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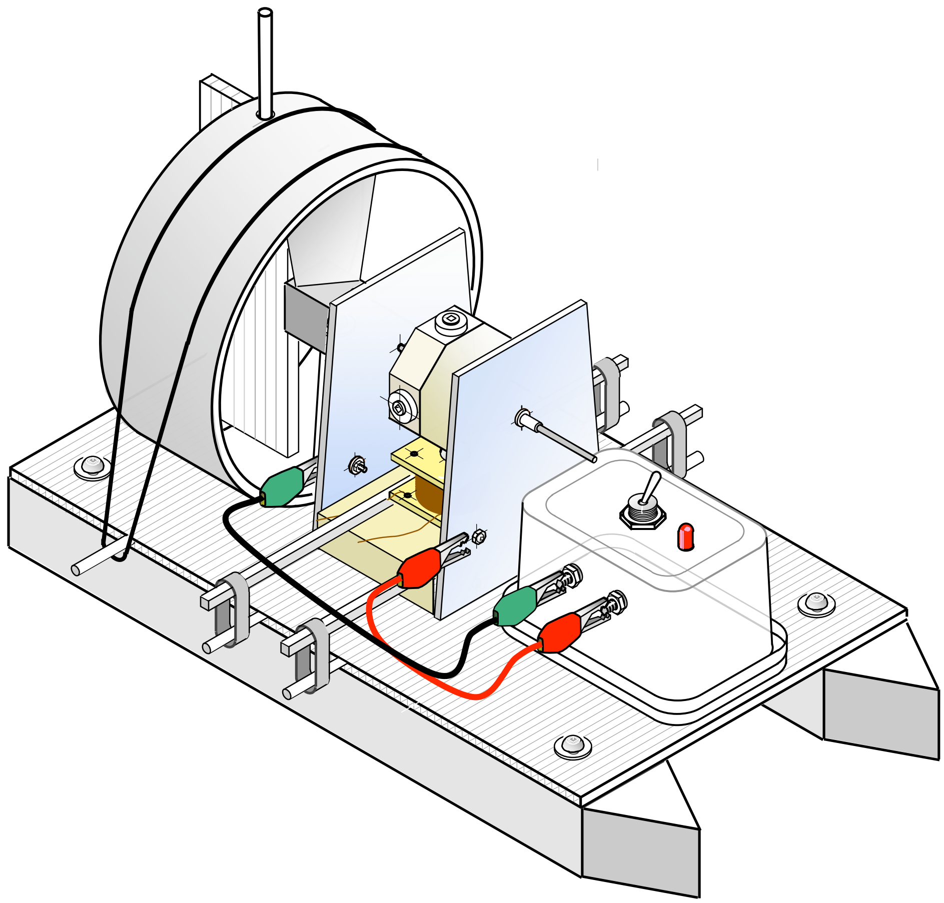
Working document

THE ELECTRIC HYDROPLANE



TEACHER'S GUIDE

October 2010

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Concepts broached in this LES

For the AST course in the fourth year of high school (without the ES course)			
World	Number of concepts in the program	Number of concepts targeted by the LES	Percentage of concepts broached
Technological	22	12	55 %
Living	7	0	0 %
Material	22	10	45 %
Earth and Space	9	0	0 %
Total:	60	22	37 %

Remarks:

- This LES takes 15 periods. This "theoretically" represents 12.5% of the available time during the course of the school year. This percentage could grow since in reality, many periods are not available for teaching (activities, storms, evaluations etc.)
- The concepts targeted by this LES are seen in a concrete, applied approach. Some, however, will have to have been introduced beforehand while others will need to be looked at in greater depth afterwards.

Arrangements possible to limit the cost of the LES:

- The Reed switch motor (RSM) can be reused year after year, which limits the material costs. The student then only has to design the bracket for the magnetic switch. This way, you would cut out 3 lessons (lessons 4, 5 and 6) in the suggested teaching plan. The number of concepts broached would, however, be fewer. Here are those that would not be broached, or would be broached perfunctorily:
    - Functional dimensioning
    - Adhesion and friction between parts
    - Drilling
    - Measurement and control (form and position, angle)

Suggested teaching plan

Lesson (75 min.)	**Summary description in relation to the student's booklet**	**To be foreseen**
Lesson 1	• Catalyst (student booklet p. 3) • Activation of previous knowledge (p. 4) • Review of learning activities (p. 6 to 8)	• Multimedia projector to present video clips. • Demonstration materials regarding circuits and magnetism. • Board for the plenary session on network of concepts.
Lesson 2	• Review of learning activities (p. 9 to 12)	• Demonstration materials regarding electromagnetism, power and energy.
Lesson 3	• Presentation of the complex task (p. 13) • Analysis of the RSM (p. 14 to 18) . Video of the RSM in action . Components of the RSM . PowerPoint on the explanation of the RSM . Questionnaire on the RSM's operation	• Multimedia projector to present video and PowerPoint clips.
Lesson 4	• Fabrication of the RSM in teams of two students (lesson 1 of 3) . beginning of the fabrication of the electromagnet (since this step is long, there must always be a team at this station) . fabrication of the base . fabrication of the shaft brackets	• The RSM's technical file • Workshop with machine tools • See range for all other necessary tools
Lesson 5	• Fabrication of the RSM (lesson 2 of 3) . finish making the electromagnet . fabrication of the rotor . start the final assembly	• The RSM's technical file • Workshop with machine tools • See range for all other necessary tools

Lesson (75 min.)	**Summary description in relation to the student's booklet**	**To be foreseen**
Lesson 6	• Fabrication of the RSM (lesson 3 of 3) . finish final assembly . wiring the circuit (soldering) . initial powering up	• The RSM's technical file • Workshop with machine tools • See range for all other necessary tools
Lesson 7	• Beginning of the design of the magnetic switch bracket (p. 21 to 24) . outlining the problem . simmering your ideas . choosing and diagramming . carrying out a prototype	• Various materials that could be used in the design • Various tools • Workshop with machine tools if necessary
Lesson 8	• Finishing the design of the magnetic switch bracket (p. 21 to 24) . Carrying out a prototype . Testing the bracket . Improving the prototype if necessary	• Various materials that could be used in the design • Various tools • Workshop with machine tools if necessary
Lesson 9	• Testing the RSM, determine experimentally (p. 25 to 28) : . resistance with Ohm's Law . power . electrical energy . potential energy generated by labour . energetic output	• One RSM per team • Laboratory materials . 9 volt power source . voltmeter . ampere meter . stopwatch . set of masses for scale …
Lesson 10	• Learning activity dealing with Archimedes' Principle (p. 30 to 34) • Beginning of the learning activity dealing with Bernoulli's principle (p. 35 to 39)	• Equipment necessary for directed laboratory 1 (p. 35) • Optional: Computer with spreadsheet for data treatment (graph)
Lesson 11	• End of the learning activity dealing with Bernoulli's principle (p. 40 to 46)	• Equipment necessary for directed laboratories 2 and 3 (p. 39, 42) • Optional: Computer with spreadsheet for data treatment (graph)

Lesson (75 min.)	**Summary description in relation to the student's booklet**	**To be foreseen**
Lesson 12	• Beginning of the propeller design (p. 47 to 50) . outlining the problem . simmering your ideas . choosing and diagramming . making the first blade	• Various materials that could be used in the design • Various tools • Workshop with machine tools if necessary
Lesson 13	• End of the propeller design (p. 47 to 50) . making the second blade . testing the propeller (finding the ideal pitch) . improving the prototype if necessary	• Various materials that could be used in the design • Various tools • Workshop with machine tools if necessary
Lesson 14	• Beginning of the synthesis activity, hydroplane race (p. 51) Note: The technical file of a hydroplane model is available on the CDP website. The hydroplane can be used by all the teams.	• Each team's hydroplane • Stopwatch • Water basin . pool for the lucky few . under bed storage bin
Lesson 15	• End of the synthesis activity (p. 52 to 55) . complete the two networks of concepts to become aware of progress . calculate the average speed of the hydroplane during the race . calculate the electrical energy consumed by the hydroplane during the race . calculate the average kinetic energy of the hydroplane during the race . think about your professional aspirations	• Each team's hydroplane • Scale to weigh the hydroplanes • Access to Internet or other sources with the objective of nourishing the students as to their professional aspirations.

Time to learn a little more!

The learning activities may be presented in a variety of ways. Each teacher must determine which they prefer, especially considering that the equipment available in each establishment may differ. These few lines attract your attention to the important elements to be considered before attacking the LES.

Circuit

The notion of electrical conductivity is imperative to understanding the electric motor. Indeed, we need only think about a glass magnetic switch or about varnished copper wire to be convinced. Circuit diagramming and its symbolism should have been covered in the AST course in third year of high school. It will surely be appropriate to foresee a review of these concepts.
Finally, different electrical circuits must be recognized. Indeed, the RSM's circuit, with its protective diode, is a mixed circuit.

