Physics Formulas: Mechanics

coddy.tech/physics/formulas/mechanics

KINEMATICS

Kinematic equations (SUVAT)

WITHOUT DISPLACEMENT

$$v = u + at$$

WITHOUT ACCELERATION

$$s = \tfrac{1}{2}(u + v)t$$

WITHOUT FINAL VELOCITY

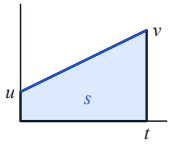
$$s = ut + \tfrac{1}{2}at^2$$

WITHOUT TIME

$$v^2 = u^2 + 2as$$

WITHOUT INITIAL VELOCITY

$$s = vt - \tfrac{1}{2}at^2$$



For a constant acceleration only.

s displacement u initial velocity v final velocity
a acceleration t time

Speed and velocity

AVERAGE SPEED

$$\bar{v} = \frac{d}{t}$$

AVERAGE VELOCITY

$$\bar{v} = \frac{\Delta x}{\Delta t}$$

d distance Δx displacement t, Δt time

Acceleration

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v - u}{t}$$

$\bar{a}$ average acceleration Δv change in velocity
t time

Projectile motion

HORIZONTAL

$$x = (u\cos\theta)\,t$$

VERTICAL

$$y = (u\sin\theta)\,t - \tfrac{1}{2}gt^2$$

TIME OF FLIGHT

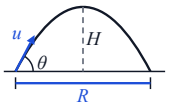
$$T = \frac{2u\sin\theta}{g}$$

MAXIMUM HEIGHT

$$H = \frac{u^2\sin^2\theta}{2g}$$

RANGE

$$R = \frac{u^2\sin 2\theta}{g}$$



No air resistance. T, H and R only when the projectile lands at the height it was launched from.

u launch speed θ launch angle
x, y horizontal and vertical distance from the launch point
t time g acceleration due to gravity

FORCES

Newton's second law

NET FORCE

$$\Sigma F = ma$$

WEIGHT

$$W = mg$$

ΣF net force m mass a acceleration
g acceleration due to gravity

Friction

STATIC FRICTION

$$f_s \le \mu_s N$$

KINETIC FRICTION

$$f_k = \mu_k N$$

μ coefficient of friction N normal force

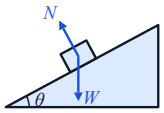
Inclined plane

FORCE ALONG THE SLOPE

$$F_{\parallel} = mg\sin\theta$$

NORMAL FORCE

$$N = mg\cos\theta$$

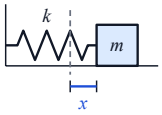


W weight N normal force
θ angle of the slope

Hooke's law

SPRING FORCE

$$F = -kx$$



k spring constant
x extension

Circular motion

CENTRIPETAL ACCELERATION

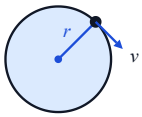
$$a_c = \frac{v^2}{r} = \omega^2 r$$

CENTRIPETAL FORCE

$$F_c = \frac{mv^2}{r}$$

SPEED IN A CIRCLE

$$v = \frac{2\pi r}{T}$$



v speed r radius T period ω angular velocity

ENERGY, WORK AND POWER

Kinetic energy

$$KE = \tfrac{1}{2}mv^2$$

m mass v speed

Potential energy

GRAVITATIONAL

$$PE = mgh$$

ELASTIC

$$PE = \tfrac{1}{2}kx^2$$

h height k spring constant x extension

Work

WORK

$$W = Fd\cos\theta$$

WORK AND ENERGY

$$W_{\text{net}} = \Delta KE$$

F force d displacement
θ angle between force and motion

Power and efficiency

AVERAGE POWER

$$\bar{P} = \frac{W}{\Delta t}$$

INSTANTANEOUS POWER

$$P = Fv\cos\theta$$

EFFICIENCY

$$\eta = \frac{E_{\text{out}}}{E_{\text{in}}} \times 100\%$$

W work Δt time
θ angle between force and motion

Conservation of energy

$$\tfrac{1}{2}mv_1^2 + mgh_1 = \tfrac{1}{2}mv_2^2 + mgh_2$$

Mechanical energy, when only gravity does work: no friction, drag or other force adding or removing energy.

