Chapter 8

Summary, Conclusions, and Suggestions for Future Work

Summary and Conclusions

The aim of the present thesis is to present a theoretical investigation of the flow of a viscous, incompressible, and electrically conducting nanofluid over a stretching sheet under the influence of a transverse magnetic field with a view to investigate the role of several effects in stabilizing/de-stabilizing the momentum and thermal boundary layers arising in the problem. Chapter 1 is presented to motivate the research work embodied in the thesis. In this chapter, the nanofluids and their application, MHD and its application, heat transfer, boundary layers, governing equations, boundary conditions, non-dimensional parameters, a short-description of the methods used in different chapters to solve the respective problems, and relevant literature survey, is presented. In Chapter 2, the viscous, incompressible, and electrically conducting nanofluid flow over a stretching sheet under the influence of a magnetic field is investigated taking into account the effects of non-linear thermal radiation, newtonian heating and partial velocity slip. The nanofluid model considered in this chapter incorporates the effect of Brownian motion and thermophoresis. The governing equations, in similarity form, are solved using Matlab’s in-built boundary value problem solver “bvp4c”. Chapter 3 presents an investigation of the effects of non-uniform heat generation/absorption and Newtonian heating on the steady two dimensional laminar stagnation point boundary layer flow of nanofluid over a stretching sheet under the influence of an external magnetic field. The nanofluid is assumed to be viscous, incompressible, and electrically conducting. The effects of Brownian motion and thermophoretic force are taken into account. The governing non-linear partial differential equations are transformed to a set of equations in
similarity form which are then solved using Spectral Relaxation Method (SRM). The effects of pertinent flow parameters on the flow, heat and nanoparticle concentration are studied with the help of graphs and tables. The effects of space/temperature dependent non-uniform heat generation/absorption and Newtonian heating on the flow of a viscous, incompressible, and electrically conducting nanofluid past a stretching sheet is studied. The theoretical solution of two dimensional steady hydromagnetic boundary layer flow of a viscous, incompressible, and electrically conducting nanofluid past a stretching sheet with Newtonian heating, in the presence of viscous and Joule dissipations is studied in Chapter 4. The transport equations include the combined effects of Brownian motion and thermophoresis. The governing nonlinear partial differential equations are transformed to a set of nonlinear ordinary differential equations which are then solved using Spectral Relaxation Method (SRM) and the results are validated by comparison with numerical approximations obtained using the Matlabs in-built boundary value problem solver bvp4c, and with existing results available in literature. Numerical results for fluid velocity, fluid temperature and nanoparticle volume fraction are displayed graphically versus boundary layer coordinate for various values of flow controlling parameters. The values of coefficient of skin-friction, co-efficient of heat transfer and coefficient of mass transfer are presented in tabular form for different values of flow parameters. Chapter 5 presents the effect of homogeneous-heterogeneous reactions on the steady two dimensional mixed convection stagnation point boundary layer flow of an incompressible, viscous, electrically conducting, and chemically reacting copper-water nanofluid along a linear stretching sheet in the presence of non-linear radiative heat transfer. The spectral local-linearization method (SLLM) is employed to obtain the numerical solution for the fluid velocity, species concentration and fluid temperature. The effects of nonlinear thermal radiation and homogeneous-heterogeneous chemical reactions were studied. In Chapter 6 we investigate the magnetohydrodynamic two dimensional steady flow of a viscous, incompressible, electrically conducting nanofluid along a stretching sheet in the presence of a uniform transverse magnetic field with a view to understand the contribution of heat absorption and homogeneous-heterogeneous reaction effects on the flow and heat transfer characteristics of the flow. The flow of fluid is caused due to linear stretching of the sheet along its length. The numerical solution of the non-linear partial differential equations governing the fluid flow model are are obtained using the spectral quasi-linearization method (SQLM). The numerical computations are carried out to obtain the numerical solution of fluid velocity, fluid temperature and species concentration. These values are then depicted graphically for various values of pertinent flow parameters to analyze the effects of various flow parameters. The values of coefficient of skin friction and local Nusselt number are presented in tabular form for different values of pertinent flow parameters. In Chapter 7, a discussion of the numerical solution of natural convection flow of a viscous, incompressible and electrically conducting...
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nanofluid under the influence of a variable magnetic field in the presence of nonlinear radiative heat transfer, hydrodynamic slip and Newtonian heating is presented. The Brownian diffusion and thermophoresis effects are taken into consideration to describe the nanofluid model. The spectral local linearization method (SLLM) is employed to find the solution for the nanofluid velocity, temperature and nanoparticle concentration.

