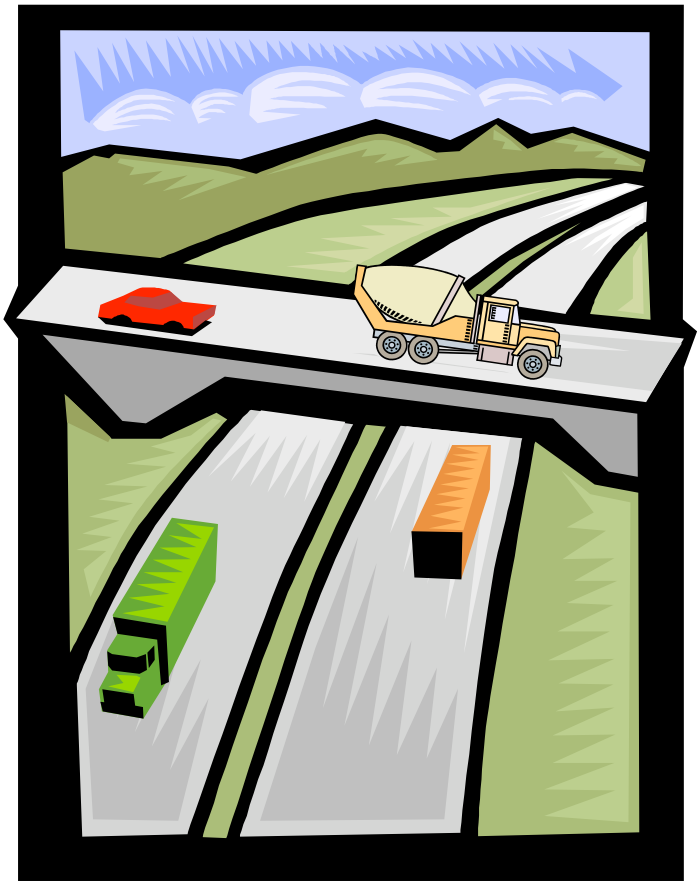
centre de développement pédagogique
pour la formation générale en science et technologie

Working document



CONCRETE

STUDENT BOOKLET

May 2008

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Context and mandate

NOTE **This activity was designed within the framework of teacher training sessions. It will require adaptation before being used with students.**

Concrete structures surround us. A picture of a big city's downtown core is enough to convince us of this fact. Concrete is also used to make hydro-electric dams, pools and, of course, roads. Concrete bridges and overpasses are very impressive structures. To build them solidly, many factors must be taken into account. Designing and building an overpass is a complex task that must not be taken lightly. The collapse of the de la Concorde overpass in Laval on September 30th 2006 is a sad example of botched work.

Complex task

We are suggesting that you act as a subcontractor for a company that builds overpasses. You must therefore design and build a concrete beam that will be a component of an overpass over an autoroute. To do so, you must respect a precise specifications booklet. At the end of the exercise, each team must submit their beam to a destructive test to determine how many times the beam can support its own weight. This test is the ideal occasion to organize a friendly competition between the teams.

Go forth, engineers in training - to your pencils, saws and trowels, there is a competition waiting to be won!

Student mandate suggested to the teaching staff

The students should:

Define the problem in relation to the specifications booklet

Become familiar with the concepts touched upon in the fabrication of a concrete structure

The students must form teams of two people and meet to complete the learning activities (the seven questionnaires or experiments).

Detail their mandate following the learning activities

Design and build the beam while respecting the specifications booklet

a) Designing the beam (drawings of the beam with its reinforcements)
b) Building the forms with the guidance of a manufacturing range
c) Installing the reinforcements
d) Pouring the concrete
e) Supervising the concrete curing

Proceed to beam testing (destructive resistance test)

Commission of inquiry regarding the collapse (analysis of results and improvements)

Specifications booklet

Each team must design a concrete beam while respecting the following parameters:

a) In terms of the *physical aspect, (elements of nature)* the beam must:

- Resist corrosion in a humid environment

b) In terms of the *technical aspect (function and maintenance),* the beam must:

- Be 19 mm (3/4 inch) or 27 mm (1 inch) wide
- Be 570 mm ±10 mm long
- Have a useful span of 500 mm
- Have reinforcement made up of AWG #14 calibre steel
- Have flexion of less than 60 mm
- Support as large a mass as possible
- Have the smallest possible mass

c) In terms of the *human aspect (security),* the beam must:

- Not have any sharp edges
- Not have any sharp elements from the reinforcement at the surface

d) In terms of the *industrial aspect (production)* the beam and its shape must:

- Be built only with the material supplied by the teaching staff
- Be built only with the tools available in class (laboratory or workshop)
- Be built in teams of two students
- Be built within two periods (1 for the form, 1 for pouring the concrete)

e) In terms of the *economical aspect (cost analysis)* the beam must:

- Contain at most 1000 mm of AWG 14 calibre steel wire
- Contain at most 150 mL of Portland cement powder
- Contain a variable quantity of gravel, sand and water

Defining your problem

1. *What must I do to fulfill this mandate?*

2. *What do you know about concrete?*

3. *What scientific and technological concepts must you become familiar with in order to fulfill the proposed mandate?*

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Safety capsule

Cement and concrete




1. Careful! Prepared cement and concrete are corrosive.
2. In case of contact, wash skin then wash your hands at the end of the manipulations.
3. Wear safety glasses to protect yourself from splashing. In case of contact with eyes, rinse them immediately using the eyewash that is present in class.
4. Use a mask if cement powder is suspended in the air. If you manipulate the powder carefully, wearing the mask will not be necessary.
5. Wear protective clothing to avoid accidental projections.
6. Clean the work surface after manipulations to avoid potential splashing. A solution of hydrochloric acid may be used to clean tough deposits.
7. Do not dispose of leftover cement or concrete in the drain, since this could block it. Instead, dispose of waste in a plastic bag in the garbage. The water from the final rinse may be put down the drain using strongly flowing water.



