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HEAT AND MASS TRANSFER OF UNSTEADY MHD FLOW OF KUVSHINSKI FLUID WITH HEAT SOURCE/SINK AND SORET EFFECTS

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ABSTRACT

The objective of the current paper is to study the effect of kuvshinski fluid on unsteady MHD flow through a porous medium past an infinite moving porous plate with consistent and variable temperatures. A uniform magnetic field is implemented perpendicular to the direction of the porous surface. The governing non – dimensional equations are solved analytically for velocity, temperature and concentration fields. Skin friction co-efficient, rate of heat and mass transfer co-efficient in terms of Nusselt number and Sherwood numbers are also derived. The effects of various parameters are presented graphically and tabulated forms.

Keywords: Kuvshinski fluid, MHD, thermal radiation, thermal diffusion, viscous dissipation

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1. INTRODUCTION

Convection is a major mode of heat and mass transfer in fluids. It takes place by both diffusion the random motion of individual particles in the fluid and advection, in which the matter or heat is transported by the large –scale motion of currents in the fluids. It occurs in atmospheres, oceans, planetary mantles and it gives the mechanism of heat transfer for an extensive portion of the peripheral insides of our sun and all stars. It emerge in many exchange process both natural and artificial in numerous branches of engineering and sciences which plays an vital role in the chemical industry, power and cooling industry for drying, chemical vapour deposition on surfaces, cooling of atomic reactors, petroleum, oil industry and so on. Hossain and Begum [1] have discussed unsteady free convective mass transfer stream past a vertical porous plate. Agrawal et al [2] have expanded about the impact of stratified viscous kuvshinski fluid on MHD free convective flow with heat and mass transfer past a vertical porous plate. Sharma and Varshney [3] have extended the problem of Agrawal et al [2] and investigated the effect of stratified kuvshinski fluid on MHD free convective flow past a vertical permeable plate with heat and mass transfer disregarding induced magnetic field in comparison to applied magnetic field.

Numerous procedures in engineering areas occurs at high temperatures and knowledge of radiation heat transfer turns out to be essential for the design of the pertinent equipment. Nuclear power plants, gas turbines and various propulsion devices for aircrafts, missiles, satellites, rockets and space vehicles are precedents of such engineering areas. Aravind Kumar Sharma et al [4] have studied the effect of kuvshinski fluid on double – diffusive unsteady convective heat and mass transfer flow past a porous vertical moving plate with heat source and Soret effect.

Combined heat and mass transfer problems with chemical reaction are of significance in numerous procedure and have therefore, received a considerable amount of attention in recent years. In processes such as drying, evaporation at the surface of a water body, energy transfer in a wet cooling tower and the flow in a desert cooler heat and the mass transfer occur simultaneously. Possible utilization of this type of flow can be found in many industries for example polymer production, manufacturing of ceramics or glassware and food processing. Gireesh Kumar et al [5] analysed the effects of chemical reaction and mass transfer on radiation and MHD free convection flow of kuvshinki fluid through a porous medium. Devasena and Leela Ratnam [6] investigated the combined effects of chemical reaction, thermo diffusion and thermal radiation and dissipation on convective heat and mass transfer flow of a kuvshinski fluid past a vertical plate embedded in a porous medium. Unsteady MHD free convective flow of a viscous, incompressible and electrically conducting, well known non-Newtonian fluid named as kuvshinski fluid past an infinite vertical porous plate in the presence of homogeneous chemical reaction, radiation absorption and heat source/sink was studied analytically by Reddy et al [7]. An unsteady MHD two dimensional free convective flow of a viscous, incompressible, radiating, chemically reacting and radiation absorbing kuvshinski fluid through a porous medium past a semi-infinite vertical plate was investigated by Vidya Sagar et al [8]. The Dufour and thermal radiation effects of kuvshinski fluid on double – diffusive convective MHD heat and mass transfer flow past a porous vertical plate in the presence of radiation absorption, viscous dissipation and chemical reaction was studied by Lalitha.P et al [9]. Krishna Reddy. V et al [10] has studied the effect of kuvshinski fluid on unsteady MHD free convective flow past a vertical moving porous plate with thermal radiation, heat source, chemical reaction and thermal diffusion effects. Siva Kumar Narsu and Rushi Kumar. B [11] made an attempt to study the diffusion- thermo effects on an unsteady heat and mass transfer MHD free convection flow of a viscous incompressible electrically conducting kuvshninski fluid through a porous medium from a vertical porous plate with varying suction velocity in slip flow regime. El-Dabe et al [12] focused on the influence of thermophoresis and thermal radiation on unsteady MHD flow of radiation absorbing kuvshinski fluid past a permeable infinite vertical plate embedded in a porous medium in the presence of viscous dissipation with chemical reaction. Praveena. D, Varma. S and Mamatha.B [13] 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 focus of this study is the extending work of Praveena. D et al (2016). The problem is concerned with the MHD convective heat and mass transfer flow of kuvshinski fluid past an infinite moving plate embedded in a porous medium with radiation temperature dependent heat source, variable suction and concentration with homogeneous chemical reaction, thermal diffusivity under slip flow regime.

2. MATHEMATICAL FORMULATION

We have considered an unsteady MHD two dimensional laminar, free convective flow of a viscous incompressible, radiating, and chemically reacting, radiation and heat generation/absorption kuvshinski fluid through a porous medium past a semi-infinite vertical plate. Let x* axis is taken along the vertical plate in the upward direction in the direction of the flow and y* axis is taken perpendicular to it. It is assumed that, initially, the plate and the fluid are at the same temperature $T_\infty{}^*$ and concentration $C_\infty{}^*$ in the entire region of the fluid. The fluid considered here is grey, emitting and absorbing radiation but non scattering medium. The presence of viscous dissipation cannot be neglected and also the presence of chemical reaction of first order and the influence of radiation absorption are considered. All the fluid properties are considered to be constant except the influence of the density variation caused by the temperature changes, in the body force term. The MHD term is derived from the order of magnitude analysis of the full Navier stokes equation. It is assumed here that the whole size of the porous medium as an assemblage of small identical spherical particles fixed in space. 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 the flow field is governed by the following set of equations.

