MHD FREE CONVECTIVE HEAT ABSORBING NEWTONIAN FLUID WITH VARIABLE TEMPERATURE

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ABSTRACT

The object of the present study is examined MHD free convective heat absorbing/generating Newtonian fluid with the consideration of variable temperature. The governing equations related to the problem are solved for velocity and temperature by using finite – difference method. The variations in velocity, temperature, local skin friction and rate of heat transfer under the effects of several parameters are studied and represented with the use of graphs.

Keywords: *MHD, Heat Source/Sink, Porous medium, Variable temperature*

INTRODUCTION

The study of heat generation or absorption effects in moving fluids is important in view of several physical problems, such as fluids undergoing exothermic or endothermic chemical reaction. Vajravelu and Sastry [1] Free convective heat transfer in a viscous incompressible fluid confined between a long vertical wavy wall and a parallel flat wall, Chamkha and Khaled [2] investigated the problem of coupled heat and mass transfer by MHD free convection from an inclined plate in the presence of internal heat generation or absorption. Hossain et.al. [3] studied the problem of natural convection flow along a vertical wavy surface with uniform surface temperature in the presence of heat generation/absorption. Chamkha [4] investigated unsteady MHD convective heat and mass transfer past a semi-infinite porous moving plate with heat absorption.Ch Kesavaiah et.al [5] investigated **e**ffects of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction, Bhavana et. al. [6] considered **t**he Soret effect on free convective unsteady MHD flow over a vertical plate with heat source, Srinathuni Lavanya and Chenna Kesavaiah [7] analyzed heat transfer to MHD free convection flow of a viscoelastic dusty gas through a porous medium with chemical reaction**.**

Many technological problems as well as natural phenomena are susceptible to MHD heat and mass transfer analysis. Geophysics concepts encounter MHD heat and mass transfer characteristics in the exchanges of conducting fluids and magnetic field. Engineers and scientists employ many principles of MHD in the drawing of heat exchangers pumps and flow meters, in space vehicle impulsion, thermal guard, braking, power and re – entry, in creating new type of power generating systems etc. In view of technical point, MHD convection and radiation flow problems are very much considerable in the areas of planetary magnetospheres, aeronautics, chemical engineering and electronics. Several studies of the above phenomena of MHD convection have been covered by many researchers. Ashraf et.al [8] presented MHD non – Newtonian micro polar fluid flow and heat transfer in channel with stretching walls. Singh [9] obtained viscoelastic mixed convection MHD oscillatory flow through a porous medium filled in a vertical channel. Ahmed et.al [10] studied analytical model of MHD mixed convective radiating fluid with viscous dissipative heat. Singh et.al [11] considered an exact solution of an oscillatory MHD flow though a porous medium bounded by rotating porous channel in the presence of hall current. Kumar [12] discussed radiative heat transfer with MHD free convection flow over a stretching porous sheet in presence of heat source subjected to power law heat flux. Seth et.al [13] formulated the effect of rotation on unsteady hydrodynamic natural convection flow past an impulsively moving vertical plate with ramped temperature in a porous medium with thermal diffusion and heat absorption.

In the present theoretical study we have examined MHD free convective heat absorbing/generating Newtonian fluid with the consideration of variable temperature. The governing equations related to the problem are solved for velocity and temperature by using perturbation technique. The variations in velocity, temperature under the effects of several parameters are studied and represented with the use of graphs.

FORMULATION OF THE PROBLEM

We considered MHD free convective heat absorbing/generating Newtonian fluid with variable temperature. A magnetic field of consistent strength is applied vertical to the plate. Let $x^* -$ axis is taken along the plate in the vertically upward direction and the $y^* -$axis is taken perpendicular to the plate. At $t \le 0,$ time the plate is maintained at the temperature higher than ambient temperature and the fluid is at rest. At $t > 0,$ time the plate is linearly accelerated with increasing time in its own plane and the temperature decreases with temperature $\left(\frac{1}{1+at}\right)$. Similarly the species concentration decreases with time t. It is assumed that the effect of viscous dissipation is negligible and by usual Boussineq's and boundary layer approximation. Based on the above considerations the flow is governed by the following equations;

$$\frac{\partial u^*}{\partial t^*} = \nu \frac{\partial^2 u^*}{\partial y^{*2}} + g\beta_T \left(T^* - T_\infty\right) - \frac{\sigma B_0^2}{\rho} u^* - \frac{\nu}{k} u^* \quad (1)$$

$$\rho C_p \frac{\partial T^*}{\partial t^*} = k_T \frac{\partial^2 T^*}{\partial y^{*2}} - Q^* \left(T^* - T_\infty\right) \quad (2)$$

