INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

OPEN ACCESS

Received: 25-05-2020

Accepted: 05-08-2020

Published: 31-08-2020

Editor: Dr. Natarjan Gajendran

Citation: Raja shekar P, Maruthi Prasad K, Vamsi Krishna N, Bhuvana Vijaya R (2020) Heat generation and chemical reaction in flow propagated by peristalsis incidence of radiation in MHD Jeffrey nanofluid. Indian Journal of Science and Technology 13(31): 3213-3221. https://doi.org/10.17485/IJST/v13i31.716

*Corresponding author.

Tel: +91-9985354264
rajoct25@gmail.com

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Heat generation and chemical reaction in flow propagated by peristalsis incidence of radiation in MHD Jeffrey nanofluid

P Raja shekar[1]*, K Maruthi Prasad[2], N Vamsi Krishna[2], R Bhuvana Vijaya[3]

1 Department of Mathematics, Vignan Institute of Technology and Science, Hyderabad, Telangana, India. Tel.: +91-9985354264
2 Department of Mathematics, GITAM Deemed to be University, Hyderabad, Telangana, India
3 Department of Mathematics, JNTUCEA, Ananthapuramu, Andra Pradesh, India

Abstract

Objectives: In the present study, the heat Source and chemical reaction in MHD Jeffrey nanofluid driven by means of peristalsis through asymmetric channel has been addressed. **Methods**: Considering low Reynolds number and long wave length assumptions the fundamental equations of mathematical model are obtained. By applying long-wavelength and low Reynolds's number the non-linear partial differential equations are transformed into ordinary differential equations. The simplified equations are solved by using Mathematica software and various effects are discussed in the form graphs. **Findings**: It is observed that influence of chemical reaction parameter on temperature and concentration profiles are increasing. The converse behavior is found in the case of Radiation and heat source parameters. **Novelty**: The present analysis is applicable for magnetic drug targeting for various treatments in a human body. The present study addresses the influence of heat source and chemical reaction in peristaltic pumping of Jeffrey nanofluid incidence of thermal radiation.

Keywords: Peristalsis; Jeffrey fluid; thermal radiation; MHD; heat generation

1 Introduction

Improvements to create heat transfer utensils more energy proficient would need to concentrate on miniaturization on the one hand and an astronomical raise in heat flux on the other. Heat transmit fluid such as mineral oil, ethylene glycol , and water play a vital role in various engineering processes, include microelectronics, chemical, heating processes, and power production. This encounters in approximately every branches of Engineering and Biosciences. Jeffrey model flow past a fixed sheet focused on power law temperature in the incidence of heat source/sinks explored[1]. The collective consequence of heat and mass transmit in Jeffrey fluid is described in this article. The heat transfer effects on the peristaltic flow of Jeffrey six-constant fluid representation have been studied[2]. In the paper boundary layer flow of nanofluid and heat transfer characteristics past a stretching sheet Studied[3]. Thermal radiation, Brownian motion, and slip boundary condition effects are examined.[4] Look into The property of soret and chemical effect on steady MHD mixed convective heat and mass transfer flow embedded in a porous medium in the incidence of heat source, viscous and Joules dissipation.

Significant consideration in modern times pooled the problems with chemical reaction, heat and mass transfer, which gained much significance in several processes. At the same time heat and mass transfer take place in process such as transport of energy in a wet cooling tower, geothermal reservoirs, and the flow in a desert cooler. J. Prakash et al.[5] presented a mathematical model to study the nanofluids flow driven by peristalsis mechanisms through asymmetric channel. Furthermore thermal radiative flux replica is deployed, to examine effects of the thermal radiation. In the article[6] Cattaneo-Christov diffusion model is introduced in describing the temperature and concentration diffusions with thermal and solutal relaxation times respectively.. Anjali Devi and Kandasamy[7] focused to find approximate solution for MHD boundary layer fluid with the effects of heat and mass transfer, chemical reaction over a block. Muthucumaraswamy[8] dealt with effects on a moving vertical plane with chemical reaction. The study[9] investigates the impact of Joule heating and velocity slip on MHD peristaltic flow in a porous space with chemical reaction. It is noticed that a generative chemical reaction is superior to the destructive one on the concentration. M. Ganapathirao[10] studied the effects of chemical reaction, heat and mass transfer on an unsteady mixed convection boundary layer flow over a vertical wedge with heat generation/absorption in the presence of uniform suction or injection. Srinivasa Raju[11] studied the effect of chemical reaction on unsteady, incompressible, viscous fluid flow past an exponentially accelerated vertical plate with heat absorption and variable temperature in a magnetic field.

Mixed convective peristaltic flow of Jeffrey nanofluid variable viscosity is studied with the consideration of viscous dissipation and Joule heating effects. In this study the viscosity is taken as temperature dependent[12]. Influences of thermal radiation and thermophoresis on peristaltic flow in a rotating frame are discussed[13]. The steady laminar 2D flow and heat transfer characteristics by boundary-layer of one phase Sisko bio-nanofluid model are discussed[14]. In the article, non-uniform hemodynamic nanofluid flow in the presence of an external magnetic field studied. Srinivasa Raju[15] studied thermal diffusion and diffusion thermo effects on an unsteady two-dimensional heat and mass transfer radiative MHD natural convective Couette flow of a viscous, incompressible, electrically conducting fluid between the two vertical parallel plates. Jithender Reddy et al.[16] studied the hall current and rotation effects on MHD free convection flow past a moving vertical plate with the presence of thermal diffusion and diffusion thermo for isothermal and ramped temperature. In the paper, influence of thermal radiation on peristaltic motion with double diffusive convection of gold nano particles through an asymmetric channel[17].

