Here are some examples from previous years quizzes and exams. Answering these questions might help you prepare for the next exam.

Problem 1. You consider applying spectroscopic tools to detect the presence or study the following molecules: H_2 ; HF ; CO_2 ; CH_4.
1. Which of these molecules may be microwave active, i.e. show a pure rotational absorption spectrum? *Explain why*.

2. Which of these molecules may be infrared active, i.e. show vibrational absorption spectra? *Explain why*.

3. Which of these molecules is rotationally Raman *inactive*? Explain why.

Problem 2. Describe in 2-3 sentences the similarity and the difference between fluorescence and phosphorescence, in terms of what transitions are involved, and how these events differ in terms of the characteristic times.

Problem 3. You perform a fluorescence resonant energy transfer (FRET) experiment to determine the distance between two groups in a protein molecule. You labeled these groups with fluorophores. The fluorophore group that you excite is called the Donor, and the one from which you read the signal is called the Acceptor.
(a) What is the requirement for the absorption and emission wavelengths (or frequencies) of the Donor and Acceptor in order for FRET to occur? (One sentence should suffice)

(b) In a control experiment, when the donor and acceptor where at a distance of 50 Å, the efficiency of energy transfer was 0.5. Use this result to answer the following questions:
-- What would be the efficiency of FRET if the distance increased by 20%?
-- Your measurement of the FRET efficiency gave 0.1. What is the donor-acceptor distance?

Problem 4. Which unique feature of spin systems (in contrast to e.g. harmonic oscillator, rotor etc) allows us to use magnetic resonance for imaging of objects in real space? (One sentence should suffice)

Problem 5. The highest magnetic field currently available in NMR spectrometers is $B_o = 22.3$ T ("T" stands for "Tesla", the unit of measurement of magnetic field). Proton's magnetogyric ratio is $\gamma = 26.75 \times 10^{7}\ T^{-1}\ s^{-1}$

1. Calculate the energy that corresponds to a transition between the two spin states of a proton at this magnetic field.

2. Compare this energy with the thermal energy ($k_B T$) at 20°C. This will tell you whether molecular motion is affected by the magnetic field.