Physics 317K
Formula Sheet

One dimensional motion
displacement: $\Delta x = x_2 - x_1$
average velocity: $v_{avg} = \frac{\Delta x}{\Delta t}$, instantaneous velocity: $v = \frac{dx}{dt}$
average acceleration: $a_{avg} = \frac{\Delta v}{\Delta t}$, instantaneous acceleration: $a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$
kinematic equation 1: $v = v_0 + at$
kinematic equation 2: $x - x_0 = v_0 t + \frac{1}{2}at^2$
kinematic equation 3: $v^2 = v_0^2 + 2a(x - x_0)$
kinematic equation 4: $x - x_0 = \frac{1}{2}(v_0+v)\,t$
kinematic equation 5: $x - x_0 = vt - \frac{1}{2}at^2$

Projectile motion
kinematic equation 1: $x - x_0 = (v_0 \cos\theta)t$
kinematic equation 2: $y - y_0 = (v_0 \sin\theta)t - \frac{1}{2}gt^2$
kinematic equation 3: $v_y = v_0 \sin\theta - gt$
kinematic equation 4: $v_y^2 = (v_0 \sin\theta)^2 - 2g(y-y_0)$

Newtons Laws
Force $F = ma$, Weight $W = mg$
equilibrium conditions: $\Sigma F_x=0$, $\Sigma F_y=0$,$\Sigma F_z=0$
non-equilibrium conditions: $\Sigma F_x=ma_x$, $\Sigma F_y=ma_y$, $\Sigma F_z=ma_z$
static friction force $f_s \leq \mu_s F_n$, kinetic friction force $f_k = \mu_k F_n$

Work and Energy
work: $W = F \cos\theta \, \Delta x$, work $\theta=0$: $W = F \Delta x$
potential energy: $U = mgy = mgh$
elastic potential energy stored in a spring: $U_s = \frac{1}{2}kx^2$
kinetic energy: $K = \frac{1}{2}mv^2$
work energy theorem: $W_{net} = K_f - K_i$
energy conservation: $K_i + U_i = K_f + U_f$
non-conservative work: $W_{nc} = (K_f + U_f) - (K_i + U_i)$
power: $P = \frac{E}{t} = Fv$

Momentum conservation and collisions
momentum: $p = mv$, impulse $= F \Delta t$
impulse-momentum theorem: $F \Delta t = \Delta p = mv_f - mv_i$
conservation of momentum in collisions: $\Sigma(mv)_{initial} = \Sigma(mv)_{final}$

Rotational motion
rotational equation 1: $\omega = \omega_0 + \alpha t$
rotational equation 2: $\theta - \theta_0 = \omega_0 t + \frac{1}{2}\alpha t^2$
rotational equation 3: $\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$
rotational equation 4: $\theta - \theta_0 = \frac{1}{2}(\omega_0+\omega)\,t$
rotational equation 5: $\theta - \theta_0 = \omega t - \frac{1}{2}\alpha t^2$
tangential velocity: $v_t = \omega r$
tangential acceleration: $a_t = \alpha r$
centripetal (radial) acceleration: $a_r = \frac{v^2}{r} = \omega^2 r$
total acceleration: $a = \sqrt{(a_r^2 + a_t^2)}$
centripetal force: $F_r = m a_r = m \frac{v^2}{r}$

Rotational equilibrium and dynamics
rotational kinetic energy: $K_r = \frac{1}{2}I \omega^2$
moment of inertia: $I = \Sigma m_i r_i^2$
torque: $\tau = Fd$ ($d=r \sin\theta$), torque: $\tau = I \alpha$

equilibrium conditions: Σ F_x=0, Σ F_y=0, Σ τ=0
angular momentum: L = I ω
angular momentum conservation: $I_i\omega_i$ = $I_f\omega_f$

Gravitation
gravitational force: $F = G\frac{Mm}{r^2}$
gravitational potential energy: $U = -G\frac{Mm}{r}$
escape speed: $v = \sqrt{\frac{2GM}{R}}$
energy in planetary motion: $E = K + U = \frac{GMm}{2r} - \frac{GMm}{r} = -\frac{GMm}{2r}$

Fluids
density: $\rho = \frac{m}{V}$, pressure: $p = \frac{F}{A}$
pressure at depth h: $p = p_0 + \rho gh$
buoyant force: $F_b = m_f g$
equation of continuity: $R_v = Av = constant$
Bernoulli's equation: $p + \frac{1}{2}\rho v^2 + \rho gy = constant$

Oscillation
simple harmonic motion: $x(t) = x_m cos(\omega t + \phi)$
$v(t) = -\omega x_m sin(\omega t + \phi)$
$a(t) = -\omega^2 x_m cos(\omega t + \phi)$
period of linear oscillator: $T = 2\pi\sqrt{\frac{m}{k}}$, $\omega = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$
total mechanical energy: $E = K + U = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kx_m^2 = \frac{1}{2}mv_m^2$
period of pendulum: $T = 2\pi\sqrt{\frac{L}{g}}$

Waves
$y(x,t) = y_m sin(kx - \omega t)$, $k = \frac{2\pi}{\lambda}$, $\omega = \frac{2\pi}{T} = 2\pi f$, $v = \lambda f = \frac{\lambda}{T}$
wave speed in a string: $v = \sqrt{\frac{\tau}{\mu}}$
average power transmitted: $P_{avg} = \frac{1}{2}\mu v\omega^2 y_m^2$
sound intensity: $I = \frac{P}{A} = \frac{P_s}{4\pi r^2}$
sound level: $\beta = (10dB)\log\frac{I}{I_0}, I_0 = 10^{-12}W/m^2$
Doppler effect: $f' = f\frac{v \pm v_D}{v \pm v_S}$

Temperature, Heat
specific heat c: $Q = mc(T_f - T_i)$
heat of transformation: $Q = Lm$
ideal gas: $pV = nRT$
work done by a given system: $\Delta W = p\Delta V$
work in isothermal process: $\Delta W = nRT\ln\frac{V_f}{V_i}$
first law of thermodynamics: $\Delta E_{int} = Q - W$
change of entropy: $\Delta S = \frac{Q}{T}$
Kelvin temperature scale T: $T = T_C + 273K$
efficiency of engine: $\varepsilon = \frac{|W|}{|Q_H|}$
efficiency of ideal engine: $\varepsilon = 1 - \frac{T_L}{T_H}$

Conversion factors and Constants:
1 ft = 12 in, 1 km = 1000 m, 1 m = 100 cm = 1000 mm = 3.28 ft
1 ton = 1000 kg
1 atm = 1.013×10^5 Pa
gravitational acceleration a = -g = -9.8 [m/s^2]
gravitational constant $G = 6.6726 \times 10^{-11}$ Nm^2/kg^2
universal gas constant $R = 8.31$ J/mol K