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RESEARCH ARTICLE

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Variability Effects on MHD for Blasius and Sakiadis Flows in the Presence of Dufour and Soret about a Flat Plate

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Abstract

A study is considered to a steady, two-dimensional boundary layer flow of an incompressible MHD fluid for the Blasius and Sakiadis flows about a flat plate in the presence of thermo-diffusion (Dufour) and thermal-diffusion (Soret) effects for variable parameters. The governing partial differential equations are transformed into a system of nonlinear ordinary differential equations using similarity variables. The transformed systems are solved numerically by Runge-Kutta Gills method with shooting techniques. The variations of the flow velocity, temperature and concentration as well as the characteristics of heat and mass transfer are presented graphically with tabulated results. The numerical computations show that thermal boundary layer thickness is found to be increased with increasing values of Eckert number (Ec), Prandtl number (Pr) and local Grashof number (Gr_x) for both Blasius and Sakiadis flow. The Blasius flow elevates the thickness of the thermal boundary layer compared with the Sakiadis flow. The local magnetic field has shown that flow is retarded in the boundary layer but enhances temperature and concentration distributions.

KEYWORDS

Soret and Dufour Effects, Flat Plate, Runge-Kutta Gill, Blasius-Sakiadis flow, MHD.

1 | INTRODUCTION

Concentration gradient often lead to mass diffusion in a mixture of two more species (gases, liquids, plasma or solids) in an isothermal system where species are not evenly distributed. Temperature gradient is also another factor that can be responsible for mass diffusion as a result of Soret effect (thermo-diffusion). Thermo-diffusion has several industrial applications such as the optimum oil recovery from hydrocarbon reservoirs, fabrication of semiconductor devices in molten metal and semiconductor mixtures, separation of species such as polymers,

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manipulation of macromolecules such as DNA, and engineering processed like wire drawing, glass fibre and paper production and crystal growth [1]. Dufour effect is the reverse of the Soret effect arising in a system where concentration gradient results in a temperature change. Dufour effect may be insignificant in liquid-liquid mixture but not when gases are involved. Blasius boundary layer equations [2] describe a steady flow of viscous incompressible fluids about a two-dimensional flat-plate and these equations were later generalized by Falkner and Skan to wedge flow. Sakiadis obtained the boundary layer equations for a flow of a quiescent ambient fluid over a moving flat surface similar to the Blasius equations except that the boundary conditions differ [3, 4].

Rafael [5] showed that there exist discrepancies when both the Blasius and Sakiadis flows are compared. Olanrewaju *et al.* [6] reported the effects thermal radiation, Eckert number, Prandtl number and convective parameter on both Blasius and Sakiadis flows with a convective surface boundary condition. Gangadhar [7] extended the work of [6] by adding the effects of buoyancy and magnetohydrodynamic on radiation and viscous dissipation for the Blasius and Sakiadis flows with a convective surface boundary condition. Hady *et al.* [8] studied the effect of porosity on the flow dynamics of both Blasius and Sakiadis flows of nanofluid in the presence of thermal radiation under a convective boundary condition. Mustafa *et al.* [9] examined the effect of magnetic field parameter on Sakiadis flow of MHD Maxwell fluid. Anjani and Suriyakumar [10] furthered the work of [9] by comparing both cases of Blasius and Sakiadis MHD nanofluids flows on an inclined plate. Krishina *et al.* [11] investigated the magnetohydrodynamic Blasius and Sakiadis flows with variable properties, thermal and diffusion slip.

In all these studies, Soret–Dufour effects were not considered. However, Makinde *et al.* [12] examined the hydrodynamic flow and mass diffusion of chemical species with first and higher-order reactions of an electrically conducting fluid over a moving vertical plate with Dufor and Soret. Animasaun and Oyem [13] considered the effects of variable fluid viscosity and thermal conductivity, Dufour and Soret on a non-Darcian free convective heat and mass transfer fluid flow past a porous flat surface. The influences of partial slips, Soret and Dufour on unsteady boundary layer flow, heat and mass transfer over shrinking sheet in copper-water nanofluid was looked into by Dzulkifli *et al.* [14]. Swamy *et al.* [15] studies the onset of convection, heat and mass transports in anisotropic densely packed porous layer filled with chemically reactive binary liquid heated at the bottom in presence of Soret and Dufour effects. Similarly, Hayat *et al.* [16] addressed the convective heat and mass transfer conditions in the radiative flow of Powell-Eyring fluid past an inclined exponentially stretching surface taking Soret and Dufour effects into account. Kafayati [17] looked into entropy generation of associated with double diffusive natural convection of non-Newtonian power-fluids in an inclined porous cavity. Shojaei *et al.* [18] examined the analytical approach of a second grade fluid flow along a stretching cylinder and the Soret and Dufour effects. Hayat *et al.* [19] investigated Soret and Dufour effects on the peristaltic flow of magnetohydrodynamic (MHD) psuedoplastic nanofluid in a tapered asymmetric channel.

In all the above mentioned studies, the interaction between Blasius-Sakiadis flows and Soret-Dufour effects about a flat plate was not investigated adequately. Gangadhar [7] neither considered Soret-Dufour effects and convective heat transfer but neglected the viscous dissipation and thermal radiation parameter. In view of this, the presented paper have extended the work of [7] to include Soret (thermal-diffusion) and Dufour (thermo-diffusion) effects as the Blasius and Sakiadis flows are considered about a flat plate with variability

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properties. A similarity transformation has been adopted to convert the governing partial differential equations into a system of nonlinear ordinary differential equations and the resulting boundary value problem has been solved numerically with Runge-Kutta-Gills method with shooting technique. Results are obtained for different values of the governing dimensionless properties and discussed extensively.

