CHUKA UNIVERSITY

UNIVERSITY EXAMINATIONS

FIRST YEAR EXAMINATION FOR THE AWARD OF DEGREE OF MASTERS OF SCIENCE IN PHYSICS

PHYS 822: LABORATORY TECHNIQUES II **TIME: 3 HRS**

MSc (PHYSICS) **DAY/DATE: ………………………**

INSTRUCTIONS:

- Answer **ANY** three Questions
- Do not write anything on the question paper
- This is a closed book exam, No reference materials are allowed in the examination room
- There will be No use of mobile phones or any other unauthorized materials
- Write your answers legibly and use your time wisely
- **Use the following constants**
  1. **Planks constant** - $6.62607004 \times 10^{-34}$ m^2 kg / s
  2. **Boltzmann's constant** - $1.38064852 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}
  3. **Magnetogyric ratios**
     a) ${}^{1}_{\square}H - 267.53\,x\,10^{6}\dfrac{rad}{Tesla\,x\,sec}$
     b) ${}^{13}_{\square}C - 67.28\,x\,10^{6}\dfrac{rad}{Tesla\,x\,sec}$
     c) ${}^{19}_{\square}F - 251.7\,x\,10^{6}\dfrac{rad}{Tesla\,x\,sec}$
  4. **Bohr magnetron** $\mu_B = 5.7883818012(26) \times 10^{-5} \cdot \square^{-1}$
  5. **Mass of an electron =** $9.10938356 \times 10^{-31}$ Kg

QUESTIONS ONE (20 Marks)

a. Define the following terms and give their mathematical expressions.

i. Number average molecular weight(Mn) **(2 marks)**

ii. Weight average molecular weight of polymers **(2 marks)**

iii. Degree of polymerization(DP) **(2 marks)**

iv. Polydispersity index(PDI) **(2 marks)**

b. Explain how determination of molecular weight of polymers is achieved using the Light Scattering Method. **(4 marks)**

c. The weight average molecular weight of two monodisperse polymer fractions (A and B) is determined with light scattering using a Zimm-plot in Figure 1. The intrinsic viscosities of polymer fractions A and B, determined by viscometry are 2 dl/g and 4 dl/4g, respectively. Calculate **K'** and **a** of this polymer in the same solvent that was used to determine the viscosity. **(8 marks)**

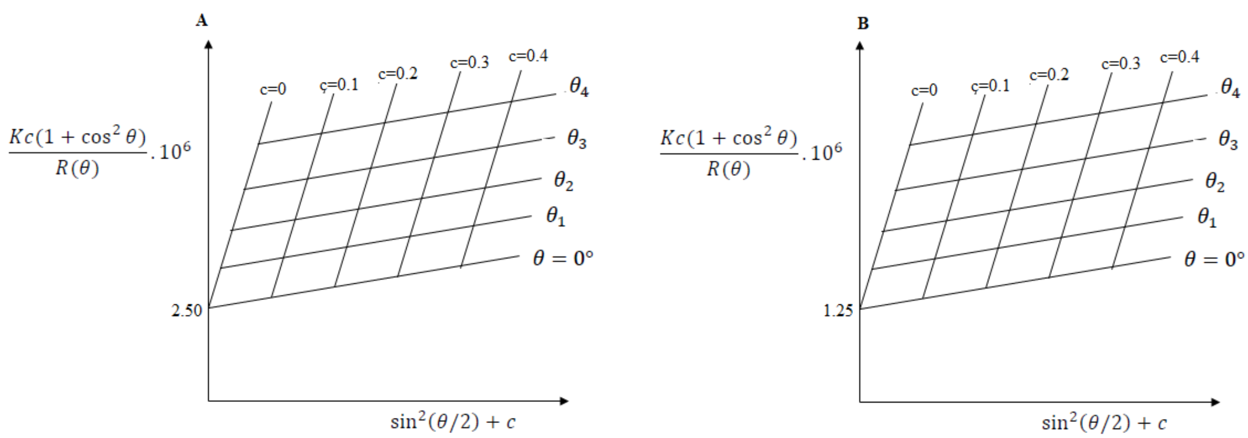

Figure 1

QUESTIONS TWO (20 Marks)

