PHYSICS 1C - Waves, Optics, and Modern Physics
Summer Session I, 2012
Final Exam

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Please read carefully before beginning!

- You have 180 minutes to complete the exam.
- Fill in your name, student ID, 3-digit code number, and the test version on your scantron.
- You are not allowed to have any materials other than a scantron, a pen and/or a pencil, and a calculator. Equations are provided below.
- Each problem is worth 1 point.

Best of luck!

Useful equations:

Simple harmonic motion:

$\frac{d^2x}{dt^2} = -\omega^2 x$	$x(t) = A\cos(\omega t + \phi)$	$T = \frac{2\pi}{\omega} \quad f = \frac{1}{T}$
$v_x = -\omega A \sin(\omega t + \phi)$	$v_{\max} = \omega A$	
$a_x = -\omega^2 A \cos(\omega t + \phi)$	$a_{\max} = \omega^2 A$	
$E = \frac{1}{2}kA^2$	$v_x = \pm\omega\sqrt{A^2 - x^2}$	
Mass attached to a spring:	$\omega = \sqrt{\frac{k}{m}}$	
Simple pendulum:	$\omega = \sqrt{\frac{g}{l}}$	
Physical pendulum:	$\omega = \sqrt{\frac{mgd}{I}}$	
Damped oscillations:	$x(t) = Ae^{-(b/2m)t}\cos(\omega t + \phi)$	
$\omega = \sqrt{\omega_0^2 - \left(\frac{b}{2m}\right)^2}$	$\omega_0 = \sqrt{\frac{k}{m}}$	
Forced oscillations:	$x(t) = A\cos(\omega t + \phi)$	$A = \frac{F_0/m}{\sqrt{\left(\omega^2 - \omega_0^2\right)^2 + \left(\frac{b\omega}{m}\right)^2}}$
Waves:	$y(x,t) = f(x \pm vt)$	$\lambda = vT$
$y(x,t) = A\sin(kx - \omega t)$	$k = \frac{2\pi}{\lambda}$	$\omega = \frac{2\pi}{T}$
$v_y = -\omega A \cos(kx - \omega t)$	$v_{y,\max} = \omega A$	
$a_y = -\omega^2 A \sin(kx - \omega t)$	$a_{y,\max} = \omega^2 A$	
Linear wave equation:	$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2}{\partial t^2}$	
Waves on strings:	$v = \sqrt{\frac{T}{\mu}}$	
Energy transfer:	$P = \frac{1}{2}\mu\omega^2 A^2 v$	
Sound waves:	$s = s_{\max}\sin(kx - \omega t)$	$\Delta P = \Delta P_{\max}\cos(kx - \omega t)$
$\Delta P_{\max} = \rho v \omega s_{\max}$	$v = 331 m/s + (0.6 m/s \cdot {}^\circ C)T_C$	$v(20^\circ C) = 343 m/s$

