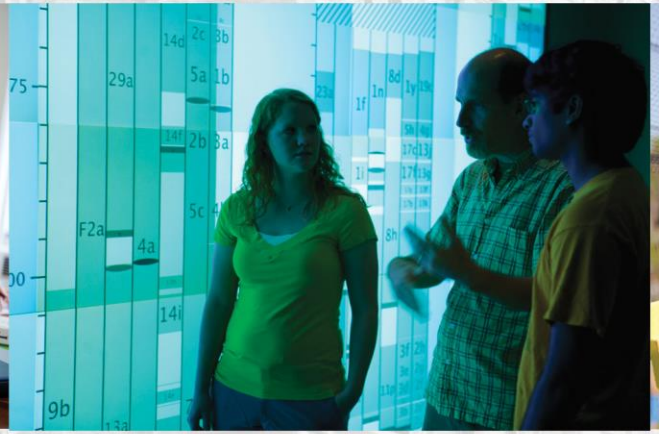
UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Physics 403. Modern Physics Laboratory

Summer 2021

Eugene V Colla, Alexey Bezryadin

COVID-19 hybrid version



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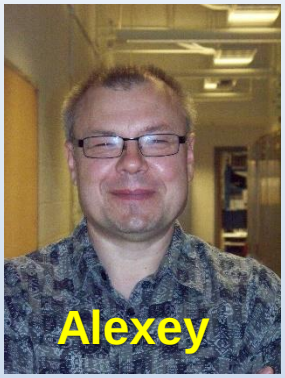
Physics 403 Modern Physics Laboratory

Summer 2021 Teaching Team



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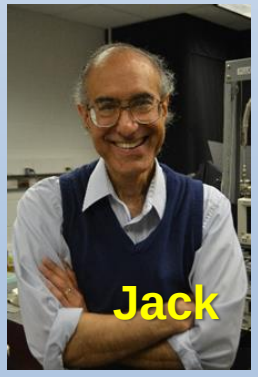

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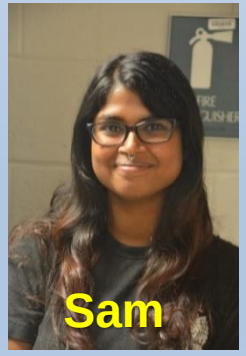

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Physics 403 Modern Physics Laboratory

Summer 2021 Teaching Team

Special thanks to Virginia Lorenz for help in preparation Physics 403 course to online version!

Outline

I. Goals of the course
II. Teamwork / grades / expectations from you
III. Syllabus and schedule
IV. Your working mode
    In class and ~~"after hours" access~~
    Safety, Responsibility
        Home and away computing
V. Take a Lab tour (only video)!
VI. Let's get started
    electronic logbooks
        digital scopes

Course Goals. Primary goals:

- **Learn how to "do" research**

  - ✓ Each project is a mini-research project
  - ✓ How are experiments actually carried out ?

    The procedures aren't all written out

    The questions are not in the back of the chapter

    The answers are not in the back of the book

    You will have to learn to guide your own activities
  - ✓ Use of modern tools and modern analysis and data-recording techniques

Course Goals. Primary goals:

- Learn how to document your work
  - Online - electronic logbook *
  - Online – saving data and projects in student area on server
  - Using traditional paper logbooks
  - Making an analysis report
  - Writing formal reports
  - Presenting your findings orally (online)

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* In red gradable assignments

Course Goals. Secondary goals:

- **Learn some modern physics**
  - Many experiments were once awarded by Nobel-prize
  - They touch on important topics in the development of modern physics
  - Some will provide additional insight to understand advanced courses you have taken

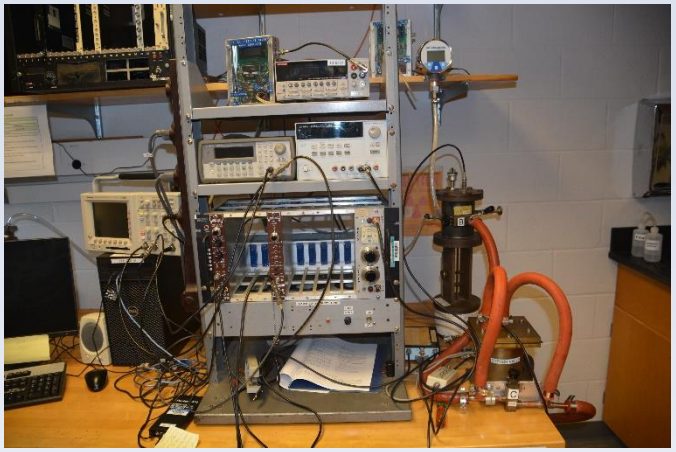
The Experiments. Three main groups

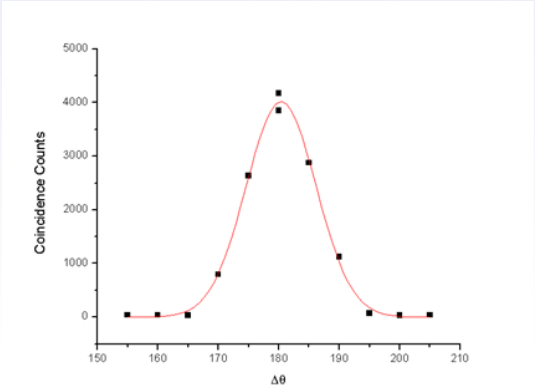
- **Nuclear / Particle (NP)**
- **Atomic / Molecular / Optics (AMO)**
- **Condensed Matter (CM)**

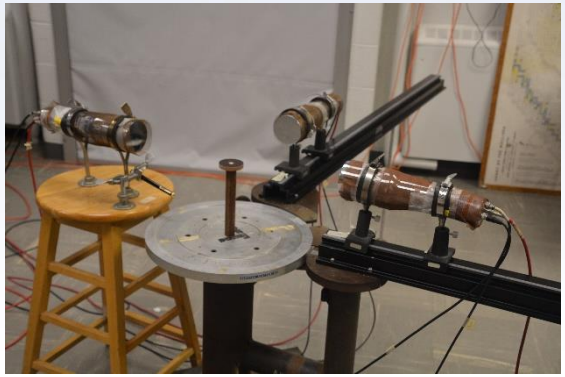
You will do the experiment from all these groups

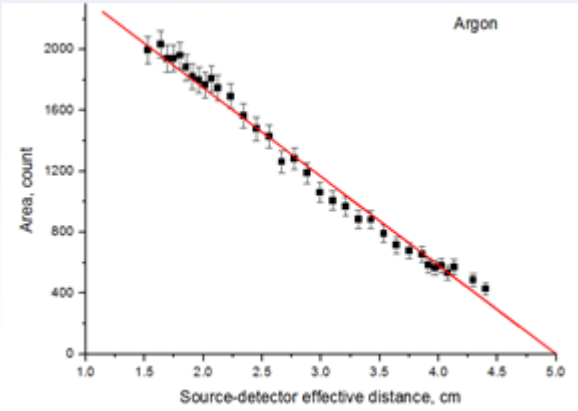
The Experiments

- **Nuclear / Particle (NP)**
  - Alpha particle range in gasses
  - γ–γ correlation experiment
  - γ – spectroscopy
  - Mössbauer spectroscopy





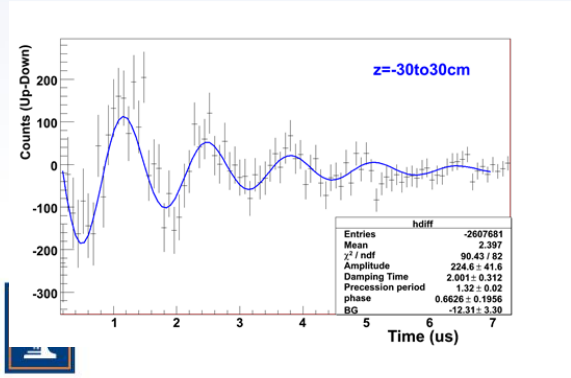


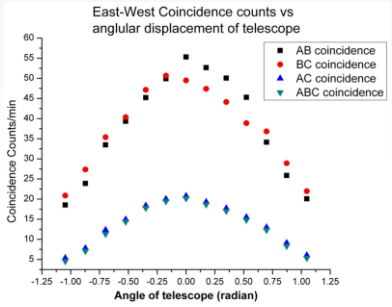


The Experiments

- **Nuclear / Particle (NP)**
  - **Cosmic ray muons:**

    Lifetime, capture rate, magnetic moment
  - **Angular distribution of cosmic rays**
  - **γ – spectroscopy**
  - **Mössbauer spectroscopy (new)**

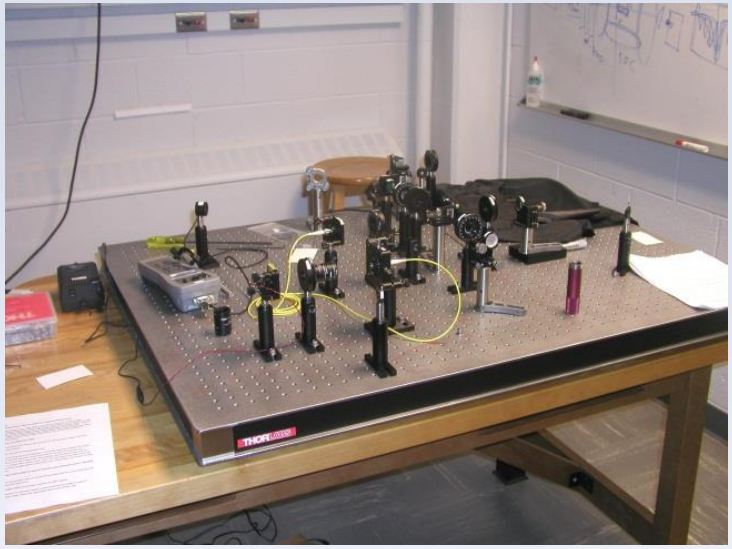


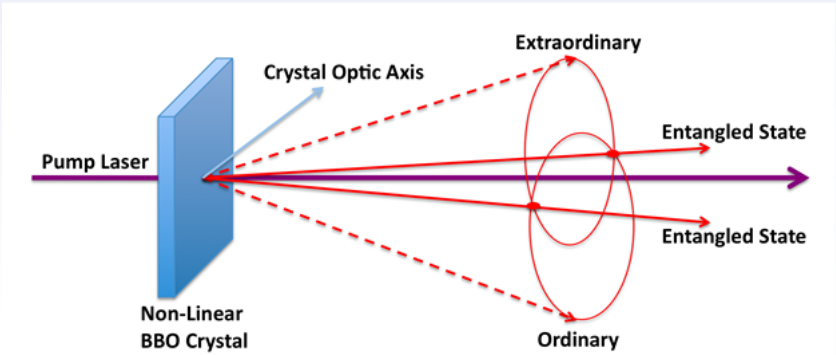


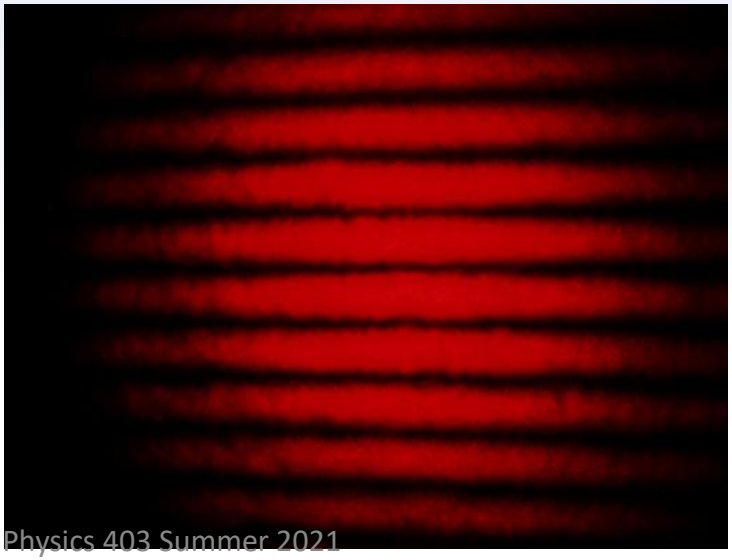
The Experiments

Atomic/Molecular/Optics (AMO)

