it possible to observe standing waves inside the container?

- What would be the resonance frequencies for rectangular container? Is it worth modeling the oscillatory modes numerically?

- What changes when we alter the position and the spatial orientation of the cell phone inside the container?

- What parameters of the container may influence the results? (linear dimensions? thickness of the walls? material?) What parameters of the hole may influence the results? (size? shape? position?)
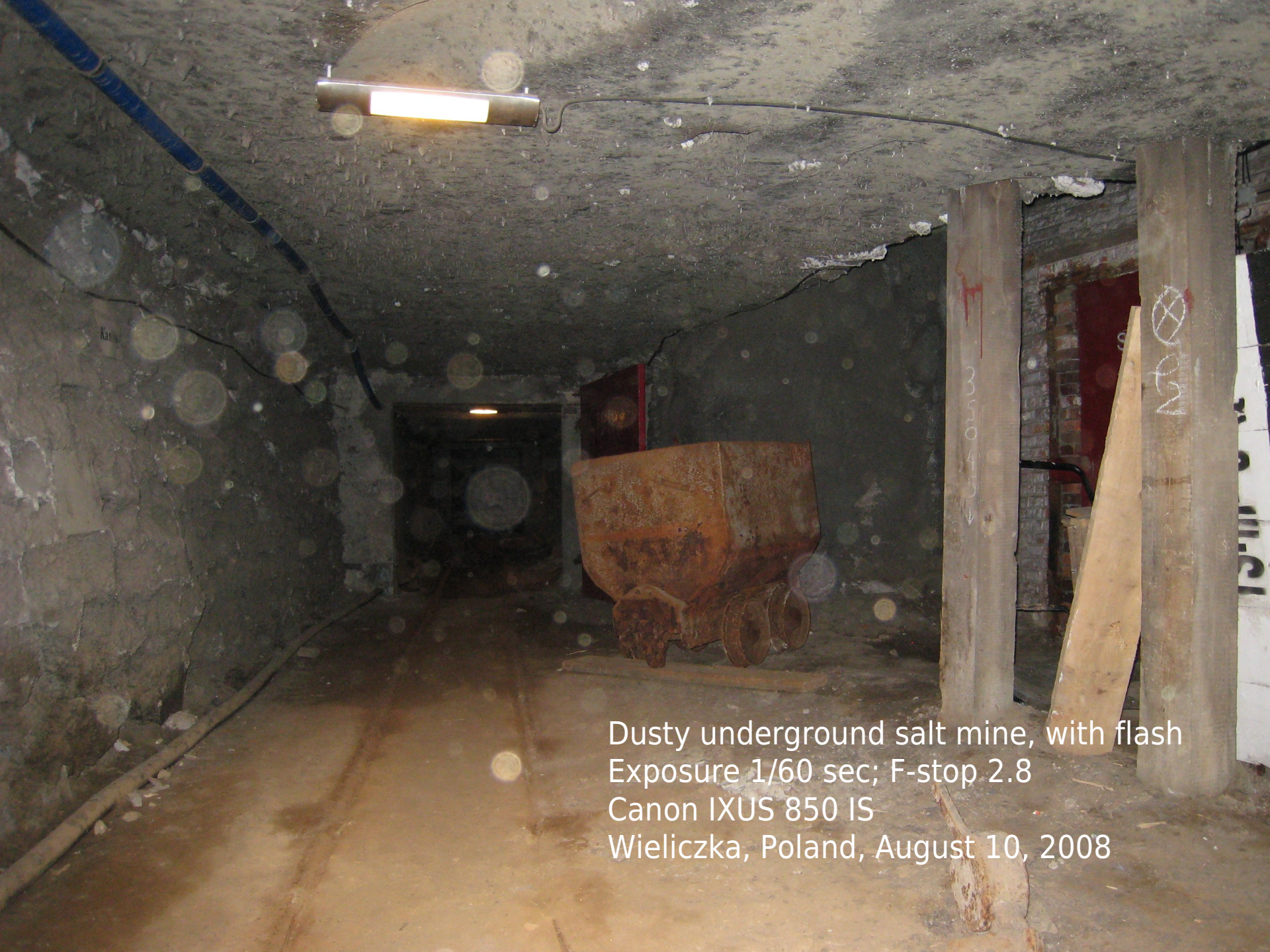
Problem No. 4 "Ghostly images"

