

Brazilian team

# Problem 01

## Adhesive Tape

reporter:

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# Problem 01

## Adhesive Tape

Determine the force necessary to remove a piece of adhesive tape from a horizontal surface. Investigate the influence of relevant parameters.

## Contents

- Introduction
  - Definitions
- Theory
- Experiment
  - Setup
  - Experimental results
  - Analysis
- Conclusion

### Introduction: Adhesive tape

- Narrow strip of flexible material that adheres to other objects.

### Introduction: Adhesion and cohesion

- Adhesion: related to different surfaces' particles.
- Cohesion: related to same body's particles.

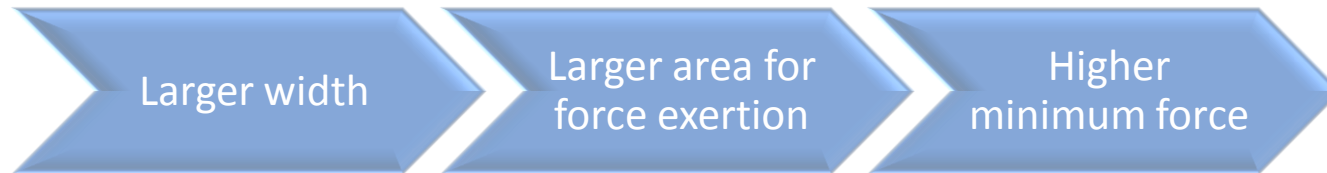


### Theory: Adhesion

- **Dispersive adhesion:**
  - Related to intermolecular interactions;
  - Van der Waals forces.
- **Influences of chemical structure:**
  - Polarity;
  - Larger molecules have higher adhesion;
  - Determine adhesion of different tapes.
- **Different tapes: different minimum forces:**
  - Chemical structure;
  - Elasticity.

### Theory: Minimum removal tension

- Minimum tension for the tape to be removed.



Equal widths but different lengths  
Equal minimum force



Equal lengths but different widths  
Different minimum force

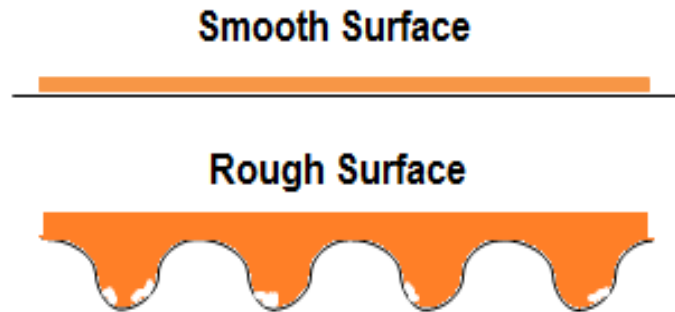


Equal areas but different widths  
Different minimum force

## Theory: Surface area

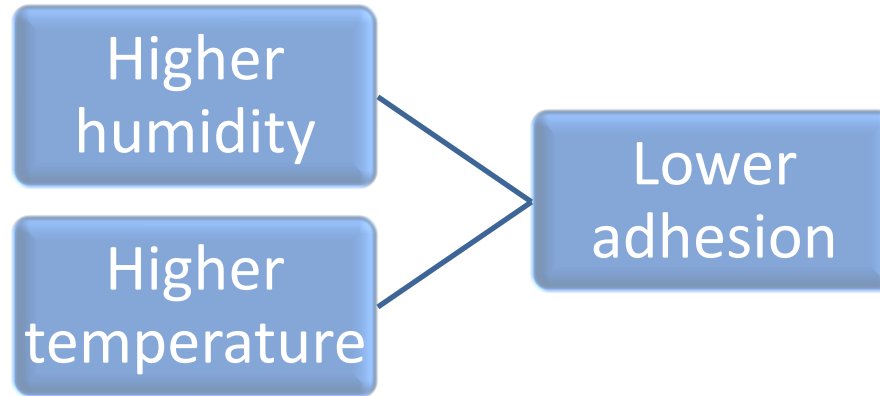


### Microscope vision of the contact



- There is a limit rugosity for the adhesion to increase:  $\sim 50 \mu\text{m}$ , by ISO1302.

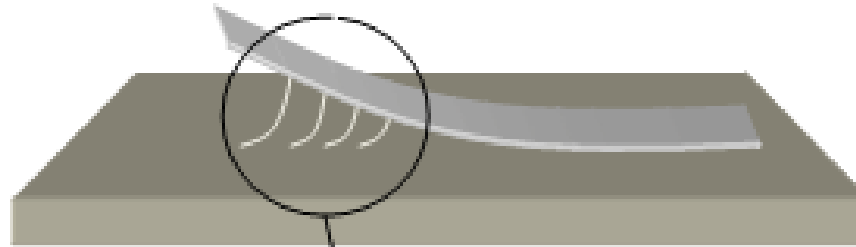
### Theory: Other parameters



- **Higher humidity:** decreases the adhesion because of the tapes particles' polarity.
- **Higher temperature:** decreases the adhesion as the polymer viscosity decreases.

