Name ____________________________ GSI Name ______________________________

EPS 20: Earthquakes

Laboratory Exercise 1

Intensity

Purpose: To investigate seismic intensity and how it is used to describe the effects of earthquakes

Background:
Several hundred years ago, before instruments for measuring earthquakes were developed, scientists observed that the amount of shaking felt by people and amount of damage to structures depended on their location. For big earthquakes in which the ground ruptured, the strongest shaking and the most damage were observed close to the rupture. In many smaller earthquakes, the ground did not rupture, but the strongest shaking and damage were still concentrated. Scientists developed a scale to quantify an earthquake's shaking by what was felt and by its effects on structures and the landscape. The most widely used scale is the *Modified Mercalli Intensity Scale* (MMI scale). It was originally introduced by the Italian seismologist Giuseppe Mercalli in 1902, and was modified and updated for “modern” building practices in 1931. It has twelve levels describing the strength of shaking.

There are two basic differences between the intensity of an earthquake and its magnitude. The magnitude of an earthquake is based on measurements from instruments, so it is objective. Intensity is a subjective measure. It is based on the observations and descriptions of people, those living in the area where the earthquake occurred and also the engineers or scientists estimating the damage to structures. The second difference is that an earthquake has only one magnitude, while its intensity will be different at the different locations. A single earthquake will usually generate a whole range of intensities. The values generally decrease as the distance from the epicenter increases.

MODIFIED MERCALLI INTENSITY SCALE OF 1931
(Abridged)

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, and doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken. Noticed by persons driving motorcars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed.

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

How do scientists use intensity? People report their observations and experience. For example, after the Loma Prieta earthquake in 1989, USGS scientists sent out hundreds of postcards to people in the Bay Area and asked where they were at the time of the earthquake and what they experienced. Nowadays, if you experience an earthquake, you can report it on-line on the USGS “Did you feel is?” webpage (http://pasadena.wr.usgs.gov/shake/ca/). From the reports and observations they collect, scientists estimate the intensity for each location, and plot it on a map. Then they draw contour lines to separate regions with different intensities. These lines are like the altitude lines on a topographic map: the intensity is higher on one side and lower on the other. The contours, called *isoseismal lines*, show how intensity varies as a function of location.

Even before seismometers were invented, scientists collected reports from earthquakes and determined the epicentral region from where the shaking and damage were greatest. In some cases, only one intensity is listed for an earthquake. Then it is the maximum value that was observed. For example, the recent San Simeon earthquake before Christmas 2003 had a maximum intensity of VIII. As you can see, the intensity is usually given in Roman numerals in order to avoid confusion with magnitudes.

Procedure: The Morgan Hill Earthquake of 1984

A. The intensity as a function of distance

The Morgan Hill earthquake, also called the Halls Valley earthquake, occurred on 24 April 1984 along the Calaveras fault 18 km east of San Jose and 22 km north of Morgan Hill. It had a magnitude of M_L=6.2 and a focal depth of 8 km. The earthquake was felt in California and Nevada over an area of 120,000 km^2 and caused damage estimated to be worth $7.5 million. After the earthquake, many cracks were found in the ground, but no unequivocal evidence of surface faulting was found. The aftershocks define an area that extends approximately 30 km southeast of the epicenter along the Calaveras fault. This is the section of the fault that has generally regarded as having ruptured at depth during the earthquake. The map (Figure 1) shows the locations of the epicenter of the main shock and some of its aftershocks.

A1. The table lists reports of the effects of the Morgan Hill earthquake from different places. It also lists: the direction from the center of the aftershock zone, the distance from the epicenter, and the distance to the closest part of the aftershock zone on the fault. Complete the table by assigning MMI intensities for all of the locations. You can assign intermediate intensities, like V-VI if you think that is appropriate. If the location is shown on the map (Figure 2), mark the intensity on the map.

