PHYS 15200 Formulas and Constants

Rolling condition:
$v_{CM} = R\omega$

$\vec{L}_{point} = \vec{r} \times \vec{p}$

$\vec{L}_{rigid} = I\vec{\omega}$

$\Sigma\vec{\tau} = \dfrac{d\vec{L}}{dt}$

Chapter 11

Static equilibrium:
$\Sigma\vec{F} = 0$; $\Sigma\vec{\tau} = 0$

Strength of materials:
Stress = modulus × strain

$\dfrac{F_\perp}{A} = Y\dfrac{\Delta\ell}{\ell_0}$

$\dfrac{F_\parallel}{A} = S\dfrac{\Delta x}{h}$

$\Delta p = B\left|\dfrac{\Delta V}{V_0}\right|$

Chapter 12

$\rho = \dfrac{m}{V}$

$p = \dfrac{F_\perp}{A}$

$\rho_w = 1\ \text{g/cm}^3 = 1000\ \text{kg/m}^3$

$p_0 = 1\ \text{atm} = 101.3\ \text{kPa}$

Fluid statics:

$p = p_0 + \rho g h$

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

$p = p_0 + p_{gauge}$

$B = \rho_f g V_f$

Fluid dynamics:

$\mathbb{R} = \dfrac{dV}{dt}$

$\mathbb{R} = Av$ (pipes)

$A_1 v_1 = A_2 v_2$

$p_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = p_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

Chapter 13

$F_{grav} = \dfrac{Gm_1 m_2}{r^2}$

$G = 6.67\times10^{-11}\ \text{N-m}^2/\text{kg}^2$

$g = \dfrac{GM}{r^2}$

$U_{grav} = -\dfrac{GMm}{r}$

$v_{orb} = \sqrt{\dfrac{GM}{r}}$

$E_{orb} = -\dfrac{GMm}{2r}$

$\left(\dfrac{T}{2\pi}\right)^2 = \dfrac{r^3}{GM}$

Chapter 14

$f = \dfrac{1}{T}$; $\omega = 2\pi f$

$F_{spring} = -kx$

$\omega_{spring} = \sqrt{\dfrac{k}{m}}$

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

$v_{\max} = \omega A$

$a_{\max} = \omega^2 A$

$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$

$E = \frac{1}{2}kA^2$; $E = \frac{1}{2}mv_{\max}^2$

$\omega_{pend} = \sqrt{\dfrac{g}{L}}$

Chapter 15

$v = \lambda f$

$k = \dfrac{2\pi}{\lambda}$

$y = A\cos(kx \pm \omega t)$

$v_{string} = \sqrt{\dfrac{F_T}{\mu}}$

$\mu = \dfrac{m}{L}$

Standing waves along string:

$f_1 = \dfrac{v}{2L}$; $f_n = nf_1$

$n = 1, 2, 3, \ldots$

Chapter 16

$I = \dfrac{P}{A}$

$I_{point} = \dfrac{P}{4\pi r^2}$

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

$\beta = (10\ \text{dB})\log\left(\dfrac{I}{I_0}\right)$

Standing sound waves:
Pipe open both ends

$f_1 = \dfrac{v}{2L}$; $f_n = nf_1$

$n = 1, 2, 3, \ldots$

Pipe closed one end

$f_1 = \dfrac{v}{4L}$; $f_n = nf_1$

$n = 1, 3, 5, \ldots$, odd

Doppler shift:

$f_L = f_S\left(\dfrac{v - v_L}{v - v_S}\right)$

v = speed of sound
v_L = listener velocity
v_S = source velocity
(+) direction is
source → listener

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Chapter 1

$\vec{A}\bullet\vec{B} = AB\cos\phi$

$\vec{A}\bullet\vec{B} = A_xB_x + A_yB_y + A_zB_z$

$|\vec{A}\times\vec{B}| = AB\sin\phi$

$$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

Chapter 2

$v_{av} = \frac{\Delta x}{\Delta t}$; $v = \frac{dx}{dt}$

$a_{av} = \frac{\Delta v}{\Delta t}$; $a = \frac{dv}{dt}$

Constant acceleration:

