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HEAT AND MASS TRANSFER ANALYSIS IN AN UNSTEADY NATURAL CONVECTIVE MAGNETHYDRODYNAMIC FLOW OF A NANO FLUID UNDER THE PRESENCE OF THERMAL DIFFUSION AND ABSORPTION RADIATION

Lakshmi R[1], R. Vijayakumar[2]

[1]Assistant Professor, Department of Mathematics, PSGR Krishnammal College For Women, Coimbatore, TamilNadu, India.

[2]Mathematics Section, FEAT, Annamalai University, Annamalainagar – 608002, India.

Corresponding author: Dr. R. Lakshmi Email:rluxmath@gmail.com

ABSTRACT

An analysis of unsteady natural convective MHD flow of nanofluid under the presence of thermal diffusion and absorption radiation with the effects of chemical reaction on heat and mass transfer without a porous medium is discussed in the present study. The governing equations were implied and were solved analytically using perturbation technique. The velocity, temperature and concentration fields are obtained. Graphical results were presented for velocity, temperature and concentration profile for various values of parameters.

INTRODUCTION

The term nanofluid refers to a fluid containing nanometer-sized particles, called nanoparticles. These fluids are designed and build for colloidal suspensions of nanoparticles in a base fluid. An unsteady natural convectional heat transfer fluids of nanofluids has importance because of its applications in different areas such as Automobiles, Thermal energy, Heat exchange reactor, optical applications, Medical applications. The nanofluids have more significance in the convectional heat transfer has motivated to carry out extensive research in this field. The new term nanofluid was set up in 1995 by Choi[1] that is the very small particles whose diameter is less than 100 nm which uses a mixture of higher thermal conductivity solid containing nanoparticles such as copper, silver, etc and the thermal conductivity for the base fluids like water, engine oil etc..is lesser then heat transfer fluids in advanced with substantial augmentation of thermal conductivities.An unsteady magneto hydrodynamics flow of a viscous and electrically conducting field past to a plate by the presence

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of radiation.The nanofluids and their thermal conductivity. They turned out into oxide nanofluids and measured their thermal conductivities by the method of a transient hot- wire .It was made that these nanofluids containing a suspension of submicronic solid particles, having higher thermal conductivities when compared with the same liquids without nano particles. It was pragmatic that the Hamilton and crosser model experimental proves that the thermal conductivity of nanofluids containing large agglomerated Al_2O_3 nanoparticles .It is enough for nanofluids containing CUO particles. Not only particle shape but also the size is measured to be foremost in enhancing the thermal conductivity of nanofluids[2-5].

LI Qiang and XuanYimin experimented and studied the flow characteristics of Cu-water nanofluids in a tube.The calculated values and data from the experiment describes correctly the correlation between the energy transport of the nanofluid are concluded. The suspended nanofluid containing nanoparticles increase heat transfer performance of the base fluid and the nanofluid has larger heat transfer coefficient than pure water under the same Reynolds number. If the coefficient of heat transfer increases for the nanofluid the volume fraction of nanoparticles increases. The friction factors of the nanofluids corresponds with the water for the drop test of pressure, since the nanoparticles are so miniature that a suspension with nano particles behaves as a pure fluid. The low volume fraction of the nanofluid incurs almost no augmentation for a drop in pressure. The characteristics of nanofluids are affected by transfer of heat convection such as volume fraction, velocity, micro convectional and diffusion. Then the convective heat transfer correlation for nanofluid containing metal nano particles over single-phase flows in tubes. The experimental data and the calculated results are compared indicates the correlation that affect factors of the heat transfer of nanofluid and can be used to forecast heat transfer coefficient of the nanofluid. Both flows the laminar and turbulent flow for Cu containing nanoparticles the convective heat transfer and the friction factor were measured[6-8].

The influence of nanoparticles on natural convection boundary-layer flow of a nanofluid past over a vertical semi-infinite plate was studied by A.V. Kuznetsov and D.A. Nield.The representation incorporates the effects of Brownian motion and thermophoresis. Thus the result for this difficulty based on five dimensionless parameters namely a Brownian motion Nb, a buoyancy-ratio Nr, a Lewis number Le, and a Prandtl number Pr.Thenusselt number decreases with Nr, Nb and Nt for different values of Pr and Le was expressed by

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correlation formulas.It was observed that minimized Nusselt number is a decreasing function of each of Nr, Nb and Nt. Then they extended their work for darcy model in the problem of cheng-minkowycz for natural convection past over a vertical plate in a porous medium saturated by a nanofluid.

Ellahi R, Aziz S and Zeeshan A. studied an analysis of the Non Newtonian nanofluids flow between two coaxial cylinders with heat transfer and variable viscosity through a porous medium.Shehzad SA,Alsaadi F, Abbasi FM, Hayat T introduce a new enchanced boundary condition ,mass flux for nanofluid containing nanoparticles throughout the surface is assumed to zero to calculate the volume fraction of nanoparticles on the surface. They made at the appealing conclusion that increase in buoyancy ratio culminates in temperature rest and the velocity retardation.

Haroun Nageeb AH and Mondal S,studied the Unsteady natural convective boundary-layer flow of MHD nanofluid over stretching surfaces with chemical reaction using the spectral relaxation method and arrived at the conclusion that the effects of heat and mass transfer on the chemical reaction have various applications in hydrometallurgical industries and chemical technology. The study of unsteady natural convectional flow of a nanofluid past over a vertical permeable semi-infinite plate moving with the constant heat source under various effects has attracted the attention of a number of researchers, because of its possible applications in Automobile, solar energy, Mechanical and electronics cooling. In view of these applications, a serious of investigations have been done by various researchers to study the problem of the free natural convective flow of a nanofluid over a past vertical permeable semi-infinite plate moving with constant heat source.

Motivated by these studies, in this paper we extend the result of P. Durga Prasad , R.V.M.S.S. Kiran Kumar, S.V.K. Varma made an attempt to study the effects of Diffusion thermo, radiation absorption and chemical reaction of nanofluids on the Magnetro hydrodynamics unsteady natural convective heat and mass transfer flow bounded by semi-infinite plate without porous medium. A constant velocity u_0 is applied when the plated is moved. A magnetic field is applied uniformly along the y- direction. The temperature and concentration profiles are assumed to be varying with respect to time at the plate. Analytical expressions were obtained. Using this expressions, calculating their behavior and the different flow characteristics for various non-dimensional parameters are discussed.

MATHEMATICAL FORMULATION:

We have considered two dimensional unsteady natural convectional flow of a nanofluid past over a vertical permeable semi-infinite movable plate with heat source as constant. The X - axis is acting vertically upwards which is taken along the plate and the y- direction is perpendicular to the plate. A uniform magnetic field of strength B $_0$ is applied externally along the y- direction. The temperature T'_∞remains constant for the plate and the fluid. The concentration C'_∞at the stationary condition is taken constant in both the fluid and the plate . The fluid we consider here is water based Copper Nano particles and Titanium oxide. Then it is assumed for both the fluid phase nanoparticles are in thermal equilibrium state as they have uniform size and shape.