$$\frac{\partial v^*}{\partial y^*} = 0 \tag{1}$$

$$\rho\left\{\left(1 + \lambda_1{}^* \frac{\partial}{\partial t^*}\right)\frac{\partial u^*}{\partial t^*} + v^* \frac{\partial u^*}{\partial y^*}\right\} = -\left(1 + \lambda_1{}^* \frac{\partial}{\partial t^*}\right)\frac{\partial p^*}{\partial x^*} + \mu\frac{\partial^2 u^*}{\partial y^{*2}} - \rho g - \left(\sigma B_0{}^2 + \frac{\mu}{K^*}\right)\left(1 + \lambda_1{}^* \frac{\partial}{\partial t^*}\right)u^* \tag{2}$$

$$\frac{\partial T^*}{\partial t^*} + v^* \frac{\partial T^*}{\partial y^*} = \frac{k}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{Q_0}{\rho C_p}(T^* - T_\infty{}^*) - \frac{1}{\rho C_p}\frac{\partial q_r{}^*}{\partial y^*} + \frac{\vartheta}{C_p}\left(\frac{\partial u}{\partial y}\right)^2 \tag{3}$$

$$\frac{\partial C^*}{\partial t^*} + v^*\left(\frac{\partial C^*}{\partial y^*}\right) = D\frac{\partial^2 C^*}{\partial y^{*2}} - Kr(C^* - C_\infty{}^*) + D_T\frac{\partial^2 T^*}{\partial y^{*2}} \tag{4}$$

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

$$u^* = u_p{}^* + L_1\frac{du^*}{dy^*}, T^* = T_w{}^* + \varepsilon A_T(T_w{}^* - T_\infty{}^*)e^{n^*t^*}, C^* = C_w{}^* + \varepsilon A_T(C_w{}^* - C_\infty{}^*)e^{n^*t^*} \; at \; y^* = 0$$

$$u^* = 0 \; T^* \to T_\infty{}^* \; C^* \to C_\infty{}^* \; as \; y^* \to \infty \tag{5}$$

Where A_T is a constant taking value 0 or 1. Where u^*, v^*- velocity components in X, Y directions respectively, g- gravitational acceleration, t^* time, ϑ- kinematic coefficient of viscosity , σ- electrical conductivity, μ- the viscosity, ρ- density of the fluid, $\lambda_1{}^*$ the coefficient of kuvshinski fluid, T^* temperature of the fluid, $T_w{}^*$ the temperature at the plate, $T_\infty{}^*$ the temperature of fluid in free stream, k thermal conductivity, C_p specific heat at constant pressure, $q_r{}^*$ radiative heat flux, K^* permeability parameter of the porous medium, $u_p{}^*$ in the direction of fluid flow, and the free stream velocity $U_\infty{}^*$ follows the exponentially increasing small perturbation law, Kr chemical reaction, D_T thermal diffusivity, S_c Schmidt number, S_0 Soret number.

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

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.

$$\rho\frac{dU_\infty{}^*}{dt^*} = -\frac{\partial p^*}{\partial x^*} - \rho_\infty g - \sigma B_0{}^2 U_\infty{}^* - \frac{\mu}{K^*}U_\infty{}^* \tag{6}$$

Eliminating $\frac{\partial p^*}{\partial x^*}$

$$\rho\left\{\left(1+{\lambda_1}^*\frac{\partial}{\partial t^*}\right)\frac{\partial u^*}{\partial t^*}+v^*\frac{\partial u^*}{\partial y^*}\right\}=\rho\left(1+{\lambda_1}^*\frac{\partial}{\partial t^*}\right)\frac{dU_\infty{}^*}{dt^*}+\mu\frac{\partial^2 u^*}{\partial {y^*}^2}+(\rho_\infty-\rho)g+\left(\sigma {B_0}^2+\frac{\mu}{K^*}\right)\left(1+{\lambda_1}^*\frac{\partial}{\partial t^*}\right)(U_\infty{}^*-u^*) \tag{7}$$

By making use the equation of state

$$(\rho_\infty-\rho)=\beta(T^*-T_\infty{}^*)+\beta^*(C^*-C_\infty{}^*)$$

Where β is the volumetric coefficient of thermal expansion and ρ_∞ is the density of the fluid far away the surface.

$$\left(1+{\lambda_1}^*\frac{\partial}{\partial t^*}\right)\frac{\partial u^*}{\partial t^*}+v^*\frac{\partial u^*}{\partial y^*}=\left(1+{\lambda_1}^*\frac{\partial}{\partial t^*}\right)\frac{dU_\infty{}^*}{dt^*}+\mu\frac{\partial^2 u^*}{\partial {y^*}^2}+g\beta(T^*-T_\infty{}^*)+g\beta(C^*-C_\infty{}^*)+\left(\sigma {B_0}^2+\frac{\mu}{K^*}\right)\left(1+{\lambda_1}^*\frac{\partial}{\partial t^*}\right)(U_\infty{}^*-u^*) \tag{8}$$

The radiation flux on the basis of the Roseland diffusion model for radiation heat transfer is expressed as $q_r{}^*=-\frac{4\sigma^*}{3{k_1}^*}\frac{\partial {T^*}^4}{\partial y^*}$ 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 $T_\infty{}^*$ and neglecting higher order terms,

$${T^*}^4\cong 4{T_\infty{}^*}^3T^*-3{T_\infty{}^*}^4$$

$$\frac{\partial T^*}{\partial t^*}+v^*\frac{\partial T^*}{\partial y^*}=\frac{k}{\rho C_p}\frac{\partial^2T^*}{\partial {y^*}^2}+\frac{Q_0}{\rho C_p}(T^*-T_\infty{}^*)+\frac{16\sigma^*{T_\infty{}^*}^3}{3\rho C_p{k_1}^*}\frac{\partial^2 {T^*}^2}{\partial {y^*}^2}+\frac{\vartheta}{C_p}\left(\frac{\partial u}{\partial y}\right)^2 \tag{9}$$

Introducing the non-dimensional variables,

$$u=\frac{u^*}{U_0},v=\frac{v^*}{V_0},y=\frac{y^*V_0}{\vartheta},U_\infty{}^*=U_\infty U_0,u_p{}^*=U_pU_0,t=\frac{t^*{V_0}^2}{\vartheta},n=\frac{n^*v}{{V_0}^2}$$

$$\theta=\frac{T^*-T_\infty{}^*}{T_w{}^*-T_\infty{}^*},\varphi=\frac{C^*-C_\infty{}^*}{C_w{}^*-C_\infty{}^*} \tag{10}$$

