

Chapter 5

Ducking first a flash and then a roar

(electricity and magnetism)

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=41>

April 2009

5.1 Lightning

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=VTztOz_EUrE&mode=related&search=
Video of very close lightning strike

<http://www.youtube.com/watch?v=EM66Nu-qCo4&mode=related&search=>
Video of lightning strike

<http://www.air-and-space.com/lightning.htm> photos and some sequenced shots (stepped movies)

http://www.youtube.com/watch?v=GR_EoW0fpws&mode=related&search=
Video of many lightning strikes

<http://wvlightning.com/types.shtml> Many photos

<http://www.prazen.com/cori/links.html> Many photos from Australia. Click on the lightning choices.

http://www.worth1000.com/entries/153500/153529qVxu_w.jpg Photo of tornado and lightning from the cloud to one side of the tornado.

http://205.243.100.155/frames/longarc.htm#Large_LF Photos and discussion, big sparks, lightning

<http://www.cabinetmagazine.org/issues/3/allaboutlightning.php> Interview with Martin Uman, an expert on lightning that I have followed for years

References

Dots • through ••• indicate level of difficulty

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

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

- Foster, H., "An unusual observation of lightning," *Bulletin American Meteorological Society*, 31, No. 4, 140-141 (April 1950)
- "First photograph of lightning," *Journal of the Franklin Institute*, 253, xxii (1952)
- Hill, R. D., "Determination of charges conducted in lightning strokes," *Journal of Geophysical Research*, 68, No. 5, 1365-1375 (1 March 1963)
- Vonnegut, B., "Some facts and speculations concerning the origin and role of thunderstorm electricity," *Meteorological Monographs*, 5, No. 27, 224-241 (September 1963)
- Matthews, J. B., "An unusual type of lightning," *Weather*, 19, 291-292 (1964)
- Berger, K., "Novel observations on lightning discharges: results of research on Mount San Salvatore," *Journal of the Franklin Institute*, 283, No. 6, 478-525 (June 1967)
- Stow, C. D., "On the prevention of lightning," *Bulletin of the American Meteorological Society*, 50, No. 7, 514-520 (July 1969)
- Orville, R. E., "Lightning photography," *Physics Teacher*, 9, 333 (September 1971)
- Hill, R. D., "Channel heating in return-stroke lightning," *Journal of Geophysical Research*, 76, No. 3, 637-645 (20 January 1971)
- Hill, R. D., "Spherical capacitor hypothesis of the Earth's electric field," *Pure and Applied Geophysics*, 84, I, 67-75 (1971)
- Hill, R. D., "Thunderbolts," *Endeavour*, 31, 3-9 (1972)
- Hill, R. D., "Optical absorption in the lightning channel," *Journal of Geophysical Research*, 77, No. 15, 2642-2647 (20 May 1972)
- Wood, E. A., "Physics for automobile passengers," *Physics Teacher*, 11, 239 (April 1973)
- Orville, R. E., and K. Berger, "An unusual lightning flash initiated by an upward-propagating leader," *Journal of Geophysical Research*, 78, No. 21, 4520-4525 (20 July 1973)
- Vonnegut, B., R. Markson, and C. B. Moore, "Direct measurement of vertical potential differences in the lower atmosphere," *Journal of Geophysical Research*, 78, No. 21, 4526-4528 (20 July 1973)
- Krider, E. P., "An unusual photograph of an air lightning discharge," *Weather*, 29, No. 1, 24-27 (January 1974)

- Uman, M. A., “The Earth and its atmosphere as a leaky spherical capacitor,” *American Journal of Physics*, 42, 1033-1035 (November 1974)
- Krider, E. P., “Location of lightning flashes to ground with a single camera,” *Weather*, 30, 72-77 (1975)
- Krider, E. P., and C. G. Ladd, “Upward streamers in lightning discharges to mountainous terrain,” *Weather*, 30, 77-81 (1975)
- Hammond, D. J., (letter) “Vivid display of coloured lightning,” *Journal of Meteorology*, 1, No. 9, 295 (1975-1976)
- Bignell, K. J., (letter) “Unusual lightning,” *Weather*, 31, 397 (1976)
- Orville, R. E., “The lightning discharge,” *Physics Teacher*, 14, 7-13 (January 1976)
- Eriksson, A. J., “An unusual lightning flash?” *Weather*, 32, 102-106 (1977)
- Turman, B. N., “Detection of lightning superbolts,” *Journal of Geophysical Research*, 82, No. 18, 2566-2568 (20 June 1977)
- Orville, R. E., and D. W. Spencer, “Global lightning flash frequency,” *Monthly Weather Review*, 107, 934-943 (July 1979)
- Clark, C. A., (letter) “Pink lightning,” *Journal of Meteorology*, 4, 256 (1979)
- Turman, B. N., “Lightning detection from space,” *American Scientist*, 67, 321-329 (May-June 1979)
- Lin, Y. T., M. A. Uman, and R. B. Standler, “Lightning return stroke models,” *Journal of Geophysical Research*, 85, No. C3, 1571-1583 (20 March 1980)
- Caranti, J. M., and A. J. Illingworth, “Surface potentials of ice and thunderstorm charge separation,” *Nature*, 284, No. 5751, 44-46 (6 March 1980)
- Waldteufel, P., P. Metzger, J.-L. Boulay, P. Laroche, and P. Hubert, “Triggered lightning strokes originating in clear air,” *Journal of Geophysical Research*, 85, No. C5, 2861-2868 (20 May 1980)
- MacGorman, D. R., A. A. Few, and T. L. Teer, “Layered lightning activity,” *Journal of Geophysical Research*, 86, No. C10, 9900-9910 (20 October 1981)
- Fuquay, D. M., “Positive cloud-to-ground lightning in summer thunderstorms,” *Journal of Geophysical Research*, 87, No. C9, 7131-7140 (20 August 1982)
- Krider, E. P., and S. B. Alejandro, “Lightning: an unusual case study,” *Weatherwise*, 36, No. 2, 71-75 (April 1983)

- Beasley, W. H., M. A. Uman, D. M. Jordan, and C. Ganesh, “Positive cloud to ground lightning return strokes,” *Journal of Geophysical Research*, 88, No. C13, 8475-8482 (20 October 1983)
- Uman, M. A., *Lightning*, Dover, 1984
- Hill, R. D., “Investigation of lightning strikes to water surfaces,” *Journal of the Acoustical Society of America*, 78, No. 6, 2096-2099 (December 1985)
- Takagi, N., T. Takeuti, and T. Nakai, “On the occurrence of positive ground flashes,” *Journal of Geophysical Research*, 91, No. D9, 9905-9909 (20 August 1986)
- Uman, M. A., *All About Lightning*, Dover, 1986
- Baker, D. G., and A. Baker-Blocker, “Watching horizontal lightning propagation,” *Weather*, 42, No. 7, 248-250 (July 1987)
- Krider, E. P., and R. H. Wetmore, “Upward streamers produced by a lightning strike to radio transmission towers,” *Journal of Geophysical Research*, 92, No. D8, 9859-9862 (20 August 1987)
- Petley, B., “Charging up raindrops,” *Physics Bulletin*, 38, 373-375 (1987)
- Ochs, H. T., and R. R. Czys, “Charging up raindrops,” *Physics Bulletin*, 38, 373-374 (1987)
- Saunders, C. P. R., “Thunderstorm electrification,” *Weather*, 43, No. 9, 318-324 (September 1988)
- Williams, E. R., “The electrification of thunderstorms,” *Scientific American*, 259, No. 5, 88-99 (November 1988)
- Monastersky, R., “Lightning pattern found in storms,” *Science News*, 133, 87 (6 February 1988)
- Orville, R. E., R. W. Henderson, and L. F. Bosart, “Bipole patterns revealed by lightning locations in mesoscale storm systems,” *Geophysical Research Letters*, 15, No. 2, 129-132 (February 1988)
- Mason, J., “The generation of electric charges and fields in thunderstorms,” *Proceedings of the Royal Society of London A*, 415, 303-315 (1988)
- Illingworth, A., “Electrification of anvil clouds,” *Nature*, 340, 21 (6 July 1989)
- Schlatter, T., “Lightning in your life,” in “Weather Queries,” *Weatherwise*, 42, 332-334 (December 1989)
- Hoddinott, M. H. O., (letter) “Lightning events---unusual or not?” *Weather*, 44, 36 (1989)
- Uman, M. A., and E. P. Krider, “Natural and artificially initiated lightning,” *Science*, 246, 457-464 (27 October 1989)

- Vonnegut, B., O. H. Vaughan, and M. Brook, “Nocturnal photographs taken from a U-2 airplane looking down on tops of clouds illuminated by lightning,” *Bulletin of the American Meteorological Society*, 70, No. 10, 1263-1271 (October 1989)
- Mattos, M. A. da F., C. Christopoulos, “A model of the lightning channel, including corona, and prediction of the generated electromagnetic fields,” *Journal of Physics D*, 23, No. 1, 40-46 (14 January 1990)
- Freedman, D. H., “Bolts from the blue,” *Discover*, 11, 50-56 (December 1990)
- Hendry Jr., J., “Panning for lightning,” and M. A. Uman, “Comments on the photos,” *Weatherwise*, 45, No. 6, 18-19 (December 1992/January 1993)
- Williams, E., “How much lightning strikes the ground?” *Physics World*, 6, No. 7, 27-28 (July 1993)
- “A shocking side to the blizzard of '93,” *Science News*, 46, 95 (7 August 1993)
- “The day the lightning broke all the records,” *New Scientist*, 134, 15 (11 September 1993)
- Seimon, A., “Anomalous cloud-to-ground lightning in an F5-tornado-producing supercell thunderstorm on 28 August 1990,” *Bulletin of the American Meteorological Society*, 74, No. 2, 189-203 (February 1993)
- Uman, M. A., “Natural lightning,” *IEEE Transactions on Industry Applications*, 30, No. 3, 785-790 (May/June 1994)
- Geffner, G., “Empire strikes,” *Weatherwise*, 48, 12-15 (October/November 1995)
- Goto, Y., and K. Narita, “Electrical characteristics of winter lightning,” *Journal of Atmospheric and Terrestrial Physics*, 57, No. 5, 449-458 (1995)
- Cervený, R., “Power of the gods,” *Weatherwise*, 51, 56-58 (January/February 1998)
- Borovsky, J. E., “Lightning energetics: estimates of energy dissipation in channels, channel radii, and channel-heating risetimes,” *Journal of Geophysical Research*, 103, No. D10, 11537-11553 (27 May 1998)
- Bering III, E. A., A. A. Few, and J. R. Benbrook, “The global electric circuit,” *Physics Today*, 51, 24-30 (October 1998)
- Mazur, V., X.-M. Shao, and P. R. Krehbiel, “‘Spider’ lightning in intracloud and positive cloud-to-ground flashes,” *Journal of Geophysical Research*, 103, No. D16, 19811-19822 (17 August 1998)
- Uman, M. A., *The Lightning Discharge*, Academic Press, 2001
- Photograph, *Weatherwise*, 55, cover (May/June 2002)

- Mazur, V., “Physical processes during development of lightning flashes,” *C. R. Physique*, 3, 1393-1409 (2002)
- Morrow, R., and T. R. Blackburn, “The stepped nature of lightning, and the upward connecting streamer,” *Journal of Physics D: Applied Physics*, 35, L69-L73 (2002)
- Aleksandrov, N. L., and E. M. Bazelyan, “Comments on ‘The stepped nature of lightning and the upward connecting streamer’ by R Morrow and T R Blackburn,” *Journal of Physics D*, 36, 2598-2600 (2003)
- Nelson, J., and M. Baker, “Charging of ice-vapor interfaces: applications to thunderstorms, *Atmospheric Chemistry and Physics*, 3, 1237-1252 (2003)
- Mazur, V., and L. H. Ruhnke, “Determining the striking distance of lightning through its relationship to leader potential,” *Journal of Geophysical Research*, 108, No. D14, article # 4409 (18 July 2003)
- Cerveny, R., “The oddities of lightning,” *Weatherwise*, 57, No. 2, 64-68 (March/April 2004)
- Singh, D. K., R. P. Singh, and A. K. Kamra, “The electrical environment of the Earth’s atmosphere: a review,” *Space Science Reviews*, 113, 375-408 (2004)
- Rachidi, F., J. L. Bermudez, M. Rubinstein, and V. A. Rakov, “On the estimation of lightning peak currents from measured fields using lightning location systems,” *Journal of Electrostatics*, 60, 121-129 (2004)
- Lowke, J. J., “On the physics of lightning,” *IEEE Transactions on Plasma Science*, 32, No. 1, 3-17 (February 2004)
- Thomas, J. N., R. H. Holzworth, and M. P. McCarthy, “In situ measurements of contributions to the global electrical circuit by a thunderstorm in southeastern Brazil,” *Atmospheric Research*, 91, 153-160 (2009)

Related references

- Orville, R. E., “The colour spectrum of lightning,” *Weather*, 21, 198-200 (1966)
- Holitza, F. J., and H. W. Kasemir, “Accelerated decay of thunderstorm electric fields by chaff seeding,” *Journal of Geophysical Research*, 79, No. 3, 425-429 (20 January 1974)
- Orville, R. E., “Spectrum of the lightning dart leader,” *Journal of the Atmospheric Sciences*, 32, 1829-1837 (September 1975)

- Guo, C., and E. P. Krider, “The optical power radiated by lightning return strokes,” *Journal of Geophysical Research*, 88, No. C13, 8621-8622 (20 October 1983)
- Uman, M. A., “Why is some lightning colored?” in “Weather Queries,” T. Schlatter, editor, *Weatherwise*, 36, 307 (December 1983)
- Mandal, G., P. P. Kumar, “A laboratory study of ice nucleation due to electrical discharge,” *Atmospheric Research*, 61, 115-123 (2002)

5.2 Lightning: people, cows, and sheep

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=CpxKEGdfDxI> Football (soccer) players hurt by ground currents

Photos

<http://www.ucar.edu/communications/quarterly/winter0506/storms.jsp>

Henson, B., “Storms and stadiums,” *UCAR Quarterly* (Winter 2005-2006)

<http://www.smh.com.au/ftimages/2002/07/22/1026898970644.html>

lightning during a baseball game

<http://wx-man.com/blog/?cat=73> scroll down to the lightning story

<http://www.abc.net.au/rural/content/2005/s1497922.htm> cattle

http://www.utahweather.org/UWC/weather_pictures/weather_photos_1900-2002.html Large number of sheep killed by lightning but, in spite of what

the captions say, not by a direct hit.

http://www.lightningsafety.com/nlsi_info/damage_photos.html Photos and description of damage to lightning rod, animals

http://205.243.100.155/frames/human_LF2.jpg Photo of Lichtenberg figure in the lightning damage to a man’s back, as described in *Flying Circus*

http://www.postgradmed.com/issues/2003/06_03/puzzles_answer.htm

Discussion and photo, lightning from a clear sky and damage done to a victim

References

Dots • through ●●● indicate level of difficulty

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

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

- Meaden, G. T., (letter) “Fulgur divom: a lightning death in Britain over 1600 years ago---and another in Mesopotamia,” *Weather*, 42, No. 8, 257-258 (August 1987)
- Taussig, H. B., “‘Death’ from lightning and the possibility of living again,” *American Scientist*, 57, No. 3, 306-316 (1969)
- “Some recent lightning misadventures,” *Journal of Meteorology*, 2, No. 22, 298-299 (1976-1977)
- Golde, R. H., and W. R. Lee, “Death by lightning,” *IEEE Reviews*, 123, No. 10R, 1163-1180 (October 1976)
- Mogil, H. M., “Lightning in 1978,” *Weatherwise*, 32, 17-20 (February 1979)
- Winterling, G. A., “Lightning bolt shatters safety rule,” *Weatherwise*, 32, 21 (February 1979)
- “Some recent lightning hazards,” *Journal of Meteorology*, 6, 187-190 (1981)
- Schlatter, T., “Thunderstorms, lightning safety,” in “Weather Queries?” *Weatherwise*, 35, No. 5, 229-230 (October 1982)
- Trevino, L., “How I survived a lightning strike,” *Journal of Meteorology*, 8, 246-248 (1983)
- “Two deaths by telephone on 16 August 1983, lightning the cause,” *Journal of Meteorology*, 8, 283-284 (1983)
- Amy, B. W., W. F. McManus, C. W. Goodwin Jr., and B. A. Pruitt Jr., “Lightning injury with survival in five patients,” *JAMA (Journal of the American Medical Association)*, 253, No. 2, 243-245 (11 January 1985)
Warning: contains graphic photos
- Beeson, R. E., (letter), “Of lines and lightning,” *IEEE Spectrum*, 23, No. 5, 8 (May 1986)
- ten Duis, H. J., H. J. Klasen, M. W. N. Nijsten, and L. Pietronero, “Superficial lightning injuries---their ‘fractal’ shape and origin,” *Burns*, 13, No. 2, 141-146 (1987) *Warning: contains graphic photos*

- Reed, M., “And not one vicious liver in the lot . . .” *Weatherwise*, 41, 172-174 (June 1988)
- Willerstein, G., (letter), “Lightning signs,” *Weatherwise*, 41, 261 (October 1988)
- Gallagher, T. J., “Lightning on the links,” *Weatherwise*, 41, 212-213 (August 1988)
- Wood, R. A., “When lightning strikes!” *Weatherwise*, 41, 206-210 (August 1988)
- Hocking, B., and C. Andrews, (letter) “Fractals and lightning injury,” *Medical Journal of Australia*, 150, 409-410 (3 April 1989)
- Smith, T., “On lightning: hair standing on end may be warning of an impending strike,” *British Medical Journal*, 303, No. 6817, 1563 (21-28 December 1991)
- Cummins, R. H., “Struck by lightning in the Bahamas,” *Journal of Geological Education*, 40, 226-227 (1992)
- Schlatter, T., “Darts and leaders, devil on the beach,” *Weatherwise*, 45, 36-37 (October/November 1992)
- Schlatter, T., “Darts and leaders,” in “Weather Queries” *Weatherwise*, 45, 36 (October/November 1992)
- Andrews, C. J., M. A. Cooper, M. Darveniza, and D. Mackerras, *Lightning Injuries: Electrical, Medical, and Legal Aspects*, CRC Press, 1992
- Kessler, E., “Twelve cattle killed by lightning,” *Weather*, 48, 178-181 (1993)
- Lifschultz, B. D., and E. R. Donoghue, “Deaths caused by lightning,” *Journal Forensic Sciences*, 38, No. 2, 353-358 (March 1993)
- Elsom, D. M., “Deaths caused by lightning in England and Wales, 1852-1990,” *Weather*, 48, 83-90 (1993)
- Dayton, L., “Secrets of a bolt from the blue,” *New Scientist*, 137, 16 (18 December 1993)
- Fontanarosa, P. B., “Electrical shock and lightning strike,” *Annals of Emergency Medicine*, 22, No. 2, Part 2, 378-387 (February 1993)
- Cerveny, R., “Power of the gods: ancient cultures were grounded on a fear of lightning,” *Weatherwise*, 47, No. 2, 20-23 (April/May 1994)
- Spieth, M. E., R. L. Kimura, and T. D. Schryer, “Air traffic controller lightning strike,” *Journal of the National Medical Association*, 86, No. 9, 713-715 (September 1994)
- Cherington, M., “Central nervous system complications of lightning and electrical injuries,” *Seminars in Neurology*, 15, No. 3, 233-240 (September 1995)

- Cherington, M., "Lightning and transportation," *Seminars in Neurology*, 15, No. 4, 362-366 (December 1995)
- Qureshi, N. H., "Indirect lightning strike via telephone wire," *Injury*, 26, No. 9, 629-630 (1995)
- Herrero, F., V. Garcia-Morato, V. Salinas, and S. Alonso, "An unusual case of lightning injury: a melted silver necklace causing a full thickness linear burn," *Burns*, 21, 4, 308-309 (1995) *Warning: contains graphic photos*
- Resnik, B. I., and C. V. Wetli, "Lichtenberg figures," *American Journal of Forensic Medicine and Pathology*, 17, No. 2, 99-102 (1996) *Warning: contains graphic photos*
- Blanco-Pampin, J. M., J. M. S. Penaranda, R. R. Boquete, and L. C. Carro, "An unusual case of death by lightning," *Journal of Forensic Sciences*, 42, No. 5, 942-944 (1997) *Warning: contains graphic photos*
- Cherington, M., "A bolt from the blue: lightning strike to the head," *Neurology*, 48, No. 3, 683-686 (March 1997)
- Cutlip, K., "Lightning: serial killer from the sky," *Weatherwise*, 51, 20-27 (July/August 1998)
- Sweeney, P. J., letter, and reply by Cherington, M., E. P. Krider, P. R. Yarnell, and D. W. Breed, "A bolt from the blue: lightning strike to the head," *Neurology*, 50, 830 (March 1998)
- Cherington, M., D. W. Breed, P. R. Yarnell, and W. E. Smith, "Lightning injuries during snowy conditions," *British Journal of Sports Medicine*, 32, No. 4, 333-335 (December 1998)
- Williams, M. A., "Lightning strike in horses," *Compendium on Continuing Education for the Practicing Veterinarian*, 22, No. 9, 860-867 (20 September 2000)
- Best, A., "One strike is all it took," *Weatherwise*, 53, 23 (March/April 2000)
- Domart, Y., and E. Garet, "Lichtenberg figures due to a lightning strike," *New England Journal of Medicine*, 343, No. 21, 1536 (23 November 2000)
- Fish, R. M., "Electric injury, part III: cardiac monitoring indications, the pregnant patient, and lightning," *Journal of Emergency Medicine*, 18, No. 2, 181-187 (2000)
- Cohen, M. A., "Clinical pearls: struck by lightning," *Academic Emergency Medicine*, 8, No. 9, 893 (September 2001)
- Duff, K., and R. J. McCaffrey, "Electrical injury and lightning injury: a review of their mechanisms and neuropsychological, psychiatric, and

neurological sequelae,” *Neuropsychology Review*, 11, No. 2, 101-116 (June 2001)

- Anderson, R. B., “Does a fifth mechanism exist to explain lightning injuries?” *IEEE Engineering in Medicine and Biology*, 20, No. 1, 105-113 (January/February 2001)
- Elsom, D. M., “Deaths and injuries caused by lightning in the United Kingdom: analyses of two databases,” *Atmospheric Research*, 56, 325-334 (2001)
- Cherington, M., “Lightning injuries in sports: situations to avoid,” *Sports Medicine*, 31, No. 4, 301-308 (2001)
- Muehlberger T., P. M. Vogt, A. M. Munster, “The long-term consequences of lightning injuries,” *Burns*, 27, 829-833, (2001)
- Cooper, M. A., “A fifth mechanism of lightning injury,” *Academic Emergency Medicine*, 9, No. 2, 172-174 (February 2002)
- Cherington, M., P. R. Yarnell, J. Lane, L. Anderson, and G. Lines, “Lightning-induced injury on an airplane: coronal discharge and ball lightning,” *Journal of Trauma*, 52, No. 3, 579-581 (March 2002)
- Paulsen, B. J., “Survivors,” *Discover*, 23, 48-49 (August 2002)
- Grim, P., “When lightning strikes: an emergency room doctor faces a summer nightmare,” *Discover*, 23, 46-51 (August 2002)
- Jonas, L, G. Dulda, H. Nizze, R. Zimmermann, G. Gross, and F. Zack, “Detection of gold particles in the neck skin after lightning stroke with evaporation of an ornamental chain,” *Ultrastructural Pathology*, 26, 153-159 (2002)
- Larsson, A., “The interaction between a lightning flash and an aircraft in flight,” *C. R. Physique*, 3, 1423-1444 (2002)
- D’Alto, N., “A stroke of genius,” *Weatherwise*, 55, No. 3, 22-29 (May/June 2002)
- Cherington, M., S. Olson, and P. R. Yarnell, “Lightning and Lichtenberg figures,” *Injury, International Journal of the Care of the Injured*, 34, 367-371 (2003)
- Cherington, M., and P. R. Yarnell, (letter) “Ball lightning encephalopathy,” *Journal of Burn Care and Rehabilitation*, 24, 175 (2003)
- Elsom, D., and J. Webb, “Lightning strikes to people in the British Isles 2002,” *Journal of Meteorology*, 28, No. 279, 183-184 (May/June 2003)
- Cherington, M., and P. R. Yarnell, (letters) “Re: Ball lightning injuries,” *Annals of Plastic Surgery*, 51, No. 5, 525 (November 2003); reply by Selvaggi, G., and S. Monstrey, pages 525-526

- Miller, S. F., “The long-term consequences of lightning injuries Muehlberger T, Vogt PM, Munster AM (Burns 2001; 27: 829-33),” *Burns*, 29, 97 (2003)
- Szczervinski, M., “Lightning hazards and risks to humans: some case studies,” *Journal of Electrostatics*, 59, 15-23 (2003)
- Uman, M. A., and V. A. Rakov, “The interaction of lightning with airborne vehicles,” *Progress in Aerospace Sciences*, 39, 61-81 (2003)
- Cervený, R., “The oddities of lightning,” *Weatherwise*, 57, No. 2, 64-68 (March/April 2004)
- Gatewood, M. O. and R. D. Zane, “Lightning injuries,” *Emergency Medicine Clinics of North America*, 22, 369-403 (2004)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, 7th edition, 2005, pages 605, 615-616, 682, 691
- Zele, D., A. Bidovec, and G. Vengust, “Atmospheric flash injuries in roe deer (*Capreolus Capreolus*),” *Acta Veterinaria Hungarica*, 54, No. 1, 43-49 (2006)
- Esprit, S., P. Kothari, and R. Dhillon, “Injury from lightning strike while using mobile phone,” *British Medical Journal*, 332, No. 7556, 1513 (24 June 2006)
- Faragher, R. M., (letter) “Statistics and physics do not suggest a link,” *British Medical Journal*, 333, No. 7558, 96 (8 July 2006)
- Althaus, C. W., (letter) “Mobile phones are not lightning strike risk,” *British Medical Journal*, 333, No. 7558, 96 (8 July 2006)
- Saglam, H., Y. Yavuz, Y. Yurumez, G. Ozkececi, and C. Kilit, “A case of acute myocardial infarction due to indirect lightning strike,” *Journal of Electrocardiology*, 40, 527-530 (2007)
- Heffernan, E. J., P. L. Munk, and L. J. Louis, “Thunderstorms and iPods – Not a good idea,” *New England Journal of Medicine*, 357, No.2, 198-199 (12 July 2007)
- Andrews, C., M. A. Cooper, “More on thunderstorms and iPods,” *New England Journal of Medicine*, 357, No. 14, 1447 (4 October 2007)
- Heffernan, E. J., P. L. Munk, and L. J. Louis, “More on thunderstorms and iPods – Reply,” *New England Journal of Medicine*, 357, No. 14, 1448 (4 October 2007)
- Vastag, B., “fryPod: Lightning strikes iPod users,” *Science News*, 172, No. 3, 46 (21 July 2007)
- Mahajan, A. L., R. Rajan, and P. J. Regan, “Lichtenberg figures: cutaneous manifestation of phone electrocution from lightning,” *Journal of Plastic, Reconstructive & Aesthetic Surgery*, 61, 111-113 (2008)

Related references

- Tiwari, V. K., and D. Sharma, “Kite-flying: a unique but dangerous mode of electrical injury in children,” *Burns*, 25, 537-539 (1999)
- Polk, C., “Cows, ground surface potentials and earth resistivity,” *Bioelectromagnetics*, 22, 7-18 (January 2001)
- MacLaren, M., “Early electrical discoveries by Benjamin Franklin and his contemporaries,” *Journal of the Franklin Institute*, 240, No. 1, 1-14 (July 1945)

5.3 Lightning: vehicles

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=eX6Xk0DRVvE&feature=related>

Lightning strikes airplane just after takeoff

<http://www.youtube.com/watch?v=036hpBvjoQw&NR=1> Lightning strikes Qantas airplane

<http://www.youtube.com/watch?v=3ydadIprhMI&NR=1> Lightning strikes car

<http://www.youtube.com/watch?v=nI79A2yXo9U&NR=1> Lightning hits car (caution: mild cursing)

<http://www.youtube.com/watch?v=K-O26xuAD1o&feature=related> Lightning strikes tree and flashes to parked car

<http://www.youtube.com/watch?v=lv006jJjo6w&NR=1> Way cool video, TV host sitting in a car while it receives huge sparks at many hundreds of kilovolts.

