THE IMPACT OF GOLD NANOPARTICLES IN THE PULSATILE FLOW OF CASSON NANOFLUID WITH HALL EFFECT AND ION SLIP THROUGH A POROUS MEDIUM

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Abstract

The current examination explores the effect of gold nanoparticles in the pulsatile stream of Casson nanofluid between two endless long equal plates installed in a permeable medium with hall current and ion slip. Administering conditions are developed and changed into common differential conditions utilizing similarity changes. The effect of different parameters is shown through diagrams, and aims to analyze in detail.

Keywords: Nanoparticles, porous medium, Magnetic parameter, Hall current parameter, Non-frequency parameter.

I INTRODUCTION

In contemporary advances of nanotechnology and clinical science, various nanoparticles and nanomaterials have risen up out of various mass components such as gold, silver, iron, copper, cobalt, platinum, and so on., which are integrated either naturally or physio synthetically . A stream with intermittent varieties is known as pulsatile stream or Womersley stream. Pulsatile stream is made out of consistent segment and occasionally fluctuating time part. The stream with periodical varieties has wide applications in designing and natural frameworks, for example, blood stream in circulatory system and turning instrument of liquid in pressure driven frameworks and so forth. The investigation of pulsatile flow have been done by the following researchers Cheng Tu and Michel Deville. [1] ,Prashanta Kumar Mandal et al. [2], Ponalagusamy R et al. [3], Mir Golam Rabby et al[4], Mohamed Y. Abou-zeid et al. [5], Pooria Akbarzadeh. [6] Mahmoud MAA.[7], Misra JC and Sinha A[8] ,Sinha A and Shit GC. [9],Subba Rao A et al. [10] Ram Prakash Sharma et al[11].

Some of the investigations on Casson fluids which have tremendous applications are mentioned by the following references like Pardeep Kumar and Hari Mohan. [12], Zaman H. [13], Sreekala L and Kesavareddy E[14], Nabil T M et al[15], Ellahi R et al. [16],Pudhari Srilatha[17] JannathBegam et al[18], Deivanayaki et al.[19] JannathBegam et al. [20].

With the above-mentioned specifics, this research paper aims to study the pulsatile flow of Casson nanofluid between two infinite long parallel plates embedded in a porous medium in the presence of hall current and ion slip.

II. MATHEMATICAL FORMULATION

The Casson fluid , rheological equation of state for an isotropic and incompressible flow is MHD pulsatile flow of Casson nanofluid with gold nano particles between two infinite long parallel plates embedded in porous medium is examined with its x axis selected as lower plate, while the y-axis is normal to it under the action of uniform magnetic field B0 acting transverse on the plate .

$$\tau_{ij} = \begin{Bmatrix} 2\left(\mu B + \frac{P_{y^*}}{\sqrt{2\pi}}\right)e_{ij}, \pi > \pi_c \\ 2\left(\mu B + \frac{P_{y^*}}{\sqrt{2\pi_c}}\right)e_{ij}, \pi < \pi_c \end{Bmatrix}$$

$$\tau_{ij} = \mu_{nf}(1 + \frac{1}{\beta})\frac{\partial V_i}{\partial x_j}$$

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$$\frac{\partial u^*}{\partial t^*} = -\frac{1}{\rho_{nf}}\frac{\partial P^*}{\partial x^*} + q\vartheta_{nf}\left(1+\frac{1}{\beta c\mu_{nf}}\right)\frac{\partial^2 u^*}{\partial y^{*2}} + (1-q)q\vartheta_{nf}\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u^*}{\partial y^{*2}} - \frac{\mu_{nf}}{\rho_{nf}}u^* + \frac{\sigma_{nf}B_0^2}{\rho_{nf}(1+m^2)}u^* \text{-------(3)}$$

$$\frac{\partial T^*}{\partial t^*} = \frac{k_{nf}}{(\rho C_P)_{nf}}\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{\mu_{nf}\left(1+\frac{1}{\beta c\mu_{nf}}\right)}{(\rho C_P)_{nf}}\left(\frac{\partial u^*}{\partial y^*}\right)^2 + \frac{Q_0}{(\rho C_P)_{nf}}(T^* - T_0) \text{ ----(4)}$$

where

$u^* = 0, T^* = T_0 \ at \ y^* = 0$---------(5)

