

Using Open Source Physics to Teach Physics and Astronomy

New Faculty Workshop

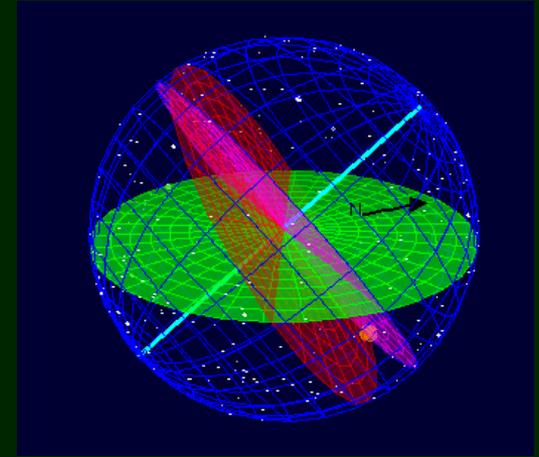
November 2-4, 2017

American Center for Physics, College Park, MD

Wolfgang Christian

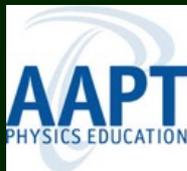
Mario Belloni

Davidson College, USA



ComPADRE ID: [14326](#)

Partial funding for OSP was obtained through NSF grants DUE-0442581 and DUE-0937836 and Davidson College. Opinions expressed here are not those of the AAPT, NSF or Davidson College.



OSP Breakout Session

- Brief description/demo of tools
- Explore OSP site/materials
- Discussion of how to use

Open Source Physics Resources/Tools

Open Source Physics (OSP) provides curriculum resources and tools that engage students in physics, computation, and computer modeling. Computational physics and computer modeling provide students with new ways to understand, describe, explain, and predict physical phenomena. This workshop explores the **AAPT-ComPADRE OSP Collection**.

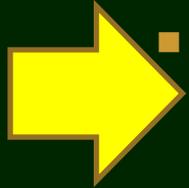
- Physlets are small interactive simulations that are designed for the teaching physics in a web-based environment. [Physlet Physics](#) is a collection of Java and JavaScript items for the introductory physics sequence.
- [Easy Java Simulations](#) encourages modeling and authoring with basic programming. EJS removes many of the complicated tasks involved in integrating computation into the classroom allowing students and teachers to focus on the science. The EJS environment allows learners to explore new physics and to test the limitations of the models being used.
- [Tracker](#) video analysis and modeling tool that analyzes video clips. Students can both analyze the motion of objects and overlay simple dynamical models on the video and see how well the model matches the real-world.

The [OSP Collection](#) is an AAPT-ComPADRE repository where OSP-based curricular materials can be organized and shared.

Simulation Terminology 101

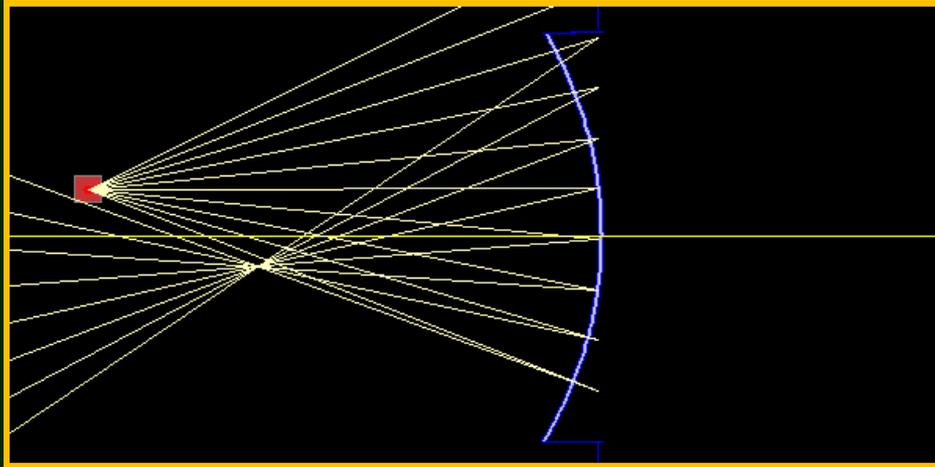
- Java: Programming language for simulations. Simulations can be run as stand-alone archives (jars) or as applets. **Caution: Java applets are deprecated and only work in small number of browsers.** All desktop Java applications (jar files) continue to function if Java the JRE is installed.
- JavaScript: Scripting language created in 1995 and is part of the HTML5 standard. Recently updated to European Computer Manufacturers Association (ECMA) Script 6.
- HTML5: Markup language standard for the Web going forward. Supports JavaScript, CSS, etc. Does not support Java Applet or Flash plug-ins.

How can we use simulations in teaching physics?



- User: Students access pre-made simulations that (hopefully) they must interact with.
- Modeler: Students are given access to a software package with a simple user interface. Students must then simulate the physics of a problem by modeling at a high level of abstraction. For example, adding the physics in the form of differential equations (rates of change) and initial conditions.
- Programmer: Students are given tools to program a physics example using traditional computational physics techniques.

