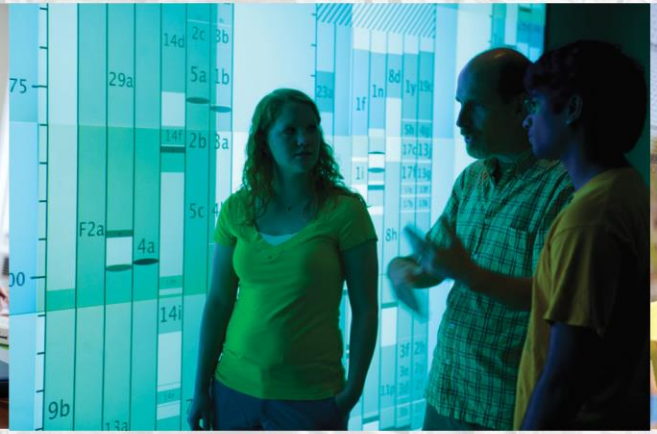
UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Physics 403. Modern Physics Laboratory

Spring 2021

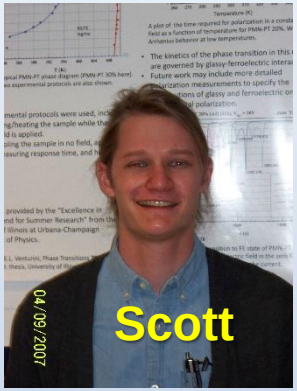
Eugene V . Colla, Virginia O. Lorenz

COVID-19 - hybrid in-person-online version



Physics 403 Modern Physics Laboratory

Fall 2020 Teaching Team



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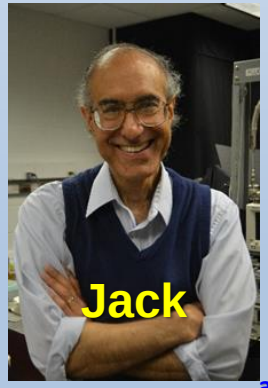

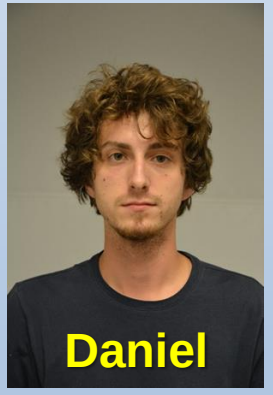

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Outline

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 (*New advanced version designed by Rebecca Wiltfong*)

Not in Sp2021

Course Goals. Primary goals:

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

  - ✓ Each lab experiment is a mini-research project
  - ✓ How are experiments 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)**

illinois.edu

*** In red gradable assignments**

Course Goals. Secondary goals:

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

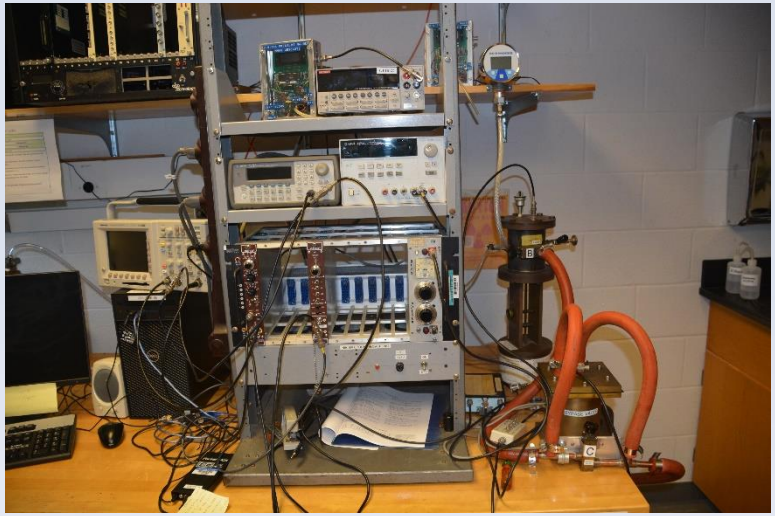
The Experiments. Three main groups

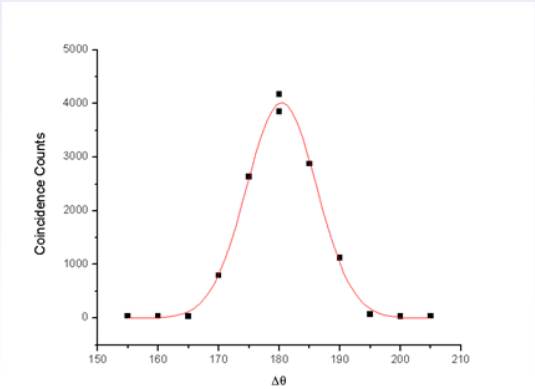
- Nuclear / Particle (NP)
- Atomic / Molecular / Optics (AMO)
- Condensed Matter (CM)

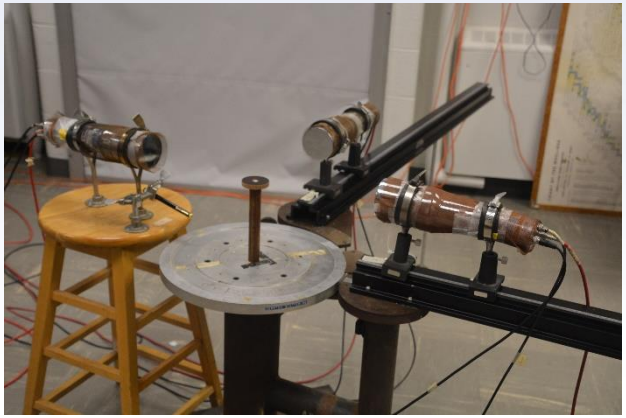
You will do the experiment from all these groups

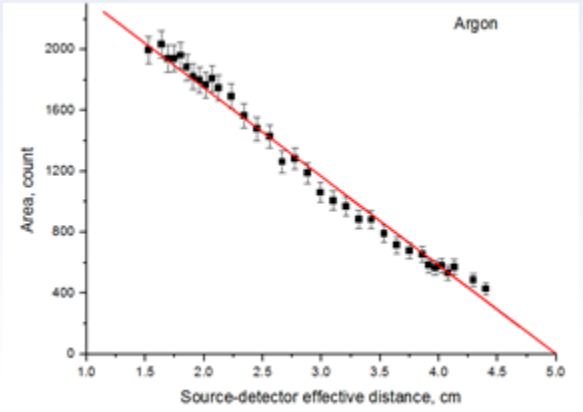
The Experiments

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





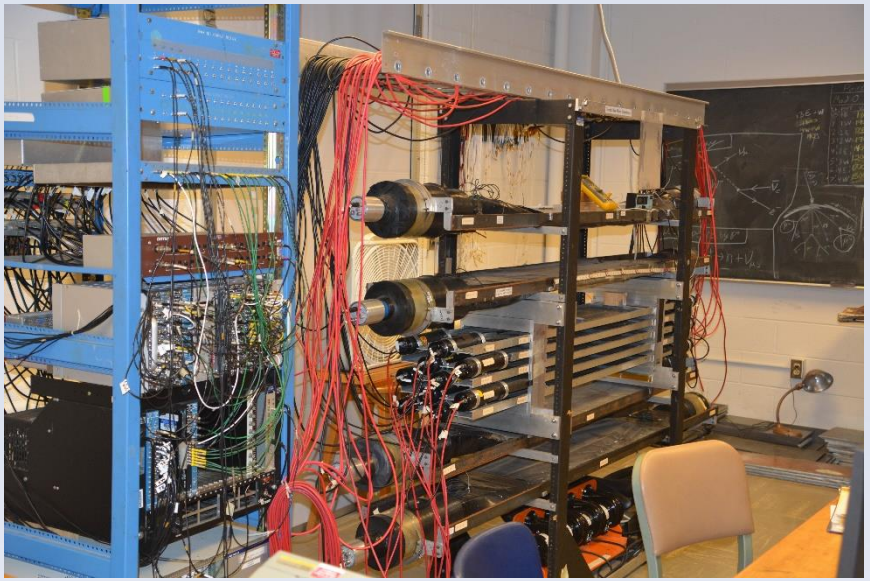


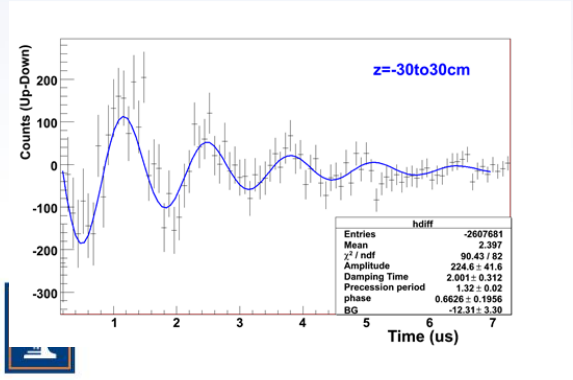


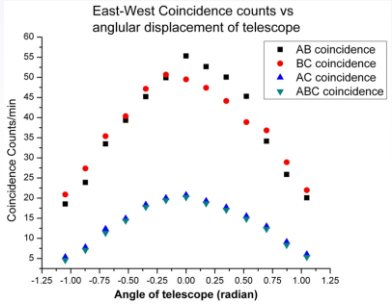
The Experiments

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

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



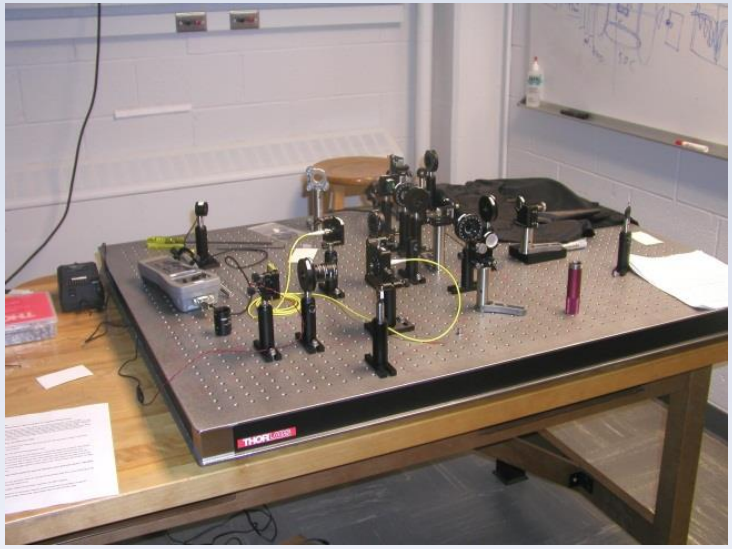


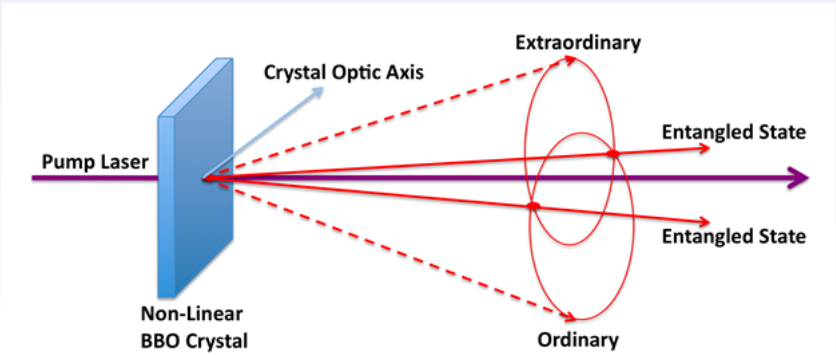


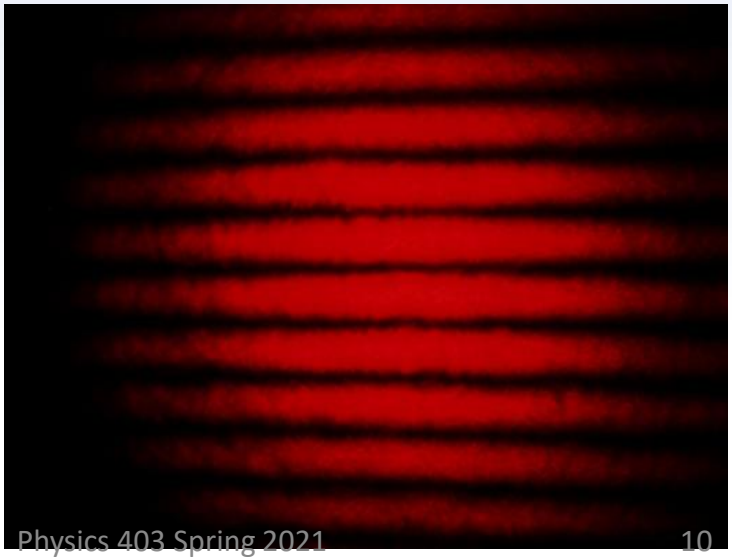
The Experiments

Atomic/Molecular/Optics (AMO)

