Name: ______________________________

PHYS 4021 Final Exam Fall 2019

$$\vec{\mu} = \frac{gq}{2m(c)}\vec{S} \qquad F_z \simeq \mu_z \frac{\partial B_z}{\partial z} \qquad \vec{F} = -\vec{\nabla} U \qquad U = -\vec{\mu}\cdot\vec{B}$$

$$\hat{A}|a_i\rangle = a_i|a_i\rangle \qquad \langle a_i|a_j\rangle = \delta_{ij} \qquad 1 = \sum_i |a_i\rangle\langle a_i| = \int dx|x\rangle\langle x|$$

$$\hat{R}(\phi\hat{k})\,|\psi\rangle = e^{-\frac{i\phi}{\hbar}\hat{J}_z}|\psi\rangle \qquad \langle\psi|\,\hat{R}^\dagger(\phi\hat{k}) = \langle\psi|e^{\frac{i\phi}{\hbar}\hat{J}_z}$$

$$[\hat{J}_x, \hat{J}_y] = i\hbar\hat{J}_z \qquad \hat{J}_\pm = \hat{J}_x \pm i\hat{J}_y \qquad \hat{J}_\pm|j,m\rangle = \sqrt{j(j+1) - m(m\pm 1)}\,\hbar\,|j,m\pm 1\rangle$$

$$(\Delta A)^2 = \langle\hat{A}^2\rangle - \langle\hat{A}\rangle^2 \qquad \Delta J_x \Delta J_y \geq \frac{\hbar}{2}|\langle J_z\rangle|$$

$$\hat{A}^{(x)} = {}_x\mathcal{S}_z^\dagger\, A^{(z)}\, {}_z\mathcal{S}_x \qquad \mathcal{S}_{ij} = \langle z_i|x_j\rangle$$

$$\hat{\vec{S}} = \frac{\hbar}{2}\hat{\vec{\sigma}} \qquad \vec{\sigma} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \quad \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

$$\hat{U}(t) = e^{-i\frac{\hat{H}}{\hbar}t} \qquad i\hbar\frac{\partial}{\partial t}|\psi(t)\rangle = \hat{H}|\psi(t)\rangle \qquad \frac{d < A >}{dt} = \langle\psi(t)|\frac{i}{\hbar}[\hat{H}, \hat{A}]|\psi(t)\rangle + \langle\psi(t)|\frac{\partial\hat{A}}{\partial t}|\psi(t)\rangle$$

$$\text{Two}-\text{particle states}: |\psi\rangle = \sum_{i,j} c_{i,j}|a_i\rangle_1|b_j\rangle_2 = \sum_{i,j} c_{i,j}|a_i, b_j\rangle$$

$$\hat{\vec{S}}^2|s,m\rangle = s(s+1)\hbar^2|s,m\rangle \qquad \hat{S}_z|s,m\rangle = m\hbar|s,m\rangle$$

$$\hat{H}_{hf} = \frac{2A}{\hbar^2}\hat{\vec{S}}_1\cdot\hat{\vec{S}}_2 = \frac{A}{\hbar^2}(\hat{S}_{1+}\hat{S}_{2-} + \hat{S}_{1-}\hat{S}_{2+} + 2\hat{S}_{1z}\hat{S}_{2z}) \qquad \hat{S}_{1+} = \hat{S}_{1x} \pm i\hat{S}_{1y}$$

$$\hat{T}(a) = e^{-i\hat{p}a/\hbar} \qquad [\hat{x}, \hat{p}_x] = i\hbar \qquad \hat{p}_x \longrightarrow -i\hbar\frac{\partial}{\partial x} \qquad \psi(x) = \langle x|\psi\rangle \qquad \langle x|\hat{p}_x|\psi\rangle = -i\hbar\frac{\partial\psi}{\partial x}$$

$$j_x = \frac{\hbar}{2mi}\left(\psi^*\frac{\partial\psi}{\partial x} - \psi\frac{\partial\psi^*}{\partial x}\right)$$

$$\langle x|p\rangle = \frac{1}{\sqrt{2\pi\hbar}}e^{ipx/\hbar} \qquad \langle x|\psi\rangle = \int dp\frac{1}{\sqrt{2\pi\hbar}}e^{ipx/\hbar}\langle p|\psi\rangle \qquad \langle p|\psi\rangle = \int dx\frac{1}{\sqrt{2\pi\hbar}}e^{-ipx/\hbar}\langle x|\psi\rangle$$

You may have brought up to twelve additional equations of your own choosing, and a calculator.

more

↓

(over)

$$\omega^2 = \frac{k}{m} \qquad \hat{a} = \sqrt{\frac{m\omega}{2\hbar}}\left(\hat{x} + \frac{i}{m\omega}\hat{p}_x\right) \qquad \hat{a}^{+} = \sqrt{\frac{m\omega}{2\hbar}}\left(\hat{x} - \frac{i}{m\omega}\hat{p}_x\right)$$

$$[\hat{a}, \hat{a}^{+}] = 1 \qquad \hat{N} = \hat{a}^{+}\hat{a} \qquad \hat{H} = \hat{N} + \frac{1}{2}$$

$$\hat{a}|n\rangle = \sqrt{n}\,|n-1\rangle \qquad \hat{a}^{+}|n\rangle = \sqrt{n+1}\,|n+1\rangle \qquad |n\rangle = \frac{(a^{+})^n}{\sqrt{n!}}|0\rangle$$

$$\hat{H} = \frac{\hat{\vec{p}}^{\,2}}{2m} + V(|\hat{\vec{r}}|) \qquad \hat{L}_z = \hat{x}\hat{p}_y - \hat{y}\hat{p}_x \qquad \hat{\vec{p}} = \frac{\hbar}{i}\vec{\nabla}$$

$$\hat{L}^2 = -\hbar^2\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right) + \frac{1}{\sin^2\theta}\frac{\partial^2}{\partial\phi^2}\right]$$