<http://www.youtube.com/watch?v=iIYQcHfSEvI> Video, include video from within airplane, showing the strike to the fuselage

http://www.youtube.com/watch?v=4sA-Hk_jnPg Video of intense St. Elmo's fire on windshield of airplane

http://www.crh.noaa.gov/pub/lrg/plane_japan.php Images of airplane being hit by lightning

<http://www.youtube.com/watch?v=6EUh-Nmp6aY> Video of lightning strike to a storm-penetrating aircraft

<http://www.youtube.com/watch?v=bZwID-Z0zmE&NR=1> Man in a Faraday cage, big sparks

<http://www.youtube.com/watch?v=IUUOdO6eEZA&mode=related&search> = Video of car as it is hit by lightning

<http://www.deas.albany.edu/deas/bvonn/707wingt.html> Photo and description of damage to wingtip of a Boeing 707.

<http://www.exo.net/~pauld/popularerrors/popularerrors.html> This is an old photograph of a large spark to a (metal) car in which a man sits. The current stays on the outside of the metal and jumps across the insulating rubber tire. The man, being in the interior of the metal enclosure, is unaffected.

http://www.wrh.noaa.gov/images/pqr/05082003_sle.jpg Photo of damage to radio antenna on a car

<http://www.prazen.com/cori/images/van1t.jpg> Photo of damage *inside* a car (yes, sometimes the lightning can damage inside a car)

<http://www.youtube.com/watch?v=w4VgkmYOUPk> Video of lightning hitting car

References

Dots • through ••• indicate level of difficulty

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

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

- Mason, Captain D., "Lightning strikes on aircraft - II," *Weather*, 19, 248-255 (1964)
- "Lightning strikes on aircraft – I," *Weather*, 19, 206-208 (1964)
- Falconer, R. E., "Lightning strikes a parked school bus," *Weather*, 21, 280-281 (1966)
- Vonnegut, B., "Effects of a lightning discharge on an aeroplane," *Weather*, 21, No. 8, 277-279 (August 1966)
- Bosart, L. F., "Weather at the launch of Apollo 12," *Weather*, 26, No. 1, 19-23 (January 1971)
- Young, J. R., C., "Lightning and aircraft," *Weather*, 35, 311-312 (1980)
- Mazur, V., B. D. Fisher, and J. C. Gerlach, "Lightning strikes to an airplane in a thunderstorm," *Journal of Aircraft*, 21, No. 8, 607-611 (August 1984)
- Rustan Jr., P. L., "The lightning threat to aerospace vehicles," *Journal of Aircraft*, 23, No. 1, 62-67 (19 January 1986)
- Pitts, F. L., B. D. Fisher, V. Mazur, and R. A. Perala, "Aircraft jolts from lightning bolts," *IEEE Spectrum*, 25, No. 7, 34-38 (July 1988)

- Christian, H. J., V. Mazur, B. D. Fisher, L. H. Ruhnke, K. Crouch, and R. P. Perala, “The Atlas/Centaur lightning strike incident,” *Journal of Geophysical Research*, 94, No. D11, 13169-13177 (30 September 1989)
- Mazur, V., “A physical model of lightning initiation on aircraft in thunderstorms,” *Journal of Geophysical Research*, 94, D3, 3326-3340 (20 March 1989)
- Freedman, D. H., “Bolts from the blue,” *Discover*, 11, 50-56 (December 1990)
- Thomson, E. M., “A critical assessment of the U. S. Code for lightning protection of boats,” *IEEE Transactions on Electromagnetic Compatibility*, 33, No. 2, 132-138 (May 1991)
- Moreau, J.-P., J.-C. Allio, and V. Mazur, “Aircraft lightning initiation and interception from in situ electric measurements and fast video observations,” *Journal of Geophysical Research*, 97, No. D14, 15903-15912 (20 October 1992)
- Mazur, V., and J.-P. Moreau, “Aircraft-triggered lightning: processes following strike initiation that affect aircraft,” *Journal of Aircraft*, 29, No. 4, 575-580 (July-August 1992)
- Mazur, V., “Lightning threat to aircraft: do we know all we need to know?” *Journal of Aircraft*, 30, No. 1, 156-159 (January-February 1993)
- Cherington, M., and K. Mathys, “Deaths and injuries as a result of lightning strikes to aircraft,” *Aviation, Space, and Environmental Medicine*, 66, No. 7, 687-689 (July 1995)
- Cherington, M., “Lightning and transportation,” *Seminars in Neurology*, 15, No. 4, 362-366 (December 1995)
- Larsson, A., P. Lalande, A. Bondiou-Clergerie, and A. Delannoy, “The lightning swept stroke along an aircraft in flight. Part I: thermodynamic and electric properties of lightning arc channels,” *Journal of Physics D*, 33, 1866-1875 (2000)
- Larsson, A., P. Lalande, A. Bondiou-Clergerie, “The lightning swept stroke along an aircraft in flight. Part II: numerical simulations of the complete process,” *Journal of Physics D*, 33, 1876-1883 (2000)
- Larsson, A., “The interaction between a lightning flash and an aircraft in flight,” *C. R. Physique*, 3, 1423-1444 (2002)
- Uman, M. A., and V. A. Rakov, “The interaction of lightning with airborne vehicles,” *Progress in Aerospace Sciences*, 39, 61-81 (2003)
- Theethayi, N., Y. Liu, R. Montano, R. Thottappillil, M. Zitnik, V. Cooray, and V. Scuka, “A theoretical study on the consequence of a direct

lightning strike to electrified railway system in Sweden,” *Electric Power Systems Research*, 74, 267-280 (2005)

••• Larsson, A., A. Delannoy, and P. Lalande, “Voltage drop along a lightning channel during strikes to aircraft,” *Atmospheric Research*, 76, 377-385 (2005)

••• Xiaoqing, Z., “Estimation of the lightning strike incidence of free-standing masts,” *Journal of Electrostatics*, 64, 296-300 (2006)

Related references

• Pywell, M., “A question of survival---military aircraft vs the electromagnetic environment,” *Aeronautical Journal*, 108, No. 1087, 453-464 (September 2004)

• Short, D. A., J. E. Sardonía, W. C. Lambert, and M. M. Wheeler, “Nowcasting thunderstorm anvil clouds over Kennedy Space Center and Cape Canaveral Air Force Station,” *Weather and Forecasting*, 19, 706-713 (August 2004)

5.4 Lightning: trees, towers, and 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.

Video

<http://www.youtube.com/watch?v=gKPwkau0Dh0&NR=1> Lightning hits a tree

<http://www.youtube.com/watch?v=f6PJdAee7qY&NR=1> Damage due to a tree that exploded when hit by lightning

<http://www.youtube.com/watch?v=w4aZYvPrOGQ&NR=1> Lightning hits a tree

http://www.metacafe.com/watch/715760/lightning_strike_tree_in_slow_motion/

Photos and descriptions

<http://www.strangedangers.com/images/content/102407.jpg>

<http://www.lightning.ece.ufl.edu/pictures/fulgurites/GUINNESS.JPG>

Fulgurite exposed by digging

http://www.celestialmonochord.org/2006/05/sidewalk_fulgar.html Sidewalk fulgurite photos and discussion

http://www.visionforum.com/hottopics/blogs/dwp/2005-05-25_fulgurite2.gif

Fulgurite photos, including cross section

<http://www.thunderbolts.info/tpod/2006/image06/060309lightning.jpg>

Pattern burned into a golfing green by lightning

<http://geology.about.com/library/bl/images/blfulgurite.htm> Fulgurite photo and brief discussion

<http://plaza.ufl.edu/rakov/figures/2.jpg> Photo showing hollow interior of fulgurite section

http://www.holoscience.com/views/view_mars.htm Scroll down to the photos of lightning damage

http://www.lightningsafety.com/nlsi_info/damage_photos.html Photos and description of damage to lightning rod, animals

http://www.electricalfun.com/lightning_building.jpg Photo

<http://www.hiltonpond.org/ThisWeek050508.html> Photos and description of damage to a tree

http://www.wrh.noaa.gov/images/pqr/05082003_sle.jpg Photo of damage to radio antenna on a car

<http://www.thenews.co.uk/ViewArticle.aspx?SectionID=455&ArticleID=1066984> Photo and news story about fire caused at a Holiday Inn

References

Dots • through ●●● indicate level of difficulty

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

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

- Green, H. E., "Lightning and electrical power lines," *Weather*, 39, No. 1, 14-20 (January 1984)
- Shipley, J. F., "Lightning and trees," *Weather*, 1, 206-210 (1946)
- Taylor, A. R., "Diameter of lightning as indicated by tree scars," *Journal of Geophysical Research*, 70, No. 22, 5693-5695 (15 November 1965)
- Fuquay, D. M., R. G. Baughman, A. R. Taylor, and R. G. Hawe, "Characteristics of seven lightning discharges that caused forest fires," *Journal of Geophysical Research*, 72, No. 24, 6371-6373 (15 December 1967)

- Orville, R. E., “Photograph of a close lightning flash,” *Science*, 162, 666-667 (8 November 1968)
- Green, F. H. W., and A. Millar, “A tree struck by lightning, July 1970,” *Weather*, 26, No. 4, 174-175 (April 1971)
- Taylor, A. R., “Lightning --- agent of change in forest ecosystems,” *Journal of Forestry*, 68, No. 8, 476-480 (August 1971)
- Golde, R. H., and W. R. Lee, “Death by lightning,” *IEEE Reviews*, 123, No. 10R, 1163-1180 (October 1976)
- Williams, D. J., and W. Johnson, “A note on the formation of fulgurites,” *Geological Magazine*, 117, No. 3, 293-296 (1980)
- Kitterman, C. G., “Concurrent lightning flashes on two television transmission towers,” *Journal of Geophysical Research*, 86, No. C6, 5378-5380 (20 June 1981)
- Krider, E. P., “On lightning damage to a golf course green,” *Weatherwise*, 37, 111 (1982)
- Idone, V. P., and R. W. Henderson, “An unusual lightning ground strike,” *Weatherwise*, 35, No. 5, 223-224 (October 1982)
- Campbell, S., “Lightning craters,” *Weather*, 38, 106-109 (1983)
- Lee, R. H., “The shattering effect of lightning – pressure from heating of air by stroke current,” *IEEE Transactions on Industry Applications*, IA-22, No. 3, 416-419 (May/June 1986)
- Faidley, W. E., and E. P. Krider, “A lucky strike,” *Weatherwise*, 42, 136-139 (June 1989)
- Jonsson, H. H., C. Breslawski-Skubis, R. Lopez-Torrijos, R. W. Henderson, and C. Shelhamer, “Unusual effects of a lightning ground strike,” *Weather*, 44, 366-369 (1989)
- Uman, M. A., “The best lightning photo I’ve ever seen,” *Weatherwise*, 44, 8-10 + cover (June 1991)
- Cabrera, V. M., S. Lundquist, and V. Cooray, “On the physical properties of discharges in sand under lightning impulses,” *Journal of Electrostatics*, 30, 17-28 (1993)
- Wang, D., Z. I. Kawasaki, K. Yamamoto, K. Matsuura, J.-S. Chang, and W. Janischewskyj, “Luminous propagation of lightning attachment to CN tower,” *Journal of Geophysical Research*, 100, D6, 11661-11667 (20 June 1995)
- Wright Jr., F. W., “Florida’s fantastic fulgurite find,” *Weatherwise*, 51, 29-31 (July/August 1998)
- Nakada, K., T. Wakai, H. Taniguchi, T. Kawabata, S. Yokoyama, T. Yokota, and A. Asakawa, “Distribution arrester failures caued by lightning

current flowing from customer's structure into distribution lines," IEEE Transactions on Power Delivery, 14, No. 4, 1527-1532 (October 1999)

- Rakov, V. A., "Transient response of a tall object to lightning," IEEE Transactions on Electromagnetic Compatibility, 43, No. 4, 654-661 (November 2001)

- Faidley, W., photo, Weatherwise, 55, No. 3, cover (May/June 2002)

- Morrow, R., and T. R. Blackburn, "The stepped nature of lightning, and the upward connecting streamer," Journal of Physics D: Applied Physics, 35, L69-L73 (2002)

- Wilson, J. F., "Lightning-induced fracture of masonry and rock," International Journal of Solids and Structures, 40, 5305-5318 (2003)

- Goda, Y., S. Yokoyama, S. Watanabe, T. Kawano, and S. Kanda, "Melting and breaking characteristics of OPGW strands by lightning," IEEE Transactions on Power Delivery, 19, No. 4, 1734-1739 (October 2004)

- Miki, M., V. A. Rakov, T. Shindo, G. Diendorfer, M. Mair, F. Heidler, W. Zischank, M. A. Uman, R. Thottappillil, and D. Wang, "Initial stage in lightning initiated from tall objects and in rocket-triggered lightning," Journal of Geophysical Research, 110, D02109 (15 pages) (2005)

- Stephens, S. L., "Forest fire causes and extent on United States Forest Service lands," International Journal of Wildland Fire, 14, No. 3, 213-222 (2005)

- Sacks, H. K., "Corona-discharge-initiated mine explosions," IEEE Transactions on Industry Application, 41, No. 5, 1316-1322 (September/October 2005)

- Appel, P. W. U., N. Abrahamsen, and T. M. Rasmussen, "Unusual features caused by lightning impact in West Greenland," Geological Magazine, 143, No. 5, 737-741 (2006)

- Perkins, S., "Stroke of good fortune," Science News, 171, No. 7, 101 (17 February 2007)

Related references

- Fuchs, F., E. U. Landers, R. Schmid, and J. Wiesinger, "Lightning current and magnetic field parameters caused by lightning strikes to tall structures relating to interference of electronic systems," IEEE Transactions on Electromagnetic Compatibility, 40, No. 4, 444-451 (November 1998)

- Pokharel, R. K., Y. Baba, and M. Ishii, "Numerical electromagnetic analysis of transient induced voltages associated with lightning to tall structure," Journal of Electrostatics, 60, 141-147 (2004)

- Zischank, W., F. Heidler, J. Wiesinger, I. Metwally, A. Kern, and M. Seevers, “Laboratory simulation of direct lightning strokes to a modeled building: measurement of magnetic fields and induced voltages,” *Journal of Electrostatics*, 60, 223-232 (2004)

5.5 Bead and ball lightning

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=sx1GJnOBzFw>

<http://www.youtube.com/watch?v=aEC-ef72Wfc&NR=1> Video of plasma balls that may be related to naturally occurring ball lightning

<http://www.unexplained-mysteries.com/gallery/displayimage.php?album=30&pos=4> Old photo of ball lightning

http://www.daviddarling.info/encyclopedia/B/ball_lightning.html Photos plus speculation

<http://www.thunderbolts.info/webnews/NewsPics/Fatal%20ball%20lightning.jpg> Classic engraving of a researcher being struck by ball lightning

http://www-personal.umich.edu/~reginald/ball_1.html Plasma ball inside a microwave oven. Link allows download of a video.

http://library.thinkquest.org/03oct/00758/en/disaster/lightning/ball_lightning.jpg Photo

<http://www.pbs.org/wgbh/nova/sciencenow/3214/02-vari-03.html> Classic drawing of ball lightning entering a room

<http://news.nationalgeographic.com/news/bigphotos/32051113.html> Classic drawing

http://www.blahblahblahg.com/wordpress/wp-content/uploads/2006/07/ball_lightning_clip.jpg Another classic drawing

Bead lightning

<http://wvlightning.com/types.shtml> Scroll down to the bead lightning

<http://www.britannica.com/ebc/art-50963> Photos

References

Dots • through ••• indicate level of difficulty

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

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

- Matthias, B. T., and S. J. Buchsbaum, “Pinched lightning,” *Nature*, 194, No. 4826, 327 (28 April 1962)
- Uman, M. A., “Bead lightning and the pinch effect,” *Journal of Atmospheric and Terrestrial Physics*, 24, 43-45 (1962)
- Lewis, H. W., “Ball lightning,” *Scientific American*, 208, No. 3, 107-116 (March 1963)
- Clark, R., (letter) “Ball lightning,” *Weather*, 20, 134 (1965)
- Uman, M. A., “Some comments on ball lightning,” *Journal of Atmospheric and Terrestrial Physics*, 30, 1245-1246 (1968)
- Powell, J. R., and D. Finkelstein, “Structure of ball lightning,” *Advances in Geophysics*, 13, 141-189 (1969)
- Jennison, R. C., (letter) “Ball lightning,” *Nature*, 224, 895 (29 November 1969)
- Powell, J. R., and D. Finkelstein, “Ball lightning,” *American Scientist*, 58, 262-264 (1970)
- Altschuler, M., D., L. L. House, and E. Hildner, “Is ball lightning a nuclear phenomenon?” *Nature*, 228, 545-546 (7 November 1970)
- Singer, S., *The Nature of Ball Lightning*, Plenum Press, 1971
- Mills, A. A., “Ball lightning and thermoluminescence,” *Nature*, 233, 131-132 (18 October 1971)
- Wagner, G. A., “Optical and acoustic detection of ball lightning,” *Nature*, 232, 187 (16 July 1971)
- Wittmann, A., (letter) “In support of a physical explanation of ball lightning,” *Nature*, 232, 625 (27 August 1971)
- Charman, W. N., “Perceptual effects and the reliability of ball lightning reports,” *Journal of Atmospheric and Terrestrial Physics*, 33, 1973-1976 (1971)
- Anderson, F. J., and G. D. Freier, “A report on ball lightning,” *Journal of Geophysical Research*, 77, No. 21, 3928-3930 (20 July 1972)
- Wooding, E. R., “Laser analogue to ball lightning,” *Nature*, 239, 394-395 (13 October 1972)
- Crawford, J. F., “Antimatter and ball lightning,” *Nature*, 239, 395 (13 October 1972)
- Charman, N., “The enigma of ball lightning,” *New Scientist*, 56, 632-633 (14 December 1972)

- Pidcocke, B. G., (letter) “Ball lightning,” *Weather*, 29, 314 (1974)
- White, R., (letter) “Ball lightning and electrometeors,” *Weather*, 30, 134 (1975)
- Brovotto, P., V. Maxia, and G. Bussetti, “On the nature of ball lightning,” *Journal of Atmospheric and Terrestrial Physics*, 38, 921-934 (1976)
- Colucci, S., (letter) “Ball lightning observation,” *Weather*, 31, 68 (1976)
- Jones, I., “Giant ball lightning,” *Journal of Meteorology*, 2, No. 21, 271 (1976-1977)
- Wooding, E. R., “Ball lightning in Smethwick,” *Nature*, 262, 379-380 (29 July 1976)
- Eriksson, A. J., “Video tape recording of a possible ball lightning event,” *Nature*, 268, 35-36 (7 July 1977)
- Barry, J. D., “Frequency of ball lightning reports,” *Journal of Geophysical Research*, 84, No. C1, 308-310 (20 January 1979)
- Rees, M., (letter) “Ball lightning in the bedroom,” *Weather*, 35, 342-343 (1980)
- Barry, J. D., “On the energy density and forms of ball lightning,” *Journal of Geophysical Research*, 85, C7, 4111-4114 (20 July 1980)
- Dijkhuis, G. C., “A model for ball lightning,” *Nature*, 284, 150-151 (13 March 1980)
- Clark, C. A., (letter) “Ball lightning,” *Weather*, 36, 155-156 (1981)
- Rice-Evans, P. C., “Ball lightning in the laboratory,” *Nature*, 299, No. 5886, 774 (1982)
- Pike, B., “A remarkable ball lightning incident in Berkshire, 3 July 1982,” *Journal of Meteorology*, 7, No. 72, 253-257 (October 1982)
- Bailey, B. H., “Ball lightning,” *Weatherwise*, 37, 99-105 (1982)
- Charman, W. N., “Ball lightning: the unsolved problem,” *Weather*, 37, 66-75 (1982)
- Campbell, S., “Ball lightning at Crail – 1968,” *Weather*, 37, 75-78 (1982)
- Home, W. S., (letter) “Lightning strike,” *Nature*, 303, 568 (16 June 1983)
- Pike, W. S., (letter) “Incidence of ball lightning,” *Weather*, 38, 255-256 (1983)
- Bailey, B. H., “Ball lightning strikes twice,” *Weather*, 39, 276-279 (1984)
- Stenhoff, M., “Ball lightning,” *Journal of Meteorology*, 10, No. 100, 231-235 (July-August 1985)
- Turner, D. J., “The structure and stability of ball lightning,” *Philosophical Transactions of the Royal Society of London A*, 347, 83-111 (1994)

- (letters) “More ball-lightning eye-witness reports,” *Journal of Meteorology*, 11, No. 109, 149-151 (June 1986)
- Lewis, M. P., (letter) “Unusual lightning events,” *Weather*, 43, No. 7, 272 (July 1988)
- Carter, G., and K. Pilsbury, (letters) “Two unusual lightning events on 22 August 1987,” *Weather*, 43, No. 2, 58-59 (February 1988)
- Sunderland, P. G., (letter) “Ball lightning in Yorkshire, May 1985,” *Weather*, 43, No. 9, 343-344 (September 1988)
- Ohtsuki, Y. H., and H. Ofurton, “Plasma fireballs formed by microwave interference in air,” *Nature*, 350, 139-141 (14 March 1991)
- Singer, S., “Ball lightning: Great balls of fire,” *Nature*, 350, 108-109 (14 March 1991)
- Witalis, E. A., (letter) “Ball lightning,” *Nature*, 352, 290 (25 July 1991)
- Chown, M., “Fire and water: a recipe for ball lightning,” *New Scientist*, 137, No. 1865, 18 (20 March 1993)
- Boichenko, A. M., “On the nature of bead lightning,” *Plasma Physics Reports*, 22, No. 11, 917-920 (November 1996)
- Ranada, A. F., and J. L. Trueba, “Ball lightning an electromagnetic knot?” *Nature*, 383, 32 (5 September 1996)
- Lowke, J. J., “A theory of ball lightning as an electric discharge,” *Journal of Physics D*, 29, 1237-1244 (1996)
- Turner, D. J., “Ball lightning and other meteorological phenomena,” *Physics Reports*, 293, No. 1, 1-60 (January 1998)
- Ranada, A. F., M. Soler, and J. L. Trueba, “A model of ball lightning as a magnetic knot with linked streamers,” *Journal of Geophysical Research*, 103, D18, 23309-23313 (27 September 1998)
- Seife, C., “Cracked it! The mystery of ball lightning may finally have been solved,” *New Scientist*, 159, 6, (26 September 1998)
- Abrahamson, J., and J. Dinniss, “Ball lightning caused by oxidation of nanoparticle networks from normal lightning strikes on soil,” *Nature*, 403, 519-521 (3 February 2000)
- Matthews, R., “Great balls of fire,” *New Scientist*, 166, No. 2233, 22-26 (8 April 2000)
- Sanduloviciu, M., and E. Lozneau, “Ball lightning as a self-organization phenomenon,” *Journal of Geophysical Research*, 105, D4, 4719-4727 (27 February 2000)
- Abrahamson, J., “Preface,” *Philosophical Transactions of the Royal Society of London A*, 360, 3 (2002)

- Abrahamson, J., A. V. Bychkov, and V. L. Bychkov, “Recently reported sightings of ball lightning: observations collected by correspondence and Russian and Ukrainian sightings,” *Philosophical Transactions of the Royal Society of London A*, 360, 11-35 (2002)
- Bychkov, A. V., V. L. Bychkov, and J. Abrahamson, “On the energy characteristics of ball lightning,” *Philosophical Transactions of the Royal Society of London A*, 360, 97-106 (2002)
- Turner, D. J., “The fragmented science of ball lightning (with comment),” *Philosophical Transactions of the Royal Society of London A*, 360, 107-152 (2002)
- Singer, S., “Ball lightning --- the scientific effort,” *Philosophical Transactions of the Royal Society of London A*, 360, 5-9 (2002)
- Merzbacher, C. I., “Materials that emit light by chemical reaction,” *Philosophical Transactions of the Royal Society of London A*, 360, 89-96 (2002)
- Abrahamson, J., “Ball lightning from atmospheric discharges via metal nanosphere oxidation: from soils, wood or metals,” *Philosophical Transactions of the Royal Society of London A*, 360, 61-88 (2002)
- Bychkov, V. L., “Polymer-composite ball lightning,” *Philosophical Transactions of the Royal Society of London A*, 360, 37-60 (2002)
- Cherington, M., P. R. Yarnell, J. Lane, L. Anderson, and G. Lines, “Lightning-induced injury on an airplane: coronal discharge and ball lightning,” *Journal of Trauma*, 52, No. 3, 579-581 (March 2002)
- Weiss, P., “Anatomy of a lightning ball: an aerial wonder, pondered for ages, no longer seems so ghostly,” *Science News*, 161, 87-89 (9 February 2002)
- Shmatov, M. L., “New model and estimation of the danger of ball lightning,” *Journal of Plasma Physics*, 69, Part 6, 507-527 (2003)
- Cherington, M., and P. R. Yarnell, (letter) “Ball lightning encephalopathy,” *Journal of Burn Care and Rehabilitation*, 24, 175 (2003)
- Cherington, M., and P. R. Yarnell, (letters) “Re: Ball lightning injuries,” *Annals of Plastic Surgery*, 51, No. 5, 525 (November 2003); reply by Selvaggi, G., and S. Monstrey, pages 525-526
- Shmatov, M. L., “New model and estimation of the danger of ball lightning,” *Journal of Plasma Physics*, 69, part 6, 507-527 (2003)
- Selvaggi, G., S. Monstrey, D. von Heimburg, M. Hamdi, K. Van Landuyt, and P. Blondeel, “Ball lightning burn,” *Annals of Plastic Surgery*, 50, No. 5, 541-544 (May 2003)

- Melnyk, J., “Strange summer fireflies,” *Weatherwise*, 57, No. 4, 52-53 (July/August 2004)
- Alexeff, I., S. M. Parameswaran, M. Thiyagarajan, and M. Grace, “An experimental study of ball lightning,” *IEEE Transactions on Plasma Science*, 32, No. 3, 1378-1382 (June 2004)
- Nikitin, A. I., “The principles of developing the ball lightning theory,” *Journal of Russian Laser Research*, 25, No. 2, 169-191 (2004)
- Torchigin, V. P., and A. V. Torchigin, “Physical nature of ball lightning,” *European Physical Journal D*, 36, 319-327 (2005)
- Tsue, K. H., “A self-similar magnetohydrodynamic model for ball lightnings,” *Physics of Plasmas*, 13, article #072102 (7 pages) (2006)
- Dikhtyar, V., and E. Jerby, “Fireball ejection from a molten hot spot to air by localized microwaves,” *Physical Review Letters*, 96, article #045002 (4 pages) (2006)
- Seidel, P., “Investigation of metastable autonomous plasma formations from atmospheric discharges,” *Technical Physics Letters*, 32, No. 7, 606-609 (2006)
- Stephan, K. D., “Microwave generation of stable atmospheric-pressure fireballs in air,” *Physical Review E*, 74, article # 055401 (4 pages) (2006)
- Varsa, P., and J. Rokne, “Simulation of the ball lightning phenomenon,” *Computers & Graphics*, 30, 485-493 (2006)
- Tennakone, K., “Ball lightning: elusive behaviour depending upon proton conductivity,” *Current Science*, 90, No. 9, 1247-1250 (10 May 2006)
- Paiva, G. S., A. C. Pavao, E. A. de Vasconcelos, O. Mendes, Jr., and E. F. da Silva, Jr., “Production of ball-lightning luminous balls by electrical discharges in silicon,” *Physical Review Letters*, 98, article #048501 (4 pages) (26 January 2007)
- Cartlidge, E., “Seeking to solve the mystery of ball lightning,” *Physics World*, 20, No. 5, 35-38 (May 2007)
- Benka, S. G., “Ball lightning in the lab,” in “Physics Update,” *Physics Today*, 60, 22-23 (February 2007)
- Castelvechi, D., “Dusty fireball,” *Science News*, 173, 36 (19 January 2008)
- Mitchell, J. B. A., J. L. LeGarrec, M. Sztucki, T. Narayanan, V. Kikhtyar, and E. Jerby, “Evidence for nanoparticles in microwave-generated fireballs observed by synchrotron X-ray scattering,” *Physical Review Letters*, 100, article # 065001 (15 February 2008)

Related reference

- Rice-Evans, P. C., N. M. Laham, and E. Buckley, “Oscillatory luminous beads in a necklace of air plasma,” *Journal of Physics D: Applied Physics*, 18, L71-L73 (1985)