Magnetism

Note*: If you experienced the "Earphone" LES, these notions have already been presented.*
The RSM is made up of non magnetic, magnetic and ferromagnetic substances. It is perfect for broaching these properties, especially since they are essential to understanding the motor's operation.
Understanding the permanent magnet, with its poles and magnetic field, is primordial. The forces exerted between two magnets must also be known. Even the use of the compass is indispensable. In fact, the student will have to determine the poles of the rotor's magnets. These will have to be properly oriented, otherwise the motor will not be functional. (You can not rely on the red dots to indicate the north pole of magnets used for the RSM. We have detected errors in these.)

Electromagnetism

***Note**: If you experienced the "Earphone" LES, these notions have already been presented.*

The solenoid has a choice spot in the structure of the RSM. It is important to understand it perfectly. The factors that influence the force of its magnetic field must be known (ferromagnetic hub, number of whorls, amperage). By studying its magnetic field and its magnetic poles the student will be able to grasp the parallels to permanent magnets.

The right hand rule can be introduced to the students. You will find a useful PowerPoint presentation on this subject, on the CDP website.

Measurement

Once the student is ready to proceed to testing his RSM, he will have to, among other things, calculate the electrical resistance of the motor <u>while it is working</u>, using Ohm's Law. To do so, the student will have to be able to measure the voltage at its terminals as well as the intensity of the current that runs through it.

Important remarks

It must be noted that resistance measured using an ohmmeter does not give the same measurement as the value calculated using current intensity and voltage. It is by far inferior. Since the ohmmeter is an instrument used while a device is not under voltage, the measurement would not reflect reality.

In fact, the current measured is an average current that takes into account the fact that the solenoid is not always under tension in the normal operation of a motor. The solenoid receives four electrical impulses for every rotation. It thus only works about 40% of the actual operating time. The effective current is thus much less than the current we would measure if the solenoid were in constant use. Since electrical resistance is obtained using the equation $R=U/I$, and that the voltage is constant, a low intensity implies high resistance. That is why the resistance calculated using intensity and voltage is much greater than that measured by an ohmmeter.

Power and electrical energy

When the student is testing his RSM, he will also have to calculate, among other things, the electrical power of the motor as well as the electrical energy consumed when it carries out a task. A stopwatch will also be used to measure the amount of time necessary to carrying out a task.

Potential gravitational energy

While testing his RSM, the student will need, among other things, to calculate its energetic output. Introducing potential gravitational energy makes the concept very easy to understand. That's why we suggest you study potential gravitational energy with all the groups, despite the fact that the concept is only associated to the ES course.

Average speed

After the race, the student must calculate the average speed of his hydroplane. To be successful, he will have available the size of the basin of water (length of the course) and the total duration of the race. The speed of the hydroplane at any given time (instantaneous speed) could be introduced in an intuitive and qualitative manner.

Kinetic Energy

After the race, the student will also have to calculate the kinetic energy (for the ES course only). To do so, he will have to weigh his hydroplane and have at his disposal the average speed previously calculated.

The energy thus calculated can not serve to calculate output as we did when testing the RSM. In this case, the energy will be underestimated. To obtain an acceptable amount of energy, we would have to use the maximum speed of the hydroplane.

Analysis of the RSM

Multi-functionality of the RSM

The **R**eed **M**otor **S**witch (RSM) is simple to make, explain, and especially, surprisingly reliable. The power of this motor allows a variety of applications accessible to students. In fact, it is possible to use the RSM as a motor for an elevator, a terrestrial vehicle or even the motor of a nautical vehicle such as the hydroplane. In addition, by having the rotor turn at the appropriate speed using a rotary tool, we could transform it into an alternating current generator. In that case, the LED would light up.

Usefulness of the light emitting diode (LED)

The diode is an electronic component that only allows current through in a single direction. In our case, it eliminates sparks that are produced inside the magnetic switch. Without it, the life expectancy of the switch would be greatly reduced due to the plates overheating. When the switch opens, the electrons continue on their way in the gas (or air) contained in the glass ampoule. The electrical inertia created by the solenoid projects them thus. Adding a diode creates a diversion lane without producing the destructive overheating. It is as if we directed a high speed train onto an avoidance track to slow it down without causing any damage. It must be noted that the diode must be polarised opposite to the battery. When the solenoid in under tension, no current should pass through the diode. The LED we are using could be replaced by an ordinary rectifying diode. This modification would reduce the cost, but the addition of a component that emits light is more interesting pedagogically. Indeed, it is interesting to note that the energy used to light up the LED would have been lost when the spark appeared. For more information on the diode, see the section entitled **"Advice for starting the RSM"**.

Correction of the questionnaire on the operation of the RSM

Notes

Before submitting the questionnaire to the students, you should:

1. Present the video of the RSM in action
2. Present the principal components of the RSM (as well as the LED)
3. Explain the operation of the magnetic switch (by approaching a magnet to the switch, it will close and make it a conductor of electricity)
4. Present the diagram of the circuit
5. View the PowerPoint presentation called "hydroplane_explanation_RSM_AST.ppt" (It allows you to explain, step by step, the operation of the RSM).

Question 1: The circuit is closed.

Question 2: Yes; the direction of the current corresponds to the polarity of the magnetic field.

Question 3: On repulsion – the south poles face one another.

Question 4: Yes; if the switch is moved upwards, repulsion will be produced sooner, thus producing an inversion in the direction of the rotation. It must be noted that an inversion of the polarity of the source of current <u>does not provoke</u> an inversion in the direction of rotation as is the case with motors working on direct current. An inversion makes the motor change from a repulsion mode to an attraction mode and vice versa.

Question 5: The circuit is open.

Question 6: No, the electromagnet is not working.

Question 7: There is a force of attraction between the hub of the electromagnet and the rotor's permanent magnet. This attraction is present even if the solenoid is not working. This residual attraction nonetheless helps the motor to turn. It is to be noted that if the motor were working on attraction, this residual attraction would slow the motor.

Question 8: It continues to turn due to its inertia and because of the residual attraction mentioned in the question above.

Question 9: Yes; they must all be oriented the same way, which is with the same pole towards the outside (on the drawing, we chose arbitrarily how to place the magnets).

Question 10: These plates are made up of a ferromagnetic substance. They thus momentarily become magnets when they are subjected to the magnetic field of the passing magnet. The plates become mutually attractive, like the opposite poles of permanent magnets.

Question 11: So that the switch closes when the magnet goes slightly beyond the solenoid.

Question 12: Yes, by inverting the polarity of the battery, we change the mode of the RSM's function (in repulsion or attraction). The performance of the RSM is significantly superior when it is in repulsion mode when the solenoid functioning.

Question 13: As little as possible to maximise the force of repulsion.

Question 14: Four times per revolution, because there are four magnets.

Question 15: Yes; the greater the number of whorls, the larger the magnetic field produced.

Question 16: Yes; the distance should be as small as possible. If the magnet is too far away, the magnetic field will be too weak to attract the plates to one another.

Fabrication of the RSM (without the bracket for the magnetic switch)

To make the RSM, you have a complete technical file at your disposal. The following documents are therein:

- The fabrication and assembly ranges
- The technical drawings
- The templates
- The safety capsules
- Details of construction costs

Notes

1. **Functional tolerance:** Certain dimensions in the detail drawings of the rotor and the brackets of the rotor shaft mention a functional tolerance. To not take into account these specific dimensions could make the design of the bracket for the magnetic switch more difficult. It is therefore important to present to the student what tolerance on a dimension is, and more specifically, what functional tolerance is.
2. **Wiring the circuit:** wiring the circuit can be done one of two ways.
    a. The first way allows the student a great deal of latitude. The teacher allows the student to wire the circuit using the "Wiring the electrical circuit" section of the student booklet (in that case, you will need to withdraw the last section from the assembly range of the RSM).
    b. The second way is much more structured. The student would follow the last section of the assembly range of the RSM. Every step of wiring the circuit is explained down to the smallest detail.
3. **Coiling the solenoid:** Do not increase the number of whorls of wire around the solenoid by much (the diameter of the suggested solenoid is in the range of 25 mm). Indeed, too great an intensity of current would then run through the LED and could damage it or render it inoperable. The protective role of the LED would then be compromised and the magnetic switch would suffer from it. The gauge of the wire (28 AWG) should not be changed either, for the same reasons.

Safety capsules

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Safety capsules





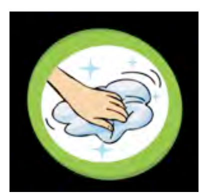
(1) Lead, tin and other soldering

1. Watch out for burns that can be caused by the iron at more than 200°C. (Do not wear rubber or latex gloves, these substances could melt on your hands).
2. Wear safety glasses to protect yourself from solder projections.
3. Use a soldering iron rest to avoid setting your clothing, hair, paper or plastic etc. on fire.
4. Do not shake the iron to clean it: use the sponge designed for the job.
5. Avoid touching the solder to your mouth or teeth - it is extremely toxic. (You must neither eat nor drink while soldering).
6. Never solder components under tension.
7. Use in a well aired room or solder under the hood designed for this use in order to limit inhaling the vapours, since they are toxic.
8. Use a desoldering bulb to remove a faulty solder.
9. Wash your hands after your work, and clean the work table to avoid any risk of intoxication.

