

PHYS 429A - 2015

CourseSpaces ID: 20150913693

HONOURS LABORATORY

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NOTES FOR PHYSICS 429A HONOURS LABORATORY

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Course Outline

CourseSpaces ID: 20150913693

Email completed reports in PDF format to: p429@phys.uvic.ca

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Scheduled Lab Time:

Physics 429A (September – December)

Time: Tuesday & Thursday, 2:30 – 5:30 pm

Place: Elliott 123

Course Description :

Introduction to research, with several research-oriented experiments and with instruction on experimental techniques and theory of measurement.

Course Prerequisites:

Normally open only to fourth year Honours students.

Course Assessment:

PHYS 429A

There are four required lab reports; two required practical exercises: mechanical design/manufacturing practice & nanofab facility practice, and an oral presentation on one of the four reports.

Each lab will be evaluated on the basis of a written formal report (80%), your logbook and your performance in the lab (20%). Each lab will count equally towards the final grade and the four labs together constitute 84% of the mark.

Overall marking distribution is as follows:

84% Lab work (4 reports × 21% each)

16% Oral Presentation

The two practical exercises require completion. Failure to complete the exercises will result in a deduction of 10% off of your final mark.

The oral presentation component will be worth 16% of the course grade. It will consist of a 12 minute presentation (10 minute talk + 2 minutes for questions). It is expected that all students attend all presentations and participate by posing questions to the speaker - a grade for participation is assigned.

If a submitted lab does not meet the standard for a 4th year honours course you may be asked to revise and resubmit it before a mark is assigned.

Final Letter Grade :

The conventional departmental conversion between numerical and letter grades will be applied.

A+	A	A-	B+	B	B-	C+	C	D	F
90-100	85-89	80-84	77-79	73-76	70-72	65-69	60-64	50-59	0-49

INTRODUCTION:

The honours laboratory is intended for fourth year honours physics students. The experiments have been selected with the following purposes in mind:

- i) to acquaint you with modern techniques in experimental physics,
- ii) to acquaint you with basic measurements of some fundamental constants,
- iii) to provide experiments relating to some topics discussed in fourth year physics courses, and
- iv) to give you experience in experimental procedures so that you will be better able to undertake independent investigations.

This is not a laboratory manual but a guide to the experiments available in the laboratory; a list of available experiments is provided later in this document along with a short description and suggested procedures. More details on the equipment and procedures are to be found in booklets in the laboratory. You are encouraged to extend the experiments beyond the procedures suggested. You should consult the references given in the experiment description and use the books available in the laboratory and the library. A wealth of information is now available online. Use the search facilities of the Internet to your advantage.

It is hoped that enough equipment can be made available so that you will have reasonable choice of experiments to perform in **the branch of physics which is of particular interest to you**. However, you should select experiments covering as broad a range of topics as possible. For some experiments, equipment may be borrowed from the research laboratories or other undergraduate physics laboratories. Some P429A experiments are shared with other courses, such as P425 and P426. You can only obtain credit in one such course, if you decide to do one of these shared experiments. However, if the experiment is modified and extended, it can then be done and credited in P429A.

You are required to do a minimum of four experiments in P429A. All four experiments should be completed before the Christmas break. There is a component in Nanofabrication techniques and a mechanical design/manufacturing project, which is mandatory and must also be completed before the Christmas break.

Physics 429A experiments require that a formal report be submitted, **on or before their due date**, before a mark is given for your work. **Marks will be deducted for late submissions.**

Email an electronic copy of your report (converted to a PDF file), to p429@phys.uvic.ca. The name of the pdf file should be the experiment code as indicated on page 8 of this manual, plus your initials. For example, the Neutron Activation experiment by John Smith, should have a filename of **NAA_JS.pdf**

DO NOT SUBMIT A PRINTED COPY of your report.

You are to use LaTeX to compose your report, since this is the preferred typesetting system used in the scientific community for all papers.

A web browser based version of Latex is at <https://www.overleaf.com>. Otherwise you can download a standalone version TeXShop for mac here: <http://pages.uoregon.edu/koch/texshop/>

Other popular programs include **Kile** and **Lyx**, two of the better ‘user-friendly’ Latex editors. More information about LaTeX is included in Appendix A. Please observe naming convention for submitted PDF file(s).

The P429A formal reports should be formatted in the style of *Physical Review Letters* (PRL) and should be **no more than four pages** including figures and references. You are encouraged to read several PRL papers in order to study and emulate their composition, writing style and sophisticated figure design, etc.

If necessary, other supplemental materials (materials of lesser importance such as additional graphs, tables, pictures, comments) can be included in an appendix. For more information see:
<http://journals.aps.org/prl/authors/supplemental-materials-journals>

P429A reports from previous years can be viewed in the Lab.

Much of the apparatus you will use in this course is similar to that which you may use when you do research. Some of it is expensive, fragile and highly precise. Try to appreciate good apparatus and learn to judge the qualities of a good instrument. Always report losses or breakages to the instructor. Do not leave broken or misbehaving equipment for the next person to try to use. Take it to the instructor and have it fixed and if necessary checked against laboratory standards.

When you have finished one experiment and are going on to the next experiment, *tidy up the spot where you were working* for the sake of other people working in the laboratory. Return equipment manuals and books when you are finished with them.

Physics 429A Timetable (2015)

September 10 th	Introductory Lecture
October 1 st	1 st report is due
October 22 nd	2 nd report is due
November 12 th	3 rd report is due
December 3 rd	4 th report is due
TBD	Oral Presentation (early December)

Lab times are Tuesdays and Thursdays 2:30-5:30pm. You are expected to attend these two sessions each week to work on your experiment and/or project. Pre-lab background reading, additional research and experimental write-ups are expected to be done outside these scheduled hours. As with your other courses, it is anticipated that the total number of hours per week spent on this course (in class and out of class) is approximately 10 hours.

If you need additional time in the lab, it can be made available on Monday, Wednesday and Friday afternoons.

Guide for Physics 429 reports (3-4 pages including graphs and diagrams)

You must use TeX/LaTeX for typesetting your reports, since this is the preferred typesetting system of the scientific community. Please use Physical's Review Letters style or something equivalent. Some examples of how to create TeX/LaTeX documents and how to include diagrams and figures, are included in Appendix A.

The following is a suggested template for P429A reports:

Title:

Name of the experiment or research project, name of author and date.

Abstract:

Briefly summarize the important results of your project. State significant results along with uncertainties and comment on whether results agreed with expectation (eg. using a time-of-flight measurement we determined the speed of light to be $2.98 \pm 0.03 \times 10^8$ m/s which agrees within error with the defined value of 299,792,458 m/s.) An abstract is often used to help the reader quickly ascertain the paper's purpose and results.

Introduction:

Provide a context for the experiment/phenomenon you will investigate and state the goal of your investigation. Provide pertinent references for the reader who is unfamiliar with the topic.

Theory:

Describe the applicable theory involved. If you plan on fitting data to a certain equation, be sure to have briefly introduced and described this equation here.

Experimental design and results:

- a) Describe your experimental set-up with sufficient detail that a **competent** 4th year honours physics student could reproduce your results. Include diagram of apparatus used and include relevant details such as dimensions, equipment model numbers, etc.
- b) Appropriate plots of your collected data along with analysis and fits to theory (remember to consider sources of error)
- c) Analysis and discussion of results presented in the context of what is already know. Do your results support or conflict with known physics? How certain are you of the results presented – what are the inherent uncertainties? What are the limitations of your apparatus and experimental method – did you attempt to address these limitations?

Conclusion:

State your results. Give an assessment of the methodology used. Give suggestions for future experiments or for improving and modifying the experiment(s).

References:

List of reference material you used during this experiment(s) as well as any citations from the introduction / theory sections.

Archiving your reports:

An electronic copy of your report, converted to PDF, should be emailed to p429@phys.uvic.ca .

Note: Reports will be archived and stored in one of the Department's computers, so that they can be searched and viewed by future students.

