

Chapter 4

Striking at the heat in the night

(thermal processes)

Here are the references and web links for the stories in the book. **Recently added references are highlighted.** For updates to those stories and for all the new stories, go to <http://www.flyingcircusofphysics.com/News/NewsDetail.aspx?NewsID=40>

August 2011

4.1 Dead rattlesnakes

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=Bb1R6xGC8HI&feature=related> slow-motion snake strike. You can see the venom squirt out of the fangs.

<http://www.keepbusy.net/play.php?id=decapitated-snake-head-attacks>

<http://www.youtube.com/watch?v=GiqxyozkCos> same video

<http://www.break.com/index/snake-attacks-after-losing-body.html> same video

http://www.metacafe.com/watch/823553/decapitated_rattle_snake_still_moves/

news items about squirrels and snakes

<http://news.mongabay.com/2007/0813-squirrels.html>

<http://acp.eugraph.com/news/news07/rundus.html>

<http://notexactlyrocketscience.wordpress.com/2007/08/19/ground-squirrels-use-infrared-signals-to-fool-heat-seeking-rattlesnakes/>

http://scienceblogs.com/grrlscientist/2007/08/squirrels_wave_hot_tails_to_co.php including videos

news item about decapitated snake biting someone

http://seattletimes.nwsourc.com/html/localnews/2003829929_dige10m.html

<http://www.scientificamerican.com/article.cfm?id=news-bytes-of-the-week-headless-snake-bites-hapless-man>

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Kardong, K. V., and H. Berkhoudt, "Rattlesnake hunting behavior: correlations between plasticity of predatory performance and neuroanatomy," *Brain, Behavior and Evolution*, 53, No. 1, 20-28 (January 1953)
- Cock Buning, T. de, S. Terashima, and R. C. Goris, "Crotaline pit organs analyzed as warm receptors," *Cellular and Molecular Neurobiology*, 1, No. 1, 69-85 (1981)
- Newman, E. A., and P. H. Hartline, "The infrared 'vision' of snakes," *Scientific American*, 246, No. 3, 116-127 (March 1982)

- Cock Buning, T. de, “Thermal sensitivity as a specialization for prey capture and feeding in snakes,” *American Zoologist*, 23, No. 2, 363-375 (1983)
- Cock Buning, T. de, “A theoretical approach to the heat sensitive pit organs of snakes,” *Journal of Theoretical Biology*, 111, No. 3, 509-529 (1984)
- Wolpert, H. D., “Infrared detection: the vision of boids and pit viper snakes,” *Photonics Spectra*, 26, No. 3, 232-233 (March 1992)
- Amemiya, F., R. C. Goris, Y. Masuda, R. Kishida, Y. Atobe, N. Ishii, and T. Kusunoki, “The surface architecture of snake infrared receptor organs,” *Biomedical Research*, 16, No. 6, 411-421 (1995)
- Theodoratus, D. H., D. Chiszar, H. M. Smith, “Rattlesnake orientation to prey as a function of thermal backgrounds and edges,” *Psychological Record*, 47, ?? (1997)
- Cohen, P., “Revenge of the undead,” *New Scientist*, 163, No. 2193, 23 (3 July 1999)
- Suchard, J. R., and F. LoVecchio, “Envenomations by rattlesnakes thought to be dead,” *New England Journal of Medicine*, 340, No. 24, 1930 (17 June 1999)
- Jones, B. S., W. F. Lynn, and M. O. Stone, “Thermal modeling of snake infrared reception: evidence for limited detection range,” *Journal of Theoretical Biology*, 209, 201-211 (2001)
- Moiseenkova, V., B. Bell, M. Motamedi, E. Wozniak, and B. Christensen, “Wide-band spectral tuning of heat receptors in the pit organ of the copperhead snake (*Crotalinae*),” *American Journal of Physiology --- Regulatory Integrative and Comparative Physiology*, 284, No. 2, R598-R606 (February 2003)
- Bleckmann, H., H. Schmitz, and G. von der Emde, “Nature as a model for technical sensors,” *Journal of Comparative Physiology A*, 190, 971-981 (2004)
- Safer, A. B., and M. S. Grace, “Infrared imaging in vipers: differential responses of crotaline and viperine snakes to paired thermal targets,” *Behavioural Brain Research*, 154, 55-61 (2004)
- Sichert, A. B., P. Friedel, and J. L. van Hemmen, “Snake’s perspective on heat: reconstruction of input using an imperfect detection system,” *Physical Review Letters*, 97, article # 068105 (4 pages) (11 August 2006)
- Schwarzchild, B., “Neural-network model may explain the surprisingly good infrared vision of snakes,” *Physics Today*, 59, No. 9, 18-20 (September 2006)
- Ebert, J., and G. Westhoff, “Behavioural examination of the infrared sensitivity of rattlesnakes (*Crotalus atrox*),” *Journal of Comparative Physiology A*, 192, 941-947 (2006)
- Westhoff, G., M. Morsch, and J. Ebert, “Infrared detection in the rattlesnake *Crotalus atrox* — from behavioural studies to midbrain recordings,” *Herpetologia Bonnensis II. Proceedings of the 13th Congress of the Societas Europaea Herpetologica*, edited by M. Vences, J. Kohler, T. Ziegler, and W. Bohme, pages 225-228 (2006)
- Bakken, G. S., and A. R. Krochmal, “The imaging properties and sensitivity of the facial pits of pitvipers as determined by optical and heat-transfer analysis,” *Journal of Experimental Biology*, 210, 2801-2810 (2007)
- Blumstein, D. T., “Feeling the heat: Ground squirrels heat their tails to discourage rattlesnake attack,” *PNAS Proceedings of the National Academy of Sciences*, 104, No. 36, 14177-14178 (4 September 2007)
- Rundus, A. S., D. H. Owings, S. S. Joshi, E. Chinn, and N. Glannini, “Ground squirrels use an infrared signal to deter rattlesnake predation,” *PNAS Proceedings of the National Academy of Sciences*, 104, No. 36, 14372-14376 (4 September 2007)
- Pulver, S., “Back off. I’m big and hot,” *Journal of Experimental Biology*, 211, No. 1, iii (August 2008)
- Gracheva, E. O., N. T. Ingolia, Y. M. Kelly, J. F. Cordero-Morales, G. Hollopter, A. T. Chesler, e. E. Sanchez, J. C. Perez, J. S. Weissman, and D. Julius, “Molecular basis of infrared detection by snakes,” *Nature*, 464, 1006-1011 (15 April 2010)

Related references

- Hill, R. W., and J. H. Veghte, "Jackrabbit ears: surface temperatures and vascular responses," *Science*, 194, 436-438 (October 1976)
- Taylor, J. H., "Radiation exchange," *Applied Optics*, 26, No. 4, 619-626 (15 February 1987)
- Mohler, F. S., J. E. Heath, "Oscillating heat flow from rabbit's pinna," *American Journal of Physiology*, 255, No. 3, R464-R469 (September 1988)
- Barnes, G., "Jackrabbit ears and other physics problems," *Physics Teacher*, 28, No. 3, 156-159 (1990)
- Barnes, G., "Nature's heat exchangers," *Physics Teacher*, 29, 330-333 (September 1991)
- O'Connor, M. P., and J. R. Spotila, "Consider a spherical lizard: animals, models, and approximations," *American Zoologist*, 32, No. 2, 179-193 (1992)
- Ring, E. F. J., "Progress in the measurement of human body temperature. From the early thermoscope to modern infrared imaging using temperature as an indication of health or disease," *IEEE Engineering in Medicine and Biology*, 17, No. 4, 19-24 (July-August 1998)
- Krochmal, A. R., and G. S. Bakken, "Thermoregulation is the pits: use of thermal radiation for retreat site selection by rattlesnakes," *Journal of Experimental Biology*, 206, 2539-2545 (2003)
- Olway, H., "Pits keep vipers cool," *Journal of Experimental Biology*, 207, No. 24, i-ii (in front pages) (2004)
- Krochmal, A. R., G. S. Bakken, and T. J. LaDuc, "Heat in evolution's kitchen: evolutionary perspectives of the functions and origin of the facial pit of pitvipers (Viperidae: Crotalinae)," *Journal of Experimental Biology*, 207, 4231-4238 (2004)

4.2 Fire-detecting beetles

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://spectre.nmsu.edu/dept/docs/armu/arthropods/beetles/photo4.jpg> Photo of the beetle

<http://insects.tamu.edu/images/insects/common/images/b-txt/bimg150.html> Photo of the beetle in bark

<http://www.forestpests.org/subject.html?SUB=354> Photos of larvae in bark

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Evans, W. G., and J. E. Kuster, "The infrared receptive fields of *Melanophila Acuminata* (Coleoptera: Buprestidae)," *Canadian Entomologist*, 112, No. 2, 211-216 (1980)
- Vondran, T., K.-H. Apel, and H. Schmitz, "The infrared receptor of *Melanophila acuminata* De Geer (Coleoptera: Buprestidae): ultrastructural study of a unique insect thermoreceptor and its possible descent from a hair mechanoreceptor," *Tissue & Cell*, 27, No. 6, 645-658 (December 1995)
- Ehnstrom, B., B. Langstrom, and C. Hellqvist, "Insects in burned forests---forest protection and faunal conservation (preliminary results)," *Entomologica Fennica*, 6, Nos. 2-3, 109-117 (5 December 1995)
- Schmitz, H., H. Bleckmann, and M. Murtz, "Infrared detection in a beetle," *Nature*, 386, No. 6627, 773-774 (24 April 1997)
- Schmitz, H., and H. Bleckmann, "Fine structure and physiology of the infrared receptor of beetles of the genus *Melanophila* (Coleoptera: Buprestidae)," *International Journal of Insect Morphology & Embryology*, 26, No. 3/4, 205-215 (1997)

- Schmitz, H., and H. Bleckmann, "The photomechanic infrared receptor for the detection of forest fires in the beetle *Melanophila acuminata* (Coleoptera: Buprestidae)," *Journal of Comparative Physiology A*, 182, 647-657 (1998)
- Schutz, S., B. Weissbecker, H. E. Hummel, K.-H. Apel, H. Schmitz, and H. Bleckmann, "Insect antenna as a smoke detector," *Nature*, 398, 298-299 (25 March 1999)
- Pain, S., "Burning desire," *New Scientist*, 163, No. 2198, 36-40 (7 August 1999)
- Gronenberg, W., and H. Schmitz, "Afferent projections of infrared-sensitive sensilla in the beetle *Melanophila acuminata* (Coleoptera: Buprestidae)," *Cell Tissue Research*, 297, 311-318 (1999)
- Schmitz, H., A. Schmitz, and H. Bleckmann, "A new type of infrared organ in the Australian 'fire-beetle' *Merimna atrata* (Coleoptera: Buprestidae)," *Naturwissenschaften*, 87, 542-545 (2000)
- Schmitz, H., M. Murtz, and H. Bleckmann, "Responses of the infrared sensilla of *melanophila acuminata* (Coleoptera: Buprestidae) to monochromatic infrared stimulation," *Journal of Comparative Physiology A*, 186, No. 6, 543-549 (June 2000)
- Schmitz, H., A. Schmitz, and H. Bleckmann, "A new type of infrared organ in the Australian 'fire-beetle' *Merimna atrata* (Coleoptera: Buprestidae)," *Naturwissenschaften* 87, 542-545 (2000)
- Milius, S., "Why fly into a forest fire?" *Science News*, 159, 140-141 (3 March 2001)
- Hazel, J., N. Fuchigami, V. Gorbunov, H. Schmitz, M. Stone, and V. V. Tsukruk, "Ultramicrostructure and microthermomechanics of biological IR detectors: materials properties from a biomimetic perspective," *Biomacromolecules*, 2, 304-312 (2001)
- Hammer, D. X., H. Schmitz, A. Schmitz, H. G. Rylander III, and A. J. Welch, "Sensitivity threshold and response characteristics of infrared detection in the beetle *Melanophila acuminata* (Coleoptera: Buprestidae)," *Comparative Biochemistry and Physiology, Part A*, 128, 805-819 (2001)
- Sowards, L. A., H. Schmitz, D. W. Tomlin, R. R. Naik, and M. O. Stone, "Characterization of beetle *melanophila acuminata* (Coleoptera: Buprestidae) infrared pit organs by high-performance liquid chromatography/mass spectrometry, scanning electron microscope and fourier transform-infrared spectroscopy," *Physiology, Biochemistry, and Toxicology*, 94, No. 5, 686-694 (September 2001)
- Hammer, D. X., J. Seigert, M. O. Stone, H. G. Rylander III, and A. J. Welch, "Infrared spectral sensitivity of *Melanophila acuminata*," *Journal of Insect Physiology*, 47, 1441-1450 (2001)
- Schmitz, H., A. Schmitz, and H. Bleckmann, "Morphology of a thermosensitive multipolar neuron in the infrared organ of *Merimna atrata* (Coleoptera, Buprestidae)," *Arthropod Structure & Development*, 30, 99-111 (2001)
- Hazel, J., N. Fuchigami, V. Gorbunov, H. Schmitz, M. Stone, and V. V. Tsukruk, "Ultramicrostructure and microthermomechanics of biological IR detectors: materials properties from a biomimetic perspective," *Biomacromolecules*, 2, 304-312 (2001)
- Campbell, A. L., R. R. Naik, L. Sowards, M. O. Stone, "Biological infrared imaging and sensing," *Micron*, 33, 211-225 (2002)
- Hammer, D. X., D. Dave, T. E. Milner, B. Choi, H. G. Rylander III, and A. J. Welch, "Investigation of the transduction mechanism of infrared detection in *Melanophila acuminata*: photo-thermal-mechanical hypothesis," *Comparative Biochemistry and Physiology, Part A*, 132, 381-392 (2002)
- Schmitz, H., A. Schmitz, S. Trenner, and H. Bleckmann, "A new type of insect infrared organ of low thermal mass," *Naturwissenschaften*, 89, 226-229 (2002)
- Schmitz, H., and S. Trenner, "Electrophysiological characterization of the multipolar thermoreceptors in the 'fire-beetle' *Merimna atrata* and comparison with the infrared sensilla of *Melanophila acuminata* (both Coleoptera, Buprestidae)," *Journal of Comparative Physiology A*, 189, 715-722 (2003)
- Bleckmann, H., H. Schmitz, and G. von der Emde, "Nature as a model for technical sensors," *Journal of Comparative Physiology A*, 190, 971-981 (2004)
- Mainz, T., A. Schmitz, and H. Schmitz, "Variation in number and differentiation of the abdominal infrared receptors in the Australian 'fire-beetle' *Merimna atrata* (Coleoptera, Buprestidae)," *Arthropod Structure & Development*, 33, 419-430 (2004)

- Evans, W. G., “Infrared radiation sensors of *Melanophila acuminata* (Coleoptera: Buprestidae): a thermopneumatic model,” *Annals of the Entomological Society of America*, 98, No. 5, 738-746 (2005)
- Kreiss, E., H. Schmitz, and M. Gebhardt, “Electrophysiological characterisation of the infrared organ of the Australian ‘little ash beetle’ *Acanthocnemus nigricans* (Coleoptera, Acanthocnemidae),” *Journal of Comparative Physiology A*, 193, 729-739 (2007)
- Schmitz, A., M. Gebhardt, and H. Schmitz, “Microfluidic photomechanic infrared receptors in a pyrophilous flat bug,” *Naturwissenschaften*, 95, 455-460 (2008)

Related reference

- Schmitz, H., S. Trenner, M. H. Hofmann, and H. Bleckmann, “The ability of *Rhodnius prolixus* (Hemiptera; Reduviidae) to approach a thermal source solely by its infrared radiation,” *Journal of Insect Physiology*, 46, 745-751 (2000)
- Vondran, T., K.-H. Apel, and H. Schmitz, “The infrared receptor of *Melanophila acuminata* Da Geer (Coleoptera: Buprestidae): ultrastructural study of a unique insect thermoreceptor and its possible descent from a hair mechanoreceptor,” *Tissue & Cell*, 27, No. 6, 645-658 (December 1995)

4.3 Bees kill hornet

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Bees kill via heating

<http://www.youtube.com/watch?v=K6m40W1s0Wc&feature=related>

<http://www.youtube.com/watch?v=JtFVQe4JRmA>

<http://www.sciencenews.org/articles/20050924/fob5.asp> News story plus photo

<http://www.boingboing.net/images/beefu.jpg> The same photo

Bees kill via suffocation

<http://www.youtube.com/watch?v=EuAfbt8-7VE>

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Ono, M., I. Okada, M. Sasaki, “Heat production by balling in the Japanese honeybee, *Apis cerana japonica* as a defensive behavior against the hornet, *Vespa simillima xanthoptera*,” *Experientia*, 43, No. 9, 1031-1032 (15 September 1987)
- Akre, R. D., and D. F. Mayer, “Bees and vespine wasps,” *Bee World*, 75, No. 1, 29-37 (1994)
- Ono, M., T. Igarashi, E. Ohno, and M. Sasaki, “Unusual thermal defense by a honeybee against mass attack by hornets,” *Nature*, 377, 334-336 (1995)
- Koeniger, N., G. Koeniger, M. Gries, S. Tingek, and A. Kelitu, “Observations on colony defense of *Apis nuluensis* Tingek, Koeniger and Koeniger, 1996 and predatory behavior of the hornet *Vespa multimaculata* Perez, 1910,” *Apidologie*, 27, No. 5, 341-352 (1996)
- Anderson, C., G. Theraulaz, and J.-L. Deneubourg, “Self-assemblages in insect societies,” *Insectes Sociaux*, 49, 99-110 (2002)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, John Wiley & Sons, 6th edition, page 446 (2003)

- Milius, S., “Balls of fire: bees carefully cook invaders to death,” *Science News*, 168, No. 13, 197 (24 September 2005)
- Ken, T., H. R. Hepburn, S. E. Radloff, Y. Yusheng, L. Yiqiu, Z. Danyin, and P. Neumann, “Heat-balling wasps by honeybees,” *Naturwissenschaften*, 92, 492-495 (2005)
- Papchristoforou, A., A. Rortais, G. Zafeiridou, G. Theophilidis, L. Garnery, A. Thrasyvoulou, and G. Arnold, “Smothered to death: Hornets asphyxiated by honeybees,” *Current Biology*, 17, No. 18, R795-796 (18 September 2007)
- Khamsi, R., “Honeybees gang up to smother deadly hornets,” *New Scientist*, video and photo are available at the right side of the web page (17 Sep 2007): http://www.newscientist.com/article.ns?id=dn12649&feedId=online-news_rss20
- Ehrenberg, R., “Enemy hornets suffocate within honeybees’ ball,” *Science news*, 176, No. 3, 13 (1 August 2009)

Related reference

- Pettis, J. S., L. C. Westcott, and M. L. Winston, “Balling behaviour in the honey bee in response to exogenous queen mandibular gland pheromone,” *Journal of Apicultural Research*, 37, No. 2, 125-131 (1998)

4.4 Huddling animals

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<http://www.youtube.com/watch?v=6AiCIZ9wM1o> Video

<http://www.youtube.com/watch?v=cgGL6SbMfKc&mode=related&search=> BBC video, David Attenborough

<http://video.google.com/videoplay?docid=1194255384237631189&q=huddling+penguins&hl=en> Video

http://notblogging.notwriting.com/2005/08/i_am_haunted_by_penguins.html News story plus photo
<http://www.youtube.com/watch?v=cgGL6SbMfKc&feature=related> penguin huddling, slow march from windward side

<http://www.aad.gov.au/default.asp?casid=3524> Scroll down to the huddling of the penguins

<http://www.kailo.org/about/images/penguins.jpg> Photo of huddling penguins

<http://www.aad.gov.au/default.asp?casid=2880> stories and photos, Australian Antarctic Division

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Glasser, M. L., and S. G. Davison, “A bundling problem,” *SIAM Review*, 20, No. 1, 178-180 (January 1978)
- Vickery, W. L., and J. S. Millar, “The energetics of huddling by endotherms,” *OIKOS*, 43, 88-93 (1984)
- Ancel, A., H. Visser, Y. Handrich, D. Masman, and Y. Le Maho, “Energy saving in huddling penguins,” *Nature*, 385, No. 6614, 304-305 (23 January 1997)

- Kirkwood, R., and G. Robertson, “The occurrence and purpose of huddling by emperor penguins during foraging trips,” *EMU*, 99, 40-45 (1999)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, John Wiley & Sons, 6th edition, page 453 (2003)
- Gilbert, C., G. Robertson, Y. Le Maho, Y. Naito, and A. Ancel, “Huddling behavior in emperor penguins: Dynamics of huddling,” *Physiology & Behavior*, 88, 479-488 (2006)
- Gilbert, C., Y. Le Maho, M. Perret, and A. Ancel, “Body temperature changes induced by huddling in breeding male emperor penguins,” *American Journal of Physiology. Regulatory, Integrative, and Comparative*, 292, No. 1, R176-R185 (January 2007)
- “How huddles help penguins weather winter,” *Journal of Experimental Biology*, 211, No. 1, i (2008)
- Gilbert, C., S. Blanc, Y. Le Maho, and A. Ancel, “Energy saving processes in huddling emperor penguins: from experiments to theory,” *Journal of Experimental Biology*, 211, No. 1, 1-8 (2008)
- Gilbert, C., G. Robertson, Y. Le Maho, and A. Ancel, “How do weather conditions affect the huddling behaviour of emperor penguins,” *Polar Biology*, 31, 163-169 (2008)

Related references

- Le Maho, Y., P. Delclitte, and J. Chatonnet, “Thermoregulation in fasting emperor penguins under natural conditions,” *American Journal of Physiology*, 231, 913-922 (1976)
- Boyles, J. G., J. J. Storm, and V. Brack, Jr., “Thermal benefits of clustering during hibernation: a field test of competing hypotheses on *Myotis sodalist*,” *Functional Ecology*, 22, 632-636 (2008)
- Kotze, J., N. C. Bennett, and M. Scantlebury, “The energetics of huddling in two species of mole-rat (Rodentia: Bathyergidae),” *Physiology & Behavior*, 93, 215-221 (2008)

4.5 Space walking without a spacesuit

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Comments

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Mullisen, R. S., “Boil-freeze-pop thermodynamics,” *International Journal of Mechanical Engineering Education*, 30, No. 2, 119-122 (2002)

4.6 Drops on a hot skillet, fingers in molten lead

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Dean Baird’s video:

<http://phyzblog.blogspot.com/2007/01/post-ptsos2-note-leidenball-video.html>

Me at UCLA:

<http://www.youtube.com/watch?v=TjEhMSADaHs>

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Sutton, R. M., *Demonstration Experiments in Physics*, McGraw-Hill, 1938, page 234
- Mackenzie, R. S., *Robert-Houdin, the Great Wizard, Celebrated French Conjurer, Author, and Ambassador*, Carl W. Jones, Publisher of Magic, 1944, pages 452-457
- Holter, N. J., and W. R. Glasscock, "Vibrations of evaporating liquid drops," *Journal of the Acoustical Society of America*, 24, No. 6, 682-686 (November 1952)
- Ruark, R., *Something of Value*, Doubleday, 1955, page 66
- Leidenfrost, J. G., "On the fixation of water in diverse fire," *International Journal of Heat and Mass Transfer*, 9, 1153-1166 (1966), translation by C. Wares and introduction by K. J. Bell of original paper published in 1756
- Gottfried, B. S., C. J. Lee, and K. J. Bell, "The Leidenfrost phenomenon: film boiling of liquid droplets on a flat plate," *International Journal of Heat and Mass Transfer*, 9, 1167-1187 (1966)
- Hall, R. S., S. J. Board, A. J. Clare, R. B. Duffey, T. S. Playle, and D. H. Poole, "Inverse Leidenfrost phenomenon," *Nature*, 224, No. 5216, 266-267 (18 October 1969)
- Konuray, M., H. B. Mead, and F. M. Page, "Fall of liquid metal into water," *Nature*, 254, 321-322 (1975)
- Emmerson, G. S., "The effect of pressure and surface material on the Leidenfrost point of discrete drops of water," *International Journal of Heat and Mass Transfer*, 18, 381-386 (1975)
- Zyszkowski, W., "On the transplosion phenomenon and the Leidenfrost temperature for the molten copper-water thermal interaction," *International Journal of Heat and Mass Transfer*, 19, 625-633 (1976)
- Walker, J., "Drops of water dance on a hot skillet and the experimenter walks on hot coals," in "The Amateur Scientist," *Scientific American*, 237, 126-131 (August 1977)
- Curzon, F. L., "The Leidenfrost phenomenon," *American Journal of Physics*, 46, 825-828 (1978)
- Goldshtik, M. A., V. M. Khanin and V. G. Ligai, "A liquid drop on an air cushion as an analogue of Leidenfrost boiling," *Journal of Fluid Mechanics*, 166, 1-20 (1986)
- Listerman, T. W., T. A. Boshinski, and L. F. Knee, "Cooling by immersion in liquid nitrogen," *American Journal of Physics*, 54, 554-558 (1986)
- Bent, H. A., "Droplet on a hot metal spoon," *American Journal of Physics*, 54, 967 (1986)
- Wolkowicz, R., "'Old Jearl' will do anything to stir an interest in physics," *Smithsonian*, 17, 112-121 (October 1986)
- Jay, R., "Incombustible men and fireproof women," in *Learned Pigs & Fireproof Women*, Villard Books, 1987, pages 237-273
- Walker, J., (essay) "Boiling and the Leidenfrost effect," in *Fundamentals of Physics*, 3rd edition, by D. Halliday and R. Resnick, John Wiley & Sons, 1988, pages E10-1 through 10-6
- Thimbleby, H., "The Leidenfrost phenomenon," *Physics Education*, 24, 300-303 (1989)
- Zhang, S., and G. Gogos, "Film evaporation of a spherical droplet over a hot surface: fluid mechanics and heat/mass transfer analysis," *Journal of Fluid Mechanics*, 222, 543-563 (1991)
- LaValle, G. G., P. Carrica, V. Garea, and M. Jaime, "A boiling heat-transfer paradox," *American Journal of Physics*, 60, No. 7, 593-597 (July 1992)
- Chandra, S., and S. D. Aziz, "Leidenfrost evaporation of liquid nitrogen droplets," *Journal of Heat Transfer*, Transactions of the ASME, 116, 999-1006 (November 1994)

- Casal, P., and H. Gouin, "Vibrations of liquid drops in film boiling phenomena," *International Journal of Engineering Science*, 32, No. 10, 1553-1560 (1994) Available at <http://arxiv.org/abs/0802.3289v1>
- Prat, M., P. Schmitz, and D. Poulikakos, "On the effect of surface roughness on the vapor flow under Leidenfrost-levitated droplets," *Journal of Fluids Engineering*, 117, 519-525 (June 1995)
- Nagal, N., and S. Nishio, "Leidenfrost temperature on an extremely smooth surface," *Experimental Thermal and Fluid Science*, 12, 373-379 (1996)
- Hatta, N., H. Fujimoto, K. Kinoshita, and H. Takuda, "Experimental study of deformation mechanism of a water droplet impinging on hot metallic surfaces above the Leidenfrost temperature," *Journal of Fluids Engineering*, 119, 692-699 (September 1997)
- Dhir, V. K., "Boiling heat transfer," *Annual Review of Fluid Mechanics*, 30, 365-401 (1998)
- Bernardin, J. D., and I. Mudawar, "The Leidenfrost point: experimental study and assessment of existing models," *Journal of Heat Transfer*, 121, 894-903 (November 1999)
- Carpenter, B., R. Hann, and D. Simmons, (letters) "Dust pucks," in "The Last Word," *New Scientist*, 170, inside back cover (5 May 2001); available at NewScientist.com, search under "Leidenfrost"
- Bernardin, J. D., and I. Mudawar, "A cavity activation and bubble growth model of the Leidenfrost point," *Journal of Heat Transfer*, 124, 864-874 (October 2002)
- Bianche, A.-L., C. Clanet, and D. Quere, "Leidenfrost drops," *Physics of Fluids*, 15, No. 6, 1632-1637 (June 2003)
- Bernardin, J. D., and I. Mudawar, "A Leidenfrost point model for impinging droplets and sprays," *Journal of Heat Transfer*, 126, 272-278 (April 2004)
- Chiu, S.-L., and T. H. Lin, "Experiment on the dynamics of a compound drop impinging on a hot surface," *Physics of Fluids*, 17, article # 122103 (9 pages) (2005)
- Ge, Y., and L.-S. Fan, "Three-dimensional simulation of impingement of a liquid droplet on a flat surface in the Leidenfrost regime," *Physics of Fluids*, 17, article #027104 (20 pages) (2005)
- Kim, H., "Floating phenomenon of a water drop on the surface of liquid nitrogen," *Journal of the Korean Physical Society*, 49, No. 4, L1335-L1338 (October 2006)
- Celata, G. P., M. Cumo, A. Mariani, and G. Zummo, "Visualization of the impact of water drops on a hot surface: effect of drop velocity and surface inclination," *Heat and Mass Transfer*, 42, 885-890 (2006)
- Bianche, A.-L., F. Chevy, C. Clanet, G. Lagubeau, and D. Quere, "On the elasticity of an inertial liquid shock," *Journal of Fluid Mechanics*, 554, 47-66 (2006)
- Linke, H., B. J. Aleman, L. D. Melling, M. J. Taormina, M. J. Francis, C. C. Dow-Hygelund, V. Narayanan, R. P. Taylor, and A. Stout, "Self-propelled Leidenfrost droplets," *Physical Review Letters*, 96, article #154502 (4 pages) (21 April 2006)
- Huang, C.-K., and V. P. Carey, "The effects of dissolved salt on the Leidenfrost transition," *International Journal of Heat and Mass Transfer*, 50, 269-282 (2007)
- Quere, D., and M. Reyssat, "Non-adhesive lotus and other hydrophobic materials," *Philosophical Transactions of the Royal Society A*, 366, 1539-1556 (2008)
- Gianino, C., "Leidenfrost point and estimation of the vapour layer thickness," *Physics Education*, 43, No. 6, 627-631 (2008)

