University of Arkansas---Department of Physics---Fall 2001

Arkansas Physics

The Home of Physics Innovation

Newsflashes

Important deadline: March 1, 2002 is the deadline for Physics scholarship applications. Call, write or see http://www.uark.edu/depts/physics/undrgrad/scholar2.html for info.

Physics Teacher Education Coalition (PhysTEC)...Funded!

PhysTEC is a project to dramatically improve the preparation of physics and physical science teachers nation-wide.

A productive Teacher-in-Residence (TIR) program is a major component of this program. The TIR, who brings the knowledge and experience of managing a student-centered science class, will assist physics faculty in revising targeted physics courses and will help team-teach the science methods courses in education. The TIR will provide continuity between science methods courses, physics courses, and activities in the local schools. The university, through **PhysTEC** support, will reimburse the school district for the cost for the TIRÕs replacement, while the school district continues to employ the TIR. The TIR will consult with pre-service teachers and provide a realistic understanding of what science is being taught and how it is now being taught in the schools. The TIR will offer valuable contacts with local teachers and school districts that will significantly improve practicum activities and the placement of student teachers. Besides those chosen to be TIR's, the program will benefit in-service teachers. A physics graduate credit class for in-service as well as pre-service HS physics teachers will be taught each summer. Contact Gay Stewart for details for either program.

Everything is A.O.K. in Fayetteville

The Physics Department at the University of Arkansas will play host to physics teachers from the tristate area (Arkansas - Oklahoma - Kansas). The meeting, a sectional meeting of the American Association of Physics Teachers, will be held on October 19 and 20. Highlights will include a series of workshops, a banquet address by Dave Wall (San Francisco City College) on the "Magic of Physics and Vice Versa". Dave will also be conducting two of the workshops. In addition, Karen Williams, national president of the Society of Physics Students, will be conducting a panel discussion on physics outreach, and local SPS chapters as resources for area high schools. Victor Montemayor (Middle Tennessee State) will give an invited talk on "Innovative Methods for Teaching Algebra-based Physics." Support for attending the meeting may be available to teachers considering applying for a TIR position (see article above). For more information on this exciting meeting, go to the web page: http://physics.uark.edu/aok.

Strength in Numbers!

As you can easily imagine, the so-called "population explosion" problem is one in which many people are acutely interested. As the population increases, questions regarding food, shelter, medicine and detente become more and more pressing. Dr. Ed Hach develops a simple model to study population growth.

Cubeworld

Introduction

Have you noticed? There are more people around than there used to be. Of course there are exceptions, but chances are that your town has more people living there now than it did when you first arrived. As a matter of fact, if you look at the population of the United States, you will discover that, according to the results of the recent 2000 census, the population of the U.S. has increased by 13.2% over its level in 1990. In 1990, there were just shy of 250 Million people living in the U.S. At this rate, the population will double, reaching about HALF of a BILLION people by around the year 2046. If you think the lines at the store are long now, give it 50 years!

As you can easily imagine, the so-called "population explosion" problem is one in which many people are acutely interested. As the population increases, questions regarding food, shelter, medicine and detente become more and more pressing. Many of the things we rely upon in our daily lives originate with non-renewable means. The paradigm case is that of fossil fuels; when we run out, we RUN OUT! We as humans are charged with the responsibility of developing viable solutions to these problems. That is not necessarily going to be an easy job.

I am writing in order to set down a basic tool for understanding the nature of population growth. I hope that you will accept this invitation to use your creative and analytical talents to build upon and improve the simple model we consider here.

Modeling Population Growth

You may be wondering; "why is there an article on population growth in a physics newsletter?" After all are these issues not better placed in the hands of biologists, or anthropologists, or sociologists, or even (perish the thought!) politicians?

Physicists use many tools in trying to understand the ways of nature. Many of these tools are rooted in mathematics. It seems that certain principles of mathematics are well suited to describe the ways in which nature works. As a case in point, perhaps you are taking a math class in calculus. Calculus was invented by physicists in order to come up with an accurate description of how objects move. The mathematical tool most relevant to a discussion of population growth is called the **technique of mathematical modeling**.

A mathematical model consists of a set of simple rules to be applied in a regular way to whatever it is you wish to study. In this case, we wish to study the population growth of some region, say the United States. In order to work the model and, hopefully, gain useful information from it, we need to choose something to **represent** the population. The thing we choose to represent the population must have specific properties so that the population will behave according to the rules of the model.

In this case we choose little wooden cubes (all six faces the same size and shape). Some of the cubes have one side painted black, others have two sides painted red. We allow these cubes to live in a region called "cube world." The idea is that, by studying what happens to the population of the cubes in cube world, we can learn about the properties of human populations in human world.