5.6 Sprites

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=PKL90WwmVjs> Video

<http://elf.gi.alaska.edu/> Images and discussion

<http://www.spritesandjets.com/> Information and diagram

<http://sprg.ssl.berkeley.edu/atmos/sprite.html> Photo plus description. Click on the button to get a menu for videos (GIF files)

<http://www.nasa.gov/centers/goddard/news/topstory/2005/sprites.html>

Photos plus news story

<http://www.everythingweather.com/lightning/other.shtml> Photo plus description

<http://www.kurasc.kyoto-u.ac.jp/~epic/figure/sprites.gif> Photo

<http://environment.newscientist.com/article/dn8733.html> Photo plus news story

<http://umbra.nascom.nasa.gov/spd/sprites.html> Photos 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

•• Wilson, C. T. R., “The acceleration of β -particles in strong electric fields such as those of thunderclouds,” *Proceedings of the Cambridge Philosophical Society*, 22, 534-538 (1925)

••• Wilson, C. T. R., “The electric field of a thundercloud and some of its effects,” *Proceedings of the Physical Society of London*, 37, 32D-37D (1925)

• Vonnegut, B., (letter) “Cloud-to-stratosphere lightning,” *Weather*, 35, 59-60 (1980)

- Vaughan Jr., O. H., and B. Vonnegut, "Lightning to the ionosphere?" *Weatherwise*, 35, 70-71 (April 1982)
- Gales, D. M., "Another account," *Weatherwise*, 35, 72 (April 1982)
- Hale, L. C., and M. E. Baginski, "Current to the ionosphere following a lightning stroke," *Nature*, 329, 814-815 (29 October 1987)
- Vaughan Jr., O. H., B. Vonnegut, "Recent observations of lightning discharges from the top of a thundercloud into the air above," *Journal of Geophysical Research*, 94, No. D11, 13179-13182 (30 September 1989)
- Franz, R. C., R. J. Nemzek, and J. R. Winckler, "Television image of a large upward electrical discharge above a thunderstorm system," *Science*, 249, No. 4964, 48-51 (1990)
- Gurevich, A. V., G. M. Milikh, and R. Roussel-Dupre, "Runaway electron mechanism of air breakdown and preconditioning during a thunderstorm," *Physics Letters A*, 165, 463-468 (1992)
- Vaughan Jr., O. H., R. Blakeslee, W. L. Boeck, B. Vonnegut, M. Brook, and J. McKune Jr., "A cloud-to-space lightning as recorded by the Space Shuttle payload bay TV cameras," *Monthly Weather Review*, 120, No. 7, 1459-1461 (July 1992)
- Sentman, D. D., and E. M. Wescott, "Observations of upper atmospheric optical flashes recorded from an aircraft," *Geophysical Research Letters*, 20, 2857-2860 (1993)
- Cowen, R., "Enigmatic bursts show their true colors," *Science News*, 146, 87 (6 August 1994)
- Monastersky, R., "Theorists grapple with high-flying sprites," *Science News*, 146, 405 (17 December 1994)
- Lyons, W. A., "Characteristics of luminous structures in the stratosphere above thunderstorms as imaged by low-light video," *Geophysical Research Letters*, 21, No. 10, 875-878 (15 May 1994)
- Milikh, G. M., K. Papadopoulos, and C. L. Chang, "On the physics of high altitude lightning," *Geophysical Research Letters*, 22, No. 2, 85-88 (15 January 1995)
- Davidson, K., "Bolts from the blue," *New Scientist*, 147, 32-37 (19 August 1995)
- Monastersky, R., "Glowing doughnuts flash high above storms," *Science News*, 148, 421 (28 & 30 December 1995)
- Monastersky, R., "Elusive beasts dance high in the night sky," *Science News*, 150, 391 (21 & 28 December 1996)

- Sentman, D. D., and E. M. Wescott, "Red sprites and blue jets: high-altitude optical emissions linked to lightning," *EOS*, 77, No. 1, 1-2 (2 January 1996)
- Wescott, E. M., D. D. Sentman, M. J. Heavner, D. L. Hampton, D. L. Osborne, and O. H. Vaughan Jr., "Blue starters: brief upward discharges from an intense Arkansas thunderstorm," *Geophysical Research Letters*, 23, No. 16, 2153-2156 (1 August 1996)
- Lyons, W. A., "Sprites, elves, and blue jets," *Weatherwise*, 50, 19-23 (August/September 1997)
- Mende, S. B., D. D. Sentman, and E. M. Wescott, "Lightning between Earth and space," *Scientific American*, 277, 56-59 (August 1997)
- Crystall, B., "Lightning brings elves to life," *New Scientist*, 154, 17 (12 April 1997)
- Raizer, Y. P., G. M. Milikh, M. N. Shneider, and S. V. Novakovski, "Long streamers in the upper atmosphere above thundercloud," *Journal of Physics D*, 31, 3255-3264 (1998)
- Boeck, W. L., O. H. Vaughan Jr., R. J. Blakeslee, B. Vonnegut, and M. Brook, "The role of the space shuttle videotapes in the discovery of sprites, jets and elves," *Journal of Atmospheric and Solar-Terrestrial Physics*, 60, 669-677 (1998)
- Wescott, E. M., D. D. Sentman, M. J. Heavner, D. L. Hampton, and O. H. Vaughan Jr., "Blue jets: their relationship to lightning and very large hailfall and their physics mechanisms for their production," *Journal of Atmospheric and Solar-Terrestrial Physics*, 60, 713-724 (1998)
- Rowland, H. L., "Theories and simulations of elves, sprites and blue jets," *Journal of Atmospheric and Solar-Terrestrial Physics*, 60, No. 7-9, 831-844 (May-June 1998)
- Wescott, E. M., D. D. Sentman, M. J. Heavner, D. L. Hampton, W. A. Lyons, and T. Nelson, "Observations of 'columniform' sprites," *Journal of Atmospheric and Solar-Terrestrial Physics*, 60, 733-740 (1998)
- Barrington-Leigh, C. P., U. S. Inan, M. Stanley, and S. A. Cummer, "Sprites triggered by negative lightning discharges," *Geophysical Research Letters*, 26, No. 24, 3605-3608 (15 December 1999)
- Cummer, S. A., and M. Stanley, "Submillisecond resolution lightning currents and sprite development: observations and implications," *Geophysical Research Letters*, 26, No. 20, 3205-3208 (15 October 1999)
- Barrington-Leigh, C. P., and U. S. Inan, "Elves triggered by positive and negative lightning discharges," *Geophysical Research Letters*, 26, No. 6, 683-686 (15 March 1999)

- Rodger, C. J., “Red sprites, upward lightning, and VLF perturbations,” *Reviews of Geophysics*, 37, No. 3, 317-336 (August 1999)
- Schneider, D., “Invisible lights in the sky,” *American Scientist*, 88, 314-315 (July-August 2000)
- Capps, K. A., (letter) “Sprites and elves are seen but seldom quantified,” *Physics Today*, 55, 12 (April 2000); response E. Williams, page 12
- Baker, O., “The importance of being electric: scientists aim to explain sprites,” *Science News*, 157, 45-47 (15 January 2000)
- “Caught on tape,” *Weatherwise*, 53, 15 (November/December 2000)
- Smirnova, E. I., E. A. Mareev, and Y. V. Chugunov, “Modeling of lightning generated electric field transitional processes,” *Geophysical Research Letters*, 27, No. 23, 3833-3836 (1 December 2000)
- Wescott, E. M., H. C. Stenbaek-Nielsen, D. D. Sentman, M. J. Heavner, D. R. Moudry, and F. T. Sao Sabbas, “Triangulation of sprites, associated halos and their possible relation to causative lightning and micrometeors,” *Journal of Geophysical Research*, 106, No. A6, 10467-10477 (1 June 2001)
- Marshall, T. C., M. Stolzenburg, W. D. Rust, E. R. Williams, and R. Boldi, “Positive charge in the stratiform cloud of a mesoscale convective system,” *Journal of Geophysical Research*, 106, No. D1, 1157-1163 (16 January 2001)
- Zobotin, N. A., and J. W. Wright, “Role of meteoric dust in sprite formation,” *Geophysical Research Letters*, 28, No. 13, 2593-2596 (1 July 2001)
- Neubert, T., T. H. Allin, H. Stenbaek-Nielsen, and E. Blanc, “Sprites over Europe,” *Geophysical Research Letters*, 28, No. 18, 3585-3588 (15 September 2001)
- Williams, H., “Rider on the storm. A lone balloon soars high above a thunderstorm, searching for sprites,” *New Scientist*, 172, No. 2321, 36-40 (15 December 2001)
- Fullekrug, M., D. R. Moudry, G. Dawes, and D. D. Sentman, “Mesospheric sprite current triangulation,” *Journal of Geophysical Research*, 106, No. D17, 20189-20194 (16 September 2001)
- Williams, E. R., “Sprites, elves, and glow discharge tubes,” *Physics Today*, 54, 41-47 (November 2001)
- Pasko, V. P., M. A. Stanley, J. D. Mathews, U. S. Inan, and T. G. Wood, “Electrical discharge from a thundercloud top to the lower ionosphere,” *Nature*, 416, 152-154 (14 March 2002)
- Bering III, E. A., J. R. Benbrook, J. A. Garnett, and A. M. Paredes, E. M. Wescott, D. R. Moudry, D. D. Sentman, H. C. Stenbaek-Nielsen, and W. A.

Lyons, “The electrodynamics of sprites,” *Geophysical Research Letters*, 29, No. 5, article # 2001GL013267 (4 pages) (March 2002)

- Morrill, J., E. Bucsela, C. Siefiring, M. Heavner, S. Berg, D. Moudry, S. Slinker, R. Fernsler, E. Wescott, D. Sentment, and D. Osborne, “Electron energy and electric field estimates in sprites derived from ionized and neutral N₂ emissions,” *Geophysical Research Letters*, 29, No. 10, article # 2001GL014018 (3 pages) (May 2002)

- Valdivia, J. A., “Lightning induced optical emissions in the ionosphere,” *Space Science Reviews*, 107, 273-291 (2003)

- Cummer, S. A., “Current moment in sprite-producing lightning,” *Journal of Atmospheric and Solar-Terrestrial Physics*, 65, 499-508 (2003)

- Lyons, W. A., T. E. Nelson, R. A. Armstrong, V. P. Pasko, and M. A. Stanley, “Upward electrical discharges from thunderstorm tops,” *American Meteorological Society*, 84, No.14, 445-454 (April 2003)

- Yair, Y., P. Israelevich, A. D. Devir, M. Moalem, C. Price, J. H. Joseph, Z. Levin, B. Ziv, A. Sternlieb, and A. Teller, “New observations of sprites from the space shuttle,” *Journal of Geophysical Research*, 109, article number D15201 (6 August 2004)

- Soula, S., O. van der Velde, J. Montanya, T. Neubert, O. Chanrion, and M. Ganot, “Analysis of thunderstorm and lightning activity associated with sprites observed during the EuroSprite campaigns: Two case studies,” *Atmospheric Research*, 91, 514-528 (2009)

- Yair, Y., C. Price, M. Ganot, E. Greenberg, R. Yaniv, B. Ziv, Y. Sherez, A. Devir, J. Bor, and G. Satori, “Optical observations of transient luminous events associated with winter thunderstorms near the coast of Israel,” *Atmospheric Research*, 91, 529-537 (2009)

5.7 Lightning rods

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.napa.ufl.edu/2002news/lightningrodph.htm> Photo of strike to lightning rod and the suggestion that the rods may not protect a house where the soil is sandy.

http://www.sas.org/tcs/weeklyIssues/2004-05-07/feature2/art/MLO_lightning_%20rod_by_Mims.jpg Photo

<http://www.britannica.com/ebi/art-19392> Encyclopaedia Britannica story and diagram

<http://www.thebakken.org/electricity/Leyden-jar.html> A lightning rod umbrella is a very bad idea, don't you think?

References

Dots • through ••• indicate level of difficulty

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

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

- MacLaren, M., "Early electrical discoveries by Benjamin Franklin and his contemporaries," *Journal of the Franklin Institute*, 240, No. 1, 1-14 (July 1945)
- Cohen, I. B., "Prejudice against the introduction of lightning rods," *Journal of the Franklin Institute*, 253, 393-440 (1952)
- McEachron, K. B., "Lightning protection since Franklin's day," *Journal of the Franklin Institute*, 253, 441-470 (1952)
- Schonland, B. F. J., "The work of Benjamin Franklin on thunderstorms and the development of the lightning rod," *Journal of the Franklin Institute*, 253, No. 5, 375-392 (May 1952)
- "Ionizing radiation: a potential lightning hazard?" *Nature*, 208, No. 5010, 577-578 (6 November 1965)
- Chalmers, J. A., "The action of a lightning conductor," *Weather*, 20, 183-185 (1965)
- Roberts, J. E., N. W. Ramsey, and P. J. Gillespie, (letters) "Ionizing radiation and lightning hazards," *Nature*, 210, No. 5035, 514-515 (30 April 1966)
- Lee, R. H., "Protection zone for buildings against lightning strokes using transmission line protection practice," *IEEE Transactions on Industry Applications*, IA-14, No. 6, 465-470 (November/December 1978)
- Carpenter Jr., R. B., "Total isolation from lightning influences," *IEEE Transactions on Industry Applications*, IA-17, 334-340 (May/June 1981)
- Moore, C. B., "Improved configurations of lightning rods and air terminals," *Journal of the Franklin Institute*, 315, No. 1, 61-85 (1983)
- Price, R. H., and R. J. Crowley, "The lightning-rod fallacy," *American Journal of Physics*, 53, No. 9, 843-848 (September 1985)
- Benn, I. M., and S. T. Shanahan, "Of lightning rods, charged conductors, curvature, and things," *American Journal of Physics*, 59, No. 7, 658-660 (July 1991)

- Zipse, D. W., “Lightning protection systems: advantages and disadvantages,” *IEEE Transactions on Industry Applications*, 30, No. 5, 1351-1361 (October 1994)
- Cherington, M., “Lightning and transportation,” *Seminars in Neurology*, 15, No. 4, 362-366 (December 1995)
- Abdel-Salam, M., “Simulation of energized Franklin rods for lightning protection,” *IEEE Transactions on Dielectrics and Electrical Insulation*, 33, No. 3, 651-659 (May/June 1997)
- Mousa, A. M., “The applicability of lightning eliminatin devices to substations and power lines,” *IEEE Transactions on Power Delivery*, 13, No. 4, 1120- 1127 (October 1998)
- Moore, C. B., G. D. Aulich, and W. Rison, “Measurements of lightning rod responses to nearby strikes,” *Geophysical Research Letters*, 27, No. 10, 1487-1490 (15 May 2000)
- Moore, C. B., W. Rison, J. Mathis, and G. Aulich, “Lightning rod improvement studies,” *Journal of Applied Meteorology*, 39, 593-609 (May 2000)
- Van Brunt, R. J., T. L. Nelson, and K. L. Stricklett, “Early streamer emission lightning protection systems: an overview,” *IEEE Electrical Insulation Magazine*, 16, No. 1, 5-23 (January/February 2000)
- Szczerbinski, M., “A discussion of ‘Faraday cage’ lightning protection and application to real building structures,” *Journal of Electrostatics*, 48, 145-154 (2000)
- Zipse, D. W., “Lightning protection systems: an update and a discredited system vindicated,” *IEEE Transactions on Industry Applications*, 37, No. 2, 407-414 (March/April 2001)
- D’Alto, N., “A stroke of genius,” *Weatherwise*, 55, No. 3, 22-29 (May/June 2002)
- D’Alessandro, F., “Striking distance factors and practical lightning rod installations: a quantitative study,” *Journal of Electrostatics*, 59, 25-41 (2003)
- Moore, C. B., G. D. Aulich, and W. Rison, “The case for using blunt-tipped lightning rods as strike receptors,” *Journal of Applied Meteorology*, 42, 984-993 (July 2003)
- D’Alessandro, F., C. J. Kossmann, A. S. Gaivoronsky, and A. G. Ovsyannikov, “Experimental study of lightning rods using long sparks in air,” *IEEE Transactions on Dielectrics and Electrical Insulation*, 11, No. 4, 638-648 (August 2004)

- Tobias, J. M., “The basis of conventional lightning protection systems,” IEEE Transactions on Dielectrics and Electrical Insulation, 40, No. 4, 958-962 (July/August 2004)
- Horvath, T., “Standardization of lightning protection based on the physics or on the tradition,” Journal of Electrostatics, 60, 265-275 (2004)
- Gratz, J., R. Church, and E. Noble, “Safeguarding the spectator,” Weatherwise, 58, No.1, 42-45 (January/February 2005)
- D’Alessandro, F., and N. I. Petrov, “Field study on the interception efficiency of lightning protection systems and comparison with models,” Proceedings of the Royal Society A, 462, 1365-1386 (2006)
- Krider, E. P., “Benjamin Franklin and lightning rods,” Physics Today, 59, 42-48 (January 2006)
- Little, J., (letter) “Points or knobs on lightning rods,” Physics Today, 60, 83 (February 2007)

Related references

- Fricker, H. S., “Why does charge concentrate on points?” Physics Education, 24, 157-161 (1989)
- Metwally, I. A., and F. H. Heidler, “Improvement of the lightning shielding performance of overhead transmission lines by passive shield wires,” IEEE Transactions on Electromagnetic Compatibility, 45, No. 2, 378-392 (May 2003)

5.8 Sweaters, playground slides, and surgery rooms

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=zeSTAbpQsQE> Video of child charged by sliding down plastic slide.

<http://www.youtube.com/watch?v=TjnNNwHqj8w> Another video of child charged by sliding down plastic slide.

<http://www.youtube.com/watch?v=ICqwTZGuDDo> Static charged seeds in a glass container

<http://www.youtube.com/watch?v=t0imJSsDAI8> Video, aluminum foil strips repel each other when they have the same sign of charge.

http://www.youtube.com/watch?v=GaY_uVjFcng Tongue-in-check use of static electricity

http://www.youtube.com/watch?v=vZL0tSnzK_4 (mild cursing) static discharge from a carpet. Funny. I laughed out loud, for a long time.

<http://www.youtube.com/watch?v=0EiGEnTvtDg> Old television, Julius Sumner Miller, electrostatic toys and other toys

http://www.youtube.com/watch?v=PS_GnFnkuVo Comedy bit about static cling.

References

Dots • through ••• indicate level of difficulty

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

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

- Harper, W. R., "The generation of static charge," *Advances in Physics*, 6, No. 24, 365-415 (October 1957)
- Webers, V. J., "Measurement of triboelectric position," *Journal of Applied Polymer Science*, 7, No. 4, 1317-1323 (July 1963)
- Moore, A. D., "Electrostatics," *Scientific American*, 226, 47-58 + 126 (March 1972)
- Eden, H. F., "Electrostatic nuisances and hazards," in *Electrostatics and Its Applications*, A. D. Moore editor, John Wiley & Sons, 1973, pages 425-440
- Fisher, L. H., and R. N. Varney, "Contact potentials' between metals: history, concepts, and persistent misconceptions," *American Journal of Physics*, 44, No. 5, 464-475 (May 1976)
- Brundrett, G. W., "A review of the factors influencing electrostatic shocks in offices," *Journal of Electrostatics*, 2, 295-315 (1976/1977)
- Chakravarti, K., and G. J. Pontrelli, "The measurement of carpet static," *Textile Research Journal*, 46, 129-134 (February 1976)
- Lowell, J., "The role of material transfer in contact electrification," *Journal of Physics D: Applied Physics*, 10, L233-L235 (1977)
- Lowell, J., and A. C. Rose-Innes, "Contact electrification," *Advances in Physics*, No. 6, 29, 947-1023 (November-December 1980)
- Verschave, R., and R. Firmin, "Hazards of static electricity in work clothing," *Journal of the Oil & Colour Chemists' Association*, 63, No. 7, 287-289 (1980)

- Baumgartner, G. T., and M. T. Brandt, “Conductive flooring and how it works,” *Evaluation Engineering*, ??, 66-68 + 70 (May/June 1980)
- Hetzel, R., C. Chiaverina, and S. Welty, “Sweater charge,” in “Doing Physics,” edited by E. Zwicker, *Physics Teacher*, 24, 55-57 (January 1986)
- Lowell, J. and A. R. Akande, “Contact electrification --- why is it variable?” *Journal of Physics D: Applied Physics*, 21, 125-137 (1988)
- Fujiwara, O., M. Okazaki, and T. Azakami, “Electrification properties of human body by walking,” *Transactions of the Institute of Electronics and Communication Engineers of Japan*, E73, No. 6, 876-878 (June 1990)
- Mellen, W. R., “Inexpensive electrostatic halos,” *Physics Teacher*, 28, 612-613 (December 1990)
- Greason, W. D., “Analysis of human body model for electrostatic discharge (ESD) with multiple charged sources,” *IEEE Transactions on Industry Applications*, 30, No. 3, 589-594 (May/June 1994)
- DeChiaro, L. F., and B. A. Unger, “ESD hazards in the electronics industry,” in *Handbook of Electrostatic Processes*, J.-S. Chang, A. J. Kelly, and J. M. Crowley editors, M. Dekker, 1995, Chapter 30, pages 687-701
- Rizvi, S. A. H., E. M. Crown, K. Osei-Ntiri, P. R. Smy, and J. A. Gonzalez, “Electrostatic characteristics of thermal-protective garments at low humidity,” *Journal of the Textile Institute*, 86, No. 4, 549-558 (1995)
- Strojny, J. A., “Some factors influencing electrostatic discharge from a human body,” *Journal of Electrostatics*, 40&41, 547-552 (1997)
- Freeman, G. R., and N. H. March, “Triboelectricity and some associated phenomena,” *Materials Science and Technology*, 15, No. 12, 1454-1458 (December 1999)
- Lim, S., “Conductive floor and footwear system as primary protection against human body model ESD event,” *IEEE Transactions on Electronics Packaging Manufacturing*, 23, No. 4, 255-258 (October 2000)
- Bailey, A. G., “The charging of insulator surfaces,” *Journal of Electrostatics*, 51 & 52, 82-90 (2001)
- Gonzalez, J. A., S. A. Rizvi, E. M. Crown, and P. R. Smy, “A laboratory protocol to assess the electrostatic propensity of protective-clothing systems,” *Journal of the Textile Institute*, 92, Part 1, No. 3, 315-327 (2001)
- Ono, H., A. Ohsawa, and Y. Tabata, “New method for evaluating antistatic effect in floor coverings,” *Journal of Electrostatics*, 57, 355-362 (2003)
- Greason, W. D., “Electrostatic discharge characteristics for the human body and circuit packs,” *Journal of Electrostatics*, 59, 285-300 (2003)

- Holdstock, P., M. J. D., Dyer, and J. N. Chubb, “Test procedures for predicting surface voltages on inhabited garments,” *Journal of Electrostatics*, 62, 231-239 (2004)
- Ficker, T., “Charging by walking,” *Journal of Physics D: Applied Physics*, 39, 410-417 (2006)
- Ficker, T., “Electrification of human body by walking,” *Journal of Electrostatics*, 64, 10-16 (2006)

5.9 Cars, fuel pumps, and pit stops

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=DcFO7lQII8I&feature=related>

<http://www.youtube.com/watch?v=IdcPeW1XwKs&feature=related>

Static discharge at a fuel station causes a fire. Note that she gets back in the vehicle, moves around, gets out, rearranges her clothing and then reaches for the pump handle. She was really charged by then.

http://www.metacafe.com/watch/729595/gas_station_fire_from_electrostatic_discharge_watch_your_car/ same video

<http://www.youtube.com/watch?v=IdcPeW1XwKs&feature=related>

same video

<http://www.youtube.com/watch?v=BBkPT-j8PNg> Brainiac show, trying to use a cell phone to blow up a trailer doused with fuel

<http://www.youtube.com/watch?v=zv5wln3m2LY> explosion on a truck.

Caution: the victim here eventually died from his injuries

<http://www.youtube.com/watch?v=1tYO4jvnJHw&feature=related> fuel fire apparently caused by static discharge

http://www.youtube.com/watch?v=vt7Q_GektqQ Video of Michael Shumacher pit stop fire during fueling, due to a spark

<http://www.youtube.com/watch?v=KHPE5BknE3I> Shumacher fire, shot from the inside

http://www.youtube.com/watch?v=l_bV5EUG9_0 Video of Eddie Irvine pit stop fire just after fueling, due to a spark

<http://www.youtube.com/watch?v=W8GR-RvpVjQ> Dramatic fire in a pit stop

References

Dots • through ••• indicate level of difficulty

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

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

- Beach, R., “Static electricity on rubber-tired vehicles,” *Electrical Engineering*, 60, 202-210 (May 1941)
- Mackeown, S. S., and V. Wouk, “Generation of electric charges by moving rubber-tired vehicles,” *Transactions of the American Institute of Electrical Engineers*, 62, 207-210 (May 1943)
- Miller, J. S., “Concerning the electric charge on a moving vehicle,” *American Journal of Physics*, 21, 316 (1953)
- Miller, R. F., “Electric charge on a moving vehicle,” *American Journal of Physics*, 21, 579 (October 1953)
- Eden, H. F., “Electrostatic nuisances and hazards,” in *Electrostatics and Its Applications*, A. D. Moore editor, John Wiley & Sons, 1973, pages 424-440, see pages 427-428
- Tolson, P., “The stored energy needed to ignite methane by discharges from a charged person,” *Journal of Electrostatics*, 8, No. 2-3, 289-293 (1980)
- Wilson, N., “The ignition of natural gas by spark discharges from the body,” *Institute of Physics Conference Series*, No. 66, Session I, 21-27 (1983)
- Edwards, R., “Filling station fires spark cars’ recall,” *New Scientist*, 145, No. 1967, 4-5 (4 March 1995)
- Mullins, J., “Easy rollers,” *New Scientist*, 146, No. 1979, 31-33 (27 May 1995)
- Bailey, A. G., “Electrostatic hazards during liquid transport and spraying,” in *Handbook of Electrostatic Processes*, J.-S. Chang, A. J. Kelly, and J. M. Crowley editors, M. Dekker, 1995, Chapter 32, pages 723-731
- Krein, P. T., “Electrostatic discharge issues in electric vehicles,” *IEEE Transactions on Industry Applications*, 32, No. 6, 1278-1284 (November/December 1996)

- Walmsley, H. L., “The electrostatic potentials generated by loading multiple batches of product into a road tanker compartment,” *Journal of Electrostatics*, 38, 177-186 (1996)
- von Pidoll, U., H. Kramer, and H. Bothe, “Avoidance of electrostatic hazards during refueling of motorcars,” *Journal of Electrostatics*, 40&41, 523-528 (1997)
- Greason, W. D., “Analysis of electrostatic discharge for the human body and an automobile environment,” *IEEE Transactions of Industry Applications*, 36, No. 2, 517-525 (March/April 2000)
- Glor, M., “Hazards and problems associated with liquids,” *Journal of Electrostatics*, 51 & 52, 359-365 (2001)
- Hearn, G. L., “Electrostatic ignition hazards arising from fuel flow in plastic pipelines,” *Journal of Loss Prevention in the Process Industries*, 15, 105-109 (2002)
- Pirici, D., J. Rivenc, T. Lebey, D. Malec, A. Agneray, and M. Cheaib, “A physical model to explain electrostatic charging in an automotive environment; correlation with experiments,” *Journal of Electrostatics*, 62, 167-183 (2004)
- von Pidoll, U., “Electrostatic ignition hazards---occurrence, detection and prevention,” *Institute of Physics Conference Series*, 178, 11-18 (2004)
- Perisse, F., J. Vazquez, T. Paillat, and G. Touchard, “Gasoline electrification: moisture and temperature influence,” *Journal of Electrostatics*, 63, 481-487 (2005)
- Kiss, I., N. Szedenik, and I. Berta, “Electrostatic hazard and protection: expert system for fuel delivery modules,” *Journal of Electrostatics*, 63, 495-499 (2005)

5.10 SHORT STORY: Shocking exchange of gum

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

- Miller, J. S., “Concerning the electric charge on a moving vehicle,” *American Journal of Physics*, 21, 316 (1953)
- Miller, R. F., “Electric charge on a moving vehicle,” *American Journal of Physics*, 21, 579 (October 1953)

5.11 Danger of powder floating in the air

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.nytimes.com/2008/02/09/us/09sugar.html> News story from the New York Times, with photo

