Integrating Data Science into Physics Laboratories

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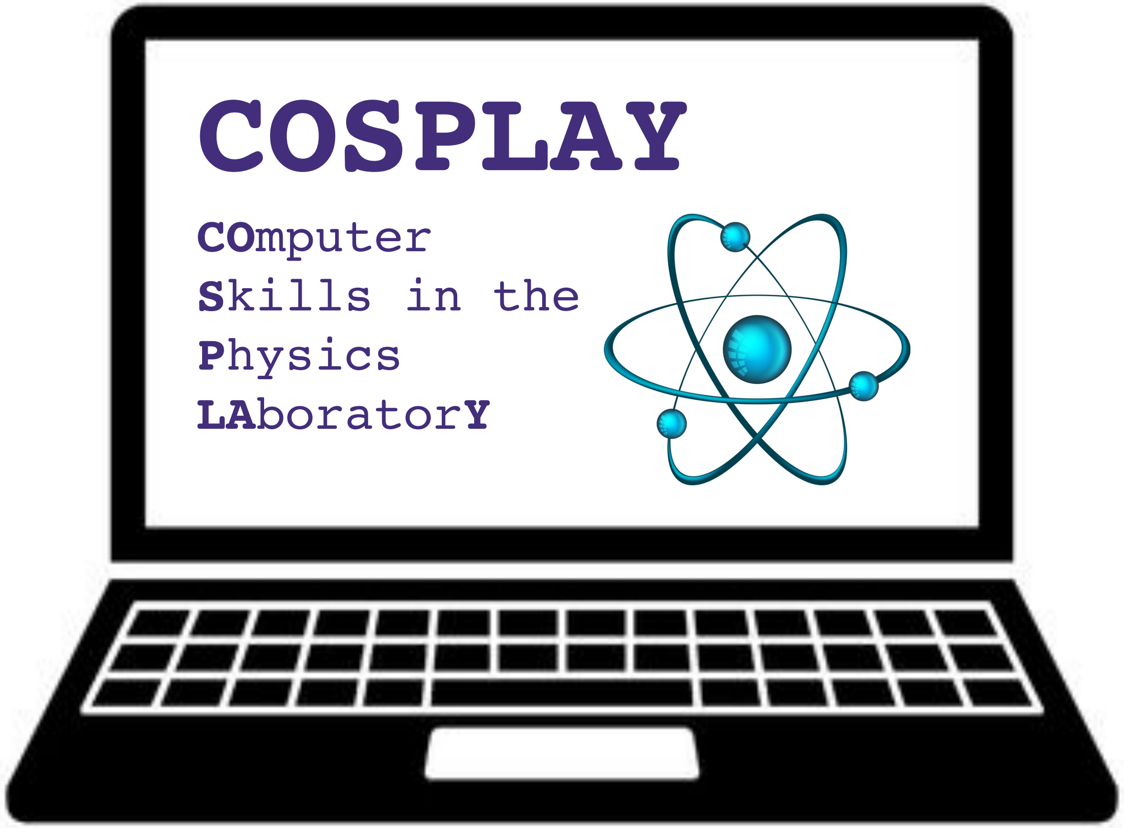

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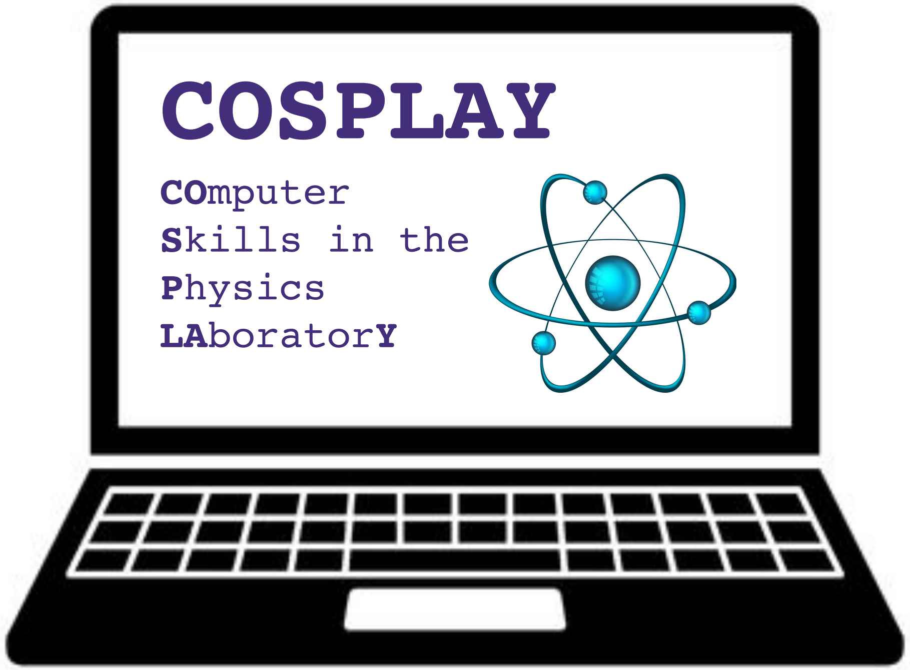
Learning Objectives

