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FLOW PAST A VERTICAL POROUS SURFACE UNDER FLUCTUATING THERMAL AND MASS DIFFUSION WITH MHD EFFECTS

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Abstract: This paper is examined with reference to critical parameters in the case of free MHD convection flow on a vertical porous surface under the fluctuating thermal and mass diffusion. An attempt has been made to understand the effects of the various critical parameters that appear in field equations and their effects over velocity field. It is noticed that, the prandtl number and velocity are inversely related. Moreover, it is observed that as the prandtl number increases, there is a decrease in the velocity and also back flow is observed. Even when the pore size of the bounding surface is decreased significant change in the velocity profiles is seen. Moreover, it is noticed that the prandtl number and temperature are directly proportional to each other.

Keywords: porous media; thermal radiation; heat and mass transfer; MHD effects.

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Nomenclature

C	Dimensionless species concentration
g	Gravity
Gc	Modified Grashof number
k	Thermal conductivity
C_r	Specific heat at constant pressure
C_w^*	Concentration at the wall
Gr	Grashof number
A	Suction parameter
C^*	Species concentration
C_∞^*	Concentration in free stream
h	Rarefaction parameter
T^*	Temperature
T_∞^*	Temperature of fluid in free stream
K^*	Permeability parameter
L^*	Constant
M	Magnetic intensity
V_0^*	Constant mean suction velocity
q_w^*	Heat flux at the wall
Sc	Schmidt number
t	Dimensionless time parameter
t^*	Time
V	Suction velocity
T_w^*	Temperature at wall
K	Dimensionless Permeability parameter
u	Dimensionless velocity component
u^*	Velocity component
Pr	Prandtl number
D	Molecular diffusivity of the species

Greek Symbols

ρ	:	Density of the fluid
υ	:	Fluid kinematic viscosity
θ	:	Dimensionless temperature
α	:	Thermal diffusivity
β	:	Coefficient of thermal expansion
ϵ	:	Amplitude (<<1)
μ	:	Viscosity
β_0:	:	Coefficient of thermal expansion with concentration
w:	:	Dimensionless frequency
σ:	:	Stefan-Boltzmann constant
τ	:	Dimensionless shearing stress
τ^*	:	Shearing stress
w^*	:	Frequency of excitation

1. INTRODUCTION

In several industrial and environmental situations radiative convective flow plays an important role. The advantages are chiefly found in astrophysical flows, energy processes, cooling chambers, solar power technology, fossil fuel combustion and space vehicle re-entry. The concept of radiative convection stream has a significant role in manufacturing sectors for the optimal design of highly precision equipment. Generally, nuclear plants, gas turbines, and propulsion devises for air craft, missiles and space vehicles are some examples.

Stokes [1] first started a force moving in its own plane, studied the last glutinous incomplete fluid problem of the infinite horizontal plate. Later, Brinkman [2] tested the viscous strength of the fluid. Later, Stewartson [3] studied a viscous flow on an analytical solution on a weakly-started partial-bound horizontal plate. Later, Berman [4] investigated a two-dimensional steady state flux case of an incomplete fluid with horizontal rigid porous walls, with the flow being driven by either suction or injection. Later, the flow between the two vertical panels is electrically non-conducting and observing the concept of the wall in the direction of the wall temperature, Mori [5] has observed the influence of the heat source in the vertical channel. Subsequently, Macey [6] studied the problem which occurs in the renal tubules as viscous flow through circular tube with a permeable boundary by prescribing their radial velocity at the wall as exponentially decreasing function as axial distance. Such a similar problem by using finite differences method of a mixed explicit and implicit time for the stability of the solution studied by Hall [7]. Later, Chang examined the influence of radioactive heat transfer in free convective systems in a chamber wrapped with special applications commonly enclosed in quadrilateral and geothermal reservoirs. Mahajan *et al* [8] has examined the devastating effect on the nature of logarithmic currents. Later, Soundlager and Thacker [9] tested thermal radiation effects of a thin gray gas exactly by the stable vertical plate. Subsequently, Hossain *et al* [10] analyzed the contribution of radiation on mixed synthesis with a vertical surface with a uniform surface temperature using Rosaland's estimation. Similar such an analysis was carried out by Rapits and Perdikis [11]. Consequently, the thermal radiation effects on the flow on the partial-infinite vertical plate with uniform heat flow during the alternate period of the magnetic field were tested by Chandrakala and Anthony Raj [12]. In an analysis by Rajakumari [13] an extensive analysis of several identified parameters on the flow entities has been made and interesting results were reported. Later, Sreedevi and Ramana Reddy *etal* [14] presented the influence of critical parameters in on MHD flow. Subsequently, the influcence of participating parameters in the velocity field has been thoroughly examied by Vedavathi [15] in the problem of Heat transfer on MHD nanofluid flow. The influence of different parameters has been explored in detail by Ramana Reddy [16] while examining the problem of heat and mass transfer flow through a highly porous medium with radiation and other effects. Fascinating conclusions have been drawn by Dhanalakshmi and Jayarami Reddy [17] while examining the contributin of time and other parameters in the problem of MHD Convective Flow over a vertical surface through Porous Medium. While studying the characteristic features in thestudy of flow and heat transfer of casson fluid over an exponentially porous stretching surface,Hymavathi and Sridhar [18] highlited the contribution of porosity and thermal radiation on the flow phenomena. The results obtained by them are note worthy and remarkable. In similar such situation, Raja Kumari [19] exhibited interesting results on the contribution of porosity and radiation while anlysing radiation absorption on convective heat and mass transfer flow of a viscous fluid. Based on the above studies, recently Vijaya [20] illustrated interesting results while investigting the influence of radiation in an unsteady situation of flow involving casson fluid. Motivated by the above studies, recently Ramana Reddy [21] highlighted theSoret and associated influence on MHD micropolar fluid flow. In the problem stated by Chandrasekhar [22], the contribution of identified parameters on the field entities are computed and the results are found to be significant from the application point of view.