Videos

<http://video.google.com/videoplay?docid=5857379787822215553&q=silo+explosion&hl=en> Rapid burning of corn starch

<http://www.youtube.com/watch?v=ctJf8BzqDUI> exploding flour

<http://www.youtube.com/watch?v=uLjQ0nGvH2g> rapid burn of sawdust

Photos and discussions

http://www.landinstruments.net/combustion/products/coal_fire_detection/mill_fire_detector.htm

<http://www.rain.org/~mkummel/stumpers/10nov00a.html> Flour explosion (scroll down)

References

Dots • through ••• indicate level of difficulty

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

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

- Eden, H. F., “Electrostatic nuisances and hazards,” in *Electrostatics and Its Applications*, A. D. Moore editor, John Wiley & Sons, 1973, pages 425-440

- Kissell, F. N., A. E. Nagel, and M. G. Zabetakis, "Coal mine explosions: seasonal trends," *Science*, 173, 891-892 (2 March 1973)
- Griffith, W. C., "Dust explosions," *Annual Review of Fluid Mechanics*, 10, 93-105 (1978)
- Hughies, J. F., and A. W. Bright, "Electrostatic hazards associated with powder handling in silo installations," *IEEE Transactions on Industry Applications*, IA-15, No. 1, 100-103 (January/February 1979)
- Lees, P., A. W. Bright, J. R. Smith, D. McAllister, and J. Diserens, "The finite-element method applied to axisymmetric field problems in silos," *IEEE Transactions on Industry Applications*, IA-16, No. 6, 749-754 (November/December 1980)
- Gibson, N., "Electrostatic hazards---a review of modern trends," *Institute of Physics Conference Series*, No. 66, Session I, 1-11 (1983)
- Owens, J. E., "Ignition hazards of charged dielectrics in flammable environments," *IEEE Transactions of Industry Applications*, IA-20, No. 6, 1424-1430 (November/December 1984)
- Singh, S., and P. Cartwright, "A study of electrostatic activity in grain silos," *IEEE Transactions on Industry Applications*, IA-20, No. 4, 863-868 (July/August 1984)
- Rehfeld, D. W., M. Barondeau, and J. W. Long, "An explosive demonstration," *Journal of Chemical Education*, 65, No. 10, 894-895 (October 1988)
- Riezenman, M. J., "Bulk solids handling: preventing the big blast," *Mechanical Engineering*, 111, No. 6, 44-46 (June 1989)
- Glor, M., and B. Maurer, "Ignition tests with discharges from bulked polymeric granules in silos (cone discharges)," *Journal of Electrostatics*, 30, 123-134 (May 1993)
- Still Jr., J. M., E. J. Law, and H. C. Pickens Jr., "Burn due to a sawdust explosion," *Burns*, 22, No. 2, 164-165 (1996)
- Glor, M., and K. Schwenzfeuer, "Occurrence of cone discharges in production silos," *Journal of Electrostatics*, 40&41, 511-516 (1997)
- Gibson, N., "Static electricity --- an industrial hazard under control?" *Journal of Electrostatics*, 40&41, 21-30 (1997)
- Glor, M., "Electrostatic ignition hazards associated with flammable substances in the form of gases, vapors, mists and dusts," *Institute of Physics Conference Series*, No. 163, 199-206 (1999)
- Hoppe, T., N. Jaeger, and J. Terry, "Safe handling of combustible powders during transportation, charging, discharging and storage," *Journal of Loss Prevention in the Process Industries*, 13, 253-263 (2000)

- Ebadat, V., “Exposing the causes of mill dust explosions,” *Chemical Processing*, 63, No. 8, 58-59 (August 2000)
- Zhong, S., and X. Deng, “Modeling of maize starch explosions in a 12 m³ silo,” *Journal of Loss Prevention in the Process Industries*, 13, 299-309 (2000)
- Glor, M., “Overview of the occurrence and incendivity of cone discharges with case studies from industrial practice,” *Journal of Loss Prevention in the Process Industries*, 14, 123-128 (2001)
- Nifuku, M., and H. Enomoto, “Evaluation of the explosibility of malt grain dust based on static electrification during pneumatic transportation,” *Journal of Loss Prevention in the Process Industries*, 14, 509-514 (2001)
- Nifuku, M., and H. Katoh, “Incendiary characteristics of electrostatic discharge for dust and gas explosion,” *Journal of Loss Prevention in the Process Industries*, 14, 547-551 (2001)
- Bailey, M., P. Hooker, P. Caine, and N. Gibson, “Incendivity of electrostatic discharges in dust clouds: the minimum ignition energy problem,” *Journal of Loss Prevention in the Process Industries*, 14, 99-101 (2001)
- Schwenzfeuer, K., and M. Glor, “Ignition tests with brush discharges,” *Journal of Electrostatics*, 51/52, 402-408 (2001)
- Schwenzfeuer, K., and M. Glor, “Ignition tests with brush discharges,” *Journal of Electrostatics*, 51 & 52, 402-408 (2001)
- Hearn, G. L., “Electrostatic ignition hazards arising from fuel flow in plastic pipelines,” *Journal of Loss Prevention in the Process Industries*, 15, 105-109 (2002)
- Kao, C.-S., and Y.-S. Duh, “Accident investigation of an ABS plant,” *Journal of Loss Prevention in the Process Industries*, 15, 223-232 (2002)
- Amyotte, P. R., F. I. Khan, and A. G. Dastidar, “Reduce dust explosions the inherently safer way,” *Chemical Engineering Progress*, 99, No. 10, 36-43 (October 2003)
- Bennett, D., G. A. Lunn, J. V. Torrent, E. Querol, J.-P. Fritze, “A test for electrical ignitions of flammable dust clouds,” *Journal of the Loss Prevention in the Process Industries*, 16, 33-40 (2003)
- Glor, M., “Ignition hazard due to static electricity in particulate processes,” *Powder Technology*, 135/136, 223-233 (2003)
- Mavrot, G., I. Sochet, P. Bailly, and M. Moisescot, “Silo vulnerability: structural aspects,” *Journal of Loss Prevention in the Process Industries*, 16, 165-172 (2003)

- Nifuku, M., and H. Katoh, “A study on the static electrification of powders during pneumatic transportation and the ignition of dust cloud,” *Powder Technology*, 135-136, 234-242 (2003)
- Pavey, I. D., “Electrostatic hazards in the process industries,” *Process Safety and Environmental Protection*, 82, B2, 132-141 (March 2004)
- Nifuku, M., H. Tsujita, K. Fujino, K. Takaichi, C. Barre, M. Hatori, S. Fujiwara, S. Horiguchi, and E. Paya, “A study on the ignition characteristics for dust explosion of industrial wastes,” *Journal of Electrostatics*, 63, 455-462 (2005)
- Kong, D., “Analysis of a dust explosion caused by several design errors,” *Process Safety Progress*, 25, No. 1, 58-63 (March 2006)
- Randeberg, E., and R. K. Eckhoff, “Initiation of dust explosions by electric spark discharges triggered by the explosive dust cloud itself,” *Journal of Loss Prevention*, 19, 154-160 (2006)
- Pilao, R., E. Ramalho, and C. Pinho, “Overall characterization of cork dust explosion,” *Journal of Hazardous Materials*, B133, 183-195 (2006)

Related references

- Kamra, A. K., “Electrification in an Indian dust storm,” *Weather*, 24, 145-146 (1969)
- Kamra, A. K., “Measurements of the electrical properties of dust storms,” *Journal of Geophysical Research*, 77, No. 30, 5856-5869 (20 October 1972)
- Roberts, J. M. C., and J. F. Hughes, “Elimination of electrostatic charging in punctured aerosol cans,” *IEEE Transactions on Industry Applications*, IA-15, No. 1, 104-108 (January/February 1979)
- Young, J. A., “The missing warning,” in “Mystery Matters” in *Chem Matters*, 3, No. 3, 12-13 (October 1985)
- Ohsawa, A., “Self-consistent particle-in-cell simulation of charged powders entering a vessel,” *Journal of Electrostatics*, 43, 187-201 (1998)
- Yarbrough, III, D. R., “Burns due to aerosol can explosions,” *Burns*, 24, 270-271 (1998)
- Pratt, T. H., and J. G. Atherton, “Electrostatic ignitions in everyday chemical operations: three case histories,” *Process Safety Progress*, 18, No. 4, 241-246 (winter 1999)
- Murtomaa, M., E. Rasanen, J. Rantanen, A. Bailey, E. Laine, J.-P. Mannermaa, and J. Yliruusi, “Electrostatic measurements on a miniaturized fluidized bed,” *Journal of Electrostatics*, 57, 91-106 (2003)

5.12 Danger of aerosol cans

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

- Roberts, J. M. C., and J. F. Hughes, “Elimination of electrostatic charging in punctured aerosol cans,” IEEE Transactions on Industry Applications, IA-15, No. 1, 104-108 (January/February 1979)
- Williams, R. P., R. E. Reusser, and C. R. Bresson, “Electrostatic charge on aerosol cans,” Journal of the Society of Cosmetic Chemists, 31, No. 6, 311-321 (November 1980)
- Young, J. A., “The missing warning,” in “Mystery Matters” in Chem Matters, 3, No. 3, 12-13 (October 1985)

5.13 Danger of spraying 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, journal, volume, pages (date)

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

- Pierce, E. T., and A. L. Whitson, “Atmospheric electricity and the waterfalls of Yosemite Valley,” Journal of the Atmospheric Sciences, 22, 314-319 (1965)

- Pierce, E. T., and A. L. Whitson, “Atmospheric electricity in a typical American bathroom,” *Weather*, 21, 449-455 (1966)
- Hughes, J. F., “Electrostatic hazards in supertanker cleaning operations,” *Nature*, 235, No. 5338, 381-383 (18 February 1972)
- Lyle, A. R., and H. Strawson, “Electrostatic hazards in tank filling operations,” *Physics Bulletin*, 23, 453-456 (1972)
- Smy, P. R., “Charge production, supertankers and supersonic aircraft,” *Nature*, 239, 269-271 (29 September 1972)
- Eden, H. F., “Electrostatic nuisances and hazards,” in *Electrostatics and Its Applications*, A. D. Moore editor, John Wiley & Sons, 1973, pages 425-440
- Makin, B., “Static electrification in supertankers,” *Physics in Technology*, ??, 109- (May 1975)
- Mills, J. S., and E. J. Haighton, “Prevention of electrostatic hazards associated with shipboard inert gas operations,” *International Physics Conferences Series No. 66, Session I*, 13-19 (1983)
- Walmsley, H. L., “Electrostatic hazards from water slugs formed during the washing of ships tanks: spark energy calculations,” *Journal of Applied Physics D*, 20, 329-339 (1987)
- Asano, K., I. Umetsu, and A. Watanabe, “Electrification of liquid ejected from a nozzle,” *IEEE Transactions on Industry Applications*, 26, No. 1, 24-28 (January/February 1990)
- Reiter, R., “Charges on particles of different size from bubbles of Mediterranean Sea surf and from waterfalls,” *Journal of Geophysical Research*, 99, No. D5, 10807-10812 (20 May 1994)
- Bailey, A. G., “Electrostatic hazards during liquid transport and spraying,” in *Handbook of Electrostatic Processes*, J.-S. Chang, A. J. Kelly, and J. M. Crowley editors, M. Dekker, 1995, Chapter 32, pages 723-731
- Chopp, R., and R. Pape, “The potential of sufficient static electricity for ignition during tanker washing,” *Process Safety Progress*, 16, No. 1, 25-31 (spring 1997)
- Luts, A., T-E. Parts, L. Laakso, A. Hirsikko, T. Gronholm, and M. Kulmala, “Some air electricity phenomena caused by waterfalls: Correlative study of the spectra,” *Atmospheric Research*, 91, 229-237 (2009)

5.14 Ski glow

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

- Latham, J., and C. D. Stow, “Electrification of snowstorms,” *Nature*, 202, 284-285 (18 April 1964)
- Stow, C. D., “The generation of electricity by blowing snow,” *Weather*, 22, 371-377 (1967)
- Colbeck, S. C., “Electrical charging of skis gliding on snow,” *Medicine and Science in Sports and Exercise*, 27, No. 1, 136-141 (January 1995)
- Petrenko, V. F., and S. C. Colbeck, “Generation of electric fields by ice and snow friction,” *Journal of Applied Physics*, 77, No. 9, 4518-4521 (1 May 1995)

5.15 Hindenburg disaster

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 of original newsreel footage of the crash:

<http://www.youtube.com/watch?v=F54rqDh2mWA>

Note the victims

escaping from the fire

<http://www.youtube.com/watch?v=8V5KXgFLia4>

Photos:

<http://flatrock.org.nz/topics/flying/assets/hindenburg.jpg>

<http://www.vidicom-tv.com/home/images/vidicom-main-hindenburg.jpg>

http://www.airfields-freeman.com/NJ/Lakehurst_NJ_Hindenburg_Hangar1_36.jpg

References

Dots • through ●●● indicate level of difficulty

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

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

- Vaeth, J. G., “What happened to the Hindenburg?” *Weatherwise*, 43, 315-322 (December 1990)
- Martin, L. C., (letter) “Another pop at the Hindenburg disaster,” *Chemical Engineering*, 105, No. 10, 8 (September 1998)
- Bain, A., and W. D. Van Vorst, “The Hindenburg tragedy revisited: the fatal flaw found,” *International Journal of Hydrogen Energy*, 24, 399-403 (1999)
- Potter, S., “May 6, 1937: The *Hindenburg* disaster,” *Weatherwise*, 60, No. 3, 16-17 (May/June 2007)

5.16 A gurney 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.

References

Dots • through ●●● indicate level of difficulty

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

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

- Hughes, J. F., and A. W. Bright, “Electrostatic charge control on hyperbaric chambers---a case history,” *IEEE Transactions on Industry Applications*, IA-16, No. 6, 762-766 (November/December 1980)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, 7th edition, 2005, pages 656 and 667-668

5.17 Glow in peeling adhesive tape

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

- Harvey, E. N., "The luminescence of adhesive tape," *Science*, 89, No. 2316, 460-461 (19 May 1939)
- Seifert, H. S., "Friction tape produces glow discharge," *American Journal of Physics*, 20, 380-381 (1952)
- Harvey, *A History of Luminescence*, American Philosophical Society (Philadelphia, Pennsylvania), 1957, page 252
- Henry, P. S. H., "'Static' in industry," *Physics Education*, 3, 3-8 (1968)
 - Walton, A. J., "Triboluminescence," *Advances in Physics*, 26, No. 6, 887-948 (November 1977). Abstract at <http://www.informaworld.com/smpp/content~db=all?content=10.1080/00018737700101483>
- Dickinson, J. T., M. K. Park, E. E. Donaldson, and L. C. Jensen, "Fracto-emission accompanying adhesive failure," *Journal of Vacuum Science and Technology*, 20, No. 3, 436-439 (March 1982)
- Dickinson, J. T., L. C. Jensen, and A. Jahan-Latibari, "Fracto-emission: The role of charge separation," *Journal of Vacuum Science and Technology A*, 2, No. 2, 1112-1116 (April-June 1984)
- Donaldson, E. E., J. T. Dickinson, and X. A. Shen, "Time and size correlations of photon and radiowave bursts from peeling pressure sensitive adhesives in air," *Journal of Adhesion*, 19, 267-286 (1986)
- Walker, J., "How to capture on film the faint glow emitted when sticky tape is peeled off a surface," in "The Amateur Scientist," *Scientific American*, 257, No. 6, 138-141 (December 1987)
- Dickinson, J. T., and E. E. Donaldson, "Autographs from peeling pressure sensitive adhesives: direct recording of fracture-induced photon emission," *Journal of Adhesion*, 24, No. 2-4, 199-220 (1987)

- Dickinson, J. T., and L. C. Jensen, "Fracto-emission from polymers, crystals, and interfaces," *Proceedings of the SPIE (the International Society for Optical Engineering)*, 743, 68-75 (1987)
- Walker, J., "How to map electrically charged patches with parsley, sage, rosemary and thyme," in "The Amateur Scientist," *Scientific American*, 258, No. 4, 114-117 (April 1988)
- Zhenyi, M., F. Jiawen, and J. T. Dickinson, "Properties of the photon emission accompanying the peeling of a pressure-sensitive adhesive," *Journal of Adhesion*, 25, No. 1, 63-77 (1988)
- Dickinson, J. T., and E. E. Donaldson, "Autographs from peeling pressure sensitive adhesives: direct recording of fracture-induced photon emission," *Journal of Adhesion*, 30, Nos. 1-4, 13-23 (1989)
- Peterson, I., "In the peel zone: Tape's electric gooeyness," *Science News*, 146, 277 (29 October 1994)
- Dickinson, J. T., L. C. Jensen, S. Lee, L. Scudiero, and S. C. Langford, "Fracto-emission and electrical transients due to interfacial failure," *Journal of Adhesion Science and Technology*, 8, No. 11, 1285-1309 (1994)
- Lee, S., L. C. Jensen, S. C. Langford, and J. T. Dickinson, "Electrical transients generated by the peel of a pressure sensitive adhesive tape from a copper substrate. Part I: Initial observations," *Journal of Adhesion Science and Technology*, 9, No. 1, 1-26 (1995)
- Scudiero, L., J. T. Dickinson, L. C. Jensen, and S. C. Langford, "Electrical transients generated by the peel of a pressure sensitive adhesive tape from a copper substrate. Part II: Analysis of fluctuations --- evidence for chaos," *Journal of Adhesion Science and Technology*, 9, No. 1, 27-45 (1995)
- De, R., A. Maybhate, and G. Ananthakrishna, "Dynamics of stick-slip in peeling of an adhesive tape," *Physical Review E*, 70, article #046223 (12 pages) (2004)
- Saunders, M. J., personal recollection
- De, R., g. Ananthakrishna, "Dynamics of the peel front and the nature of acoustic emission during peeling of an adhesive tape," *Physical Review Letters*, 97, article #165503 (4 pages) (2006)
- Miura, T., M. Chini, and R. Bennewitz, "Forces, charges, and light emission during the rupture of adhesive contacts," *Journal of Applied Physics*, 102, article # 103509 (6 pages) (2007)
- Camara, C. G., J. V. Escobar, J. R. Hird, and S. J. Putterman, "Correlation between nanosecond X-ray flashes and stick-slip friction in peeling tape," *Nature*, 455, No. 7216, 1089-1090 (23 October 2008)

Related references

- Dickinson, J. T., E. E. Donaldson, and M. K. Park, “The emission of electrons and positive ions from fracture of materials,” *Journal of Materials Science*, 16, 2897-2908 (1981)
- Langford, S. C., M. Zhenyi, and J. T. Dickinson, “Photon emission as a probe of chaotic processes accompanying fracture,” *Journal of Materials Research*, 4, No. 5, 1272-1279 (September/October 1989)
- Gandur, M. C., M. U. Kleinke, and F. Galembeck, “Complex dynamic behavior in adhesive tape peeling,” *Journal of Adhesion Science and Technology*, 11, No. 1, 11-28 (1997)
- Ciccotti, M., B. Giorgini, and M. Barquins, “Stick-slip in the peeling of an adhesive tape: evolution of theoretical model,” *International Journal of Adhesion & Adhesives*, 18, 35-40 (1998)
- Kogan, L., C. Y. Hui, E. J. Kramer, and E. Wallace Jr., “Rate dependence of the peel force in peel-apart imaging films,” *Journal of Adhesion Science and Technology*, 12, 71-94 (1998)
- Ficker, T., “Electron avalanches II --- Fractal morphology of partial microdischarge spots on dielectric barriers,” *IEEE Transactions on Dielectrics and Electrical Insulation*, 10, No. 4, 700-707 (August 2003)

5.18 Parsley, sage, rosemary, and thyme

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=FWOst4VwwEU> Video of Lichtenberg figures

http://205.243.100.155/frames/human_LF2.jpg Photo of Lichtenberg figure in the lightning damage to a man's back, as described in *Flying Circus*

http://205.243.100.155/frames/longarc.htm#Large_LF Photos and discussion, big sparks, lightning

<http://teslamania.delete.org/frames/coilgallery.html> Click on any of the photos to enlarge them.

<http://www.orau.org/ptp/collection/Lichtenberg%20figures/Largemendonca.htm> Photo and discussion of a Lichtenberg figure in a block of Lucite; the discharge was “heard several buildings away.”

<http://www.sgsmp.ch/lichtenberg.htm> Lichtenberg: discussion and photos

References

Dots • through ••• indicate level of difficulty

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

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

- Merrill, F. H., and A. von Hippel, “The atomphysical interpretation of Lichtenberg figures and their application to the study of gas discharge phenomena,” *Journal of Applied Physics*, 10, 873-887 (December 1939)
- Cobine, J. D., *Gaseous Conductors. Theory and Engineering Applications*, McGraw-Hill, 1941, pages 201-203
- Zeleny, J., “Variation of size and charge of positive Lichtenberg figures with voltage,” *American Journal of Physics*, 13, 106-109 (1945)
- Hull, H. H., “A method for studying the distribution and sign of static charges on solid materials,” *Journal of Applied Physics*, 20, No. 12, 1157-1159 (December 1949)
- Thomas, A. M., “‘Heat developed’ and ‘powder’ Lichtenberg figures and the ionization of dielectric surfaces produced by electrical impulses,” *British Journal of Applied Physics*, 2, 98-109 (April 1951)
- 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)
- Gross, B., “Irradiation effects in Plexiglas,” *Journal of Polymer Science*, 27, No. 115, 135-143 (1958)
- Montgomery, D. J., “Static electrification of solids,” *Solid State Physics*, 9, 139-197 (1959), see pages 150-154
- Loeb, L. B., *Electrical Coronas: Their Basic Physical Mechanisms*, University of California Press, 1965
- Donald, D. K., “Contact electrification of insulators and its relevance to electrets,” *Journal of the Electrochemical Society: Solid State Science*, 115, No. 3, 270-272 (March 1968)
- Rice-Evans, P. and I. Hassairi, “The ringing of Lichtenberg figures,” *Physics Letters*, 38A, No. 3, 196-198 (1972)
- Takahashi, Y., “Two hundred years of Lichtenberg figures,” *Journal of Electrostatics*, 6, 1-13 (1979)

- Boschung, P., and M. Glor, "Methods for investigating the electrostatic behaviour of powders," *Journal of Electrostatics*, 8, 205-219 (1980)
- Walker, J., "How to map electrically charged patches with parsley, sage, rosemary and thyme," in "The Amateur Scientist," *Scientific American*, 258, No. 4, 114-117 (April 1988)
- Sampson, H., personal communication, 1988
- Beuthe, T. G., and J.-S. Chang, "Gas discharge phenomena," in *Handbook of Electrostatic Processes*, J.-S. Chang, A. J. Kelly, and J. M. Crowley editors, M. Dekker, 1995, Chapter 9, pages 147-193
- Vonnegut, B., "Adventures in fluid flow: generating interesting dendritic patterns," *Leonardo*, 31, No. 3, 205-207 (1998)
- Ficker, T., "Electrostatic discharges and multifractal analysis of their Lichtenberg figures," *Journal of Physics D: Applied Physics*, 32, No. 3, 219-226 (1999)
- Sumawi, H., and S. A. Barringer, "Positive vs. negative electrostatic coating using food powders," *Journal of Electrostatics*, 63, 815-821 (2005)
- Mayr, M. B., and S. A. Barringer, "Corona compared with triboelectric charging for electrostatic powder coating," *Journal of Food Science E: Food Engineering and Physical Properties*, 71, No. 4, E171-E177 (2006)

Related references

- Williams, I. W., "Nobili's rings," *Science Teacher*, 46, 36 (December 1979)
- Dickinson, J. T., S. C. Langford, and L. C. Jensen, "Recombination on fractal networks: photon and electron emission following fraction of materials," *Journal of Materials Research*, 8, No. 11, 2921-2932 (November 1993)
- Belosheev, V. P., "Leader discharge over a water surface in a Lichtenberg figure geometry," *Technical Physics*, 43, No. 11, 1329-1332 (November 1998)
- Belosheev, V. P., "Self-consistent development and fractal structure of leader discharges along a water surface," *Technical Physics*, 44, No. 4, 381-386 (April 1999)
- Belosheev, V. P., "Discharge leader self-organization on the water surface," *Technical Physics*, 45, No. 7, 922-927 (2000)
- Schumacher, B. M., "After 60 years of EDM the discharge process remains still disputed," *Journal of Materials Processing Technology*, 149, 376-381 (2004)

5.19 Wintergreen glow in the closet

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.metacafe.com/watch/331709/sugar_emit_green_light_in_the_dark/

References

Dots • through ••• indicate level of difficulty

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

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

- Harvey, *A History of Luminescence*, American Philosophical Society (Philadelphia, Pennsylvania), 1957, Chapter 10
- Edwards Jr., H., and D. W. Edwards, (letter) “Wintergreen mints eschewed,” *New England Journal of Medicine*, 278, No. 18, 1024-1025 (2 May 1968)
- Walton, A. J., “Triboluminescence,” *Advances in Physics*, 26, No. 6, 887-948 (1977), see pages 904-907
- Chandra, B. P., “Kinetics of triboluminescence in crystals,” *Journal of Physics D: Applied Physics*, 10, 1531-1538 (1977)
- Walton, A. J., “From sweetness to light,” *Physics Bulletin*, 29, 355-356 (1978)
- “Scraped crystals light up from inside,” *New Scientist*, 80, ?? (5 October 1978)
- Zink, J. I., “Triboluminescence,” *Accounts of Chemical Research*, 11, No. 8, 289-295 (August 1978)
- Angelos, R., J. I. Zink, and G. E. Hardy, “Triboluminescence spectroscopy of common candies,” *Journal of Chemical Education*, 56, No. 6, 413-414 (June 1979)
- Chandra, B. P., and J. I. Zink, “Triboluminescence and the dynamics of crystal fracture,” *Physical Review B*, 21, No. 2, 816-826 (15 January 1980)

- Chandra, B. P., and J. I. Zink, "Mechanical characteristics and mechanism of the triboluminescence of fluorescent molecular crystals," *Journal of Chemical Physics*, 73, No. 12, 5933-5941 (15 December 1980)
- Zink, J. I., "Squeezing light out of crystals triboluminescence," *Naturwissenschaften*, 68, 507-512 (1981)
- Sweeting, L. M., M. L. Cashel, M. Dott, J. M. Gingerich, J. L. Guido, J. A. Kling, R. F. Pippin III, M. M. Rosenblatt, A. M. Rutter, and R. A. Spence, "Spectroscopy and mechanism in triboluminescence," *Molecular Crystals and Liquid Crystals*, 211, 389-396 (1992)
- Dickinson, J. T., S. C. Langford, and L. C. Jensen, "Recombination on fractal networks: photon and electron emission following fraction of materials," *Journal of Materials Research*, 8, No. 11, 2921-2932 (November 1993)
- Lea, A., and D. Fell, (letters) "Tonic blues," *New Scientist*, 165, No. 2224, inside back cover (6 February 2000)
- Sweeting, L. M., "Triboluminescence with and without air," *Chem. Mater*, 13, 854-870 (2001)

5.20 Earthquake lights

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.

