

Suggestion Sheet

Lab 1: Introduction to Science and the Scientific Method

Each Lab 1 box contains enough materials for FOUR groups:

- 4 graduated plastic cylinders (p. 2)
- 4 samples each of basalt, andesite and peridotite (p. 2, 7)
- 4 red and 4 green plastic cubes (p. 3)
- 4 bottles of tap water (A), 4 bottles of salt water (B) (p. 4)
- 4 wood blocks (p. 8)
- 4 rulers (p. 8)
- 4 plastic beakers (p. 8)

Also available:

- 1 scale per room
- Take 4 big post-its from 2109 (p. 1)
- Optional: pyrite (p. 7)

Before class:

- Print and copy post-lab assessment and syllabus
- Print and copy student version of the lab (1st week only)
- Fill out four big post-it notes with the titles from the gallery walk (p. 1) and place around room
- Collect pre-labs as students walk into class

Suggestions

- Introduce yourself, and have students introduce themselves – give your own reasons for studying geology
- Let students know what to expect about the assessment at the end of lab
- “What did you think of the two articles?”
- “What are some of the reasons someone might choose a career in the geosciences? Why might they not?”
- Explain transition between activities when possible; for example -
 - “We’re going to start by talking about some of the things that are studied by earth scientists, etc.” (Introduction → Gallery walk, p. 1)
 - “Now that you know what this course is about, let’s see what you remember from your past math and science courses.” (Gallery walk → Systems of measurement, p. 2)
- Hand out supplies right before they need them to keep groups together
- Alternate between asking questions to the class and individual groups
- Make a point to talk to EVERY student

Brainstorming activities/Gallery walk, p. 1

- This is the first exercise. The intent is to get student involved with each other and moving around immediately. Have fun with it, and improv, but don’t spend too much time since there’s lot to do.
- Everything before Part I is to help them with the pre-lab, and later reference.

Rock measurements and working hypothesis, p. 3-5

- Draw a chart on the board showing the rock densities from all four groups
- “Is there a lot of variation?” “Why do you think there is variation?” “Should we expect every rock to be the same? Can you explain why?”
- Tell students they’ll be seeing these rocks again in 2 weeks.
- “Enter the following into the ‘Data’ sheet” contains a hint for one of the potential answers to 1.3
- Show of hands for question at the bottom of p. 4 – have volunteers explain their answers. If there are multiple answers, have students try to convince each other – guide the discussion, but don’t give them the correct answer!
- “Read the definition of a hypothesis on p. 5. Can anyone give me an example of a hypothesis?” “What kind of observations would support/refute that hypothesis?”, “Can someone else give a prediction for this hypothesis?”
 - Get everyone talking – you are setting the tone for the semester
 - Visit each table individually and have them explain to you their answers on p. 5. Make sure they are being precise.

Wood as an analogy for Earth’s crust, p. 6-8

- Now the volume of an object can be measured as $L*W*H$
- Class vote on wood block being more/less than 0.5 g/cm^3 . Ask volunteer(s) to explain their answer.

Plate Tectonics Started Over 4 Billion years ago, geochemists report, p. 8-9

- Redirect groups as necessary, but do **not** give the correct answer
- “Why did you choose A?”, “Why doesn’t answer D make sense?”, “What else do you know about Earth’s formation?”, “How many zeroes are in a billion?”, etc.

Density and elevations of ocean floor and continents, p. 10-11

- Question class: “What is density?”
- Regular vs. lead bricks – ask students to compare
- Ask them individually to explain why their values are different from the 4.84 km estimate given. Push them to give at least two reasons (density, thickness – from thickness above/below formulas).

Experimental modeling of Earth’s layers, p. 11-12

- Circulate throughout the room to be sure students come up with something similar to this. They may need to revisit their hypothesis and methods.
- Have 2-3 student volunteers draw their sketches on the board – ask the class to explain what is good about each one - focus on the positive, but make sure that students leave with the right idea.
- Also, to help them draw cross-sections in future labs: Encourage them to draw the continental and oceanic crust as one plate. When we introduce trenches and subduction, then they can deviate from this.

