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MHD Oscillatory Rotation Flow With Radiation Effects Along a Porous Medium Bounded by Two Vertical Porous Plates Under the Influence of Hall Current And Heat Absorption With Chemical Reaction

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Abstract: Magnetohydrodynamics oscillatory flow in between two vertical porous plates through porous medium in presence of hall current has been studied. One plate is kept stationary and other plate is kept as oscillating. The basic governing equations of the problem are transformed into a system of non dimensional differential equations. Effect of various parameters on velocity , temperature and concentration, skin friction and rate of heat and mass transfer were studied. The non dimensional parameters influences are discussed graphically using perturbation method.

Keywords: Hall Current, Chemical Reaction, MHD, Radiation, Porous Medium Oscillatory, Heat Source.

1. Introduction

In the present era, most of the research scholars investigate the effects of radiation on MHD oscillatory rotation flow over a porous medium bounded by two vertical porous plates in the presence of strong magnetic field and heat absorption with the first order chemical reaction. The velocity, temperature and concentration of fluid flow under the influence of various parameters, are used to studied the fluid characteristics in different systems such as reciprocating engines, pulse combustors and chemical reactors etc., Abdul Maleque and Abdus Sattar [1] studied the effects of variable properties and Hall current on steady MHD laminar convective fluid flow due to a porous rotating disk. Ahmed [2] has studied the Magnetic field effect on a three dimensional mixed convective flow with mass transfer along an infinite vertical porous plate under the influence of various parameters. Balamurugan, Anuradha and Karthikeyan [3] have investigated the influence of chemical reaction effects on Heat and Mass Transfer of Unsteady flow over an infinite vertical porous plate embedded in a porous medium with heat source. Goldstein [4] has given modern developments in fluid dynamics. Jain and Sharma [5], have explained the effects of viscous heating on flow past a vertical plate in slip flow regime with periodic temperature variations. Kim [6] has studied the Unsteady MHD convective heat transfer past a semi infinite vertical porous moving plate with variable suction. Lighthill [7] have investigated that the response of laminar skin friction and heat transfer to fluctuation in the stream velocity of the fluid flow. Mudagi [8] has studies that heat transfer in three dimensional hydromagnetic flow along a porous infinite plate in the presence of viscous dissipative heat. Muthucumarasamy [9] has investigated the effect of Heat and mass transfer on flow

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past an oscillatory vertical plate with variable temperature. Ram and Mishra [10] have studied the MHD flow of conducting fluid through porous media. Sattar [11] has studied the free convection and mass transfer flow through a porous medium past an infinite vertical porous plate with time dependent temperature and concentration. Sudhakar Reddy and Raju [12] have investigated the effect of slip condition, Radiation and chemical reaction on Unsteady MHD periodic flow of a viscous fluid through satured porous medium in a planer channel, by using regular perturbation technique.

2. Flow Description and Governing Equations

Consider an oscillatory rotation flow through a porous medium bounded by two vertical porous plates in the presence heat absorption with homogeneous first order chemical reaction under the influence of strong magnetic field is studied. One plate is kept stationary and another plate is oscillating with uniform velocity. The x'-axis is taken in vertically upward direction along the plate and y'-axis is chosen normal to it. The governing equations of the flow field are written as follows.

$$\frac{\partial v'}{\partial y'} = 0;\ v' = -V_0\ (Constant) \tag{1}$$

$$\frac{\partial u'}{\partial t'} + V_0\frac{\partial u'}{\partial y'} + 2\Omega w' = \nu\frac{\partial^2 u'}{\partial y'^2} - \frac{\sigma B_0^2}{\rho\left(1+m^2\right)}\left(u' + mw'\right) + g\beta\left(T' - T_d'\right) + g\beta_c\left(C' - C_d'\right) - \frac{\nu}{K'}u' \tag{2}$$

$$\frac{\partial w'}{\partial t'} + V_0\frac{\partial w'}{\partial y'} - 2\Omega u' = v\frac{\partial^2 w'}{\partial y'^2} + \frac{\sigma B_0^2}{\rho\left(1+m^2\right)}\left(mu' - w'\right) - \frac{v}{K'}w' \tag{3}$$

$$\frac{\partial T'}{\partial t'} + V_0\frac{\partial T'}{\partial y'} = \frac{k}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y'} + \frac{Q}{\rho C_p}\left(T' - T_d\right) + Q_1'(C' - C_d) \tag{4}$$

$$\frac{\partial C'}{\partial t'} + V_0\frac{\partial C'}{\partial y'} = D\frac{\partial^2 C'}{\partial y'^2} - K'\left(C' - C_d'\right) \tag{5}$$

Where ρ is the density, g is the acceleration due to gravity, T' is the temperature of the fluid, C' is the species concentration, β is the coefficient of thermal expansion, β_c s the volumetric expansion coefficient, ν is the kinematic viscosity of the fluid, k is effective thermal conductivity, K' is the chemical reaction parameter, D is the diffusion coefficient, k_T is the thermal diffusion ratio, C_s is the concentration susceptibility, C_p is the specific heat at constant pressure, B_0 is the electromagnetic induction, ρ is the conductivity of the fluid, d is the distance between two plates.

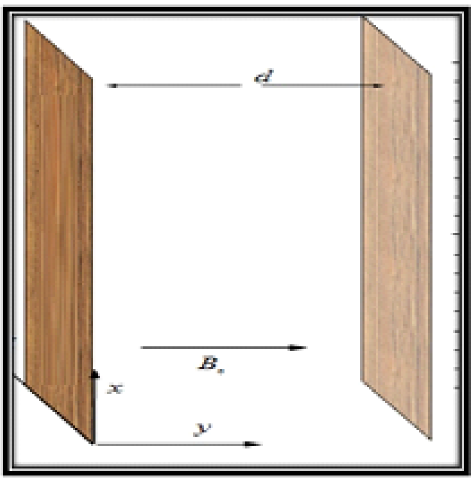

Figure 1. **Physical Configuration of the problem**

The appropriate boundary conditions are

$$\begin{aligned} &u' = 0,\ w' = 0,\ T' = T_0 + \varepsilon\left(T_0 - T_d\right)\cos\omega' t',\ C' = C_0 + \varepsilon\left(C_0 - C_d\right)\cos\omega' t'\ at\, y = 0 \\ &u' = U'(t') = U_0(1 + \cos\omega' t'),\ w' = 0,\ T' = T_d,\ C' = C_d\ at\, y = d \end{aligned} \tag{6}$$

