MHD Oscillatory flow along a porous medium bounded by two vertical porous plates under the influence of hall current with dufour effects in presence of temperature gradient with heat source and chemical reaction

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Abstract

In this paper, MHD Oscillatory flow over through a porous medium which is bounded by two vertical non insulated vertical porous plates under the influence of strong magnetic field that is commonly known as hall effects with dufour and temperature gradient is studied. One plate is kept as stationary and another plate is oscillating with uniform velocity. The Plates are subjected to the constant injection and suction velocities respectively. The velocity of fluid flow is analyzed with two velocity components u *and* w *respectively. The basic governing equations of the problem are transformed into a system of non dimensional differential equations, then the equation are solved analytically by using the method of Perturbation techniques. The dimensionless Velocities, temperature of the fluid flow and concentration profiles are displayed graphically with the effects of different values of the parameters involving in this problem. Under the influence of parameters, velocity, temperature and concentration profiles were enhances and retards.*

Keywords: *Hall Current, Dufour Effect, Chemical Reaction, MHD, Porous Medium, Oscillatory flow, Heat Source, Rotation effect, temperature gradient.*

I. Introduction

In the modern trend, most of the research scholars shows interest in the investigation of the effects of temperature gradient on MHD oscillatory rotation flow over a porous medium bounded by two vertical porous plates under the influence of strong magnetic field and temperature gradient 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 like as reciprocating engines, pulse combustors and chemical reactors etc., Ahmadi G and Manvi R. [1] have investigated of motion for viscous flow through a rigid porous medium under the influence of various parameters. Ahmed N [2] has studied the MHD Convection with soret and dufour effect in the Three dimensional flow past an infinite vertical porous plate. His research put highly impact in the temperature and concentration of the fluid. Attia H.A [3] has investigated the transisent MHD flow and heat transfer between two parallel plates with temperature dependent viscosity.

Barik R.N., G.C. Dash and P.K. Rath [4] have studied the Heat and mass Transfer on MHD flow through a porous medium over a stretching surface with heat source. Bisht V., Kumar. M., and Uddin. Z.,[5] have studied the effect of variable thermal conductivity and chemical reaction on steady mixed convection boundary layer flow with heat and mass transfer inside a cone due to a point. After their research so many researches were carried out their research in the field of mixed convection flow.

Cheng.P., and Minkowycz W.J.[6] have investigated the free Convection about a vertical plate which is embedded in a porous medium with application to Heat Transfer from a dike.

Das S.S.,Tripathy R.K., Padhy R.K., Sahu M [7] put their investigation in the field of combined natural convection and mass transfer effects on unsteady flow past an infinite vertical porous plate embedded in a porous medium with heat source. Elbashbeshy E.M.A.,[8] has studied the Heat and mass transfer along a vertical plate with variable surface temperature and concentration in the presence of the magntic field. Govindarajan. A, Ramamurthy V, and Sundarammal K., [9] have investigated the 3D Couette flow of dusty fluid with transpiration cooling. Hossain. M.A., and Das. S.K**.,** [10] have investigated the heat transfer response of MHD free convection flow along a vertical plate to surface temperature oscillations.

Jaiswal B.S and Soundalgekar V.M**.,** [11] have studied the oscillating plate temperature effects on a flow past an infinite porous plate with constant suction and embedded in a porous medium. Kim Y.J**.,** [12] has investigated unsteady MHD convective heat transfer past a semi – infinite vertical porous moving plate with variable suction. Yu. S., and Ahen. T.A., [13] have studied the nature of Slip flow heat transfer in rectangular micro channel.

II. Flow Description and Governing Equations

Consider an MHD oscillatory rotation flow through a porous medium bounded by two vertical porous plates under the influence of temperature gradient 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.

$$\frac{\partial v'}{\partial y'} = 0;\ v' = -V_0 \quad \text{(Constant)} \tag{1.1}$$

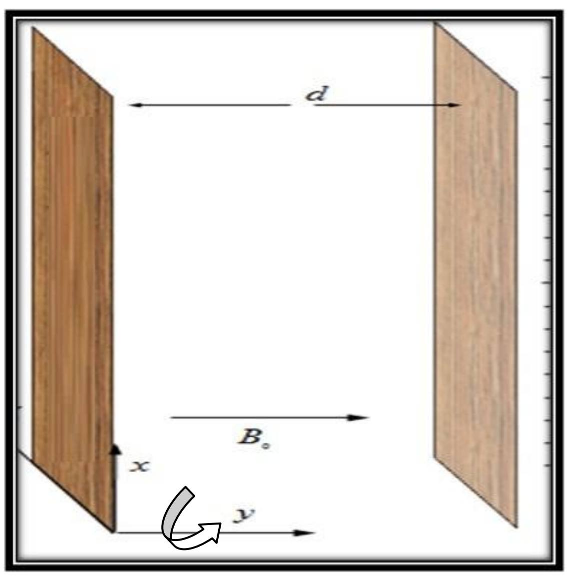
$$\frac{\partial u'}{\partial t'} + V_0 \frac{\partial u'}{\partial y'} + 2\Omega w' = \nu \frac{\partial^2 u'}{\partial y'^2} - \frac{\sigma B_0^{\ 2}}{\rho\left(1+m^2\right)}\left(u' + m w'\right) + g\beta\left(T' - T_d'\right) + g\beta_c\left(C' - C_d'\right) - \frac{\nu}{K'} u' \tag{1.2}$$

$$\frac{\partial w'}{\partial t'} + V_0 \frac{\partial w'}{\partial y'} - 2\Omega u' = \nu \frac{\partial^2 w'}{\partial y'^2} + \frac{\sigma B_0^{\ 2}}{\rho\left(1+m^2\right)}\left(m u' - w'\right) - \frac{\nu}{K'} w' \tag{1.3}$$

$$\frac{\partial T'}{\partial t'} + V_0 \frac{\partial T'}{\partial y'} = \frac{k}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} + \frac{Q'}{\rho C_p}\frac{d\theta}{dy} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y'} + \frac{Q}{\rho C_p}\left(T' - T_d\right) + \frac{D_m K_T}{C_s C_p}\frac{\partial^2 C'}{\partial y'^2} \tag{1.4}$$

$$\frac{\partial C'}{\partial t'} + V_0 \frac{\partial C'}{\partial y'} = D\frac{\partial^2 C'}{\partial y'^2} - K'\left(C' - C'_d\right) \tag{1.5}$$

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 is 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. These are the parameters are used in the governing equation of the fluid flow.