When a photo is taken with a flash, bright "disks" may appear as shown in the picture. Investigate and explain the phenomenon.
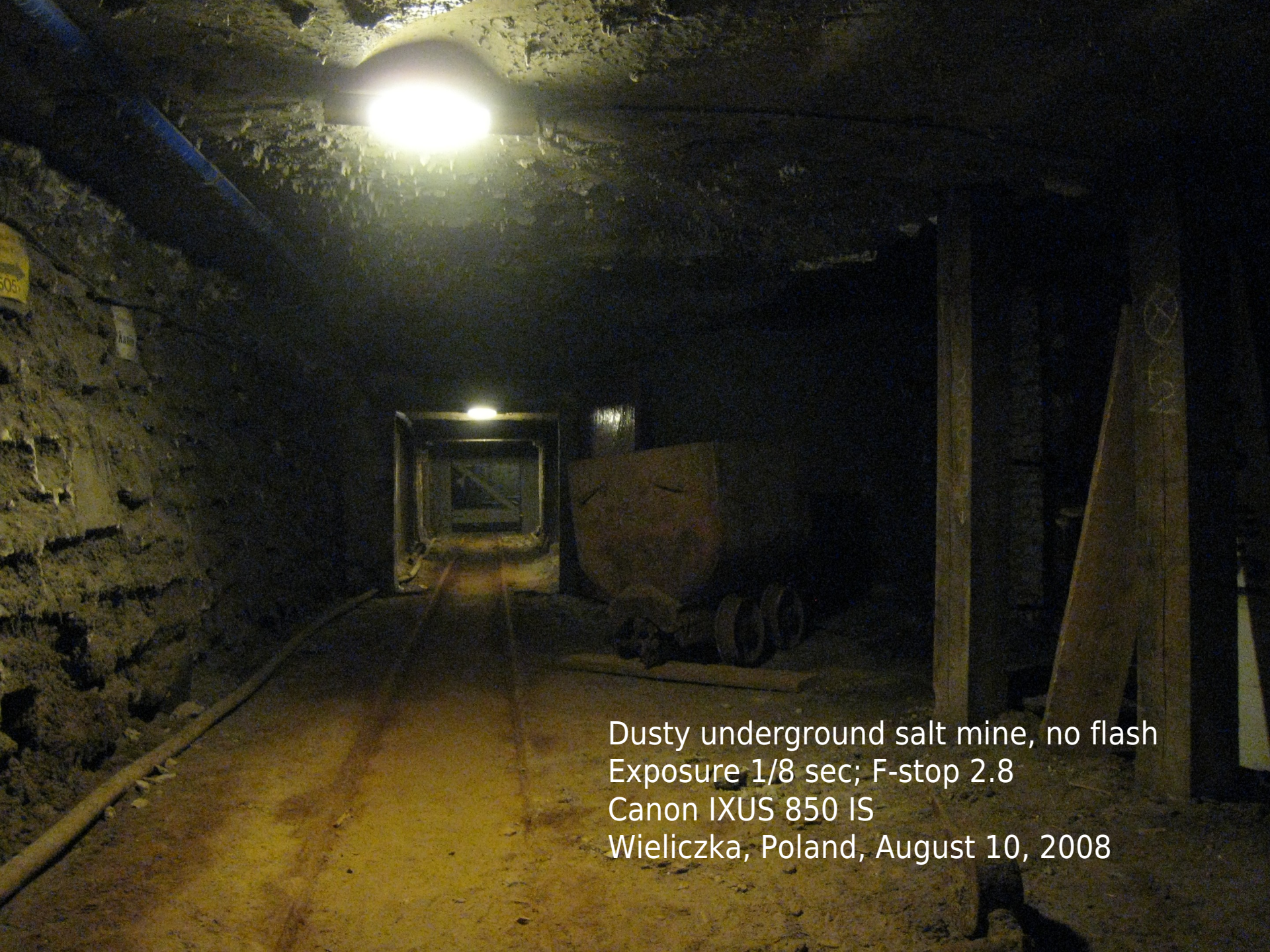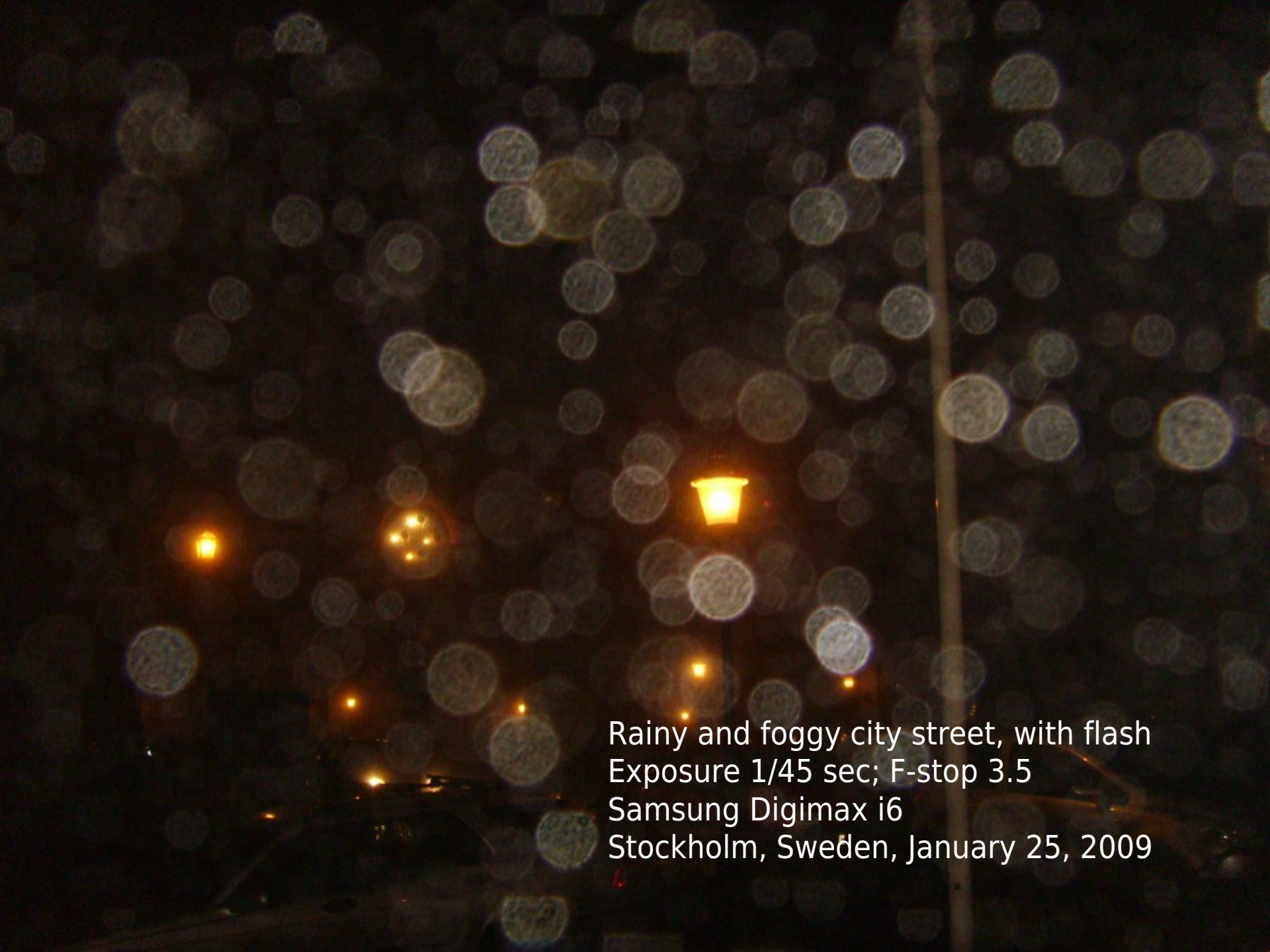
Dusty underground salt mine, no flash
Exposure 1/8 sec; F-stop 2.8
Canon IXUS 850 IS
Wieliczka, Poland, August 10, 2008

Dusty underground salt mine, with flash
Exposure 1/60 sec; F-stop 2.8
Canon IXUS 850 IS
Wieliczka, Poland, August 10, 2008

Rainy and foggy city street, no flash
Exposure 1.00 sec; F-stop 3.5
Samsung Digimax i6
Stockholm, Sweden, January 25, 2009

Rainy and foggy city street, with flash
Exposure 1/45 sec; F-stop 3.5
Samsung Digimax i6
Stockholm, Sweden, January 25, 2009

Background reading

- Gail Bjork. Dust halos. Digicamhelp. http://www.digicamhelp.com/taking-photos/lighting-techniques/dust/

- Paul van Walree. Flashlight and ghosts. In: Depth of field. Toothwalker. http://toothwalker.org/optics/dof.html

- What are orbs? Rendlesham Forest incident. http://www.rendlesham-incident.co.uk/orbs-are-just-dust.php

- Maurice Townsend. Introduction to orbs. ASSAP. http://www.assap.org/newsite/htmlfiles/Orbs%20centre.html

- Maurice Townsend. Orbs - are they paranormal? ASSAP (2009). http://www.assap.org/newsite/articles/Paranormal%20orbs.html

- Maurice Townsend. A scientific case study: The orb zone theory. ASSAP (2007). http://www.assap.org/newsite/articles/Orb%20Zone%20Theory.html

- Forums for amateur photographers, http://photo.net/digital-camera-forum/00Etue, http://photography-on-the.net/forum/showthread.php?t=514215, http://macgroup.infopop.cc/eve/forums/a/tpc/f/8041031462/m/8121065792

Key questions

- Rumors on this effect circulate on the web and in sensationalist media. What qualitative experiments may directly prove the explanation you propose? Why not to take a long exposure shot with a separate camera (shielded from your camera's flash) to reveal illuminated particles before your camera's lens?

- What parameters of the camera besides focal length, aperture and exposure may be controlled? Would disks be more blurred for a camera with larger focal length? Would the shape of the aperture influence on the shape of disks? Are the dust particles inside or outside of the depth of field range?