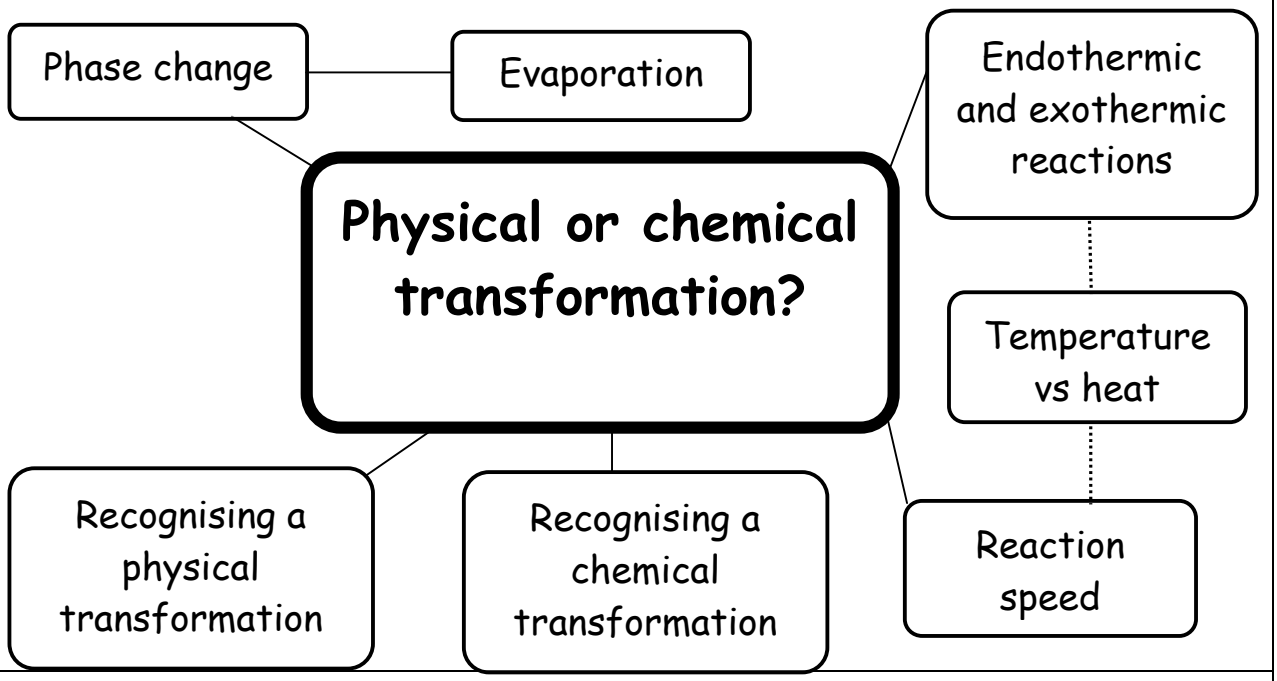

Ensure that any modifications to this safety capsule do not compromise student safety. The person at fault would have to assume responsibility for his choices.

I- Laboratory about cement hardening

Question: Is the hardening of cement due to simple dehydration or to a chemical reaction?

Prove it experimentally

Exploration card



Objective and justified hypothesis

Details of the action plan (Protocol)

Material

- 100 mL of quick set cement
- 2 glasses of expanded polystyrene
- 1 alcohol thermometer
- 50 mL of water
- 1 metallic spatula
- 1 disposable plastic test tube

Sketch

Manipulations

Substantiate the action plan
(Executing the protocol, gathering the data or observations)

Analyse the results (Treat the data [calculations, graphs], conclusion ,discussion)

II- Questionnaire about cement hardening

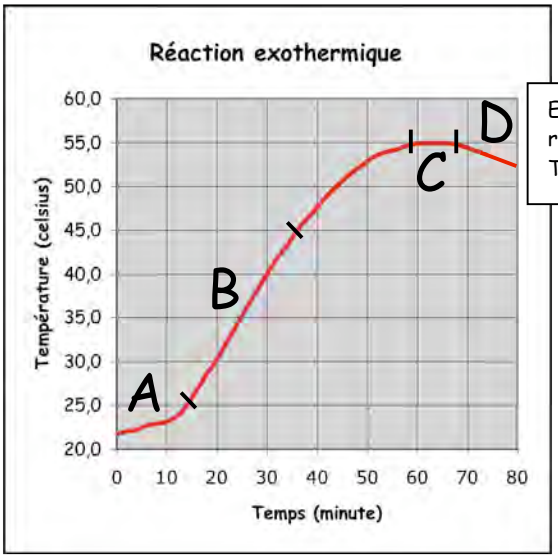
Question 1
Is the hardening of cement a physical or chemical reaction? Why?

Question 2
Given the fact that the reaction began with the addition of water, is it preferable to keep the cement moist or to promote its dehydration during the transformation? Why?

Question 3
What distinction can you make between heat and temperature?

Question 4
The adjoining graph shows the variation in temperature during an exothermic chemical reaction. **Which parts of the curve correspond to the following situations? (Associate)**

(The reaction releases less heat than heat is lost in the environment) ( )
(The reaction releases heat at a constant rate) ( )
(The reaction releases as much heat as heat is lost in the environment) ( )
(The reaction begins to release heat) ( )



Exothermic reaction
Time (minut

Question 5

What could be the effect of excessive temperature on the hardening of cement? (Hint: What will happen to the water in the mix?)

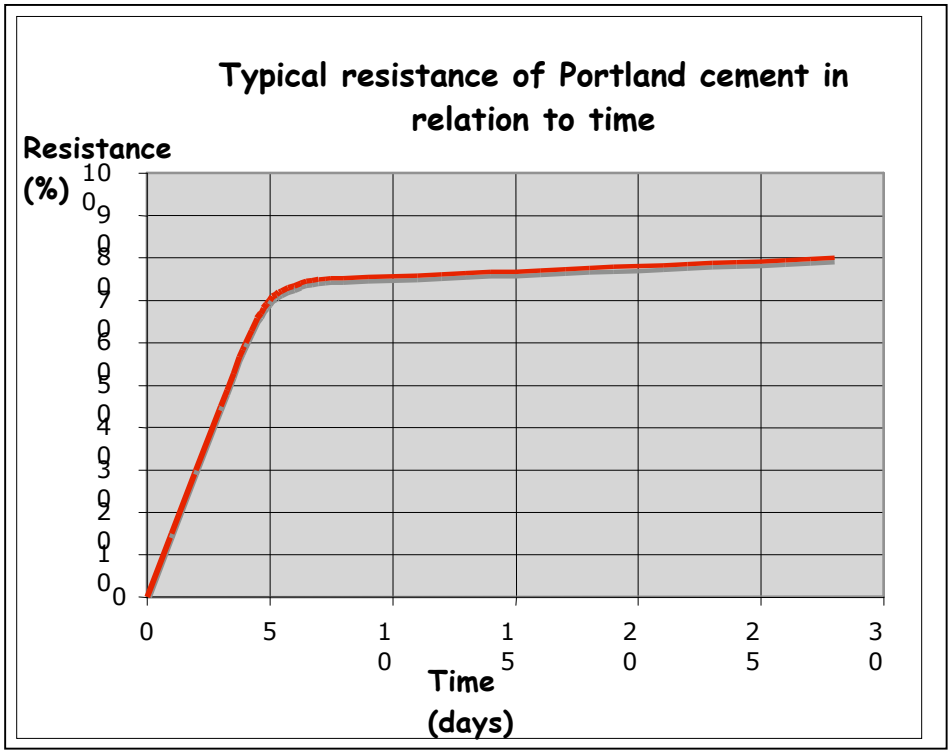
Question 6

Cement powder can be ground more or less finely. The smaller the grains, the greater the total surface of all the grains combined. In chemistry this is called an efficient surface or a contact surface.

In your opinion, how large must the cement grains be so that the cement hardens quickly (large or small)?

