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Preparation to the Young Physicists' Tournaments' 2011

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Habits and customs

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

Important information

- The basic goal of this kit is not in providing students with a start-to-finish manual or in limiting their creativity, but in encouraging them to
  - regard their work critically,
  - look deeper,
  - have a better background knowledge,
  - be skeptical in embedding their projects into the standards of professional research,
  - and, as of a first priority, be attentive in not “re-inventing the wheel”
- An early exposure to the culture of scientific citations, and developing a responsible attitude toward making own work truly novel and original, is assumed to be a helpful practice and experience
- Even if linked from iypt.org, this file is not an official release of the IYPT, and should under no circumstances be considered as a collection (even unofficial) of “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 citing the kit itself as a “user guide”
- This version is a draft, that will be updated and reviewed until July 2011
- All suggestions and criticism about the draft are warmly appreciated :-)

These problems have no solution?

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

Arkady Strugatsky and Boris Strugatsky

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

Requirements for a successful IYPT report

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

The jury would like to understand…

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


Is the novel research limited and discouraged by the existing common knowledge and the ongoing work of competing groups? :-)
Molecular Quantum Mechanics
Quantum Electrochemistry
Valency and Molecular Structure
Quantum Theory of Chemical Reactions, II
Hydrogen Bonding in Solids
The HMO-Model-1
Hydrogen Bonding
Introduction to Molecular-Orbital Theory
Computer Simulation of Liquids
Molecular Crystals, Liquids & Glasses
Theory of Electric Polarization
From Watt to Clausius
Statistical Mechanics
Molecular Dynamics
Statistical Mechanics and Dynamics
Theory of Molecular Relaxation
Dielectric Properties and Molecular Behaviour
Elementary Statistical Physics
Introduction to Chemical Thermodynamics
Progress in Colloid & Polymer Science
Intermolecular Forces

Problem No. 1 “Adhesive tape”

Determine the force necessary to remove a piece of adhesive tape from a horizontal surface. Investigate the influence of relevant parameters.

IYPT history

- **16.** Adhesive tape (14th IYPT, 2001)
  - Investigate and explain the light produced, when adhesive tape is ripped from a smooth surface.

What physical properties of commercially available tapes can be measured and precisely controlled?

[woodley wonderworks 2010]

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Key questions

- What interactions cause the tape to stick to the surface? How to describe these interactions quantitatively?
- What parameters of the surface and the film are relevant?
- How does the force depend on the direction of pulling?
- Is the measured force constant over the time of peeling?
- How to measure the parameters of the film and the adhesive layer? How relevant they are?
- At what degree the measured forces and the motion of tape may be reproduced, if the experiment is repeated?
- Would it be difficult to develop a theory including all relevant parameters as tunable variables? Is it worth modeling the system numerically?

Problem No. 2 “Air drying”

Table utensils (dishes, cutlery, etc.), after being washed, dry differently. Investigate how the time of drying depends on relevant parameters.

IYPT history

- **9.** Air dryer (12th IYPT, 1999)
  - During 4 minutes collect as much water as possible from the air in the room. The mass of the equipment must not exceed 1 kg. The water should be collected in a glass test tube, provided by the jury.
- **8.** Condensation (20th IYPT, 2007)
  - Water droplets form on a glass filled with cold water. Explain the phenomenon and investigate the parameters that determine the size and number of droplets on the glass.
- **6.** Liquid stain (21st IYPT, 2008)
  - When a drop of liquid such as coffee dries on a smooth surface, the stain usually remains at the edge of the drop. Investigate why the stain forms at the edge and what parameters affect the characteristics of the stain.
- **9.** Drying (22nd IYPT, 2009)
  - Investigate the drying process of a vertical wet paper sheet. How does the boundary of drying move?


Large droplets, small droplets, films...?

Hand washing vs a dishwasher?

- Exposed to water briefly, temperature not exceeding 40-50°C
- Rinsed in pure water
- Dried almost at an "open air"

- Exposed to hot water at up to 75°C
- Rinsed with water with special additives
- Dried in a confined environment

These may be quite influential parameters. Which of them should be investigated, and which are not essential? How to keep the necessary parameters under control?

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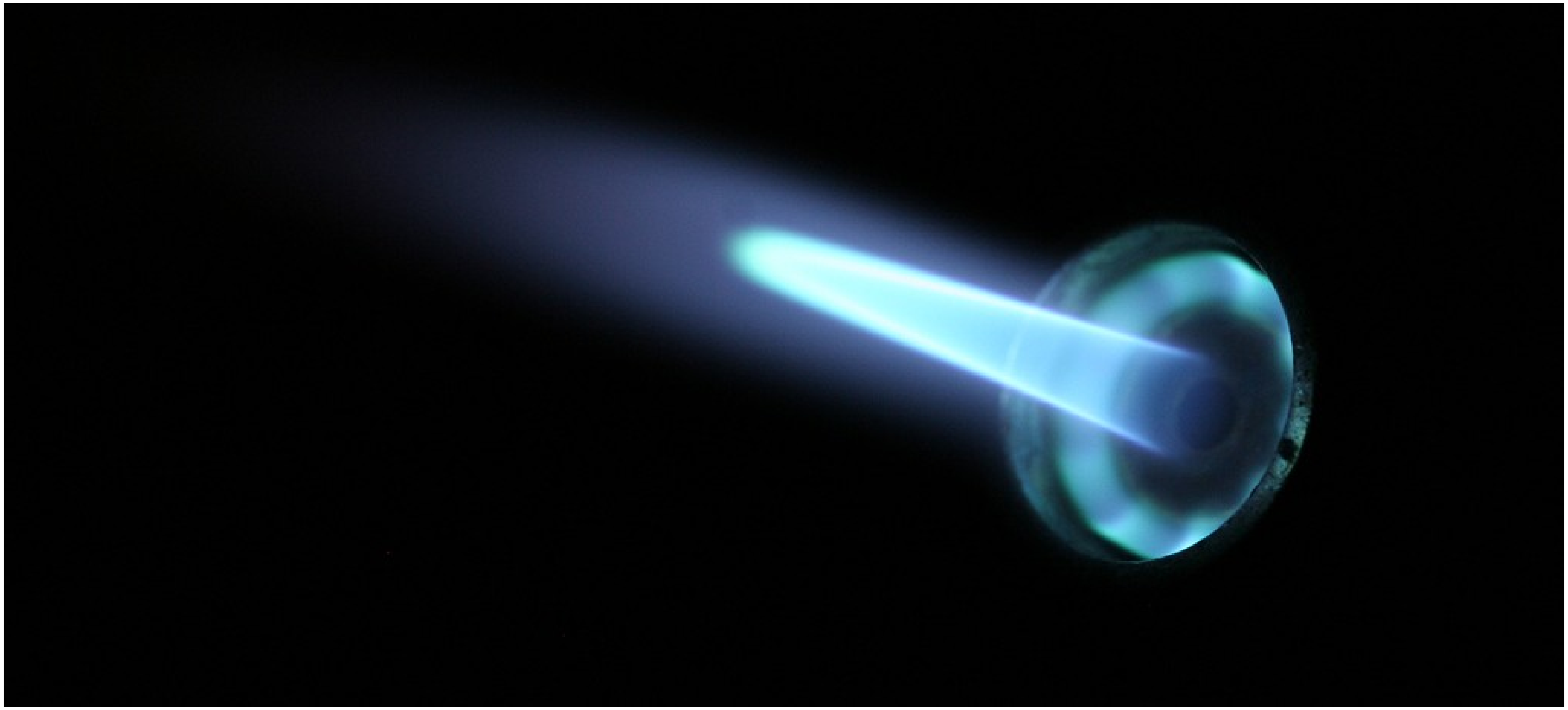
Key questions

- Unlike manual washing, commercial automatic dishwashers may use rinse agents that suppress droplet formation, and also leave the objects at significantly elevated temperatures. How does the effect depends on the initial "washing" procedure, and which procedure do you establish in your research?
- How does the water initially behave on a substrate? Does it form droplets (of what mean size?), films (of what thickness?), of other structures? How does it depend on properties of surface, such as wettability? What physical forces are responsible for initial structuring of liquid on the substrate?
- Is all water deposited only on the surface? How relevant is the porosity of substrates?
- How does the liquid geometry change during evaporation? What are the time dependences for contact areas, contact angles, total mass of water? How to measure them experimentally?
- What parameters of surfaces may be relevant for the evaporation dynamics? (initial temperature? wettability? radius of curvature?)
- What parameters of liquid may be relevant for the evaporation dynamics? (surface tension? residue of detergent? density? viscosity? specific heat capacity, specific evaporation heat, boiling point?)
- Is the evaporation rate constant over time?
- How to define "evaporation"? Is it a first-order, or second-order phase transition? What happens to entropy of the system during evaporation? What are the thermodynamic aspects of the problem?
- What parameters of ambient atmosphere may influence on the effect? (air temperature and humidity? presence of air flows?) Which of these parameters need to be controlled to make experiments coherent?
- How relevant to the problem are Marangoni flows, other fluid microflows, heat transfer inside the droplets or films?
- Above all, how to determine the "time of drying" and at which point an object is already "dry"?



Problem No. 3 “Bouncing flame”

Place a flame (e. g. from a Bunsen burner) between two charged parallel metal plates. Investigate the motion of the flame.

[Arthur Jan Fijałkowski 2005]

(Very) basic facts

Should we systematically investigate influence on the field on flames of different combustion degree and speed, or just take one particular flame, such as of a candle?

Flames are open and very hot, and electric equipment is all around!

Air valve in Bunsen burner fully closed:
Diffusion, reducing, silent, relatively cold and non-luminous flame, with incandescent soot particles

→

Air valve in Bunsen burner fully opened:
Premixed, oxidizing, roaring, relatively hot and luminous flame, with color due to band emission

Wichtigkeit, eine Lichtquelle von noch grösserer Unveränderlichkeit benutzen zu können. Wir haben daher die Bedingungen noch weiter vorfolgt, unter denen Leuchtgasflammen die grösste Unveränderlichkeit zeigen. Flammen, die aus einem gewöhnlichen einfachen Brenner unter einem Drucke von einigen Linien Wasserhöhe erhalten werden, flattern und schwanken viel zu sehr, um zu genauen Lichtmessungen dienen zu können. Schon bessere Resultate erhält man, wenn sich der Brenner auf einem kleinen Windkasten befindet, der als Compensator für die kleinen Schwankungen des Gaszuflusses dient. Vollkommen fest und constant aber sind die Dimensionen der Flammen erst dann, wenn die seitlichen Zuströmungen der atmosphärischen Luft in den Flammenkörper so viel als möglich gemässigt werden. Dies ist am einfachsten dadurch zu erreichen, dass man das Gas unter einem Drucke ausströmen lässt, der nicht mehr als 1 bis 0,5 mm Wasserhöhe beträgt, und dass man die in der Luft frei brennende Flamme mit einem Kasten umgiebt, durch welchen sie vor den Einflüssen eines unregelmässigen Luftzuges geschützt bleibt. Alle diese Bedingungen finden sich in dem Beleuchtungsapparate Fig. 5 vereinigt. AA_1 ist ein inwendig geschwärzter Kasten, dessen Boden zur Herstellung des freien Luftzutritts siebartig durchlöchert ist und dessen vordere Wand A_1 aus einem Schieber besteht, in dessen Mittelpunkt ein durch zwei parallele Spiegelplatten geschlossenes, mit Wasser gefülltes Gefäss *a* eingesetzt ist. Dasselbe dient zur [80] besseren Abhaltung der von der Flamme *l* ausgehenden strahlenden Wärme.

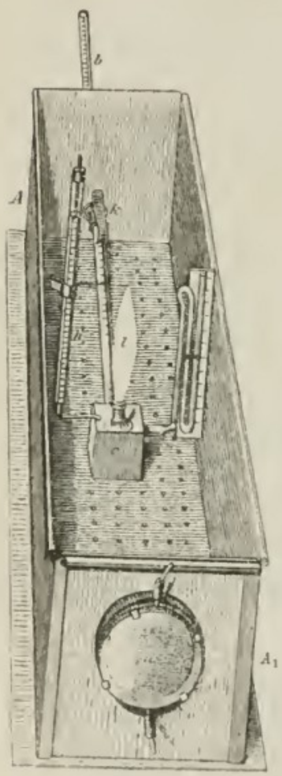


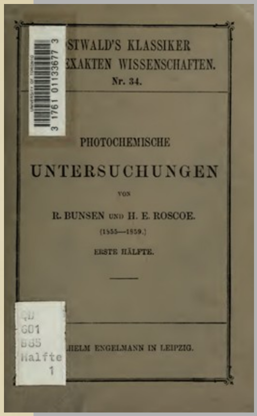
Fig. 5.

Das Leuchtgas, welches diese Flamme speist, wird durch das zur Gasleitung dienende Glasrohr *b* in den kleinen Windkasten *c*

zu erfahren, von welchen in der Flamme vorhandenen Gemengtheilen die Menge der chemisch wirkenden Strahlen vornehmlich bedingt wird. Es diente zu diesen Versuchen die Brennervorrichtung, welche Einer von uns angegeben und statt der Drahtnetzlampen im hiesigen Laboratorium eingeführt hat, und die sich besser als irgend eine andere Vorrichtung zur Hervorbringung regelmässiger Flammen von verschiedener Leuchtkraft, Färbung und Form eignet. Das Princip dieser Lampen beruht einfach [85] darauf, dass man das Leuchtgas unter Verhältnissen ausströmen lässt, wo es gerade so viel Luft vermöge seiner eigenen Bewegung aspiriren und mit sich vermischen kann, dass das gebildete lufthaltige Gasgemenge auf der Grenze steht, wo es die Fähigkeit eben noch nicht erlangt hat, die Entzündung durch sich hindurch fortzupflanzen. Diese Bedingung wird durch folgende einfache Vorrichtung erfüllt. *a* Fig 6 ist ein gewöhnlicher Kreuzschnittbrenner*), der sich im Mittelpunkte der cylindrischen Höhlung *b*, zu gleicher Höhe mit der Oberfläche des Würfels *cccc* erhebt. Dieser cylindrische Raum *b*, der 15^{mm} tief ist und 10^{mm} im Durchmesser hat, communicirt mit der äusseren Luft durch vier 7^{mm} im Durchmesser haltende Löcher *dd*. Wird die $8,5^{mm}$ weite, 76^{mm} lange Röhre ee_1 in den Cylinder *b* eingeschraubt und lässt man das Leuchtgas von dem Brenner *a* durch dieselbe strömen, so saugt es durch die Oeffnungen *d* so viel Luft auf, dass es an der Mündung der Röhre *e* mit nicht leuchtender völlig russfreier Flamme verbrennt. Die Helligkeit des so mit Luft vermischten Gases übertrifft kaum die einer Wasserstoffflamme. Nach Verschluss der Oeffnungen *d*

Fig. 6.

*) Aus einem solchen Brenner strömt das Gas in drei divergirenden Flammen aus, deren Spitzen in die Scheitel eines gleichseitigen Dreiecks fallen.



What is actually a Bunsen burner?

IYPT history

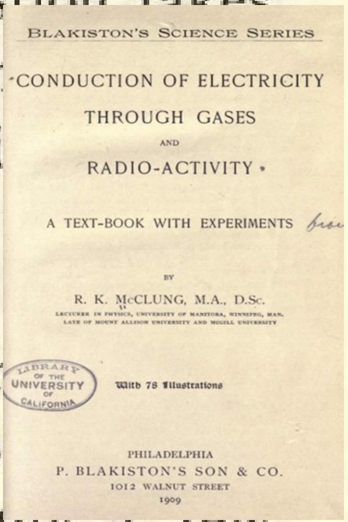
- **13.** Gas flow (12th IYPT, 1999)
  - Measure the speed distribution of the gas flow in and around the flame of a candle. What conclusions can be drawn from the measurements?
- **3.** Plasma (13th IYPT, 2000)
  - Investigate the electrical conductivity of the flame of a candle. Examine the influence of relevant parameters, in particular, the shape and polarity of the electrodes. The experiments should be carried out with a voltage not exceeding 150 V.

from the effects due to the flame alone. The following simple experiments will however serve to illustrate the electrical properties of flames.

Place an ordinary coal gas flame between two parallel metal

plates so that there is a space of half a centimeter or so on each side of the flame between it and the plates. Charge one of these plates to a high positive potential and the other to a high negative potential by a set of accumulators. Observe that the outer part of the flame where the most combustion takes place is drawn towards the negative plate while th
or cooler part of the flame is attracted to the posi
showing that the hotter part is positively charged
cooler part is negatively electrified.

In a Bunsen flame place the ends of two platin
and connect one of these through a sensitive D'Ars
vanometer to one pole of a storage battery of only a few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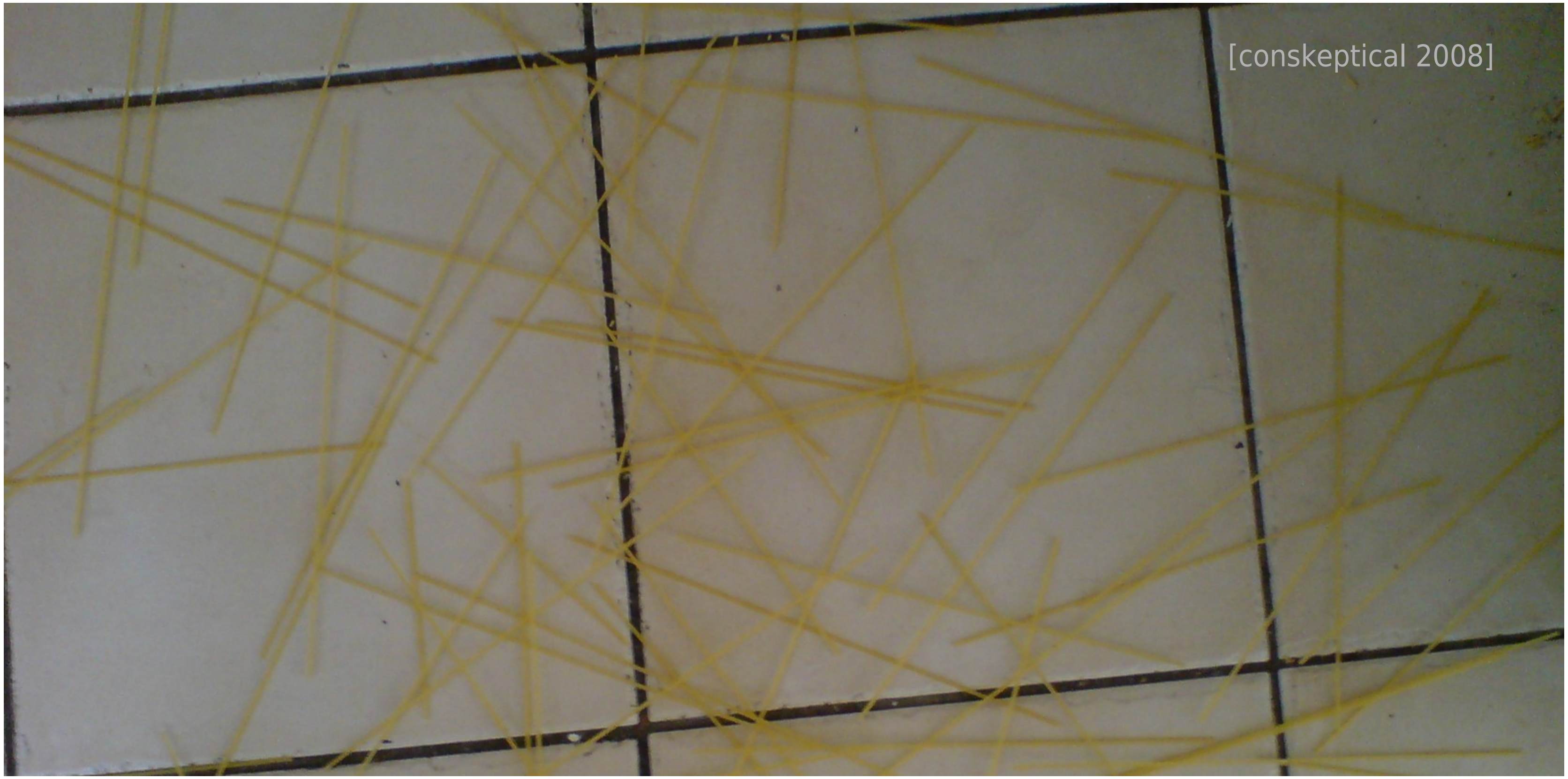
Key questions

- What are the key differences between various types of flames, such as diffusion flame and premixed flame? Does the task specify that only a fixed, particular, type of flame need to be analyzed?
- What information can be retrieved from color, rate of flickering, and other visible parameters of the flame?
- What is the temperature field, concentration of charge carriers, fluid viscosity, and other physical parameters, inside the flame? How to measure them?
- Many people and sources argue if flames are plasmas or not. Is there a general scientific consensus on the point? If not, what are the basic arguments of both sides?
- Different flames may have not only different distribution and concentration of charge carriers, but also different vertical airflow speed. How does the behavior in electric field depends on all these parameters?
- What possible types of “bouncing” in electric field can be observed? Is a logical, physically validated classification possible?
- Why the flame may move as a whole, if the electric field acts on the charge carriers only? What acts as a restoring force, if the flame “oscillates”?



Problem No. 4 “Breaking spaghetti”

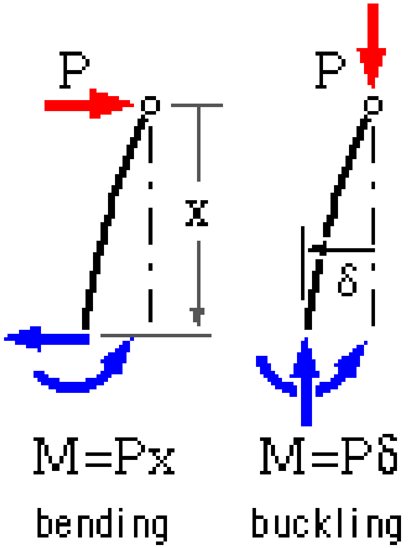
Find the conditions under which dry spaghetti falling on a hard floor does not break.

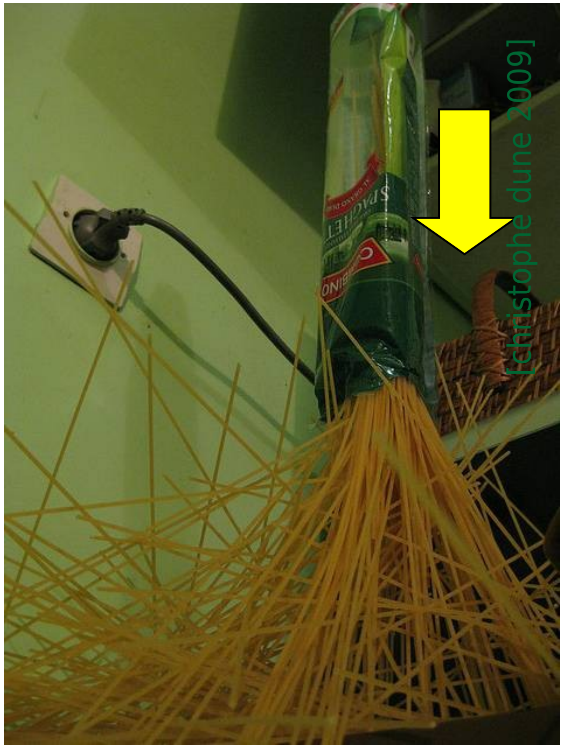
Curved spaghetti are likely to break into multiple pieces →
2006 Ig Nobel Prize in Physics awarded to Sébastien Neukirch and Basile Audoly
http://www.lmm.jussieu.fr/~neukirch/work-images/spaghetti_photos/index.html

Spaghetti hits the floor…

- vertically…?
- horizontally…?
- inclined, under a certain angle…?

- For what time is the spaghetti subject to impact load, and how do the stresses depend on time, in different points?



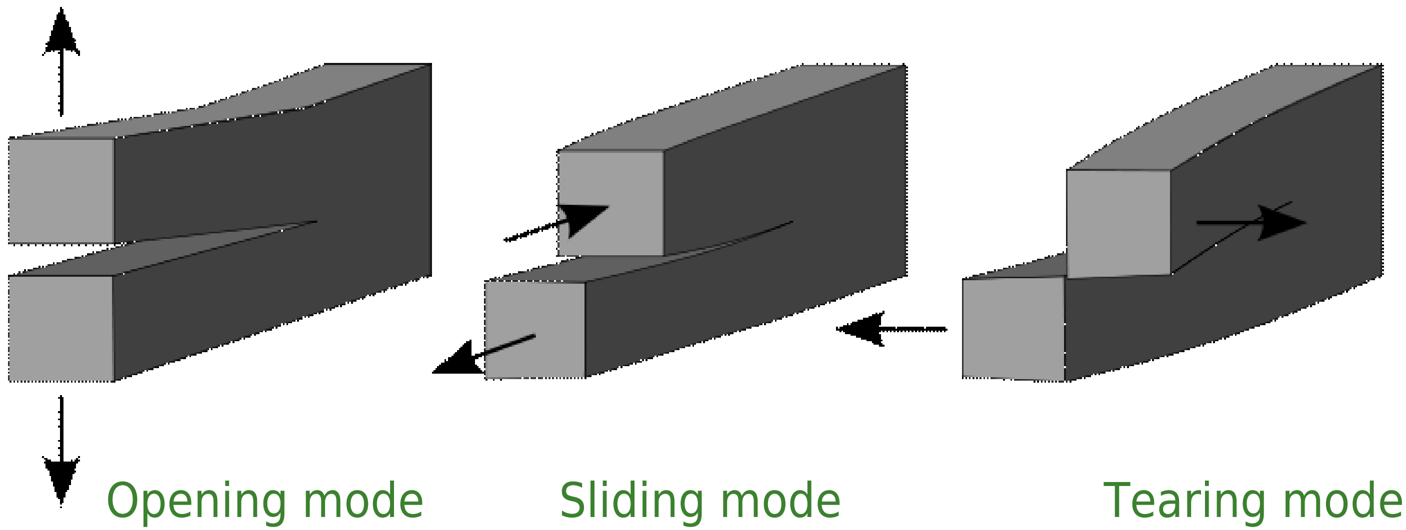


Bending deformation is usually proportional to the load

Buckling is a displacement of a structure (subjected usually to compression) transverse to the load. Moments, deflections and stresses are not proportional to loads

http://school.mech.uwa.edu.au/~dwright/DANotes/buckling/home.html

Fracture modes in spaghetti?

