Physics 1 – Mechanics: Formula Sheet

Vectors

$\vec{F} = \langle F_x, F_y \rangle$

$F_x = |\vec{F}| \cos(\theta)$

$F_y = |\vec{F}| \sin(\theta)$

$|\vec{F}| = \sqrt{F_x^{\,2} + F_y^{\,2}}$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$

Kinematics

$s_{avg} = \frac{D}{\Delta t}$

$v_{avg} = \frac{\Delta x}{\Delta t}$, $v(t) = \frac{d}{dt}\big(x(t)\big)$

$a_{avg} = \frac{\Delta v}{\Delta t'}$, $a(t) = \frac{d}{dt}\big(v(t)\big)$

$x(t) = x(0) + v(0) + \frac{1}{2}at^2$

$v(t) = v(0) + at$

$v(t)^2 = v(0)^2 + 2a\big(x(t) - x(0)\big)$

$x(t) = x(0) + \frac{1}{2}\big(v(t) + v(0)\big)t$

$x(t) = x(0) + v(t)t - \frac{1}{2}at^2$

Relative Motion

$x_{PA} = x_{PB} + x_{BA}$

$v_{PA} = v_{PB} + v_{BA}$

$a_{PA} = a_{PB} + x_{BA}$

Dynamics

$\sum \vec{F} = m\boldsymbol{a}$

$F_g = mg$

$f_{s,max} = u_s N$

$f_k = u_k N$

Circular Motion

$F_C = ma_c$

$a_c = \frac{v^2}{R}$

Linear Momentum and Impulse

$\sum \vec{F} = \frac{d\vec{p}}{dt}$

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

$\sum_{k=1}^{N} \vec{p}_{k,i} = \sum_{k=1}^{N} \vec{p}_{k,f}$

$\vec{J} = \int_{t_1}^{t_2} \vec{F}_{net}(t)dt$

$\vec{J} = \vec{F}_{net,avg}\Delta t$, $\vec{F}_{net,avg} = \frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2} \vec{F}_{net}(t)dt$

$\vec{J} = \Delta\vec{p}$

Work and Energy

$W = \vec{F} \cdot \vec{d} = |\vec{F}||\vec{d}| \cos(\theta)$

$W_{ab} = \int_a^b \vec{F} \cdot \vec{dl}$

$K = \frac{1}{2}mv^2$

$W_{net} = \Delta K$

$\Delta U = -W_c$

$U_g(y) = mgy$

$U_s(y) = \frac{1}{2}kx^2$

$U(x) = -\int_0^x F_c(\tau)d\tau$, $F_c(x) = -\frac{dU}{dx}$

$U_i + K_i + W_{nc} = U_f + K_f$

$P = \frac{dW}{dt}$

$P = \vec{F} \cdot \vec{v} = |\vec{F}||\vec{v}| \cos(\theta)$

Center of Mass

$x_{com} = \frac{1}{M}\sum_{i=1}^{N} x_i m_i$	$y_{com} = \frac{1}{M}\sum_{i=1}^{N} y_i m_i$	$z_{com} = \frac{1}{M}\sum_{i=1}^{N} z_i m_i$
$M = \sum_{i=1}^{N} m_i$		

Rotational Kinematics

$\omega(t) = \frac{d\theta}{dx}$

$\alpha(t) = \frac{d\omega}{dx}$

$x = r\theta$

$v = r\omega$

$a_t = r\alpha$, $a_r = r\omega^2 = \frac{v^2}{r}$

$\theta_f = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega_f = \omega_0 + \alpha t$

$\omega_f^{\,2} = \omega_0^{\,2} + 2\alpha(\theta_f - \theta_0)$

$\theta_f = \theta_0 + \frac{1}{2}(\omega_f + \omega_0)t$

Torque and Static Equilibrium

$\vec{\tau} = \vec{F} x \vec{d}$

$|\vec{\tau}| = |\vec{F}||\vec{d}| \sin(\theta)$

Static Equilibrium:

$\sum \vec{F} = 0, v = 0$ AND $\sum \vec{\tau} = 0, \omega = 0$

Rotational Dynamics

$\sum \vec{\tau} = I\boldsymbol{\alpha}$

$I = \sum_{i=1}^{N} m_i R_i^{\,2}$, $I = \int R^2 dm$

$I = I_{cm} + Mx^2$

Rotational Energy

$W_{rot} = \int_{\theta_1}^{\theta_1} \tau d\theta$

$K_{rot} = \frac{1}{2}I\omega^2$

$W_{rot} = \Delta K_{rot}$

$P_{rot} = \tau\omega$

$K_{rolling} = K_{trans} + K_{rot}$

Universal Gravitation

$\vec{F_g} = G\frac{m_1 m_2}{r_{12}^{\,2}}\hat{\boldsymbol{r}}_{12}$

$F_g = G\frac{M_{total}\, m}{R^3}r$

$U_g(R) = -\frac{GMm}{R}$

$v_{esc} = \sqrt{\frac{2GM}{R}}$

$E_{satellite} = K + U$

$E_{satellite} = \frac{GMm}{2R} - \frac{GMm}{R}$

$E_{satellite} = -\frac{GMm}{2R}$

$v_{circularOrbit} = \sqrt{\frac{GM}{R}}$

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

$G = 6.67E^{-11}\, Nm^2/kg^2$

Simple Harmonic Motion

$\frac{d^2x(t)}{dt^2} = -Cx(t)$

$x(t) = x_{max} \cos(\omega t + \varphi)$

$v(t) = v_{max} \sin(\omega t + \varphi)$

$a(t) = a_{max} \cos(\omega t + \varphi)$

$v_{max} = -x_{max}\,\omega$

$a_{max} = -x_{max}\,\omega^2$

$\omega = \sqrt{C}$

Mass-Spring: $\omega = \sqrt{k/m}$

Simple Pendulum: $\omega = \sqrt{g/L}$

Angular Momentum

$\vec{L} = I\vec{\omega}$

$\vec{L}_{par} = m(\vec{r}\, x\, \vec{v})$

$\vec{L}_{par} = m|\vec{r}||\vec{v}| \sin(\theta)$

$\sum_{k=1}^{N} \vec{L}_{i,k} = \sum_{k=1}^{N} \vec{L}_{f,k}$

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