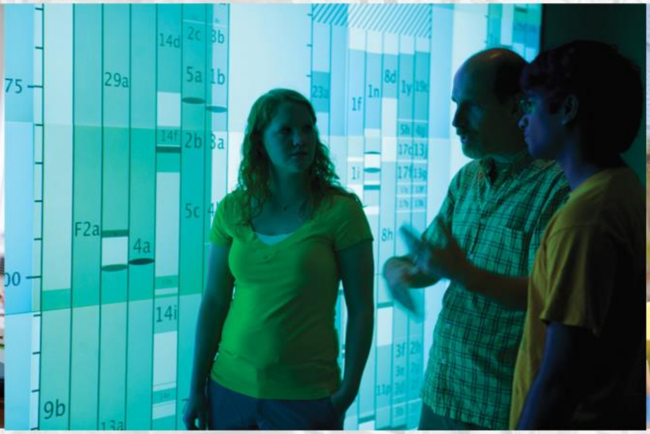
UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Physics 403. Modern Physics Laboratory

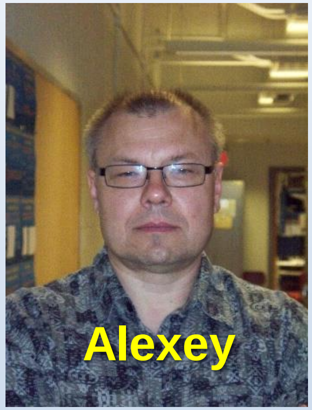
Summer 2016

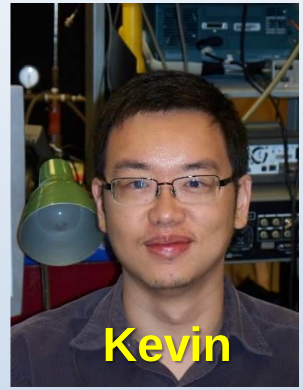
Eugene V Colla

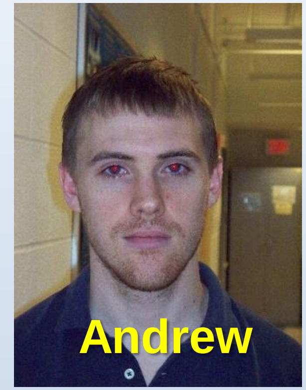


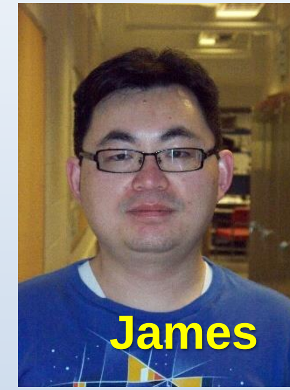
Physics 403 Modern Physics Laboratory

Summer 2016 Teaching Team









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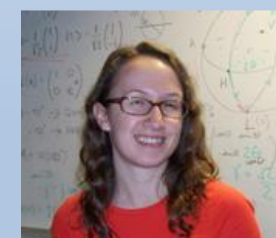
Michelle

Joseph



Rebecca

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

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Course Goals. Primary goals:

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

  ✓ Each project is a mini-research effort

  ✓ 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

* In red gradable assignments

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Course Goals. Secondary goals:

- Learn some modern physics
  - Many experiments were once Nobel-prize-worthy efforts
  - They touch on important themes in the development of modern physics
  - Some will provide additional insight to understand advanced courses you have taken
  - Some are just too new to be discussed in textbooks

The Experiments. Three main groups.

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

You will do the experiment from all these groups

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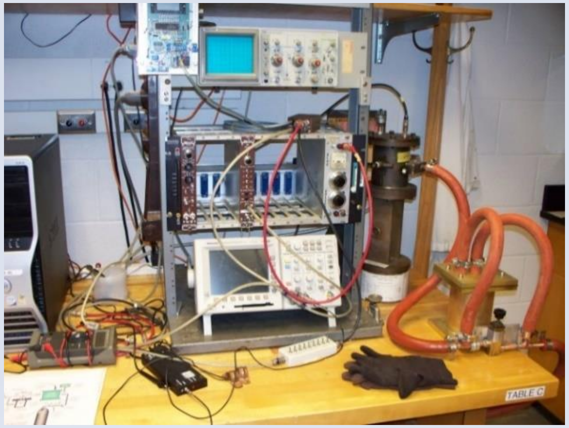
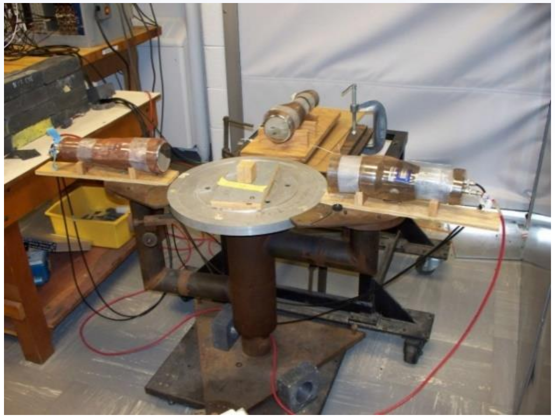
The Experiments

- **Nuclear / Particle (NP)**
  - Alpha particle range in gasses
  - Cosmic ray muons:

    Lifetime, capture rate, magnetic moment
  - Angular correlations in nuclear decay
  - Angular distribution of cosmic rays
  - γ–γ correlation experiment
  - γ – spectroscopy
  - Mössbauer spectroscopy (new)





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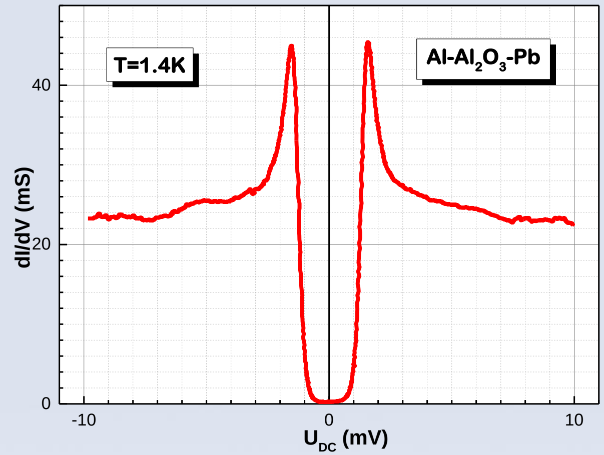
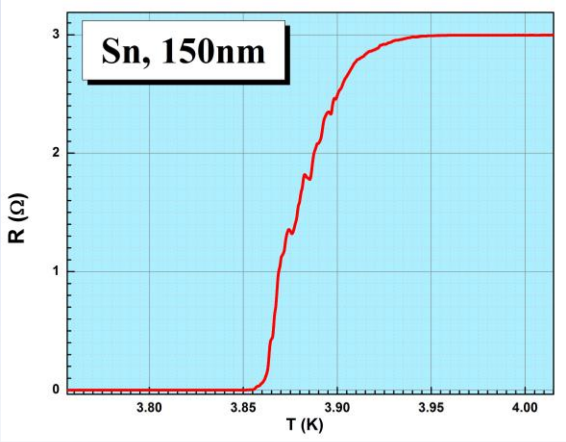
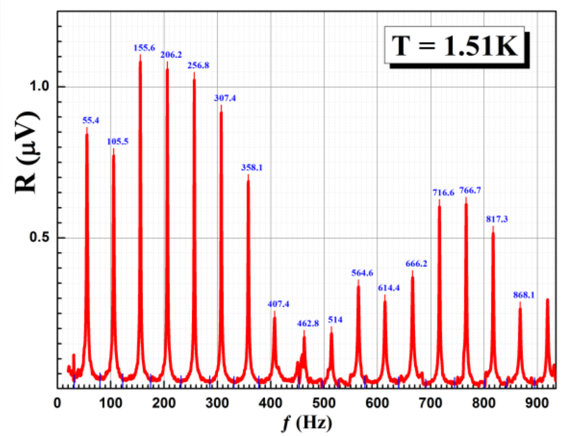
The Experiments

- **Condensed Matter (CM)**
  - Superconductivity
  - Tunneling in superconductors
  - 2[nd] sound in [4]He superfluid state