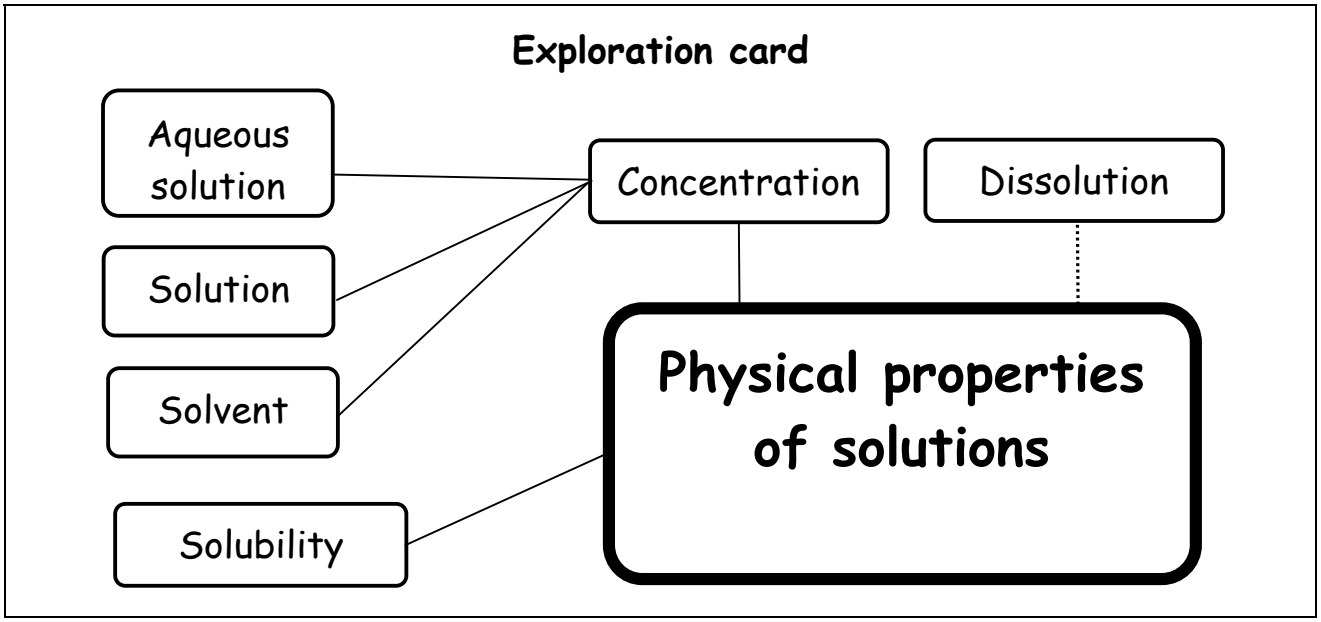
Question 7

Referring to the graph below, determine how many days are required for the cement to attain 75% of its final resistance.



III- Questionnaire about the composition of concrete

Questions: What is the difference between cement and concrete? What is the composition of a concrete mix that is both solid and inexpensive?



To better understand the composition of concrete, let us study the following notions.

Question 1
In the case of a salt water solution, what is the aqueous solution?

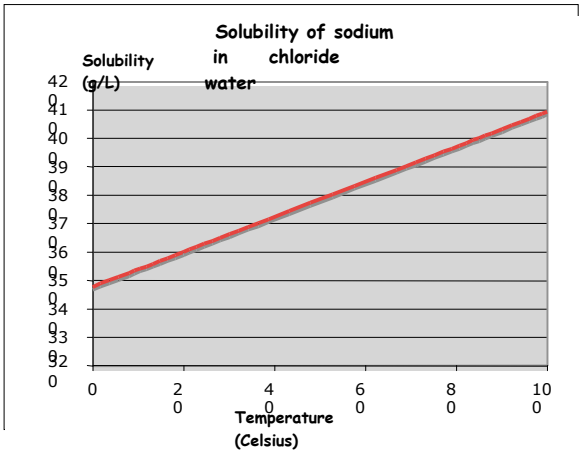
Question 2
In the case of a salt water solution, what is the solvent?

Question 3
Imagine that the marbles present in the adjoining beaker represent water molecules. **When salt dissolves, where could these new molecules reside?**

Question 4
At what point can we refer to a saturated solution?

Question 5

Solubility is the maximum quantity of aqueous solution that can be dissolved in a liter of solvent at a given temperature. **Referring to the adjoining graph, what is the largest quantity of NaCl that can be dissolved in a liter of water at 20°C?**



Question 6

If we try to dissolve 420g of sodium chloride in a litre of water at 80°C, what will happen? Where will the salt reside?

Question 7

Let us now use the knowledge acquired in the 6 preceding questions to better understand the composition of concrete. **Look in the dictionary and find the difference between cement and concrete.**

Question 8 (To be verified experimentally)

By analogy, the gravel used in the fabrication of concrete may be compared to the molecules of water present in the beaker in question 3. As is the case with the molecules, there are chinks between the pieces of gravel. When concrete is made, all these chinks must be filled with sand. You must thus determine the volume that is called interstitial volume (the volume between the chinks) in order to have an indication of the quantity of sand to be used. (Careful, gravel may absorb water!)

What is the interstitial volume of 100 mL of gravel?

(Water may be very useful for this purpose.)

Interstitial volume: _____ /100 mL of gravel

Percentage of air in this gravel _____ v/v%

N.B. The v/v% is a unit of concentration.

Question 9 (To be verified experimentally)
Sand can also be used when making concrete. It may be compared to the water molecules present in the beaker in question 3. The same reasoning used in the previous question can be used again. You must therefore determine the volume of interstitial sand in order to have an indication of the quantity of cement to be used. Indeed, the cement must fill all the chinks in the sand.
What is the interstitial volume of 100 mL of sand?
(Water may again be very useful for this purpose.)
Interstitial volume: _____ /100 mL of sand

Percentage of air in this sand _____ v/v%

Question 10
Given the two previous manipulations, you must now determine what the composition of your concrete will be. **What composition of gravel, sand, cement and water will you use when making your concrete?** Here are some comments that will help you prepare a very resistant concrete:

- **The chinks in the gravel must be completely filled** with sand, cement and water; otherwise the concrete will be weaker.
- **The chinks in the sand must be completely filled** with concrete and water; otherwise the concrete will be weaker.
- The quantity of cement powder is limited, because of its relatively high cost. As little as possible must therefore be used, all the while aiming for these two objectives.
    - Maximise the volume of concrete.
    - Do not sacrifice the quality of the concrete with a lack of binding agent between the granules.
- **You must add as little water as possible to the concrete.** Adding too much water to the concrete spreads out the components that should react during the chemical reaction of curing. Beyond a certain point, the more water there is, the less resistant the concrete becomes.

Question 10 (continued)
What quantity of gravel, sand, cement and water will you use when you make your concrete?

Use the space below to think about the question. A drawing may be very illuminating.

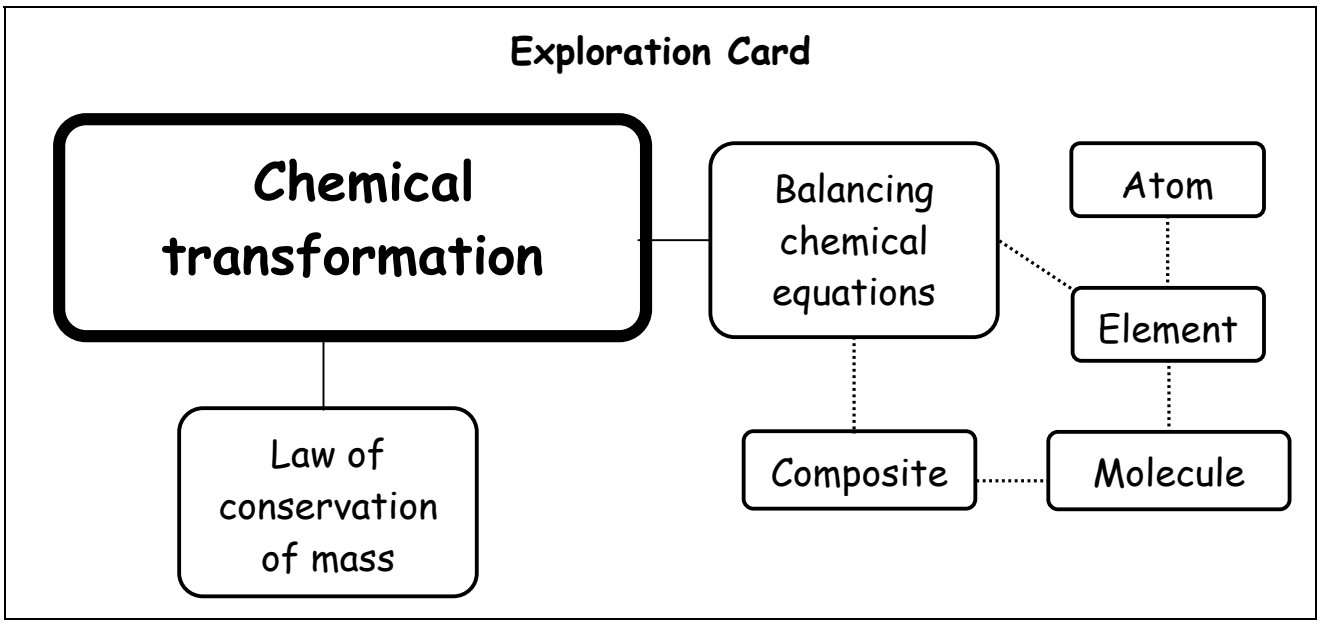
Keep in mind that:

- The chinks in the gravel must be completely filled
- The chinks in the sand must be completely filled.
- You must maximise the volume of concrete for a given quantity of cement powder.
- You must not sacrifice the quality of the concrete with a lack of binding agent between the granules.
- You must add as little water as possible.