Ensure that any modification to this capsule does not compromise student safety. Any person at fault will bear the consequences of his choices.







Safety capsules

(3) Retractable blade knife



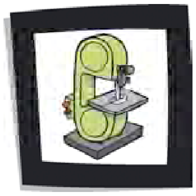
1. Watch out for injury. Never place the hand holding the part in the trajectory of the blade.
2. Use a profiled metal ruler to guide straight cuts.
3. Use a clean, rigid, slip resistant work surface that may get slightly marked (piece of hard paneling).
4. Use a sharp blade, otherwise unnecessary effort could cause injuries.
5. Take the time to think about each of your gestures.
6. Use pliers to break off and remove the worn ends of blades.

Ensure that any modification to this capsule does not compromise student safety. Any person at fault will bear the consequences of his choices.



Safety capsules

(7) Band saw





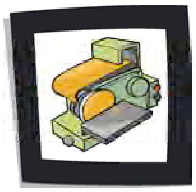
1. Wear safety glasses to protect against projections.
2. Tie long hair and roll your sleeves to avoid them becoming entangled in the mechanism.
3. Do not wear bracelets, necklaces, jewellery, etc.
4. Clean the work surface of any debris that could lead to dangerous movements or that could hamper the proper operation of the saw.
5. Use a sharp blade, otherwise unnecessary effort could cause injuries.
6. Take the time to think about each of your gestures. Keep your hands further than 5 cm. from the cut line at all times.
7. Use a pusher for small parts in order to keep your hands far from the blade.
8. Respect the security perimeter on the floor. The proximity of another person could distract the user.
9. Activate the dust hood or wear a dust mask.
10. Wear acoustic protection to avoid auditory problems if the exposure to noise attains 85 decibels for a period of 8 consecutive hours.




Ensure that any modification to this capsule does not compromise student safety. Any person at fault will bear the consequences of his choices.

Safety capsules

(8) Disk and band sanders





1. Wear safety glasses to protect against projections.
2. Tie long hair and roll your sleeves to avoid them becoming entangled in the mechanism.
3. Do not wear bracelets, necklaces, jewellery, etc.
4. Clean the work surface of any debris that could lead to dangerous movements or that could hamper the proper operation of the sander.
5. Take the time to think about each of your gestures.
6. Respect the security perimeter on the floor. The proximity of another person could distract the user.
7. It is compulsory that the dust hood be activated when using the disk or band sander. If you are in the presence of a cancer causing contaminant (such as silica) the mask is also mandatory.
8. Call the workshop supervisor if the belt becomes misaligned.
9. Wear acoustic protection to avoid auditory problems if the exposure to noise attains 85 decibels for a period of 8 consecutive hours.




Ensure that any modification to this capsule does not compromise student safety. Any person at fault will bear the consequences of his choices.

Safety capsules

(9) Press drill




1. Wear safety glasses to protect against projections.
2. Tie long hair and roll your sleeves to avoid them becoming entangled around the chuck.
3. Do not wear bracelets, necklaces, jewellery, etc.
4. Careful! Risk of serious injury! Firmly affix materials to the table using clamps to avoid a part being hooked to the bit and spun around at great speeds.
5. Adjust the height and depth of the table and tidy the work surface before starting the drill.
6. Use a well sharpened bit, otherwise unnecessary effort could cause break the bit and cause injury.
7. Remove the chuck key immediately after having tightened the drilling tool.
8. Take the time to think about each of your gestures.
9. Respect the security perimeter on the floor. The proximity of another person could distract the user.
10. Unplug the tool from the power source before changing a bit.

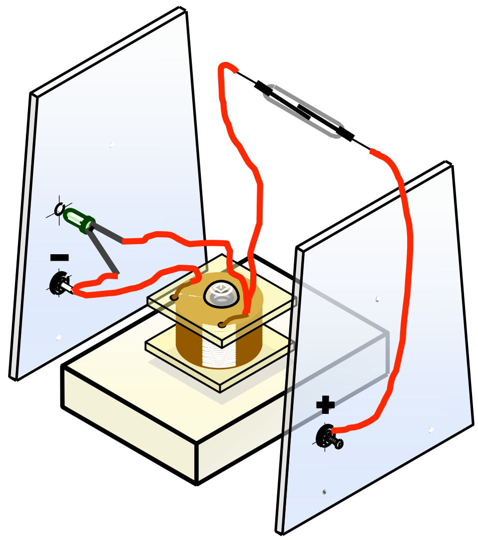



Ensure that any modification to this capsule does not compromise student safety. Any person at fault will bear the consequences of his choices.

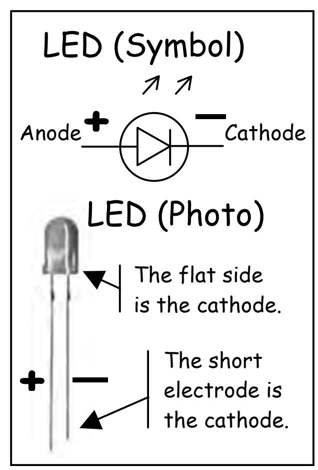
Advice for starting the RSM

WATCH YOUR EYES

Since the exterior part of the magnetic switch is made of glass, it is relatively fragile. Be careful that the magnets do not collide with it during design and testing. In addition, in no case should an attempt be made to bend the electrodes. **To ignore these warnings could cause serious injury to the eyes from projected glass.**



- When connecting the motor for the first time, you will notice that it is much more powerful when it is polarised a certain way. By trying the two possible polarities, the choice will be obvious. If your motor turns faster, that means it is in repulsion mode (when the solenoid is working) and that is perfect.
- The RSM turns: that's great, but notice the sparks that are produced inside the magnetic switch. These will greatly reduce the lifespan of the switch due to the plates overheating. One way to eliminate them is to add an LED to the circuit (see the section entitled "The usefulness of the light emitting diode"). The LED must be connected in parallel with the electromagnet and polarised opposite to the battery (see the diagrams in the "Questionnaire about the function of the RSM" section). You must avoid connecting it in the direction where it overheats. If this is the case, it will still light up, but will stop working within a few minutes and will bring about destructive overheating of the switch.



For more detail on starting the RSM, consult the "Wiring the circuit" section of the assembly range for the RSM

Design of the magnetic switch bracket

The shape and the dimensions of the rotor shaft brackets have been carefully chosen. This configuration allows the installation of the magnetic switch bracket on the three available sides. This in turn, allows the student a great deal of latitude while designing.

Notes

- While they are designing the bracket, it's a good idea to remind the students that the switch must be as close as possible to the rotating magnets and that by moving the switch, it is possible to reverse the direction of the rotation of the motor. For more information as to the ideal position of the switch, consult the "Questionnaire on the operation of the RSM".
- In stage 3 of the design process, we have added face and side views of the RSM. The objective here is to help the student to adapt his switch bracket to the rest of the RSM. These drawings are at a 1:1 scale, which should simplify the student's task.
- Annex 2, included in this document, contains photos of examples of possible designs.

Testing the RSM

Electrical resistance

It is now time to test the RSM. Using Ohm's Law, we must calculate the electrical resistance of the motor while it is functioning. To do so, the student must measure the tension at the motor terminals as well as the intensity of current running through them.

It is important to note that resistance measured by means of an ohmmeter would not give an accurate measure, but one that is underestimated. Since the ohmmeter should be used when the device is not under tension, this measurement would not reflect reality. In fact, current measured while the motor is working is an average current that takes into account the fact that the solenoid is not constantly under tension. The effective current is thus much less than the current we would measure if the solenoid were in constant use.

Resistance obtained from the equation $R=U/I$ is in some way impedance.

The notion of impedance is usually used in the field of alternating current. In our opinion, this notion is too complex to be approached in a high school course.

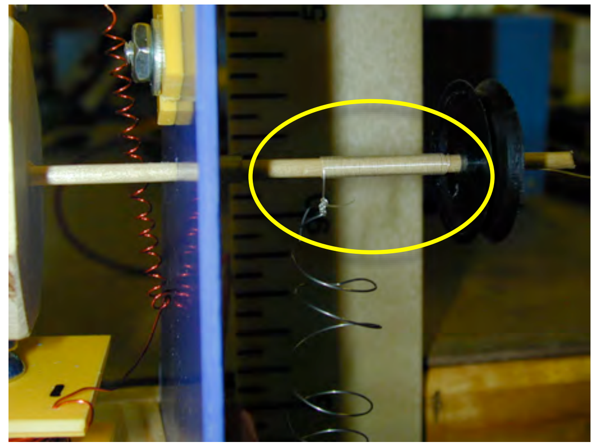
Electrical power

The student must also calculate the electrical power of the motor, using the intensity and tension values measured previously. Please note that this means the electrical power consumed by the motor and not its mechanical power, which is necessarily weaker because of energy losses.