Introduce the following non- dimensional variables and parameters.

$$
\begin{aligned}
& y=\frac{y'}{d},\, t=\frac{t' V_0}{d},\, \omega=\frac{\omega' d}{V_0},\, u=\frac{u'}{U_0'},\, w=\frac{w'}{U_0'},\, K=\frac{K' V_0}{\nu d},\, \theta=\frac{T'-T_d}{T_0-T_d},\, C=\frac{C'-C_d}{C_0-C_d} \\
& Pe=\frac{\rho C_p V_0 d}{k},\, K=\frac{K' d}{V_0},\, Re=\frac{V_0 d}{\nu},\, S=\frac{Q' d}{\rho C_p V_0'},\, U=\frac{U'}{U_0},\, Gr=\frac{\nu g \beta\left(T_0-T_d\right)}{U_0 V_0^2} \\
& Gm=\frac{\nu g \beta_c\left(C_0-C_d\right)}{U_0 V_0^2},\, S_c=\frac{\nu}{D'},\, M=B_0 d \sqrt{\frac{\sigma}{\mu}},\, f=\frac{4 I_1 d}{\rho C_p V_0} \\
& \frac{\partial q_{r'}}{\partial y'}=4 I_1\left(T'-T_d\right),\, \Omega=\frac{d^2 \Omega^*}{\nu},\, Q_1=\frac{Q_1'(C'-C_d) d}{(T_0-T_d) V_0}
\end{aligned}
\tag{7}
$$

Where $I_1 = \int_0^\infty K_{\lambda w} \frac{\partial e_{b\lambda}}{\partial T'} d\lambda$, $K_{\lambda w}$ is the absorption coefficient at wall and $e_{b\lambda}$ is Planck's function. Substituting (7) in the equations (2), (3), (4) and (5) under the boundary conditions (6), we get a system of differential equations in the non-dimensional variables as like as follows.

$$
\frac{\partial u}{\partial t}+\frac{\partial u}{\partial y}+\frac{1}{Re} 2 \Omega w=\frac{1}{Re} \frac{\partial^2 u}{\partial y^2}-\frac{M^2}{Re\left(1+m^2\right)}(u+m w)+Gr\, \theta\, Re+Gm\, C\, Re-\frac{1}{K} u \tag{8}
$$

$$
\frac{\partial w}{\partial t}+\frac{\partial w}{\partial y}-\frac{1}{Re} 2 \Omega u=\frac{1}{Re} \frac{\partial^2 w}{\partial y^2}+\frac{M^2}{Re\left(1+m^2\right)}(m u-w)-\frac{1}{K} w \tag{9}
$$

$$
\frac{\partial \theta}{\partial t}+\frac{\partial \theta}{\partial y}=\frac{1}{Pe} \frac{\partial^2 \theta}{\partial y^2}+(S-f) \theta+Q_1 C \tag{10}
$$

$$
\frac{\partial C}{\partial t}+\frac{\partial C}{\partial y}=\frac{1}{Sc\, Re} \frac{\partial^2 C}{\partial y^2}-K\, C \tag{11}
$$

The relevant boundary conditions

$$
\begin{aligned}
& u=0,\, w=0,\, \theta=1+\frac{\varepsilon}{2}\left(e^{i \omega t}+e^{-i \omega t}\right),\, C=1+\frac{\varepsilon}{2}\left(e^{i \omega t}+e^{-i \omega t}\right) \; at\; y=0 \\
& u=1+\frac{\varepsilon}{2}\left(e^{i \omega t}+e^{-i \omega t}\right),\, w=0,\, \theta=0,\, C=0 \; at\; y=1
\end{aligned}
\tag{12}
$$

where,

$Gr = \frac{\nu g\beta(T_0-T_d)}{U_0 V_0^2}$ is the Grashof number,

$Gm = \frac{\nu g\beta_c(C_0-C_d)}{U_0 V_0^2}$ is the modified Grashof number

$Sc = \frac{\nu}{D}$ is the Schmidt number

$M = B_0 d\sqrt{\frac{\sigma}{\mu}}$ is the Hartmann number,

$Re = \frac{v_0 d}{\nu}$ is the Reynolds number,

$K = \frac{K' d}{V_0}$ is the chemical reaction parameter,

$\Omega = \frac{d^2\Omega^*}{\nu}$ is the angular velocity,

$Pe = \frac{\rho C_p V_0 d}{k}$ is the Peclet number,

$S = \frac{Q' d}{\rho C_p V_0}$ is the heat source,

$Q_1 = \frac{Q_1'(C'-C_d)d}{(T_0-T_d)V_0}$ is the Heat absorption

Introducing the complex velocity

$$
F=u+i w, \quad M_1=\frac{M^2}{\left(1+m^2\right)}(1-i m)
$$

the equations (8) and (9) can be combined into a single equation of the form

$$
\frac{\partial F}{\partial t}+\frac{\partial F}{\partial y}=\frac{1}{Re} \frac{\partial^2 F}{\partial y^2}-\left(\frac{M_1}{Re}+\frac{1}{K}-\frac{1}{Re} 2 i \Omega\right) F+Gr\, \theta\, Re+Gm\, C\, Re \tag{13}
$$

The corresponding boundary conditions are

$$
\left.\begin{aligned}
& F=0, && at\, y=0 \\
& F=1+\tfrac{\varepsilon}{2}\left(e^{i \omega t}+e^{-i \omega t}\right), && at\, y=1
\end{aligned}\right\}
\tag{14}
$$

2.1. Method of Solution

To solve equations (10), (11) and (13) assuming ε to be small so that one can express F, θ and C as a perturbation series in terms of ε in the neighborhood of the plate as

$$\left.\begin{aligned}\theta &= \theta_0(y) + \tfrac{\varepsilon}{2}\theta_1(y)e^{i\omega t} + \tfrac{\varepsilon}{2}\theta_2(y)e^{-i\omega t}\\ C &= C_0(y) + \tfrac{\varepsilon}{2}C_1(y)e^{i\omega t} + \tfrac{\varepsilon}{2}C_2(y)e^{-i\omega t}\\ F &= F_0(y) + \tfrac{\varepsilon}{2}F_1(y)e^{i\omega t} + \tfrac{\varepsilon}{2}F_2(y)e^{-i\omega t}\end{aligned}\right\} \tag{15}$$

