Chapter 1: Concepts of Motion	
displacement:	$\Delta\vec{r} = \vec{r}_f - \vec{r}_i$
Average speed:	$s_{ave} = \dfrac{\text{total distance}}{\Delta t} = \dfrac{d}{\Delta t}$
Average velocity:	$\vec{v}_{ave} = \dfrac{\Delta\vec{r}}{\Delta t}$
Average Acceleration:	$\vec{a}_{ave} = \dfrac{\Delta\vec{v}}{\Delta t}$

Chapter 2: Kinematics in one dimension	
displacement:	$\Delta x = x_f - x_i$
	$x_f = x_i + \int_{t_i}^{t_f} v_x dx$
Average speed:	$s_{ave} = \dfrac{\text{total distance}}{\Delta t}$
Instantaneous velocity:	$v = \lim_{\Delta t \to 0} \dfrac{\Delta x}{\Delta t} = \dfrac{dx}{dt}$
Instantaneous acceleration:	$a = \dfrac{dv}{dt} = \dfrac{d^2x}{dt^2}$
For Constant Acceleration	
constant acceleration:	$a = a_{ave} = \dfrac{v_f - v_i}{\Delta t}$
velocity (with a and t):	$v(t) = v_0 + at$
position (with a and t):	$x(t) = \frac{1}{2}at^2 + v_0 t + x_0$
velocity (with a and x):	$v^2 = v_0^2 + 2a(x - x_0)$
position (with v and t):	$x(t) = \frac{1}{2}(v_0 + v)t + x_0$
average velocity:	$v_{ave} = \frac{1}{2}(v_0 + v)$
average velocity:	$v_{ave} = v_0 + \frac{1}{2}at^2$
free fall acceleration:	$a_{freefall} = -g$

Chapter 3: Vectors and Coordinate Systems	
Unit Vectors:	have magnitude (length) = 1
	x-direction, $(\hat{i})$
	y-direction, $(\hat{j})$
	z-direction, $(\hat{k})$
Vector equation:	$\vec{s} = \vec{a} + \vec{b}$
Vector commutative law:	$\vec{a} + \vec{b} = \vec{b} + \vec{a}$
Vector associative law:	$(\vec{a} + \vec{b}) + \vec{c} = \vec{a} + (\vec{b} + \vec{c})$
Vector subtraction:	$\vec{d} = \vec{a} - \vec{b} = \vec{a} + (-\vec{b})$
Vector components:	$\vec{a} = a_x\hat{i} + a_y\hat{j}$
	$a_x = a \cos\theta$ and $a_y = a \sin\theta$
	$a = \sqrt{a_x^2 + a_y^2}$ and $\tan\theta = \dfrac{\mathrm{a_y}}{\mathrm{a_x}}$
Vector addition:	$\vec{r} = \vec{a} + \vec{b}$
	$\vec{r} = r_x\hat{i} + r_y\hat{j} + r_z\hat{k}$
	$r_x = a_x + b_x$
	$r_y = a_y + b_y$
	$r_z = a_z + b_z$
vector by scalar multip.:	$2\vec{a} = 2a_x\hat{i} + 2a_y\hat{j} + 2a_z\hat{k}$
Scalar Product:	$\vec{a} \cdot \vec{b} = ab \cos\phi$
	$\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z$
	$\vec{a} \cdot \vec{b} = \vec{b} \cdot \vec{a}$
Vector Product:	$\vec{c} = \vec{a} \times \vec{b}$
	$\lvert c \rvert = ab \sin\phi$
	direction from Right-hand rule
	$\vec{c} = (a_y b_z - a_z b_y)\hat{i} + (a_z b_x - a_x b_z)\hat{j}$
	$+ (a_x b_y - a_y b_x)\hat{k}$
	$\vec{a} \times \vec{b} = -(\vec{b} \times \vec{a})$