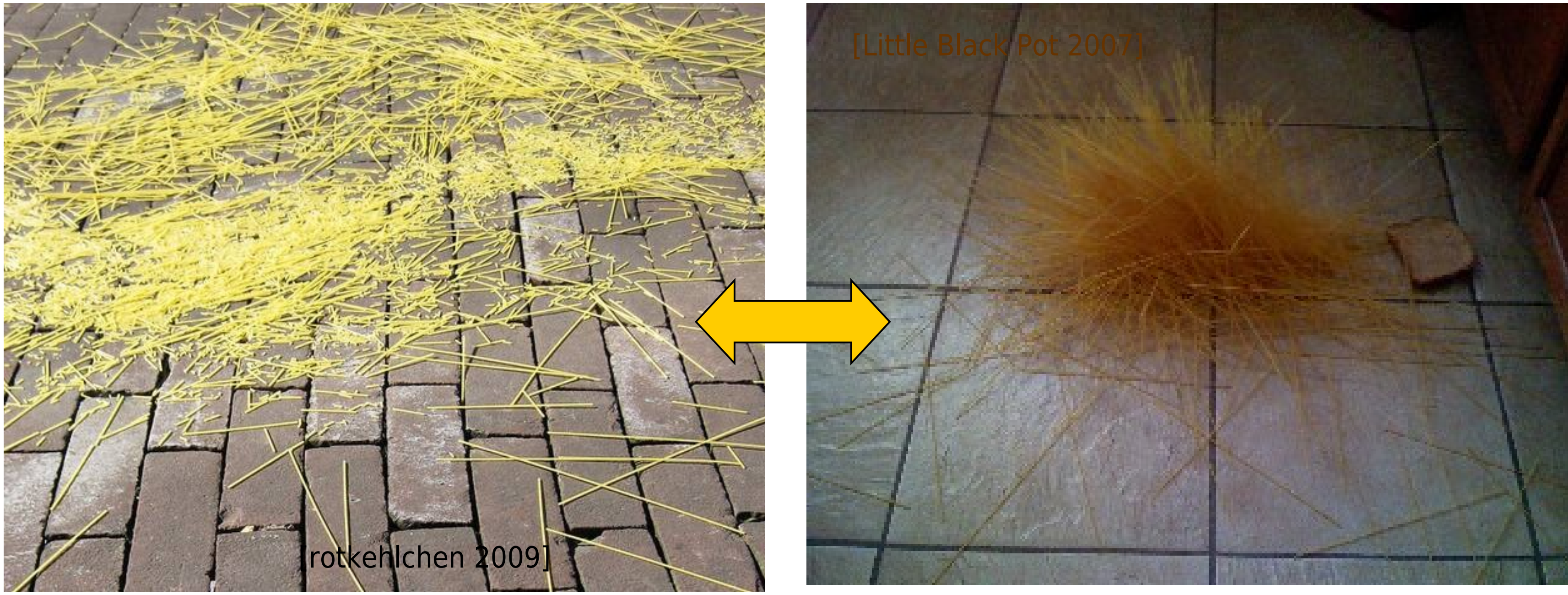


http://www.math.psu.edu/belmonte/sg9.gif

- Longitudinal compression causes buckling

http://www.lmm.jussieu.fr/~neukirch/work-images/spaghetti/animation_10.gif

Chances to break?



- Harder floor or more fragile spaghetti?
- Different impact speed, angular velocity?
- Different impact angles?
- A single rod or bulk?

Is it worth speaking of a probability of fracture, under given conditions? Is it possible to measure and/or theoretically predict it?

- What about posing a reverse problem: what information about the impact can be retrieved from the spaghetti debris?

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Key questions

- Unlike the well-studied phenomenon of spaghetti breaking under gradual, controlled bending, we have an instant impact stress. What is common and what is different between these two cases? What is the time lag between initial contact and final rupture? What are the time scales for deformation and fracture?
- How to measure the mechanical properties of the spaghetti you work with? How do these properties vary among different brands?
- What are the ultimate criteria for fracture? (stress limits?)
- If a spaghetti falls with a random spatial orientation, what is the probability of fracture? Is there a way to determine the probability experimentally?
- How to measure, control or predict the impact and fracture dynamics?
- How to best record the process (with high-speed camera?)
- What is the role of the friction between the spaghetti and the floor in case of non-horizontal orientation at impact? Is the surface roughness relevant?
- How hard is a “hard” floor? What of its parameters can be controlled?
- At what degree the effect is reproducible, if the experiment is repeated under “identical” conditions?

“Final optimization”...?

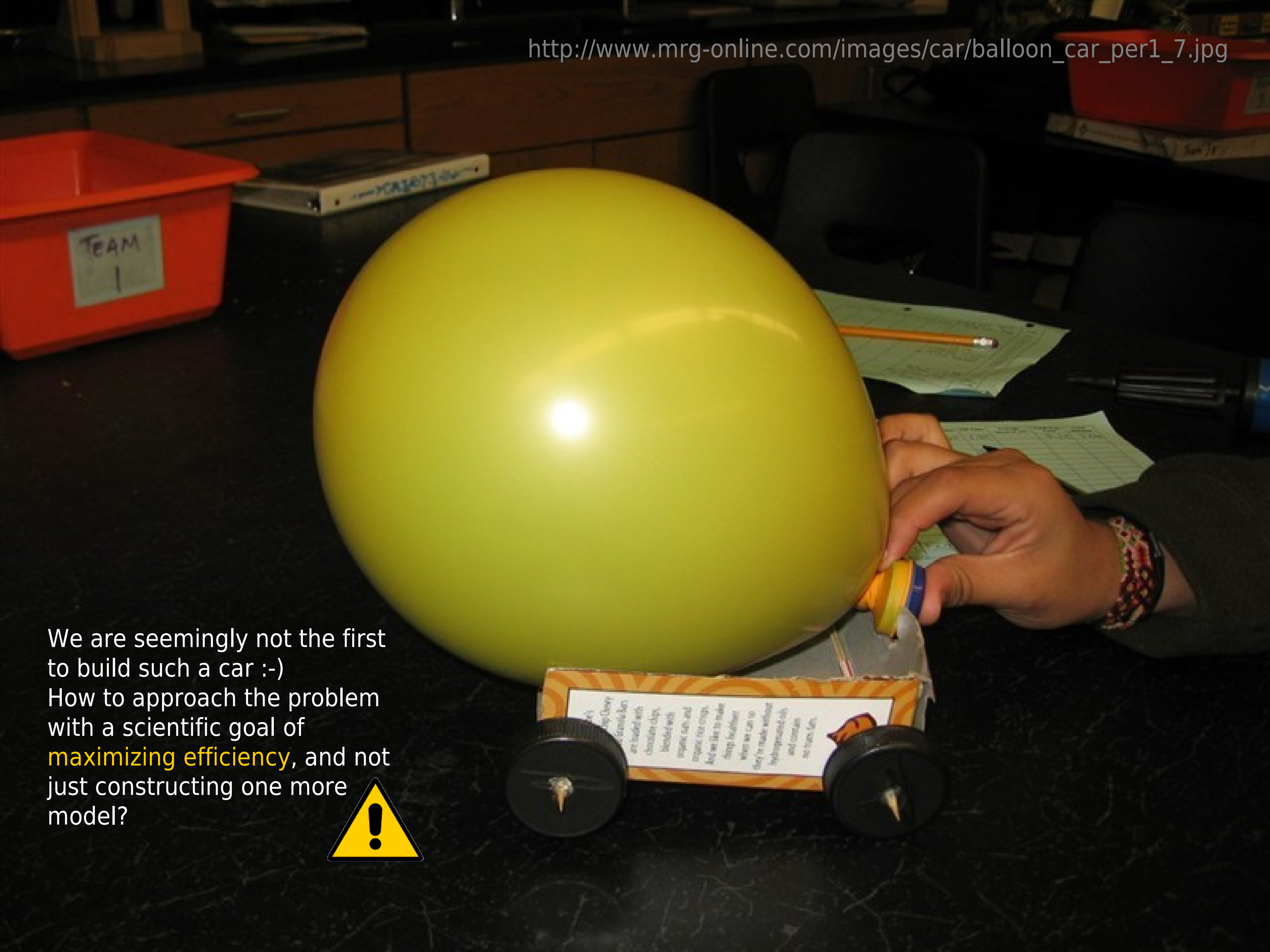
- What is the safest impact speed? (less seems better :-))
- What is the safest impact angle? (why? what maximum stresses are expected for different impact angles?)
- What are the mechanical properties for a floor to be still considered “hard”?
- What is the minimum safe curvature for a spaghetti to withstand?
- Above all, if all conditions are fulfilled and all parameters are optimized, what is the probability of fracture?

Problem No. 5 “Car”

Build a model car powered by an engine using an elastic air-filled toy-balloon as the energy source. Determine how the distance travelled by the car depends on relevant parameters and maximize the efficiency of the car.

IYPT history

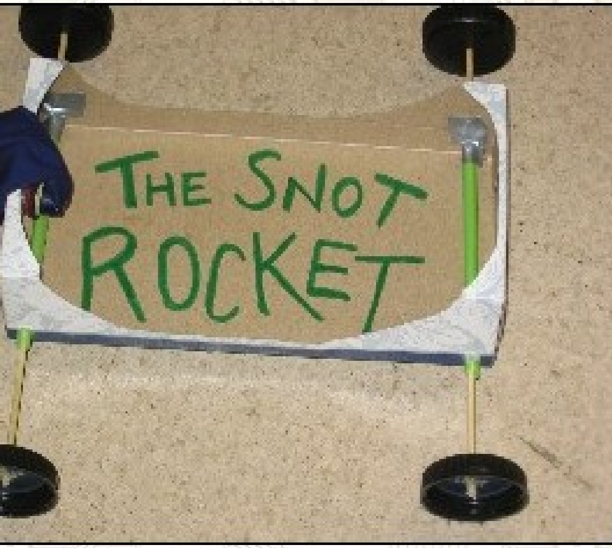
- **10.** Sound cart (15th IYPT, 2002)
  - Construct and demonstrate a device that can be propelled solely by sound. Investigate its properties. Study this effect and use a model to explain it.
- **8.** Wind car (18th IYPT, 2005)
  - Construct a car, which is propelled solely by wind energy. The car should be able to drive straight into the wind. Determine the efficiency of your car.

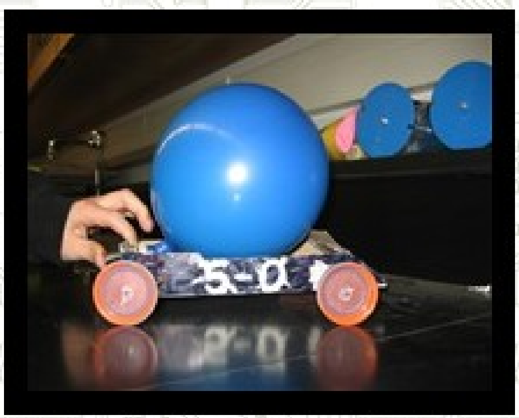


http://www.mrg-online.com/images/car/balloon_car_per1_7.jpg

We are seemingly not the first to build such a car :-)
How to approach the problem with a scientific goal of maximizing efficiency, and not just constructing one more model?

Ballon Powered Car Project





2007 Fastest Speed Winner

2.39 Meters per Second

2007 Total Distance Winner

21.31 Meters

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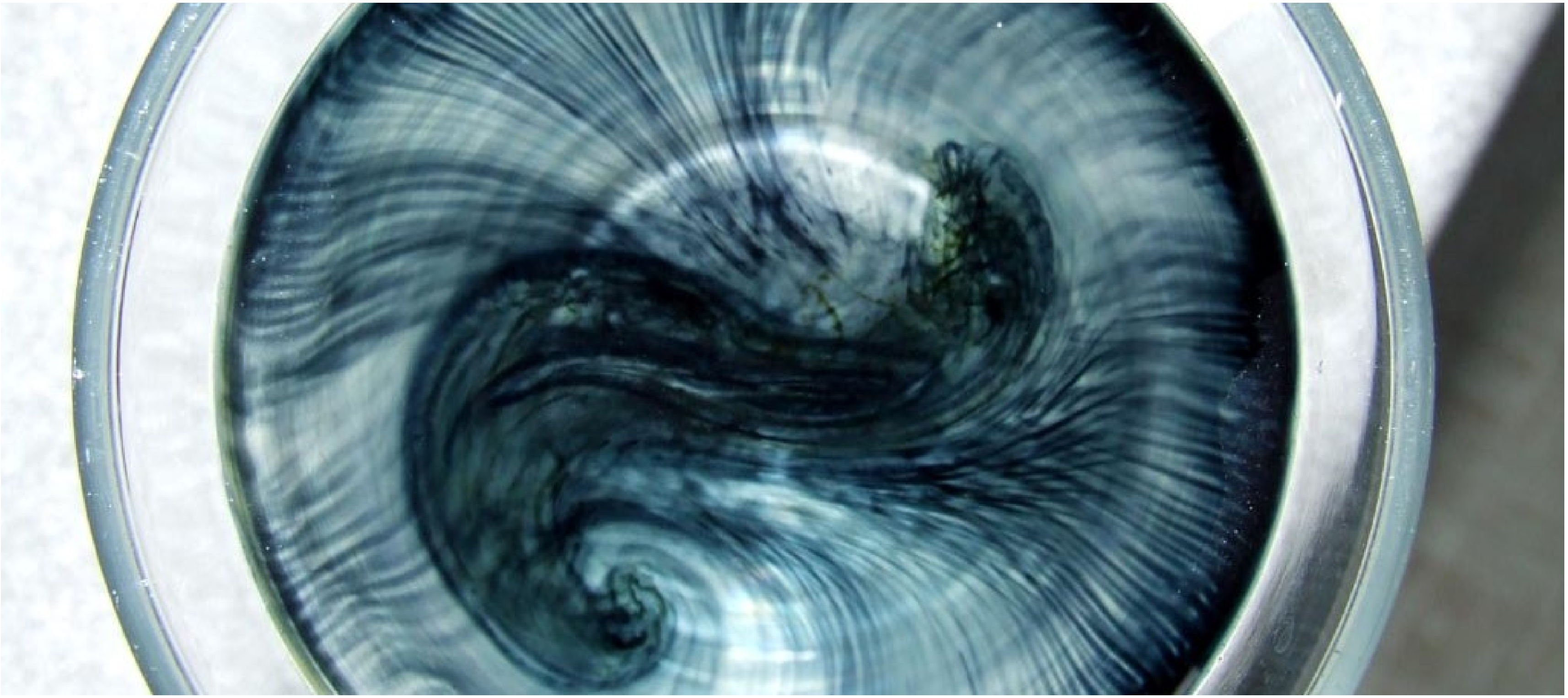
Key questions

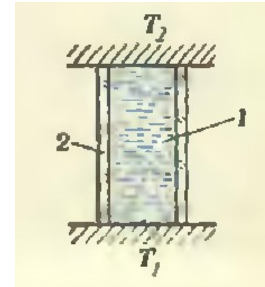
- The elastic properties of a balloon gradually change with each new launch of the car. For how many times can we use a single balloon? How do the elastic properties of a balloon determine the pressure inside and other relevant parameters? What is the Mullins effect, and is it relevant?
- How ethical and appropriate is a “verbalist” solution that car may not necessarily be wheeled and may not necessarily move horizontally? Such assumptions would definitely increase both efficiency and distance of travel, especially if car is lifted vertically.
- Maximizing efficiency means that many parameters need to optimized at once, to find a global maximum for a function of several variables. What are these parameters?
- Which of them are fixed by the task itself and which should be frozen for coherence of experiments, but which can be tuned? (size, aerodynamic shape, type and brand of the balloon? gas, possibly not only air, used as a “fuel”? sizes, masses, friction factors of gears, wheels, transmissions, suspensions and other mechanical parts? shape and size of the nozzle, if a “rocket car” concept is chosen? basic engineering concept behind the car?)
- Maximizing efficiency and maximizing the distance of travel is not one and the same thing. How to clarify and deeply investigate the topic?
- How to establish the definition and to determine the efficiency for a balloon car? What total energy is stored in the inflated rubber membrane and in the compressed air?
- What are your basic conclusions on the problem?



Problem No. 6 “Convection”

In a container filled with a liquid, heat transport will occur when the bottom of the container is heated and the top surface is cooled. How does the phenomenon change when the container rotates about its vertical axis?

IYPT history



- **13.** Heat transfer (1st IYPT, 1988)
  - Research the heat transfer through the vertical water column in the two cases: *T1<T2* and *T1>T2*. ("*1*" is water column, "*2*" is heat-insulating tube.)
- **7.** Merry-go-round (13th IYPT, 2000)
  - A small, light, ball is kept at the bottom of a glass filled with an aqueous solution and then set free. Select the properties of the solution, so that a moving up time of several seconds is achieved. How will this time change if you put your glass on the surface of a rotating disk?
- **10.** Liquid fingers (13th IYPT, 2000)
  - When a layer of hot salt solution lies above a layer of cold water, the interface between the two layers becomes unstable and a structure resembling fingers develops in the fluid. Investigate and explain this phenomenon.
- **17.** Ocean "Solaris" (18th IYPT, 2005)
  - A transparent vessel is half-filled with saturated salt water solution and then fresh water is added with caution. A distinct boundary between these liquids is formed. Investigate its behaviour if the lower liquid is heated.
- **13.** Spinning ice (21st IYPT, 2008)
  - Pour very hot water into a cup and stir it so the water rotates slowly. Place a small ice cube at the centre of the rotating water. The ice cube will spin faster than the water around it. Investigate the parameters that influence the ice rotation.

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Key questions

- Is the problem all about axisymmetrical vessels? What internal velocity fields (transitory and stationary) are developed when the vessel is rotated? What physical properties of the vessel are relevant? (depth? shape?)
- How relevant are the parameters of heating? (all bottom is heated uniformly, or not?) What are the roles of temperature gradients or heat fluxes?
- Aside from density, what other parameters of liquid change with heating (viscosity?) Is there an interface “tension” between miscible layers of different temperatures? Can we neglect the change of momentum, or inertial forces, for the heated flows?
- What models or concepts may be introduced to describe the time scales for the flows of positive buoyancy and the rotational displacement? Is it physically correct to say that upward convection may be considered “slower” or “faster” than rotation? As there is an interplay and superposition between the two phenomena, and can they be analyzed independently?
- What are the values and the physical sense for the dimensionless criteria relevant to the effect?
- Is there a way to separate particular miscible flows? How to visualize experimentally the overall flow lines?
- Can the observed convection patterns be structured into physically different types?

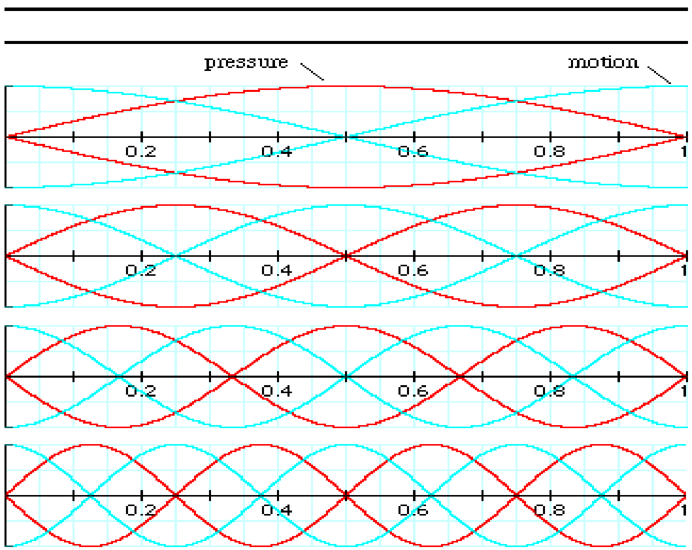
Problem No. 7 "Cup drum"

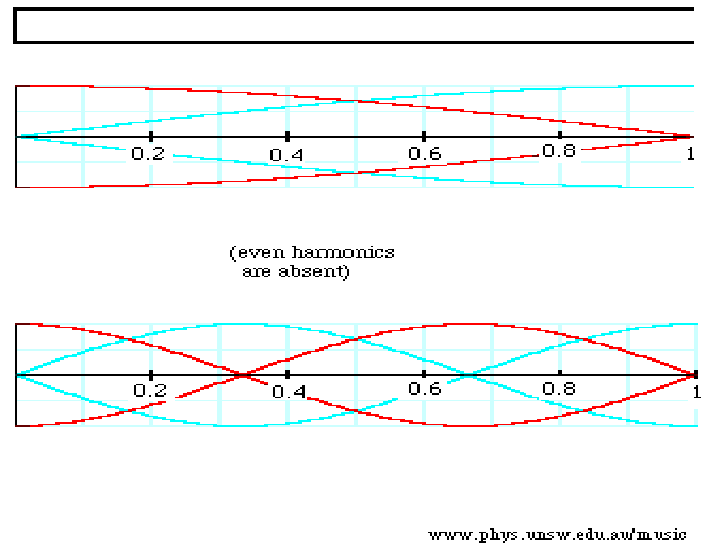
A plastic cup is held upside-down and tapped on its base. Investigate the sound produced when the open end of the cup is above, on or below a water surface.

IYPT history

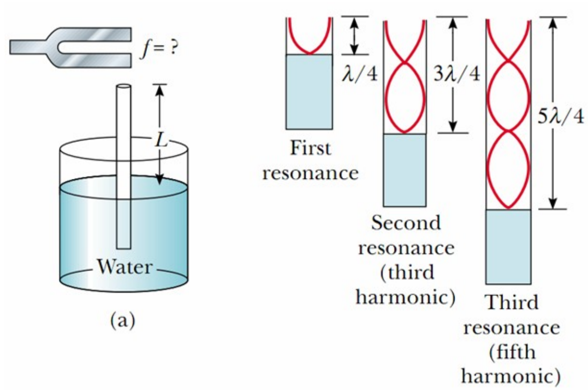
- **6.** Singing glass (12th IYPT, 1999)
  - When rubbing the rim of a glass containing a liquid a tone can be heard. The same happens if the glass is immersed in a liquid. How does the pitch of the tone depend on different parameters.
- **9.** Flute (21st IYPT, 2008)
  - Drill a hole into the side of a tube that is open at one end and produce a sound by blowing the open end. Investigate the pitch and timbre of the sound of your flute and how they depend on the position and the diameter of the hole.

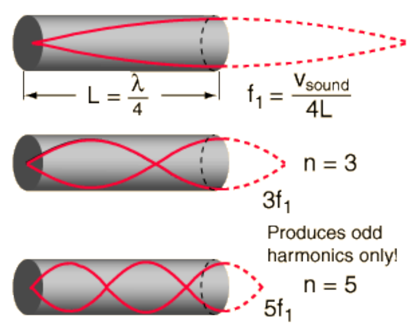
Flute vs clarinet, and water-filled tubes?





- A flute (open from both ends)
- Clarinet (open from one end…)





Are any of these simple models appropriate and applicable to describe our complex system?

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- Open *vs* Closed pipes (University of New South Wales), http://www.phys.unsw.edu.au/jw/flutes.v.clarinets.html

Key questions

- What are the key differences between a cup (a cylinder open at one end) and a cylinder open at both ends? What changes when the mouth of the cup is immersed in water? What determines the positions of nodes and antinodes for the cup in question?
- What physical properties of the cup are relevant? (volume, shape, height, radius of curvature? spatial orientation? material and thickness of the walls? elastic properties, such as compressibility?)
- Are there any standing waves in the air column inside the cup? What do the amplitudes and frequencies of the standing waves depend on?
- What parameters describe the sound produced by the cup? Which of them are "physical" and which are "subjective"? (timber? tone color? volume? pitch?)
- What properties of the air change when it is compressed by the water column? How exactly they depend on the immersion depth? What physical properties of the water and basin are relevant (density? compressibility? depth in a given point?)
- What are the spectra of the produced sounds? Do they change with time? After the initial excitation, how is the energy re-distributed among various oscillatory modes? Are any resonance effects relevant to this phenomenon? It is correct to speak of a fundamental frequency for the oscillations? What is an acoustic impedance and what is its influence on the produced sound?
- It seems to be reasonable to record the tube's sound. What should be the requirements for the sound-recording equipment? Where to place the microphone? What is the sound inside the cup?
- What total acoustic energy is produced by the oscillating cup? How does it correspond to the energy of tapping?