JiTT or ILD Examples



A point source is located to the left of a mirror. You can click-drag the point source to any position (**position is given in centimeters**).

1. Find the focal length of the mirror.
2. Describe the technique(s) you used to determine the focal length.

OSP ComPADRE seach:

- **Focal Length JS (Answer: [ID 14037](#))**
- **Incline Plane JS (Answer: [ID 14054](#))**

EJS Sims & Physlet Physics

Java applets – but not Java programs! – have been deprecated by Oracle and will no longer run in most browsers. The 3rd Edition of Physlet Physics is being developed using HTML 5 + JavaScript so it can be run on any platform including mobile devices.

Physlets by Wolfgang Christian and Mario Belloni

Hosted by AAPT ComPADRE

1. Kinematics 2. Newton's Laws 3. Gravitation 4. Oscillations and Waves 5. Heat and Temperature



Physlets

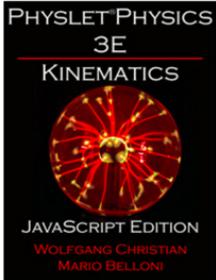
Physlet® Physics 3Ed is a fully functional electronic book. On a desktop or laptop computer or on a mobile device with an appropriate size screen, such as a tablet, the interactive simulations can be read and accessed via a browser.

- [Kinematics](#)
- [Newton's Laws](#)
- [Gravitation](#)
- [Oscillations and Waves](#)
- [Heat and Temperature](#)

[About this book](#)

Edit

- [Manage Book](#)
- [Manage Folder](#)
- [Rename Folder](#)



Physlet® Physics 3Ed

The **Physlets® Physics** interactive book contains JavaScript adaptations of Physlet® curricular material developed using version 5 of the [Easy Java/JavaScript Simulations](#) (EJS) authoring and modeling tool. The Illustrations and Problems in this book are JavaScript adaptations of the Java applet version of [Physlet Physics 2E](#) by Wolfgang Christian and Mario Belloni. Unlike the Java version, these new JavaScript simulations run on both desktop computers and mobile devices.

The **Third Edition** of *Physlet® Physics* is being developed using HTML 5 + JavaScript so that simulations can be delivered as stand-alone pages on web servers or in electronic books that can be read on EPUB 3 readers which support Math ML and JavaScript.

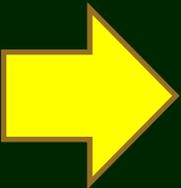
©2017 Wolfgang Christian
Released under a [Creative Commons Attribution-Noncommercial-No derivatives 3.0 license](#)

Hosted by AAPT ComPADRE as a member service

<http://www.compadre.org/books/Physlets-3E>

How can we use simulations in teaching physics?

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Interactive Engagement



One problem with our system of education is....

...that we reward students for knowing the answers....

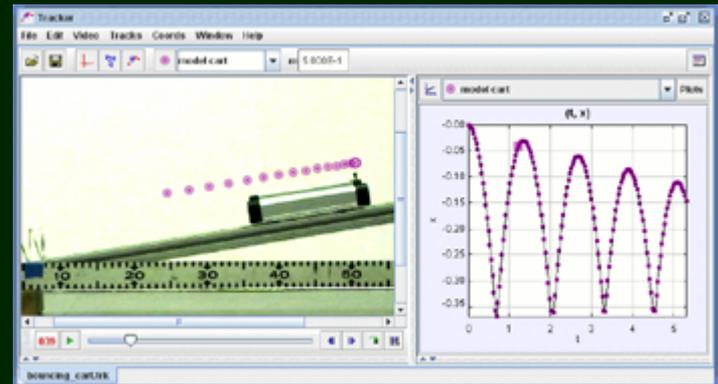
....to questions they have never asked.

Video Modeling with Tracker

Download and install Tracker: <https://physlets.org/tracker/>

Three easy steps:

- Load Video
- Set scale and origin
- Shift-click to take motion data



[Time for a demo!](#)

Easy Java/JavaScript Simulations

Task Selectors

Workpanel

Message

Tree of elements

Simulation view

- mainFrame
 - menuBar
 - functionPanel
 - plottingPanel
 - controlPanel
 - buttonPanel
 - startStopButton
 - stepButton
 - resetTime
 - resetButton
 - descriptionButton
 - ioPanel
 - evolParamDialog
 - viewParamDialog
 - interactionDialog

View Elements

Drawing and Plotting Tools Pallets

Elements for the view

- Interface
 - New
 - Open DL
 - Save As
 - Run
 - Package
- 2D Drawables
- 3D Drawables

Sim. Info

Open

Save

Search

Translate

Options

Wiki Help

Output

File successfully read ParallelTwoDimensionalQM.ejs

EJS console 5.0 beta

Basic options | Advanced options | Output area

Launch EJS in this alternate Java VM:

Virtual Machine parameters: -Xmx256m

Additional arguments for EJS:

