

# Index

## • A •

- Aarau Cantonal School, 25, 26, 338
- Abbot, Edwin (author), 295
- absolute motion, 39–40, 42–43, 128–130
- absolute spacetime, 224
- absolute zero temperature, 70, 74–75
- acceleration
- due to gravity, 113, 169
  - equivalence with gravity, 169
  - mass and, 150
  - Newton's second law of motion and, 63
  - special theory of relativity and, 143–144
  - thought experiment, 168–169
  - time and, 181–182
  - universe expansion, 307
- action and reaction, law of, 63, 64
- Adams, John (scientist), 82
- Advanced Camera for Surveys, 148, 307
- aging, general theory of relativity and, 181–185
- air drag, 166, 170
- Albert Einstein, A Biographical Portrait* (Anton Reiser), 336
- Albert Einstein: Creator and Rebel* (Banesh Hoffman and Helen Dukas), 337
- Albert Einstein, the Human Side* (Banesh Hoffman and Helen Dukas), 337
- Alder, Frederick (scientist), 158–159
- algebra, 22, 257
- allowed orbits, 245
- Alpha Centauri (star), 145
- alpha decay, 339
- alpha particles, 237–240, 273, 339
- alpha ray, 237, 271, 339
- amber, 82–83
- Ampère, André Marie (physicist), 92
- Ampère-Maxwell law, 95–96
- Ampère's law, 92
- Andromeda (galaxy), 146
- Annalen der Physik* (journal), 38, 41, 176, 188
- Annual Review of Radioactivity and Electronics* (journal), 163
- anthropomorphism, 324
- antigravity, 208, 304–305
- Archimedes (Greek scientist), 53
- Aristarchus (Greek philosopher/scientist), 50, 51
- Aristotle (Greek philosopher/scientist), 50, 57, 232
- arrow of time, 70, 76–78
- art, appreciation by Einstein, 11
- Aspect, Alain (physicist), 267
- astigmatism, 109
- astronaut training, 167
- astronomy
- ancient Greeks and, 50–52
  - Babylonians and, 50
  - Copernicus and, 54
  - Galileo Galilei and, 60
  - Kepler and, 54–56
- atomic bomb
- chain reactions, 281–282
  - critical mass, 284
- Einstein's letter to Roosevelt, 10, 270, 286–287
- $E=mc^2$  equation and, 10, 13, 43–44
- Little Boy*, 285
- use in World War II, 44, 287
- atomic clock, 182, 214–217, 220–221
- atoms
- Bernoulli's use in calculating gas properties, 234
  - Bohr model of, 245–246, 257
  - composition, 154–156
  - Democritus and, 53, 231–232
  - elements and, 234–235
  - light emission from, 152
  - mechanics, 257
  - nuclear forces, 154–155, 272–273, 282–284, 317–318
  - number in salt grain, 234
  - plum pudding analogy, 236–237
  - probing with alpha particles, 237–240
  - Rutherford's nuclear model of, 240–241
  - size, 241
  - spectra of, 256–257
  - superatoms, 255
  - visualizing with scanning tunneling microscope, 232–233
- Australian National University, 306
- Avenarius, Richard (philosopher), 326
- Avogadro, Amadeo (physicist), 232
- Avogadro's number, 45, 232

• **B** •

- Baade, Walter  
(physicist), 195
- Babylonians, 50
- barium, 278
- Becquerel, Henri (scientist),  
236, 271, 338
- Bekenstein, Jacob  
(physicist), 74
- Bell, Jocelyn  
(astronomer), 198
- Bell, John (physicist), 266
- Bell's inequality, 266
- Bennett, Charles  
(scientist), 268
- Bernoulli, Daniel  
(mathematician), 234
- Bernstein, Aaron (*Popular  
Books on Natural  
Science*), 21
- Bessel, Friedrich  
(astronomer), 51
- Besso, Michelangelo  
(Michele) (friend of  
Einstein), 131, 291
- beta decay, 274–275, 316
- beta particle, 339
- beta ray, 237, 271, 274, 339
- Betelgeuse (star), 129
- Bethe, Hans (physicist), 288
- binary system, 306
- binding energy, of the  
nucleus, 156
- biological processes, speed  
of, 142–143
- black body, 339
- black dwarf, 200, 339
- black holes  
dark stars, 191–192  
definition, 187, 339  
Einstein's skepticism about,  
187, 194–195  
entropy, 74  
escape velocity and,  
190–192  
event horizon, 202, 205, 340  
general theory of relativity  
and, 190–194
- Hawking-Thorne wager,  
201  
hunting for, 199  
journey into, 204–205  
properties, 201–205  
quasars, 198  
radiation from, 203–204  
rotating, 197  
roundness of, 202  
Schwarzschild radius,  
192–194  
worm holes connecting, 342
- Black Holes and Time Warps*  
(Kip Thorne), 201
- Blinov, Boris (scientist), 268
- Bohr, Niels (physicist)  
arguments concerning  
reality, 325  
atomic model, 245–246, 257  
attitude toward Einstein, 9  
Copenhagen interpretation  
of quantum physics, 266  
Heisenberg and, 255  
liquid drop as model for  
heavy nucleus, 278–279  
response to Einstein's EPR  
argument, 266  
uncertainty principle  
and, 264
- Boltzmann, Ludwig  
(physicist), 77
- Born, Max (physicist),  
255, 257, 259, 260
- Bose, Saryendra (physicist),  
79, 254
- Bose-Einstein condensate,  
79, 255
- Bose-Einstein statistics,  
254
- Boyle, Robert (scientist), 234
- Boyle's law, 234
- Brahe, Tycho (astronomer),  
54–55
- brain, examination of  
Einstein's, 7–8
- Braun, K. (scientist), 225
- A Brief History of Time*  
(Stephen Hawking), 201
- Brookhaven National  
Laboratory, 316
- Brown, Robert  
(botanist), 232
- Brownian motion, 41, 45, 78
- Bulletin of the Atomic  
Scientists*, 288
- buoyancy, principle of, 53
- Burger, Dionys  
(mathematician), 295

• **C** •

- calculus, 22–23, 62, 65
- calendar, Babylonian, 50
- Caltech, 195–196, 198, 201,  
204, 206
- Cambridge University,  
198, 201
- Cannon, Robert  
(scientist), 222
- Carnegie Institution, 305
- Carter, Brandon  
(physicist), 197
- Casimir effect, 209, 312
- Casimir, Hendrik (physicist),  
209, 312
- Cassini, Jean-Dominique  
(astronomer), 98–99
- cathode ray tube (CRT),  
235–236
- cathode rays, 236
- Cavendish laboratory  
(Cambridge,  
England), 236
- Cepheid stars, 300
- CERN (European Particle  
Physics Laboratory),  
213–214, 317, 318
- cesium, atomic clock, 182
- chain reactions, 281–282
- Chandrasekhar limit, 306
- Chandrasekhar,  
Subrahmanyan  
(physicist), 195
- charge, electric, 84–89
- Charon (moon of Pluto), 145
- Chavan, Louis (student of  
Einstein), 160

