Introduction to 21st-century physics

Luca

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Lecture notes on introductory mechanics and thermodynamics (ING175)

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0 Introduction

The loss implied in such an acquisition can be estimated only by those who have been compelled to unlearn a science that they might at length begin to learn it.
J. C. Maxwell (1878)

Until some decades ago, the 18th-century physical notions typically taught in introductory Bachelor physics courses were enough to prepare an engineer for future specializations and jobs. Students who wanted to venture into modern theories, such as Relativity, were required to **re-learn** some of the most important physical notions – *Energy*, mass, time, entropy above all – which in these theories are quite different from the 18th-century ones. But at that time the modern theories still mostly had only theoretical, not practical, importance. So the re-learning efforts of the curious students could perhaps be justified.

That situation has changed today. Modern theories are an essential part of many everyday technologies, like nuclear reactors and the Global Positioning System[1]; and they are required for developing new technological possibilities, from quantum computers[2] to solar sails[3]. An engineering student (including communication and data engineering) may likely end up in a job that requires an understanding of modern physical notions. The diffusion of large language models[4] will moreover require future engineers who actually **understand** those physical notions, not little monkeys who have been trained to manipulate some equations and to throw some technobabble around. Automated large language models are faster, cheaper, and more precise in doing the latter kind of monkey activities. So why should one hire a human to do the same?

While moving from the older to the newer notions often requires re-learning efforts and conceptual re-orientations, the move in the opposite direction is less demanding. The modern physical notions are more encompassing than their 18th-century parents. Their understanding leads to an understanding of their older counterparts as approximate

[1] https://www.gps.gov; see Fliegel & DiEsposti 1996; Ashby 2002; Müller et al. 2008. [2] https://www.ibm.com/topics/quantum-computing. [3] see for instance https://www.planetary.org/sci-tech/lightsail, https://www.cubesail.us. [4] https://www.ibm.com/topics/large-language-models.

and special cases. Students, moreover, have often been hearing quite early from mass media about the new notions; for instance about the equivalence of mass and energy. Owing to this early exposure, students sometimes ask very intelligent questions – "should the mass of the body be included in its internal energy?" – when exposed to the old notions.

It is therefore high time that introductory Bachelor physics courses be based on modern physical notions. Students should not be required to waste time and mental effort to learn something that they must unlearn and re-learn, only because of academia's and teachers' inertia.

Some teachers say "it would be too difficult for students to understand modern ideas, because they are too familiar with the old ones. This is why we need to teach the old and slightly incorrect ideas first, and correct them later". I think that this kind of reasoning is scientifically unacceptable and leads to a vicious circle. Students are unfamiliar with new notions only because they were raised by a generation who was taught the old. New notions become familiar after a couple of generations learn them early. This is obvious if you consider that notions such as "energy", "electromagnetic field", "vector" are very familiar today, but were absolutely *un*familiar a couple centuries ago. If we had always taught what's familiar, then we would still be teaching about the elements *air, earth, water, fire*, and that the Sun revolves around the Earth. Arguments in favour of teaching old notions are just pretexts for laziness.

The present lecture notes are an experiment and attempt to introduce classical mechanics and thermodynamics from modern physical notions. The core equations remain the same, but the students should have a broader conception of their meaning and of the symbols that appear in them.

1 The Seven Wonders of the world

Bibliography

("de *X*" is listed under D, "van *X*" under V, and so on, regardless of national conventions.)

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