$$\mu(T) = \mu_0 \cdot e^{-\left(\frac{C_1(T-T_r)}{C_2+T-T_r}\right)}$$

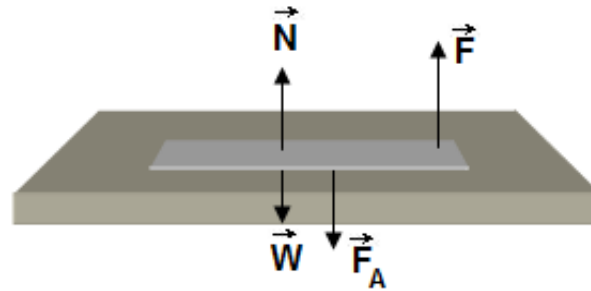
## Theory: Stringing



**Stringing happening between the separating surfaces.**

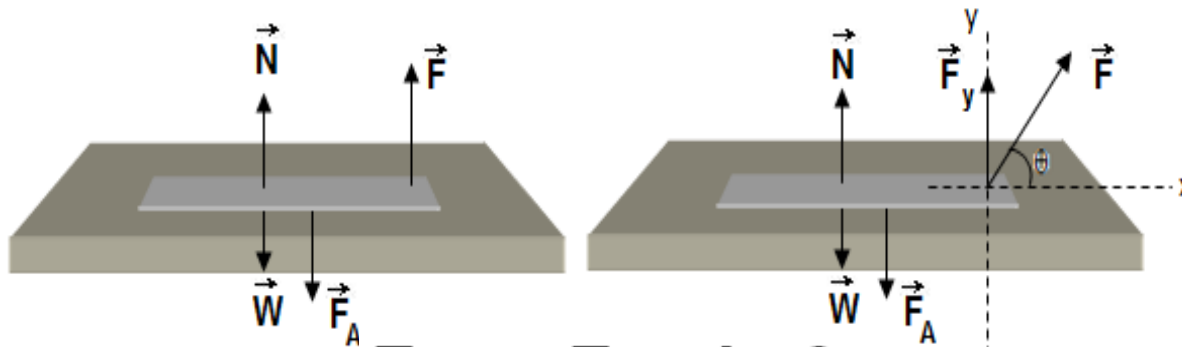
- The stringing can stop the crack. But, once the crack is initiated, it is easier to remove the tape.

Theory: Forces acting on the tape



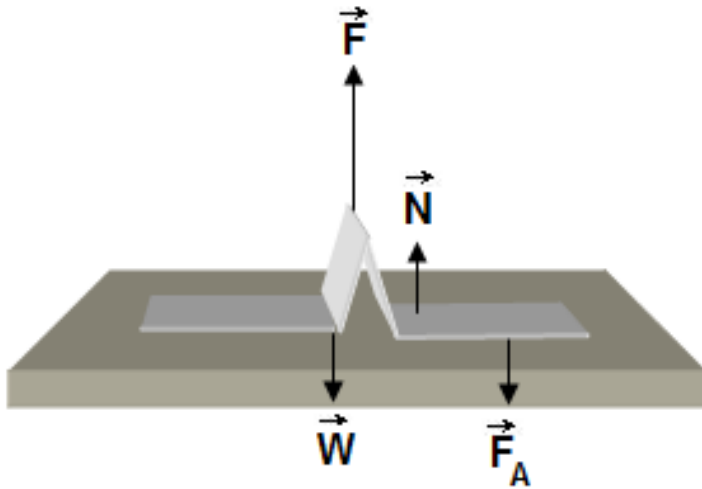
$$N \cong 0 \quad W \cong 0$$

$$F \cong F_A \text{ or } F > F_A$$



$$F_A \leq F \cdot \sin\theta$$

### Theory: Second form of resolution



- Used to control the experimental parameters easily.

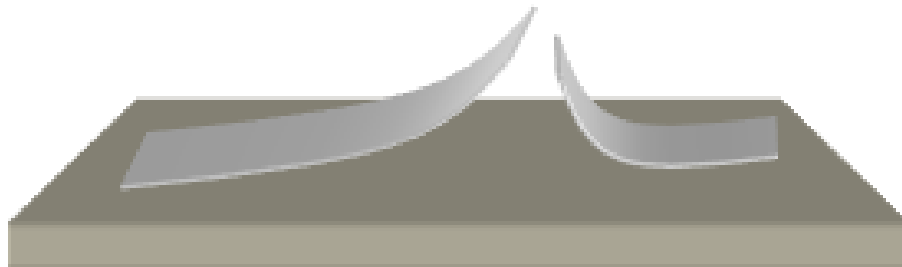
$$N \cong 0$$

$$W \cong 0$$

$$F \cong F_A \text{ or } F > F_A$$

## Theory: Maximum force

- Maximum force supported by the tape without tearing it off.



### Experiment: Experimental description

- **Standard experiment:** duct tape, in ambient temperature and glass surface.
- **Experiment 1:** vary width.
- **Experiment 2:** vary length (same width).
- **Experiment 3:** vary humidity.
- **Experiment 4:** vary temperature.
- **Experiment 5:** different surfaces.
- **Experiment 6:** different adhesive tapes.