Related references

- Hickman, K. D., "Floating drops and boules," *Nature*, 201, 985-987 (1964)
- Mills, A. A., "Pillow lavas and the Leidenfrost effect," *Journal of the Geological Society of London*, 141, 183-186 (1984)
- Agrawal, D. C., and V. J. Menon, "Boiling and the Leidenfrost effect in a gravity-free zone: a speculation," *Physics Education*, 29, 39-42 (1994)

- Gakhar, L., and J. M. Wiencek, "A possible additional role of mineral oil in successful flash cooling," *Journal of Applied Crystallography*, 38, 945-950 (2005)
- Raudensky, M., and J. Horsky, "Secondary cooling in continuous casting and Leidenfrost temperature effects," *Ironmaking and Steelmaking*, 32, No. 2, 159-164 (2005)
- Myers, T. G., and J. P. F. Charpin, "A mathematical model of the Leidenfrost effect on an axisymmetric droplet," *Physics of Fluids*, 21, article # 063101 (8 pages) (2009)
- Boreyko, J. B., and C-H. Chen, "Self-propelled jumping drops on superhydrophobic surfaces," *Physics of Fluids*, 22, article # 091110 (1 pages) (2010)

4.7 Short Story: A rather dreadful swallow

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Majdalany, F., *The Red Rocks of Eddystone*, Longmans, 1959, pages 107-118

4.8 Walking over hot coals

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

http://www.sptimes.com/2003/10/05/images/xlarge/B_1_1bfire_169174_1005.jpg Photo

<http://mangalorean.com/images/feature/0314dance8.jpg> Photo

http://news.nationalgeographic.com/news/2005/09/0901_050901_firewalking.html Photo (at the bottom) plus news story

http://www.straightdope.com/classics/a3_036.html Cecil Adams in his "Straight Dope" column

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Gaddis, V. H., *Mysterious Fires and Lights*, David McKay Co., Inc. (1967), pages 133-155 isbn: 0945685130
- Walker, J., "Drops of water dance on a hot skillet and the experimenter walks on hot coals," in "The Amateur Scientist," *Scientific American*, 237, 126-131 (August 1977)
- Leikind, B. J., and W. J. McCarthy, "An investigation of firewalking," *Skeptical Inquirer*, 10, No. 1, 23-34 (fall 1985)
- Dennett, M. R., "Firewalking: reality or illusion?" *Skeptical Inquirer*, 10, No. 1, 36-40 (fall 1985)
- Lockhart, R., (letter) "Fire walking---the Leidenfrost effect," *New Zealand Medical Journal*, 98, No. 788, 869 (9 October 1985)
- Malloch, J. A., "Fire walking," *New Zealand Medical Journal*, 98, No. 785, 713-714 (28 August 1985)

- Wolkomir, R., "'Old Jearl' will do anything to stir an interest in physics," *Smithsonian*, 17, 112-121 (October 1986)
- Inglis, B., "The fire-walk," *Speculations in Science and Technology*, 9, No. 3, 163-167 (1986)
- Delorenzo, R., "Fire walking, temperature, and heat," *Journal of Chemical Education*, 63, No. 11, 976-977 (November 1986)
- Jay, R., "Incombustible men and fireproof women," in *Learned Pigs & Fireproof Women*, Villard Books, 1987, pages 237-273
- Pankratz, L., "Fire walking and the persistence of charlatans," *Perspectives in Biology and Medicine*, 31, No. 2, 291-298 (winter 1988)
- Leikind, B. J., and W. J. McCarthy, "Firewalking," *Experientia*, 44, No. 4, 310-315 (15 April 1988)
- McClenon, J., "Firewalking in Japan, Sri Lanka, and the USA: social ecology and applied ideology," *International Journal of Comparative Sociology*, 29, No. 3-4, 202-213 (1988)
- Forrester, J., and J. Hadjiminias, "Fire walking," *British Medical Journal*, 297, No. 6645, 426 (6 August 1988)
- Taylor, J. R., "Firewalking: a lesson in physics," *Physics Teacher*, 27, 166-168 (1989)
- Sayampanathan, S. R. E., R. C. K. Ngim, and C. L. Foo, "Fire walking in Singapore: a profile of the burn patient," *Journal of the Royal College of Surgeons of Edinburgh*, 42, No. 2, 131-134 (April 1997)
- Willey, D., "Fire-walking," *Physics Education*, 45, No. 5, 487-493

4.9 Short Story: Fire-walking accounts

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

http://www.straightdope.com/classics/a3_036.html Cecil Adams in his "Straight Dope" column

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Sheaffer, R., "Psychic vibrations," *Skeptical Inquirer*, 9, 218-219 (1985)
- Krakauer, J., "Get it while it's hot," *Rolling Stone*, issue 429, pages 22-23 (30 August 1984)
- Blackmore, S., "Playing with fire," *New Scientist*, 127, No. 1725, 64-65 (14 July 1990)

4.10 Freezing and supercooling water

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.kentchemistry.com/KentsDemos2.htm> One of Kent's videos is about the sudden freezing of a very cold soda

http://www.youtube.com/watch?v=n_H5ZIoZSBo&mode=related&search= Video showing how mechanical disturbance to a supercooled beer causes rapid freezing. Way cool!

<http://www.youtube.com/watch?v=4xTHSf1I2BY&NR=1> Similar

<http://www.youtube.com/watch?v=KqQu7wIOYwU&mode=related&search=> Rapid freezing of beer

<http://www.youtube.com/watch?v=CC3DUwseZn8&mode=related&search=> At a temperature well below the freezing point, pouring out water at the boiling point produces instant ice crystals

http://www.youtube.com/watch?v=fSPzMva9_CE Video #2 in which a few ice crystals suddenly cause supercooled liquid water to freeze

http://www.youtube.com/watch?v=fSPzMva9_CE Video # 3

http://www.youtube.com/watch?v=fSPzMva9_CE Video # 4 in which supercooled liquid water is poured into a container where it immediately freezes

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Dorsey, N. E., "The freezing of supercooled water," Transactions of the American Philosophical Society, 38, Part 3, 247-328 (November 1948)
- Chalmers, B., "How water freezes," Scientific American, 200, 114-122 + 172 (February 1959)
- Geer, I. W., "A simple technique for supercooling water," in "Weather Talk," Weatherwise, 32, 84-85 (April 1979)
- Walker, J., "Exotic patterns appear in water when it is freezing or melting" in "The Amateur Scientist," Scientific American, 255, 114-119 (July 1986)
- Sadtchenko, V., and G. E. Ewing, "Instability of ice films," Langmuir, 18, 4632-4636 (2002)
- Gianino, C., "An easy classroom experiment on the supercooling of water," Physics Education, 42, No. 3, 289-292

4.11 Eating sea ice

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Chalmers, B., "How water freezes," Scientific American, 200, 114-122 + 172 (February 1959)
- Pounder, E. R., *The Physics of Ice*, Pergamon Press, pages 26-28 (1965)
- Knight, C. A., *The Freezing of Supercooled Liquids*, D. Van Nostrand, 1967, pages 95-97
- Wakatsuchi, M., and N. Ono, "Measurements of salinity and volume of brine excluded from growing sea ice," Journal of Geophysical Research, 88, No. C5, 2943-2951 (30 March 1983)
- Criminale, W. O., Jr., and M-P. Lelong, "Optimum expulsion of brine from sea ice," Journal of Geophysical Research, 89, No. C3, 3581-3585 (20 May 1984)
- Woods, A. W., "Melting and dissolving," Journal of Fluid Mechanics, 239, 429-448 (1992)
- Vrbka, L., and P. Jungwirth, "Brine rejection from freezing salt solutions: a molecular dynamics study," Physical Review Letters, 95, article # 148501 (4 pages) (30 September 2005)
- Tison, J-L., and V. Verbeke, "Chlorinity/salinity distribution patterns in experimental granular sea ice," Annals of Glaciology, 33, 13-20 (2001)

4.12 Cooling rates of initially hot and warm water

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

http://www.straightdope.com/classics/a2_098b.html Cecil Adams in his "Straight Dope" column

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Erlander, S. R., "The structure of water," *Science Journal A*, 5, No. 5, 60-65 (November 1969)
- Ahtee, M., "Investigation into the freezing of liquids," *Physics Education*, 4, 379-380 (1969)
- Kell, G. S., "The freezing of hot and cold water," *American Journal of Physics*, 37, 564-565 (May 1969)
- Ranken, M. B. F., (letter) "Mpemba explained," *New Scientist*, 45, 225-226 (29 January 1970)
- Firth, I., "Cooler?" *Physics Education*, 6, 32-41 (1971)
- Deeson, E., "Cooler---lower down," *Physics Education*, 6, 42-44 (1971)
- Wray, E. M., (letter) "Cool origins," *Physics Education*, 6, 385 (1971)
- Frank, F. C., "The Descartes-Mpemba phenomenon," *Physics Education*, 9, 284 (1974)
- Deeson, E., and G. S. Leadstone, "Bacon-Descartes-Mpemba," *Physics Education*, 10, 124-125 (1975)
- Mpemba, E. B., and D. G. Osborne, "Cool?" *Physics Education*, 4, 172-175 (1969), reprinted: 14, 410-413 (1979)
- Walker, J., "Hot water freezes faster than cold water. Why does it do so?," in "The Amateur Scientist," *Scientific American*, 237, 246-257 (September 1977)
- Walker, J., "How to make dazzling photomicrographs with simple and inexpensive equipment," in "The Amateur Scientist," *Scientific American*, 240, 152-160 (January 1979); see page 160
- Osborne, D. G., "Mind on ice," *Physics Education*, 14, 414-417 (1979)
- Freeman, M., "Cooler still - an answer?" *Physics Education*, 14, 417-421 (1979)
- Jarvis, W. H., (letter) "Mpemba effect," *Physics Education*, 15, 67 (1980)
- Kumar, K., (letter) "Mpemba effect and 18th century ice-cream," *Physics Education*, 15, 268 (1980)
- Wojciechowski, B., I. Owczarek and G. Bednarz, "Freezing of Aqueous Solutions Containing Gases," *Crystal Research and Technology*, 23, 843-848 (1988)
- Stewart, I, C. Reynolds, F. Gordon, and J. K. Wood, (letters) "Freezing faster," *New Scientist*, 135, 48 (15 August 1992)
- Auerbach, D., "Supercooling and the Mpemba effect: when hot water freezes quicker than cold," *American Journal of Physics*, 63, No. 10, 882-885 (October 1995)
- Chown, M., "Supercool theory solves hot ice cream puzzle," *New Scientist*, 148, 22 (2 December 1995)
- Knight, C. A., "The Mpemba effect: the freezing times of hot and cold water," *American Journal of Physics*, 64, No. 5, 524 (May 1996)
- Maciejewski, P. K., "Evidence of a convective instability allowing warm water to freeze in less time than cold water," *Journal of Heat Transfer*, 118, No. 1, 65-72 (February 1996)
- Ball, P., "Does hot water freeze first?" *Physics World*, 19, No. 4, 19-21 (April 2006)
- Simmons, D., Z. Yao, and J. Lewis, (letters) "Freezing debate hots up," *Physics World*, 19, No. 7, 16-17 (July 2006)
- Jeng, M., "The Mpemba effect: When can hot water freeze faster than cold?" *American Journal of Physics*, 74, No. 6, 514-522 (June 2006)

- Chown, M., “Why water freezes faster after heating,” *New Scientist*, 190, No. 2554, 10 (3 June 2006)
- Esposito, S., R. De Risi, and L. Somma, “Mpemba effect and phase transitions in the adiabatic cooling of water before freezing,” *Physica A*, 387, 757-763 (2008)
- Katz, J. I., “When hot water freezes before cold,” *American Journal of Physics*, 77, No. 1, 27-29 (January 2009)
- Chown, M., “The random roots of hot freezing,” *New Scientist*, 205, No. 2753, 10 (27 March 2010). Online title is “Revealed: why hot water freezes faster than cold”
- Brownridge, J. D., “When does hot water freeze faster than cold water? A search for the Mpemba effect,” *American Journal of Physics*, 79, No. 1, 78-84 (January 2011)

4.13 Water frozen by the sky

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Catalanotti, S., V. Cuomo, G. Piro, D. Ruggi, V. Silvestrini, and G. Troise, “The radiative cooling of selective surfaces,” *Solar Energy*, 17, No. 2, 83-89 (1975)
- Ellis, G. F. R., “Utilization of low-grade thermal energy by using the clear night sky as a heat sink,” *American Journal of Physics*, 47, 1010 (1979)
- Kumar, K., “Mpemba effect and 18th century ice-cream,” *Physics Education*, 15, 268 (1980)
- Hanneken, J. W., (letter) “Mpemba effect and cooling by radiation to the sky,” *Physics Education*, 16, 7 (1981)
- Crane, H. R., “The cold night sky,” *Physics Teacher*, 22, 248 (1984)
- Bohren, C. F., “An essay on dew,” in “Simple Experiments in Atmospheric Physics,” *Weatherwise*, 41, 226-231 (August 1988)
- Corken, W. H., and L. H. Holmes, Jr., “Why there’s frost on the pumpkin,” *Journal of Chemical Education*, 68, No. 10, 825 (October 1991)
- Nilsson, T. M. J., W. E. Vargas, G. A. Niklasson, and C. G. Granqvist, “Condensation of water by radiative cooling,” *Renewable Energy*, 5, Part I, No. 1-4, 310-317 (August 1994)
- Saitoh, T. S., “A highly-advanced solar house with solar thermal and sky radiation cooling,” *Applied Energy*, 64, 215-228 (1999)
- Khedari, J., J. Waewsak, S. Thepa, J. Hirunlabh, “Field investigation of night radiation cooling under tropical climate,” *Renewable Energy*, 20, 183-193 (2000)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, John Wiley & Sons, 5th edition, pages 473-474 (1997), 7th edition, page 497 (2005)

Related reference

- Bostrom, M., and B. E. Sernelius, “Wetting problems for coatings on windshields,” *Applied Surface Science* 142, 375-380 (1999)

4.14 Saving the stored vegetables with a tub of water

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Weld, L. D., *A Textbook of Heat*, Macmillan, 1948, page 70
- Osborn, F. A., *Physics of the Home*, McGraw-Hill, 1929, page 161

4.15 Spraying an orchard to preventing freezing

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Gerber, J. F., and D. S. Harrison, "Sprinkler irrigation for cold protection of citrus," *Transactions of the ASAE (American Society of Agricultural Engineers)*, 7, 464-467 (1964)
- Barfield, B. J., L. R. Walton, and R. E. Lacey, "Prediction of sprinkler rates for night-time radiation frost protection," *Agricultural Meteorology*, 24, No. 1, 1-9 (1981)
- Braud, H. J., "Reduction of freeze loss in citrus with water spray," *Transactions of the ASAE (American Society of Agricultural Engineers)*, 24, No.2 396-400 (1981)
- Sastry, S. K., J. R. Phillips, and C. T. Morrow, "Numerical solution of a phase-change problem encountered during frost protection with overhead sprinkling," *Journal of Agricultural Engineering Research*, 31, No. 4, 283-295 (1985)
- Cooper, H. J., E. A. Smith, and J. D. Martsolf, "Spray irrigation effects on surface-layer stability in an experimental citrus orchard during winter freezes," *Journal of Applied Meteorology*, 36, 155-166 (February 1997)
- Lyrene, P., "Blueberries on ice --- coping with Florida's frosts," *Weatherwise*, 57, No. 3, 20-24 (May/June 2004)

4.16 Throwing hot water into very cold air

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<http://www.youtube.com/watch?v=CC3DUwseZn8&NR=1> At a temperature well below the freezing point, pouring out water at the boiling point produces instant ice crystals

<http://www.youtube.com/watch?v=nUDuPyod1WU>

http://www.youtube.com/watch?v=PQEVcCv_xkQ&mode=related&search= Video # 2, including infrared images

<http://www.youtube.com/watch?v=A38iIubSBFQ>

<http://www.youtube.com/watch?v=bDlb3MmwAzE&feature=related>

http://www.youtube.com/watch?v=K-GSrrk_ATM&feature=related

<http://www.youtube.com/watch?v=aRwlrFimnZk&NR=1>

<http://www.youtube.com/watch?v=2ny3hKUG-n0&NR=1>

<http://www.youtube.com/watch?v=R0Adtrjnogc>

<http://www.youtube.com/watch?v=FwknH931pLw>

http://www.youtube.com/watch?v=zFj_i6HtebM&feature=related

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Drew, L. W., "Ice magic," *New Scientist*, 172, No. 2322/2323, 54-55 (22/29 December 2001)

4.17 Icicles

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

Videos

<http://www.youtube.com/watch?v=WE4hZn1YgAY&mode=related&search=> Icicles can kill you, and that is a really embarrassing way to die

<http://www.youtube.com/watch?v=CeSvYK2RvWw>

Photos

http://curiouslee.typepad.com/photos/best_of_curiouslee/icicle_tip.html tip of icicle

<http://gallery.spacebar.org/f/a/photo/viewpic/1/91/1/>

http://www.raglanroad.org/weblog/archives/2005_12.html the ribs often seen on an icicle

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Dorsey, N. E., *Properties of Ordinary Water-Substance*, Hafner, 1968 reprint of 1940 edition, pages 417-418
- Hatakeyama, H., and S. Nemoto, "A note on the formation of horizontal stripes on icicle," *Geophysical Magazine*, 28, No. 4, 479-482 (1958)
- Knight, C. A., and E. LaChapelle, "Further observations on stress-generated ice in the Blue Glacier, Washington, U. S. A.," *Journal of Glaciology*, 9, 87-101 (1970)
- Lenggenhager, K., "Uber wellige, stumpfe, glatte und spitze eiszapfen. 1. Wellige und stumpfe eiszapfen," *Zeitschrift fur Meteorologie*, 28, 292-297 (1978)
- Laudise, R. A., and R. L. Barns, "Are icicles single crystals?" *Journal of Crystal Growth*, 46, 379-386 (1979)
- Knight, C. A., "Icicles as crystallization phenomena," *Journal of Crystal Growth*, 49, 193-198 (1980)
- Geer, I. W., "The not-so-ordinary icicle," *Weatherwise*, 34, 6, 257 (December 1981)

- Burt, S. D., "The curious case of the horizontal icicles," *Meteorology Magazine*, 111, 183-184 (1982)
- Maeno, N., and T. Takahashi, "Studies on icicles. I. General aspects of the structure and growth of an icicle," *Low Temperature Science, Series A*, 43, 125-138 (1984), in Japanese except for the summary on page 138 and the figures
- Woodley, K., "Ice pictures," *Weather*, 43, 10-15 + cover (1988)
- Makkonen, L., "A model of icicle growth," *Journal of Glaciology*, 34, 64-70 (1988)
- Walker, J., "Icicles ensheath a number of puzzles: just how does the water freeze?" in "The Amateur Scientist," *Scientific American*, 258, No. 5, 114-117 (May 1988)
- Chung, K. K., and E. P. Lozowski, "On the growth of marine icicles," *Atmosphere-Ocean*, 28, 393 (1990)
- Makkonen, L., and Y. Fujii, "Spacing of icicles," *Cold Regions Science and Technology*, 21, No. 3, 317-322 (1993)
- Maeno, N., L. Makkonen, K. Nishimura, K. Kosugi, and T. Takahashi, "Growth rates of icicles," *Journal of Glaciology*, 40, No. 135, 319-326 (1994)
- Szilder, K., and E. P. Lozowski, "Stochastic modeling of icicle formation," *Journal of Offshore Mechanics and Arctic Engineering. Transaction of the ASME*, 116, 180-184 (August 1994)
- de Bruyn, J. R., "On the formation of periodic arrays of icicles," *Cold Regions Science and Technology*, 25, 225-229 (1997)
- Szilder, K. and E. P. Lozowski, "Numerical simulations of pendant ice formations," *Cold Regions Science and Technology*, 31, 1-11 (2000)
- Makkonen, L., "Models for the growth of rime, glaze, icicles and wet snow on structures," *Philosophical Transactions of the Royal Society of London A*, 358, 2913-2939 (2000)
- Ogawa, N., and Y. Furukawa, "Surface instability of icicles," *Physical Review E*, 66, article no. 041202 (2002)
- Weiss, P., "Icicle waves go with the flow," *Science News*, 162, 381 (14 December 2002)
- Ueno, K., "Pattern formation in crystal growth under parabolic shear flow," *Physical Review E*, 68, article no. 021603 (2003)
- Ueno, K., "Pattern formation in crystal growth under parabolic shear flow. II," *Physical Review E*, 69, article no. 051604 (8 pages) (May 2004)
- Short, M. B., J. C. Baygents, and R. E. Goldstein, "A free-boundary theory for the shape of the ideal dripping icicle," *Physics of Fluids*, 18, article # 083101 (2006)
- Ueno, K., "Characteristics of the wavelength of ripples on icicles," *Physics of Fluids*, 19, article # 093602 (10 pages) (2007)
- "Ice maths," *The Last Word*, *New Scientist*, posted online Wednesday, 16 July 2008 <http://www.newscientist.com/blog/lastword/2008/07/ice-maths.html>
- Neufeld, J. A., R. E. Goldstein, and M. G. Worster, "On the mechanics of icicle evolution," *Journal of Fluid Mechanics*, 647, 287-308 (2010)
- Chen, A. S-H., and Stephen W. Morris, "Experiments on the morphology of icicles," arXiv:1008.1922v1 (11 August 2010). This and other information are available at the following University of Toronto sites:
<http://www.physics.utoronto.ca/~nonlin/abstracts/CM10abstract.html>
<http://www.physics.utoronto.ca/~smorris/edl/icicleripples/icicleripples.html>

Related references

- Brunet, P., G. Gauthier, L. Limat, and D. Vallet, "Structure and dynamics of a bidimensional pattern of liquid columns," *Experiments in Fluids*, 37, 645-652 (2004)
- Short, M. B., J. C. Baygents, J. W. Beck, D. A. Stone, R. S. Toomey III, and R. E. Goldstein, "Stalactite growth as a free-boundary problem: a geometric law and its platonic ideal," *Physical Review Letters*, 94, article number 018501 (14 January 2005)

4.18 Ice dams at eaves

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.extension.umn.edu/distribution/housingandclothing/DK1068.html> Discussion plus nice diagram

http://www.umass.edu/bmatwt/publications/articles/ice_dams.html Discussion plus good photos, near bottom

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Tobiasson, W., J. Buska, and A. Greatorex, "Ventilating attics to minimize icings at eaves," *Energy and Buildings*, 21, No. 3, 229-234 (1994)

Related references

- Kemp, A. K., "The formation of ice on electrical conductors during heavy falls of wet snow," *Meteorological Magazine*, 109, No. 1292, 69-74 (March 1980)
- Hughes, T., and M. Nakagawa, "Bending shear: the rate-controlling mechanism for calving ice walls," *Journal of Glaciology*, 35, No. 120, 260-266 (1989)
- Makkonen, L., "Models for the growth of rime, glaze, icicles and wet snow on structures," *Philosophical Transactions of the Royal Society of London A*, 358, 2913-2939 (2000)
- Druez, J., M. Farzaneh, and P. McComber, "Atmospheric icing on a test power line," *Transactions of the Canadian Society for Mechanical Engineering*, 24, No. 2, 359-374 (2000)

4.19 Rime ice and glaze ice on cables

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.michelestapleton.com/MtWash/pages/Mt%20Wash%20Rime%20ice%20on%20ro00006.htm> Photo

<http://www.zakon.org/robert/album/washington-winter02/> Photo

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Lenhard, R. W., Jr., "An indirect method for estimating the weight of glaze on wires," *Bulletin of the American Meteorological Society*, 36, No. 1, 1-5 (January 1955)
- Hallett, J., "Jogging in riming weather, Christmas Day 1985," *Weather*, 41, 234 (1986)

- Makkonen, L., and M. M. Oleskiw, “Small-scale experiments on rime icing,” *Cold Regions and Technology*, 25, 173-182 (1997)
- Makkonen, L., “Modeling power line icing in freezing precipitation,” *Atmospheric Research*, 46, 131-142 (1998)
- Makkonen, L., “Models for the growth of rime, glaze, icicles and wet snow on structures,” *Philosophical Transactions of the Royal Society of London A*, 358, 2913-2939 (2000)
- Druetz, J., M. Farzaneh, and P. McComber, “Atmospheric icing on a test power line,” *Transactions of the Canadian Society for Mechanical Engineering*, 24, No. 2, 359-374 (2000)
- Szilder, K., E. P. Lozowski, and G. Reuter, “A study of ice accretion shape on cables under freezing rain conditions,” *Journal of Offshore Mechanics and Arctic Engineering; Transactions of the ASME*, 124, No. 3, 162-168 (August 2002)
- Gurung, C. B., H. Yamaguchi, and T. Yukino, “Identification of large amplitude wind-induced vibration of ice-accreted transmission lines based on field observed data,” *Engineering Structures*, 24, 179-188 (2002)

Related reference

- Brunet, P., G. Gauthier, L. Limat, and D. Vallet, “Structure and dynamics of a bidimensional pattern of liquid columns,” *Experiments in Fluids*, 37, 645-652 (2004)

4.20 Ice spikes and other ice formations

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

Video

<http://www.youtube.com/watch?v=zAQ00QUKDXA> Watch the spikes grow

Photos:

<http://www.its.caltech.edu/~atomic/snowcrystals/icespikes/icespikes.htm>

http://www.uweb.ucsb.edu/~cdelacerda/Ice_Spike2.jpg

<http://www.nbb.cornell.edu/neurobio/land/images/Crystal1.jpg>

http://upload.wikimedia.org/wikipedia/commons/thumb/d/d1/Ice_spike.jpg/800px-Ice_spike.jpg

http://upload.wikimedia.org/wikipedia/commons/thumb/d/d1/Ice_spike.jpg/800px-Ice_spike.jpg

Photo

plus news story

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Prew, R. D., and B. J. Legg, “An unusual freezing phenomenon,” *Weather*, 29, 217 and 219 (1974)
- Satake, K., “Disappearance of puddle water during the night with growth of ice needles and its reappearance during the day,” *Nature*, 265, 519-520 (10 February 1977)
- Timco, G. W., and D. B. Coveney, (letter) “A peculiar melt pattern in fresh-water ice,” *Journal of Glaciology*, 25, No. 93, 499-501 (1980)
- Josberger, E. G., (letter) “One peculiar ice-melt pattern explained, another peculiar pattern observed,” *Journal of Glaciology*, 28, No. 99, 391-392 (1982)
- Knight, C. A., and A. L. DeVries, “Growth forms of large frost crystals in the Antarctic,” *Journal of Glaciology*, 31, No. 108, 127-135 (1985)