- classical physics, Newton's  
creation of, 61
- Clausius, Rudolf  
(scientist), 242
- clock  
atomic, 182, 214–217,  
220–221  
Galileo's wine bottle,  
58, 113  
satellite, 220–221
- CMB (Cosmic Microwave  
Background), 309
- coherent beams,  
108, 125, 339
- coincidence of an event, 176
- CoKu Tau 4 (star), 145
- collapsing stars, 195–196
- collisions of objects, 151
- color  
from hot objects, 38–39,  
241–244  
Newton's theory of colors,  
62, 104–106
- Columbia University, 173
- compass, 19, 90–91
- concept, 326
- Conference on Science,  
Philosophy, and Religion  
(1940), 323
- conservation laws, 203, 339
- conservation of energy,  
70–72, 151, 339
- Contact* (movie), 207
- Copenhagen interpretation of  
quantum physics, 266
- Copernicus, Nicolaus  
(astronomer), 54
- Cornell, Eric A.  
(scientist), 255
- corpuscles, Newton's,  
190–192
- Cosmic Microwave  
Background (CMB), 309
- cosmic rays, 141
- cosmological constant  
antigravity and, 304–305  
dark energy, 309, 311,  
313, 314  
Friedmann's removal of, 296  
introduction of by Einstein,  
16, 295, 301, 303  
revival of, 303, 307
- Coulomb, Charles Augustin  
de (scientist), 86, 87
- covariance, principle of, 176
- critical density, 310
- critical mass, 284–285
- critical size, star, 191, 192
- Critique of Pure Reason*  
(Immanuel Kant), 21, 326
- crow's nest, dropping ball  
from, 114
- CRT (cathode ray tube),  
235–236
- Curie, Marie (scientist), 174,  
236, 271, 338
- Curie, Pierre (scientist), 236,  
271, 338
- curved spacetime, 177–178,  
180, 197, 222–228, 294
- curved surfaces, geometry  
of, 174
- Cygnus X-1 (black hole),  
199, 201
- **D** •
- Dalton, John (scientist),  
53, 231, 235
- dark energy, 309, 310,  
311, 313, 314
- dark matter, 305–306,  
310, 339
- dark star, 191–192
- de Broglie, Louis (scientist),  
254, 259
- de Sitter, Willem  
(astronomer), 296
- Democritus (Greek philoso-  
pher), 53, 231–232
- Descartes, René  
(philosopher/  
mathematician), 150
- determinism, 324, 325
- deuterium, 285
- Dicke, Robert (scientist), 170
- diffraction, 108, 340
- dilating time, 137–138, 140,  
194, 214–215, 217
- Dirac, Paul (physicist),  
90, 187, 260, 311
- Discourses and Mathematical  
Demonstrations  
Concerning Two New  
Sciences Pertaining to  
Mechanics and Local  
Motion. See The Two New  
Sciences* (Galileo Galilei)
- disorder, 73–74
- Doppler effect  
black holes and, 205  
definition, 340  
expanding universe  
and, 298  
general theory of relativity  
and, 183, 193
- Drude, Paul  
electromagnetism and, 32  
*Physics of the Ether*, 32  
theory of metals, 233
- du Fay, Charles (scientist), 83
- Dukas, Helen (secretary to  
Einstein)  
*Albert Einstein: Creator and  
Rebel*, 337  
*Albert Einstein, the Human  
Side*, 337  
as secretary, 337, 338
- **E** •
- Earth  
geocentric model of  
universe, 50, 51–52  
gravitational force of, 171  
movement through  
ether, 119  
rotation of, 50, 51, 54  
eclipse, solar, 178–179
- Eddington, Arthur  
(astronomer), 15,  
178–179, 185, 296
- education, of Einstein  
in algebra and calculus,  
22–23  
college, 27–35

- education, of Einstein  
(*continued*)  
description, 8  
elementary school,  
19–20, 322  
in geometry, 21  
in Greek, 20  
PhD dissertation, 41, 45  
in physics, 27  
rejected thesis, 233  
religious, 22, 322, 323  
secondary school,  
20–21, 322  
self-taught, 22–23  
senior thesis, 34–35  
Swiss Cantonal school in  
Aarau, 25, 26  
teachers, relationships  
with, 20–21, 31, 38
- Einstein, Albert *The Meaning of Relativity*, 301
- Einstein: An Intimate Study of a Great Man* (Dimitri Marianoff), 337
- Einstein and Religion* (Max Jammer), 321
- Einstein, Eduard (son of Albert), 333, 334
- Einstein, Elsa (wife of Albert), 11, 334, 335–336
- Einstein, Fanny (aunt of Albert), 335
- Einstein, Hans Albert (son of Albert), 333
- Einstein, Hermann (father of Albert)  
death, 331  
education of Albert,  
19, 23–24  
marriage, 329  
occupation, 17, 23  
views on religion, 322
- Einstein, Ilse (stepdaughter of Albert), 336–337
- Einstein, Jakob (uncle of Albert), 22, 23
- Einstein, Lieserl (daughter of Albert), 334–335
- Einstein, Maja (Maria) (sister of Albert)  
birth, 17, 329, 331  
childhood, 18  
closeness to Albert, 18, 31  
death, 332  
education, 31, 158, 331  
music, 11, 19  
writings about Albert,  
18, 20, 155, 156, 332
- Einstein, Margot (stepdaughter of Albert), 331, 337
- Einstein, Mileva. *See* Maric, Mileva
- Einstein, Pauline (mother of Albert)  
birth of Albert, 7, 329  
death, 331  
disapproval of Mileva,  
36, 330  
education of Albert,  
19, 20, 23  
marriage, 329  
music and, 11, 19, 329–330
- Einstein, Rudolf (uncle of Albert), 335
- Einstein x-ray telescope*, 199
- Einstein-Rosen bridge, 207
- Einstein's field equation,  
188–189
- electric charge, 84–89
- electric current  
definition, 90, 340  
magnetic field generation  
by, 90–91  
produced from magnetic  
field, 92–94, 127
- electric fields, 86–88, 127–128
- electric generator, 94
- electricity  
attraction and repulsion,  
84–85  
du Fay's experiments  
with, 83  
Franklin's experiments  
with, 83–84  
similarity to magnetism, 89
- electrodynamics of moving  
bodies, 41
- electromagnetic  
radiation, 275
- electromagnetic wave  
light, 100, 102  
movement through  
space, 96  
speed of waves, 100–103  
thermal radiation as, 242  
wavelength, 103
- electromagnetism  
absolute motion and, 40  
Ampère's law, 92  
compass, 19  
current production,  
92–94
- Einstein's reformulation of,  
43, 129
- Einstein's study of, 32
- Hertz and, 100–103
- inconsistency with  
mechanics, 126–130
- Maxwell's theory, 31, 33,  
38, 95–96, 127–128
- motion and, 127–130
- Oersted's experiments,  
90–92
- radio invention, 102
- relativity and, 126–130
- spectrum, 104
- electron microscope, 254
- electrons  
beta decay and, 274–275  
charge, 84, 236  
collapse, failure to, 241,  
244  
definition, 340  
detection of, 274  
discovery, 84, 154,  
235–236  
energy, 245–246  
Heisenberg's uncertainty  
principle, 264  
Lorentz's theory of  
matter, 120  
mass, 236  
orbits, 245–246

