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Magneto hydro dynamics analysis of convection flow between two parallel plates inclined at an angle with constant heat flux

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Abstract: ***The study of magneto hydrodynamics (MHD) free convection flow between two parallel semi-infinite plates inclined at an angle, incompressible fluid is considered. The effects of magnetic field parameter*** M^2***, plate angle of inclination*** γ***, Schmidt number*** Sc ***and Prandtl number*** $\Pr$ ***on velocity profiles and temperature distribution of the fluid at constant heat flux is determined. The momentum, energy and species concentration equations governing the flows are solved using finite difference method. The resulting set of algebraic equations is solved using Matlab in computer programme. The results are presented in tabular and graphical form to show the effects of the various parameters arising in the flow. The results showed that a rise in plate angle of inclination lead to increase in velocity profiles while a decrease was realized with increase magnetic field parameter. Also, the results revealed that an increase in Prandtl number lead to an increase in temperature distribution and an increase in Schmidt number results to decrease in fluid concentration.***

INDEX TERMS: **magnetic field parameter, plate angle of inclination, Schmidt number and prandtl number, angle of inclination.**

INTRODUCTION

The study of MHD analysis of convection flow between two parallel plates inclined at an angle with constant heat flux is receiving considerable attention due to its useful applications in different branches of Science and Technology such as cosmical and geophysical science, fire engineering, combustion, modeling etc. The word Magneto Hydrodynamics (MHD) is derived from: Magneto –meaning magnetic field, Hydro-meaning liquid and Dynamics which means movement Therefore, Magneto Hydrodynamics refers to the study of flow of an electrically conducting fluid in the presence of magnetic field. As fluid flows, it comes into contact with the solid surface that are used to direct motion. Whenever the fluid come into contact with the boundaries interaction occurs that involve the transfer of momentum and kinetic energy between the fluid and the boundary as a consequence transport properties of the fluid namely, viscosity and thermal conductivity occurs. As a result, gradients of fluid velocity and temperature develop in a direction normal to the surface. Similarly, in a flow field, heat is transferred from one point to another. Convection is a mode of heat transfer in fluids. Besides, fluids do not flow in isolation, it involves solids and vacuum which causes conduction and Radiation respectively. Heat transfer can be categorized as either free or forced convection depending on how fluid motion is initiated. Despite of the classification the fluid motion may be, it enables heat transfer with the higher the velocity the faster the heat transfer. To yield the best rate of heat transfer, the fluid flow is turbulent and this condition can only be efficient in forced convection system. Natural convection is less fast than forced convection and therefore greater heat is transferred. In free convection, the flow is steady and heat transferred within this layer region is by conduction. Forced convection on the other hand creates convectional currents, this causes fluid particles to move to opposing walls within magnetic field. Electromagnetic forces act on the fluid particles thereby altering the geometry of the motion. The resulting current combine to produce a force that resist the fluid motion as well distorts the original magnetic field. In MHD devices design is desirable to design both turbulent flow and in-built magnetic field for efficiency. Many authors have done studies under MHD .The initiator of this project is Otieno *et al*,. [9] they studied the numerical Computation of Steady Buoyancy Driven MHD Heat and Mass Transfer Past An Inclined Infinite Flat Plate with Sinusoidal Surface Boundary conditions .He discovered that the flow field is influenced by certain parameters .In particular they studied velocity profile and fluid concentration on thermal and solutal Grash of numbers and Schmidt numbers .The aim of this project is to investigate the flow of a viscous incompressible electrically conducting fluid between two parallel semi-infinite plate inclined at angle with constant heat flux. For a wide range of application, Magneto Hydrodynamics analysis of free convection has been studied adversely. It was first detected by Michael Faraday in 1931. He performed experiments with mercury as conducting fluid flowing in a glass tube placed in a magnetic field and observed that voltage was induced in the direction perpendicular to