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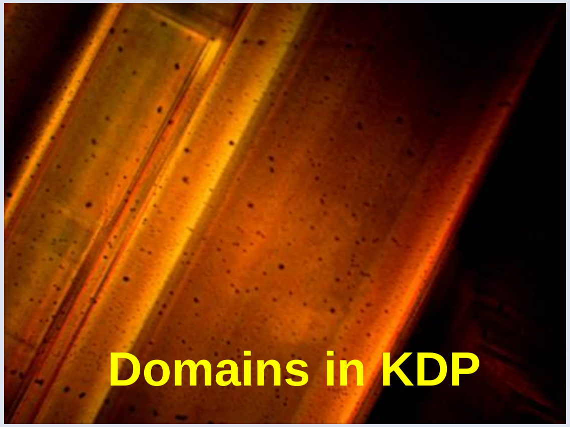
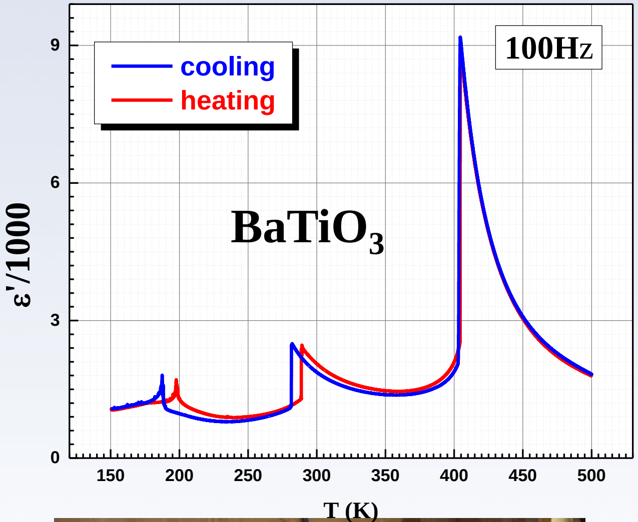
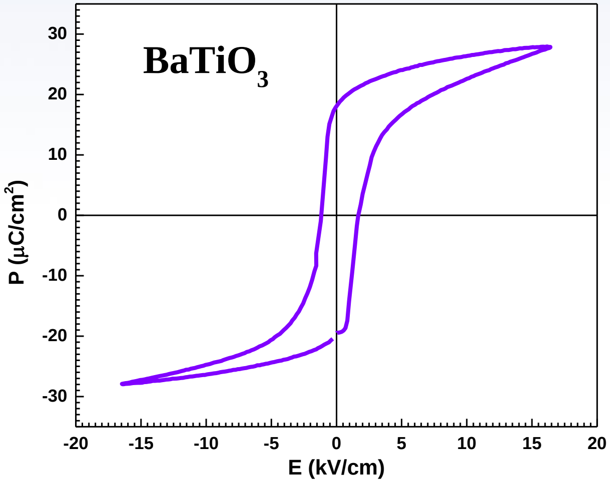
The Experiments

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







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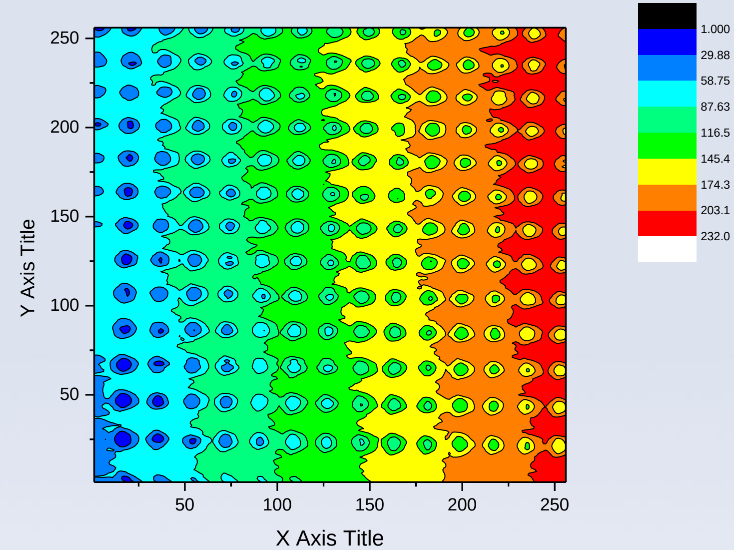
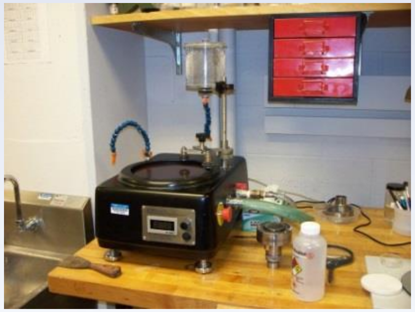
The Experiments

- **Condensed Matter (CM)**

- **Special Tools:**
- **Vacuum film deposition**
- **Atomic Force Microscope**
- **Polarizing microscope**

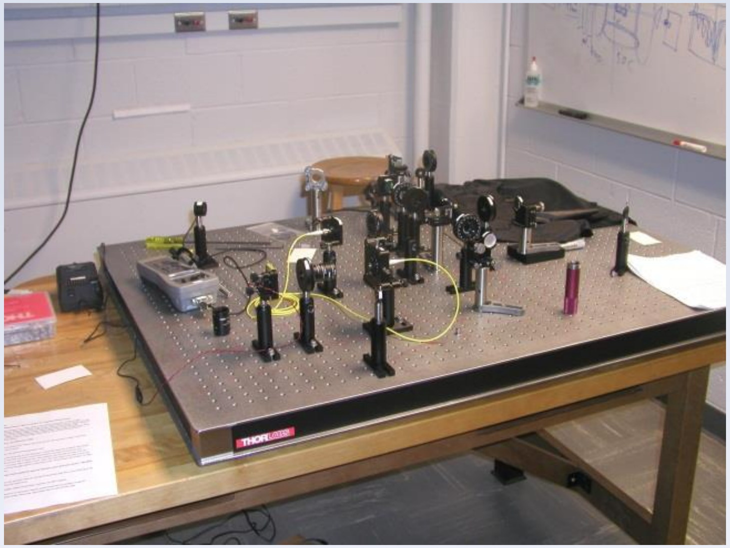


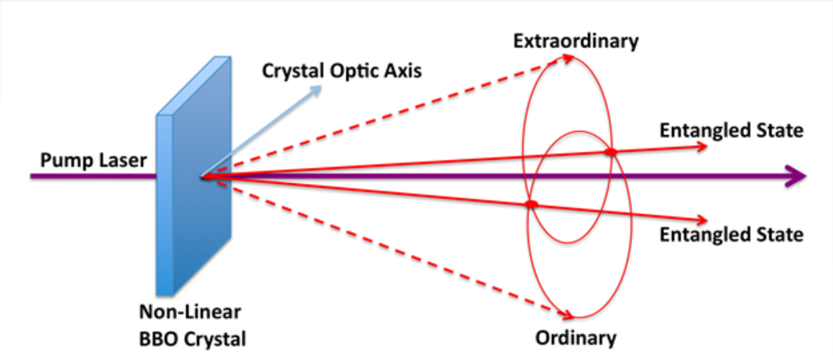


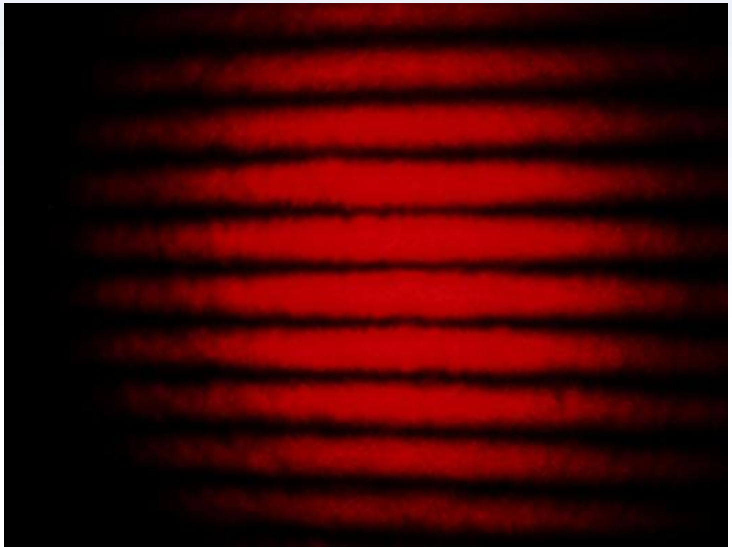
The Experiments

Atomic/Molecular/Optics (AMO)

