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Influence of MHD and Porous Media on Peristaltic Transport for Nanofluids in An Asymmetric Channel

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Abstract
The aim of this paper is to discuss the influence of nanoparticles and porous media, and magnetic field on the peristaltic flow transport of a couple stress fluid in an asymmetric channel with different wave forms of non-Newtonian fluid. Initially, mathematical modeling of the two dimensions and two directional flows of a couple stress fluid with a nanofluid is first given and then simplified beneath hypothesis of the long wave length and the low Reynolds number approximation. After making these approximations, we will obtain associated nonlinear differential equations. Then, the exact solutions of the temperature distribution, nanoparticle concentration, velocity, stream function, and pressure gradient will be calculated. Finally, the results of drawings for many physical parameters that are of importance for examining the behavior of fluid flow quantities are discussed.

Keyword: Porous media, Magnetic field , Peristaltic flow , Asymmetric channel, Nanofluids particles, Couple stress.

تأثير الحقل المغناطيسي والوسط المتسامي بالانتقال التمعجي للموائع من النمط النانو في قناة غير متناظرة

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الخلاصة
في هذا البحث ، نناقش تأثير الجسيمات النانوية والوسائط المسامية والمجال المغناطيسي على نقل التدفق التمعجي لسائل ضغط مزدوج في قناة غير متماثلة ذات أشكال موجية مختلفة للسائل غير النيوتوني. في البداية ، يتم إعطاء النمذجة الرياضية للتدفقات ثنائية الأبعاد والتدفقات الاتجاهية المزدوجة لسائل إجهاد مع مائع نانوي أولاً ثم تبسيطها وفقًا لفرضية طول الموجة الطويلة وتقريب عدد رينولدز المنخفض. بعد إجراء هذه التقديرات ، سنحصل على المعادلات التفاضلية غير الخطية المرتبطة. ثم سيتم حساب الحلول الدقيقة لتوزيع درجة الحرارة وتركيز الجسيمات النانوية والسرعة ووظيفة التدفق وتدرج الضغط. أخيرًا ، تمت مناقشة نتائج الرسومات للعديد من المعلمات الفيزيائية ذات الأهمية لفحص سلوك كميات تدفق السوائل.

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1. Introduction

Nanofluids are those liquids that consist a tiny quantum of nanoparticles which have of roughly of size thousands of the width of human hair. These runny possess a higher single phase heat transfer coefficient especially for laminar flow because to increase thermal conductivity than any other liquid made by other theories. This makes them more attractive than other fluids, such as heat transfer fluids in many applications in heat transfer including microelectronics, fuel cell's pharmaceutical processes and hybrid powered engines, engine cooling, domestic refrigerator and heat exchanger in machining and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. For liquids, they are of great importance in many life applications, so they took a large space among researchers. Choi shed light on the peristaltic flows of nanofluids. After that, a lot of research discussed the phenomenon of nanofluids using different flow geometries, in particular, the research that was done by Safia Akram [1].

Peristalsis is the mechanism of transporting fluids by means of wave trains when they propagate at a constant velocity resulting from region contraction or expansion along the perimeter of the walls of a rotating two-dimensional infinite channel. the most common method is the method of fluid transport by peristaltic pumping. An example of this in the digestive system is the transfer of bile through the bile ducts from the liver to the gallbladder to be stored in the digestive juices and then transferred to the small intestine and this peristalsis is the result of involuntary muscle contractions in the digestive system. physiological peristaltic fluids play an important role inside living bodies, so the peristaltic flow mechanism attracted many researchers after the first exploration by the scientist Latham [2-7]. There are many researchers discussed the peristaltic flows in a symmetrical canal, cylinder, and tube of Newtonian and non-Newtonian fluids [8-10]. However, scientists shed light on the peristaltic flows in a symmetric and asymmetric canal, for example, the contractions of the myometrium that occur in both directions [11-13]. In this research, the porous medium will be added, and a porous medium is a group of solid bodies or a solid material consisting of porous structures with sufficient space in or around the solid materials to enable the liquid to penetrate through or around them. Porous media can be distinguished through its spatial properties such as permeability, porosity, hardness and many other properties, but one of the most prominent characteristics is permeability and porosity. There are many materials in porous media such as man-made materials, cement, natural materials such as rocks, and biological tissues such as bone and wood. Porous media are used in many applications in science and engineering fields, namely petroleum engineering, construction engineering, earth sciences, petroleum geology, geophysics, and materials science. Also, liquids flow through the porous medium and this is done by the friction of the liquid with the walls of the structure of the porous medium, which causes impeding its movement. This process is called filtration, and the used porous media is called filters [14-17].

The aim of the current study in this paper is to study the effect of nanoparticles, magnetic field, and porous medium on the peristaltic transport of a couple of stress fluids in an asymmetric channel. The couple stress fluid and particle size fraction governing equations for two-dimensional flow in a Cartesian coordination system were designed and simplified according to the lubrication approach. Then the exact solution of velocity, temperature, nanopractic concentration, pressure equation, and stream function will be calculated. The effect of the relevant physical parameters will be also studied through graphs of temperature, pressure gradient, nanopractic concentration and stream lines along with different forms of waves using the Mathematica program.

2.Mathematicalformulation

The motion of the peristaltic flow of an electrically conductive incompressible stress fluid in a two-dimensional channel of width $d_1 + d_2$ is taken into account. The movement of the flow is stimulated by sine wave trains that will travel at a constant speed c along the walls of the channel. We will choose a rectangular coordinate system for the channel with x along the center line of the channel and y transverse to it. The left wall temperature is maintained atT_1 and the right wall has a temperatureT_0 . Therefore, the velocity field of the two-dimensional flow and two directional of the from will be $V = [U(X,Y,T), V(X,Y,T), 0]$. Assuming that the fluid is subject to a constant tangential magnetic fieldB_0. It is assumed that the Reynolds number and the induced magnetic field are very small, therefore the induced magnetic field can be neglected. When the fluid is transferred to the magnetic field, two main physical effects will be generated, the first will cause an electric field E in the flow, and under the assumption that there is no excess charge density and therefore$\nabla B = 0$. Since the induced magnetic field is neglected this means that $\nabla E = 0$and therefore the electric field. The stimulus is not mentioned. The second effect is the cally dynamics in nature, which is the Lorenz force$(J \times B)$, where J is the density of the current and this force affects the fluid and modifies the movement. This will result in the transfer of energy from the electromagnetic field to the fluid

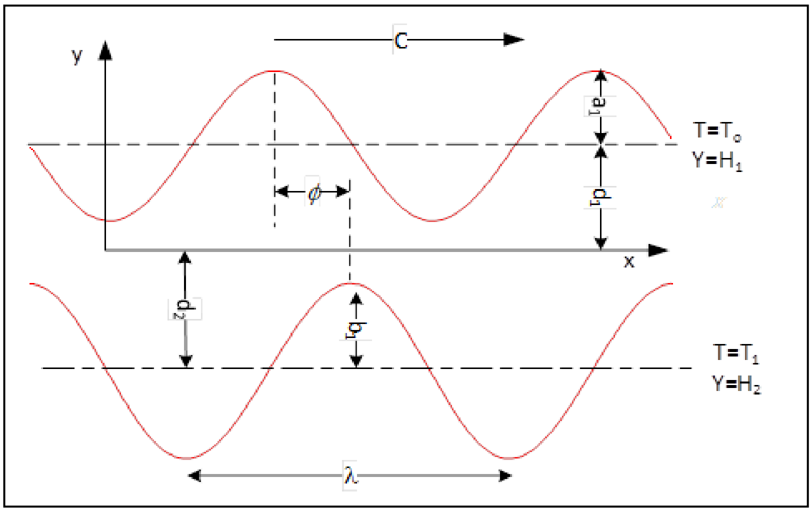


Figure 1: Geometric representation for the flow phenomeno

the wall equations are:

$$Y = H_1(X,t) = d_1 + a_1 \cos[\frac{2\pi}{\lambda}(X - ct)], \qquad (1)$$

$$Y = H_2(X,t) = -d_2 - b_1 \cos[\frac{2\pi}{\lambda}(X - ct) + \phi], \qquad (2)$$