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magnetic field. The results showed that when an electric field is applied to a direction of conducting fluid in the direction perpendicular to a magnetic field, force is exerted on the fluid to both electric and magnetic field. Since then, a lot has been done on MHD and its related fields. Sheikholeslami *et al*,. [11] studied influence of induced magnetic field on free convection of Al_2O_3-water nanofluid on permeable plate by means of Koo-Kleinstreuer-Li (KKL) model. The resulting equations were solved using Runge-Kutta integration method. Results obtained indicate that the velocity profile reduces with rise of the suction parameter, magnetic field, Prandtl number and Hartmann numbers but it increases with addition of Nanoparticles. Shear stress enhances rise of suction parameter, magnetic, Prandtl and Hartmann numbers. Alfuzzams *et al*, [2] investigated combined heat and mass of viscous fluid a long a semi –infinite plate with large suction. They discussed dimensionless similarity equations for momentum, energy and concentration equations which were solved analytically by perturbation technique. Findings were; velocity profile increases with increase of suction parameter while the velocity profile decreases with increase of Grashof number, the temperature increases with the increase of suction parameter while temperature decrease with the increase of Prandtl number and concentration decrease with the increase of Grashof number and Schmidt number. Rajput *et al*,. [10] studied convection of unsteady hydro magnetic couette flow through a vertical channel in the presence of thermal radiation .The effects of different parameters like magnetic parameter, Prandtl number, radiation parameter, thermal Grashof number accelerating parameter and time on the temperature velocity skin – friction and Nusselt were discussed. The results revealed that an increase in Prandtl number leads to a fall in temperature distribution because thermal is actually overcome by momentum diffusivity. Baoku *et al* [3] investigated the problem of hydro magnetic couette flow of a high viscous fluid through a porous channel in the presence of an applied uniform transverse magnetic field and thermal radiation. Effects of permeability parameter for the cases of low, moderate and high permeability on the numerical solutions were obtained for different magnetic parameters and Nahme number. Temperature Nahme and magnetic field parameters to reveal the coupled effects of thermal radiation and magnetic field were shown. They concluded that an increase in thermal radiation of fluid results to decrease in thermal radiation of fluid results to decrease in temperature profiles of the hydro magnetic couette fluid, the permeability of the porous medium and thermal radiation have insignificant effects on the steady hydro magnetic couette fluid flow and that an increase in magnetic field leads to an increase in the velocity profiles. Sing and Okwoyo [13] performed a study on steady laminar flow of viscous incompressible fluid between two parallel infinite plates when upper plate is held stationery under the influence of transverse magnetic field. The results showed that kinetic energy is higher near the upper plate in relation to thermal energy difference across the boundary layer. Findings were increase in Eckert number result to increase in temperature distribution. Sigey *et al* [12] carried out a study of magnetic hydrodynamic free convective flow past an infinite vertical porous plate in an incompressible electrically conducting fluid. The investigation of the effect of viscous dissipation on the velocity profiles and temperature distribution of the fluid in the presence of a transverse magnetic field subject to a constant sunction velocity was conducted. The results of the study showed that an increase in the viscous dissipation increase in velocity profiles and temperature distribution of the fluid. Amenya *et al* [1] carried study of magnetic hydrodynamic free convective flow past an infinite vertical porous plate in an incompressible electrically conducting fluid was considered. The results of the study showed that an increase in the Grashof number causes an increase in the velocity profiles, and increase in Hartman number causes a decrease of velocity profile whereas an increase of Prandtl number causes a decrease in temperature distribution. Manyonge *et al* [6] examined on the Steady MHD Poiseuille Flow Between two Infinite Parallel Plates in an Inclined Magnetic Field where the governing equations were solved analytically and expressions for the fluid velocity obtained expressed in terms of Hartmann number. The results of the study showed that high magnetic field strength decreases the velocity profile. In view of the foregoing literature presented above, it can be inferred that the problem of MHD analysis of convection flow between two parallel plates inclined at an angle with constant heat flux has received little attention particularly in determining the effects of varying plate angle of inclination, magnetic field parameter, Prandtl number and Schmidt number on the fluid flow. However, there exists a gap for further investigation of these parameters on the velocity profile, temperature distribution and fluid concentration.

II.MATHEMATICAL ANALYSIS

Let us consider a steady two-dimensional laminar flow of a viscous, incompressible, electrically conducting fluid moving past a fixed inclined semi-infinite plate surface. The motion is in the presence of a uniform magnetic field of intensity B_o applied normal to the plate surface. Assume the x- axis of a Cartesian coordinate system (x, y) is directed along the plate and the y- axis is perpendicular to the plate surface. The origin of the

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coordinate system is taken to be the leading edge of the plate. The acceleration due to gravity (g) is taken to be acting vertically downwards. The plate surface is inclined to the vertical direction by an angle. The physical model and geometrical co-ordinate system are as shown below.

