

EFFECT OF CHEMICAL REACTION ON MHD FREE CONVECTION FLOW THROUGH POROUS MEDIUM WITH SUCTION AND HEAT FLUX AND RADIATION EFFECTS ON PERISTALTIC TRANSPORT

Submitted in partial fulfilment of the requirements for the award of Bachelor
of Science Degree in Mathematics

By

S. Aishwarya Ganavati (39060002)



DEPARTMENT OF MATHEMATICS
SCHOOL OF SCIENCE AND HUMANITIES

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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JEPPIAAR NAGAR, RAJIV GANDHI SALAI,

CHENNAI - 600 119

APRIL – 2022



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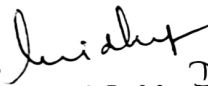
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of
Aishwarya Ganavati. S (39060002) who carried out the project entitled "
**EFFECT OF CHEMICAL REACTION ON MHD FREE CONVECTION
FLOW THROUGH POROUS MEDIUM WITH SUCTION AND HEAT
FLUX AND RADIATION EFFECTS ON PERISTALTIC TRANSPORT**"
under our supervision from January to April 2022.


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Submitted for Viva voce Examination held on 11/05/22

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DECLARATION

I **AISHWARYA GANAVATI. S (39060002)** hereby declare that the Project Report entitled "**EFFECT OF CHEMICAL REACTION ON MHD FREE CONVECTION FLOW THROUGH POROUS MEDIUM WITH SUCTION AND HEAT FLUX AND RADIATION EFFECTS ON PERISTALTIC TRANSPORT**" done by me under the guidance of **Dr.M.Vidhya** (Internal) at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** submitted in partial fulfillment of the requirements for the award of Bachelor of Science Degree in Mathematics

DATE: 25.04.2022

PLACE: CHENNAI



SIGNATURE OF THE CANDIDATE

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A handwritten signature in black ink, appearing to read 'Dr. M. Vidhya', is written over a horizontal line.

Internal Guide
Dr.M. VIDHYA

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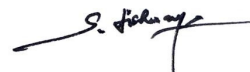
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ABSTRACT

- This investigation is concerned with the two-dimensional flow of an electrically conducting fluid bounded by a vertical infinite surface with constant suction velocity and constant heat flux. The fluid fills the porous medium. Mass transfer in presence of chemical reaction is considered. Variations of Grashof numbers for heat and mass transfer, Schmidt number, Eckert number, permeability parameter, chemical reaction parameter and magnetic number on the velocity and temperature profiles are discussed graphically.
- This paper deals with the effect of the thermal radiation on peristaltic transportation of a couple stress fluid in an asymmetric channel in the presence of external magnetic field. The governing equations are reduced by using very low Reynolds number and long-wavelength rough calculations. Closed-form analytical expressions for axial velocity and temperature distribution have been obtained. Graphs are plotted and analyzed by using various parameters and the effects are seen in the graph.

KEYWORDS USED: Couple stress fluid, peristaltic, tapered, asymmetric channel, MHD, conducting fluid, porous medium, chemical reaction and heat transfer.

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CHAPTER – 1

1. INTRODUCTION

1.1 FLUID DYNAMICS

- Fluid dynamics offers a systematic structure which underlines these practical disciplines that embraces empirical and semi empirical laws derived from flow measurement and used to solve practical problems. The solution to a fluid dynamics problem typically involves the calculation of various properties of the fluid, such as flow velocity, pressure, density and temperature as functions of space and time.
- Chemical reaction can be classified as either heterogeneous or homogeneous processes. This depends on whether they occur at an interface or as a single phase volume reaction. In well-mixed systems, the reaction is heterogeneous, if it takes place at an interface and homogeneous, if it takes place in solution. In most cases of chemical reactions, the reaction rate depends on the concentration of the species itself. A reaction is said to be of first order, if the rate of reaction is directly proportional to the concentration itself.
- Porous media are widely used in high temperature heat exchangers, turbine blades, jet nozzles, etc. In practice cooling of porous structure is achieved by forcing the liquid or gas through capillaries of solid. In order to make heat insulation of surface more effective it is necessary to study the free convection flow through a porous medium and to estimate its effect in heat and mass transfer.

1.2 APPLICATIONS

- Fluid dynamics is used to measure the forces acting on the aircraft.
- This is used to track content flow levels such as oil from pipelines.
- This may also be used in traffic engineering (traffic viewed as a continuous flow of liquids).

1.3 IMPORTANCE OF FLUID DYNAMICS

Fluid dynamics provides methods for studying the evolution of stars, ocean currents, weather patterns, plate tectonics and even blood circulation. Some

important technological applications of fluid dynamics include rocket engines, wind turbines, oil pipelines and air conditioning systems.

1.4 POROUS MEDIUM :

- ✓ Porous medium are solid materials that are composed of pore structures, which are typically fluid filled in biological applications
- ✓ Most naturally occurring minerals like sand, lime stones are consolidated having been subjected to compressive forces for long times.
- ✓ Porous media may be characterized at two distinct levels:
 1. Microscopic
 2. Macroscopic
- ✓ A porous material is said to have a permeability of 1 darcy if a pressure gradient of 1 atm/cm results in a flow of $1 \text{ cm}^3 / \text{s}$ of a fluid having viscosity of 1 cP through an area of 1 cm^2 .

1.5 MAGNETO HYDRODYNAMICS:

- ✓ It is also called magneto-fluid dynamics or hydromagnetics.
- ✓ MHD is the study of magnetic properties and behavior of electrically conducting fluids.
- ✓ Magneto- magnetic field, hydro- water and dynamics- movement.
- ✓ The concept behind MHD is that the magnetic fields induce currents in a moving conductive fluid, which in turn polarizes the fluid and reciprocally changes the magnetic field itself.
- ✓ Eg: plasmas, liquid metals, salt water and electrolytes.

1.6 THERMAL RADIATION

- ✓ Heat travelling by radiation is called as radiant heat or thermal radiation.

- Thermal Radiation is the transmission of thermal energy without any physical contact between the bodies involved.
- Unlike heat transfer by conduction and convection, transport of thermal radiation does not necessarily affect the material medium between heat source and receiver.
- Energy released by a radiating surface is not continuous but it is in the form of successive .

1.7 PROPERTIES OF THERMAL RADIATION

- Thermal radiation having the phenomenon of interference, diffraction, polarization of light.
- They travels in straight lines like light.
- It can travel through empty space with velocity of light.
- Thermal radiation are reflected and refracted like light.
- Obeys the law of Inverse square.

1.8 COUPLE STRESS FLUID

The theory of couple stresses in fluids, developed by stokes in 1966, represents the simplest generalization of the classical theory and allows for polar effects such as the presence of couple.

- Couple Stress fluid theory is a simple generalization of the classical theory of viscous Newtonian fluids that allow the sustenance of couple stresses and body couples in the fluid medium.
- The concept of couple stresses arises due to the way in which the mechanical interactions in the fluid medium are modeled.
- The solution to Couette flow for couple stress fluid is same as that of Newtonian fluid.
- The velocity in Couette flow increases significantly when the lower plates moves in the directions of upper plates.
- The presence of couple stress has a decreasing effect on the fluid velocity and the volume flow rate.