Optional, before students start/get too far on pp. 10-11:

- Challenge: Ask each table to come up with a guess of what the highest and lowest points on earth are, and their elevations. List these on the board and see who's the closest. (Mt. Everest, 8,850m / 29,035ft; the Challenger Deep in the Mariana Trench, -11,000m / -36,000ft – each lab has a globe if you want to point these out)
- If Earth were the size of a basketball, it would be hard to find the bump or fold that represented either – would be less than the thickness of a piece of paper
- “We will talk more about these high and low points next week in our Plate Tectonics lab and explain why they are the way they are.”
- “Has anyone ever seen the Earth's mantle or core?”
- Have 2-3 student volunteers draw their sketches from question 12 on the board – ask class to explain what is good about each one - focus on the positive, but make sure that students leave with the right idea

Optional, if a group is getting very far ahead:

- Conspiratorially show students a piece of pyrite. Tell them you have a larger cube that weighs roughly 40 grams and measures 2 cm on each side. Offer to sell it to them as real gold for \$600. Try to convince them you're giving them a deal. If this works, split the profits with Katherine. (Note: Gold has a density of approximately 19.2 gm/cm³ and is worth about \$32/gram, assuming a price of ~\$1000/troy ounce.) If they're doubtful (which they should be!), ask them how they could use a density calculation to make an informed decision.

Name (print and sign): _____

Lab 1: Introduction to Physical Geology and the Scientific Method

Pre-lab Activity (5 pts). Due at the beginning of lab

Read through the lab worksheets and then answer the following questions.

1. Conduct the following unit conversions that have not been completed for you.

Part	Question	Answer
A	Lack of oxygen prevents permanent human habitation above 5400 meters. How high is that in feet?	
B	The volcano Olympus Mons rises 16.7 miles above the mean surface level of Mars. What is its elevation in meters and kilometers?	26,875 meters; 26.87 km
C	Particles that are 0.05-2 millimeters in diameter are called sand. What is the diameter of these grains in centimeters and inches? (Give the range.)	
D	North Carolina moves at approximately 2 centimeters west each year. How far will it have traveled in meters and feet in a century?	
E	The Amazon river dumps 200,000 cubic meters of water into the Atlantic Ocean every second. How much is that in gallons?	

2. We will be using computer spreadsheet programs in some labs. It is not necessary for you to have prior experience with these programs since we will learn the basics of it during this lab. For now, see the lab worksheets to learn how to construct a function.

In the screenshot of a spreadsheet program below, write values in the appropriate cells. Conduct the same unit conversion for Part A in the question above. Write the function where it is indicated.

Spreadsheet Program				
Function in D2				
	A	B	C	D
1	original value	original unit	converted unit	converted value
2				

Write the function in cell address notation in this box.

On a computer the function is typed here, and the output (the answer) is shown.

Write the output here.

3. The state of equilibrium of an object that determines how much of it floats above a fluid: _____

Hint: this is not density.

This state is determined by the object's: _____ and _____

Hint: neither of these is "mass".

Name (print and sign): _____



Large variations in the elevations of Earth's surface—above and below oceans—have motivated research upon what controls topography. Shown above, Grytøya Island, which is off the coast of northern Norway, exemplifies landscapes with such high relief (range in elevation over a given distance).

Introduction

Density is an important concept in explaining why Earth is divided into compositional layers, why magma rises to the surface, and how tectonic plates interact to give us oceans and continents. The knowledge you gain in today's lab serves as the foundation for the rest of the course. In this lab, we will use the scientific method to explore the role that density has upon shaping our world.

Objectives

When you have completed this lab, you should be able to...

1. Define *density*.
2. Measure density for a small object.
3. Explain how to test a hypothesis.
4. Predict how density would change if the physical properties of materials change.
5. Discuss how density differs between rocks of oceanic crust and continental crust and the implications for the elevations of the ocean floor and continents.

