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The Divide Between Notions Of Mathematics And Physical Sciences In The School's Curriculum

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Abstract
This scientific and action-oriented work aims to study the incompatibility and inconsistency between the mathematics and physics curricula in the Moroccan educational system. Based on teaching practices, particularly in the second year of the Baccalauréat in experimental sciences, we defined the relationship between mathematics and physics. It is noted that the divide between Physics and Mathematics is emphasized by the fact that the physicist's intuitions are validated only through experimentation, while those of the mathematician are validated solely by rigorous theoretical proofs. Mathematics greatly contributes to the representation of physical concepts, and at times, physics helps to better understand and grasp mathematical objects. An analysis of the school curricula and pedagogical orientations for the final year of the Baccalauréat in Morocco, along with questionnaires for practicing teachers and students, allowed us to conclude that there is a lack of compatibility and complementarity. The order of lessons for the two subjects creates a set of difficulties that hinder the smooth progression of the educational process. The ability to master mathematics is one of the most important aspects for properly approaching physical phenomena. Finally, to remedy this situation, we will detail a range of proposed solutions.
Keywords: *Devide between mathematics and physics, educational training, curriculum, didactics.*

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I. Introduction

Mathematics is the language of science, as this science is only complete when we transform its results into equations and its constants into graphs. Physics is an experimental science based on precise observations and measurements to deduce laws and access theories that help us understand natural phenomena.

There has always been a relationship of interdependence and complementarity between mathematics and physics. For example, there is a branch of mathematics called applied mathematics, which is very close to theoretical physics, explaining physical equations such as Schrödinger's equation, quantum physics, mathematical physics, Laplace, Hamilton, and many others.

Professor E. Zahar considers mathematics to be a human invention inspired by our innate ability to process abstract ideas with precision, while physics refers to the physical world, in which we had no part in its creation. Denis Bernard and Philippe di Francesco believed that the physical problems that can be solved exactly—known as integrable problems—are rare. Physicists have been able to link different phenomena by transforming complex problems into problems that can be integrated by leveraging hidden analogies.

Many research areas, such as water research, information technologies, renewable energies, advanced materials, and nanotechnology, primarily rely on major research in physics and mathematics. Physics and mathematics work together to establish a solid foundation for innovative scientific research to achieve technical solutions effectively and sustainably. However, the divide between Physics and Mathematics is emphasized by the fact that the physicist's intuitions are validated only through experimentation, while those of the mathematician are validated solely by rigorous theoretical proofs. Mathematics greatly contributes to the representation of physical concepts, and physics helps to better understand and grasp mathematical objects.

II. Chronological Overview

Mathematics: [8] [9][10]
3000 BC: The ancient Egyptians used the decimal system. They also developed engineering techniques and methods for calculating areas.
370 BC: Eudoxus of Cnidus invented the method of exhaustion, a first step towards integral calculus.
33 BC: Euclid created a geometry using logical reasoning.
628: The Indian mathematician and astronomer Brahmagupta was the first to define zero in his work Brâhma Siddhânta.
825: The Persian mathematician Al-Khwarizmi wrote the first treatise on Algebra.
888: Arab mathematicians developed the early foundations of analytical geometry, using geometry to solve algebraic equations.
1029: The translation of Euclid's Elements from Arabic led to the rediscovery of Euclid's work in Europe.
12th century: Indian numerals were brought from Muslim Spain to Christian Europe around the year 1000 by Gerbert of Aurillac, who became Pope Sylvester II.
1397: Al-Kashi calculated 10 sexagesimal digits of π, equivalent to 16 exact decimal digits.
1489: Johannes Widmann used the symbols "+" and "-" for the first time.
1595: The Silesian mathematician Bartholomäus Pitiscus published a remarkable work on trigonometry, which gave its name to the discipline.
1591: Algebraic calculations appeared with the publication of François Viète's Sigogne.
1623: Galileo published a work on comets, Il Saggiatore, in which he stated the mathematization of physics.
1637: Descartes discovered what is known as analytical geometry.
1669: Isaac Newton and Gottfried Wilhelm Leibniz independently created infinitesimal calculus, bringing mathematics into the era of analysis (derivatives, integrals, differential equations).
1770: Leonhard Euler, in Differential Calculus (1755) and Institutions of Integral Calculus (1770), attempted to establish the rules for using infinitesimals and developed methods for integration and solving differential equations.
1746: A proof of the fundamental theorem of algebra by d'Alembert was published in the annals of the Berlin Academy.
1798: Legendre published his Theory of Numbers, which gathered many results from arithmetic.

