

Numerical Study of Homann Jaffery Nanofluid Flow Over a Spiraling Disk

Farhan Ali

School of Computer and IT, Beaconhouse National University, P.O. Box 53700
Lahore Pakistan Email: farhan32748@gmail.com

ABSTRACT

An incompressible laminar Homann flow of Jeffrey nanofluid about a stagnation region of spiraling disk is main objective of the current thesis. The disk is subjected to a uniform mass blowing using Stefan blowing phenomenon. Thermal phenomenon will investigate using Hall current influence, Buongiorno theory of nanofluid and Cattaneo-Christov theories. By applying similarity transformations, The modelled statements are then transformed into a format of ODE's . The system will be treated through the Runge-Kutta-Fehlberg (RKF-45) technique in order to present the results of physical quantities in graphical formats and in tabular way.

Introduction

Von Karman [1] for the first time discovered the scheme similarity functions to solve the viscous fluid flow model by an infinite rotating disk. Further, Benton [2] reported the initial value problem generated by impulsively progressive disk. Flow through a revolving disk is a traditional problem in these field of fluid mechanics which has both practical and theoretical values. Many scientists have analyzed fluid (Newtonian and non-Newtonian) flow over rotating/vertical disk , due to various practical application in numerous area such as medical equipment , rotating machinery, and computer storage devices [3-6].

Homann [7] addressed the the concept of axisymmetric stagnation point flows by level surface which is view as irrational far-field flow. Weidman [8] explored the Homann Agrawal flows of non-Newtonian fluids problem in view of spiraling disk. A differential equation (non-linear) of singular type arising from the Homann flow was discussed by Shin [9]. The thermal attributes for Homann flow of second-grade fluid were depicted by Sahoo and Labropulu [10]. Weidman [11] characterized the nano-axisymmetric Homann flow about a stagnation region by adding up periodic velocities. Demir and Baris [12] examined the Haomann flow about translating plate and investigated the thermal features. The numerical findings for micropolar (non-Newtonian) Homann flow by spiraling disk rotation were simulated by Sajid et al. [13].

The impacts of chemically reactive Homann nanofluid flow close to stagnation zone were scrutinized from Khan's et al. [14]. Ahmad et al. [15] discussed radiative phenomenon for hybrid nanofluid in Homann flow stagnation region.

The role of nano-fluids is the initiative significance in the small electronic devices consists of microchips and other. Nanofluid consist of magnesium oxide particles and are widely utilized in various systems in order to attain improved thermal efficiently.

The fact of solid phase nanoparticles remarkably upgraded the liquid's thermal conductivity. The improvement in this property of the nanofluid is affected by various item such as volume fraction, phase dimensions, and temperature. A nanofluid is consistent and stable interruption of nano-sized solid particles (<100 nm) is ordinary liquids [16]. The recent advancements of nanofluid flows can be recognized in Refs. [17-20].

The advanced research is focused on the direction of strong magnetic field and low density due to its application like Hall accelerators, space flight, electric transformers refrigeration coils, nuclear fusions and magnetohydrodynamic etc. The suction/injection (uniform) impacts in time-dependent flow subjected to spinning disk under Hall current influence was determined by Attia and Hassan [21]. Wahed and Akl [22] studied the Hall current significance for thermally nanofluid flow along with the fluid's variable features owing to swirling disk. The Hall current influence in Johnson-Segalman fluid across revolving eccentric disks was analyzed by Maqbool et al. [23]. Acharya et al. [24] addressed Hall currents features in nanofluids about revolving disks. Ahmad et al. [25] examined the Hall current and entropy generation impacts for second-grade fluid phenomenon by disk rotation. The approach of Hall current in hybrid nanofluid by adopting the rotating configurations was signified by Khan et al. [26]. The Hall currents impact in radiative viscous flow about revolving rotation of disk was presented by Pathak and Joshi [27].

The Cattaneo in the constitutive and the partial derivative connection around the heat flux and temperature achieved success in solve better Fourier model's problem. The propagation of heat in such disorder model has finite speed [28]. Cattaneo proposed the Cattaneo's law through the inclusion of relaxation factors in the Fourier theory of heat diffusion. This law is used by various investigators for versatile problem of energy transfer analysis [29-32].

The non-Newtonian fluids grew much importance in the research because of polymer food processing, industries, lubricants, and emulsion. The formula of non-Newtonian fluids are more sophisticated due to higher order non-linear relationship between strain and stress. Research community has studies different characteristics of non-Newtonian fluids of various kinds. The Jeffery model admit to regularly utilized newtonian fluid models for the reason that reality that its equating may be decrease the newtonian model of particular instance. The Jeffery fluid representation able of report the stress characteristics in non-Newtonian fluid and depicts the features of retardations and relaxations fact. Kahshan et al. [33] evaluated creeping movement of Jeffrey fluid confined in permeable walled channel. Abro et al. [34] observed the outcomes of radiative flow in Jeffrey fluid using Caputo-Fabrizio scheme of fractional derivative. Rehman et al. [35] discussed the physical scenario of chemically reactive Jeffrey fluid in stagnation region of the cylindrical surface. Sadiq et al. [36] discussed the numerical findings of Jeffrey fluid swirl flow due to spiraling disk.

The present thesis is focused on phenomenon on Jeffrey fluid means of spiraling disk. The thermal features the flow phenomenon will be incorporated by Hall current, nanofluid (Buongiorno model), and Cattaneo-Christov theories. Furthermore, the influence of mass blowing using Stefan blowing will also be investigated.

Mathematical Formulation

Problem Statement

Let us observe a incompressible, steady, and axisymmetric Homann flow of nano-fluids by a spiraling disks in plane $z = 0$. Due to spiraling disk configuration the velocity component (u, v, w) are examine in system of cylindrical coordinate (r, θ, z) . The instantaneous rotation of the disk is (Ω) . The stagnation flow of stable laminar type is assumed. The spiraling disk assumed wall concentration and reference temperature c_w and T_f while c_∞ and T_∞ represent ambient fluid concentration and temperature respectively.