- as particles, 262–264  
 Paul Drude and, 233  
 photoelectric effect and, 252–253  
 photons and, 312–313  
 quantum theory and, 13–14  
 tunneling of, 267  
 wavelike behavior, 254, 259, 261, 263
- electroweak field, 316–317
- elements  
   Aristotle's, 232  
   description, 234–235  
   transuranic, 276
- ellipse, 55
- Elsa (wife of Einstein), 11
- E=mc<sup>2</sup>* equation  
   bending of light and, 172  
   Christian Huygens and, 150–151  
   description, 12  
   Einstein's paper of 1905, 41, 43  
   first law of thermodynamics and, 71  
   formulation of, 152–155  
   uses, 12–13, 43–44
- Emergency Committee of Atomic Scientists, 288
- energy  
   binding of nucleus, 156  
   changes in, 71  
   conservation of, 70–72, 151, 339  
   dark, 309, 310, 311, 313, 314  
   definition, 70, 340  
   electrons, 245–246  
   invention of word, 71  
   living force, 71  
   mass and, 12, 43, 71, 147, 152–153  
   missing, 72, 156  
   of motion, 151  
   negative, 208–209  
   quanta, 248–251  
   quantum theory and, 13  
   radiation by hot objects, 241–244  
   release by nuclear fission, 281–284  
   sun, 71  
   superstring theory and, 318  
   of the vacuum, 311  
   work and, 70, 147  
   zero point, 75
- entropy, 73–75, 340
- epicycles, 51, 340
- EPR problem, 265–268, 325
- equivalence, principle of, 169, 171–173, 175
- escape velocity, 190–192, 340
- ether  
   absolute motion and, 40, 43  
   definition, 40, 340  
   Earth movement through, 119, 123–125  
   Einstein's thoughts on, 33–34, 43, 130  
   light movement through, 119, 123–125  
   time measured relative to, 121  
   wind, 125
- Euclidian geometry, 173, 174
- Euler, Leonhard (mathematician), 318
- European Particle Physics Laboratory (CERN), 213–214, 317, 318
- European Southern Observatory Very Large Telescope, 145
- event horizon, 202, 205, 340
- Everitt, Francis (scientist), 226
- F •**
- Fairbank, William (scientist), 222
- falling, weightlessness and, 164–167
- fame  
   effect on Einstein, 9  
   Einstein's use of, 10  
   from general theory of relativity, 185–186
- Faraday, Michael (scientist), 81, 92–94, 235
- Federal Polytechnic Institute. *See* Polytechnic
- Fermi, Enrico (physicist), 276, 282, 284
- Feynman, Richard (physicist), 311
- field  
   definition, 87, 340  
   electric, 86–88, 127–128  
   electroweak, 316–317  
   magnetic, 88–93  
   field ion microscope, 233  
   first law of thermodynamics, 70–72
- FitzGerald, George (scientist), 120
- five-dimensional spacetime, 314–315
- Florentine Academy, 57
- flying, effect on aging, 213–215
- F=ma* equation, 63
- Foppi, August (*Introduction to Maxwell's Theory of Electricity*), 32
- force  
   attraction between objects, 64–65  
   electric, 85–86  
   electroweak, 316–317  
   Newton's laws of motion, 63–64  
   nuclear, 154–155, 272–273, 317, 318  
   unbalanced, 62
- Ford, Kent (scientist), 305
- fourth dimension, 174–175
- frame dragging, 222–228
- Franklin, Ben (scientist), 83–84
- French, Einstein's study of, 26
- Freundlich, Erwin (astronomer), 178, 331
- friction, 60–61, 63

Friedmann, Alexander (scientist), 296–297, 301  
 Frisch, Otto (physicist), 278–279, 287  
 future, prediction of, 13–14

## • G •

### galaxy

Andromeda, 146  
 brightness, 198  
 dark matter, 305–306  
 definition, 340  
 distances to, 299–300  
 gravity and, 308  
 Hubble's discovery of, 299  
 Large Magellanic Cloud, 200  
 Milky Way, 198, 200, 298  
 universe expansion and, 308

### Galilean principle of relativity, 118

### Galileo Galilei

astronomy and, 60  
 clock, wine bottle, 58, 113  
 education, 56  
 gravitational mass, 170  
 motion experiments, 57–61, 113–115  
 music and, 57  
 relativity and, 113–118  
 scientific method, 59  
 speed of light experiments, 98

*The Starry Messenger*, 60

thought experiments, 59–61, 115

*The Two New Sciences*, 57, 115

gamma rays, 237, 275, 285, 340

Gamow, George (physicist/cosmologist), 301

### gases

Avogadro and, 232  
 Bernoulli and, 234  
 Boyle's law, 234

Geiger, Hans (scientist), 237–239

### general theory of relativity.

*See also* relativity

bending of light, 171–172  
 confirmation of, 15  
 description, 14–15  
 Einstein's fame from, 185–186  
 Einstein's field equation, 188–189  
 equivalence of gravitational and inertial mass, 170–171  
 equivalence of gravity and accelerated motion, 169  
 predictions, 213  
 principle of covariance, 176  
 principle of equivalence, 169, 171–173  
 Riemannian geometry and, 174  
 treating space and time the same, 175–176  
 weightlessness, 164–167

