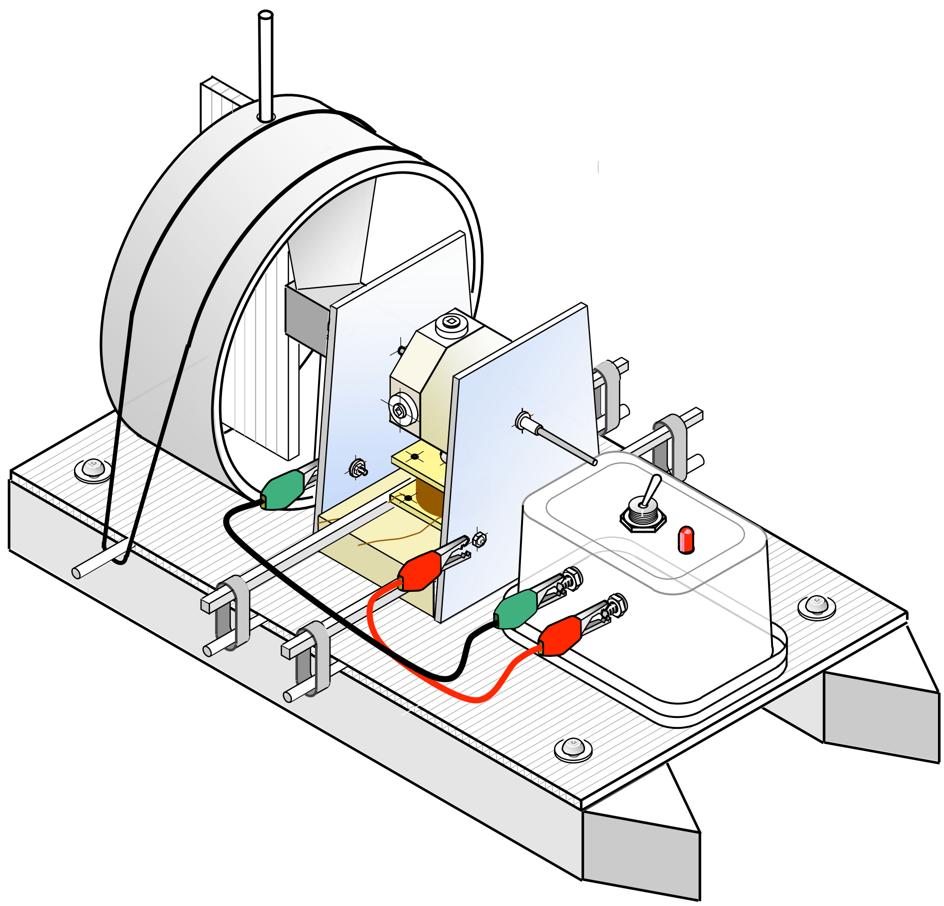
centre de développement pédagogique
pour la formation générale en science et technologie

Working document

THE ELECTRIC HYDROPLANE



STUDENT BOOKLET

October 2010

Table of contents

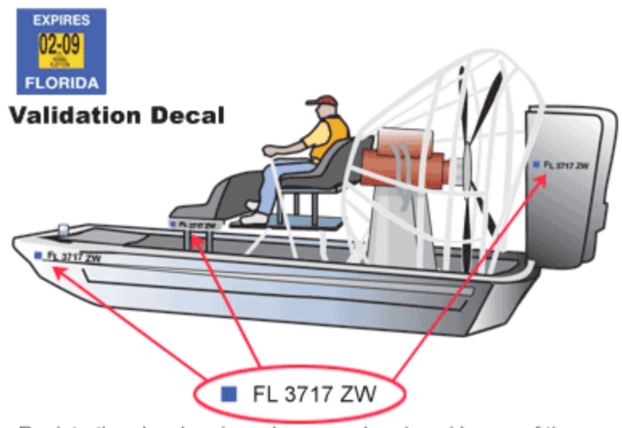
On your marks, get set…

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

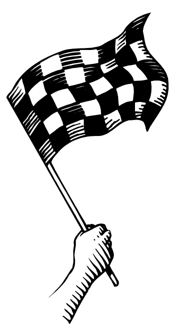
What would you say about a race? An electric hydroplane competition. Yes, a hydroplane, the type of boat propelled by a plane's propeller. The Americans use it to get around in marshes, like the Everglades in Florida. Airboats, as they're called there, can easily move around the brush. It is very practical in order not to come face to face with an alligator. You can see one in action at: http://www.jimpinson.com/boat.htm

We could host our race at the local frog pond, but a local pool or even a bathtub may do just as well. This kind of project will allow us to touch upon many things in the program in a very amusing and concrete way. Come on - I'm sure you'll "flip" for it!

O.K., it's decided, we're going for it! You'll have to think about lots of things: the performance of the motor and propeller you will make, battery life, the balance of the hydroplane, etc.



Registration decal and numbers may be placed in one of three areas on the port side of an airboat.



Let's go, budding engineers, to your pencils, drills and soldering irons. There's a race to be won!

Let's warm up a bit!

Here is a web link that shows you how to make a very easily understood electric motor. Even if this motor can't really do any work, it may nevertheless arouse your curiosity.

Making a very simple electric motor:
http://www.bofunk.com/video/6361/make_a_cool_simple_electric_motor_in_minutes.html

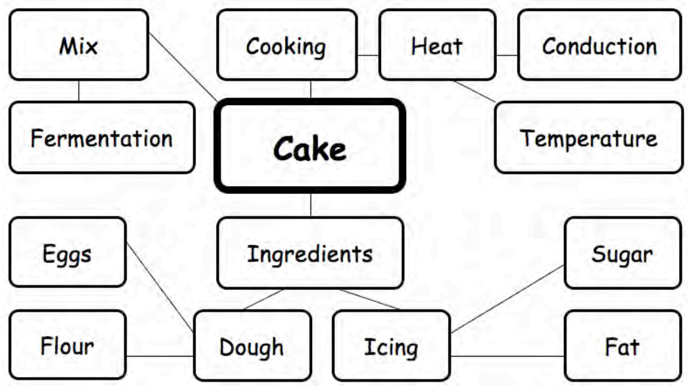
In the course of the last few years, you have had the opportunity to study several concepts useful for making your hydroplane's electric motor. This section will allow you to refresh your memory.

Why don't you take a few minutes to try and complete the card related to the study of electricity.

This card will allow you to organise your knowledge visually.

A plenary session will then allow the whole class to share their thought processes.

Example of a network of concepts



Network of concepts

Electrical engineering

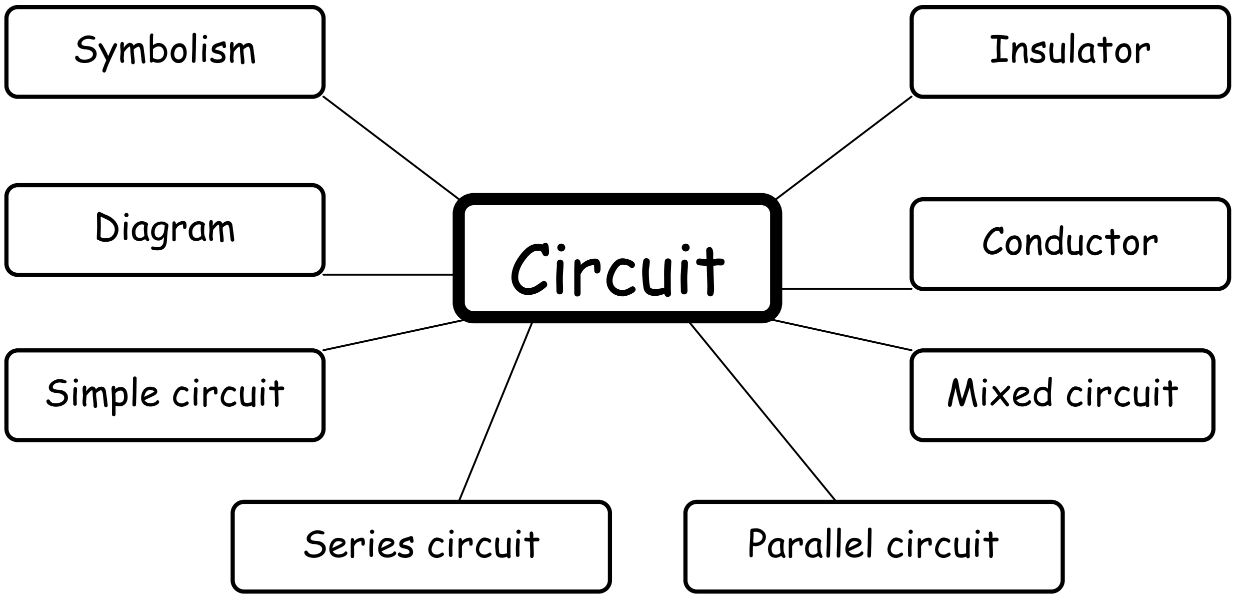
Time to learn a little more!

