NMR THEORY AND LABORATORY COURSE. CHEN: 696-Section 626.

1998 Fall Semester (3 Credit Hours)
Lectures: M, W 10-10.50 a.m., Richardson: 910
Laboratory Fri. 10-12, Richardson 912.

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INTRODUCTION.

The main purpose of this course is to introduce the important principles of Nuclear Magnetic Resonance (NMR) to students in petroleum and chemical engineering. No prior background or experience in NMR is assumed. Our goal is to introduce the essential ideas of NMR in a one semester course so that the student can understand the meaning of NMR experiments performed in the Engineering Imaging Laboratory (EIL) and elsewhere without difficulty. Since this is a one semester course, we are forced to make selections from a wide range of topics. The selections presented here are very much limited to the major experiments conducted in the EIL for chemical engineering applications. Students who are interested in learning more about NMR are provided with references on other specialized topics. It is our hope that if sufficient interest exists among students for NMR applications, we can expand this course by including more specialized topics in future renditions. The outline of this course represents our main philosophy that learning occurs very efficiently when abstract principles and concepts are accompanied by hands-on experiments. Thus we have placed a laboratory session immediately following the introduction of main principles and experimental techniques. We hope that by performing these experiments and doing exercises, students will gain a good understanding of the NMR theory and experiments in general and will be able to carry out experiments on their own with confidence. The last part of this course, a laboratory project, is included to give opportunity to demonstrate their skills learned in this course.

The main references for this course are:


2) Experiments in Modern Physics: S. Melissinos, Chapter 8 is on NMR,


6) Solving Problems with NMR, A. Rahman and M. Choudhary, Associate Press, 1996.

Grading Policy: Homework: 40%
               Project: 60%

List of Topics Covered.

**Lecture 1  Sept.10**

Nuclei in a Magnetic Field.

Larmor Precession.

**Lecture 2  Sept.12**

NMR signal, Free Induction Decay (FID).

NMR Lineshape.

**Lecture 3  Sept. 17**


The Effect of r.f pulses on spins.

**Experiment # 1. Sept. 15**

**Lecture 4  Sept. 19**

Spin-lattice Relaxation(T₁).

Spin-Spin Relaxation (T₂).

Introduction to Fourier Transform NMR.
Experiment #2. Sept. 22

Lecture 5 Sept. 24
Multipulse Operations.
Formation of Spin Echo.

Lecture 6 Sept. 26
Measurement of $T_1$ by Inversion Recovery.

Experiment #3. Sept. 29

Lecture 7 Oct. 1
Spin Echoes and measurement of $T_2$.
Relaxation Mechanisms in spin 1/2 nuclei.

Lecture 8 Oct. 3
Theory of Nuclear Spin Relaxation.

Experiment #4 Oct. 6

Lecture 9 Oct. 8
Introduction to Diffusion.
Effect of Pulsed Field Gradient on Spins.

Lecture 10 Oct. 10
Measurement of Diffusion using Pulsed Field Gradients.

Experiment #5. Oct. 13

Lecture 11 Oct. 15
Intrinsic $T_2$ Vs $T_2^*$. 

Lecture 12 Oct. 17
The CPMG technique for measuring $T_2$.

**Lecture 13 Oct. 22**

Hahns Echo technique Vs CPMG.

**Experiment #6. Oct. 20**

**Lecture 14 Oct. 24**

Introduction to 2D NMR.

Homo and Heteronuclear J-Resolved Spectroscopy.

**Experiment #7. Oct. 27**

**Lecture 15 Oct. 29**

Introduction to NMR Imaging.

Various Imaging Techniques.

**Lecture 16 Oct. 31**

$T_1$ Weighted Imaging.

**Experiment #8. Nov. 3 and 10**

**Lecture 17 Nov. 5**

Theory of Velocity Imaging.

**Lecture 18 Nov. 7**

MRI Application to Velocity Imaging.

**Experiment #9. Nov. 17 and 24**

**Lecture 19, 20, 21 on Nov. 12, 14 and 19.**
1) **Experiment #1**

**Introduction to NMR Spectrometer.**

Purpose of this experiment is to deal with various components of the NMR spectrometer. The student should perform all the preliminary adjustments such as tuning of the coil, adjustment of phase, setting of pulse width and gain etc. to obtain an NMR signal from a sample of water. The necessary adjustment are performed to setup a 90 degree pulse. The height of the Free Induction Decay (FID) is monitored as a function of pulse width and pulse height.

2) **Experiment #2**

**Introduction to Fourier Transform NMR.**

This experiment is conducted to demonstrate the relation between NMR lineshape and FID. From the NMR lineshape, the linewidth is obtained for water signal. Also T$_2^*$ is obtained from the FID directly and compared to the NMR linewidth.

3) **Experiment #3**

**Inversion Recovery Experiment.**

T$_1$ is measured and analyzed for a standard sample using inversion recovery sequence.

4) **Experiment #4**
Hahn Echo Experiment.

$T_2$ is measured and analyzed for a standard sample using Hahn spin echo experiment.

5) Experiment #5

Measurement of Diffusion using Pulsed Field Gradients.

A standard sample is used to measure self diffusion coefficient.

6) Experiment #6

Measurement of $T_1$ using 90-tau-90-echo sequence.

7) Experiment #7

Measurement of $T_2$ using CPMG sequence.

8) Experiment #8

Introduction to NMR Imaging.

We will image a sponge with water to obtain various concentration (contrasts) of water in the sponge. $T_1$ weighted imaging will be applied to this sample.

9) Experiment #9

Velocity Imaging Experiments.

Measurement of flow of fluid in a cylindrical tube using MRI.