We have chosen 9 volts of tension, equivalent to a small battery, to simplify an eventual concrete application. Indeed, a 9 volt battery can easily be stowed in a hydroplane or small terrestrial vehicle. Please note an alkaline battery must be used. An ordinary battery would not produce sufficient intensity of current.

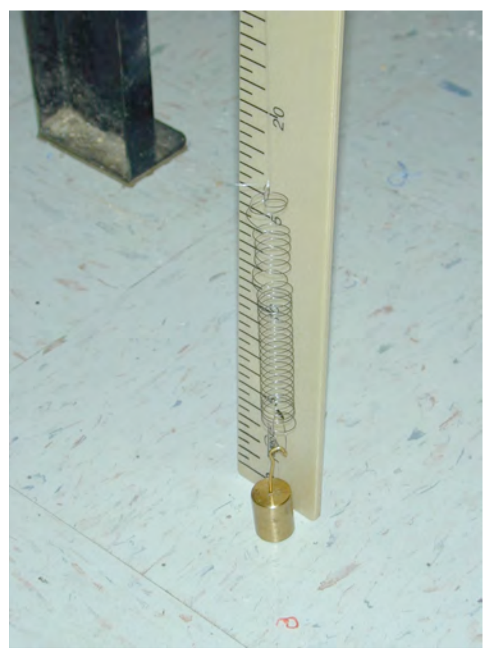
Suggested mechanical effort (without potential gravitational energy)
There are many ways to make a motor work. Using potential gravitational energy is simple way of quantifying the labour carried out by a motor. Since potential gravitational gravity is only studied in the ES course, however, we allow the student the opportunity to find a qualitative method to evaluate the motor's efficiency.

Suggested mechanical effort (with potential gravitational energy)



We suggest an easy way to cause mechanical effort that will allow for easy and in our opinion, very interesting, calculations.
The task is simply to lift a weight of a known mass by attaching it to the end of a string and rolling it around the rotor tree.
The mass of the chosen weight is also important. If the mass is too great, the RSM will stop. If the mass is too small, the weight will rise too quickly and will be difficult to time .

The string should be as thin as possible. This will make the motor’s effort more constant while lifting the weight. A fishing line will no doubt suffice.
A spring may be attached between the end of the line and the weight. This will give the motor time to attain its working speed before the weight leaves the ground. Note that we begin timing when the weight leaves the ground and stop timing when it reaches a predetermined point.



Calculation of electrical energy

We must now calculate the energy consumed by the RSM while it carries out the mechanical effort chosen on the previous page.
A stopwatch must be used to measure the time elapsed while carrying out the task.

The electrical energy has been transformed into many forms:

- Mechanical energy (thankfully)
- Thermal energy (joule effect in the electromagnet)
- Thermal energy due to friction between parts
- Acoustic energy (operating noise)
- Magnetic energy (field generated by the electromagnet) etc.

Calculation of the potential gravitational energy

Even if the concept of potential gravitational energy is usually seen only in the optional course, we recommend that you present it to all your groups. The little time invested here will be largely compensated by the satisfaction of obtaining an output in percentage. In fact without broaching the subject, you would be condemned to speaking of output in merely qualitative terms. To calculate potential gravitational energy, you must use the following equation:

E_p=mgh where m is the mass of the weight in kg,
g is the gravitational terrestrial acceleration in m/s^2,
h is the displacement of weight during the task in m.

Finally, the energetic output of the RSM must be calculated using the following equation:

Output = E_p / E_e x 100

Where **E_p** is the potential gravitational energy gained by the weight
E_e is the electrical energy consumed by the RSM.

Again! Time to learn a little more

Correction of the questionnaire on Archimedes' principle

Question 1: Since the density of the marble is greater than that of water, the marble will sink to the bottom. The marble does not displace enough water to compensate for its weight.

Question 2: The density of the log is less than that of water. When the logs sinks into the water, it displaces a large volume of water. As soon as the log has displaced the amount of water equivalent to its mass, it stops sinking.

Question 3: As soon as the boat displaces the amount of water equivalent to its mass, it stops sinking.

Question 4: *The mass of the gold bar is:*
$\rho = m/V \rightarrow m = \rho \cdot V \rightarrow m = 19.3\ g/cm^3 \cdot 1000\ cm^3 \rightarrow m = 19{,}300\ g = 19.3\ kg$

The mass of the gold bar in the water is: (density of water = 1 g/cm^3*)*
$Mass_{\text{of displaced water}} = 1000\ cm^3 = 1000\ g = 1\ kg$
$Mass_{\text{in the water}} = Mass_{\text{in the air}} - Mass_{\text{of displaced water}}$
$Mass_{\text{in the water}} = 19.3\ kg - 1\ kg = 18.3\ kg$

Question 5: $Mass_{\text{for the whole system}} = Mass_{\text{RSM}} + Mass_{\text{block}} = 400g + 100g = 500g$

For the water 500g = 500 ml = 500 cm^3

The base of the block has a surface of 100 cm^2

If the block sinks 5 cm into the water, it will thus have displaced 500 cm^3 therefore 500 g of water.

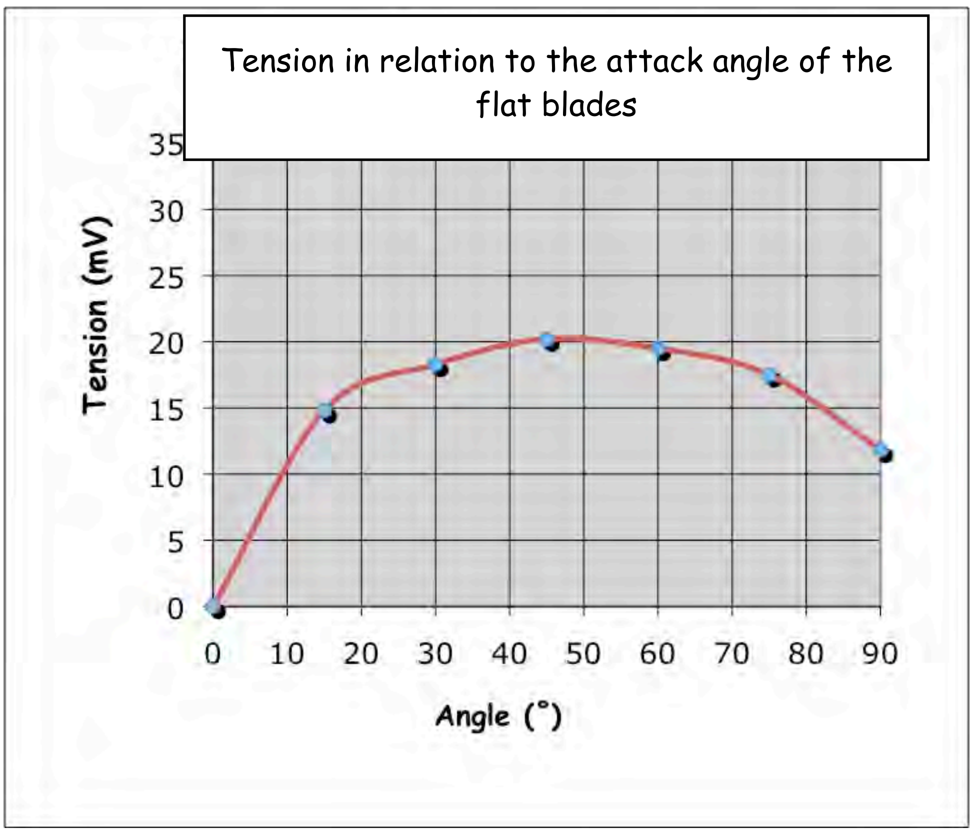
The system will therefore draw 5 cm.

Propeller and Bernoulli's principle (Directed laboratory 1)

Data Table		
Trial	**Attack angle (°)**	**Voltage (mV)**
1	0	0
2	15	14.8
3	30	18.3
4	45	20.2
5	60	19.5
6	75	17.5
7	90	11.8

Question 1:
45° is the angle that produces the greatest tension, therefore the greatest displacement of air.

Question 2:
At 90°, the blades displace the air as much towards the alternator as towards the rotary tool. This configuration would make the propulsion of a vehicle impossible.



Propeller and Bernoulli's principle (Directed laboratory 2)

Data Table		
	Direction of rotation of the alternator propeller	**Direction of air flow indicated by the strip of paper**
Blades curved towards the alternator	**"in one direction"**	**Towards the rotary tool**
Blades curved towards the rotary tool	**"in the other direction"**	**Towards the alternator**

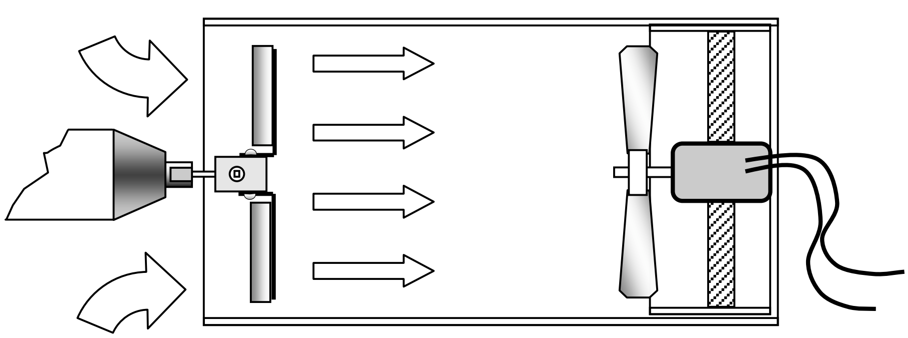
Question 1:
The curved blades must be placed on the rotary tool side.