The governing equations for Jeffrey fluid are [36]:

$$\frac{\partial u}{\partial r} + \frac{u}{r} + \frac{\partial w}{\partial z} = 0 \quad (4.1)$$

$$\left\{ \rho \left(w \frac{\partial u}{\partial z} + u \frac{\partial u}{\partial r} - \frac{v^2}{r} \right) = -\frac{\partial p}{\partial r} + \frac{\mu}{1+\lambda_1} \left(\frac{\partial^2 u}{\partial r^2} - \frac{u}{r^2} + \frac{\partial^2 u}{\partial z^2} + \frac{1}{r} \frac{\partial u}{\partial r} \right) \right. \\ \left. + \frac{\mu\lambda_2}{1+\lambda_1} \left(w \frac{\partial^3 u}{\partial z^3} + \frac{\partial w}{\partial z} \frac{\partial^2 u}{\partial z^2} - \frac{1}{r} \left(\frac{\partial v}{\partial z} \right)^2 + u \frac{\partial^3 u}{\partial r \partial z^2} + \frac{\partial u}{\partial z} \frac{\partial^2 u}{\partial r \partial z} - \frac{v}{r} \frac{\partial^2 v}{\partial z^2} \right) - \frac{\delta_e \beta_o^2}{1+m^2} (v+m_1 u) \right. \quad (4.2)$$

$$\left\{ \rho \left(\frac{uv}{r} + u \frac{\partial v}{\partial r} + w \frac{\partial v}{\partial z} \right) = \frac{\mu}{1+\lambda_1} \left(\frac{\partial^2 v}{\partial r^2} - \frac{v}{r^2} + \frac{1}{r} \frac{\partial v}{\partial r} + \frac{\partial^2 v}{\partial z^2} \right) + \frac{\mu\lambda_2}{1+\lambda_1} \right. \\ \left. \left(\frac{1}{r} \frac{\partial u}{\partial z} \frac{\partial v}{\partial z} + u \frac{\partial^3 v}{\partial r \partial z^2} + \frac{v}{r} \frac{\partial^2 u}{\partial z^2} + \frac{\partial w}{\partial z} \frac{\partial^2 v}{\partial z^2} + \frac{\partial u}{\partial z} \frac{\partial^2 v}{\partial r \partial z} + w \frac{\partial^3 v}{\partial z^3} \right) + \frac{\delta_e \beta_o^2}{1+m^2} (u-m_1 v) \right. \quad (4.3)$$

$$\left\{ u \frac{\partial T}{\partial r} + w \frac{\partial T}{\partial z} - \alpha \left(\frac{1}{r} \frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial z^2} + \frac{\partial^2 T}{\partial r^2} \right) + \tau \left(D_B \left(\frac{\partial C}{\partial z} \frac{\partial T}{\partial z} + \frac{\partial C}{\partial r} \frac{\partial T}{\partial r} \right) + \frac{D_T}{T_\infty} \left\{ \left(\frac{\partial T}{\partial z} \right)^2 + \left(\frac{\partial T}{\partial r} \right)^2 \right\} \right) \right. \\ \left. - \tau_o \left(\left(u \frac{\partial u}{\partial r} + w \frac{\partial u}{\partial z} \right) \frac{\partial T}{\partial r} + u^2 \frac{\partial^2 T}{\partial r^2} + 2uw \frac{\partial^2 T}{\partial r \partial z} + w^2 \frac{\partial^2 T}{\partial z^2} + \left(u \frac{\partial w}{\partial r} + w \frac{\partial w}{\partial z} \right) \frac{\partial T}{\partial z} \right) \right. \quad (4.4)$$

$$\left\{ w \frac{\partial C}{\partial z} + u \frac{\partial C}{\partial r} = \frac{D_T}{T_m} \left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial z^2} \right) + D_B \left(\frac{\partial^2 C}{\partial r^2} + \frac{1}{r} \frac{\partial C}{\partial r} + \frac{\partial^2 C}{\partial z^2} \right) - \tau_1 \right. \\ \left. \left(w^2 \frac{\partial^2 C}{\partial z^2} + u^2 \frac{\partial^2 C}{\partial r^2} + 2uw \frac{\partial^2 C}{\partial r \partial z} + \left(u \frac{\partial u}{\partial r} + w \frac{\partial u}{\partial z} \right) \frac{\partial C}{\partial r} + \left(w \frac{\partial w}{\partial z} + u \frac{\partial w}{\partial r} \right) \frac{\partial C}{\partial z} \right) \right. \quad (4.5)$$

$$\left\{ \rho \left(w \frac{\partial w}{\partial z} + u \frac{\partial w}{\partial r} \right) = -\frac{\partial p}{\partial z} + \frac{\mu}{1+\lambda_1} \left(\frac{\partial^2 w}{\partial r^2} + \frac{\partial^2 w}{\partial z^2} + \frac{1}{r} \frac{\partial w}{\partial r} \right) + \frac{\mu\lambda_2}{1+\lambda_1} \right. \\ \left. \left(2 \frac{\partial w}{\partial z} \frac{\partial^2 w}{\partial z^2} + \frac{\partial^2 u}{\partial r \partial z} \frac{\partial u}{\partial r} + \frac{\partial^2 u}{\partial z^2} \frac{\partial w}{\partial r} + \frac{w}{r} \frac{\partial^2 u}{\partial z^2} + \frac{u}{r} \frac{\partial^2 u}{\partial r \partial z} + 2u \frac{\partial^3 w}{\partial r \partial z^2} + w \frac{\partial^3 u}{\partial r \partial z^2} + 2u \frac{\partial u}{\partial z} \frac{\partial w}{\partial r \partial z} + 2w \frac{\partial^3 w}{\partial z^3} + u \frac{\partial^3 u}{\partial r^2 \partial z} \right) \right. \quad (4.6)$$

Boundary conditions of present problems are

$$\begin{cases} u = br, w = \frac{-D_B}{1-C_w} \left(\frac{\partial C}{\partial z} \right), T = T_w, v = \Omega r, C = C_w & \text{at } z = 0, \\ u \rightarrow ar, v \rightarrow 0, C \rightarrow C_\infty, w \rightarrow -2az, T \rightarrow T_\infty & \text{at } z \rightarrow \infty \end{cases}$$

(4.7)

Where

$p, \rho, \mu, \lambda_1, \lambda_2, \delta_e, \beta_0, \alpha, \gamma_1, \gamma_2, D_T, T_m, D_B, \tau$ and a stand for pressure, density, kinematic viscosity, ratio parameter, retardation time, electrical conductivity, magnetic field strength, thermal relaxations times, concentrations relaxations times, thermophoretic co-efficient, Brownian diffusion ratios of heat capacity, nanoparticles and based fluid and strain rate of Homann flow respectively.