Then substituting the non-dimensional form we obtain

$$\left(1+\lambda_1\frac{\partial}{\partial t}\right)\frac{\partial u}{\partial t}-(1+\varepsilon Ae^{nt})\frac{\partial u}{\partial y}=\left(1+\lambda_1\frac{\partial}{\partial t}\right)\frac{dU_\infty}{dt}+\frac{\partial^2u}{\partial y^2}+G_r\theta+G_c\varphi+N\left(1+\lambda_1\frac{\partial}{\partial t}\right)(U_\infty-u) \tag{11}$$

$$Pr\frac{\partial\theta}{\partial t}-Pr(1+\varepsilon Ae^{nt})\frac{\partial\theta}{\partial y}=\left(1+\frac{4R}{3}\right)\frac{\partial^2\theta}{\partial y^2}+Pr\eta\theta+EcPr\left(\frac{\partial u}{\partial y}\right)^2 \tag{12}$$

$$\frac{\partial\varphi}{\partial t}-(1+\varepsilon Ae^{nt})\frac{\partial\varphi}{\partial y}=\frac{1}{S_c}\frac{\partial^2\varphi}{\partial y^2}-Kr\varphi+S_0\frac{\partial^2\theta}{\partial y^2} \tag{13}$$

where

$$G_r=\frac{\vartheta g\beta(T_w{}^*-T_\infty{}^*)}{{V_0}^2U_0},M=\frac{\sigma {B_0}^2\vartheta}{\rho {V_0}^2},K=\frac{K^*{V_0}^2}{\vartheta^2},\eta=\frac{\vartheta Q_0K^*}{\rho {V_0}^2C_p},R=\frac{4\sigma^*{T_\infty{}^*}^3}{k{k_1}^*},Pr=\frac{\rho\vartheta C_p}{k},$$

$$\lambda_1=\frac{{\lambda_1}^*{V_0}^2}{\vartheta},N=\left[M+\frac{1}{K}\right],S_c=\frac{v}{D},Ec=\frac{{v_0}^2}{C_p(T_w{}^*-T_\infty{}^*)},S_0=\frac{D_Tv(C_w{}^*-C_\infty{}^*)}{{V_0}^2}$$

The corresponding boundary conditions are

$$u = u_p + h_1 \frac{du}{dy}, T = 1 + \varepsilon A_T e^{nt}, C = 1 + \varepsilon A_T e^{nt} \; at \; y = 0$$

$$u \to 0, T \to 0, C \to 0 \; as \; y \to \infty \quad (14)$$

3. METHOD OF SOLUTION

In order to reduce the system of partial differential equation to ordinary differential equations in non-dimensional form, we obtain

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

$$\theta = \theta_0(y) + \varepsilon e^{nt} \theta_1(y) + O(\varepsilon^2) \quad (15)$$

$$\varphi = \varphi_0(y) + \varepsilon e^{nt} \varphi_1(y) + O(\varepsilon^2)$$

Substituting the above expression (15) into the equations (11) - (13) and equating the coefficients in (15), we obtain the following set of ordinary differential equations.

$$u_0'' + u_0' - N u_0 = -(N + Gr\theta_0 + Gc\varphi_0) \quad (16)$$

$$u_1'' + u_1' - (N + n)(1 + \lambda_1 n) u_1 = -(1 + n\lambda_1)(N + n) - A u_0' - Gr\theta_1 - Gc\varphi_1 \quad (17)$$

$$(3 + 4R)\theta_0'' + 3Pr\theta_0' + 3Pr\eta\theta_0 = 0 \quad (18)$$

$$(3 + 4R)\theta_1'' + 3Pr\theta_1' - 3Pr(n - \eta)\theta_1 = -3PrEc u_0'^2 - 3APr\theta_0' \quad (19)$$

$$\varphi_0'' + S_c\varphi_0' - S_c Kr\varphi_0 = -S_c S_0 \theta_0'' \quad (20)$$

$$\varphi_1'' + S_c\varphi_1' - S_c(n + Kr)\varphi_1 = -AS_c\varphi_0' - S_c S_0 \theta_1'' \quad (21)$$

The corresponding boundary conditions are

$$u_0 = u_p + h_1 \frac{du_0}{dy}, u_1 = h_1 \frac{du_1}{dy}, \theta_0 = 1, \theta_1 = A_T, \varphi_0 \to 1, \varphi_1 \to A_T \, at \; y = 0$$

$$u_0 \to 0, u_1 \to 0, \theta_0 \to 0, \theta_1 \to 0, \varphi_0 \to 0, \varphi_1 \to 0 \; as \; y \to \infty \quad (22)$$

The equations from (16) to (21) are second order linear differential equations with constant coefficients. The solutions of these paired equations under the corresponding boundary conditions (22) and we get the expression for velocity, temperature and concentration as

$$u(y,t) = [B_1 e^{-m_3 y} + 1 + (R_2 + R_4)e^{-m_1 y} + R_3 e^{-m_2 y}] + \varepsilon e^{nt}[B_4 e^{-m_6 y} + 1 + R_{16} e^{-m_3 y} + (R_{17} + R_{23} + R_{26})e^{-m_1 y} + (R_{18} + R_{25})e^{-m_2 y} + (R_{19} + R_{27})e^{-m_4 y} + (R_{20} + R_{28})e^{-2m_3 y} + (R_{21} + R_{29})e^{-2m_1 y} + (R_{22} + R_{30})e^{-2m_2 y}] \quad (23)$$

$$\theta(y,t) = e^{-m_1 y} + \varepsilon e^{nt}[B_2 e^{-m_4 y} + R_5 e^{-2m_3 y} + R_6 e^{-2m_1 y} + R_7 e^{-2m_2 y} + R_8 e^{-m_1 y}] \quad (24)$$

$$\varphi(y,t) = [(1 - R_1)e^{-m_2 y} + R_1 e^{-m_1 y}] + \varepsilon e^{nt}[B_3 e^{-m_5 y} + R_9 e^{-m_2 y} + (R_{10} + R_{15})e^{-m_1 y} + R_{11} e^{-m_4 y} + R_{12} e^{-2m_3 y} + R_{13} e^{-2m_1 y} + R_{14} e^{-2m_2 y}] \quad (25)$$

Skin friction: The expression for Skin friction (τ)

$$C_f = -\left(\frac{\partial u}{\partial y}\right)_{y=0} = [B_5] + \varepsilon e^{nt}[B_6]$$

Nusselt number: The expression for Nusselt number (Nu) in terms of heat transfer is

$$N_u = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0} = m_1 + \varepsilon e^{nt}[B_7]$$

Sherwood number: The expression for Sherwood number (Sh) in terms of mass transfer is

$$S_h = -\left(\frac{\partial \varphi}{\partial y}\right)_{y=0} = B_8 + \varepsilon e^{nt}[B_9]$$

4. RESULT AND DISCUSSION

In order to get a physical understanding of the problem, the numerical calculations are carried out to illustrate the influence of thermal radiation parameter R, Prandtl number Pr, thermal Grashof number Gr, permeability parameter K, magnetic field parameter M, direction of fluid flow Up, visco-elastic fluid λ_1, thermal heat generation η, modified Grashof number Gc through figures 1-30