- Would it be difficult to extract necessary parameters from EXIF data?

- What parameters of particles themselves are relevant? (distance between the lens and the particles? their size?) How do they influence on features of bright disks? What physical parameters may quantitatively describe the properties of bright disks, such as sharpness, color intensity or shape?

- Do the bright disks possess a fine structure? Is it possible to reveal on your photos the concentrical rings or color spots? How can they be explained? May wave effects be responsible for such color aberration and rings?

- Bright spots are nice to study, but they do spoil a photograph? Is there a way to suppress this effect?

- Is it possible to extract information on the room air conditions from a photograph? Dust particles would not fly too far in a time of 1 or 2 seconds. What information may be extracted from a sequence of shots?

- Is it worth compiling a program to imitate bright spots images on computer? Would it be possible to control the aperture's diameter and shape, flash radiant intensity, linear dimensions of the system and the spatial distribution of particles in your program?

Problem No. 5 "Stop a drip"

To prevent dripping from a bottle after pouring, it can be turned slightly. Investigate the motion of the bottle for no drop to fall.

Background reading

- Verser le vin / Dans: « Préposé au service des mets et boissons » (2003), p. 49, http://www.cqrht.qc.ca/CQRHTWeb/fr/public/commun/normes/contenu/documents/FBS_ed2_H.pdf

- Help me pour wine, question by Ricardo Vacapinta. Discussion at Metafilter.com (February 9, 2009), http://ask.metafilter.com/113756/Help-me-pour-wine

- Le savoir-vivre autour d'une grande table. Bollog, http://www.nikibar.com/tremplin-idees/trucs-cuisine/grande-table.html

- Comment bien servir le vin ? (15 mai 2009). mamzelle.B. http://mamzelleb.over-blog.com/article-29558415.html

- Service du vin. Union de la somellerie française. http://www.sommelier-france.org/technique_eff.php

- The slide technique - the wine expert, by Gary Vaynerchuk. http://www.eatdrinkordie.com/videos/38df3cc273/the-slide-technique-the-wine-expert-from-gary-vaynerchuk-the-wine-expert

- Marcus Reiner. A tea-pot effect. Bulletin of the Res. Council of Israel, 2, 265-266 (Sept. 1952)

- Marcus Reiner. The teapot effect. . . a problem. Phys. Today, 9, 16-20 (Sept. 1956)

- Joseph B. Keller. Teapot effect. J. Appl. Phys., 28, 8, 859-864 (1957)

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- 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)

Background reading

- Г. Майер. Липкая струя // Квант, №11, 1977, http://kvant.mirror1.mccme.ru/1977/11/lipkaya_struya.htm

- Video of the Coanda effect. http://www.youtube.com/watch?v=AvLwqRCbGKY, http://www.youtube.com/watch?v=o_-Eph9w6_A

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- Jean-Marc Vanden-Broeck and Joseph B. Keller. Pouring flows. Phys. Fluids 29, 3958 (1986)

- Edward J. Covington. The flow from the spout of a teapot. http://home.frognet.net/~ejcov/teapot.html

- Professor spills secret of the dripping teapot. BBC, December 3, 1998. http://news.bbc.co.uk/2/hi/science/nature/227572.stm

- Sanat Shetty and Ramon 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)

Key questions

- How would a professional sommelier perform such a trick?

- What energy does a droplet need to take off from the neck? On what parameters does this energy depend? Are we really interested in increasing this energy?

- What is the primary cause of the flow at the external surface of the neck? Is it due to surface tension, adhesion or pressure difference at the neck due to Bernoulli principle? What part of the neck the droplets typically take off from?

- What points in the flow experience higher pressure due to Bernoulli effect and can this result in turning the corner of the lip? What is the difference between the adhesion force of droplets to wet and to dry bottle glass?

- What is the role of the bottle material (glass, plastic?) and the shape of the lip?

- What is the role of the properties of the liquid (viscosity? density? surface tension?)

- What physical parameters of the bottle motion may influence the flow (angular speed? exact trajectory?)

- How to experimentally measure the motion of the bottle? How to measure rotational speeds and accelerations with respect to different axes, as well as translational velocities and accelerations?

- Is it worth modeling the system numerically?

- Are commercially available aluminum non-drip pourers relevant to the problem?

- Above all, can you give clear practical advices for common wine, beer or coke bottles?

Problem No. 6 "Roundabout"

Put a plastic cup on a thin layer of liquid on a flat solid surface. Make the cup rotate. On what parameters does the rotational deceleration of the cup depend?

Background reading

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- Hua-Shu Dou, Boo Cheong Khoo, and Khoon Seng Yeo. Flow transition in plane Couette flow, arXiv:nlin/0501048v3 [nlin.CD]

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Background reading

- Michael C. Wendl and Ramesh K. Agarwal. Viscous dissipation in finite thin-gap Couette devices. J. Heat Transfer, 124, 200 (2002)

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Background reading

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- U. Ehrenstein and W. Koch. Three-dimensional wavelike equilibrium states in plane Poiseuille flow. J. Fluid Mech. 228, 111 (1991)

- A. Cherhabili and U. Ehrenstein. Finite-amplitude equilibrium states in plane Couette flow. J. Fluid Mech. 342, 159 (1997)

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- H. L. Swinney and J. P. Gollub, Hydrodynamic instabilities and the transition to turbulence (Springer-Verlag, Berlin, 1981)

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- Marino Arroyo and Antonio DeSimone. Relaxation dynamics of fluid membranes. Phys. Rev. E, 79, 3, 031915, Part 1 (March 2009)

Key questions

- Is the cup in direct contact with the solid substrate? If not, why? (due to buoyancy force? viscous, capillary forces?)

- What parameters of the water layer influence the deceleration process? (viscosity, density, surface tension of water?)

- What parameters of the cup influence the deceleration process? (mass, shape, surface of the cup?)

- What forces oppose the cup rotation? (capillary? viscous?) What are the energy losses ad the rate of energy dissipation?

- Would it be difficult to develop a theory for the time dependence of cup's angle, angular speed and acceleration, and including all relevant parameters as tunable variables? Is it worth modeling the system numerically?

- What are the flow lines for water under and around the cup? Can they be visualized in experiments? Is the flow laminar or turbulent and what is the Reynolds number?

- Can we classify the liquid flow under and around the cup as the Couette flow? What are the shear rates and shear stresses for each point of the flow

- Are the properties of rigid substrate relevant to the problem?

- At what degree the motion of cup is reproducible?

Problem No. 7 "Skateboarder"

A skateboarder on a horizontal surface can accelerate from rest just by moving the body, without touching external support. Investigate the parameters that affect the motion of a skateboard propelled by this method.

A skateboard is quite complicated to be described theoretically. What simplest models may be employed?

Background reading

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Background reading

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- M. Wisse and A. L. Schwab. Skateboards, bicycles, and three-dimensional biped walking machines: Velocity-dependent stability by means of lean-to-yaw coupling. International Journal of Robotics Research, 24, Issue 6, 417-429 (June 2005)

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- J. P. Ostrowski. The mechanics and control of undulatory robotic locomotion. PhD thesis at the California Institute of Technology, Pasadena (September 1995)

- Recreational injury to older children (10-14 year olds). Hazard, Monash University, No. 31 (June 1997), http://monash.edu.au/muarc/VISU/hazard/haz31.pdf

Key questions

- What is the name of this trick and how exactly would an experienced skater perform it? Can you try to perform this trick personally?

