

Index

Page numbers in *italics* refer to illustrations.

- accelerators
 - Cockcroft and Walton's
 - research and, 93–95
 - Cockcroft-Walton generator and, 80–82, *81*
 - Cockcroft's attempt to break nuclear targets and, *77*
 - complex realm of particles on, 115
 - definition of, 13–14
 - early experiments with, 75–98
 - at Fermilab, 128, 131
 - Gamow's quantum tunneling formula and, 78
 - Ising's prototype of, 79–80
 - Lawrence's cyclotron and, 90–92, *91*, 93, 95, 108, 117, 118
 - lightning strikes as, 85–86
 - Powell's construction of, 106–7
 - recycling of, 164, 167
 - Superconducting Super Collider (SSC) and, 156–57
 - Van de Graaff's work with, 83–85, 90
 - Wideröe's design of, 128–29
 - Wideröe's ray transformer and, 78–79, 86, 89
- ADD model, 202–4, 205
- Adelberger, Eric, 204
- ADM formulation, 114
- air (element), 24
- Akeley, Lewis, 87
- ALICE (A Large Ion Collider Experiment) detector, 5, 19, 168, 174, 175–76
- alpha particles, 58–60, 62–66, 68, 72, 78
- Alpher, Ralph, 109
- Alternate Gradient Synchrotron (AGS), 121
- Ampère, André-Marie, 31
- ancient Greece, 24, 29
- Anderson, Carl, 93, 105
- Andromeda galaxy, 181–82
- angular momentum, 67
- anthropic principle, 196–97

- antigravity, 189
- antimatter, 13, 15, 42, 73
- antineutrinos, 102
- antiprotons, 137, 142, 227
- antiquarks, 14, 137, 142
- Antoniadas, Ignatius, 202
- Aref'eva, Irina, 222, 223
- argon, in particle detectors, 169
- Aristotle, 24
- Arkani-Hamed, Nima, 202, 220
- Arnowitz, Richard, 114
- Ashcroft, Neil, 159
- astronomy, 178, 180
- ATLAS (A Toroidal LHC ApparatuS) detector, 1–5, 18–19, 168, 169–70, 171, 171, 172, 174, 176–77, 206, 215, 216, 229
- atomic bomb, development of, 100
- atomic number, 65–66
- atomism, 24–25, 28–30
- atoms
 - ancient Greek concepts of, 24, 30
 - Dalton's work with, 25, 58
 - electrostatic force and, 29
 - first use of term, in modern sense, 25
 - Lawrence's time interval measurements involving, 88, 89
 - nucleus of, 65–66
 - radioactive processes and, 58
 - relative weights of, 25
 - solar system comparison with, 27
 - Thomson's "plum pudding" model of, 61, 62, 65
- attractive forces, 28
- axions, 186
- Bardeen, John, 44
- Barish, Barry, 158, 169, 230
- baryons, 103, 137
- Beams, Jesse, 88
- Becquerel, Henri, 58
- Bednorz, Johannes, 158
- Bekenstein, Jacob, 213–14
- Benford, Gregory, 222
- Berkeley Radiation Laboratory ("Rad Lab"), 92, 118–19, 187
- beta decay, 93, 101–103, 112, 113
- beta particles, 58, 61
- Bethe, Hans, 108, 109
- Bevatron, 120
- Big Bang conditions
 - dark energy scenarios and, 188
 - general theory of relativity on, 37–38
 - measurement of background radiation left over from, 38
 - particle detectors to reproduce conditions of, 13, 19, 22, 39, 42
- Big Bang theory, 38, 109, 110–11
- Big Crunch, 188
- Big Rip, 189
- Big Whimper, 188
- blackbodies, 35
- Blackett, Patrick, 73, 96
- black holes
- Bekenstein's theory on expansion of, 213–14
 - first use of term, 213
- Large Hadron Collider (LHC)
 - research and creation of, 20–21, 22
- MACHOs (Massive Compact Halo Objects) and, 184
- microscopic, 216, 220–21
- physics of, 212
- public concern over, 212

