Teaching and Learning Computational Mathematics with Intensive Application of the Virtual Campus

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Abstract: - Nowadays, the field of professional development in engineering requires appropriate and relevant training for a satisfactory insertion in the labor market. This requires that educational institutions provide not only the specific knowledge of the career being studied but also must complement it with other skills necessary for adequate performance in the work environment. Based on these premises, this paper describes the design of a classroom experience to be implemented in the subject of Advanced Calculus (AC), a third-level subject of the Mechanical Engineering course. The proposed activities are developed in the Computer and Multidisciplinary Laboratory of Basic Sciences available at the faculty and seek to encourage the use of the virtual campus, where the mediation between the content of the subject and the concrete applications of simple engineering models are the axis to develop the topic: Analytical Functions of Complex Variables (AFCV).

Key-Words: - Virtual Campus, Advanced Calculus, Laboratory, Complex Variables, Multidisciplinary, Mathematics.

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1 Introduction

Engineering is influenced by mathematical modeling, i.e. increasingly complex elements provided by mathematical science are becoming more and more useful in concrete applications.

In engineering achievements, there is a rapid transfer of theoretical results to the technological field due to the explosive computational progress.

Technological advances in recent years have had a strong impact on higher education, broadening educational scenarios. Physical campuses are being replaced or complemented by others of a virtual nature, and relationships within the community are developed preferably in a non-presential format and not always synchronously.

The presence of physical campuses and virtual campuses to develop teaching and learning processes give rise to new educational environments.

In these environments, there is not only a change in space and time but also in responsibilities, tasks, materials, activities, and evaluations.

In short, decisions about what, when, where, how, and how much to teach transform the traditional conceptions of educational environments.

Virtual workspaces, modeling systems, and simulations complement real classroom work and allow students to verify hypotheses, and explore dynamic relationships to show the same element in different contexts.

In the training of the Mechanical Engineer, basic knowledge indispensable to approach the analysis and resolution of complex systems, which involve advanced mathematics, must be contemplated.

Students are expected to develop analytical, qualitative, and numerical methods capable of solving diverse mathematical models that describe real-life systems or phenomena.

The modeling process is articulated by means of a network of components of determined specificity, where the student is subjected to constant decision-making that induce him/her to systemic thinking.

Based on these premises, this paper describes the design of a classroom experience to be implemented in the subject of Advanced Calculus (AC), a third-level subject of the Mechanical Engineering course.

The proposed activities are developed in the Computer and Multidisciplinary Laboratory of Basic Sciences available at the faculty and seek to encourage the use of the virtual campus, where the mediation between the content of the subject and the concrete applications of simple engineering models are the axis to develop the topic: Analytical Functions of Complex Variables (AVCF).

2 Laboratory as a Classroom

The class is held at the Mathematics Multidisciplinary Computer Laboratory of the faculty. The Laboratory is an area where activities are carried out to support the Mathematics area courses to fulfill the numerical, symbolic, and graphic calculation aspects of the subjects of the area.

The teaching team is involved in the implementation of new methodological strategies for the development of the curricular contents, generating the necessary didactic material for the realization of theoretical, practical, and technological workshops.

From the line of educational innovation in engineering, we continue working on new teaching paradigms to achieve, in Higher Education, greater development of intellectual capacities, acquisition of skills, the substitution of obsolete techniques for more efficient and faster means, and better interaction in the teaching-learning process.

Based on this, and thanks to the inclusion of new advances in computer science, we have implemented the use of new pedagogical methodologies and diverse didactic strategies, aiming at the interdisciplinary work that is considered necessary in the area of Engineering and that must be approached from Mathematics.

From all angles, dimensions, perspectives of any issue, problem, idea, or concept can be contemplated from different disciplinary areas and presented immediately through hypertext links and search engines, [1].

Working in the laboratory offers vast possibilities for incorporating new educational technologies and online applications that propose a more dynamic and participatory teaching-learning environment.

The use of the virtual campus has created, through activities, educational resources, interaction, and communication, an expanded educational space that transcends the classroom and brings new forms of communication and expression to the daily lives of both students and teachers.