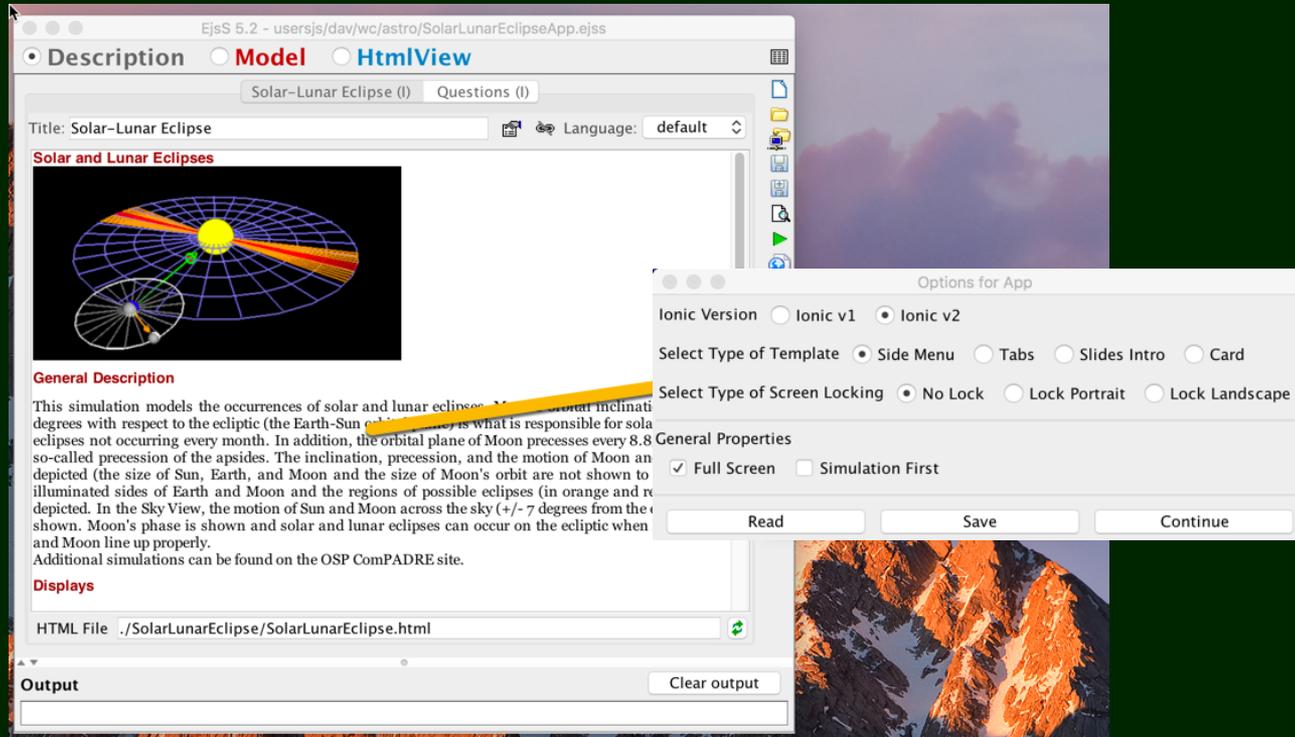
Programming language: Javascript

Launch EJS | Compile directory | Package simulations | Rebuild package

Supports Java and JavaScript models.
Exports JavaScript models as xhtml
and as ePub.

Demonstrate how to load, modify, and save a model.

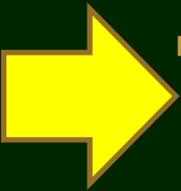
EJS + Ionic creates iOS and Android Apps



Examples: [Compadre ID 14328](#) ID [14326](#) and ID [13337](#)

How can we use simulations in teaching physics?

- User: Students access pre-made simulations that (hopefully) they must interact with.
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Why might we want to integrate computation into teaching physics?

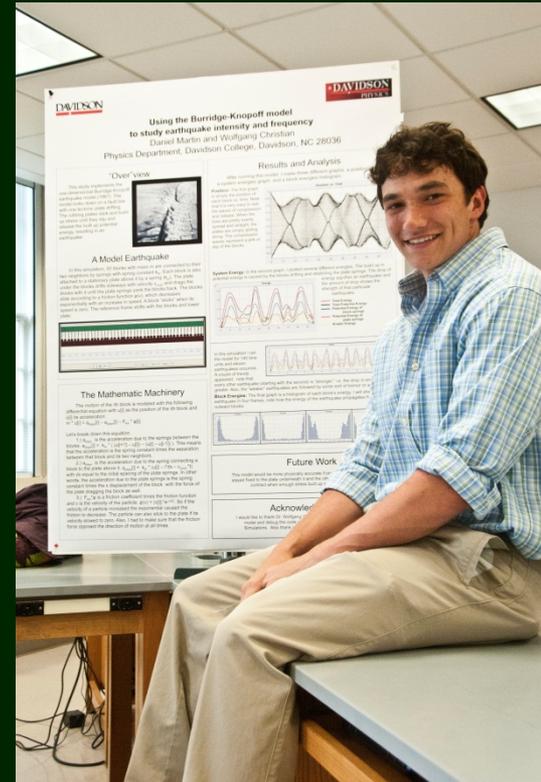
- Models allow students to think about things in terms of simpler artificial things.
- Computer-based modeling
 - Exploratory simulations engage the student in ideas presented by an expert. Students are led to confront another's view of a problem.
 - Simulation-based and programming activities are expressive exercises that require students to externalize their own ideas and assumptions and to create concrete representations that they can reflect on.



