

First Draft of IYPT Reference Kit 2019

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This reference kit is based on my internet searches and knowledge. Here, all the figures are from Google website. Although, it is not a comprehensive and exact solutions for the problems, but it can be considered as a background reading and an initial point for student researches. Please feel free to contact me if you have any comment or question.



1. Invent Yourself

Build a simple motor whose propulsion is based on corona discharge. Investigate how the rotor's motion depends on relevant parameters and optimize your design for maximum speed at a fixed input voltage.

- https://en.wikipedia.org/wiki/Corona_discharge
- https://en.wikipedia.org/wiki/Electrostatic_motor
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- http://www.aun.edu.eg/journal_files/144_J_740.pdf
- https://www.researchgate.net/publication/305084128_Analysis_of_Electrostatic_Motors_as_Influenced_by_Corona_Discharge_on_Stator_Periphery
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- Van Wyk, J. D. N., and G. J. Kühn. "A Novel Electrostatic Machine: the Corona Motor." *Nature* 192.4803 (1961): 649.
- <https://www.youtube.com/watch?v=9uEjXsX1F14>
- <https://www.youtube.com/watch?v=9THGyOzMXjo>
- <https://www.youtube.com/watch?v=WkmH2ECctzw>
- <https://www.youtube.com/watch?v=4zKrphJmHnQ>
- <https://www.youtube.com/watch?v=fEQYa7tCujg>
- <https://www.youtube.com/watch?v=Hfj50Jixt0A>
- <https://www.youtube.com/watch?v=RsvnfzmVVr4>
- <https://www.youtube.com/watch?v=f8JguqFxpZ4>



2. Aerosol

When water flows through a small aperture, an aerosol may be formed. Investigate the parameters that determine whether an aerosol is formed rather than a jet for example. What are the properties of the aerosol?

- <https://en.wikipedia.org/wiki/Aerosol>
- https://en.wikipedia.org/wiki/Spray_nozzle
- <http://elte.prompt.hu/sites/default/files/tananyagok/AtmosphericChemistry/ch09s02.html>
- [https://en.wikipedia.org/wiki/Deposition_\(aerosol_physics\)](https://en.wikipedia.org/wiki/Deposition_(aerosol_physics))
- Lin, S. P., and R. D. Reitz. "Drop and spray formation from a liquid jet." Annual Review of Fluid Mechanics 30.1 (1998): 85-105. https://www.researchgate.net/profile/Rolf_Reitz/publication/234151141_Drop_and_spray_formation_from_a_liquid_jet/links/55d5e71608aeb38e8a821213.pdf
- Guha, Anirban, Ronald M. Barron, and Ram Balachandar. "An experimental and numerical study of water jet cleaning process." Journal of Materials Processing Technology 211.4 (2011): 610-618. <https://arxiv.org/pdf/1009.0531>
- Mahoney, Lenna A., et al. *Small-Scale Spray Releases: Initial Aerosol Test Results*. No. PNNL-21367 Rev. 1. Pacific Northwest National Lab.(PNNL), Richland, WA (United States), 2013. <https://www.osti.gov/servlets/purl/1133999>
- https://webpace.clarkson.edu/projects/crcd/public_html/me437/downloads/P_Aerosol_Meas_Suresh.pdf
- Colbeck, Ian. Physical and chemical properties of aerosols. Blackie Academic and Professional, 1998.
- <https://www.youtube.com/watch?v=fRqqNa5vyPk>



3. Undertone Sound

Allow a tuning fork or another simple oscillator to vibrate against a sheet of paper with a weak contact between them. The frequency of the resulting sound can have a lower frequency than the tuning fork's fundamental frequency. Investigate this phenomenon.

