# PHYS 3650: Modern Physics Lab S21

Still under review

**General Information**

Office E-mail

Instructor: R. Michalak, 215 PS rudim@uwyo.edu

GA: Afiq Suhaimi asuhaim@uwyo.edu

TA: Chris Masi cmasi@uwyo.edu

**Office hours (RM):** PS215, Zoom W 10-11 pm, F 12-1:30, and by appointment

First Three Weeks: lecture # 1-21 synchronous on Zoom (add link)

After that: asynchronous on Zoom and webpage video

When labs start: *each experiment consists of two or three three-hour lab days*

 *short reports, lab 1-3, do not feature all report chapters*

 *lab 1 short report: Introduction, Experimental Details, with shortened Results chapters*

 *lab 2 short report: Results, Discussion chapters*

 *lab 3 short report Conclusion, Bibliography, with shortened Results chapters*

 *after that: full reports, lab 4-8 - lab 9 is oral exam prep time on the experiment you are going to deal with in the exam.*

Text: Melissinos ‘Experiments in Modern Physics’

Additional texts (recommended not required):

Taylor ‘Error Theory’

Born ‘Atomic Physics’ or Taylor ‘Modern Physics’ – your old texts from Phys 2320

 (Free download available at <https://archive.org/details/AtomicPhysics8th.ed>.)

Webpage: You will find course related information on my website [www.physics.uwyo.edu/~rudim](http://www.physics.uwyo.edu/~rudim)

 Wyocourses: I communicate through “Announcements” in Wyocourses. Compounded grades in Wyocourses may not be weighted correctly. The actual grades in my gradebook are what counts.

***This course fulfils USP 2015 COM3 and USP 2003 WC requirements for four credit hours.***

***Before the first day of lab***, accesshttps://cornell.qualtrics.com/jfe/form/SV\_3HPnqVopymxjX1A

The date the pre-survey is currently set to close is:
12-Feb-2021 23:59:59 EST the post-survey ends on 4/30.

Fill the questionnaire on the site out for bonus points on the final grade. Complete your feedback by doing the follow-up post-survey in late April. Participation is rewarded, not number of correct answers. Challenge yourself with this unfamiliar focus on lab and data aspects. The purpose of the pre-survey is to draw a baseline for each student. The final survey allows to determine learning outcomes and comparison to a nationwide roster of advanced labs and their students.

**A link to google-sheets standard grades will be posted via email invite when we get closer to lab week.**

**Please see the syllabus addendum “General Requirements” for university regulated requirements that are part of the syllabus for this class and read the related Wyocourse link all courses have.**

**All of the following information is tentative, and I reserve the right to change any of it as seems necessary to keep the *class average* on course.** If such changes are made, they will be announced in Zoom class and on Wyocourses under “Announcements”. It is your responsibility to keep yourself informed about any such changes.

**Course Specific Information**

**The total grades you see in Wyocourses do NOT represent your course grade, neither current nor final. They only inform you of grades you have earned in lab reports, seminar, etc. If Wyocourses displays a current overall grade, it will not be weighted correctly. I think I have switched that function off, so it should not show a total grade, but just in case.**

**Course Content:**

This course is an introduction to experimentation techniques and experiments in modern physics. We also learn about proper techniques for report writing, data analysis, literature research, and measuring techniques including functional principles of measurement instrumentation.During the initial block lectures, writing the laboratory report will be introduced chapter by chapter, and it will be practised chapter by chapter in the short reports. To make the lengthy lecture endurable, frequent interactive tasks are interspersed during which the students can earn grade points called standards.

We study a variety of landmark experiments, learn about the uses of electronics, with a specific focus on noise, and experimental techniques as well as data analysis. Before we enter the lab phase we perform a comprehensive safety training, even though in the online lab there won’t be any exposure to the usual risks in a lab. Lab safety standards are a fundamental skill all majors have to master.