Similarity functions are use to convert the above system an ode's system [36]:

$$\begin{cases} u = raf'(\eta), v = r ag(\eta), \phi = \frac{C - C_\infty}{C_w - C_\infty}, w = -2\sqrt{av} f(\eta), \eta = \sqrt{\frac{a}{v}} z \\ \theta = \frac{T - T_\infty}{T_f - T_\infty}, \end{cases}$$

(4.8)

Equation (4.8) leads the system:

$$\begin{cases} f''' + (1 + \lambda_1) \left(2ff'' - f'^2 + 1 + g^2 \right) + \xi \left(-2f''''f + f''''^2 - gg'' - g'^2 - f''f' \right) \\ -M^2(1 + \lambda_1)(1 + m^2)^{-1} (g + mf') = 0 \end{cases}$$

(4.9)

$$\begin{cases} g'' + (1 + \lambda_1) (2fg' - 2gf') + \xi (f''g - 2fg'' + 2g'f'' - g''f') \\ +M^2(1 + \lambda_1)(1 + m^2)^{-1} (f' - mg) = 0 \end{cases}$$

(4.10)

$$\theta'' + 2prf\theta' + prNb\theta'\phi' + prNt\theta'^2 - 4prr_1(f^2\theta'' + ff'\theta') = 0$$

(4.11)

$$\phi'' + 2prLef\phi' + \frac{Nt}{Nb}\theta'' - 4prLer_2(f^2\phi'' - ff'\phi') = 0$$

(4.12)

In the boundary conditions that have been established:

$$\begin{cases} f(0) = \frac{f_w}{Le.pr}\phi', f'(0) = \lambda, \theta(0) = 1, g(0) = S, g(\infty) = 0, \\ \phi(0) = 1, \theta(\infty) = 0, f'(\infty) = 1, \phi(\infty) = 0. \end{cases}$$

(4.13)

Where

$r_1 = \tau_0 a$: Time parameter of thermal

$r_2 = \tau_1 a$: Time parameter of concentration

$$Le = \frac{\alpha}{D_B} : \text{Lewis numbers}$$

$$Pr = \frac{\nu}{\alpha} : \text{Prandtl numbers}$$

$$Sc = Lepr : \text{Schmidt number}$$

$$Nt = \frac{\tau D_t}{\nu T_\infty} (T_f - T_\infty) : \text{Thermophoretic parameter}$$

$$Nb = \frac{\tau D_B}{\nu} (C_f - C_\infty) : \text{Brownian motion parameter}$$

$$f_w = \frac{C_f - C_\infty}{2(1 - C_w)} : \text{Injection/suction parameter}$$

S, λ, ξ Stand for rotation parameter, stretching parameter, retardation parameter respectively.

Where

$$S = \frac{\Omega}{a} : S \text{ is rotation parameter}$$

$$\lambda = \frac{b}{a} : \lambda \text{ is stretching parameter}$$

$$\xi = a\lambda_2 : \xi \text{ is retardation parameter}$$

The pressure field for a Homann flow as follows:

$$p = p_o - \rho \left[-av \left(2f' + 2(1 + \lambda_1)f'^2 - \xi(3f'^2 + 4ff'') \right) + \frac{a^2 r^2}{2} \right]$$

(4.14)

Where p_o stand for stagnation pressure.

$$\begin{cases} \tau_r = \frac{\mu}{\lambda_1 + 1} \left[\lambda_2 \left(u \frac{\partial^2 u}{\partial r \partial z} - \frac{v}{r} \frac{\partial v}{\partial z} + w \frac{\partial^2 u}{\partial z^2} \right) + \frac{\partial u}{\partial z} \right]_{z=0} \\ \tau_\theta = \frac{\mu}{\lambda_1 + 1} \left[\frac{\partial v}{\partial z} + \lambda_2 \left(\frac{v}{r} \frac{\partial u}{\partial z} + w \frac{\partial^2 v}{\partial z^2} + u \frac{\partial^2 v}{\partial r \partial z} \right) \right]_{z=0} \end{cases}$$

(4.15)

Utilizing (4.8) in (4.15), we have

$$\begin{cases} \tau_r = \frac{\nu^{1/2} \rho r a^{3/2}}{1 + \lambda_1} \left[\xi \left(-2f(0)f'''(0) - g(0)g'(0) + f'(0)f''(0) \right) + f''(0) \right] \\ \tau_\theta = \frac{r \rho \nu^{1/2} a^{3/2}}{1 + \lambda_1} \left[\xi \left(f'(0)g'(0) + f''(0)g(0) \right) + g'(0) - 2f(0)g'(0) \right] \end{cases}$$

(4.16)

The torque T can be calculated as follows:

Torque

=

$$\int_0^{2\pi} \int_0^R \tau_\theta r^2 dr d\theta = \frac{\pi}{2(1+\lambda_1)} \rho \left[\xi \left(f''(0)g(0) - 2f(0)g''(0) + f'(0)g'(0) \right) + g'(0) \right] a^{3/2} v^{1/2} R^4$$

(4.17)

Disk of the radius is R

$$\phi = \tan^{-1} \left(\frac{\lambda}{S} \right)$$

Motion is produced by the constant rotation caused only and for $\phi = 0^\circ$ there are no stretching effects. Where $\phi = 90^\circ$

$$\tau = \rho a^{3/2} v^{1/2} r \sigma,$$

$$\phi_\sigma = \frac{\pi}{2} - \tan^{-1} \left(\frac{\xi \left(-2f(0)g''(0) + f'(0)g'(0) + f''(0)g(0) \right) + g'(0)}{\xi \left(-2f(0)f'''(0) + f'(0)f''(0) - g(0)g'(0) \right) + f''(0)} \right)$$

(4.18)

$$\sigma(\sin \phi_\sigma, \cos \phi_\sigma) = \frac{1}{1+\lambda_1} \left[\frac{\xi \left(f'(0)f''(0) - 2f(0)f'''(0) - g(0)g'(0) \right) + f''(0)}{\xi \left(f'(0)g'(0) + f''(0)g(0) - 2f(0)g''(0) \right) + g'(0)} \right]$$

(4.19)

Where

ϕ_σ : is the action angle

σ : is the dimensionless total stress parameter

$$V_{total} = arV,$$

$$(\lambda, S) = V(\sin \phi, \cos \phi)$$

$$V = \sqrt{S^2 + \lambda^2}$$

Where

$$C_f = \frac{\tau_r}{\rho(ar)^2} : \text{Nusselt Number}$$

(4.20)

$$C_g = \frac{\tau_\theta}{\rho(ar)^2} : \text{Tangential skin friction coefficient}$$

(4.21)

Using (4.15, 4.16) in (4.20) and (4.21), we have:

$$\begin{cases} \text{Re} r^{1/2} C_f = \frac{1}{\lambda_1 + 1} \left[\xi \left(-2f(0)f'(0) - g(0)g'(0) + f'(0)f''(0) \right) + f''(0) \right] \\ \text{Re} r^{1/2} C_g = \frac{1}{\lambda_1 + 1} \left[\xi \left(g'(0)f'(0) - 2g''(0)f(0) + f''(0)g(0) \right) + g'(0) \right] \end{cases}$$

(4.22)

Where: $\text{Re} = \frac{ar^2}{\nu}$ is the local radial Reynolds number.