- What are the principal structural elements of a skateboard? Is there a suspension? What creates the major friction?

- How to describe the conservation of momentum for the system?

- Experimental results would be certainly slightly various for different skaters and even for a certain skater in different experiments. How to approach the obtained data statistically?

- What parameters may be controlled and recorded during a live experiment? (translational and angular velocities and accelerations? reaction from the ground? friction coefficients?)

- What is the efficiency of such a motion in terms of ratio between muscle power and kinetic energy per unit time?

- Above all, what is your conclusion on the problem?

Problem No. 8 "Air pocket"

A vertical air jet from a straw produces a cavity on a water surface. What parameters determine the volume and depth of the cavity?

Background reading

- R. D. Collins and H. Lubanska. The depression of liquid surfaces by gas jets. British Journal of App. Phys., 5, 22-26 (1954)

- W. E. Olmstead. Depression of an infinite liquid surface by an incompressible gas jet. J. Fluid Mech., 19, 561 (1964)

- G. Bouchet, E. Climent, and A. Maurel. Instability of a confined jet impinging on an water/air free surface. Europhys. Let., 59, 6, 827-833 (Sept. 2002)

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Background reading

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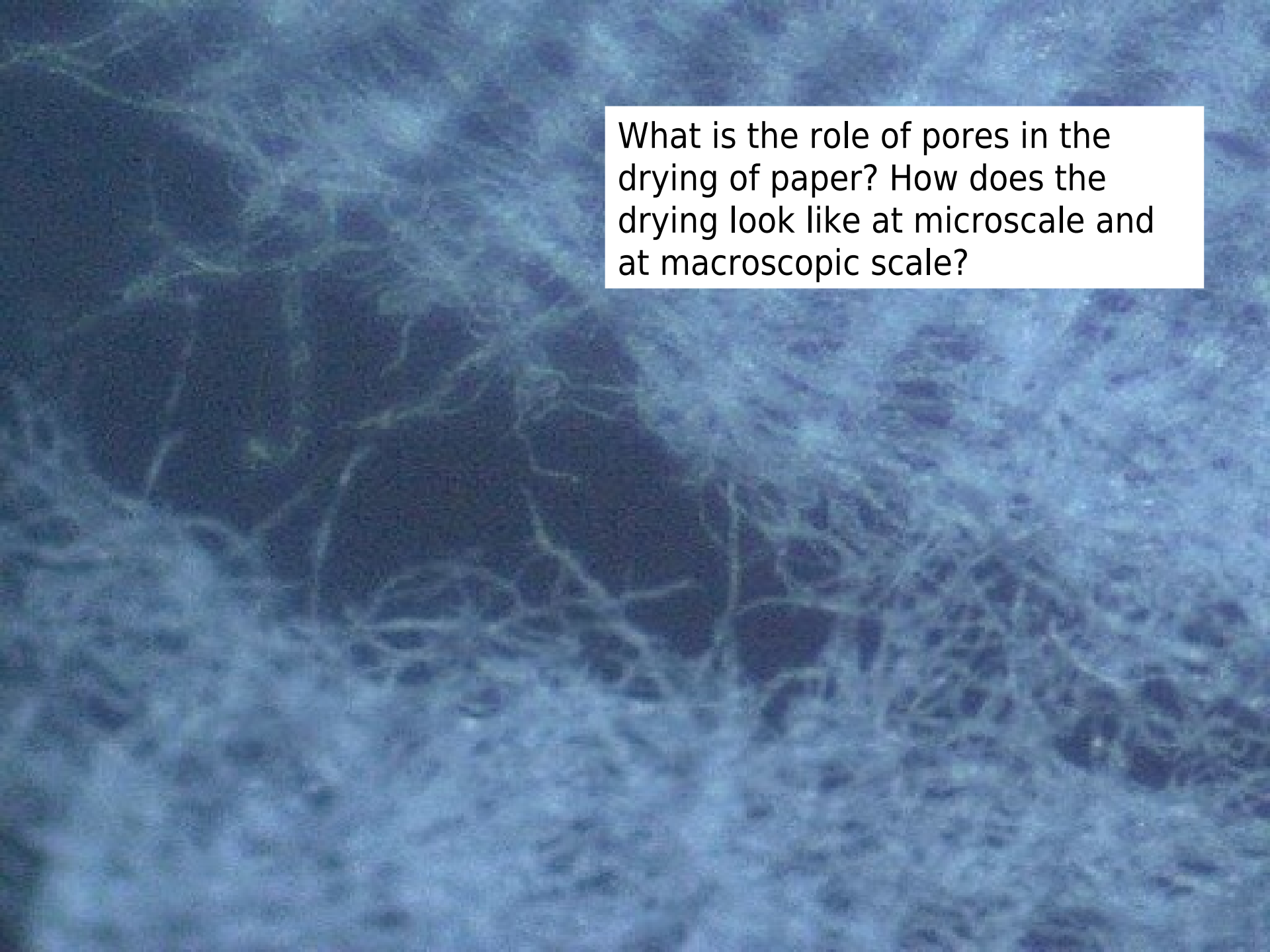- G. Birkhoff. Jets wakes cavities (1957), p. 224

Key questions

- How to describe the shape, the depth and other geometrical parameters of the cavity? If they are not quite stable, can they be approached statistically?

- It might be reasonable to photograph the cavity from different angles or with different exposures. Where to place the camera and how to treat the obtained images or videos?

- When we blow towards the water surface, we produce an air flow. How exactly does this air flow develops in space and in time? What are the magnitudes of the Reynolds number? Is the flow laminar or turbulent? Does the Reynolds number change with time? What are the flow lines and can they be visualized? What do parameters of the straw determine?

- What interactions between the air flow and the water cause the cavity and determine its parameters? What forces most oppose the cavity formation? (viscous? capillary? gravitational?)

- What geometrical parameters of the system are relevant? (diameter of the tube? distance between the tube and the water? depth of the water layer?)

- What physical parameters of water influences on the shape of cavity? (viscosity? density? surface tension?) What dimensionless criteria may be relevant (Weber? Bond? Froude? Reynolds?)

- How does the cavity evolve in time when air flow appears? How does it evolve in time when air flow is "switched off"?

- Is it possible to observe waves on the water surface? How do they propagate? What is their wave length, amplitude and total energy? Are they capillary or gravitational?

- What is the kinetic energy of the air flow in comparison to the energy needed to dynamically deform the water surface?

- Above all, what is your conclusion on the problem?

Problem No. 9 "Drying"

Investigate the drying process of a vertical wet paper sheet. How does the boundary of drying move?

What is the role of pores in the drying of paper? How does the drying look like at microscale and at macroscopic scale?

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Key questions

- The boundary between the wet and the dry areas is not sharp. Is it possible to describe the spatial distribution of paper "wetness"? What methods may be used for that (color density measured with a software? attenuation of a light beam measured with a proper sensor?)

- How to define "the boundary of drying"? (a line that corresponds to a certain mass density of water in the paper sheet?)

