Artist rendition of impact on Mars courtesy William Hartman (Planetary Science Institute)

A more useful earthquake severity scale is the Moment Magnitude scale represented by the logarithmic number Mw. Instead of giving the amount of ground displacement, it is directly related to the amount of seismic energy released by the earthquake. On this scale, Mw = 5.5 represents $E=2.0\times10^{17}$ Joules of energy released.

The InSight seismometer experiment (called SEIS) will be able to detect marsquakes with magnitudes from M=3.5 to 6. The relationship between E and M_W is given by the formula:

$$M_W = 2/3 \mathrm{Log} E - 6.0$$

Problem 1 - What is the seismic energy range for the InSight SEIS instrument in Joules? How many megatons of TNT does this range equal if 1 megaTon TNT = 4.2×10^{15} Joules?

Problem 2 – The energy, E, of an earthquake (or marsquake) can be estimated from the formula E = R x A x d where A is the area of the fault slippage, d is the amount of slippage by the fault and R is the rigidity of the crust. Typically, R = 3.3×10^{10} Newton/m^2 and A and d are given in square-meters and meters respectively and E is in Joules of energy. A) What is the energy of an earthquake for which the area is 2000 km^2 and the slippage was 2 meter? B) What is the Moment Magnitude for this event?

Problem 3 - Most of the marsquakes detected by InSight will be due to meteors of various masses impacting the surface of Mars. Each impact will deliver an amount of energy equal to its kinetic energy or E = ½ mV^2 where E is in Joules if v is in meters/sec and m is in kilograms. Typical impact speeds will be about 15 km/sec. What is the formula that relates the Moment Magnitude to the mass of the meteorite in kilograms? What is the range of InSight sensitivites in terms of the mass range of the meteors in metric tons?

Problem 1 - What is the seismic energy range for the InSIght SEIS instrument in Joules? How many megatons of TNT does this range equal if 1 megaTon TNT = 4.2x1015 Joules?

Answer: $3.5 < M_w < 6.0$ then solving for E in the above equation we get

$$E = 10^{(1.5M_w + 9.0)}$$

and so for $M_w = 3.5$ we have **$E = 1.8\times10^{14}$ Joules** and for $M_w=6.0$ we have **$E = 1.0\times10^{18}$ Joules**. This range of energy corresponds to **0.4 mTons < E < 238 mTons**.

Problem 2 – The energy, E, of an earthquake (or marsquake) can be estimated from the formula E = R x A x d where A is the area of the fault slippage, d is the amount of slippage by the fault and R is the rigidity of the crust. Typically, $R = 3.3\times10^{10}$ Newton/m^2 and A and d are given in square-meters and meters respectively and E is in Joules of energy. A) What is the energy of an earthquake for which the area is 2000 km^2 and the slippage was 2 meter? B) What is the Moment Magnitude for this event?

Answer: A) $E = 3.3\times10^{10} \times 2000 \times 2 =$ **1.3×10^{14} Joules**.
B) Mw = 2/3 logE – 6 so **Mw = 3.4**.

Problem 3 - Most of the marsquakes detected by InSight will be due to meteors of various masses impacting the surface of Mars. Each impact will deliver an amount of energy equal to its kinetic energy or $E = ½ mV^2$ where E is in Joules if v is in meters/sec and m is in kilograms. Typical impact speeds will be about 15 km/sec. What is the formula that relates the Moment Magnitude to the mass of the meteorite in kilograms? What is the range of InSight sensitivites in terms of the mass range of the meteors in metric tons?

Answer: For v = 15 km/sec we have $E = 1.125\times10^{8}$m. We have Mw = 2/3LogE – 6 and substituting for E we get Mw = 2/3 log(1.125×10^{8}m) – 6 ; and so the formula is

Mw = 2/3Log(mass) – 0.633.

For Mw = 3.5 we have $m = 1.58\times10^{6}$ kg or 1580 metric tons.
For Mw = 6.0 we have $m = 8.9\times10^{9}$ kg or 8.9 megatons.
So **1580 tons < m < 8.9 megatons** is the mass range.