Materials

Worksheet 8

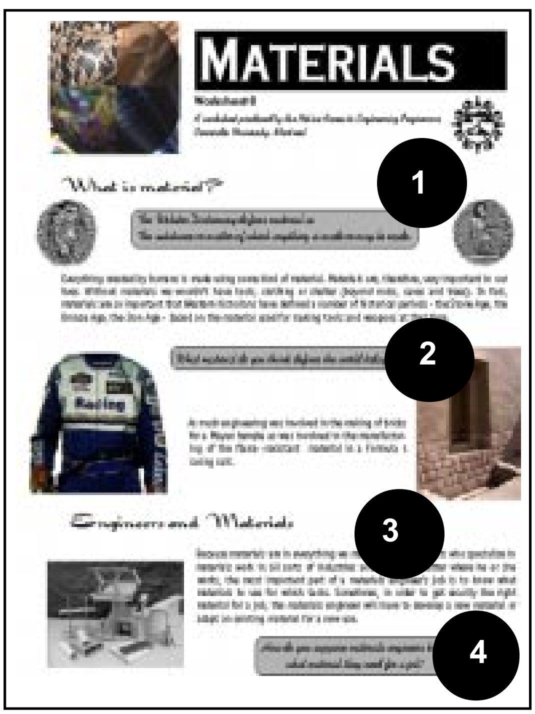
A worksheet produced by the Native Access to Engineering Programme

Teacher's Guide

This guide contains some suggestions for how you can work with worksheet 8, "Materials."

1. Definition
   Do the students understand the definition of materials? Can they identify materials from the definition? Strictly speaking from the definition just about any kind of matter could be considered a material. For the purposes of engineering, however, materials are usually substances which can be used for building, manufacturing and construction - metals, ceramics, cloth etc.

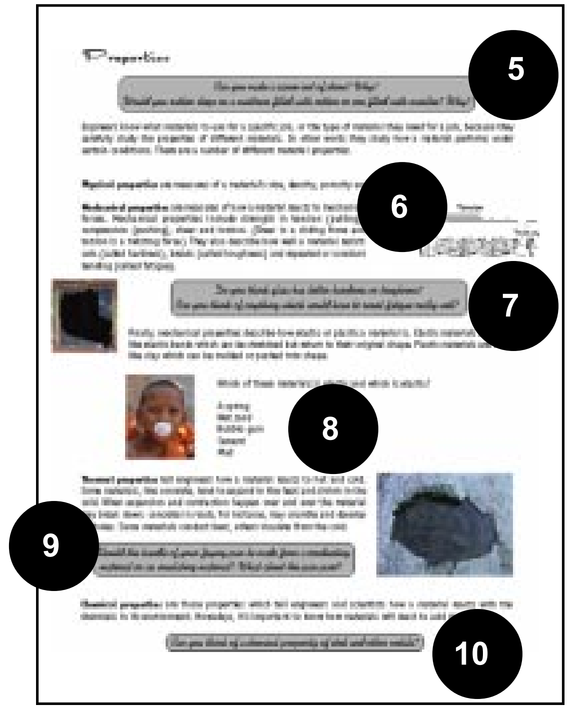
2. There are many materials which the students might pick, two of the best are plastics and silicon.
   Plastics are used in an uncountable number of things which we use everyday - refrigerators, cars, furniture, clothing (polar fleece is made in part from recycled pop bottles), aircraft, boats, running shoes, food wrappings etc. It is also key in medicine where it has become a cheap, sterile, light weight replacement for glass. Silicon is the material which serves as a base for computer chips and, therefore, a huge part of the current communications infrastructure.



3. Materials engineers are involved in just about every major sector of the economy (and most of the other sectors too). Here are a few examples:

   - In construction they develop new, more energy efficient materials for building homes.
   - In transportation they look for materials which are lighter or more resistant to heat and fatigue.
   - In communications technology the materials which carry messages - copper, fibre - are studied in order to optimise their use.
   - In computing, engineers and scientist are looking for new materials which will allow computers to process information faster. Leading edge research is focusing on using biological materials instead of mineral ones.
   - The oil and gas industry employs many materials engineers since by-products from oil and gas production can be used in the manufacture of many types of plastic products.

4. Like all other engineers, materials engineers have to know in detail what it is they are trying to accomplish. So before they look at what materials to use, they'll ask lots of questions about what is expected from the material. Does it need to be strong? Does it need to last a long time? Does it need to be a specific colour? These are just a few of the questions they might ask. Actually most of the work of a materials engineer occurs when people, often other engineers, cannot find the material they want for a specific job. It is up to the materials engineer to try and develop a new - or modified - material which meets the specified requirements.



