PHYS 121/122 Formula Sheet — November 9, 2005

Constants

$\mathbb{P}_{\text{atm.}} = 1.013 \times 10^5$ Pa
$g = 9.8$ m/s
$c = 2.9979 \times 10^8$ m/s
$G = 6.673 \times 10^{-11}$ N m^2/kg^2
$M_{\text{Earth}} = 5.98 \times 10^{24}$ kg
$M_{\text{Sun}} = 1.991 \times 10^{30}$ kg
$R_{\text{Earth}} = 6.37 \times 10^6$ m
$R_{\text{Sun}} = 6.96 \times 10^8$ m
$N_{\text{A}} = 6.022 \times 10^{23}$ $\frac{\text{atoms}}{\text{mol}}$
$k_{\text{B}} = 1.381 \times 10^{-23}$ J/K
$R = 8.314$ J/mol·K
$R = k_{\text{B}} N_{\text{A}}$

Kinematics

$\vec{v}(t) = \vec{v}_\circ + \vec{a}t$
$\vec{x}(t) = \vec{x}_\circ + \vec{v}_\circ t + \frac{1}{2}\vec{a}t^2$
$|\vec{v}_{\text{f}}|^2 = |\vec{v}_{\text{i}}|^2 + 2\vec{a} \cdot (\vec{x}_{\text{f}} - \vec{x}_{\text{i}})$

Newton's Law

$\sum \vec{F} = m\vec{a}$
$f_{\text{s}} \leq \mu_{\text{s}} F_{\text{N}}$
$f_{\text{k}} = \mu_{\text{k}} F_{\text{N}}$
$a_{\text{r}} = \dfrac{v^2}{r}$
$a_{\text{t}} = \dfrac{d\,|\vec{v}|}{dt}$
$\vec{F}_{\text{s}} = -k\vec{x}$

Work & Energy

$K = \frac{1}{2}mv^2$
$U_{\text{g}} = mgh$
$U_{\text{s}} = \frac{1}{2}kx^2$
$E = K + U_{\text{g}} + U_{\text{s}}$
$E_{\text{f}} = E_{\text{i}} + W$
$W = \int \vec{F} \cdot d\vec{x}$
$W = \vec{F} \cdot \Delta\vec{x}$, (constant force)
$P = \dfrac{dW}{dt}$
$P = \vec{F} \cdot \vec{v}$, (constant force)
$F = -\dfrac{dU}{dx}$

Momentum

$\vec{p} = m\vec{v}$
$\vec{I} = \int \vec{F}dt = \bar{\vec{F}}\Delta t = \Delta\vec{p}$
$\vec{I} = \vec{F}\Delta t$, (constant force)
$\sum \vec{p}_{\text{i}} = \sum \vec{p}_{\text{f}}$
$\Delta v = v_{\text{ex}} \ln(M_i/M_f)$
$F_{\text{thrust}} = v_{\text{ex}} \left|\frac{dm}{dt}\right|$

Angular Momentum

$\vec{\ell} = \vec{r} \times \vec{p}$
$\sum \vec{\tau} = \dfrac{d}{dt}\vec{\ell} = I\alpha$

Elastic Properties of Solids

elastic modulus $= \dfrac{\text{stress}}{\text{strain}}$
$Y = \dfrac{\Delta F/A}{\Delta\ell/\ell_i}$
$S = \dfrac{\Delta F/A}{\Delta x/h}$
$B = \dfrac{-\Delta\mathbb{P}}{\Delta V/V_i}$
$P = kA\Delta T/\ell$

Universal Gravitation

$F_g = \dfrac{GMm}{r^2}$
$T^2 = \dfrac{4\pi^2}{GM}a^3$
$U_g = -\dfrac{GMm}{r}$
$v^2_{\text{escape}} = 2GM/r$

Fluid Mechanics

$m = \rho V$
$R = Av =$ constant
$F = \mathbb{P}A$
$\mathbb{P} = \mathbb{P}_\circ + \rho gh$
$F_{\text{B}} = \rho_f V g$
$\mathbb{P} + \frac{1}{2}\rho v^2 + \rho gh =$ constant

SHM

$a = -\omega^2 x$
$\omega = 2\pi f = 2\pi/T$
$\omega^2 = k/m$
$\omega^2 = g/\ell$
$\omega^2 = mgd/I$
$x(t) = A\cos(\omega t + \phi)$
$v(t) = -\omega A \sin(\omega t + \phi)$
$a(t) = -\omega^2 A\cos(\omega t + \phi)$
$E = \frac{1}{2}kA^2 = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$