1.9APPLICATION OF COUPLE STRESS FLUID

Couple stress fluid has been the subject of interest due to its numerous industrial and scientific applications such as extrusion of polymer fluids, solidification of liquid crystals and animal bloods.

1.10 PERISTALSIS

Peristalsis is a mechanism whereby waves of contraction propagate along the exterior of a fluid filled tube or chamber. Peristaltic pumping is observed in numerous physiological contexts where tubular smooth muscle structures are common such as in the gastrointestinal tract, the bile ducts and the Fallopian tubes.

1.11ADVANTAGES

- ✓ No contamination. Because the only part of the pump in contact with the fluid being pumped is the interior of the tube, it is easy to sterilize and clean the inside surfaces of the pump.
- ✓ Low maintenance needs and easy clean; their lack of valves, seals and glands makes them comparatively inexpensive to maintain.
- ✓ They are able to handle slurries, viscous, shear-sensitive and aggressive fluids.
- ✓ Pump design prevents back flow and siphoning without valves.
- ✓ A fixed amount of fluid is pumped per rotation, so it can be used to roughly measure the amount of pumped fluid.

1.12 DISADVANTAGE

- ✓ The flexible tubing will tend to degrade with time and require periodic replacement.
- ✓ The flow is pulsed, particularly at low rotational speeds. Therefore, these pumps are less suitable where a smooth consistent flow is required. An alternative type of positive displacement pump should be considered.

1.13 APPLICATION

- Peristalsis have a wide applications in manufacturing engineering and physiology.
- It is also used in the urine transport from a kidney to the bladder and the transport of the spermatozoa in the cervical canal, the chime movement in the large intestine.

CHAPTER -2

2.1 LITERATURE SURVEY:

M. Kothandapani, J. Prakash, V. Pushparaj (1) (2015) analysed on analysis of heat and mass transfer on MHD peristaltic flow through a tapered asymmetric channel. The peristaltic flow of an incompressible viscous fluid in a tapered asymmetric channel with heat and mass transfer. In the presence of the magnetic field the fluid is electrically conducting fluid. The propagation of waves on the non uniform channel walls have different amplitudes and phase but with the same speed which is generated by the tapered asymmetric channel. The complicated problem was simplified into a relatively simple problem by using the assumptions of low Reynolds number and long wavelength approximation. An analytical expression for velocity, temperature and concentration was obtained. The flow characteristics for various embedded parameter are shown through graphs.

Y.C. Fung and C.S. Yih (2) in (1991) discussed peristaltic pumping at moderate amplitudes of motion is analysed in the two-dimensional case. The non-linear convective acceleration was considered and the nonslip condition was applied on the wavy wall in order to account for the mean flow induced by the wall motion. The mean flow induced by the peristaltic motion of the wall is proportional to the square of the amplitude ratio. The velocity profile depends on the mean pressure gradient. If the pressure gradient is positive and equal to a certain value, then the velocity is zero on the center line. Pumping against a positive pressure gradient greater than the critical value would induce a backward flow in the core region of the stream. There will be no reflux if the pressure gradient is smaller than the critical value. The velocity profile and the value of the critical pressure gradient were presented.

M. Gnaneswara Reddy, K. Venugopal Reddy, O. D. Makinde (3) (2016) studied on Hydro magnetic peristaltic motion of a reacting and radiating couple stress fluid in an inclined asymmetric channel filled with porous medium. The mathematical modeling was investigated by using long wavelength and low Reynolds number. The exact solution was evaluated for the stream function, velocity, temperature, concentration and pressure gradient. By using numerical integration the pressure rise solution was simplified. The effects of Hartmann number, Darcy number, thermal Grashof number, couple stress parameter, thermal radiation parameter,

species Grashof number, heat generation parameter, inclination angle and chemical reaction reaction parameter on the velocity characteristics, heat and mass transfer characteristics and pumping characteristics were discussed and presented graphically.

J.C. Mishra and S.K. Pandey (4) in 1995 analysed on peristaltic transport in a tapered tube. The axisymmetric peristaltic flow of a viscous incompressible Newtonian fluid through a circular tube of varying cross section was studied when the wave propagating along the wall of the tube is sinusoidal and the initial flow is Hagen- Poiseuille. A perturbation technique was employed to analyze the problem for nonlinear convective acceleration terms. Two particular cases were found. The Reynolds number is small and the wave number is small.

K S Mekheimer, Shehawey (5) (1994) analysed on Couple stresses in peristaltic transport of fluids using a peristaltic pump by a sinusoidal travelling wave in the walls of a two-dimensional channel filled with viscous incompressible couple-stress fluid. A perturbation solution was obtained, which satisfies the equation of momentum for the case in which the amplitude ratio is small. It shows that the mean axial velocity decreases with increase in couple stress parameter. The phenomenon of mean flow reversal was discussed. A reversal of velocity in the neighbourhood of the centre line occurs when the pressure gradient is greater than that of the critical reflux condition. It was found that the critical reflux pressure increases with the couple stress parameter.

A Sinha, G C Shit, NK Ranjit (6) (2015) presented a theoretical study on Peristaltic transport on MHD flow and heat transfer in an asymmetric channel. The energy equation was formulated by including a heat source term which stimulates either absorption or generation. The governing equations of motion and energy were simplified using long wavelength and low Reynolds number. The coupled non-linear differential equations were solved analytically by means of perturbation method for small values of Reynolds model viscosity parameter. The salient features of pumping and trapping with we discussed with particular focus on the effects of velocity-slip parameter, Grashoff number and magnetic parameter. The study reveals that the velocity at the central region diminishes with increase values of velocity-slip parameter. The size of trapped bolus decreases and finally vanishes for large values of magnetic parameter.

J. Suresh Goud, R. Hemadri Reddy (7) (2018) investigated on Hall effects on peristaltic flow of a couple stress fluid in an inclined asymmetric channel with permeable walls. They investigated the peristaltic mechanism in the digestive system by considering the particle size effects. Perturbation method was used to get the solution using long wavelength approximation with low Reynolds number and dynamic boundary conditions. As a result, The pressure gradient increases in the narrow part of the channel and decreases the major part of the channel with increasing of couple stress parameter η and permeability parameter β . The pressure rise ΔP_λ decreases in the retrograde region and it increases in the co pumping region when the Hall parameter m increases. Pressure rise ΔP_λ decreases in all pumping regions when permeability parameter β increases. With an increase of Hall parameter m , the magnitude of velocity profile $u(y)$ increases.

