Newton's Laws

First: Momentum stays the same as long as $\vec{F_{\text{net}}} = 0$.
Second: $\vec{F_{\text{net}}} = m\vec{a}$.
Third: Every force occurs as one member of an action/reaction pair of forces.

Conservation

Momentum, energy, angular momentum, charge are conserved for an isolated system. Mass is conserved in normal situations.

Linear Motion

$d = v_i t + \frac{1}{2}at^2 \quad v_f = v_i + at \quad v_f^2 = v_i^2 + 2ad \quad v_f^2 = v_i^2 + 2ad$

$K = \frac{1}{2}mv^2 \qquad \vec{p} = m\vec{v}$

$\Delta K = J_x = \int_{t_i}^{t_f} F_x(t)\ dt \qquad \Delta p_s = W = \int_{s_i}^{s_f} F_s\ ds$

Springs

Hooke's law: $(F_{sp})_s = -k\Delta s \qquad U_s = \frac{1}{2}k(\Delta s)^2$

Rotational Motion

$\omega_f = \omega_i + \alpha\Delta t \quad \theta_f = \theta_i + \omega_i \Delta t + \frac{1}{2}\alpha(\Delta t)^2 \quad \omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$

$a_{\text{tangential}} = \alpha r \quad a_{\text{centripital}} = v^2/r = \omega^2 r \quad x_{\text{cm}} = \frac{1}{M}\int x\ dm$

$I = \sum_i m_i r_i^2 \qquad I = \int r^2 dm$

$K_{\text{rot}} = \frac{1}{2}I\omega^2 \qquad E_{\text{mech}} = K_{\text{rot}} + U_g = \frac{1}{2}I\omega^2 + Mgy_{\text{cm}}$

parallel axis theorem: $I = I_{\text{cm}} + Md^2 \quad \tau \equiv rF\sin\phi \quad \alpha = \frac{\tau_{\text{net}}}{I}$

$v_{\text{cm}} = R\omega \quad K_{\text{rolling}} = K_{\text{rot}} + K_{\text{cm}} \quad \vec{\tau} = \vec{r} \times \vec{F} \quad \vec{L} = \vec{r} \times \vec{p}$

$d\vec{L}/dt = \vec{\tau}_{net} \qquad \vec{L} = I\vec{\omega}$

Planets

$F_{1\text{on}2} = F_{2\text{on}1} = \frac{Gm_1m_2}{r^2} \qquad$ Satellite Speed: $v = \sqrt{\frac{GM}{r}}$

Escape Velocity: $v = \sqrt{\frac{2GM}{r}} \qquad$ On Surface: $g = \frac{GM}{R_L}$

$U_g = \frac{Gm_1m_2}{r} \qquad$ Kepler's 3rd: $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$

Kepler's 2nd: $\frac{\Delta A}{\Delta t} = \frac{L}{2m}$

Simple Harmonic/Circular Motion

Uniform circular motion projected onto one dimension is simple harmonic motion.
Any system with a linear restoring force will undergo simple harmonic motion around the equilibrium position.

$x(t) = A\cos(\omega t + \phi_0) \qquad v_x(t) = -\omega A\sin(\omega t + \phi_0)$

pendulum: $\omega = 2\pi f = \sqrt{\frac{g}{L}}$

damped oscillator: $x(t) = Ae^{-bt/2m}\cos(\omega t + \phi_0)$

time constant: $\tau = m/b \qquad$ damped system: $E = E_0 e^{-t/\tau}$

Fluids and Elasticity

Archimedes' principle: The magnitude of the buoyant force equals the weight of the fluid displaced by the object.
Ideal-fluid model: Incompressible. Smooth, laminar flow. Nonviscous.
Bernoulli's is a statement of energy conservation.

$p = F/A \qquad p_g = p - 1 \qquad \rho = m/V$

$v_1A_1 = v_2A_2 \qquad$ Bernoulli's: $p_1 + \frac{1}{2}\rho g y_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

$(F/A) = Y(\Delta L/L) \qquad p = -B(\Delta V/V)$

Matter

Phases: solid, liquid gas. Ideal-gas model. Isochoric process $\rightarrow V$ constant and W=0, Isobaric $\rightarrow p$=constant, Isothermal $\rightarrow T$ constant and $\Delta E_{th} = 0$, Adiabatic $\rightarrow Q$=0. conduction, convection, radiation, evaporation.
Second law: entropy cannot decrease.