The peristaltic transport of liquid has gained exceptional interest in the recent time owing to its extensive application in physiology as it is considered a vital method for flow in bio fluids. This course is exceedingly essential in numerous physiological systems and in engineering includes swallowing food through esophagus, arterioles and capillaries, in sanitary fluid transportation, toxic fluid move in the nuclear engineering etc. Several investigators have analyzed the peristaltic motion of both Newtonian and non-Newtonian fluids in mechanical as well as physiological systems[18–20].

To acquire improved quantitative and qualitative characteristics concerning the rheological activities of blood, several authors presented numerous non Newtonian fluid models. Jeffrey fluid amongst them is a well-known model in studying vascular dynamics. The magnetic field effect in two-dimensional mixed convection boundary layer flow and heat transfer of a Jeffreyfluid over a stretched sheet immersed in a porous medium is studied by Kartini Ahmad, Anuar Ishak[21]. M.M. Bhatti, M. Ali Abbas[22] reported concurrent slip and hydro magnetic effects on peristaltic blood transport of Jeffrey model fluid through a non-uniform channel in porous medium. M. Gnaneswara Reddy[23] investigated the impact of velocity slip on MHD peristaltic flow through a porous medium with heat and mass transfer.

The published studies about the heat generation in peristaltic MHD flows of non-Newtonian fluids are still scarce. In fact heat generation and absorption concepts in fluids have relevance in problems dealing with chemical reactions, geo-nuclear repositions and these concerned with dissociating fluids. The nanofluid flow with thermal and chemical reaction has broad applications in cooling, expulsion procedures and polymer industry. The magnetic field plays an essential role in targeting drugs by magnetic nano particles for different kinds of diseases in a human body. The Jeffrey fluid model is employed to simulate non-Newtonian characteristics. Hence the current model is to describe heat generation and chemical reaction peristaltic pumping of MHD Jeffrey nanofluid. Thermal radiation in addition to chemical reaction effects has been addressed.

Nomenclature	
a1, a2	Wave amplitude
Br	Brinkman number
C	Concentration
C0	Speed of the wave

Continued on next page

Table 1 continued

cp	Specific heat at constant pressure
d1 + d2	Width of channel
Ec	Eckert number
Gm	Local nano particle Grashoff number
I	Identity tensor
K	Mean absorption coefficient
M	Hartman number
Nb	Brownian motion
Nt	Thermophoresis
p	Pressure in wave
P	Pressure in fixed frame
Pr	Prandtl number
Re	Reynolds number
S	Extra stress tensor
Sc	Schmidt number
Sij	Components of the exra tensor
Tm	Mean temperature
T	Temperature
t	Time
U, V	Velocity components in the laboratory frame (X, Y)
u, v	Velocity components in the wave frame (x, y)
Greek Symbols	
μ	Coefficient of viscosity
λ	Wavelength
τ	Cauchy stress tensor
$\lambda 1$	Ratio of relaxation to retardation times
γ	Shear rate
$\lambda 2$	Retardation time
σ	Stefan–Boltzmann constant
ν	Kinematic viscosity
α	Thermal diffusivity
pf	Fluid density
β	Heat Source/Sink parameter
γ	Chemical Reaction Parameter

2 Formulation of the problem

An incompressible Jeffrey nanofluid in an unsymmetrical channel of non-uniform width is considered in two-dimensional flow. Flow is considered to be free from the electric field. The movement in the fluid is shaped in reaction to the promulgation of couple of sinusoidal wave trains of stable speed c_0 with wavelength λ along the flexible channel walls. $\eta = \eta_1$, $\eta = \eta_2$ are considered to be upper and lower walls. A magnetic field of intensity B_0 is applied and the effect of induced magnetic field is negligible for small magnetic Reynolds number. The wave shape is represented by the following equation

$$H_1 = \eta_1(\xi, t) = d_1 + (\xi - c_0 t)\tan\alpha + a_1 cos\frac{2\pi}{\lambda}(\xi - c_0 t) \tag{1}$$

$$H_2 = \eta_2(\xi, t) = -d_2 - (\xi - c_0 t)\tan\alpha - a_2 cos[\frac{2\pi}{\lambda}(\xi - c_0 t) + \varnothing] \tag{2}$$

Where the constitutive relation for Cauchy stress tensor (τ) in an incompressible Jeffrey fluid is

$$\tau = -pI + S, \qquad S = \frac{\mu}{1+\lambda_1}\left(\gamma + \lambda_2 \frac{d\gamma}{dt}\right) \tag{3}$$