All models have limitations. After all, the model itself is a simplification of what really happens. In order to get useful information about the real population, we must try to make the model as life-like as possible. The trade off is, the more life-like the more complicated. We start with a very simple model, understand it, and then add in new features to try to make the model into a more true representation of reality. For instance, we might change the "birth rate" of the cubes into cube world and see how this affects the population growth.

The idea is that by studying the effects of new features, we can learn what courses of action may be worth consideration in terms of dealing with population expansion. The making of the model is a lot of fun. You can play around with all kinds of variations; some will be quite fruitful and others will not. Either way, we can learn a great deal about things by constructing mathematical models.

Cube World

In this article we deal with a simple model we call cube world. Cube world is populated by a bunch of little cubes. The cubes have a particular birth rate. Time proceeds by rolling the cubes. In other words, each new roll of the cubes will represent the passage of a certain amount of time.

We will call the cubes with ONE SIDE painted BLACK the "black cubes," and those with TWO SIDES painted RED the "red cubes." (See the Appendix for suggestions on how to make these).

The simple mathematical properties of these cubes are as follows:

1. If you randomly throw a black cube onto the table, there is a "one-in-six" chance that the black face will be "up."
2. If you randomly throw a red cube onto the table, there is a "two-in-six" (which is the same as one-in-three") chance that the red face will be "up."

The birth rate in cube world can be fixed by choosing to use either the red or the black cubes. Here we use the black cubes. You can use the red cubes on your own to be sure that you understand the workings of the basic model.

The Basic Model: A Simple Experiment

The general rules of the simple model are these:

1. Start with a certain population,N_o , at a certain time. For example, you can begin with N_o=1 cube in year zero if you like.
2. Roll all of the cubes at once like a bunch of dice. You may want to use a small bucket, remember this is a model of population explosion!
3. For every cube that turns up black, add another cube to the population.
4. Keep a careful record in two columns. The entries on each row should be the roll number, starting with ZERO, in column one and the corresponding population of cube world, starting with N_o, in column two.
5. Repeat steps two though four as many times as you like.

Let's say that at some point in time, there are 6 cubes living in cube world. When next we roll the cubes we expect $\frac{1}{6}\times 6 = 1$ new birth in cube world. If this happens that the new population of cube world *should* be 6+1=7. In other words, based on the model, we *expect* one new cube for every six already present.

We quickly find out that not every roll of the cubes produces the expected result! Sometimes there are fewer cubes born and sometimes there are more cubes born than expected. The reason for this is that the rolling of cubes is, for all practical purposes, a random process. Sure, we know what is most likely going to be the outcome of a given roll, but no one can say for sure what will happen on any give roll. As is often the case, this random aspect of our model cube world actually corresponds, to some degree, with the reality of human population growth. After all, no one (not even Miss Cleo) can predict if, or how many, children will come from any particular combination of man and woman. In other words, the randomness of the rolling of the cubes provides a simple model for complicated things such as individual personal decisions not to have children and families with many children.

There is another type of randomness built into the model. Imagine that, at some point in time, the population of cube world is, say, 13. How many offspring should this population produce? Well, perhaps you are quick to think that the answer is $\frac{1}{6} \times 13 = 2\,{}^{1}\!/_{6} = 2.1667$. But how can a cube have ${}^{1}\!/_{6}$ of a "baby" cube? It can't! How does nature decide how to round this off? It doesn't! The number of offspring at a given roll is the result of many complicated physical interactions. It is the complexity of these interactions which gives the appearance of pure randomness. This random feature of cube world mimics the situation in the human world. Whether or not a baby is born is the result of many, many biophysical processes. In each case, the exact circumstances will not be known, just by virtue of the shear number of variables. In a figurative sense, it is a toss of the dice!

To summarize, cube world gives us a simple model of population growth in which, on average, one out of every six cubes produces one offspring during a given interval of time (a roll). Built into this model is a general random feature, which corresponds to results that deviate from the "average" behavior.

Exponential Growth: Population Explosion!

Imagine you get a job and your new boss offers to pay you in either of two ways. You can either receive a flat rate of $1000 per day OR you can start out earning $.01 (one cent) per day and receive a 1% pay raise each day. Which would you choose? I would choose the second option. Perhaps your are thinking; "that is stupid, doesn't he realize that it will be about 70 days before he is earning 2 cents per day?" Before you make up your mind though, let me tell you this. The worker paid by way of the 1% daily raise will earn about 1.92 Million dollars on the 1917th day of employment alone! This is roughly the amount earned by the flat rate employee during the entire 1917 days (=5.25 years)! Now which would you choose?