Solution Methodology

A single way that guarantee accurate the solution of an (IVP) is to solve the problem two time by using step size $\frac{h}{2}$ and h and differentiate answer on the mesh point corresponding to the great size. The method of Runge-Kutta Fehlberg indicate by RKF45 is single way to solve the problem. It offers a procedure for determining whether the correct step size is used. In every stage, two non-identical estimation for solution are differentiate. The approximation is approved if the two responses are almost identical. The level size is larger if the result goes to more significant digits than necessary. Each step requires the following six values:

$$k_1 = hf(m_i, n_i)$$

$$k_2 = hf\left(n_i + \frac{k_1}{4}, m_i + \frac{h}{24}\right)$$

$$k_3 = hf\left(m_i + \frac{3h}{8}, n_i + \frac{3k_1}{32} + \frac{9k_2}{32}\right)$$

$$k_4 = hf\left(m_i + \frac{12h}{13}, n_i + \frac{1932k_1}{2197} - \frac{7200k_2}{2197} + \frac{7296k_3}{2197}\right)$$

$$k_6 = hf\left(m_i + \frac{h}{2}, n_i + \frac{1859}{4104}k_4 - \frac{11}{40}k_5 + 2k_2 + \frac{8}{27}k_1 - \frac{3544}{2565}k_3\right)$$

$$k_5 = hf\left(m_i + h, n_i + \frac{3680}{513}k_3 - \frac{845}{4104}k_4 - 8k_2 + \frac{439}{216}k_1\right)$$

Then the approximation using fourth order Runge-Kutta method is :

$$n_{i+1} = n_i + \frac{25}{216}k_1 - \frac{1}{5}k_5 + \frac{1408}{2565}k_3 + \frac{2197}{4104}k_4 \quad (4.23)$$

Note that the value of k_2 is not used in above formula. The other value of n is determined by fifth order Runge-Kutta method as follows:

$$n_{i+1}^* = n_i + \frac{16}{135}k_1 + \frac{2}{55}k_6 + \frac{28561}{56430}k_4 - \frac{9}{50}k_5 + \frac{6656}{12825}k_3 \quad (4.24)$$

Method is close if $|n_{i+1} - n_{i+1}^*|$ is small enough . Otherwise, computation is repeated by reducing the size h . The local truncation error of this method is $n_{i+1} - n_{i+1}^*$. The Cash and Karp (1990) expand the particular coefficient used in the above equation. So, this is known as Cash-Karp RK method.

The nonlinear system of expressions will be re-structured through the suitable transformations. The resulting expressions will be tackled through RKF-45 numerical approach. The graphical and tabular evaluation of the results will be presented and reported through physical background.

Results and Discussion

An incompressible laminar Homann flow of Jeffrey nanofluid about a stagnation region of spiraling disk is analyzed. The disk is subjected to a uniform mass blowing

using Stefan blowing phenomenon. Thermal phenomenon is investigated by Hall current, Buongiorno theory of nanofluids and Cattaneo-Christov theories. The similarity transformations modelled the governing model into ODE's. The system is treated through the Runge-Kutta-Fehlberg (RKF-45) technique to present the results of physical quantities in graphical formats.

we illustrate the pictorial representation of the physical quantities on velocities, temperature, and concentration fields. The magnetic parameter significance onto the axial, radial and tangential traces is pictured in Fig. 01-03. The axial velocity is first enhanced in the neighboring region of the disk surface while after some distance along axial axis, the profiles are turned down by the enhanced magnetic parameter (see Fig. 01). Fig 02. Demonstrated the magnetic field consequence onto radial traces. The radial traces exhibited the declining phenomenon against increased M due to the imposition of strong magnetic field along axial axis which turns down the flow phenomenon. Fig. 03 presented the significance of magnetic parameter onto the tangential field. By increased M values the profiles are depicting the enhancing nature. Fig. 04-05 are delineated the effects of Hall current onto the radial and tangential fields respectively. The influence of Hall current has not much significant effect onto the velocity fields. Both the radial and tangential traces are declined against increased m values. Figs. 06-08 are portrayed to illustrate the outcomes of the parameter λ_1 onto the velocity fields. The axial traces are preserving enhancing phenomenon for λ_1 enhanced values (see Fig. 06), however an alternative trend is noticed in radial traces against λ_1 values in Fig. 07. From Fig. 08, we noticed that the tangential traces are also turned down due to magnification in the λ_1 values. Figs. 09-11 are sketched to discuss the consequences of the relaxation time onto three different velocity fields. Through Fig. 09, it is elaborated that the increment in the parameter ζ reduced the tangential field. Moreover, larger values of ζ has larger effect on the flow phenomenon as mentioned through Fig. 09. Fig. 10 exhibited the implication of ζ onto the axial traces. The axial curved are declined owing to enlargement in ζ values. Fig. 11 is portrayed the outcomes of the ζ distinct values onto radial field. The radial is also enhanced against ζ values. Similar to the influence of Fig. 09, the ζ has dominant effect of radial traces for the larger values. For smaller values of ζ the effect is not so much significance. The Prandtl number examination onto the thermal traces are elaborated through Fig. 012. The effect of the Prandtl number is turned down the thermal traces because Prandtl number recognized the inverse relation to the thermal diffusivity. Figs. 13 and 14 are sketched to discuss the impacts of Nt and Nb on the thermal traces. Thermophoresis is a type of phenomenon is which the fluid's particles accelerate from the region of larger temperature to the region of lower one through collision process. Due to which, the kinetic energy of the molecules is enhanced and as a result the thermal field is increased (see Fig. 13). Brownian movement is a zig-zag type motion of the molecules. According to which, the temperature field is enhanced as prescribed in Fig. 14.

Conclusions

The following conclusions are drawn:

The magnetic parameter forces to decline the radial velocity field.

The parameter λ enhances the $f(\eta)$, while it reduces the field $f'(\eta)$.

Relaxation time parameter enlarges the radial traces.

Prandtl no. decline the thermal phenomenon.

Enlarge Nt and Nb values modify the thermal field.

