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# **An international acoustic's test for our students?**

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## **ABSTRACT**

Having a measure of students' understanding of the main concepts useful in acoustics is a way to optimize the content of your teaching. Making this measurement at the end of the course also provides information on the effectiveness of the course.

International tests exist in the physics community. They have been optimized in terms of question formulation, redundancy of concepts within several questions, and false answers, which are the most common ones given by students. In mechanics, several tests are being disseminated on a French scale: point mechanics, point statics, solid statics, fluid mechanics. They have been translated into French and made available from any LMS platform at your university. The teacher who uses it to test his students must commit himself to respect a certain number of rules. The students' answers are processed by the members of the AFM's GTT-AUM teaching committee and a summary is sent to the teacher. A comparison of a cohort's results with the national average is also provided. For some tests, remediation tools have been put online, free for the teacher to use them or to invite students to self-study on concepts he failed. Perhaps it is time to create a specific acoustic test, respecting the optimization process of it?

Who's up for it?

# AN INTERNATIONAL ACOUSTICS TEST FOR OUR STUDENTS ?

## ABSTRACT

International tests exist in the physics community [1]. They have been optimized in terms of question formulation, redundancy of concepts within several questions, and false answers, which are the most common ones given by students.

In mechanics, several tests are being disseminated: point mechanics, point statics, solid statics, fluid mechanics. They have been translated into French and made available from any LMS platform at your university. The teacher who uses it to test his students must commit himself to respect a certain number of rules. The students answers are processed by the members of the AFMs GTT-AUM teaching committee and a summary is sent to the teacher. A comparison of a cohorts results with the national average is also provided. For some tests, remediation tools have been put online, free for the teacher to use them or to invite students to self-study on concepts he failed.

Perhaps it is time to create a specific acoustic test, respecting the optimization process of it ? Whos up for it ?

## 1. INTRODUCTION

Measuring students' understanding of some scientific concepts allows us to adapt our teaching. If a pre-test is performed before the start of teaching, it gives a picture of what has been learned by the student and permit to target activities on the proximal development zone. This can be completed by a post-test to measure the efficiency of the teaching method, or even by a post-post-test to quantify the long-term resilience of the taught concepts.

The website [www.physport.org/assessments/](http://www.physport.org/assessments/) proposes 95 research-based assessments which are classified into four level of validations. The 19 "gold star validated assessments" have passed the 7 following criteria:

- based on research into: student thinking (for observation protocols: Classroom behavior),
- studied using:
  - student interviews (for observation protocols: Iterative observations),
  - expert review (for observation protocols: Inter-rater reliability),
  - appropriate statistical analysis (for observation protocols: Training materials),
- research conducted:
  - at multiple institutions,

- by multiple research groups,
- peer-reviewed publication.

These tests, based on the understanding and not the quantified application of concepts, have highlighted recurring design errors that can be obstacles to student progress. The development process of these tests follows several phases [2] [3] [4].

- A first job is to make an inventory of the concepts involved.
- A second is the creation of questions relevant enough to test only one concept at a time, each concept being tested several times in the same test. The question statements are diverse and explicit enough to be understandable by everyone.
- A first batch of students then answer these open-ended questions.
- Their spontaneous answers help to detect errors in the perception of the concepts. The frequency of these design errors makes it possible to arrive at multiple-choice test for which, among the choice of answers, only one is correct and the others are propositions reflecting the misconceptions most perceived by the students.
- The test is then offered to a second larger batch of students.
- The test is then checked to make sure that the closed-ended questions are indeed discriminating. If this is the case, the test is then stabilized.

For our community of acousticians, 4 tests are available including the *Mechanical Waves Conceptual Survey 2* (MWCS2) which concerns waves propagation, superposition and reflection, but also standing waves. It is a multiple-choice test for intro college level which has passed 5 of the 7 criteria. For upper-level classrooms, the *Wave Concept Inventory* (WCI) tests the visualization of waves, mathematical depiction of waves and wave definitions.

