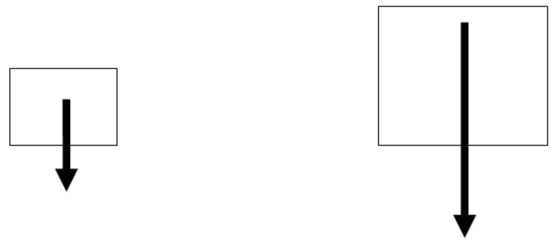
GEOL 308 Natural Hazards
Activity 4: Landslides

Name (Last, First): ____ Date: _____________

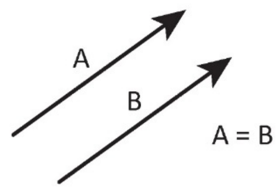
Part I. Vector Addition

Forces are usually represented by vectors; graphically we draw these as arrows. The length of the arrow represents the amount of force, and the while the direction of the arrow is the direction of the force. So a gravitational force is represented by an arrow downward, and the larger the arrow the larger the mass of the object.

A small mass object has a smaller arrow. In this case the arrow on the second object is twice as long showing the object is twice as heavy.

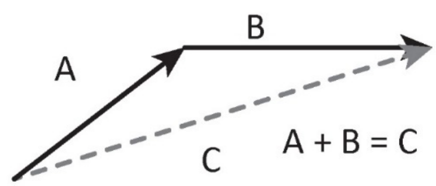


Two vectors are equal if they have the same magnitude and direction, regardless of whether they have the same starting points.



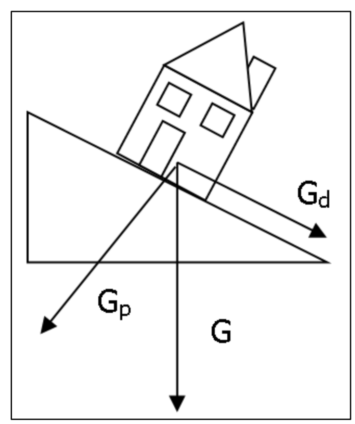
Vectors are added graphically by placing the initial point of one vector on the final point of the other. This is sometimes referred to as the "Tip-to-Tail" method.

Notice that you could also have moved the tail of A to be at the head of B and still get the same result



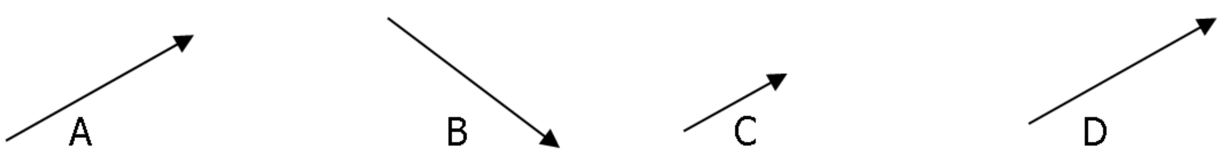
The length of A plus the length of B does NOT equal the length of C. Vectors are not just lengths, but lengths AND directions!

Just as you can add vectors, you can divide them into multiple forces. This is called “resolving a vector.” In the above example, you can divide C into two components A and B.

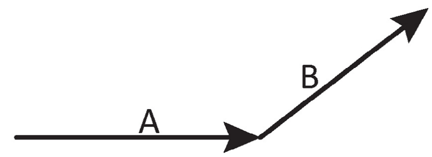


When dealing with landslides, we are interested in the interplay between two forces, friction (F), which works against objects moving downslope, and the pull of gravity down-slope (Gd). To find Gd we must resolve the gravitational force (G) into two components, one perpendicular to the slope (Gp) and one down the slope (Gd).

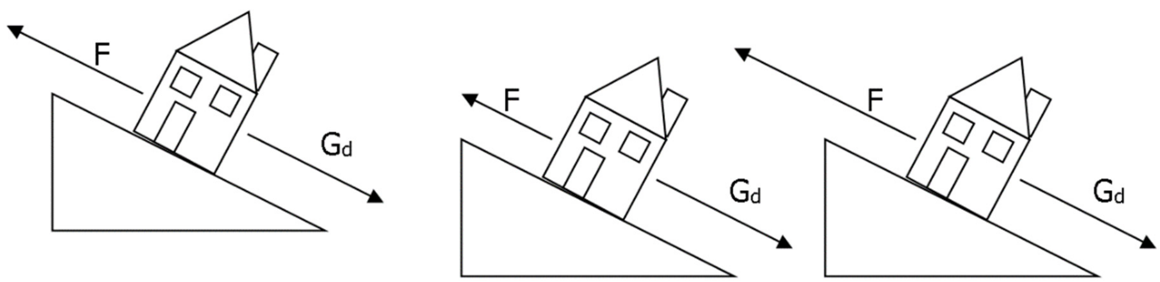
1. Which of the following vectors are equal? _______________