Using the equation (15) in equation (11) we get the following set of equations

$$\frac{d^2C_0}{dy^2} - Sc\,Re\,\frac{dC_0}{dy} - Sc\,Re\,K\,C_0 = 0 \tag{16}$$

$$\frac{d^2C_1}{dy^2} - Sc\,Re\,\frac{dC_1}{dy} - Sc\,Re\,(K + i\omega)\,C_1 = 0 \tag{17}$$

$$\frac{d^2C_2}{dy^2} - Sc\,Re\,\frac{dC_2}{dy} - Sc\,Re\,(K - i\omega)\,C_2 = 0 \tag{18}$$

The relevant boundary conditions are

$$\begin{aligned}&C_0 = 1,\ C_1 = 1,\ C_2 = 1\ when\ y = 0\\ &C_0 = 0,\ C_1 = 0,\ C_2 = 0\ when\ y = 1\end{aligned} \tag{19}$$

Solving the equations (16) to (18), using the boundary conditions, we get the solutions as

$$C_0 = A_1e^{m_1y} + A_2e^{m_2y} \tag{20}$$

$$C_1 = A_3e^{m_3y} + A_4e^{m_4y} \tag{21}$$

$$C_2 = A_5e^{m_5y} + A_6e^{m_6y} \tag{22}$$

Using the equation (15) in equation (10) we get the following set of equations

$$\frac{d^2\theta_0}{dy^2} - Pe\,\frac{d\theta_0}{dy} + (S - f)\,Pe\,\theta_0 = -Pe\,Q_1\,C_0 \tag{23}$$

$$\frac{d^2\theta_1}{dy^2} - Pe\,\frac{d\theta_1}{dy} + ((S - f) - i\omega)\,Pe\theta_1 = -Pe\,Q_1\,C_1 \tag{24}$$

$$\frac{d^2\theta_2}{dy^2} - Pe\,\frac{d\theta_2}{dy} + ((S - f) + i\omega)\,Pe\,\theta_2 = -Pe\,Q_1\,C_2 \tag{25}$$

Solving the equations (23) to (25), we get the solutions as

$$\theta_0 = A_9e^{m_7y} + A_{10}e^{m_8y} + A_7e^{m_1y} + A_8e^{m_2y} \tag{26}$$

$$\theta_1 = A_{13}e^{m_9y} + A_{14}e^{m_{10}y} + A_{11}e^{m_3y} + A_{12}e^{m_4y} \tag{27}$$

$$\theta_2 = A_{17}e^{m_{11}y} + A_{18}e^{m_{12}y} + A_{15}e^{m_5y} + A_{16}e^{m_6y} \tag{28}$$

Using the equation (15) in the equation (13) we get the following set of equations

$$\frac{d^2F_0}{dy^2} - Re\,\frac{dF_0}{dy} - \left(M_1 + \frac{Re}{K} - 2i\Omega\right)F_0 = -Gr\,Re^2\,\theta_0 - Gm\,Re^2\,C_0 \tag{29}$$

$$\frac{d^2F_1}{dy^2} - Re\,\frac{dF_1}{dy} - \left(M_1 + \frac{Re}{K} + Re\,i\omega - 2i\Omega\right) F_1 = -Gr\,Re^2\,\theta_1 - Gm\,Re^2\,C_1 \tag{30}$$

$$\frac{d^2F_2}{dy^2} - Re\,\frac{dF_2}{dy} - \left(M_1 + \frac{Re}{K} - Re\,i\omega - 2i\Omega\right) F_2 = -Gr\,Re^2\,\theta_2 - Gm\,Re^2\,C_2 \tag{31}$$

The relevant boundary conditions are

$$\begin{aligned} &F_0 = 0,\ F_1 = 0,\ F_2 = 0\ when\,y = 0 \\ &F_0 = 1,\ F_1 = 1,\ F_2 = 1\ when\,y = 1 \end{aligned} \tag{32}$$

Solving the equations (30) - (32), we get the solutions as,

$$F_0 = A_{27}e^{m_{13}y} + A_{28}e^{m_{14}y} + A_{19}e^{m_1y} + A_{20}e^{m_2y} + A_{21}e^{m_7y} + A_{22}e^{m_8y} + A_{23}e^{m_1y} + A_{24}e^{m_2y} \tag{33}$$

$$F_1 = A_{37}e^{m_{15}y} + A_{38}e^{m_{16}y} + A_{29}e^{m_9y} + A_{30}e^{m_{10}y} + A_{31}e^{m_3y} + A_{32}e^{m_4y} + A_{33}e^{m_3y} + A_{34}e^{m_4y} \tag{34}$$

$$F_2 = A_{47}e^{m_{17}y} + A_{48}e^{m_{18}y} + A_{39}e^{m_5y} + A_{40}e^{m_6y} + A_{41}e^{m_{11}y} + A_{42}e^{m_{12}y} + A_{43}e^{m_5y} + A_{44}e^{m_6y} \tag{35}$$

2.2. Skin Friction

The Skin friction for the velocity F at the moving plate is given by

$$\begin{aligned} \tau_w = -\mu\left(\tfrac{\partial F}{\partial y}\right) &= A_{27}m_{13}e^{m_{13}} + A_{28}m_{14}e^{m_{14}} + A_{19}m_1e^{m_1} + A_{20}m_2e^{m_2} + A_{21}m_7e^{m_7} + A_{22}m_8e^{m_8} \\ &+A_{23}m_1e^{m_1} + A_{24}m_2e^{m_2} + \tfrac{\varepsilon}{2}(A_{37}m_{15}e^{m_{15}} + A_{38}m_{16}e^{m_{16}} + A_{29}m_9e^{m_9} + A_{30}m_4e^{m_{10}} \\ &+A_{31}m_3e^{m_3} + A_{32}m_4e^{m_4} + A_{33}m_3e^{m_3} + A_{34}m_4e^{m_4})e^{\omega t} + \tfrac{\varepsilon}{2}(A_{47}m_{17}e^{m_{17}} + A_{48}m_{18}e^{m_{18}} \\ &+A_{39}m_5e^{m_5} + A_{40}m_6e^{m_6} + A_{41}m_{11}e^{m_{11}} + A_{42}m_{12}e^{m_{12}} + A_{43}m_5e^{m_5} + A_{44}m_6e^{m_6})e^{-\omega t} \end{aligned} \tag{36}$$

