Physics 220 Exam 2 review sheet

The exam, primarily over Ch. 7 and Ch 8.1-8.3 (but as with any physics course the earlier material may still be relevant), will be held in class Tuesday, March 31. Expect 3-4 problems (similar to homework) and 1-2 pages of short answer/qualitative questions. You will be provided with an equation sheet (see below) and information from the inside front cover of the book, as well as atomic data where needed (e.g. periodic table, masses, etc.), other needed conversion factors (e.g. for pressures), and any needed integrals (such as those given in homework problems).

Studying hint: a lot of the equations look similar, and the same symbol may be used for different physical quantities. Be sure you know to which situations each of the equations below apply, and what physical quantities the symbols refer to in each case.

DRAFT Equation sheet:

$E = mc^2 + K$ $\quad E^2 = (pc)^2 + (mc^2)^2$ $\quad E = \gamma mc^2$ $\quad \gamma = \frac{1}{\sqrt{1-(v/c)^2}}$

$K = \frac{p^2}{2m}$ $\quad \vec{p} = m\vec{v}$ $\quad \frac{v}{c} = \frac{pc}{E}$

$R = R_0 A^{1/3}$ $\quad pV = nRT = Nk_BT$ $\quad \lambda = \frac{1}{n\sigma}$ $\quad D_{rms} \propto \sqrt{t}$

$\vec{F} = q(\vec{E} + \vec{v} \times \overrightarrow{B})$ $\quad a = \frac{v^2}{r}$ $\quad F = \frac{kqQ}{r^2}$ $\quad E = \frac{kq}{r^2}$

$K_{max} = hf - \phi$

$E = hf$ $\quad E = \frac{hc}{\lambda}$ $\quad f = \frac{c}{\lambda}$

$p = \frac{h}{\lambda}$

$2d \sin\theta = n\lambda$ $\quad \Delta\lambda = \lambda - \lambda_0 = \frac{h}{mc}(1 - \cos\theta)$

$\frac{1}{\lambda} = R\left(\frac{1}{n'^2} - \frac{1}{n^2}\right)$ $\quad R = \frac{E_R}{hc}$ $\quad L = mvr = n\hbar$

$a_B = \frac{\hbar^2}{ke^2m}$ $\quad r = n^2 a_B$ $\quad E_R = \frac{ke^2}{2a_B} = \frac{m(ke^2)^2}{2\hbar^2}$ $\quad E_n = -\frac{E_R}{n^2}$

$E_n = -Z^2\frac{E_R}{n^2}$ $\quad r = \frac{n^2 a_B}{Z}$ $\quad \mu = \frac{m}{1+m/m_{nuc}}$

$E_\gamma = E_{n'} - E_n$

$|\Psi(r,t)|^2 dV = P(r,t)$

$y(x,t) = A\sin(kx \mp \omega t + \phi)$ $\quad k = \frac{2\pi}{\lambda}$ $\quad \omega = 2\pi f = \frac{2\pi}{T}$ $\quad v = \frac{\lambda}{T} = \frac{\omega}{k}$

$\Delta x \Delta p \geq \frac{\hbar}{2}$ $\Delta t \Delta E \geq \frac{\hbar}{2}$

------new stuff------

$\frac{d^2\psi}{dx^2} = \frac{2m}{\hbar^2}[U(x) - E]\psi$ $i\hbar\frac{\partial}{\partial t}\Psi(x,t) = \left(-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + U(x)\right)\Psi(x,t)$

$\Psi(x,t) = \psi(x)e^{-i\omega t}$ $e^{i\theta} = \cos\theta + i\sin\theta$

$k = \sqrt{\frac{2mE}{\hbar^2}}$ $\alpha = \sqrt{\frac{2m(U-E)}{\hbar^2}}$

$\psi(x) = \sqrt{\frac{2}{a}}\sin\frac{n\pi x}{a}$ $E_n = n^2\frac{\pi^2\hbar^2}{2ma^2}$