Problem No. 8 “Domino amplifier”

A row of dominoes falling in sequence after the first is displaced is a well known phenomenon. If a row of “dominoes” gradually increases in height, investigate how the energy transfer takes place and determine any limitations to the size of the dominoes.

IYPT history

- **8.** Dominoes (6th IYPT, 1993)
  - Dominoes are placed vertically at a small distance from each other in a long row on a table surface. Make the first domino fall and the “wave of the falls” will proceed along the row. Calculate and measure experimentally the maximum speed of this wave.

θ_∞ is the angle at which the dominoes are stacked against each other at the end of the train. We call θ_∞ the stacking angle.

[van Leeuwen 2010]

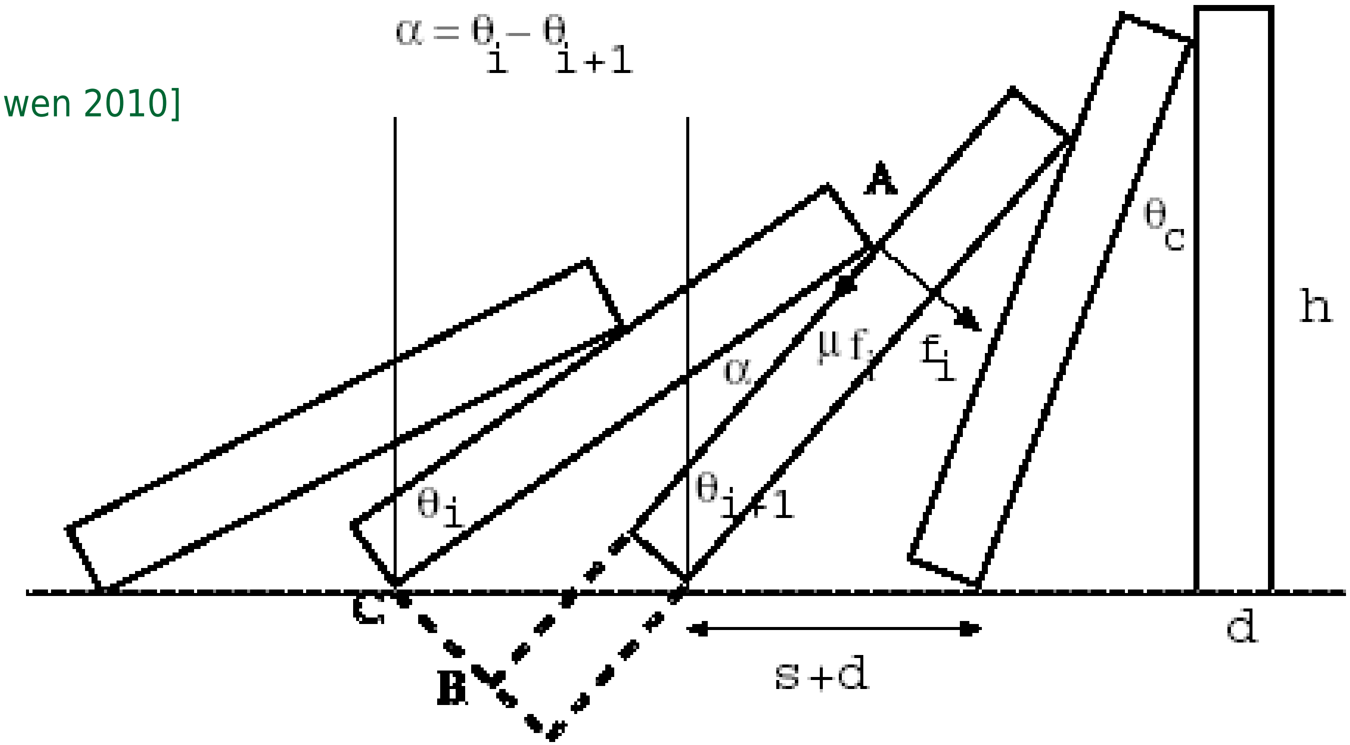

Figure 1: Successive dominoes. The tilt angle θ_i is taken with respect to the vertical. In the rectangular traingle ABC the top angle is $\alpha = \theta_i - \theta_{i+1}$, the hypotenuse has the length h and the base BC the length $(s+d)\cos\theta_{i+1} - d$. Expressing this base in the hypotenuse and the top angle yields relation (1). In the picture the tilt angle of the head of chain θ_n has reached its final value $\theta_c = \arcsin(s/h)$. The first domino has almost reached the stacking angle θ_∞. The normal force f_i and the friction force μf_i that domino i exerts on $i+1$ are also indicated.

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Key questions

- How valid is an assumption that a wave of dominoes is a sequence of physically similar cycles of interactions between two (or a finite number) of dominoes?
- The exact procedure of initial “excitation” may certainly influence on the dynamics of the first dominoes in the row. Is the system “forgetting” initial conditions, and if so, when it happens?
- What parameters may be safely neglected (slipping? air resistance?) and which may not?
- If a theory is proposed, can it be used to describe not only individual collisions, but the system as a whole? Is your theory capable of predicting certain parameters, or retrieving information about other parameters through fitting experimental dependences? Is it worth modelling the system numerically?
- The height of individual dominoes may be growing linearly with number, but may also not. Can the problem be understood from a point of view that dominoes are identical, but their height (or, spatial position) increases, i.e. dominoes are on a staircase (vertical dominoes) or an inclined plane (tilted dominoes)? How to formalize and fix the initial approach to the problem?
- What parameters of the substrate are relevant? How does the dynamics of the wave depend on these parameters?
- What parameters of dominoes themselves are relevant (sizes and law of growth in height? friction factors?) How relevant is the step between dominoes, and it grow or decrease in the row?
- How to measure, tune, and control all necessary parameters in the experiments? Are the sizes and the ultimate speed of the wave the only major parameters?
- Above all, what happens to potential, kinetic translational, kinetic rotational, and other energies for individual dominoes and for a system as a whole? How the energy is actually transferred? What are the criteria for a particular domino to withstand, or not, when hit by a neighbor?

Problem No. 9 “Escaping powder”

When a hot wire is plunged into a beaker of water with powder (e.g. lycopodium) floating on the surface, the powder moves rapidly. Investigate the parameters that alter the speed of movement of the powder.

IYPT history

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

What changes in the system when we immerse the hot wire?

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- Experiment 446.1: Surface Tension of Liquids (University of Delaware, 2006), http://www.udel.edu/pchem/C446/Experiments/exp1.pdf

Surface tension is temperature dependent, but is it the only or the major factor?

Basic questions

- At least, several explanations may come to mind,
  - surface tension is temperature-sensitive; particles are repelled due to the different menisci, as the heating is not uniform…
  - oxide layer (hydrophilic) on the wire is being degraded; particles get repelled from a pure metal (hydrophobic) wall…
  - surface layer is being contaminated with surfactants from the wire, changing the surface tension and making the particles repelled…
- 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 directly validate or invalidate your explanation? What is a "confirmability" and a "falsifiability" or a physical theory?

MOUVEMENTS SPONTANÉS

DE CERTAINS CORPS A LA SURFACE DE QUELQUES LIQUIDES

Le camphre, diverses substances solides odorantes, les corps poreux imbibés de liquides volatils, offrent à la surface de l'eau des mouvements singuliers de rotation et de translation, qui ont beaucoup préoccupé le monde savant dans la première moitié du siècle. On a voulu les attribuer tantôt à l'électricité, et tantôt à de simples phénomènes mécaniques de recul produits par le dégagement des vapeurs ou de parties fluides émanées du corps et venant frapper l'air ou l'eau; mais aucune solution définitive, aucune explication claire et satisfaisante n'a été donnée pour ces phénomènes.

Dutrochet, l'illustre auteur de la découverte de l'endosmose, après des études malheureusement entachées de graves erreurs à leur début (1841), mais aussi appuyées à la fin (1843) sur des expériences d'une haute valeur, ne trouva rien d'autre, pour expliquer les mouvements qui nous occupent, que l'existence hypothétique d'une force inconnue, apparaissant à la surface de séparation de deux liquides quelconques et qu'il nomma force épipolique (ἐπιπολῆ, surface). Cette notion d'une nouvelle force quelconque est aussi le siège d'une force qui agit exactement comme si la masse liquide se terminait par une membrane très mince, élastique et tendue. On a reconnu que c'est à cette force que sont dus les phénomènes de la capillarité et peut-être bien d'autres moins connus; disons même, pour terminer ces notions succinctes, que cette *tension superficielle* des liquides n'est très probablement qu'un cas particulier de l'attraction qui s'exerce entre tous les corps.

Nous savons donc qu'il existe constamment à la surface de tous les liquides une force parfois puissante dans ses effets. Mais il e
que l'intensité de cette force c
du liquide considéré; on le re
un même tube capillaire dans
voit ceux-ci monter à des niv
Il suffit même de répandre une
liquide quelconque sur l'eau po
superficielle; presque toujours
une diminution, à cause de la t
l'eau à sa surface, supérieur
tous les autres liquides.

C'est guidé par ces notions th
de construire le petit jouet s
sur la figure (fig. 1). C'est un bateau taillé avec des

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Key questions

- Above all, what types of motion can be observed?
- What is a hot-wire anemometer, and is it relevant to the problem?
- Why do floating particles attract or repulse, and how does the effect depend on their contact angles with liquid, on surface tension, and on other parameters?
- How is the heat transferred from the wire into the liquid? If the wire is initially heated, how does the temperature field in the beaker evolve with time? What changes, if the wire is being heated by electric current when already immersed? What parameters (initial temperature, heat conductivities, specific heat capacities) are relevant?
- How does the surface tension depend on temperature? What other parameters of water change with temperature (viscosity, density,…?)
- Does the oxide on the metal wire effectively withstand heating and immersion? How to check this aspect?
- Do particles move before the wire is immersed? Is the motion after immersing wire connected to overcoming viscous drag? Singh *et al.* explain the cause for constant-temperature repulsion not only by unbalanced capillary forces due to unequal contact angles, but also by vertical oscillations of particles. Is there a way to investigate deeper into the topic, and provide visual and straightforward experimental evidence for what happens?
- What are the speeds, accelerations, and directions of particles' motion? How to record and analyze them? How do they depend on multiple relevant parameters, such as the temperature gradient?
- What physical information can be retrieved if two hot wires are immersed? Is the observed motion consistent with the (assumed) superposition of interactions? Are the observed accelerations indeed the vector sums only?
- Does your explanation permit a direct experimental proof or disproof? If surface tension is considered changing, is it possible to measure it via generating capillary waves or other techniques?
- It maybe uneasy to buy lycopodium in a local pharmacy. What parameters of lycopodium particles are important, and what replacement (a model system) may be appropriate? What parameters need to be kept under control? (wettability? mass? mean size and shape?)
- Is it possible to measure the lateral forces acting on particles? Is there a room for Brownian motion?

Problem No. 10 “Faraday heaping”

When a container filled with small spheres (e.g. mustard seeds) is vibrated vertically with a frequency between 1—10 Hz, so called Faraday heaping occurs. Explore this phenomenon.

XVII. *On a peculiar class of Acoustical Figures; and on certain Forms assumed by groups of particles upon vibrating elastic Surfaces.* By M. FARADAY, *F.R.S. M.R.I., Corr. Mem. Royal Acad. Sciences of Paris, &c. &c.*

Read May 12, 1831.

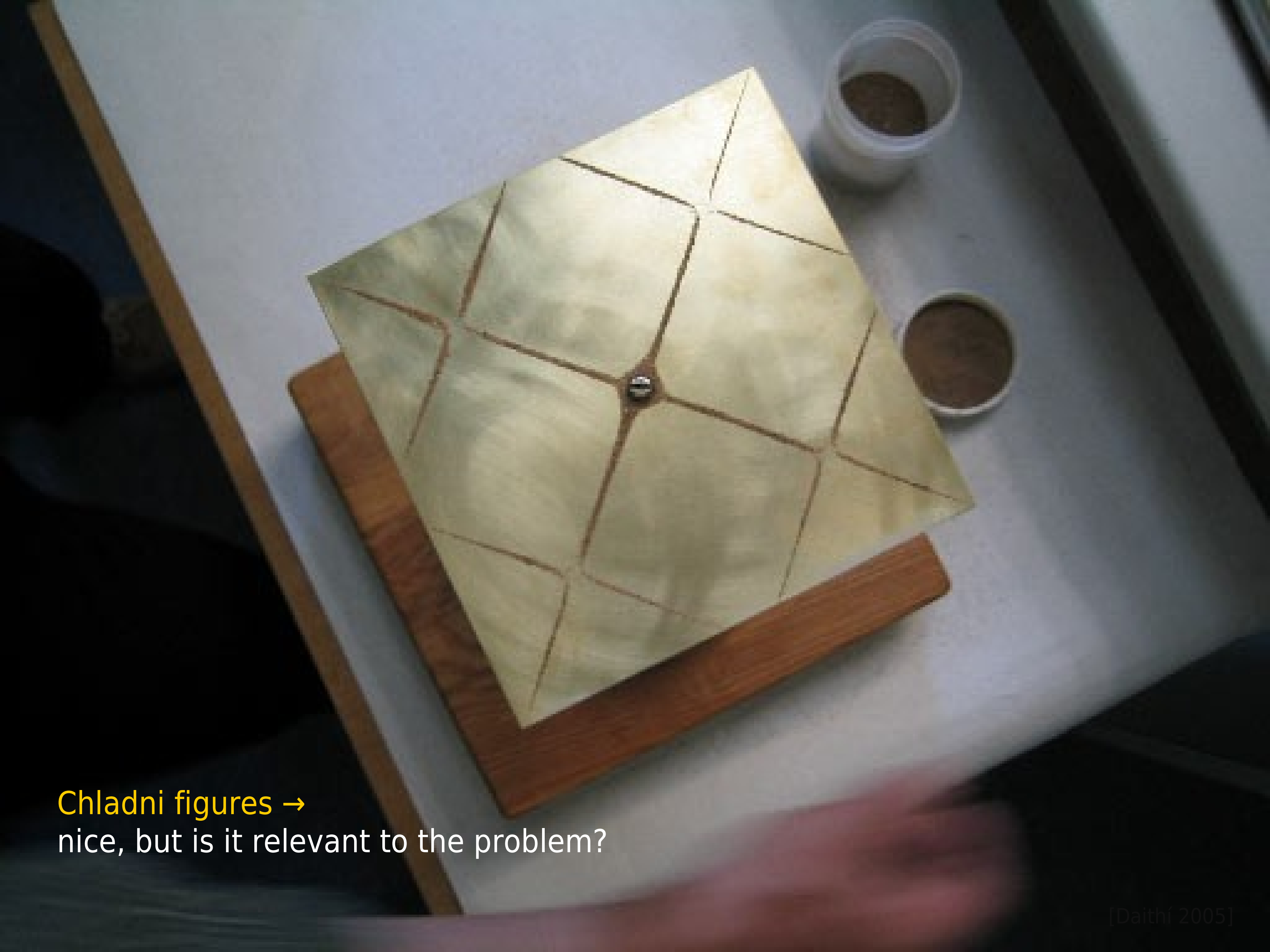
1. THE beautiful series of forms assumed by sand, filings, or other grains, when lying upon vibrating plates, discovered and developed by CHLADNI, are so striking as to be recalled to the minds of those who have seen them by the slightest reference. They indicate the quiescent parts of the plates, and visibly figure out what are called the nodal lines.

2. Afterwards M. CHLADNI observed that shavings from the ha
citing violin bow did not proceed to the nodal lines, but were gath
on those parts of the plate the most violently agitated, i. e. at t
oscillation. Thus when a square plate of glass held horizontall
above and below at the centre, and made to vibrate by the ap
violin bow to the middle of one edge, so as to produce the lo
sound, sand sprinkled on the plate assumed the form of a di
but the light shavings were gathered together at those parts towar
of the four portions where the vibrations were most powerful a
sions of the plate greatest.

PHILOSOPHICAL
TRANSACTIONS
OF THE
ROYAL SOCIETY
OF
LONDON.
FOR THE YEAR MDCCCXXXI.
PART I.

LONDON:
PRINTED BY RICHARD TAYLOR, RED LION COURT, FLEET STREET.
MDCCCXXXI.

3. Many other substances exhibited the same appearance. Lycopodium,

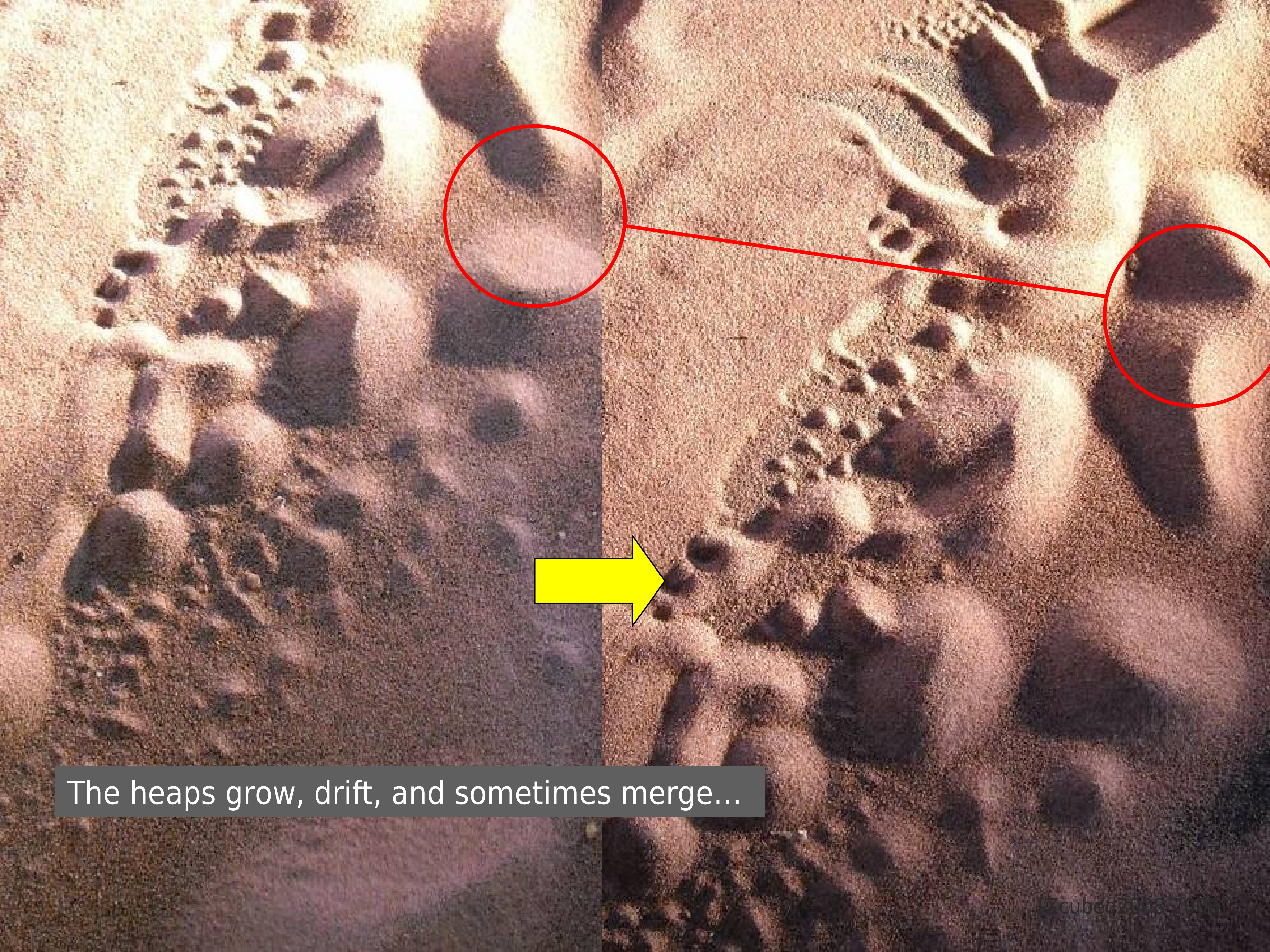


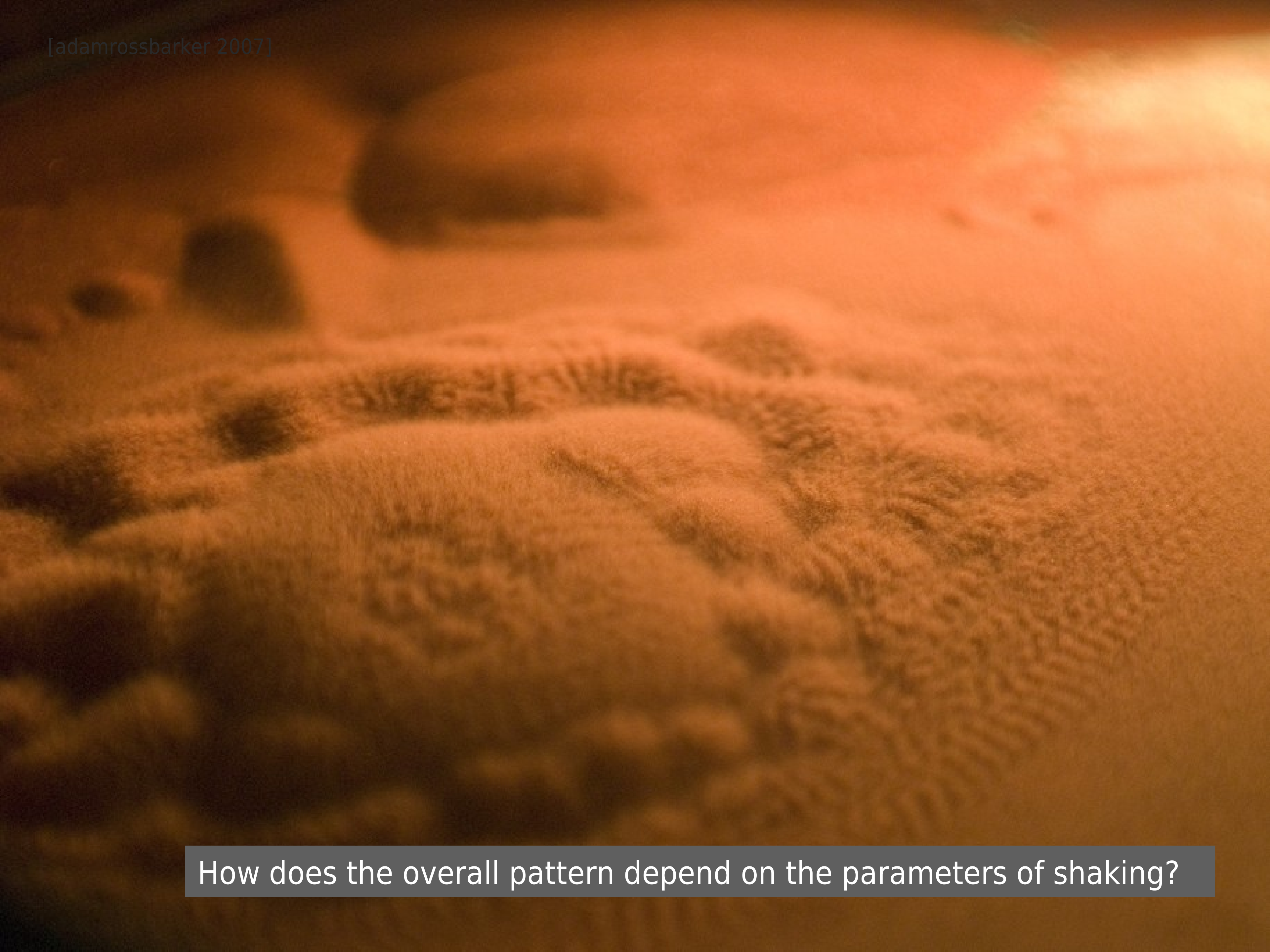
Chladni figures →
nice, but is it relevant to the problem?

[Daithí 2005]

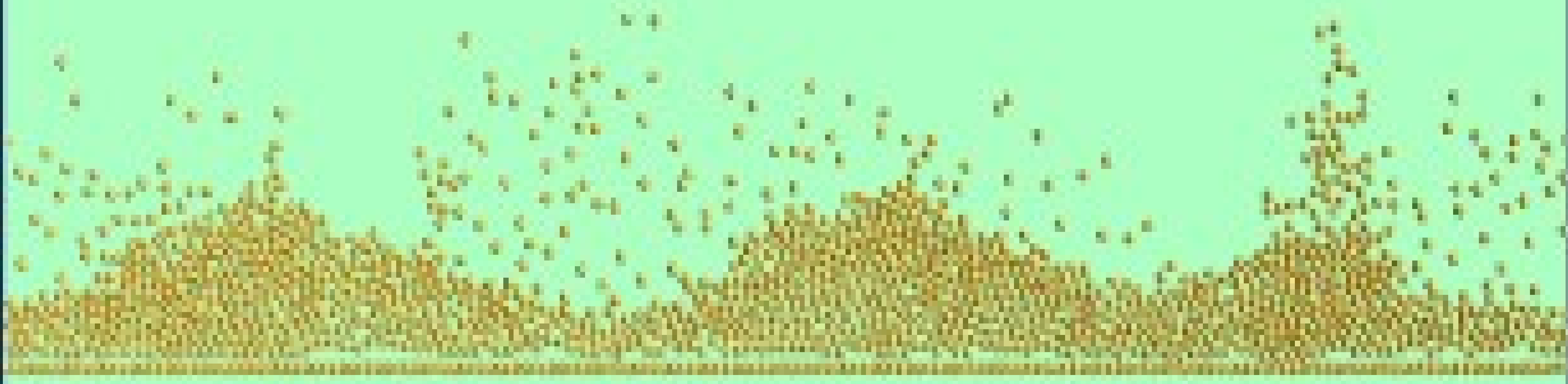
Heaps and ripples appear on many different length scales...