Naming your files:

To allow us to easily identify the files, we have created 3-letter codes for all the experiments and you should use the following convention to name your files:

a) Main report file should be named as EXP_NAM.EXT

where: EXP = the 3-letter experiment code

NAM = you name initials

EXT = the file extension such as TEX or DOC or PS...etc

(eg. John Smith is submitting his X-Ray diffraction report, ie: XRD_JS.pdf)

b) Attached figures (if needed), should be named as EXPF#NAM.EXT

where: EXP = the 3-letter experiment code

F# = the figure number (e.g. F1)

EXT = the file extension such as PS,TIF,GIF...etc

For new experiments, please create your own 3-letter code

List Of Experiments

NUMBER	NAME	CODE	Rm#
1	NUCLEAR MAGNETIC RESONANCE	NMR	E11123
2	SHOCK TUBE	SHK	E11042
3	LIFETIME OF COSMIC MUONS	MUO	E11123
4	MAGNETO-OPTICAL KERR EFFECT	MOK	E11044
5	SCANNING PROBE MICROSCOPY	SPM	E11019
6	X-RAY DIFFRACTION	XRD	E11123
7	MICROWAVES	MWV	E11123
8	NEUTRON ACTIVATION ANALYSIS	NAA	E11031
9	THERMAL DIFFUSION OF NEUTRONS IN GRAPHITE	TDN	E11031
11	THE STATISTICS OF COUNTING	STA	E11123
12	THERMIONIC EMISSION	TEM	E11123
13	AMPLIFIERS (permission required)	AMP	E11123
14	PULSE CIRCUITS (permission required)	PUC	E11123
15	ANALOG ELECTRONICS	ANA	E11123
19	DIGITAL LOGIC (permission required)	DLL	E11123
20	RENEWABLE ENERGY	REN	E11123
21	HYDRAULICS BENCH	HYB	E11042
22	FLUID FLOW	FLF	E11042
23	FLUID LOGIC	FLL	E11123
24	WIND TUNNEL EXPERIMENTS	WTL	E11042
27	FLUID OSCILLATIONS	FOS	E11042
28	SOLITARY WAVES AND SOLITONS	SWS	E11042
30	FOURIER OPTICS	FOP	E11042
31	HOLOGRAPHIC TECHNIQUES	HOL	E11019
32	HIGH SPEED IMAGING	HSI	E11042
33	DIODE LASER SPECTROSCOPY	DLS	E11123
35	GRAVITY SURVEY	GRA	Field
36	MAGNETIC SURVEY	MAG	Field
40	X-Ray CT Lab (Medical Physics)	XCT	BCCA
43	X-RAY FLUORESCENCE	XRF	E11123
45	SCHLIEREN IMAGING	SCL	E11042
46	NANOFABRICATION LAB PRACTICE	NFP	E11018
47	MECHANICAL DESIGN & MANUFACTURING	MSP	E11020

Others:

Ground Conductivity Survey
Sonoluminescence

ADVICE ON THE EXPERIMENTAL METHOD:

The first step in any experiment is to write down in your laboratory notebook a summary of your present knowledge of the problem and an outline of your proposed method of solution. This will normally give rise to many additional questions, some of which can be answered by reading books, review articles and research publications. You should make frequent use of the books and periodicals in the Physics & Astronomy Reading Room and the Main Library. A lot of information is now available online and you are encouraged to use the Internet to find what you need.

Having decided what you are to do in an experiment, you should then decide what measurements are necessary to achieve your aim and perform a short experiment over a wide range of the variables to be measured. This short experiment should tell you

1. what precautions are needed to measure the parameters to the required accuracy,
2. what range of variables should be covered
3. the reproducibility of your readings, and
4. the success or failure of your plan of attack.

This initial procedure must not take too long but it should give you the "feel" of the experiment. Once you have the experiment proceeding satisfactorily it often saves time to push right ahead as much as you can and finish the experiment with as few breaks as possible.

Sometimes due to a malfunction of the measuring equipment, sometimes due to a wrong procedure, difficulties will certainly arise in the course of your experiments, but you are expected to look out for them and to solve them for yourself. Only seek the advice of the instructor when you are unable to find the answer to your problem and you feel that you are wasting *your time*. In experimental physics you learn a lot from your mistakes.

Being left on your own, it is easy to waste time. You should make a conscious effort to complete each task as quickly as possible, consistent with the care required for the measurement. If you find you are slow, look for a reason; sometimes it may be due to inadequate preparation and/or understanding.

Most experiments are designed to measure some quantity; a precise estimate of the accuracy of the final result given is an *essential part* of the experiment. By changing conditions and by repeating your observations some idea of the accuracy can be obtained. Whenever you give a numerical result you must also give the standard deviation if it is statistically significant, and you should estimate, if possible, the magnitude of systematic errors.

It is important to acquire the habit of using notebooks, as you will, when you come to solve research problems on your own. When research is being done it may not be certain for several months which of the readings will be useful, so it is of the utmost importance to record them all, good, bad or indifferent as they appear to be, so they can be easily referred to and understood later. The habit should be acquired of writing down just enough about every observation to enable you to know even one year later exactly what was done and with what apparatus. Your notes should read much like a diary. Each observation should be noted at the time it is made and at suitable intervals the useful observations collected together in tabular or graphical form and finally a result evaluated. Plotting a rough graph of each data

point as it is measured is a valuable method of indicating those regions where more readings of the variables are required. For example, in regions where the results are extremely linear few readings may be required, whereas additional readings should be made where there is large scatter in the measurements or where the dependence is non linear. Interim evaluation and conclusions should be reasonably neat even though the original observations may turn out to be untidy. Try to cultivate neatness but remember that in research there is no copying of original observations into a neat book. In summary, the following guidelines should be followed:

- a) Enter date & time on each task you describe and, when finished, enter the date you started and finished an experiment and the approximate number of hours taken on it.
- b) Summarize for your own purpose any theory, references, equations etc., while doing the preliminary reading. Additional references may be made later in the experiment.
- c) Describe your procedure accurately and concisely; do not copy out instructions from your manual.
- d) Enter your observations as you make them and try to cultivate some neatness doing this. Do it the first and only time in the lab notebook and never transfer from loose leaf paper. For this reason use a bond notebook and not a loose leaf folder as the temptation to rewrite more neatly and leave out data which later proves to be useful is then avoided.
- e) Tabulate your final results, draw graphs and do the final data reduction neatly so it is easy to follow. Your results should include calculations and some discussion of experimental uncertainties.
- f) Test the clarity of your notes for yourself by looking back after a few months and checking whether you understand what you did then.
- g) Complete a report write-up as described below including a discussion of your results, and conclusions.

PRACTICAL EXPERIENCE:

Mechanical design & manufacturing

Since original research often requires the design and construction of novel pieces of apparatus, it is important that the student gain some knowledge of machine shop practice. Toward this end, each student will be required to spend one or two afternoons during the first term in the Physics & Astronomy Shop under the supervision of one of the machinists. You will be required to design and build a simple item, using **CAD** software, the **3-D** printer to print the model and the **CnC** milling machine to build the final product.

You should also acquaint yourself with the equipment available in the machine shop - being careful, of course, not to go into restricted areas or to interfere with work in progress. All persons in the shop are responsible to the shop supervisor.

Nanofabrication Facility Practice

Students will design and construct a nanostructure.

Under the supervision of the Facility Manager, the student will be trained on how to use the facility to design and construct a nanostructure.

Please make sure you sign up for the above two exercises. Use the signup form in the lab. Since shops technicians are quite busy, they need to know in advance when to set aside time for our students.

Both exercises have to be completed BEFORE the first week in December.

COMPUTING FACILITIES

There are a number of systems available for you to use for computations associated with your experiments.

- 1) Four PCs with Windows, MATLAB, Open Office and a number of other software packages.
- 2) Four PC's running Linux are also available and can be used for data analysis and programming.
- 3) Four MS Windows laptops, AmpTek MCA software and Microsoft Office are available for field work. These units need to be signed out on an as needed basis

All of the above systems are connected to the University network, and can be used to access other systems on campus and beyond. ***No personal data should be stored on these systems. Please use your own portable storage device to store sensitive data.***

Programs are available on these various computers to enable the transfer of information between different systems.