The available lab sets include:

Nuclear Gamma Radiation, Alpha/Beta,

Atomic Millikan, Photoelectric Effect, Thomson e/m, Franck-Hertz,

Other Chaos, Michelson, Speed of Light,

**Please see the syllabus addendum “COM3” for university regulated USP requirements with specifics listed for our course that are part of the syllabus for this class.**

**Lecture** During the first three and a half weeks, three hour long interactive lecture blocks will be given on Tuesdays and Thursdays. These block lectures introduce:

(1) Course intro syllabus and preliminary remarks about measurement

(2) Data distributions I (Taylor 3-6)

(3) Data distributions II (Taylor 8-12)

(4) Lab Report instruction and practice I

(5) Lab Report instruction and practice II

(6) Literature: Citing, Quoting, and Plagiarism instruction and practice

(7) Origin software, introduction & data fitting, interactive

All block lectures are *interactive and provide opportunities to earn standards* (see below). This requires your synchronous attendance. Arrange ahead of time with me for absences.

On the course website information about the main subject areas is provided that is known from prior courses such as 2320, 4310, etc.:

 Atomic/Quantum: Photoelectric effect, Franck-Hertz, Millikan, Hall Effect, e/m

 Nuclear: half-life, penetration into matter, models and facts, radiation , ,  General:Speed of light, Polarization, Michelson Interferometer, Chaos, Noise

*Note that this amounts to 21 lecture hours, whereas a purely lecture based course has 42 lectures. Thus, this course has a significant lecture load. The difficulty for you will be to keep track of all things you have learned or reviewed in lecture when you need it in labs, prelabs, and exams. I recommend that you review material after a lecture on the same day and follow-up on unclear points to improve knowledge retention.*

## Laboratory Eight complex modern physics experiments

## Three with two lab days and five with three lab days each. The “lab days” are assigned times, which you can treat asynchronously, but which give you a sense what is a good amount of time to spend on working and learning about the experiment.

## In addition, for each lab you will have to plan 20 minutes for a prelab per student. Prelabs happen during the synchronous class time. Arrange ahead of time if you have time constraints during those six hours each week.

In the three lab day course phase some prelabs happen on day 1, others on days 2 and 3. The early day prelab will cover all aspects of an experiment, but at a more superficial level to get students used to the format and the expectations. Students can earn standards during prelabs (see addendum file).

Six to seven students will have prelab during Lab day1, lab day 2, and lab day 3. During two day labs, ~ 10 students have prelab per day. Prelabs will use Zoom with a wait room set up for the next in line to wait.

## On lab day one, you use your time for your understanding of the experimental setup and trouble-shooting, including the identification and minimizing of systematic errors and deciding on necessary number of repetitions for data statistics and the researching of accepted values. Early processing of numbers extracted from the data to check that results are within what is expected are encouraged: Catch mistakes early. In the context of online lab this means that you should reserve time for this work because it will be part of what is going to be tested. Some of the data you get in a spread sheet may be suffering from some systematic error.

## Standards will explore these techniques further. In the online mode this part is rather abstract. To facilitate your work, I and the TA’s offer a one hour time slot\* where students can Zoom in and observe us use the equipment, can direct us to try out certain operations or tests. The time for this will be limited and we will group students, who do the same or similar experiments, to make best use of limited time. In the past, I have filmed videos that show the equipment in use and which explore some ideas how to address systematic or random errors. Time permitting, we may double up on the videos. \*this feature may be cancelled if it does not yield the wanted results

On the remainder of day one and on day two students usually collect the bulk of the data, make modifications to the experimental setup and experiment plan if necessary (see lab manual). The thoughtfulness of such decisions will be evaluated and graded and standards will be applied. In an online course, during this time a student evaluates data files that have been provided, analyses by plotting, performing calculations, error progression, distribution analysis, and data fitting.

