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HEAT AND MASS TRANSFER EFFECTS ON UNSTEADY MHD FREE CONVECTION FLOW OVER STRETCHING SHEET WITH THE EFFECT OF THERMAL RADIATION AND SORET NUMBER IN POROUS MEDIUM

[1]Piroja Begum and [2]Dipak Sarma
[1& 2]Department of Mathematics, Cotton University, Guwahati, Assam, India
E-mail: [1]pirojabegum928@gmail.com , [2]dipaksarma11@yahoo.com,
[1]Corresponding author

Abstract: The flow problem presented in the paper is a study on unsteady two dimensional MHD laminar forced convective and stable boundary layer flow of incompressible viscous fluid past a heated stretching sheet moving with variable velocity in a porous medium subjected to a magnetic field, thermal diffusion, thermal radiation, viscous dissipation and chemical reaction effects. The partial differential equations appearing in the governing equations of the problem are transformed into a couple of nonlinear ordinary differential equations with the help of similarity transformations. The transformed equations are solved numerically by the Runga-Kutta forth order method along with shooting technique. The effects of various parameters on the velocity, temperature and concentration distributions are analyzed and discussed with the help of graphs. Skin-friction coefficient, Nusselt number and Sherwood number are discussed numerically and presented through tables.

Keywords: MHD, Heat and mass transfer, thermal radiation, Soret effect, chemical reaction.

1. Introduction

The study of unsteady MHD laminar forced convection flow with mass transfer along a heated stretching sheet moving with variable velocity in a porous medium is receiving considerable attention of many researchers because of its applications in many areas of science and technology such as geophysics, astrophysics, chemical engineering and electronics. Analysis of forced and free convective flow for fluids of electrically conducting in presence of chemical reaction has a great importance in many applications in science and technology such as geothermal reservoirs, catalytic reactions, thermal insulation etc. The effect of thermal radiation on convective flow and heat transfer problems has become a significant branch of engineering sciences due to its wide range of applications. It is a fundamental mechanism for industrial applications such as glass production, designing of appropriate equipments, nuclear power plants, gas turbines and various propulsion devices for aircraft, etc. If the temperature of the surrounding fluid is rather high, then radiation effects play an important role, for example in space technology, geophysics, etc. Abbas and Hayata[1] studied radiation effects on MHD flow in a porous space. Makinde and Ogulu[14] analyzed the effect of thermal radiation on the heat and mass transfer flow of a variable viscosity fluid past a vertical porous plate permeated by a transverse magnetic field. Free convective flow involving heat and mass transfer in non-porous and porous media was studied by a number of researchers like Rapties [22], Bejan and Khair [5] etc. Carragher and Crane [6] discussed heat transfer on a continuous stretching sheet. Sivaiah, Jayarami Reddy [24] analyzed the unsteady MHD heat and mass transfer flow of a radiating fluid past an accelerated inclined porous plate with hall current. Chand and Sapna [7,8] studied on perturbation analysis of unsteady heat and mass transfer in slip flow regime. Raju et al. [21] analyzed Heat and mass transfer in MHD mixed convection flow on a moving inclined porous plate. Numerical modeling of combined heat and mass transfer flows is important in many industrial applications including geothermal energy, solar energy systems, biomechanics. Wang and Chen [26] studied heat and mass transfer model of dielectric-material-assisted microwave freeze-drying of skim milk with hygroscopic effect. Vrentas and Vrentas[25] analyzed axial moment analyses of convective heat and mass transfer processes. Prasad et al.[19] studied radiation and mass transfer effects on two-dimensional flow past an impulsively started infinite vertical plate. Soret effect is very important characteristics in various chemical engineering flow domains. Its significance can be seen in various phenomenons such as separation of mixtures in thermal diffusion columns, planetary dynamics, thermal reaction electrochemical process, etc. Ahmed[3] analyzed the Soret and radiation effects on transient MHD free convection from an impulsively started infinite vertical plate. Afify [2] have investigated similarity solution in MHD effects of thermal diffusion and diffusion thermo on free convective heat and mass transfer over a stretching surface considering suction or injection. Andersson[4] studied MHD flow of a viscoelastic fluid past a stretching surface. Rajagopal et al.[20] studied flow of a viscoelastic fluid over a stretching sheet. Liao[13] had studied unsteady boundary-layer flows caused by an impulsively stretching plate. Sarma and Pandit [23] studied effects of Hall current; rotation and Soret effects on MHD free convection heat and mass transfer flow past an accelerated vertical plate through a porous medium. The study of effect of chemical reaction processes is of great practical importance to the engineers and scientists because of its almost universal occurrences in several branches of science and technology. The problems dealing with combined effects of heat and mass transfer with chemical reaction have great practical importance to scientists and engineers. The chemically reacting MHD boundary layer flow of heat and mass transfer over a moving vertical plate with suction was analyzed by Ibrahim and Makinde[12]. Prakash et al.[17,18] studied the Characterization of rotatory hydrodynamic Triply Diffusive convection.