Physical description of the fluid flow problem

The appropriate boundary conditions are

$$u' = 0,\ w' = 0,\ T' = T_0 + \varepsilon\left(T_0 - T_d\right)\cos\omega' t',\ C' = C_0 + \varepsilon\left(C_0 - C_d\right)\cos\omega' t'\ \ at\ y = 0$$

$$u' = U'(t') = U_0(1+\cos\omega' t'),\ w' = 0,\ T' = T_d,\ C' = C_d \qquad at\ \ y = d \qquad (1.6)$$

Introduce the following non- dimensional variables and parameters.

$$y = \frac{y'}{d}, t = \frac{t' V_0}{d}, \omega = \frac{\omega' d}{V_0}, u = \frac{u'}{U_0{}'}, w = \frac{w'}{U_0{}'} K = \frac{K' V_0}{\nu d}, \theta = \frac{T' - T_d}{T_0 - T_d}, C = \frac{C' - C_d}{C_0 - C_d}$$

$$Pe = \frac{\rho C_p V_0 d}{k}, K = \frac{K' d}{V_0}, \mathrm{Re} = \frac{V_0 d}{\nu}, S = \frac{Q' d}{\rho C_p V_0{}'}, U = \frac{U'}{U_0}, Gr = \frac{\nu g\beta\left(T_0 - T_d\right)}{U_0 V_0{}^2}$$

$$Gm = \frac{\nu g\beta_c\left(C_0 - C_d\right)}{U_0 V_0{}^2}, S_c = \frac{\nu}{D'}, M = B_0 d\sqrt{\frac{\sigma}{\mu}}, f = \frac{4 I_1 d}{\rho C_p V_0},$$

$$\frac{\partial q_{r'}}{\partial y'} = 4 I_1\left(T' - T_d\right), \Omega = \frac{d^2\Omega^*}{\nu}, H = \frac{Q_0 d}{\rho C p \nu_0 (T_0 - T_d)} \qquad (1.7)$$

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 (1.7) in the equations (1.2),(1.3), (1.4) and (1.5) under the boundary conditions (1.6), we get a system of differential equations in the non-dimensional variables

$$\frac{\partial u}{\partial t} + \frac{\partial u}{\partial y} + \frac{1}{\mathrm{Re}}2\Omega w = \frac{1}{\mathrm{Re}}\frac{\partial^2 u}{\partial y^2} - \frac{M^2}{\mathrm{Re}(1+m^2)}(u + mw) + Gr\,\theta\,\mathrm{Re} + Gm\,C\,\mathrm{Re} - \frac{1}{K}u \qquad (1.8)$$

$$\frac{\partial w}{\partial t}+\frac{\partial w}{\partial y}-\frac{1}{\mathrm{Re}}2\Omega u=\frac{1}{\mathrm{Re}}\frac{\partial^2 w}{\partial y^2}+\frac{M^2}{\mathrm{Re}(1+m^2)}(mu-w)-\frac{1}{K}w \tag{1.9}$$

$$\frac{\partial \theta}{\partial t}+\frac{\partial \theta}{\partial y}=\frac{1}{Pe}\frac{\partial^2 \theta}{\partial y^2}+H\frac{d\theta}{dy}+S\theta+Du\frac{\partial^2 C}{\partial y^2} \tag{1.10}$$

$$\frac{\partial C}{\partial t}+\frac{\partial C}{\partial y}=\frac{1}{Sc\,\mathrm{Re}}\frac{\partial^2 C}{\partial y^2}-KC \tag{1.11}$$

The relevant boundary conditions

$$u=0,w=0,\theta=1+\frac{\varepsilon}{2}\left(e^{i\omega t}+e^{-i\omega t}\right),C=1+\frac{\varepsilon}{2}\left(e^{i\omega t}+e^{-i\omega t}\right) \quad at\ \ y=0$$

$$u=1+\frac{\varepsilon}{2}\left(e^{i\omega t}+e^{-i\omega t}\right),w=0,\theta=0,C=0 \quad at\ \ y=1 \tag{1.12}$$

where,

$Gr=\frac{\nu g\beta\left(T_0-T_d\right)}{U_0V^2{}_0}$ is the Grashof number,

$Gm=\frac{\nu g\beta_c\left(C_0-C_d\right)}{U_0V^2{}_0}$ is the modified Grashof number

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

$M=B_0d\sqrt{\frac{\sigma}{\mu}}$ is the Hartmann number,

$\mathrm{Re}=\frac{v_0d}{\nu}$ is the Reynolds number,

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

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

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

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

$H = \dfrac{Q_0 d}{\rho C p v_0 (T_0 - T_d)}$ is the gradient parameter

Introducing the complex velocity

$$F = u + iw,\ M_1 = \frac{M^2}{(1+m^2)}(1 - im)$$

the equations (1.8) and (1.9) can be combined into a single equation of the form

$$\frac{\partial F}{\partial t} + \frac{\partial F}{\partial y} = \frac{1}{\mathrm{Re}}\frac{\partial^2 F}{\partial y^2} - \left(\frac{M_1}{\mathrm{Re}} + \frac{1}{K} - \frac{1}{\mathrm{Re}} 2i\Omega\right) F + Gr\,\theta\,\mathrm{Re} + Gm\,C\,\mathrm{Re} \tag{1.13}$$

the corresponding boundary conditions are

$$\left.\begin{aligned} &F = 0\ , && at\ \ y = 0 \\ &F = 1 + \frac{\varepsilon}{2}\left(e^{i\omega t} + e^{-i\omega t}\right), && at\ \ y = 1 \end{aligned}\right\} \tag{1.14}$$

1. 3 Method of Solution

To solve equations (1.10), (1.11) and (1.13) assuming ε to be small so that one can express F, θ *and* C as a perturbation series interms of ε in the neighborhood of the plate as

$$\left.\begin{aligned}\theta &= \theta_0(y)+\frac{\varepsilon}{2}\theta_1(y)e^{i\omega t}+\frac{\varepsilon}{2}\theta_2(y)e^{-i\omega t}\\ C &= C_0(y)+\frac{\varepsilon}{2}C_1(y)e^{i\omega t}+\frac{\varepsilon}{2}C_2(y)e^{-i\omega t}\\ F &= F_0(y)+\frac{\varepsilon}{2}F_1(y)e^{i\omega t}+\frac{\varepsilon}{2}F_2(y)e^{-i\omega t}\end{aligned}\right\} \quad (1.15)$$

