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Magnetohydrodynamic Peristaltic motion with heat and mass transfer of a Jeffery fluid in a tube through porous medium

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Abstract

The effects of radiation on the unsteady flow of an incompressible non-Newtonian (Jeffrey) fluid through porous medium have been discussed. The thermal diffusion and diffusion thermo effect are taken to our consideration. The non-linear partial differential equations which govern this problem are simplified by making the assumptions of long wave length approximation. The analytical formula of the velocity, temperature and concentration have been obtained. In addition, it has been illustrated graphically for significant various parameters such as, magnetic parameter, permeability parameter, and thermal parameters.

Keywords: Magnetohydrodynamic, Peristaltic, Heat transfer, Mass transfer, Porous medium

1. Introduction

The study of peristaltic motion has gained considerable interest because of its extensive applications in urine transport from the kidney to bladder vasomotion of the small blood of the chyme in gastrointestinal tract, and so forth. Peristaltic pumping is found in many applications, for example, vessels movements, such as the transport of slurries, sensitive or corrosive fluids, sanitary fluid, and noxious fluids in the nuclear industry.

Theory of non-Newtonian fluids has received a great attention during the recent years, because the traditional viscous fluids cannot precisely describe the characteristics of many physiological fluids, see. Hayat & Ali (2008)a . Hayat et al. (2008)a have investigated the effects of compliant walls and porous space on the MHD peristaltic flow of Jeffery fluids. Srinivas (2009) investigated the influence of heat and mass transfer on MHD peristaltic flow through a porous space with compliant walls. The influence of heat transfer and temperature dependent viscosity on peristaltic flow of a Jeffrey-six constant fluid has been studied by Nadeem (2010). Kothandapani (2008)a have analysed the MHD peristaltic flow of a viscous fluid in asymmetric channel with heat transfer. Kothandapani (2008)b studied the influence of wall properties in the MHD peristaltic transport with heat transfer and porous medium. Hayat & Ali (2008)b studied the peristaltic motion of a Jeffrey fluid in a tube with sinusoidal wave travelling down its wall.

Recently, the effect of magnetic field on viscous fluid has been reported for treatment of the following pathologies: Gastroenric pathologies, rheumatisms, constipation and hypertension that can be treated by placing one electrode either on the back or on the stomach and the other on the sole of the foot; this location will induce a better blood circulation. El-Dabe et al. (2002), (2007)a have been studied heat and mass transfer of a steady slow motion of a Rivilin-Ericksen fluid in tube of varying cross-section with suction. Also, they investigated the effect of both magnetic field and porous medium on non-Newtonian fluid by studying the unsteady flow of a compressible biviscosity fluid in a circular tube, in which the flow is induced by a wave traveling on the tube wall. The incompressible flow of electrically conducting biviscosity fluid, through an axisymmetric non-uniform tube with a sinsusoidal wave under the considerations of long wave length and law Reynolds number, is discussed by El-Dabe et al. (2007)b.

The objective of this chapter is to study the influence of radiation, uniform magnetic field and permeability of the medium on the dynamics of unsteady flow of an incompressible Jeffrey fluid in a tube with heat and mass transfer. The governing equations of Jeffrey fluid in the cylindrical coordinates have been modeled. The equations are simplified using long wavelength and low Reynolds number approximations. The governing equations of fluid flow are solved subject to the relevant the boundary conditions, analytically. The effects of various parameters such as: magnetic parameter M^2, permeability k, Reynolds number R_e ,Prandtl number P_r, Schmidt number S_c ,Soret number S_r on these solutions are discussed and illustrated graphically.

2.Mathematical Formulation

Consider a peristaltic flow of an incompressible Jeffrey fluid in a coaxial uniform circular tube. The cylindrical coordinates are considered, where R is along the radius of the tube and Z coincides with the axes of the tube as shown in figure (1). A uniform magnetic field B_0 is imposed and acting along axis.

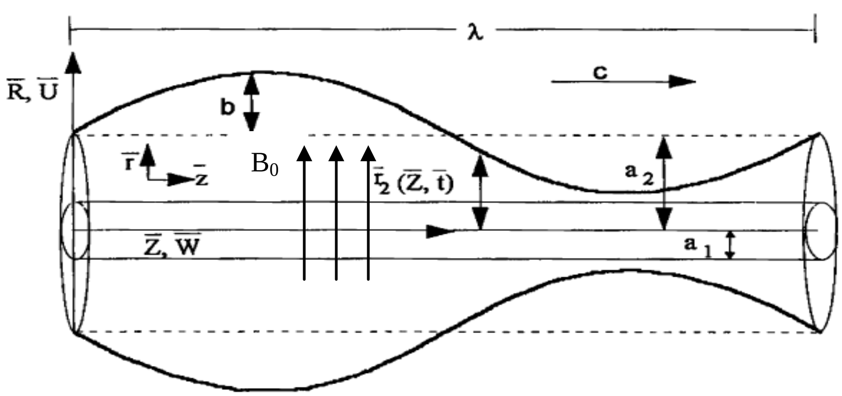

Fig (1): Geometry of the problem.

The geometry of wall surface is described as:

$$H(Z,t) = a + b\sin\left[\frac{2\pi}{\lambda}(Z - ct)\right], \quad (1)$$

where a is the average radius of the undisturbed tube, b is the amplitude of the peristaltic wave, λ is the wavelength, c is the wave propagation speed, and t is the time.

