1. (2 pts) Which of the following spectroscopic techniques would you expect to employ a photomultiplier tube as a detector?
   a) UV/visible absorption  
   b) atomic emission  
   c) Raman  
   d) a and b  
   e) all of the above

2. (3 pts) Advantages of Fourier transform infrared spectroscopy include:
   a) The speed and repeatability of mirror movement makes it possible to ensemble average hundreds to thousands of interferometer scans and thereby enhance spectral S/N.
   b) To achieve a spectral resolution of 2 cm⁻¹ requires a minimum mirror displacement of 0.5 cm.
   c) Using a mirror speed of 1.0 cm/s, radiation at the frequency of the H₂O bending mode (1650 cm⁻¹) would be modulated at a frequency of 3.30 kHz.
   d) a and b  
   e) a, b and c

3. (4 pts) The energy level diagram to the right is for a typical organic dye molecule. Indicate which of the transitions in the figure corresponds to each of the processes below by writing the letter marking the transition next to the term (Refer to Fig 15-1 in the text for more information):
   Intersystem crossing
   Fluorescence emission
   Light Absorption
   Vibrational relaxation

4. (2 pts) Which of the following represents a term symbol for the ground electronic state of a Hg atom:
   a) ¹P½  
   b) ²S½  
   c) ¹S₀  
   d) ³S₁  
   e) ³P₁

5a. (6 pts) The following spectroscopic techniques are often employed for the determination of metal ions present in samples at trace levels: Flame Atomic Absorption (FAA), Graphite Furnace AA, ICP Atomic Emission. Identify distinct advantages and disadvantages of each technique in terms of sensitivity, cost, ability to minimize interferences, and ease of use.
5b. (3 pts) Explain why a hollow cathode lamp source enables accurate Beer’s law determinations in atomic absorption measurements.

6. The April 4, 2003 issue of *Science* featured a series of articles on Biological Imaging. An article titled "Development and Use of Fluorescent Protein Markers in Living Cells" presented fluorescence excitation and emission spectra for several fluorescent proteins. A figure from the paper is shown at the right. In the figure, Normalized Fluorescence is reported on the y-axis and wavelength in nanometer units is plotted on the x-axis of each spectrum.

a. (5 pts) For quantitation of blue fluorescent protein (BFP), approximately what wavelengths should the excitation and emission monochromators be set to to achieve selectivity? Briefly explain your choices.

b. (5 pts) Sketch an energy level diagram and use it to explain why the fluorescence emission peak of BFP appears at higher wavelengths than the fluorescence excitation peak.

![Fluorescence spectra](image)

Fig. 2. The excitation (A) and emission (B) spectra of blue (BFP), cyan (CFP), green (GFP), yellow (YFP), and red (mRFP1) fluorescent proteins.