- https://en.wikipedia.org/wiki/Fundamental_frequency
- https://en.wikipedia.org/wiki/Tuning_fork
- Knapman, Herbert. "An Experiment Illustrating Harmonic Undertones." *Proceedings of the Royal Society of London* 74 (1904): 118-120. https://www.jstor.org/stable/116664?seq=1#page_scan_tab_contents
- Irvine, Tom. "THE NATURAL FREQUENCY OF A RECTANGULAR PLATE WITH FIXED-FREE-FIXED-FREE BOUNDARY CONDITIONS." (2011). http://www.academia.edu/download/44502212/fixed_free_fixed_free_plate.pdf
- Rossing, Thomas D., Daniel A. Russell, and David E. Brown. "On the acoustics of tuning forks." *American journal of physics* 60.7 (1992): 620-626. https://www.researchgate.net/profile/Daniel_Russell/publication/259017541_On_the_acoustics_of_tuning_forks/links/5435277e0cf2dc341daf936a/On-the-acoustics-of-tuning-forks.pdf
- <http://moodle.wmchs.net/mod/resource/view.php?id=5392>
- http://www.answers.com/Q/What_happens_when_you_tuning_fork_touche_s_paper
- <https://www.quora.com/What-occurs-when-paper-is-touched-with-a-tuning-fork>



4. Funnel and Ball

A light ball (e.g. ping-pong ball) can be picked up with a funnel by blowing air through it. Explain the phenomenon and investigate the relevant parameters.

- https://en.wikipedia.org/wiki/Bernoulli%27s_principle
- https://en.wikipedia.org/wiki/Coand%C4%83_effect
- http://www.abc.net.au/science/surfingscientist/pdf/teachdemo_6.pdf
- http://www.csun.edu/scied/4-discrpeant-event/discrep_events/index.htm
- <https://teachingfluids.wordpress.com/2013/12/04/levitating-a-ping-pong-ball-in-a-funnel/>
- <https://airport.unimelb.edu.au/science/physlog/vote.php?entry=2>
- <http://practicalphysics.org/bernoulli-effect-demonstration.html>
- <http://spmphysics.onlinetuition.com.my/2013/06/experiments-related-to-bernoullis.html>
- https://www.123homeschool4me.com/2016/02/anti-gravity-ping-pong-ball-science_9.html
- <http://www.thecrazyscientist.com/looney-lab/experiments-2/amazing-air/superhuman-breath-2/>
- <http://physicscentral.com/experiment/physicsquest/upload/Turbulent-Times-Extension-Activities.pdf>
- http://www.academia.edu/download/36868099/Bernoulli_s_Principle_Disputatation_2015g_doc.pdf
- <https://www.youtube.com/watch?v=nsnMt8erxH8>
- <https://www.youtube.com/watch?v=1TQL1ju3RoQ>
- <https://www.youtube.com/watch?v=K8Oxbb82sMQ>
- <https://www.youtube.com/watch?v=wuAUJPUupfE>
- <https://www.youtube.com/watch?v=n7U0H05Kduw>