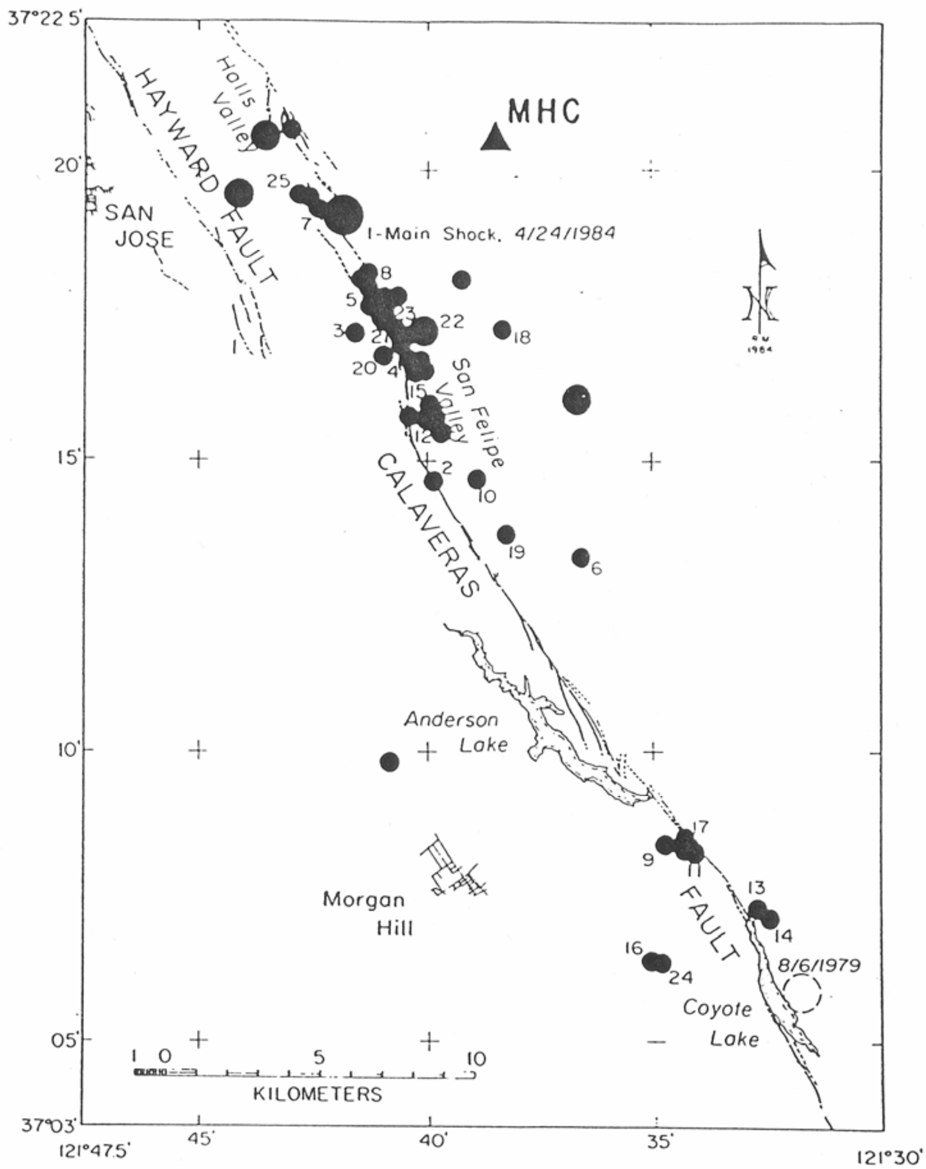

Figure 1

Epicenters of the mainshock of April 24, 1984, and principal aftershocks (M_L 3.0) through December 31, 1984, are plotted as circles. The numbering indicates the relative timing of the first 25 earthquakes in the sequence. The Coyote Lake 1979 mainshock is plotted as a large broken circle.

A2. On the semilog (log vs linear) graph paper (Figure 3), plot the intensity (vertical axis) as a function of the distance from the epicenter (horizontal axis). Then plot the intensity as a function of the distance from the fault segment which probably ruptured during the earthquake.

A3. Compare the two curves from part A2. Is it better to show intensity as a function of distance from the fault or as a function of distance from the epicenter? Why?