Granules are not closely packed. Can we safely neglect the air involved?


The heaps grow, drift, and sometimes merge…


[adamrossbarker 2007]
How does the overall pattern depend on the parameters of shaking?

http://www.ph.biu.ac.il/~rapaport/anim_gif/vibgran_anim.gif



spontaneous pattern formation in a dynamical system outside of equilibrium [4].

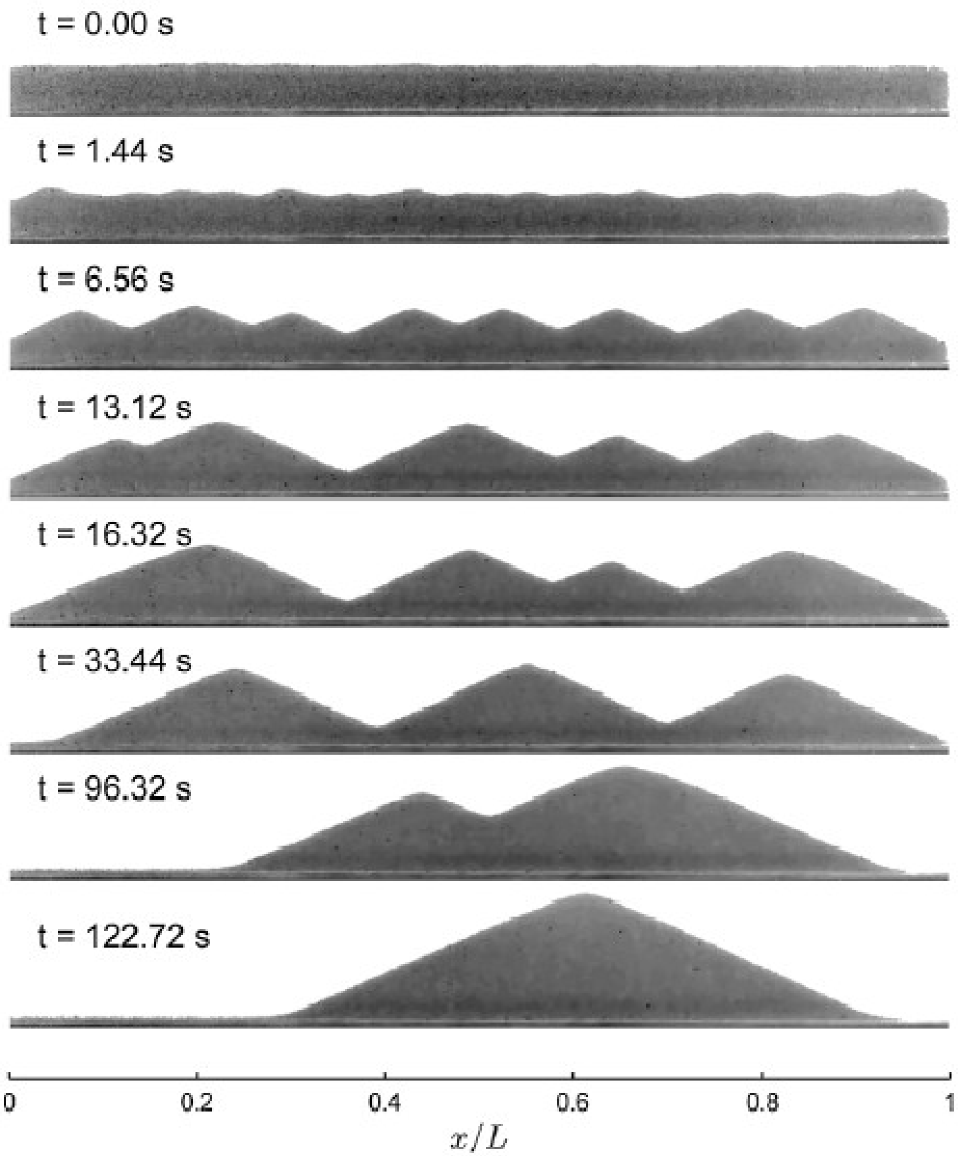
The dynamic stabilization of a single heap (last snapshot of Fig. 1) is well understood: The outward avalanches in the upper layers are balanced by the inward motion of the deeper layers (induced by the airflow through the vibrating bed [2,3]), together forming the convective flow of particles known as Faraday circulation. By contrast, the merging of small heaps into larger ones—the coarsening process (Fig. 1)—is much less understood, and quantitative experiments have been scarce [5,6].

In the present study we introduce a model for the coarsening behavior, validated by experiments and detailed numerical simulations. This threefold approach leads to the identification of the average life span τ_N of the N-heap state as the proper coarsening quantity. It is proven to scale, in our 1D setup, as $\tau_N \propto N^{-3}$.

Experiments.—A glass box of dimensions $L \times H \times D = 300 \times 100 \times 2.1\ \text{mm}^3$ is vertically vibrated using a

proce

[van Gerner *et al.* 2009]



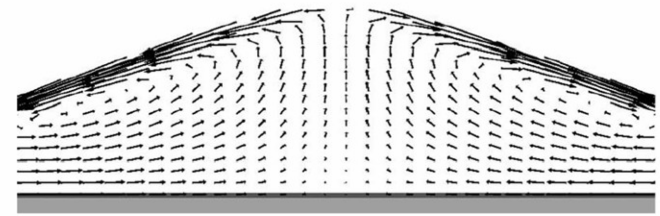


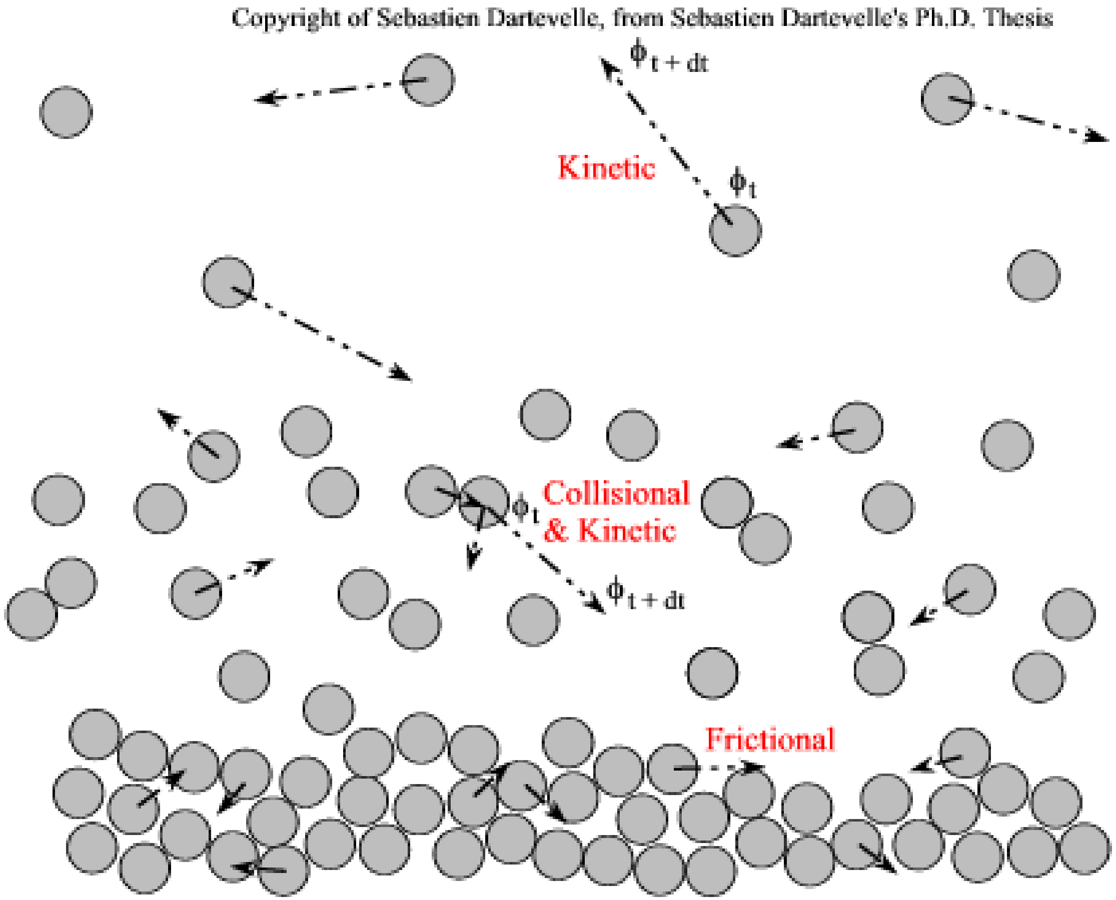
FIG. 2. Circulation in the Faraday heap: The arrows indicate the ticle displacement (multiplied by 2 for clarity) during one driv- cycle, averaged over 25 cycles. The part of the heap shown here responds to the black box in Fig. 1.

[van Gerner *et al.* 2007]

[van Gerner *et al.* 2009]

FIG. 1. Coarsening of a vertically vibrated 1D granular bed, as recorded in our experiments. It takes roughly two minutes to evolve from a flat landscape to a single Faraday heap. Every image is taken at the same point during the vibration cycle, when the container moves upward and the bed is pressed against the floor.

Interactions in granular medium



kinetic → dilute part of the flow, grains randomly translate; viscous dissipation and stress

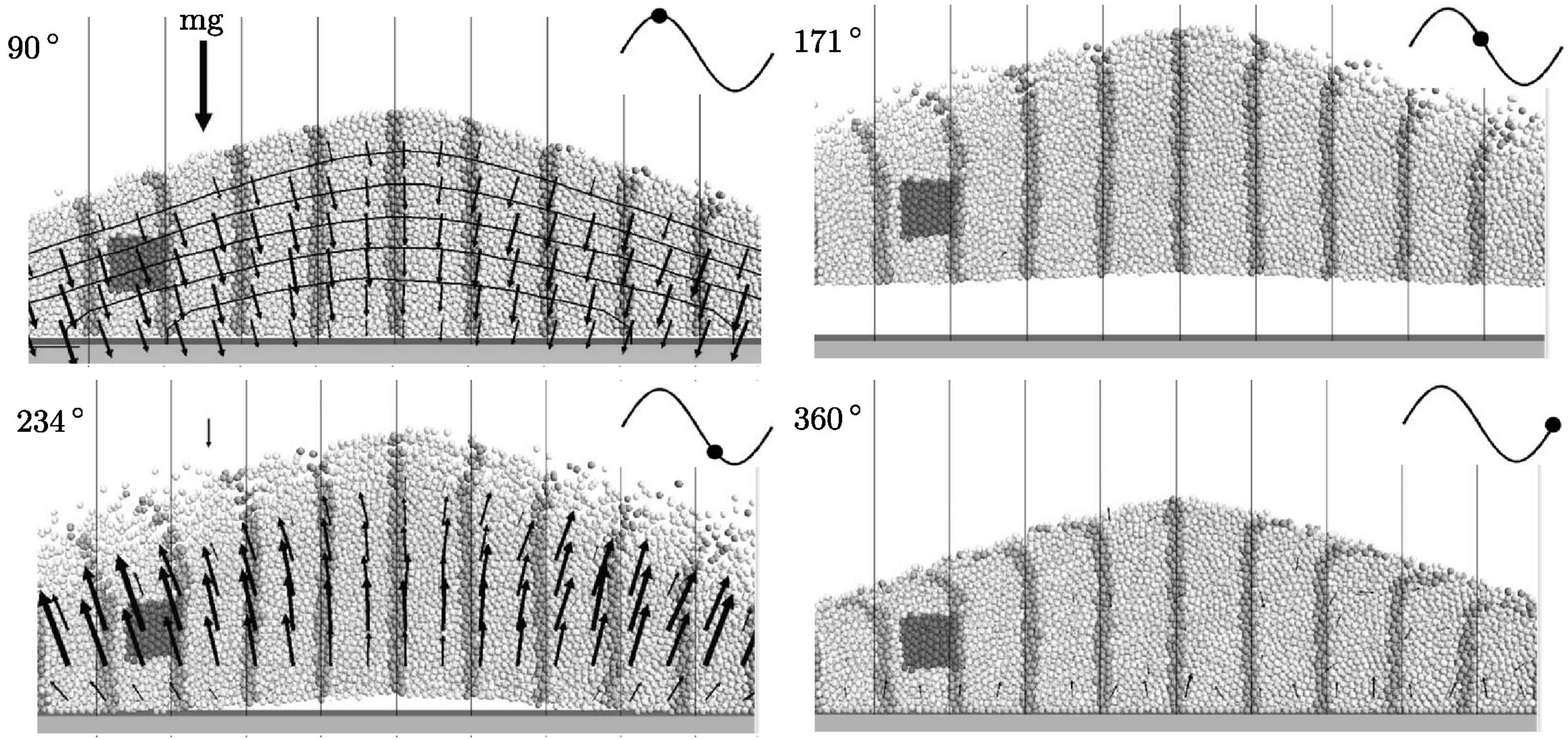
collisional → higher concentration, grains also collide shortly; collisional dissipation and stress

frictional → very high concentration (>50% volume fraction), grains endure long, sliding and rubbing contacts

http://www.granular-volcano-group.org/granular_theory.html

Earlier research…

[van Gerner *et al.* 2007]

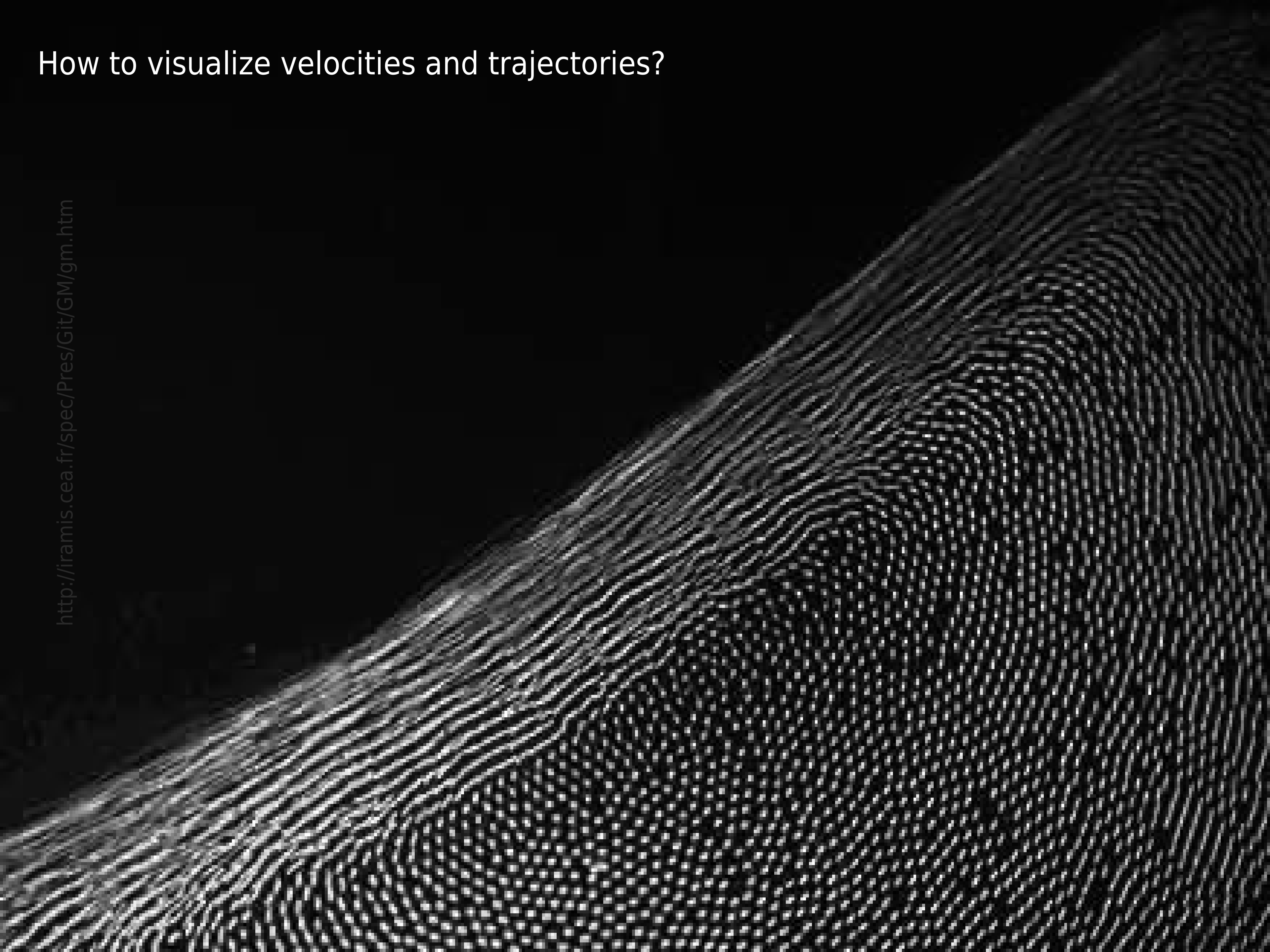


Stokesian forces (drag, air pressure) → drive particles towards the center?
Newtonian forces (from collisions and gravity) → drive particles outward?

IYPT history

- **4.** Self-formation of a pile (9th IYPT, 1996)
  - A horizontal rigid plate vibrates vertically at a frequency of the order of 100 Hz. A cone-shaped pile of fine dispersed powder (e.g. Licopodium or talc) which is heaped up on the plate remains stable at small amplitudes of the vibration. If the amplitude is increased the cone decays. Further increase of the amplitude yields a distribution confined by a sharp border and at still higher amplitudes a pile appears again. Investigate and explain this phenomenon.
- **16.** Coloured sand (13th IYPT, 2000)
  - Allow a mixture of differently coloured, granular materials to trickle into a transparent, narrow container. The materials build up in distinct bands. Investigate and explain this phenomenon.
- **7.** Oscillating box (16th IYPT, 2003)
  - Take a box and divide it into a number of small cells with low walls. Distribute some small steel balls between the cells. When the box is made to oscillate vertically, the balls occasionally jump from one cell to another. Depending on the frequency and the amplitude of the oscillation, the distribution of the balls can become stable or unstable. Study this effect and use a model to explain it.
- **15.** Brazil Nut Effect (17th IYPT, 2004)
  - When a granular mixture is shaken the larger particles may end up above the smaller ones. Investigate and explain this phenomenon. Under what conditions can the opposite distribution be obtained?

How to visualize velocities and trajectories?



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Open questions

- Theory may require advanced tensor analysis :-/
  - but maybe it is possible to simplify everything with a rough, but clear theoretical approach? :-)
- Numerical simulations can help a lot
- What about making experiments and developing a theory for a 2D case? (grains are limited by two parallel glass plates)
- Visualizing the motion and structure of heaps can be very helpful!
  - playing with exposure time for still images?
  - using colored grains?
  - making clear, informative videos (slow-motion?)
- How far the heaps are reproducible, if everything is repeated? When does the system “forgets” initial conditions? Why?
- How about reading more about relevant concepts from granular or soft matter physics, such as percolation, close packing, dynamic arrest?

Key questions

- Above all, what is the cause of the phenomenon?
- Does the phenomenon appear with different granular materials (sand…)?
- Why the frequency is proposed to be limited by 1-10 Hz? What happens at lower or higher amplitudes, and is it still possible to observe the effect with different grains?
- What parameters of the granular particles determine the shape of heaps? (density? particle shape? average particle size?) Do particles need to be monodisperse?
- How relevant are the properties of air (density? viscosity?)
- What are the relevant parameters during the shaking
  - amplitude, frequency, sine/non-sine oscillations?
- Is there a way to describe the 3D shape of heaps?
- How exactly does the wave pattern evolve in time?
- The heaps on initially almost plane layer. What is the maximum possible amplitude of the heaps?
- How to model such a phenomenon experimentally? What are the basic requirements for the equipment?
- Above all, what is your conclusion on the effect?
- What new we can add to this profoundly researched problem?

Problem No. 11 “Fingerprints”

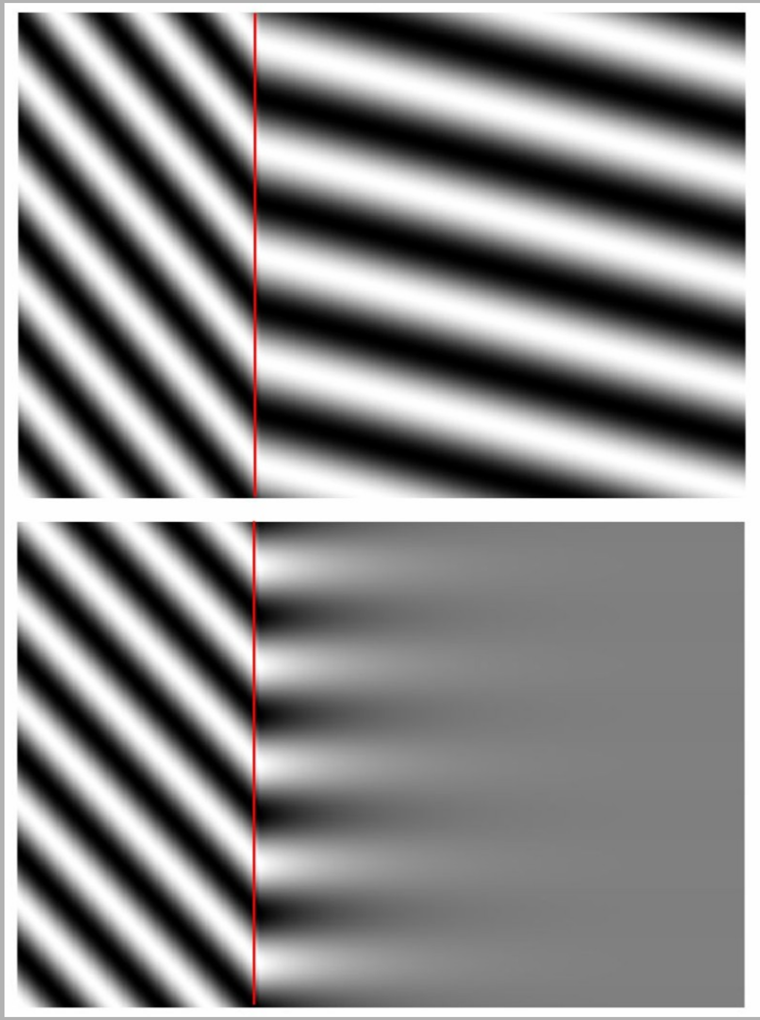
Fill a glass with a liquid and hold it in your hands. If you look from above at the inner walls of the glass, you will notice that the only thing visible through the walls is a very bright and clear image of patterns on your fingertips. Study and explain this phenomenon.

What is the approximate gap between the skin and the glass for the raised epidermal ridges, and for the grooves between them?

Why the light is reflected from a “transparent” glass surface?

[Walt K 2006]

Transmitter or detector?



- Yes, a weak, exponentially decaying wave exists behind the interface at the distances comparable to a single wavelength :-)
- → Why?

Hey! Your eyes are not a light source, and your fingers are not your eyes

The optical information is transmitted from, not into the “evanescent wave” zone

The fingers are also neither a laser pointer, nor a light bulb :-)

- How to correctly describe the system?

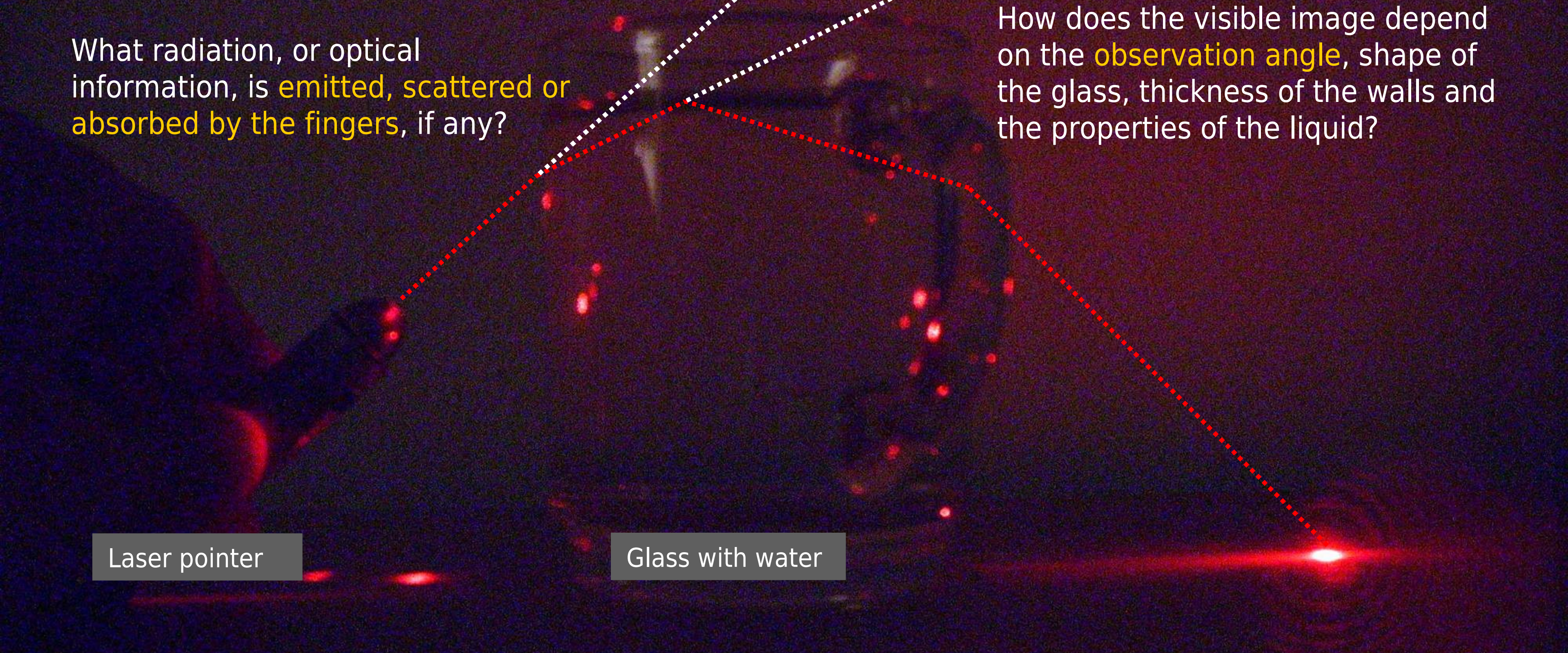
Such demonstrations may tell a story about reflections and refractions, but how relevant they are to the problem?