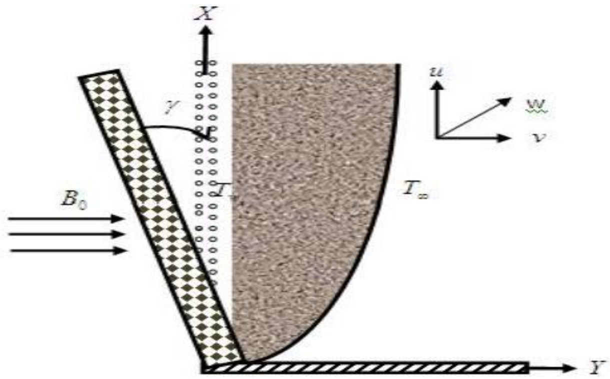

Fig 1: Physical configuration and co-ordinate system

We assume that the fluid property variations due to temperature and chemical species concentration are limited to fluid density. In addition, there is no applied electric field and all of the Hall effects and Joule heating are neglected. Since the magnetic Reynolds number is very small for most fluids used in industrial applications, we assume that the induced magnetic field is negligible, Singh [13]. Further, we shall neglect the Soret and Dufour effects as in Begum [4] since we assume that the fluid under consideration has very small concentration of diffusing species in comparison to other chemical species and the concentration of species far from the plate wall, i.e. C_∞-is infinitesimally small. Let u and v be the velocity components in the x and y ax directions respectively. Under the Finite Difference Approximation within the boundary layer, the steady, laminar, two-dimensional boundary layer flow under consideration is governed by the equations of momentum, energy and species concentration respectively as follows; Otieno *et al* [9]:

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\frac{\partial^2 u}{\partial y^2}+g\beta(T-T_\infty)\cos\gamma+g\beta^*(C-C_\infty)\cos\gamma-\frac{\sigma_c B_o^2}{\rho}u \tag{1}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}+\Pr\left(\frac{\partial u}{\partial y}\right)^2 \tag{2}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=Sc\frac{\partial^2 C}{\partial y^2} \tag{3}$$

If we take

$$Gr=g\beta \quad , Gc=g\beta^* \quad , T-T_\infty=\theta \quad ,C-C_\infty=C$$

$$M^2=\frac{\sigma\beta_o^2}{\rho} \quad ,\Pr=\frac{\rho C_p}{\kappa} \quad ,Sc=\frac{\upsilon}{D_m}$$

We get the following equations

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\frac{\partial^2 u}{\partial y^2}+[Gr\theta+GcC]\cos\gamma-M^2u \tag{4}$$

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$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{\rho C_P}{\kappa}\frac{\partial^2 T}{\partial y^2} \quad (5)$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=\frac{\upsilon}{D_m}\frac{\partial^2 C}{\partial y^2} \quad (6)$$

With the following boundary conditions

$$u=0,T=T_\infty,C=C_\infty \text{ for all } y=0;t\le 0 \text{ where } t=time$$

$$u=0,T=T_w\in(T-T_\infty)\cos\gamma,C=C_\infty \text{ at } y=0;\ t>0$$

$$u\to 0,T\to T_\infty,C\to C_\infty \text{ as } y\to\infty;\quad \text{at} \quad t>0$$

III. METHODS OF SOLUTION

The problem under investigation generates partial differential equations whose solution is determined using Finite Difference Method. The resulting linear equations is solved by the central difference approximations which involves selecting a uniform mesh that consist of network of rectangles of width Δx and Δy .

Governing Equations

The viscous incompressible flow, velocity profiles, temperature distribution and concentration between two parallel infinite plates are described by the momentum, concentration and energy equations. Systems of Navier-Stokes and energy partial differential equations with appropriate boundary conditions governing our problem are solved using a Finite Difference Method.

Discretization of Momentum Equation

We consider momentum equation. We investigate both the vertical velocities of the fluid in the vertical parallel plates. For the Central Difference Scheme (CDS), the values u_x, u_y and u_{yy} are replaced by central difference approximation. When these values are substituted into

Equation (3.2.1), we get

$$\left[\frac{U_{i+1,j}-U_{i-1,j}}{2\Delta x}+V\frac{U_{i,j+1}-U_{i,j-1}}{2\Delta y}\right]=V\frac{U_{i,j+1}-2U_{i,j}+U_{i,j-1}}{(\Delta y)^2}+\left[Gr\left(\frac{\theta_{i,j+1}-\theta_{i,j}}{2}\right)+Gc\left(\frac{C_{i,j+1}-C_{i,j}}{2}\right)\right]\cos\gamma-M^2\left[\frac{U_{i,j+1}-U_{i,j}}{2}\right] \quad (7)$$

We investigate the effect of angle of inclination γ on the fluid velocity profile. Taking $\Delta x=0.25$ and $\Delta y=0.01$, Gr = Gc = 10, M^2 = 0.5 and V = 1, $\gamma=0^o$ and initial and boundary conditions $U_{i,o}=\theta_{i,0}=1$ and $U_{0,j+1}=1,\ \theta_{0,j+1}=10^o c, C_{0,j+1}=0$ respectively. We get the scheme

$$-0.58U_{i-1,j+1}-0.43U_{i-1,j}-0.2U_{i-1,j-1}=100 \quad \textbf{(8)}$$

Taking j = 1,2,3…….6 and i = 1 we form the following systems of linear algebraic equations.

