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EDITORIAL

Bridging Physical Laws and Machine Intelligence: Physics-Informed Neural Networks in Research and Pedagogy

A Preface to the Special Issue on Physics-Informed Neural Networks (PINNs)

In recent years, the convergence of computational physics and artificial intelligence has given rise to a transformative paradigm: Physics-Informed Neural Networks (PINNs). By embedding fundamental physical principles—such as conservation laws, non-linear partial differential equations (PDEs), and boundary conditions—directly into the loss function of deep neural architectures, PINNs bridge the traditional divide between purely data-driven machine learning and physics-based analytical modeling. This Special Issue of the *Journal of Physics Education* (Vol. 40, ICTRIBT 2026/Special Issue/1) brings together a compelling collection of eight research articles showcasing the pedagogical, conceptual, and practical application of PINNs across diverse physics domains.

> **Core Theme:** Incorporating mathematical conservation laws into deep learning frameworks not only regularizes neural network training but also provides highly intuitive computational tools for physics education and research.

HIGHLIGHTS OF THE SPECIAL ISSUE

The contributed manuscripts in this volume span key disciplines in theoretical, computational, and applied physics, illustrating the versatility of the PINN paradigm:

1. **Quantum Mechanics & Wave Equations:** Quantum systems provide a fertile ground for PINN applications. *Thakur and Awasthi* demonstrate the solution of the time-independent Schrödinger equation for double-well potentials in quantum plasma systems (pp. 1–8). Complementing this, *Walia and Awasthi* explore the time-dependent Schrödinger equation for harmonic oscillators while extracting the Bohm quantum potential (pp. 1–12). Furthermore, *Saklani and Awasthi* apply PINNs to solve the Woods-Saxon potential to elucidate the shell structure of ^{40}Ca (pp. 1–8), and *Kanika et al.* determine the ground state of the hydrogen atom (pp. 1–8).

2. **Molecular Dynamics & Nuclear Physics:** Expanding beyond fundamental wave equations, *Kashyap et al.* employ PINNs to determine the vibrational energy levels of the HCl molecule (pp. 1–7), highlighting molecular spectroscopy applications. In nuclear physics, *Anjali and Awasthi* utilize PINNs to estimate the coefficients of the Semi-Empirical Mass Formula (SEMF) (pp. 1–10), offering a fresh computational perspective on nuclear binding energy.

3. **Thermal & Differential Systems:** Addressing fundamental transport phenomena, *Rathore et al.* present a PINN-based numerical formulation for the classic heat equation (pp. 1–10). In a broader mathematical context, *Sharma et al.* establish general frameworks for learning solutions of coupled differential equations using physics-informed architectures (pp. 1–6).

EDUCATIONAL SIGNIFICANCE & OUTLOOK

Beyond their numerical efficacy, PINNs hold tremendous potential for physics pedagogy. They empower students and researchers to explore non-linear, multi-dimensional, and inverse problems that were previously intractable using standard introductory software. By demystifying deep learning through the lens of physical conservation laws, this special issue serves both as a milestone in computational research and a practical roadmap for modernizing physics education curricula.

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