Materials

Rock samples of andesite, basalt, and peridotite; wood blocks; ruler, scale, calculator

Brainstorming activities/Gallery walk

Review the following list in your groups and post your responses on the big post-it notes:

A volcanic eruption - A glacier - A river in flood - A cave system - An underground mine - A canyon - An earthquake - An erosional coastline (rocky cliffs) - A depositional coastline (beaches) - A hot desert - The continental divide - Rock layers with fossils - A big, assembled, dinosaur skeleton - A meteorite crater - A mountain range over 10,000 feet in elevation

- Which Earth science phenomena have you experienced?
- Which would you most like to experience?
- Think of three more natural phenomena related to Earth to add to the list.
- What three questions about Earth would you like to be able to answer by the end of this course?

Systems of measurement

Many everyday units may have to be converted into their SI (International System of Units) equivalents.

1 kilometer = 1,000 meters	1 kilometer = 0.6214 miles
1 meter = 100 centimeters	1 meter = 3.28 feet
1 centimeter = 10 millimeters	1 centimeter = 0.394 inches
1 square kilometer = 0.3861 square miles	1 mile = 1.609 kilometers
1 square mile = 2.59 square kilometers	1 kilometer per second = 2237 miles per hour
1 meter per second = 2.237 miles per hour	1 metric ton = 2204.6 lbs
1 liter = 1000 milliliters	1 milliliter = 1 cubic centimeter
1 kilogram = 1000 grams	1 kilogram = 2.2 pounds
1 ounce = 28.35 grams	1 pound = 454 grams
1 gallon = 3.78 liters	1 cubic meter = 1000 liters

Example

The distance from North America to Europe is approximately 3944 kilometers [km]. How far is this in miles?

We need to determine how many miles are equal to 3944 km. We can set up a conversion ratio of km to miles (see the table above). Then we multiply the original value by the ratio in order to determine a converted value with the desired units.

$$\begin{array}{ccccc} \text{Original value} & & \text{Conversion ratio} & & \text{Converted value} \\ 3944 \text{ km} & = & \frac{0.6214 \text{ miles}}{1 \text{ km}} & = & 2451 \text{ miles} \end{array}$$

Spreadsheet Explanation

We are going to examine how density plays a role in the dynamics of Earth's crust. We will do so with models of floating wood and Earth's crust. These models are in spreadsheet, so first we need to learn the basics of this program.

We have several calculations to do, but we will create functions to automate this process. Here's an example of a spreadsheet function for the unit conversion example above:

$$= 3944 * (0.6214/1)$$

Some things to notice:

- Spreadsheet functions begin with an equal sign (=)
- Units, such as km or grams, are not included
- Note the mathematical operators: add [+], minus [-], multiply [*], and divide [/]. Parentheses are used to indicate the order of operations.
- The function as it is written above doesn't save us any time. Each time we have different values to convert, we have to rewrite the function. Computer spreadsheet programs provide a solution.

Imagine a scientist who wishes to automate the above unit conversion. The diagram below shows a snapshot of a spreadsheet. Columns are labeled 'A' to 'E' and rows are labeled '1' to '3'. Values, functions, and text can be stored in "cells."

Spreadsheet Program					- □ x
	A	B	C	D	E
1	original value	original unit	converted unit	converted value	
2	3944	0.6214	1	2451	
3					

The scientist has entered text into Row 1, and has entered the values needed to do the unit conversion into cells A2, B2, and C2. She entered a function into cell D1, and the program automatically determined the answer. However, she did not type " $= 3944 * (0.6214/1)$ " into this cell. Instead, she typed the cell addresses. The function she wrote in cell address notation was:

$$= A2 * (B2/C2)$$

When she needs to conduct additional conversions, she can type the values into cells A3, B3, and C3. Now she can copy the function in D2 and place it in D3, so she does not need to set up the mathematical operation again. This can be repeated hundreds of times in seconds.

Part I: Rock Measurements and Working Hypothesis

We will begin with predictions and then we will collect data that is needed to answer questions later in lab.