2.3. Heat Flux

The rate of heat transfer at the moving plate of non dimensional nusselt number is given by

$$\begin{aligned} N_u = -\left(\tfrac{\partial\theta}{\partial y}\right)_{y=1} &= A_9m_7e^{m_7} + A_{10}m_8e^{m_8} + A_7m_1e^{m_1} + A_8m_2e^{m_2} + \tfrac{\varepsilon}{2}(A_{13}m_9e^{m_9} + A_{14}m_{10}e^{m_{10}} \\ &+A_{11}m_3e^{m_3} + A_{12}m_4e^{m_4})e^{\omega t} + \tfrac{\varepsilon}{2}(A_{17}m_{11}e^{m_{11}} + A_{18}m_{12}e^{m_{12}} + A_{15}m_5e^{m_5} + A_{16}m_6e^{m_6})e^{-\omega t} \end{aligned} \tag{37}$$

2.4. Mass Flux

The rate of mass transfer at the moving plate of non dimensional Sherwood Number is given by

$$Sh = -\left(\frac{\partial\varphi}{\partial y}\right)_{y=1} = A_1m_1e^{m_1} + A_2m_2e^{m_2} + A_3m_3e^{m_3} + A_4m_4e^{m_4} + A_5m_5e^{m_5} + A_6m_6e^{m_6} \tag{38}$$

2.5. Results and Discussion

In order to get physical output of the problem we have studied the main flow, cross section flow, skin friction, heat and mass flux as a functions of various parameters like Reynolds number(Re), Prandtl Number, Suction parameter, Frequency parameter, Schmidt number, Thermal Grashof number and mass Grashof number.

The effect of flows under the influence of above parameters have been analyzed numerically and discussed with the help of numerical values and graphs.Figure 1.1 depicts that increase of Schmidt number increases the concentration of the fluid flow. This is clearly understand the fact that increase values of Schmidt parameter is fall in the chemical molecular diffusivity that is less diffusion therefore takes place by species transfer causing a reduction in concentration. In the figure 1.2, we

observed the increase of Reynolds number decreases the concentration of the fluid flow. Due to heat absorption of the fluid flow, the temperature of the fluid flow goes on decrease as shown in the figure 1.3. Figure 1.4 depicts that the increase of peclet number retardation of temperature of the fluid flow. Figure 1.6 depicts, that the radiation parameter decreases the temperature profile of the fluid. Because of the effect of radiation decreases the rate of energy transport to the fluid. In the figure 1.8, we observed that the increase of Grashof number retards the secondary velocity of the fluid flow.
This indicates that the thermal buoyancy acts like a favourable pressure gradient which retards the fluid within the boundary layer but the reverse process exist for the primary velocity as shown in the figure 1.6. Figure 1.14 depicts that the increase Due to resistance force which opposes to the velocity of the fluid flow which retards the velocity of the fluid. Like that under the influence of various parameter for primary and secondary velocities were graphically shown in the various diagrams.
From the figure 1.19, we observed that the skin friction at the moving plate of fluid increases if increase of heat absorption. From these we conclude that thermal absorption acts like a favorable pressure gradient which accelerates the skin friction of the fluid within the boundary layer. Figure 1.20 depicts that the increase of heat absorption, increases the heat flux of the fluid. Figure 1.21 depicts that the increase of chemical reaction retards mass flux of the fluid flow.

3. Conclusion

Here, some of the results of physical interest on the velocity, temperature, concentration distribution and also on the wall shear stress and the rate of heat transfer, rate of mass transfer at the wall were discussed. The governing equations are solved by using perturbation techniques. An asymptotic solution of the resulting differential equations under the prescribed boundary conditions is obtained. Results are discussed through both numerical values and graphs. Presence of Grashof number for heat, enhance the primary velocity of fluid flow. It is also noticed that an increase in Reynolds number increases the velocity of the flow domain.The effect of magnetic parameter is just opposite to the velocity of the flow.The effect of hall parameter enhances the primary velocity of fluid flow. Increasing of heat absorption enhances the skin friction and heat flux of the fluid flow enhances with increase of heat absorption. The increasing of chemical reaction decreases the mass flux of the fluid flow domain.

