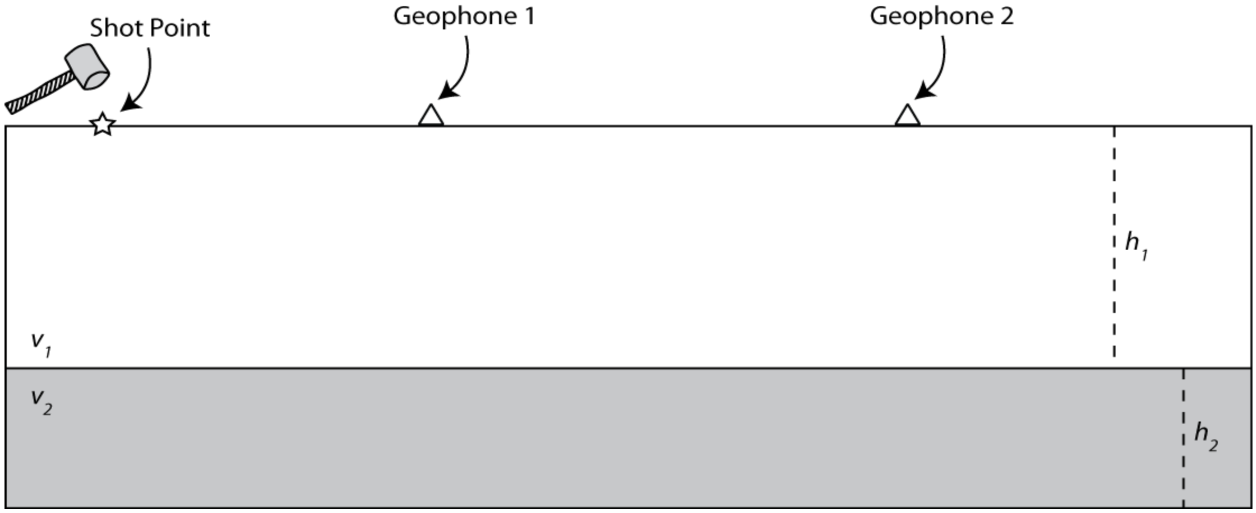
NAME: ________________________________

LAB 6 :: SEISMIC REFRACTION

The following lab will introduce you to the basic concepts of seismic refraction as well as some actual data collected during seismic refraction surveys. You will use your knowledge of seismic refraction to calculate various parameters of interest.

Part I :: Ray Paths

1) On the picture below: Draw and label the paths of the direct ray, the reflected ray, and the refracted ray to both geophones. Note that geophone 1 is at the critical distance and geophone 2 is at the crossover distance. You don't have to make your drawing perfectly to scale, but use a straight edge and label the critical angle, i_c , everywhere that it occurs.



2) Which ray is the first arrival at distances less than geophone 1's location? Why?

3) What ray arrives first between geophone 1 & 2? Why? What ray arrives first after geophone 2? Why?

4) Which ray is never the first arrival? Why?

5) Using your trigonometry and algebra skills, show that the equation for the critical distance is:

$$X_c = 2h_1\, tan\left[arcsin\left(\frac{v_1}{v_2}\right)\right]$$

Where h_1, is the upper layer thickness and v_1 and v_2 are the velocities of the two layers. Make sure to include a sketch of your setup and describe what you are doing. Please be neat and explain your steps. Hint: recall that the critical angle, i_c, depends on the two velocities, v_1 and v_2.

Any student that can show that $X_c = 2h_1\, tan\left[arcsin\left(\frac{v_1}{v_2}\right)\right] = \frac{2h_1}{\left[\left(\frac{v_2}{v_1}\right)^2 - 1\right]^{1/2}}$ will receive bonus points.

6) What are the equations for the arrival times of the direct ray and the first refracted ray given the layer thicknesses and the layer velocities? Describe each parameter in these equations.