The couple stress and the force represent couple stress will be added to the motion equation

$$\frac{\partial U}{\partial X} + \frac{\partial V}{\partial Y} = 0, \qquad (3)$$

$$\rho_f\left(\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial X} + V\frac{\partial U}{\partial Y}\right) = -\frac{\partial P}{\partial X} + \mu\left(\frac{\partial^2 U}{\partial Y^2} + \frac{\partial^2 U}{\partial X^2}\right) - \eta\left(\frac{\partial^4 U}{\partial Y^4} + \frac{\partial^4 U}{\partial X^4} + 2\frac{\partial^4 U}{\partial X^2 \partial Y^2}\right)$$
$$-\sigma B_0^2 \mathrm{U} + \rho g a(\mathrm{T_1} - \mathrm{T_0}) + \rho g a(\mathrm{C_1} - \mathrm{C_0}) - \frac{\mu}{k}\,\mathrm{U} \qquad (4)$$

$$\rho_f\left(\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial X} + V\frac{\partial V}{\partial Y}\right) = -\frac{\partial P}{\partial Y} + \mu\left(\frac{\partial^2 V}{\partial Y^2} + \frac{\partial^2 V}{\partial X^2}\right) - \eta\left(\frac{\partial^4 V}{\partial Y^4} + \frac{\partial^4 V}{\partial X^4} + 2\frac{\partial^4 V}{\partial X^2 \partial Y^2}\right) - \frac{\mu}{k}\,\mathrm{V} \qquad (5)$$

$$\left(\frac{\partial T}{\partial t}+U\frac{\partial T}{\partial X}+V\frac{\partial T}{\partial Y}\right)=$$
$$\alpha\left(\frac{\partial^2 T}{\partial X^2}+\frac{\partial^2 T}{\partial y^2}\right)+\tau\left\{D_B\left(\frac{\partial C}{\partial X}\frac{\partial T}{\partial X}+\frac{\partial C}{\partial Y}\frac{\partial T}{\partial Y}\right)+\left(\frac{D_T}{T_0}\right)\left[\left(\frac{\partial T}{\partial X}\right)^2+\left(\frac{\partial T}{\partial X}\right)^2\right]\right\} \tag{6}$$
$$\left(\frac{\partial C}{\partial t}+U\frac{\partial C}{\partial X}+V\frac{\partial C}{\partial Y}\right)=D_B\left(\frac{\partial^2 C}{\partial X^2}+\frac{\partial^2 C}{\partial Y^2}\right)+\left(\frac{D_T}{T_0}\right)\left[\left(\frac{\partial T}{\partial X}\right)^2+\left(\frac{\partial T}{\partial Y}\right)^2\right] \tag{7}$$

Where U and V are velocities in X- and Y-directions in a fixed frame, respectively. ρ_f is the constant density of base fluid,k is the porous media, $P$is the pressure, ν is the kinematic viscosity, σ is the electrical conductivity, T is the temperature, C is the concentration, D_B is the Brownian diffusion coefficient, $D_T$is the thermophoretic diffusion coefficient and c is the volumetric volume expansion coefficient. In the laboratory frame (X, Y), the flow is unsteady. However, in a coordinate system that moves with the wave speed c (the wave frame) the motion is steady. The coordinates and velocities in the two frames are related by the following transformation:

$$x=X-ct,\quad y=Y,\quad u=U-c,\quad v=V,\quad and\quad p(x,y)=P(X,Y,t) \tag{8}$$

3. Dimensional analysis

We define the following transformation

$$\bar{x}=\frac{x}{\lambda},\bar{y}=\frac{y}{d_1},\bar{u}=\frac{u}{c},\bar{v}=\frac{v}{c\delta},\delta=\frac{d_1}{\lambda},d=\frac{d_2}{d_1},\bar{p}=\frac{d_1^2 p}{\mu c\lambda},\bar{t}=\frac{ct}{\lambda},h_1=\frac{H_1}{d_1}$$
$$h_2=\frac{H_2}{d_1},a=\frac{a_1}{d_1},b=\frac{b_1}{d_1},Re=\frac{\rho_f c d_1}{\mu},\theta=\frac{T-T_0}{T_1-T_0},\phi=\frac{C-C_0}{C_1-C_0},Pr=\frac{\upsilon}{\alpha}$$
$$Nt=\frac{\tau D_T(T-T_0)}{T_0\upsilon},Nb=\frac{\tau D_B(C-C_0)}{\upsilon},Gr=\frac{\rho g\alpha d_1^2(T_1-T_0)}{\mu c},\ Br=\frac{\rho g\alpha d_1^2(C-C_0)}{\mu c}\ Le=\frac{\upsilon}{D_B},\gamma=\sqrt{\frac{\mu}{\eta}}\,d_1,M=\sqrt{\frac{\sigma}{\mu}}\,B_0 d_1 \tag{9}$$

Where $Re,\ \theta,\phi,\delta,Pr,Nt,Nb,Gr,Br,Le,\ \gamma,\ M,\ \mu$ are the Reynolds number, temperature distribution, Nanopractic concentration, wave number Prandtl number, thermophoresis parameters, the Brownian motion parameter, local temperature Grashof number, nanoparticle Grashof number, regular Lewis number, couple stress parameter, magnetic parameter and viscosity, respectively.

With the help of eq.(8) and the transformation (9), we get

$$\mathrm{Re}\delta\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial p}{\partial x}+\delta^2\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}-\frac{1}{\gamma^2}\left(\frac{\partial^4 u}{\partial y^4}-\delta^4\frac{\partial^4 u}{\partial x^4}-2\delta^2\frac{\partial^4 u}{\partial x^2\partial y^2}\right)-M^2(u+1)+Gr\,\theta+Br\,\phi-\frac{1}{D1}u \tag{10}$$
$$\mathrm{Re}\delta^3\left(u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial p}{\partial y}+\delta^4\frac{\partial^2 v}{\partial x^2}+\delta^2\frac{\partial^2 v}{\partial y^2}-\frac{\delta}{\gamma^2\lambda}\frac{\partial^4 v}{\partial y^4}-\frac{\delta^4}{\gamma^2\lambda^2}\frac{\partial^4 v}{\partial x^4}-2\frac{\delta}{\gamma^2\lambda^3}\frac{\partial^4 v}{\partial x^2\partial y^2}-\frac{\delta^2 d_1^2}{k}v \tag{11}$$
$$\mathrm{Re}\delta\left(u\frac{\partial\theta}{\partial x}+v\frac{\partial\theta}{\partial y}\right)=\frac{1}{Pr}\left(\delta^2\frac{\partial^2\theta}{\partial x^2}+\frac{\partial^2\theta}{\partial y^2}\right)+Nb\left(\delta^2\frac{\partial\theta}{\partial x}\frac{\partial\phi}{\partial x}+\frac{\partial\theta}{\partial y}\frac{\partial\phi}{\partial y}\right)+Nt\left(\delta^2\left(\frac{\partial\theta}{\partial x}\right)^2+\left(\frac{\partial\theta}{\partial y}\right)^2\right) \tag{12}$$
$$\mathrm{Re}\delta\,Le\left(u\frac{\partial\phi}{\partial x}+v\frac{\partial\phi}{\partial y}\right)=\left(\delta^2\frac{\partial^2\phi}{\partial x^2}+\frac{\partial^2\phi}{\partial y^2}\right)+\delta^2\frac{Nt}{Nb}\frac{\partial^2\theta}{\partial x^2}+\frac{Nt}{Nb}\frac{\partial^2\theta}{\partial y^2} \tag{13}$$

Now, if we apply the long wave length and neglect the wave number $(\delta\ll 1)$ and low Reynolds number approximation, then the equations (10) -(13) reduce in the from:

$$-\frac{\partial p}{\partial x}+\frac{\partial^2 u}{\partial y^2}-\frac{1}{\gamma^2}\frac{\partial^4 u}{\partial y^4}-u\left(M^2+\frac{1}{D1}\right)-M^2+Gr\,\theta+Br\,\phi=0 \quad (14)$$

$$-\frac{\partial p}{\partial y}=0 \quad (15)$$

$$\frac{1}{Pr}\frac{\partial^2\theta}{\partial y^2}+Nb\frac{\partial\theta}{\partial y}\frac{\partial\phi}{\partial y}+Nt\left(\frac{\partial\theta}{\partial y}\right)^2=0 \quad (16)$$

$$\frac{\partial^2\phi}{\partial y^2}+\frac{Nt}{Nb}\frac{\partial^2\theta}{\partial y^2}=0 \quad (17)$$