2. MATHEMATICAL FORMULATION

In this paper, the flow is assumed to be unsteady and the fluid is assumed to be viscous and incompressible. The flow is over an infinite vertical porous flat plate. In this situation, a periodic temperature and concentration with variable suction velocity distribution

$\left[V^* = -V_0^*\left(1 + \varepsilon A e^{iw^*t^*}\right)\right]$ is considered. A rectangular Cartesian co-ordinate system is employed. The x^*-axis is considered vertically upwards along the vertical porous plate and y^*-axis is taken normal to the plate.

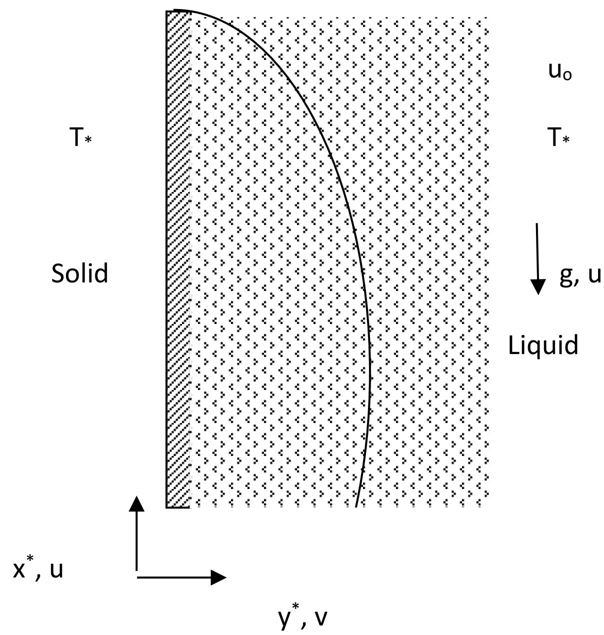

FIGURE: FLOW GEOMETRY OF THE PROBLEM

Plate is endless x * - in the direction. So, all physical parameters are independent of x *. Under these assumptions, the physical variables are only y * and t *. Hence, the difficulty can be controlled by the following equations equation by ignoring the viscosity of the viscosity and guessing the diversity of the body.

$$\frac{\partial u^*}{\partial t^*} - V_0^*\left(1 + \varepsilon A e^{iw^*t^*}\right)\frac{\partial u^*}{\partial y^*} = g\beta(T^* - T_\infty^*) + g\beta^0(C^* - C_\infty^*) + v\frac{\partial^2 u^*}{\partial y^{*2}} - \frac{\sigma\beta_0^2}{\rho}u^* - \frac{v}{K^*}u^* \quad (1)$$

$$\rho C_P\left[\frac{\partial T^*}{\partial t^*} - V_0^*\left(1 + \varepsilon A e^{iw^*t^*}\right)\frac{\partial T^*}{\partial y^*}\right] = k\frac{\partial^2 T^*}{\partial y^{*2}} \quad (2)$$

$$\frac{\partial C^*}{\partial t^*} - V_0^*\left(1 + \varepsilon A e^{iw^*t^*}\right)\frac{\partial C^*}{\partial y^*} = D\frac{\partial^2 C^*}{\partial y^{*2}} \quad (3)$$