**Inaccuracies:** precision of the dynamometer ( $\pm 0.05\text{N}$  for each dynamometer used in parallel) and precision of the ruler ( $\pm 0.05\text{cm}$ ).

## Experiment: Experimental setup



### Experiment: Material

- Duct Tape
- Scotch tape
- Dynamometer (precision of 0.05N)
- Ruler (precision of 0.05cm)
- Humidifier
- Hair dryer
- Thermocouple type K (precision of 0.1°C)
- Glass surface
- Wood surface
- Corrugated fiberboard surface
- String



### Experiment: Standard experiment

Ambient conditions

- **Experimental conditions:** dry duct tape, in ambient temperature and glass surface.

Width

- **Width:** 4.5cm

Length

Humidity

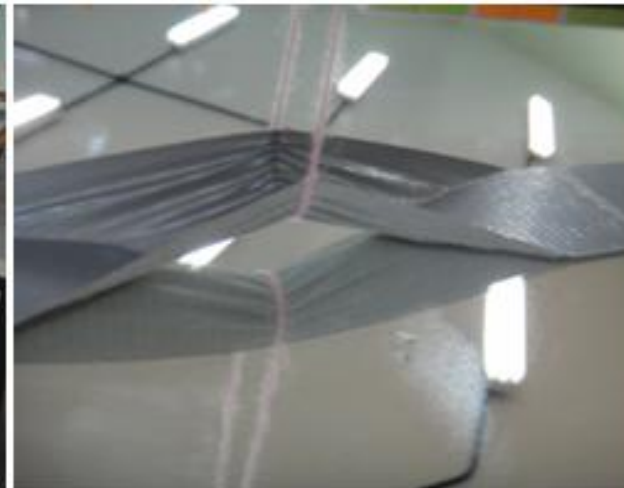
Temperature

Surface

Tape's type



Experimental setup



Minimum force applied

### Experiment: Standard experiment

Ambient conditions

Width

Length

Humidity

Temperature

Surface

Tape's type

	<b>Force (N)</b>
<b>1st</b>	41
<b>2nd</b>	35
<b>3rd</b>	39
<b>4th</b>	33
<b>Average</b>	<b>37.0</b>
<b>Standard Deviation</b>	3.7

