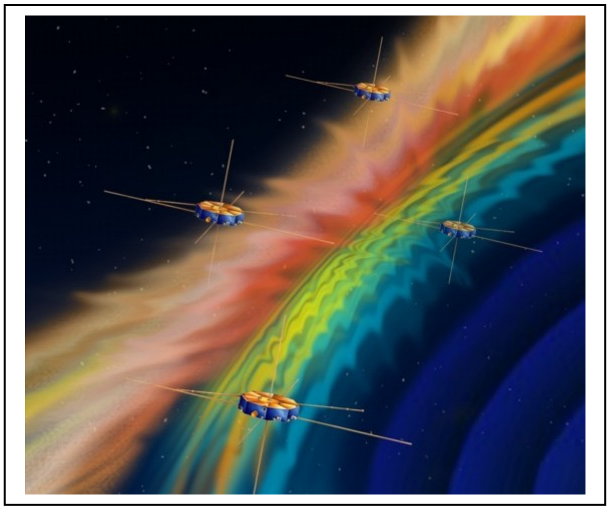
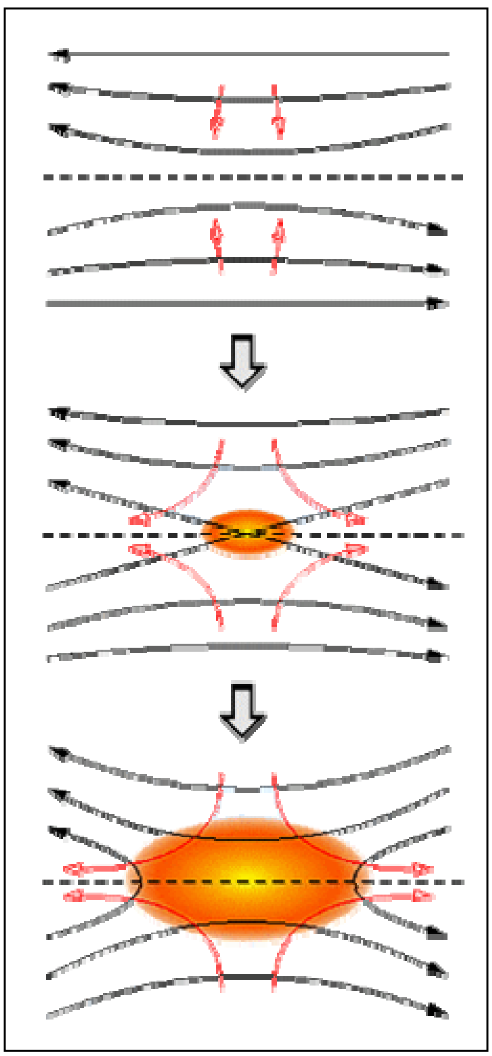
NASA Juggles Four Satellites at Once:



In 2013, NASA will launch the Magnetosphere Multi-Scale (MMS) satellite constellation; a set of four identical satellites that will study the 3-dimensional properties of Earth's magnetosphere. The spacecraft will travel in a tetrahedral formation with inter-spacecraft distances that will vary from ten kilometers to tens of thousands of kilometers.

At the center of the investigations is magnetic reconnection. This process, as shown in the sequence of figures below, breaks and reconnects magnetic lines of force. This converts stored magnetic energy into kinetic energy that causes trapped particles (the expanding spot in the figure) to also gain energy. MMS scientists hope that they will witness a few of these events inside the tetrahedral volume.

MMS will measure the physical properties of the reconnection process including the factors that control it, such as its distribution in space, and its minute-by-minute changes in time. This will help scientists test various theories of how this important process is triggered, evolves in time, and how magnetic energy is transferred into particle motion.



Problem 1: The volume of a regular tetrahedron with an edge length of A is given by the formula:

$$V = \frac{1}{12} A^3 (2)^{1/2}$$

What will be the volume of the MMS constellation: A) at its minimum size of A = 10 km? B) at its maximum size of A = 10,000 km?

Problem 2: The speed of the reconnection event is predicted to be about 500 kilometers/sec. About how long will it take disturbances to travel across the region of space being studied by MMS at its largest and its smallest satellite configuration?

Problem 3: Magnetic reconnection process (see the figure to left) releases stored magnetic energy (shaded region) which can then be transformed into kinetic energy in the motion of trapped, charged particles. The amount of stored magnetic energy is given by the formula:

$$E = \frac{1}{8\pi} B^2 \times V \quad \text{ergs}$$

Where B is the magnetic field strength in Gauss, and V is the volume of the magnetic field in cubic centimeters. If B = 0.0002 Gauss, how much energy could be stored within the tetrahedral volumes of the largest and smallest configurations of MMS?

Answer Key:

Problem 1: The volume of a regular tetrahedron with an edge length of A is given by the formula:

$$V = \frac{1}{12} A^{3} (2)^{1/2}$$

What will be the volume of the MMS constellation:

A) at its minimum size of A = 10 km? Answer = 118 cubic kilometers
B) at its maximum size of A = 10,000 km? Answer = 118 billion cubic kilometers

Problem 2: The speed of the reconnection event is predicted to be about 500 kilometers/sec. About how long will it take disturbances to travel across the region of space being studied by MMS at its largest and its smallest satellite configuration?

Answer: Largest: 10,000 km / (500 km/sec) = **20 seconds.**
Smallest 10 km / (500 km/sec) = **0.02 seconds.**

Problem 3: Magnetic reconnection releases stored magnetic energy which can then be transformed into kinetic energy in the motion of trapped, charged particles. The amount of stored magnetic energy is given by the formula:

$$E = \frac{1}{8\pi} B^{2} \times V \quad \text{ergs}$$

Where B is the magnetic field strength in Gauss, and V is the volume of the magnetic field in cubic centimeters. If B = 0.0002 Gauss, how much energy could be stored within the tetrahedral volumes of the largest and smallest configurations of MMS?

Largest volume:

$$V = 118 \text{ billion km}^{3} \times (1.0 \times 10^{15} \text{ cm}^{3}/\text{km}^{3}) = 1.2 \times 10^{26} \text{ cm}^{3}$$

$$E = 0.039 \times (0.0002)^{2} \times 1.2 \times 10^{26} \text{ cm}^{3} = \mathbf{1.9 \times 10^{17} \text{ ergs}}$$

Smallest volume:

$$V = 118 \text{ km}^{3} \times (1.0 \times 10^{15} \text{ cm}^{3}/\text{km}^{3}) = 1.2 \times 10^{17} \text{ cm}^{3}$$

$$E = 0.039 \times (0.0002)^{2} \times 1.2 \times 10^{17} \text{ cm}^{3} = \mathbf{1.9 \times 10^{8} \text{ ergs}}$$