Student Guide

Design Challenge: Incorporating Shape Memory Alloy into a Rube Goldberg

Lesson Overview: This lesson consists of two parts. In Part 1, you will determine which of a set of wires is a unique metal alloy called Nitinol. Nitinol is called a shape memory alloy (an SMA) because it can "remember" its original shape under certain conditions after being bent, twisted, or stretched out of shape. Part 2 of this activity will have you design a Rube Goldberg device which will perform a simple task that will be activated by Nitinol.

Part 1. Wire Activity

Objectives: At the end of this activity you will:

- Know that a shape memory alloy "remembers" original shape after being deformed.
- Know that Nitinol can undergo phase changes while in the solid state, and these phases are temperature dependent.

Procedures:

Part A.

Read about the history of Nitinol wire and answer in your lab notebook the questions below.

1. What two metals make up Nitinol?
2. What is Nitinol an acronym for?
3. What larger project was William J. Buehler working on when he discovered something unique about nickel-titanium alloys?
4. What initially compelled Buehler to drop one of the cooled bars on the concrete floor?
5. Why did Dr. Muzzey heat the demo wire with his pipe lighter?
6. How do your answers for questions d and e show that doing science involves curiosity, imagination, and creativity?
7. Provide evidence from the reading that shows how science is **NOT** a solitary activity.

Part B.

Materials: (per group)

- pieces of wire
- beaker
- water
- ice
- hot plate
- candle
- matches
- tongs
- plastic container
- thermometer

Developed by Joyce Palmer Allen
*Development and distribution partially funded by the **National Science Foundation***

Procedure:

1. Prepare two bowls of water: one that contains hot water (80º C or higher) and another that contains ice water.
2. Deform each of your pieces of wire (bend, twist, pull, reshape, but do not tie in a knot) then place each piece in the hot water and record your observations below.
3. Using tongs or tweezers, try to bend the wire while it is still in the hot water. Are any of the wires easily deformable at this temperature?
4. Now remove each piece of wire from the hot water, USING TONGS or TWEEZERS, and drop the wires into the ice water WITHOUT deforming them. Observe the wires for a few moments and they cool down. Record your observations below.

5. Decide which of the wires is the Nitinol wire. Check your choice with your teacher.
6. Read the information below:

How Nitinol Works

We're all familiar with such phase changes as the melting of ice or vaporization of water. Less known is that such phase changes can occur when both phases are solid such as the change from graphite to diamond. Many materials undergo such transformations, which involve rearrangement of the position of atoms, molecules, or ions within the crystal lattice. In a non-memory metal the strain of deformation is absorbed by the rearrangement of the crystals, and it is impossible to get the crystals back into exactly the original position. In Nitinol, the crystals stay in place; the atoms within the crystals rearrange themselves, and the distorted object reverts to its original shape. This is called a solid state phase change

Part C.

Next you will try to change the pre-set shape of your piece of Nitinol wire by holding it into a desired shape over a candle. **DO NOT DO THIS WITH YOUR BARE HANDS!** Follow direction below:

1. Choose a simple shape, such as a loop, horseshoe, V, and use your forceps to hold your piece of Nitinol in this shape.
2. Hold the wire in tight with forceps at each end as you place the wire in the flame. The wire will initially resist (you will feel a pull) and attempt to return to its original shape. You must continue to hold the wire tight with the forceps and keep the wire in its new position.

Developed by Joyce Palmer Allen
*Development and distribution partially funded by the **National Science Foundation***

3. As soon as you feel a release of tension while you are heating the wire, you may then remove it from the flame.
4. Let the wire cool down before touching it.
5. After the wire is completely cooled, straighten it out.
6. Place the wire in the container of hot water from Part B. Does your wire remember the shape from part C?

Developed by Joyce Palmer Allen
Development and distribution partially funded by the ***National Science Foundation***

Part 2. The Rube Goldberg Challenge

Introduction: You work for the "Physics is Fun" public relations firm and you have been hired by the Nanotechnology Technology Industry to produce a two minute commercial that shows a Rube Goldberg device that will launch a ping pong ball at least one meter. The Rube Goldberg device must be started by the activation of a Nitinol wire. A Rube Goldberg device is a device that performs a simple task with a chain reaction of events.

Goal: Your team must design and produce a device that will launch a ping pong ball at least 1 meter when activated by a Nitinol wire.

Items to be completed and presented to your teacher by: _____ (due date)

- Rube Goldberg device (one per team)
- Diagram of device showing all energy transformations (one per team)
- A video of a two minute commercial (one per team)
- One page essay over how a shape memory alloy works (one per person)

Rules:

1. Machine must complete the main task which is to launch a ping pong ball at least 1 meter.
2. Machine must fit within the dimensions 3 ft x 3 ft x 3 ft.
3. Machine must run a minimum of 15 energy transformations.
4. Machine must not run longer than 3 minutes.
5. Any flying or loose objects must remain inside the machine except for launched ping pong ball.
6. No explosives or hazardous materials allowed.
7. Only heat source used to activate Nitinol wire allowed.
8. No external or AC power.
9. The machine must be determined safe by the teacher.
10. Only materials given to group can be used except for glue or tape.
11. Only human intervention allowed is activation of Nitinol wire.
12. Energy Transformations allowed are mechanical or thermal. Examples are: mechanical-kinetic/potential, thermal and magnetic
13. Materials given to each group include:
    4"x4" Styrofoam block
    17 large tongue depressors
    2 small magnets
    8 bathroom size paper cups
    1 ping pong ball
    2 meters of string or cord
    2 small hinges
    6 plastic spoons
    2 regular mousetraps
    2 small wooden spools
    50 small tongue depressors
    15 rubber bands (assorted sizes)
    10 drinking straws
    3 metal springs (assorted sizes)

Developed by Joyce Palmer Allen
*Development and distribution partially funded by the **National Science Foundation***

15 flat sticks (balsa wood)
15 square sticks (balsa wood)
4 different types of dowel rods
8 balloons
6 different pulleys
1 sheet tissue paper
4 gears,
25 marbles
5 black plastic wheels
1 sheet graph paper

*All rules are subject to changes or clarification by the teacher.

Developed by Joyce Palmer Allen
*Development and distribution partially funded by the **National Science Foundation***