- 1.1. Without making any measurements, **predict** which of the following igneous rocks has the greatest density. (Circle your choice)

Andesite *Basalt* *Peridotite*

- 1.2. **Predict** which of the igneous rocks "floats" the highest in a fluid. (Circle your choice)

Andesite *Basalt* *Peridotite*

With the provided computers:

- Go to the course's Moodle page, go to the link "Lab 1 In-lab Files", and download the "Lab 1 Spreadsheet"
 - Enter the following into the "Data" sheet:
 - Mass and volume of the provided rocks. Measure 3 samples of each rock type to account for mineral proportion variations amongst samples.
 - Construct functions to calculate the density of each sample.
 - Construct functions to average the density for each rock type.
- 1.3. How much variation was there between groups in your section? How does your group's calculation compare to the average densities of all sections? Why do you think they might be different? Assume "human error" is not a factor. (2 pts)

Density Demonstration and Scientific Method Exercise

Take a red plastic cube; hold it in your hand.

The **mass** of the cube = 1 gram (1 gm)

The **volume** of the cube = 1 cubic centimeter (1 cm³)

1.4 What is the density of the cube? (1 gram per cubic centimeter, 1 gm/cm³)

- a) What is the **mass** of 2 cubes?
- b) What is the **volume** of 2 cubes?
- c) What is the **density** of the two cubes?

1.5 Describe how you would calculate the density of water given a scale, an empty plastic bottle of known volume, and access to a faucet. (1 pt)

1.6 Bottle A contains water with a density of 0.9965 gm/cm³

What will happen if we drop one of the red cubes into the water bottle?

Think about it and discuss what will happen with your group members. Choose an answer below BEFORE adding the cube to the water bottle. (Don't worry, this question isn't being graded.)

- a) The cube will float at the top of the water
- b) The cube will sink to the bottom of the bottle
- c) The cube will float about half-way down the bottle
- d) The cube will float a few centimeters below the water surface

To “do science”, we need **observations**, a testable **hypothesis**, and one or more **predictions** based on the hypothesis.

- **Hypothesis** – a testable explanation that can be verified or falsified
- **Observations** – facts, measurements, information, **data** collected using the senses
- **Prediction** – a statement of what will happen in a given situation or set of circumstances

Two observations:

- What happens when a red cube is added to bottle A?

- What happens when a green cube is added to bottle B?

1.7 Suggest at least two **hypotheses** to explain these observations. (1 pt)

1.8 Describe experiments to **test** of your hypotheses. (1 pt)

1.9 **Predict** what you think would happen if you were to conduct the tests. (1 pt)

Part II: Wood as an analogy for Earth's crust

2.1. Take a wood block (this is beech wood). Use the tools at hand to calculate its density. Show your calculations below. (1 pts)

2.2. Place the wood block in a beaker of water. (Note: the block will not float evenly in the water.) Approximately, what proportion of the block lies above/below the water's surface? (1 pts)

Approximate proportion of block above water = _____ %

Approximate proportion of block below water = _____ %

Different types of wood have different densities. For example, the density of pine (0.5 g/cm^3) is less than ebony (0.9 g/cm^3) but more than balsa wood (0.14 g/cm^3). All would float in water but with different proportions of each block lying above and below the surface. A block of wood with a density that is half of that of water would float with half of its volume above the water's surface and half below the surface.

2.3. On the basis of your observations: Is the density of your wood block more or less than 0.5 gm/cm^3 ? (1 pt)

a) more

b) less

How much of a wood block lies above or below the water is determined by isostasy, which is the state of equilibrium in which objects float at levels determined by their thickness and density. Larger blocks of wood will rise higher above the water but also extend farther below the surface. More dense blocks will float lower in the water than less dense blocks of similar size. (Assume the density of water = 1 gm/cm^3).