Now it's time to learn some new things. Here now are the various activities that will allow you to better understand how an electric motor works. Here is a list of subjects we will deal with:

1. **Electricity** (Ohm's Law, electric circuits, power and electrical energy)
2. **Electromagnetism** (Forces of attraction and repulsion, magnetic field of a solenoid)
3. **Transformation of energy** (Law of conservation of energy, output) and *potential gravitational energy for the optional course only*
4. **Electrical engineering** (Supply, conduction, insulation, protection, command and transformation of energy functions)

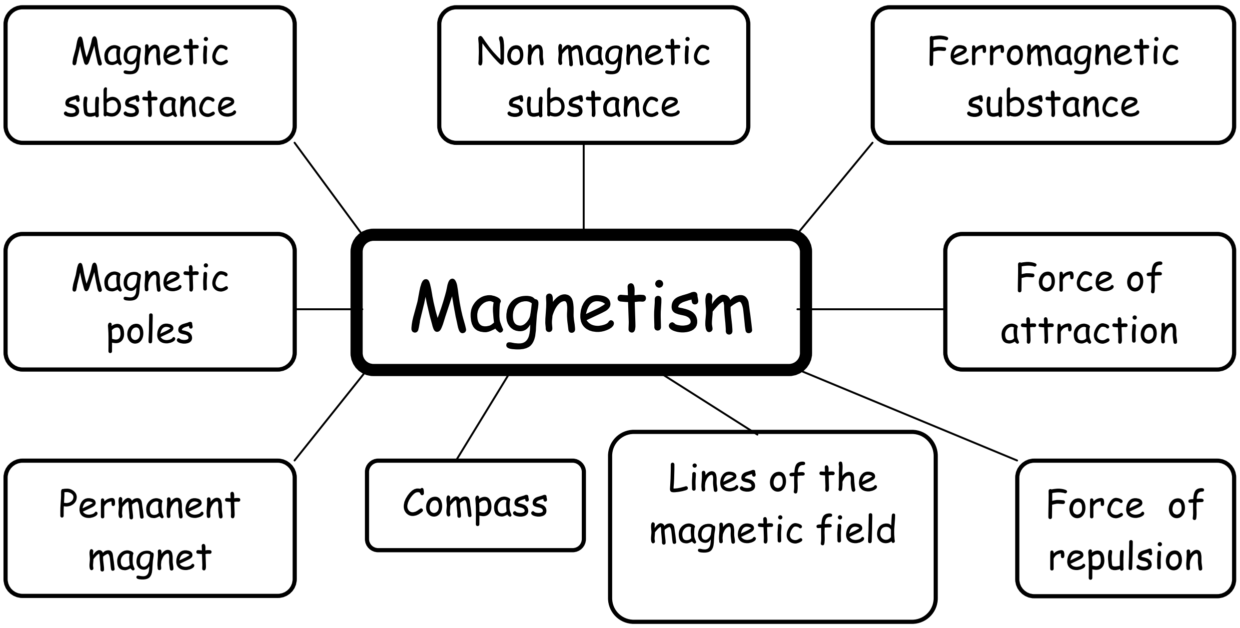
On the following pages, you will find exploration cards that cover the learning activities experienced in class. For each of these cards, indicate what is important to remember.

"Circuit" Exploration card



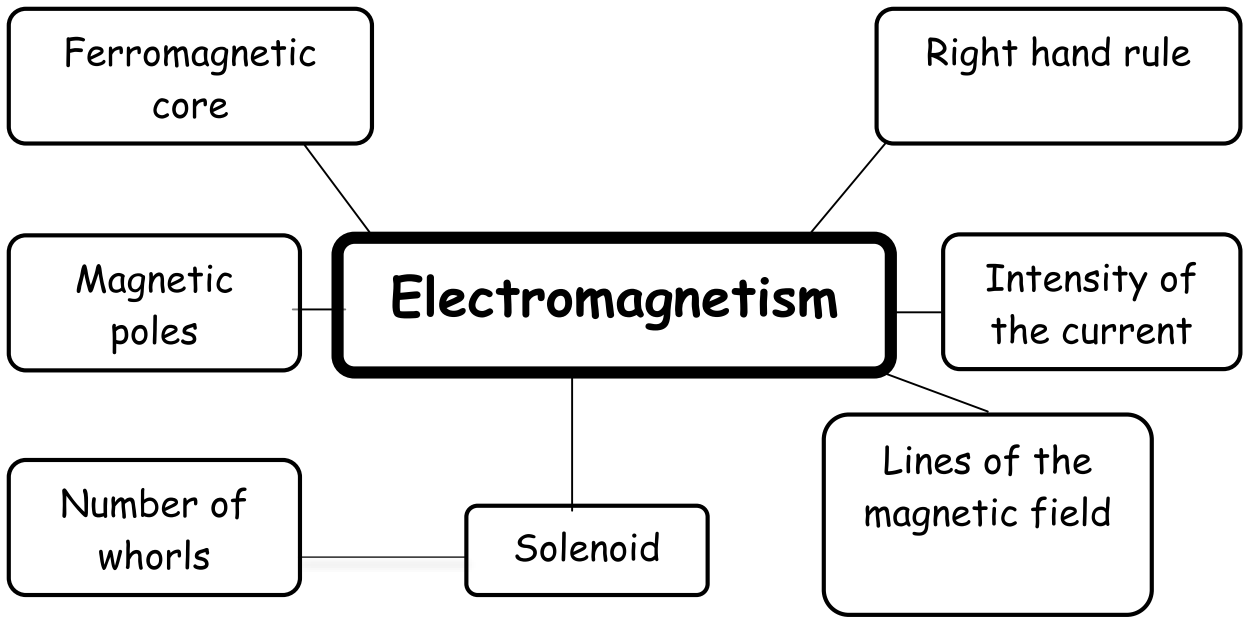
What I need to remember

"Magnetism" Exploration card



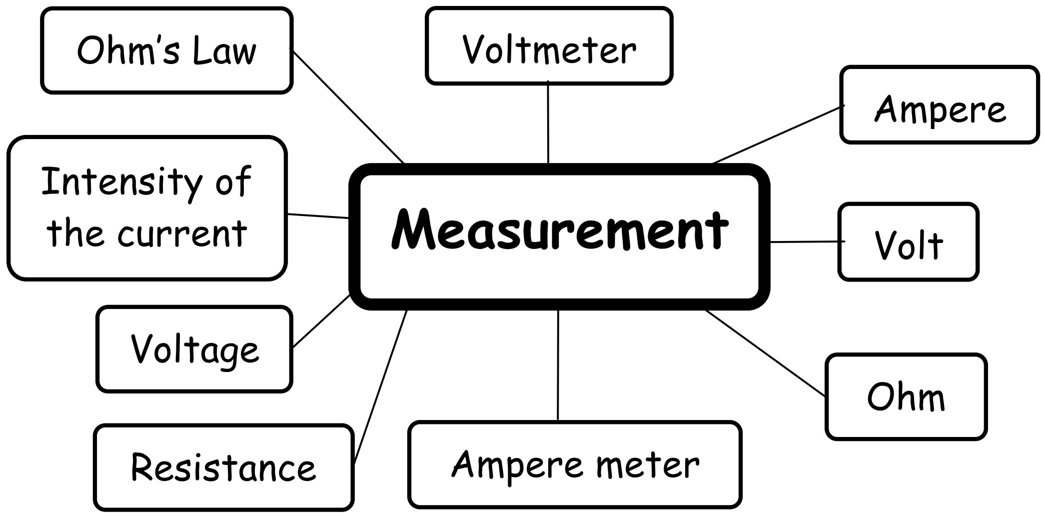
What I need to remember

"Electromagnetism" Exploration card



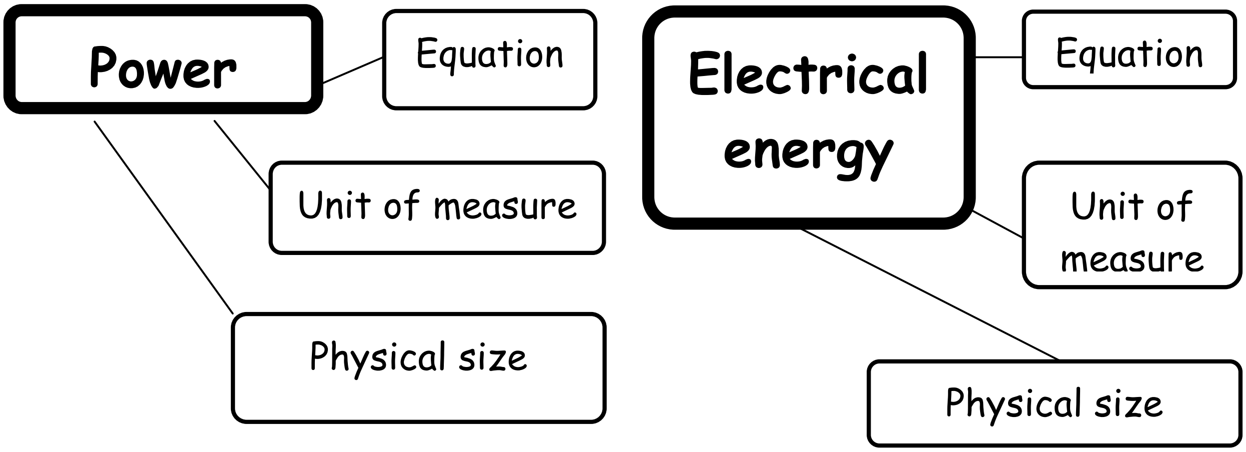
What I need to remember

"Measurement" Exploration card



What I need to remember

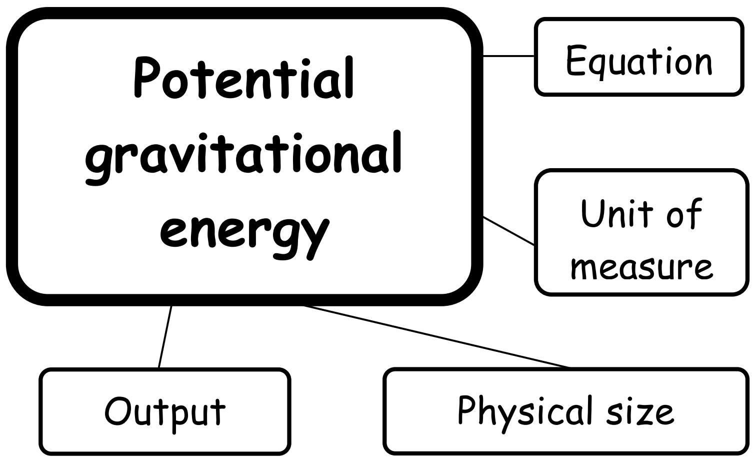
"Power and electrical energy" Exploration card



What I need to remember

"Potential gravitational energy" Exploration card

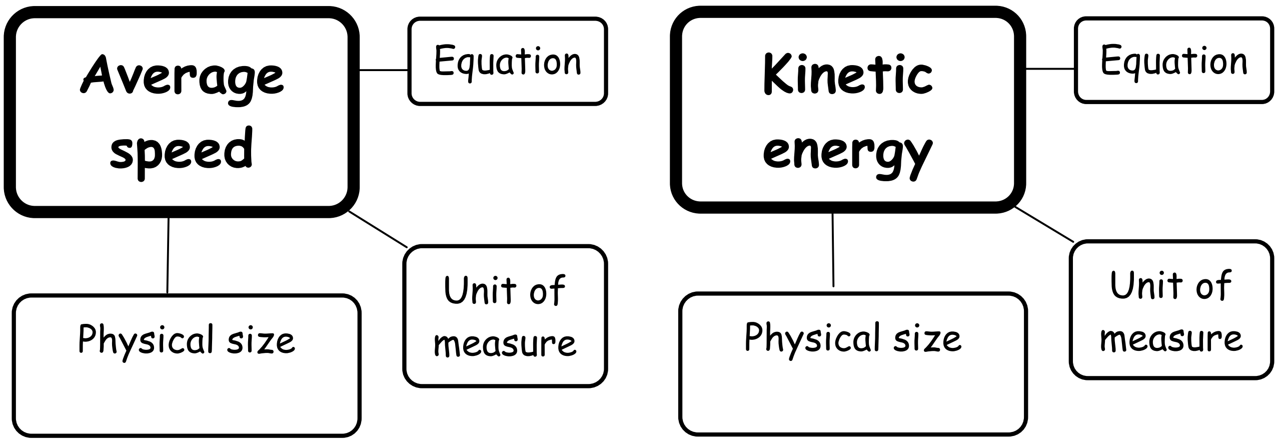
For the ES course only



What I need to remember

"Average speed and kinetic energy" Exploration card

"Kinetic energy" For the ES course only



What I need to remember

Now it's your turn to play !