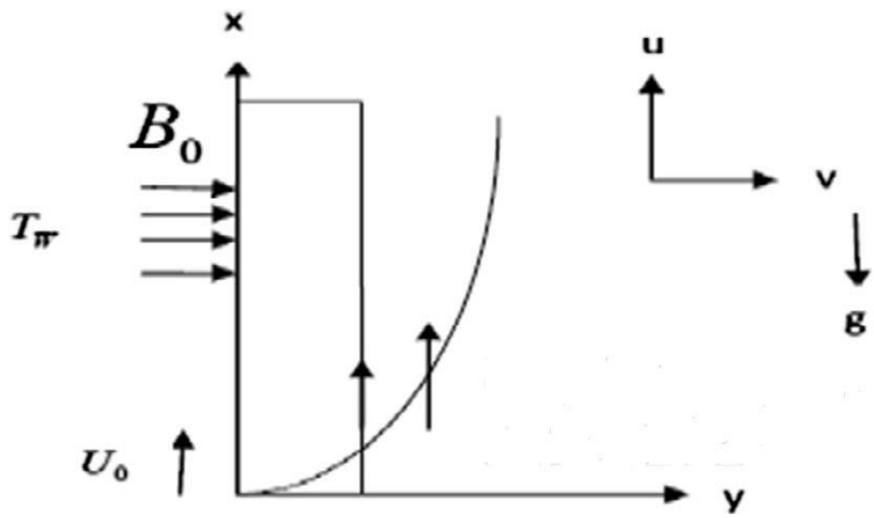

Figure 1. Schematic diagram of the physical properties.

From the above assumptions the equation that govern the two dimensional unsteady natural free convective MHD flow of heat and mass transfer analysis for the nanofluid occupying the plate are given below.

The Continuity equation

$$\frac{\partial v'}{\partial y'} = 0. \qquad (1)$$

The Momentum equations

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$$\rho_{nf}\left(\frac{\partial v'}{\partial t'}+ v'\frac{\partial u'}{\partial y'}\right) = \mu_{nf}\ \frac{\partial^2 u'}{\partial y'^2}+(\rho\beta)_{nf}g(T'- T'_\infty)-\sigma B_0^2u' \quad (2)$$

The Energy equation

$$\left(\frac{\partial T'}{\partial t'}+ v'\ \frac{\partial T'}{\partial y'}\right) = \alpha_{nf}\frac{\partial^2 T'}{\partial y'^2}- \frac{Q'}{(\rho Cp)nf}(T'- T'_\infty)+Q'(C'-C'_\infty)+ \frac{D_mK_T}{C_s(\rho Cp)nf}\cdot\frac{\partial^2 C'}{\partial y'^2} \quad (3)$$

The Species equation

$$\frac{\partial C'}{\partial t'}+v'\ \frac{\partial C'}{\partial y'} = D_B\ \frac{\partial^2 C'}{\partial y'^2}-K_l(C'-C'_\infty) \quad (4)$$

The boundary conditions are given by,

$$t' < 0,\ u'(y',t') = 0,\ T' = T'_\infty, C' = C'_\infty$$

$$t' \geq 0\ , u'(y',t') = U_{0,}T' = T'_w + (T'_w - T'_\infty)\varepsilon e^{iw't'}, C' = C'_w + (C'_w - C'_\infty)\varepsilon e^{iw't'}\ at\ y' = 0$$

$$u'(y',t') = 0\ , \qquad T' = T'_\infty, \qquad C' = C'_\infty\ \ as\ \ y' \to \infty$$

All physical and parameter are defined in the nomenclature section

Then, $\mu_{nf} = \frac{\mu_f}{(1-\varphi)^{2.5}},\quad k_{nf} = k_f\left(\frac{k_s+2k_f-2\varphi(k_f-k_s)}{k_s+2k_f+2\varphi(k_f-k_s)}\right),\quad \rho_{nf} = (1-\varphi)\rho_f + \varphi\rho_s\ ,$ (5)

$(\rho Cp)_{nf} = (1-\varphi)(\rho Cp)_f + \varphi(\rho Cp)_s\ , (\rho\beta)_{nf} = (1-\varphi)(\rho\beta)_f + \varphi(\rho\beta)_s\ ,$

$$\alpha_{nf} = \frac{k_{nf}}{(\rho Cp)_{nf}} \quad (6)$$

$$v' = -V_0 \quad (7)$$

where $-V_0$ constant indicates the normal velocity at the plate that is the positive suction $(V_0 > 0)$ and the negative suction represents the blowing injection $(V_0 < 0)$.

By applying 7 in (2) – (4), we get

$$\rho_{nf}\left(\frac{\partial v'}{\partial t'}- v_0\frac{\partial u'}{\partial y'}\right) = \mu_{nf}\ \frac{\partial^2 u'}{\partial y'^2}+(\rho\beta)_{nf}g(T'- T'_\infty)-\sigma B_0^2u' \quad (8)$$

$$\left(\frac{\partial T'}{\partial t'}- v_0\frac{\partial T'}{\partial y'}\right) = \alpha_{nf}\frac{\partial^2 T'}{\partial y'^2}- \frac{Q'}{(\rho Cp)nf}(T'- T'_\infty)+Q'(C'-C'_\infty)+ \frac{D_mK_T}{C_s(\rho Cp)nf}\cdot\frac{\partial^2 C'}{\partial y'^2} \quad (9)$$

$$\frac{\partial C'}{\partial t'}- v_0\frac{\partial C'}{\partial y'} = D_B\ \frac{\partial^2 C'}{\partial y'^2}-K_l(C'-C'_\infty) \quad (10)$$

Substitute (6) in (9),

$$\left(\frac{\partial T'}{\partial t'}- v_0\frac{\partial T'}{\partial y'}\right) = \frac{k_{nf}}{(\rho Cp)_{nf}}\cdot\frac{\partial^2 T'}{\partial y'^2}- \frac{Q'}{(\rho Cp)nf}(T'- T'_\infty)+Q'(C'-C'_\infty)+ \frac{D_mK_T}{C_s(\rho Cp)nf}\cdot\frac{\partial^2 C'}{\partial y'^2} \quad (11)$$

$$\rho_{nf}\left(\frac{\partial v'}{\partial t'}- v_0\frac{\partial u'}{\partial y'}\right) = \mu_{nf}\ \frac{\partial^2 u'}{\partial y'^2}+(\rho\beta)_{nf}g(T'- T'_\infty)-\sigma B_0^2u' \quad (12)$$

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$$\frac{\partial C'}{\partial t'} - v_0 \frac{\partial C'}{\partial y'} = D_B \frac{\partial^2 C'}{\partial y'^2} - K_l (C' - C'_\infty) \tag{13}$$

