Multidisciplinary learning, another way of teaching maths in engineering

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POLITÉCNICA

MAMI Mejora Aprendizaje Matemáticas Ingenierías

Abstract

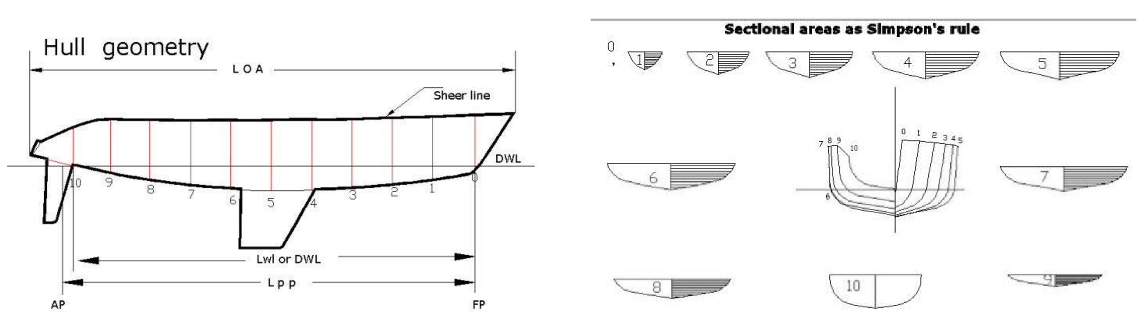
Multidisciplinary training is widely appreciated in industry and business, and nevertheless usually is not addressed in the early stages of most undergraduate programs.
We outline here a multidisciplinary course for undergraduates studying engineering in which mathematics would be the common language, the transverse tool. The goal is motivating students to learn more mathematics and as a result, improve the quality of engineering education.
The course would be structured around projects in four branches in engineering: mechanical, electrical, civil and bio-tech. The projects would be chosen among a wide variety of topics in engineering practice selected with the guidance of professional engineers. In these projects mathematics should interact with at least two other basic areas of knowledge in engineering: chemistry, computers science, economics, design or physics.
In each project, instructors and students would work together in a team defining the **purpose** of the project, the **tools** needed to solve it (the relevant concepts in mathematics, physics, chemistry,...), the **development**, the **final outcomes** and their **connections** with other problems. In each team there should be faculty from all different areas related to the project.
This multidisciplinary course would enhance the role of mathematics as a key tool for engineers as well as give students, at an early stage in their training, an integrated perspective on their chosen area of study, and on engineering in general.

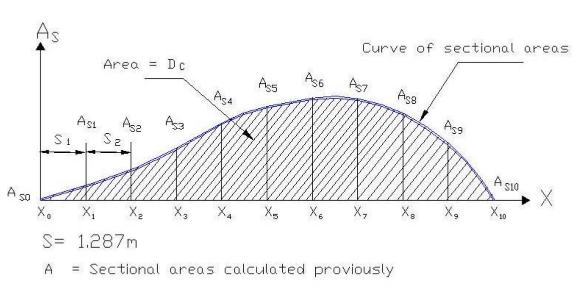
Organization of the course

The projects would be organized with the following structure:

1. **Purpose**: the goal and the need of the project. Should be clearly defined.
2. **Tools**: the ideas and concepts from the different disciplines that are relevant for the project.
3. **Development**: The resolution of the project, the different stages to get to the final outcome.
4. **Conclusions**: The analysis of the solution giving its strengths and weaknesses.
5. **Connections with other problems**, that arise in different contexts but that are closely related.

Development



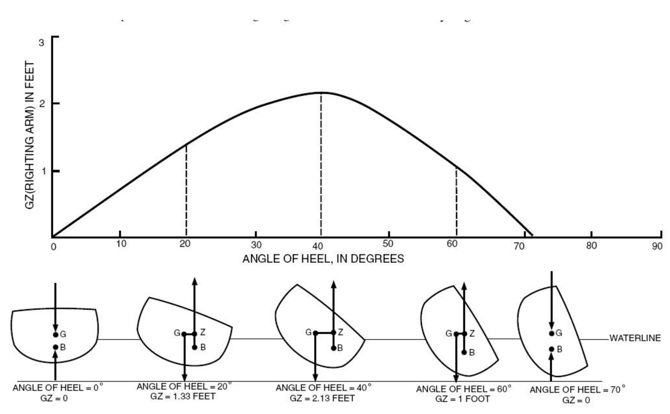


The main task is to find the coefficients of the equation (1) with the aid of mathematics, physics and computer sciences.

- b and I_{ad} are found empirically, the data are fitted to the model.
- Δ is obtained by calculating the volume of the displaced water (Archimede's principle). The volume is obtained by integrating sectional areas of the hull of the ship using Simpson's rule.
- I depends on the geometry of the hull.
- M is the center of curvature of the curve described by buoyancy center.