<u>Mandate</u>

Each team must:

1. Analyse the **R**eed **S**witch **M**otor (RSM)
2. Make an RSM
3. Design a bracket for the RSM's magnetic switch
4. Test your RSM

<u>Instructions</u>

1. To analyse the RSM, become familiar with its nomenclature, then answer the questionnaire relating to its operation. This exercise will allow you to understand how the RSM works.
2. To make the RSM, become familiar with the technical drawings, the follow the fabrication ranges. The motor you will have made will be practically complete, missing only the bracket for the magnetic switch.
3. To design a bracket for the magnetic switch, become familiar with the specifications booklet, then follow the steps of the suggested design process.
4. To test your RSM, study its characteristics, carrying out various measurements and calculations.

Analysis of the RSM

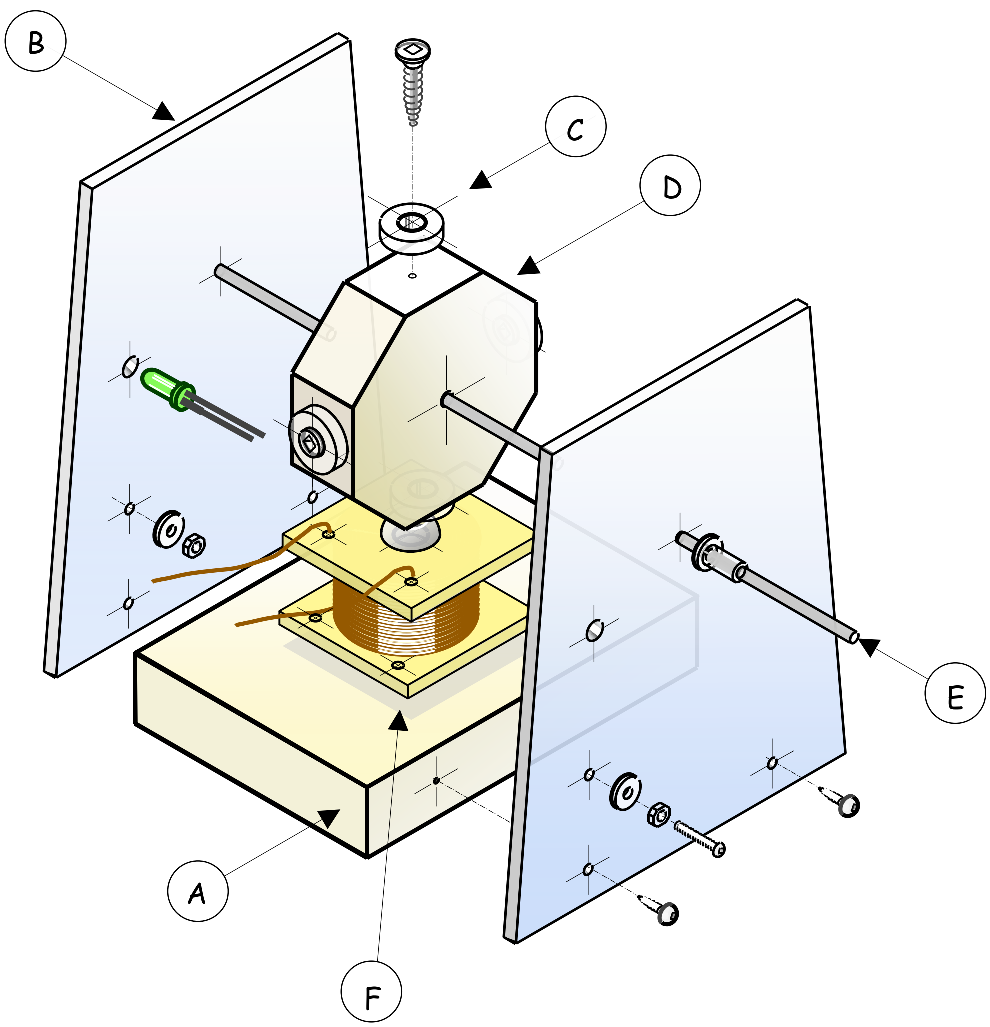
Before analysing the RSM's operation, it is preferable to see one in action. The motor shown on the video is complete, but a part necessary to its operation has been hidden. Indeed, you will have to design this adjustment part later on in the project.

Link to the video of the RSM in action:

http://www2.cslaval.qc.ca/cdp/UserFiles/File/telechargement/hydroglisseur_video_MIM_ATS.mpg

Principal components of the RSM

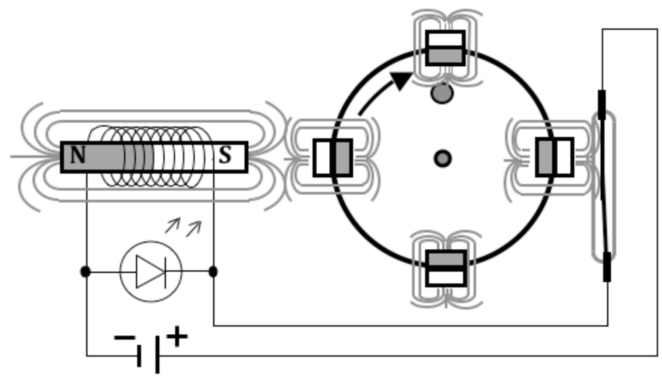
	Designation		Designation
A	Base of the motor	D	Rotor
B	Side of the motor	E	Rotor shaft
C	Magnet	F	Electromagnet



Questionnaire on the operation of the RSM

The purpose of the following questions is to guide you in your thought process after having seen the "PowerPoint" presentation of the RSM's operation. On the four following principles diagrams, you will find the electromagnet on the left and the rotor on the right. Each diagram presents the motor's rotor in a different position. You must study all these diagrams and understand what is going on in each of them. The direction of the rotation is shown by the arrow.

Principles diagram no 1 (Questions 1 to 4)



Question 1
In this diagram, is the circuit open or closed?

____

Question 2
Is the right hand rule respected on the diagram? Why?

____

____

____

Question 3
Does this motor work on attraction or repulsion?

____

Question 4
Could this motor work in the opposite direction? Why?

____

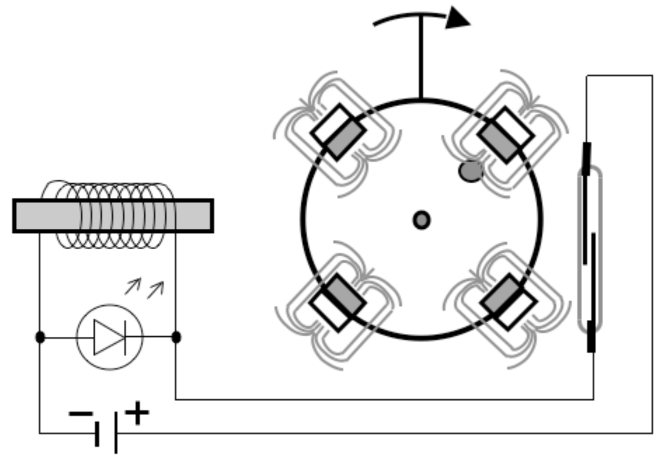
____

____

Question 5
In this diagram, is the circuit open or closed?

Question 6
At this time, is the electromagnet functioning or not?

Principles diagram no 2 (Questions 5 to 8)

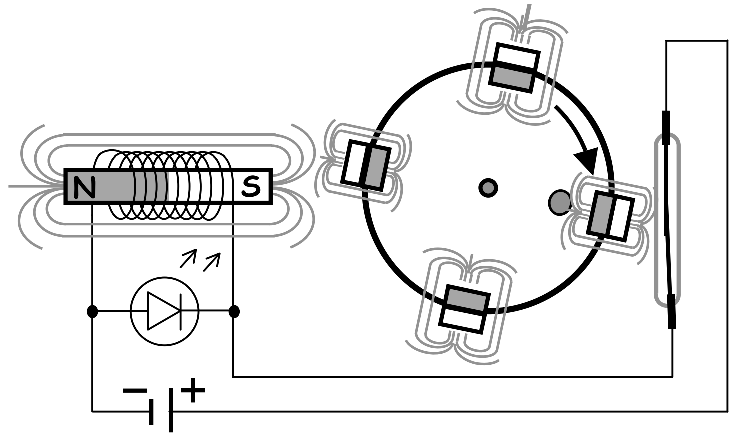


Question 7
What type of force is there between the ferromagnetic core of the electromagnet and the magnet?

Question 8
Why is the motor continuing to turn?

Question 9
When the magnets are installed must we consider the orientation of their poles or not? Why?