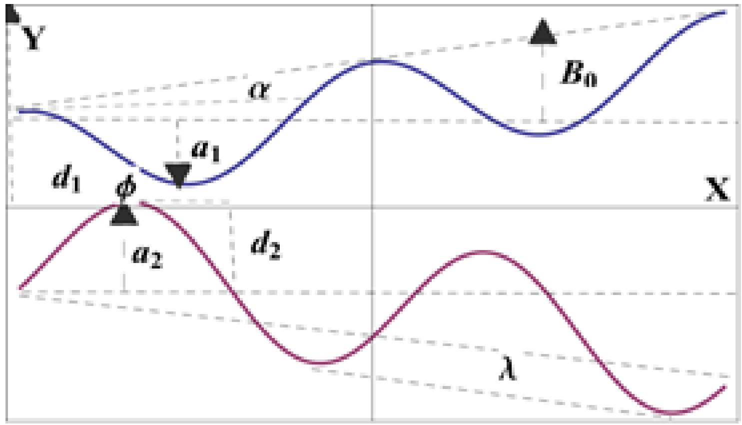

Fig 1. The geometry of the problem

The equations governing the flow for incompressible nanofluid are given as [5,24,25]

$$\frac{\partial U}{\partial \xi}+\frac{\partial V}{\partial \eta}=0 \tag{4}$$

$$\begin{aligned}\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial \xi}+V\frac{\partial U}{\partial \eta} &= -\frac{1}{\rho_f}\frac{\partial p}{\partial \xi}+\frac{1}{\rho_f}\left[\frac{\partial}{\partial \xi}(S_{XX})+\frac{\partial}{\partial \eta}(S_{XY})\right]\\ -\frac{\sigma B_0^2 U}{\rho_f} &+(1-C_0)g\alpha(T-T_0)+\left(\frac{\rho_p-\rho_f}{\rho_f}\right)g\beta'(C-C_0)\end{aligned} \tag{5}$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial \xi}+V\frac{\partial V}{\partial \eta} = -\frac{1}{\rho_f}\frac{\partial p}{\partial \eta}+\frac{1}{\rho_f}\left[\frac{\partial}{\partial \xi}(S_{XY})+\frac{\partial}{\partial \eta}(S_{YY})\right] \tag{6}$$

$$\begin{aligned}\frac{\partial T}{\partial t}+U\frac{\partial T}{\partial \xi}+V\frac{\partial T}{\partial \eta} &= \alpha\left(\frac{\partial^2 T}{\partial \xi^2}+\frac{\partial^2 T}{\partial \eta^2}\right)+\frac{1}{\rho_f C_f}\left[S_{XX}\frac{\partial U}{\partial \xi}+S_{XY}\left(\frac{\partial U}{\partial \eta}+\frac{\partial V}{\partial \xi}\right)+S_{YY}\frac{\partial V}{\partial \eta}\right]\\ -\frac{1}{\rho_f C_f}\left(\frac{\partial q_r}{\partial \eta}\right)&+\frac{\sigma B_0^2 U^2}{\rho_f C_f}+\tau\left[D_B\left(\frac{\partial C}{\partial \xi}\frac{\partial T}{\partial \xi}+\frac{\partial C}{\partial \eta}\frac{\partial T}{\partial \eta}\right)+\frac{D_T}{T_m}\left(\left(\frac{\partial T}{\partial \xi}\right)^2+\left(\frac{\partial T}{\partial \eta}\right)^2\right\}\right]+Q_0\end{aligned} \tag{7}$$

$$\frac{\partial C}{\partial t}+U\frac{\partial C}{\partial \xi}+V\frac{\partial C}{\partial \eta}=D_B\left(\frac{\partial^2 C}{\partial \xi^2}+\frac{\partial^2 C}{\partial \eta^2}\right)+\frac{D_T}{T_m}\left(\frac{\partial^2 T}{\partial \xi^2}+\frac{\partial^2 T}{\partial \eta^2}\right)-k_1(C-C_0) \tag{8}$$

Radiative heat flux q_r is given by

$$q_r=-\frac{4\sigma}{3k}\frac{\partial T^4}{\partial \eta} \tag{9}$$

The wave and laboratory frame transformation is given by

$$\xi=X-ct,\ \eta=Y,\ u=U-c,\ v=V,\ p(\xi)=P(X,t) \tag{10}$$

Introducing the following non-dimensional quantities:

$$\begin{aligned} &u^{'}=\frac{u}{c},v^{'}=\frac{v}{c},\xi^{'}=\frac{\xi}{\lambda},\eta^{'}=\frac{\eta}{d_1},t^{'}=\frac{tc}{\lambda},p^{'}=\frac{d_1^2p}{c\lambda\mu},k^{'}=\frac{k}{d^2}\\ &\theta=\frac{T-T_0}{T_1-T_0},\varnothing=\frac{c-C_0}{c_1-c_0},Gr=\frac{(T_1-T_0)\,\rho_f g\alpha d^2\,(1-C_0)}{c\mu},Gm=\frac{\left(\rho_c-\rho_f\right)g\alpha d^2\,(1-C_0)}{c\mu}\\ &Nb=\frac{\tau D_B\,(C_1-C_0)}{v},Nt=\frac{\tau D_T\,(T_1-T_0)}{T_0 v},a=\frac{a_1}{d_1},b=\frac{b_1}{d_1},Re=\frac{cd_1}{v},Rn=\frac{16\sigma T_0^3}{3k\mu c_f},h_1=\frac{H_1}{d_1},h_2=\frac{H_2}{d_1}\\ &\delta=\frac{d_1}{\lambda},\lambda_2^{'}=\frac{\lambda_2 c}{d_1},M=\sqrt{\frac{\sigma}{\mu}}B_0 d_1,Sc=\frac{\vartheta}{D_B},Ec=\frac{c^2}{c_f\,(T_1-T_0)},pr=\frac{\theta\rho c_p}{k},\beta=\frac{Q_0 d_1^2}{kT_0},\gamma=\frac{k_1 d_1^2}{v} \end{aligned} \tag{11}$$