The example in the previous paragraph illustrates mathematical known as exponential growth. If something, be it a rate of pay or the population of a nation, is allowed to follow a pattern of exponential growth for a long enough period of time, the results are very dramatic.

Our simple model of cube world gives us a hands-on example of exponential growth. Perhaps you started out with only a single cube in cube world. How many rolls, call them cube-years if you like, did it take to reach a population of, say, 200 cubes? Is it close to the expected number of around 34 cube years? If population growth is allowed to follow an exponential pattern, with the growth rate we have set, the population will grow to 200 times its initial size in only about 34 cube-years!

To better picture the mathematical trend of exponential growth, find a piece of graph paper. On the vertical axis (usually called the "y-axis") pick a scale covering the range 0 to 200. This scale will represent the population of cube world. On the horizontal axis (usually the "x-axis") pick a scale covering the domain 0 to 40. This scale will represent the time (the number of cube-years). Now treat the rows of your data table as ordered pairs and plot the points on your graph. Do not connect the dots! Do you notice the general trend of your data when plotted in this fashion? Does the simple model predict population explosion?

Exponential Growth: Mathematical Analysis

For the sake of comparing our simple model cube world to what we expect from exponential growth, we must take a more detailed look at the mathematics describing what we expect in a case of exponential growth.

Suppose we start at cube-year zero with an initial population of N_o cubes. We set the birth rate such that each year any given cube has a one in six chance of producing an offspring. The expected populations of cube world for the first few cube years are:

Year 0	N_o	$=N_o$
Year 1	$\left(1+\frac{1}{6}\right)N_0$	$=\left(\frac{7}{6}\right)N_0$
Year 2	$\left(1+\frac{1}{6}\right)^2 N_0$	$=\left(\frac{7}{6}\right)^2 N_0$
Year 3	$\left(1+\frac{1}{6}\right)^3 N_0$	$=\left(\frac{7}{6}\right)^3 N_0$
Etc., etc., etc.		
Year k	$\left(1+\frac{1}{6}\right)^k N_0$	$=\left(\frac{7}{6}\right)^k N_0$

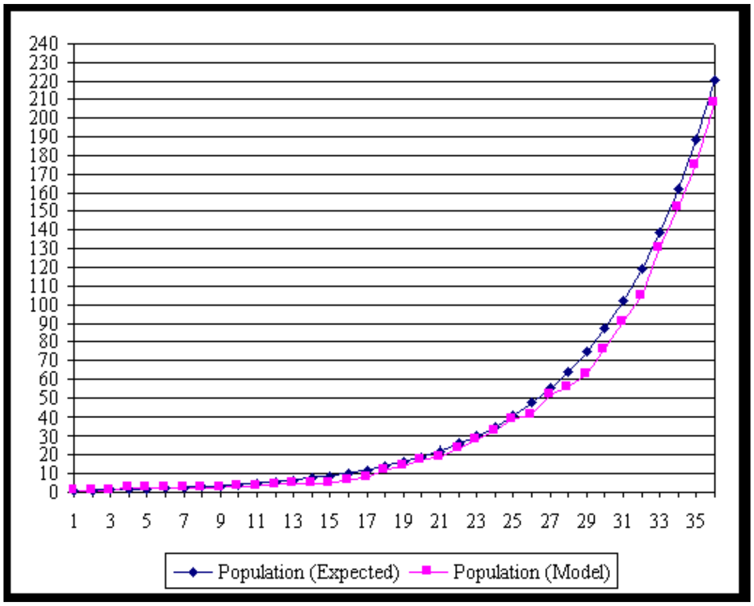

Figure 1

Compare figure 1 with your own graph. How are the two similar, how (and why) do they differ? How many cube-years does it take for the population of cube world to double? In particular, how long does it take for the population to increase from 20 to 40? How about from 40 to 80? How about from 80 to 160?

With the birth rate set such that there is a 1 in 6 chance that any given cube will produce and offspring in any given year, the time it takes the population to double is only about 4.5 cube-years. The "doubling time" is a characteristic of the system experiencing exponential growth. In other words, no matter where you look on the graph of the expected results, if you measure carefully, you will always come up with about 4.5 cube-years for the doubling time. The population of the red cubes should double every 2.41 years. Verify this for yourself!

Outlook: Refining the Model

The simple model of exponential growth is not the whole story. There are other factors which affect the rate at which populations grow (or shrink). Some of these factors can be included in the model by adjusting the birth rate accordingly. For instance, you may wish to model a society in which it is honorable to have as many children as possible. Perhaps a model cube world corresponding to such a society should give cubes a 1 in 5 chance of producing offspring. If you are clever, you can think of a way to simulate this with the black cubes. Try it. Also, see if you can come up with models which incorporate effects such as life-span, medical advances, epidemics, birth control, economic prosperity, etc.

