Prefixes

z=10^{-21},	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},	E=10^{18},	Z=10^{21}
zepto,	atto,	femto,	pico,	nano,	micro,	milli,	centi,	kilo,	mega,	giga,	tera,	peta,	exa,	zeta.

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)
$c = 299\ 792\ 458$ m/s (speed of light)
u $= 1.6605402 \times 10^{-27}$ kg (atomic mass unit)
$k_B = 1.3806 \times 10^{-23}$ J/K (Boltzmann's 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)
$N_A = 6.02214 \times 10^{23}$/mol (Avogadro's number)
$R = k_B N_A = 8.31446 \frac{\text{J}}{\text{mol·K}} = 0.082057 \frac{\text{L·atm}}{\text{mol·K}}$ (gas constant)

Units & 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 = 1.6605×10^{-27} kg, or, molar masses for the element (1 mole = 6.022×10^{23} atoms), measured in grams. ($N_A \times 1$ 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: $A = 4\pi r^2$, $V = \frac{4\pi}{3} r^3$

$\sin\theta = (\text{opp})/(\text{hyp})$, $\cos\theta = (\text{adj})/(\text{hyp})$, $\tan\theta = (\text{opp})/(\text{adj})$, $(\text{opp})^2 + (\text{adj})^2 = (\text{hyp})^2$.

$\sin^2\theta + \cos^2\theta = 1$, $a^2 + b^2 - 2ab\cos\gamma = c^2$, $\frac{\sin\alpha}{a} = \frac{\sin\beta}{b} = \frac{\sin\gamma}{c}$, $\alpha + \beta + \gamma = 180° = \pi$ rad.

Chapter 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%.

Chapter 2 - Vectors - Magnitude & Direction

2D Vectors:	$\vec{\mathbf{a}} = a_x\hat{\mathbf{i}} + a_y\hat{\mathbf{j}}$,	magnitude = $a = \sqrt{a_x^2 + a_y^2}$,	direction $\to \tan\theta = a_y/a_x$.
Components:	$a_x = a\cos\theta$,	$a_y = a\sin\theta$,	θ=angle to $+x$-axis.
Addition:	$\vec{\mathbf{a}} + \vec{\mathbf{b}}$, head to tail.	Subtraction: $\vec{\mathbf{a}} - \vec{\mathbf{b}}$ is $\vec{\mathbf{a}} + (-\vec{\mathbf{b}})$,	$-\vec{\mathbf{b}}$ is $\vec{\mathbf{b}}$ reversed.
Scalar product:	$\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = ab\cos\phi$,	$\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = a_xb_x + a_yb_y + a_zb_z$,	$\hat{\mathbf{i}} \cdot \hat{\mathbf{i}} = 1$, $\hat{\mathbf{i}} \cdot \hat{\mathbf{j}} = 0$, etc.
Cross product:	$\lvert\vec{\mathbf{a}} \times \vec{\mathbf{b}}\rvert = ab\sin\phi$,	$\hat{\mathbf{i}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}}$, etc.	$\hat{\mathbf{i}} \times \hat{\mathbf{i}} = \hat{\mathbf{j}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}} \times \hat{\mathbf{k}} = 0$.

Chapter 3 - 1D Kinematics - Straight-line motion

Velocity:	$v_{\text{avg}} = \Delta x/\Delta t$	$\Delta x = x - x_0$	$v(t) = \frac{dx}{dt}$= slope of $x(t)$
Acceleration:	$a_{\text{avg}} = \Delta v/\Delta t$	$\Delta v = v - v_0$	$a(t) = \frac{dv}{dt}$= slope of $v(t)$
Integrals = areas:	$x(t) = x_0 + \int_0^t v(t')dt'$,	$v(t) = v_0 + \int_0^t a(t')dt'$.	
Constant acceleration:	$v = v_0 + at$,	$v_{\text{avg}} = \frac{1}{2}(v_0 + v)$,	$\Delta x = v_{\text{avg}}\Delta t$.
	$x = x_0 + v_0t + \frac{1}{2}at^2$,	$x = x_0 + v_{\text{avg}}t$,	$v^2 = v_0^2 + 2a\Delta x$.
Free fall ($+y$-axis is up):	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$,	$v_y = v_{0y} - gt$,	$v_y^2 = v_{0y}^2 - 2g\Delta y$.