- Blewett, John, 120
- Bohr, Niels, 66–68, 72, 96, 98, 99–100, 115, 121
- Born, Max, 69
- bosons, 103
- asymmetry involving fermions and, 12
 - beginning of the universe and, 42
 - as category of elementary particles, 44
 - exchange particles and, 102
 - intermediate vector bosons, 131
 - Standard Model prediction of, 121
 - string theory and, 49
 - supersymmetry for uniting fermions and, 139–40
 - Yukawa's electromagnetic research and, 104–5
- bottom quarks, 14, 19, 130, 136, 141
- Boyle, Robert, 24–25, 29
- Boyle's Law, 25
- braneworld hypothesis, 192–93, 199
- Brasch, Arno, 85
- Breit, Gregory, 90
- bremstrahlung, 127
- Brin, David, 218
- Brobeck, William, 120
- Brout, Robert, 45
- brown dwarfs, 183–84
- bubble chambers, Fermilab, 125–26, 126, 128, 133
- Burstein, David, 183
- Bush, George Herbert Walker, 153, 155
- Calabi, Eugenio, 201
- Calabi-Yau spaces, 201
- Caldwell, Robert, 189
- calibration, 144
- calorimeters, 18, 126, 127–28, 143, 144, 169, 170–71, 172
- carbon, 108, 109
- Carter, Brandon, 196
- cathode rays, 57
- Cavendish, Henry, 54–55
- Cavendish Laboratory, Cambridge
- Chadwick's research on neutrons at, 73–74, 92–93, 97
 - Cockcroft and Walton's splitting of a lithium nucleus at, 93–95
 - Cockcroft-Walton generator at, 74, 80–82, 81
 - cyclotron proposal for, 97
 - description of, 54–55
 - Gamow's research at, 75, 76–77
 - Rutherford as director of, 55–56, 72, 74, 82, 96, 97, 98, 106
 - Thomson as director of, 55, 56, 66, 72
 - Walton's linear accelerator at, 80–82
- CDF (Collider Detector at Fermilab) Collaboration, 143–44, 144–45
- Central Design Group (CDG), 150
- Central Tracking Chamber, Tevatron, 143
- CERN (European Organization for Nuclear Research)
- description of, 1, 5–6
 - founding of, 219
 - funding of, 17
 - hardware knowledge of researchers at, 228

- CERN (*Continued*)
 location of, 1, 5, 22, 121
 public fears of work of, 220–22
- Chadwick, James, 73–75, 92–93, 96, 97
- Charge-Parity (CP) violation, 175
- charginos, 186
- charm quarks, 14, 130
- Cherenkov, Pavel, 127
- Cherenkov detectors, 126, 127, 144
- Chu, Paul, 158
- Citizens Against Large Hadron Collider, 217
- Cline, David, 132, 134
- Clinton, Bill, 16, 160
- closed strings, 202
- closed timeline curves (CTCs), 222
- cloud chambers, 73, 106, 143
- CMS (Composer Muon Solenoid) detector, 5, 19, 168, 172, 173, 174, 206, 216, 229
- COBE (Cosmic Background Explorer) satellite, 110, 195
- Cockcroft, John Douglas, 77, 80–82, 91, 93–95, 96
- cold dark matter, 186
- Collider Detector at Fermilab (CDF) Collaboration, 143–44, 144–45
- Coma Cluster, 180
- Collins, C. B., 195–97
- Congress, and Superconducting Super Collider (SSC), 16–17, 152, 153, 154, 156, 159, 160
- conservation of parity, 113
- Cooper, Leon, 44
- Cooper pairs, 44
- corpuscles (small particles), 24–25, 28–29, 57, 61. *See also* electrons
- Cosmic Background Explorer satellite, 187
- cosmic rays, 221
- cosmological constant, 37–38, 189
- Cosmotron, 120–21
- Coulomb, Charles-Augustin de, 29, 31
- Coulomb's law, 31
- Courant, Ernest, 120, 121
- Cowan, Clyde, 112
- CP (Charge-Parity) violation, 175
- Cronin, James, 175
- cryostats, 170
- Curie, Marie, 58, 83, 96
- Curie, Pierre, 58
- D0 Collaboration, Tevatron, 144
- Dai, J., 201
- Dalton, John, 25–26, 58
- dark energy
 definition of, 180, 189
 gravitational theories on, 190–91
 interest in mystery of, 178, 186–87
 Large Hadron Collider (LHC) and, 179–80, 186, 190
 Supernova Cosmology Project (SCP) on, 187–88
- dark matter, 179–86
 axions and, 186
 cold dark matter and, 186
 definition of, 179–80
 gravitational theories on, 190–91
 hot dark matter and, 185–86
 interest in mystery of, 52, 178, 180–81
 Large Hadron Collider (LHC) and, 190
 MACHOs (Massive Compact Halo Objects) and, 183–85, 186