Case (i): The plate with variable wall temperature (VWT) i.e., $A_T = 1$ has been discussed from figures 1-15. Fig 1 depicts the radiation parameter effect on velocity, as radiation increases, velocity also increases. This is a direct result of the fluid considered here which is grey, emitting and absorbing radiation but not-scattering medium. Fig 2 exhibits the velocity profiles for various values of Prandtl number. From this figure it is observed that velocity decreases with an increase in Prandtl number. This is physically true because, the Prandtl number is a dimensionless number which is the proportion of momentum diffusivity to thermal diffusivity. In many of the heat transfer problems, the Prandtl number controls the relative thickness of the momentum and thermal boundary layers. At the point when Pr is small, it means that the heat diffuses immediately compared to the velocity. This means that for fluid metals the thickness of the thermal boundary layer is considerably greater than the velocity boundary layer. In fig 3, effect of thermal Grashof number on velocity is presented. As Gr increases, velocity also increases. This is due to the buoyancy which is acting on the fluid particles due to gravitational force that enhances the fluid velocity. The effect of permeability parameter is shown in fig 4 were the velocity increases as the parametric esteem expands this is because permeability is a measure of ability of a porous material to allow fluids to pass through it. In fig 5 velocity profiles are displayed with the variation in the magnetic parameter. From this figure it is noticed that the velocity gets reduced by the increases of magnetic parameter. Because the magnetic force which is connected perpendicular to the plate, retards the flow which is known as Lorentz force. From fig 6 it is clear that the variation of velocity distribution across the boundary layer for several estimations of plate moving velocity in the direction of fluid flow. The velocity increases with the increase in the direction of fluid flow in porous plate. Fig 7 presents the velocity profiles for different values of visco-elastic parameter λ. Velocity is observed to be increasing with the increase in visco-elastic parameter. Expanding nature of the momentum boundary layer thickness with increasing λ is noted. Fig 8 displays the effect of velocity in terms of heat generation parameter as its value increases the velocity also increases. From fig 9 it is noticed that in presence of solute Grashof number which also increases the fluid velocity as its value increases. Effects of radiation parameter on temperature are examined from fig 10. From this fig it is seen that temperature increases as radiation parameter increases. This is due to the thermal radiation is associated with high temperature, thereby increasing the temperature distribution of the fluid flow. Fig 11 exhibits the effect of Prandtl number Pr on the temperature profiles with increasing Pr the temperature profiles decreases. An increase in Prandtl number means a decrease of fluid thermal conductivity which causes a reduction in temperature. It is observed from fig 12 that the temperature increases with increase in heat generation parameter. Effects of chemical reaction parameter on concentration are presented in fig 13 respectively. From this figure it is noticed that the concentration boundary layer shrink once the values of chemical reaction parameter increases. The effect of soret number S_0 on the concentration profile is shown in fig 14. From this figure we have the tendency to see that concentration profiles increase with increasing values of S_0, from which we conclude that the fluid concentration rises due to greater thermal diffusion. It is found that the concentration boundary layer thicknes increases with an increase in soret number. The effect of Schmidt number Sc on the concentration profiles is shown in fig 15. It is observed that the species concentration increases as the Schmidt number Sc increases. Case (ii) Plate is with constant wall temperature (CWT) i.e. $A_T = 0$ is discussed from fig 16-30 as such in case (i). Case (ii) also has the similar variations in terms of various parameters.

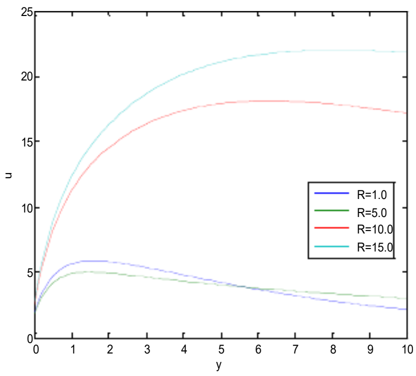


Figure 1 Effect of thermal radiation on velocity

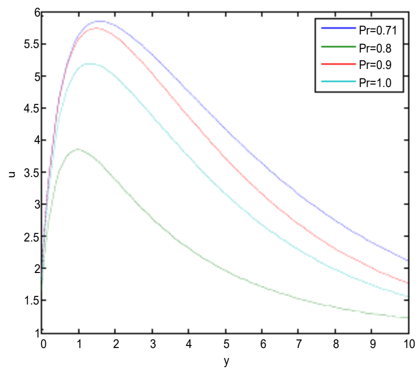


Figure 2 Effect of Prandti number on velocity

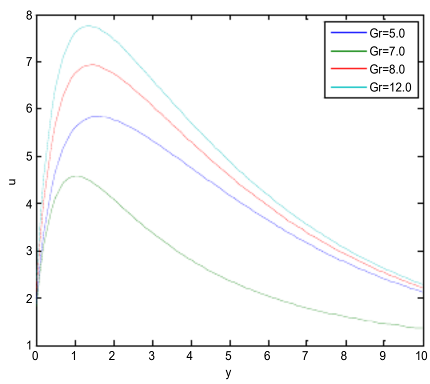


Figure 3 Effect of Grashof number on velocity

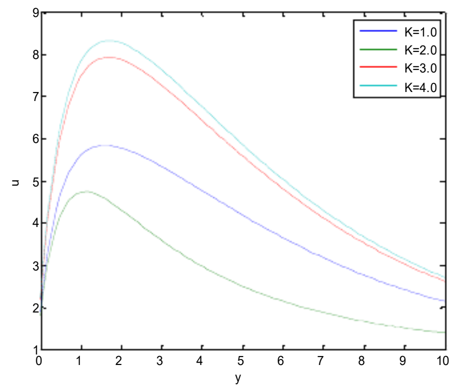


Figure 4 Effect of permeability parameter on velocity

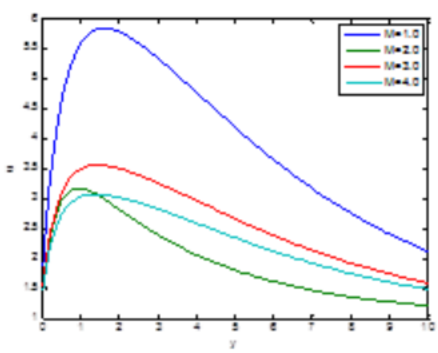


Figure 5 Effect of Magnetic parameter on velocity

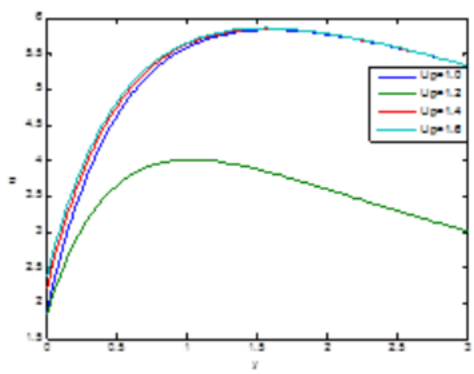
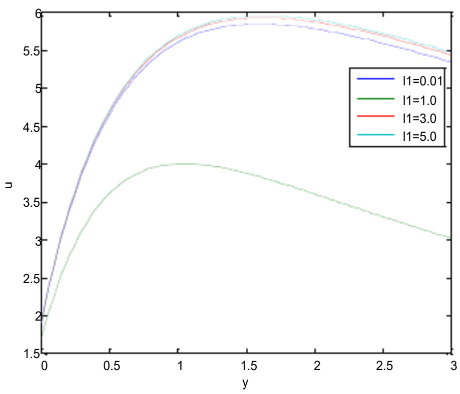