- Berry's phase
- Quantum erasure
- Quantum Entanglement



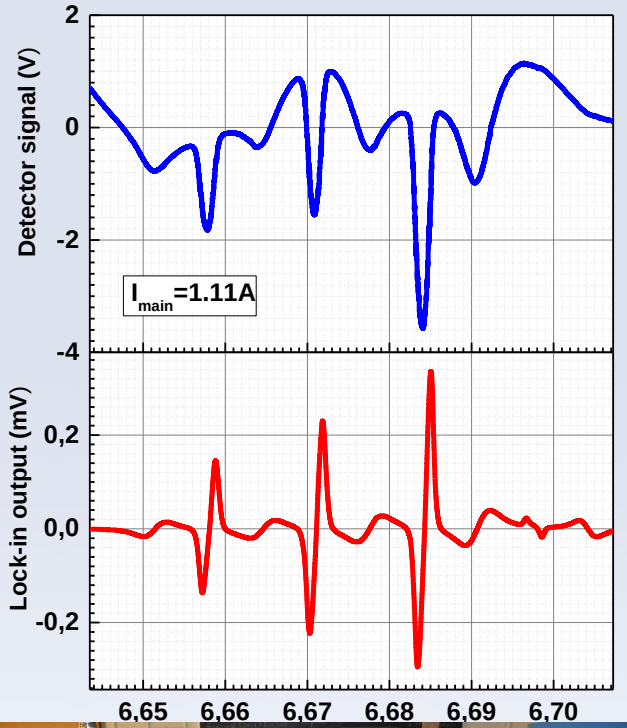


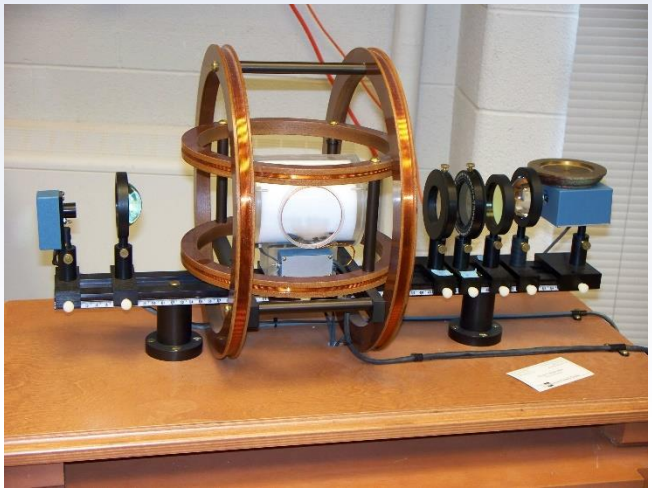


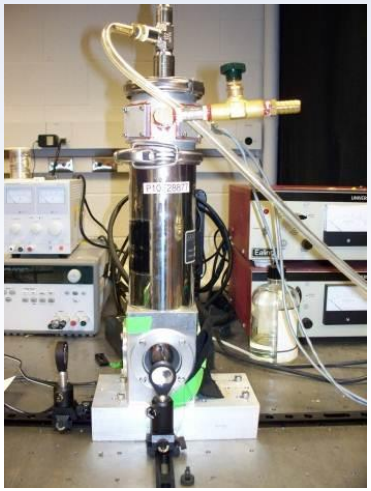
The Experiments

Atomic/Molecular/Optics (AMO)

- Optical pumping of rubidium gas
- Fluorescence spectroscopy

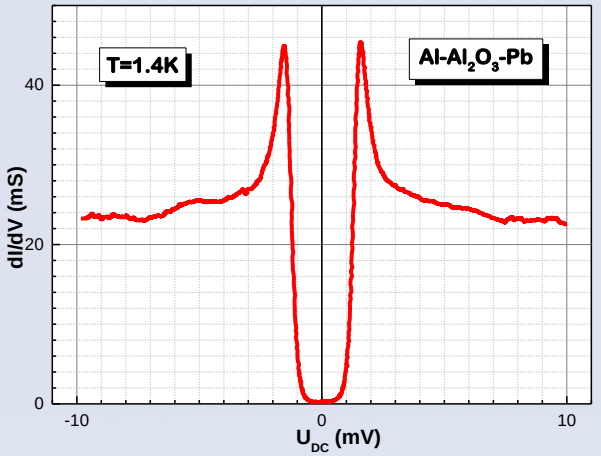


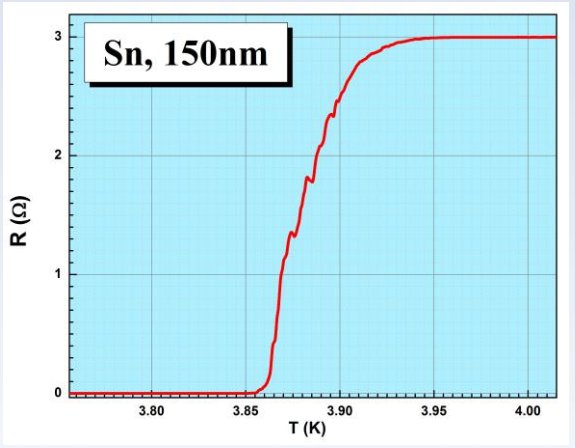


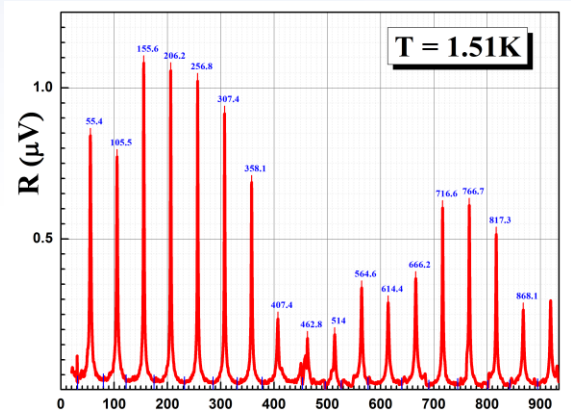


The Experiments

- **Condensed Matter (CM)**
  - **Superconductivity**
  - **Tunneling in superconductors**
  - **2nd sound in ^{4}He superfluid state**

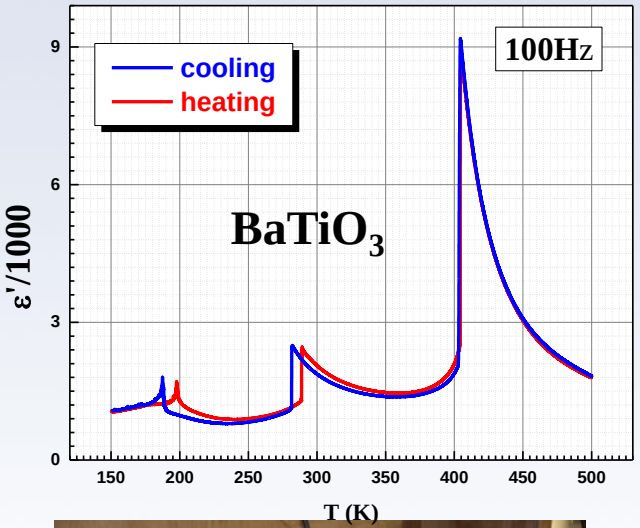


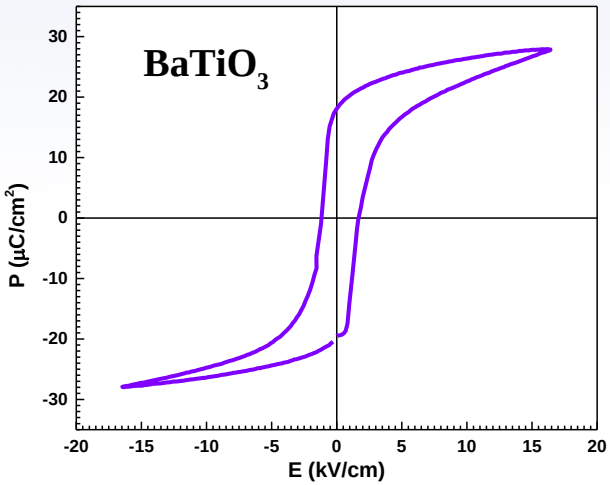


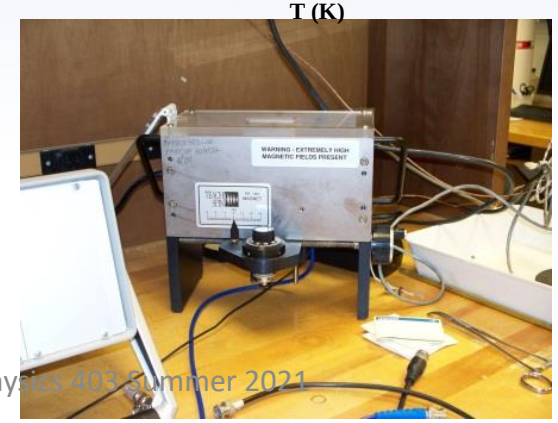


The Experiments

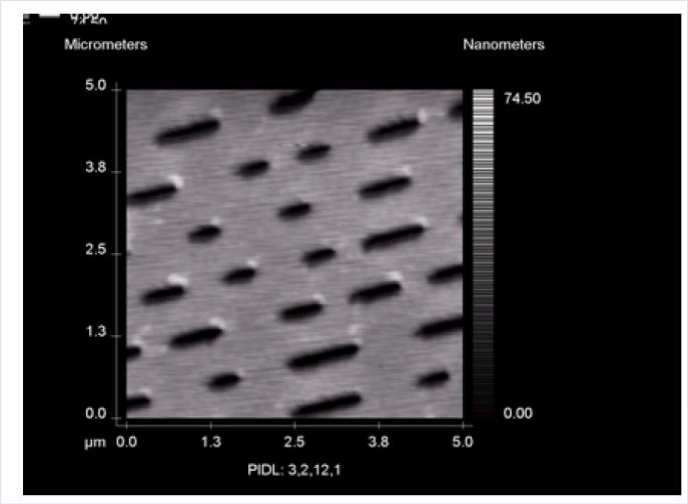
- **Condensed Matter (CM)**
  - Ferroelectrics and ferroelectric phase transition
  - Pulsed NMR
  - Calibration of temperature sensors



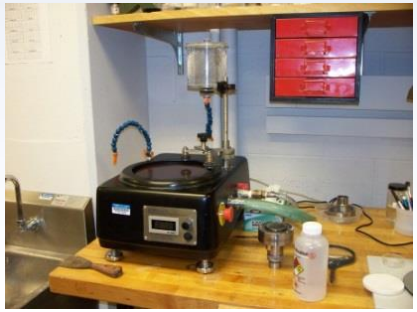




The Experiments

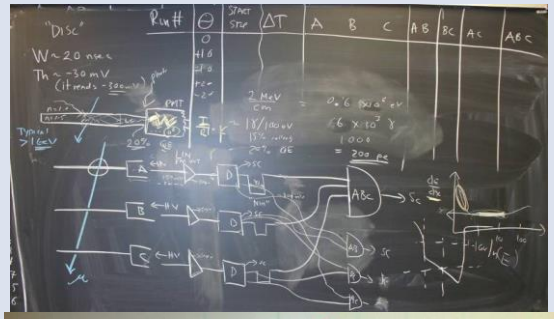


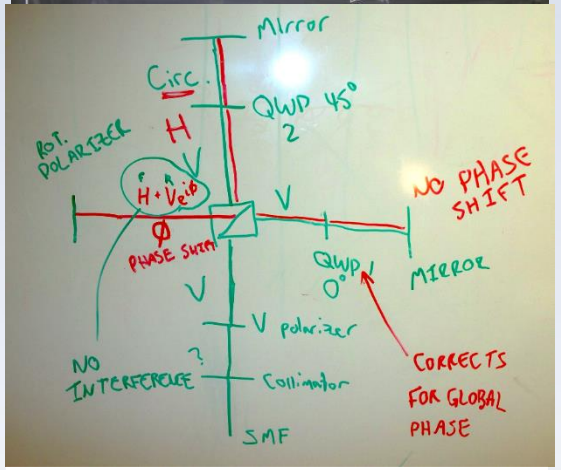
- **Condensed Matter (CM)**
  - **Special Tools:**
  - **Vacuum film deposition**
  - **Atomic Force Microscope**
  - **Polarizing microscope**



The "manuals"

- Many are just guides
- A only few purchased experiments have "real" manuals
- We serve as your guides … like real research … yes, we will do it in "online" mode too. We have prepared the materials explaining how to do the experiments and data analysis and you can find all these materials and examples of data analysis in folder in common drive.





TEACH SPIN
Instruments Designed for Teaching

OPTICAL PUMPING OF RUBIDIUM OP1-A

The "manuals"

- For most of the P403 experiments we have prepared the folders containing the most important materials related to the experiment. These folders are located on the shelves in ESB5105. You can borrow the folders until working on experiment and on the report.

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Safety, Responsibility

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VI. Let's get started

electronic logbooks

digital scopes

Grading: Distribution of "740" points

ASSIGNMENT	Points
Expt. documentation: elog reports, shift summaries, plot quality; paper logbooks	**120 Total** **60 / cycle**
Formal reports: physics case, quality of results, depth of analysis, conclusions	**400 Total** **100 / report**
1st Oral report: motivation, organization of presentation; fielding questions	**100**
Final Oral Presentation ≡ Final Exam	**120**
Total **Effective point total will be**	**740**

The grading scale will be a percentage out of "740" :

Letter grading scale is approximately 97% = A+, 93% = A, 90% = A-, 87% = B+, 83% = B, 80% = B-, etc