We define the following dimensionless variables

$$u = \frac{u'}{U_0}, \quad y = \frac{U_0 y'}{v_f}, \quad t = \frac{U_0^2 t'}{v_f}, \quad \omega = \frac{v_f\, \omega'}{U_0^2}, \quad \theta = \frac{(T' - T'_\infty)}{(T'_w - T'_\infty)}$$

$$M = \frac{\sigma B_0^2 V_f}{\rho_f U_0^2}, \quad Du = \frac{D_m K_T (C'_w - C'_\infty)}{K_f C_s (T'_w - T'_\infty)}, \quad Q_L = \frac{Q'_l (C'_w - C'_\infty)}{U_0^2 (T'_w - T'_\infty)}, \quad Kr = \frac{k_f v_f}{U_0^2},$$

$$Sc = \frac{v_f}{D_B}, \quad Q = \frac{Q' v_f^2}{K_f U_0^2}, \quad \Pr = \frac{v_f}{\alpha_f}, \quad K = \frac{k' \rho_f U_0^2}{v_f^2},$$

$$Gr = \frac{(\rho\beta)_f g\, v_f (T'_w - T'_\infty)}{\rho_f U_0^3}, \quad \Psi = \frac{(C' - C'_\infty)}{(C'_w - C'_\infty)}, \quad S = \frac{V_0}{U_0}.$$

The governing equation (11)-(13) together with the dimensionless variables becomes:

$$A\left(\frac{\partial u}{\partial t} - \frac{\partial u}{\partial y}\right) = D\frac{\partial^2 u}{\partial y^2} + BGr\theta - Mu = 0. \tag{14}$$

$$C\left(\frac{\partial \theta}{\partial t} - S\frac{\partial \theta}{\partial y} - Q_L \Psi\right) = \frac{1}{Pr}\left(E\frac{\partial^2 u}{\partial y^2} - Q\theta\right) + \frac{Du}{Pr} \cdot \frac{\partial^2 \Psi}{\partial y^2} \tag{15}$$

$$\frac{\partial \Psi}{\partial t} - S\frac{\partial \Psi}{\partial y} = \frac{1}{Sc}\frac{\partial^2 \Psi}{\partial y^2} - Kr\Psi \tag{16}$$

The boundary conditions are given by

$t<0$: $u=0$, $\theta = 0$, $\Psi = 0$

$t \geq 0$: $u=1$, $\theta = 1+\varepsilon e^{i\omega t}$, $\Psi = 1+\varepsilon e^{i\omega t}$, at $y=0$

$u=0$, $\theta = 0$, $\Psi=0$ as $y \to \infty$

SOLUTION OF THE PROBLEM:

Equations 14 – 16 are joined non-linear partial differential equations which are in the closed-form whose solutions are difficult to obtained. To obtain the solution of the equations, we are converting the non-linear partial differential equations into ordinary differential equations. The expressions for velocity, temperature and concentration are considered as follows, for the reason that the unsteady flow is placed on the mean steady flow in the neighbourhood of the plate .

$$u(y,t) = u_0 + \varepsilon u_1 e^{i\omega t} \tag{17}$$

$$\theta(y,t) = \theta_0 + \varepsilon \theta_1 e^{i\omega t} \tag{18}$$

$$\Psi(y,t) = \Psi_0 + \varepsilon \Psi_1 e^{i\omega t} \tag{19}$$

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where $\varepsilon \ll 1$ is a parameter.

Equation (14) – (16) are reduced to

$$Du_0'' + ASu_0' - MU_0 = -BGr\theta_0 \tag{20}$$

$$DU_1'' + ASu_1' - (M + Ai\omega)u_1 = -BGr\theta_1 \tag{21}$$

$$E\theta_0'' + PrCS\theta_0' - Q\theta_0 = -Du\Psi_0'' - PrCQ_L\Psi_0 \tag{22}$$

$$E\theta_1'' + PrCS\theta_1' - (Q+PrCi\omega)\theta_1 = -Du\Psi_1'' - PrCQ_L\Psi_1 \tag{23}$$

$$\Psi_0'' + SSc\Psi_0' - KrSc\Psi_0 = 0 \tag{24}$$

$$\Psi_1'' + SSc\Psi_1' - (i\omega + Kr)Sc\Psi_1 = 0 \tag{25}$$

The boundary conditions are

$$u_0 = 1, \quad u_1 = 0, \ \theta_0 = 1, \theta_1 = 1, \Psi_0 = 1, \Psi_1 = 1 \ at \ y = 0.$$

$$u_0 = 0, \quad u_1 = 0, \ \theta_0 = 0, \theta_1 = 0, \Psi_0 = 0, \Psi_1 = 0 \ at \ y = \infty.$$

Equations (20) –(25) were solved and the solution for fluid velocity, temperature and the concentration was given by:

$$u(y,t) = (B_5e^{-m_5y} + B_3e^{-m_3y} + B_4e^{-m_1y}) + \varepsilon(B_8e^{-m_6y} + B_6e^{-m_4y} + B_7e^{-m_2y})e^{i\omega t} \tag{26}$$

$$\theta(y,t) = (B_1e^{-m_3y} + A_1e^{-m_1y}) + \varepsilon(B_2e^{-m_4y} + A_2e^{-m_2y})e^{i\omega t} \tag{27}$$

$$\Psi(y,t) = (e^{-m_1y}) + \varepsilon(e^{-m_2y})e^{i\omega t} \tag{28}$$

Shearing stress

The dimensional form of the shearing stress at the plate is given by

$$\tau = \left(\frac{\partial u}{\partial t}\right) \ at \ y = 0$$

$$= (-B_5m_5 - B_3m_3 - B_4m_1) + \varepsilon(B_8m_6 - B_6m_4 - B_7m_2)e^{i\omega t} \tag{29}$$

Heat Transfer Coefficient

The non-dimensional heat transfer coefficient in terms of Nusselt number is given by

$$Nu = -\left(\frac{\partial \theta}{\partial t}\right) at \ y = 0.$$

$$= (B_1m_3 + A_1m_1) + \varepsilon(B_2m_4 + A_2m_2)e^{i\omega t} \tag{30}$$

Sherwood Number

The non-dimensional mass transfer coefficient in terms of Sherwood number is given by