- WIMPs (Weakly Interacting Massive Particles) and, 185, 186
- Dave, Rahul, 189
- de Broglie, Louis, 70, 96
- deceleration of the universe, 188
- decupole magnets, 167
- Democritus, 24, 30
- Denegri, Daniel, 138
- Department of Energy (DOE), 149–50, 151, 152, 153, 154, 155, 159, 217
- Deser, Stanley, 114
- deuterons, 95
- deuterium, 60–61, 92, 108
- DeWitt, Bryce, 13, 194, 197
- Dicke, Robert, 110
- Dimopoulos, Savas, 50–51, 202, 215, 216
- dipole magnets, 167
- Dirac, Paul, 72, 96, 199, 218
- Dirichlet brane (D-brane), 201–2
- Displacement Law, 61
- Doppler shifts, 182, 187
- down quarks, 14, 130
- drift chambers, 126, 128
- dualities, 200
- duality of dualities, 200–201
- Duff, Michael, 199–200
- Duffield, Priscilla, 124
- Dvali, Gia, 202
- Dyson, Freeman, 111
- earth (element), 24
- Edlefsen, Niels, 91–92
- Einstein, Albert
 - cosmological constant theory of, 37–38, 189
 - on electron “spin-down,” 71
 - equivalence of energy and mass equation of, 10, 14, 82, 95
 - equivalence principle and, 36–37
 - general theory of relativity of, 11–12, 37, 190, 194, 212
 - Heisenberg’s matrix mechanics and, 68
 - photoelectric effect and, 36, 66, 88
 - quantum mechanics and, 72
 - Rutherford compared to, 62
 - special theory of relativity of, 34, 36, 46
 - speed of light research by, 34
 - Szilard’s letter to Roosevelt signed by, 100
 - unification model sought by, 42–43, 49, 99–100
- electromagnetic calorimeters, 4, 127, 143, 170–71, 172
- electromagnetic interaction, 29, 111
- electromagnetic radiation, 32–34
- electromagnetic waves, 31, 32
- electromagnetism, 8–9, 12, 30–32, 42–43, 47, 54, 104–5
- electron-positron colliders, 129–30, 230
- electron synchrotrons, 119–20
- electrostatic force, 29–30, 31
- electroweak unification. *See* Standard Model
- element-building models, 185
- elements
 - ancient Greek concepts of, 24
 - atomist views of, 24–25
 - Boyle’s use of term, 24
 - Dalton’s work with, 25, 58
 - Mendeleev’s listing of, in table form, 26

- elements (*Continued*)
 predicting discovery of new
 elements, 26
 theories on production of, 109
 Empedocles, 24, 190
 “Energy Production in Stars”
 (Bethe), 108
 Engler, François, 45
 equivalence principle, 36–37
 ether hypothesis, 33–34
Eureka (Poe), 8
 European Organization for
 Nuclear Research. *See*
 CERN
 Evans, Lyn, 17–18, 19, 21
 Eve, Arthur, 61
 Everett, Hugh, 193–94
 Everett, Kenneth, 122–23
 exchange particles, 9, 102, 137
 exclusion principle (Pauli),
 44, 71

 false vacuum, 10
 Faraday, Michael, 30, 78
 Fermi, Enrico, 100–3, 112, 113,
 210
 Fermi National Accelerator
 Laboratory (Fermilab),
 123
 accelerators at, 128, 131, 134
 detector design at, 169
 establishment of, 108, 122
 future of, 226–27
 HPWF collaboration to find
 the W boson at, 132
 Wilson’s design of, 122–25
 Wilson’s directorship at, 134,
 141
 fermions, 102, 103
 asymmetry involving
 bosons and, 12
 beginning of the
 universe and, 42
 as category of elementary
 particles, 44
 neural current events
 involving, 133
 string theory and, 49
 superpartners to, 140
 supersymmetry for uniting
 bosons and, 139–40
 Fermi weak coupling constant,
 102–3
 Feynman, Richard, 50, 111–12,
 115, 193
 Feynman diagrams, 112, 113
 fire (element), 24, 32
 Fitch, Val, 175
 fixed-target accelerators, 128–20
 Ford, Kent, 181–83
 Franklin, Benjamin, 29
 Friedman, Alexander, 38
 Frisch, Otto, 100
 Fry, Jack, 133–34

 galactic recession, law of, 187
 galactic rotation curve, 182
 gamma decay, 74
 gamma radiation, 33, 58
 Gammas, Electrons, and Muons
 (GEM) group, 158, 230
 Gamow, George, 75–77, 78,
 96, 109, 181
 Geiger, Hans, 63–65, 74
 Geiger counter, 63
 GEM (Gammas, Electrons, and
 Muons) group, 158
 General Dynamics, 157
 general theory of relativity,
 11–12, 37, 190, 194, 212
 Georgi, Howard, 50–51
 Glashow, Sheldon, 9, 47,
 50, 131
 gluinos, 140, 186
 gluons, 14, 103, 140
 “God particle.” *See* Higgs boson