The corresponding initial and boundary conditions governed are

$$\begin{aligned} &u^* = 0, T^* = T_\infty, && \text{for all} \quad y^*, t^* \le 0 \\ &t^* > 0 : u^* = U_0 a^* t^*, T^* = T_\infty + \left(\frac{T_s^* - T_\infty}{1 + At^*}\right) && \text{at} \quad y^* = 0 \\ &u^* \to 0, T^* \to T_\infty && \text{as} \quad y \to \infty \end{aligned} \quad (3)$$

where $A = \frac{t^* U_0^2}{\nu}$ the non-dimensionless quantities are as follows

$$\begin{aligned} &u = \frac{u^*}{U_0}, y = \frac{y^* U_0}{\nu}, t = \frac{t^* U_0{}^2}{\nu}, \theta = \frac{T^* - T_\infty}{T_s^* - T_\infty}, K = \frac{kU_0{}^2}{\nu^2}, a = \frac{\nu a^*}{U_0{}^2} \\ &Gr = \frac{\nu \beta_T g\left(T_s^* - T_\infty\right)}{U_0{}^3}, \quad \Pr = \frac{\nu \rho C_p}{k_T}, \quad Q = \frac{\nu^2 Q^*}{k_T U_0{}^2}, \quad M = \frac{\sigma B_0{}^2 \nu}{\rho U_0{}^2} \end{aligned} \quad (4)$$

The non – dimensional parameters applied to the equations (1) – (3) and they reduces to following form

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr\theta - Mu - \frac{1}{K} u \quad (5)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr} \frac{\partial^2 T\theta}{\partial y^2} - \frac{1}{\Pr} Q\theta \quad (6)$$

The corresponding initial and boundary conditions are

$$\begin{aligned} &u = 0, \theta = 0, && \text{for all} \quad y, t \le 0 \\ &t > 0 : u = at, \theta = \frac{1}{1+t} && \text{at} \quad y = 0 \\ &u \to 0, \theta \to 0 && \text{as} \quad y \to \infty \end{aligned} \quad (7)$$

SOLUTION OF THE PROBLEM

The linear partial differential equations (5) – (6) with initial and boundary conditions (7) are to be solved. In general the exact solution is impossible for this type of set of equations and so we have solved the above equations by introducing finite – difference method. The comparable finite difference schemes pertaining the equations (5) – (6) are as follows:

$$\left(\frac{u_{i,j+1} - u_{i,j}}{\Delta t}\right) = \left(\frac{u_{i-1,j} - 2u_{i,j} + u_{i+1,j}}{(\Delta y)^2}\right) + Gr\left(\theta_{i,j}\right) - M\left(u_{i,j}\right) - \frac{1}{K}\left(u_{i,j}\right) \quad (8)$$

$$\left(\frac{\theta_{i,j+1}-\theta_{i,j}}{\Delta t}\right)=\frac{1}{\Pr}\left(\frac{\theta_{i-1,j}-2\theta_{i,j}+\theta_{i+1,j}}{(\Delta y)^2}\right)-\frac{Q}{\Pr}\left(\theta_{i,j}\right) \quad (9)$$

Here, index i refer to y and j refers to time; the mesh system is divided by taking $\Delta y = 0.1$

From the initial conditions in (7) we have the following equivalent

$$\begin{aligned} &u(o,j)=at, \theta(0,j)=\frac{1}{1+t} \quad for \;\; all \;\; j \\ &u(i_{\max},j)=0, \theta(i_{\max},j)=0 \quad for \;\; all \;\; j \end{aligned} \quad (10)$$

(here $i_{\max}$ was taken as 200), the velocity at the end of time step viz, $u(i, j+1)(i=1,200)$ is coupled form (8) in terms of velocity and temperature at points on the earlier time – step. After that $\theta(i, j+1)$ is computed for (9). The procedure is repeated until $t = 0.5(i.e. \;\; j = 500)$, during the computation Δt was chosen as 0.001.

