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Mhd Convective Heat Transfer Flow Of Kuvshinski Fluid Past An Infinite Moving Plate Embedded In A Porous Medium With Thermal Radiation Temperature Dependent Heat Source And Variable Suction

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Abstract: *This chapter deals with the MHD convective heat transfer flow of kuvshinski fluid through a porous medium past an infinite moving porous plate in the presence of temperature dependent heat source radiation and variable suction. The fluid flow direction is taken as x-axis and normal to it as y-axis. A uniform magnetic field is applied perpendicular to the flow. The governing non-dimensional equations are analytically when i) The plate is with constant temperature (CWT) and ii) Theplate is variable temperature (VWT). The expressions for velocity, temperature fields are obtained. Skin friction coefficient and the rate of heat transfer in terms of nusselt number (Nu) are also derived. Results are discussed and analysed for various material parameters through graphs and tables.*
Keywords: *Kuvshinski fluid; MHD; boundary layer; porous medium; thermal radiation; heat generation.*

I. Introduction

The study of radiation in thermal engineering is of great interest for industry point of view,Many processes in thermal engineering areas occur at high temperature and radiative heat transfer becomes very important for design of pertinent equipment. The study of flow and heat transfer for an electrically conducting fluid past a porous plate under the influence of magnetic field has attraction in the interest of many investigators in view of its applications in many engineering problems such as magnetohydrodynamics generator, plasma studies, nuclear reactors, geothermal energy extractions and the boundary layer control in the field of aerodynamics. In In recent times chemical reaction and radiation absorption influences the fluid flow attracted the attention of engineers and scientists. There are many interesting aspects and analytical solutions to such problems of flow have been presented by many authors [1] Pohlhausen et al. studied the free convection flow past a semi – infinite vertical plate by the momentum integral method because free convection flows have wide applications in industry. [2] Ostrach S solved the non-liner coupled ordinary differential equations numerically on a computer. [3] P.G. Saffirman studied the stability of laminar flow of a dusty gas. [4] Gill et al. observed diffusion and heat transfer in laminar free convection boundary layers on a vertical plate. [5] Takhar et al. studied radiation effects on MHD free convection flow of a radiating gass past a semi-infinite plate. [6]Soundalker studied approximate solutions for the two diffusional flow of an impressible viscous fluid past an infinite porous vertical plate with constant suction velocity normal the plate. [7] V.M.Soundalger et al. studied magnetohydrodynamics (MHD) generator, plasma nuclear reactors, geothermal energy extractions and the boundary layer control in the field of aerodynamics. [8] Raptis and Kafousians studied influence of a magnetic field upon the steady free convection flow through a porous medium bounded by an infinite vertical plate with constant suction velocity. [9].A.A.Raptisstudied Time-varying two-dimensional natural convective heat transfer on an incompressible, electrically-conductive viscous fluid via a highly porous medium bounded by an infinite vertical porous plate. [10].H.T.Chenand C.K.Chen observed free convection of non-newtonian Fluid Flow along a vertical plate embedded in a porous medium. [11] KeeSoohan et al. analysed heat transfer in a pipe carrying two – phase gas particle suspension. [12]Sharma PR and PankajMathur studied steady laminar free convection flow of an electrically conducting fluid along a porous hot vertical plate in the presence of heat source/sink. [13]Takhar H.S et al. observed radiation effects on MHD free convection flow of a radiating gas past a semi-infinite vertical plate. [14] M.A.Mansour observed forced convection-radiation interaction heat transfer in boundary layer over a flat plate submerged in a porous medium.[15] Helmy A.K studied MHD unsteady free convection flows past a vertical porous plate.[16] Edmundo M. et al. analysed Numerical model for radiative heat transfer analysis in arbitrary shaped axisymmetric enclosures with gases media. [17] A. Raptis studied radiation and free convection flow through a porous medium.[18] M.A.Hossain et al. observed the effect of radiation in free convection from a porous vertical plate.[19] M.A. El.Hakiem considered MHD oscillatory flow on free convection-radiation through a porous medium with constant suction velocity. [20] Acharya M.et al. observed magnetic field effects on the free convection and mass transfer flow through porous medium with constant suction and constant heat flux. [21] Kim Youn J. studied unsteady MHD convective heat transfer past a semi-infinite vertical porous moving plate with variable suction. [22] E.M.AboEldahab and M.S.E.Gendy observed radiation effects on convective heat transfer in an electrically conducting fluid at a stretching surface with variable viscosity and uniform free stream.[23] E.M.AboEldahab and M.S.E.Gendy studied convective heat transfer past a continuously moving plate embedded in a non-darcian porous medium in the presence of a magnetic field. [24] Sahoo P.K et al. studied magnetohydrodynamic unsteady free convection flow past an infinite vertical plate with constant suction and heat sink. [25] Isreal-cookey et al. observed Influence of viscous dissipation and radiation on unsteady MHD free –convection flow past an infinite heated vertical plate in a porous medium with time dependent suction. [26] Raptis et al. observed effect of thermal radiation on MHD flow.[27] R.K.Varshney and Ram Prakash studied the effects of MHD free convection flow of a visco-elastic dusty gas through a porous medium induced by the motion of a semi-infinite flat plate moving with velocity decreasing exponentially with time. [28] R. Muthukumaraswamy and G. Kumar Senthil, observed the heat and Mass transfer effect on moving vertical plate in the presence of thermal radiation. [29]Chamkaali J. studied unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption. [30] S.Shateyi et al. observed magnetohyderodynamics flow past a vertical plate with radiative heat transfer. [31] Ibrahim et al. studied effect of the chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with het source and suction.[32] P.M Patil, andP.S.Kulkarni studied effects of chemical reaction on free convection flow of a polar fluid through a porous medium in the presence of Internal heat generation. [33] O.A. Beg et al. observed magneto hydrodynamic convection flow from a sphere to a non-darcian porous medium with heat generation or absorption effects network simulation. [34] Kumar H. studied radiativeheat transfer with hydromagenatic flow and viscous dissipation over a stretching surface in the presence of variable heat flux. [35] O.D.Makinde and T. Chinyoka, studied numerical investigation of transient heat transfer to hydromagnetic channel flow withradiative heat and convective cooling. [36] J. Gireesh Kumar, P.V.Satynarayanaobserved Mass transfer effect on MHD unsteady free convective walterns memory flow with constant suction and heat sink. [37] R.M. Mishra, G.C.Dash premeditated mass and heat transfer effect on MHD flow of a visco-elastic fluid through porous medium with oscillatory suction and heat source. [38] Reddy et al. studied combined effect of heat absorption and MHD on convective Rivlin-Erichsen flow past a semi-infinite vertical porous plate with variable temperature and suction. [39] M. Umamaheswar et al. studied combined radiation and ohmic heating effects on MHD free Convective visco-elastic fluid flow past a porous plate with viscous dissipation. [40] B.Seshaiah et al. studied the effects of chemical reaction and radiation on unsteady MHD free convective fluid flow embedded in a porous medium with time-depended suction with temperature gradient heat source. [41] M.C.raju et al. studied unsteady MHD free convection and chemically reactive flow past an infinite vertical porous plate. [42] B. Vidyasagar et al. Observed unsteady MHD free convection boundary layer flow of radiation absorbing Kuvshinski fluid through porous medium. [43] M.C.Rajuet al. radiation absorption effect on MHD free convection chemically reacting visco-elastic fluid past an oscillatory vertical porous plate in slip regime.MHD three dimensional Couette flow past an exponentially accelerated vertical plate with variable temperature and concentration in the presence of Soret and Dufour effects by Umamaheswar et al. [46].

In the past few years, there are several papers on MHD flows and chemical reactions i.e., combined effect of heat absorption and MHD on convective Rivin – Erichsen flow past a semi-infinite vertical porous plate with variable temperature and suction, combined radiation and ohmic heating effects on MHD free convective visco-elastic fluid flow past a porous plate with viscous dissipation, effects of chemical reaction and radiation on unsteady MHD free convective fluid flow embedded in porous medium with time-depended suction with temperature gradient heat source, MHD free convection and chemical reactive flow past an infinite vertical porous plate, Unsteady MHD free convection boundary layer flow of radiation absorbing kuvshinski fluid through a porous medium, radiation absorption effect on MHD free convection chemically reacting visco-elastic fluid past an oscillatory vertical porous plate in slip regime, for example papers by B. Umamaheswar et al. [39], B. Sesaiah et al. [40], M.C.Raju et al. [41], Vidyasagar et al. [42], Raju et al.[43] and Rao et al [45] . However, none of these papers discussed the effects of the MHD convective heat transfer flow of kuvshinski fluid past an infinite moving plate embedded in a porous medium with radiation temperature dependent heat source and variable suction. Thus, the aim of the present paper is to investigate the MHD convective heat transfer flow of kuvshinski fluid past an infinite moving plated embedded in a porous medium with radiation temperature dependent heat source and variable suction.