3 Technology in the Classroom

The incorporation of information and communication technologies (ICTs) into the educational field is a central issue, which has gained relevance in higher education centers and especially in engineering careers, in which the disciplines must present a line of work, research, or study dedicated to digital technologies in their specific schedule.

Within the line of work proposed to be carried out in the classroom intervention project, it is essential to generate new work environments, apply modern methodologies, and provide innovative strategies in the course of mathematical subjects.

This is achieved with a computer-mediated design and planning system, where a set of activities and communicational expressions are created as fundamental axes of the teaching process for the achievement of independent learning.

The computer environment generated has the characteristic of concentrating state-of-the-art intercommunication technologies and highlights the use of summary generation, immediate and collaborative answers between students and teachers; links to videoconferences and presentations of topics with great deployment of graphic teaching methods.

This solves the availability of material and information, accessing it from different workstations and solving the problems associated with learning through a process of real-time feedback.

This virtual environment, implemented in parallel with the lectures and laboratory activities, favors and encourages self-management of learning and efficient use of time, since it provides an interactive medium that enriches the curricular planning of the courses and interdisciplinary activities.

4 Regulatory Context

Nowadays, the field of professional development in engineering requires appropriate and relevant training for a satisfactory insertion in the labor market. This requires that educational institutions provide not only the specific knowledge of the career being studied but also must complement it with other skills necessary for adequate performance in the work environment.

It is necessary to increase intensive practice, promote collaborative work, impose an environment where the formation of groups and teams is natural, and ensure that the student acquires a good disposition towards the other members of his group, [2], [3].

The new managerial lines in the working environments aim at a special ductility and conditions of adaptation to new technologies, a tangible facility for the acquisition of their operability, and a clear inclusion within the staff as a whole.

The accreditation bodies of all countries echo these new demands, so they urge universities to promptly adapt their curricular contents to the

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competencies that engineers must possess, [3], [4].

The national commission for university evaluation and Accreditation is a governmental organization for the accreditation of engineering careers that in its methodological proposal mentions standards to be followed, among which it is highlighted that the curriculum should include, [3]:

- Experimental laboratory, workshop, or field training that trains the student in the specialty to which the program refers.
- Engineering problem-solving activities, real or hypothetical, in which knowledge of basic sciences and technologies are applied.
- Engineering project and design activities, contemplating significant experience in these fields that require the integrated application of fundamental concepts of basic sciences, basic and applied technologies.
- Skills that stimulate the student's capacity for analysis, synthesis, and critical spirit, awaken their creative vocation, and train for teamwork and evaluation of alternatives.
- Supervised instances of training in professional practice, even if ideal, for all students.

The university needs to make educational spaces expand and transcend the classroom, to get closer to the everyday environments of the people involved, and the Internet offers the possibility of using new educational technologies to achieve this.

With the evolution and development of ICT, on the one hand, and the need for better and more effective online communication and collaboration tools, on the other, technological platforms have emerged that integrate a wide variety of communication and collaboration resources and are applied both for work and education and their use is based on cooperative and collaborative work/study methodologies, [5].

In this work, this sign of progress in the teaching-learning process is considered and a site is incorporated, the virtual classroom of AC, with the characteristic of concentrating hypermedia technologies to collaborate in the educational process.

5 Organization of the Virtual Space

The university provides a virtual campus based on a platform called Moodle that allows academic units to manage online courses.

The word Moodle is an acronym for Module Object-Oriented Dynamic Learning Environment. This platform is a learning management system installed on a server, which is used to manage, distribute and control non-face-to-face training activities.

Moodle is a free distribution tool, it is a global project designed for the development of educational environments in continuous growth and with the possibility of incorporating contributions from the national and international academic technological environment, allowing exploring new ways or generating their own, [3].

Within the virtual campus of the university, a virtual space was built and configured for the Computer and Multidisciplinary Laboratory of Basic Sciences, among others, and also virtual classrooms for the subjects AC, Mathematical Analysis I, Algebra and Analytical Geometry, Mathematical Analysis II, Computational Mathematics and Engineering.