7) Define the term “crossover distance”. (We will work more with crossover distance later in this lab.)

Part II :: Seismic Refraction Survey Data

1) Construct a t-x diagram in Excel using the data below. Plot all of the data as discrete symbols (use circles), and once you have determined the different ray arrivals, re-plot each arrival in a different color (again using circles). Plot a best-fitting line (and show the equations on the graph) for each group so that you can later determine the layer velocities and thicknesses. Include your graph in your write-up. I will not look at your excel file, so your description, graph, and work should be clear and stand on its own.

DISTANCE (M)	TRAVEL TIME (MILLISECONDS)
5	7.1
10	14.3
15	21.4
20	28.6
25	35.7
30	42.9
35	48.5
40	51.0
45	53.5
50	56.0
55	58.4
60	60.9
65	63.4
70	65.9
75	68.4
80	70.8
85	73.3
90	75.8
95	77.5
100	78.3
105	79.1
110	80.0
115	80.8
120	81.6

2) How many layers did you detect? How did you distinguish where a new layer started on the t-x diagram?

3) What are the velocities of each layer? Show/Explain your work (as always!).

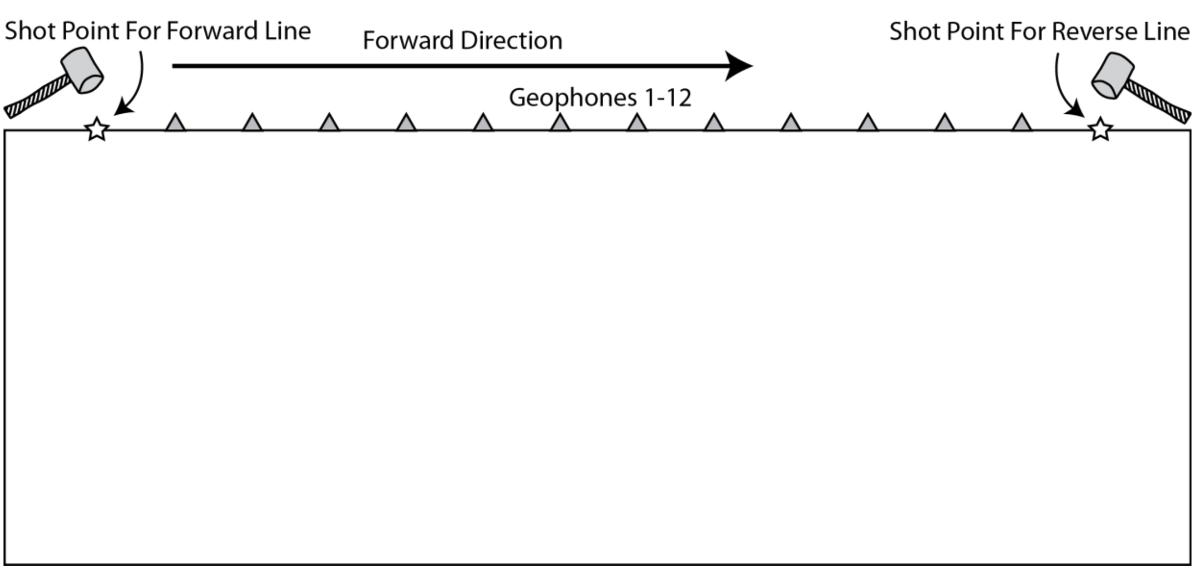
4) How many layer thicknesses can you determine from this data? What are the thicknesses of each layer? Excluding the first layer, what are the depths to the top of each layer?

5) Construct a t-x diagram (using Excel) from the data below. Note that both surveys had the same geophone locations but the reverse was shot backwards. Hint: Instead of plotting them like the forward lines and reverse lines in your textbook, I recommend plotting them both as forward lines and seeing if each data set is similar.