- Berry's phase
- Quantum erasure
- Quantum Entanglement



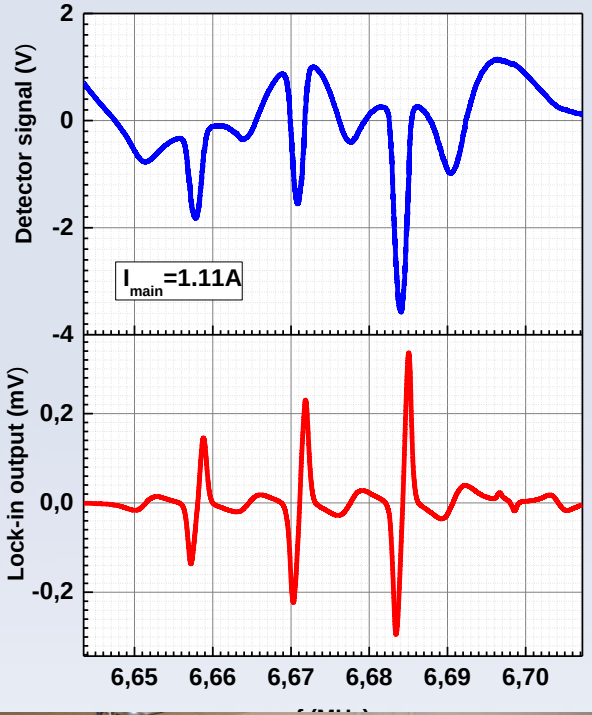


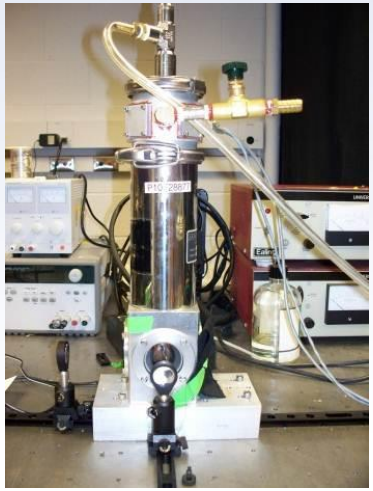


The Experiments

Atomic/Molecular/Optics (AMO)

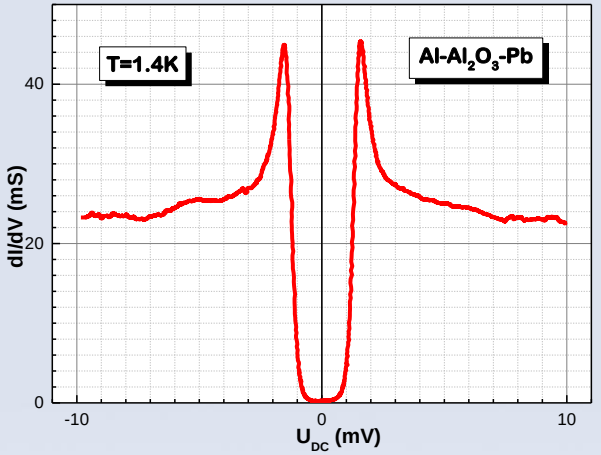
- Optical pumping of rubidium gas
- Fluorescence spectroscopy

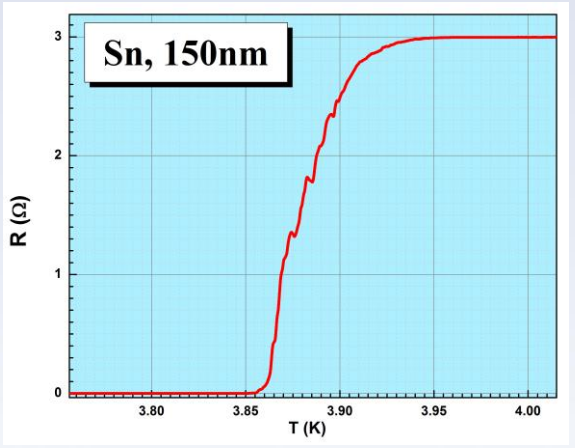


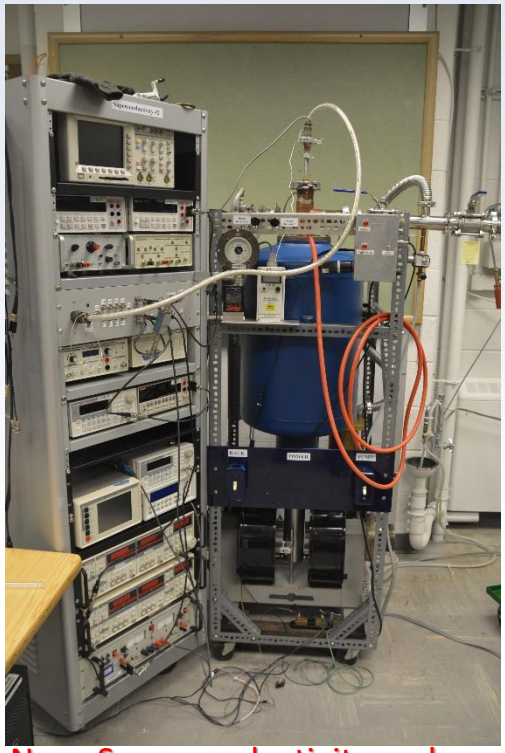


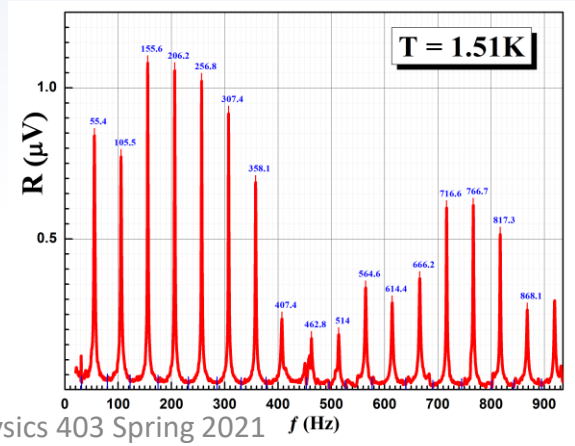
The Experiments

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





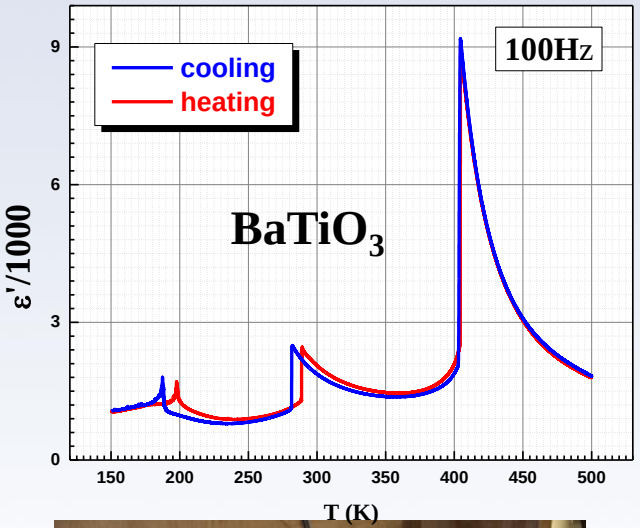


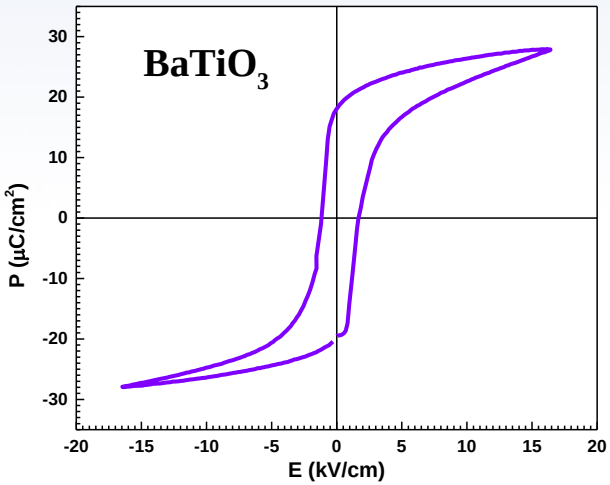


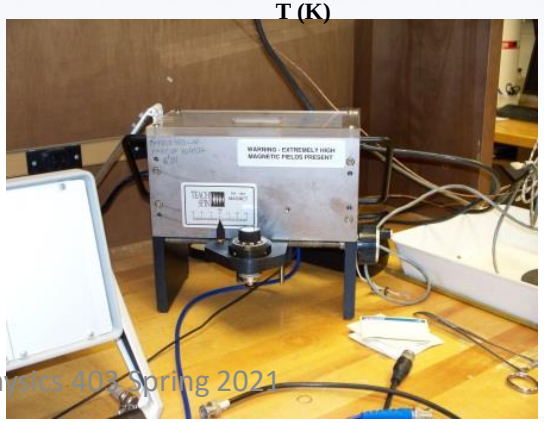
New: Superconductivity and magnetic field

The Experiments

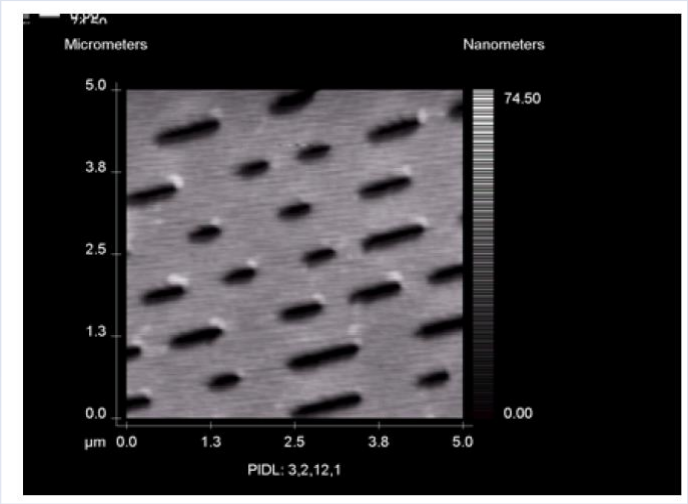
- **Condensed Matter (CM)**
  - Ferroelectrics and ferroelectric phase transition
  - Pulsed NMR
  - Calibration of temperature sensors