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$$Sh = -\left(\frac{\partial \Psi}{\partial t}\right) \ at \ y = 0.$$

$$= m_1 + \varepsilon m_2 e^{i\omega t} \qquad (31)$$

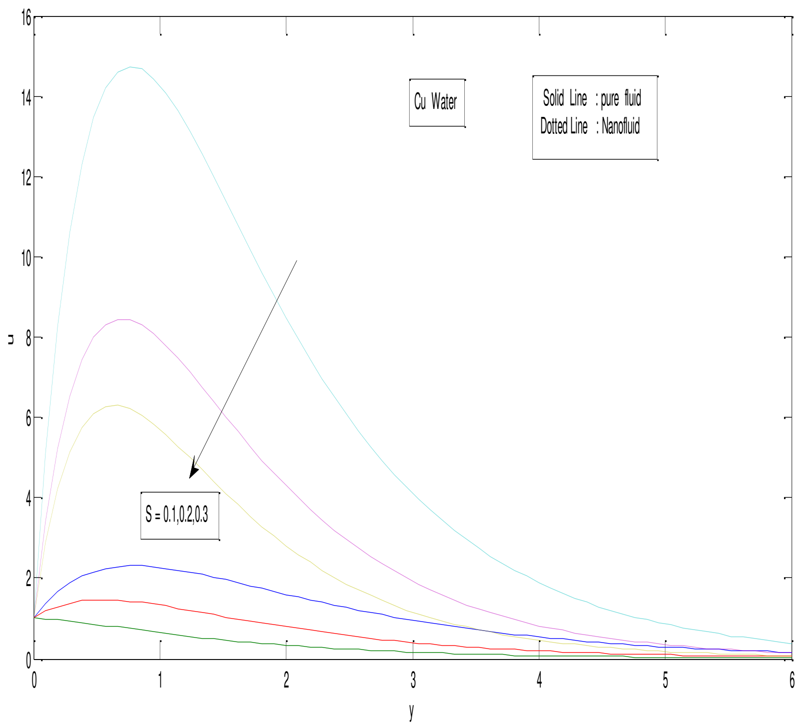

Figure 1.Velocity profile for Suction Parameter S

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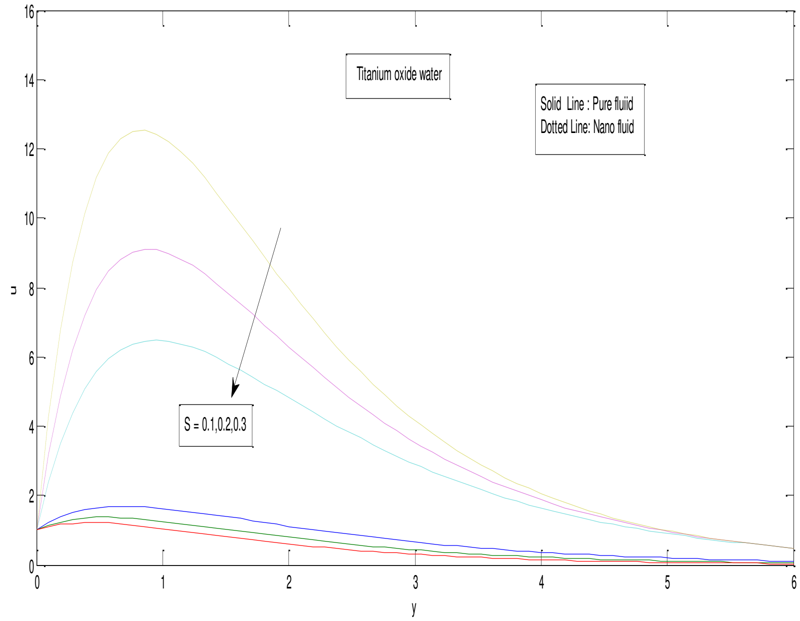

Figure 2 .Velocity Profile For Suction Parameter S

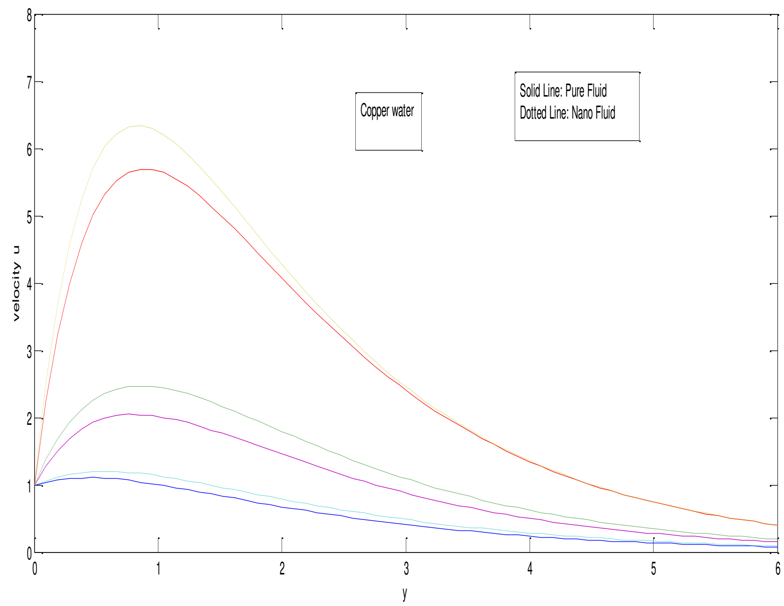

Figure 3. Velocity Profile For Radiation absorption parameter Q_L = 1,2,3.

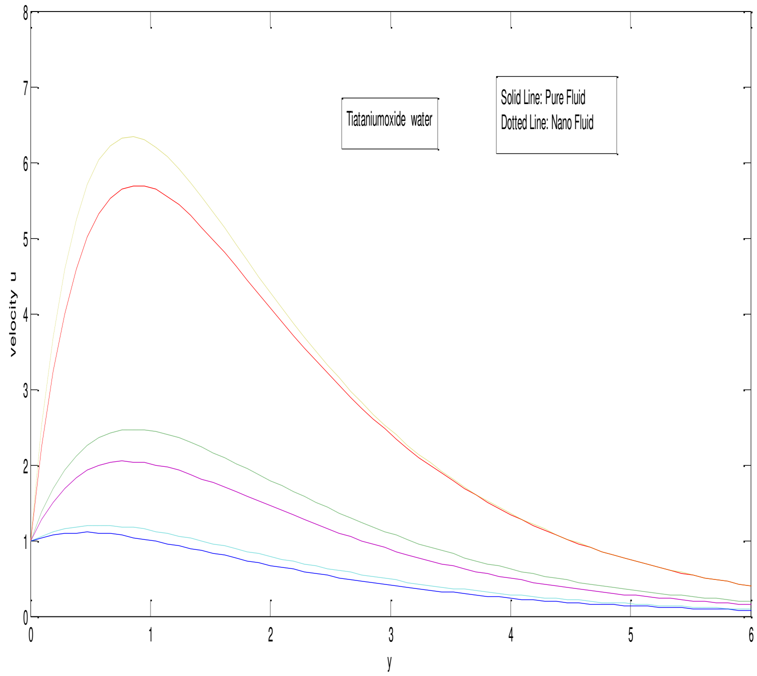

Figure 4. Velocity Profile For Radiation absorption parameter Q_L = 1,2,3.