Carl Friedrich Gauss (1777–1855) was undoubtedly the greatest mathematician in history. He made groundbreaking discoveries in almost every area of mathematics, from algebra and number theory to statistics, calculus, geometry, geology, and astronomy.

Bernhard Riemann (1826–1866) was a German mathematician working in the fields of analysis and number theory. He proposed the first rigorous definition of integration, studied differential geometry that laid the foundations for general relativity, and made revolutionary discoveries concerning the distribution of prime numbers.

Arthur Cayley (1821–1895) proposed the modern definition of groups.

The German mathematician Georg Cantor (1845–1918) was the inventor of set theory and a pioneer in our understanding of infinity.

George Boole (1815–1864) created Boolean algebra.

David Hilbert (1862–1943) was one of the most influential mathematicians of the 20th century. He worked on almost every area of mathematics and was particularly interested in establishing formal and logical foundations for mathematics.

Paul Erdős (1913–1996) solved countless problems in the fields of graph theory, number theory, combinatorics, analysis, probability, and other aspects of mathematics.

Alan Turing (1912–1954) was an English mathematician often referred to as the "father of computer science."

PHYSICS: [11] [12][13]
Aristotle proposed original theories about rainbows, coronas, lunar and solar halos, dew, and the aurora borealis.

Archimedes founded statics and hydrostatics, and invented the water screw, the Archimedean screw, the hydrometer, and the balance.

In his Optics, the famous astronomer Ptolemy (128-168) addressed all the known light phenomena of the Greeks.

Ibn al-Haytham made significant contributions to the principles of optics and visual perception, his most influential work being the Book of Optics (كتاب المناظر).

The works of Geber, Albateginus, Alhazen, and other Arab and Persian commentators ended the long decline of physics.

Leonardo da Vinci discovered capillarity and studied friction.

The physician Fracastor indicated the law of the composition of forces (1538).

Cardano focused primarily on applying mathematics to physics.

Tycho Brahe and Kepler, with their remarkable astronomical discoveries, overshadowed their optical work.

With Galileo, modern physics solidified. He is particularly credited with a rigorous conception of material inertia, the principle of virtual speeds, the laws of falling bodies, the pendulum, and projectile motion; he also laid the foundations of hydrodynamics and perfected the astronomical telescope, which had just been developed by Lippershey. Galileo also invented the thermometer.

Descartes definitively established the laws of refraction and the theory of the rainbow in his Dioptrique, followed by Torricelli, who constructed the barometer, which Pascal used shortly thereafter to measure heights.

Newton, through universal gravitation, unveiled the mystery of planetary motions; he renewed optics (decomposing light into elementary colors, colored rings, mirror telescope, etc.).

Papin constructed, in addition to his autoclave, the first draft of the steam engine.

Volta discovered the voltaic pile (1800), the origin of dynamic electricity.

The mechanical theory of heat led to significant developments in atomism; the molecular theory of gases (Joule, Clausius, Maxwell, Van der Waals, Boltzmann, Gibbs) became one of the most vibrant areas of theoretical physics.

Fizeau, Foucault, and Cornu measured the speed of light using terrestrial methods.

Photography was created through the collaboration of Niepce and Daguerre (1839).

Faraday discovered induction (1831) and shortly thereafter formulated the laws of electrolysis.