Cortell[9] has studied the effects of viscous dissipation and radiation on the thermal boundary layer over a nonlinearly stretching sheet. Hydromagnetic flow near an oscillating wall with constant/periodic suction studied by Chand and Sapna [8]. Prakash et al. [16] studied on the Characterization of Non-oscillatory Motions in Triply Diffusive Convection. Dhanalakshmi and Reddy [10] studied heat and mass transfer effects on

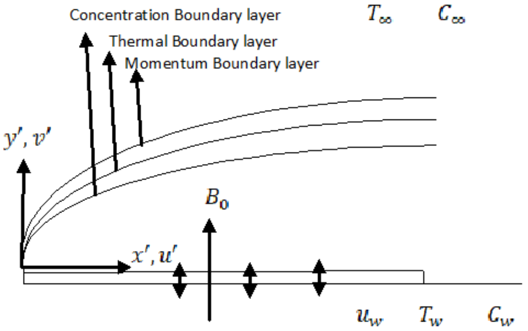
MHD free convective flow over a permeable stretching surface with suction, viscous dissipation and heat generation in the presence of chemical reaction. Nazar et al.[15] had studied stagnation point flow of a micro polar fluid towards a stretching sheet.

The objective of the present work is to analyze the effects of Soret, radiation and chemical reaction on unsteady two dimensional MHD laminar forced convective and stable boundary layer flow of incompressible viscous fluid past a heated stretching sheet moving with variable velocity in a porous medium subjected to a magnetic field, thermal diffusion, thermal radiation, viscous dissipation and chemical reaction effects. The present work is a generalization of the work done by Hunegnaw and Kishan [11] to consider the Soret effects and radiation on the flow characteristics.

In the present investigation a study of MHD free convective heat and mass transfer in a conducting fluid over a permeable stretching surface with suction, viscous dissipation and heat generation/absorption in the presence of chemical reaction. 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 equations governing the flow are solved numerically by Runge-Kutta fourth order along with shooting technique. The expressions for velocity, temperature and concentration are obtained graphically. The effects of unsteadiness parameter, Radiation Parameter, thermal conductivity, porous media parameter, Eckert number, variable viscosity, Suction parameter, Soret number, Schmidt number and chemical reaction are studied graphically.

2. Mathematical Analysis

We consider an unsteady two dimensional MHD laminar forced convective and stable boundary layer flow of incompressible viscous fluid past a heated stretching sheet moving with variable velocity u_w in a porous medium. It is assumed that the surface temperature is uniform and higher than the ambient temperature and all forces except magnetic field are neglected .The x'-axis runs along the stretching surface in the direction of motion and the y'-axis is measured normal to the sheet, $u'$and v'velocity components of the fluid in the x' and y' direction. A magnetic field of uniform strength B_0 is applied to the sheet.



Physical configuration of the geometry

Using the Boussinesq and usual boundary layer approximations, following Hunegnaw and Kishan [11] the equations governing the fluid flow reduce to:

$$\frac{\partial u'}{\partial x'} + \frac{\partial u'}{\partial y'} = 0 \tag{1}$$

$$\frac{\partial u'}{\partial t'} + u'\frac{\partial u'}{\partial x'} + v'\frac{\partial u'}{\partial y'} = -\frac{1}{\rho}\frac{\partial p}{\partial x'} + \frac{1}{\rho}\frac{\partial}{\partial y'}\left(\mu\frac{\partial u'}{\partial y'}\right) - \mu\frac{\varphi}{k}u' - \frac{\sigma {B_0}^2}{\rho}u' \tag{2}$$

$$\frac{\partial T}{\partial t'} + u'\frac{\partial T}{\partial x'} + v'\frac{\partial T}{\partial y'} = \frac{1}{\rho c_p}\frac{\partial}{\partial y'}\left(k\frac{\partial T}{\partial y'}\right) + \frac{\mu}{\rho c_p}\left(\frac{\partial u'}{\partial y'}\right)^2 - \frac{1}{\rho c_p}\frac{\partial {q'}_r}{\partial y'} \tag{3}$$

$$\frac{\partial C}{\partial t'} + u'\frac{\partial C}{\partial x'} + v'\frac{\partial C}{\partial y'} = D_m\frac{\partial^2 C}{\partial y'^2} - k'(C - C_\infty) + \mathrm{D_T}\frac{\partial^2 \mathrm{T}}{\partial \mathrm{y}'^2} \tag{4}$$

