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Heat and Mass Transfer Effects on a Viscous Dissipative Fluid Flow Past a Vertical Plate in the Presence of Induced Magnetic Fluid

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Abstract: The present study examines the effects of induced magnetic field on dissipative fluid flow past a vertical plate in the presence of Joules dissipation, heat source/sink and first order destructive chemical reaction. The convection boundary condition on temperature is taken into account. The sets of transformed ordinary differential equations are solved analytically by using regular perturbation technique. The impact of various flow parameters on velocity, temperature, induced magnetic field and concentration fields are discussed through graphs. Also, the friction factor coefficients and the rate of heat transfer coefficients are derived and discussed through tables. It is to found convection parameter helps to improve the thickness of thermal boundary layer.

Keywords: Induced Magnetic field, viscous dissipation, Destructive Chemical reaction, Heat source/sink, Vertical plate.

Nomenclature			
C_p	Specific heat at constant pressure		Greek symbols
E_c	Eckert number	β	Coefficient of volume expansion due to temperature
g	acceleration due to gravity	μ_0	magnetic diffusivity
G_m	mass Grashof number	ϑ	Kinematic viscosity
Gr	thermal Grashof number	k	Thermal conductivity
H	induced magnetic field	ρ	Density
H_0	uniform magnetic field	σ	electrical conductivity
H_x	induced magnetic field along x-axis	θ	dimensionless fluid temperature
J	current density		
M	Hartmann number		
P_r	Prandtl number		
P_{rm}	Magnetic Prandtl number		
$\bar{T}$	Temperature		
$\bar{T}_W$	Fluid temperature at the surface		
$\bar{T}_\infty$	Fluid temperature in the free stream		
u	Velocity component in x-direction		
U_0	dimensionless free stream velocity		
ϑ_0	suction velocity		
Sc	Schmidt number		
Q	Heat absorption parameter		
D	Destructive Chemical reaction,		
Φ	non dimensional concentration.		

I. INTRODUCTION

The steady free convection of heat and mass transfer flow is of great importance in designing control systems for modern free convection heat exchangers. Also, the convection with MHD has been studied due to their application in metrology, astrophysics, geophysics, solar physics, aeronautics and electronics. Noticeable among them are [4–7]. The free convective hydrodynamic fluid flow over a stretching sheet under the influence of thermal radiation and buoyancy forces was studied by Rashidi et al. [1]. Umemura and Law [8] developed a generalized formulation for the natural convection boundary layer flow over a flat plate with arbitrary inclination. They found that the flow characteristics depend not only on the extent of inclination but also on the distance from the leading edge. Hossain et al. [9] studied the free convection flow from an isothermal plate inclined at a small angle to the horizontal. Anghel et al. [10] presented a numerical solution of free convection flow past an inclined surface. Chaudhary et al. [11] investigated the hydromagnetic and mass diffusion effects on free convection flow past an oscillating plate in a porous medium. Free convection MHD flow of an incompressible, viscous, absorbing fluid past an accelerated vertical plate with constant surface heat flux embedded in a porous medium was studied by Mohamed and Aishah [12]. Bejan and Khair [35] investigated the free convective boundary layer flow in a porous medium owing coupled to combined heat and mass transfer. The suction and blowing effects on free convective coupled heat and mass transfer over a vertical plate in a saturated porous medium were studied by Raptis et al. [36.]

The combined effects of viscous dissipation and joules heating occurs in natural convection in various devices. Such effects may also be present in stronger gravitational fields and in process wherein the scale of the process is very large, e.g., on larger planets, in large masses of gas in space, and in geological processes in fluids internal to various bodies. Venkateswarlu et al. [20] discussed the hydromagnetic free convection flow of a Casson fluid over a vertical porous plate in the presence of radiation absorption and viscous dissipation. The free convection boundary layer flow along a vertical wavy surface in the presence of joules heating and uniform magnetic field is explored by Parveen and Alim [23].The combined effects of viscous dissipation and joules heating on free convective heat and mass transfer flow over a vertical plate in the presence of H. In fluid mechanics, destruction of fluctuating velocity gradients due to viscous stresses is known as viscous dissipation. Makinde [32] reported an increase in the moving plate surface temperature and thermal layer thickness. Depending on the admissible grouping of variables, Eckert number and Brinkmann number may be used to quantify viscous dissipation. Raju and Sandeep [33] focused on the motion of Casson fluid over a moving wedge with slip and observed a decrement in the temperature field with rising values of Eckert number. Rajeswari et al. [34] observed that due to the uniform magnetic field and suction at the wall of the surface, the concentration of the fluid decreases with the increase in chemical reaction.

All current and thermal diffusion was analyzed by Ajay Kumar and Rama Subba Reddy [3]. The hydromagnetic flow of a viscous fluid over a vertical porous plate in the presence of Hall current, viscous dissipation, Joule heating, heat source, transpiration and thermal diffusion for large suction was analyzed by Ajay Kumar[17]. Alam and Sattar [18] have discussed a viscous flow with Hall current, viscous dissipation and Joule heating in rotating system. Singh [36] extended this study for infinite vertical porous plate. Singh [19] studied the hydromagnetic free and forced convection flow with Hall current effects under the influence of viscous dissipation with Joule heating. The combined effects of viscous dissipation and joules heating on free convective MHD flow over a permeable stretching surface with radiation is examined by Chien-Hsin Chen [22]. The viscous dissipation and joules heating effects on hydromagnetic flow past an inclined plate with variable wall temperature is investigated by Palani and Kim [24]. Recently, Prasanna et al [37] studied MHD Boundary layer flow of heat and mass transfer over a moving vertical plate in a porous medium with suction and viscous dissipation.