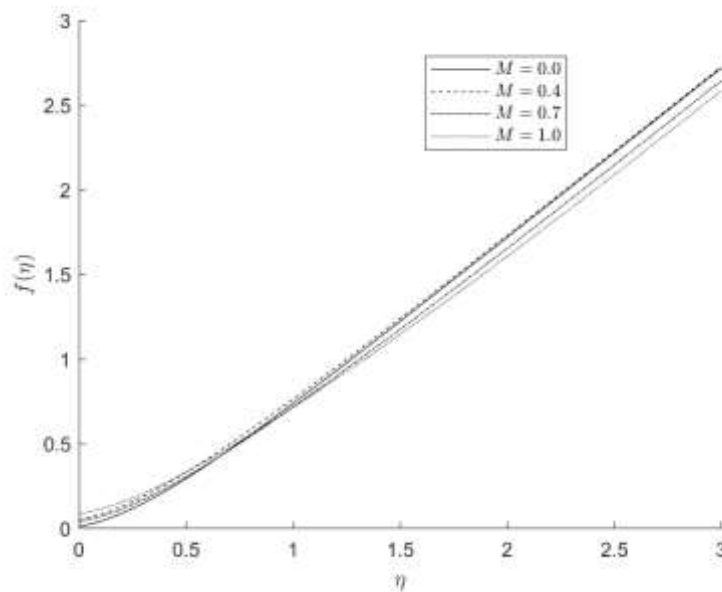


Fig. 01: Magnetic parameter influence on f

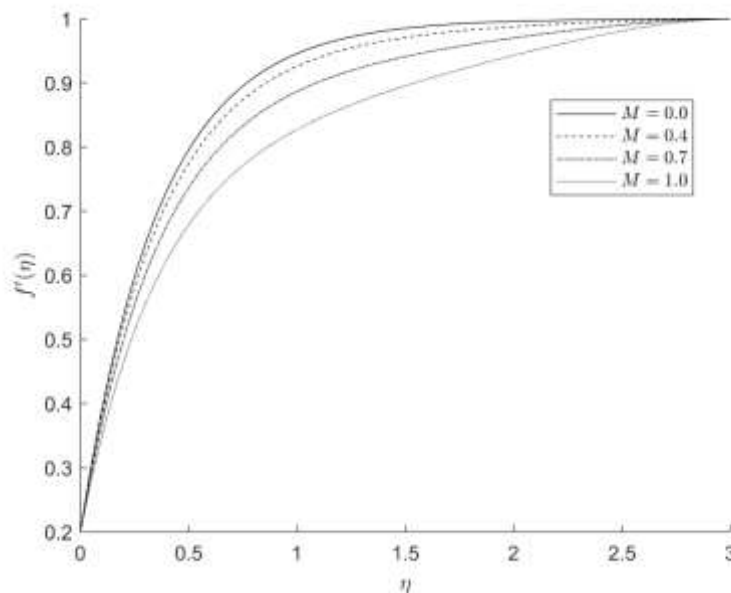


Fig. 02: Magnetic parameter influence on f'

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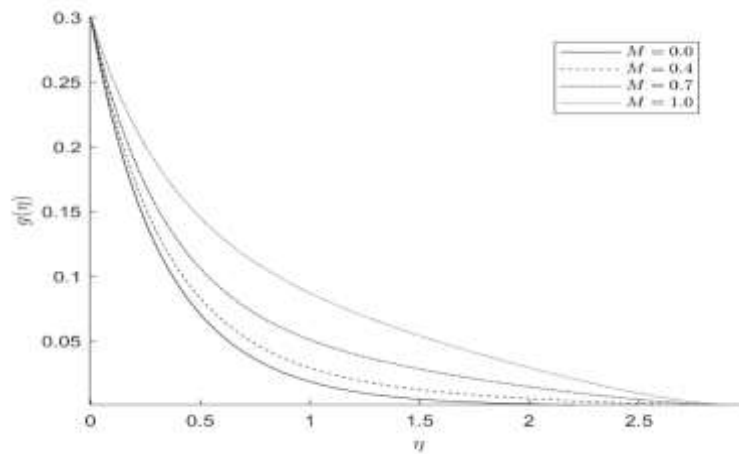


Fig. 03: Magnetic parameter influence on g

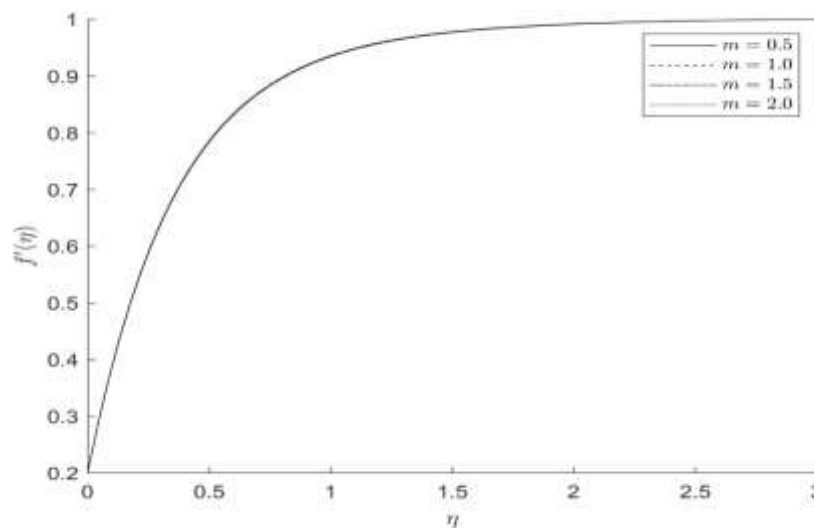


Fig. 04: Hall current influence on f'