Your secret recipe (hypotheses)	Gravel	Sand	Cement	Water
Volume (mL)			150	
Ratio			1	

IV- Questionnaire about concrete curing

Questions: During the transformation in the curing process of concrete, is there conservation of mass? How is this reality expressed at the atomic level?



Question 1 (To be verified experimentally)

It is now time to prepare your concrete for the first time following your secret recipe. You must use very small quantities here. The total volume of prepared concrete should be about 30 mL. (Place the prepared concrete in a sealed container in order not to lose water to evaporation!)

Does the mass of the concrete change during hardening?

N.B. Observe the texture of the formed concrete carefully. If it is not satisfactory, you will have to adjust your recipe.

Question 2

In your opinion, has the number of atoms present in the concrete changed during curing? Why?

Question 3

Here are the principal components found in Portland cement. **How many atoms of each kind are there in the following components?**

Name	Formula	Calcium	Oxygen	Silicon	Iron	Aluminium
Dicalcium silicate	$(CaO)_2SiO_2$ *{simplified}* or $2CaO{\cdot}SiO_2$					
Tricalcium silicate	$(CaO)_3SiO_2$ *{simplified}* or $3CaO{\cdot}SiO_2$					
Tricalcium aluminate	$(CaO)_3Al_2O_3$ *{simplified}* or $3CaO{\cdot}Al_2O_3$					
Tetracalcium aluminoferrite	$(CaO)_4Al_2O_3Fe_2O_3$*{simplified}* or $4CaO{\cdot}Al_2O_3{\cdot}\ Fe_2O_3$					

Question 4

Here is an important chemical reaction that is produced when normal (type 10) Portland cement solidifies. This reaction brings about crystal formations that give concrete its mechanical resistance. The number of atoms differs on each side of the equation, however. The well known expression "Nothing is lost, nothing is created, everything is transformed" is therefore not verified. **Find the coefficients necessary in front of each term in order to balance the equations.**

	Reagents	Products
	☐ $(CaO)_3Al_2O_3$ + ☐ H_2O →	☐ $Ca_3Al_2O_6(H_2O)_6$
O		
H		
Ca		
Al		

Question 5

Here is another important chemical reaction produced when concrete solidifies. It also brings about crystal formations that give concrete its solidity. The number of atoms differs on each side of the equation, however. **Find the coefficients necessary in front of each term in order to balance the equations.**

	Reagents	Products
	☐ $(CaO)_2SiO_2$ + ☐ H_2O ⟶	☐ $Ca_3Si_2O_7(H_2O)_3$ + ☐ $Ca(OH)_2$
O		
H		
Ca		
Si		

Question 6

Here is another important chemical reaction produced when concrete solidifies. It also brings about crystal formations. **Balance this equation.**

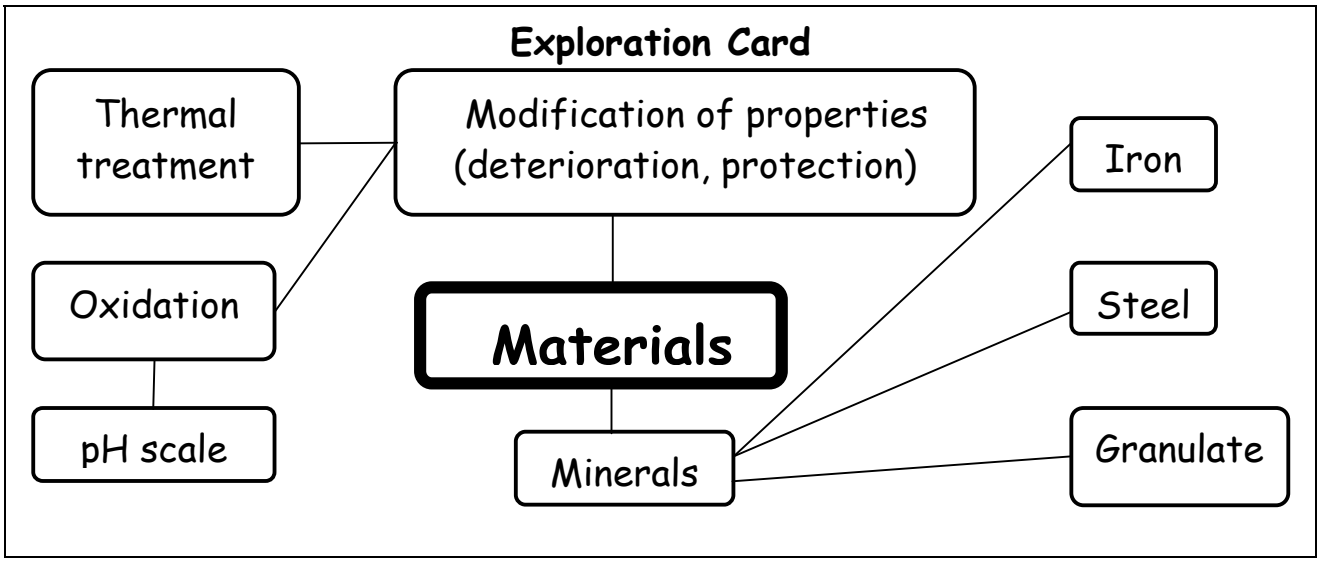
	Reagents	Products
	☐ $(CaO)_3SiO_2$ + ☐ H_2O ⟶	☐ $Ca_3Si_2O_7(H_2O)_3$ + ☐ $Ca(OH)_2$
O		
H		
Ca		
Si		

Question 7

Observing the three previous reactions, is it better to keep the concrete moist during curing? Why?

V- Questionnaire about concrete as a building material

Questions: What is the pH of concrete? Chemically, what is the effect of concrete on the steel reinforcements in the concrete? What type of granulate must be avoided?



Question 1 (To be verified experimentally)

Here you must again prepare a small quantity of concrete following your recipe. It may be adjusted in relation to the results obtained in the first test. The total volume of prepared concrete should be about 30 mL. Place the prepared concrete in a sealed container in order not to lose water to evaporation. (Use Litmus paper to determine whether the concrete is acid, basic or neutral.)

Is the concrete acid, basic or neutral?

Question 2 (To be verified experimentally)

Using the same sample of concrete, determine its approximate pH using a pH test paper strip.

Question 3

Look at the chemical equations of the principal reactions occurring during concrete solidification in the previous section.

Which substance could be responsible for such a pH level? Why?