The author of this paper is an administrator in several virtual classrooms. Figure 1 shows the author's virtual classroom session with all the virtual classes he is in charge of.

Fig. 1: Virtual classrooms

All the quality standards inherent to virtual training sites were considered in their design, and multiple educational resources were provided to make the best possible use of the hypermedia tools available and those offered by the platform. Educational material in different formats is included.

Figure 2 below shows the front page of the CA virtual classroom page and some of the incorporated resources currently in use.

6 Methodological Criteria

The basic problem of how to teach lies in creating the conditions for the knowledge schemas constructed by the learner to evolve in a given direction.

The key question is not whether learning should give priority to content or processes, but to ensure that they are meaningful and functional.

Considering that Mathematics influences all aspects of human life and culture, it would be desirable that any student, at any level, be able to obtain the necessary skills to build his or her knowledge. At the same time, it should be good that teachers were able to provide with skills to promote creative and meaningful teaching-learning situations and activities that encourage students to learn, [6].

The learner needs to have sufficient prior knowledge from which to approach the proposed contents, to establish relationships between them as complex and rich as possible that will allow him/her to increase the meaning of his/her learning.

Therefore, it is convenient to help the student to remember, reorder or assimilate the necessary previous knowledge related to the proposed content, to successfully address the programmed learning, designing cognitive bridges between the new content and the structure of knowledge that the student has -previous organizers- and develop appropriate strategies to put students in a favorable situation to learn.

Fig. 2: CA virtual environment

This implies an intense activity on the part of the student and a real commitment on the part of the teacher in terms of direction, coordination, and pedagogical assistance.

The aim is to get the student out of his passive role, acquiring a memorizing capacity that does not allow him to think on his own and create.

In addition, the widespread availability of new interactive information and communication technologies provides an immense amount of possibilities that materialize with the development of new models of teaching and learning, and given that the work of engineering analysis is based on a computer-mediated system and communication, it is considered important to generate a space in which a set of activities, exchanges, and communicative relations are produced as the fundamental axis of the educational process. The Cover of the AFCV theme is presented in Figure 3.

The proposed didactic activities consist of analyzing the students' previous ideas, emphasizing a theoretical investigation by the students under the guidance of the teachers, to make an analogy with the physical parameters of the system under study, and finally, with the information gathered, solve the problematic situation proposed for the conceptualization of the topic.

Fig. 3: Cover of the AFCV theme

7 Objectives

The programmed activities are aimed at:

- To carry out non-demonstrative laboratory experiences that allow for the real participation of small groups of students in the first years of their careers and to facilitate the conceptualization of the topics by designing activities through the Moodle platform and with digitalized didactic material specially prepared for each topic.
- Transform the Mathematics class into an experimental workshop, in which learning is generated through techniques that shift the focus from the teacher to the student, understanding that the construction of concepts, skills, and attitudes acquired by students should lead them to achieve autonomy in the study of analytical functions of complex variables, knowing their mathematical basis and recognizing when and where to apply them.
- The main objective of the implemented proposal is to integrate computational mathematics with technological areas in the Engineering curriculum and to incorporate new work styles based on organizing principles that allow linking knowledge and giving it meaning, transforming what is generated by disciplinary frontiers.
- To understand in depth the processes of change initiated from the potentialities offered by the different computational resources in the construction of knowledge, being of utmost importance to investigate the implementation of classroom strategies that allow, from the

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mathematics-computing relationship, to articulate the basic disciplines with the technological ones.

- To facilitate the construction of the necessary knowledge for the management of the complex: to design and implement applications that involve the resolution of engineering systems and to use symbolic computation and advanced graphic methods, different integrating proposals were organized to present applications from the department.

8 Classroom Intervention Project

8.1 Methodological Changes

The development of the AFCV subject is carried out respecting the qualitative paradigm framed in what is known as classroom experiences. We are working with a population of approximately 25 students of the Mechanical Engineering course within the subject AC, a third-level subject of this course.