3.Basic equations

The basic equations governing the non-Newtonian Jeffrey fluid are given by:

The continuity equation is given by:

$$\nabla.\underline{V} = 0. \tag{2}$$

The momentum equation is given by:

$$\rho(\underline{V}.\nabla)V = \nabla.\underline{\tau} + \mu_e \underline{J}\wedge\underline{B} - \frac{\mu}{k^*}\underline{V} \ . \tag{3}$$

The temperature equation is given by:

$$c_p\rho(\underline{V}.\nabla)T = k\nabla^2 T - \nabla.q_r - \mathrm{Q}\,\mathrm{T}. \tag{4}$$

The concentration equation is given by:

$$(\underline{V}.\nabla)C = D_m\nabla^2 C + \frac{D_m k_T}{T_m}\nabla^2 T, \tag{5}$$

where $\underline{V}$ is the velocity, μ is the dynamic viscosity, k^* is the permeability, $\underline{B} = (B_0, 0, 0)$ is the magnetic field, σ is theelectrical conductivity, μ_e is the magnetic permeability, and $\underline{\tau}$ is the Cauchy stress tensor. Also, T and C are the temperature and concentration of the fluid, k is the thermal conductivity, c_p is the specific heat capacity at constant pressure, D_m is the coefficient of mass diffusivity, T_m is the mean fluid temperature, k_T is the thermal diffusion ratio.

The constitutive equations for an incompressible Jeffrey fluid are given by:

$$\underline{\tau} = -\underline{P}\,\underline{I} + \underline{S}, \tag{6}$$

$$\underline{S} = \frac{\mu}{1+\lambda_1}\left(\underline{\dot{\gamma}} + \lambda_2\underline{\ddot{\gamma}}\right), \tag{7}$$

where $\underline{S}$ is the extra stress tensor. $\underline{P}$ is the pressure, $\underline{I}$ is the identity tensor, λ_1 is the ratio of relaxation to retardation times, $\underline{\dot{\gamma}}$ is the shear rate, λ_2 the retardation time .

4.method of solution

Let U and W be the respective velocity components in the radial and axial directions in the fixed frame, respectively.

For the unsteady two-dimensional flow, the velocity components may be written as follows:

$$\underline{V} = (U\,(r,z)\,, W(r,z)\,, 0). \tag{8}$$

Also, the temperature and the concentration functions may be written as follows,

$$T = T(r,z), \ \text{ and } \ C = C(r,z). \tag{9}$$

The equations of motion (2)-(5) and the constitutive relations (6), (7) take the form:

$$\frac{\partial U}{\partial R} + \frac{U}{R} + \frac{\partial W}{\partial Z} = 0, \tag{10}$$

$$\rho\left(\frac{\partial \mathrm{U}}{\partial \mathrm{t}} + U\frac{\partial U}{\partial R} + W\frac{\partial U}{\partial Z}\right) = -\frac{\partial p}{\partial R} + \frac{1}{R}\frac{\partial}{\partial R}(RS_{RR}) + \frac{\partial}{\partial Z}(S_{RZ}) - \frac{S_{\theta\theta}}{R} - \frac{\mu}{k}U, \tag{11}$$

$$\rho\left(\frac{\partial \mathrm{W}}{\partial \mathrm{t}} + U\frac{\partial W}{\partial R} + W\frac{\partial W}{\partial z}\right) = -\frac{\partial p}{\partial z} + \frac{1}{R}\frac{\partial}{\partial R}(RS_{RZ}) + \frac{\partial}{\partial z}(S_{ZZ}) - \frac{\mu}{k}W - \sigma B_0{}^2(W-c), \tag{12}$$

$$\frac{\partial \mathrm{T}}{\partial \mathrm{t}} + U\frac{\partial T}{\partial R} + W\frac{\partial T}{\partial Z} = \frac{k}{c_p\rho}\left(\frac{\partial^2 T}{\partial R^2} + \frac{1}{R}\frac{\partial T}{\partial R} + \frac{\partial^2 T}{\partial Z^2}\right) + \frac{16\sigma_0 T_2^3}{3k_0}\frac{1}{R}\frac{\partial}{\partial R}\left(R\frac{\partial T}{\partial R}\right) - \mathrm{Q}\,\mathrm{T}, \tag{13}$$

$$\left(\frac{\partial \mathrm{C}}{\partial \mathrm{t}} + U\frac{\partial \mathrm{C}}{\partial \mathrm{R}} + w\frac{\partial \mathrm{C}}{\partial \mathrm{Z}}\right) = D_m\left(\frac{\partial^2 \mathrm{C}}{\partial \mathrm{R}^2} + \frac{1}{R}\frac{\partial C}{\partial R} + \frac{\partial^2 \mathrm{C}}{\partial Z^2}\right) + \frac{D_m k_T}{T}\left(\frac{\partial^2 T}{\partial R^2} + \frac{1}{R}\frac{\partial T}{\partial R} + \frac{\partial^2 T}{\partial Z^2}\right). \tag{14}$$

In the fixed coordinates (R, Z) the flow between the two tubes is unsteady. It becomes steady in a wave frame (r, z)moving with the same speed as wave in the Z-direction. The transformations between the two frames is given by

$$r = R,\ \ z = Z - ct. \tag{15}$$

The velocities in the fixed and moving frames are related by

$$u = U,\ \ w = W - c, \tag{16}$$

where u and w are components of the velocity in the moving coordinate system.

$$\frac{\partial u}{\partial r} + \frac{u}{r} + \frac{\partial w}{\partial z} = 0, \tag{17}$$

$$\rho\left(u\frac{\partial u}{\partial r} + w\frac{\partial u}{\partial z}\right) = -\frac{\partial p}{\partial r} + \frac{1}{r}\frac{\partial}{\partial r}(rS_{rr}) + \frac{\partial}{\partial z}(S_{rz}) - \frac{S_{\theta\theta}}{r} - \frac{\mu}{k}u\,, \tag{18}$$

$$\rho\left(u\frac{\partial w}{\partial r} + w\frac{\partial w}{\partial z}\right) = -\frac{\partial p}{\partial z} + \frac{1}{r}\frac{\partial}{\partial r}(rS_{rz}) + \frac{\partial}{\partial z}(S_{zz}) - \frac{\mu}{k}w - \sigma {B_0}^2(w - c), \tag{19}$$

$$u\frac{\partial T}{\partial r} + w\frac{\partial T}{\partial z} = \frac{k}{c_p\rho}\left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial z^2}\right) + \frac{16\sigma_0 T_2^3}{3k_0}\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) - \mathrm{Q\,T}, \tag{20}$$

$$\left(u\frac{\partial C}{\partial r} + w\frac{\partial C}{\partial z}\right) = D_m\left(\frac{\partial^2 C}{\partial r^2} + \frac{1}{r}\frac{\partial C}{\partial r} + \frac{\partial^2 C}{\partial z^2}\right) + \frac{D_m k_T}{T}\left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial z^2}\right), \tag{21}$$