II. Mathematical formulation

Two dimensional unsteady flows of a laminar, conducting and heat generation / absorption fluid past a semi-infinite vertical moving porous plate embedded in a uniform porous medium and subject to a uniform magnetic field in the presence of a pressure gradient have been considered with free convection and thermal radiation effects. According to the coordinate system the x^* -axis is taken along the porous plate in the upward direction and y^*-axis normal to it. The fluid is assumed to be gray, absorbing-emitting but non-scattering medium. The radiative heat flux in the x^*-direction is considered negligible in comparison with that in the y^*-direction. It is assumed that there is no applied voltage of which implies the absence of an electric field. The transversely applied magnetic field and magnetic Reynolds number are very small and hence the induced magnetic field is negligible. Viscous and Darcy resistance terms are taken into account in the constant permeability porous medium. The MHD term is derived from the order of magnitude analysis of the full Navier-stokes equation. It is assumed here that the hole size of the porous plate is significantly larger than a characteristics microscopic length scale of the porous medium. We regard the porous medium as an assemblage of small identical spherical particles fixed in space. The fluid properties are assumed to be constant except that the influence of density variation with temperature has been considered in the body-force term. Due to the semi-infinite place surface assumption furthermore, the flow variable are function of y^* and t^* only. The governing equation for this investigation is based on the balance of linear momentum energy. Taking into consideration the assumption made above, these equations can be written in Cartesian frame of reference, as follows;

$$\frac{\partial v^*}{\partial y^*} = 0 \qquad \text{---(1)}$$

$$\rho\left\{\left(1+\lambda_1^*\frac{\partial}{\partial t^*}\right)\frac{\partial u^*}{\partial t^*} + v^*\frac{\partial u^*}{\partial y^*}\right\} = -\left(1+\lambda_1^*\frac{\partial}{\partial t^*}\right)\frac{\partial p^*}{\partial x^*} + \mu\frac{\partial^2 u^*}{\partial y^{*2}} - \rho g$$
$$-\left(\sigma B_o^2 + \frac{\mu}{K^*}\right)\left(1+\lambda_1^*\frac{\partial}{\partial t^*}\right)u^* \qquad \text{---(2)}$$

$$\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*} = \frac{\kappa}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{Q_0}{\rho C_p}(T^* - T_\infty^*) - \frac{1}{\rho C_p}\frac{\partial q_r^*}{\partial y^*} \qquad \text{---(3)}$$

The boundary conditions at the wall and in the free stream are:

$$u^* = u_p^*,\ T^* = T_W^* + \varepsilon A_T(T_W^* - T_\infty^*)e^{n^*t^*} \quad at \quad y^* = 0 \qquad \text{---(4)}$$

$$u^* \to U_\infty^* = U_0(1+\varepsilon e^{n^*t^*}),\ T^* \to T_\infty^* \text{ as } y^* \to \infty \qquad \text{---(5)}$$

Where A_T is a constant taking value 0 or 1.

If plate is with Variable Wall Temperature (VWT) then $A_T = 1$

If plate is with Constant Wall Temperature (CWT) then $A_T = 0$

Where u^*, v^*-velocity components in X, Y directions respectively, g -Gravitational acceleration, t^* -Time, υ -Kinematic coefficient of viscosity, σ -Electrical conductivity, μ -The viscosity, ρ -Density of the fluid, λ_1^* -the coefficient of Kuvshinski fluid, T^* -Temperature of the fluid, T_w^* -The temperature at the plate , T_∞^* -The temperature of fluid in free stream, κ - Thermal conductivity, C_P -Specific heat at constant pressure, q_r^* -Radiative heat flux, K^* -Permeability parameter of the porous medium, U_0 and n^* - constants. The magnetic and viscous dissipations are neglected in the study. It is assumed that the porous plate moves with a constant velocity, u_p^* in the direction of fluid flow, and the free stream velocity U_∞^* follows the exponentially increasing small perturbation law. In addition, it is assumed that the temperature and concentration at the wall as well as the suction velocity are exponentially varying with time.

It is clear from equation (1) that the suction velocity at the plate surface is a function of time only. Assuming that it takes the following exponential form:

$$v^* = -V_0\left(1+\varepsilon A e^{n^*t^*}\right) \qquad \text{---(6)}$$

Where A is a real positive constant, ε and εA are small less than unity and V_0 is a scale of suction velocity which has non-zero positive constant

In the free steam, from equation (2) we get

$$\rho\frac{dU_\infty^*}{dt^*} = -\frac{\partial p^*}{\partial x^*} - \rho_\infty g - \sigma B_0^2 U_\infty^* - \frac{\mu}{K^*}U_\infty^* \qquad \text{---(7)}$$

Eliminating $\frac{\partial P^*}{\partial x^*}$ between equation (2) and equation (7), we obtain

$$\rho\left\{\left(1+\lambda_1^*\frac{\partial}{\partial t^*}\right)\frac{\partial u^*}{\partial t^*} + v^*\frac{\partial u^*}{\partial y^*}\right\} = \rho\left\{\left(\left(1+\lambda_1^*\frac{\partial}{\partial t^*}\right)\right)\right\}\frac{dU_\infty^*}{dt^*} + \mu\frac{\partial^2 u^*}{\partial y^{*2}}$$
$$+(\rho_\infty - \rho)g + \left(\sigma B_0^2 + \frac{\mu}{K^*}\right)\left(1+\lambda_1^*\frac{\partial}{\partial t^*}\right)(U_\infty^* - u^*) \qquad \text{---(8)}$$

By making use the equation of state

$$(\rho_\infty - \rho) = \rho\beta(T^* - T_\infty^*) \qquad \text{---(9)}$$

Where β is the volumetric coefficient of thermal expansion and ρ_∞ is the density of the fluid far away the surface. Then from equation (9) and (8) we obtain

$$\left(1+\lambda_1^*\frac{\partial}{\partial t^*}\right)\frac{\partial u^*}{\partial t^*} + v^*\frac{\partial u^*}{\partial y^*} = \left(1+\lambda_1^*\frac{\partial}{\partial t^*}\right)\frac{dU_\infty^*}{dt^*} + \upsilon\frac{\partial^2 u^*}{\partial y^{*2}} + g\beta(T^* - T_\infty^*)$$
$$+\left(\frac{\sigma B_0^2}{\rho} + \frac{v}{K^*}\right)\left(1+\lambda_1^*\frac{\partial}{\partial t^*}\right)(U_\infty^* - u^*) \qquad \text{---(10)}$$

The radiation flux on the basis of the Rosseland diffusion model for radiation heat transfer is expressed as:

$$q_r^* = -\frac{4\sigma^*}{3k_1^*}\frac{\partial T^{*4}}{\partial y^*} \qquad \text{---(11)}$$

Where σ^* and k_1^* are respectively Stefan – Boltzmann constant and the mean absorption coefficient. We assume that the temperature difference within the flow are sufficiently small such that T^{*4} may be expressed as a linear function of the temperature. This is accomplished by expanding in Taylor series about T_∞^* and neglecting higher order terms, thus

$$T^{*4} \cong 4T_\infty^{*3}T^* - 3T_\infty^{*4} \qquad \text{---(12)}$$

By using equation (12) and (13) into equation (3) is reduced to

$$\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*} = \frac{\kappa}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{Q_0}{\rho C_p}(T^* - T_\infty^*) - \frac{16\sigma^* T_\infty^{*3}}{3\rho C_p k_1^*}\frac{\partial^2 T^{*4}}{\partial y^{*2}} \qquad \text{---(13)}$$

We now introduce the dimension less variables, as follows:

$$\left.\begin{array}{l} u = \frac{u^*}{U_0},\ v = \frac{v^*}{V_0},\ y = \frac{y^* V_0}{\upsilon},\ U_\infty^* = U_\infty U_0,\ u_p^* = U_p U_0 \\ t = \frac{t^* V_0^2}{\upsilon},\ n = \frac{n^* v}{V_0^2},\ \theta = \frac{T^* - T_\infty^*}{T_w^* - T_\infty^*} \end{array}\right\} \qquad \text{---(14)}$$

Then substituting from equation (14) into equations (10) and (13) and taking into account equation (6), we obtain

$$\left(1+\lambda_1\frac{\partial}{\partial t}\right)\frac{\partial u}{\partial t} - (1+\varepsilon A e^{nt})\frac{\partial u}{\partial y} = \left(1+\lambda_1\frac{\partial}{\partial t}\right)\frac{dU_\infty}{dt} + \frac{\partial^2 u}{\partial y^2}$$

$$+G_r\theta + N\left(1+\lambda_1\frac{\partial}{\partial t}\right)(U_\infty - u) \qquad \text{---(15)}$$

$$\frac{\partial\theta}{\partial t} - (1+\varepsilon Ae^{nt})\frac{\partial\theta}{\partial y} = \frac{1}{P_r}\left(1+\frac{4R}{3}\right)\frac{\partial^2\theta}{\partial y^2} + \eta\theta \qquad \text{---(16)}$$

Where

$G_r = \dfrac{\upsilon g\beta(T_w^* - T_\infty^*)}{V_0^2 U_0}$ (Thermal Grashof number)

$M = \dfrac{\sigma B_o^2 \upsilon}{\rho V_0^2}$ (Magnetic field parameter)

$K = \dfrac{K^* V_0^2}{\upsilon^2}$ (Permeability parameter)

$\eta = \dfrac{\upsilon Q_0 K^*}{\rho V_0^2 C_p}$ (Heat generation / absorption parameter)

$R = \dfrac{4\sigma^* T_\infty^{*3}}{kk_1^*}$ (Thermal radiation parameter)

$P_r = \dfrac{\rho\upsilon C_p}{k}$ (Prandtl number)