- Toland, R. B., (letter) "Ice vortices," *Weatherwise*, 38, 7 (February 1985)
- Lobeck, R., (letter) "Another unusual ice formation," *Weather*, 41, 371 (1986)
- Whiddett, S. G., (letter) "Unusual ice formation," *Weather*, 41, 269 (1986)
- Walker, E. R., (letter) "Unusual underside ice ridges," *Weather*, 42, 328-329 (October 1987)
- Bohren, C. F., "Five faces of freezing," *Weatherwise*, 42, 315-319 (December 1989)
- Redd, E., "Puddle ice ridges," *Weatherwise*, 44, 47-50 (April 1991)
- Wascher, T., "Generation of slanted gas-filled icicles," *Journal of Crystal Growth*, 110, No. 4, 942-946 (1991)
- Perry, H. F., "Ice spikes---Can you explain them?" *Physics Teacher*, 31, No. 2, 112-113 (February 1993)
- Evans, L., R. McLachlan, and S. Morris, (letters) "The spikes/whiskers phenomenon," *Physics Teacher*, 31, 264-265 (1993)
- Yuse, A., and M. Sano, "Transitions between crack patterns in quenched glass plates," *Nature*, 362, No. 6418, 329-331 (1993)
- Brausch, J., and C. Knight, "Puddle wonders," *Weatherwise*, 47, 19-24 (December 1994/January 1995)
- Bjorbaek, G., "Unusual ice formations," *Weather*, 49, 188-189 (1994)
- Perry, H. F., "A 'last word' on ice spikes," *Physics Teacher*, 33, 148-149 (March 1995)
- Knight, C., (letter) "Supercool," *New Scientist*, 149, inside back cover (16 March 1996)
- Ragnarsson, R., J. L. Ford, C. D. Santangelo, and E. Bodenschatz, "Rifts in spreading wax layers," *Physical Review Letters*, 76, No. 18, 3456-3459 (29 April 1996). The print version had a corrected photograph: 77, No. 5, 982 (29 July 1996). The online version is ok.
- Nordell, B., and G. Westerstrom, "Large rotating ice discs on ice-covered rivers," *Weather*, 52, No. 1, 17-21 (1997)
- Abrusci, G., (letter) "Question #65. What conditions determine crystal growth?" *American Journal of Physics*, 65, No. 10, 941 (1997)
- Knight, C. A., (letter) "Answer to question #65. What conditions determine crystal growth? The triangular ice spike," *American Journal of Physics*, 66, No. 12, 1041-1042 (December 1998)
- Matthews, V., III, "Origin of horizontal needle ice at Charit Creek Station, Tennessee," *Permafrost and Periglacial Processes*, 10, 205-207 (1999)
- Ball, P., *The Self-Made Tapestry: Pattern Formation in Nature*, Oxford University Press, 1999, pages 143-146
- Perry, H. F., (letter) "Answer to Question #65. What conditions determine crystal growth?" *American Journal of Physics*, 69, No. 2, 106 (February 2001)
- Trout, K. P., "Homemade ice spike," *Physics Teacher*, 39, 190 (March 2001)
- Mullisen, R. S., "Boil-freeze-pop thermodynamics," *International Journal of Mechanical Engineering Education*, 30, No. 2, 119-122 (2002)
- Mehrotra, R., and D. Kumar, "Patterns in melting snow and vapor deposited layers," *Physical Review Letters*, 92, No. 25, article number 254502 (25 June 2004)
- Libbrecht, K. G., K. Lui, "An investigation of laboratory-grown ice spikes," *Journal of Glaciology*, 50, No. 170, 371-374 (2004)
- Hill, L., E. Lozowski, and R. D. Sampson, "Experiments on ice spikes and a simple growth model," *Journal of Glaciology*, 50, No. 170, 375-381 (2004)
- Schlatter, T., "Weather Queries," *Weatherwise*, 58, No.1, 58-60 (January/February 2005)
- Knight, C. A., "An exploratory study of ice-cube spikes," *Journal of Glaciology*, 51, No. 173, 191-200 (2005)
- Tsai, V. C., and J. S. Wettlaufer, "Star patterns on lake ice," *Physical Review E*, 75, article # 066105 (2007)

Related references

- Lewis, E. L., and R. G. Perkin, "Ice pumps and their rates," *Journal of Geophysical Research*, 91, No. C10, 11,756-11,762 (15 October 1986)
- Colbeck, S. C., "The layered character of snow covers," *Reviews of Geophysics*, 29, No. 1, 81-96 (February 1991)
- Mason, B. J., "Snow crystals, natural and man made," *Contemporary Physics*, 33, No. 4, 227-243 (1992)
- Kipfstuhl, J., G. Dieckmann, H. Oerter, H. Hellmer, and W. Graf, "The origin of green icebergs in Antarctica," *Journal of Geophysical Research (Oceans)*, 97, No. C12, 20319-20324 (15 December 1992)
- Davey, R., and D. Stanley, "All about ice," *New Scientist*, 140, 33-37 (18 December 1993)
- Warren, S. G., C. S. Roesler, V. I. Morgan, R. E. Brandt, I. D. Goodwin, and I. Allison, "Green icebergs formed by freezing of organic-rich seawater to the base of Antarctic ice shelves," *Journal of Geophysical Research (Oceans)*, 99, No. C4, 6921-6928 (15 April 1993)
- Goodwin, I. D., "Basal ice accretion and debris entrainment within the coastal ice margin, Law Dome, Antarctica," *Journal of Glaciology*, 39, 157-166 (1993)
- Kameda, T., H. Yoshimi, N. Azuma, and H. Motoyama, (letter) "Observation of 'ukimarimo' at the snow surface of the inland plateau, Antarctic ice sheet," *Journal of Glaciology*, 45, No. 150, 394-396 (1999)
- Ferney, B. D., M. R. DeVary, and K. J. Hsia, "Oscillatory crack growth in glass," *Scripta Materialia*, 41, No. 3, 275-281 (1999)
- Fricker, H. A., N. W. Young, I. Allison, and R. Coleman, "Iceberg calving from the Amery Ice Shelf, East Antarctica," *Annals of Glaciology*, 34, 241-246 (2002)

4.21 Cloudy ice cubes

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Carte, A. E., "Air bubbles in ice," *Proceedings of the Physical Society of London*, 77, 757-768 (1961)
- Knight, C. A., "Spiral air bubbles in ice," *Nature*, 214, 1324-1325 (1967)
- Nakawo, M., and G. Wakahama, "Preliminary experiments on the formation of elongated air bubbles in glacier ice by stress," *Journal of Glaciology*, 27, 141-146 (1981)
- Walker, J., "Exotic patterns appear in water when it is freezing or melting" in "The Amateur Scientist," *Scientific American*, 255, 114-119 (July 1986)

Related references

- Knight, C. A., "Formation of crystallographic etch pits on ice, and its application to the study of hailstones," *Journal of Applied Meteorology*, 5, No. 5, 710-714 (October 1966)
- Pearman, G. I., D. Etheridge, F. de Silva, and P. J. Fraser, "Evidence of changing concentrations of atmospheric CO₂, N₂O and CH₄ from air bubbles in Antarctic ice," *Nature*, 320, 248-250 (20 March 1986)

4.22 Figures inside melting ice

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Tyndall, J., *The Forms of Water: in Clouds and Rivers, Ice and Glaciers*, J. A. Hill and Company, 1904, pages 23-25
- Dorsey, N. E., *Properties of Ordinary Water-Substance*, Hafner, 1968 reprint of 1940 edition, pages 404-406
- Chalmers, B., "How water freezes," *Scientific American*, 200, 114-122 + 172 (February 1959)
- Higuchi, K., "Tyndall figures formed in crystallographic plane perpendicular to basal plane of ice crystals," *Nature*, 202, No. 4931, 485-487 (2 May 1964)
- Knight, C. A., and N. C. Knight, "Negative crystals in ice: a method for growth," *Science*, 150, 1819 (1965)
- Knight, C. A., *The Freezing of Supercooled Liquids*, D. Van Nostrand, 1967, page 127
- Knight, C. A., "Growth of ice crystals after a method by Helmholtz," *Nature*, 220, 62-63 (1968)
- Knight, C. A., and N. C. Knight, "Superheated ice: true compression fractures and fast internal melting," *Science*, 178, 613-614 (1972)
- Mae, S., "Tyndall figures at grain boundaries of pure ice," *Nature*, 257, 382-383 (1975)
- Josberger, E. G., (letter) "One peculiar ice-melt pattern explained, another peculiar pattern observed," *Journal of Glaciology*, 28, No. 99, 391-392 (1982)
- Walker, J., "Exotic patterns appear in water when it is freezing or melting" in "The Amateur Scientist," *Scientific American*, 255, 114-119 (July 1986)
- McLaurin, G. E., and E. Whalley, "Negative octahedral snowflakes or Tyndall figures in tetrahydrofuran clathrate hydrate," *Nature*, 332, 711 (1988)

Related references

- Knight, C. A., and N. C. Knight, "'Negative' crystals in ice: a method for growth," *Science* 150, No. 3705, 1819-1821 (31 December 1965)
- Knight, C. A., "Formation of crystallographic etch pits on ice, and its application to the study of hailstones," *Journal of Applied Meteorology*, 5, No. 5, 710-714 (October 1966)

4.23 Freezing of ponds and lakes

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Birge, E. A., "The apparent sinking of ice in lakes," *Science*, 32, 81-82 (1910)

- Dorsey, N. E., *Properties of Ordinary Water-Substance*, Hafner, 1968 reprint of 1940 edition, pages 248, 275-276
- Chalmers, B., “How water freezes,” *Scientific American*, 200, 114-122 + 172 (February 1959)
- Eklund, H., “Stability of lakes near the temperature of maximum density,” *Science*, 149, 632-633 (6 August 1965)
- Myrup, L. D. Gross, L. S. Hoo, and W. Goddard, “Upside down convection,” *Weather*, 25, 150-157 (1970)
- Katsaros, K. B., “Convection patters in a pond,” *Bulletin of the American Meteorological Society*, 62, No. 10, 1446-1453 (October 1981)
- Woodcock, A. H., and R. B. Lukas, “Comments concerning ‘convection patterns in a pond’,” *Bulletin of the American Meteorological Society*, 64, No. 3, 274-277 (March 1983)
- Katsaros, K. B., response, *Bulletin of the American Meteorological Society*, 64, No. 3, 277-279 (March 1983)
- Greenslade, T. B., Jr., “The maximum density of water,” *Physics Teacher*, 23, 474-477 (November 1985)
- McKay, C. P., G. D. Clow, R. A. Wharton, Jr., and S. W. Squyres, “Thickness of ice in perennially frozen lakes,” *Nature*, 313, 561-562 (14 February 1985)
- Bohren, C., “The freezing of lakes,” in “Simple Experiments in Atmospheric Physics” in *Weatherwise*, 39, 328-331 (December 1986); contained in C. F. Bohren, *Clouds in a Glass of Beer: Simple Experiments in Atmospheric Physics*, John Wiley & Sons, Inc., 1987, Chapter 9
- Knight, C. A., “Formation of slush on floating ice,” *Cold Regions and Technology*, 15, No. 1, 33-38 (February 1988)
- Knight, C., “On frozen pond. Nature creates unusual shapes and patterns where ice, snow, and water come together,” *Weatherwise*, 52, 35-40 (January/February 1999)
- Mironov, D., A. Terzhevik, G. Kirillin, T. Jonas, J. Malm, and D. Farmer, “Radiatively driven convection in ice-covered lakes: Observations, scaling, and a mixed layer model,” *Journal of Geophysical Research*, 107, No. C4, article # 3032 (15 April 2002)
- Habeebullah, B., G. M. Zaki, and M. Akyurt, “Prototype device for converting freezing energy into mechanical work,” *Energy Conversion & Management*, 44, 251-265 (2003)

Related references

- Ashton, G. D., “River ice,” *Annual Review of Fluid Mechanics*, 10, 369-392 (1978)
- Ashton, G. D., “River ice,” *American Scientist*, 67, No. 1, 38-45 (January-February 1979)
- Greenslade, T. B., Jr., “The maximum density of water,” *Physics Teacher*, 23, 474-477 (November 1985)
- Kelley, D. E., “Convection in ice-covered lakes: effects on algal suspension,” *Journal of Plankton Research*, 19, No. 12, 1859-1880 (1997)
- Wells, A., (letter) “Whirled patterns in thawing snow,” *Journal of Glaciology*, 45, No. 150, 403 (1999)

4.24 Freezing carbonated drinks

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

http://www.youtube.com/watch?v=n_H5ZIoZSBo&mode=related&search= Video showing how mechanical disturbance to a supercooled beer causes rapid freezing. Way cool!

<http://www.youtube.com/watch?v=4xTHSf1I2BY&NR=1> Similar

<http://www.youtube.com/watch?v=KqQu7wIOYwU&mode=related&search=> Rapid freezing of beer

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Dorsey, N. E., “The freezing of supercooled water,” Transactions of the American Philosophical Society, 38, Part 3, 247-328 (November 1948)
- Batt, R., “Pop! goes the champagne bottle cork,” in “Chemical Principles Exemplified,” edited by R. C. Plum, “Journal of Chemical Education, 48, No. 1, 75 (January 1971)
- Zemansky, M., “Why does the slush form?” Physics Teacher, 12, 517-518 (November 1976)

4.25 Bursting pipes

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Brown, F. C., “The frequent bursting of hot water pipes in household plumbing systems,” Physical Review, 8, No. 5, 500-503 (1916)
- Dorsey, N. E., *Properties of Ordinary Water-Substance*, Hafner, 1968 reprint of 1940 edition, pages 638-643
- Dorsey, N. E., “The freezing of supercooled water,” Transactions of the American Philosophical Society, 38, Part 3, 247-328 (November 1948), see pages 293-295
- Reese, H. M., “Freezing in water pipes,” American Journal of Physics, 19, 425-426 (1951)
- Check Turnbull, D., “The undercooling of liquids,” Scientific American, 212, No. 1, 38-46 (January 1965)
- Knight, C., *Freezing of Supercooled Liquids*, D. Van Nostrand, 1967, pages 35-36
- Gilpin, R. R., “The effects of dendritic ice formation in water pipes,” International Journal of Heat and Mass Transfer, 20, No. 6, 693-699 (1977)
- Gilpin R. R., “Modes of ice formation and flow blockage that occur while filling a cold pipe,” Cold Regions Science and Technology, 5, No. 2, 163-171 (1981)
- Epstein, M., and F. B. Cheung, “Complex freezing-melting interfaces in fluid flow,” Annual Review of Fluid Mechanics, 15, 293-319 (1983)
- Keary, A. C., S. Syngellaskis, and R. J. Bowen, “Experimental and analytical study of thermal stresses during pipe freezing,” Proceedings of the Institute of Mechanical Engineers, 215, E1, 63-77 (2001)
- Akyurt, M., G. Zaki, and B. Habeebullah, “Freezing phenomena in ice-water systems,” Energy Conversion & Management, 43, 1773-1789 (2002)
- Habeebullah, B., G. M. Zaki, and M. Akyurt, “Prototype device for converting freezing energy into mechanical work,” Energy Conversion & Management, 44, 251-265 (2003)
- Jeng, M., “The Mpemba effect: When can hot water freeze faster than cold?” American Journal of Physics, 74, No. 6, 514-522 (June 2006)

4.26 Touching or licking a cold pipe

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Havenith, G., E. J. G. Vandelinde, and R. Heus, "Pain, thermal sensation and cooling rates of hands while touching cold materials," *European Journal of Applied Physiology and Occupational Physiology*, 65, No. 1, 43-51 (July 1992)
- Geng, Q., I. Holmer, and Coldsurf research group, "Change in contact temperature of finger touching on cold surfaces," *International Journal of Industrial Ergonomics*, 27, 387-391 (2001)

Related reference

- Jay, O., and G. Havenith, "Skin cooling on contact with cold materials: The effect of blood flow during short-term exposure," *Annals of Occupational Hygiene*, 48, No. 2, 129-137 (2004)

4.27 Bumps in winter, pingos in permafrost

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.geo.uu.nl/fg/berendsen/pictures/photography/alaska/Pingo.jpg> Photo

<http://www.arctic.uoguelph.ca/cpe/environments/land/features/freeze-thaw/pingoes.htm> Photos plus short discussion

http://www.mbari.org/news/news_releases/2003/paull_pingos.html Photos plus discussion

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Chalmers, B., "How water freezes," *Scientific American*, 200, 114-122 + 172 (February 1959)
- Lacy, R. E., (letter) *Weather*, 21, 456-457 (1966)
- Knight, C. A., *The Freezing of Supercooled Liquids*, D. Van Nostrand, 1967, pages 131-133
- Walder, J., and B. Hallet, "A theoretical model of the fracture of rock during freezing," *Geological Society of America Bulletin*, 96, 336-346 (1985)
- Tharp, T. M., "Conditions for crack propagation by frost wedging," *Geological Society of America Bulletin*, 99, 94-102 (1987)
- Fowler, A. C., "Secondary frost heave in freezing soils," *SIAM Journal of Applied Mathematics*, 49, 991-1008 (August 1989)
- Dash, J. G., "Thermomolecular pressure in surface melting: motivation for frost heave," *Science*, 246, 1591-1593 (1989)
- Williams, P. J., "Permafrost and other frozen ground," *Endeavour*, 14, No. 3, 117-123 (1990)

- Yoshikawa, K., and K. Harada, "Observations on nearshore pingo growth, Adventdalen, Spitsbergen," *Permafrost and Periglacial Processes*, 6, No. 4, 361-372 (October-December 1995)
- Dash, J. G., H. Fu, and J. S. Wettlaufer, "The premelting of ice and its environmental consequences," *Report on Progress in Physics*, 58, 115-167 (1995)
- Worsley, P., and S. D. Gurney, "Geomorphology and hydrogeological significance of the Holocene pingos in the Karup Valley area, Traill Island, northern east Greenland," *Journal of Quaternary Science*, 11, No. 3, 249-262 (1996)
- Padilla, F., J-P., Villeneuve, and J. Stein, "Simulation and analysis of frost heaving in subsoils and granular fills of roads," *Cold Regions and Science and Technology*, 25, 89-99 (1997)
- Gurney, S. D., "Aspects of the genesis and geomorphology of pingos: perennial permafrost mounds," *Progress in Physical Geography*, 22, No. 3, 307-324 (1998)
- Simonsen, E., and U. Isacsson, "Thaw weakening of pavement structures in cold regions," *Cold Regions Science and Technology*, 29, 135-151 (1999)
- Lomborinchen, R., "Frost heaving and related landforms, Mongolia," *Permafrost and Periglacial Processes*, 11, 85-90 (2000)
- Guseva-Lozinski, E., "The mathematical modelling of salinity changes in ice and frozen soil as a result of thermal variations," *Annals of Glaciology*, 31, 295-299 (2000)
- Rempel, A. W., J. S. Wettlaufer, and M. G. Worster, "Premelting dynamics in a continuum model of frost heave," *Journal of Fluid Mechanics*, 498, 227-244 (2004)
- Shoop, S., R. Haehnel, V. Janoo, D. Harjes, and R. Liston, "Seasonal deterioration of unsurfaced roads," *Journal of Geotechnical and Geoenvironmental Engineering*, 132, No. 7, 852-860 (July 2006)

Related references

- Kovacs, A., (letter) "Ice-blister observations on glaciers, sea ice and rivers," *Journal of Glaciology*, 38, No. 129, 314-316 (1992)
- Pissart, A., "Remnants of lithalsas of the Hautes Fagnes, Belgium: a summary of present-day knowledge," *Permafrost and Periglacial Processes*, 11, 327-355 (2000)
- Pissart, A., "Palsas, lithalsas and remnants of these periglacial mounds. A progress report," *Progress in Physical Geography*, 26, No. 4, 605-621 (2002)
- Iannicelli, M., "Reinterpretation of the original Dekalb mounds in Illinois," *Physical Geography*, 24, No. 2, 170-182 (2003)
- Pissart, A., "The remnants of Younger Dryas lithalsas on the Hautes Fagnes Plateau in Belgium and elsewhere in the world," *Geomorphology*, 52, 5-38 (2003)
- Walker, D. A., H. E. Epstein, W. A. Gould, A. M. Kelley, A. N. Kade, J. A. Knudson, W. B. Krantz, G. Michaelson, R. A. Peterson, C-L. Ping, M. K. Reynolds, V. E. Romanovsky, and Y. Shur, "Frost-boil ecosystems: complex interactions between landforms, soils, vegetation and climate," *Permafrost and Periglacial Processes*, 15, 171-188 (2004)

4.28 Arctic ice polygons

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

http://www.crrel.usace.army.mil/permafrosttunnel/lg3d_Wedges.htm Discussion plus photos

<http://sis.agr.gc.ca/cansis/taxa/landscape/ground/nwt.html> Photos

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Gleason, K. J., W. B. Krantz, N. Caine, J. H. George, R. D. Gunn, "Geometrical aspects of sorted patterned ground in recurrently frozen soil," *Science*, 232, 216 (1986)
- Williams, P. J., "Permafrost and other frozen ground," *Endeavour*, 14, No. 3, 117-123 (1990)
- Burn, C. R., and M. W. Smith, "Issues in Canadian permafrost research," *Progress in Physical Geography*, 17, No. 2, 156-172 (1993)
- Mellon, M. T., "Small-scale polygonal features on Mars: seasonal thermal contraction cracks in permafrost," *Journal of Geophysical Research*, 102, 25,617-25,628 (1997)
- MacKay, J. R., "Thermally induced movements in ice-wedge polygons, Western Arctic Coast: a long-term study," *Geographie Physique et Quaternaire*, 54, No. 1, 41-68 (2000)
- Murton, J. B., P. Worsley, and J. Gozdzik, "Sand veins and wedges in cold Aeolian environments," *Quaternary Science Review*, 19, 899-922 (2000)
- Plug, L. J., and B. T. Werner, "Fracture networks in frozen ground," *Journal of Geophysical Research*, 106, No. B5, 8599-8613 (10 May 2001)
- Matsuoka, N., "Direct observation of frost wedging in alpine bedrock," *Earth Surface Processes and Landforms*, 26, 601-614 (2001)
- Yoshikawa, K., "Origin of the polygons and the thickness of Vastitas Borealis Formation in Western Utopia Planitia on Mars," *Geophysical Research Letters*, 30, No. 12, article # 1603 (17 June 2003)
- Sletten, R. S., B. Hallet, and R. C. Fletcher, "Resurfacing time of terrestrial surfaces by the formation and maturation of polygonal patterned ground," *Journal of Geophysical Research*, 108, No. E4, article # 8044 (2003)
- Mangold, N., S. Maurice, W. C. Feldman, F. Costard, and F. Forget, "Spatial relationships between patterned ground and ground ice detected by the Neutron Spectrometer on Mars," *Journal of Geophysical Research*, 109, article # E08001 (2004)
- Burn, C. R., "A field perspective on modelling 'single-ridge' ice-wedge polygons," *Permafrost and Periglacial Processes*, 15, 59-65 (2004)

4.29 Growing stones in a garden, and patterned ground

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.hi.is/~oi/patterned%20ground%20Thule%201986.jpg> Photo of patterned ground

<http://carbon.hampshire.edu/~sroof/images/hol14.jpg> Photo

<http://www.yukoncollege.yk.ca/~agraham/svalbardpictures/pages/abe%20Zeipelodden%20patterned%20ground%203028.1.html> Photo

<http://www.uspermafrost.org/images/permafrost.jpg> Photo

http://www.uspermafrost.org/gallery/swalker/swalker_gallery.shtml Photos and discussion

<http://geoimages.berkeley.edu/GeoImages/Johnson/Landforms/GlacialPeriglacial/PatternedGround01.html>

<http://sis.agr.gc.ca/cansis/taxa/landscape/ground/nwt.html> Photos

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Corte, A. E., "Particle sorting by repeated freezing and thawing," *Science*, 142, 499-501 (25 October 1963)
- Inglis, D. R., and A. E. Corte, (letters) "Particle sorting and stone migration by freezing and thawing," *Science*, 148, 1616-1617 (18 June 1965)
- "Particle sorting and stone migration due to frost heave," *Science*, 152, No. 3721, 545-546 (22 April 1966)
- Gleason, K. J., W. B. Krantz, N. Caine, J. H. George, R. D. Gunn, "Geometrical aspects of sorted patterned ground in recurrently frozen soil," *Science*, 232, 216 (1986)
- Untitled photo of Spitsbergen circles, *Nature*, 330, 603 (1987)
- Krantz, W. B., K. J. Gleason and Nelson Caine, "Patterned ground," *Scientific American*, 259, No. 6, 68-76 (December 1988)
- Anderson, S. P., "The unfreezing process: experiments with a single clast," *Geological Society of America Bulletin*, 100, 609-621 (1988)
- McKenzie, A., "Explaining and exploiting a winter worry," *Science News*, 136, 407 (1989)
- Raybin, D. M., "The stones of spring and summer," *Physics Teacher*, 27, 500-502 (October 1989)
- Hallet, B., "Spatial self-organization in geomorphology: from periodic bedforms and patterned ground to scale-invariant topography," *Earth-Science Reviews*, 29, Nos. 1-4, 57-75 (1990)
- Hallet, B., "Self-organization in freezing soils: from microscopic ice lenses to patterned ground," *Canadian Journal of Physics*, 68, No. 9, 842-852 (September 1990)
- Krantz, W. B., "Self-organization manifest as patterned ground in recurrently frozen soils," *Earth-Science Reviews*, 29, Nos. 1-4, 117-130 (October 1990)
- Anderson, R. S., "Sorting out natural stone stripes," *Nature*, 361, 117 (1993)
- Werner, B. T., and B. Hallet, "Numerical simulation of self-organized stone stripes," *Nature*, 361, 142-145 (1993)
- Grab, S. W., "Annually re-forming miniature sorted patterned ground in the high Drakensberg, Southern Africa," *Earth Surface Process and Landforms*, 22, 733-745 (1997)
- Kling, J., "Observations on sorted circle development, Abisko, Northern Sweden," *Permafrost and Periglacial Processes*, 8, 447-453 (1997)
- Viklander, P., "Laboratory study of stone heave in till exposed to freezing and thawing," *Cold Regions Science and Technology*, 27, 141-152 (1998)
- Matthews, J. A., R. A. Shakesby, M. S. Berrisford, and L. J. McEwen, "Periglacial patterned ground on the Styggedalsbreen Glacier Foreland Jotunheimen, southern Norway: micro-topographic, paraglacial and geoecological controls," *Permafrost and Periglacial Processes*, 9, 147-166 (1998)
- Warburton, J., and N. Caine, "Sorted patterned ground in the English Lake District," *Permafrost and Periglacial Processes*, 10, 193-197 (1999)
- Ball, P., *The Self-Made Tapestry: Pattern Formation in Nature*, Oxford University Press, 1999, pages 180-181
- Viklander, P., and D. Eigenbrod, "Stone movements and permeability changes in till caused by freezing and thawing," *Cold Regions Science and Technology*, 31, 151-162 (2000)
- Holness, S. D., "The orientation of sorted stripes in the maritime subantarctic, Marion Island," *Earth Surface Processes and Landforms*, 26, 77-89 (2001)
- Francou, B., N. Le Mehaute, and V. Jomelli, "Factors controlling spacing distances of sorted stripes in a low-latitude, alpine environment (Cordillera Real, 16° S, Bolivia)," *Permafrost and Periglacial Processes*, 12, 367-377 (2001)
- Ballantyne, C. K., "The sorted stone stripes of Tinto Hill," *Scottish Geographical Journal*, 117, No. 4, 313-324 (2001)
- Kessler, M. A., A. B. Murray, and B. T. Werner, "A model for sorted circles as self-organized patterns," *Journal of Geophysical Research*, 106, No. B7, 13287-13306 (10 July 2001)

