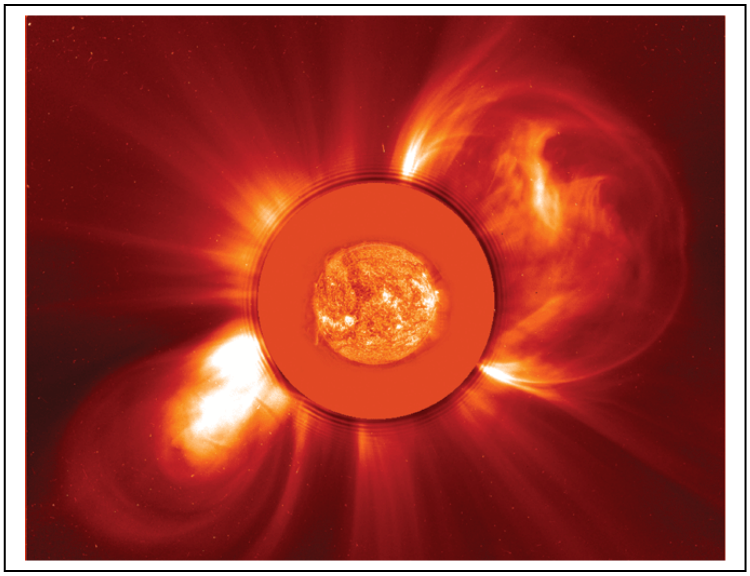
CME Kinetic Energy and Mass



Kinetic energy is the energy that a body has by virtue of its mass and speed. Mathematically, it is expressed as one-half of the product of the mass of the object (in kilograms), times the square of the objects speed (in meters/sec).

$$K.E. = 0.5\ m\ V^2$$

Between October 1996 and May 2006, the SOHO satellite detected and catalogued 11,031 coronal mass ejections like the one seen in the figure to the left. There was enough data available to determine the properties for 2,131 events. The table below gives values for ten of these CMEs.

Date	Speed (km/s)	K.E. (Joules)	Mass (kilograms)
4/8/1996		1.1×10^{20}	2.2×10^{9}
8/22/2000	388	1.3×10^{22}	
6/10/2001	731	8.2×10^{23}	
1/18/2002	64		2.6×10^{10}
5/16/2002	1,310		7.8×10^{10}
10/7/2002		7.8×10^{21}	3.0×10^{10}
1/24/2003	387	9.1×10^{18}	
10/31/2003	2,198	1.6×10^{24}	
11/2/2003		9.3×10^{25}	4.5×10^{13}
11/10/2004	3,387		9.6×10^{12}

Problem 1: Complete the table by determining the value of the missing entries using the formula for Kinetic Energy.

Problem 2: What is the minimum and maximum range for the observed kinetic energies for the 10 CMEs? The largest hydrogen bomb ever tested was the Tsar Bomba in 1961 and was equivalent to 50 megatons of TNT. It had a yield of 5×10^{23} Joules. What is the equivalent yield for the largest CME in megatons, and 'Tsar Bombas'?

Problem 3: What are the equivalent masses of the smallest and largest CMEs in metric tons?

Problem 4: Compare the mass of the largest CME to the mass of a small mountain. Assume that the mountain can be represented as a cone with a volume given by $1/3\ \pi\ R^2\ H$ where R is the base radius and H is the height in meters, and assume the density of rock is 3 grams/cm^3.

Date	Speed (km/s)	K.E. (Joules)	Mass (kilograms)
4/8/1996	**316**	1.1×10^{20}	2.2×10^{9}
8/22/2000	388	1.3×10^{22}	**1.7×10^{11}**
6/10/2001	731	8.2×10^{23}	**3.1×10^{12}**
1/18/2002	64	**5.3×10^{19}**	2.6×10^{10}
5/16/2002	1,310	**6.7×10^{22}**	7.8×10^{10}
10/7/2002	**721**	7.8×10^{21}	3.0×10^{10}
1/24/2003	387	9.1×10^{18}	**1.2×10^{8}**
10/31/2003	2,198	1.6×10^{24}	**6.6×10^{11}**
11/2/2003	**2,033**	9.3×10^{25}	4.5×10^{13}
11/10/2004	3,387	**5.5×10^{25}**	9.6×10^{12}

Problem 1: Complete the table by determining the value of the missing entries using the formula for Kinetic Energy.

Answer: See above answers in red.

Problem 2: What is the minimum and maximum range for the observed kinetic energies for the 10 CMEs?

Answer: Maximum = 9.3×10^{25} Joules. Minimum = 5.3×10^{19} Joules

The largest hydrogen bomb ever tested was the *Tsar Bomba* in 1961 and was equivalent to 50 megatons of TNT. It had a yield of 5×10^{23} Joules. What is the equivalent yield for the largest CME in megatons, and 'Tsar Bombas'?

Answer: The CME on November 2, 2003 was equal to $(9.3 \times 10^{25} / 5 \times 10^{23})$ = 186 Tsar Bombas, and an equivalent TNT yield of 186 x 50 megatons = 9,300 megatons!

Problem 3: What are the equivalent masses of the smallest and largest CMEs in metric tons?

Answer: One metric ton is 1,000 kilograms. The smallest mass was for the January 24, 2003 CME with about 120,000 tons. The largest mass was for the November 2, 2003 'Halloween Storm' with about 45 billion metric tons.

Problem 4: Compare the mass of the largest CME to the mass of a small mountain. Assume that the mountain can be represented as a cone with a volume given by $V = 1/3 \pi R^2 H$ where R is the base radius and H is the height in meters, and assume the density of rock is 3 grams/cm^3.

Answer: One possibility is for a mountain with a base radius of R = 1 kilometers, and a height of 50 meters. The cone volume is $0.33 \times 3.14 \times (1000)^2 \times 50 = 5.2 \times 10^7$ cubic meters. The rock density of 3 gm/cm^3 converted into kg per cubic meters is $0.003 \text{ kg}/(.01)^3 = 3000 \text{ kg/m}^3$. This yields a mountain with a mass of 156 billion tons, which is close to the largest CME mass in the table. So CMEs, though impressive in size, carry no more mass than a small hill on Earth!