Republic Polytechnic

**A107 Physics**

**Worksheet 13: The Material Matters!**

**Introduction**

1. You noticed how a golf ball deforms when it is hit by a golf club (From **Video 1**). List five examples of objects changing shape in everyday life and what might cause them to do so.

**Action of force and deformation of materials**

1. From everyday activities like stretching rubber bands, bending wires, or pulling springs – we are all familiar with the fact that objects can deform or change shape under the action of forces. Now let us consider what happens when we apply a downward force on wire hanging from a stand.

Scenario 3

Scenario 2

Scenario 1

2 kg

1 kg

Figure. 1. Wire suspended from a stand, with a mass attached at the end of the wire

Figure 1 above shows a series of actions done to a wire suspended from a stand.

In scenario 1, the wire is left suspended from a stand.

In scenario 2, a mass of 1 kg is attached to the end of the wire.

In scenario 3, a mass of 2 kg is attached to the end of the wire.

1. How would you expect the length of the wire to differ in the 3 scenarios above?
2. Would the length of the wire be different across the 3 scenarios?
3. If there is difference in length of the wire, which of the scenario would the length of the wire be the longest and why?
4. Watch **Video 2** in the problem package. From **Video 2**, verify whether your answer to Q2 is correct.
5. Now let us consider the situation as shown below in Figure 2. Two wires of equal length made of same material but of different thickness are suspended on a stand.

Mass attached to the wires

Wires of same length

Thick wire

Thin wire

Thick wire

Thin wire

2 kg

2 kg

Figure. 2. Wires of different thickness with mass attached at the end of the wire

A mass of 2 kg is subsequently hung over the free end of both the wires.

1. How would you expect the extension of the two wires to differ when the mass of 2 kg is attached to the end?
2. Which of these two wires will extend more and why?
3. Watch **Video 3** in the problem package. From **Video 3**, verify whether your answer to Q4 is correct.
4. From the two videos, we know that when a tension force is applied to a wire, the length of the wire will extend.

Would the extension of the wire be restricted to the free end of the wire or would the extension of the wire be spread across the entire wire?

1. Watch **Video 4** in the problem package. The attached file “Extension of wire.doc” is the snapshot pictures of the starting scene and ending scene of **Video 4**.



From **Video 4**, verify whether your answer to Q6 is correct.

1. From your discussion from Q1 – Q7, summarise the ideas you have obtained.

**The physics of materials**

1. The distribution of the force exerted over the cross-sectional area normal to the applied force is known as the stress (generally denoted by ******with the S.I. units of Pa or N/m2).



Force

Wall

Cross-sectional Area

Figure 3. Consideration of stress: Cross-sectional area is perpendicular to applied force

Which of the wires in Q4 experiences a higher stress? Why? What is the unit for stress?

1. When stress is applied across wire, the wire will extend in length (deformation). Scientists measure the degree of deformation by a measure called **strain**. Figure 4 shows the strain undergone by a wire when it is subjected to stress.

Applied

stress

Before:

Original distance between markings, *L*0

Figure 4. Concept of strain

Wall

Final distance between markings , *Lf*

Change in length, ********= *Lf – L*0

After:

Strain, **, is defined as: ******

*L*f = final length

*L*0 = original length

*δ* = change in length

1. What is a possible unit of strain?
2. Find the strains incurred for Rod A and Rod B in Table 1:

Table 1: Comparison of strains

|  |  |  |
| --- | --- | --- |
|  | Rod A | Rod B |
| Original length (m) | 1.0 | 2.0 |
| Final length (m) | 1.1 | 2.2 |
| Strain |  |  |

1. Comment on the change in overall length and the strain for each of the two rods.
2. A bar undergoes a strain of −0.2 due to a force. When would the strain be negative?

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1. A rod of length of 20 cm and diameter of 5 mm is subjected to a tensile (pulling) force of 1540 N, and the rod extended by 0.5 mm.

Force = 1540 N

wall

Figure 5. Rod pulled with a force of 1540 N

* + - 1. What is the stress experienced by the rod?
      2. What is the strain in the rod?

**Stress-Strain Relationship: Linear, non-linear**

1. The stress-strain graph for a rod has a shape as shown below:

Figure 6. Example of stress-strain c)brittle, ductile, stiff, flexible, etc.f elastic and plastic deformatio ormation before failure due to imposed load.type of decurve

*Strain*

**x** Fracture

(b)

(a)

**0**

*Stress*

(c)

* + - 1. When loaded from zero up to Point (a), the graph is a straight line. Scientists call Point (a) the proportional limit. What could be the reason for this name?
      2. If the stress did not go beyond Point (b), when the force is released, the rod retraces back the same stress-strain path to the original shape. This kind of regaining of shape is known as elasticity. Propose a name for the limit Point (b).
      3. Once a material is loaded beyond Point (b), it undergoes permanent deformation which means that the material does not regain its original shape and size upon removal of the load. This type of deformation is termed as “plastic deformation”. Ductile materials like mild steel are known to undergo large plastic deformation before failure due to imposed load. What happens to a deforming material when it reaches the Fracture Point (c), as indicated in Figure 6?

1. The following stress-strain graph is for another material. Comment on this material.

Strain

Stress

**x** fracture

Elastic deformation

Figure 7. Stress strain curve for another material

**Characteristic properties for different materials**

1. The following stress-strain curves are for three bars of the same size and shape but made of different materials.

Stress

Strain

Material A

100 kN/m2

Material B

Material C

Figure 8. Stress-Strain behaviour of three different materials

1. Which material deforms most? Which deforms the least?
2. Which is the stiffest? Which is the most flexible?
3. The gradient of the stress-strain curve within the proportional limit gives the Young’s modulus of the material.
4. Referring to Figure 8, which has the largest Young’s modulus? Which has the smallest Young’s modulus?
5. Briefly describe what the Young’s modulus tells us about a material.
6. Comparing steel and rubber, which would have a larger Young’s modulus? Explain your answer.