1) Foundation
2) Interfacing, Input, and Output
3) Processing and Computation
4) Troubleshooting



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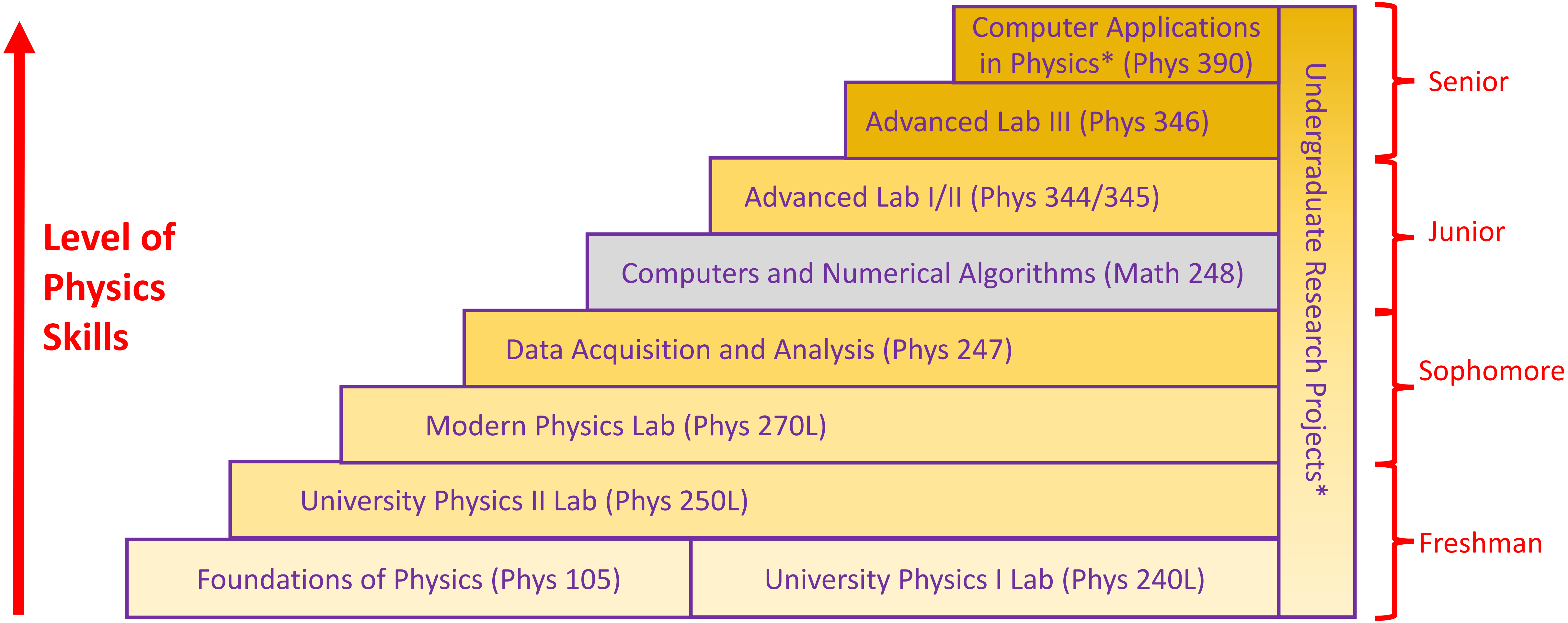
COmputer Skills in the Physics LAboratorY