$u^* = 0, T^* = T_1 \ at \ y^* = h$----------(6)

The physical properties of nanofluid such $\mu_{nf}, \rho_{nf}, (\rho C_P)_{nf}$ and k_{nf} are given as:

$\mu_{nf} = \frac{\mu_f}{(1-\phi)^{2.5}}$---------(7)

$\rho_{nf} = (1-\phi)\rho_f + \phi\rho_s$----------(8)

$(\rho C_P)_{nf} = (1-\phi)(\rho C_P)_f + \phi(\rho C_P)_s$------(9)

$\frac{k_{nf}}{k_f} = \frac{k_s+2k_f-2\phi(k_f-k_s)}{k_s+2k_f+\phi(k_f-k_s)}$------(10)

$q_r = -\frac{4\sigma^*}{3k^*}\frac{\partial T^{*4}}{\partial y^*}$ -----(11)

$T^{*4} \cong 4T_1^3 T^* - 3T_1^4$ ---(12)

Using Equations (11) and (12), equation (4) becomes

$$\frac{\partial T^*}{\partial t^*} = \frac{k_{nf}}{(\rho C_P)_{nf}}\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{\mu_{nf}\left(1+\frac{1}{\beta c\mu_{nf}}\right)}{(\rho C_P)_{nf}}\left(\frac{\partial u^*}{\partial y^*}\right)^2 + \frac{Q_0}{(\rho C_P)_{nf}}(T^* - T_0) \text{----(13)}$$

The pulsatile flow is

$-\frac{1}{\rho_f}\frac{\partial P^*}{\partial x^*} = A(1+\epsilon e^{iwt})$ ------(14)

By introduce the following dimensionless variables and parameters,

$u = \frac{u^*\omega}{A}, t = t^*\omega, x = \frac{x^*}{h}, y = \frac{y^*}{h}, \theta = \frac{T^*-T_0}{T_1-T_0}, P = \frac{P^*}{A\rho_f h}, k_0 = \frac{1}{\beta c\mu_f}$---- (15)

Equations (14), (3) and (13) become

$-\frac{\partial P}{\partial x} = 1 + \epsilon e^{it}$ ------(16)

$\frac{\partial u}{\partial t} = -\frac{1}{A_1}\frac{\partial P}{\partial x} + \frac{A_2}{A_1}\left(1+\frac{k_0}{A_2}\right)\frac{1}{R}\frac{\partial^2 u}{\partial y^2} - \frac{A_2}{A_1}\left(\frac{1}{RD_a} + M_1\right)u$ ------(17)

$\frac{\partial \theta}{\partial t} = \left(\frac{A_4}{A_3} + \frac{4}{3A_3}\right)\frac{1}{RP_r}\frac{\partial^2\theta}{\partial y^2} + \frac{A_2}{A_3}\left(1+\frac{k_0}{A_2}\right)\frac{Ec}{R}\left(\frac{\partial u}{\partial y}\right)^2 + \frac{Q}{A_3 R}\theta$----(18)

The relating dimensionless limit conditions are

$u = 0, \theta = 0 \ at \ y = 0$----(19)

$u = 0, \theta = 1 \ at \ y = 1$----(20)

where $A_1 = (1-\phi) + \phi\frac{\rho_s}{\rho_f}$, $A_2 = \frac{1}{(1-\phi)^{2.5}}$,

$A_3 = (1-\phi) + \phi\frac{(\rho C_P)_s}{(\rho C_P)_f}$, $A_4 = \frac{k_s+2k_f-2\phi(k_f-k_s)}{k_s+2k_f+\phi(k_f-k_s)}$,

