PHY3101
4-29-99

Name:______________________

E-mail:
(optional, for grade notification)

Final Exam

Closed book exam. One 8.5x11" study sheet is allowed. A calculator is allowed also.
Exam is composed of 12 problems worth 60 points, 30% of your total grade.
Formulas and constants are on both sides of this first page.

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 | $\lambda\nu = c$ | 1 eV $= 1.6022 \cdot 10^{-19}$ J

$hc = 1240$ eV-nm | $E_\gamma = h\,\nu$ | 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 | 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

1 u $= 1.6605 \cdot 10^{-27}$ kg | 1 u $= 931.5$ MeV / c^2

$v = H_0\, r$ | H_0 = 65 km/s/Mpc | $\lambda T = 2.898 \cdot 10^{-3}$ m-K

1 Mpc = $3.26 \cdot 10^6$ light-years | 1 light-year = $0.946 \cdot 10^{16}$ m

$z = \sqrt{(1+\beta)/(1-\beta)} - 1$ | $E^2 = p^2c^2 + m^2c^4$

$\gamma = \dfrac{1}{\sqrt{1-\beta^2}}$ | $\beta = \dfrac{v}{c}$ | $E = \gamma\, m\, c^2 = K + m\, c^2$

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

$R_\infty = \dfrac{E_0}{hc} = 1.09737 \cdot 10^7$ m^{-1} | $R_H = \dfrac{E_0}{hc} = 1.09678 \cdot 10^7$ m^{-1}

$\dfrac{1}{\lambda} = R\left(\dfrac{1}{n_l^2} - \dfrac{1}{n_u^2}\right)$ | $a_0 = \dfrac{4\pi\varepsilon_0\hbar^2}{me^2} = 0.53 \cdot 10^{-10}$ m

$E_n = \dfrac{-Z^2e^4m_e}{2\hbar^2(4\pi\varepsilon_0)^2n^2} = (-13.6\text{ eV})\ \dfrac{Z^2}{n^2}$ | $\alpha_B = \dfrac{e\hbar}{2m_e} = 5.7884 \cdot 10^{-5}$ eV / T

$\Delta x\,\Delta p \ge \hbar/2$ | $\Delta E\,\Delta t \ge \hbar/2$ | $\langle f(x)\rangle = \int \psi^*(x) f(x)\psi(x)dx$

$I_n = \int_0^\infty x^n \exp(-\alpha x^2)\,dx = \dfrac{1\cdot3\cdot5\cdots(n-1)}{2^{(n/2)+1}\cdot\alpha^{(n/2)}}\sqrt{\dfrac{\pi}{\alpha}}$ for even n | $I_0 = \dfrac{1}{2}\sqrt{\dfrac{\pi}{\alpha}}$

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

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1. [5 points] You are the captain of a starship travelling at a constant velocity of 0.98 c toward Earth. Your ship's engineer informs you that the engines will explode in 2 minutes. You need to get to Earth so that you can instantaneously beam off the ship, but you only just crossed the orbit of Mars. In the rest frame of the solar system, calculate the distance you can travel before the engines explode. Will you be able to reach Earth? The orbital radius of Earth is 1 AU, and the orbital radius of Mars is 1.5 AU, where $1\ \text{AU} = 1.5 \cdot 10^{11}\ \text{m}$.

2. [5 points] The work function of Aluminum is 4.1 eV. Calculate the maximum kinetic energy of electrons ejected from the metal when ultraviolet light with a wavelength of 200 nm shines on the surface.

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3. [5 points] Calculate the deBroglie wavelength of an electron travelling at a velocity of $8.6 \cdot 10^5$ m/s.

4. [5 points] The mean lifetime of the Z^0 particle (a force carrying particle of the weak nuclear force) is only $1.3 \cdot 10^{-25}$ s. The mean mass of this particle is measured to be 91 GeV/c^2, but because of the finite lifetime there must be some spread around this value for every particle measured. Estimate this spread. (1 GeV = 10^9 eV)

5. [5 points] An electron in the $n = 3$ excited state of hydrogen makes a transition to the ground state. What is the wavelength of the photon emitted in the transition?