Scientific Notation and Scaled Models

Topic

Scientific notation is a practical way to compare the sizes of bodies in the solar system.

Introduction

Scientific notation was developed to aid scientists in mathematical computations involving very large or very small numbers. For instance, the distance of Neptune from the Sun is 2.79 trillion miles, an extremely large number. In standard notation, that distance is written as 2,790,000,000,000 miles. The distance is more easily expressed in scientific notation as 2.79×10^{12} miles. Small scales can also be expressed in scientific notation. A human body cell, in standard notation, is 0.00005 meters in diameter. In scientific notation, this distance is expressed as 5×10^{-5} meters (m).

Writing numbers with a lot of zeros can be tedious and leads to error. The system of scientific notation helps to represent these numbers in an easy-to-read style. Scientific notation is based on the powers of 10. The small number on the upper right of the 10 is the *exponent.* It represents the number of zeros in the number. To convert a number from standard to scientific notation, one moves the decimal to the location in the number that makes it greater than 1 but less than 10. In the number 245,000, the decimal is moved five places from the right of the last 0 so that it is positioned between the 2 and 4, resulting in 2.45000. The last 3 zeros are dropped to make the number 2.45. Next, an exponent is added to indicate the number of places the decimal was moved. The final answer is 2.45×10^{5}.

When dealing with numbers less than 1, the same process is used, but the decimal is moved to the right to convert the original number to a value between 1 and 10. Moving of the decimal to the right results in a number with a negative exponent. For example, 0.000000022 will be changed to 2.2 (a move of 8 places to the right). When the exponent is added, the final answer is 2.2×10^{-8}.

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Computations with large or small numbers are much easier when the numbers are written in scientific notation. Astronomers have to multiply and divide large numbers many times. When you multiply values in scientific notation, you add your exponents. When you divide numbers, you subtract the exponents. For example, if you wanted to multiply 1.5×10^{11} kilometers (km) by 3×10^{-5} km, you would multiply 1.5×3 to get 4.5 and then add $11 + -5$ to get 6 for your exponent. Your answer would be 4.5×10^{6}. In division, you subtract exponents rather than dividing. If you divided 1.5×10^{11} km by 3×10^{-5} km, you would get $.5 \times 10^{16}$. Change the .5 to a number between one and ten, 5, and then move the exponent down one place. The answer would be 5×10^{15}.

In this experiment, you will develop a scale model using scientific notation.

Time Required

60 minutes

Materials

- tennis ball
- ruler
- simple calculator

Safety Note Please review and follow the safety guidelines.

Procedure

1. One way to get a sense of the relative sizes of very large objects is to make scale models and compare them. With scale models, everything is reduced by the same amount. In this experiment, a tennis ball will be used to represent the Sun. The real Sun is 1.392×10^{6} km in diameter. The scale model will reduce the diameters of the planets to the same scale as the tennis ball.
2. Use a ruler to measure the diameter of a tennis ball in centimeters

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(cm). Record this value on the data table in the second column of the row labeled "Sun."

3. Use the following formula to find the scaled sizes of the planets:

$$\frac{\text{diameter of the tennis ball (cm)}}{\text{real diameter of Sun (km)}} = \frac{X \text{ (scaled value of planet being calculated [cm])}}{\text{real diameter of planet (km)}}$$

Here is an example of how to solve a problem using this formula.

Problem: What is the scaled diameter of Venus if a large Nerf™ ball represents the Sun? The Nerf™ ball is 16 cm in diameter. The actual diameter of Venus is about 1.2104×10^4 km.

$$\frac{16 \text{ cm}}{1.392 \times 10^6 \text{ km}} = \frac{X}{1.2104 \times 10^4 \text{ km}}$$

$$X = \frac{16 \text{ cm} \times 1.2104 \times 10^4 \text{ km}}{1.392 \text{ x } 10^6 \text{ km}} = \frac{17.21 \times 10^4 \text{ cm}}{1.392 \text{ x } 10^6 \text{ km}} = 12.36 \times 10^{-2} \text{ cm} = 1.236 \times 10^{-1} \text{ cm}$$

In this scale model, Venus would be $1.236 \text{ x } 10^{-1}$ cm in diameter.

4. Use the formula to find the diameters of the planets if the diameter of a tennis ball represents the Sun. Record your answers in the data table.

Data Table

Object	Real diameter (km)	Scaled size (cm)
Sun	1.392×10^6	
Mercury	4.88×10^3	
Venus	1.2104×10^4	
Earth	1.2742×10^4	
Mars	6.78×10^3	
Jupiter	1.39822×10^5	
Saturn	1.16464×10^5	
Uranus	5.0724×10^4	
Neptune	4.9248×10^4	
Pluto	2.274×10^3	

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Analysis

1. How did scientific notation simplify the calculations in this experiment?
2. What does a negative exponent in scientific notation mean?
3. Which of the planets had the smallest scaled size in comparison to the tennis ball (Sun)?
4. Suggest items that are the appropriate sizes to represent four of the planets.

What's Going On?

Scientific notation is a valuable tool for writing extremely small or large numbers. Astronomers, working with long distances and large planetary bodies, are better able to do computations and make comparisons between celestial objects by using scientific notation. Knowing how to multiply and divide using scientific notation makes calculations much more manageable for astronomers.