- gold-foil experiments in
 - radiation, 52, 64–65
- Goldhaber, Gerson, 187
- Goldhaber, Maurice, 187–88
- Goudsmit, Samuel, 71
- Grand Unified Theories (GUTs),
 - 139, 149, 218–19, 221
- gravitons, 103, 199, 202, 215
- gravitational microlensing, 184
- gravity (gravitation)
 - ADD model and, 202–3
 - deceleration of the universe
 - and, 188
 - Einstein’s equivalence principle
 - on, 36–37
 - galaxies held together
 - by, 180
 - hierarchy problem linking
 - other forces to, 114
 - microscopic black holes
 - and, 216
 - natural interactions involving,
 - 9, 12
 - Newton’s research on,
 - 28, 29, 36
 - quantum theory applied to,
 - 114–15
 - string theory on, 49
 - supersymmetry research on
 - differences between other
 - interactions and, 13, 49
- Gray, Julia, 219
- Greece, ancient, 24, 29
- Green, G. Kenneth, 120
- Green, Michael, 50
- Grid global computing network,
 - 4–5, 19, 228
- Guralnik, Gerald, 45
- Guth, Alan, 197–98

- hadron colliders, 130
- hadronic calorimeter, 4,
 - 127–28, 143
- hadrons, 14, 103, 105, 127–28,
 - 133, 164, 172
- Hafstad, Lawrence, 90
- Hagen, C. Richard, 45
- Hahn, Otto, 100
- Haidt, Dieter, 133–34
- Hawking, Stephen, 195–97,
 - 213–14, 220
- Hawking radiation, 21, 216
- heavy hydrogen, 60
- Heisenberg, Werner, 68–69,
 - 70–71, 72, 96, 115
- helium, 60, 66, 108, 109
- hermeticity, 136
- Hernandez, Paul, 125
- Herschel, William, 32
- Hertz, Heinrich, 33, 54
- hierarchy problem, 114, 202
- Higgs, Peter, 10, 21, 45–47
- Higgs boson, 103
 - CERN particle detector
 - research on, 15, 19, 48
 - description of, 10–11
 - Higgs’s work with, 3, 10–11,
 - 45–47
 - Large Hadron Collider (LHC)
 - search for, 48, 162,
 - 173–74, 178, 226
 - lepton collider in search
 - for, 141
 - nickname of “God
 - particle” for, 11, 46
 - original reception to first
 - publication of research by
 - Higgs on, 46–47
 - possibility of multiple Higgs
 - particles, 19–20, 48
 - Standard Model prediction of,
 - 131–32, 139, 140,
 - 149, 226
- Higgs field. *See* Higgs boson
- Higgs mechanism, 45–47
- Higgs particle. *See* Higgs boson

- high-temperature superconductivity, 158
 Hoddeson, Lillian, 148
 hot dark matter, 185–86
 Hoyle, Fred, 109, 110
 Hubble, Edwin, 38, 109, 180, 182, 187
 Hughes, James, 199
 hydrogen, 66, 108, 126, 179, 227

 IBM, 158
 induction, 30, 78
 inflation, 198
 infrared radiation, 32
 inner detector, 169
 Interacting Storage Rings (ISR), 130
 intermediate vector bosons, 131
 International Linear Collider (ILC), 229–31
 inverse-square laws, 27
 ionization, for tracking charged particles, 143
 ISABELLE collider, 139, 148, 169
 Ising, Gustav, 79–80, 82, 83
 isotopes, 60–61, 115

 Jackson, J. David, 124
 Joliot-Curie, Irene and Frédéric, 96
 J/psi particle, 130, 187

 Kahn, Herman, 211
 Kaluza, Theodor, 206
 Kaluza-Klein excitation, 206, 207
 kaons, 103, 113
 Kasper, Raphael, 160
 Kepler, Johannes, 182
 Kerst, Donald, 129
 Kibble, Tom, 45
 Kirschner, Robert, 186

 Klein, Oskar, 50, 201, 206
 Kolb, Adrienne W., 148

 Landsberg, Greg, 215, 216
 Lange, Fritz, 85
 Large Electron Positron Collider (LEP), 16, 140–41, 149–50, 164, 167
 large extra dimension, 201, 203
 Large Hadron Collider (LHC), 163–78
 American researchers at, 16
 antiprotons and, 227
 black hole research and, 215–16
 braneworld hypothesis and, 192–93
 CERN and, 163–64
 completion of, 15, 17
 damage from helium leak in, 17–18
 dark energy and, 190
 dark matter and, 179–80, 186, 190
 decision to build, 164–65
 description of, 2, 18
 detectors in, 168–69, 174–75
 electricity in region drained by, 166–67
 funding of, 17, 152, 165
 future uses of high-end physics and findings of, 225–26, 232
 Higgs particle research using, 19–20, 162, 173–74, 178
 law suits to halt operations of, 21–22, 217–19
 limitations of, 177
 location of, 15–16, 22, 165–66
 magnets in, 17, 18, 44, 164, 167, 168, 170, 171, 171, 176–77
 research on origins of the universe and conditions in, 19, 22, 39, 42

