



# PICUP

PARTNERSHIP FOR INTEGRATION OF COMPUTATION INTO UNDERGRADUATE PHYSICS

## EXERCISE SETS, FACULTY COMMONS, AND RESOURCES OF THE PICUP WEBSITE

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University of Wisconsin – Stout

Summer AAPT Meeting

July 12, 2022



[Link to slides](#)



PICUP

# Mission of PICUP

- Lower the barriers to integrating computation into classes
  - *Community*
  - *Training*
  - *Resources*



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# Computation in Physics - Definition

Having students work with simulations and/or algorithms, giving students pieces of code to complete on their own, and/or advising students on undergraduate research projects where they write code from scratch<sup>1</sup>

1. [Caballero, Marcos D., and Laura Merner. "Prevalence and nature of computational instruction in undergraduate physics programs across the United States." \*Physical Review Physics Education Research\* 14.2 \(2018\): 020129.](#)



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# A Brief History

- 2006 – [Shodor Visioning Workshop](#) – PICUP is born
- 2006 - Special issue on computation in physics in Computing in Science and Engineering
  - Fuller – “Numerical Computations in US Undergraduate Physics Courses”<sup>1</sup>
- 2008 – “Integrating computation into the undergraduate curriculum: A vision and guidelines for future developments”<sup>2</sup>
  - *AJP article by Chonacky and Winch*
- 2011-2013 – Development workshops
- 2013 – Present Workshops at various conferences
- 2015 – Two NSF proposals for PICUP funded
  - *M.D. Caballero, K. Roos, L. Engelhardt, M. Lopez, R. Hilborn, N. Chonacky*
- 2016 - First Faculty Development Workshop
  - [gopicup.org](http://gopicup.org)
- 2018 – “On the Prevalence and Nature of Computational Instruction in Undergraduate Physics Programs across the United States”<sup>3</sup>
- 2020 First virtual workshop



# Numerical Computations in US Undergraduate Physics Courses<sup>1</sup>

- Survey for faculty on importance and use of computation (N=187)
- Large fraction thought computation important
- <20% included computation in grades

1) [Fuller, Robert G. "Numerical computations in US undergraduate physics courses." \*Computing in science & engineering\* 8.5 \(2006\): 16-21.](#)



# On the Prevalence and Nature of Computational Instruction in Undergraduate Physics Programs across the United States<sup>1</sup>

- Response: 357 departments and 1246 faculty
- >50% of departments have 1 faculty teaching computation in intro and upper level courses
- >25% of departments have  $\frac{1}{2}$  of faculty teaching computation in intro and upper level courses

Related paper on barriers<sup>2</sup>

1. [Caballero, Marcos D., and Laura Merner. "Prevalence and nature of computational instruction in undergraduate physics programs across the United States." \*Physical Review Physics Education Research\* 14.2 \(2018\): 020129.](#)
2. [Leary, Ashleigh, Irving, Paul W., and Caballero, Marcos D. The difficulties associated with integrating computation into undergraduate physics. \*Proceedings of the Physics Education Research Conference\* \(2018\).](#)



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# PICUP

- Website:
  - *Exercise Sets*
  - *Faculty Commons*
  - *Resources Tab*
  - *Community and Events*
- Training:
  - *FDW*
  - *Regional Workshops*
  - *Virtual Workshops*
  - *Site Visits*
  - *Webinars*
- Community
  - *Webinars and Workshops*
  - *Slack Channel*




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# PICUP

- Website:
  - *Exercise Sets*
    - Peer-reviewed activities
  - *Faculty Commons*
    - All other curricular material
  - *Resources Tab*
    - Tips and best practices
  - *Community and Events*
    - Stay connected, get help



[HOME](#)
[UPCOMING EVENTS](#)
[INSTRUCTIONAL MATERIALS](#)
[ABOUT](#)



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COMPUTATION INTO UNDERGRADUATE PHYSICS

## Falling Sphere Exercise Set

Primary\_Materials\_Falling\_Sphere: Educational Objectives; Computational Exercises

Supporting\_Materials\_Falling\_Sphere: Comments, Tips, and Suggestions; Numerical Approach; Pseudocode; Sample Solutions to the Exercises

### Program Implementations

[Falling\\_Sphere\\_Excel](#)  
[Falling\\_Sphere\\_Mathematica](#)  
[Falling\\_Sphere\\_MATLAB/Octave](#)  
[Falling\\_Sphere\\_Python](#)

# Then and Now

Old site: <https://picupsite.wordpress.com/>

[Home](#)
[Exercise Sets](#)
[Faculty Commons](#)
[Resources](#)
[Community](#)
[Events](#)
[About PICUP](#)

[Exercise Sets](#)
 » Falling Sphere with Air Resistance Proportional to  $v^2$

## Falling Sphere with Air Resistance Proportional to $v^2$

Developed by [Kelly Roos](#) - Published July 17, 2016

This set of exercises requires the student to generate a computational model of the 1D motion of a spherical object dropped from a tall building, and then graph and analyze the output of the model. It also guides the student in exploring the accuracy of a computational algorithm by comparing the computational results with an exact solution obtained analytically. The numerical approach used is the simple Euler method.