We can use the equations below to calculate the thickness of the wood block found below and above the water's surface.

$$\text{Thickness}_{\text{below}} = \text{Total Thickness} \times (D_{\text{wood}} / D_{\text{water}}) \quad (\text{Eq 1})$$

$$\text{Thickness}_{\text{above}} = \text{Total thickness} - \{ \text{Total Thickness} \times (D_{\text{wood}} / D_{\text{water}}) \} \quad (\text{Eq 2})$$

where D is density.

For example we can determine the thickness below the water line for a pine block that is 5 cm in thickness with a density of 0.5 gm/cm^3 .

$$\text{Thickness}_{\text{below}} = 5 \text{ cm} \times (0.5/1.0) = 2.5 \text{ centimeters}$$

- 2.4. Assuming a density of 0.65 gm/cm^3 for the block of beech wood you analyzed. Determine the average thickness of the block that should lie below the water's surface (T_{below}). (2 pts)
- 2.5. In the space below, divide your determined $\text{Thickness}_{\text{below}}$ value with the total thickness of the block and multiply by 100 to determine the percentage of the block that should be below the surface. How does your calculated T_{below} compare with your estimated value? Show your work. (2 pts)

We will now model the isostatic response of beech and ebony wood in water. We will use the density and thickness you calculated for beech wood. Assume that the block of ebony wood is the same size, but its density is 0.90 g/cm^3 .

Isostasy Model procedures

- Return to the spreadsheet program on the computer. Open the "Isostasy_Model" tab.
 - Set M1 to "beech wood", M2 to "ebony wood", and M3 to water.
 - Enter in thicknesses of wood blocks in millimeters (mm).
 - Determine the average thickness of the block that should lie above the water's surface. Do this by constructing functions, based upon Equation 2 above, for the two woods in the "Thickness above M3 surface column". Entering a function now, instead of just the values, is necessary for later steps in the lab.
- 2.6. Sketch the Isostasy Model that was produced with your data. Label accordingly. (2 pts)

2.7. Now lets explore isostatic rebound of wood. We will change one variable at a time to do so.

- Change M1, M2, and M3 to “Manual entry”.
- Enter the thicknesses and densities into the model and sketch the results. (2 pts)

Trial	Thickness	Density	Sketch and label results
A	beech = 10 cm ebony = 20 cm	beech = 0.5 g/cm ³ ebony = 0.5 g/cm ³ water = 1 g/cm ³	water surface
B	beech = 10 cm ebony = 10 cm	beech = 0.5 g/cm ³ ebony = 0.9 g/cm ³ water = 1 g/cm ³	water surface

2.8. Describe the influence that thickness and density have upon isostatic equilibrium. (2 pts)

Part III: Plate Tectonics Started Over 4 Billion years ago, geochemists report¹

Read the article below and answer the related questions that follow. Consider the difference between observations, hypotheses, and predictions. (3 pts)

A new picture of the early Earth is emerging, including the surprising finding that plate tectonics may have started more than 4 billion years ago - much earlier than scientists had believed, according to new research by UCLA geochemists reported in the journal Nature. "We are proposing that there was plate-tectonic activity in the first 500 million years of Earth's history," said geochemistry professor Mark Harrison, co-author of the Nature paper. "We're revealing a new picture of what the early Earth might have looked like," said lead author Michelle Hopkins, a UCLA graduate student in Earth and space sciences. "In high school, we are taught to see the Earth as a red, hellish, molten-lava Earth. Now we're seeing a new picture, more like today, with continents, water, blue sky, ocean, much earlier than we thought." The Earth is 4.5 billion years old. Some scientists think plate tectonics - the geological phenomenon involving the movement of huge crustal plates that make up the Earth's surface over the planet's molten interior - started 3.5 billion years ago, others that it began even more recently than that.

The research by Harrison, Hopkins and Craig Manning, is based on their analysis of ancient mineral grains known as zircons found inside once molten rocks from Western Australia. Hopkins analyzed the zircons with a microprobe instrument that enables scientists to date and learn the exact composition of samples. The analysis determined that some of the zircons were

more than 4 billion years old. They were also found to have been formed in a region with heat flow far lower than the global average at that time.