Figure 6 Effect of fluid flow on velocity



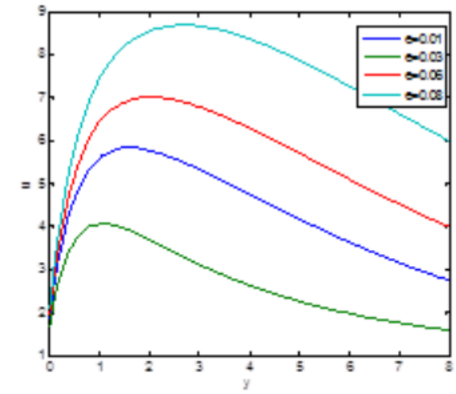
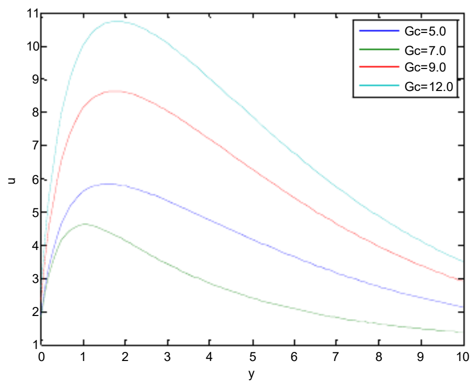


Figure 7 Effect of visco-elastic parameter on velocity **Figure 8** Effect of heat generation on velocity

The effect of various material parameters on skin friction, Nusselt number and Sherwood number are presented in the tables 1 and 2 for both the cases i.e. at varying wall temperature and at constant wall temperature. From table 1 it is noticed that the skin friction for both VWT and CWT increases in terms of Prandtl number, magnetic parameter, direction of fluid flow and visco-elastic fluid whereas it decreases in terms of radiation parameter, thermal and mass Grashof number, chemical reaction parameter and also thermal heat generations. Table 2 explains about both Nusselt and Sherwood numbers. In terms of radiation parameter and thermal heat generation as the value increases the Nusselt value also increases but in terms of Prandtl number it reacts oppositely. But in case of Sherwood number it is reverse.



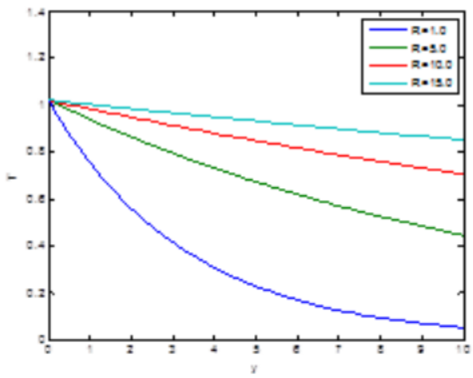
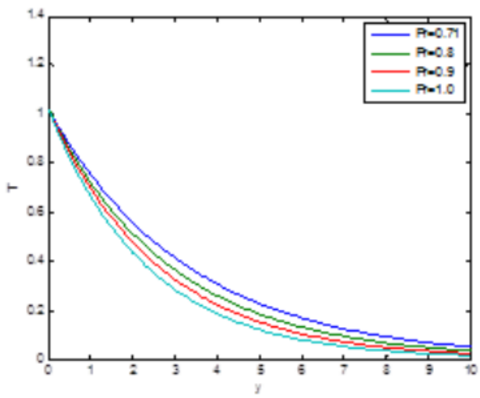


Figure 9 Effect of modified Grashof number on velocity **Figure 10** Effect of thermal radiation on temperature



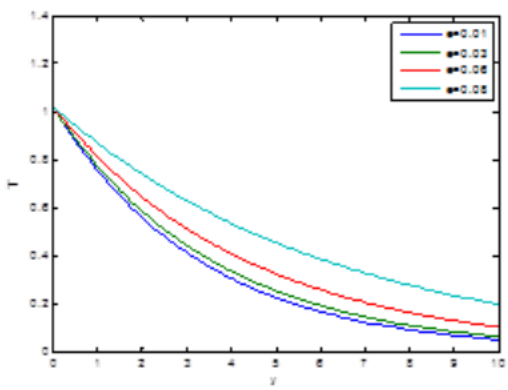


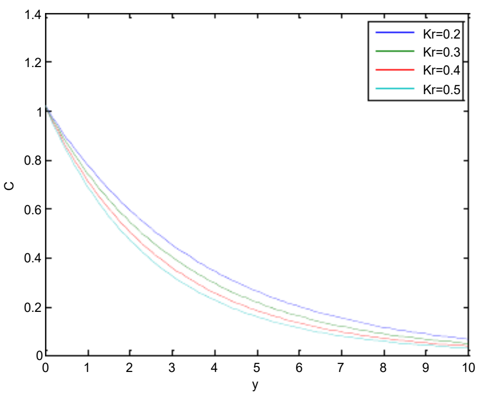
Figure 11 Effect of Prandtl number on temperature **Figure 12** Effect of heat generation on temperature

5. CONCLUSION

In this paper a theoretical study is carried out for an unsteady MHD two dimensional free convection flow of a viscous, incompressible, radiating, chemically reacting and radiation absorbing Kuvshinski fluid through a porous medium past a semi-infinite vertical plate. The dimensionless equations governing the flow are solved by simple perturbation technique. The basic parameters found to have own associate with the influence on the problem under consideration of magnetic field parameter, radiation parameter, permeability of the porous medium, radiation absorption parameter, Grashof number, modified Grashof number, Schmidt number, chemical reaction parameter and Prandtl number.

The main conclusions are as follows. When plate is maintained at variable and constant temperature,

- The velocity is observed to increases with increasing value of R, Gr, K, Up, λ, η, Gc where as it has reverser effect in the case of Pr and M.
- Temperature boundary layer increased with increase in R, η but decrease for increasing values of Pr.
- Concentration boundary layer increases with increase of S_0, Sc, and Kr.
- Skin friction increases in terms of increases in terms of Prandtl number, magnetic parameter, direction of fluid flow and visco-elastic fluid whereas it decreases in terms of radiation parameter, thermal and mass Grashof number, chemical reaction parameter and also thermal heat generations.
- Nusselt number will increases with the raise of radiation parameter and thermal heat generation and in terms of Prandtl number reacts oppositely.
- Sherwood number decreases with the increase of radiation parameter and thermal heat generation but in terms of Prandtl number it increases.