Subject Area

Levels

Available Implementations

Learning Objectives

Mechanics

First Year and Beyond the First Year

C/C++, Fortran, Glowsript, Haskell, IPython/Jupyter Notebook, Mathematica, MATLAB, Python, and Spreadsheet

Students who complete these exercises will be able to:

- model the motion of a falling sphere with air resistance in one dimension using the Euler algorithm (**Exercise 1**);
- produce graphs (position and velocity vs. time) of the computational solution (**Exercises 2-6**);
- assess the accuracy of the computational solution by comparing it to the analytical solution (**Exercises 2 and 3**);
- describe changes in the behavior of the model (e.g., time to approach terminal velocity) based on changes to properties of the falling sphere (e.g., mass and cross-sectional area) (**Exercises 4-6**);
- describe ways to test the accuracy of a computational solution when there does not exist a known analytical solution (**Exercise 7**).

[Instructor's Guide](#)
[Theory](#)
[Exercises](#)
[Code](#)
[Solutions](#)
[1 Comment](#)
[Add Errata](#)

These exercises are not tied to a specific programming language. Example implementations are provided under the [Code](#) tab, but the Exercises can be implemented in whatever platform you wish to use (e.g., Excel, Python, MATLAB, etc.).

### Exercise 1: Computational Model of a Falling Sphere with Air resistance

Produce a working computational model of a sphere that has been dropped from rest from a very tall building

Admin

Status: **Published**

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[Creating a Variation](#)

Credits and Licensing

[Kelly Roos](#), "Falling Sphere with Air Resistance Proportional to  $v^2$ ," Published in the PICUP Collection, July 2016, <https://doi.org/10.1119/PICUP.Exercise.fallsph>.

DOI: [10.1119/PICUP.Exercise.fallsph](https://doi.org/10.1119/PICUP.Exercise.fallsph)

The instructor materials are ©2016 [Kelly Roos](#).

The exercises are released under a



# Exercise Sets (ES)

- An Exercise Set is a set of peer-reviewed material that contains the following:
  - *A brief description of the physics and computation*
  - *A list of learning objectives for the set*
  - *An instructor's guide and theory section for background*
  - *A series of activities and questions (the exercises)*
  - *Code template and solutions in at least one programming language*
  - *Solutions*
- All Exercise Sets are peer-reviewed through semi-automated process
  - *Collaborative peer-review*



# Peer Review

- Emails auto-generated
  - Due dates/reminder emails handled by server
- 
1. Author submits Exercise Set (ES) material
  2. Editor take responsibility for ES
  3. Editor emails potential reviewers
  4. Reviewers submit reviews
  5. Editor contacts author for possible changes
  6. Author submits changes
  7. Published!



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# Why are ES special?

- Complete package
- Easy to download and modify
- Can upload variants
- Language agnostic
  - *Templates and solutions available in one or more platforms*
- Peer-reviewed

## Download Options

Download Exercises - Word

Full Download - Zip

## Share a Variation

Did you have to edit this material to fit your needs? Share your changes by

Creating a Variation



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# Multiple authors, non-faculty authors

## Study of rectilinear motion with a smartphone: Elevators and Slides

Developed by Amador García Fuente, María Rita Sierra Sánchez, Maria Velez, and  
Maria Rosario Diaz Crespo - Published May 21, 2018

- Exercise sets can now have multiple authors
- Students can be included as authors
  - Select “Non-Faculty Verification” on Registration page

Instant Verification ?

Standard Verification ?

**Non-Faculty Verification ?**



# Experiments

- Exercise sets can combine experiments with computation

<b>Instructor's Guide</b>	<b>Theory</b>	<b>Experiment</b>	<b>Exercises</b>	<b>Code</b>	<b>Solutions</b>	<b>References</b>	<b>Add Comment</b>	<b>Add Errata</b>
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These exercises combine computational data analysis with experimental activities that can be performed by the students on their own, without the need of traditional laboratory equipment, simply using their smartphones as portable labs.