5. Your students may think these are silly questions, stone canoes would sink and marble mattresses would be really uncomfortable, but ask them how they know these things. It is precisely because they know about the properties of stone and marbles that they will think the questions are nonsense. Materials engineers have to know the properties of the materials they work with that well.

6. Tension and compression were explained in Worksheet #1, "Structures."

7. Glass usually breaks easily but resists cuts well. It has better hardness.
Fatigue is wear or breakage which results from continuous or frequent use, so the students should think of things which get used often. Door hinges, airplane wings, diving boards, wheel axles, joy sticks on video games are some examples of items which need to resist fatigue.

8. Spring: elastic (Usually only in compression, in tension it is probably somewhat plastic.)
wet sand: plastic
bubble gum: elastic
cement: plastic
mud: plastic

9. If you don't want to get burned, the handle should be made out of some type of insulating material. The pan, on the other hand, should conduct heat evenly so you can cook your food.

10. Many metals corrode in reaction to the oxygen in the air. This is a process known as oxidation or more commonly as rusting.

11. Some sunglasses are just darker than regular glasses to help us see more easily in bright light. These days, however, most glasses are also polarized in order to protect our eyes from harmful Ultra Violet rays from the sun. When lenses are polarized they act to filter out harmful UV Rays (and other wave lengths which cause glare) and allow only light in the visible spectrum to reach our eyes.

12. Often when you yell into a canyon you'll hear an echo. Rock does not absorb sound very well, so an echo is actually your voice being reflected off the rock. If you hear your voice several times, it has been bounced off the rock that many times.

13. Rubber is an insulator which does not carry electrical charge. Wearing rubbers boots or rubber-soled shoes while working with electricity reduces the risk of being shocked.

14. The answer to this question will vary from community to community. In general, the students should find that the materials used the most were those which were readily available in the local area.

15. There are often many solutions to any engineering problem, as is indicated by the many ways in which housing needs were met by Aboriginal peoples. It might be an interesting project for your students to look at other engineering issues - like transportation, communication, food storage and preservation etc - to see how they were addressed in different ways by different peoples and nations.

16. Because the branch is hollow it will hold air. While being held under water the change in pressure will force the trapped air out of any cracks or holes along the branch's length. The person making the didgeridoo will be able to see where the hole is by watching for the source of any escaping air bubbles.

 The didgeridoo maker would want the branch to be completely sealed along its length in order to make the instrument play. If air were to escape along the branch's length it make not play the desired note. If enough air escapes, it might not be playable at all.

17. For a lot more information regarding polymers visit the Macrogalleria at http://vmesa17.u-3mrs.fr:10085/~www-pol/macrogalleria.html

 You can make a polymer with your students.

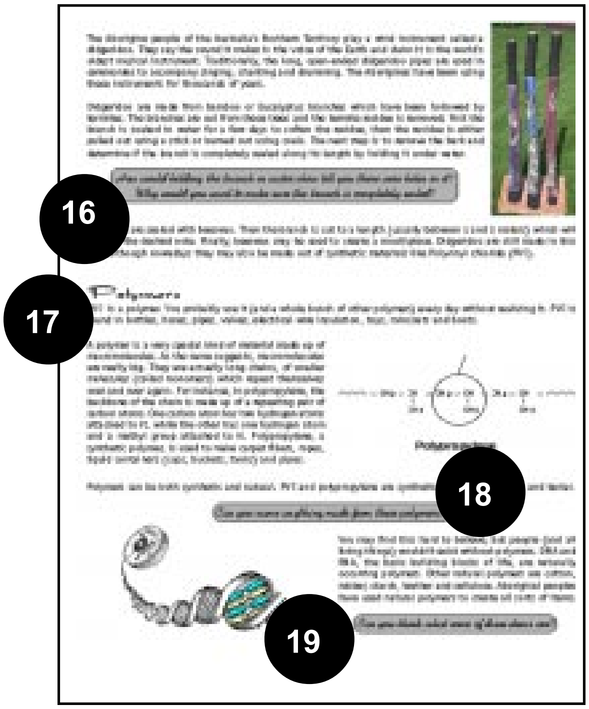
 You need:
 2 empty 2l pop bottles
 water
 1l white glue
 borax (a laundry product available at most grocery stores)
 styrofoam cups
 Food colouring (optional)

 Preparation:
 (You can make this part of the activity if you wish.)