### Experiment: Experiment 1 - vary width

Ambient conditions

Width

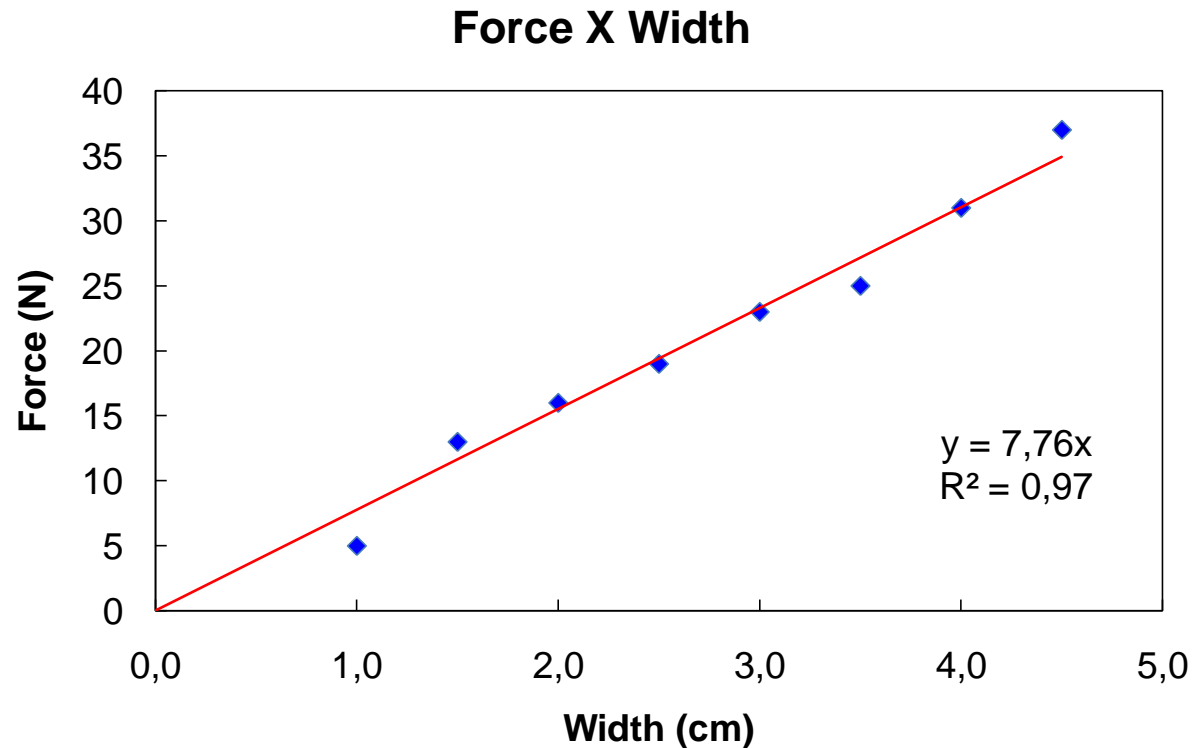
Length

Humidity

Temperature

Surface

Tape's type



### Experiment: Experiment 2 - vary length

Ambient conditions

Width

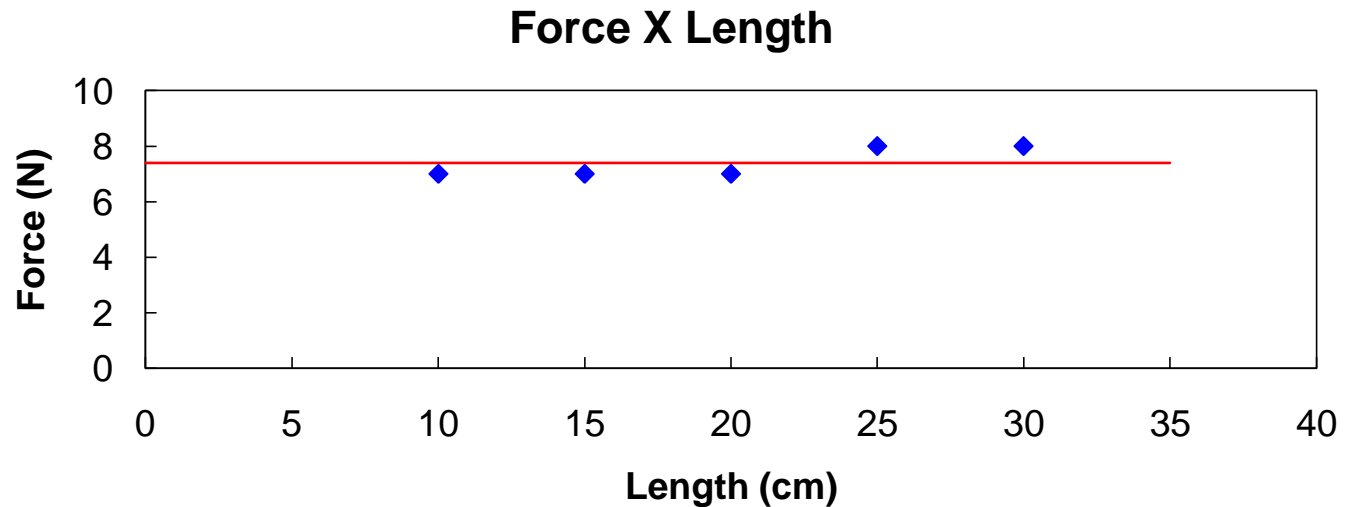
Length

Humidity

Temperature

Surface

Tape's type



## Experiment: Experiment 3 - vary humidity

Ambient conditions

Width

Length

Humidity

Temperature

Surface

Tape's type



**The humidifier is used**



**The humidified tape is easily removed**

### Experiment: Experiment 3 - vary humidity

Ambient conditions

Width

Length

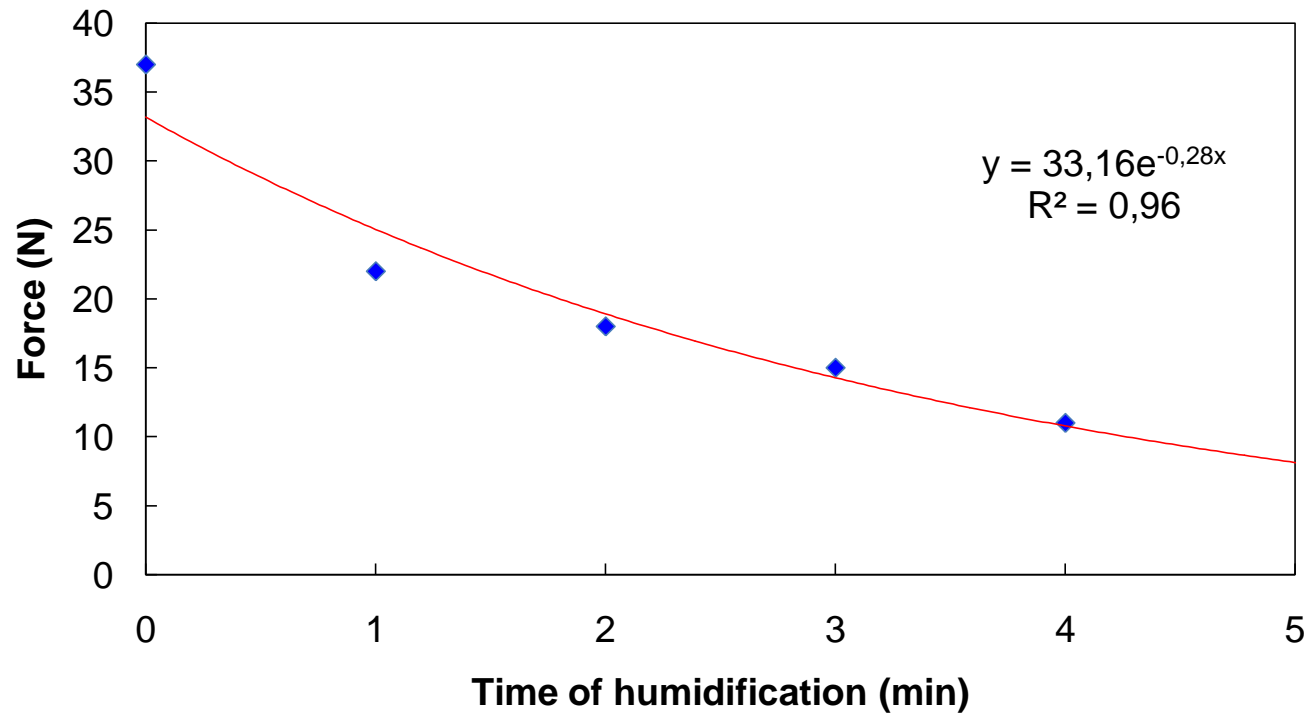
Humidity

Temperature

Surface

Tape's type

Time of humidification X Force



## Experiment: Experiment 4 - vary temperature

Ambient conditions

Width

Length

Humidity