Maxwell (1831-1879), in his Treatise on Electricity (1873), established the characteristic equations of electric and magnetic fields.

Marconi (1896) invented wireless telegraphy.

Henri Poincaré and Henri Becquerel (1896) were pioneers in radioactivity research, enabling physicists to conduct new and fruitful investigations.

Wilhelm Röntgen caused a sensation with his discovery of X-rays in 1895.

In 1897, J. J. Thomson discovered the electron.

At the beginning of the 20th century, following the work of Max Planck and Einstein, which demonstrated the existence of the photon (quantum of light), the greatest conceptual revolution in physics occurred: the birth of quantum mechanics.

Einstein developed the theory of general relativity, with the help of David Hilbert, using a very area of mathematics.

Based on Einstein's general relativity, Lemaître and Gamow formulated what would become the Big Bang theory.

The formulation of a relativistic quantum theory by Paul Dirac in 1928.

The invention of the laser (Nobel Prize in Physics, 1964).

On July 4, 2012, physicists working at the Large Hadron Collider at CERN announced they had discovered a new subatomic particle resembling the Higgs boson, a potential key to understanding why elementary particles have mass and the existence of diversity in the universe.

III. Analysis Of The Contents Of The Mathematics And Physics Curricula

A. Contents Of The Physics And Mathematics Curricula

The curriculum content is one of the three pillars of the didactic triangle and the main source of information for both learners and teachers in the educational learning process.

Table 1. The Mathematics Curriculum Content for the Second Year of the Baccalauréat in Science.

	Semester 1	
	Topic	Hour Volume
Mathematics	Continuity, differentiation, and study of functions	30 hours
	Numerical sequences	15 hours
	Primitive functions	10 hours
	Logarithmic and exponential functions	5 hours

	Complex numbers	10 hours
	Semester 2	
	Logarithmic and exponential functions	12 hours
	Integral calculus	10 hours
	Differential equations	4 hours
	Complex numbers	10 hours
	Geometry in space	15 hours
	Probability	20 hours

Table 2: Physics Curriculum Content - 2nd Bachelor's Degree in Sciences

	Semester 1	
Physics	Topic	Hour volume
	Progressive Mechanical Waves	5h
	Periodic Progressive Mechanical Waves	5h
	Propagation of Light Waves	6h
	Nuclear Transformations	5h
	The Nucleus (Mass and Energy)	5h
	Semester 2	
	Topic	Hour volume
	RC Circuit	7h
	RL Circuit	7h
	Free Oscillations of an RLC Circuit	8h
	Newton's Laws	5h
	Some Applications of Newton's Laws	8h
	Rotation of a Solid Around a Fixed Axis	6h
	Oscillating Mechanical Systems	8h

B. Comparisons

When studying the content of the mathematics and physics curricula for the second year of the Bachelor's degree proposed by the Ministry of National Education, we notice that:

A good understanding of physics largely depends on the assimilation of several mathematical concepts (periodic functions, relativity, linear functions, relational functions).

There is a lack of coordination, correlation, and compatibility in the order of mathematics and physics courses. For example:

The introduction of logarithmic and exponential functions (applications, limits, and function graphs) in physics is necessary for the nuclear transformations and electricity courses, even though they have not yet been covered in mathematics classes.

Physics directly uses new concepts that have not been sufficiently mastered in mathematics (logarithmic and exponential functions, vector calculus, geometry in space, differential equations, integration).

IV. Physics, Mathematics, And Our Practices

To determine the degree of compatibility between the mathematics and physics curricula, a field study was conducted involving a group of mathematics and physics teachers, as well as a group of second-year experimental science students. The goal of this research is to gain insights into the difficulties students face in physics and mathematics and the complementarity of the two subjects.

At The Learner Level

A survey of 73 second-year science students aimed to determine whether learners have a preference for mathematics, their views on subjects most related to mathematics, the relationship between the two disciplines, the necessity of mathematics for physics, and whether mastery of mathematics implies a good understanding of physics.