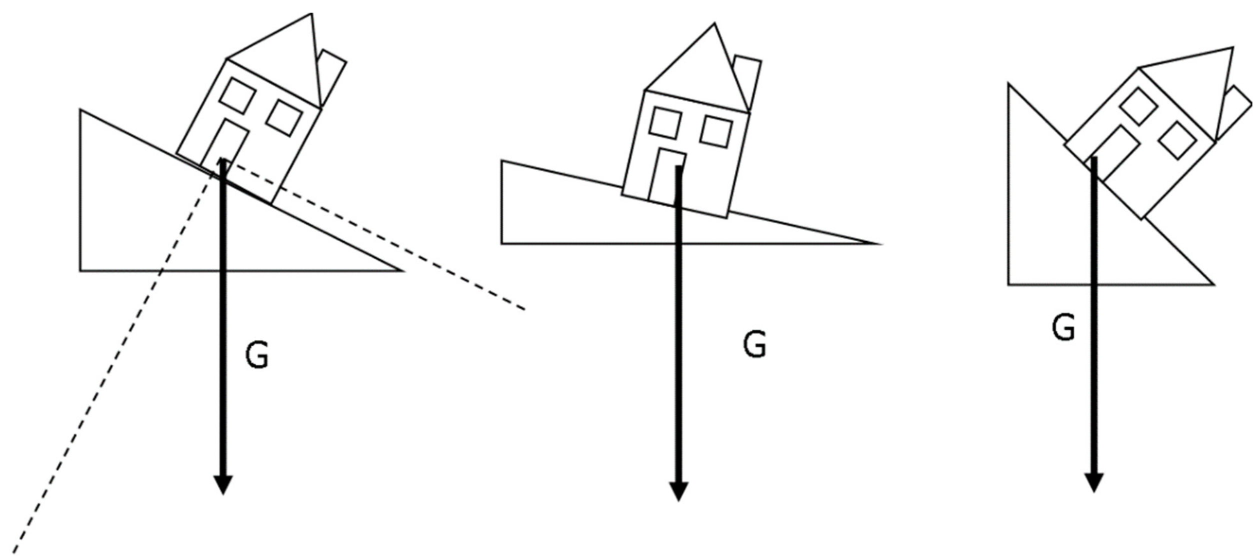
4. In the diagram at the right, what vector must be added to vector A to get vector C? Draw it in. What is its length?



5. Mark the following diagrams of houses on slopes as "stable" "unstable" or "just about to slide".



6. On the following diagrams, resolve the gravitational force (G) into a downslope (Gd) and a perpendicular (Gp) force. In the first example, the dashed lines show the direction of the Gd and Gp forces. You just need to draw the two vectors so that they add up to G. In the others, you will need to make sure the directions and lengths are correct. Please label the vectors you draw.



7. The G vectors in the previous example are all the same length, 40 mm.

If the house weighs 40,000 pounds, then each millimeter of length of the vector in this diagram equals how many pounds? ______________

How long would the G vector be if the house was 60,000 pounds? ______________

Measure Gd in each diagram in problem 6. How many pounds of force are pulling the house downhill in each case?

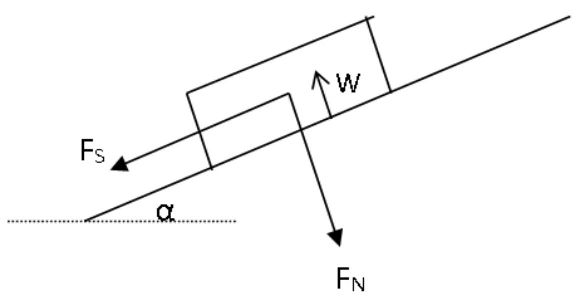
8. A boring (drilling) into the ground examines the friction on the slope below the house and finds that the frictional force is equal to 21,000 lbs. Draw this force into the pictures above, then label each figure as stable, unstable, or just about to slide.