Using the equation (1.15) in equation (1.11) we get the following set of equations

$$\frac{d^2C_0}{dy^2}-Sc\,\mathrm{Re}\frac{dC_0}{dy}-Sc\,\mathrm{Re}\,K\,C_0=0 \quad (1.16)$$

$$\frac{d^2C_1}{dy^2}-Sc\,\mathrm{Re}\frac{dC_1}{dy}-Sc\,\mathrm{Re}\left(K+i\omega\right)C_1=0 \quad (1.17)$$

$$\frac{d^2C_2}{dy^2}-Sc\,\mathrm{Re}\frac{dC_2}{dy}-Sc\,\mathrm{Re}\left(K-i\omega\right)C_2=0 \quad (1.18)$$

The relevant boundary conditions are

$$\left.\begin{aligned}&C_0=1, C_1=1, C_2=1 \quad when \;\; y=0\\ &C_0=0, C_1=0, C_2=0 \quad when \;\; y=1\end{aligned}\right. \quad (1.19)$$

Solving the equations (1.16) to (1.18), using the boundary conditions, we get the solutions as

$$C_0=A_1e^{m_1y}+A_2e^{m_2y} \quad (1.20)$$

$$C_1=A_3e^{m_3y}+A_4e^{m_4y} \quad (1.21)$$

$$C_2=A_5e^{m_5y}+A_6e^{m_6y} \quad (1.22)$$

Using the equation (1.15) in equation (1.10) we get the following set of equations

$$\frac{d^2\theta_0}{dy^2}-P\mathrm{e}(1-\mathrm{H})\frac{d\theta_0}{dy}+\left(S-f\right)Pe\,\theta_0=-Pe\,Du\frac{d^2C_0}{dy^2} \quad (1.23)$$

$$\frac{d^2\theta_1}{dy^2}-P\mathrm{e}(1-\mathrm{H})\frac{d\theta_1}{dy}+\left(\left(S-f\right)-i\omega\right)Pe\,\theta_1=-Pe\,\frac{d^2C_1}{dy^2} \quad (1.24)$$

$$\frac{d^2\theta_2}{dy^2} - Pe(1-H)\frac{d\theta_2}{dy} + \left((S-f)+i\omega\right)Pe\,\theta_2 = -Pe\frac{d^2C_2}{dy^2} \qquad (1.25)$$

Solving the equations (1.23) to (1.25), we get the solutions as

$$\theta_0 = A_9e^{m_7y} + A_{10}e^{m_8y} + A_7e^{m_1y} + A_8e^{m_2y} \qquad (1.26)$$

$$\theta_1 = A_{13}e^{m_9y} + A_{14}e^{m_{10}y} + A_{11}e^{m_3y} + A_{12}e^{m_4y} \qquad (1.27)$$

$$\theta_2 = A_{17}e^{m_{11}y} + A_{18}e^{m_{12}y} + A_{15}e^{m_5y} + A_{16}e^{m_6y} \qquad (1.28)$$

Using the equation (1.15) in the equation (1.13) we get the following set of equations

$$\frac{d^2F_0}{dy^2} - Re\frac{dF_0}{dy} - \left(M_1 + \frac{\mathrm{Re}}{K} - 2i\Omega\right)F_0 = -Gr\,Re^2\,\theta_0 - Gm\,Re^2\,C_0 \qquad (1.29)$$

$$\frac{d^2F_1}{dy^2} - Re\frac{dF_1}{dy} - \left(M_1 + \frac{\mathrm{Re}}{K} + \mathrm{Re}\,i\,\omega - 2i\Omega\right)F_1 = -Gr\,Re^2\,\theta_1 - Gm\,Re^2\,C_1 \qquad (1.30)$$

$$\frac{d^2F_2}{dy^2} - Re\frac{dF_2}{dy} - \left(M_1 + \frac{\mathrm{Re}}{K} - \mathrm{Re}\,i\,\omega - 2i\Omega\right)F_2 = -Gr\,Re^2\,\theta_2 - Gm\,Re^2\,C_2 \qquad (1.31)$$

The relevant boundary conditions are

$$F_0 = 0, F_1 = 0, F_2 = 0 \quad when \;\; y = 0 \qquad (1.32)$$

$$F_0 = 1, F_1 = 1, F_2 = 1 \quad when \;\; y = 1$$

Solving the equations (1.30) – (1.32), we get the solutions as,

$$F_0 = A_{27}e^{m_{13}y} + A_{28}e^{m_{14}y} + A_{19}e^{m_1y} + A_{20}e^{m_2y} + A_{21}e^{m_7y} + A_{22}e^{m_8y} + A_{23}e^{m_1y} + A_{24}e^{m_2y} \qquad (1.33)$$

$$F_1 = A_{37}e^{m_{15}y} + A_{38}e^{m_{16}y} + A_{29}e^{m_9y} + A_{30}e^{m_{10}y} + A_{31}e^{m_3y} + A_{32}e^{m_4y} + A_{33}e^{m_3y} + A_{34}e^{m_4y} \qquad (1.34)$$

$$F_2 = A_{47}e^{m_{17}y} + A_{48}e^{m_{18}y} + A_{39}e^{m_5y} + A_{40}e^{m_6y} + A_{41}e^{m_{11}y} + A_{42}e^{m_{12}y} + A_{43}e^{m_5y} + A_{44}e^{m_6y} \qquad (1.35)$$

1.4 Skin Friction

The Skin friction is the derivative of velocity at the plate. Here derivative of velocity F at the moving plate is given by

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

(1.36)

1. 5 Heat Flux

Heat flux is the derivative of temperature at the moving plate. It is non dimensional nusselt number. It is denoted by Nu.

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

(1.37)

1.6 Mass Flux

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

$$Sh = -\left(\frac{\partial \varphi}{\partial y}\right)_{y=1} = A_1 m_1 e^{m_1} + A_2 m_2 e^{m_2} + A_3 m_3 e^{m_3} + A_4 m_4 e^{m_4} + A_5 m_5 e^{m_5} + A_6 m_6 e^{m_6} \quad (1.38)$$

1. 7 Results and Discussion

We have studied the main flow, cross section flow, skin friction, heat and mass flux as a functions of various parameters like Reynolds number, 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. depicts that increase of Reynolds number enhances the primary velocity of the fluid flow. This is because of while increase of interia force enhance velocity. From the figure 2, we observed the increase of dufour number increases the velocity of the fluid flow. Remaining figures from 3 to 7 indicates the primary and secondary velocities profiles for various values parameters.