Scaled values allow the user to put the extremely large sizes of astronomical objects into perspective. In a scaled size, planets and stars can be compared to each other in terms that make sense to the viewer. Most people can grasp the differences in the sizes of common objects more easily than they can the differences in celestial spheres. For example, when a Nerf™ ball represents the Sun, Venus is about the size of a grain of sand and Jupiter the size of a dime. These differences are easy to see and comprehend.

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OUR FINDINGS

SCIENTIFIC NOTATION AND SCALED MODELS

Suggestion for class discussion: Ask students why it would be impractical to multiply 45 trillion by 900 trillion using standard notation? Ask them if they know of an easier way to work with these numbers.

Teacher notes: Find out if students have had previous instruction in using exponential notation. Prior to doing the lab, spend some time converting numbers from standard notation to scientific notations. Demonstrate how to multiply and divide with numbers in scientific notation. Discuss some concepts such as Avogadro's number that make use of scientific notation.

Completed Data Table 1

Object	Real Diameter (km)	Scaled Size (cm)
Sun	1.392×10^{6}	7.5×10^{1}
Mercury	4.88×10^{3}	2.63×10^{3}
Venus	1.2104×10^{4}	1.52×10^{-2}
Earth	1.2742×10^{4}	6.86×10^{-2}
Mars	6.78×10^{3}	3.65×10^{2}
Jupiter	1.39822×10^{5}	7.53×10^{-1}
Saturn	1.16464×10^{5}	6.27×10^{-1}
Uranus	5.0724×10^{4}	2.73×10^{-1}
Neptune	4.9248×10^{4}	2.65×10^{-1}
Pluto	2.274×10^{3}	1.22×10^{-2}

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Analysis

1. Instead of working with numbers that have a lot of zeros, one works with the base numbers only.
2. A number that is less than 1.
3. Pluto, Mars, and Mercury
4. Answers will vary. Students might suggest planets such as Pluto are the size of a grain of sand. All of the planets should be spheres that are significantly smaller than a tennis ball.

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SAFETY PRECAUTIONS

Review Before Starting Any Experment

Each experiment includes special safety precautions that are relevant to that particular project. These do not include all the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read and remain mindful of the General Safety Precautions that follow. Experimental science can be dangerous, and good laboratory procedure always includes following basic safety rules. Things can happen very quickly while you are performing an experiment. Materials can spill, break, or even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following the basic safety guidelines during the entire experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. For one reason, we want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical.

Read the safety precautions here and at the beginning of each experiment before performing each lab activity. It is difficult to remember a long set of general rules. By rereading these general precautions every time you set up an experiment, you will be reminding yourself that lab safety is critically important. In addition, use your good judgment and pay close attention when performing potentially dangerous procedures. Just because the book does not say “Be careful with hot liquids” or “Don’t cut yourself with a knife” does not mean that you can be careless when boiling water or using a knife to punch holes in plastic bottles. Notes in the text are special precautions to which you must pay special attention.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking an unnecessary risk can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to

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check the individual experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone. When you are working off-site, keep in groups with a minimum of three students per groups, and follow school rules and state legal requirements for the number of supervisors required. Ask an adult supervisor with basic training in first aid to carry a small first-aid kit. Make sure everyone knows where this person will be during the experiment.

PREPARING

- Clear all surfaces before beginning experiments.
- Read the instructions before you start.
- Know the hazards of the experiments and anticipate dangers.

PROTECTING YOURSELF

- Follow the directions step by step.
- Do only one experiment at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure there is adequate ventilation.
- Do not horseplay.
- Keep floor and workspace neat, clean, and dry.
- Clean up spills immediately.
- If glassware breaks, do not clean it up; ask for teacher assistance.
- Tie back long hair.
- Never eat, drink, or smoke in the laboratory or workspace.
- Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult.

USING EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives or other sharp-pointed instruments with care.

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- Pull plugs, not cords, when removing electrical plugs.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.
- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use alcohol-filled thermometers, not mercury-filled thermometers.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read labels carefully.
- Avoid chemical contact with skin and eyes (wear safety glasses, lab apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING SUBSTANCES

- Wear safety glasses, apron, and gloves when boiling water.
- Keep your face away from test tubes and beakers.
- Use test tubes, beakers, and other glassware made of Pyrex™ glass.
- Never leave apparatus unattended.
- Use safety tongs and heat-resistant gloves.
- If your laboratory does not have heat-proof workbenches, put your Bunsen burner on a heat-proof mat before lighting it.
- Take care when lighting your Bunsen burner; light it with the airhole closed, and use a Bunsen burner lighter in preference to wooden matches.

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- Turn off hot plates, Bunsen burners, and gas when you are done.
- Keep flammable substances away from flames and other sources of heat.
- Have a fire extinguisher on hand.

FINISHING UP

- Thoroughly clean your work area and any glassware used.
- Wash your hands.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Do not dispose of materials in the sink unless instructed to do so.
- Clean up all residues and put them in proper containers for disposal.
- Dispose of all chemicals according to all local, state, and federal laws.

BE SAFETY CONSCIOUS AT ALL TIMES!

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