

Name:

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PROBLEM I:

In the 2015 Nepal earthquake, many years of accumulated motion on the locked boundary fault between the Indian and Eurasia plates was released. If India moves north at 20 mm/yr and the fault moved 3 m in the earthquake, how many years should it be until the next such earthquake?

PROBLEM II: Using an earthquake catalog and Excel to estimate how often great earthquakes happen in Nepal

When doing science, it helps to build a toolbox that you can use to solve problems. In this class we'll introduce you to one such tool, Microsoft's Excel program, which can be used to quickly make plots and draw inferences from datasets. Many of the homeworks and labs in this class will ask you to work with Excel to solve various types of problems.

1. Introduction

How can we estimate how often large earthquakes occur in Nepal? One way to do this is to study the history of smaller earthquakes. In the 1940s, Beno Gutenberg and Charles F. Richter noticed that if you simply count the number of earthquakes that happen with a given magnitude M or larger, you end up with a logarithmic relationship,

$$\log N(M) = a - bM.$$

Getting the actual number of earthquakes that will occur then requires raising both sides as a power of ten,

$$\begin{aligned} 10^{\log N(M)} &= 10^{a-bM}, \\ N(M) &= 10^{a-bM}. \end{aligned}$$

If we knew what the values of a and b were, we would be able to plug in a magnitude and calculate the number of earthquakes to expect. For example, the global a value is about 8.2, while the b value is approximately 1. Therefore, for $M = 6$ we might expect

$$N(6) = 10^{8.2-1*6} \cong 160 \frac{\text{earthquakes}}{\text{year}}.$$

So we can see that worldwide, we might expect about 160 earthquakes per year that are a magnitude 6 or higher. If we plug in $M = 7$ or $M = 8$, we find about 16 magnitude M7+ earthquakes per year, and one or two M8+ earthquakes per year. So that's what we'll do in this lab. Using Excel, let's try to fit a line to data from an earthquake catalog to estimate the number of earthquakes to expect in Nepal.

2. Fitting a line to data using Excel

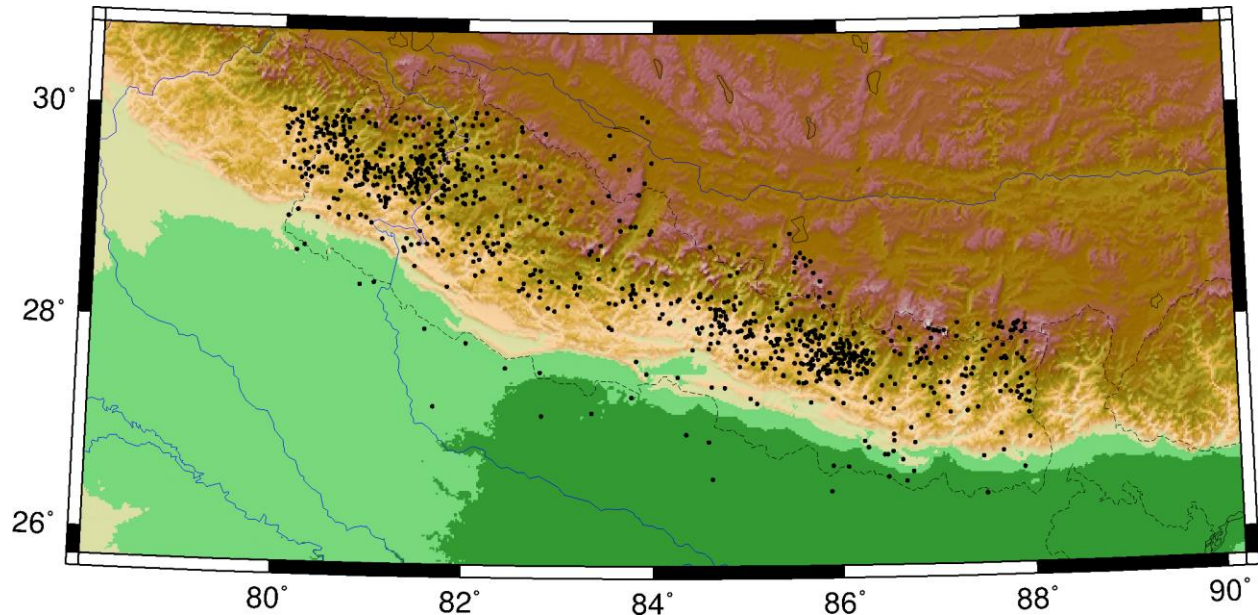


Figure 1. A map of Nepal with black dots showing the distribution of earthquakes since 1970.