- string theory and research
 - at, 52
- tunnel design in, 167–69
- undercurrent of fear about
 - potentially dangerous events from operations at, 20–22
- Large Magellanic Cloud, 184
- Lattes, César, 107
- law of galactic recession, 187
- law of multiple proportions, 25
- Lawrence, Ernest Orlando,
 - 86–92, 95–98, 232
 - atomic process time interval measurements of, 88, 89
 - cyclotron of, 90–92, 91, 93, 95, 108, 117, 118
 - family background of, 86–87
 - University of California, Berkeley, research of, 88–89, 92, 97–98, 119, 120
- Lawrence Berkeley National Laboratory, 92, 150, 186, 187
- lead ions, in particle detectors, 19
- Lederman, Leon, 136, 141, 142, 148, 149, 151, 154, 162
- Lee, Tsung Dao, 113–14, 175
- Leibniz, Gottfried, 191–92, 193
- Leigh, R. G., 201
- Lemaitre, Georges, 109
- length contraction, 34
- lepton colliders, 141
- leptons, 14, 42, 102, 103, 105, 128, 130, 144, 202
- Leucippus, 24
- LHC. *See* Large Hadron Collider
- LHCb (Large Hadron Collider beauty) particle detector, 5, 19, 169, 174
- LHCf (Large Hadron Collider forward) detector, 174, 176
- light
 - Einstein’s research on, 34, 35, 36
 - electric charges and, 32
 - invisible region of, 32
 - rainbow of colors of, 32
 - speed of, 34, 35, 36
 - wavelength measurement of, 32
- lightning strikes, as accelerators, 85–86
- Linde, Andrei, 198
- lithium, 80, 93, 95, 109
- Liu, Jun, 199
- Livingston, M. (Milton) Stanley, 93, 120
- lodestone, 29
- Lofgren, Edward, 120
- London, Jack, 151
- MACHO Project, 184
- MACHOs (Massive Compact Halo Objects), 183–85, 186
- magnetic fields, 30, 31, 57
- magnetic monopoles, 2, 218–19
- magnetism, 29
- magnets
 - at Fermilab, 124–25
 - hadrons as, 164
 - at Large Hadron Collider (LHC), 17, 18, 44, 164, 167, 168, 170, 171, 171, 176–77
 - in Superconducting Super Collider (SSC), 150, 156, 157
 - in synchrotrons, 119–20, 120–21
- Manhattan Project, 100, 119, 124, 210–11, 219
- Mann, Alfred K., 132
- Manyfold Universe, 203

- Many World Interpretation, 194–95
 Marsden, Ernest, 63–65, 72, 74, 77
 matrix mechanics, 68, 69, 70
 Maxwell, James Clerk, 8, 30–32, 33, 34, 54, 55, 115
 May, Brian, 231
 McGill University, 59–60, 61–62, 100
 McIntyre, Peter, 134, 150
 Meitner, Lise, 100
 membrane theory, 200
 Mendeleyev, Dmitri, 26
 mesons, 103, 105, 106, 108, 113, 127, 130, 137
 Michelson, Albert, 34
 microlensing, gravitational, 184
 Milky Way, 180, 182, 184
 Minimal Supersymmetric Standard Model (MSSM), 50–51, 203
 Minkowski, Hermann, 36
 Misner, Charles, 114
 missing matter mystery, 52
 Mitchell, Maria, 181
 momentum, in atomic research, 69
 Morley, Edward, 34
 M-theory, 13, 200–201
 Müller, Karl, 158
 multiple proportions, law of, 25
 muon neutrinos, 130
 muons, 103, 105–6, 107, 112, 130
 muon system, 4, 171

 Nambu, Yoichiro, 44–45
 National Academy of Engineering, 153
 National Academy of Sciences, 153
 National Science Foundation, 217
 neutralinos, 186
 neutrinos, 103, 172, 185–86
 detection of, 4, 74, 206
 Fermi’s beta decay theory and, 101, 112
 neural current events involving, 133
 neutrons, 103
 Chadwick’s research on, 73–74, 92–93
 Fermi’s beta decay theory and, 101, 102, 112
 Lawrence’s estimate of mass of, 96
 particle detectors and, 4, 115, 127
 similar in mass to protons, 43
 neutron stars, 184
 “New Genesis” (Gamow), 109–10
 Newton, Sir Isaac, 27–30, 69, 98
New York Times, 84, 121, 139, 152–53
 Nobel Prizes, 58, 63, 72, 108, 131, 187
 nuclear fission, 99, 100
 nucleosynthesis, 185