The aim of this paper is to present a work which was performed the two last years by the "teaching commission" of the Association Française de Mécanique (AFM) concerning three tests in mechanics. The work is decomposed into several phases:

- tests selection or creation of questions and answer if necessary,

- French version,
- transfer to an LMS server which permit to use the tests from an other university,
- analysis of cohort results and comparison with national averages,
- suggestion of remediation pathways associated with each non-assimilated concept,
- diffusion to the mechanical community,

and to propose to our acoustical community to create a group project to develop a French version of an acoustical test.

## 2. PROCESS AND RESULTS, FOR THREE MECHANICS TESTS

### 2.1 Tests selection

Each of the three chosen tests checks the understanding of several concepts (Tab. 1) [5].

Force Concept Inventory	Fluid Mechanics Concept Inventory	Solid Concept Inventory
force balance	static of perfect fluid	isolation and representation
dynamic	perfect fluid and conservation laws	equilibrium
action-reaction	external viscous fluid (boundary layers and drag)	links
static*	internal viscous fluid (pipes, between plates)	frictions
kinematics*		

**Table 1.** Mechanics tests and the tested concepts in each of them. \* *ongoing stabilization*.

### 2.2 French translations

Some tests are proposed in several languages: for example 29 translations are proposed for the Force Concept Inventory (FCI) [6]. In the absence of French version, the French translation of the questions and the answers performed by the teaching committee of the AFM, have been tested iteratively in recent years in some UFRs and engineering schools. The French formulation is adapted according to the student's reactions. Some explanatory figures have been enriched with annotation for a better understanding.

### 2.3 Transfer to an LMS server which permit to use the tests from an other university

The three tests are implemented on the LMS server of Le Mans University and a LTI procedure creates a link between the LMS platform of the interested teacher and the Le Mans University platform. The identification of the student stays on the LDAP system of the student's university.

### 2.4 Analysis of cohort results and comparison with national averages

For example, the FCI tests three concepts with 15 questions. Each concept is tested 5 times. By the number of correct answers  $n(\text{concept}, \text{student})$ , the robustness of each student's concept is measured (Fig. 1) and a success rate  $sr(\text{concept}, \text{student}) = \frac{n(\text{concept}, \text{student})}{5}$  is calculated. By averaging for a student group  $gsr(\text{concept}, \text{group})$  can be plotted according to the number of year after the bachelor's degree (Fig. 2).

Average success rates depend on the tested group. For each concept and for groups of same year, the average success rate  $ysr(\text{concept})$  and its uncertainty with a confidence level of 95% are calculated [7]. Figure 4 shows the growth of them with year. Note that the uncertainties on the year-success-rate 2 years after the bachelor's degree is not be evaluate, because only two L2 groups are for the moment included into the data base. Nevertheless, it appears that the concept of "force balance" is increasingly being assimilated. It is also the case for the concept "dynamic" although the uncertainty is greater (Fig. 4). On the other hand, the growth of the concept "action-reaction" could not be highlighted, perhaps because the database is still too weak.

At the beginning of a particular training course, the average success rate of each concepts can be measured and observed over time. It can also be done for the success rate of all the 3 concepts included in a test:  $gsr3(\text{group})$ .

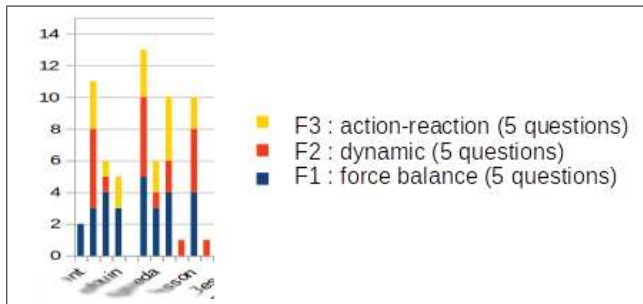
Figure 5 shows the evolution of the global success rate of the three concepts tested by the FCI for a specific French engineering school. For this school, the decrease of the concept's assimilation is observed. This fact can be used during exchanges with the *Commission des titres d'ingénieur* (CTI), during the application phases for accreditation.