Outcome

Analysis of the stability curve of the ship



Project: Ship stability

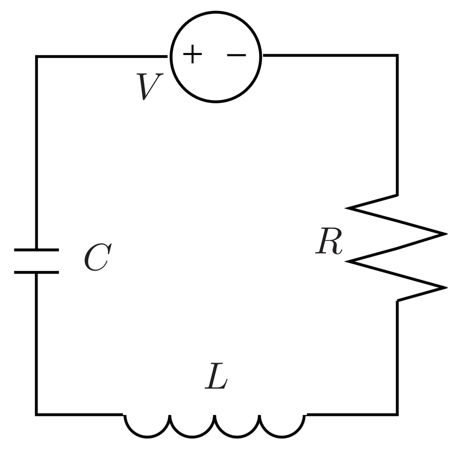
Cargo that transports chemical products

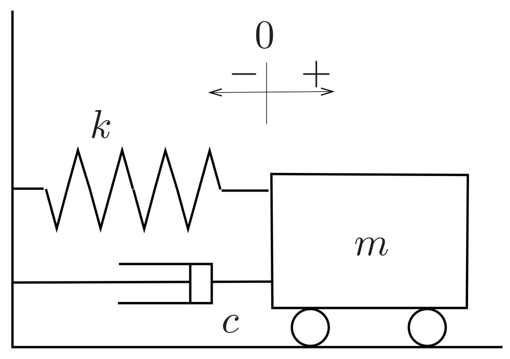
Purpose

Ships are the only way to transport heavy cargoes around the world, and ship cruises are becoming a popular way of spending holidays. Ship stability is of vital importance for ships not only for unquestionable safety reasons but also for the comfort of the crew and passengers.
The motion of a freely moving ship on the water has six degrees of freedom, but a simple model (with one degree of freedom) gives insight in the forces and parameters that describe the motion.

Connections

RLC **circuits**: Kirchoff's laws applied to a series *RLC* circuit with a voltage source yield to the equation $L\ddot{Q} + R\dot{Q} + \frac{1}{C}Q = E_0 \cos(wt)$ with L inductance, Q the charge, R the resistance and C the capacitance.





The vibration of structures can be modelled by a system of rigid bodies connected with springs, and sometimes, with a damping force. By Newton's second law the equation of the position of the body is $m\ddot{x}(t) + c\dot{x}(t) + kx(t) = 0$ where m is the mass of the body, c is the damping coefficient and k is the constant of stiffness of the spring.

References

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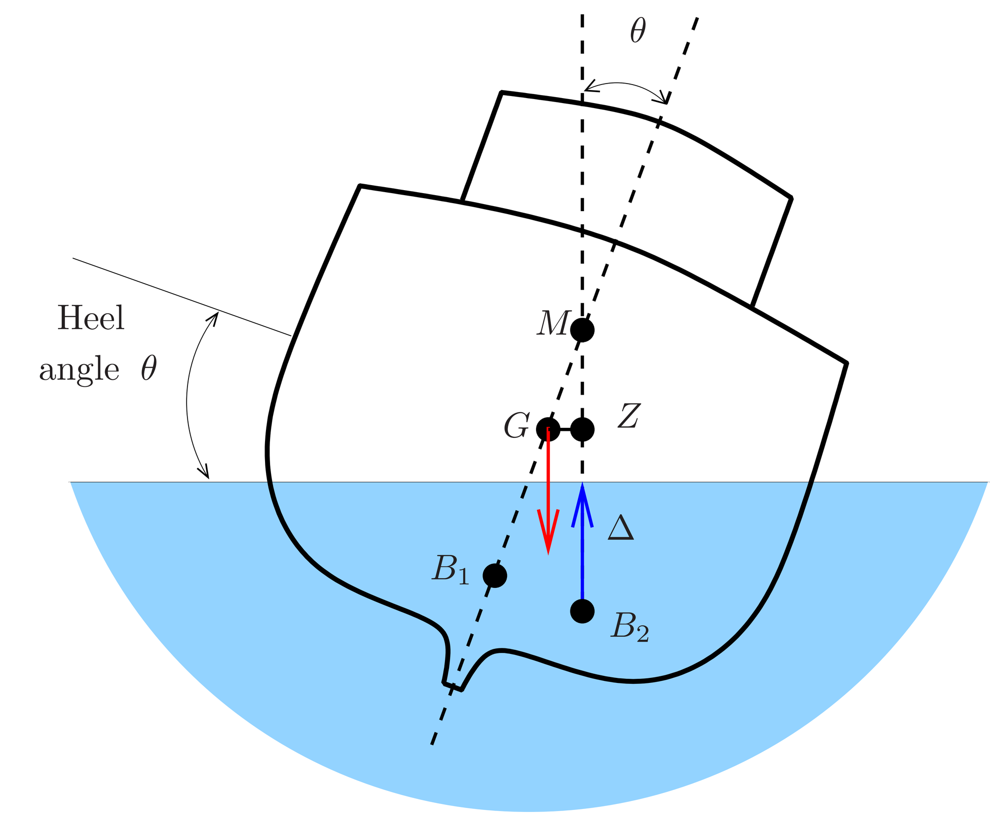
Tools



Neglecting the action of the waves and wind, there are two main forces that act on the ship: the buoyancy force and the weight. The buoyancy force is usually denoted by Δ as, by Archimede's principle, is equal to the weight of the displaced water. When the ship is in upright position (in equilibrium) the center of gravity, G, and the buoyancy center, B_1, lie on the same vertical line. As the ship heels the buoyancy center moves, B_2, creating a moment of forces that act on the ship. If G is below the metacenter, M, (the point at which the verticals through B_1 and B_2 meet) this moment tends to restore the equilibrium position, it is called the righting moment (that can be increased by increasing the distance GZ).
When the ship heels, the equation that describes the roll motion of the ship is obtained by applying Newton's second law to the angular motion. The equation obtained is the equation of the **damped harmonic oscillator**:

$$(I + I_{ad})\ddot{\theta} + b\dot{\theta} + GM\Delta\,\theta = 0 \qquad (1)$$

where, θ, heel angle, I, moment of inertia of the ship, I_{ad}, added moment of inertia due the water pulled by the ship b, damping due to water, GM, metacentric height is the distance between G and M, metacentric height and Δ, buoyancy force.

The goal is to understand how the different parameters affect the stability of the ship.

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