The appropriate boundary conditions are

$$\left.\begin{array}{l} w = -1\,,\quad u = 0\,,\quad T = T_1\,,\quad C = C_1\quad at\quad r = r_1 = \epsilon \\ w = -1\,,\quad u = 0\,,\quad T = T_0\,,\quad C = C_0\quad at\quad r = r_2(z,t) = 1 + \phi\sin(2\pi z) \end{array}\right\}, \tag{22}$$

In order to simplify the governing equations of the motion, we may introduce the following dimensionless transformations as follows:

$$\left.\begin{array}{lll} r^* = \frac{r}{a_2}\,, & z^* = \frac{z}{\lambda}\,, & \delta = \frac{a_2}{\lambda}\,, \\ u^* = \frac{\lambda u}{a_2 c}, & w^* = \frac{w}{c}\,, & p^* = \frac{{a_2}^2 p}{\mu c\lambda}\,, \\ {r_1}^* = \frac{r_1}{a_2} = \epsilon < 1, & {r_2}^* = \frac{r_2}{a_2} = 1 + \phi\sin(2\pi z), & \\ \theta = \frac{T - T_0}{T_1 - T_0}, & \varphi = \frac{C - C_0}{C_1 - C_0}, & S^* = \frac{aS}{\mu c} \end{array}\right\}, \tag{23}$$

Substituting (23) into equations (17)-(21), drop star mark, for simplify we obtain the following non- dimensional equations:

$$R_e\delta^3\left(u\frac{\partial u}{\partial r} + w\frac{\partial u}{\partial z}\right) = -\frac{\partial p}{\partial r} + \delta\frac{\partial S_{rr}}{\partial r} + \delta^2\frac{\partial S_{rz}}{\partial z} - \delta\frac{(S_{rr} - S_{\theta\theta})}{r} - \frac{R_e\delta^2}{D_a}u, \tag{24}$$

$$\delta R_e\left(u\frac{\partial w}{\partial r} + \delta w\frac{\partial w}{\partial z}\right) = -\frac{\partial p}{\partial z} + \frac{S_{rZ}}{r} + \frac{\partial S_{rZ}}{\partial r} + \delta\frac{\partial S_{zz}}{\partial z} - \left[\left(M^2 + \frac{1}{D_a}\right)w + M^2\right], \tag{25}$$

$$\delta\left(u\frac{\partial\theta}{\partial r} + w\frac{\partial\theta}{\partial z}\right) = \frac{1}{p_r}\left(\frac{\partial^2\theta}{\partial r^2} + \frac{1}{r}\frac{\partial\theta}{\partial r} + \delta^2\frac{\partial^2\theta}{\partial z^2}\right) + \frac{4}{3R_n}\left(\frac{\partial^2\theta}{\partial r^2} + \frac{1}{r}\frac{\partial\theta}{\partial r}\right) - \Omega\theta, \tag{26}$$

$$\delta\left(u\frac{\partial\varphi}{\partial r} + \delta w\frac{\partial\varphi}{\partial z}\right) = \frac{1}{S_c}\left(\frac{\partial^2\varphi}{\partial r^2} + \frac{1}{r}\frac{\partial\varphi}{\partial r} + \delta^2\frac{\partial^2\varphi}{\partial z^2}\right) + S_r\left(\frac{\partial^2\theta}{\partial r^2} + \frac{1}{r}\frac{\partial\theta}{\partial r} + \delta^2\frac{\partial^2\theta}{\partial z^2}\right), \tag{27}$$

where

$$S_{rr} = \frac{2\delta}{1+\lambda_1}\left[1 + \frac{c\lambda_2\delta}{a}\left(u\frac{\partial}{\partial r} + w\frac{\partial}{\partial z}\right)\right]\left(\frac{\partial u}{\partial r}\right), \tag{28}$$

$$S_{rz} = \frac{1}{1+\lambda_1}\left[1 - \frac{c\lambda_2\delta}{a}\left(u\frac{\partial}{\partial r} + w\frac{\partial}{\partial z}\right)\right]\left(\frac{\partial w}{\partial r} + \delta^2\frac{\partial u}{\partial z}\right), \tag{29}$$

$$S_{\theta\theta} = -\frac{2\delta}{1+\lambda_1}\left[1 - \frac{c\lambda_2\delta}{a}\left(u\frac{\partial}{\partial r} + w\frac{\partial}{\partial z}\right)\right]\left(\frac{u}{r}\right), \tag{30}$$

$$S_{zz} = \frac{2\delta}{1+\lambda_1}\left[1 - \frac{c\lambda_2\delta}{a}\left(u\frac{\partial}{\partial r} + w\frac{\partial}{\partial z}\right)\right]\left(\frac{\partial w}{\partial z}\right), \tag{31}$$

where, the previous dimensionless parameters are defined by:

$R_e = \frac{c\rho a}{\mu}$ (the Reynolds number) ,

$S_c = \frac{\gamma}{D}$ (the Schmidt number),

$P_r = \frac{cc_p\rho}{K}$ (the Prandtl number) ,

$S_r = \frac{DK_T(T_1-T_0)}{T_m(c_1-c_0)}$ (the Soret number),

$R_n = \frac{\rho k_0 c_p \nu}{4T_2^3\sigma_0}$ (the Radiation parameter),

$D_a = \frac{k}{a^2}$ (the Darcy number) ,

$M^2 = \frac{\sigma B_0 a_2}{\mu c^2}$ (the magnetic parameter) ,

and $\delta = \frac{a_1}{\lambda}$ (the Wave number).