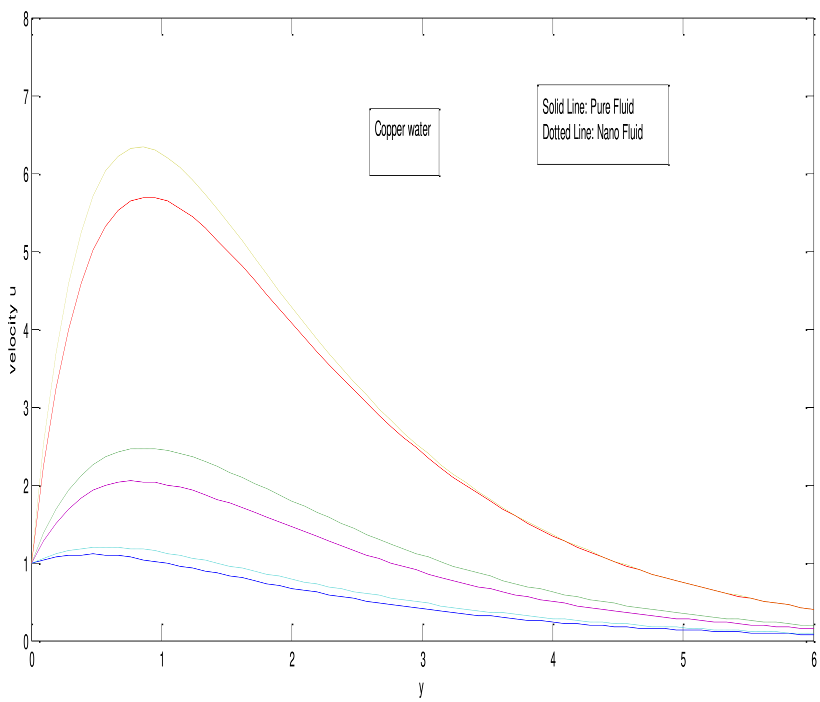

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Figure 5. Velocity Profile For Magnetic field parameter M= 0.2, 0.4, 0.6