Photos and descriptions

<http://nisee.berkeley.edu/elibrary/list?e=5440&start=1>

<http://www.spectrum.ieee.org/print/2367> Scroll down

References

Dots • through ••• indicate level of difficulty

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

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

- Finkelstein D., and J. Powell, "Earthquake lightning," *Nature*, 228, No. 5273, 759-760 (21 November 1970)

- Finkelstein, D., R. D. Hill, and J. R. Powell, “The piezoelectric theory of earthquake lightning,” *Journal of Geophysical Research*, 78, No. 6, 992-993 (20 February 1973)
- Derr, J. S., “Earthquake lights: a review of observations and present theories,” *Bulletin of the Seismological Society of America*, 63, No. 6, 2177-2187 (December 1973)
- “Quake lights: explaining the earthly glow,” *Science* 82, ??, 10 (September 1982)
- Lockner, D. A. M. J. S. Johnston, and J. D. Byerlee, “A mechanism to explain the generation of earthquake lights,” *Nature*, 302, 28-32 (3 March 1983)
- Hedervari, P., “Earthquake light phenomena,” *Nature*, 301, No. 5899, 368 (3 February 1983)
- Hedervari, P., “Quake lights examined,” *Geotimes*, 28, No. 5, 11 (May 1983)
- Hedervari, P., “Project on collection and evaluation of data on earthquake light phenomena,” *Bulletin of the Seismological Society of American*, 73, No. 3, 889-890 (June 1983)
- Pounder, C., “Solution contact charging with respect to earthquake lights,” *Nature*, 307, 389 (26 January 1984)
- Hedervari, P., “Quake lights recorded,” *Geotimes*, 29, No. 7, 4-5 (July 1984)
- Lockner, D. A., and J. D. Byerlee, “Complex resistivity of fault gouge and its significance for earthquake lights and induced polarization,” *Geophysical Research Letters*, 12, No. 4, 211-214 (April 1985)
- Hedervari, P., and Z. Noszticzius, “Recent results concerning earthquake lights,” *Annales Geophysicae*, 3, No. 6, 705-708 (November-December 1985)
- Derr, J. S., “Luminous phenomena and their relationship to rock fracture,” *Nature*, 321, 470-471 (29 May 1986)
- Peterson, I., “The light side of rock fractures,” *Science News*, 129, 373 (14 June 1986)
- Derr, J. S., and M. A. Persinger, “Luminous phenomena and earthquakes in southern Washington,” *Experientia*, 42, No. 9, 991-999 (15 September 1986)
- Brady, B. T., and G. A. Rowell, “Laboratory investigation of the electrodynamic of rock fracture,” *Nature*, 321, No. 6069, 488-492 (29 May 1986)

- Johnston, M. J. S., “Tectonomagnetism and tectonoelectricity,” *Reviews of Geophysics*, 25, No. 5, 983-988 (June 1987)
- Ouellet, M., “Earthquake lights and seismicity,” *Nature*, 348, 492 (6 December 1990)
- Johnston, A. C., “Light from seismic waves,” *Nature*, 354, No. 6352, 361 (5 December 1991)
- Ikeya, M., and S. Takaki, “Electromagnetic fault for earthquake lightning,” *Japanese Journal of Applied Physics*, 35, No. 3A, L355-L357 (March 1996)
- Enomoto, Y., and Z. Zheng, “Possible evidences of earthquake lightning accompanying the 1995 Kobe earthquake inferred from the Nojima fault gouge,” *Geophysical Research Letters*, 25, No. 14, 2721-2724 (15 July 1998)
- Enomoto, Y., F. Asuke, Z. Zheng, and H. Ishigaki, “Hardened foliated fault gouge from the Nojima Fault zone at Hirabayashi: evidence for earthquake lightning accompanying the 1995 Kobe earthquake?” *Island Arc*, 10, 447-456 (2001)
- Roder, H., R. Buttner, and B. Zimanowski, “Seismo-electrical effects: experiments and field measurements,” *Applied Physics Letters*, 80, No. 2, 334-336 (14 January 2002)
- Freund, F., “Charge generation and propagation in igneous rocks,” *Journal of Geodynamics*, 33, 543-570 (2002)
- Stothers, R. B., “Ancient and modern earthquake lights in northwestern Turkey,” *Seismological Research Letters*, 75, No. 2, 199-204 (March/April 2004)

Related reference

- Ikeya, M., and H. Matsumoto, “Reproduced earthquake precursor legends using a Van de Graaff electrostatic generator: candle flame and dropped nails,” *Naturwissenschaften*, 84, 539-541 (1997)

5.21 St. Elmo’s fire and Andes glow

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=6rAX0YR0wvs> St. Elmo's fire as seen through the cockpit window on an airplane!

http://www.youtube.com/watch?v=4sA-Hk_jnPg Video of intense St. Elmo's fire on windshield of airplane and very scary moments for the flight crew.

<http://www.youtube.com/watch?v=6ioN-3UWYrY> Video. Note the lights off to the right.

<http://atmospherical.blogspot.com> Way cool blog site with lots of photos and descriptions. Go through the archived blogs by clicking on the button at the bottom of the page. The blog started in April 2006. A photo of St. Elmo's fire on a wing tip is given for May 3, 2006.

References

Dots • through ••• indicate level of difficulty

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

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

- Markson, R., and R. Nelson, "Mountain-peak potential-gradient measurements and the Andes glow," *Weather*, 25, 350-360 (1970)
- Young, J. R. C., "The Andes glow," *Weather*, 26, 39 (1971)
- Lantham, J., "Mountain peak potential gradients," *Weather*, 26, 80 (1971)
- Kamra, A. K., "Visual observation of electric sparks on gypsum dunes," *Nature*, 240, 143-144 (17 November 1972)
- Ette, A. I. I., and E. U. Utah, "Studies of point-discharge characteristics in the atmosphere," *Journal of Atmospheric and Terrestrial Physics*, 35, 1799-1809 (1973)
- "The curious case of the electrified fisherman," *Journal of Meteorology*, 1, No. 2, 71 (1975-1976)
- Golde, R. H., and W. R. Lee, "Death by lightning," *IEEE Reviews*, 123, No. 10R, 1163-1180 (October 1976)
- Chapman, S., "The magnitude of corona point discharge current," *Journal of the Atmospheric Sciences*, 34, 1801-1809 (November 1977)
- Hillmar, K. E., "Saint Elmo's fire. A Christmas to remember," *Oceans*, 11, No. 6, 2-4 (November-December 1978)
- Standler, R. B., and W. P. Winn, "Effects of coronae on electric fields beneath thunderstorms," *Quarterly Journal of the Royal Meteorological Society*, 105, 285-302 (1979)
- "Another case of electrified fishermen," *Journal of Meteorology*, 5, 254 (1980)

- Standler, R. B., “Estimation of corona beneath thunderclouds,” *Journal of Geophysical Research*, 85, No. C8, 4541-4544 (20 August 1980)
- Vonnegut, B., “Reduction of thunderstorm electric field intensity produced by corona from a nearby object,” *Journal of Geophysical Research*, 89, No. D1, 1468-1470 (20 February 1984)
- Soula, S., and S. Chauzy, “The effects of ground coronae during lightning flashes,” *Annales Geophysicae, Series B*, 4, No. 6, 613-624 (1986)
- Wescott, E. M., D. D. Sentman, M. J. Heavner, T. J. Hallinan, D. L. Hampton, and D. L. Osborne, “The optical spectrum of aircraft St. Elmo’s fire,” *Geophysical Research Letters*, 23, No. 25, 3687-3690 (15 December 1996)
- Borra, J.-P., R. A. Roos, D. Renard, H. Lazar, A. Goldman, and M. Goldman, “Electrical and chemical consequences of point discharges in a forest during a mist and a thunderstorm,” *Journal of Physics D*, 30, 84-93 (1997)
- Pavey, I. D., “Electrostatic hazards in the process industries,” *Process Safety and Environmental Protection*, 82, B2, 132-141 (March 2004)

5.22 High-voltage lines

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=9tzga6qAaBA> Video of man doing repair work on a high-voltage line while the line is live. He comes in a helicopter. Just watch the sparking.

<http://www.youtube.com/watch?v=uEKbMMHAWm0> Similar video but shot from the ground.

<http://www.glumbert.com/media/highpower> Similar video

<http://www.youtube.com/watch?v=eYUmdqQ94Ao> Video of big flashover on power lines that are weighted down with ice and snow

<http://www.youtube.com/watch?v=WHSBph71GX8> Repeated arcing and then explosion on a transformer.

<http://www.youtube.com/watch?v=PWDsjch4XTs> Flashover burns wood pole so badly that the top falls over

<http://www.youtube.com/watch?v=QdhExznMuME> Flashover and explosion of a transformer

http://www.youtube.com/watch?v=DPvonY2_kRY Flashover video

<http://www.youtube.com/watch?v=xkuXMeW2TQ4> Video: the arcing and burning of a truck after its crane has touched a power line

<http://www.youtube.com/watch?v=-Q7qATVBEW8> Video of sparks racing along power lines during flashover

http://205.243.100.155/frames/longarc.htm#Large_LF Photos and discussion, big sparks, lightning

<http://www.youtube.com/watch?v=CWHC6Twujdk> Controlled arc on high-voltage line

References

Dots • through ••• indicate level of difficulty

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

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

- Markus, M. B., “Mortality of vultures caused by electrocution,” *Nature*, 238, 228 (28 July 1972)
- Jolly, D. C., (letter) “Bird dropping research continues apace,” *Nature*, 319, No. 6055, 625-626 (20 February 1986)
- Maddock, B., and J. Male, “Power-line fields and people,” *Physics Bulletin*, 38, 346-347 (1987)
- Stix, G., “Working hot: life at 765 kV,” *IEEE Spectrum*, 25, No. 9, 54-56 (September 1988)
- Gillies, D. A., “Electrical considerations in establishing working clearances for energized line maintenance,” *IEEE Transactions on Power Delivery*, 4, No. 2, 1164-1174 (April 1989)
- Farzaneh, M., and O. T. Melo, “Properties and effect of freezing rain and winter fog on outline insulators,” *Cold Regions Science and Technology*, 19, 33-46 (1990)
- Conntz, R., “War of the currents,” *Exploratorium Quarterly*, 12-15 (Fall 1990)
- Harris, E. L., B. D. Rindall, N. J. Tarko, and O. C. Norris-Elye, “The effect of a helicopter on DC fields and ions,” *IEEE Transactions on Power Delivery*, 8, No. 4, 1837-1841 (October 1993)
- Fishlock, D., “Working live wires,” *New Scientist*, 143, No. 1936, 23-25 (30 July 1994)

- Bodger, P. S., and J. J. Woudberg, “High voltage live-line maintenance laboratory,” *International Journal of Electrical Engineering Education*, 31, No. 3, 195-205 (1994)
- Burnham, J. T., “Bird streamer flashovers on FPL transmission lines,” *IEEE Transactions on Power Delivery*, 10, No. 2, 970-977 (April 1995)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, 5th edition, 1997, see photo on page 811; 6th edition, 2003, see photo on page 768
- Hotte, P. W., G. Gela, J. D. Mitchell Jr., and P. F. Lyons, “Electrical performance of conductive suits,” *IEEE Transactions on Power Delivery*, 12, No. 3, 1193-1201 (July 1997)
- Cameron, G. W., P. S. Bodger, and J. J. Woudberg, “Incomplete Faraday cage effect of helicopters used in platform live-line maintenance,” *IEE Proceedings – Generation, Transmission, and Distribution*, 145, No. 2, 145-148 (March 1998)
- Janss, G. F. E., and M. Ferrer, “Mitigation of raptor electrocution on steel power poles,” *Wildlife Society Bulletin*, 27, No. 2, 263-273 (1999)
- “Recommended practices for helicopter bonding procedures for live-line work,” *IEEE Transactions on Power Delivery*, 15, No. 1, 333-349 (January 2000)
- Manosa, S., “Strategies to identify dangerous electricity pylons for birds,” *Biodiversity and Conservation*, 10, 1997-2012 (2001)
- IEEE Task Force on Reducing Bird Related Power Outages, “Preventive measures to reduce bird-related power outages---Part I: electrocution and collision,” *IEEE Transactions on Power Delivery*, 19, No. 4, 1843-1847 (October 2004)
- Farzaneh, M., Y. Li, J. Zhang, L. Shu, X. Jiang, W. Sima, and C. Sun, “Electrical performance of ice-covered insulators at high altitudes,” *IEEE Transactions on Dielectrics and Electrical Insulation*, 11, No. 5, 870-880 (October 2004)
- Martin, D. S., “Smart birds,” *Physics Teacher*, 46, No. 2, 118 (February 2008)

5.23 Current, voltage, and people

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=THT5al8kaLk&NR=1> Electric flash sets one of the two electricians on fire

http://www.search.com/reference/Electric_chair Photo of the first electric chair

References

Dots • through ••• indicate level of difficulty

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

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

- Rudenberg, R., "Grounding principles and practice I ---Fundamental considerations on ground currents," *Electrical Engineering*, 64, No. 1, 1-13 (January 1945)
- Dalziel, C. F., and W. R. Lee, "Reevaluation of lethal electric currents," *IEEE Transactions on Industry and General Applications*, IGA-4, No. 5, 467-476 (September/October 1968)
- Dalziel, C. F., "Electric shock hazard," *IEEE Spectrum*, 9, 41-50 (February 1972)
- Harvie, R. A., "Avoiding hazards from earth currents in industrial plants," *IEEE Transactions on Industry Applications*, IA-13, No. 3, 207-214 (May/June 1977)
- Crawford, L. E., and M. S. Griffith, "A closer look at 'the facts of life' in ground mat design," *IEEE Transactions on Industry Applications*, IA-15, No. 3, 241-250 (May/June 1979)
- Lee, R. H., "The other electrical hazard: electric arc blast burns," *IEEE Transactions on Industry Applications*, IA-18, 246-251 (May/June 1982)
- Sances Jr., A., J. B. Myklebust, J. F. Szablya, T. J. Swiontek, S. J. Larson, M. Chilbert, T. Prieto, J. F. Cusick, D. J. Maiman, and K. Pintar, "Current pathways in high-voltage injuries," *IEEE Transactions on Biomedical Engineering*, BME-30, No. 2, 118-124 (February 1983)
- Budnick, L. D., "Bathtub-related electrocutions in the United States, 1979-1982," *Journal of the American Medical Association*, 252, No. 7, 918-920 (17 August 1984)
- Brown, C., "Electric shock and the human body--- or 'Is it amps or volts that kill you, sir?'" *Physics Education*, 21, 350-353 (1986)

- Geddes, L. A., J. D. Bourland, and G. Ford, "The mechanism underlying sudden death from electric shock," *Medical Instrumentation*, 20, No. 6, 303-315 (November-December 1986)
- Chilbert, M. A., T. Swiontek, J. B. Myklebust, T. E. Prieto, A. Sances Jr, C. Leffingwell, and J. D. Henderson Jr., "Fibrillation induced at powerline current levels," *IEEE Transactions on Biomedical Engineering*, 36, No. 8, 864-869 (August 1989)
- Logan, M. A., "Electrical burns caused by fishing rod contact with overhead electric cables: a potential hazard to fishermen," *Burns*, 19, No. 6, 535-537 (December 1993)
- Durham, M. O., "Safe work practices: a real world implementation," *IEEE Transactions on Industry Applications*, 30, No. 1, 179-187 (January/February 1994)
- Lee, R. C., G. Russo, and G. Kicska, "Kinetics of heating in electrical shock," *Annals of the New York Academy of Sciences*, 720, 56-64 (1994)
- Jumbelic, M. I., "Forensic perspectives of electrical and lightning injuries," *Seminars in Neurology*, 15, No. 4, 342-350 (December 1995)
- Leibovici, D., J. Shemer, and S. C. Shapira, "Electrical injuries: current concepts," *Injury*, 26, No. 9, 623-627 (1995)
- Jumbelic, M. I., "Forensic perspectives of electrical and lightning injuries," *Seminars in Neurology*, 15, No. 4, 342-350 (December 1995)
- Mackenzie, E. C., "Electrocution in a bath," *Science & Justics*, 35, No. 4, 253-258 (October-December 1995)
- Jones, J. L., and O. H. Tovar, "The mechanism of defibrillation and cardioversion," *Proceedings of the IEEE*, 84, No. 3, 392-403 (March 1996)
- Chi, L., Y. D. Ning, Q. F. Jun, C. Zhong, and S. Y. Hua, "Electrical injuries from graphite fishing rods," *Burns*, 22, No. 8, 638-640 (1996)
WARNING: graphic contents
- Campbell, D. C., T. Nano, and S. P. Pegg, "Pattern of burn injury in hang-glider pilots," *Burns*, 22, No. 4, 328-330 (1996) *WARNING: graphic contents*
- Rabban, J., J. Adler, C. Rosen, J. Blair, and R. Sheridan, "Electrical injury from subway third rails: serious injury associated with intermediate voltage contact," *Burns*, 23, No. 6, 515-518 (1997)
- Fox, B., "Live wires. How safe is the electricity supply to some homes?" *New Scientist*, 159, No. 2152, 6 (19 September 1998)
- Pfeiffer, H., and B. Karger, "Attempted homicide by electrocution," *International Journal of Legal Medicine*, 111, 331-333 (1998) *Warning: contains graphic photos*

- Garcia-Sanchez, V., and P. G. Morell, “Electric burns: high-and low-tension injuries,” *Burns*, 25, 357-360 (1999)
- Gordon, J. S., “Thomas Edison’s deadly game,” *American Heritage*, 51, No. 6, 15-17 (October 2000)
- Marc, B., F. Baudry, H. Douceron, A. Ghaith, J.-L. Wepierre, and M. Garnier, “Suicide by electrocution with low-voltage current,” *Journal of Forensic Sciences*, 45, No. 1, 216-222 (2000)
- Capelli-Schellpfeffier, M., H. L. Floyd II, K. Eastwood, and D. P. Liggett, “How we can better learn from electrical accidents,” *IEEE Industry Applications Magazine*, 6, No. 3, 16-23 (May/June 2000)
- Sternick, I., R. D. Gomes, M. C. Serra, H. N. Radwanski, and I. Pitanguy, “‘Train surfers’: analysis of 23 cases of electrical burns caused by high tension railway overhead cables,” *Burns*, 26, 470-473 (2000)
- Thomas, P. C., and P. Kumar, “High tension electrical injury from a telephone receiver,” *Burns*, 27, 502-503 (2001)
- Sacks, H. K., J. C. Cawley, G. T. Homce, and M. R. Yenchek, “Feasibility study to reduce injuries and fatalities caused by contact of cranes, drill rigs, and haul trucks with high-tension lines,” *IEEE Transactions on Industry Applications*, 37, No. 3, 914-919 (May/June 2001)
- Di Nunno, N., L. Vimercati, L. Viola, and F. Vimercati, “A case of electrocution during illegal fishing activities,” *American Journal of Forensic Medicine and Pathology*, 24, No. 2, 164-167 (June 2003)
- Taylor, A. J., G. McGwin Jr, R. M. Brissie, L. W. Rue III, G. G. Davis, “Death during theft from electric utilities,” *American Journal of Forensic Medicine and Pathology*, 24, No. 2, 173-176 (June 2003)
- Ramey, J., “The bloody blonde and the marble woman: gender and power in the case of Ruth Snyder,” *Journal of Social History*, 37, No. 3, 625-650 (2004)
- Bligh-Glover, W. Z., F. P. Miller, and E. K. Balraj, “Two cases of suicidal electrocution,” *American Journal of Forensic Medicine and Pathology*, 25, No. 3, 255-258 (September 2004)

Related references

- Gustafson, R. J., and V. D. Albertson, “Neutral-to-earth voltage and ground current effects in livestock facilities,” *IEEE Transactions on Power Apparatus and Systems*, PAS-101, 2090-2095 (July 1982)
- Corcoran, E., “Whatever happened to electroconvulsive therapy?” *IEEE Spectrum*, 22, 24 (November 1985)

- Grossblatt, R., and R. Jannini, “Stun gun,” *Radio-Electronics*, ??, 41-43 + 94 (September 1986)
- Roy, O. Z., and A. S. Podgorski, “Tests on a shocking device---the stun gun,” *Medical & Biological Engineering & Computing*, 27, 445-448 (July 1989)
- Robinson, M. N., C. G. Brooks, and G. D. Renshaw, “Electric shock devices and their effects on the human body,” *Medicine, Science, and the Law*, 30, No. 4, 285-300 (October 1990)
- Greatbatch, W., and C. F. Holmes, “History of implantable devices,” *IEEE Engineering in Medicine and Biology*, 10, No. 3, 38-41 + 49 (September 1991)
- Barker, A., “Electromagnetic therapies --- real or imaginary?” *Physics World*, 5, No. 1, 14-15 (January 1992)
- Kilpatrick, D., and P. R. Johnston, “Origin of the electrocardiogram,” *IEEE Engineering in Medicine and Biology*, 13, No. 4, 479-486 (August-September 1994)
- Reinemann, D. J., L. E. Stetson and N. K. Laughlin, “Response of dairy cattle to transient voltages and magnetic fields,” *IEEE Transactions on Industry Applications*, 31, No. 4, 708-713 (July/August 1995)
- Jeffrey, K., “Many paths to the pacemaker,” *Invention & Technology*, 12, No. 4, 28-39 (Spring 1997)
- Eisenberg, M. S., “Defibrillation: the spark of life,” *Scientific American*, 278, 86-91 (June 1998)
- Fish, R. M., “Electric injury, part I: treatment priorities, subtle diagnostic factors, and burns,” *Journal of Emergency Medicine*, 17, No. 6, 977-983 (1999)
- Tiwari, V. K., and D. Sharma, “Kite-flying: a unique but dangerous mode of electrical injury in children,” *Burns*, 25, 537-539 (1999)
- Fish, R. M., “Electric injury, part II: specific injuries,” *Journal of Emergency Medicine*, 18, No. 1, 27-34 (2000)
- Fish, R. M., “Electric injury, part III: cardiac monitoring indications, the pregnant patient, and lightning,” *Journal of Emergency Medicine*, 18, No. 2, 181-187 (2000)
- Scarano, V. R., A. R. Felthous, and T. S. Early, “The state of electroconvulsive therapy in Texas. Part I: reported data on 41,660 ECT treatments in 5971 patients,” *Journal of Forensic Sciences*, 45, No. 6, 1197-1202 (December 2000)
- “Shock tactics. Our reporter experiences what it’s like to be shot with a Taser,” *New Scientist*, 171, No. 2303, 11 (11 August 2001)

5.24 Short story: An act of indiscretion

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=Bbht8fCGpfQ&feature=related> A TV ad and thus not real

http://www.metacafe.com/watch/525160/electrocuted_men_security_footage/ Probably real

<http://www.youtube.com/watch?v=fDeGfWVp9sI&feature=related> A prank by “friends”

References

Dots • through ••• indicate level of difficulty

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

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

- Houts, M., *Where Death Delights: The Story of Dr. Milton Helpert and Forensic Medicine*, Coward-McCann, Inc., 1967, Chapter 15, pages 284-289
- Rabban, J., J. Adler, C. Rosen, J. Blair, and R. Sheridan, “Electrical injury from subway third rails: serious injury associated with intermediate voltage contact,” *Burns*, 23, No. 6, 515-518 (1997)

5.25 Use of current in surgery

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

- Schellhammer, P. F., “Electrosurgery. Principles, hazards, and precautions,” *Urology*, 3, No. 3, 261-268 (March 1974)
- Gullini, S., M. Caselli, and D. Cantarini, “Electrical hazards in endoscopic services,” *Endoscopy*, 18, No. 6, 211-212 (1986)
- Geddes, L. A., *Medical Device Accidents and Illustrative Cases*, 2nd edition, Lawyers & Judges Publishing Company, Inc., 2002, Chapter 3

5.26 Surgical fires and explosions

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=17uwTLEHTPM> Training video

References

Dots • through ••• indicate level of difficulty

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

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

- Lieberman, W., “Inflammable physiologic gases in the rectum and colon, with a report of a case,” *Review of Gastroenterology*, 11, 259-261 (1944)
- Carter, H. G., “Explosion in the colon during electrodesiccation of polyps,” *American Journal of Surgery*, 84, 514-517 (November 1952)
- Galley, A. H., “Combustible gases generated in the alimentary tract and other hollow viscera and their relationship to explosions occurring during anaesthesia,” *British Journal of Anaesthesia*, 26, 189-193 (1954)
- Carroll, K. J., “Unusual explosion during electrosurgery,” *British Medical Journal*, 2, 1178 (1964)
- Barrkman, M. F., “Intestinal explosion after opening a caecostomy with diathermy,” *British Medical Journal*, 1, 1594-1595 (19 June 1965)
- Schellhammer, P. F., “Electrosurgery. Principles, hazards, and precautions,” *Urology*, 3, No. 3, 261-268 (March 1974)

- Robinson, J. S., J. M. Thompson, and A. W. Wood, "Fire and explosion hazards in operating theatres: a reply and new evidence," *British Journal of Anaesthesia*, 51, 908 (1979)
- Bigard, M.-A., P. Gaucher, and C. Lassalle, "Fatal colonic explosion during colonoscopic polypectomy," *Gastroenterology*, 77, 1307-1310 (1979)
- Bowdle, T. A., M. Glenn, H. Colston, and D. Eisele, "Fire following use of electrocautery during emergency percutaneous transtracheal ventilation," *Anesthesiology*, 66, 697-698 (1987)
- Bailey, M. K., H. R. Bromley, J. G. Allison, J. M. Conroy, and W. Krzyzaniak, "Electrocautery-induced airway fire during tracheostomy," *Anesthesia and Analgesia*, 71, No. 6, 702-704 (December 1990)
- Aly, A., M. McIlwain, and J. A. Duncavage, "Electrosurgery-induced endotracheal tube ignition during tracheostomy," *Annals of Otolaryngology, Rhinology and Laryngology*, 100, No. 1, 31-33 (1991)
- Lew, E. O., R. E. Mittleman, and D. Murray, "Endotracheal tube ignition by electrocautery during tracheostomy: case report with autopsy findings," *Journal of Forensic Science*, 36, 1586-1591 (1991)
- MacDonald, A. G., "A brief historical review of non-anaesthetic causes of fires and explosions in the operating room," *British Journal of anaesthesia*, 73, 847-856 (1994)
- Brechtelsbauer, P. B, W. R. Carroll, and S. Baker, "Intraoperative fire with electrocautery," *Otolaryngology – Head and Neck Surgery*, 114, No. 2, 328-331 (February 1996)
- Thompson, J. W., W. Colin, T. Snowden, A. Hengesteg, R. M. S. Stocks, and S. P. Watson, "Fire in the operating room during tracheostomy," *Southern Medical Journal*, 91, No. 3, 243-247 (March 1998)
- Baur, D. A. and R. C. D. Butler, "Electrocautery-ignited endotracheal tube fire; case report," *British Journal of Oral Maxillofacial Surgery*, 37, 142-143 (April 1999)
- Wolf, G. L., and G. W. Sidebotham, "Endotracheal tube fire: comments on the advisability of not extubating," *Anesthesiology*, 91, 888-889 (1999)
- Rogers, M. L., R. W. D. Nickalls, E. T. Brackenbury, F. D. Salama, M. G. Beattie, and A. G. B. Perks, "Airway fire during tracheostomy: prevention strategies for surgeons and anaesthetists," *Annals of the Royal College of Surgeons of England*, 83, No. 6, 376-380 (November 2001)
- Lowry, R. K., and R. B. Noone, "Fires and burns during plastic surgery," *Annals of Plastic Surgery*, 46, No. 1, 72-76 (January 2001)

- Handa, K. K., A. P. S. Bhalla, and A. Arora, “Fire during the use of Nd-Yag laser,” *International Journal of Pediatric Otorhinolaryngology*, 60, No. 3, 239-242 (September 2001)
- Wheatley, T. J., and G. J. Maddern, “Airway fire during formation of tracheostomy,” *ANZ Journal of Surgery*, 72, 157-158 (2002)

5.27 Lemon battery, tingling of teeth fillings

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.

To see me on television, go to

<http://www.gumfrog.com/dailyplanet> and use Username: previewguest
New Password: d1sc0very (use the number "1" and the number zero "0" instead of letters)

Video 1 (electric pickle): choose Dec 2007.