Some users' manuals are available in the laboratory for all these systems

The following software is available for the Windows systems:

Utility	System	Description
Data Analysis		
Matlab	Windows/Linux	Data analysis package
Maple/WMaxima	Windows	Symbolic math package
Maxima	Linux	Symbolic math package
PAW	Windows	Data Analysis/Display package

Imaging/Graphics

XView	Windows	Imaging/graphics
Gimp	Linux	Imaging/graphics
MS PhotoEditor	Windows	Image display and manipulation

COMPILERS and PROGRAMMING TOOLS

C/C++	Windows	Microsoft C/C++
BASIC	Windows	Microsoft Visual Basic
LABVIEW	Windows	Data Acquisition System

OTHER UTILITIES (CW= run from Command Window)

TeX/LaTeX	Windows	Type-setting systems. (CW)
DVIPS	Windows	Convert DVI files to Postscript (CW)
GS	Windows	Ghostscript PS converter (under GSTools)
GSview	Windows	Ghostview PS viewer (under GSTools)
XDVI	Windows	X-Window viewer of DVI files.(CW)
YAP	Windows	Windows NT viewer of DVI files. (CW)
Open Office	Windows	Word processor, spread sheet, database package
ZIP/UNZIP	Windows	compression utility. (CW)

Similar software is also available for the P429A Linux workstations.

EXPERIMENT 1 NUCLEAR MAGNETIC RESONANCE

Nuclear Magnetic Resonance is a phenomenon, in which the nuclei of material placed in a strong magnetic field will absorb radio waves supplied by a transmitter at particular frequencies. Some nuclei experience this phenomenon, and others do not, dependent upon whether they possess a property called spin.

The energy of the radio-frequency photons is used to promote the nucleus from a low-energy state, in which the nuclear spin is aligned parallel to the strong magnetic field, to a higher-energy state in which the spin is opposed to the field. When the source of the radio waves is turned off, many nuclei will revert to the lower state by emitting photons at the characteristic resonance frequencies, providing information about the sample material.

A nuclear magnetic resonance spectrometer, a TeachSpin PS2-A system, is used to measure the magnetic moment of protons in water and fluorine.

Overview of the PS2-A System

- High-Field, High Homogeneity Permanent Magnet
 - 0.49 Tesla, 21 MHz proton resonance
 - field stabilized to 1 part in 10^6 over a 20 minute interval.
- RF sample probe with
 - single coil and a 50 ohm input impedance; a matched unit.
 - four independently adjustable gradient coils (x, y, z, z^2) available to:
 - enhance homogeneity
 - provide known gradients for diffusion measurements and one dimensional imaging

REFERENCES:

Pulsed NMR/CW Spectrometer Manual, TeachSpin Inc, 2009

A.C. Melissinos, Experiments in Modern Physics, Academic Press, 1966, Chapter 8, Sections 1 to 4.

A. Abragam, Nuclear Magnetism, Oxford University Press, 1961

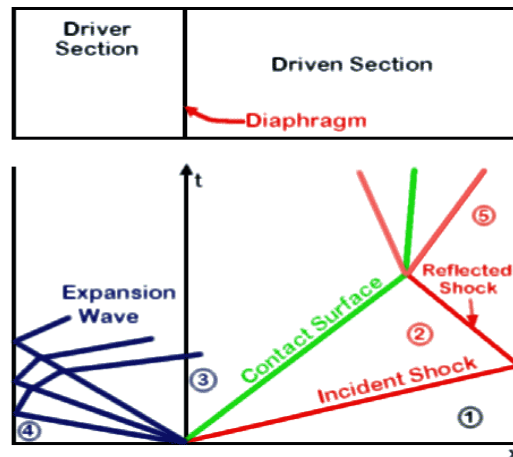
EXPERIMENT 2 SHOCK TUBE

With the development of intercontinental ballistic missiles and satellites, the problem of flight at extremely high velocities has been encountered. A blunt body reentering the Earth's atmosphere at a Mach number of 20 can produce a normal shock wave which could yield a temperature behind it as high as 6000 K. A gas subjected to such extreme temperatures may no longer be considered as obeying the perfect gas law.

Phenomena such as ionization, dissociation, and chemical reactions between constituents may occur which tend to greatly alter the characteristics of the flow. The effects of these phenomena are commonly termed "real gas effects". Due to the temperature limitations of conventional methods for obtaining aerodynamic information, such as supersonic wind tunnels, it became necessary to devise new methods for simulating high Mach number and high enthalpy (high stagnation temperature) flows. The shock tunnel is one method which can, for a short time duration, simulate high free flight Mach numbers and stagnation temperatures. One of the basic components of a shock tunnel is a shock tube. We now will illustrate the principle of operation of a shock tube.

Constant Area Shock Tube

The simplest of shock tubes consists basically of two constant area sections separated by a diaphragm. The diaphragm allows one to maintain different pressures in each section. The high pressure section of the tube is called the driver while the low pressure end is called the driven section. When the diaphragm is suddenly removed, normally by manually puncturing, compression waves are generated which eventually coalesce into a shock wave. This shock then propagates into the low pressure driven section. Simultaneously an expansion or rarefaction wave is propagated into the high pressure driver section (see Figure).



REFERENCES:

Shock Wave Reflection Phenomena, Ben-Dor, Gabi 2nd ed. 2007

The Design of a Holographic Interferometer...., M.S Thesis, Van Netten, Alexander, UVic 1988

EXPERIMENT 3 LIFETIME OF COSMIC RAY MUONS

Cosmic ray protons from outer space interact with nuclei in the earth's upper atmosphere; amongst other reaction products are pions, which decay into muons. The muons have a sufficiently long lifetime ($2 \mu\text{s}$) that some of them reach the surface of the earth. The purpose of this experiment is to measure the muon lifetime by first detecting muons stopping in a scintillator, by means of a scintillator telescope, and then counting muon decays as a function of time.

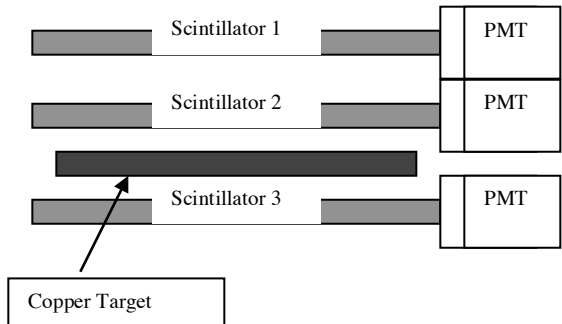
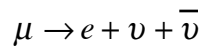


Figure 1 shows the arrangement of three scintillators, with a muon stopping in scintillator #2. Such a stopping muon is detected electronically by a coincidence between counters #1 and #2 with no coincident pulse in counter #3.

The muon subsequently decays into an electron and two neutrinos:



The electron may be detected in counter #2 so that at some time after $1 \bullet 2 \bullet \bar{3}$ coincidence, a subsequent "2" pulse indicates the muon decay. The time of the subsequent "2" pulse after the muon stop ($1 \bullet 2 \bullet \bar{3}$) is the lifetime of a particular muon. By measuring the lifetimes of many individual muons one can determine the mean lifetime of the muon.

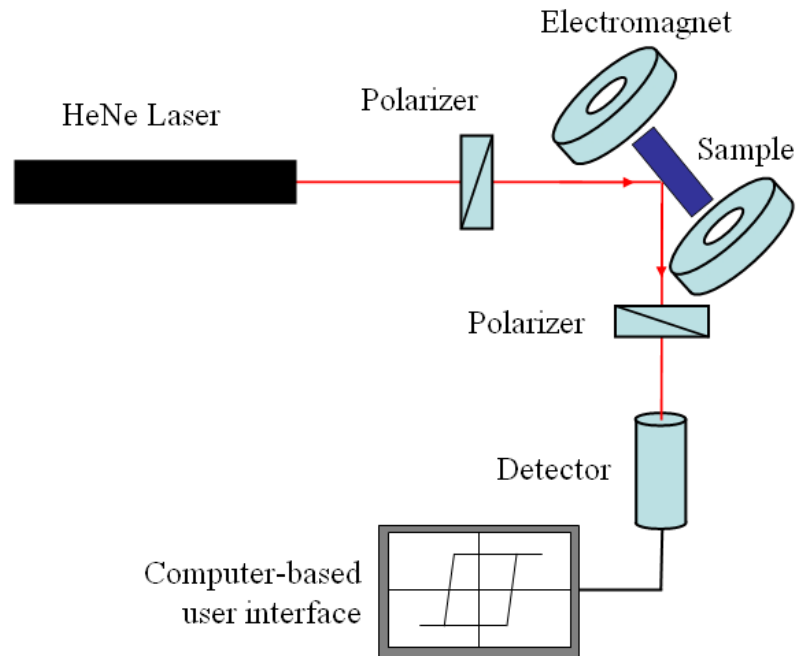
Details of the experiment are given in the booklet accompanying the apparatus in the laboratory.