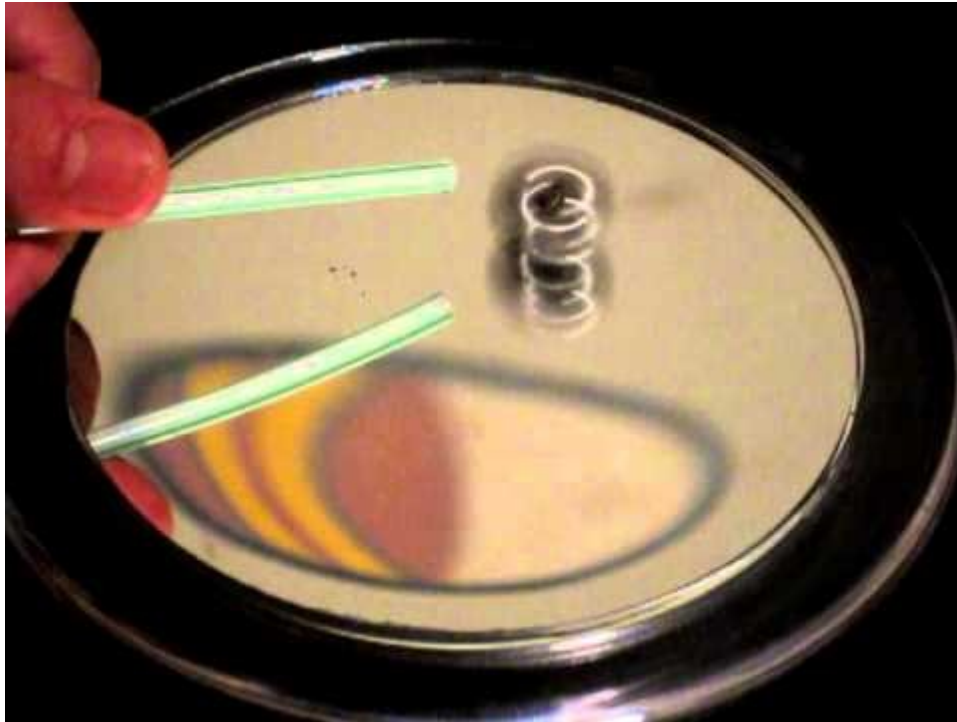


5. Filling Up a Bottle

When a vertical water jet enters a bottle, sound may be produced, and, as the bottle is filled up, the properties of the sound may change. Investigate how relevant parameters of the system such as speed and dimensions of the jet, size and shape of the bottle or water temperature affect the sound.

- https://en.wikipedia.org/wiki/Acoustic_resonance
- [https://en.wikipedia.org/wiki/Splash_\(fluid_mechanics\)](https://en.wikipedia.org/wiki/Splash_(fluid_mechanics))
- Franz, G. J. "Splashes as sources of sound in liquids." *The Journal of the Acoustical Society of America* 31.8 (1959): 1080-1096.
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- Frizell, Kenneth Warren, and Roger EA Arndt. "Noise Generation of Air Bubbles in Water: An Experimental Study of Creation and Splitting." (1987).
<https://conservancy.umn.edu/bitstream/handle/11299/114029/1/pr269.pdf>
- Velasco, Carlos, et al. "The sound of temperature: What information do pouring sounds convey concerning the temperature of a beverage." *Journal of Sensory Studies* 28.5 (2013): 335-345.
<https://onlinelibrary.wiley.com/doi/abs/10.1111/joss.12052>
- Doel, Kees van den. "Physically based models for liquid sounds." *ACM Transactions on Applied Perception (TAP)* 2.4 (2005): 534-546.
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- <https://www.quora.com/Why-does-the-sound-of-water-change-as-a-bucket-is-filling-from-empty-to-full>
- <https://www.quora.com/When-we-fill-a-vessel-with-water-why-does-the-sound-of-the-pouring-change-as-the-level-increases>
- <https://intelligentsoundengineering.wordpress.com/2017/05/20/why-can-you-hear-the-difference-between-hot-and-cold-water/>
- <https://www.audioblocks.com/stock-audio/filling-glass-bottle-with-water.html>
- <https://physics.stackexchange.com/questions/357512/why-the-sound-of-filling-water-into-a-bottle-rise-in-its-frequency>
- <https://www.youtube.com/watch?v=pVbaRYoSBYk>
- <https://www.youtube.com/watch?v=ayNzH0uygFw>
- <https://www.youtube.com/watch?v=X08NDXMvdz0>
- <http://www.cs.cornell.edu/projects/HarmonicFluids/>



6. Hurricane Balls

Two steel balls that are joined together can be spun at incredibly high frequency by first spinning them by hand and then blowing on them through a tube, e.g. a drinking straw. Explain and investigate this phenomenon.