## Each prelab features questions about the theoretical and experimental background (see appendix A). All students will have a pre-arranged prelab Zoom time slot during which a one on one professional conversation takes place between instructor (TA) and student. If your prelab is on the first experiment day, focus will be on the theoretical background and apparatus fundamentals, day two focuses on experimental aspects and problems and day three on data analysis. *Some* of the respective other material will be talked about on each day as well. Students will rotate between day one, two, and three prelabs so that each will have roughly the same exposure to all question types. The rotation pattern is set so that it is for the student hard to predict to encourage a well-rounded preparation. In the online mode, it is more important to make the available time slots work for students than to stick with the strict division of days and topics. Thus, it is possible that a student will be tested on day 1 but is due for day 2 or 3 questions, etc. The student will be informed ahead of time what question to expect. Where it fits the student schedule the proper order can be held up.

## Students should do some research about the topic ahead of time. A good journal to consult for research is the American Journal of Physics. The lab manual and course homepage also provide links to useful papers. The bibliography of these papers is a good starting point for further research.

## The answers given during prelab can earn the student standard grades (see below). There is no failing of prelabs, however, standards will only be earned if the answers given rise to the level expected (see addendum Standards).

Students are encouraged to come to Zoom office hours before lab time and address questions they have about the lab instructions and the experimental and theoretical background of an experiment.

Lab 9 is a lab on the experiment that you will be tested on in the final exam. You can familiarize yourself with the theory, experimental details, and data during the prep days in dead week. During the exam there may be applied tasks and questions and the equipment may have to be used.

***Participation in all laboratory sessions is mandatory*** for the successful completion of this course. Excused absence requires a valid doctor’s note, specific instructor approval, or a university excuse. In that case, an appointment can be made for a makeup session. Students will have the opportunity to choose Zoom meeting times from a roster of available time slots and should communicate scheduling problems right away.

Each student works individually and writes his, her, or their own lab report. Students are responsible for making sure the data they analyse are meaningful and comment on unexpected or wrong results in the ways learned in lecture. Statistically meaningless, or wrong data will lead to lower lab grades under category “\*” (see below). ###

***Lab Safety***

*Safety advice is given at the beginning of the first lab and students sign a consent form, which also proves that the students have been instructed about lab related dangers and have been instructed how to proceed in the event of an accident. Without attendance or signature in this event students are not cleared for lab.*

*Even though the safety issues are not as pressing in an online version of lab, the learning goals’ importance remains.*

***Lab Reports***

Lab reports have to be handed in according to the schedule and will be handed back at the beginning of the next but one lab day or as soon as possible (delays can be expected when the instructor has committee deadlines that are non-negotiable). Expectations for reports will be further specified in lecture.Each student hands in his/her/their own report and multiple copies of almost identical reports will not be accepted. Simply paraphrasing sources counts as plagiarism (see special lecture an plagiarism).

In finals week each student has a 1 ½ hour oral and experimental lab-based exam. The schedule will be decided after midterm (see schedule).

**Grades**

Labs with short reports: 3 10% (3, 4, 3%)