Evidence for water on Earth during the planet's first 500 million years is now overwhelming, according to Harrison. "The inclusions we found tell us the zircons grew in water-saturated magmas. We now observe a surprisingly low geothermal gradient, a low rate at which temperature increases in the Earth. The chemistry of the inclusions in the zircons is characteristic of the two kinds of magmas today that we see at plate-tectonic boundaries." There is only one place where you have heat flow that low in which magmas are forming: convergent plate-tectonic boundaries."

"You can't make a magma at any lower temperature than what we're seeing in these zircons. You look at artists' conceptions of the early Earth, with flying objects from outer space making large craters; that should make zircons hundreds of degrees hotter than the ones we see. The only way you can make zircons at the low temperature we see is if the melt is water-saturated. There had to be abundant water. That's a big surprise because our longstanding conception of the early Earth is that it was dry."

¹Press release from The University of California at Los Angeles

Questions

3.1. What was the key **hypothesis** from the article?

- a) Scientists can use a microprobe to prove that Earth is older than was originally thought.
- b) Magma is produced by plate tectonic processes that are associated with water.
- c) Zircon is formed in magmas and can be analyzed to determine the age of Australia.
- d) Plate tectonics has been going on for half-a-billion years longer than previously thought.

3.2. What was an **observation** used to develop the hypothesis?

- a) Zircon was found in rocks that used to be magmas
- b) Zircons were shown to have formed in a region with low heat flow.
- c) The geochemistry of ancient magmas was analyzed to show they formed in oceans.
- d) There was water on the early Earth.

3.3. What was an example of a **prediction** that could have been tested to prove the hypothesis?

- a) The chemistry of the zircons should be similar to that found at present-day convergent plate boundaries.
- b) The zircons should contain water.
- c) Zircons in craters formed by asteroids should be shown to have formed in higher temperature conditions.
- d) Rocks of similar ages should contain fossils of organisms that lived in the early oceans.

Part IV: Density and Elevations of Ocean floor and Continents

Earth's surface is characterized by two major elevation levels:

- The average elevation of the continents = 0.84 km
- The average elevation of the floor of the oceans is approximately -4.0 km.

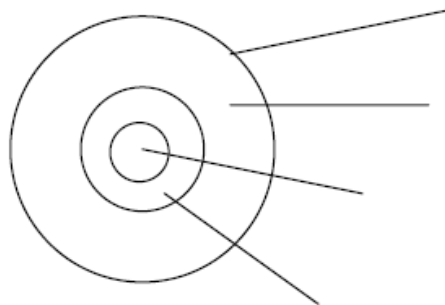
4.1. What is the difference in elevation of continental and ocean rocks? _____ km (1 pts)

Earth is composed of compositional layers (i.e. crust, mantle, core) of different densities. Early in Earth's formation, our planet was completely molten. Denser materials, like iron, sank down to the core, while less dense silicates migrated toward the crust, resulting in density stratification. The outer core is so hot that the metals present are always molten, while the higher pressures at the inner core are enough to keep it a solid, despite the 5000-6000°C temperature! The movement of the liquid outer core generates Earth's magnetic field, which shields us from harmful cosmic radiation, keeps our atmosphere in place and allows life to flourish.

4.2. Identify the properties of these layers and label the cross section through the Earth below. (3 pts)

Table 1

Earth Layer	Average Density [g/cm ³]	Layer Thickness [km]	Properties (circle property)
Continental Crust	2.8	30-40	solid liquid gas
Oceanic Crust	3.0	5-10	solid liquid gas
Mantle	3.4-5.4	2850	solid liquid gas
Outer Core	10-12.3	2260	solid liquid gas
Inner Core	15	1220	solid liquid gas



The continent and oceanic crust float in the mantle like wood blocks float in water. The continental crust is thicker and composed of less dense rocks than the oceanic crust. Just as we calculated how much of the block would float above the water level, we can do the same for the continental and oceanic crust. We can modify Equation 2 accordingly.