Principles diagram no 3 (Questions 9 to 12)



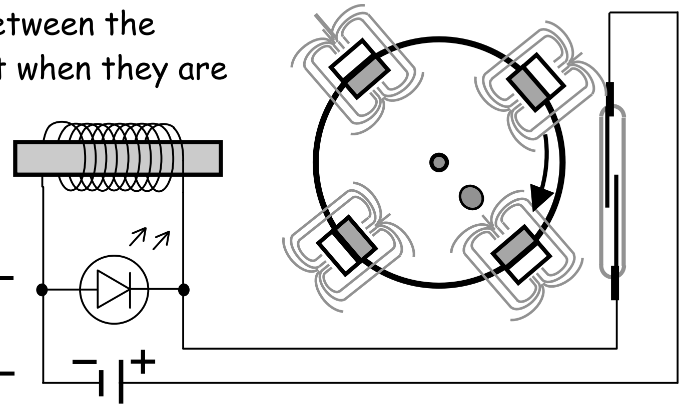
Question 10
Why do the plates inside the switch touch one another?

Question 11
In these diagrams why is the switch placed slightly lower?

Question 12
When the switch is off, is the polarity of the source of current important? Why?

Question 13

Principles diagram no 4 (Questions 13 to 16)



Ideally, what distance should there be between the electromagnet and the permanent magnet when they are opposite one another? Why?

Question 14

How many times per revolution does the electromagnet work?

Question 15

Does the number of whorls of wire on the solenoid matter? Why?

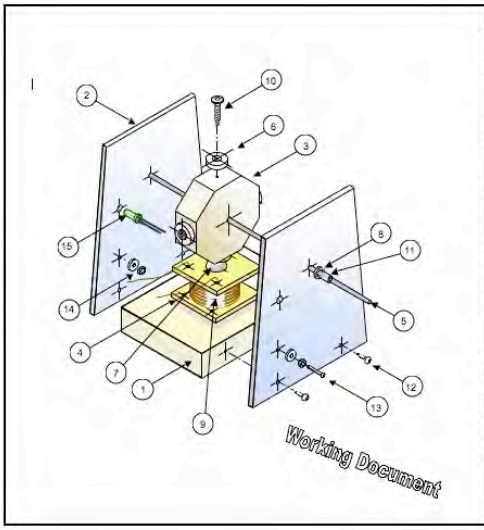
Question 16

Does the distance set between the permanent magnet and the magnetic switch matter? Explain.

Building the RSM (without the bracket for the magnetic switch)

It is now time to make the principal components of the Reed switch motor. To do so, you have at your disposal a complete technical file. This document contains, among other things, the following documents.

The technical drawings

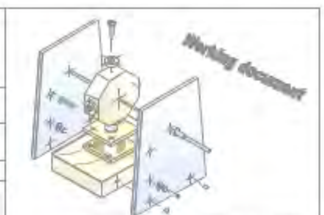


NOMENCLATURE			
LOC	DESIGNATION	No.	OBSERVATIONS
15	LED	1	∅ 5
14	Bolt	4	n° 6 x 32
13	Input terminals	2	Mechanical screw n° 6 x 32 x 1/2"
12	Screw – round head	4	N° 6 x 3/4"
11	Butt tube	2	Flexible vinyl tubing 1/8" int.
10	Milled cap screw	4	Wood screw n° 6 X 3/4
9	Solenoid	1	Enameled copper wire 28 gauge
8	Washer	4	n° 8 flat washer
7	Solenoid core	1	Screw 1/4" x 20 x 1 1/2"
6	Magnet	4	Rare-Earth magnet washers ∅ exterior 1/2" ∅ interior 1/4"
5	Rotor shaft	1	Dowel ∅ 1/8", length 150
4	Solenoid butt	2	Polystyrene 35 x 35 x 3
3	Rotor	1	Pine 50 x 50 x 16
2	Side of motor	2	Polystyrene 90 x 100 x 3
1	Base of motor	1	Pine slat 64 x 90 x 16

centre de développement pédagogique	TITLE : Reed Switch Motor	
	GENERAL TOLERANCE ± 1mm	N° 5
	DATE : 10 NOV 2009	NOT TO SCALE

The fabrication ranges

centre de développement pédagogique			
ASSEMBLY RANGE			
Reed Switch Motor (RSM)			
RANGE: 5	SHEET: 1 of 5		
DRAWING: 4	MATERIALS : Various		
NUMBER : 1			



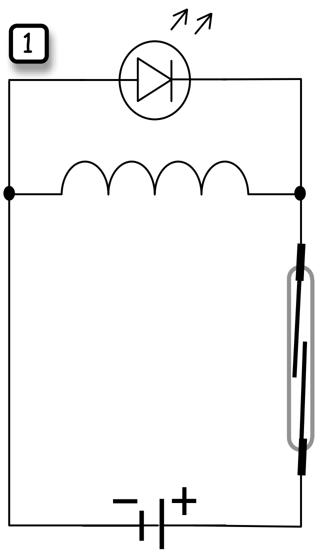
N°	PHASE, SUB-PHASE OR OPERATION	PHOTO OR DRAWING	MACHINE-TOOL, TOOLS
10	WORK AT WORKBENCH		
11	Manually screw electromagnet onto the base. __Note__: Loosely screwing the electromagnet allows you to adjust the distance between it and the rotor magnets.		
12	Insert the rotor shaft into the holes in the brackets (N° 2). Position the brackets on the base.		
13	Screw the brackets onto the base ensuring that they are well aligned.		- Screwdriver - N° 6 x 3/4" round head screw

Wiring the electrical circuit

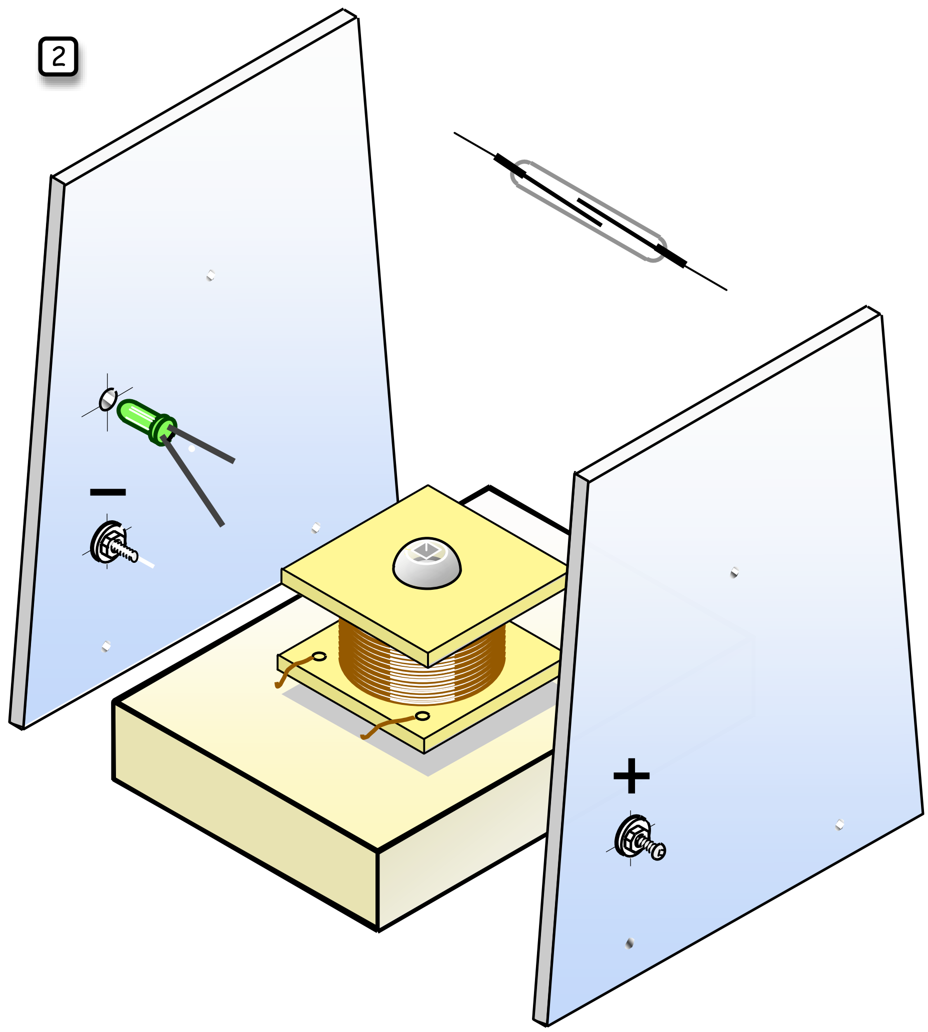
You're done: you have your RSM in hand. Now, it needs to turn. To make it do so, you must wire your motor, following n° 1 circuit drawing below. A review of the "Questionnaire on the operation of the RSM" may help you to better understand the circuit to be assembled. Complete drawing n° 2 below in order to be prepare to correctly solder the components. Using a coloured pencil, trace the wires as they will be soldered to the prototype.

N. B. The polarities of the supply terminal are indicated over the bolts. The long LED electrode is positive (see n° 3 below).

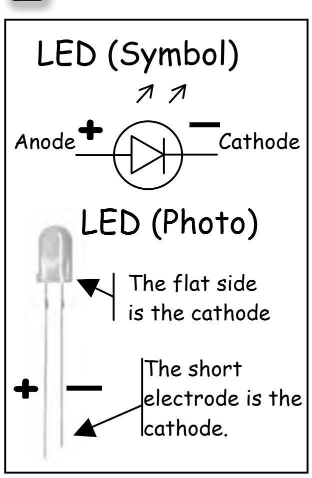
1



2



3



Specifications booklet for the magnetic switch bracket

Global function

Using the process described on the following pages, each team must design a bracket for the RSM's magnetic switch while respecting the following parameters.

