Phys 211 Formula Sheet

Kinematics

$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$
$\mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0 t + at^2/2$
$v^2 = v_0^2 + 2a(x - x_0)$

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

$V_{A,B} = V_{A,C} + V_{C,B}$

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

$F_{spring} = -k\Delta x$

Friction

$f = \mu_k N$ (kinetic)
$f \leq \mu_S N$ (static)

Work & Kinetic energy

$W = \int \mathbf{F}\cdot\mathbf{dl}$
$W = \mathbf{F}\cdot\mathbf{\Delta r} = F\ \Delta r \cos\theta$
(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

$U_{grav} = mgy$ (near earth surface)
$U_{grav} = -GMm/r$ (in general)
$U_{spring} = kx^2/2$
$\Delta E = \Delta K + \Delta U = W_{nc}$

Power

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

System of Particles

$\mathbf{R}_{CM} = \Sigma m_i\mathbf{r}_i / \Sigma m_i$
$\mathbf{V}_{CM} = \Sigma m_i\mathbf{v}_i / \Sigma m_i$
$\mathbf{A}_{CM} = \Sigma m_i\mathbf{a}_i / \Sigma m_i$
$\mathbf{P} = \Sigma m_i\mathbf{v}_i$
$\Sigma\mathbf{F}_{EXT} = M\mathbf{A}_{CM} = d\mathbf{P}/dt$

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

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

$$\left.\begin{array}{l}\theta = \theta_0 + \omega_0 t + \tfrac{1}{2}\alpha t^2\\ \omega = \omega_0 + \alpha t\\ \omega^2 = \omega_0^2 + 2\alpha\Delta\theta\end{array}\right\}$$

Rotational Dynamics

$I = \Sigma m_i r_i 2$
$I_{parallel} = I_{CM} + MD^2$
$I_{disk} = I_{cylinder} = \tfrac{1}{2}MR^2$
$I_{hoop} = MR^2$
$I_{solid\text{-}sphere} = \tfrac{2}{5}MR^2$
$I_{spherical\text{-}shell} = \tfrac{2}{3}MR^2$
$I_{rod\text{-}cm} = \tfrac{1}{12}ML^2$
$I_{rod\text{-}end} = \tfrac{1}{3}ML^2$
$\tau = I\alpha$ (rotation about a fixed axis)
$\tau = r \times F,\ |\tau| = rF\sin\phi$

Work & Energy

$K_{rotation} = \tfrac{1}{2}I\omega^2$
$K_{translation} = \tfrac{1}{2}MVcm^2$
$K_{total} = K_{rotation} + K_{translation}$
$W = \tau\theta$

Statics

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

Angular Momentum

$\mathbf{L} = \mathbf{r} \times \mathbf{p}$
$L_z = I\omega_z$
$\mathbf{L}_{tot} = \mathbf{L}_{CM} + \mathbf{L}^*$
$\tau_{ext} = d\mathbf{L}/dt$
$\tau_{cm} = d\mathbf{L}^*/dt$
$\Omega_{precession} = \tau / L$

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)

General harmonic transverse waves:

$y(x,t) = A\cos(kx - \omega\tau)$
$k = 2\pi/\lambda,\ \omega = 2\pi f = 2\pi/T$
$v = \lambda f = \omega/k$

Waves on a string:

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

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

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

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

Fluids:

$$\rho = \frac{m}{V} \qquad p = \frac{F}{A}$$

$A_1v_1 = A_2v_2$

$$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = p2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2$$

$F_B = \rho_{liquid}\, g V_{liquid}$

$$F_2 = F_1\frac{A_2}{A_1}$$

Uncertainties:

$$\delta = \frac{\sigma}{\sqrt{N}}$$

$$t' = \frac{|\mu_A - \mu_B|}{\sqrt{\delta_{A^2} + \delta_{B^2}}}$$

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