Distance	**Travel Times (milliseconds)**	
(m)	**Forward**	**Reverse**
10	33.3	33.3
20	66.7	66.7
30	100.0	100.0
40	111.4	119.8
50	114.3	125.1
60	117.3	134.1
70	120.2	137.0
80	123.1	140.0
90	133.6	142.9
100	138.9	145.8
110	144.1	148.8
120	149.4	151.7

6) What does this data tell you about the interface(s) geometry at depth?

7) Fill in the box below with a simplified sketch of the subsurface interface geometry suggested by this data.



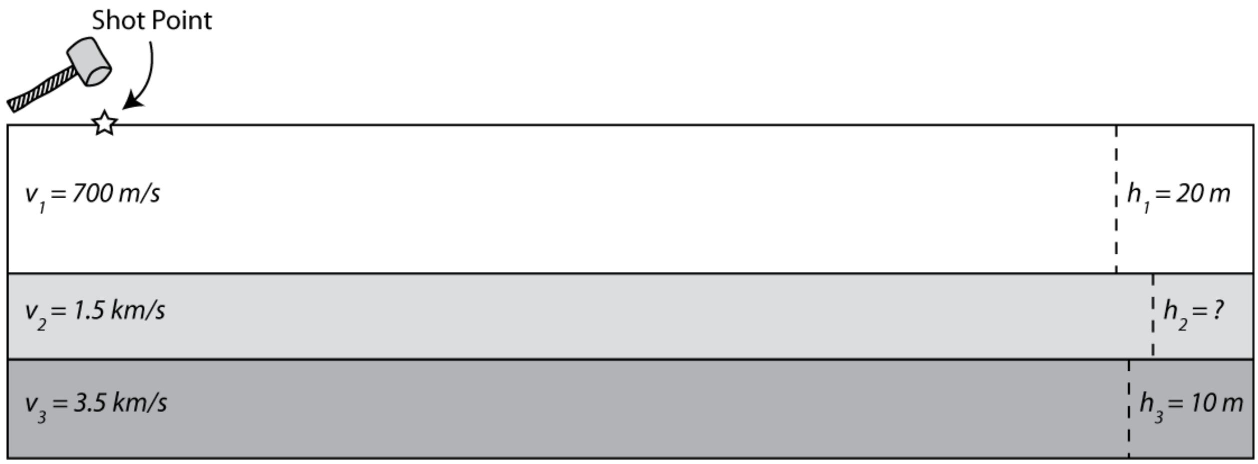
Part III :: Caveats of Seismic Refraction & Fun With Maple

1) To get a better understanding of what the crossover distance depends on, derive the equation for the crossover distance, X_{cr} , using Maple . Hint: Think about the ray travel time equations and how you could use these to figure out the crossover distance. Before you start in Maple, write the two appropriate travel time equations here.

2) You should have found that one of the parameters that controls the crossover distance is the layer thickness. So, this means that the crossover distance could be used to determine layer thickness. Why then, do geophysicists use the y-intercept of the refracted ray on the t-x diagram to determine layer thickness? Hint: Mathematically speaking, both yield the same answer, so why in practice is the y-intercept approach more accurate?

3) In what ways is it useful to know the crossover distance (or at least have some idea of what a likely crossover distance will be) before conducting a survey?

4) Using your existing Maple solution, determine the maximum thickness of layer 2 that would remain mathematically impossible to detect using seismic refraction. Use the parameters in the figure below. Be sure to put text comments into your Maple file so that I know what you did and why. To double check your answer, plot the predicted linear functions for the direct ray (red), the 1st refracted ray (blue) and the second refracted ray (green) on the same plot. Explain your graph in the Maple file using text comments.



5) In practice, how much thicker than this maximum thickness would the layer need to be in order to be detectable in a reasonable seismic refraction survey? Why? Hint: Most seismic refraction surveys are limited to 12 or 24 geophones.

6) The previous question highlighted one of the known caveats of seismic refraction. What is the other known limitation of seismic refraction and why does this happen?