Equation Sheet For Physics 133: Final Exam (Schumacher)

Simple Harmonic Motion

$x(t) = x_m \cos(\omega t + \phi_o)$

$v(t) = -x_m\omega \sin(\omega t + \phi_o)$

$a(t) = -x_m\omega^2 \cos(\omega t + \phi_o)$

Horizontal Spring-Block SHO

$E = U(t) + K(t) = \frac{1}{2} k x_m^2$

$U_s(t) = \frac{1}{2} k x^2(t)$

$K(t) = \frac{1}{2} m v^2(t)$

SHO frequencies

$\omega = \sqrt{k/m}$

$\omega = \sqrt{g/L}$

Waves

$y(x,t) = y_m \sin(kx \pm \omega t + \phi_o)$ $\quad s(x, t) = s_m \cos(kx \pm \omega t + \phi_o)$ $\quad v = \omega/k = \lambda f = \lambda/T$

Superposition

$y_1(x,t) = y_m \sin(kx - \omega t)$ $\quad y_2(x,t) = y_m \sin(kx - \omega t + \phi_o)$ $\rightarrow y'(x,t) = [2\, y_m \cos\frac{1}{2}\phi_o] \sin(kx - \omega t + \frac{1}{2}\phi_o)$

$y_1(x,t) = y_m \sin(kx - \omega t)$ $\quad y_2(x,t) = y_m \sin(kx + \omega t)$ $\rightarrow y'(x,t) = [2\, y_m \sin kx] \cos\omega t$

Standing Wave Resonance (both ends nodes or antinodes, one end node)

$\lambda = 2L/n$ (n = 1,2,3…) $\quad \lambda = 4L/n$ (n = 1,3,5…) $\quad$ n = "harmonic number"

Interference

$\Delta\phi = n\, 2\pi, (n+\frac{1}{2})\, 2\pi$ $\quad \Delta\phi = 2\pi\, \Delta x/\lambda$ $\quad f_{beat} = |f_1 - f_2|$

Intensity

$I = P/A$ $\quad I = P/(4\pi r^2)$

Doppler Effect: (for mechanical waves) $f' = f\,\dfrac{v \pm v_D}{v \pm v_S}$ $\quad$ *(for light)* $f = f_o\sqrt{\dfrac{1 \mp v/c}{1 \pm v/c}}$

Specific Waves

String $\quad v = \sqrt{\tau/\mu}$ $\quad P_{ave} = \frac{1}{2} \mu v \omega^2 y_m^2$

Sound $\quad v = \sqrt{B/\rho}$ = 343 m/s (in air) $\quad I = \frac{1}{2} \rho v \omega^2 s_m^2$ $\quad \Delta p = \Delta p_m \sin(kx - \omega t + \phi)$ $\quad \Delta p_m = (v\rho\omega)\, s_m$

$\beta = (10\text{ dB}) \log I/I_o$ $\quad I_o = 10^{-12}\text{ W/m}^2$ $\quad \Delta\beta = (10\text{ dB}) \log I_2/I_1$

EM $\quad E = E_m \sin(kx \pm \omega t + \phi_o)$ $\quad B = B_m \sin(kx \pm \omega t + \phi_o)$ $\quad E = cB$ $\quad I = (1/2c\mu_o)\, E_m^2$

$v = c/n$ $\quad n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\quad \sin\theta_c = n_2/n_1$ $\quad I_{out} = I_{in} \cos^2\theta$

Images

$p = -i$ $\quad 1/f = 1/p + 1/i$ $\quad m = -i/p$ $\quad |m| = h'/h$

Young's Experiment and Diffraction

$d \sin\theta = m\lambda$ $\quad d \sin\theta = (m+\frac{1}{2})\, \lambda$ $\quad m = 0,1,2,...$ $\quad I = I_m \cos^2 \beta$ $\quad \beta = \dfrac{\pi d}{\lambda}\sin\theta$

$a \sin\theta = m\lambda$ $\quad m = 1,2,3,…$ $\quad I = I_m\left(\dfrac{\sin\alpha}{\alpha}\right)^2$ $\quad \alpha = \dfrac{\pi a}{\lambda}\sin\theta$

$I = I_m \cos\beta^2\left(\dfrac{\sin\alpha}{\alpha}\right)^2$

Special Relativity

$\Delta x = \gamma(\Delta x' + v\Delta t')$ $\quad \Delta x' = \gamma(\Delta x - v\Delta t)$ $\quad \Delta t = \gamma\Delta t_o$ $\quad u = \dfrac{u' + v}{1 + u'v/c^2}$ $\quad p = \gamma mv$ $\quad E = \gamma mc^2 = K + mc^2$

$\Delta t = \gamma\left(\Delta t' + \dfrac{v\Delta x'}{c^2}\right)$ $\quad \Delta t' = \gamma\left(\Delta t - \dfrac{v\Delta x}{c^2}\right)$ $\quad L = L_o/\gamma$ $\quad \gamma = \dfrac{1}{\sqrt{1 - v^2/c^2}}$ $\quad K = mc^2(\gamma-1)$ $\quad E^2 = (pc)^2 + (mc^2)^2$

Quantum Mechanics

$E = hf$ $\quad p = h/\lambda$

$\Delta x\, \Delta p_x \geq \hbar$ $\quad hf = \Phi + K_{max}$

Probability $\approx \psi^2(x)\, \Delta x$ (for small Δx)

$E_n = n^2\dfrac{h^2}{8mL^2}$ $\quad \psi_n(x) = \sqrt{2/L}\,\sin(n\pi x/L)$

Important constants, combinations and conversions

$h = 6.63 \times 10^{-34}$ J s $= 4.14 \times 10^{-15}$ eV s $\quad \hbar = 1.05 \times 10^{-34}$ J s $= 6.58 \times 10^{-16}$ eV s

$c = 3.00 \times 10^8$ m/s $\quad hc = 1240$ eV nm

$m_e = 9.11 \times 10^{-31}$ kg $\quad m_e c^2 = 511$ keV

$e = 1.602 \times 10^{-19}$ C

$\varepsilon_o = 8.85 \times 10^{-12}$ F m $\quad \mu_o = 4\pi \times 10^{-7}$ H/m

1 eV $= 1.602 \times 10^{-19}$ J