Resubmission

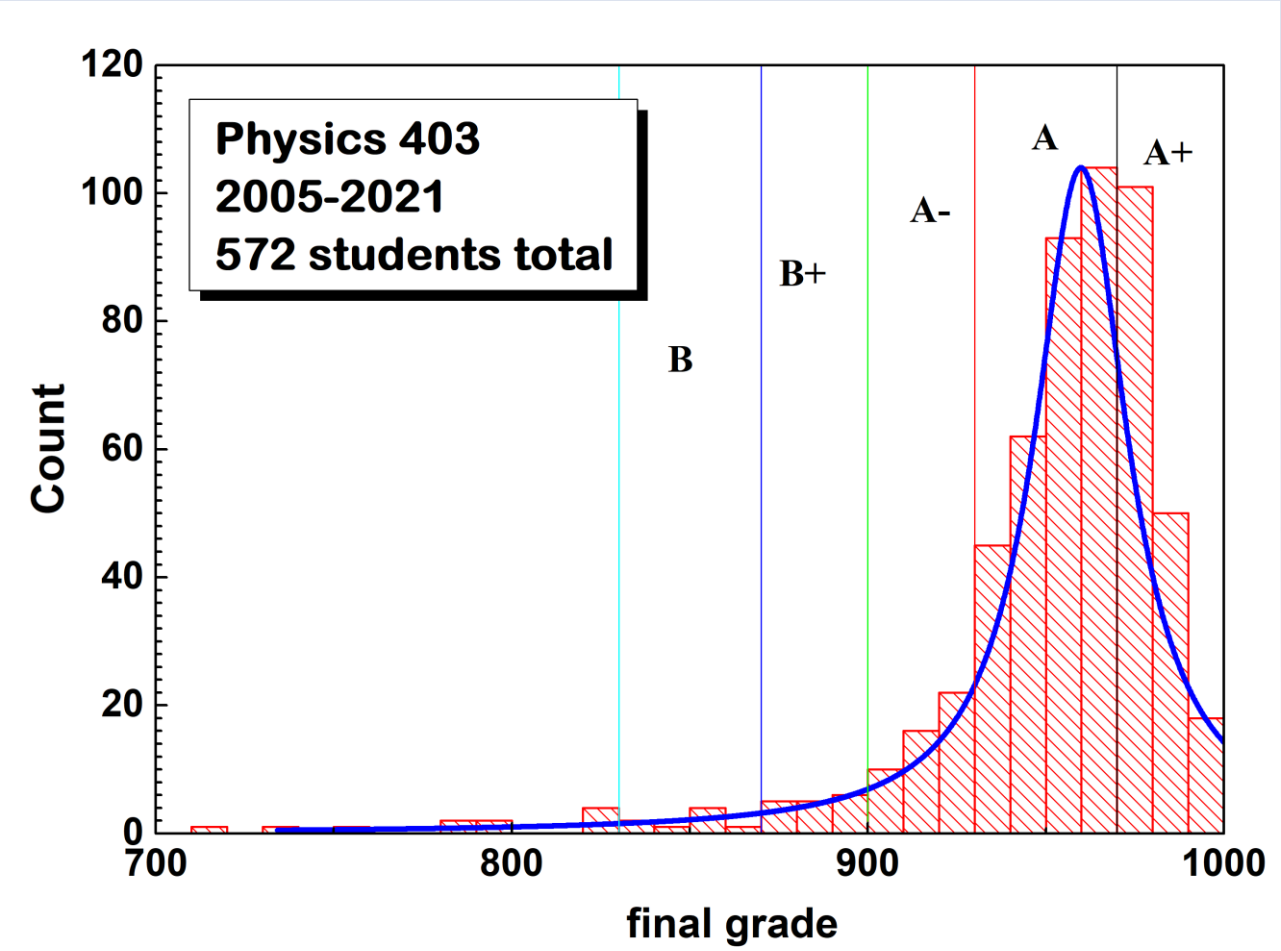
You can RESUBMIT one lab report to improve your grade

(deadline for resubmissions and for report #4 August 6th 2021)

The general rules for resubmission:

1. **Original report should be submitted in time with no using of the late ticket**
2. **The original report should be a real report but not only the title page**
3. **We do not recommend to resubmit the report if the original grade was over 90 points**

Grading: a piece of history and analysis of the results



Submission of Lab-Reports

- Due dates as on syllabus at midnight
- The reports should be uploaded to the server:
- https://my.physics.illinois.edu/courses/upload/
- Accepted MS-Word or PDF*
- For orals – MS-PowerPoint* or PDF

** preferable*

Absences

- If you are sick, let Eugene know by email (kolla@lllinois.edu). Don't come in and get others sick. We are working side-by-side in a close environment for many hours.

- You can "make up" the time with arrangements and you can have access to the rooms. We will be accommodating.

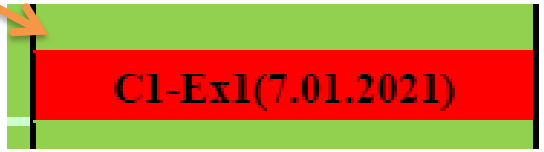
Absences. Excuse Policy.

- • You can be excused from only one missed assignment, and only if you provide medical or any other acceptable documentation[1].
- • If you have missed the oral presentation (oral #1) by acceptable reason, you need to discuss this with us and we will arrange the date for your oral talk.
- The Final Oral cannot be excused, as it is equivalent to a final exam. You cannot pass the course without credit for this assignment [2]

1. **Student Code:** https://studentcode.illinois.edu/article1/part5/1-501/
2. **Ibid:** https://studentcode.illinois.edu/article3/part2/3-201/

Late Reports

- **Policy for late reports**
  - You can have ONE "late ticket" for a "free" delay of up to 3 business days, but you must tell us you are using the ticket
  - Reports are due at midnight on the date shown on the syllabus. After that we will charge:
    - 5 points for up to 1 week late. 10 points for up to 2 weeks late.
    - After that, it's too late.



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Syllabus

Cycles

	Date	Day	Activity		Lectures: 10am Journal club: 3pm	Note	Due days
			8am-noon	1pm-5pm			
1	6/15	Tuesday	Orientation		About Phy403		
2	6/16	Wednesday	Cycle 1-1	Cycle 1-1	OriginPro, ROOT Intro		
3	6/22	Tuesday	Cycle 1-1	Cycle 1-1	Ferroelectricity		
4	6/23	Wednesday	Cycle 1-1	Cycle 1-1	Written Reports		
5	6/29	Tuesday	Cycle 1-2	Cycle 1-2	Error analysis		
6	6/30	Wednesday	Cycle 1-2	Cycle 1-2	Lock-in Amps and FT		C1-Ex1(7.01.2021)
7	7/06	Tuesday	Cycle 1-2	Cycle 1-2	Oral Reports/Talks		
8	7/07	Wednesday	Cycle 2-1	Cycle 2-1	Superconductivity	Rotate	
9	7/13	Tuesday	ORALS Cycle 1				
10	7/14	Wednesday	Cycle 2-1	Cycle 2-1	TBA		C1-Ex2(7.15.2021)
11	7/20	Tuesday	Cycle 2-1	Cycle 2-1	Nuclear Physics		
12	7/21	Wednesday	Cycle 2-2	Cycle 2-2	Measuring Temperature		
13	7/27	Tuesday	Cycle 2-2	Cycle 2-2	Entanglement		C2-Ex1(7.29.2021)
14	7/28	Wednesday	Cycle 2-2	Cycle 2-2	TBA		
15	8/03	Tuesday	FINAL ORALS				
16	8/05	Thursday			READING DAY		C2-Ex2(8.06.2021)

* Lecture topics are subject to change

	NP A. Cosmic Muon Stand i. Muon lifetime ii. Capture rate iii. Magnetic moment B. Alpha range C. Gamma Gamma D. Cosmic angular distribution E. Mössbauer spectroscopy	CM A. Ferro 1 B. Ferro 2 (imaging) C. 2nd sound of ^{4}He D. pNMR E. Hysteresis loops F. Tunneling G. AFM H. T calibration	Atomic + CM A.Optical pumping B.Superconductivity C.Mutual inductance	Optics A. Quantum Table i. Berry's phase ii. Quantum erasure iii. Entanglement B. Florescence spectroscopy
	Alexey, Abid, Vishal	Eugene, Jack	Eugene, Sai, Andrew	Abid, Sai and TA's from Kwiat Lab
C1-1	4 – 9; 10 - 13	1 – 6; 5- 14;	7 – 8;	11– 12; 2 -3
C1-2	1 – 8; 3 – 5	9-12; 13 – 14	2 – 6	4 – 10; 7 - 11
C2-1	10 - 14	2 – 3, 1 - 11	4 – 7; 9– 12	5 – 6; 8 - 13
C2-2	2 – 14; 4 – 6	5 – 8, 4 – 6, 7 - 11	1 - 9;	12 - 13

Summer 2021 Physics

Cycle	#	Experiment
C1-1	4,9	Mössbauer spectroscopy
	10,13	Gamma-gamma
	5, 14	Ferro 1
	1,6	Second Sound
	7,8	Superconductivity
	11, 12	Fluorescence
	2,3	Quantum Optics
C1-2	3,5	Cosmic ray muons
	1,8	Gamma-gamma
	13,14	Tunneling
	9,12	Ferro 2
	2,6	Optical Pumping
	4,10	Fluorescence
	7,11	Quantum Optics

Cycle	#	Experiment
C2-1	10,14	Alpha range
	2,3	Tunneling
	1,11	NMR
	9,12	Superconductivity
	4,7	Optical pumping
	8,13	Fluorescence
	5,6	Quantum Optics
C2-2	2,14	Gamma-gamma
	4,6	Ferro 1
	5,8	Second Sound
	7, 11	AFM
	3,10	Superconductivity
	1,9	Optical Pumping
	12,13	Quantum Optics

Assignment of experiments

2 cycles with 2 experiments

➔ teams change after cycle or

by starting new experiment

➔ joint team reports and elogs but oral

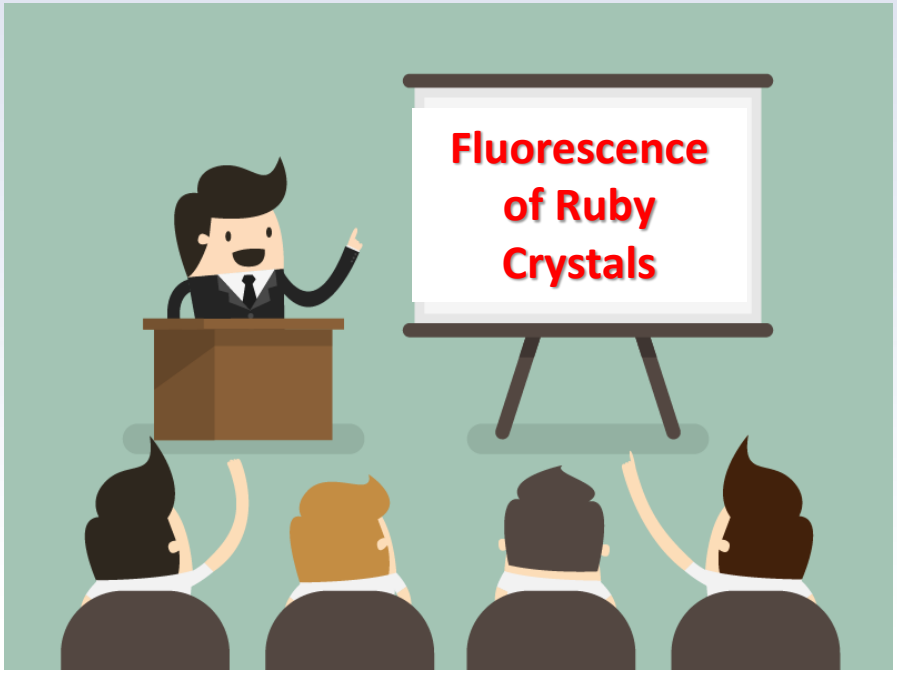
presentations will be

done by each student

personally

Spring 2019 Orals Physics 403

After 2 experiments (1 cycle) we will have oral session. The topic of the presentation will be chosen from the experiments done in this cycle.



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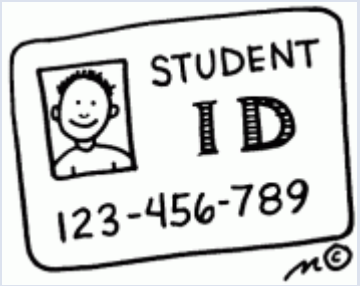
Lab Access



Use Your ID Card to Access the Lab

You can access the Lab not only on "Lab days"

Late time rules:

You can stay in the Lab until 8pm but need to

Sorry, not for hybrid option

After 8pm and on weekend days – *you have to discuss this schedule with your instructor* and in general it is preferable to avoid working after 8 pm and on week

Safety is your responsibility !

Hazards: ***high voltage, radioactive sources,***

cryogens, chemical materials, high pressure

In class work and "after hours" access & work requires responsible conduct with regards to

(I) safety/hazards and with

(II) equipment

Discuss potential hazards at the beginning of each experiment with an instructor or TA

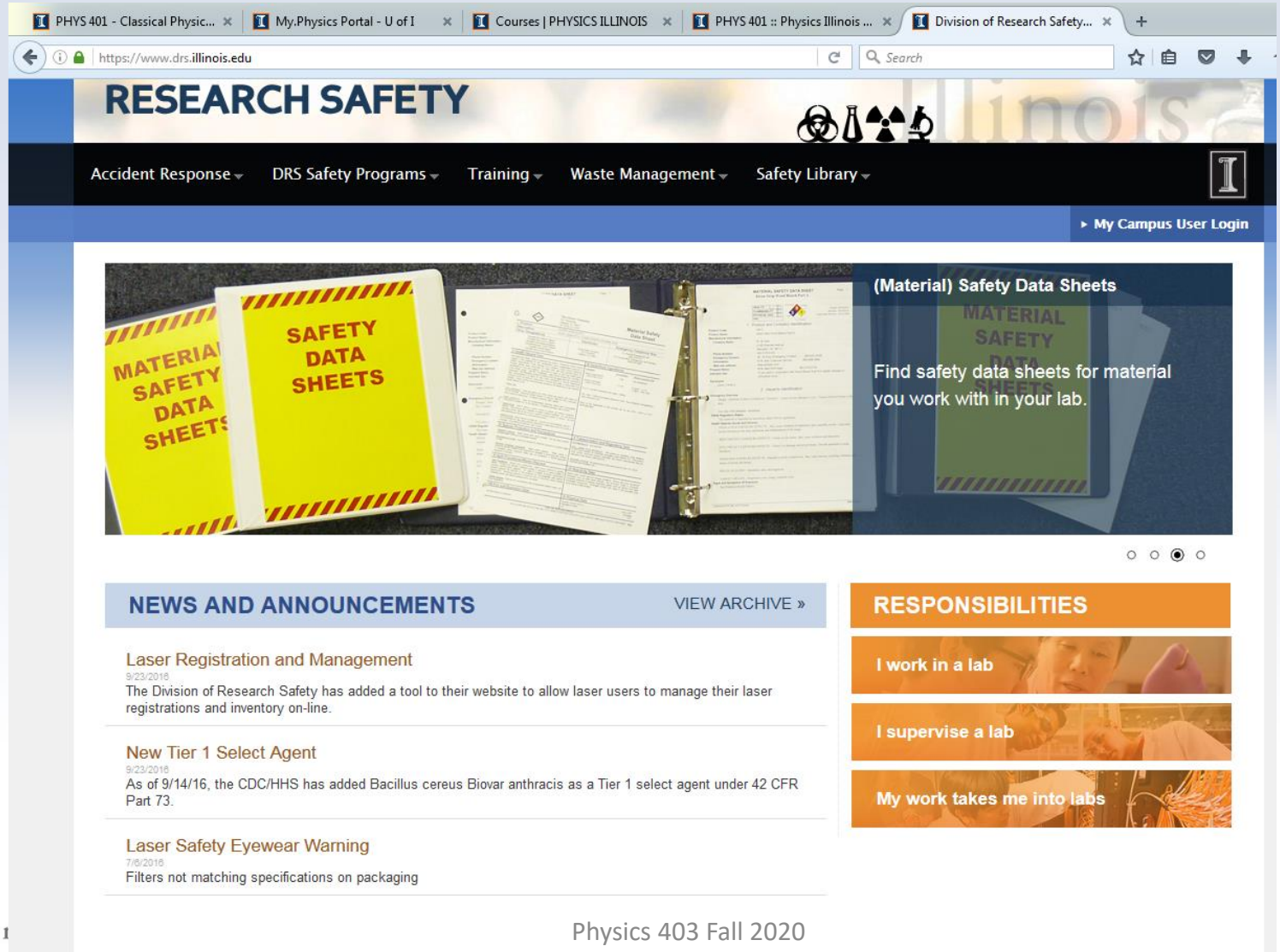
When in doubt stop and ask

Problems after hours: 217 493 1576 (Eugene's cell)