- Marchant, D. R., A. R. Lewis, W. M. Phillips, E. J. Moore, R. A. Souchez, G. H. Denton, D. E. Sugden, N. Potter, Jr., and G. P. Landis, "Formation of patterned ground and sublimation till over Miocene glacier ice in Beacon Valley, southern Victoria Land, Antarctica," *Geological Society of America Bulletin*, 114, 718-730 (June 2002)
- Kessler, M. A., and B. T. Werner, "Self-organization of sorted patterned ground," *Science*, 299, No. 5605, 380-383 (17 January 2003)
- Mann, D., "On patterned ground," *Science*, 299, No. 5605, 354-355 (17 January 2003)
- Perkins, S., "Patterns from nowhere. Natural forces bring order to untouched ground," *Science News*, 163, No. 20, 314-316 (17 May 2003)
- Matsuoka, N., M. Abe, and M. Ijiri, "Differential frost heave and sorted patterned ground: field measurements and a laboratory experiment," *Geomorphology*, 52, 73-85 (2003)
- Holness, S. D., "Sorted circles in the maritime subantarctic, Marion Island," *Earth Surface Processes and Landforms*, 28, 337-347 (2003)
- Blau, S. K., "Stone cold: patterned ground in alpine and Arctic regions," *Physics Today*, 56, No. 4, 23 (April 2003)
- Hogan, J., "Centuries of 'frost-heave' created the stone circles of the frozen north," *New Scientist*, 177, No. 2379, 20 (25 January 2003)
- Holness, S. D., "Sediment movement rates and processes on cinder cones in the maritime subantarctic (Marion Island)," *Earth Surface Processes and Landforms*, 29, 91-103 (2004)
- Rempel, A. W., J. S. Wettlaufer, and M. G. Worster, "Premelting dynamics in a continuum model of frost heave," *Journal of Fluid Mechanics*, 498, 227-244 (2004)
- Gozdziak, J. S., and H. M. French, "Apparent upfreezing of stones in Late-Pleistocene coversand, Belchatow Vicinity, Central Poland," *Permafrost and Periglacial Processes*, 15, 359-366 (2004)

4.30 Ploughing boulders

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Chattopadhyay, G. P., "Ploughing blocks on the Drumochter Hills in the Grampian Highlands, Scotland: A quantitative report," *Geographical Journal*, 149, No. 2, 211-215 (July 1983)
- Wilson, P., "Ploughing-boulder characteristics and associated soil properties in the Lake District and southern Scotland," *Scottish Geographical Magazine*, 109, No. 1, 18-26 (April 1993)
- Berthling, I., T. Eiken, H. Madsen, and J. L. Sollid, "Downslope displacement rates of ploughing boulders in a mid-alpine environment: Finse, southern Norway," *Geografiska Annaler Series A-Physical Geography*, 83A, No. 3, 103-116 (2001)
- Berthling, I., T. Eiken, and J. L. Sollid, "Frost heave and thaw consolidation of ploughing boulders in a mid-alpine environment, Finse, southern Norway," *Permafrost and Periglacial Processes*, 12, 165-177 (2001)
- Hall, K., J. Boelhouwers, and K. Driscoll, "Some morphometric measurements on ploughing blocks in the McGregor Mountains, Canadian Rockies," *Permafrost and Periglacial Processes*, 12, 219-225 (2001)
- Ballantyne, C. K., "Measurement and theory of ploughing boulder movement," *Permafrost and Periglacial Processes*, 12, 267-288 (2001)

4.31 Short Story

Dead-cat bomb and a frozen disappearance

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=QaprCLxG5Tg> Liquid nitrogen and flower

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Meade, L. T., and R. Eustace, "The man who disappeared," in *Death Locked In*, edited by D. G. Greene and C. S. Adey, International Polygonics, Ltd., 1987, pages 367-391 1987

4.32 Snowflake formation

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Woodland, P. C., and E. E. Ziegler, "Static dust collection on plastics," *Modern Plastics*, 28, No. 9, 95-106 + 169-178 (neglect full page ads) (May 1951)
- Tolansky, S., "Symmetry of snow crystals," *Nature*, 181, No. 4604, 256-257 (25 January 1958)
- Mason, B. J., "The growth of snow crystals," *Scientific American*, 204, No. 1, 120-131 (January 1961)
- Knight, C. and N. Knight, "Snow crystals," *Scientific American*, 227, No. 1, 100-107 + 128 (January 1973)
- Kobayashi, T., and Y. Furukawa, "On twelve-branched snow crystals," *Journal of Crystal Growth*, 28, 21-28 (1975)
- Battan, L. J., "Weather Queries?" *Weatherwise*, 32, 215-216 (October 1979)
- Langer, J. S., "Instabilities and pattern-formation in crystal-growth," *Reviews of Modern Physics*, 82, No. 1, 1-28 (1980)
- Frank, F. C., "Snow crystals," *Contemporary Physics*, 23, No. 1, 3-22 (1982)
- Maddox, J., "Snowflakes are far from simple," *Nature*, 306, 13 (3 November 1983)
- Hallett, J., "How snow crystals grow," *American Scientist*, 72, 582-589 (November-December 1984)
- Schrack, R. A., (letter) "Electrical aspects of the snowflake crystal," *Nature*, 314, 324 (28 March 1985)
- Mortley, W. S., and A. Fulton, (letters) "No pattern yet for snowflakes," *Nature*, 313, 638 (21 February 1985)

- Fujiyoshi, Y., “Melting snowflakes,” *Journal of Atmospheric Sciences*, 43, No. 3, 307-311 (1 February 1986)
- Maddox, J., “Towards understanding snowflakes,” *Nature*, 321, 645 (12 June 1986)
- Nittman, J., and H. Eugene Stanley, “Tip splitting without interfacial tension and dendritic growth patterns arising from molecular anisotropy,” *Nature*, 321, 663-668 (12 June 1986)
- Knight, N. C., “No two alike?” *Bulletin of the American Meteorological Society*, 69, No. 5, 496 (May 1988)
- Mason, B. J., “Snow crystals, natural and man made,” *Contemporary Physics*, 33, No. 4, 227-243 (1992)
- Davey, R., and D. Stanley, “All about ice,” *New Scientist*, 140, 33-37 (18 December 1993)
- Mason, B. J., “Growth habits and growth rates of snow crystals,” *Proceedings of the Royal Society of London A*, 441, No. 1911, 3-16 (1993)
- Mason, B. J., “The shapes of snow crystals---fitness for purpose? *Quarterly Journal of the Royal Meteorological Society*, 120, No. 518, Part A, 849-860 (July 1994)
- Kikuchi, K., and H. Uyeda, “Formation mechanisms of multibranching snow crystals (twelve-, eighteen-, twenty-four-branched crystals),” *Atmospheric Research* 47-48, 169-179 (1998)
- Battersby, S., “Designer snowflakes,” *New Scientist*, 168, 26-31 (23/30 December 2000)
- Libbrecht, K. G., and H. Yu, “Crystal growth in the presence of surface melting: supersaturating dependence of the growth of columnar ice crystals,” *Journal of Crystal Growth*, 222, 822-831 (2001)
- Libbrecht, K. G., *The Snowflake: Winter’s Secret Beauty*, Voyageur Press, 2003
- Westbrook, C. D., R. C. Ball, P. R. Field, and A. J. Heymsfield, “Theory of growth by differential sedimentation, with application to snowflake formation,” *Physical Review E*, 70, part 1, article # 021403 (7 pages) (August 2004)
- Libbrecht, K. G., “The physics of snow crystals,” *Reports on Progress in Physics*, 68, 855-895 (2005)
- Libbrecht, K. G., *Ken Libbrecht’s Field Guide to Snowflakes*, Voyageur Press, 2006
- Libbrecht, K. G., “The formation of snow crystals,” *American Scientist*, 95, No. 1, 52-59 (January-February 2007)

Related references

- Hooton, R., “Remarkable fall of large ice-flakes,” *Journal of Meteorology*, 4, 280-281 (1979)
- Pearson, M. G., “Snowflakes of remarkable size,” *Journal of Meteorology*, 7, 315 (1982)
- Pike, W. S., “Unusually-large snowflakes,” *Journal of Meteorology*, 13, No. 125, 3-16 (January 1988)
- Rappaz, M., and W. Kurz, “Dendrites solidified by computer,” *Nature*, 375, 103 (11 May 1995)
- Gollub, J. P., and J. S. Langer, “Pattern formation in nonequilibrium physics,” *Reviews of Modern Physics*, 71, No. 2, S396-S403 (1999)
- Weiss, P., “What a flake: Computers get the hang of ice-crystal growth,” *Science News*, 170, 408-410 (23 & 30 December 2006)

4.33 Skiing

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Bowden, F. P., and T. P. Hughes, "The mechanism of sliding of ice and snow," Proceedings of the Royal Society of London, Series A, 172, 280-298 (1939)
- Bowden, F. P., and D. Tabor, *The Friction and Lubrication of Solids*, Part II, Oxford University Press, 1964, pages 148-158
- Outwater, J. O., "On the friction of skis," *Medicine and Science in Sports*, 2, No. 4, 231-234 (1970)
- Plumb, R. C., "Sliding friction and skiing," in "Chemical Principles Exemplified," *Journal of Chemical Education*, 49, 830 (1972)
- Chase, A., "Cross-country skiing: the hows of wax," *Science* 82, 3, 90-91 (March 1982)
- Slotfeldt-Ellingsen, D., and L. Torgersen, "Water in ice: influence on friction," *Journal of Physics D: Applied Physics*, 16, 1715-1719 (1983)
- Perlman, E., "Anatomy of a ski," *Science* 85, 6, 90-91 (February 1985)
- Mendelson, K. S., (letter) "Why is ice so slippery?" *American Journal of Physics*, 53, No. 5, 393 (May 1985)
- Glenne, B., "Sliding friction and boundary lubrication of snow," *Transactions of the ASME. Journal of Tribology*, 109, 614-617 (October 1987)
- Colbeck, S. C., "The kinetic friction of snow," *Journal of Glaciology*, 34, No. 116, 78-86 (1988)
- Colbeck, S., C. "The thermal response of downhill skis," *Journal of Glaciology*, 37, No. 126, 228-235 (1991)
- Colbeck, S. C., "A review of the friction of snow skis," *Journal of Sports Sciences*, 12, 285-295 (1994)
- Colbeck, S. C., "Bottom temperatures of skating skis on snow," *Medicine and Science in Sports and Exercise*, 26, No. 2, 258-262 (February 1994)
- Colbeck, S. C., "Capillary bonding of wet surfaces," *Surface and Coatings Technology*, 81, 209-214 (1996)
- Sahashi, T., and S. Ichino, "Coefficient of kinetic friction of snow skis during turning descents," *Japanese Journal of Applied Physics*, 37, Part 1, No. 2, 720-727 (1998)
- Buhl, D., M. Fauve, and H. Rhyner, "The kinetic friction of polyethylen on snow: the influence of the snow temperature and the load," *Cold Regions Science and Technology*, 33, 133-140 (2001)
- Muller, E., and H. Schwameder, "Biomechanical aspects of new techniques in alpine skiing and ski-jumping," *Journal of Sports Sciences*, 21, No. 9, 679-682 (September 2003)
- Colbeck, S. C., and D. K. Perovich, "Temperature effects of black versus white polyethylene bases for snow skis," *Cold Regions Science and Technology*, 39, 33-38 (2004)
- Wu, Q. H., Y. Andreopoulos, and S. Weinbaum, "From red cells to snowboarding: a new concept for a train track," *Physical Review Letters*, 93, No. 19, 194-501, article # 194501 (4 pages) (5 November 2004)
- Biever, C., "Skiing blood cells inspire pillow tech," *New Scientist*, 184, No. 2473, 9 (13 November 2004)

Related references

- Rhodes, J. J., R. L. Armstrong, and S. G. Warren, "Mode of formation of 'ablation hollow' controlled by dirt content of snow," *Journal of Glaciology*, 33, No. 114, 135-139 (1987)
- Swinson, D. B., "Physics and snowboarding," *Physics Teacher*, 32, No. 10, 530-534 (December 1994)
- von Herten, R., U. Holmlund, and M. A. Ranta, "On the velocity maximization in downhill skiing," *Journal of Biomechanics*, 30, No. 5, 525-529 (1997)

4.34 Ice skating and making a snowball

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=66CVS6drH-M> Penn State snowball fight, an uncontrolled fascination with the physics of hard-packing snow with pressure

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Weyl, W. A., "Surface structure of water and some of its physical and chemical manifestations," *Journal of Colloid Science*, 6, 389-405 (1951)
- Evans, D. C. B., J. F. Nye, and K. J. Cheeseman, "The kinetic friction of ice," *Proceedings of Royal Society of London A*, 347, 493-512 (1976)
- Gubler, H., "Strength of bonds between ice grains after short contact times," *Journal of Glaciology*, 28, No. 100, 457-473 (1982)
- Slotfeldt-Ellingsen, D., and L. Torgersen, "Water in ice: influence on friction," *Journal of Physics D: Applied Physics*, 16, 1715-1719 (1983)
- Mendelson, K. S., (letter) "Why is ice so slippery?" *American Journal of Physics*, 53, No. 5, 393 (May 1985)
- Colbeck, S. C., "Of wet snow, slush & snowballs," *Weatherwise*, 39, 314-318 (December 1986)
- Hayes, W., "Premelting," *Contemporary Physics*, 27, No. 6, 519-532 (1986)
- Colbeck, S. C., "The kinetic friction of snow," *Journal of Glaciology*, 34, No. 116, 78-86 (1988)
- Silberman, R., (letter) "Ice-skating and the ice-water equilibrium," *Journal of Chemical Education*, 65, No. 2, 186 (February 1988)
- Edmiston, M. D., and R. D. Edge, (letters) "Does skating melt ice?" *Physics Teacher*, 27, 327 (May 1989)
- Dash, J. G., "Surface melting," *Contemporary Physics*, 30, No. 2, 89-100 (1989)
- Frenken, J. W. M., "Surface melting," *Endeavour*, 14, No. 1, 2-7 (1990)
- Oxtoby, D. W., "New perspectives on freezing and melting," *Nature*, 347, 725-730 (25 October 1990)
- de Koning, J. J., G. de Groot, and G. J. van Ingen Schenau, "Ice friction during speed skating," *Journal of Biomechanics*, 25, No. 6, 565-571 (1992)
- White, J. D., "The role of surface melting in ice skating," *Physics Teacher*, 30, 495-497 (November 1992)
- Fowler, A. J., and A. Bejan, "Contact melting during sliding on ice," *International Journal of Heat and Mass Transfer*, 36, No. 5, 1171-1179 (March 1993)
- Colbeck, S. C., "Pressure melting and ice skating," *American Journal of Physics*, 63, No. 10, 888-890 (October 1995)
- Dash, J. G., H. Fu, and J. S. Wettlaufer, "The premelting of ice and its environmental consequences," *Reports on Progress in Physics*, 58, 115-167 (1995)
- Kestenbaum, D., "The secret of ice's slippery character," *New Scientist*, 152, 19 (21/28 December 1996)
- Knight, C. A., "Surface layers on ice," *Journal of Geophysical Research*, 101, No. D8, 12,921-12,928 (27 May 1996)
- Baker, M. B., and J. G. Dash, "Comment on 'Surface layers on ice' by C. A. Knight," *Journal of Geophysical Research*, 101, No. D8, 12,929-12,931 (27 May 1996)

- Knight, C. A., “Reply,” *Journal of Geophysical Research*, 101, No. D8, 12,933-12,936 (27 May 1996)
- Colbeck, S. C., L. Najarian, and H. B. Smith, “Sliding temperatures of ice skates,” *American Journal of Physics*, 65, No. 6, 488-492 (June 1997)
- Makkonen, L., “Surface melting of ice,” *Journal of Physical Chemistry B*, 101, 6196-6200 (1997)
- Dash, J. G., “History of the search for continuous melting,” *Reviews of Modern Physics*, 71, No. 5, 1737-1743 (October 1999)
- Doppenschmidt, A., and H-J. Butt, “Measuring the thickness of the liquid-like layer on ice surfaces with atomic force microscopy,” *Langmuir*, 16, 6709-6714 (2000)
- Wettlaufer, J. S., and J. G. Dash, “Melting below zero,” *Scientific American*, 280, 50-53 (February 2000)
- Maeda, N., and V. V. Yaminsky, “Experimental observations of surface freezing,” *International Journal of Modern Physics B*, 15, 3055-3077 (2001)
- Ewing, G. E., “Thin film water,” *Journal of Physical Chemistry B*, 108, No. 41, 15953-15961 (14 October 2004)
- Ladd, B., and M. Follows, (letters) “No-ball snow,” in “The Last Word,” *New Scientist*, 186, No. 2490, inside back cover (12 March 2005)
- Mills, A., “The coefficient of friction, particularly of ice,” *Physics Education*, 43, No. 4, 392-395 (July 2008)

Related references

- Gilpin, R. R., “Wire regelation at low temperatures,” *Journal of Colloid and Interface Science*, 77, No. 2, 435-448 (October 1980)
- Ettema, R., and J. A. Schaefer, “Experiments on freeze-bonding between ice blocks in floating ice rubble,” *Journal of Glaciology*, 32, No. 112, 397-403 (1986)
- Chang, R., and J. F. Skinner, “Ice under pressure,” *Journal of Chemical Education*, 67, No. 9, 789-790 (September 1990)
- Houdijk, H., A. J. Wijker, J. J. de Koning, M. F. Bobbert, and G. de Groot, “Ice friction in speed skating: can klapskates reduce ice frictional loss?” *Medicine & Science in Sports & Exercise*, 33, No. 3, 499-504 (2001)

4.35 Ice walking

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Bruce, M., C. Jones, and D. P. Manning, “Slip-resistance on icy surfaces of shoes, crampons and chains---a new machine,” *Journal of Occupational Accidents*, 7, 273-283 (1986)
- Gronqvist, R., and M. Hirvonen, “Slipperiness of footwear and mechanism of walking on icy surfaces,” *International Journal of Industrial Ergonomics*, 16, 191-200 (1995)
- Gao, C., J. Abeysekera, M. Hirvonen, and C. Aschan, “The effect of footwear sole abrasion on the coefficient of friction on melting and hard ice,” *International Journal of Industrial Ergonomics*, 31, 323-330 (2003)

- Gao, C., J. Abeysekera, M. Hirvonen, and R. Gronqvist, “Slip resistant properties of footwear on ice,” *Ergonomics*, 47, No. 6, 710-716 (2004)

Related reference

- Fathallah, F. A., R. Gronqvist, and J. P. Cotnam, “Estimated slip potential on icy surfaces during various methods of exiting commercial tractors, trailers, and trucks,” *Safety Science* 36, 69-81 (2000)

4.36 Igloos

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=Pia4i5sr0o0> video: Building an igloo

<http://www.youtube.com/watch?v=dTB666s8wwY> Video: building an igloo

http://www.youtube.com/watch?v=83YIR_k542w&mode=related&search= Building an igloo in a blizzard, part 1, TV news clips

<http://www.youtube.com/watch?v=j8KdTjf-zcw&mode=related&search=> More on the news clips

<http://www.phototour.ca/pop/igloo.htm> Photo

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Cook, J., “Architecture indigenous to extreme climates,” *Energy and Buildings*, 23, 277-291 (1996)
- Gonzalez-Espada, J. J., L. A. Bryan, and H-H. Kang, “The intriguing physics inside an igloo,” *Physics Education*, 36, No. 4, 290-292 (July 2001)

4.37 Snowrollers

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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Photos

<http://surfaquarium.com/eIDITAROD/2003/snowrollers.htm> More good photos

http://www.enquirer.com/editions/2003/02/13/tem_snowrollers13.html Photos plus news story

<http://epod.usra.edu/archive/epodviewer.php3?oid=45408> Photo plus description

<http://www.usatoday.com/weather/resources/askjack/wasnow1.htm> Scroll down to the news item and photo

<http://www.atmos.uiuc.edu/~jgrim/photos/wx/photos/roller2.jpg> Photo

<http://www.crh.noaa.gov/ilx/events/roller/roller.php> NOAA’S National Weather Service, brief description plus several really good photos

<http://surfaquarium.com/eIDITAROD/2003/snowrollers.htm> More good photos

http://www.enquirer.com/editions/2003/02/13/tem_snowrollers13.html Photos plus new story

<http://epod.usra.edu/archive/epodviewer.php3?oid=45408> Photo plus description

<http://www.usatoday.com/weather/resources/askjack/wasnow1.htm> Scroll down to the news item and photo

<http://www.atmos.uiuc.edu/~jgrim/photos/wx/photos/roller2.jpg> Photo

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Bridgman, D., (photos) "Snow rollers," *Weather*, 24, 103 (1969)
- Perry, M. J., " Snow Rollers - Lakeburn, N. B., April 5, 1972," *Atmosphere*, 10, 138-139 (1972)
- Goldthorpe, P. R., P. J. Taylor, and B. Fox-Holmes, "Snow rollers," *Weather*, 34, 455-458 (1979)
- Taylor, P. J., and B. Fox-Holmes, (letter) "Snow rollers at Coningsby," *Weather*, 35, 342 (1980)
- Schaefer, D. G., "Snowrollers," *Chinook*, ??, 6-7 (Fall 1980)
- Membro, D. A., "Snow rollers," *Weather*, 36, 16-19 (1981)
- Tam, F. M., "Snowrollers," *Weatherwise*, 35, 276-277 (1982)
- Fox-Holmes, B., (letter) "Snow Rollers," *Weather*, 38, 59 (1983)
- Schakenbach, J. T., (letter) "Snowrollers," *Weatherwise*, 36, No. 2, 93 (April 1983)
- Tam, F. M., (letter) "'Gear teeth' snowrollers," *Weatherwise*, 37, No. 2, 62 (1984)
- Pankratz, A., "Snow rollers," *Chinook*, ??, 54-55 (Fall 1985)
- Malcolm, J., (letter) "Snow rollers," *Weather*, 40, 365, (1985)
- DeMarbre, J.-Y., (letter) "Snow rollers, Winnipeg, 5 December 1990," *Weather*, 46, 327-328 (1991)
- Schlatter, T., "Snowrollers," in "Weather Queries," *Weatherwise*, 49, 42 (December 1996/January 1997)

4.38 Snow avalanche

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=6qVwIuznFW0> Video of skier who causes an avalanche, which then sweeps down the cameraman

http://www.youtube.com/watch?v=Z2L_3QIEgiI&mode=related&search= Video: snowboarder triggers an avalanche

<http://www.youtube.com/watch?v=B0RWLxOFGLY&mode=related&search=> Video of avalanches

<http://www.youtube.com/watch?v=JhUhhbiNHIs&mode=related&search=> Video of snowboarder; very, very dangerous: racing with an avalanche. Music by Wolfmother (one of my favorite groups)

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Lind, D. A., "The physics of snow and avalanche phenomena," *Physics Teacher*, 17, 103-114 (February 1980)
- Colbeck, S. C., "The layered character of snow covers," *Reviews of Geophysics*, 29, No. 1, 81-96 (February 1991)
- McClung, D. M., and J. Schweizer, "Skier triggering, snow temperatures and the stability index for dry-slab avalanche initiation," *Journal of Glaciology*, 45, No. 150, 190-200 (1999)
- Henson, R., "Avalanche! When the snow comes tumbling down," *Weatherwise*, 52, 14-21 (January/February 1999)
- Roach, M., "Avalanche!" *Discover*, 20, No. 12, 88-93 (December 1999)

- Schweizer, J., "Review of dry snow slab avalanche release," Cold Regions Science and Technology, 30, 43-57 (1999)
- Schweizer, J., and J. B. Jamieson, "Snow cover properties for skier triggering of avalanches," Cold Regions Science and Technology, 33, 207-221 (2001)
- Astrom, J. A., and J. Timonen, "Fracture mechanics of snow avalanches," Physical Review E, 64, article # 011305 (4 pages) (2001)
- Perkins, S., "Avalanche! Scientists are digging out the secrets of lethal flows of snow," Science News, 161, 136-137 (2 March 2002)
- Schweizer, J., J. B. Jamieson, and M. Schneebeli, "Snow avalanche formation," Reviews of Geophysics, 41, No. 4, article number 1016 (15 November 2003)
- Wolman, D., "Charge of the ice brigade," New Scientist, 180, 44-46 (20/27 December 2003/3 January 2004)

Related references

- Falk, M., H. Brugger, and L. Adler-Kastner, "Avalanche survival chances," Nature, 368, 21 (3 March 1994)
- Burtscher, M., "Avalanche survival chances," Nature, 371, No. 6497, 482 (6 October 1994)
- Radwin, M. I., C. K. Grissom, "Technological advances in avalanche survival," Wilderness and Environmental Medicine, 13, No. 2, 143-152 (summer 2002)

4.39 Patterns formed by melting snow

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Mehrotra, R., and D. Kumar, "Patterns in melting snow and vapor deposited layers," Physical Review Letters, 92, No. 25, article # 254502 (4 pages) (25 June 2004)

4.40 Salting icy sidewalks

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Walker, J., "The physics of grandmother's peerless homemade ice cream," in "The Amateur Scientist," Scientific American, 250, No. 4, 150-153 (April 1984)

- Franzen, H. F., "The freezing point depression law in physical chemistry. Is it time for a change?" *Journal of Chemical Education*, 65, No. 12, 1077-1078 (December 1988)
- Ball, J., R. C. Cooke, and G. Willis, "Teaching freezing point lowering," *Journal of Chemical Education*, 67, No. 8, 676-677 (August 1990)
- Bohren, C., "Melting with salt and heating with ice," in "Simple Experiments in Atmospheric Physics," *Weatherwise*, 46, No. 6, 46-48 (December 1993/January 1994)
- Herrmann, F., "Answer to Question #56. Ice cream making," *American Journal of Physics*, 65, No. 12, 1135-1136 (December 1997)
- Mitschele, J., "Answer to Question #56. Ice cream making," *American Journal of Physics*, 65, No. 12, 1136 (December 1997)

4.41 Homemade ice cream

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<http://www.youtube.com/watch?v=l9c5rmDQ9DE&mode=related&search=> Video

http://www.country-freezer.com/cf_20.JPG Photo

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Martino, J., "Ice cream: delicious chemistry," *Journal of Chemical Education*, 60, 1004 (1983)
- Walker, J., "The physics of Grandmother's peerless homemade ice cream," in "The Amateur Scientist," *Scientific American*, 250, No. 4, 150-153 (April 1984)
- Rathjen, D., "The sweet taste of science," *Exploratorium Quarterly*, 13, 16 (summer 1989)
- Ball, J., R. C. Cooke, and G. Willis, "Teaching freezing point lowering," *Journal of Chemical Education*, 67, No. 8, 676-677 (August 1990)
- Donhowe, D. P., R. W. Hartel, and R. L. Bradley Jr., "Determination of ice crystal size distributions in frozen desserts," *Journal of Dairy Science*, 74, 3334-3344 (1991)
- Gibbon, D. L., K. Kennedy, N. Reading, and M. Quiroz, "The thermodynamics of home-made ice cream," *Journal of Chemical Education*, 69, No. 8, 658-661 (August 1992)
- Bohren, C., "Melting with salt and heating with ice," in "Simple Experiments in Atmospheric Physics," *Weatherwise*, 46, No. 6, 46-48 (December 1993/January 1994)
- Kurti, N., and H. This-Benckhard, "Chemistry and physics in the kitchen," *Scientific American*, 270, No. 4, 66-71 (April 1994)
- Funderburg, A., "The inside scoop," *Invention & Technology*, 11, No. 3, 44-49 (Winter 1996)
- Donhowe, D. P., and R. W. Hartel, "Recrystallization of ice during bulk storage of ice cream," *International Dairy Journal*, 6, 1209-1221 (1996)
- Hagiwara, T., and R. W. Hartel, "Effect of sweetener, stabilizer, and storage temperature on ice recrystallization in ice cream," *Journal of Dairy Science*, 79, 735-744 (1996)
- Donhowe, D. P., and R. W. Hartel, "Recrystallization of ice in ice cream during controlled accelerated storage," *International Dairy Journal*, 6, 1191-1208 (1996)
- Hartel, R. W., "Ice crystallization during the manufacture of ice cream," *Trends in Food Science & Technology*, 7, 315-321 (October 1996)