Question 2:
The low pressure zone predicted in Bernoulli's principle is on the side of the rotary tool.

Question 3:
The ambient air is displaced towards this low pressure zone.

Question 4:
The high pressure zone predicted by Bernoulli's Principle is located on the alternator side.

Question 5:
The air leaves this high pressure zone and goes towards the alternator.

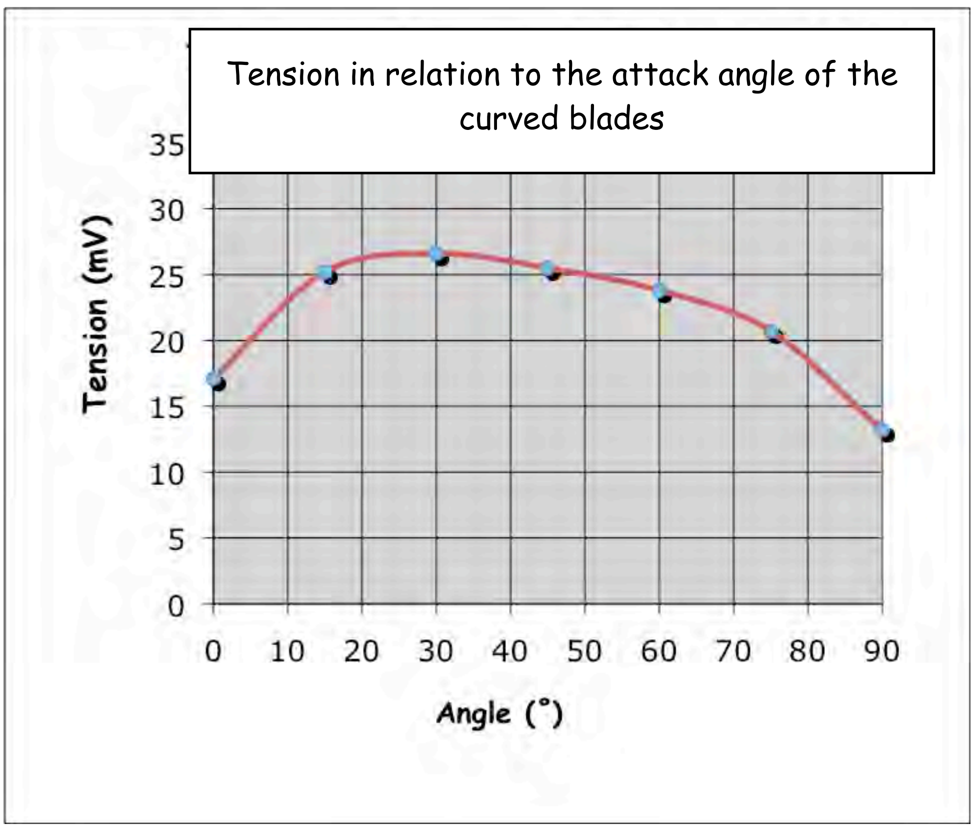


Propeller and Bernoulli's principle (Directed laboratory 3)

Data Table		
Trial	**Attack angle (°)**	**Voltage (mV)**
1	0	17.1
2	15	25.2
3	30	26.6
4	45	25.5
5	60	23.8
6	75	20.7
7	90	13.2

Question 1:
A 30° is the angle that produces the greatest tension, therefore the greatest displacement of air.

Question 2:
Comparing the two graphs, we notice that the tensions are clearly greater with curved blades.



Question 3:
Comparing the three manipulations, we can conclude that curved blades are clearly more efficient. Bernoulli's Principle can therefore help us make the propeller more efficient. The ideal angle for the curved blades seems to be 30°.

Question 4:
We could modify the size of the propeller:

- width of blades
- length of blades

We could also modify the shape of the propeller:

- shape of blades
- curvature of blades

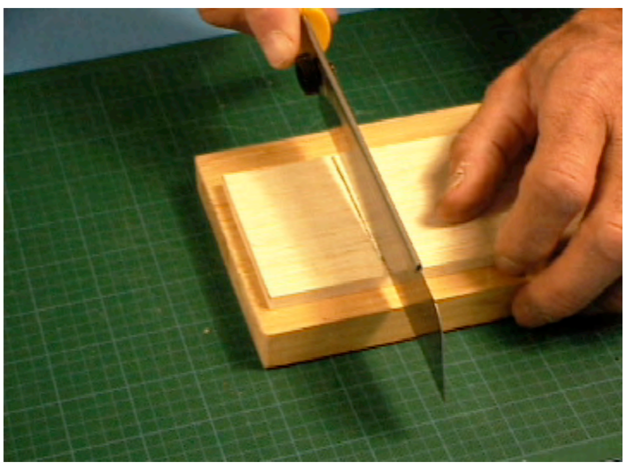
Question 5:
Yes, Bernoulli's Principle can be used. There is great similarity between a rudder and an airplane wing.

Propeller design

Video on "Balsa as a construction material"

This video dealing with how to shape balsa is available on the CDP website.

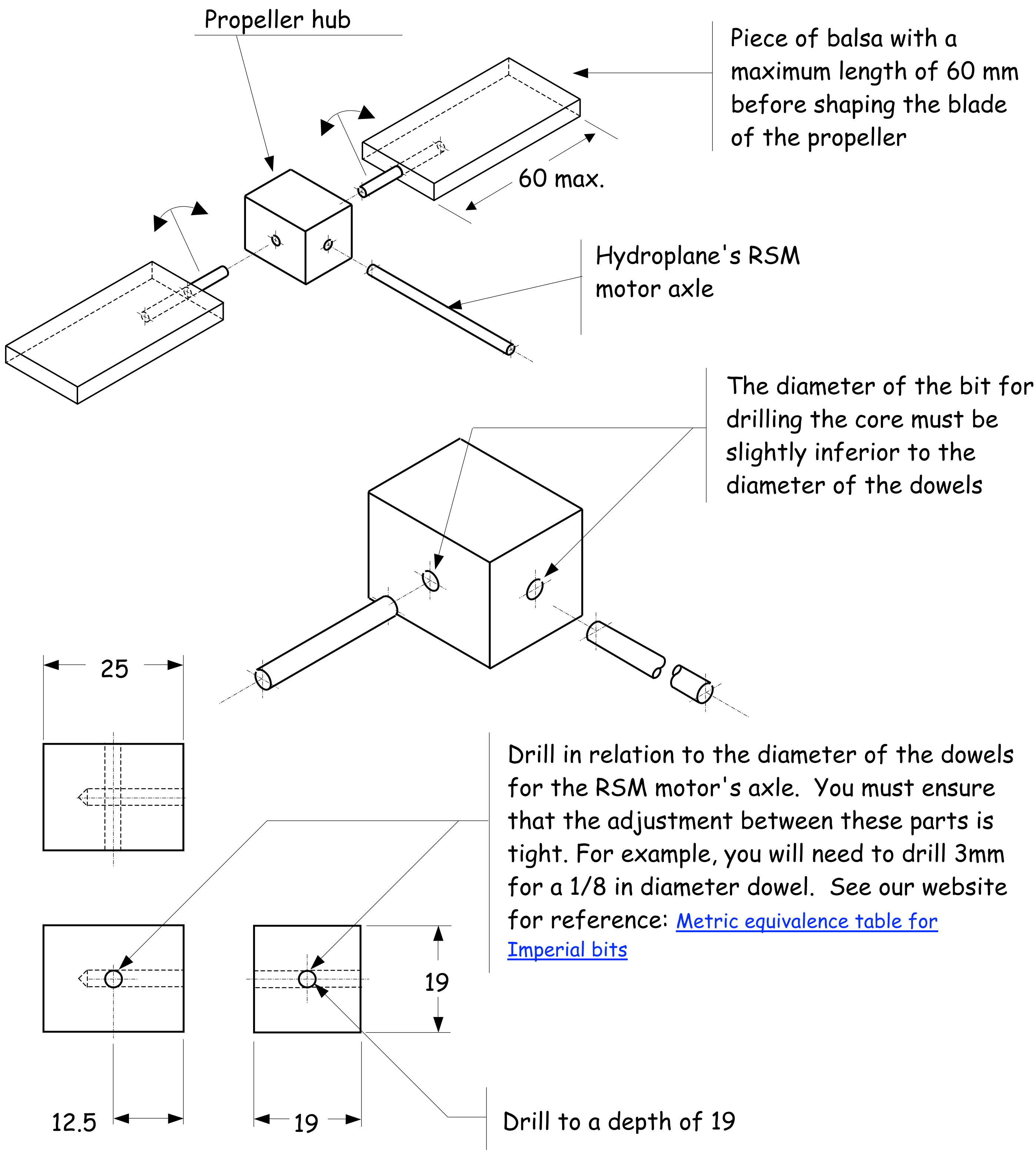
Balsa is available in many dimension of sheets and rods. It is simple to glue several together to make a larger piece.



