Prefixes

a=10^{-18},	f=10^{-15},	p=10^{-12},	n=10^{-9},	$\mu = 10^{-6}$,	m=10^{-3},	c=10^{-2},	k=10^{3},	M=10^{6},	G=10^{9},	T=10^{12},	P=10^{15}.
atto,	femto,	pico,	nano,	micro,	milli,	centi,	kilo,	mega,	giga,	tera,	peta.

Physical Constants

$g = 9.80$ m/s^2 (gravitational acceleration)
$M_E = 5.98 \times 10^{24}$ kg (mass of Earth)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass)
$c = 299792458$ m/s (exact speed of light)
$u = 1.6605 \times 10^{-27}$ kg (atomic mass unit)
$R = 8.314$ J/mol·K (gas constant)

$G = 6.67 \times 10^{-11}$ N·m^2/kg^2 (Gravitational constant)
$R_E = 6380$ km (mean radius of Earth)
$m_p = 1.67 \times 10^{-27}$ kg (proton mass)
$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4 (Stefan-Boltzmann constant)
$N_A = 6.022 \times 10^{23}$/mol (Avogadro's number)
$k = 1.38 \times 10^{-23}$ J/K (Boltzmann's constant)

Units and Conversions

1 inch = 1 in = 2.54 cm	1 foot = 1 ft = 12 in = 0.3048 m	
1 mile = 5280 ft =1760 yards	1 mile = 1609.344 m = 1.609344 km	
1 m/s = 3.6 km/hour	88 ft/s = 60 mile/hour	1 m^3 = 1000 L
1 acre = (1 mile)^2/640 = 43 560 ft^2	1 hectare = (100 m)^2 = 10^4 m^2	1 cal = 4.186 J
1 lb = 4.45 N	1 N = 0.225 lb	1 J = 1 joule = 1 N·m

symbol	element	atomic number	mass number
H	hydrogen	1	1.00794
He	helium	2	4.00260
C	carbon	6	12.0107
N	nitrogen	7	14.0067
O	oxygen	8	15.9994
Ne	neon	10	20.180
Ar	argon	18	39.948
Fe	iron	26	55.845
Ni	nickel	28	58.693
Cu	copper	29	63.546
Au	gold	79	196.97
U	uranium	92	238.03

Mass numbers are atomic masses in units of "u" where 1 u = 1.6605×10^{-27} kg, or, molar masses for the element (1 mole = 6.02×10^{23} atoms), measured in grams/mole. ($N_A \times 1$ u = 1 gram)

Algebra, Geometry, Trigonometry

Quadratic equations: $ax^2 + bx + c = 0$, solved by $x = \left(-b \pm \sqrt{b^2 - 4ac}\right)/(2a)$.
Triangles: $A = \frac{1}{2}bh$, Circles; $C = 2\pi r$, $A = \pi r^2$, arc $= s = r\theta$. Spheres: $A = 4\pi r^2$, $V = \frac{4\pi}{3} r^3$.
$\sin\theta = (\text{opp})/(\text{hyp})$, $\cos\theta = (\text{adj})/(\text{hyp})$, $\tan\theta = (\text{opp})/(\text{adj})$, $(\text{opp})^2 + (\text{adj})^2 = (\text{hyp})^2$.
$\sin\theta = \sin(180^\circ - \theta)$, $\cos\theta = \cos(-\theta)$, $\tan\theta = \tan(180^\circ + \theta)$, $\sin^2\theta + \cos^2\theta = 1$.

OpenStax Ch 1: Units, measurements, errors or uncertainties

Unit conversions: value = # (old units), (old units) $\times \left(\frac{\text{new units}}{\text{old units}}\right)$ = (new units).
Percent error: measurement = value ± error, percent error = (error / value)×100%.

OpenStax Ch 2: 1D Kinematics - Straight-line motion

Velocity:	$\bar{v} = \Delta x/\Delta t$	$\Delta x = x - x_0$	$v(t)$ = slope of $x(t)$
Acceleration:	$\bar{a} = \Delta v/\Delta t$	$\Delta v = v - v_0$	$a(t)$ = slope of $v(t)$
Constant acceleration:	$v = v_0 + at$,	$\bar{v} = \frac{1}{2}(v_0 + v)$,	$\Delta x = \bar{v}\Delta t$.
	$x = x_0 + v_0 t + \frac{1}{2}at^2$,	$x = x_0 + v_{\text{avg}} t$,	$v^2 = v_0^2 + 2a\Delta x$.
Free fall (+y-axis is up):	$y = y_0 + v_{0y} t - \frac{1}{2}gt^2$,	$v_y = v_{0y} - gt$,	$v_y^2 = v_{0y}^2 - 2g\Delta y$.

