

## **Flow and wall heat transfer due to a continuously moving slender needle in hybrid nanofluid with stability analysis**

### **ABSTRACT**

Present work deals with the numerical study of flow due to a continuously moving slender needle in a hybrid nanofluid. The mathematical model of this work is developed in terms of nonlinear partial differential equations. By adopting the relevant similarity transformations, these equations are reduced to a system of nonlinear ordinary differential equations. Afterward, the solution is determined computationally via a `bvp4c` solver in MATLAB software. The influences of nanoparticle volume fraction, needle thickness and velocity ratio parameter on the rate of heat transfer, coefficient of skin friction, velocity as well as temperature distributions are illustrated in graphical form to describe the important features of the solution. The multiple solutions seem to appear when the needle opposes the free stream flow. It is revealed from the study that the composite (hybrid) nanoparticles augment the heat transfer rate between the flow and the needle in a certain domain of the velocity ratio parameter. The analysis of stability has proved that the upper branch solution represents stable flow, whereas the lower branch solution represents unstable flow.

**Keyword:** Hybrid nanofluid; Dual solutions; Stability analysis; Numerical study