

Event	Magnitude R	Tons of TNT
Hand grenade	0.2	0.00003
1 stick dynamite	1.2	0.0012
Chernobyl	3.9	9.5
2010 Quebec	5.0	480
2011 Washington	5.8	15,000
2010 Haiti	7.0	480,000
1906 San Francisco	8.0	15 million
1883 Krakatoa	8.8	200 million
1964 Anchorage	9.2	950 million
Chicxulub Impact	12.6	100 trillion

On Earth, the severity of an earthquake is measured by the amount of ground movement that it produces. The Richter Scale has been in use for many years and is an example of a logarithmic scale.

Logarithmic scales are linear scales in 'x' such as 1.0, 2.0, 3.0 etc, but they represent magnitude changes of 10, 100 and 1000 etc. Because natural phenomena span such a large range in energy, logarithmic scales are often used to represent them.

**Problem 1** – The common earthquake Richter Scale is a measure of how much ground movement a local earthquake produces. For example, an  $R=5.0$  earthquake produces 10 times more ground movement than an  $R=4.0$  earthquake. This scale is calibrated so that an  $R=0$  earthquake at a distance of 100 km produces a ground change of 1 micron ( $10^{-6}$  meters), which is measured by a seismometer. In 2011, the Washington DC area was struck by an  $R=6.0$  earthquake. About how much ground movement was produced in Washington DC, about 100 km from the epicenter?

**Problem 2** – One of the largest modern earthquakes occurred in Anchorage Alaska in 1964 and was measured as  $R=9.2$ . How much ground motion occurred 100 km from the epicenter of this quake?

**Problem 3** – The detonation of three tons of TNT produces an energy similar to an  $R=3.5$  earthquake. If the energy of an earthquake is proportional to  $10^{1.5R}$ , how many tons of TNT is the equivalent energy for the Krakatoa Explosion in 1883 which was recorded as  $R=8.8$ ?

**Problem 1** – The common earthquake Richter Scale is a measure of how much ground movement a local earthquake produces. An R=5.0 earthquake produces 10 times more ground movement than an R=4.0 earthquake. This scale is calibrated so that an R=0 earthquake at a distance of 100 km produces a vertical ground change of 1 micron ( $10^{-6}$  meters). In 2011, the Washington DC area was struck by an R=5.8 earthquake. About how much ground movement was produced near Washington DC, which was about 100 km from the epicenter?

Answer: 1 micron  $\times 10^{(5.8)} = 0.6$  meters.

**Problem 2** – One of the largest modern earthquakes occurred in Anchorage Alaska in 1964 and was measured as R=9.2. How much ground motion occurred 100 km from the epicenter of this quake?

Answer: 1 micron  $\times 10^{(9.2)} = 1.6$  kilometers.

Note: Actual vertical displacements were only about 11 meters in some locations.

**Problem 3** – The detonation of three tons of TNT produces an energy similar to an R=3.5 earthquake. If the energy of an earthquake is proportional to  $10^{1.5R}$ , how many tons of TNT is the equivalent energy for the Krakatoa Explosion in 1883 which was recorded as R=8.8?

Answer:  $8.8 - 3.5 = 5.3$  then  $E = 3 \text{ tons} \times 10^{1.5(5.3)} = 267$  megatons.