The boundary conditions are

$$u' = u_w(x,t) = \frac{cx}{(1-\alpha t)}, v' = v_w(t) = -v_0\sqrt{\frac{v^* x}{(1-\alpha t)}}, T = T_w(x,t), C = C_w(x,t) at\ y' = 0$$

$$u' \to 0,\ T \to T_\infty,\ C \to C_\infty\ as\ y' \to \infty \tag{5}$$

The radiative heat flux $q_r{}'$ is given by

$$q_r' = -\frac{4\sigma}{3a^*}\frac{\partial T^4}{\partial y'}, \tag{6}$$

where σ is the Stefan-Boltzmann constant and a^* is the Rosseland mean absorption coefficient

As we consider the temperature difference within the flow are sufficiently small, so that T^4 can be expressed in Taylor series about T_∞ and neglecting higher order terms,

$$T^4 = 4{T_\infty}^3 T - 3{T_\infty}^4 \tag{7}$$

We introduce a stream function $\Psi(x,y)$ such that

$$u' = \frac{\partial\Psi}{\partial y'}, v' = -\frac{\partial\Psi}{\partial x'} \tag{8}$$

The continuity equation (1) is obviously satisfied by Ψ.

To normalize the equations (2)-(4) into a set of ODE, the following similarity transformation and non-dimensional quantities are introduced as:

$$\eta = y\sqrt{\frac{c}{v^*(1-\alpha t)}}, \Psi = \sqrt{\frac{v^* c}{(1-\alpha t)}}\, xf(\eta), T = T_\infty + \frac{c}{2v^* x^2}\sqrt{\frac{1}{(1-\alpha t)^3}}\,\theta(\eta),$$

$$C = C_\infty + \frac{c}{2v^* x^2}\sqrt{\frac{1}{(1-\alpha t)^3}}\,\varphi(\eta), \theta = \frac{T-T_\infty}{T_W - T_\infty}, \varphi = \frac{C - C_\infty}{C_W - C_\infty}$$

$$k = k_\infty(1+\beta\theta), \theta = \frac{T-T_\infty}{T_W-T_\infty} + \theta_r, \theta_r = \frac{T_r - T_\infty}{T_W - T_\infty}, T_r = T_\infty - \frac{1}{a},$$

$$\mu = \mu_\infty\frac{\theta_r}{(\theta_r - \theta)}, Pr = \frac{\mu c_p}{k}, Sc = \frac{v^*}{D_m}, A = \frac{\alpha}{c}, v^* = \frac{\mu_\infty}{\rho}, \tag{9}$$

$$M = \frac{\sigma {B_0}^2(1-\alpha t)}{\rho c}, Ec = \frac{{u_w}^2}{c_p(T_W - T_\infty)}\ k_1 = \frac{k'(1-\alpha t)}{c}\ , \lambda = \frac{3N+4}{3N}\ N = \frac{k a^*}{4\sigma {T_\infty}^3}\ , Sr = \frac{D_T}{D_m}\ \frac{(T_w - T_\infty)}{(C_w - C_\infty)}$$

Using the above dimensionless quantities, the equations (2)-(4) in non-dimensional form are:

$$f''' = A\frac{\theta_r - \theta}{\theta_r}\left(\frac{\eta}{2}f'' + f'\right) + \frac{\theta_r - \theta}{\theta_r}f'^2 - \frac{\theta_r - \theta}{\theta_r}ff'' - \frac{\theta'}{\theta_r - \theta}f'' + M\frac{\theta_r - \theta}{\theta_r}f' + Kf' \tag{10}$$

$$(\lambda + \beta\theta)\theta'' = \mathrm{Pr}\left(1 - \frac{\theta}{\theta_r}\right)\left(\frac{1}{2}A\eta\theta' + \frac{3}{2}A\theta + 2f'\theta - f\theta'\right) - EcPrf''^2 \tag{11}$$

$$\varphi'' = Sc\left(\frac{3}{2}A\,\eta\varphi' - f\varphi' + 2f'\varphi + k'\varphi\right) - Sr\,\theta'' \tag{12}$$

Where,

G_r is the Grashof Number, Pr is the Prandtl Number, N is the thermal radiation parameter, Sc is the Schmidt Number, S_r is the Soret Number, k' is the Chemical Reaction Parameter, A is the Unsteadiness parameter, M is the Magnetic parameter, Ec is the Eckert number, Sc is the Schmidt number f_w is the Suction parameter, θ_r is the viscosity parameter,k is the thermal conductivity K is the porous medium parameter and k_∞ is the thermal diffusivity at the surface, respectively.