$$\left.\begin{aligned}
-0.58U_{0,2}-0.43U_{0,1}-0.2U_{0,0}&=100\\
-0.58U_{0,3}-0.43U_{0,2}-0.2U_{0,1}&=100\\
-0.58U_{0,4}-0.43U_{0,3}-0.2U_{0,2}&=100\\
-0.58U_{0,5}-0.43U_{0,4}-0.2U_{0,3}&=100\\
-0.58U_{0,6}-0.43U_{0,5}-0.2U_{0,4}&=100\\
-0.58U_{0,7}-0.43U_{0,6}-0.2U_{0,5}&=100
\end{aligned}\right\} \quad (9)$$

The above algebraic equations can be written in matrix form as

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$$\begin{bmatrix} -0.43 & -0.58 & 0 & 0 & 0 & 0 \\ -0.2 & -0.43 & -0.58 & 0 & 0 & 0 \\ 0 & -0.2 & -0.43 & -0.58 & 0 & 0 \\ 0 & 0 & -0.2 & -0.43 & -0.58 & 0 \\ 0 & 0 & 0 & -0.2 & -0.43 & -0.58 \\ 0 & 0 & 0 & 0 & -0.2 & -0.43 \end{bmatrix} \begin{bmatrix} U_{0,1} \\ U_{0,2} \\ U_{0,3} \\ U_{0,4} \\ U_{0,5} \\ U_{0,6} \end{bmatrix} = \begin{bmatrix} 100 \\ 100 \\ 100 \\ 100 \\ 100 \\ 100 \end{bmatrix} \tag{10}$$

If γ is varied to 30^o,40^o and 60^o and Solving the above matrix equation (10), we get the solutions;

$\gamma = 0^o$	$\gamma = 30^o$	$\gamma = 40^o$	$\gamma = 60^o$
$U_{0,1} = -861.2114$	$U_{0,1} = -740.6418$	$U_{0,1} = -602.848$	$U_{0,1} = -430.6057$
$U_{0,2} = -466.0705$	$U_{0,2} = -400.8206$	$U_{0,2} = -326.2494$	$U_{0,2} = -233.0353$
$U_{0,3} = -470.0907$	$U_{0,3} = -404.278$	$U_{0,3} = -329.0635$	$U_{0,3} = -235.0453$
$U_{0,4} = -336.8157$	$U_{0,4} = -289.6615$	$U_{0,4} = -235.771$	$U_{0,4} = -168.4079$
$U_{0,5} = -239.3947$	$U_{0,5} = -205.8794$	$U_{0,5} = -167.5762$	$U_{0,5} = -119.6973$
$U_{0,6} = -121.2118$	$U_{0,6} = -104.2421$	$U_{0,6} = -84.84825$	$U_{0,6} = -60.6059$

If M^2 is varied to 0.7, 0.9 and 1.0 and solving the above matrix equation (7), we get the solutions.

$M^2 = 0.5$	$M^2 = 0.7$	$M^2 = 0.9$	$M^2 = 1.0$
$U_{0,1} = -430.6057$	$U_{0,1} = -689.0885$	$U_{0,1} = -1199.141$	$U_{0,1} = -1619.258$
$U_{0,2} = -233.0353$	$U_{0,2} = -305.8507$	$U_{0,2} = -389.3144$	$U_{0,2} = -516.3218$
$U_{0,3} = -235.0453$	$U_{0,3} = -325.434$	$U_{0,3} = -481.6731$	$U_{0,3} = -601.3617$
$U_{0,4} = -168.4079$	$U_{0,4} = -204.423$	$U_{0,4} = -339.0477$	$U_{0,4} = -443.9819$
$U_{0,5} = -119.6973$	$U_{0,5} = -142.3214$	$U_{0,5} = -214.6821$	$U_{0,5} = -396.8777$
$U_{0,6} = -60.6059$	$U_{0,6} = -65.25977$	$U_{0,6} = -65.49384$	$U_{0,6} = -59.02476$

Discretization of Energy Equation

$$\frac{T_{i+1,j} - T_{i,j}}{\Delta x} + v\frac{T_{i,j+1} - T_{i,j}}{\Delta y} = \Pr\frac{U_{i,j+1} - 2U_{i,j} + U_{i,j-1}}{(\Delta y)^2} \tag{11}$$

We investigate the effect of Prandtl number on the fluid temperature. Taking $\Delta x = \Delta y = 0.25$ and multiplying the equation by $(\Delta y)^2$ .we get the scheme

$$0.125T_{i,j+1} - 0.125T_{i,j-1} + 2T_{i,j} = -0.125T_{i,j-1} + 0.125T_{i-1,j} \tag{12}$$