The related boundary conditions in the wave frame are given by:

$$\left.\begin{array}{llllll} w=-1, & u=0, & T=1, & C=1, & at & r=r_1=\epsilon \\ w=-1\,, & u=0 & T=0 & C=0 & at & r=r_2=1+\phi\sin(2\pi z) \end{array}\right\}, \tag{32}$$

The general solution of the governing equations (24)-(27) in the general case seems to be impossible; therefore, we shall confine the analysis under the assumption of small dimensionless wave number. It follows that $\delta \ll 1$. In other words, we considered the long-wavelength approximation. Along to this assumption, equations (24)-(27) become:

$$\frac{\partial p}{\partial r} = 0, \tag{33}$$

$$\frac{\partial p}{\partial z} = \frac{\partial}{\partial r}\left[\frac{1}{1+\lambda_1}\frac{\partial w}{\partial r}\right] + \frac{1}{r(1+\lambda_1)}\frac{\partial w}{\partial r} - \left[\left(M^2 + \frac{1}{D_a}\right)w + M^2\right], \tag{34}$$

$$\left(\frac{1}{P_r} + \frac{3}{4}R_n\right)\left(\frac{\partial^2\theta}{\partial r^2} + \frac{1}{r}\frac{\partial\theta}{\partial r}\right) - \Omega\theta = 0, \tag{35}$$

and

$$\frac{1}{S_c}\left(\frac{\partial^2\varphi}{\partial r^2}+\frac{1}{r}\frac{\partial\varphi}{\partial r}\right)=-S_r\left(\frac{\partial^2\theta}{\partial r^2}+\frac{1}{r}\frac{\partial\theta}{\partial r}\right), \tag{36}$$

Equation (33) indicates that p dependents on z only. The solution of Eq. (34) subject to conditions (32) is

$$w=C_1\,I_0(A_5\,r)+C_2\,K_0(A_5\,r)+\frac{1}{\left(M^2+\frac{1}{D_a}\right)}\left(\frac{\partial p}{\partial z}+M^2\right), \tag{37}$$

Where

$$C_2=\frac{\left(I_0(A_5r_1)-I_0(A_5r_2)\right)\left(1+\frac{A_2}{A_1}\right)}{K_0(A_5r_1)\,I_0(A_5r_2)-K_0(A_5r_2)\,I_0(A_5r_1)},\qquad C_1=\frac{-\left(1+\frac{A_2}{A_1}\right)-c_2\,K_0(A_5\,r_1)}{I_0(A_5\,r_1)},$$

$$A_1=M^2+\frac{1}{D_a},\qquad A_2=-\left(\frac{\partial p}{\partial z}+M^2\right),$$

$$A_3=A_1(1+\lambda_1),\qquad A_4=A_2(1+\lambda_1),$$

and $A_5=\sqrt{\left(M^2+\frac{1}{D_a}\right)(1+\lambda_1)}$.

In fact, the solution of equations (33) and (34) give:

$$\theta=C_3\,I_0(A_7\ \ r)+C_4\,K_0(A_7\ \ r), \tag{38}$$

$$\varphi=-s_c\,s_r\,\theta+C_5\log r+C_6, \tag{39}$$

where

$$C_4=\frac{I_0(A_7r_2)}{K_0(A_7r_1)\,I_0(A_7r_2)-K_0(A_7r_2)\,I_0(A_7r_1)},\qquad C_3=\frac{-C_4\,K_0(A_7r_2)}{I_0(A_7r_2)},$$

$$C_5=\frac{1-A_8+A_9}{\log\frac{r_1}{r_2}},\qquad C_6=1-A_8-C_5\log r_1,$$

$$A_6=\frac{1}{R_eP_r}+\frac{4}{3R_n},\qquad A_7=\sqrt{\frac{\Omega}{A_6}},$$

$$A_8=-s_c\,s_r\left(c_3\,I_0(A_7r_1)+c_4\,K_0(A_7r_1)\right),$$

and $A_9=-s_c\,s_r\left(c_3\,I_0(A_7r_2)+c_4\,K_0(A_7r_2)\right)$,

6.Results and discussion

The previous analysis discussed the problem of an incompressible non-Newtonian Jeffrey fluid in a tube with heat and mass transfer. A mathematical two dimensions model in the presence of a uniform magnetic field and porous medium is considered. The analytical results have been obtained in case of long wave length approximation. This approximation transform on the nonlinear system of partial differential equations to a linear. We shall make numerical calculations for the previous analytical results. In these calculation, the distribution function of $\boldsymbol{w}, \boldsymbol{\theta}$ **and** $\boldsymbol{\varphi}$ will be plotted versus the radius $\boldsymbol{r}$ to show the behavior of the other parameters of the model.

Figure (2) illustrates the change of the velocity distribution function w with several value of the magnetic parameter M. In this figure, it is found that w increases with the increasing of M. Though Figure (3), we see that the w decreases with the increasing of D_a. The effect of the material parameter λ_1 on the velocity distribution function is illustrated in Figure (4); it is observed that the velocity w increases as the material parameter λ_1 increases.

Figures (5)-(7) illustrate the effects of the parameters $\boldsymbol{P_r}, \boldsymbol{R_n}$ **and** $\boldsymbol{R_e}$ on the temperature distribution function. From figure (5), we see that the temperature distribution function decreases with the increase of the Prandtl number $\boldsymbol{P_r}$. In figure (6), it is found that the increase of $\boldsymbol{R_n}$ leads to an increase in the temperature of fluid. Figure (7) illustrates the effect of Reynolds number $\boldsymbol{R_e}$ on the temperature distribution function. It is obvious that the increase of $\boldsymbol{R_e}$ leads to a decrease in the temperature of fluid.