Labs with full reports: 5 40%

draft 1 up to 2.0% bonus on final grade

Seminar 1+ 7.5%

Midterm : 1 7.5%

Final exam lab: 1 15%

Standards: in 4 categories 20%

*Attendance: full attendance no tardiness 2% bonus on final grade*

 *Absence/ tardiness penalty 1% each on final grade*

*Cornell Survey, 2 parts 2 2% bonus for participation in both*

***Course Scale:***

 A > 85% GPA 4.0

 B > 70% 3.0

 C > 55% 2.0

D ≥ 40% 1.0  this counts as passing for graduation but

 fails the COM3 grade

 F < 40% 0

**Grading rubric for full and short reports: (under review)**

 **short**

Relevant chapter 1 25%

Relevant chapter 2 25%

Shortened Results 10%

Labbook 10%

Category W 30%

 **full**

|  |
| --- |
|  |
|  |  |  |
| Report intro | 15% |
| Report exp detail | 15% |
| Report Results  | 15% |
| Report Discussion  | 15% |
| Report Conclusion | 5% |
| Report Labbook (data) | 5% |
|  |  |  |
| category Q | 5% |
| category E | 10% |
| category W | 10% |
| category \* | 5% |
|  |
|  |  |  |
| total |  | 100% |
|  |  |  |
| Legend categories: (summary) |  | short version of important criteria (see lecture for full list) |
|  *category E* | *error progression/propagation with formula derived* |
|  |  | *error statistic, use of error bar(s)* |
|  |  | *data distribution and fitting technical details* |
|  |  |  |
|  *category W* | *maturity of writing* |
|  |  | *analysis and synthesis in reasoning* |
|  |  | *style, tone, grammar, appropriate jargon* |
|  |  |  |
|  |  |  |
|  *category Q* | *citations, bibliography* |
|  |  | *Quotations, effectiveness* |
|  |  | *audience level* |
|  |  |  |
|  *category \** | *data quality (evaluate actual data)* |
|  |  | *data quantity (evaluate whether good no. of rep. etc.)* |
|  |  | *independent repetition (describe how you would have)* |
|  |  |  |
|  *report intro* | *motivation why, how does expt fit bigger course picture* |
|  |  | *order consistent with use in results, signposts used* |
|  |  | *relation to current level of knowledge* |
|  |  | *model and approximation limits addressed* |
|  |  | *from general to specific**describes all theory necessary to understand results and discussion, and all theory and background necessary to create a satisfactory reading experience* |
|  |  |  |
|  *report expt details* | *apparatus, functioning and setup, no black boxes* |
|  |  | *describe experiments (not cookbook style)**parts which limit range* |
|  |  | *anticipated systematic errors* |
|  |  | *all parameters relevant for reproducibility* |
|  |  |  |
|  *report results* | *summary of main data and main result within error* |
|  |  | *graphs to illustrate results, apply fits, distributions**clear line of thought / logical sequence of expt: why, how, what* |
|  |  | *important sources of actual error, how corrected or minimized* |
|  |  | *use of handbook of physics to evaluate results I really use this criterion! Check also for the conditions under which the handbook lists data, extrapolate or interpolate as needed* |
| *results, short reports* |  | *Main calculation, main graph, main error* |
|  *report discussion* | *What do results mean, how were they interpreted,*  |
|  | *expt result within error, compare to theoretical, fitting* |
|  *report conclusion* | *results meaning in bigger picture*  |
|  |  | *not a repetition or summary of discussion**non-trivial suggestions how to improve* |
|  |  |  |
|  *report labbook* | *raw data with relevant observations*  |
|  |  | *all info needed to reproduce results**dated (often useful to continue dating through lengthy work)**no erasing/ making unreadable (APS standard)* |
|  |  | *completeness* |
|  |  | *tidiness* |
|  |  | *organization* |