Taking j = 1,2,3…….10 and i = 1. we form the following systems of linear algebraic equations

$$\left.\begin{aligned} 0.125T_{1,2} - 0.125T_{1,0} + 2T_{1,1} &= -0.125T_{2,0} + 0.125T_{0,1} \\ 0.125T_{1,3} - 0.125T_{1,1} + 2T_{1,2} &= -0.125T_{2,1} + 0.125T_{0,2} \\ 0.125T_{1,4} - 0.125T_{1,2} + 2T_{1,3} &= -0.125T_{2,2} + 0.125T_{0,3} \\ 0.125T_{1,5} - 0.125T_{1,3} + 2T_{1,4} &= -0.125T_{2,3} + 0.125T_{0,4} \\ 0.125T_{1,6} - 0.125T_{1,4} + 2T_{1,5} &= -0.125T_{2,4} + 0.125T_{0,5} \\ 0.125T_{1,7} - 0.125T_{1,5} + 2T_{1,6} &= -0.125T_{2,5} + 0.125T_{0,6} \end{aligned}\right\} \tag{13}$$

When initial and boundary conditions;

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$U_{i,0} = T_{i,0} = T_{i,j+1} = 0 \; U_{i,j+1} = T_{0,j+1} = 1 \; u = v$

The above algebraic equations are written in matrix form

$$\begin{bmatrix} 2 & 0.125 & 0 & 0 & 0 & 0 \\ -0.125 & 2 & 0.125 & 0 & 0 & 0 \\ 0 & -0.125 & 2 & 0.125 & 0 & 0 \\ 0 & 0 & -0.125 & 2 & 0.125 & 0 \\ 0 & 0 & 0 & -0.125 & 2 & 0.125 \\ 0 & 0 & 0 & 0 & -0.125 & 2 \end{bmatrix} \begin{bmatrix} T_{0,1} \\ T_{0,2} \\ T_{0,3} \\ T_{0,4} \\ T_{0,5} \\ T_{0,6} \end{bmatrix} = \begin{bmatrix} 0.125 \\ 0.125 \\ 0.125 \\ 0.125 \\ 0.125 \\ 0.125 \end{bmatrix} \quad (14)$$

If Pr is varied to 0.7, 1,0.9 and 1.7 .Then Solving the above matrix equation (14), we get the solutions;

$\Pr = 0.5$	$\Pr = 0.71$	$\Pr = 0.9$	$\Pr = 1.7$
$T_{0,1} = 0.058437$	$T_{0,1} = 0.08114$	$T_{0,1} = 0.1534929$	$T_{0,1} = 0.169013$
$T_{0,2} = 0.062314$	$T_{0,2} = 0.088306$	$T_{0,2} = 0.1813713$	$T_{0,2} = 0.2037583$
$T_{0,3} = 0.062432$	$T_{0,3} = 0.088933$	$T_{0,3} = 0.1861793$	$T_{0,3} = 0.2103385$
$T_{0,4} = 0.062514$	$T_{0,4} = 0.089056$	$T_{0,4} = 0.1884153$	$T_{0,4} = 0.2139299$
$T_{0,5} = 0.062312$	$T_{0,5} = 0.088306$	$T_{0,5} = 0.1812979$	$T_{0,5} = 0.2036096$
$T_{0,6} = 0.062432$	$T_{0,6} = 0.096859$	$T_{0,6} = 0.2214933$	$T_{0,6} = 0.255767$

Discretization of Concentration Equation

Discretizing the concentration, equation (3) becomes

$$Sc\frac{C_{i+1,j} - C_{i-1,j}}{2(\Delta x)} + Sc\frac{C_{i,j+1} - C_{i,j-1}}{2(\Delta y)} = \frac{C_{i,j+1} - 2C_{i,j} + C_{i,j-1}}{(\Delta y)^2} \quad (15)$$

We investigate the effect Sc number on the fluid concentration. Taking $\Delta x = \Delta y = 0.25$ we get the scheme

$$0.05C_{i+1,j} - 0.045C_{i-1,j} + 0.2C_{i,j} = 0.95T_{i,j+1} + 1.05C_{i,j-1} \quad (16)$$

Taking j = 1,2,3…….10 and i = 1,we form the following systems of linear algebraic equations;

$$\left.\begin{aligned} 0.05C_{2,1} - 0.045C_{0,1} + 2C_{1,1} &= 0.95T_{1,2} + 1.05C_{1,0} \\ 0.05C_{2,2} - 0.045C_{0,2} + 2C_{1,2} &= 0.95T_{1,3} + 1.05C_{1,1} \\ 0.05C_{2,3} - 0.045C_{0,3} + 2C_{1,3} &= 0.95T_{1,4} + 1.05C_{1,2} \\ 0.05C_{2,4} - 0.045C_{0,4} + 2C_{1,4} &= 0.95T_{1,5} + 1.05C_{1,3} \\ 0.05C_{2,5} - 0.045C_{0,5} + 2C_{1,5} &= 0.95T_{1,6} + 1.05C_{1,4} \\ 0.05C_{2,6} - 0.045C_{0,6} + 2C_{1,6} &= 0.95T_{1,7} + 1.05C_{1,5} \end{aligned}\right\}$$