The purpose of this design is to make a methodological change in the way of teaching the subject, using the virtual classroom and the physical space provided by the Computer and Multidisciplinary Laboratory of Basic Sciences.

The experience corresponds to a class that does not have the character of a traditional class, nor is it a master class. The class is taught in a theoretical and practical way, encouraging the active participation of the students, and is oriented to the understanding of the subject in an integrative way, with isolated tools of symbolic calculus.

The development of the class is based on group learning applying different dynamics: group discussion, problem-solving technique, case method, use of the virtual platform and the use of computer resources will be encouraged whenever possible and appropriate.

The teacher will assume the role of learning facilitator, performing the functions of organizer, stimulator, and supervisor of the task performed by the group. The teacher interacts with the students at all times to achieve the construction of knowledge.

The purpose of the teachers who carry out the experience is to obtain active and critical participation of the students, which will be achieved by selecting and grading all classroom activities according to their complexity and always providing adequate modeling according to the problems of the career or profession.

The teaching strategies are established from different activities without neglecting the theoretical foundation, respecting the interdisciplinary approach and based on constructivist learning.

The methodology applied aims to create a learning space where a set of experimental activities are developed as a fundamental line of the educational process.

If we focus on Higher Education, and more specifically on Engineering, we can observe that some authors propose that teacher should emphasize that students develop capacities and skills, as well as stimulate them to think, reason and deduce. In other words, we should not only transmit concepts, formulas, etc., but also provide them, from a functionalist, utilitarian and practical approach, with knowledge that allows them to develop in life, as well as skills that improve their mathematical culture and autonomy in learning [6].

8.2 Didactic Material

Students have at their disposal didactic material for the development of the subject in the virtual space of the subject AC.

The different files include videos with exercises, texts with theory, solved exercises, self-assessments, multiple-choice questionnaires with self-correction, and space for forums and consultations.

Figure 4 shows the cover page of the material available on the virtual campus.

Fig. 4: Materials available in the virtual classroom

8.3 Teaching Sequences

In the first instance, the aim is to motivate the students with the presentation of an engineering model of the Transport Phenomena branch of an ideal fluid that corresponds to a case that in the future they could study more exhaustively in the upper cycle Fluid Mechanics course.

Motivation plays a fundamental role in making the teaching-learning process functional and meaningful.

Motivation is a commonly used concept when pointing at individuals' desire to do something. In, [7] is described the motivation as the potential to

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direct behavior through the mechanisms that control emotion or simplified as the inclination to do certain things and avoid others.

Motivations are reasons individuals have for behaving in a given manner in a given situation, [8]. This means that a motive is, therefore, something that causes a person to act. These definitions provide us a good starting point to consider undergraduate engineering students' motivation in a mathematics course.

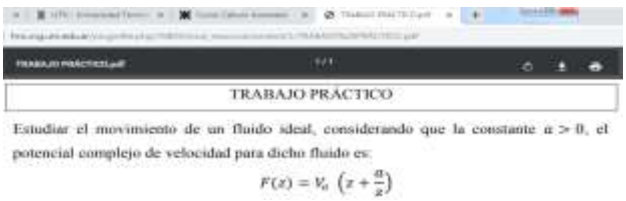
The motivation to do something, in this case to learn mathematics, is commonly divided into two distinct types according to the source of the motivation. Intrinsic motivation describes the desire to do academic tasks because one enjoys them. A student who is intrinsically motivated is interested in learning the content of a course. Extrinsic motivation, in contrast, describes the desire to do such tasks to earn rewards, such as credits, grades, or simply approval, [9].

It has been observed that the incorporation of practical cases in this course improves the overall mechanical performance of the students. It is explained by an inherent motivation for practical applications that is useful to better understand the course basis, [10].

For the training of engineers and other professionals in the field of engineering, it is attractive to use models and methods provided by mathematics, since they are the ones who must offer the most optimal solutions to the various models proposed to achieve abstract thinking.