(Alexey's cell)

Follow Directly the Recommendations of Safety Working

https://www.drs.illinois.edu/



Follow Directly the Recommendations of Safety Working

Related Units @ Illinois Questions?

Division of
RESEARCH SAFETY

Accident Response | DRS Safety Programs | Training | Waste Management | Safety Library

Chemical Waste Collection and Storage

Before generating chemical waste, the researcher should determine how it will be collected and stored and obtain the necessary equipment (containers, labels) in advance. The choice of procedures depends on the type of waste and its final disposition. This section explains how to determine the final disposition of waste, select the appropriate waste container, and store waste in the lab or work area. It also suggests waste minimization strategies.

Determining How to Dispose of a Chemical Waste

The final disposition of a chemical waste is determined by the answers to a series of questions:

Step 1. Is the waste Contaminated Debris (glassware, paper towels, clean-up materials), or is it a chemical or chemical mixture?
If it is contaminated debris: Go to Step 5.
If it is a chemical or chemical mixture: Go to Step 2.

Step 2. Is the chemical a DEA (Drug Enforcement Agency) controlled substance? (Refer to the DEA list controlled substances)
Yes: Refer to the DEA Controlled Substances Guide for disposal procedures.
No: Go to Step 3.

Step 3. Is the chemical a solid (not liquid or gas)?
Yes: Collect and store the waste as described in the waste container and storage guidelines listed below and dispose of it through the Division of Research Safety (DRS) chemical waste disposal program. See the section Procedures for Requesting Chemical Waste Disposal for the disposal procedures. (No solid chemical waste, hazardous or non-hazardous, should be placed in the regular trash.)
No: Go to Step 4.

Step 4. Is the chemical a liquid non-hazardous waste as listed in the section Liquid Non-Hazardous Chemical Waste Disposal?
Yes: The chemical may be poured down the sanitary sewer (sink drain) with copious amounts of water.
No: Collect and store the waste as described in the waste container and storage guidelines listed below, and dispose of it through the DRS chemical waste disposal program. See the section Procedures for Requesting Chemical Waste Disposal for the disposal procedures.

Step 5. Is the contaminated debris laboratory glassware (broken and unbroken)?
Yes: See the Laboratory Glassware Waste Disposal section.
No: Go to Step 6.

Step 6. Is the debris contaminated with a substance listed in the section Liquid Non-Hazardous Chemical Waste Disposal?
Yes: The contaminated debris can be disposed of in the regular trash.
No: Collect and store the contaminated debris as described in the waste container and storage guidelines listed below: dispose

Waste container for ethanol, acetone, methanol, isopropanol.

Waste container for mineral spirits.

Waste containers for chemicals used in NMR experiment

Follow Directly the Recommendations of Safety Working

Related Units @ Illinois Questions? Search Go

Division of
RESEARCH SAFETY

Accident Response DRS Safety Programs Training Waste Management Safety Library

Profile Eugene V Colla Log off

Laboratory Sharps

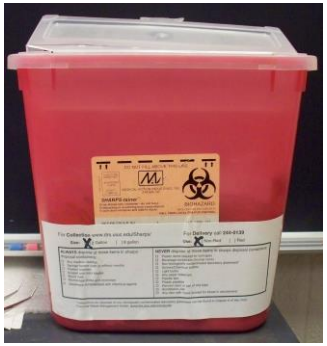
Definition

Materials that qualify as "sharps" are defined at the state level and shall be disposed of as Potentially Infectious Medical Waste (PIMW). In Illinois, the Illinois Environmental Protection Agency (IEPA) has designated the following material (used or unused) as sharps:

- **Any medical needles,**
- **Syringe barrels (with or without needle),**
- **Pasteur pipettes (glass),**
- **Scalpel and razor blades,**
- **Blood vials,**
- **Microscope slides and coverslips,**
- **Glassware contaminated with infectious agents.**

NEVER dispose of these items in SDCs:

- **Plastic items (except for syringes),**
- **Beverage containers (no pop cans!),**
- **Non-biologically contaminated laboratory glassware,**
- **Solvent/chemical bottles,**
- **Light bulbs,**
- **Any paper materials,**
- **Pipette tips,**
- **Plastic pipettes,**
- **Aerosol cans or cans of any type,**
- **Scintillation vials,**
- **Any item with liquid (except for blood in vacutainer tubes).**



Waste container for sharps

Follow Directly the Recommendations of Safety Working

https://www.drs.illinois.edu/

Safety working in online mode is completely your responsibility. Working from home you are only faced to your electronic gadgets, no radiation from isotopes used in Lab, no cryogenics, no chemistry components, no high voltage.

Outline

V. Take a Lab tour ! It will be virtual tour.

VI. Let's get started

electronic logbooks

digital scopes

Outline

I. Goals of the course
II. Teamwork / grades / expectations from you
III. Syllabus and schedule
IV. Your working mode
    In class and "after hours" access
    Safety, Responsibility
        Home and away computing
V. Take a Lab tour !
VI. Let's get started
    electronic logbooks
        digital scopes

How to record the data

- Work together
- Write down the equipment used
- Make a diagram of the setup
- Note the settings of dials, switches, gauges
- Take a digital photo if appropriate (we have prepared and will prepare more pictures of the setups equipment etc.)
- Use a software drawing program to make a detailed sketch (PowerPoint works this very well)

How to record the data

- Use the eLog (see next).
- Write down what you did in real sentences.
- Provide enough detail that you can reconstruct later what you did!
- How will you look at the data later?
- Do you have enough information?
- Did the equipment perform as expected?

How to record the data

- Many experiments require you to "change and measure" something by hand
  - Make a table in a paper logbook or put the data directly into electronic worksheet (*preferable*).
  - Make a "quick sketch" of your by plotting the data using OriginPro or other software

Looking on the graph you can answer the questions:

- Do you have enough points?
- Do you have any obvious anomalies?
- You can repeat points but do not throw them out. Use other measurements to check reliability

How to record the data

- Many experiments have built-in, computer-based data acquisition (DAQ)
  - You will not have time to fully understand the DAQ, but
    - Be sure you know functionally what it is doing – ask
    - A good idea is to make test measurements of something you know
  - As before, anomalies? enough points? uncertainties?

Where to exchange, store and retrieve course information.

P403 Lab server

\\engr-file-03\PHYINST\APL Courses\PHYCS403

Connecting to the PHYS403 server

Connect to VPN following the instructions on the UIUC VPN website:
https://techservices.illinois.edu/services/virtual-private-networking-vpn/download-and-set-up-the-vpn-client

To connect to the PHYS403 Server:

- **Connect to the VPN first, then enter the following as the share to connect to:**
  - ***Mac users:*** Open Finder: Go: Connect to Server, type in address: smb://engr-file-03.engr.illinois.edu/PHYINST/APL Courses/PHYCS403
  - ***Windows users:*** Open Windows Explorer, type in address: \\engr-file-03.engr.illinois.edu\PHYINST\APL Courses\PHYCS403

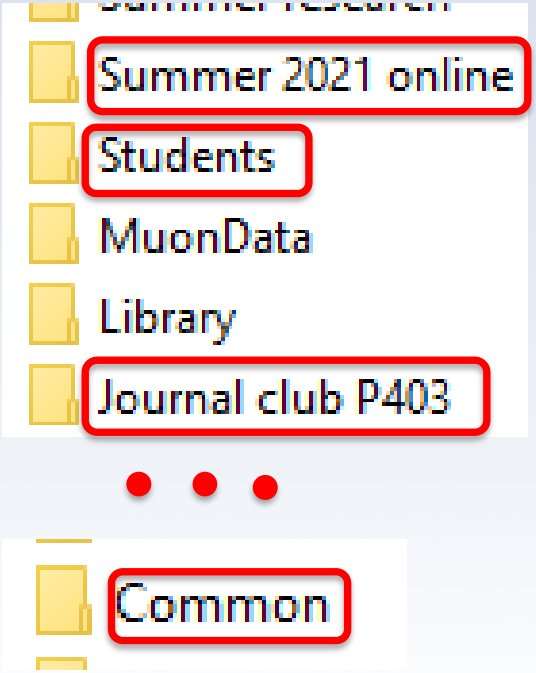
- ***When prompted for username and password, enter:***
  "Uofl\[your netID]" and "[your netID password]"

Where to exchange, store and retrieve course information.

(i) Your data, projects, tables etc

\\engr-file-03\PHYINST\APL Courses\PHYCS403

There is a lot useful and not very useful stuff in many folders you can find there



"Useful" folders are shown in red frames

Where to exchange, store and retrieve course information.

(i) Your data, projects, tables etc

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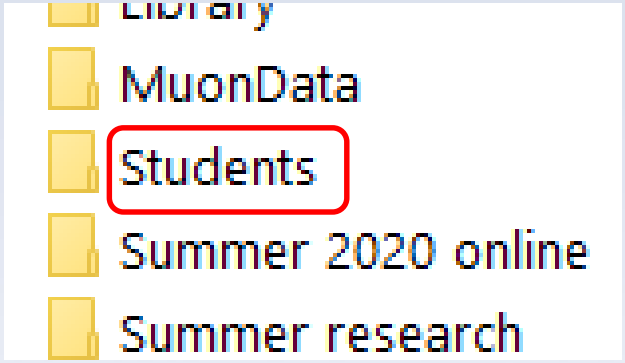
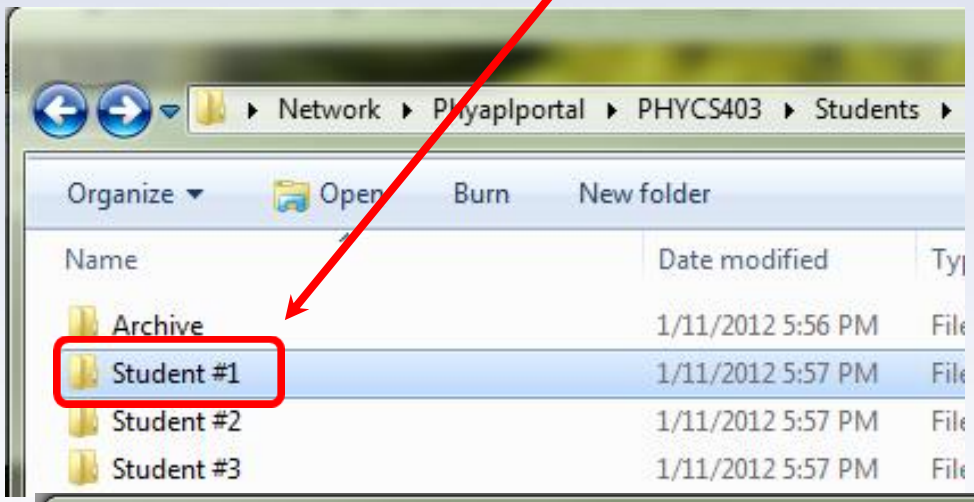
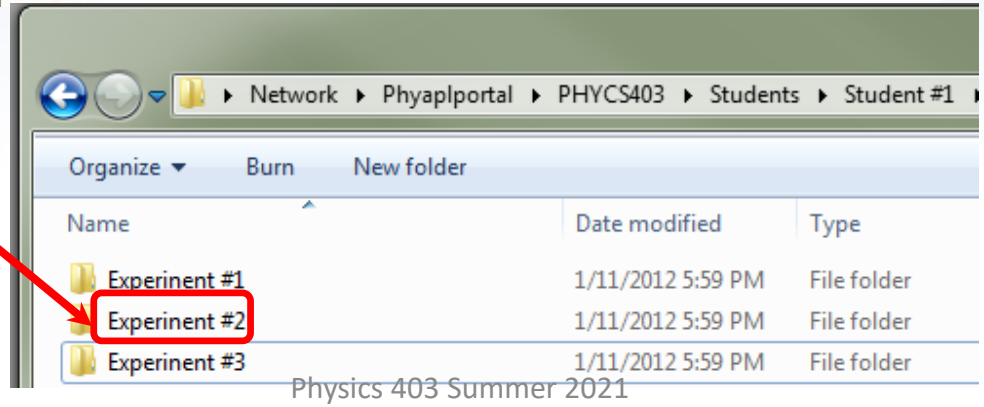