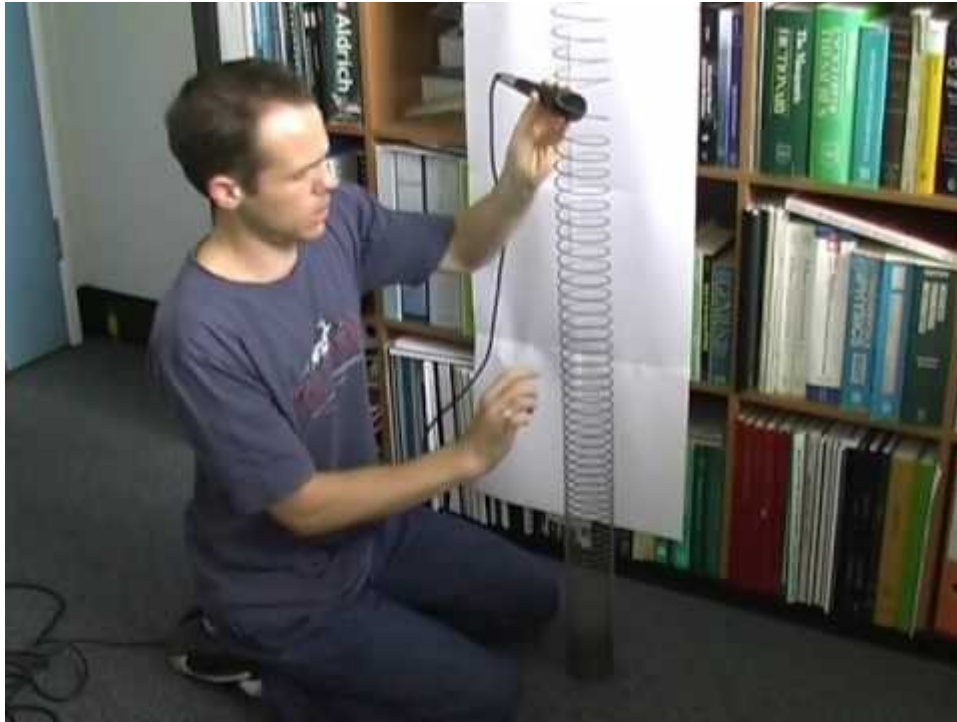
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- https://en.wikipedia.org/wiki/Magnus_effect
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- <https://makezine.com/projects/remaking-history-louis-poinsot-and-the-dancing-spheres/>
- <https://www.youtube.com/watch?v=rFZrwMPNVvk>
- <https://aapt.scitation.org/doi/full/10.1119/1.4973116>
- <https://www.youtube.com/watch?v=cvq8laPb498>
- <https://www.youtube.com/watch?v=0J58SNJWDt4>
- <https://www.youtube.com/watch?v=CfaZyEmzlhE>



7. Loud Voices

A simple cone-shaped or horn-shaped object can be used to optimize the transfer of the human voice to a remote listener. Investigate how the resulting acoustic output depends on relevant parameters such as the shape, size, and material of the cone.