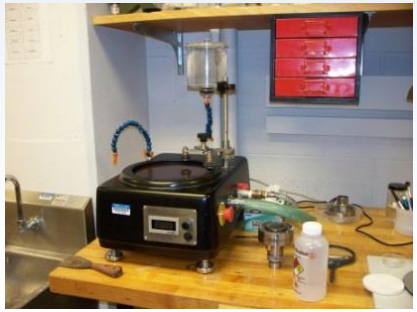




The Experiments

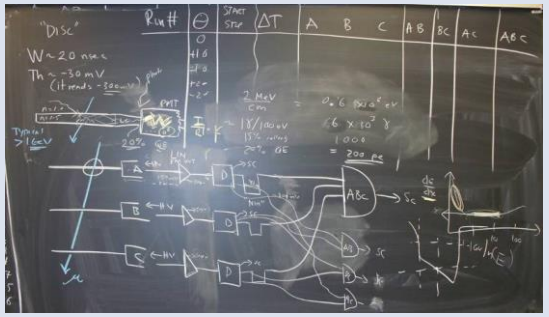


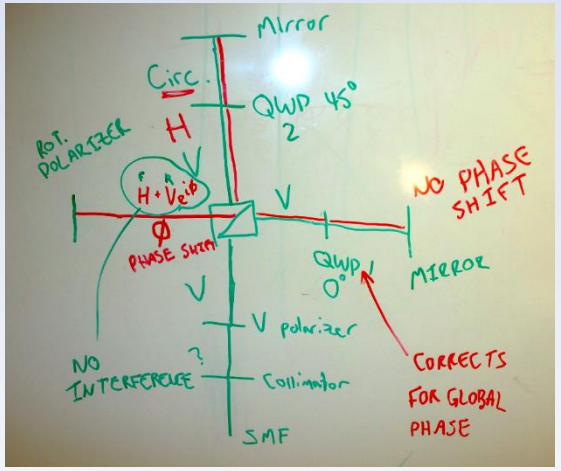
- **Condensed Matter (CM)**
  - **Special Tools:**
  - **Vacuum film deposition**
  - **Atomic Force Microscope**
  - **Polarizing microscope**



The "manuals"

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





TEACH SPIN
Instruments Designed for Teaching

OPTICAL PUMPING OF RUBIDIUM OP1-A

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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

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 Total**
Final Oral Presentation ≡ Final Exam	**120**
Total **Effective point total will be**	**740**

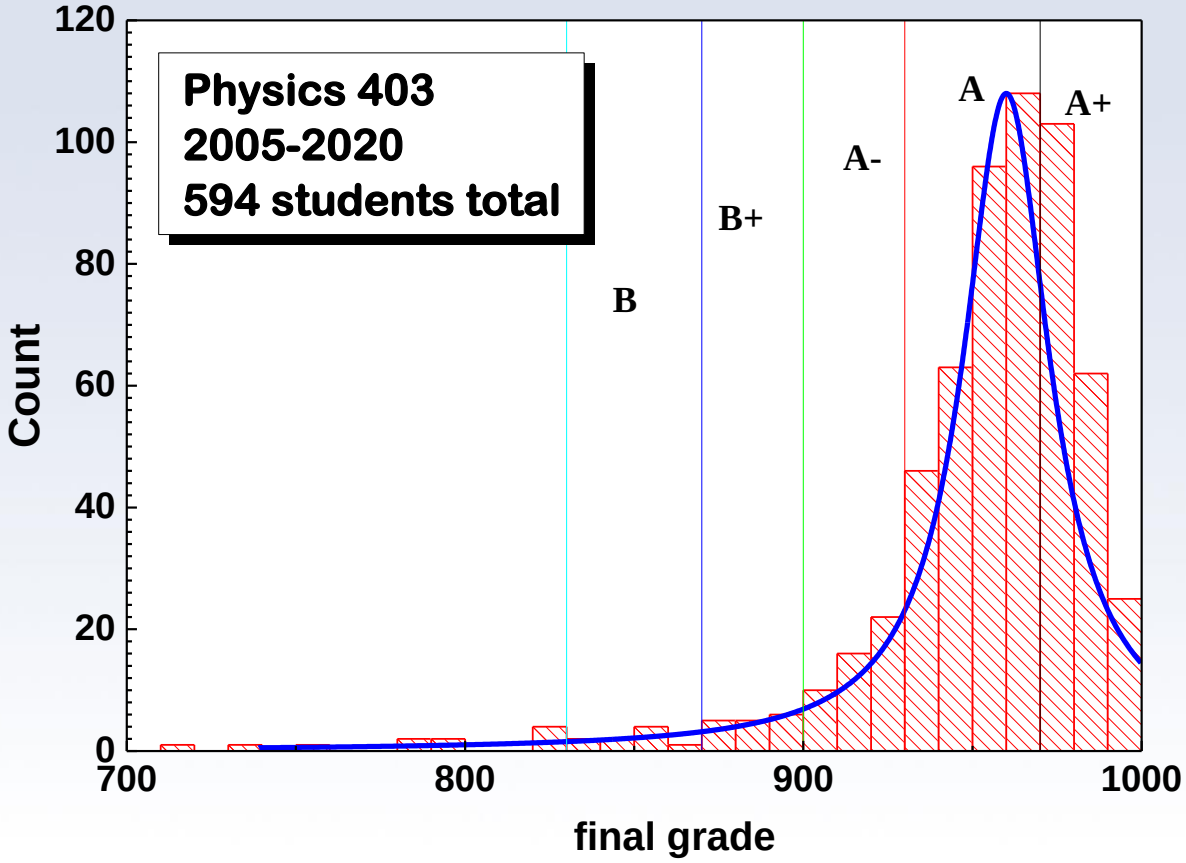
The grading scale will be a percentage out of "740" :

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

You can RESUBMIT one lab report to improve your grade

(deadline for resubmissions and for report #4 May 7th 2021)

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 formats: PDF* or MS-Word
- For orals – MS-PowerPoint* or PDF

** preferable*

Absences

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

- *COVID19 comment*: if the student assigned to be "in person" can not attend the session he/she can be replaced by their partner and continue to work "online".

- You can "make up" time by arranging with us 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 the excused you have missed the oral presentation (oral #1), you have 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.

C1-Ex1(2.07.18)

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        digital scopes

Syllabus

Cycles

	Date	Day	Activity	Comment	Note
1	1/26	Tues	Orientation	About Phy403	
2	1/28	Thurs	Cycle 1-1		
3	2/02	Tues	Cycle 1-2	OriginPro Intro/Root	
4	2/04	Thurs	Cycle 1-3	Elog Comments	
5	2/09	Tues	Cycle 1-4	Written Reports	
6	2/11	Thurs	Cycle 1-5		
7	2/16	Tues	Cycle 1-6	Error analysis	
8	2/18	Thurs	Cycle 1-7		
9	2/23	Tues	Cycle 1-8	Oral Reports/Talks	C1-Ex1(2.24.21)
10	2/25	Thurs	Cycle 1-9		
11	3/02	Tues	Cycle 1-10	Optical spectroscopy	
12	3/04	Thurs	Cycle 1-11		
13	3/09	Tues	Cycle 1-12	Ferroelectricity	
14	3/11	Thurs	Cycle 2-1		Rotate
15	3/16	Tues		ORALS 1	
16	3/18	Thurs			
17	3/23	Tues	Cycle 2-2	High Energy Physics	C1-Ex2 (3.24.21)
18	3/25	Thurs	Cycle 2-3		
19	3/30	Tues	Cycle 2-4	AFM	
20	4/01	Thurs	Cycle 2-5		
21	4/06	Tues	Cycle 2-6	Lock-in Amps and FT	
22	4/08	Thurs	Cycle 2-7		
23	4/15	Thurs	Cycle 2-8	Entanglement	C2-Ex1 (4.16.21)
24	4/20	Tues	Cycle 2-9		
25	4/22	Thurs	Cycle 2-10	Measuring Temp	
26	4/27	Tues	Cycle 2-11		
27	4/29	Thurs	Cycle 2-12	To be announced	
28	5/04	Tues		Final Orals #1	
	5/06			READING DAY	
29	5/11	Tues		Final Orals #2	
					C2-Ex2 (5.7.21)

* Lecture topics are subject to change

	NP	CM	Atomic + CM	Optics
	A. Cosmic Muon Stand i. Muon lifetime ii. Capture rate iii. Magnetic moment B. Alpha range C. Gamma Gamma D. Muon telescope E. Mössbauer spectroscopy	A. Ferro 1 B. Ferro 2 (imaging) C. 2nd sound of ^{4}He D. Hysteresis loops E. Tunneling F. T calibration	A. Optical pumping B. Superconductivity C. Mutual inductance D. pNMR	A. Quantum Table i. Berry's phase ii. Quantum erasure iii. Entanglement B. Fluorescence spectroscopy C. AFM
	Virginia, Daniel	Eugene	Eugene, Scott, Andrew	Abid, Gabi, TAs from Kwiat Lab
C1-1	1-2; 3-4; 5-6	11-12; 13-14; 15-16	17-18; 19-20	7-8; 9-10
C1-2	5-6; 7-8; 9-10	17-18; 19-20	11-12; 13-14; 15-16	1-2; 3-4
C2-1	12-13; 14-15; 16-17	2-3; 4-5; 6-7	8-9; 1-10	18-19; 11-20
C2-2	18-19; 11-20	6-7; 8-9; 1-10	4-5; 6-7	12-13; 14-15; 16-17

Cycle	#	Experiment
C1-1	1-2	Cosmic ray muons
	3-4	Alpha range
	5-6	Gamma-gamma
	11-12	Ferro 1
	13-14	Ferro 3
	15-16	Second Sound
	17-18	NMR
		Superconductivity
	19-20	Optical Pumping
	7-8	Fluorescence
	9-10	Quantum Optics
C1-2	5-6	Cosmic ray muons
	7-8	Alpha range
	9-10	Mössbauer spectroscopy
	17-18	Ferro 1
	19-20	Tunneling
		Ferro 2
	11-12	NMR
	13-14	Superconductivity
	15-16	Optical Pumping
	1-2	Quantum Optics
	3-4	Quantum Optics

Assignment of experiments

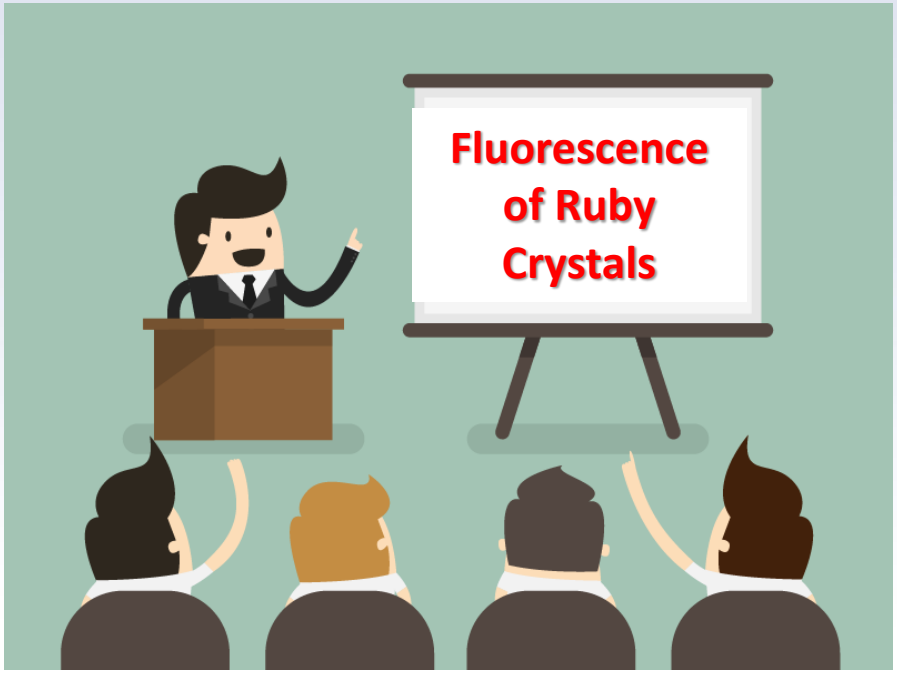
2 cycles with 2 experiments

➔ teams change after cycle

➔ joint team reports and elogs but oral presentations will be done by each student individually

Spring 2019 Orals Physics 403

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



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Spring 2021 working mode*

This semester we plan to work in hybrid mode:

Each experiment will take six lab days and you will work in teams of two.