The induced magnetic field has many important applications in the experimental and theoretical studies of MHD flow due to its use in many scientific and technological phenomena, for example in MHD electrical power generation, geophysics, purification of crude oil, and glass manufacturing. The role of induced magnetic field is important when the magnetic Reynolds number is large enough [29]. The free convective boundary layer flow of an electrically conducting hydromagnetic fluid past a vertical plate in the presence of induced magnetic field is studied by Ghosh et al. [25]. The induced magnetic field effect on hydromagnetic free convection flow between two insulated vertical walls is studied by Rajiv et al. [26]. The MHD mixed convection flow past a vertical porous plate in the presence of thermal radiation and induced magnetic field is analyzed by Ahmed [30].The hydromagnetic free convective heat transfer flow between parallel vertical porous plates in the presence of induced magnetic field is analyzed by Sarveshanand and Singh [27].The MHD natural convection flow over a vertical micro channel formed by two vertical plates in the presence of induced magnetic field is considered by Jha and Aina [28] and conclude that magnetic field parameter on the induced current density is found to have a decreasing nature at the central region of the micro channel. Kumar and Singh [31] discussed the induced magnetic field effect on free convection heat transfer flow in vertical concentric annuli. He concluded that the induced magnetic field is to enhance the fluid in comparison to the case of neglecting the induced magnetic field. An aligned magnetic field and radiation effect on the flow over a stretching surface was discussed by Raju et al. [38].Ramana Reddy et al. [39] studied the influence of inclined magnetic field, radiation and chemical reaction on an unsteady dusty viscous flow in the presence of heat generation or absorption.

The study of convective flow with heat and mass transfer under the influence of chemical reaction has practical applications in many areas of science and engineering. This phenomenon plays an important role in the chemical industry, petroleum industry, cooling of nuclear reactors, and packed-bed catalytic reactors so that it has received a considerable amount of attention in recent years. Prakash et al. [21] investigated the free convection radiative flow of a hydromagnetic fluid over a vertical porous plate in the presence of diffusion thermo and first order chemical reaction. The free convective heat and mass transfer hydromagnetic flow in a porous channel over a vertical plate with first order chemical reaction was analyzed by Barik et al. [2]. The hydromagnetic free convection flow in a vertical porous channel in the presence of first order chemical reaction was considered by Barik et al. [16]. The effect of a chemical reaction on a moving isothermal vertical surface with suction has been considered by Muthucumarswamy [14]. Considering this in the study of a chemical reaction, Das et al. [15] considered the effects of a first-order chemical reaction on the flow past an impulsively started infinite vertical plate with constant heat flux and mass transfer. The effects of radiation on free convective heat and mass transfer past an isothermal vertical oscillating porous plate in the presence of a chemical reaction and heat generation is studied by Fagbade and Omowaye [13].

The aim of the present study is investigate the influence of viscous dissipation and joules heating on hydromagnetic free convection flow over a vertical plate in the presence of induced magnetic field, heat source and first order chemical reaction. The set of non linear ordinary differential equations are solved by using regular perturbation technique. The impact of various important flow parameters on velocity, temperature and concentration as well as the friction factor coefficient and the rates of heat and mass transfer coefficients are derived and analyzed through graphs and tables.

II. MATHEMATICAL FORMULATION

The two-dimensional steady magneto-hydrodynamic mixed convective heat transfer flow of a Newtonian, electrically conducting, viscous incompressible fluid over a porous vertical infinite plate with the viscous/magnetic dissipation of energy has been considered. The $\bar{x}$-axis is taken vertically upwards along the plate,$\bar{y}$-axis normal to the plate in the fluid region.It is assumed that the plate is electrically non-conducting and the applied magnetic field is of uniform strength (H_0) and perpendicular to the plate (see Fig.1).The magnetic Reynolds number of the flow is taken into consideration, so that the presence of induced magnetic field is also considered.

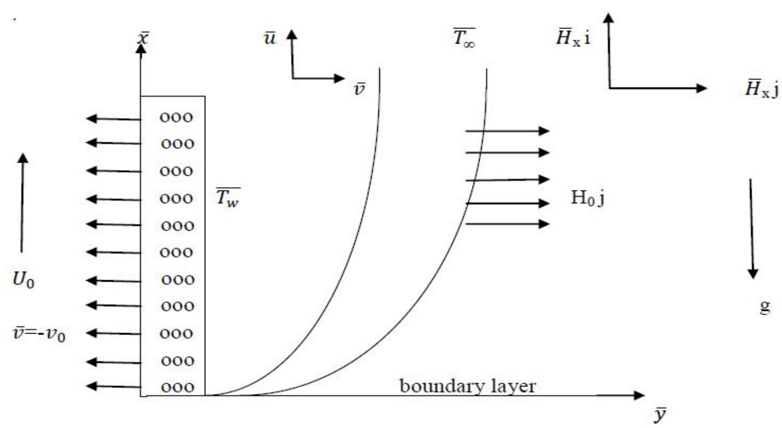

Fig.1:Physical configuration and coordinate system.

Let the plate be long enough in $\bar{x}$ -direction for the flow to be parallel. Let $(\bar{u}, \bar{v}, 0)$ be the be fluid velocity and $(\bar{H}_x, \bar{H}_y, 0)$ be the magnetic induction vector at a point $(\bar{x}, \bar{y}, \bar{z})$ in the fluid since the plate is infinite in length in $\bar{x}$ –direction, therefore all the physical quantities except possibly the pressure are assumed to be independent of the $\bar{x}$. The wall is maintained at a constant temperature $\overline{T_w}$ higher than ambient temperature $\overline{T_\infty}$. All the gas properties are considered constant except that the influence of density variation with temperature has been considered only in the body force term. The plate is subjected to a constant suction

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velocity. The equation of conservation of electric charge is $\nabla . J = 0$. where $J = (J_x, J_y, J_z)$ .The direction of propagation is considered only along $\bar{y}$- axis and does not have any variation along the $\bar{y}$- axis and so $\frac{\partial J_y}{\partial y} = 0$, which gives J_y =constant.