In equations (4)–(7) after omitting primes and writing stream function $\psi(\xi,\eta,\mathrm{t})$

$$u=\psi_\eta,\ v=-\delta\psi_\xi, \tag{12}$$

The above governing equation (5)-(8) after eliminating pressure term using long wavelength and low Reynolds number approximations can be obtained in non dimensional form as follows

$$\left(\frac{1}{1+\lambda_1}\right)\frac{\partial^4\psi}{\partial\eta^4}+Gr\,\frac{\partial\theta}{\partial\eta}+Gm\,\frac{\partial\phi}{\partial\eta}-M^2\frac{\partial^2\psi}{\partial\eta^2}=0 \tag{13}$$

$$\begin{aligned} &\left(1+Rn\,Pr\,(1+\ \varnothing)^3\right)\frac{\partial^2\psi}{\partial\eta^2}+NbPr\frac{\partial\theta}{\partial\eta}\frac{\partial\phi}{\partial\eta}+\left(3Rn\,(1+\theta)^2+Nt\right)Pr\left(\frac{\partial\theta}{\partial\eta}\right)^2\\ &+Br\left[\frac{1}{1+\lambda_1}\frac{\partial^2\psi}{\partial\eta^2}^2+M^2\left(\frac{\partial\psi}{\partial\eta}\right)^2\right]+\ \beta=0 \end{aligned} \tag{14}$$

$$\frac{\partial^2\varnothing}{\partial\eta^2}+\frac{Nt}{Nb}\frac{\partial^2\theta}{\partial\eta^2}-\ \gamma\phi=0 \tag{15}$$

The relevant boundary conditions are

$$\psi=\frac{q}{2},\frac{\partial\psi}{\partial\eta}=-1,\theta=0,\varphi=0,\ at\ y=h_1=1+\tan\alpha+a\cos(2\pi\xi) \tag{16}$$

$$\psi=-\frac{q}{2},\frac{\partial\psi}{\partial\eta}=-1,\theta=1,\varphi=1,\ \mathrm{at}\ y=h_2=-d-\tan\alpha-b\cos(2\pi\xi+\varphi) \tag{17}$$

Where q is the flux in the wave frame and the constants a, b, d, φ must satisfy the relation

$$a^2+b^2+\ 2\,ab\,cos\varphi\ \leq\ (1+d)^2 \tag{18}$$

The flow rate in wave frame and fixed frame are related by

$$Q=q+1+d \tag{19}$$

3 Discussion

3.1 Dimensionless velocity

Variations in magnetic parameter (M) are presented in Figure 2 (a). One can find that the velocity diminishes at hub part of the walls with rising in M. The reason behind this aspect is that application of magnetic field to an electrically conducting fluid gives to a resistive type force called the Lorentz force which opposes the fluid motion. Features of Grash of number (Gr), thermophoresis (Nt) and Jeffrey fluid parameter (λ) are plotted through the Figure 2(b), Figure 2(c) and Figure 2(d) velocity. Figure 2(e) shows the effect of λ on dimensionless velocity. The physical parameter λ is inversely proportional to the retardation time of the non Newtonian fluid. Hence, an increase in λ means a decrease in fluid retardation time which in effect prevents the hastening of fluid motion. From figure it can be depicted velocity is decreased in the upper part of the channel with increasing λ similar behavior is found in Gr, Nt as well. Figure 2(d) demonstrates effect of chemical reaction parameter (γ). It is observed that velocity diminishes at hub part of the walls with rising in γ.