**Tentative Class Schedule Spring 2021 – PHYS 3650 course online Summary of deadlines**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Week** | **T**red = synchronous  | **R**black =asynchronous  | **Lab online**  **Standards & grades: notable events** | **D Deadlines** |
| 1 Jan 21 – Jan 22  | --- | Intro syll.: Standards, Safety & Data  Sources, Basic Eq.  | Underlinedstdd introducedthis week *Standards during interactive assgn in lecture*  |  All reports ONLY as pdf (not cloud storage,  actual file) formatted as single document pdf deadline criterion = inbox time in wyocourse shell  **small penalties apply to format violations** |
| 2 Jan 25 – Jan 29 | Data Distributions I*Taylor* | Data Distributions IITaylor |  *Standards during interactive assgn in lecture*  |  |
| 3 Feb 1– Feb 5 | Lecture ReportWriting I |  Lecture ReportWriting II | *Standards during interactive assgn in lecture,* *seminar draft* | Seminar draft outline meet by 2/13*last day to drop 2/3* |
| 4 Feb 8 – Feb 12 | Lecture Citing, Quoting, Plagiarism  | Lecture*Origin, gen. Use,fitting*  | *Standards all: during seminar*Seminar WR 5-8pm |  |
| 5 Feb 15 – Feb 19 |  Lab1\*Day1 | Lab1Day2 | *Standards all: during prelab, draft rep.*\* = during actual lab time, remote access via Zoom to manipulate equipment | *draft deadline rep #1 Sun 2/21 by email**concise draft replies by Mon 2/22 by email* Short Lab report #1 (intro, exp det, main res.) due S 2/20 11pm  |
|  6 Feb 22 – Feb 26 |  Lab 2\* Day1 | Lab 2Day 2 | *Standards during prelab and report*  **Midterm exam slot signup by 2/25**  |  Short Lab report #2 (res, dis) due S 2/27 11 pm  |
| 7 Mar 1 – Mar 5 |  Lab 3\*Day1 | Lab 3 Day2  | *Standards during prelab* *and inlab* *and report*   |  Short Lab report #3 (main results, concl, bibl)  due S 3/6 11 pm  |
|  8 Mar 8 – Mar 12 | Lab 4\*Day 1--  | Lab 4 Day 2 | *Standards during midterm exam* WR Midterm exams 5-8pm | Draft rep 4: due S 3/14, grading response by T 3/16 10pm |
| 9 Mar 15 – Mar19 | Lab 4Day 3 | Lab 5\*Day 1 | midterm grades due on 3/23*Standards during prelab* *and inlab* + draft +report | Full Lab report #4 due S 3/20 11pm  |
|  10 Mar22– Mar 26 |  Lab 5 Day 2 | Lab 5Day 3 |  advising week get your PERC *Standards during prelab* *and inlab + report* |  **3/25 midterm grades due at noon** |
| 11 Mar29 – Apr 2 | Lab 6\*Day1 | Lab 6Day2 | *Standards during prelab* *and inlab* + report  Apr 10 last day to withdraw from course  | Late group 2nd reportFull Lab report #5 due W 3/31 11pm *spring break 3/31-4/2* |
| 12 Apr 5 – Apr9 | Lab 6Day 3 | Lab 7\*Day 1  | *Standards during prelab* *and inlab* + report  | Full Lab report #6 due S 4/10 11pm  |
|  13 Apr12 – Apr16 | Lab 7Day 2 | Lab 7Day 3 | *Standards during prelab* *and inlab* + report  |   |
|  14 Apr 19 – Apr 23 |   Lab 8 \*Day 1  |  Lab 8Day 2 | *Standards report*  | *R 4/30 5pm notify instructor by email about* *3 chosen final exam time slots* Full Lab report #7 due S 4/24 11pm  |
|  15 Apr 26 – Apr30 | Lab 8Day 3 | Lab 9\**Oral exam* *Prep day* | *Standards* report *last day of incomplete negotiation: 4/30, 5pm**by email* |   |
| 16 May 3-May7 | Lab 9\**Oral exam**prep day* |  |  | *Full Lab report #8 due W 5/5 11pm* |
| **May 10 – May 14** | Lab Exam student 1Lab Exam Student 2Lab Exam Student 3 | **Monday,****Tuesday,****Wednesday****Thursday,****Friday** | *Standards during oral exam* | **Exam Time Slot 1- 8:30am to 10:00am****Exam Time Slot 2- 10:30am to 12:00pm****Exam Time Slot 3- 1:15pm to 2:45pm****Exam Time Slot 4- 3:15pm to 4:45pm** |

**Oral Exam** Email me your exam day and time preferences from among the available time slots by Apr 29th. Email three alternative exam slots so I can make a schedule that fits everyone.

