PHYSICS I FORMULAS

Physics 106:

$360° = 2\pi$ radians = 1 revolution. $s = r\theta$ $v_t = r\omega$ $a_t = r\alpha$ $a_c = a_r = v_t^2/r = \omega^2 r$ $a_{tot}^2 = a_r^2 + a_t^2$

$\omega = \omega_o + \alpha t$ $\theta_f - \theta_o = \omega_o t + ½\alpha t^2$ $\omega_f^2 - \omega_o^2 = 2\alpha(\theta - \theta_o)$ $\theta - \theta_o = ½(\omega + \omega_o)t$ $K_{rot} = 1/2 I\omega^2$ $I = \Sigma m_i r_i^2$

$I_{point} = mr^2$ $I_{hoop} = MR^2$ $I_{disk} = 1/2\ MR^2$ $I_{sphere} = 2/5\ MR^2$ $I_{shell} = 2/3\ MR^2$ $I_{rod\ (center)} = 1/12\ ML^2$ $I_{rod\ (end)} = 1/3\ ML^2$

τ = force×moment arm $= F \times r \times \sin(\phi)$ $\mathbf{t_{net}} = \Sigma t = I a$ $\mathbf{F_{net}} = \Sigma\mathbf{F} = m\mathbf{a}$ $t = \mathbf{r} \times \mathbf{F}$ $I_p = I_{cm} + Mh^2$

$W_{tot} = \Delta K = K_f - K_I$ $W = \tau_{net}\Delta\theta$ $K = K_{rot} + K_{cm}$ $E_{mech} = K + U$ $P_{average} = \Delta W/\Delta t$

$P_{instantaneous} = \tau \times \omega$ (for τ constant) $\Delta E_{mech} = 0$ (isolated system) $v_{com} = \omega r$ (rolling, no slipping)

$\mathbf{l} = \mathbf{r} \times \mathbf{p}$ $\mathbf{p} = m\mathbf{v}$ $\mathbf{L} = \Sigma\ \mathbf{l_i}$ $\mathbf{t_{net}} = d\mathbf{L}/dt$ $L = I\omega$ $\mathbf{l}_{point\ mass} = m \times r \times v \times \sin(\phi)$

For isolated systems: $t_{net} = 0$ **L** is constant $\Delta\mathbf{L} = 0$ $L_0 = \Sigma\ I_0\omega_0 = L_f = \Sigma\ I_f\omega_f$

Equilibrium: Σ forces = 0 and Σ torques = 0, If net force on a system is zero, then the net torque is the same for any chosen rotation axis. COG definition: point about which torques due to gravity alone add to zero.

$F = G\dfrac{m_1 \cdot m_2}{R^2}$; $G = 6.67 \times 10^{-11}$ [$N \times m^2/kg^2$]; $F_{net} = m\dfrac{v^2}{R}$; $a_g = G\dfrac{m}{R^2}$; $E_{mech} = K + U_g$ $K = \dfrac{1}{2}mv^2$;

$U_g = -G\dfrac{m_1 \cdot m_2}{R}$; $v_{escape} = \sqrt{\dfrac{2GM}{R}}$; $T^2 = \dfrac{4\pi^2}{GM}R^3$ (T^2 / R^3) = Const for all satellites of a given planet.

Angular momentum and mechanical energy are conserved for masses moving under gravitational forces.
$E_{mech} < 0$ → Bound, elliptical orbit.; $E_{mech} > 0$ → Free particle, hyperbolic orbit; $E_{mech} = 0$ → Escape threshold. For circular orbits: $F_{centri} = mv^2/r = F_{grav} = GmM/r^2$, v_{orb} = sqrt[GM/r], $E_{orb} = 1/2U_{orb} = -1/2K_{orb}$

Earth: $M_E = 5.98 \times 10^{24}$ kg, $R_E = 6.37 \times 10^6$ m, orbital radius about Sun = 1.5×10^{11} m.

Mars: $M_m = 6.4 \times 10^{23}$ kg, $R_m = 3.395 \times 10^6$ m

Moon: $M_{moon} = 7.36 \times 10^{22}$ kg, $R_{moon} = 1.74 \times 10^6$ m, orbital radius about earth = 3.82×10^8 m

Oscillators in SHM: ω = angular frequency [rad/s] = $2\pi f = 2\pi/T$. Period $T = 2\pi/\omega$

$x(t) = x_m\cos(\omega t + \phi)$ $v(t) = v_m\sin(\omega t + \phi)$ with $v_m = -\omega x_m$ $a(t) = a_m\cos(\omega t + \phi)$ with $a_m = -\omega^2 x_m$

