PHYSICS 2111
Formula Sheet

Definitions

$\vec{v} = \Delta x/\Delta t$

$\vec{a} = \Delta v/\Delta t$

$g = 9.81\ m/s^2 = 32.2\ ft/s^2$

Kinematics

$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$

$\mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0 t + at^2/2$

$v^2 = v_0^2 + 2a(x-x_0)$

Uniform Circular Motion

$a = v^2/r = \omega^2 r$

$v = \omega r$

$\omega = 2\pi/T = 2\pi f$

Dynamics

$\mathbf{F}_{net} = m\mathbf{a} = d\mathbf{p}/dt$

$\mathbf{F}_{A,B} = -\mathbf{F}_{B,A}$

$F = mg$ (near earth's surface)

$F_{12} = -Gm_1m_2/r^2$ (in general)

(where $G = 6.67\times10^{-11}\ Nm^2/kg^2$)

$F_{spring} = -kx$

Friction

$f = \mu_k N$ (kinetic)

$f \leq \mu_S N$ (static)

Work & Kinetic energy

$W = \int \mathbf{F}\cdot d\mathbf{s}$

$W = \mathbf{F}\cdot\mathbf{S} = FS\cos\theta$

(constant force)

$W_{grav} = -mg\Delta y$

$W_{spring} = -k(x_2^2 - x_1^2)/2$

$K = mv^2/2 = p^2/2m$

$W_{NET} = \Delta K$

Potential Energy

$U = -W_{con} - \int \mathbf{F}_{con}\cdot d\mathbf{s}$

$U_{grav} = mgy$ (near earth surface)

$U_{grav} = -GMm/r$ (in general)

$U_{spring} = kx^2/2$

$\Delta E = \Delta K + \Delta U = W_{nc}$

System of Particles

$\mathbf{R}_{CM} = \Sigma m_i \mathbf{r}_i / \Sigma m_i$

$\mathbf{V}_{CM} = \Sigma m_i \mathbf{v}_i / \Sigma m_i$

$\mathbf{A}_{CM} = \Sigma m_i \mathbf{a}_i / \Sigma m_i$

$\mathbf{P} = \Sigma m_i \mathbf{v}_i$

$\Sigma \mathbf{F}_{EXT} = M\mathbf{A}_{CM} = d\mathbf{P}/dt$

Power

$P = dW/dt$

$P = \mathbf{F}\cdot\mathbf{v}$ (for constant force)

Impulse

$\mathbf{I} = \int \mathbf{F}\, dt$

$\Delta\mathbf{P} = \mathbf{F}_{av}\Delta t$

Collisions:

If $\Sigma\mathbf{F}_{EXT} = 0$ in some direction, then

$\mathbf{P}_{before} = \mathbf{P}_{after}$ in this direction:

$\Sigma m_i\mathbf{v}_i$ (before) $= \Sigma m_i\mathbf{v}_i$ (after)

<u>In addition, if the collision is elastic:</u>

* $E_{before} = E_{after}$

* *Rate of approach = -(Rate of recession)*

* *The speed of an object in the Center-of-Mass reference frame is unchanged by an elastic collision.*

Rotational kinematics

$s = R\theta,\ v = R\omega,\ a = R\alpha$

For Constant α:

$\theta = \theta_0 + \omega_0 t + \tfrac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

Rotational Dynamics

$I = \Sigma m_i r_i^2$

$I_{parallel} = I_{CM} + MD^2$

$I_{disk} = I_{cylinder} = \tfrac{1}{2}MR^2$

$I_{hoop} = MR^2$

$I_{solid\text{-}sphere} = \tfrac{2}{5}MR^2$

$I_{spherical\ shell} = \tfrac{2}{3}MR^2$

$I_{rod\text{-}cm} = \tfrac{1}{12}ML^2$

$I_{rod\text{-}end} = \tfrac{1}{3}ML^2$

$\tau = I\alpha$ (rotation about a fixed axis)

$\boldsymbol{\tau} = \mathbf{r}\times\mathbf{F}$, $|\tau| = rF\sin\phi$

Work & Energy

$K_{rotation} = \tfrac{1}{2}I\omega^2$,

$K_{translation} = \tfrac{1}{2}MV_{cm}^2$

$K_{total} = K_{rotation} + K_{translation}$

$W = \tau\theta$

Statics

$\Sigma\mathbf{F} = 0$, $\Sigma\tau = 0$ (about any axis)

$F/A = Y\ \Delta L/L$

Angular Momentum:

$\mathbf{L} = \mathbf{r}\times\mathbf{p}$

$L_z = I\omega_z$

$\mathbf{L}_{tot} = \mathbf{L}_{CM} + \mathbf{L}^*$

$\boldsymbol{\tau}_{ext} = d\mathbf{L}/dt$

$\boldsymbol{\tau}_{cm} = d\mathbf{L}^*/dt$

$\Omega_{precession} = \tau / L$

Simple Harmonic Motion:

$d^2x/dt^2 = -\omega^2 x$

(differential equation for SHM)

$x(t) = A\cos(\omega t + \phi)$

$v(t) = -\omega A\sin(\omega t + \phi)$

$a(t) = -\omega^2 A\cos(\omega t + \phi)$

$\omega^2 = k/m$ (mass on spring)

$\omega^2 = g/L$ (simple pendulum)

$\omega^2 = mgR_{CM}/I$ (physical pendulum)

$\omega^2 = \kappa/I$ (torsion pendulum)

Damped Harmonic Motion :

$x(t) = x_m e^{-bt/2m}\cos(\omega' t + \phi)$

$\omega' = \sqrt{k/m - (b/2m)^2}$

$Q = \omega_o(m/b)$

General harmonic waves:

$$\frac{d^2y}{dx^2} = \frac{1}{v^2}\frac{d^2y}{dt^2}$$

$y(x,t) = A\cos(kx - \omega t + \phi)$

$k = 2\pi/\lambda$, $\omega = 2\pi f = 2\pi/T$

$v = \lambda f = \omega/k$

$f_n = n(v/2L)\ n=1,2,3,4\ldots.$

$f_n = n(v/4L)\ n=1,3,5,7\ldots.$

Waves on a string:

$$v^2 = \frac{F}{\mu} = \frac{(\text{tension})}{(\text{mass per unit length})}$$

Sound Waves:

$$\bar{P} = \frac{1}{2}\mu v\omega^2 A^2$$

$$\frac{d\bar{E}}{dx} = \frac{1}{2}\mu\omega^2 A^2$$

$I = P/A$

$\beta = 10db\ \log(I/I_0)$

$I_0 = 10^{-12}\ W/m^2$

$f_0 = f_s(1 \pm v_0/v)/(1 \mp v_s/v)$

$$y(t) = 2A\sin\left(\frac{1}{2}(\omega_1 + \omega_2)t\right)\cos\left(\frac{1}{2}(\omega_1 - \omega_2)t\right)$$

Gravitation:

$F = Gm_1m_2/r^2$

$U = -Gm_1m_2/r$

$G = 6.67\times10^{-11}\ Nm^2/kg^2$