WARNING: It takes a minimum of four (4) weeks of running in order to collect enough data to do the analysis.

EXPERIMENT 4 MAGNETO-OPTICAL KERR EFFECT

WARNING: A two week notice is required, in order to prepare a new sample for this experiment.

The Magneto-Optical Kerr Effect (MOKE) is a branch of modern optics known for its applications in an expanding area of magneto-optical recording media. This technique is one of the standard methods used in the investigation of magnetic properties. The purpose of this experiment is to enable the student to monitor magnetic properties with light. The light source for the experiment is a HeNe laser (632 nm). In the experiment, polarized laser light reflects from a magnetic surface in the presence of a sweeping magnetic field. Since light is an electromagnetic field, the magnetic field of the sample interacts with the light to cause a very slight change in the light's polarization. The magnitude of the rotational angle of the Kerr effect for a ferromagnetic material is generally between 10^{-4} to 10^{-3} degrees. We measure these changes in the light as an intensity change through nearly-crossed polarizer, recording the intensity as a function of the applied magnetic field, using an apparatus like the one shown below.



EXPERIMENT 5 SCANNING PROBE MICROSCOPY

Scanning Probe Microscopy (SPM) is a technique that is used to study the properties of surfaces at the atomic level. A Scanning Probe Microscope scans an atomically sharp probe over a surface, typically at a distance of a few angstroms or nanometers. The interaction between the sharp probe and surface provides 3-D topographic image of surface at the atomic scale. The modes are the most popular in Scanning Probe Microscopy: Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy (AFM).

Scanning Tunneling Microscopy

The Scanning Tunneling Microscope (STM) uses the quantum mechanical tunneling effect to determine the distance between the probe and the surface. Typically, the STM is set up to scan a surface at a constant distance away from the surface. Naturally, the probe will have to be moved up and down to follow the height of the surface, and this up and down motion can be used to make a three dimensional image of the surface.

Atomic Force Microscopy

The Atomic Force Microscope (AFM) uses various forces that occur when two objects are brought within nanometers of each other. An AFM can work either when the probe is in contact with a surface, causing a repulsive force, or when it is a few nanometers away, where the force is attractive. Scanning works similarly to the STM, and also creates three dimensional images.

Scanning probe microscopy covers several related technologies for imaging and measuring surfaces on a fine scale, down to the level of molecules and groups of atoms.

For a Virtual tour of the EasyScan STM/AFM microscope that you will be using, please visit the Web Site <http://virlab.virginia.edu/VL/home.htm> , and select the Scanning Tunneling and Atomic Force Microscopes options.

EXPERIMENT 6 X-RAY DIFFRACTION

An X-ray spectrometer is available to measure the crystal structure using X-ray diffraction. The X-ray generator is a Phillips type PW1008 X-ray diffraction unit. A Debye-Scherrer camera and a universal flat plate camera are available.

REFERENCES

G.L. Clark, Applied X-rays, McGraw-Hill (1955).

R.B. Leighton, Principles of Physics, McGraw-Hill (1959), pp. 405-457.

Methods of Experimental Physics, Vol. 1, Section 7.10.

Elements of X-ray Diffraction, Cullity QC481, C87.

EXPERIMENT 7 MICROWAVES

A Microwave kit, the FEEDBACK Microwave Trainer, is available for the student to investigate the properties of microwaves.

The student will be required to perform the twelve exercises that are outlined in the student manual, or designed and perform an experiment using the microwave components of the student kit (requires the permission of the instructor).

REFERENCES

Experiment 7 student manual

Reference Data for Radio Engineers, Howard W. Sams & Co. , ITT

EXPERIMENT 8 NEUTRON ACTIVATION ANALYSIS

This experiment is described in the Physics 413 laboratory manual. The americium beryllium neutron source surrounded by a moderator of graphite supplies a source of thermal and epi-thermal neutrons for activation.

The experiment consists of two parts:

Part 1:

You will measure the half lives of the radioactive nuclides ^{116}In , ^{108}Ag and ^{110}Ag produced from neutron capture in Indium and silver foils. Other foils are available such as rhodium, copper and gold and can be studied.

As part of the activation measurement, the neutron flux at the place of activation can be determined from the neutron absorption cross sections.

Part 2:

You will measure the γ -ray spectra from the above sources at different periods of the decay (if there is more than one isotope present) using a γ -ray detector and a pulse height analyzer. Unknown samples can also be irradiated and their respective spectra measured, in order to determine the elemental compositions of these unknowns. Known composition samples can be used for calibration purposes.

EXPERIMENT 9 THE DIFFUSION OF THERMAL NEUTRONS IN GRAPHITE

The object of the experiment is to measure the distribution of neutrons in the graphite pile by activating metal foils (e.g. indium, rhodium...etc) and from the neutron distribution to calculate the diffusion area for graphite.

REFERENCES:

QC786/G58 S. Glasstone and M. Edlunds, The Elements of Nuclear Reactor Theory.

TK9820/W4 A.M. Weinberg, The physical Theory of Neutron Chain Reactors.

QC721/D334 B. Davisson, Neutron Transport Theory.

EXPERIMENT 11 THE STATISTICS OF COUNTING

The student will use a NIM scaler/counter to make repeated observations of statistically distributed events. Hundreds of observations can be made in this way, and recorded over a period of time. The observations will then be analyzed and compared with theoretical predictions of various distribution formulae. The collection of the experimental information should take only a comparatively short time, so that most of the laboratory session can be devoted to the analysis of the data.

The interested student may wish to perform further experiments and analyses of , for example, the distribution of the intervals between events or binomial distributions, as outlined in reference 1.

In the second part of this experiment, you will record the spectra of known isotopes and use the statistical methods of the first part, to fit the spectral peaks to a known distribution. The fitted data will then be used to calibrate your Multi Channel Analyzer (MCA). The calibrated MCA can now be used to determine the energy peaks of an unknown isotope.

REFERENCES:

Robinson, B.L. , Am. J. of Physics, 33 (1965), 496-8.....(Appendix A)

Taylor, J.R., An Introduction to Error Analysis, QC39 T386
(University Science Books, Sausalito California, 1997)

Parratt, L. G., Probability and Experimental Errors in Science, QA273 P24
(John Wiley and Sons, Inc., New York, 1961).

Sokolnikoff, I. S., and Redheffer, R. M., Mathematics of Physics and Modern Engineering, (McGraw-Hill, 1958 or 1966). QA401.564

EXPERIMENT 12 THERMIONIC EMISSION

This experiment studies the current-voltage relationship for a vacuum tube diode which depends on the thermionic emission of electrons from the filament given by the Richardson-Dushman Equation and on the space charge effects given by the Child-Langmuir Relation.

REFERENCES:

C.N. Wall and R.B. Levine, Physics Laboratory Manual, Prentice-Hall Inc. (1962) Experiment 48, p. 177; also p.293, and expt. 47.

I. Langmuir and K.T. Compton, Review of Modern Physics 3 (1931) 191-157; particularly pp. 245-9.

J. Millman and S. Seely, Electronics (1951) McGraw-Hill, p. 193, Chapters 4,5,6.

Melissinos, Experiments in Modern Physics Chapter 3, Section 2.3, p. 71.

EXPERIMENT 13 AMPLIFIERS

The experiment can be divided into two parts;

- i) Part A - a simple transistor amplifier
- ii) Part B - an operational amplifier.