The study presented in Chapter 2 reveals that the momentum boundary layer associated with the nanofluid velocity gets thinner with increasing effects of partial velocity slip. The thickness of the nanofluid thermal boundary layer increases with increasing magnetic field, velocity partial slip, thermal radiation, Brownian and thermophoretic diffusion, and convective heating while the stretching velocity decreases the thickness of the thermal boundary layer. Nanoparticle volume fraction behaves as an increasing function of magnetic field, velocity partial slip, thermophoretic force, and convective heating while it is decreasing function of stretching velocity and Brownian diffusion. From Chapter 3 we conclude that the space dependent and temperature dependent heat generation have increasing effect on the nanofluid temperature while the heat absorption has a decreasing effect on it. However, the observed effects were found to be very less in these cases. The Newtonian heating at the surface of the sheet has an increasing effect on the nanofluid temperature and nanoparticle concentration. The effect on the nanofluid temperature is significant. One of the interesting results observed in this chapter is the increasing effect of the magnetic field on the nanofluid velocity and an opposite one on the nanofluid temperature where these two physical quantities behave opposite to their usual trend with a change in the strength of the applied magnetic field. It is observed from Chapter 4 that the effect of magnetic field is to decelerate the nanofluid flow whereas to enhance the nanofluid temperature and nanoparticle concentration. The nanofluid temperature gets increased with the increasing effect of Brownian motion and thermophoretic force of nanoparticles. However, the effects of Brownian motion and thermophoretic force due to nanoparticles are opposite on the species concentration. The Brownian motion of the nanoparticles tend to reduce the species concentration while the thermophoretic force has reverse effect on it. Newtonian heating and viscous dissipation both contribute toward the enhancement in nanofluid temperature and species concentration. It is found from Chapter 5 that the Magnetic field enhances the thickness of thermal boundary layer while it reduces the thickness of momentum and concentration boundary layer region. The species concentration, fluid velocity, and fluid temperature are getting enhanced by nanoparticle volume fraction in Cu-water nanofluid. The nanoparticle volume fraction, mixed convection, thermal radiation, temperature ratio and stretching of the sheet were found to be increasing the rate of heat transfer. It is perceived from Chapter 6 that the nanoparticle volume fraction has increasing effects on nanofluid velocity, nanofluid temperature, and species concentration. The strength of the Lorentz force appearing
in the flow field due to the presence of magnetic field is measured by an increase in
the magnetic parameter and is found to be retarding the nanofluid velocity and species
concentration, while it has an increasing effect on the nanofluid temperature. The ho-
mogeneous and heterogeneous reaction rates affects the species concentration inversely
however the observed effect is more significant due to heterogeneous reaction. The
nanofluid temperature gets decreased with increase in heat generation by the nanofluid
particles. Chapter 7 demonstrate that the magnetic field and buoyancy ratio have retard-
ing influences on the nanofluid velocity only near the surface of the sheet and they tend
to increase the fluid motion once we move away from the surface. The nanofluid tem-
perature and nanoparticle volume fraction both increases with increasing magnetic field
and buoyancy ratio. The nonlinear thermal radiation tends to decrease the nanofluid
velocity and nanofluid temperature while it increases the nanoparticle volume fraction.
The Brownian motion has the tendency to increase the fluid motion and temperature
near the surface of the sheet whereas it has reverse effect on these physical quantities
away from the sheet. The velocity slip effect increases the fluid velocity near the sur-
face while it decreases the fluid velocity away from the surface. The velocity slip has a
decreasing effect on the nanofluid temperature and nanoparticle volume fraction.

8.1 Suggestions for Future Work

In the present thesis, the governing nonlinear partial differential equations modeling the
fluid flow problems were transformed to a set of similar nonlinear ordinary differential
equations by using a suitable similarity transformation and then the appropriate numer-
ical techniques were used to solve the similar form of the equations. Further research
may be carried out by considering the equations in its non-similar form. The induced
magnetic field effects were neglected in comparison to the applied one which may also
be retained for fluids with sufficiently large magnetic Prandtl numbers.