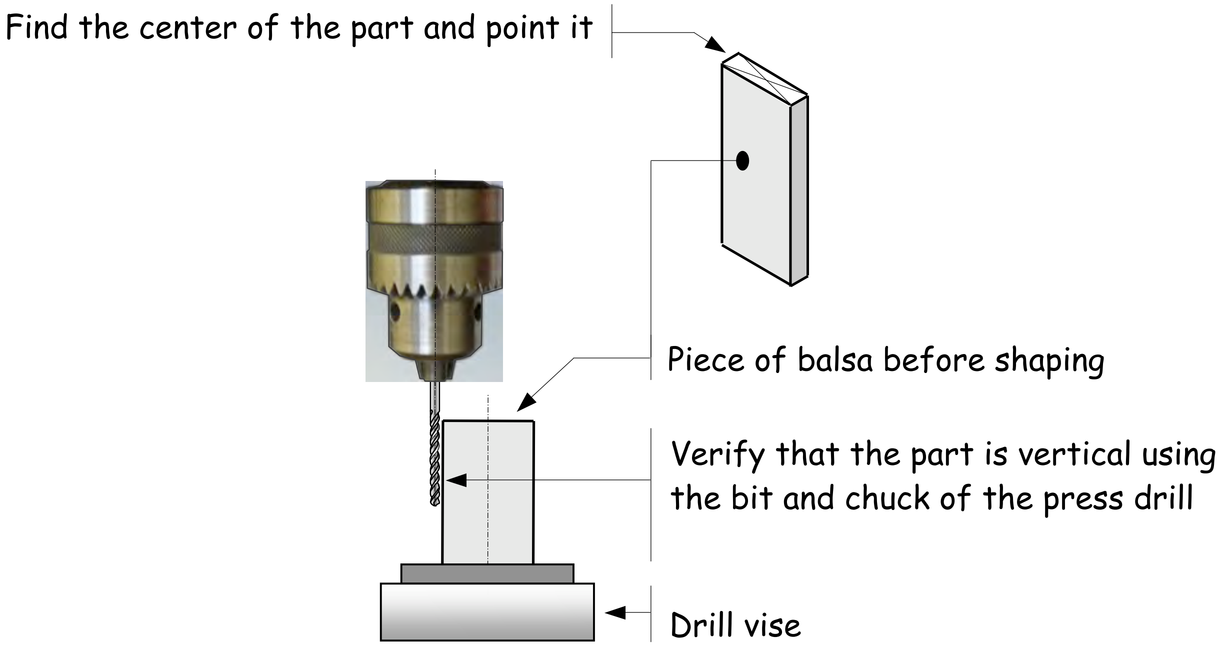
Balsa is easily cut with a small saw or retractable blade knife. When the sheet is thin, it is even possible to cut it using scissors.

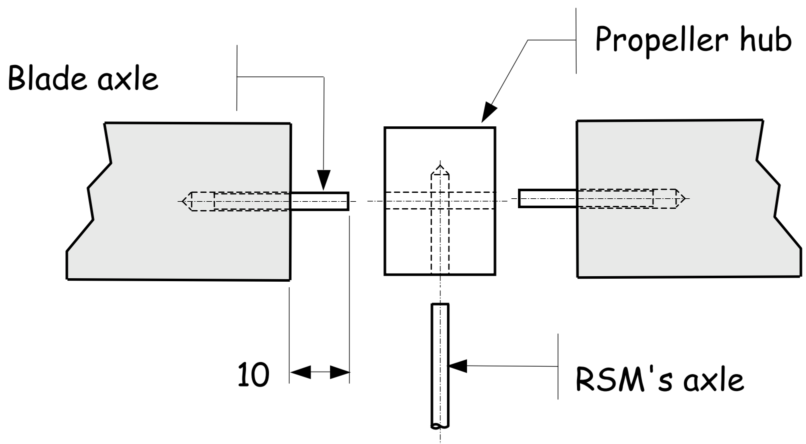
Finally, it is possible to shape it using sandpaper or a file. For the student, it is therefore a material of choice to make his propeller.

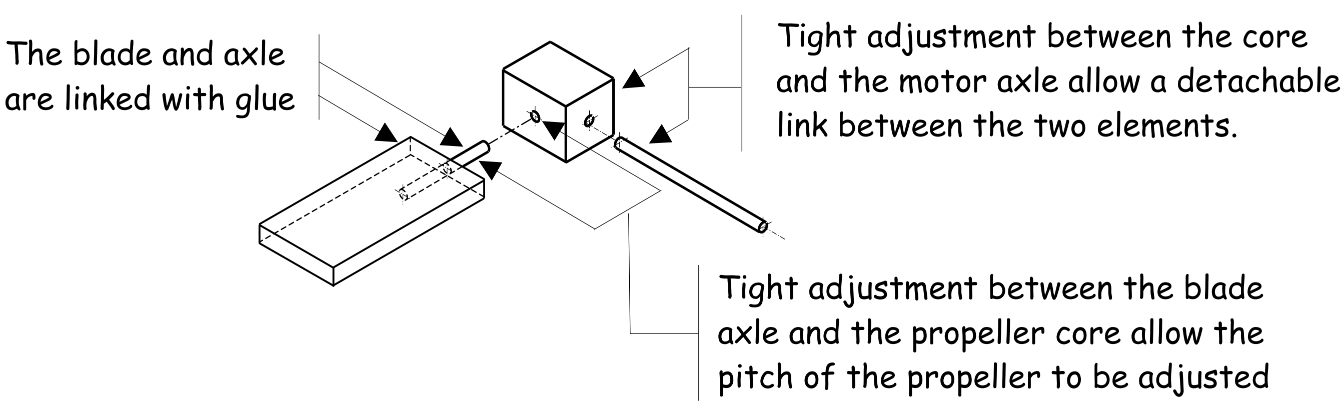
Fabrication of the hub



Drilling the blades and assembling the propeller





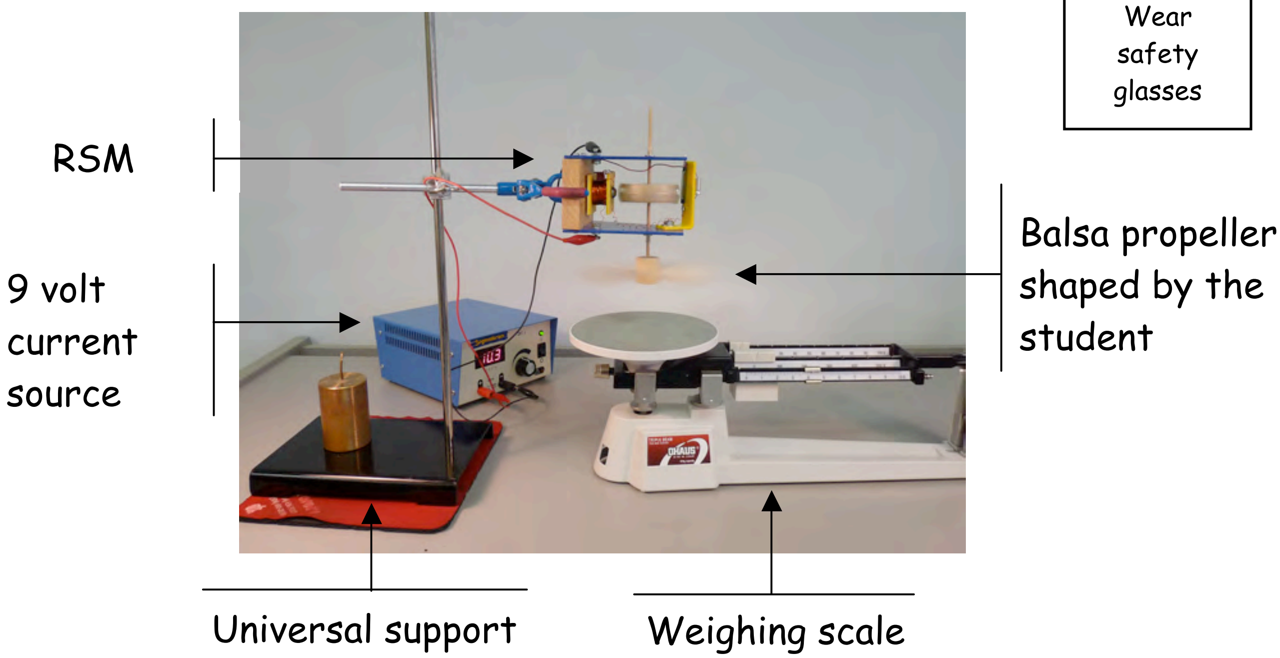


Determining the ideal pitch for the blades

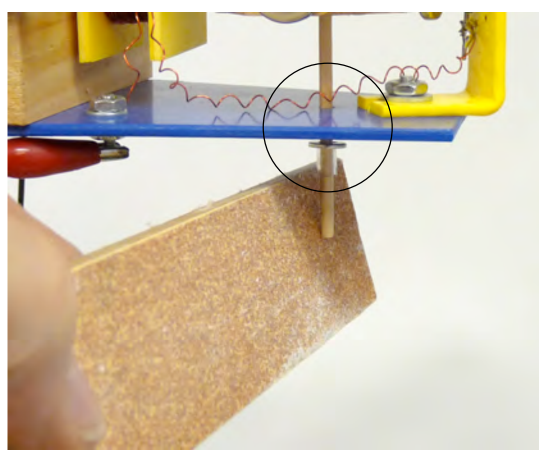
We experimented with installations allowing the students to check the performance of their propeller and their RSM. Using the thrust applied by the propeller on a weighing scale, we succeeded in quantifying the phenomenon.
Several factors may influence the thrust of the propeller:

- the quality of the design work;
- optimising motor adjustments;
- the pitch given to the propeller blades.

