Using the Open Source Physics Library to Teach Statistical and Thermal Physics

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Programs

- Java is an excellent choice of programming language for writing software for educational applications.
- The use of the Open Source Physics Library makes writing programs with a GUI much easier.
- Programs can be written as applications and embedded in a html page without any change in the code.
- Programs can be embedded in a self-contained Launcher.
- Approximately 20 simulations and their source code are freely available.
- Associated online textbook is also freely available.

Simulations for Statistical and Thermal Physics

Web sites: <www.opensourcephysics.org/> <stp.clarku.edu>

The applets/applications were written for the Statistical and Thermal Physics curriculum development project and are released under the GNU General Public License.

The simulations can be run as applets or as a stand-alone application. You must have at least Java 1.4 installed on your computer.

Programs written by Kipton Barros, Harvey Gould, Joshua Gould, Natali Gulbahce, Jan Tobochnik, Nicholas Tung, and Peter Sibley with the assistance of Wolfgang Christian.

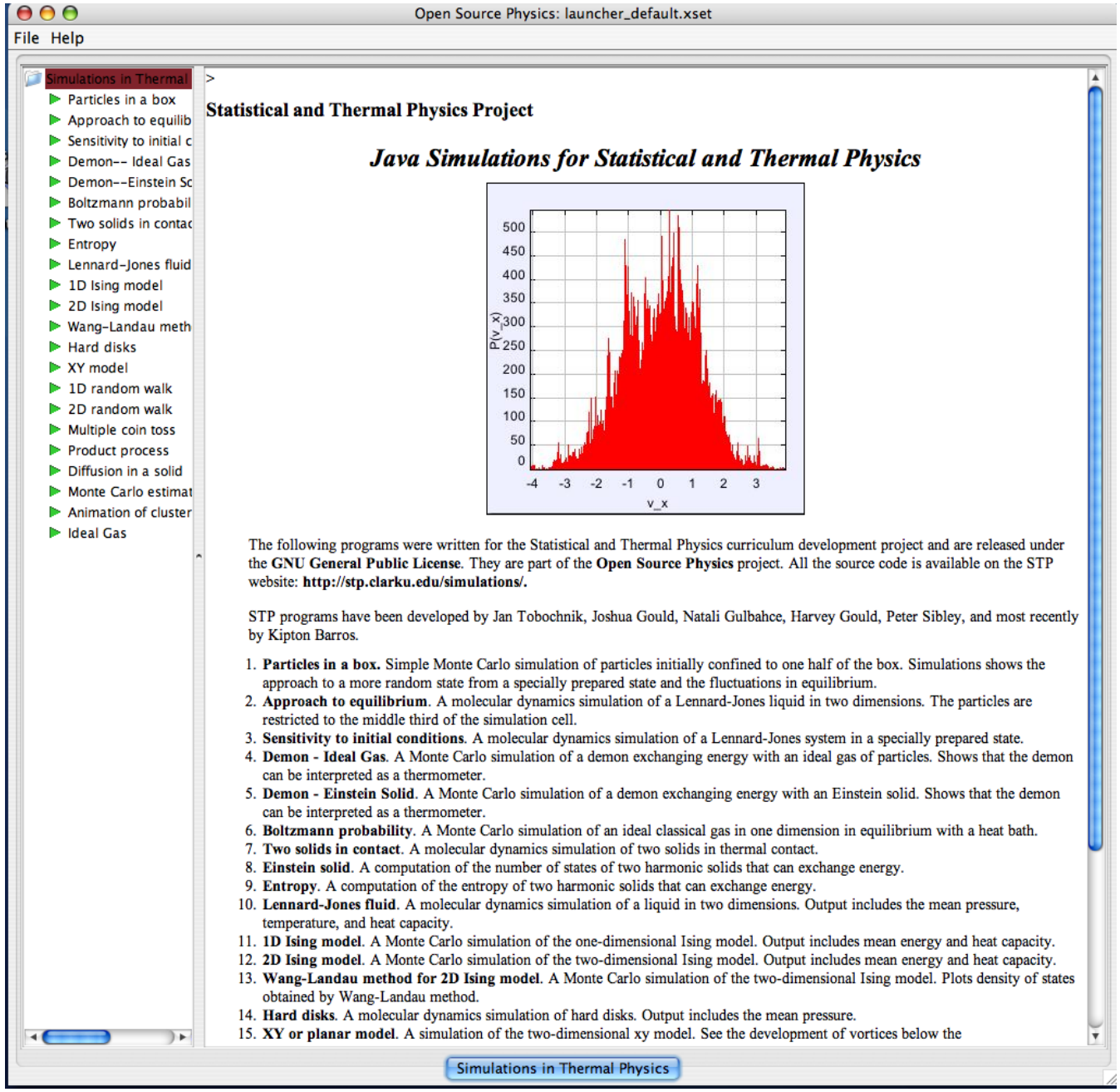
Applets/Applications

1. Particles in a box. MC simulation of particles initially confined to one half of the box. Show the approach to a more random state from a specially prepared state and fluctuations in equilibrium.
2. Approach to equilibrium. MD simulation of a 2D Lennard-Jones liquid. The particles are initially restricted to the middle third of the simulation cell.
3. Sensitivity to initial conditions. MD simulation of a Lennard-Jones system in a specially prepared state.
4. Demon – ideal gas. MC simulation of a demon exchanging energy with an ideal gas. Shows that the demon can be interpreted as a thermometer.
5. Demon – Einstein solid. MC simulation of a demon exchanging energy with a system of harmonic oscillators.

