Mechanics Formula Sheet

Kinematics, projectiles, forces, energy, momentum, circular motion, and gravitation

Motion in a Straight Line

$v_{\text{avg}} = \dfrac{\Delta x}{\Delta t}$	average velocity
$a = \dfrac{\Delta v}{\Delta t}$	acceleration
$v = v_0 + a\,t$	constant a
$\Delta x = v_0\,t + \tfrac{1}{2}\,a\,t^2$	constant a
$v^2 = {v_0}^2 + 2\,a\,\Delta x$	constant a
$\Delta x = \dfrac{v_0 + v}{2}\,t$	constant a
$a = -g$	free fall, up positive

Projectile Motion

$v_{0x} = v_0 \cos\theta,\ v_{0y} = v_0 \sin\theta$	launch components
$x = v_{0x}\,t$	horizontal: constant velocity
$y = y_0 + v_{0y}\,t - \tfrac{1}{2}\,g\,t^2$	vertical: free fall
$v_y = v_{0y} - g\,t$	vertical velocity
$t_{\text{flight}} = \dfrac{2\,v_0 \sin\theta}{g}$	level ground
$R = \dfrac{{v_0}^2 \sin 2\theta}{g}$	range, level ground
$H = \dfrac{(v_0 \sin\theta)^2}{2g}$	maximum height gain

Forces and Newton's Laws

$\Sigma F = m\,a$	second law (each axis)
$F_g = m\,g$	weight
$f_k = \mu_k\,F_N$	kinetic friction
$f_s \le \mu_s\,F_N$	static friction
$F_{\parallel} = m\,g \sin\theta,\ F_{\perp} = m\,g\cos\theta$	incline components
$F_N = m\,(g + a)$	apparent weight, up positive
$F_{AB} = -F_{BA}$	third law

Work, Energy, and Power

$W = F\,d\cos\theta$	work by a constant force
$\text{KE} = \tfrac{1}{2}\,m\,v^2$	kinetic energy
$\text{PE}_g = m\,g\,h$	gravitational potential energy
$\text{PE}_s = \tfrac{1}{2}\,k\,x^2$	spring potential energy
$W_{\text{net}} = \Delta\text{KE}$	work–energy theorem
$\text{KE}_i + \text{PE}_i + W_{\text{other}} = \text{KE}_f + \text{PE}_f$	energy accounting
$P = \dfrac{W}{t} = F\,v$	power

Momentum and Collisions

$p = m\,v$	momentum
$J = F_{\text{avg}}\,\Delta t = \Delta p$	impulse
$\Sigma p_i = \Sigma p_f$	isolated system
$v_f = \dfrac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$	perfectly inelastic
$v_1' = \dfrac{m_1 - m_2}{m_1 + m_2}\,v_1$	elastic, 2 at rest
$v_2' = \dfrac{2\,m_1}{m_1 + m_2}\,v_1$	elastic, 2 at rest
$\text{KE} = \dfrac{p^2}{2m}$	kinetic energy from momentum

Circular Motion and Gravitation

$a_c = \dfrac{v^2}{r} = \dfrac{4\pi^2\,r}{T^2}$	centripetal acceleration
$v = \dfrac{2\pi\,r}{T}$	speed in a circle
$\Sigma F_{\text{toward center}} = \dfrac{m\,v^2}{r}$	second law in a circle
$F_g = \dfrac{G\,m_1\,m_2}{r^2}$	universal gravitation
$g = \dfrac{G\,M}{r^2}$	gravitational field
$v_{\text{orbit}} = \sqrt{\dfrac{G\,M}{r}}$	circular orbit
$T^2 = \dfrac{4\pi^2}{G\,M}\,r^3$	Kepler's third law

Constant	Symbol	Value
Gravitational constant	G	6.67430×10^{-11} N·m²/kg²
Standard acceleration of gravity	g_n	9.80665 m/s² (exact)
Value of g used in this book	g	9.8 m/s²
Mass of Earth	M_E	5.972×10^{24} kg
Mean radius of Earth	R_E	6.371×10^{6} m
Mass of the Moon	M_M	7.346×10^{22} kg
Mean Earth–Moon distance		3.844×10^{8} m
Mass of the Sun	M_S	1.989×10^{30} kg
Astronomical unit	au	1.495978707×10^{11} m (exact)
Surface gravity of Mars	g_{Mars}	3.71 m/s²
Sidereal day (one rotation of Earth)		86,164 s

Unit Conversion	Value
1 mile	1609.344 m (exact)
1 mile per hour	0.44704 m/s (exact)
1 kilometer per hour	0.2778 m/s (1 m/s = 3.6 km/h)
1 foot	0.3048 m (exact)
1 inch	2.54 cm (exact)
1 pound (mass)	0.45359237 kg (exact)
1 pound (force)	4.448 N
1 horsepower	745.7 W
1 kilowatt-hour	3.6×10^{6} J (exact)
1 food Calorie (kcal)	4184 J
1 hour	3600 s
1 day	86,400 s
1 year	about 3.156×10^{7} s
1 revolution	2π rad = 360°

The Five-Step Method

1. Sketch It
Draw the situation, the positive directions, and a free-body diagram for force problems.

2. List Knowns
Write each given with its unit and sign, then the unknown you need.

3. Choose the Principle
Kinematics, Newton's laws, energy, momentum, or circular motion?

4. Symbols, Then Numbers
Solve for the unknown in symbols, then substitute values with units.

5. Check
Units, sign, and size. Does the answer make physical sense?

Quick Checks Before You Move On

- **Units.** Carry units through every line; the answer's unit must match the quantity asked for.
- **Signs.** Choose a positive direction once and keep it; a negative result means the opposite direction.
- **Size.** Compare with something familiar: g is 9.8 m/s², and highway speed is about 30 m/s.
- **Limits.** Try an extreme case (θ = 0°, θ = 90°, no friction) and see whether the formula behaves.

Choosing a Principle

If the problem involves…	Start with	Chapter
Constant acceleration in a straight line; asked for a time, distance, or speed	Kinematics equations	1
An object launched and then moving under gravity alone	Split into horizontal (constant velocity) and vertical (free fall) motion	2
Forces are given or asked for, or the acceleration comes from forces	Free-body diagram and ΣF = ma along each axis	3
A speed after a change in height, a spring, or friction over a distance; a curved path	Work and energy	4
Collisions, explosions, recoil, or a brief, large force	Momentum conservation and impulse	5
Motion in a circle, a loop, a banked curve, or an orbit	ΣF toward the center = mv²/r, and universal gravitation	6
Asked "how long?"	Kinematics or impulse; energy alone cannot give a time	1–5



Mechanics, Solved

60 original problems with full step-by-step solutions, from straight-line motion to orbits. Find it, and more free physics help, at PhysicsIsAwesome.com.

Sources: G, standard gravity, and c are CODATA 2022 recommended values from the National Institute of Standards and Technology (NIST), physics.nist.gov/constants. Exact unit conversions follow NIST Special Publication 811. Earth, Moon, Sun, and Mars values are from NASA planetary fact sheets; the astronomical unit is defined by the International Astronomical Union (IAU).