- How does the total mass of water in a drying paper depend on time? Is it possible to obtain this dependence experimentally?

- What parameters of paper sheets are relevant? (average diameter, average length and spatial geometry of pores? chemical properties of fibers? thickness of the sheets?) How does each of them influence on the evolution of drying front?

- What types of interactions between the macromolecular chains of paper and molecules of water may influence the evaporation process? Are the water molecules absorbed either adsorbed by the paper fibers?

- What ambient physical conditions may influence on the drying process (humidity of the air? temperature of the air?)

- What changes, if in experiment we take an entirely wet sheet, a sheet slightly imbued with water, or a sheet with a wet spot surrounded by dry paper?
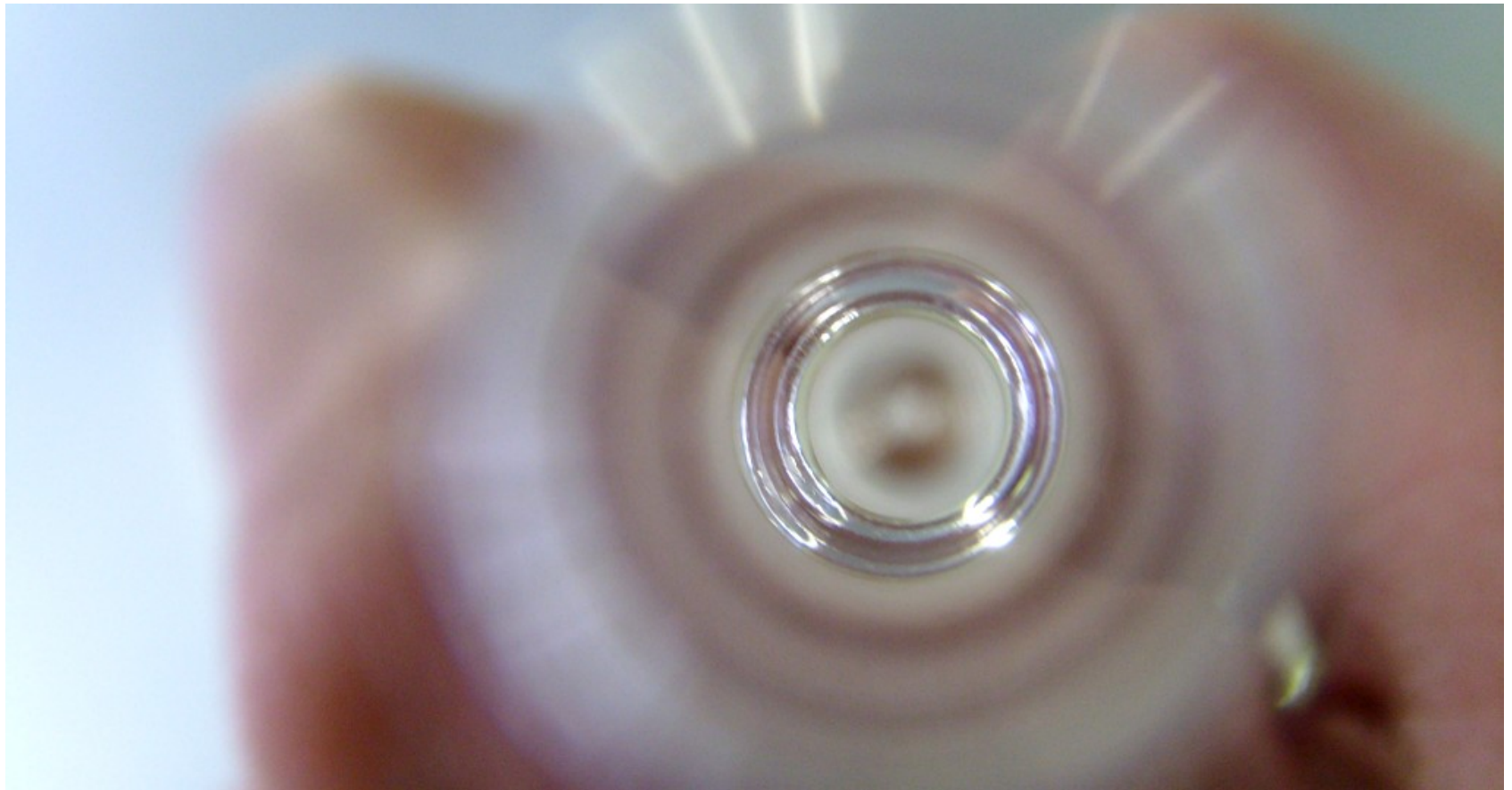
Problem No. 10 "Optical tube"

Look down a cylindrical metal tube which is shiny on the inside. You will notice dark and light bands. Investigate the phenomenon.

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Key questions

- What is the cause of the effect? Is the explanation in the limits of classical optics, or certain wave effects are relevant? Does the tube behave as a concave cylindrical mirror? Is there a direct evidence to the explanation you propose?

- What is the minimum length of the tube to observe the effect?

- What determines the angles under which we see the bands? What possible patterns may be observed?

- What parameters determine the visible pattern (radius, length of the tube? position of the observer's eye? positions, sizes and shapes of light sources? material and smoothness of the surface?)

- What materials of the tube besides glossy metals are suitable to observe the effect? (glass?) Is the angle of total internal reflection relevant?

- What is the Brewster's angle and may the light polarization be relevant? How to check possible polarization?

Problem No. 11 "Transformers"