- **Berry's phase**
- **Quantum erasure**
- **Quantum Entanglement**







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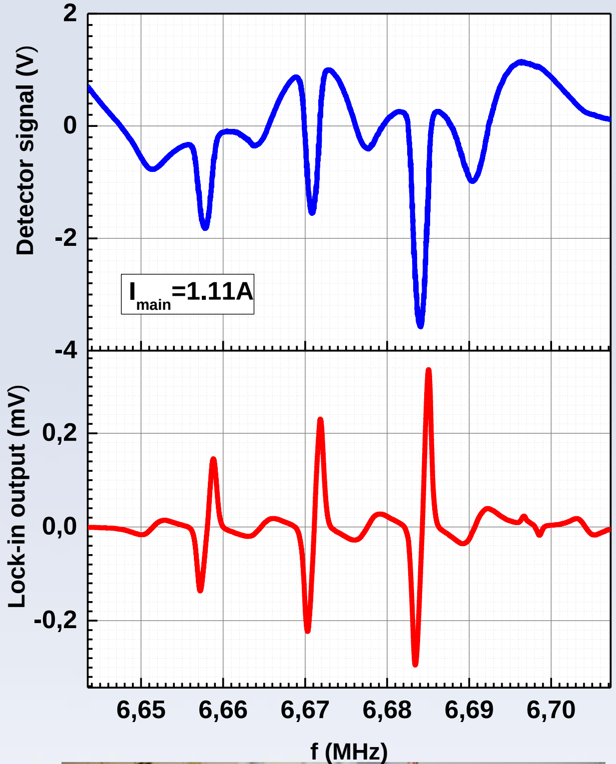
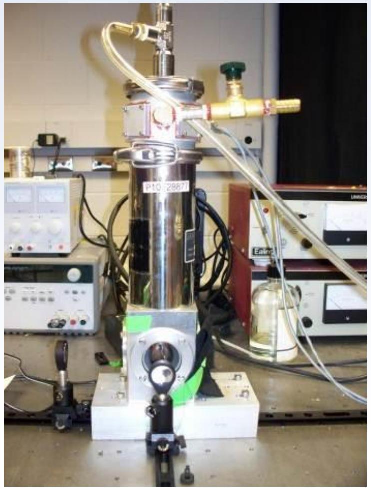
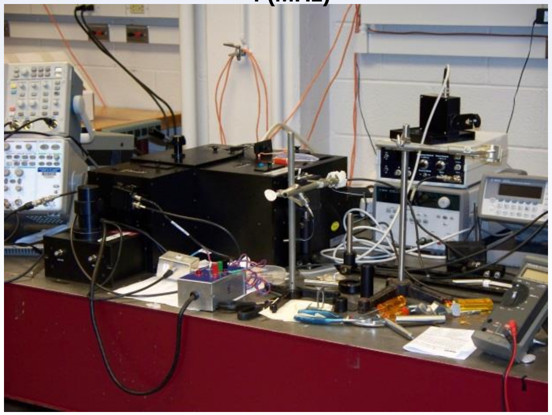
The Experiments

Atomic/Molecular/Optics (AMO)

- Optical pumping of rubidium gas
- Fluorescence spectroscopy







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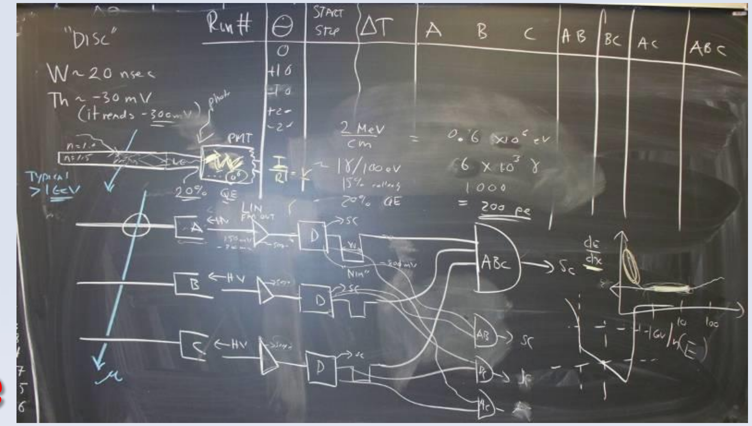
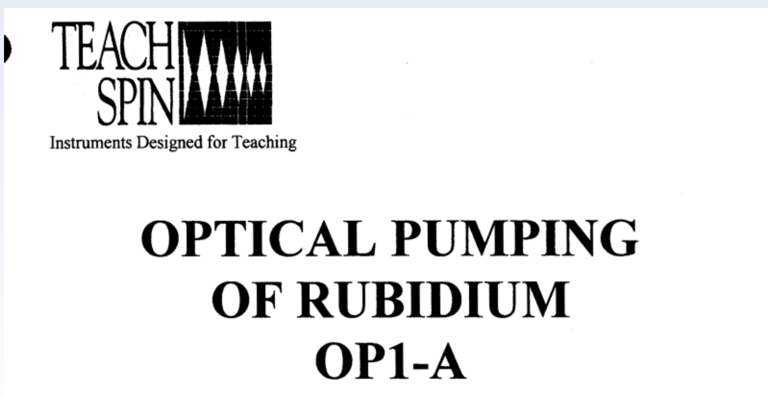
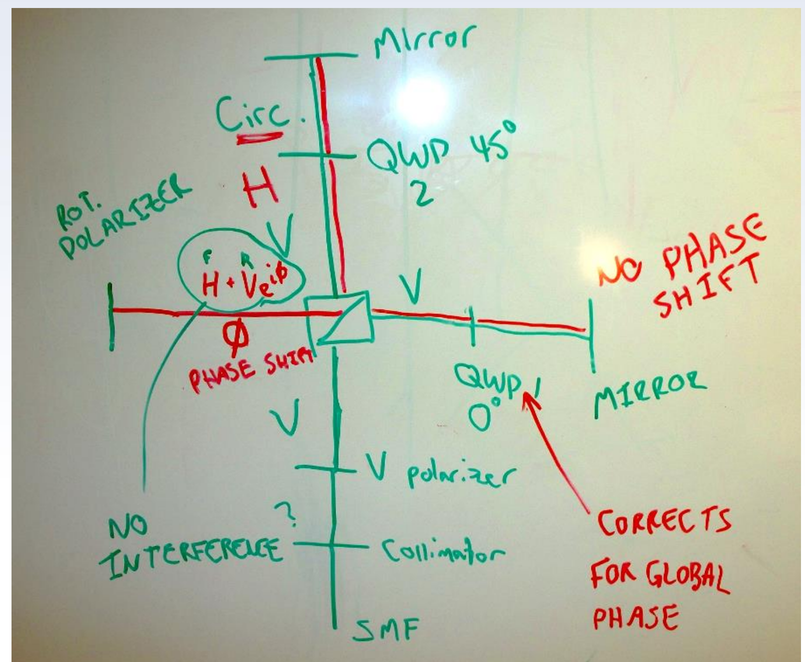
The "manuals"

- Many are just guides
- A only few purchased experiments have "real" manuals
- We serve as your guides … like real research




TEACH SPIN
Instruments Designed for Teaching

OPTICAL PUMPING
OF RUBIDIUM
OP1-A



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Grading: Distribution of "670" points

Item	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
Oral reports: motivation, organization of presentation; fielding questions	150 75 / oral
Total	670

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 August, 5)

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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

Absences

- If you are sick, let Eugene know by email. 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.

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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.

