PHY 121 Equation Sheet – Updated Spring 2020

Volume of a sphere
$V = 4/3\pi r^3$

Area of a circle
$A = \pi r^2$

Weight
Weight = mass x gravity
$W = mg$
$g = 9.80$ m/s/s

Law of Gravitation
$F_g = Gm_1m_2/r^2$
$G = 6.67\times10^{-11}$ Nm²/kg²

Friction
Maximum Static Friction Force = coefficient of static friction x Normal Force
$f_s \leq \mu_s N$
Kinetic Friction Force = coefficient of kinetic friction x Normal Force
$f_k = \mu_k N$

Displacement
displacement = final position – initial position
$\Delta r = r_f - r_i$

Average Velocity
average velocity = displacement/change in time
$v_{av} = \Delta r/\Delta t$
$v_{av} = (r_f - r_i)/(t_f - t_i)$

Average Speed
Average speed = distance/time
$s_{av} = d/t$

Acceleration
Acceleration = change in velocity/change in time
$a = \Delta v/\Delta t$
$a = (v_f - v_i)/(t_f - t_i)$

Net Force
Net Force = mass x acceleration
$F_{net} = ma$

Kinematics Equations
$v_f = v_i + at$
$v_f^2 = v_i^2 + 2a\Delta x$
$\Delta x = 1/2(v_i + v_f)t$
$\Delta x = v_it + 1/2at^2$

Angular Displacement
angular disp. = final angle – initial angle
$\Delta\theta = \theta_f - \theta_i$

Average Angular Velocity
average angular velocity = angular displacement/change in time
$\omega_{av} = \Delta\theta/\Delta t$

Angular/Linear Speed
$v = r\,|\omega|$

Period & Frequency
1/period = frequency
$f = 1/T$

Radial Acceleration
$a_r = v^2/r$ OR $a_r = \omega^2 r$

Angular Kinematics Equations
$\omega_f = \omega_i + \alpha\Delta t$
$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$
$\Delta\theta = 1/2(\omega_f + \omega_i)\Delta t$
$\Delta\theta = \omega_i\Delta t + 1/2\alpha(\Delta t)^2$

Work
$W = F\Delta r\cos\theta$

Translational Kinetic Energy
$K = 1/2\ mv^2$

Gravitational Potential Energy
$U_{grav} = mgy$

Mechanical Energy
$E_{mech} = K + U_{grav}$

Law of Conservation of Energy
(when nonconservative forces do no work, mechanical energy is conserved)
$E_f = E_i$

Hooke's Law for an ideal spring
$F = -kx$

Elastic Potential Energy for an Ideal Spring
$U_{elastic} = 1/2kx^2$

Average Power
$P_{ave} = \Delta E/\Delta t$

Linear Momentum
$\mathbf{p} = m\mathbf{v}$

Impulse
Impulse = $\Delta\mathbf{p} = \mathbf{F}_{net}\Delta t$

Conservation of Linear Momentum
(if the net external force acting on a system is zero)
$\mathbf{p}_i = \mathbf{p}_f$

Elastic Collisions
$v_{1i} + v_{1f} = v_{2i} + v_{2f}$

Rotational Kinetic Energy
$K_{rot} = 1/2\ I\omega^2$

Rotational Inertia
$I = \Sigma\ mr^2$

Conservation of Energy – Big Ugly
$W_{nc} = \Delta K_{trans} + \Delta K_{rot} + \Delta U_{grav} + \Delta U_{spr}$
Where $Wnc = W_f + W_T + W_A$

Torque
$\tau = \pm rF\sin\theta$

Work from Torque
$W = \tau\Delta\theta$

Power from Torque
$P = \tau\omega$

For an Object in Equilibrium
$\Sigma F = 0$ AND $\Sigma\tau = 0$

Rotational Form of Newton's 2nd Law
$\Sigma\tau = I\alpha$

Average Pressure
$P_{av} = F/A$

Pascal's Principle Application/Hydraulics
$F_1/A_1 = F_2/A_2$
$F_1d_1 = F_2d_2$

Density
$\rho = m/V$

Pressure Variation with depth in a static fluid with uniform density
$P_2 = P_1 + \rho gd$