The "simple transformer law" relates output voltage to input voltage and turns ratio. Investigate the importance of frequency and other parameters in determining the non-ideal behaviour of transformers.
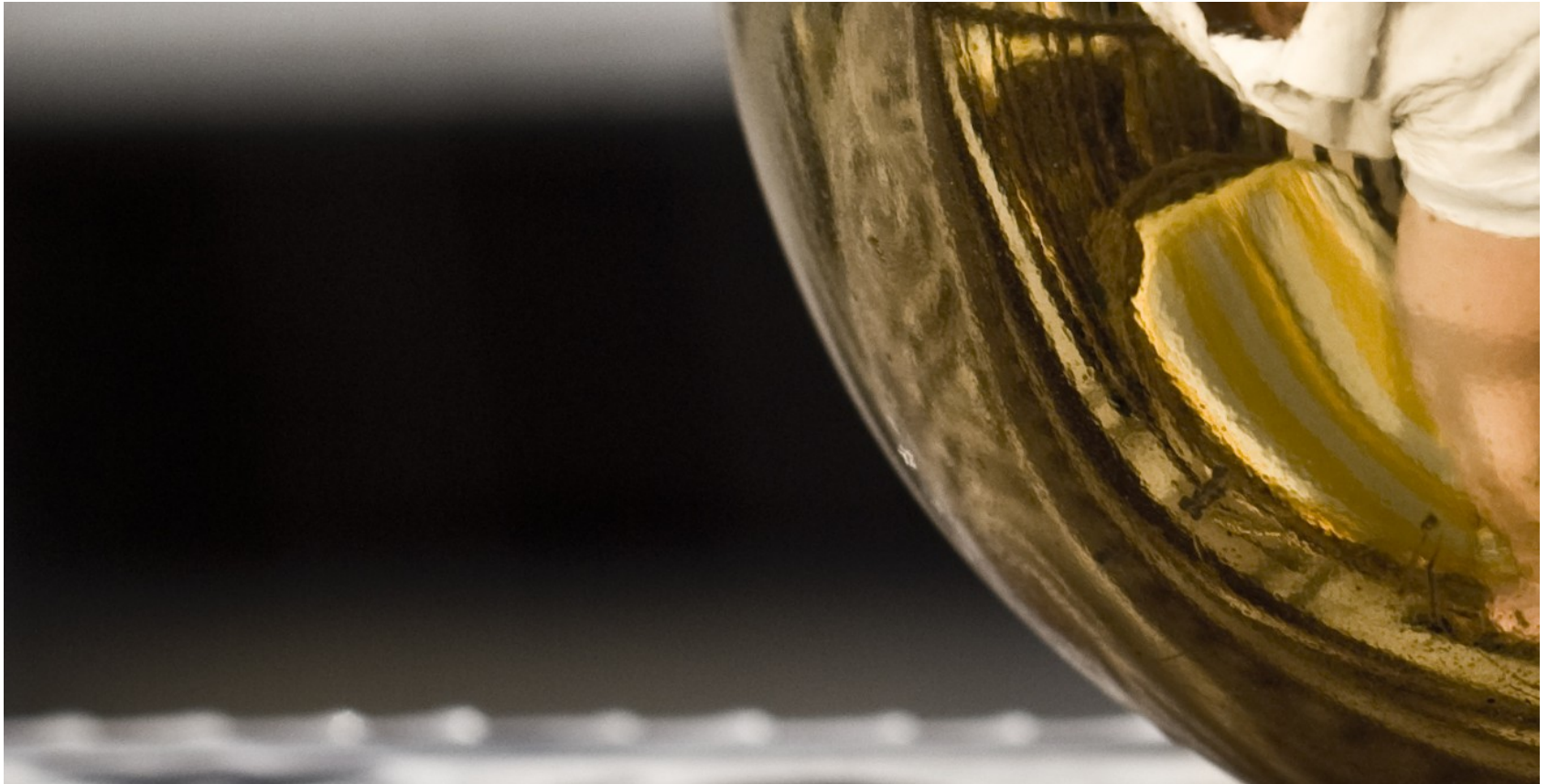
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Key questions

- What actually is the "simple transformer law", and under what assumptions it is derived from the Faraday's law of induction?

- What are the frequency dependences for various energy losses in a real transformer, e.g.,

  - heating of the iron core?

  - heating of the wires?

  - eddy currents in the core?

  - repeated magnetizing of the core?

- Do the flux always pass through windings? What is leakage flux and leakage inductance?

- What parameters may, in the end, influence on the output voltage (magnetic permeability, heat conductivity, resistivity of the core's material? volume and shape of the core? active and reactive resistances of the windings? input voltage?)

- What is the initial magnetizing current needed to produce the magnetic field in the core? Is there a counter-EMF due to Lenz law? How does the field in the secondary circuit influence on the field?

- Can you check your theoretical approach on various types of transformers, e.g. of various operating voltages, with different cores?) Is it worth modeling the system numerically?

Problem No. 12 "Hot ball"

Put a hot metal ball on parallel horizontal rails. The ball starts to move. Investigate the phenomenon.

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Key questions

- **Above all, what is the cause of the motion?** If you propose an explanation, does it look like a subject to direct experimental proof or disproof? What experiments may help to directly validate or invalidate your explanation?

- People at forums are complaining that the ball doesn't move regardless of the temperature difference. What conditions and materials for rails and the ball are necessary to finally observe the effect?

- What is the dependence of density on temperature for the rail's metal? Can the metal rail be deformed due to non-uniform heating? How fast does the rail conduct heat after being heated and deformed in a certain point?

- Is there a dependence of the ball's speed on the temperature difference? ball's or rails' heat capacity? thermal expansion coefficient? thermal conductivity? mass? surface properties?

- Can we describe the system in general as a heat engine? Is the Carnot principle concerning the temperature difference relevant here? What energy transitions take place?

- How to measure experimentally the rail temperatures in different points? What measurement techniques may work best? (thermocouples? IR sensors?)

- How to describe the heat transfer from the ball to the rail? Is it possible to develop a theory based on the Fourier's law? Is it possible to model the shape of a deformed rail that was heated via heat transfer from a body of a certain temperature distribution? Can a rail be heated due to radiation from the ball?

- What may determine the direction of the ball's motion on rails? Is the motion reproducible? What determines the direction of motion?

Problem No. 13 "Sand ripples"

Investigate how the formation of sand ripples under shallow water depends on various parameters.

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Key questions

- Above all, how the effect is explained?

- Are the ripples stable? Do they drift or somehow evolve with time?

- What parameters of the water basin are relevant? (depth? wave length and amplitude of gravitational waves on the surface?)

- What parameters of sand are relevant? (density? particle shape? average particle size?)

- Is there a way to describe the 3D shape of "waves"? If the wave pattern is not quite perfect, can it be approached statistically?

- What is the maximum possible "amplitude" of the ripples?

- What new we can add to this profoundly researched problem?
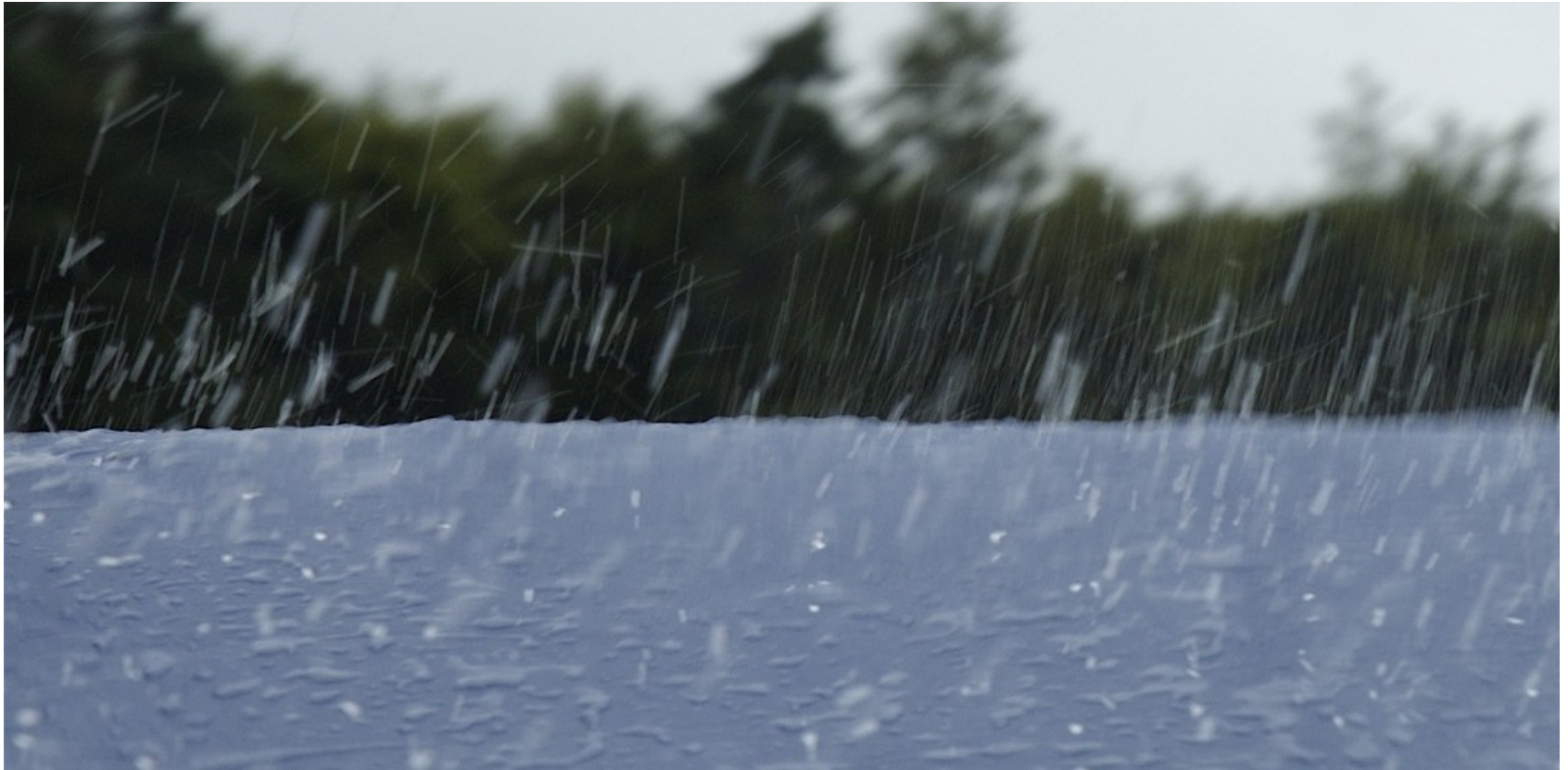
Problem No. 14 "Bouncing drop"