Figures (8) and (9) illustrate the effects of $\boldsymbol{S_r}$ and $\boldsymbol{S_c}$ on the concentration distribution function $\boldsymbol{\varphi}$. Figure (8) illustrates the effects of the thermal-diffusion parameter $\boldsymbol{S_r}$ (Soret number) on the concentration distribution function. It is shown that the concentration distribution function decreases with the decrease of $\boldsymbol{S_r}$. In figure (9), it is found that the concentration distribution function $\boldsymbol{\varphi}$ decreases with the decrease of Schmidt number $\boldsymbol{S_c}$.

7.Conclusion

The problem of an incompressible MHD Jeffrey fluid in a tube with heat and mass transfer with peristalsis has been analyzed. The momentum, energy and concentration equations have been linearized under a long-wavelength approximation. Analytical solutions have also been developed for velocity, temperature, concentration. The features of the flow characteristics are elaborately analyzed by plotting graphs and discussed in detail. The main findings are summarized as follows:

- The effects of λ_1, and M on the velocity function are qualitatively similar.
- Temperature profile increases with an increase in P_r, R_n and R_e.
- The behavior of S_c on the concentration rise is similar to that of S_r.
- Our results for effects of λ_1, and M on the velocity function are in good agreement with Hayat T. et. al. (2008) b .

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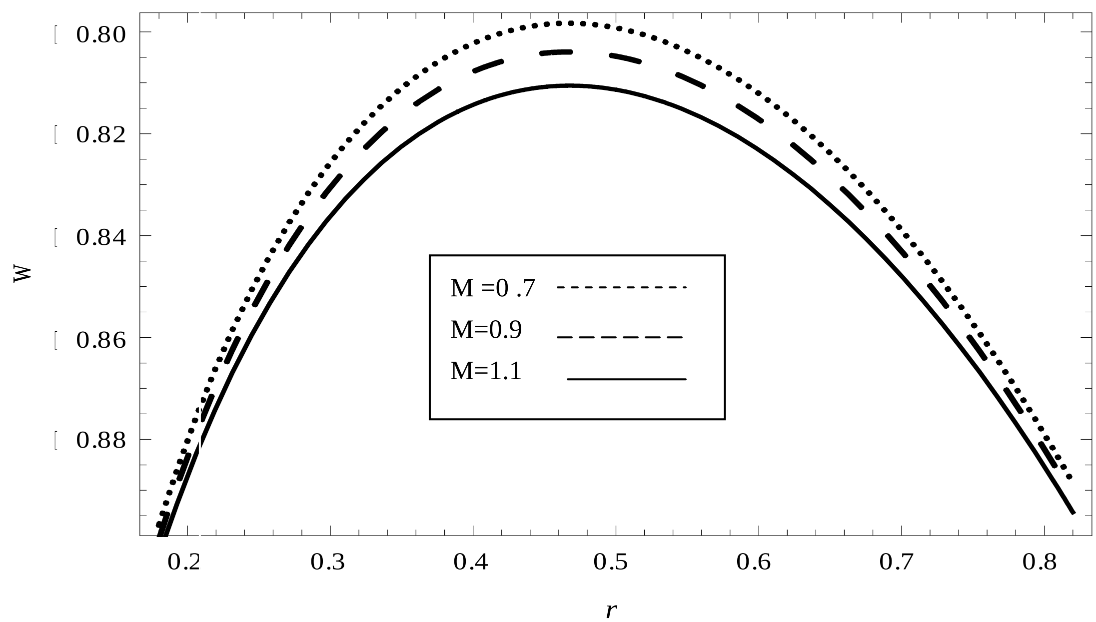

Fig (2): The variation the velocity distribution w with different values of M for a system having the particulars $Da = 0.7, \lambda_1 = 0.1, r_1 = 0.1$ and $\phi = 0.3$.

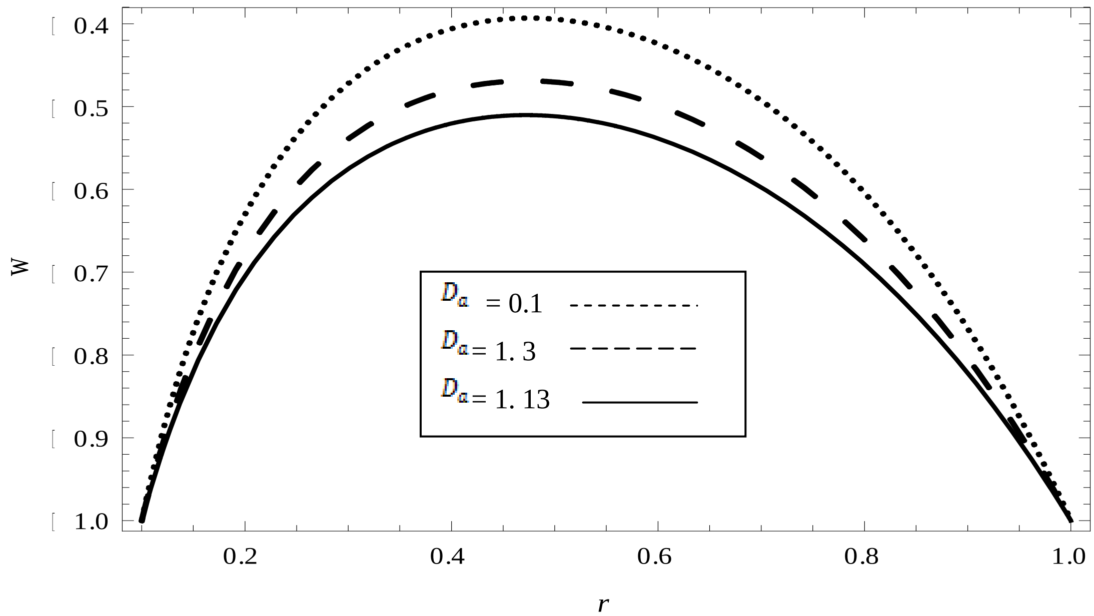

Fig (3): The variation the velocity distribution w with different values of D_a for a system having the particulars $M = 1.7,\ \lambda_1 = 0.1,\ r_1 = 0.1$ and $\phi = 0.3$