**If you miss the final exam, you receive a 0% final exam grade toward the final grade, i.e. no extension or make up on the final exam. If you have a time conflict for the final exam, email me about this no later than May 9th.**

Appendix

1. Explanation - Prelabs, Inlabs, Seminar, Midterm and Final Exam

Prelabs are professional *conversations between instructor and student* about topics that relate to a particular experiment. The student can start freely and should choose a topic that she is strong at and/or a topic that will satisfy a needed standard. After the introductory period I will begin to ask questions, but still with an open mind toward where the student wants to go. Over time this may change and in later prelabs I may push toward covering standards a student still needs. In later prelabs, the topic may also depart from the immediately relevant for the experiment if the conversation drifts. During most prelabs it will be okay to say ‘I don’t want to cover this topic right now’, but you can’t give that answer for everything all the time, even though it may be the truth 

Inlabs are professional *conversations between an experimenter and a person who needs to assess whether the data are reliable*. The experimenter carries the chief responsibility and defends, if necessary, the choices made and is ready to present a rationale why measurements were made the way they were, including choices of how many different experiments were carried out compared to how many repetitions were performed per experiment, which errors were identified and how they were eliminated or minimized.

The seminar is a *professional presentation* that gives an overview over the relevant theory regarding the object of presentation, a polished and previously practiced talk, evidence of thorough research into the subject matter, and is generally a major playground for COM3 skills, such as body language, confidence, clarity of presentation, speaking volume, professional jargon, etc. The seminar follows a stand-alone approach (meaning that a peer should be able to understand the topic based on normal prior knowledge and based on the presentation, and without having to rely on what other students may have talked about in their seminar).

The exams are *professional discussions among colleagues*. Unlike with prelabs this expects a different level of competence in your answers. Expect that the topic may veer off the particular experiment in question. Emphasis is also put toward professional conduct, which includes behaviour, preparedness, and a number of COM3 categories. One can compare the experience somewhat to presenting a poster at a scientific conference or giving a talk at a conference which has a question and answer section attached to it.

Note about exams

A good thing about oral exams: You are not stuck with an answer you once give and can demonstrate reasoning skills to dig yourself out of holes. Even in a relatively poor oral exam you can score many standards. You can also look for cues I may be giving you through the progression of questions.

The prior prelabs and inlabs have prepared the student for the exam situation. Unlike in the prelabs, students will have to answer a number of question types and cannot ‘skip’ without grade penalty to keep exams comparable between students. All standards that are assessable during an oral exam can be earned, and unlike during prelabs, multiple levels of the same standard can be earned in the same exam.

The material of the midterm exam covers all previously conducted experiments, their theoretical and experimental aspects, and all lecture material. The student is encouraged to demonstrate research to earn related standards.

The final exam is like the midterm, but lasts longer, and has a practical component where you demonstrate that you can perform aspects of the lab and have mastered equipment and software. The focus is on a specific lab that you will know ahead of time and will perform as lab 11 before exam week. The exam conversation can veer into any related material, which includes other labs you have performed or related material from prior courses. The student should talk about relevant research publications and should be prepared to have a good answer to ‘Is there anything you want to add?’.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1. Explanation of grading symbols

(under review) |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
| grading symbols | #1 | evidence lacking |  |  |  |  | $1  | some confusion b/w what is a major and whata minor point |  |
|  |  | #2 | reason not fully appropriate |  |  |  | $2  | wordiness |  |
|  |  | #3 | vague reasoning |  |  |  |  | $3  | minor point missing |  |
|  |  | #4 | insufficient reasoning |  |  |  | $4  | somewhat incomplete |  |
|  |  | #5 | inappropriate reasoning |  |  |  | $5  | majorly incomplete |  |
|  |  | #6 | pov deficient |  |  |  |  | $6  | no distinction b/w important and unimportant |  |
|  |  | #7 | no pov |  |  |  |  |  | $7  | no concept of what is necessary |  |
|  |  | #8 | wordiness |  |  |  |  |  |  |  |  |
|  |  | &1 | some lack of focus |  |  |  |  |  | \*1 |  |
|  |  | &2 | lack of organization |  |  |  |  |  | \*2 |  |
|  |  | &3 | problem with progression of ideas |  |  |  | \*3 |  |
|  |  | &4 | incoherent |  |  |  |  |  | \*4 |  |
|  |  | &5 | disorganized to a degree where understanding your point is affected |  |  |
|  |  | &6 | expression off |  |  |  |  |  |  |  |  |
|  |  &7 jargon wrong  &8 abrupt  &9 quotation unspecific or trivial &10 personal voice |  |  |  |  |  |  |  |
|  |  | ~1 | problem with diagram axis |  |  |  |  | ~8 |  |
|  |  | ~2 | problem with vector |  |  |  |  |  | ~9 |  |
|  |  | ~3 | tidiness figure/sketch |  |  |  |  | ~10 |  |
|  |  | ~4 | figure poorly related to problem |  |  |  | ~11 |  |
|  |  | ~5 | no figure, eqn, example where necessary |  |  |  | ~12 |  |
|  |  | ~6 | no derivation/ re-arrangement of textbook eqn demonstrated |  | ~666 |  |
|  |  | ~7 | wrong result in calculation |  |  |  |  |  |  |