RESULTS AND DISCUSSION

In order to get clear insight into the problem, numerical computations are carried out for various parameters like t, M, Q, K, a are plotting the velocity profiles, temperature profiles, skin friction and Nusselt number are pictorially has been showed from figures (1) - (9). Figure (1) illustrates the effects of the dimensionless time parameter (t). It is observed from this figure that velocity goes on increasing with the increase of dimensionless time parameter. The influence of magnetic parameter (M) is presented graphically in figure (2). As expected, the mean velocity decreases with increasing magnetic parameter. The effect of the transverse magnetic field leads to a resistive type of force similar to drag force, which tends to resist the retarding flow of viscoelastic fluid flow. Figure (3) depicts the effect of heat absorption (Q) on velocity profiles, it is clear that the velocity decreases with increasing values of heat absorption. This is expected since the presence of a heat sink in the boundary layer absorbs energy. Which in turn cause the temperature of the fluid to decrease. This decrease in temperature produces a decrease in the flow field due to the buoyancy effect which couples the flow and thermal field. The variation of velocity profiles with dimensionless permeability parameter is presented in figure (4). This figure clearly indicates that the value of velocity profiles decreases with increasing the dimensionless permeability parameter. Figure (5) represents the velocity profiles for different values of accelerating parameter (a). From the figure the velocity is found to increase with an increase in accelerating parameter. It is also found that the fluid velocity due to the impulsive start of the plate (accelerating parameter is equal to zero) is less than due to the exponentially accelerated start (accelerating parameter is not equal to zero). Figure (6) shows the variation of temperature profiles for different values of heat absorption parameter (Q). It is seen from this figure that temperature profiles decrease with an increasing of heat absorption parameter in the kinematic energy as well as thermal energy of the fluid. Typical variation of the temperature profiles are shown in figure (7) for different values of dimensionless time parameter (t). The results show that an increase of dimensionless time parameter results in a decreases. Hence the momentum and thermal boundary layers get thinner in case of heat absorbing fluids. Figure (8) depicts the variations in skin friction. The skin friction increases with increases in magnetic parameter (M). Figure (9) displays the effect of heat absorption parameter (Q) on Nusselt number. It is clear that the Nusselt number increases with the increasing values of heat absorption parameter.

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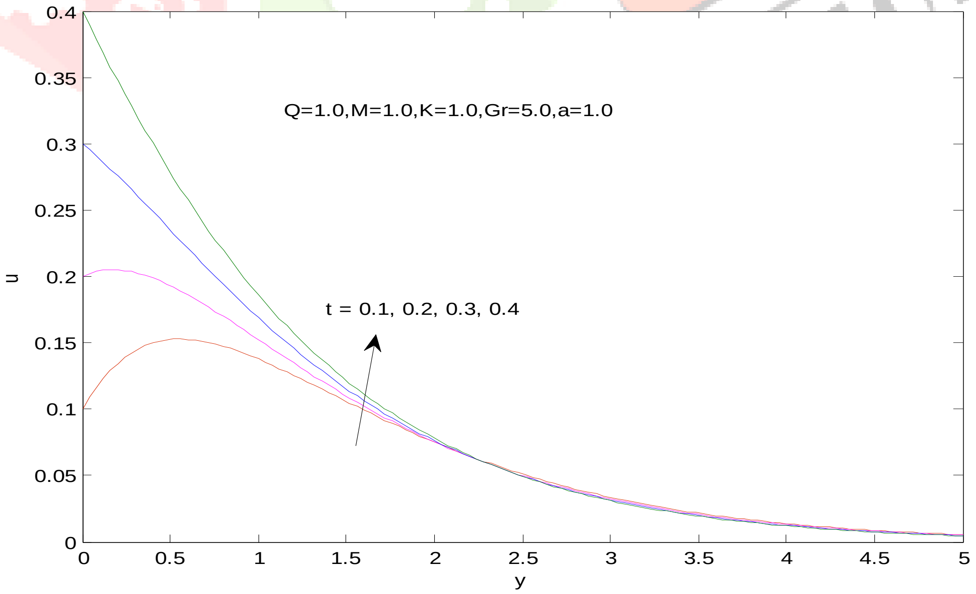