 - In the first pop bottle, mix equal amounts of water and white glue (~ 3/4 of litre each). Shake the bottle to mix well. Add food colouring and shake again.
 - Fill the second pop bottle almost to the top with water and add about 1/2 cup of borax. Shake until the borax is dissolved.

 Activity:
 Give each student a styrofoam cup. Fill each cup about half way with the glue mixture. Then add a small amount (about 30 ml or 2 tbsp. or fill the cup to about 3/4 full) of the borax mixture to each cup. Have the students mix the two liquids together with their fingers. Alternatively, they can pour it out on a desk and knead until the liquid disappears. The result should be a slimy plastic material. If the liquids don't combine add a little bit more glue to the mixture.

 Explanation:
 The borax and white glue have undergone a chemical reaction and created a polymer. Have the students study its properties.



18. Nylon, rayon and kevlar are fairly common polymers.

Rayon is used mostly for making clothes. It was developed as a synthetic silk and can be used for most of the same purposes.

Nylon is one of the most common polymers. It was also developed as a silk replacement. It is used in clothing, hosiery, ropes, thread, and sporting equipment of all types.

Kevlar is actually a member of the nylon family called aramids. It is used to make things like bullet proof vests, puncture resistant bicycle tires and canoes. Blends of Kevlar are used to make fireproof clothing. Kevlar in blends with another aramid called Nomex also protects fire fighters.

19. Natural polymers include leather and cellulose (found in wood and plants). Aboriginal peoples have used these materials for all sorts of items including clothing, sleds, canoes, weapons, and all sorts of tools.

20. Any kind of tape is a composite material. Other composites include plywood, mirrors, reinforced concrete, concrete, many insulating materials and even the materials used to make airplanes. Natural composites include trees, spider webs and shells.

Solutions

Problem 1

I. What do you know?

	Cement	Sand	Gravel
Mixing Proportion	1	2	5
Amount on hand (tonnes)	237	572	1180
Cost/tonne ($/tonne)	20.00	12.50	22.50

II. Determine the limiting factor
All the elements have to be mixed together in a specific proportions, but we have to determine which material will limit the amount of concrete we can make.

Start by assuming you want to use all of the cement and see if there is enough sand and gravel to do so.

Sand:

$$\begin{aligned} \text{Sand}_{\text{req'd}} &= 2 \times \text{cement} \\ &= 2 \times 237 \text{ tonnes} \\ &= 474 \text{ tonnes} \end{aligned}$$

Since we actually have 572 tonnes of sand, there is more than enough sand to mix with the cement.

Gravel:

$$\begin{aligned} \text{Gravel}_{\text{req'd}} &= 5 \times \text{cement} \\ &= 5 \times 237 \text{ tonnes} \\ &= 1185 \text{ tonnes} \end{aligned}$$

We only have 1180 tonnes of gravel which is not enough to mix with the cement. Gravel is, therefore, the limiting factor.

III. Based on the limiting factor, determine how much of the other materials will be used.

We want to use as much of the available materials as possible to minimize any waste, so we want to try and use all of the gravel.

Cement:

$$\text{Cement}_{\text{req'd}} = \frac{\text{Gravel}}{5} = \frac{1180 \text{ tonnes}}{5} = 236 \text{ tonnes}$$

Sand:

$$\begin{aligned} \text{Sand}_{\text{req'd}} &= 2 \times \text{cement} \\ &= 2 \times 236 \text{ tonnes} \\ &= 472 \text{ tonnes} \end{aligned}$$

Answer:
You will use:
236 tonnes of cement
472 tonnes of sand
1180 tonnes of gravel

III. Determine how much money the leftover materials represent.

There is no leftover gravel.

Cement:

$\$_{cement} = (cement_{on\ hand} - cement_{req'd}) \times \text{price of cement}$

$= (237 \text{ tonnes} - 236 \text{ tonnes}) \times \$20.00/\text{tonne}$

$= 1 \text{ tonne} \times \$20.00/\text{tonne}$

$= \$20.00$

Sand:

$\$_{sand} = (sand_{on\ hand} - sand_{req'd}) \times \text{price of sand}$

$= (572 \text{ tonnes} - 472 \text{ tonnes}) \times \$12.50/\text{tonne}$

$= 100 \text{ tonnes} \times \$12.50/\text{tonne}$

$= \$1250.00$

$\$_{total} = \$_{cement} + \$_{sand} + \$_{gravel}$

$= \$20.00 + \$1250.00 + 0$

$= \$1270.00$

Answer:
The leftover materials represent $1270.00

Problem 2

I. What do you know?

- 40 hectares of land
- 2500 trees per hectare
- 2 years before replanting can begin
- Get 20 natural seedling from every 10,000 trees
- Trees need 10 years to mature
- Plan 1 harvests 10% of the trees per year
- Plan 2 harvests 5% of the trees per year
- Project is not sustainable if
  - The number of trees constantly declines in any 5 year period
  - The number of immature trees is ever more than 50%

II. Evaluate Plan 1

This problem is quite involved, however the math is basic addition and subtraction. If the students make a table as explained below and shown in Table 1 on page X, it should be easier to do.

Column I: Year

Column II: Number of trees in the forest at the beginning of the year.

For year 1 the number of trees is:

Area x # trees per unit area =
40 hectares x 2500 trees/hectare =
100,000 trees

In every other year, it is equal to the previous year end's total which will appear in Column XII.

Column III: Number of trees cut
This number is equal to 10% of Column II.

For any year (using year 1 as an example):

# of trees cut = # trees x 0.1
= Column II x 0.1
= 100,000 trees x 0.1
= 10,000 trees

Column IV: Number trees remaining
For any year (using year 1 as an example):

trees left = # trees - # trees cut
= Column II - Column III
= 100,000 trees - 10,000 trees
= 90,000 trees

Column V: Planting
This column just is a check to see whether you can plant or not. In year 1 and year 2 there can be no planting as the ground has to recover for two years before any planting can be done.

Column VI: Number of trees planted
The number of trees planted in any year is equal to the number cut 2 years previously. So, in year 3, Column VI should be the same as Column III for year 1 and in year 4, Column VI should be the same as Column III for year 2 and so on.

Column VII: #trees/10,000
This number will be used to determine the number of natural seedlings which survive each year. It is determined by dividing the number of trees at the beginning of the year (Column I) by 10,000.

For any year (using year 1 as an example):

trees/10,000 =
Column I/10,000 =
100,000/10,000 = 10

Column VIII: Number of natural seedlings
For any year (using year 1 as an example):

seedlings = Column VII x 20 trees
= 10 x 20 trees
= 200 trees

Column IX: Number of trees planted 10 years ago
This column will equal zero until year 11, at which point trees planted 10 years previously will be mature.

Column X: Number of immature trees
For any year (using year 1 as an example):

immature trees = # immature trees from the previous year + # trees planted + # seedlings - # planted 10 yrs. ago
= Column X (previous entry) + Column VI + Column VIII - Column IX
= 0 trees + 0 trees + 200 trees - 0 trees
= 200 trees

Column XI: Total number of trees at end of year.
For any year (using year 1 as an example):

Total # trees = # trees left + # trees planted + # seedlings
= Column IV + Column VI + Column VIII
= 90,000 trees + 0 trees + 200 trees
= 90,200 trees

Column XII: Percentage of immature trees

For any year (using year 1 as an example):

$$\% \text{ immature trees} = \frac{\# \text{ immature trees}}{\text{total } \# \text{ trees}} \times 100$$

$$= \frac{\text{Column X}}{\text{Column XI}} \times 100$$

$$= \frac{200 \text{ trees}}{90{,}200 \text{ trees}} \times 100$$

$$= 0.2\%$$

Column XIII Is it sustainable?

At this point students should check whether the forestry is sustainable given the two requirements for sustainability. It is unsustainable if

- The number of trees constantly declines in any 5 year period
- The number of immature trees is ever more than 50%

From the table students will be able to see that harvesting 10% of the forest each year will become unsustainable after 7 years as the number of immature trees will exceed 50%.

II. Evaluate Plan 2

The students should follow the same steps in evaluating Plan 2 (see Table 2). You can tell them that they can stop calculating when they are reasonably sure the project is sustainable (they should be able to be sure after about 13-15 years).

Answer:
To practice sustainable forestry the community should choose Plan 2, harvesting 5% of the forest each year.

Enrichment:

If you want to make the exercise a bit more challenging you can ask them to determine if the % of immature trees ever stabilizes. To do this they should calculate Plan 2 through 25 - 40 years, as shown in Table 3. If they are learning to use a spread sheet programme like Excel or Lotus the easiest way to do this would be to set up a table within the programme and get them to generate the values by programming the appropriate formulae in each column.

Answer:
The % of immature trees stabilizes around 41.1%.