The boundary conditions are:

$$u^* = L^*\left(\frac{\partial u^*}{\partial y^*}\right), T^* = T_w^* + \varepsilon(T_w^* - T_\infty^*)e^{iw^*t^*}, C^* = C_w^* + \varepsilon(C_w^* - C_\infty^*)e^{iw^*t^*} at\ y^* = 0$$

$$u^* \to 0,\ \ T^* \to T_\infty^*,\ \ C^* \to C_\infty^*\ as\ y^* \to \infty \tag{4}$$

The following non-dimensional quantities are introduced

$$y = \frac{y^* V_0^*}{v}, t = \frac{t^* V_0^{*2}}{4v}, u = \frac{4vw^*}{V_0^{*2}}, \theta = \frac{T^* - T_\infty^*}{T_w^* - T_\infty^*}, C = \frac{C^* - C_\infty^*}{C_w^* - C_\infty^*}, Gr = \frac{g\beta v(T^* - T_\infty^*)}{V_0^{*3}},$$

$$Gc = \frac{g\beta v(C_w^* - C_\infty^*)}{V_0^{*3}}, Pr = \frac{\mu C_p}{k} = \frac{v\rho C_p}{k}, Sc = \frac{v}{D}, M = \frac{\sigma\beta_0^2 v}{\rho V_0^{*2}}, K = \frac{K^* V_0^{*2}}{v^2}, h = \frac{V_0^* L^*}{v}$$

Above equations (1) to (3) reduce to dimension less form as given below:

$$\frac{1}{4}\frac{\partial u}{\partial t} - \left(1 + \varepsilon A e^{iwt}\right)\frac{\partial u}{\partial y} = Gr\theta + GcC + \frac{\partial^2 u}{\partial y^2} - Mu - \frac{u}{k} \tag{5}$$

$$\frac{1}{4}\frac{\partial \theta}{\partial t} - \left(1 + \varepsilon A e^{iwt}\right)\frac{\partial \theta}{\partial y} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial y^2} \tag{6}$$

The conditions on the boundary in the Non-dimension form are as follows:

$$\left.\begin{aligned} &u = h\left(\frac{\partial u}{\partial y}\right), \theta = 1 + \varepsilon e^{iwt}\ at\ y = 0 \\ &u, \theta \to 0\ \text{ and }\ \text{ as }\ y \to \infty \end{aligned}\right\} \tag{7}$$

3. SOLUTION METHODOLOGY

Under the assumption that the oscillations are sufficiently small ($\varepsilon \ll 1$), We represent the speed θ and concentration c, at the bottom of this plate:

$$u(y,t) = u_0(y)e^{iwt} \tag{8}$$

$$\theta(y,t) = \theta_0(y)e^{iwt} \tag{9}$$

Substituting (8) and (9) in (5) and (6) respectively and equating the like terms on both sides

$$u_0'' + u_0' - \left(M + \frac{1}{K} + \frac{iw}{4}\right)u_0 = -Gr\theta_0 - GcC_0 - Au_0' \tag{10}$$

$$\theta_0'' + Pr\theta_0' - \frac{iwPr}{4}\theta_0 = -A\theta_0' Pr \tag{11}$$

The respective boundary conditions will now be:

$$u_0 = 0,\ \frac{\partial u_0}{\partial y} = 0\quad at y = 0\quad,\ \theta_0 = 1, \frac{\partial \theta_0}{\partial y} = 0\quad at\ y = 0 \tag{12}$$

The solution for equations (10) and (11) satisfying the boundary conditions (12) gives rise to

$$u_0(y) = c_1 e^{m_1 y} + c_2 e^{m_2 y} + \frac{Gr\theta_0 + GcC_0}{\left(M + \frac{1}{K} + \frac{iw}{4}\right)} \tag{13}$$

$$\theta_0(y) = c_3 e^{m_3 y} + c_4 e^{m_4 y} \tag{14}$$

Wherein: $m_1 = \frac{-(1+A)+\sqrt{(1+A)^2+4(M+\frac{1}{K}+\frac{iw}{4})}}{2}$, $m_2 = \frac{-(1+A)-\sqrt{(1+A)^2+4(M+\frac{1}{K}+\frac{iw}{4})}}{2}$,

$$c_1 = \frac{m_2}{m_1 - m_2} \cdot \frac{Gr\theta_0 + GcC_0}{\left(M + \frac{1}{K} + \frac{iw}{4}\right)},$$

$c_2 = \frac{-m_1}{m_1-m_2} \cdot \frac{Gr\theta_0+GcC_0}{\left(M+\frac{1}{K}+\frac{iw}{4}\right)}$, $m_3 = \frac{-(1+A)Pr+\sqrt{(\Pr(1+A))^2+iwPr}}{2}$, $m_4 = \frac{-(1+A)Pr-\sqrt{(\Pr(1+A))^2+iwPr}}{2}$

$$c_3 = \frac{m_3 - m_4 - 1}{m_3 - m_4}, c_4 = \frac{1}{m_3 - m_4}$$

4. RESULTS AND DISCUSSIONS

1. Fig. 1 and Fig. 2illustrates the contribution of prandtl number over velocity field. It is seen the prandtl number and velocity are directly proportional to each other. Further, in this situation, aretarded flow is noticed.