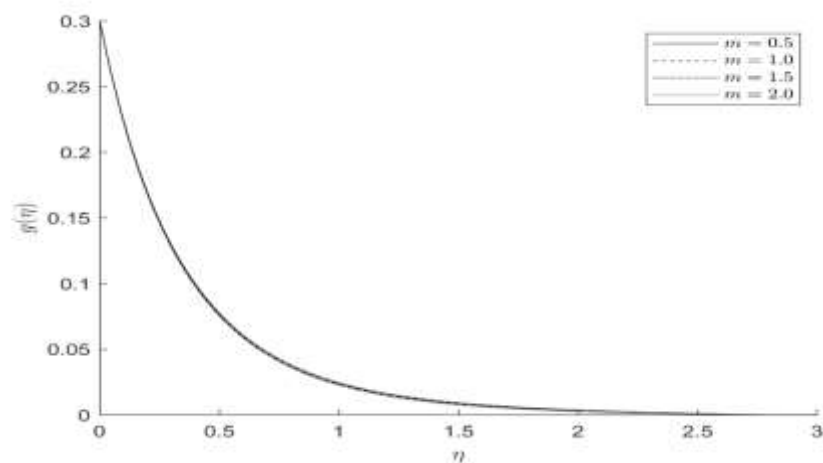


Fig. 05: Hall current influence on g

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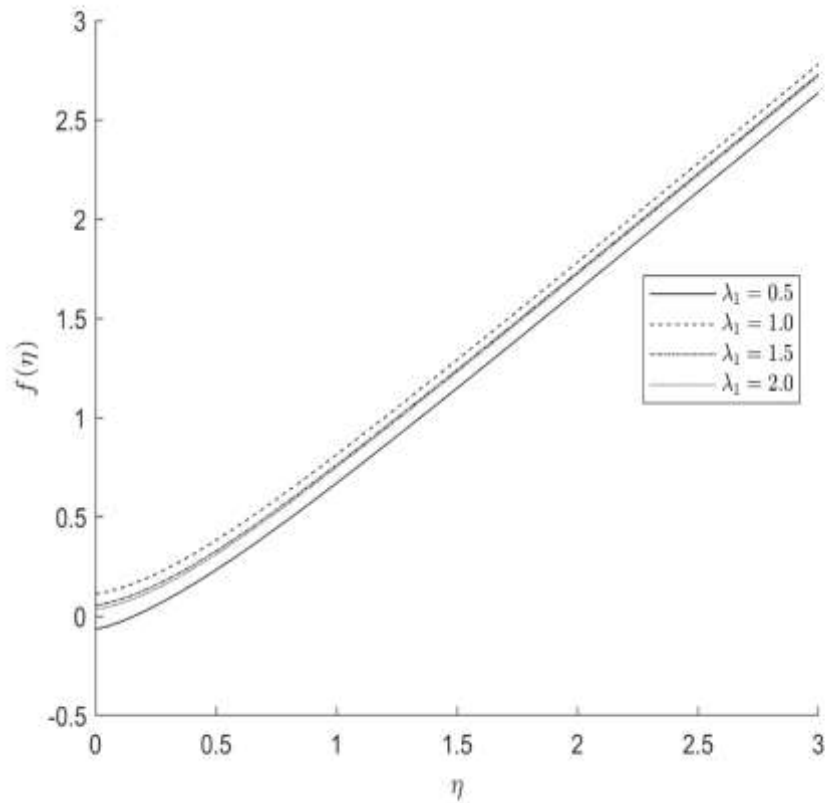


Fig. 06: The paramete λ_1 influence on f

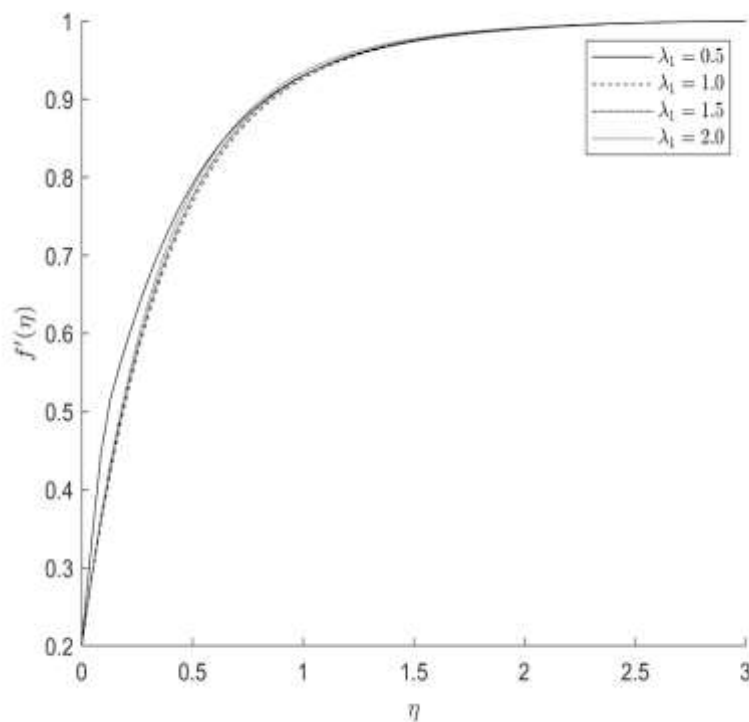


Fig. 07: The paramete λ_1 influnce on f'

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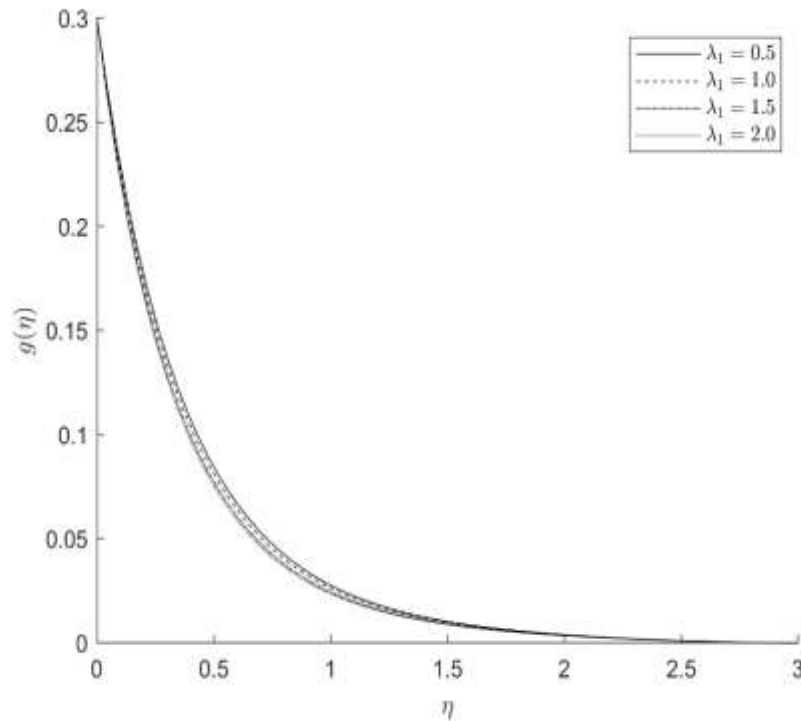


