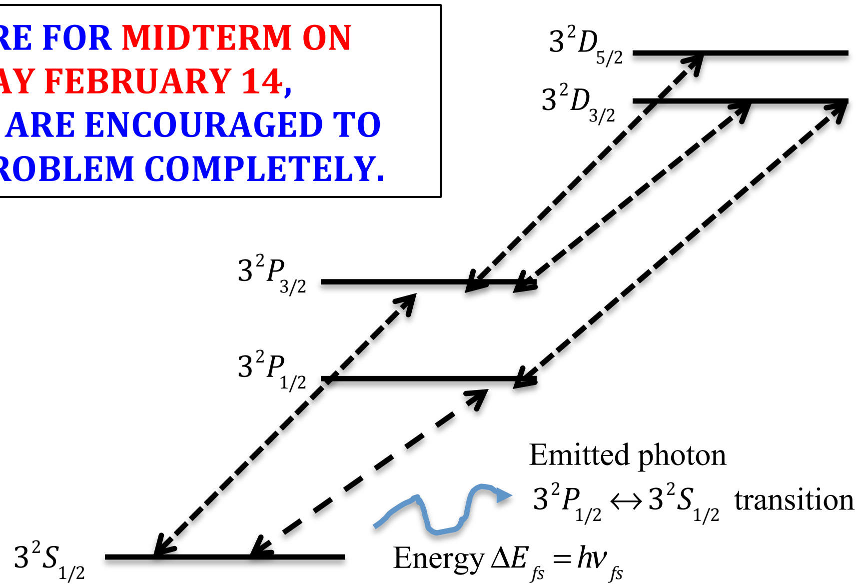
To help student do **Problem 36 of Chapter 8** on the Zeeman Effect of Sodium, I have prepared the note and hints below.

<u>**Fine Structure of Sodium, Z = 11**</u> Do the following exercise

Write down the **ground-state** electronic configurations of Na. Derive the **term symbol (spectroscopic notation, see equation sheets)** of the **ground state**. The two lowest excited states of Sodium involve a **single electron** in an **unfilled 3p, subshell**, and in the **3d subshell**. Each of the **two excited states** has **two states** (doublets). Use the rule of addition of angular momentum to derive the **term symbol (spectroscopic notation)** of these **excited states**. Briefly explain why there are doublet states. Draw the energy-level diagram involving the **ground state** (part a) and the **3p** and **3d excited states**. Use the **selection rules** to **draw all allowed transitions** between states.

PARTIAL ANSWER BELOW

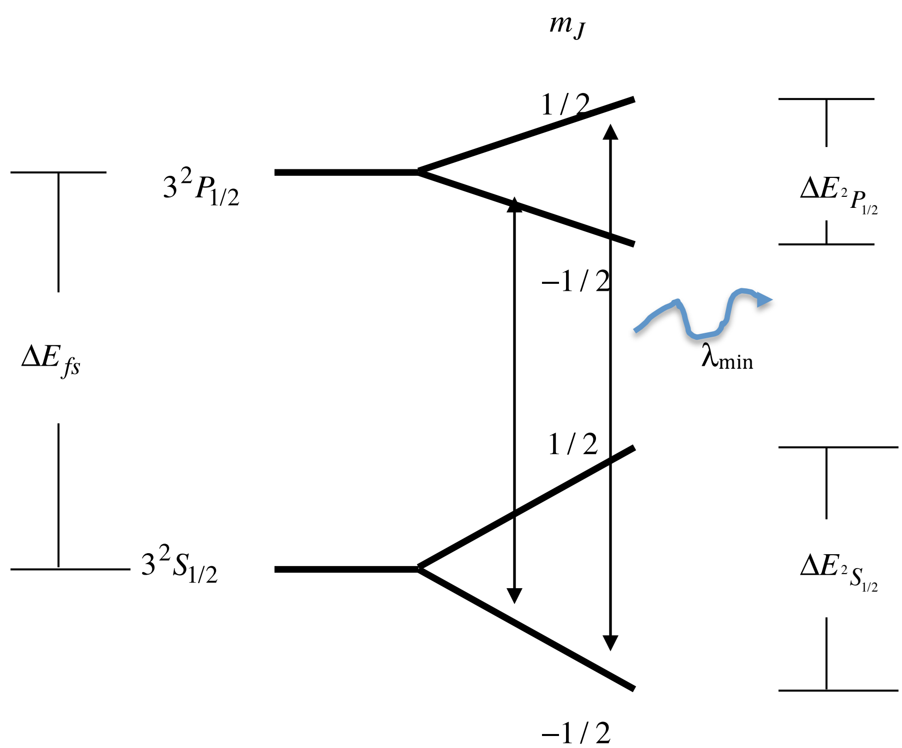
TO PREPARE FOR MIDTERM ON WEDNESDAY FEBRUARY 14, STUDENTS ARE ENCOURAGED TO DO THIS PROBLEM COMPLETELY.



NOTE: The photon emitted (or absorbed) in the transition between sodium states $3^2P_{1/2} \leftrightarrow 3^2S_{1/2}$, with fine-structure (fs) energy $\Delta E_0 = h\nu_{fs}$ is indicated above. This part is crucial in understanding how to do problem 36 of chapter 8. The hints are shown on the next page.

The diagram below shows the initial levels of the $3^2S_{1/2}$ and $3^2P_{1/2}$ states when there is no applied magnetic field (B_{ext} = 0). In the transition between $3^2P_{1/2} \leftrightarrow 3^2S_{1/2}$, the energy of the photon emitted or absorbed is $\Delta E_{fs} = h\nu_{fs}$, as discussed earlier, and also shown in the diagram below. In the presence of an applied magnetic field $\vec{B}_{ext} = B_{ext}\hat{k}$, the initially degenerate (same energy) $3^2P_{1/2}$ states split into **two energies (doublet)**, m_J = ½ and m_J = –½ , with the former have higher energy, and where the difference between the two levels is given by the Zeeman energy splitting $\Delta E_{^2P_{1/2}}$.

Similarly, the initially degenerate (same energy) $3^2S_{1/2}$ states split into **two energies (doublet)**, m_J = ½ and m_J = –½ , with the former have higher energy, and where the difference between the two levels is given by the Zeeman energy splitting $\Delta E_{^2S_{1/2}}$.



The difference between the **minimum** ($\lambda_{\min}$) and **maximum** ($\lambda_{\max}$) wavelengths of the emitted/absorbed photons is easy to find by looking at the above diagram. $\lambda_{\min}$ is associated with the **maximum energy**, ΔE_{max}, of the transition between the m_J = ½ of the $3^2P_{1/2}$ state, and m_J = – ½ of $3^2S_{1/2}$, $\Delta E_{\max} = \Delta E_{fs} + \frac{\Delta E_{^2P_{1/2}}}{2} + \frac{\Delta E_{^2S_{1/2}}}{2}$, where $\Delta E_{fs} = \frac{hc}{\lambda_{fs}}$, and $\lambda_{fs} = 589.76nm$, as given in the problem. For $^2P_{1/2}$ the energy difference between the $m_J = 1/2$ and $m_J = -1/2$ states is found by using equation

8.22 $V(m_J) = \mu_B B_{ext} g m_J$, which will give you $\Delta E_{^2P_{1/2}}$. Note that in the equation g is the Lande factor of equation 8.23. $\Delta E_{^2S_{1/2}}$ can be similarly computed. Once found, use $\Delta E_{\max} = \frac{hc}{\lambda_{\min}}$ to find $\lambda_{\min}$. You can find $\lambda_{\max}$ using the same method.