(17)

When initial and boundary conditions;

$C_{i,0} = C_{i+1,j} = 0 \; C_{0,j} = 1$

The above algebraic equations are written in matrix form

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$$\begin{bmatrix} -2 & 0.95 & 0 & 0 & 0 & 0 \\ 1.05 & -2 & 0.95 & 0 & 0 & 0 \\ 0 & 1.05 & -2 & 0.95 & 0 & 0 \\ 0 & 0 & 1.05 & -2 & 0.95 & 0 \\ 0 & 0 & 0 & 1.05 & -2 & 0.95 \\ 0 & 0 & 0 & 0 & 1.05 & -2 \end{bmatrix} \begin{bmatrix} C_{0,1} \\ C_{0,2} \\ C_{0,3} \\ C_{0,4} \\ C_{0,5} \\ C_{0,6} \end{bmatrix} = \begin{bmatrix} 0.045 \\ 0.045 \\ 0.045 \\ 0.045 \\ 0.045 \\ 0.045 \end{bmatrix} \quad (18)$$

If Sc is varied from 0.22 to 0.7 and 1.4 and Solving the above matrix equation (18), we get the solutions;

$Sc = 0.22$	$Sc = 0.7$	$Sc = 1.4$
$C_{0,1} = 0.3522705$	$C_{0,1} = -0.6164569$	$C_{0,1} = -0.7278296$
$C_{0,2} = -0.3030345$	$C_{0,2} = -2.453751$	$C_{0,2} = -2.958626$
$C_{0,3} = -0.7355353$	$C_{0,3} = -3.688789$	$C_{0,3} = -4.672706$
$C_{0,4} = -0.9338051$	$C_{0,4} = -4.206479$	$C_{0,4} = -5.631800$
$C_{0,5} = -0.8858323$	$C_{0,5} = -3.867644$	$C_{0,5} = -5.505677$
$C_{0,6} = -0.578989$	$C_{0,6} = -2.503998$	$C_{0,6} = -3.838349$

V. RESULTS AND DISCUSSION

Effects of Plate Angle of Inclination on Fluid Velocity

Solving equation (1) the values fluid velocity with variations with plates height and angle of inclination are presented in the fig 3 below.

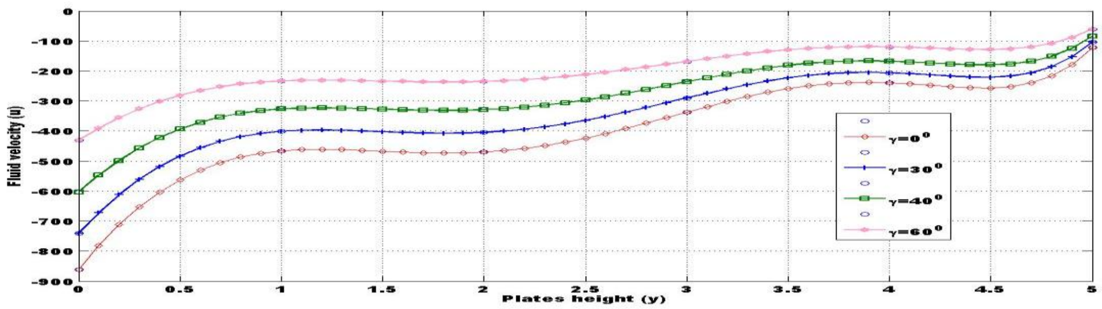

Fig 3: Fluid velocity against plate height at varying Plate Angle of inclination.

Fig 3 shows the effect of angle of inclination to the vertical direction on the velocity profiles. From this figure we observe that the velocity is increasing followed by decreasing then increasing as the angle of inclination rises. The fluid has higher velocity when the surface is vertical than when inclined because of the fact that the buoyancy effect increases due to gravity components (g), as the plate is inclined. The angle influences velocity distribution in the boundary layer more than at higher free stream velocities.

Effects of Magnetic Field Parameter on Fluid Velocity

Solving equation (1) the values of velocity profiles with varying magnetic field parameter and plate heights for M^2 = 0.5, 0.7,0.9 and 1.0 are presented in the fig 4 below.