The following diagrams represent the results of the questionnaire:

Figure 1: Preferred Subject

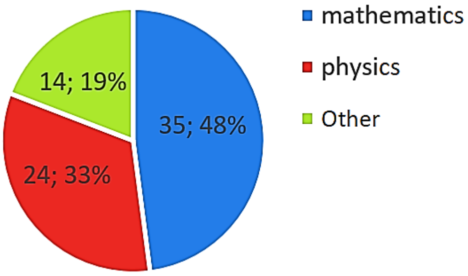


Figure 2: Subjects Related to Mathematics

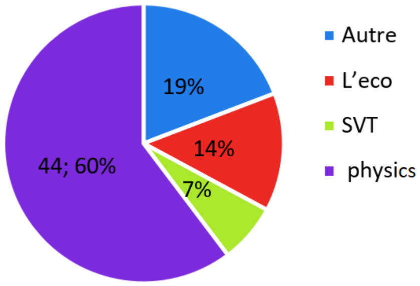


Figure 3: Existence of Relationship Between Physics and Mathematics

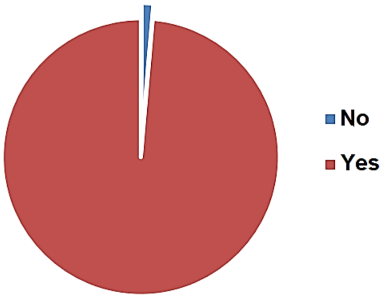


Figure 4: Can One Study Physics Without Mathematics?

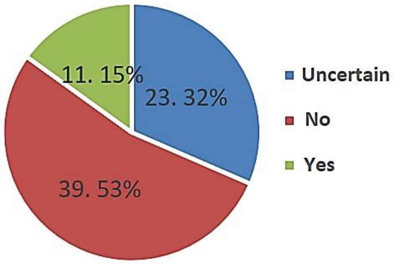
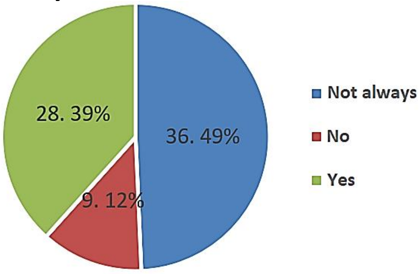


Figure 5: Mastery of Mathematics Leads to Excellence in Physics



Conclusion

Students were unanimous about the complementarity between physics and mathematics, noting that it is often difficult to study physics without referring to mathematics. The study also showed that the ability to master mathematics is one of the most important aspects for effectively understanding physical phenomena.

At The Level Of Teachers

For a sample of 60 mathematics teachers, data were collected to validate the understanding of the complementarity and compatibility between mathematics and physics.

The following diagrams summarize the results:
For Mathematics :

Figure 6: Mastery of Knowledge on the Physics Curriculum

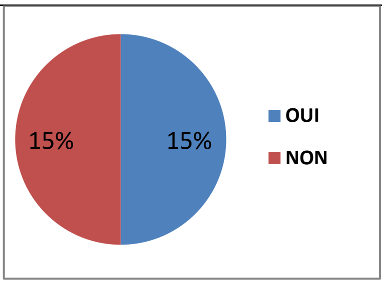


Figure 7: Mastery and Compatibility of the Curricula

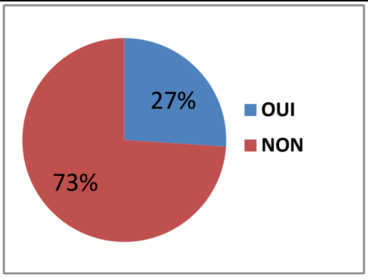


Figure 8: The Proper Order of Mathematics and Physics Lessons

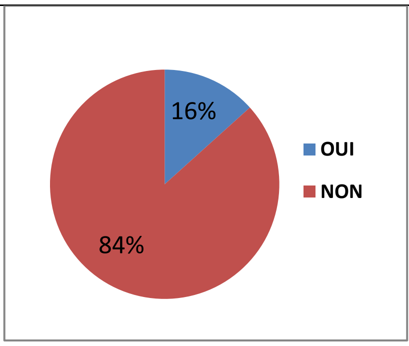


Figure 9: Can One Teach Physics Without Mathematics?