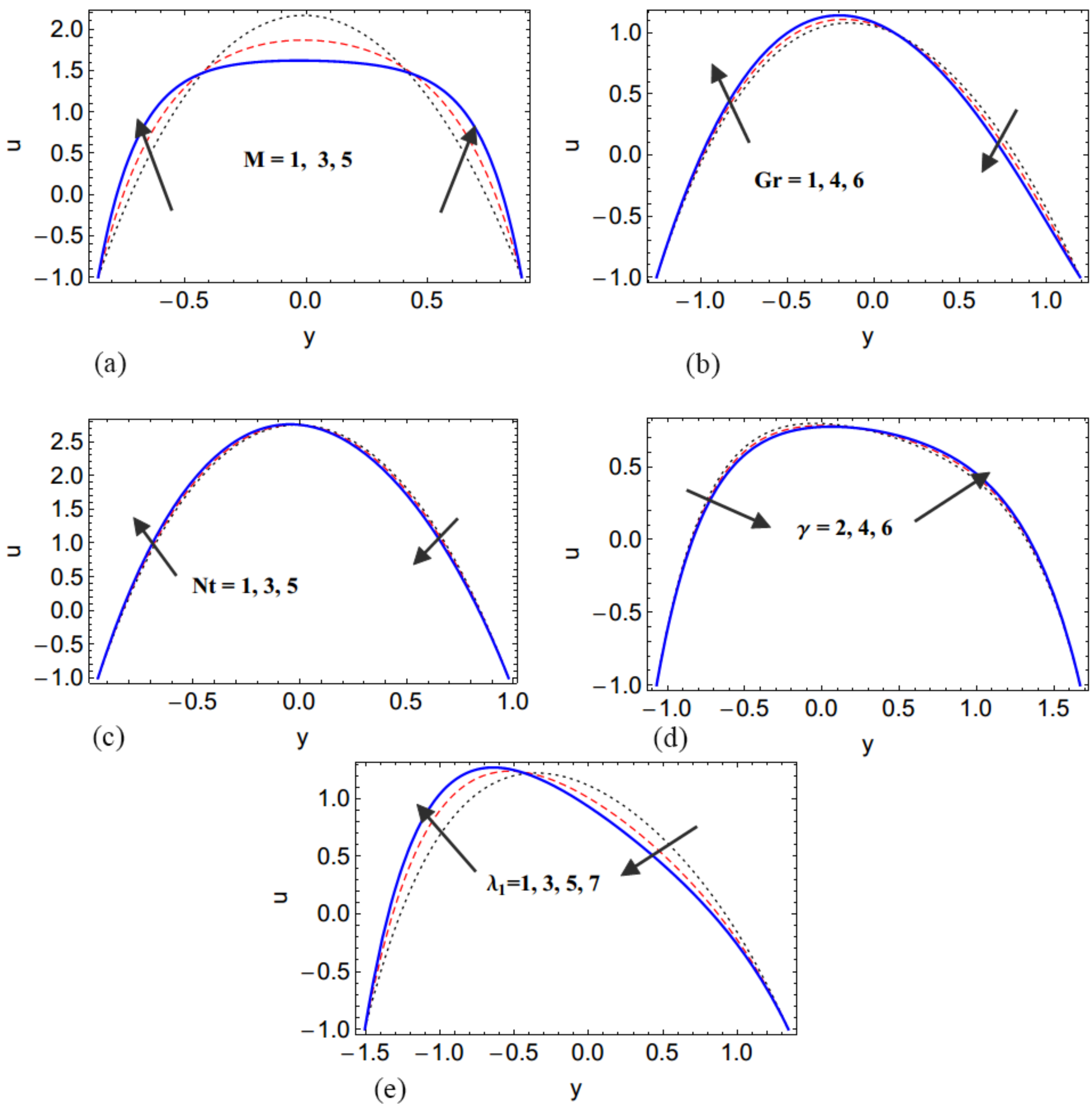

Fig 2. (a) Velocity Profiles for M, 2(b) Velocity Profiles for Gr, (c) Velocity Profiles for Nt, (d) Velocity Profiles for γ, (e) Velocity Profiles for λ_1

3.2 Dimensionless temperature

Figure 3 (a)-(d) is made to see the effects of Radiation parameter (Rn), Jeffrey fluid parameter (λ), Chemical reaction parameter (γ) and heat source parameter (β) on temperature. Influence of radiation parameter Rn, λ is illustrated in Figure 3(a), Figure 3(b). Figure 3(a) shows that the enhancing of radiation parameter Rn leads to decrease in the fluid temperature near the surface region. This is because rises in Rn have the tendency to increase the conduction effects. Therefore, higher value of radiation parameter implies higher surface heat flux and so, decreases the temperature at each point away from the surface. It is observed from Figure 3(b) that temperature (θ) decreases with λ. This is due to the reason that, the transverse magnetic field gives rise to a resistive force known as the Lorentz force of an electrically conducting fluid. This force makes the fluid experience a resistance by increasing the friction between its layers and thus decreases its temperature. Figure 3(c), Figure 3(d) is made to see the variation of γ, β on θ. It is found that θ increases with increase in γ, β. Obviously in heat source parameter β process more heat is produced which result in the enhancement of temperature field.