The identical dimension less boundary conditions which governed the flow is defined as follows:

$$u=-1,\ \frac{\partial^2 u}{\partial y^2}=0 \text{ at } y=h_1=1+a\cos 2\pi x \quad (18)$$

$$u=-1,\frac{\partial^2 u}{\partial y^2}=0 \text{ at } y=h_2=-d-b\cos(2\pi x+\phi) \quad (19)$$

$$\theta=0,\phi=0 \quad at\ y=h_1 \quad (20)$$

$$\theta=0,\ \phi=1 \quad at\ y=h_2 \quad (21)$$

The dimension less means flow Q, which is defined by:

$$Q=F+1+d \quad (22)$$

where

$$F=\int_{h_1}^{h_2}u\,dy$$

4. Solution of the problem

The aim of this section is to find the exact solution for the equation (17) that can be obtained as follows:

$$\phi(x,y)=-\frac{Nt}{Nb}\ \theta+a1(x)y+a2(x) \quad (23)$$

Where $a1(x)$ and $a2(x)$are two unknow functions which can be found by using the boundary conditions.
Now, substitute eq.(23)into (16) we get the exact solution of eq.(23)

$$\theta(x,y)=\frac{a3(x)}{\Pr Nb\ a1(x)}+a4(x)e^{-\Pr Nb\ a1(x)} \quad (24)$$

Where $a3(x)$ and $a4(x)$ are unknown functions.
Now, sub the equation (24) in to (23) the dimensionless concentration can be obtained and given by

$$\phi(x,y)=-\frac{Nt}{Nb}\left[\frac{a3(x)}{\Pr Nb\ a1(x)}+a4(x)e^{-\Pr Nb\ a1(x)}\right]+a1(x)y+a2(x) \quad (25)$$

Now, to find the values of unknown function $a1(x)$, $a2(x)$, $a3(x)$, and $a4(x)$
We need to use the boundary conditions (20), (21).

By using the boundary condition for θ and ϕ on equation (25) it follows that

$$a1(x)=\frac{1+\frac{\mathrm{Nt}}{\mathrm{Nb}}}{h_2-h_1} \quad (26)$$

$$a2(x)=-h_1\left(\frac{1+\frac{\mathrm{Nt}}{\mathrm{Nb}}}{h_2-h_1}\right) \quad (27)$$

To calculat the values of $a3(x)$ and $a4(x)$, we apply the boundary condition for ϕon equation (24) ,then we get

$$a3(x) = -\Pr Nb \; a1(x)\left(\frac{e^{-PrNb\,a1(x)h_1}}{e^{-PrNb\,a1(x)h_2} - e^{-PrNb\,a1(x)h_1}}\right) \tag{28}$$

$$a4(x) = \frac{1}{e^{-PrNb\,a1(x)h_2} - e^{-PrNb\,a1(x)h_1}} \tag{29}$$

Thus the exact expressions for the temperature distribution θ and nano particle concentration ϕ are given:

$$\theta(x,y) = \left(\frac{e^{-\mathrm{PrNba1(x)}y} - e^{-\mathrm{PrNba1(x)}h_1}}{e^{-\mathrm{PrNba1(x)}h_2} - e^{-\mathrm{PrNba1(x)}h_1}}\right) \tag{30}$$

$$\phi(x,y) = \left(1 + \frac{\mathrm{Nt}}{\mathrm{Nb}}\right)\left(\frac{y - h_1}{h_2 - h_1}\right) - \frac{\mathrm{Nt}}{\mathrm{Nb}}\left(\frac{e^{-\mathrm{PrNba1(x)}y} - e^{-\mathrm{PrNba1(x)}h_1}}{e^{-\mathrm{PrNba1(x)}h_2} - e^{-\mathrm{PrNba1(x)}h_1}}\right) \tag{31}$$

With the help of equation (30) and (31) the solution of velocity is obtained from equation (14) and is defined as follows :

$$\mathrm{u1} = e^{y*\mathrm{s1}}\mathrm{c1} + e^{-y*\mathrm{s1}}\mathrm{c2} + e^{y*\mathrm{s2}}\mathrm{c3} + e^{-y*\mathrm{s2}}\mathrm{c4} - (16e^{-\mathrm{a1NbPr}y}(\mathrm{Br}(e^{\mathrm{a1NbPr}(y+h_1)} - \cdots \tag{32}$$

where

$$\mathrm{s1} = \left(\frac{\sqrt{\gamma^2 - \frac{\sqrt{\gamma^2(-4-4\mathrm{D1}M^2+\mathrm{D1}\gamma^2)}}{\sqrt{\mathrm{D1}}}}}{\sqrt{2}}\right), \quad \mathrm{s2} = \left(\frac{\sqrt{\gamma^2 + \frac{\sqrt{\gamma^2(-4-4\mathrm{D1}M^2+\mathrm{D1}\gamma^2)}}{\sqrt{\mathrm{D1}}}}}{\sqrt{2}}\right),$$

$$\mathrm{s3} = \left(\sqrt{2\gamma^2 - \frac{2\sqrt{\gamma^2(-4-4\mathrm{D1}M^2+\mathrm{D1}\gamma^2)}}{\sqrt{\mathrm{D1}}}}\right),$$

where c1, c2, c3, and c4 are constants. The constants c1, c2, c3, and c4 are calculated with help of the boundary conditions in equation (18) -(19)
The pressure is given by following:

$$\frac{dp}{dx} = -((e^{-((\mathrm{s1}+\mathrm{s2})y)}(\mathrm{Br}e^{(\mathrm{a1NbPr}+\mathrm{s1}+\mathrm{s2})y}(e^{\mathrm{a1NbPr}h_1} - e^{\mathrm{a1NbPr}h_2})(\mathrm{Nb} + \cdots \tag{33}$$

5. Results and discussion:

The purpose of this section is to study the effect of various factors on temperature, concentration, pressure gradient, and stream function (See Figures (2) -(35)).
In the current study, the value of the following default parameters was adopted for the calculations $\phi = Pi/6$, $Pr = 1, a = 0.5, N = 0.1, Nt = 0.9, d = 1.8, b = 1, Gr = 0.8, Br = 0.1, Q = 2, M = 0.2, \gamma = 2.5, D1 = 1$ and $x = 0$ in temperature and concentration, therefore all graphs correspond to these values unless they are specified on the appropriate graph.
All the results in this section are made through plotting by using MATHEMATICA package.

5.1 Variation of temperature:

The behavior of temperature profile for different values $\phi, Pr, a, Nb, Nt, d\ and\ b$ can be seen in Figures (2)-(8), respectively. We observe that the temperature decreases with increasing values of width number d and amplitude of wave b. The temperature increases with an increase in concentration ϕ and the Prandtl number Pr because it appears in the exponential, thermophoresis parameters Nt, Brownian motion Nb and amplitude of the wave a. This is physically valid because the parameter d and b show an inverse relationship and ϕ, Pr, Nt, Nb, and a show a direct relationship with temperature.

5.2 Variation of concentration:

The behavior of concentration profile for different values $\phi, Pr, a, Nb, Nt, d\ and\ b$ can be seen in Figures (9)-(15) , respectively. We observe that the concentration decreases with increasing values of Prandtl number Pr, thermophoresis parameters Nt, width number d and amplitude of the wave b . The concentration increases with increasing in concentration, the Brownian motion Nb and amplitude of the wave number a . This means the parameter $Pr, Nt, d\ and\ b$ show an inverse relationship and ϕ, Nb and a show a direct relationship with concentration.

5.3 Variation of pressure gradient:

The behavior of the pressure gradient profile for different values $\phi, Pr, a, Nb, Nt, d, b, Gr, Br, Q, M, \gamma\ and\ D_1$ can be seen in Figures (16)-(23), respectively. It is depicted that for $x \in [0,0.2]$ and $x \in [0.6,0.8]$ the pressure gradient is small. That means the flow can easily pass. Without prescription of a large pressure gradient. While in the region $x \in [0,0.8]$ pressure gradient decreases with an increasing $d, b\ and\ M$ and increases with an increase in d, Q, γ, D_1. In the concentration when $x \in [0.2,0.35]$, the pressure gradient decreases with increasing in concentration, and when $x \in [0.4,0.8]$ the pressure gradient increases with an increase in ϕ and Gr, Nt, Br, Nb have a small pressure effect. A big amount of pressure gradient is desired to keep the flow passing.

5.4 Stream line:

The structure of inside circulating bolus of fluid through closed stream line is called trapping and this trapped bouls is payment forward along peristaltic wave. The effect of $\phi, Pr, a, Nb, Nt, d, b, Gr, Br, M, \gamma\ and\ D_1$ can be seen through Figures (24)-(35) ,respectively. That the size and number of the trapping bouls decrease with increases in values of concentration ϕ and nanoparticle Grashof number Br. Notice that the size and number of trapping bouls increase with increasing of the Prandtl number Pr, the amplitude of the wave number a, b, magnetic parameter M, porosity parameter $D_1$and width number d and γ, Nt, Nb, Gr have little effect on the stream line.