9. A developer buys a plot of land with a 25° slope. The friction in the slope is measured at 60,000 kilograms. Calculate this using trigonometry figure out what the maximum weight a house can be on this property.

Part II. Factor of Safety

A. Assessing Slope Stability Using Factor of Safety

Engineering geologists often use the relations between shear stress (the component of stress that operates in the down-slope direction, Fs) and shear strength (the properties that resist shear stress, i.e., cohesion + normal stress (FN)) to carry out a slope stability analysis. The ratio of shear strength to shear stress is called the factor of safety. We can consider this ratio for the simplified case of a planar failure on an infinite slope as pictured below. When this ratio is greater than 1, shear strength is greater than shear stress and the slope is considered stable. When this ratio is close to 1, shear strength is nearly equal to shear stress and the slope is unstable.



F_S = shear stress
F_N = normal stress
α = slope angle
W = height of water table

In this exercise, you will consider the different variables that go into calculating the factor of safety. You will then assess which variables are likely to change over the relatively short time scale of weeks to years and which variables are intrinsic to the slope or the material making up the slope. The primary goal of this exercise will then be to carry out a sensitivity analysis. This analysis will allow you to determine which variables most affect the factor of safety (and thus slope stability) when they change.

1. Write out the equation for the factor of safety and define all of the variables. The numerator is the shear strength and the denominator is the shear stress.

2. You own a geotechnical engineering firm in central California and your company has been hired to conduct a slope stability analysis. Consider a 10.0 m-thick mass of regolith sitting on top of a bedrock surface with a slope of 14 degrees. A home is located at the top of this slope (and set back from the edge only 20 m). Upon an initial visit, you determine that the regolith is unsaturated. You also estimate the following additional parameters for this site:

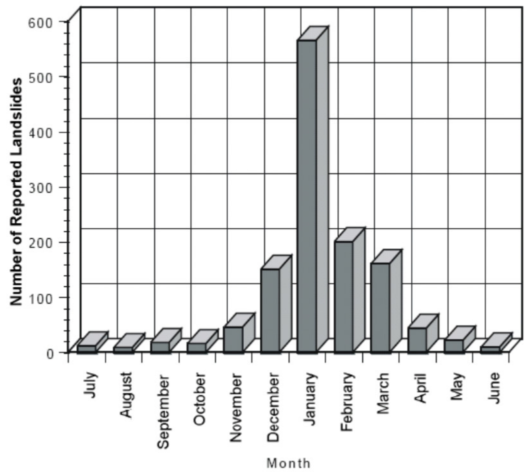
- regolith cohesion = 1100 N/m2
- regolith angle of internal friction = 15°
- density of regolith = 2200 kg/m^3
- (density of water = 1000 kg/m^3)

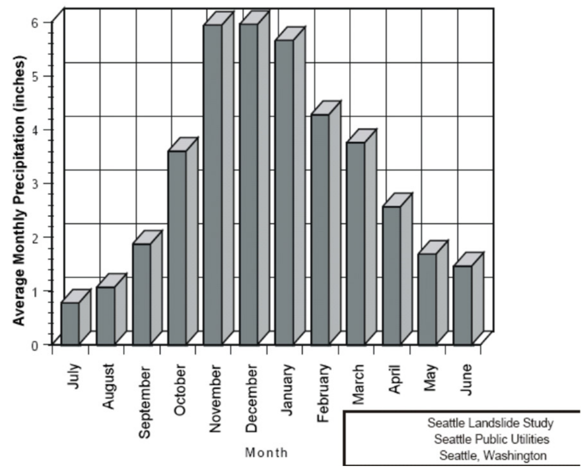
a. Calculate current values for shear strength and shear stress on this slope.

b. What is the value for the Factor of Safety? Would you consider the slope currently stable? Explain your answer.

c. What advice would you give to the homeowners regarding the safety of their home? What remediation can you suggest if any is needed?

Use the graphs below to answer the following questions.