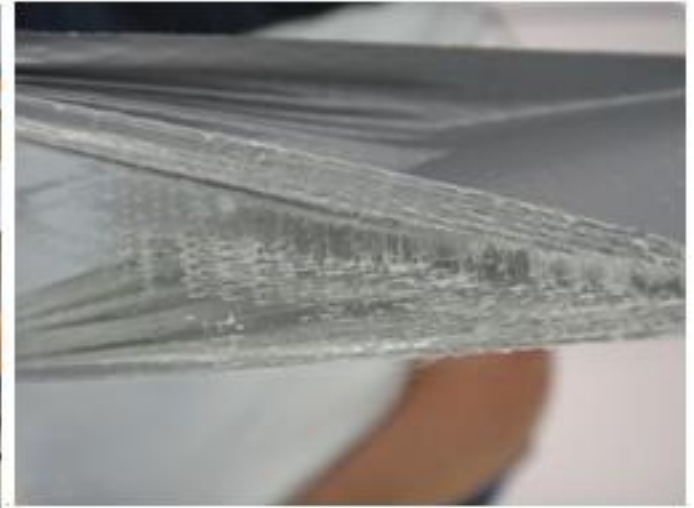
Temperature

Surface

Tape's type



**Experimental setup**



**Stringing**

### Experiment: Experiment 4 - vary temperature

Ambient conditions

Width

Length

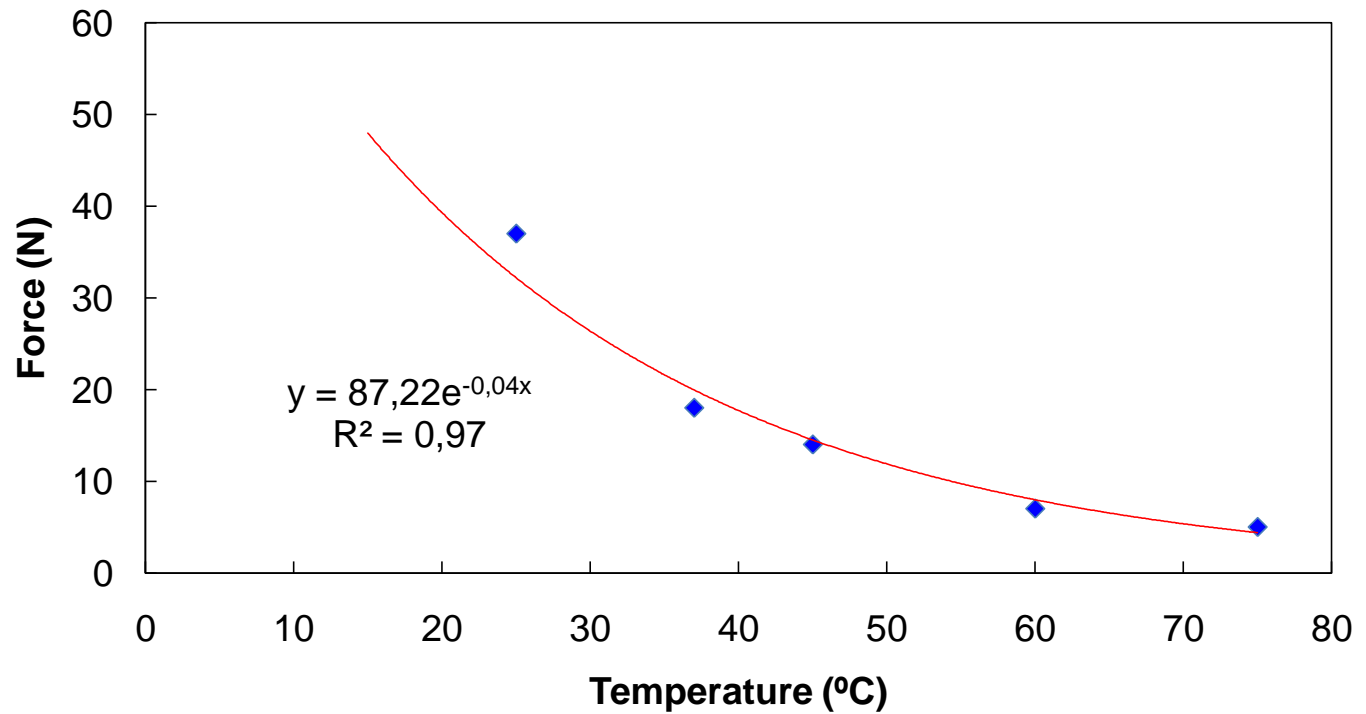
Humidity

Temperature

Surface

Tape's type

#### Force X Temperature



## Experiment: Experiment 5 - vary surface

Ambient conditions

Width

Length

Humidity

Temperature

Surface

Tape's type



Wood



Floor

### Experiment: Experiment 5 - vary surface

Ambient conditions

Width

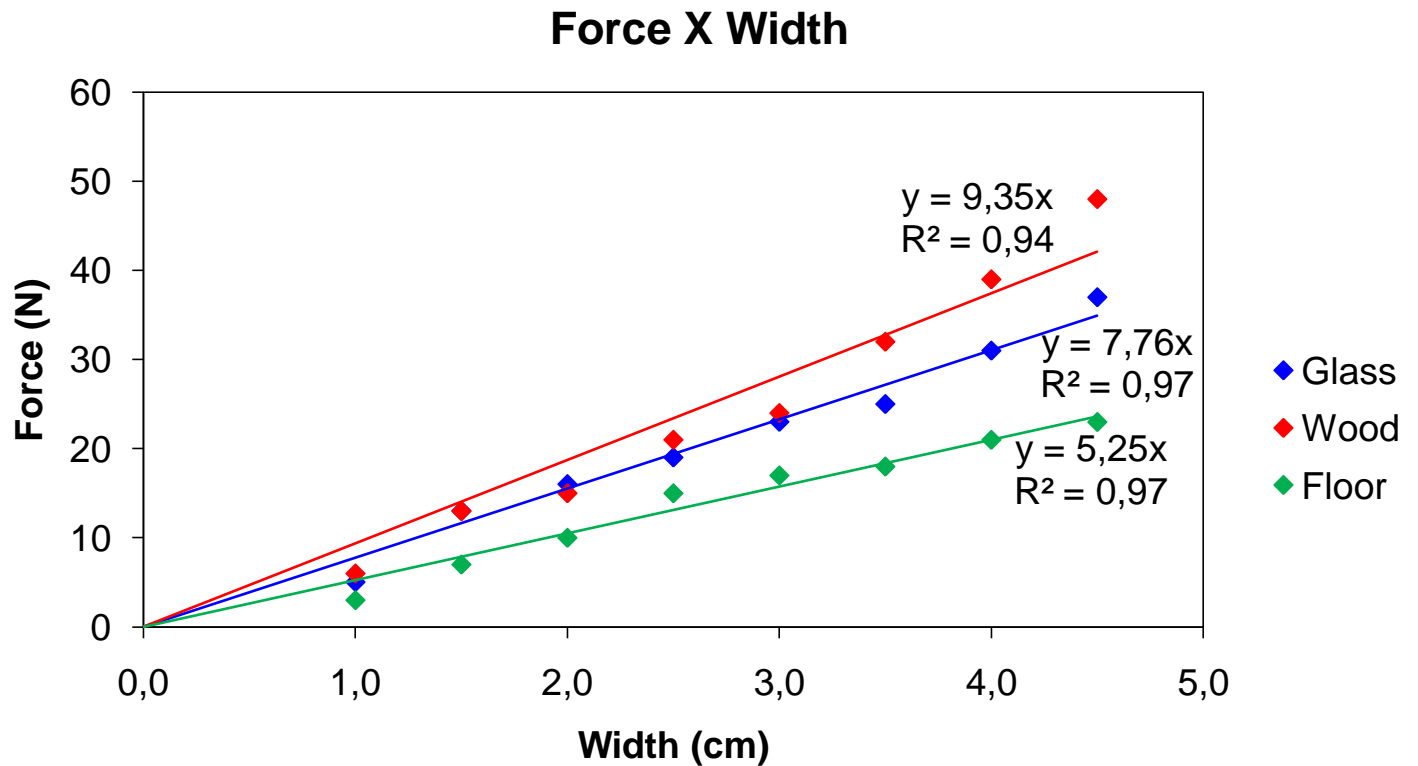
Length

Humidity

Temperature

Surface

Tape's type



### Experiment: Experiment 5 - vary surface

Ambient conditions

Width

Length

Humidity

Temperature

Surface

Tape's type



Experimental setup



Corrugated fiberboard pulled together with the tape

- **Minimum force: 28N**

### Experiment: Experiment 6 - vary tape's type

Ambient conditions

Width

Length

Humidity

Temperature

Surface

Tape's type

- **Duct tape:** polyethylene and cotton fabric film based on resin and rubber.
- **Scotch tape:** bopp film and water-based acrylic adhesive.



Duct tape



Scotch Tape

### Experiment: Experiment 6 - vary tape's type

Ambient conditions

Width

Length

Humidity

Temperature

Surface

Tape's type

	Force (N)	
	Duct Tape	Scotch Tape
<b>1st</b>	41	14
<b>2nd</b>	35	14
<b>3rd</b>	39	14
<b>4th</b>	33	14
<b>Average</b>	<b>37.0</b>	<b>14.0</b>
<b>Standard deviation</b>	3.7	0.0

## Conclusion

- Minimum force found in the standard experiment: 37N
- Parameters that alter the minimum force:
  - Tape's width;
  - Contact surface;
  - Humidity;
  - Temperature;
  - Adhesive tape's type.