The corresponding non dimensional boundary conditions are:

$$f = f_w\ , f' = 1, \theta = 1, \varphi = 1\ at\ \eta = 0$$

$$f' = 0, \theta = 0, \varphi = 0\ at\ \eta \to \infty \tag{13}$$

From the process of numerical computation skin friction coefficient, Nusselt number and Sherwood number are worked out and their numerical values presented in tabular form.

3. Solution of the Problem

The governing boundary layer equations (2) to (4) subject to boundary conditions (5) are solved numerically by applying the fourth order Runge-Kutta method by using shooting technique. At First higher order non-linear differential equations (2) to (4) are converted into simultaneous linear differential equations of first order and they are further transformed into initial value problem by applying Runge Kutta fourth order along with shooting technique. From the process of numerical computation skin friction coefficient Nusselt number and Sherwood number are worked out and their numerical values presented in tabular form.

4. Results and Discussion

Under the above consideration the problem is solved numerically and observed the behaviors of velocity, temperature and concentration for various parameters such as unsteadiness parameter(A), Radiation Parameter(N), thermal conductivity (β), porous media parameter(K), Eckert number(Ec), variable viscosityθ_r, Suction parameterf_w, Soret number (Sr),Schmidt number(Sc) and chemical reaction (k') are depicted in graphs in Figs.1-20. Figures 1 and 2 are explored the effect of radiation parameter (N) on the velocity and temperature distributions, respectively. As shown in Figure 1 the values of the velocity increased under the effect of the radiation parameter. The increase in velocity with an increase in radiation parameter leads the boundary layer thickness to be wider. Furthermore, Figure 2 shows that the temperature of fluid increases with the increase of the radiation parameter. This means that higher radiation occur for higher values of temperature which cause the increase of velocity as well. From fig. 3-5 we have observed that the velocity and temperature decreases with the increase of unsteadiness parameter A but the concentration increases with the increase of A. It is found that the velocity boundary layer thickness increases with an increase in the unsteadiness parameter. From fig. 6-8 we observed that the effect of permeability parameter on the velocity, temperature and concentration profiles. Temperature and concentration increases with the increase of K but velocity decreases. It is noticed that increasing the porous media parameter is concluded retarding effect of porous medium on the flow. Figure 9 is a graphical representation of the temperature distribution for different values of Eckert number versus η. From fig. 10-12 we observed that the Velocity, temperature and concentration increases with the increase of viscosity parameterθ_r. Physically, the thermal viscosity cause a rise in friction, when friction increases, the area of the stretching surface in contact with the flow increases so generated heat from the friction on the surface is transferred to the flow. Therefore the surface temperature arises and the flow is heated. From fig. 13-15 we observed that the Velocity, temperature and concentration decreases with the increase of f_w i.e. imposition of wall fluid suction has the effect of reducing the velocity boundary layer causing the fluid velocity tends to decreases. Also fluid suction causing a lower thermal boundary layer which corresponds to a higher temperature gradient. So the temperature reaches a minimum value and similarly for concentration distribution. It is known that the imposition of wall suction has the tendency to reduce all the momentum, thermal as well as concentration boundary layer thickness. This causes reduction in all the velocity, temperature and concentration profiles .From fig. 16, 17 & 18 we observed that the concentration increases with the increase of Soret number but decreases with the increase of Schmidt Number and chemical reaction parameter .The Schmidt number is defined as the ratio of momentum diffusivity and mass diffusivity. Thus, increasing the Schmidt number is leading to a fall in the concentration values. Moreover, when the reaction rate parameter increases, the consumption of the species increases. This means that the concentration of the species tends to drop. For different values of Pr, the velocity and temperature profiles are shown in fig 19 and fig 20. An increase in Prandtl number is lead to fall in the velocity and temperature. In heat transfer problem, Pr controls the relative thickening of the momentum and thermal boundary layers. So to increase the rate of cooling in conducting flows, Prandtl number may be used.