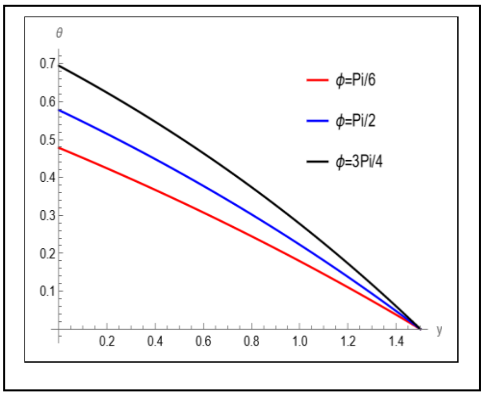


Figure 2: variation of temperature $\theta$for different value of ϕ

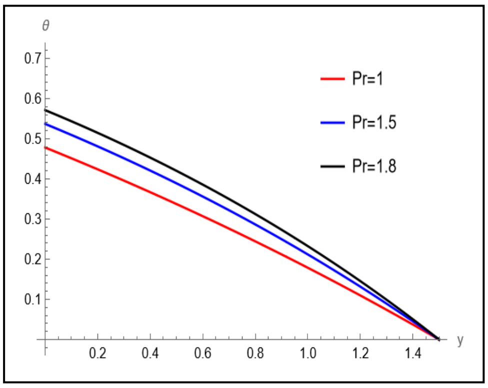


Figure 3: variation of temperature $\theta$for different value of Pr

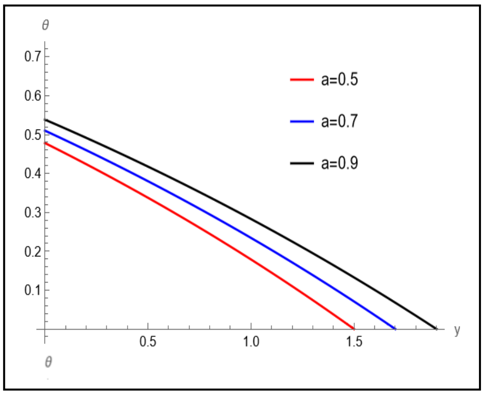


Figure 4: variation of temperature θ for different value of a

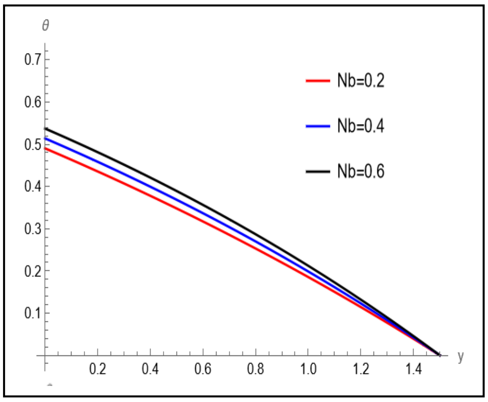


Figure 5: variation of temperature θ for different value of Nb

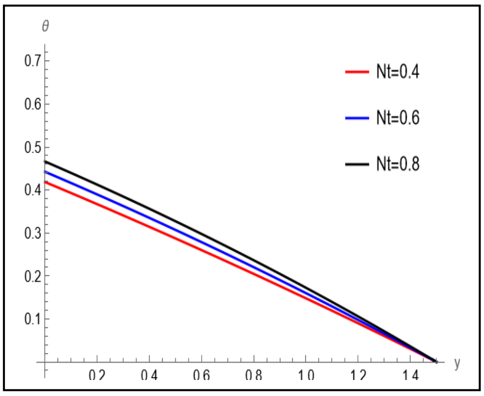


Figure 6: variation of temperature θ for different value of Nt

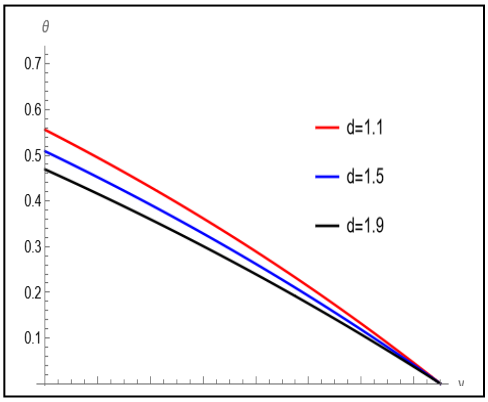


Figure 7: variation of temperature θ for different value of d

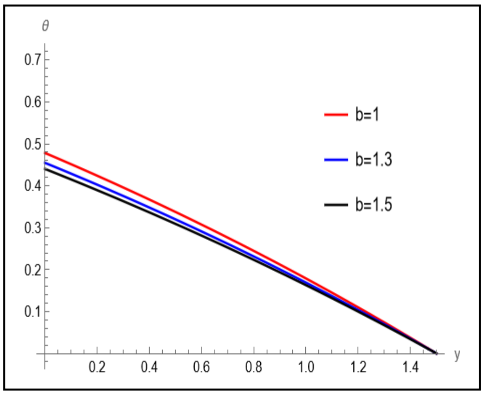


Figure 8: variation of temperature θ for different value of b

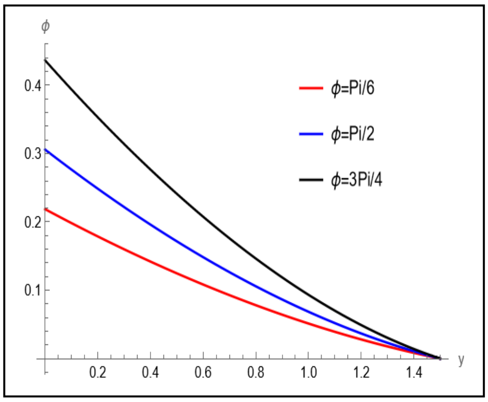


Figure 9: variation of concentration ϕ for different values of ϕ

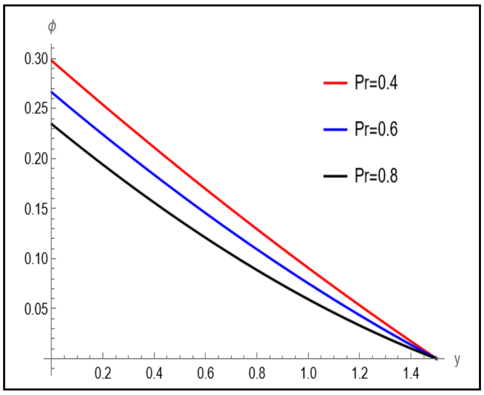


Figure 10: variation of concentration ϕ for different values of Pr

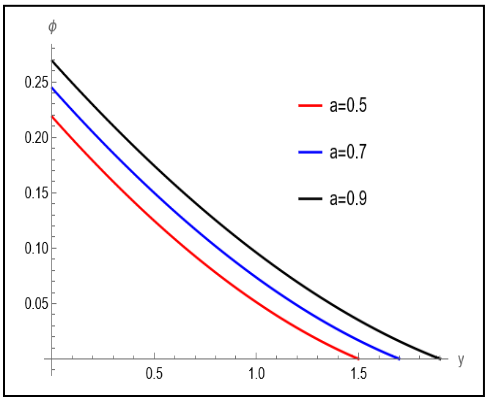


Figure 11: variation of concentration ϕ for different values of a

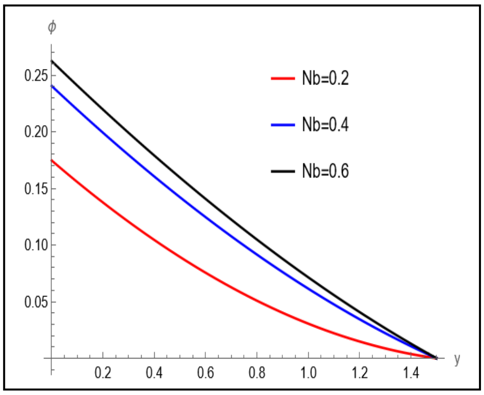


Figure 12: variation of concentration ϕ for different values of Nb

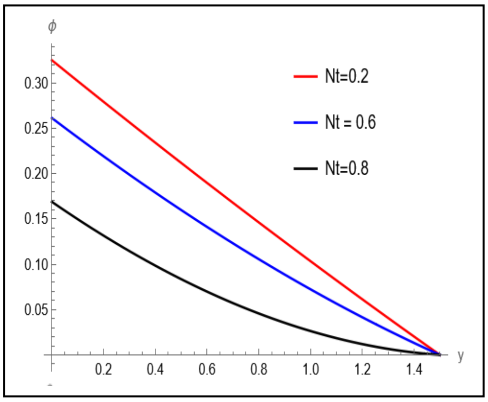