Syllabus

Cycles

	Date	Day	Activity		Lectures*: 10am Journal club: 3pm	Note	Due days
			8am-noon	1pm-5pm			
1	6/14	Tues	Orientation		About Phy403		
2	6/15	Wed	Cycle 1-1	Cycle 1-2	OriginPro Intro		
3	6/21	Tues	Cycle 1-3	Cycle 1-4	Elog Comments		
4	6/22	Wed	Cycle 1-5	Cycle 1-6	Lock-in Amps and FT		
5	6/28	Tues	Cycle 1-7	Cycle 1-8	Written Reports		
6	6.29	Wed	Cycle 1-9	Cycle 1-10	High Energy Physics		C1-Ex1(7.09.15)
7	7/05	Tues	Cycle 1-11	Cycle 1-12	Error analysis		
8	7/06	Wed	Cycle 2-1	Cycle 2-2	Oral Reports/Talks	Rotate	
9	7/12	Tues	ORALS Cycle 1				
10	7/13	Wed	Cycle 2-3	Cycle 2-4	Optical spectroscopy		C1-Ex2(7.22.15)
11	7/19	Tues	Cycle 2-5	Cycle 2-6	Noise		
12	7/20	Wed	Cycle 2-7	Cycle 2-8	Measuring Temperature		
13	7/26	Tues	Cycle 2-9	Cycle 2-10	Entanglement		C2-Ex1(7.30.15)
14	7/27	Wed	Cycle 2-11	Cycle 2-12	Ferroelectricity		
15	8/2	Tues			Working Day / Catch-up		
16	8/3	Wed	ORALS Cycle 2				
17	8/4	Thurs-day			READING DAY		C2-Ex2(8.05.15)

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* **Lecture topics are subject to change**

Assignment of experiments

2 cycles with 2 experiments

- → **teams change after cycle**
- → **joint team reports and oral presentations**

	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. Cosmic angular distribution	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	A.Optical pumping B.Superconductivity C.Mutual inductance	A. Quantum Table i. Berry's phase ii. Quantum erasure iii. Entanglement B. Florescence spectroscopy
	Alexey, Andrew	Eugene	Eugene, James	Kevin and TA's from Kwiat Lab
C1-1	1,2; 3,4; 5,6	7,8, 9,10; 11,12; 13,14; 15,16	17,18; 19,20	21,22; 23,24
C1-2	9,10; 11,12; 13,14; 15,16	21,22; 23,24; 17,18; 19,20	1,2; 3,4;	5,6; 7,8;
C2-1	18,19; 20,21; 22,23; 17,24	2,3; 4,5; 6,7; 1,8	10,11; 12,13	14,15; 9,16
C2-2	4,5; 1,8; 17,24; 9,16	18,19; 20,21; 14,15; 12,13	22,23; 6,7	2,3; 10,11

Summer 2016

Physics 403

Cycle	#	Experiment
C1-1	1,2	Cosmic Muon
	3,4	Alpha Range
	5,6	Gamma-Gamma
	7,8	AFM
	9,10	Ferroelectricity in BaTiO3 – dielectric study
	11,12	Pulsed NMR water-glycerol solution
	13,14	Second sound in He4
	15,16	Ferroelectricity in BaTiO3 – hysteresis loops
	17,18	Superconductivity in Sn films – contact measurements
	19,20	Optical pumping
	21,22	Fluorescence
	23,24	Quantum Optics
C1-2	1,2	Superconductivity in Sn films – mutual inductance experiment
	3,4	Optical pumping
	5,6	Fluorescence
	7,8	Quantum Optics
	9,10	Cosmic Muon
	11,12	Gamma-Gamma
	13,14	Alpha Range
	15,16	Mössbauer spectroscopy
	21,22	pNMR water with paramagnetic impurities experiment
	23,24	Ferroelectricity in KH_2PO_4 – dielectric study
	17,18	Ferroelectricity in KH2PO4 – optical experiment (domains study)
	19,20	Tunneling in Al-Al_2O_3-Pb junctions

Summer 2016 Physics 403

Cycle	#	Experiment
C2-1	1,8	Tunneling in Al-Al_2O_3-Sn Junctions
	2,3	NMR in water with paramagnetic impurities
	4,5	Ferroelectric Phase transition in KD_2PO_4. Dielectric Study. (Ferro1)
	6.7	Ferroelectric Phase transition in KD_2PO_4 (domains) Ferro2
	9,16	Fluorescence
	10,11	Optical Pumping
	12,13	Superconductivity in In Films
	14,15	Quantum Optics
	17,24	Cosmic Muon
	18,19	Gamma-Gamma
	20,21	Alpha Range
	22,23	Muon Telescope
C2-2	1,8	Alpha Range
	2,3	Fluorescence
	4,5	Cosmic Muon
	6,7	Optical Pumping
	9,16	Gamma-Gamma
	10,11	Quantum Optics
	12,13	Antiferroelectrics. Polarization Study. (Ferro3)
	14,15	pNMR Curing the Epoxy
	17,24	Mössbauer spectroscopy
	18,19	Tunneling in Al-Al_2O_3-In Junctions
	20,21	Ferroelectric Relxors (Ferro1)
	22,23	Superconductivity in In Films. Mutual Inductance Experiment

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Orals

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. 9

Cycle	#	Experiment
C1-1	1,2	Cosmic Muon

C1-2	1,2	Superconductivity in Sn films – mutual inductance experiment

It is possible to split the team and give two talks in sole by each partner

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)