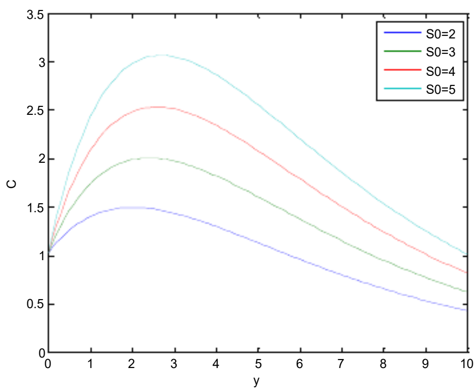
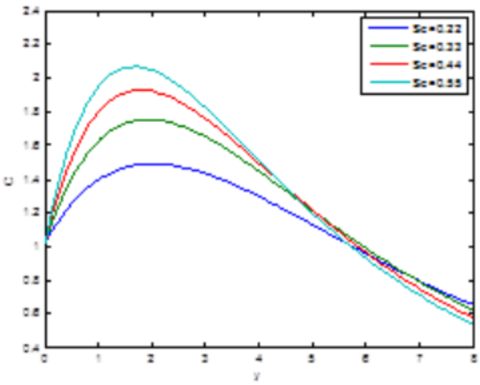


Figure13 Effect of chemical reaction on concentration **Figure 14**:Effect of soret number on concentration



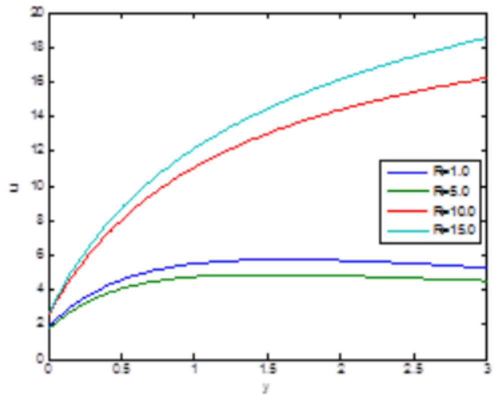
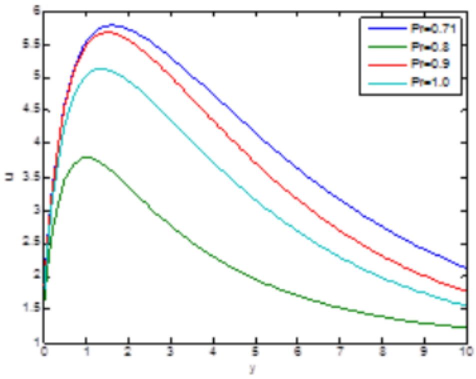


Figure 15 Effect of Schmidt number on concentration **Figure 16** Effect of thermal radiation on velocity



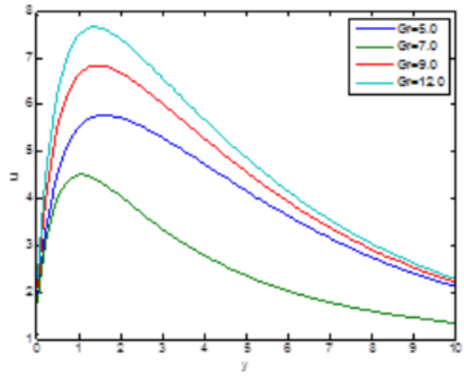
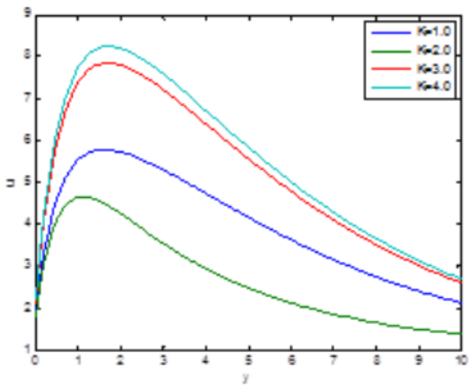


Figure 17 Effect of Prandti number on velocity **Figure 18** Effect of Grashof number on velocity



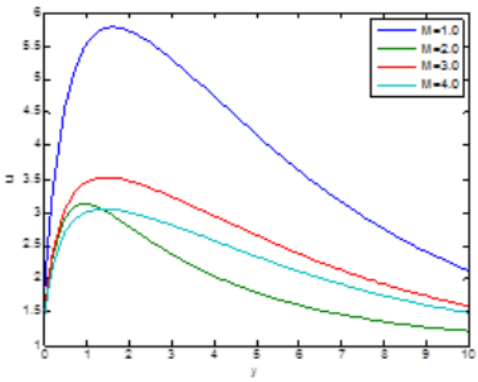
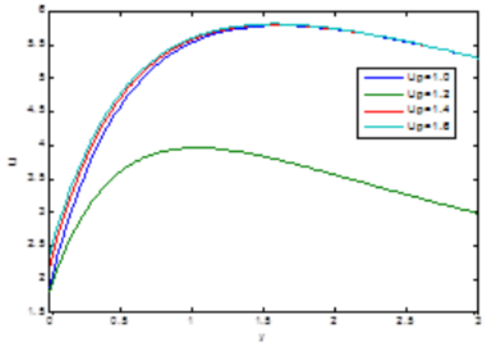


Figure 19 Effect of permeability parameter on velocity **Figure 20** Effect of Magnetic parameter on velocity



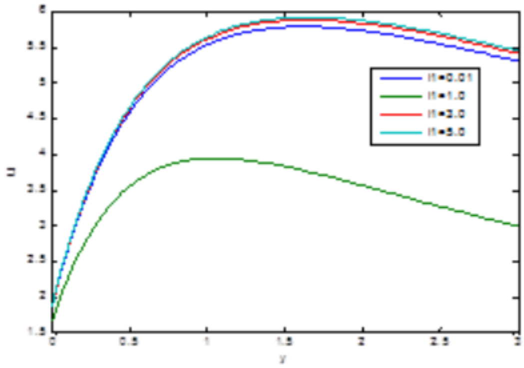
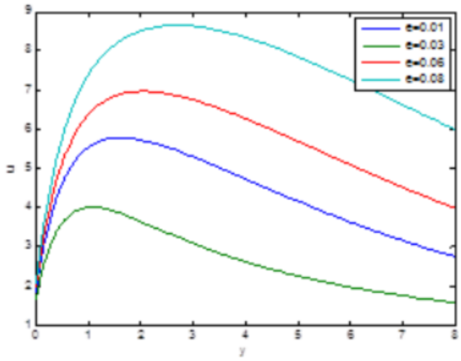


