ASTRONOMICAL JOURNEY TIMES

Introduction

Distances between planets are very large, in the hundreds of millions to billions of miles. Interstellar distances are even larger, tens to trillions of miles, and intergalactic distances much larger still. The numbers get to be so large that we prefer to define new scales, to keep the numbers from becoming too unwieldy

- Astronomical Unit (AU) - the distance from the Sun to the Earth
- Light year (lyr) - the distance that light travels in one year

The task in this exercise is to take some of these very large distances and calculate just how long we would take to get to another planet, or another star system, or another galaxy. Hopefully, it will not be too much of surprise that these turn out to be longer (much longer!) than the length of a one hour episode of Star Trek.

Don't be afraid of the Math!

Before delving into the details I would like to make three points:

- The procedure for doing this is one with which you are likely already familiar, even though you might not have thought of it these terms. If I were to ask you how far you would go in 3 hours if you drive at 50 miles an hour, then you can likely answer without much difficulty - 150 miles. If I ask you how you arrive at this number then you might realize all you did was multiply the numbers together. In other words you used the physics equation

  $$\text{Distance} = \text{Speed} * \text{Time}$$

  We shall use exactly the same logic, and the same physics equation, to calculate the times for these astronomical journeys.
- The numbers involved are indeed very large. Don't let these put you off. You will find it more convenient to use scientific notation (e.g. 4.5×10^9) rather than the equivalent decimal notation (4,500,000,000). Just remember that your calculator is set up to do all the work for you. (Assuming you have scientific calculator. If you don't, get one. I've seen them for less than $10. You don't need the expensive graphing calculators, you'll spend more time learning how to use it than you will solving these problems.)
- The hardest part of this is making sure that you have consistent units. Even if you know how to use the equation above it does no good to calculate the time for a distance in light years if the speed is in miles per hour. The first task is to make the units consistent.

If you bear these points in mind, then you should find this to be well within your capabilities. Just remember, attack these problems in three distinct steps, rather than trying to do everything at once.
The three steps

- Convert units to make them consistent
- Calculate the answer
- If you want to express the answer in a more useful form, then convert again. For example, if you calculate a journey time using a speed in miles per hour, then the answer will be a time in hours. It would be useful to know just how many years this is.

Converting units

There is detailed help on the web site regarding converting units and on the use of scientific notation

- Converting units - http://physics.csustan.edu/astro/help/convert/convert.htm
- Scientific notation - http://physics.csustan.edu/astro/help/math/notation.htm

Let's look at a few examples. First review the links above (if necessary), then start with some simple problems.

Some useful conversion factors

1 day = 86,400 seconds
1 year = 365 * 24 * 60 * 60
= 3,156,000 seconds (3.156×10^6 s)
1 mile = 1609 metres
1 AU = 1.5×10^{11} metres = 9.3×10^7 miles
1 lyr = 9.46×10^{15} metres = 5.88×10^{12} miles

Examples

Q: How many seconds in 45 days?
A: 45 days * 86400 seconds / 1 day = 3,888,00 seconds

Q: How many days contain 1 million seconds?
A: 1,000,000 s * 1 day / 86,400 s = 11.6 days (rounding to three significant figures)

Q: how far is 5.2 AU? (The distance from the Sun to Jupiter)
A: 5.2 AU * 9.3×10^7 miles / 1 AU = 4.84×10^8 miles

Q: Uranus is 1.84×10^9 miles from the Sun. How far is this is AU?
A: 1.84×10^9 miles * 1 AU / 9.3×10^7 miles = 19.8 AU

Q: how far is 75 lyr?
A: 75 lyr * 5.88×10^{12} miles / 1 lyr = 4.41×10^{14} miles

Q: 150,000,000 hours (1.5×10^8 hours) is how many years? (Note this requires two conversions, from hours to days and then days to years.)
A: 1.5×10^8 hours * (1 day / 24 hours) * (1 year / 365 days) = 17,000 years

Calculations

Q: At its closest Jupiter is about 3.9×10^8 miles away. If we can travel at 40,000 miles per hour, how long will it take to get there?
A: distance = speed * time
3.9×10^8 miles = 40,000 miles/hour * time
time = 3.9×10^8 miles / 40,000 miles/hour
= 9750 hours (a little over 400 days)
Note that in this case there was no need to convert any units. We have units of 'miles' in both the distance and in the speed, so they are already consistent. Note also that because the unit of time in the given speed was 'hours' then the final answer is also in hours.

Q: How long will it take to go 200 lyr at a speed of 450,000 miles per hour?
A: Note that this time we do have inconsistent units, 'miles' in the speed but 'lyr' for the distance. This time you will have to convert one of them first. In principle you can convert either, but you will probably find it easier to convert the distance.

Distance = 200 lyr * 5.88 x 10^{12} miles / 1 lyr = 1.18 x 10^{15} miles
Now calculate the time using distance = speed * time
1.18 x 10^{15} miles = 4.5 x 10^{5} miles/hour * time
time = 1.18 x 10^{15} miles / 4.5 x 10^{5} miles/hour
time = 2.6 x 10^{9} hours

Q: Although the answer to the last question is strictly speaking correct, it is not easy to interpret. Just exactly, how long is 2.6 billion hours?
A: 2.6 x 10^{9} hours * (1 day / 24 hours) * (1 year / 365 days) = 297,000 years

Putting it all together - one last problem

Q: At a speed of 600,000 miles per hour how long will it take to go 40 million light years?
A: 4 x 10^{7} lyr * 5.88 x 10^{12} miles / 1 lyr = 2.35 x 10^{20} miles (that's a lot!)
Time = 2.35 x 10^{20} miles / 6 x10^{5} miles/hour = 3.92 x 10^{14} hours
3.92 x 10^{14} hours * (1 day / 24 hours) * (1 year / 365 days) = 4.5 x 10^{10} years

45 BILLION YEARS! That's a very long time. Longer than the age of the universe in fact.