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# HEAT AND MASS TRANSFER EFFECTS ON CONVECTIVE LAMINAR FLOW OVER HEAT GENERATION, VISCOUS DISSIPATION AND RADIATION ABSORPTION IN THE PRESENCE OF TRANSVERSE MAGNETIC FIELD

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## ABSTRACT

This paper presents the study of boundary layer flow due to an exponentially stretching surface in the presence of an applied magnetic field. Analysis is carried out in the presence of thermal radiation, radiation absorption, transverse magnetic field and Chemical reaction. The governing partial differential equations are firstly converted into nonlinear ordinary differential equations by using appropriate transformations and then solved numerically by using $4^{th}$ order Runge Kutta method along with shooting technique. The effect of Magnetic field, Porous parameter, Radiation parameter, Heat generation parameter, Chemical reaction parameter, Prandtl number, Suction parameter and Eckert number on the flow variables is analyzed.

**KEYWORDS**: Thermal radiation, Radiation Absorption, Transverse Magnetic Field, and Chemical Reaction

## INTRODUCTION

In the present paper a study of radiation absorption on MHD free converting fluid flow over a vertical porous plate with suction and chemical reaction in the presence of thermal radiation and viscous dissipation. The basic equations governing the flow are in the form of partial differential equations and have been reduced to a set of non-linear ordinary differential equations by applying suitable similarity transformations. The governing equations of the flow are numerically solved by shooting technique. The expressions for velocity, temperature and concentration are obtained graphically.

## FORMULATION OF THE PROBLEM

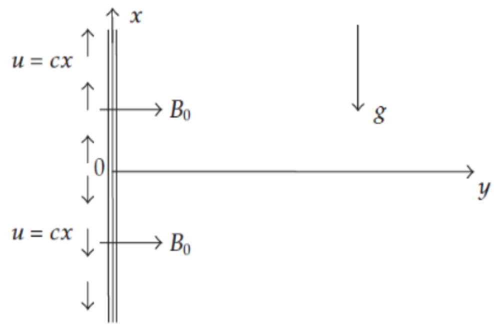



**Figure A. Physical Model for flow geometry**

We study the steady two-dimensional stagnation point flow of a viscous incompressible electrically conducting fluid near a stagnation point at a surface coinciding with the plane y = 0, with the flow being restricted to y > 0. Two equal and opposing forces are applied along the x-axis so that the surface is stretched (while keeping the origin fixed). The potential flow that arrives from the y-axis (impinges on the flat wall at y = 0), divides into two streams on the wall and leaves in both directions. The flow is through a porous medium where the Darcy model is assumed. The components of the fluid velocity by (u, v) at any point (x, y) for the viscous flow, while (U, V) denote the velocity components for the potential flow. We consider the case in which there may be a suction velocity (-w) on the stretching surface. The velocity distribution of the frictionless flow in the neighborhood of the stagnation point is becomes

$$U\left(x\right)=ax,\ \ V(x)=-ay \qquad 1$$

where the parameter a > 0 is proportional to the free stream velocity. The continuity and momentum equations for the two-dimensional steady flow, using the usual boundary layer approximations reduces to

**Continuity equation**

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \qquad 2$$

**Momentum equation**

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial p}{\partial x}+\mu\frac{\partial^2 u}{\partial y^2}+g\beta\rho(T-T_\infty)+g\beta^*\rho(C-C_\infty)-\sigma B_o^{\,2}u-\frac{\mu}{K}u \qquad 3$$

where $-\frac{\partial p}{\partial x}=U\frac{dU}{dx}+\frac{\sigma B_o^{\,2}}{\rho}U+\frac{\upsilon}{K}U$ 4