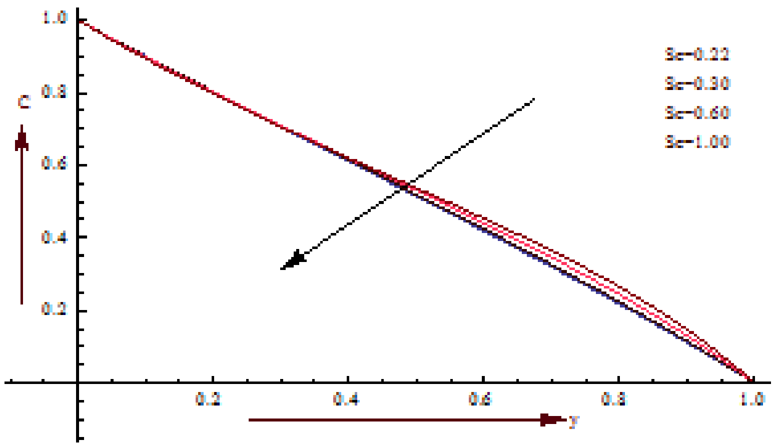

Figure 2. **Concentration profile for various values of Schmidt Number**

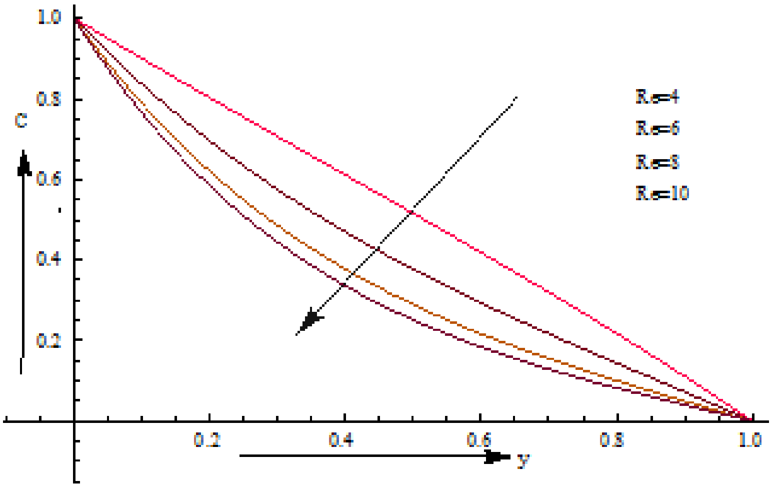

Figure 3. Concentration Profile for various values of Reynolds number

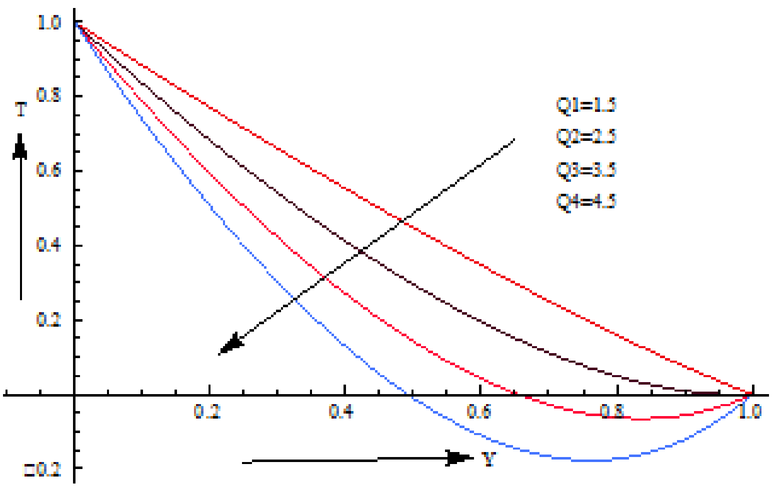

Figure 4. Temperature Profile for various values of Heat absorption

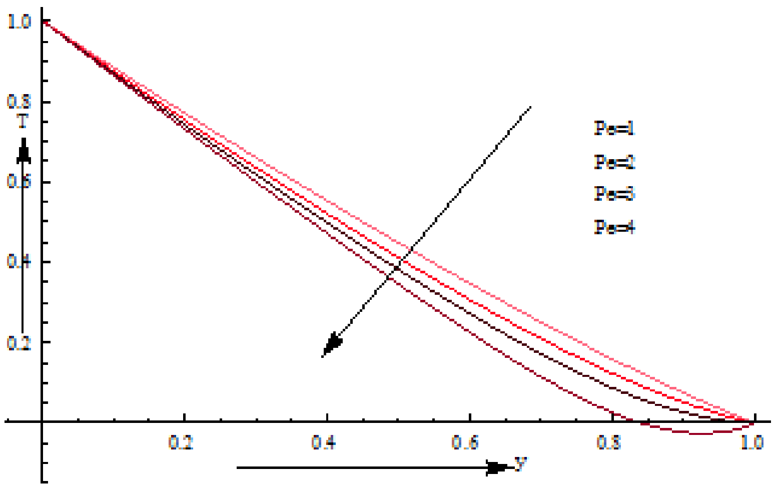

Figure 5. Temperature Profile for various values of Peclet number

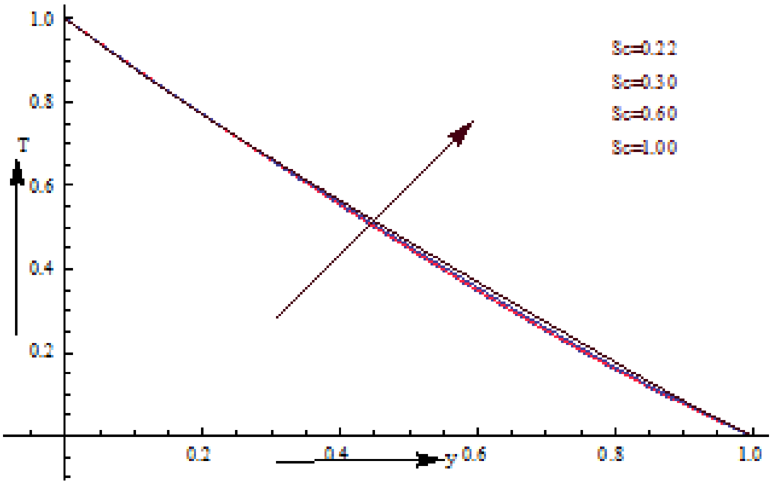

Figure 6. **Temperature profile for various values of Schmidt number**

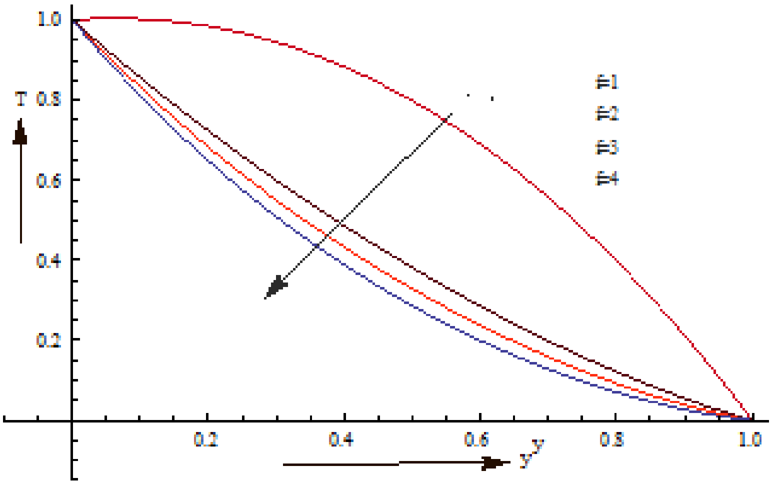