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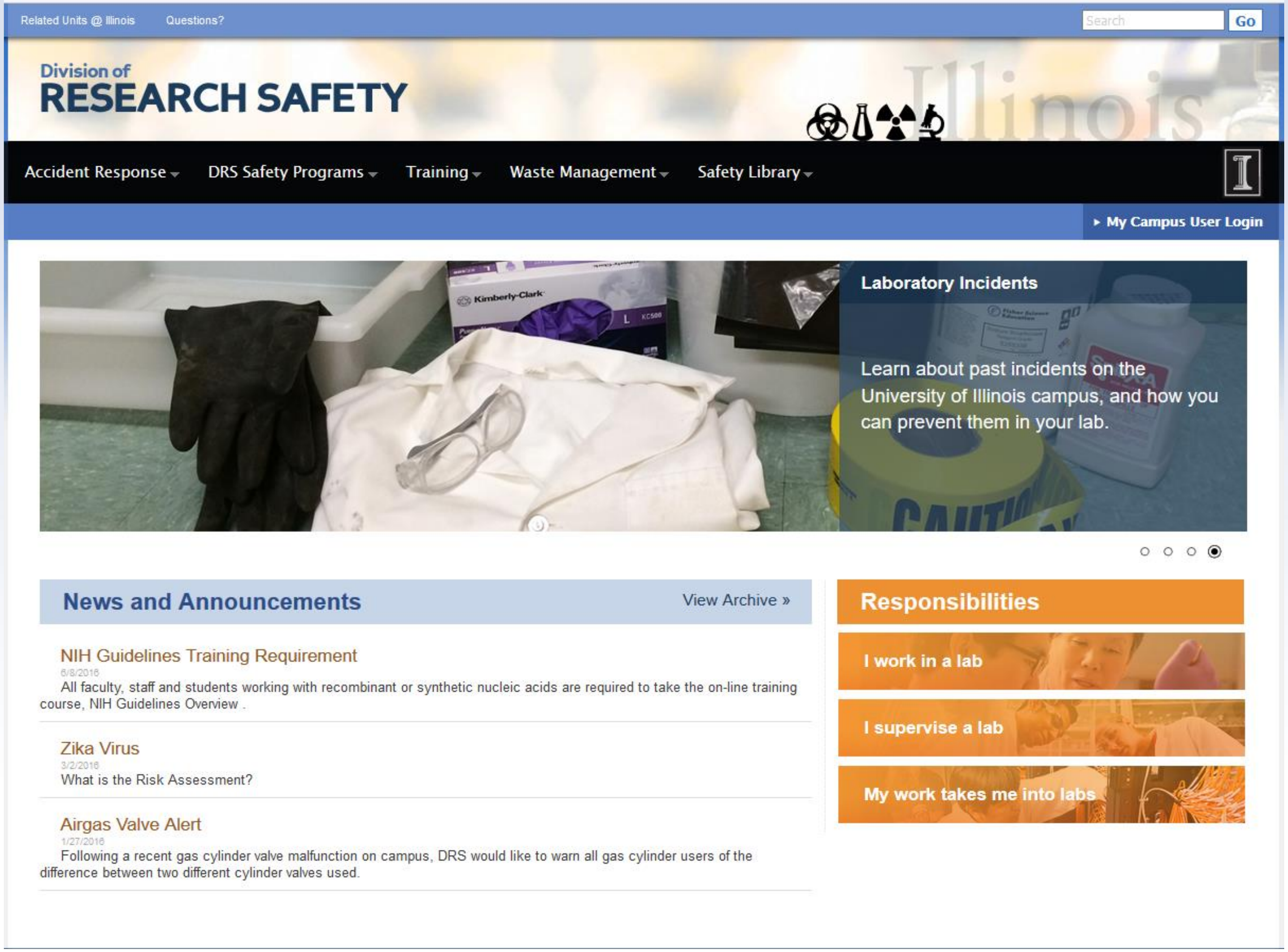
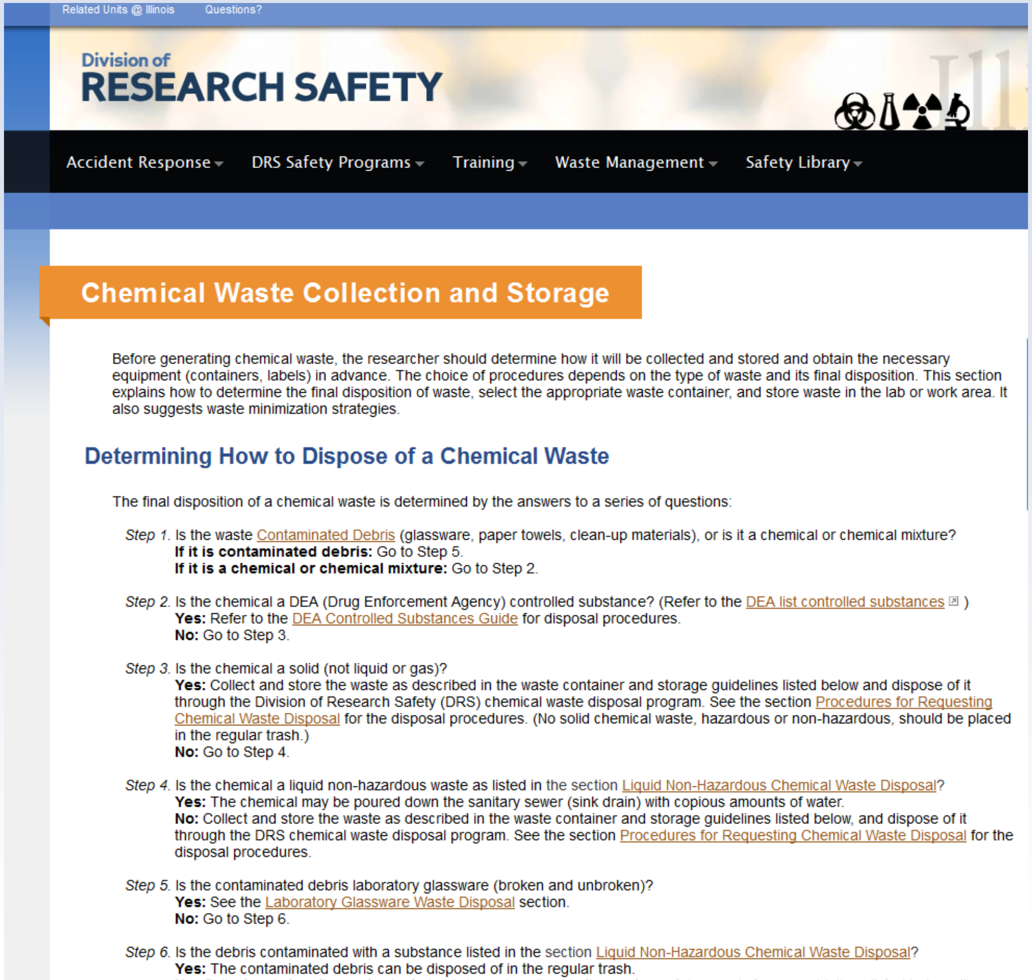
Follow Directly the Recommendations of Safety Working

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

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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

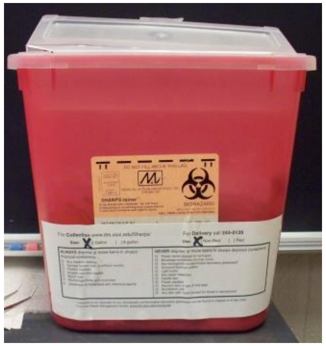
Definition

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

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How to record 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
- Use a software drawing program to make a detailed sketch

How to record 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 data

- Many experiments require you to “change and measure” something by hand
  - Make a table in a paper logbook for this
  - Be prepared to state your measurement uncertainty
  - Make a “quick sketch” of your results by hand; then, enter the data in an electronic table and make a final plot
    - 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 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.

(i) Your data, projects, tables etc

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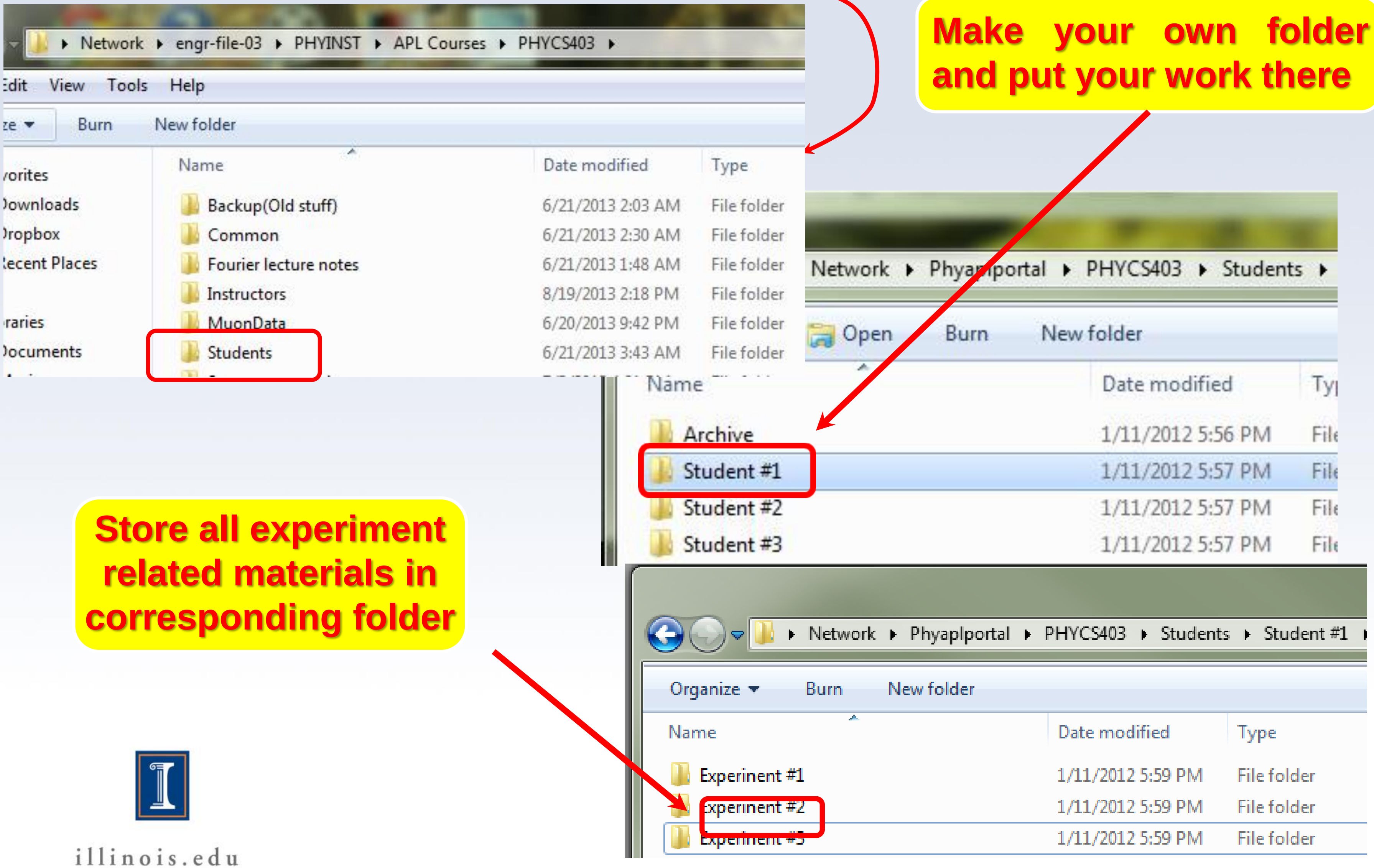
Make your own folder and put your work there