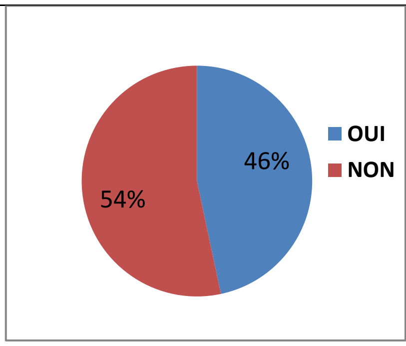
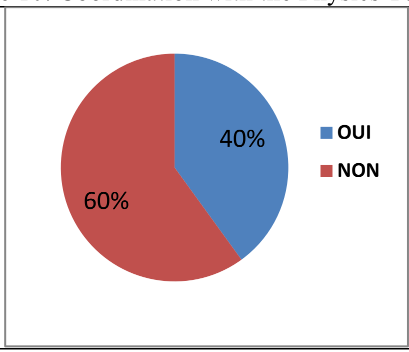


Figure 10: Coordination with the Physics Teacher



For physics :

Figure.11 **L**es connaissances sur le programme des mathématiques.

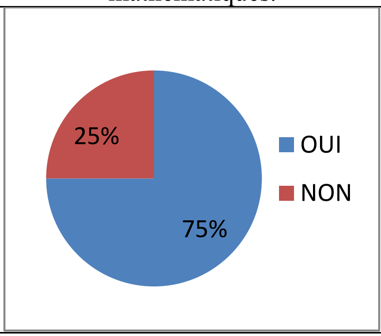


Figure.12 **S**uffisance du volume horaire.

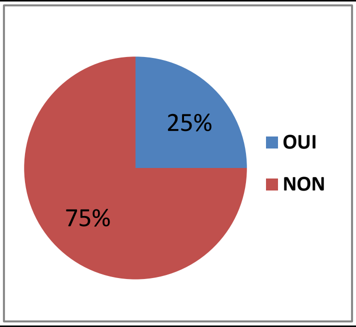
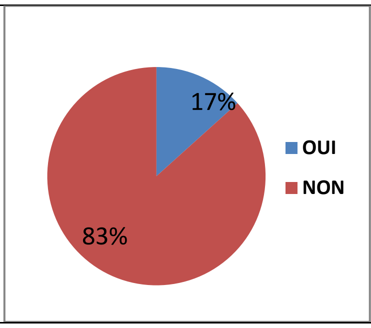
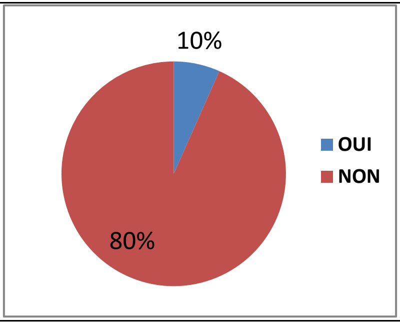


Figure.13 Cohérences des programmes des deux matières.

Figure.14 Enseigner la physique sans l'apport des mathématiques.





Conclusion

The study showed that half of the mathematics teachers have information about the physics courses. The inconsistency between the lesson content and the allocated hours for each lesson, as well as the lack of coordination in the order of the lessons, creates numerous obstacles for teachers of both subjects. Regarding the possibility of teaching mathematics without referencing physical concepts, most teachers prefer not to propose exercises that require knowledge of a specific physical concept. Additionally, there is a lack of dialogue with physics teachers regarding the content and order of lessons throughout the school year.