Level of Computer Skills

Introduction (I)	Reinforcement (R)	Mastery (M)

*optional courses

Complementary Instruction

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Learning Objectives

LO's	240L	250L	105	270L	247	344/345	346
1a			I	I/R	R	R	M
1b			I	I/R	M	M	M
1c			I	I/R	M	M	M
1d			I	I/R	M	M	M
1e			I	I/R	R	R	M

1. Foundation

1.a Write a statement that produces a desired output (print, plot, make a sound)

1.b Demonstrate proper declaration and uses of variable types (integers, float, strings)

1.c Write a conditional statement (if-then-else) to solve a logical question (is variable > x)

1.d Write a recursive loop (for-loop, while-loop) to solve basic equations (summations, factorials, etc.)

1.e Create and manipulate data structures (arrays, lists, and math operations such as product, determinant, cross product, etc.)

Introduction (I)	Reinforcement (R)	Mastery (M)

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Learning Objectives

2. Interfacing, Input, and Output

LO's	240L	250L	105	270L	247	344/345	346
2a			I	I/R	R	R	M
2b	I	I/R		R	R	R	M
2c				I		I/R	R/M
2d			I	I/R	R	R	R/M

2.a Write code to read or write a variety of computer files (CSV, numerical, plots, graphs, images, sound, text, binary, etc.)

2.b Physically interface an instrument or sensor (Labview, Pasco sensors, oscilloscopes, etc.) with a data collecting device or computer

2.c Write code to automate data reading from an instrument or sensor (Labview, Pasco sensors, oscilloscopes, etc.)

2.d Write code to access or provide information through a human computer interface (keyboard, mouse, screen, print out, LED light, etc.)

Introduction (I)	Reinforcement (R)	Mastery (M)

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Learning Objectives

3. Processing and Computation

LO's	240L	250L	105	270L	247	344/345	346
3a	I	R		R	R	R	M
3b	I	R		R	R	R	M
3c	I	R		R	R	R	M
3d			I			I	R*
3e				I	I	I/R	R*
3f						I/R	M

3.a Design the investigation of a physical phenomenon in a way that enables the use of computers (and other tools) to help analyze them

3.b Logically organize and analyze data (sorting, averaging or smoothing, error analysis)

3.c Represent data through abstractions (models and simulations)

3.d Automate solutions through algorithmic thinking (a series of ordered steps or loops)*

3.e Identify, analyze, and implement possible solution methods with the goal of achieving the most efficient and effective combination of steps and resources (time, lines of code, fitting)*

3.f Generalize and transfer this problem solving process to a wide variety of problems (universal algorithm of physics experiments, reusable scripts, feedback control systems)

Introduction (I)	Reinforcement (R)	Mastery (M)

*Mastery may be achieved in Phys 390 or Research

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Learning Objectives

4. Troubleshooting

LO's	240L	250L	105	270L	247	344/345	346
4a	I	R	(I)	R	R	M	M
4b				I	I/R	R	M
4c			(I)	I	R	R	M
4d			(I)	I	R	R	M

4.a Identify range then evaluate the reasonableness of experimental outcomes both with respect to (a) physics and/or (b) output of programming code.

4.b Identify test cases for programming code. Generate synthetic data/results at the modular level and complete code. Test code at edge cases (extreme conditions)

4.c Isolate errors by following logical steps, printing statements at various points

4.d Identify appropriate modifications to the physics or programming code as necessary: a) to adapt existing code to a new use, and b) correct non-working code

Introduction (I)	Reinforcement (R)	Mastery (M)