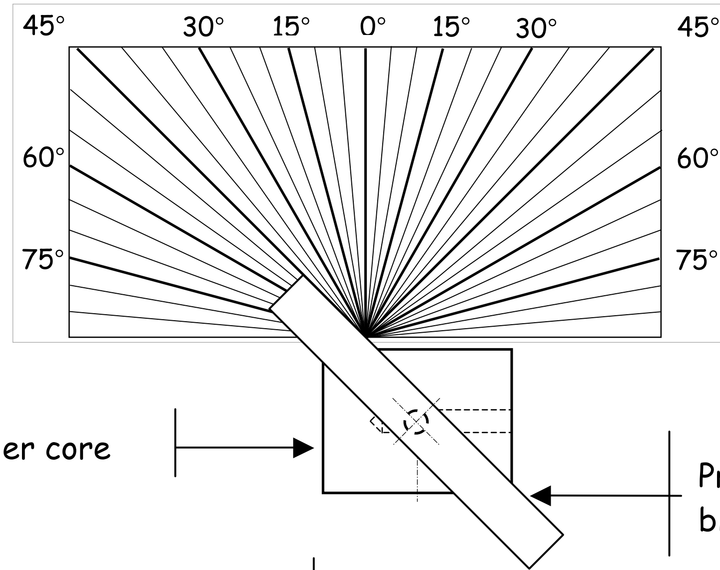
Wear safety glasses



The following few observations may facilitate your experiment.
Make the end of the motor axle slightly conical. This allows easier assembly and dismantling of the propeller hub on the motor shaft. To do so, simple lean a piece of sandpaper on the rotating axle.



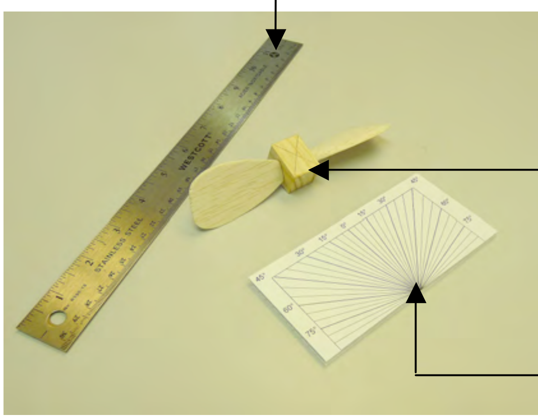
The use of an adapted protractor allows you to adjust or check the pitch of the propeller blades



Propeller core

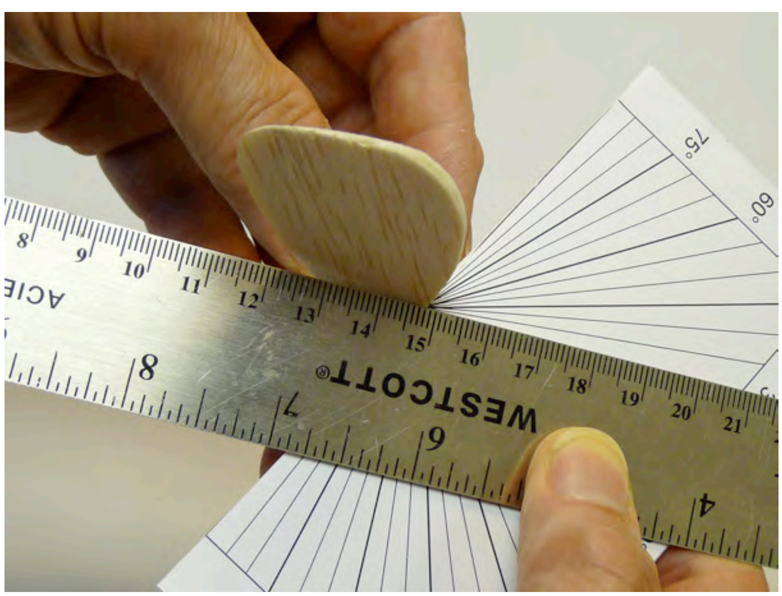
Propeller blade

Ruler used to lean



Blades and hub

Paper protractor glued onto Coroplast

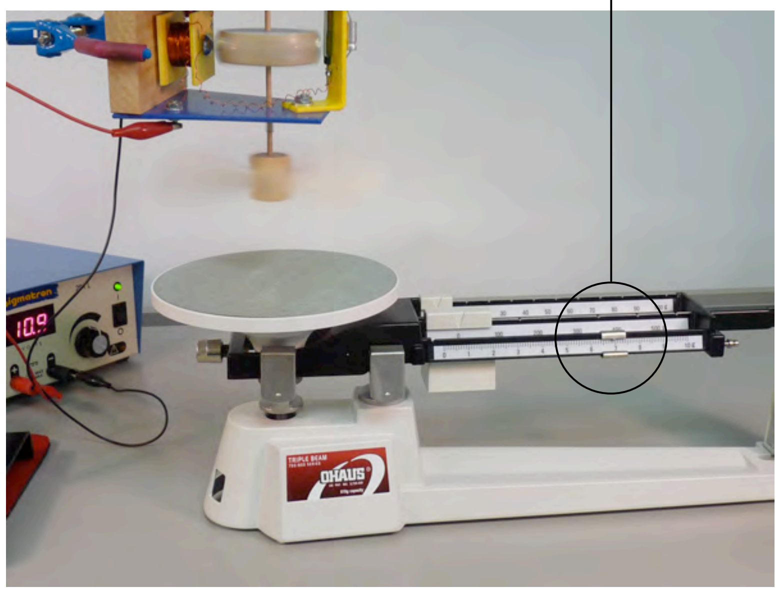


With this assembly, it is possible to determine:

- the ideal position for RSM's magnetic switch bracket;
- the ideal pitch for the propeller blades.

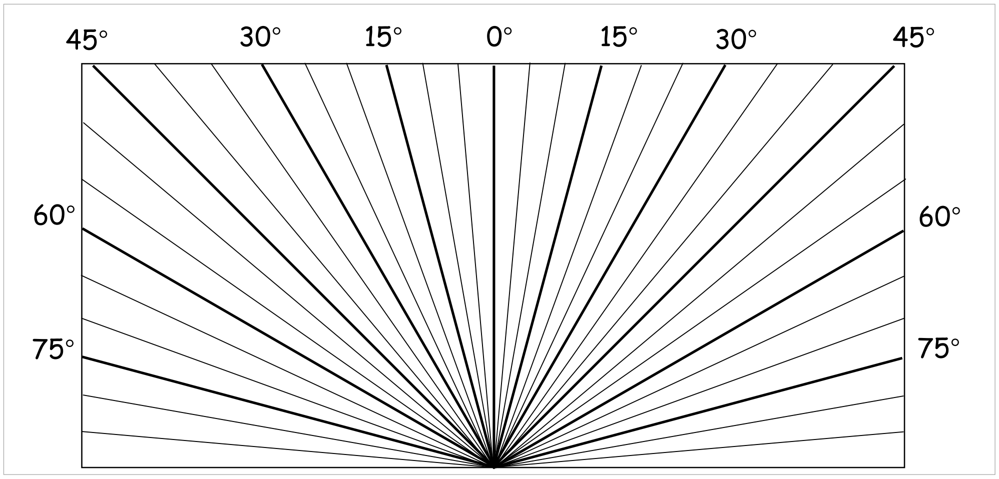
The photos below show two situations where we modified the propellers' pitch.

