

LAB1: SCIENTIFIC NOTATION, SCALE IN THE UNIVERSE, LOGARITHMIC SCALE**PART1: SCALING THE SOLAR SYSTEM - INTRODUCTION**

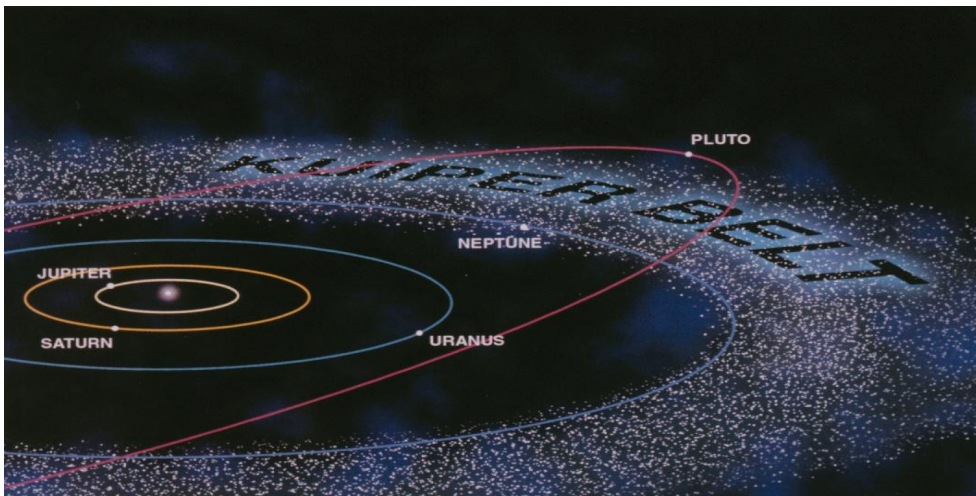
I am sure you know that our solar system includes 9 planets. Some Astrophysics have decided, during a committee, to strip Pluto from his status of Planet to the less prestigious status of dwarf planet. But many disagree with this decision so I will consider Pluto as part of the Planet family. All the planets, along with asteroids, comets and dwarf planets, orbit our Sun, our closest star.

Do you know the names of the planets starting from the closest to the Sun? List them below:

Which ones are called the rocky inner planets? Do you know why they are called “rocky” ?

What about the outer planets or gas giants? What do you know about them?

Did you know that other planets, called dwarf planets, have been found in our Solar system? One of these dwarf planets is called Eris and is larger than Pluto. They belong to the Kuiper belt.



For more information you can refer to the website of the NASA : <http://solarsystem.nasa.gov/planets/>

Some planets have been also found around other stars in our galaxy but this is another story.

Do you know how scientists called these planets ?

To get an idea of the distance between the planets and the Sun you are going to “scale down” the solar system so it can fit on a poster about 75cm or 2.5 ft long (about 1 yard)/

Scaling down means the proportions will stay the same. The ratios between the distances between the objects (Sun and planets) will be the same. It is like using the reducing function on a photocopier.

PART2: SCALING DOWN THE SOLAR SYSTEM, SCIENTIFIC NOTATION

CONSIDER THE TABLE BELOW. USE a TI 30 if you have one.

The first column gives the distance between a planet and the Sun. The distance is in kilometers.

You need to convert these long numbers in scientific notation. That is, you need to use powers of 10. For example 58,000,000 km can be written as 5.8×10^7 that means $5.8 \times 10,000,000$.

Move to the left until you reach a number between 1 and 10. The exponent on the base 10 is positive because the number is greater than 1. It is negative when the number is smaller than 1. Don't fill column 4 yet.

Planet	average distance from sun in Km standard notation	distance in km scientific notation	scaled distance in cm
Mercury	58 000 000	= $5.8 \cdot 10^7$	
Venus	108 000 000	=	
Earth	150 000 000	=	
Mars	229 000 000	=	
Jupiter	777 000 000	=	
Saturn	1 426 000 000	=	
Uranus	3 000 000 000	=	
Neptune	4 500 000 000	=	
Pluto	5 910 000 000	=	75cm

Now you want to scale down the solar system on the poster. Only the distance of the planets from the Sun are scaled down. (not the sizes). The scale is distance Pluto-Sun = 75 cm on your poster.
 Or $5.91 \cdot 10^9 = 75 \text{ cm}$ (E stands for the base 10, your scientific calculator uses this notation)

Now you can fill column 4. Example: for Neptune you are solving the proportion:
 $5.91 \cdot 10^9 = 75 \text{ cm}$

$4.5 \cdot 10^9 = ?$

cross-multiply and divide to find “?” $? = (75 \times 4.5 \cdot 10^9) / 5.91 \cdot 10^9$

This is called solving a proportion.