Is the effect at all related to rays coming from behind of the glass?

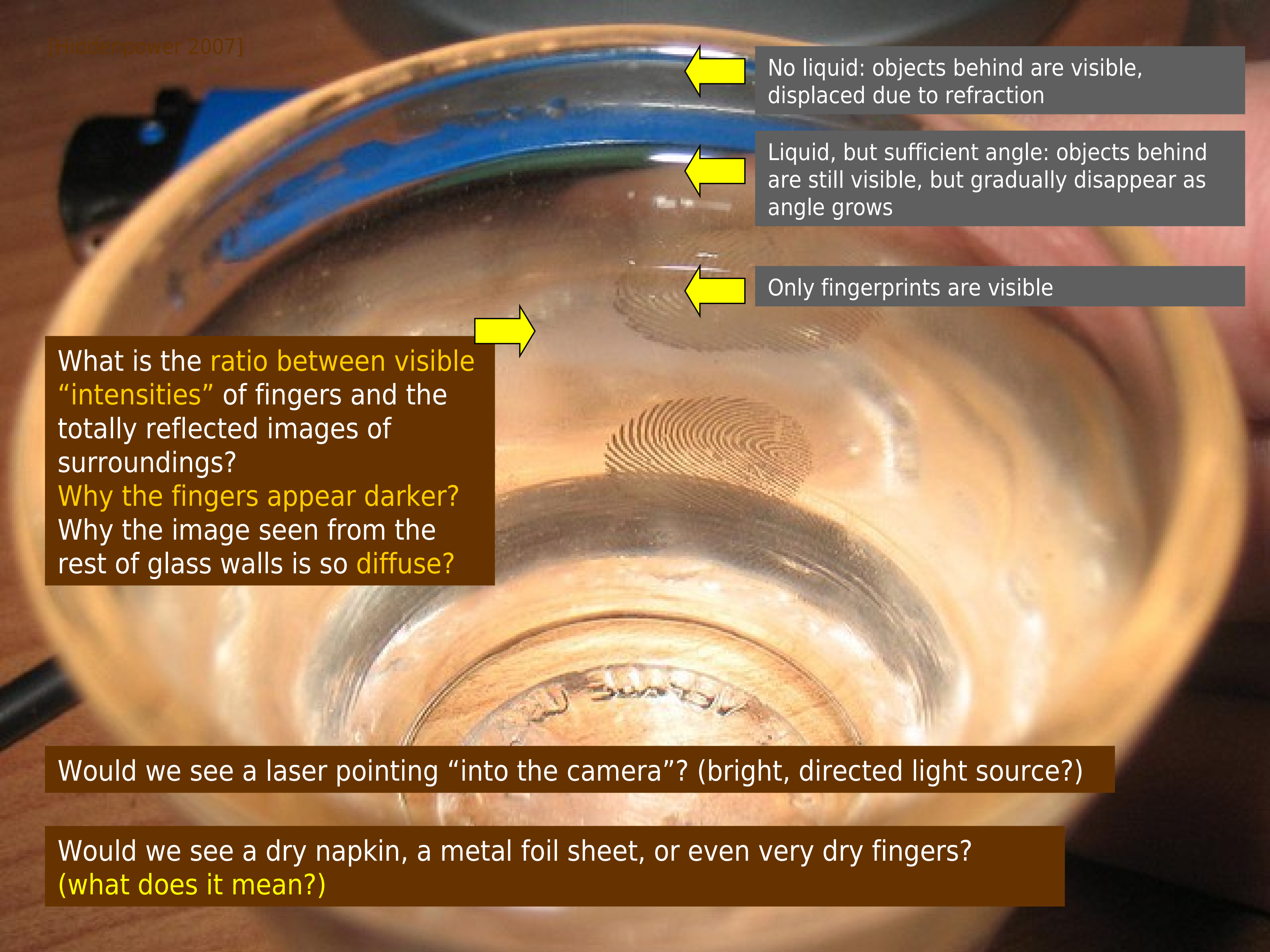
What radiation, or optical information, is emitted, scattered or absorbed by the fingers, if any?

What is actually "visible" from these angles?

How does the visible image depend on the observation angle, shape of the glass, thickness of the walls and the properties of the liquid?

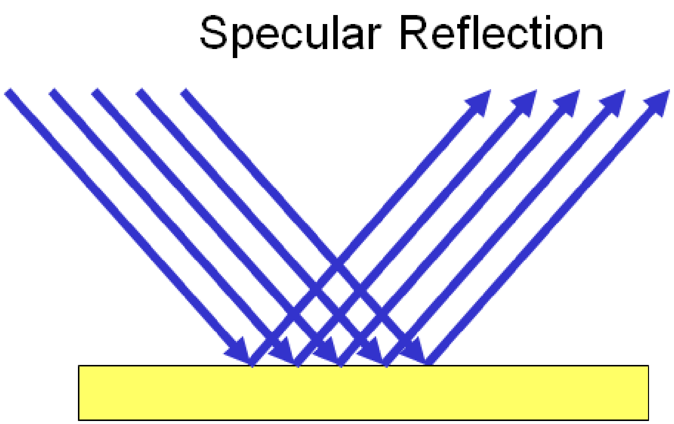


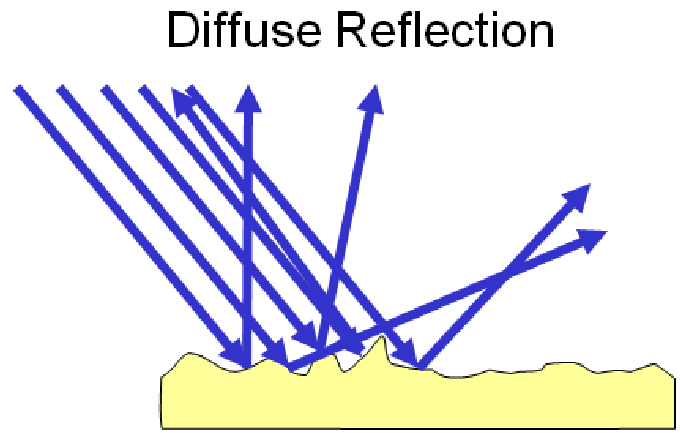
An unexpected reflection can send the beam straight into the eye. Light power below 1...5 mW is unpleasant, but comparably safe; higher powers may cause retinal injuries and should never be used.
Stefan Wyrsch, Philipp B. Baenninger, Martin K. Schmid. Retinal injuries from a handheld laser pointer. N. Engl. J. Med. 363, 1089-1091 (2010)



[Hiddenpower 2007]
No liquid: objects behind are visible, displaced due to refraction
Liquid, but sufficient angle: objects behind are still visible, but gradually disappear as angle grows
Only fingerprints are visible
What is the ratio between visible "intensities" of fingers and the totally reflected images of surroundings?
Why the fingers appear darker?
Why the image seen from the rest of glass walls is so diffuse?
Would we see a laser pointing "into the camera"? (bright, directed light source?)
Would we see a dry napkin, a metal foil sheet, or even very dry fingers? (what does it mean?)

(Very) basic concepts

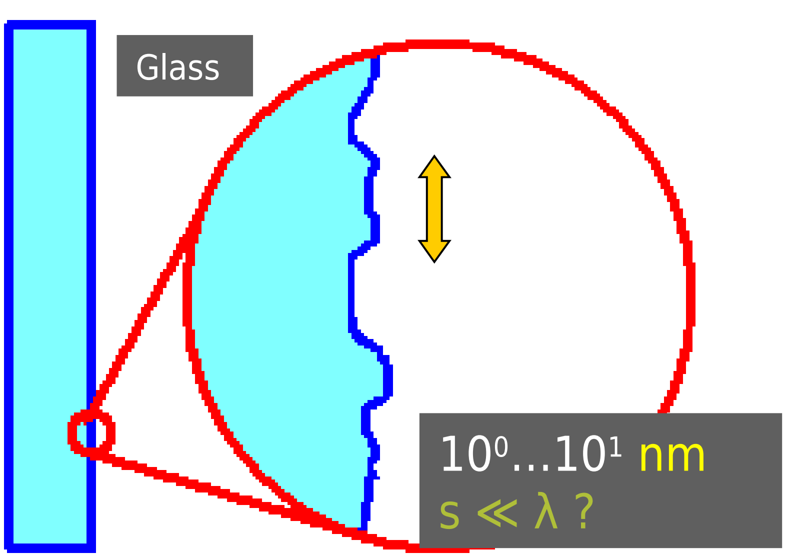


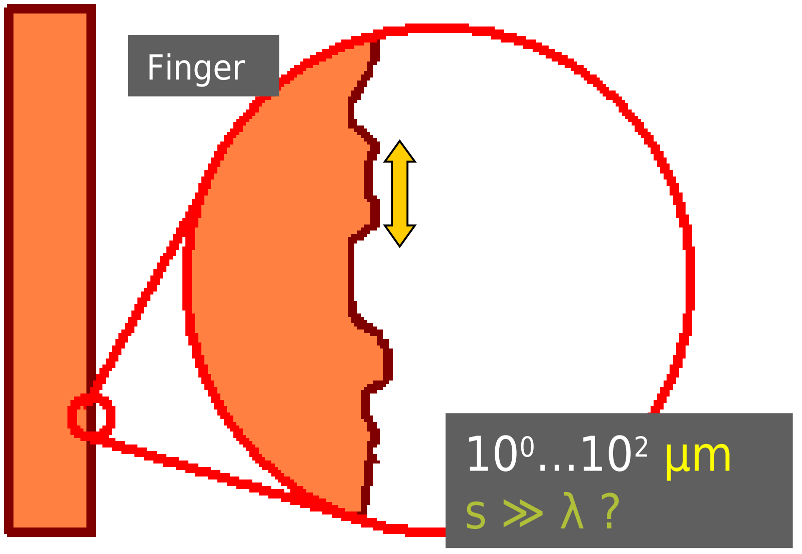


What is the role, if there are any, of light absorption by fingers?

http://twistedphysics.typepad.com/cocktail_party_physics/optics/

How rough is the World?



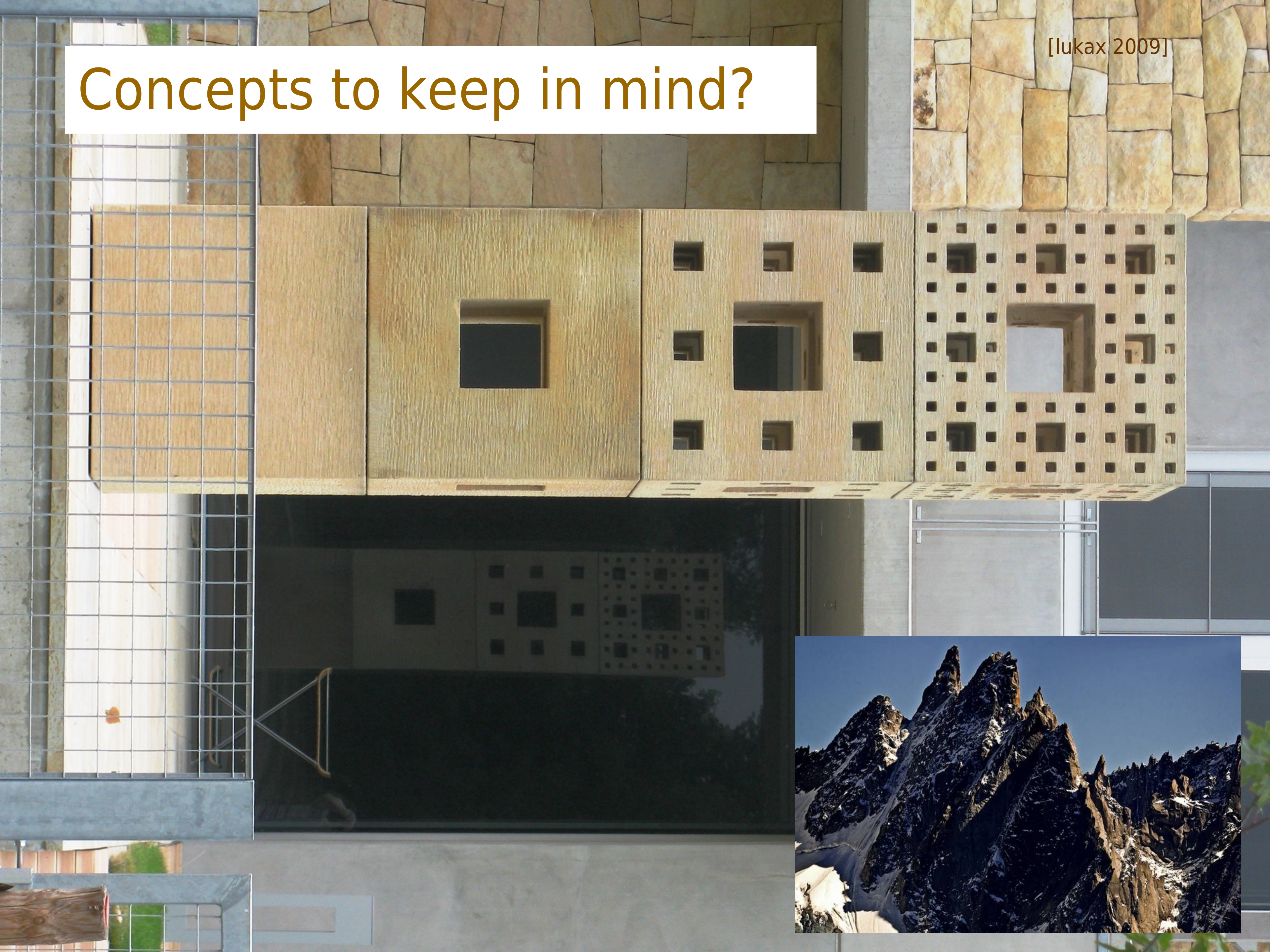


- Is it clear and evident why:
  - rough glass looks turbid?
  - rough surfaces do not work as mirrors?
  - rough surfaces scatter light?


[Daydream Designs 2010]

Concepts to keep in mind?

[lukax 2009]



Contact area?

[Persson 2006]

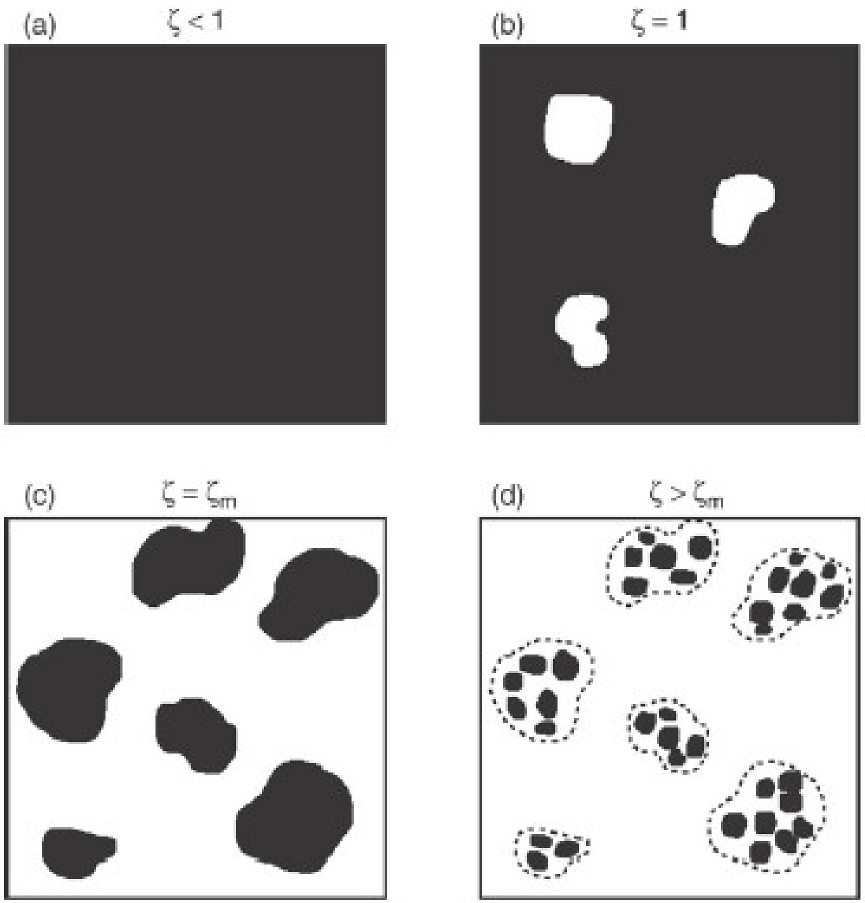


Fig. 12. The contact area at increasing magnification (a)–(d). The macroasperity contact area (c) breaks up into smaller contact areas (d) as the magnification is increased.

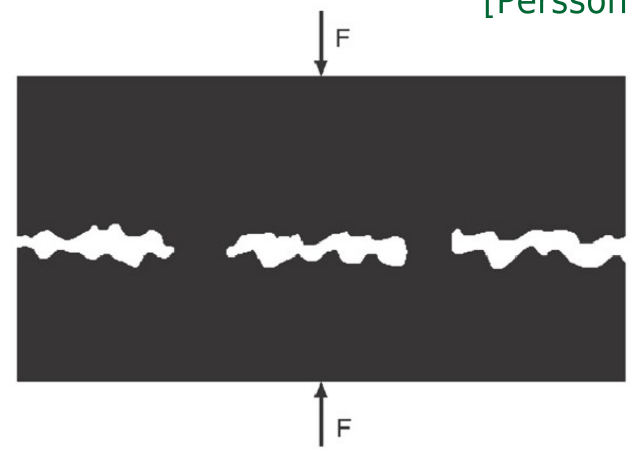


Fig. 1. Two solid blocks squeezed in contact with the force F. The area of real (atomic) contact A is usually an extremely small fraction of the nominal (or apparent) contact area A_0.

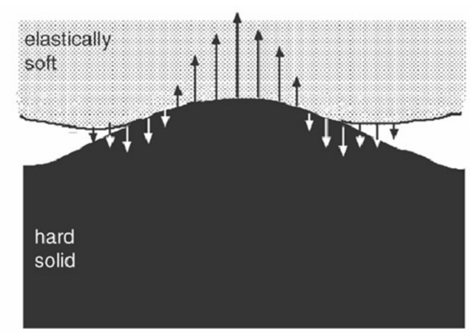
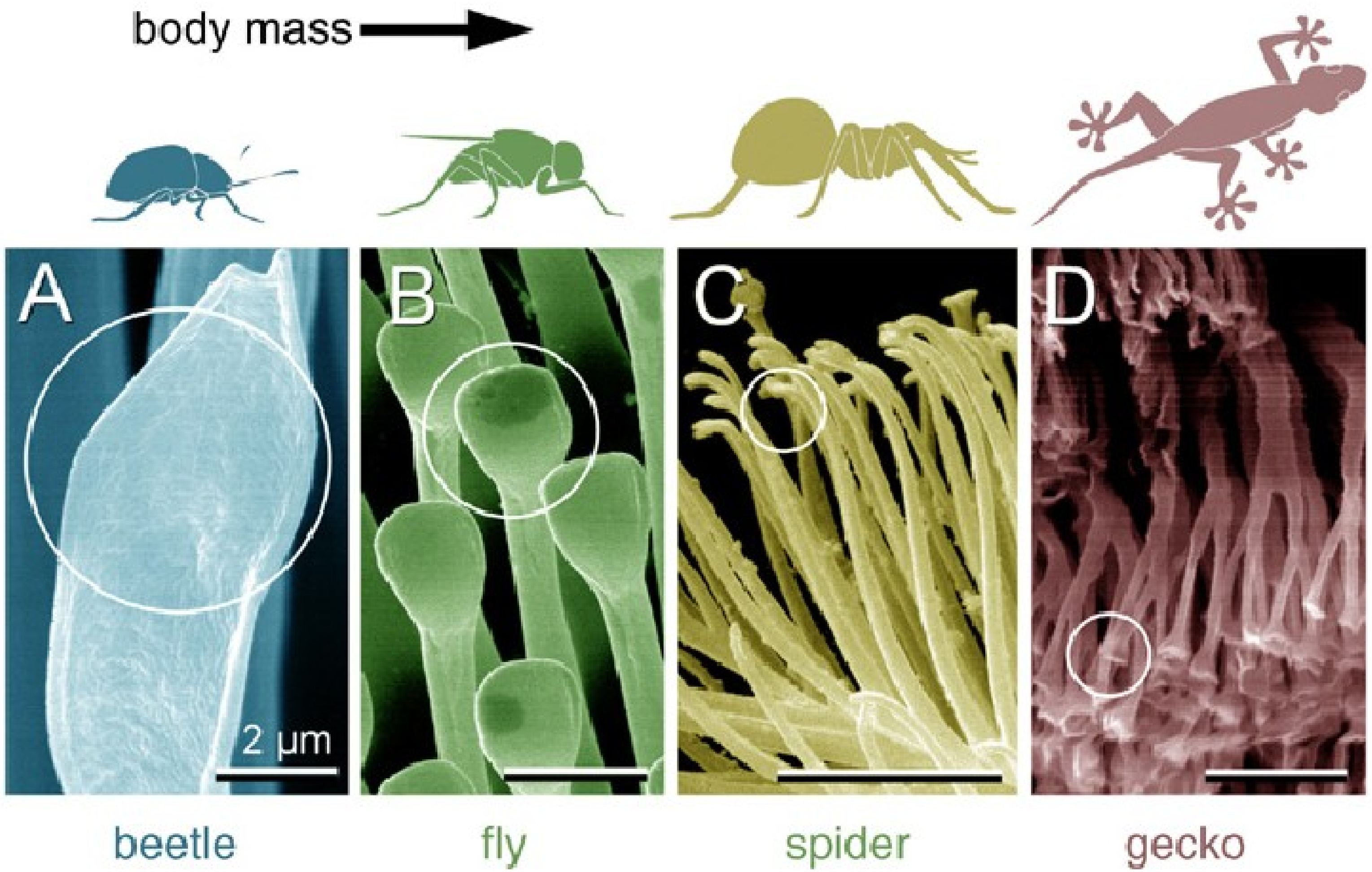


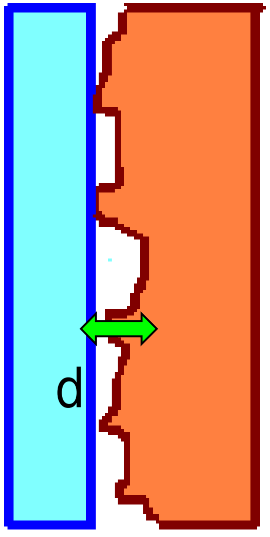
Fig. 17. The stress distribution in an asperity contact region. The stress is tensile close to the boundary line of the contact area. An attractive wall–wall interaction occurs also outside the area of real contact and this interaction determines the detachment stress σ_a and the work of adhesion γ.

Off-the-point remark :-)

[Persson 2006]

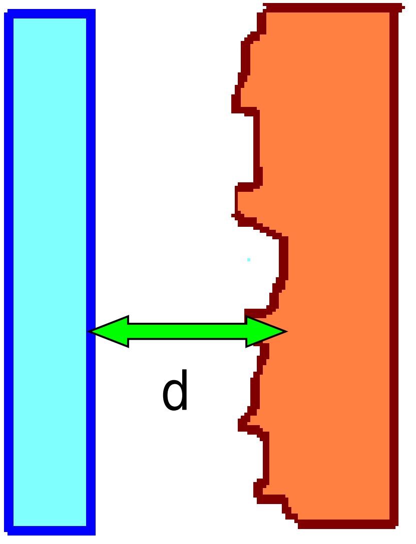


What touches glass?