Chapter 4 - 2D and 3D Motion - Vector displacement, velocity, acceleration

Position:	$\vec{\mathbf{r}} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}$	$\vec{\mathbf{r}} = (x, y, z)$	$\Delta\vec{\mathbf{r}} = (\Delta x, \Delta y, \Delta z)$
Velocity:	$\vec{\mathbf{v}}_{\text{avg}} = \Delta\vec{\mathbf{r}}/\Delta t$	$\vec{\mathbf{v}} = d\vec{\mathbf{r}}/dt$	$\Delta\vec{\mathbf{r}} = \vec{\mathbf{r}} - \vec{\mathbf{r}}_0$
Acceleration:	$\vec{\mathbf{a}}_{\text{avg}} = \Delta\vec{\mathbf{v}}/\Delta t$	$\vec{\mathbf{a}} = d\vec{\mathbf{v}}/dt$	$\Delta\vec{\mathbf{v}} = \vec{\mathbf{v}} - \vec{\mathbf{v}}_0$
Projectiles:	$a_x = 0$	$v_x = v_{0x}$	$x = x_0 + v_{0x}t$
(+y-axis is up)	$a_y = -g$	$v_y = v_{0y} - gt$	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$
Relative Motion:	$\vec{\mathbf{v}}_{\text{BS}} = \vec{\mathbf{v}}_{\text{BW}} + \vec{\mathbf{v}}_{\text{WS}}$	**B**oat, **S**hore, **W**ater.	BS is "boat relative to shore", etc.
Circular motion:	$a_c = v^2/r = \omega^2 r$	$v = 2\pi r/T = \omega r$	$\omega = 2\pi/T$, T=period of 1 rev.

Chapter 5 - Newton's laws and forces

Newton's 1st Law:	$\vec{a} = \frac{d\vec{v}}{dt} = 0$ 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.

Chapter 6 - Friction, circular motion

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.
Centripetal acceleration:	$a_c = v^2/r$,	Points towards the center of the circle.
Rates of circular motion:	speed $v = 2\pi r/T = 2\pi r f$,	frequency $f = \frac{1}{T}$, T=period of one revolution.

Chapter 7 - Work and kinetic energy

Work done by a force:	$dW = \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}} = F\ dr\ \cos\theta$	$W_{AB} = \int_A^B \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$ (along the path $A \to B$)
Examples:	$W = \vec{\mathbf{F}} \cdot \Delta\vec{\mathbf{r}}$ (constant $\mathbf{F}$),	$W_s = -\frac{1}{2}k(x_B^2 - x_A^2)$ (spring $F = -kx$).
Work-KE theorem, power:	$\Delta\text{KE} = W_{\text{net}}$ = all works on m.	$\text{KE} = \frac{1}{2}mv^2$, $P = \frac{dW}{dt}$, $P_{\text{ave}} = \frac{\Delta W}{\Delta t}$.

Chapter 8 - Potential energy and Conservation of energy

PE for gravity:	$\Delta U = mg\Delta y$,	$U(y) = mgy+$ constant,	$\leftarrow$(near Earth' surface).
PE for springs:	$\Delta U = \frac{1}{2}k(x_B^2 - x_A^2)$,	$U(x) = \frac{1}{2}kx^2$ + constant.	
Any arbitrary system:	$\Delta E_{\text{mec}} = W_{\text{nc}}$	$E_{\text{tot}} = E_{\text{mec}} + E_{\text{thermal}} + E_{\text{other}}$,	$\Delta E_{\text{tot}} = 0$.

Chapter 9 - Linear momentum and collisions

Linear Momentum:	$\vec{\mathbf{p}} = m\vec{\mathbf{v}}$,	Impulse Theorem:	$\Delta\vec{\mathbf{p}} = \vec{\mathbf{J}} = \int \vec{\mathbf{F}}(t)\,dt = \vec{\mathbf{F}}_{\text{ave}}\Delta t$.
Instantaneous force:	$\vec{\mathbf{F}} = \frac{d\vec{\mathbf{p}}}{dt}$,	Average force:	$\vec{\mathbf{F}}_{\text{ave}} = \frac{\Delta\vec{\mathbf{p}}}{\Delta t}$.
Conservation (@ $\vec{\mathbf{F}}_{\text{net}} = 0$):	$\Delta\vec{\mathbf{p}}_{\text{total}} = 0$,	$\vec{\mathbf{p}}_{1\text{i}} + \vec{\mathbf{p}}_{2\text{i}} = \vec{\mathbf{p}}_{1\text{f}} + \vec{\mathbf{p}}_{2\text{f}}$,	i=initial, f=final.

Center of mass:	$\vec{\mathbf{r}}_{\text{com}} = \frac{m_1\vec{\mathbf{r}}_1 + m_2\vec{\mathbf{r}}_2 + \ldots}{m_1 + m_2 + \ldots}$,	$\vec{\mathbf{v}}_{\text{com}} = \frac{m_1\vec{\mathbf{v}}_1 + m_2\vec{\mathbf{v}}_2 + \ldots}{m_1 + m_2 + \ldots}$	
1D elastic collisions:	$v_{1\text{f}} = 2v_{\text{com}} - v_{1\text{i}}$	$v_{2\text{f}} = 2v_{\text{com}} - v_{2\text{i}}$,	Equal masses swap velocities.
Other collisions:	$\vec{P}_{\text{total}} = M\vec{\mathbf{v}}_{\text{com}}$ = const.	$\vec{P}_{\text{total}} = m_1\vec{\mathbf{v}}_1 + m_2\vec{\mathbf{v}}_2$ = const.	

