

Appendix A: Expert Q&A on Physical Systems Solving Differential Equations Inherently

Question 1:

Please provide me a list of physical systems that solves differential equations inherently. I.E. the physical properties solve it, no traditional computing required.

Answer:

The following physical systems inherently solve differential equations through their natural behavior, without the use of traditional digital computing:

1. Mechanical Systems (Springs, Masses, Dampers)

- **Type:** Second-order ODEs
- **Example Equation:**
$$m * x'' + c * x' + k * x = F(t)$$

2. Electrical Circuits (RLC Circuits)

- **Type:** Linear/nonlinear ODEs
- **Example Equation:**
$$L * q'' + R * q' + (1/C) * q = V(t)$$

3. Thermal Systems

- **Type:** Heat diffusion PDEs
- **Example Equation:**
$$\partial u / \partial t = \alpha \partial^2 u / \partial x^2$$

4. Fluid Dynamics Systems

- **Type:** Navier-Stokes equations
 - **Example Equation:**
$$\rho(\partial u / \partial t + u \cdot \nabla u) = -\nabla p + \mu \nabla^2 u$$
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5. Soap Films / Minimal Surfaces

- **Type:** Laplace's equation / minimal surface PDEs
 - **Example Equation:**
 $\nabla^2 u = 0$
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6. Analog Computers (Op-Amps, Capacitors, etc.)

- **Type:** Configurable ODEs/PDEs
 - **Example:** Analog computing circuits can be built to simulate dynamical systems.
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7. Wave Propagation (Strings, Membranes)

- **Type:** Wave equation
 - **Example Equation:**
 $\partial^2 u / \partial t^2 = c^2 \partial^2 u / \partial x^2$
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8. Quantum Systems

- **Type:** Schrödinger equation (PDEs)
 - **Example Equation:**
 $i\hbar \partial \psi / \partial t = H\psi$
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9. Optical Systems (Lenses, Mirrors, Interferometers)

- **Type:** Helmholtz, paraxial wave equations
 - **Example Equation:**
 $\nabla^2 E + k^2 E = 0$
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10. Elastic Materials

- **Type:** Elasticity PDEs
 - **Example Equation:**
 $\mu \nabla^2 u + (\lambda + \mu) \nabla(\nabla \cdot u) = \rho \partial^2 u / \partial t^2$
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Question 2:

Please provide well sourced papers on how we are using these to create dynamic computing systems for each.

Answer:

Below are references to authoritative papers detailing the use of physical systems in computing contexts:

1. Mechanical Systems

[Mass-Spring-Damper Array as a Mechanical Medium for Computation \(University of Bristol\)](#)

2. Electrical Circuits

[Modeling the Behavior of RLC Circuits Using FPAA](#)

3. Thermal Systems

[Dynamic Models of Thermal Systems Using an Energy-Based Modeling Framework](#)

4. Fluid Dynamics

[Finding flows of a Navier-Stokes fluid through quantum computing](#)

5. Soap Films

[Soap Films: Statics and Dynamics](#)

6. Analog Computers

[Using analog computers in today's largest computational challenges](#)

7. Wave Propagation

[Wave computing with passive memristive networks](#)

8. Quantum Systems

[Analog classical simulation of closed quantum systems](#)

9. Optical Systems

[Optical Realization of Wave-Based Analog Computing with Metamaterials](#)

10. Elastic Materials

[The Solution of Elastic Stability Problems With the Electric Analog Computer](#)