To keep the number of students in the lab to only 10 P403 students we will grant lab access to only half the class at a time.

This means that one lab day partner no1 will be in lab and partner no2 online.

Next lab day you will be swapped – no2 in lab and no1 online.

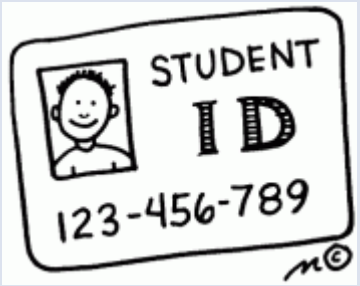
Thus each student will be able to work in lab for 3 days per experiment (50% of total time).

**** Subject to change dependable on COVID19 situation and "recommendations" provided by UofI administration.***

Spring 2021 working mode.

Each team works together and will have *common grades for report and elogs*. The prepared team schedule may vary depending on presence or absence of teammates. The P403 lab *works in real time* according the course schedule and both partners should work on experiments during the *whole lab time in person or online*.

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 work with partner~~

~~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~~

These will be not the options for Spring 2021 semester

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

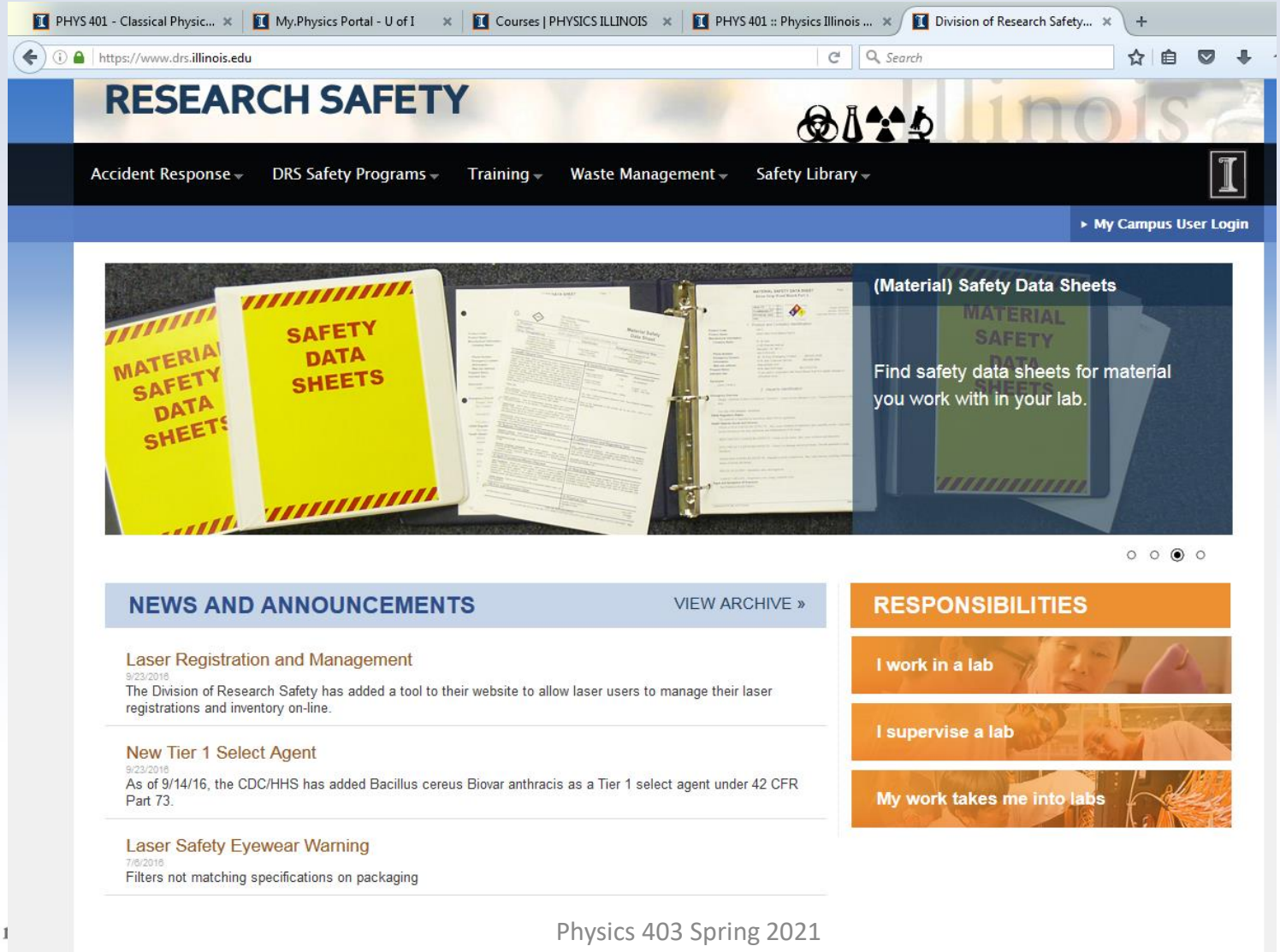
(II) equipment

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

When in doubt stop and ask

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

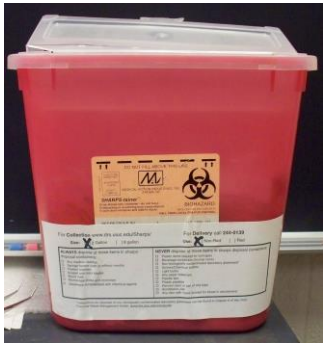
Definition

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

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 for 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

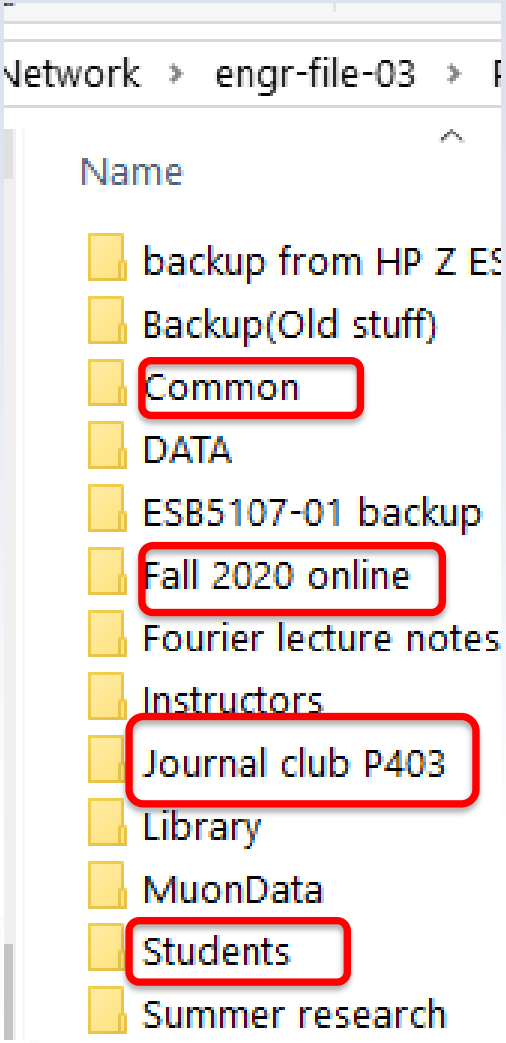
- ***When prompted for username and password, enter:***
  "Uofl\[your netID]" and "[your netID password]"

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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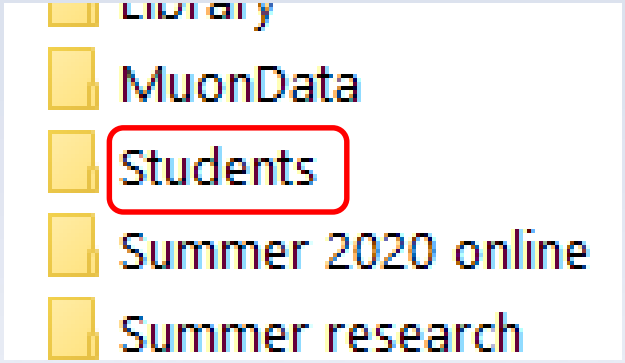
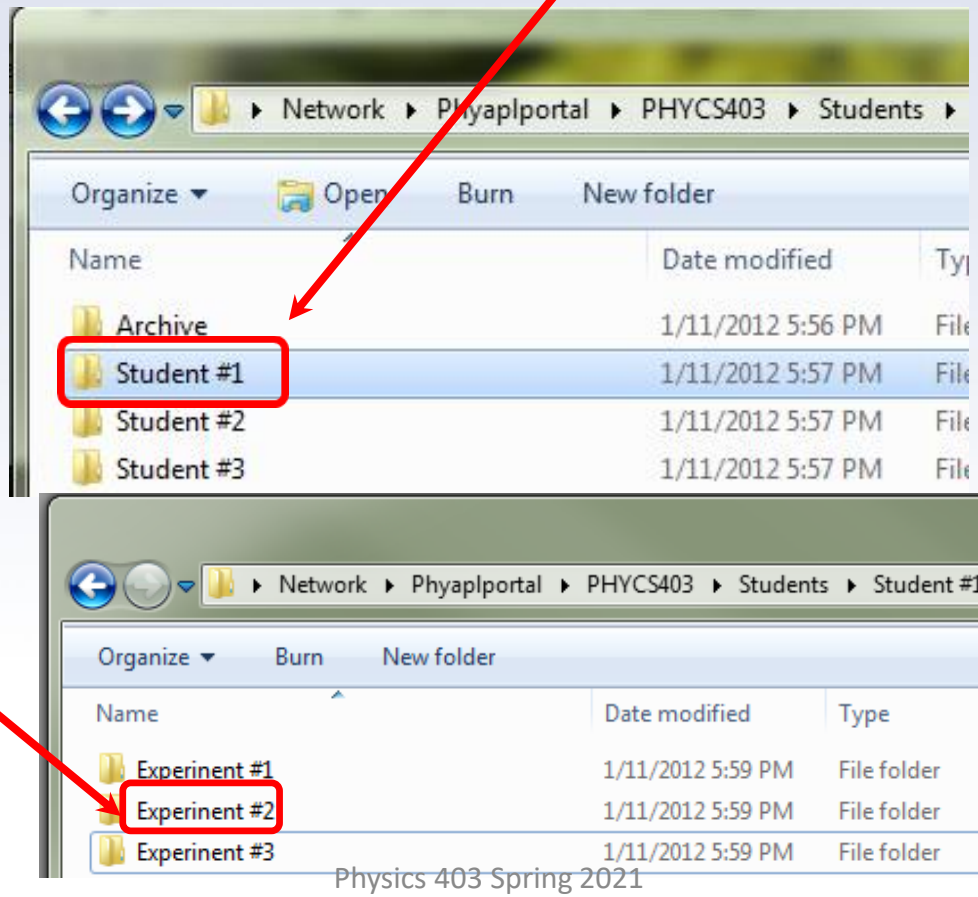