The values of skin friction, Nusselt number and Sherwood number are shown in Table 1. It is observed from the table that the local skin-friction coefficient, local heat and mass transfer rates at the plate increases with an increase in the buoyancy forces. It was noticed that the local heat and mass transfer rates at the plate decreases but the local skin-friction coefficient with an increase in the M, K andβ. As Pr or N increases, both the skin-friction and Sherwood number decrease, whereas the Nusselt number increases. It was found that the local heat and mass transfer rate at the plate decreases, but Skin-friction coefficient increases with an increase in θ_r or A. As the f_w increases, the skin-friction increase, the Nusselt number and Sherwood number increases. The effect of the Soret number is to decrease but the effect of the Schmidt number and chemical reaction are to increase the Sherwood number.

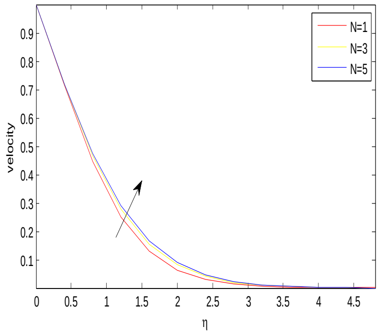


Fig-1. Velocity profile for different values of Radiation parameter N
A=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71;
β=1;K=.5;k'=0.5;Sc=2;f_w=1 ;Sr=1

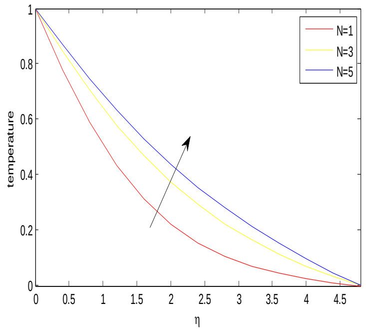


Fig-2. Temperature profile for different values of Radiation parameter N
A=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71;
β=1;K=.5;k'=0.5;Sc=2;f_w=1 ;Sr=1

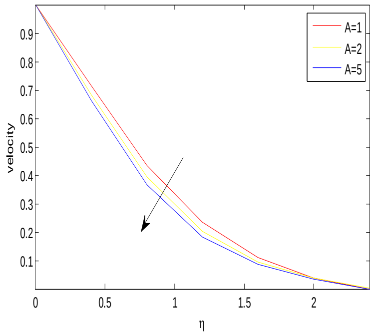


Fig-3. Velocity profile for different values of Unsteadiness parameter A
N=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71;
β=1;K=.5;k'=0.5;Sc=2;f_w=1 ;Sr=1

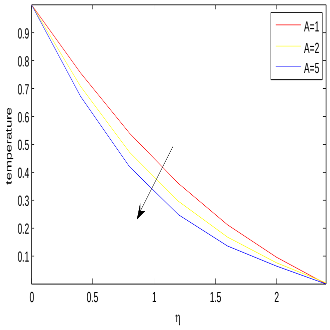


Fig-4. Temperature profile for different values of Unsteadiness parameter A
N=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71;
β=1;K=.5;k'=0.5;Sc=2;f_w=1 ;Sr=1

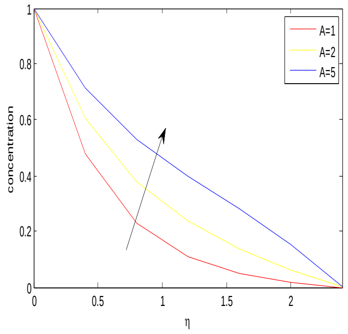


Fig-5. Concentration profile for different values of Unsteadiness parameter A
N=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71;
β=1;K=.5;k'=0.5;Sc=2;f_w=1 ;Sr=1

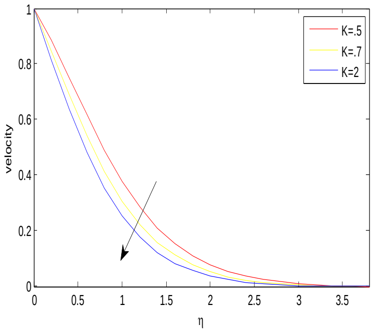


Fig-6. Velocity for different values of porous media parameter K
A=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71;
N=1;K=.5;k' =0.5;Sc=2;f_w=1 ;Sr=1

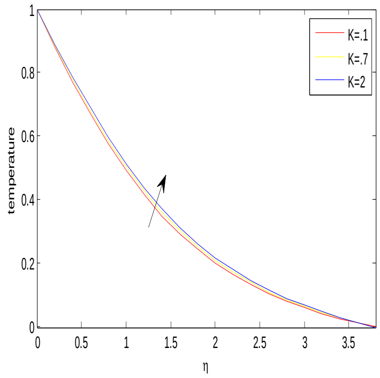


Fig-7. Temperature profile for different values of porous media parameter K
A=1; M=0.2; Ec=.5; θ_r=1.2; Pr=.71; N=1; K=.5; k'=0.5; Sc=2;f_w=1; Sr=1

