Algorithm: THNF Flow and Heat Transfer Analysis with AI (LMFA)

Input:

- Physical constants (ρf, cp, kf, σf, etc.)

- Nanoparticle properties (MWCNT, Ag, Au)

- Base fluid properties (blood)

- Volume fractions φ1, φ2, φ3

- Parameters: M, S, Da, Bi, Pr, Rd, R

- Boundary conditions

Step 1: Define Governing Equations

1.1 Continuity equation

1.2 Momentum equations in x, y, z directions

1.3 Energy equation with thermal radiation and convective BCs

Step 2: Apply Similarity Transformations

- u = ax f’(η), v = ay g’(η), w = -√(a/v) f(η)

- θ = (T - T∞) / (Tf - T∞)

- η = z√(a/v)

Step 3: Derive Non-dimensional ODE System

- f''' + ... = 0

- g''' + ... = 0

- θ'' + ... = 0

- Include Biot number, Darcy number, magnetic parameter, radiation term

Step 4: Apply Correct Boundary Conditions

- f’(0) = 1, g’(0) = S, θ’(0) = -(kf/kthnf)Bi[1 - θ(0)]

- f’(∞) → 0, g’(∞) → 0, θ(∞) → 0

Step 5: Compute Effective Properties (Mixture Rules)

- ρthnf, (ρcp)thnf, μthnf, kthnf, σthnf

- Use Maxwell–Garnett / Tiwari–Das models

- Ensure Φ → 0 recovery to pure blood

Step 6: Numerical Solution (Python/SciPy)

- Discretize η-domain (0 → η∞)

- Solve ODEs using `solve\_bvp` or finite difference method

- Store profiles: f’(η), g’(η), θ(η)

Step 7: Data Preparation for AI

- Generate dataset of (η, f’, g’, θ) for varying parameters (M, S, Da, Bi, R, Rd)

- Normalize inputs/outputs using min–max scaling

- Partition data: 70% training, 15% validation, 15% testing

Step 8: Train Neural Network (LMFA)

- Architecture: input layer → 10 hidden neurons → output layer

- Loss function: MSE

- Optimization: Levenberg–Marquardt update

- Stopping criteria: error < 1e-6 OR max 1000 epochs

- Track RMSE, MAE, regression R²

Step 9: Validation and Error Analysis

- Compare AI-predicted profiles vs. numerical solution

- Plot error histograms, regression fits

- Perform mesh-independence check (200–600 nodes)

- Verify limiting cases (pure fluid, hybrid fluid)

Step 10: Uncertainty Quantification

- Monte Carlo sampling: vary Bi, R, M ± 5%

- Compute distributions of Cf, Nu

- Plot 95% confidence bands

Output:

- Velocity profiles f’(η), g’(η)

- Temperature profile θ(η)

- Skin-friction coefficients Cf\_x, Cf\_y

- Nusselt number Nu\_x

- AI vs. numerical error metrics

- Confidence intervals on Cf and Nu