The absence induced magnetic field we may have

$$\frac{\partial p}{\partial x} = -\rho_\infty g \tag{1}$$

By using Boussinesq's approximation $\rho_\infty - \rho = \rho_\infty \beta(\bar{T} - \bar{T}_\infty)$, equation form

$$\bar{v}\frac{\partial \bar{u}}{\partial \bar{y}} = g\beta(\bar{T} - \bar{T}_\infty) + g\bar{\beta}(\bar{C} - \bar{C}_\infty) + v\frac{\partial^2 \bar{u}}{\partial \bar{y}^2} + \frac{\mu_0 H_0}{\rho}\frac{\partial \bar{H}_x}{\partial \bar{y}} \tag{2}$$

Similarity the equation of energy, magnetic induction, Mass diffusion equations are given below respectively.

$$\bar{v}\frac{\partial \bar{T}}{\partial \bar{y}} = \frac{k}{\rho C_p}\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} + \frac{v}{C_p}\left(\frac{\partial \bar{u}}{\partial \bar{y}}\right)^2 + \frac{1}{\sigma \rho C_p}\left(\frac{\partial \bar{H}_x}{\partial \bar{y}}\right)^2 + \bar{Q}\frac{\partial}{\partial \bar{y}}(\bar{T} - \bar{T}_\infty) \tag{3}$$

$$\bar{v}\frac{\partial \bar{H}_x}{\partial \bar{y}} = \frac{1}{\sigma \mu_0}\frac{\partial^2 \bar{H}_x}{\partial \bar{y}^2} + H_0\frac{\partial \bar{u}}{\partial \bar{y}} \tag{4}$$

$$\bar{v}\frac{\partial \bar{u}}{\partial \bar{y}} = D\frac{\partial^2 \bar{C}}{\partial \bar{y}^2} - k_r(\bar{C} - \bar{C}_\infty) \tag{5}$$

The boundary conditions are

$$\bar{y}=0; \bar{u}=L\frac{\partial \bar{u}}{\partial u y}, \quad \bar{v} = -v_0, -\kappa\frac{\partial \bar{T}}{\partial y} = -(T_w - T_\infty), \overline{H_x} = 0, \bar{C} = C_w$$

$$\bar{y} \to \infty : \bar{u} \to U_0, \bar{T} \to \bar{T}_\infty, \overline{H_x} \to 0, \bar{C} \to \bar{C}_\infty \tag{6}$$

The non-dimensional quantities are:

$$y = \frac{v_0 \bar{y}}{v}, u = \frac{\bar{u}}{U_0}, \theta = \frac{\bar{T} - \bar{T}_\infty}{\bar{T}_w - \bar{T}_\infty}, \Pr = \frac{\rho v C_p}{k}, Gr = \frac{vg\beta(\overline{T_w} - \bar{T}_\infty)}{U_0 v_0^2},$$

$$H = \sqrt{\frac{\mu_0}{\rho}}\frac{\bar{H}_x}{U_0}, E_c = \frac{U_0^2}{C_p(\overline{T_w} - \bar{T}_\infty)}, P_{rm} = \sigma v \mu_0, M = \sqrt{\frac{\mu_0}{\rho}}\frac{\bar{H}_0}{v_0}, Q = \frac{\bar{Q}}{v_0}, \tag{7}$$

$$\phi = \frac{\bar{C} - \bar{C}_\infty}{\bar{C}_w - \bar{C}_\infty}, Gm = \frac{vg\bar{\beta}(\bar{C}_w - \bar{C}_\infty)}{U_0 v_0^2}, Sc = \frac{\bar{v}}{D}, \gamma = \frac{K_r v}{v_0^2}.$$

Using the transformations (7), the non–dimensional governing equations in sets of Ordinary are as follows:

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$$\frac{d^2u}{dy^2}+\frac{du}{dy}+M\frac{dH}{dy}=-(Gr\theta+Gm\phi) \quad (8)$$

$$\frac{d^2\theta}{dy^2}+(1+Q)\Pr\frac{d\theta}{dy}=-\left(Ec\Pr\left(\frac{du}{dy}\right)^2+\frac{Ec\Pr}{\Pr m}\left(\frac{dH}{dy}\right)^2\right) \quad (9)$$

$$\frac{d^2H}{dy^2}+M\Pr m\frac{du}{dy}+\Pr m\frac{dH}{dy}=0 \quad (10)$$

$$\frac{d^2\phi}{dy^2}+Sc\frac{d\phi}{dy}-\gamma Sc\phi=0 \quad (11)$$

The corresponding boundary conditions are

$$y=0;u=0,\theta=1;H=0,\phi=1.$$
$$y\to\infty;u\to 1,\theta\to 0;H\to 0,\phi\to 0; \quad (12)$$

III. METHOD OF SOLUTIONS

In order to solve the Eqs. (8)-(11) under the boundary conditions (12), we note that Ec for all incompressible fluids and it is assumed the solutions of the form

$$u(y)=u_0(y)+E_cu_1(y)+O(E_c{}^2) \quad (13)$$

$$\theta(y)=\theta_0(y)+E_c\theta_1(y)+O(E_c{}^2) \quad (14)$$

$$H(y)=H_0(y)+E_cH_1(y)+O(E_c{}^2) \quad (15)$$

We now substitute Eqs. (13)- (15) in Eqs. (8)- (12) and equating the coefficient of the same degree terms and neglecting term $O(E_c{}^2)$, the following Ordinary differential equations are obtained.

