CHUKA UNIVERSITY

UNIVERSITY EXAMINATIONS

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

PHYS 822: LABORATORY TECHNIQUES II

STREAMS: Y2S1

TIME: 3 HOURS

DAY/DATE: THURSDAY 8/4/2021 **2.30 PM – 5.30 PM**

INSTRUCTIONS:

- Answer all 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**
  i. **Planks constant** - $6.62607004 \times 10^{-34}$ m^2 kg / s
  ii. **Boltzmann's constant** - $1.38064852 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}
  iii. 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) ${}^{19}_{\square}F - 251.7\,x\,10^{6}\dfrac{rad}{Tesla\,x\,sec}$
  iv. **Bohr magnetron** $\mu_B = 5.7883818012(26) \times 10^{-5} \cdot \square^{-1}$

QUESTIONS ONE (30 Marks)

a. What is NMR? Explain the Quantum theory of NMR up to the formation of an energy gap between spin states. **(5 marks)**

b. Discuss two important aspects that makes NMR spectroscopy different from other forms of spectroscopy. **(4 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)**

j. Magnetic resonance imaging is a medical application of nuclear magnetic resonance (NMR). Discuss the physics of MRI. **(3 marks)**

k. Give two examples of diagnosis that can be done for each of the following MRI's **(3 marks)**

   i. MRI of the brain
   ii. MRI of the heart and blood vessels
   iii. MRI of the bones and joints

QUESTION TWO (30 MARKS)

a. Differentiate between Electron Spin Resonance, Nuclear Magnetic Resonance and Magnetic Resonance Imaging by filling in the table below. **(9 marks)**

Definition	
ESR	
NM R	
MRI	
Type of Radiation used	
ESR	
NM R	
MRI	
Type of Matter targeted	
ESR	
NM R	
MRI	

b.

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

ii. 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 below). What is the strength of the solar magnetic field B in that region if the wavelength difference __ between the shortest and the longest wavelengths is 0.022 nm? (The wavelength of the D_1 line is 589.8 nm). **(10 marks)**

iii. Discuss applications of ESR in the following fields **(10 marks)**

i. In Biological Systems

ii. Study of Free Radicals

iii. Study of Catalysts

iv. Spin Labels

v. Study of Inorganic Compounds

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