$v = v_0 + at$

$x = x_0 + v_0t + \frac{1}{2}at^2$

$x = x_0 + \frac{1}{2}(v_0 + v)t$

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

Chapter 3

$\vec{r} = \langle x, y, z\rangle = x\hat{i} + y\hat{j} + z\hat{k}$

$\vec{v} = \langle v_x, v_y, v_z\rangle = \frac{d\vec{r}}{dt}$

$\vec{a} = \langle a_x, a_y, a_z\rangle = \frac{d\vec{v}}{dt}$

Projectile motion:

$x = v_{0x}t$

$v_y = v_{0y} - gt$

$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$

$v_y^2 = v_{0y}^2 - 2g(y - y_0)$

$a_x = 0$; $a_y = -g$

$g = 9.81\ \text{m/s}^2$

Uniform circular motion:

$a_{rad} = \frac{v^2}{r}$; $v = \frac{2\pi r}{T}$

Relative motion:

$\vec{v}_{out} = \vec{v}_{in} + \vec{v}_{frame}$

Chapters 4, 5

$\Sigma\vec{F} = m\vec{a}$

$w = mg$

$f_k = \mu_k n$

$0 \le f_s \le \mu_s n$

Chapter 6

$W = \vec{F}\bullet\Delta\vec{r}$

$W = \int_{x_1}^{x_2} F_x\,dx$

$W_{total} = \Delta K$

$K = \frac{1}{2}mv^2$

$P = \frac{dW}{dt}$

$P = \vec{F}\bullet\vec{v}$

Chapter 7

$\Delta U = -W_{con}$

$U_{grav} = mgy$

$U_{elastic} = \frac{1}{2}kx^2$

$E = K + U$

$E_1 + W_{noncon} = E_2$

Chapter 8

$\vec{p} = m\vec{v}$

$\vec{J} = \int_{t_1}^{t_2}\vec{F}\,dt = \vec{F}_{av}\Delta t$

$\Sigma\vec{J} = \Delta\vec{p}$

$\Sigma\vec{F} = \frac{d\vec{p}}{dt}$

1-d elastic collision:

$v_2 = 0$

$v_1' = \frac{m_1 - m_2}{m_1 + m_2}v_1$

$v_2' = \frac{2m_1}{m_1 + m_2}v_1$

Center of mass:

$\vec{r}_{CM} = \frac{\Sigma m_i\vec{r}_i}{M}$

$\vec{p}_{total} = M\vec{v}_{CM}$

$\Sigma\vec{F}_{ext} = M\vec{a}_{CM}$

Chapter 9

$\omega = \frac{d\theta}{dt}$

$\alpha = \frac{d\omega}{dt}$

$s = r\theta$; $v = r\omega$

$a_{\tan} = r\alpha$

$K_{rot} = \frac{1}{2}I\omega^2$

Constant acceleration:

$\omega = \omega_0 + \alpha t$

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

$\theta = \frac{1}{2}(\omega_0 + \omega)t$

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

Moment of inertia:

$I_{point} = mr^2$

$I_{\substack{solid\\sphere}} = \frac{2}{5}MR^2$

$I_{\substack{hollow\\sphere}} = \frac{2}{3}MR^2$

$I_{\substack{solid\\cylinder}} = \frac{1}{2}MR^2$

$I_{\substack{hollow\\cylinder}} = MR^2$

$I_{\substack{rod,axis\\thru\ CM}} = \frac{1}{12}ML^2$

$I_{\parallel} = I_{CM} + Md^2$

Chapter 10

$\vec{\tau} = \vec{r}\times\vec{F}$

$\Sigma\vec{\tau} = I\vec{\alpha}$

$K_{total} = \frac{1}{2}Mv_{CM}^2 + \frac{1}{2}I_{CM}\omega^2$