

North Carolina State University

**The Science of Papermaking and Paper Recycling: A Research Experience for
Students**

Lab Manual:

Measuring Paper Strength

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Measuring Paper Strength:

Objective: Be able to perform a simple experiment to determine the strength of paper.

Background: This activity provides students with a way to test their paper. Manufacturers of paper have to meet strict requirements for the strength, thickness, weight, smoothness, and appearance of their product. They have to do this in order to consistently meet the needs of their customers and get repeat business. The test described in this activity is modified a modified/simplified version of the most common strength test, “tensile strength.” In addition to providing a way to test paper sheets made by the students, the activity also can help develop skills in calculating with units, looking for root causes, and learning some concepts about why paper is recyclable.

Equipment Needed:

1. Paper Samples
2. Table with thick, flat edge.
3. Approximately \$20 in pennies (or other suitable heavy small objects).
4. Light plastic bucket with handle (about ½ -1 gallon volume).
5. Strong Duct Tape.
6. Mass balance for items 1, 3 and 4.
7. Scissors
8. Ruler with mm scale.

Suggested Paper Samples to Test:

It is recommended to use thin paper. Thick board samples will require too much weight to break. At the very high weights needed to break the thick paper, the adhesion between the tape and paper may fail (see procedure) rendering the results not useful. Some suitable paper samples are listed below:

Copy Paper

Paper

Newspaper

Paper

Magazine Paper

Thin Paper Bags

Coffee Filter

Handmade

Construction Paper

Wax Paper

Note: Tissue paper, paper towels and toilet paper may be too weak to test unless a very light bucket is used. Also extra care must be used to not damage these papers when preparing for testing. For these types of weak paper, the width of the paper strip can be increased to up to a couple of mm less than the width of the duct tape used.

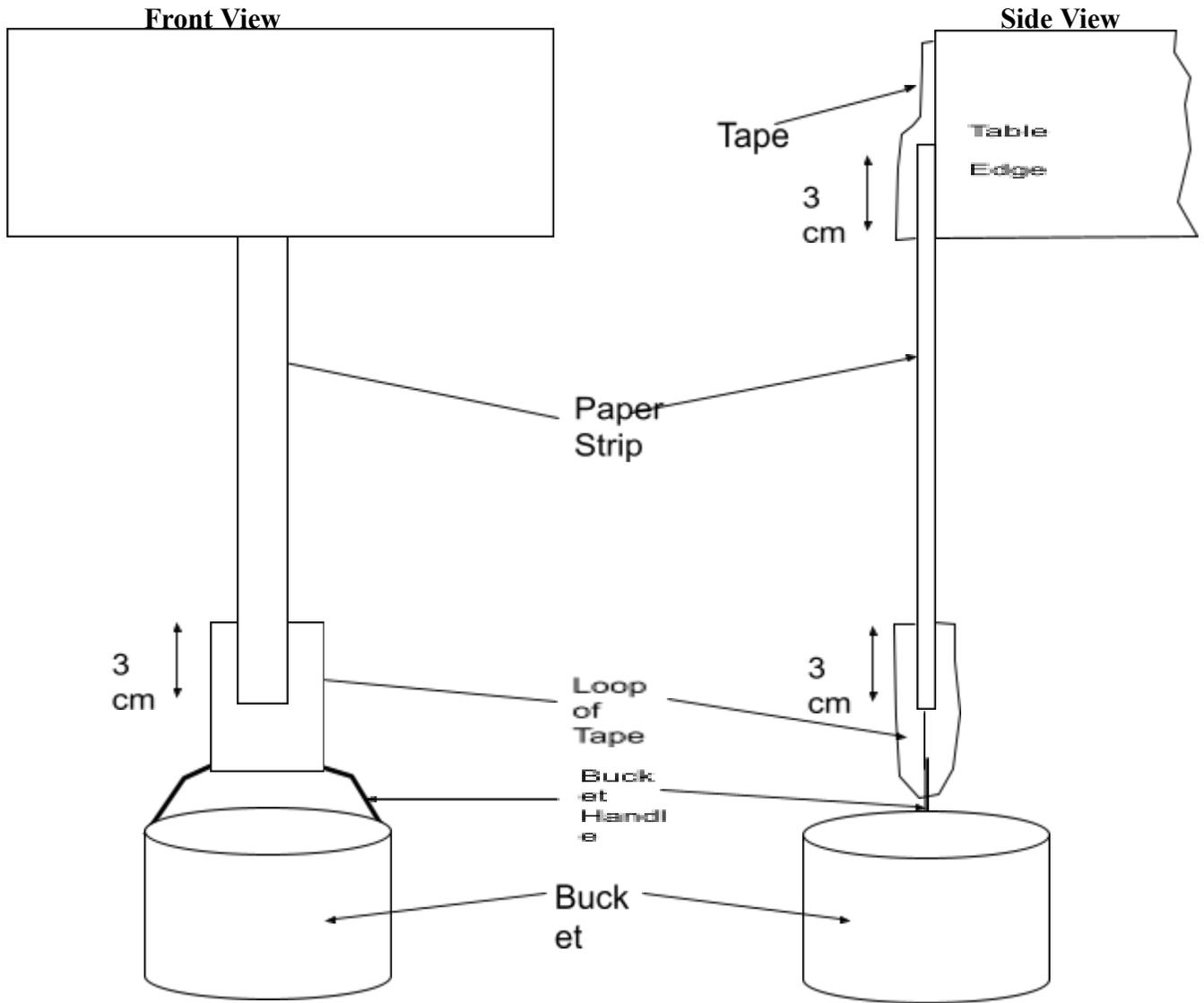
Procedure:

The following page shows illustrations for the experimental set-up to measure the strength of the paper. Also, a calculation sheet is attached to organize data collection and analysis.

1. Weigh the bucket and record in the calculation sheet. (page 4)
2. Weigh several pennies and determine the weight per penny.
3. Measure the area of the paper that you want to test using a ruler. Convert the area into m^2 and record on the calculation sheet. Measure the corresponding weight of the paper using a balance. Calculate the basis weight in $grams/m^2$.
4. Carefully cut a strip of paper so that it is 5 mm wide. The length should be between 8 and 20 cm, depending on the dimensions of your initial sheet of paper. Do not wrinkle or tear the strip. When cutting try to make the edges as smooth as possible.
5. Using a 10 cm length of strong Duct tape, tape at least a 3 cm of length of the strip to the table edge so that the strip hangs vertically. *See illustration.*
6. Using about a 20 cm length of strong Duct tape, attach the bucket to the bottom of the paper strip. The tape should loop around the bucket handle and then sandwich the bottom part of the paper strip. *See illustration.* Again make sure to tape at least a 3 cm length of the bottom of the paper strip.
7. Add pennies to the bucket until the paper snaps. Make sure that the paper has not slipped out from the tape, if it has, the experiment is not useful. Count the number of pennies to break the paper and record. (This first test may be used as a scoping experiment in order to find out approximately the number of pennies needed.)
8. Measure the width of the paper at the region where it snapped and record.
9. Repeat steps 4-8 twice more and take an average of the results.
10. Use the calculation sheet to determine the breaking length.

Suggested Additional Experiments.

1. After hanging a strip of paper in testing position (with bucket but no pennies), lightly coat the strip with water using a paintbrush, sponge, wet cloth or other method until the paper is wet. Then perform the strength test. Do the same experiment except coat the strip with a cooking oil instead of water. Also do the test on the dry strip. Are there significant differences and can you interpret the results?
2. Make recycled paper out of a variety of types of paper, e.g., newsprint, corrugated boxes, copy paper, etc. Compare their strengths with each other and the strengths of the original paper. Try to explain why some are stronger than others.
3. Collect mixed office waste. Devise a lab-scale recycle process that includes multiple operations. After each operation, make a handsheet of the accepts. Make observations (such as ink content) and perform strength testing on each handsheet sample. Determine which operations impact the strength of the paper most significantly. Can you correlate any changes in strength with observations of the handsheets after each operation?
4. Determine if aging of newspapers affects the strength. Test the strength of a newspaper sheet after 0, 1, 2, 4, and 8 days in the sun. Also test a newspaper sheet that has not been exposed to sunlight but stored for the same days. Plot the strength versus time. Is there a significant difference between the two samples? What do you think is happening?



PAPER STRENGTH CALCULATION SHEET

Sample ID _____

Mass of Bucket _____ g

Mass of a penny _____ g

Sheet area = _____ m²

Sheet mass = _____ g

Basis weight = Sheet mass/Sheet area = _____ g/m²

of pennies to break strip (result 1) = _____

of pennies to break strip (result 2) = _____

of pennies to break strip (result 3) = _____

of pennies to break strip (Average) = _____

Mass of pennies to break strip (Average) = _____

Total mass to break strip (pennies + bucket), m_b = _____ g

Width at break (W) (result 1) = _____ mm

Width at break (W) (result 2) = _____ mm

Width at break (W) (result 3) = _____ mm

Width at break (Average) = _____ mm = _____ m

$$\text{Breaking length} = \frac{m_b}{W \times \text{Basis Weight}} = \frac{(\quad \text{g})}{(\quad \text{m})(\quad \text{g/m}^2)}$$

Breaking length = _____ m

Note: In order to obtain the breaking length in meters, be careful to use the appropriate units specified in the formula.