$\lambda_1 = \dfrac{\lambda_1^* V_0^2}{\upsilon}$ (Visco-elastic parameter)

$$N = \left[M + \frac{1}{K}\right] \qquad \text{---(17)}$$

The corresponding boundary conditions are

$$u = U_p,\ T = 1+\varepsilon A_T e^{nt}\ \ at\ y = 0 \qquad \text{---(18)}$$

$$u \to U_\infty = 1+\varepsilon e^{nt},\ T \to 0,\ \ as\ y \to \infty \qquad \text{---(19)}$$

Analytical Approximate Solution

In order to reduce the above system of partial differential equations to a system of ordinary equations in dimensionless form, we may represent the velocity and temperature as

$$u = u_0(y) + \varepsilon e^{nt} u_1(y) + O(\varepsilon^2) \qquad \text{---(20)}$$

$$\theta = \theta_0(y) + \varepsilon e^{nt}\theta_1(y) + O(\varepsilon^2) \qquad \text{---(21)}$$

By substituting the above equations (20),(21) into equations (15)&(16), equating the harmonic and non-harmonic term and neglecting the higher – order terms of O ((ε^2) ,we obtain the following pairs of equations for (u_o, θ_0) and (u_1, θ_1)

$$u_o'' + u_o' - Nu_o = -N - G_r\theta_o \qquad \text{---(22)}$$

$$u_1'' + u_1' - (N+n)(1+n\lambda_1)u_1 = -(1+n\lambda_1)(N+n) - Au_o' - G_r\theta_1 \qquad \text{---(23)}$$

$$(3+4R)\theta_o'' + 3\Pr\theta_0' + 3\eta\Pr\theta_o = 0 \qquad \text{---(24)}$$

$$(3+4R)\theta_1'' + 3\Pr\theta_1' - 3(n-\eta)\theta_1 = -3A\Pr\theta_o' \qquad \text{---(25)}$$

Where, the primes denote differentiation with respect to y.

The corresponding boundary conditions are

$$u_o = U_p,\ u_1 = 0,\ \theta_0 = 1,\ \theta_1 = A_T \quad at \quad y = 0 \qquad \text{---(26)}$$

$$u_o = 1,\ u_1 = 1,\ \theta_0 \to 0\ \theta_1 \to 0\ \ as\ y \to \infty \qquad \text{---(27)}$$

The analytical solutions of equations (22) to (25) with satisfying boundary conditions (26) and (27) are given by

$$u_0 = (u_p + P_1 - 1)e^{-L_0 y} + 1 - P_1 e^{-m_0 y} \qquad \text{---(28)}$$

$$u_1 = c_1 e^{-L_1 y} + 1 + R_1 e^{-L_0 y} - R_2 e^{-m_0 y} - R_3 e^{-m_1 y} \qquad \text{---(29)}$$

$$\theta_o = e^{-m_0 y} \qquad \text{---(30)}$$

$$\theta_1 = (A_T - P_0)e^{-m_1 y} + P_0 e^{-m_0 y} \qquad \text{---(31)}$$

Where

$a_0 = 3 + 4R$	$A_0 = u_p + P_1 - 1$	$m_0 = \dfrac{b_0 + \sqrt{b_0^2 - 4a_0 c_0}}{2}$	$R_1 = \dfrac{B_0}{L_0^2 - L_0 - A_1}$
$b_0 = 3P_r$	$B_0 = AA_0 L_0$	$m_1 = \dfrac{b_0 + \sqrt{b_0^2 - 4a_0 a_1}}{2}$	$R_2 = \dfrac{C_0}{m_0^2 - m_0 - A_1}$
$c_0 = 3\eta P_r$	$C_0 = AP_1 m_0 + G_r P_0$	$P_0 = \dfrac{-m_0 b_1}{a_0 m_0^2 + b_0 m_0 + a_1}$	$R_3 = \dfrac{B_1}{m_1^2 - m_1 - A_1}$
$a_1 = -3(n - \eta)$	$A_1 = (N + n)(1 + n\lambda_1)$	$P_1 = \dfrac{G_r}{m_0^2 - m_0 - N}$	
$b_1 = -3AP_r$	$B_1 = G_r(A_T - P_0)$	$L_0 = \dfrac{1 + \sqrt{1 + 4N}}{2}$	
$A_T = C_1 + P_0$	$C_1 = A_T - P_0$	$L_1 = \dfrac{1 + \sqrt{1 + 4A_1}}{2}$	

In view of the above solution, the velocity and temperature distribution in the boundary layer become

$$u(y,t) = (u_p + P_1 - 1)e^{-L_0 y} + 1 - P_1 e^{-m_0 y}$$
$$+ \varepsilon e^{nt}(c_1 e^{-L_1 y} + 1 + R_1 e^{-L_0 y} - R_2 e^{-m_0 y} - R_3 e^{-m_1 y}) \qquad \text{---(32)}$$

$$\theta(y,t) = e^{-m_0 y} + \varepsilon e^{nt}[(A_T - P_0)e^{-m_1 y} + P_0 e^{-m_0 y}] \qquad \text{---(33)}$$

It is now important to calculate the physical quantities of primary interest, which are the local wall shear stress, the local surface heat flux. Given the velocity field in the boundary layer, we can now calculate the local wall shear stress (i.e., skin-friction) is given by

$$\tau_w^* = \mu\left(\frac{\partial u^*}{\partial y^*}\right)_{y=0} \qquad \text{---(34)}$$

And in dimensionless form, we obtain

$$C_f = \frac{\tau_w^*}{\rho U_o V_o} = -\left(\frac{\partial u}{\partial y}\right)_{y=0} = L_0(u_P + P_1 - 1) - P_1 m_0$$
$$+\varepsilon e^{nt}(C_1 L_1 + R_1 L_0 - R_2 m_0 - R_3 m_1) \qquad \text{---(35)}$$

Similarly we calculate the heat transfer coefficient in terms of Nusselt number, as follows

$$N_u = \left(\frac{\partial \theta}{\partial y}\right)_{y=0} = -m_0 + \varepsilon e^{nt}[-m_1(A_T - P_0) - m_0 P_0] \qquad \text{---(36)}$$

III. Results and Discussions

In order to get physical insight into the problem , the velocity and temperature fields have been discussed by assigning numerical values of Thermal radiation parameter R ,Prandtlnumbe P_r , Thermal Grashof number G_r, Permeability parameter K, Magnetic field parameter M, Visco-elastic parameter λ_1, heat generation / absorption η and U_p in two cases.

Case i):- The plate with variable wall temperature (VWT),i.e $A_T = 1$

Fig. 1 illustrates the behavior of the velocity for different values of R. It seen that the velocity increases with the increasing R. Fig.2 presents the variation of velocity component for various values of P_r. The result shows that the effect increasing values P_r in a decreasing velocity. The velocity profile against y for different values of G_r described in fig.3 it is observed that an increase in G_r leads to a rise the velocity.

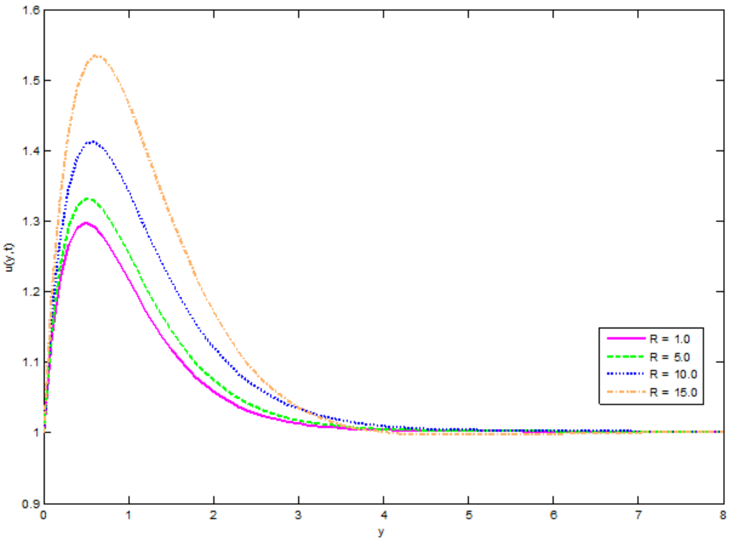

Fig 1: Velocity profile against y for different values of R at $A_T = 1.0$

$$\Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ K = 1.0;\ M = 1.0$$
$$Up = 1.0;\ \lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$$

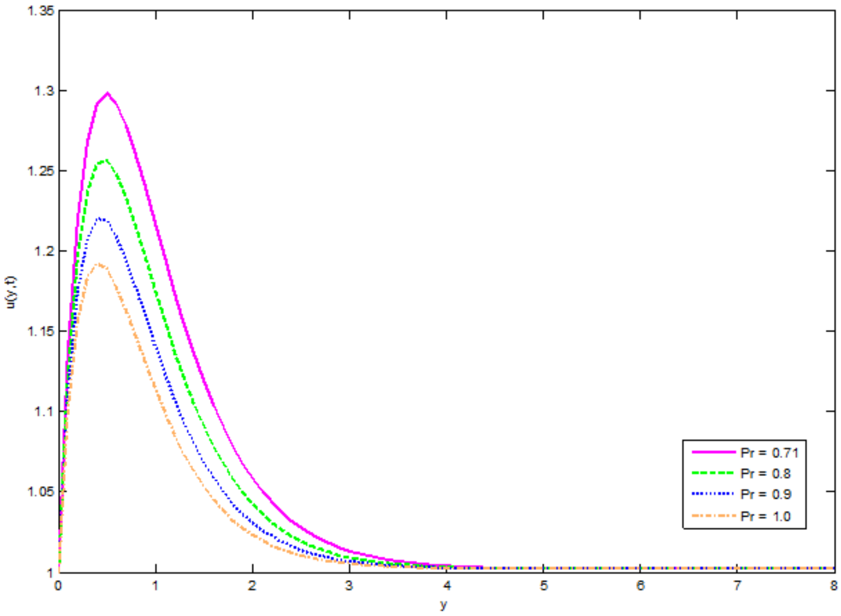

Fig 2: Velocity profile against y for different values of R at $A_T = 1.0$

$$R = 1.0;\ A = 1.0\ Gr = 5.0;\ K = 1.0;\ M = 1.0$$
$$Up = 1.0;\ \lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$$