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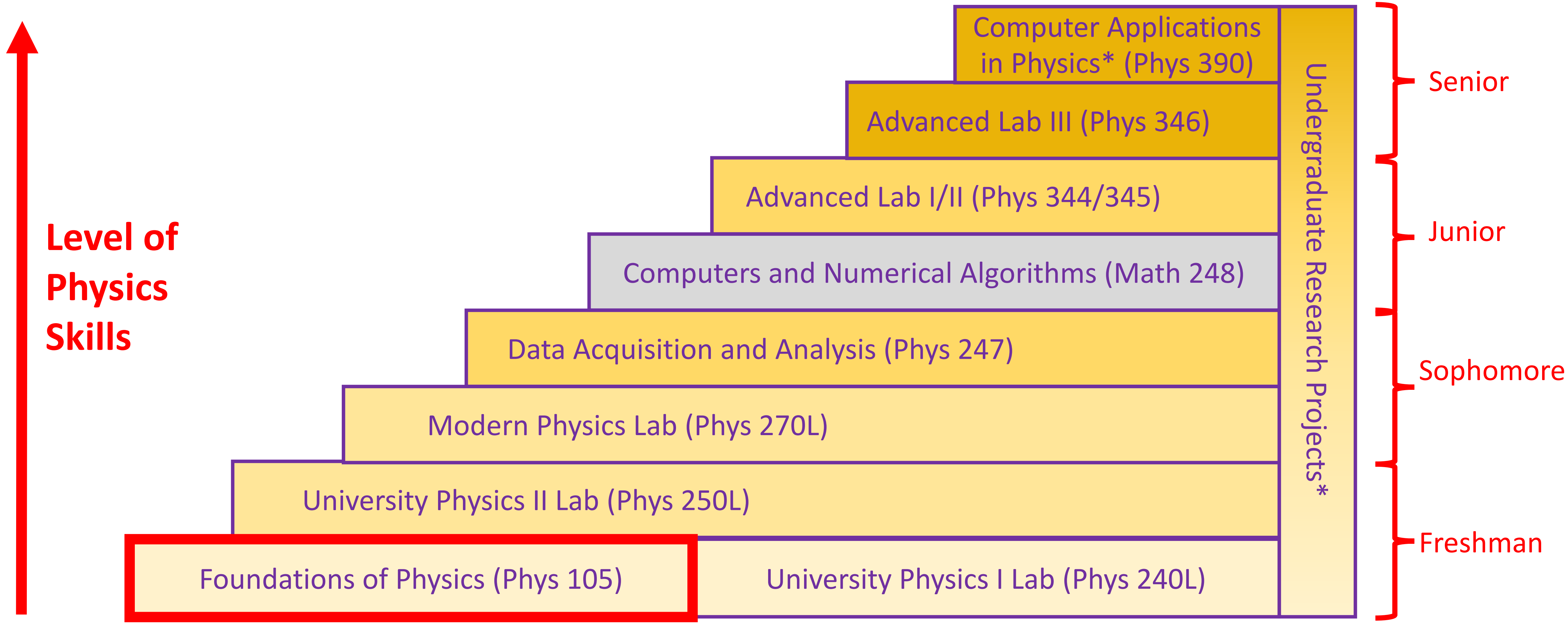

Level of Computer Skills

Introduction (I)	Reinforcement (R)	Mastery (M)

*optional courses

Complementary Instruction

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Programming Skills of Incoming Physics Majors (2019-2021)

Self-Assessed Programming Skills

0/75 Ⓐ Expert

6/75 Ⓑ Proficient

38/75 Ⓒ Beginner

31/75 Ⓓ Do not have previous programming experience

Programming Languages Utilized

Python: ~25% students

Java: ~30% students

C/C#/C++: ~15% students

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Phys 105: Foundations of Physics

