

# INDEX

## A

absolute value symbols, 37, 40, 42  
acceleration ( $a$ )  
  defined, 37, 46–47, 50–52, 66–69, 112, 225  
  downward, 25–26, 41, 79–82, 88, 90–91, 95–97, 172–173  
  gravitational, 80, 82, 94–96, 172  
  law of, 40–41, 58, 66–72, 90–93, 100, 111–116, 139–140, 146, 179  
  orientation of, 78–84, 90–92  
  three rules of, 85–86  
  uniform accelerated motion, 51, 85–86, 90, 101  
  units for measuring, 50, 92  
  using calculus to find, 99–100  
  velocity and, 50–52, 90, 225  
action and reaction, law of, 4, 15–20, 33–36, 40, 42, 43, 74, 83, 92, 93, 142, 143, 209  
  vs. equilibrium, 23–30  
  vs. law of conservation of momentum, 120–125, 146  
atoms, 143, 201  
attractive forces, 43, 201

## B

balance of forces, 21, 25–26, 39–41, 61, 87  
base units, 225  
body temperature, 157  
braking distance ( $d$ ), 180–183

## C

calculus, 55, 99–100, 101, 146, 148, 203, 205–207  
calories (cal), 161, 200, 201  
center of gravity, 42, 126

centripetal force, 205  
circular motion, 96, 205  
coefficient of friction ( $\mu$ ), 207–208  
collisions  
  coin, 210–213  
  elastic and inelastic, 143–144  
commutative law, 38  
conservation of energy, law of, 155–156, 163, 171–174, 189, 190, 196, 202–203, 207, 210–212  
conservation of mechanical energy, law of, 184, 187–193, 195–197  
conservation of momentum, law of, 120–128, 141–149, 155, 162, 210  
constant velocity. *See* uniform velocity  
cosine, 89

## D

deceleration, 51, 67, 205  
direction  
  of a force, 18, 21–22, 29, 37–39, 40, 42–43, 47, 49, 62, 67, 75, 78–79, 82  
  horizontal ( $x$ ), 61–62, 87–92, 96–98, 144–146, 204, 210  
  vertical ( $y$ ), 61, 79, 87–91, 92, 96–98, 144–146, 204, 210  
disorder state, 201–202  
displacement, 47, 52, 85, 99, 100, 101, 167, 201, 202, 204–206  
distance  
  braking ( $d$ ), 180–183  
  calculating using  $v$ - $t$  graphs, 100–101  
  calculating when velocity varies, 53–57  
  defined, 47  
  energy and, 167, 168, 171, 175, 178, 191, 200

downward acceleration, 25–26, 41, 79–82, 88, 90–91, 95–97, 172–173

## E

Einstein, Albert, 93, 95  
elastic collisions, 143, 210–213  
elastic potential energy, 164–165, 166, 202  
electrical energy, 156–157, 161, 201  
electromagnetic forces, 43  
electrostatic fields, 201  
energy  
  conservation of, law of, 155–156, 163, 171–174, 189, 190, 196, 202–203, 207, 210–212  
  conservation of mechanical, law of, 184, 187–193, 195–197  
  defined, 153–161, 200–201  
  elastic potential, 164–165, 166, 202  
  electrical, 156–157, 161, 201  
  friction and, 207–210  
  gravitational potential, 165–166, 226  
  kinetic, 178–180, 184–185, 187, 189–193, 196–197, 200, 201, 203, 205, 207, 211, 226  
  light, 156  
  mechanical, 158, 164, 184–193, 195–197, 200  
  vs. momentum, 159–163  
  nuclear, 155  
  potential, 155, 158, 164–171, 174, 175, 184–189, 192–197, 201–203, 226  
  thermal, 155, 157, 200  
  transforming, 184–187  
  units for measuring, 161, 200–201

equilibrium  
  breaking, 27, 41  
  defined, 20–22  
  vs. law of action and reaction,  
  23–30  
  vector forces and, 38, 39–40  
equivalence principle, 93  
equivalent magnitudes, 40,  
  62, 162

## F

forces ( $F$ ), 18, 43  
  attractive, 43, 201  
  balance of, 21, 25–26, 39–41,  
  61, 87  
  composition and decomposi-  
  tion of, 87–88  
  defined, 3, 6–7, 21, 71–72,  
  92, 112  
  electromagnetic, 43  
  equilibrium and, 38, 39–40  
  finding precise value of, 73  
  gravity, 21–27, 30–32, 39, 40,  
  42, 58–59, 76, 77, 79, 88,  
  91–94, 96, 172, 173, 191,  
  200, 209–210  
  horizontal, 87–88  
  maximum possible, 208  
  net, 39, 40–41, 58, 60–61,  
  64–66, 72, 90, 210  
  nonconservative, 207  
  nonuniform, 205  
  nonzero net, 41  
  normal, 207–208, 210  
  orientation of, 75–78, 90–92,  
  169, 204–205  
  repulsive, 43, 201  
  splitting, 87–89  
  units for measuring, 43, 70,  
  72, 92, 119, 144, 200  
  vertical, 87–88  
free-body diagrams, 41–42  
friction  
  air resistance and, 64,  
  190, 197  
  coefficient of, 207–208  
  energy and, 207–210