In contrast to mathematics teachers, most physics teachers have information about the mathematics curriculum but also suffer from a lack of coherence between the course content and the allocated hours. They have also noted the lack of compatibility in the order of lessons. Teachers unanimously agree on the impossibility of studying and teaching physics without relying on mathematical tools and concepts.

V. Analytical Study Of Mathematics And Applications In Physics Of Differential Equations

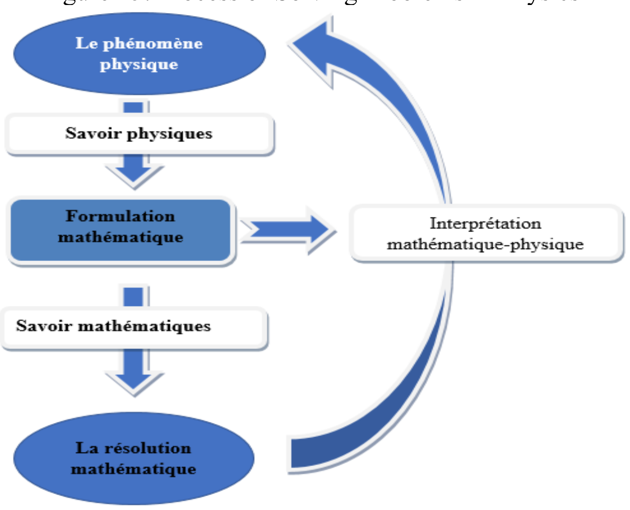
The Process Of Solving Physical Problems

Solving any physical problem involves modeling or mathematical formulation, with physical knowledge playing a crucial role in understanding the phenomenon at hand.

To effectively tackle a physical problem, the following steps are essential:

- Identify the phenomenon: Grasp the fundamental physical principles involved.
- Model the problem: Create a differential equation that captures the system's behavior.
- Apply mathematical techniques: Utilize analytical or numerical methods to find a solution to the equation.
- Interpret the results: Connect the mathematical solutions to their physical implications, ensuring they align with experimental data.
- This methodology establishes a strong connection between mathematics and physics, enhancing both understanding and prediction of physical system behaviors.

Figure 25: Process of Solving Problems in Physics



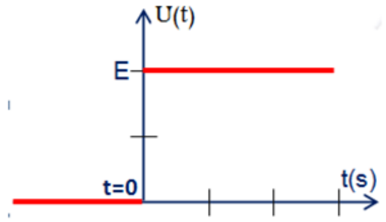
This process highlights the importance of the interaction between physics and mathematics in understanding and solving physical problems.

The purpose of this section is to determine the role of mathematics in the introduction of physical phenomena and the verification of experimentally obtained results, ultimately demonstrating the degree of compatibility between the two subjects through the example of solving differential equations in the second year of the experimental sciences baccalaureate.
Electrical Physical Application of Differential Equations in the Response of the RC Circuit

Problem Statement:

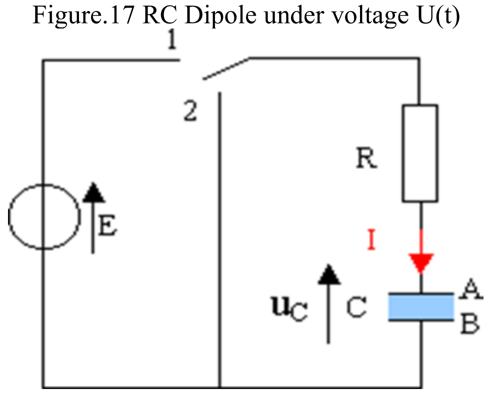
A physical model that requires the resolution of differential equations is the RC dipole, which is a series combination of a capacitor and an ohmic conductor (or resistor). U(t) is the step voltage applied across the terminals of the RC dipole (represented in the graph below).