Chapters 10 - Rotational motion

Coordinates:	1 rev = 2π rad	1 rev = $360°$,	$\omega = 2\pi f$,	$f = \frac{1}{T}$.
Averages:	$\omega_{\text{ave}} = \frac{\Delta\theta}{\Delta t}$,	$\Delta\theta = \omega_{\text{ave}}\Delta t$,	$\alpha_{\text{ave}} = \frac{\Delta\omega}{\Delta t}$,	$\Delta\omega = \alpha_{\text{ave}}\Delta t$.
Radius factors:	$l = \theta r$,	$v = \omega r$,	$a_{\tan} = \alpha r$,	$a_c = \omega^2 r$.
Const. acceleration:	$\omega = \omega_0 + \alpha t$,	$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$,	$\omega_{\text{ave}} = \frac{1}{2}(\omega_0 + \omega)$,	$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$.

Torque:	$\vec{\tau} = \vec{\mathbf{r}} \times \vec{\mathbf{F}}$,	$\tau = rF\sin\theta$,	$\tau = r_\perp F = rF_\perp$,	$\hat{\mathbf{i}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}}$, etc.	
Dynamics, inertia:	$I = \Sigma\, m\, r^2$,	$I = \int dm\, r^2$,	$\tau_{\text{net}} = I\alpha$,	$K_{\text{rot}} = \frac{1}{2}I\omega^2$.	
Rotational inertias:	$I_0 = MR^2$,	$I_0 = \frac{1}{2}MR^2$,	$I_0 = \frac{2}{5}MR^2$,	$I_0 = \frac{1}{12}ML^2$,	$I = I_0 + md^2$.
(about centers)	thin hoop,	solid cylinder,	solid sphere,	thin rod,	$\uparrow$ about parallel axis.
Work, power:	$dW = \tau\, d\theta$,	$W = \int \tau\, d\theta$,	$W = \tau_{\text{ave}}\Delta\theta$,	$P = \tau\omega$.	

Chapter 11 - Angular momentum

Angular momentum:	$\vec{\mathbf{l}} = \vec{\mathbf{r}} \times \vec{\mathbf{p}}$,	$l = rp\sin\theta$,	$l = r_\perp p = rp_\perp$,	$\vec{\mathbf{L}} = \int \vec{\mathbf{r}} \times \vec{\mathbf{v}}\, dm$,	$L = I\omega$.
Dynamics:	$\frac{d}{dt}\vec{\mathbf{L}} = \vec{\tau}_{\text{net}}$,	$\Delta\vec{\mathbf{L}} = \vec{\tau}_{\text{ave}}\Delta t$,	conservation$\rightarrow$	$\vec{\mathbf{L}}_{\text{total}}$ =const.	$\leftarrow$(@ $\vec{\tau}_{\text{net}} = 0$).

Chapter 12 - Static equilibrium

Statics requirements:	$\sum F_x = \sum F_y = \sum F_z = 0$,	$\sum \tau = 0$,	$\tau = rF\sin\theta$.
Stress & strain:	stress $= F_\perp / A$,	strain $= \Delta L / L_0$,	stress $= Y\times$ strain.
Shear forces:	stress $= F_\parallel / A$,	strain $= \Delta x / L_0$,	stress $= S\times$ strain.
Bulk modulus B:	b-stress $= \Delta p$,	b-strain $= \Delta V / V_0$,	b-stress $= B\times$ b-strain.
Units:	stress in Pa=N/m^2,	strain = % or no units,	Y, S, B in Pa=N/m^2.

Chapter 13 - Gravitation

Gravitational force:	$F = Gm_1m_2/r^2$,	$F = mg$,	$g = GM/r^2$,	$v_{\text{escape}} = \sqrt{2GM/r}$.
Gravitational PE:	$U = -Gm_1m_2/r$,	$\Delta U + \Delta K = 0$,	$\Delta K = -\Delta U$,	$\Delta K = \frac{1}{2}m(v_{\text{f}}^2 - v_{\text{i}}^2)$.
Orbits:	$F = mv^2/r$,	$v = 2\pi r/T$,	$v_{\text{orb}} = \sqrt{GM/r}$,	Kepler: $T^2 = \frac{4\pi^2}{GM}\bar{r}^3$.