$Pr = \frac{(\rho C_P)_f v_f}{k_f}$, $Ec = \frac{A^2}{\omega^2(\rho C_P)_f(T_1-T_0)}$, $R = \frac{\omega h^2}{\mu_f}$, $k_0 = \frac{1}{\beta c\mu_f}$

$M = \frac{\sigma_{nf}B_0^2}{\rho_{nf}}$

$Da = \frac{k}{h^2}$, $Rd = \frac{4\sigma^* T_1^3}{k_f k^*}$, $Q = \frac{Q_0 h^2}{(\rho C_P)_f \mu_f}$, $M_1 = \frac{M}{1+m^2}$

To obtain the solution, u and θ can be expressed as follows:

$u = u_0(y) + \epsilon u_1(y)e^{it}$----(21)

$\theta = \theta_0(y) + \epsilon\theta_1(y)e^{it} + \epsilon^2\theta_2(y)e^{2it}$-----(22)

Using equations (16), (21) and (22) in equations (17) and (18), we get

$\frac{A_2}{A_1}\left(1+\frac{k_0}{A_2}\right)\frac{1}{R}u_0'' - \frac{A_2}{A_1}\left(\frac{1}{RD_a} + M_1\right)u_0 = -\frac{1}{A_1}$ ----(23)

$\frac{A_2}{A_1}\left(1+\frac{k_0}{A_2}\right)\frac{1}{R}u_1'' - \frac{A_2}{A_1}\left(\frac{1}{RD_a} + M_1\right)u_1 - iu_1 = -\frac{1}{A_1}$----(24)

$\left(\frac{A_4}{A_3} + \frac{4Rd}{3A_3}\right)\frac{1}{RP_r}\theta_0'' + \frac{A_2}{A_3}\left(1+\frac{k_0}{A_2}\right)(u_0')^2 + \frac{Q}{A_3 R}\theta_0 = 0$----(25)

$$\left(\frac{A_4}{A_3}+\frac{4Rd}{3A_3}\right)\frac{1}{RP_r}\theta_1''+2\,\frac{A_2}{A_3}\left(1+\frac{k_0}{A_2}\right)u_0'u_1'+\frac{Q}{A_3R}\theta_1-i\theta_1=0\text{----}(26)$$

$$\left(\frac{A_4}{A_3}+\frac{4Rd}{3A_3}\right)\frac{1}{RP_r}\theta_2''+2\,\frac{A_2}{A_3}\left(1+\frac{k_0}{A_2}\right)(u_1')^2+\frac{Q}{A_3R}\theta_2-2i\theta_2=0\text{----}(27)$$

And

$$u_0=0,\theta_0=0\ at\ y=0\text{-----}(28)$$

$$u_0=0,\theta_0=1\ at\ y=1\text{----}(29)$$

$$u_1=0,\theta_1=0,\theta_2=0\ \ at\ y=0\text{-----}(30)$$

$$u_1=0,\theta_1=0,\theta_2=0\ at\ y=1\text{----}(31)$$

By solving equations (23) to (27) with the corresponding boundary conditions (28) to (31), we obtain,

$$u_0=B_7e^{\sqrt{B_3}y}+B_6e^{-\sqrt{B_3}y}-\frac{B_4}{B_3}\text{------}(32)$$

$$u_1=B_9e^{\sqrt{B_5}y}+B_8e^{-\sqrt{B_5}y}-\frac{B_4}{B_5}\text{------}(33)$$

$$\theta_0=\ c_{11}\cos\sqrt{d_2}\,y+c_{12}\sin\sqrt{d_2}\,y+\ c_8e^{2\sqrt{B_3}y}+c_9e^{-2\sqrt{B_3}y}+c_{10}\text{------}(34)$$

$$\theta_1=\ D_6e^{\sqrt{C_4}y}+D_5e^{-\sqrt{C_4}y}+D_1e^{m_1y}+D_2e^{m_2y}+D_3e^{m_3y}+D_4e^{m_4y}\text{----}(35)$$

$$\theta_2=\ D_{11}e^{\sqrt{C_6}y}+D_{10}e^{-\sqrt{C_6}y}+\ D_7e^{2\sqrt{B_5}y}+D_8e^{-2\sqrt{B_5}y}+D_9\text{----}(36)$$