Question 4

Metal oxidation is an important phenomenon. Here are three chemical reactions that represent metal oxidation.

$$2Cu + O_2 \rightarrow 2CuO$$
$$4Al + 3O_2 \rightarrow 2Al_2O_3$$
$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

a) **With what substances do the metals react?** _____

b) **What are the products that are formed called?** _____

c) **Do the metals gain or lose electrons?** _____

d) What atmospheric substance may promote the mobility of electrons?

Question 5

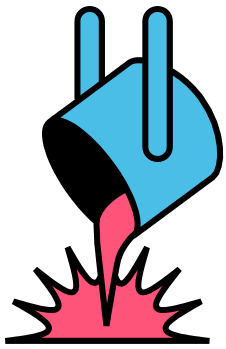
Since the steel reinforcements enclosed in reinforced concrete contain an enormous amount of iron, they may also oxidise. Certain factors can accelerate this rust forming process. **In your opinion, how can pH influence the speed of corrosion?**

Question 6

Given the pH you measured in the concrete, is it necessary to protect the reinforcements before encasing them in concrete? Why?

Question 7

In terms of its composition, what is the difference between iron and steel?



Question 8
What type of treatment is used in industry while preparing alloys such as steel?

Question 9
Why is steel, as opposed to iron, used as reinforcement in concrete?

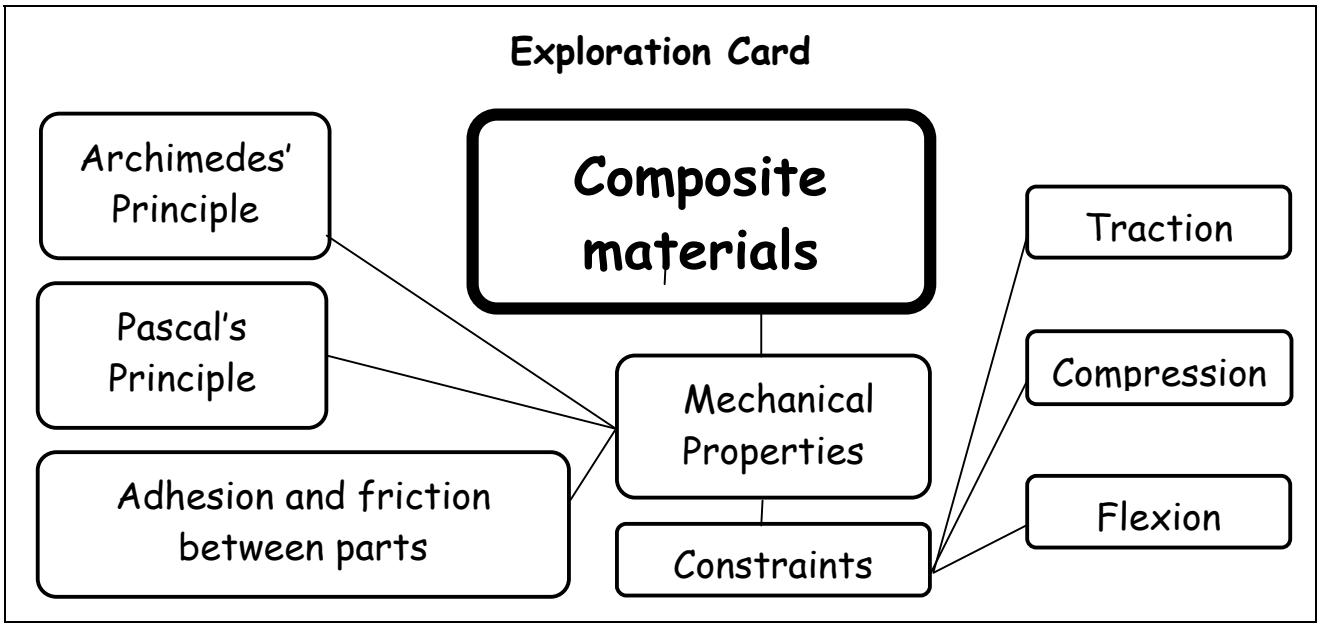
Question 10
You recognise ferrous oxide on an automobile's surface. Its brownish red colour ensures that it does not go unnoticed. **When steel oxidizes, what happens to its volume? Why?**

Question 11
In this context, what will happen if the reinforcements are not adequately buried in the concrete?

Question 12
The choice of sand and gravel contained in concrete is also important. Indeed, chemical reactions between Portland cement and granulates may be produced if these contain sulphates or alkalis, for instance. For your information cases of the presence of pyrite (FeS_2) in the soil in the Greater Montreal area has made headlines in recent years.
What is the negative effect of the presence of such substances in concrete?

VI- Questionnaire about the mechanics of concrete

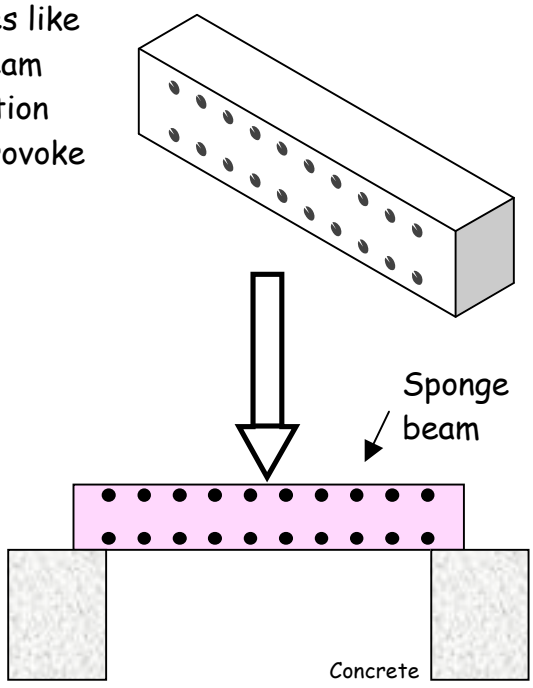
Questions: How are forms built? What configurations must be given to reinforcements in a beam? Where must the concrete be reinforced?



Question 1 (To be verified experimentally)

Let us now simulate what happens inside the beams of an overpass. Let's discover the forces reigning inside a beam on which we have placed a weight. To clearly see what is happening inside the beam, we will use a sponge. You need only cut it to give it the shape of a beam.

Next, you must draw several spots along its surfaces like on the drawing at right. Let's now place this foam beam between two tables. Press on its center in the direction indicated by the big arrow. This applied force will provoke a « U » shaped **flexion** of the beam.



What do you notice on the top of the beam?

_____

Question 2

What do you notice on the underside of the beam?

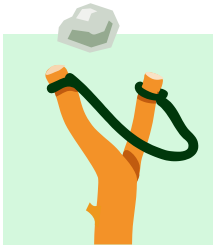
_____

Question 3

An object is in compression when it is crushed. A big exercise ball, for example, is in compression when we sit on it.

In which section of the beam (superior or inferior) does a compression force appear?

Question 4



An object is in traction when it is stretched. The elastic of a slingshot, for instance, is in traction just before throwing.

In which section of the beam (superior or inferior) does a traction force appear?

Question 5

Concrete resists very well to the forces of compression. Compression forces are found in multi level parking garage columns, for example. Concrete resists very poorly to forces of traction, however. In fact, concrete's resistance to compression is at least 8 times greater than its resistance to traction. When concrete is subjected to the forces of traction, it must therefore be reinforced.

In which section of the beam should we add a steel reinforcement? Why?