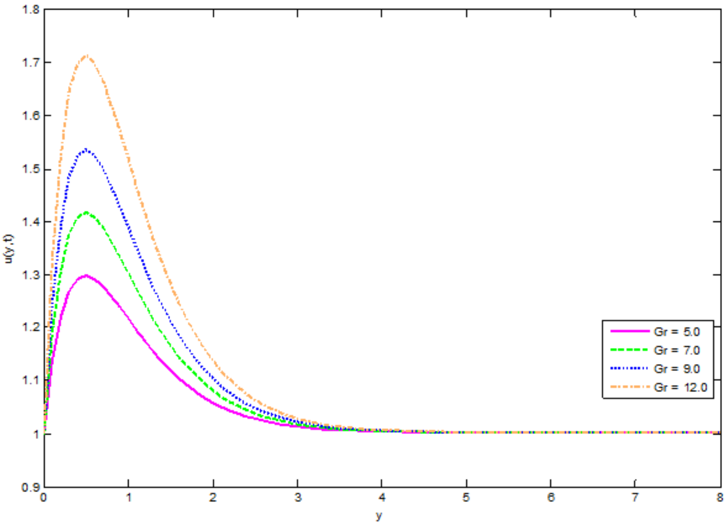

Fig 3: Velocity profile against y for different values of Gr at $A_T = 1.0$

$$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ K = 1.0;\ M = 1.0$$

$$Up = 1.0;\ \lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$$

The effect of the K on the velocity profile has been shown in Fig. 4. It is observed that the velocity increases as K increases. Fig. 5 shows that the velocity profiles for different values of M . It is noticed that velocity decreases with the increase of M . Fig.6 illustrates the variation of velocity distribution across the boundary layer for several values of plate moving velocity in the direction of fluid flow. The velocity increases with the increase of U_p . From Fig.7 it is observed that velocity profile increases with increasing λ_1. It is observed from Fig. 8 that the velocity increases it increasing the η .

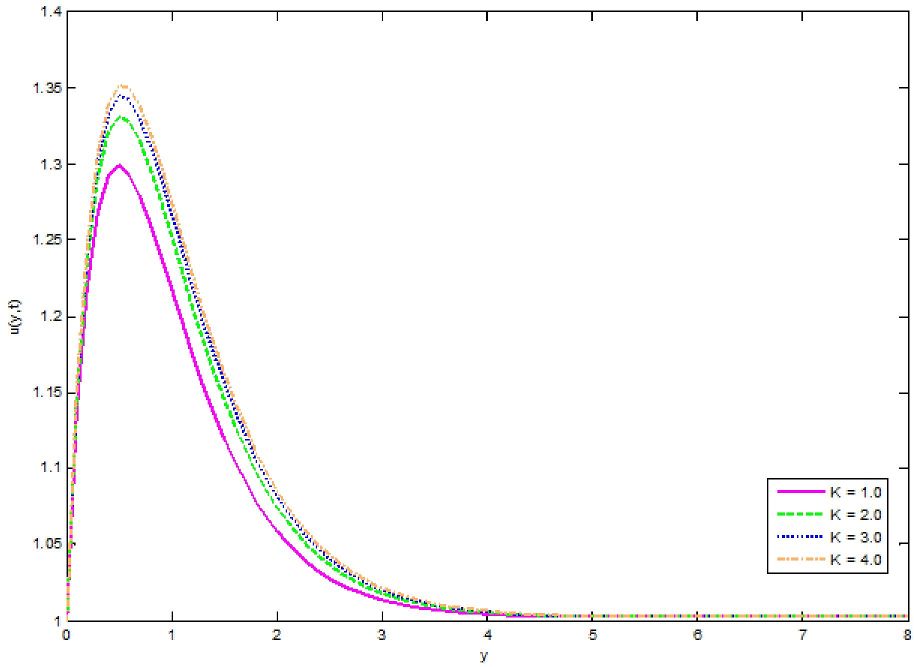

Fig 4: Velocity profile against y for different values of K at $A_T = 1.0$

$$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ M = 1.0$$

$$Up = 1.0;\ \lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$$

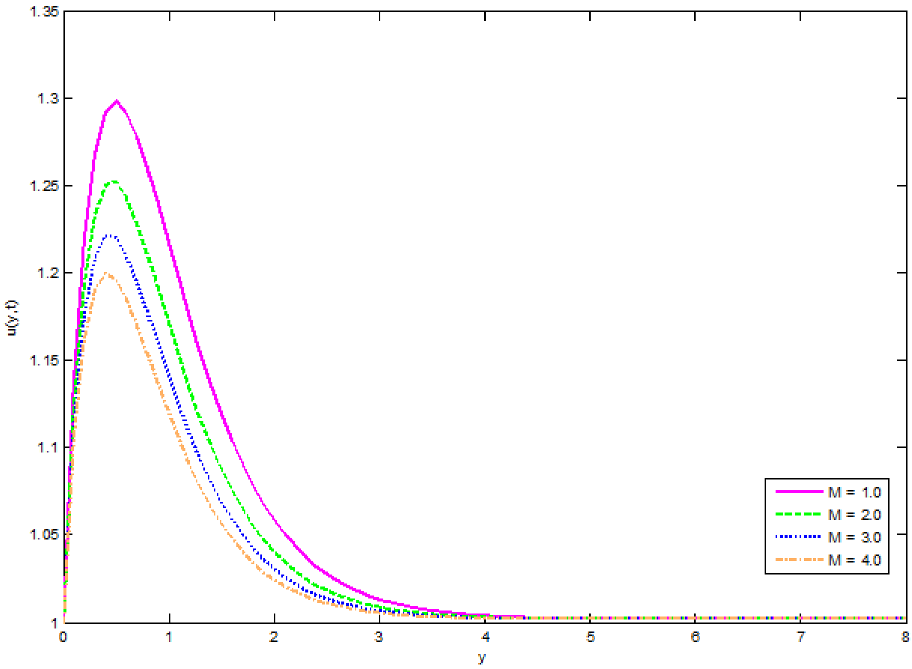

Fig 5: Velocity profile against y for different values of M at $A_T = 1.0$
$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ K = 1.0;$
$Up = 1.0;\ \lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$

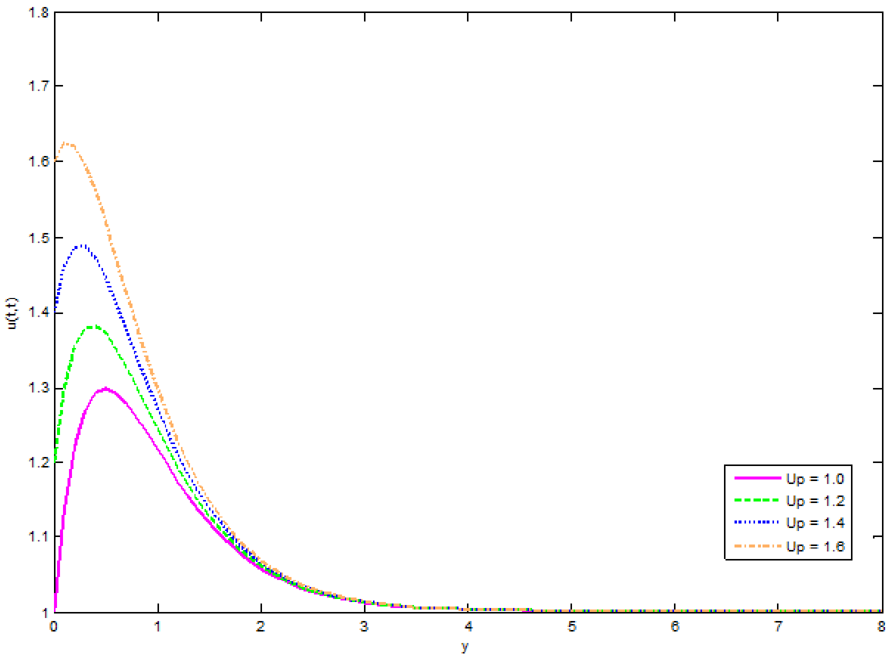

Fig 6: Velocity profile against y for different values of Up at $A_T = 1.0$
$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ K = 1.0;\ M = 1.0$
$\lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$