general theory of relativity, implications of

aging more slowly, 181–185, 214–215

black holes, 190–194

deflection of light, 177–179

Global Positioning Satellite (GPS) receivers, 220

orbit of Mercury explained, 179–181

time travel, 205–210

warped spacetime, 177

geocentric model, 50, 51–52, 340

geometry

Einstein's study of, 21

Euclidian, 173, 174

Riemannian, 174

Schwarzschild, 189, 192

of spacetime, 187–189

German citizenship, 24

Gilbert, William (*The Magnet*), 82

Glashow, Sheldon (physicist), 316, 317

Global Positioning Satellite (GPS) receivers, 220–221

gluons, 317

goals of science, 327–328

### God

Einstein's idea of, 324

playing dice, 247, 264

Goldstein, Eugen

(scientist), 241

GPS (Global Positioning Satellite) receivers, 220–221

Grand Unified Theory, 317

gravitational field, 88, 193

gravitational mass, 148, 170–171

gravitational repulsion, 208

### gravity

acceleration due to, 113, 169

as curved spacetime, 88

energy and, 304

equivalence with

acceleration, 169

general theory of relativity

and, 15, 169–171, 176–177, 193

geometry and, 177

light time-delay effect, 217–219

Newton and, 62, 63, 65

pressure and, 304, 307

quantum, 318

relative nature of, 169

slowing of time by, 184, 208

*Gravity Probe A* (NASA mission), 216–217, 226

*Gravity Probe B* (NASA mission), 211, 226–228

Greek, Einstein's study of, 20

Greeks, ancient, 50–53, 82, 232

Green, Michael (physicist), 318

Grimaldi, Francesco Maria (scientist), 108

Grossmann, Marcel (friend of Einstein), 28, 173

gyroscopes, 222, 226–228

## • H •

H bomb, 285  
 Habicht, Conrad (friend of Einstein), 132, 153, 155  
 Hafele, J.C. (scientist), 214–215  
 Hahn, Otto (chemist), 277–280  
 harmonic law, Kepler's, 55, 56  
 Harvard University, 196, 216, 299, 316–317  
 Harvey, Thomas (pathologist), 7  
 Hauptman, Gerhart (novelist), 322  
 Hawking radiation, 204  
 Hawking, Stephen (physicist) black holes, 74, 201, 203, 204  
*A Brief History of Time*, 201  
 chronology protection hypothesis, 209–210  
 heat, direction of flow, 70, 72  
 Heisenberg, Werner, 255–257  
 Heisenberg's uncertainty principle, 264, 266–267, 325, 340, 342  
 heliocentric model, 51, 54  
 helium, 256, 282, 285  
 Hertz, Heinrich (physicist), 32, 33, 96, 100–103, 252  
 Hewitt, Anthony (astronomer), 198  
 High-z Supernova Search Team, 306  
 Hilbert, David (mathematician), 144  
 Hoffman, Banesh (professor) *Albert Einstein: Creator and Rebel*, 337  
*Albert Einstein, the Human Side*, 337  
 Hubble, Edwin (astronomer), 16, 299–301  
 Hubble Space Telescope, 16, 148, 306–307  
 Hume, David (philosopher), 326

Hurwitz, Adolf (professor), 27  
 Huygens, Christian (scientist), 44, 99, 150–151  
 hydrogen, 241, 256, 260  
 hydrogen bomb, 285

## • I •

icons, used in book, 4  
 Imperial College London, 316  
 induction law, Faraday's, 94  
 inertia, 148, 341  
 inertial mass, 148–150, 170–171  
 infrared telescope, 146  
 Institute for Advanced Studies (Princeton, New Jersey), 9, 10  
 interference definition, 341  
 Michelson-Morley experiment, 125–126  
 patterns of electrons, 254, 261, 263–264  
 Young's experiments, 108, 109  
 interferometer, 125  
 International Congress of Arts and Sciences (1904), 121  
 International Space Station, 165, 166, 168  
 interstellar travel, 145–146  
*Introduction to Maxwell's Theory of Electricity* (August Foppi), 32  
 inverse square law, 85–86, 89  
 Io (Jupiter moon), 98–99  
 iron-56, 283  
 irreversibility, 77  
 island universes, 299  
 Italy, Einstein's life in, 23–24

## • J •

Jammer, Max (*Einstein and Religion*), 321

Jet Propulsion Laboratory (JPL), 206, 218, 219  
 Jordan, Pascual, 257, 259  
 Josephson junction, 267  
*Journal of Applied Chemistry*, 276  
 Judaism, 322  
 Jupiter's moons, 98–99

## • K •

Kaluza, Theodor (mathematician), 314–315  
 Kant, Immanuel (*Critique of Pure Reason*), 21, 326  
 Karl-Ferdinand University, 173  
 Kayser, Rudolf (husband of Ilse Einstein), 336  
 Keating, Richard (scientist), 214–215  
 Kepler, Johannes (astronomer), 54–56  
 Kerr, Roy (scientist), 197, 207  
 Ketterle, Wolfgang (scientist), 255  
 Kirkchhoff, Gustav (physicist), 36, 242  
 Klein, Oscar (physicist), 315  
 Kleiner, Alfred (professor), 157, 158, 233  
 Koch, Caesar (uncle of Einstein), 34

## • L •

Lagrange, Joseph-Louis (mathematician), 11  
 landmark experiment, 109  
 Langevin, Paul (professor), 254  
 Laplace, Pierre Simon de (*The System of the World*), 191  
 Large Magellanic Cloud, 200  
 laser, 16, 341  
 law of areas, Kepler's, 56

- law of induction, Faraday's, 94  
 law of orbits, Kepler's, 56  
 law of universal gravitation, Newton's, 62, 63, 65, 85–86  
 Lawrence Berkeley National Laboratory, 306  
 Le Verrier, Urbain Jean Joseph (scientist), 82, 179  
 League of Nations  
   commission, 338  
 Leavitt, Henrietta (scientist), 299–300  
 length contraction equation, Lorentz's, 120–121  
 Lense, Josef (physicist), 222  
 Levine, Martin (scientist), 216–217  
 life extension of muons, 213–214  
 life of Einstein  
   birth, 17  
   childhood, 8, 17–23  
   children, 333–334  
   discipline, aversion to, 19  
   education, 8, 19–23, 24–35  
   fame, 9  
   first love, 25  
   fortune, 9–10  
   in Italy, 23–24  
   marriages, 333, 335  
   miracle year, 37, 40, 66  
   mountain accident, 27  
   music, love of, 19  
   Olympic Academy, 132, 326  
   patent office work, 37, 38  
   politics, 10  
   speech development, 17, 18  
   teaching, 157–160  
   timeline, 343–347  
   work, 10–11  
 light. *See also* speed of light  
   bending of, 15, 108, 171–172, 177–179  
   black holes and, 187, 190–194, 203  
   in curved spacetime, 177–178  
   diffraction, 108, 340  
   Doppler-shifted, 193, 298  
   as electromagnetic wave, 100, 102  
   energy of emitted, 152  
   gravity effect on, 193, 217–219  
   interference, 108, 109, 125–126  
   movement through ether, 119  
   Newton's corpuscles, 190–192  
   Newton's theory of colors and, 104–106  
   as particles, 101, 249  
   photoelectric effect and, 252–253  
   photon, 13, 42, 341  
   quanta, 13, 39, 248–251  
   quantum theory, 41–42  
   refraction, 60  
   time standing still, 145, 149  
   ultraviolet catastrophe, 38–39  
   as a wave, 40, 42, 108–110, 192  
   wavelength of, 104, 108–109, 193  
 lightning, Franklin's experiments, 83  
 liquid drop, as model  
   for heavy nucleus, 278–279  
*Little Boy* (bomb), 285  
 living force, 71  
 Loewenthal, Max (first husband of Elsa Einstein), 335  
 Lorentz, Hendrik Antoon (scientist), 120–121, 173, 188  
 Lorentz-FitzGerald contraction, 120  
 Luitpold Gymnasium, 20–21  
 Lynden-Bell, Donald (astronomer), 198
- M •
- Mach, Ernst (*Mechanics*), 32  
*The Magnet* (William Gilbert), 82  
 magnetic fields  
   black holes and, 202  
   description, 88–89  
   electric current produced from, 92–94, 127  
   generation by electricity, 90–92  
   propagation of, 93  
 magnets, 88–91  
 Manhattan Project, 196, 287, 288  
 Marianoff, Dimitri (*Einstein: An Intimate Study of a Great Man*), 337  
 Maric, Mileva (wife of Einstein)  
   children, 333–334  
   death, 334  
   depression, 333  
   divorce, 334  
   final exams, 35  
   as intellectual companion, 29–30  
   jealousy, 31  
   letter exchange, 30, 332  
   marriage, 333  
   meeting Einstein, 29  
   Olympic Academy, 132  
   Pauline Einstein's disapproval of, 36, 330  
*Mariner* missions (NASA), 219  
 Mars, motion of, 55  
 Marsden, Ernest (scientist), 239  
 mass  
   acceleration and, 150  
   decrease after emission of light, 152  
   definition, 71, 341  
   electron, 236  
   energy and, 12, 43, 71, 147, 152–153  
   gravitational, 148, 170–171  
   inertial, 148–150, 170–171