Figure 13: variation of concentration ϕ for different values of Nt

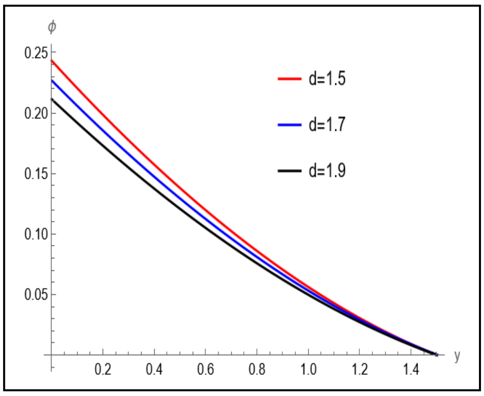


Figure 14: variation of concentration ϕ for different values of d

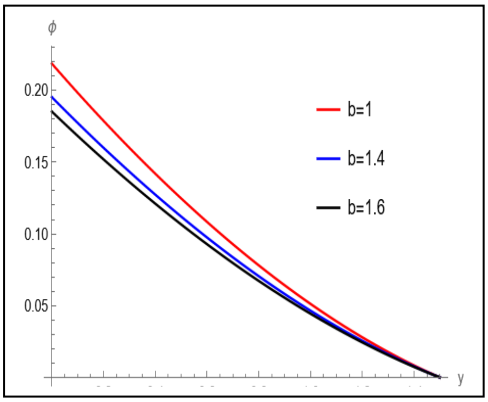


Figure 15: variation of concentration ϕ for different values of b

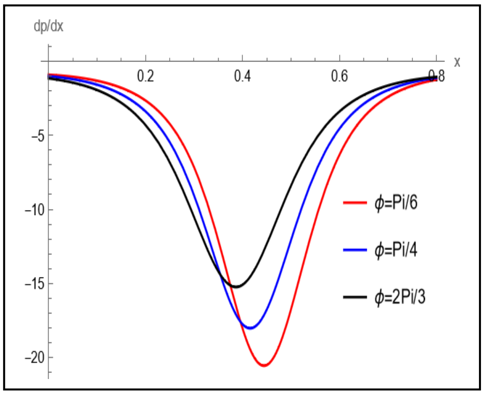


Figure 16: variation of pressure gradient dp/dx with x for different values of ϕ

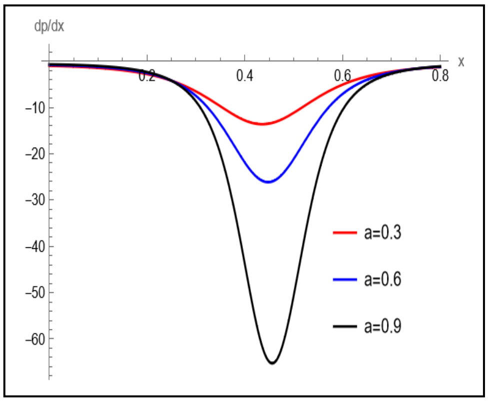


Figure 17: variation of pressure gradient dp/dx with x for different values of a

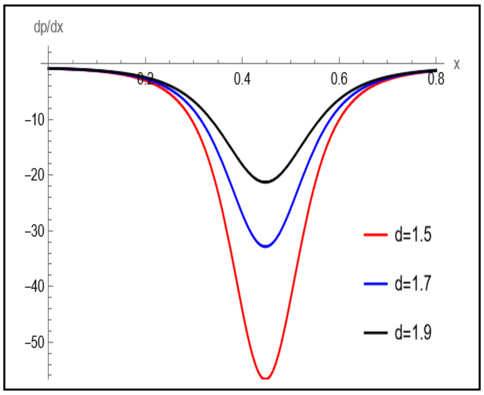


Figure 18: variation of pressure gradient dp/dx with x for different values of d

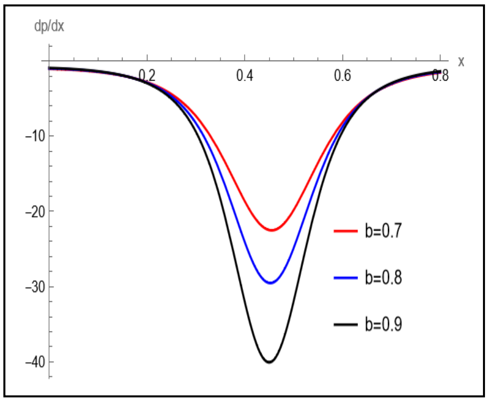


Figure19: variation of pressure gradient dp/dx with x for different values of b

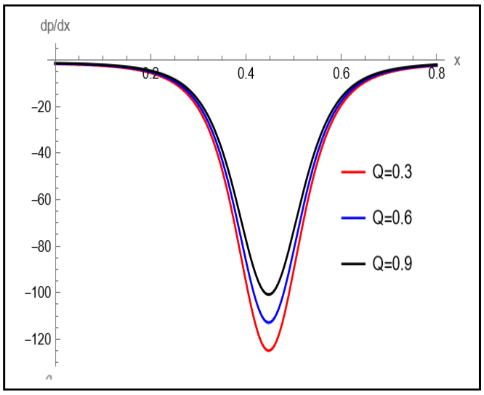


Figure 20: variation of pressure gradient dp/dx with x for different values of Q

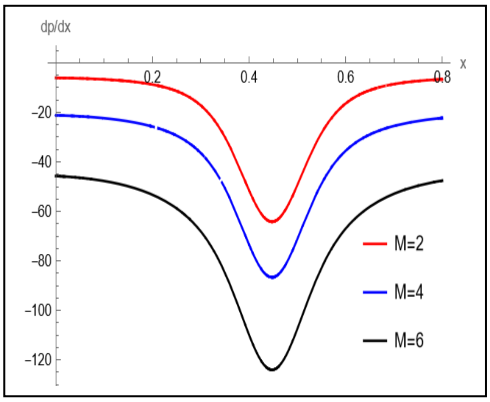


Figure 21: variation of pressure gradient dp/dx with x for different values of M

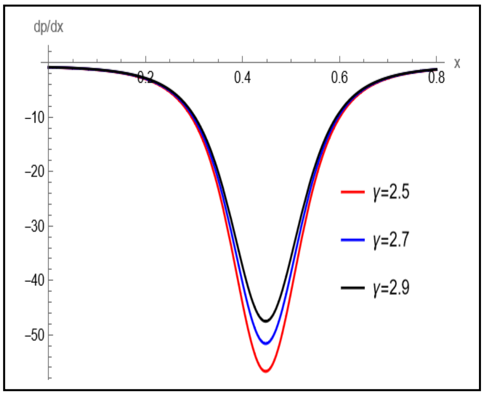


Figure 22: variation of pressure gradient dp/dx with x for different values of γ

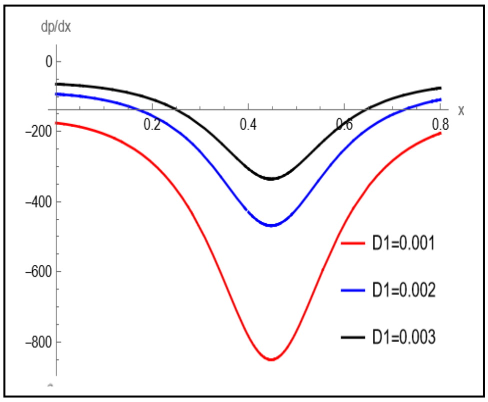


Figure 23 variation of pressure gradient dp/dx with x for different values of $D1$