Ideal Gas Law: $pV = nRT$

First Law of Thermo: $\Delta E_{th} = W + Q \qquad W = -\int_{V_i}^{V_f} p\ dV$

specific heat: $Q = Mc\Delta T \qquad \epsilon_{\text{avg}} = \frac{3}{2}k_B T \qquad p = \frac{2}{3}\frac{N}{V}\epsilon_{\text{avg}}$

Waves

Transverse, Longitudinal. Snapshot graph, history graph. Superposition, nodes, and antinodes.

$v = \lambda f \quad \omega = vk \quad D(x,t) = A\sin(kx - \omega t + \phi_0) \quad I = P/a \quad I \propto A^2$

Doppler: $f_\pm = \frac{f_0}{1 \mp v_s/v} \qquad$ Doppler: $f_\pm = 1 \pm \frac{v_o}{v}f_0$

Double slit. angles of bright fringes: $\theta_m = m\frac{\lambda}{d}$ where m $= 0, 1, 2, \ldots$, d is slit spacing. $I_{double} = 4I_1\cos^2\frac{\pi d}{\lambda L}y$.
Diffraction grating: angles of bright fringes: $d\sin\theta_m = mA$, $m = 0, 1, 2, \ldots$.
Single slit: angles of dark fringes $\theta_p = p\frac{\lambda}{a}$, $p = 1, 2, 3, \ldots$
Circular aperture: $w = 2y_1 = 2L\tan\theta_1 \approx \frac{2.44\lambda L}{D}$

Electricity and Magnetism

Coulomb's $F_{1\text{ on }2} = F_{2\text{ on }1} = \frac{K|q_1||q_2|}{r^2}$

$\vec{E}(x,y,z) = \frac{\vec{F}_{\text{on q}}\text{ at }(x,y,z)}{q} \qquad$ point charge: $\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$

$\vec{E}_{\text{dipole}} = \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{r^3}$ (on axis) $\qquad$ gauss's law $\phi_e = \oint \vec{E}\cdot d\vec{A} = \frac{Q_{\text{in}}}{\epsilon_0}$

unif. elec. field: $U_{\text{elec}} = U_0 + qEs \quad$ point charges: $U_{\text{elec}} = \frac{Kq_1q_2}{r}$

dipole: $U_{\text{dipole}} = -\vec{p}\cdot\vec{E}$

New

de broglie: $\lambda = \frac{h}{p} = \frac{h}{mv} \qquad E_n = n^2\frac{h^2}{8mL^2},\ n = 1, 2, 3, \ldots$

snells: $n_1\sin(\theta_1) = n_2\sin(\theta_2)$

Base SI Units length: m, mass: kg, time: s, current: A(ampere), temp: K, amount: mol, luminous intensity: cd(candela)