NaveedIqbal, HumairaYasmin, Bawfeh K. Kometa , Adel A. Attiya (8) (2020) analysed on Effects of Convection on Sisko Fluid with Peristalsis in an Asymmetric Channel. This article deals with Sisko fluid flow exhibiting peristaltic mechanism in an asymmetric channel with sinusoidal wave propagating down its walls. The channel walls in heat transfer process satisfy the convective conditions. The flow and heat transfer equations are modeled and non-dimensionalized. Analysis has been carried out subject to low Reynolds number and long wavelength considerations. Analytical solution is obtained by using the regular perturbation method by taking Sisko fluid parameter as a perturbed parameter. The shear-thickening and shear-thinning properties of Sisko fluid in the present nonlinear analysis are examined. Comparison is provided between Sisko fluid outcomes and viscous fluids. Velocity and temperature distributions, pressure gradient and streamline pattern are addressed with respect to different parameters of interest. Trapping and pumping processes have also been studied. As a result, the thermal analysis indicates that the implementation of a rise in a non-Newtonian parameter, the Biot numbers and Brinkman number increases the thermal stability of the liquid.

CHAPTER – 3

3.1 AIM

- Our aim is to investigate the analysis of velocity profile and temperature profile using various parameters.
- To study the flow of the couple stress fluid moving through porous asymmetric channel.
- The effects of velocity and temperature are studied for the increase and decrease with various parameters.

3.2 SCOPE

- It includes theoretical, numerical and experimental studies that contributes to the fundamental understanding and application of fluid phenomena.
- It includes the urine transport from a kidney to bladder and the transport of the spermatozoa in the cervical canal, the chime movement in the large intestine.

3.3 DESCRIPTION OF RESEARCH WORK:

This research work gives the interpretation of analytical solution obtained for various fluid flow problems using matlab . Here the problem is solved by using perturbation technique.

3.4 RESEARCH METHODOLOGIES:

Analytical solutions are obtained by transforming the partial differential equation concerning the flow into an ordinary linear differential equation with constant coefficients by using perturbation method. The arbitrary constants are then calculated by using boundary conditions of the respective non-linear equations. The results are interpreted by using MATLAB applications.

CHAPTER – 4

4.1 .MATHEMATCAL FORMULATION

The flexible tapered asymmetric channel filled with porous medium is considered.

The channel walls are given by

$$H_2(X,t') = d + m' X + b_2 \sin \frac{2\pi}{\lambda} (X - ct') \quad (1)$$

$$H_2(X,t') = -d - m' X - b_1 \sin \left[\frac{2\pi}{\lambda} (X - ct') + \phi \right] \quad (2)$$

Where b_1 and b_2 are the amplitudes of walls,

d is the semi-average width of the channel,

λ is the wavelength,

m' ($m' \leq 1$) is the parameter of non uniform

b_1 , b_2 , d and ϕ satisfy the following condition.

$$b_1^2 + b_2^2 + 2b_1 b_2 \cos(\phi) \leq (2d)^2 \quad (3)$$

where T_1 is temperature of the lower wall

T_0 is temperature of the higher wall

The governing equations of continuity and momentum are given as

$$\frac{\partial U}{\partial X} + \frac{\partial V}{\partial Y} = 0 \quad (4)$$

$$\rho \left[\frac{\partial U}{\partial t'} + U \frac{\partial U}{\partial X} + V \frac{\partial U}{\partial Y} \right] = - \frac{\partial P}{\partial X} + \mu \nabla^2 U - \eta \nabla^4 U \quad (5)$$

$$\rho \left[\frac{\partial V}{\partial t'} + U \frac{\partial V}{\partial X} + V \frac{\partial V}{\partial Y} \right] = - \frac{\partial P}{\partial Y} + \mu \nabla^2 V - \eta \nabla^4 V \quad (6)$$

$$\begin{aligned} \rho c_p \left[\frac{\partial T}{\partial t'} + U \frac{\partial T}{\partial X} + V \frac{\partial T}{\partial Y} \right] \\ = k \left[\frac{\partial^2 T}{\partial X^2} + \frac{\partial^2 T}{\partial Y^2} \right] + \mu \left\{ 2 \left[\left(\frac{\partial U}{\partial X} \right)^2 + \left(\frac{\partial V}{\partial Y} \right)^2 \right] + \left(\frac{\partial U}{\partial Y} + \frac{\partial V}{\partial X} \right)^2 \right\} - \frac{\partial q_r}{\partial Y} \end{aligned} \quad (7)$$

Where U and V are velocities.

X and Y are directions

t' - time

μ - viscosity

ρ - fluid density

C_p - specific heat

P - pressure

T - temperature

η - constant associated with couple stress

k - thermal conductivity

q_r -radiative heat flux

By using Rosseland approximation for radiation, the radiative heat flux q_r is given by

$$q_r = - \frac{16\sigma^* T_0^3}{3k^*} \frac{\partial T}{\partial Y} \quad (8)$$

Where σ^* , k^* are the Stefan – Boltzmann constant and mean absorption coefficient respectively.

Where

$$\begin{aligned} \nabla^2 &= \frac{\partial^2}{\partial X^2} + \frac{\partial^2}{\partial Y^2} = 0 \\ \nabla^4 &= \nabla^2 \nabla^2 \end{aligned} \quad (9)$$

Introducing the following non – dimensional variables,

$$x = \frac{x}{\lambda}, y = \frac{y}{\lambda}, h_2 = \frac{H_2}{d}, t = \frac{ct'}{\lambda}, u = \frac{U}{c}, v = \frac{V}{c}, \delta = \frac{d}{\lambda}, h_1 = \frac{H_1}{d},$$

$$h_2 = \frac{H_2}{d}, p = \frac{d^2 P}{c\lambda\mu}, \theta = \frac{T-T_0}{T_1-T_0}, a = \frac{b_1}{d}, b = \frac{b_2}{d}, S^2 = \frac{d^2\mu}{\eta}$$

$$R_n = \frac{16\sigma^* T_0^3}{3k^* \mu C_p}$$

The problem statement in the dimensionless form is given by

$$R\delta \left[\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} \right] = - \frac{\partial p}{\partial x} + \left(\delta^2 \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) \quad (10)$$

$$\begin{aligned} & -\frac{1}{S^2} \left(\delta^2 \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \right) \left(\delta^2 \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) \\ R\delta^2 \left[\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} \right] &= - \frac{\partial p}{\partial y} + \delta^2 \left(\delta^2 \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) \\ & -\frac{1}{S^2} \left(\delta^2 \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \right) \left(\delta^2 \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) \end{aligned} \quad (11)$$

$$\begin{aligned} R\delta \left[\frac{\partial \theta}{\partial t} + u \frac{\partial \theta}{\partial x} + v \frac{\partial \theta}{\partial y} \right] &= \frac{1}{Pr} \left[\delta^2 \frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} \right] \\ & + E \left[2 \left[\delta^2 \left(\frac{\partial u}{\partial x} \right)^2 + \left(\frac{\partial v}{\partial y} \right)^2 \right] + \left[\frac{\partial u}{\partial y} + \delta \frac{\partial v}{\partial x} \right]^2 \right] + R_n \frac{\partial^2 \theta}{\partial y^2} \end{aligned} \quad (12)$$

By assuming the long wavelength ($\delta \ll 1$) and low R_θ .