Scroll down to Dec 20 / 07

Click on "Fact of the Matter"

Videos on making a lemon battery

<http://www.youtube.com/watch?v=AY9qcDCFVI>

<http://www.youtube.com/watch?v=PaLj9NPG-YI&mode=related&search=>

Videos on making a vinegar-salt battery

http://www.youtube.com/watch?v=V_P27iln1Qk

<http://www.youtube.com/watch?v=I1-82111tjY&mode=related&search=>

References

Dots • through ••• indicate level of difficulty

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

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

- Worley, J. D., and J. Fournier, “A homemade lemon battery,” *Journal of Chemical Education*, 65, No. 2, 158 (February 1988)

- Kluger-Bell, B., “Pickle power,” *Exploratorium Quarterly*, ??, 25-29 (Fall 1990)
- Willis, C. W., and L. Nicholson, “The lemon screamer, the lasagna cell, and the physics teacher,” *The Physics Teacher*, 28, 329-331 (May 1990)
- Gale, K., (letter) “Shocking teeth,” *New Scientist*, 136, 51 (10 October 1992)
- Fortman, J. J., and R. Battino, “Determining the metal activity series using a potato porcupine,” in “Overhead Projector Demonstrations,” edited by D. Kolb, *Journal of Chemical Education*, 70, No. 11, 939-940 (November 1993)
- Krause, P., and J. Manion, “A novel approach to teaching electrochemical principles,” in “Tested Demonstrations,” edited by G. L. Gilbert, *Journal of Chemical Education*, 73, No. 4, 354-355 (April 1996)
- Swartling, D. J., and C. Morgan, “Lemon cells revisited---the lemon-powered calculator,” *Journal of Chemical Education*, 75, No. 2, 181-182 (February 1998)
- Radhakrishnamurty, P., “Lemon cells revisited,” *Journal of Chemical Education*, 76, No. 9, 1190 (September 1999)
- Goodisman, J., “Observations on lemon cells,” *Journal of Chemical Education*, 78, No. 4, 516-518 (April 2001)
- Mills, A., “Cooking with electricity,” *Physics World*, 19, No. 5, 56 (May 2006)

Related references

- Morris, S., “Is a hot-wired dill kosher? Making your pickle glow in the dark could have some serious, but spectacular, consequences,” *Omni*, ??, 142 (??)
- Appling, J. R., F. J. Yonke, R. A. Edgington, and S. Jacobs, “Sodium D line emission from pickles,” in “Tested Demonstrations,” edited by G. L. Gilbert, *Journal of Chemical Education*, 70, No. 3, 250-251 (March 1993)
- Murov, S., and J. Niewahner, “A chemistree,” in “Tested Demonstrations,” edited by G. L. Gilbert, *Journal of Chemical Education*, 71, No. 12, 1082-1083 (December 1994)
- Weimer, P. M., and R. Battino, “The incredible ‘glowing’ pickle and onion and potato and ...,” in “Tested Demonstrations,” edited by G. L. Gilbert, *Journal of Chemical Education*, 73, No. 5, 456-457 (May 1996)
- Scharlin, P., A. A. Cleveland, R. Battino, and M. E. Thomas, “Glowing veggies,” in “Tested Demonstrations,” edited by G. L. Gilbert, *Journal of Chemical Education*, 73, No. 5, 457-459 (May 1996)

5.28 Electric fish and eels

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=AMPAhnXWz18&NR=1> Brief video of electric eels but no electric stuff

References

Dots • through ••• indicate level of difficulty

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

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

- Grundfest, H., “Electric fishes,” *Scientific American*, 203, 115-124 (October 1960)
- Lissmann, H. W., “Electric location by fishes,” *Scientific American*, 208, No. 3, 50-?? (March 1963)
- Rommel Jr., S. A., and J. D. McCleave, “Oceanic electric fields: perception by American eels?” *Science*, 176, 1233-1235 (16 June 1972)
- Bullock, T. H., “Seeing the world through a new sense: electroreception in fish,” *American Scientist*, 61, 316-325 (May-June 1973)
- Hopkins, C. D., “Lightning as background noise for communication among electric fish,” *Nature*, 242, 268-269 (23 March 1973)
- Hopkins, C. D., “Electric communication in fish,” *American Scientist*, 62, No. 4, 426-437 (July-August 1974)
- Hopkins, C. D., “Electric communication in fish,” *American Scientist*, 62, No. 4, 426-437 (July-August 1974)
- Moller, P., “Electric signals and schooling behavior in a weakly electric fish, *Marcusenius cyprionoides* L. (mormyriiformes),” *Science*, 193, 697-699 (20 August 1976)
- Hopkins, C. D., and A. H. Bass, “Temporal coding of species recognition signals in an electric fish,” *Science*, 212, 85-87 (3 April 1981)
- Fleckenstein, K., “Etienne Marey and the electric torpedo fish,” *Medical Instrumentation*, 18, No. 5, 288-289 (September-October 1984)
- Wu, C. H., “Electric fish and the discovery of animal electricity,” *American Scientist*, 72, 598-607 (November-December 1984)

- Scheich, H., G. Langner, C. Tidemann, R. B. Coles, and A. Guppy, “Electroreception and electrolocation in platypus,” *Nature*, 319, 401 (30 January 1986)
- Schluger, J. H., and C. D. Hopkins, “Electric fish approach stationary signal sources by following electric current lines,” *Journal of Experimental Biology*, 130, 359-367 (1987)
- von der Emde, G., and T. Ringer, “Electrolocation of capacitive objects in four species of pulse-type weakly electric fish,” *Ethology*, 91, No. 4, 326-338 (August 1992)
- Kawasaki, M., “Temporal hyperacuity in the Gymnotiform Electric Fish, *Eigenmannia*,” *American Zoologist*, 33, 86-93 (1993)
- von der Emde, G., “The sensing of electrical capacitances by weakly electric mormyrid fish: effects of water conductivity,” *Journal of Experimental Biology*, 181, 157-173 (1993)
- Shieh, K.-T., W. Wilson, M. Winslow, D. W. McBride Jr, and C. D. Hopkins,” *Journal of Experimental Biology*, 199, 2383-2393 (1996)
- Caputi, A. A., R. Budelli, K. Grant, and C. C. Bell, “The electric image in weakly electric fish: physical images of resistive objects in *Gnathonemus petersii*,” *Journal of Experimental Biology*, 201, 2115-2128 (1998)
- Milius, S., “Death risk drives shocking love songs,” *Science News*, 156, 37 (17 July 1999)
- Assad, C., B. Rasnow, and P. K. Stoddard, “Electric organ discharges and electric images during electrolocation,” *Journal of Experimental Biology*, 202, 1185-1193 (1999)
- von der Emde, G., “Active electrolocation of objects in weakly electric fish,” *Journal of Experimental Biology*, 202, 1205-1215 (1999)
- Hopkins, C. D., “Design features for electric communication,” *Journal of Experimental Biology*, 202, 1217-1228 (1999)
- Piccolino, M., and M. Bresadola, “Drawing a spark from darkness: John Walsh and electric fish,” *Endeavour*, 26, No. 1, 19-26 (2002)

Related reference

- Coghlan, A., “Protecting bathers with a short shark shock,” *New Scientist*, 132, No. 1792, 27 (26 October 1991)

5.29 Charging by blown dust, sand, and 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.

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

Photos

http://www.nasa.gov/vision/universe/solarsystem/2005_dust_devil_prt.htm

<http://media.graytvinc.com/images/dust+devil.jpg>

http://www.gc.maricopa.edu/earthsci/imagearchive/dust_devils.htm

Video

<http://video.google.com/videoplay?docid=899964669942411501&q=dust+devils&hl=en>

Movies and other images of Martian dust devils

http://science.nasa.gov/headlines/y2005/14jul_dustdevils.htm

<http://antwrp.gsfc.nasa.gov/apod/ap050426.html>

http://www.msss.com/mars_images/moc/7_1_99_devils/

<http://mars.jpl.nasa.gov/gallery/duststorms/>

http://www.msss.com/mars_images/moc/lpsc2000/3_00_dustdevil/

http://www.lpl.arizona.edu/~lemmon/mer_dd.html

References

Dots • through ••• indicate level of difficulty

Journal reference style: author, 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 704-705
- Freier, G. D., “The earth’s electric field during a tornado,” *Journal of Meteorology*, 16, 333-334 (June 1959)
- Freier, G. D., “The electric field of a large dust devil,” *Journal of Geophysical Research*, 65, 3504 (1960)
- Latham, J., and C. D. Stow, “Electrification of snowstorms,” *Nature*, 202, 284-285 (18 April 1964)
- Crozier, W. D., “The electric field of a New Mexico dust devil,” *Journal of Geophysical Research*, 69, 5427 (15 December 1964)
- Vonnegut, B., and J. R. Weyer, “Luminous phenomena accompanying tornadoes,” *Weather*, 19, No. 2, 66-68 + 95 (April 1966)

- Vonnegut, B., and J. R. Weyer, "Luminous phenomena in nocturnal tornadoes," *Science*, 153, No. 3741, 1213-1220 (9 September 1966)
- Brook, M., "Electric currents accompanying tornado activity," *Science*, 157, No. 3795, 1434-1436 (22 September 1967)
- Stow, C. D., "The generation of electricity by blowing snow," *Weather*, 22, 371-377 (1967)
- Latham, J., and C. D. Stow, "A laboratory investigation of the electrification of snowstorms," *Quarterly Journal of the Royal Meteorological Society*, 93, 55-68 (1967)
- Stow, C. D., "Dust and sand storm electrification," *Weather*, 24, 134-140 (1969)
- Kamra, A. K., "Electrification in an Indian dust storm," *Weather*, 24, 145-146 (1969)
- Crozier, W. D., "Dust devil properties," *Journal of Geophysical Research*, 75, 4583 (1970)
- Kamra, A. K., "Measurements of the electrical properties of dust storms," *Journal of Geophysical Research*, 77, No. 30, 5856-5869 (20 October 1972)
- Watkins, D. C., J. D. Cobine, and B. Vonnegut, "Electric discharges inside tornadoes," *Science*, 199, 171-174 (1978)
- Sozou, C., "Electrical discharges and intense vortices," *Proceedings of the Royal Society of London A*, 392, 415-426 (1984)
- Vonnegut, B., "Presters," *Weather*, ??, 360-361 (1993??)
- Kanagy II, S. P., and C. J. Mann, "Electrical properties of eolian sand and silt," *Earth-Science Review*, 36, No. 3-4, 181-204 (1994)
- Hall, R. S., "Inside a Texas tornado," *Weatherwise*, 40, 72-75 (April 1987); reprinted in January/February 1998
- Petrenko, V. F., and S. C. Colbeck, "Generation of electric fields by ice and snow friction," *Journal of Applied Physics*, 77, No. 9, 4518-4521 (1 May 1995)
- Hall, R. S., "Inside a Texas tornado," *Weatherwise*, 51, 16-20 (January/February 1998); also see the excerpt by Snyder, C. H., "Looking at tornado in the eye" on page 19
- Melnik, O., and M. Parrot, "Electrostatic discharge in Martian dust storms," *Journal of Geophysical Research*, 103, No. A12, 29107-29117 (1 December 1998)
- Schmidt, D. S., and R. A. Schmidt, "Electrostatic force on saltating sand," *Journal of Geophysical Research*, 103, No. D8, 8997-9001 (27 April 1998)

- Ravichandran, M., and A. K. Kamra, "Spherical field meter to measure the electric field vector---measurements in fair weather and inside a dust devil," *Review of Scientific Instruments*, 70, No. 4, 2140-2149 (April 1999)
- Schmidt, D. S., R. A. Schmidt, and J. D. Dent, "Electrostatic force in blowing snow," *Boundary-Layer Meteorology*, 93, 29-45 (1999)
- Farrell, W. M., M. L. Kaiser, M. D. Desch, J. G. Houser, S. A. Cummer, D. M. Wilt, and G. A. Landis, "Detecting electrical activity from Martian dust storms," *Journal of Geophysical Research*, 104, No. 2, 3795-3801 (25 February 1999)
- Winn, W. P., S. J. Hunyady, and G. D. Aulich, "Electric field at the ground in a large tornado," *Journal of Geophysical Research*, 105, No. D15, 20,145-20,153 (16 August 2000)
- Fabian, A., C. Krauss, A. Sickafoose, M. Horanyi, and S. Robertson, "Measurements of electrical discharges in Martian regolith stimulant," *IEEE Transactions on Plasma Science*, 29, No. 2, 288-291 (April 2001)
- Cerveny, R., and J. T. Schaefer, "Tornado oddities," *Weatherwise*, 55, No. 4, 20-27 (July/August 2002)
- Renno, N. O., A-S. Wong, S. K. Attreya, I. de Pater, and M. Roos-Serote, "Electrical discharges and broadband radio emission by Martian dust devils and dust storms," *Geophysical Research Letters*, 30, No. 22, article number 2140 (2003)
- Krauss, C. E., M. Horanyi, and S. Robertson, "Experimental evidence for electrostatic discharging of dust near the surface of Mars," *New Journal of Physics*, 5, article #70, 9 pages (2003)
- Nelson, J., and M. Baker, "Charging of ice-vapor interfaces: applications to thunderstorms," *Atmospheric Chemistry and Physics*, 3, 1237-1252 (2003)
- Zheng, X. J., N. Huang, and Y.-H. Zhou, "Laboratory measurement of electrification of wind-blown sands and simulation of its effect on sand saltation movement," *Journal of Geophysical Research*, 108, No. D10, article # 4322 (9 pages) (31 May 2003)
- Farrell, W. M., G. T. Delory, S. A. Dummer, and J. R. Marshall, "A simple electrodynamic model of a dust devil," *Geophysical Research Letters*, 30, No. 20, article # 2050 (2003)
- Zheng, X.-J., L.-H. He, and Y.-H. Zhou, "Theoretical model of the electric field produced by charged particles in windblown sand flux," *Journal of Geophysical Research*, 109, article # D15208 (2004)
- Farrell, W. M., P. H. Smith, G. T. Delory, G. B. Hillard, J. R. Marshall, D. Catling, M. Hecht, D. M. Tratt, N. Renno, M. D. Desch, S. A. Cummer, J. G. Houser, and B. Johnson, "Electric and magnetic signatures of dust

devils form the 2000-2001 MATADOR desert tests,” *Journal of Geophysical Research*, 109, article # E03004 (13 pages) (2004)

- Balme, M., and R. Greeley, “Dust devils on Earth and Mars,” *Reviews of Geophysics*, 44, article # RG3003 (22 pages) (2006)
- Farrell, W. M., N. Renno, G. T. Delory, S. A. Cummer, and J. r. Marshall, “Integration of electrostatic and fluid dynamics within a dust devil,” *Journal of Geophysical Research*, 111, article # E01006 (10 pages) (28 January 2006)
- Krauss, C. E., M. Horani, and S. Robertson, “Modeling the formation of electrostatic discharges on Mars,” *Journal of Geophysical Research*, 111, article #E02001 (8 pages) (2006)
- Stanzel, C., M. Patzold, R. Greeley, E. Hauber, and G. Neukum, “Dust devil on Mars observed by the High Resolution Stereo Camera,” *Geophysical Research Letters*, 33, article # L11202 (5 pages) (10 June 2006)
- Jackson, T., and W. M. Farrell, “Electrostatic fields in dust devils: an analog to Mars,” *IEEE Transactions on Geoscience and Remote Sensing*, 44, No. 10, 2942-2949 (10 October 2006)
- Zheng, X. J., N. Huang, and Y. Zhou, “The effect of electrostatic force on the evolution of sand saltation cloud,” *European Physics Journal E*, 19, 129-138 (2006)
- Egan, T., *The Worst Hard Time*, Mariner Book, Houghton Mifflin Company, 2006, pages 153, 171-172, 195, 197
- Kok, J. F., and N. O. Renno, “Electrostatics in wind-blown sand,” *Physical Review Letters*, 100, article # 014501 (4 pages) (11 January 2008)
- Shinbrot, T., and H. J. Herrmann, “Static in motion,” *Nature*, 451, 773-774 (14 February 2008)
- Williams, E., N. Nathou, E. Hicks, C. Pontikis, B. Russell, M. Miller, and M. J. Bartholomew, “The electrification of dust-lofting gust fronts (‘haboos’) in the Sahel,” *Atmospheric Research*, 91, 292-298 (2009)

Related references

- Vonnegut, B., C. B. Moore, and C. K. Harris, “Stabilization of a high-voltage discharge by a vortex,” *Journal of Meteorology*, 17, No. 4, 468-471 (August 1960)
- Freier, G. D., “The Earth’s electric field during a tornado,” *Journal of Meteorology*,
- Beebe, R. G., “Funnel cloud illuminated by lightning?” *Weatherwise*, 37, 152-153 (June 1984)

- Johnson, H. H., and B. Vonnegut, “Miniature vortices produced by electrical corona,” *Journal of Geophysical Research*, 98, No. D3, 5245-5248 (20 March 1993)

5.30 Lightning-like discharges above a volcano

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://volcano.und.edu/vwdocs/volc_images/southeast_asia/indonesia/galung_gung.html Photo of discharge above volcano in Indonesia

<http://volcano.und.edu/pics/lightning.jpg> Photo of discharge above volcano

http://glaciercaves.com/html/welcom_1.HTM Photo plus description Sakurajima volcano in Japan

References

Dots • through ••• indicate level of difficulty

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

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

- Blanchard, D. C., “Charge separation from saline drops on hot surfaces,” *Nature*, 201, No. 4925, 1164-1166 (21 March 1964)
- Anderson, R., S. Bjornsson, D. C. Blanchard, S. Gathman, J. Hughes, S. Jonasson, C. B. Moore, H. J. Survilas, and B. Vonnegut, “Electricity in volcanic clouds,” *Science*, 148, No. 3674, 1179-1189 (28 May 1965)
- Blanchard, D. C., “Volcanic electricity, *Oceanus*, 13, 2-5 (1966)
- Blanchard, D. C., and S. Bjornsson, “Water and the generation of volcanic electricity,” *Monthly Weather Review*, 95, 895-898 (1967)
- Pounder, C., “Electrification from salt water on heated metals,” *Journal of Physics D*, 5, 753-755 (1972)
- Brook, M., C. B. Moore, and T. Sigurgeirsson, “Lightning in volcanic clouds,” *Journal of Geophysical Research*, 79, No. 3, 472-475 (20 January 1974)
- Sheldon, J. W., “Charge separation from drops of NaCl solution on a heated metal,” *Journal of Physics D*, 7, No. 8, L91-L93 (1974)

- Pounder, C., “Investigation of a charge carrying particle from boiling solutions,” *Journal of Electrostatics*, 1, 395-397 (1975)
- Pounder, C., “Volcanic lightning,” *Weather*, 35, 357-360 (1980)
- Blong, R. J., *Volcanic Hazards: A Sourcebook on the Effects of Eruptions*, Academic Press, 1984, pages 62-64
- Gilbert, J. S., S. J. Lane, R. S. J. Sparks, and T. Koyaguchi, “Charge measurements on particle fallout from a volcanic plume,” *Nature*, 349, No. 6310, 598-600 (14 February 1991)
- Hoblitt, R. P., “An experiment to detect and locate lightning associated with eruptions of Redoubt Volcano,” *Journal of Volcanology and Geothermal Research*, 62, 499-517 (1994)
- Ikeya, M., and S. Takaki, “Electromagnetic fault for earthquake lightning,” *Japanese Journal of Applied Physics*, 35, No. 3A, L355-L357 (March 1996)
- Buttner, R., H. Roder, and B. Zimanowski, “Electrical effects generated by experimental volcanic explosions,” *Applied Physics Letters*, 70, No. 14, 1903-1905 (7 April 1997)
- James, M. R., S. J. Lane, and J. S. Gilbert, “Volcanic plume electrification: experimental investigation of a fracture-charging mechanism,” *Journal of Geophysical Research*, 105, No. B7, 16641-16649 (10 July 2000)
- Buttner, R., B. Zimanowski, and H. Roder, “Short-time electrical effects during volcanic eruption: experiments and field measurements,” *Journal of Geophysical Research*, 105, No. B2, 2819-2827 (10 February 2000)
- McNutt, S. R., and C. M. Davis, “Lightning associated with the 1992 eruptions of Crater Peak, Mount Spurr Volcano, Alaska,” *Journal of Volcanology and Geothermal Research*, 102, 45-65 (2000)
- Miura, T., T. Koyaguchi, and Y. Tanaka, “Measurements of electric charge distribution in volcanic plumes at Sakurajima Volcano, Japan,” *Bulletin of Volcanology*, 64, 75-93 (2002)

Related references

- Goyer, G. G., “Mechanical effects of a simulated lightning discharge on the water droplets of ‘Old Faithful’ geyser,” *Nature*, 206, No. 4991, 1302-1304 (26 June 1965)
- James, M. R., J. S. Gilbert, and S. J. Lane, “Experimental investigation of volcanic particle aggregation in the absence of a liquid phase,” *Journal of Geophysical Research*, 107, No. B9, article number 2191 (2002)
- Lee, S.-A., K. Willeke, G. Mainelis, A. Adhikari, H. Wang, T. Reponen, and S. A. Grinshpun, “Assessment of electrical charge on airborne

microorganisms by a new bioaerosol sampling method,” *Journal of Occupational and Environmental Hygiene*, 1, No. 3, 127-138 (March 2004)

5.31 Bacterial contamination in surgery

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=c5ZVyhwdNWk> Video showing dust rearrangement on monitor due to charged finger

References

Dots • through ••• indicate level of difficulty

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

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

Reference

- 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)
- Becker, R., A. Kristjanson, and J. Waller, “Static electricity as a mechanism of bacterial transfer during endoscopic surgery,” *Surgical Endoscopy*, 10, No. 4, 397-399 (1996)
- Mainelis, G., K. Willeke, P. Baron, T. Reponen, S. A. Grinshpun, R. L. Gorny, and S. Trakumas, “Electrical charges on airborne microorganisms,” *Journal of Aerosol Science*, 32, 1087-1110 (2001)
- Mainelis, G., K. Willeke, P. Baron, S. A. Grinshpun, and T. Reponen, “Induction charging and electrostatic classification of micrometer-size particles for investigating the electrobiological properties of airborne microorganisms,” *Aerosol Science and Technology*, 36, 479-491 (2002)
- Mainelis, G., R. L. Gorny, T. Reponen, M. Trunov, S. A. Grinshpun, P. Baron, J. Yadav, and K. Willeke, “Effect of electrical charges and fields on injury and viability of airborne bacteria,” *Biotechnology and Bioengineering*, 79, No. 2, 229-241 (20 July 2002)
- Allen, J. E., D. L. Henshaw, H. Wynne, F. Ross, and A. Oakhill, (letter) “Static electric charge may contribute to infections in bone marrow

transplant wards,” *Journal of Hospital Infection*, 54, No. 1, 80-81 (May 2003)

- Li, B., and B. E. Logan, “Bacterial adhesion to glass and metal-oxide surfaces,” *Colloids and Surfaces B: Biointerfaces*, 36, 81-90 (2004)
- Salerno, M. B., B. E. Logan, and D. Velegol, “Importance of molecular details in predicting bacterial adhesion to hydrophobic surfaces,” *Langmuir*, 20, 10625-10629 (2004)
- Hall, N. J., J. Hartley, N. Ade-Ajayiu, K. Laughlan, D. Roebuck, T. Kleidon, D. Powis, and A. Pierro, “Bacterial contamination of central venous catheters during insertion: a double blind randomised controlled trial,” *Pediatric Surgery International*, 21, 507-511 (2005)
- Allen, J. E., J. J. Close, and D. L. Henshaw, “Static electric fields as a mediator of hospital infection,” *Indoor and Built Environment*, 15, 1, 49-52 (2006)

Related references

- Pohl, H. A., “Nonuniform electric fields,” *Scientific American*, 203, 106-116 (December 1960)
- Mainelis, G., S. A. Grinshpun, K. Willeke, T. Reponen, V. Ulevicius, and P. J. Hintz, “Collection of airborne microorganisms by electrostatic precipitation,” *Aerosol Science and Technology*, 30, 127-144 (1999)
- Lighthart, B., K. Prier, G. M. Loper, and J. Bromenschenk, “Bees scavenge airborne bacteria,” *Microbial Ecology*, 39, 314-321 (2000)
- Mainelis, G., A. Adhikari, K. Willeke, S-A. Lee, T. Reponen, and S. A. Grinshpun, “Collection of airborne microorganisms by a new electrostatic precipitator,” *Journal of Aerosol Science*, 33, 1417-1432 (2002)
- Bu, D., Y. Liu, Y. Zhou, Z. Xu, L. Guo, B. Zhang, X. Liang, and Z. Guan, “Inactivation effects of electrostatic field on *Bacillus subtilis*,” *Journal of Electrostatics*, 63, 847-852 (2005)

5.32 Bees and pollination

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://en.wikipedia.org/wiki/Pollinator> Photo and description

<http://www.answers.com/topic/pollinator> Photo and description

[http://www.microscopy-](http://www.microscopy-uk.org.uk/mag/indexmag.html)

[uk.org.uk/mag/indexmag.html?http://www.microscopy-](http://www.microscopy-uk.org.uk/mag/artaug03/iwheath.html)

[uk.org.uk/mag/artaug03/iwheath.html](http://www.microscopy-uk.org.uk/mag/artaug03/iwheath.html) Scroll down to the bee photo; note the pollen adhering to the head.

References

Dots • through ●●● indicate level of difficulty

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

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

- Edwards, D. K., “Electrostatic charges on insects due to contact with different substrates,” *Canadian Journal of Zoology*, 40, 579-584 (1962)
- Erickson, E. H., “Surface electric potentials on worker honeybees leaving and entering the hive,” *Journal of Apicultural Research*, 14, Nos. 3-4, 141-147 (1975)
- Erickson, E. H., “Surface electric potentials on worker honeybees leaving and entering the hive,” *Journal of Apicultural Research*, 14, Nos. 3-4, 141-147 (1975)
- Corbet, S. A., J. Beament, and D. Eisikowitch, “Are electrostatic forces involved in pollen transfer?” *Plant, Cell and Environment*, 5, 125-129 (1982)
- Corbet, S. A., J. Beament, and D. Eisikowitch, “Are electrostatic forces involved in pollen transfer?” *Plant Cell and Environment*, 5, 125-129 (1982)
- Colin, M. E., D. Richard, and S. Chauzy, “Measurement of electric charges carried by bees: evidence of biological variations,” *Journal of Bioelectricity*, 10, No. 1-2, 17-32 (1991)
- Colin, M. E., D. Richard, V. Fourcassie, and L. P. Belzunces, “Attraction of *Varroa jacobsoni*, parasite of *Apis mellifera*, by electrical charges,” *Journal of Insect Physiology*, 38, No. 2, 111-117 (1992)
- Ish-Am, G., and D. Eisikowitch, “The behaviour of honey bees (*Apis mellifera*) visiting avocado (*Persea americana*) flowers and their contribution to its pollination,” *Journal of Apicultural Research*, 32, Nos.3-4, 175-186 (1993)
- Gan-Mor, S., Y. Schwartz, A. Bechar, D. Eisikowitch, and G. Manor, “Relevance of electrostatic forces in natural and artificial pollination,” *Canadian Agricultural Engineering*, 37, No. 3, 189-194 (July/August/September 1995)

- Philippe, G., and P. Baldet, “Electrostatic dusting: an efficient technique of pollination in larch,” *Annales des Sciences Forestieres*, 54, No. 3, 301-310 (1997)
- Banerjee, S., and S. E. Law, “Characterization of chargeability of biological particulates by triboelectrification,” *IEEE Transactions on Industry Applications*, 34, No. 6, 1201-1205 (November/December 1998)
- Bechar, A., I. Shmulevich, D. Eisikowitch, Y. Vaknin, B. Ronen, and S. Gan-Mor, “Modeling and experiment analysis of electrostatic date pollination,” *Transactions of the ASAE (American Society of Agricultural Engineers)*, 42, No. 6, 1511-1516 (November-December 1999)
- Lighthart, B., K. Prier, G. M. Loper, and J. Bromenschenk, “Bees scavenge airborne bacteria,” *Microbial Ecology*, 39, 314-321 (2000)
- Vaknin, Y., S. Gan-Mor, A. Bechar, B. Ronen, and D. Eisikowitch, “The role of electrostatic forces in pollination,” *Plant Systematics and Evolution*, 222, Nos. 1-4 133-142 (2000)
- Armbruster, W. S., “Evolution of floral form: electrostatic forces, pollination, and adaptive compromise,” *New Phytologist*, 152, 181-186 (2001)
- Vaknin, Y., S. Gan-mor, A. Bechar, B. Ronen, and D. Eisikowitch, “Are flowers morphologically adapted to take advantage of electrostatic forces in pollination?” *New Phytologist*, 152, 301-306 (2001)
- Widmer, A., “A new force in the evolution of floral form,” *Trends in Ecology & Evolution*, 17, No. 2, 62 (February 2002)
- Law, S. E., and H. Scherm, “Electrostatic application of a plant-disease biocontrol agent for prevention of fungal infection through the stigmatic surfaces of blueberry flowers,” *Journal of Electrostatics*, 63, 399-408 (2005)

Related references

- Pohl, H. A., “Nonuniform electric fields,” *Scientific American*, 203, 106-116 (December 1960)
- Bindokas, V., J. R. Gauger, and B. Greenberg, “Mechanism of biological effects observed in honey bees (*Apis mellifera*, L.) hived under extra-high-voltage transmission lines: implications derived from bee exposure to simulated intense electric fields and shocks,” *Bioelectromagnetics*, 9, No. 3, 285-301 (1988)
- Philippe, G., and P. Baldet, “Electrostatic dusting: an efficient technique of pollination in larch,” *Annales des Sciences Foresti'eres*, 54, No. 3, 301-310 (1997)

- Jefferes, D. E., “Electric fields, polarization and the transport of bacteria,” *Radiation Protection Dosimetry*, 76, No. 4, 257-260 (1998)
- Vaknin, Y., S. Gan-Mor, A. Bechar, B. Ronen, and D. Eisikowitch, “Effects of desiccation and dilution on germinability of almond pollen,” *Journal of Horticultural Science & Biotechnology*, 74, No. 3, 321-327 (1999)
- Lighthart, B., K. Prier, G. M. Loper, and J. Bromenshenk, “Bees scavenge airborne bacteria,” *Microbial Ecology*, 39, 314-321 (2000)
- Vaknin, Y., S. Gan-Mor, A. Bechar, B. Ronen, and D. Eisikowitch, “Improving pollination of almond (*Amygdalus communis* L., Rosaceae) using electrostatic techniques,” *Journal of Horticultural Science & Biotechnology*, 76, No. 2, 208-212 (March 2001)
- McGonigle, D. F., C. W. Jackson, and J. L. Davidson, “Triboelectrification of houseflies (*Musca domestica* L.) walking on synthetic dielectric surfaces,” *Journal of Electrostatics*, 54, 167-177 (2002)
- Gaunt, L. F., J. F. Hughes, and N. M. Harrison, “Electrostatic deposition of charged insecticide sprays on electrically isolated insects,” *Journal of Electrostatics*, 57, 35-47 (2003)

5.33 Short Story: Fire ants and electrical equipment

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://pubs.caes.uga.edu/caespubs/pubcd/B1191.htm> Discussion plus photos; scroll down to the electrical equipment damage photo
<http://www.cdfa.ca.gov/phpps/pdep/rifa/html/english/mediaroom/Resources.html> Photos plus description. Click on the electrical box photo to expand it.
<http://ipmworld.umn.edu/chapters/lockley/ant5.jpg> Photo of fire ant stings to an arm. These ants are very dangerous.