Oscillator equation: $a(t) = d^2x(t)/dt^2 = -\omega^2 \times x(t)$

Energy: $E_{osc} = 1/2mv(t)^2 + 1/2k\ x(t)^2$ if no damping, then $dE_{osc}/dt = 0$ and E_{osc} is constant

Spring osc: $F = -kx$ ω = sqrt(k/m) Torsion pendulum.: $\tau = -\kappa\theta$ ω = sqrt(κ / I)

Pendulums: Simple ω = sqrt(g / L) Physical ω = sqrt(mgh / I), h = dist. to COM from pivot, I = rot. inertia

Physics 105:

$W = mg$ $g = 9.8\ m/s^2$ 1 m = 100 cm = 1000 mm, 1 kg = 1000 g

$v = v_o + at$ $x - x_o = v_o t + ½at^2$ $v^2 - v_o^2 = 2a \times (x - x_o)$ $x - x_o = ½(v + v_o)t$

$F_{net} = ma$ $\Sigma\mathbf{F} = m\mathbf{a} = d\mathbf{P}/dt$ $F_{st,max} = \mu_s N$ $F_k = \mu_k N$ incline: $W_{mgx} = mg \times \sin[\theta]$ $W_{mgy} = mg \times \cos[\theta]$

$F_r = ma_r = mv^2/r$ $a_r = v^2/r$ $f = 1/T$ $T = (2\pi r/v)$ Impulse: $F_{avr}\Delta t = mv_f - mv_I$

Momentum is conserved if net Impulse = 0. Then $(\Sigma mv)_{initial} = (\Sigma mv)_{final}$

Work: $W = F \times d \times \cos(\theta)$, $W_{grav} = -mg \times (y - y_0)$, $W_{spring} = -1/2k(x^2 - x_0^2)$, $W_{frict} = -F_k d$, $W_{tot} = K_f - K_i$

$U_g = mg \times (y - y_0)$, spring: $F = -kx$, $U_s = 1/2kx^2$, $KE = 1/2mv^2$

$W_{nc} = K_f - K_I + U_{gf} - U_{gi} + U_{sf} - U_{si}$ or $K_I + U_{gi} + U_{si} + W_{nc} = K_f + U_{gf} + U_{sf}$

Mass center: $X_{com} = \Sigma(x_i m_i)/\Sigma m_i$, similarly for Y_{com}, Z_{com} **:** ($Y_{com} = \Sigma(y_i m_i)/\Sigma m_i$ and $Z_{com} = \Sigma(z_i m_i)/\Sigma m_i$)

Vectors:

Components: $a_x = a \times \cos(\theta)$ $a_y = a \times \sin(\theta)$ $a = a_x\mathbf{i} + a_y\mathbf{j}$ $|a|$ = sqrt[$a_x^2 + a_y^2$] $\theta = \tan^{-1}(a_y/a_x)$

Addition: $\mathbf{a} + \mathbf{b} = \mathbf{c}$ implies $c_x = a_x + b_x$, $c_y = a_y + b_y$

Dot product: $\mathbf{a} \times \mathbf{b} = a \times b \times \cos(\phi) = a_x b_x + a_y b_y + a_z b_z$ unit vectors: $\mathbf{i} \times \mathbf{i} = \mathbf{j} \times \mathbf{j} = \mathbf{k} \times \mathbf{k} = 1$; $\mathbf{i} \times \mathbf{j} = \mathbf{i} \times \mathbf{k} = \mathbf{j} \times \mathbf{k} = 0$

Cross product: $|\mathbf{a} \times \mathbf{b}| = a \times b \times \sin(\phi)$; $\mathbf{c} = |\mathbf{a} \times \mathbf{b}| = (a_y \times b_z - a_z \times b_y) \times \mathbf{i} + (a_z \times b_x - a_x \times b_z) \times \mathbf{j} + (a_x \times b_y - a_y \times b_x) \times \mathbf{k}$

$\mathbf{a} \times \mathbf{b} = -\mathbf{b} \times \mathbf{a}$, $\mathbf{a} \times \mathbf{a} = \mathbf{0}$ always; $\mathbf{c} = \mathbf{a} \times \mathbf{b}$ is perpendicular to **a-b** plane; if **a** || **b** then $|\mathbf{a} \times \mathbf{b}| = 0$

$\mathbf{i} \times \mathbf{i} = \mathbf{j} \times \mathbf{j} = \mathbf{k} \times \mathbf{k} = 0$, $\mathbf{i} \times \mathbf{j} = \mathbf{k}$ $\mathbf{j} \times \mathbf{k} = \mathbf{i}$ $\mathbf{k} \times \mathbf{i} = \mathbf{j}$