**Energy equation**

$$\rho c_p\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=k\frac{\partial^2 T}{\partial y^2}-\frac{\partial q_r}{\partial y}+Q(T-T_\infty)+Q_0(C-C_\infty)+\mu\left(\frac{\partial u}{\partial y}\right)^2+\sigma B_0^{\,2}u^2+\frac{D_M K_T}{C_s}\frac{\partial^2 C}{\partial y^2} \qquad 5$$

where $\frac{\partial q_r}{\partial y}=4\alpha^2(T-T_\infty)$

**Concentration equation**

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_M\frac{\partial^2 C}{\partial y^2}+D_T\frac{\partial^2 T}{\partial y^2}+K_1(C-C_\infty) \qquad 6$$

From equation (3) & (4), then the equation (3) reduces to

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=U\frac{dU}{dx}+\mu\frac{\partial^2 u}{\partial y^2}+g\beta\rho\left(T-T_\infty\right)+g\beta^*\rho\left(C-C_\infty\right)+\sigma B_o^{\,2}(U-u)+\frac{\mu}{K}(U-u) \qquad 7$$

The corresponding boundary conditions are

$$u = cx,\ v = 0, T = T_w, C = C_w \quad at \quad y = 0$$
$$u = ax, T \to T_\infty, C \to C_\infty \quad as\ y \to \infty \qquad 8$$

where c > 0.

We introduce non-dimensional quantities are:

$$M = \frac{\sigma B_0^{\ 2}}{\rho},\ B = \frac{Q}{c\rho C_p},\ \Pr = \frac{\rho \upsilon C_p}{k},\ K = \frac{\upsilon}{ck'},\ Sc = \frac{\upsilon}{D_M},\ s = \frac{W}{\sqrt{cv}},\ Gr = \frac{g\beta(T - T_\infty)}{c^2}$$

$$Gc = \frac{g\beta^*(C - C_\infty)}{c^2}, \theta = \frac{T - T_w}{T_w - T_\infty}, \theta = \frac{C - C_w}{C_w - C_\infty}, Ra = \frac{4\alpha^2}{c\rho C_p}, B = \frac{Q}{c\rho C_p}, Ec = \frac{c^2 x^2}{C_p(T - T_\infty)}$$

$$Sr = \frac{D_T(T_w - T_\infty)}{(C_w - C_\infty)}, Ch = \frac{K_1}{c}, Df = \frac{D_M K_T(C_W - C_\infty)}{C_S C_P(T_W - T_\infty)}$$

$$Q_0 = \frac{Q}{\rho c C_9} \qquad 9$$

$$\eta = \sqrt{\frac{c}{v}} y,\ \psi = \sqrt{cv}\, x f(\eta) \qquad 10$$

where $\psi$ is the stream function defined as

$$u(x, y) = \frac{\partial \psi}{\partial y} = xcf'(\eta), \quad v(x, y) = -\frac{\partial \psi}{\partial x} = -\sqrt{cv}\, f(\eta) \qquad 11$$

The Equations (4.5) to (4.7) take the form

$$f''' + ff'' - (f')^2 + Gr\theta + Gc\phi + (M + K)(C - f') + C^2 = 0 \qquad 12$$

$$\theta^{11} + \Pr f\theta^1 - \Pr(Ra - B)\theta + \Pr Ec\left(f^1\right)^2 + M^2 u^2 + Df\phi^1 - Q_0\phi = 0 \qquad 13$$

$$\phi^{11} + Scf\phi^1 + SrSc\theta^{11} + ScCh\phi = 0 \qquad 14$$

where the primes denote the differentiation with respect to$\eta$, K is the porosity parameter, M is the magnetic parameter, C = a/c > 0 is the stretching parameter, $B$ is the dimensionless heat generation or absorption parameter, $\Pr$ is the Prandtl number, $Sc$ is the Schmidt number, Sr is the Soret effect, Ec is the Eckert number, Ra is the Radiation parameter and Ch is the Chemical Reaction.

