General Physics Equation Summary Sheet

SI UNITS

Length	m
Mass	kg
Time	s
Electric current	A
Temperature	K
Luminous intensity	Cd

DERIVED UNITS

Volume	m^3
Force	N
Energy/Work	J
Power	W
Pressure	Pa
Charge	C
Resistance	Ω
Capacitance	F

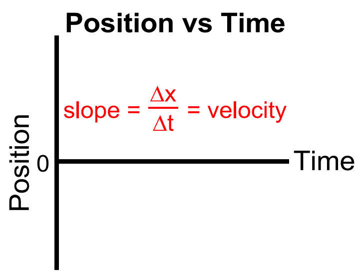
METRIC PREFIXES

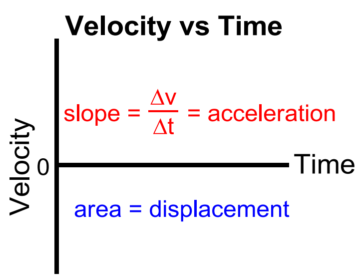
Terra	10^{12}
Giga	10^{9}
Mega	10^{6}
kilo	10^{3}
centi	10^{-2}
milli	10^{-3}
μicro	10^{-6}
nano	10^{-9}
pico	10^{-12}
femto	10^{-15}
atto	10^{-18}

KINEMATICS

Δx	Displacement
$v = \frac{\Delta x}{\Delta t}$	Velocity
$a = \frac{\Delta v}{\Delta t}$	Acceleration

No Acceleration	**Uniform Acceleration**
$\Delta x = vt$	$\Delta x = v_{avg}t$
	$\Delta x = v_i t + \frac{1}{2}at^2$
	$v_f^2 = v_i^2 + 2a\Delta x$
	$v_f = v_i + at$





MECHANICS

Newton's Laws of Motion	
1^{st} Law	If $\Sigma F = 0$, then v = constant
2^{nd} Law	$\Sigma F = ma$
3^{rd} Law	$F_{1\rightarrow 2} = -F_{2\rightarrow 1}$

$F_g = G\frac{m_1 m_2}{r^2}$	Gravity
$G = 6.67 \times 10^{-11}\frac{N \cdot m^2}{kg^2}$	Gravitational Constant
$W = mg$	Weight
$F_{fmax} = \mu_s F_N$	Static Friction
$F_f = \mu_k F_N$	Kinetic Friction

WORK AND ENERGY

$W = (F\cos\theta)d$	Work
$E = KE + U$	Mechanical Energy
$KE_i + U_i = KE_f + U_f$	Conservation of Mechanical Energy
$KE = \frac{1}{2}mv^2$	Kinetic Energy (Translational)
$U_{gravitational} = mgy$	Gravitational Potential Energy
$U_{elastic} = \frac{1}{2}kx^2$	Elastic Potential Energy
$W_{NC} = \Delta E$	Work of Nonconservative Forces
$W_{net} = \Delta KE$	Work-Energy Theorem
$F = -kx$	Hooke's Law (Spring Force)
$P = \frac{W}{\Delta t} = Fv$	Power

MOMENTUM AND COLLISIONS

$p = mv$	momentum
$F\Delta t = \Delta p$	Impulse-Momentum Theorem
Elastic Collisions	**Perfectly Inelastic Collisions**
$p_i = p_f$	$p_i = p_f$
$KE_i = KE_f$	$KE_i > KE_f$

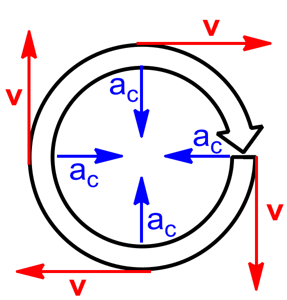
ROTATIONAL KINEMATICS

	Linear	Angular	Relation
Displacement	Δx	$\Delta\theta$	$\Delta x = r\,\Delta\theta$
Velocity	$v = \frac{\Delta x}{\Delta t}$	$\omega = \frac{\Delta\theta}{\Delta t}$	$v = r\omega$
Acceleration	$a = \frac{\Delta v}{\Delta t}$	$\alpha = \frac{\Delta\omega}{\Delta t}$	$a = r\alpha$

No Acceleration		**Uniform Acceleration**	
linear	**angular**	**linear**	**angular**
$\Delta x = vt$	$\Delta\theta = \omega t$	$\Delta x = v_{avg}t$	$\Delta\theta = \omega_{avg}t$
		$\Delta x = v_i t + \frac{1}{2}at^2$	$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$
		$v_f^2 = v_i^2 + 2a\Delta x$	$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$
		$v_f = v_i + at$	$\omega_f = \omega_i + \alpha t$

