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Measuring Force on Materials Worksheet Answer Key

Part 1: Introduction to Young's Modulus

1. Fill in the following table by researching the Young's Modulus value for each material:

Material	Young's Modulus
Paper	1-4 GPa
Rubber eraser	0.01-0.1 GPa
Silicon	70-80 GPa
Aluminum foil	69-73 GPa
Sheet plastic	2.8-3.2 GPa
Cardboard	0.5-2.5 GPa

2. Based on your findings, what kind of conclusions can you make? Write at least three. (Young's Modulus= YM)

Possible answers:

- Silicon and aluminum foil have close YM ranges.

- Rubber has a really low YM and is flexible.

- Silicon has the highest YM and is more tough.

- Cardboard can have a lower YM than paper.

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Part 2: Average Rate of Change

1. Fill in the following table by finding the average rate of change (ARC) of force over the given time intervals for each material:
   Answers will vary.

Material	ARC (0-5 sec)	ARC (5-10 sec)	ARC (10-15 sec)
Paper			
Rubber eraser			
Silicon			
Aluminum foil			
Sheet plastic			
Cardboard			

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2. What do you notice about the rate of change for each material over the different time intervals? Were they the same, or different?
   Average rate of change is different over the course of time. This is true for all materials, but especially the more flexible ones.

3. Based on your answer above, why do you think that happened?
   Over time, the angle at which the force was applied was changed.

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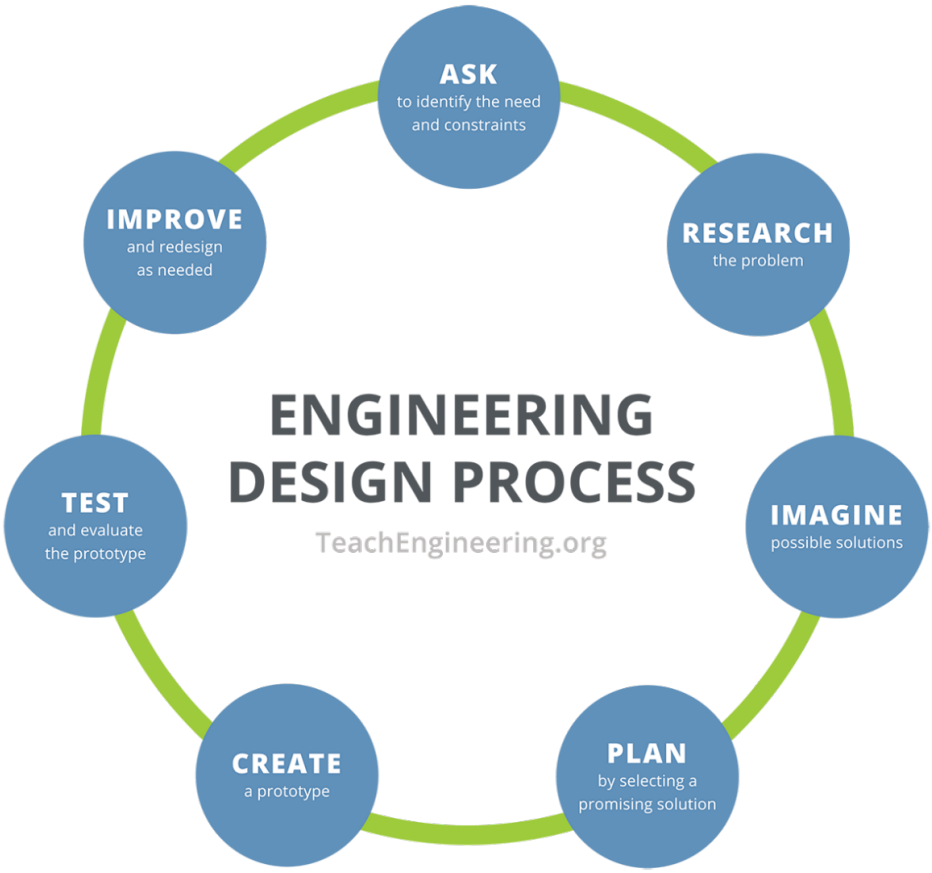
Part 3: Engineering Design Challenge

Instructions: Now you are going to use the engineering design process to prototype a device to that will allow you to apply pressure at the same angle every time for each material.



1. **Ask** – Identify the need and constraints of your problem.
   Answers will vary but should include something about creating a device to stabilize the applied pressure.

   Potential constraints: materials, time, cost

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2. **Research –** What do we know about measuring Young's Modulus? What did we learn in the previous activities?
   Average rate of change is different over the course of time. This is true for all materials, but especially the more flexible ones.

3. **Imagine** – Individually sketch out four possible solutions. Answers will vary.

a.	b.
c.	d.

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4. **Plan** – Have each team member share their ideas. As a team, select ONE solution. This can be one specific solution or a mixture of ideas. Draw your team's solution in the box below. Make sure to identify which materials you will be using.

Answers will vary.

5. **Create** – Build your prototype as shown in your group's drawings.

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6. **Test** – Test your design by measuring and recording the average rate of change in the table below.
   Answers will vary.

Material	ARC (0-5 sec)	ARC (5-10 sec)	ARC (10-15 sec)

7. **Improve** – Based on your testing and results, how would you improve your design? Why?
   Answers will vary.

Reflection Questions:

8. What do you notice about the rate of change for one material over the different time intervals? Were they the same or different?.
   Although the average rate of change for each material varied, different time intervals for the same material were more constant.

9. Based on your answer above, why do you think that happened?
   The structure allowed the force to be applied at a consistent angle over time.