During the design process, only take into account the un-ticked aspects. The necessary choices have already been made where the aspects are ticked. ☑

☑	a)	**In terms of the *physical aspect*** *(effect of natural elements: water, air, earth, radiation etc.) on the object,* ***the bracket must:*** • be comprised of materials adapted to normal inside usage conditions.
☐	b)	**In terms of the *technical aspect*** *(constraints related to operation: contacts with other technical objects, imposed components),* ***the bracket must:*** • be affixed to the rotor shaft(s); • allow the replacement of the switch; • be adjustable, to obtain maximum efficiency of the motor at a tension of 9 volts (turn at high speed and start by itself); • be adjustable in order to be able to reverse the direction of rotation of the motor.
☐	c)	**In terms of the *human aspect*** *(security, ergonomics, aesthetics, ethics),* ***the bracket must:*** • protect the glass envelope of the magnetic switch against impacts caused by the rotating magnets; • be free from any sharp edges or pointed elements.
☑	d)	**In terms of the *industrial aspect*** *(production: workshop, tooling, labour, manufacturing delays),* ***the bracket must:*** • be carried out with the materials and tools available in the workshop.
☑	e)	**In terms of the *economic aspect*** *(cost, etc.),* ***the bracket must:*** • be made from simple elements in order to minimise costs.
☑	f)	**In terms of the *environmental aspect*** *(impact of the object on the environment: end of life recycling, life cycle, etc.),* ***the bracket must:*** • be made of sturdy elements that will ensure durability.

Design of the magnetic switch bracket

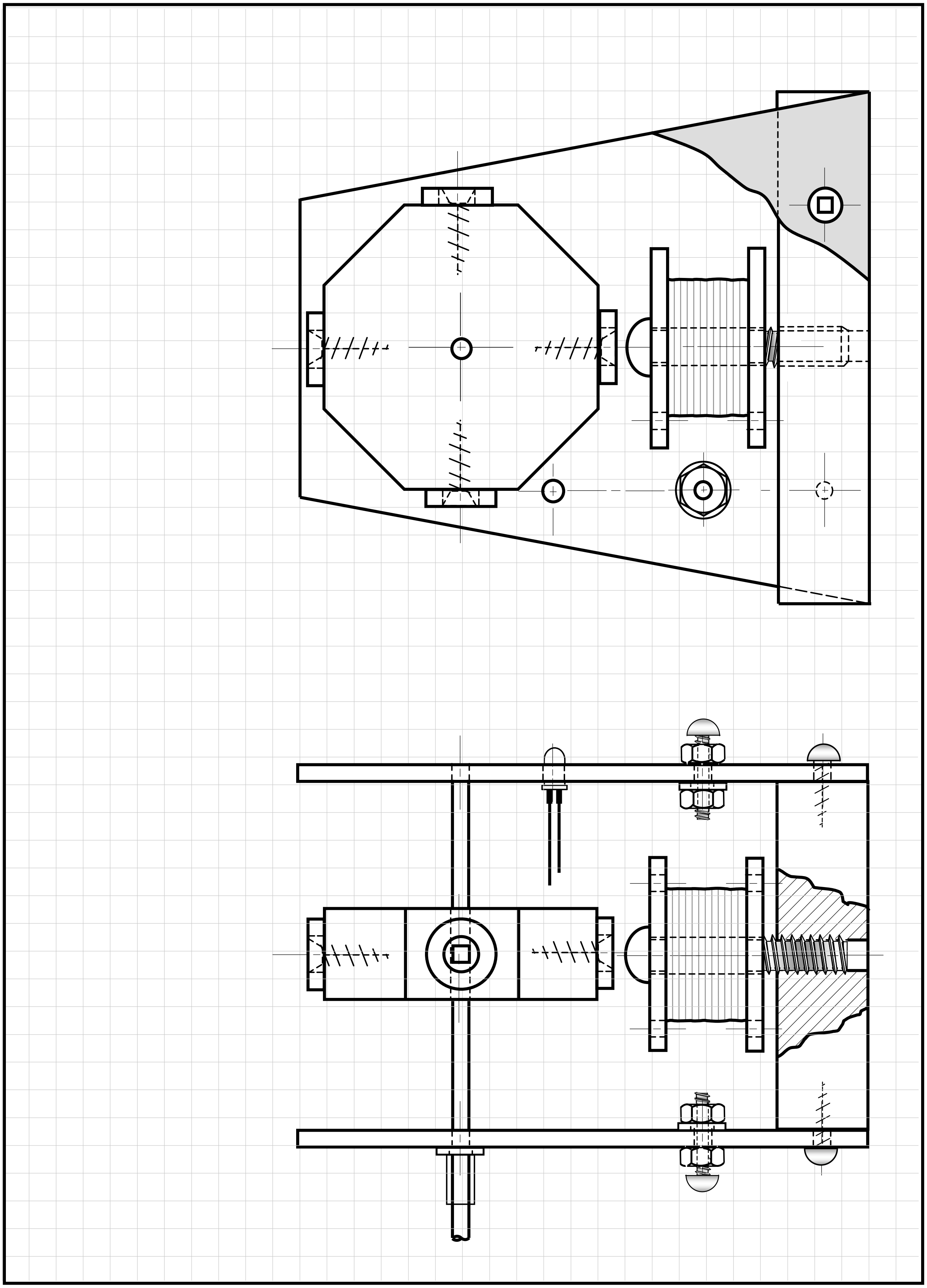
1. Outline the problem, keeping in mind the drawings, ranges and specifications booklet

2. Simmer your ideas (written and sketched)

3. Evaluate your ideas and choose (justify your choice)

Draw the retained solution on the next page

Your choice and its justification



4. Carry out a prototype of the retained solution

Record all decisions made

____

____

Design and/or construction problems	**Adjustments or modifications**

5. Carry out a test of the bracket

Evaluate its efficacy and improve the solution

 ***Test performed and results obtained***	 ***Improvements***

Testing the RSM (study of its characteristics)

Determine its electrical resistance while under 9 volts of tension.	
Data	*Calculation(s)* Answer:__________________
Equation(s)	

Calculate its power at 9 volts of tension.	
Data	*Calculation(s)* Answer:__________________
Equation(s)	

SUGGEST a way to evaluate the efficiency of the RSM.

To what kind of mechanical effort could you submit your motor?
My suggestions:
My final solution:
Detailed explanation:

TEST *Using your testing solution, calculate the electrical energy consumed by the motor. You must use 9 volts of tension.*	
Data	*Calculation(s)* Answer:_________________
Equation(s)	

How does your RSM compare to that of the other teams? Did the other teams use the same solution for mechanical effort as you did? Do you think that energy is conserved during the operation of your RSM? If energy is not conserved, into what forms was the electrical energy transformed? Can the output of the motor by 100%? Explain.

<table>
<tr><td colspan="2">For those following the (ES) optional course, calculate the potential gravitational energy.</td></tr>
<tr><td>Data</td><td rowspan="2">Calculation(s)

Answer:__________________</td></tr>
<tr><td>Equation(s)</td></tr>
</table>

<table>
<tr><td colspan="2">Now calculate its output using the following equation.</td></tr>
<tr><td>Data</td><td rowspan="2">Calculation(s)

Answer:__________________</td></tr>
<tr><td>Equation(s)
Output $= E_p/E_e \bullet 100$,
where E_p is the potential gravitational energy.</td></tr>
</table>

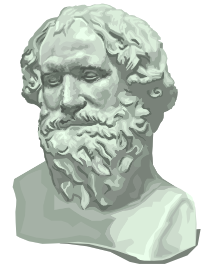
Again! Time to learn a little more!

Now it is time to acquire new knowledge. Here now are two activities that will allow you to better understand the operation of a hydroplane.

1. **Archimedes' Principle**
   - To understand the reason certain objects float.
   - To facilitate the balance of the hydroplane on the water.
2. **Bernoulli's Principle**
   - To improve the performance of the propeller that you will design.

Presentation of Archimedes' Principle

A discovery from long ago, but that could be useful...



Archimedes, a scholar from Antiquity (287-212 B.C.), left us a considerable heritage, as much in mathematics as in science and technology. Inventions such as the worm drive, levers and gears are attributed to him, to name but a few. He is also said have discovered an important principle while taking his bath: **"Any object, immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object."** This principle is known today as "Archimedes' Principle."

Translated from Wikipedia – September 2008 (http://fr.wikipedia.org/wiki/Poussée_d'Archimède)

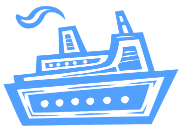
The crown of King Hiero II

Vitruvius reports that King Hiero II of Syracuse (306-214 B.C.) asked his young friend and scientific counsellor Archimedes (then only 22 years old) to verify if a golden crown, that he had had made as an offering to Jupiter, was made entirely of gold or if the artisan had put some silver in it. The constraint was, of course, that the crown could not be damaged. Its shape was too complex to carry out a calculation of the volume of the ornament. Archimedes reputedly found the way to verify that the crown was truly all gold while at the public baths, by observing objects floating there. He is said to have come out into the streets yelling the famous: "Eureka!" (I found it!)

At the public bath, Archimedes notices that for the same volume, objects do not have the same apparent weight, that is a different mass per unit of volume. Today, this is called density. The density of silver (density: 10 500 kg·m-3) is weaker than gold's (density 19 300 kg·m-3). From this premise, Archimedes deduced that if the artisan had hidden silver in the king's crown, the density would be lower. Thus was the jeweller's deceit was discovered.

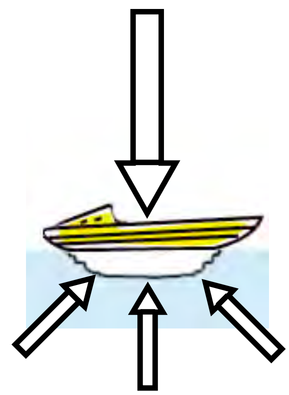
But concretely, what does this really mean?

You have surely already lifted somebody in your arms while in the water. The person seems much lighter than usual. The reason for this phenomenon is quite simple. The water that was where the person was before getting into the water, is trying to return to where it was. The water particles thus push the person, trying to lift them out of the water. This phenomenon helps synchronised swimmers raise themselves out of the water when they are swimming.

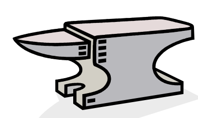


The same phenomenon can be observed with all fluids. The greater the density of the fluid, however, the harder it pushes to return to its place. That is why we float better in salt water. For this same reason, boats float better on salt water, which is more dense than fresh water. The boat will sink much less into the salt water than the fresh.