We find from equations (11) to (13) that

$$0 = \frac{\partial p}{\partial x} + \frac{\partial^2 u}{\partial y^2} - \frac{1}{S^2} \frac{\partial^4 u}{\partial y^4} \quad (13)$$

$$0 = \frac{\partial p}{\partial x} \quad (14)$$

$$0 = \xi \frac{\partial^2 \theta}{\partial y^2} + E \left(\frac{\partial u}{\partial y} \right)^2 \quad (15)$$

$$\xi = R_n + \frac{1}{P_r} \quad (16)$$

where R – Reynolds number

ρ – dimension less pressure

a & b – amplitudes of lower and upper walls

δ – wave number

m – Non-uniform parameter

θ – dimension less temperature

P_r – Prandtl number

R_n – radiation parameter

S – couple stress parameter

E – Eckert number

The corresponding boundaries conditions are,

$$u=0, \frac{\partial^2 u}{\partial y^2} = 0, \theta = 0 \text{ at}$$

$$H_1(x,t) = -1 - mx - \text{asin}[2\pi (x-t) + \phi] \quad (17)$$

$$U=0, \frac{\partial^2 u}{\partial y^2} = 0, \theta = 0 \text{ at}$$

$$H_2(x,t) = 1 + mx + b \sin 2\pi (x - t) \quad (18)$$

4.2 ANALYTICAL SOLUTION OF THE PROBLEM

(i) VELOCITY DISTRIBUTION:

$$u = c_1 + c_2 y + c_3 \cosh Sh_1 + c_4 \sinh Sy + \frac{\partial p}{\partial x} y^2 \quad (19)$$

Where

$$C_1 = -\left[\frac{\partial p}{\partial x} h_1^2 + c_2 h_1 + c_3 \cosh Sh_1 + c_4 \sinh Sh_1\right]$$

$$C_2 = -\left[\frac{\partial p}{\partial x} \left(\frac{h_1^2}{2} - \frac{h_2^2}{2}\right) + c_3 (\cosh Sh_1 - \cosh Sh_2) + c_4 (\sinh Sh_1 - \sinh Sh_2)\right]$$

$$(h_2 - h_1)$$

$$C_3 = -\left[\frac{\partial p / \partial x + C_4 S^2 \sinh Sh_1}{S^2 \cosh Sh_1}\right]$$

$$C_4 = -\left[\frac{\partial p / \partial x (\cosh Sh_2 - \cosh Sh_1)}{S^2 \sinh S (h_2 - h_1)}\right]$$

(ii) **TEMPERATURE DISTRIBUTION.**

$$\begin{aligned}
 & c_5 y + c_6 + A_1 y^2 + A_2 \cosh 2Sy + A_3 y^4 + A_4 \sinh 2Sy \\
 & A_5 \sinh Sy + A_6 y \cosh Sy + A_7 y^3 + A_8 \cosh Sy \\
 & + A_9 y \sinh S = 0
 \end{aligned} \tag{20}$$

Where

$$A_1 = \frac{E}{\xi} \left[\frac{C_2^2}{2} - \frac{C_3^2 S^2}{4} + \frac{C_4^2 S^2}{4} \right]$$

$$A_2 = \frac{-E}{\xi} \left[\frac{C_3^2}{8} + \frac{C_4^3}{8} \right]$$

$$A_3 = \frac{E \frac{\partial p}{\partial x}}{12\xi}$$

$$A_4 = \frac{-E C_3 C_4}{4\xi}$$

$$A_5 = \frac{-E}{\xi} \left[\frac{C_2 C_3}{2S} - \frac{4C_4 \frac{\partial p}{\partial x}}{S^2} \right]$$

$$A_6 = - \frac{2E C_4 \frac{\partial p}{\partial x}}{\xi S}$$

$$A_7 = \frac{-E C_2 \frac{\partial p}{\partial x}}{3 \xi S} \quad A_8 = \frac{-E}{\xi} \left[\frac{2 C_2 C_4}{S} - \frac{C_3 \frac{\partial p}{\partial x}}{S^2} \right]$$

$$A_9 = - \frac{2 E C_3 \frac{\partial p}{\partial x}}{S \xi}$$

$$A_{10} = 1 - [A_1 h_1^2 + A_2 \cosh 2Sh_1 + A_3 h_1^2 + \\ A_4 \sinh 2Sh_1 + A_5 \sinh Sh_1 + A_6 h_1 \cosh Sh_1 \\ + A_7 h_1^2 + A_8 \cosh Sh_1 + A_9 h_1 \sinh Sh_1]$$

$$A_{10} = 1 - [A_1 h_2^2 + A_2 \cosh 2Sh_2 + A_3 h_2^2 + \\ A_4 \sinh 2Sh_2 + A_5 \sinh Sh_2 + A_6 h_2 \cosh Sh_2 \\ + A_7 h_2^2 + A_8 \cosh Sh_2 + A_9 h_2 \sinh Sh_2]$$

$$C_5 = \frac{A_{10} - A_{11}}{h_1 - h_2}$$

$$C_6 = A_{11} - C_5 h_2$$

CHAPTER – 5

5.1 RESULT AND DISCUSSION

In this study the behaviour of the various parameters on axial velocity (u) and the temperature distribution (θ)

- (i) Flow characteristics
- (ii) Heat transfer distributions

5.2 FLOW CHARECTERISTICS

The behaviour of couple stress parameter (S), a non-uniform parameter (m), phase shift (ϕ), and amplitude of the lower wall (a) on the axial velocity u .