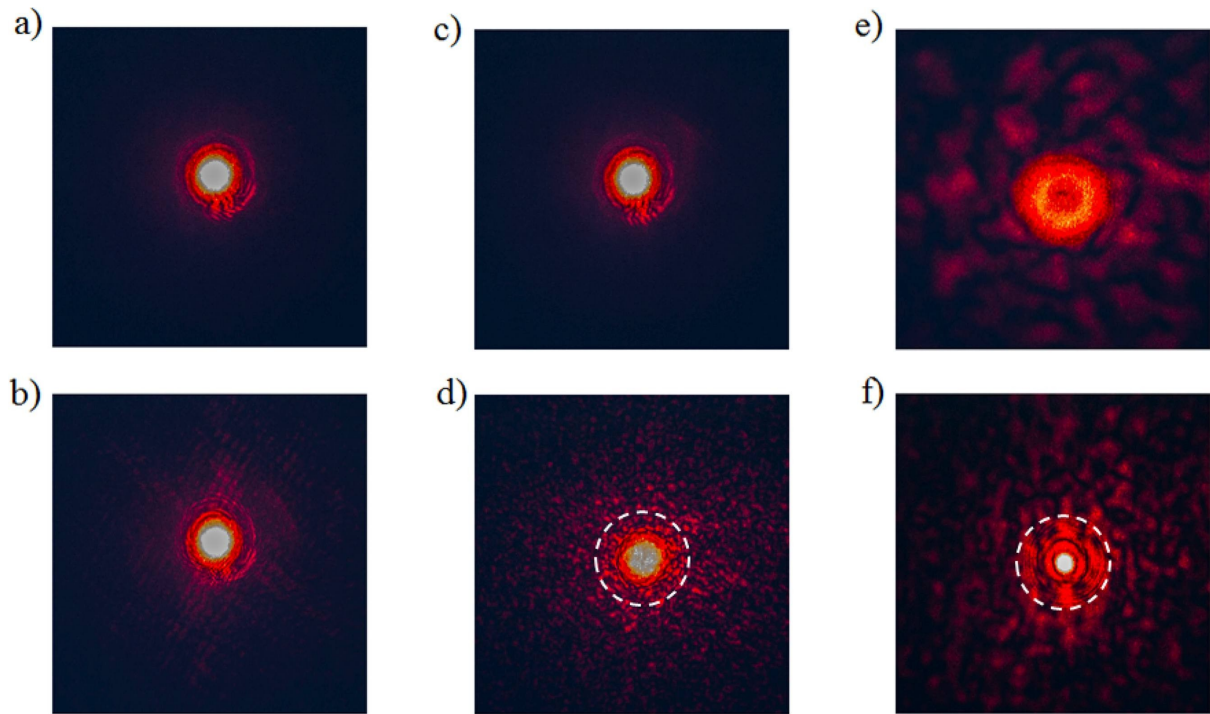
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- https://en.wikipedia.org/wiki/Horn_loudspeaker
- <https://en.wikipedia.org/wiki/Megaphone>
- Kolbrek, Bjørn. "Horn Theory: An Introduction, Part." *Audio Express* 1 (2008): 1-8. <https://www.rdacoustic.cz/wp-content/uploads/an-introduction-to-horn-theory.pdf>
- Jorge, Rogério. "Nonlinear Acoustics--Perturbation Theory and Webster's Equation." *arXiv preprint arXiv:1311.4238*(2013). <https://arxiv.org/pdf/1311.4238>
- <https://www.radiomuseum.org/forumdata/users/133/PDF/Speaker.pdf>
- <https://www.quora.com/How-does-a-megaphone-amplify-sound>
- http://www.vias.org/crowhurstba/crowhurst_basic_audio_vol1_049.html
- Chaverri, Gloriana, and Erin H. Gillam. "Sound amplification by means of a horn-like roosting structure in Spix's disc-winged bat." *Proceedings of the Royal Society of London B: Biological Sciences* 280.1772 (2013): 20132362. <http://rspb.royalsocietypublishing.org/content/280/1772/20132362.short>
- https://www.reddit.com/r/explainlikeimfive/comments/las2b/eli5_how_does_a_horn_amplify_sound_without_adding/
- <https://www.quora.com/How-does-a-megaphone-amplify-sound>
- <https://www.youtube.com/watch?v=EffsDcZxRr4>
- <https://www.youtube.com/watch?v=TVdrjm1BVP0>



8. Sci-Fi Sound

Tapping a helical spring can make a sound like a “laser shot” in a science-fiction movie. Investigate and explain this phenomenon.

- <https://en.wikipedia.org/wiki/Slinky>
- https://en.wikipedia.org/wiki/Euler%E2%80%93Bernoulli_beam_theory
- Parker, Julian, et al. "Modeling methods for the highly dispersive slinky spring: a novel musical toy." *Proceedings of the 13th International Conference on Digital Audio Effects (DAFx'10)*. 2010.
http://dafx10.iem.at/papers/ParkerPenttinenBilbaoAbel_DAFx10_P80.pdf
- Lee, J., and D. J. Thompson. "Dynamic stiffness formulation, free vibration and wave motion of helical springs." *Journal of Sound and Vibration* 239.2 (2001): 297-320. <https://www.sciencedirect.com/science/article/pii/S0022460X00931699>
- Rutherford, Casey. "A Fresh Look at Longitudinal Standing Waves on a Spring." *The Physics Teacher* 51.1 (2013): 22-24.
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- https://www.researchgate.net/post/Why_does_tapping_in_air_not_produce_any_sound_but_tapping_against_a_metal_does_produce_sound
- <https://www.youtube.com/watch?v=g2Sa0dRmHgA>
- <https://www.youtube.com/watch?v=CpZkNWBmKNM>
- <https://www.youtube.com/watch?v=7VGIBZOywlq>
- <https://www.youtube.com/watch?v=aqtqiuSMJqM>
- <https://www.youtube.com/watch?v=rajPbk3CJr4>
- <https://www.youtube.com/watch?v=SVAd6zxjiow>
- <https://www.youtube.com/watch?v=XACHZbgcH5M>



9. Soy Sauce Optics

Using a laser beam passing through a thin layer (about 200 μm) of soy sauce the thermal lens effect can be observed. Investigate this phenomenon.