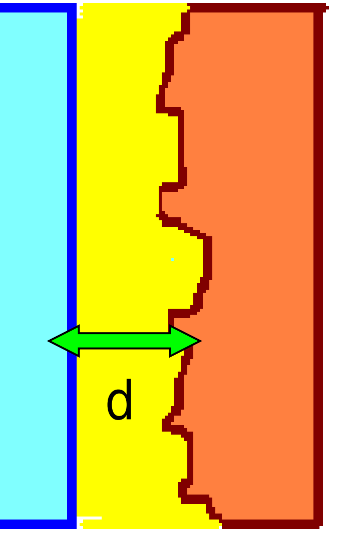
d ≪ λ → direct glass-finger interface?

Do the fingers stick to the glass through molecular adherence?



d ≳ λ → air gap?

Frustrated total internal reflection, optical tunelling?



water/grease fills the gap between “raised ridges” and glass?

Direct glass-liquid and liquid-finger interfaces?

- washed and dry hands vs greasy and/or wet hands?
- liquid on fingers scatters or works as immersion fluid or both or none correct?
- are fingerprints visible when fingers are removed? (whatever yes or no, what does the result mean?)

Does grease scatter light?

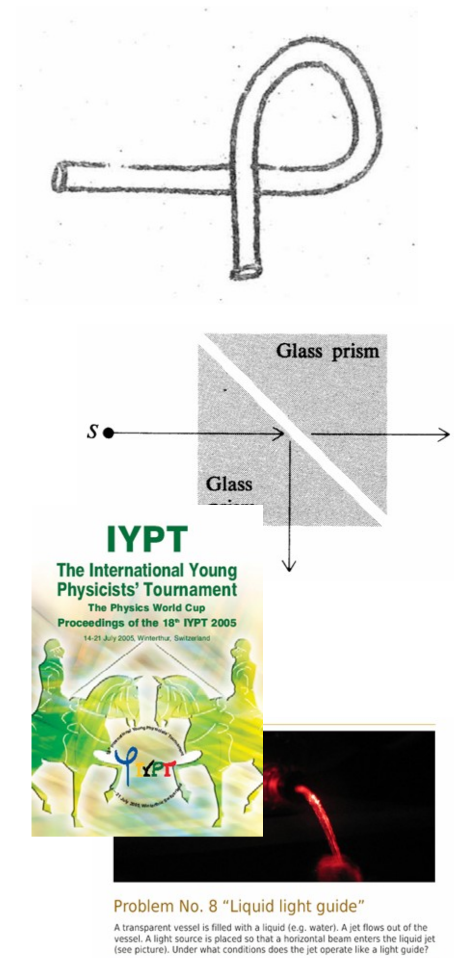
[Pink Sherbet Photography 2009]

[Wolax 2009]

http://creativebits.org/files/images/dont_touch.png

IYPT history

- **2.** Light guide (3rd YPT, Correspondence Competition, 1981)
  - The properties of light guides are well illustrated by a glass or a plexiglas rod, bent e.g. as shown in the picture. Study the properties of a similar, or a more interesting, light guide made in the school laboratory. Construct a device illustrating or using the properties of a light guide.
- **15.** Optical tunneling (18th IYPT, 2005)
  - Take two glass prisms separated by a small gap. Investigate under what conditions light incident at angles greater than the critical angle is not totally internally reflected.
- **8.** Liquid light guide (23rd IYPT, 2010)
  - A transparent vessel is filled with a liquid (e.g. water). A jet flows out of the vessel. A light source is placed so that a horizontal beam enters the liquid jet (see picture). Under what conditions does the jet operate like a light guide?



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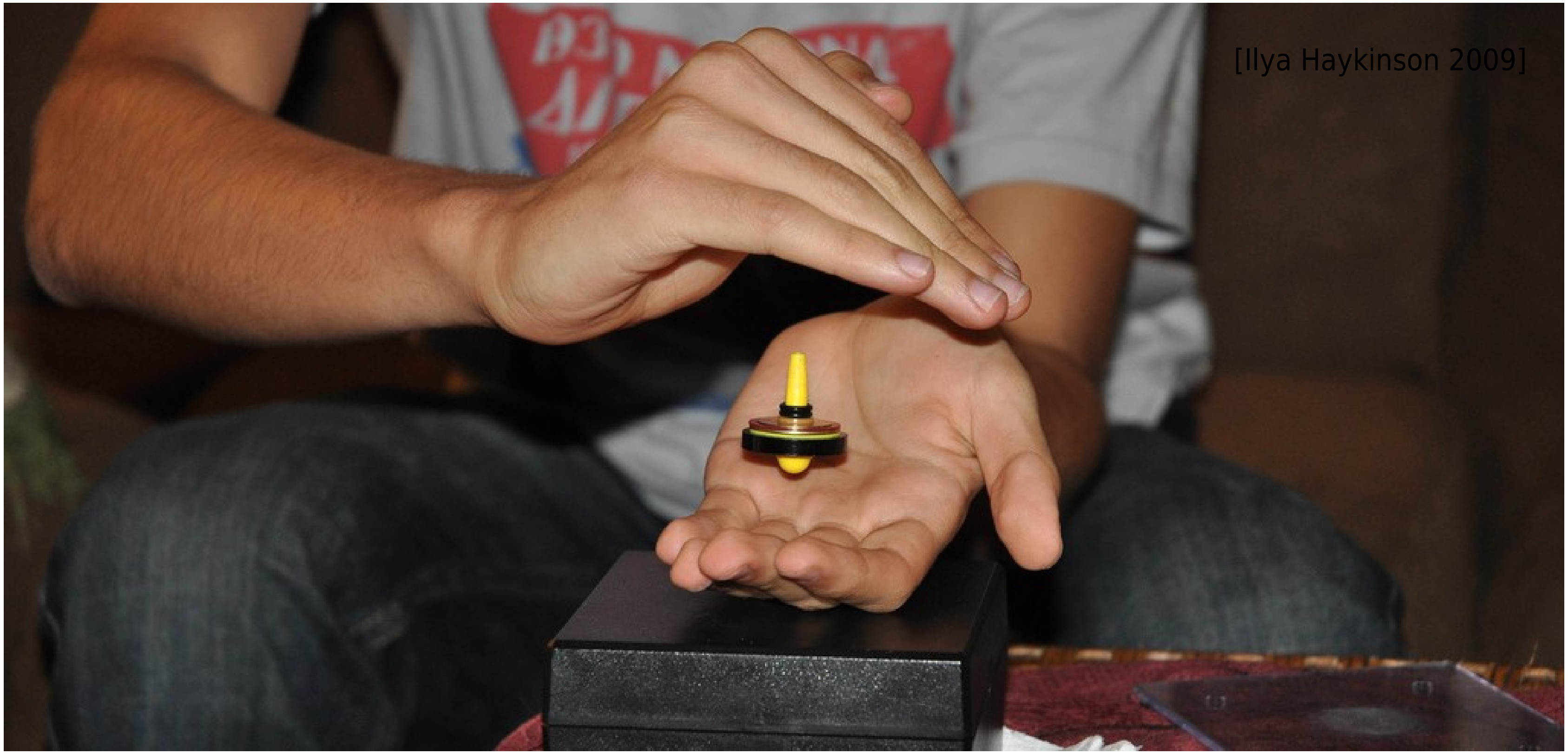
Open questions

- What is the role of liquid in the effect? How does the image depend on its refractive index?
- What happens, if there is no liquid at all in the glass? How to quantitatively characterize the dependence of visible pattern on the amount of liquid involved?
- On what does the visible light intensity ("brightness of fingerprints") depend?
  - applied force → "effective contact area"?
  - observation angle and the position of ambient light sources?
  - amount of grease/water on fingertips?
  - …?

Key questions

- In the simplest case, if there are no fingers touching the glass, why there is nothing visible through the walls?
- Above all, what is the physical reason of the fingerprint effect? Is the visible color of fingerprints determined by scattering, reflection, adsorption, or the interplay between all of them?
- What is the approximate gap between the skin and the glass for the raised epidermal ridges, and for the grooves between them? How to best approach the question, as the finger surface is fractal-like and the gap varies considerably from point to point?
- What is the approximate length scale for roughness of the glass surface and of the finger skin? Is it physically correct to speak of such length scales? What other approaches would be more useful?
- How does the effect depend on skin properties, and is the finger grease relevant?
- How does the apparent contact area depend on length scale?
- What are the dependences of the reflective indexes in the system the angle of incidence? Are the Fresnel's relations relevant?
- Does the effect depend on wavelengths of incident or scattered light, refractive indexes of media in question, surface properties?
- Is it possible to establish a model experimental system to measure the radiation density at controlled distances from the interface? What range of wavelength would be optimum for such a system?
- Many approaches and concepts may emerge at discussions (momentum of photons, Pointing vector, tunneling, evanescent wave, potential barrier, probability distribution, absorption, scattering.) Can you discuss their relevance and re-formulate your explanation with a different basic concept?
- Is there a physically relevant time lag for the wave to pass through the gap?
- How to best record the visible fingerprint image for further analysis, and what information can be retrieved from such images?



Problem No. 12 “Levitating spinner”

A toy consists of a magnetic spinning top and a plate containing magnets (e.g. "Levitron"). The top may levitate above the magnetic plate. Under what conditions can one observe the phenomenon?

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Spin the top - and watch it float! The Levitron spins and surfs on magnetic waves! Pass your hand above, underneath, and around the top. It will continue to spin and float only touching air! The LEVITRON floats free in space, supported only by the repelling magnetic force produced by permanent magnets (no batteries required!). A scientific theorem, that was advanced over a century ago, states that this is impossible - yet this amazing top levitates right before your eyes! You must see it to believe it!

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What spatial arrangements of magnets in the base, and in the spinning top, are necessary? Are there limitations for minimum or maximum speed of spinning?
[David Vo 2007]

IYPT history

- **1.** Invent yourself (5th IYPT, 1992)
  - “Magnetic suspension” may be used in high speed trains of the future. Design and make an experimental model of such a suspension.
- **12.** Rolling magnets (19th IYPT, 2006)
  - Investigate the motion of a magnet as it rolls down an inclined plane.
- **14.** Magnetic spring (23rd IYPT, 2010)
  - Two magnets are arranged on top of each other such that one of them is fixed and the other one can move vertically. Investigate oscillations of the magnet.

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Key questions

- The problem has been extensively investigated before. How should we approach the task and what aspects to investigate, in order not to repeat earlier work and seriously contribute to the understanding of the tricky problem?
- What is your conclusion on the translational and rotational stability of the spinner? What interactions maintain the spinner levitated? How to describe these interactions quantitatively? What are the opportunities in analyzing the physics of different magnetic levitation toys, not only Levitron as such? Is a potential well a must for any magnetic levitator?
- What are the critical conditions for rotational instability and further re-orientation of poles?
- What are the roles for the air resistance, or induction heating? What is the expected and actual lifetime for levitation?
- How to measure the magnetic field in the vicinity of the spinner without influencing the system as such?
- What parameters of the magnetic spinner are relevant? (magnetic moment? mass? moment of inertia?) What other interactions, besides magnetic and gravitational, are relevant?
- What possible oscillatory modes may be observed? How to classify them? What is the total energy of the system, and what are the contributions of potential energies and kinetic energy of the spin?
- How to best record and analyze the rotation, oscillations, or stability of the spinner? (stroboscopic, time lapse video?)
- Above all, what is your conclusion on the problem?

Problem No. 13 “Light bulb”

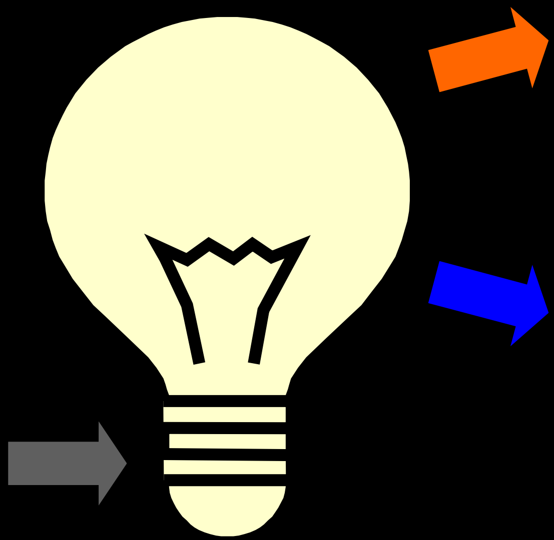
What is the ratio between the thermal energy and light energy emitted from a small electric bulb depending on the voltage applied to a bulb?

(Very) basic ideas

Metal wires are heated by filament → quick heat transfer by metal?

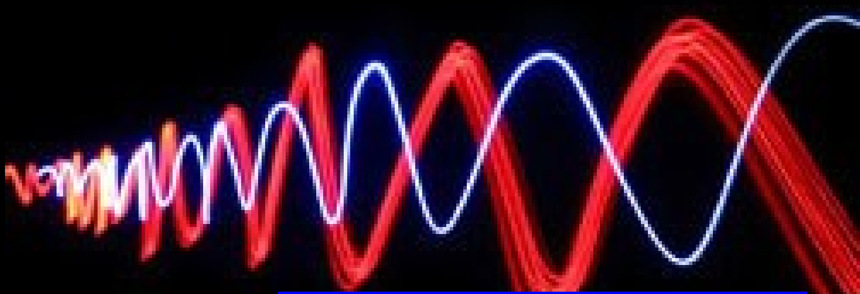
Air is heated at interface with glass bulb (via inert gas) → convection?

$P = U\,I$



Heat

Light



What is the radiation spectrum for a light bulb? Does it only produce optical radiation?

It is actually our task to investigate those, and other, paths for energy transfer :-)

What is the difference between “small” and “large” bulbs?

IYPT history

- **7.** Incandescent lamp (9th YPT, Correspondence Competition, 1987)
  - An incandescent lamp is connected to a power circuit of
    - a) direct current
    - b) alternate current with a frequency of *50 Hz*
  - Study the current in the circuit as a function of voltage on the lamp. Estimate the amplitude of temperature oscillations of the filament in a lamp connected to AC circuit of *50 Hz*.
- **11.** Incandescent lamp (1st IYPT, 1988)
  - It is said that two 60 *W* light bulbs shine brighter than three 40 *W* bulbs. Is it true? Investigate how a small change in supplied voltage will affect light emission and a light bulb's lifetime.
- **15.** Incandescent lamp (5th IYPT, 1992)
  - Estimate the amplitude of temperature variations of the spiral filament of a light bulb powered by alternating current.
- **6.** Transmission of signals (13th IYPT, 2000)
  - Using a bulb, construct the optimum transmitter of signals without any modulation of the light beam between transmitter and receiver. Investigate the parameters of your device. The quality of the device is defined by the product of the information rate (bits/sec) and the distance between transmitter and receiver.
- **14.** Illumination (13th IYPT, 2000)
  - Two bulbs, *100* and *40 watts*, respectively, illuminate a table tennis ball placed between them. Find the position of the ball, when both sides of the ball appear to be equally lit. Explain the result.
- **10.** Tungsten lamp (16th IYPT, 2003)
  - The resistance of the tungsten filament in a light bulb shows a strong temperature dependence. Build and demonstrate a device based on this characteristic.
- **1.** Filament (20th IYPT, 2007)
  - There is a significant current surge when a filament lamp is first switched on. Propose a theoretical model and investigate it experimentally.

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Key questions

- How does the ratio between thermal and light energies evolve over time, when the lamp is switched on?
- Is there a way to directly measure the temperature of the filament and other elements of the lamp? Is it possible to measure or calculate the radiation intensity?
- What physical parameters of the system may be relevant? (voltage provided by the power supply? resistance of the filament as a function of temperature? inductance of the filament? heat conductivity of contact wires and the gas? surface properties of the filament?)
- What is the radiation spectrum of the lamp and does it evolve over time? Are the Planck's law and the black body approximation relevant?
- The filament in a "used" lamp is possibly thinner and more likely to burn out. How does it influence on ratio between energies in question?
- In the end, what are the overall energy losses via radiation and via heat transfer? What amount of heat is leaving through contact wires and through gas and glass? What are the time scales for these energy losses?

Problem No. 14 “Moving cylinder”

Place a sheet of paper on a horizontal table and put a cylindrical object (e.g. a pencil) on the paper. Pull the paper out. Observe and investigate the motion of the cylinder until it comes to rest.

IYPT history

- **4.** Rolling friction (2nd IYPT, 1989)
  - Investigate how the friction force depends on speed. To be more specific, consider the rolling of a wooden puck on wood (a wooden surface of a table.)

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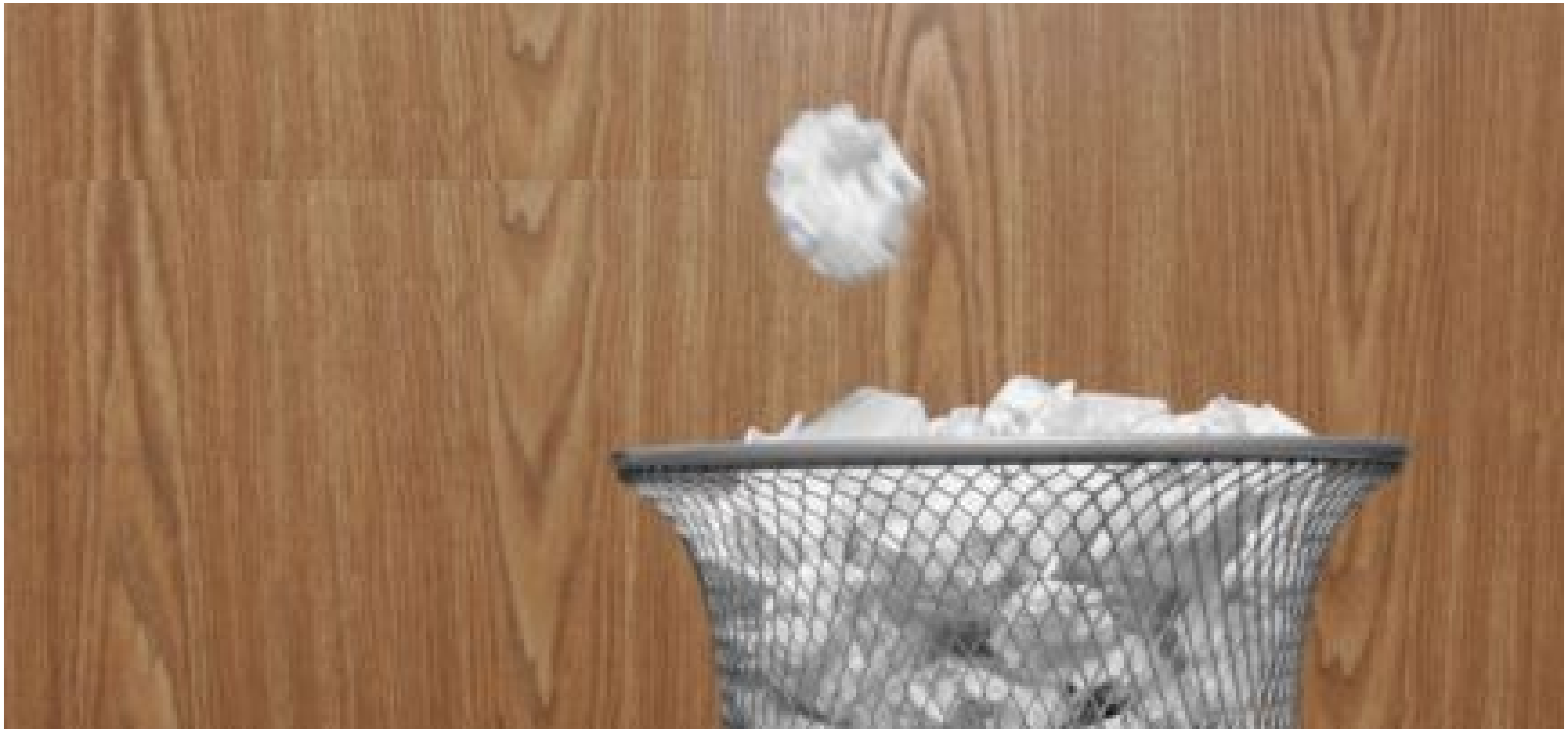
Key questions

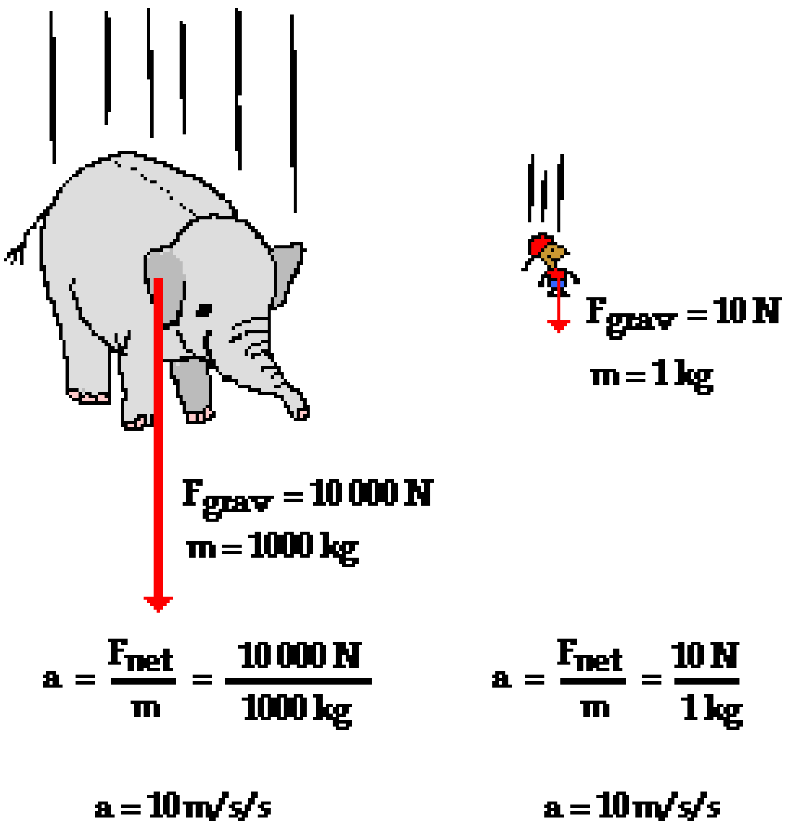
- Is the problem all about the steady rolling? Should we also investigate other rotational modes, such as the revolution around an axis normal to the principal axis of the cylinder? (e.g. passing through the center-of-the-masses, or not?)
- How does the initial motion of the sheet determine further dynamics of the cylinder? What is the role of the speed or acceleration of the sheet, and its exact 3D trajectory?
- How does the co-ordinate, as well as translational and angular speeds and accelerations depend on time?
- To what degree the motion is reproducible, if the experiment is repeated?
- What is the direction of rolling in dependence of initial parameters? Can the pencil show the hula hooping effect? Is there a possibility of slipping?
- How does evolve over time the ratio between the kinetic energy of rotation and the kinetic energy of translational motion?
- An exponential or likewise decceleration means very slow motion at certain time scales. What is the kinetics of the cylinder before the final rest, and what additional forces or interactions may influence on it?
- What physical parameters of the cylinder may determine the quantitative or qualitative (e.g. rotational modes) features of the dynamics? (length? density? shape? surface friction coefficients?)
- Are any aerodynamic forces relevant to the problem? How significant is air resistance?
- Is it worth modeling the system numerically?

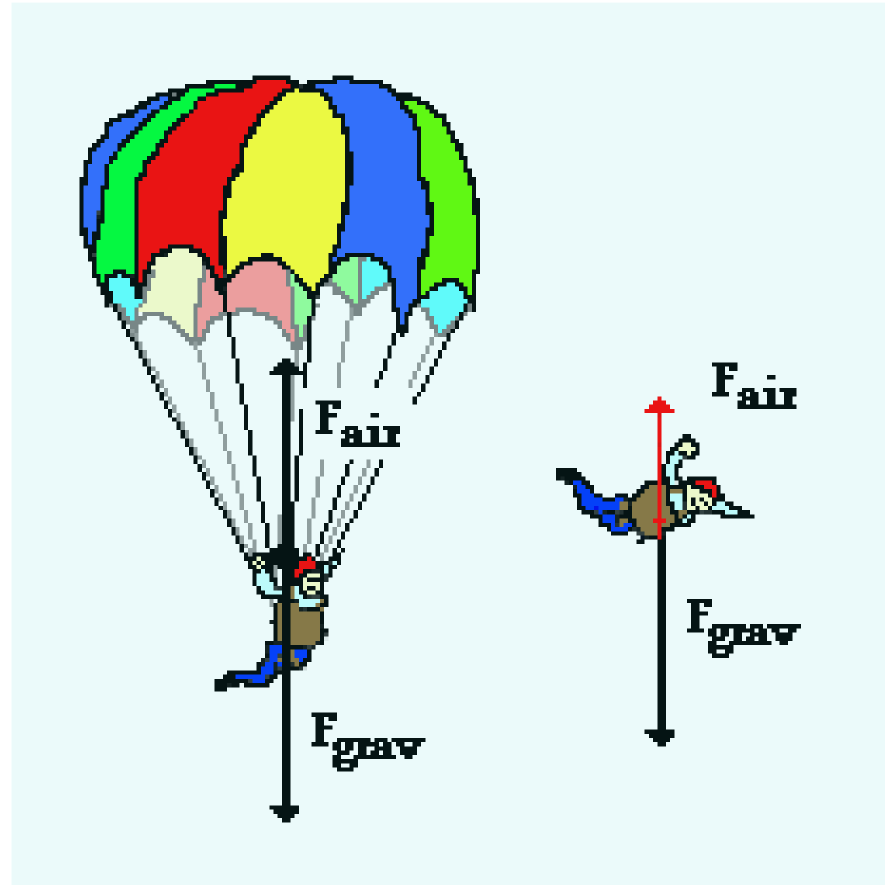


Problem No. 15 “Slow descent”

Design and make a device, using one sheet of A4 80 g/m^2 paper that will take the longest possible time to fall to the ground through a vertical distance of 2.5 m. A small amount of glue may be used. Investigate the influence of the relevant parameters.