$$\text{Thickness of crust}_{\text{above}} = \text{Total thickness} - \{ \text{Total Thickness} \times (D_{\text{crust}}/D_{\text{mantle}}) \} \quad (\text{Eq 3})$$

4.3. Use Equation 3 to determine the following. Use the average densities for the Mantle:

a. How much of the continental crust would float above the level of the top of the mantle? (1 pt) _____

b. How much of the oceanic crust would float above the level of the top of the mantle? (1 pt) _____

4.4. On the basis of these calculations, what is the calculated elevation difference between the continental and oceanic crust? (1 pts) _____ kilometers

4.5. Explain why your values were not the same as the 4.84 km difference above. How could you change the values you used to arrive at a number closer to 4.84 km? (2 pts)

Part V: Experimental modeling of Earth's layers

5.1. In the space below, revise or expand upon your hypothesis in Part I. Incorporate what you have learned about the layers of the Earth. You may assume that each of the three igneous rocks we examined earlier represent either the continental crust, oceanic crust, or mantle. Be aware that this hypothesis must be testable with the Isostasy Model. (3 pts)

5.2. Describe how you will use the Isostasy Model to test your hypothesis. Be specific and include inputs (which "Materials") and values you will use. (3 pts)

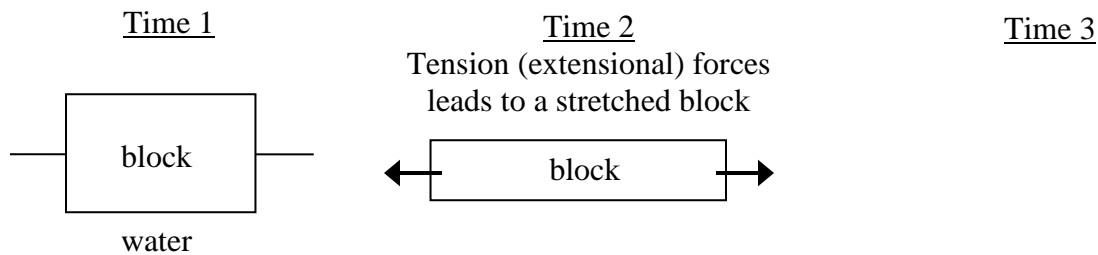
- 5.3. Examine the Isostasy Model produced by your inputs. Draw a labeled sketch in the space below showing the relative thicknesses and distribution of the two types of crust and upper mantle. Before you begin sketching, consider necessary adjustments you will need to make to make this model more realistic, and include these adjustments in your sketch. Hint: the mantle is not exposed at the surface. (3 pts)
- 5.4. Extra Credit: “Break the Model”. Enter values into the Isostasy Model that produce results that are not realistic. Indicate the values you used and describe why the results are not realistic. (2 bonus pts)

Once you are done with the lab, ask your instructor for your post-lab assessment. Hand in your lab and post-lab before you leave the lab room.

Name (print and sign): _____

Post-lab Activity (5 pts). Complete on your own. You may use your lab for reference.

1. Consider that the wood blocks represent the “crust” and the part of each block below the surface of the water represents the “root of the mountains” that extends downward into the “mantle” (the water). Using the diagram below, draw how the block will float in water during Time 3. (2 pts)



2. Draw and label a cross section of the crust and mantle from Raleigh east to offshore. Be sure to show differences in thickness, and label any density differences in the crust. (2 pts)

3. Metamorphic rocks are formed deep within the crust. However, this rock type is seen at the surface in some places in North Carolina. Explain how removal of mass from the top of the crust explains exposure of these rocks at the surface. Consider that the ground surface of North Carolina is slowly eroding. (1 pts)
 - a. As the top of the crust is removed, the metamorphic rocks slowly convect their way to the top.
 - b. As the top of the crust is weathered and eroded, the root rises, eventually exposing the metamorphic rocks formed at depth.
 - c. As the top of the crust is eroded, the root spreads out laterally, which exposes the metamorphic rocks.
 - d. As the top of the crust is removed, this lowers the density of the crust and causes the metamorphic rocks to rise and get exposed.