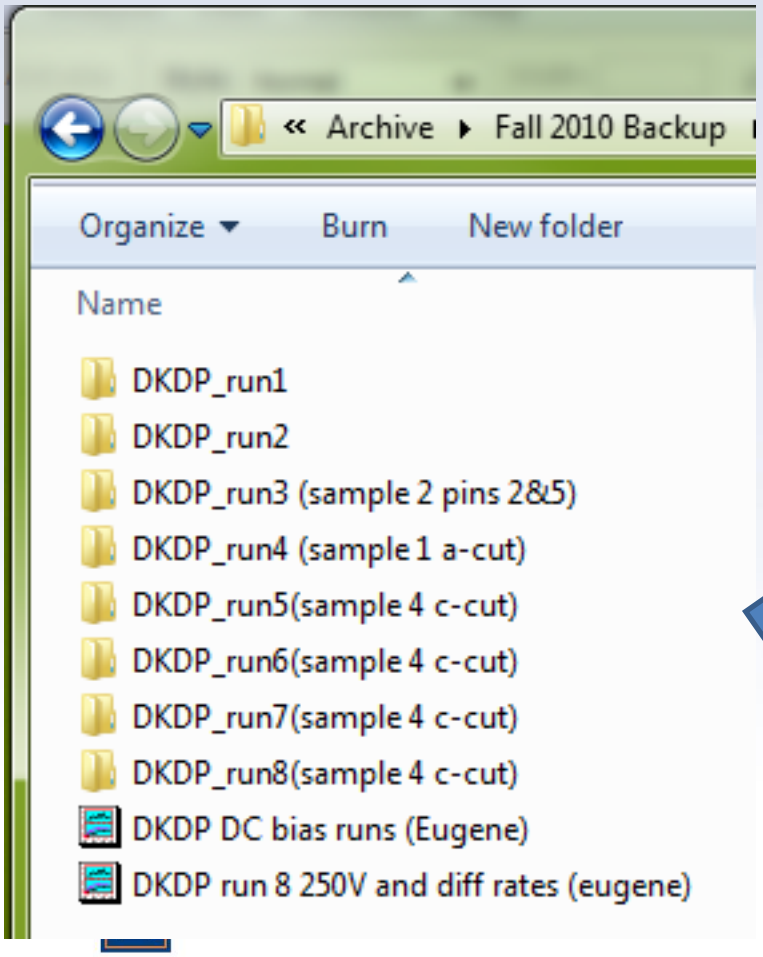
Each student has a folder

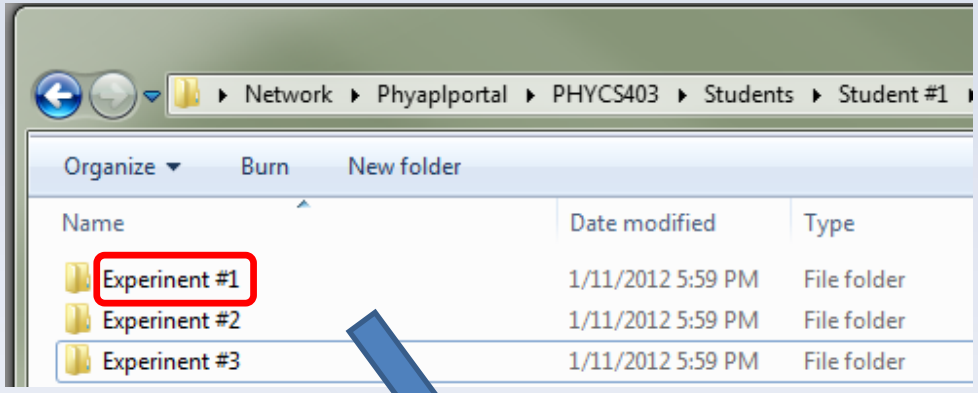


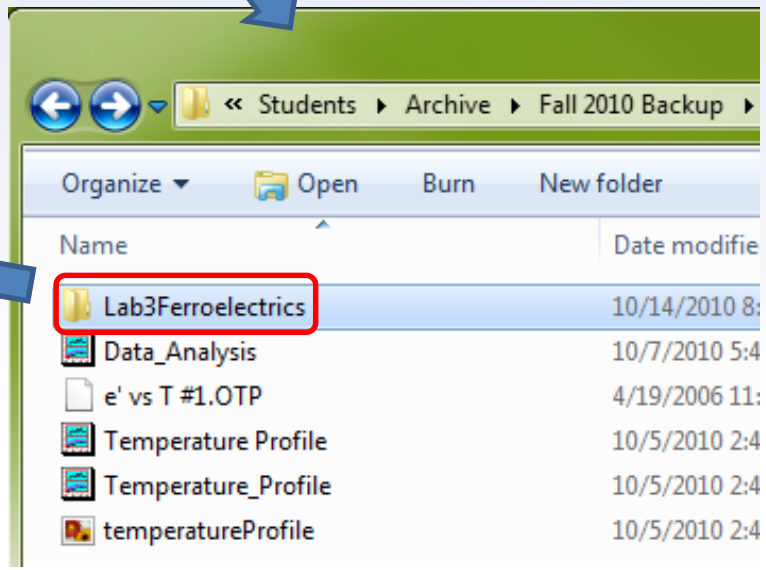
Store all experiment related materials in corresponding folder

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

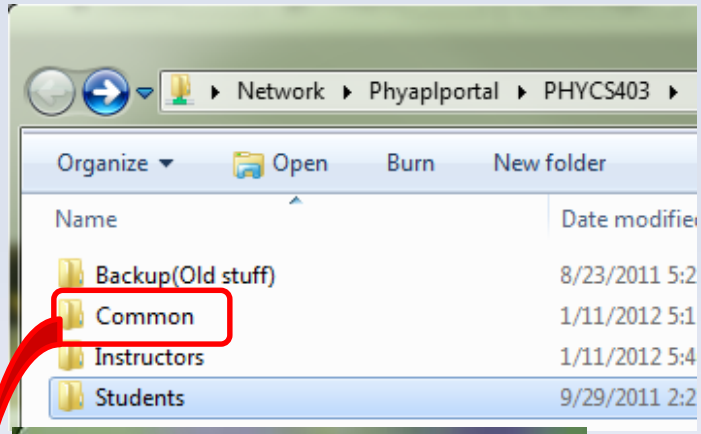


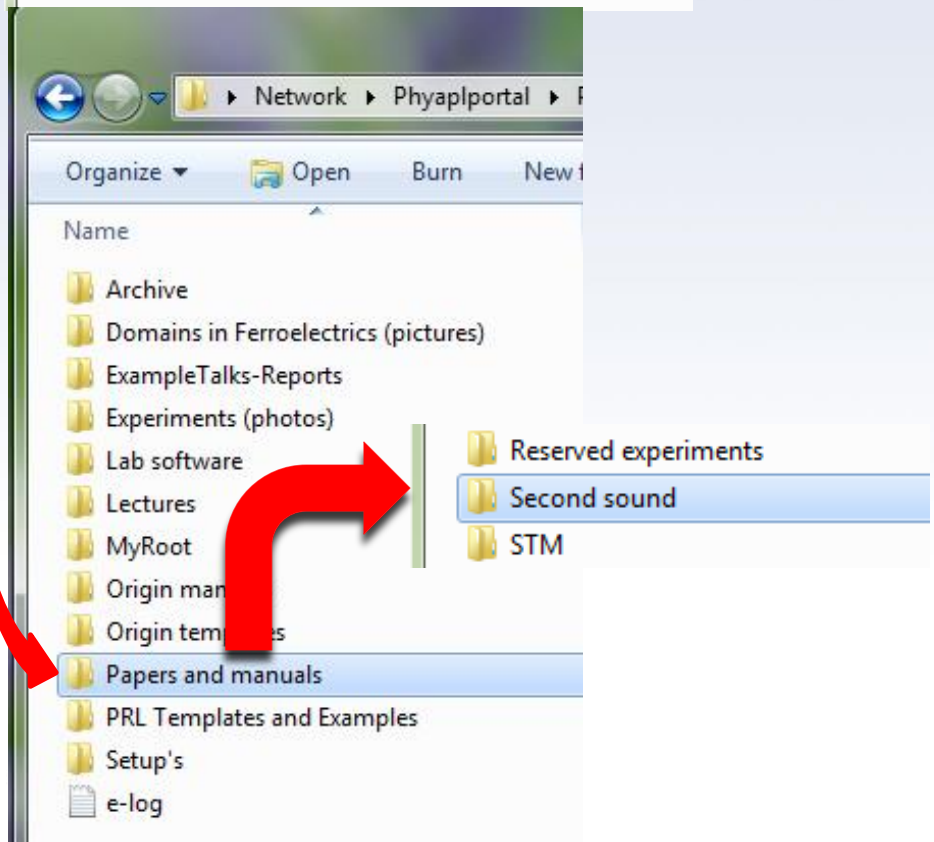


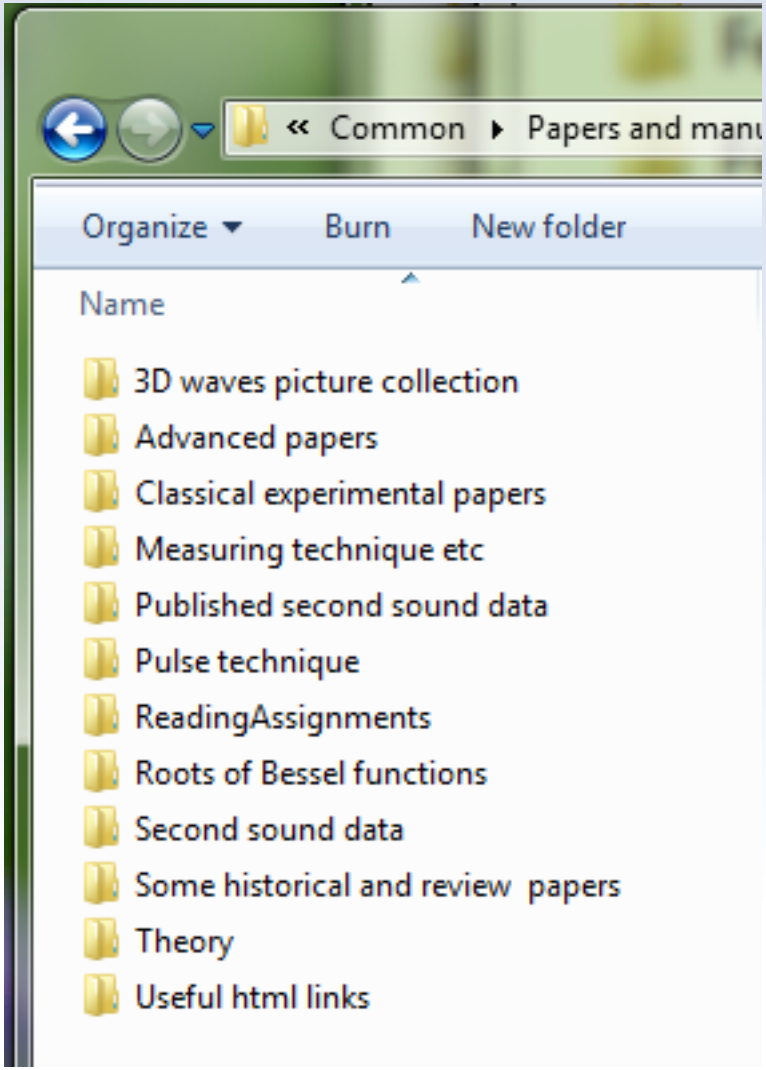


Where to retrieve course information.