Chapter 14 - 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:	$\rho = m/V$,	$\rho_{\text{H}_2\text{O}} = 10^3$ kg/m^3 (4°C),	10^3 kg/m^3 = 1 g/cm^3.
Pressure:	$p = F/A$,	$p_2 = p_1 + \rho g d$,	$p_{\text{abs}} = p_{\text{atm}} + p_{\text{gauge}}$.
Archimedes:	$F_B = \rho_{\text{fluid}} g V_s$,	Bernoulli energy conserv.$\rightarrow$	$p + \rho g y + \frac{1}{2}\rho v^2 =$ const.
Flow rates:	$Q = Av$,	$Q_m = \rho A v$,	$Q = (p_2 - p_1)\pi r^4/(8\eta L)$.
Viscosity:	$F = \eta v A/L$,	$N_R = 2\rho v r/\eta$,	$N_R < 2000$ laminar, $N_R > 3000$ turbulent.

V2 - Chapter 1 - Temperature & Heat transfer

Moles:	$n = N/N_A$,	$n = M/M_A$,	$N_A = 6.022\times 10^{23}$/mol,	1 u $\times N_A$ = 1 gram.
Temperatures:	$T_{\text{C}} = \frac{5}{9}(T_{\text{F}} - 32)$,	$T_{\text{F}} = \frac{9}{5}T_{\text{C}} + 32$,	$T_{\text{K}} = T_{\text{C}} + 273.15$,	$T = \frac{p}{p_{\text{TP}}}T_{\text{TP}}$.
Expansion:	$\Delta L = \alpha L_0 \Delta T$,	$\Delta A = 2\alpha A_0 \Delta T$,	$\Delta V = \beta V_0 \Delta T$,	$\beta = 3\alpha$ (solids).
Heat transfers:	$Q = mc\Delta T$,	$Q = mL_F$,	$Q = mL_V$,	1 cal = 4.186 J.
Heat flow rates:	$P_{\text{cond}} = kA\Delta T/d$,	$P_{\text{rad}} = \sigma e A(T_2^4 - T_1^4)$,	$P_{\text{solar}} \approx (1\ \frac{\text{kW}}{\text{m}}^2)eA\cos\theta$.	

V2 - Chapter 2 - Kinetic theory & Ideal gases

Ideal gases:	$pV = nRT$,	$pV = Nk_{\text{B}}T$,	$R = 8.314\ \frac{\text{J}}{\text{mol}\cdot\text{K}}$,	$k_{\text{B}} = R/N_A$.
Kinetic theory:	$\overline{\text{KE}}_{\text{trans}} = \frac{m}{2}v_{\text{rms}}^2 = \frac{3}{2}k_{\text{B}}T$,	$v_{\text{rms}} = \sqrt{\frac{3k_{\text{B}}T}{m}} = \sqrt{\frac{3RT}{M_A}}$,	$m = M_A/N_A$,	m =molecule.
Internal energy:	$E_{\text{int}} = nC_VT$,	$E_{\text{int}} = n\frac{d}{2}RT$,	$E_{\text{int}} = N\frac{d}{2}k_{\text{B}}T$,	$d = 3, 5, 6$
Molecules:	monatomic, $d = 3$,	diatomic, $d = 5$,	polyatomic, $d = 6$,	$\leftarrow$ room temp.
Specific heats:	$Q = nC\Delta T$,	$C_V = \frac{d}{2}R$,	$C_P = C_V + R$,	$\gamma \equiv C_P/C_V$.

V2 - Chapters 3,4 - 1$^{\text{st}}$ and 2$^{\text{nd}}$ Laws of Thermodynamics

Process (constant):	isobaric (p)	isothermal (T)	isochoric (V)	adiabatic (pV^γ with $Q = 0$)
1$^{\text{st}}$ Law:	$\Delta E_{\text{int}} = Q - W$,	$W = \int_i^f p\ dV$,	$W_{\text{isobaric}} = p\ \Delta V$,	$W_{\text{isothermal}} = nRT\ln(V_f/V_i)$.
2$^{\text{nd}}$ Law:	$\Delta S_{\text{total}} \geq 0$,	$\Delta S \equiv \int_i^f dQ/T$,	$\Delta S = mc\ln(T_f/T_i)$,	$\Delta S = mL/T$.
Heat engines:	$W = Q_H - Q_L$,	$\varepsilon = W/Q_H$,	Carnot: $\frac{Q_L}{Q_H} = \frac{T_L}{T_H}$,	$P_{\text{mech}} = W/t$.
AC, heat pumps:	$K_{\text{AC}} = Q_L/W$,	$P_{\text{cool}} = Q_L/t$,	$K_{\text{HP}} = Q_H/W$,	$P_{\text{heat}} = Q_H/t$.