PART A - Transistor amplifier

In this exercise, the student is to wire a common-emitter amplifier circuit and perform certain measurements as described in Ch. 10 of Experiments in Semiconductor Applications and Design. In addition, the student may wish to do one or more other experiments suggested in the above reference. For example: Ch. 8, Small Signal Common-Base Amplifier; Ch. 9, Small Signal Common-Collector Amplifier; and Ch. 11-15, concerned with refinements in common-emitter amplifier design.

PART B - Operational amplifier

- i) The student can study the gain-bandwidth product of a fed-back operational amplifier as suggested in experiment 4-1 of Optimization of Electronic Measurements.
- ii) The student can investigate the use of operational amplifiers in various current and voltage configurations as given in Experiments 3-1 to 3-4 of Malmstadt, Enke and Crouch Module 3. The use of op. amps as difference amplifiers, absolute value circuits and logarithmic amplifiers is studied in experiments 3-5 to 3-7 of the above reference.

Numerous other interesting circuits are given in Operational Amplifiers and their Applications.

In addition to a number of integrated circuits available in the laboratory there is also a Tektronix type "0" operational amplifier plug-in.

REFERENCES:

T.B. Brown (ed.), The Taylor Manual, Addison-Wesley Publishing Co., Inc., (1959), Ch. 7.

J.J. Brophy, Basic Electronics for Scientists, McGraw Hill (1972), Ch. 6 & 7.

H.V. Malmstadt, C.G. Enke, S.R. Crouch, G. Horlick, Control of Electrical Quantities in Instrumentation, (Module 2), Digital and Analog Data Conversions (Module 3), Optimization of Electronic Measurements (Module 4).

C.N. Herrick and M.s. Estrada, Experiments in Semi-conductor Applications and Design, 1963. John Wiley and Sons. Inc. Operational Amplifiers and their Applications, 1965, Tektronix Inc.

EXPERIMENT 14 PULSE CIRCUITS

The experiment can be divided into three parts:

- i) Part A - Pulse shaping circuits
- ii) Part B - Switching circuits
- iii) Part C - Oscillator circuits

PART A

The purpose of this part is to investigate circuits for integrating, differentiating, clamping and stretching pulses.

PART B

The purpose of this part is to study the construction and characteristics of various switching circuits including a free running multivibrator, a bistable multivibrator, a univibrator and a Schmidt trigger. These circuits may be constructed from discrete components as outlined in the notes available with the experiment or by using operational amplifiers. Procedures for the latter are given in Experiment 2-28 of Module 2 and Experiment 3-42 of Module 3 of Malmstadt, Enke, and Crouch.

PART C

The purpose of this part is to construct and test at least one transistor oscillator as suggested, for example, in chapters 22, 23, and 24 of Experiments in Semiconductor Applications and Design, by C.N. Herrick and M.S. Estrada.

Alternatively, waveform generators using operational amplifiers may be studied using procedures suggested in Experiment 2-27 of Malmstadt Enke and Crouch, Module 2, Control of Electrical Quantities in Instrumentation and the feed-back oscillator described in experiment 4-5 of Module 4, Optimization of Electronic Measurements.

REFERENCES:

Malmstadt, Enke and Crouch, Control of Electrical Quantities in Instrumentation (Module 2) Digital and Analog Data Conversion (Module 3) Electronic Measurements for Scientists (Module 2) and (Module 4).

A. Melissinos, Experiments in Modern Physics, Ch. 4, Section 2.

J.J. Brophy, Basic Electronics for Scientists, Ch. 11

C.N. Herrick, M.S. Estrada, Experiments in Semiconductor Applications and Design.

EXPERIMENT 15 ANALOG ELECTRONICS

A number of experiments have been chosen so as to present the student with a review of basic analog theory, as well as practical work that parallels the Physics 425 course.

Students can select a starting point that matches their own ability and interests, and then proceed to more advanced work.

A number of practical work guides is available in the lab. A recommended one is the “Student Manual – The Art of Electronics” by Horowitz.

A wealth of information exists online, with a number of sites listing detailed descriptions of electronics projects. A couple of the more popular sites, are <http://circuitcellar.com/> and <http://www.electronics-lab.com/>

EXPERIMENT 19 DIGITAL LOGIC LABORATORY

The purpose of this experiment is to enable the student to become familiar with the basic building blocks of a digital logic system. A program of experiments is described in the work book "Practical Digital Electronics Laboratory Manual". The student can decide what experiments should be done and how far exercises should be proceeded with. Alternatively, the experiments suggested in books Bugbook I and Bugbook II may be followed.

The equipment available is similar but not identical to that described in the Hewlett Packard Manual.

REFERENCES:

J. Blukis, and M. Baker, Practical Digital Electronics, Hewlitt-Packard Co.

M. Bird, and R. Schmidt, Practical Digital Electronics, Laboratory Workbook, Hewlitt-Packard Co.

H.V. Malmstadt, and C.G. Enke, Digital Electronics for Scientists.

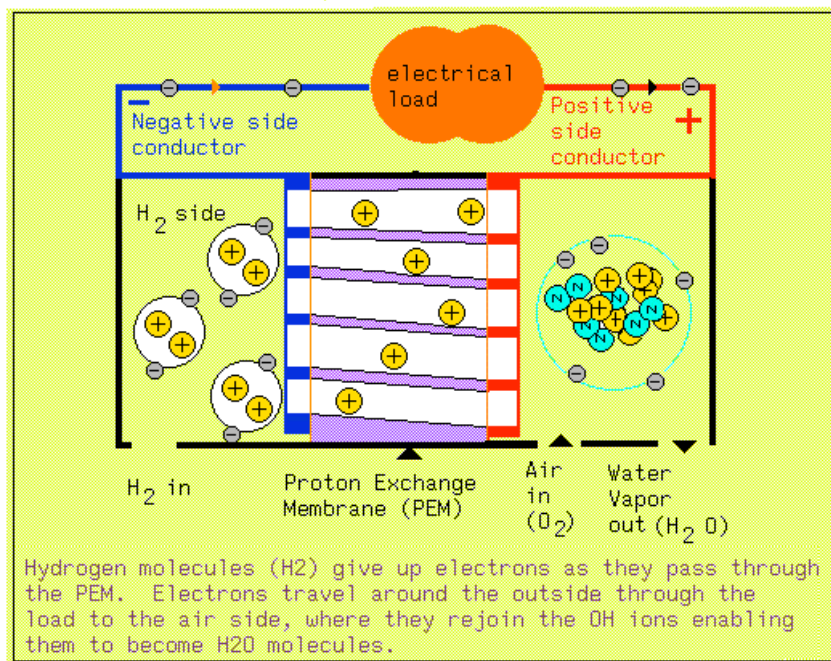
H.V. Malmstadt, C.G. Enke, S.R. Crouch, Digital and Analog Data Conversion (Module 3).

EXPERIMENT 20 RENEWABLE ENERGY

Fuel Cells constitute an alternative source of energy to the more traditional internal combustion and chemical sources. Even though the initial discovery of such processes dates from the 1830s, serious research has not begun until very recently.

In this experiment, the properties of a **Proton Exchange Membrane (PEM)** fuel cell will be investigated.

The following diagram demonstrates the workings of a PEM fuel cell



Solar Cells for producing electricity, and solar collectors for hot water, are now becoming more popular as the cost of fossil fuels is rising.

There are two different types of solar cells available in the lab, to investigate and characterize.

REFERENCES:

<http://www.fuelcells.org/>

<http://pveducation.org/>

EXPERIMENT 21 HYDRAULICS BENCH

The hydraulics "bench" is a large commercially-built tank with a motor and water pump for maintaining a flow of water within a closed system. A number of hydraulics experiments can be done with this unit, including

- i) the observation of laminar and turbulent flow, and of velocity profiles using an auxiliary Osborne Reynolds' apparatus,
 - ii) the investigation of Bernoulli's Theorem as applied to water flow, using an auxiliary Bernoulli apparatus,
- and iii) the investigation of open-channel flow over weirs of various shapes and sizes

EXPERIMENT 22 FLUID FLOW

In this experiment the stream lines in a flowing fluid are made visible by putting polyethylene beads or nitrogen bubbles in the fluid. By photographing these beads or bubbles the velocity field around objects inserted in the flow can be determined. Lift, drag, and other interesting parameters can be calculated from such data.