Investigate the motion of water droplets falling on a hydrophobic surface (e.g. coated with soot or teflon.)

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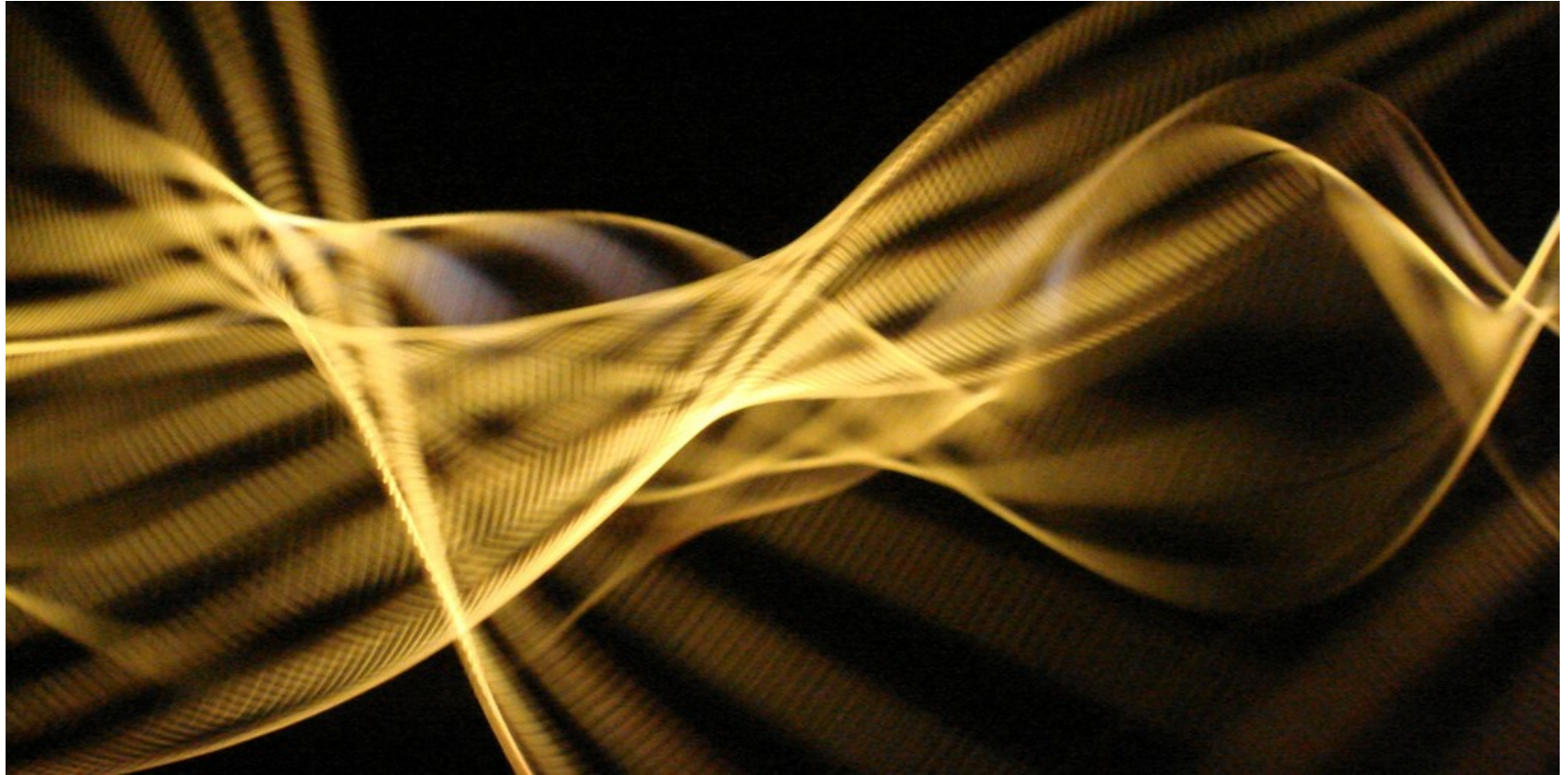
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Key questions

- Unlike elastic balls falling on rigid surfaces, droplets do not bounce quite often. What forces oppose the bouncing? (capillary? viscous? inertial? molecular adhesion?)

- What properties of hydrophobic surface are distinctive? Is it smooth on the microscopic level? Where to find or how to produce a very hydrophobic surface?

- What transitions of energy take place during the bounce?

- What is the dependence of the bounce altitude on the height from which the drop is released?

- What is the total contact time between the droplet and the substrate?

- Can a bouncing drop produce secondary cumulative jets? What is the maximum height that may be reached by droplets formed from cumulative jets?

- The Weber number describes the ratio between gravitational and capillary forces acting on a drop and may correspond to the shape of a drop and its chances to break apart. Is that relevant to the problem?

- It might be reasonable to take videos of the bouncing drops. What would be the requirements for the image-capturing equipment?

- Are any aerodynamic forces relevant to the problem? How significant is air resistance?

Problem No. 15 "Electro-oscillator"

A mass is hung from the middle of a horizontal wire. When a current is passed through the wire, the mass may start to oscillate. Describe and explain this phenomenon.

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Key questions

- Many possible explanations may be proposed. What qualitative/quantitative experiments or theoretical estimations may help to validate or invalidate each of them, e.g.,

  - drag force from the convective air flow?