- Herrmann, F., “Answer to Question #56. Ice cream making,” American Journal of Physics, 65, No. 12, 1135-1136 (December 1997)
- Mitschele, J., “Answer to Question #56. Ice cream making,” American Journal of Physics, 65, No. 12, 1136 (December 1997)
- Goff, H. Douglas, “Colloidal aspects of ice cream---A review,” Internal Dairy Journal, 7, 363-373 (1997)
- Goff, H. D., “Instability and partial coalescence in whippable dairy emulsions,” Journal of Dairy Science, 80, 2620-2630 (1997)
- Dubey, U. K., and C. H. White, “Ice cream shrinkage: a problem for the ice cream industry,” Journal of Dairy Science, 80, 3439-3444 (1997)
- Goff, H. D., “controlling ice-cream structure by examining fat: protein interactions,” Australian Journal of Dairy Technology, 55, No. 2, 78-81 (June 2000)
- Ablett, S., C. J. Clarke, M. J. Izzard, and D. R. Martin, “Relationship between ice recrystallisation rates and the glass transition in frozen sugar solutions,” Journal of the Science of Food and Agriculture, 82, 1855-1859 (2002)
- Clarke, C., “The physics of ice cream,” Physics Education, 38, No. 43, 248-253 (2003)
- Cogne, c., P. Laurent, J. Andrieu, and J. Ferrand, “Experimental data and modelling of ice cream freezing,” Chemical Engineering Research & Design, Transactions IChemE, 81, A9, 1129-1135 (October 2003)
- Caillet, A., C. Cogne, J. Andrieu, P. Laurent, and A. Rivoire, “Characterization of ice cream structure by direct optical microscopy. Influence of freezing parameters,” Lebensmittel-Wissenschaft und Technologie. Food Science and Technology, 36, 743-749 (2003)
- Marschall, R. T., and D. Goff, “Formulating and manufacturing ice cream and other frozen desserts,” Food Technology, 57, No. 5, 32-45 (May 2003)
- Cailliau, R., L. Wallace, T. Jackson, S. Scarle, and R. Hancock, (letters) “Ice makers,” in “The Last Word,” New Scientist, 183, 2458, inside back cover (31 July 2004); available at NewScientist.com under “freezing”
- McGee, H., *On Food and Cooking. The Science and Lore of the Kitchen*, revised, Scribner, 2004, pages 39-44
- Clarke C., *The Science of Ice Cream*, Royal Society of Chemistry, 2004
- Pronk, P., T. M. Hansen, C. A. Infante Ferreira, and G. J. Witkamp, “Time-dependent behavior of different ice slurries during storage,” 28, 27-36 (2005)

Related references

- Kerr, W. L., and D. S. Reid, “Thermodynamics and frozen foods,” Physics Teacher, 31, 52-55 (January 1993)
- Pronk, P., T. M. Hansen, C. A. I. Ferreira, and G. J. Witkamp, “Time-dependent behavior of different ice slurries during storage,” International Journal of Refrigeration, 28, 27-36 (2005)

4.42 Drinking hot coffee, eating hot pizza

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Nahlieli, O., E. Eliav, Y. Shapira, and A. M. Baruchin, “Central palatal burns associated with the eating of microwaved pizzas,” *Burns*, 25, 465-466 (1999)
- Lee, Y-S., E. Carstens, and M. O’Mahony, “Drinking hot coffee: why doesn’t it burn the mouth?” *Journal of Sensory Studies*, 18, No. 1, 19-32 (March 2003)

4.43 Boiling water

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Aitken, J., “On boiling, condensing, freezing, and melting,” *Transactions of the Royal Scottish Society of Arts*, 9, ?? (1874-1875), reprinted in *Collected Scientific Papers of John Aitken*, Cambridge University Press, 1923, pages 7-17
- Rohsenow, W. M., “Boiling,” *Annual Review of Fluid Mechanics*, 3, 211-236 (1971)
- Walker, J., “What happens when water boils is lot more complicated than you might think,” in “The Amateur Scientist,” *Scientific American*, 247, No. 6, 162-171 + 178 (December 1982)
- Walker, J., (essay) “Boiling and the Leidenfrost effect,” in *Fundamentals of Physics*, 3rd edition, by D. Halliday and R. Resnick, John Wiley & Sons, 1988, pages E10-1 through E10-6
- Bohren, C., “Boil and bubble, toil and trouble,” in “Simple Experiments in Atmospheric Physics,” *Weatherwise*, 42, 104-108 (April 1989)
- Aljishi, S., and J. Tatarkiewicz, “Why does heating water in a kettle produce sound,” *American Journal of Physics*, 59, No. 7, 628-632 (July 1991)
- Zahn, D., “How does water boil?” *Physical Review Letters*, 93, article # 227801 (2004)

Related references

- Winterton, R. H. S., “Nucleation of boiling and cavitation,” *Journal of Physics D: Applied Physics*, 10, 2041-2056 (1977)
- Mahoney, J., “Heating water: to cover or not to cover?” *Physics Teacher*, 17, No. 4, 259 (April 1979)
- Gallagher, J. P., and R. H. S. Winterton, “Confirmation of the pressure history theory of boiling nucleation,” *Journal of Physics D: Applied Physics*, 18, 843-859 (1985)
- Zablotskii, V. A., Y. A. Mamalui, and T. A. Polyakova, “Bubbles and vortices in boiling water,” *European Journal of Physics*, 14, 189-190 (1993)

4.44 Boiling an egg

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Trotman-Dickerson, A. F., “High altitude egg-boiling,” *Journal of Chemical Education*, 45, No. 9, 557 (September 1968)
- Rund, J. V., and A. O. Long, (letters) “The hard-boiled controversy,” *Journal of Chemical Education*, 46, No. 12, 879 (December 1969)
- Gatz, C. R., (letter) “Egg boiling,” *Journal of Chemical Education*, 46, No. 8, 534-535 (August 1969)
- Dwek, R. A., and G. Navon, (letter) “On boiling an egg,” *Nature*, 240, 491 (22 December 1972)
- Plassman, E. H., (letter) “On boiling an egg,” *Nature*, 242, 258 (23 March 1973)
- Grosser, A. E., “The culinary alchemy of eggs,” *American Scientist*, 71, 129-131 (March-April 1983)
- Schlotzhauer Jr., W., and A. E. Grosser, (letters) “Egg alchemy,” *American Scientist*, 71, 345-346 (July-August 1983)
- Negret, J. P., “Boiling water and the height of mountains,” *Physics Teacher*, 24, No. 5, 290-292 (May 1986)
- Bohren, C., “Boil and bubble, toil and trouble,” in “Simple Experiments in Atmospheric Physics,” *Weatherwise*, 42, 104-108 (April 1989)
- Kurti, N., and H. This-Benckhard, “Chemistry and physics in the kitchen,” *Scientific American*, 270, No. 4, 66-71 (April 1994)
- Roura, P., J. Fort, and J. Saurina, “How long does it take to boil an egg? A simple approach to the energy transfer equation,” *European Journal of Physics*, 21, 95-100 (2000)
- McGee, H., *On Food and Cooking. The Science and Lore of the Kitchen*, revised, Scribner, 2004, pages 87-89
- Buay, D., S. K. Foong, D.Kiang, L. Kuppan, and V. H. Liew, “How long does it take to boil an egg? Revisited,” *European Journal of Physics*, 27, 119-131 (2006)

Related references

- Frost, D. L., “Dynamics of explosive boiling of a droplet,” *Physics of Fluids*, 31, No. 9, 2554-2561 (September 1988)
- Bressani, R., and C. Chon, “Effects of altitude above sea level on the cooking time and nutritional value of common beans,” *Plant Foods for Human Nutrition*, 49, 53-61 (January 1996)

4.45 Cooking in a stove or over flames

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Klamkin, M. S., “On cooking a roast,” *SIAM Review*, 3, No. 2, 167-169 (April 1961)
- Kurti, N., “The physicist in the kitchen,” *Proceedings of the Royal Institution of Great Britain*, 42, 451-467 (1969)
- Plumb, R. C., and A. Davis, “Cooking succulent roasts,” in “Chemical Principles Exemplified,” *Journal of Chemical Education*, 50, No. 6, 425 (June 1973)
- Bengtsson, N. E., B. Jakobsson, and M. Dagerskog, “Cooking of beef by oven roasting: a study of heat and mass transfer,” *Journal of Food Science*, 41, 1047-1053 (1976)

- Kamman, M., *The Making of a Cook*, Atheneum, 1978
- Ruebush, J., and R. Fisk, "Cooking a turkey," *Mathematics Magazine*, 53, No. 4, 237-239 (September 1980)
- Gorsser, A. E., *The Cookbook Decoder, or Culinary Alchemy Explained*, Beufort Books, 1981
- McGee, H., *On Food and Cooking: The Science and Lore of the Kitchen*, Charles Scribner's Sons, pages 608-624 (1984)
- Cox, G., "Some like it hot. . ." *Physics Bulletin*, 38, 444 (1987)
- Townsend, M. A., S. Gupta, and W. H. Pitts, "Optimal roasting," *Journal of Food Process Engineering*, 11, 117-145 (1989)
- Townsend, M. A., S. Gupta, and W. H. Pitts, "The roast: nonlinear modeling and simulation," *Journal of Food Process Engineering*, 11, 17-42 (1989)
- Barham, P., "Talking turkey," *New Scientist*, 128, 18-20 (22/29 December 1990)
- Fowler, A. J., and A. Bejan, "The effect of shrinkage on the cooking of meat," *International Journal of Heat and Fluid Flow*, 12, No. 4, 375-383 (December 1991)
- Kurti, N., and H. This-Benckhard, "Chemistry and physics in the kitchen," *Scientific American*, 270, No. 4, 66-71 (April 1994)
- Chang, H. C., J. A. Carpenter, and R. T. Toledo, "Modeling heat transfer during oven roasting of unstuffed turkeys," *Journal of Food Science*, 63, No. 2, 257-261 (1998)
- Chang, H. C., J. A. Carpenter, and R. T. Toledo, "Temperature histories at critical points recommended cooking time for whole turkeys baked in a conventional oven," *Journal of Food Science*, 63, No. 2, 262-266 (March-April 1998)
- McGee, H., J. McInerney, and A. Harrus, "The virtual cook: modeling heat transfer in the kitchen," *Physics Today*, 52, No. 11, 30-36 (November 1999)
- Obuz, E., T. H. Powell, and M. E. Dikeman, "Simulation of cooking cylindrical beef roasts," *Lebensmittel-Wissenschaft und Technologie*, 35, No. 8, 637-644 (2002)
- Tran, N. L., C. P. Salmon, M. G. Knize, and M. E. Colvin, "Experimental and simulation studies of heat flow and heterocyclic amine mutagen/carcinogen formation in pan-fried meat patties," *Food and Chemical Toxicology*, 40, 673-684 (2002)
- Obuz, E., M. E. Dikeman, L. E. Erickson, M. C. Hunt, and T. J. Herald, "Predicting temperature profiles to determine degree of doneness for beef *biceps femoris* and *longissimus lumborum* steaks," *Meat Science*, 67, 101-105 (2004)
- McGee, H., *On Food and Cooking. The Science and Lore of the Kitchen*, revised, Scribner, 2004, page 147-165

Related references

- Walker, J., "Gismos that apply non-obvious physical principles to the enjoyment of cooking," in "The Amateur Scientist," *Scientific American*, 250, 146-153 + 154 (June 1984)
- Walker, J., "Cooking outdoors with simple equipment demonstrates aspects of thermal physics," *Scientific American*, 253, No. 2, 114-118 (August 1985)
- Wandsnider, L., "The roasted and the boiled: food composition and heat treatment with special emphasis on pit-hearth cooking," *Journal of Anthropological Archaeology*, 16, 1-48 (1997)

4.46 Campfire cooking

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.kickassbbq.com/chimney.jpg> Photo

<http://www.campfiredude.com/campfire-cooking.shtml> Photos plus descriptions

References

Dots • through ●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Thomas, D., *Roughing It Easy*, Warner Books, 1975
- Thomas, D., *Roughing It Easy 2*, Warner Books, 1977
- Bosell, J., *The U.S. Armed Forces Survival Manual*, Rason, Wade Publishers, Inc., 1980
- Brown, T., Jr., and B. Morgan, *Tom Brown's Field Guide to Wilderness Survival*, Berkley Books, Chapter 7, ISBN 0425077020
- Walker, J., "Cooking outdoors with simple equipment demonstrates aspects of thermal physics," in "The Amateur Scientist," *Scientific American*, 253, No. 2, 114-118 + 120 (August 1985)

Related references

- Ficken, G. W., Jr., "Convection-driven roasting spits," *Physics Teacher*, 29, 386 (September 1991)
- Kammen, D. M., "Cookstoves for the developing world," *Scientific American*, 273, 72-75 (July 1995)
- Wandsnider, L., "The roasted and the boiled: food composition and heat treatment with special emphasis on pit-hearth cooking," *Journal of Anthropological Archaeology*, 16, 1-48 (1997)

4.47 Cooking pizza

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Rudan, M. A., and D. M. Barbano, "A model of mozzarella cheese melting and browning during pizza baking," *Journal of Dairy Science*, 81, No. 8, 2312-2318 (August 1998)
- Dumas, C., and G. S. Mittal, "Heat and mass transfer properties of pizza during baking," *International Journal of Food Properties*, 5, No. 1, 161-177 (2002)

4.48 Heating in a microwave oven

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=nkM8XpY3ItA&feature=related> Adding powder to water that has been superheated in a microwave oven

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Perlman, A., “Hazards of a microwave oven,” *New England Journal of Medicine*, 302, No. 17, 970-971 (24 April 1980)
- Washisu, S., and I. Fukai, “A simple method for indicating the electric field distribution in a microwave oven,” *Journal of Microwave Power*, 15, No. 1, 59-61 (1980)
- Watkins, K. W., “Heating in microwave ovens. An example of dipole moments in action,” *Journal of Chemical Education*, 60, No. 12, 1043-1044 (December 1983)
- Apfel, R. E., and R. L. Day, (letter) “Initiating boiling with ice,” *Nature*, 321, 657 (12 June 1986)
- Parsons, A., (letter) “Espresso coffee emporia take note,” *Nature*, 322, 316 (24 July 1986)
- Walker, J., “The secret of a microwave oven's rapid cooking action is disclosed,” in “The Amateur Scientist,” *Scientific American*, 256, No. 2, 134-138 (February 1987)
- Lin, Y. E., and R. C. Anantheswaran, “Studies on popping of popcorn in a microwave oven,” *Journal of Food Science*, 53, No. 6, 1746-1749 (November-December 1988)
- Davis, J., (letter) “Storm in a teacup,” *New Scientist*, 121, 72 (14 January 1989)
- Steyn-Ross, A., and A. Riddell, “Standing waves in a microwave oven,” *Physics Teacher*, 28, 474-475 (October 1990)
- Bowden, P., “Cook it and see,” *New Scientist*, 125, 69 (17 March 1990)
- Andereck, B. S., (letter) “Microwave hot spots,” *Physics Teacher*, 28, 580 (December 1990)
- Newman, S. B., (letter, with reply by C. Bohren) “Foamy coffee,” *Weatherwise*, 43, 182 + 235 (August 1990)
- Singh, J., P. Shah, G. A. Sutton, (letter) “Exploding eggs,” *New England Journal of Medicine*, 325, No. 24, 1749 (12 December 1991)
- Bradford, G. E., and R. A. Burstine, (letter) “Exploding eggs,” *New England Journal of Medicine*, 325, No. 24, 1749 (12 December 1991)
- Ng, K.-H., “Microwave ovens: mapping the electrical field distribution,” *Medical Laboratory Sciences*, 48, No. 3, 189-192 (July 1991)
- Corridan, P., J. Hsuan, N. J. Price, and P. J. McDonnell, “Exploding microwaved eggs,” *British Medical Journal*, 304, No. 6833, 1053 (18 April 1992)
- Mounsey, G., (letter) “Exploding eggs,” *New Scientist*, 133, 62 (1 February 1992)
- DeMatteo, M. P., and M. P. Vrabc, (letter) “Intraocular trauma from a microwave oven,” *American Journal of Ophthalmology*, 114, No. 1, 99-100 (July 1992)
- Jason, A. C., and D. H. Tomlin, (letter), “Something’s cookin’,” *Physics World*, 6, 13-14 (February 1993)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, 4th edition, 1993, pages 670-671; 5th edition, 1997, page 570
- Fu, Y. C., C. H. Tong, and D. B. Lund, “Microwave bumping: quantifying explosions in foods during microwave heating,” *Journal of Food Science*, 59, No. 4, 899-904 (1994)
- Kurti, N., and H. This-Benckhard, “Chemistry and physics in the kitchen,” *Scientific American*, 270, No. 4, 66-71 (April 1994)
- Ford, G. R., and C. L. Horrocks, “Hazard of microwave cooking: direct thermal damage to the pharynx and larynx,” *Journal of Laryngology and Otology*, 108, No. 6, 509-510 (June 1994)
- Bucheit, F., “Hot spots in the morning,” *Physics Teacher*, 32, 199 (April 1994)
- Shukla, P. C., “Ocular burn from microwaved egg,” *Pediatric Emergency Care*, 10, No. 4, 229-230 (August 1994)
- Bohren, C. F., “Answer to Question #46 [“How does the microwave oven really work?,” Clifford Swartz, *Am. J. Phys.* 64 (7), 839 (1996)],” *American Journal of Physics*, 65, No. 1, 12 (January 1997)

- Peyre, F., A. Datta, and C. Seyler, "Influence of the dielectric property on microwave oven heating patterns: application to food materials," *Journal of Microwave Power and Electromagnetic Energy*, 32, No. 1, 3-15 (1997)
- Yook, R. T., P. M. Rivera, J. P. Campbell, and S. I. Butrus, (letter) "Corneal injury from explosion of microwaves eggs," *American Journal of Ophthalmology*, 125, No. 3, 390-392 (March 1998)
- Godwin, Y., (letter) "Egg on your face," *Burns*, 24, 584-586 (1998)
- Viiri, J., "Temperature distribution in a microwave oven," *Physics Teacher*, 36, 48 (January 1998)
- Nahlieli, O., E. Eliav, Y. Shapira, and A. M. Baruchin, "Central paplatal burns associated with the eating of microwaved pizzas," *Burns*, 25, 465-466 (1999)
- Wolf, Y., N. Adler, and D. J. Hauben, "Exploding microwaved eggs---revisted," *Burns*, 27, 853-855 (2001)
- Fung, A. E., and K. W. Oxford, "Microwave-superheated Vics Vapo-Rub: an ocular public health danger," *American Journal of Ophthalmology*, 137, No. 2, 379-380 (February 2004)
- Gagnon, M. R., and K. A. Walter, "Ocular surface injury from a microwave superheated liquid," *Cornea*, 23, No. 2, 204-206 (March 2004)
- Gianino, C., "A lesson in the physics laboratory on the superheating of water," *American Journal of Physics*, 75, No. 6, 496-498 (June 2007)
- Kamol, S., P. Limsuwan, and W. Onreabroy, "Three-dimensional standing waves in a microwave oven," *American Journal of Physics*, 78, No. 5, 492-495 (May 2010)

Related reference

- Routhier, P., A. H. Matlin, and R. E. Ishman, (letter) "Eye injury from microwave popcorn," *New England Journal of Medicine*, 315, No. 21, 1359 (20 November 1986)

4.49 Popping popcorn

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Hosney, R. C., K. Zeleznak, and A. Abdelrahman, "Mechanism of popping popcorn," *Journal of Cereal Science*, 1, 43-52 (1983)
- Lin, Y. E., and R. C. Anantheswaran, "Studies on popping of popcorn in a microwave oven," *Journal of Food Science*, 53, No. 6, 1746-1749 (November-December 1988)
- Pordesimo, L. O., R. C. Anatheswaran, A. M. Fleischmann, Y. E. Lin, and M. A. Hanna, "Physical properties as indicators of popping characteristics of microwave popcorn," *Journal of Food Science*, 55, No. 5, 1352-1355 (September-October 1990)
- Hunt, R. G., "The physics of popping popcorn," *Physics Teacher*, 29, 230-235 (April 1991)
- Mohamed, A. A., R. B. Ashman, and A. W. Kirleis, "Pericarp thickness and other kernel physical characteristics relate to microwave popping quality of popcorn," *Journal of Food Science*, 58, No. 2, 342-346 (March-April 1993)
- Da Silva, W. J., B. C. Vidal, M. E. Q. Martins, H. Vargas, A. C. Pereira, M. Zerbetto, and L. C. M. Miranda, "What makes popcorn pop," *Nature*, 362, No. 6419, 417 (1 April 1993)

- Singh, J., and N. Singh, “Effects of different ingredients and microwave power on popping characteristics of popcorn,” *Journal of Food Engineering*, 42, 161-165 (1999)
- Hong, D. C., and J. A. Both, “Controlling the size of popcorn,” *Physica A*, 289, 557-560 (2001)
- Shimoni, E., E. M. Dirks, and T. P. Labuza, “The relation between final popped volume of popcorn and thermal-physical parameters,” *Lebensmittel-Wissenschaft und Technologie*, 35, 93-98 (2002)
- Gokmen, S., “Effects of moisture content and popping method on popping characteristics of popcorn,” *Journal of Food Engineering*, 65, 357-362 (2004)
- Ceylan, M. and E. Karababa, “The effects of ingredients on popcorn popping characteristics,” *International Journal of Food Science and Technology*, 39, 361-370 (2004)
- McGee, H., *On Food and Cooking. The Science and Lore of the Kitchen*, revised, Scribner, 2004, pages 479-480
- Byrd, J. E., and M. J. Perona, “Kinetics of popping of popcorn,” *Cereal Chemistry*, 82, No. 1, 53-59 (January-February 2005)
- Tandjung, A. S., S. Janaswamy, R. Chandrasekaran, A. Aboubacar, and B. R. Hamaker, “Role of the pericarp cellulose matrix as a moisture barrier in microwaveable popcorn,” *Biomacromolecules*, 6, 1654-1660 (2005)

Related references

- Allen, T. J., and J. S. Huebner, “Popping corn in a vacuum,” *Physics Teacher*, 14, 168-169 (March 1978)
- Parker, M. L., A. Grant, N. M. Rigby, P. S. Belton, and J. R. N. Taylor, “Effects of popping on the endosperm cell walls of sorghum and maize,” *Journal of Cereal Science*, 30, 209-216 (1999)
- Allred-Coyle, T. A., R. B. Toma, W. Reiboldt, and M. Thakur, “Effects of bag capacity, storage time and temperature, and salt on the expansion volume of microwave popcorn,” *Journal of the Science of Food and Agriculture*, 81, 121-125 (2000)
- Ceylan, M., and E. Karababa, “Comparison of sensory properties of popcorn from various types and sizes of kernel,” *Journal of the Science of Food and Agriculture*, 82, 127-133 (2001)
- Glenn, G. M., and W. J. Orts, “Properties of starch-based foam formed by compression/explosion processing,” *Industrial Crops and Products*, 13, 135-143 (2001)
- Williams, G., “Popping corn packs a punch: but how do you measure the force?” *Physics Education*, 39, 28-30 (January 2004)

4.50 Cooking scrambled eggs

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=C1SM73Qi1BQ> Instruction video. Note the rule about not using salt before the eggs cook.

References

- Dots • through ••• indicate level of difficulty
- Journal reference style: author, title, journal, volume, pages (date)
- Book reference style: author, title, publisher, date, pages
- Kamman, M., *The Making of a Cook*, Atheneum, 1978, Chapter 3
- Walker, J., “The physics and chemistry of the lemon meringue pie,” in “The Amateur Scientist,” *Scientific American*, 244, No. 6, 194-200 (June 1981)
- Gorrser, A. E., *The Cookbook Decoder, or Culinary Alchemy Explained*, Beaufort Books, 1981

- Kurti, N., and H. This-Benckhard, “Chemistry and physics in the kitchen,” *Scientific American*, 270, No. 4, 66-71 (April 1994)
- Kurti, N., and H. This-Benckhard, “The kitchen as a lab,” in “The Amateur Scientist,” *Scientific American*, 270, No. 4, 120-123 (April 1994)
- McGee, H., *On Food and Cooking. The Science and Lore of the Kitchen*, revised, Scribner, 2004, pages 91-92

4.51 Geysers and coffee percolators

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Dort, W., Jr., A. W. Hogan, and G. W. Reynolds, Jr., “Initial periodicity of New Geysers, Yellowstone National Park,” *Journal of Geophysical Research*, 74, 17, 4206-4208 (15 August 1969)
- Rinehart, J. S., “Old Faithful Geysers,” *Physics Teacher*, 7, 221-224 (April 1969)
- Fournier, R. O., “Old Faithful: a physical model,” *Science*, 163, 304-305 (17 January 1969)
- Kieffer, S. W., “Geologic nozzles,” *Reviews of Geophysics*, 27, 1, 3-38 (February 1989)
- Dowden, J., P. Kapadia, G. Brown, and H. Rymer, “Dynamics of geyser eruption,” *Journal of Geophysical Research*, 96, No. B11, 18059-18071 (10 October 1991)
- Ingebritsen, S. E., and S. A. Rojstaczer, “Controls on geyser periodicity,” *Science*, 262, 889-892 (5 November 1993)
- Kedar, S., B. Sturtevant, and H. Kanamori, “The origin of harmonic tremor at Old Faithful Geysers,” *Nature*, 379, No. 6567, 708-711 (22 February 1996)
- Hutchinson, R. A., J. A. Westphal, and S. W. Kieffer, “In situ observations of Old Faithful Geysers,” *Geology*, 25, No. 10, 875-878 (October 1997)
- Perkins, S., “Inside Old Faithful. Scientists look down the throat of a geyser,” *Science News*, 152, 232 (11 October 1997)
- Julian, B. R., “Rumbling geysers (and volcanoes),” *Nature*, 396, No. 6709, 311-312 (26 November 1998)
- Lorenz, R. D., “Thermodynamics of geysers: application to titan,” *Icarus*, 156, 176-183 (2002)
- Rojstaczer, S., D. L. Galloway, S. E. Ingebritsen, and D. M. Rubin, “Variability in geyser eruptive timing and its causes: Yellowstone National Park,” *Geophysical Research Letters*, 30, No. 18, article # 017853 (25 September 2003)
- Gianino, C., “Experimental analysis of the Italian coffee pot ‘moka’,” *American Journal of Physics*, 75, 1, 43-47 (January 2007)

4.52 Toy putt-putt boat

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=boqUUPMT6Gc> Video

<http://www.youtube.com/watch?v=pHf2Ujl3s0c> Video

<http://www.youtube.com/watch?v=K-BoCDiouMU> Video: boat takes a few second before it begins to move

<http://www.sciencetoymaker.org/boat/index.htm> descriptions plus a button to see boats built by lots of people, a button to see patents, and other buttons

<http://www.nmia.com/~vrbaass/pop-pop/> Web site devoted to putt-putt (pop-pop) boats

<http://www.glue-it.com/boats/general-information/glossary/p/putt-putt.html> Sketch plus description

<http://www.puttputtboats.com/edu.html> Description plus photos

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Baker, J. G., “Self-induced vibrations,” *Journal of Applied Mechanics*, 1, No. 1, 5-13 (January-March 1933)
- MacKay, R. S., “Boat driven by thermal oscillations,” *American Journal of Physics*, 26, 583-584 (1958)
- Miller, J. S., “Physics in a toy boat,” *American Journal of Physics*, 26, 199 (1958)
- Finnie, I., and R. L. Curl, “Physics in a toy boat,” *American Journal of Physics*, 31, 289-293 (1963)
- Crane, H. R., “The pop-pop boat,” in “How Things Work,” *Physics Teacher*, 35, 175-177 (March 1997)
- Dobson, R. T., “An open oscillatory heat pipe steam-powered boat,” *International Journal of Mechanical Engineering Education*, 31, No. 4, 339-358 (2003)
- Dijkink, R. J., J. P. van der Dennen, C. D. Ohl, and A. Prosperetti, “The ‘acousticed scallop’: a bubble-powered actuator,” *Journal of Micromechanics and Microengineering*, 16, 1653-1659 (2006)
- Guemez, J., C. Fiolhais, and M. Fiolhais, “Toys in physics lectures and demonstrations---a brief review,” *Physics Education*, 44, No. 1, 53-64 (January 2009)

4.53 Thermal effects on lengths

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.upscale.utoronto.ca/IYearLab/Intros/ThermalExpans/Images/Train1.gif> Old newspaper photo of railway tracks that have buckled by thermal expansion

<http://www.physics.brocku.ca/courses/1p23/Heat/rail.html> Similar photo, with a short discussion

http://tapseis.anl.gov/guide/photo/Above_Ground_Pipe_and_Dalton.html Photo of zig-zag pipe

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Lindsay, D., “The stability of long welded railway track,” *Physics Education*, 1, 182-184 (1966)
- Anderson, C. H., and W. H. Morewood, “Long rails,” in “How Things Work,” *Physics Teacher*, 17, No. 9, 601 + 613 (December 1979)

