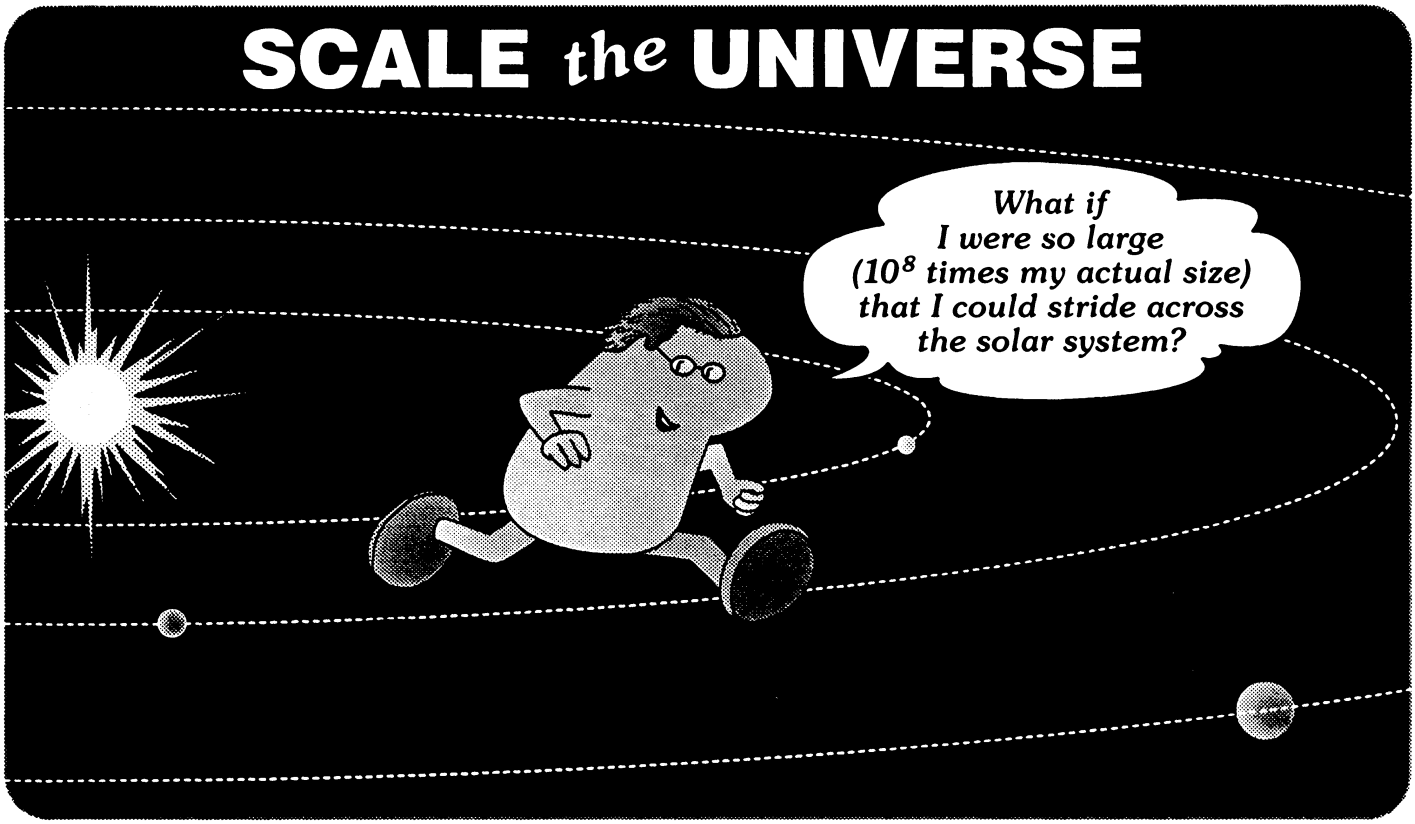
SCALE *the* UNIVERSE



SCIENCE WITH SIMPLE THINGS SERIES

Conceived and
written by
RON MARSON

Illustrated by
PEG MARSON

TOPS LEARNING SYSTEMS

10970 S. Mulino Road
Canby OR 97013
www.topscience.org

WHAT CAN YOU COPY?

Dear Educator,

Please honor our copyright restrictions. We offer liberal options and guidelines below with the intention of balancing your needs with ours. When you buy these labs and use them for your own teaching, you sustain our work. If you "loan" or circulate copies to others without compensating TOPS, you squeeze us financially, and make it harder for our small non-profit to survive. Our well-being rests in your hands. Please help us keep our low-cost, creative lessons available to students everywhere. Thank you!