But how deeply will it sink? Imagine a miniature boat weighing 1000 grams. When we place it in the water, its hull displaces a certain amount of water. Since the water seeks to return to its place, it applies an upward force on the hull. The deeper the boat sinks, the greater the number of water particles pushing it upwards. At a certain depth, the force of this thrust is exactly equal to the force of gravity on the boat. At this moment, the boat stops sinking deeper. **At this precise instant, the mass of water displaced by the hull is exactly equal to the mass of the boat.** In our case, since the boat weighs 1000 grams, There will be precisely 1000 grams of water displaced. In fresh water, we can even say that there will be a 1000 mL volume displaced, since the density of water is 1 g/mL.



In the case of a heavy object like an anvil, we know it will not float on the water. Nevertheless, the force of the displaced water when it is immersed does reduce its mass. The following equation describes this phenomenon.



$$\textbf{Mass}_{\text{(in the water)}} = \textbf{Mass}_{\text{(in the air)}} - \textbf{Mass}_{\text{(of the displaced water)}}$$

You now know enough about Archimedes' Principle to design a hydroplane that will float every time.

Questionnaire on Archimedes' principle

The questions that follow will allow you to better understand Archimedes' famous principle. Since the first questions are easier, answer them in sequential order.

Reminder of a useful equation

$\rho = m/V$ Where $\rho \Rightarrow$ density in g/cm^3, m $\Rightarrow$ mass in g, V $\Rightarrow$ volume in cm^3

Question 1
What will happen to a marble with a density of 2.6 g/cm^3 when it is plunged in water[1]?

Question 2
Why does a log float on the water?

Question 3
To what depth will a boat sink into the water?

[1] The density of water being 1 g/cm^3

Question 4

You have to transport a gold bar whose dimensions are the following: 20 cm x 10 cm x 5 cm.
The density of gold is 19.3 g/cm^3.

What is the mass of the bar? (Leave traces of your calculations)

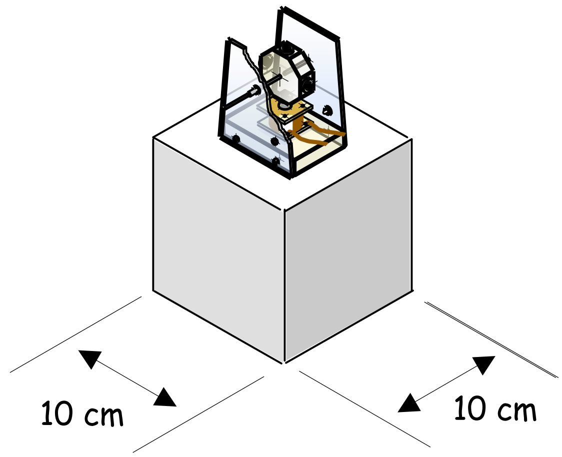
What is the mass of the bar in the water? (Leave traces of your calculations)

QUESTION 5

We place a 400 g miniature RSM on the block of expanded polystyrene at right. The mass of the block is 100g. Being careful to maintain its balance, the assembly is placed in a basin of water (this assembly is hypothetical - balancing it would be difficult because of its high center of gravity).

To what depth would the block sink (we could also say: how much water does the system draw[2])?

We again consider that the density of water is 1 g/cm^3.



(Leave all the traces of your calculations)

[2] Vertical distance between the floatation line of a boat and the lowest point of its hull.

Presentation of Bernoulli's Principle

Translated from Wikipedia – September 2009
(*http://fr.wikipedia.org/wiki/Théorème_de_Bernoulli*)

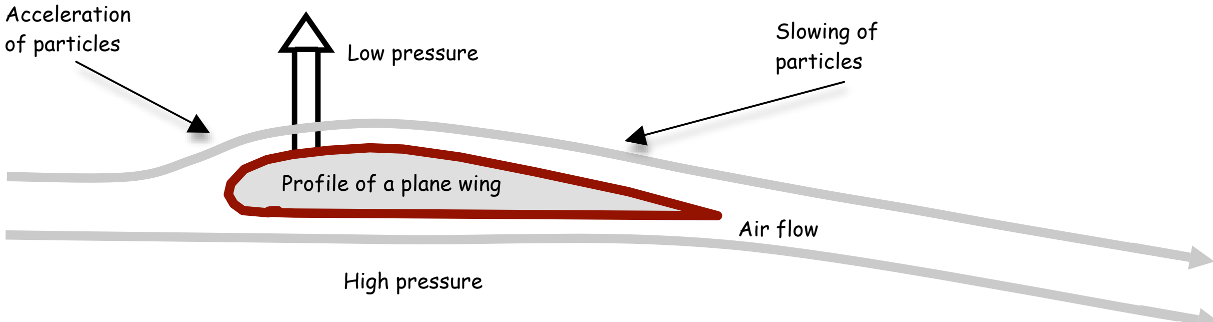
Daniel Bernoulli (1700 – 1782)
Swiss physicist and mathematician

Bernoulli's Theorem *was established by Daniel Bernoulli in 1738 and expresses the simplified balance of a hydraulic fluid in a pipe. He established the bases for hydrodynamics and in a more general fashion, for fluid dynamics.*

Essentially, Bernoulli showed that the speed and pressure of a fluid vary in inverse proportions. Thus, great speed in a fluid creates low pressure in it. Conversely, slow speed will engender strong pressure.

A simplistic way to understand this phenomenon is to imagine that when the particles accelerate, they get further away from one another. In an area where the fluid has great speed, there are therefore fewer particles present. As we know, pressure is generated by the collision of particles with objects. We can thus conclude that the fact that there are fewer particles implies lower pressure.

Increase in the speed of the particles → Increase in the distance between the particles → Decrease in the number of particles in a given volume → Decrease in the number of collisions made by the particles → Decrease in the pressure exerted by the particles



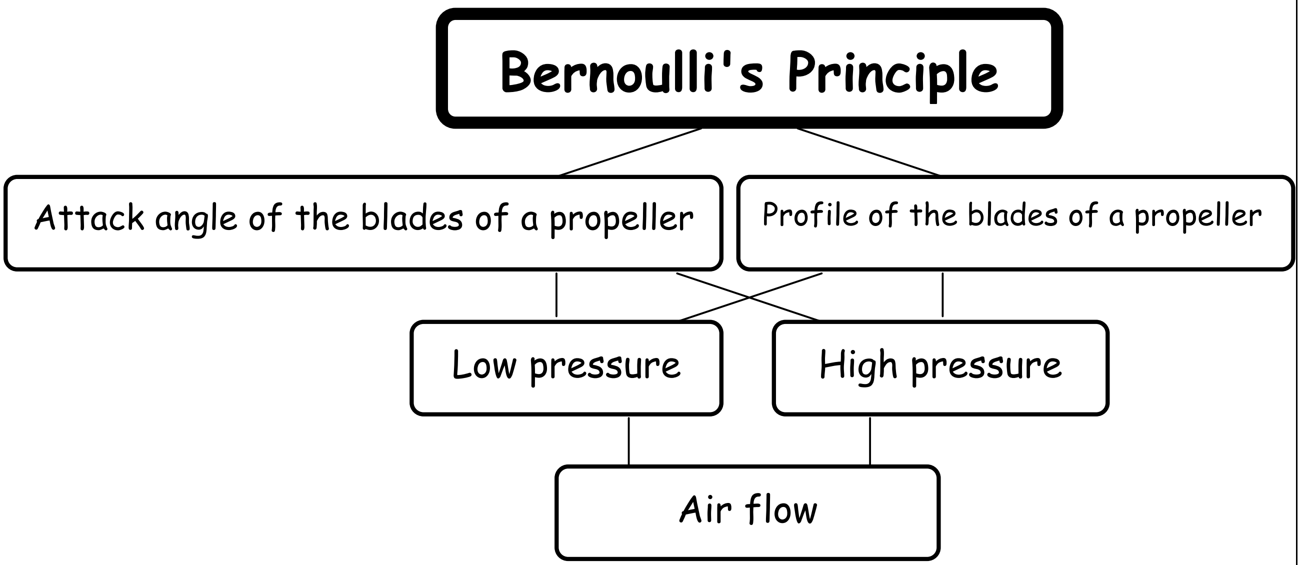
To resume:

The airflow around the wing generates these high and low pressure zones. Objects always tend to move from a high pressure to a low pressure zone. We need only think of a bullet in the canon of a revolver, a sneezing person or the simple presence of wind. An ascending force thus appears and this force supports the plane in flight.

Propeller and Bernoulli's principle

Questions: What is the effect of the variation of the attack angle of a propeller on the quantity of air it can drive away? What is the effect of the variation of the curvature of the blades of a propeller on the quantity of air it can drive away? What kind of curve can we draw, experimentally? What mathematical relation links these two physical sizes? What should remain constant during the experiment? How can this study help you to design a better hydroplane?