Fig. 08: The paramete λ_1 influence on g

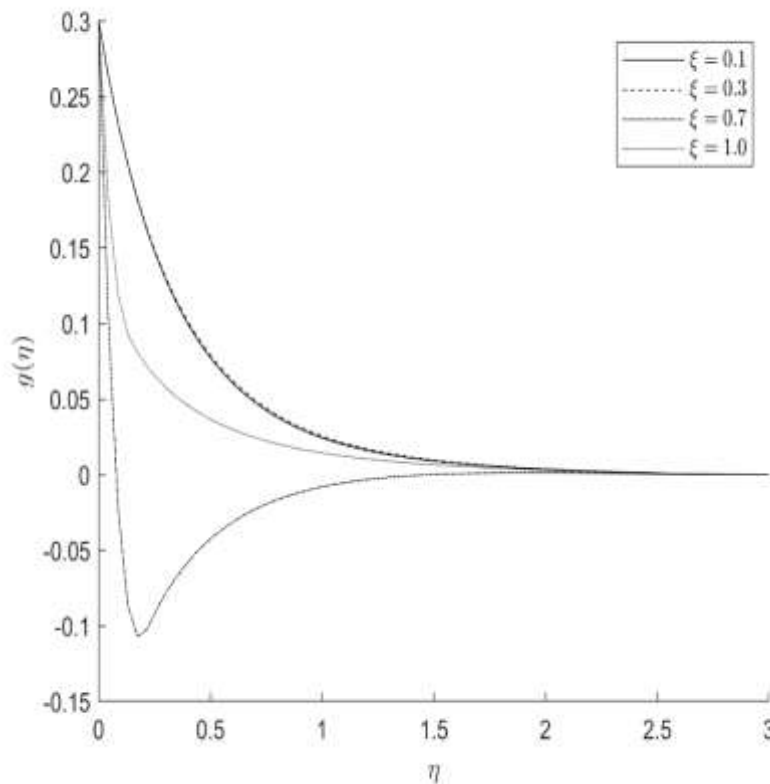


Fig. 09: Relaxation time parameter influence on g

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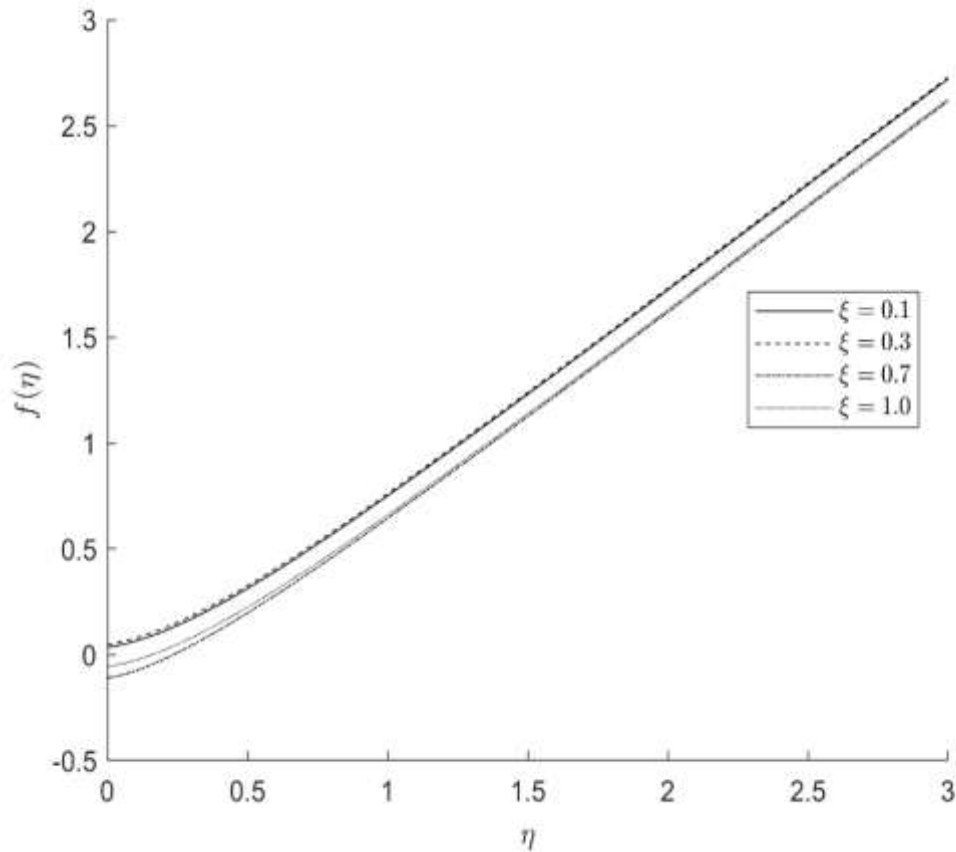


Fig. 10: Relaxation time parameter influence on f

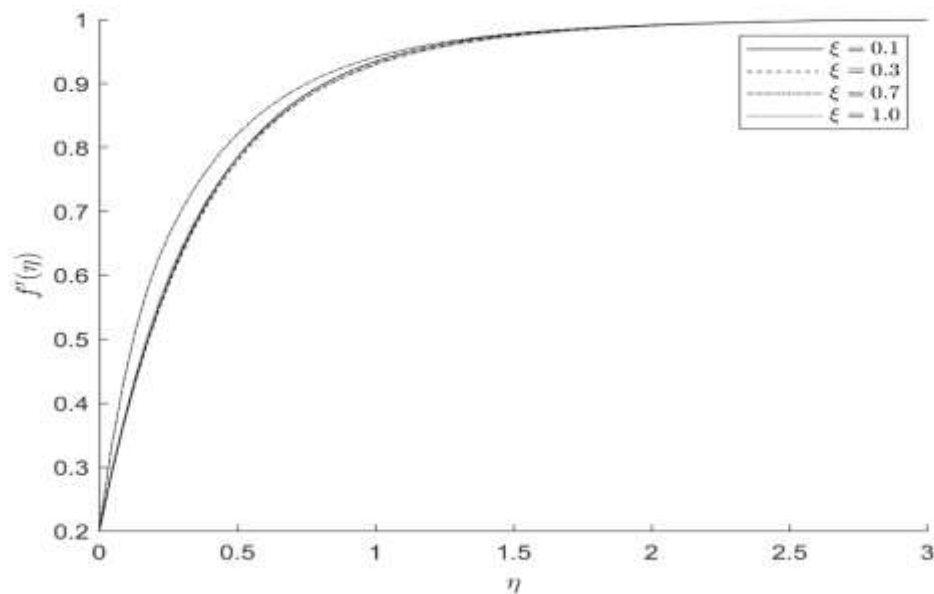


Fig. 11: Relaxation time parameter influence on f'