### References

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- 6. <http://www.infoescola.com/fisica/coesao-e-adesao-da-agua/>
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- 10. <http://www.infoescola.com/fisica/coesao-e-adesao-da-agua/>
- 11. [http://en.wikipedia.org/wiki/Temperature\\_dependence\\_of\\_liquid\\_viscosity](http://en.wikipedia.org/wiki/Temperature_dependence_of_liquid_viscosity)
- 12. International Standard – ISO1302 – Geometrical Product Specification (GPS) – **Indication of surface texture in technical product documentation**

### Acknowledgements

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## Dynamometer Calibration



- Maximum measurement of the dynamometer: 10N
- Bottle of water with 1Kg measured with a scale with precision of 0.05g.

## Elastic properties

$$E = \frac{\sigma}{\varepsilon}$$

↙  
↘  
Coefficient of elasticity or Young's Modulus

Higher  
coefficient

Harder tape

Higher  
absorbance of  
energy before  
rupturing

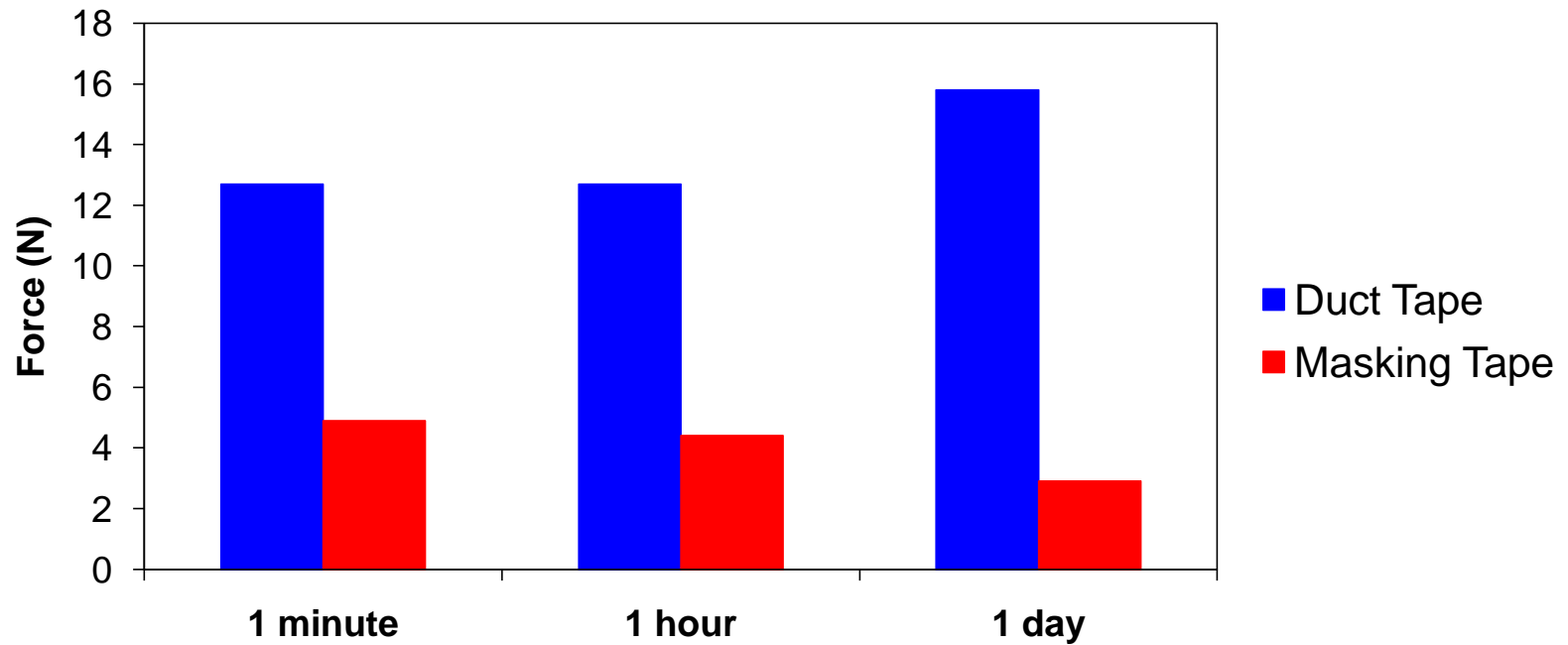
Higher  
minimum force

## Time stuck to the surface

- The **glue** is **oxidized with the air** (small balls and ambient).
- Depending on the type of glue we have a **residue more adhesive or less adhesive**.
- The **adhesion** can **increase or decrease** with time **depending on the tape**.