6. Boltzmann probability. MC simulation of an ideal 1D gas in equilibrium with a heat bath.
7. MD simulation of two solids in thermal contact.
8. Einstein solid. Computation of the number of states of two harmonic solids that can exchange energy.
9. Computation of the entropy of two harmonic solids that can exchange energy.
10. MD simulation of 2D Lennard-Jones fluid.
11. MC simulation of 1D Ising model.
12. MC simulation of 2D Ising model.
13. Density of states of the 2D Ising model (Wang-Landau algorithm).
14. MD simulation of hard disks.
15. Simulation of the 2D XY model showing the development of vortices below the Kosterlitz-Thouless transition.

16. 1D random walk.
17. 2D random walk.
18. MC simulation of the statistical properties of the outcome of the tosses of many coins.
19. A simple multiplicative random process.
20. Diffusion in a solid. A simple Monte Carlo simulation of particles on a lattice with a maximum of one particle per site.
21. Monte Carlo estimation of area under a curve using “hit or miss.”
22. Animation o the Hoshen-Kopelman cluster labeling algorithm.

Launcher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Hard disks
XY model
1D random walk
2D random walk
Multiple coin toss
Product process
Diffusion in a solid
Monte Carlo estimat
Animation of cluster
Ideal Gas
Statistical and Thermal Physics Project
Java Simulations for Statistical and Thermal Physics
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The following programs were written for the Statistical and Thermal Physics curriculum development project and are released under the GNU General Public License. They are part of the Open Source Physics project. All the source code is available on the STP website: http://stp.clarku.edu/simulations/.
STP programs have been developed by Jan Tobochnik, Joshua Gould, Natali Gulbahce, Harvey Gould, Peter Sibley, and most recently by Kipton Barros.
1. Particles in a box. Simple Monte Carlo simulation of particles initially confined to one half of the box. Simulations shows the approach to a more random state from a specially prepared state and the fluctuations in equilibrium.
2. Approach to equilibrium. A molecular dynamics simulation of a Lennard-Jones liquid in two dimensions. The particles are restricted to the middle third of the simulation cell.
3. Sensitivity to initial conditions. A molecular dynamics simulation of a Lennard-Jones system in a specially prepared state.
4. Demon - Ideal Gas. A Monte Carlo simulation of a demon exchanging energy with an ideal gas of particles. Shows that the demon can be interpreted as a thermometer.
5. Demon - Einstein Solid. A Monte Carlo simulation of a demon exchanging energy with an Einstein solid. Shows that the demon can be interpreted as a thermometer.
6. Boltzmann probability. A Monte Carlo simulation of an ideal classical gas in one dimension in equilibrium with a heat bath.
7. Two solids in contact. A molecular dynamics simulation of two solids in thermal contact.
8. Einstein solid. A computation of the number of states of two harmonic solids that can exchange energy.
9. Entropy. A computation of the entropy of two harmonic solids that can exchange energy.
10. Lennard-Jones fluid. A molecular dynamics simulation of a liquid in two dimensions. Output includes the mean pressure, temperature, and heat capacity.
11. 1D Ising model. A Monte Carlo simulation of the one-dimensional Ising model. Output includes mean energy and heat capacity.
12. 2D Ising model. A Monte Carlo simulation of the two-dimensional Ising model. Output includes mean energy and heat capacity.
13. Wang-Landau method for 2D Ising model. A Monte Carlo simulation of the two-dimensional Ising model. Plots density of states obtained by Wang-Landau method.
14. Hard disks. A molecular dynamics simulation of hard disks. Output includes the mean pressure.
15. XY or planar model. A simulation of the two-dimensional xy model. See the development of vortices below the
Simulations in Thermal Physics

Can there be an open source textbook?

Online Lecture Notes on Thermal and Statistical Physics

1. “From classical mechanics to statistical mechanics,” pp. 1–25.
2. “Thermodynamic concepts and processes,” pp. 26–81.
3. “Concepts of probability,” pp. 82–137.
4. “The methodology of statistical mechanics,” pp. 138–189.
5. “Magnetic systems,” pp. 190–229.
6. “Noninteracting particle systems,” pp. 230–287.
7. “Thermodynamic relations and processes,” pp. 288–305.

Following chapters are more suitable for a graduate course:

8. “Theories of Gases and Liquids,” pp. 306–349.
9. “Critical Phenomena and the Renormalization Group,” pp. 350–386.
10. “Introduction to Many-Body Perturbation Theory,” pp. 387–396.

Appendix, pp. 397–403.