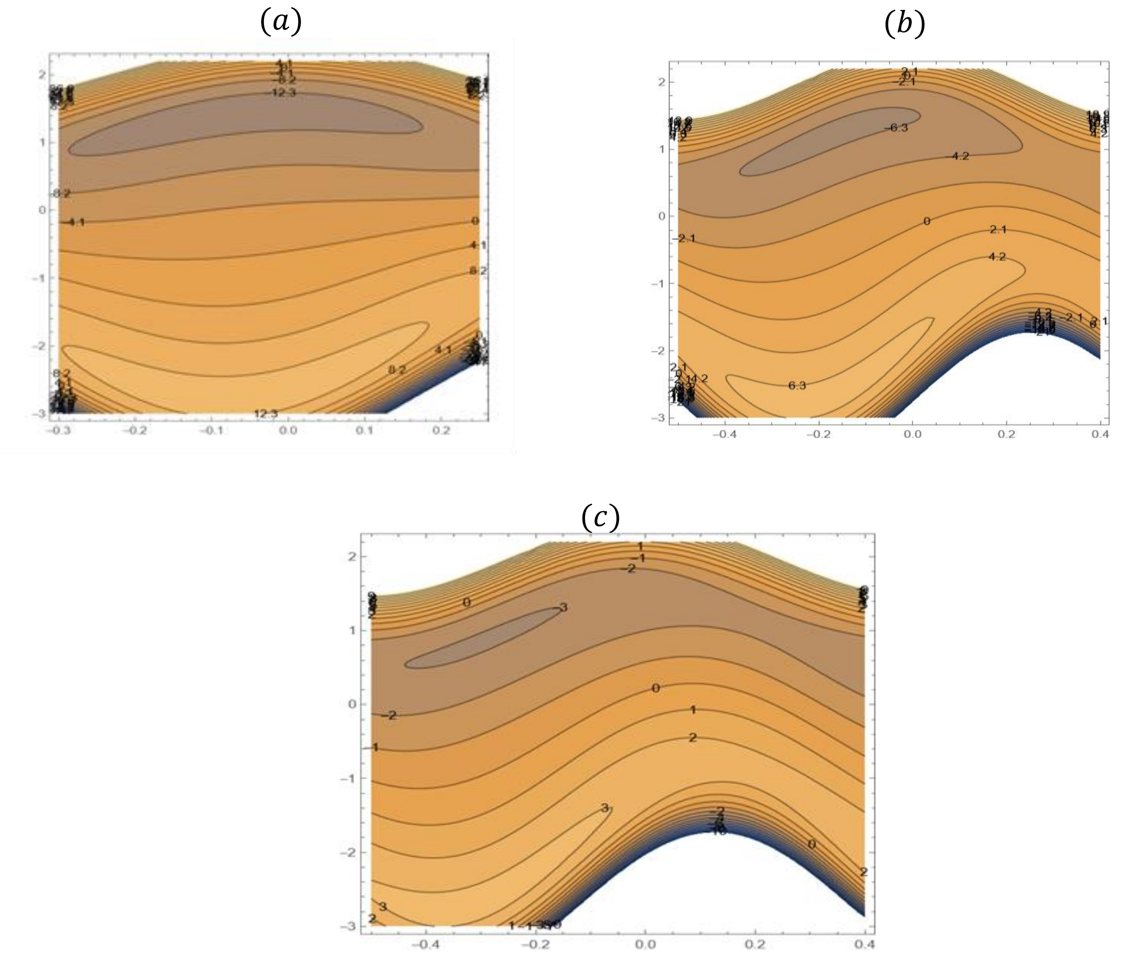
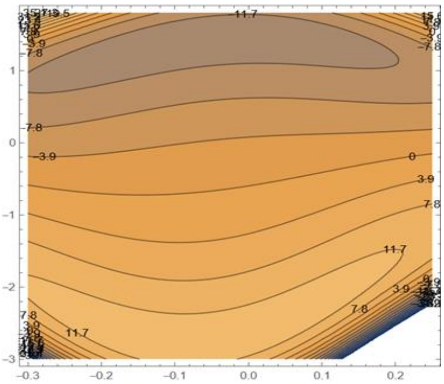
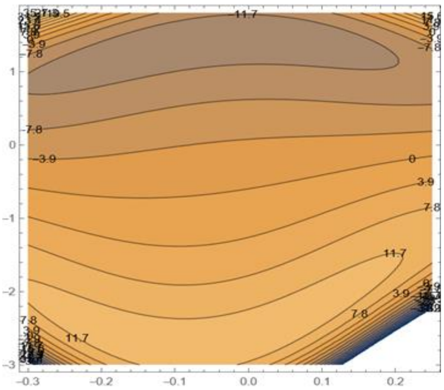


Figure 24: stream lines for different values of ϕ; $(a)\ for\ \phi = Pi/6\ and\ (b)\ for\ \phi = Pi/2\ and\ (c)\ for \phi = 3 * Pi/4$;

(a) (b)





(c)

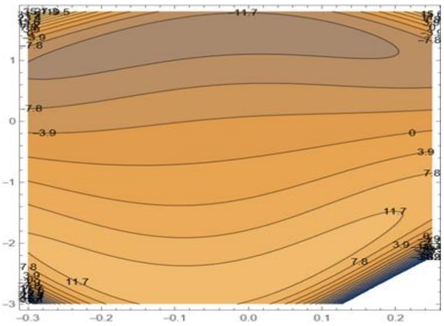
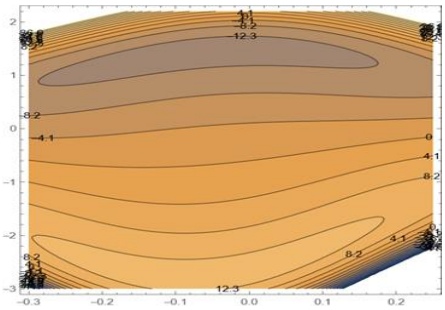
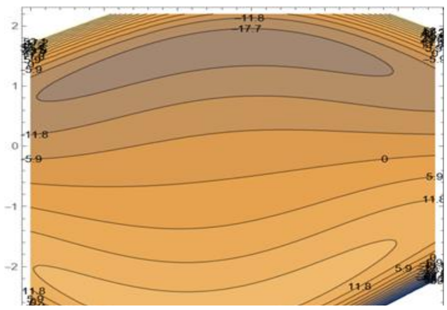


Figure 25: stream lines for different values of $Pr (a)\ for\ Pr = 0.4\ and\ (b)\ for\ Pr = 0.6\ and\ (c)\ for Pr = 0.8$;

(a) (b)





(c)

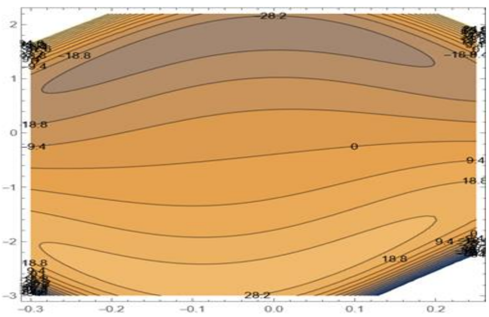
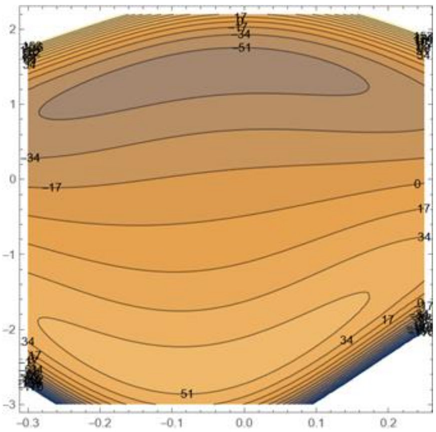
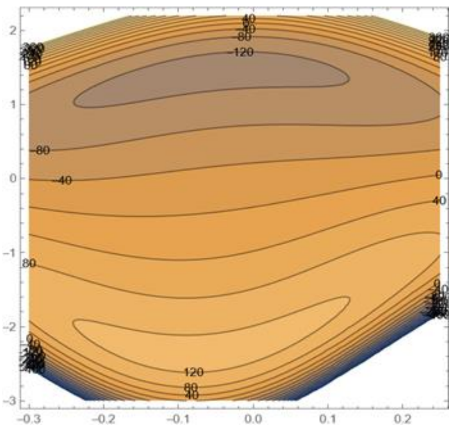


Figure 26: stream lines for different values of $a\ (a)\ for\ a = 0.5\ and\ (b)\ for\ a = 0.7\ and\ (c)\ for\ a = 0.9$;

(a) (b)





(c)