Computational-Physics-Education

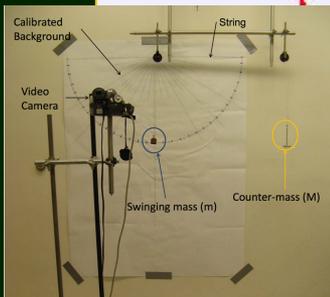
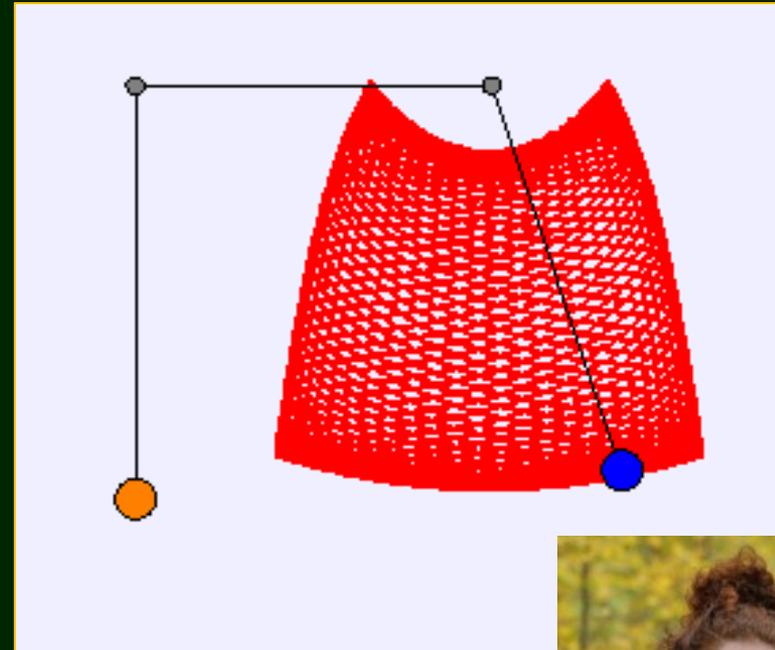
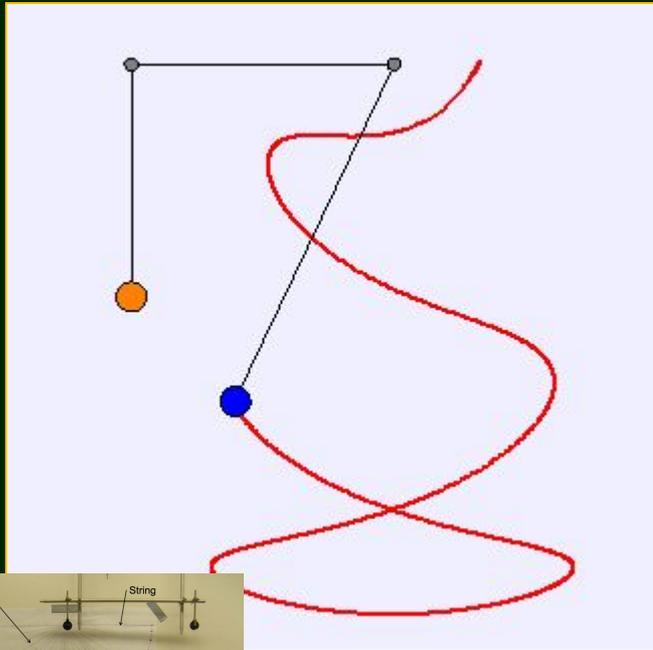
Teaching should reflect current research and professional practice. Every undergraduate physics major should know about computational physics, including essential algorithms, some level of programming experience, and computational ways of thinking.

- Differential equations and ODE numerical algorithms: oscillators, Newtonian orbits, and few-body problems.
- PDEs and boundary value problems: Laplace and Poisson equations.
- Stochastic models and Monte Carlo algorithms: Random walks and the Ising model.
- Chaos theory: Logistic map and driven pendulum.
- **Final project of the student's choice.**



[See shared filing cabinet.](#)

Example of Computational Physics and Experimental Physics: The Swinging Atwood's Machine



OSP ComPADRE [Item 11247](#)

Modeling Cycle

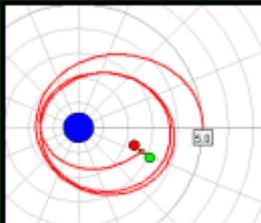
- The goal of modeling is to teach in a student-centered environment where students do not solve problems in a formula-centered way.
- Modeling Instruction attempts to enhance student achievement through a process called the **Modeling Cycle**, (following [Robert Karplus'](#) Learning Cycle).
- Throughout the Modeling Cycle we rely on student engagement and explanation as the dynamic of learning.
- The start of the modeling cycle is the development phase:
 - Qualitative description
 - Identification of variables
 - Planning an experiment
 - Performing the experiment
 - Analysis of experiment
 - Presentation of results
 - Generalization

Although the Modeling Cycle can be used without computers, it is well suited for computer modeling if we replace the word “experiment” with “simulation” in the development phase.