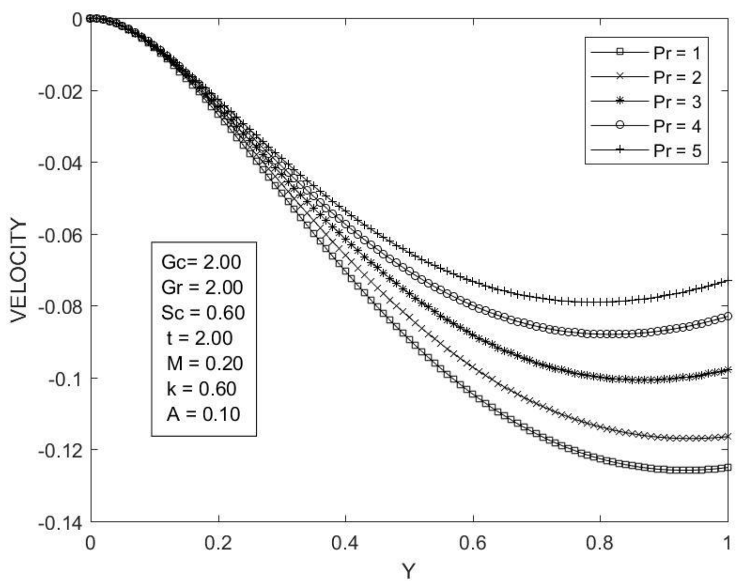

Fig:-1: Influence of Prandtl number over velocity profiles

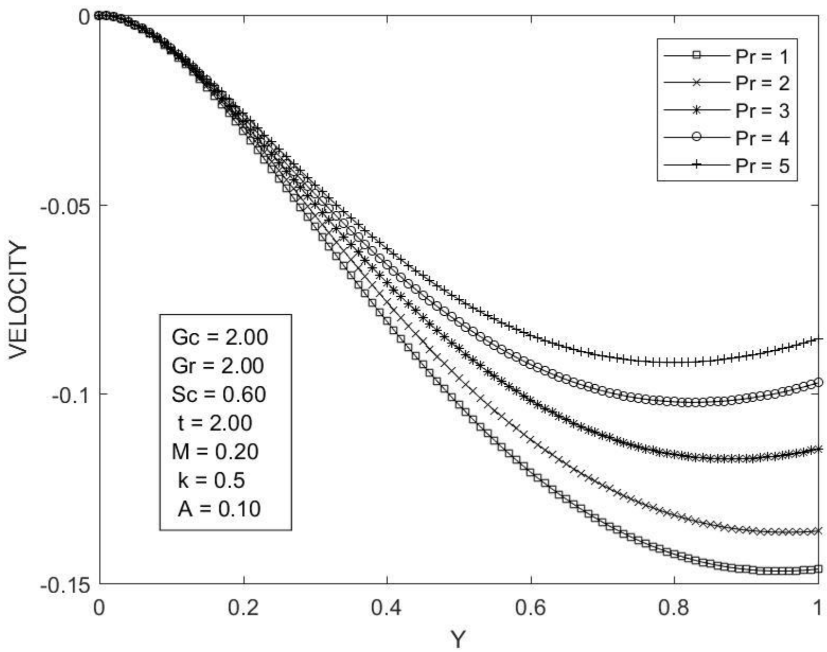

Fig:-2: Effect of Prandtl number over velocity profiles

2. Fig. 3, Fig. 4, Fig. 5 and Fig. 6depicts the effects of prandtl number over the velocity field for the pore size of 0.4, 0.3, 0.2 and 0.1 respectively. A retarded flow is noticed in this case. It is noticed that the prandtl number and the velocity field are directly proportional to each other.