- Kerr, A. D., "An improved analysis for thermal track buckling," *Int. J. Non-linear Mech.*, 15, 99-114 (1980)
- Tvergaard, V., and A. Needleman, "On localized thermal track buckling," *International Journal of Mechanical Science*, 23, No. 10, 577-587 (1981)
- Hobbs, R. E., "In-service buckling of heated pipelines," *Journal of Transportation Engineering*, 110, No. 2, 175-189 (March 1984)
- Donley, M. G., and A. D. Kerr, "Thermal buckling of curved railroad tracks," *International Journal of Non-Linear Mechanics*, 22, No. 3, 175-192 (1987)
- Versluis, A., W. H. Douglas, and R. L. Sakaguchi, "Thermal expansion coefficient of dental composites measured with strain gauges," *Dental Materials*, 12, 290-294 (September 1996)
- Hayn, C. H., "Thermal contraction and stretching," *Physics Teacher*, 36, 14 (January 1998)
- Agrawal, D. C., and V. J. Menon, "Incandescent bulbs," *Quantum*, ?? , 35-36 (January/February 1998)
- Miles, D. J., and C. R. Calladine, "Lateral thermal buckling of pipelines on the sea bed," *Journal of Applied Mechanics*, 66, No. 4, 891-897 (December 1999)
- Kishen, A., and A. Asundi, "Investigations of thermal property gradients in the human dentine," *Journal of Biomedical Materials Research*, 55, No. 1, 121-130 (2001)
- Soo, S., R. Palmer, and R. V. Curtis, "Measurement of the setting and thermal expansion of dental investments used for the superplastic forming of dental implant superstructures," *Dental Materials*, 17, 247-252 (2001)
- Panas, A. J., J. Terpilowski, J. Trykowski, P. Zaborowski, and S. Zmuda, "Thermophysical properties of dental filling materials. Part II: thermal expansivity," *High Temperatures-High Pressures*, 33, No. 5, 589-597 (2001)
- Nystrom, P. R., K. Tornes, J. S. Karlsen, G. Endal, and E. Levold, "Design for thermal buckling of Asgard transport gas trunkline," *International Journal of Offshore and Polar Engineering*, 12, No. 4, 271-279 (December 2002)
- Lim, N-H., N-H. Park, and Y-J. Kang, "Stability of continuous welded rail track," *Computers and Structures*, 81, 2219-2236 (2003)

Related reference

- Palmer, A. C., and P. J. Williams, "Frost heave and pipeline upheaval buckling," *Canadian Geotechnical Journal*, 40, 1033-1038 (2003)

4.54 Collapse of railroad storage tank

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://video.aol.com/video-detail/railroad-tank-car-implosion/108399741> video, a railroad tanker car

http://www.youtube.com/watch?v=E_hci9vrvfw&feature=related same video

<http://blog.onlinemetals.com/?tag=rail-car-implosion> photos of accident

<http://mattson.creighton.edu/BarometricPressure/Tankerview1.jpg> Photo of the crushed tanker car

<http://www.delta.edu/slime/can crush.html> Another photo

<http://www.youtube.com/watch?v=Uy-SN5j1ogk&feature=related> barrel heated, sealed, and then floated in water to cool

<http://www.youtube.com/watch?v=GgRjPdkPkzs&feature=related> high-speed video of can being crushed by air pressure

<http://www.youtube.com/watch?v=z1657tCCudw&feature=related> can crush in a classroom setting
<http://www.youtube.com/watch?v=0fy4TLMNb6s&feature=related> classic television with Julius
 Summer Miller
<http://www.youtube.com/watch?v=XejHq8AQxQE> Barrel is first heated, then sealed, and then cooled
 with water.
<http://www.youtube.com/watch?v=r2yUcnnQX1Q&NR=1> University of Minnesota physics
 demonstration
http://www.youtube.com/watch?v=_yRBb8k1ScI&feature=related Rhodes College, barrel crush and a
 bit of football chanting

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- de Nevers, N., “Vacuum collapse of vented tanks,” *Process Safety Progress*, 15, No. 2, 74-79 (Summer 1996)
- Griffin, M. L., “Protecting atmospheric storage tanks against vacuum collapse,” *Journal of Loss Prevention*, 13, 83-89 (2000)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, John Wiley & Sons, 7th edition, 2005, page 507
- Griffin, M. L., “Protecting atmospheric storage tanks against vacuum collapse,” *Journal of Loss Prevention in the Process Industries*, 13, 83-89 (2000)
- Cronin, K., and S. Baker, “Prediction of the collapse time of a process storage vessel due to internal steam condensation,” *Proceedings of the Institute of Mechanical Engineers, Part E, Journal of Process Mechanical Engineering*, 220, E2, 89-98 (May 2006)
- Cronin, K., and S. Baker, “Analysis of the variability in collapse time of a process storage vessel due to internal steam condensation,” *Proceedings of the Institute of Mechanical Engineers, Part E, Journal of Process Mechanical Engineering*, 222, E3, 171-181 (August 2008)

4.55 Drying of hanging laundry

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Hansen, E. B., “On drying of laundry,” *SIAM Journal of Applied Mathematics*, 52, No. 5, 1360-1369 (October 1992)

Related reference

- Ilic, M., “A class of moving boundary problems arising in drying processes,” *SIAM Journal of Applied Mathematics*, 52, No. 5, 1342-1359 (October 1992)

4.56 Warm coats

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Kelley, J. B., "Heat, cold and clothing," *Scientific American*, 194, 109-116 + 146 (February 1956)
- Irving, L., "Adaptations to cold," *Scientific American*, 214, 94-101 + 135 (January 1966)
- Dixon, J. C., "Wind-chill---it's sensational," *Weather*, 46, 141-144 (1991)
- Danielsson, U., "Windchill and the risk of tissue freezing," *Journal of Applied Physiology*, 81, No. 6, 2666-2673 (1996)
- Yan, Y. Y., and J. E. Oliver, "The clo: a utilitarian unit to measure weather/climate comfort," *International Journal of Climatology*, 16, No. 9, 1045-1056 (1996)

Related reference

- Gamble, W. B., and E. R. Bonnetcarre, "Coffee, tea, or frostbite? A case report of inflight freezing hazard from dry ice," *Aviation, Space, and Environmental Medicine*, 67, No. 9, 880-881 (September 1996)

4.57 Warm plants

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.sciencenews.org/articles/20031213/bob9.asp> News item plus photos, including one of a plant that has melted snow

<http://www.darbycreeks.org/skunk%20cabbage%2072.jpg> Skunk cabbage has melted the snow around it.

<http://biolessondeblog.blogspot.com/2007/01/interesting-fact.html> The blog spot that contains that photo.

<http://www.uwgb.edu/biodiversity/phenology/2003/symfoe20030316uwgb.jpg> Photo

http://www.deanswildflowers.com/Blog/Fe08_WL_SCabbage1.jpg Photo

<http://www.fosc.org/Images/SkunkCabbage.jpg> Photo

<http://www.pathcom.com/~wgbz/xv040tri.jpg> Photos

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Knutson, R. M., "Plants in heat," *Natural History*, 88, 42-47 (1979)
- Diamond, J. M., "Hot sex in voodoo lilies," *Nature*, 339, No. 6222, 258-259 (25 May 1989)

- Lamprecht, I., K. Drong, B. Schaarschmidt, and G. Welge, "Some like it hot --- calorimetric investigations of voodoo lilies," *Thermochimica Acta*, 187, 33-40 (30 September 1991)
- Seymour, R. S., and P. Schultze-Motel, "Thermoregulating lotus flowers," *Nature*, 383, No. 6598, 305 (26 September 1996)
- Seymour, R. S., "Plants that warm themselves," *Scientific American*, 276, No. 3, 104-109 (March 1997)
- Seymour, R. S., and P. Schultze-Motel, "Heat-producing flowers," *Endeavour*, 21, No. 3, 125-129 (1997)
- Seymour, R. S., P. Schultze-Motel, and I. Lamprecht, "Heat production by sacred lotus flowers depends on ambient temperature, not light cycle," *Journal of Experimental Botany*, 49, 1213-1217 (1998)
- Seymour, R. S., and P. Schultze-Motel, "Physiological temperature regulation by flowers of the sacred lotus," *Philosophical Transactions of the Royal Society of London*, B, 353, 935-943 (1998)
- Seymour, R. S., "Pattern of respiration by intact inflorescences of the thermogenic arum lily *Philodendron selloum*," *Journal of Experimental Botany*, 50, 335, 845-852 (June 1999)
- Seymour, R. S., and P. Schultze-Motel, "Respiration, temperature regulation and energetics of thermogenic inflorescences of the dragon lily *Dracunculus vulgaris* (Araceae)," *Proceedings of the Royal Society of London B*, 266, 1975-1983 (1999)
- Seymour, R. S., and A. J. Blaylock, "Switching off the heater: influence of ambient temperature on the thermoregulation by eastern skunk cabbage *Symplocarpus foetidus*," *Journal of Experimental Botany*, 50, No. 338, 1525-1532 (September 1999)
- Lytle, C. M., B. N. Smith, M. S. Hopkin, L. D. Hansen, and R. S. Criddle, "Oxygen-dependence of metabolic heat production in the appendix tissue of the voodoo lily (*Sauromatum guttatum* Schott)," *Thermochimica Acta*, 349, 135-140 (2000)
- Patino, S., J. Grace, and H. Banziger, "Endothermy by flowers of *Rhizanthus lowii* (Rafflesiaceae)," *Oecologia*, 124, 149-155 (2000)
- Lamprecht, I., E. Schmolz, L. Blanco, and C. M. Romero, "Flower ovens: thermal investigations on heat producing plants," *Thermochimica Acta*, 391, 107-118 (2002)
- Lamprecht, I., E. Schmolz, S. Hilsberg, and S. Schlegel, "A tropical water lily with strong thermogenic behaviours---thermometric and thermographic investigations on *Victoria cruziana*," *Thermochimica Acta*, 382, 199-210 (2002)
- Milius, S., "Warm-blooded plants? Ok, there's no blood, but they do make their own heat," *Science News*, 164, No. 24, 379-381 (13 December 2003)
- Sacks, O., and G. Almond, (letters) "Warm topic," *Science News*, 165, 95 (7 February 2004)

4.58 Polar-bear hairs

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

- Dots • through ••• indicate level of difficulty
- Journal reference style: author, title, journal, volume, pages (date)
- Book reference style: author, title, publisher, date, pages
- Lavigne, D. M., letter, *Scientific American*, 259, 8 (September 1988)
- Koon, D. W., "Is polar bear hair fiber optic?" *Applied Optics*, 37, No. 15, 3198-3200 (20 May 1998)

4.59 Black robes and black sheep in the desert

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.wonderquest.com/black-robres.htm> News item plus photo

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Shkolnik, A., C. R. Taylor, V. Finch and A. Borut, "Why do Bedouins wear black robes in hot deserts?" *Nature*, 283, 373-375 (24 January 1980)
- Dmi'el, R., A. Prevulotzky and A. Shkolnik, "Is a black coat in the desert a means of saving metabolic energy?" *Nature*, 283, 761-762 (12 February 1980)
- Finch, V. A., R. Dmi'el, R. Boxman, A. Shkolnik, and C. Richard Taylor, "Why black goats in hot deserts? Effects of coat color on heat exchanges of wild and domestic goats," *Physiological Zoology*, 53, No. 1, 19-25 (1980)
- Cloudsley-Thompson, J. L., "Multiple factors in the evolution of animal colouration," *Naturwissenschaften*, 86, 123-132 (1999)

4.60 Cooling rate of a cup of coffee

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Walker, J., "Wonders of physics that can be found in a cup of coffee or tea," in "The Amateur Scientist," *Scientific American*, 237, 246-257 (September 1977)
- Otis, D. R., "Coffee-cup heat transfer," *International Journal of Mechanical Engineering Education*, 5, 239-243 (1977)
- Dennis, C. M., Jr., "Newton's law of cooling or is ten minutes enough time for a coffee break?" *Physics Teacher*, 18, 532-533 (1980)
- Rees, W. G., and C. Viney, "On cooling tea and coffee," *American Journal of Physics*, 56, 434-437 (1988)
- Bartels, R.A., "Do darker objects really cool faster?" *American Journal of Physics*, 58, 244-248 (1990)
- Ward, A., S. Beck, and C. Forrester, (letters) "Milk in tea," *New Scientist*, 135, 52-53 (11 July 1992)
- Greenslade, T. B., Jr., "The coffee and cream problem," *Physics Teacher*, 32, 145-147 (1994)
- Lee, W., (letter) "Coffee and cream," *Physics Teacher*, 32, No. 6, 326-327 (September 1994)
- Lee, H. S., and M. O'Mahony, "At what temperatures do consumers like to drink coffee? Mixing methods," *Journal of Food Science*, 67, No. 7, 2774-2777 (2002)

4.61 Cool water from porous pottery

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Shoemaker, V. H., and C. Sigurdson, (abstract) “Brain cooling via evaporation from the eyes in waterproof treefrog,” *American Zoologist*, 29, No. 4, 106A (1989)
- Zubizarreta, J. I., and G. Pinto, “An ancient method for cooling water explained by mass and heat transfer,” *Chemical Engineering Education*, 29, 96-99 (1995)

Related reference

- Onmura, S., M. Matsumoto, and S. Hokoi, “Study on evaporative cooling effect of roof lawn gardens,” *Energy and Buildings*, 33, 653-666 (2001)

4.62 Dunking bird

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=kjqjWv4eZiE> Video

http://scienceblogs.com/clock/2006/08/bird_magic.php History of the dunking bird

<http://science.howstuffworks.com/question608.htm> Photo plus description

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Raghuram, P. T., and K. K. Rao, “Serendipity in the development of demonstration experiments,” *Indian Chemical Engineering*, 39, 313-320 (1997)
- Miller, J. S., “Physics of the dunking bird,” *American Journal of Physics*, 26, No. 1, 42-43 (January 1958)
- Gaines, J. L., “Dunking duck,” *American Journal of Physics*, 27, 189-190 (1959)
- Kolb, K. B., “‘Reciprocating’ engine,” *Physics Teacher*, 4, 121-122 (March 1966)
- Murrow, R. B., “The research frontier,” *Saturday Review*, 50, 51-55 (3 June 1967)
- Wagner, R. E., “Physical chemistry of the drinking duck,” *Journal of Chemical Education*, 50, No. 3, 213 (March 1973)
- Frank, D. L., “The drinking bird and the scientific method,” *Journal of Chemical Education*, 50, No. 3, 211 (March 1973)
- Plumb, R., “Physical chemistry of the drinking duck,” *Journal of Chemical Education*, 50, No. 3, 212-213 (March 1973), see page 213

- Bent, H. A., and H. J. Teague, "The hydro-thermal-dynamical duck: a sketch of his uses in the classroom and the laboratory," *Journal of College Science Teaching*, 8, No. 1, 18-28 (September 1978)
- Ikuta, K., and S. Fujiwaka, "The sun-mill -- a version of dunking-bird as an energy convertor of Sun's radiation," *Japanese Journal of Applied Physics*, 19, 1173-1176 (1980)
- Bohren, C. F., "Happy ducks, like happy people, perform best with cool heads," in "Simple Experiments in Atmospheric Physics," *Weatherwise*, 35, 234-236 (1982); contained in C. F. Bohren, *Clouds in a Glass of Beer: Simple Experiments in Atmospheric Physics*, John Wiley & Sons, Inc., 1987, Chapter 3
- Bachhuber, C., "Energy from the evaporation of water," *American Journal of Physics*, 51, 259-264 (1983)
- Preston, R. S., "Comment on 'Remark on the second law of thermodynamics'," [*American Journal of Physics* 52, 720 (1984)], *American Journal of Physics*, 53, 1104 (1985)
- Crane, R., "What does the drinking bird know about jet lag?" In "How Things Work," *Physics Teacher*, 27, 470-471 (September 1989)
- Vemulapalli, G. K., "A discourse on the drinking bird," *Journal of Chemical Education*, 67, 457-458 (1990)
- Leinoff, S. E., (letter) "Keeping a cool head," *Physics Teacher*, 31, 263 (1993)
- Ng, L. M., and Y. S. Ng, "The thermodynamics of the drinking bird toy," *Physics Education*, 28, 320-324 (1993)
- Mentzer, R., "The drinking bird---the little heat engine that could," *Physics Teacher*, 31, 126-127 (1993)
- Rogers, G. L., "Duck tale," *Physics World*, 7, 21 (August 1994)
- Kurti, N., (letter) "Discerning ducks," *Physics World*, 7, 19 (September 1994)
- Chagnon, P., "Animated displays V: relaxation oscillators," *Physics Teacher*, 32, No. 7, 432-436 (October 1994)
- Richmond, P., "Thermodynamics and the drinking duck," *Physics World*, 7, No. 6, 80 (June 1994)
- Guemez, J., R. Valiente, C. Fiolhais, and M. Fiolhais, "Experiments with a sunbird," *American Journal of Physics*, 71, No. 12, 1264-1267 (December 2003)
- Guemez, J., R. Valiente, C. Fiolhais, and M. Fiolhais, "Experiments with the drinking bird," *American Journal of Physics*, 71, No. 12, 1257-1263 (December 2003)
- Abraham, N., and P. Palfy-Muhoray, "A dunking bird of the second kind," *American Journal of Physics*, 72, No. 6, 782-785 (June 2004)
- Quickenden, T. I., K. M. Hindmarsh, and K.-G. Teoh, "Experimental study of the Minto engine---a heat engine for converting low grade heat to mechanical energy," *Journal of Solar Energy Engineering—Transactions of the ASME*, 126, No. 1, 661-667 (February 2004)
- Guemez, J., R. Valiente, C. Fiolhais, M. Fiolhais, "A big sunbird," *Physics Teacher*, 42, 307-309 (May 2004); see warning about explosion hazard, "Editor's note: CAUTION: Explosion hazard with ether use in "A big Sunbird" [*Phys. Teach.* 42, 307-309 (May 2004)]," *Physics Teacher*, 42, L-1 (June 2004)
- Lorenz, R., "Finite-time thermodynamics of an instrumented drinking bird toy," *American Journal of Physics*, 74, No. 8, 677-682 (August 2006)
- Guemez, J., C. Fiolhais, and M. Fiolhais, "Toys in physics lectures and demonstrations---a brief review," *Physics Education*, 44, No. 1, 53-64 (January 2009)

4.63 Short Story: Large dunking birds

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Murrow, R. B., "The research frontier," Saturday Review, 50, 51-55 (3 June 1967)
- Abraham, N., and P. Palffy-Muhoray, "A dunking bird of the second kind," American Journal of Physics, 72, No. 6, 782-785 (June 2004)
- Quickenden, T. I., K. M. Hindmarsh, and K-G. Teoh, "Experimental study of the Minto engine---a heat engine for converting low grade heat to mechanical energy," Journal of Solar Energy Engineering—Transactions of the ASME, 126, No. 1, 661-667 (February 2004)

4.64 Heat pipes and potato stickers

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Grover, G. M., T. P. Cotter and G. F. Erickson, "Structures of Very High Thermal Conductance," Journal of Applied Physics, 35, 1990-1991 (1964)
- Eastman, G. Y., "The heat pipe," Scientific American, 218, 38-46 (May 1968)
- Modestino, S. A., "Faster dinner via molecular potential energy," Journal of Chemical Education, 49, 706 (October 1972)
- Tien, C. L., "Fluid Mechanics of Heat Pipes," Annual Review of Fluid Mechanics, 7, 167-185 (1975)
- Walker, J., "Gismos that apply non-obvious physical principles to the enjoyment of cooking," in "The Amateur Scientist," Scientific American, 250, 146-153 + 154 (June 1984)
- Reay, D. A., "Heat Pipes," Physics in Technology, 16, 69-75 (1985)
- James, C., and S. J. James, "The heat pipe and its potential for enhancing the freezing and thawing of meat in the catering industry," International Journal of Refrigeration, 22, 414-424 (1999)
- Ketteringham, L., and S. James, "The use of high thermal conductivity inserts to improve the cooling of cooked foods," Journal of Food Engineering, 45, 49-53 (2000)

4.65 Foggy mirrors

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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<http://www.youtube.com/watch?v=nL0KeVmDRBc> Writing on a foggy mirror, with a bit of music.

http://www.metacafe.com/watch/838882/fun_halloween_prank/

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Baker, T. J., "Breath figures," *Philosophical Magazine*, 44, 752-765 (1952)
- Davey, B. A., "Unusual road surface condensation," *Meteorological Magazine*, 111, 19-22 (1982)
- Bohren, C., "Dew drops on a bathroom mirror" in "Simple Experiments in Atmospheric Physics," *Weatherwise*, 40, 102-106 (1987); contained in C. F. Bohren, *Clouds in a Glass of Beer: Simple Experiments in Atmospheric Physics*, John Wiley & Sons, Inc., 1987, Chapter 7
- Bohren, C., "Window watching," in "Simple Experiments in Atmospheric Physics," *Weatherwise*, 40, 150-153 (1987)
- Briscoe, B. J., and K. P. Galvin, "Breath figures," *Journal of Physics D: Applied Physics*, 23, 1265-1266 (1990)

Related references

- Bohren, C., "All that glistens isn't dew," in "Simple Experiments in Atmospheric Physics," *Weatherwise*, 43, 284-287 (October 1990)
- Fritter, D., C. M. Knobler, and D. A. Beysens, "Experiments and simulation of the growth of droplets on a surface (breath figures)," *Physical Review A*, 43, No. 6, 2858-2869 + Fig. 1 (15 March 1991)
- Noever, D. A., "Order and statistical crystallography of patterned breath figures," *Journal of Colloid and Interface Science*, 174, 92-96 (1995)
- Gau, H., "Ripening of ordered breath figures," *Physical Review Letters*, 84, No. 18, 4156-4159 (1 May 2000)
- Aroussi, A., A. Hassan, and Y. S. Morsi, "Numerical simulation of the airflow over and heat transfer through a vehicle windshield defrosting and demisting system," *Heat and Mass Transfer*, 39, 401-405 (2003)
- Park, W. G., M. S. Park, Y. R. Jung, and K. L. Jang, "Numerical study of defrosting phenomena of automotive windshield glass," *Numerical Heat Transfer, Part A*, 47, No. 7, 725-739 (15 April 2005)

4.66 Condensation on eyeglasses

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Furzeland, R. M., and E. B. Hansen, "The Steaming up of Glasses on Entering a Sauna -- a Novel Moving-Boundary Problem," *IMA Journal of Applied Mathematics*, 34, 247-257 (1985)

Related references

- Briscoe, B. J., and K. P. Galvin, "The effect of surface fog on the transmittance of light," *Solar Energy*, 46, No. 4, 191-197 (1991)

- Aroussi, A., A. Hassan, and Y. S. Morsi, "Numerical simulation of the airflow over and heat transfer through a vehicle windshield defrosting and demisting system," *Heat and Mass Transfer*, 39, 401-405 (2003)

4.67 Water collection in arid regions

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The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.fes.uwaterloo.ca/faculty/newsletter/march2004/fog.html> News story plus photos

<http://www.sciam.com/article.cfm?articleID=000CECBE-91F8-1C75-9B81809EC588EF21&pageNumber=3&catID=4> News story plus photos

<http://www.technovelgy.com/ct/Science-Fiction-News.asp?NewsNum=655> News story plus photos

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Jumikis, A. R., "Aerial wells: secondary sources of water," *Soil Science*, 100, No. 2, 83-95 (1965)
- Hamilton, W. J. and M. K. Seely, "Fog basking in the Namib Desert beetle, *Onymacris unguicularis*," *Nature*, 262, 284-285 (1976)
- Broza, M., "Dew, fog and hygroscopic food as a source of water for desert arthropods," *Journal of Arid Environments*, 2, 43-49 (1979)
- Seely, M. K., "Irregular fog as a water source for desert dune beetles," *Oecologia*, 42, 213-227 (1979)
- Brown, T., Jr., and B. Morgan, *Tom Brown's Field Guide to Wilderness Survival*, Berkley Books, pages 52-54, ISBN 0425077020
- Schwenk, K. and H. W. Greene, "Water collection and drinking in *Phrynocephalus helioscopus*: a possible condensation mechanism," *Journal of Herpetology*, 21, No. 2, 134-139 (1987)
- Schemenauer, R. S., H. Fuenzalida, and P. Cereceda, "A neglected water resource: the Camanchaca of South America," *Bulletin of the American Meteorological Society*, 69, No. 2, 138-147 (February 1988)
- Schemenauer, R. S., and P. Cereceda, "Fog water collection in arid coastal location," *Ambio*, 20, No. 7, 303-308 (November 1991)
- Schemenauer, R. S., and P. Cereceda, "The quality of fog water collected for domestic and agricultural use in Chile," *Journal of Applied Meteorology*, 31, No. 3, 275-290 (March 1992)
- Pearce, F., "Fogs yield drinking water in the desert," *New Scientist*, 140, 19 (16 October 1993)
- Schemenauer, R. S., and P. Cereceda, "Fog collection's role in water planning for developing countries," *Natural Resources Forum*, 18, No. 2, 91-100 (1994)
- Nilsson, T. M. J., W. E. Vargas, G. A. Niklasson, and C. G. Granqvist, "Condensation of water by radiative cooling," *Renewable Energy*, 5, Part I, No. 1-4, 310-317 (August 1994)
- Schemenauer, R. S., and P. Cereceda, "A proposed standard fog collector for use in high-elevation regions," *Journal of Applied Meteorology*, 33, No. 11, 1313-1322 (November 1994)
- Beysens, D., "The formation of dew," *Atmospheric Research*, 39, 215-237 (1995)
- Nikolayev, V. S., D. Beysens, and A. Gioda, "Water recovery from dew," *Journal of Hydrology*, 182, 23-32 (1996)
- Porta-Gandara, M. A., E. Rubio-Cerda, J. L. Fernandez-Zayas, "Visualization of natural convection inside shallow solar stills," *Experiments in Fluids*, 25, 369-370 (1998)

- Alnaser, W. E., and A. Barakat, "Use of condensed water vapour from the atmosphere for irrigation in Bahrain," *Applied Energy*, 65, 3-18 (2000)
- Parker, A. R., and C. R. Lawrence, "Water capture by a desert beetle. This insect has a tailor-made covering for collecting water from early-morning fog," *Nature*, 414, 33-34 (1 November 2001)
- Cloudsley-Thompson, J. L., "Thermal and water relations of desert beetles," *Naturwissenschaften*, 88, No. 11, 447-460 (2001)
- Quere, D., "Rough ideas on wetting," *Physica A*, 313, 32-46 (2002)
- Muselli, M., D. Beysens, J. Marcillat, I. Milimouk, T. Nilsson, and A. Louche, "Dew water collector for potable water in Ajaccio (Corsica Island, France)," *Atmospheric Research*, 64, 297-312 (2002)
- Hamilton, W. J. III, J. R. Henschel, and M. K. Seely, (letter) "Fog collection by Namib desert beetles," *South African Journal of Science* 99, 181 (March/April 2003)
- Kogan, B., and A. Trahtman, "The moisture from the air as water resource in arid region: hopes, doubts and facts," *Journal of Arid Environments*, 53, 231-240 (2003)
- Camuffo, D., and R. Giorio, "Quantitative evaluation of water deposited by dew on monuments," *Boundary-Layer Meteorology*, 107, 655-672 (2003)
- Beysens, D., I. Milimouk, V. Nikolayev, M. Muselli, and J. Marcillat, "Using radiative cooling to condense atmospheric vapor: a study to improve water yield," *Journal of Hydrology*, 276, 1-11 (2003)
- Shanyengana, E. S., R. D. Sanderson, M. K. Seely, and R. S. Schemenauer, "Testing greenhouse shade nets in collection of fog for water supply," *Aqua*, 52, No. 3, 237-241 (May 2003)
- Porta-Gandara, M. A., J. G. Cervantes, and F. J. Solorio, "Periodic enclosed natural convection in a laboratory solar still," *Experiments in Fluids*, 37, 483-487 (2004)
- Richards, K., "Observation and simulation of dew in rural and urban environments," *Progress in Physical Geography*, 28, No. 1, 76-94 (2004)
- Pearce, F., "Pyramids of dew," *New Scientist*, 186, No. 2495, 52-53 (16 April 2005)
- Fischetti, M., "Call it beetle guard," *Scientific American*, 295, No. 6, 31-32 (December 2006)
- Vazquez, A., J. Arias, and R. M. Sanchez, "Calcite and hematite minerals: a promising application as dew water collectors," *European Journal of Physics*, 27, 667-673 (2006)
- Cereceda, P., H. Larrain, P. Osses, M. Farias, and I. Egana, "The spatial and temporal variability of fog and its relation to fog oases in the Atacama Desert, Chile," *Atmospheric Research*, 87, 312-323 (2008)
- Estrela, M. J., J. A. Valiente, D. Corell, and M. M. Millan, "Fog collection in the western Mediterranean basin (Valencia region, Spain)," *Atmospheric Research*, 87, 324-337 (2008)
- Marzol, M. V., "Temporal characteristics and fog water collection during summer in Tenerife (Canary Islands, Spain)," *Atmospheric Research*, 87, 352-361 (2008)
- Henschel, J. R., and M. K. Seely, "Ecophysiology of atmospheric moisture in the Namib Desert," *Atmospheric Research*, 87, 362-368 (2008)
- Jacobs, A. F. G., B. G. Heusinkveld, and S. M. Berkowicz, "Passive dew collection in a grassland area, The Netherlands," *Atmospheric Research*, 87, 377-385 (2008)