OpenStax Ch 3: Vectors & 2D & 3D Motion

Vector $\mathbf{V} = \vec{V} = (V_x, V_y)$,	magnitude=$V = \sqrt{V_x^2 + V_y^2}$,	direction=$\theta = \tan^{-1}(V_y/V_x)$.
θ = angle from x-axis to $\mathbf{V}$,	$V_x = V\cos\theta$,	$V_y = V\sin\theta$.
Addition: $\mathbf{A} + \mathbf{B}$, head to tail,	Subtraction: $\mathbf{A} - \mathbf{B}$ is $\mathbf{A} + (-\mathbf{B})$,	$-\mathbf{B}$ is $\mathbf{B}$ reversed.

Projectiles:	$a_x = 0$,	$v_x = v_{0x}$,	$x = x_0 + v_{0x}t$,	(horizontal x-axis),	$R = (v_0^2/g)\sin 2\theta_0$.
	$a_y = -g$,	$v_y = v_{0y} - gt$,	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$,	(upward y-axis).	

Relative Motion: $\mathbf{V}_{\text{BS}} = \mathbf{V}_{\text{BW}} + \mathbf{V}_{\text{WS}}$, **B**oat, **S**hore, **W**ater. BS = "boat relative to shore", etc.

OpenStax Ch 4: Newton's Laws

Newton's 1st Law:	$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = 0$ unless $\vec{F}_{\text{net}} \neq 0$,	$\vec{F}_{\text{net}} = \sum \vec{F}_i$ = sum of all forces on a mass.
Newton's 2nd Law:	$\vec{F}_{\text{net}} = m\vec{a}$,	$F_{\text{net},x} = ma_x,\ F_{\text{net},y} = ma_y,\ F_{\text{net},z} = ma_z$.
Newton's 3rd Law:	$\vec{F}_{AB} = -\vec{F}_{BA}$,	Forces exist in action-reaction pairs.
Gravitational force near Earth:	$F_G = mg$, downward.	Apparent weight is force measured by a scales.
Gravity components on inclines:	$F_\parallel = mg\sin\theta,\ F_\perp = mg\cos\theta$,	$\leftarrow$ for incline at angle θ to horizontal.
Spring force:	$F_s = -kx$,	x is the displacement from equilibrium.

OpenStax Ch 5: Friction

Normal force:	N or F_N,	acts perpendicular to a surface, acts on the object.
Static friction (object is stuck):	$f_s \leq \mu_s N$,	Can balance other forces in any direction.
Kinetic friction (object sliding):	$f_k = \mu_k N$,	Acts **against** the relative motion of surfaces.

OpenStax Ch 6: Circular Motion

Centripetal Acceleration:	$a_c = v^2/r = \omega^2 r$,	towards the center of the circle,	Use ω in rad/sec!
Circular motion:	speed $v = 2\pi r/T$,	frequency $f = 1/T$,	T = period of one revolution.
	speed $v = \omega r$,	angular speed $\omega = 2\pi f = 2\pi/T$,	ω is in rad/sec.
Gravitation:	$F = Gm_1m_2/r^2$,	free fall $g = GM/r^2$,	$G = 6.67 \times 10^{-11}$ Nm^2/kg^2.
Orbits:	$v^2/r = g = GM/r^2$;	speed $v = \sqrt{GM/r}$,	centripetal a_c = free fall g.

OpenStax Ch 7: Work & Energy

Forces:	F_x,	$F_{\text{gravity},y} = -mg$,	$F_{\text{spring}} = -kx$.
Work:	$W = F_x \Delta x \cos\theta$,	$W_{\text{gravity},y} = -mg\Delta y$,	$W_{\text{spring}} = -\frac{1}{2}k(x_f^2 - x_i^2)$.
PE:	$\Delta\text{PE} = -W_{\text{force}}$,	$\text{PE}_{\text{gravity}} = mgy$,	$\text{PE}_{\text{spring}} = \frac{1}{2}kx^2$.
KE:	$\text{KE} = \frac{1}{2}mv^2$,	$\Delta\text{KE} = W_{\text{net}}$,	W_{net} = work of all forces.
Conservation of Energy:	$\Delta\text{KE} + \Delta\text{PE} = W_{\text{NC}}$,	NC = non-conservative forces.	
Power:	$P_{\text{ave}} = W/t$,	or use P_{ave} = energy/time.	