Each student has a folder



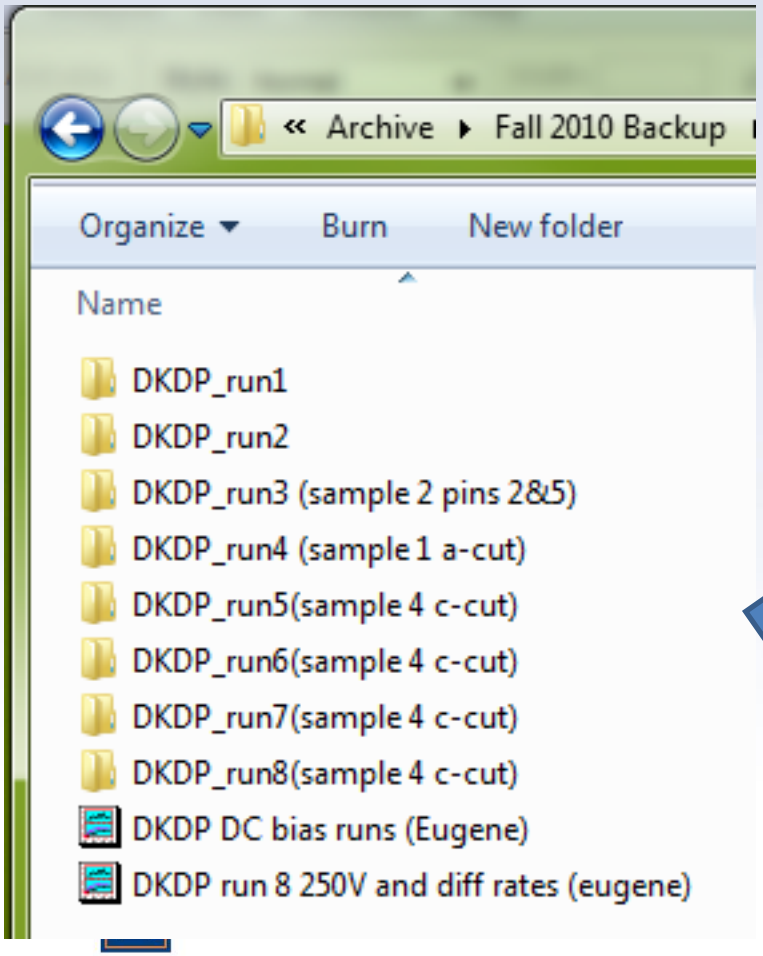
Store all experiment related materials in corresponding folder

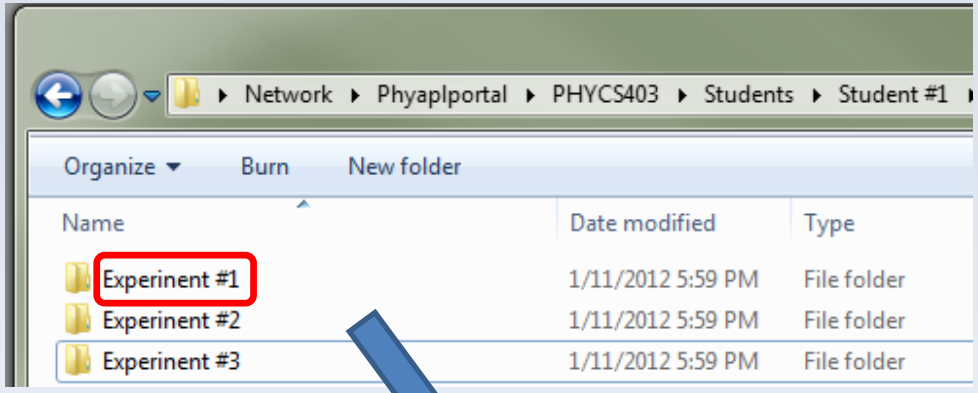


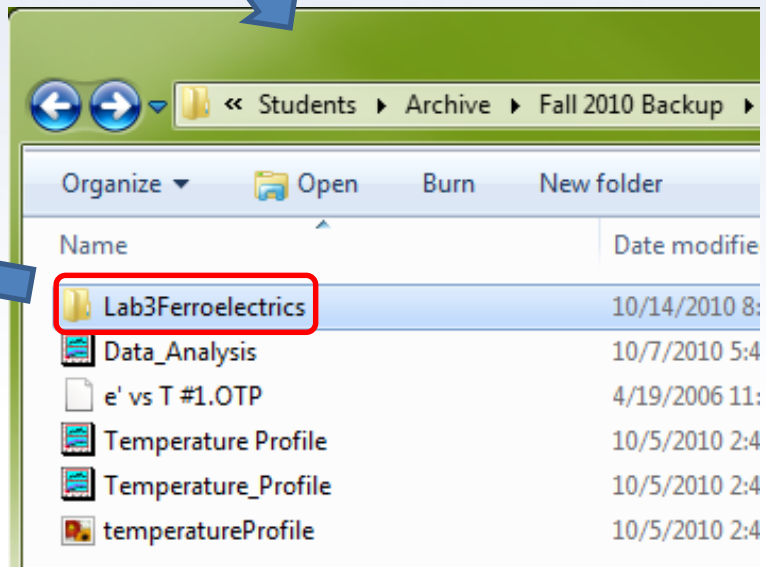
illinois.edu

Where to exchange, store and retrieve course information. *(i)*
Your data, projects, tables etc

An example of the "smart" structure of folders containing the raw data and data analysis projects

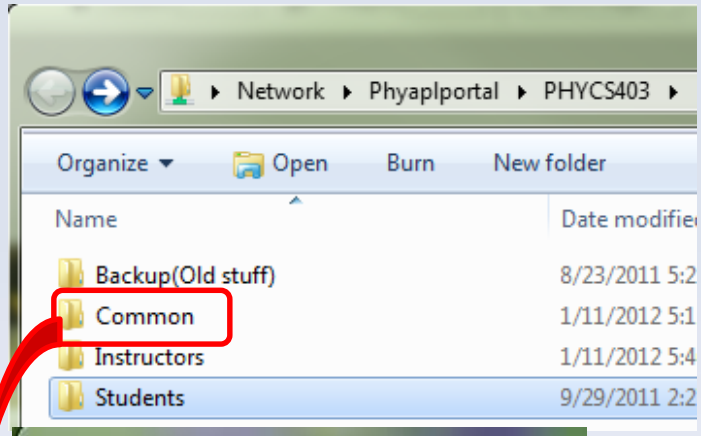


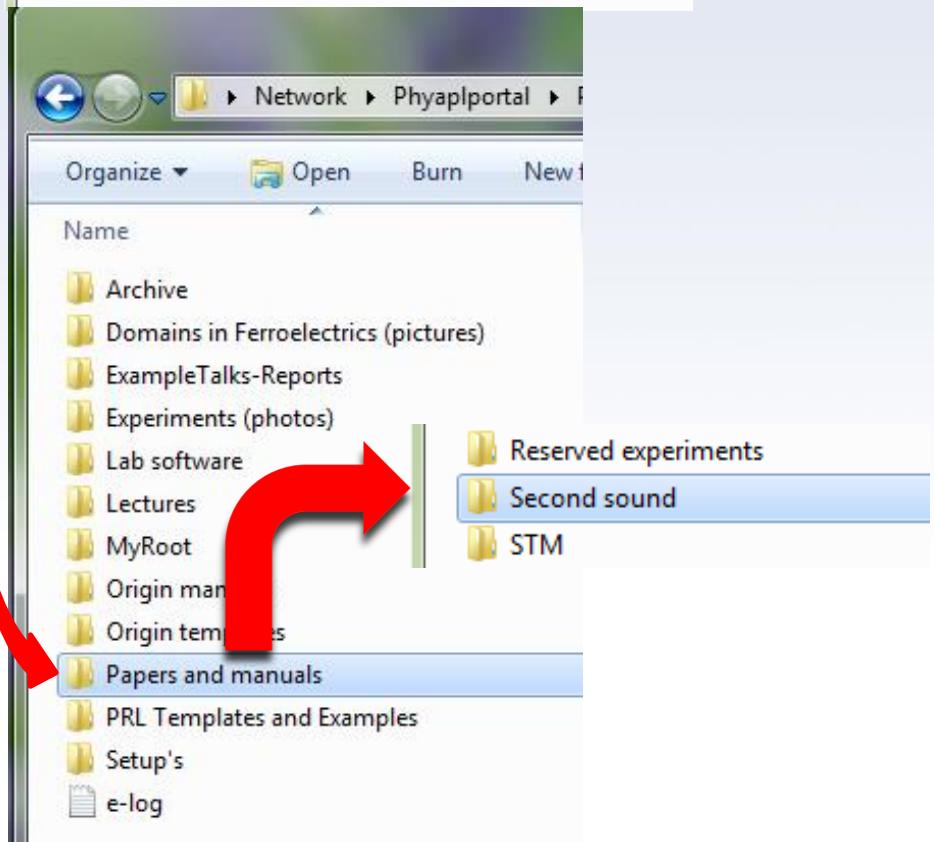


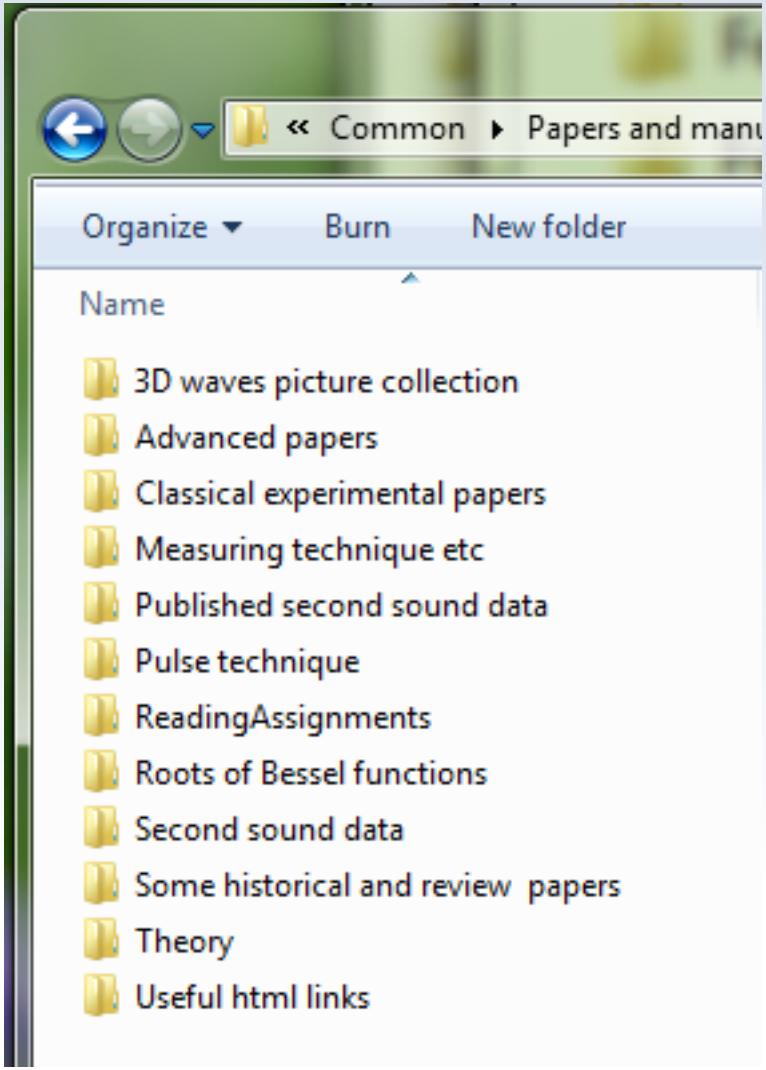


Where to retrieve course information.

