Physics 403. Modern Physics Laboratory

Fall 2016

Eugene V Colla, Virginia Lorenz
Physics 403 Modern Physics Laboratory

Fall 2016 Teaching Team

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Longxiang Zhang

Support from Kwiat research group

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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
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
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
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
  – $\gamma-\gamma$ correlation experiment
  – $\gamma$ – spectroscopy
  – Mössbauer spectroscopy (new)
The Experiments

- Condensed Matter (CM)
  - Superconductivity
  - Tunneling in superconductors
  - 2nd sound in 4He 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 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 “manuals”

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

OPTICAL PUMPING OF RUBIDIUM
OP1-A
Grading: Distribution of “1000” points

<table>
<thead>
<tr>
<th>Item</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Expt. documentation</strong></td>
<td><strong>180 Total</strong></td>
</tr>
<tr>
<td>eelog reports, shift summaries,</td>
<td>60 / cycle</td>
</tr>
<tr>
<td>plot quality; paper logbooks</td>
<td></td>
</tr>
<tr>
<td><strong>Formal reports</strong></td>
<td><strong>600 Total</strong></td>
</tr>
<tr>
<td>physics case, quality of results,</td>
<td>100 / report</td>
</tr>
<tr>
<td>depth of analysis, conclusions</td>
<td></td>
</tr>
<tr>
<td><strong>Oral reports</strong></td>
<td><strong>225 Total</strong></td>
</tr>
<tr>
<td>motivation, organization of</td>
<td>75 / oral</td>
</tr>
<tr>
<td>presentation; fielding questions</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1005</td>
</tr>
<tr>
<td><strong>Effective point total will be</strong></td>
<td>1000 grade</td>
</tr>
</tbody>
</table>

The grading scale will be a percentage out of “1000”:

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 May 6th).
Grading: a piece of history and analysis of the results

Physics 403
2005-2016
290 students total
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.
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

<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>Activity</th>
<th>Comment</th>
<th>Due</th>
<th>Note</th>
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<tbody>
<tr>
<td>8/23</td>
<td>Tues</td>
<td>Orientation</td>
<td>About Phy403 (ec)</td>
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<tr>
<td>8/25</td>
<td>Thurs</td>
<td>Cycle 1-1</td>
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<td>8/30</td>
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<td>OriginPro/Root (ec/vl)</td>
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<tr>
<td>9/1</td>
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<td>Cycle 1-3</td>
<td>Elog Comments (ec/vl)</td>
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<tr>
<td>9/6</td>
<td>Tues</td>
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<td>Written Reports (ec)</td>
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<tr>
<td>9/13</td>
<td>Tues</td>
<td>Cycle 1-6</td>
<td>Error analysis (vl)</td>
<td>C1-Ex1 (9.14.16)</td>
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<tr>
<td>9/15</td>
<td>Thurs</td>
<td>Cycle 1-7</td>
<td></td>
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<tr>
<td>9/20</td>
<td>Thurs</td>
<td>Cycle 1-8</td>
<td>Oral Reports/Talks(ec/vl)</td>
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<tr>
<td>9/22</td>
<td>Thurs</td>
<td>Cycle 2-1</td>
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<tr>
<td>9/27</td>
<td>Tues</td>
<td>ORALS Cycle 1</td>
<td></td>
<td></td>
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<tr>
<td>9/29</td>
<td>Thurs</td>
<td>Cycle 2-2</td>
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<tr>
<td>10/4</td>
<td>Tues</td>
<td>Cycle 2-3</td>
<td>Optical spectroscopy (Kevin)</td>
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<tr>
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<td>Thurs</td>
<td>Cycle 2-4</td>
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<tr>
<td>10/11</td>
<td>Tues</td>
<td>Cycle 2-5</td>
<td>Measuring Temp (ec)</td>
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<td>Thurs</td>
<td>Cycle 2-6</td>
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<td>10/18</td>
<td>Tues</td>
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<td>Noise (mw)</td>
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<td>Thurs</td>
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<td>10/25</td>
<td>Tues</td>
<td>Cycle 3-1</td>
<td>ORALS Cycle 2</td>
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<td>10/27</td>
<td>Thurs</td>
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<td>Lock-in Amps and FT(ec)</td>
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<td>11/3</td>
<td>Thurs</td>
<td>Cycle 3-4</td>
<td>Ferroelectricity (ec)</td>
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<td>11/8</td>
<td>Tues</td>
<td>Cycle 3-5</td>
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<td>Rotate</td>
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<td>11/10</td>
<td>Thurs</td>
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<td>High Energy Physics (tba)</td>
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<td>11/19</td>
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<td>Thanksgiving Break</td>
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<td>Tues</td>
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<td>Thurs</td>
<td>Cycle 3-9</td>
<td>Entanglement (tba)</td>
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<td>12/3</td>
<td>Thurs</td>
<td>Working Day / Catch-up</td>
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<tr>
<td>12/6</td>
<td>Tues</td>
<td>ORALS Cycle 3</td>
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<tr>
<td>12/8</td>
<td></td>
<td>READING DAY</td>
<td>C3-Ex2 (12.10.16)</td>
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</tbody>
</table>