OpenStax Ch 8: Momentum

Linear momentum:	$\vec{p} = m\vec{v}$,	impulse $\Delta\vec{p} = m\Delta\vec{v} = \vec{F}_{\text{ave}}\ \Delta t$.
Conservation of Momentum:	$m_A\vec{v}_A + m_B\vec{v}_B = m_A\vec{v}_A^{\,'} + m_B\vec{v}_B^{\,'}$,	(2-body collisions, $\vec{F}_{\text{net}} = 0$).
1D elastic collision:	$\frac{1}{2}m_Av_A^2 + \frac{1}{2}m_Bv_B^2 = \frac{1}{2}m_Av_A^{'2} + \frac{1}{2}m_Bv_B^{'2}$,	or $v_A - v_B = -(v_A' - v_B')$.

OpenStax Ch 9: Rotational Motion

Coordinates:	1 rev = 2π rad,	1 rev = 360°,	$\omega = 2\pi f$,	$f = \frac{1}{T}$.
Averages:	$\bar{\omega} = \frac{\Delta\theta}{\Delta t}$,	$\Delta\theta = \bar{\omega}\Delta t$,	$\bar{\alpha} = \frac{\Delta\omega}{\Delta t}$,	$\Delta\omega = \bar{\alpha}\Delta t$.
Linear vs. angular:	$l = \theta r$,	$v = \omega r$,	$a_{\tan} = \alpha r$,	$a_c = \omega^2 r$, use radians!
Constant acceleration:	$\omega = \omega_0 + \alpha t$,	$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$,	$\bar{\omega} = \frac{1}{2}(\omega_0 + \omega)$,	$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$.
Torque, Dynamics:	$\tau = rF\sin\theta$,	$I = \Sigma mr^2$,	$\tau_{\text{net}} = I\alpha$.	
Rotational Inertias:	$I = MR^2$,	$I = \frac{1}{2}MR^2$,	$I = \frac{2}{5}MR^2$,	$I = \frac{1}{12}ML^2$.
(about centers)	(hoop)	(solid cylinder)	(sphere)	(thin rod)
KE, A. Momentum:	$\text{KE}_{\text{rot}} = \frac{1}{2}I\omega^2$,	$L = I\omega$,	$\Delta L = \tau_{\text{net}}\Delta t$.	
Work, power:	$W = \bar{\tau}\Delta\theta$,	$P = \tau\omega$.		

OpenStax Ch 10: Static Equilibrium

$\Sigma F_x = \Sigma F_y = \Sigma F_z = 0$, $\Sigma\tau = 0$, $\tau = rF\sin\theta = r_\perp F = rF_\perp$, τ=torque around a chosen axis.

OpenStax Ch 11: Static Fluids

1 atmosphere = 1 atm = 101.3 kPa = 1.013 bar = 760 torr = 760 mm Hg = 14.7 lb/in^2.

Units:	1 Pa = 1 N/m^2,	1 bar = 10^5 Pa,	1 mm Hg = 133.3 Pa.
Density:	$\rho = m/V$,	$\rho_{\mathrm{H_2O}} = 10^3$ kg/m^3 (4°C),	10^3 kg/m^3 = 1 g/cm^3.
Pressure:	$P = F/A$,	$P_2 = P_1 + \rho g d$,	$P_{\mathrm{abs}} = P_{\mathrm{atm}} + P_{\mathrm{gauge}}$.
Archimedes:	$F_B = \rho_{\mathrm{fluid}} g V_s$,	F_B = weight of displaced fluid.	

OpenStax Ch 12: Fluid Dynamics

Moving fluid:	$Q = Av$ = constant,	Bernouli Eqn: $P + \frac{1}{2}\rho v^2 + \rho g y$ = constant.
Viscosity:	Definition: $F = \eta A v/\ell$,	Poiseuille Eqn: $Q = \pi r^4 (P_2 - P_1)/(8\eta L)$.

OpenStax Ch 16: Oscillations and Waves

Oscillators:	$F = -kx = ma$,	$f = 1/T$,	$\omega = 2\pi f = 2\pi/T$,	$\omega = \sqrt{k/m}$,	$\omega = \sqrt{g/L}$.
Energy, speed:	$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$,	$E = \frac{1}{2}kA^2 = \frac{1}{2}mv_{\mathrm{max}}^2$,	$v_{\mathrm{max}} = \omega A$.		
Waves:	$\lambda = vT$,	$v = f\lambda$,	$I = P/A$,	$I = P/4\pi r^2$.	