Figure (1): Velocity profiles for different values of t

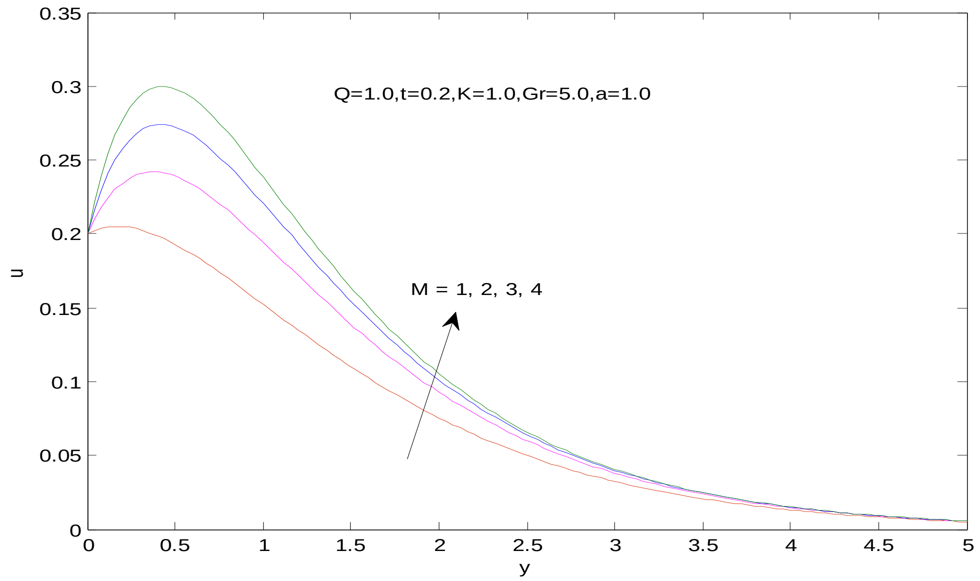

Figure (2): Velcoity profiles for different values of M

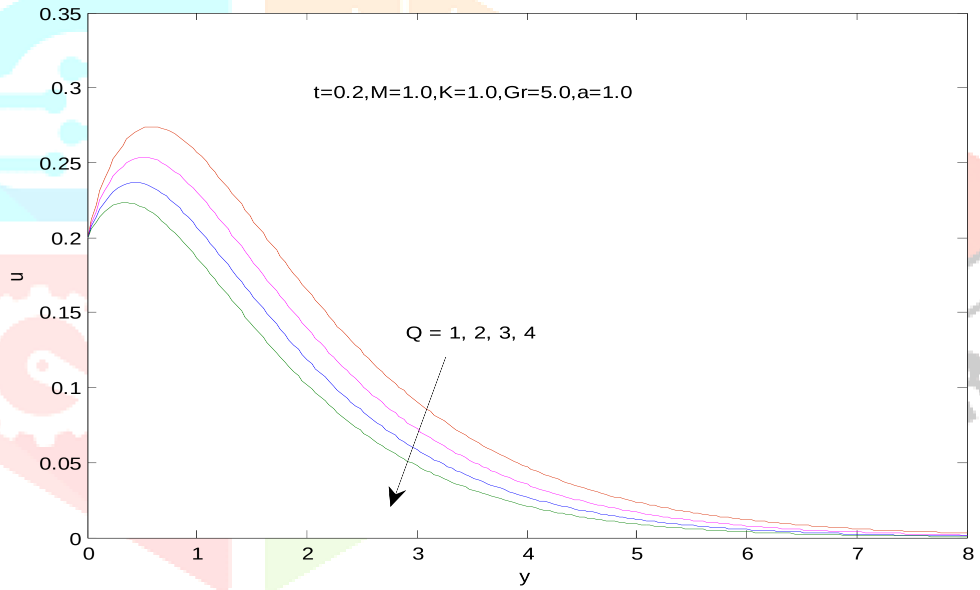