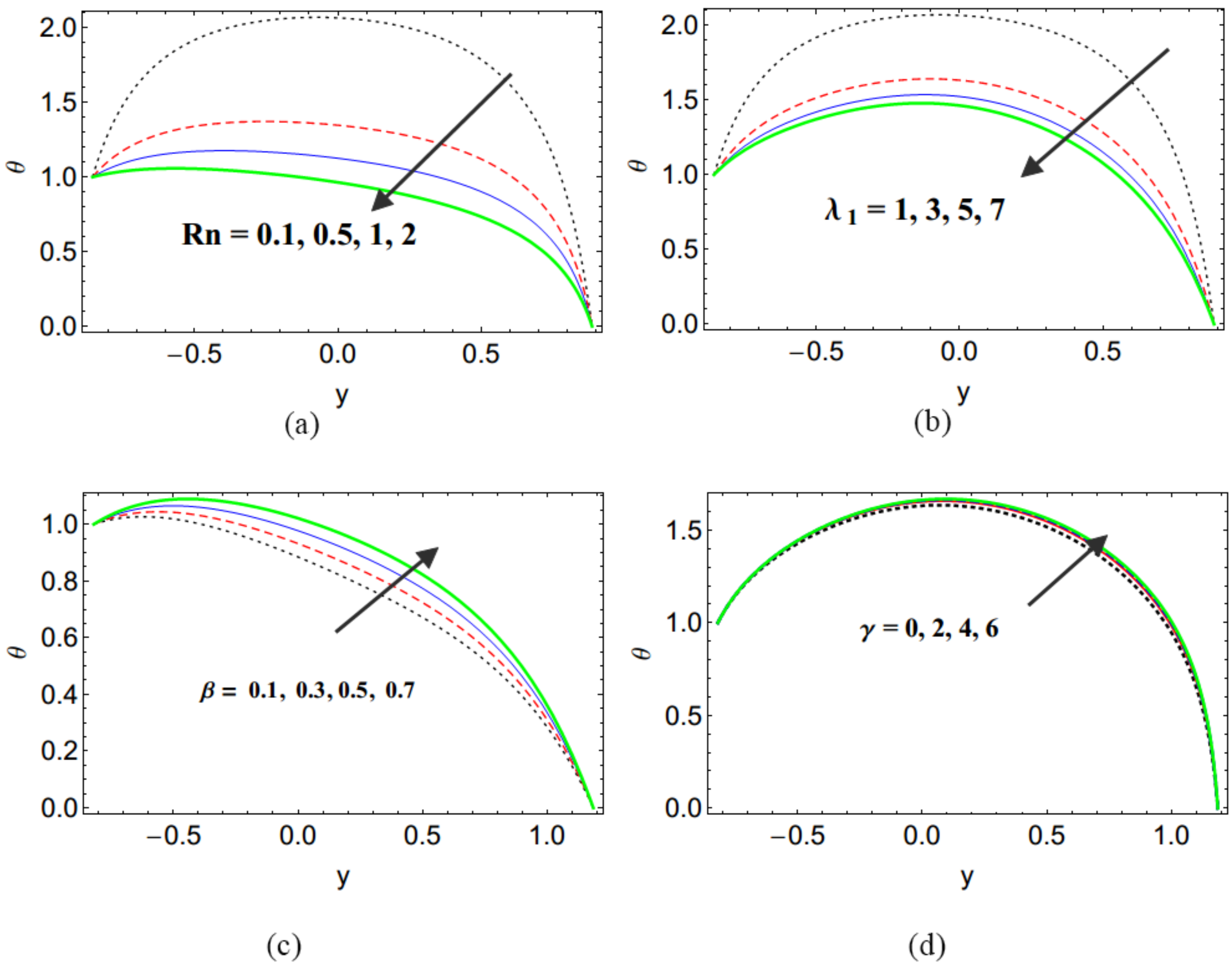

Fig 3. (a) Temperature Profile for Rn, (b) Temperature Profile for λ_1 , (c) Temperature Profile for β, (d) Temperature Profile for γ

3.3 Dimensionless concentration

It is clear from Figure 4 (a) that increasing chemical reaction parameter (γ) the concentration would be exhibited. Increase in γ increase in concentration profile (ϕ). Physically, fluid becomes thicker due to increasing value in γ which is reduced concentration profiles. Similar behavior is found with the case radiation parameter (Rn) Figure 4(d). A converse behavior can be found with the case of thermophoresis (Nt), heat source parameter (β) Figure 4(b) and Figure 4(c)