Figure 21 Effect of fluid flow on velocity **Figure 22** Effect of visco-elastic parameter on velocity



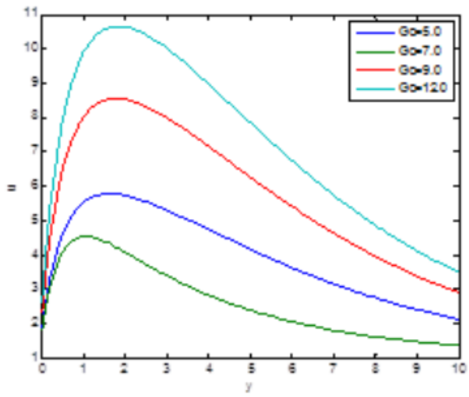
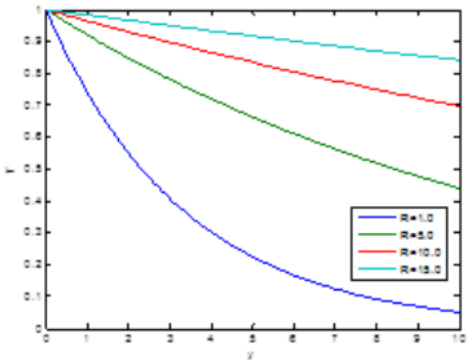


Figure 23 Effect of heat generation on velocity **Figure 24** Effect of modified grashof number on velocity



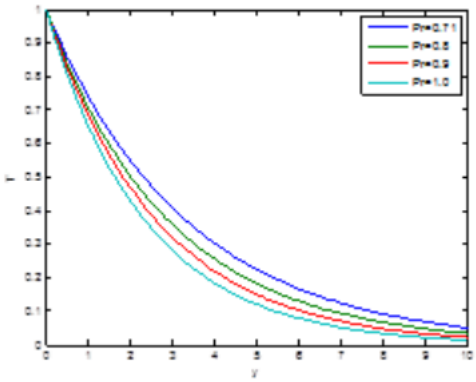
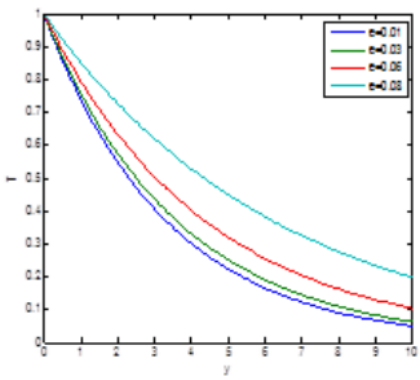


Figure 25 Effect of thermal radiation on temperature **Figure 26** Effect of Prandtl number on temperature



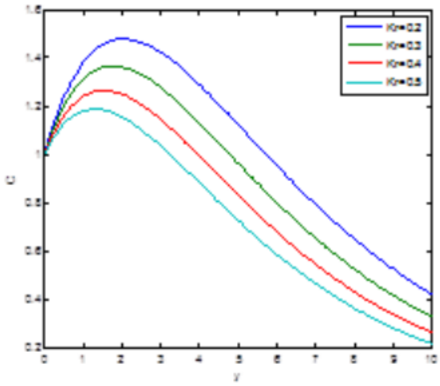
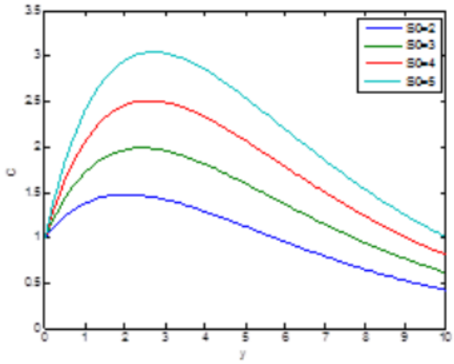


Figure 27 Effect of heat generation on temperature **Figure 28** Effect of chemical reaction on concentration



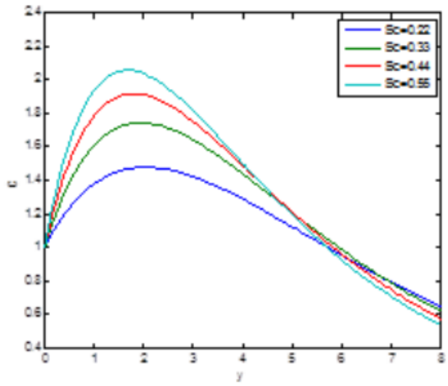


Figure 29 Effect of Soret number on concentration **Figure 30** Effect of Schmidt number on concentration

Table 1 Skin friction

R	Pr	Gr	Gc	K	M	Up	λ_1	η	τ (A_T=1)	τ (A_T=0)
1	0.71	5	5	1	1	1	0.01	0.01	-10.32	-9.89
5	0.71	5	5	1	1	1	0.01	0.01	-13.58	-13.41
10	0.71	5	5	1	1	1	0.01	0.01	-15.84	-15.67
15	0.71	5	5	1	1	1	0.01	0.01	-17.15	-16.97
1	0.8	5	5	1	1	1	0.01	0.01	-12.23	-12.01
1	0.9	5	5	1	1	1	0.01	0.01	-6.11	-5.92
1	1	5	5	1	1	1	0.01	0.01	-4.2	-4.01
1	0.71	7	5	1	1	1	0.01	0.01	-11.63	-11.17
1	0.71	9	5	1	1	1	0.01	0.01	-12.95	-12.46
1	0.71	12	5	1	1	1	0.01	0.01	-14.92	-14.39
1	0.71	5	7	1	1	1	0.01	0.01	-12.93	-12.35
1	0.71	5	9	1	1	1	0.01	0.01	-15.43	-14.71
1	0.71	5	12	1	1	1	0.01	0.01	-18.99	-18.05
1	0.71	5	5	2	1	1	0.01	0.01	-12.52	-11.99
1	0.71	5	5	3	1	1	0.01	0.01	-13.53	-12.96
1	0.71	5	5	4	1	1	0.01	0.01	-14.11	-13.52
1	0.71	5	5	1	2	1	0.01	0.01	-7.8	-7.48
1	0.71	5	5	1	3	1	0.01	0.01	-6.37	-6.12
1	0.71	5	5	1	4	1	0.01	0.01	-5.45	-5.23
1	0.71	5	5	1	1	1.2	0.01	0.01	-9.98	-9.55
1	0.71	5	5	1	1	1.4	0.01	0.01	-9.65	-9.22

1	0.71	5	5	1	1	1.6	0.01	0.01	-9.31	-8.88
1	0.71	5	5	1	1	1	1	0.01	-10.12	-9.74
1	0.71	5	5	1	1	1	3	0.01	-9.85	-9.55
1	0.71	5	5	1	1	1	5	0.01	-9.68	-9.44
1	0.71	5	5	1	1	1	0.01	0.03	-3.08	-7.33
1	0.71	5	5	1	1	1	0.01	0.06	-9.98	-9.96
1	0.71	5	5	1	1	1..0	0.01	0.08	-11.35	-11.26

