Radiation Dose and Distance

This iconic photo was taken at the Shibuya train station in Toyko on March 15, a few days after the Japan 2011 earthquake, which caused severe damage to the Fukushima Nuclear Plant in northern Japan located 250 km from Tokyo. The monitor indicates a reading of 0.6 microSeiverts per hour. The normal background dose rate is about 0.4 microSeiverts per hour.*(Courtesy Associated Press/Kyodo News)*

The devastating Japan 2011 earthquake damaged the nuclear reactors in Fukushima, which emitted clouds of radioactive gas and dust into the atmosphere. News reports indicated the radiation levels at many different locations and times through out the following week. Because radioactivity decays with time and distance, it is difficult to compare the many measurements to know if the dosages are declining as expected. The following table of measurements was collected from a variety of news reports:

Date	Distance (km)	Location	Dose Rate (microSeiverts/hr)
March 15	1 km	Fukushima #2 plant	8,200
March 15	20 km	Namai	330
March 16	30 km	Iwaki City	150
March 16	50 km	Koriyama City	2.7
March 16	70 km	Kitaibaraki City	1.2
March 16	160 km	Maebiashi City	4.0
March 15	250 km	Tokyo	0.9 maximum

Problem 1 - Graph the base-10 log of the radiation dose rate versus the base-10 log of distance from the Fukushima nuclear plant.

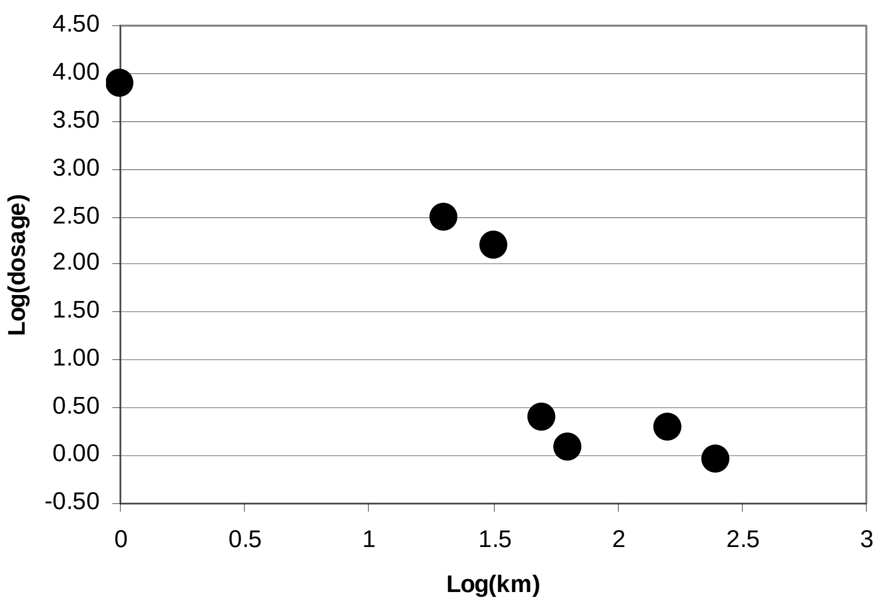
Problem 2 - On the Log-Log graph you just created, what is the approximate slope of the line that fits the data best? Show that an 'inverse-square law' has a slope of -2 on this graph.

Problem 3 - Using the graph, what would you predict for the dose rates near the city of Tamura, located 40 km from the nuclear reactors, and a position located at 10-kilometers, which is inside the limit to the evacuation zone?

Problem 1 - Graph the base-10 log of the radiation dose rate versus the base-10 log of distance from the Fukushima nuclear plant.

Distance	Dose Rate	Log(km)	Log(D)
1 km	8,200	0	3.9
20 km	330	1.3	2.5
30 km	150	1.5	2.2
50 km	2.7	1.7	0.4
70 km	1.2	1.8	0.08
160 km	4.0	2.2	0.3
250 km	0.9	2.4	-0.05

The graph of the Log(Dose Rate) and Log(distance) is as follows:



Problem 2 - On the Log-Log graph, what is the approximate slope of the line that fits the data best? Show that an 'inverse-square law' has a slope of -2 on this graph.
Answer: Using the first (0.0, 3.8) and last (2.4, -0.05) points, Slope = (-0.05 – 3.8)/(2.4 – 0.0), slope = -3.85/2.4); **Dose rate slope = -1.6**. An inverse square law is written as $y = x^{-2}$ Taking the log of both sides we get log(y) = -2 log(x). So the slope of an inverse-square law on a log-log graph would be exactly -2.0

Problem 3 – Using the graph, what would you predict for the radiation dose rates near the city of Tamura (d= 40 km), and a position located at 10-kilometers, which is inside the 20-kilometer limit to the evacuation zone?

Answer: Log(40km) = 1.6, so for x = 1.6, we can estimate from the graph that y = 1.4, and so Log(dosage) = +1.5 so that dosage = $10^{+1.5}$ = **32 microSeiverts/hour**. At a distance of 10-km, X = log(10) = 1.0 and so y = 2.0 and the dosage would be **1,000 microSeiverts/hour.**