DECLARATION

I, **Sujesh A S**, hereby declare that the thesis entitled, ***"Mathematical Modelling of Biological Variations due to Application of Nanofluids in Body Fluids"***, submitted to the **University of Calicut** in partial fulfillment of the requirements for the award of the Degree of ***Doctor of Philosophy in Mathematics*** is a bonafide research work done by me under the supervision and guidance of **Dr. Alphonsa Mathew**, Assistant Professor, Department of Mathematics, St. Thomas' College (Autonomous), Thrissur, Kerala. I further declare that this thesis has not previously formed the basis of any degree, diploma or any other similar title.

Thrissur **Sujesh A S**

12 December, 2022

CERTIFICATE

This is to certify that the thesis titled ***"Mathematical Modelling of Biological Variations due to Application of Nanofluids in Body Fluids"*** submitted by **Sujesh A S** to the **University of Calicut** in partial fulfillment of the requirements for the award of the Degree of ***Doctor of Philosophy in Mathematics*** is a record of original research work carried out by him under my supervision. The content of this thesis, in full or in parts, has not been submitted by any other candidate to any other University for the award of any degree or diploma.

Thrissur
12 December, 2022

Dr. Alphonsa Mathew
Research Supervisor

CERTIFICATE

I hereby certify that, this is the revised version of the thesis entitled ***"Mathematical Modelling of Biological Variations due to Application of Nanofluids in Body Fluids"*** submitted by **Sujesh A S**, under my guidance, after incorporating the necessary corrections/suggestions made by the adjudicators. I also certify that the contents in the thesis and the soft copy are one and the same.

Thrissur
20 March, 2023

Dr. Alphonsa Mathew
Research Supervisor

ABSTRACT

A substance capable of flowing is termed as a fluid. Fluids are of two types, namely liquids and gases. The study of fluid's behaviour at rest (termed fluid statics) and in motion (termed fluid dynamics) is combinedly known as fluid mechanics.

The fluid produced and circulated within the human body or secreted outside the human body is known as body fluid. Blood, saliva, urine, tears, sweat, and breast milk are a few examples of body fluid. Water is the basis of all body fluids and the human body is composed of about 60% of water.

Nanofluid is a colloidal mixture in which a base fluid (water, oil, ethylene glycol, etc.) is mixed with nanometer-sized particles (metals, carbides, oxides or carbon nanotubes). Fluids constituting two nanometer-sized particles are termed hybrid nanofluids. Nanofluids tend to upgrade and stabilize the thermal properties of the fluid which marked a revolution in the field of fluid dynamics.

The description of a system using mathematical concepts and language is known as mathematical model and the process of developing a mathematical model is known as mathematical modelling. Mathematical models find its use in natural sciences, engineering disciplines and social sciences. A mathematical model helps to explain a system and to study the effects of different components and also to make predictions about its behaviour.

The thesis entitled *Mathematical Modelling of Biological Variations due to Application of Nanofluids in Body Fluids* has been arranged into 12 chapters. Chapter 1 introduces the basic concepts, preliminaries and definitions to the reader. An extensive review of related literature has been presented in Chapter 2. Owing to the practical applications (like biomedical imaging, hyperthermia, pharmaceuticals, biosensors, medical instruments, bio-chromatography, microchip pump, theranostic, biomedical science, targeted drug delivery, and cancer therapy), nine fluid flow problems are modelled and investigated in this thesis.

In Chapter 3, the bioconvective stagnation point flow involving carbon nanotubes along a lengthening sheet subject to induced magnetic field and multiple stratification effects is investigated. The dynamics of water conveying single-wall

carbon nanotubes (SWCNTs) and magnetite nanoparticles on the bioconvective stagnation-point flow along a stretching sheet subject to chemical reaction, viscous dissipation, induced magnetic field, and stratification effects is investigated in Chapter 4. Non-spherical nanoparticles have gained popularity for their ability in changing the thermophysical properties of a nanofluid. Chapter 5 elucidates the significance of multiple slip and nanoparticle shape on stagnation point flow of blood-based silver nanofluid considering chemical reaction, induced magnetic field, thermal radiation, nanoparticle shape and linear heat source.

The numerical study on the stratification effects of bioconvective electromagnetohydrodynamic (EMHD) flow past a stretching sheet using water-based CNT has been presented in Chapter 6. The focal concern of Chapter 7 is to numerically scrutinize the consequences of multiple slip, linear radiation and chemically reactive species on MHD convective Carreau nanoliquid flow over an elongating cylinder. Moreover, statistical scrutiny on the impact of Hartmann number, thermal radiation and thermal slip parameter over heat transfer rate employing Response Surface Methodology (RSM) and sensitivity analysis is also performed. The nanomaterial flow of Chapter 8 has been modelled using the modified Buongiorno nanofluid model. The impact of the stratification constraints and magnetic field are also accounted. Further, the influence of magnetic field parameter, thermal stratification parameter, volume fraction of magnetite nanoparticles, and velocity ratio parameter on the heat transfer rate has been scrutinized statistically using a five-level four-factor response surface optimized model.

In Chapter 9, the dynamics of the $TiO_2 - H_2O$ nanomaterial over a nonlinearly stretched surface and modelled using modified Buongiorno model is investigated. Experimentally derived correlations of the thermal conductivity and dynamic viscosity of the nanomaterial are utilized. The hydromagnetic bioconvective flow of a nanomaterial over a lengthening surface is investigated in Chapter 10. Realistic nanomaterial modelling is achieved by incorporating passive control of the nanoparticles at the boundary. The impact of the Newtonian heating and Stefan blowing constraints are also accounted. The sensitivity

of heat transport rate is also computed. Chapter 11 numerically elucidates the dynamics of electro-magnetohydrodynamic flow of blood-gold nanomaterial over a nonlinearly stretching surface utilizing the Casson model. The impact of second-order hydrodynamic-slip, nanoparticle radius, first-order thermal-slip, inter-particle spacing and non-uniform heat source are also accounted.

Lastly, Chapter 12 presents the concluding remarks of the thesis and proposals for future work.

I dedicate this work

to my parents who paved the way for me during their lifetime and

to my beloved teachers and friends for their unconditional love and support.

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