Due to temperature gradient of the fluid flow, the temperature of the fluid flow goes on decrease as shown in the figure 8. The radiation parameter decreases the temperature profile of the fluid as shown in the figure 13. Because of the effect of radiation decreases the rate of energy transport to the fluid. From the figure 19, we observed that the skin friction at the moving plate of fluid decreases if increase of Grashof number. From these we conclude that thermal acts like a unfavorable, which retards the skin friction of the fluid within the boundary layer.

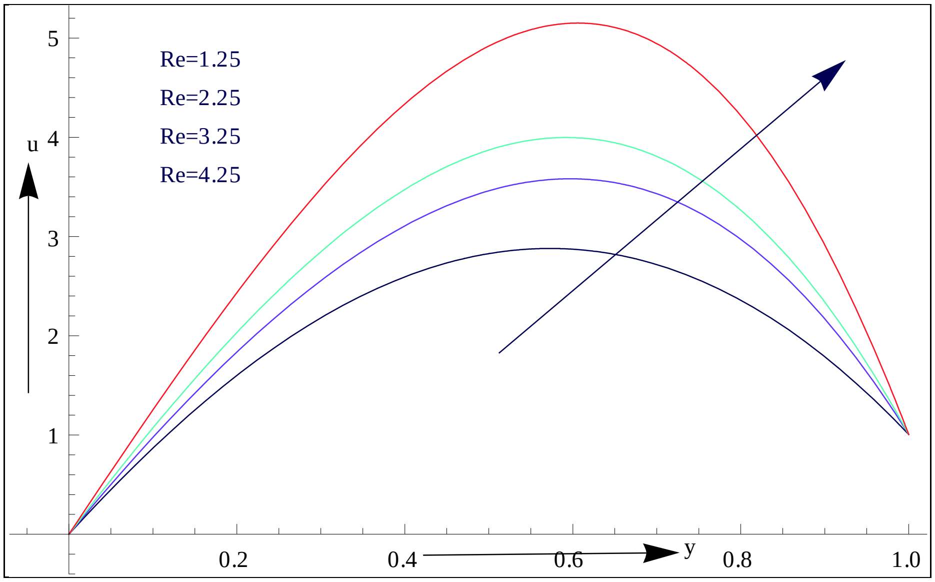
Figure 18 depicts that the increase of temperature gradient, decreases the heat flux of the fluid. Figure 17 depicts that the increase of chemical reaction retards mass flux of the fluid flow.

1.8. Conclusion

Some of the physical parameter induced 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. Solution of the resulting differential equations under the prescribed boundary conditions is obtained. Results are discussed through both numerical values and graphs.

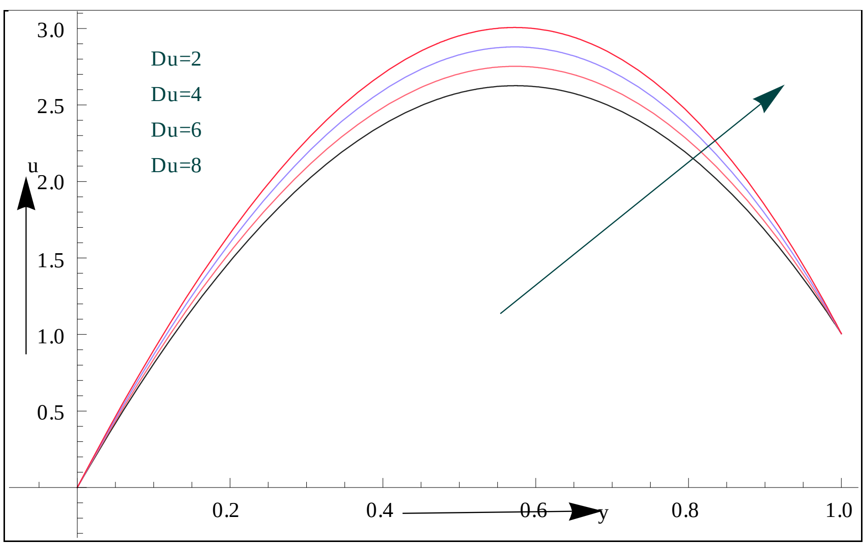
Presence of Grash of number for heat, enhance both primary and secondary velocities of fluid flow. It is also noticed that an increase in Reynolds number increases the velocity of the flow domain. The effect of magnetic parameter is maximum opposite to the primary velocity of the flow. The effect of hall parameter enhances the primary velocity of fluid flow. Increasing of Grash of number enhances the skin friction and heat flux of the fluid flow decreases with increase of temperature gradient. The increasing of chemical reaction decreases the mass flux of the fluid flow domain.

Figure No:- 1



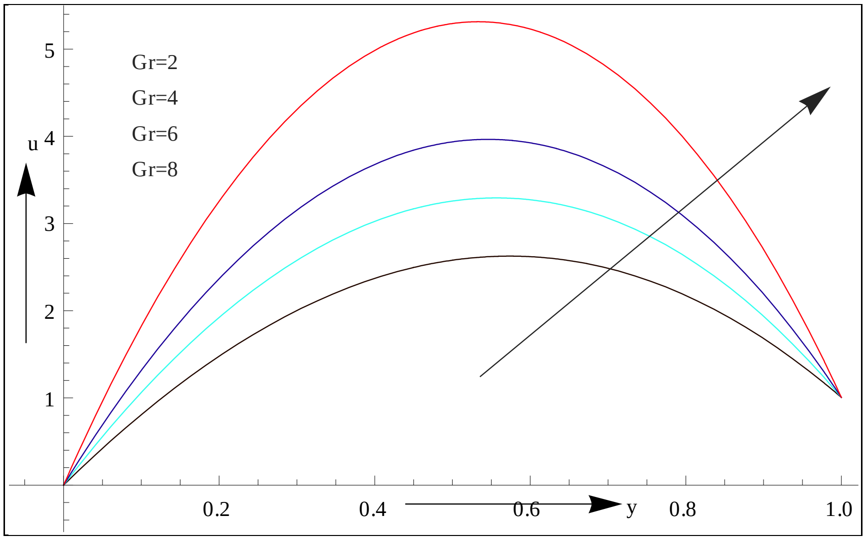
Velocity Profiles for various values of Reynolds Number