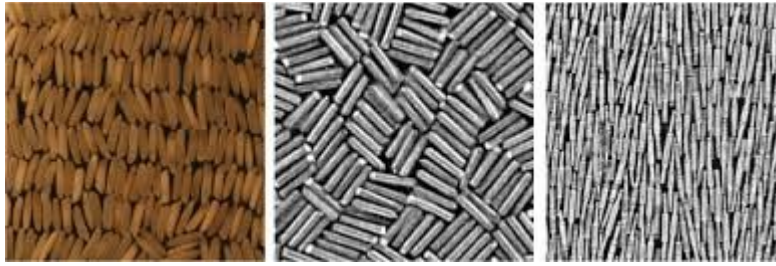
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- http://photonics.cusat.edu/Research_Thermal%20lens.html
- Sivasubramanian, Dhanuskodi, Rajeswari Ponnusamy, and Vinitha Gandhiraj. "Low power optical limiting and thermal lensing in Mn doped ZnO nanoparticles." *Materials Chemistry and Physics* 159 (2015): 93-100. <https://www.sciencedirect.com/science/article/pii/S0254058415002266>
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- https://www.rp-photonics.com/thermal_lensing.html
- https://www.schott.com/d/advanced_optics/3794eded-edd2-461d-aec5-0a1d2dc9c523/1.0/schott_tie-19_temperature_coefficient_of_refractive_index_eng.pdf



10. Suspended Water Wheel

Carefully place a light object, such as a Styrofoam disk, near the edge of a water jet aiming upwards. Under certain conditions, the object will start to spin while being suspended. Investigate this phenomenon and its stability to external perturbations.

- https://en.wikipedia.org/wiki/Bernoulli%27s_principle
- https://en.wikipedia.org/wiki/Magnus_effect
- https://en.wikipedia.org/wiki/Coand%C4%83_effect
- https://www.researchgate.net/post/Can_you_explain_Veritasiums_Hydrodynamic_levitation_or_Fluid_Juggling
- <https://physics.stackexchange.com/questions/356284/any-solutions-to-veritasiums-hydrodynamic-levitation>
- <https://sploid.gizmodo.com/what-sorcery-keeps-this-giant-ball-floating-on-a-tiny-s-1796416838>
- <http://forums.xkcd.com/viewtopic.php?t=123045>
- <https://gizmodo.com/the-physics-of-how-a-water-jet-can-keep-a-ball-floating-1445828275>
- <https://www.youtube.com/watch?v=mNHp8iyyIjo>
- <https://www.youtube.com/watch?v=WZrQy7zKM4Y>
- https://www.youtube.com/watch?v=p9_aUQDGDbU&hd=1
- https://www.youtube.com/watch?v=_jYoQu3PvIk
- <https://www.youtube.com/watch?v=ST6hDiUBSJQ>
- <https://www.youtube.com/watch?v=gXfSUqiWOZ4>
- <https://www.youtube.com/watch?v=7IGm3MrjDX0>
- <https://www.youtube.com/watch?v=WZ1nvvMfdYc>
- https://www.youtube.com/watch?v=IHjFx2lp_kw



11. Flat Self-Assembly

Put a number of identical hard regular-shaped particles in a flat layer on top of a vibrating plate. Depending on the number of particles per unit area, they may or may not form an ordered crystal-like structure. Investigate the phenomenon.