PURCHASE, ROYALTY and LICENSE OPTIONS

TEACHERS, HOMESCHOOLERS, LIBRARIES:

We do all we can to keep our prices low. Like any business, we have ongoing expenses to meet. We trust our users to observe the terms of our copyright restrictions. While we prefer that all users purchase their own TOPS labs, we accept that real-life situations sometimes call for flexibility.

Reselling, trading, or loaning our materials is prohibited unless one or both parties contribute an Honor System Royalty as fair compensation for value received. We suggest the following amounts – let your conscience be your guide.

HONOR SYSTEM ROYALTIES: If making copies from a library, or sharing copies with colleagues, please calculate their value at 50 cents per lesson, or 25 cents for homeschoolers. This contribution may be made at our website or by mail (addresses at the bottom of this page). Any additional tax-deductible contributions to make our ongoing work possible will be accepted gratefully and used well.

Please follow through promptly on your good intentions. Stay legal, and do the right thing.

SCHOOLS, DISTRICTS, and HOMESCHOOL CO-OPS:

PURCHASE Option: Order a book in quantities equal to the number of target classrooms or homes, and receive quantity discounts. If you order 5 books or downloads, for example, then you have unrestricted use of this curriculum for any 5 classrooms or families per year for the life of your institution or co-op.

2-9 copies of any title: 90% of current catalog price + shipping.

10+ copies of any title: 80% of current catalog price + shipping.

ROYALTY/LICENSE Option: Purchase just one book or download *plus* photocopy or printing rights for a designated number of classrooms or families. If you pay for 5 additional Licenses, for example, then you have purchased reproduction rights for an entire book or download edition for any **6** classrooms or families per year for the life of your institution or co-op.

1-9 Licenses: 70% of current catalog price per designated classroom or home.

10+ Licenses: 60% of current catalog price per designated classroom or home.

WORKSHOPS and TEACHER TRAINING PROGRAMS:

We are grateful to all of you who spread the word about TOPS. Please limit copies to only those lessons you will be using, and collect all copyrighted materials afterward. No take-home copies, please. Copies of copies are strictly prohibited.

Ask us for a ***free shipment*** of as many of our ***TOPS IDEAS Catalogs*** as you need to support your efforts. Every catalog is a rich, attractive resource magazine packed with free sample teaching ideas.

For licensing, honor system royalty payments, or catalog requests, contact: **www.TOPScience.org**; or

TOPS Learning Systems, 10970 S Mulino Rd, Canby OR 97013; or inquire at **tops@canby.com**

ISBN 978-0-941008-44-0

SCALE *the* UNIVERSE

This book is organized in **3 stand-alone sections**: you can teach them independently or all together. **Series A** reviews the base-ten logic of our metric system, and helps students comprehend exponential change by means of problem solving and unit analysis. In **Series B** students compare distances relative to each other, plot these on a log scale, and compute orders of magnitude. In **Series C**, students construct Books of Scale that tie the space-time universe together. The wide-ranging scale drawings and creative problem-solving challenges in this learning system result in an assessment portfolio students will be proud of.

Table of Contents

Getting Ready

❑ Decide which parts of this book you want to teach, then budget appropriate class time. See Scope and Sequence on pages 8-9 to overview a variety of options for science and math classes. There are rich possibilities for independent study and extra credit for students who are motivated to do additional, or superlative, work.

❑ Photocopy relevant student materials as per photocopy table opposite. For your convenience, copying instructions for each page are also summarized near the copyright notice at the bottom of that page.

❑ Gather these simple materials. Here is a master list of everything you'll need to teach all 9 lessons. See the teaching notes that accompany each activity for more details concerning materials that relate to specific lessons.

ruled notebook paper
pencils with good erasers
calculators (scientific calculators are a nice option)
a roll of masking tape
scissors
rolls of clear tape (or pre-hang strips from students' desks)
straight pins
several soda cans
meter sticks
a stapler
metric desk rulers
paper clips
hand lenses (optional)
magnetic compasses (optional)
drawing compasses (optional)
waxed paper (alternative to drawing compass)
a roll of string (nonelastic kite string is ideal)

❑ Organize a way to track assignments. It may be a good idea to keep student work on file in class. If you lack file space, substitute an empty copy paper box and brick. File folders and notebooks both make suitable assignment organizers. Students will feel a sense of accomplishment as their completed papers accumulate into an impressive portfolio. Since all assignments stay together, reference and review are easy. Ask students to tape a sheet of notebook paper inside the front covers of their folders or notebooks. Track individual progress by listing and initialing lesson numbers as they are completed.