Exploration card

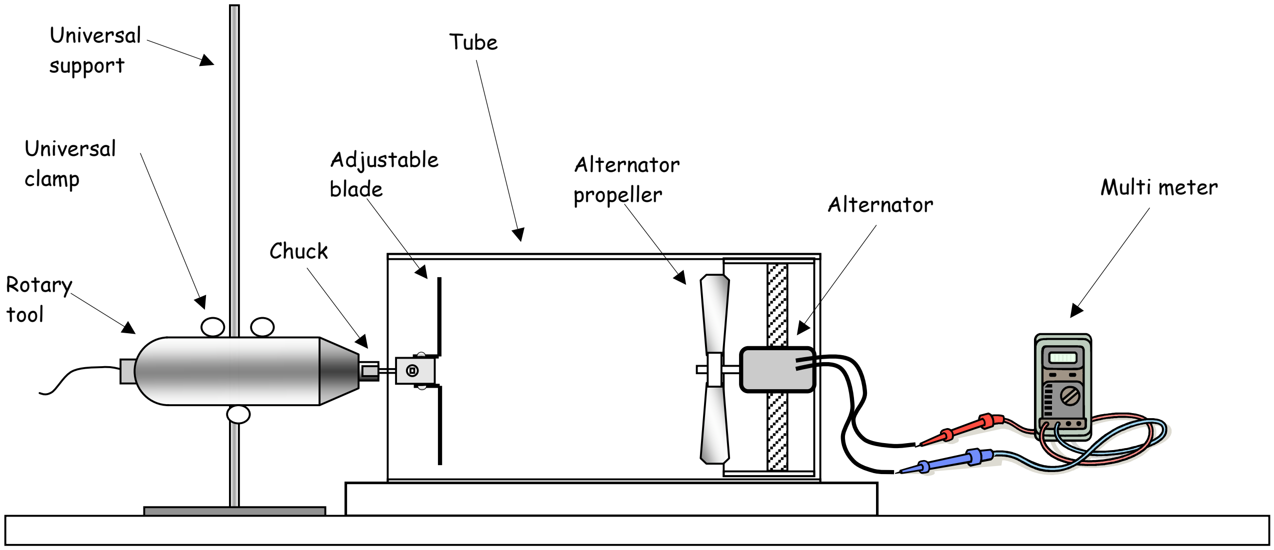


Directed Laboratory 1 (with flat blade propeller)

Equipment

- 1 universal support
- 1 universal clamp (nut)
- 1 high speed rotary "Dremel" tool (about 10,000 rpm)
- 1 propeller with two adjustable blades
- 1 multi meter
- 1 trial tube
  - 150 Ø x 300 mm «Sonotube»
  - tube support
  - alternator propeller
  - alternator (toy motor)
- 1 No. 1 square head screwdriver

Assembly diagram



Manipulations

1. Affix the rotary tool to the universal support using the universal clamp.
2. Insert the axle of the adjustable propeller into the chuck of the rotary tool.
3. Connect the multi meter onto the alternator of the trial tube.
4. Adjust the multi meter in alternate current mode in the millivolt scale (mV).
5. Adjust the attack angle of the two blades by positioning them vertically (0° angle) using the No. 1 screwdriver (in this position, the blades should cleave the air without pushing the air one way or the other.)
6. Adjust the universal support in such a way as to:
    a. Introduce the adjustable propeller into the tube approximately 4 cm from the edge (the tube guides the air and protects the user from possible projections).
    b. Center the propeller in the tube.
7. Wear protective glasses to protect yourself from possible projections.
8. Start the rotary tool (the speed has been preset).
9. Measure and record the voltage on the multi meter (the voltage should be nil, since no wind should be present).
10. Repeat steps 5 to 9 with angles of 15, 30, 45, 60, 75 and 90 degrees (the air flow should be towards the alternator).

In one sentence, resume your goal:

In one sentence, formulate your hypothesis:

What are the constant factors during this experiment? (examples: speed, distance, position etc.)?

Resume your protocol in the form of a diagram.

Data Table		
Trial	**Attack angle (˚)**	**Voltage (mV)**
1	**0**	
2	**15**	
3	**30**	
4	**45**	
5	**60**	
6	**75**	
7	**90**	

Analyse the results

Treat your data

Highlight the trends

Question 1
In your opinion, what would the ideal attack angle for your blades be?

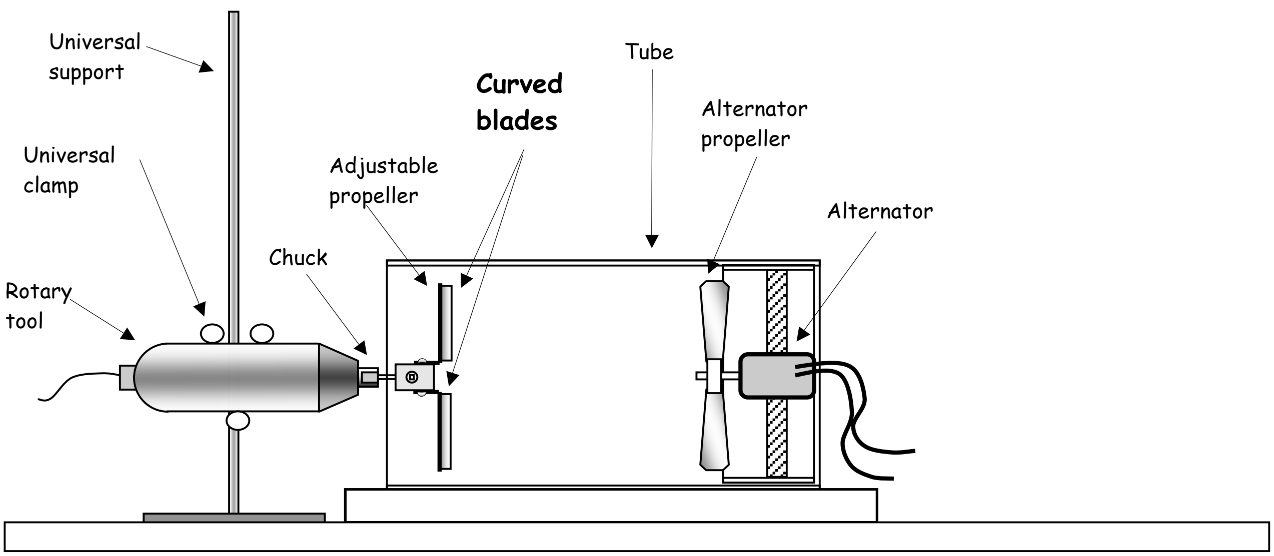
Question 2
Why is the graph asymmetrical? In other words, why does the curve not go back down to 0 mV at an attack angle of 90°?

Directed laboratory 2 **(with the non inclined, curved blade propeller)**

Equipment

- 1 universal support
- 1 universal clamp (nut)
- 1 high speed rotary tool
- 1 propeller with two adjustable blades
- **2 half dowels**
- **1 strip of paper (1x28 cm)**
- **4 - No. 0 square head screws**
- 1 trial tube
  . 150 Ø x 300 mm «Sonotube»
  . tube support
  . alternator propeller
  . alternator (toy motor)
- **2 square head screwdrivers, No. 1 and No. 0.**

Assembly diagram



Manipulations

1. Affix the rotary tool to the universal support using the universal clamp.
2. Insert the axle of the adjustable propeller into the chuck of the rotary tool.
3. Affix the two half dowels to the blades using the four No 0 square screws.
4. Adjust the attack angle of the blades to 0° with the curved blades (dowels) toward the alternator, as in the drawing above.

5. Adjust the universal support in such a way as to insert the adjustable propeller into the tube approximately 4 cm from the edge and center the propeller in the tube.
6. Wear protective glasses to protect yourself from possible projections.
7. Start the rotary tool (the speed has been preset).
8. Observe and record the direction that the alternator propeller is turning (clockwise or counter clockwise, looking from the alternator side).
9. In order to determine and record the direction of the air flow, hold the strip of paper by one of its ends and position it near the opening of the tube, at the alternator end.
10. Repeat steps 6 to 11 with the curved blades towards the rotary tool.

In one sentence, resume your goal:

In one sentence, formulate your hypothesis:

What are the constant factors during this experiment? (examples: speed, distance, position etc.)?

Resume your protocol in the form of a diagram.

Data Table		
	Direction of rotation of the alternator propeller	**Direction of air flow indicated by the strip of paper**
Blades curved towards the alternator		
Blades curved towards the rotary tool		

Analyse the results

Treat your data.

Question 1

How must the curved blades be placed in order to promote air flow in the tube toward the alternator?

Question 2

In this case, on which side of the propeller is the low pressure zone predicted in Bernoulli's principle? (rotary tool side or alternator side)

Question 3

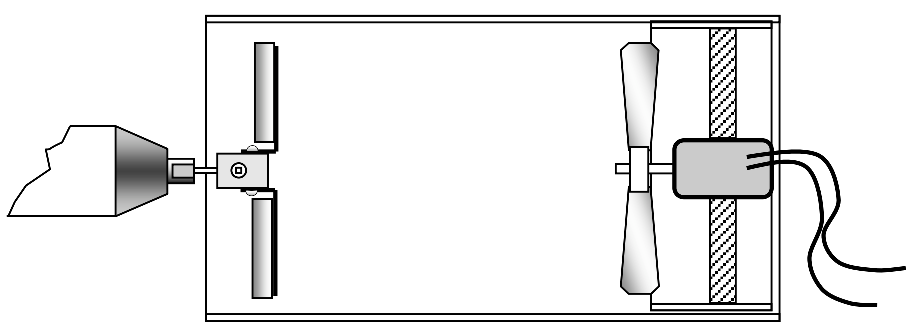
Air is always displaced from a high pressure zone to a low pressure zone. We need only think about the air escaping from a punctured tire to be convinced of this. On the drawing below, use arrows to indicate the displacement of the ambient air (at atmospheric pressure) towards the low pressure zone.

Question 4

Still using this same scenario, the high pressure zone predicted by Bernoulli's Principle is located on which side of the propeller (rotary tool side or alternator side)?

Question 5

Again on the same drawing below, use arrows to indicates the air displacement from the high pressure zone to the lower pressure zone close to the alternator.