## G

general relativity, 93  
gravitation, universal, 32, 43,  
  94–95  
gravitational acceleration, 80, 82,  
  94–96, 172  
gravitational mass, 93  
gravitational potential energy,  
  165–166, 226  
gravity, center of, 42, 126  
gravity, force of, 21–27, 30–32,  
  39, 40, 42, 43, 58–59,  
  76, 77, 79, 88, 91–94,  
  96, 172, 173, 191, 200,  
  209–210

## H

head-to-tail method, 62, 86–87,  
  88, 145  
height, determining, 165, 169,  
  171–174, 189, 191–197,  
  203–204  
horizontal ( $x$ ) direction, 61–62,  
  87–92, 96–98, 144–146,  
  204, 210

## I

impulse and momentum,  
  104–105, 111, 113–116,  
  118, 129–130, 132, 136,  
  139–144, 215, 225  
inelastic collisions, 143  
inertia, law of, 40, 41, 58–65, 69,  
  82–83, 90–92, 126, 207  
inertial mass, 93  
integral calculus, 101, 146, 148  
International System of Units (SI),  
  prefixes, 227

## J

Joule, James Prescott, 226  
joules (J), 161, 200–201, 226

## K

kilocalories (kcal), 161, 200, 201  
kilograms (kg), 92, 119, 201, 225  
kilowatt hours (kWh), 161

kinetic energy, 178–180,  
  184–185, 187, 189–193,  
  196–197, 200, 201, 203,  
  205, 207, 211, 226

## L

laws  
  conservation of energy,  
  155–156, 163, 171–174,  
  189, 190, 196, 202–203,  
  207, 210–212  
  conservation of mechanical  
  energy, 184, 187–193,  
  195–197  
  conservation of momentum,  
  120–128, 141–149, 155,  
  162, 210  
  Newton's first, 40, 41,  
  58–65, 69, 82–83, 90–92,  
  126, 207  
  Newton's second, 40–41,  
  58, 66–72, 90–93, 100,  
  111–116, 139–140, 146,  
  179, 225  
  Newton's third, 4, 15–20,  
  23–30, 33–36, 40, 42, 43,  
  74, 83, 92, 93, 120–125,  
  142, 143, 146, 209  
light energy, 156

## M

magnitude, 19, 21–22, 24, 25,  
  27, 29, 37–42, 49, 59, 77,  
  86–87, 90–96, 100, 108,  
  117, 118, 139, 144, 159,  
  160, 173, 207  
mass ( $m$ ), 32, 43, 90  
  defined, 41–42, 68–69,  
  90, 207  
  determining weight with,  
  94–96  
  gravitational, 93  
  gravity and, 43, 80  
  inertial, 93  
  kilograms (kg), 92, 119,  
  201, 225  
  measuring, 68–72, 74, 80,  
  93–94