Question 6 (To be verified experimentally)

In real life, concrete must be poured in molds called forms. Concrete is a fluid that acts like water. When making forms, you must take into account Pascal's principle. To discover this principle, take a milk carton and pierce three holes at different heights. (See spots on drawing at right). Next, fill the carton with water and observe. Be careful not to make a mess.

Which hole lets the most water escape?

Question 7
At what height does the pressure seem the strongest?

Question 8
To what is this pressure due?

Question 9
Where must the concrete filled forms be the strongest?

Question 10
How can we get around the problem posed by Pascal's principle when building reinforced concrete walls several stories high?

Question 11
Now that we have thought about the fabrication of forms, let us go on to the reinforcements. The most commonly used reinforcement material in reinforced concrete is steel. Some plastics, like polypropylene, may be used for components in concrete under certain circumstances. But steel is without a doubt the champion in this field.
Steel, like iron, has a tendency to oxidise when submitted to the elements. On building sites, reinforcements left out in the rain rust very quickly.
In your opinion, why do people working with concrete often let the reinforcements rust on site before using them?

Question 12
What is the purpose of the striations at the surface of these steel arming rods?

Question 13
The quality of concrete is also related to the adhesion between its component granulates. The sand or gravel used may be contaminated by organic residue of all sorts (animal or vegetal residue). The "organic burden" indicates the quantity of organic substances found between the granules. Since the solidity of these organic substances is very weak, the aim is to keep as low an organic burden as possible between each grain of sand and between each piece of gravel.
What can be done to keep the organic burden present between our granules as low as possible?

Question 14
Finally, Archimedes' Principle must be taken into account when building concrete structures. Indeed, the density of certain granules may be very different from that of concrete. Plastics like polystyrene and polypropylene can enter into the composition of concrete. Even when it is time to position the reinforcements in the forms, you must consider this famous principle.
State Archimedes' Principle (see the dictionary definition).

Question 15
Supposing that concrete has a density of 2.6 g/cm^3, what will happen to granulates with a density of 2.1 g/cm^3?

Question 16
What will happen to air bubbles trapped in the mix?

Question 17
What will happen if air bubbles remain trapped just below the reinforcing bars? How will the adhesion between the concrete and the bar be affected?

Question 18
To what depth will a boat sink into the water?

Question 19

Supposing that concrete has a density of 2.6 g/cm^3, what will happen to reinforcing bars with a density of 7.8 g/cm^3?

Question 20

What can we do to ensure that the reinforcements stay positioned at the proper places, which is where the forces of traction are felt?

Question 21

What can be done to ensure that the concrete coats the reinforcement and forms perfectly and that no air bubbles remain trapped under the reinforcements?

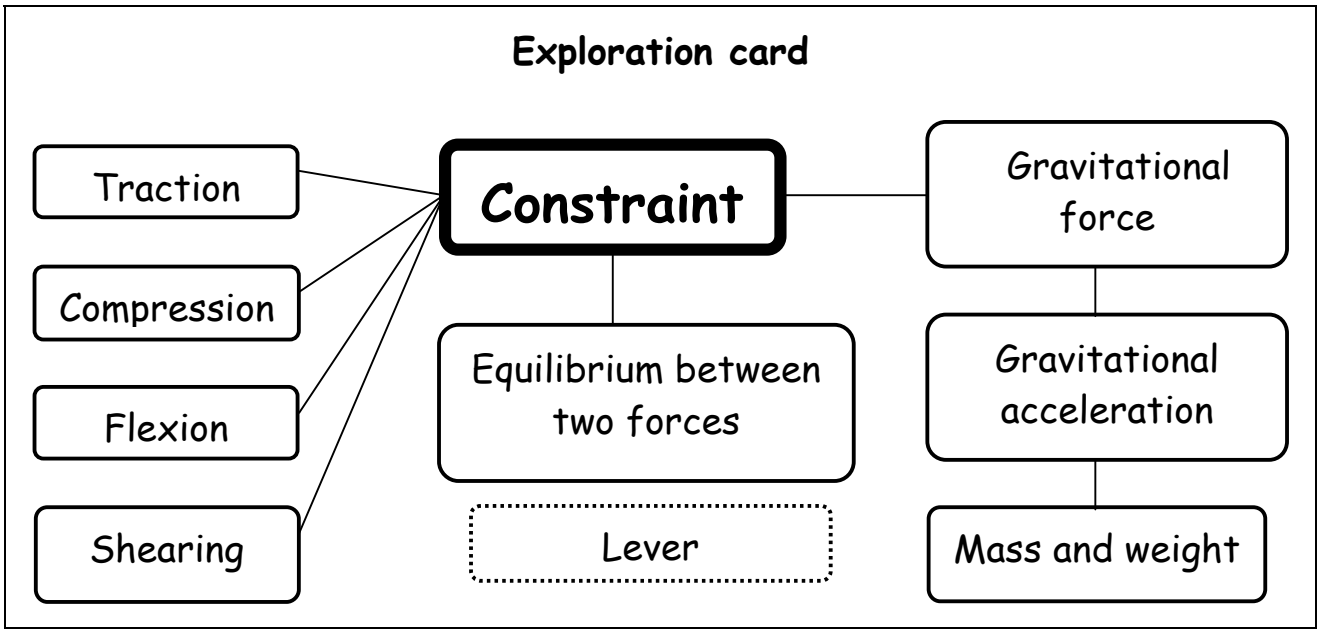
Question 22 (just a few calculations to better understand)
Supposing that you have to transport a gold bar with the following dimensions: 20cm x 10cm x 5cm. The density of gold is 19.3 g/cm^3.

What is the mass of this bar?

What is the mass of this bar in water? (Density of water = 1 g/cm^3**)**

VII- Questionnaire about testing a beam

Questions: How do the forces act when the beam is submitted to gravitational attraction? How will the beam break when it is submitted to a large load at its center?



Question 1
What distinction can you make between mass and weight?

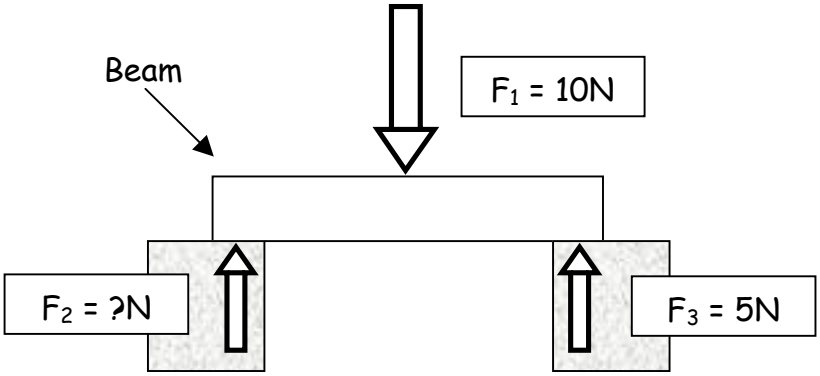
Question 2
What is Newton's second law? By what equation can it be expressed? What units of measure must be used?

Question 3

What is the size of the gravitational force sustained by a 200 gram apple? N.B. The apple is here, on Earth. Your answer must be given in Newton (N).