Figure (3): Velocity profiles for different values of Q

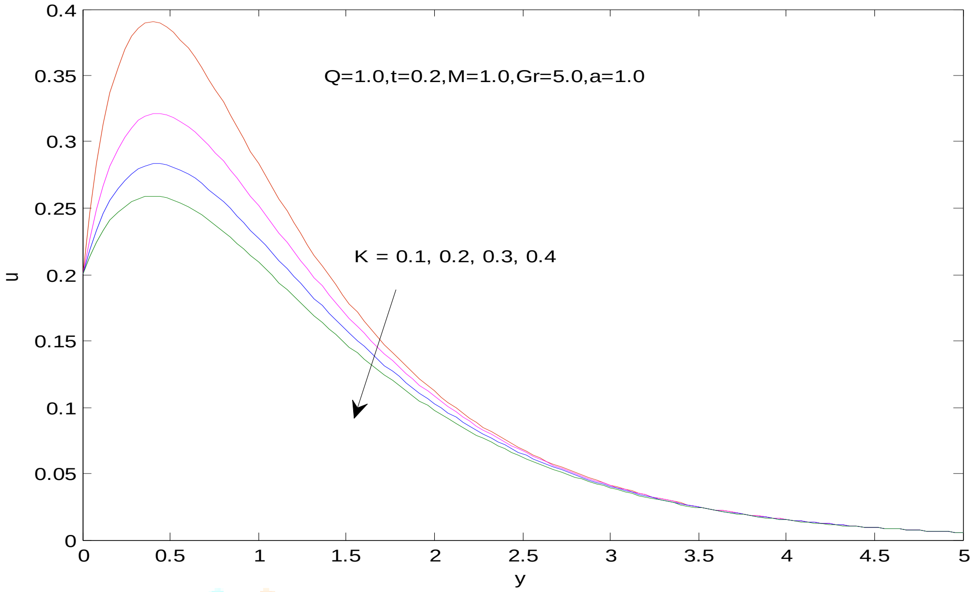

Figure (4): Velocity profiles for different values of K

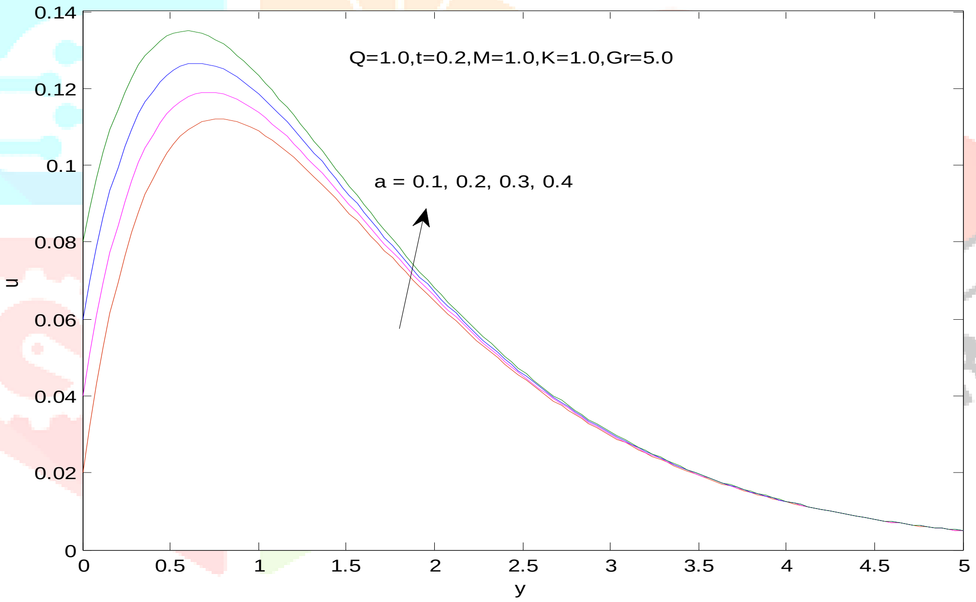

Figure (5): Velocity profiles for different values of a