Figure No:- 2



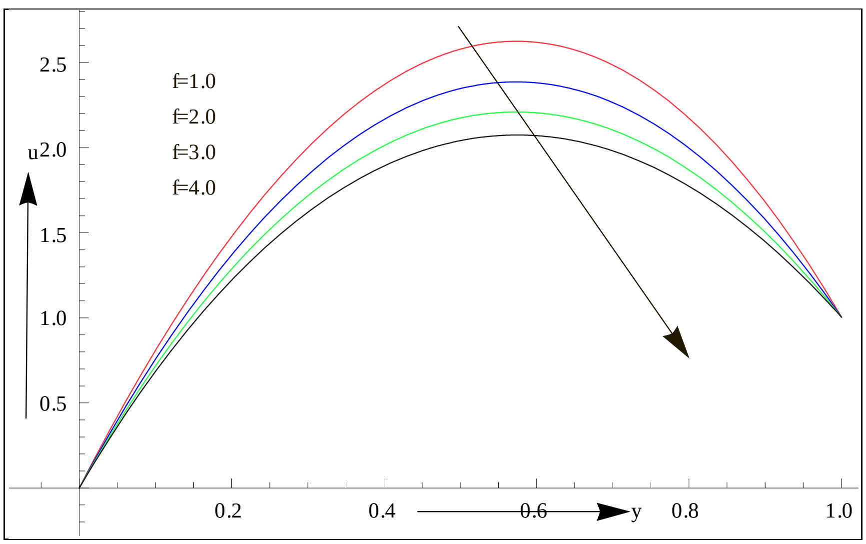
Velocity Profiles for various values of Dufour number

Figure No:- 3



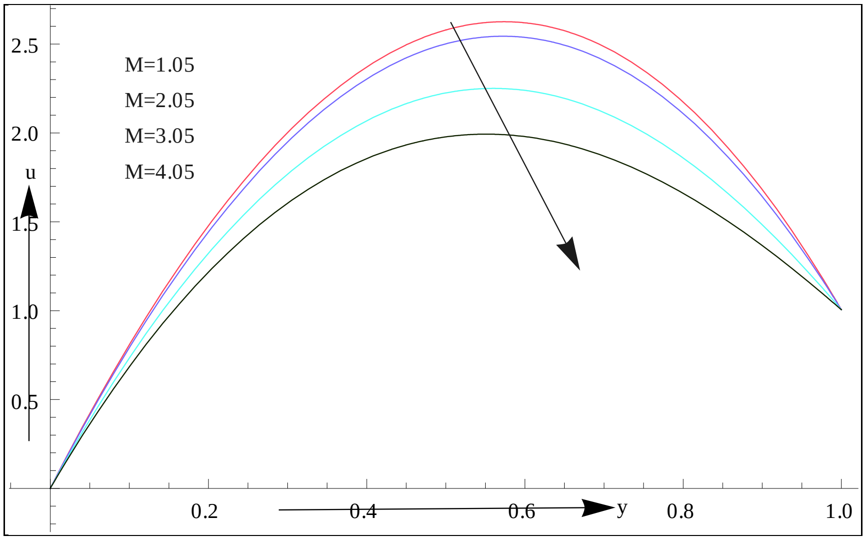
Velocity Profiles for various values of Grashof number

Figure No:- 4



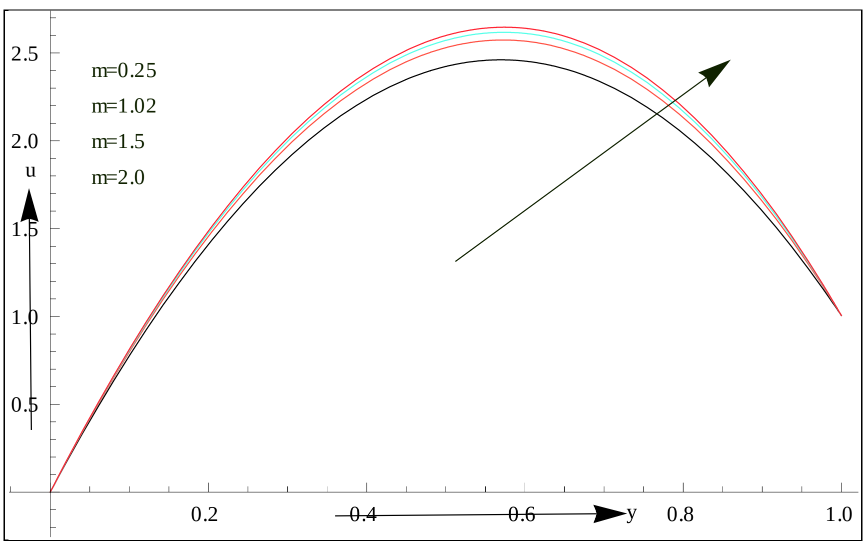
Velocity Profiles for various values of radiation effects

Figure No:- 5



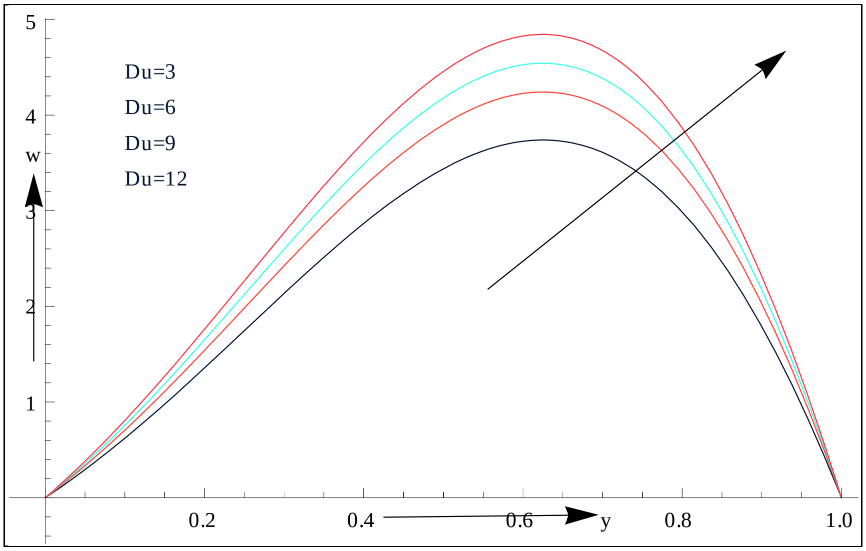
Velocity Profiles for various values of Magnetic effects