Manuals, papers, setup diagrams and other useful materials

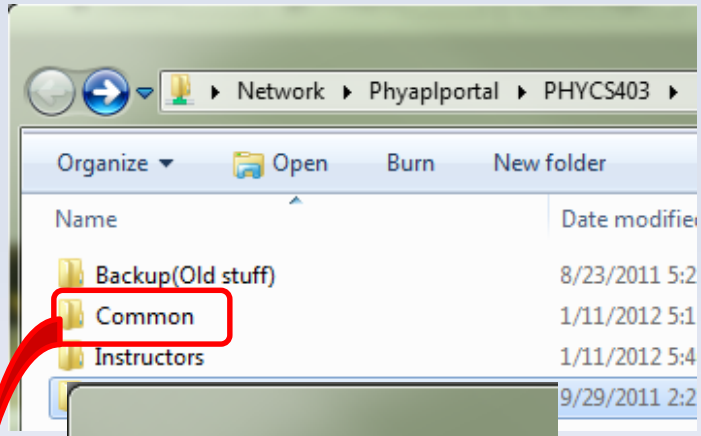


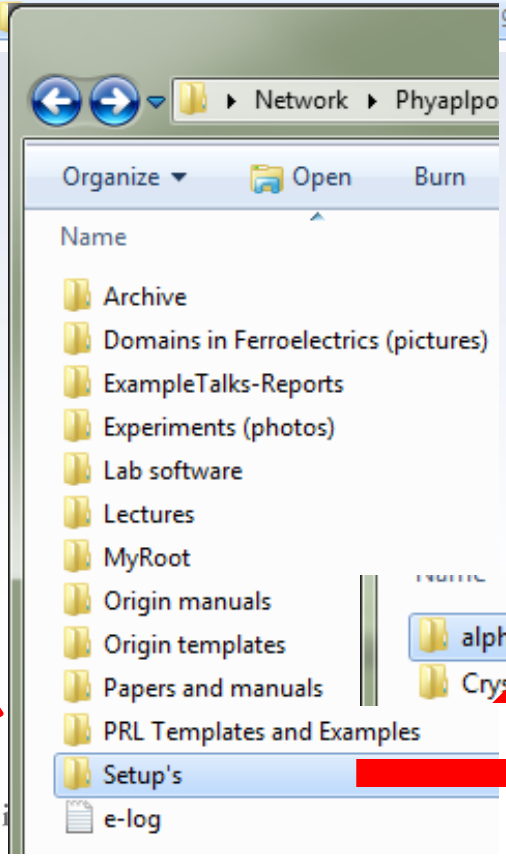


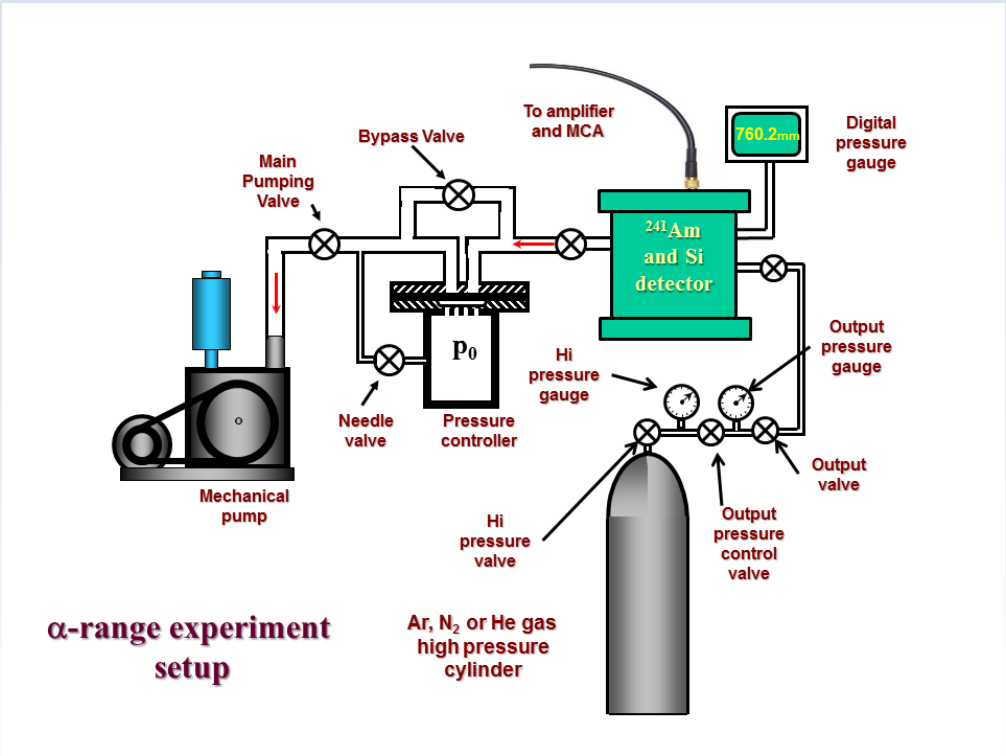


Where to retrieve course information.

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



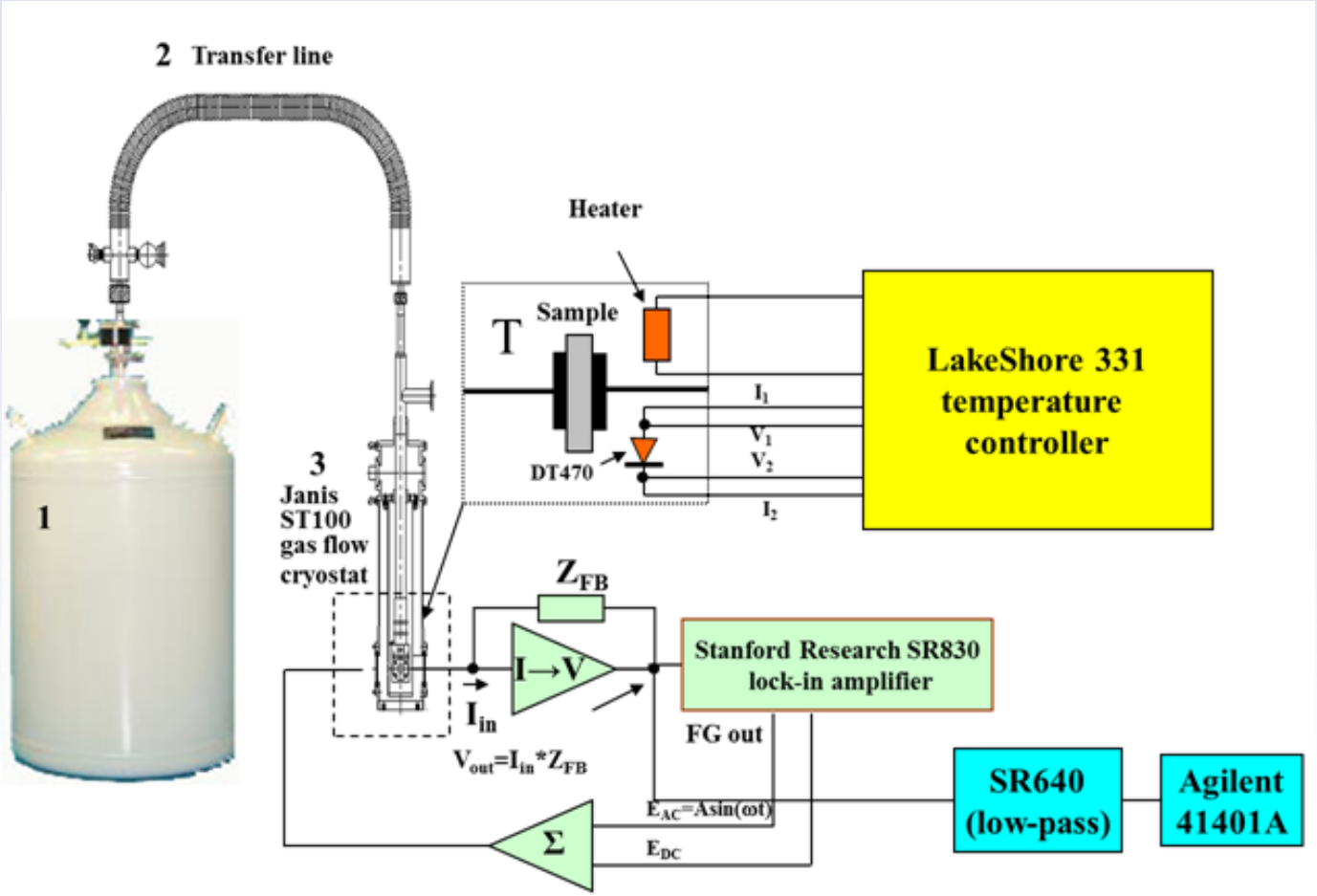




α-range experiment setup diagram

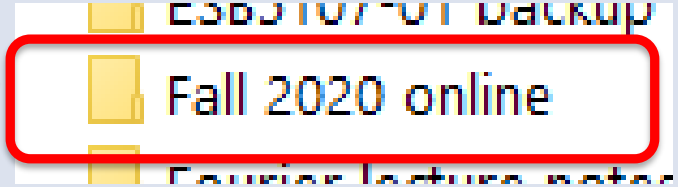
Where to retrieve course information.

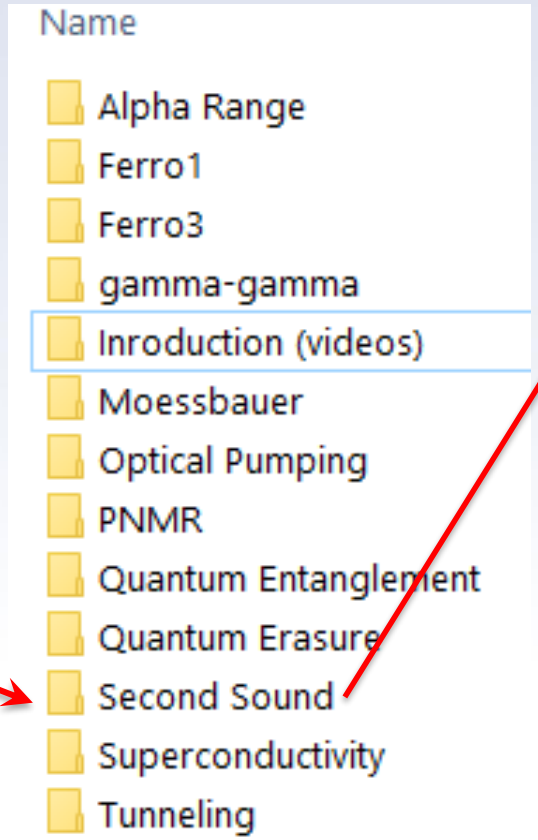
Setup diagrams – do not use cellphones to take the image of the setup from manual – for most setups we have PowerPoint projects with setups.

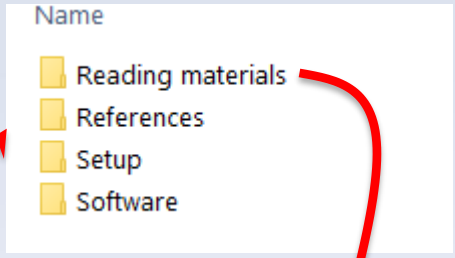


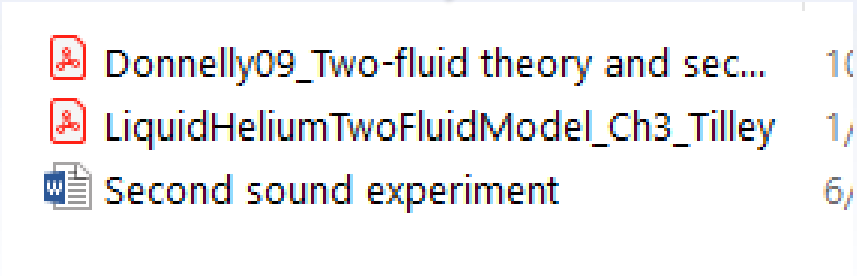
Where to retrieve course information.