- Galanis, Jennifer, et al. "Spontaneous patterning of confined granular rods." *Physical review letters* 96.2 (2006): 028002. <https://arxiv.org/pdf/cond-mat/0508202>
- Narayan, Vijay, Narayanan Menon, and Sriram Ramaswamy. "Nonequilibrium steady states in a vibrated-rod monolayer: tetratic, nematic, and smectic correlations." *Journal of Statistical Mechanics: Theory and Experiment* 2006.01 (2006): P01005. <https://arxiv.org/pdf/cond-mat/0510082>
- Windows-Yule, C. R. K. "Do granular systems obey statistical mechanics? A review of recent work assessing the applicability of equilibrium theory to vibrationally excited granular media." *International Journal of Modern Physics B* 31.10 (2017): 1742010.
- Daniels, L. J., et al. "Dynamics of gas-fluidized granular rods." *Physical Review E* 79.4 (2009): 041301. <https://arxiv.org/pdf/0811.2751>
- Olafsen, J. S., and J. S. Urbach. "Clustering, order, and collapse in a driven granular monolayer." *Physical review letters* 81.20 (1998): 4369. <https://arxiv.org/pdf/cond-mat/9807148>
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- Dai, Weijing, et al. "Modes of wall induced granular crystallisation in vibrational packing." *arXiv preprint arXiv:1805.07865* (2018). <https://arxiv.org/pdf/1805.07865>
- Trittel, Torsten, Kirsten Harth, and Ralf Stannarius. "Mechanical excitation of rodlike particles by a vibrating plate." *Physical Review E* 95.6 (2017): 062904.
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12. Gyroscope Teslameter

A spinning gyroscope made from a conducting, but nonferromagnetic material slows down when placed in a magnetic field. Investigate how the deceleration depends on relevant parameters.

- https://en.wikipedia.org/wiki/Eddy_current
- https://en.wikipedia.org/wiki/Eddy_current_brake
- https://en.wikipedia.org/wiki/Angular_momentum#Conservation_of_angular_momentum
- <https://www.youtube.com/watch?v=1ZeClejt2NY>
- <https://www.youtube.com/watch?v=who1wlf-i0A>
- <https://www.youtube.com/watch?v=SK0EdikjC24>



13. Moiré Thread Counter

When a pattern of closely spaced non-intersecting lines (with transparent gaps in between) is overlaid on a piece of woven fabric, characteristic moiré fringes may be observed. Design an overlay that allows you to measure the thread count of the fabric. Determine the accuracy for simple fabrics (e.g. linen) and investigate if the method is reliable for more complex fabrics (e.g. denim or Oxford cloth).

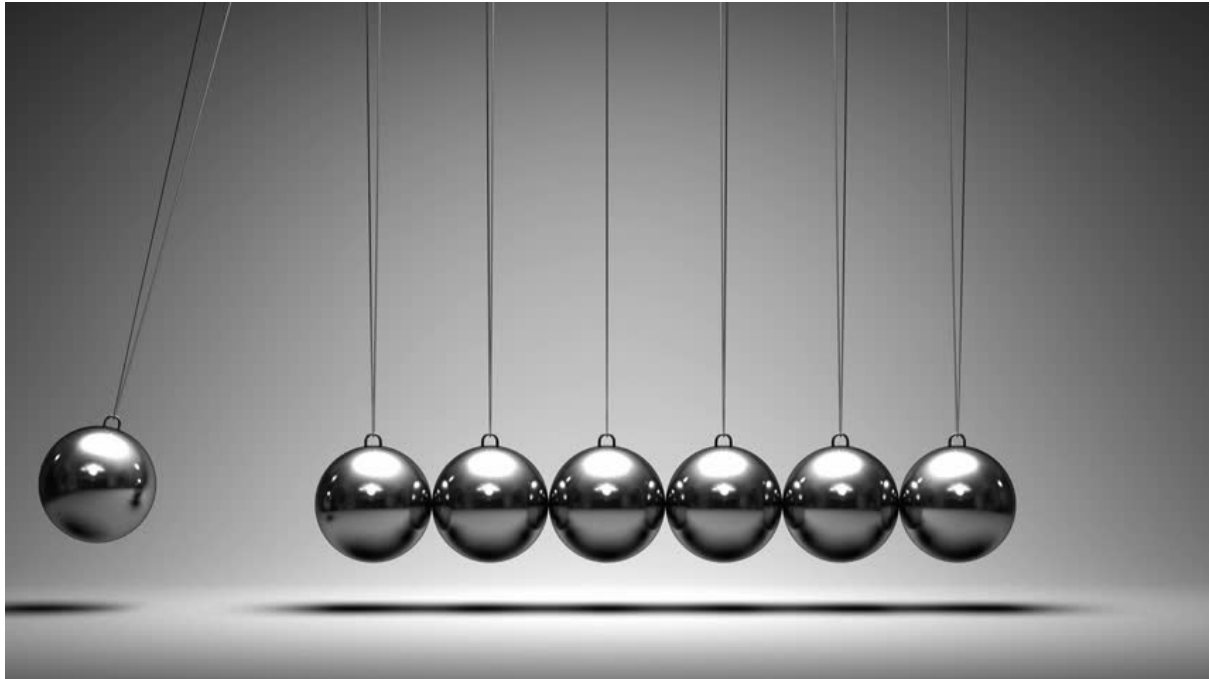
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- <https://www.indiamart.com/arhamsscientific/textile-testing-instruments.html>
- <http://www.lunometer.com/what.html>
- <http://www.lunometer.de/tech-e.htm>