* Lecture topics are subject to change*
Assignment of experiments

3 cycles with 2 experiments

→ teams change after cycle

→ joint team reports and oral presentations
<table>
<thead>
<tr>
<th>NP</th>
<th>CM</th>
<th>Atomic + CM</th>
<th>Optics</th>
</tr>
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<tbody>
<tr>
<td>A. Cosmic Muon Stand</td>
<td>A. Ferro 1</td>
<td>A. Optical pumping</td>
<td>A. Quantum Table</td>
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<tr>
<td>i. Muon lifetime</td>
<td>B. Ferro 2 (imaging)</td>
<td>B. Superconductivity</td>
<td>i. Berry’s phase</td>
</tr>
<tr>
<td>ii. Capture rate</td>
<td>C. 2nd sound of 4He</td>
<td>C. Mutual inductance</td>
<td>ii. Quantum erasure</td>
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<tr>
<td>iii. Magnetic moment</td>
<td>D. pNMR</td>
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<td>iii. Entanglement</td>
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<tr>
<td>B. Alpha range</td>
<td>E. Hysteresis loops</td>
<td></td>
<td>B. Florescence spectroscopy</td>
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<tr>
<td>C. Gamma Gamma</td>
<td>F. Tunneling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Cosmic angular</td>
<td>G. AFM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>distribution</td>
<td>H. T calibration</td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Virginia, Mathew</th>
<th>Eugene</th>
<th>Eugene, James</th>
<th>Phil and TA’s from Kwiat Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1-1</td>
<td>1-2; 3-4; 5-6</td>
<td>7-8; 9-10; 11-12; 13-14; 23</td>
<td>15-16; 17-18; 19-20; 21-22;</td>
</tr>
<tr>
<td>C1-2</td>
<td>1-2; 3-4; 5,6</td>
<td>7-8; 9-10; 11-12; 13-14</td>
<td>19-20; 21-22</td>
</tr>
<tr>
<td>C2-1</td>
<td>16-17; 18-19; 20-21; 15-22</td>
<td>2-3; 4-5; 1-6</td>
<td>12-13; 7-14</td>
</tr>
<tr>
<td>C2-2</td>
<td>16-17; 18-19; 20-21; 15-22</td>
<td>2-3; 4-5; 1-6</td>
<td>8-9; 10-11</td>
</tr>
<tr>
<td>C3-1</td>
<td>7-11; 8-12; 9-13; 10-14</td>
<td>15-19; 16-20; 17-21; 18-22</td>
<td>1-4; 2-5</td>
</tr>
<tr>
<td>C3-2</td>
<td>7-11; 8-12; 9-13; 10-14</td>
<td>15-19; 16-20; 17-21; 18-22</td>
<td>3-6</td>
</tr>
</tbody>
</table>

[illinois.edu]
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.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>#</th>
<th>Experiment</th>
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</thead>
<tbody>
<tr>
<td>C1-1</td>
<td>1,2</td>
<td>Cosmic Muon</td>
</tr>
<tr>
<td>C1-2</td>
<td>1,2</td>
<td>Gamma-Gamma</td>
</tr>
</tbody>
</table>

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)
Follow Directly the Recommendations of Safety Working

https://www.drs.illinois.edu/
Follow Directly the Recommendations of Safety Working

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

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
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

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

Make your own folder and put your work there

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
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/
Walking with Coffee: Why Does it Spill?

Growth of Diamond Films from Tequila

J. Morales$^{1,2}$, L. M. Apátiga$^2$, V. M. Castaño$^2$

1. Facultad de Ciencias Físico Matemáticas, Universidad Autónoma de Nuevo León
2. Centro de física Aplicada y Tecnología Avanzada, Universidad Nacional Autónoma de México

Fabrication and Characterization of Ultrathin Three-Dimensional Thermal Cloak

The Physics of Beer Tapping

PRESENTATION BY JOSEPH MIRABELLI
JAVIER RODRIGUEZ-RODRIGUEZ, J. ALMUDENA CASADO-CHACÓN, AND DANIEL PUSTER
1. FLUID MECHANICS GROUP, CARLOS III UNIVERSITY OF MADRID
2. CNRS, UNIVERSITÉ PIERRE ET MARIE CURIE
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.
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
• 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.