❑ Communicate your grading expectations. We recommend that you grade on individual effort, attitude and overall achievement:

✔ Effort: How many pages of work has the student produced? Of what quality?

✔ Attitude: Has the student worked to capacity, or wasted time? What evidence of personal initiative and responsibility?

✔ Achievement: Assign tasks that assess how well students have mastered key concepts. You might ask them to compare distances on their Long Tapes and Log Scales, or to complete questions in their Books of Scale as a take-home test.

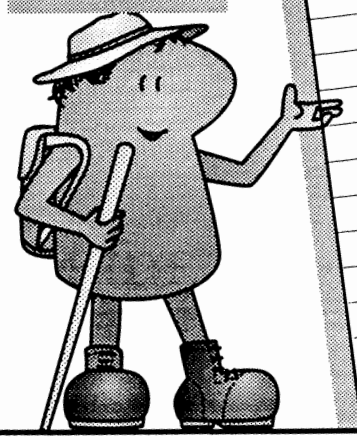
ORDERS OF MAGNITUDE

Activity A1

1. Get a ***LongTape*** page. Imagine taking a journey that begins at zero millimeters on this tape, and ends 620 miles (1 megameter) above Earth, twice as high as NASA's* orbiting gamma-ray telescope, called GLAST*. Write a story about your adventures. It might begin like this, or in any way you like:

*NASA: The National Aeronautics and Space Administration

**GLAST: Gamma-ray Large Area Space Telescope



My Metric Journey

Well, by taking only one step, I passed these 4 orders of magnitude, each one ten times farther from my starting point:

$0.1\ mm = 10^{-4}\ m$, about as thin as paper money,

$1\ mm = 10^{-3}\ m$, about as thin as a dime,

$1\ cm = 10^{-2}\ m$, about as thick as a big fat pencil,

$10\ cm = 10^{-1}\ m$, about wide as my hand.

Even an ant would have reached those markers really fast! I now find myself leaving behind the 1 meter marker, which reads:

$1\ m = 10^{0}\ m$ – a giant step.

With 5 markers down and only 6 more to go, it feels like this trip won't last long! My progress has been remarkable so far. Already, I'm 10,000 times farther along than when I passed the first marker. And the 6th marker is already in sight, it's just over the hill....

2. **Compare these units mm, cm, m, km** and **Mm** as follows:

a. Copy these METRIC COMPARISONS on lined paper, then extend your list. Vary your phrasing as underlined:

1 m is 100 times longer than 1 cm.
1 km is 3 powers of ten shorter than 1 Mm.
1 m is 3 orders of magnitude longer than 1 mm.

b. Copy these EQUATION PAIRS and extend your list. Write numbers in different ways, using decimals, powers of ten or words as shown.

1 km = 1,000 m (and) 1 m = 0.001 km
10^{0} cm = 10^{-2} m (and) 10^{0} m = 10^{2} cm
one mm = one millionth km (and) one km = one million mm

c. List INTERESTING FACTOIDS. Start with these and extend your list.

10,000 fat pencils placed side by side reach goal to goal on a soccer field.
A car traveling 100 km/hr takes .00001 hours to travel 1 meter.
A 1 mm stack of hundred dollar bills is worth $1,000.

 Copy 1 per student; collate/staple reusable workbooks

OVERVIEW / OBJECTIVES

To review metric prefixes, visualize metric distances, and explore decimal relationships on a "meter-tape" graphic that spans 10 orders of magnitude.

TIME: 1 hour.

INTRODUCTION

Photocopy and distribute the LongTape supplement.

★ Count up *and* down the LongTape in different ways, depending on the level of your students. Always begin at the **meter** marker:

- *Say:* **1 m**, 10 m, 100 m, **1 km**, 10 km, 100 km, **1 Mm**.
- *Say:* **1 m**, 10 cm, 1 cm, **1 mm**, 0.1 mm.

- *Say:* giant step, length of a classroom, length of soccer field, ...
- *Say:* giant step, hand's width, wide as a fat pencil, ...

- *Say:* **one**, ten, hundred, **thousand**, ten thousand, hundred thousand, **million**, ... *(keep going)* ..., ten million, hundred million, **billion**, ten billion, hundred billion, **trillion**.
- *Say:* **one**, tenth, hundredth, **thousandth**, ten thousandth, ... *(keep going)* ... , hundred thousandth, **millionth**, ten millionth, hundred millionth, **billionth**, ten billionth, hundred billionth, **trillionth**.