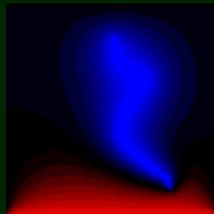
After the development phase, the model is deployed in a variety of new physical situations in a variety of different ways.

Projects in ComPADRE ([shared filing cabinet](#))

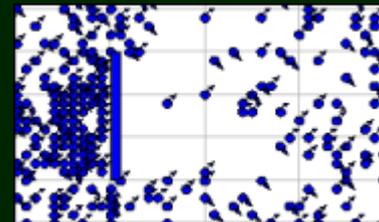
- Hyperion Orbit
(J. Barrick)



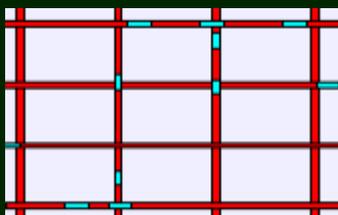
- Lightning
(S. Castle)



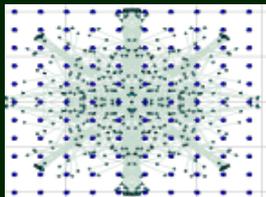
- Lattice gas
(B. Gautier)



- 2D Traffic Flow
(F. Healy)



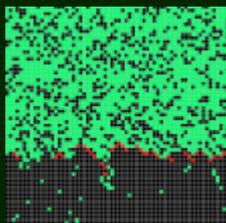
- Lorentz Gas
(S. Keller)



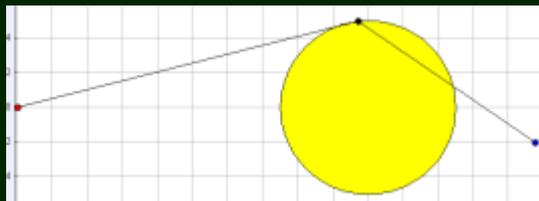
- Fractals
(S. Mohammed)



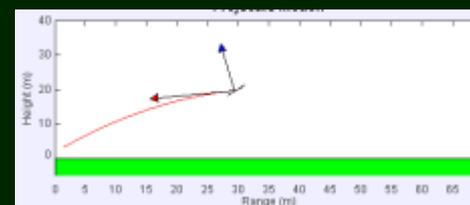
- Forest Fires
(M. Mohorn)



- Catastrophe Theory
(D. Glassman)

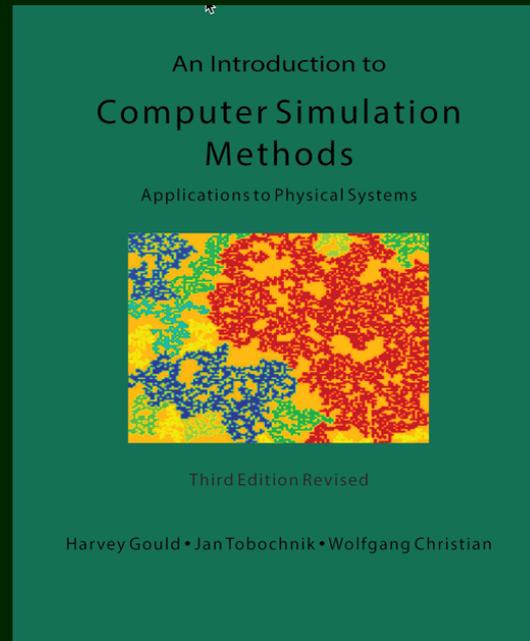


- Javelin Throw
(P. Wall)



Computational Physics Book

PDF available at no cost on ComPADRE: [ID 7375](#)



Available at low cost on Amazon using print on demand.

Need for Digital Libraries

A Google search for “*pendulum*” returns 11,600,000 pages; while “*pendulum simulation*” returns 2,490 pages (The search for *pendulum simulation* without the quotes returns 449,000 pages).

- Most of the simulations (or animations that “fake” the physics) are inappropriate for teaching.
- There is usually no instructional material, no support materials for teachers, and no information about how these materials are correlated to state or national science standards.
- Most of these simulations also support a passive (viewing) pedagogy versus an active (interacting) pedagogy.

In order to be effective for instruction, simulations need to be easy to find, simple, adoptable, adaptable, and coupled with support content for students and teachers.

ComPADRE

We are out of the business of web hosting and let the experts do it.

Standard and Custom Library and Web Services

Connections to NSDL Users

500 OSP Resources

800 Physlet Resources

12,000+ visitors/month

5,000 simulation downloads/month

Logged in as Bruce, ComPADRE Dir (brmason@ou.edu) - [my profile](#) - [logout](#)
[filing cabinet](#) - [suggest a resource](#) - [administrate](#)

Search the OSP Collection...