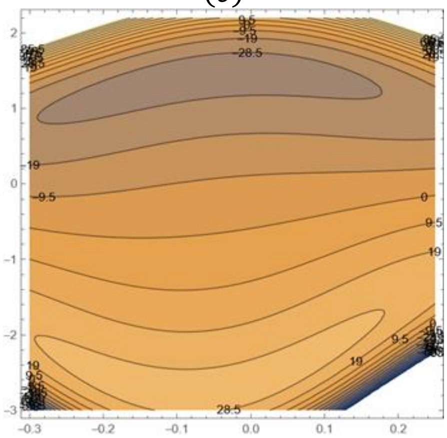
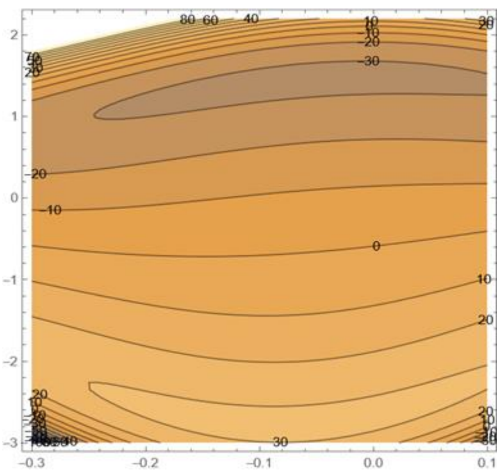
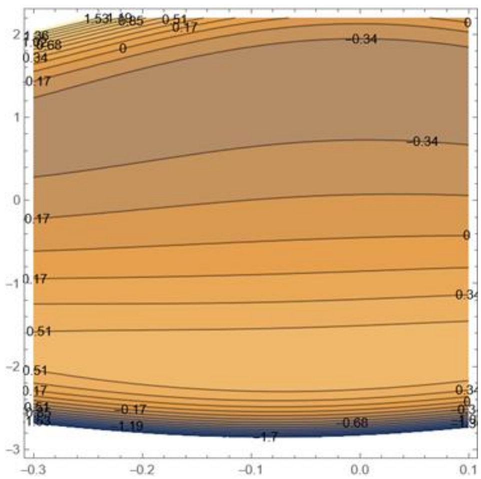


Figure 27: stream lines for different values of $d(a)$ $for\ d = 1.4\ and\ (b)\ for\ d = 1.6\ and\ (c)\ ford = 1.8;$

(a) (b)





(c)

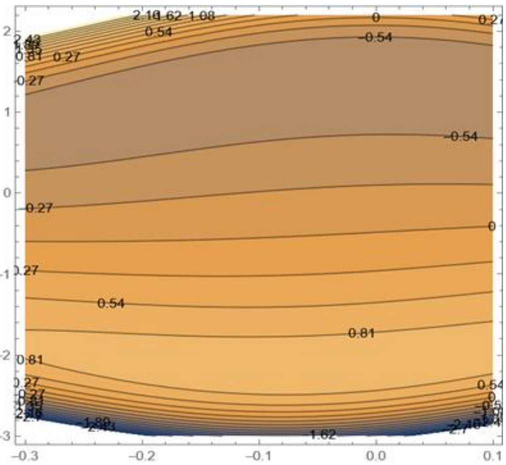
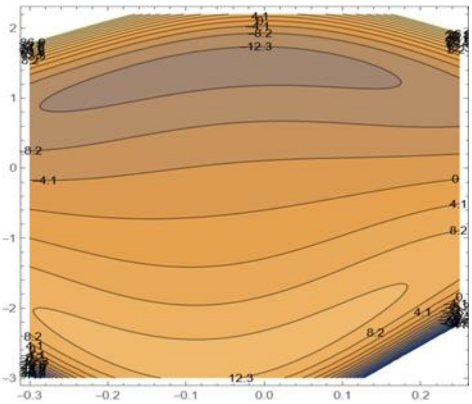
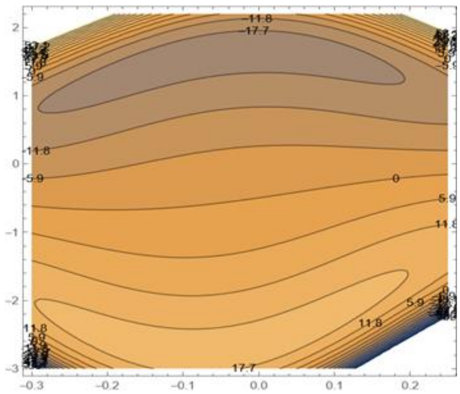


Figure 28: stream lines for different values of b (a) for $b = 1$ and (b) for $b = 0.2$ and (c) $forb = 0.4$;

(a)



(b)



(c)

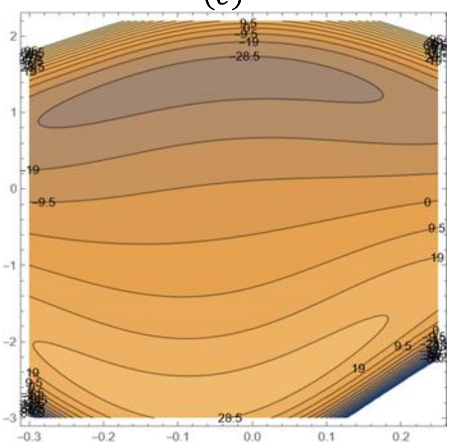


Figure 29: stream lines for different values of Br (a) for $Br = 0.1$ and (b) for $Br = 0.5$ and (c) $forBr = 0.9$;

(a) (b) (c)

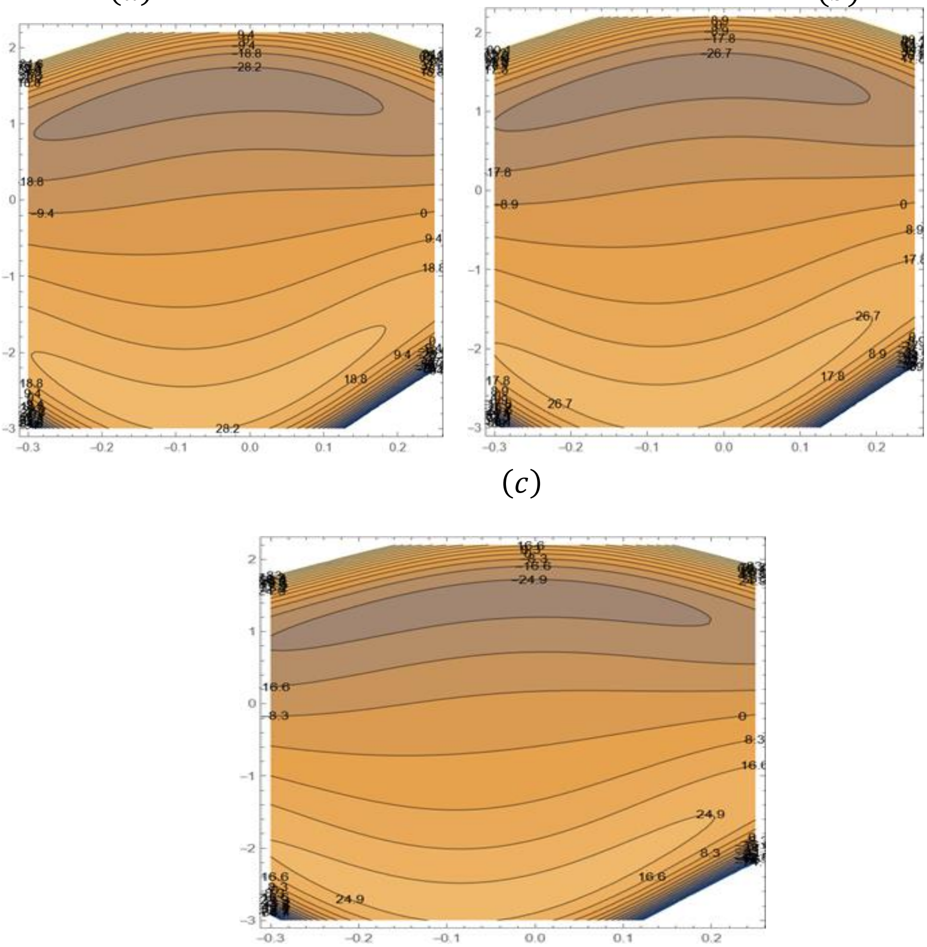
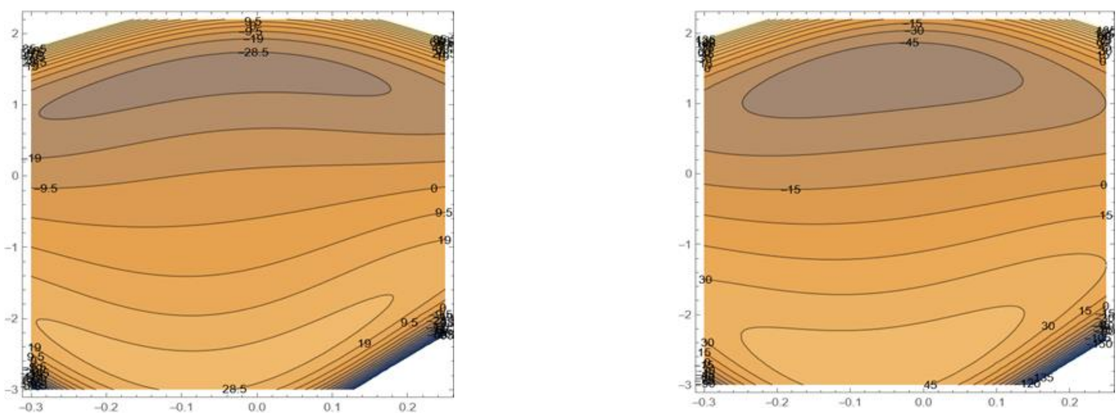