## Time stuck to the surface

Minimum force in function of time of adhesion to the glass surface



## Experiment 7: removal from corners



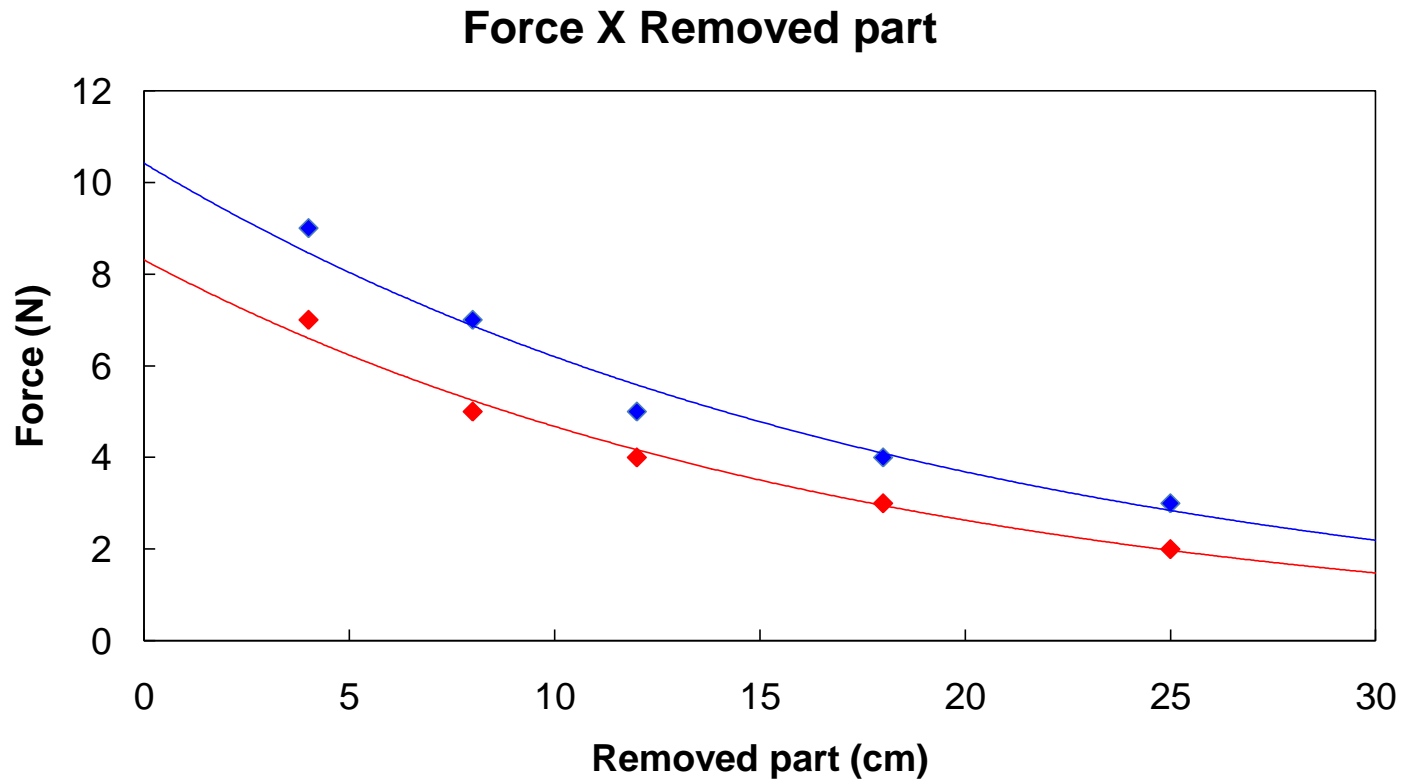
**90° with the surface**



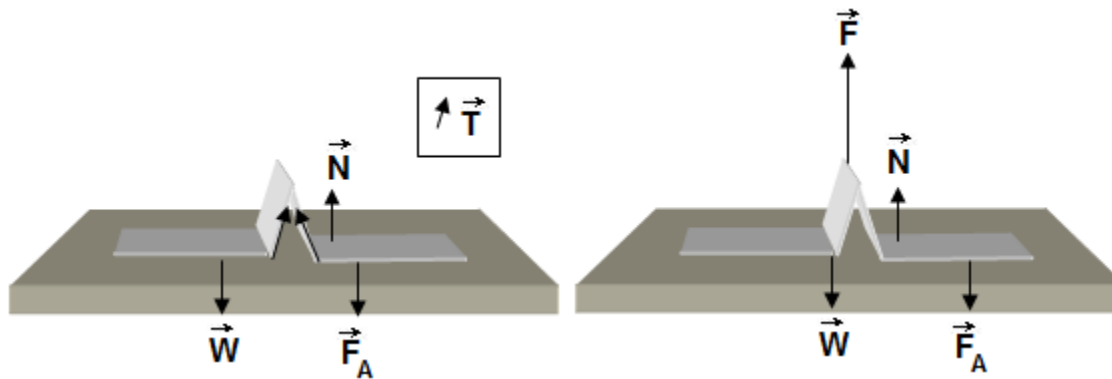
**180° with the surface**

- Experimental difficulties:
  - Control the angle;
  - Find the removal threshold;
  - Control the force as it reduces with the pulling movement.

## Experiment 7: removal from corners



## Traction forces



- The  $F$  force is the sum of traction forces.