Store all experiment related materials in corresponding folder

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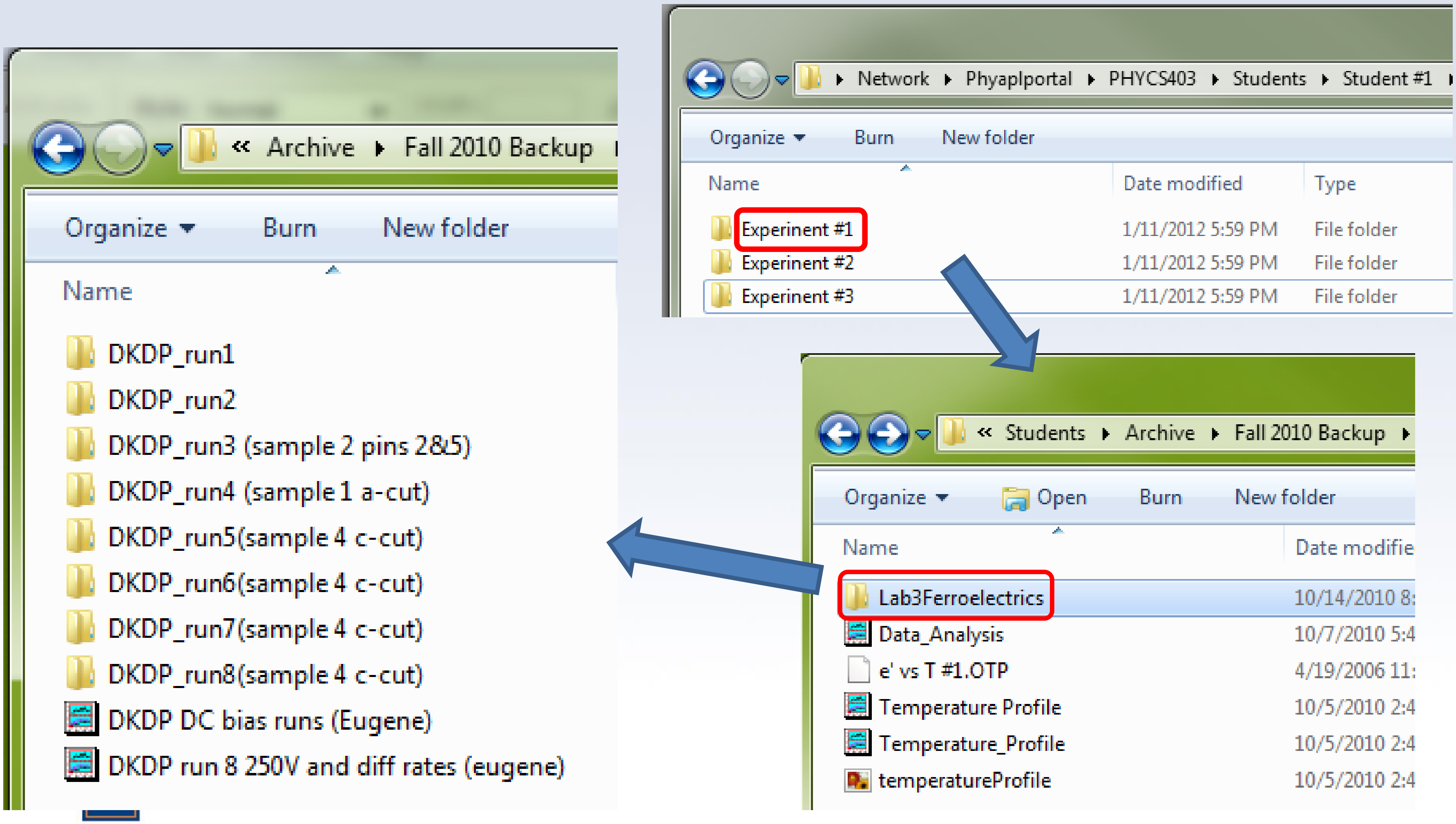
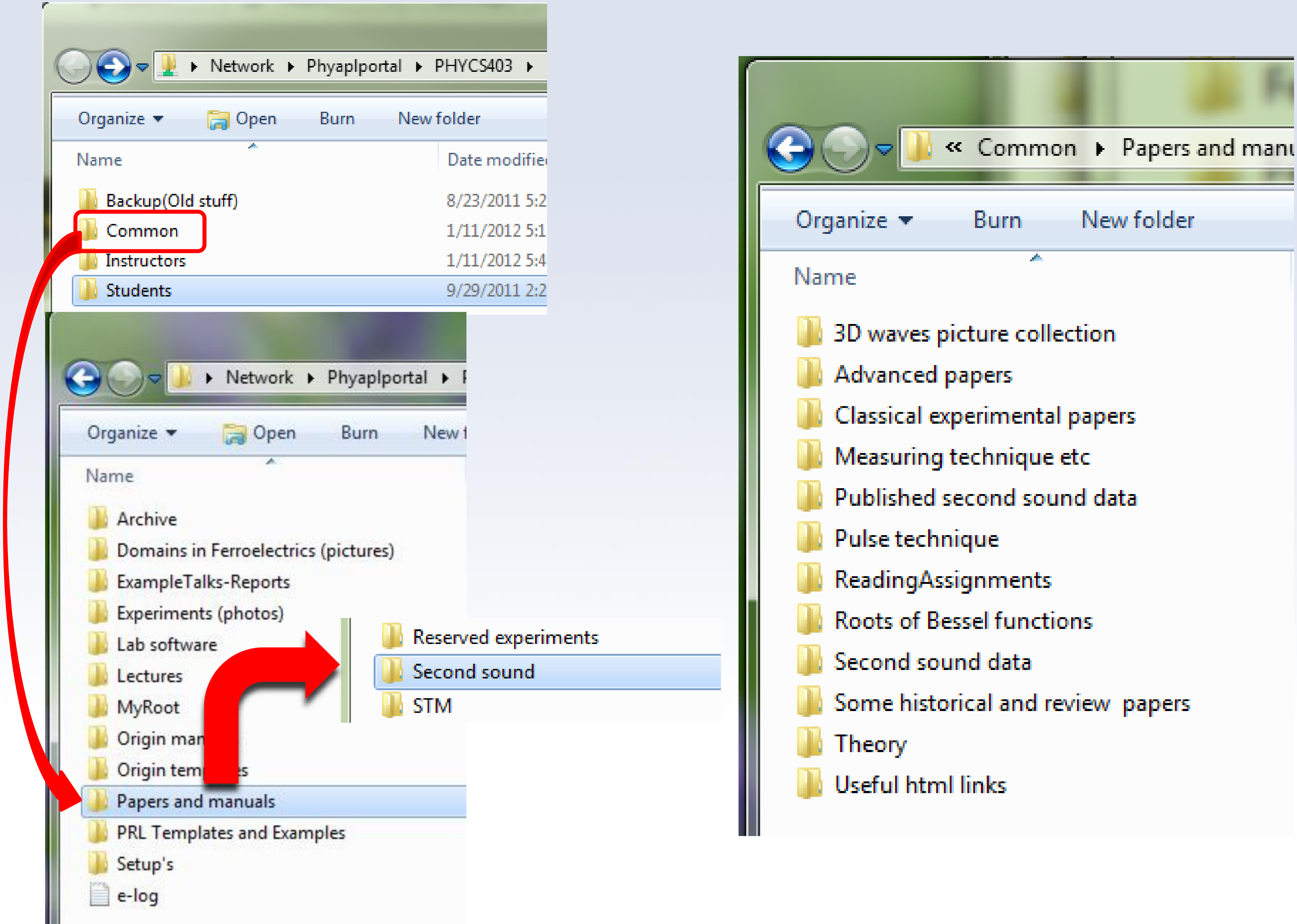
Where to exchange, store and retrieve course information. *(i)* *Your data, projects, tables etc*

