A Test of Adhesive Strength

An experiment with the Forces of Adhesion

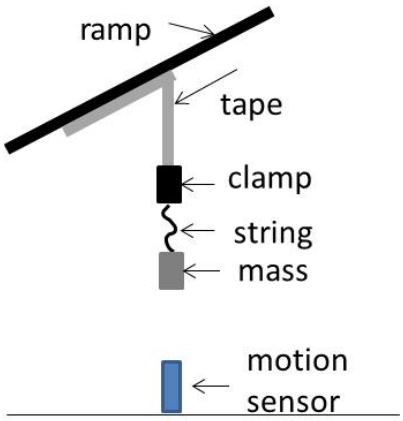
Background information: Adhesives are all around us. They come in the form of tapes, wall/window/floor decals, and glues. Millions of dollars each year are invested in purchasing these products as well as doing research to design more efficient products. The strength of these adhesives determines their use. Stronger adhesives such as duct tape leave a residue and are very difficult to remove from most surfaces. Weaker adhesives such as wall decals must be strong enough to stay on the wall but must be able to be easily removed. The strength of theses adhesives is measured by doing a peel test. A peel test measures the force required to remove the adhesive from the surface.

Experimental Problem/Question: Your grandmother is having trouble opening her yogurt cup with her old brittle and carpal tunnel filled hands. She asks you to investigate what angle she should peel the lid back to exert the least amount of force. You decide to investigate it a little further and ask; what variables may impact the force required to peel an adhesive from a surface?

(Factors such as the type of adhesive, peel force, angle, width of sample, and velocity of pull all may play a role. Although all these may be tested some relationships are trivial for high school students. So we will test angle, width, and velocity.)

Materials needed: Ramp which can be changed to various angles, 3 c-clamps, mass hook set, motion detector, protractor (or iHandy level app for cell phone), ruler, string. For the adhesive a strip of tape can be used, this includes office tape, packaging tape, masking tape and duct tape for example. A piece of approximately x inches long should be used.

Setup: A surface is clamped to the ramp and the adhesive tape is applied to the surface along half its length. A clamp is then attached to the end of the adhesive material. A string is tied around the clamp and the mass hook set is then attached to the string. The mass should be placed on a stand to prevent the peeling of the adhesive until the motion detector is set up. The ramp should be high enough that the after the tape peels along its length the mass is still freely hanging above the motion sensor. Clamp the other end of the adhesive to the ramp. A motion detector is placed on the floor/table to measure the pull velocity. If the motion detector cannot detect the motion of the mass you will have to place a piece of cardboard on the end of the mass, which can be attached using double sided tape. When the motion detector is in place remove the stand and allow the mass to hang freely and record the motion of the mass during the peeling of the tape. The picture below shows the basic setup:



Pre-experiment question: Draw a force diagram showing all relevant forces acting on the tape as it is pulled from the surface by a weight:

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Procedure & Data Sheet:

Part I: Angle vs. average velocity: You will try to get a relationship between the angle of the ramp and the average velocity of the peel. You will do this by varying the angle of peel and recording the average velocity with the motion detector. To measure the angle you may use either a protractor or iHandy level app on your phone. The average velocity can be obtained by highlighting the section on the velocity vs. time graph where the peeling occurred and clicking on the "stat" button at the top and recording the mean value.

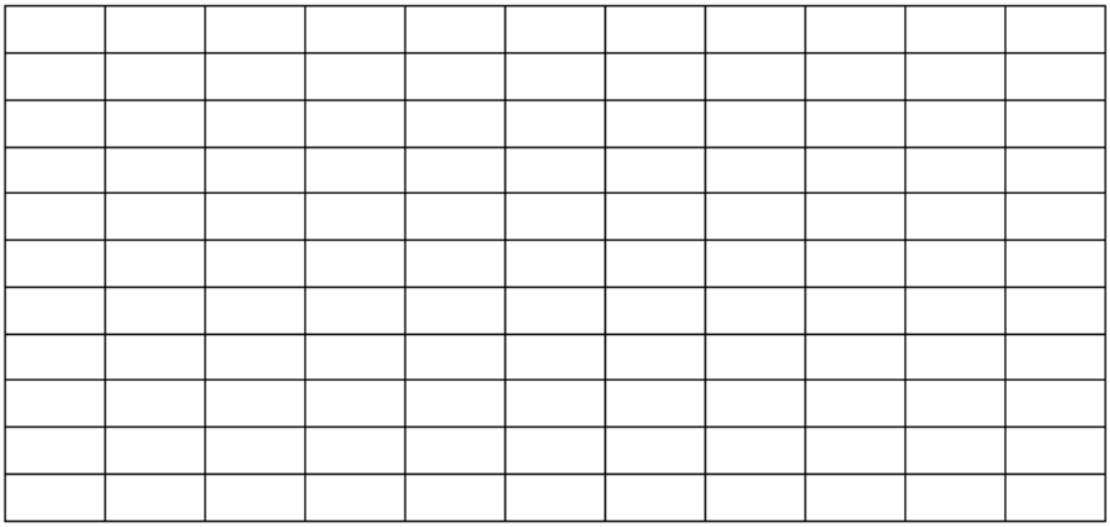
Before starting note the width of adhesive: _____ and the force that will be used: _____ as these variables will be held constant in this part of the experiment. Be sure to choose a force that will be large enough to peel the tape for all angles from 90° to 180° don't forget to include the force from the clamp.