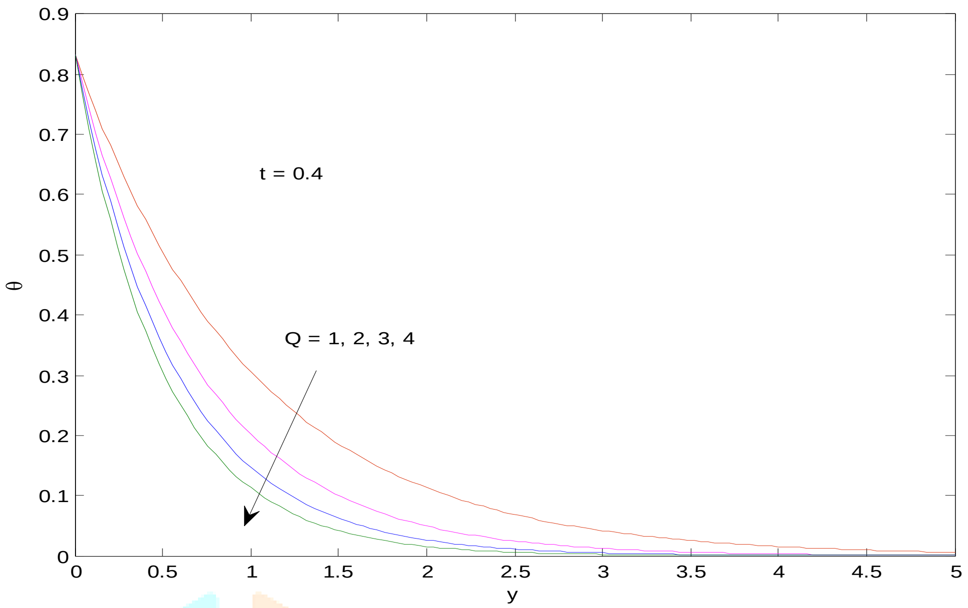

Figure (6): Temperature profiles for different values of Q

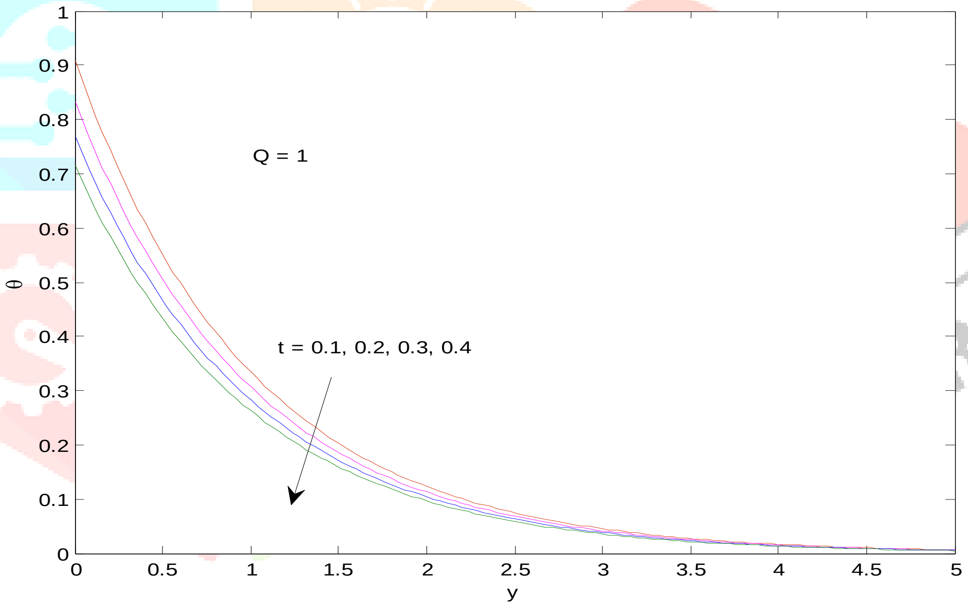

Figure (7): Temperatur profiles for different values of t

