Scientific notation is an important way to represent very big, and very small, numbers. Here is a sample of astronomical problems that will test your skill in using this number representation.

**Problem 1:** The sun produces $3.9 \times 10^{33}$ ergs per second of radiant energy. How much energy does it produce in one year ($3.1 \times 10^7$ seconds)?

**Problem 2:** One gram of matter converted into energy yields $3.0 \times 10^{20}$ ergs of energy. How many tons of matter in the sun is annihilated every second to produce its luminosity of $3.9 \times 10^{33}$ ergs per second? (One metric ton = $10^6$ grams)

**Problem 3:** The mass of the sun is $1.98 \times 10^{33}$ grams. If a single proton has a mass of $1.6 \times 10^{-24}$ grams, how many protons are in the sun?

**Problem 4:** The approximate volume of the visible universe (A sphere with a radius of about 14 billion light years) is $1.1 \times 10^{31}$ cubic light-years. If a light-year equals $9.2 \times 10^{17}$ centimeters, how many cubic centimeters does the visible universe occupy?

**Problem 5:** A coronal mass ejection from the sun travels $1.5 \times 10^{13}$ centimeters in 17 hours. What is its speed in kilometers per second?

**Problem 6:** The NASA data archive at the Goddard Space Flight Center contains 25 terabytes of data from over 1000 science missions and investigations. (1 terabyte = $10^{15}$ bytes). How many CD-roms does this equal if the capacity of a CD-rom is about $6 \times 10^8$ bytes? How long would it take, in years, to transfer this data by a dial-up modem operating at 56,000 bits/second? (Note: one byte = 8 bits).

**Problem 7:** Pluto is located at a distance of $5.9 \times 10^{14}$ centimeters from Earth. At the speed of light ($2.99 \times 10^10$ cm/sec) how long does it take a light signal (or radio message) to travel to Pluto and return?

**Problem 8:** The planet HD209458b, now known as Osiris, was discovered by astronomers in 1999 and is at a distance of 150 light-years (1 light-year = $9.2 \times 10^{12}$ kilometers). If an interstellar probe were sent to investigate this world up close, traveling at a maximum speed of 700 km/sec (about 10 times faster than our fastest spacecraft: Helios-1), how long would it take to reach Osiris?
Problem 1: The sun produces $3.9 \times 10^{33}$ ergs per second of radiant energy. How much energy does it produce in one year ($3.1 \times 10^7$ seconds)? Answer: $3.9 \times 10^{33} \times 3.1 \times 10^7 = 1.2 \times 10^{41}$ ergs.

Problem 2: One gram of matter converted into energy yields $3.0 \times 10^{20}$ ergs of energy. How many tons of matter in the sun is annihilated every second to produce its luminosity of $3.9 \times 10^{33}$ ergs per second? (One metric ton = $10^6$ grams). Answer: $3.9 \times 10^{33} / 3.0 \times 10^{20} = 1.3 \times 10^{13}$ grams per second, or $1.3 \times 10^{13} / 10^6 = 1.3 \times 10^5$ metric tons of mass.

Problem 3: The mass of the sun is $1.98 \times 10^{33}$ grams. If a single proton has a mass of $1.6 \times 10^{-24}$ grams, how many protons are in the sun? Answer: $1.98 \times 10^{33} / 1.6 \times 10^{-24} = 1.2 \times 10^{57}$ protons.

Problem 4: The approximate volume of the visible universe (A sphere with a radius of about 14 billion light years) is $1.1 \times 10^{31}$ cubic light-years. If a light-year equals $9.2 \times 10^{17}$ centimeters, how many cubic centimeters does the visible universe occupy? Answer: $1$ cubic light year $= (9.2 \times 10^{17})^3 = 7.8 \times 10^{53}$ cubic centimeters, so the universe contains $7.8 \times 10^{53} \times 1.1 \times 10^{31} = 8.6 \times 10^{84}$ cubic centimeters.

Problem 5: A coronal mass ejection from the sun travels $1.5 \times 10^{13}$ centimeters in 17 hours. What is its speed in kilometers per second? Answer: $1.5 \times 10^{13} / (17 \times 3.6 \times 10^3) = 2.4 \times 10^8$ cm/sec $= 2,400$ km/sec.

Problem 6: The NASA data archive at the Goddard Space Flight Center contains 25 terabytes of data from over 1000 science missions and investigations. (1 terabyte $= 10^{15}$ bytes). How many CD-roms does this equal if the capacity of a CD-rom is about $6 \times 10^8$ bytes? How long would it take, in years, to transfer this data by a dial-up modem operating at 56,000 bits/second? (Note: one byte $= 8$ bits). Answer: $2.5 \times 10^{16} / 6 \times 10^8 = 4.2 \times 10^7$ Cdroms. It would take $2.5 \times 10^{16} / 7,000 = 3.6 \times 10^{12}$ seconds or about $1.1 \times 10^5$ years.

Problem 7: Pluto is located at a distance of $5.9 \times 10^{14}$ centimeters from Earth. At the speed of light ($2.99 \times 10^{10}$ cm/sec) how long does it take a light signal (or radio message) to travel to Pluto and return? Answer: $2 \times 5.98 \times 10^{14} / 2.99 \times 10^{10} = 4.0 \times 10^4$ seconds or 11 hours.

Problem 8: The planet HD209458b, now known as Osiris, was discovered by astronomers in 1999 and is at a distance of 150 light-years (1 light-year $= 9.2 \times 10^{12}$ kilometers). If an interstellar probe were sent to investigate this world up close, traveling at a maximum speed of 700 km/sec (about 10 times faster than our fastest spacecraft: Helios-1), how long would it take to reach Osiris? Answer: $150 \times 9.2 \times 10^{12} / 700 = 1.9 \times 10^{12}$ seconds or about 64,000 years!