Figure 7. **Temperature Profile for various values of Radiation Parameter**

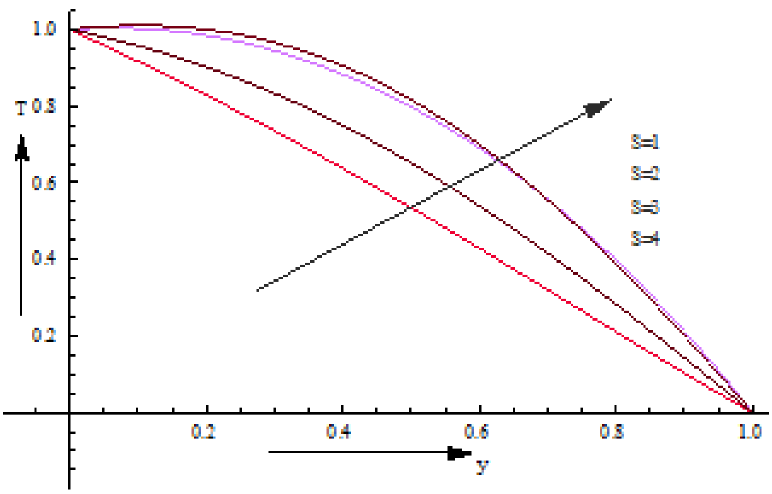

Figure 8. **Temperature Profile for various values of Heat Source**

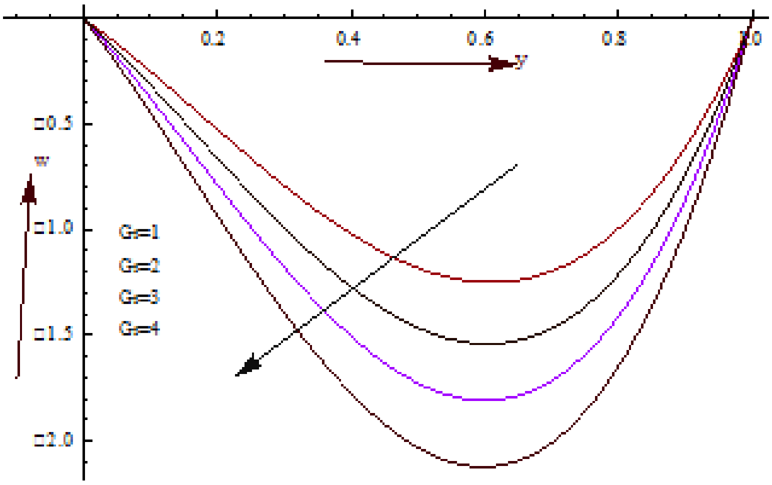

Figure 9. Secondary velocity for various values of Grashof Number

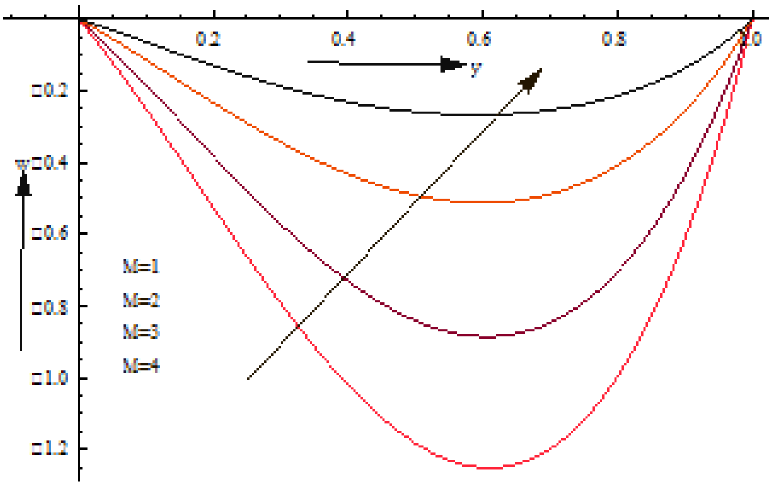

Figure 10. Secondary Velocity for various values of Magnetic Parameter

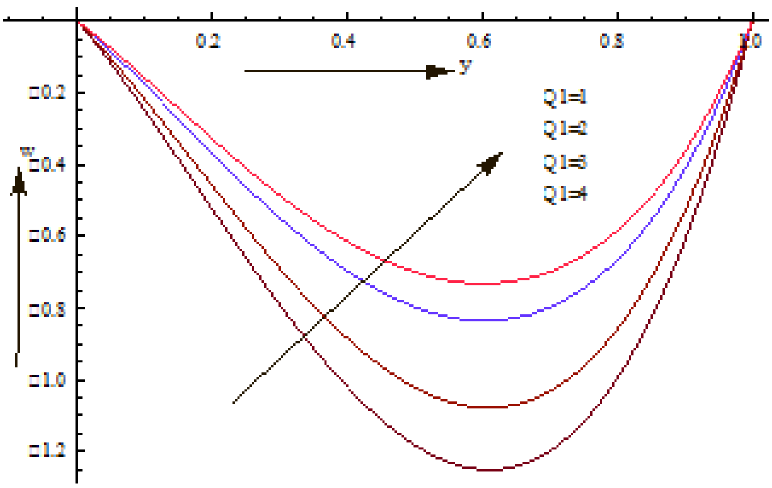

Figure 11. Secondary Velocity for various values of Heat absorption

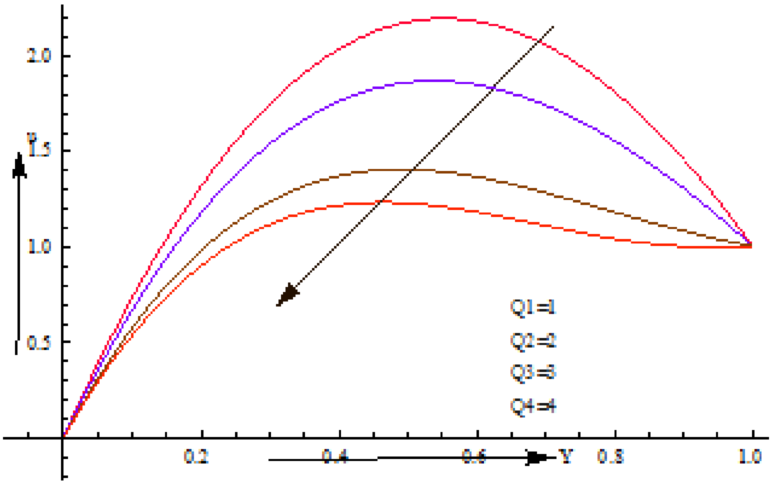