Related reference

- Coghlan, A., "Sun-soaked wicks purge salty water," *New Scientist*, 137, 21, (16 January 1993)

4.68 Mud cracks

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

http://www.gps.caltech.edu/~rkopp/photos/Andros2005/images/pc120611_mudcracks.jpg Photo

<http://www.terrageria.com/america/nevada/black-rock-desert/picture.usnv9106.html> Photo

<http://www.geology.wisc.edu/~struct/trips.html> Photo

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Kindle, E. M., "Some factors affecting the development of mud-cracks," *Journal of Geology*, 25, 135-144 (1917)
- Longwell, C. R., "Three common types of desert mud-cracks," *American Journal of Science*, 215, 136-145 (1928)
- Lang, W. B., "Gigantic drying cracks in Animas Valley, New Mexico," *Science*, 98, No. 2557 (31 December 1943)
- Conrad, V., "Polygon nets and their physical development," *American Journal of Science*, 244, No. 4, 277-296 (April 1946)
- Willden R., and D. R. Mabey, "Giant desiccation fissures on the Black Rock and Smoke Creek Deserts, Nevada," *Science*, 133, 1359-1360 (1961)
- Tomkins, J. Q., "Polygonal sandstone features in Boundary Butte anticline area, San Juan County, Utah," *Geological Society of America Bulletin*, 76, 1075-1080 (September 1965)
- Neal, J. G., and W. S. Motts, "Recent geomorphic changes in playas of western United States," *Journal of Geology*, 75, No. 5, 511-525 (September 1967)
- Neal, J. T., A. M. Langer, and P. F. Kerr, "Giant desiccation polygons of Great Basin playas," *Geological Society of America Bulletin*, 79, 69-90 (January 1968)
- Minter, W. E. L., "Origin of mud polygons that are concave downward," *Journal of Sedimentary Petrology*, 40, No. 2, 755-756 (June 1970)
- DeVito, A., "Mud cracks---an elementary school earth science investigation," *Journal of Geological Education*, 21, 158-159 (September 1973)
- Underwood, J. R., Jr., photographs of mudstone desiccation polygons, *Journal of Geological Education*, 21, cover + explanation of the cover + page 13 (January 1973)
- Plummer, P. S., and V. A. Gostin, "Shrinkage cracks: Desiccation or synaeresis?" *Journal of Sedimentary Petrology*, 51, 1147-1156 (1981)
- Walker, J., "Cracks in a surface look intricately random but actually develop rather systematically," in "The Amateur Scientist," *Scientific American*, 255, 204-209 (October 1986)
- Allen, J. R. L., "On the curl of desiccation polygons," *Sedimentary Geology*, 46, 23-31 (1986)
- Mulheran, P. A., "Crack networks in thin films," *Philosophical Magazine Letters*, 68, No. 2, 63-68 (1993)
- Groisman, A., and E. Kaplan, "An experimental study of cracking induced by desiccation," *Europhysics Letters*, 25, 415-420 (1994)
- Grossenbacher, K. A., and S. M. McDuffie, "Conductive cooling of lava: columnar joint diameter and stria width as functions of cooling rate and thermal gradient," *Journal of Volcanology and Geothermal Research*, 69, 95-103 (1995)
- Kargel, J. S., J. F. Schreiber, Jr., and C. P. Sonett, "Mud cracks and dedolomitization in the Wittencoom Dolomite, Hamersley Group, Western Australia," *Global and Planetary Change*, 14, 73-96 (1996)
- Ball, P., *The Self-Made Tapestry: Pattern Formation in Nature*, Oxford University Press, 1999, pages 149-151

- Ronsin, O., and B. Perrin, “Dynamics of quasistatic directional crack growth,” *Physical Review E*, 58, No. 6, 7878-7886 (December 1998)
- Kitsunozaki, S., “Fracture patterns induced by desiccation in a thin layer,” *Physical Review E*, 60, No. 6, 6449-6464 (December 1999)
- Weinberger, R., “Initiation and growth of cracks during desiccation of stratified muddy sediments” *Journal of Structural Geology*, 21, 379-386 (1999)
- Leung, K-t., and Z. Neda, “Pattern formation and selection in quasistatic fracture,” *Physical Review Letters*, 85, No. 3, 662-665 (17 July 2000)
- Cafiero, R., G. Caldarelli, and A. Gabrielli, “Damage and cracking in thin mud layers,” *Journal of Physics A - Mathematical and General*, 33, No. 45, 8013-8028 (17 November 2000)
- Weinberger, R., “Evolution of polygonal patterns in stratified mud during desiccation: The role of flaw distribution and layer boundaries,” *Bulletin of the Geological Society of America*, 113, 20-31 (January 2001)
- Jagla, E. A., “Propagation of an ordered array of cracks during directional drying,” *Physical Review E*, 65, article no. 046147 (2002)
- Jagla, E. A., and A. G. Rojo, “Sequential fragmentation: the origin of columnar quasihexagonal patterns,” *Physical Review E*, 65, article No. 026203 (2002)
- Liang, J., R. Huang, J. H. Prevost, and Z. Suo, “Evolving crack patterns in thin films with the extended finite element method,” *International Journal of Solids and Structures*, 40, 2343-2354 (2003)
- Karalis, T. K., “Integrated effects on the shrinkage stresses from the water loss in soft cohesive soils,” *International Journal of Engineering Science*, 41, 371-385 (2003)
- Jagla, E. A., “Maturation of crack patterns,” *Physical Review E*, 69, article no. 056212 (2004)
- Lee, W. P., and A. F. Routh, “Why do drying films crack? *Langmuir*, 20, No. 23, 9885-9888 (9 November 2004)
- Otsuki, M., “Memory effect on the formation of drying cracks,” *Physical Review E*, 72, article #046115 (2005)
- “Desiccation cracks,” *Physics Today*, 60, 9116 (September 2007)
- Nakahara, A., and Y. Matsuo, “Transition in the pattern of cracks resulting from memory effects in paste,” *Physical Review E*, 74, article # 045102(R) (4 pages) (October 2006)
- Mal, D., S. Sinha, T. Dutta, S. Mitra, and S. Tarafdar, “Formation of crack patterns in clay films: Desiccation and relaxation,” *Journal of the Physical Society of Japan*, 76, No. 1, # 014801 (5 pages) (January 2007)

Related references

- Allain, C., and L. Limat, “Regular patterns of cracks formed by directional drying of a colloidal suspension,” *Physical Review Letters*, 74, No. 15, 2981-2984 (10 April 1995)
- Pauchard, L., F. Parisse, and C. Allain, “Influence of salt content on crack patterns formed through colloidal suspension desiccation,” *Physical Review E*, 59, No. 3, 3737-3740 (March 1999)

4.69 Inflating juice containers on airplanes

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Mattila, J. O., "A post-prandial altimeter," *Physics Teacher*, 19, 410 (1981)
- Walker, J., "Some entertaining lessons in optics that may make air travel easier to endure" in "The Amateur Scientist," *Scientific American*, 259, 100-103 (August 1988)
- Kozuka, M., T. Nakashima, S. Fukuta, and N. Yanagita, "Inner ear disorders due to pressure change," *Clinical Otolaryngology*, 22, No. 2, 106-110 (April 1997)
- Stevenson, J., (letter) "When can patients blow their nose and fly after treatment for fractures of the zygomatic complex," *Injury*, 36, No. 1, 231-232 (January 2005)
- Berilgen, M. S., and B. Mungen, "Headache associated with airplane travel: report of six cases," *Cephalalgia*, 26, 707-711 (2006)

Related references

- Broniec, R., "Boyle's law and the monster marshmallow," *Journal of Chemical Education*, 59, No. 11, 974 (November 1982)
- Hickman, P., "Boyled marshmallows revisited," *Physics Teacher*, 25, 430 (October 1987)

4.70 Inflating bubbles and balloons

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Miller, J. S., (note) "Pressure within a bubble," *American Journal of Physics*, 20, 115 (1952)
- Stein, R. S., "On the inflating of balloons," *Journal of Chemical Education*, 35, 203-204 (1958)
- Boys, C. V., *Soap Bubbles*, Doubleday Anchor Books, 1959, pages 56-57, 73-75
- Chapin, E. K., "The strange world of surface film," *Physics Teacher*, 4, 271-275 + 286 (September 1966)
- Crane, H. D., "Switching properties in bubbles, balloons, capillaries and alveoli," *Journal of Biomechanics*, 6, 411-422 (1973)
- Weinhaus, F., and W. Baker, "On the equilibrium states of interconnected bubbles or balloons," *American Journal of Physics*, 46, 978-982 (1978)
- Merritt, D. R., and F. Weinhaus, "The pressure curve for a rubber balloon," *American Journal of Physics*, 46, No. 10, 976-977 (October 1978)
- Dreyer, W., I. Muller, and P. Strehlow, "A study of equilibria of interconnected balloons," *Quarterly Journal of Mechanics and Applied Mathematics*, 35, part 3, 419-440 (August 1982)
- Chater, E., and J. W. Hutchinson, "On the propagation of bulges and buckles," *Journal of Applied Mechanics*, 51, 269-277 (1984)
- Read, G., "An application of elementary calculus to balloons," *European Journal of Physics*, 7, 236-241 (1986)
- Walker, J., "Why are the first few puffs the hardest when you blow up a balloon?" in "The Amateur Scientist," *Scientific American*, 261, 136-139 (December 1989)
- Sewell, M. J., "Demonstrations of buckling by bifurcation and snapping," in *mathematical Methods and Applications. The Ian Sneddon 70th Birthday Volume*, G. Eason and R. W. Ogden, editors, Ellis Horwood Ltd, 1990, pages 315-345

- Wilson, T. W., and A. L. Andradý, “Burst testing of condoms. I. Basic features of the force-deformation curve of latex-rubber condoms,” *Journal of Applied Biomaterials*, 3, 117-122 (1992)
- Khayat, R. E., A. Derdouri, and A. Garcia-Rejon, “Inflation of an elastic cylindrical membrane: non-linear deformation and instability,” *International Journal of Solids and Structures*, 29, No. 1, 69-87 (1992)
- Fox, J. N., “The baffling balloons!” *Physics Education*, 28, 325-327 (1993)
- Johnson, M. A., and M. F. Beatty, “The Mullins effect in equibiaxial extension and its influence on the inflation of a balloon,” *International Journal of Engineering Science*, 33, No. 2, 223-245 (1995)
- Muller, I., “Two instructive instabilities in non-linear elasticity: biaxially loaded membrane, and rubber balloons,” *Meccanica*, 31, No. 4, 387-395 (1996)
- Muller, I., and H. Struchtrup, “Inflating a rubber balloon,” *Mathematics and Mechanics of Solids*, 7, No. 5, 569-577 (2002)
- Verron, E., and G. Marckmann, “Numerical analysis of rubber balloons,” *Thin-Walled Structures*, 41, 731-746 (2003)
- Levin, Y., and F. L. da Silveira, “Two rubber balloons: phase diagram of air transfer,” *Physical Review E*, 69, article #051108 (4 pages) (2004)
- Selby, J. C., and M. A. Shannon, “Inflation of a circular elastomeric membrane into a horizontally semi-infinite liquid reservoir of finite vertical depth: Quasi-static deformation model,” *International Journal of Engineering Science*, 47, 700-717 (2009)

Related references

- Stevenson, A., and A. G. Thomas, “On the bursting of a balloon,” *Journal of Physics D: Applied Physics*, 12, 2101-2109 (1979)
- Bogdanov, K. Y., “How do we breathe?” *Quantum*, ??, 5-7 + 42 (May 1990)
- Hendrickson, R., “Since 1928 it’s been boom and bust with bubble gum,” *Smithsonian*, 21, No. 4, 74-83 (July 1990)
- Quick, C. M., H. L. Baldick, N. Safabakhsh, T. J. Lenihan, J. K-J. Li, H. W. Weizsacker, and A. Noordergraaf, “Unstable radii in muscular blood vessels,” *American Journal of Physiology. Heart and Circulatory Physiology*, 40, No. 6, H2669-H2676 (December 1996)
- Weiss, P., “Balloon bursts give clue to fast cracks,” *Science News*, 161, 77 (2 February 2002)
- Petersan, P. J., R. D. Deegan, M. Arder, and H. L. Swinney, “Cracks in rubber under tension exceed the shear wave speed,” *Physical Review Letters*, 93, No. 1, article # 015504 (4 pages) (2 July 2004)
- Marder, M., “Shock-wave theory for rupture of rubber,” *Physical Review Letters*, 94, article # 048001 (4 February 2005)

4.71 Making cakes at high altitudes

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

- Dots • through ••• indicate level of difficulty
- Journal reference style: author, title, journal, volume, pages (date)
- Book reference style: author, title, publisher, date, pages
- Nason, E. H., *Introduction to Experimental Cookery*, McGraw-Hill, 1939, pages 184-186

- Charley, H., *Food Science*, 2nd edition, John Wiley & Sons, 1982, pages 343, 363
- Ferreira, R., “Lowering the boiling temperature of liquids with altitude,” *Journal of Chemical Education*, 70, No. 6, 483-484 (June 1993)
- Negret, J. P., “Boiling water and the height of mountains,” *Physics Teacher*, 24, No. 5, 290-292 (May 1986)
- Morr, C. V., W. Hoffmann, and W. Buchheim, “Use of applied air pressure to improve the baking properties of whey protein isolates in angel food cakes,” *Lebensmittel-Wissenschaft und Technologie*, 36, 83-90 (2003)
- McGee, H., *On Food and Cooking. The Science and Lore of the Kitchen*, revised, Scribner, 2004, page 559

4.72 Champagne in a tunnel

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.tmk.com/books/eastriver/east.shtml> Report on the construction of the tunnel under the East River in New York City. Scroll down to the material on air pressure.

<http://www.tmk.com/books/tunnel/tunnel.shtml> Report on the construction of the tunnel under the Hudson River in New York City.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Loose, T. C., “Champagne recompression,” in “Chemical Principles Exemplified,” edited by R. C. Plumb, *Journal of Chemical Education*, 48, 154 (March 1971)
- Hateley, R. J., “A footnote to the champagne recompression. Exemplum of Henry’s law,” in “Chemical Principles Exemplified,” edited by R. C. Plumb, *Journal of Chemical Education*, 48, 837 (1971)
- Lam, T. H., and K. P. Yau, “Manifestations and treatment of 793 cases of decompression sickness in a compressed air tunneling project in Hong Kong,” *Undersea Biomedical Research*, 15, No. 5, 377-388 (September 1988)
- McIver, N. K. I., “Treatment of compressed-air decompression accidents,” *Journal of the Royal Society of Medicine*, 82, No. 2, 74-79 (February 1989)
- Diaz, D., “Under pressure,” *Invention & Technology*, 11, No. 4, 52-63 (Spring 1996)
- Kindwall, E. P., “Compressed air tunneling and caisson work decompression procedures: development, problems, and solutions,” *Undersea and Hyperbaric Medicine*, 24, No. 4, 337-345 (winter 1997)
- Andersen, H. L., “Decompression sickness during construction of the Great Belt Tunnel, Denmark,” *Undersea and Hyperbaric Medicine*, 29, No. 3, 172-188 (fall 2002)

4.73 Short story: Stuck in a bottle

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Guha, S. J., N. D. Catz, "Lingual ischemia following tongue entrapment in a glass bottle," Journal of Emergency Medicine, 15, No. 5, 637-638 (1997)

4.74 Wintertime thunder

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Schaefer, J. T., "Weather Queries," Weatherwise, 32, 255 (1979) 1979

4.75 Stack plumes

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.colorado.edu/MCEN/flowvis/galleries/2003/assignment3.html> Photo of stack plume becoming unstable

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Turner, J. S., "A comparison between buoyant vortex rings and vortex pairs," Journal of Fluid Mechanics, 7, 419-432 (1960)
- Birely, E. W., and E. W. Hewson, "Some restrictive meteorological conditions to be considered in the design of stacks," Journal of Applied Meteorological, 1, 383-390 (1962)
- Lilly, D. K., "Comments on 'case studies of a convective plume and a dust devil'," Journal of Applied Meteorology, 10, 590-591 (June 1971)
- Weil, J. C., "The rise of moist, buoyant plumes," Journal of Applied Meteorology, 13, No. 4, 435-443 (June 1974)
- Walker, J., "What plumes of smoke tell about the structure of the atmosphere" in "The Amateur Scientist," Scientific American, 238, 162-171 (May 1978)
- Walker, J., "Moire effects, the kaleidoscope and other Victorian diversions" in "The Amateur Scientist," Scientific American, 239, 182-189 (December 1978), see page 188

- Hanna, S. R., M. Pike, and K. Seitter, "Observations of vortices in cooling tower plumes," *Journal of Applied Meteorology*, 17, 1068-1071 (July 1978)
- Cinderey, M. J., (letter) "A factory-plume funnel cloud at Wilton, 2nd March 1987," *Journal of Meteorology*, 12, No. 119, 171-172 (May/June 1987)
- Blackadar, A. K., "Smoke signals," *Weatherwise*, 41, 159-161 (1988)
- Scorer, R. S., *Natural Aerodynamics*, Pergamon Press, 1958, Chapter 8
- Macdonald, R. W., R. K. Strom, and P. R. Slawson, "Water flume study of enhancement of buoyant riss in pairs of merging plumes," *Atmospheric Environment*, 36, 4603-4615 (2002)
- Gillon, J., "Plumes and flumes," *Nature*, 419, 798 (24 October 2002)

Related reference

- Csanady, G. T., "Bent-over vapor plumes," *Journal of Applied Meteorology*, 10, 36-42 (February 1971)

4.76 Smoke signals and mushroom clouds

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Sutton, O. G., "The atom bomb trial as an experiment in convection," *Weather*, 2, 105-110 + photo facing page 105 (1947)
- Richards, J. M., "The effect of wind shear on a puff," *Quarterly Journal of the Royal Meteorological Society*, 96, 702-714 (1970)
- Taylor, R. J., S. T. Evans, N. K. King, E. T. Stephens, D. R. Packham and R. G. Vines, "Convective Activity above a Large-Scale Bushfire," *Journal of Applied Meteorology*, 12, 1144 (1973)
- Walker, J., "What plumes of smoke tell about the structure of the atmosphere" in "The Amateur Scientist," *Scientific American*, 238, 162-171 (May 1978)
- Ogden, R. J., "Smoke-screens---the early years," *Meteorological Magazine*, 114, 173-178 (1985)

4.77 Fire in a fireplace

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Williams, S. R., "On the trail of the molecule—II. What makes some chimneys 'draw' poorly, boomerangs soar, rotor ships move and golf balls curve? 'Bernoulli's principle' explains it," *Scientific American*, ??, 433-435 (November 1927)

- Achenbach, P. R., "Physics of chimneys," *Physics Today*, 2, 18-23 (December 1949)
- Wilson, M., "Count Rumford," *Scientific American*, 203, 158-168 (October 1960)
- Anderson, R. C., "Combustion and flame," *Journal of Chemical Education*, 44, No. 5, 248-260 (May 1967)
- Stone, R. L., "Fireplace operation depends upon good chimney design," *ASHRAE Journal*, 11, 63-69 (February 1969)
- Daws, L. F., and R. E. Lacy, "Cows in the Old Deer Park," *Weather*, 24, 513-518 (1969)
- Haber-Schaim, U., "The 'critical mass-configuration' in chemical reactions," in "Chemical Principles Exemplified," edited by R. C. Plumb, *Journal of Chemical Education*, 48, No. 8, 524-525 (August 1971), see page 525
- Wigley, T. M. L., and M. C. Brown, "The physics of caves" in *The Science of Speleology*, edited by T. D. Ford and C. H. D. Cullingford, Academic Press, 1976, Chapter 9, see pages 330-334
- Walker, J., "Observations on grinding glass by hand and on making the most of a fireplace" in "The Amateur Scientist," *Scientific American*, 239, 140-146 (August 1978)
- Trefil, J., "Fireplace-efficiency boosters -- how do they rate?" *Popular Science*, ??, 40-44 (January 1980)
- Cranberg, L., "Domestic fire and its improvement: some qualitative insights," *American Journal of Physics*, 49, 596-599 (1981)
- Pochop, L. O., J. Borrelli, and M. A. McNamee, "Fireplace performance," *Transactions of the American Society of Agricultural Engineers*, 24, No. 1, 146-150 (1981)
- Cranberg, L., "Convection jets, the slot fire, and fire safety," *American Journal of Physics*, 50, No. 11, 1045-1047 (November 1982)
- De Freitas, C. R., R. N. Littlejohn, T. S. Clarkson, and I. S. Kristament, "Cave climate: assessment of airflow and ventilation," *Journal Climatology*, 2, No. 4, 383-397 (1982)
- Lyons, J. W., *Fire*, Scientific American Library, 1985, Chapter 3
- Jennings, A., "Hearth and home," *Exploratorium Quarterly*, 13, 20 (spring 1989)
- Smithson, P. A., "Inter-relationships between cave and outside air temperatures," *Theoretical and Applied Climatology*, 44, No. 1, 65-73 (1991)
- Bishop, S. R., P. G. Holborn, A. N. Beard, and D. D. Drysdale, "Dynamic modeling of building fires," *Applied Mathematical Modeling*, 17, No. 4, 170-183 (April 1993)
- Massen, F., M. Duser, W. Loy, and N. Vandenberghe, "Cave volume computed on the behaviour of a blowing well (Tournai basin, W. Belgium)," *Terra Nova*, 10, 131-135 (1998)
- Pflitsch, A., and J. Piasecki, "Detection of an airflow system in Niedzwiedzia (Bear) Cave, Kletno, Poland," *Journal of Cave and Karst Studies*, 65, No. 3, 160-173 (2003)
- Lee, Y-P., M. A. Delichatsios, and G. W. H. Silcock, "Heat fluxes and flame heights in facades from fires in enclosures of varying geometry," *Proceedings of the Combustion Institute*, 31, 2521-2528 (2007)
- Sand, U., J. Sandberg, J. Larfeldt, and R. Bel Fdhila, "Numerical prediction of the transport and pyrolysis in the interior and surrounding of dry and wet wood log," *Applied Energy*, 85, 1208-1224 (2008)

Related references

- Marsella, G., "Fireside dreams," *Chem Matters*, ??, 13-14 (December 1988)
- Pojman, J. A., "A simple demonstration of convective effects on reaction-diffusion systems: a burning cigarette," *Journal of Chemical Education*, 67, No. 9, 792-794 (September 1990)
- Forbes, L. K., and B. F. Gray, "Burning down the house: the time to ignition of an irradiated solid," *Proceedings of the Royal Society of London A*, 454, 2667-2688 (1998)
- Atreya, A., "Ignition of fires," *Philosophical Transactions of the Royal Society of London A*, 356, 2787-2813 (1998)

4.78 A candle flame

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Faraday, M., *The Chemical History of a Candle*, Dover Publications, 2002 reprint of original publication circa 1885-1889
- Pimentel, G. C., editor, "A description of a burning candle," in *Chemistry – An Experimental Science*, W. H. Freeman, 1960, pages 449-450
- Lamprecht, I., and B. Schaarschmidt, "The flickering of a dying flame," *Nature*, 240, 445-446 (1972)
- Ashby, R. A., "Flames: a study in molecular spectroscopy," *Journal of Chemical Education*, 52, No. 10, 632-637 (October 1975)
- Walker, J., "The physics and chemistry underlying the infinite charm of a candle flame" in "The Amateur Scientist," *Scientific American*, 238, No. 4, 154-162 (April 1978)
- Gaydon, A. G., and H. G. Wolfhard, *Flames. Their Structure, Radiation and Temperature*, 4th edition, Chapman and Hall, 1979, pages 154-155 + Plate 12a
- Cranberg, L., (abstract) "Convection jet from candle flame," *Bulletin of the American Physical Society*, 25, No. 1, 23 (1980)
- Cranberg, L., "Convection jets, the slot fire, and fire safety," *American Journal of Physics*, 50, No. 11, 1045-1047 (November 1982)
- Lyons, J. W., *Fire*, Scientific American Library, Scientific American Books, 1985, pages 7-35
- Murphy, P., "Experiments by candlelight," *Exploratorium Quarterly*, 13, 10 (spring 1989)
- Luizova, L. A., B. M. Smirnov, A. D. Khakhaev, and V. P. Chugin, "Radiative properties of a candle flame," *High Temperature*, 28, No. 5, 674-679 (September-October 1990)
- Riley, N., "A sheet model for the candle flame," *Proceedings of the Royal Society of London A*, 442, 361-372 (1993)
- Beckman, C., O. Nilsson, and L.-E. Paulsson, "Intraocular light scattering in vision, artistic painting, and photography," *Applied Optics*, 33, No. 21, 4749-4753 and 4963-4964 (20 July 1994)
- Maxworthy, T., "The flickering candle: transition to a global oscillation in a thermal plume," *Journal of Fluid Mechanics*, 390, 297-323 (1999); see small correction, "Corrigendum," *Journal of Fluid Mechanics*, 399, 377 (1999)
- Arai, M., H. Sato, and K. Amagai, "Gravity effects on stability and flickering motion of diffusion flames," *Combustion and Flame*, 118, 293-300 (1999)
- Shaddix, C. R., and T. C. Williams, "Soot: giver and taker of light," *American Scientist*, 95, No. 3, 232-239 (May-June 2007)
- Kitahata, H., J. Taguchi, M. Nagayama, T. Sakurai, Y. Ikura, A. Osa, Y. Sumio, M. Tanaka, E. Yokoyama, and H. Miike, "Oscillation and synchronization in the combustion of candles," *Journal of Physical Chemistry A*, 113, 8164-8168 (2009)

Related references

- Bowser, R. J., and F. J. Weinberg, "Electrons and the emission of soot from flames," *Nature*, 249, 339-341 (24 May 1974)

- Thorne, P. F., “The physics of fire extinguishment,” *Physics Technology*, 16, 263-268 (1985)
- Jones, A. R., “Combustion physics,” *Physics Education*, 20, 292-298 (1985)
- Carleton, F. B., and F. J. Weinberg, “Electric field-induced flame convection in the absence of gravity,” *Nature*, 330, 635-636 (17 December 1987)
- Dietrich, D. L., H. D. Ross, Y. Shu, P. Chang, and J. S. Tien, “Candle flames in non-buoyant atmospheres,” *Combustion Science and Technology*, 156, 1-24 (2000)
- Wisniak, J., “Candle: a light into the past,” *Indian Journal of Chemical Technology*, 7, No. 4, 319-326 (July 2001)

4.79 Spraying a fire

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

Videos:

http://www.youtube.com/watch?v=d96ywpu_-R4&mode=related&search=flashover

[http://www.youtube.com/watch?v=CMEg6x3HYFQ&mode=related&search=Flashover traps a firefighter on the roof](http://www.youtube.com/watch?v=CMEg6x3HYFQ&mode=related&search=Flashover+traps+a+firefighter+on+the+roof)

[http://www.youtube.com/watch?v=uYAdffzkYlw&mode=related&search=Video: look for the flashover near the end, almost gets the firefighter on the roof](http://www.youtube.com/watch?v=uYAdffzkYlw&mode=related&search=Video:look+for+the+flashover+near+the+end,+almost+gets+the+firefighter+on+the+roof)