- Newton's second law of  
   motion and, 63, 64  
 nucleus, 240  
 proton, 241  
 radiation and, 152  
 relative nature of, 149  
 weight compared, 71  
 mass-energy equation. *See*  
    $E=mc^2$  equation  
*The Mathematical Collection*  
   (Claudius Ptolemy), 52  
 matrix, 257–259  
 matrix mechanics, 257, 260  
 matter  
   Bose-Einstein condensate,  
     255  
   dark, 305–306, 310, 339  
   Lorentz's theory of  
     matter, 120  
   wavelike behavior, 254  
 Maxwell, James Clerk  
   (scientist)  
   electromagnetism theory,  
     31, 33, 38, 95–96  
   statistical mechanics, 77  
*The Meaning of Relativity*  
   (Albert Einstein), 301  
 mechanics  
   celestial, 62  
   Galileo and, 57–61  
   matrix, 257, 260  
   Newton's laws of motion,  
     38, 62–64, 118  
   statistical mechanics,  
     69, 77–78  
   wave, 259–260  
*Mechanics* (Ernst Mach), 32  
 Meitner, Lise (physicist),  
   276–280  
 Merck, Marie (wife of Max  
   Planck), 242  
 Mercury, orbit of, 15,  
   179–181, 194  
 Michell, John (scientist),  
   190–191  
 Michelson, Albert (physicist),  
   34, 119, 124–126  
 Michelson-Morley  
   experiment, 119, 124–126  
   microscope, 232–233, 254  
   microwave, 103  
   militant activist/pacifist,  
     Einstein as, 10, 288  
   Milky Way (galaxy),  
     198, 200, 298  
 Mill, John Stuart  
   (philosopher), 326  
 Mills, Robert (physicist), 316  
 Minkowski, Hermann  
   (professor), 27, 144, 174  
 miracle year  
   Einstein's, 37, 40, 66  
   Newton's, 61, 62, 66, 104  
 MIT, 218–219, 255  
 molecules  
   Avogadro's number, 232  
   calculating diameter of, 232  
   quantum mechanics, 75  
   realness and measurability  
     of, 15, 41, 45  
   temperature as measure of  
     speed of, 70, 74, 234  
   zero point energy, 75  
 monochromatic light, 253  
 monopoles, 90  
 moon, 64, 165  
 Morley, Edward (physicist),  
   34, 119, 124–126  
 Morris, Michael (scien-  
   tist), 206  
 motion  
   absolute, 39–40, 42–43,  
     128–130  
   Brownian, 41, 45, 78  
   detection by electric fields,  
     127–128  
   electromagnetism and,  
     127–130  
   Galileo and, 57–61, 113–115  
   Newton's laws, 62–64  
   reference frame for, 116, 118  
   relative, 129–130  
   shrinkage of objects in, 120  
   statistical mechanics, 69,  
     77–78  
   uniform, 116, 118, 143,  
     163–164  
 Mount Santis, Einstein's  
   climb of, 27  
 Mount Wilson Observatory,  
   299, 300  
 Mt. Palomar telescope, 197  
 Muhleman, Duane (scientist),  
   218, 219  
 muons, 141–142, 213–214  
 Museum of Natural History in  
   Paris, 271  
 music, Einstein's love of, 9,  
   11, 19, 330
- *N* ●
- nanometers, 104  
 nanotubes, 156  
 NASA  
   *Gravity Probe A* mission,  
     216–217, 226  
   *Gravity Probe B* mission,  
     211, 226–228  
   Jet Propulsion Laboratory  
     (JPL), 206, 218, 219  
   *Mariner* missions, 219  
   Reduced Gravity Research  
     program, 167  
   Space Telescope Science  
     Institute, 307  
   *Viking* missions, 219  
   Wilkinson Microwave  
     Anisotropy Probe  
     (WMAP), 309–311  
 National Institute for  
   Standards, 75  
*Nature* (journal), 276, 279  
*Navstar* (satellite), 220  
 nebula, 200, 299  
 negative energy, 208–209  
 negative pressure, 304, 307  
 Neptune, discovery of, 82  
 neutrino, 72, 274, 341  
 neutron stars, 195–196,  
   198, 200, 208, 341  
 neutrons  
   alpha particle, 273  
   beta decay and, 274  
   bombarding uranium  
     with, 276