### 2.5 Suggestion of remediation pathways associated with each non-assimilated concept

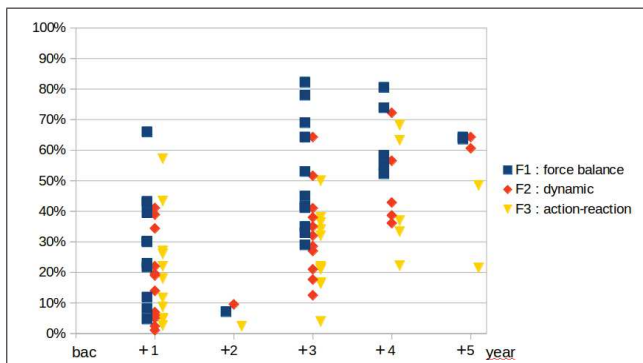
Based on individual results, remediation activities are made available to students and teachers. Accessible online without a password [8], they can be done independently by the student, with or without instructions from the teacher who selects the training elements that interest him/her from the resource base.

The resource bank is composed of various activities. For each concept :

- filmed experiments with results displayed,



**Figure 1.** Number of correct answers  $n(\text{concept}, \text{student})$ , associated to each student and each concept, for the FCI test.



**Figure 2.** For the three concepts tested by the FCI, average success ratio of each group  $gsr(\text{concept}, \text{group})$  according to the number of years after the bachelor's degree.

- do-it-yourself filmed experiments with no results displayed,
- numerical simulations,
- synthetic courses,
- enforcement exercises with or without corrections,

have been selected or created.

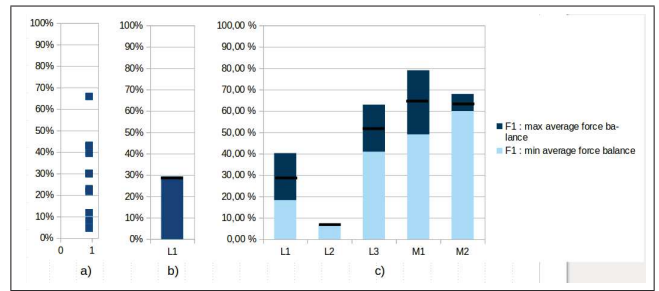
## 2.6 Diffusion to the mechanical community

Information relating to these tests translated into French, remediation tools and the creation of a database of results from French schools and universities, is disseminated to fellow mechanics via the AFM as well as at the French Mechanics Congress.

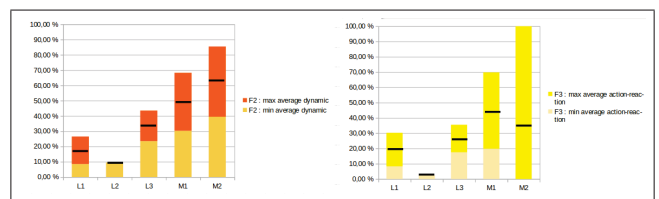
## 3. ACOUSTIC TESTS

*Mechanical Waves Conceptual Survey* uses 22 questions to test 4 concepts : "link between frequency, amplitude, celerity", "fluid-movement", "propagative waves" and "standing waves" [9]. The questions can be similar to those presented figure 6. No French translation is available. This test seems to be appropriate for the first 3 years after the bachelor's degree.

Between 3 to 5 years after the bachelor's degree, the Wave Concept Inventory (WCI) [10] may use more math-



**Figure 3.** 1 year after the bachelor's degree, for 12 groups of students of several French universities and engineering schools, for the concept "force balance" tested by the FCI a) average success ratio of each group, b) average value for the 12 groups, c) evolution of the average values and their uncertainties with a confidence level of 95% according to the number of years after the bachelor's degree.



