

## Sand's Angle of Repose Lab

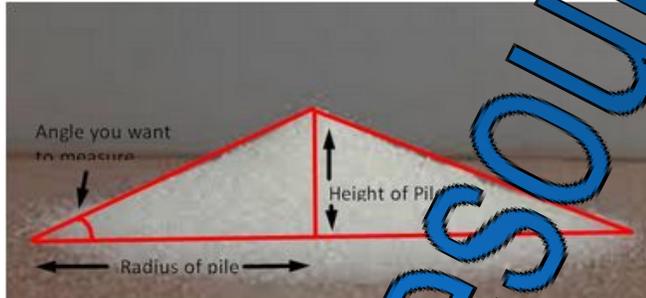
**Materials Needed:**

Pan, tray, or some other wide container	Dry Sand, Ruler	Cups
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**Info:** Angle of repose = The steepest angle at which a sloping surface formed from a particular loose material is stable. Once the material has hit the angle of repose, a mass movement event is inevitable if the angle gets any steeper.

**Instructions:**

1. Place a ruler in the middle of the tray.
2. Slowly pour 1 cup of dry sand onto the 15 cm mark of the ruler. Do all of your calculations in millimeters.
  - a. Avoid disturbing your pile and causing human made landslides.
  - b. Measure the radius of the sand pile and record it in the table.
  - c. Measure the height of the sand pile using another ruler and record it in the table.
  - d. An easy way to measure the sand pile's angle is to use trigonometry. As you can see from the image, the pile can be thought of as 2 right triangles.



- i.
  - ii. For a right triangle:  $TAN(\alpha) = \frac{\text{Opposite}}{\text{Adjacent}}$  (remember SOHCAHTOA)
    1.  $\alpha$  is symbol alpha which means angle
  - iii. So  $TAN(\alpha) = \frac{\text{height of the sand pile (h)}}{\text{radius of the sand pile (r)}}$
  - iv. To find the angle, you need to take the inverse tangent of both sides:  $\alpha = \tan^{-1}\left(\frac{h}{r}\right)$
  - v. For most calculators you will need to first divide the height by the radius and then press the  $TAN^{-1}$  button on your calculator. Make sure your calculator is in degree mode and not radian mode. **(If you don't have a scientific calculator, use [web2.0calc.com](http://web2.0calc.com). To use the inverse tangent, just hold the "tan<sup>-1</sup>" down for a second until it changes the key to "atan," which is the same thing as the reverse tangent.)**
  - e. Write the formula using your numbers from radius and height in the 4th column.
  - f. Calculate the angle of repose and put your answer in the 5th column. **Use the metric system.**
3. Repeat step two, three more times, each time adding the same amount of sand to your sand pile.

	Radius of sand pile	Height of sand pile	Angle of repose trig formula using your numbers.	Angle of Repose
Cup 1				
Cup 2				
Cup 3				
Cup 4				
			Average of all your angles:	

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4. What do you notice about the angle of repose?

5. Now really, really, really, slowly pour another cup onto the pile of sand. Describe how the sand behaves with regards to both the falling of individual grains and the instant landslide that occurs as the angle of repose is reached.

6. Now take your second ruler and slowly move the sand found closest to the base of your pile. Describe what happens as you move sand away from the base.

7. Swipe away more sand getting closer to the peak of your mound of sand. What do you visually notice about the apparent angle of repose?

8. Now hypothesize what the angle of repose would be for angular gravel. Would the angle of repose be the same or different? If different would it be steeper or more gentle? Explain your reasoning.

9. Now hypothesize what the angle of repose would be for this same type of sand, but moist. Would the angle of repose be the same or different? Would it be steeper or more gentle? Explain your reasoning.

10. What are the two forces acting upon the sand that determine the angle of repose? (Force that makes the sand fall and the force that holds it together.)

11. Why would scientists/engineers care about the angle of repose?

# Sand's Angle of Repose Teacher Notes, Insights, and Procedures

## The materials that you are going to need as a teacher are:

- **cups**, I used graduated beakers so that students could document exactly how much sand they ended up using.
- **sand**, I just "borrowed" a sandbag that our school was using to keep the halls from flooding. Don't worry, I did it after the monsoon season for our area.
- **large trays**, I used lab trays, but last year I just used pizza boxes and those worked well if you don't have the lab trays. Just know that it was a little messier with the pizza boxes. Students can also just use tables or desks, but having a tray will contain the sand better so you don't get it all over your floor.
- **rulers**, preferably 2 rulers for each group. One to measure the radius, and the other to measure the height.

## Teacher Procedure:

- The first thing I did was actually explain what the angle of repose is.
- Next I taught them a little trigonometry. They used the inverse tangent formula to find the angle. Angle of repose =  $\tan^{-1}(h/r)$  Because of the range of math ability with the students I only taught the formula and how to use the calculator. I didn't teach what tangent actually was.
- I then passed out the Angle of Repose lab sheet which really helps them perform the lab correctly.

## Things we discovered as a class to make this lab better.

- To measure the radius of the sand pile, students found it easier to lay one of the ruler on the tray first, and then pour the sand on the center of the ruler, at about 15 cm. They could then take the difference between one side of the sand pile and the other to find the diameter. Finally they could then divide the diameter by 2 in order to get the radius.



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- Take some time as a teacher to teach students how to use their calculator to get the inverse tangent. It is amazing how many high school students still do not know how to use the 2nd function key.
- If you don't have scientific calculators and some of my students didn't, then they can just go to <http://web2.0calc.com/> and long click the tangent button until it says "atan" which is the same as the inverse tangent. Most now have a cell phone that should be able to calculate reverse tangents.
- Before students begin the Angle of Repose lab, make sure that you let them know to be careful not to bump their desk or a neighbor's table as that will cause artificial landslides.

- Students discovered that one of the easier methods of measuring the height of their sand pile was to take the second ruler and stand it up vertically while gently placing or holding a pencil slightly above the pile trying their best not to cause an artificial landslide.
- Let students know also well in advance that they shouldn't put their materials away prematurely as some of the lab follow up questions require them to have a sand pile.
- Due to the lack of awesome scientific equipment, some of their angles were off. Have them take all 4 trials and get an average as that should help show the what their angle of repose is most likely to be.
- In science, you of course are going to use the metric system side of the ruler. I didn't let my students know this year, but will next year that they should be using millimeters instead of centimeters. I think their angles of repose will be more accurate if they are not rounding off centimeters to halves and quarters and instead using the millimeter mark.

**Time:** 55 Minutes