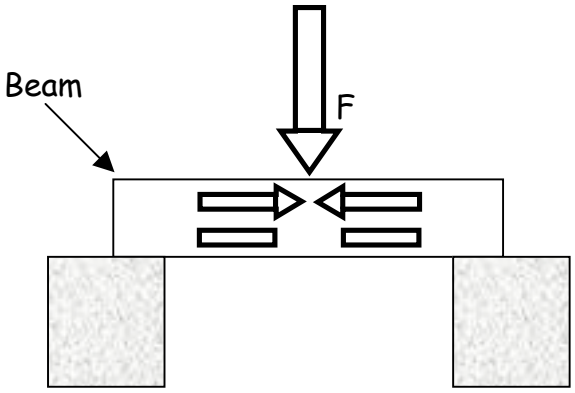
Question 4

This beam is placed between two tables and is immobile. The forces acting upon it should all cancel one another out, since there is no movement. **If a 10N force is applied to its center, what is the size of the missing force? Prove it with a small calculation.**



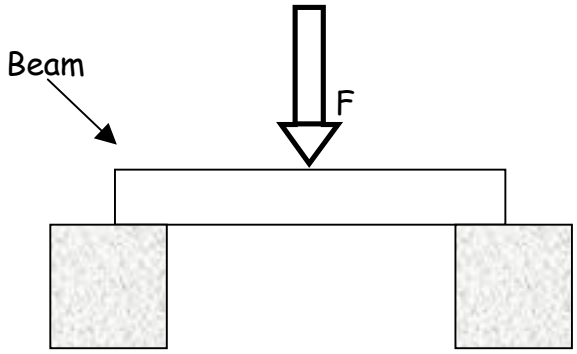
Question 5

When we press downwards on the beam, an imperceptible flexion appears. Compression and traction constraints then appear in the beam. These constraints should cancel each other out as long as the beam holds. **Complete the double arrow in such a way as to correctly describe the force of traction that reigns at the bottom of the beam.**



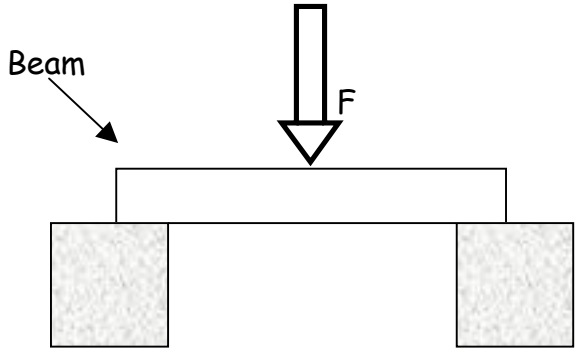
Question 6

What form would the break take if too great a compression constraint reigned inside the beam? Illustrate and describe the break below.



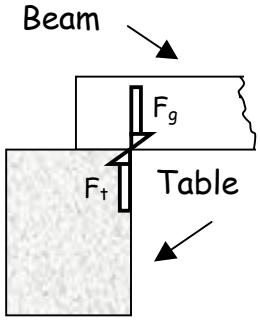
Question 7

What form would the break take if too great a traction constraint reigned inside the beam? Illustrate and describe the break below.

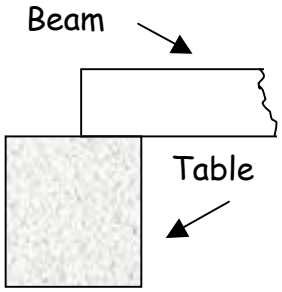


Question 8

When the de la Concorde overpass collapsed on September 30th 2006, another type of constraint was blamed: a shearing constraint. It appears at the ends of the beams (see drawing at right). In the case of our homemade beam, this constraint appears opposite the corner of the table. It is the result of two opposing forces, the force of gravity (F_g) and the force of the reaction of the table (F_t). This concurs with Newton's third law. The two forces presented here are very similar to those found between two blades of a pair of scissors (or shears), hence the term shearing to describe this constraint.



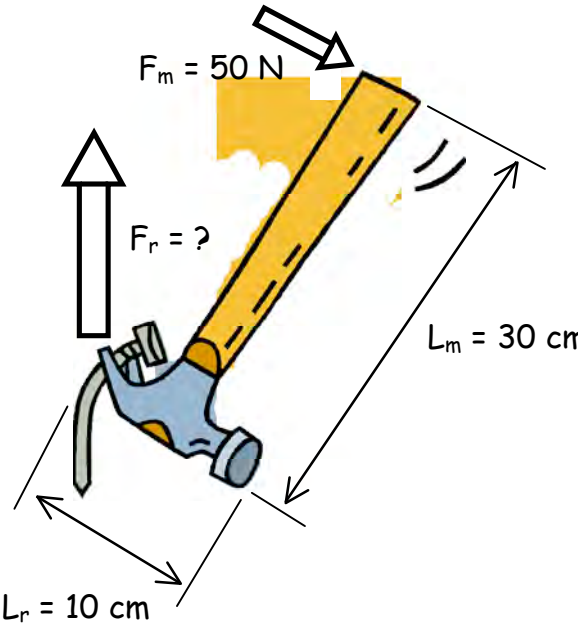
What form would the break take if too great a shearing constraint reigned inside the beam? Illustrate the break on the drawing at left.



Question 9

To clearly understand what is going on inside a beam, we must illustrate one last concept. In the first cycle of secondary school, when you studied simple machines, you probably saw the concept of the lever. That is:

a) F_m, The drive force
b) F_r, the force of resistance
c) L_m, the drive length
d) L_r, the length of resistance



The mechanical advantage (A_m) indicates how the force we apply is increased by the lever (hammer). The two following equations allow us to calculate the mechanical advantage of a lever:

$A_m = L_m / L_r$ $\quad$ $A_m = F_r / F_m$

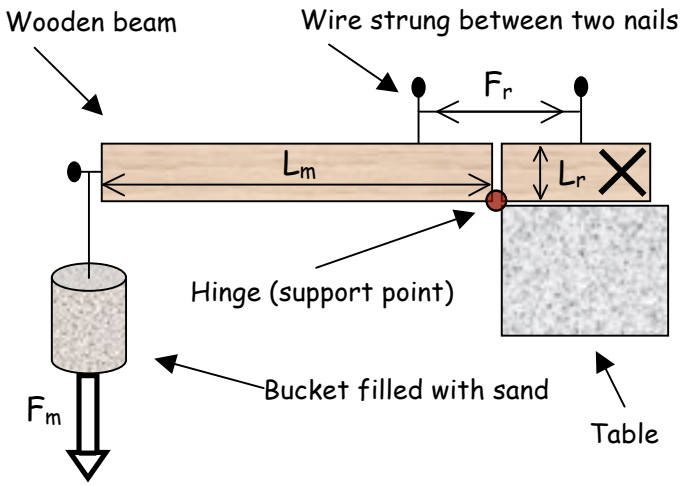
a) **Calculate the mechanical advantage of this hammer using the given lengths.**

b) **Explain in your own words what the preceding answer means.**

c) **Isolate F_r in the second equation and find the force necessary to pull the nail out (F_r).**

Question 10

Let us now apply the lever concept to the study of our beam. In the laboratory, the following assembly allows us to validate the influence of the height of the beam on the resistance of the reinforcements. Imagine two half-beams united with a hinge. The half-beam on the right is affixed to the table by a vise. We suspend a bucket of sand on the free extremity in such a way as to create a force great enough to break the wire strung between two nails. In this assembly, the wire represents the reinforcement usually used to reinforce concrete. Now let us compare two beams of different heights.