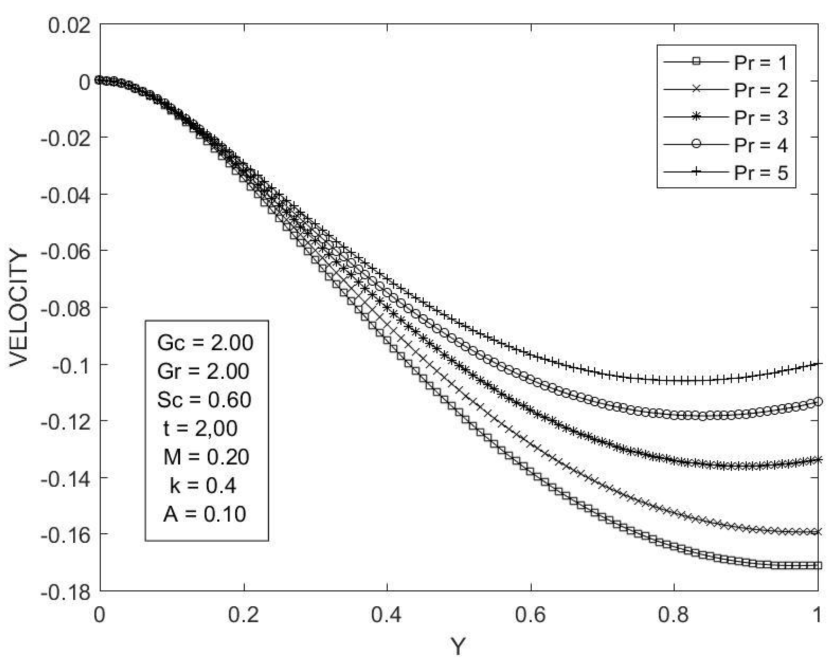

Fig:-3: Contribution of Prandtl number over velocity

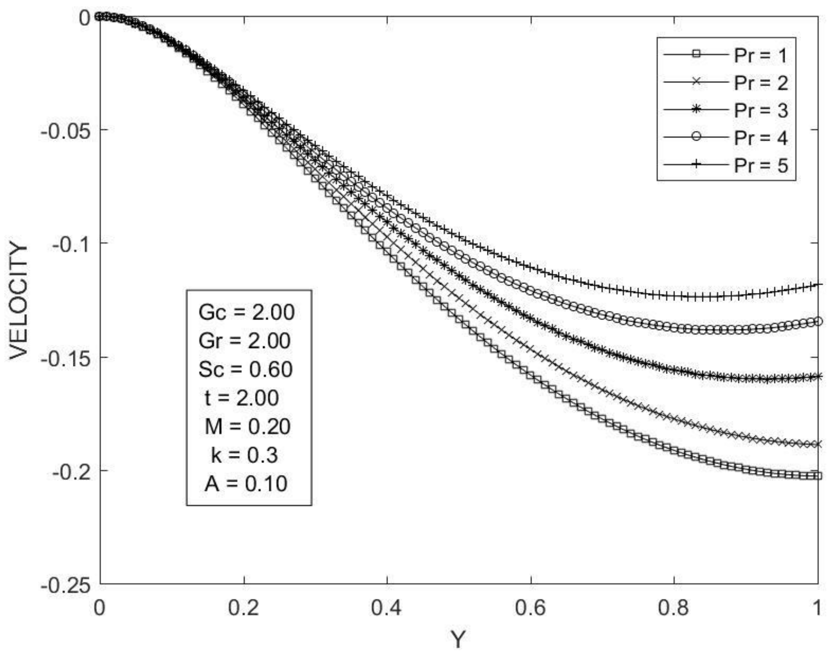

Fig: -4: Contribution of Prandtl number w.r.t velocity

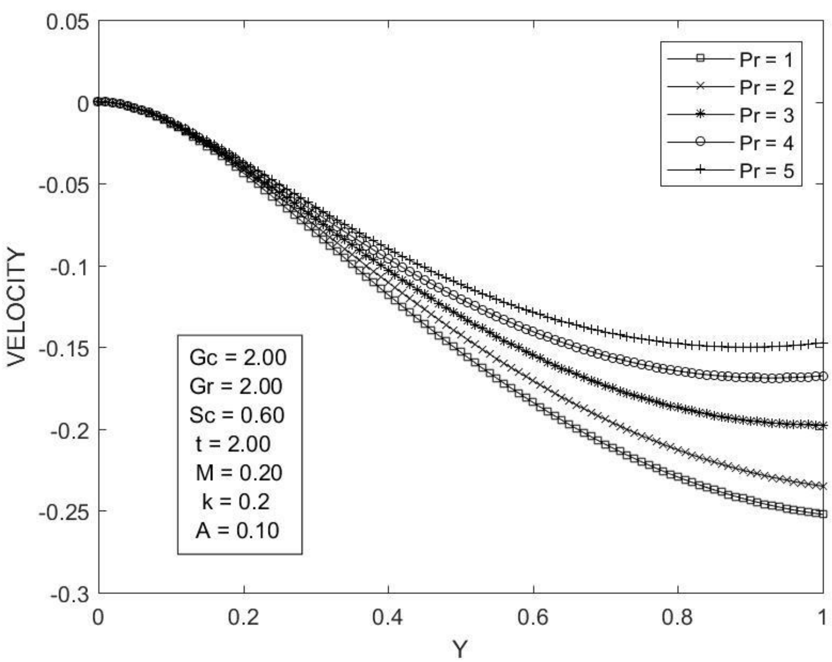

Fig:-5: Contribution of Prandtl number on velocity

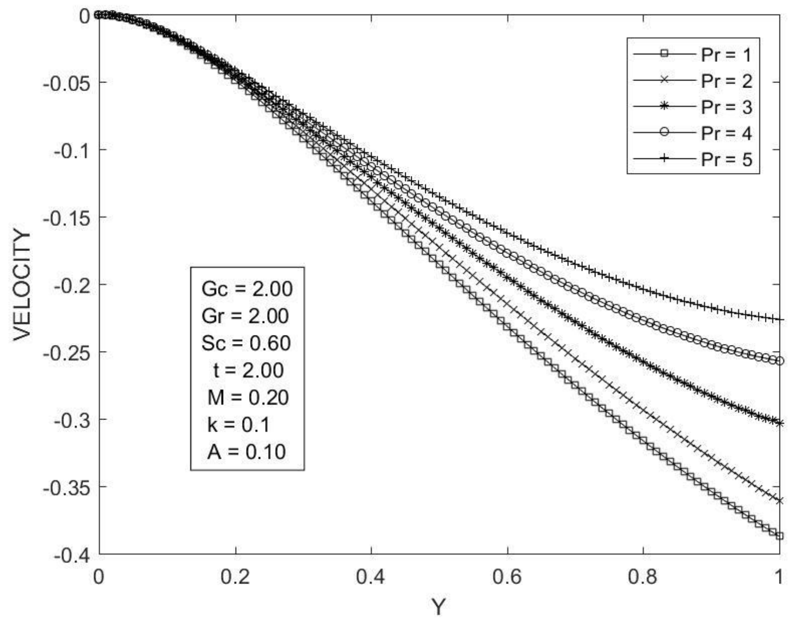

Fig:-6: Contribution of Prandtl number w.r.t velocity profiles

3. Fig. 7 to Fig. 12 shows the influence of prandtl number on temperature profiles. The pore sizes considered are 0.6, 0.5, 0.4, 0.3, 0.2 and 0.1 respectively. It is observed that as the prandtl number increases, the temperature also increases.