 Occhialini, Giuseppe, 107, 108
 octupole magnets, 167
 Oddone, Pier, 141
 Oliphant, Mark, 97, 98
 O’Neill, Gerald, 129–30
 “On Physical Lines of Force” (Maxwell), 31
 Oort, Jan, 180, 181
 Oort Limit, 180
 open strings, 201–2
 Oppenheimer, J. Robert, 210–11
 Ørsted, Hans Christian, 30
 oxygen, 109

 pair production, 127
 parallel universe idea, 192
 parity, 113, 114, 175

- particle detectors
 - calibration of, 144
 - description of, 3–4
 - Grid global computing network in, 4–5, 19, 228
 - high-energy physics and, 126–28
 - particles detected in, 4
 - particles not detected in, 4
- Pauli, Wolfgang, 70–71, 74, 96, 101
- Pauli exclusion
 - principle, 44, 71
- Penzias, Arno, 110, 159
- Peoples, John, 141
- periodic table, 26, 65–66, 115
- Perl, Martin, 130
- Perlmutter, Saul, 186, 187, 188
- phase angle, 10
- phase transition, 44, 45
- photinos, 186
- photoelectric effect, 36, 66, 88
- photomultipliers, 126, 127
- photons
 - early research on, 8–9
 - as an example of a boson, 44, 47, 103
 - particle detectors and, 4
 - quantum electrodynamics (QED) on, 111, 113
 - in string theory, 202
 - superpartners of, 140
 - Yukawa’s electromagnetic research and, 104–5
- pions, 103, 108
- Planck, Max, 36, 66
- Planck length, 48
- Planck scale, 51, 203
- Planck’s constant, 36, 66, 67, 88
- Planck time, 51
- plutonium bomb, 210
- Poe, Edgar Allen, 8
- Polchinski, Joseph, 199, 201, 202
- polonium, 58
- Polychronakos, Venetios, 230
- position, in atomic research, 69
- positrons, 72–73, 93, 112, 140
- potentials, 45
- Powell, Cecil, 106–7, 108
- Price, Larry, 1–2
- Priestley, Joseph, 29
- quadrupole magnets, 167
- quanta, 36
- quantum chromodynamics (QCD), 137, 139, 186
- quantum electrodynamics (QED), 111–13, 114
- quantum gravity, 51, 114
- quantum mechanics, 11, 26, 44, 51, 69, 72, 194
- quantum theory of electromagnetic interaction, 111, 131
- quantum theory of matter and energy, 36, 44
- quantum tunneling
 - formula, 78
- quark-gluon plasma, 175
- quarks, 14, 42, 102, 103, 128, 130, 137, 140, 142, 202, 216
- quenching, 177
- quintessence, 189–90
- Rabi, Isidor I., 106, 121, 219
- radioactive decay, 58
- radioactivity
 - atomic particle research using, 58
 - Becquerel’s experiments on uranium and, 58
 - Marie Curie’s research on, 58
 - Rutherford’s research on alpha particle and, 58–59
 - radio waves, 33
 - radium, 58, 60, 63

- “Rad Lab” (Berkeley Radiation Laboratory), 92, 118–19, 187
 Ramond, Pierre, 49
 Ramsay, William, 60, 63
 Randall, Lisa, 204–5
 Randall-Sundrum model, 204–5
 ray transformer, 78–79, 86, 89
 Reagan, Ronald, 150–52
 Recycler antiproton storage ring, 227
 red dwarfs, 184
 Reference Designs Study (RDS), 149–50
 Reines, Frederick, 112
 Relativistic Heavy Ion Collider (RHIC), 220–21
 religion, and atomist views, 29
 reverse beta decay, 112
 Richter, Burton, 130
 Riess, Adam, 186
 Riordan, Michael, 155
 Ritter, Johann, 32–33
 Rochester, George, 108
 Roentgen, Wilhelm, 33, 58
 Roosevelt, Franklin D., 100
 rotation curves of galaxies, 182, 183
 Rutherford, Ernest, 54, 232
 accelerator at Cavendish and, 74, 80, 82, 83, 94
 alpha particles research of, 58–60, 62–66, 68, 72, 115
 on atomic power, 82
 as Cavendish Laboratory director, 55–56, 72, 74, 82, 94, 96, 97, 98, 106
 cyclotron proposal and, 97
 death of, 98
 Einstein compared to, 62
 family background of, 53–54, 55–56
 Gamow’s research and, 76–77, 78, 80
 lithium nucleus splitting and, 94
 at McGill University, 59–60, 61–62, 100
 proton research and, 72–73
 Rubbia, Carlo, 131, 132, 134, 135, 136, 137, 164, 174, 232
 Rubin, Vera Cooper, 181–83
 Run II (D0 experiment), 227