Because the student may already have done some introductory experiments on this apparatus, ingenuity should be used to investigate flows around objects other than simple foils (the box of objects with the experiment indicates some interests of previous students).

A large water tank is also available, to allow for the investigation of flow over larger objects.

EXPERIMENT 23 FLUID LOGIC

This experiment is conceptually very similar to experiment 19, Digital Logic, and is intended to enable the student to construct and understand some simple fluid logic systems. This equipment is called a "Fluidkit" and the accompanying manual describes its operation as well as a number of experiments which the student can perform. However, one should not hesitate to use imagination and attempt some original experiments.

EXPERIMENT 24 WIND TUNNEL EXPERIMENTS

Two Wind tunnels are available in Elliott 042. A subsonic tunnel, capable of producing air flow speeds of 25Km/hr, and a supersonic one capable of speeds of Mach 1.6. A number of techniques can be used to visualize and measure flow speeds and characteristics. The student is encourage to use different targets in the test section of the tunnels, and investigate their aerodynamic properties.

REFERENCES:

Kundu, P.K., Cohen, I.M, Fluid Mechanics, Elsevier Academic Press, San Diego 2004

Settles, G.S, Schlieren and Shadowgraph Techniques, Springer Press 2001

EXPERIMENT 27 FLUID OSCILLATORS

This experiment involves the analysis of three different types of fluid oscillator.

- 1) The salt oscillator which consists of a very small capillary tube containing salt water which is placed so that it discharges into a beaker of fresh water. The discharge is oscillatory in nature and can be approximated mathematically.
- 2) The thermal oscillator which is a U shaped piece of pipe, filled with water which is heated at the bottom. This results in small amplitude oscillations of long period which are again mathematically predictable to some extent.
- 3) The Rijke - Pipe oscillator. This is a remarkable curiosity whereby a vertically oriented pipe with a wire screen placed inside it will howl loudly when heated. The experiment is largely qualitative in nature.

EXPERIMENT 28 SOLITARY WAVES AND SOLITONS

In this experiment, the student will examine properties of solitary waves using a 5m. wave tank. Many properties of these waves can be approximated mathematically and the exercise will consist mainly of checking the validity of this theoretical work and explaining any shortcomings of it.

EXPERIMENT 30 FOURIER OPTICS

Numerous studies have been conducted about diffraction patterns formed by apertures, aperture arrays, and film-recorded objects. Given monochromatic, coherent incident light, e.g., from a laser, or a mercury arc source with the selected wavelength filtered through, all the information from a periodic object can be diffracted into a very minute area where it may easily be studied or recorded on film. Appropriate filtering in this plane thus allows only the desired information to pass through to the final imaging plane. Recently, seismologists have found that Optical Data Processing (spatial filtering) of film-recorded seismic data enhances the signal to noise ratio, resulting in more rapid analysis of the signal output.

The Fraunhofer diffraction pattern associated with the field distribution existing across an aperture is the Fourier transform of that field. To be precise the Fraunhofer diffraction pattern of an aperture distribution is obtained when the point of observation is infinitely distant from a coherently illuminated aperture. In practice, of course, this condition never describes a physical situation. However, the Fraunhofer theory provides an adequate approximation in many physical significant experiments.

The student should set up and align the apparatus and do a number of exercises as described in the supplementary material for this experiment.

For references to this experiment see p. 27 of the supplementary binder for this experiment.

EXPERIMENT 31 HOLOGRAPHIC TECHNIQUES (Pending)

The introduction of lasers in the the 1960s for the first time allowed the investigation of photography with coherent light beams. The most significant advance to come out of this investigation was the achievement of practical holography.

A hologram is a photographic record of both the amplitude and phase of an incident light beam. This is achieved through interference with a reference beam that is coherent in amplitude and phase, and does not vary in phase randomly with respect to the incident beam. This requires that both beams be from the same source and travel approximately the same path length. The second of these requirements has become less crucial through the use of the long coherence-length lasers that have become available.

The holographic image is unintelligible by itself, requiring an inverse process of reconstruction to view the image. In this process, a laser beam is shone through the image, captured on transparent film, at the same angle as the original reference beam. The transmitted light is then scattered by the interference pattern of the image to recreate the object beam, exactly as recorded. Thus, the three dimensional subject of the hologram appears to be present through the `window' of the holographic image.

~~In double exposure holographic interferometry, one uses the interference pattern of the hologram to measure minute displacements on the order of the light wavelength. A loaded steel beam cantilever will be used to demonstrate this procedure.~~

REFERENCES:

Holographic Interferometry, Charles M. Vest

EXPERIMENT 32 HIGH SPEED IMAGING

In conventional photographic procedures, the subject is illuminated continuously while the shutter on the camera opens for a fraction of a second and records the image. This has two problems when being used to capture a very fast event. The first and larger of the problems is the problem of ensuring, repeatedly, that the camera's shutter is open during the event and is also open at the correct time during the event. The second problem is that typical exposure times are on the order of 1/60 to 1/100 of a second. For very fast-moving objects, this will blur out the detail of the object.

Both of these problems can be mitigated by reversing the usual process with the help of a strobe light. In this process, the shutter of the camera is held open continuously while the the subject is illuminated briefly by a strobe pulse. This solves the second problem by illuminating the subject with a very short, very bright pulse of light that appears to the naked eye to 'freeze' the subject. The first problem is solved because a strobe light can be controlled by external input in a very accurate fashion.

To synchronize the strobe light to the event, some sort of sensor and delay mechanism is needed. Photodiodes are often used to detect the passage of an object, or microphones can be used with an event that generates significant noise, such as the detonation of a small explosive charge.

In general, the choice of sensor is highly dependent on the high-speed event to be captured.

The student is required to design an experiment that uses High Speed Imaging to observe and capture an event or a sequence of events, that can then be analyzed.

EXPERIMENT 33 DIODE LASER SPECTROSCOPY

The ideal spectroscopic experiment would involve illuminating a free, unperturbed atomic system with perfectly monochromatic light, and then seeing what happens, to the light, and to the atom, as a function of the frequency of the light. Nowadays it's feasible for undergraduates to get hands-on experience of this very scenario in a tabletop, real-time experiment.

The nearly-ideal monochromatic light comes most conveniently from solid-state diode lasers, mass-produced for the needs of the optical data-storage industry.

Photons of wavelength 785 nm each convey an energy of only 1.58 eV, insufficient to excite most atoms from their ground states even to their lowest excited states. The exceptions are alkali metals, particularly rubidium (Rb) and cesium (Cs). In fact, rubidium's lowest excited states are split (by the spin-orbit interaction) into states accessible from the ground state by photons of wavelengths 780 and 795 nm (the output wavelength could be varied by changing the laser's temperature, and further fine-tuned by changing the DC current operating the laser)

Using the apparatus provided by TeachSpin (www.teachspin.com), you will be able to perform a number of experiments such as, but not limited to:

- Observe Doppler-Free Spectroscopy of Rubidium Gas (Saturated Absorption)
- Michelson Interferometer Used to Calibrate Laser Sweep
- Observe Resonant Faraday Rotation in Rb Vapor
- Measure Temperature Dependence of Absorption and Dispersion Coefficients of Rb Vapor
- Lock Laser to Rubidium Hyperfine Transition
- Study Zeeman Splitting in Rb Spectrum at Two Wavelengths
- Study Stabilized Diode Laser Characteristics

REFERENCES:

TeachSpin Diode Laser Spectroscopy Experiment#33 Manual

Precision Spectroscopy, Diode Lasers, and Optical Frequency Measurement technology, NIST, Boulder, Colorado May 1998 (<https://archive.org/details/precisionspectro1504holl>)

EXPERIMENT 35 GRAVITY SURVEY USING A LACOSTE & ROMBERG MODEL G GRAVITY METER

This experiment is of particular interest to those students interested in the area of Geophysics. The LaCoste & Romberg Gravity Meter, which is used to measure changes in the Earth's acceleration due to gravity at various locations, is the instrument which is preferred by geophysical exploration companies for oil and mineral exploration, and by government for general gravity surveys.