The corresponding boundary conditions are

$$f' = 1, f = s,\ \theta = 1, \phi = 1 \quad \text{at} \quad \eta = 0$$
$$f' = C,\ \theta = 0, \phi = 0 \quad \text{as} \quad \eta \to \infty \qquad 15$$

**METHOD OF SOLUTION**

The governing equations are (12) to (14) subject to boundary conditions (4.15) are solved numerically by using shooting method. The resulting nonlinear ordinary differential equations are solved by $4^{th}$ order Range-Kutta Method along with shooting technique.

**DISCUSSION OF THE RESULTS**

In order to analyze the results, numerical computations have been carried out for various values of free convection parameter Gr, modified Grashof number Gc, suction parameter S, porosity parameter K, magnetic parameter M, heat generation/absorption parameter B, Prandtl number $\Pr$, stretching parameter C, Schmidt number Sc, Chemical Reaction Ch, Soret effect Sr, Radiation parameter Ra and

Echet number Ec are depicted in Figs 2-19, on the velocity $f^{'}(\eta)$, temperature $\theta(\eta)$ and concentration $\phi(\eta)$.

The effects of the grashof number (free convection parameter) Gr on the velocity, temperature and concentration are shown in Figs 2-4. Form this figure the results indicates that the velocity in the y direction decreases in magnitude with an increase in the free convection parameter Gr for air and an increase in Gr yields a uniform increase in temperature and concentration. Figs. 5-7 illustrate the dissimilarity of modified Grashof number Gc on velocity, temperature as well as concentration. From this figure it was observed that the velocity decreases with the increase of modified Grashof number Gc, but the effect was occurred in case of temperature and concentration.

The effect of suction/injection parameter (S) on velocity, temperature and concentration is presented in the Figs. 8-10. We find that the velocity increases with the increase of suction parameters. We notice that increases in S results in a uniform increase in the temperature and concentration. The effects of the porosity parameter K on velocity is shown in Fig. 11. It was perceived that the velocity declined by means of the rise of permeability parameter K.

The influence of the Prandtl number Pr the temperature is shown in Fig. 12. It was observed that the temperature diminished with the enhancement of Prandtl number Pr. Fig 13-14 represents the dissimilarity of stretching parameter (C) on temperature as well as concentration. From this figure it was observed that the velocity rises with the rise of stretching parameter (C), but the effect was declined the temperature and concentration.

Figs. 15-16 demonstrated that the velocity and concentration for various values of chemical reaction Ch. From this figure it was cleared that the velocity reduces with the rise of Ch, but inverse effect was occurred in case of Ch. Figs. 17 gives evidence for the temperature profile for diverse estimators of Echet number Ec. It was observed that the temperature enhancement with the rise of Ec.

Fig. 18 conforms that the concentration for diverse physical values of Soret number (Sr). We have seen that the velocity enhancement of Sr, but the effect was dissimilar values of Sr in concentration.

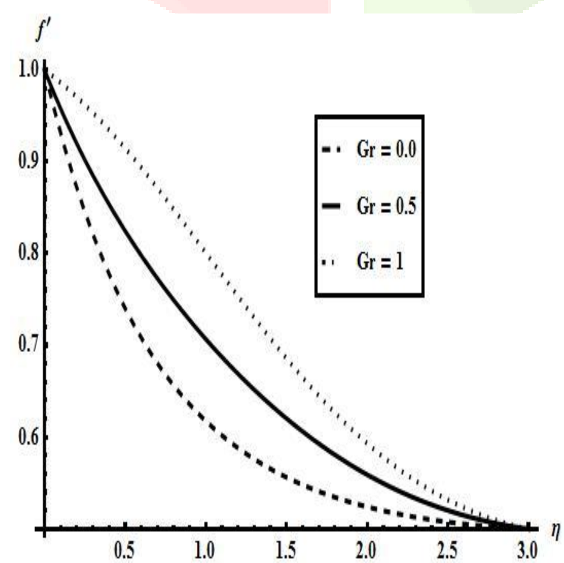



Fig (2) : The velocity profile for différent values of Gr.