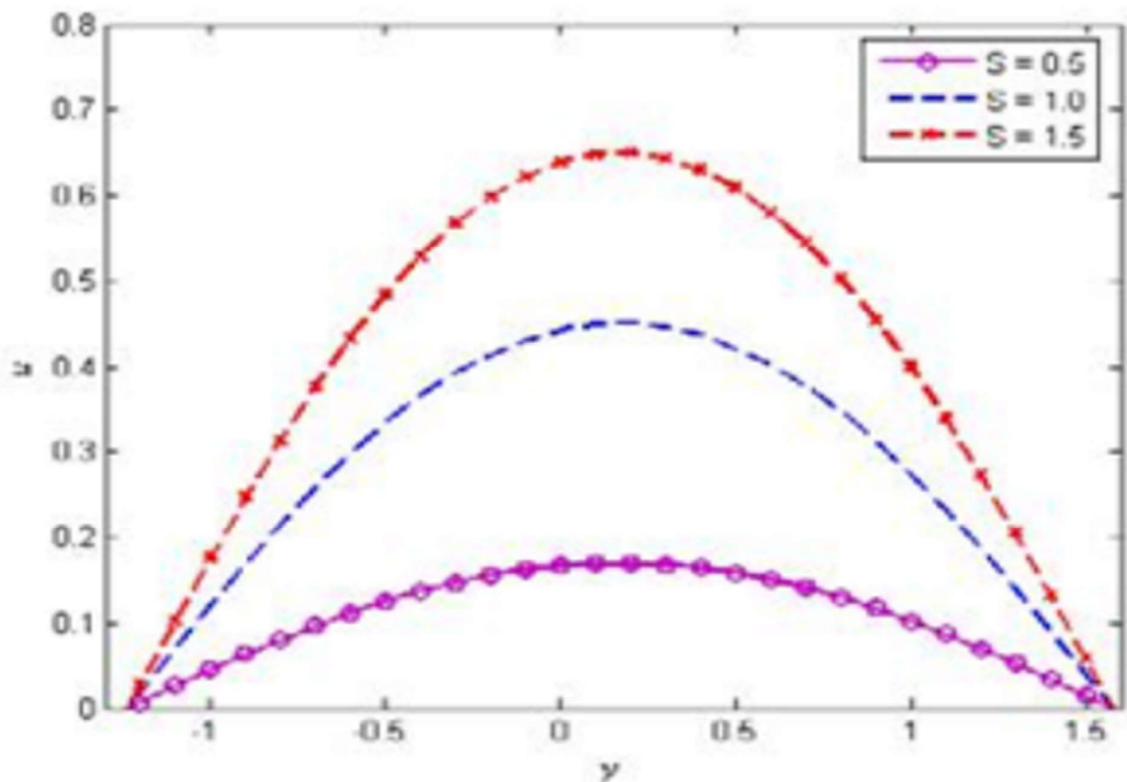


Figure 5.1: variation of S on u for $a = 0.3$, $b = 0.5$, $\phi = \pi/4$, $x = 0.5$, $t = 0.2$.

In this graph increase in S causes increases in velocity u

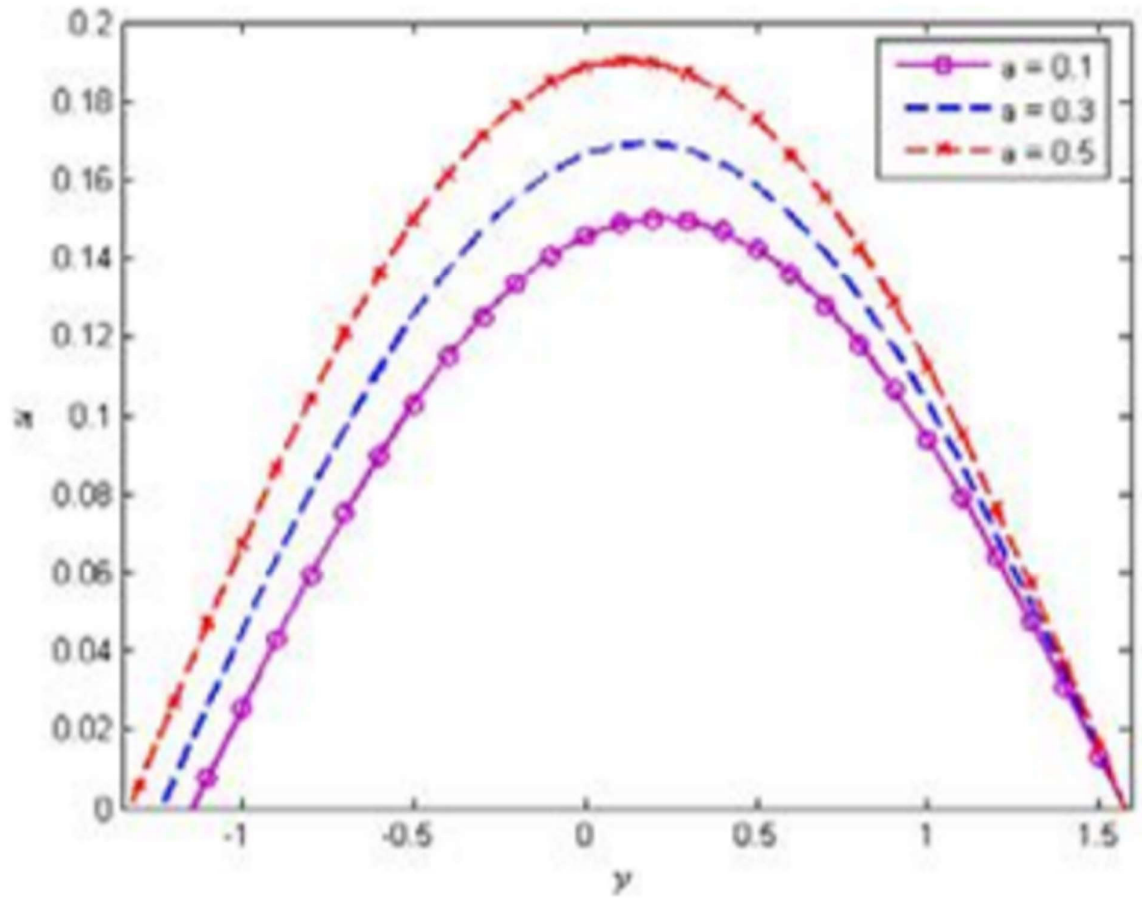


Figure 5. 2: Variation of m on u for $a = 0.3$, $b = 0.5$, $\phi = \pi/4$, $x = 0.5$, $m = 0.5$,
 $t = 0.2$, $S = 0.5$.

In this graph the axial velocity increases in the amplitude of the lower wall a

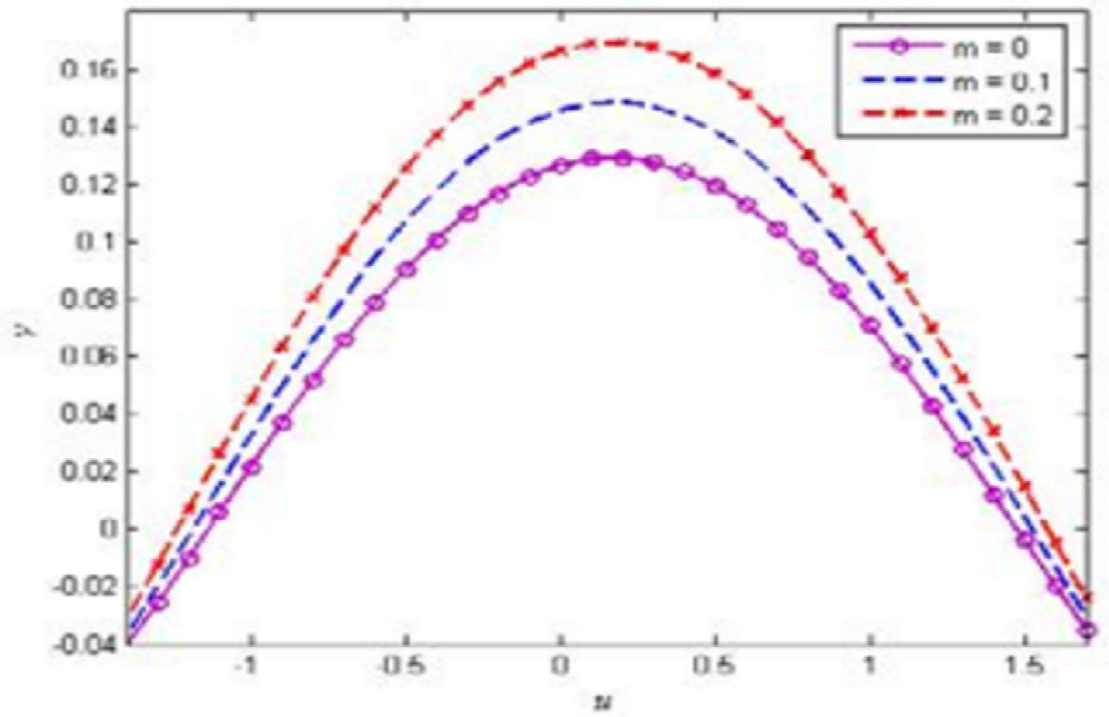


Figure 5.3: Variation of m on u for $a = 0.3$, $b = 0.5$, $\phi = \pi / 4$, $x = 0.5$, $t = 0.2$, $S = 0.5$.

