Open Educational Resources in Physics and Computer Science at Whittier College

Open-source, Free, and Fully Integrated

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Whittier College

Outline

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1. **Motivations**
    - Open-source tradition in STEM
    - Accessibility issues
    - Integration
2. **OER in Physics**
    - OpenStax textbooks
    - Physics Education Technology (PhET) simulations
3. **OER in Computer Science**
    - Digital Signal Processing text, with counter-example
    - PYNQ-Z1 system-on-a-chip (SoC)

Motivations, OSS

Motivations

Motivation 1: You cannot sell the number π:

```
import numpy as np
import math as mm
import matplotlib.pyplot as plt
time_data = np.linspace(0,2*mm.pi,1000)
x_data = np.cos(
        np.multiply(2.0*mm.pi*10.0,time_data)
        )
plt.plot(time_data,x_data)
```

This software code is an example of a usage of the open-source python package *numpy* to plot the cosine of some data.

Motivations

Motivation 2: It's not really *your* algorithm.

```
t = 2*pi*linspace(0,1,1024)';
y = sin(3.14*t) +
    0.5*cos(6.09*t) +
    0.1*sin(10.11*t+1/6) +
    0.1*sin(15.3*t+1/3);
data = abs(y + 0.1*randn(length(y),1)); # Positive values -
[pks idx] = findpeaks(data,"MinPeakHeight",1);
...
```

This user deploys **octave** code to find the peaks in some data, using a user-generated algorithm called *findpeaks* in the **signal** package.

Motivations

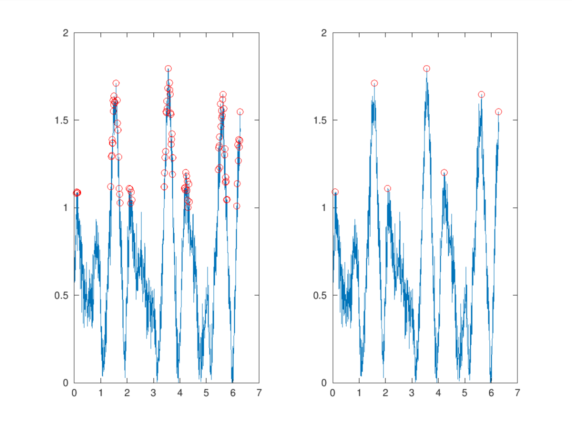

Figure 1: The algorithm worked, and can be obtained by downloading the signal package from the octave source-forge page.

Motivations

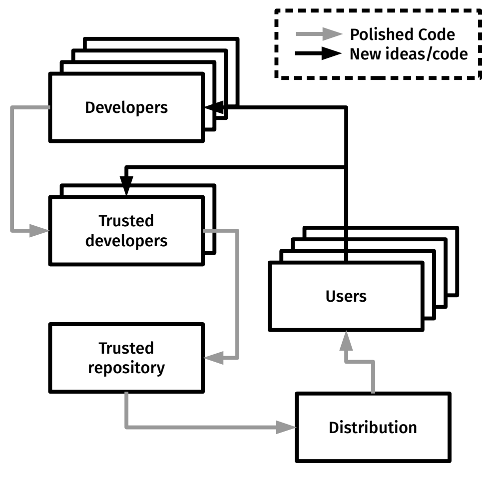

Figure 2: The design model for OSS.

Motivations, Access

Motivations

Physics textbooks are some of the highest priced (to buy new).

- Average introductory text price $\approx$ \$120.00
- For physics/engineers, $\approx$ \$100.00 per course
- Lab fees add additional cost
- Online features limited to those created by the publisher

Motivations, Access

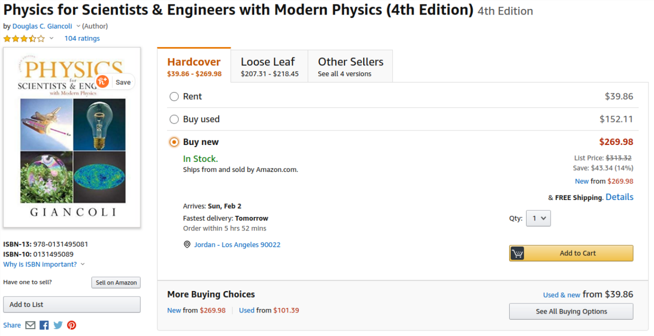

Figure 3: An example of a traditional physics textbook. A student purchasing this book would be able to use it for three semesters, implying $90.00 per semester. Examples of online features include online courses for $140.00 each, and instructor test banks.