IV RESULTS AND DISCUSSION

As a result, the research paper arrays a few outcomes which describes the problem. Here u,θ_s,θ_t represent velocity, steady temperature and unsteady temperature respectively. Figure 1 shows the influence of Magnetic parameter (M), Hall current parameter(m), Non-Newtonian fluid parameter(k0), Frequency parameter (R) and Nanoparticles' volume fraction(φ).

The graph of M is depicted in Figure (1a). The pictorial representation shows that an enrichment in M depreciates u. Because of Lorentz force, which retracts the flow.Since m balances the resistive influence of applied magnetic field, one can observe that u raises when m increases as shown in Figure (1b).

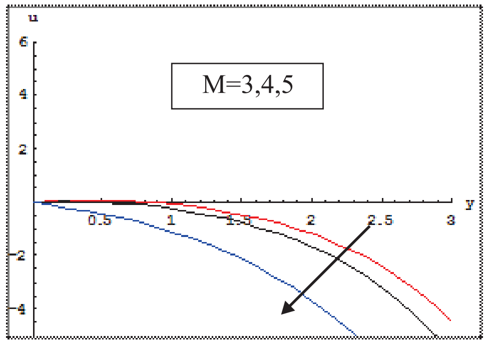

Figure (1a): Impact of Mon Velocity profile u

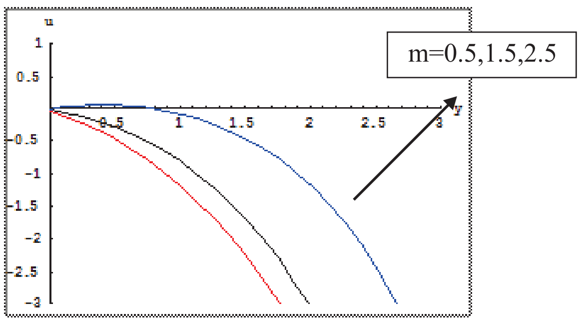

Figure (1b): Impact of m on Velocity profile u

`Figure (1c) indicates that u diminishes when k0 enhances due to viscoelasticity of blood. Figure (1d) reveals that u is decreasing the function of frequency parameter R.

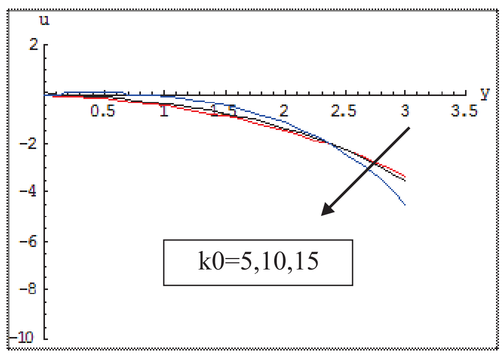

Figure (1c): Impact of k0 on Velocity profile u

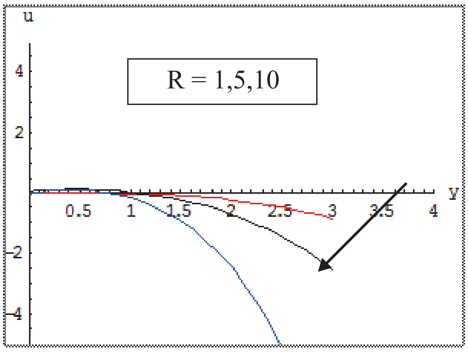

Figure (1d): Impact of R on Velocity profile u

The effect of β on flow profiles has been discussed in the figure (1e). It is noticed that the thick-ness of momentum boundary layer and velocity diminishes as β increase.A rise in nanoparticles' volume fraction φ reduces the velocity distribution as presented in figure (1f).