Chapter 4: Kinematics in two dimensions	
Position:	$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$
Displacement:	$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$
	$\Delta\vec{r} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}$
Average Velocity:	$\vec{v}_{ave} = \frac{\Delta\vec{r}}{\Delta t}$
Instantaneous Velocity:	$\vec{v} = \frac{d\vec{r}}{dt}$
	$\vec{v} = v_x\hat{i} + v_y\hat{j} + v_z\hat{k}$
	$v_x = \frac{dx}{dt}$, $v_y = \frac{dy}{dt}$, $v_z = \frac{dz}{dt}$
Average acceleration:	$\vec{a}_{ave} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t} = \frac{\Delta\vec{v}}{\Delta t}$
Instantaneous acceleration:	$\vec{r} = \frac{d\vec{v}}{dt}$
	$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$
	$a_x = \frac{dv_x}{dt}$, $a_y = \frac{dv_y}{dt}$, $a_z = \frac{dv_z}{dt}$
Projectile Motion	
Initial velocity:	$v_0 = v_{0x}\hat{i} + v_{0y}\hat{j}$
	$v_{0x} = v_0 \cos\theta$ and $v_{0y} = v_0 \sin\theta$
Horizonatal Motion:	$x(t) = v_{0x}t + x_0$
Vertical Motion:	$y(t) = -\frac{1}{2}gt^2 + v_{0y}t + y_0$
	$v_y = v_{0y}t - gt$
	$v_y^2 = v_{0y}^2 - 2g(y - y_0)$
Equation of the path (trajectory):	$y = (\tan\theta_0)\mathrm{x} - \frac{\mathrm{gx}^2}{2(\mathrm{v}_0 \cos\theta_0)^2}$
Horizontal Range:	$R = \frac{v_0^2}{g}\sin 2\theta_0$

Relative Motion: Labels are for a point P in reference frames A,B	
1-dimension:	$x_{PA} = x_{PB} + x_{BA}$
	$v_{PA} = v_{PB} + v_{BA}$
	$a_{PA} = a_{PB}$
2-dimensions:	$\vec{r}_{PA} = \vec{r}_{PB} + \vec{r}_{BA}$
	$\vec{v}_{PA} = \vec{v}_{PB} + \vec{v}_{BA}$
	$\vec{a}_{PA} = \vec{a}_{PB}$
Uniform Circular Motion	
angular position:	$\theta(radians) = \frac{\text{arclength}}{\text{radius}} = \frac{s}{r}$
	$\theta_f = \theta_i + \omega\Delta t$
arclength:	$s = r\theta$
angular velocity:	$\omega_{ave} = \frac{\Delta\theta}{\Delta t}$
	$\omega = \frac{d\theta}{dt}$
centripedal acceleration:	$\vec{a} = \frac{v^2}{r}, towardscenterofcircle$
Period of revolution:	$T = \frac{2\pi r}{v}$ (Uniform Circular Motion)

Units	
Length:	1 m = 3.28 ft
	1 mi = 1.61 km
	1 ft = 12 in
Time:	1 min = 60 s
	60 min = 1 hr
	24 hr = 1 day
	365 days = 1 year
Speed:	1 m/s = 3.28 ft/s
	1 km/hr = 0.621 mi/hr

SI Prefixes

Exponent	Prefix	SI Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	cento	c
10^{-1}	deci	d
10^{1}	deca	da
10^{2}	hecto	h
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T

Chapter 5: Force and Motion-I	
Newton's 1st law:	if $\vec{F}_{net} = 0$, then $\vec{a} = 0$
Newton's 2nd law:	$\vec{F}_{net} = m\vec{a}$
	$F_{net,x} = ma_x$
	$F_{net,y} = ma_y$
	$F_{net,z} = ma_z$
Superposition of Forces: (Net force)	$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ...$
Gravitational Force:	$F_g = mg$ (magnitude)
Weight:	$W = mg$
Newton's 3rd law: (for two objects, B & C)	$\vec{F}_{BC} = -\vec{F}_{CB}$

Chapter 6,7,8: Forces	
Static Friction:	$f_{s,max} = \mu_s F_N$
Kinetic Friction:	$f_k = \mu_k F_N$
Drag Force:	$D = \frac{1}{2}C\rho Av^2$
Terminal speed:	$v_t = \sqrt{\dfrac{2F_g}{C\rho A}}$
Centripetal acceleration:	$a = \dfrac{v_2}{R}$
Centripetal Force:	$F = m\dfrac{v_2}{R}$

Constants	
Gravitational Acceleration:	$g = 9.8\frac{m}{s^2}$
Atomic Mass Units:	$1 \text{ u} = 1.66 \times 10^{-27}\text{kg}$

Chapter 9: Kinetic Energy and Work	
Kinetic Energy:	$K = \frac{1}{2}mv^2$
Work from a constant force:	$W = Fd\ cos\ \phi$
	$W = \vec{F} \cdot \vec{d}$
Work-Kinetic Energy Theorem:	$\Delta K = K_f - Ki = W$
Work done by the gravitational force:	$W_g = mgd\ cos\ \phi$
Work down lifting and lowering object:	$\Delta K = K_f - Ki = W_a + W_g$
Hooke's Law (spring force):	$\vec{F}_s = -k\vec{d}$
1-D:	$F_x = -kx$
Work done by a spring force:	$W_s = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2$
Work done by a variable force (1-D):	$W = \int_{x_i}^{x_f} F(x)\mathrm{d}x$
Work done by a variable force (3-D):	$W = \int_{r_i}^{r_f} \mathrm{d}W = \int_{x_i}^{x_f} F_x\mathrm{d}x + \int_{y_i}^{y_f} F_y\mathrm{d}y + \int_{z_i}^{z_f} F_z\mathrm{d}z$
Average power:	$P_{ave} = \dfrac{W}{\Delta t}$
Instantaneous power:	$P = \dfrac{\mathrm{d}W}{\mathrm{d}t}$
Instantaneous power:	$P = \vec{F} \cdot \vec{v}$