UNIFORM CIRCULAR MOTION

$a_c = \frac{v^2}{r}$	Centripetal Acceleration
$F = ma_c = \frac{mv^2}{r}$	Centripetal Force



ROTATIONAL DYNAMICS

$\tau = F_{\perp} r$ $\tau = (F\sin\theta)\,r$	Torque
$I = \sum mr^2$	Moment of Inertia
$x_{CG} = \frac{\sum m_i x_i}{\sum m_i}$	Center of Gravity
$\Sigma F = 0$ $\Sigma\tau = 0$	Conditions for Equilibrium
Angular	**Linear**
$\Delta\theta$	d
ω	v
α	a
I	m
τ	F
$\Sigma\tau = I\alpha$	$\Sigma F = ma$
$KE_{rot} = \frac{1}{2}I\omega^2$	$KE = \frac{1}{2}mv^2$
$W = \tau(\Delta\theta)$	$W = Fd$
$L = I\omega$	$p = mv$

ELASTICITY OF SOLIDS

$\frac{F}{A} = Y\frac{\Delta L}{L_0}$	Stretching/Compression
$\frac{F}{A} = S\frac{\Delta x}{h}$	Shear Deformation
$\Delta P = -B\frac{\Delta V}{V}$	Volume Deformation

GASES

$P = \frac{F}{A}$	Pressure
$p_1V_1 = p_2V_2$	Boyle's Law
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	Charles' Law
$\frac{V_1}{n_1} = \frac{V_2}{n_2}$	Avogadro's Principle
$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$	Combined Gas Law
$pV = nRT$	Perfect Gas Law
$p_{total} = p_A + p_B + p_C + \dots$ $p_A = \chi_A p_{total}$	Dalton's Law of Partial Pressures

SIMPLE HARMONIC MOTION

$x = A\cos(\omega t)$	Displacement
$v = -A\omega\sin(\omega t)$ $v_{max} = A\omega$	Velocity
$a = -A\omega^2\cos(\omega t)$ $a_{max} = A\omega^2$	Acceleration
$f = \frac{1}{T}$	Frequency / Period
$\omega = 2\pi f = \frac{2\pi}{T}$	Frequency Factor
$\omega = \sqrt{\frac{k}{m}}$	Frequency Factor for Springs
$\omega = \sqrt{\frac{g}{L}}$	Frequency Factor for Pendulums
$x = A\cos(\omega t + \varphi)$	φ = phase shift
$y(x,t) = A\cos(\omega t \pm kx)$	$\omega = 2\pi f$ $k = \frac{2\pi}{\lambda}$
Standing Waves	
$\lambda f = v$	Wave Speed
$\lambda_n = \frac{2L}{n} \quad n = 1,2,3\dots$	String fixed at both ends Pipe open at both ends
$\lambda_n = \frac{4L}{n} \quad n = 1,3,5\dots$	String fixed at one end Pipe open at one end
$v = \sqrt{\frac{T}{\mu}}$	Wave Velocity on a String

FLUIDS

$\rho = \frac{m}{V}$	Density
$S.G. = \frac{\rho}{\rho_{H_2O}}$	Specific Gravity
$P = \rho_{fluid}\, g\, h$	Hydrostatic Pressure (Gauge Pressure)
$P = P_0 + \rho_{fluid}\, g\, h$	Absolute Pressure
$F_B = W_{fluid\ displaced}$ $F_B = (\rho_{fluid})(V_{submerged})(g)$	Buoyancy Force
$\%\ submerged = \frac{\rho_{object}}{\rho_{fluid}} \times 100$	
$\frac{F_1}{A_1} = \frac{F_2}{A_2}$	Pascal's Principle (Hydraulic Jack)
$A_1d_1 = A_2d_2$	Hydraulic Jack
$F = Av$	Flow Rate
$A_1v_1 = A_2v_2$	Continuity Equation
$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$	Bernoulli's Equation

THERMODYNAMICS

$C = \frac{q}{\Delta T}$	Heat Capacity
$C_s = \frac{C}{m}$	Specific Heat Capacity
$C_m = \frac{C}{n}$	Molar Heat Capacity
$C_V = \left(\frac{\delta U}{\delta T}\right)_V = \frac{\Delta U}{\Delta T}$	Constant Volume Heat Capacity
$C_P = \left(\frac{\delta H}{\delta T}\right)_P = \frac{\Delta H}{\Delta T}$	Constant Pressure Heat Capacity
$\Delta U = q + w$	Change in Internal Energy