MOMENTUM

Momentum and impulse

MOMENTUM

$$p = mv$$

IMPULSE

$$J = \bar{F}\Delta t = \Delta p$$

p momentum J impulse $\bar{F}$ average force

Collisions

CONSERVATION OF MOMENTUM

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

OBJECTS STICK TOGETHER

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

u velocity before v velocity after

Center of mass

$$x_{\text{cm}} = \frac{\Sigma mx}{\Sigma m}$$

m mass x position

ROTATION

Angular motion

ANGULAR VELOCITY

$$\omega = \frac{\Delta\theta}{\Delta t}$$

LINEAR AND ANGULAR SPEED

$$v = r\omega$$

$$\omega = \omega_0 + \alpha t$$

$$\Delta\theta = \omega_0 t + \tfrac{1}{2}\alpha t^2$$

The last two: for a constant angular acceleration only.

ω angular velocity α angular acceleration
$\Delta\theta$ angle in radians

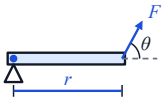
Torque

TORQUE

$$\tau = rF\sin\theta$$

SECOND LAW FOR ROTATION

$$\Sigma\tau = I\alpha$$



MOMENT OF INERTIA

$$I = \Sigma m r^2$$

PARALLEL AXIS THEOREM

$$I = I_{\text{cm}} + Md^2$$

r distance from the pivot I moment of inertia
M mass d distance between the two parallel axes

Rotational energy and angular momentum

ROTATIONAL KINETIC ENERGY

$$KE = \tfrac{1}{2}I\omega^2$$

ANGULAR MOMENTUM

$$L = I\omega$$

I moment of inertia ω angular velocity
L angular momentum

OSCILLATIONS

Mass on a spring

PERIOD

$$T = 2\pi\sqrt{\frac{m}{k}}$$

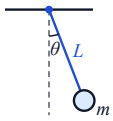
m mass k spring constant

Simple pendulum

PERIOD

$$T = 2\pi\sqrt{\frac{L}{g}}$$

For small swings only, up to about 15°.



L length
g acceleration due to gravity

Simple harmonic motion

FREQUENCY

$$f = \frac{1}{T}$$

ANGULAR FREQUENCY

$$\omega = 2\pi f$$

POSITION

$$x = A\cos(\omega t)$$

A amplitude T period

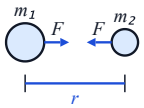
GRAVITATION

Newton's law of gravitation

$$F = G\frac{m_1 m_2}{r^2}$$

FIELD STRENGTH

$$g = \frac{GM}{r^2}$$



G gravitational constant
r distance between the centers
M mass of the planet

Orbits

ORBITAL SPEED

$$v = \sqrt{\frac{GM}{r}}$$

ORBITAL PERIOD

$$T^2 = \frac{4\pi^2}{GM}r^3$$

GRAVITATIONAL POTENTIAL ENERGY

$$U = -\frac{GMm}{r}$$

For a circular orbit.

M mass of the planet r orbit radius

FLUIDS

Density

$$\rho = \frac{m}{V}$$

ρ density m mass V volume

Pressure and buoyancy

PRESSURE

$$P = \frac{F}{A}$$

PRESSURE AT A DEPTH

$$P = P_0 + \rho g h$$

BUOYANT FORCE

$$F_b = \rho V g$$

A area ρ density of the fluid h depth
V volume under the surface

Fluid flow

CONTINUITY

$$A_1 v_1 = A_2 v_2$$

BERNOULLI'S EQUATION

$$P_1 + \rho g y_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \tfrac{1}{2}\rho v_2^2$$

Steady flow of a fluid that does not compress, with no friction.

A area v flow speed y height

CONSTANTS

Constants

GRAVITY AT THE EARTH'S SURFACE

$$g = 9.81\ \text{m/s}^2$$

GRAVITATIONAL CONSTANT

$$G = 6.67 \times 10^{-11}\ \text{N m}^2/\text{kg}^2$$

MASS OF THE EARTH

$$M_E = 5.97 \times 10^{24}\ \text{kg}$$

RADIUS OF THE EARTH

$$R_E = 6.37 \times 10^{6}\ \text{m}$$