Introducing high-pressure physics into physics education through digital simulations

Ilia SHOLIN (Independent researcher, Bahrain)

Abstract

The current educational landscape of high-pressure physics remains relatively limited and fragmented. To the author's knowledge, high-pressure physics educational activities are largely confined to formats such as summer schools and workshops and primarily target postgraduate students. At the same time, this field of physics offers significant educational potential.

As a part of condensed matter physics, high-pressure physics explores the relationship between phenomena at the microscopic level and the macroscopic properties of matter. In this context, it provides a framework for connecting classical areas of physics in education, such as atomic physics, thermodynamics, and mechanics. Industrial applications of high-pressure physics, such as the synthesis of diamond, provide a relevant context for modernising physics education.

The ongoing digitalisation of education creates new opportunities to integrate high-pressure physics into education. This work presents digital educational simulations based on high-pressure physics (work-in-progress).

Digital Simulation of Sapphire and Diamond Anvil Cells (SAC and DAC)

The simulation enables users to explore the design and operating principles of SAC and DAC. Users can select one of the predefined samples for the SAC or the DAC and simulate an increase in pressure. A section of the screen shows what can be observed through a microscope as pressure increases. Visual observation is currently the only method used in the simulation.

The visual content used in the simulation is based on materials from multiple sources, including:

- photographs and video recordings obtained during our experiments in the SAC at pressures up to 9.5 GPa;
- images from key works in high-pressure physics, as well as video recordings from lecture courses by high-pressure researchers, for example the lecture series “The Diamond Anvil Cell” by Prof. William Bassett.

Pressure Scale

There is a wide range of simulations designed to develop an understanding of distance scales. To the author's knowledge, there are no comparable simulations for pressure. One possible reason is that distance is a much more intuitive physical quantity than pressure. The work presents an approach to understanding pressure scales in nature and technology by ‘Pressure Scale’ simulation.

The ‘Pressure Scale’ consists of several independent simulations. Each simulation is focused on a specific theme.

One simulation explores pressure scales in the context of pressures found in the cores of various astronomical bodies. The simulation includes the planets of the Solar System and their moons as reference points.

Another focuses on techniques for generating high pressures. It shows the range of pressures achieved in different high-pressure devices, such as piston–cylinder apparatus, SAC, and DAC. In addition to understanding pressure scales, this simulation also reflects the historical development of high-pressure physics.

Each simulation covers only the range of pressures relevant to the objects it represents.

To reinforce knowledge after engaging with the “Pressure Scale” simulation a mini-game titled “Which Option Has the Higher Pressure?” is used. In this mini-game, users choose between two options and select the one with the higher pressure. The options are drawn from various “Pressure Scale” simulations and allow users to integrate this knowledge into a unified framework. Additionally, the mini-game can be used as a standalone activity, independent of the “Pressure Scale” simulation. This can be done in a mode where the pressure values are either given directly or can be estimated by users with basic school-level physics knowledge, without requiring specialised knowledge in high-pressure physics.