SIMULATIONS
EJS MODELING
CURRICULUM
PROGRAMMING
TOOLS
BROWSE MATERIALS
RELATED SITES
DISCUSSION
ABOUT OSP

Computational Resources for Teaching

The **OSP Collection** provides curriculum resources that engage students in physics, computation, and computer modeling. Computational physics and computer modeling provide students with new ways to understand, describe, explain, and predict physical phenomena.

Simulations

OSP Simulations are compiled programs on specific topics. The models can be used for concept building, exploring physical systems that are not accessible otherwise, or as a basis for other student exercises.

[Browse simulations](#)

EJS Modeling

Student modeling, the guided exploration of physical systems and concepts, is a powerful approach to engaged learning. Easy Java Simulations provides the computational tools for students and faculty to explore physics without the need for learning details of java programming.

[Learn more about EJS](#)

Featured Simulation

Polarizer Program
The Polarizer program displays the effect of a plane polarizer on an incident electromagnetic wave. The default electromagnetic wave is plane polarized but this polarization can be changed using

Featured EJS Model

Orbiting Mass on a Cone 3D Model
The EJS Orbiting Mass on a Cone 3D model displays the frictionless dynamics of a mass constrained to orbit on the inside of a

Upcoming OSP Events

[Incorporating Computation and Modeling into Physics Teaching](#)
Workshop for New Physics and Astronomy Faculty
ACP, College Park, MD
November 13-15, 2009

[SC 09: Educational Program](#)
EJS, Pathways, and Digital Libraries Presentations
SC 09: International Conference on High Performance Computing, Networking, Storage, and Analysis
Portland, OR
November 14-17, 2009

[Open Source Physics Content Delivery: Computation, Curriculum, and Libraries](#)
A presentation at the 2009 NSDL annual meeting on use and dissemination of OSP and EJS resources

[Building a National Digital Library of Physics Simulations](#)
Presentations by Wolfgang Christian and Fu-Kwun Hwang at the CCP 2009 conference in Kaohsiung, Taiwan December 2009

The Open Source Physics Project is supported by NSF DUE-0442581.

Personalization

Content ...

- Find
- Collect
- Sort
- Relate
- Annotate
- Share

The screenshot displays a web application interface for quantum mechanics resources. The main content area shows a 'Computer Program Detail Page' for the 'Superposition Package' by Mario Belloni and Wolfgang Christian. The page includes a description of the package and a 'Save into folder' dropdown menu with options like 'de Raedt', 'Dephasing', and 'Entanglement'. Below this, there are search results for 'Quantum Spin' with three entries: 'Spins Package', 'QM Spins Program', and 'Open Source Physics Curricular Material for Quantum Mechanics'. Each entry has a 'Save into Folder' dropdown menu. The interface also features a 'Folder Management' tab and a 'Citation Guide' section.

Computer Program Detail Page

Superposition Package
written by Mario Belloni and Wolfgang Christian

The Superposition package is a self-contained file for the teaching of the time evolution and visualization of energy eigenstates and their superpositions in quantum mechanics. The file contains ready-to-run OSP programs and a set of curricular materials. One can choose from several real-time visualizations, such as the position and momentum expectation values and the Wigner quasi-probability distribution for position and momentum.

The Superposition package is an Open Source quantum mechanics. It is distributed as a resp_superposition.jar file will run the package are also available. They can be found by searching Quantum Mechanics.

Open Source Physics Results Partner Results

Search Terms: Quantum Spin

Results #1-#3 of 3

sort by: relevance | subject | date | title | author

1. **Spins Package** [Computer Program] [A]
The Spins package is a self-contained file for the teaching of measurement and time mechanics. The file contains ready-to-run OSP programs and a set of curricular ...
<http://www.compadre.org/OSP/document/ServeFile.cfm?ID=7329&DocID=491>

2. **QM Spins Program** [Computer Program] [A]
The QM Spins program simulates the quantum-mechanical measurement of spin-1/2 shows the result of measuring the z component of spin on a beam of spin-1/2 particles.
<http://www.compadre.org/OSP/document/ServeFile.cfm?ID=7011&DocID=344>

3. **Open Source Physics Curricular Material for Quantum Mechanics** [A]
M. Belloni, W. Christian, and D. Brown, Comp. Sci. Eng., 9 (4), 24-31 (2007).
The Open Source Physics Curricular Material paper describes the interactive curricular material created as part of the Open Source Physics project for the teaching and learning of quantum mechanics. Here ...
<http://www.compadre.org/OSP/document/ServeFile.cfm?ID=7286&DocID=456>

Quantum Relations folder

Filing Cabinet Root

Quantum Relations

- de Raedt
- Dephasing
- Entanglement
- Falstad
- Joffre
- Spin
- Vis Quantum Mechanics

Bookmarks | Sharing | Folder Management | Citation Guide

Quantum Relations

- Superposition Package: Eigenstates and Sums
Quantum 1: 1D Quantum States
This package of exercises and tutorial materials introduces students to 1D quantum eigenstates and sums of eigenstates. Relations to potential functions and time dependence are stressed.
[details](#) - [download page](#) - [edit personal note](#) - [cite](#)
- Spins Package: 2-state Physics
This simulation of Stern-Gerlach experiments provides a powerful tool to teach quantum physics as linear algebra. Examples of measurements and time dependence are given.
[details](#) - [download page](#) - [edit personal note](#) - [cite](#)

Quantum Relations Options

Copy or Move bookmarks selected above to the [] folder [X]

Visit the [Folder Management](#) tab to create sub-folders, rename, move, or delete this folder. You may also provide an [annotation](#) for this folder. Visit the [Sharing](#) tab for information on sharing this folder.

