PHY3101
11-8-00

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Midterm 2

Closed book exam. One 8.5x11" study sheet is allowed. A calculator is allowed also.
Exam is worth 30 points, 15% of your total grade.

Forms of the Schrodinger equation:

$$-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2}+V(x,t)\psi = i\hbar\frac{\partial\psi}{\partial t} \qquad -\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2}+V(x)\psi = E\psi$$

Constants and equations:

$h = 6.6261 \cdot 10^{-34}$ J-s	$c = 3.0 \cdot 10^8$ m/s	$e = 1.6022 \cdot 10^{-19}$ C
$h = 4.1357 \cdot 10^{-15}$ eV-s	$\lambda f = c$	1 eV $= 1.6022 \cdot 10^{-19}$ J
$hc = 1240$ eV-nm	$f = E/h$	1 MeV = 10^6 eV
$\hbar = h/2\pi = 1.0546 \cdot 10^{-34}$ J-s	$\lambda = h/p$	1 nm = 10^{-9} m
$\hbar = 6.5821 \cdot 10^{-16}$ eV-s	$k = 2\pi/\lambda$	$\omega = 2\pi f$
	1 Watt = 1 J/s	1 MHz = 10^6 s^{-1}
$m_e = 9.11 \cdot 10^{-31}$ kg	$m_p = 1.673 \cdot 10^{-27}$ kg	$m_\alpha = 1.881 \cdot 10^{-28}$ kg
$m_e = 0.511$ MeV$/c^2$	$m_p = 938.3$ MeV$/c^2$	$m_\alpha = 105.7$ MeV$/c^2$

$$\frac{e^2}{4\pi\varepsilon_0} = 1.44 \cdot 10^{-9} \text{ eV-m} \qquad \mathbf{F} = q(\mathbf{E}+\mathbf{v}\cdot\mathbf{B}) \qquad W = qV$$

$$R_\infty = \frac{E_0}{hc} = 1.09737 \cdot 10^7 \text{ m}^{-1} \qquad R_H = \frac{E_0}{hc} = 1.09678 \cdot 10^7 \text{ m}^{-1}$$

$$\frac{1}{\lambda} = Z_{\text{eff}}^2 R\left(\frac{1}{n_l^2}-\frac{1}{n_u^2}\right) \qquad a_0 = \frac{4\pi\varepsilon_0\hbar^2}{me^2} = 0.53 \cdot 10^{-10} \text{ m}$$

$$E_n = \frac{-Z^2e^4m_e}{2\hbar^2(4\pi\varepsilon_0)^2n^2} = (-13.6 \text{ eV})\ \frac{Z^2}{n^2} \qquad E_n = \frac{\pi^2\hbar^2}{2mL^2}n^2 \qquad \alpha = \left(\frac{1}{m_e}+\frac{1}{m_N}\right)^{-1}$$

$$\Delta x\,\Delta p \ge \frac{\hbar}{2} \qquad \Delta E\,\Delta t \ge \frac{\hbar}{2} \qquad \hat{p} = -i\hbar\frac{d}{dx} \qquad \hat{x} = x$$

$$\langle \hat{f}\rangle = \int \psi^*(x)\hat{f}\psi(x)dx \qquad \int_0^\infty x^n e^{-x/\alpha}dx = n!\alpha^{n+1} \qquad n! = n\cdot(n-1)\cdot(n-2)\cdots 2\cdot 1$$

$$\int dx \sin^2 x = \frac{x}{2}-\frac{1}{4}\sin 2x \qquad \int dx\, x^2\sin^2 x = \frac{x^3}{6}-\left(\frac{x^2}{4}-\frac{1}{8}\right)\sin 2x - \frac{x\cos 2x}{4}$$

$$I_n = \int_0^\infty x^n \exp(-\alpha x^2)\, dx \qquad I_0 = \frac{1}{2}\sqrt{\frac{\pi}{\alpha}} \qquad I_1 = \frac{1}{2\alpha} \qquad I_2 = \frac{1}{4\alpha}\sqrt{\frac{\pi}{\alpha}}$$

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1. (a) [4 points] Show that the wavefunction $\psi(x) = A\,e^{-m\omega x^2/2\hbar}$ is a solution to the time-independent Schrodinger Equation for a particle of mass m in the potential energy well $V(x) = V_0 + \frac{1}{2}m\omega^2 x^2$, where V_0 and ω are constants.

(b) [3 points] Find the energy of the particle described by this wavefunction.

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1. **(c)** [3 points] Normalize the previous wavefunction over the interval $-\infty < x < \infty$.

2. [3 points] An electron is confined to a 1-dimensional region of width 10^{-10} m. What is the minimum kinetic energy of the electron, as measured in electron-volts?