 ~8 grammar causes misunderstanding

√ correct 14-15

(√) mostly correct 11.5-14

~ somewhat correct 9-11.5

$≈$ vague 4-9

(-) incomplete or sudden end 4-9

- missing 0-4 if chapter summary grade

# wrong 0-4

 (/) misses the point, off topic

* original, imaginative, good illustration

:-( sloppy, much too short

˅ repetitive, wordy

? confused or logic cannot be followed or lack of focus

& good research

$ well organized or well structured

+ mature writing

\* precise or insightful or thoughtful

^ concise, to the point

! strong reasoning

(+) furthers pov

[] lack of structure or needs paragraph separation or abrupt change

% evidence missing or incomplete

 ? purpose or message unclear

language metrics

  expression or phrase

  new paragraph needed

I use any or all of these symbols by underlining a relevant phrase or paragraph and adding the symbols.

In that way I can grade the reports in a reasonable amount of time. You are always welcome to inquire in person in more detail what was wrong.

**C- Safety Advice and Student Contract (to be updated)**

In the advanced modern physics lab equipment is in use which can hurt a person if used in inappropriate ways. Participating students are expected to behave in a mature way and follow the safety instructions.

Particular risks arise from the following:

 High voltage (eg electronics, Millikan, photoelectric effect)

**Risk of electrocution. High currents kill or harm. Under certain circumstances, electric sparks can emerge from charged objects and jump across empty space and shock you. The human body is a mild conductor and can act as a short cut for the power in a circuit to earth/ground if one part of the body touches a non-zero potential and the other part touches the ground or a different potential point. If ones skin is wet the resistance may be as low as 1 k. By contrast, a dry body may have on the outside a resistance of up to 500 k. The resistance inside your body is typically between 100 and 600 .**

|  |  |  |
| --- | --- | --- |
| *Effect on body* | *DC current* | *60 [Hz] AC current* |
| *Noticeable* | *0.5 – 1 [mA]* |  *> 0.3 [mA]* |
| *Painful, voluntary action possible* | *40-60 [mA]* |  *6 – 9 [mA]* |
| *Painful, unable to let go of wires* | *60-75 [mA]* | *~ 15 [mA]* |
| *Difficulty breathing* | *60-90 [mA]* | *15-20 [mA]* |

**The data in the table are approximate threshold values for healthy average people. For women, often the lower values apply.**

 Diode lasers (eg Speed of Light, Law of Gravitation)

**Diode lasers are lasers. Their power is usually low, but inadvertent self-administered LASIK effects can still happen. Do not stare into the laser beam.**

 Radioactivity (eg nuclear ; Millikan )

**Radioactive radiation is harmful when the body is exposed to it. It decays in intensity with the inverse square law if it is not a focussed beam. Our alpha radiation can be shielded by about 6 inches of air or a thin sheet of paper. Beta radiation is more penetrating. Gamma radiation can reach your inner organs or pass through your body altogether. Some parts of the body tend to absorb the radiation more and exposure can lead to cancer.**

 Poisonous chemicals (eg broken radioactive pellets, scintillator)

**Handle pellets with care, do not break them, avoid dust from broken pellets, do not touch scintillators with bare hands.**

 Trace gases (eg Thomson e/m, FH, Photoelectric)