So 1cm in your poster is _____ km (divide $5.91 \cdot 10^9$ by 75)

or 1cm in your poster is _____ cm (1km=100,000 cm)

The solar system has been scaled down almost 10 trillion times. (1 trillion = 10^{12})

Comment on the relative positions of the planets.

Is it compatible with what you already know about the solar system?

PART 2 : INTRODUCTION TO LOG AND LOGARITHMIC SCALE. Use a TI 34

In part1, you built a scaled model of the solar system.

Do you know the name of our second closest star ?

This star is 4.3 light years away. It means, it takes 4.3 YEARS for the star's light to reach us.

It is really far because light is really fast. (Light covers 1 foot in a billionth of a second = 0.000000001s)

By comparison, it takes the light from the Sun 8 minutes to reach us.

Andromeda is the closest large galaxy. 2.48 million light years away ! Now you get it. It takes the light from Andromeda _____ years to reach us. So surprisingly, we don't see Andromeda like it is now but it was _____ ago. The modern man was not even around at the time.

To get an idea of how far is the star and Andromeda from the Sun, we need to represent them along with the Sun and the planets on the same line. Let's see if you can fit these 2 far objects on your model of the solar system.

First you need to find the distance of the star (from the Sun) in million of km.

1 light year = 10^7 million km so 4.3 light years = _____ million km

Andromeda is 2.48 million light years away or 2.48×10^6 light years away.
 1 light year = 10^7 million km so 2.48×10^6 light years = _____ million km.
 (multiply by $E7=10,000,000 = 10^7$ or $E6 \times E7 = E13$)

REPORT THESE DISTANCES IN the 2nd COLUMN of the TABLE BELOW

In the previous part, 75cm in your poster was 5,910 million km in space.
 Find the distance in cm of the star and Andromeda if you were to place them in your model.
 (solve proportions again). Report the numbers in the table below.

distance from Sun in poster (cm)	distance from Sun in reality (in million km)	objects
75 cm	5,910	pluto
_____	_____	Proxima
_____	_____	Andromeda

Discuss these numbers. Can you fit the solar system, Proxima and Andromeda on the same poster or even in the classroom? to get these numbers in miles, divide my 161,000 (161,000 cm is about 1 mile). Round to the nearest mile. Discuss.

It seems impossible to plot on the same line the solar system and Proxima and Andromeda and maybe other galaxies using this scale or any scale. What will happen if you try a greatest scaling down factor to reduce the distances? (will you be able to visualize the relative distances of the planets?)

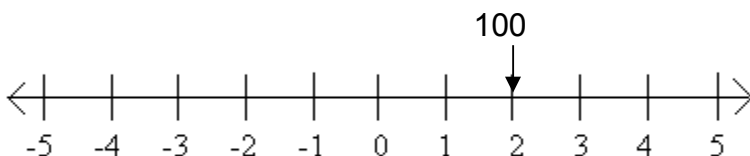
Actually, here is a way around. It is an amazing Mathematics tool called the logarithmic scale.

PART3: LOGARITHMIC FUNCTION and LOGARITHMIC SCALE
A WAY TO EXTRACT THE EXPONENT ON A BASE 10

We need another way to plot a very large range of distances or numbers on the same line.
 (broad range of values) . You are going to use what we call a logarithmic scale. It is very simple.
 First we express the large distances as a power of ten (like $100 = 10^2$) and instead of plotting the number on your poster (100), you plot the exponent (2).

Take as an example 4 distances : 100 miles (10^2), 10,000 miles (10^4), 1000,000 miles (10^6) and 100,000,000 () and say you wish to plot these distances on the same line. First you draw a number line. (I did it for you) 100 miles will be at 2, 10,000 will be at 3 , 1000,000 miles will be at 6 and 100,000,000 will be at _____.

I plot the first distance for you. Can you do the same for the other 3 distances ? (extend the number line)



Distance in miles

Keep in mind that if you take on STEP on this line, the distance is **MULTIPLIED by 10** or the distance increases by a factor of 10.

To achieve this type of representation all the distances have to be expressed as powers of 10.

Say you want to express the distance Sun- Mercury 58 (in million of km) as a power of 10.