Manuals, papers, setup diagrams and other useful materials

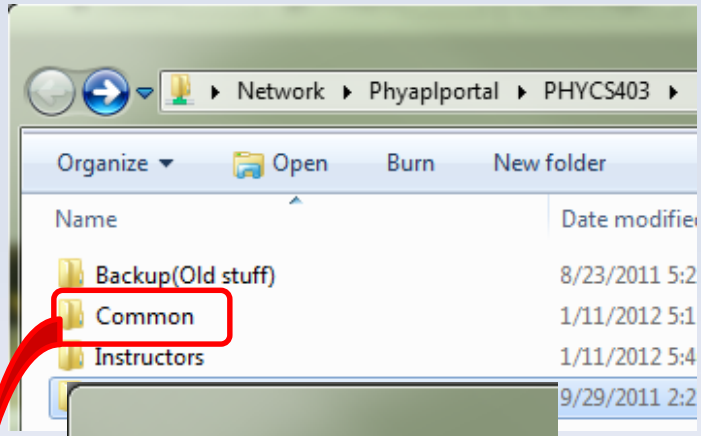


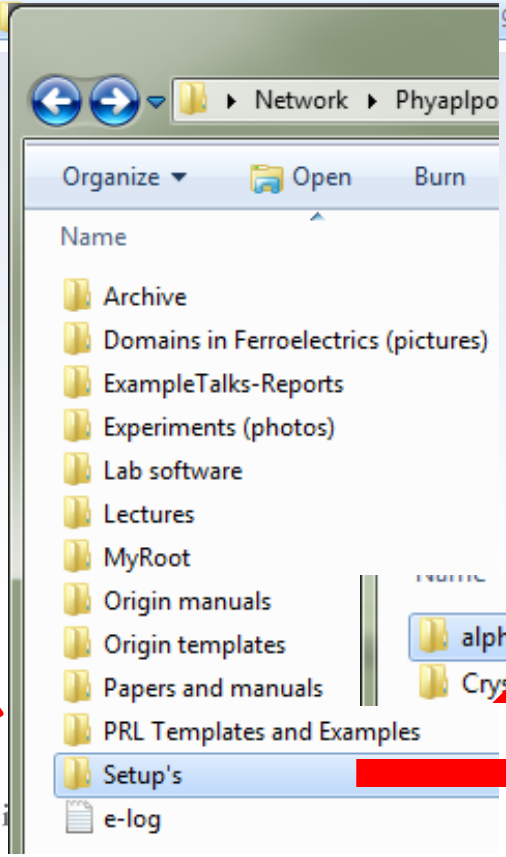


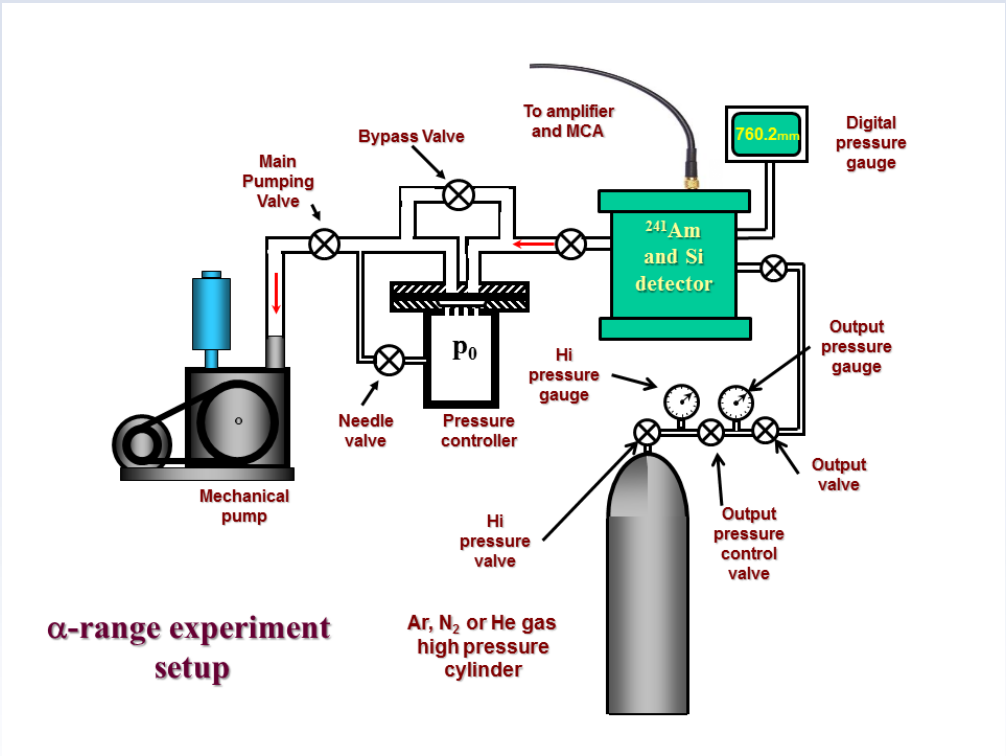


Where to retrieve course information.

Manuals, papers, *setup diagrams* and other useful materials



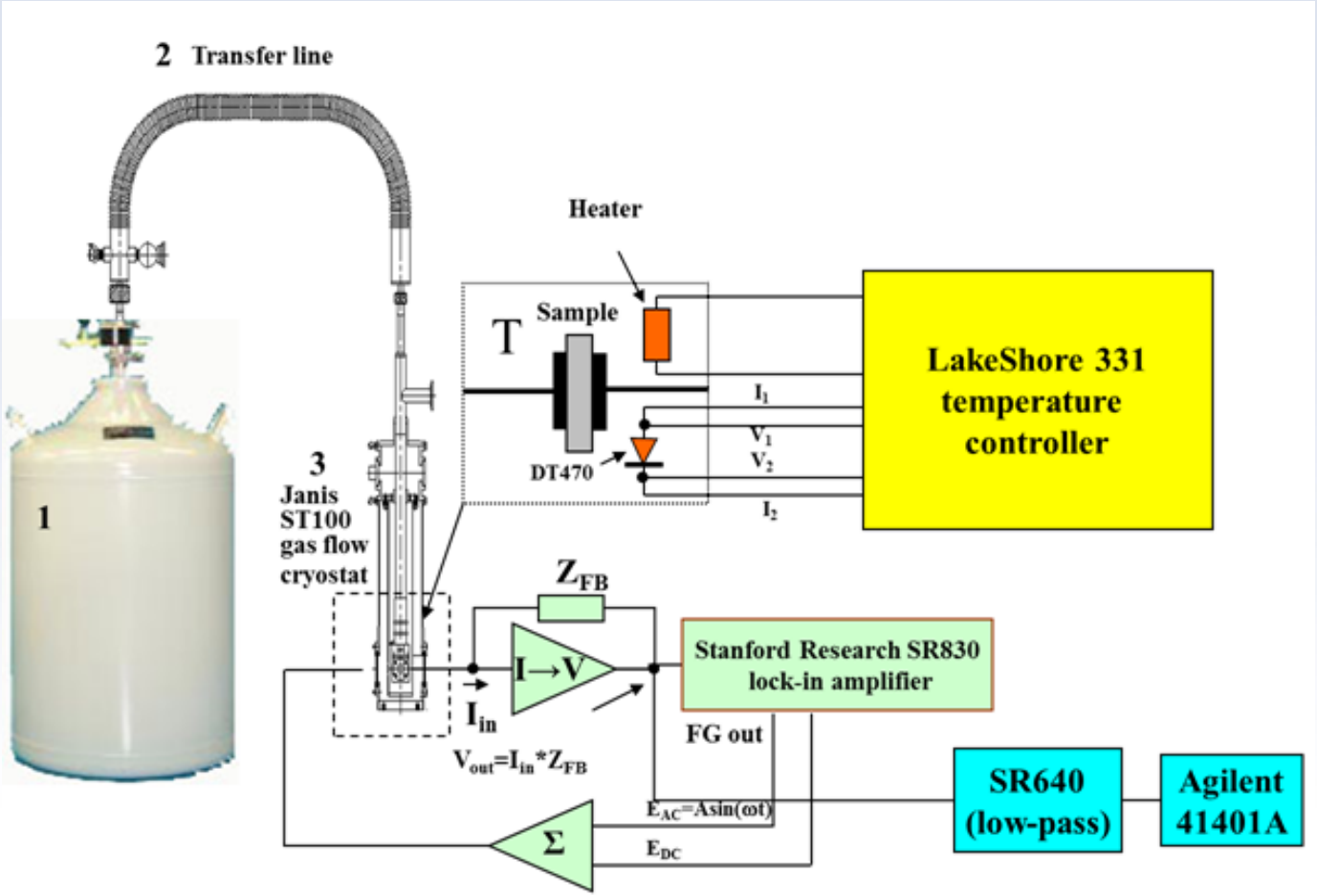




α-range experiment setup diagram

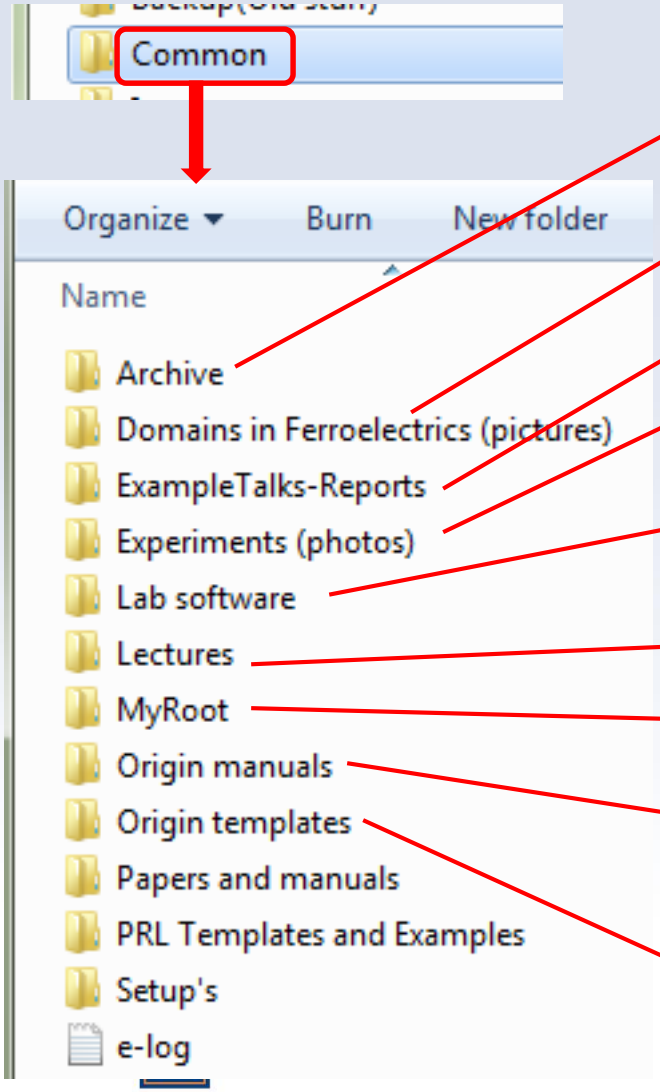
Where to retrieve course information.

Setup diagrams – do not use cellphones to take the image of the setup from manual – for most setups we have PowerPoint projects with setups.



Where to retrieve course information.

Manuals, papers, setup diagrams and *other useful materials*



Some old stuff (not very useful)

Sample pictures of ferroelectric domains

Examples of report and oral presentation

Pictures of the setups of the experiments

Software including DAQ software for different experiments. Newest version of Origin is also there

P403 lecture notes

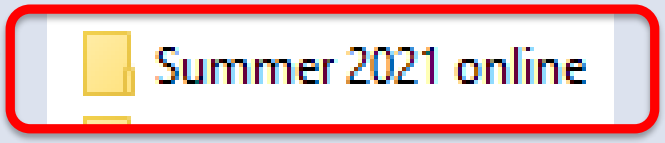
C++ scripts for Root

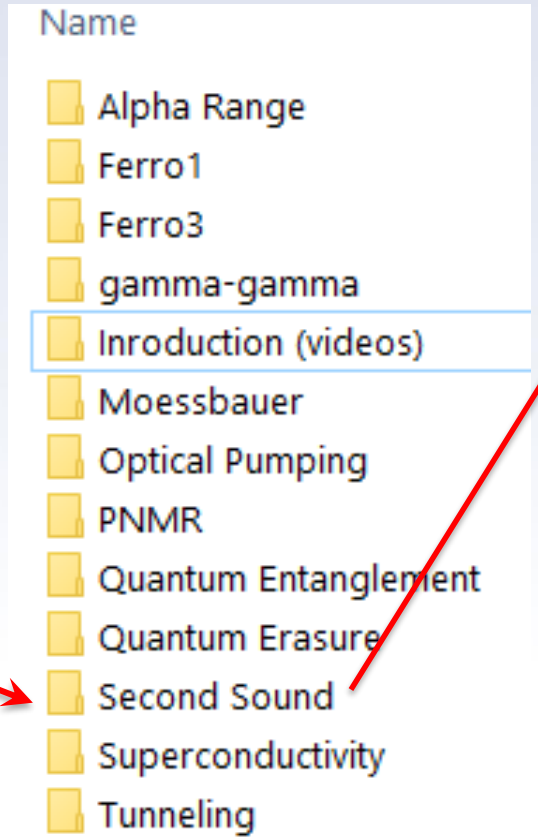
Origin manuals + a very compressed version written by Eugene

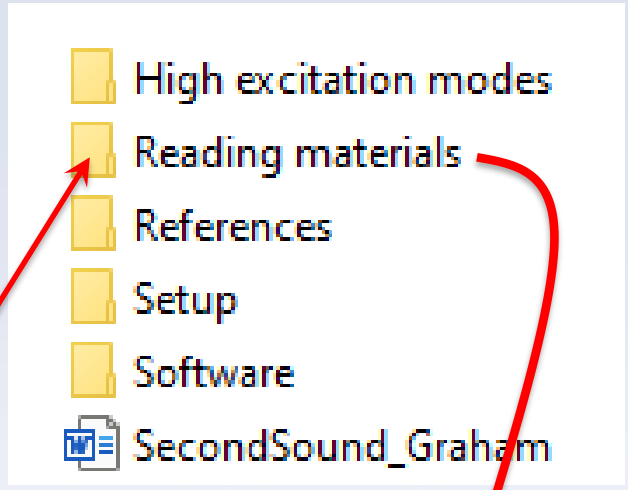
Origin templates (how to use them will be discussed in next lecture)

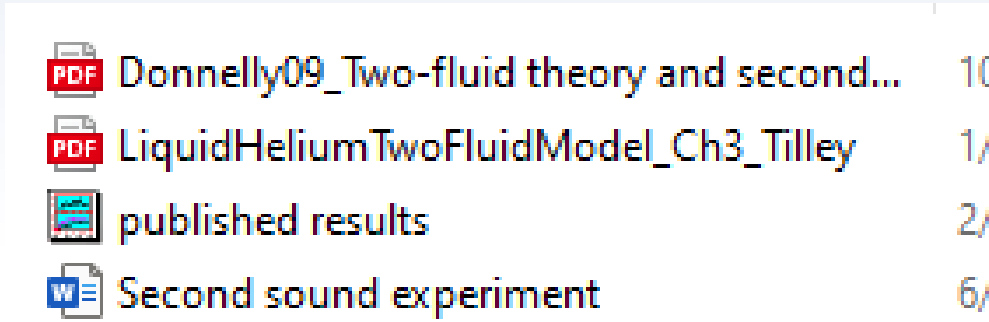
Where to retrieve course information.