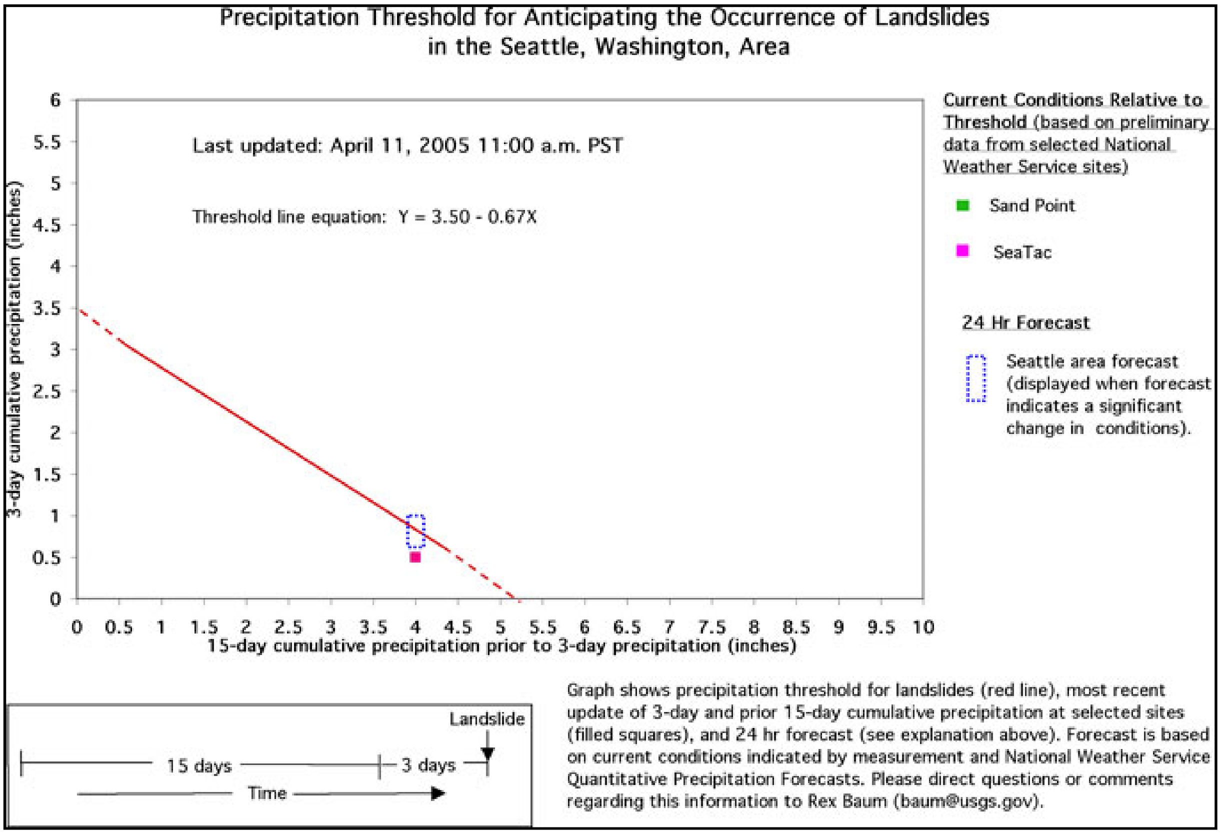
Source of data: City of Seattle, 1999. Seattle Landslide Study

14. In the Seattle area, which four months experience the greatest amount of rainfall?

15. In the Seattle area, which four months experience the highest number of landslides?

16. Explain why the peak landslide activity occurs later than the peak rainfall activity.

The USGS has recently developed and tested a model that establishes a precipitation threshold for the Puget Sound Area as it relates to landslides. In this area, landslides tend to occur if the precipitation amount for a 15 day period exceeds a specified level, and that 15 day period is followed by 3 days of rain at certain levels. The graph below shows the Precipitation Threshold for Anticipating the Occurrence of Landslides.



Source: Chleborad, A.F., (2003) Preliminary Evaluation of a Precipitation Threshold for Anticipating the Occurrence of Landslides in the Seattle, Washington, Area. U.S. Geologic Survey OFR 03-463. http://pubs.usgs.gov/of/2003/ofr-03-463/ofr-03-0463.html

17. Place and label a point on the graph for the following days

Date	15 day cumulative precipitation	3 day cumulative precipitation	Landslides expected? (Yes, no, maybe)
1/5/56	4.73	3.38	
1/6/96	1.27	0.55	
1/7/96	1.33	1.27	
2/11/96	4.94	0.07	
2/21/96	5.87	0.56	

18. Explain why the 15 day and 3 day cumulative precipitation would be critical in determining when landslides might occur.

19. Why might landslides not occur after even several inches of rain in 3 days if the amount of rain in the preceding 2 weeks has been low?

20. Why would landslides not occur even if there had been a large amount of rain in the previous 2 weeks, but little rain in the last 3 days?