I. Objectives

1. Define the units commonly used in science.
2. Perform calculations using time, distance, mass, temperature and related units using the characteristics of solar system and other celestial objects.

II. Introduction

Read the entire lab and identify which conversion factors will be required **before** we begin the lab.

The ability to convert among time, distance, mass, and temperature units enables astronomers to compare and contrast the characteristics of planets, stars, galaxies and other objects in the universe. Throughout the semester you will be required to make these kinds of conversions so it is important that you understand how they are done and that you are able to do them yourself. None of the conversions require more than a working knowledge of arithmetic, scientific notation and a calculator.

The process of converting one time, distance, or mass unit to another time, distance, or mass unit is the same no matter which units are required. Simply find a "chain" of conversion factors needed to change the existing units to the desired units and multiply the conversion factors together, "cancelling" units. This process is called dimensional analysis.

III. Sample Calculations

1. Convert the velocity of light, 2.997925×10^8 *m/s* to *km/hr*.

$$\frac{2.997925 \times 10^8\ m}{1\ s} \times \frac{1\ km}{1{,}000\ m} \times \frac{60\ s}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ hr}$$

$$= 1{,}079{,}253{,}000 \text{ km/hr} = 1.079253 \times 10^9 \text{ km/hr}$$

Answer: 2.997925×10^8 m/s = 1.079253×10^9 km/hr

2. Convert the beginning of the Cenozoic Era, which began 65 million years ago on Earth, to the time on the Cosmic Calendar in *hrs*.

$$\text{Cosmic Calendar time} = \frac{real\ time}{1.2 \times 10^{10}} = \frac{65 \times 10^6\ yrs}{1.2 \times 10^{10}} = 5.417 \times 10^{-3} \text{ yrs}$$

$$= 5.417 \times 10^{-3} \text{ yrs} \times \frac{365.25\ days}{1\ yr} \times \frac{24\ hrs}{1\ day} = 47.483 \text{ hrs}$$

Answer: 65 million years ago = 47.483 hrs on the Cosmic Calendar

3. The average density of the Earth is 5,520 kg/m^3. Convert it to g/cm^3.

$$\frac{5{,}520\ kg}{1\ m^3} \times \frac{1{,}000\ g}{1\ kg} \times \left(\frac{1\ m}{100\ cm}\right)^3 = 5.52\ \text{g/cm}^3$$

Answer: 5,520 kg/m^3 = 5.52 g/cm^3

4. Convert the Earth's sidereal period of rotation, 23*h* 56*m* 04.1*s*, to *s*.

$$\left(23\ hr \times \frac{3{,}600\ s}{1\ hr}\right) + \left(56\ \text{min} \times \frac{60\ s}{1\ \text{min}}\right) + 4.1\text{s}$$

$$= 82{,}800\text{s} + 3{,}360\text{s} + 4.1\text{s} = 86{,}164\text{s} = 8.6164 \times 10^4\ \text{s}$$

Answer: 23h 56m 04.1s = 8.61641 x 10^{4}s

Note: if a time is negative, remove the negative sign, perform the calculations and insert the negative sign in front of the result.

Note: h indicates hours, m indicates minutes, and s indicates seconds. Do not confuse m for meters and m for minutes. The context of the problem should make it clear which is being used.

5. Convert the Moon's sidereal period, 27.3217 days, to days, h, m, and s.

Subtract the integer part: 27.3217 days - 27 days = 0.3217 days

$$0.3217\ \text{days} \times \frac{24\ h}{1\ day} = 7.7208\text{h}$$

Subtract the integer part: 7.7208h - 7 h = 0.7208 h

$$0.7208\text{h} \times \frac{60\ m}{1\ h} = 43.248\text{m}$$

Subtract the integer part: 43.248 m - 43 m = 0.248 m

$$0.248\text{m} \times \frac{60\ s}{1\ m} = 14.88\text{s}$$

Answer: 27.3217 days = 27 days 7h 43m 14.88s

Note: if a time is negative, add 24 hours, simplify the result, and remove the negative sign.

Note: h indicates hours, m indicates minutes, and s indicates seconds. Do not confuse m for meters and m for minutes. The context of the problem should make it clear which is being used.

6. Convert the right ascension, *a*, of Antares, 16h 29m 23.0s to h.

$$16h + \left(29m \ x \ \frac{1h}{60m}\right) + \left(23.0s \ x \ \frac{1h}{3{,}600s}\right)$$

= 16h + 0.483h + 0.00639h = 16.4893h

Answer: 16h 29m 23.0s = 16.4893h

7. Convert the angular distance between the stars Bellatrix and Saiph, 16d 58' 51" to arcminutes.

$$\left(16d \ x \ \frac{60'}{1d}\right) + 58' + \left(51'' \ x \ \frac{1'}{60''}\right)$$

= 960' + 58' + 0.85' = 1,018.85'

Answer: 16d 58' 51" = 1,018.85'

8. Convert the declination, *d*, of the star Spica, -11d 09' 27", to arcseconds.

$$\left(11d \ x \ \frac{3{,}600''}{1\,d}\right) + \left(9' \ x \ \frac{60''}{1'}\right) + 27''$$

= 39,600" + 540" + 27" = 40,167"

Answer: -11d 09' 27" = -40,167"

Note: if an angular measure is negative, remove the negative sign, perform the calculations and insert the negative sign in front of the result.