Doppler effect:	$f' = f\frac{v+v_o}{v-v_s}$	v_o, v_s positive when moving toward
Interference:	$y = \left(2A\cos\frac{\phi}{2}\right)\sin\left(kx - \omega t + \frac{\phi}{2}\right)$	$\Delta r = \frac{\phi}{2\pi}\lambda$
constructive:	$\phi = 0,\ 2\pi,\ 4\pi, ...$	
destructive:	$\phi = \pi,\ 3\pi,\ 5\pi, ...$	
Standing waves:	$y = (2A\sin kx)\cos\omega t$	distance between (anti)nodes: $\lambda/2$
In strings:	$f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$	$n = 1, 2, 3, ...$
In air columns:		
open both ends:	$f_n = n\frac{v}{2L}$	$n = 1, 2, 3, ...$
one end closed:	$f_n = n\frac{v}{4L}$	$n = 1, 3, 5, ...$
Beats:	$y = \left[2A\cos 2\pi\left(\frac{f_1 - f_2}{2}\right)t\right]\cos 2\pi\left(\frac{f_1+f_2}{2}\right)t$	$f_b = \lvert f_1 - f_2\rvert$
Displ. current:	$I_d = \epsilon_0\frac{d\Phi_E}{dt}$	
Maxwell's eq's:	$\oint \vec{E}\cdot d\vec{A} = \frac{q}{\epsilon_0}$	$\oint \vec{B}\cdot d\vec{A} = 0$
	$\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$	$\oint \vec{B}\cdot d\vec{s} = \mu_0 I + \epsilon_0\mu_0\frac{d\Phi_E}{dt}$
EM waves:	$c = \frac{1}{\sqrt{\epsilon_0\mu_0}} = 3\times 10^8 m/s$	$\frac{E}{B} = c$
	$\epsilon_0 = 8.85\times 10^{-12}\frac{C^2}{N\cdot m^2}$	$\mu_0 = 4\pi\times 10^{-7}\frac{V\cdot s}{A\cdot m}$
Doppler effect:	$f' = f\sqrt{\frac{c+v}{c-v}}$	v positive when approaching
LC circuit:	$\omega = \frac{1}{\sqrt{LC}}$	
Poynting vec.:	$\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$	$S = \frac{EB}{\mu_0} = \frac{E^2}{\mu_0 c} = \frac{cB^2}{\mu_0}$
Intensity:	$I = S_{avg} = \frac{E_{\max}B_{\max}}{2\mu_0} = \frac{E_{\max}^2}{2\mu_0 c} = \frac{cB_{\max}^2}{2\mu_0}$	
Energy dens.:	$u_E = \frac{\epsilon_0 E^2}{2}$	$u_B = \frac{B^2}{2\mu_0}$
	$u_{avg} = \frac{\epsilon_0 E_{\max}^2}{2} = \frac{B_{\max}^2}{2\mu_0}$	$I = cu_{avg}$
Momentum:	$p = \frac{U}{c}$	
Pressure:	$P = \frac{S}{c}$	for complete absorption
Poloarization:	$I = I_0\cos^2\theta$	$I = \frac{I_0}{2}$ for unpolarized
Reflection:	$\theta_1' = \theta_1$	
Refraction:	$n = \frac{c}{v}$	$n_1\sin\theta_1 = n_2\sin\theta_2$
		$\lambda_1 n_1 = \lambda_2 n_2$
Tot. int. refl.:	$\sin\theta_c = \frac{n_2}{n_1}$	for $n_2 < n_1$
Mirrors:	$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$	$f = \frac{R}{2}$
Signs:	$p > 0$ obj. in front (real)	$q > 0$ image in front (real)
	$h' > 0$ image upright	$f, R > 0$ concave
Refr. surface:	$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R}$	
Signs:	$p > 0$ obj. in front (real)	$q > 0$ image behind (real)
	$h' > 0$ image upright	$R > 0$ center behind
Lenses:	$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$	$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
Signs:	$p > 0$ obj. in front (real)	$q > 0$ image behind (real)
	$h' > 0$ image upright	$R_1, R_2 > 0$ center behind
	$f > 0$ converging	
Magnification:	$M = \frac{h'}{h} = -\frac{q}{p}$	
Double slit:	max: $d\sin\theta = m\lambda$	min: $d\sin\theta = \left(m + \frac{1}{2}\right)\lambda$
	$m = 0, \pm 1 \pm 2, ...$	$m = 0, \pm 1 \pm 2, ...$
	$y = L\tan\theta$	$I = I_{\max}\cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)$