B. The Relationship between Intensity and Acceleration

When human beings feel movement, they seem to be more sensitive to acceleration than to velocity (speed) or displacement. The smallest movement we feel is about 1 cm/s^2. Damage to structures also seems to be closely related to acceleration, since it is proportional to force. Ordinary structures begin to suffer damage when the acceleration reaches about 100 cm/s^2. We will now try to relate the intensity to acceleration. In his book, Richter (famous from the Richter scale) gives an empirical formula:

$$\log_{10}(A) = (I / 3) - 0.5$$

where A is the acceleration in the units cm/s^2 and I is the MMI intensity. Empirical means that Richter took many earthquakes for which intensities were observed at locations where acceleration was measured. He plotted all the values and decided that all the points are best fit by the line described by the above equation.

B1. Use the empirical formula to predict accelerations from the intensities that were determined in part A1 (fill in the last column in the table).

B2. Plot the acceleration as a function of distance from the fault on a log-log plot (Figure 4).

B3. There were many recordings of acceleration from this earthquake. Some of the measurements are listed below. The table gives the location of the strong motion seismograph, the distance from the fault, and the average of the peak ground acceleration from the horizontal components. The acceleration is given in “g”, the acceleration due to force of gravity (g=981 cm/s^2 so you will need to multiply the numbers in the table by 981 before plotting them). Plot the measured accelerations on the graph using a different symbol.

Location	**Distance from fault**	**Acceleration (g)**
Anderson Dam	3.8 km	0.355
Coyote Dam	3.2 km	1.095
Gilroy	12.0 km	0.290
Halls Valley	3.2 km	0.220
Hayward	45.6 km	0.015
Hollister	32.1 km	0.090
Livermomre	31.0 km	0.019
Salinas	50.0 km	0.035
San Jose	16.0 km	0.060
San Jose	12.0 km	0.103
Watsonville	29.5 km	0.085

B4. How good is the empirical relation converting intensity to acceleration? i.e. is there good agreement between the two sets of accelerations?

C. Summary

Having completed the graphs and the questions about them, answer the following questions.

C1. Do intensity observations contain useful information about the shaking of the ground during an earthquake or is it too subjective?

C2. When we want to study how the shaking of an earthquake decreases as distance from the event increases, is it better to use the distance from the epicenter or the distance to the closest point on the fault that ruptured during the earthquake?

C3. Comparing the acceleration to the intensity, do you think there is a relationship between the acceleration of the ground during an earthquake and the damage? Explain your answer.

A1. Table of felt reports and map of epicentral area and
B1. Calculated accelerations

Location	Direction	Distance to Epicenter	Distance to Fault	Report	MMI Intensity	Acceler-ation
Antioch	N	72 km	72 km	Felt by several; frightened a few; hanging objects swung slightly.		
Berkeley	NW	70 km	70 km	Felt by many and frightened some; small objects moved but did not overturn; hanging pictures swung out of place.		
Coyote	SE	32 km	8 km	Felt by all; some windows broken out; light and heavy furniture was overturned; many objects thrown from store shelves; chimneys fell.		
Gilroy	SE	36 km	12 km	Many items thrown from store shelves; hairline cracks in walls; one chimney fell.		
Hollister	S	58 km	32 km	Plate glass window jumped from the frame and shattered; several windows broken out; many dishes broken; light furniture overturned; few items thrown from shelves; hairline cracks in walls.		
Jackson Oaks subdivision	S	18 km	2 km	At least four houses knocked off foundations; walls shifted; many chimneys down; pictures fell off walls; refrigerator toppled and furniture broke.		
Los Angeles	S	530 km	500 km	Not felt.		
Morgan Hill	S	22 km	6 km	Felt by all; light damage to 47 homes; a few chimneys fell; mobile homes fell off supports; many items thrown from store shelves.		
Sacramento	N	145 km	145 km	Felt by a few; slight swaying of curtains on the 16th floor of downtown building.		
Salinas	S	75 km	49 km	Hanging pictures fell; windows cracked; light and heavy furniture overturned.		
San Jose	NE	18 km	18 km	Cracks in some walls and plaster fell; no glass broken; dishes broken; many items thrown from store shelves; pictures fell; some chimneys cracked.		
San Martin	S	27 km	6 km	Felt by all; many cans of paint fell from shelves; many dishes broken; heavy furniture overturned; many items thrown from store shelves; some chimneys fell; cracks in walls.		