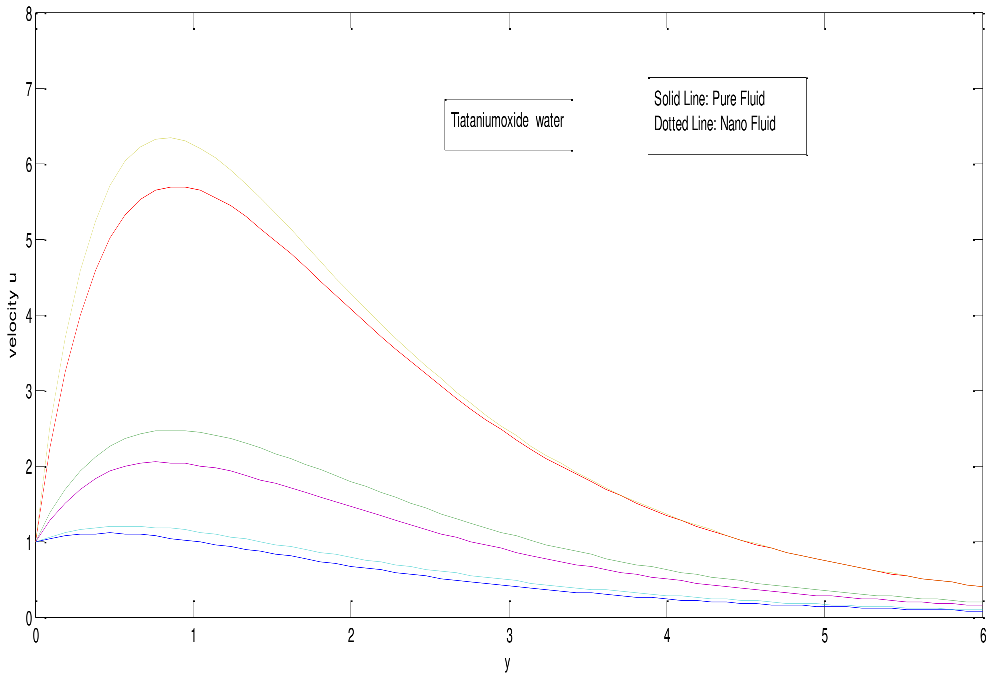

Figure 6. Velocity Profile For Magnetic field parameter M= 0.2, 0.4, 0.6

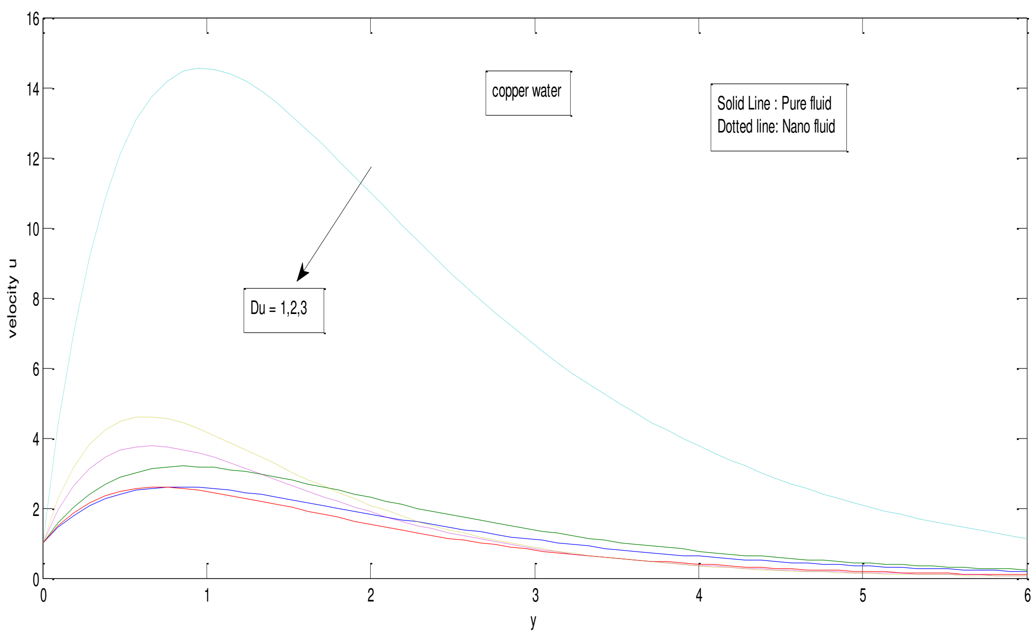

Figure 7: Velocity profiles For Dufour Number

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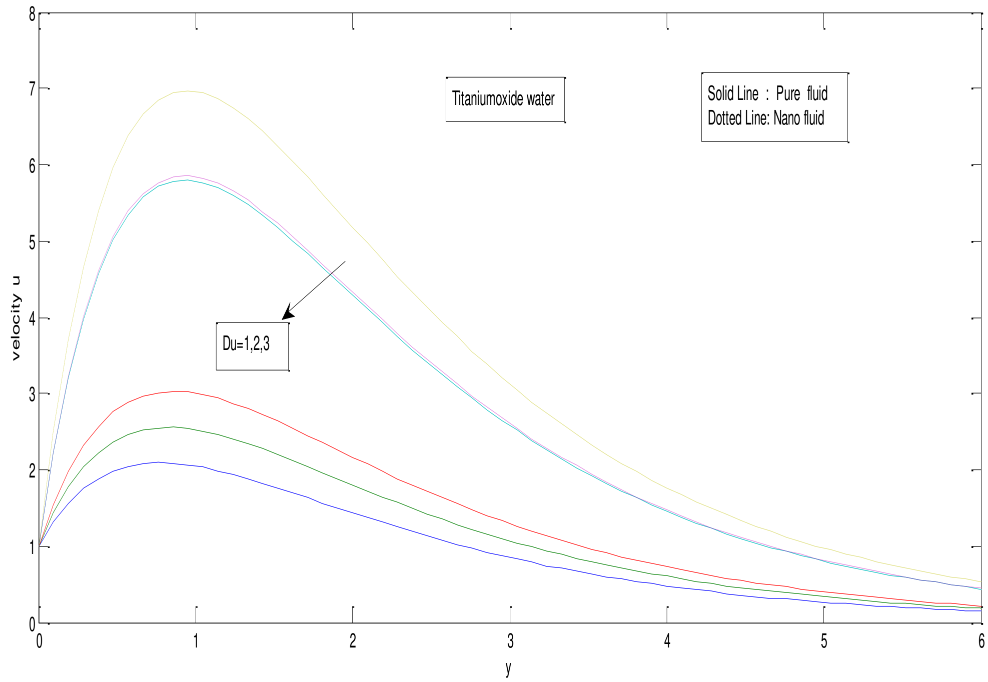

Figure 8: Velocity profiles For Dufour Number

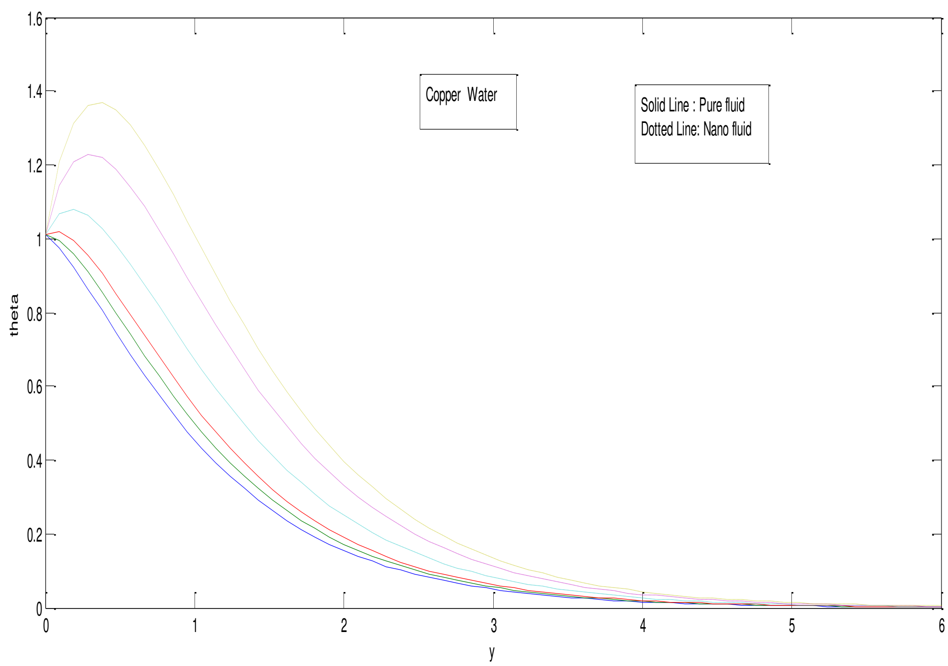

Figure 9: Temperature profiles for Radiation absorption Parameter Q_L = 1,2,3.

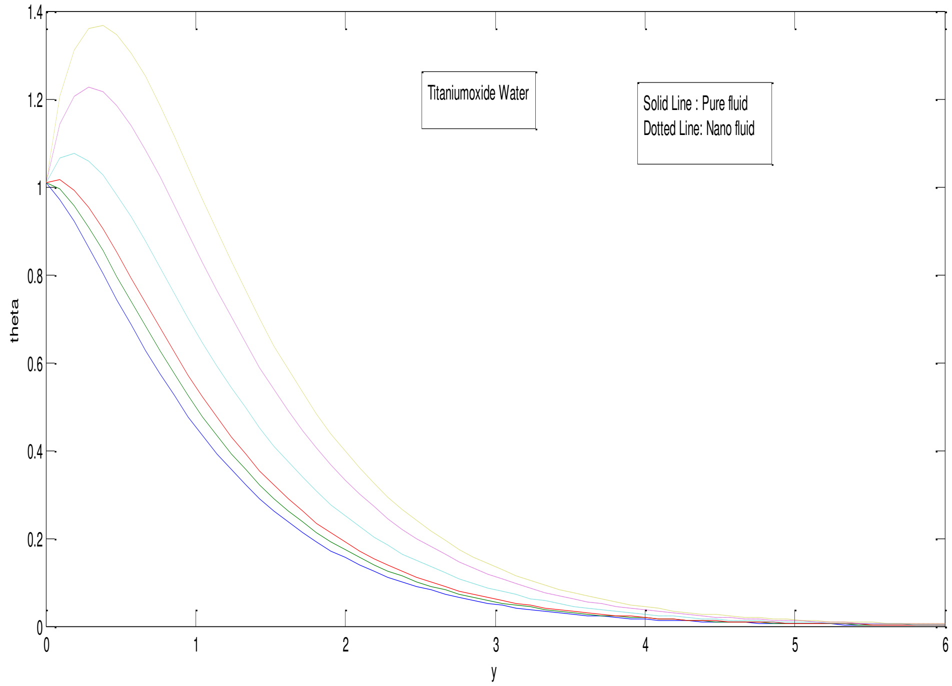

Figure 10: Temperature profiles for Radiation absorption Parameter Q_L = 1,2,3.

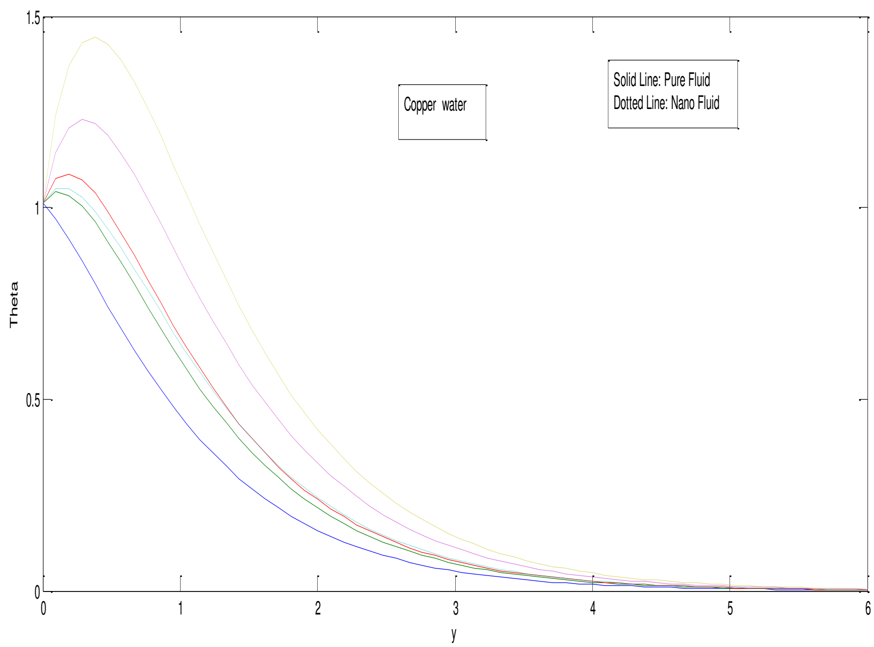

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Figure 11. Temperature profile for Dufour number Du = 1,2,3.