Symbols

	Name	Units
A	area	m^2
	amplitude	
a	acceleration	$\mathrm{m/s}^2$
	area	
$\vec{B}$	magnetic field 1	1 tesla = 1 T ≡ 1 N/A m (flux density)
b	damping constant	kg/s
C	capacitance	1 farad = 1 F ≡ 1 C/V
c	speed of light	299,792,458 m/s
	specific heat	J / kg K
d	distance	m
$\vec{E}$	electric field	1 N/C = 1 V/m
E	energy	1 joule = 1 J = 1 kg $\mathrm{m}^2/\mathrm{s}^2$
e	various	2.71828..., electron, elem. charge.
	electron	
	elem. charge	1.60×10^{-19}
	various	2.71828..., electron, elem. charge.
F	force	1 N = 1 kg $\mathrm{m/s}^2$
f	frequency	frequency (1 Hz = 1/s)
	various	function, friction (N)
G	gravity constant	$6.674 * 10^{-11}$ N $\mathrm{m}^2/\mathrm{kg}^2$
g	accel. d.t. gravity	$\mathrm{m/s}^2$
$\vec{H}$	magnetic field 2	A/m (field strength)
h	height	m
h	planck's constant	$6.626 * 10^{-34}$ J s
$\hbar$	reduced planck's	h/2π
I	intensity	$\mathrm{W/m}^2$
	electric current	1 ampere = 1 A = 1 C/s
	mmnt. of inertia	kg m^2 – "rotational mass"
i	imaginary unit	$\sqrt{-1}$
$\hat{\mathbf{i}}$	x-axis unit vec	also $\hat{\mathbf{j}}$, $\hat{\mathbf{k}}$ for y and z axes
J	impulse	kg m/s – equiv to ΔP
K	kinetic energy	J
	electrostatic c.	8.99×10^9 N $\mathrm{m}^2/\mathrm{C}^2$
k_{B}	boltzmann const.	$1.381 * 10^{-23}$ J/K = R/N_A
	wave number	rad/m – "spacial freq. of wave"
	spring constant	$\mathrm{J/m}^2$
L	inductance	1 henry = 1 H ≡ 1 Wb/A = 1 T m^2/A
	ang. momentum	kg m^2/s
l	length	m
m	mass	kg
N	various	normal vector, atomic number
N_{A}	avogadro's num	$6.02 * 10^{23}$ 1/mol
n	ind. of refraction	unitless – n = c/v
	quantum number	$n = 1, 2, 3, \ldots$, parameterizes quantum energy state for particle
$\vec{p}$	momentum	kg m/s – $\vec{p} \equiv m\vec{v}$
p	pressure	1 pascal = 1 Pa ≡ 1 $\mathrm{N/m}^2$
$\vec{p}$	dipole moment	qs, from the negative to the positive charge
Q	heat	1 joule = 1 J = 0.2389 cal
q	elect. charge	1 coulomb = 1 C = 1 A s – (q or Q)
R	elect. resistance	1 ohm = 1 Ω = 1 V/A
	gas constant	8.314 J/mol K
r	radius	m
S	entropy	
S	entropy	
s	arc length	m
	position	m
T	period	s
	abs. temperature	1 kelvin = 1 K = T_C+273
t	time	s
U	potential energy	1 joule = 1 J
u	atomic mass unit	1 u = $1.66 * 10^{-27}$ kg
V	voltage	1 volt = 1 V = 1 J/C
	volume	m^3
$\vec{v}$	velocity	m/s
W	work	1 N m = 1 kg $\mathrm{m}^2/\mathrm{s}^2$ = 1 J
w	width	m
x	displacement	m
Z	elec. impedance	1 ohm = 1 Ω
α	ang. accel	rad/s^2
Δ	change in var.	used to signify change i.e. Δx
ϵ	permittivity	F/m = $\epsilon_r \epsilon_0$
ϵ_0	vac. permittivity	$8.854 * 10^{-12}$ F/m
θ	angle	rad
λ	wavelength	m
μ	mag. moment	A m^2
μ	coeff. friction	unitless
μ	permeability	H/m = N/A^2 – $\mu = \mu_0 \mu_r$
μ_0	perm const.	$r\pi * 10^-7$T m/A
π	π	3.14159...
ρ	mass density	$\mathrm{kg/m}^3$ — $\rho = m/V$
	resistivity	Ω m — $\rho = 1/\sigma$
σ	conductivity	1/Ω m
τ	torque	N m — $\tau = \vec{r} \times \vec{F}$
	time constant	different for circuits, oscillations, etc...
	2π	6.28319...
Φ	field strength	units vary dep. on context
Φ_e	electric flux	$\int_{\text{surface}} \vec{E} \cdot d\vec{A}$
Φ_m	magnetic flux	1 weber = 1 Wb = 1 T m^2
ϕ	phase	radians — operand to sinusoidal fn.
ψ	wave function	unitless, represents q.m. state
Ω	elec. resistance	1 ohm = 1 Ω = 1 V/A
ω	ang. velocity	rad/s

$$F \to N = \frac{kg\ m}{s^2}$$

Miscellaneous

$\vec{A} \times \vec{B} \equiv AB \sin \alpha$, in the direction given by right-hand rule