(Very) basic ideas





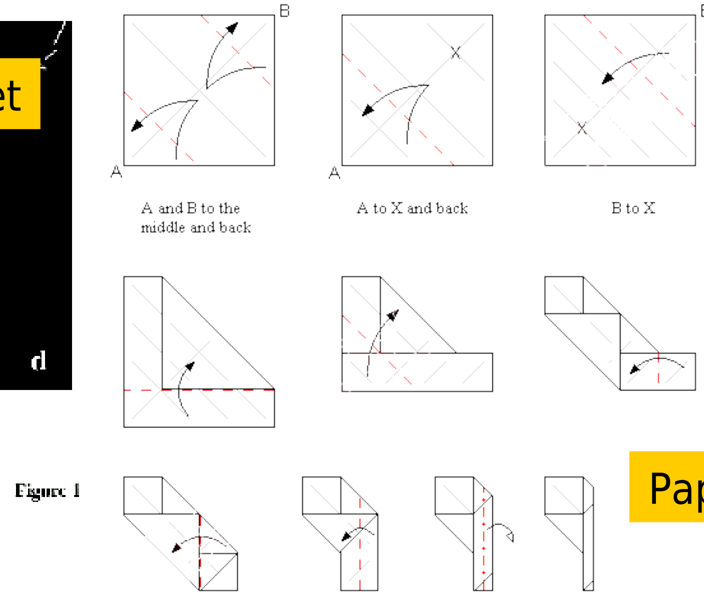
Vacuum, no air drag → *a≠f(mass, shape)*

Air drag → *a≠f(mass), a=f(shape)*

http://www.physicsclassroom.com/class/newtlaws/u2l3e.cfm

Brainstorming what model to choose?

Unmodified paper sheet



Paper maple seed

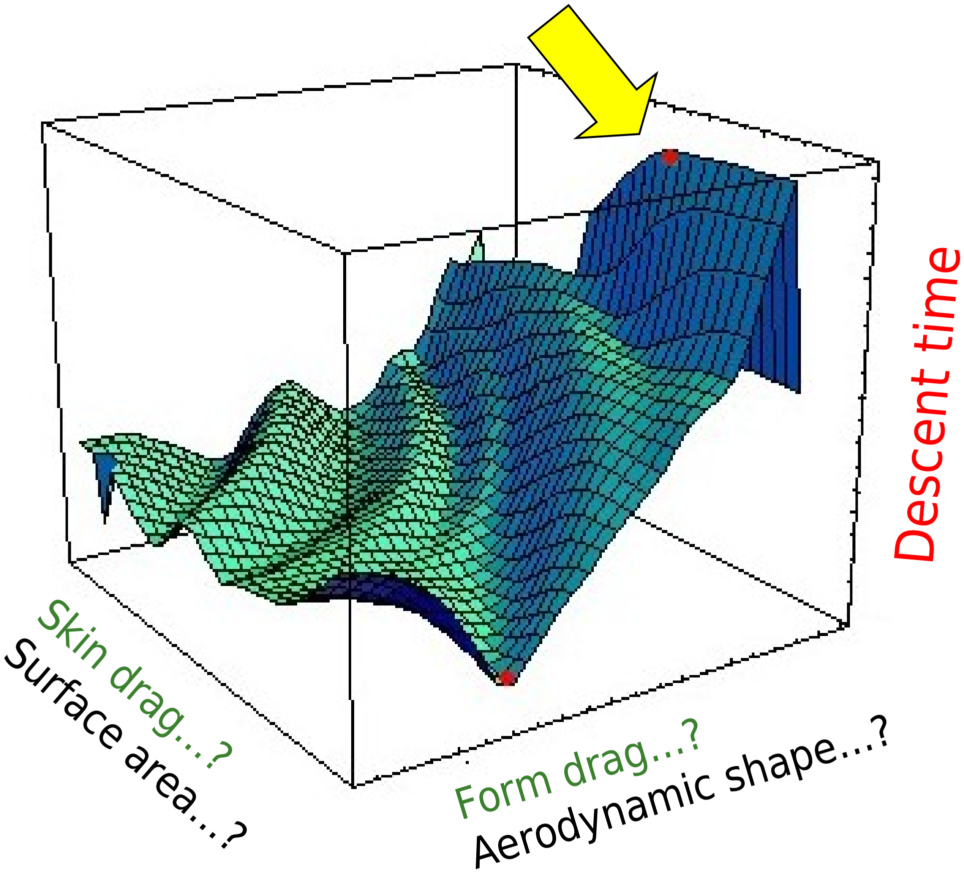
Paper airglider

Paper parachute

Paper propeller

Hey, the problem is in physics and not in checking all possible engineering concepts!

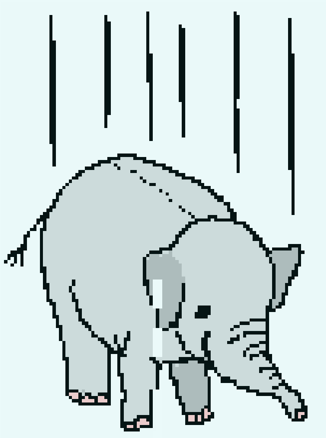
Maximizing the descent time?



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

- Amount of material? (fixed?)
- Initial height? (fixed?)
- Air density and viscosity? (fixed?)
- Ambient airflows (wind), not induced by the devise itself? (fixed as zero?)
- Surface properties? (fixed or not?)
- Aerodynamic shape (not fixed?)
- Surface area (not fixed?)
- Linear dimensions, e.g. cross-section (not fixed?)

Energy conservation approach…?



$U = mgh$
$mv^2/2 = 0$
$I\omega^2/2 = 0$

That means the
minimum descent time!

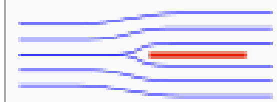
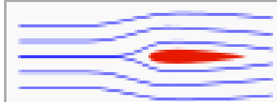
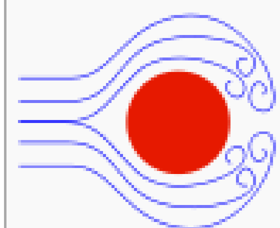
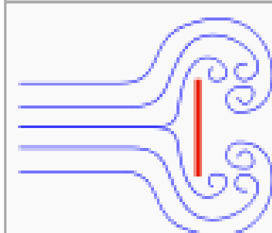
~~$U = 0$~~
~~$mv^2/2 = mgh$~~
~~$I\omega^2/2 = 0$~~

$U = 0$
$mv^2/2 \rightarrow 0$:-)

How to achieve it?

How to maximize the descent time...?

- Make the device transferring its initial potential energy into anything but kinetic energy of vertical descent?
  - into kinetic energy of rotational motion? (rotating propeller?)
  - into kinetic energy of horizontal motion? (glider?)
  - into kinetic energy of airflow or into fluid friction? (specific shape to induce turbulence, higher air drag?)
  - into vibrations, or elsewhere? (any ideas how?)
- Make the device experiencing higher air resistance?
  - form drag → adjusting shape and size
  - skin drag → adjusting surface area
- What about the stiffness of the entire construction?
  - can internal motion and friction in a non-rigid body be helpful?

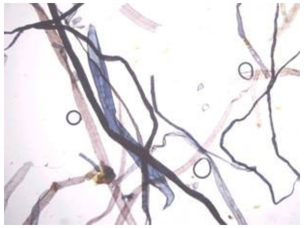
Shape and flow	Form drag	Skin friction
	0%	100%
	~10%	~90%
	~90%	~10%
	100%	0%

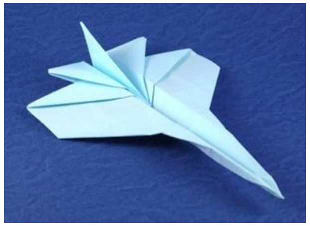
To keep in mind...

- Is the drag always proportional to translational speed? What about rotational speed, if the device rotates?
- Is the air density constant in all points around the falling body?
- How does the aerodynamic behavior depends on Reynolds' number? Is the Reynolds number constant over time of flight?
- Is the air viscosity not at all relevant?
- How do the translational and angular speeds and accelerations for your device depend on time?
- Is there any regularity in the spatial orientation of the device during falling?
- What features of the device's geometry make it fall as it falls?
- From the energy point of view, what is the initial potential energy (mgh) in comparison to translational or rotational kinetic energies during different stages of the flight?

Tricky points: interpretation of the task

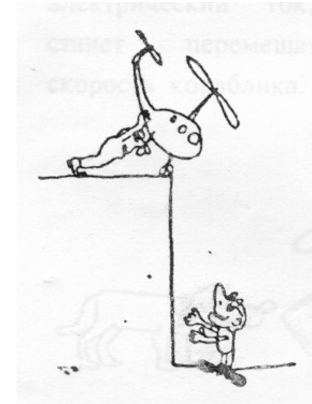
- Can we use only a fraction of the A4 sheet?
  - A tiny paper particle will descend for the longest time, and a nanoscale paper particle will never descend due to Brownian motion. But are we violating the task?
- If no, can we make a highly porous device by grinding the entire A4 sheet into dry fibers and stabilizing it with an aerosole of "a small amount of glue" ("dandelion")
  - Larger surface area means higher air drag. But are we violating the task?
- Can we focus efforts on a glider or a paper plane?
  - The vertical speed (descent rate) will be quite small, but can we say this motion is "falling"?
- Certain devices may require a particular "lauch procedure" (to establish a good angle of attack, to gain an initial torque, or a spatial orientation)
  - Do we violate the task by imposing any of such conditions?
- Finally, what about making a hot-air paper balloon with "a small amount of glue" as fuel?
  - It may look like an unethical, forbidden trick, but is such a solution consistent with the task?

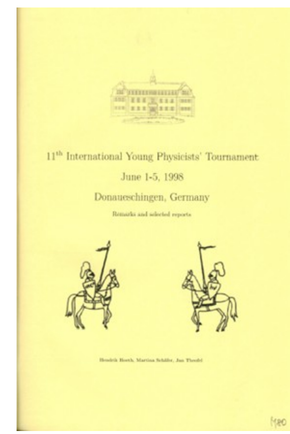




IYPT history

- **9.** Passive motor (4th IYPT, 1991)
  - An apple dropped from a balcony of a multi-storey building will calmly descend into the hands of your friend, if you attach to the apple a propeller cut out of dense paper. Explain the principle of work for such a parachute and study the dependence of the drag force on the descent rate and on the sizes of the propeller's blades.
- **1.** Invent yourself (11th IYPT, 1998)
  - Construct an aeroplane from a sheet of paper (A4, 80 g/m^2). Make it fly as far and/or as long as possible. Explain why it was impossible to reach a greater distance or a longer time.
- **5.** Dropped paper (12th IYPT, 1999)
  - If a rectangular piece of paper is dropped from a height of a couple of meters, it will rotate around its long axis whilst sliding down at a certain angle. How does this angle depend on various parameters?
- **2.** Winged seeds (21st IYPT, 2008)
  - Investigate the motion of falling winged seeds such as those of the maple tree.





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Key questions

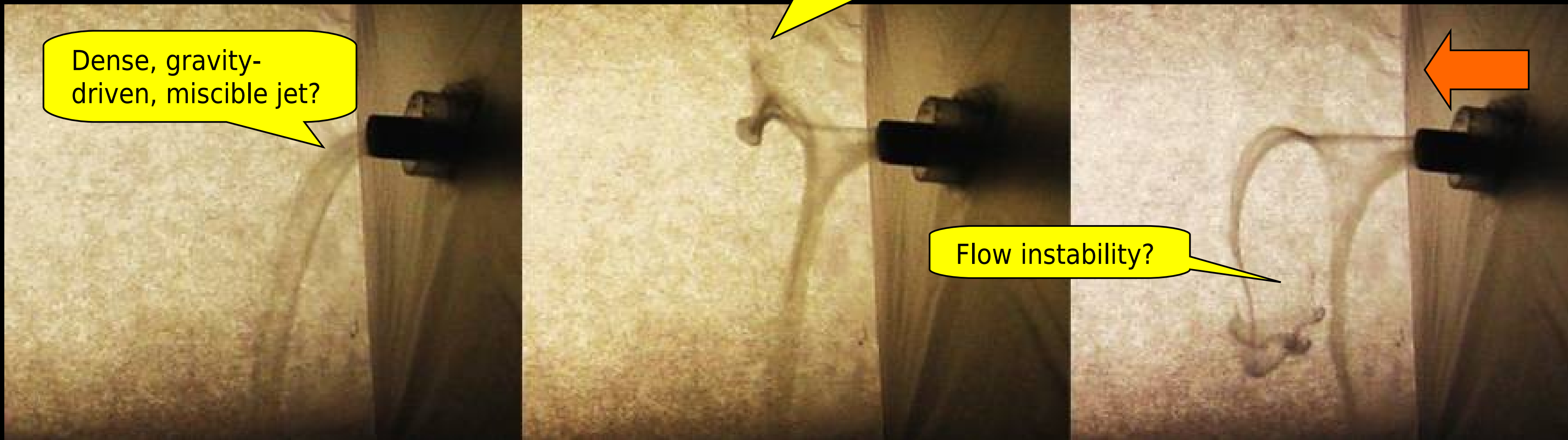
- What physical parameters determine the angle of attack and the spatial orientation of the falling paper device?
- What kind of motion is preferential for the device to maximize the descent time? (stable rotational motion? gliding? translational motion?)
- What are the magnitudes of the Reynolds number for the flow around the device? Is the flow laminar or turbulent? Does the Reynolds number change with time?
- How to visualize the flow around the falling device?
- What is the actual descent rate, in comparison to the speed of horizontal displacement, for your device?
- If your device shows a maximum descent time from the height of 2.5 m, would it be still showing a best result for smaller or larger heights?
- What is the dependence of descent rate on time for your device?

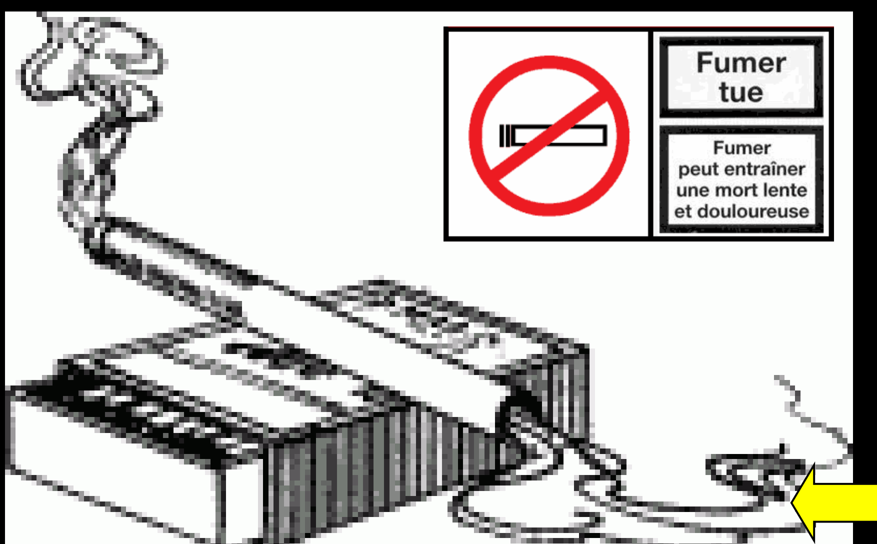
Problem No. 16 “Smoke stream”

A glass jar is covered with cellophane. A tightly folded paper tube of length 4–5 cm is inserted hermetically into the jar through the cellophane cover. The tube is oriented horizontally. If one burns the outside end of the tube the dense smoke flows into the jar. Explore this phenomenon.

(Very) basic ideas

[Alexei Shekochikhin 2010]





[Перельман: Занимательная физика]

Smoke particles are unlikely to move independently from the surrounding air (why?) :-)

There should be a physical mechanism, like pressure difference, that drives air inside the jar :-)

How to identify and validate the physics behind the effect?

In cigarettes without filter, smoke shows positive buoyancy near the lit end, but negative buoyancy at the open end. Is this effect relevant?

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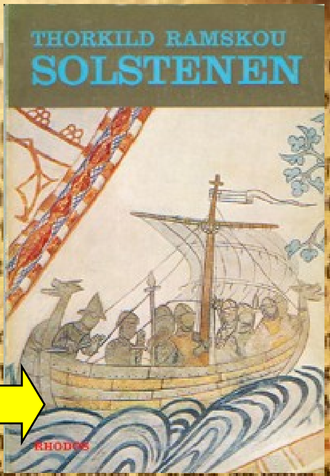
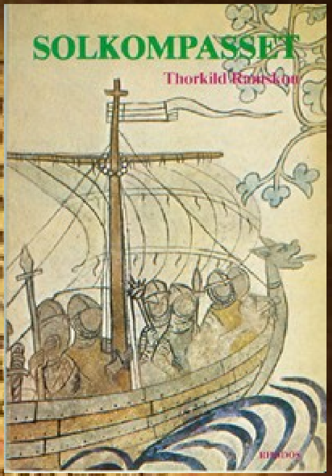
Key questions

- Above all, what is the basic mechanism that drives the smoke into the jar? What is the ratio between the “amounts” or convection-driven smoke flowing from the open end of the tube and the smoke flowing into the jar?
- What changes, if the jar is not closed hermetically?
- How to measure the properties of the smoke stream (flow lines and velocities? temperature fields? pressure fields? density or viscosity?)
- The direction of the flow depends on the average density of fluid, which is determined by an interplay between density of solid smoke particles and the density of air. What conclusions can be drawn from known gas temperatures and viscosities, and concentration of particles?
- What are the magnitudes of the Reynolds’ or Nusselt numbers for the observed flows? Is the flow laminar or turbulent; negatively or positively buoyant; miscible or not? Are there particular, critical conditions that qualitatively change the geometry of the flow?
- How relevant is the Hagen-Poiseuille equation to describe the flow inside the tube?
- How does the effect depend on the geometry of the tube (length? diameter? specific combustion heat and the amount of smoke produced?)
- How does the effect depend on the geometry of the jar (total internal volume?)
- How to best visualize the phenomenon? What information about the system can be retrieved from the flow lines? Is there a contact-free (optical?) method to determine the concentration of smoke particles in a particular point?
- How reproducible is the overall effect? Is there a correlation between the instant combustion rate and the immediate parameters of the stream?
- What happens, if the tube is lit from the end inside the tube? What are your conclusions on the problem?

Problem No. 17 “Vikings”

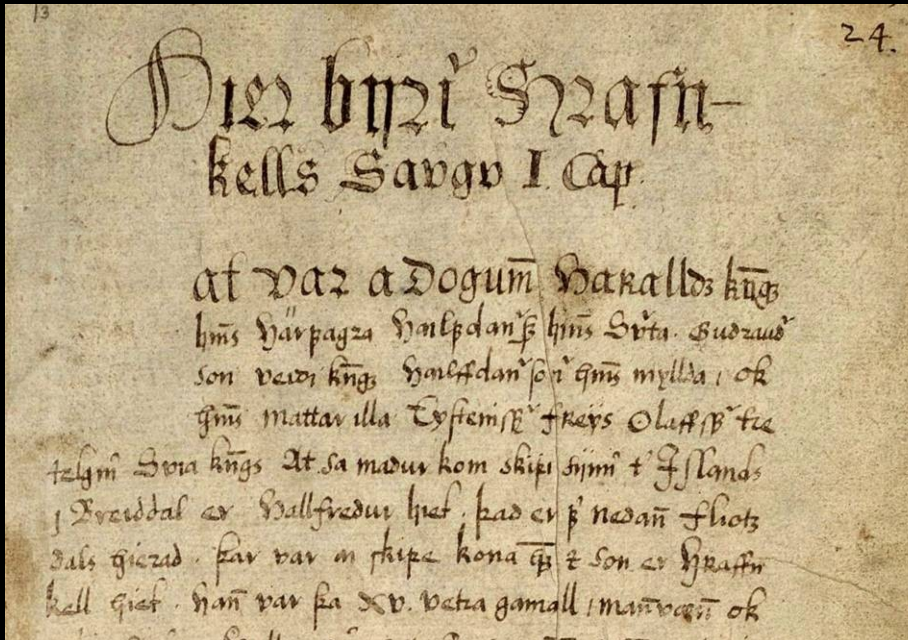
According to a legend, Vikings were able to navigate in an ocean even during overcast (dull) weather using tourmaline crystals. Study how it is possible to navigate using a polarizing material. What is the accuracy of the method?





- Problems that required knowledge in humanities were not so common at the YPTs after 1980s :-)

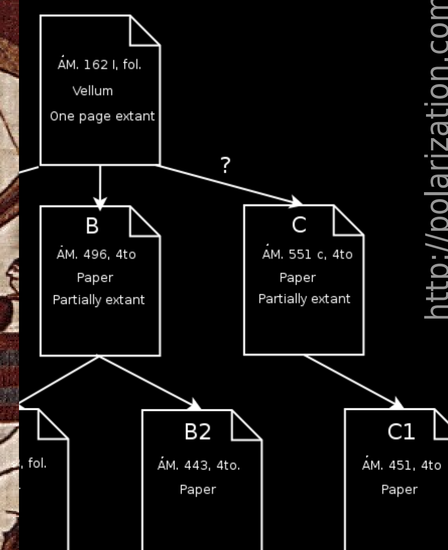
- What is the primary source of the “legend”?
- When was it written: at the times of Vikings, or recently?
- Did the original source contain a detailed description of the procedure used by Vikings, or just suggestions and speculations?
- What earlier historical research was undergone to validate or invalidate these “legends”?



“It was in the days of King Harold Fairhair that a man brought his ship to Iceland into Breiðdal, his name being Hallfreðr [...]

The weather was thick and stormy [...] The king looked about and saw no blue sky [...] then the king took the sunstone and held it up, and then he saw where [the Sun] beamed from the stone [...]”

Hrafnkels saga Freysgoða (10th cent. AD)



http://polarization.com/viking/viking.html

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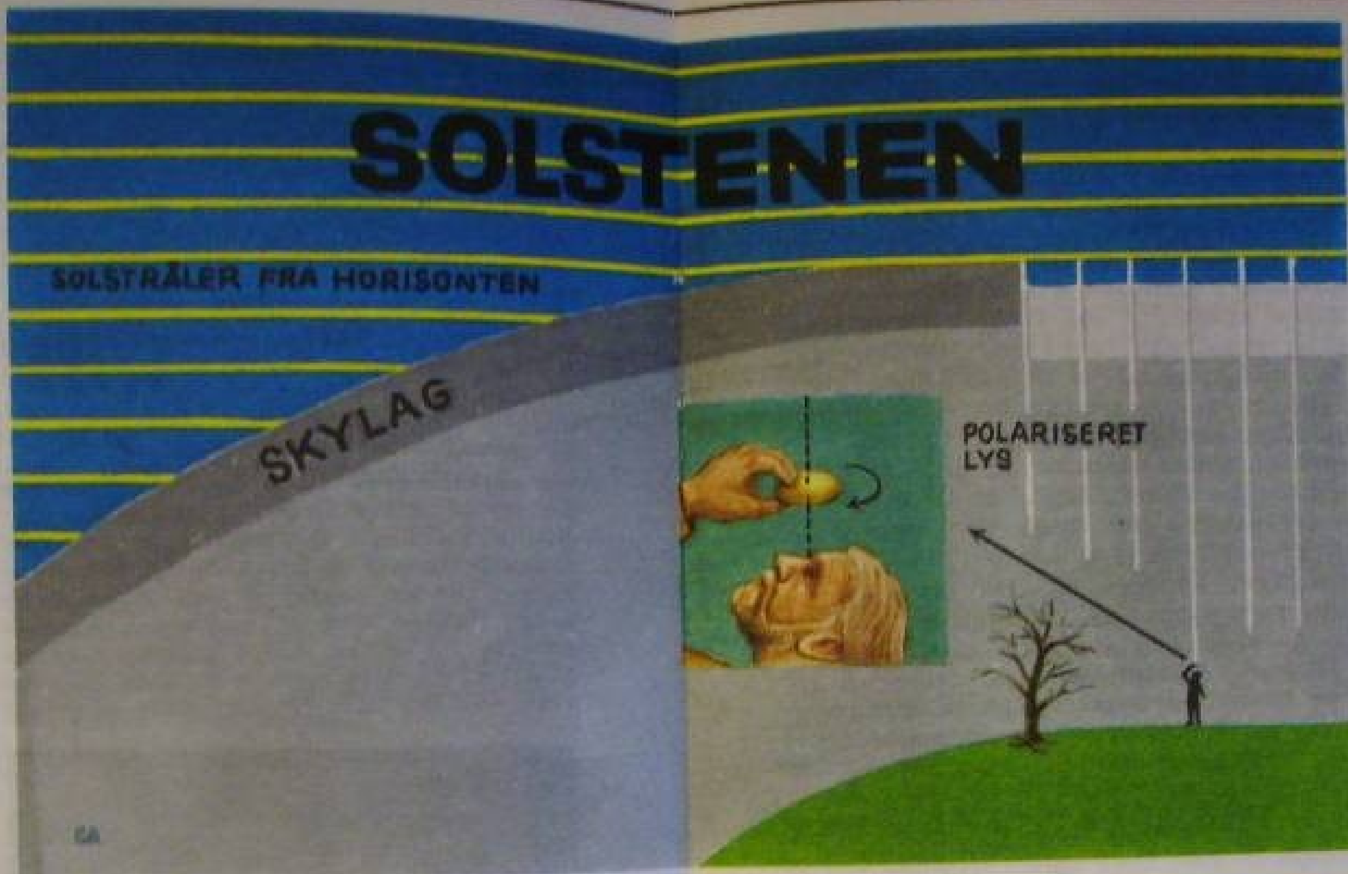

re og supplere vore skolekundskaber i fysik. Lys er som bekendt en bølgebevægelse; elementer i lysstrålen svinger omkring en ligevægtsstilling, og bevægelsen foregår på tværs af stråleretningen. I almindelighed foregår udsvingene i alle retninger ud fra strålen, men under visse omstændigheder kan lyset blive pola-

et skylag, som dog ikke dækker hele himlen, hvis det er tilfældet, er solstenen til ringe nytte. Manden nede på jorden kan ikke se solen for skyerne, men nok den blå himmel lige over sit hoved. Når han ser lodret op mod den, rammes hans øje af det polariserede lys, som sollyset har fremkaldt i atmosfæren. Holder han solstenen, polarisationsfilteret, for øjet og drejer den om en lodret akse som vist på billedet, vil han opleve det mærkelige, at stenen i en bestemt stilling er lys og gennemskinnelig, mens den, hvis han derefter drejer den en kvart omgang, bliver

en til den store lysgiver, og
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» - og han så dér, hvor
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dicroit og andalucit opsamles

finder anvendelse
af moderne foretagende

Herjolfsson indicates. Immediately after land disappeared, the following sequence of events is narrated:[69]

> Then the wind dropped and they were beset by winds from the north and fog; for many days they did not know where they were sailing. After that they saw the sun and could take their bearings.