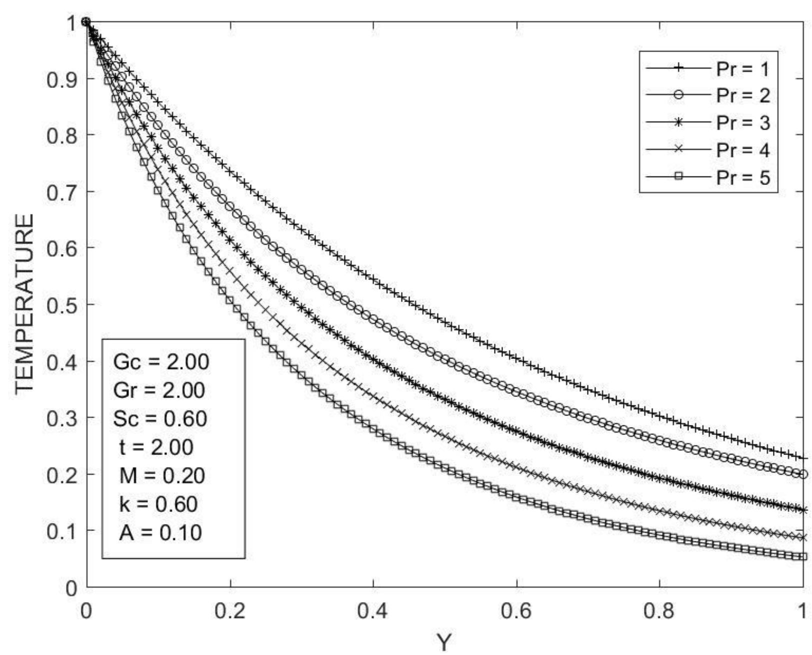

Fig:-7: Contribution of prandtl number w.r.t temperature

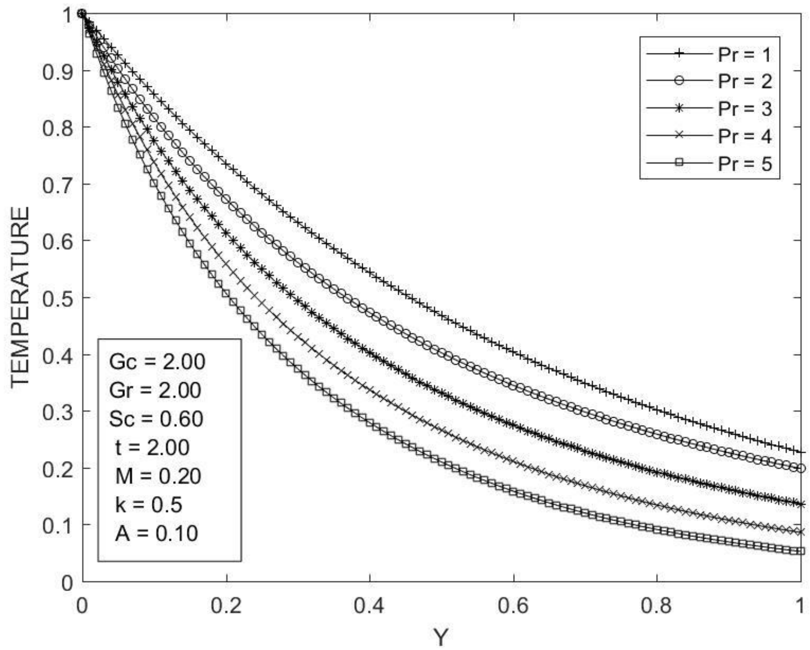

Fig:-8: Influence of prandtl number on temperature

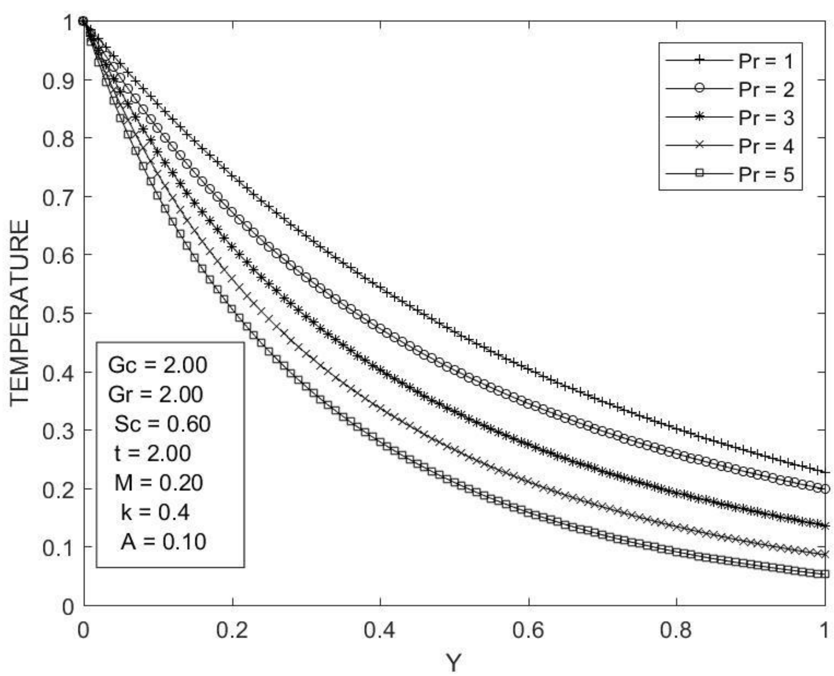

Fig:-9: Contribution of prandtl number on temperature

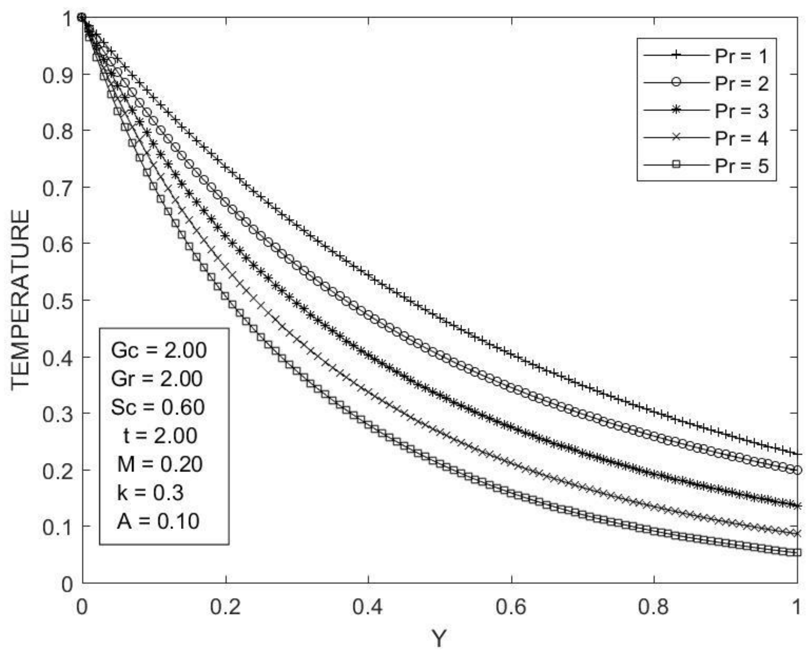