- neutrons (*continued*)  
 chain reactions and, 281–282  
 definition, 341  
 hydrogen bomb and, 285  
 neutron stars and, 195  
 nuclear force and,  
 154–156, 272  
 nuclear fusion and, 196
- New Horizons (spacecraft), 145
- New Idea icon, 4
- The New York Times*, 288, 324
- Newton, Isaac  
 calculus, 62, 65  
 celestial mechanics, 62  
 celibacy of, 66–67  
 corpuscles, 190–192  
 education, 61–62  
 Einstein compared, 66–67  
 frame dragging and,  
 223–225  
 law of universal gravitation,  
 62, 63, 65, 85–86  
 miracle year, 61, 62, 66, 104  
 motion, 39, 62–64  
*Principia*, 118, 165  
 red as favorite color, 105  
 theory of colors,  
 62, 104–106  
 theory of fluxions, 65  
 universe model, 67, 118,  
 289–290, 304
- niobium, 227–228
- Nobel Prize  
 de Broglie’s 1929 prize, 254  
 Einstein’s 1922 prize,  
 10, 42, 248  
 Hahn’s 1944 prize, 280  
 Planck’s 1918 prize, 242  
 Rubbia and van der Meer’s  
 1984 prize, 317  
 Weinberg, Glashow, and  
 Salam’s 1979 prize, 317
- Noddack, Ida (chemist), 276
- nuclear bomb. *See* atomic  
 bomb
- nuclear fission  
 chain reactions, 281–282  
 definition, 285  
 discovery of, 276–280  
 energy release by,  
 44, 281–284  
 hydrogen bomb and,  
 285–286  
 liquid drops as model of,  
 278–279
- nuclear force  
 description, 154–155  
 limitations, 272–273, 282  
 sensing, 282–284  
 strong, 317, 318
- nuclear fusion, 196, 200
- nuclear physics  
 alpha decay, 273  
 beta decay, 274–275  
 Einstein and, 270  
 limitations of nuclear force,  
 272–273  
 radiating particles, 271
- nucleus, 240
- 0 •
- Oersted, Hans Christian  
 (professor), 90–92
- Olympic Academy, 132, 326
- Oppenheimer, J. Robert  
 (scientist), 195–197, 287
- Orion Nebula, 150, 200
- oscillation, electromagnetic  
 wave, 103
- p •
- pacifism, 10, 288
- Pais, Abraham (physicist), 9
- parallax, 51, 299
- particles  
 muons, 141–142, 213–214  
 Newton’s corpuscles,  
 190–192  
 radiation of nuclear,  
 271–275  
 subatomic, 14  
 superstring theory and,  
 318  
 virtual, 313, 342  
 W and Z, 317
- past, visiting, 206
- patent office, Einstein’s  
 employment in,  
 37, 38, 131, 159
- Pauli, Wolfgang (physicist),  
 9, 72
- Pauling, Linus (scientist), 288
- Peierls, Rudolf  
 (physicist), 287
- Penrose, Roger (physicist),  
 197, 203
- period, planet, 55, 56
- Perlmutter, Saul (scientist),  
 306, 307
- Pernet, Jean (professor), 32
- Pfister, Herbert  
 (scientist), 225
- philosophy  
 Einstein’s study of, 21, 326  
 goals of science, 327–328  
 scientific method and, 327  
 thinking defined, 326–327
- phone, cordless, 312
- photoelectric effect,  
 13, 42, 252–253
- photons  
 charged, 316–317  
 definition, 13, 42, 341  
 Einstein and, 40  
 electrons and, 312–313  
 energy, 249–251, 253  
 EPR experiments with, 267  
 lifetime, 309  
 photoelectric effect  
 and, 253  
 teleportation, 268
- Physical Review*  
 (journal), 202
- Physical Review Letters*  
 (journal), 206
- physics  
 Newtonian, 62–65  
 unifying, 314–318
- Physics of the Ether* (Paul  
 Drude), 32
- Planck, Max (physicist)  
 biography, 242  
 Einstein and, 42, 155, 156

- energy radiation by hot objects, 39, 241–244, 248–251
- light-quantum idea, 253
- quanta and, 39, 244
- Planck's constant, 251, 259, 264
- Planck's law, 244, 249
- planetary motion
- ancient Greeks and, 50–52
  - Babylonians and, 50
  - Copernicus and, 54
  - elliptical orbits, 55–56
  - Kepler and, 55–56
  - Newton and, 64–65
  - periods, 55, 56
- Plato (philosopher), 326
- Pluto, 145
- Podolsky, Boris (scientist), 265
- Poincaré, Jules Henri (scientist), 120–121, 174
- polarization, 267
- polonium, 271
- Polytechnic
- admissions test, 24
  - Einstein's 1912 return to, 173–174
  - final exams, 35
  - intermediate exams, 28
  - senior thesis, 34
- Popular Books on Natural Science* (Aaron Bernstein), 21
- Preskill, John (scientist), 204
- pressure, 304, 307
- Priestley, Joseph (scientist), 85–86
- Princeton University, 170
- Principia* (Isaac Newton), 118, 165
- principle of covariance, 176
- principle of equivalence, 169, 171–173, 175
- prism, 104–106, 256
- Privatdozent, 157, 158, 242
- probability, waves of, 260
- Proceedings of the Prussian Academy of Science* (journal), 189
- protons
- alpha particle, 273
  - beta decay and, 274
  - charge, 241
  - definition, 341
  - mass, 241
  - nuclear force and, 154–156, 272
- protostars, 200
- Proxima (star), 145
- Prussian Academy of Sciences, 253, 289, 327
- Ptolemy, Claudius (Greek astronomer)
- geocentric model and, 50, 51–52
  - The Mathematical Collection*, 52
- pulsar, 198, 341
- Pythagoras (Greek mathematician/scientist), 50, 57
- Pythagorean theorem, 22
- *Q* •
- quanta
- definition, 13, 341
  - Max Planck and, 39, 244, 248
- quantum electrodynamics (QED), 311, 313
- quantum field theory, 311
- quantum mechanics, and zero point energy, 75
- quantum physics, 154, 274, 311, 325
- quantum theory
- acceptance of, 253
  - Bose-Einstein condensate, 255
  - Bose-Einstein statistics, 254
  - description, 13–14
  - determinism and, 325
- Einstein and, 41–42, 247–249, 251–254, 264–267
- light-quanta, 248–251, 253
- photoelectric effect, 252–253
- Planck's constant, 251, 259, 264
- uncertainty principle, 260–267
- wave mechanics, 259–260
- quasar, 198, 341
- Queen Mary College, 318
- *R* •
- radar, Doppler, 183
- radiation
- energy radiation by hot objects, 39, 241–244, 248–251
  - Hawking, 204
  - mass and, 152
  - stimulating emission of, 16
  - thermal, 242–244
  - x-ray, 236
- radio
- emissions from pulsars and quasars, 198
  - invention of, 102
  - radio telescope, 146
  - radioactive decay, 152
  - radioactivity
    - definition, 341
    - discovery of, 236, 271, 338  - radium, 238, 271
  - reality, meaning of, 325
  - receiver, radio, 102
  - red giant, 200, 341
  - Reduced Gravity Research program (NASA), 167
- reference frame
- description, 116, 341
  - muon movement and, 141
  - simultaneity and, 136–137
  - uniform motion and, 118, 129
- refraction, 60