Pressure at a depth d below the surface of a liquid open to the atmosphere:
$P = P_{atm} + \rho gd$

Gauge Pressure
$P_{gauge} = P_{abs} – P_{atm}$

Buoyant Force
$F_B = \rho gdA = \rho gV$

Specific Gravity
$S.G. = \rho/\rho_{water}$

Mass Flow Rate
$\Delta m/\Delta t = \rho Av$

Volume Flow Rate
$\Delta V/\Delta t = Av$

Continuity Equation for Incompressible Fluid
$A_1v_1 = A_2v_2$

Bernoulli's Equation for Ideal Fluid Flow
$P_1 + \rho g y_1 + 1/2\ \rho v_1^2 = P_2 + \rho g y_2 + 1/2\ \rho v_2^2$

Energy for a Horizontal Spring System
$E = 1/2mv^2 + 1/2kx^2$
$E_{total} = 1/2kA^2$
$E_{total} = 1/2mv_{max}^2$

Acceleration in Simple Harmonic Motion
$a_x = -(k/m)x$
$a_{max} = (k/m)A$

Angular Frequency
$\omega = \sqrt{(k/m)}$
$\omega = 2\pi f$

Period for an Ideal Mass-Spring System
$T = 2\pi\sqrt{(m/k)}$

Maximum Angular Speed & Acceleration
$v_m = \omega A$
$a_m = \omega^2 A$

Pendulum Equations
$\omega = \sqrt{(g/L)}$
$T = 2\pi\sqrt{(L/g)}$

Wave Intensity
$I = \text{Power}/\text{Area} = P/(4\pi r^2)$

Transverse Wave on a String
$v = \sqrt{(FL/m)}$
$\mu = m/L$ **(linear mass density)**
$v = \sqrt{(F/\mu)}$

Wavelength and Wavespeed for Periodic Waves
$v = \lambda/T = f\,\lambda$

Equation for Harmonic Traveling Wave
$y(x,t) = A \cos [\omega(t - x/v)]$

Wavenumber
$k = \omega/v = 2\pi/\lambda$

Reflection/Change in Wavelength at a Boundary
$f = v_1/\lambda_1 = v_2/\lambda_2$

Intensity for Interfering Waves
$(A_1/A_2)^2 = I_1/I_2$

Speed of Sound in Air
$v = 331 + 0.606\ Tc$

Displacement Amplitude/Pressure Amplitude of a Harmonic Sound Wave
$p_0 = \omega v \rho s_0$

Intensity of a Harmonic Sound Wave
$I = p_0^2/(2\rho v)$

Decibels
$\beta = (10\text{ dB})\log_{10}(I/I_0)$
where $I_o = 1\text{x}10^{-12}\ W/m^2$

Standing Sound Waves (Pipe Open at Both Ends)
$\lambda_n = 2L/n$
$f_n = v/\lambda_n = (nv)/(2L) = nf_1$
where n = 1, 2, 3, …

Standing Sound Waves (Pipe Closed at One End)
$\lambda_n = 4L/n$
$f_n = v/\lambda_n = (nv)/(4L) = nf_1$
where n = 1, 3, 5, 7 …

Doppler Effect
o = observed
s = source
v = speed of sound in air

$$f_o = f_s\left(\frac{v - v_o}{v - v_s}\right)$$

rule: v_o, v_s are + when in the same direction as wave propagation.

Temperature Conversions
$T_F = 1.8T_C + 32$
$T_C = T - 273.15$

Linear/Area/Volume Expansion
$\Delta L/L_o = \alpha\Delta T$
$\Delta A/A_o = 2\alpha\Delta T$
$\Delta V/V_o = \beta\Delta T$
where $\beta = 3\alpha$ for solids

Heat Conversion
1 cal = 4.186 Joules

Heat Req'd to Cause Temperature Change
$Q = mc\Delta T$

Heat Req'd to Change Temp. in Ideal Gas
$Q = nC_v\Delta T$
C_v = 12.5 J/(mol K) for monatomic
C_v = 20.8 J/(mol K) for diatomic

Ideal Gas Law
$PV = nRT$
R = 8.31 J/(mol K)

Latent Heat for Phase Changes
$|Q| = mL$
where L = Latent Heat of Fusion OR
L = Latent Heat of Vaporization