 Salam, Abdus, 9, 47, 131
 Sancho, Luis, 217–19
 satellites, 110, 187, 195–96
Sceptical Chemist, The (Boyle), 24
 Schmidt, Brian, 186
 Schopper, Herwig, 142
 Schrieffer, J. Robert, 44
 Schrödinger, Erwin, 70–71, 72, 96
 Schrödinger’s position, 70
 Schwarz, John, 50
 Schwarzschild, Karl, 212
 Schwarzschild radius, 214–15
 Schwarzschild solution, 212–13, 214
 Schwinger, Julian, 111, 115
 Schwitters, Roy, 155, 159
 Science and Technology Facilities Council (STFC), 231
 scintillation counters, 126, 127
 SDC (Solenoidal Detector Collaboration), 157
 Segrè, Emilio, 101
 selectrons, 140
 Seventh Solway Conference (Brussels, 1933), 95–96, 101
 sextupole magnets, 167
 Shane, Donald, 90
 signatures, 5

- Silicon Vertex Tracker, Tevatron, 143
- SLAC, 130, 169
- sleptons, 186
- Smoot, George, 187
- Soddy, Frederick, 60–61
- Solenoidal Detector
 - Collaboration (SDC), 157
- space-time, 36–37
- spark chambers, 126, 128
- SPEAR ring, 130
- special theory of relativity, 34, 36, 46
- spectral lines, 60, 66, 67
- “spin-up” and “spin-down,” 71
- squarks, 140, 186
- Stabler, Ken, 152
- stacking, 130–31
- standard candles, 187
- Standard Model
 - CERN teams researching, 132–34
 - description of electroweak unification and, 9–10, 11, 42–43
 - development of, 47
 - Higgs particle research and possible revisions to, 19–20, 47–48, 139, 226
 - Minimal Supersymmetric Standard Model (MSSM) and, 50–51
 - possible bosons predicted by, 121–22, 139, 140
 - spontaneous symmetry breaking concept and, 43–44
- standing wave, 70
- Stanford Linear Accelerator Center, 149, 187
- stars
 - energy production in, 108
 - missing matter dilemma and, 180
 - state of inertia, 27
- Steinhardt, Paul, 189
- Stern, Otto, 91
- strangelets, 20, 218, 220–21
- strange quarks, 14, 130
- Strassmann, Fritz, 100
- string theory
 - bosons in, 49
 - braneworld hypothesis and, 199–202, 215
 - particle detector research and, 17
 - supersymmetry and, 13, 49–50, 52
 - as a unification model, 48–50, 52
- strong focusing, 121
- strong force, 104
- strong interactions
 - natural interactions involving, 9, 12
 - supersymmetry research on differences between other interactions and, 13
- Sulak, Larry, 132–33
- Sundrum, Raman, 204–5
- superconducting magnets, 43–44, 150
- Superconducting Super Collider (SSC), 16–17, 147–62
 - abandoned site of, 147–48, 161–62
 - accelerators and synchrotrons in, 156–57
 - cancellation of, 160–61, 164, 226
 - federal support for, 150–52, 155
 - funding of, 155–56, 160, 229
 - location of, 153–54
 - magnets in, 150, 156, 157
 - opposition to, 158–59
 - planning and design of, 149–50
 - rationale for building, 149