References

Dots • through ••• indicate level of difficulty

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

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

- MacKay, W. P., D. Sparks, and S. B. Vinson, “Destruction of electrical equipment by *Solenopsis Xyloni* McCook (Hymenoptera: Formicidae),” *Pan-Pacific Entomologist*, 66, No. 2, 174-175 (1990)
- MacKay, W. P., S. B. Vinson, J. Irving, S. Maji, and C. Messer, “Effect of electrical fields on the red imported fire ant (Hymenoptera: Formicidae),” *Environmental Entomology*, 21, No. 4, 866-870 (August 1992)
- MacKay, W. P., S. Majdi, J. Irving, S. B. Vinson, and C. Messer, “Attraction of ants (Hymenoptera: Formicidae) to electric fields,” *Journal of the Kansas Entomological Society*, 65, No. 1, 39-43 (1992)
- Slowik, T. J., H. G. Thorvilson, and B. L. Green, “Red imported fire ant (Hymenoptera: Formicidae) response to current and conductive material of active electrical equipment,” *Journal of Economic Entomology*, 89, No. 2, 347-352 (April 1996)
- Slowik, T. J., H. G. Thorvilson, and B. L. Green, “Response of red imported fire ant to magnetic fields in the nest environment,” *Southwest Entomologist*, 22, No. 3, 301-306 (September 1997)
- MacKay, W. P., A. F. Van Pelt, and I. Moreno, “Malfunction of electrical equipment caused by *Solenopsis aurea* Wheeler (Hymenoptera: Formicidae),” *Pan-Pacific Entomologist*, 77, No. 2, 126 (2001)
- Vander Meer, R. K., T. J. Slowik, and H. G. Thorvilson, “Semiachemicals released by electrically stimulated red imported fire ants,” *Journal of Chemical Ecology*, 28, No. 12, 2585-2600 (December 2002)

Related reference

- Slowik, T. J., B. L. Green, and H. G. Thorvilson, “Detection of magnetism in the red imported fire ant (*Solenopsis invicta*) using magnetic resonance imaging,” *Bioelectromagnetics*, 18, No. 5, 396-399 (1997)

5.34 Plastic food wrap

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

Reference

- 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)
- Randow, C. L., C. A., Williams, T. C. Ward, D. A. Dillard, J. G. Dillard, and J. P. Wightman, “An investigation of the cling of thin polymeric films,” *Journal of Adhesion*, 63, No. 4, 285-307 (1997)

Related references

- Brown, H. R., “The adhesion between polymers,” *Annual Review of Materials Science*, 21, 463-489 (1991)
- von Harrach, H. G., and B. N. Chapman, “Charge effects in thin film adhesion,” *Thin Solid Films*, 13, 157-161 (1972)
- Kinloch, A. J., C. C. Lau, and J. G. Williams, “The peeling of flexible laminates,” *International Journal of Fracture*, 66, No. 1, 45-70 (1994)

5.35 Flies on ceilings, geckos on walls

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.nanooze.org/english/interviews/danielsoto.html> Photo: Gecko on wall, discussion with a graduate student

<http://www.nrem.iastate.edu/ECOS/weblogs/NathanOLearly/Weblog1.html>

Photo: Gecko on wall

<http://www.youtube.com/watch?v=2r4Wq0jmiRM> Video of baby gecko on wall

References

Dots • through ••• indicate level of difficulty

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

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

- Nir, S., “Van der Waals interactions between surfaces of biological interest,” *Progress in Surface Science*, 8, No. 1, 1-58 (1976)
- Wigglesworth, V. B., “How does a fly cling to the under surface of a glass sheet?” *Journal of Experimental Biology*, 129, 373-376 (May 1987)
- Walker, G., “Adhesion to smooth surfaces by insects---a review,” *International Journal of Adhesion and Adhesives*, 13, No. 1, 3-7 (January 1993)
- Autumn, K., Y. A. Liang, S. T. Hsieh, W. Zesch, W. P. Chan, T. W. Kenny, R. Fearing, and R. J. Full, “Adhesive force of a single gecko foot-hair,” *Nature*, 405, 681-685 (8 June 2000)
- Pain, S., “Sticking power. Want to walk on the ceiling? All it takes is a bit of fancy footwork,” *New Scientist*, 168, 63-67 (23/30 December 2000)
- Autumn, K., M. Sitti, Y. A. Liang, A. M. Peattie, W. R. Hansen, S. Sponberg, T. W. Kenny, R. Fearing, J. N. Israelachvili, and R. J. Full, “Evidence for van der Waals adhesion in gecko setae,” *PNAS (Proceedings of the National Academy of Sciences of the United States of America)*, 99, No. 19, 12252-12256 (17 September 2002)
- Autumn, K., and A. M. Peattie, “Mechanisms of adhesion in geckos,” *Integrative and Comparative Biology*, 42, 1081-1090 (2002)
- Artz, E., S. Gorb, and R. Spolenak, “From micro to nano contacts in biological attachment devices,” *PNAS (Proceedings of the National Academy of Sciences of the United States of America)*, 100, No. 19, 10603-10606 (16 September 2003)
- Huber, G., S. N. Gorb, R. Spolenak, and E. Arzt, “Resolving the nanoscale adhesion of individual gecko spatulae by atomic force microscopy,” *Biology Letters*, 1, 2-4 (March 2005)
- Persson, B. N. J., O. Albohr, U. Tartaglino, A. I. Volokitin, and E. Tosatti, “On the nature of surface roughness with application to contact mechanics, sealing, rubber friction and adhesion,” *Journal of Physics: Condensed Matter*, 17, R1-R62 (2005), see pages R45-R49
- Autumn, K., “How gecko toes stick,” *American Scientist*, 94, No. 2, 124-132 (March-April 2006)
- Rizzo, N. W., K. H. Gardner, D. J. Walls, N. M. Keiper-Hrynko, T. S. Ganzke, and D. L. Hallahan, “Characterization of the structure and composition of gecko adhesive setae,” *Journal of the Royal Society Interface*, 3, 441-451 (2006)

- Gorb, S. N., “Biological attachment devices: exploring nature’s diversity for biomimetics,” *Philosophical Transactions of the Royal Society A*, 366, 1557-1574 (2008)
- Autumn, K., and N. Gravish, “Gecko adhesion: evolutionary nanotechnology,” *Philosophical Transactions of the Royal Society A*, 366, 1575-1590 (2008)
- Kim, T. W., and B. Bhushan, “The adhesion model considering capillarity for gecko attachment system,” *Journal of the Royal Society Interface*, 5, 319-327 (2008)
- Gravish, N., M. Wilkinson, and K. Autumn, “Frictional and elastic energy in gecko adhesive detachment,” *Journal of the Royal Society Interface*, 5, 339-348 (2008)
- Chen, S., and A. K. Soh, “Tuning the geometrical parameters of biominimetic fibrillar structures to enhance adhesion,” *Journal of the Royal Society Interface*, 5, 373-382 (2008)

Related references

- Stork, N. E., “Experimental analysis of adhesion of *Chrysolina polita* (Chrysomelidae: coleopteran) on a variety of surfaces,” *Journal of Experimental Biology*, 88, 91-107 (1980)
- “How flies walk up walls,” *New Scientist*, 106, 24, (18 April 1985)
- Dixon, A. F. G., P. C. Croghan, and R. P. Gowing, “The mechanism by which aphids adhere to smooth surfaces,” *Journal of Experimental Biology*, 152, 243-253 (1990)
- Bell, E. C., and J. M. Gosline, “Mechanical design of mussel byssus: material yield enhances attachment strength,” *Journal of Experimental Biology*, 199, 1005-1017 (1996)
- Attygalle, A. B., D. J. Aneshansley, J. Meinwald, and T. Eisner, “Defense by foot adhesion in a chrysomelid beetle (*Hemisphaerota cyanea*): characterization of the adhesive oil,” *Zoology*, 103, Nos. 1-2, 1-6 (2000)
- Jiao, Y., S. Gorb, and M. Scherge, “Adhesion measured on the attachment pads of *Tettigonia viridissima* (Orthoptera, insecta),” *Journal of Experimental Biology*, 203, 1887-1895 (2000)
- Eisner, T., and D. J. Aneshansley, “Defense by foot adhesion in a beetle (*Hemisphaerota cyanea*),” *PNAS (Proceedings of the National Academy of Sciences of the United States of America)*, 97, No. 12, 6568-6573 (6 June 2000)

- “High-friction microfibers,” in “Back Scatter,” *Physics Today*, 59, No. 10, 116 (October 2006)
- Varenberg, M., and S. Gorb, “Close-up of mushroom-shaped fibrillar adhesive microstructure: contact element behaviour,” *Journal of the Royal Society Interface*, 5, 785-789 (2008)

5.36 Meringue pie

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.atartec.co.il/atarchef/wp-images/lemon_pie.jpg Photo of a meringue pie

References

Dots • through ••• indicate level of difficulty

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

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

- Walker, J., “The physics and chemistry of the lemon meringue pie,” in “The Amateur Scientist,” *Scientific American*, 244, No. 6, 194-200 (June 1981)
- McGee, H. J., S. R. Long, and W. R. Briggs, “Why whip egg whites in copper bowls?” *Nature*, 308, 667-668 (1984)
- Rose, S., (letter) “Trouble whipping up,” *Nature*, 310, 178 (19 July 1984)
- “Copper: whipping egg whites into shape,” *Science News*, 125, No. 19, 296 (1984)
- 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 102-103, 106-109

5.37 Sauce béarnaise

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=47iO09yegkw> Video about making the sauce

<http://ericveren.com/food/sauces.asp> Photo plus description of making the sauce

References

Dots • through ••• indicate level of difficulty

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

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

- Perram, C. M., C. Nicolau, and J. W. Perram, “Interparticle forces in multiphase colloid systems: the resurrection of coagulated *sauce béarnaise*,” *Nature*, 270, No. 5638, 572-573 (15 December 1977)
- Johnson, R., G. Stearns, R. Weininger, J. F. Loutit, and T. S. Tweedie, (letters) “Sauce béarnaise,” *Nature*, 271, 402 (2 February 1978)
- Small, D. M., and M. Bernstein, “Doctor in the kitchen: experiments on sauce béarnaise,” *New England Journal of Medicine*, 300, No. 14, 801-802 (5 April 1979)
- Egelman, E. H., C. H. Wharton, D. M. Small, and M. Bernstein, (letters) “Sauce Bearnaise,” *New England Journal of Medicine*, 301, No. 5, 276-277 (2 August 1979)
- Walker, J., “The physics and chemistry of a failed sauce béarnaise,” in “The Amateur Scientist,” *Scientific American*, 241, No. 6, 178-199 (December 1979)
- Walker, J., “More about edifying visual spectacles produced by laser,” in “The Amateur Scientist,” *Scientific American*, 244, No. 1, 164-170 (January 1981), see pages 168-169
- McGee, H., *On Food and Cooking: The Science and Lore of the Kitchen*, Charles Scribner’s Sons, 1984, pages 348-366
- Kurti, N., and H. This-Benckhard, “Chemistry and physics in the kitchen,” *Scientific American*, 270, 66-71 (April 1994)

- Mine, Y., “Emulsifying characterization of hens egg yolk proteins in oil-in-water emulsions,” *Food Hydrocolloids*, 12, 409-415 (1998)
- Aveyard, R., B. P. Binks, J. Esquena, P. D. I. Fletcher, R. Buscall, and S. Davies, “Flocculation of weakly charged oil-water emulsions,” *Langmuir*, 15, No. 4, 970-980 (1999)
- Weiss, J. and D. J. McClements, “Influence of Ostwald ripening on rheology of oil-in-water emulsions containing electrostatically stabilized droplets,” *Langmuir*, 16, 2145-2150 (2000)
- Aveyard, R., B. P. Binks, J. Esquena, P. D. I. Fletcher, R. Buscall, and S. Davies, “Flocculation transitions of weakly charged oil-in-water emulsions stabilized by different surfactants,” *Langmuir*, 18, 3487-3494 (2002)
- McGee, H., *On Food and Cooking. The Science and Lore of the Kitchen*, revised, Scribner, 2004, page 635-637

Related references

- Bockris, J. O’M., “Teaching the double layer,” *Journal of Chemical Education*, 60, No. 4, 265-268 (April 1983)
- Kabalnov, A. S., A. V. Pertzov, and E. D. Shchukin, “Ostwald ripening in emulsions: I. Direct observation of Ostwald ripening in emulsions,” *Journal of Colloid Interface Science*, 118, 590-597 (1987)
- Aranberri, I., K. J. Beverley, B. P. Binks, J. H. Clint, and P. D. I. Fletcher, “How do emulsions evaporate?” *Langmuir*, 18, 3471-3475 (2002)

5.38 Lodestones

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.buylodestones.com/bigdemo.htm> Photos

http://www.pha.jhu.edu/dept/lecdemo/img/EM-g1a_400x300.jpg Photo

<http://www.teachersource.com/catalog/images/rm429.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

- Graham, K. W. T., “The re-magnetization of a surface outcrop by lightning currents,” *Geophysical Journal*, 6, 85-102 (1961)
- Washilewski, P. J., “Magnetic and microstructural properties of some lodestones,” *Physics of the Earth and Planetary Interiors*, 15, 349-362 (1977)
- Blackman, M., and N. D. Lisgarten, “On the intensity of magnetization of lodestones,” *Journal of Magnetism and Magnetic Materials*, 30, 269-272 (1982)
- Blackman, M., “The lodestone: a survey of the history and the physics,” *Contemporary Physics*, 24, 319-331 (1983)
- Overshott, K. J., “Magnetism: it is permanent,” *IEE Proceedings A, Science Measurement and Technology*, 138, No. 1, 22-30 (January 1991)
- Wasilewski, P., and G. Kletetschka, “Lodestone: nature's only permanent magnet---what it is and how it gets charged,” *Geophysical Research Letters*, 26, No. 15, 2275-2278 (1 August 1999)
- Sukumaran, P. V., and A. R. Nambiar, “Occurrence of chromiferous lodestone near Chalingal, Kasaragod District, Kerala,” *Journal of the Geological Society of India*, 58, No. 2, 171-173 (August 2001)
- Stern, D. P., “A millennium of geomagnetism,” *Reviews of Geophysics*, 40, No. 3, article number 1007 (29 pages) (September 2002), see pages 1-3
- Verrier, V., and P. Rochette, “Estimating peak currents at ground lightning impacts using remanent magnetization,” *Geophysical Research Letters*, 29, No. 18, article # 1867 (4 pages) (2002)
- Mills, A. A., “The lodestone: history, physics, and formation,” *Annals of Science*, 61, No. 3, 273-319 (July 2004)

Related reference

- Elliott, R., “The story of magnetism,” *Physica A*, 384, 44-52 (2007)

5.39 Earth's magnetic field and archaeology

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

- Joukowsky, M., *A Complete Manual of Field Archaeology: Tools and Techniques of Field Work for Archaeologists*, Prentice-Hall, 1980, pages 454-455, 605
- Aitken, M. J., P. A. Alock, G. D. Bussell, and C. J. Shaw, "Archaeomagnetic determination of the past geomagnetic intensity using ancient ceramics: Allowance for anisotropy," *Archaeometry*, 23, 53-64 (February 1981)
- Quing-Yun, W., Z. Wei-Xi, L. Dong-Jie, M. J. Aitken, G. D. Bussell, and M. Winter, "Geomagnetic intensity as evaluated from ancient Chinese pottery," *Nature*, 328, No. 6128, 330-333 (23 July 1987)
- Hussain, A. G., "The secular variation of the geomagnetic field in Egypt in the last 5000 years," *Pure and Applied Geophysics*, 125, No. 1, 67-90 (1987)
- Merrill, R. T., "A slow-moving field," *Nature*, 345, 575-576 (14 June 1990)
- Renfrew, C., and P. Bahn, *Archaeology: Theory, Methods and Practice*, Thames and Hudson, 1991, pages 138-139
- Liritzis, Y., and M. Kovacheva, "Some evidence for sharp changes in the archaeomagnetic intensity variation during the last 2000 years," *Physics of the Earth and Planetary Interiors*, 70, No. 102, 85-89 (February 1992)
- Yang, S., J. Shaw, and Q. Y. Wei, "A comparison of archaeointensity results from Chinese ceramics using Thellier's and Shaw's palaeointensity methods," *Geophysical Journal International*, 113, 499-508 (1993)
- Shaw, J., S. Yang, and Q. Y. Wei, "Archaeointensity variations for the past 7,500 years evaluated from ancient Chinese ceramics," *Journal of Geomagnetism and Geoelectricity*, 47, No. 1, 59-70 (1995)
- Chiari, G., and R. Lanza, "Pictorial remanent magnetization as an indicator of secular variation of the Earth's magnetic field," *Physics of the Earth and Planetary Interiors*, 101, 79-83 (1997)
- van Hoof, A. A. M., C. G. Langereis, I. Joosten, J. R. A. M. Thijssen, E. Nijhof, H. A. Groenendijk, and G. R. M. van den Eynde, "Archaeomagnetic dating of seven archaeological fireplaces in the Netherlands," *Geologie en Mijnbouw*, 76, 155-162 (1997)
- Chiari, G., and R. Lanza, "Remanent magnetization of mural paintings from the *Bibliotheca Apostolica* (Vatican, Rome)," *Journal of Applied Geophysics*, 41, 137-143 (1999)
- Zanella, E., L. Gurioli, G. Chiari, A. Ciarallo, R. Cioni, E. De Carolis, and R. Lanza, "Archaeomagnetic results from mural paintings and pyroclastic

rocks in Pompeii and Herculaneum,” *Physics of the Earth and Planetary Interiors*, 118, 227-240 (2000)

- Kovacheva, M., V. Spatharas, and I. Liritzus, “New archaeointensity results from Greek Materials,” *Archaeometry*, 42, No. 2, 415-429 (2000)
- Hedley, I. G., “New directions in archaeomagnetism,” *Journal of Radioanalytical and Nuclear Chemistry*, 247, No. 3, 663-672 (2001)
- van Klinken, J., “Magnetization of ancient ceramics,” *Archaeometry*, 43, No. 1, 49-57 (January 2001)
- Genevey, A., Y. Gallet, and J.-C. Margueron, “Eight thousand years of geomagnetic field intensity variations in the eastern Mediterranean,” *Journal of Geophysical Research*, 108, No. B5, article # 2228 (18 pages) (2 May 2003)
- Hus, J., S. Ech-Chakrouni, D. Jordanova, and R. Geeraerts, “Archaeomagnetic investigation of two mediaeval brick constructions in North Belgium and the magnetic anisotropy of bricks,” *Geoarchaeology: An International Journal*, 18, No. 2, 225-253 (2003)
- Pratt, S., “Magnetic murals,” *Geotimes*, 49, No. 9, 12 (September 2004)
- Hueda-Tanabe, Y., A. M. Soler-Arechalde, J. Urrutia-Fucugauchi, L. Barba, L. Manzanilla, M. Rebolledo-Vieyra, and A. Goguitchaichvili, “Archaeomagnetic studies in central Mexico---dating of Mesoamerican lime-plasters,” *Physics of the Earth and Planetary Interiors*, 147, 269-283 (2004)
- Linford, P., “Archaeomagnetic dating,” *Physics Education*, 39, No. 2, 145-154 (2004)
- Schnepf, E., R. Pucher, J. Reinders, U. Hambach, H. Soffel, and I. Hedley, “A German catalogue of archaeomagnetic data,” *Geophysical Journal International*, 157, 64-78 (2004)
- Hus, J., R. Geeraerts, and J. Plumier, “On the suitability of refractory bricks from a mediaeval brass melting and working site near Dinant (Belgium) as geomagnetic field recorders,” *Physics of the Earth and Planetary Interiors*, 147, 103-116 (2004)
- Goguitchaichvili, A., A. M. Soler, E. Zanella, G. Chiari, R. Lanza, J. Urrutia-Fucugauchi, and T. Gonzalez, “Pre-Columbian mural paintings from Mesoamerica as geomagnetic field recorders,” *Geophysical Research Letters*, 31, article number L12607 (2004)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, 7th edition, 2005, page 879
- Lanza, R., A. Meloni, And E. Tema, “Historical measurements of the Earth’s magnetic field compared with remanence directions from lava flows

in Italy over the last four centuries,” *Physics of the Earth and Planetary Interiors*, 148, 97-107 (2005)

- Schnepf, E., and P. Lanos, “Archaeomagnetic secular variation in Germany during the past 2500 years,” *Geophysical Journal International*, 163, 479-490 (2005)

Related references

- Malin, S. R. C., and E. Bullard, “The direction of the Earth’s magnetic field at London, 1570-1975,” *Philosophical Transactions of the Royal Society of London, A*, 299, No. 1450, 357-423 (11 February 1981)
- Gubbins, D., “The Earth’s magnetic field,” *Contemporary Physics*, 25, No. 3, 269-290 (1984)
- Bucur, I., “The direction of the terrestrial magnetic field in France during the last 21 centuries. Recent progress,” *Physics of the Earth and Planetary Interiors*, 87, 95-109 (1994)
- Jacobs, J. A., “Variations in the intensity of the Earth’s magnetic field,” *Surveys in Geophysics*, 19, 139-197 (1998)
- Peters, C., M. J. Church, and G. Coles, “Mineral magnetism and archaeology at Galson on the Isle of Lewis, Scotland,” *Physics and Chemistry of the Earth Part A---Solid Earth and Geodesy*, 25, No. 5, 455-460 (2000)
- Zhang, X., S. B. Kroonenberg, and C. B. de Boer, “Dating of coal fires in Xinjiang, north-west China,” *Terra Nova*, 16, No. 2, 68-74 (2004)
- Olson, P., and H. Amit, “Changes in earth’s dipole,” *Naturwissenschaften*, 93, 519-542 (2006)

5.40 MRI complications

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.chipple.net/mt/archives/20050616mri.jpg> Photo of an MRI machine

References

Dots • through ••• indicate level of difficulty

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

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

- Davis, P. L., L. Crooks, M. Arakawa, R. McRee, L. Kaufman, and A. R. Margulis, "Potential hazards in NMR imaging: heating effects of changing magnetic fields and RF fields on small metallic implants," *American Journal of Roentgenology*, 137, 857-860 (October 1981)
- Jackson, J. G., and J. D. Acker, (letter) "Permanent eyeliner and MR imaging," *American Journal of Roentgenology*, 149, 1080 (1987)
- Shellock, F. G., and G. L. Slimp, "Severe burn of the finger caused by using a pulse oximeter during MR imaging," *American Journal of Roentgenology*, 153, No. 5, 1105 (1989)
- Bashein, G., and G. Syrovy, "Burns associated with pulse oximetry during magnetic resonance imaging," *Anesthesiology*, 75, No. 2, 382-383 (August 1991)
- Young, I. R., (letter) "Getting to the bottom of things," *Physics World*, , 25 (September 1991)
- Hall, S. C., G. W. Stevenson, and S. Suresh, (letter) "Burn associated with temperature monitoring during magnetic resonance imaging," and reply by R. Susi, *Anesthesiology*, 76, No. 1, 152 (January 1992)
- Brown, T. R., B. Goldstein, and J. Little, "Severe burns resulting from magnetic resonance imaging with cardiopulmonary monitoring," *American Journal of Physical Medicine and Rehabilitation*, 72, No. 3, 166-167 (June 1993)
- Shellock, F. G., S. Morisoli, and E. Kanal, "MR procedures and biomedical implants, materials, and devices: 1993 update," *Radiology*, 189, 587-599 (1993)
- Kanal, E., and F. G. Shellock, "The value of published data on MR compatibility of metallic implants and devices," *American Journal of Neuroradiology*, 15, No. 7, 1394-1396 (August 1994)
- Shellock, F. G., and E. Kanal, "Re: metallic foreign bodies in the orbits of patients undergoing MR imaging: prevalence and value of radiography and CT before MR," *American Journal of Roentgenology*, 162, No. 4, 985-986 (April 1994)
- Carr, J. J., letter about permanent cosmetic injections, *American Journal of Roentgenology*, 165, No. 6, 1546-1547 (December 1995)

- Jones, S., W. Jaffe, and R. Alvi, “Burns associated with electrocardiographic monitoring during magnetic resonance imaging,” *Burns*, 22, No. 5, 420-421 (1996)
- Knopp, M. V., M. Essig, J. Debus, H-J. Zabel, and G. van Kaick, “Unusual burns of the lower extremities caused by a closed conducting loop in a patient at MR imaging,” *Radiology*, 200, No. 2, 572-575 (August 1996)
- Shellock, F. G., and E. Kanal, “Burns associated with the use of monitoring equipment during MR procedures,” *Journal of Magnetic Resonance Imaging*, 6, No. 1, 271-272 (January-February 1996)
- Kreidstein, M. L., D. Giguere, and A. Freiberg, “MRI interaction with tattoo pigments: case report, pathophysiology, and management,” *Plastic and Reconstructive Surgery*, 99, No. 6, 1717-1720 (May 1997)
- Lemieux, L., P. J. Allen, F. Franconi, M. R. Symms, and D. R. Fish, “Recording of EEG during fMRI experiments: patient safety,” *Magnetic Resonance in Medicine*, 38, No. 6, 943-952 (1997)
- Kanal, E., and F. G. Shellock, “MRI interaction with tattoo pigments,” *Plastic and Reconstructive Surgery*, 101, No. 4, 1150-1151 (April 1998)
- Price, R. R., “MR imaging safety considerations,” *Radiographics*, 19, No. 6, 1641-1651 (November-December 1999)
- Shellock, F., (letter) “MRI in patients with intraspinal bullets,” *Journal of Magnetic Resonance Imaging*, 10, 107 (1999)
- Kanal, E., and F. G. Shellock, “Aneurysm clips: effects of long-term and multiple exposures to a 1.5-T MR system,” *Radiology*, 210, 563-565 (1999)
- Condon, B., and D. M. Hadley, “Potential MR hazard to patients with metallic heart valves: the Lenz effect,” *Journal of Magnetic Resonance Imaging*, 12, 171-176 (2000)
- Robertson, N. M., M. Diaz-Gomez, and B. Condon, “Estimation of torque on mechanical heart valves due to magnetic resonance imaging including an estimation of the significance of the Lenz effect using a computational model,” *Physics in Medicine and Biology*, 45, 3793-3807 (2000)
- Shellock, F. G., “Radiofrequency energy-induced heating during procedures: a review,” *Journal of Magnetic Resonance Imaging*, 12, 30-36 (2000)
- Vahlensieck, M., (letter) “Tattoo-related cutaneous inflammation (burn grade 1) in a mid-field MR scanner,” *European Radiology*, 10, No. 1, 197, (2000)

