REMINDERS:

• Mastering Astronomy Homework #0 due this Friday

• Office Hours:  
  Tuesday & Thursday afternoons, 2:00-3:00 PM (that’s today!)

• Email: lscuderi@ifa.hawaii.edu
SCALE IN ASTRONOMY: OUR PLACE IN THE UNIVERSE
SCALE IN ASTRONOMY

• Astronomy spans a huge range in scale from the distances between atoms to the size of the universe.

• For example, distances are measured in many different units:
  • Ångstroms (Å), Nanometers (nm)
  • Centimeters (cm), Meters (m)
  • Kilometer (km), Astronomical Unit (AU)
  • Light-year (ly), Parsec (pc)
POWERS OF TEN

- Use powers of ten to compare very different scales easily:
  - $1,000 = 10 \times 10 \times 10 = 10^3$
  - $10 = 10^1$
  - $0.1 = 1/10 = 10^{-1}$
  - $0.001 = 1/1000 = 1/(10 \times 10 \times 10) = 1/10^3 = 10^{-3}$
SCIENTIFIC NOTATION

• A number in scientific notation has several parts:

  Coefficient          Exponent
  ↓                     ↓
  • 1.99 × 10^{33} grams

  Base          Units

• In scientific notation, the base is always 10

• KEEP IN MIND: many rules only apply to numbers with the same base
SCIENTIFIC NOTATION

• We can use powers of ten to express any number:
  • $6,325,000 = 6.325 \times 10^6$
  • $0.000006325 = 6.325 \times 10^{-6}$

• Any number to the 0th power $(x^0)$ equals 1:
  • $0.00002^0 = 940000^0 = 3^0 = 1$

• Most importantly for us, $10^0 = 1$
SCIENTIFIC NOTATION

• To convert a number to scientific notation, move the decimal point and count the number of places moved:

• The distance from Earth to the Sun is 149,598,000,000 m
  • In scientific notation, this is \(1.49598 \times 10^{11}\) m

• Going left increases the number. Going right decreases it:
  • The wavelength of green light is 0.000 000 510 m
  • In scientific notation, this is \(5.10 \times 10^{-7}\) m
SCIENTIFIC NOTATION

• To convert a number to scientific notation, move the decimal point and count the number of places moved:

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    \[2 + 3 + 3 + 3 = 11\]
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CLASS ACTION!
THE RADIUS OF THE SUN IS 696,000,000 METERS

• This size could also be expressed as:
  • (A) 6.96×10^7 meters
  • (B) 6.96×10^{10} meters
  • (C) 6.96×10^6 meters
  • (D) 6.96×10^8 meters
THE RADIUS OF THE SUN IS 696,000,000 METERS

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  • (A) $6.96 \times 10^7$ meters
  • (B) $6.96 \times 10^{10}$ meters
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  • (D) $6.96 \times 10^8$ meters
THE AGE OF THE UNIVERSE IS 13,700,000,000 YEARS

• This age could also be expressed as:
  • (A) $1.37 \times 10^{10}$ years
  • (B) $1.37 \times 10^{8}$ years
  • (C) $13.7 \times 10^{9}$ years
  • (D) $1.37 \times 10^{6}$ years
THE AGE OF THE UNIVERSE IS 13,700,000,000 YEARS

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THE RAPIDLY SPINNING PULSAR PSR 1937+21 HAS A ROTATIONAL PERIOD OF $1.56 \times 10^{-3}$ seconds.

- This period could also be expressed as:
  - (A) 0.00156 seconds
  - (B) 0.156 seconds
  - (C) 0.000156 seconds
  - (D) 0.0000156 seconds
THE RAPIDLY SPINNING PULSAR PSR 1937+21 HAS A ROTATIONAL PERIOD OF $1.56 \times 10^{-3}$ seconds

• This period could also be expressed as:

• (A) 0.00156 seconds

• (B) 0.156 seconds

• (C) 0.000156 seconds

• (D) 0.0000156 seconds
MATH WITH SCIENTIFIC NOTATION

- Multiplication:
  - Separate bases with exponents from coefficients and multiply separately. Exponents add:

\[
(4 \times 10^{11}) \times (3.5 \times 10^4) = (4 \times 3.5) \times (10^{11} \times 10^4) = 14 \times (10^{11+4}) = 14 \times 10^{15} = 1.4 \times 10^{16}
\]
MATH WITH SCIENTIFIC NOTATION

• Division:
  
  • Again, separate bases with exponents from coefficients and divide separately. Exponents now subtract:
  
  • \((4 \times 10^{11}) / (3.5 \times 10^{4}) = (4 / 3.5) \times (10^{11} / 10^{4}) \Rightarrow \)
  
  • \(= 1.14 \times (10^{(11-4)}) = 1.14 \times 10^{7}\)
THE ASTRONOMICAL UNIT

• The average distance between the Earth and the Sun, 149,597,871 kilometers (92,955,807 miles)

• Not an SI unit, but useful in astronomy
THE LIGHT-YEAR

• Not a measure of time!

• A measure of the distance that light travels in one year

• Roughly $9.46 \times 10^{15}$ meters ($5.87 \times 10^{12}$ miles)

• You can use a light-second, minute, hour, or any length of time to describe a distance traveled in that time

• Also describes how long ago you are looking
A light-year is about $10^{16}$ meters, and an astronomical unit is about $10^{11}$ meters.

• How many AU are in one light year?
  
  • (A) $10^7$
  • (B) $10^4$
  • (C) $10^5$
  • (D) $10^3$
A LIGHT-YEAR IS ABOUT $10^{16}$ METERS, AND AN ASTRONOMICAL UNIT IS ABOUT $10^{11}$ METERS.