It is noted that the velocity profile u increases with a corresponding increasing in m .

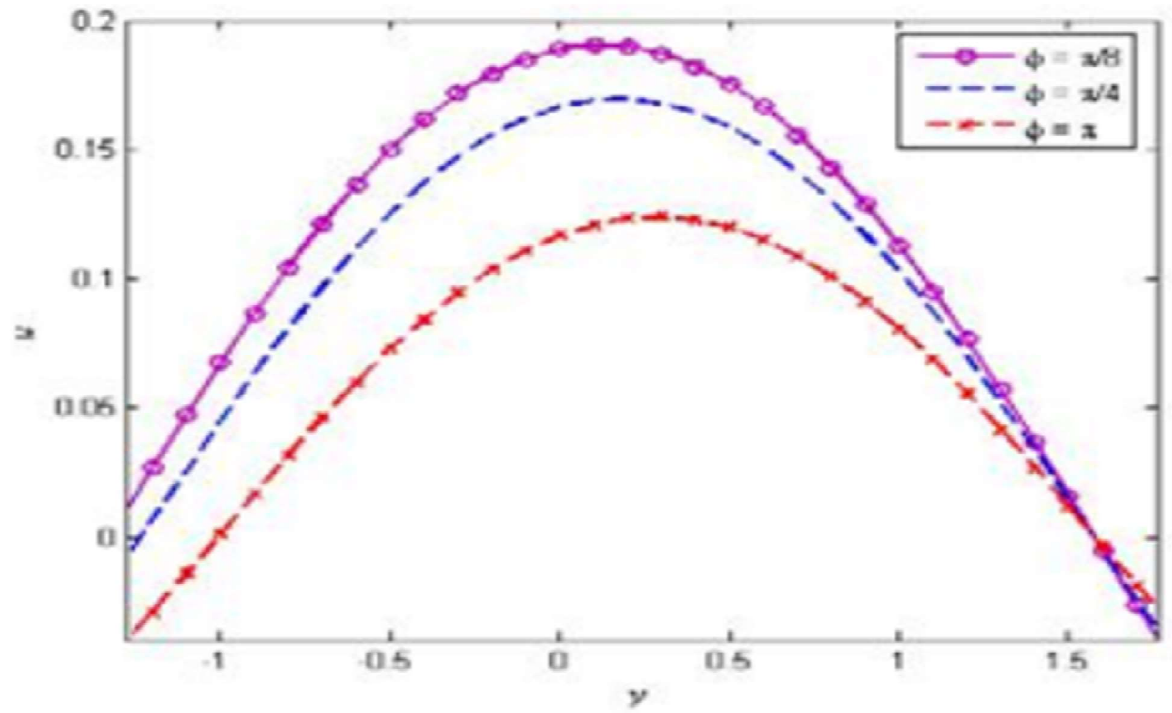


Figure 5.4: Variation of ϕ on u for $a = 0.3$, $b = 0.5$, $x = 0.5$, $m = 0.5$, $t = 0.2$, $S = 0.5$

Here opposite behaviour observed for the phase shift ϕ .

5.3 Heat Transfer distributions

The temperature profiles for several values of radiation parameter (R_n), Eckert number (E), Prandtl number (Pr), couple stress parameter (S), a non-uniform parameter (m) and amplitude of the lower wall (a).

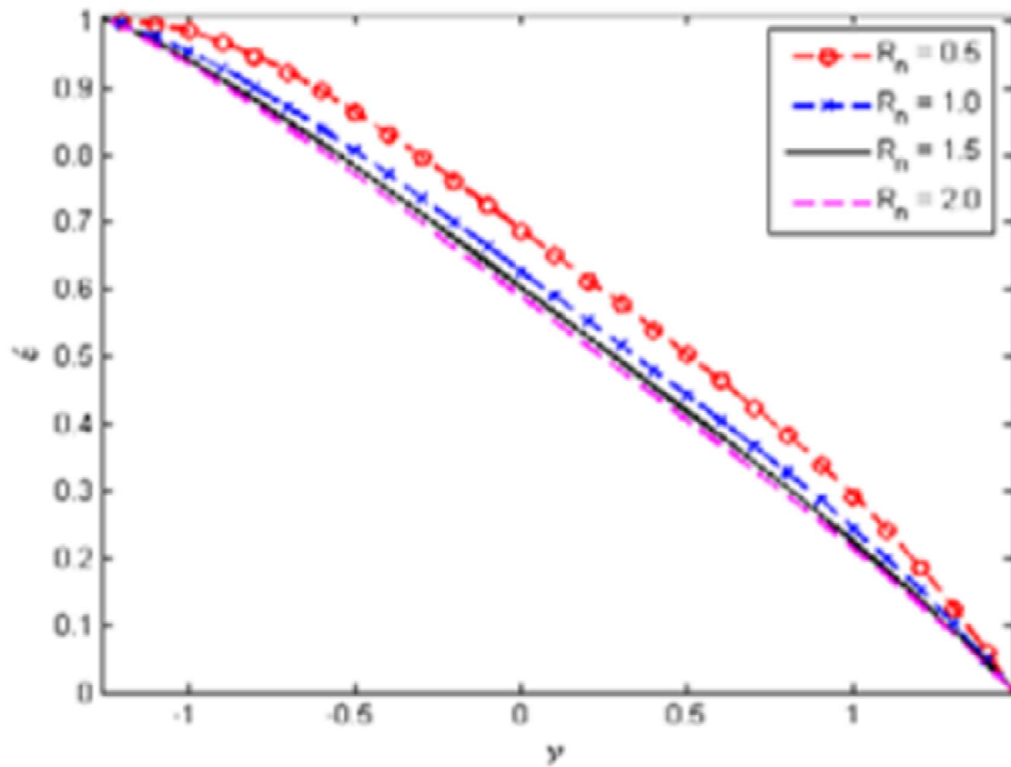


Figure 5.5: Variation of R_n on Θ for $a = 0.3$, $b = 0.4$, $\phi = \pi$, $x = 0.5$, $m = 0.2$, $t = 0.2$, $Pr = 6.2$, $E = 0.75$, $S = 1.5$

The influence of the thermal radiation parameter R_n on temperature θ is plotted
(i.e) The temperature distribution θ increases with a decrease in R_n

