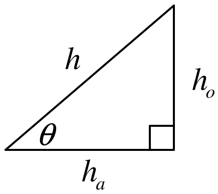
PH1110 Formula Sheet

Introduction and Mathematical Concepts

$\sin\theta \equiv \frac{h_o}{h}$

$\cos\theta \equiv \frac{h_a}{h}$

$\tan\theta \equiv \frac{h_o}{h_a}$



$h^2 = h_o^2 + h_a^2$

Kinematics in One Dimension

$\Delta\vec{x} \equiv \vec{x} - \vec{x}_o$

$\Delta t \equiv t - t_o$

$avg\ speed \equiv \frac{distance}{elapsed\ time}$

$\vec{v}_{avg} \equiv \frac{\Delta\vec{x}}{\Delta t} \qquad \vec{v} \equiv \lim_{\Delta t\to 0}\frac{\Delta\vec{x}}{\Delta t}$

$\vec{a}_{avg} \equiv \frac{\Delta\vec{v}}{\Delta t} \qquad \vec{a} \equiv \lim_{\Delta t\to 0}\frac{\Delta\vec{v}}{\Delta t}$

$v = v_o + at$

$x = \frac{1}{2}(v_o + v)t$

$x = v_o t + \frac{1}{2}at^2$

$v^2 = v_o^2 + 2ax$

Kinematics in Two Dimensions

$\Delta\vec{r} \equiv \vec{r} - \vec{r}_o$

$\vec{v}_{avg} \equiv \frac{\Delta\vec{r}}{\Delta t} \qquad \vec{v} \equiv \lim_{\Delta t\to 0}\frac{\Delta\vec{r}}{\Delta t}$

$\vec{a}_{avg} \equiv \frac{\Delta\vec{v}}{\Delta t} \qquad \vec{a} \equiv \lim_{\Delta t\to 0}\frac{\Delta\vec{v}}{\Delta t}$

$v_x = v_{ox} + a_x t \qquad v_y = v_{oy} + a_y t$

$x = \frac{1}{2}(v_{ox} + v_x)t \qquad y = \frac{1}{2}(v_{oy} + v_y)t$

$x = v_{ox}t + \frac{1}{2}a_x t^2 \qquad y = v_{oy}t + \frac{1}{2}a_y t^2$

$v_x^2 = v_{ox}^2 + 2a_x x \qquad v_y^2 = v_{oy}^2 + 2a_y y$

Force and Newton's Laws of Motion

$\Sigma\vec{F} = m\vec{a}$

$F = G\frac{m_1 m_2}{r^2}$

$W = mg$

$f_s \le f_s^{MAX} = \mu_s F_N \qquad f_k = \mu_k F_N$

Dynamics of Uniform Circular Motion

$v = \frac{2\pi r}{T}$

$a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r}$

$T^2 = \frac{4\pi^2 r^3}{GM}$

Work and Energy

$W \equiv (F\cos\theta)s$

$KE \equiv \frac{1}{2}mv^2$

$\Sigma W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2 = KE_f - KE_o$

$PE = mgh$

$W_{gravity} = mgh_o - mgh_f = PE_o - PE_f$

$W_{nc} = \Delta KE + \Delta PE$

$E \equiv KE + PE$

$\overline{P} \equiv \frac{Work}{Time} = \frac{W}{t} \qquad \overline{P} = F\overline{v}$

Impulse and Momentum

$\vec{Impulse} \equiv \vec{F}_{avg}\Delta t$

$\vec{p} \equiv m\vec{v}$

$\vec{F}_{avg}\Delta t = m\vec{v}_f - m\vec{v}_o$

$\vec{P}_o = \vec{P}_f$ isolated system

$x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$

$v_{cm} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$

Rotational Kinematics

$\theta(rad) \equiv \frac{Arc\ length}{Radius} = \frac{s}{r}$

$\overline{\omega} \equiv \frac{\theta - \theta_o}{t - t_o} = \frac{\Delta\theta}{\Delta t}$

$\overline{\alpha} \equiv \frac{\omega - \omega_o}{t - t_o} = \frac{\Delta\omega}{\Delta t}$