In the initial phase of learning, the aim is to motivate the student so that the new learning situation awakens curiosity in him/her. At this stage, the learner must be mobilized and effectively committed to the new activities to be performed, [11].

For this purpose, a two-dimensional flow system of an incompressible, non-viscous fluid corresponding to an irrotational field moving in a steady state for an expression of the complex velocity potential is presented to the students for analysis. The instructions are attached to the virtual site of the course. The Practical work assignment is presented in Figure 5.


TRABAJO PRÁCTICO

Estudiar el movimiento de un fluido ideal, considerando que la constante $a > 0$, el potencial complejo de velocidad para dicho fluido es:

$$F(z) = V_0 \left(z + \frac{a}{z}\right)$$

Fig. 5: Practical work assignment

Another issue to take into account is that the approach of a simple and real situation to introduce the new content is to answer the constant question that students repeat to Mathematics teachers: What is this good for?

The choice of the motivating example is based on the fact that there is a direct relationship between the concepts of analytical functions of complex variables with the velocity of an ideal fluid and other physical parameters that will be used in the planned model.

In the virtual classroom, there is a series of files of different formats that will serve as a tutorial guide to be able to face all the activities.

After the presentation of the case, the students are informed that from the following day, they will have available on the virtual campus a brief self-evaluation with a google drive form, with questions that they will have to answer through the multiple choice selection system, immediately after finishing it, they can see the answers online and thus have an assessment of what their previous knowledge of the subject is.

In all work sessions, both in the classroom and in the virtual classroom, students work in small groups of a maximum of three students.

Students themselves choose the pair to work in the laboratory during all the sessions. The objective is to enhance the discussion and to help each other in the experimental setup. Working with groups with large number of students may enhance the discussion but each student will not have the chance to experiment in the laboratory as much as if they were only two. Another issue about the grouping is the way that the pairs are done. If lecturers know in advance the students, they could propose the pairs in order to guarantee that they will cooperate and collaborate during the experiment (and avoid discussions between members of a group). Due to the schedule, this never happens, and students organize the groups themselves, [12].

Google Drive allows them to work collaboratively on the same document and all at the same time.

The day after the previous activity they will have a questionnaire of previous ideas, more extensive than the previous one, which they have to deliver with a duly completed report that must be attached in the virtual classroom, and they have an inexorable deadline of 72 hours for its delivery. The Previous ideas questionnaire is presented in Figure 6.

Previous knowledge is organized in our mind in the form of cognitive structures. A cognitive structure is a set of already acquired knowledge that are interrelated with each other, and are those that allow us not to make sense of any new knowledge, [13].

Fig. 6: Previous Ideas questionnaire

The proposed questionnaire is a vehicle for the teacher to detect the preconceptions that the students have, and as these ideas manifest themselves it is possible to construct and incorporate the new knowledge.

Lots of skills related to research and presentation of the results are worked in this activity, as well as those more related to the theoretical concepts. It is important to have a clear guideline to perform this activity to help the students to focus on the different parts of the experiment that they have to prepare, [12].

In the following class, a discussion is organized where students exchange opinions about the preconceptions questionnaire. Then, in the same class, after exposing the students' preconceptions, the aim is to establish, analyze, discuss, and formalize the theoretical concepts inherent to the subject under study. For this purpose, a series of activities are designed, which will be complemented by the previous ideas they have.

The student-student interaction intends that in all class sessions, the students work collaboratively as they will do in their future professional life, but always under the supervision of the teachers who carry out the experience, who assume the role of guide of the teaching-learning process.

The students have at their disposal in the Laboratory specific bibliography to be able to investigate and analyze the topic to be taught, besides, the Internet connectivity of all the PCs helps them to explore and search for material on the whole web.

All the groups of students will meet with the same conformation that they had already chosen, and with the suggested bibliographic material, the articles that they search on the Internet and that will be uploaded to the virtual campus to share them, they will obtain a theoretical tutorial guide of the concepts to be used in the work proposal. According to our request, the conclusions reached by each group will be listened to and reviewed to carry out a debate on the concepts of the topic and then propose a theoretical framework.