$q = \int C_V dT$	Constant V	$w = \int -p_{ext} dV$	Universal
$q = \int C_P dT$	Constant P	$w = -p\Delta V$	Constant p_{ext}
$q = -w$	Constant T	$w = -nRT\ln\frac{V_f}{V_i}$	Reversible, Isothermal

$H = U + pV$	Enthalpy
$\Delta H = q_p$	Enthalpy Change at Constant p
$C_P - C_V = nR$	For a Perfect Gas

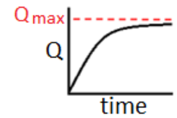
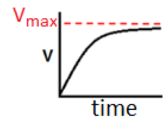
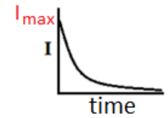
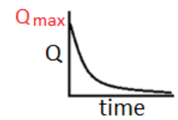
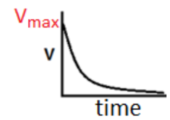
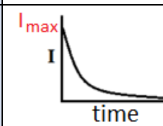
Laws of Thermodynamics

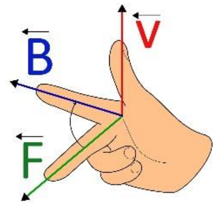
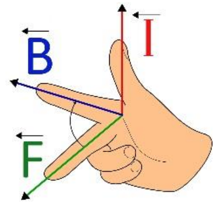
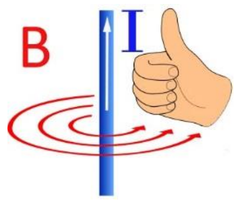
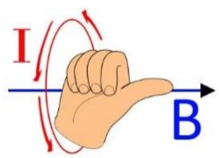
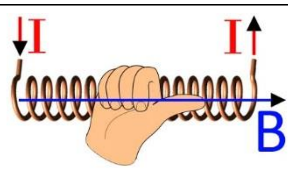
1st Law	Energy can't be created or destroyed.
2nd Law	For a spontaneous process, $\Delta S_{universe} > 0$.
3rd Law	A perfectly ordered crystal at 0K has zero entropy.

$\Delta S = \frac{q_{rev}}{T}$	Entropy Change
$\Delta S = nR\ln\frac{V_f}{V_i} = nR\ln\frac{p_i}{p_f}$	Entropy Change during Expansion/Compression
$\Delta S = nC\ln\frac{T_f}{T_i}$	Entropy Change during heating

SOUND	
$v = \lambda f$	Speed of Sound
$v = \sqrt{\frac{Y}{\rho}}$	Speed of Sound in a Metal Rod
$v = \sqrt{\frac{P}{\rho}}$	Speed of Sound in a Gas
$v = 331\text{m/s}\sqrt{\frac{T}{273\text{K}}}$	Temperature Dependence on the Speed of Sound
$I = \frac{P}{A} = \frac{P}{4\pi r^2}$	Intensity of Sound
$\beta = 10\log\frac{I}{I_0}$ $I_0 = 10^{-12}\frac{W}{m^2}$	Intensity Level
$f_0 = f_s\frac{v \pm v_0}{v \mp v_s}$	Doppler Effect

ELECTRIC FIELDS AND FORCES	
$e = 1.602\times10^{-19}$C	Fundamental charge
$F = \left\lvert k\frac{q_1 q_2}{r^2}\right\rvert$	Coulomb's Law
F = qE	Force due to an Electric Field
$E = \left\lvert k\frac{q}{r^2}\right\rvert$	Electric Field due to a Point Charge
$\Phi_E = EA\cos\theta = \frac{Q}{\epsilon_o}$	Gauss's Law (Electric Flux)
$V = k\frac{q}{r}$	Potential due to a Point Charge
U = qV	Potential Energy of a Point Charge
ΔV = -Ed	Relationship between ΔV and E
W = qΔV W = -qΔV	Work done against an electric field Work done by an electric field