**Do not inhale trace gases if seal brakes, remove yourself from the room and warn others immediately**

 Strong Magnetic fields (research labs)

**Magnetic fields can switch medical implants, batteries, pacemakers; they also delete credit cards**

 Lasers (research labs and Michelson lab)

**Always follow eye protection instructions. Never look directly or indirectly (eg after refection at a surface) into a laser**



**Our big Michelson laser has a 3b rating and the research lab lasers go beyond that. Always be aware of the beam location and its reflections.**

Hot surfaces (eg BlackBody radiation, photoelectric effect)

 **Do not touch the equipment without gloves when hot**

 Erratically moving heavy parts (eg Chaos)

 **Never turn your back to the equipment**

 Use of Chemicals (eg Sodium hydroxide is corrosive and can cause severe burns**)**

 **Use gloves and protective eyewear, rinse immediately where exposed**

(eg polonium alpha emitter)

 **Do not touch the polonium directly. Handle the shielded pellet carefully.**

Cryogens (eg liquid nitrogen)

 **Liquid nitrogen causes skin irritation similar to burns with a flame.**

Other risks may be present. Ask if in doubt.

Student with special health conditions are charged to inform the instructor about their condition so that impact that equipment may have can be evaluated to keep the student safe. This charge extends throughout the whole term, should your condition change.

High voltage can lead to severe electrocution shock. Currents kill.

Laser light, as well as its reflections, can damage the unprotected eye.

Radioactive radiation leads to ionized particles in the body, which can cause cancer.

Gases emerge from volatile material and broken vacuum vessels. They can be poisonous on inhalation. Large pressure or temperature changes may set some gas free.

Solid chemicals can smear onto hands and from there get into the body. Some of our chemicals are poisonous. The radioactive samples can cause ionization damage in the body until they have been removed. In some cases this can take a long time.

Magnetic fields can affect battery controlled devices like pacemakers. They can also erase credit cards and other magnetic storage media.

Direct contact with small amounts of cryogenic liquids leads to skin burns similar to heat skin damage. In case of a magnet quench, large amounts of cryo-gas will be set free within a few seconds, which can lead to asphyxiation. The lab area has to be evacuated instantly.

Hot surfaces cause skin burn.

Erratically moving parts can cause collision accidents or can catch loose clothing or hair, etc.

Special safety advice will be given for research labs. Non-compliant students may be sent off the premises and forfeit grade points associated with the research labs.

**Student contract:**

My participation in this lab course expresses my awareness of the risks inherent in the experiments and my consent to (a) follow safety advice and (b) apply common sense judgment and be watchful to avoid accidents.

I acknowledge that I have received safety instructions on 2/18/2020 before lab.

I will be held responsible to take the initiative and ask questions if any risks involved in my actions are unclear to me.

In case of accidents, I will inform the course supervisor or his present TA

instantly. I will then seek medical help as needed as soon as possible and as advised.

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 date name signature

Safety Quiz: mark all which apply

 \_\_\_\_\_\_\_\_

 name

1. How can radioactivity cause damage to the body?

 a) by exposure on the outside of the body

 b) by inhalation

 c) by ingestion

 d) only if one gets very close/ works with the material directly

 e) all of the above

 f) none of the above

2. The danger of Laser light

a) beam intensity diminishes with distance the same way as that from other light forms

 b) depends on the laser power rating

 c) persists also for secondary laser beams, like light reflected off a

surface

 d) is irrelevant for short periods of times (fractions of seconds)

 e) all of the above

 f) none of the above

3. Electrocution risks – you cannot electrocute yourself if

 a) you do not touch the live lines

 b) your resistance is higher than that of the circuit you touch

 c) if you touch not just a conductor but also insulating material

 d) if you touch not just a conductor but also ground

 e) all of the above

 f) none of the above

4. Lab safety risks:

 a) List the dangerous aspects of the lab you are doing today:

 b) What is best practice in the lab today that keeps you safe?

 c) What do you do if you have safety concerns about a lab?