For this portion of the lab, we have prepared a dataset for you to estimate the number of earthquakes to expect in Nepal. We have collected a catalog of earthquakes in Nepal that have occurred since 1970 (figure 1), with 905 earthquakes in total. After counting up the average number of earthquakes per year, the results are shown in the table below.

| M | N(M) |
|----------|-------------|
| 4.2 | 10.3 |
| 4.8 | 3.46 |
| 5.4 | 0.652 |
| 6.6 | 0.109 |
| 7.0 | 0.0435 |

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Open an Excel spreadsheet, and enter these values. Next, create a new column that contains the logarithm of the number of earthquakes. To insert an equation into an empty cell, click on the empty cell and then click on the f_x button. This will show a dialog as in figure 2. Find the LOG10 function, and then select the cell you want to take the logarithm. Next, use the Fill Down (Ctrl+D) command to automatically copy and paste the function into other cells.

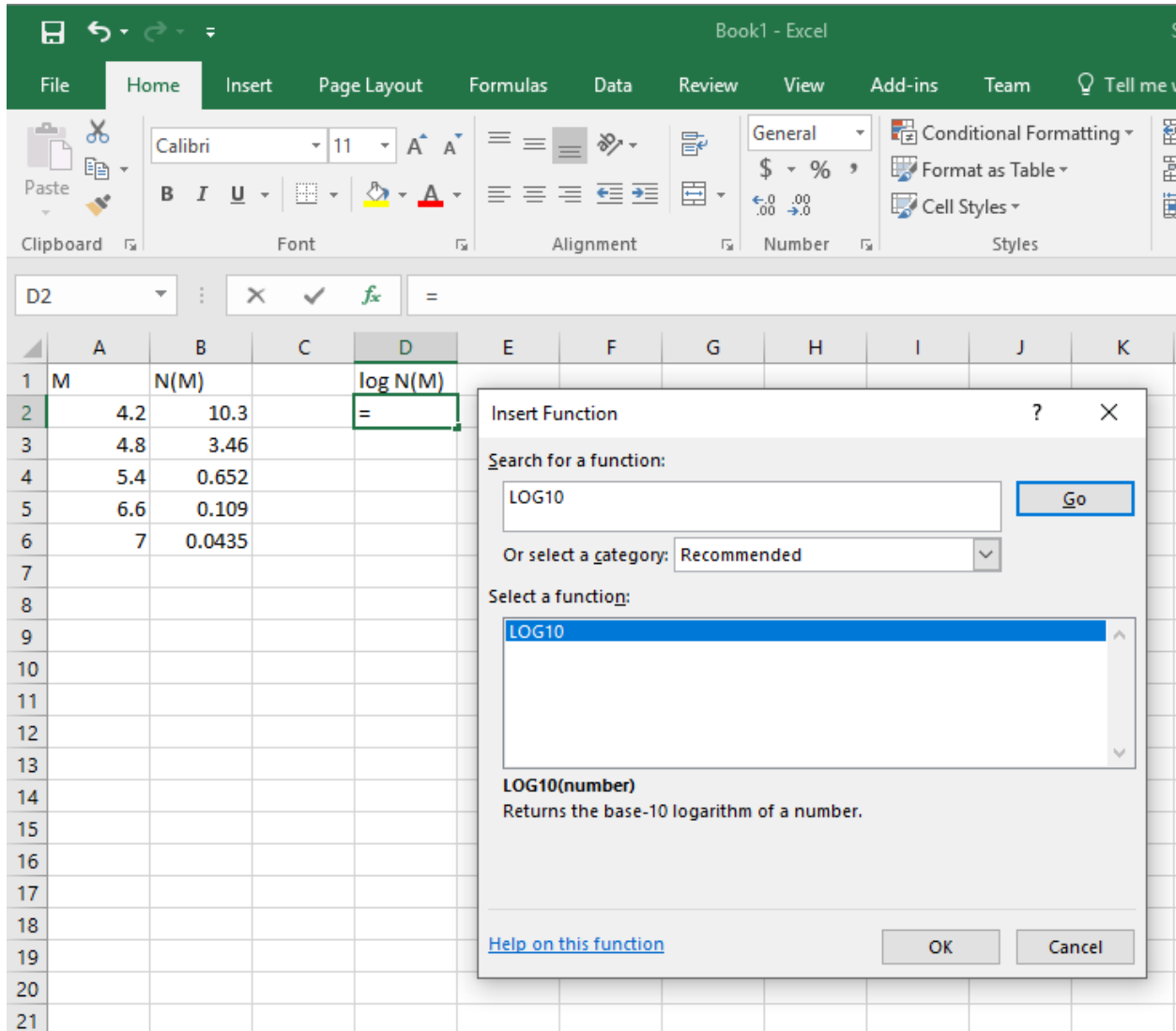


Figure 2. Taking the base-10 logarithm of a value.

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After creating a new column containing the logarithms of the number of earthquakes, let's try to create a scatter plot. The simplest way to do this is to select two columns side-by-side, and then inserting a scatter plot, as in figure 3, where we have pasted the earthquake magnitudes column next to our logarithms column.

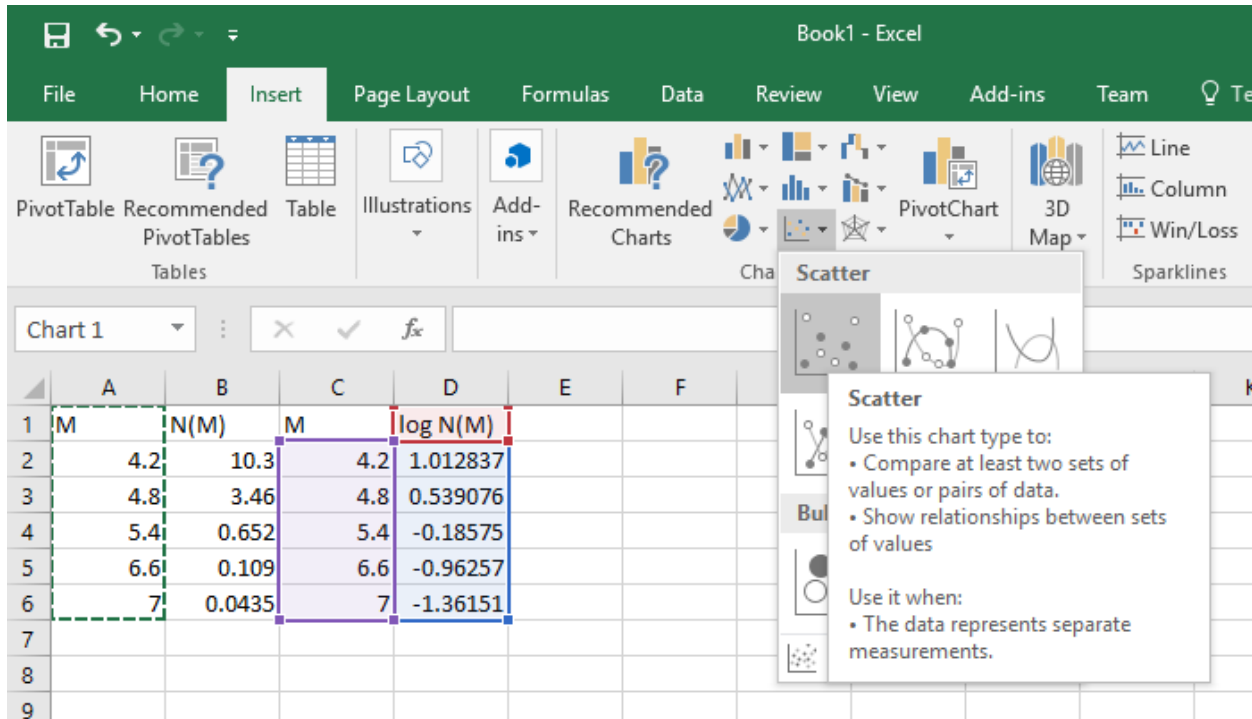


Figure 3. Selecting two columns to insert a plot.

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Next, we would like to fit a line to the data. Fortunately, Excel provides a relatively simple way to do this, shown in figure 4. After inserting the scatter plot, we can select the **Design** tab along the top, and then **Add Chart Element**, then **Trendline**, and finally **Linear**.