$$u_0{}^{11}+u_0{}^1=-MH_0^1-G_r\theta_0-G_me^{-B_2y} \quad (16)$$

$$u_1{}^{11}+u_1{}^1=-MH_1^1-Gr\theta_1 \quad (17)$$

$$\theta_0^{11}+\mathrm{P}_r(1+Q)\theta_0^1=0 \quad (18)$$

$$\theta_1^{11}+\mathrm{P}_r(1+Q)\theta_1^1=-P_r\left(u_0^1\right)^2-\frac{\Pr}{\Pr m}\left(H_0^1\right)^2 \quad (19)$$

$$H_0{}^{11}+\mathrm{P}_{rm}H_0{}^1=-M\,\mathrm{P}_{rm}u_0^1 \quad (20)$$

$$H_1{}^{11}+\mathrm{P}_{rm}H_1{}^1=-M\,\mathrm{P}_{rm}u_1^1 \quad (21)$$

The boundary conditions reduce to

$$y=0;u_0=0,u_1=0,\theta_0=1,\theta_1=0,H_0=0,H_1=0,\phi_0=1,\phi_1=0;$$
$$y\to\infty;u_0=1,u_1=0,\theta_0=0,\theta_1=0,H_0=0,H_1=0,\phi_0=0,\phi_1=0; \quad (22)$$

A. *Skin friction*

The boundary layer produces a drag force on the plate due to the viscous stress which developed at wall and is defined by

$$\tau=\left(\frac{\partial u}{\partial y}\right)_{y=0}=u_0^1(0)+E_cu_1{}^1(y) \quad (23)$$

B. *Rate of Heat transfer*

The coefficient heat transfer can be calculated in non-dimensional form at the plate, which is generally known as Nusselt number as follows:

$$Nu = \left(\frac{\partial \theta}{\partial y}\right)_{y=0} = \theta_0^1(0) + E_c\theta_1^1(0) \qquad (24)$$

C. Rate of Mass transfer

Physical processes that involve diffusive and convective transport of chemical species within physical systems. The coefficient mass transfer can be transfer can be calculated in non-dimensional form, which is generally known as Sherwood number as follows:

$$Sh = \left(\frac{\partial \phi}{\partial y}\right)_{y=0} = \phi_0^1(0) + E_c\phi_1^1(0) \qquad (25)$$

D. Complete solutions applying boundary conditions.

By solving equations (16) - (21) using approximation boundary conditions (22), we get

$$\phi = e^{-B_2 y},$$

$$\theta_0 = e^{-A_1 y},$$

$$u_0 = 1 + A_5 e^{-A_3 y} + B_3 e^{-B_2 y},$$

$$H_0 = A_8 e^{-P_{rm} y} + A_6 e^{-A_3 y} + A_7 e^{-A_1 y} + B_4 e^{-B_2 y}$$

$$\theta_1 = \{B_9 e^{-A_1 y} + A_9 e^{-2A_3 y} - A_{10} e^{-2A_1 y} + B_5 e^{-2B_2 y} - A_{11} e^{-(A_3+A_1)y}$$
$$+ B_6 e^{-(B_2+A_1)y} - B_7 e^{-(B_2+A_3)y} + A_{12} e^{-2P_{rm} y} - A_{14} e^{-(P_{rm}+A_3)y} - B_8 e^{-(P_{rm}+B_2)y} - A_{13} e^{-(P_{rm}+A_1)y}\}$$

$$u_1 = \{B_{15} e^{-A_{17} y} + B_{10} e^{-A_1 y} + B_{11} e^{-2B_2 y} + B_{12} e^{-(B_2+A_1)y} + B_{13} e^{-(B_2+A_3)y} + B_{14} e^{-(B_2+P_{rm})y} +$$
$$A_{19} e^{-2A_3 y} + A_{20}{}^{-2A_1 y} + A_{21} e^{-(A_3+A_1)y} + A_{22} e^{-2P_{rm} y} + A_{23} e^{-(P_{rm}+A_1)y} + A_{24} e^{-(P_{rm}+A_3)y}\}$$

$$H_1 = \{B_{22} e^{-P_{rm} y} + B_{16} e^{-A_{17} y} + B_{17} e^{-A_1 y} + B_{18} e^{-2B_2 y} + B_{19} e^{-(B_2+A_3)y} + B_{20} e^{-(B_2+A_3)y} + B_{21} e^{-(B_2+P_{rm})y} +$$
$$A_{28} e^{-2A_3 y} + A_{29} e^{-2A_1 y} + A_{30} e^{-(A_3+A_1)y} + A_{31} e^{-2P_{rm} y} + A_{32} e^{-(P_{rm}+A_1)y} + A_{33} e^{-(P_{rm}+A_3)y}\}$$

IV. RESULTS AND DISCUSSION

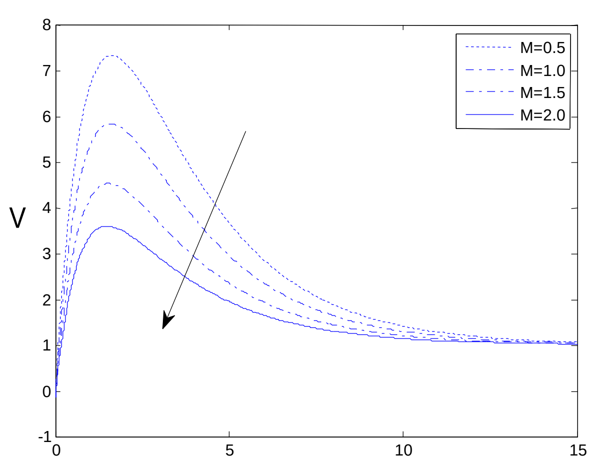

Fig. 2. Velocity Profiles for different values of Magnetic parameter (M)
Ec=0.001; Q=5.0; Prm=0.1; Pr=0.71; Gr=5;Sc=0.30;r=0.1;Gm=5;y=0:0.001:15;h=0.5;