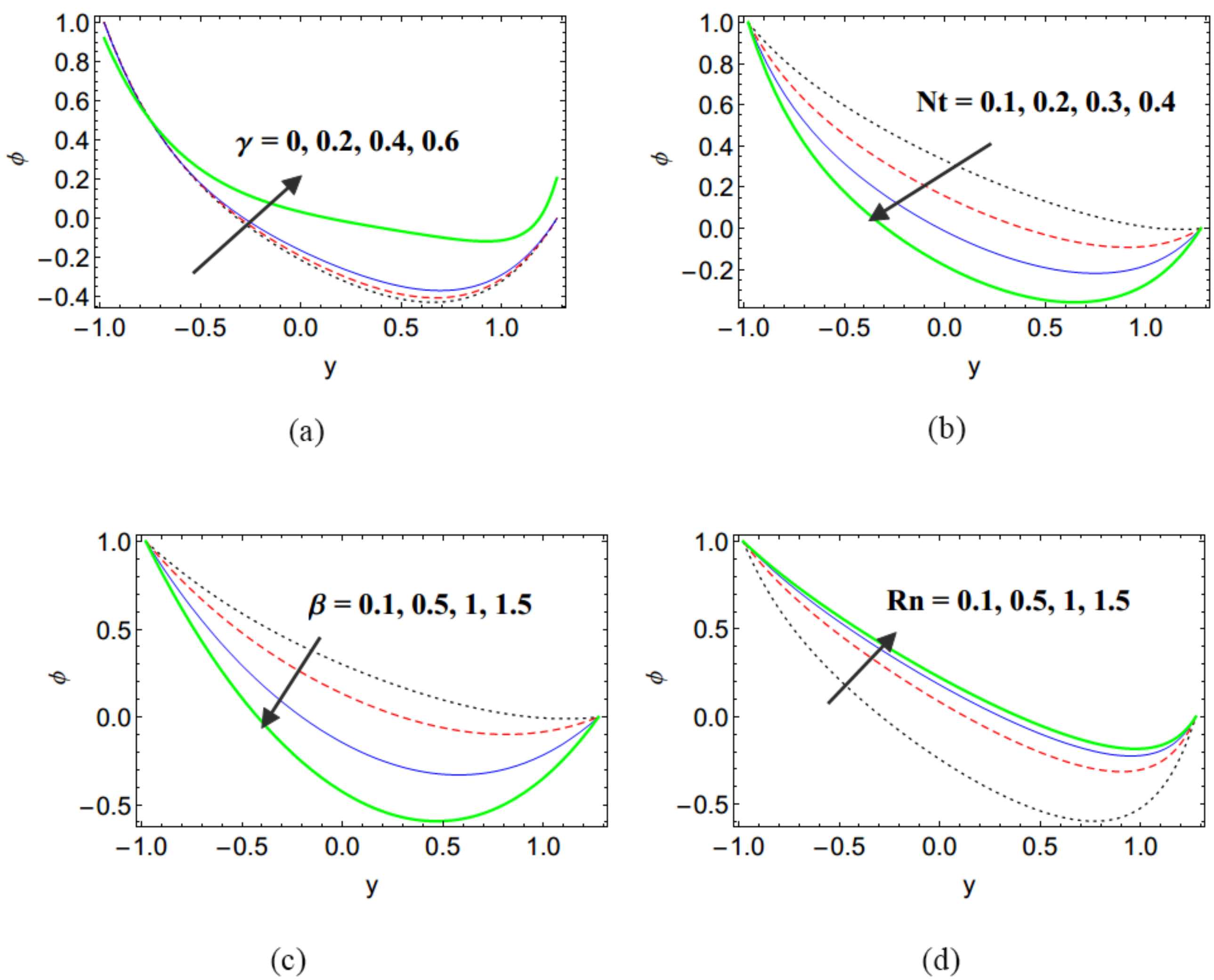

Fig 4. (a) Concentration Profile for γ, (b) Concentration Profile for Nt, (c) Concentration Profile for β, (d) Concentration Profile for Rn

4 Conclusion

The impact of nanofluid particles on the peristaltic bloodstream has been explored scientifically under the effects of thermal radiation and chemical response with the guide of the computational program Mathematica. The base liquid is considered as a Jeffrey fluid model within sight of an applied magnetic field. The administering flow is displayed for low Reynolds number and long wavelength.The present paper focused on heat generation and chemical reaction in flow propagated by peristalsis in hydro magnetic Jeffrey fluid with thermal radiation taking into consideration. The main findings are listed below.

- Velocity increases with the larger values of M at the channel walls. Velocity is enhanced in the lower part of the channel with increasing Gr, Nt and λ, whereas it behaves in converse with the chemical reaction parameter.
- It is observed that temperature (θ) decreases with Rn, λ. It is found that θ increases with increase in γ, β.
- Increase in γ increase in concentration profile (ϕ). Similar behavior is found with the case radiation parameter (Rn). A converse behavior can be found with the case of thermophoresis (Nt), heat source parameter (β).

