Formulas for PHY 141

Kinematics	
Constant acceleration	$\mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0 t + \frac{1}{2}\mathbf{a}t^2$ $\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$ $v^2 = v_0{}^2 + 2\mathbf{a}\cdot(\mathbf{r}-\mathbf{r}_0)$
Circular motion	$\mathbf{a} = \mathbf{a}_r + \mathbf{a}_t$ $a_r = v^2 / r = r\omega^2$ $a_t = r\alpha,\ v = r\omega$
Dynamics	
Gravity near earth's surface	$\mathbf{F}_g = m\mathbf{g}$
Elastic force	$F = -kx$
Friction	$f_k = \mu_k N$ $f_s \le \mu_s N$
Effective gravity	$\mathbf{g}_{eff} = \mathbf{g} - \mathbf{a}$
Potential Energy	
Gravity near earth's surface	$U = mgy$
Elastic force	$U = \frac{1}{2}kx^2$
Rotational Motion	
Circular motion vectors	$\mathbf{v} = \boldsymbol{\omega} \times \mathbf{r}$
Radial acceleration	$\mathbf{a}_r = -\omega^2 \mathbf{r}$
Tangential acceleration	$\mathbf{a}_t = \boldsymbol{\alpha} \times \mathbf{r}$
Moment of inertia (particle)	$I = mr^2$
Rotational kinetic energy	$K_{rot} = \frac{1}{2}I\omega^2$
Symmetric rigid body	$\boldsymbol{\tau} = I\boldsymbol{\alpha}$ $\mathbf{L} = I\boldsymbol{\omega}$

Rolling	$v_{CM} = R\omega$ $a_{CM} = R\alpha$
Angular momentum (particle)	$\mathbf{L} = \mathbf{r} \times \mathbf{p}$
Gravity and Satellite Motion	
Point masses or spherically symmetric objects	$F = G\frac{Mm}{r^2}$ $U = -G\frac{Mm}{r}$
Planet with small satellite in orbit	$E = -G\frac{Mm}{2a}$
Oscillations (SHM)	
Displacement	$x = A\cos(\omega t + \phi)$
Force	$F = -m\omega^2 x$
Potential Energy	$U = \frac{1}{2}m\omega^2 x^2$
Total energy	$E = \frac{1}{2}m\omega^2 A^2$
Mass on ideal spring	$\omega = \sqrt{k/m}$
Wave Motion	
Harmonic wave	$y = A\cos(kx - \omega t + \delta)$ $k = 2\pi/\lambda,\ \omega = 2\pi f$ $v = f\lambda = \omega / k$
Interference, waves of equal intensity	$I = 2I_0(1 + \cos\delta)$
Phase difference due to path difference	$\delta = k\Delta x$
Loudness level	$\beta = 10\log_{10}(I / I_0)$

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Doppler effect, source chasing fleeing receiver	$f = f_0 \frac{v - v_R}{v - v_S}$
Standing wave, string fixed at both ends, pipe open at both ends	$f_n = nf_1,\ n = 1,2,3,\ldots$ $f_1 = v / 2L$
Standing wave, string fixed at one end, pipe open at one end	$f_n = nf_1,\ n = 1,3,5,\ldots$ $f_1 = v / 4L$
Wave in string	$v = \sqrt{T / \mu}$
Beat frequency	$f_B = \lvert f_2 - f_1 \rvert$
Approximations	
Small angles (radians)	$\sin\theta \approx \tan\theta \approx \theta$ $\cos\theta \approx 1$
Binomial approximation	$(1+x)^n \approx 1 + nx$ $\lvert x \rvert << 1$
Numerical Constants	
Gravity near earth's surface	$g \approx 9.81\ \mathrm{m/s^2}$
Gravitation constant	$G = 6.67 \times 10^{-11}$ (SI units)
Earth's mass	$M_E = 5.98 \times 10^{24}$ kg
Earth's radius	$R_E = 6.37 \times 10^{6}$ m
Earth-moon distance	3.82×10^{8} m
Earth=sin distance	1.50×10^{11} m
Pressure	$1\ \mathrm{atm} = 1.01 \times 10^{5}$ Pa

Derivatives	
Powers	$\frac{d}{dx} x^n = nx^{n-1}$, $\frac{d}{dx} \ln x = \frac{1}{x}$
Exponentials	$\frac{d}{dx} e^{ax} = ae^{ax}$
Trigonometry	$\frac{d}{dx} \sin ax = a \cos ax$, $\frac{d}{dx} \cos ax = -a \sin ax$
Integrals	
Powers	$\int x^n\, dx = \frac{x^{n+1}}{n+1}$, $\int \frac{1}{x} dx = \ln x$
Exponentials	$\int e^{ax}\, dx = \frac{1}{a} e^{ax}$
Trigonometry	$\int \sin ax\, dx = -\frac{1}{a} \cos ax$, $\int \cos ax\, dx = \frac{1}{a} \sin ax$
Trigonometry	
General	$\sin\theta / \cos\theta = \tan\theta$, $\sin^2\theta + \cos^2\theta = 1$
Two angles	$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \sin\beta\cos\alpha$, $\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$
Double angles	$\sin 2\theta = 2\sin\theta\cos\theta$, $\cos 2\theta = \cos^2\theta - \sin^2\theta$
Logarithms	
General	$\ln a + \ln b = \ln(ab)$, $\ln a - \ln b = \ln(a/b)$