$\omega = \omega_o + \alpha t$

$\theta = \frac{1}{2}(\omega_o + \omega)t$

$\theta = \omega_o t + \frac{1}{2}\alpha t^2$

$\omega^2 = \omega_o^2 + 2\alpha\theta$

$v_T = r\omega$

$a_T = r\alpha$

$a_c = r\omega^2$

no slipping: $v = r\omega \quad a = r\alpha$

Rotational Dynamics

$\tau \equiv Fl$

equilibrium: $\Sigma\vec{F} = 0 \quad \Sigma\tau = 0$

$x_{cg} = \frac{W_1 x_1 + W_2 x_2 + \ldots}{W_1 + W_2 + \ldots}$

$I \equiv \Sigma mr^2$

$\Sigma\tau = I\alpha$

$W_R = \tau\theta$

$KE_R = \frac{1}{2}I\omega^2$

$L = I\omega$

$L_f = L_o$ no net external torque

Temperature and Heat

$T_C = T - 273$

$T_C = \frac{5}{9}(T_F - 32)$

$\Delta L = \alpha L_o \Delta T$

$\Delta V = \beta V_o \Delta T$

$Q = cm\Delta T$

$Q = mL$

$Q_{gained} = Q_{lost}$

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The Transfer of Heat

$Q = \frac{(kA\Delta T)t}{L}$

$Q = e\sigma T^4 At$

The Ideal Gas Law and Kinetic Theory

$n = \frac{N}{N_A}$

$P \equiv \frac{F}{A}$

$PV = nRT$

$k = R/N_A$

$\overline{KE} = \frac{1}{2}mv_{rms}^2 = \frac{3}{2}kT$

$U = \frac{3}{2}nRT$ monatomic ideal gas

Thermodynamics

$\Delta U = U_f - U_i = Q - W$

$W = P\Delta V = P(V_f - V_i)$ isobaric process

$W = nRT \ln\left(\frac{V_f}{V_i}\right)$ $\frac{\text{isothermal process}}{\text{ideal gas}}$

$W = \frac{3}{2}nR(T_i - T_f)$ $\frac{\text{adiabatic process}}{\text{monatomic ideal gas}}$

$P_iV_i^{\gamma} = P_fV_f^{\gamma}$ $\frac{\text{adiabatic process}}{\text{ideal gas}}$

$\gamma \equiv C_P/C_V$

$C \equiv \frac{Q}{n(T_f - T_i)}$

$C_P - C_V = R$

$C_V = \frac{3}{2}R$ monatomic ideal gas

$C_P = \frac{5}{2}R$ monatomic ideal gas

$e \equiv \frac{\text{Work done}}{\text{Heat input}} = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$

$e = 1 - \frac{T_C}{T_H}$ Carnot engine

$COP \equiv \frac{Q_C}{W}$ refrigerator

$COP \equiv \frac{Q_H}{W}$ heat pump

$\frac{Q_C}{Q_H} = \frac{T_C}{T_H}$ Carnot device

$\Delta S = \left(\frac{Q}{T}\right)_R$

$W_{unavailable} = T_o \Delta S_{universe}$

Fluids

$\rho = \frac{m}{V}$

$P_2 = P_1 + \rho gh$

$F_2 = F_1\left(\frac{A_2}{A_1}\right)$

$F_B = W_{fluid}$

$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$

$Q = Av$

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

Simple Harmonic Motion and Elasticity

$F = -kx$

$x = A\cos\omega t$

$f = 1/T$

$\omega = 2\pi f = \sqrt{k/m}$ mass on spring

$v_{max} = A\omega$

$a_{max} = A\omega^2$

$PE_{elastic} = \frac{1}{2}kx^2$

$\omega = \sqrt{g/L}$ simple pendulum

$F = Y\left(\frac{\Delta L}{L_o}\right)A$

$F = S\left(\frac{\Delta X}{L_o}\right)A$

$\Delta P = -B\left(\frac{\Delta V}{V_o}\right)$

Waves and Sound

$v = f\lambda$

$v = \sqrt{\frac{F}{m/L}}$

$I = \frac{P}{A}$

$\beta = (10\text{dB})\log\left(\frac{I}{I_o}\right)$

$f_o = f_s\left(\frac{1 \pm \frac{v_o}{v}}{1 \mp \frac{v_s}{v}}\right)$ $\frac{upper: approach}{lower: recession}$

Superposition & Interference

$f_{beat} = |f_1 - f_2|$

string fixed at both ends and open pipe:

$f_n = n\left(\frac{v}{2L}\right)$ $n = 1, 2, 3, \ldots$

closed pipe:

$f_n = n\left(\frac{v}{4L}\right)$ $n = 1, 3, 5, \ldots$

Physical Constants

$g = 9.80 \frac{\text{m}}{\text{s}^2}$

$G = 6.67 \times 10^{-11} \frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}$

$\sigma = 5.67 \times 10^{-8} \frac{\text{J}}{\text{s}\cdot\text{m}^2\cdot\text{K}^4}$

$N_A = 6.022 \times 10^{23}$ particles per mole

$R = 8.31 \frac{\text{J}}{(\text{mol}\cdot\text{K})}$

$k = 1.38 \times 10^{-23}$ J/K

$I_o = 10^{-12}$ W/m^2