a. What is NMR? Explain the Quantum theory of NMR up to the formation of an energy gap between spin states. **(3 marks)**

b. Discuss two important aspects that makes NMR spectroscopy different from other forms of spectroscopy. **(2 marks)**

c. How many possible orientations do spin 1/2 nuclei have when they are located in an applied magnetic field? **(1 mark)**

d. When radiation energy is absorbed by a spin 1/2 nucleus in a magnetic field, what happens to the angle of precession? **(1 mark)**

e. What is Spin - lattice relaxation **(1 mark)**

f. What two other terms are used to refer to the Larmor frequency? **(1 mark)**

g. Calculate the Larmor frequency (in Hz and in rad s^{-1}) of a carbon-13 resonance with chemical shift 48 ppm when recorded in a spectrometer with a magnetic field strength of 9.4 T. **(3 marks)**

h. The nucleus, ^{1}H, in water resonates at 400 MHz in a magnetic field of 9.39 T. The earth's magnetic field is 0.00005 T.

   i. What is the ^{1}H precession frequency in the earth's magnetic field and **(2 marks)**

   ii. What is the excess population of nuclei in the lower energy state in this field at 300K? **(3 marks)**

i. Calculate and compare the EM radiation frequency required for the transition from the lower to upper spin states of ^{1}H, ^{13}C and ^{19}F when a field strength $B_0 = 1\,Tesla$ is applied. In which region of the EM spectrum are these frequencies? **(3 marks)**

QUESTION THREE (20 MARKS)

a. What is Zeeman splitting? **(1 mark)**

b. The magnetic field of the Sun and stars can be determined by measuring the Zeeman-effect splitting of spectral lines. Suppose that the sodium D_1 line emitted in a particular region of the solar disk is observed to be split into the four-component Zeeman effect (see Figure 2).

What is the strength of the solar magnetic field B in that region if the wavelength difference $\Delta\lambda$ between the shortest and the longest wavelengths is 0.022 nm? (The wavelength of the D_1 line is 589.8 nm). **(9 marks)**

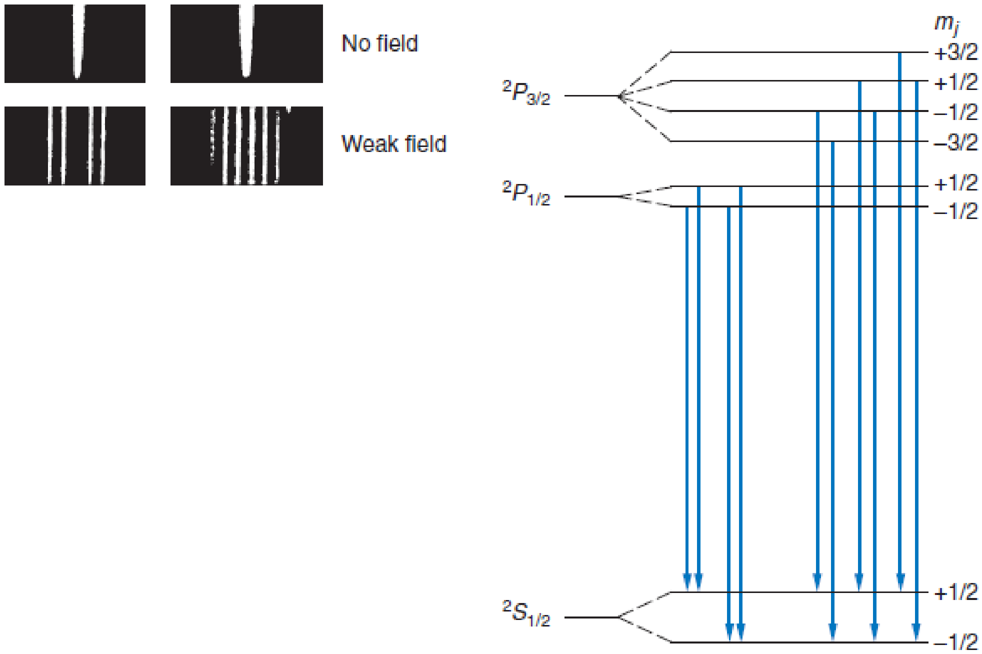

Figure 2

c. What are the criteria for the types of molecules that will exhibit a signal in ESR? Comment on the generality of ESR spectroscopy relative to its sister technique for looking at nuclear spins (NMR). **(4 marks)**

