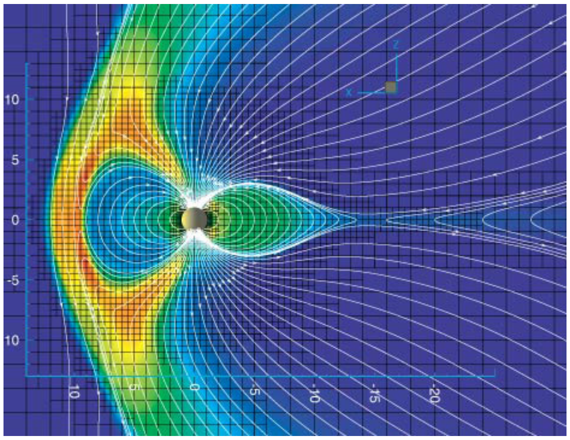

$$R = \left(\frac{1.8x10^{12}}{NV^2} \right)^{\frac{1}{6}}$$

$$Pr=1.6x10^{-8}NV^2$$

$$Pm=4.0x10^{-6}B^2$$

The ACE satellite measures the density and speed of the solar wind as it approaches Earth, and also measures the strength of its magnetic field. Both the magnetic field, and the kinetic energy of the particles, cause a build-up of pressure acting upon Earth's magnetic field. This forces Earth's magnetic field closer to the planet's surface, and can expose satellites orbiting Earth to the potentially harmful effects of cosmic rays and other high-energy particles. Based on actual data from the ACE satellite, in this problem you will calculate the particle and magnetic pressure and determine the distance from Earth of the pressure equilibrium region of the magnetic field, called the magnetopause.

The equations to the left give the magnetopause distance, R, in multiples of Earth's radius (6,378 km), and the magnetic (Pm) and ram (Pr) pressures in units of microErgs/cm^3, once the sped of the cloud (V in km/sec), density of the cloud (N in particles/cm^3) and the strength of the cloud's magnetic field (B in nanoTeslas) are specified.

Date	Flare	N (particle/cc)	V (km/s)	B (nT)	Pr	Pm	Distance (Re)
9-7-2005	X-17	50	2500	50	5.0	0.01	4.2
7-13-2005	X-14	30	2000	20			
1-16-2005	X-2.8	70	3700	70			
10-28-2003	X-17	100	2700	70			
11-4-2003	X-28	80	2300	49	6.8	0.01	4.0
4-21-2002	X-1.5	20	2421	10			
7-23-2002	X-4.8	40	1200	15			
4-6-2001	X-5.6	20	1184	20			
7-14-2000	X-5.7	30	2300	60			
11-24-2000	X-1.8	50	2000	10	3.2	0.0004	4.6
8-24-1998	X-1	15	1500	10			

Problem 1: Use the formulae and the values cited in the table to complete the last three columns. A few cases have been computed as examples.

Problem 2: A geosynchronous communications satellite is orbiting at a distance of 6.6 Re (1 Re = 1 Earth radius= 6,378 km). For which storms will the satellite be directly affected by the solar storm particles?

Date	Flare	N (particle/cc)	V (km/s)	B (nT)	Pr	Pm	Distance (Re)
9-7-2005	X-17	50	2500	50	5.0	0.01	4.2
7-13-2005	X-14	30	2000	20	**1.9**	**0.002**	**5.0**
1-16-2005	X-2.8	70	3700	70	**15.3**	**0.02**	**3.5**
10-28-2003	X-17	100	2700	70	**11.7**	**0.02**	**3.7**
11-4-2003	X-28	80	2300	49	6.8	0.01	4.0
4-21-2002	X-1.5	20	2421	10	**1.9**	**0.0004**	**5.0**
7-23-2002	X-4.8	40	1200	15	**0.9**	**0.0009**	**5.6**
4-6-2001	X-5.6	20	1184	20	**0.4**	**0.002**	**6.3**
7-14-2000	X-5.7	30	2300	60	**2.5**	**0.01**	**4.7**
11-24-2000	X-1.8	50	2000	10	3.2	0.0004	4.6
8-24-1998	X-1	15	1500	10	0.5	0.0004	6.1

Note: Density and magnetic field strength are estimates for purposes of this calculation only.

Problem 1: Use the formulae and the values cited in the table to complete the last three columns.

Answer: See above shaded table entries. This is a good opportunity to use an Excel spreadsheet to set up the calculations. This also lets students change the entries to see how the relationships change, as an aid to answering the remaining questions.

Problem 2: A geosynchronous communications satellite is orbiting at a distance of 6.6 Re. For which storms will the satellite be directly affected by the solar storm particles?

Answer: If the equilibrium radius is less than 6.6 Re, the satellite will be outside Earth's protective magnetosphere and within the region of space directly affected by the storm particles and fields. This condition is satisfied for all of the storms except for the ones on April 6, 2001 and August 24, 1998

Note to Teacher: Ram pressure is the pressure produced by a cloud of particles traveling at a particular speed with a particular density. We call this a 'ram' pressure because it is also the pressure that you feel as you 'ram' your way through the air when you are in motion. Because only the relative speed is important, you will feel the same pressure if you are 'stationary' and a gas is moving past you at a particular speed, or if the gas is 'stationary' and you are trying to move through it at the same speed. Technically, ram pressure is the product of the gas density and the square of this relative speed.

The values for the ram pressure (Pr) are all substantially larger than the values for the magnetic pressure (Pm), so we conclude that ram pressure is stronger than the cloud's magnetic pressure. This means that when the cloud impacts another object such as Earth, it is mostly the ram pressure of the cloud that determines the outcome of the interaction.

The image used in this problem shows a computer-calculated model of Earth's magnetic field during compression. The yellow coloration indicates regions of maximum pressure. Image courtesy the University of Michigan

http://www.tecplot.com/showcase/studies/2001/michigan.htm