Figure No:- 6



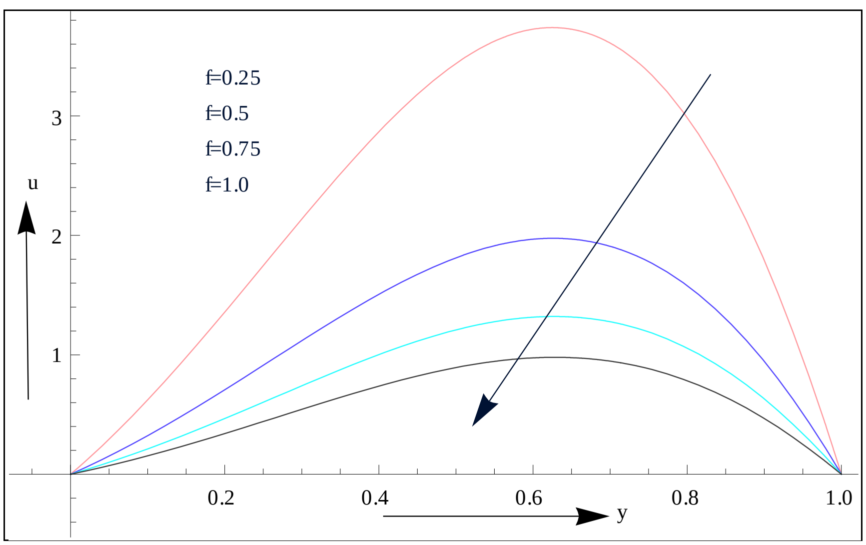
Velocity Profiles for various values of Hall effects

Figure No:- 7



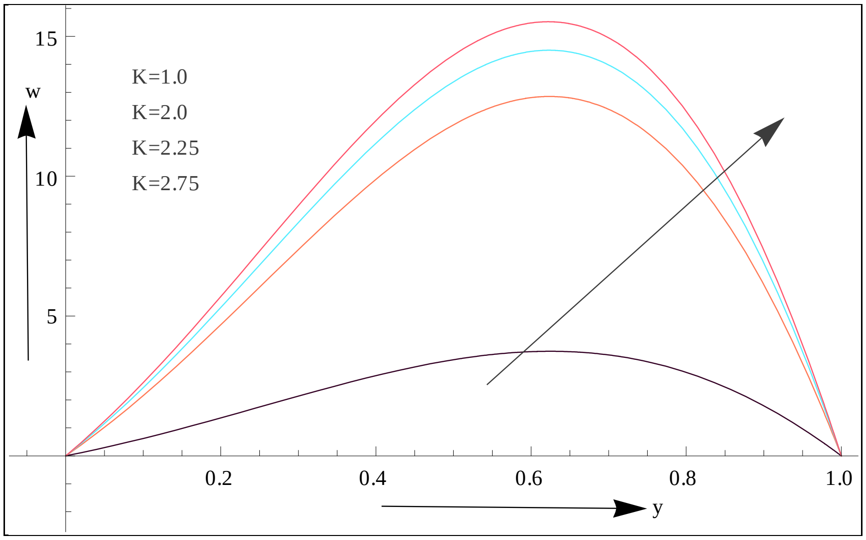
Secondary velocity Profiles for various values of Dufour effects

Figure No:- 8



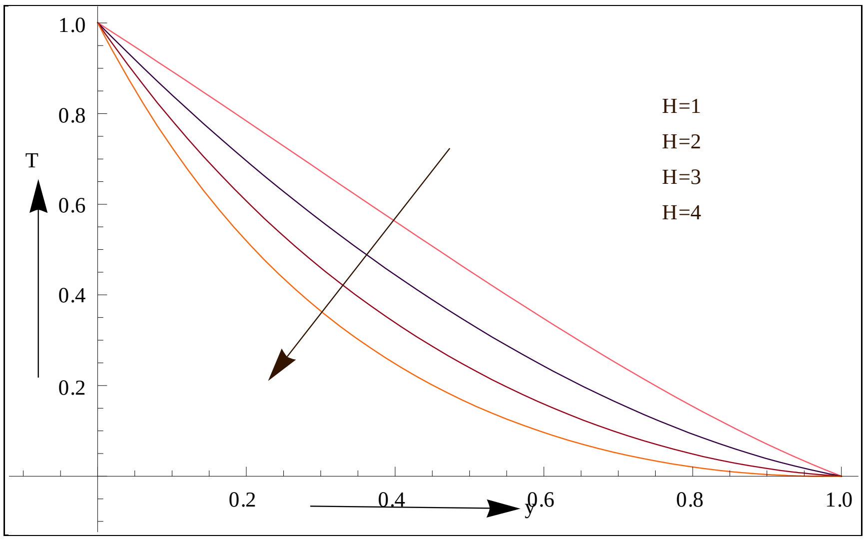
Secondary velocity Profiles for various values of radiation effects

Figure No:- 9



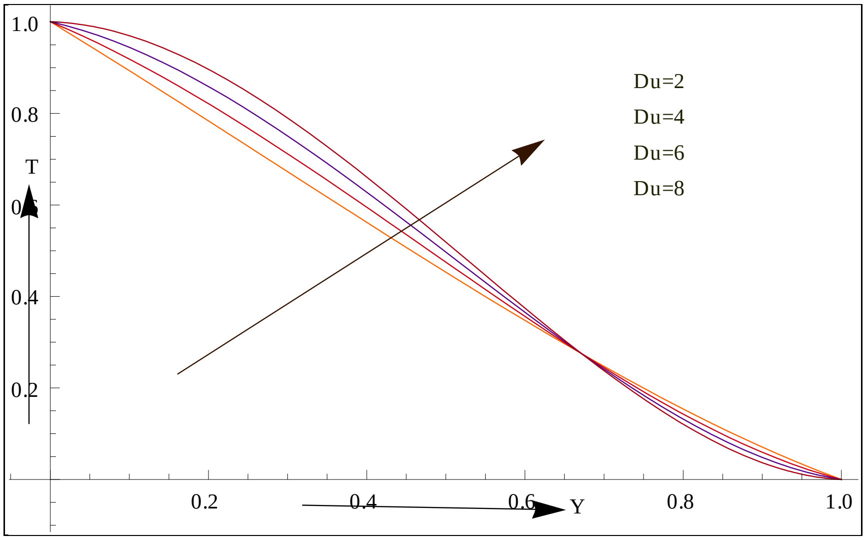
Secondary velocity Profiles for various values of chemical reaction