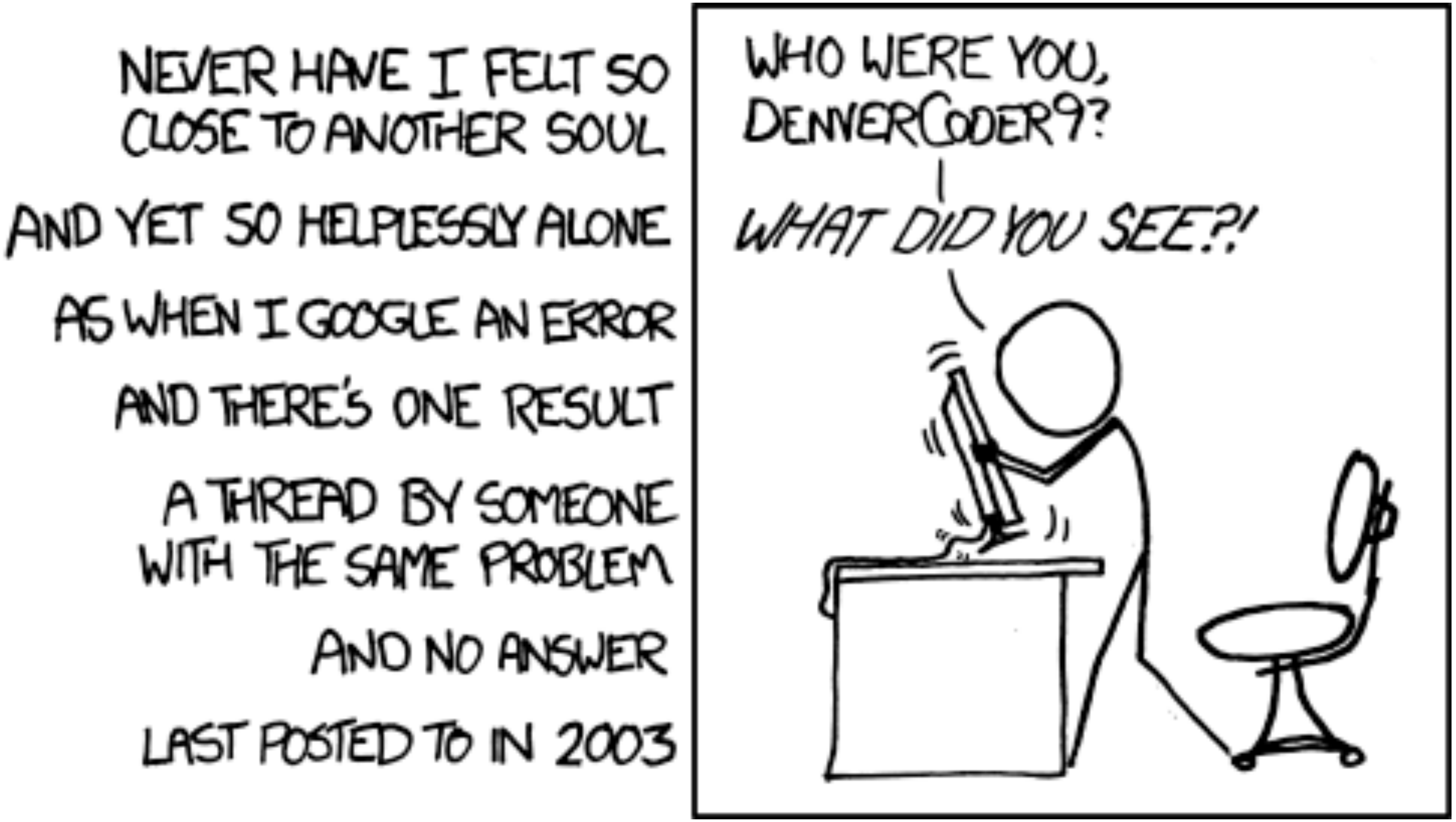
- Introduces students to Python programming language, importing scientific and plotting libraries, iPython console, and interactive development environment (IDE).

- Fosters positive student attitudes and habits surrounding programming style, commenting, learning new syntax, troubleshooting errors, and debugging code.

- **Textbook(s)**: “A Student's Guide to Python for Physical Modeling: Updated Edition”, Kinder and Nelson, “Introduction to Python for Science”, Pine.

- **Topics Covered:** 0. Installing and Launching Python, 1. Organizing Data, 2. Structure and Control, 3. File I/O and Plotting, 4. User-Defined Functions, 5. Multidimensional Arrays and Image Processing, 6. Curve-Fitting and Error Analysis

How to Debug Code?