Material Prepared for Online Teaching





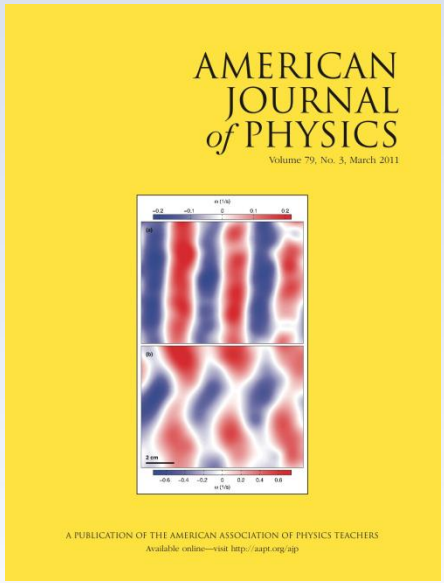


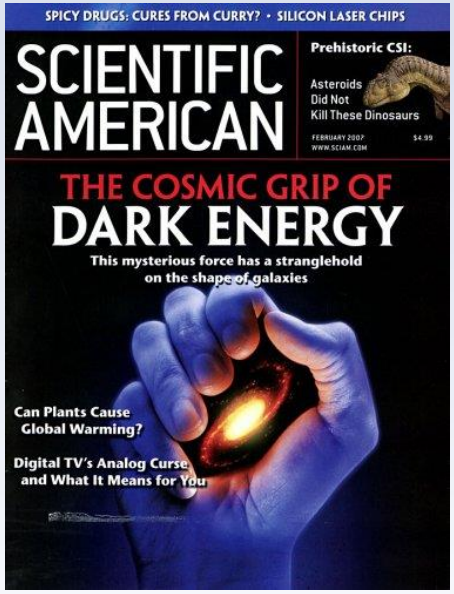


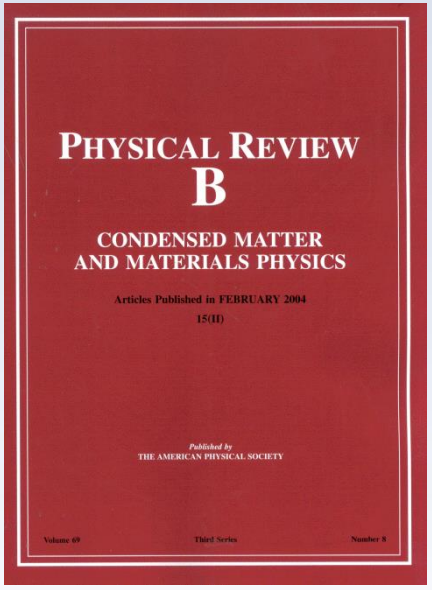
"Journal club"

Lectures: 10am
Journal club: 3pm

About Phy403







http://ajp.aapt.org/#mainWithRight

http://www.nature.com/nature/index.htm

http://www.scientificamerican.com/

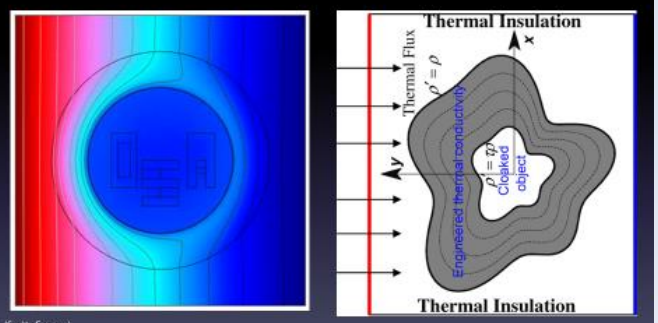
http://www.sciencemag.org/journals

http://publish.aps.org or http://prola.aps.org/

"Journal club"

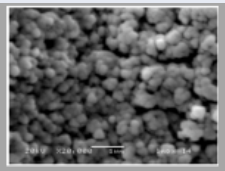
Walking with Coffee: Why Does it Spill?

Fabrication and Characterization of Ultrathin Three-Dimensional Thermal Cloak



Student #1

University of Illinois at Urbana-Champaign



Growth of Diamond Films from Tequila

J. Morales[1,2], L. M. Apátiga[2], V. M. Castaño[2]

1. Facultad de Ciencias Fisico Matemáticas, Universidad Autónoma de Nuevo León
2. Centro de fisica Aplicada y Tecnologia Avanzada, Universidad Nacional Autónoma de México

The Physics of Beer Tapping

PRESENTATION BY JOSEPH MIRABELLI

JAVIER RODRÍGUEZ-RODRÍGUEZ,1,* ALMUDENA CASADO-CHACÓN, AND DANIEL FUSTER

1 FLUID MECHANICS GROUP, CARLOS III UNIVERSITY OF MADRID
2 CNRS. UNIVERSITÉ PIERRE ET MARIE CURIE

"Journal club"

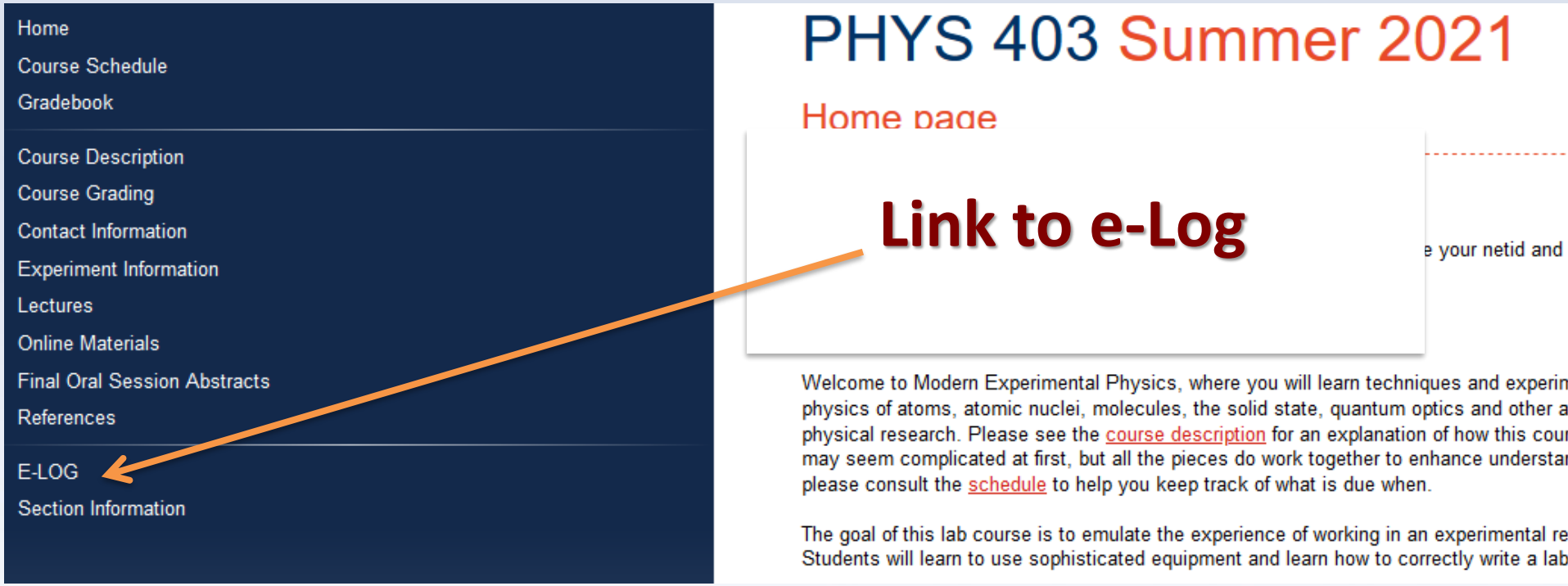
Journal Access

If you cannot access journal papers using VPN, go to UIUC's library proxy test site and enter the address of the paper you want to read:
http://www.library.illinois.edu/proxy/test/

Recommended journal websites

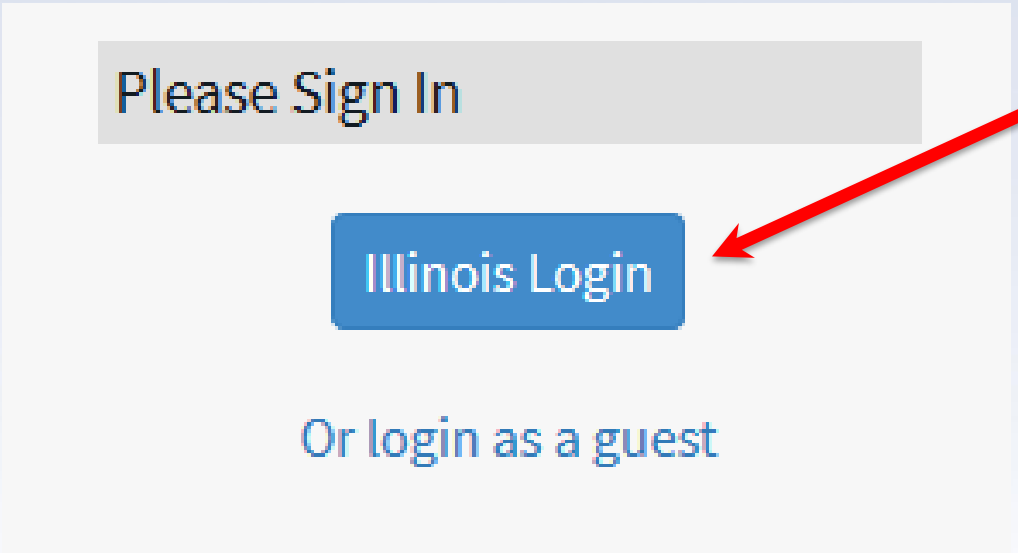
- **American Physical Society Journals**: https://journals.aps.org/about
- **Nature**: http://www.nature.com/nature/index.html
- **Science**: http://www.sciencemag.org/journals
- **American Journal of Physics**: http://scitation.aip.org/content/aapt/journal/ajp

