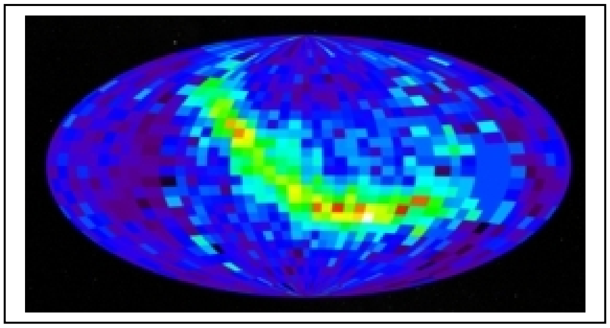

$$K.E. = \frac{1}{2} m V^2$$

NASA's IBEX satellite has detected fast-moving atoms streaking into the solar system from interstellar space. The energetic neutral atoms (called ENAs) are created in an area of our solar system known as the interstellar boundary region. This region is where charged particles from the sun, called the solar wind, flow outward far beyond the orbits of the planets and collide with material between stars.

The NASA Press release says that the ENAs "…travel inward toward the sun from interstellar space at speeds from 100,000 mph to more than 2.4 million mph."

Question: How do scientists know the speeds of these particles?

Answer: It's all about Kinetic Energy!

The IBEX satellite detects energetic neutral atoms with a kinetic energy (K.E.) of 1,000 electron volts (1 keV), where 1 electron volt (eV) equals 1.6 x 10^{-19} Joules of energy. In the formula above, with KE expressed in Joules and the particle mass, m, expressed in kilograms, the speed of the particle, V, will be in meters/sec.

Problem 1 - What is the formula for the particle speed, V, in terms of the particle's mass and kinetic energy?

Problem 2 - Show that, if the particle is a proton with a mass of 1.7 x 10^{-27} kg and it has a speed of 450 kilometers/sec, to two significant figures, its energy is A) 1.7 x 10^{-16} Joules, or B) 1,100 eV.

Problem 3 - The IBEX satellite measures ENAs with an energy of 1 keV in order to make the image shown above. The most common element in the universe is hydrogen (1 proton). If the detected ENAs are all protons, what is the speed of the protons, in kilometers/sec, detected by IBEX to two significant figures?

Problem 1 - What is the formula for the particle speed, V, in terms of the particle's mass and kinetic energy? Answer:

$$E = \frac{1}{2} m V^2$$

so

$$V = \sqrt{\frac{2E}{m}}$$

Problem 2 - Show that, if the particle is a proton with a mass of 1.7 x 10^{-27} kg and it has a speed of 450 kilometers/sec, to two significant figures its energy is A) 1.7 x 10^{-16} Joules, or B) 1,076 eV.

Answer A) In order to use the formula for K.E., we have to convert km/s to meters/sec, so 450 km/s x (1000 m/km) = 450,000 m/s, then K.E = 1/2 (1.7 x 10^{-27} kg) x (4.5 x 10^{5} m/s)^{2} = 1.7 x 10^{-16} Joules. B) Since 1 eV = 1.6 x $10^{\mathbf{-19}}$ Joules we have
1.7 x 10^{-16} Joules x (1 eV/1.6 x $10^{\mathbf{-19}}$ Joules) = 1,063 eV
which to two significant figures is 1,100 eV.

Problem 3 - The IBEX satellite measures ENAs with an energy of 1 keV in order to make the image shows above. The most common element in the universe is hydrogen (1 proton). If the detected ENAs are all protons, what is the speed of the protons in kilometers/sec, detected by IBEX to two significant figures?

Answer: 1 keV = 1,000 eV. The equivalent energy in Joules is 1,000 eV x (1.6 x $10^{\mathbf{-19}}$ Joules/eV) = 1.6 x $10^{\mathbf{-16}}$ Joules. The mass of a proton is 1.7 x 10^{-27} kg, so from the formula derived in Problem 1,

$$V = \sqrt{\frac{2\text{x}(1.6\text{x}10^{-16})}{1.7\text{x}10^{-27}}}$$

$$V = \sqrt{1.88x10^{11}}$$

So V = 433,861 m/s by the calculator display, or to 2 significant figures we get 430,000 m/s or 430 kilometers/sec.

Note: 430 km/sec is equivalent to 960,000 miles/hour or nearly 1 million miles per hour. Also, IBEX measures higher-energy ENAs with energies up to 6 keV, which corresponds to protons with speeds of 2,400,000 million miles/hour as stated in most press releases.

IBEX Press Release: http://www.nasa.gov/mission_pages/ibex/index.html