Motivations, Integration

Motivations

OpenStax is my favorite alternative:
`https://openstax.org/`

1. Cost: $0.00. No, seriously, it's free.
2. Wide selection of science, math, and social science texts
3. Mostly introductory level (i.e. common material)
4. Text is accessed via HTML, PDF, iOS app, Android app
5. **Fully integrated HTML5 simulations inside the text, as additional explanations and learning content.**
6. Administered through grants and donations, coordinated at Rice University
7. Content contribution from a wide variety of professors

Motivations

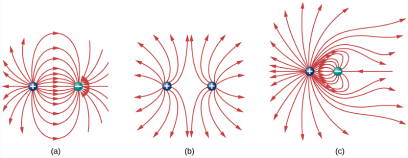

Figure 5.31 Three typical electric field diagrams. (a) A dipole. (b) Two identical charges. (c) Two charges with opposite signs and different magnitudes. Can you tell from the diagram which charge has the larger magnitude?

The ability to construct an accurate electric field diagram is an important, useful skill; it makes it much easier to estimate, predict, and therefore calculate the electric field of a source charge. The best way to develop this skill is with software that allows you to place source charges and then will draw the net field upon request. We strongly urge you to search the Internet for a program. Once you've found one you like, run several simulations to get the essential ideas of field diagram construction. Then practice drawing field diagrams, and checking your predictions with the computer-drawn diagrams.

INTERACTIVE

One example of a field-line drawing program is from the PhET "Charges and Fields" simulation.

Figure 4: Students encounter the section in PHYS180 (electromagnetism). The HTML open-access simulation is integrated in the text.

`https://phet.colorado.edu/en/simulation/charges-and-fields`.

OER in Introductory Physics at Whittier College

OER in Introductory Physics at Whittier College

1. *PHYS135A: OpenStax College Physics* ... mechanics
2. *PHYS135B: OpenStax College Physics* ... electricity and magnetism
3. *PHYS150: OpenStax University Physics vol. 1* ... mechanics
4. *PHYS180: OpenStax University Physics vol. 2* ... electricity and magnetism
5. *PHYS185: OpenStax University Physics vol. 3* ... thermodynamics, oscillations and waves, and optics

OER in Introductory Physics at Whittier College

The text is integrated into the lecture in three phases:

1. Reading assessment module
2. "Traditional form" lecture module
3. Peer instruction module
4. PhET or laboratory activity (ideally both)
5. Conclusion and next reading assignment
    - Homework sets are integrated into online homework system
    - I've chosen ExpertTA: pulls in problems from OpenStax, students work and submit online
    - Solution manual still applies
    - Up-to-date statistics on performance (I cover what the data tells me to cover in class).

OER in Introductory Physics at Whittier College: Reading Assessment

Wednesday Reading Assessment: Unit 8, Momentum

Prof. Jordan C. Hanson

November 13, 2019

1 Memory Bank

- $\vec{p} = m\vec{v}$ ... Definition of momentum.
- $\vec{p}_f = \vec{p}_i$ ... Momentum conservation: no net forces.

2 Momentum

1. A gas molecule has a mass of 20×10^{-25} kg and an average speed of 350 m/s. What is the momentum in kg m/s?

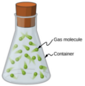

Figure 1: A beaker full of gas molecules.

2. Suppose this molecule collides with the side of the glass beaker, turns around, and flies off in exactly the opposite direction at the same speed. What is the *change* in momentum, $\Delta\vec{p} = \vec{p}_f - \vec{p}_i$? (This is how we build up the **kinetic theory of gases** in Physics 3...stay tuned).

3 Momentum Conservation

1. Two molecules collide and stick together, forming one larger molecule. Each molecule weighs 20×10^{-25} kg. One has a velocity of 350 m/s, and the other has a velocity of -350 m/s. (a) What is the total initial momentum (adding the two momenta)? (b) What is the final speed of the big new molecule?

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Figure 5: An example figure from the text, integrated into my database, covering momentum conservation.

OER in Introductory Physics at Whittier College: Traditional Lecture and examples

CHARGE, CONDUCTORS AND INSULATORS

The rest of the properties of charge are connected to the development of the structure of the atom, and we will return to this topic at the end of the semeter.

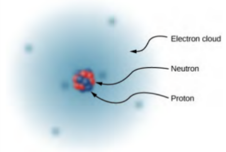

Figure 5.8 The nucleus of a carbon atom is composed of six protons and six neutrons. As in hydrogen, the surrounding six electrons do not have definite locations and so can be considered to be a sort of cloud surrounding the nucleus.