A1. Map of Epicentral Area: Plot intensities from the table:

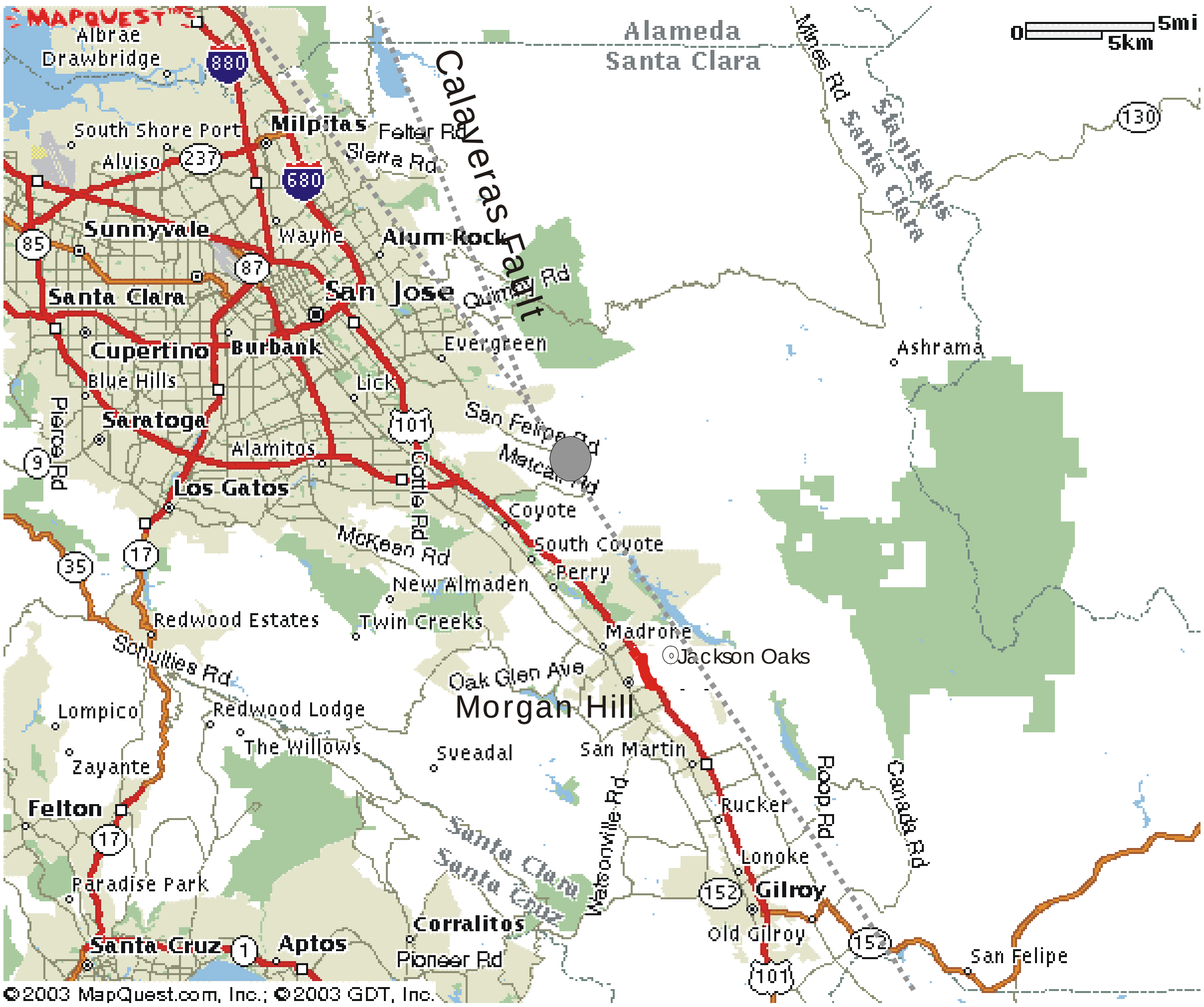

Figure 2

A2. Plot of intensity versus distance