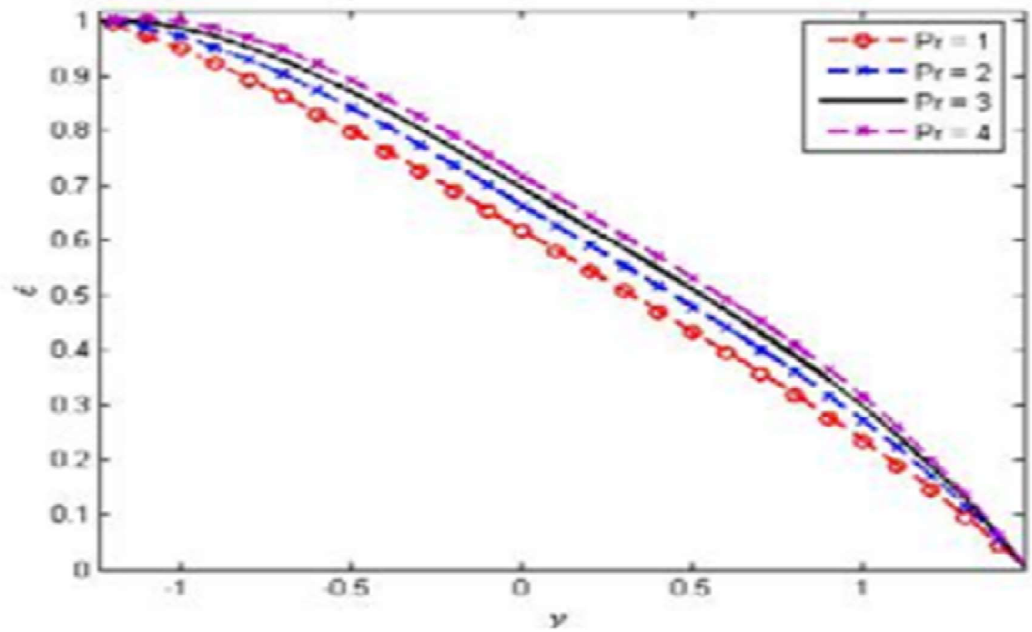


Figure 5.6: Variation of E on Θ for $a = 0.3$, $b = 0.4$, $\phi = \pi$, $x = 0.5$, $m = 0.2$, $t = 0.2$, $Rn = 0.3$, $Pr = 6.2$, $S = 1.5$.

The variation of Eckert number E on θ .

(i.e) The increase in Eckert number E results an increase in θ .

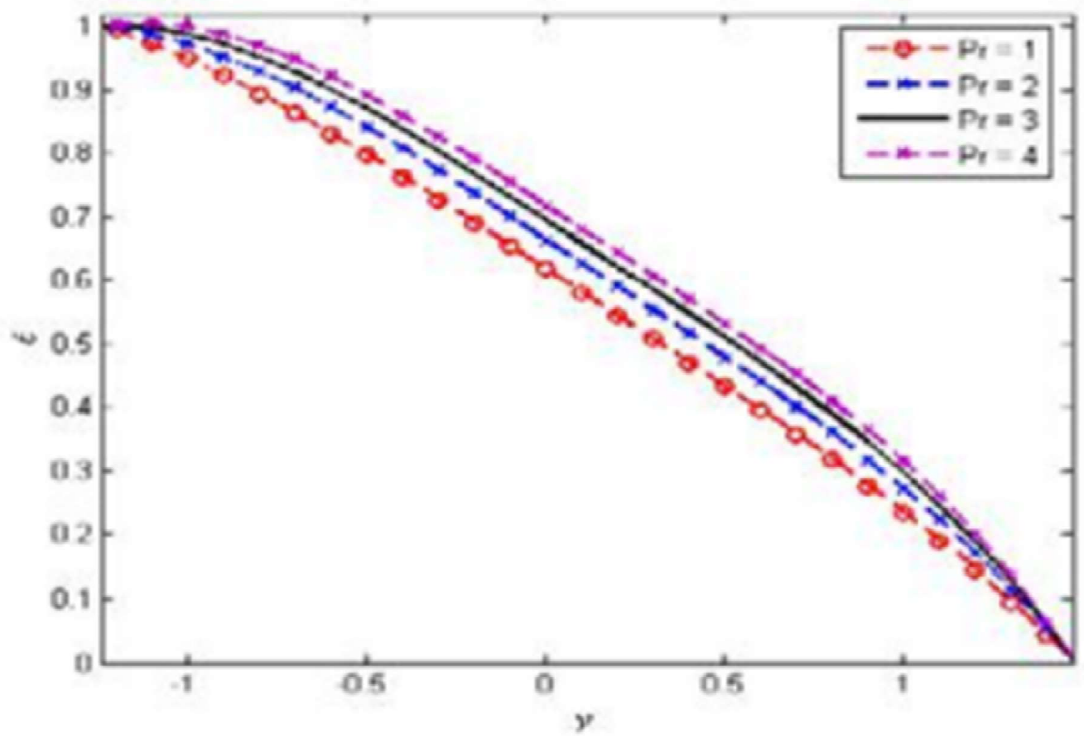


Figure 5.7: Variation of Pr on Θ for $a = 0$, $b = 0.4$, $\phi = \pi$, $x = 0.5$, $Rn = 0.3$, $m = 0.2$, $t = 0.2$, $E = 0.75$, $S = 1.5$

This depicts the effect for various values of Prandtl no P_r ,

(i.e) The temperature θ increases as prandtl number Pr increases.