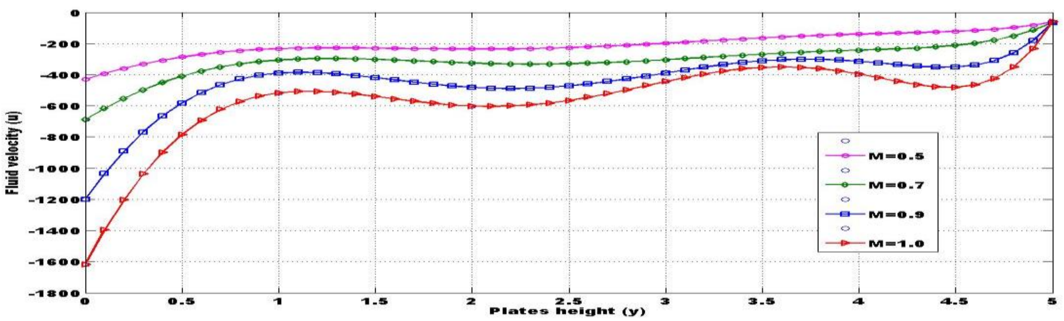

Fig 4: Fluid Velocity against Plate Height at Varying Magnetic Field Parameter.

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For various values of the Magnetic field parameter, the velocity profiles are plotted in Fig 4. Magnetic field parameter is the ratio of magnetic conduction to viscous force. Increase in magnetic field parameter reduces viscosity. From the figure it is seen that, increase in magnetic field parameter M^2, is observed to strongly decrease the velocity in the regime. Maximum velocity corresponds to $M^2 = 0$ i.e. electrically non conducting heat and mass transfer. Physically, it is true due to the fact that the application of a magnetic field to an electrically conducting fluid gives rise to a body force known as a Lorentz hydromagnetic drag which comes into play resulting from interaction of magnetic field with the conducting fluid. This force impedes the flow and decreases velocities i.e. decrease the hydrodynamic boundary layer thickness.

Effects of Prandtl Number on Temperature

Solving equation (2) the values for Pr = 0.5, 0.71 and 0.9are presented in the fig 5 below.

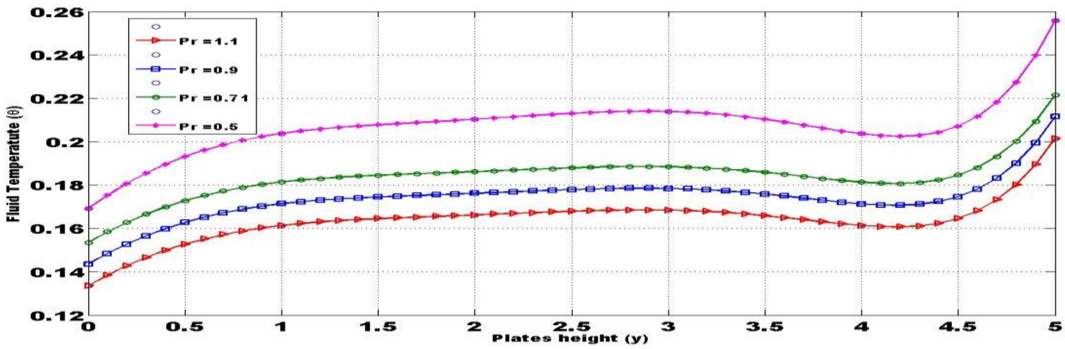

Fig 5: Fluid Temperature against Plate Height at Varying Prandtl Number Explanation

Fig 5 illustrates the temperature distribution for different values of the Prandtl number Pr. The Prandtl number defines the ratio of momentum diffusivity to thermal diffusivity. As depicted there is an increase, decrease then an increase of temperature distribution. This is due to more diffuse character of the temperature in the presence of a strong toroidal part of motion which leads to less transport at low values of Prandtl number. It is observed that an increase in the Prandtl number results in a decrease of the thermal boundary layer thickness and in general higher average temperature within the boundary layer. The reason is that smaller values of Prandtl is equivalent to increasing the thermal conductivities, and therefore fluid is able to diffuse away from the most heated plate region more rapidly than for lower values of Prandtl number.

Effects of Schmidt Number on Fluid Concentration

Solving equation (3) the values for Sc = 0.22, 0.7 and 1.4are presented in the fig 6 below.