A more modest laboratory experiment may be carried out by taking gravity readings on the various levels near the south stairwell in the Elliott Building. If g can be determined as a function of height, then making use of the gravitational constant, G , and a reasonable value for the radius of the Earth, the mass of the Earth may be estimated.

The LaCoste & Romberg gravity meter can be used to carry out a field-survey project, which may be of interest to those intending to specialize in the area of Geophysics. Near Victoria, there are two interesting geological-fault structures. These are the Leech River Fault and the Juan de Fuca Fault. Gravity readings cross the regions of these faults may reveal gravity anomalies which will delineate the faults. The Leach River Fault appears to cross the spit at Esquimalt Lagoon and appears to lead into the ocean again near Port Renfrew.

REFERENCES:

Instruction Manual for LaCoste & Romberg, Inc. Model G Land Gravity Meter, No. 585.

Marathon Battery Instruction Manual.

Gravity Survey over the Colwood Section of the Leech River Fault. Jeff Paul and Ulrich Suesser, Ph 429 Project, January 1983.

Milsom, John, Field Geophysics, Wiley Press 2003

Gravity Meter Simulation: check the web for new site.

EXPERIMENT 36 MAGNETIC SURVEY

This experiment is of particular interest to those students interested in the area of Geophysics. To locate buried ferrous materials a magnetic survey is usually conducted. The section of ground to be surveyed is typically divided into a grid and using a magnetometer, the surveyor systematically scans the area.

The magnetic object interacts with the Earth's ambient magnetic field, creating a "magnetic anomaly". The magnetometer can detect the strength and shape of the anomaly, and through analysis certain information such as the object's size, depth, and orientation can be determined.

For this experiment a magnetic survey of the Mystic Vale Field will be conducted with the Scintrex ENVI magnetometer system to locate and map a pair of buried fire hydrants.

The Scintrex ENVI Geophysical System magnetometer is a sophisticated proton-precession magnetometer designed to measure total field strength. The magnetometer consists of a computerized instrument console connected to a large sensor head. The sensor head contains a proton-enriched fluid surrounding a coil of wire. When a reading is taken with the sensor, a current is briefly run through the coil, producing an electric field, which aligns the protons in the fluid. When the current is turned off, the protons will return to their original positions, but aligned with any external magnetic field. As the protons move, their spins precess at a rate proportional to the strength of this external field. This precession induces an alternating current in the coil, which is then measured and interpreted as magnetic field strength by the ENVI system. Using this method, the ENVI system has a total operating range of 20,000 to 100,000 nT, with an absolute accuracy of +/- 1 nT using its 2-second sampling time. As cited in the Scintrex Operations Manual, optimum performance with this design of magnetometer is achieved when the axis of the sensor coils is aligned perpendicular to the Earth's magnetic field.

REFERENCES:

ENVI Geophysical System Operations Manual, Scintrex Limited, Revision 1.0, 1997

ENVIMAP Software Manual, Scintrex Limited, Revision 1.0, 1997

Magnetic Applications Guide, Scintrex Limited, Revision 2.0, 1996

Milsom, John, Field Geophysics, Wiley Press 2003

EXPERIMENT 40 X-Ray CT Lab – Medical Physics

This lab involves the investigation of x-ray computed tomography for medical imaging. Contrast in CT imaging is directly related to the attenuation properties of the medium being imaged. In this lab one first explores the relationship between image CT number (related to contrast) and object density. The influence of image acquisition parameters (e.g. tube voltage, tube current, number of image averages) are explored. The second portion of the lab is generally more open and allows for the investigation of the capabilities of x-ray CT imaging.

The student will be required to travel to the Cancer Clinic, located at the Royal Jubilee Hospital, to use the equipment and collect the data. This lab is subject to equipment availability and time constraints of the Cancer Clinic personnel. Please check with your instructor at least 2-3 weeks prior to starting this lab.

EXPERIMENT 43 X-RAY FLUORESCENCE

X-ray Fluorescence refers to the emission of X-rays after atoms of a substance have been excited by some external radiation. For electron transitions to the lowest energy states, the emitted x-rays, called 'characteristic X-rays', depend strongly upon the atomic number, Z. Recall that the energy of a hydrogen-like atom is given, in the simple Bohr model, by

$$E = -\frac{1}{2} mc^2 \frac{Z^2 \alpha^2}{n^2}$$

where (mc^2) is the rest energy of the reduced mass of the electron-nucleus system ,
 α is the fine-structure constant,
and n is the principal quantum number.

For Z ranging from 1 to 92, the corresponding values of E range from -13.6 eV to -115 keV.

X-ray fluorescence may be used for chemical analysis of materials by measuring the energy of the X-rays. The basic requirements are

- i) a high-resolution detector to measure the energy of the characteristic radiation,
 - ii) associated electronics and data-handling apparatus,
- and
- iii) an experimental arrangement which allows the detector to view the sample being irradiated but not the activating source.

For this experiment, the student will be expected to set up the apparatus and to determine the chemical composition of a few samples provided.

REFERENCES :

Muller, R.O. "Spectrochemical Analysis by X-ray Fluorescence", Plenum Press, New York, 1972.

Lederer, C.M. and Shirley, V.S. eds.; "Table of Isotopes, 7th edn.", Wiley-Interscience, New York, 1978.

EXPERIMENT 45 SCHLIEREN IMAGING

When light passes from a region of one index of refraction to another region it is refracted. Thus, the place where a ray of light hits a screen is, in general, deviated from its "straight line" position. A slit or pinhole in front of the screen makes these changes in index of refraction visible as varying intensity.

The index of refraction of a fluid varies with temperature and density. Thus the effect of a disturbance in such a media which causes changes in index of refraction is made visible and can be studied.

In this experiment, the detonation of a charge is used to produce a supersonic shock wave. This shock wave can then be reflected from targets of various shapes to produce a variety of distortion and interference effects. With the Schlieren photography apparatus of this experiment, the student is able to produce multiple exposure photographs of the shock wave showing its progression through a variable time interval. Through the use of electronic timing systems, the exact value of this time interval is available to the student and from this, the velocity of the shock wave can be found.

It is required that an instructor is always present when a charge is detonated!

REFERENCES :

Settles, G.S. "Schlieren and Shadowgraph Techniques", Springer Press, Berlin 2001.

EXPERIMENT 46 NANOFABRICATION FACILITY PRACTICE

Students will spend one or two afternoons learning how to use the Nanofabrication facility. They will then use the facility to construct a nanostructure. The facility is housed in a 'clean' environment, so proper protocol has to be followed every time one enters the facility.

EXPERIMENT 47 MACHINE SHOP PRACTICE (3-D printing, CNC mill)

Students will design, 3-D print and then use the CNC milling machine, under the direction of the machinist, to mill a simple keychain. The design software is called Autodesk 123D Design and it is available on two of the Windows PCs in the lab (or you install on on your computer).



Note:

Students are required to select a time and day for the above two labs. A sign up sheet is located in the P429Alab. Both of the above labs have to be completed by the end of November.

Please confirm with the Nanofab and Machine shop supervisors one week before you start the labs.

OPTIONAL P426 FLUID EXPERIMENTS (Instructor's permission required)

A number of P426 experiments are available for further investigation. Please select from the following list, and discuss it with the P429A instructors before proceeding.

1. Open Channel Flow
2. Stratified Flow
3. Viscous Flow (using syrup or glycerine)
4. Rotating Flow
5. Convection

Details:

1) Open Channel Flow:

- a) Solitary waves. (Some simple experiments can be done easily, and a guide to a project has been prepared.)
- b) Small amplitude surface waves. Possible projects include the characteristics of waves breaking on a slope.
- c) Hydraulics, such as critical flow over a bump. Flow through a constriction can also be investigated, but needs a little construction work first.