Good luck with your adventures in cube world. I would really appreciate hearing about your ideas. You can contact me anytime via e-mail at ehach@uark.edu.

New Resources and Opportunities for Teachers

As part of its ongoing education outreach mission, the University of Arkansas Microelectronics-Photonics (MicroEP) graduate program has appointed Sarah Faitak as its K-12 Education Outreach director. This position was created as a part of the Center for Semiconductor Physics In Nanostructures, (C-SPIN). The center, funded by a $4.5 million grant from the National Science Foundation, combines the knowledge of physics, chemistry, engineering and other sciences to develop nanostructures, or sub-microscopic structures that are assembled atom by atom. Nanostructure research develops smaller and faster components for computers and other technical equipment. "Our hope is to stimulate students throughout Arkansas to consider careers in science, math and engineering." Ms. Faitak said.

This past summer the program sponsored 3 middle school teachers who actively participated in a Research Experience for Teachers (RET) program on campus. James Miller, 5th grade teacher at Lynch Middle School in Farmington, Melissa Miller, 6th grade teacher at Holt Middle School in Fayetteville, and June Claunch, teacher at Paris Middle School, participated in research on optics communication and holograms. The Millers and Ms. Claunch created websites that tell about their projects and the science behind them. In these sites the teachers have linked to several resources for interactive lessons and inexpensive equipment and supplies. To learn more about their experience and about the Education Outreach Program, visit the microEP website at http://www.uark.edu/depts/microep.

In addition to the RET program, a teacher workshop, "Teaching Science through Inventing Toys" was held on campus this past summer. The workshop, presented by nationally known inventor and teacher, Ed Sobey, provided teachers with inexpensive experiments that teach children how to build, assess and improve upon common toys. Teachers themselves invented toys, then addressed questions like: "What would make my car go farther?" or "What would make my top spin longer?" Using similar techniques in the classroom helps to motivate students to find out the answers and interest them in the science behind the inventions.

This fall Ms. Faitak will support efforts to involve additional schools in B.E.S.T. competitions. B.E.S.T., which stands for Boosting Engineering, Science and Technology, is an extra-curricular activity that encourages students to work together as a team to build and promote a robot for competition in a local match. The robots are to be designed for a specific purpose, which is not released until six weeks before the competition. The students must design, create test and improve their robots within the time frame, using only specified materials. The concept simulates an industry environment where a client requests that a manufacturer design an item under a tight budget and time frame.

B.E.S.T. competitions began in Sherman, Texas in 1993, sponsored by Texas Instruments as a means of creating interest in science and engineering in high school students. A local hub was created in Northwest Arkansas in 1998 and there are currently over 20 hubs and 400 teams in the U.S. Plans are underway to develop a regional hub in Northwest Arkansas, expanding the number of local teams able to participate in final competitions.

As the K-12 Education Outreach Program develops, these and many other resources will be made available to students, teachers and schools to enhance science education throughout the state. For more information, or if you have ideas you would like to share, you may reach Ms. Faitak at 501-575-3671 or sfaitak@uark.edu

Physics Undergraduates Soar for NASA

A team of undergraduates from the University of Arkansas participated in NASA's Undergraduate Reduced Gravity Program this summer at Johnson Space Center and NASA's Ellington Field. The team consists of Ryan Godsey, a senior in physics, Amber Straughn, a senior physics major, Mike Meyer, a junior physics/math major, and Jim Czlapinski, a sophomore in physics. After designing the experiment, getting accepted for the program, and building their apparatus, the team traveled to Houston for 10 days to prepare for and fly their experiment in microgravity. The team is working on an experiment for the new Arkansas-Oklahoma Center for Space and Planetary Sciences to discover what happens to dust particles on the surface of asteroids when the particles are disturbed by impact or volcanism.

NASA's reduced gravity facility is a military KC-135 plane that flies 30 to 40 parabolas, consisting of steep climbs and dives, over the Gulf of Mexico. During the climbs and dives, passengers in the plane are under micro-gravity conditions. The experiment the UA team designed must be conducted on the KC-135 because the gravity on Earth is much stronger than the micro-gravity conditions on asteroids. During the flight, the team members will lose gravity and float through the air while their equipment is anchored to the floor. Digital video was taken of two cylinders filled with sand and iron (the most abundant constituents of asteroids) and is being analyzed presently.

Editor: Prof. Gay Stewart. Please contact me with comments and suggestions, Dept. of Physics, University of Arkansas, Fayetteville, AR 72701; call: (501) 575-2408, e-mail:gstewart@comp.uark.edu, or fax: (501)575-4580.