- maximum possible force, 208
  - measurement, 68–72, 93–94
  - measurement units
    - base, 225
    - calories (cal), 161, 200, 201
    - joules (J), 161, 200–201, 226
    - kilocalories (kcal), 161, 200, 201
    - kilograms (kg), 92, 119, 201, 225
    - kilowatt hours (kWh), 161
    - meters (m), 49, 53, 225
    - meters per second (m/s), 49, 118
    - meters per second squared ( $\text{m/s}^2$ ), 50, 92
    - newtons (N), 43, 70, 72, 92, 119, 144, 200, 225
    - seconds (s), 49, 53, 54, 75, 81–82, 118, 132, 225
    - SI prefixes for, 227
  - mechanical energy, 158, 164, 184–193, 195–197, 200
  - mechanics, 34, 41, 134, 138, 167, 168, 198
  - meters (m), 49, 53, 225
  - meters per second (m/s), 49, 118
  - meters per second squared ( $\text{m/s}^2$ ), 50, 92
  - momentum ( $p$ )
    - calculating, 107–110, 117–119, 225
    - changes in, 111–116, 119, 121–122, 134–136, 140
    - collisions, 143–144, 145, 146
    - conservation of, law of, 120–128, 141–149, 155, 162, 210
    - vs. energy, 159–163
    - defined, 37, 84, 106–110, 139–140, 159, 225
    - impact reduction, 129–132
    - impulse and, 104–105, 111, 113–116, 118, 129–130, 132, 136, 139–144, 215, 225
    - mass differences, 109–110
    - orientation of, 139, 144–145
    - outer space and, 126–128, 147–149
    - velocity and, 107–110, 112–113, 113–116
  - motion. *See also* acceleration; Newton's three laws of motion
    - calculating, 10, 75–84
    - circular, 96, 205
    - parabolic, 96–99
    - simple, 46
    - uniform, 65, 90, 149
    - uniform accelerated, 51, 85–86, 90, 101
    - units for measuring, 144, 226
  - $\mu$  ( $\mu$ ), 207–208
- N**
- negative vectors, 38
  - net forces, 39, 40–41, 58, 60–61, 64–66, 72, 90, 210
  - Newton, Isaac, 40, 43, 92, 122
  - newtons (N), 43, 70, 72, 92, 119, 144, 200, 225
  - Newton's first law, 40, 41, 58–65, 69, 82–83, 90–92, 126, 207
  - Newton's second law, 40–41, 58, 66–72, 90–93, 100, 111–116, 139–140, 146, 179, 225
  - Newton's third law, 4, 15–20, 33–36, 40, 42, 43, 74, 83, 92, 93, 142, 143, 209
    - vs. equilibrium, 23–30
    - vs. law of conservation of momentum, 120–125, 146
  - Newton's three laws of motion, 33–35, 40–42, 83–84, 90
  - nonconservative forces, 207
  - nonuniform forces, 205
  - nonzero net forces, 41
  - normal forces, 207–208, 210
  - nuclear energy, 155
- O**
- orientation
    - of acceleration, 78–84, 90–92
    - of force, 75–78, 90–92, 169, 204–205
    - of momentum, 139, 144–145
    - of velocity, 76, 78, 81–82, 90–92, 196, 197
    - of work, 204–205
  - outer space, 43, 63–64, 69, 90, 95, 126–127, 147
- P**
- parabolas, 78, 91, 98
  - parabolic motion, 96–99
  - physics, defined, 34–36, 83
  - potential energy, 155, 158, 164–171, 174, 175, 184–189, 192–197, 201–203, 226
  - propulsion, rocket, 147–149
- Q**
- quadratic functions, 98
- R**
- reaction forces. *See* action and reaction, law of
  - relative velocity, 63, 147–148
  - repulsive forces, 43, 201
  - rubber/rubber bands, 166–167, 170, 201, 202, 208
- S**
- scalars, 37–39, 40
  - seconds (s), 49, 53, 54, 75, 81–82, 118, 132, 225
  - SI (International System of Units), prefixes, 227
  - simple motion, 46
  - sine, 89
  - space. *See* outer space
  - speed
    - braking distance and, 180–183

speed, *continued*  
defined, 3, 29, 41, 46, 47–49,  
53–55, 81, 159  
finding, 194, 200, 205  
springs, 166, 187, 201–203  
static state, 21, 25, 30, 40, 41,  
59–62, 65  
stored energy. *See* elastic poten-  
tial energy

## T

tangent, 89  
thermal energy, 155, 157, 200  
time, 49, 53–57, 75, 81–82,  
85–86, 100–101, 118, 132  
trigonometry, 88–89

## U

uniform accelerated motion, 51,  
85–86, 90, 101  
uniform motion, 65, 90, 149  
uniform velocity, 53, 55, 64, 81,  
90, 91, 96, 99, 100, 178  
units. *See also* measurement  
units  
base, 225  
converting, 225–226  
SI prefixes for, 227  
universal gravitation, 32, 43,  
94–95

## V

vectors, 21, 37–40, 49, 160  
adding, head-to-tail method,  
62, 86–87, 88, 145

velocity ( $v$ ), 37, 85–86  
acceleration and, 50–52,  
90, 225  
change in, 50–52, 74, 81, 85,  
90–91, 112–113  
defined, 46–49, 225  
orientation of, 76, 78, 81–82,  
90–92, 196, 197  
relative, 63, 147–148  
uniform, 53, 55, 64, 81, 90,  
91, 96, 99, 100, 178  
units for measuring, 49, 118  
using calculus to find, 99–100  
vertical ( $y$ ) direction, 61, 79,  
87–91, 92, 96–98,  
144–146, 204, 210  
 $v$ - $t$  graphs, 53–57, 73, 85,  
100–101

## W

weight, determining, 60–62, 68,  
94–96  
weightless state, 63, 69, 93  
work ( $W$ )  
conservation of energy and,  
172–174  
defined, 167–169, 226  
kinetic energy and, 175–179,  
180, 226  
orientation of, 204–205  
potential energy and,  
169–171, 175–177, 226

## Z

zero-gravity feeling, 63, 96  
zero vectors, 38