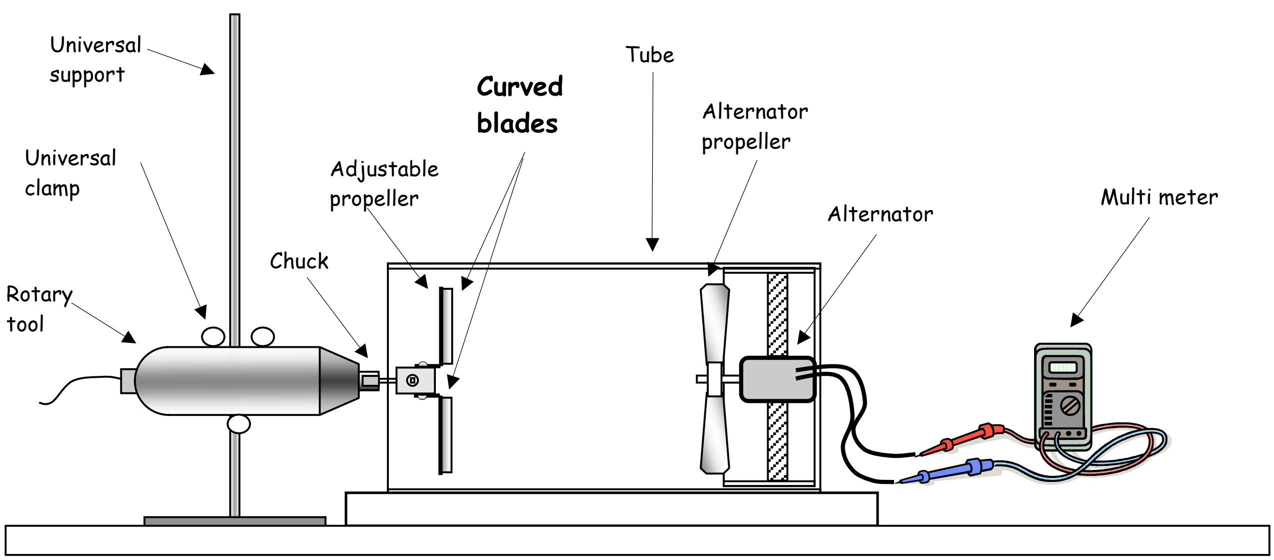


Directed laboratory 3 **(with the variable inclination, curved blade propeller)**

Equipment

- 1 universal support
- 1 universal clamp (nut)
- 1 high speed rotary tool
- 1 propeller with two adjustable blades
- 2 half dowels
- **1 multi meter**
- 4 - No. 0 square head screws
- 1 trial tube
  . 150 Ø x 300 mm «Sonotube»
  . tube support
  . alternator propeller
  . alternator (toy motor)
- 2 square head screwdrivers, No. 1 and No. 0

Assembly diagram



Manipulations

1. Affix the rotary tool to the universal support using the universal clamp.
2. Insert the axle of the adjustable propeller (equipped with curved blades) into the chuck of the rotary tool.
3. Connect the multi meter to the alternator on the trial tube.
4. Adjust the multi meter in alternate current mode in the millivolt scale (mV).
5. Adjust the attack angle of the two blades by positioning them at a 0˚angle using the No. 1 screwdriver (the curved side of the blades should be placed in such a way as to promote air flow towards the alternator)

6. Adjust the universal support in such a way as to insert the adjustable propeller into the tube approximately 4 cm from the edge and center the propeller in the tube.
7. Wear protective glasses to protect yourself from possible projections.
8. Start the rotary tool (the speed has been preset).
9. Measure and record the voltage on the multi meter.
10. Repeat steps 5 to 9 with angles of 15, 30, 45, 60, 75 and 90 degrees (the air flow should always be towards the alternator).

In one sentence, resume your goal:

In one sentence, formulate your hypothesis:

What are the constant factors during this experiment? (examples: speed, distance, position etc.)?

Resume your protocol in the form of a diagram.

Data Table		
Trial	**Attack angle (˚)**	**Voltage (mV)**
1	**0**	
2	**15**	
3	**30**	
4	**45**	
5	**60**	
6	**75**	
7	**90**	

Analyse the results

Treat your data

Highlight the trends

Question 1
In your opinion, what would the ideal attack angle for your curved blades be?

Question 2
Comparing the graphs from laboratories 1 and 3, what can you conclude?

Draw your conclusions

Question 3

Taking into account the three previous manipulations, what would the best configuration be for your propeller (angle of the blades and orientation of the curved blades)?

Question 4

What could you do to make the propeller of your hydroplane even more efficient?

Question 5

In your opinion, can Bernoulli's Principle be applied to the rudder of your hydroplane? Why?

Specifications booklet for the propeller

Global function

Using the design process described on the following pages, each team must design a propeller that will allow the RSM to propel a hydroplane, while respecting the following parameters.

During the design process, only take into account the un-ticked aspects. The necessary choices have already been made where the aspects are ticked. ☑

☑	a)	**In terms of the** ***physical aspect*** *(effect of natural elements: water, air, earth, radiation etc.) on the object,* ***the propeller must:*** • be comprised of materials adapted to normal inside usage conditions.
☐	b)	**In terms of the** ***technical aspect*** *(constraints related to operation: contacts with other technical objects, imposed components)*, ***the propeller must:*** • be affixed by the core to the rotor shaft of the RSM; • Have a maximum length of 140 mm in order to be able to be installed on the hydroplane (60mm for the first blade + ≈20 mm for the core + 60 mm for the second blade); • allow the rotation of the blades on themselves so as to adjust the pitch of the propeller. This adjustment will allow the propeller to adapt to the direction of rotation and power of the motor.
☐	c)	**In terms of the** ***human aspect*** *(security, ergonomics, aesthetics, ethics)*, ***the propeller must:*** • be free from any sharp edges or pointed elements; • be equipped with solidly affixed blades.
☑	d)	**In terms of the** ***industrial aspect*** *(production: workshop, tooling, labour, manufacturing delays)*, ***the propeller must:*** • be carried out with the materials and tools available in the workshop.
☑	e)	**In terms of the** ***economic aspect*** *(cost, etc.)*, ***the propeller must:*** • be made from simple elements in order to minimise costs.
☑	f)	**In terms of the** ***environmental aspect*** *(impact of the object on the environment: end of life recycling, life cycle, etc.)*, ***the propeller must:*** • be made from recyclable or biodegradable components.

Design of two identical blades

1. Outline the problem keeping in mind the learning activities and specifications booklet

____

____

____

2. Simmer your ideas (written and sketched)

3. Evaluate your ideas and choose (justify your choice)

Draw the retained solution on the next page

Your choice and its justification

____

____

____

1. Draw the silhouette (top view) of the blade in a rectangle including the length (60 cm) and the width.
2. Draw the profile of the blade (side opposite the drilling) in another rectangle including the length (60 cm) and the width.

4. Carry out two identical prototypes of the retained solution

N.B. Drill the block of balsa beforehand in order to receive the axle.

Record all decisions made

Design and/or construction problems	Adjustments or modifications

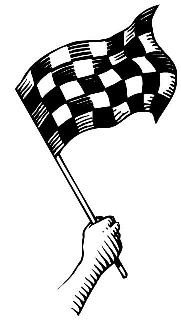
5. Carry out a test of the propeller

Evaluate its efficacy and improve the solution

Test performed and results obtained	*Improvements*

Synthesis activity

I now invite you to submit your propulsion system (RSM and propeller) to the ultimate test. You will measure yourself against the other teams in the course of a friendly race. The points allotted during the race are only there to add a little spice. After the race, a short synthesis and reflection activity will also be required.



The race unfolds

<table>
<tr><th colspan="17">Evaluation table for the propulsion system during the race</th></tr>
<tr><td colspan="3">Team name</td><td colspan="14"></td></tr>
<tr><th colspan="17">Design Points</th></tr>
<tr><td colspan="15">Successful design of the magnetic switch bracket (30 points)</td><td colspan="2">Tick (   )</td></tr>
<tr><td colspan="15">Design of the balsa propeller (30 points)</td><td colspan="2">Tick (   )</td></tr>
<tr><th colspan="17">Points for the speed of the hydroplane</th></tr>
<tr><td colspan="9">Distance covered (meters)</td><td colspan="8"></td></tr>
<tr><td colspan="9">Duration of the race (seconds)</td><td colspan="8"></td></tr>
<tr><td>Rank</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td></tr>
<tr><td>Points</td><td>32</td><td>30</td><td>28</td><td>26</td><td>24</td><td>22</td><td>20</td><td>18</td><td>16</td><td>14</td><td>12</td><td>10</td><td>8</td><td>6</td><td>4</td><td>2</td></tr>
<tr><td>Tick</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th colspan="17">Points for the precision of the guidance system</th></tr>
<tr><td colspan="9">Distance from the center of the target (cm)</td><td colspan="2">0 to 4</td><td colspan="2">4 to 8</td><td colspan="2">8 to 12</td><td colspan="2">12 to 16</td></tr>
<tr><td colspan="9">Points</td><td colspan="2">8</td><td colspan="2">6</td><td colspan="2">4</td><td colspan="2">2</td></tr>
<tr><td colspan="9">Tick</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th colspan="13">Total points:</th><td colspan="4"></td></tr>
</table>

Disqualification if the hydroplane:

- has a remote controlled guidance system;
- is touched by anyone after the start of the race;
- has a power source other than a standard 9 volt alkaline battery

May the best hydroplane win!

Various calculations related to the race

Calculate the average speed of the hydroplane	
Data	*Calculation(s)*
Equation(s)	Answer :__________________

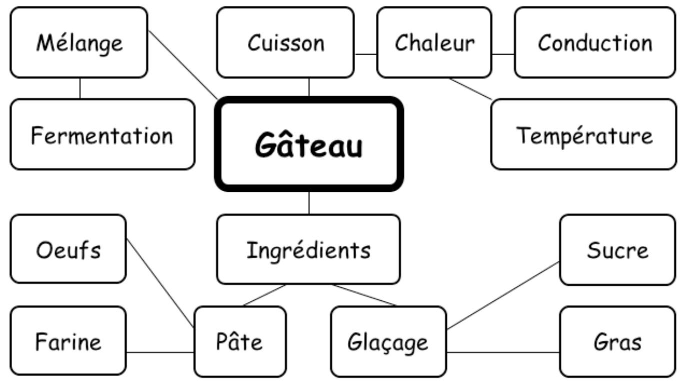
Calculate the electrical energy consumed by the hydroplane (see page 28)	
Data	*Calculation(s)*
Equation(s)	Answer :__________________

Calculate the average kinetic energy of the hydroplane (for the ES course)	
Data	*Calculation(s)*
Equation(s)	Answer :__________________

Network of concepts

Following the study and fabrication of your Reed Switch Motor, build a network of concepts related to the electric motor. Making this new network will allow you to appreciate the path travelled since the beginning of this LES. You probably know a lot more on the subject!

Example of a network of concepts



Network of concepts

Electric motor

Build a network of concepts related to the hydroplane. **The word bank at right may inspire your work.** **Take care to organise it logically.**	**Word bank** • Archimedes' Principle • Hull • Density • Mass • Volume • Water displacement • Floatability • Bernoulli's Principle • Propeller • Rudder • Pressure • Speed • Particle • Flow

Network of concepts

Hydroplane

Thinking about your professional aspirations

Think about your professional aspirations as they relate to this LES