Figure No:- 10



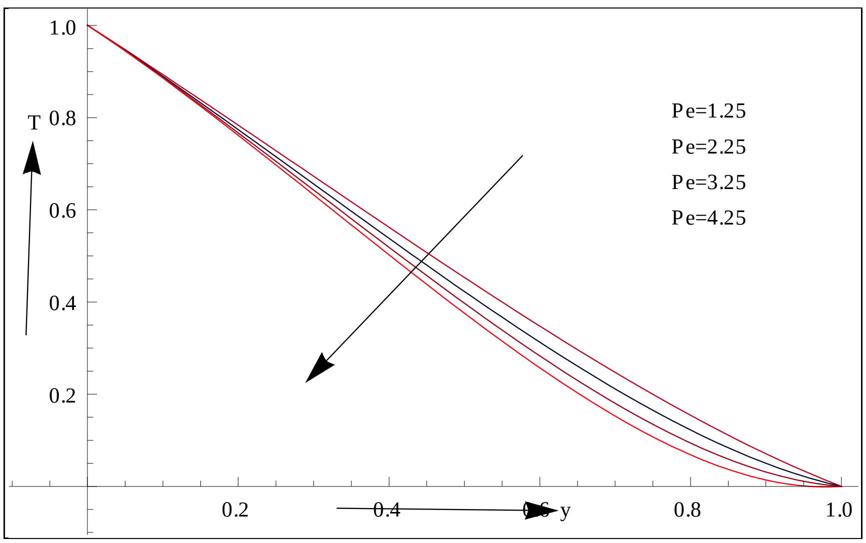
Temperature Profiles for various values of temperature gradient

Figure No:- 11



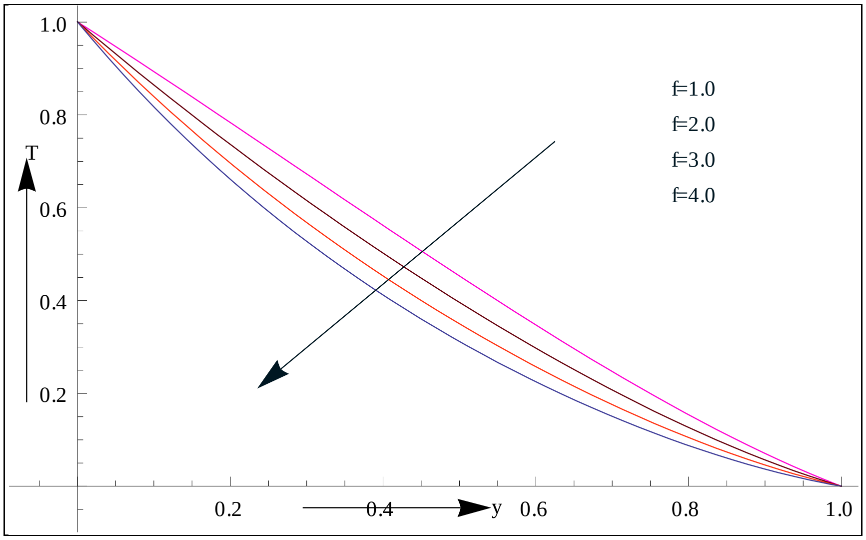
Temperature Profiles for various values of Dufour effects

Figure No:- 12



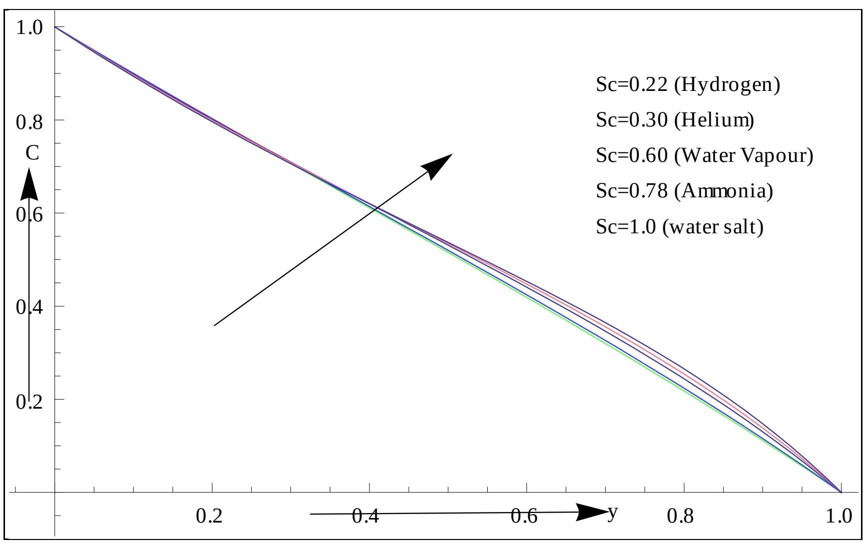
Temperature Profiles for various values of Peclet number

Figure No:- 13



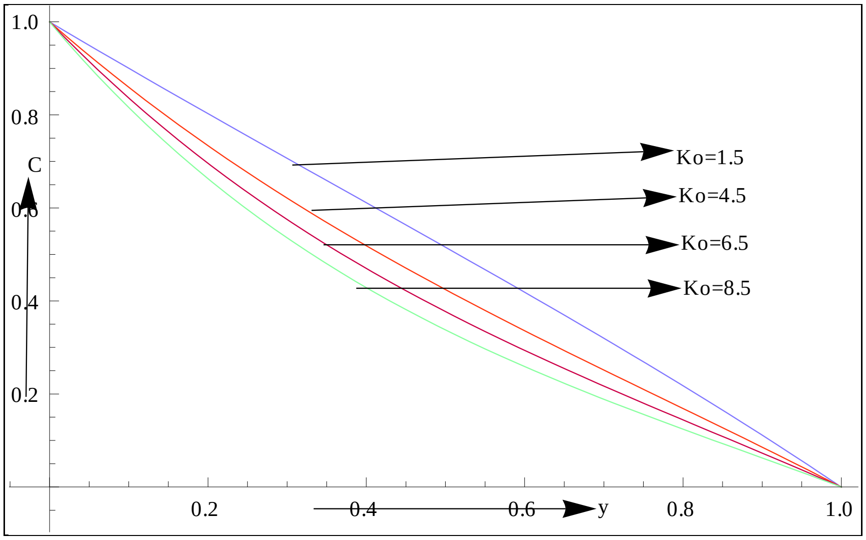
Temperature Profiles for various values of Radition parameter