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



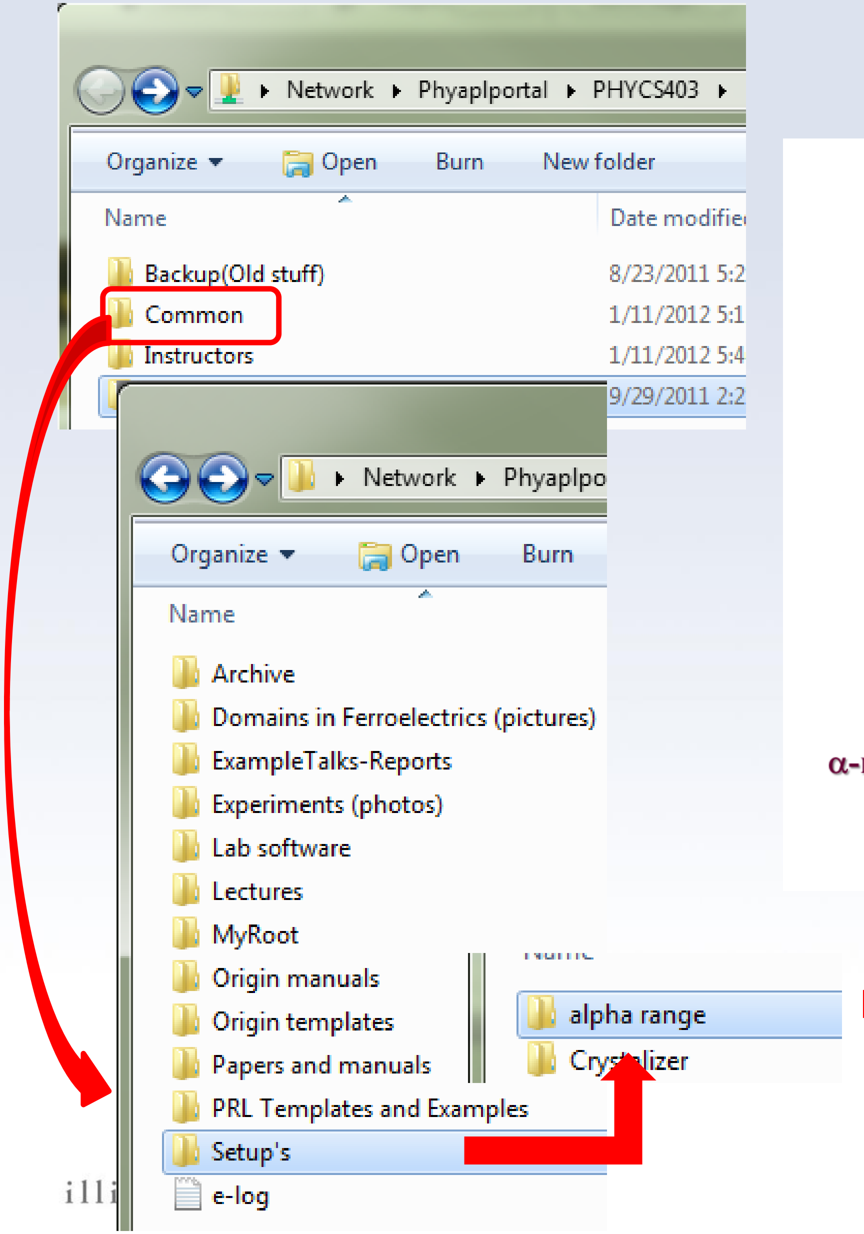
Where to retrieve course information.

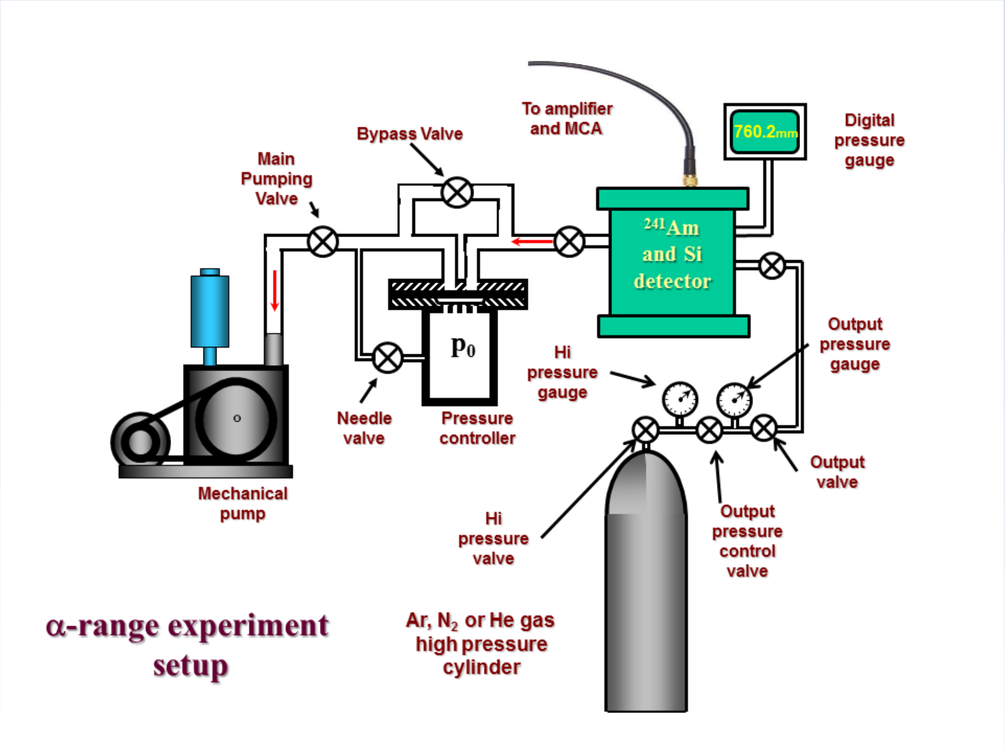
Manuals, papers, **setup diagrams and other useful materials**



Where to retrieve course information.