Another way to estimate a linear fit to the data would be to use the `LINEST` function, in a way similar to how we found the `LOG10` function.

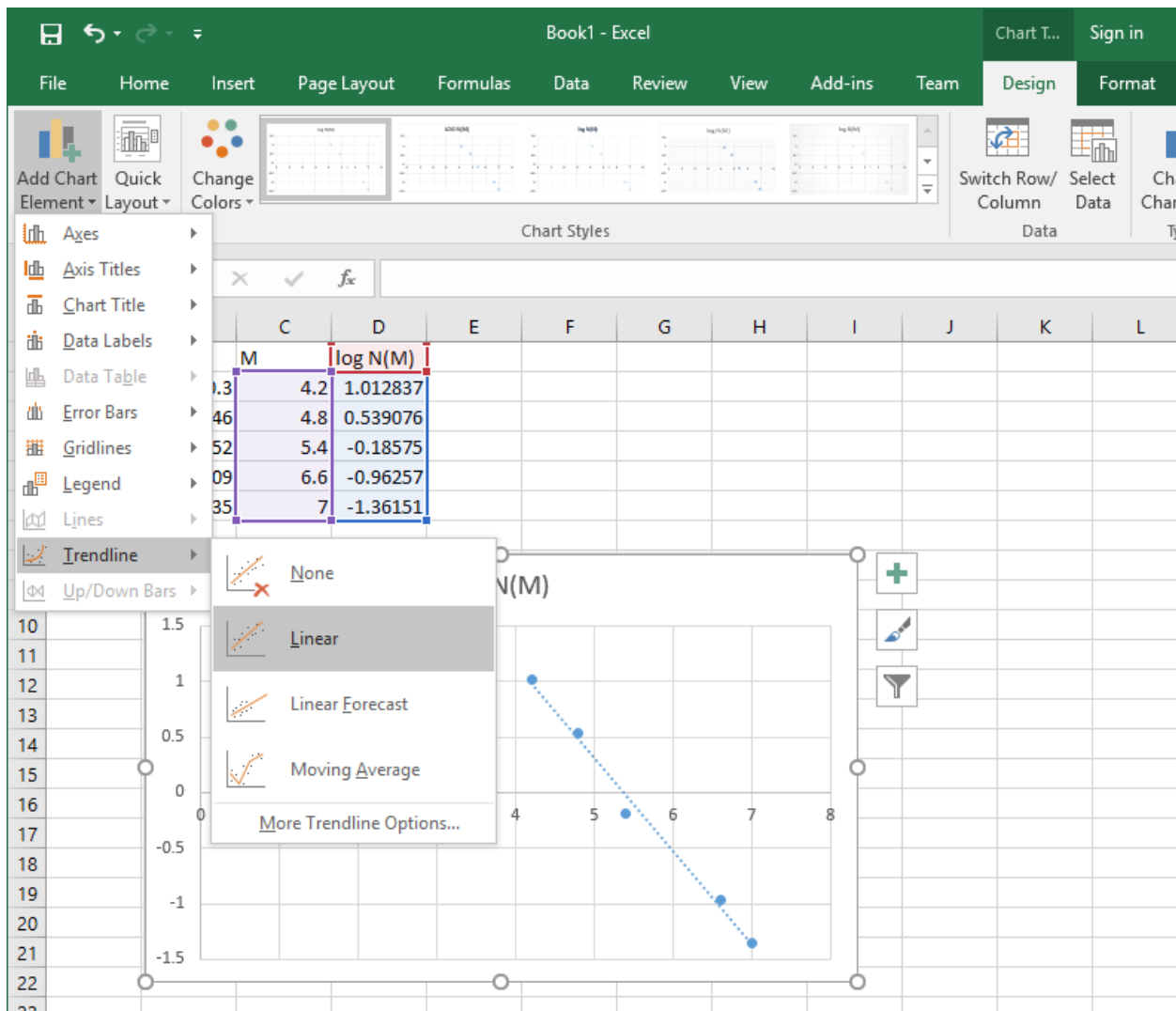


Figure 4. Adding a linear trendline to the scatter plot.