Figure 36: Voltage Across the RC Dipole



We denote U_c as the response voltage corresponding to the voltage U(t) across the amplifier terminals I_c as the response current intensity I(t) across the RC dipole

Figure.17 RC Dipole under voltage U(t)



Taking the initial moment as the time when the switch (D) is closed, and applying the law of voltage additivity (the loop law) in a series electrical circuit, we obtain the following equation:

$$U = U_R + U_c = E \qquad (1)$$

According to Ohm's Law $U_R = R.i$ and we have a $q = C.U_c$ *and* $i = \frac{dq}{dt}$

Therefore : $i = C.\frac{dU_C}{dt}$ et $U_R = R.C.\frac{dU_C}{dt}$ then quation (1) began :

$$R.C.\frac{dU_C}{dt} + U_C = E$$

If we let : τ = RC, then starting from equation (2) :

$$\tau\,\frac{dU_C}{dt} + U_C = E \qquad (2)$$

The quantity τ is expressed in seconds and is called the **time constant** of the RC dipole.

Differential Equation's Solving In A Physics Lesson:

The solution of the differential equation (2) is expressed as follows: $U_C(t) = Ae^{-mt} + B$; where A, B and m are constantes to determine.

If we remplace $U_C(t)$ in equation (2) we'll have : $U_C(t) = Ae^{-mt}(1 - m\tau) = E - B$ where E-B is a constante so $1 - m\tau$ is zero then $m = 1/\tau$; therefore : $U_C(t) = Ae^{-(1/\tau)t} + B$.

To find the constant A, let's examine the initial conditions at t=0. At this moment, the amplifier is not charged, so: $U_C(0)$=0 et donc $A = -E$.
So, the final expression of U(t) is :

$$U_C(t) = E(1 - e^{-\left(\frac{1}{\tau}\right)t}) \quad (3)$$

How to determine the time constante :

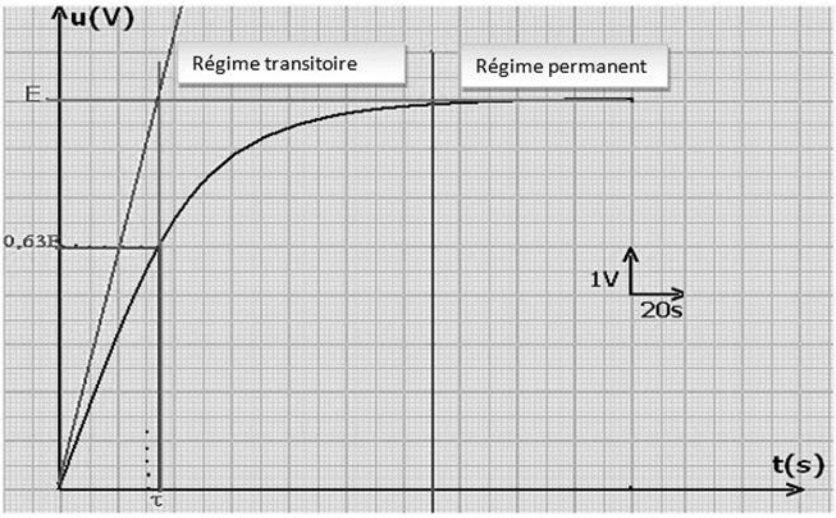
- **First methode :**

We have $U_C(\tau)$ = E (1–e-1) = 0,63E ; where τ is the abscissa corresponding to the ordinate 0,63E (see figure. 18)

- **Seconde methode :**

τ is the abscissa of the intersection point of the tangente to function $U_C(t)$ graph at the instant t=0 and theasymptote $U_C(t)$ =E at the instant τ (see figure. 18).

Figure 18: Voltage Across the Dipole as a Function of Time



The Mathematical Model For Solving Differential Equations

The Resolution of First-Order Differential Equations of the Type: $y' = ay + b$ avec $a \in \mathbb{R}^*$ et $b \in \mathbb{R}$

$y' = ay + b$ i.e $(y + b/a)' = a(y + \frac{b}{a})$ that means : $z' = az$ quation without second member. The zero function $y = 0$ is a solution. The other solution can be found by writing $z'/z = a$ and taking a primitive of each member ; so we'll have $\ln(|z|) = a + C$ where C is an arbitrary constante.