2) Stratified Flow:

- a) Two-layer (could be done in the big tank if available or in an intermediate size tank). Possible projects include investigation of:
 - o gravity currents, bottom, surface and interfacial,
 - o interfacial waves,
 - o selective withdrawal.
- b) Linear salt stratification can be achieved using a "two-bucket" filling technique. Possible projects (in a small to medium tank) include investigation of:
 - o a turbulent plume of dense water entering from above but settling at mid-depth because of entrainment,
 - o an ice block melting in a stratified fluid,
 - o internal waves.

3) Viscous Flow (using corn syrup or glycerin):

- a) Viscous coiling; what determines the frequency?
- b) Magma convection; how does a buoyant source of light fluid force its way up through a denser but very viscous fluid?

c) Fingering on an inclined plane; what happens when a viscous fluid is released from behind a barrier on a slope?

4) Rotating Flow (record players are surprisingly effective, but a new rotating table is also available):

- a) Spin-up and spin-down.
- b) Taylor columns.
- c) Rotating convection; how is it different?
- d) The "annulus experiment" (outside wall heated, inside wall cooled).
- e) A melting ice block in either fresh or salty water.

5) Convection:

- a) Double diffusive convection (heater and beaker).
- b) Salt fingering.

6) Miscellaneous:

- a) The salt oscillator (syringe and beaker), and various other systems which are unstable and show oscillatory behaviour.
- b) Vortex rings (syringe and beaker, or larger scale smoke rings in air).
- c) River meanders (best done outside!).
- d) Spinning bucket with holes (ditto).
- e) Suspensions (particles and beaker).

How to use TeX/LaTeX

TeX/LaTeX is a typesetting system that uses 'mark-up' commands to format documents. 'Mark-up' commands are included in plain English in the document and are parsed by the TeX/LaTeX program. TeX/LaTeX commands start with a back-slash (eg. `\begin`, `\title`,...etc). Comments can be inserted in TeX/LaTeX documents, by starting a line with the percent sign (eg. `% this is a comment`).

Most systems use the `TEX` or `LATEX` command to 1) read a TeX/LaTeX documents and 2) produce a binary PDF file that can now be sent to a printer or display.

The following pages contain a number of examples on how to write TeX/LaTeX code and how to include figures and diagrams.

Using TeX/LaTeX:

LaTeX is just a superset of the TeX typesetting system. It is TeX with a number of macros (small programs) that perform common functions and make TeX much easier to use for the novice.

The following example illustrates some of the more common functions of the TeX/LaTeX system. First you see the TeX/LaTeX coded text file, and then the printed typeset document.

```

% This is a sample LaTeX input file. (Version of 9 April 1986)
%
% A '%' character causes TeX to ignore all remaining text on the line,
% and is used for comments like this one.

\documentstyle{article} % Specifies the document style.

% The preamble begins here.

\title{A Sample Document} % Declares the document's title.
\author{Leslie Lamport} % Declares the author's name.
\date{December 12, 1984} % Deleting this command produces today's date.

\begin{document} % End of preamble and beginning of text.

```

```

\maketitle % Produces the title.

```

This is a sample input file. Comparing it with the output it generates can show you how to produce a simple document of your own.

```

\section{Ordinary Text} % Produces section heading. Lower-level
                        % sections are begun with similar
                        % \subsection and \subsubsection commands.

```

The ends of words and sentences are marked by spaces. It doesn't matter how many spaces you type; one is as good as 100. The end of a line counts as a space.

One or more blank lines denote the end of a paragraph.

Since any number of consecutive spaces are treated like a single one, the formatting of the input file makes no difference to `\TeX`, % The `\TeX` command generates the TeX logo. but it makes a difference to you.

When you use `\LaTeX`, % The `\LaTeX` command generates the LaTeX logo. making your input file as easy to read as possible will be a great help as you write your document and when you change it. This sample file shows how you can add comments to your own input file.

Because printing is different from typewriting, there are a number of things that you have to do differently when preparing an input file than if you were just typing the document directly.

Quotation marks like

```
``this''
```

have to be handled specially, as do quotes within quotes:

```
``\,`this'          % \, separates the double and single quote.
is what I just
wrote, not `that\",
```

Dashes come in three sizes: an
intra-word
dash, a medium dash for number ranges like
1--2,
and a punctuation
dash---like
this.

A sentence-ending space should be larger than the space between words within a sentence. You sometimes have to type special commands in conjunction with punctuation characters to get this right, as in the following sentence.

```
Gnats, gnus, etc.\ % \ ' makes an inter-word space.
all begin with G\@. % \@ marks end-of-sentence punctuation.
You should check the spaces after periods when reading your output to
make sure you haven't forgotten any special cases.
```

Generating an ellipsis

```
\ldots\ % \ ' needed because TeX ignores spaces after
% command names like \ldots made from \ + letters.
%
% Note how a `%' character causes TeX to ignore the
% end of the input line, so these blank lines do not
% start a new paragraph.
```

with the right spacing around the periods
requires a special command.

\TeX\ interprets some common characters as commands, so you must type special commands to generate them. These characters include the following:

```
\$ \& \% \# \{ and \}.
```

In printing, text is emphasized by using an

```
{\em italic\} % The \ command produces the tiny extra space that
% should be added between a slanted and a following
% unslanted letter.
```

type style.

```
\begin{em}
```

A long segment of text can also be emphasized in this way. Text within such a segment given additional emphasis

```
with\ {\em Roman}
```

type. Italic type loses its ability to emphasize and become simply distracting when used excessively.

```
\end{em}
```

It is sometimes necessary to prevent \TeX\ from breaking a line where it might otherwise do so. This may be at a space, as between the

``Mr." and ``Jones" in

``Mr.~Jones", % ~ produces an unbreakable interword space.
or within a word---especially when the word is a symbol like
 $\mbox{\em itemnum}$
that makes little sense when hyphenated across
lines.

Footnotes\footnote{This is an example of a footnote.}
pose no problem.

\TeX\ is good at typesetting mathematical formulas like

$$\backslash(x-3y = 7 \backslash)$$

or

$$\backslash(a_{1} > x^{2n} / y^{2n} > x' \backslash).$$

Remember that a letter like

$\$x\$$ % \$... \$ and $\backslash(... \backslash)$ are equivalent
is a formula when it denotes a mathematical symbol, and should
be treated as one.

\section{Displayed Text}

Text is displayed by indenting it from the left margin.

Quotations are commonly displayed. There are short quotations

\begin{quote}

This is a short a quotation. It consists of a
single paragraph of text. There is no paragraph
indentation.

\end{quote}

and longer ones.

\begin{quotation}

This is a longer quotation. It consists of two paragraphs
of text. The beginning of each paragraph is indicated
by an extra indentation.

This is the second paragraph of the quotation. It is just
as dull as the first paragraph.

\end{quotation}

Another frequently-displayed structure is a list.

The following is an example of an $\backslash\em itemized$ list.

\begin{itemize}

\item This is the first item of an itemized list. Each item
in the list is marked with a ``tick". The document
style determines what kind of tick mark is used.

\item This is the second item of the list. It contains another
list nested inside it. The inner list is an $\backslash\em enumerated$
list.

\begin{enumerate}

\item This is the first item of an enumerated list that
is nested within the itemized list.

```

\item This is the second item of the inner list. \LaTeX\
      allows you to nest lists deeper than you really should.
\end{enumerate}
This is the rest of the second item of the outer list. It
is no more interesting than any other part of the item.
\item This is the third item of the list.
\end{itemize}
You can even display poetry.
\begin{verse}
  There is an environment for verse \\\ % The \ command separates lines
  Whose features some poets will curse. % within a stanza.

      % One or more blank lines separate stanzas.

  For instead of making\
  Them do {\em all\} line breaking, \
  It allows them to put too many words on a line when they'd
  rather be forced to be terse.
\end{verse}

Mathematical formulas may also be displayed. A displayed formula is
one-line long; multiline formulas require special formatting
instructions.
\[\ x' + y^{2} = z_{i}^{2}\]
Don't start a paragraph with a displayed equation, nor make
one a paragraph by itself.
\end{document}      % End of document.

```

You can download a more complete and up-to-date Latex2e guide from the P429AWeb site.