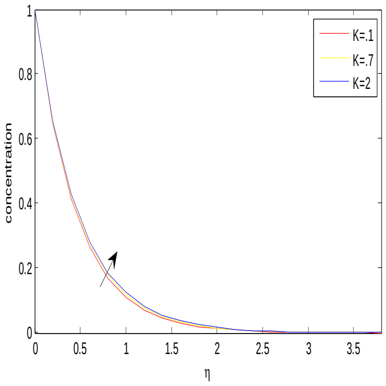


Fig-8. Concentration profile for different values of porous media parameter K
A=1; M=0.2; Ec=.5; θ_r=1.2; Pr=.71; N=1; K=.5; k'=0.5;Sc=2;f_w=1; Sr=1;

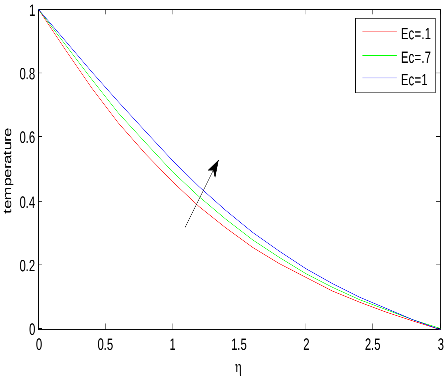


Fig-9. Temperature profile for different values of Eckert number Ec
A=1;M=0.2; θ_r=1.2;Pr=.71; N=1; K=.5;k'_1=0.5;Sc=2;f_w=1 ;Sr=1; β=1

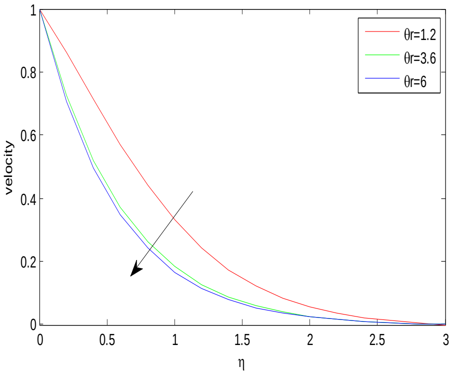


Fig-10. Velocity profile for different values of variable viscosity θ_r
A=1;M=0.2;Ec=.5;Pr=.71; N=1; K=.5;k'_1=0.5;Sc=2;f_w=1 ;Sr=1; β=1

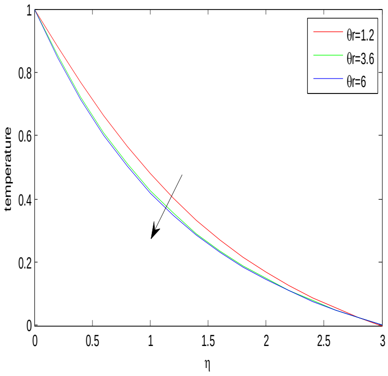


Fig-11. Temperature profile for different values of variable viscosity θ_r
A=1; M=0.2; Ec=.5;Pr=.71; N=1; K=.5;k'=0.5;Sc=2;f_w=1 ;Sr=1

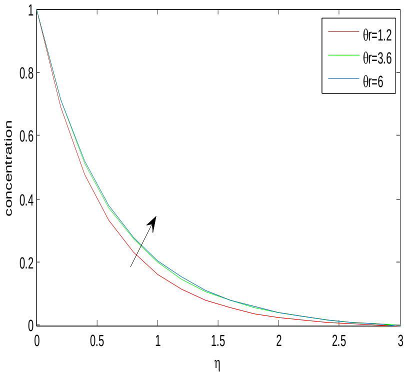


Fig-12. Concentration profile for different values of variable viscosity θ_r
A=1; M=0.2; Ec=.5;Pr=.71; N=1; K=.5;k'=0.5;Sc=2; f_w=1 ;Sr=1

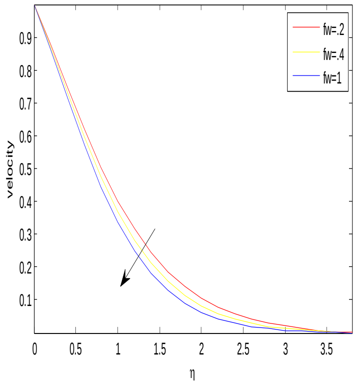


Fig-13. Velocity profile for different values of suction parameter f_w
A=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71; N=1;
K=.5;k'=0.5;Sc=2;Sr=1; β=1