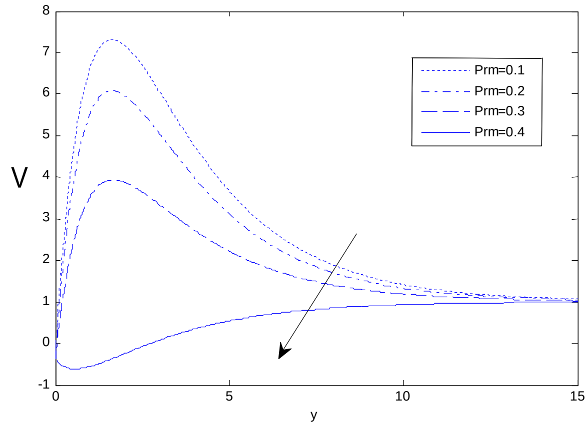

Fig.3. Velocity Profiles for different values of Magnetic Prandtl Number (P_{rm})
M=0.5; Ec=0.001;Q=5.0; Pr=0.71;Gr=5;Sc=0.30;r=0.1;Gm=5;y=0:0.001:15;h=0.5;

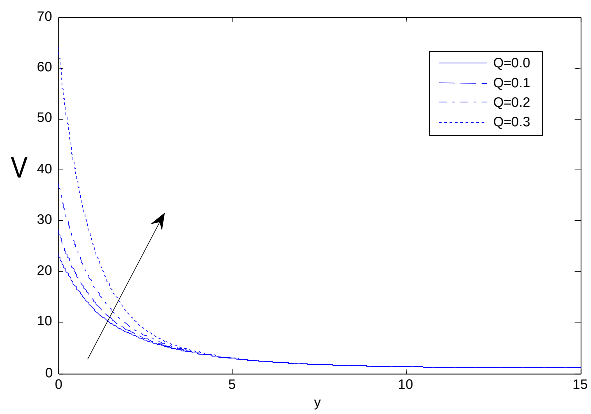

Fig. 4. Velocity Profiles for different values of Heat absorption parameter (Q)
M=0.25; Ec=0.001;Prm=0.1;Pr=0.71;Gr=5;Sc=0.30;r=0.1;Gm=10;y=0:0.001:15;h=0.5;

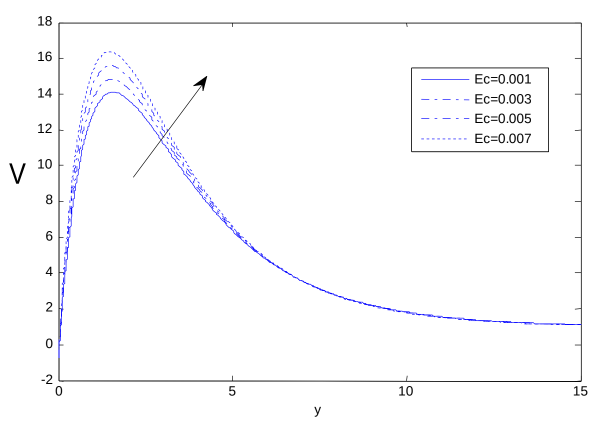

Fig. 5. Velocity Profiles for different values of Eckert number (E_c)
M=0.5; Q=5.0; Prm=0.1; Pr=0.71;Gr=10;Sc=0.30;r=0.1;Gm=10;y=0:0.001:15;h=0.5;

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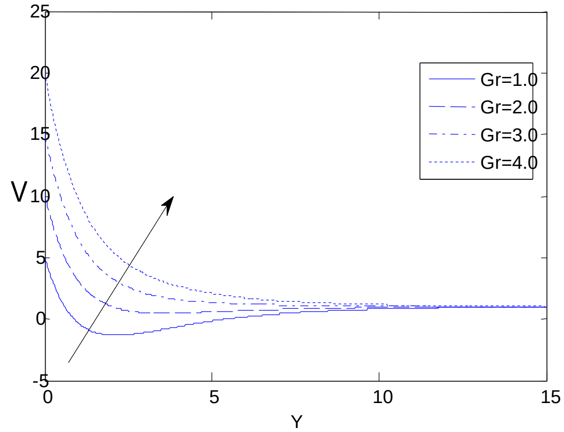

Fig.6. Velocity Profiles for different values of Thermal Grashof number (G_r)
M=0.5;Ec=0.001;Q=0.1;Prm=0.1;Pr=0.71;Sc=0.3;r=0.1;Gm=10;y=0:0.001:15;h=0.5;

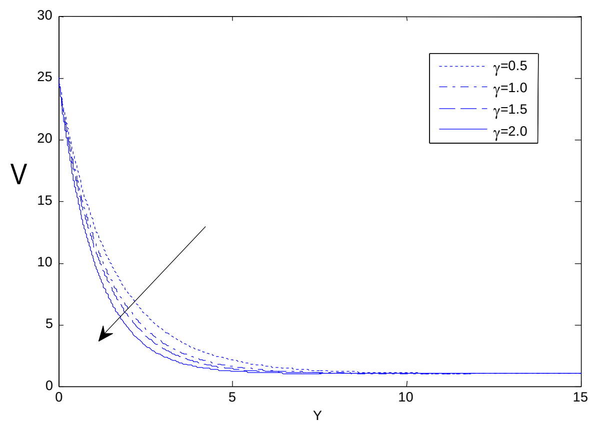

Fig. 7.Velocity Profiles for different values of Convection parameter (γ)
M=0.5; Ec=0.001;Q=0.1;Prm=0.1;Pr=0.71;Gr=5;Sc=0.30 ;Gm=5;y=0:0.001:15;h=0.5;