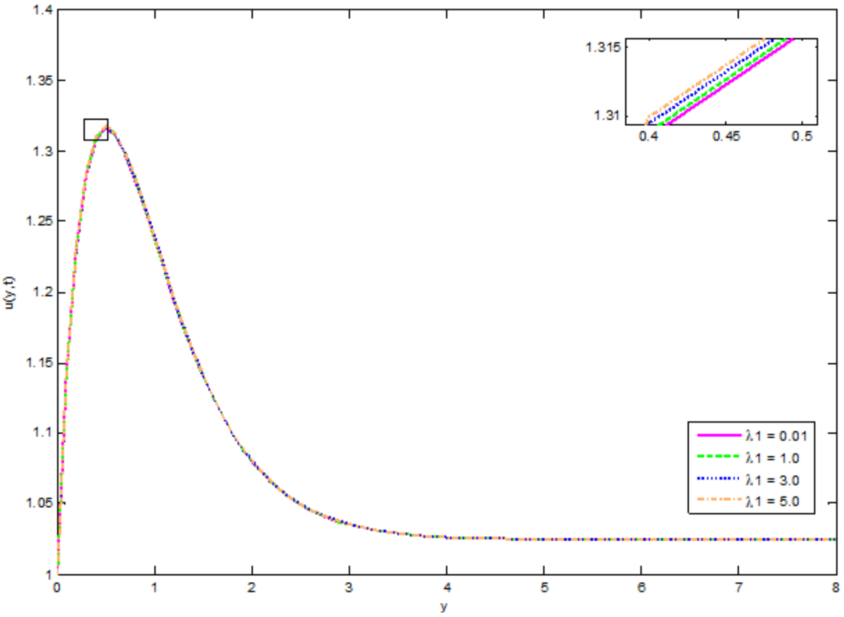

Fig 7: Velocity profile against y for different values of λ_1 at $A_T = 1.0$

$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ K = 1.0;\ M = 1.0$

$Up = 1.0;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$

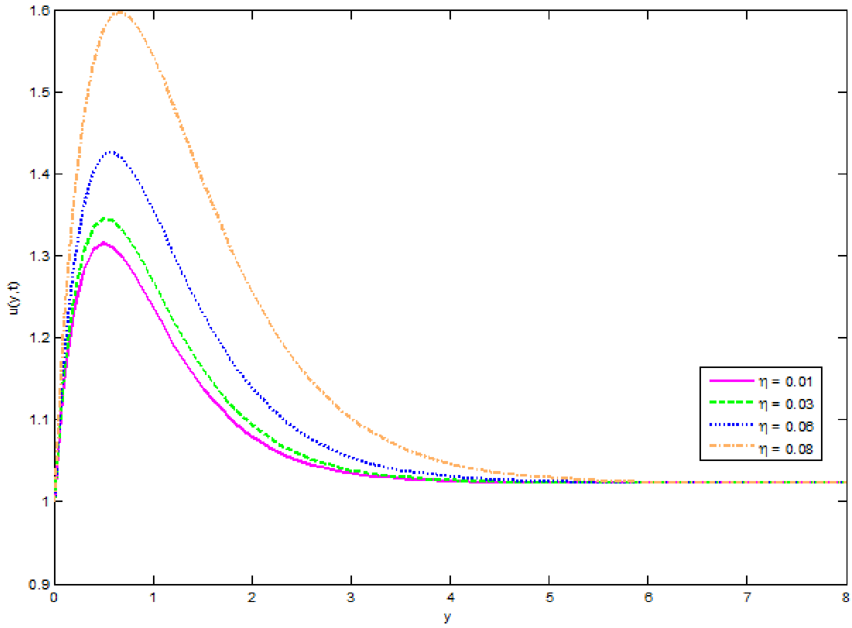

Fig 8: Velocity profile against y for different values of η at $A_T = 1.0$

$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ K = 1.0;\ M = 1.0$

$Up = 1.0;\ \lambda_1 = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$

The effect of R on temperature profiles are shown in Fig.9. It is observed that the temperature increases with the increase of R. Fig.10 shows the effects of P_r on temperature profile. It is noticed that temperature decreases with the increase in P_r. It is observed in Fig. no.11 that temperature increases with increasing η.

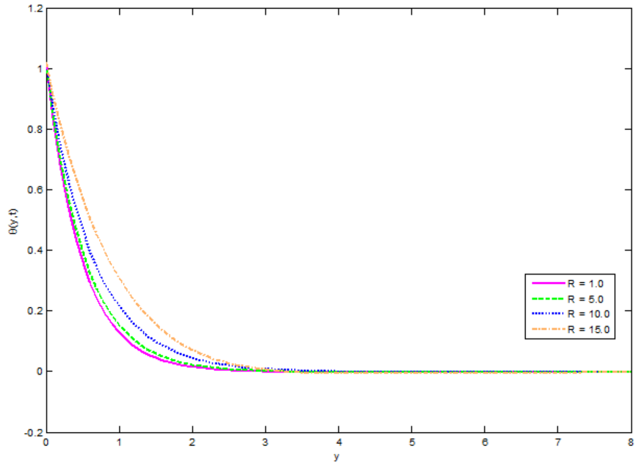

Fig 9: Temperature profile against y for different values of R at $A_T = 1$
$\Pr = 0.71;\ A = 1.0\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.1;\ t = 1.0$

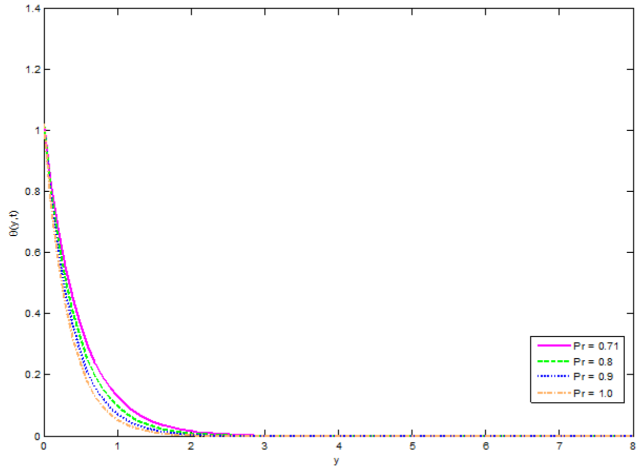

Fig 10: Temperature profile against y for different values of $\Pr$ at $A_T = 1$
$R = 1.0;\ A = 1.0\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.1;\ t = 1.0$

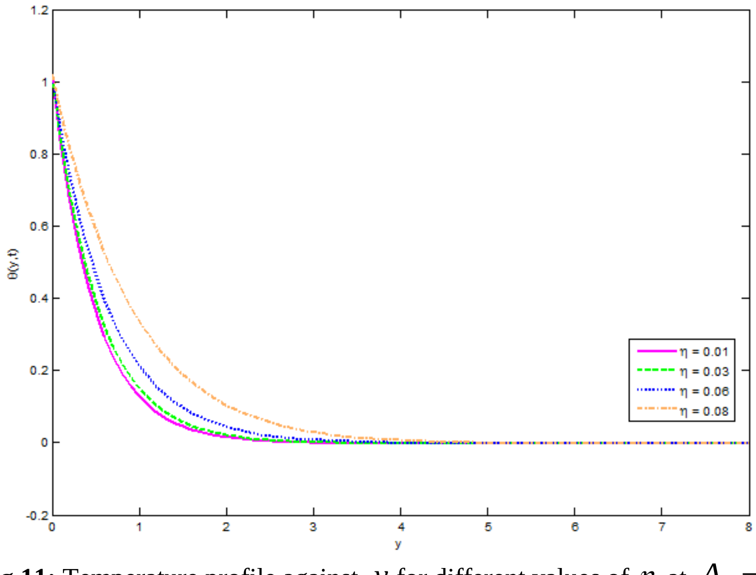

Fig 11: Temperature profile against y for different values of η at $A_T = 1$
$\Pr = 0.71;\ R = 1.0;\ A = 1.0\ \varepsilon = 0.02;\ n = 0.1;\ t = 1.0$

Case ii):- Plate is with Constant wall temperature (CWT),i.e., $A_T = 0$

The velocity profile against y for different values of R described in fig. 12. It is observed that an increase in R leads to a rise the velocity. Fig.13 shows the effects of P_r on velocity profile. It is noticed that velocity decreases with the increase in P_r .The effect of the G_r on the velocity profile has been shown in Fig. 14. It is observed that the velocity increases with increasing the G_r .

