Advanced Physics Teaching Lab
Introduction
Edited by Wolfgang Hammer
General Remarks.

The aim of a lab course in the Advanced Physics Teaching Lab is:

- Learn physics by a proper preparation for the experiments and by doing.
- Learn experimental techniques. All theories have to be proven by experiments and new discoveries mostly come from very advanced measurements.
- Working in experimental research requires techniques at the technical limits and the knowledge can be acquired by training.
- The fight for better experimental results can only be won “in the field”. The subsequent treatment of data on a computer cannot serve as a substitute for good experimental procedures but it should complement those.
- Training with established classical experiments should give the students confidence that physics “works” and enables them later to explore new fields.
General Remarks continued:

- It is time required for appropriate preparation of the lab (homework).
- Use the precious lab time for measurement and learning.
- The final evaluation of the measurements and the writing of the reports is mainly homework! But some diagrams and preliminary results should be obtained in the lab immediately after the measurement, to get an idea whether the measurement was right.
- Of course questions about the evaluation and the writing of the reports should be discussed with the teaching persons.
- All measures are taken in international standards, the SI-system (95% of the world’s population and all scientists are using it).
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<th>Primary SI Units</th>
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<td><strong>Meter</strong></td>
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<td><strong>Kilogram</strong></td>
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<td><strong>Second</strong></td>
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<td><strong>Ampere</strong></td>
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Organizational Remarks (I).

- The experiments are performed by the students in groups of two.
- Each group has to prepare about the physics of the experiment before the lab starts. The students should understand the experiment before they start with setup and measuring.
- Each group writes down all important information in a bound logbook, which is a document and a lab diary. All information which can be plotted should be shown graphically already during the lab.
- Finishing of an experiment needs to be approved.
- After the lab an experimental report has to be written and handed in within 14 days after completion of the experiment as a first draft. This draft will be corrected by the teaching people and returned quickly for a second draft which should be final. Final report version needs to be approved.
All set-ups using electronic equipment should be performed by using an oscilloscope and watching and understanding the signals. No trials without understanding! Ask the TA’s and the professor!

For most of the experiments an appropriate selection of electronic units has been made which is required for a successful measurement. If you want to try out something different, discuss first with the teaching personnel.

Follow the safety rules given below and in the risk management course. In case you are not sure, ask first! Never play with or abuse radioactive sources.

Don’t change the settings of the computers, don’t install your or downloaded software; repairs for that are time-wasting and we need our time for you.
Organizational Remarks Continued (III).

Grading for the course is based on a selection of the following (will be announced):

1. Preparation for the scheduled experiment
2. Efforts during the laboratory session and volume of the work done
3. Quality of the reports
4. Midterm and final examination
5. Special tasks can be defined by the professor as for example a presentation at the whiteboard (or ppt) or the preparation of a poster (format DIN A0) with high quality.
6. A special task can also be a very accurate and exceptionally well prepared and detailed lab report on an experiment or a new variant of it.
The reports should include the following:

1. Header with course title and number, date of the experiment, experiment title, author, coworker, group number, supervisor, draft or final version.

2. Physical and mathematical basis of the experiment, present all required formulas and definitions, scarce and no copy of books!

3. Description of tasks.

4. Principles of the measurement with sketches, setup, list of all used equipment and description of all procedures.

5. Raw measured data, measuring curves and depending on the tasks data in tabular form.

6. Evaluation and conversion of data with clear and well formatted diagrams.

7. Realistic computation and / or estimation of uncertainties and errors.

8. Summary, final results, discussion of the obtained results and comparison with the results from other sources.

9. List of references.

10. As an orientation use Physical Review style!
Experiments in the Advanced Physics Teaching Lab

A. General
1. Statistics
2. Speed of Light

B. Atomic Physics
3. Optical Diffraction and Interference
4. Saturation Spectroscopy
5. Moseley’s Law and X-Ray Spectroscopy

C. Nuclear Physics
6. Alpha-Spectroscopy
7. Beta-Spectroscopy
8. Gamma-Spectroscopy
9. Compton-Scattering
10. Rutherford-Scattering
11. Lifetime of Excited Nuclear States
12. $\gamma-\gamma$-Angular Correlation
13. Multiple Coincidences
14. Neutron Spectroscopy
14b. Neutron Diffusion

D. Elementary Particles
15. Cosmic Ray Experiment
16. Muon Lifetime Experiment

E. Condensed Matter Experiments
17. X-Ray Diffraction and Crystal Structure
18. Material Analysis (XRFA)
19. Electron Spin Resonance (ESR)
20. Nuclear Magnetic Resonance (NMR)
21. Mößbauer Spectroscopy
22. ACAR
23. Positron Lifetime
24. PAC
General Literature and Textbooks


Philip R. Bevington, D. Keith Robinson, Data Reduction and Error Analysis, Mc Graw Hill, Boston ... Toronto (2003 third ed.)


Hugh D. Young, Roger A. Freedman, Lewis Ford, University Physics with Modern Physics, Addison Wesley (2007)
More General Literature and Textbooks


Safety in the Experimental Course.

The students need to learn how to safely handle risks in a lab environment:

- **Potential Mechanical, Thermal and Chemical Dangers**: Falling objects, negative pressure, positive pressure, refrigerants, chemicals.

- **Potential Electrical Danger**: Voltages exceeding ~50 Volts can be dangerous – never touch, report defects.

- **Radioactivity**: Special rules apply, take a **short course** from Risk Management. Keep a **minimum distance** from the sources as required. All radioactive **sources** are handled only by the TA’s or the professor. Report any suspects to the personnel in charge.

- **Lasers**: There are several strong lasers in use, cover the beam as far as possible, take safety googles, be aware of reflections!

- **No food or drink in the lab!**
In the experimental areas of the Advanced Teaching Lab the permanent dose rate to which a person is exposed should not exceed:

\[ 10 \, \mu\text{Sv/h} \]

For a short time period, for example changing the position of the source, this limit might be exceeded, but taken these short higher dose rates into an hourly limit, the above limit should be observed. Keep always distance from sources (1/r² – rule)!

The dose for arbitrary matter is given in units of absorbed energy, 1 Gray = 1 J/kg (SI)

Old units: 1 Gy = 100 rad; 1 μGy = 100 μrad;

The dose rate is given in Gray/h or Gray/year

For biological tissue one takes the equivalent dose measured in Sievert (Sv).

One has introduced an equivalent dose rate factor \( \rho \), which is 1 for X-rays, \( \gamma \) rays and beta’s, but 5 for slow neutrons, 10 for fast neutrons and 20 for alphas.

For X-rays the dose 1 Gray = 1 Sv.

The units for the dose rate are mSv/year or μSv/h

Compared to the old units rem and mrem: 1 mrem/h \( \wedge = 10 \) μSv/h;

1 μSv/h = 100 μrem/h 1 mSv/h = 100 mrem/h