24th International Young Physicists’ Tournament

Team of Belarus

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Ministry of Education
Republic of Belarus
Team of Belarus

presents

Adhesive tape
Problem

Determine the force necessary to remove a piece of adhesive tape from a horizontal surface. Investigate the influence of relevant parameters.
Social science #1

Peeling
Experimental setup

Coordinate

Weight

X

0
Coordinate vs. time
Pressure sensitive adhesive

Van der Waals interaction
Hrmm...
You call this “pressure sensitive”?

Peeling weight: 0.5 kg
Pressing mass: 0.5 – 30 kg
Pressed area: 5 X 4.8 cm
Highlands

1.1 mm
“Contact area”
Bring some light…

LED

Sample

Glass

Camera
...and admire.
Under pressure

After applying 638 Pa (89 gr)

After applying 43 kPa (6 kg)
Contact area vs. pressure

Pressing mass: 0.01 – 10 kg
Sample area: 3.7 X 3.7 cm
\[
N(x) = \frac{1}{2\pi \sigma^2} \cdot e^{-\frac{(x-\mu)^2}{2\sigma^2}};
\]

\[
\mu = X_{\text{average}}; \quad \sigma = \frac{X_{\text{max}} - X_{\text{min}}}{6};
\]
A lot of weird symbols

\[ F(x) = \int_{x}^{X_{\text{max}}} (N(x_n + \Delta x) - N(x_n)) S \cdot E \cdot \frac{x_n - x}{x_n} \cdot dx_n \]

Area, covered with glue with original height between \((x_n)\) and \((x_n + \Delta x)\)

Relative deformation of such glue

\[ S(x) = 1 - N(x) \]
F(x) vs. S(x)
Velocity vs. contact area
Wait a second…
Microstretch Windows

\[ T = 0.7 \text{ s}; \quad k = m \left( \frac{2\pi}{T} \right)^2; \quad E = \frac{k \cdot h}{S}; \quad E = 20 \text{ Pa} \]
This statement is false
or
Contradiction

\[ \Delta U; \Delta S \]

\[ \Delta t; \]

\[ h = v \cdot \Delta t; \]

\[ U = \beta \cdot v \Delta t \cdot d; \]

\[ mg \cdot v \Delta t = U = \beta \cdot v \Delta t \cdot d; \]
It’s not a spring, still…

Peeling mass: 8.8 gr
Velocity vs. peeling force

Average error of velocity: 0.02 mm/min
of force: 0.05 N
$V_{mm/min} = (0.40 \pm 0.01) F_N^2 - (0.43 \pm 0.09) F_N + (0.2 \pm 0.2)$
Have you seen me?
Angle

\[ \alpha \]
Social science #3

How do we peel?

Average $\alpha=136.4^\circ$
Velocity vs. angle

Peeling weight: 0.5 kg
Fever

Peeling weight: 0.5 kg
Conclusions

• There is no such thing as "force necessary to remove", only connection between force and time of detaching.

• Tape detaches with constant velocity, if constant peeling force applied. This happens due to viscous and non-Newton effects in glue, so theoretical analysis is impossible. Experimental dependence of velocity on force is square parabola.
Parameters

- Increase in temperature causes increase in velocity;
- There is maximum value of velocity, depending on peeling angle: about 135°;
- Dependence on contact area is close to linear;
- However, applied pressure changes effect not for all pressure sensitive adhesives.
Did you know that…

• Dependence on applied pressure can be caused by difference in height of parts of glue. Those differences can be described through Gauss distribution, and it will give result, close to experiment.

• Young’s modulus of glue can be measured through period of small oscillations, if small weight is attached to the tape.
People, who didn’t know how to attach and detach adhesive tape, got extinct, proving Darwin’s theory of evolution. I don’t believe it, though.
Background reading

• D. Sivuhin “General course of physics” vol. 5 “Mechanics”
• Seung-Ho Moong, Mark D. Foster; “Scanning probe microscopy study of PSAS: recent developments”
• Ginger Cushing, “Chemical primers as surface modifiers for film substrates”
• Charles Darwin, “Origin of species”;