In *Grænlendinga Saga* this combination of fog and wind is termed *hafvilla*;[70] and we now know that when conditions are such as to cause refraction the mirage produced is often followed by fog.[71] The saga then paints a plausible picture of what anyone blown off course and with no instruments to guide them would do – look to the sun's position. If the zenith was higher in the sky than it was in Iceland, Bjarni would conclude that he was much too far south to be in the area of Greenland. Had Bjarni[72] possessed a sun-compass, or rather had the composer of the saga known about them, it is unlikely that he would have been portrayed as relying on dead-reckoning to sail out of a tight spot. There is also no possibility that Bjarni, or anyone else lost in fog at sea for that matter, used a *sólarsteinn* or sunstone. It has been argued that this entirely fictional contrivance acted as a prism allowing polarised light to filter through, thereby indicating the sun's position.[73] However, experiments with Icelandic felspar have proved that this does not work. Moreover, literary scholars agree that references to *sólarsteinar* only appear after 1200 and probably refer to a 'burning-glass' and not a navigational instrument.[74] Even attempts to calculate approximate latitude by reference to the sun's elevation above the rim of the horizon, using such simple tools as a notched stick or even one's hand, knuckles or thumb, might result in mishap where the true horizon was obscured by fog and one's position estimated on the basis of a false sighting.

69 *The Saga of the Greenlanders*, trans. K. Kunz. In *The Sagas of Icelanders*, see note 2 above, p. 637.
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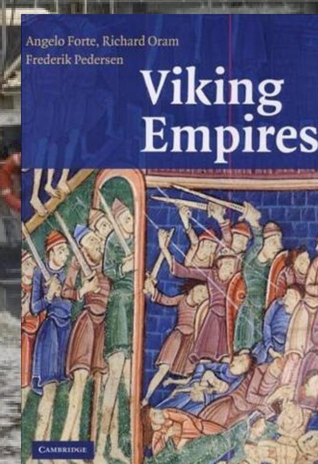
71 *Arctic Pilot*, p. 18.
72 Or, for that matter, Olaf Peacock or Orn, when they too suffered 'sea-bewilderment' in the episode described above, p. 328.
73 T. Ramskou, Solstenen. *Skalk*, 2, 1967, pp. 16–17.
74 P. Foote, Icelandic sólarsteinn and the medieval background. In *Aurvandilstá*, see note 25 above, pp. 140–54.



Last Updated: Wednesday, 7 February 2007, 15:23 GMT

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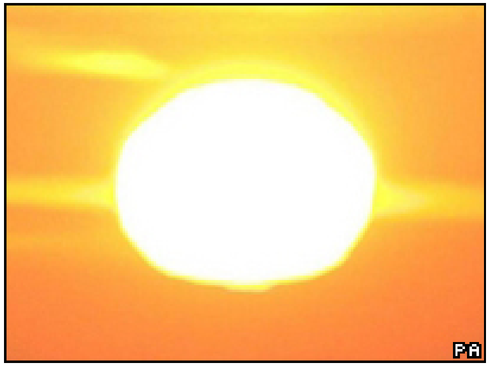
Crystals 'helped Viking sailors'

Vikings may have used a special crystal called a sunstone to help navigate the seas even when the sun was obscured by fog or cloud, a study has suggested.



The sun was not necessary for Vikings to navigate, say researchers

Researchers from Hungary ran a test with sunstones in the Arctic ocean, and found that the crystals can reveal the sun's position even in bad weather.

This would have allowed the Vikings to navigate successfully, they say.

The sunstone theory has been around for 40 years, but some academics have treated it with extreme scepticism.

Researcher Gabor Horvath from Eotvos University in Budapest led a team that spent a month recording polarisation - how rays of light display different properties in different directions - in the Arctic.

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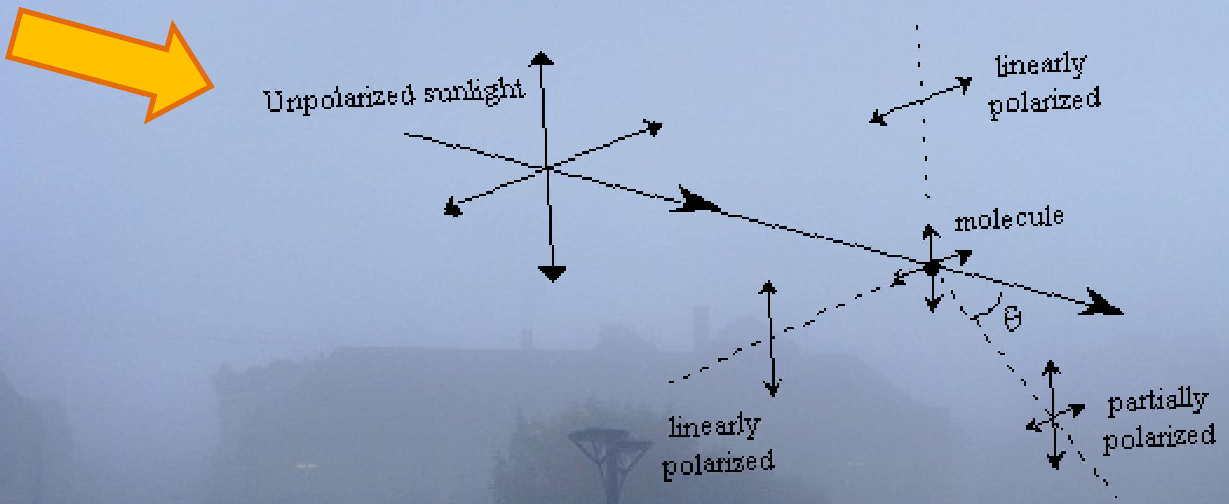
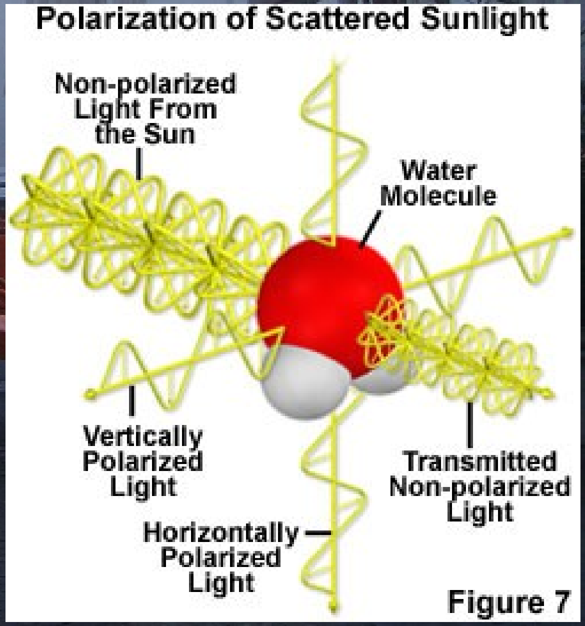
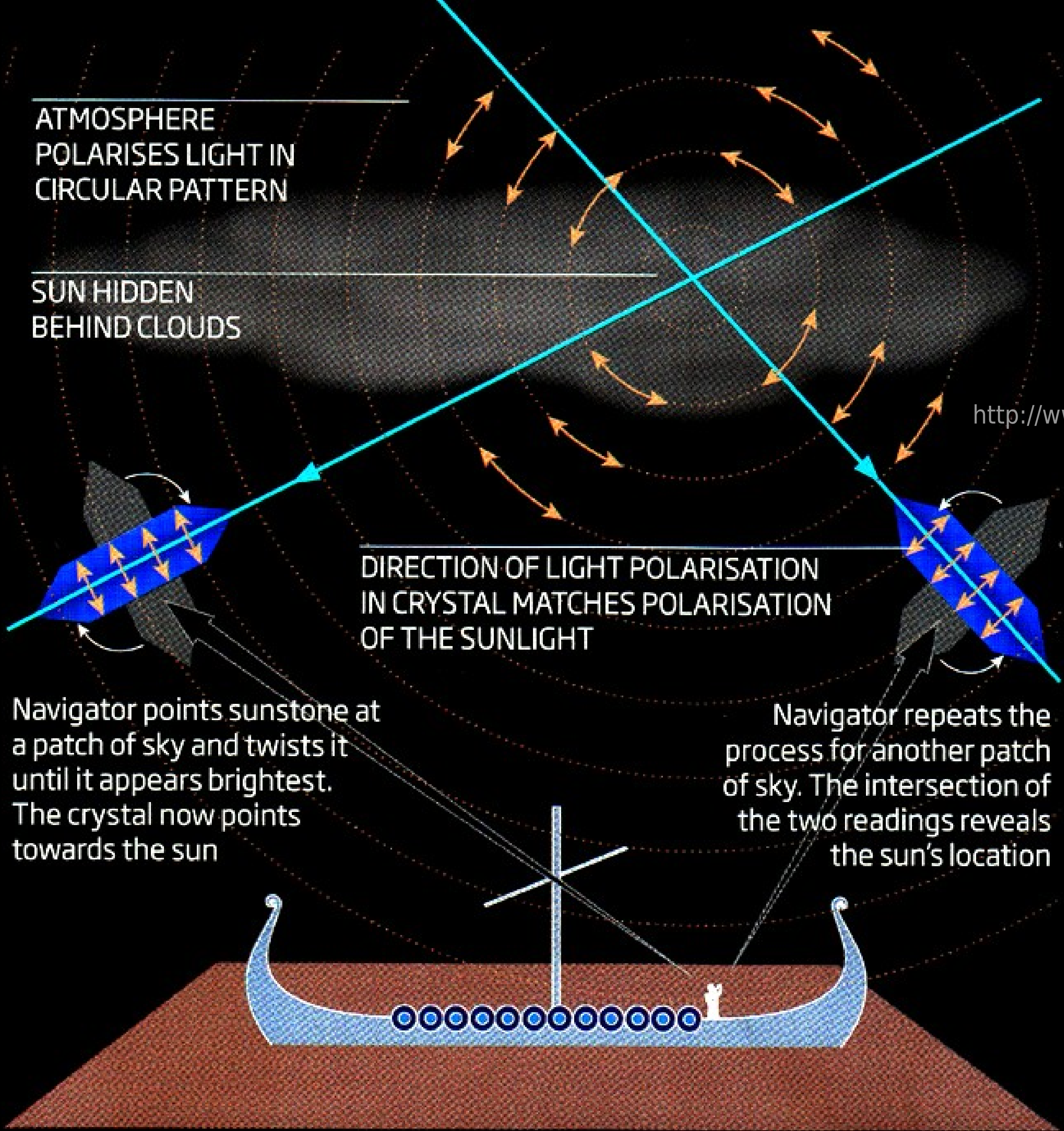
Polarization and scattering





Rayleigh scattering?

http://www.microscopyu.com/articles/polarized/polarizedlightintro.html



Despite the latest evidence, not everyone is convinced. "The sky is strongly polarised only in certain regions relative to the sun," says Tom Cronin of the University of Maryland, Baltimore, and an authority on polarisation. "If the light is not very polarised, the sunstone won't get [bright or] dark enough [when rotated]," he says. "So I think it would work, but not very accurately."

http://www.newscientist.com/issue/2798

No sun here

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Key questions

- The problem has been quite profoundly investigated by Horváth *et al.*, and other groups. How should we approach the task and what aspects to investigate, in order not to repeat earlier work and seriously contribute to the understanding of the tricky problem?
- Above all, what is your conclusion on the problem? Aside from a strictly physical analysis of navigation with polarizers,
  - what are the overall chances that Vikings were indeed using such devices?
  - what arguments did the initial proponents of the hypothesis use to validate such an idea?

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

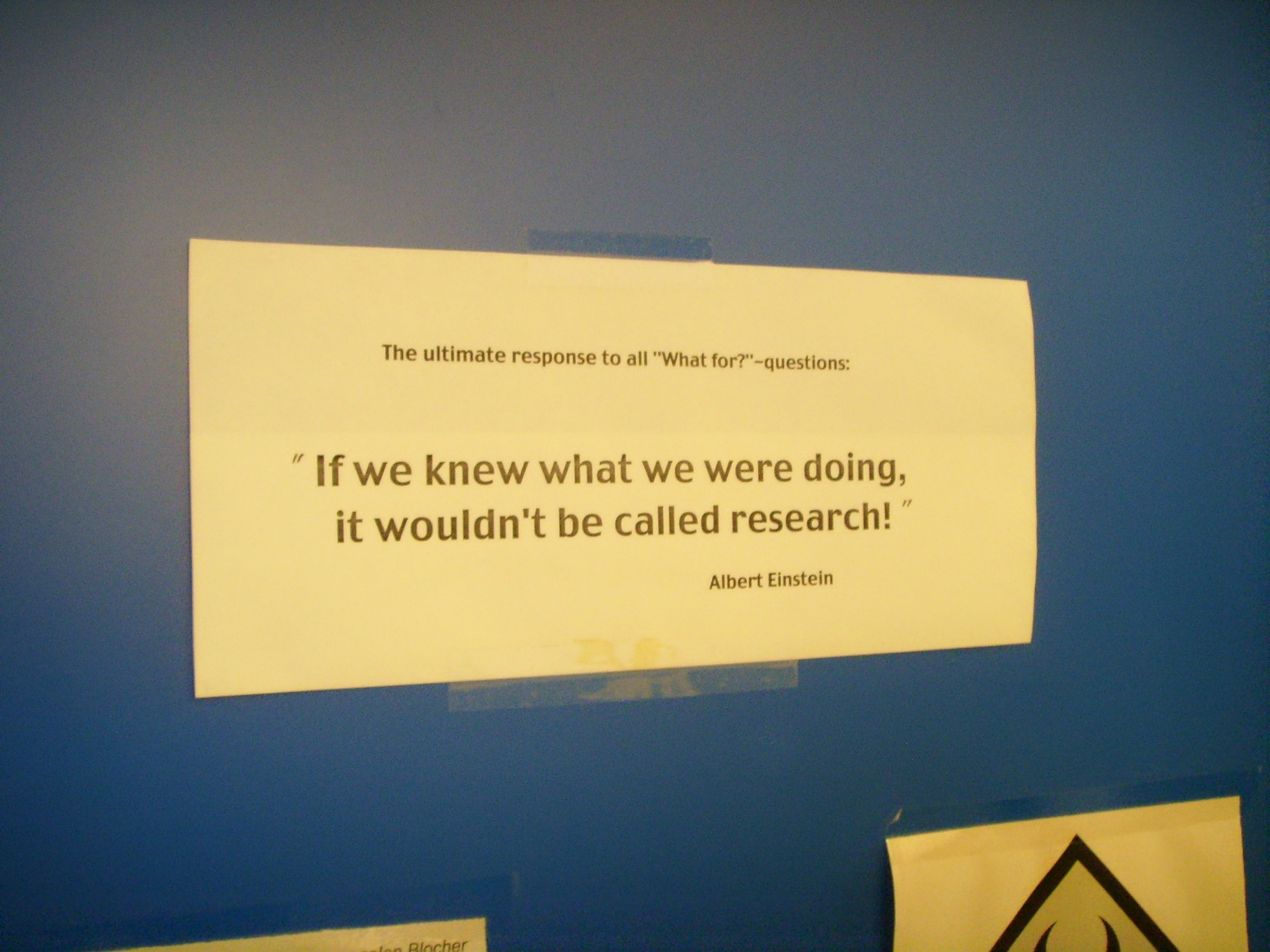
(b) Compute $(\hat{\mathbf{r}} \cdot \nabla)\hat{\mathbf{r}}$, where $\hat{\mathbf{r}}$ is the uni[...]

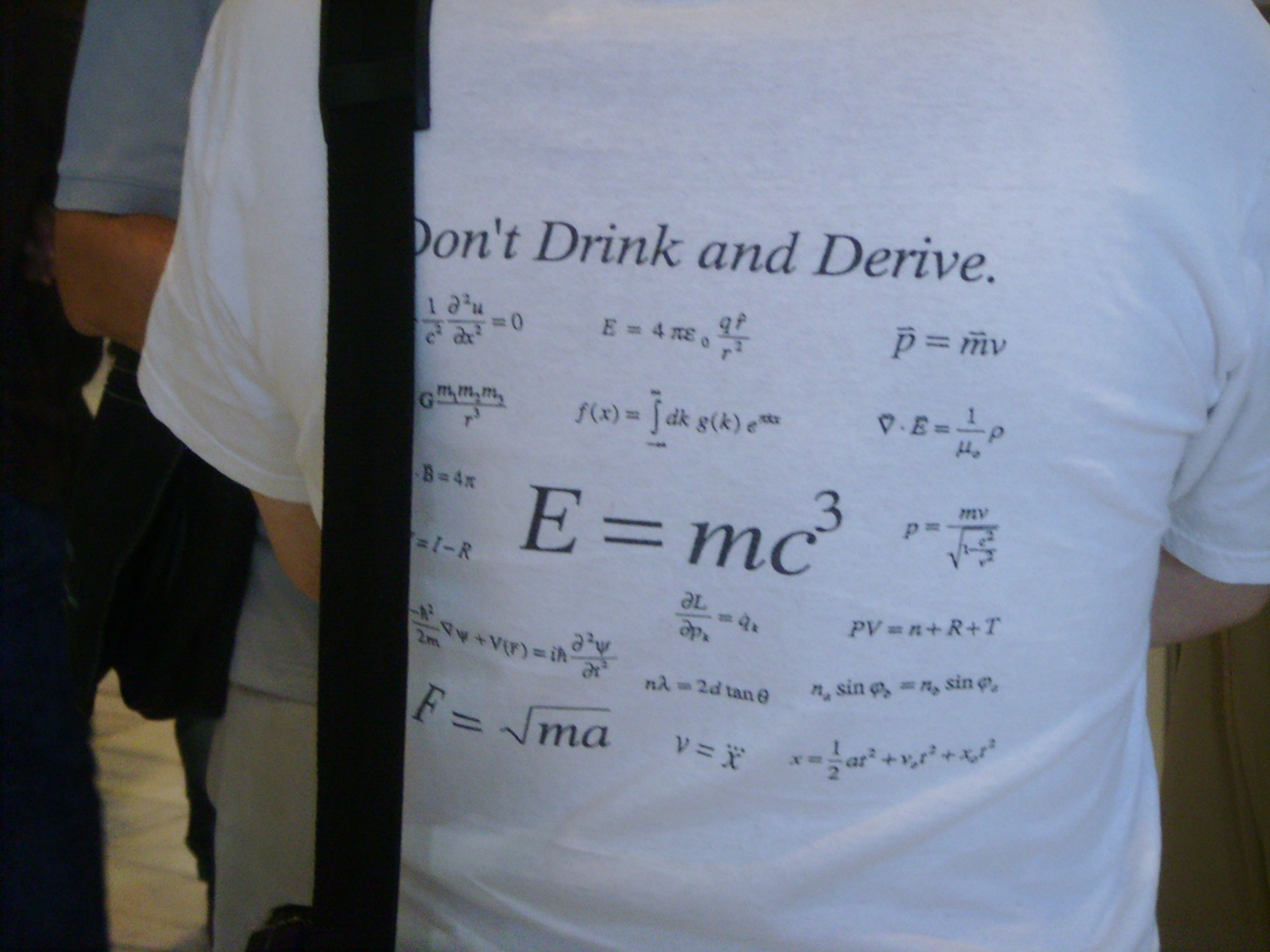
(c) For the functions in Prob. 1.15, evalu[...]

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

Problem 1.23 Derive the three quotien[...]

Problem 1.24


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


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

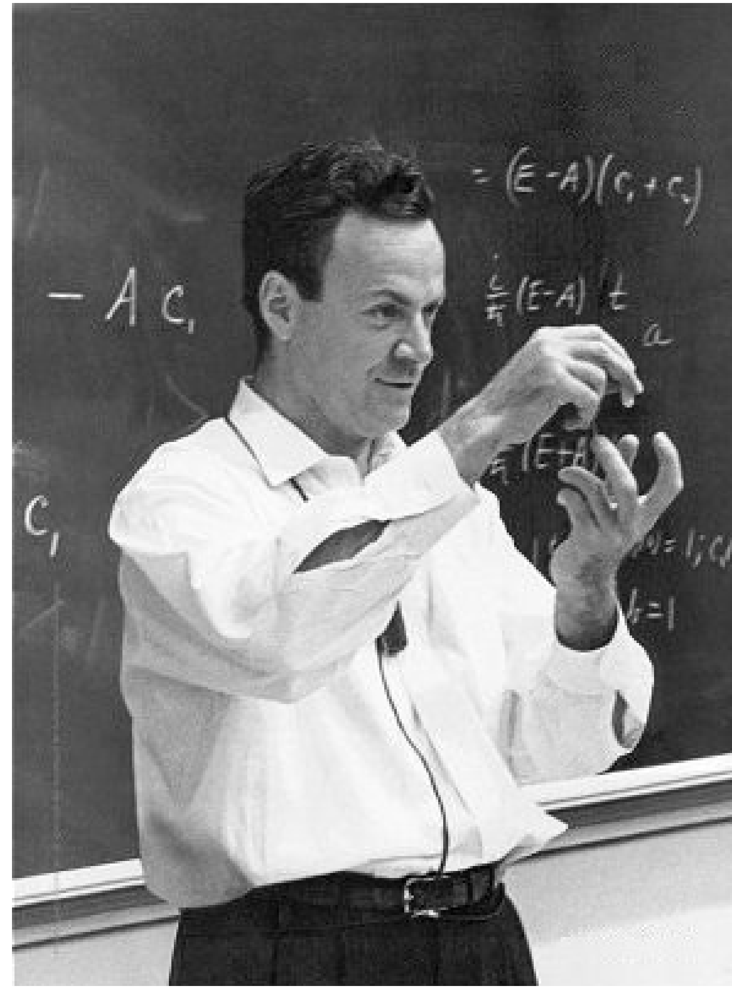
To work towards results?

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

Feynman: to be self-confident?

- “I’ve very often made mistakes in my physics by thinking the theory isn’t as good as it really is, thinking that there are lots of complications that are going to spoil it

- — an attitude that anything can happen, in spite of what you’re pretty sure should happen.”



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

Final draft // June 19, 2011

Preparation to 24th IYPT' 2011: references, questions and advices

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Proceeded in Fribourg, Geneva, Zürich, Villigen (CH), Lund, Malmö (SE), Frankfurt, Hamburg, Berlin, Munich, Düsseldorf (DE), Bratislava (SK), Vienna, Leoben (AT), St Petersburg (RU), Kraków, Warsaw (PL), Brussels, Leuven (BE), Polotsk, Minsk (BY), Vilnius (LT), Copenhagen (DK), Doha (QA), Tehran, Isfahan (IR) :-)

Tiki Torch Triptych, by Phineas X. Jones, is used on the cover with kind permission

Call for cooperation

- If you are interested in the idea behind the kit — to structure the earlier knowledge about the problems and to encourage students to contrast their personal contribution from this knowledge — and you are interested to join the project, your cooperation is welcome
- If several contributors start bringing together the kit for 2012, a good draft can be ready within weeks after the problems are selected
- It will be of benefit for everybody,
  - students and team leaders, who will 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 “re-inventing the wheel”
  - jurors, who will have a brief, informal auxiliary material, possibly making them more skeptical and objective about the presentations
  - people outside IYPT, who can benefit from the structured references in e. g. physics popularization activities
  - and also the author(s) of the kit, who can rapidly acquire some competence for future activities and have a great learning experience