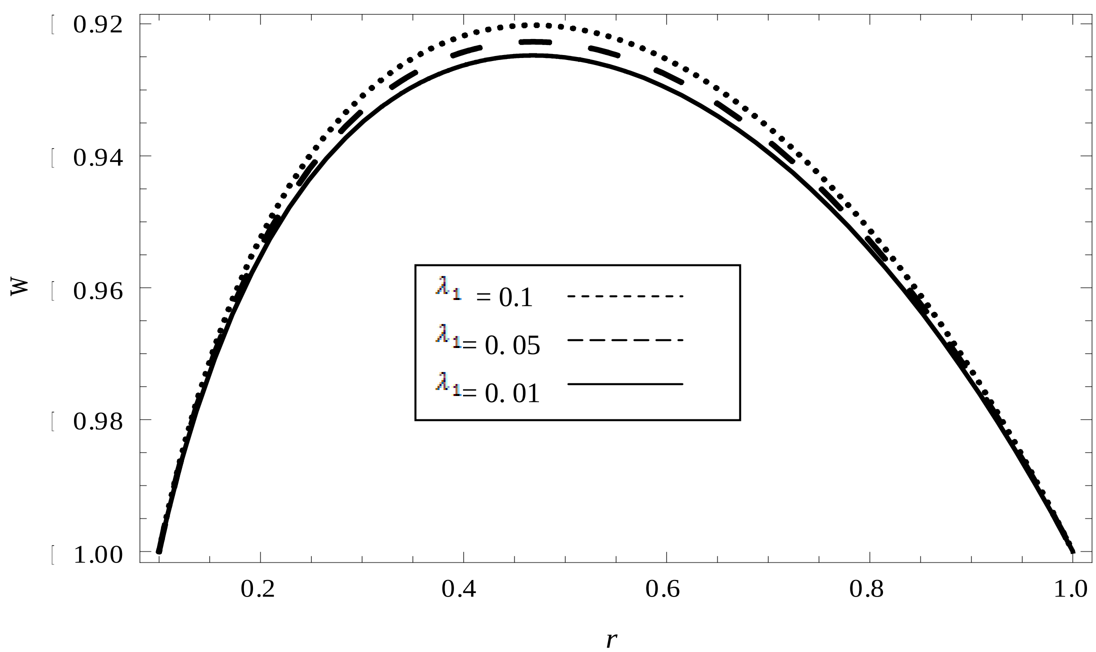

Fig (4): The variation the velocity distribution w with different values of λ_1 for a system having the particulars $M = 1.7, \mathrm{Da} = 0.7, r_1 = 0.1$ and $\phi = 0.3$

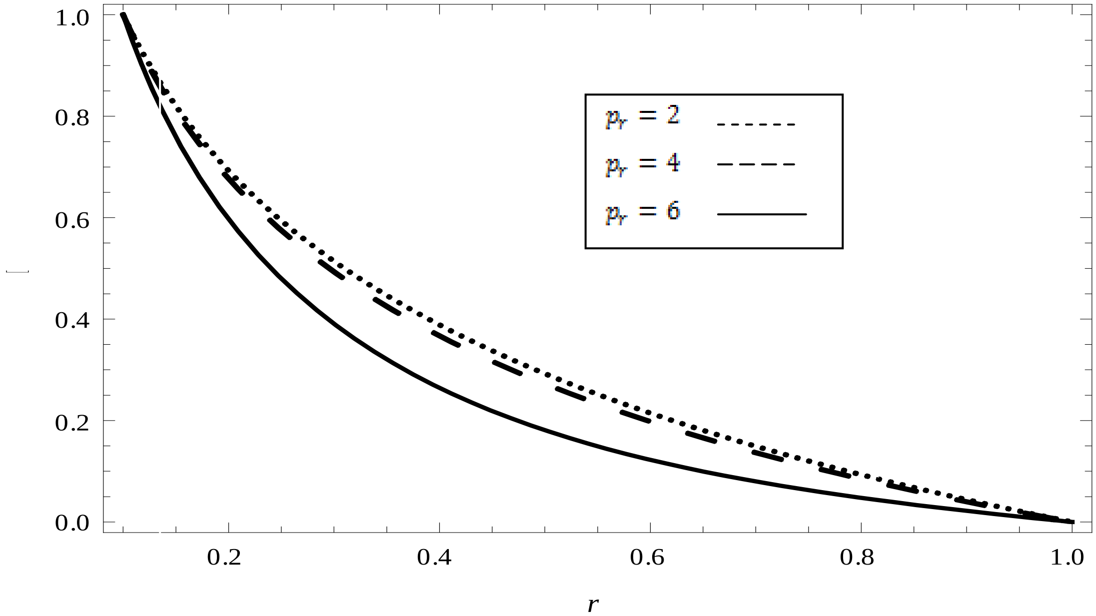

Fig (5): The variation of temperature with different values of Prandtl number P_r for a system having the particulars $\Omega = 1, R_n = .5, r_1 = 0.1, \phi = 0.3$ and $R_c = 1.5$