- Reichley, Paul (scientist), 218, 219
- Reiser, Anton (*Albert Einstein, A Biographical Portrait*), 336
- relative motion, 129–130
- relativistic time, 214–215
- relativity. *See also* general theory of relativity; special theory of relativity
- Einstein's papers on, 41, 43, 126, 129
- electromagnetism and, 126–130
- extended principle, Einstein's, 129
- Galileo and, 113–118
- Lorentz-FitzGerald contraction, 120
- Poincaré and, 120–121
- of space and time, 131
- relativity, testing
- description, 212–213
- GPS receivers, 220–221
- Gravity Probe A* mission, 216–217, 226
- Gravity Probe B* mission, 211, 226–228
- light time-delay effect, 217–219
- by NASA, 211, 216–217, 226–228
- religion
- classes, 22, 322, 323
- cosmic, 324
- determinism and, 324, 325
- Einstein's definition of being religious, 322–323
- Einstein's idea of God, 324
- Judaism, 22, 322
- origin of, 324
- reconciling science with, 323
- Remember icon, 4
- resistance, inertia as, 148–150, 170
- rest, uniform motion equivalence to, 116, 118
- reversibility, 77
- Riemann, Behrhard (mathematician), 174
- Riemannian geometry, 174
- Riess, Adam (scientist), 307
- Roemer, Olaus (astronomer), 98–99
- Roentgen, Wilhelm (scientist), 236
- Roosevelt, Franklin Delano (President), 10, 270, 286–287
- Rosen, Nathan (scientist), 207, 265
- rotation, relative nature of, 224
- Royal Society of London, 150, 191
- Rubbia, Carlo (physicist), 317
- Rubin, Vera (scientist), 305
- Ruess, Ferdinand (teacher), 21
- Rutherford, Ernest (scientist), 237–241, 271
- S •
- Sachs, Alexander (banker), 286–287
- Sagan, Carl (astronomer), 207
- sailing, Einstein's love of, 9–10
- Salam, Abdus (physicist), 316, 317
- Sandage, Allan (astronomer), 197
- satellite, launching, 165–166
- Saturn, rings of, 150
- scale, 156
- scanning tunneling microscope, 232–233
- Schiff, Leonard (physicist), 222, 226–227
- Schmidt, Brian (scientist), 306, 307
- Schrödinger, Erwin, 259–260
- Schwartz, John (physicist), 318
- Schwarzschild geometry, 189, 192
- Schwarzschild, Karl (astro-physicist), 189, 192
- Schwarzschild radius, 192–194, 340, 341
- Schwarzschild singularities, 194
- Schwinger, Julian (physicist), 311
- science
- goals of, 327–328
- reconciling religion with, 323
- scientific method
- Einstein and, 327
- Galileo and, 59
- second law of thermodynamics, 70, 72–74
- Shapiro, Irwin (physicist), 218–219
- shortening of space, 139–141
- shrinkage of objects in motion, 120
- silk, transfer of electrons to, 83–84
- simultaneity, 136–137
- singularity, 203, 342
- Slipher, Vesto (astronomer), 298
- Small Magellanic Cloud, 299, 300
- Snyder, Hartland (physicist), 196
- solar eclipse, 178–179
- solar wind, 199
- Solovine, Maurice (friend of Einstein), 132, 156

- Sommerfeld, Arnold  
(physicist), 174
- sound, as wave, 107
- space  
change with movement,  
133, 139  
electric field, 86–88  
electromagnetic wave  
movement through, 96  
empty, 130, 307  
flat, 309–311  
general theory of relativity  
and, 15  
relative nature of,  
131, 140–141  
shortening, 139–141  
special theory of relativity  
and, 11–12  
warping of, 15
- Space Shuttle, 148–149, 212
- Space Telescope Science  
Institute (NASA), 307
- spacetime  
absolute, 224  
curved, 177–178, 180, 197,  
222–228, 294  
description, 12, 145, 342  
drag, 222–225  
Einstein-Rosen bridge, 207  
five-dimensional, 314–315  
four-dimensional, 174–175  
geometry of, 187–189  
gravitational field and, 88  
inside black holes, 203  
mathematical origins  
of, 144  
singularity, 203  
in two dimensions, 177  
warping of, 177, 180,  
188–189
- sparks, 101
- special theory of relativity.  
*See also* relativity  
acceleration and, 143–144  
description, 11–12  
development of, 126–134
- Einstein's thought  
experiments, 26  
limitations of, 163–164, 173  
predictions, 213  
seeing the past, 206  
uniform motion and,  
163–164
- special theory of relativity,  
implications of  
dilating time, 137–138, 140,  
214–215, 217
- Global Positioning Satellite  
(GPS) receivers, 220
- inertial mass and, 150
- interstellar travel, 145–146
- mixing space and time,  
144–145
- simultaneity, 136–137
- space shortening, 139–141
- spectrum, 104, 256–257, 342
- speed of light  
Einstein and, 130  
 $E=mc^2$  equation and,  
44, 150, 153  
in ether, 125  
examples, 100
- Galileo's experiments, 98
- integrating laws of motion  
with, 119
- Michelson-Morley  
experiment, 119, 124–126
- Roemer's experiments,  
98–99
- special theory of relativity  
and, 11–12
- tests of, 217
- Spinoza, Benedict de  
(philosopher), 326
- standard candle, 306–307
- Stanford University, 222, 226
- Star Trek*, 268
- Stark, Johannes (editor),  
163
- The Starry Messenger* (Galileo  
Galilei), 60
- stars  
binary system, 306  
birth of, 200  
black dwarf, 200  
brightness, 300, 306–307  
Cepheid, 300  
collapsing, 195–196  
critical size, 191, 192  
dark, 191–192  
distances, 299–300  
escape velocity, 190–192  
geometry of spacetime  
around, 189  
interstellar travel, 145–146  
island universes, 299  
neutron, 195–196, 198, 200,  
208, 341  
parallax, 51, 299  
protostars, 200  
red giant, 200, 341  
supernova, 195, 200,  
306–307  
variable, 299  
white dwarf, 195, 200, 342  
wind from, 199
- stationary orbits, 245–246
- statistical mechanics,  
69, 77–79
- strong nuclear force, 317, 318
- subatomic particles, 14
- sugar molecules, size of,  
44–45
- sun  
changes in spacetime  
geometry by, 177, 179  
eclipse, 178–179  
energy of, 71  
escape velocity, 190  
life of, 200  
light time-delay effect and,  
218–219  
warping of spacetime by,  
177, 180, 188
- superatoms, 255
- superconductor, 227–228
- supernova, 195, 200, 306–307