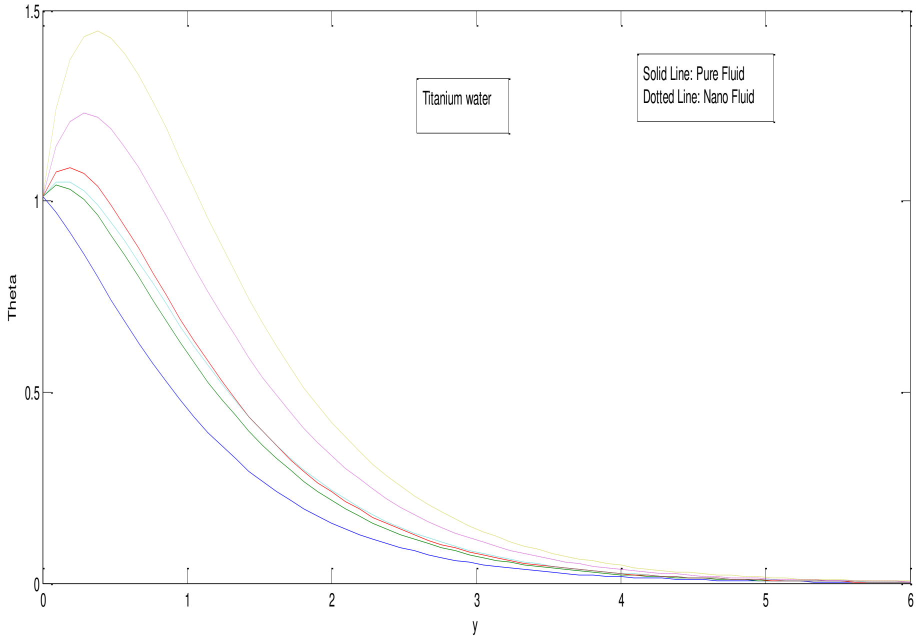

Figure 12. Temperature Profile for Dufour number Du = 1,2,3.

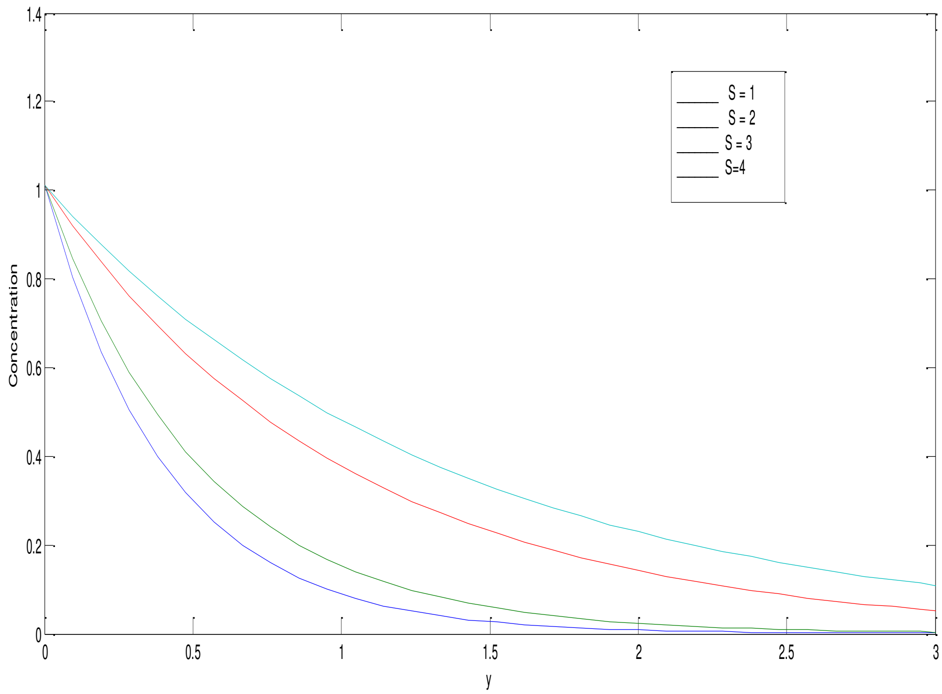

Figure 13. Concentration Profiles For Suction Parameter S.