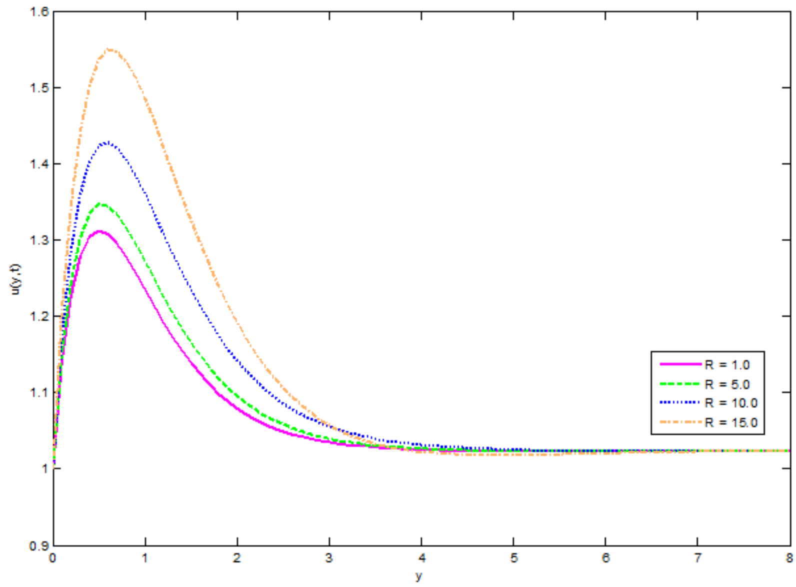

Fig 12: Velocity profile against y for different values of R at $A_T = 0$

$$\Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ K = 1.0;\ M = 1.0$$

$$Up = 1.0;\ \lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$$

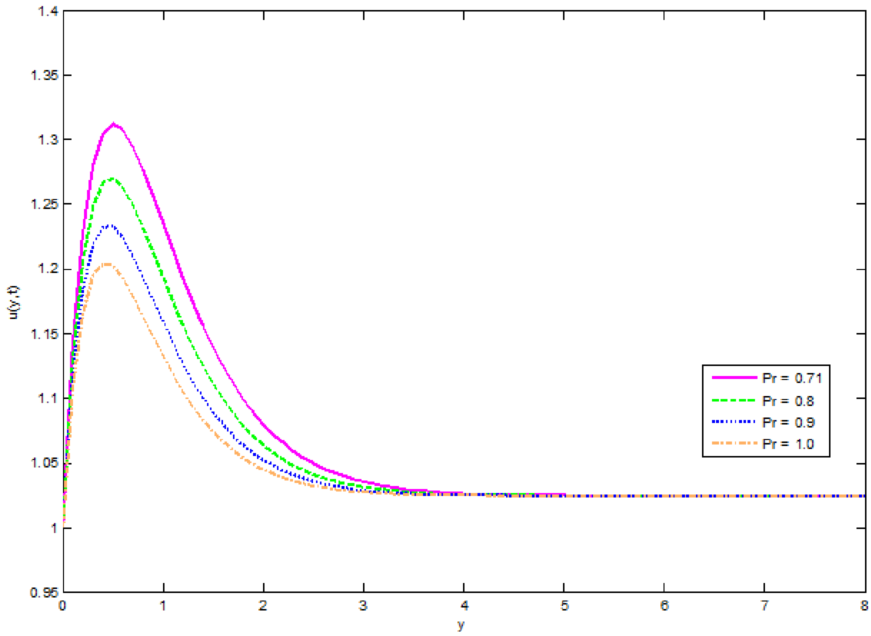

Fig 13: Velocity profile against y for different values of $\Pr$ at $A_T = 0$

$$R = 1.0;\ A = 1.0\ Gr = 5.0;\ K = 1.0;\ M = 1.0$$

$$Up = 1.0;\ \lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$$

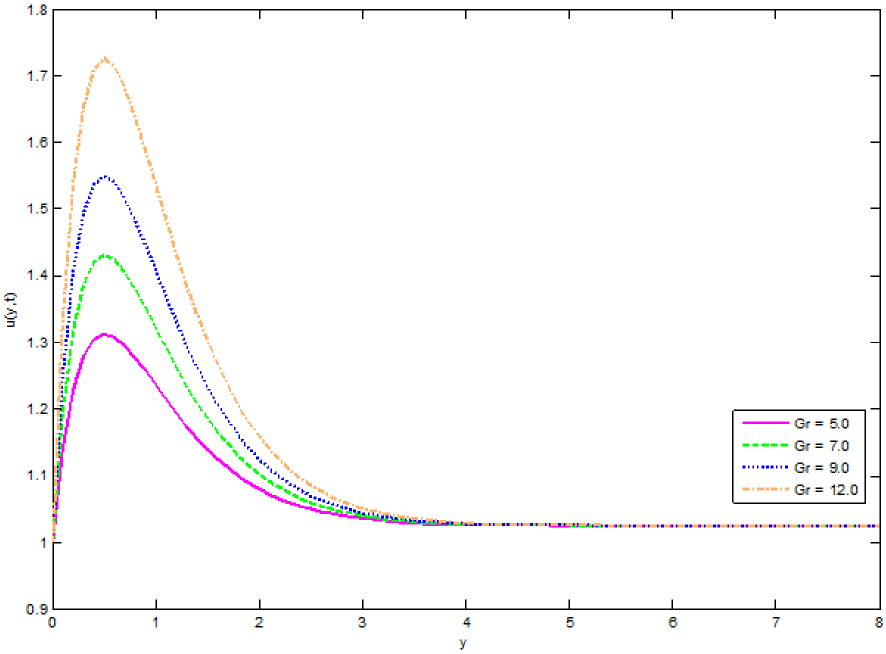

Fig 14: Velocity profile against y for different values of Gr at $A_T = 0$

$$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ K = 1.0;\ M = 1.0$$
$$Up = 1.0;\ \lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$$

The effect of K on velocity profiles are shown in Fig.15. It is observed that the velocity increases with the increase of K .Fig.16 shows that the velocity profile decreases with increasing M . Fig.17 illustrates the variation of velocity distribution across the boundary layer for several values of plate moving velocity in the direction of fluid flow. The velocity increases with the increase of U_p . Fig.18 shows that the velocity increases with increase on λ_1 Fig.19 illustrate that the velocity increases with increase on η

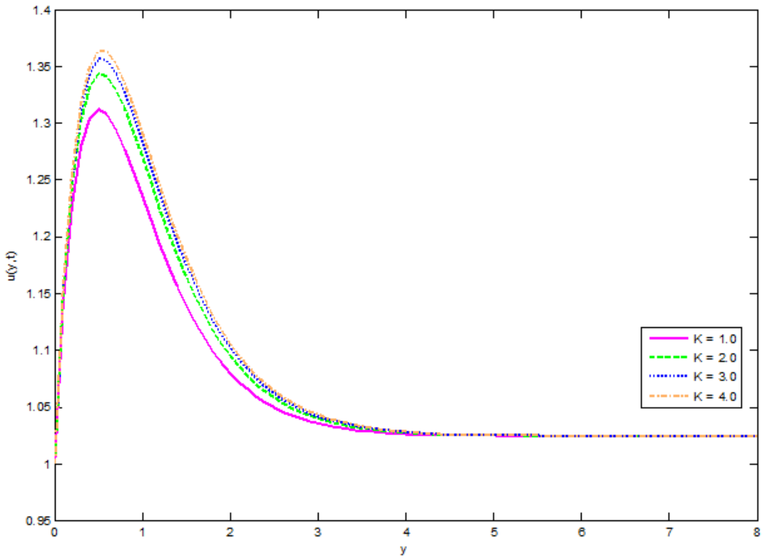

Fig 15: Velocity profile against y for different values of K at $A_T = 0$

$$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ M = 1.0$$
$$Up = 1.0;\ \lambda_1 = 0.01;\ \eta = 0.01;\ n = 0.2;\ t = 1.0$$