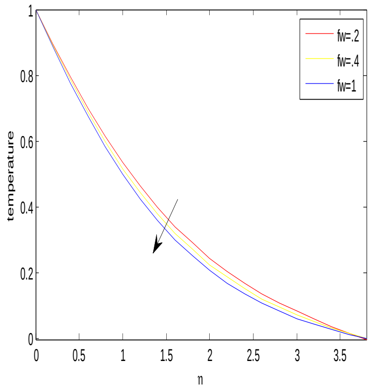


Fig-14. Temperature profile for different values of suction parameter f_w
A=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71; N=1;
K=.5;k'=0.5;Sc=2;Sr=1; β=1

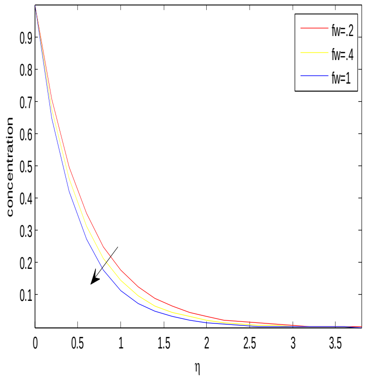


Fig-15. Concentration profile for different values of suction parameter f_w
A=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71; N=1;
K=.5;k'=0.5;Sc=2;f_w=1 ;Sr=1; β=1

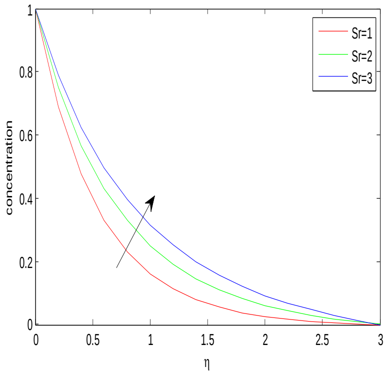


Fig-16. Concentration profile for different values of Soret number Sr
A=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71; N=1;
K=.5;k'=0.5;Sc=2;f_w=1; β=1

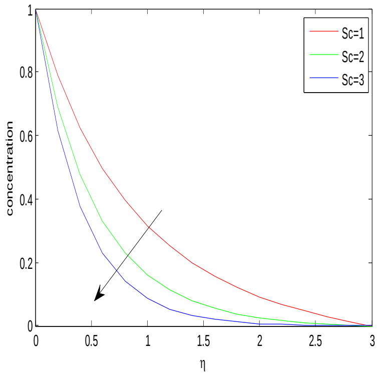


Fig-17. Concentration profile for different values of Schmidt number Sc
A=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71; N=1;
K=.5;k'=0.5;f_w=1 ;Sr=1; β=1

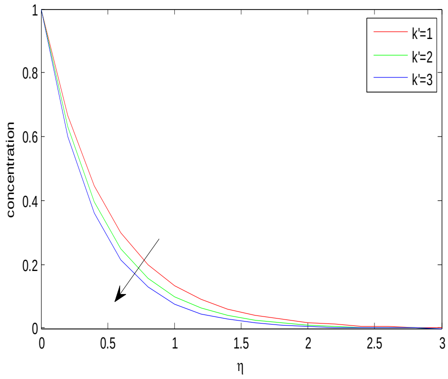


Fig-18. Concentration profile for different values of Chemical reaction k'
A=1;M=0.2;Ec=.5;θ_r=1.2;Pr=.71; N=1;
K=.5;Sc=2;f_w=1 ;Sr=1; β=1

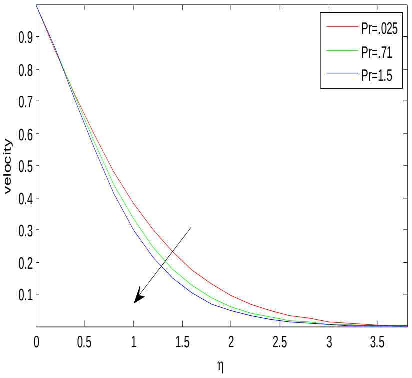


Fig-19. Velocity profile for different values of Prandtl number Pr
A=1;M=0.2;Ec=.5;θ_r=1.2;$k' = .5$; N=1; K=.5;Sc=2;f_w=1;Sr=1; β=1