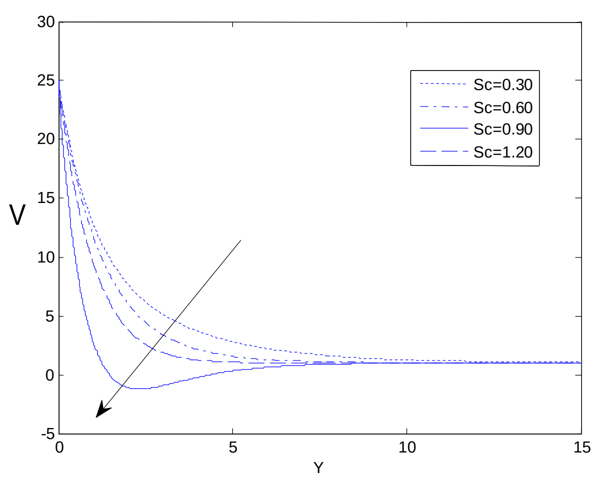

Fig.8.Velocity Profiles for different values of Schmidt Number (Sc)
M=0.5; Ec=0.001;Q=0.1;Prm=0.1;Pr=0.71;Gr=5;r=0.1;Gm=10;y=0:0.001:15;h=0.5;

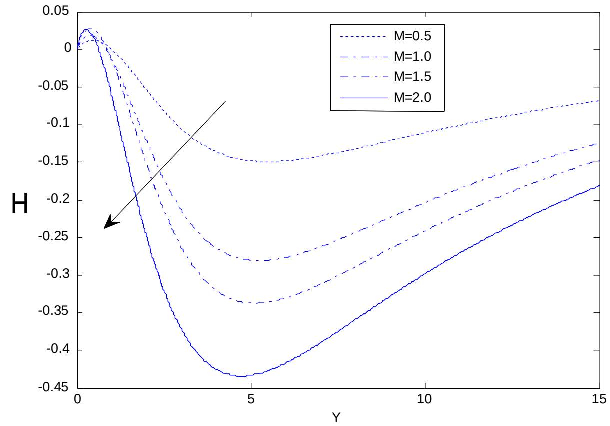

Fig. 9. Induced magnetic field Profiles for different values of Magnetic parameter (M)
Ec=0.001;Q=1.0;Prm=0.1;Pr=0.71;Gr=5;Sc=0.3;r=1.0;Gm=5;h=0.5;

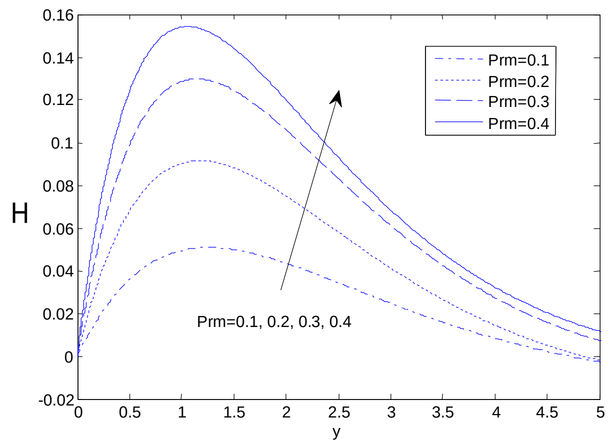

Fig. 10. Induced magnetic field Profiles for different values of Magnetic Prandtl Number .M=1;
Ec=0.001;Q=0.1;Pr=0.71;Gr=5;Sc=0.3;r=1;Gm=5;h=0.5;

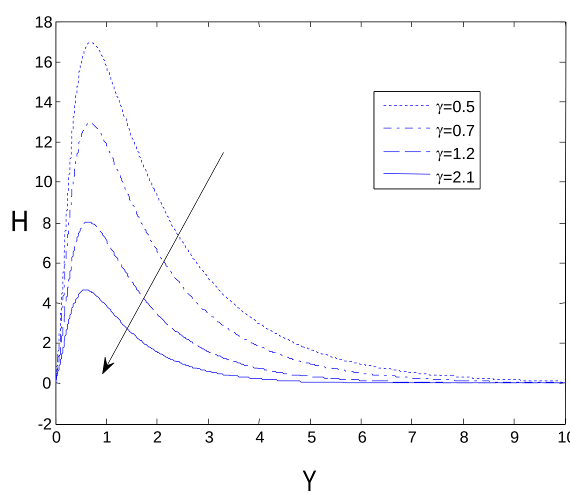

Fig.11.Induced magnetic field Profiles for different values of Convection parameter(γ)
M=1.0;Ec=0.001;Q=5;Prm=5.0;Pr=0.71;Gr=10;Sc=0.3;Gm=10;h=0.5;

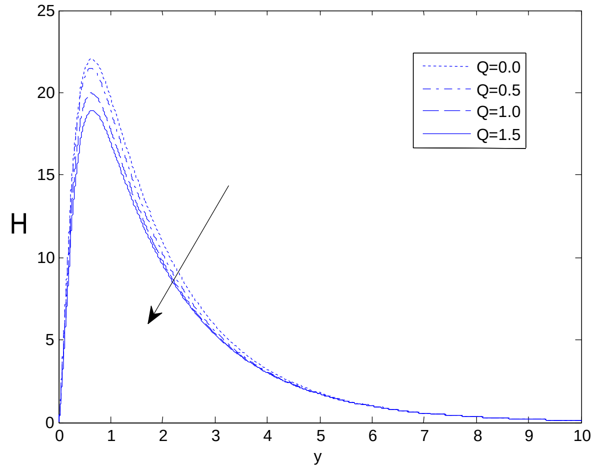

Fig. 12. Induced magnetic field Profiles for different values of Heat absorption parameter (Q) M=1.0;Ec=0.001;Q=2.0;Prm=5.0;Pr=0.71;Gr=10;Sc=0.3;r=0.5;Gm=10;h=0.5;