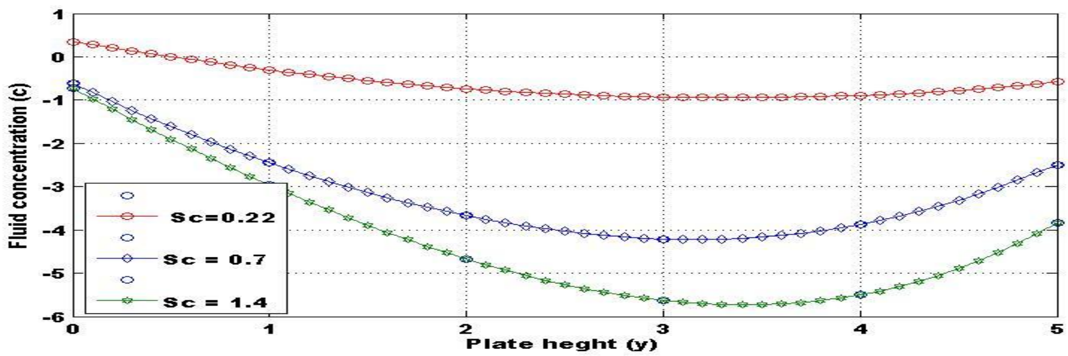

Fig 6: Fluid Concentration against parallel plate height at varying Schmidt Number

The influences of the Schmidt number Sc on concentration profiles are plotted in Fig 6. The Schmidt number defines the ratio of the momentum to the mass diffusivity. The Schmidt number therefore quantifies the relative effectiveness of momentum and mass transport by diffusion in the hydrodynamic (velocity) and concentration (species) boundary layers. As the Schmidt number increases the concentration decreases. This causes the concentration buoyancy effects to decrease yielding a reduction in the fluid velocity. The reductions in concentration profiles are accompanied by simultaneous reductions in the concentration boundary layers. It is worth to mention that for hydrogen (Sc = 0.22) the velocity profiles is much higher than that of other Sc.

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Discussions

From figure 3 as the plate height increases, also the fluid velocity increases i.e. when plate distance increases, there is gain in kinetic energy and this lead to an upward motion. The larger the distance the stronger the interaction between the fluid and the boundary. The interactions influences the motion of the fluid in the a manner such that the strongest influence occurs in the immediate neighborhood of the boundary .The influence diminishes rapidly with distance far from the boundary, the fluid behaves as though it had no viscosity and its motion can be described with the aid of Bernoulli equation. Similarly, the fluid flow rate increases as the angle of inclination increases. As seen in figure 4, this is brought about by variation in magnetic field parameter from the plate region downwards. Hence at the upper plate region the fluid lost energy became denser resulting in downward motion. Therefore, at larger magnetic field number the fluid velocity decreases. From figure 5 temperature increases at higher Prandtl number than low Pr number fluid flow is higher at high temperature than at low temperature since at high Prandtl number the momentum diffusivity is dominant. From figure 6 the fluid velocity profile and concentration is low at high Schmidt number since at low Schmidt number, the amount of mass transfer is dominant. Therefore, as the Schmidt number increases fluid concentration decreases. The results show that free convection affects velocity profiles and temperature distribution in the fluid flow.

V. CONCLUSION AND RECOMMENDANTIONS

The following were the compressive conclusions which were thoroughly worked in chapter 3 of this project under the use of the selected software programme basing on the specified objectives**.** First objective in our project was to investigate the effects of angle of inclination of the plate and magnetic field parameter on the velocity profiles .The results revealed that an increase in plate angle of inclination lead to increase in velocity profiles and increase in magnetic parameter lead to decrease. The second objective was to determine the effects of Prandtl number on temperature distribution .The findings were increase in Prandtl number gave rise to increase in temperature distribution. The third objective was to determine effects of Schmidt number on fluid concentration. It was found that increase in Schmidt number lead to decrease in fluid concentration.

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NOMENCLATURE

T	Temperature of a fluid (K)
T	Time in seconds (s)
μ	Coefficients $(Kg^{-1}m^{-1})$
g	Acceleration due to gravity (ms^{-2})
β	Coefficient of volume expansion
q	Velocity vector with components u ,v, w in the x ,y ,z directions respectively (ms^{-1})
MHD	Magneto hydrodynamics
$\boldsymbol{B_o}$	The magnetic field [wbm^{-2}]
Gr	Grashof number
g	Acceleration due to gravity (ms^{-2})
M^2	Magnetic Parameter
R	Radiation Parameter
H	Magnetic field intensity vector in Ampere per meter [Am^{-1}]
J	Current density [AM^{-2}]
P	Pressure force [Nm^{-2}]
σ	Electrical conductivity [Ω^{-1} m^{-1}]
θ	Dimensional Fluid Temperature (K)
γ	Kinematic Viscosity (m^2s^{-1})

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ρ	Fluid Density (Kg/m^3)
β	Coefficient of Thermal Expansion
PDE	Partial Differential Equation
IFDS	Implicit Finite Difference Scheme
ODE	Ordinary Differential Equation
FDM	Finite Difference Method

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