Fig:-10: Contribution of prandtl number over temperature

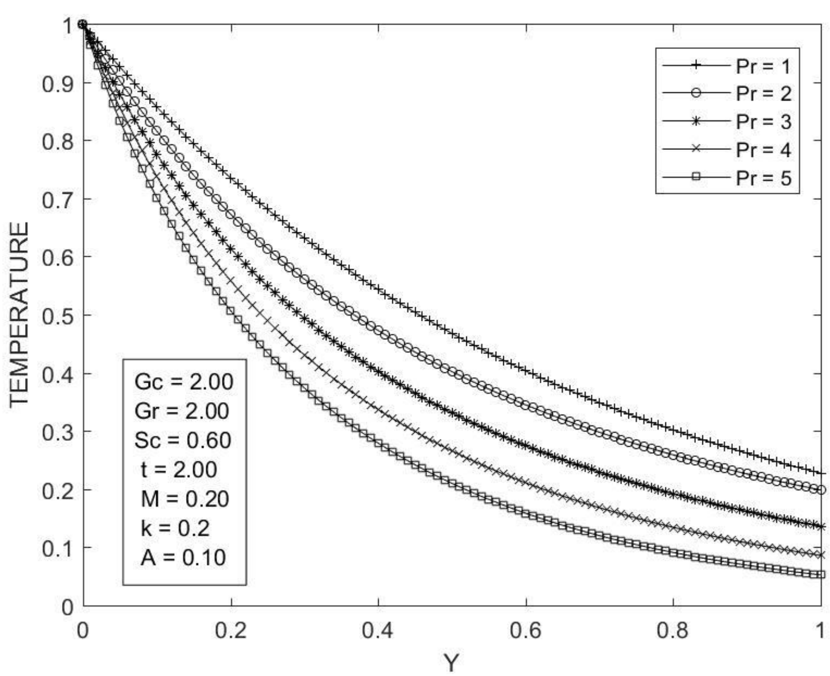

Fig:-11: Contribution of prandtl number on temperature

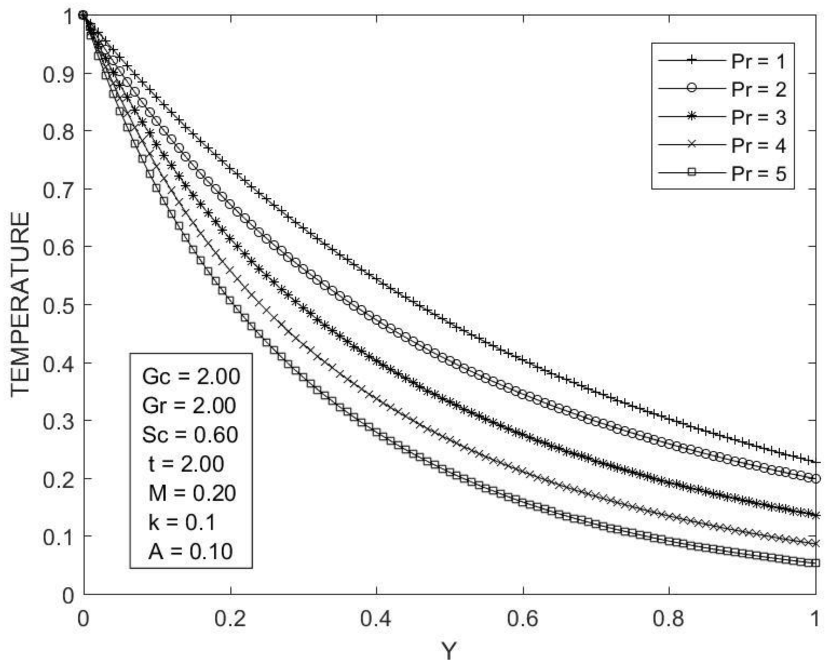

Fig:-12: Contribution of prandtl number on temperature

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

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