Figure 12. **Primary velocity for various values of Heat obsorption**

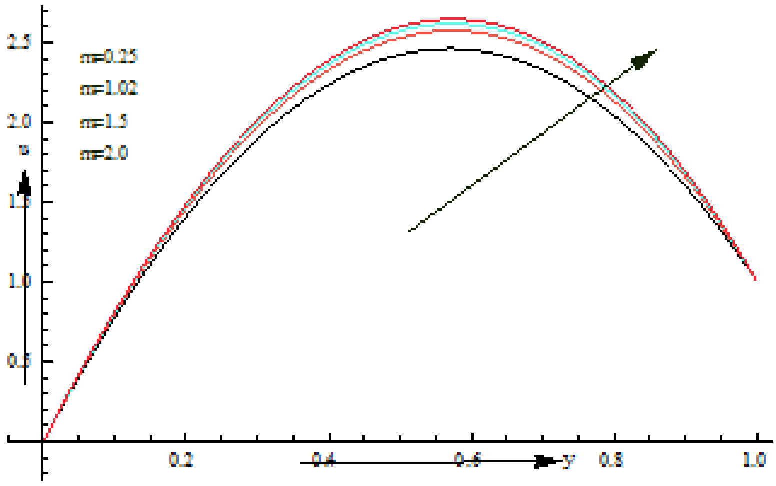

Figure 13. **Primary velocity for various values of hall parameter**

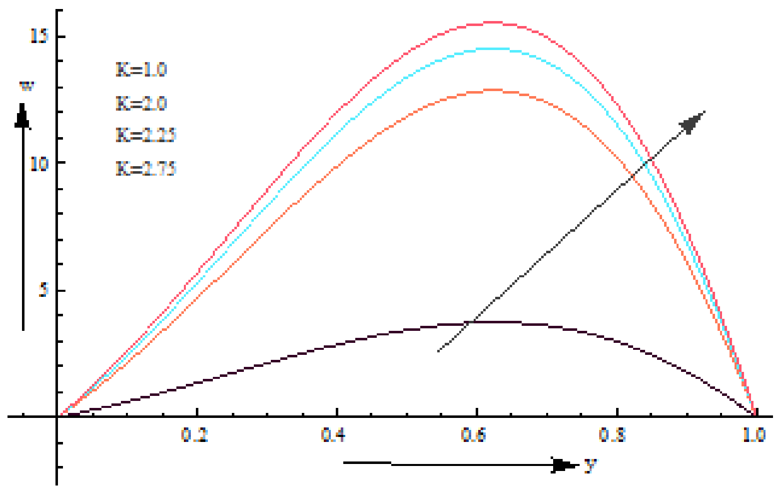

Figure 14. **Secondary velocity for various values of chemical reaction**

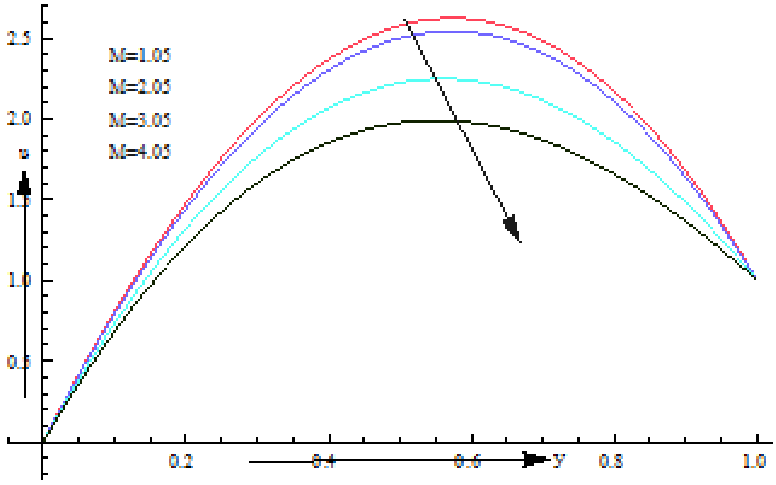

Figure 15. Primary velocity for various values of Magentic parameter

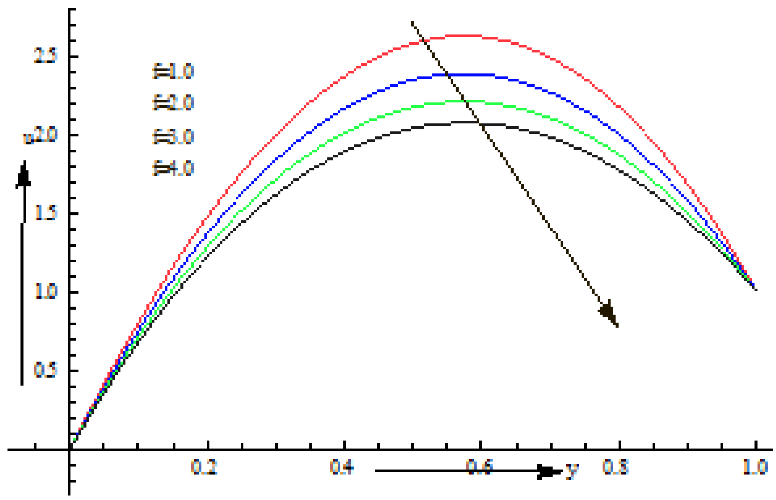

Figure 16. Primary velocity for various values of radiation parameter

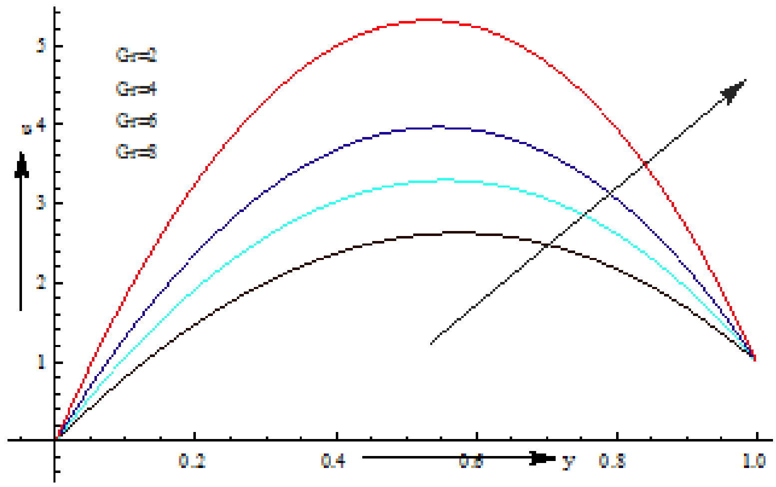

Figure 17. Primary velocity for various values of Grashof number