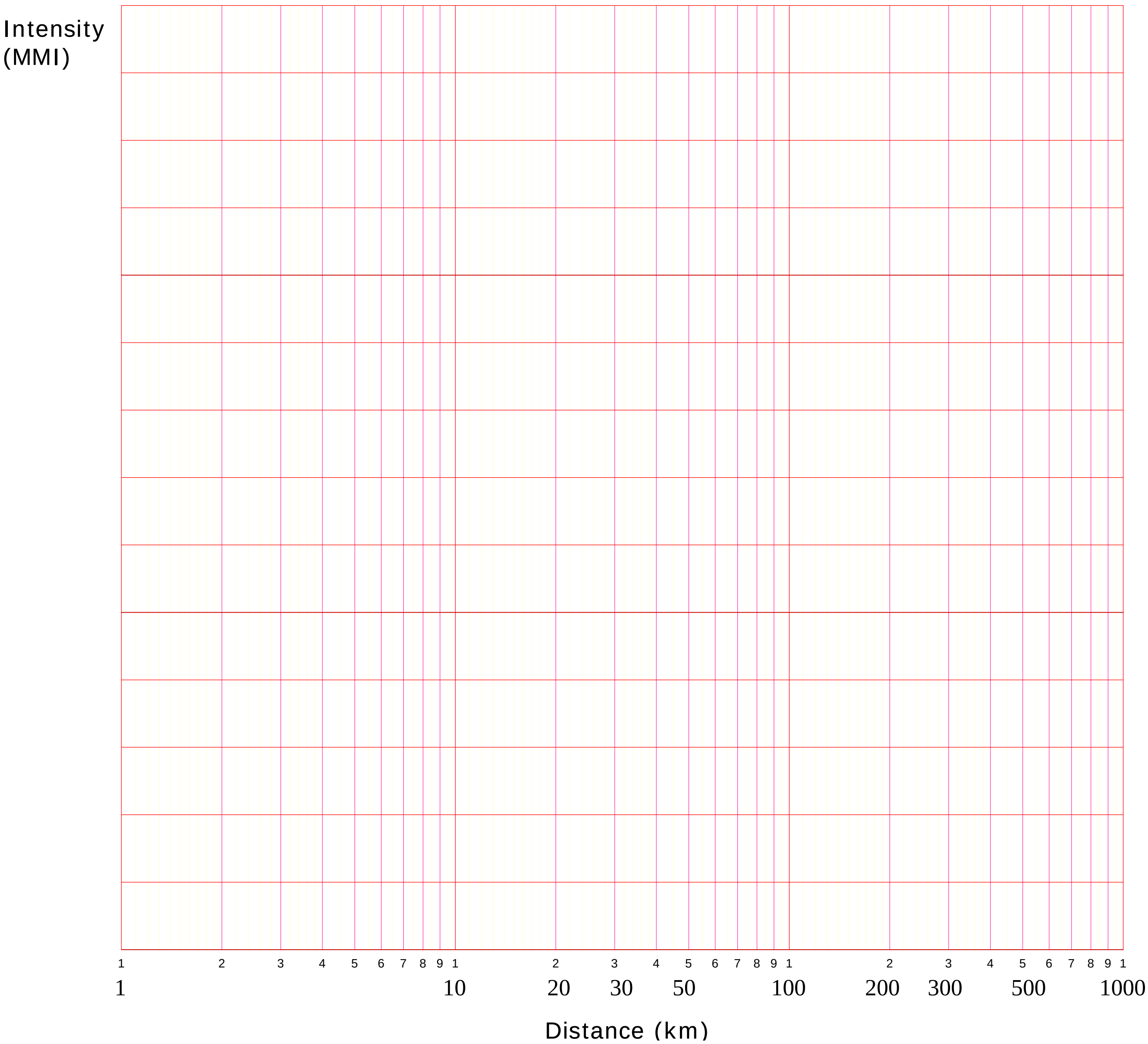

Figure 3

B2. Plot of calculated acceleration versus distance
B3. Plot of measured acceleration versus distance