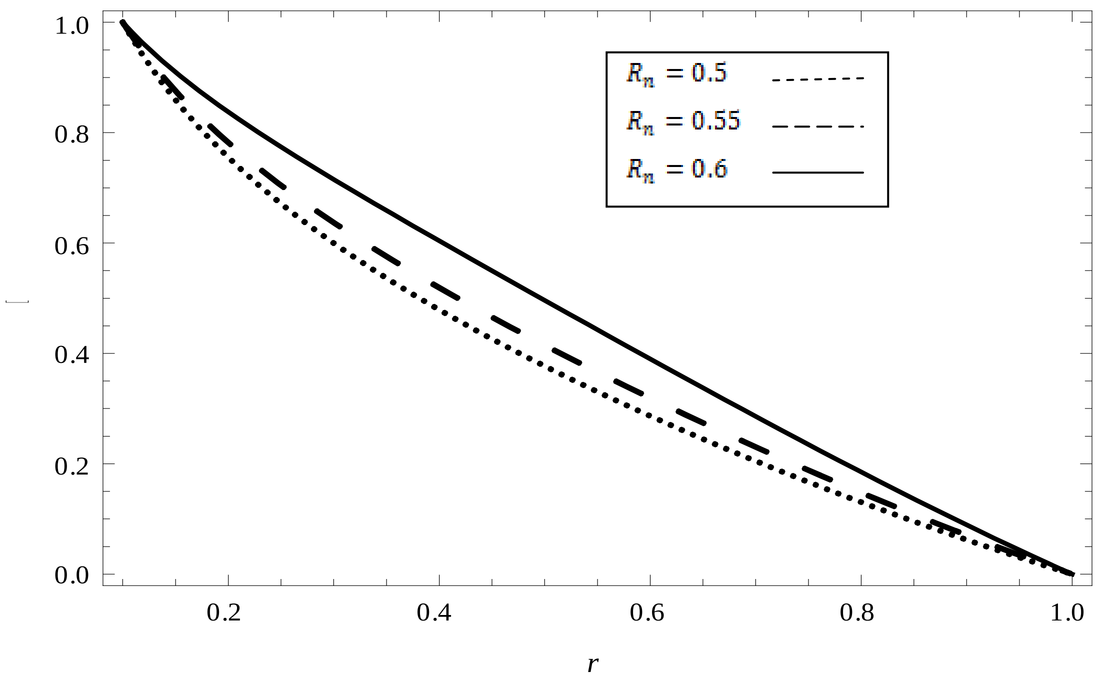

Fig (6): The variation of temperature with different values of R_n for a system having the particulars $\Omega = 1, P_r = 2, r_1 = 0.1, \phi = 0.3$ and $R_c = 1.5$

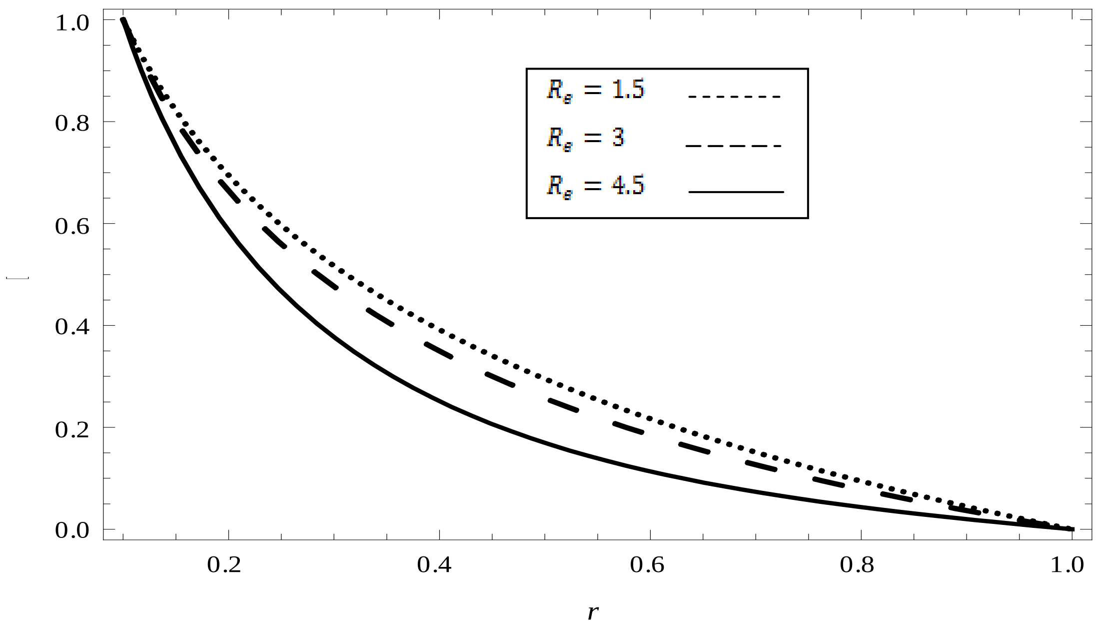

Fig (7): The variation of temperature with different values of R_c for a system having the particulars $\Omega = 1, P_r = 2, r_1 = 0.1, \phi = 0.3$ and $R_n = 0.5$

