Physics 151 - Formula

Uniformly accelerated motion: $\langle v \rangle = (v + v_0)/2$; $\mathbf{x} = \mathbf{v_0}t + 1/2\, \mathbf{a}t^2$; $\mathbf{v} = \mathbf{v_0} + \mathbf{a}t$; $v^2 - v_0^2 = 2\, \mathbf{a} \cdot \Delta\mathbf{x}$

Newton laws of motion: 1. absence of net force, $\mathbf{v}$=constant; 2. $\mathbf{F} = m\mathbf{a}$; 3. $\mathbf{F}_{A,B} = -\mathbf{F}_{B,A}$

Forces, gravity $\mathbf{W} = m\mathbf{g}$; Friction $F_{max} = \mu_s N$ (static) $F = \mu_k N$ (kinetic), spring $\mathbf{F}_S = -k\mathbf{x}$

Kinetic Energy: $K = ½\, mv^2$ linear motion; $K = ½\, I\omega^2$ rotational motion

Potential energy gravity: $U = mgh$

spring: $U = 1/2\, kx^2$

conservation of total energy: $E = U + K$

linear momentum: $\mathbf{p} = m\mathbf{v}$ ($\mathbf{F} = d\mathbf{p}/dt$)

conservation of linear momentum if $\mathbf{F}_{ext}=0 \rightarrow d\mathbf{p}/dt = 0$ or $\mathbf{p}_1 = \mathbf{p}_2$

Impulse = $\int \mathbf{F}(t)\, dt = \Delta\mathbf{p}$

Momentum Conservation: $\Sigma \mathbf{P}_i = \Sigma\, m\mathbf{v}_i = constant$

Elastic collision: $\Sigma K_i = \Sigma ½ m v_i^2 = constant$

Center of mass: $M X_{cm} = m_1x_1 + m_2x_2 + \ldots$

Angular kinematics: $\varpi = 1/2(\omega + \omega_0)$; $\theta = \varpi t$; $\Delta\theta = \omega_0 t + 1/2\, \alpha t^2$; $\omega = \omega_0 + \alpha t$; $\omega^2 = \omega_o^2 + 2\alpha\theta$

Tangential quantities: $S = r\theta$; $v = r\omega$; $a = r\alpha$

Circular motion: $a_{cent} = \omega^2 r = v^2/r$ also $v=2\pi R/T$

Moment of inertia: $I = \Sigma r_i^2 m_i$

$I = I_{CM} + MR^2$ (parallel axis)

$I = MR^2$ for cylindrical shell about its CM or a hoop.

$I = ½\, MR^2$ for cylinder or disk about its CM

$I = 1/12\, ML^2$ for a thin rod about its CM

$I = 2/5\, MR^2$ for a sphere about its CM

Rotational Kinetic Energy: $K = 1/2\, I\omega^2$

Combined rotation plus linear motion: $K = 1/2\, mv^2 + 1/2\, I\omega^2$

Rolling without slipping: $v_{cm} = R\omega$

torque as a vectorial (cross) product: $\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$; $\boldsymbol{\tau} = I\boldsymbol{\alpha}$

angular momentum: $\mathbf{L}_z = \mathbf{r} x \mathbf{p} = I\boldsymbol{\omega}$; $\boldsymbol{\tau} = d\mathbf{L}/dt$

Power $P = \tau\, \omega$

conservation of angular momentum ($\boldsymbol{\tau}_{ext} = 0$) then $d\mathbf{L}/dt = 0$; or $\mathbf{L}_1 = \mathbf{L}_2$

static equilibrium: $\Sigma\, \mathbf{F}_i = 0$ and $\Sigma\, \boldsymbol{\tau}_i = 0$

center of mass: $R_{cm} = \Sigma\, r_i m_i / M_{total}$

Mass on a spring $\omega = \sqrt{k/m}$; $T = 2\pi/\omega$; $f = 1/T = \omega/2\pi$; $\omega = 2\pi f$

Displacement: $x = x_o \cos(\omega t + \phi)$ Velocity: $v = -v_o \sin(\omega t + \phi)$ $(v_o = \omega x_o)$

Acceleration: $a = -\omega^2 x = -\omega^2 x_o \cos(\omega t + \phi)$

pendulum: $T = 2\pi\sqrt{L/g}$ $\omega = \sqrt{g/L}$; Resonance at $\omega=\omega_o$

general pendulum $\omega = \sqrt{mgd/I}$; Torsional Pendulum $\omega = \sqrt{k/I}$

Gravity

Newton's Law of Gravity: $F = Gm_1m_2/r^2$

$g = GM_E/R_E^2$

Kepler's Third Law: $T^2 = K_S r^3$

Second Law: $dA/dt = constant$

Gravitational Potential: $U = -GM_E m/r$

Total Energy of Satellite $E = GMm/2r - GMm/r = -GMm/2r$

escape velocity: $v = \sqrt{\frac{2GM_E}{R_E}}$

Fluids

Statics: Pressure: $P = F/A = P_O + \rho gh$ (P constant at a given height)

continuity equation: $Av = constant$

Dynamics: Bernoulli's equation: $P + ½ \rho v^2 + \rho gy = constant.$

Archimeme's Principle: $B = \rho_{fluid} V_{disp} g$

Waves

In general,

Any Wave: $y(x,t) = f(x-vt)$

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

Superposition: $y_{total} = y_1(x,t) + y_2(x,t)$

out of phase by ϕ $y_{total} = 2A\cos(\phi/2)\cos(kx-\omega t+\phi/2)$

Wave number: $k = 2\pi/\lambda$

Angular frequency: $\omega = 2\pi f = 2\pi/T$

phase velocity: $v = \omega/k = \lambda/T = \lambda f$

velocity: $v = \sqrt{\frac{F}{\mu}}$ string

power: $\overline{P} = \frac{1}{2}\mu v\omega^2 A^2$ string; $\overline{P} = \frac{1}{2}\rho(Area)v\omega^2 A^2$ sound

energy per unit length: $\frac{d\overline{E}}{dx} = \frac{1}{2}\mu\omega^2 A^2$ Intensity: $I = \frac{\overline{P}}{Area} = \frac{1}{2}\rho v\omega^2 A^2$

Standing waves on a string: $\lambda = 2L/n$

Thermo

$PV=nRT$ or $PV=NkT$

Conversion $0^\circ C = 273\ K$ *unit* size the same, or $K = {}^\circ C + 273$; ${}^\circ C = ({}^\circ F - 32)*5/9$

$\Delta L = \alpha L_i \Delta T$; $\Delta V = \beta V_i \Delta T$; $\beta = 3\alpha$

α for some materials, all times 10^{-6}: Al 24; Brass 19; Cu 17, glass 9, Pyrex 3.2, lead 29, steel 11, concrete 12, Invar 0.9

β for some materials, all times 10-4: Alcohol 1.12, benzene 1.24, acetone 1.5, glycerin 4.85, Mercury 1.82, turpentine 9.0, gasoline 9.6, air 36.7, Helium 36.7

$Q = mc\Delta T$ defines c, specific heat

$Q = mL$ defines L, latent heat

$\Delta E_{int} = Q + W$