(b) Now let us ask what happens if the agents save a fraction λ of their money before the transaction. We write

$$m_i' = m_i + \delta m \tag{1.2a}$$

$$m_j' = m_j - \delta m \tag{1.2b}$$

$$\delta m = (1-\lambda)[\epsilon m_j - (1-\epsilon) m_i]. \tag{1.2c}$$

Modify your program so that this savings model is implemented. Consider $\lambda = 0.25$, 0.50, 0.75, and 0.9. For some of the values of λ, as many as 10^7 transactions will need to be considered. Does the form of $f(m)$ change for $\lambda > 0$? ■

The form of $f(m)$ for the model in Problem 1.1a can be found analytically and is known to students who have had a course in statistical mechanics. However, the analytical form of $f(m)$ in Problem 1.1b is not known. More information about this model can be found in the article by Patriarca, Chakraborti, and Kaski (see the references at the end of this chapter).

Problem 1.1 illustrates some of the characteristics of simulations that we will consider in the following chapters. Implementing this model on a computer would help you to gain insight into its behavior and might encourage you to explore variations of the model. Note that the model lends itself to asking a relatively simple "what if" question, which in this case leads to qualitatively different behavior. Asking similar questions might require modifying only a few lines of code. However, such a change might convert an analytically tractable problem into one for which the solution is unknown.

Problem 1.2 Questions to consider

(a) You are familiar with the fall of various objects near the earth's surface. Suppose that a ball is in the earth's atmosphere long enough for air resistance to be important. How would you simulate the motion of the ball?

(b) Suppose that you wish to model a simple liquid such as liquid Argon. Why is such a liquid simpler to simulate than water? What is the maximum number of atoms that can be simulated in a reasonable amount of time using present computer technology? What is the maximum real time that is possible to simulate? That is, if we run our program for a week of computer time, what would be the equivalent time that the liquid has evolved?

(c) Discuss some examples of systems that would be interesting to you to simulate. Can these systems be analyzed by analytical methods? Can they be investigated experimentally?

(d) An article by Post and Votta (see references) claims that "... (computers) have largely replaced pencil and paper as the theorist's main tool." Do you agree with this statement? Ask some of the theoretical physicists that you know for their opinions. ■

APPENDIX 1 A: LABORATORY REPORTS

Laboratory reports should reflect clear writing style and obey proper rules of grammar and correct spelling. Write in a manner that can be understood by another person who has not done the research. In the following, we give a suggested format for your reports.

Introduction. Briefly summarize the nature of the physical system, the basic numerical method or algorithm, and the interesting or relevant questions.

Method. Describe the algorithm and how it is implemented in the program. In some cases this explanation can be given in the program itself. Give a typical listing of your program. Simple modifications of the program can be included in an appendix if necessary. The program should include your name and date and be annotated in a way that is as self-explanatory as possible. Be sure to discuss any important features of your program.

Verification of program. Confirm that your program is not incorrect by considering special cases and by giving at least one comparison to a hand calculation or known result.

Data. Show the results of some typical runs in graphical or tabular form. Additional runs can be included in an appendix. All runs should be labeled, and all tables and figures must be referred to in the body of the text. Each figure and table should have a caption with complete information, for example, the value of the time step.

Analysis. In general, the analysis of your results will include a determination of qualitative and quantitative relationships between variables and an estimation of numerical accuracy.

Interpretation. Summarize your results and explain them in simple physical terms whenever possible. Specific questions that were raised in the assignment should be addressed here. Also give suggestions for future work or possible extensions. It is not necessary to answer every part of each question in the text.

Critique. Summarize the important physical concepts for which you gained a better understanding and discuss the numerical or computer techniques you learned. Make specific comments on the assignment and suggestions for improvements or alternatives.

Log. Keep a log of the time spent on each assignment and include it with your report.

REFERENCES AND SUGGESTIONS FOR FURTHER READING

Programming

We list some of our favorite Java programming books here. The online Java documentation provided by Sun at `<java.sun.com/docs/>` is essential (look for API specifications), and the tutorial `<java.sun.com/docs/books/tutorial/>` is very helpful. There are many other useful tutorials on the Web.

Joshua Bloch, *Effective Java* (Addison–Wesley, 2001). This excellent book is for advanced Java programmers and should be read after you have become familiar with Java.

Rogers Cadenhead and Laura Lemay, *Teach Yourself Java in 21 Days*, 4th ed. (Sams, 2004). An inexpensive self-study guide that uses a step by step tutorial approach to cover the basics.

Stephen J. Chapman, *Java for Engineers and Scientists*, 2nd ed. (Prentice Hall, 2004).

Wolfgang Christian, *Open Source Physics: A User's Guide with Examples* (Addison–Wesley, 2006). This guide is a useful supplement to our text.