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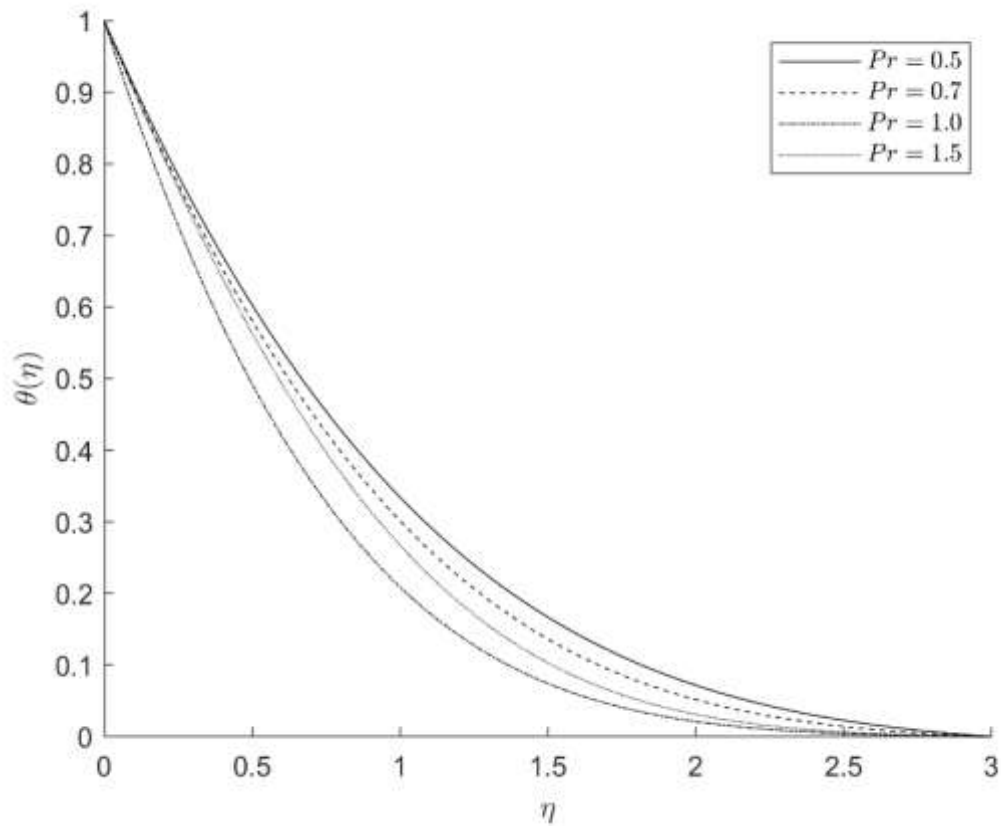


Fig. 12: Prandtl number influence on θ

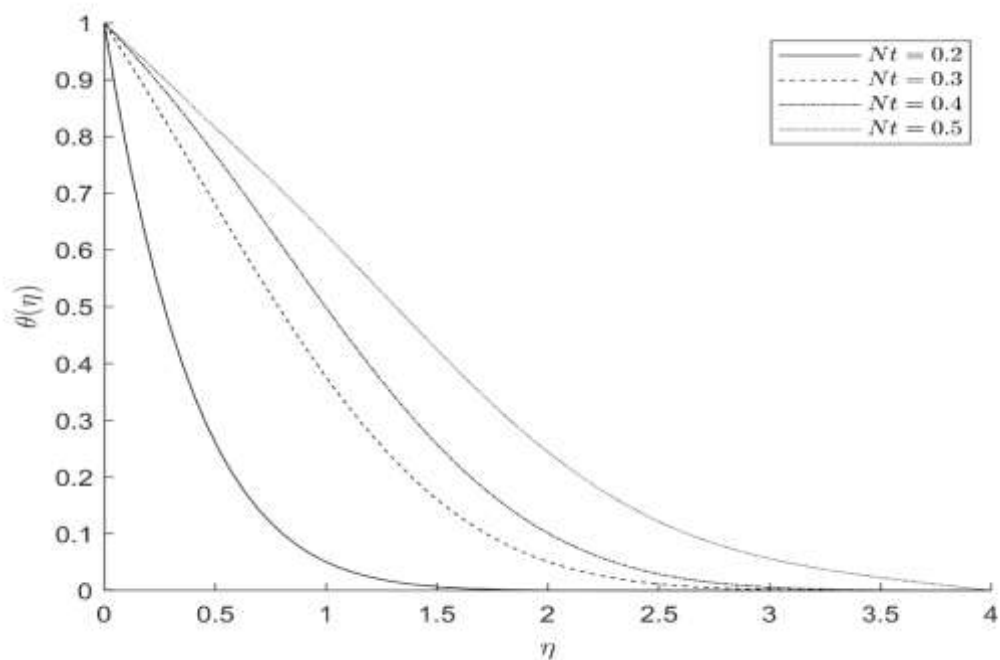


Fig. 13: Thermophoretic parameter influence on θ

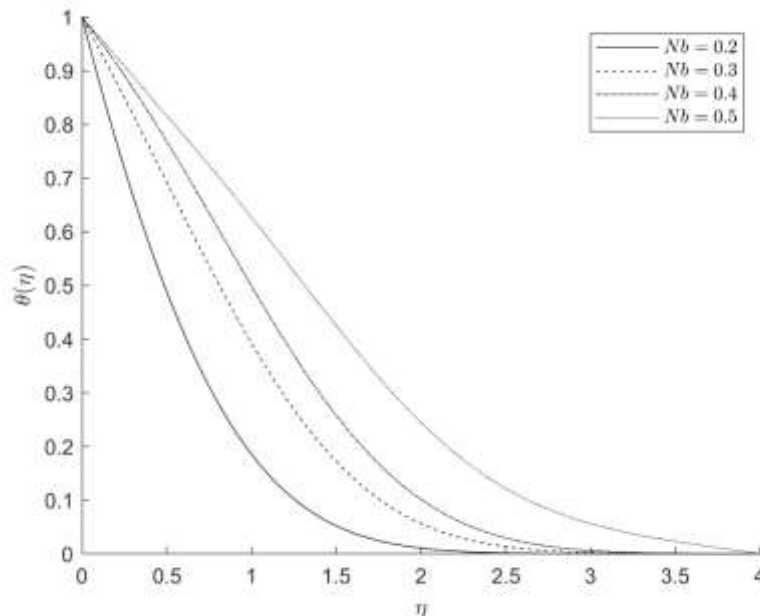


Fig. 14: Brownian motion parameter influence on θ

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