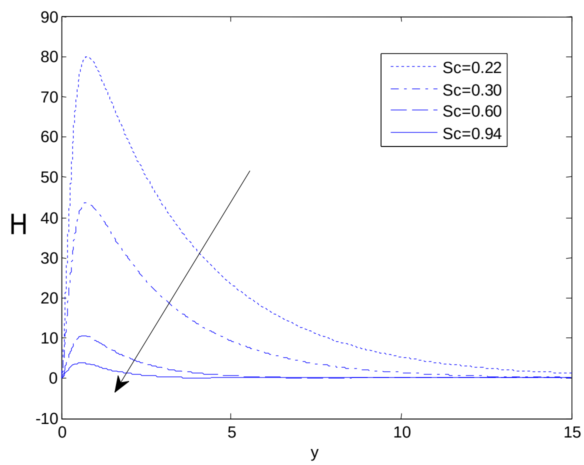

Fig. 13. Induced magnetic field Profiles for different values of Schmidt Number (Sc) M=1.0; Ec=0.001;Q=5;Prm=5.0;Pr=0.71;Gr=10;r=0.1;Gm=10;h=0.5;

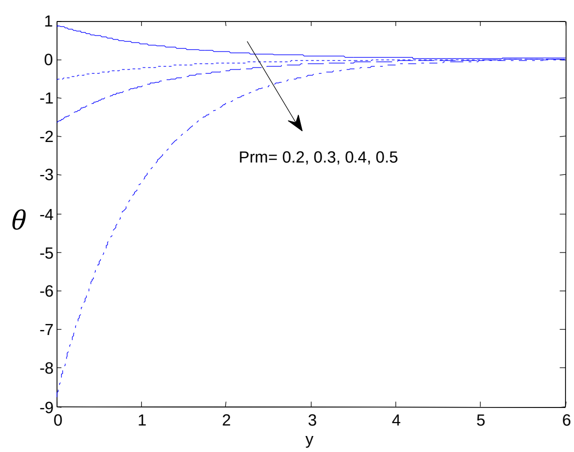

Fig. 14. Temperature Profiles for different values of Magnetic Prandtl Number (P_{rm})M=0.25; Ec=0.001;Q=0.1;Pr=0.71;Gr=5;Sc=0.3;r=0.3;Gm=5;

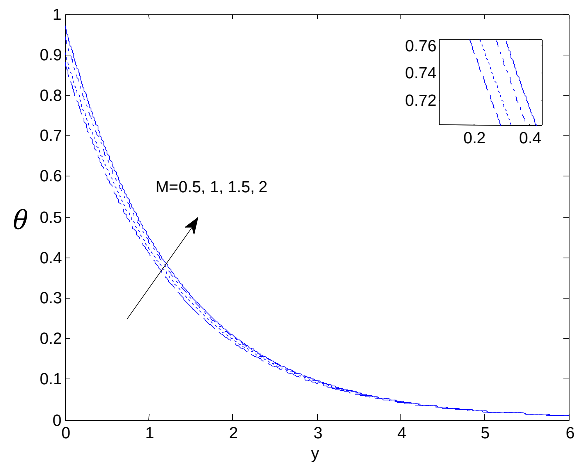

Fig. 15. Temperature Profiles for different values of Magnetic parameter (M)
Ec=0.001; Q=0.1;Prm=0.2;Pr=0.71;Gr=5;Sc=0.3;r=0.3;Gm=5;

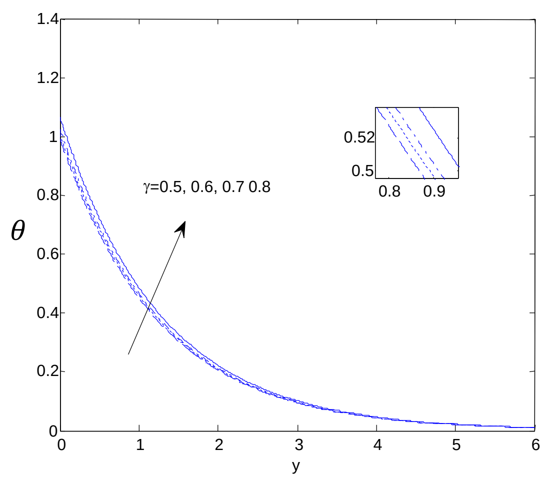

Fig. 16. Temperature Profiles for different values of Convection parameter(γ)
M=0.25; Ec=0.001;Q=0.1;Prm=0.1;Pr=0.71;Gr=5;Sc=0.3;r=0.5;Gm=5;

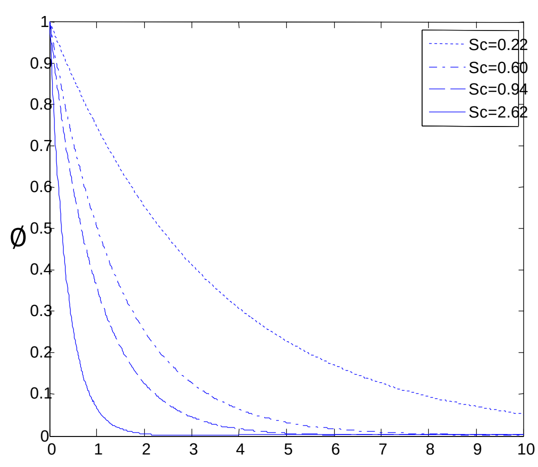

Fig.17 Concentration Profiles for different values of Schmidt number (Sc)