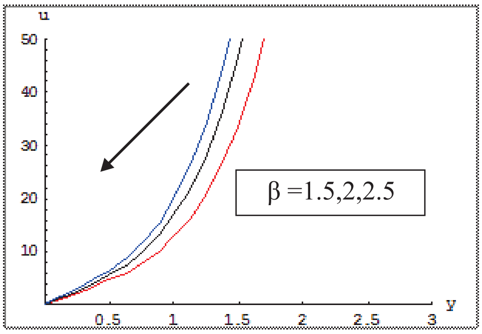

Figure (1e): Impact of βonVelocity profile u.

The concequence of Ec, Rd, Q, k0 , φ and R on steady and unsteady temperatures of blood–gold nanofluid are shown in figures (2-7). Figure (2) depicts that both θ_s and θ_tdecrease with a raise in Ec because, θ_t exhibits an oscillating character .

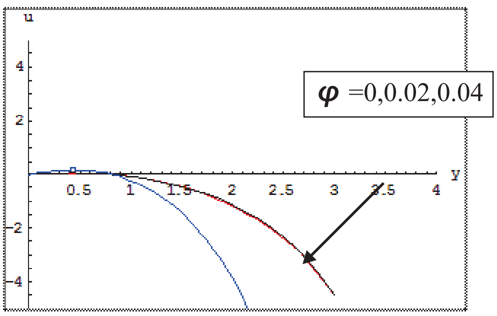

Figure (1f): Impact of φ on Velocity profile u.

The concequence of Ec, Rd, Q, k0 , φ and R on steady and unsteady temperatures of blood–gold nanofluid are shown in figures (2-7). Figure (2) depicts that both θs and θt decrease with a raise in Ec because, θt exhibits an oscillating character.

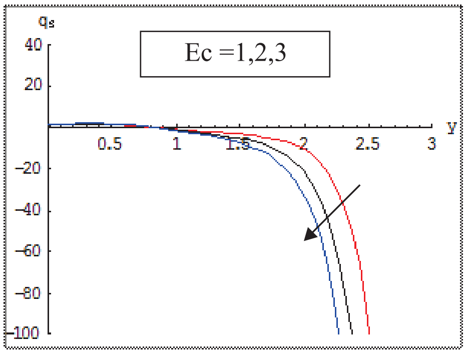

Figure (2a): Impact of Econ steady temperature profile θs

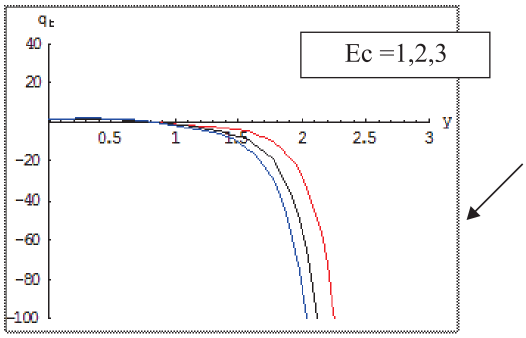

Figure (2b): Impact of Econ unsteady temperature profile θt

When the temperature raises then R provides more heat to the fluid, as shown in Figure (3).