Table 1. Analogy between the definitions of the derivative of real and complex functions

Derivative of a real function of a real variable x with $x = c$	$f'(c) = \lim_{x->c} \frac{f(x) - f(c)}{x - c}$
Derivative of the function of complex variable z with $z = w$	$f'(z_o) = \lim_{z->w} \frac{f(z) - f(w)}{z - w}$

As shown in Table 1, the analogy between the definitions of the derivative of a function at a point for a real function f of a real variable and the derivative of a function at a point for a function of a complex variable is used as a trigger for the topic.

From the analogy in both definitions, it must be emphasized that they are different expressions, because c is a real number, so it can be represented by a point on the real line, while about the complex variable and the functions dependent on them, it is known that a plane is required to represent the complex numbers, so w is a fixed point in the Argand diagram, somewhere in the plane.

Students are then asked to develop the definition in two different ways. From both developments, students, with teacher guidance, can formalize the theory of the topic.

After answering and discussing all the answers, a joint document is written as a guide to continue learning the topic.

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Solving a situation proposed by the teacher to seek information from the student about their knowledge of the topics covered in the strategy, which will vary according to the type of situation: bibliographic, experiments, teacher intervention, and audiovisual, [14].

With the definitions, developments, and conclusions that have been exposed, the students can elaborate a written theoretical material that is submitted to the virtual site of the subject to continue with the activity.

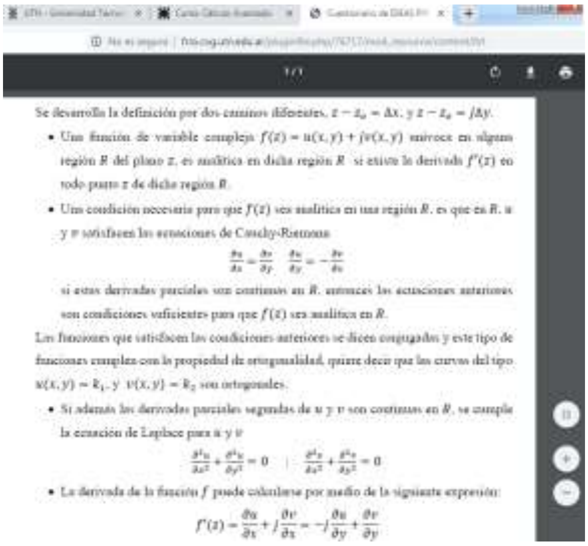

Fig. 7: Theoretical material

Figure 7 shows an extract of a possible theory uploaded to the virtual classroom by the students.

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TRABAJO PRÁCTICO

Estudiar el movimiento de un fluido ideal, considerando que la constante $a > 0$, el potencial complejo de velocidad para dicho fluido es:

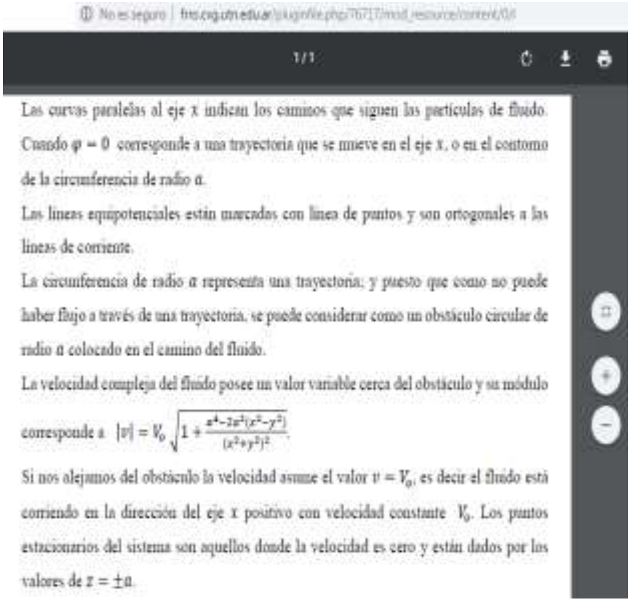
a) De acuerdo a las consideraciones teóricas ya vistas, modelizar el sistema en estudio
b) Obtener las ecuaciones de las líneas de corriente y las curvas equipotenciales
c) Realizar una representación gráfica de las trayectorias de las ecuaciones obtenidas en el ítem anterior
d) De las gráficas obtenidas en el punto b, analizar cómo es el régimen del fluido
e) Analizar cómo será el perfil de velocidades en los distintos puntos de su trayectoria
f) Individualizar los puntos estacionarios del sistema.