Peel Angle (°)	Average velocity (m/s)
90	
180	

Plot a graph of average velocity vs. angle:

Average Velocity

(m/s)



Angle (°)

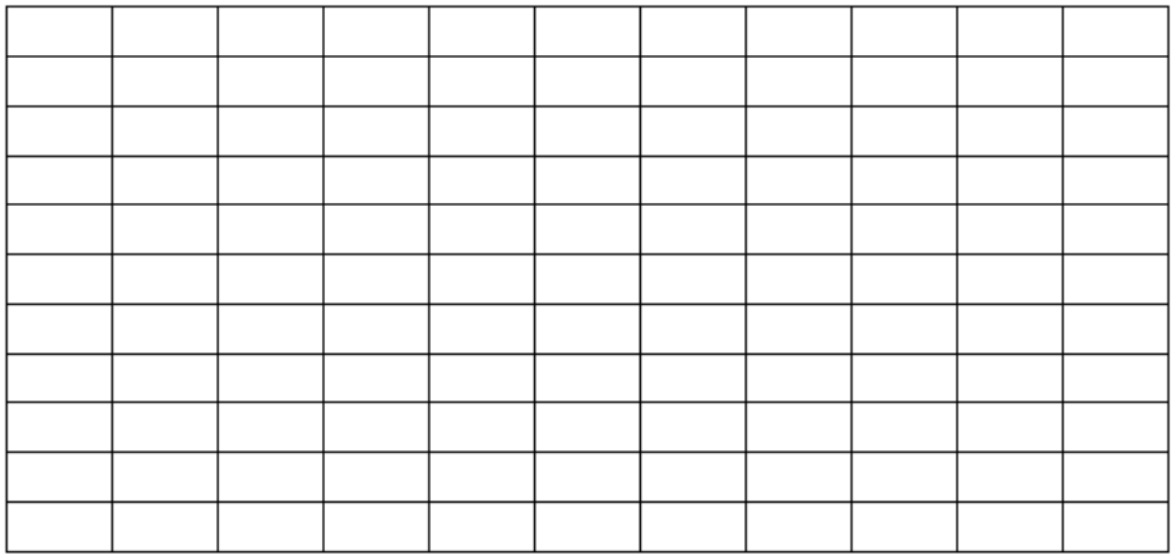
Part II: Width of sample vs. average velocity: You will try to get a relationship between the width of the adhesive and the average velocity of the peel. You will do this by varying the width of the adhesive and recording the average velocity with the motion detector.

Before starting note the angle: _____ and the force that will be used: _____ as these variables will be held constant in this part of the experiment.

Width of adhesive (cm)	Average Velocity (m/s)

Plot a graph of average velocity vs. width of adhesive:

Average Velocity (m/s)



Width of Adhesive (cm)

Analysis questions:

1. If there is a larger average velocity what does this mean about the force required to peel it from the surface?

2. Your grandma asked you at the beginning of this experiment what angle she should peel the lid back to exert the least amount of force. Based upon your data which peel angle would require the least amount of force to peel? How do you know?

3. Based upon your data what happens to the peel force as the width of the sample increases?

Further Investigations/Application Questions:

Assuming the elastic energy term can be ignored for large peel angles the equation for the peel force according to Kendall, 1975 is given by:

$$\frac{F}{b} = \frac{R}{(1-\cos\theta)}$$

Where : F = force (N)

b = width of sample (m)

R = adhesive energy of sample (N/m) (depends on the peel velocity)

θ = angle of peel with respect to the surface

1. The adhesive energy for rubber on a glass surface is 5 N/m. What force would be required to peel a 5 cm piece of rubber at an angle of 150°?

2. Engineering Application: Can you design a device that Grandma could use to help her open her yogurt cup?