Comic from xkcd

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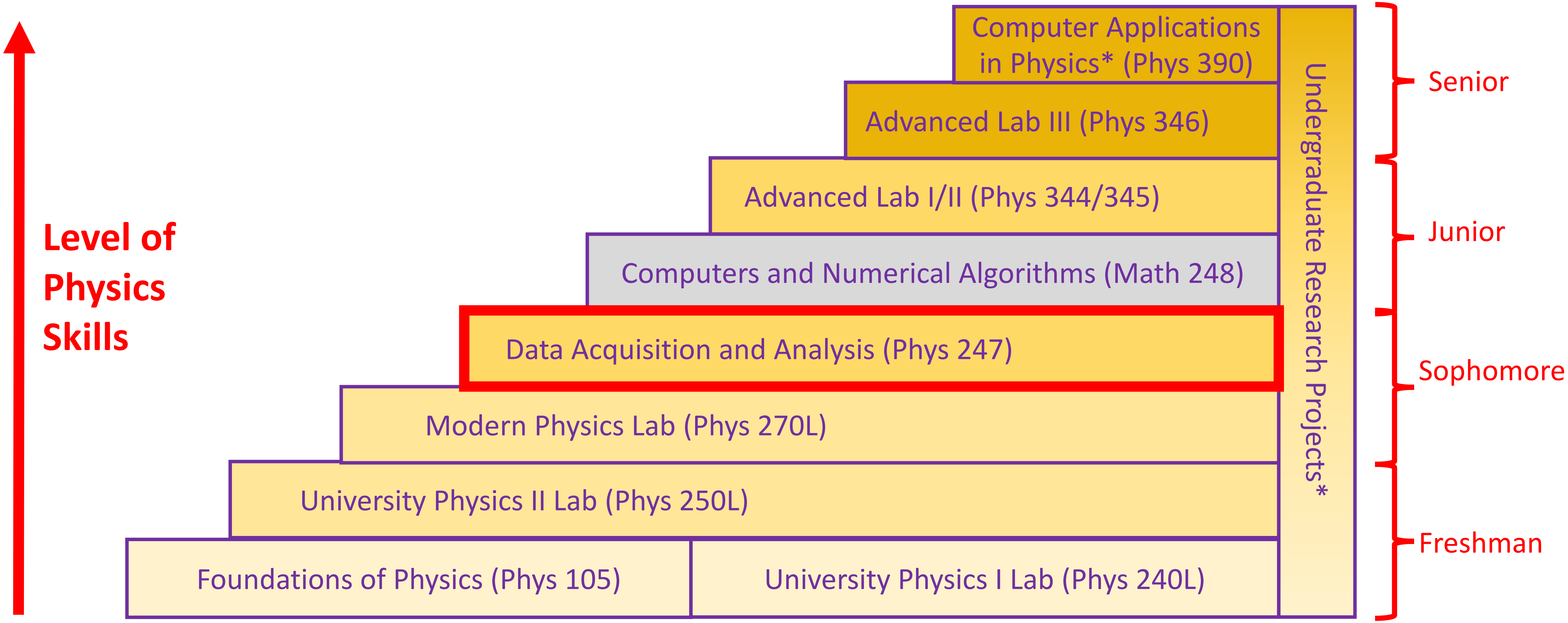

Level of Computer Skills

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Introduction (I)	Reinforcement (R)	Mastery (M)

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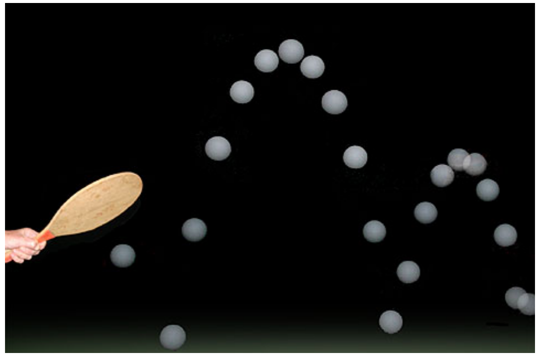
Phys 247: Data Acquisition and Analysis

Air Drag, Part 1



Task description:

In this three part series of activities learners will study how drag forces influence the motion of a projectile in Earth's atmosphere. Learners will design a setup that will launch a light projectiles (table tennis balls) at different initial angles and with different initial speeds. They will also devise a way to record and subsequently analyze videos of the projectile in order to determine its trajectory. Subsequently they will develop a computer model that takes into account the possible influence of drag, and use the experimental data to infer the parameters of the model and use the model to predict the motion of the projectile for different initial conditions.

- The first part of the activity will be strictly 1D, using coffee filters rather than table tennis balls.
- The second part of the activity will be a 2D projectile motion w/ drag.
- The third part of the activity will add the (possible) effect of the Magnus force as the projectiles will be launched with spin[1]

Exercise written by G. Niculescu

Phys 247: Data Acquisition and Analysis

Common Requirements for All Experiments.