Figure No. 14



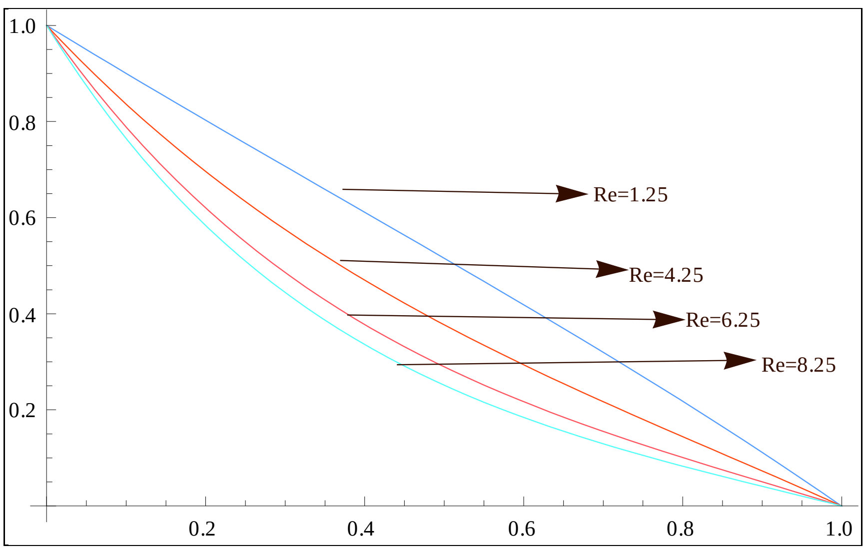
Concentration Profiles for various values of Schmidt Number

Figure No.15



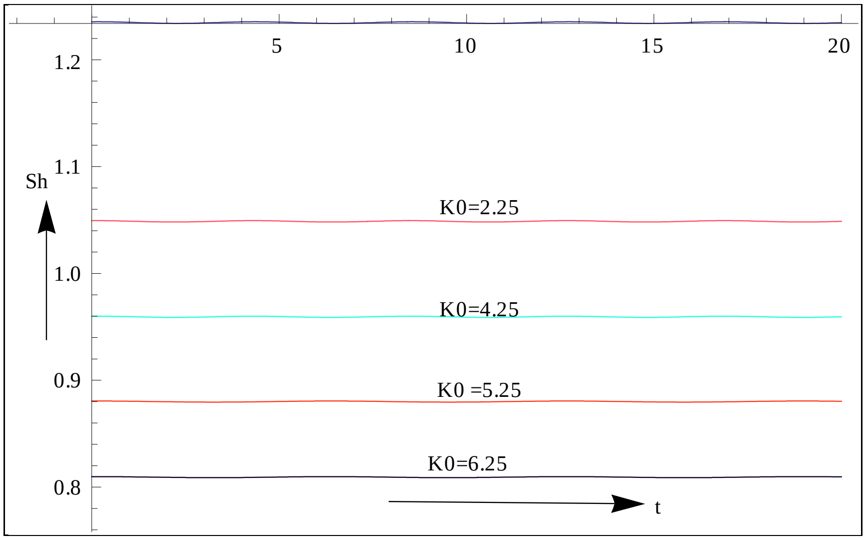
Temperature Profiles for various values of Chemical reaction parameter

Figure No. 16



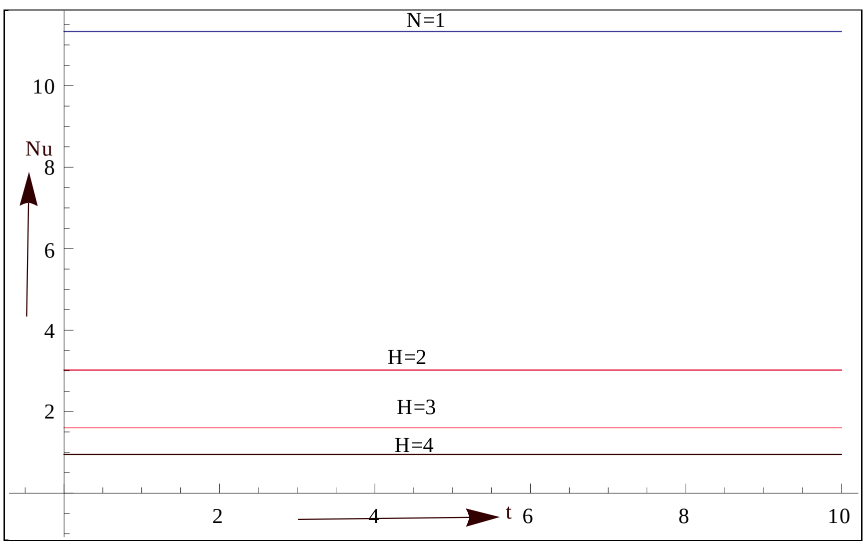
Temperature Profiles for various values of Reynolds number

Figure No. 17



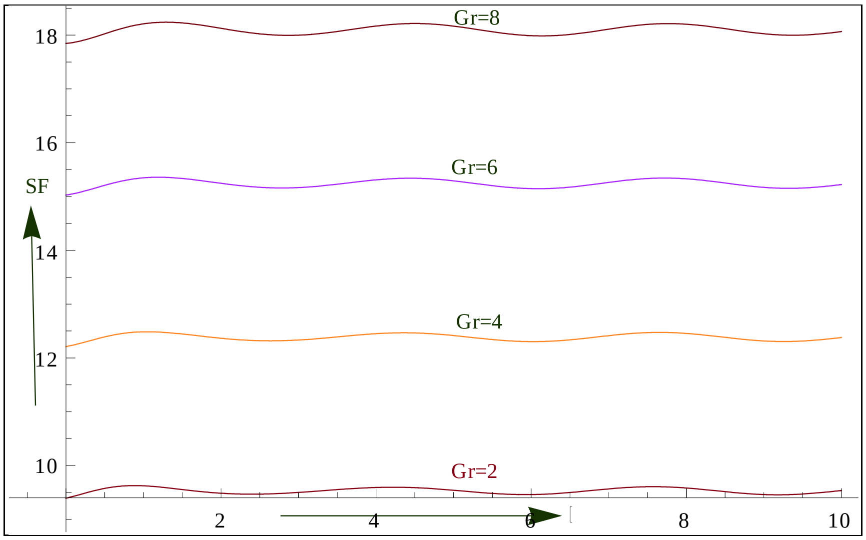
Mass flux for various values of Chemical reaction

Figure No. 18



Heat flux for various values of temperature gradient

Figure No. 19



Skin friction for various values of Grash of Number

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