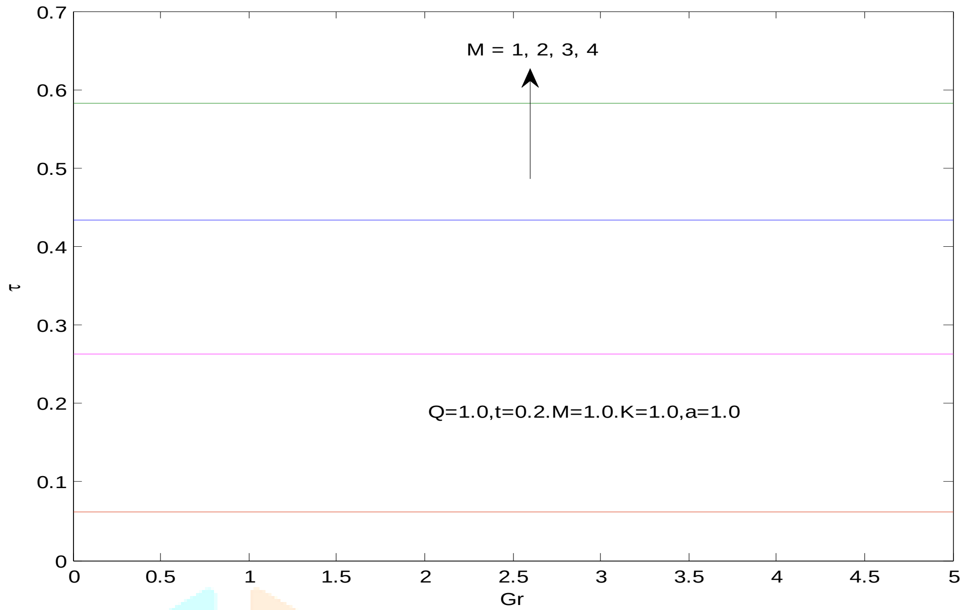

Figure (8): Skin friction for different values of M

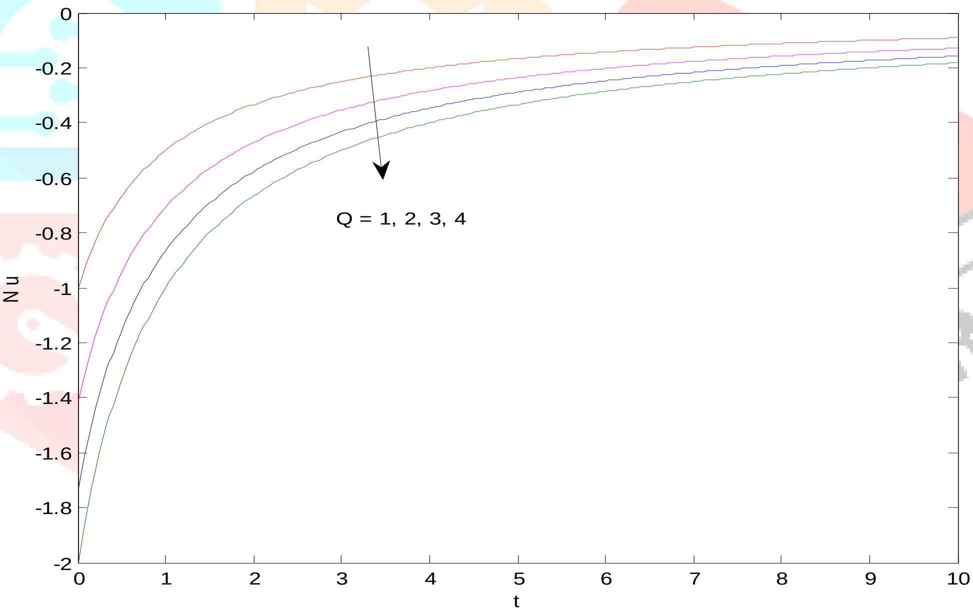

Figure (9): Nusselt number for different values of Q

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