Figure 30: stream lines for different values of M (a) for $M = 0.2$ and (b) for $M = 0.4$ and (c) $form = 0.6$;

(a) (b)



(c)

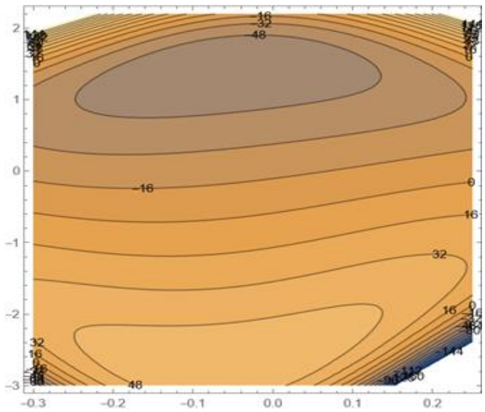


Figure 31: stream lines for different values of b (a) $for\ b = 1$ and (b) $for\ b = 5$ and (c) $forb = 9$;$\phi = \mathrm{Pi}/6$, $\mathrm{Pr} = 0.9$, $a = 0.5$, $\mathrm{Nb} = 0.3$, $\mathrm{Nt} = 0.5$, $d = 1.8$, $b = 1$, $\mathrm{Gr} = 0.5$, $\mathrm{Br} = 0.1$, $\mathrm{p1} = -43.9504$, $M = 0.2$, $\gamma = 2.5$, $\mathrm{D1} = 1$

6. Conclusions

In this section, the influence of MHDand porous media on the peristaltic flow of a couple of stress fluids in an asymmetric channel. The mathematical modeling of the proplem is discussed in detail under the assumption of wave length and low Reynolds number after which we will get a nonlinear related solution in differential equations**.** Then, the exact solutions of the temperature distribution, nanoparticle concentration, velocity, stream function and pressure gradient have been calculated. The result is summarized as follows:

1- The temperature decreases with increasing values of width number d and amplitude of the wave b. This is physically valid because the parameter d and b show an inverse relationship.

2- The temperature increases with an increase in concentration ϕ, the Prandtl number Pr, thermophoresis parameters Nt, Brownian motion Nb and amplitude of the wave a, because the parameter ϕ, Pr, Nt, Nb and a show a direct relationship with temperature.

3- The concentration decreases with increasing values of the Prandtl number Pr, thermophoresis parameters Nt, width number d and amplitude of the wave b This means the parameter $Pr, Nt, d\ and\ b$ show an inverse relationship.

4- The concentration increases with an increase in concentration ϕ, , Brownian motion Nb and amplitude of the wave number a.the parameter ϕ, Nb and a show a direct relationship with concentration.

5- The pressure gradient decreases with an increase in $d, b\ and\ M$ and it increases with an increasing in d, Q, γ, D_1 when $x \in [0.2,0.35]$ the pressure gradient decreases with increasing concentration, and when x∈[0.4,0.8] the pressure gradient increases with an increase in ϕ and Gr,Nt,Br. Nb has a small pressure effect. A big amount of pressure gradient is desired to keep the flow passing.

6- The size and number of the trapping bouls decrease with increases in values of concentration ϕ and nanoparticle Grashof number Br.

7- the size and number of trapping bouls increase with increasing of the Prandtl number Pr, amplitude of the wave number a, b, magnetic parameter M, porosity parameter D_1

References

[1] Akram, Safia, Farkhanda Afzal, and Qamar Afzal,Impact of nanofluids and magnetic field on the peristaltic transport of a couple stress fluid in an asymmetric channel with different wave forms. Thermal Science 24.2 Part B (2020): 1407-14.

[2] A. Aziz, W.A. Khan, I. Pop. Free convection boundary layer flow past a horizontal flat plate embedded in porous medium filled by nanofluid containing gyrotactic microorganisms. International Journal of Thermal Sciences 56 (2012) 48, pp. 48-57.

[3] Choi, S. U. S., Enhancing Thermal Conductivity of Fluid with Nanoparticles Developments and Applica tions of Non-Newtonian Flow. ASME FED, 231 (1995), 66, pp. 99-105.

[4] Latham T. W., Fluid motion in a peristaltic pump [D]. Master Thesis, Massachusetts, USA: Massachusetts Institute of Technology, 1966.

[5] Noreen S. A., and Wahid B. A. ,Physiological transportation of casson fluid in a plumb duct [J]. Communications in Theoretical Physics, 63(2015), 3,pp. 347–352.

[6] Shapiro A.H., Jaffrin M.Y, andWeinberg S.L., (1969), "Peristaltic pumping with long wave lengths at low Reynolds number", Journal of Fluid Mechanics, 37, 799-825.

[7] Akbar, N. S., Nadeem, S., Endoscopic Effects on Peristaltic Flow of a Nanofluid, Communication in The ortical Physics, 56 (2011), 4, pp. 761-768.

[8] Rashidi, M. M., et al., Heat and Mass Transfer Analysis on MHD Blood Flow of Casson Fluid Model Due to Peristaltic Wave, Thermal Science, 22 (2018), 6A, pp. 2439-2448

[9] A. Riaz , A. Zeeshan , S. Ahmad , A. Razaq, M. Zubair, Effects of external magnetic field on Non-newtonian two phase fluid in an annulus with peristaltic pumping, Journal of Magnetics24 (2019), 1, pp. 62-69.

[10] Ellahi, R., et al., A Mathematical Study of Non-Newtonian Micropolar Fluid in Arterial Blood Flow through Composite Stenosis, Journal of Applied Mathematics and Information Sciences, 8 (2014), 4, pp. 1567-1573.

[11] Safia Akram, S. Nadeem, Anwar Hussain, Effects of heat and mass transfer on peristaltic flow of a Bingham fluid in the presence of inclined magnetic field and channel with different wave forms, Journal of Magnetism and Magnetic Materials, 362 (2014), Aug., pp. 184-192.

[12] Nadeem, Safia Akram, Noreen Sher Akbar, Simulation of heat and chemical reactions on peristaltic flow of a Williamson fluid in an inclined asymmetric channel, Iranian journal of chemistry and chemical engineering, 32 (2013),2, pp.93-107.

[13] Yldrm, A., Sezer, S. A., Effects of Partial Slip on the Peristaltic Flow of a MHD Newtonian Fluid in an Asymmetric Channel, Mathematical and Computer Modeling, 52 (2010), 3-4, pp. 618-625.

[14] Haroun, M. H. Non-Linear Peristaltic Flow of a Fourth Grade Fluid in an Inclined Asymmetric Channel Computer Material Science, 39 (2007), 2, pp. 324-333,

[15] Martinez M.J., McTigue D.F. (1996) Modeling in Nuclear Waste Isolation: Approximate Solutions for Flow in Unsaturated Porous Media. In: Wheeler M.F. (eds) Environmental Studies. The IMA Volumes in Mathematics and its Applications, vol 79. Springer, New York, NY

[16] Elshehawey E. F., Eldabe N.T., Elghazy E. M. and Ebaid A., (2006), peristaltic transport in an asymmetric channel through a porous medium, Applied Mathematics and Computation, 182.

[17] Bhattacharyya, A., R. Kumar, and G. S. Seth. "Capturing the features of peristaltic transport of a chemically reacting couple stress fluid through an inclined asymmetric channel with Dufour and Soret effects in presence of inclined magnetic field." Indian Journal of Physics 95.12 (2021): 2741-2758.