Wave speed:	$v = \sqrt{F_T/(m/L)}$ (strings),	$v = (331\ \mathrm{m/s})\sqrt{T/(273\ \mathrm{K})}$ (sound in air).
Standing waves:	node to node = $\lambda/2$,	sketch displacement of string or molecules.
	nodes at both ends of strings.	nodes (antinodes) at closed (open) ends of pipes.

OpenStax Ch 17: Sound

Sound in air:	$v = (331\ \mathrm{m/s})\sqrt{T/273\ \mathrm{K}}$,	$v = 343$ m/s at 20°C,	$d = vt$,	$I = P/A$.
Sound level:	$\beta = (10\ \mathrm{dB})\log(I/I_0)$,	$I = I_0\ 10^{\beta/(10\ \mathrm{dB})}$,	$I_0 = 10^{-12}$ W/m^2.	

OpenStax Ch 13: Ideal Gases & Kinetic Theory

Moles:	$n = N/N_A$,	$n = M/M_A$,	M=sample mass.
Avogadro number:	$N_A = 6.022 \times 10^{23}$/mol,	1 u = (1 gram)/N_A ,	1 u = 1.6605×10^{-27} kg.
Temperature scales:	T(°C) = $\frac{5}{9}$[T(°F)-32],	T(°F)=$\frac{9}{5}$ T(°C)+32,	T(K)=T(°C)+273.15.
Thermal expansion:	$\Delta L = \alpha L_0 \Delta T$,	$\Delta V = \beta V_0 \Delta T$.	
Ideal Gas Law:	$PV = nRT = Nk_{\mathrm{B}}T$,	$R = 8.314$ J/mol·K,	$k_{\mathrm{B}} = R/N_A = 1.38 \times 10^{-23}$ J/K.
Kinetic Theory:	$\overline{\mathrm{KE}} = \frac{1}{2}mv_{\mathrm{rms}}^2 = \frac{3}{2}k_{\mathrm{B}}T$,	$v_{\mathrm{rms}} = \sqrt{3k_{\mathrm{B}}T/m} = \sqrt{3RT/M_A}$,	$m = M_A/N_A$ = atom or molecule.

OpenStax Ch 14: Heat Transfer

Heat units:	1.00 cal = 4.186 J,	1.00 Cal = 1.00 kcal = 4186 J.
Internal Energy:	$U = \frac{3}{2}NkT = \frac{3}{2}nRT$,	←(ideal monatomic gases).
Heats absorbed:	$Q = mc\Delta T$ (c =specific heat),	$Q = mL$ (L_F =fusion, L_V =vaporization).
For water:	c_{liq} = 1.00 cal/(g·C°) = 4.186 kJ/(kg ·C°),	c_{ice} = 0.50 cal/(g·C°) = 2.1 kJ/(kg ·C°).
	L_F = 79.7 kcal/kg = 333 kJ/kg,	L_V = 539 kcal/kg = 2260 kJ/kg.
Heat transfer:	Conduction: $P = \frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{l}$,	Radiation: $P_{\mathrm{net}} = \frac{\Delta Q}{\Delta t} = e\sigma A(T_1^4 - T_2^4)$.
Solar Energy:	$P = \frac{\Delta Q}{\Delta t} \approx (1000\ \mathrm{W/m^2})\ eA\cos\theta$,	$\sigma = 5.67 \times 10^{-8}$ W/m^2· K^4.

OpenStax Ch 15: The Laws of Thermodynamics

Process (const):	isobaric (P).	isothermal (T).	isochoric (V).	adiabatic ($Q = 0$).
1$^{\mathrm{st}}$ Law:	$\Delta U = Q - W$	W = area under $P(V)$.	$W = P\Delta V$ for isobaric.	
Heat Engines:	$W = Q_H - Q_L$,	$e = \frac{W}{Q_H} = 1 - \frac{Q_L}{Q_H}$		
AC, Heat Pumps:	$W = Q_H - Q_L$,	AC: COP = $\frac{Q_L}{W}$,	heat pumps: COP = $\frac{Q_H}{W}$.	
Power:	$P_{\mathrm{ave}} = W/t$,	or use $P_{\mathrm{ave}} = \frac{\text{energy}}{\text{time}}$,	$\frac{Q_L}{Q_H} = \frac{T_L}{T_H}$ for Carnot cycle.	
2$^{\mathrm{nd}}$ Law, Entropy:	$\Delta S_{\mathrm{total}} \geq 0$,	$\Delta S_{\mathrm{reversible}} = 0$,	$\Delta S_{\mathrm{system}} = Q/T_{\mathrm{ave}}$.	