- Wagle, W. A., and M. Smith, "Tattoo-induced skin burn during MR imaging," *American Journal of Roentgenology*, 174, No. 6, 1795 (June 2000)
- Dempsey, M. F., and B. Condon, "Thermal injuries associated with MRI," *Clinical Radiology*, 56, 457-465 (2001)
- Dempsey, M. F., B. Condon, and D. M. Hadley, "Investigation of the factors responsible for burns during MRI," *Journal of Magnetic Resonance Imaging*, 13, 627-631 (2001)
- Nakamura, T., K. Fukuda, K. Hayakawa, I. Aoki, K. Matsumoto, T. Sekine, H. Ueda, and Y. Shimizu, "Mechanism of burn injury during magnetic resonance imaging (MRI)---simple loops can induce heat injury," *Frontiers of Medical and Biological Engineering*, 11, No. 2, 117-129 (June 2001)
- Chung, S. M., "Safety issues in magnetic resonance imaging," *Journal of Neuro-Ophthalmology*, 22, No. 1, 35-39 (2002)
- Edwards, M.-B., R. J. Ordidge, D. L. Thomas, J. W. Hand, and K. M. Taylor, "Translational and rotational forces on heart prostheses subjected ex vivo to a 4.7-T MR system," *Journal of Magnetic Resonance Imaging*, 16, 653-659 (2002)
- Shellock, F. G., "Magnetic resonance safety update 2002: implants and devices," *Journal of Magnetic Resonance Imaging*, 16, 485-496 (2002)
- Tope, W. D., and F. G. Shellock, "Magnetic resonance imaging and permanent cosmetics (tattoos): survey of complications and adverse events," *Journal of Magnetic Resonance Imaging*, 15, 180-184 (2002)
- Kugel, H., C. Bremer, M. Puschel, R. Fischbach, H. Lenzen, B. tombach, H. Van Aken, and W. Heindel, "Hazardous situation in the MR bore: induction in ECG leads cause fire," *European Radiology*, 13, No. 4, 690-694 (2003)
- Armenean, C., E. Perrin, M. Armenean, O. Beuf, F. Pilleul, and H. Saint-Jalmes, "RF-induced temperature elevation along metallic wires in clinical magnetic resonance imaging: influence of diameter and length," *Magnetic Resonance in Medicine*, 52, 1200-1206 (2004)
- Kampen, J., C. Liess, C. Casadio, P. H. Tonner, M. Reuter, and J. Scholz, (letter) "Safety of the Pulsioath for haemodynamic monitoring during magnetic resonance imaging," *Anesthesia*, 59, 822-836 (2004)
- Kampen, J., P. H. Tonner, and J. Scholz, (letter) "Patient safety during anaesthesia for magnetic resonance imaging," *European Journal of Anaesthesiology*, 21, 320-335 (2004)

- Ratnapalan, S., M. Greenberg, and D. Armstrong, “Tatoos and MRI,” *American Journal of Roentgenology*, 183, No. 2, 541 (August 2004)
- Shellock, F. G., and J. V. Crues, “MR procedures: biologic effects, safety, and patient care,” *Radiology*, 232, No. 3, 635-652 (September 2004)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, 7th edition, 2005, pages 800-801

Related references

- Ward, V. M. M., and D. Selvadurai, “A magnetic nasal attraction,” *Journal of Accident and Emergency Medicine*, 17, 53-56 (2000)
- Prasad, R., H. C. Amstutz, and E. A. Sparling, “Use of a magnet to retrieve a broken scalpel blade,” *Journal of Arthroplasty*, 15, No. 6, 806-808 (2000)
- Huzaira, M., and R. R. Anderson, “Magnetite tattoos,” *Lasers in Surgery and Medicine*, 31, 121-128 (2002)

5.41 Short story: Magnetic search for the Garfield bullet

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

- Stevens, R. L., “A president’s assassination,” *JAMA – Journal of the American Medical Association*, 246, No. 15, 1673-1674 (9 October 1981)
- Davis, R. S., “Bell’s use of induction balance: searching for a bullet in President Garfield,” *Materials Evaluation*, 46, No. 12, 1528-1560 (November 1988)
- Kuhfeld, E. R., (letter) “Imaging before X rays,” *Invention & Technology*, 15, No. 4, 5 (spring 2000)

5.42 Magnets, tattoos, and body jewelry

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

- Ward, V. M. M., and D. Selvadurai, “A magnetic nasal attraction,” *Journal of Accident and Emergency Medicine*, 17, No.1, 53-56 (January 2000)
- Huzaira, M., and R. R. Anderson, “Magnetite tattoos,” *Lasers in Surgery and Medicine*, 31, 121-128 (2002)

Related references

- Domingo, J. C., M. Mercadal, J. Petriz, and M. A. de Madariaga, “Preparation of PEG-grafted immunomagnetoliposomes entrapping citrate stabilized magnetite particles and their application in CD34+ cell sorting,” *Journal of Microencapsulation*, 18, No. 1, 41-54 (2001)
- Zhang, Y., N. Kohler, and M. Zhang, “Surface modification of superparamagnetic magnetite nanoparticles and their intracellular uptake,” *Biomaterials*, 23, 1553-1561 (2002)

5.43 Breakfast and cow magnetism

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://demo.physics.uiuc.edu/LectDemo/scripts/demo_descript.idc?DemoID=1113 Photo of a cow magnet

<http://www.luminet.net/~wenonah/new/magfield.htm> Fields of a cow magnet and other magnets

http://www.metacafe.com/watch/yt-1nTRys771kQ/the_cow_magnet/
<http://www.youtube.com/watch?v=1nTRys771kQ>

References

Dots • through ••• indicate level of difficulty

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

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

- Mackay, R. S., “Two startling demonstrations with a magnet,” *American Journal of Physics*, 28, No. 7, 678 (October 1960)
- Restivo, E. and H. T. Hudson, “‘Iron-enriched’ cereal---literally,” *Physics Teacher*, 28, 608 (December 1990)
- Cannon, R., “Three-dimensional magnetic field in a bottle,” *Physics Teacher*, 29, 311 (May 1991)
- Rusanov, V., V. Angelov, V. Jordanov, and S. Ormandjiev, “Mossbauer test for forgery,” *Nature*, 349, 199 (17 January 1991)
- Rusanov, V., V. Angelov, T. Tsacheva, and S. Ormandjiev, “On the possibility of the use of the Mossbauer test for bank-note forgeries and printer ink control,” *Nuclear Instruments and Methods in Physics Research*, 73, No. 3, 417-424 (1993)

5.44 Electric guitars

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=QJ6B8bKKTS4&mode=related&search=Jimi Hendrix at Woodstock “Let Me Stand Next to Your Fire”](http://www.youtube.com/watch?v=QJ6B8bKKTS4&mode=related&search=Jimi+Hendrix+at+Woodstock+\)

[http://www.youtube.com/watch?v=5hSW67ySCio&mode=related&search=Hendrix “Purple Haze”](http://www.youtube.com/watch?v=5hSW67ySCio&mode=related&search=Hendrix+\)

[http://www.youtube.com/watch?v=nLxhRwnFhag&mode=related&search=Hendrix “Hey Joe”](http://www.youtube.com/watch?v=nLxhRwnFhag&mode=related&search=Hendrix+\)

Photo

<http://www.cathedralstone.net/Pages/JimiHendrix.htm> Jimi Hendrix, the master of the electric guitar

References

Dots • through ●●● indicate level of difficulty

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

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

- Kozinn, A., P. Welding, D. Forte, and G. Santoro, *The Guitar: the History, the Music, the Players*, William Morrow and Company, Inc., 1984
- Smith, M. M., “The electric guitar. How we got from Andres Segovia to Kurt Cobain,” *Invention & Technology*, 20, No. 1, 12-21 (Summer 2004)
- Millard, A., *The Electric Guitar*, Johns Hopkins University Press, 2004

Related reference

- Lenssen, K.-M. H., G. H. J. Somers, and J. B. A. D. van Zon, “Magnetoresistive sensors for string instruments,” *Journal of Applied Physics*, 91, No. 10, 7777-7779 (15 May 2002)

5.45 Electric-guitar amplifiers

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

- Barbour, E., “The cool sound of tubes,” *IEEE Spectrum*, 35, No. 8, 24-35 (August 1998)
- Wolverson, M., “The tube is dead. Long live the tube. The vacuum tube has been obsolete for decades---and it’s here to stay,” *Invention & Technology*, 18, No. 2, 28-37 (Fall 2002)

5.46 Auroras

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=yRpY2zOn2hU&feature=dir> Nice, short video

<http://www.youtube.com/watch?v=qIXs6Sh0DKs> Video

http://www.metacafe.com/watch/890459/northern_lights_aurora_borealis_a_wesome_video/ Video from Anarctica

<http://www.youtube.com/watch?v=jopsNu172YA&mode=related&search=> Slide show

<http://www.youtube.com/watch?v=YJBrMXSn-hU&mode=related&search=> Video with explanation

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

<http://www.ptialaska.net/~hutch/aurora.html>

Dick Hutchinson, aurora images and tips for photographing auroras

References

Dots • through ••• indicate level of difficulty

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

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

- Chapman, S., "Sun storms and the Earth: the aurora polaris and the space around the Earth," *American Scientist*, 49, 248-284 (September 1961)
- Akasofu, S.-I., "The aurora," *Scientific American*, 213, 54-62 (December 1965)
- Heikkila, W. J., "Aurora," *EOS*, 54, No. 8, 764-768 + front cover + inside front and back covers (August 1973)
- Akasofu, S.-I., "The aurora: an electrical discharge process around the Earth," *Endeavour*, 2, No. 1, 7-11 (1978)
- Akasofu, S.-I., "The aurora," *Physics Teacher*, 16, 228-234 (April 1978)
- Shepher, G. G., and C.-G. Falthammar, "Implications of extreme thinness of pulsating auroral structures," *Journal of Geophysical Research*, 85, No. A1, 217-218 (1 January 1980)
- Akasofu, S.-I., "The aurora," *American Scientist*, 69, 492-499 (September-October 1981)

- Akasofu, S.-I., “The aurora: an electrical discharge phenomenon surrounding the Earth,” *Reports on Progress in Physics*, 44, 1123-1149 (1981)
- Akasofu, S.-I., “The aurora: new light on an old subject,” *Sky & Telescope*, 64, 534-537 (December 1982)
- Egeland, A., and A. Brekke, “The northern light: from mystery to modern space science,” *Endeavour*, 8, No. 4, 188-193 (1984)
- Simmons, D. A. R., “An introduction to the aurora,” *Weather*, 40, 147-155 (1985)
- MacRobert, A., “Backyard astronomy,” *Sky & Telescope*, 71, 30-32 (January 1986)
- Akasofu, S.-I., “The dynamic aurora,” *Scientific American*, 260, 90-97 (May 1989)
- Zaffo, P. A., “Tabletop aurora demonstrator,” *Journal of Geological Education*, 39, 12-14 (1991)
- Lyons, L. R., “Formation of auroral arcs via magnetosphere-ionosphere coupling,” *Reviews of Geophysics*, 30, No. 2, 93-112 (May 1992)
- Henbest, N., “Chaos triggers the northern lights,” *New Scientist*, 133, No. 1812, 19 (14 March 1992)
- Otto, A., and G. T. Birk, “Formation of thin auroral arcs by current striation,” *Geophysical Research Letters*, 20, No. 24, 2833-2836 (23 December 1993)
- Borovsky, J. E., “Auroral arc thicknesses as predicted by various theories,” *Journal of Geophysical Research*, 98, No. A4, 6101-6138 (1 April 1993)
- Cowley, S., “The auroras that don’t shine in the daytime,” *Physics World*, 9, 23-25 (September 1996)
- Burtnyk, K., “Anatomy of an aurora,” *Sky & Telescope*, 99, 34-40 (March 2000)
- Eather, R. H., “An aurora watcher’s guide,” *Sky & Telescope*, 99, 42-48 (March 2000)
- Newell, P. T., R. A. Greenwald, and J. M. Ruohoniemi, “The role of the ionosphere in aurora and space weather,” *Reviews of Geophysics*, 39, No. 2, 137-149 (May 2001)
- Vaquero, J. M., and M. C. Gallego, “Two early observations of aurora at low latitudes,” *Annales Geophysicae*, 19, 809-811 (2001)
- Knudsen, D. J., E. F. Donovan, L. L. Cogger, B. Jackel, and W. D. Shaw, “Width and structure of mesoscale optical auroral arcs,” *Geophysical Research Letters*, 28, No. 4, 705-708 (15 February 2001)

- Lynch, D. K., and W. Livingston, *Color and Light in Nature*, 2nd edition, Cambridge University Press, 2001, pages 63-68
- Stern, D. P., “A millennium of geomagnetism,” *Reviews of Geophysics*, 40, No. 3, article number 1007 (29 pages) (September 2002), see pages 18-20

5.47 Solar eruptions and power outages

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

- Campbell, W. H., “Observation of electric currents in the Alaska oil pipeline resulting from auroral electrojet current sources,” *Geophysical Journal of the Royal Astronomical Society*, 61, No. 2, 437-449 (1980)
- Kappenman, J. G., V. D. Albertson, and N. Mohan, “Current transformer and relay performance in the presence of geomagnetically-induced currents,” *IEEE Transactions on Power Apparatus and Systems*, PAS-100, 1078-1088 (March 1981)
- Smart, A. L., “The Trans Alaska Pipeline --- potential measurements and telluric current,” *IEEE Transactions on Industry Applications*, IA-18, No. 5, 557-567 (September/October 1982)
- Meloni, A., L. J. Lanzerotti, and G. P. Gregori, “Induction of currents in long submarine cables by natural phenomena,” 21, No. 4, 795-803 (May 1983)
- Lanzerotti, L. J., “Geomagnetic induction effects in ground-based systems,” *Space Science Reviews*, 34, No. 3, 347-356 (1983)
- Pirjola, R., “On currents induced in power transmission systems during geomagnetic variations,” *IEEE Transactions on Power Apparatus and Systems*, PAS-104, No. 10, 2825-2831 (October 1985)

- Campbell, W. H., “An interpretation of induced electric currents in long pipelines caused by natural geomagnetic sources of the upper atmosphere,” *Surveys in Geophysics*, 8, No. 3, 239-259 (September 1986)
- Allen, J., L. Frank, H. Sauer, and P. Reiff, “Effects of the March 1989 solar activity,” *EOS*, 70, No. 46, 1479 + 1486-1488 (14 November 1989)
- Kappenman, J. G., and V. D. Albertson, “Bracing for the geomagnetic storms,” *IEEE Spectrum*, 27, No. 3, 27-33 (March 1990)
- Kurth, W. S., “The great solar storms of 1989,” *Nature*, 353, 705-706 (24 October 1991)
- Appenzeller, T., “Hope for magnetic storm warnings,” *Science*, 255, 922-924 (21 February 1992)
- Girgis, R. S., and C.-D. Ko, “Calculation techniques and results of effects of GIC currents as applied to two large power transformers,” *IEEE Transactions on Power Delivery*, 7, No. 2, 699-705 (April 1992)
- “Geomagnetic disturbance effects on power systems,” *IEEE Transactions on Power Delivery*, 8, No. 3, 1206-1216 (July 1993)
- Leshner, R. L., J. W. Porter, and R. T. Byerly, “SUNBURST --- A network of GIC monitoring systems,” *IEEE Transactions on Power Delivery*, 9, No. 1, 128-135 (January 1994)
- Boteler, D. H., “Geomagnetically induced currents: present knowledge and future research,” *IEEE Transactions on Power Delivery*, 9, No. 1, 50-58 (January 1994)
- Muir, H., “Watch out, here comes the Sun,” *New Scientist*, 149, 22-26 (3 February 1996)
- Cowan, R., “Solar cloud hits Earth’s magnetosphere,” *Science News*, 151, 68 (1 February 1997)
- Frank, A., “Blowin’ in the solar wind,” *Astronomy*, 26, No. 10, 60-65 (October 1998)
- Kappenman, J. G., “Geomagnetic storm forecasting mitigates power system impacts,” *IEEE Power Engineering Review*, 18, No. 11, 4-7 (November 1998)
- Boteler, D. H., R. J. Pirjola, and H. Nevanlinna, “The effects of geomagnetic disturbances on electrical systems at the Earth’s surface,” *Advances in Space Research*, 22, No. 1, 17-27 (1998)
- Bolduc, L., P. Langlois, D. Boteler, and R. Pirjola, “A study of geoelectromagnetic disturbances in Quebec, 1. General results,” *IEEE Transactions on Power Delivery*, 13, No. 4, 1251-1256 (October 1998)

- Viljanen, A., O. Amm, and R. Pirjola, "Modeling geomagnetically induced currents during differing ionospheric situations," *Journal of Geophysical Research*, 104, A12, 28059-28071 (1 December 1999)
- Appell, D., "Fire in the sky," *New Scientist*, 161, 29-32 (27 February 1999)
- Cowan, R., "Model tracks storms from the Sun," *Science News*, 157, 404 (24 June 2000)
- Luhmann, J., "Space weather: physics and forecasts," *Physics World*, 13, 31-36 (July 2000)
- Odenwald, S., "Solar storms: the silent menace," *Sky & Telescope*, 99, 50-56 (March 2000)
- Pirjola, R., A. Viljanen, A. Pulkkinen, and O. Amm, "Space weather risk in power systems and pipelines," *Physics and Chemistry of the Earth part C*, 25, No. 4, 333-337 (2000)
- Pirjola, R., D. Boteler, A. Viljanen, and O. Amm, "Prediction of geomagnetically induced currents in power transmission systems," *Advances in Space Research*, 26, No. 1, 5-14 (2000)
- Alpert, M., "Fire in the sky," *Scientific American*, 281, 20 (July 2000)
- Bolduc, L., P. Langlois, D. Boteler, and R. Pirjola, "A study of geoelectromagnetic disturbances in Quebec, 2. Detailed analysis of a large event," *IEEE Transactions on Power Delivery*, 15, No. 1, 272-277 (January 2000)
- Osella, A., and A. Favetto, "Effects of soil resistivity on currents induced on pipelines," *Journal of Applied Geophysics*, 44, 303-312 (2000)
- Pirjola, R., "Geomagnetically induced currents during magnetic storms," *IEEE Transactions on Plasma Science*, 28, No. 6, 1867-1873 (December 2000)
- Burch, J. L., "The fury of space storms," *Scientific American*, 284, 86-94 (April 2001)
- Newell, P. T., R. A. Greenwald, and J. M. Ruohoniemi, "The role of the ionosphere in aurora and space weather," *Reviews of Geophysics*, 39, No. 2, 137-149 (May 2001)
- Nevanlinna, H., P. Tenhunen, R. Pirjola, J. Annanpalo, and A. Pulkkinen, "Breakdown caused by a geomagnetically induced current in the Finnish telesystem in 1958," *Journal of Atmospheric and Solar-Terrestrial Physics*, 63, 1099-1103 (2001)
- Trichtchenko, L., and D. H. Boteler, "Specification of geomagnetically induced electric fields and currents in pipelines," *Journal of Geophysical Research*, 106, A10, 21039-21048 (1 October 2001)

- Boteler, D. H., “Assessment of geomagnetic hazard to power systems in Canada,” *Natural Hazards*, 23, Nos. 2-3, 101-120 (March 2001)
- Huttunen, K. E. J., H. E. J. Koskinen, T. I. Pulkkinen, A. Pulkkinen, M. Palmroth, E. G. D. Reeves, and H. J. Singer, “April 2000 magnetic storm: solar wind driver and magnetospheric response,” *Journal of Geophysical Research*, 107, No. A12, 1440, doi: 10.1029/2001JA009154 (2002)
- Lam, H.-L., D. H. Boteler, and L. Trichtchenko, “Case studies of space weather events from their launching on the Sun to their impacts on power systems on the Earth,” *Annales Geophysicae*, 20, 1073-1079 (2002)
- Pirjola, R., and D. Boteler, “Calculation methods of the electric and magnetic fields at the Earth’s surface produced by a line current,” *Radio Science*, 37, No. 3, article # 1042 (2002)
- Pirjola, R., “Fundamentals about the flow of geomagnetically induced currents in a power system applicable to estimating space weather risks and designing remedies,” *Journal of Atmospheric and Solar-Terrestrial Physics*, 64, 1967-1972 (2002)
- Molinski, T. S., “Why utilities respect geomagnetically induced currents,” *Journal of Atmospheric and Solar-Terrestrial Physics*, 64, 1765-1778 (2002)
- Pirjola, R., “Review on the calculation of surface electric and magnetic fields and of geomagnetically induced currents in ground-based technological systems,” *Surveys in Geophysics*, 23, 71-90 (2002)
- Bolduc, L., “GIC observations and studies in the Hydro-Quebec power system,” *Journal of Atmospheric and Solar-Terrestrial Physics*, 64, 1793-1802 (2002)
- Trichtchenko, L., and D. H. Boteler, “Modelling of geomagnetic induction in pipelines,” *Annales Geophysicae*, 20, No. 7, 1063-1072 (July 2002)
- Lahtinen, M., “GIC occurrences and GIC test for 400 kV system transformer,” *IEEE Transactions on Power Delivery*, 17, No. 2, 555-561 (April 2002)
- Beamish, D., T. D. G. Clark, E. Clarke, and A. W. P. Thomson, “Geomagnetically induced currents in the UK: geomagnetic variations and surface electric fields,” *Journal of Atmospheric and Solar-Terrestrial Physics*, 64, 1779-1792 (2002)
- Osella, A., P. Martinelli, A. B. Favetto, and E. Lopez, “Induction effects of 2-D structures on buried pipelines,” *IEEE Transactions on Geoscience and Remote Sensing*, 40, No. 1, 197-205 (January 2002)

- Pulkkinen, A., A. Thomson, E. Clarke, and A. McKay, “April 2000 geomagnetic storm: ionospheric drivers of large geomagnetically induced currents,” *Annales Geophysicae*, 21, 709-717 (2003)
- Boteler, D. H., “Geomagnetic hazards to conducting networks,” *Natural Hazards*, 28, 537-561 (2003)
- Pirjola, R., A. Pulkkinen, and A. Viljanen, “Studies of space weather effects on the Finish natural gas pipeline and on the Finish high-voltage power system,” *Advances in Space Research*, 31, No. 4, 795-805 (2003)
- MacRobert, A., “Fireworks on the Sun,” *Sky & Telescope*, 107, 16-17 (February 2004)
- Perkins, S., “Parting shots: Just as the Sun was calming down, it flared with a vengeance,” *Science News*, 166, No. 5, 74 (31 July 2004)
- Viljanen, A., A. Pulkkinen, O. Amm, R. Pirjola, T. Korja, and BEAR Working Group, “Fast computation of the geoelectric field using the method of elementary current systems and planar Earth models,” *Annales Geophysicae*, 22, 101-113 (2004)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, 7th edition, 2005, pages 851-852
- Cartlidge, E., “Solar explosions in 3D,” *Physics World*, 19, No. 7, 25-27 (July 2006)

Related references

- Webb, D. F., and A. J. Hundhausen, “Activity associated with the solar origin of coronal mass ejections,” *Solar Physics*, 108, 383-401 (1987)
- Osella, A. M., A. Favetto, and E. Lopez, “Currents induced by geomagnetic storms on buried pipelines as a cause of corrosion,” *Journal of Applied Geophysics*, 38, 219-233 (1998)
- Osella, A., G. Chao, and F. Sanchez, “How to detect buried structures through electrical measurements,” *American Journal of Physics*, 69, No. 4, 455-461 (April 2001)
- Rastogi, R. G., “Electromagnetic induction due to solar flares at equatorial stations,” *Journal of Atmospheric and Solar-Terrestrial Physics*, 63, 599-604 (2001)
- Singh, D. K., R. P. Singh, and A. K. Kamra, “The electrical environment of the Earth’s atmosphere: a review,” *Space Science Reviews*, 113, 375-408 (2004)

5.48 Levitating frogs

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=A1vyB-O5i6E> Video

<http://www.radionetherlands.nl/features/science/magnets990813.html>

Description and photo of levitating frog

<http://www.youtube.com/watch?v=2FvWtEdY4sE> water is diamagnetic

References

Dots • through ●●● indicate level of difficulty

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

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

- Beaugnon E, and R. Tournier, “Levitation of organic materials,” *Nature*, 349, No. 6309, 470 (7 February 1991)
- Berry, M. V., “The Levitron™: an adiabatic trap for spins,” *Proceedings of the Royal Society of London A*, 452, 1207-1220 (1996)
- Buchanan, M., “And God said . . . let there be levitating strawberries, flying frogs and humans that hover over Seattle,” *New Scientist*, 155, 42-43 (26 July 1997)
- Wu, C., “Floating frogs. Magnets help living organisms defy gravity,” *Science News*, 152, 362-363 (6 December 1997)
- “Molecular magnetism takes off,” *Physics World*, 10, 28 (April 1997)
- Valles Jr., J. M., K. Lin, J. M. Denegre, K. L. Mowry, “Stable magnetic field gradient levitation of *Xenopus laevis*: Toward low-gravity simulation,” *Biophysical Journal*, 73, 1130-1133 (August 1997)
- Berry, M. V., and A. K. Geim, “Of flying frogs and Levitrons,” *European Journal of Physics*, 18, 307-313 (1997)
- Simon, M. D., L. O. Heflinger, and S. L. Ridgway, “Spin stabilized magnetic levitation,” *American Journal of Physics*, 65, No. 4, 286-292 (April 1997)
- Geim, A., “Everyone’s magnetism,” *Physics Today*, 51, No. 9, 36-39 (September 1998)
- Ikezoe, Y., N. Hirota, J. Nakagawa, and K. Kitazawa, “Making water levitate,” *Nature*, 393, No. 6687, 749-750 (25 June 1998)

- Wu, C., “Abracadabra! Magnets float in midair,” *Science News*, 156, 54 (24 July 1999)
- Geim, A. K., M. D. Simon, M. I. Boamfa, and L. O. Heflinger, “Magnet levitation at your fingertips,” *Nature*, 400, No. 6742, 323-324 (22 July 1999)
- Simon, M. D., and A. K. Geim, “Diamagnetic levitation: flying frogs and floating magnets (invited),” *Journal of Applied Physics*, 87, No. 9, 6200-6204 (1 May 2000)
- Pelrine, R. E., “Diamagnetic levitation,” *American Scientist*, 92, No. 5, 428-435 (September-October 2004)

Related references

- Ueno, S., and M. Iwasaka, “Parting of water by magnetic fields,” *IEEE Transactions on Magnetics*, 30, No. 6, 4698-4700 (November 1994)
- Motokawa, M., M. Hamai, T. Sato, I. Mogi, S. Awaji, K. Watanabe, N. Kitamura, and M. Makihara, “Magnetic levitation experiments in Tohoku University,” *Physica B*, Vols. 294-295, 729-735 (2001)
- Yamane, R., S. Tomita, J. Mai, M. K. Park, and S. Oshima, “Oscillation of a diamagnetic liquid bubble suspended by magnetic force,” *Journal of Magnetism and Magnetic Materials*, 252, 268-270 (2002)

5.49 Fizzing sound from a magnet

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=jy0E3gjm59w>

<http://www.youtube.com/watch?v=iWdbRX5Nyg4>

<http://www.youtube.com/watch?v=8-0UytwADgo&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

- Schwarz, A., M. Liebmann, U. Kaiser, and R. Wiesendanger, “Visualization of the Barkhausen effect by magnetic force microscopy,”

Physical Review Letters, 92, No. 7, article number 077206, 4 pages (20 February 2004)

- Lonc, W., “A simple demonstration of the Barkhausen effect,” American Journal of Physics, 60, No. 9, 860 (September 1992)
- Halliday, D., R. Resnick, and J. Walker, *Fundamentals of Physics*, 7th edition, 2005, pages 878-879
- Kraftmakher, Y., “Demonstration of the Barkhausen effect,” American Journal of Physics, 73, No. 4, 367-369 (April 2005)

5.50 Currents in you at a train station

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

- Rabban, J., J. Adler, C. Rosen, J. Blair, and R. Sheridan, “Electrical injury from subway third rails: serious injury associated with intermediate voltage contact,” *Burns*, 23, No. 6, 515-518 (1997)
- Elliot, J., “Commuter conductor,” in “The Last Word,” *New Scientist*, 164, No. 2216, inside back cover (11 December 1999)
- Dolezaler, H., (letter) “Atmospheric electric field is too small for humans to feel,” *Physics Today*, 52, 15 + 95 (May 1999)