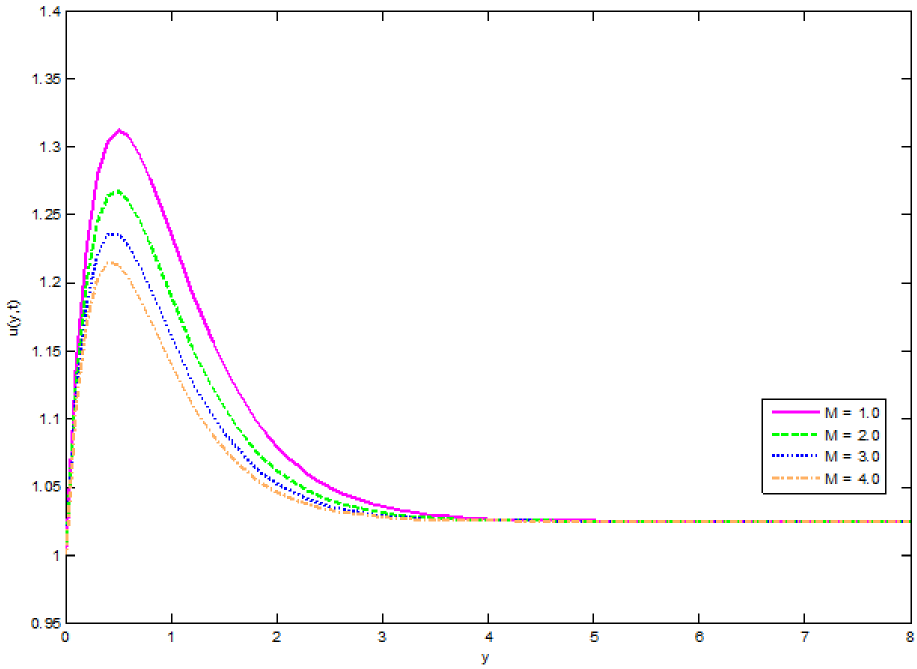

Fig 16: Velocity profile against y for different values of M at $A_T = 0$

$$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ K = 1.0;$$

$$Up = 1.0;\ \lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$$

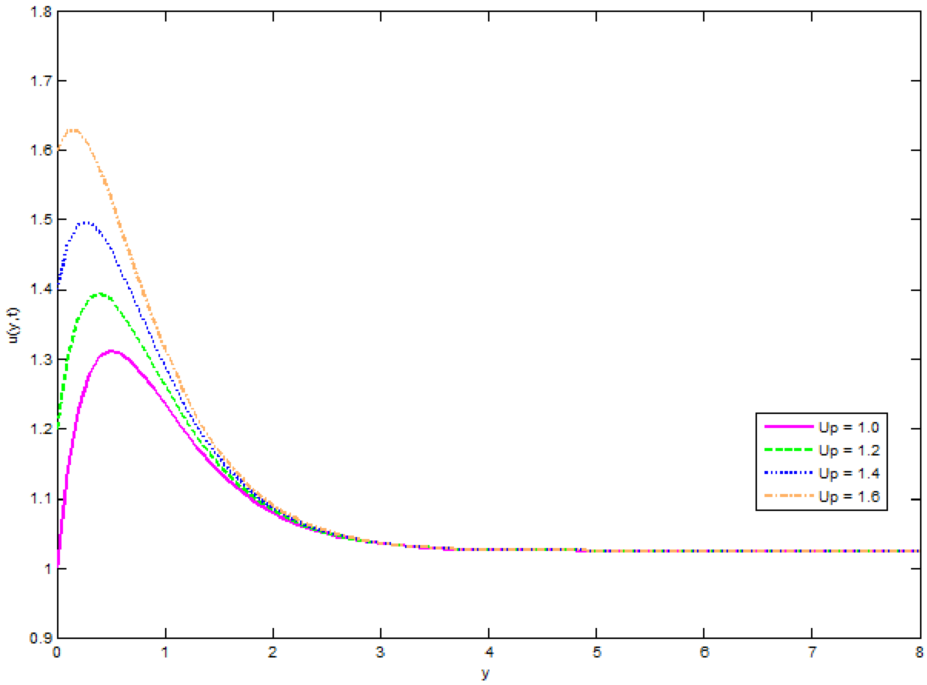

Fig 17: Velocity profile against y for different values of Up at $A_T = 0$

$$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ K = 1.0;\ M = 1.0$$

$$\lambda_1 = 0.01;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$$

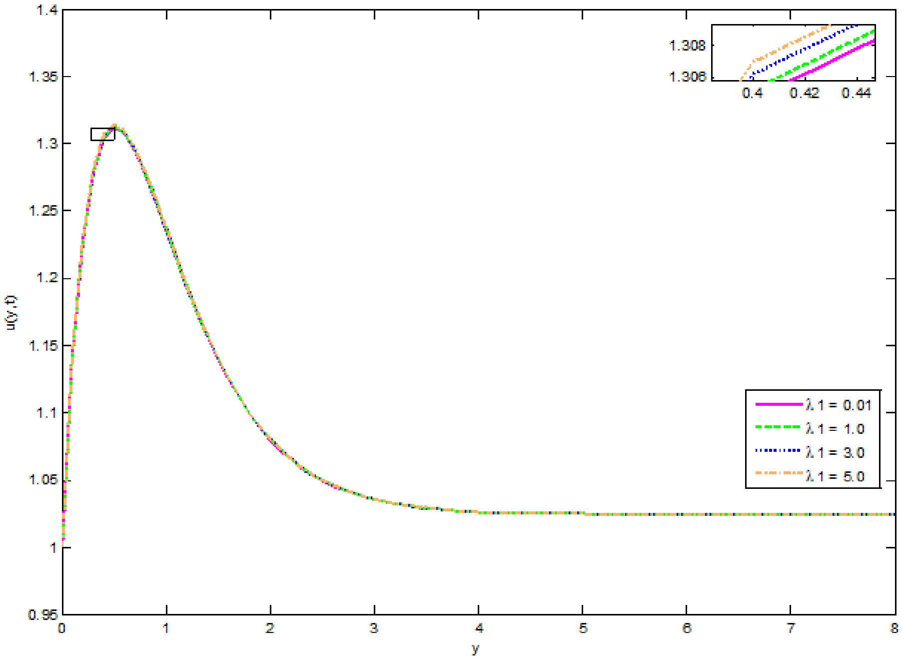

Fig 18: Velocity profile against y for different values of λ_1 at $A_T = 0$
$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ K = 1.0;\ M = 1.0$
$Up = 1.0;\ \eta = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$

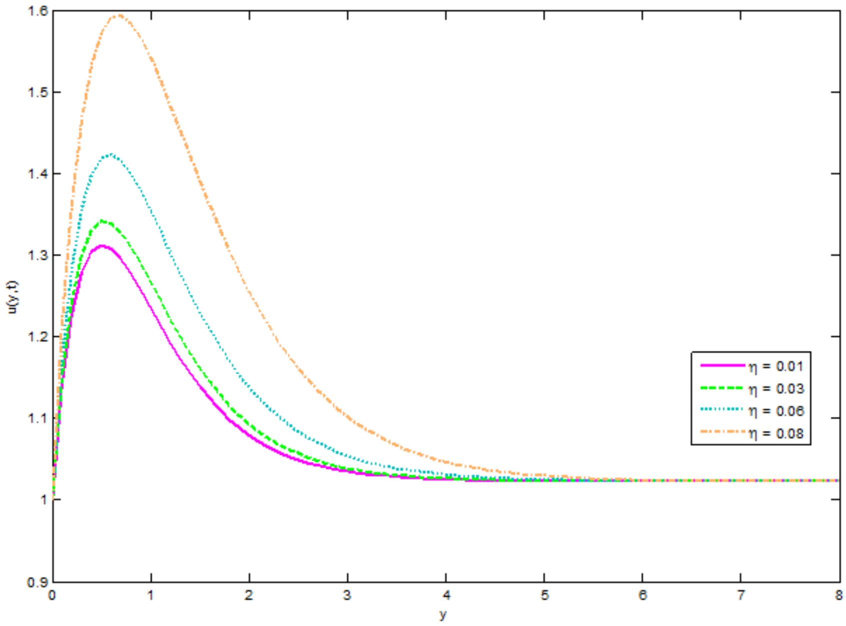

Fig 19: Velocity profile against y for different values of η at $A_T = 0$
$R = 1.0;\ \Pr = 0.71;\ A = 1.0\ Gr = 5.0;\ K = 1.0;\ M = 1.0$
$Up = 1.0;\ \lambda_1 = 0.01;\ \varepsilon = 0.02;\ n = 0.2;\ t = 1.0$

Fig.20 presents the variation of temperature component for various values of R. The result shows that the effect of increasing values R results in an increasing temperature. Fig. 21 illustrates the behavior of the temperature for different values of P_r. It is seen that the temperature decreases with the increasing P_r .Fig.22 shows that the temperature increases with increase on η.

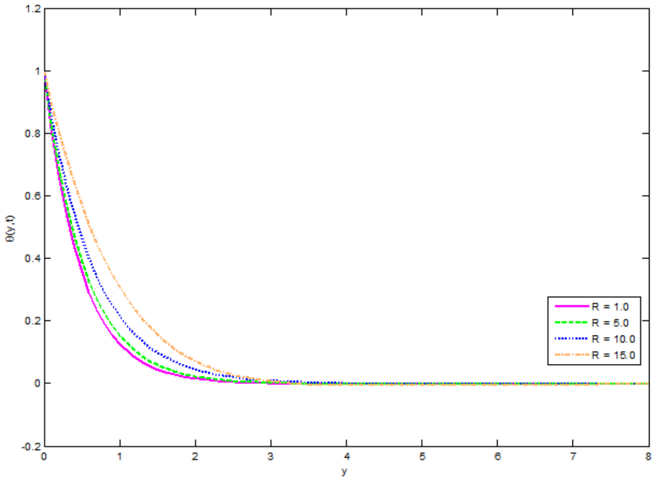

Fig 20: Temperature profile against y for different values of R at $A_T = 0$
$R = 1.0$; $\Pr = 0.71$; $A = 1.0$ $\eta = 0.01$; $\varepsilon = 0.02$; $n = 0.1$; $t = 1.0$

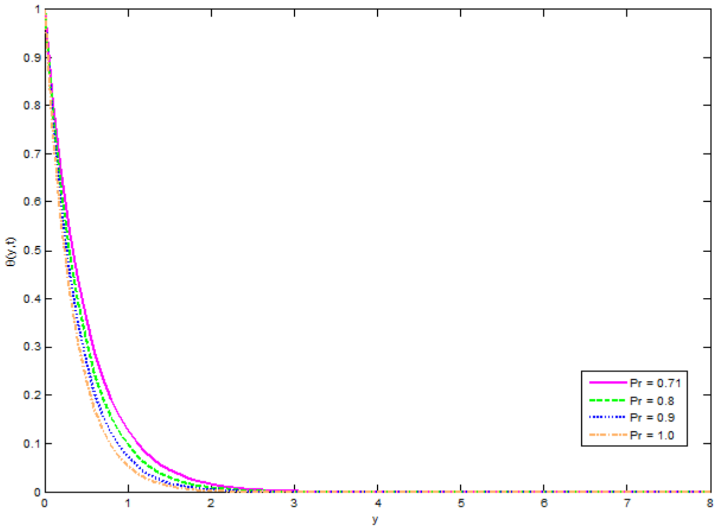

Fig 21: Temperature profile against y for different values of $\Pr$ at $A_T = 0$
$R = 1.0$; $A = 1.0$ $\eta = 0.01$; $\varepsilon = 0.02$; $n = 0.1$; $t = 1.0$