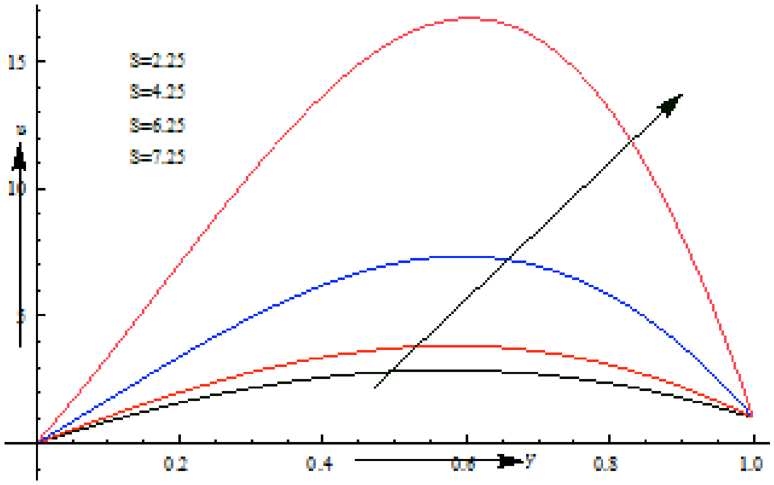

Figure 18. **Primary velocity for various values of heat source**

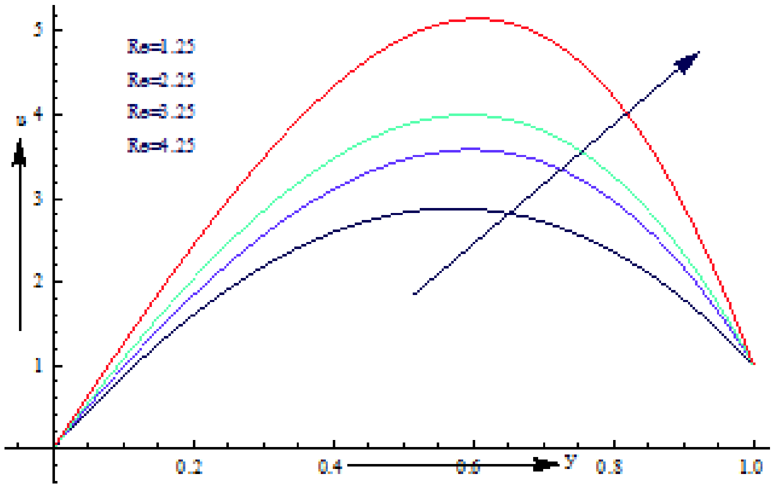

Figure 19. **Primary velocity for various values of Reynolds number**

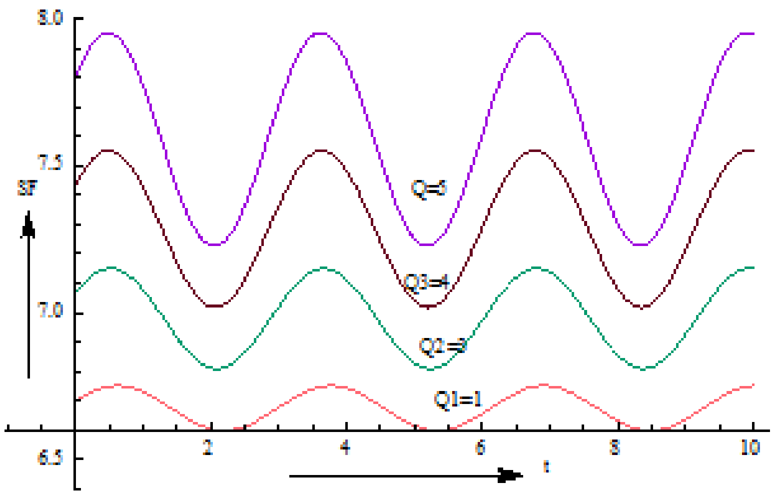

Figure 20. **Skin friction for various values of heat obsorption**

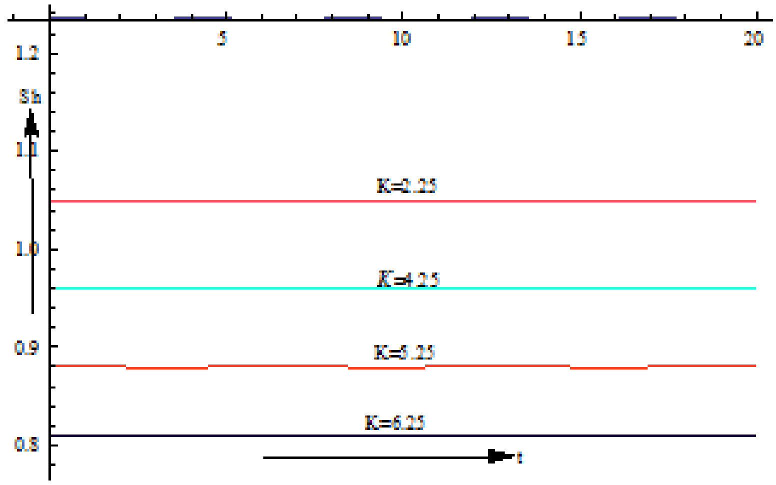

Figure 21. **Mass flux for various values of chemical reaction**

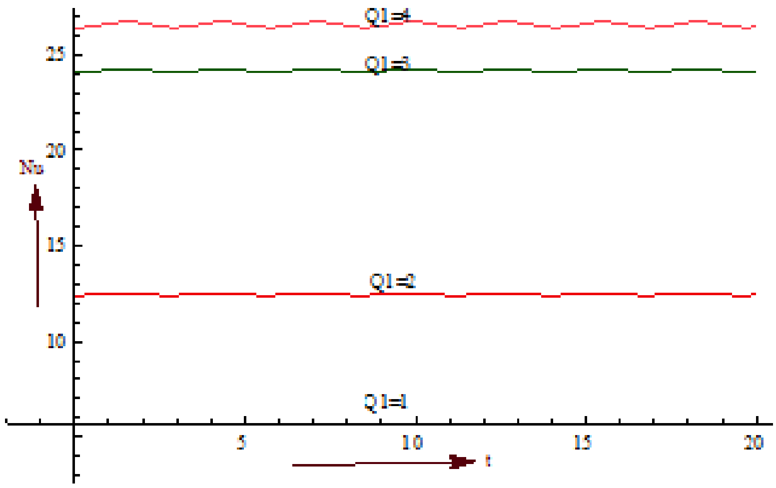

Figure 22. **Heat flux for various values of heat absorption**

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