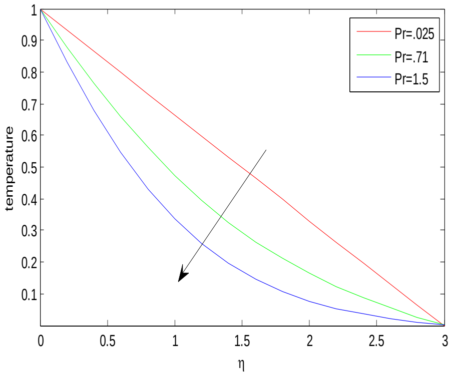


Fig-20. Temperature profile for different values of Prandtl number Pr
A=1;M=0.2;Ec=.5;θ_r=1.2;$k' = .5$; N=1; K=.5;Sc=2;f_w=1;Sr=1; β=1

Table 1.Numerical values of skin friction, Nusselt number and Sherwood number for different values of A,M, θ_r ,Pr,N, β ,K, k',Sc, f_w and Sr

A	M	θ_r	Pr	N	β	K	Sc	f_w	Sr	k'	c_f	Nu	Sh
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.248181	0.406226	0.828079
3	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.263932	0.496199	0.574877
5	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.277617	0.558040	0.404890
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.248181	0.406226	0.828079
1	**.6**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.263552	0.400173	0.824184
1	**1**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.278303	0.394487	0.820531
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.250253	0.402529	0.827208
1	**.2**	**3.6**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.694730	0.528922	0.773752
1	**.2**	**6**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.761636	0.550857	0.766327
1	**.2**	**1.2**	**.025**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.294117	0.186057	0.834600
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.247125	0.413476	0.827853
1	**.2**	**1.2**	**1.5**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.226202	0.593443	0.822358

1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.250253	0.402529	0.827208
1	**.2**	**1.2**	**.71**	**3**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.279679	0.246339	0.831748
1	**.2**	**1.2**	**.71**	**5**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.289550	0.208286	0.832720
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.307135	0.152040	0.833945
1	**.2**	**1.2**	**.71**	**1**	**.5**	**.5**	**2**	**1**	**1**	**1**	0.314910	0.131273	0.834279
1	**.2**	**1.2**	**.71**	**1**	**1**	**.5**	**2**	**1**	**1**	**1**	0.320120	0.119258	0.834393
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.248181	0.406226	0.828079
1	**.2**	**1.2**	**.71**	**1**	**.1**	**1.2**	**2**	**1**	**1**	**1**	0.321864	0.388017	0.814974
1	**.2**	**1.2**	**.71**	**1**	**.1**	**2**	**2**	**1**	**1**	**1**	0.391459	0.371285	0.803340
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.307135	0.152040	0.542029
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**4**	**1**	**1**	**1**	0.307135	0.152040	1.295833
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**.2**	**1**	**1**	0.227030	0.353918	0.636772
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**.6**	**1**	**1**	0.238014	0.377173	0.726109
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.250253	0.402529	0.827208
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**1**	0.250253	0.402529	0.827208
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**3**	**1**	0.250253	0.402529	0.53440
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**.5**	0.559583	0.900082	1.849694
1	**.2**	**1.2**	**.71**	**1**	**.1**	**.5**	**2**	**1**	**1**	**2**	0.559583	0.900082	2.215075

5. Conclusion

In this paper, we have studied an unsteady two dimensional MHD laminar forced convective and stable boundary layer flow of incompressible viscous fluid past a heated stretching sheet moving with variable velocity in a porous medium under the effect of thermal diffusion and radiation. The governing equations which describe the problem are transformed to ODE by using similarity transformation. These equations are solved by Runge-Kutta fourth order method along with shooting technique. The results are presented graphically and analyzed. The following results are investigated**.**

The present work investigation leads to the following conclusions:

- Arise in A decreases the velocity, temperature profile but increases concentration distribution.

- Arise in θ_r, f_w decreases the velocity profile, temperature and concentration distribution.
- An increase in K contributes to decrease the velocity and concentration profile but increase the temperature distribution.
- An increase in Soret number contributes to increase the concentration profile and increase in Sc contributes to decrease the concentration profile.
- An increase N, β, Ec contributes to increase the velocity field and temperature distribution but decrease in concentration profile.
- An increase in the M, K and β contributes to increase local skin-friction coefficient but local heat and mass transfer rates at the plate decreases with an increase in the M, K and β.
- The effect of the Soret number is to decrease but the effect of the Schmidt number and chemical reaction are to increase the Sherwood number.

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