DC CIRCUITS	
$C = \frac{q}{\Delta v}$	Capacitance
Capacitor Charging	
$Q(t) = Q_{max}\left(1 - e^{-\frac{t}{\tau}}\right)$	
$V(t) = \varepsilon\left(1 - e^{-\frac{t}{\tau}}\right)$	
$I(t) = \frac{\varepsilon}{R}e^{-\frac{t}{\tau}}$	
Capacitor Discharging	
$Q(t) = Q_{max}e^{-\frac{t}{\tau}}$	
$V(t) = \varepsilon\, e^{-\frac{t}{\tau}}$	
$I(t) = \frac{\varepsilon}{R}e^{-\frac{t}{\tau}}$	
$C = \varepsilon_0\frac{A}{d}$ $C = \kappa\left(\varepsilon_0\frac{A}{d}\right)$	Parallel Plate Capacitor
$U_{stored} = \frac{1}{2}C\Delta V^2 = \frac{1}{2}Q\Delta V$	Potential Energy Stored by a Capacitor
$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$	Capacitors in Series
$C_{eq} = C_1 + C_2 + \ldots$	Capacitors in Parallel
$I = \frac{\Delta q}{\Delta t}$	Current
ΔV = IR	Ohm's Law
$R = \rho\frac{L}{A}$	Resistance of a Wire
$\rho = \rho_0(1 + \alpha\Delta T)$ $R = R_0(1 + \alpha\Delta T)$	Temperature Dependence of the Resistivity and Resistance
$P = \Delta VI = I^2R = \frac{\Delta V^2}{R}$	Power Dissipated by a Resistor
$R_{eq} = R + R_2 + \ldots$	Resistors in Series
$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R_2} + \ldots$	Resistors in Parallel
Current entering a junction = Current exiting a junction	Kirchoff's Junction Rule
The potential difference around any closed loop sums to zero.	Kirchoff's Loop Rule

MAGNETIC FIELDS AND FORCES		
$F = qvB\sin\theta$	Magnetic Force on a Charged Particle in Motion	
$F = BI\ell\sin\theta$	Magnetic Force on a Current-carrying Wire	
$\tau = BIAN\sin\theta$	Torque on a Current-Carrying Loop	
$B = \frac{\mu_0 I}{2\pi r}$	Magnetic Field Due to a Current Carrying Wire	
$B = N\frac{\mu_0 I}{2R}$	Magnetic Field at the Center of a Circular Current-Carrying Loop	
$B = \frac{\mu_0 NI}{L} = \mu_0 nI$	Magnetic Field Inside an Ideal Solenoid	

INDUCED VOLTAGES AND INDUCTANCE	
$\Phi_B = B_\perp A = BA\cos\theta$	Magnetic Flux
$\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$	Faraday's Law (Induce Emf)
$\Delta V = B\ell v_\perp$	Motional Emf
$\varepsilon = NBA\omega\sin\omega t$	Generator Emf
$\varepsilon_1 = -N_1\frac{\Delta\Phi_{B21}}{\Delta t} = -M\frac{\Delta I}{\Delta t}$ $\varepsilon_2 = -N_2\frac{\Delta\Phi_{B12}}{\Delta t} = -M\frac{\Delta I}{\Delta t}$	Mutual Inductance
$\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t} = -L\frac{\Delta I}{\Delta t}$ $L = N\frac{\Delta\Phi_B}{\Delta I} = N\frac{\Delta\Phi_B}{I}$	Self-Inductance
$\Delta V_1 I_1 = \Delta V_2 I_2$ $\frac{\Delta V_1}{\Delta V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$	Transformers
$\varepsilon = -L\frac{\Delta I}{\Delta t}$	Emf in an RL Circuit
$I(t) = \frac{\varepsilon}{R}\left(1 - e^{-\frac{t}{\tau}}\right) \quad \tau = \frac{L}{R}$	Current in an RL Circuit
$PE_L = ½ LI^2$	Potential Energy Stored in an Inductor

AC (ALTERNATING CURRENT) CIRCUITS	
$\Delta V = \Delta V_{max}\sin\omega t$	AC Potential
$\Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}}$	Rms Potential
$\Delta I_{rms} = \frac{\Delta I_{max}}{\sqrt{2}}$	Rms Current
$P = I_{rms}^2 R$	Power Dissipated in a Resistor
$\Delta V_{max} = I_{max} R$ $\Delta V_{rms} = I_{rms} R$	Ohm's Law
$X_C = \frac{1}{2\pi fC} = \frac{1}{\omega C}$ $\Delta V_{C,rms} = I_{rms} X_C$	Capacitive Reactance
$X_C = 2\pi fL$ $\Delta V_{L,rms} = I_{rms} X_L$	Inductive Reactance
$Z = \sqrt{R^2 + (X_L - X_C)^2}$ $\Delta V_{max} = I_{max} Z$ $\Delta V_{rms} = I_{rms} Z$	Impedance of RLC Circuits
$f_0 = \frac{1}{2\pi\sqrt{LC}}$	Resonance Frequency in LC Circuits