<http://www.youtube.com/watch?v=Io15LR6XTJI> Big flashover near the end, almost gets the firefighters

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Emmons, H. W., “Scientific progress on fire,” *Annual Review of Fluid Mechanics*, 12, 223-236 (1980)
- Egler, R. A., “The physics of firefighting,” *Physics Teacher*, 28, 599 (December 1990)
- “Firefighters’ fatal error means it can all be over in a flash,” *New Scientist*, 150, 13, (27 April 1996)
- Bishop, S. R., and D. D. Drysdale, “Fires in compartments: the phenomenon of flashover,” *Philosophical Transactions of the Royal Society of London A*, 356, 2855-2872 (1998)
- Lilley, D. G., “Fire dynamics---a primer,” *Journal of Propulsion and Power*, 15, No. 2, 204-215 (March-April 1999)
- Grant, G., J. Brenton, and D. Drysdale, “Fire suppression by water sprays,” *Progress in Energy and Combustion Science*, 26, 79-130 (2000)
- Wenguo, W., F. Weicheng, W. Quing’an, and Y. Lizhong, “A model of backdraft phenomenon in building fires,” *Progress in Natural Science*, 12, No.2, 131-135 (February 2002)
- Liang, F. M., W. K. Chow, and S. D. Liu, “Preliminary studies on flashover mechanism in compartment fires,” *Fire Sciences*, 20, No. 2, 87-112 (March 2002)
- Weng, W. G., W. C. Fan, L. Z. Yang, H. Song, Z. H. Deng, J. Qin, and G. X. Liao, “Experimental study of back-draft in a compartment with openings of different geometries,” *Combustion and Flame*, 132, 709-714 (2003)
- Weng, W. G., and W. C. Fan, “Nonlinear analysis of the backdraft phenomenon in room fires,” *Fire Safety Journal*, 39, 447-464 (2004)
- Yuen, W. W., and W. K. Chow, “The role of thermal radiation on the initiation of flashover in a compartment fire,” *International Journal of Heat and Mass Transfer*, 47, 4265-4276 (2004)

- Liu, Z., D. Carpenter, and A. K. Kim, “Characteristics of large cooking oil pool fires and their extinguishment by water mist,” *Journal of Loss Prevention in the Process Industries*, 19, 516-526 (2006); comment by Jones, J. C., 20, 182 (2007)

Related references

- Forbes, L. K., and B. F. Gray, “Burning down the house: the time to ignition of an irradiated solid,” *Proceedings of the Royal Society of London A*, 454, 2667-2688 (1998)
- Nam, S., “Boilover upon suppression of cooking oil fire by water spray,” *Fire Safety Journal*, 39, 429-432 (2004)

4.80 Cooking-oil fires

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Manzello, S. L., J. C. Yang, and T. G. Cleary, “On the interaction of a liquid droplet with a pool of hot cooking oil,” *Fire Safety Journal*, 38, 651-659 (2003)

Related references

- Ma, T., S. M. Olenick, M. S. Klassen, R. J. Roby, and J. L. Torero, “Burning rate of liquid fuel on carpet (porous media),” *Fire Technology*, 40, 227-246 (2004)
- Nam, S., “Boilover upon suppression of cooking oil fire by water spray,” *Fire Safety Journal*, 39, 429-432 (2004)
- Liu, Z., D. Carpenter, and A. K. Kim, “Characteristics of large cooking oil pool fires and their extinguishment by water mist,” *Journal of Loss Prevention in the Process Industries*, 19, 516-526 (2006); comment by Jones, J. C., 20, 182 (2007)

4.81 Brush fires and forest fires

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Forbes, L. K., and B. F. Gray, “Burning down the house: the time to ignition of an irradiated solid,” *Proceedures of the Royal Society of London A*, 454, 2667-2688 (1998)
- Viegas, D. X., “Forest fire propagation,” *Philosophical Transactions of the Royal Society of London A*, 356, 2907-2928 (1998)

- Butler, B. W., J. Cohen, D. J. Latham, R. D. Schuette, P. Sopko, K. S. Shannon, D. Jimenez, and L. S. Bradshaw, "Measurements of radiant emissive power and temperatures in crown fires," *Canadian Journal of Forest Research*, 34, No. 8, 1577-1587 (August 2004)
- Butler, B. W., M. A. Finney, P. L. Andrews, and F. A. Albini, "A radiation-driven model for crown fire spread," *Canadian Journal of Forest Research*, 34, No. 8, 1588-1599 (August 2004)
- Cohen, J. D., "Relating flame radiation to home ignition using modeling and experimental crown fires," *Canadian Journal of Forest Research*, 34, 1616-1626 (2004)

4.82 Firestorms

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

Videos

<http://www.youtube.com/watch?v=gXzhYgOpvuw> San Diego fires 2007

<http://www.youtube.com/watch?v=5Fw1qiAld2U> Whirlwind races along burning material

<http://www.youtube.com/watch?v=Wwn-PHMnz6Q>

<http://www.youtube.com/watch?v=YFwzNNEuOSY&mode=related&search>

http://www.youtube.com/watch?v=XaX_Hm5DI5E Watch the swirling in the fire

<http://www.youtube.com/watch?v=YFwzNNEuOSY&mode=related&search=> Dust devil (vortex) produced by a fire

<http://www.youtube.com/watch?v=OnevoZZvbig> Larger scale swirling from a fire

<http://www.youtube.com/watch?v=c8kQbGa72tM&mode=related&search=> Swirling in a controlled fire demonstration

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Graham, H. E., "Fire whirlwinds," *Bulletin of the American Meteorological Society*, 36, No. 3, 99-103 (March 1955)
- Dessens, J., "Man-made tornadoes," *Nature*, 193, No. 4810 (6 January 1962)
- Ebert, C. H., "The meteorological factor in the Hamburg fire storm," *Weatherwise*, 16, 70-75 (April 1963)
- Atallah, S., "Some observations on the Great Fire of London, 1666," *Nature*, 211, No. 5044, 105-106 (2 July 1966)
- Lawrence, E. N., "Meteorology and the Great Fire of London, 1666," *Nature*, 213, 168-169 (14 January 1967)
- Heighes, J. M., (letter) "Vortices produced by the *Torrey Canyon* smoke plume," *Weather*, 22, 508 (1967)
- Idso, S. B., "Tornadic vortices spawned by a desert brush fire," *Weather*, 29, 280-283 (1974)
- Heighes, J. M., "Airflow around a fire and the whirlwind as a by-product," *Journal of Meteorology*, 1, No. 1, 31 (1975-1976)
- Meade, G. T., "The fire whirlwind which destroyed a farm," *Journal of Meteorology*, 4, 209-210 (1979)
- Church, C. R., J. T. Snow, and J. Dessens, "Intense atmospheric vortices associated with a 1000 MW fire," *Bulletin of the American Meteorological Society*, 61, 682-694 (1980)

- Moran, J. M., and R. D. Stieglitz, "Tornadoes of fire: the tragic story of Williamsonville, Wisconsin, October 8, 1871," *Weatherwise*, 36, No. 6, 298-300 (December 1983)
- Hannes, G. P., and S. M. Hannes, "Fire whirls in Oregon," *Weatherwise*, 37, No. 5, 267 (October 1984)
- Small, R. D., D. A. Larson, and H. L. Brode, "Asymptotically large area fires," *Journal of Heat Transfer*, 106, No. 2, 318-324 (May 1984)
- Carrier, G. F., F. E. Fendell, and P. S. Feldman, "Firestorms," *Journal of Heat Transfer---Transactions of the ASME*, 107, No. 1, 19-27 (February 1985)
- Carrier, G. F., and F. E. Fendell, "Firestorm. The thermohydrodynamics of destruction," *Mechanical Engineering*, 108, No. 12, 50-54 (December 1986)
- Snow, J. T., "Atmospheric columnar vortices," *Reviews of Geophysics*, 25, No. 3, 371-385 (April 1987)
- McRae, D. J., M. D. Flannigan, "Development of large vortices on prescribed fires," *Canadian Journal of Forest Research*, 20, 1878-1887 (1990)

Related reference

- Stong, C. L., "How to make and investigate vortexes in water and flame," in "The Amateur Scientist," 209, 133-142 (October 1963)

4.83 Temperature regulation in mounds and buildings

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=tdnVmOzYofw> Video showing Iranian "wind catcher"

<http://www.hinduonnet.com/fline/fl2208/stories/20050422000106500.htm> Scroll down to the cooling tower

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Vogel, S., C. P. Ellington, and D. L. Kilgore, "Wind-induced ventilation of the burrow of the prairie-dog, *Cynomys ludovicianus*," *Journal of Comparative Physiology*, 85, 1-14 (1973)
- Bahadori, M. N., "Passive cooling systems in Iranian architecture," *Scientific American*, 238, 144-154 + 162 (1978)
- Jacklyn, P. M., "'Magnetic' termite mound surfaces are oriented to suit wind and shade," *Oecologia*, 91, 385-395 (1992)
- Webb, R., "Offices that breathe naturally," *New Scientist*, 142, 38-41 (11 June 1994)
- Aboulnaga, M. M., "A roof solar chimney assisted by cooling cavity for natural ventilation in buildings in hot arid climates: an energy conservation approach in Al-Ain City," *Renewable Energy* 14, Nos. 1-4, 357-363 (1998)
- Korb, J., and K. E. Linsenmair, "The effects of temperature of the architecture and distribution of *Macrotermes bellicosus* (Isoptera, Macrotermitinae) mounds in different habitats of a West African Guinea savanna," *Insectes Sociaux*, 45, 51-65 (1998)
- Korb, J., and K. E. Linsenmair, "Experimental heating of *Macrotermes bellicosus* (Isoptera, Macrotermitinae) mounds: what role does microclimate play in influencing mound architecture?" *Insectes Sociaux*, 45, 335-342 (1998)

- Linden, P. F., “The fluid mechanics of natural ventilation,” *Annual Review of Fluid Mechanics*, 31, 201-238 (1999)
- Korb, J., and K. E. Linsenmair, “Thermoregulation of termite mounds: what role does ambient temperature and metabolism of the colony play?” *Insectes Sociaux*, 47, 357-363 (2000)
- Korb, J., and K. E. Linsenmair, “Ventilation of termite mounds: new results require a new model,” *Behavioral Ecology*, 11, No. 5, 486-494 (2000)
- Aboulnaga, M. M., and S. N. Abdrabboh, “Improving night ventilation into low-rise buildings in hot-arid climates exploring a combined wall-roof solar chimney,” *Renewable Energy*, 19, 47-54 (2000)
- Ziskind, G., V. Dubovsky, and R. Letan, “Ventilation by natural convection of a one-story building,” *Energy and Buildings*, 34, 91-102 (2002)
- Korb, J., “Thermoregulation and ventilation of termite mounds,” *Naturwissenschaften*, 90, 212-219 (2003)
- Rajapaksha, I., H. Nagai, and M. Okumiya, “A ventilated courtyard as a passive cooling strategy in the warm humid tropics,” *Renewable Energy*, 28, 1755-1778 (2003)
- Letan, R., V. Dubovsky, and G. Ziskind, “Passive ventilation and heating by natural convection in multi-storey building,” *Building and Environment*, 38, 197-208 (2003)
- Ong, K. S., and C. C. Chow, “Performance of a solar chimney,” *Solar Energy*, 74, 1-17 (2003)
- Korb, J., “The shape of compass termite mounds and its biological significance,” *Insectes Sociaux*, 50, 218-221 (2003)
- Bordy, E. M., A. J. Bumby, O. Catuneanu, and P. G. Eriksson, “Advanced early Jurassic termite (Insecta: Isoptera) nests: evidence from the Clarens Formation in the Tuli Basin, Southern Africa,” *Palaios*, 19, 68-78 (2004)
- Drori, U., and G. Ziskind, “Induced ventilation of a one-story real-size building,” *Energy and Buildings*, 36, 881-890 (2004)
- Oz, S., S. Fogel, V. Dubovsky, G. Ziskind, and R. Letan, “Solar-assisted induced ventilation of small field structures,” *Journal of Solar Energy Engineering*, 126, No. 2, 781-788 (May 2004)
- Phillips, J. C., and A. W. Woods, “On ventilation of a heated room through a single doorway,” *Building and Environment*, 39, 241-253 (2004)
- Fitzgerald, S. D., and A. W. Woods, “Natural ventilation of a room with vents a multiple levels,” *Building and Environment*, 39, 505-521 (2004)
- Asfour, O. S., and M. B. Gadi, “Using CFD to investigate ventilation characteristics of valuts as wind-inducing devices in buildings,” *Applied Energy*, 85, 1126-1140 (2008)

Related references

- Onmura, S., M. Matsumoto, and S. Hokoi, “Study on evaporative cooling effect of roof lawn gardens,” *Energy and Buildings*, 33, 653-666 (2001)
- Tantasavasdi, C., J. Srebric, and Q. Chen, “Natural ventilation design for houses in Thailand,” *Energy and Buildings*, 33, 815-824 (2001)

4.84 Warmth of greenhouses and closed cars

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The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Wood, R. W., "Note on the theory of the greenhouse," *Philosophical Magazine*, 17, 319-320 (1909)
- Lee, R., "The 'greenhouse' effect," *Journal of Applied Meteorology*, 12, 556-557 (April 1973)
- Berry, E. X., "Comments on 'The greenhouse effect'," *Journal of Applied Meteorology*, 13, 603-606 (August 1974)
- Silverstein, S. D., "Effect of infrared transparency on the heat transfer through windows: a clarification of the greenhouse effect," *Science*, 193, 229-231 (16 July 1976)
- Silverstein, S. D., "All season thermal control greenhouse glasses with selective transmission of photosynthesis active radiation," *Solar Energy Materials*, 4, 47-65 (1980)
- Young, M., "The greenhouse effect," in "Questions Students Ask," *Physics Teacher*, 21, 194-195 (March 1983)
- Bohren, C., "The greenhouse effect: Part III," in "Simple Experiments in Atmospheric Physics," *Weatherwise*, 38, 106-109 (April 1985)
- Garstang, R. H., "How hot does your parked car become?" *Physics Teacher*, 29, 58 (January 1991)
- Chakroun, W., and S. Al-Fahed, "Thermal comfort analysis inside a car," *International Journal of Energy Research*, 21, 327-340 (1997)
- Marty, W., T. Sigrist, and D. Wyler, "Temperature variations in automobiles in various weather conditions. An experimental contribution to the determination of time of death," *American Journal of Forensic Medicine and Pathology*, 22, No. 3, 215-219 (2001)

Related references

- Young, M., "Solar energy: the physics of the greenhouse effect," *Applied Optics*, 14, No. 7, 1503-1508 (July 1975)
- Briscoe, B. J., and K. P. Galvin, "The effect of surface fog on the transmittance of light," *Solar Energy*, 46, No. 4, 191-197 (1991)
- Willits, D. H., "The effect of cloth temperature on the cooling efficiency of shade cloths in greenhouses," *Transactions of the ASAE (American Society of Agricultural Engineers)*, 46, No. 4, 1215-1221 (2003)
- Crichton, B., "Keep in a cool place: exposure of medicines to high temperatures in general practice during a British heatwave," *Journal of the Royal Society of Medicine*, 97, No. 7, 328-329 (July 2004)

4.85 Heat islands

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=LPIFcABniYk> Pink Floyd's "Money" is the music; images and photos of the development around Atlanta is the visual. (Mild cursing in the song.)

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Lee, D. O., "Urban warming?---an analysis of recent trends in London's heat island," *Weather*, 47, 50-56 (February 1992)
- Mitchell, J. M., "The temperature of cities," *Weatherwise*, 14, 224-258 (December 1961)
- Lowry, W. P., "The climate of cities," *Scientific American*, 217, No. 2, 15-23 (August 1967)

- Hutcheon, R. J., R. H. Johnson, W. P. Lowry, C. H. Black, and D. Hadley, "Observations of the urban heat island in a small city," *Bulletin of the American Meteorological Society*, 48, 7-9 (1967)
- Preston-Whyte, R. A., "A spatial model of an urban heat island," *Journal of Applied Meteorology*, 9, No. 4, 571-573 (August 1970)
- Lee, D. O., "Rural atmospheric stability and the intensity of London's heat island," *Weather*, 30, 102 (1975)
- Lyall, I. T., "The London heat-island in June-July 1976," *Weather*, 32, 296-302 (1977)
- Vukovich, F. M., and J. W. Dunn, "A theoretical study of the St. Louis heat island: some parameter variations," *Journal of Applied Meteorology*, 17, 1585-1594 (1978)
- Vukovich, F. M., W. J. King, J. W. Dunn III, and J. J. B. Worth, "Observations and simulations of the diurnal variation of the urban heat island circulation and associated variations of the ozone distribution: a case study," *Journal of Applied Meteorology*, 18, 836-854 (July 1979)
- Vukovich, F. M., and W. J. King, "A theoretical study of the St. Louis heat island: Comparisons between observed data and simulation results on the urban heat island circulation," *Journal of Applied Meteorology*, 19, 761-770 (1980)
- Unwin, D. J., "The synoptic climatology of Birmingham's urban heat island, 1965-1974," *Weather*, 35, 43-50 (1980)
- Adebayo, Y. R., "Land-use approach to the spatial analysis of the urban 'heat island' in Ibadan, Nigeria," *Weather*, 42, 273 (1987)
- Yague, C., E. Zurita, and A. Martinez, "Statistical analysis of the Madrid urban heat island," *Atmospheric Environment*, 25B, No. 3, 327-332 (1991)
- Doherty, P., "Hot times in the city," *Exploratorium Quarterly*, pages 26-29 (spring 1992)
- Harrington, W. Z., B. L. Strohschein, D. Reedy, J. E. Harrington, and W. R. Schiller, "Pavement temperature and burns---streets of fire," *Annals of Emergency Medicine*, 26, No. 5, 563-568 (November 1995)
- Runnalls, K. E., and T. R. Oke, "Dynamics and controls of the near-surface heat island of Vancouver, British Columbia," *Physical Geography*, 21, No. 4, 283-304 (2000)
- Gedzelman, S. D., S. Austin, R. Cermak, N. Stefano, S. Partridge, S. Quesenberry, and D. A. Robinson, "Mesoscale aspects of the urban heat island around New York City," *Theoretical and Applied Climatology*, 75, 29-42 (2003)
- Shashua-Bar, L., and M. E. Hoffman, "Geometry and orientation aspects in passive cooling of canyon streets with trees," *Energy and Buildings*, 35, 61-68 (2003)
- Perkins, S., "City heat: urban areas' warmth affects plant growth," *Science News*, 166, 21-22 (10 July 2004)
- Doulos, L., M. Santamouris, and I. Livada, "Passive cooling of outdoor urban spaces. The role of materials," *Solar Energy*, 77, 231-249 (2004)
- Richards, K., "Observation and simulation of dew in rural and urban environments," *Progress in Physical Geography*, 28, No. 1, 76-94 (2004)
- Zhang, X. Y., "The footprint of urban climates on vegetation phenology," *Geophysical Research Letters*, 31, No. 12, article # L12209 (4 pages) (28 June 2004)
- Perkins, S., "Urban heat," *Science News*, 175, No. 8, 26-29 (11 April 2009)

4.86 Rubber-band thermodynamics

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The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

<http://www.youtube.com/watch?v=OW6aEmOsXv0> Video of a rubber band heat engine

http://www.haverford.edu/physics-astro/Demonstrations/thermo/rubber_band_heat_engine.htm Photo and description of a rubber band heat engine

http://www.haverford.edu/physics-astro/Demonstrations/thermo/rubber_band_heat_engine.htm Photo and description of a rubber band heat engine

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Elliott, D. R., and S. A. Lippmann, "The thermodynamics of rubber at small extensions," *Journal of Applied Physics*, 16, 50-54 (January 1945)
- Hayward, R., in "The Amateur Scientist," edited by C. L. Stong, *Scientific American*, 194, No. 5, 154-158 (May 1956)
- Brown, J. B., "Thermodynamics of a rubber band," *American Journal of Physics*, 31, No. 5, 397 (May 1963)
- Archibald, P. A., "Some delightful engines driven by the heating of rubber bands," in "The Amateur Scientist," C. L. Stong, editor, *Scientific American*, 224, 118-122 + 130 (April 1971)
- Mullen, J. G., G. W. Look, and J. Konkel, "Thermodynamics of a simple rubber-band heat engine," *American Journal of Physics*, 43, No. 4, 349-353 (April 1975)
- Mullen, J. G., "On optimizing an Archibald rubber-band heat engine," *American Journal of Physics*, 46, No. 11, 1107-1110 (November 1978)
- Clough, S. B., "Stretched elastomers. A case of decreasing length upon heating," *Journal of Chemical Education*, 64, No. 1, 42-43 (January 1987)
- Mathias, L. J., "Converting sunlight to mechanical energy. A polymer example of entropy," *Journal of Chemical Education*, 64, No. 10, 889-890 (October 1987)
- Savarino, G., and M. R. Fisch, "A general physics laboratory investigation of the thermodynamics of a rubber band," *American Journal of Physics*, 59, No. 2, 141-145 (February 1991)
- Pellicer, J., J. A. Manzanares, J. Zuniga, P. Utrillas, and J. Fernandez, "Thermodynamics of rubber elasticity," *Journal of Chemical Education*, 78, No. 2, 263-267 (February 2001)
- Smith, B., "Using rubber-elastic material-ideal gas analogies to teach introductory thermodynamics. Part 1: equations of state," *Journal of Chemical Education*, 79, No. 12, 1444-1452 (December 2002)

4.87 The foehn and the chinook

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

The material here is located at www.flyingcircusofphysics.com and will be updated periodically.

References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Ives, R. L., "Weather phenomena of the Colorado Rockies," *Journal of Franklin Institute*, 226, 691-755 (1938), see pages 697-699
- Cook, A. W., and A. G. Topil, "Some examples of chinooks east of mountains in Colorado," *Bulletin of the American Meteorological Society*, 33, No. 2, 42-47 (1952)

- McClain, E. P., "Synoptic investigation of a typical chinook situation in Montana," *Bulletin of the American Meteorological Society*, 33, No. 3, 87-94 (March 1952)
- Thambyahpillay, G., "The kachchan---a foehn wind in Ceylon," *Weather*, 13, 107-114 (1958)
- Glenn, C. L., "The Chinook," *Weatherwise*, 14, 175-182 (October 1961)
- Virgo, S. E., "Hazards of the foehn wind in Switzerland," *Weather*, 21, 306-307 (1966)
- Holmes, R. M., and K. D. Hage, "Airborne observations of three chinook-type situations in Southern Alberta," *Journal of Applied Meteorology*, 10, No. 6, 1138-1153 (December 1971)
- Riehl, H., "An unusual chinook case," *Weather*, 26, 241-246 (June 1971)
- Brinkmann, W. A. R., "What is a foehn?" *Weather*, 26, 230-239 (June 1971); missing figure is in September 1971 issue
- Friedman, H., "Weather queries," *Weatherwise*, 32, 254-255 (December 1979)
- Kerr, R. A., "Chinook winds resemble water flowing over a rock," *Science*, 231, 1244-1245 (1986)
- Smith, R. B., "Aerial observations of the Yugoslavian bora," *Journal of the Atmospheric Science*, 44, 269-297 (15 January 1987)

4.88 The boiling water ordeal

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Gibson, W., *Master Magicians*, Doubleday & Company, 1966, page 204

4.89 Energy in a heated room

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Emden, R., "Why do we have winter heating?" *Nature*, 141, 908-909 (May 1938)
- Sommerfeld, A., *Thermodynamics and Statistical Physics*, Academic Press, 1964, pages 40-41
- Bilkadi, Z., and W. B. Bridgman, "When you heat your house does the thermal energy content increase?" in "Chemical Principles Exemplified," edited by R. C. Plumb, *Journal of Chemical Education*, 49, No. 7, 493-494 (July 1972)
- Campbell, J. A., "Footnote to the house heating exemplum," in "Chemical Principles Exemplified," edited by R. C. Plumb, *Journal of Chemical Education*, 50, No. 5, 365-366 (May 1973)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, John Wiley & Sons, 5th edition, 1997, page 498

•• Kreuzer, H. J., and S. H. Payne, "Thermodynamics of heating a room," *American Journal of Physics*, 79, No. 1, 74-77 (January 2011)

4.90 Icehouse orientation

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Bainbridge, J. W., "Stocking Northumbrian icehouses: an exercise in relating climate to history," *Weather*, 28, No. 2, 68-79 (February 1973)

4.91 A radiometer toy and its reversal

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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<http://www.newenergyshop.com/pic.Extraordinary.Engines/Extraordinary.Engines.Radiometer.jpg>

Photo

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Bell, R. E., (letter) "The reversing radiometer," *American Journal of Physics*, 51, No. 7, 584 (July 1983)
- Crawford, F. S., "Running Crooke's radiometer backwards," *American Journal of Physics*, 53, No. 11, 1105 (November 1985)
- Bartels, R.A., "Do darker objects really cool faster?" *American Journal of Physics*, 58, 244-248 (1990)
- Arenas, A., L. Victoria, F. J. Abellan, and J. A. Ibanez, "Dynamic characterization of a windmill radiometer," *European Journal of Physics*, 17, 331-336 (1996)
- Guemez, J., C. Fiolhais, and M. Fiolhais, "Toys in physics lectures and demonstrations---a brief review," *Physics Education*, 44, No. 1, 53-64 (January 2009)

4.92 Water wells and storms

This item is discussed in the book *The Flying Circus of Physics, second edition*, by Jearl Walker, published by John Wiley & Sons, June 2006, ISBN 0-471-76273-3.

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Keene, E. S., *Mechanics of the Household*, McGraw-Hill, 1918, page 143
- Wigley, T. M. L., and M. C. Brown, “The physics of caves” in *The Science of Speleology*, edited by T. D. Ford and C. H. D. Cullingford, Academic Press, 1976, Chapter 9, see pages 330-334
- De Freitas, C. R., R. N. Littlejohn, T. S. Clarkson, and I. S. Kristament, “Cave climate: assessment of airflow and ventilation,” *Journal Climatology*, 2, No. 4, 383-397 (1982)
- Smithson, P. A., “Inter-relationships between cave and outside air temperatures,” *Theoretical and Applied Climatology*, 44, No. 1, 65-73 (1991)
- Massen, F., M. Duser, W. Loy, and N. Vandenberghe, “Cave volume computed on the behaviour of a blowing well (Tournai basin, W. Belgium),” *Terra Nova*, 10, 131-135 (1998)
- Pflitsch, A., and J. Piasecki, “Detection of an airflow system in Niedzwiedzia (Bear) Cave, Kletno, Poland,” *Journal of Cave and Karst Studies*, 65, No. 3, 160-173 (2003)

4.93 Insect and shrimp plumes

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References

Dots • through ●●● indicate level of difficulty

Journal reference style: author, title, journal, volume, pages (date)

Book reference style: author, title, publisher, date, pages

- Peterson, E. B., and A. W. H. Damman, (letter) “Convection plumes from *Ulmus Americana* L.,” *Science*, 148, No. 3668, 392-393 (16 April 1965)
- Corbet, P. S., J. A. Downes, and G. Steyskal, (letters) “Convection plumes from trees,” *Science*, 150, 1629 (17 December 1965)
- Ward, D. B., J. Beckner, and R. Hackman, (letters) “Convection plumes from trees,” *Science*, 149, 764 (1965)
- Drapeau, R. E., (letter) “Convection-plume-like phenomenon,” *Science*, 150, 509 (October 1965)
- Rigby, M., (letter) “Convection plumes and insects,” *Science*, 150, 783 (November 1965)
- Wiersma, J. H., (letter) “Convection plumes and insects,” *Science*, 152, No. 3720, 387 (15 April 1966)
- Mason, D. T., “Density-current plumes,” *Science*, 152, No. 3720, 354-356 (15 April 1966)
- Paterson, M. P., “Les mouches de Point Sublime,” *Weather*, 30, 301-303 (1975)
- White, R., (letter) “Again---curious phenomenon at Woodford Green,” *Journal of Meteorology*, 2, No. 13, 24-25 (1976-1977)
- White, R., “A further observation of insect swarms,” *Journal of Meteorology*, 2, No. 14, 58-59 (1976-1977)