Entering the e-Log …

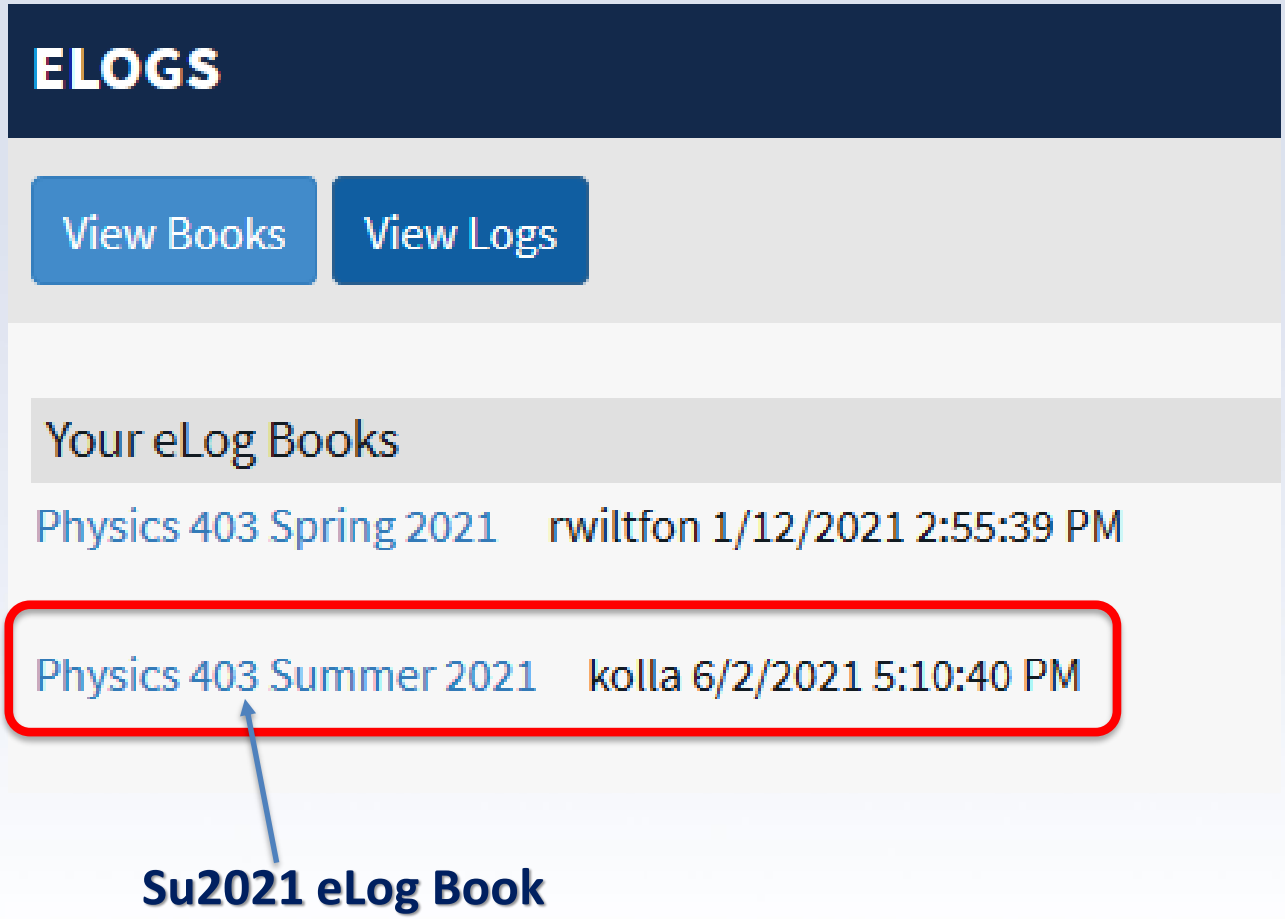


Entering the e-Log …

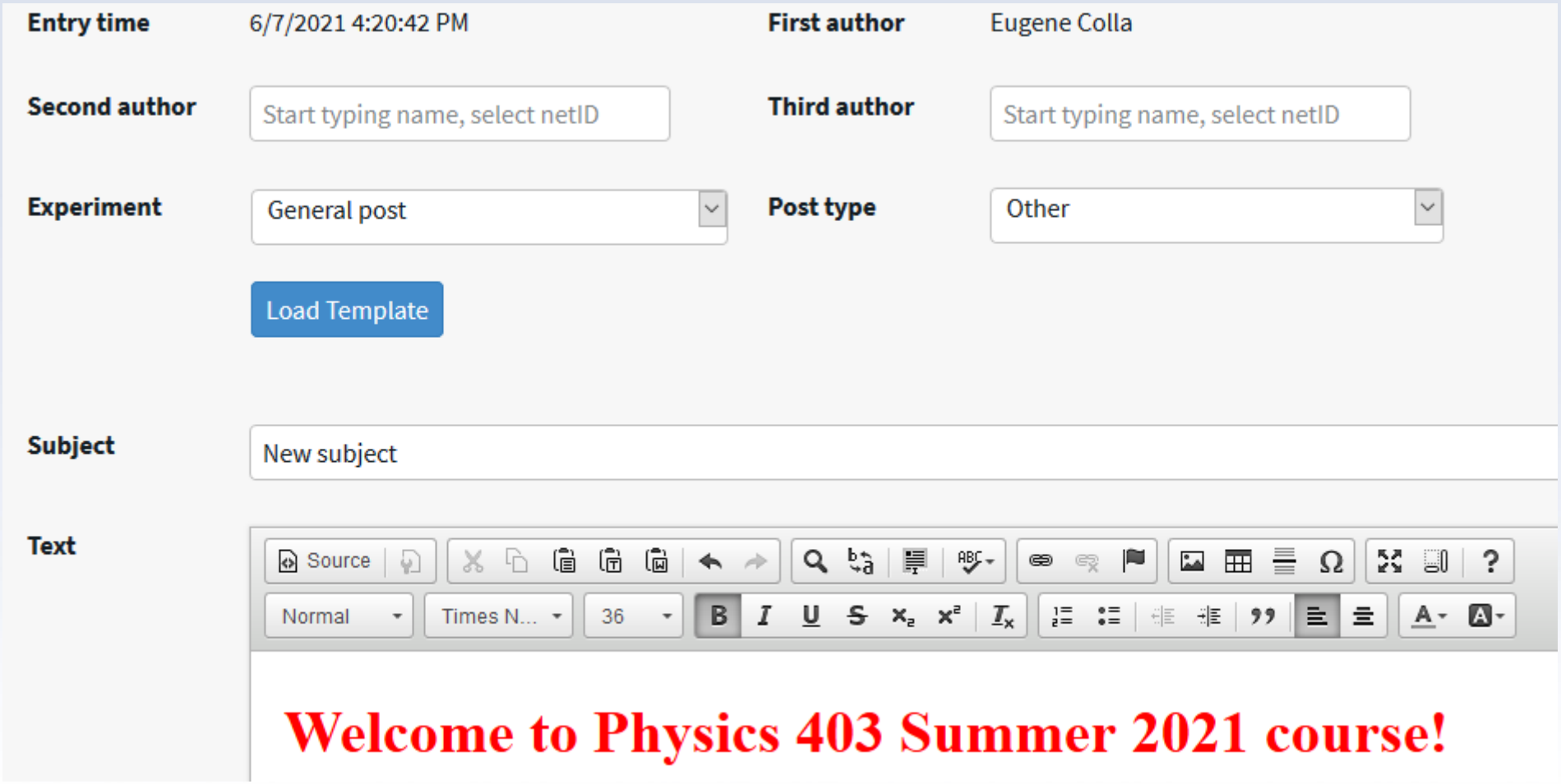
Use your University Username and Password



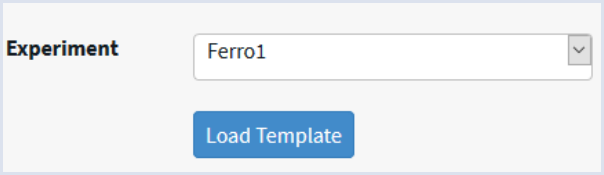
Entering the e-Log …



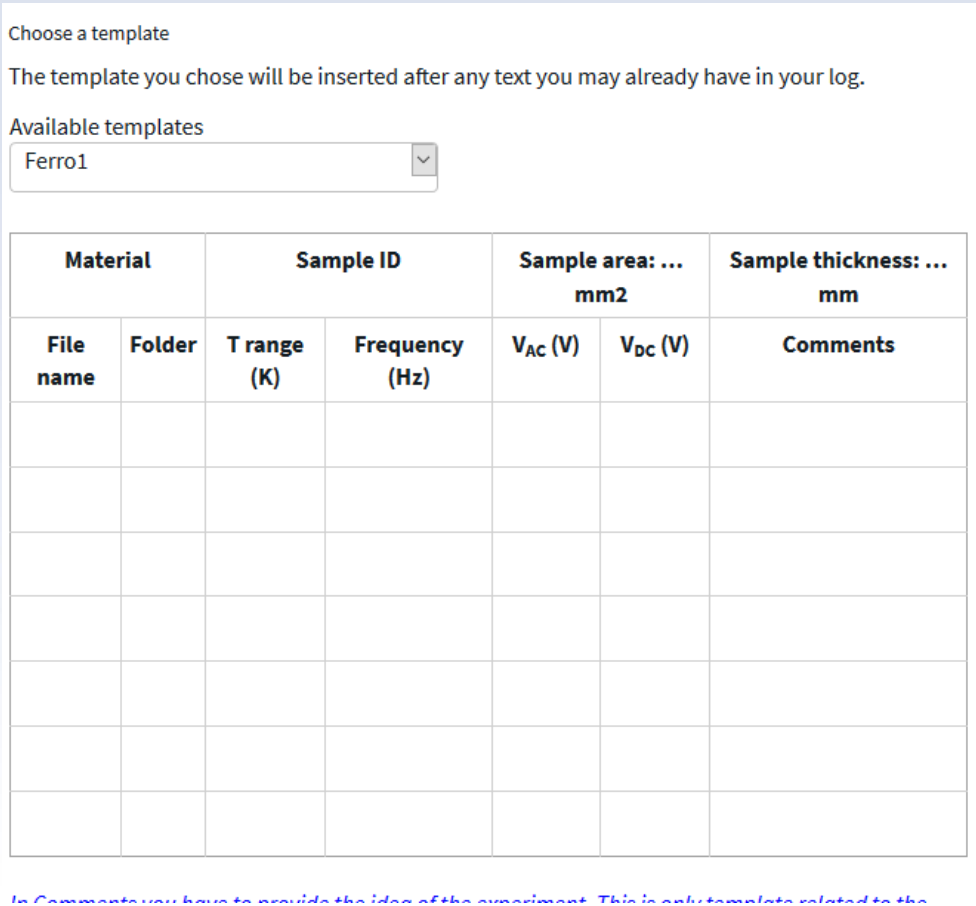
Entering the e-Log …



e-Log . Using *Templates*



Templates are not "ready to go" eLog records. There are some suggestions and comments which you need to read, accept/decline and remove from the final version of the eLog record.



e-logs: First a brief tour

How to use it

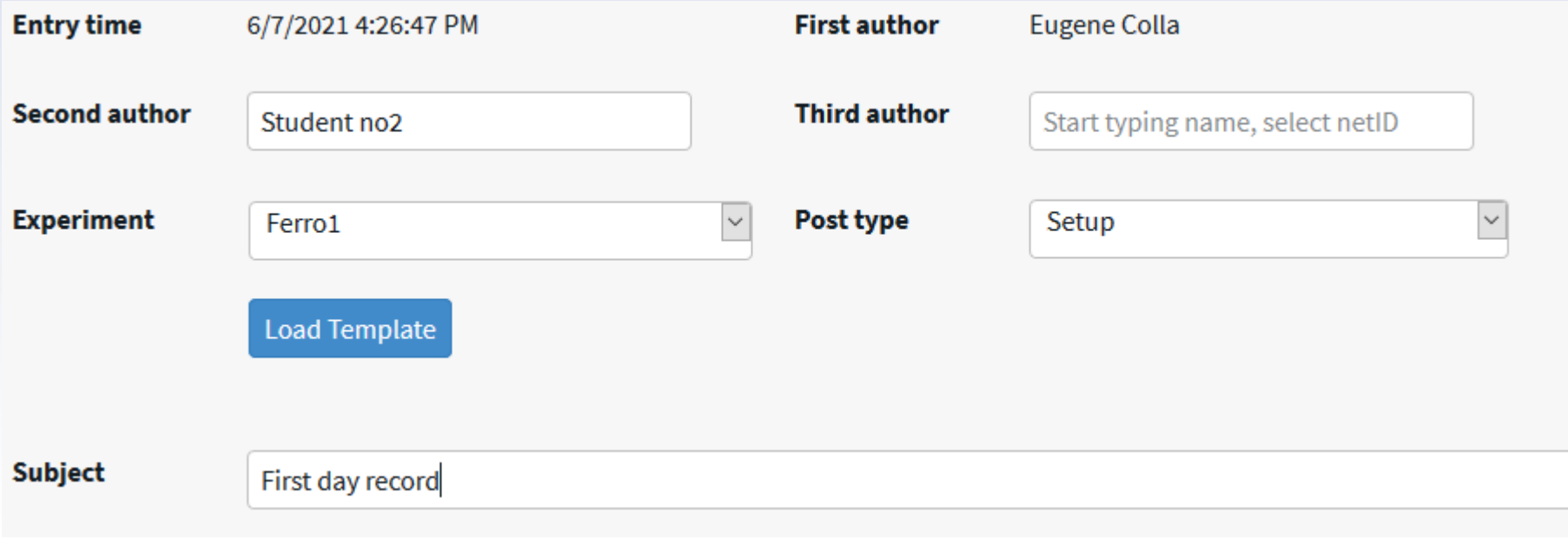
- **Pause and summarize your work at natural stopping points in the action. This is useful for particular findings and measurement sequences.**
- **Along the way, save data, plots, scope shots to your folder on the server.**
- **Near the end of the class, add a summary/conclusion, indicate future directions, and make sure the e-log provides a rather complete overview of the highlights of your work. Upload your plots, scope shots, etc. and describe the data.**

e-logs: Making a post …

- To create a new post, click 

- Fill in the *Author, Experiment, Post Type, and Subject.*

  Don't forget to enter the name of the second author



e-logs: Making a post …

Goal: Be specific. Not, "Learn about experiment," but, for example, "In helium below temperatures of 2.17K, a second sound due to thermal effects becomes measurable. We will measure the speed of the second sound using a resonant cavity…"

Settings / Equipment Notes: Note important environmental and experimental parameters such as atmospheric pressure, settings on equipment, etc.

[Time Range 1]: Give time range, not just "before tea."

- **Note important steps and results**
- **Include plots, photos, or scope shots in attachments below**
- **Use bullet points to make it easy to read**

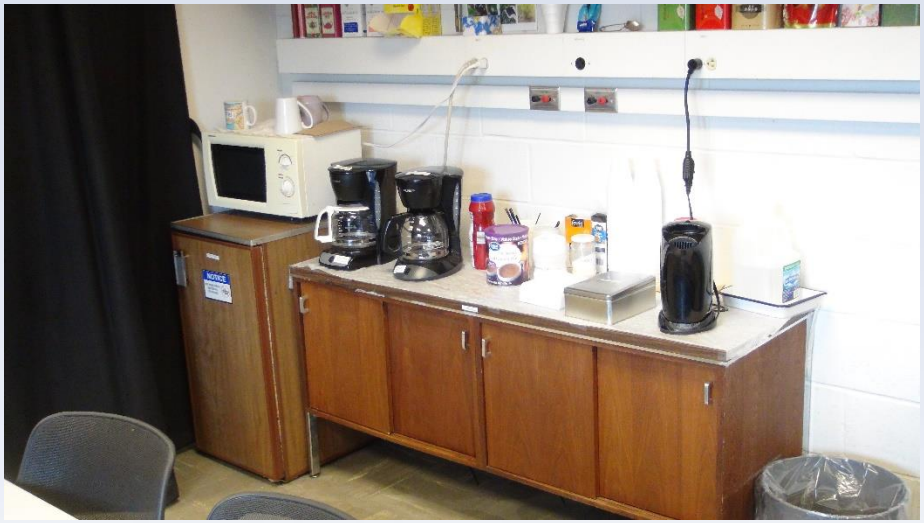
[Time Range 2]: …

Conclusions & Future Plans: What did you find and what is the next step? Be specific. Not, "We measured decay times," but, for example, "Ruby #2 sample with higher concentration chromium was observed to decay with a form…"

Some General Physics 403 Rules.

No Food or Drinks in Lab except ESB 5105

Some General Physics 403 Rules.



You can have a short break in ESB 5105 where you will find coffee, tea, cookies

Some General Physics 403 Rules.

Because of COVID19 restriction we can't invite all of you at the same time in ESB 5105. Please follow the room capacity as shown on the wall in this room.