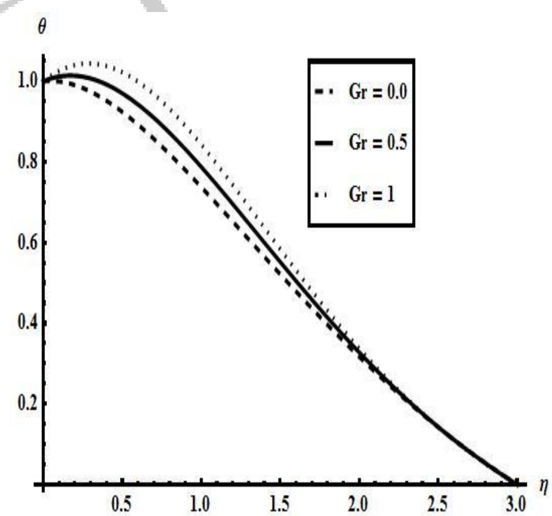



Fig (3) : The Température profile for différent values of Gr.

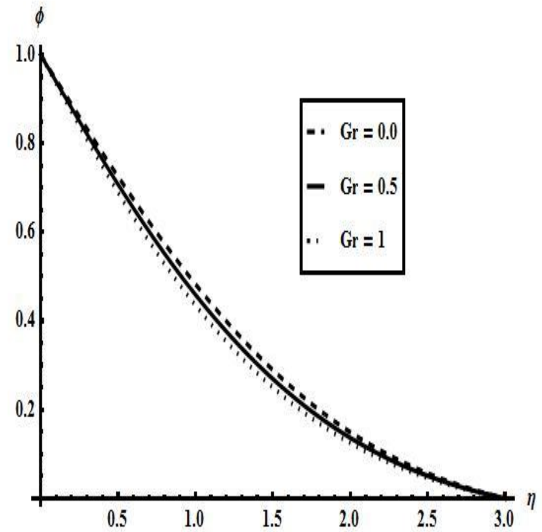
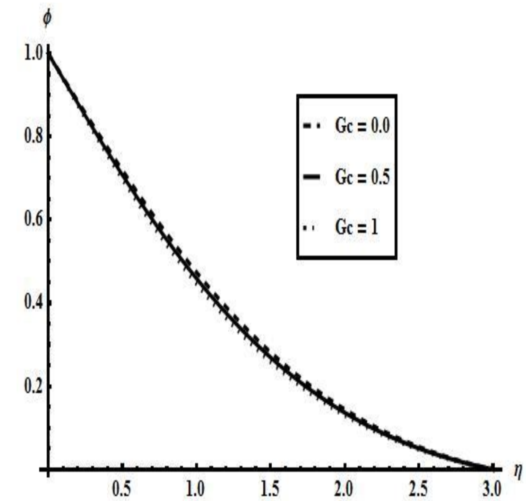



Fig (4) : The Concentration profile for different values of Gr




Fig(7) : The Concentration profile for different values of Gc

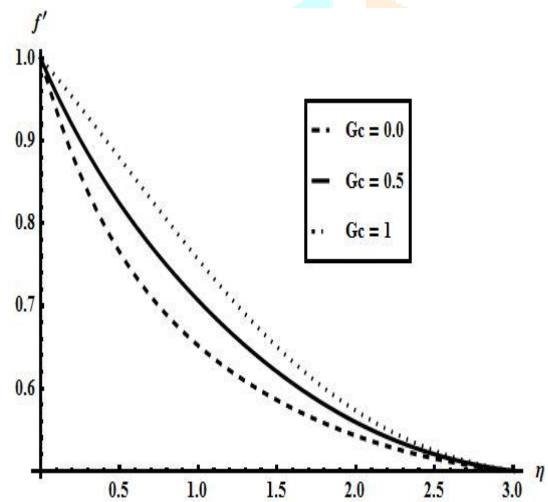
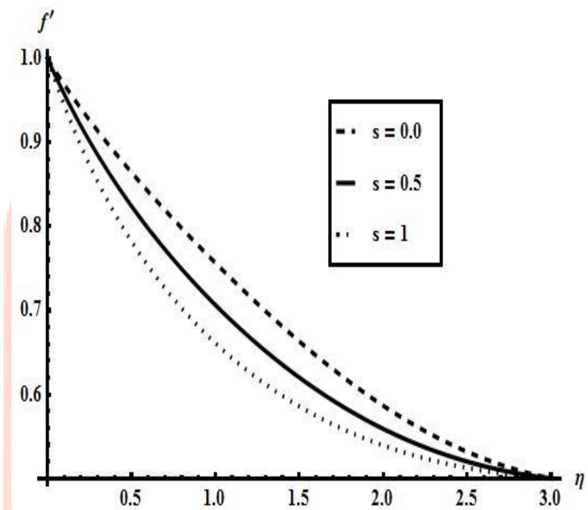