For each value of C , we have two solutions, one of them is always positive z(x) $= e^C e^{ax}$, the other one always negative z(x) $= -e^C e^{ax}$.

All these solutions, including the zero solution, can be expressed by stating that the general solution can be written in the form: z(x) $= e^C e^{ax}$ K *is an arbitrary constant.*
Notice that K is the solution value in $x = 0$, the general solution is then z(x) $= z(0)e^{ax}$.

Therefore: y(x) $= Ke^{ax} + b/a$ with $K \in \mathbb{R}$

For $y = U(t)$, we find the equation : $\frac{dU_C}{dt} + \frac{1}{\tau}U_C = \frac{E}{\tau}$

Then for $a = -\frac{1}{\tau}$ and b= $-\frac{E}{\tau}$ the equation have as solution $U_C(t) = Ke^{-(1/\tau)t} + E$ and the initial condition U (0) =0 lead to $K = -E$, so :

$$U_C(t) = E(1 - e^{-\left(\frac{1}{\tau}\right)t}) \quad (3)$$

Study of the function U(t) :

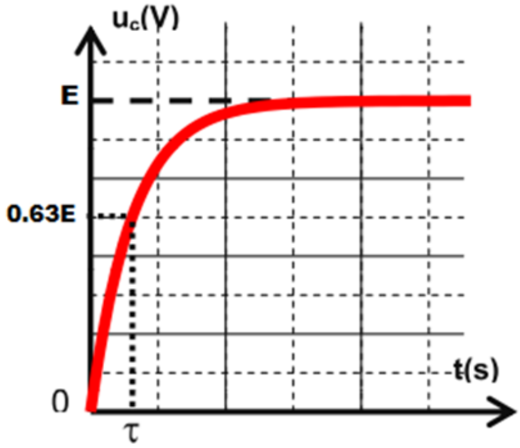
Variantion table :

t	**0** → **+ ∞**
U'(t)	+
U(t)	**E** ↗ **1**

The formulas are numbered, with the number tabulated to the right.

Graph of the function U(t):

Figure.27 graphical représentation of U(t) as fonction of time



In permanent regime, the voltage remains constant: Uc(t) = E and the physical approximation concorde with the mathematical solution since:

$$\lim_{t\to+\infty} \boldsymbol{U(t)} = \lim_{t\to+\infty} E(1 - e^{-\left(\frac{1}{\tau}\right)t}) = \boldsymbol{E} \quad (4)$$

Conclusions :

We note that the difference in notation between mathematics and physics can confuse students and may prevent them from grasping physical concepts that require mathematical concepts in their application. This is why we have proposed a range of solutions that we will detail in the following paragraph.

VI. Conclusion And Perspectives: Analytical Study Of Mathematics And Applications In Physics Of Differential Equations

The proposed communication must necessarily include a conclusion summarizing the objectives of the proposed work, the results obtained, and offering future perspectives.

Proposed Solutions:

After studying the results of the questionnaires and the content and order of courses in the two subjects, we find that:
Mathematics is essential for a good understanding of concepts in physics.
There is a lack of coordination among teachers, which needs to be addressed.
Mastery of physics is dependent on mastery of mathematics.

We propose the following solutions:
Coordinate efforts between teachers of both subjects by rearranging the courses in a coherent manner.

Co-teach sessions by mathematics and physics teachers to build new mathematical concepts and see their applications in physics.

These solutions are not unique or absolute; many research studies should propose other solutions and determine the extent to which they are feasible within education to improve students' learning in physics and mathematics, while emphasizing the critical importance of coherence and compatibility in teaching mathematics and physics.
A study of possible translations of lessons in mathematics and physics seems essential in our future work.

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