References

1) Qasim M. Heat and mass transfer in a Jeffrey fluid over a stretching sheet with heat source/sink. *Alexandria Engineering Journal*. 2013;52(4):571–575. Available from: https://dx.doi.org/10.1016/j.aej.2013.08.004.
2) Rehman M, Noreen S, Haider A, Azam H. Effect of heat sink/source on peristaltic flow of Jeffrey fluid through a symmetric channel. *Alexandria Engineering Journal*. 2015;54(3):733–743. Available from: https://dx.doi.org/10.1016/j.aej.2015.03.011.
3) Ibrahim W, Shankar B. MHD boundary layer flow and heat transfer of a nanofluid past a permeable stretching sheet with velocity, thermal and solutal slip boundary conditions. *Computers & Fluids*. 2013;75:1–10. Available from: https://dx.doi.org/10.1016/j.compfluid.2013.01.014.
4) Ibrahim SM, Suneetha K. Heat source and chemical effects on MHD convection flow embedded in a porous medium with Soret, viscous and Joules dissipation. *Ain Shams Engineering Journal*. 2016;7(2):811–818. Available from: https://dx.doi.org/10.1016/j.asej.2015.12.008.
5) Prakash J, Siva EP, Tripathi D, Kothandapani M. Nanofluids flow driven by peristaltic pumping in occurrence of magnetohydrodynamics and thermal radiation. *Materials Science in Semiconductor Processing*. 2019;100:290–300. Available from: https://dx.doi.org/10.1016/j.mssp.2019.05.017.
6) Hayat T, Qayyum S, Shehzad SA, Alsaedi A. Chemical reaction and heat generation/absorption aspects in flow of Walters-B nanofluid with Cattaneo-Christov double-diffusion. *Results in Physics*. 2017;7:4145–4152. Available from: https://dx.doi.org/10.1016/j.rinp.2017.10.036.
7) Devi SPA, Kandasamy R. Effects of chemical reaction, heat and mass transfer on non-linear MHD laminar boundary layer flow over a wedge with suction or injection. *International Communications in Heat and Mass Transfer*. 2002;29(5):707–716. Available from: https://dx.doi.org/10.1016/s0735-1933(02)00389-5.
8) Muthucumaraswamy R. Effects of suction on heat and mass transfer along a moving vertical surface in the presence of chemical reaction. *Forschung im Ingenieurwesen*. 2002;67(3):129–132. Available from: https://dx.doi.org/10.1007/s10010-002-0083-2.
9) Machireddy GR, Kattamreddy VR. Impact of velocity slip and joule heating on MHD peristaltic flow through a porous medium with chemical reaction. *Journal of the Nigerian Mathematical Society*. 2016;35(1):227–244. Available from: https://dx.doi.org/10.1016/j.jnnms.2016.02.005.
10) Ganapathirao M, Ravindran R, Momoniat E. Effects of chemical reaction, heat and mass transfer on an unsteady mixed convection boundary layer flow over a wedge with heat generation/absorption in the presence of suction or injection. *Heat and Mass Transfer*. 2015;51(2):289–300. Available from: https://dx.doi.org/10.1007/s00231-014-1414-1.
11) Srinivasa R, Aruna G, Naidu S, Varma SVK, Rashidi MM. Chemically reacting fluid flow induced by an exponentially accelerated infinite vertical plate in a magnetic field and variable temperature via LTT and FEM. *Theoretical and Applied Mechanics*. 2016;43:49–83. Available from: https://dx.doi.org/10.2298/tam151214003s.
12) Alvi N, Latif T, Hussain Q, Asghar S. Peristalsis of nonconstant viscosity Jeffrey fluid with nanoparticles. *Results in Physics*. 2016;6:1109–1125. Available from: https://dx.doi.org/10.1016/j.rinp.2016.11.045.
13) Hayat T, Zahir H, Alsaedi A, Ahmad B. Numerical study of thermal radiation and thermophoresis on peristalsis with rotational aspects. *Results in Physics*. 2016;6:1044–1050. Available from: https://dx.doi.org/10.1016/j.rinp.2016.11.037.
14) Eid RM, Alsaedi A, Muhammad T, Hayat T. Comprehensive analysis of heat transfer of gold-blood nanofluid (Sisko-model) with thermal radiation. *Results in Physics*. 2017;7:4388–4393. Available from: https://dx.doi.org/10.1016/j.rinp.2017.11.004.
15) Raju RS, Reddy GJ, Rao JA, Rashidi MM. Thermal diffusion and diffusion thermo effects on an unsteady heat and mass transfer magnetohydrodynamic natural convection Couette flow using FEM. *Journal of Computational Design and Engineering*. 2016;3(4):349–362. Available from: https://dx.doi.org/10.1016/j.jcde.2016.06.003.
16) Reddy GJ, Raju RS, Manideep P, Rao JA. Thermal diffusion and diffusion thermo effects on unsteady MHD fluid flow past a moving vertical plate embedded in porous medium in the presence of Hall current and rotating system. *Transactions of A Razmadze Mathematical Institute*. 2016;170(2):243–265. Available from: https://dx.doi.org/10.1016/j.trmi.2016.07.001.
17) Asha SK, Sunitha G. Influence of thermal radiation on peristaltic blood flow of a Jeffrey fluid with double diffusion in the presence of gold nanoparticles. *Informatics in Medicine Unlocked*. 2019;17. Available from: https://dx.doi.org/10.1016/j.imu.2019.100272.
18) Abbas MA, Bhatti MM, Sheikholeslami M. Peristaltic Propulsion of Jeffrey Nanofluid with Thermal Radiation and Chemical Reaction Effects. *Inventions*. 2019;4(4):68–68. Available from: https://dx.doi.org/10.3390/inventions4040068.
19) Kavitha A, Reddy RH, Saravana R, Sreenadh S. Peristaltic transport of a Jeffrey fluid in contact with a Newtonian fluid in an inclined channel. *Ain Shams Engineering Journal*. 2017;8(4):683–687. Available from: https://dx.doi.org/10.1016/j.asej.2015.10.014.
20) Akbar NS, Nadeem S, Lee C. Characteristics of Jeffrey fluid model for peristaltic flow of chyme in small intestine with magnetic field. *Results in Physics*. 2013;3:152–160. Available from: https://dx.doi.org/10.1016/j.rinp.2013.08.006.
21) Ahmad K, Ishak A. Magnetohydrodynamic (MHD) Jeffrey fluid over a stretching vertical surface in a porous medium. *Propulsion and Power Research*. 2017;6(4):269–276. Available from: https://dx.doi.org/10.1016/j.jppr.2017.11.007.
22) Bhatti MM, Abbas MA. Simultaneous effects of slip and MHD on peristaltic blood flow of Jeffrey fluid model through a porous medium. *Alexandria Engineering Journal*. 2016;55(2):1017–1023. Available from: https://dx.doi.org/10.1016/j.aej.2016.03.002.
23) Reddy MG. Heat and mass transfer on magnetohydrodynamic peristaltic flow in a porous medium with partial slip. *Alexandria Engineering Journal*. 2016;55(2):1225–1234. Available from: https://dx.doi.org/10.1016/j.aej.2016.04.009.
24) Tripathi D, Bég OA. A study on peristaltic flow of nanofluids: Application in drug delivery systems. *International Journal of Heat and Mass Transfer*. 2014;70:61–70. Available from: https://dx.doi.org/10.1016/j.ijheatmasstransfer.2013.10.044.
25) Akbar NS, Nadeem S. Endoscopic Effects on Peristaltic Flow of a Nanofluid. *Communications in Theoretical Physics*. 2011;56:761–768. Available from: https://doi.org/10.1088/0253-6102/56/4/28.