PHYSICS X0323: Scientific Analysis & Modeling - Fall 2024
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**1: An electron is found to be in the spin state (in the z-basis):**
**(a) (5 points) Determine the possible values of A such as that the state is normalized.**
**(b) (5 points) Find the expectation values of the operators,text $\langle S_x \rangle$, $\langle S_y \rangle$, $\langle S_z \rangle$, and $\langle \vec{S}^2 \rangle$.**

$$\chi = A \begin{pmatrix} 3i \\ 4 \end{pmatrix}$$

**The Matrix representation in the z-basis for the components of electron spin operators are given by:**

$$S_x = \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad S_y = \frac{\hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \quad S_z = \frac{\hbar}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

**2. The average electrostatic field in the earth's atmosphere in fair weather is approximately given:**

$$\mathbf{E} = E_0 \left( A e^{-\alpha z} + B e^{-\beta z} \right) \hat{z}$$

**Where A, B, $\alpha$, $\beta$ are positive constants and z is the height above the (locally flat) earth surface.**
**(a) (5 points) Find the average charge density in the atmosphere as a function of height**
**(b) (5 points) Find the electric potential as a function height above the earth**

**3. The following questions refer to stars in the Table below.**
**Note: There may be multiple answers.**

| Name | Mass | Luminosity | Lifetime | Temperature | Radius |
|---|---|---|---|---|---|
| **$\beta$ Cyg.** | **1.3** $M_\odot$ | **3.5** $L_\odot$ | | | |
| **$\alpha$ Cen.** | **1.0** $M_\odot$ | | | | **1** $R_\odot$ |
| **$\eta$ Car.** | **60.**$M\odot$ | **60.**$M$ | $8.0 \times 10^5$ | **20,000 K** | |
| **$\varepsilon$ Eri.** | **6.0**$M\odot$ | | | | |
| **$\delta$ Scu.** | **2.0**$M\odot$ | | $5.0 \times 10^8$ | | **2** $R_\odot$ |
| **$\gamma$ Del.** | **0.7**$M\odot$ | | $4.5 \times 10^10$ | **5000 K** | |

**(a) (4 points) Which of these stars will produce a planetary nebula?**

**(b) (4 points) Elements heavier than Carbon will be produced in which stars?**

**Latex Example**