OSP Support for new technologies

EJS creates ePubs and Apps that run on mobile devices.

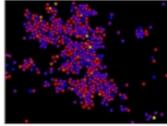
» home » Search Results » Detail Page

Computer Program Detail Page

Molecular Dynamics Exploration JS Model

written by Wolfgang Christian and Daniel Schroeder

The EJS Molecular Dynamics Exploration JavaScript Model shows the dynamics of simple atoms and molecules in a two-dimensional container. The force between the atoms is weakly attractive at short distances, but strongly repulsive when they touch. Use the simulation to explore phases of matter, emergent behavior, irreversibility, and thermal effects at the nanoscale.



The motion of the molecules is governed by Newton's laws, approximated using the Verlet algorithm with the indicated Time step. For sufficiently small time steps dt , the system's total energy should be approximately conserved. Users can select various initial configurations using the drop down menu.

The Molecular Dynamics Exploration was developed by Wolfgang Christian at Davidson College using the Easy Java/JavaScript Simulation (EjsS) modeling and authoring tool created by Francisco Esquembre. This EjsS simulation is based on a pure [JavaScript + HTML 5 simulation](#) developed by [Daniel V. Schroeder, Physics Department, Weber State University](#). Although EjsS is a Java program, it can create stand alone JavaScript programs that run in almost any PC or tablet.

Molecular Dynamics Exploration JS Model
download 352kb
Published: March 27, 2016
[previous versions](#)

Molecular Dynamics Exploration
The Molecular Dynamics Exploration packaged in an ePub 3 document.
download 319kb
Last Modified: March 31, 2016

Molecular Dynamics Android App
The Molecular Dynamics Exploration packaged as a stand alone Android app.
download 4255kb
Last Modified: July 14, 2016

2 ready-to-run examples are available

EJSS model
Edit

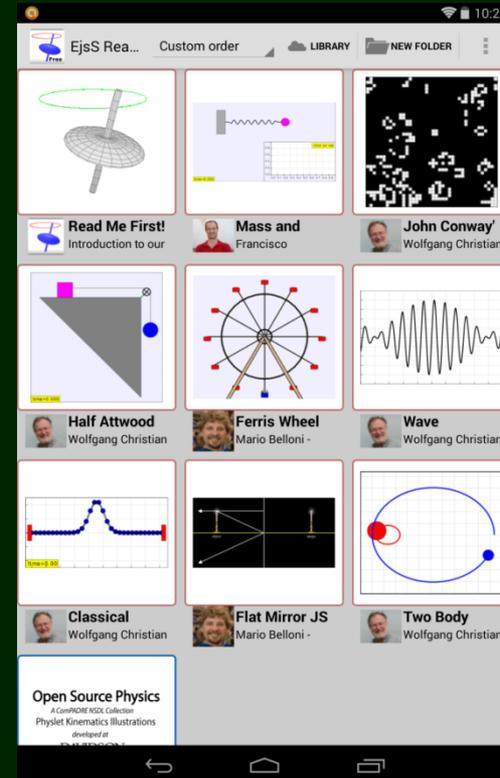
Molecular Dynamics Exploration
Edit

Molecular Dynamics with Mobile Device Gravity Sensor
Edit

1 supplemental document is available

1 source code document is available

Subjects	Levels	Resource Types
Thermo & Stat Mech <ul style="list-style-type: none">- Kinetics and Dynamics<ul style="list-style-type: none">= Kinetic Theory- Models<ul style="list-style-type: none">= Lennard-Jones Potential- Thermal Properties of Matter<ul style="list-style-type: none">= Pressure= Temperature	<ul style="list-style-type: none">- Lower Undergraduate- Upper Undergraduate	<ul style="list-style-type: none">- Instructional Material<ul style="list-style-type: none">= Interactive Simulation



EjsS Reader App interface showing a grid of physics simulation thumbnails. The thumbnails include:

- Read Me First! Introduction to our
- Mass and Francisco
- John Conway Wolfgang Christian
- Half Attwood Wolfgang Christian
- Ferris Wheel Mario Belloni
- Wave Wolfgang Christian
- Classical Wolfgang Christian
- Flat Mirror JS Mario Belloni
- Two Body Wolfgang Christian
- Open Source Physics A COMPARE BOOK Collection Physlet Kinematics Illustrations developed at Davidson College

Reader App ([Android](#)) ([iTunes](#))

Why open source curricular material?