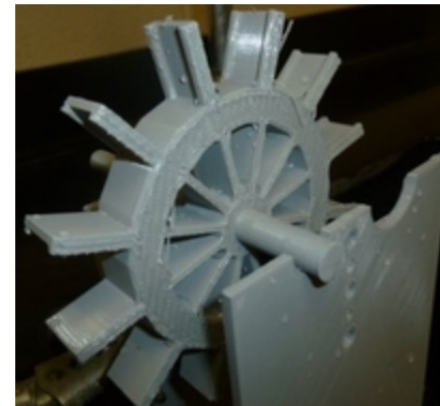
# 3D Printing

- Can find 3D files under Additional Resources on the Code tab

## Efficiency of a Water Turbine (3D Printing Lab)

Developed by [Deva O'Neil](#), [Benjamin Hancock](#), and [Benjamin Hanks](#) - Published June 7, 2021

This Exercise Set describes one way to incorporate 3D printing into lab sessions in Physics I: Students design and print a water-wheel, and measure its efficiency in lifting a load. An optional exercise at the end uses video analysis to verify that the system is approximately in equilibrium for almost all of the lift process. Concepts applied include power, energy, and efficiency.

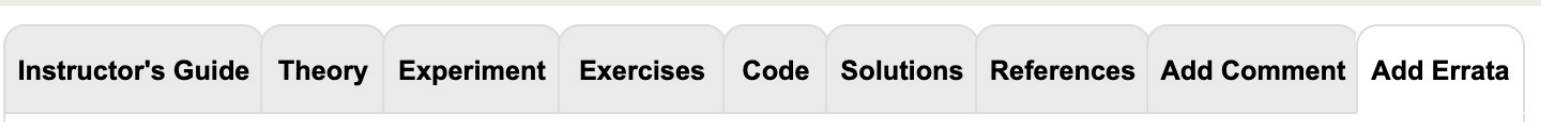




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# Errata Tab

- You can point out errors in ES





# Digital Object Identifier (DOI)



- All ES now have DOI's

## Credits and Licensing

[Deva O'Neil](#), [Benjamin Hancock](#), and [Benjamin Hanks](#), "Efficiency of a Water Turbine (3D Printing Lab)," Published in the PICUP Collection, June 2021, <https://doi.org/10.1119/PICUP.Exercise.waterturbine>.

DOI:  
[10.1119/PICUP.Exercise.waterturbine](https://doi.org/10.1119/PICUP.Exercise.waterturbine)



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# Resources Tab

- Important Resources
- Practices

## Resources

### Important Resources

#### PICUP Capstone Report

A short summary of the 2021 PICUP Virtual Capstone Conference Report, along with links to the report itself.

[Read more »](#)

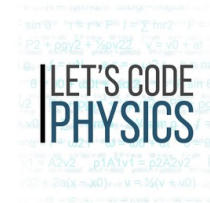
#### Numerical Integration of Newton's Equation of Motion

Numerical integration methods from Appendix 3B of **An Introduction to Computer Simulation Methods** 3rd Ed., by H. Gould, J. Tobochnik, and W. Christian (2007).

[Read more »](#)

### Practices

#### A Welcome to Let's Code Physics



by W. Brian Lane

March 17, 2021

The Let's Code Physics YouTube channel has many tutorials freely available for you to integrate into your physics course. Designed for physics courses of any level, these tutorials introduce physics concepts and computational methods together to help your students explore interesting problems that would otherwise

remain inaccessible.

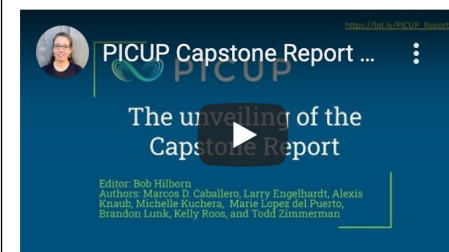
[Read more »](#)

**Tags:** [python](#), [intro classical](#), [intro e&m](#), [numerical methods](#), [labs](#), [tracker](#)

# Community Tab

- Collection of previous PICUP Webinar Series
- Now include DOIs

## PICUP Spring Webinar Series: The Unveiling of the PICUP Capstone Report



May 11, 2022, DOI: [10.1119/PICUP.Webinar.2022-05-11](https://doi.org/10.1119/PICUP.Webinar.2022-05-11)

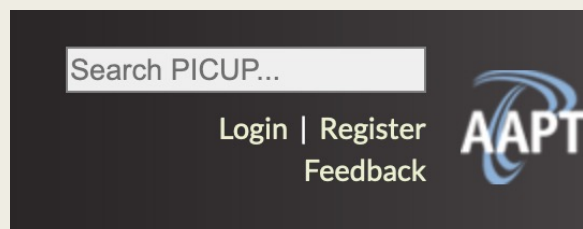
Presenters: Robert Hilborn, Kelly Roos, Larry Engelhardt, Michelle Kuchera, Alexis Knaub, Todd Zimmerman, Brandon Lunk, Marie Lopez del Puerto

The long-awaited [PICUP Capstone Report](#) on the state of computation in undergraduate physics (from a PICUP perspective!) is now ready for public. Several of the report authors will be available for comments and discussion surrounding the report.