**Figure 4.** Evolutions of the average success rate of the concepts "dynamic" and "action-reaction" versus the formation level. The uncertainties are given with a confidence level of 95%.

ematical formulations, with questions that may be similar to the question presented in the figure 7.

## 4. CONCLUSION

Similar to what has been done in point, solid and fluid mechanics, the extraction of a set of questions to scan the spectrum of underlying concepts in acoustics remains to be done. Subsequently, it will be necessary to translate them into French, develop a procedure for disseminating the tests and analyzing the results and, why not, develop remediation paths for each concept.

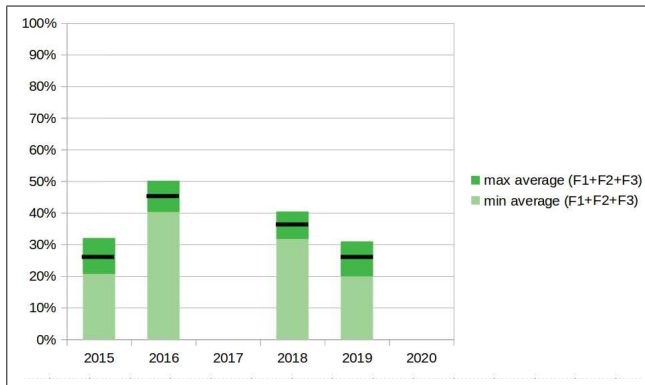
To do this, an international team has yet to be created with the support of The European Acoustical Association and the French Acoustical Society.

## 5. ACKNOWLEDGEMENTS

Thanks to Jean-François Parmentier who provided the results of the FCI passage on 20 groups of French students following various training courses, to Franck Delvare, Daniel Huilier of the teaching commission of the AFM who participate to the development of the French tests in mechanics and to Tiphaine Galpin who has developed the web versions of the tests and remediations.

## 6. REFERENCES

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**Figure 5.** Evolution of the average success rate of all the three concepts "force balance", "dynamic" and "action-reaction" for the third year groups of one specific French engineering school. The uncertainties are given with a confidence level of 95%.

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**Consider the following description and answer questions**

Two pulses are moving towards each other. Each pulse has a speed of 1 cm/s. The figure on the right shows the pulses at time  $t = 0$  s. Each square width corresponds to 1 cm x 1 cm. The dashed lines indicate the correct positions of the individual pulses after 2 s.

Select the drawing that corresponds to the shape of the resultant pulse after 2 s.

If the mass that is hung from the string is increased by a factor of four while everything else stays the same, a different harmonic standing wave is created. Which of the following statements about the wavelength of the new harmonic standing wave is true?

- A. The wavelength increases, because as the tension increases, the speed of the wave increases.
- B. The wavelength increases, because as the tension increases, it is harder to get the string to vibrate.
- C. The wavelength decreases, because as the tension increases, the speed of the wave increases.
- D. The wavelength decreases, because as the tension increases, it is harder to get the string to vibrate.
- E. The wavelength stays the same, because it is inversely proportional to the frequency.

**Figure 6.** Example of a question, similar to some contained in the MWCS test.

The x-component of an electromagnetic wave propagating in free space is described by:

$$E_x(x, y, z, t) = E_0 \exp[j(\alpha x + \beta y + \gamma z - \omega t)]$$

This wave is known as a plane wave because:

- a It is the simplest mathematical description of a propagating wave.
- b The amplitude is constant.
- c The surface of constant phase at any instant of time is planar.
- d The displacement direction is perpendicular to the propagation direction.

Plane waves impinge on a barrier that contains a linear opening (slit). After passing through the slit, the light strikes a screen, and the intensity pattern on the screen looks like:

**Figure 7.** Example of a question, similar to some contained in the WCI test..