- All experiments have: Introduction, Theory, Exp. Setup, Data Acquisition, Data Analysis parts.
- The introduction part is brief. Historic references can be added but are not (typically) needed.
- The theory part includes all equations (numbered if need be) that will be used in the experiment. Provide brief explanations/descriptions of the quantities that appear. For experiments you will also be required to derive some of the equations needed, see below.
- There is a **computer-generated schematic** of the experimental setup and (if needed/relevant) free body diagrams, energy bargraphs, etc. - all computer-drawn. Make sure the coordinate system(s) used in the experiment are: a) described (including incorporating them on the schematic) and b) are consistently used throughout the experiment.
- The data acquisition part makes clear how the data was acquired and presents the data (tables, graphs, etc. as needed). Snapshots of the data might be added, especially if they help substantiate points that would otherwise require extensive explanatory text.
- The data analysis part (calculations, plotting, error analysis, etc) is all done in **Python** and has an (extended and CORRECT) error analysis part.

Exercise written by G. Niculescu

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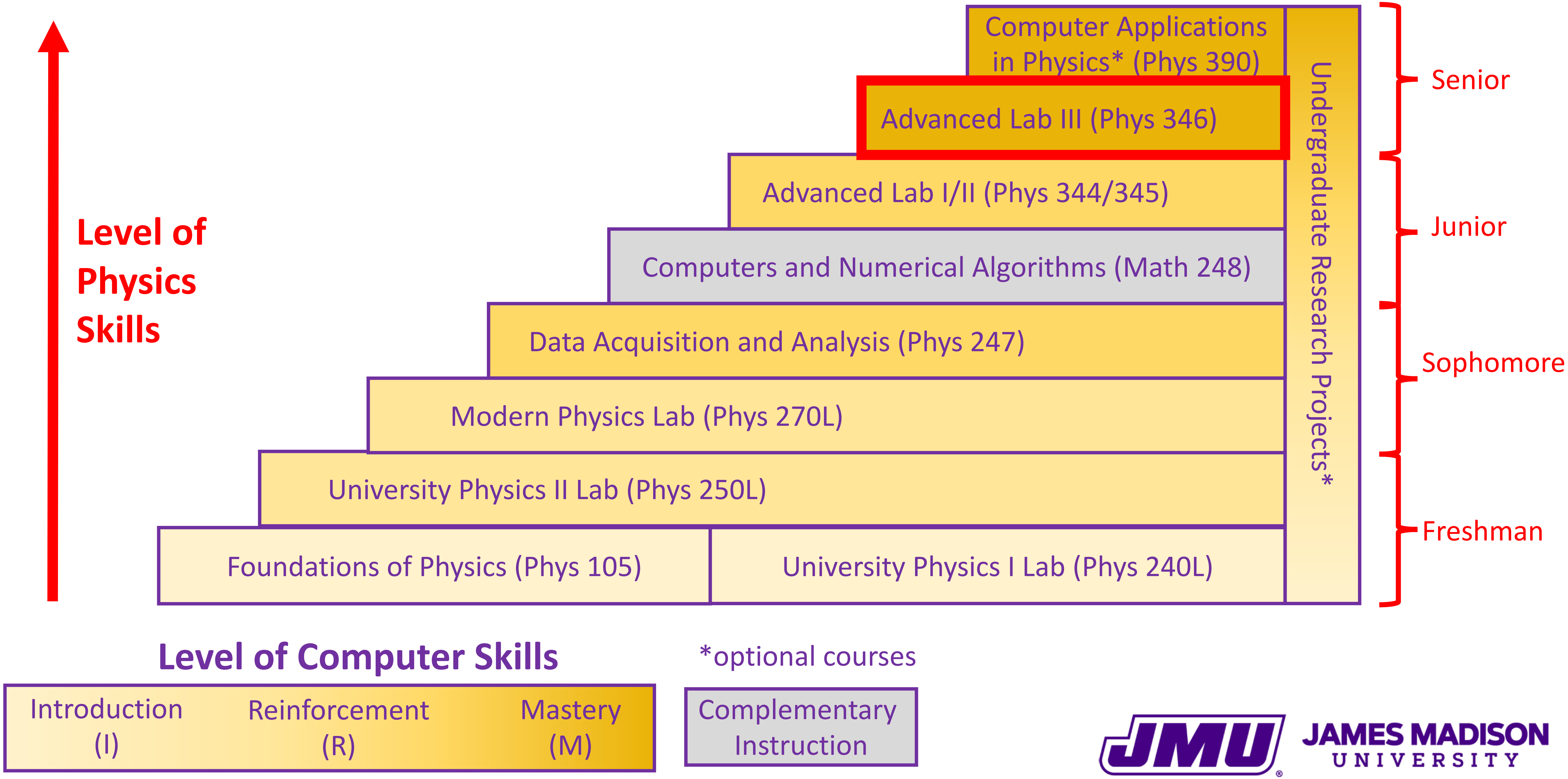