Traveling Waves

$y(x,t) = f(x \pm v_{\text{w}}t)$
$y(x,t) = A\sin(kx - \omega t)$
$k = 2\pi/\lambda$
$v_{\text{w}} = f\lambda = \sqrt{F_t/\mu}$
$\mathbb{P} = \frac{1}{2}\mu\omega^2 A^2 v_2$

Sound Waves

$v_{\text{w}} = f\lambda = \sqrt{B/\rho}$
$s(x,t) = s_m \cos(kx - \omega t)$
$\Delta\mathbb{P} = \Delta\mathbb{P}_m \sin(kx - \omega t)$
$\Delta\mathbb{P}_m = \rho v_{\text{w}} \omega s_m$
$f' = f\frac{v_{\text{w}} \pm v_{\text{obs.}}}{v_{\text{w}} \mp v_{\text{source}}}$
$\sin\theta = v_{\text{w}}/v$
mach # $= v/v_{\text{w}}$
$v_{\text{w}} \propto T$

Standing Waves

$y(x,t) = 2A\sin(kx)\cos(\omega t)$
$\ell = 2n\frac{\lambda}{4}$
$\ell = (2n-1)\frac{\lambda}{4}$

Temperature

$\Delta L/L_i = \alpha\Delta T$
$\Delta V/V_i = \beta\Delta T$
$PV = nRT$

Heat

$P = kA\frac{\Delta T}{\Delta x}$
$Q = mc\Delta T$
$Q = nC_V\Delta T$ $\left(\substack{\text{constant}\\ \text{volume}}\right)$
$Q = nC_{\mathbb{P}}\Delta T$ $\left(\substack{\text{constant}\\ \text{pressure}}\right)$
$Q = \pm mL$
$W = -\int_i^f \mathbb{P}dV$
$\Delta E_{\text{int}} = Q + W$

Kinetic Theory of Gasses

$N_{\text{A}} k_{\text{B}} = R$
$\frac{3}{2}k_{\text{B}}T = \frac{1}{2}m\bar{v^2}$
$\Delta E_{\text{int}} = nC_V\Delta T$
$C_V = \frac{d}{2}R$
$C_{\mathbb{P}} = \frac{d+2}{2}R$
$\gamma = C_{\mathbb{P}}/C_V$
$\mathbb{P}V^\gamma =$ constant along adiabat

Engines & Entropy

$e = \frac{W}{Q_{\text{h}}}$
$\text{COP}_{\text{h}} = |Q_{\text{h}}|/W$
$\text{COP}_{\text{c}} = |Q_{\text{c}}|/W$
$\left|\frac{Q_{\text{h}}}{Q_{\text{c}}}\right| = \frac{T_{\text{h}}}{T_{\text{c}}}$ (Carnot cycle)
$dS = \frac{dQ_{\text{r}}}{T}$

Geometry

Circle: $A = \pi R^2$
Sphere: $A = 4\pi R^2$, $V = \frac{4}{3}\pi R^3$, $I = \frac{2}{5}mr^2$
Cylinder: $A = 2\pi R(R+h)$, $V = \pi R^2 h$, $I = \frac{1}{2}mr^2$
Rect. Plate: $A = 2(ab+bc+ca)$, $V = abc$, $I = \frac{1}{12}m(a^2+b^2)$
Parallel Axis: $I_\circ = I_{\text{CoM}} + md^2$

Trigonometry

$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$
$a^2 = b^2 + c^2 - 2bc\cos A$
$\sin^2\theta + \cos^2\theta = 1$
$\sec^2\theta = 1 + \tan^2\theta$
$\sin 2\theta = 2\sin\theta\cos\theta$
$\cos 2\theta = \cos^2\theta - \sin^2\theta$
$\tan 2\theta = \frac{2\tan\theta}{1-\tan^2\theta}$
$\sin(A \pm B) = \begin{matrix}\sin A\sin B\\ \pm\cos A\cos B\end{matrix}$
$\cos(A \pm B) = \begin{matrix}\cos A\sin B\\ \mp\sin A\sin B\end{matrix}$

Series

$(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + ...$
$e^x = 1 + x + \frac{1}{2!}x^2 + ...$
$\sin x = x - \frac{1}{3!}x^3 + ...$
$\cos x = 1 - \frac{1}{2!}x^2 + ...$
$\tan x = x + \frac{1}{3}x^3 + \frac{2}{15}x^5 + ...$

Integrals

$\int dx x^n = \frac{1}{n+1}x^{n+1}, (x \neq -1)$
$\int \frac{dx}{x} = \ln x$
$\int dx \sin(ax) = -\frac{1}{a}\cos(ax)$
$\int dx \cos(ax) = \frac{1}{a}\sin(ax)$