Fig (5): The Velocity profile for different values of Gc




Fig(8) : The Velocity profile for different values of s

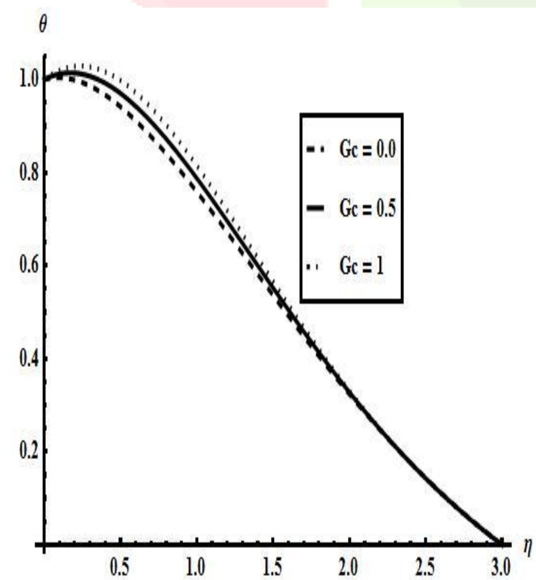
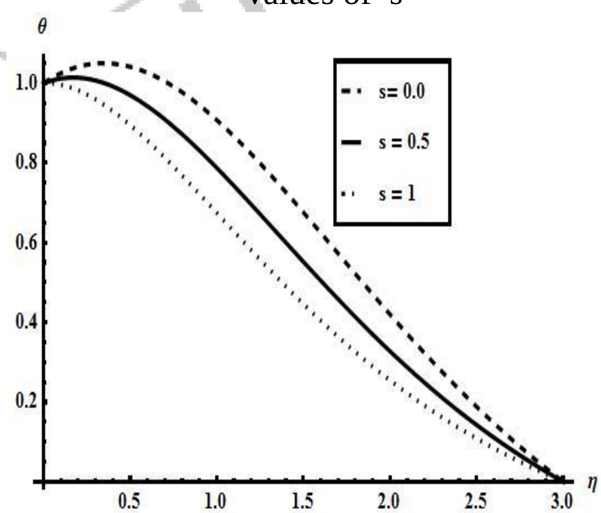
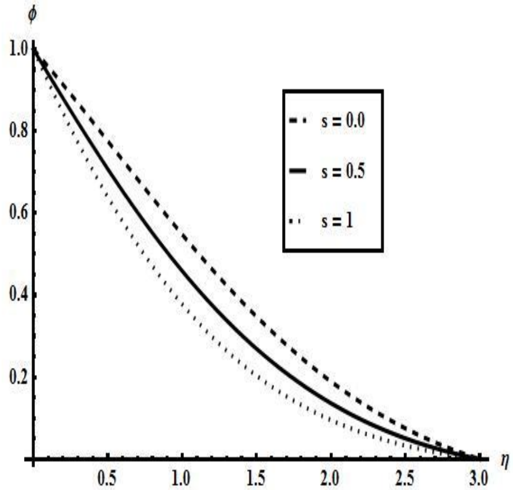