Figure 2: A sketch of our current atomic paradigm.

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Figure 6: An example figure from the text, integrated into my database, covering charge.

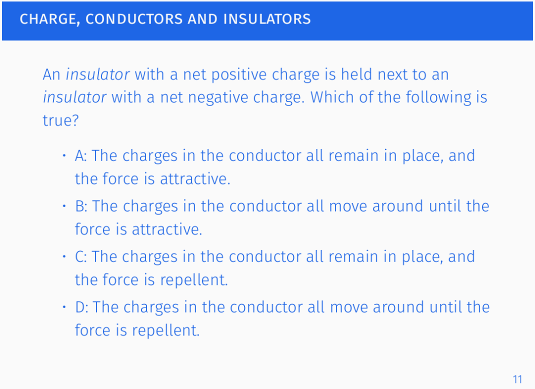

Figure 7: This multiple choice question is answered via electronic device, and the results are used to modify the lecture to suit students' needs.

OER in Introductory Physics at Whittier College: PhET or Lab Activity

ACTIVITY: PHET CHARGES AND FIELDS

At your tables, go to the following URL:

`https://phet.colorado.edu/en/simulation/charges-and-fields`

Click on the java app to get it running. Notice the following:

1. This is a 2D coordinate space, and you can activate the grid lines at right, by clicking *grid*.
2. Clicking *values* gives you the measurement scale.
3. Click *electric field*, or make sure it is activated.
4. Verify the length scale with the **ruler tool**, shaped like a tape measure. It can be dragged from the box at right.

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Figure 8: The charge and electric field PhET is integrated into the slides, so on-screen students see the link to the open access simulation (laptops, tablets, and in-class PCs).

OER in Introductory Physics at Whittier College: PhET or Lab Activity

OHM'S LAW, KIRCHHOFF'S RULES AND SIMPLE CIRCUITS

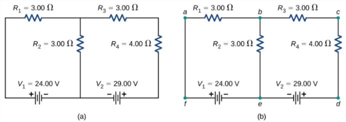

Figure 10.26 (a) A multi-loop circuit. (b) Label the circuit to help with orientation.

Figure 16: (1) Label the circuit. (2) Identify nodes with current labels, and loops. (3) Apply Kirchhoff's Rules.

Work together in groups at tables. (We'll take this in steps. First identify two loops and a node...)

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Figure 9: These figures are DC circuits, from the OpenStax book that ask us to solve for the current. Students work together at their tables to solve the system of equations. This is a medium-difficulty problem.

OER in Introductory Physics at Whittier College: PhET or Lab Activity

OHM'S LAW, KIRCHHOFF'S RULES AND SIMPLE CIRCUITS

Use DC circuit PhET simulation to model Fig. 16, checking the currents I_1, I_2, and I_3.

https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc-virtual-lab

Do you obtain the same results as the example? What is the power consumption of this circuit?

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Figure 10: Using open-access PhET, the students model the circuit they just analyzed. We then build the circuit and confirm the resuts.

https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc

OER in Computer Science at Whittier College

OER in Computer Science at Whittier College: Open-access textbook

Computer Science 390: Digital Signal Processing. - *The study of digitized and sampled signals in electronic systems.*

- Text: *The Scientist and Engineer's Guide to Digital Signal Processing*, by Steven W. Smith
- Website of the text for open-access: `http://dspguide.com/`
- Open-source code: gnu-octave (Octave), a free-version of MATLAB
  1. The students may download the source code, so it's truly open-source
  2. We write and share code examples with each other via Moodle and Dropbox (eventually, **git**).

OER in Introductory Physics at Whittier College: PhET or Lab Activity

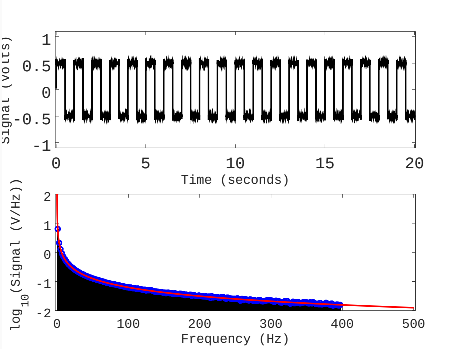

Figure 11: Code shared with the students written in open-source language octave helps them understand the mathematical concept of Fourier series, useful in DSP. This figure was created with octave code.