ELECTROMAGNETIC RADIATION	
$c = \frac{1}{\sqrt{\varepsilon_0\mu_0}} = 3.0 \times 10^8 m/s$	Speed of Light in a Vacuum
$n = \frac{c}{v}$	Index of Refraction
$\lambda f = v$	Wavelength/Frequency of Light
$E_{photon} = hf$	Energy of a Photon
$u_E = \frac{1}{2}\varepsilon_0 E^2$	Energy density of the Electric Field
$u_B = \frac{1}{2\mu_0}B^2$	Energy density of the Magnetic Field
$I = \frac{P}{A}$	Intensity of Light
$f_O = f_S\left(1 \pm \frac{u}{c}\right)$	Doppler Effect
$I = \frac{1}{2}I_0$	Unpolarized light transmitted through a polarizing filter
$I = I_0\cos^2\theta$	Polarized light transmitted through a polarizing filter

REFLECTION AND REFRACTION

$\theta_{incidence} = \theta_{reflection}$	Law of Reflection
$n_1 \sin\theta_1 = n_2 \sin\theta_2$	Snell's Law of Refraction
$n = \frac{c}{v}$	Index of Refraction
$\sin\theta_{critical} = \frac{n_2}{n_1}$	Critical Angle for Total Internal Reflection
$d' = d\frac{n_2}{n_1}$	Apparent depth

MIRRORS AND LENSES

$f = \frac{1}{2} R$	Focal Length
$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$	Thin Mirror and Lens Equation
$m = \frac{h_i}{h_o} = -\frac{q}{p}$	Magnification
$Lens\ Power = \frac{1}{f_m}$	Lens Power
$f\ number = \frac{f}{D}$	F number

Diverging Mirror/Lens

	p	q	f
Always	$\oplus$	$\ominus$ virtual	$\ominus$

Converging Mirror/Lens

	p	q	f
$p > f$	$\oplus$	$\oplus$ real	$\oplus$
$p < f$	$\oplus$	$\ominus$ virtual	$\oplus$

q $\oplus$	real, inverted image
q $\ominus$	virtual, upright image
m $\oplus$	upright
m $\ominus$	inverted
$\lvert m \rvert < 1$	reduced image
$\lvert m \rvert > 1$	enlarged image

Combinations of Lenses

$m = (m_1)\times(m_2)$	magnification
$\frac{1}{f_{net}} = \frac{1}{f_1} + \frac{1}{f_2}$	Two lenses in direct contact
$\frac{1}{f_{net}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{d}{f_1 f_2}$	Two lenses not in direct contact

Optical Instruments

$M_1 = -\frac{q_1}{p_1} \approx \frac{L}{f_o}$	Lateral magnification of objective
$m_e = \frac{25cm}{f_e}$	Angular magnification of eyepiece
$m = \frac{\theta}{\theta_o} = \frac{f_o}{f_e}$	Angular magnification of a telescope
$\theta_{min} \approx \frac{\lambda}{a}$	Telescope Resolution (Single Slit)
$\theta_{min} \approx \frac{1.22\lambda}{D}$	Telescope Resolution (circular aperture)

WAVE OPTICS

$d \sin\theta_{bright} = m\lambda$ $y_{bright} = \frac{\lambda L}{d} m$	Bright Fringes (Double Slit Interference)
$d \sin\theta_{dark} = (m + \frac{1}{2})\lambda$ $y_{bright} = \frac{\lambda L}{d}\left(m + \frac{1}{2}\right)$	Dark Fringes (Double Slit Interference)
$2t = \left(m + \frac{1}{2}\right)\lambda_{film}$	Thin Film Interference Destructive Interference (No Phase Shift)
$2t = m\lambda_{film}$	Thin Film Interference Destructive Interference (Phase Shift)
$d \sin\theta_{bright} = m\lambda$	Bright Fringes (Diffreaction Grating)
$a \sin\theta_{dark} = m\lambda$	Dark Fringes (Single Slit Interference)

CONSTANTS

g	$9.80\ m/s^2$	Gravitational acceleration near the surface of the Earth
G	$6.67\times10^{-11}\ N\cdot m^2/kg^2$	Gravitational constant
M_E	5.98×10^{24} kg	Mass of the Earth
R_E	6.38×10^{6} m	Radius of the Earth
R	8.314 J/mol·K	Universal gas constant
k_e	$8.99\times10^{9}\ N\cdot m^2/C^2$	Coulomb constant
ε_0	$8.85\times10^{-11}\ C^2/N\cdot m^2$	Permitivity of Free Space
e	1.62×10^{-31} C	Fundamental charge
m_e	9.11×10^{-31} kg	Mass of an electron
m_p	1.67×10^{-27} kg	Mass of a proton
μ_0	$4\pi\times10^{-7}$ T·m/A	Permeability of Free Space
c	3.00×10^{8} m/s	Speed of Light (vacuum)