Note: d indicates degrees of arc, ' indicates arcminutes, and " indicates arcseconds.

9. Convert the angular distance between the stars Betelgeuse and Rigel, 18.6053^o to degrees, arcminutes, and arcseconds.

Subtract the integer part: 18.6053d - 18d = 0.6053d

$$0.6053d \ x \ \frac{60'}{1d} = 36.318'$$

Subtract the integer part: 36.318' - 36' = 0.318'

$$0.318' \ x \ \frac{60''}{1'} = 19.08''$$

Answer: 18.6053^o = 18d 36' 19.08"

Note: we will us the symbol ^{o} for degrees interchangeably with d for degrees. Do not confuse ^{o} used with temperatures and ^{o} for angular measurements. The context of the problem should make it clear which is being used.

10. Convert 80^oF to ^oC and K.

$$^oC = \frac{5}{9}(^oF - 32^oF) = \frac{5}{9}(80^oF - 32^oF) = 26.67^oC$$

$$K = {}^oC + 273^oC = 26.67^oC + 273^oC = 299.67K$$

Answer: $80^oF = 26.67^oC = 299.67K$

11. Convert 45^oC to ^oF and K.

$$^oF = \frac{9}{5}(^oC) + 32^oF = \frac{9}{5}(45^oC) + 32^oF = 113^oF$$

$$K = {}^oC + 273^oC = 45^oC + 273^oC = 318K$$

Answer: $45^oC = 113^oF = 318K$

12. Convert 95K to ^oC and ^oF.

$$^oC = K - 273^oC = 95K - 273^oC = -178^oC$$

$$^{o}F = \frac{9}{5}(^{o}C) + 32^{o}F = \frac{9}{5}(-178^{o}C) + 32^{O}F = -288.4^{o}F$$

IV. Prelab Definitions

1. conversion factor

2. meter

3. kilometer

4. Ångstrom

5. astronomical unit

6. light year

7. angular degree

8. arcminute

9. arcsecond

10. parsec

11. kiloparsec

12. mass

13. gram

14. kilogram

15. volume

16. density

17. weight

18. force

19. newton

20. energy

21. joule

22. power

23. watt

24. speed

25. velocity

26. momentum

27. angular momentum

28. temperature

29. Fahrenheit

30. Celsius

31. Kelvin

32. Cosmic Calendar

33. right ascension

34. declination

V. Lab Procedure

Perform each of the following calculations. Be sure that your answers include the correct units and write the answers for problems 1 through 10 and 19 through 21 and 22 (if appropriate), using **scientific notation**. **You must show your work to receive credit for the answers!** Be sure that your answers make sense.

1. Convert 1 day to s.

2. The orbital period of Neptune is 164.793 yrs. Convert it to min.

3. The equatorial radius of Jupiter is 71,494 km. Convert it to cm.

4. Convert the orbital velocity of Mercury, 47.89 km/sec, to m/hr.

5. Convert the average density of Saturn, 0.69 g/cm^3, to kg/m^3.

6. Convert the distance in ly, 4.24, to the closest star, Proxima Centauri to km.

7. The speed of the space shuttle is about 17,600 miles/hr. How many years would it take the space shuttle to reach Proxima Centauri?

8. How long does light from the Sun take to reach the Earth in min?

9. Convert the mass of Pluto, 0.0022 M_{Earth}, to kg.

10. Sirius has a radius of 2.1 R_{Sun}. Convert it to m.

11. The star Betelgeuse is 420 ly away. This means that the light we see from that star left it 420 years ago. Convert 420 yrs to Cosmic Calendar time in s.

12. Convert the tilt of the Earth's axis of rotation, 23.5^o, from the ecliptic plane to degrees and arcminutes.

13. The declination, *d*, of the star Procyon is 05d 13' 30" . Convert it to arcseconds.

14. Convert the right ascension of the star Pollux, 07h 45m 14.5s, to h.

15. The angular distance between Antares and Shaula, 17d 16' 49". Convert it to degrees.

16. The angular distance between the stars Caph and Schedar is 4.91472^o. Convert it to degrees, arcminutes, and arcseconds.

17. The synodic period of the Moon is 29 days 12h 44m 2.82s. Convert it to days.

18. The surface temperature of Venus is 882^{o}F. Convert it to both ^{o}C and K.

19. The temperature of the star Sirius is 9,150 K. Convert it to both ^{o}C and ^{o}F.

20. Pluto is 39.44 AU from the Sun. Calculate the approximate area of the solar system in km^2. Assume that Pluto marks the edge of our solar system and its distance from the Sun is the radius of our solar system. Remember that the formula for area is $A = \pi r^2$.

21. The radius of the Sun is 695,000 km. The radius of the Earth is 6,378 km. Calculate how many Earths would fit inside the Sun. Remember that the formula for volume is $V = \frac{4}{3}\pi r^3$.

22. The amount of mass contained in stars in our neighborhood is about 0.039 $M_{Sun}/parsec^3$ (*Sky & Telescope*, p. 44, June, 1999). Convert it to kg/m^3.

VI. Lab Discussion

1. Why is it important to use the correct units in astronomical calculations?

2. Explain how the units used in astronomy are different from those we use in everyday life and why are they different.