- *Write:* **1**, 10, 100, **1000**, ... *(Continue to a trillion.)*
- *Write:* **1**, 0.1, 0.01, **0.001**, 0.0001, ... *(to a trillionth)*

- *Say:* **1**, 10, 10x10, **10x10x10**, 10x10x10x10 ...
- *Say:* **1**, 1/10, 1/10/10, **1/10/10/10**, ...

- *Write:* $\mathbf{10^0}$, 10^1, 10^2, $\mathbf{10^3}$, ... *(to a trillion)*
- *Write:* $\mathbf{10^0}$, 10^{-1}, 10^{-2}, $\mathbf{10^{-3}}$, ... *(to a trillionth)*

- *Say:* 0 **orders of magnitude** larger, 1 order of magnitude larger, 2 OM's larger, **3 OM's** larger, ...
- *Say:* **0 OM's** smaller, 1 OM smaller, 2 OM's smaller, **3 OM's** smaller, ...

- *Write:* **1 m**, 10 m, 100 m, **1000 m**, ...
- *Write:* **1 m**, 1/10 m, 1/100 m, **1/1000 m**, ...

★ Convert decimals and powers of ten:

- You say the number and students say the power of ten.

one = "ten to the zero power"
billion = "ten to the ninth power"
ten thousandth = "ten to the minus four power"

- You say the power of ten and students say the number.

ten to the first power = "ten"
ten to the sixth power = "million"
ten to the minus two = "hundredth"

★ Place paper clips on any two OM markers. Write equalities in scientific notation and decimal forms as follows.

EXAMPLE 1: Markers placed on 1 kilometer and 1 meter are separated by 3 orders of magnitude. Thus...

1 km = 10^3 (1 m)	***and***	1 m = 10^{-3} (1 km)
1 km = 1 x 10^3 m		1 m = 1x10^{-3} km
1 km = 1,000 m		1 m = 0.001 km

In all of these equations, notice that...

One big = many small
AND
One small = a fraction of big

EXAMPLE 2: Markers on 10 kilometers and 1 centimeter are separated by 6 orders of magnitude.

10 km = 10^6 (1 cm)	***and***	1 cm = 10^{-6} (10 km)
10 km = 1 x 10^6 cm		1 cm = 10 x10^{-6} km
1 km = 1 x 10^5 cm		1 cm = 1 x10^{-5} km
1 km = 100,000 cm		1 cm = 0.00001 km

NOTES / ANSWERS

Steps 1 and 2 serve as stand-alone, open-ended reviews of the metric system that all students can use at multiple levels of understanding. Consider assigning these for a specified time period, say one class period plus homework. Students might explore some questions in depth, or choose to answer all questions in less depth. Ultimately, each learner is responsible for his or her own learning. Allow students to exercise their muscles of choice and responsibility whenever possible.

1. Here the "language arts majors" in your class have a chance to shine. Consider pairing them with students who wield numbers with more confidence. Assign these teams to create stories for a travel magazine.

Encourage students to use both imagination and math skills as they develop this story. If it takes 12 minutes to walk 1 kilometer, for example, when multiplying by powers of ten, it takes (10)(10)(10)(12 minutes) = 200 hours to walk a megameter (if that distance were on level ground).

2a,b. Here is a summary of metric distance relationships:

1 mm: 10^{-1}cm, 10^{-3}m, 10^{-6}km, 10^{-9}Mm
1 cm: 10^{1}mm, 10^{-2}m, 10^{-5}km, 10^{-8}Mm
1 m: 10^{3}mm, 10^{2}cm, 10^{-3}km, 10^{-6}Mm
1 km: 10^{6}mm, 10^{5}cm, 10^{3}m, 10^{-3}Mm
1 Mm: 10^{9}mm, 10^{8}cm, 10^{6}m, 10^{3}km

2c. A few more interesting "factoids." (Students may list others.):

- The difference between a **million** dollars and a **billion** dollars is like the difference between a **meter** stack of $100 bills and a **kilometer** stack!
- A ten kilometer stack of dimes is worth $1 million.
- A jogger runs 10,000 meters/hour or 2.8 meters/sec.
- A jogger runs 1 meter in 0.0001 hours.

MATERIALS

☐ Photocopy the LongTape supplement on page 32.
☐ Notebook paper, pencil and eraser. These common student materials are assumed in all later lessons.
☐ Calculators (optional).