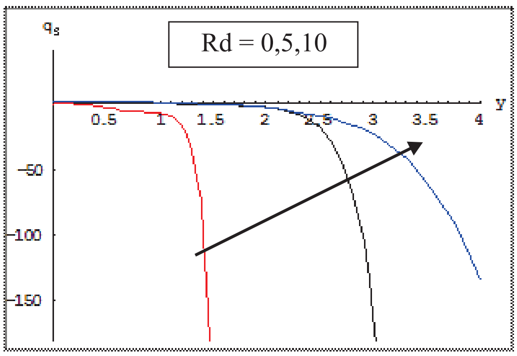

Figure (3a): Impact of Rdon steady temperature profile θs

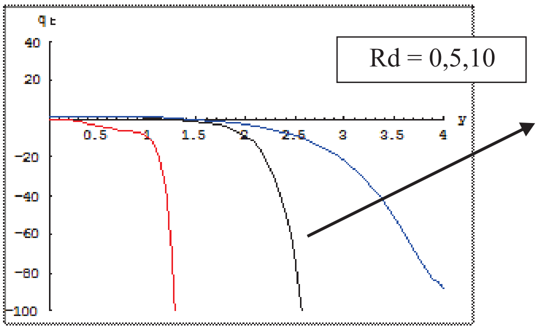

Figure (3b): Impact of Rd on unsteady temperature profile θt

Escalating Q elevates the temperature as the thermal boundary layer thickness raises as displayed in figure (4).

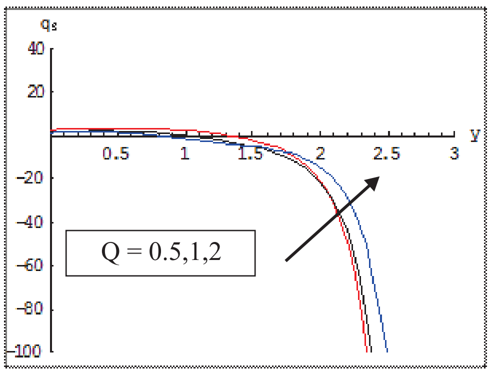

Figure (4a):Impact of Q on steady temperature profile θs

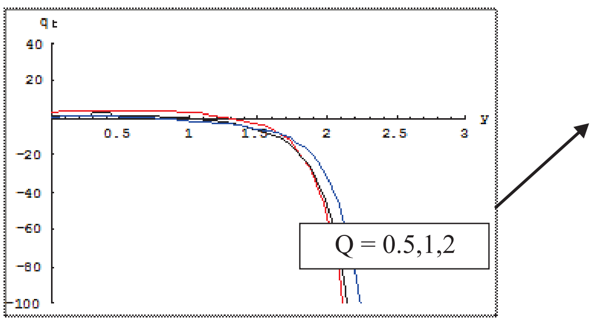

Figure (4b): Impact of Q on unsteady temperature profile θt

The effect of Non-Newtonian fluid parameter k0 onθ_s and $\theta_t$are shown in figure (5). The amplitude of unsteady temperature increases with k0.

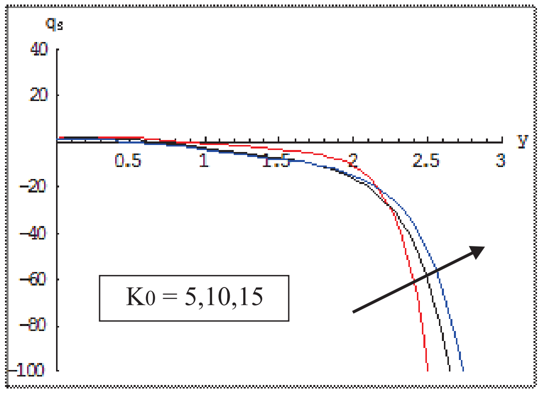

Figure (5a): Impact of K_0 on steady temperature profile θs

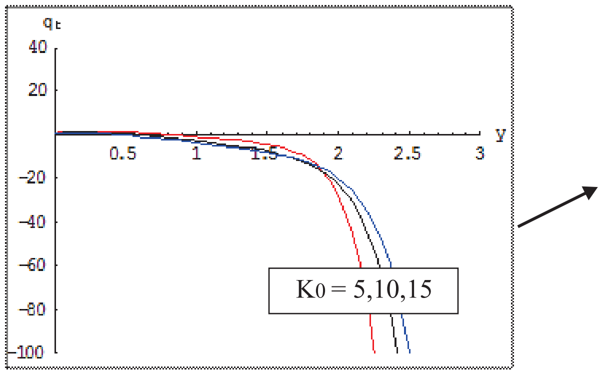

Figure (5b): Impact of K_0 on unsteady temperature profile θt

Figure (6) illustrates the variation of the temperatures with φ.