How can you do that ?

You know that $58 = 10^n$ and that n has to be between 1 and 2 (since 58 is between 10 and 100), but how to find the exact exponent ?

The function LOG () of your calculator can do that for you. Use your TI and try that:

LOG(100) = ___, LOG (1000) = ___, LOG (10,000) = ____, LOG (1000,000) = ____,
LOG(1,000,000,000) = _____

Can you explain, in your own words, what the function LOG does ?

So if you type LOG(58) you find _____, that means $58 = 10^{1.76}$

Check if this is true, with your TI type $10^{1.76} =$ _____ (round to the nearest one)

Now, we can fit the whole solar system and more on a line again. First, you are going to express the distances in million of km, then use the function LOG to find the exponent of the base 10. You will use the exponent of the base 10 to plot on your new scale model of the universe.

Planet	average distance from sun in Km standard notation	distance in million of km standard notation (divide by 1,000,000)	LOG (distance)	distance as a power of 10, in million of km
Mercury	58 000 000	= 58	=log(58)=1.76	= $10^{1.76}$
Venus	108 000 000	=	=	=
Earth	150 000 000	=	=	=
Mars	229 000 000	=	=	=
Jupiter	777 000 000	=	=	=
Saturn	2 969 000 000	=	=	=
Uranus	3 000 000 000	=	=	=
Neptune	4 500 000 000	=	=	=
Pluto	5 910 000 000	=	=	=
Proxima	43,000,000,000,000	= $4.3 \cdot 10^7$	=	=
Andromeda	24800000000000000000	= $2.48 \cdot 10^{13}$	=	=

Now on the back of your poster you can trace a number line with marks evenly spaced from 0 to 15.

Plot all the planets and the first star and the galaxy. Round the exponent to plot to the nearest tenth.

0 is the Sun, 2.2 is the Earth Label the line **distance in million km**

You can even plot other objects on your chart. Like the large Magellanic Cloud (another galaxy in our local group) = 160,000 light years away = _____ million km. (1 light year = 10^7 million km).

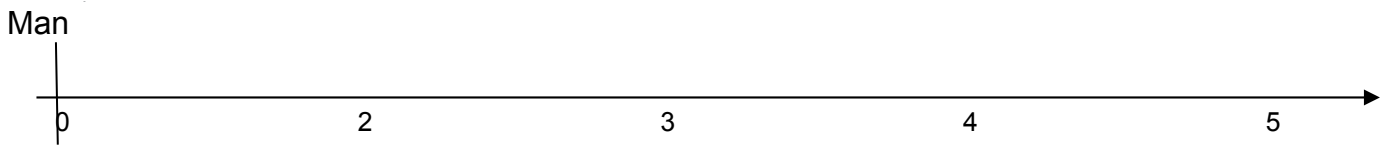
Keep in mind that the distance is multiplied by 10 million each time to take one step on the line. This is called a logarithmic scale.

PART4: USE YOUR SKILL
time line for the history of the world

Consider ages of various events in earth's history

events	Age (million years)	LOG(age)	exponent
Man emerges	1	LOG(1) =0	0
ape man fossils	5		
rise of small mammals	37		
extinction of dinosaurs	67		
rise of mammals	245		
Cambrian explosion, vertebrae	570	LOG(570)=2.8	2.8
first plants	2500		
Earth forms	4450		

You are going to build a scale to visualize these events. Use the log function of your TI to find the exponents on base 10 and plots the exponents on the number line below. Complete the line my drawing marks. Discuss and compare with your partners. Don't forget the label the line *millions of years*



Each step represent a date _____ million years times older than the previous one.

The mark 4 is for an event that occurred _____ million years ago while the mark 5 is for event that occurred _____ million years ago. You can look for other events and plot them. You can make this line longer and get more events to fit on.

Scale for sizes in the universe

Now you are on your own. You know what to do. Fit all the distances on one line. Do not use your calculator. You don't need it.