  - mechanical stresses in the wire caused by non-uniform heating? (due to changes of resistivity? heat conductance?)

  - repeated elongations and contractions of the wire due to the heat produced by electric current and cooling in the air?

- What heat is generated when current passes through the wire? How fast the wire is cooled in air flow? Is the process time dependent? What changes if we use DC or AC?

- How to measure and describe the amplitude and frequency of the oscillations?

- What materials for the wire and applied voltages are required to observe the effect? At what conditions the effect is stable and reproducible, and at what conditions is not? Can some smoke help in visualizing the convective flow patterns as the wire is heated?

- Can we describe the oscillations as parametric excitations, or oscillations with feedback? Is there a possibility of parametric resonance? What is the resonant frequency of the mass on the wire? Where are nodes and antinodes on the oscillating wire?

- What physical parameters may be controlled in a certain experiment:

  - mechanical tension in the wire? resistivity, heat conductivity of the metal? length, diameter, linear density of the wire?

  - applied voltage? temperature of the wire and ambient temperature?

  - mass, material, position of the load?

Problem No. 16 "Electromagnetic motor"

Attach a strong light magnet to the head of a steel screw. The screw can now hang from the terminal of a battery. Completing the circuit by a sliding contact on the magnet causes the screw to rotate. Investigate the parameters that determine the angular velocity of the screw.

"You have one drywall screw, one 1.5 V alkaline cell, six inches of plain copper wire, one small neodymium disk magnet, and no other tools or supplies. You have 30 seconds to make an electric motor running in excess of ten thousand RPM. Can you do it? Surprisingly enough, you can."

Oskay, the image author

http://www.youtube.com/watch?v=w2f6RD1hT6Q

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Key questions

- Is your motor a real homopolar motor? Does it converge electricity into rotational motion?

- How to measure its angular speed and acceleration at start up?

- What physical parameters determine the maximum angular speed (voltage of the battery? internal resistance of the battery? magnetic field?)

- How much energy is lost on sliding contact? (due to mechanical friction? due to electric resistance?)

- How much energy is lost due to resistance of the magnet?

- What is the motor's efficiency in comparison to common motors? What limits its efficiency? (much energy wastes to overcoming friction? countercurrents? heating?)

- How stable is the rotation of the screw? What may destabilize it?

- Can electric magnets replace the magnet that you use in experiments? What is the dependence of the motor's efficiency on the magnetic field?

- What parameters of the screw itself may influence the efficiency (material? roughness?)

Problem No. 17 "Corrugation"

After traffic has used an unpaved road for some time the surface of the road gets a "wave" structure with a well defined wavelength. Investigate and explain this phenomenon.

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$\lambda = ?$

Road between Hory and Šnitaŭka
Belarus, July 21, 2008

What is common and what is different between the washboard on a real road and your experiments? Is the theory of similarity somehow relevant?

Key questions

- Above all, what is the cause of the phenomenon? If you propose an explanation, does it look as a subject to direct experimental proof or disproof? What qualitative or quantitative experiments may be held to validate or invalidate your explanation?

- Is the wheel always in contact with the road? Under what conditions it may take off?

- Does the phenomenon appear with different granular materials (sand, snow, hard spheres…)?

- What parameters of the wheel determine the shape of wave pattern an the "wavelength"? (mass? radius? width? elasticity of the rubber? properties of the surface?)

- Is there a possibility for resonance?

- What parameters of the granular substrate determine the shape of wave pattern and the "wavelength"? (density? particle shape? average particle size?) What type of mechanical response can the substrate demonstrate? Does it have elastic properties?

- Is there a way to describe the 3D shape of "waves"? If the wave pattern is not quite perfect, can it be approached statistically?

- How does the wave pattern evolve in time?

- The ripples grow on initially almost plane road. What is the maximum possible amplitude of the ripples?

- How to model such a phenomenon experimentally? Which of these approaches are simplest to implement in practice? Is it difficult to assemble such devices?

- What constitutes a similarity between an experimental model and a real corrugated road? What physical parameters of such systems may be considered similar?

- Above all, what is your conclusion on the effect?

- What new we can add to this profoundly researched problem?

what are its x, y, and z componeiits iii t

(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

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

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!

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 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

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)
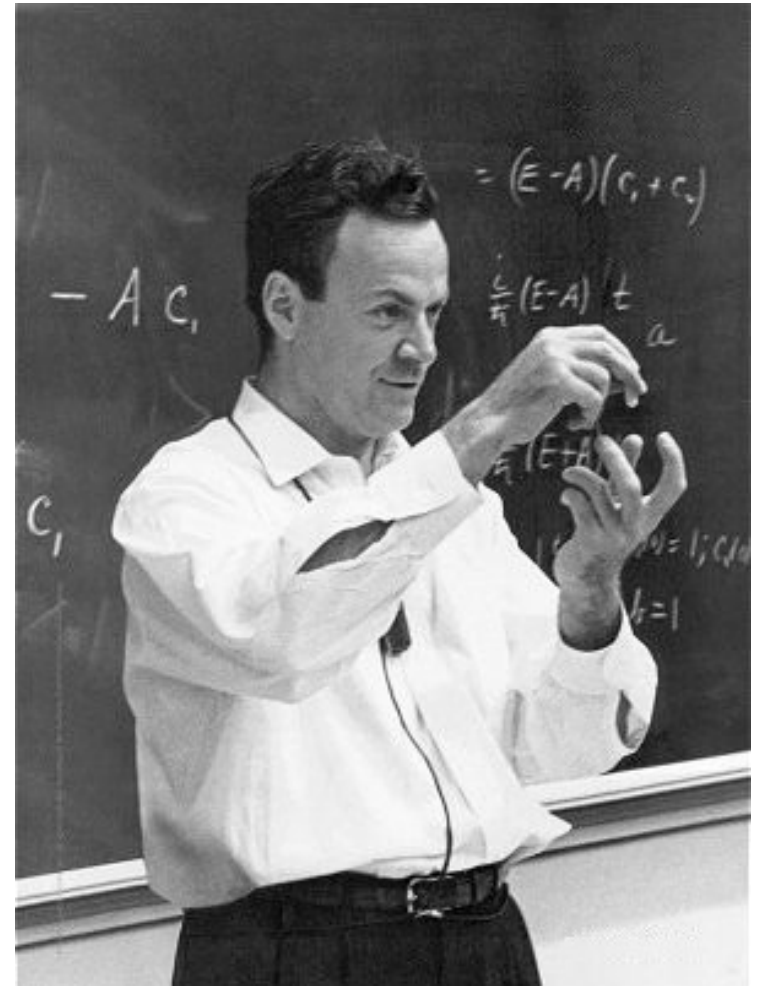
Preparation to 22nd IYPT' 2009:

questions, references and advices

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May 31, 2008…July 28, 2009

Proceeded in St Petersburg, Beli (RU), Prague (CZ), Turku (FI), Stockholm (SE), Strasbourg (FR), Vienna, Leoben (AT), Bratislava (SK), Kraków, Warsaw (PL), Hory (BY), Schönefeld (DE), Fribourg, Villigen, Geneva, Zürich (CH) :-)

Светлой памяти
Роберта Павловича Колалиса

In loving memory of
Robert Kolalis

1942—2009