Homework Set #1

Due Date: Before class Friday January 24th

1) You *(2 points)*

(a) What is your major/minor ?

(b) When do you plan on graduating?

(c) What do you want to do after graduation ? (eg: grad school ? if so, what subject ? if not, what industry?)

(d) What do you most want to get out of this course ?

2) Solid State Physics *(5 points)*

(a) Assume a solid is composed of closely packed atoms. What is the spacing between atoms? Express your result in terms of α, α_G, m_{proton}, and m_{electron}.

(b) If you wanted to study the crystal structure of a solid material with $Z \sim 10$ using light, what wavelength of photons would you need ? Express your result in terms of α, α_G, m_{proton}, and m_{electron}.

(c) Where in the spectrum of EM radiation do these photons lie?

3) Strength of Gravity on Earth *(5 points)*

(a) Calculate the local strength of gravity g_{local} in terms of α, α_G, m_{proton}, and m_{electron}.

(b) What is your estimated value in mks units ?

(c) How does this compare with the well-known value of 9.8 m/s^2 ?

4) Neutron Stars *(5 points)*

(a) Estimate the radius, mass, and speed of sound for neutron stars in terms of α, α_G, m_{proton}, and m_{electron}. Assume that a neutron star is a solid made of neutrons and $m_{\text{proton}} \sim m_{\text{neutron}}$.
(Hint: the speed of sound is given by the square-root of the pressure over the mass density)

(b) What are you estimated values in mks units ?

(c) Compare your estimates to actual values for Neutron Stars quoted online.

(d) Look up m_{neutron}. How does this compare with the assumption of $m_{\text{proton}} \sim m_{\text{neutron}}$?

5) 2D Rotations *(3 points)*

(a) Show that $R(\Theta) = e^{I\Theta} = cos(\Theta) + Isin(\Theta)$ where, $I = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$

(b) Show that 2D rotations commute. (ie: $R(\Theta_1)R(\Theta_2) = R(\Theta_2)R(\Theta_1)$)

6) 3D Rotations *(5 points)*

(a) Work the "algebra" of the generators of 3D rotations J_i.

Where $J_3 = \begin{bmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$, $J_2 = \begin{bmatrix} 0 & 0 & -i \\ 0 & 0 & 0 \\ i & 0 & 0 \end{bmatrix}$ $J_1 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{bmatrix}$

(These generators different from the T's derived in class by a factor of i)

Working out the algebra means calculating the commutation relations $[J_i, J_j]$. You dont need to do all of them, but convince yourself that what I said in class is true.

(b) Let M be a traceless 2×2 hermitian matrix and U be a 2×2 unitary matrix with determinant = 1. Show that $M' = U^\dagger MU$ is also traceless and hermitian and that is has the same determinant as M.