Objects in universe	Size in meters	exponent on base 10
quarks	10^{-15}	
atoms	10^{-12}	
DNA	10^{-6}	
cell	10^{-5}	
humans	10^1	
Earth	10^6	
Solar system	10^{12}	

galaxy	10^{19}	
Cluster of galaxies	10^{23}	
Universe	10^{25}	

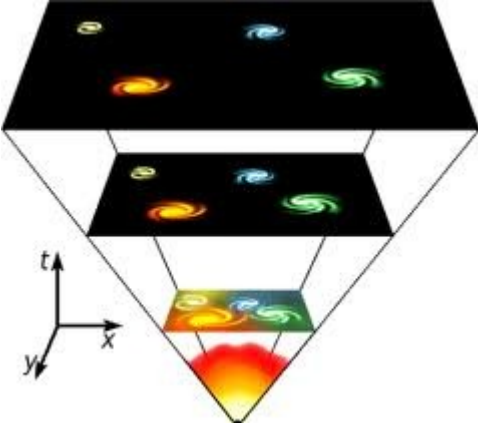


Draw your model below and label the line.

PART5: The history of the Universe in 24 hours

In the table are 7 important dates for our universe and us. The universe is 14 billion years old. Let's compress the age of the universe in 24 hours and see how old are these events. I solved some of date for you. you need to solve ratios and use $1 \text{ year} = 3.15 \cdot 10^7 \text{ seconds}$ (or about $\pi \cdot 10^7$ to remember).

For the ratios, use the same units for the numerator and the denominator.

(like millions years both top and bottom, or hours, or seconds or billions years, or minutes..)

7 important date	for a 24 hours day
<p>birth of the universe = 14 billion years ago</p> 	<p>24 hours ago</p>
<p>milky way and other galaxies = 13 billion years ago</p> 	<p> $13 = x$ $14 = 24$ so $x = (13 \times 24) / 14$ $x =$ hours ago </p>
<p>solar system (oldest meteorite) = 4.5 billion year ago</p> 	<p> $4.5 = x$ $14 = 24$ so $x =$ _____ hours ago </p>

emergence of life, first fossilized life
= [stromatolites](#) (blue green algae) = 3.5 billion year ago



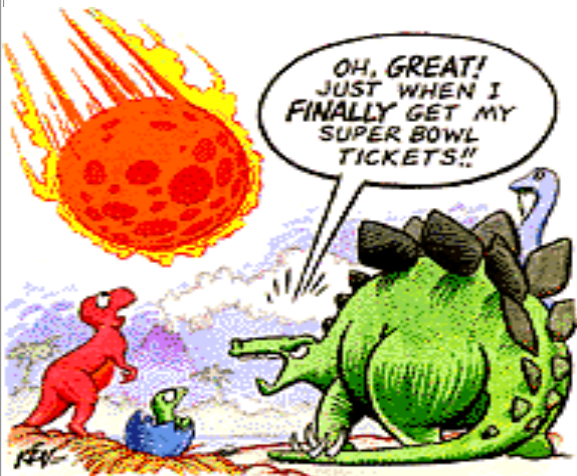
so x = _____ hours ago

!!! units since we go to millions, use 14 billion = 14,000 million!!!
550 million years ago Cambrian explosion of life,
appearance of hard body parts golden age of [trilobite](#).



$550 = x$
 $14,000 = 24$
so x = _____ hours ago or
(keep all decimals, in your TI then multiply by 60)
x = _____ minutes ago

65 million years ago, extinction of dinosaurs 2/3 of living species were wiped out.
which ,, is a good thing for us



x = _____ hours ago
(keep all decimals, in your TI then multiply by 60)

x = _____ minutes ago (round)

4.5 million years ago, [the first hominid](#)
(Lucy is a young hominid 3.5 million years old)



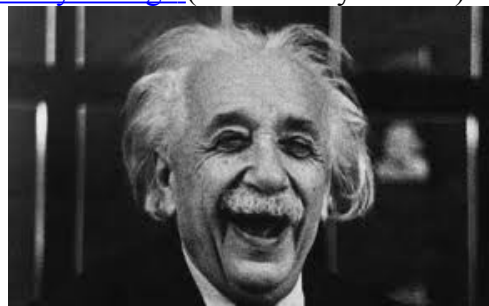
x = _____ hours ago
(keep all the decimals and then multiply by 60)
= _____ minutes ago
(keep all the decimals multiply by 60 again to find in seconds)
x = _____ seconds ago

about 195 000 years ago ? [first homo sapiens.](#)
!!! convert to standard notation !!!
use 14 billion = 14,000,000,000 and 24 hours = 86400
seconds



14,000,000,000=86,400 s
195,000 = x
(cross – multiply / divide and get x)
x = _____ seconds ago

[100 years ago](#) (modern Physics era) or our life time



x = _____ seconds compared to the
Universe history. Use scientific notation.
(order of 10,000th of a second !!!)