• How many AU are in one light year?

• (A) $10^7$
• (B) $10^4$
• (C) $10^5$
• (D) $10^3$
METRIC PREFIXES

• In the metric system, we can use prefixes before a unit to modify the size of the unit by factors of ten:

  • Prefix + unit = new bigger or smaller unit

• Examples:

  • centi (0.01) + meter (distance) = centimeter, 0.01 meters
  • kilo (1,000) + gram (mass) = kilogram, 1000 grams
# METRIC PREFIXES: LARGE

<table>
<thead>
<tr>
<th>Text</th>
<th>Symbol</th>
<th>Factor</th>
<th>$10^n$</th>
<th>Word</th>
</tr>
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<tbody>
<tr>
<td>peta-</td>
<td>P</td>
<td>1 000 000 000 000 000</td>
<td>15</td>
<td>quadrillion</td>
</tr>
<tr>
<td>tera-</td>
<td>T</td>
<td>1 000 000 000 000 000</td>
<td>12</td>
<td>trillion</td>
</tr>
<tr>
<td>giga-</td>
<td>G</td>
<td>1 000 000 000</td>
<td>9</td>
<td>billion</td>
</tr>
<tr>
<td>mega-</td>
<td>M</td>
<td>1 000 000</td>
<td>6</td>
<td>million</td>
</tr>
<tr>
<td>kilo-</td>
<td>k</td>
<td>1 000</td>
<td>3</td>
<td>thousand</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>1</td>
<td>0</td>
<td>one</td>
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## METRIC PREFIXES: SMALL

<table>
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<td>-</td>
<td>-</td>
<td>$1$</td>
<td>$0$</td>
<td>one</td>
</tr>
<tr>
<td>centi-</td>
<td>c</td>
<td>0.01</td>
<td>-2</td>
<td>hundredth</td>
</tr>
<tr>
<td>milli-</td>
<td>m</td>
<td>0.001</td>
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<td>thousandth</td>
</tr>
<tr>
<td>micro-</td>
<td>µ</td>
<td>0.000 001</td>
<td>-6</td>
<td>millionth</td>
</tr>
<tr>
<td>nano</td>
<td>n</td>
<td>0.000 000 001</td>
<td>-9</td>
<td>billionth</td>
</tr>
<tr>
<td>Ång.*</td>
<td>Å</td>
<td>0.000 000 000 001</td>
<td>-10</td>
<td>-</td>
</tr>
</tbody>
</table>

*Ångstrom is not an SI unit, but still useful*
THE EARTH

Size: 6370 kilometers
THE EARTH AND THE MOON

Distance: 384,000 km (1 light-second)
THE SUN

Distance : $1.49 \times 10^8$ km (8 light-minutes)
THE SOLAR SYSTEM

Size: $7.48 \times 10^9$ km (6.9 light-hours)
SOLAR SYSTEM DISTANCES

Better, but is it completely correct now?
STILL WRONG!
FIELD TRIP!

Tuesday, July 8, 2014
FIELD TRIP!

...to the hallway.
## SCALE SOLAR SYSTEM

<table>
<thead>
<tr>
<th>Planet</th>
<th>Size</th>
<th>Distance from Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>30 cm (12 in)</td>
<td>0</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.1 cm (0.04 in)</td>
<td>13 m (43 feet)</td>
</tr>
<tr>
<td>Venus</td>
<td>0.27 cm (0.1 in)</td>
<td>24 m (78 feet)</td>
</tr>
<tr>
<td>Earth</td>
<td>0.28 cm (0.11 in)</td>
<td>33 m (109 feet)</td>
</tr>
<tr>
<td>Mars</td>
<td>0.15 cm (0.06 in)</td>
<td>50 m (163 feet)</td>
</tr>
<tr>
<td>Jupiter</td>
<td>3.02 cm (1.19 in)</td>
<td>173 m (566 feet)</td>
</tr>
<tr>
<td>Saturn</td>
<td>2.51 cm (0.99 in)</td>
<td>0.32 km (0.21 miles)</td>
</tr>
<tr>
<td>Uranus</td>
<td>1.11 cm (0.43 in)</td>
<td>0.66 km (0.41 miles)</td>
</tr>
<tr>
<td>Neptune</td>
<td>1.08 cm (0.42 in)</td>
<td>0.98 km (0.61 miles)</td>
</tr>
</tbody>
</table>
ALPHA CENTAURI

Distance: 4.37 light-years
THE NEAREST STARS

Distance: < 10 light-years
NEBULAE

Distance: varies (100s to 100,000s of ly)
STAR CLUSTERS

Distance: varies (100s to 100,000s of ly)
THE MILKY WAY GALAXY

Size: 120,000 light-years across
THE ANDROMEDA GALAXY

Distance: $2.5 \times 10^6$ light years

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THE LOCAL GROUP

Size: $10^7$ light years
THE VIRGO SUPERCLUSTER

Size: $1.1 \times 10^8$ light years

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THE OBSERVABLE UNIVERSE

Size: $9.3 \times 10^{10}$ light years
LECTURE-TUTORIAL GUIDELINES

• Read both the instructions and questions carefully.

• Discuss the concepts and their answers with one another.

• Take time to understand it now! If you get stuck, talk to a nearby group.

• Come to a consensus answer your group all agrees on and record it in detail.

• If you can’t come to a consensus, or are unsure of your answer, flag us down, and we will try to help.
LECTURE-TUTORIAL GUIDELINES

• Break into groups of no more than 2-3.

• In your group, work through the following:
  • Looking at Distant Objects, page 149-150
  • Discuss answers---don't be silent!

• We will be walking around if you need help.

• If your group finishes early, check your answers with groups around you.