- Supernova Cosmology Project, 306
- superstring theory, 318, 342
- surface tension, 278–279
- Swiss citizenship, 24
- symmetric operation, 316
- The System of the World* (Pierre Simon de Laplace), 191
- Szilard, Leo (physicist), 270, 286–288
- T •
- Talmud, Max (medical student), 21, 326
- Talmud, Bernard (physician), 23
- Tanner, Hans (student of Einstein), 159
- Technical Stuff icon, 4
- teleportation, 268
- telescope
- European Southern Observatory Very Large Telescope, 145
  - Galileo and, 60
  - Hubble Space Telescope, 16, 148
  - Mt. Palomar, 197
  - x-ray, 199
- Teller, Edward (physicist), 287
- temperature
- absolute zero, 70, 74–75
  - Cosmic Microwave Background (CMB), 309
  - speed of molecules and, 70, 74, 234
  - thermal equilibrium, 70, 75
- theoretical physicist, 9, 66
- theory of colors, Newton's, 62, 104–106
- theory of fluxions, Newton's, 65
- theory of metals, Drude's, 233
- thermal energy, 249, 250
- thermal equilibrium, 70, 75
- thermal radiation, 242–244
- thermocouples, 34
- thermodynamics
- definition, 70, 342
  - first law, 70–72
  - relationship to statistical mechanics, 77–78
  - second law, 70, 72–74
  - third law, 70, 74–75
  - zeroth law, 70, 75
- thermonuclear bomb, 285
- thinking, Einstein's definition of, 326
- third law of thermodynamics, 70, 74–75
- Thirring, Hans (physicist), 222
- Thomson, J.J. (physicist), 236–237
- Thomson, William (Lord Kelvin) (physicist), 74
- Thorne, Kip (scientist)
- black holes, 201, 204
  - Black Holes and Time Warps*, 201
  - time travel, 206–209
- thought experiment
- on accelerated motion, 168–169
  - on curved space, 292–293
  - on dilating time, 137–138
  - Einstein and, 26, 168–171
  - EPR problem, 265–266
  - Galileo Galilei, 59–61, 115
  - on gravitational and inertial mass, 170–171
  - on simultaneity, 136–137
  - on space changes with movement, 139
- time
- arrow, 70, 76–78
  - change with movement, 133, 137–138, 139–140
  - curved, 296
  - dilating, 137–138, 140, 194, 214–215, 217
  - elasticity of, 121
  - flow, direction of, 72–74
  - general theory of relativity and, 181–185
  - gravity effect on, 184, 194, 208
  - interstellar travel, 145–146
  - relative nature of, 131, 139, 141
  - simultaneity, 136–137
  - slowing of, 194, 208, 214–217
  - special theory of relativity and, 11–12
  - standing still, 145, 149
  - statistical mechanics and, 77
  - time travel, 78, 205–210
  - timeline, Einstein's life, 343–347
- Tip icon, 4
- Titan (moon of Saturn), 150
- Tomonaga, Sin-Itiro (physicist), 311
- torsion balance, Coulombs', 87
- Townes, Charles (inventor), 16
- trains, 116, 117
- transmitter, radio, 102
- transuranic elements, 276
- Trinity College (Cambridge, England), 61
- Trinity College (Dublin, Ireland), 120
- tritium, 285
- Turner, Michael (scientist), 309
- The Two New Sciences* (Galileo Galilei), 57, 115
- Tycho (astronomer), 54–55
- U •
- Uhuru (satellite), 199
- ultraviolet catastrophe, 38–39, 243
- unbalanced force, 62

- uncertainty principle, 13–14, 260–267, 313  
 unification of physics, 314–318  
 unified field theory, Einstein's, 315, 317  
 uniform motion  
   definition, 342  
   relativity and, 143, 163–164  
   rest equivalence to, 116, 118  
 universe  
   closed, 297, 310  
   curvature, 292–293  
   de Sitter's model of, 296  
   edge, 290–292  
   Einstein's model of, 16, 290–297, 303–305  
   empty, 296  
   expanding, 16, 296–301, 305–308  
   flat, 297, 309–311  
   island, 299  
   laws of physics, unchanging nature of, 129  
   Newton's model of, 67, 118, 289–290, 304  
   open, 297, 310  
   static, 295, 304  
   structure of, 298  
   two-dimensional, 291–293  
 University of Berlin, 9, 158, 242, 277, 333  
 University of Bern, 132, 157, 158, 331  
 University of California, Berkeley, 195  
 University of Chicago, 282, 284, 288, 309  
 University of Colorado, 255  
 University of Dacca, 254  
 University of Geneva, 160, 338  
 University of Göttingen, 196, 255  
 University of Heidelberg, 30  
 University of Leyden, 120, 173  
 University of Michigan, 206, 268  
 University of Munich, 242, 243, 255  
 University of Paris, 254  
 University of Pisa, 56, 57  
 University of Prague, 159  
 University of Texas, 197  
 University of Utrecht, 173  
 University of Vienna, 173  
 University of Washington, 312  
 University of Zurich, 41, 45, 157–160, 173, 233  
 uranium  
   critical mass, 284–285  
   Curie experiments with, 236  
   neutron bombardment of, 276  
   splitting, 276–278, 282  
   x-rays and, 271  
 Uranus, orbit of, 82  
 Urey, Harold (scientist), 288  
 U.S. Federal Aviation Administration, 221  
 U.S. Naval Observatory, 214
- *V* •
- van der Meer, Simon (physicist), 317  
 variable stars, 299  
 Veneziano, Gabriele (scientist), 318  
 Vessot, Robert (scientist), 216–217  
*Viking* missions (NASA), 219  
 virtual particle, 313, 342  
 viscosity, 44–45  
 voltage, 101–102  
 von Eötvös, Baron Roland (scientist), 170  
 von Helmholtz, Hermann (physicist), 32, 242  
 von Jolly, Philipp (professor), 242
- Vulcan (proposed planet), 180
- *W* •
- W particle, 317  
 WAAS (wide-area augmentation system), 221  
 warping of spacetime, 177, 180, 188–189  
 Washington University, 214  
 wave  
   definition, 342  
   light as, 108–110  
   properties of, 107  
   sound, 107  
 wave mechanics, 259–260  
 wavelength, 103–104, 108–109, 248–251, 342  
 waves of probability, 260  
 Weber, Heinrich (physics professor), 24, 27, 31–32, 34–35, 123  
 weight, 71, 147–148  
 weightlessness, 164–167  
 Weinberg, Steven (physicist), 316, 317  
 Weisskopf, Victor (physicist), 288  
 Weyl, Hermann (mathematician), 305, 314  
 Wheeler, John (physicist), 202  
 white dwarf, 195, 200, 342  
 white light, 106  
 wide-area augmentation system (WAAS), 221  
 Wieman, Carl E. (scientist), 255  
 Wigner, Eugene (physicist), 286  
 Wilkinson Microwave Anisotropy Probe (WMAP), 309–311  
 wind, ether, 125  
 Winteler, Anna (friend of Einstein), 25

Winteler, Jost (teacher), 25  
Winteler, Marie (first love of Einstein), 25, 28, 31, 338  
Winteler, Paul (brother-in-law of Einstein), 25, 331  
Winteler, Pauline (friend of Einstein), 25  
Witelson, Sandra (pathologist), 7  
WMAP (Wilkinson Microwave Anisotropy Probe), 309–311  
work, energy and, 70, 147

worm hole, 207, 342



x-ray telescope, 146, 199  
x-rays, 103, 236, 271



Yang, C.N. (physicist), 316  
Young, Thomas (scientist), 39, 71, 108–110, 192, 260–261

Yurtsever, Ulvi (scientist), 206



Z particle, 317  
Zel'dovich, Yakov (physicist), 199, 203–204, 313  
zero point energy, 75  
zeroth law of thermodynamics, 70, 75  
Zwicky, Fritz (astronomer), 195, 305