Chapter 10: Potential Energy and Conservation of Energy	
Potential Energy:	$\Delta U = -W$
1-D:	$\Delta U = -\int_{x_i}^{x_f} F(x)dx$
Gravitational Pot. Energy (change):	$\Delta U = mg(y_f - y_i)$
Gravitational Pot. Energy:	$U(y) = mgy$
Elastic Potential Energy, (spring):	$U(x) = \frac{1}{2}kx^2$
Mechanical Energy:	$E_{mech} = K + U$
Cons. of Mechanical Energy:	$K_2 + U_2 = K_1 + U_1$
	$\Delta E_{mech} = \Delta K + \Delta U = 0$
Force from Pot. Energy curve, 1-D:	$F(x) = -\frac{dU(x)}{dx}$
Kinetic energy from Pot. Energy curve, 1-D:	$K(x) = E_{mech} - U(x)$
Work done on System, no friction:	$W = \Delta E_{mech}$
Increase in thermal Energy by sliding:	$\Delta E_{th} = f_k d$
Work done on System, with friction:	$W = \Delta E_{mech} + \Delta E_{th}$
Total Energy change of a system:	$W = \Delta E = \Delta E_{mech} + \Delta E_{th} + \Delta E_{int}$
Total Energy change of an isolated system:	$\Delta E_{mech} + \Delta E_{th} + \Delta E_{int} = 0$
Average Power:	$P_{ave} = \frac{\Delta E}{\Delta t}$
Instantaneous Power:	$P = \frac{dE}{dt}$

Chapter 11: Impulse and Momentum	
	$F_{net,x} = Ma_{com,x}$ $\quad F_{net,y} = Ma_{com,y}$ $\quad F_{net,z} = Ma_{com,z}$
Linear momentum of a particle:	$\vec{p} = m\vec{v}$
Newton's 2nd, Force and Momentum (particle):	$\vec{F}_{net} = \frac{d\vec{p}}{dt} = m\vec{a}$
Linear momentum of a system of particles:	$\vec{P}_system = \sum_{i=1}^{n} m_i\vec{v}_i$
Newton's 2nd, Force and Momentum (system):	$\vec{F}_{net} = \frac{d\vec{P}_{system}}{dt}$
Impulse (collision):	$\vec{J} = \int_{t_i}^{t_f} \vec{F}(t)dt$
Linear momentum-impulse theorem:	$\Delta\vec{p} = \vec{J}$
linear momentum, closed, isolated system:	$\vec{P}_{system} = constant$
Cons. of linear momentum, system:	$\vec{P}_i = \vec{P}_f$
Cons. of linear momentum, two body,closed system:	$\vec{p}_{1,i} + \vec{p}_{2,i} = \vec{p}_{1,f} + \vec{p}_{2,f}$
Completely inelastic collision ($v_{2,i} = 0$), 1-D:	$V = \frac{m_1}{m_1 + m_2}v_{1,i}$
Elastic Collision, 1-D final velocities:	$v_{1,f} = \frac{m_1 - m_2}{m_1 + m_2}v_{1,i} + \frac{2m_2}{m_1 + m_2}v_{2,i}$
	$v_{2,f} = \frac{2m_1}{m_1 + m_2}v_{1,i} + \frac{m_2 - m_1}{m_1 + m_2}v_{2,i}$
Collision in 2-D: momentum:	$\vec{P}_{1,i} + \vec{P}_{2,i} = \vec{P}_{1,f} + \vec{P}_{2,f}$
Collision in 2-D (elastic only):	$K_{1,i} + K_{2,i} = K_{1,f} + K_{2,f}$

Geometry and other useful equations			
Surface Area:		Volume:	
square:	$l \times w$	Cube:	$l \times w \times h$
circle:	πr^2	Sphere:	$\frac{4}{3}\pi r^3$
sphere:	$4\pi r^2$	Cylinder:	$\pi r^2 h$
cylinder:	$2\pi r^2 + 2\pi r h$		
Circumference of a circle:	$C = 2\pi r$		
Area of a circle:	$A_{circle} = \pi r^2$		
Density:	$\rho = \frac{m}{V}$		
Quadratic formula:	$(ax^2 + bx + c = 0)$		
	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$		
Angular velocity, ω:	$\omega = \frac{v}{r}$		