Table 2 Nusselt and Sherwood numbers

R	Pr	η	Nu (A_T=1)	Nu (A_T=0)	Sh (A_T=1)	Sh (A_T=0)
1	0.71	0.01	-0.3	-0.3	-0.27	-0.26
5	0.71	0.01	-0.08	-0.08	-0.34	-0.33
10	0.71	0.01	-0.03	-0.03	-0.35	-0.34
15	0.71	0.01	-0.01	-0.01	-0.35	-0.34
1	0.8	0.01	-0.35	-0.34	-0.29	-0.28
1	0.9	0.01	-0.38	-0.37	-0.2	-0.19
1	1	0.01	-0.43	-0.42	-0.19	-0.19
1	0.71	0.03	-0.28	-0.27	-0.27	-0.27
1	0.71	0.05	-0.25	-0.24	-0.28	-0.28
1	0.71	0.07	-0.2	-0.2	-0.3	-0.29

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APPENDIX

$$m_1 = \frac{b+\sqrt{b^2-4ac}}{2a},\ m_2 = \frac{Sc-\sqrt{Sc^2+4ScKr}}{2},\ R_1 = \frac{-ScS_0 m_1^2}{m_1^2-Scm_1-ScKr},\ m_3 = \frac{1+\sqrt{1+4N}}{2},\ R_2 = \frac{-Gr}{m_1^2-m_1-N},$$

$$R_3 = \frac{-Gc(1-R_1)}{m_2^2-m_2-N},\ R_4 = \frac{-GcR_1}{m_1^2-m_1-N},\ B_1 = \frac{U_p-h_1(R_2+R_4)m_1-h_1 m_2 R_3-(1+R_2+R_3+R_4)}{1+h_1 m_3},$$

$$R_5 = \frac{-3PrEcB_1 m_3}{4m_3^2 a-2bm_3-c_1},\ R_6 = \frac{-3PrEcm_1(R_2+R_4)}{4m_1^2 a-2bm_1-c_1},\ R_7 = \frac{-3PrEcR_3 m_2}{4m_2^2 a-2bm_2-c_1},\ R_8 = \frac{3PrAm_1}{am_1^2-bm_1-c_1},\ B_2 = A_T - (R_5+R_6+R_7+R_8),\ m_5 = \frac{Sc+\sqrt{Sc^2+4Sc(n+Kr)}}{2},\ R_9 = \frac{AScm_2(1-R_1)}{m_2^2-Scm_2-Sc(n+Kr)},$$

$$R_{10} = \frac{AScm_1 R_1}{m_1^2-Scm_1-Sc(n+Kr)},\ R_{11} = \frac{-ScS_0 B_2 m_4^2}{m_4^2-Scm_4-Sc(n+Kr)},\ R_{12} = \frac{-4ScS_0 R_5 m_3^2}{4m_3^2-2Scm_3-Sc(n+Kr)}$$

$$R_{13} = \frac{-4ScS_0 R_6 m_1^2}{4m_1^2-2Scm_1-Sc(n+Kr)},\ R_{14} = \frac{-4ScS_0 R_7 m_2^2}{4m_2^2-2Scm_2-Sc(n+Kr)},\ R_{15} = \frac{-ScS_0 R_8 m_1^2}{m_1^2-Scm_1-Sc(n+Kr)},$$

$$B_3 = A_T - (R_9+R_{10}+R_{11}+R_{12}+R_{13}+R_{14}+R_{15}),\ m_6 = \frac{1+\sqrt{1+4a_1}}{2},\ R_{16} = \frac{Am_3 B_1}{m_3^2-m_3-a_1},$$

$$R_{17} = \frac{Am_1(R_2+R_4)}{m_1^2-m_1-a_1},\ R_{18} = \frac{Am_2 R_3}{m_2^2-m_2-a_1},\ R_{19} = \frac{-GrB_2}{m_4^2-m_4-a_1},\ R_{20} = \frac{-GrR_5}{4m_3^2-2m_3-a_1},\ R_{21} = \frac{-GrR_6}{4m_1^2-2m_1-a_1}$$

$$R_{22} = \frac{-GrR_7}{4m_2^2-2m_2-a_1},\ R_{23} = \frac{-GrR_8}{m_1^2-m_1-a_1},\ R_{24} = \frac{-GcB_3}{m_5^2-m_5-a_1},\ R_{25} = \frac{-GcR_9}{m_2^2-m_2-a_1},\ R_{26} = \frac{-Gc(R_{10}+R_{15})}{m_1^2-m_1-a_1}$$

$$R_{27} = \frac{-GcR_{11}}{m_4^2-m_4-a_1},\ R_{28} = \frac{-GcR_{12}}{4m_3^2-2m_3-a_1},\ R_{29} = \frac{-GcR_{13}}{4m_1^2-2m_1-a_1},\ R_{30} = \frac{-GcR_{14}}{4m_2^2-2m_2-a_1}$$

$$B_4 = \frac{\begin{array}{c}-h_1 m_3 R_{16} - h_1 m_1(R_{17}+R_{23}+R_{26}) - h_1 m_2(R_{18}+R_{25}) - h_1 m_4(R_{19}+R_{27}) \\ -2h_1 m_3(R_{20}+R_{28}) - 2h_1 m_1(R_{21}+R_{29}) - 2h_1 m_2(R_{22}+R_{30}) - 1 - R_{16} \\ -R_{17}-R_{23}-R_{18}-R_{25}-R_{19}-R_{27}-R_{26}-R_{20}-R_{28}-R_{21}-R_{29}-R_{22}-R_{30}\end{array}}{1+h_1 m_6},$$

$$B_5 = B_1 m_3 + m_1(R_2+R_4) + m_2 R_3,$$

$$B_6 = B_4 m_6 + R_{16} m_3 + m_1(R_{17}+R_{23}+R_{26}) + m_2(R_{18}+R_{25}) + m_4(R_{19}+R_{27}) + 2m_3(R_{20}+R_{28}) + 2m_1(R_{21}+R_{29}) + 2m_2(R_{22}+R_{30})$$

$$B_7 = -m_4 B_2 - 2m_3 R_5 - 2m_1 R_6 - 2m_2 R_7 - m_1 R_8,\ B_8 = -m_2(1-R_1) - m_1 R_1,$$

$$B_9 = -m_5 B_3 - m_2 R_9 - m_1(R_{10}+R_{15}) - m_4 R_{11} - 2m_3 R_{12} - 2m_1 R_{13} - 2m_2 R_{14}$$