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Phys 346: Advanced Lab III

PHYS 346 Project: Motion Data Logging and Analysis System

As this is the last part of the PHYS344-346 Physics Laboratory it is fitting that the learners tackle a complex project, where many (and different) sub–tasks or challenges need to be identified and addressed. The task chosen for Spring 2019 was inspired by an ongoing study carried out in the JMU Biology Department.

It involves tracking the motion of lemurs, both in Madagascar and at the Duke Lemur Center in North Carolina. One attaches a data logging device (DLD) capable of recording several different sensor readings on the back a/o neck of the subject. The data is recorded/transmitted and then it is subsequently analyzed in an attempt to gauge what fraction of the time the subject spends doing various of its daily tasks (sitting, jumping, climbing, etc.)[1].

Exercise written by G. Niculescu

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Phys 346: Advanced Lab III

PHYS 346 Project:
Motion Data Logging and Analysis System

Tasks/Deliverables (Software):

- Develop protocol for transferring of the data from DLD to a computer. Pay attention to storage requirements and scaling capabilities.
- Develop/adapt software that allows visualization of the data.
- Develop/adapt software that allows the classification of the subject movement using Machine Learning techniques (supervised learning is suggested).

Exercise written by G. Niculescu

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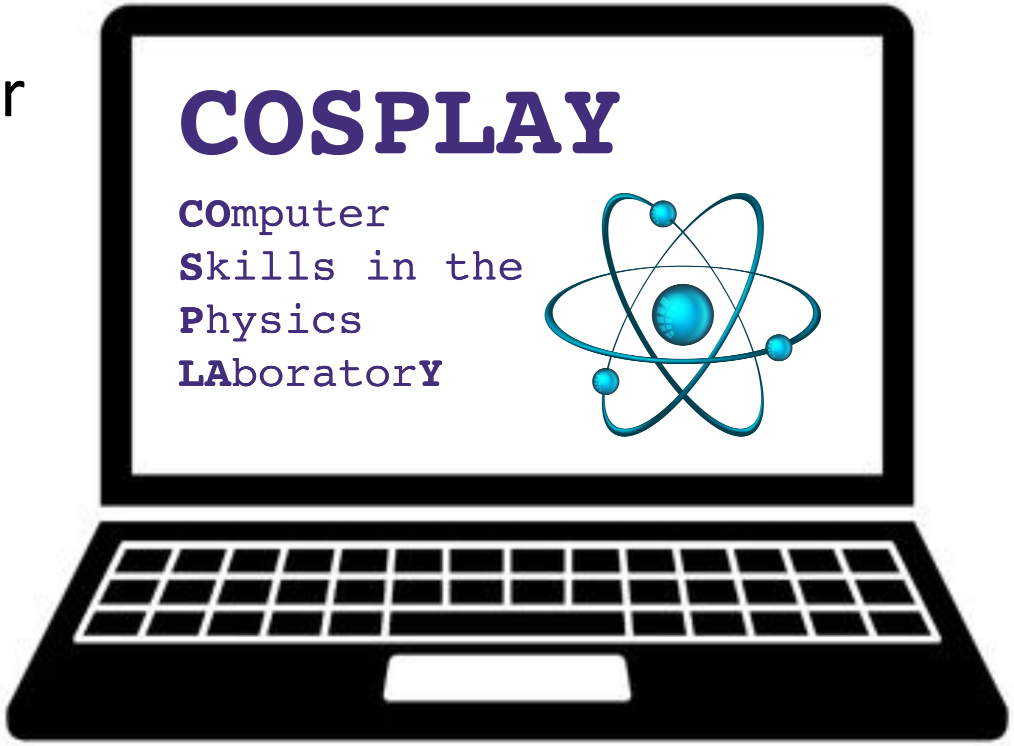
Thank you for your attention!

Please contact the COSPLAY team if you are interested in being an early adopter/beta tester of our final assessment tool!

Email: cosplay@jmu.edu

Kendra Letchworth-Weaver: letchwkl@jmu.edu



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