*Wednesday, May 11, 2022; 5:00pm PDT | 6:00pm MDT | 7:00pm CDT  
8:00pm EDT*

The [PICUP Capstone Report](#) is now available!

# Site-Wide Searching



- You can search:
  - *Exercise Sets*
  - *Faculty Commons*
  - *Resources*
  - *Webinar abstracts*
  - *Conference abstracts*

## PICUP Search Results

### Search Terms

quantum

### Resource Type

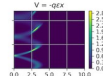
- ☐ Standard Exercise Set (11)
- ☐ Specialized Exercise Set (0)
- ☐ Faculty Commons Item (3)
- ☐ Computational Practice (1)
- ☐ Spotlight (0)
- ☐ Virtual Meeting (1)
- ☐ Presentation Abstract (3)

19 Matches

Search term "quantum"

[Quick Filter](#)

1. Faculty Commons Item (99% Match)



### 1D Quantum Dynamics Assignment

by Larry Engelhardt

This is an assignment that I have given in my upper-level undergraduate quantum mechanics course. In class, we develop the theory to simulate quantum dynamics in an \*arbitrary\* 1D potential. Then I provide the students with "minimally working..."



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# Workshop!

## ■ Summer 2022 Virtual Workshop

- Aug 2-4
- Sign up by July 19
- Go to Events Tab

[Events](#) » 2022 Virtual Workshop

## PICUP Summer 2022 Virtual Workshop

### Integrating Computation into Your Introductory Physics Course

**An online workshop for faculty without previous experience inserting computation into their courses**

[Edit this page](#)  
Version: 13  
[< Previous Version](#)

*This workshop is a very basic primer on integrating computation into introductory courses with easy-to-use, readily available computational tools. No programming experience whatsoever is necessary to participate.*

### Important Dates

**Registration - Open Now - Spots are filling**

**July 19, 2022: Final Registration Deadline**

[Click Here to Register \(Cost is \\$10\)](#)

**Asynchronous Workshop Component:**

**July 20, 2022:** Compulsory Asynchronous Materials will be emailed to all registered participants





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# What can you do?

- Submit Exercise Sets
- Share activities in Faculty Commons
- Write posts for Resources
- Stay connected with the community



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# ES Needs<sup>1</sup>

- EJS
- C++
- PhET-style simulations
- High-school material
- Upper-level material
- Condensed Matter Physics
- High Energy/Particle Physics
- Biophysics
- Chemical/Molecular Physics

1) [Lane, W. Brian. "Analysis of the PICUP Collection: Strengths and Areas for Development." arXiv preprint arXiv:2103.02408 \(2021\).](#)



# A Short History of Computation

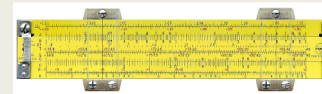
- Hand-written math: ~ 3000 BCE - ...



- Logarithm Tables: 1614 to ?



- Slide Rules: 1620 to 1975



- Handheld Calculator: 1972 - ...



- Personal Computer: 1977 - ...



- Python: 1989 - ...







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# Thank You

- Resource Development: Lyle Barbato, Kelly Roos, Larry Engelhardt
- Other PICUP Leadership: Marie Lopez del Puerto, Danny Caballero, Robert Hilborn, and Norman Chonacky
- Evaluator: Alexis Knaub
- PICUP Associate Editors and Reviewers
- You, the PICUP community



[Link to slides](#)

- Thank you to the UW-Stout Chancellor, STEMM Dean, and Department of Chemistry and Physics Chair for funding

# Links



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- [Shodor Visioning Workshop](#)
- [Computing in Science and Engineering Special Issue on Physics Computation](#)
- [Fuller, Robert G. "Numerical computations in US undergraduate physics courses." \*Computing in science & engineering\* 8.5 \(2006\): 16-21.](#)
- [Caballero, Marcos D., and Laura Merner. "Prevalence and nature of computational instruction in undergraduate physics programs across the United States." \*Physical Review Physics Education Research\* 14.2 \(2018\): 020129.](#)
- [Leary, Ashleigh, Irving, Paul W., and Caballero, Marcos D. The difficulties associated with integrating computation into undergraduate physics. \*Proceedings of the Physics Education Research Conference\* \(2018\).](#)