Material Prepared for Online Teaching





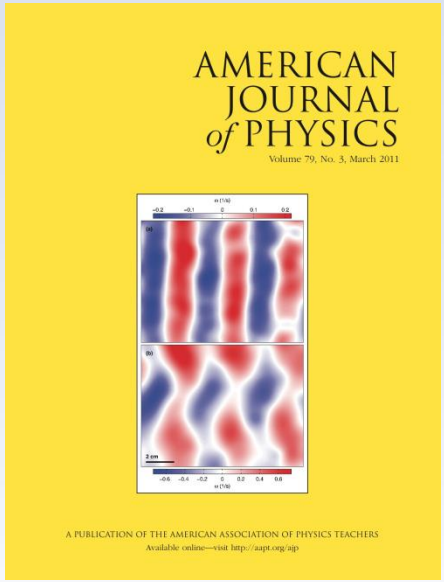


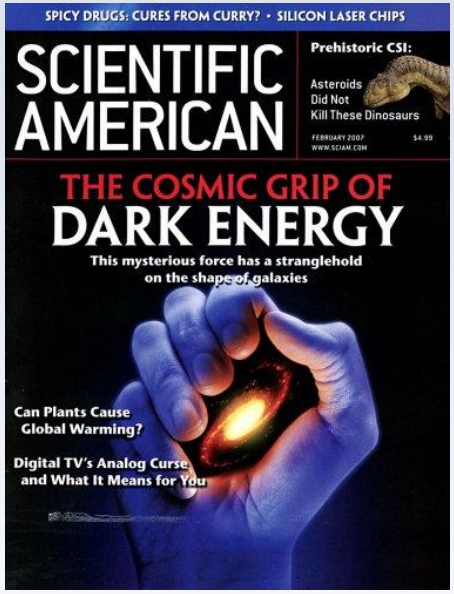


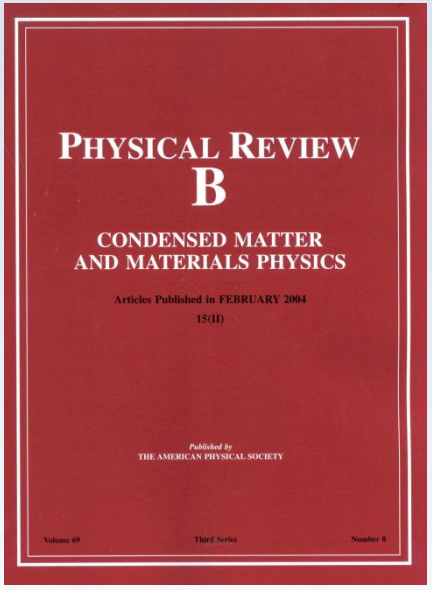
"Journal club"

Lectures – Tuesdays 3pm

Journal Club – Thursdays 3pm







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

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

http://www.scientificamerican.com/

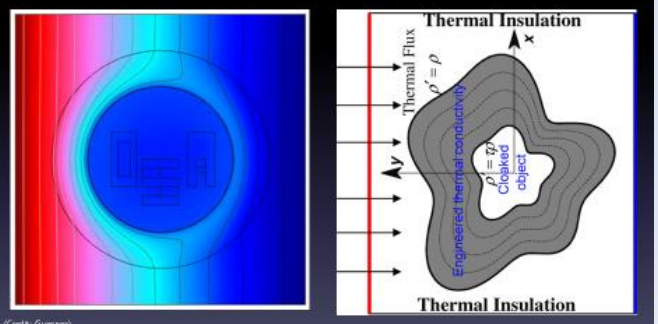
http://www.sciencemag.org/journals

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

"Journal club"

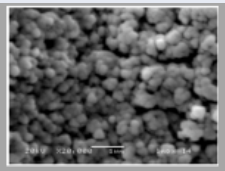
Walking with Coffee: Why Does it Spill?

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

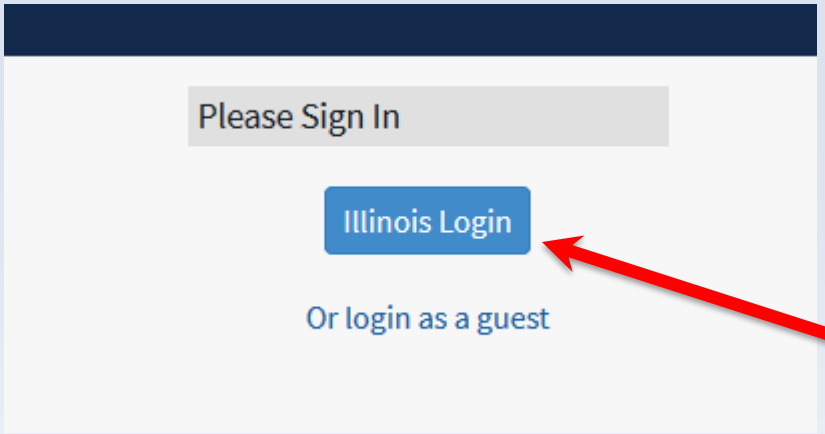
If you cannot access journal papers using VPN, go to UIUC's library proxy test site and enter the address of the paper you want to read:
http://www.library.illinois.edu/proxy/test/

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

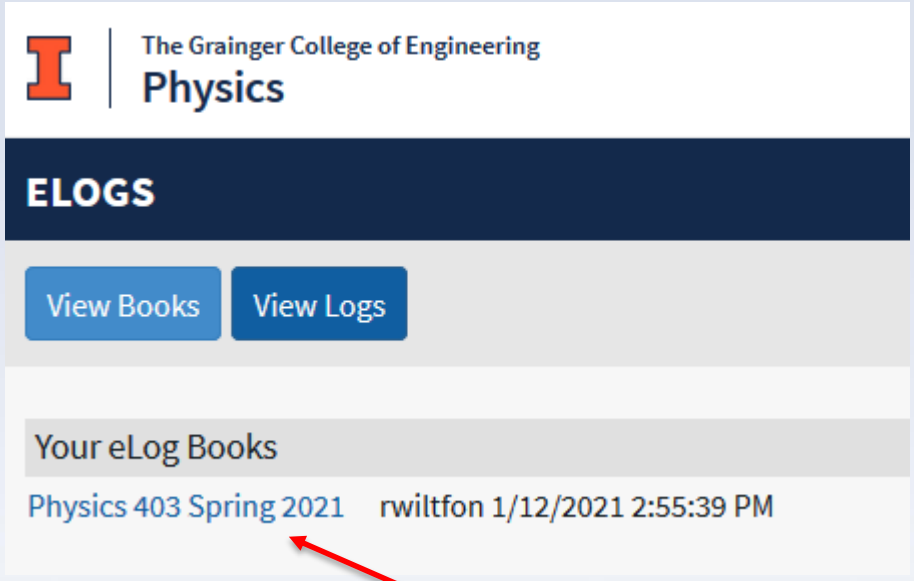
Entering the e-Log …

Entering the e-Log …



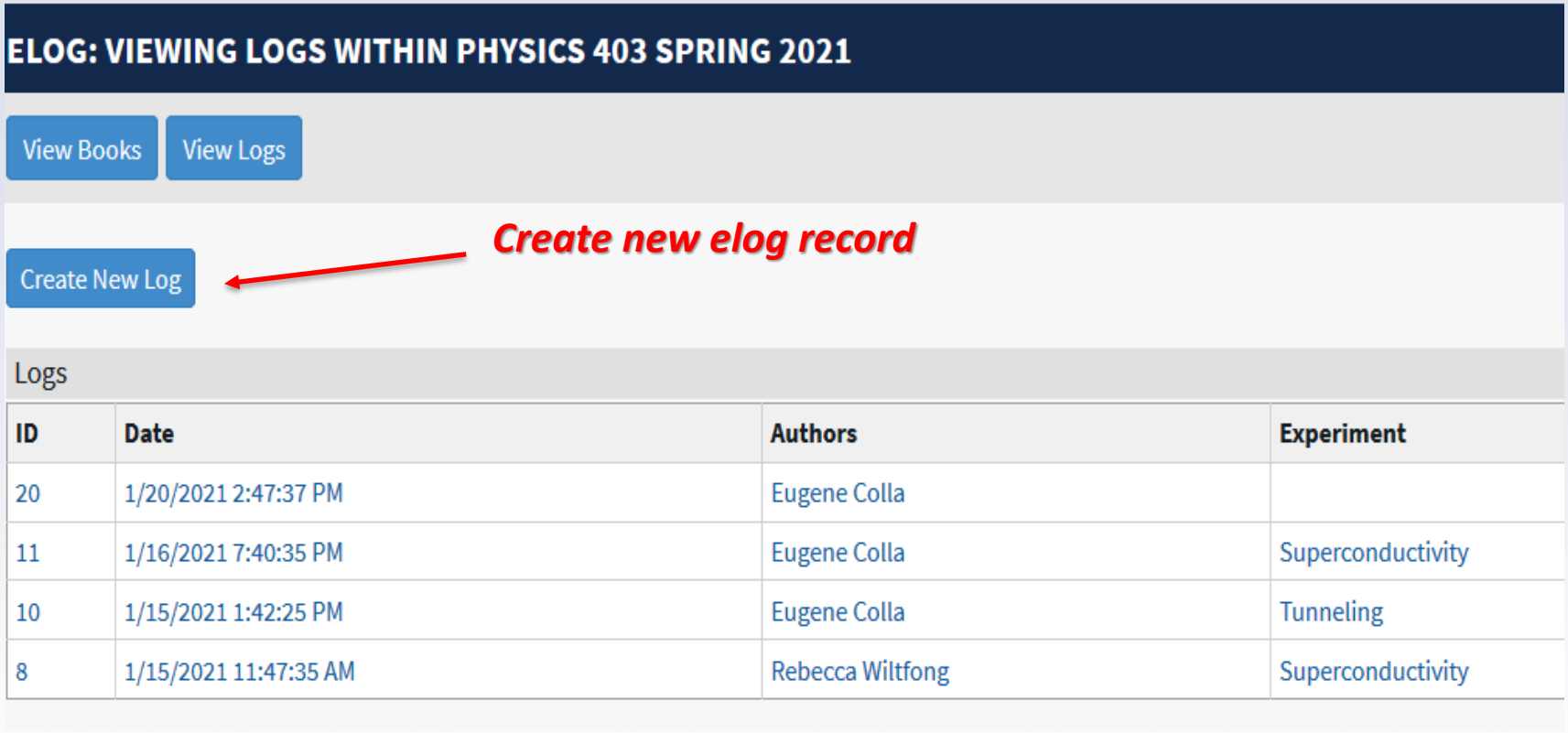
Use your University Username and Password