Table 1.Skin-fricition for cooling of the plate (Gr>0)

Pr	Prm	Gr	Sc	Skin-friction
0.71	1	5	0.22	-26.7447
0.71	2	5	0.22	-5.7189
7.0	1	5	0.22	17.386
7.0	1	5	0.30	13.878
0.71	1	10	0.22	9.6323

Table 2. Nusselt number and Sherwood number

Pr	Gm	M	Sc	Nu	Sh
0.71	5	1.0	0.22	-0.0390	-0.2947
0.71	5	2.0	0.22	-0.7732	-0.3469
0.71	5	1.0	0.30	-3.2749	-0.3791
7.0	5	1.0	0.30	-7.2836	-0.4372
7.0	10	1.0	0.22	2.2946	-0.4594

In the preceding sections, the set of ordinary differential equations (16-21) along with the boundary conditions are solved analytically employing the perturbation technique. The main impact on controlling, parameters as they appear in the governing equations are discussed on velocity, temperature, concentration, induced magnetic fields, as well as the Skin-friction coefficient, the local Nusselt number and the local Sherwood number .without calculate Sherwood number decreases as Schmidt number increases in atmospheric pressure.

Fig.2, delineates the Magnetic parameter (M), on velocity field, it is observed that there is fall in velocity as Magnetic parameter (M) increases. This is occur to the application of transverse magnetic field, which turns acts as Lorentz forces that retards the fluid flow.Fig.3 shows that Magnetic prandtl number (P_{rm}) effect on the velocity field. It is noticed that there is decrease in the velocity as Magnetic prandtl number is upgraded. Figs.(4-6) depicts the Heat absorption parameter (Q),Eckert number (Ec),Thermal Grashof number (Gr) effects on velocity field. It is examined that upgrading in the velocity with the increasing the values of Heat absorption parameter (Q), Eckert number (Ec), Thermal Grashof number (Gr).Fig.7 for different values of Convective parameter (γ) on velocity profile. It is seen that the rising values of Convective parameter (γ) depreciates the fluid velocity as well as hydromagnetic boundary layer thickness.

Fig.8, In order to the realistic values of Schmidt number are chosen at the atmospheric temperature (25^0 C) and atmospheric pressure of Helium (Sc=0.3), Water vapour(Sc=0.6), Carbon dioxide(Sc=0.94),Sulphur dioxide (Sc=1.24), with the increase of in Schmidt number the velocity profiles decreases because kinematic viscosity increases that leads to reduce on velocity .Fig.9, Illustrate the effect of Induced Magnetic parameter , from this figure it is to understanding that there is decreases in Induced Magnetic field as the Magnetic parameter upgrading. The same phenomenon is observed for Magnetic prandtl (see Fig.10). From these figures (Fig.9-10), it is concluded that the Induced Magnetic field flux reversal arises for all distance in to boundary layer and transverse to the plate. Also noticed that the Induced Magnetic field increases a short distance from the plate and then decays to be zero in the free stream. Figs. (11-13) depicts, the Convection parameter, Heat absorption parameter, Schmidt parameter, effects on the induced magnetic field. It is observed that decreases in the velocity where as the increase in the Heat absorption parameter, Convection parameter, Schmidt number.

Fig.(14) shows that the Magnetic prandtl number (P_{rm}) effect on temperature distribution .It is seen that the fluid temperature upgraded when the Magnetic prandtl number (P_{rm}) decreases. This is due increase in magnetic diffusivity over the surface of the boundary layer while the fluid viscous diffusion rate increased. Fig.(15) depicts the Magnetic parameter effect on Temperature profiles. It is examined that fluid temperature increases with the enhancing values of Magnetic parameter. Also we observed an

improved in thermal boundary layer. Fig.(16) delineates ,The temperature profiles for various values of Convective parameter (γ), it is perceived that the Temperature will distribute increase with increasing in Convection parameter (γ), Also we observed that the significant effect away from the plate it converges to boundary point. Fig.17. depicts that the Schmidt number (Sc) effect on Concentration distribution. It is seen that concentration decreases when the Schmidt number increases with different cases of atmospheric pressure of Hydrogen (Sc=0.22), Water vapour (Sc=0.6), Carbon-dioxide (Sc=0.94), Propyl benzene (Sc=2.62).
Table. (1-2) The numerical values of Skin friction Co-efficient and the rate of heat transfer Co-efficient are presented. From table.1, it is noticed that the Skin friction Co-efficient increases with an increase in Magnetic prandtl number. But an opposite trend is observed for Grash of number .Table.2 , local Nusselt number Various values of Magnetic field parameter (M) and modified Grashof number (Gm).It is seen that the improving values of Magnetic parameter depreciates the heat transfer rate. While it is improved for increasing values of Grashof number. It is observed that the convection parameter and Schmidt number increases with an decreases the Sherwood number.

V. CONCLUSIONS

In the present study, we investigate the effects of viscous dissipation and joules heating on hydromagnetic free convection flow over a vertical plate in the presence of induced magnetic field, heat source and first order chemical reaction. The obtained results are presented through graphs and tables. From these results the main conclusions are

A. The rising values of magnetic filed Prandtl number improve the skin friction coefficient.
B. The magnetic field parameter reduces the heat transfer rate.
C. The convection parameter, the magnetic Prandtl number depreciates the hydromagnetic boundary layer thickness.
D. The increasing values of heat absorption parameter reduce the induced magnetic field.
E. The convection parameter enhances the fluid temperature.
F. The increasing values of Schmidt number reduce the concentration.

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