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

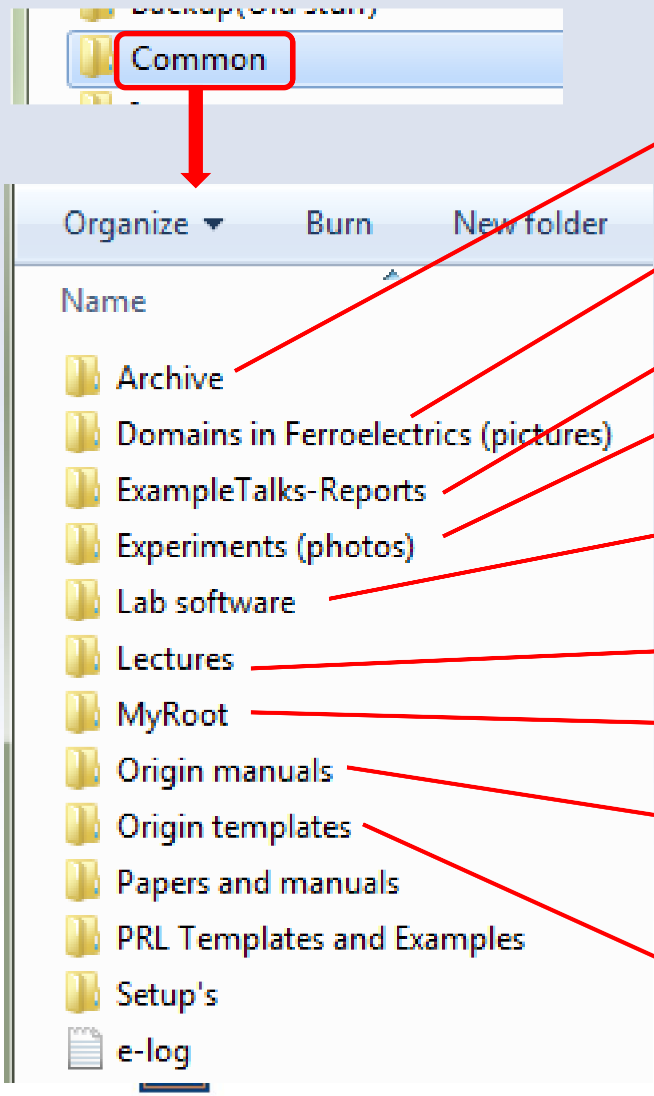




α-range experiment setup diagram

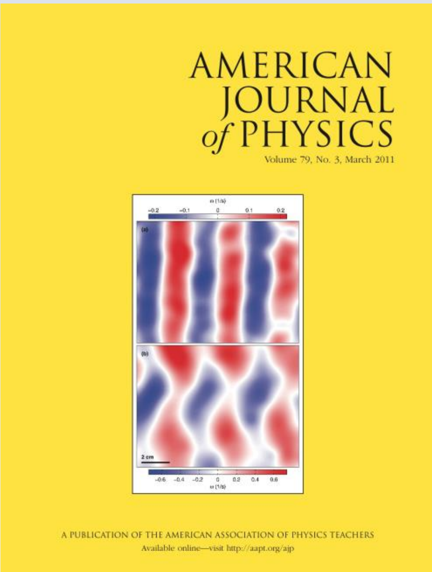
Where to retrieve course information.

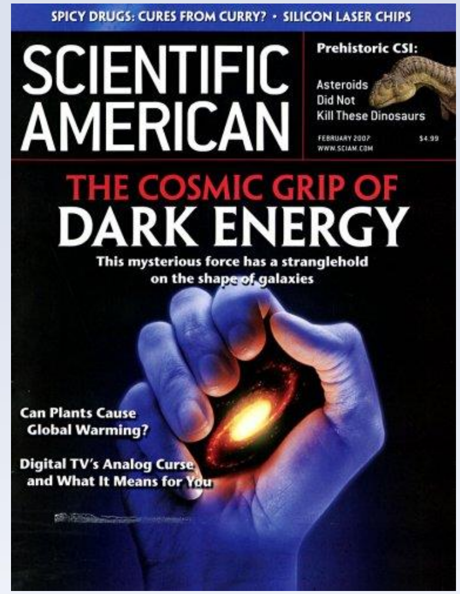
Manuals, papers, setup diagrams and *other useful materials*

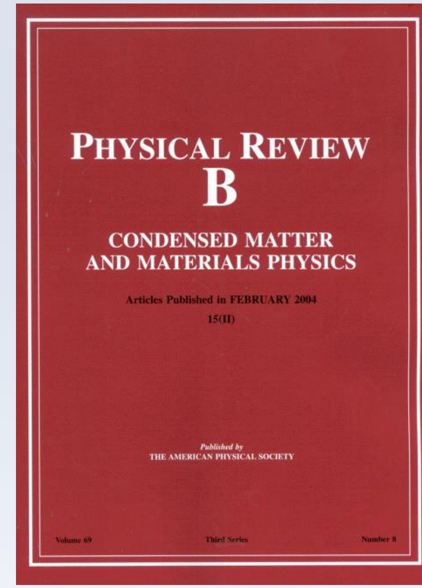


- Some old stuff (not very useful)
- Sample pictures of ferroelectric domains
- Examples of report and oral presentation
- Pictures of the setups of the experiments
- Software including DAQ software for different experiments. Newest version of Origin is also there
- P403 lecture notes
- C++ scripts for Root
- Origin manuals + a very compressed version written by Eugene
- Origin templates (how to use them will be discussed in next lecture)

"Journal club"







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

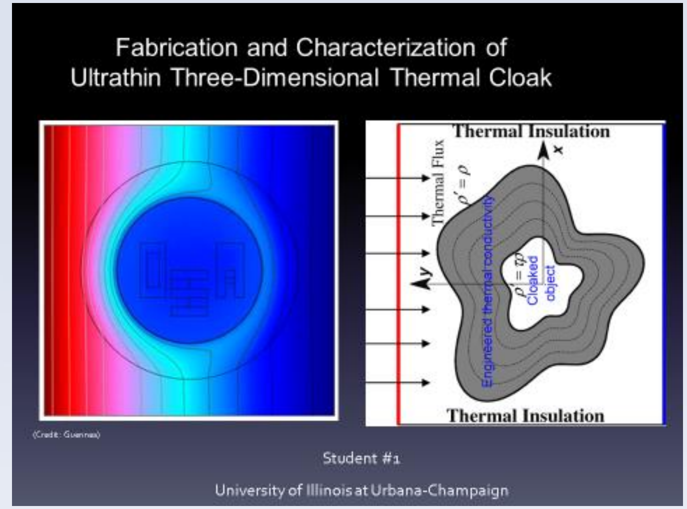
http://www.nature.com/nature/index.htm

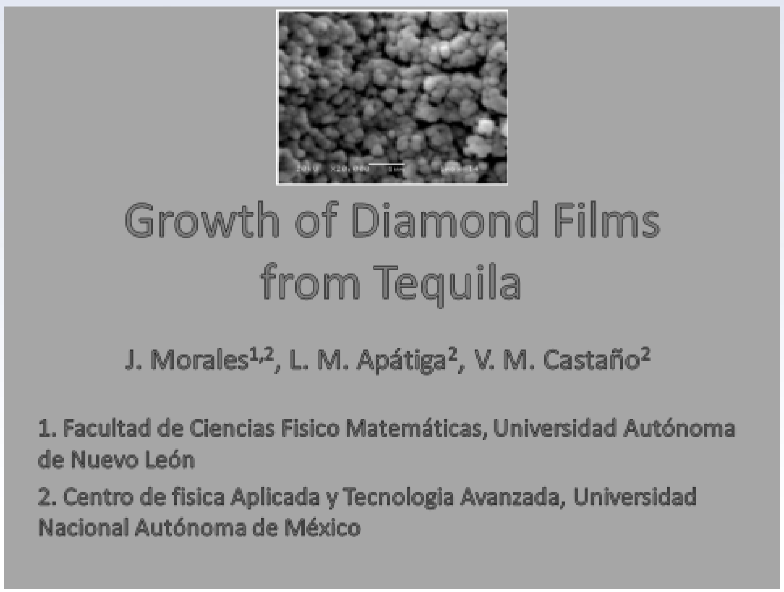
http://www.scientificamerican.com/

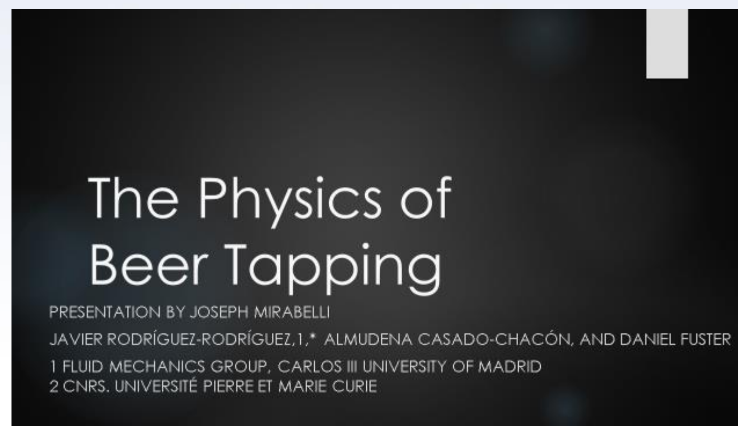
http://publish.aps.org
or http://prola.aps.org/

illinois.edu

"Journal club"







e-logs: First a brief tour …

http://www.npl.illinois.edu/elog/modphys/

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 a temporary folder on your desktop.
- Near the end of the class, make a "Shift Summary" providing a rather complete overview of the highlights of your work. There, you can upload your plots, scope shots, etc. and describe the data

Entering the e-Log …
(at this point, you need to work on a computer)

Registering as a new user

- Go to http://elog.npl.illinois.edu/phys403//
- Click "Register as new user" on the bottom right

- Fill in information for login name, Full Name, e-mail address, and password

PASSWORD IS NOT SECURE, DO NOT USE A "SENSITIVE" PASSWORD

- Click "Save" in the upper left hand corner

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.