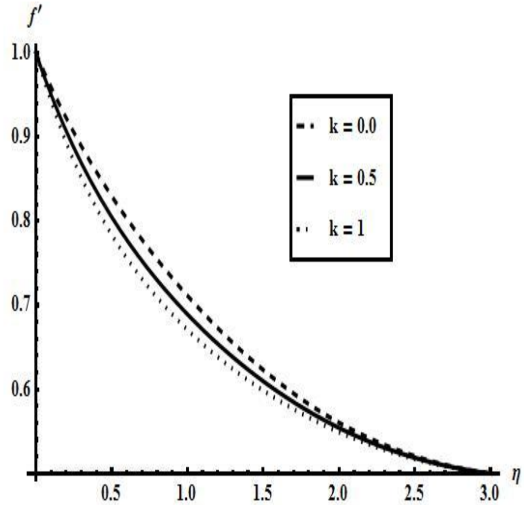

Fig (6) : The Temprature profile for different values of Gc



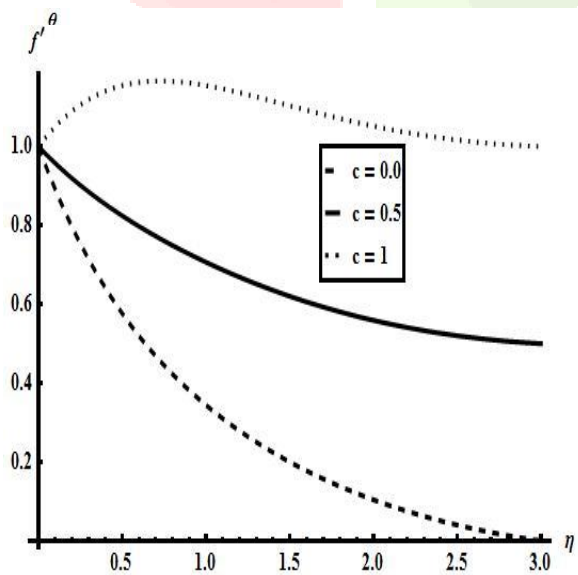

Fig(9) : The Temprature profile for different values of s



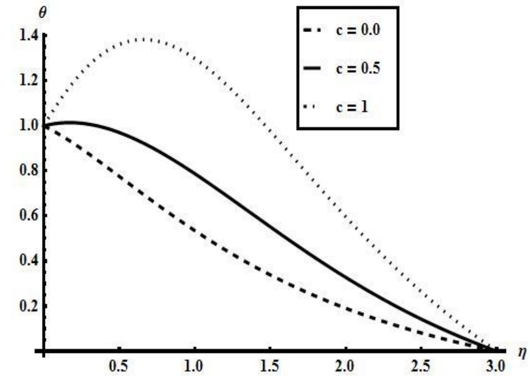

Fig(10) : The concentration profile for different values of s



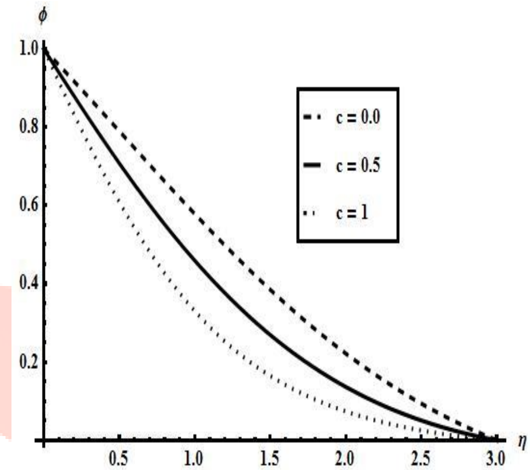

Fig(11) : The Velocity profile for different values of K



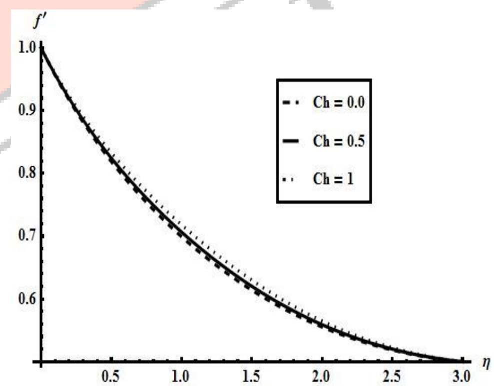

Fig(12) : The Temprature profile for different values of Pr



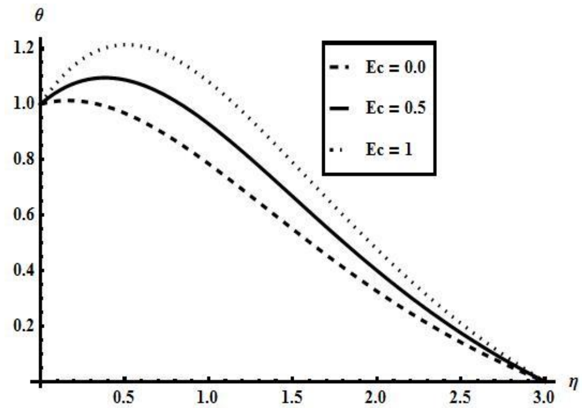

Fig(13) : The Temprature profile for different values of C



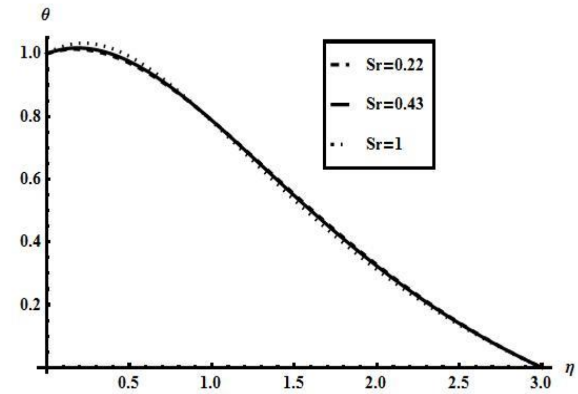

Fig(14) : The concentration profile for different values of c



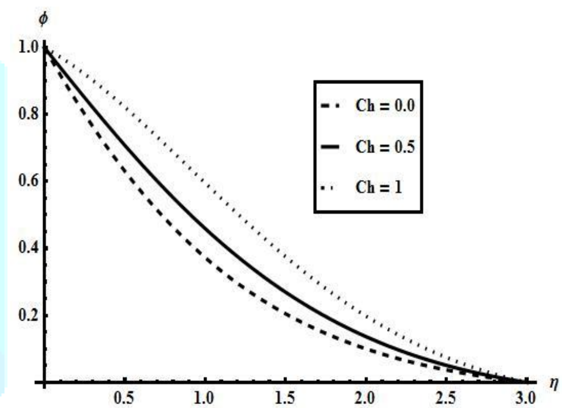

Fig(15) : The Velocity profile for different values of Ch




Fig(17) : The Temprature profile for different values of Ec




Fig(18) : The Concentration profile for different values of Sr




Fig(16) : The Concentration for different values of Ch

## CONCLUSION

In the chapter we discuss of heat and mass transfer on MHD free convective flow over a permeable stretching surface with suction, viscous dissipation, thermal absorption and chemical reaction. The expressions for the velocity, temperature and concentration distributions are the equations governing the flow are numerically solved by shooting technique.

- An enhancement of dissimilar estimators of stretching parameter leads to rise in the velocity, but the effect was declined with the rise of stretching parameter in the temperature or concentration.
- It was perceived that the velocity declined by means of the rise of permeability parameter K.
- From this figure it was cleared that the velocity reduces with the rise of Ch, but inverse effect was occurred in case of Ch.
- It was observed that the temperature enhancement with the rise of Ec.
- We observed that the Concentration enhancement of Sr, but the effect was dissimilar values of Sr in concentration.

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