- superconductivity, 42–43
- supergroups of researchers, 135–36
- Super Large Hadron Collider, 229
- Supernova Cosmology Project (SCP), 187–88
- Supernova Ia, 187
- supernovas, 187
- superpartners, 139–40
- Super Proton Synchrotron (SPS), 134, 135, 136, 137, 138, 140, 148, 164
- superstring theory, 50
- supersymmetry (SUSY)
 - gravity and, 49
 - Higgs particle research and, 12, 13, 178
 - implications for Standard Model of, 19–20, 49
 - Minimal Supersymmetric Standard Model (MSSM) and, 50–51
 - string theory and, 13, 49–50, 52
- Swann, W. F. G., 87–88
- symmetry
 - origins of the universe and clues in, 42–43
 - Standard Model and concept of breaking of, 43–44
- synchrotrons
 - early examples of, 119–21
 - fixed-target, 128–20
 - in Superconducting Super Collider (SSC), 157
- Szilard, Leo, 82–83, 100
- tau leptons, 130, 136
- tau neutrino, 130, 139
- tauons, 103
- Teller, Edward, 211
- Tesla coils, 90
- Tevatron, Fermi National Accelerator Laboratory, 14–15, 17, 118, 134–35, 141–44, 148, 149, 154, 205, 226, 227
- Texas Accelerator Center, 150
- Texas National Research Laboratory Commission (TNRLC), 153, 154
- Thomson, J. J. (Joseph John)
 - Bohr and, 66
 - at Cavendish Laboratory, 55, 56, 66, 72
 - “plum pudding” model of atoms of, 61, 62, 65
 - research on elementary particles by, 57–58, 61
- Thomson, Thomas, 25
- Thonnard, Norbert, 183
- 't Hooft, Gerard, 132
- thorium, 60
- Tigner, Maury, 149, 150, 154, 155
- time, as the fourth dimension, 36
- time dilation, 34
- time-reversal invariance, 113
- Tomonaga, Sin-Itiro, 111, 115
- top quarks, 14–15, 130, 139, 140, 141, 144–45, 226
- TOTEM (TOTAl Elastic and diffractive cross-section Measurement), 174, 176
- Townshend, Paul, 199–200
- transformers, 78–79
- Trilling, George, 157
- Trinity test, Manhattan Project, 210–11, 219
- tritium, 61
- true vacuum, 10
- Turner, Michael, 189
- Tuve, Merle, 86, 87, 90, 91, 96

- UA1 (Underground Area 1), 136, 137, 138, 142
 UA2 (Underground Area 2), 136, 137, 138, 142
 Uhlenbeck, George, 71, 108
 ultraviolet catastrophe, 35
 ultraviolet radiation, 33
 uncertainty principle, 69
 U.S. Department of Energy (DOE), 149–50, 151, 152, 153, 154, 155, 159, 217
 Universal Fermi Interaction, 112
 Universities Research Association (URA), 154–55
 up quarks, 14, 130
 upsilin, 141
 uranium, 58, 60, 99, 100
 Urban, Kurt, 85
 Urey, Harold, 92

 Van de Graaff, Robert Jemison, 83–85, 90, 91
 Van de Graaff generator, 84, 85, 90
 Van der Meer, Simon, 130–31, 135, 174
 Van Hove, Leon, 135
 velocities of galaxies, 182, 183
 Veltman, Martinus, 132, 226
 Villard, Paul, 33, 58
 void (element), 24
 Volovich, Igor, 222, 223
 Voltaire, 191–92

 W^+ and W^- bosons, 47, 103, 131, 132, 133, 134, 137–38, 140, 141
 Wagner, Walter L., 217–19, 221
 Walton, Ernest Thomas Sinton, 78, 80–82, 91, 93–95, 96
 water (element), 24
 Watkins, James, 159
 wave function collapse, 71
 wavelengths, color, 32
 wave mechanics, 70
 wave phenomena, 33, 182
 weak exchange particles, 47
 weak interaction
 Fermi's beta decay theory and, 101, 113
 Higgs particle research on, 11
 natural interactions involving, 9
 supersymmetry research on differences between other interactions and, 13
 symmetries in, 113–14
 unification of electromagnetism and, 9–10, 11, 42–43
 Weinberg, Steven, 9, 13, 47, 131, 132
 Weizmann, Chaim, 62
 Westinghouse, 157
 Wheeler, John, 99, 193, 194–95, 213
 Wideröe, Rolf, 78–80, 82, 83, 86, 89, 90, 128–29
 Wilkinson Microwave Anisotropy Project, 190, 231
 Willis, William, 158, 169
 Wilson, Charles, 73, 106
 Wilson, Robert R. (Bob), 118–25, 232
 at Berkeley Radiation Laboratory (“Rad Lab”), 118–19
 at Cornell University Laboratory for Nuclear Studies, 119, 120, 121–22
 cyclotron design and, 119
 family background of, 118
 Fermilab design of, 122–25
 Fermilab directorship of, 134, 141
 Tevatron commitment by, 134–35, 141

- Wilson, Robert W., 110
WIMPs (Weakly Interacting Massive Particles), 185, 186
winos, 140
Witherell, Michael, 141
Witten, Ed, 50, 200–201
WMAP (Wilkinson Microwave Anisotropy Probe) satellite, 110, 195–96, 198
Womersley, William John, 161
wormholes, 222
X rays, 33, 58
Yang, Chen Ning (Frank), 113–14, 175
Yau, Shing-Tung, 201
Young, Charlie, 1–2
Yukawa, Hideki, 103–6, 108, 114
Z boson, 47, 103, 131, 132, 137, 138, 140, 141
zinos, 140
Zwicky, Fritz, 180, 181