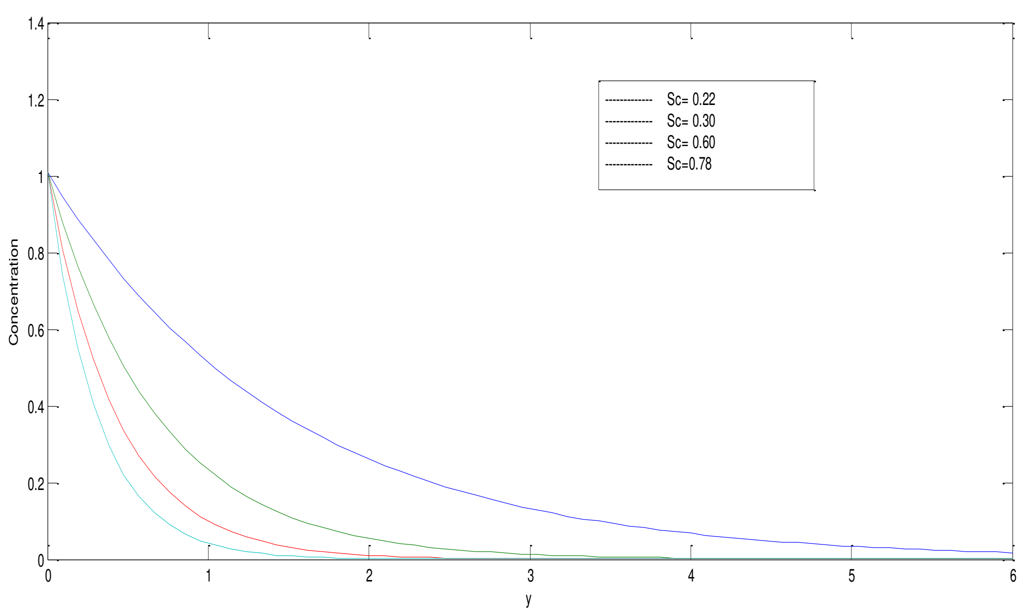

Figure 14. Concentration Profiles for Schmidt number Sc

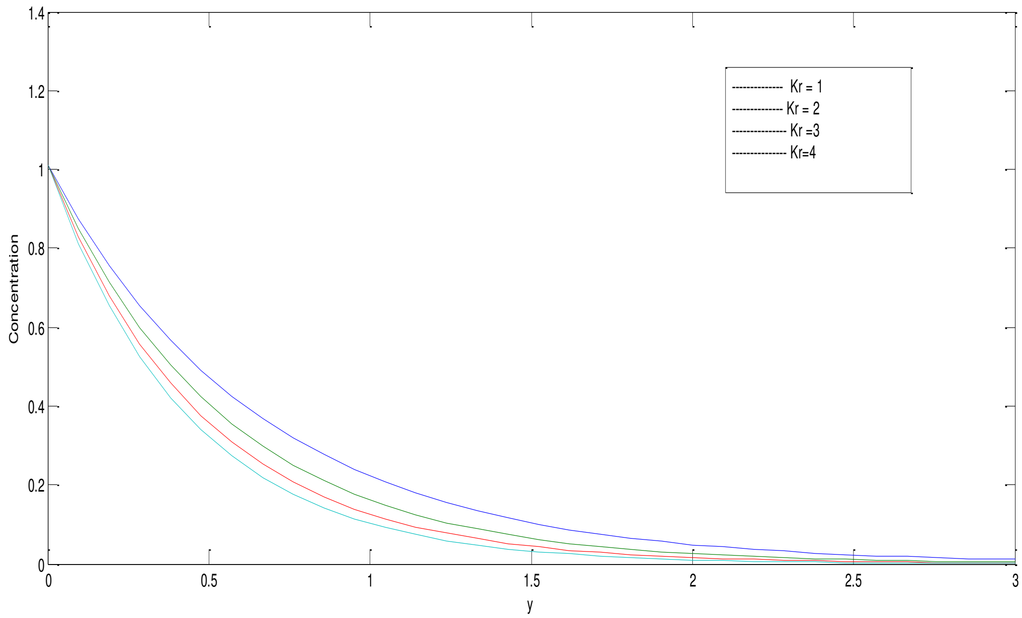

Figure 15: Concentration Profile for Suction Parameter S

RESULT AND DISCUSSION

The study of unsteady natural convective Magnetro hydrodynamics flow of a past over a vertical permeable semi-infinite moving plate without with heat and mass transfer was investigated in the presence of thermal diffusion, chemical reaction and radiation absorption. The temperature, velocity and the concentrations equations are solved analytically .The shearing stress coefficient, heat transfer coefficient and the mass transfer coefficient were also found. From the available analytical solutions the numerical values for the distributions of velocity, temperature, concentration, skin friction coefficient, Nusselt number and Sherwood number are calculated by considering different values of the non-dimension parameters involved in the problem.

In order to get physical insight into the problem, we have carried out numerical calculations for dimensionless variables for velocity field, temperature field, spices concentration field, shearing stress, heat and mass transfer coefficient at the nanoparticles by assigning some specific values to the parameters entering into the problem and the effects of these values are confirmed graphically. In this study, the values of the parameter , t, ω and Pr are taken fixed at 0.02, 1, 1, 0.71 respectively and the other parameters are chosen arbitrarily.

Velocity profiles:

The velocity profiles were represented in Figures 1 to 8.Figure 1 and 2 represents the effect of Suction parameter (S) on the velocity at an point in the fluid whereas Schmidt Number Sc, Chemical reaction parameter Kr, Heat source Q,Dufour number Du, Permeability Parameter K, Magnetic Parameter M, Q_L radiation absorption parameter, Grashof number Gr were taken as constant. From these figures, it was observed that velocity of the fluid across the boundary layer decreases with an increase in the suction parameter S for both regular fluid and nanofluid with cu and Tio_2 nanoparticles

Figure 3 and 4 illustrates the effect of Radiation absorption parameter Q_L on velocity at any point in the fluid. From these graphs we arrived that the velocity profile increases with an increase in the radiation absorption parameter Q_L for both the regular fluid and nanofluid containing Cu and Tio_2 nanoparticles. Figure 5 and 6 exhibits the effect of magnetic field parameter M. It was observed that the velocity profile decreases with an increases in the strength of the magnetic field for both the base fluid and the nanofluid with Cu and Tio_2 nanoparticles.

Figure 7 and 8 demonstrates the effect of Dufour number Du. It indicates that the velocity profile increases with an increase in Dufour number for both the base fluid and the nanofluid with Cu and Tio_2nanoparticles.It results in the boundary layer thickness.

Temperature profiles:

Figure 9 and 10 represent the effect of the Radiation absorption parameter Q_L on temperature at any point in the fluid. From these graphs we arrived that the temperature increases with an increase in the radiation absorption parameter Q_L for both the regular fluid and nanofluid containing Cu and Tio_2 nanoparticles. It results in thermal boundary layer thickness. The nanofluid containing Cu –nanoparticles have thicker thermal boundary layer than the TiO_2 – nanoparticles. Figure 11 and 12 depicts the effect of Dufour number Du. It indicates that the increasing values of Dufour number, the temperature was found to increase for both the base fluid and the nanofluid with Cu and Tio_2 nanoparticles. It results in the boundary layer thickness.

concentration profiles:

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Figure 13 exhibit the effect of the Suction parameter S in the concentration profile. It shows that the concentration decreases with increasing the value of suction parameter(S). Figure 14 exhibit the effect of the Schmidt number Sc in the concentration profile. It shows that the concentration decreases with increasing the value of suction parameter(S). Figure 15 exhibit the effect of the Chemical reaction parameter Kr in the concentration profile. It shows that the increase in the value of chemical reaction parameter(Kr) will decrease the concentration for both the base fluid and the nanofluid with Cu and Tio_2 nanoparticles.

CONCLUSION

We have assumed the two dimensional unsteady natural convective flow of a incompressible nanofluid past over a vertical permeable semi-infinite moving plate with constant heat source. The governing equations are solved analytically by using simple perturbation technique. The effects of different fluid flow parameter on velocity, temperature, the species concentration, rate of heat and mass transfer coefficient and the skin friction coefficient are derived and discussed through graphs.

- The fluid velocity increases with an increasing value of Radiation absorption Q_L and the Dufour number Du and decreases with an increasing value of Suction (S) and magnetic field M for both the nanoparticles Cu and Tio_2.
- The temperature of the fluid increases with an increasing value of Dufour number Du and the radiation absorption Q_L for both the nanofluid containing Cu and Tio_2 containing nanoparticles. It results in the thermal boundary layer thickness.
- The species concentration decreases with an increasing value of Chemical Reaction Kr, Suction Parameter S and the Schmidt number Sc.

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