14. Looping Pendulum

Connect two loads, one heavy and one light, with a string over a horizontal rod and lift up the heavy load by pulling down the light one. Release the light load and it will sweep around the rod, keeping the heavy load from falling to the ground. Investigate this phenomenon.

- <https://en.wikipedia.org/wiki/Pendulum>
- [https://en.wikipedia.org/wiki/Pendulum_\(mathematics\)](https://en.wikipedia.org/wiki/Pendulum_(mathematics))
- https://en.wikipedia.org/wiki/Centripetal_force
- <https://sciencedemonstrations.fas.harvard.edu/presentations/rope-friction-around-pole>
- https://en.wikipedia.org/wiki/Capstan_equation
- <https://www.stevespanglerscience.com/lab/experiments/magic-pendulum/>
- https://www.istitutotrento5.it/images/test/bre_15_16_looping_pendulum_2_bil.pdf
- <https://www.youtube.com/watch?v=SXQ9VaYm3yQ>
- <https://www.youtube.com/watch?v=ZyhHidThQR8>
- <https://www.youtube.com/watch?v=XSFxzL4vCPg>



15. Newton's Cradle

The oscillations of a Newton's cradle will gradually decay until the spheres come to rest. Investigate how the rate of decay of a Newton's cradle depends on relevant parameters such as the number, material, and alignment of the spheres.

- https://en.wikipedia.org/wiki/Newton%27s_cradle
- https://en.wikipedia.org/wiki/Inelastic_collision
- Hutzler, Stefan, et al. "Rocking Newton's cradle." *American Journal of Physics* 72.12 (2004): 1508-1516. https://openresearch-repository.anu.edu.au/bitstream/1885/95080/1/01_Hutzler_Rocking_Newton%E2%80%99s_cradle_2004.pdf
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16. Sinking Bubbles

When a container of liquid (e.g. water) oscillates vertically, it is possible that bubbles in the liquid move downwards instead of rising. Investigate this phenomenon.

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- https://en.wikipedia.org/wiki/Added_mass
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- http://math.arizona.edu/~gabitov/teaching/131/math_485_585/Midterm_Reports/Sinking_Bubbles.pdf
- http://math.arizona.edu/~gabitov/teaching/141/math_485/Final_Report/Bubble_Dynamics_Final_Report.pdf



17. Popsicle Chain Reaction

Wooden popsicle sticks can be joined together by slightly bending each of them so that they interlock in a so-called "cobra weave" chain. When such a chain has one of its ends released, the sticks rapidly dislodge, and a wave front travels along the chain. Investigate the phenomenon.

- https://en.wikipedia.org/wiki/Linear_elasticity
- https://en.wikipedia.org/wiki/Euler%E2%80%93Bernoulli_beam_theory
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- <https://aapt.scitacion.org/doi/full/10.1119/1.5000797>
- <https://www.youtube.com/watch?v=glwZ9d361A8>
- <https://www.youtube.com/watch?v=F0jQgGz7GfY>
- <https://www.instructables.com/id/Cobra-Weave-Exploding-Stick-Bomb/>
- <http://clubhousebeat.org/wp-content/uploads/2017/08/PopsicleStickReactionGuide.pdf>
- <https://www.youtube.com/watch?v=T5vYrxC5kmg>
- <https://www.youtube.com/watch?v=vyFDGczUdQQ>
- <https://www.youtube.com/watch?v=IX6kkuuMaQw>