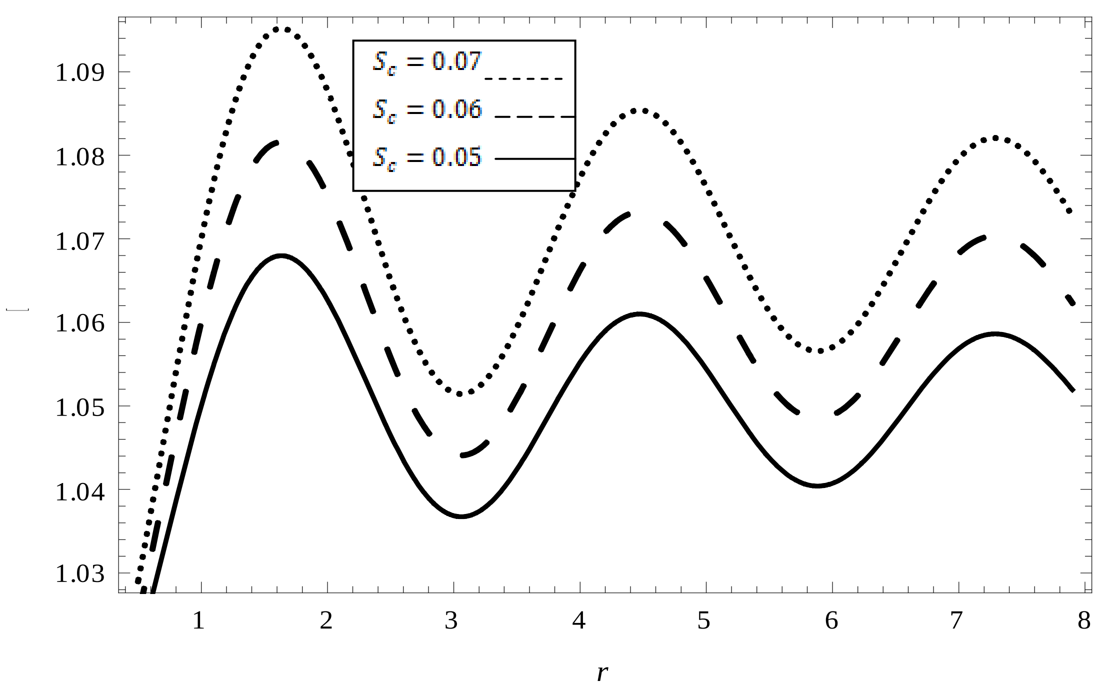

Fig (8): The variation of concentration with different values of Schmidt number S_c for a system having the particulars $s_c = 0.07, r_1 = 0.1, \phi = 0.3$

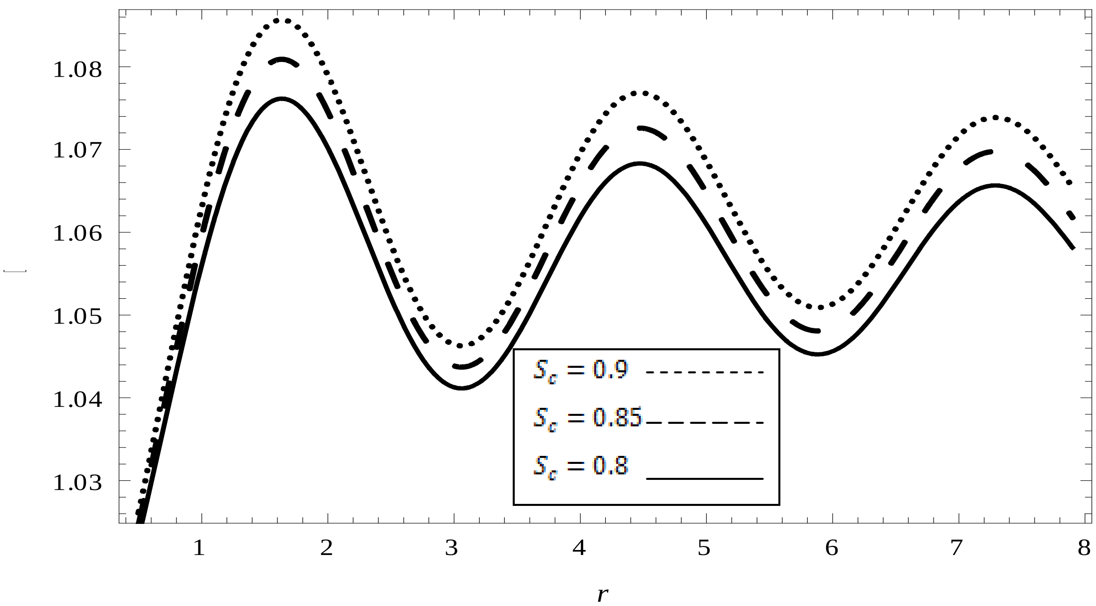

Fig (9): The variation of concentration with different values of Soret number S_r for a system having the particulars $s_r = 1, r_1 = 0.1$ and $\phi = 0.3$

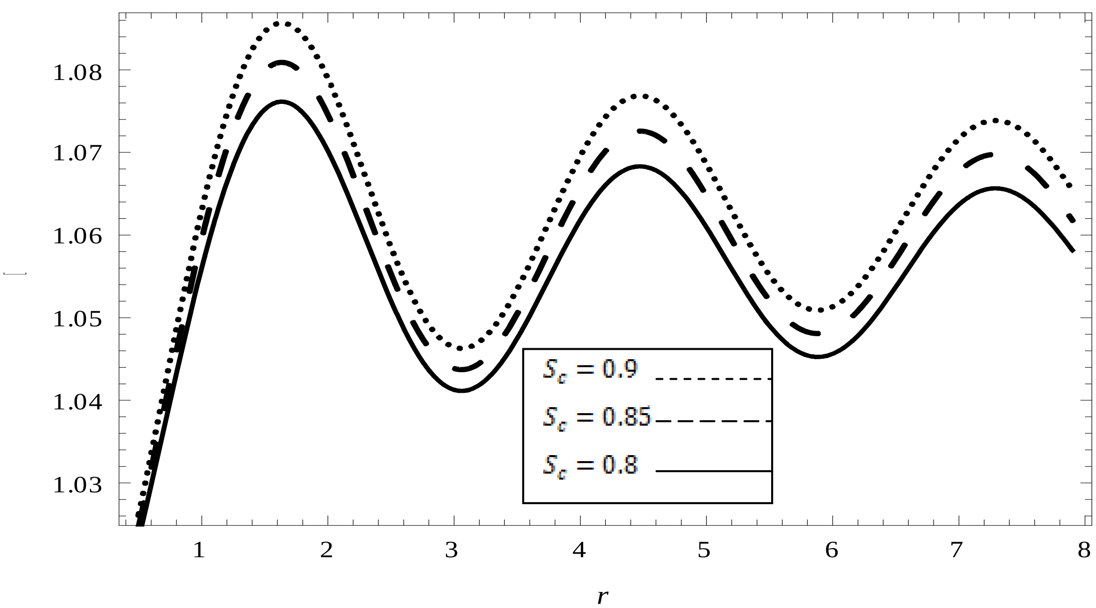

Fig (10): The variation of concentration with different values of Soret number S_r for a system having the particulars $s_r = 1, r_1 = 0.1$ and $\phi = 0.3$