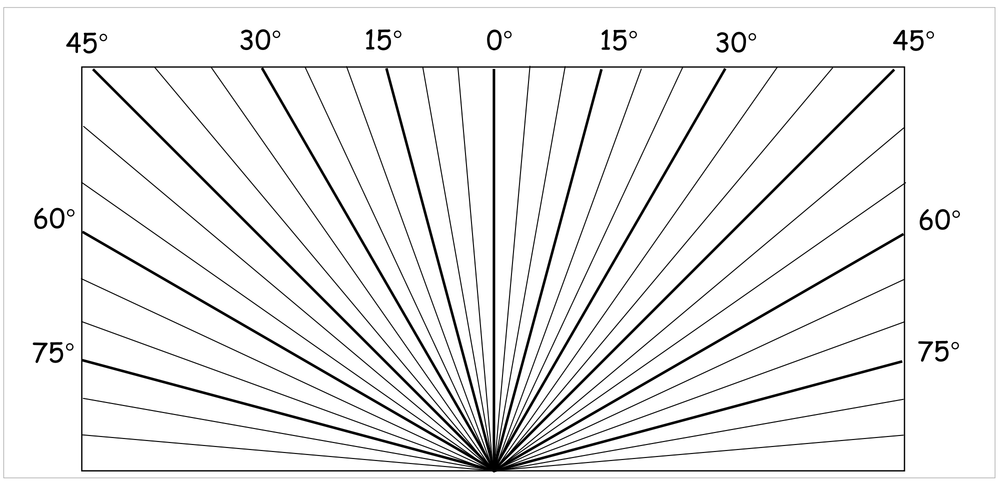
7 grams

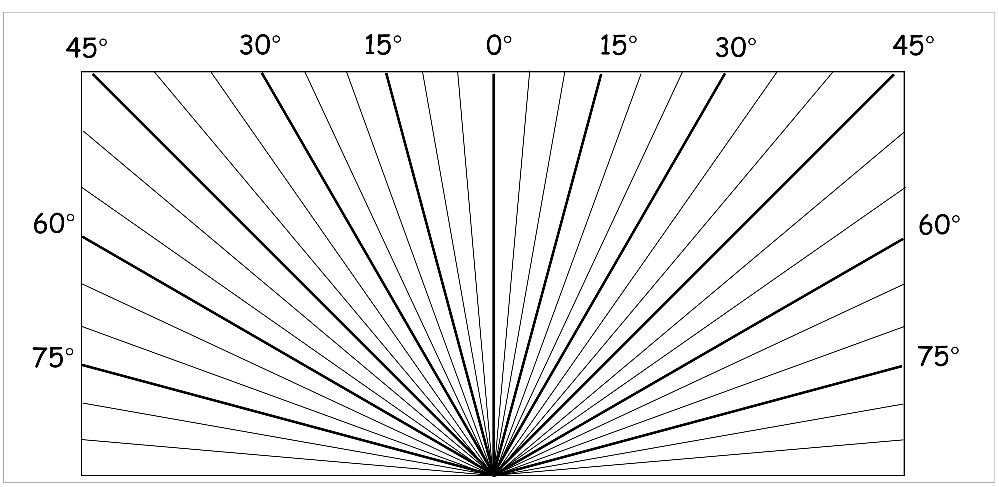


8.8 grams

Protractor for blades, to be printed



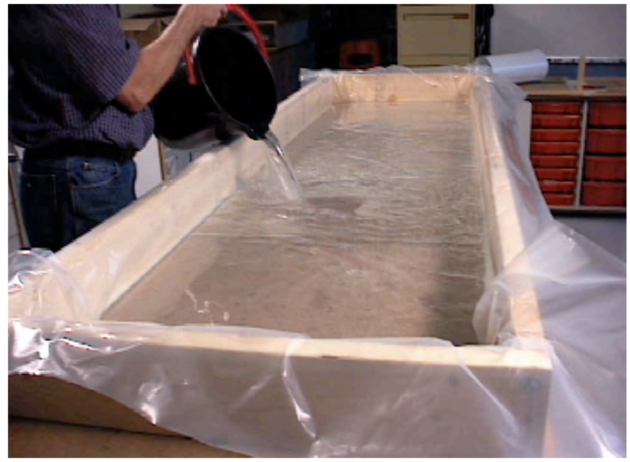


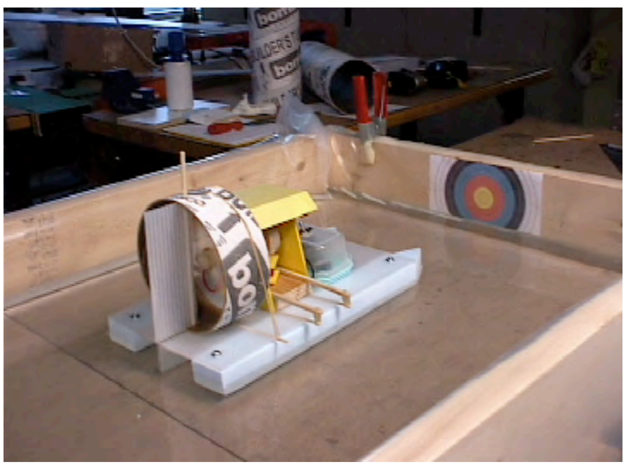


Video on the "Race being prepared and taking place"

This video is available on the CDP website.

This video shows how to assemble a basin.

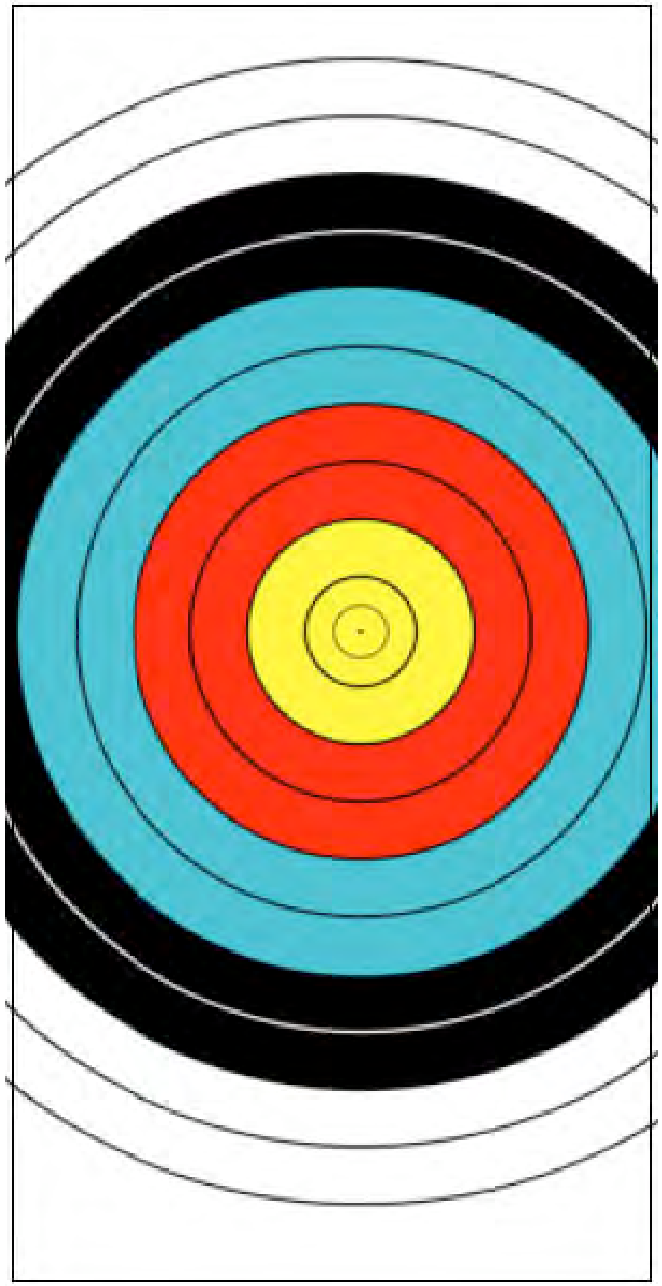




You can also see a hydroplane move towards the target at the far end of the basin.

Finally, a method for draining the basin is presented.

Target to be used during the race



Annex 1 (Useful information)

Stan Pozmantir's website

http://www.simplemotor.com/

N. B. This equipment is also available elsewhere; these suppliers are provided as a suggestion.

Enamelled copper wire (varnished)

Prolabec
2213 rue le Chatelier
Laval (Québec) H7L 5B3
CANADA
Telephone: (450) 682-5118 or (800) 556-5226
Fax: (450) 682-6468 or (800) 556-8182
http://www.prolabscientific.com/Electricity-p-1-c-688.html

Enamelled copper wire (varnished)

Les distributions Cyme
561 Lindbergh
Laval (Québec) H7P 2N8
CANADA
Telephone: (450) 625-2428 or (800) 563-1030
Fax: (450) 625-2429

Powerful magnets

Lee Valley Tools Ltd.
P.O. Box 6295, Station J
Ottawa, ON K2A 1T4
Tel: (613) 596-9202
Fax: (613) 596-9502
http://www.leevalley.com/hardware/page.aspx?c=1&p=42348&cat=3,42363

Annex 2 (Examples of design solutions for the RSM)