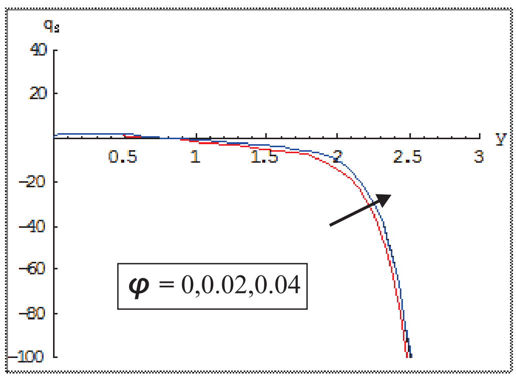

Figure (6a): Impact of φ on steady temperature profile θs

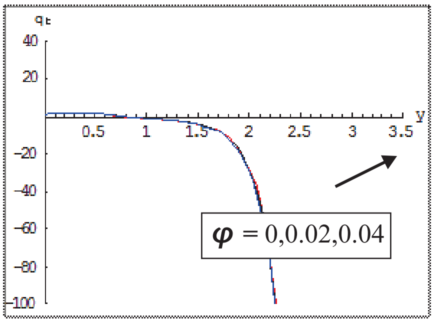

Figure (6b): Impact of φ on unsteady temperature profile θt

Figure (7) demonstrates θ_s and θ_t are decreasing functions of R.

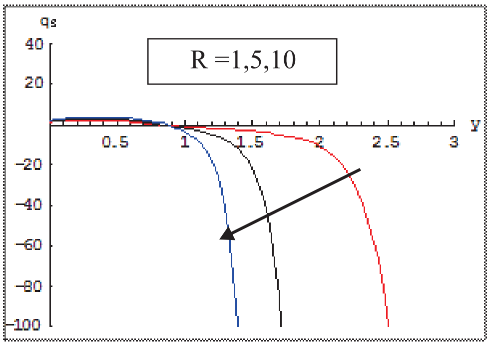

Figure (7a): Impact of R on steady temperature profile θs

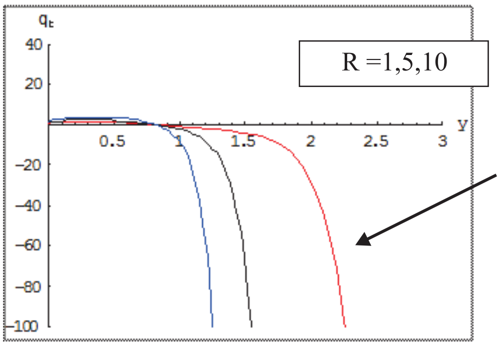

Figure (7b): Impact of R on unsteady temperature profile θt

V CONCLUSION

In this examination, stream and warmth move of Casson nanofluid with gold nanoparticles in a permeable channel with the nearness of hall current has been investigated. Blood has been considered as Non-Newtonian liquid.

For Casson nanofluid, the velocity of the nanofluid decreases with increasing k0andβ.

Increasing the value of m enhances the u profile, whereas increasing the values of M,R and φ suppress the u profile.

The θ raises for a given increase in the nanoparticles volume fraction, Ec, Rd, Q, k0and φ, while they reduce with increasing R.

The heat transfer rate increases with an increase in the nanoparticle volume fraction .But the behaviour is different for radiation parameter.

The results of Srinivas and Vijayalakshmi can be captured from the present analysis in the absence of Hall current and Casson nanofluid parameter (i.e., m=β= 0).

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