MIT Blossoms lesson
on
“Elasticity: studying how Solids change shape and size”
Data Analysis and Figures for Activities 1, 2, 3

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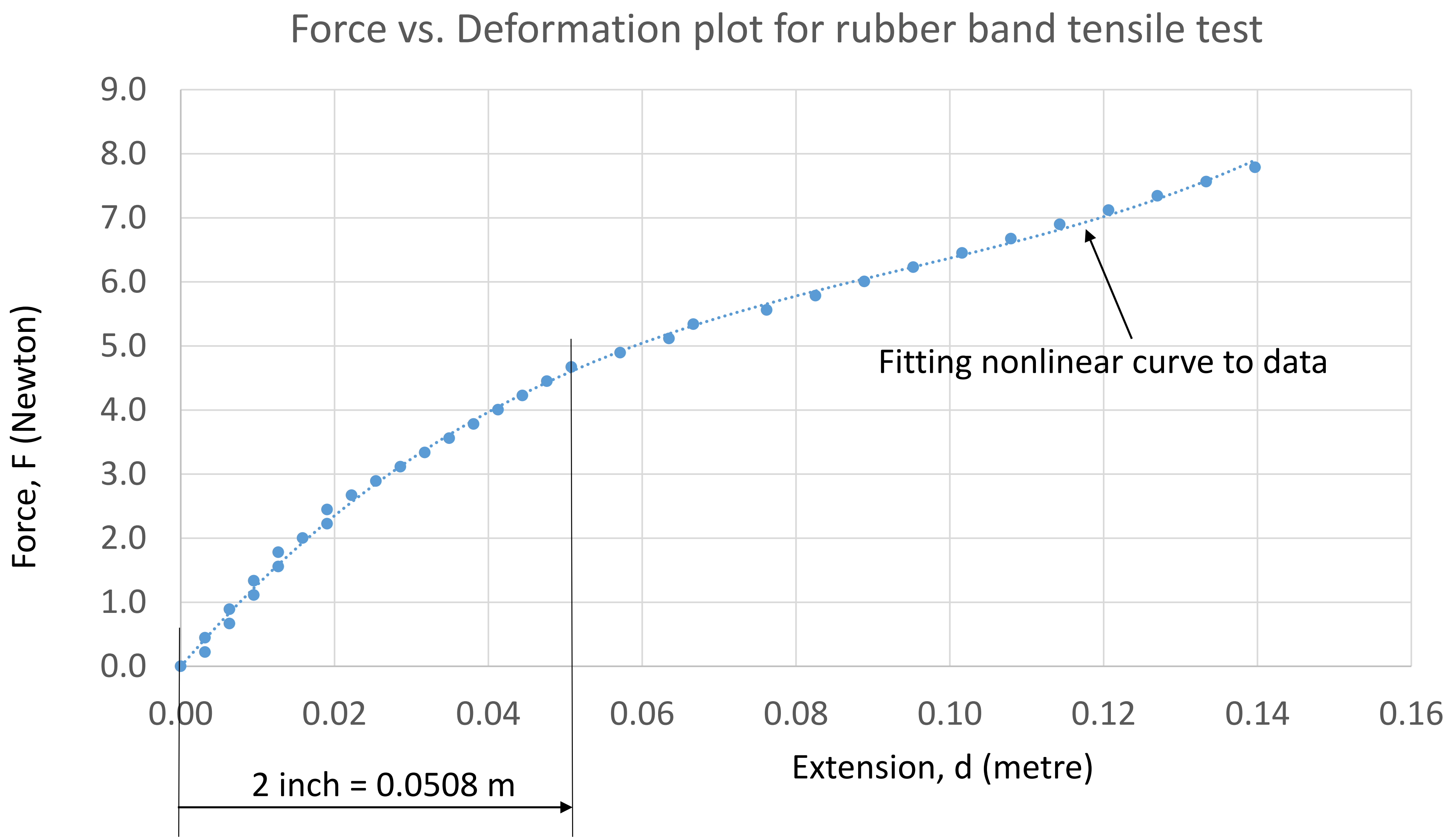
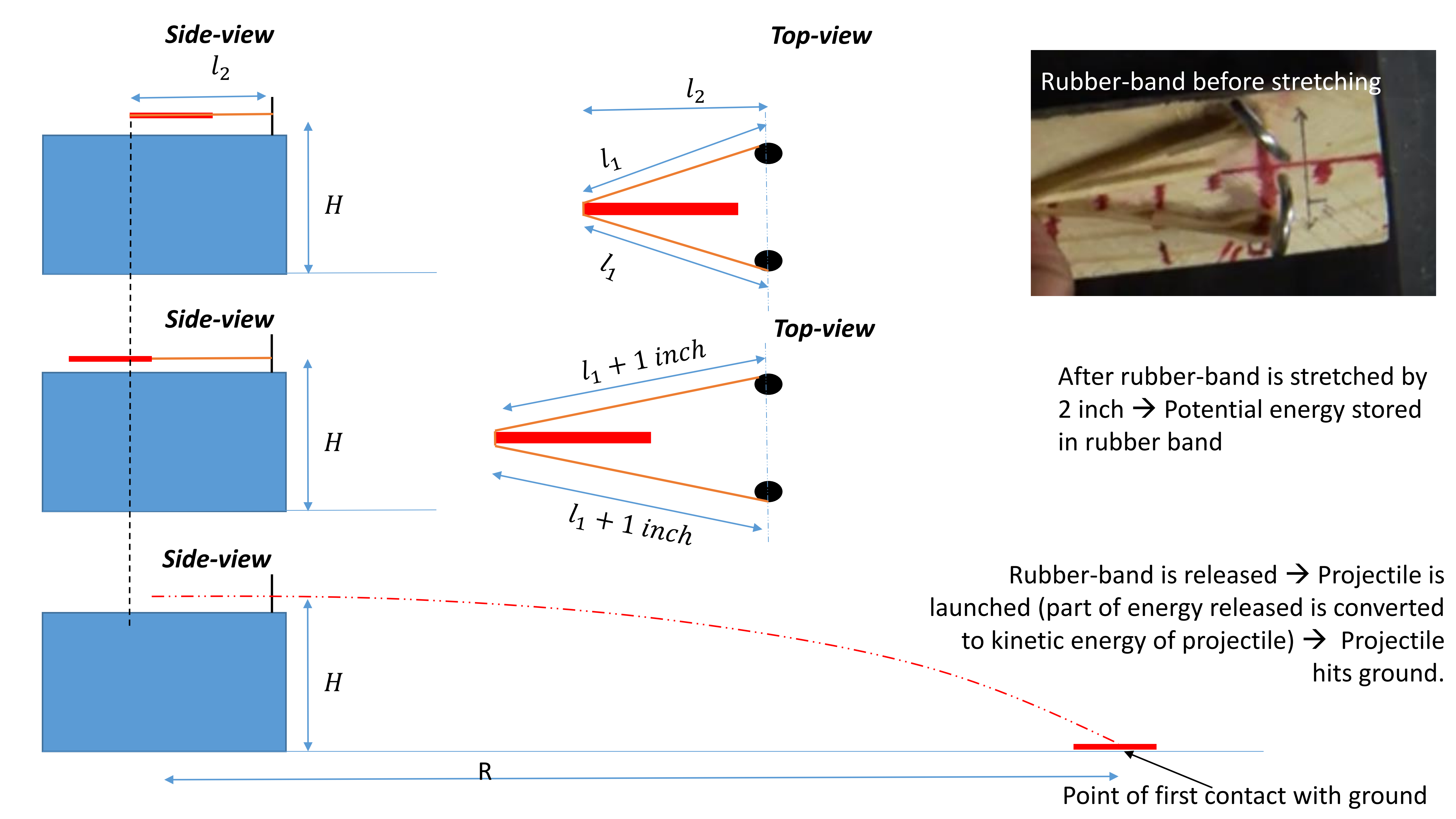
Activity 3