That is:	That is:
e) L_m = 30 cm **f)** L_r = 5 cm **g)** F_m = ? N **h)** F_r = 120 N	**i)** L_m = 30 cm **j)** L_r = 3 cm **k)** F_m = ? N **l)** F_r = 120 N
a) Find the mechanical advantage using the lengths of the lever.	**a) Find the mechanical advantage using the lengths of the lever.**
b) What will the drive force (F_m) necessary to break the wire be, knowing that this steel wire can support a force of 120 Newtons?	**b) What will the drive force (F_m) necessary to break the wire be, knowing that this steel wire can support a force of 120 Newtons?**
c) To what mass does the drive force correspond in the preceding question?	**c) To what mass does the drive force correspond in the preceding question?**

Question 10 (continued)

d) Which beam supports the greatest mass?

e) It is possible to change the mechanical advantage of a hammer by modifying the length of its handle. **In this context, what should the mechanical advantage of a high performance hammer be (large or small)?**

f) What should the mechanical advantage of a high performing beam be (large or small)?

g) At what height should your reinforcement be within the beam to make it as solid as possible?

N.B. In the case of our beam, the mass it can support is greater. Indeed, since our beam is support on both sides, the load it can bear is twice as large. The masses calculated in question 10 should therefore be multiplied by a factor of 2.

Detailing your mandate following the learning activities

What will my new plan of action be to fulfill this mandate?
(I state what must be done.)

Designing your beam

This section must stipulate all the details of your beam and of its reinforcements:

1. Technical drawings on a scale of 1:3 allowing us to see two faces (face and top). All dimension and position quotes must be shown.
2. The recipe used for your concrete (quantities : cement, sand, gravel and water)
3. The pour date and curing time
4. The environment during curing (temperature, humidity…)
5. The mass of the beam without its forms
6. And following the test, the mass supported by the beam and the resistance factor

So, complete the following page being sure to include all the information mentioned above.

Drawing of the beam with its reinforcements

Top cut view

Front cut view

SCALE OF DRAWING : 1:3

Data regarding the beam

Names of team members: **Group No. :**

Concrete recipe Volume cement: (mL): Volume gravel (mL):

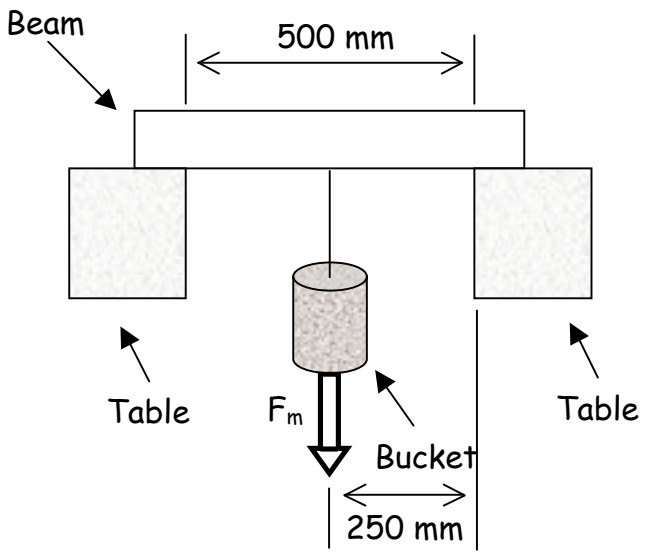
Volume sand (mL): Volume water (mL):

Pour date: / / Curing time: Ambient humidity :

Mass of the beam: Mass supported by the beam: Resistance Factor:

Testing the beam (destructive resistance test)

Before beginning, the previous page must be completed.

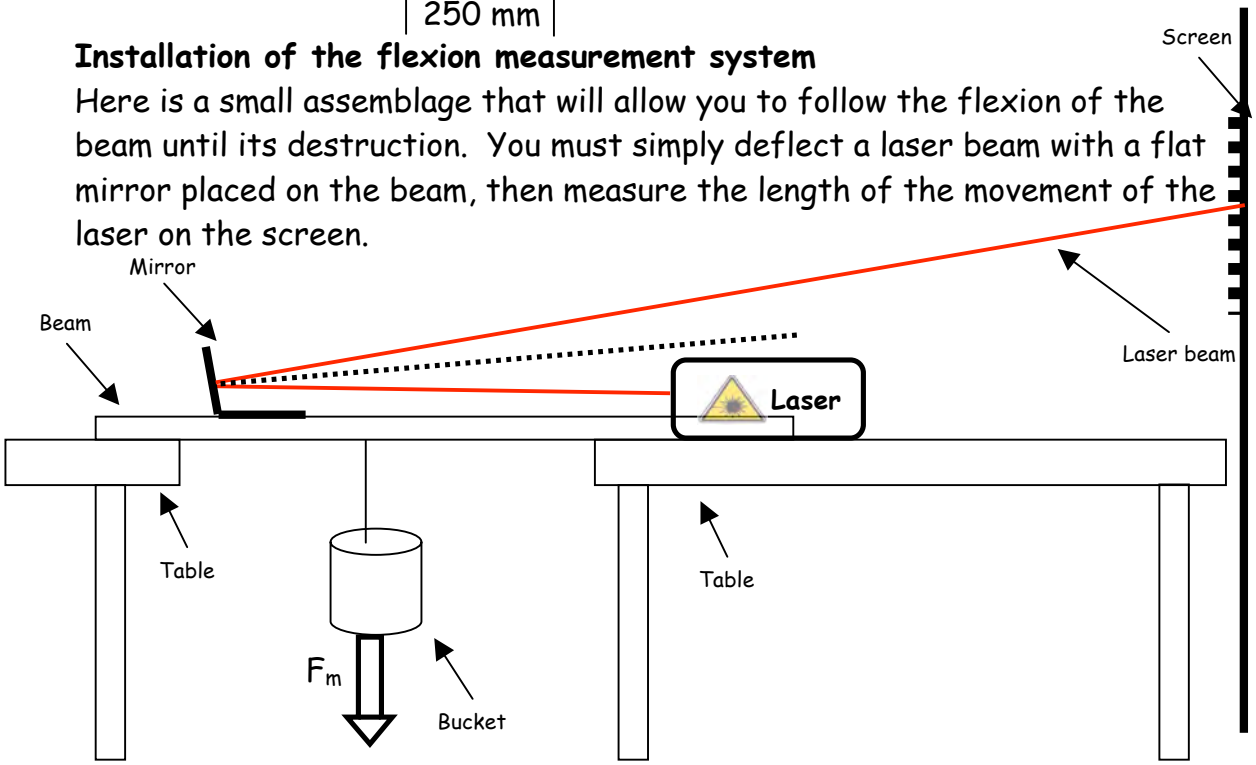


Installing the beam

Here is how the destructive test will proceed. The beam must be placed between two tables in such a way that its free span is 500mm (see drawing). You must ensure that it stays in a vertical position and that it does not pivot during the test. An empty bucket is suspended to the beam from a chain exactly in the center (250 mm from one of the tables).

Installation of the flexion measurement system

Here is a small assemblage that will allow you to follow the flexion of the beam until its destruction. You must simply deflect a laser beam with a flat mirror placed on the beam, then measure the length of the movement of the laser on the screen.



Since the flexion movement is essentially vertical at the center of the beam, the mirror must be placed at one quarter of the span.

Execution of the test

Now you must simply add sand to the bucket until the beam gives way. Next, you must weight the mass of the sand and the bucket to calculate the resistance factor by dividing the mass supported by the mass of the beam. **Note that a flexion at the center of greater than 60mm will disqualify the competitors.**

Commision of inquiry regarding the collapse of your beam

(Analysis of results and improvements to the beam)

Explain, using as much detail as possible, the causes of the collapse. To do so, you must rely on scientific and technological concepts. Finally, what improvements could you bring to your beam to make it more resistant?

Your explanation may include the following terms: constraint, flexion, traction, compression, shearing, adhesion, force, curing, load, resistance, composition, hardening, hydration, reinforcement, granulate and lever.