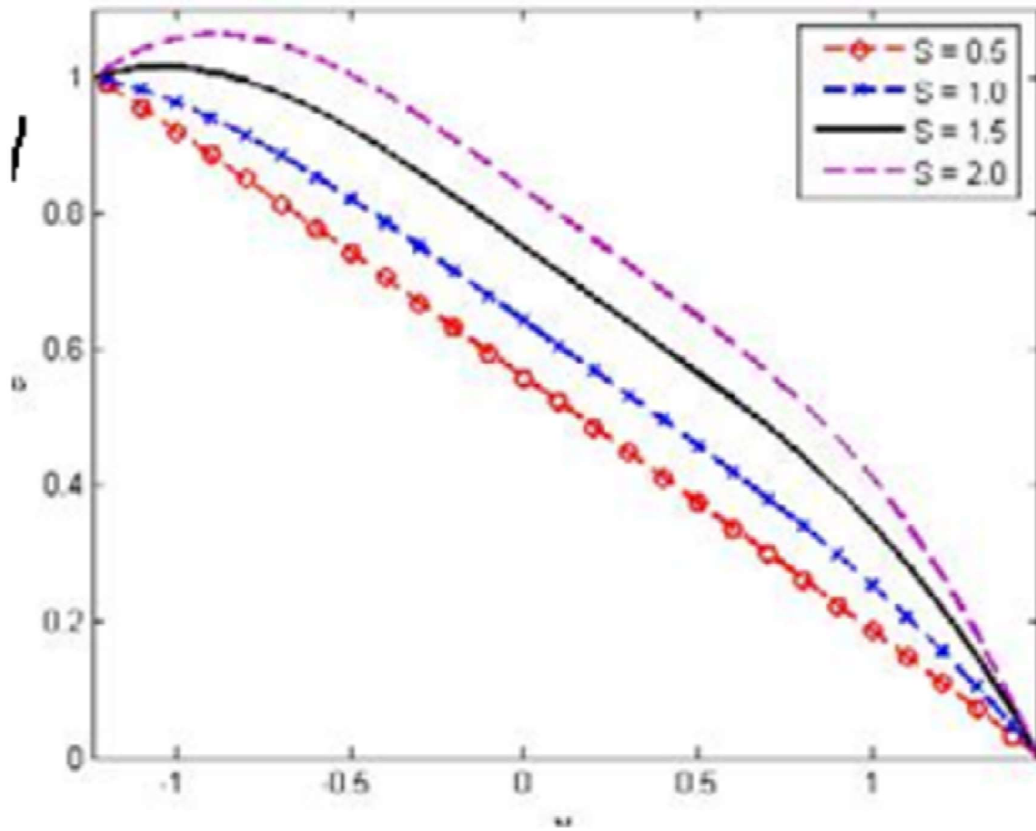


Figure 5.8: Variation of S on Θ for $a = 0.3$, $b = 0.4$, $\phi = \pi$, $x = 0.5$, $m = 0.2$, $t = 0.2$, $Rn = 0.3$, $Pr = 6.2$, $E = 0.75$

This shows that the temperature profile θ increases with increase of couple stress parameter S

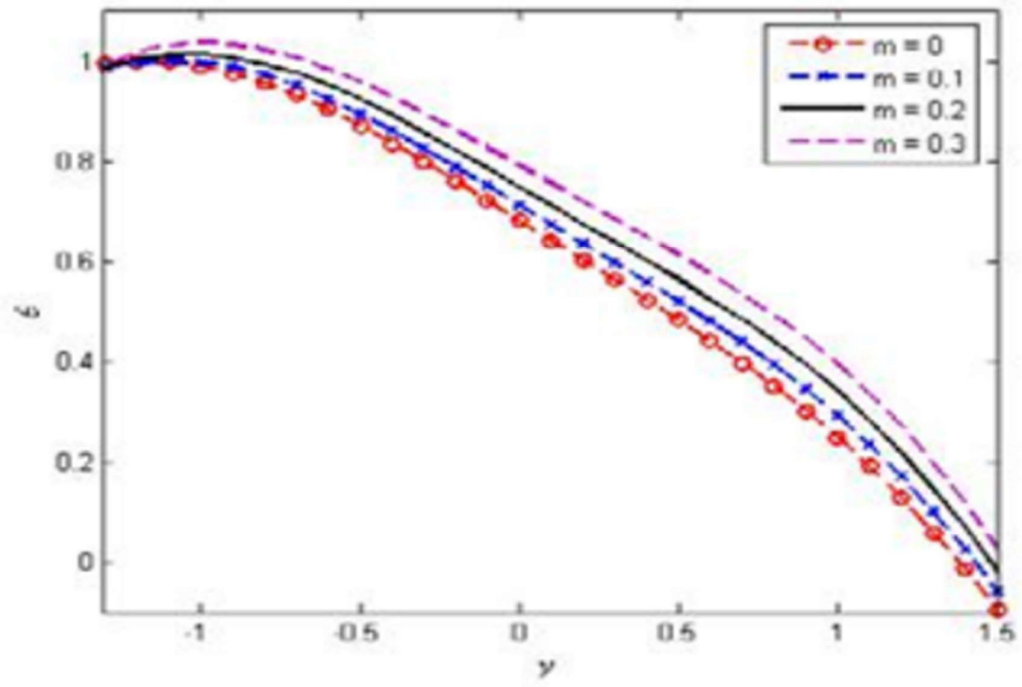


Figure 5.9: Variation of m on Θ for $a = 0.3$, $b = 0.4$, $\phi = \pi$, $x = 0.5$, $t = 0.2$, $Rn = 0.3$, $Pr = 6.2$, $E = 0.75$, $S = 1.5$

This graph shows that the fluid temperature increases with an increase in uniform parameter m .

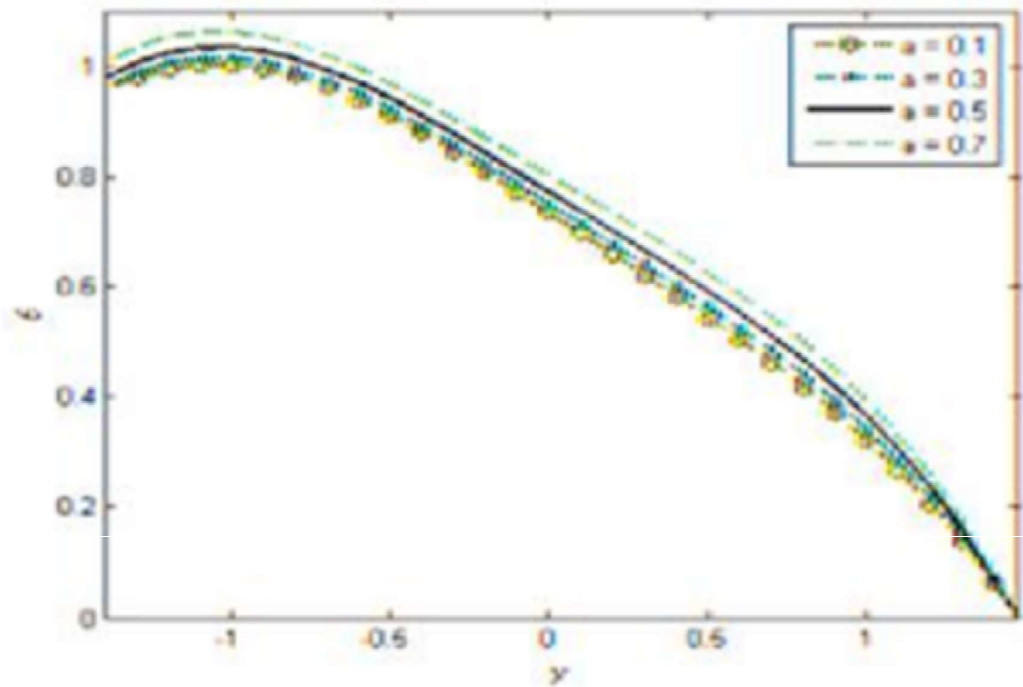


Figure 5.10 Variation of a on Θ for $b = 0.4$, $\phi = \pi$, $x = 0.5$, $m = 0.2$, $t = 0.2$,
 $Rn = 0.3$, $Pr = 6.2$, $E = 0.75$, $S = 1.5$

This represents the temperature profile θ for variables values of amplitude lower wall a .

It is noticed that increase in a leads to an increase in the fluid temperature θ .

CHAPTER – 6

6.1 CONCLUSION

- The velocity profile increases with an increase in couple-stress parameter, non uniform parameter and amplitude of the lower wall.
- The velocity of the fluid decreases with an increase in phase shift ϕ .
- The temperature profile increases with an increase in Prandtl number Pr , Eckert number, couple- stress parameter and non uniform parameter m .
The temperature distribution decreases with increase in Rn .

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