Thin film:	max: $2nt = \left(m + \frac{1}{2}\right)\lambda$	min: $2nt = m\lambda$
	$m = 0, 1, 2, ...$	$m = 0, 1, 2, ...$
	reversed in some cases	
Single slit diffr.:	min: $a \sin\theta = m\lambda$	$m = \pm 1, \pm 2, \pm 3, ...$
Resolution:	slit: $\theta_{\min} = \frac{\lambda}{a}$	circular: $\theta_{\min} = 1.22\frac{\lambda}{D}$
Diffraction grating:	max: $d \sin\theta = m\lambda$	$m = 0, \pm 1, \pm 2, ...$
X-ray diffraction:	max: $2d \sin\theta = m\lambda$	$m = 1, 2, 3, ...$
Photoel. effect:	$K_{\max} = e\Delta V_s$	$1eV = 1.6 \times 10^{-19} J$
	$K_{max} = hf - \phi = \frac{hc}{\lambda} - \phi$	$\lambda_c = \frac{hc}{\phi}$, $f_c = \frac{\phi}{h}$
Planck's constant:	$h = 6.63 \times 10^{-34} J \cdot s$, $\hbar = \frac{h}{2\pi}$	$hc = 1240 eV \cdot nm$
Particles as waves:	$\lambda = \frac{h}{p}$	$f = \frac{E}{h}$
Uncertainty princ.:	$\Delta x \Delta p \geq \frac{\hbar}{2}$	$\Delta E \Delta t \geq \frac{\hbar}{2}$
Hydrogen atom:	$E_n = -\frac{k_e e^2}{2a_0 n^2} = -\frac{13.6eV}{n^2}$	$n = 1(K), 2(L), 3(M), 4(N), ...$
	$r_n = a_0 n^2$	$a_0 = \frac{\hbar^2}{m_e k_e e^2} = 0.0529nm$
	$hf = E_n - E_m$ (emit)	$hf = E_m - E_n$ (absorb)
Quant. num.:	$l = 0(s), 1(p), 2(d), 3(f), 4(g), ..., n-1$	$L = \sqrt{l(l+1)}\hbar$
	$m_l = -l, -l+1, ..., l$	$L_z = m_l \hbar$
Spin (electron):	$s = \frac{1}{2}$	$S = \sqrt{s(s+1)}\hbar = \frac{\sqrt{3}}{2}\hbar$
	$m_s = \pm\frac{1}{2}$	$S_z = m_s \hbar$
Spin magn. mom.:	$\mu_{sz} = \pm\mu_B$	$\mu_B = \frac{e\hbar}{2m_e} = 9.274 \times 10^{-24} \frac{J}{T}$
Periodic table:	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 ...$	
Mass units:	$1\,u = 1.66 \times 10^{-27}\,kg = 931.5\,MeV/c^2$	$M_p = 1.007276\,u$
	$M_n = 1.008665\,u$	$M_e = 0.0005486\,u$
Rutherford scatt.:	$d = \frac{4k_e Z e^2}{mv^2}$	
Radius of nuclei:	$r = r_0 A^{1/3}$	$r_0 = 1.2 \times 10^{-15}\,m$
Binding energy:	$E_b = [ZM_p + NM_n - M(X)] \cdot 931.5\frac{MeV}{u}$	
Radioactivity:	$N = N_0 e^{-\lambda t}$	$R = N_0 \lambda e^{-\lambda t} = R_0 e^{-\lambda t}$
Units:	$1\,Ci = 3.7 \times 10^{10}\,decays/s$	$1\,Bq = 1\,decay/s$
Half-life:	$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$	
α-decay:	${}^A_Z X \to {}^{A-4}_{Z-2} Y + \alpha$ ($\alpha = {}^4_2 He$)	$Q = (M_X - M_Y - M_\alpha) \cdot 931.5\frac{MeV}{u}$
β-decay:	$n \to p + e^- + \bar{\nu}$	$p \to n + e^+ + \nu$
	${}^A_Z X \to {}^A_{Z+1} Y + e^- + \bar{\nu}$	${}^A_Z X \to {}^A_{Z-1} Y + e^+ + \nu$
γ-decay:	${}^A_Z X^* \to {}^A_Z X + \gamma$	