- Shift from low-value work to high-value work. We like to say in open source that all the easy problems have already been solved.
- Lower total cost. Using open source curriculum shifts the cost from licensing and purchasing to customization and implementation.
- Given enough eyeballs, many problems are shallow (Linus's Law). Empirically, open source tends to produce better quality material because more people can contribute.
- Open source provides many advantages. First, you have the opportunity to tap the knowledge of the world's best educators, not just those in your organization. Second, the number of potentially contributors and thus the potential knowledge pool is orders of magnitude larger. Finally, open source curricular material gets adapted to a variety of use cases, not just the one the creator originally intended.
- Open source promotes the sharing of ideas. Open source isn't a fad, or a bunch of hippies experimenting with illicit substances.

What you use will be related to the course you are teaching, your student body, and your expertise.

In general...

...the less sophisticated the student,
the more sophisticated the user interface
...and the more interactive, the better....

...keeping in mind that
technology without **pedagogy**...
...is just **technology**.



Summary

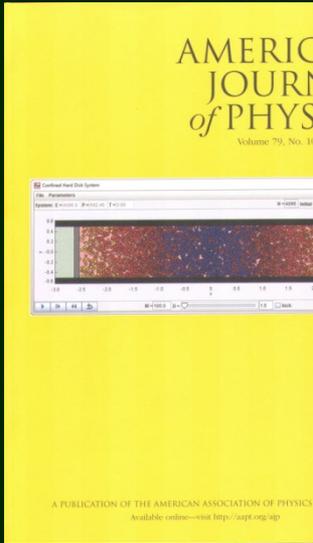
The **OSP Collection** removes many of the complicated tasks involved in integrating computation into the classroom allowing teachers to focus on the science.

- OSP provides computational tools, including a computational physics textbook, for our project.
- OSP allows learners to engage in computational physics modeling.
- OSP encourages the sharing of curricular materials by allowing instructors to adapt existing EJS models to their particular needs.
- ComPADRE supports distribution and collaboration by providing an internet portal and a web service of models that are directly downloadable into the EJS and Tracker modeling tools.

The OSP Collection in ComPADRE is a repository where programs, models, and curricular materials can be organized and shared by developers and instructors around the world.

AAPT - ComPADRE Team

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 - Wolfgang Christian - Davidson College
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 - Harvey Gould - Clark University
 - Jan Tobochnik - Kalamazoo College
- **Tracker and OSP Tools Developer:**
 - Doug Brown - Cabrillo College
- **Easy Java Simulations Developer:**
 - Francisco Esquembre - Universidad de Murcia
- **OSP Java Library Editor:**
 - Wolfgang Christian - Davidson College
- **AAPT-ComPADRE :**
 - Bruce Mason – University of Oklahoma
 - Lyle Barbato - AAPT
 - Caroline Hall - AAPT
 - Erwin Campbell- AAPT



October 2015 Volume 53 Number 7

The Physics Teacher



Open Source

During the past year, we have received over 100,000 visitors. More importantly, we have received many additional subscriptions and during the past year, Physics Teacher has been viewed over 100,000 times.

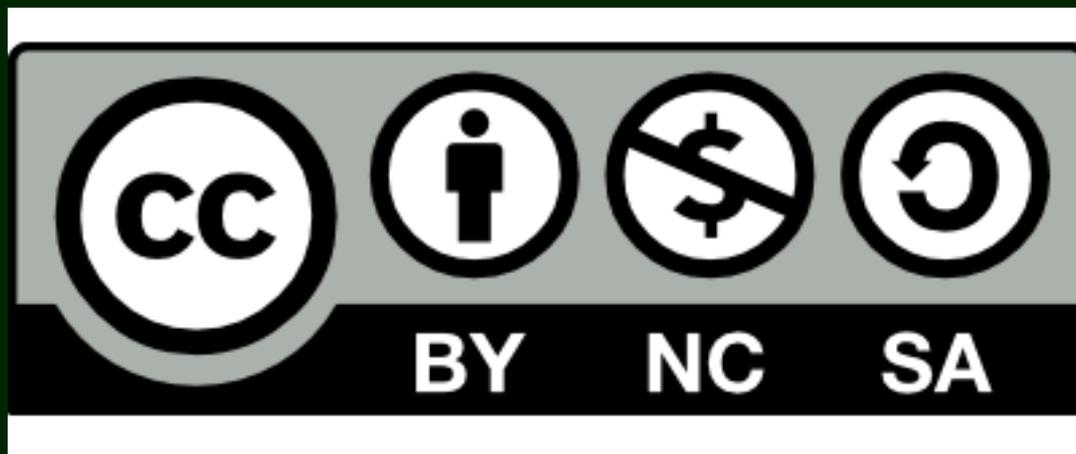
views and 100,000 from the Collection workspaces. During the past year, Physics Teacher has been viewed over 100,000 times.

A publication of the American Association of Physics Teachers



www.compadre.org/osp

Thank your for your attention.



Download our work from the [OSP Collection](#) on AAPT-ComPADRE