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After adding the trendline, we of course would like to know the values of a and b . To do so, we can click on the newly added trendline, which should result in a new sidebar on the right, shown in figure 5. Close to the bottom, there is an option to display the equation of the line, among other options.

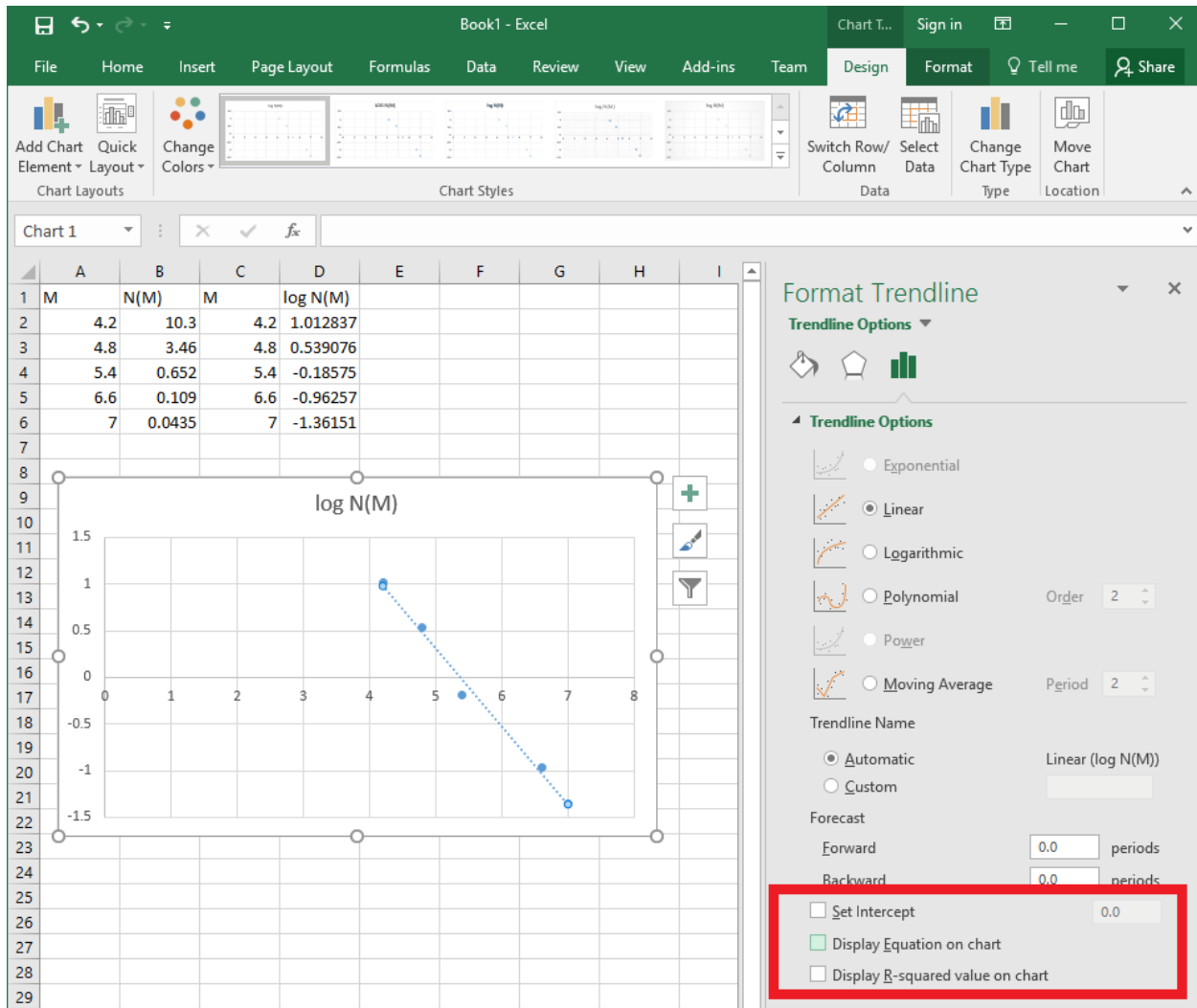


Figure 5. Red box shows the option to display the equation of the line on the plot.

What are your estimates for the a and b values of Nepal?

Using your estimated values for a and b , and using the equations given in the introduction, what is your estimate for how often earthquakes with a magnitude larger than 8 will occur in Nepal?