Entering the e-Log …

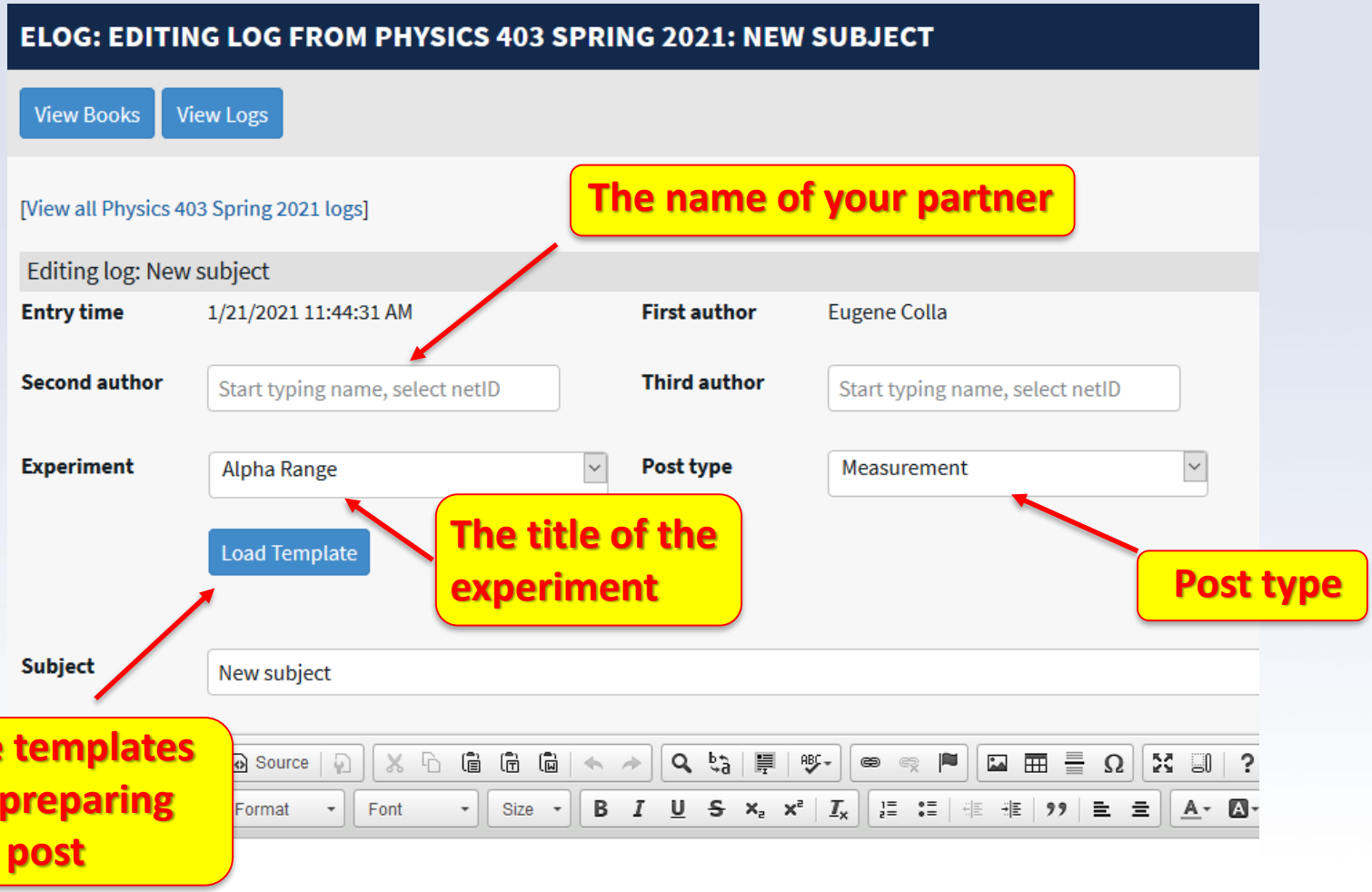


Spring 2021 elog folder

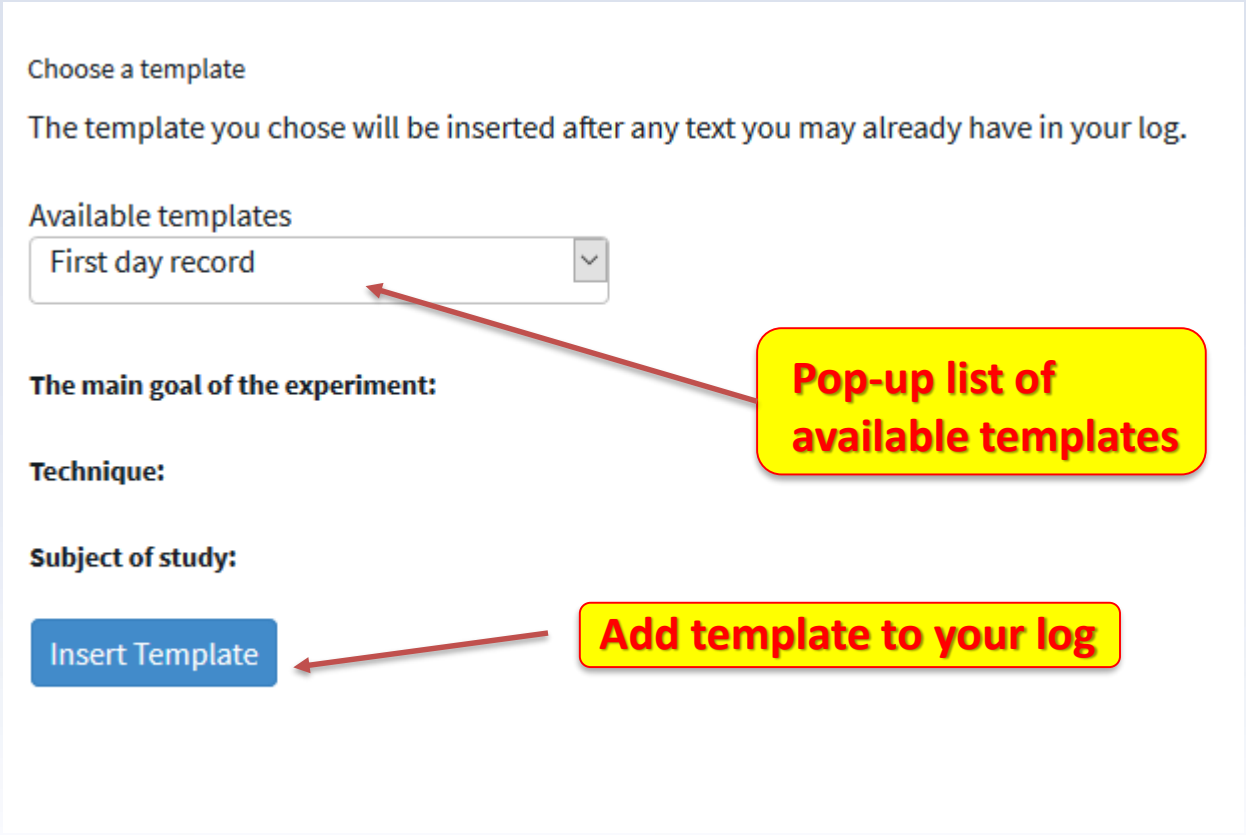
Entering the e-Log …



Entering the e-Log …



Entering the e-Log …



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 …

- **Create a New Post**
- **To create a new post, click "New" from the menu bar.**
- **Fill in the *Author, Experiment, Post Type, and Subject***

  If the post is written by more than one person, use a comma separated list.

  Be sure the Author name is the same you used when registering so that you can edit/delete the post if necessary.

e-logs: Making a post …

Author:	Your name and your partner's name
Experiment:	General
Post Type:	How-To
Subject:	Day [#]: brief description of work

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 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…"

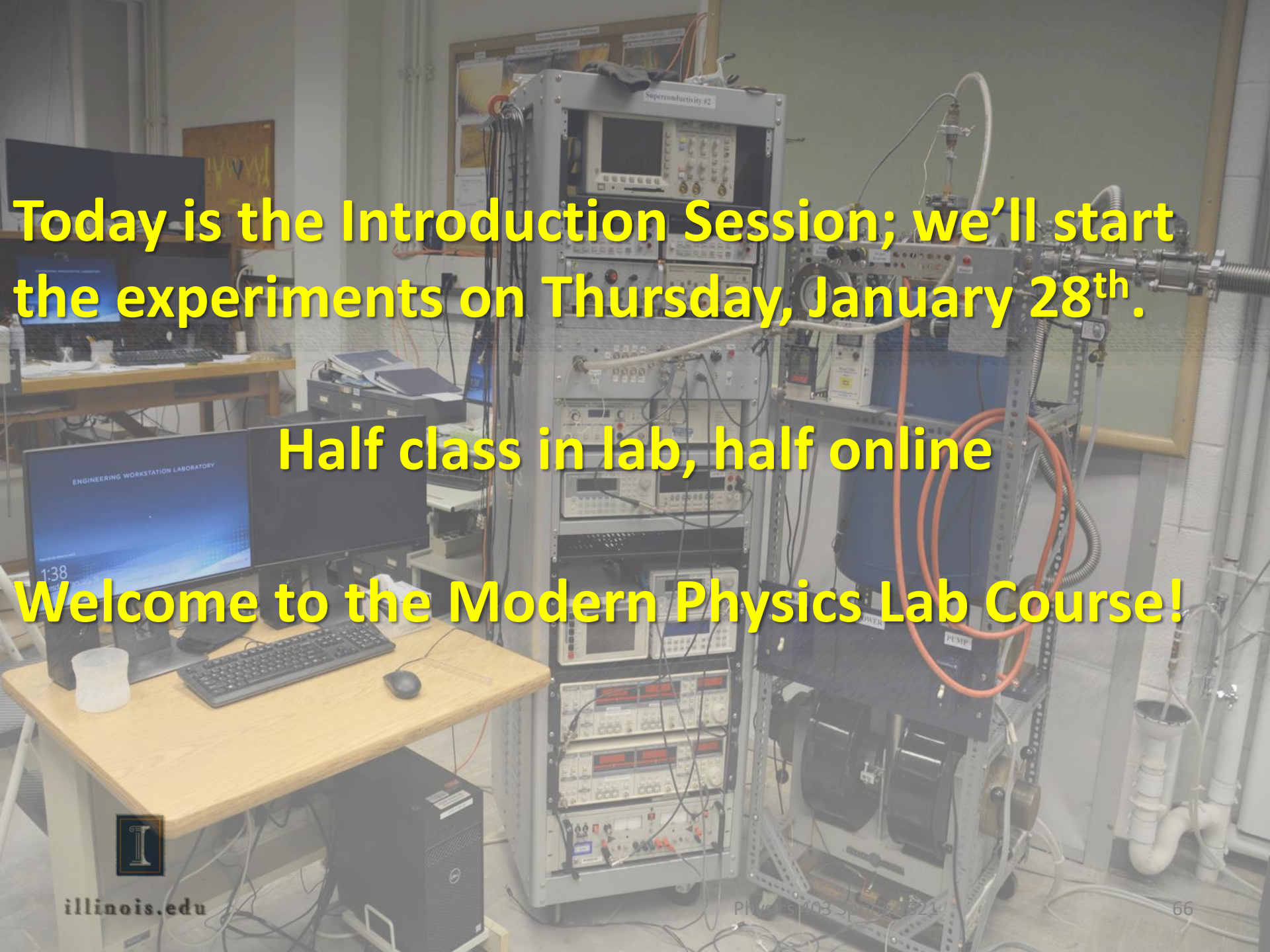
Some General Physics 403 Rules.

No Food or Drinks in Lab !
Except ESB5105

Some General Physics 403 Rules.

ESB5105

This is the area where you can have a short brake to drink coffee or tea… Keep the social distance and do not overload the declared room capacity



Today is the Introduction Session; we'll start the experiments on Thursday, January 28th.

Half class in lab, half online

Welcome to the Modern Physics Lab Course!