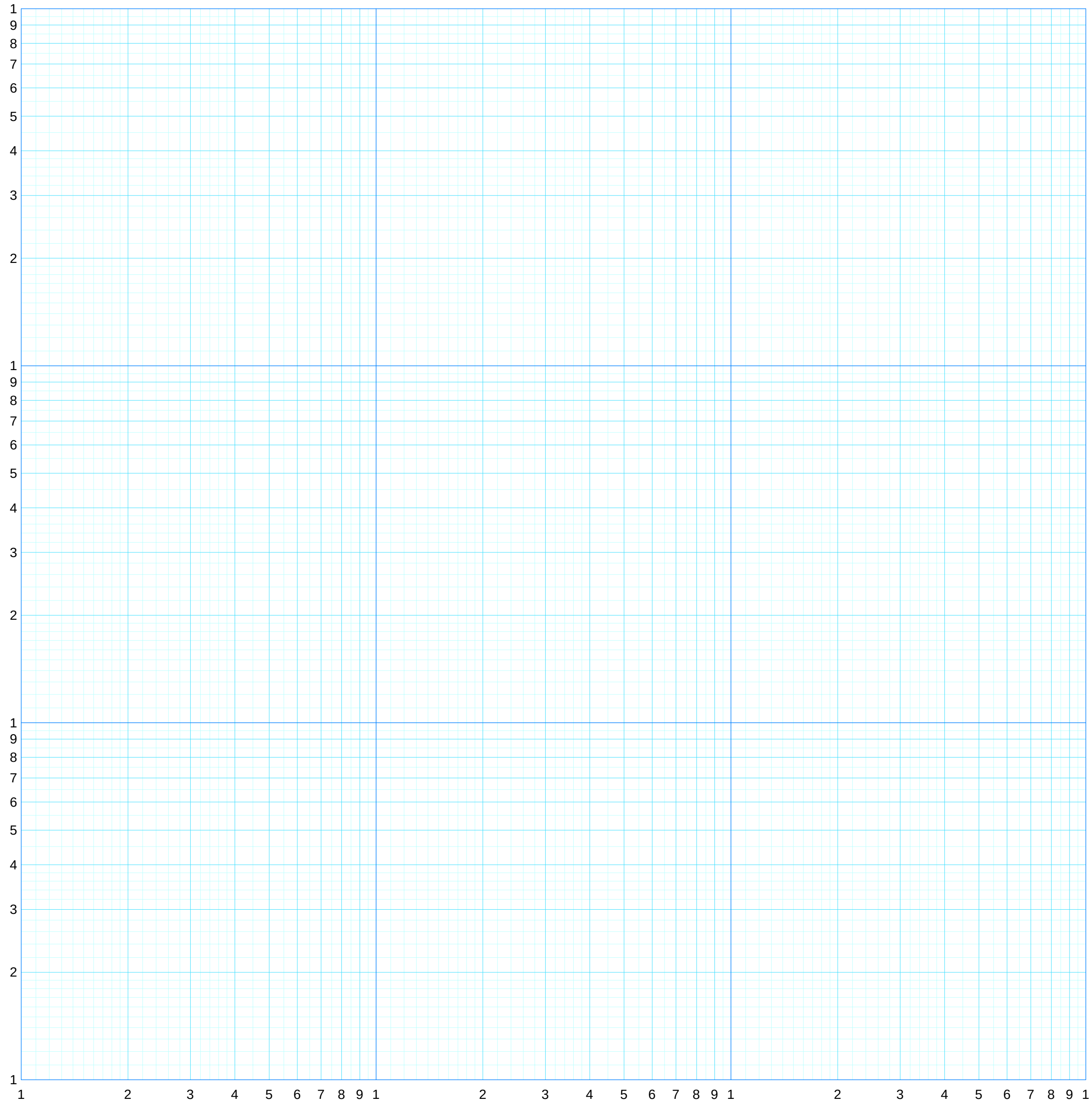

Figure 4