d. Calculate the ESR transition frequency in cm^{-1} for a spin ½ electron with g = 2.0031 in a 5126.8 gauss field (assume zero nuclear spin). You must report your answer with the correct number of significant digits. **(3 marks)**

e. What is the principle that we intended to exemplify by looking at the concentration series of TEMPOL samples in the ESR experiments? **(1 marks)**

f. Suppose that you could double the DC magnetic field available to you in the ESR experiment. Assuming that the microwave source and detector behave equally well at the new resonance frequency, calculate the improvement you expect in your signal to noise ratio. (If you cannot reach a numerical value, please at least explain the principle). **(2 marks)**

QUESTIONS FOUR (20 Marks)

a. Make a comparison between the optical microscopy (OM) and Scanning Electron Microscopy (SEM) in terms of the following. Beam source and type, lenses and need of vacuum, magnification, depth of focus, contrast, EDS capabilities and resolution. **(7 marks)**

b. What makes SEM one of the most heavily used instruments in academic lab research areas and industry? **(3 marks)**

c. If you want to examine a metallic alloy for microstructural features (grain structure and phases) and fracture surface of impact fractured sample using SEM, what type of sample preparation you need in any case? **(2 marks)**

d. What are the information derivable from optical microscopy investigation? Explain briefly each type of information **(5 marks)**

e. Consider a beam of electrons in Transmission electron microscopy (TEM), moving at $5.2\,x\,10^{5}\,m/s$ downwards. They enter a region with a filed which causes them to accelerate towards the sample. If the acceleration required is$4.8\,x\,10^{17}\,m/s^{2}$, what magnitude of electric field will be required? **(5 marks)**

QUESTION FIVE (20 Marks)

a. There is synthesized powder magnetic sample and its magnetic properties need to be evaluated. If the amount of sample is limited (say, 5mg) and extremely low-temperature data are not required (say as low as 5 K is enough) explain the suitability (or lack of) of the following measurements methods.

i. Guoy balances **(2 marks)**

ii. Faraday balances **(2 marks)**

iii. Vibrating sample magnetometer **(2 marks)**

iv. Superconducting quantum interference device (SQUID) magnetometer **(2 marks)**

b. The Figure 3 shows the hysteresis loop for an iron alloy

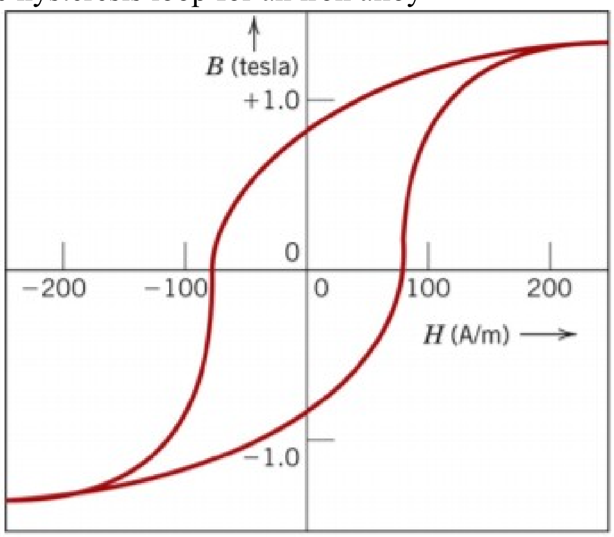

Figure 3

i. Classify this material as either antiferromagnetic, paramagnetic or ferromagnetic **(2 marks)**

ii. What is the value of the saturation flux density? **(2 marks)**

iii. What is the value of the saturation magnetization? **(2 marks)**

iv. What is the value of the remanence? **(2 marks)**

v. What is the value of coercivity? **(2 marks)**

c. Briefly describe the differences between "hard" and "soft" magnetic materials, within an illustration of hysteresis loops, and their respective different applications. **(4 marks)**