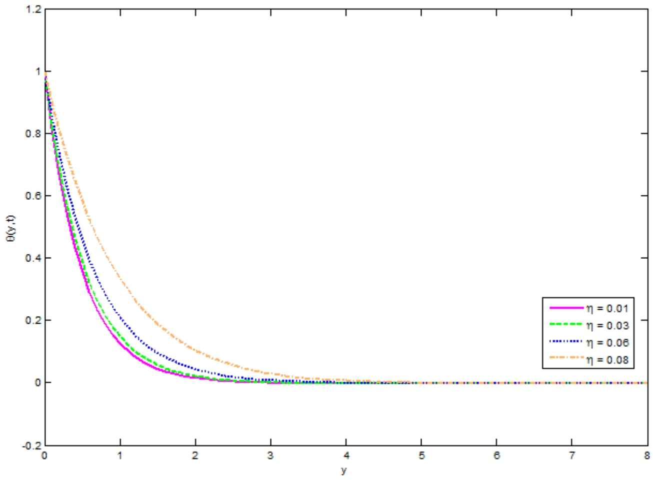

Fig 22: Temperature profile against y for different values of η at $A_T = 0$
$\Pr = 0.71$; $R = 1.0$; $A = 1.0$ $\varepsilon = 0.02$; $n = 0.1$; $t = 1.0$

From table 1&2 it is noticed that an increases in P_r, λ_1, η increases the co-efficient of skin-friction in both cases $A_T = 1$ and $A_T = 0$. We also observed that $R,\ G_r,\ K,\ M$ and Up increases the co-efficient of skin-friction decreases in both cases $A_T = 1$ and $A_T = 0$.

Table 3&4 shows that an increase in $\Pr$ decreases the rate of heat transfer Nu in both cases $A_T = 1$ and $A_T = 0$. And we noticed that an increase in R, η increases the rate of heat transfer in both cases $A_T = 1$ and $A_T = 0$.

Table 1: Co-efficient of skin-friction at variable wall temperature (VWT),i.e $A_T = 1$

R	$\Pr$	Gr	K	M	Up	λ_1	η	τ
1.0	0.71	5.0	1.0	1.0	1.0	0.01	0.01	**-1.7200**
5.0	0.71	5.0	1.0	1.0	1.0	0.01	0.01	**-1.8209**
10.0	0.71	5.0	1.0	1.0	1.0	0.01	0.01	**-2.0494**
15.0	0.71	5.0	1.0	1.0	1.0	0.01	0.01	**-2.3835**
1.0	**0.8**	5.0	1.0	1.0	1.0	0.01	0.01	**-1.5850**
1.0	**0.9**	5.0	1.0	1.0	1.0	0.01	0.01	**-1.4584**
1.0	**1.0**	5.0	1.0	1.0	1.0	0.01	0.01	**-1.3512**
1.0	0.71	**7.0**	1.0	1.0	1.0	0.01	0.01	**-2.3879**
1.0	0.71	**9.0**	1.0	1.0	1.0	0.01	0.01	**-3.0557**
1.0	0.71	**12.0**	1.0	1.0	1.0	0.01	0.01	**-4.0579**
1.0	0.71	5.0	**2.0**	1.0	1.0	0.01	0.01	**-1.8181**
1.0	0.71	5.0	**3.0**	1.0	1.0	0.01	0.01	**-1.8570**
1.0	0.71	5.0	**4.0**	1.0	1.0	0.01	0.01	**-1.8779**
1.0	0.71	5.0	1.0	**2.0**	1.0	0.01	0.01	**-1.5773**
1.0	0.71	5.0	1.0	**3.0**	1.0	0.01	0.01	**-1.4752**
1.0	0.71	5.0	1.0	**4.0**	1.0	0.01	0.01	**-1.3966**
1.0	0.71	5.0	1.0	1.0	**1.2**	0.01	0.01	**-1.3168**
1.0	0.71	5.0	1.0.	1.0	**1.4**	0.01	0.01	**-0.9137**
1.0	0.71	5.0	1.0	1.0	**1.6**	0.01	0.01	**-0.5105**
1.0	0.71	5.0	1.0	1.0	1.0	**1.0**	0.01	**-1.7225**
1.0	0.71	5.0	1.0	1.0	1.0	**3.0**	0.01	**-1.7270**
1.0	0.71	5.0	1.0	1.0	1.0	**5.0**	0.01	**-1.7311**
1.0	0.71	5.0	1.0	1.0	1.0	0.01	**0.03**	**-1.8142**
1.0	0.71	5.0	1.0	1.0	1.0	0.01	**0.06**	**-2.0479**
1.0	0.71	5.0	1.0	1.0	1.0	0.01	**0.08**	**-2.4876**

Table 2: Co-efficient of skin-frictionatat constant wall temperature (CWT),i.e $A_T = 0$

R	$\Pr$	Gr	K	M	Up	λ_1	η	τ
1.0	0.71	5.0	1.0	1.0	1.0	0.01	0.01	**-1.6922**
5.0	0.71	5.0	1.0	1.0	1.0	0.01	0.01	**-1.8002**
10.0	0.71	5.0	1.0	1.0	1.0	0.01	0.01	**-2.0325**
15.0	0.71	5.0	1.0	1.0	1.0	0.01	0.01	**-2.3687**
1.0	**0.8**	5.0	1.0	1.0	1.0	0.01	0.01	**-1.5584**
1.0	**0.9**	5.0	1.0	1.0	1.0	0.01	0.01	**-1.4331**
1.0	**1.0**	5.0	1.0	1.0	1.0	0.01	0.01	**-1.3271**
1.0	0.71	**7.0**	1.0	1.0	1.0	0.01	0.01	**-2.3489**
1.0	0.71	**9.0**	1.0	1.0	1.0	0.01	0.01	**-3.0057**
1.0	0.71	**12.0**	1.0	1.0	1.0	0.01	0.01	**-3.9907**
1.0	0.71	5.0	**2.0**	1.0	1.0	0.01	0.01	**-1.7892**
1.0	0.71	5.0	**3.0**	1.0	1.0	0.01	0.01	**-1.8277**
1.0	0.71	5.0	**4.0**	1.0	1.0	0.01	0.01	**-1.8484**
1.0	0.71	5.0	1.0	**2.0**	1.0	0.01	0.01	**-1.5513**
1.0	0.71	5.0	1.0	**3.0**	1.0	0.01	0.01	**-1.4504**
1.0	0.71	5.0	1.0	**4.0**	1.0	0.01	0.01	**-1.3730**
1.0	0.71	5.0	1.0	1.0	**1.2**	0.01	0.01	**-1.2891**
1.0	0.71	5.0	1.0.	1.0	**1.4**	0.01	0.01	**-0.8859**
1.0	0.71	5.0	1.0	1.0	**1.6**	0.01	0.01	**-0.4827**
1.0	0.71	5.0	1.0	1.0	1.0	**1.0**	0.01	**-1.6955**
1.0	0.71	5.0	1.0	1.0	1.0	**3.0**	0.01	**-1.7014**
1.0	0.71	5.0	1.0	1.0	1.0	**5.0**	0.01	**-1.7066**
1.0	0.71	5.0	1.0	1.0	1.0	0.01	**0.03**	**-1.7850**
1.0	0.71	5.0	1.0	1.0	1.0	0.01	**0.06**	**-2.0185**
1.0	0.71	5.0	1.0	1.0	1.0	0.01	**0.08**	**-2.4574**

Table 3: Nusselt Number at variable wall temperature (VWT),i.e $A_T = 1$

R	Pr	η	Nu
1.0	0.71	0.01	-2.1166
5.0	0.71	0.01	-1.9489
10.0	0.71	0.01	-1.6324
15.0	0.71	0.01	-1.1802
1.0	**0.8**	0.01	-2.3920
1.0	**0.9**	0.01	-2.6980
1.0	**1.0**	0.01	-3.0041
1.0	0.71	**0.03**	-1.9497
1.0	0.71	**0.05**	-1.7405
1.0	0.71	**0.07**	-1.4122

Table 4: Nusselt Number at constant wall temperature (CWT),i.e $A_T = 0$

R	Pr	η	Nu
1.0	0.71	0.01	-2.0546
5.0	0.71	0.01	-1.8655
10.0	0.71	0.01	-1.5300
15.0	0.71	0.01	-1.0625
1.0	**0.8**	0.01	-2.3251
1.0	**0.9**	0.01	-2.6256
1.0	**1.0**	0.01	-2.9260
1.0	0.71	**0.03**	-1.8905
1.0	0.71	**0.05**	-1.6843
1.0	0.71	**0.07**	-1.3593

IV. Conclusion

We have discussed the effects of the MHD convective heat transfer flow of Kuvshinski fluid past an infinite moving plate embedded in a porous medium with radiation temperature dependent heat source and variable suction. Thus, the aim of the present paper is to investigate the MHD convective heat transfer flow on Kuvshinski fluid past an infinite moving plate embedded in a porous medium with temperature dependent heat source and variable suction. The following are the concluding remarks.

a. When the plate is maintained at variable temperature, the velocity is observed to increases with the increasing values of $Gr, k, Up, R, \lambda_1, \eta$ where as it has reverser effect in the case of P_r and M . Temperature boundary layer increased with the increase in R, η but decrease for increasing values of P_r .

b. When the plate is maintained at constant wall temperature, the velocity is observed to increase with the increasing values of $Gr, k, Up, R, \lambda_1, \eta$ where as it has reverser effect in the case of P_r and M . Temperature boundary layer increased with the increase in R, η but decrease for increasing values of P_r .

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