(Launching match-stick using rubber-band as a projectile)



Potential energy stored in the rubber band for 2 inch extension ≈ 0.14 Joule (area under the Force vs. Deformation curve from d= 0 m up to d = 0.0508 m)

DataAnalysisForActivities2and3.xlsx (sheet 1)


Side-view
l_2
H
Top-view
l_2
l_1
l_1
Rubber-band before stretching
Side-view
H
Top-view
$l_1 + 1$ inch
$l_1 + 1$ inch
After rubber-band is stretched by 2 inch → Potential energy stored in rubber band
Side-view
H
R
Rubber-band is released → Projectile is launched (part of energy released is converted to kinetic energy of projectile) → Projectile hits ground.
Point of first contact with ground

#	Range, R (metre)
1	4.2
2	4.3
3	4.4
4	4.5
5	4.1
Median	4.3

Activity 3: Launching a match-stick using the rubber-band as a projectile

- Range, R = 4.3 m (median of range values from 5 repetitions of projectile launch)
- Elevation of launch, H = 0.6604 m
- Acceleration due to gravity, g = 9.81 m/sec^2
- Mass of projectile (a match-stick), M = 0.15 x 10^{-3} kg
- Velocity of launch of projectile, $\mathrm{v} = \mathrm{R}\sqrt{g/2H}$
- Kinetic energy of projectile at launch, $\mathrm{KE}^{(\mathrm{Pr})} = \mathrm{Mv}^2/2$= 0.01 Joule
- Potential energy stored in rubber-band for 2 inch of extension, $\mathrm{PE}^{(\mathrm{Rb})} =$ 0.14 Joule
- **Ratio = $\mathbf{KE}^{(\mathbf{Pr})}/\mathbf{PE}^{(\mathbf{Rb})}$ = 0.07 = 7%**

DataAnalysisForActivities2and3.xlsx (sheet 2)

Discussion of the ratio calculated

- If we imagine the phenomena in slow motion, then the rubber band is given an instantaneous high velocity upon release. The interaction between the rubber band in motion and the projectile can be viewed as a *Collision problem*. After the collision occurs and momentum is imparted to the projectile, and the contact force gradually becomes zero, the rubber band may still be in motion until the decelerating forces, primarily from the pegs, gradually brings it to rest.
- **So the potential energy stored is being used to impart kinetic energy only to the rubber band prior to collision and then this imparted kinetic energy is shared between the rubber band and the projectile (match-stick) after the collision. The amount of kinetic energy imparted on the projectile immediately after the collision will depend on the contact mechanics (geometry of surface of contact and mechanical properties of the colliding bodies).** From our observations and model, we infer that only a small fraction (7%) of the kinetic energy of the rubber band (before collision) was transferred to the match-stick after collision. Changing the projectile (shape, size, mass) will change this ratio.

$$\text{Ratio} = \frac{\textit{Kinetic Energy of Projectile at launch}}{\textit{Potential Energy stored in Rubber Band}} \approx \frac{0.01\ \textit{Joule}}{0.14\ \textit{Joule}} = 0.07 = 7\%$$

Initial assumption that: "most of the potential energy in the rubber band is converted to kinetic energy of the projectile" does not agree with observation

Significant portion (approximately 93%) of the potential energy stored in the rubber band released in other forms of energy

For example,
Kinetic energy of rubber band immediately after projectile loses contact with rubber band

And, in the duration between release of rubber band and projectile's loss of contact with rubber band

- Sound heard when rubber band is released
- Heating of rubber
- Friction at the two end pegs where the rubber band is fixed
- Air drag on rubber band while in motion
- Energy loss due to friction and inelastic deformation at the contact between rubber band and match-stick

Major sources of measurement error

- Imprecise measurements of lengths and mass in Activities 2 and 3
- Approximating the curve that describes the Force vs. Deformation data
- Simplistic integration scheme used to calculate potential energy from Force vs. Deformation curve