$\int_{-\infty}^{\infty}|\psi(x)|^2 dx = 1$ $\langle x\rangle = \int_{-\infty}^{\infty} x|\psi(x)|^2 dx$ $P(b \leq x \leq c) = \int_b^c |\psi(x)|^2 dx$

$E_n = \left(n + \frac{1}{2}\right)\hbar\omega_c$ $\omega_c = \sqrt{\frac{k}{m}}$ $U = \frac{1}{2}kx^2$ $b = \sqrt{\frac{\hbar}{m\omega_c}}$

$\psi_0 = A_0 e^{-x^2/2b^2}$ $\psi_1 = A_1\frac{x}{b}e^{-x^2/2b^2}$

$P \approx e^{-2\alpha L}$

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} = \frac{2M}{\hbar^2}[U - E]\psi$$

$\psi(x,y) = A\sin\frac{n_x\pi x}{a}\sin\frac{n_y\pi y}{a}$ $E = \frac{\hbar^2\pi^2}{2Ma^2}({n_x}^2 + {n_y}^2)$

Possibly useful mathematical relations:

$\sin^2\theta = \frac{1-\cos 2\theta}{2}$ $\int \sin x\, dx = -\cos x + C$ $\int \cos x\, dx = \sin x + C$

$\int_{\mathbf{0}}^{\infty} \boldsymbol{e^{-\lambda x^2}} = \sqrt{\frac{\boldsymbol{\pi}}{\mathbf{4}\boldsymbol{\lambda}}}$

Some other things you should know (won't be on equation sheet)
(this isn't a complete list, of course, just some of the more difficult or important concepts that I wanted to point out)

Mass of an object (e.g. molecule or atom) in u is the same numerical value as its molecular or atomic weight in g/mole; be able to use that to determine how many molecules or atoms are in a given mass

Order of magnitude size of atomic, nuclear radii

How to determine Z, A, and N for a given isotope

Approximate relative masses and mass scales for e, p, and n (electron about 1/1800 of proton, neutron mass; electron mass energy about 0.5 MeV)

Be able to briefly describe (not just name) some of the major experiments that led to our current view of the atom's structure, or that led to our current view of photons as having particle as well as wave properties.

The equations $E = \frac{hc}{\lambda}$ and $f = \frac{c}{\lambda}$ only apply to photons (m=0)!

How to calculate a photon wavelength for a transition between two atomic energy levels

When it's OK to use non-relativistic expressions for momentum (p=mv) and kinetic energy ($K=mv^2/2=p^2/2m$) rather than the relativistic ones (note that it's always OK to use the relativistic expressions, but the non-relativistic ones might be more convenient if they apply)

That you can get equations for r and E in hydrogen-like ions by replacing ke^2 by Zke^2 (and why)

That you can get equations for r and E for an innermost electron by replacing ke^2 by $(Z-1)ke^2$ (and why)

The equation $\frac{1}{\lambda} = R\left(\frac{1}{n'^2} - \frac{1}{n^2}\right)$ with R=0.0110 nm^{-1} applies only to the H atom

That periodic waves can be written as Fourier sums (and what that means), and wave packets can be written as Fourier integrals (and what that means), and the relationship between spatial spread (Δx) and wavenumber spread (Δk) (or between time spread Δt and angular frequency spread Δω)

How to go from an equation relating two quantities to an equation relating the spread in those quantities (see, for example, (6.29))

How to get the minimum kinetic energy from the uncertainty relations

---------------------------new stuff----------------------

Standing wave terminology: nodes, antinodes

Qualitative features of wavefunctions: oscillatory/decaying/zero, how the wavelength depends on U and E, how to relate the wavefunction to the probability of finding the particle at a given location

The process by which the time-independent Schrödinger equation is solved (writing it down in different regions according to what U and E are, solving the differential equation, applying conditions (boundary conditions, continuity, etc.) on the wavefunction, normalizing)—I could ask you to set up/explain each of the steps, though if it leads to math too complicated for me to ask you to do in an hour and a half, you won't be asked to do the math

Where quantization of energy comes from (boundary conditions for bound particle), and why E=0 is not allowed for a bound particle

How to find classical turning points (and what they are) for a given U(x) and E