Counter example: OER in Computer Science at Whittier College

Computer Science at Whittier College: Not open-access

Computer Science 330: Computer Logic and Digital Circuit Design
- *Binary, boolean algebra, logic gates, complex logic functions, firmware, digital instruments and microprocessers.*

- Text: *Digital Fundamentals, 11th ed.*, by Thomas L. Floyd
    1. Access key granted to online resources
    2. Excellent, full-color diagrams and examples
    3. Test banks, solution manuals, etc.
    4. Image banks for reuse in lecture
    5. Example code
- **Open-source hardware and firmware**
    1. The PYNQ-Z1 python enabled system on a chip (SoC)
    2. Allows students to learn to control programmable logic via iPython and Jupyter notebooks
    3. Open source software and firmware
    4. We provide these to lab groups

Counter example: OER in Computer Science at Whittier College

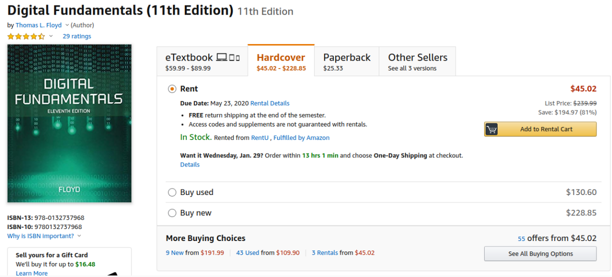

Figure 12: There are not many good open-access computer logic and digital circuit design texts. Features handsome figures, many problem/solution sets, test banks, online student resources (Pearson), and code examples.

Counter example: OER in Computer Science at Whittier College

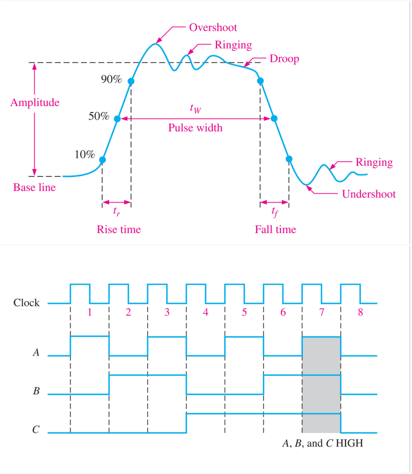

Figure 13: Professional diagrams with examples in the text.

Counter example: OER in Computer Science at Whittier College

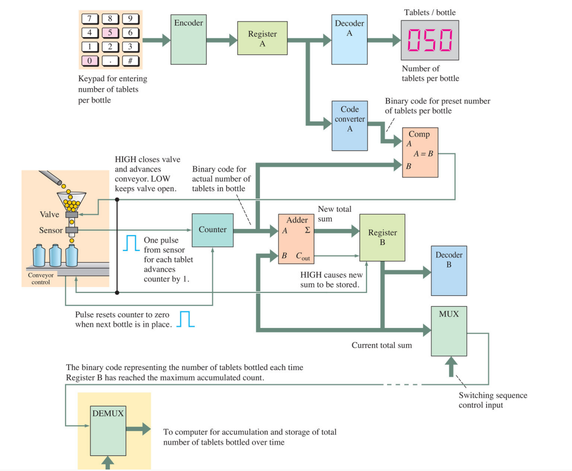

Figure 14: Extended designs.

Counter example: OER in Computer Science at Whittier College

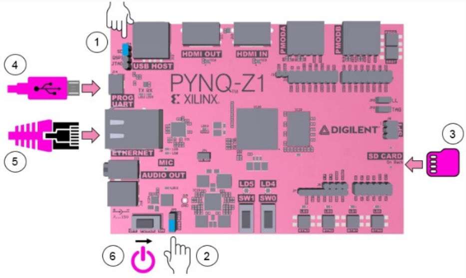

Figure 15: The SoC is operated with open source Jupyter notebooks. The board can offers HDMI input/output, audio, SD card memory, WiFi, digital I/O, PWM and ADC/DAC control, LEDs and push-buttons.

`http://www.pynq.io/community.html`

Conclusion

Outline

1. **Motivations**
    - Open-source tradition in STEM
    - Accessibility issues
    - Integration
2. **OER in Physics**
    - OpenStax textbooks
    - Physics Education Technology (PhET) simulations
3. **OER in Computer Science**
    - Digital Signal Processing text, with counter-example
    - PYNQ-Z1 system-on-a-chip (SoC) **Show the Jupyter notebook.**