Fig. 8: Practical work assignments

After formalizing the theory, the students can model the system under study, as requested by the tutorial guide shown in Figure 8, trying to relate the theoretical concepts with the variables that make up the dynamic system.

From the formalization of the theory, the students can model the system under study, as requested in the tutorial guide that can be visualized in Figure 8, trying to relate the theoretical concepts with the variables that make up the dynamic system.

In Figure 9, we can see a possible modeling of the system under study requested in the tutorial guide to solve the practical work.



Las curvas paralelas al eje x indican los caminos que siguen las partículas de fluido.
Cuando $\varphi = 0$ corresponde a una trayectoria que se mueve en el eje x, o en el contorno de la circunferencia de radio a.
Las líneas equipotenciales están marcadas con línea de puntos y son ortogonales a las líneas de corriente.
La circunferencia de radio a representa una trayectoria; y puesto que como no puede haber flujo a través de una trayectoria, se puede considerar como un obstáculo circular de radio a colocado en el camino del fluido.
La velocidad compleja del fluido posee un valor variable cerca del obstáculo y su módulo corresponde a $|v| = V_0\sqrt{1+\frac{a^4-2a^2(x^2-y^2)}{(x^2+y^2)^2}}$
Si nos alejamos del obstáculo la velocidad asume el valor $v = V_0$, es decir el fluido está corriendo en la dirección del eje x positivo con velocidad constante V_0. Los puntos estacionarios del sistema son aquellos donde la velocidad es cero y están dados por los valores de $z = \pm a$.

Fig. 9: Modeling the system under study

The students use software to carry out the activity, the groups expose their answers and final data. Throughout the process, the students can consult with the teachers to clarify any doubts or conflicts that may arise. Figure 10 shows the graph of the system under study.

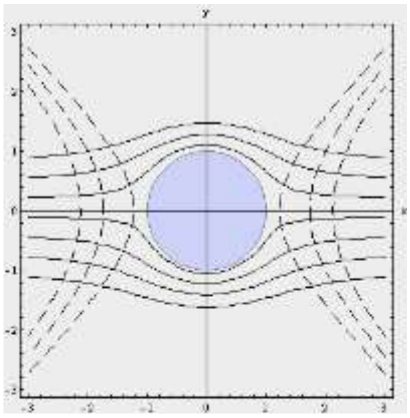


Fig. 10: Model graphic

The experience has not yet been evaluated.

9 Conclusion

The use of the virtual space provides several opportunities for students to participate in the activities proposed in the Advanced Calculus course, opening communication channels between teachers and students.

The greater availability and variety of the material promotes a better and faster understanding of the topics, and encourage students to self-manage their learning.

All the elements of the virtual classroom are permanently available to the student, not depending on schedules or fortuitous events, and the most complex items are dealt with through different media, which constitutes an enrichment of the materials related to that topic and a deepening of its approach.

The use of technological means invites the student to operate with different applications and software packages, to download special complements for their operation, incorporating in parallel knowledge on how to operate the different resources available.

The virtual classroom establishes better communication, facilitating conceptualization in areas of difficulty, and even the detection of particular needs. Teachers can better organize help for students who have some difficulty, both conceptual and technical, and even explore and propose new activities.

The space brings together a set of tools that evolve according to the planned activities, to the needs of the students, and to the detection of the most frequent problems and the most marked complexities.

The work environment and the virtual context become a space for students to meet, and exchange opinions, knowledge, and doubts that reinforce the relationship between students and teachers, making the activities more dynamic and motivating.

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The authors have no conflict of interest to declare.