2 | GOVERNING EQUATIONS

We consider the steady, two-dimensional incompressible, laminar boundary layer flow with heat and mass transfer for Blasius and Sakiadis flows in the presence of variable parameters about a flat plate in a stream of cold fluid temperature T_∞ and hot fluid at temperature T_f which provides a heat transfer coefficient h_f. Let the x-axis be taken along the direction of plate and y-axis normal to it. If u, v, T and C are the fluid x-component of velocity, y-component of velocity, temperature and concentration respectively, then under the Boussinesq and boundary layer approximations, the governing partial differential equations are given as $[\mathbf{7}, \mathbf{20}, \mathbf{21}, \mathbf{22}]$;

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{1}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \upsilon\frac{\partial^2 u}{\partial y^2} - \frac{\sigma B_0^2}{\rho}u + g\beta(T - T_\infty) + g\beta^*(C - C_\infty) \tag{2}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{1}{\rho c_p}\left[\frac{\partial}{\partial y}\left(\kappa(T)\frac{\partial T}{\partial y}\right) - \left(\frac{\partial q_r}{\partial y}\right) + q(T - T_\infty)\right] + \frac{Dk_t}{c_p c_s}\left(\frac{\partial^2 C}{\partial y^2}\right) + \frac{\mu}{c_p}\left(\frac{\partial u}{\partial y}\right)^2 \tag{3}$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D\frac{\partial^2 C}{\partial y^2} + \frac{Dk_t}{T_m}\left(\frac{\partial^2 T}{\partial y^2}\right), \tag{4}$$

where u, v is the velocity components in the x, y directions, υ is the kinematic viscosity, σ is the fluid electric conductivity, B_0 is applied magnetic field strength, ρ is fluid density, g is gravitational acceleration, β is thermal expansion coefficient, β^* is concentration expansion coefficient, T is temperature, T_∞ is free stream temperature, $\kappa(T)$ is thermal conductivity variation, q_r is radiative heat flux, q is volumetric rate, D is mass diffusivity, k_t is thermal diffusion ratio, c_p is specific heat at constant pressure, c_s is concentration susceptibility, C is concentration, C_∞ is free stream concentration, T_m is mean fluid temperature. The Dufour and Soret effects are described by a second order concentration and temperature derivatives respectively $[\mathbf{12}]$ in Eq. (3) and Eq. (4). The boundary conditions are given as

$$u = U_w \quad at \quad y = 0; \quad u = U_\infty \quad at \quad x = 0; \quad u \to U_\infty \quad as \quad y \to \infty, \tag{5}$$

for Blasius flat plate flow problem and

$$u = U_w; \quad v = 0 \quad at \quad y = 0; \quad x = 0; \quad u \to 0 \quad as \quad y \to 0 \tag{6}$$

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for classical Sakiadis flat plate flow problem where U_w, U_∞ are the plate velocity and free stream velocity respectively. The boundary conditions at the flat plate and far into the cold fluid are written as

$$-\kappa \frac{\partial T}{\partial y}(x,0) = h_f\left[T_f - T(x,0)\right];\;\; T(x,\infty) = T_\infty, C(x,0) = C_w, C(x,\infty) = C_\infty. \tag{7}$$

Introducing a dimensional stream function ψ, satisfies the continuity Eq. (1). Resolving Eqs. (2) – (7), a similarity solution is obtained by defining an independent variable η, dimensionless stream function f, dimensionless temperature T and concentration C as

$$\eta = y\sqrt{\frac{U}{\upsilon x}} = \frac{y}{x}\sqrt{Re_x}\,;\;\; \frac{u}{U} = f'\,;\;\; v = \frac{1}{2}\sqrt{\frac{U\upsilon}{x}}\,(\eta f' - f)\,; \tag{8a}$$

$$\theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty}\;;\;\;\; \phi(\eta) = \frac{C - C_\infty}{C_w - C_\infty}, \tag{8b}$$

where, prime denotes differentiation with respect to η and Re_x is the local Reynolds number $\left(Re_x = {}^{Ux}/_{\upsilon}\right)$. Applying Eqs. (8a) – (8b) to Eqs. (2) – (7), the coupled nonlinear ordinary differential equations are obtained as

$$\frac{d^3 f}{d\eta^3} + \frac{1}{2} f \frac{d^2 f}{d\eta^2} - M\frac{df}{d\eta} + Gr\theta + Gc\phi = 0 \tag{9}$$

$$\frac{d^2\theta}{d\eta^2} + k_0 Pr\left[\frac{1}{2} f \frac{d\theta}{d\eta} + Ec\left(\frac{d^2 f}{d\eta^2}\right)^2 + Q\theta\right] + k_0\left[\varepsilon\left(\frac{d\theta}{d\eta}\right)^2 + D_f\frac{d^2\theta}{d\eta^2}\right] = 0 \tag{10}$$

$$\frac{d^2\phi}{d\eta^2} + Sc\left(\frac{1}{2} f\frac{d\phi}{d\eta} + Sr\frac{d^2\theta}{d\eta^2}\right) = 0, \tag{11}$$

with Blasius boundary condition

$$\begin{gathered} f = 0\,;\;\; f' = 0\;;\;\; \theta' = -\varepsilon[1 - \theta(0)] \quad at \quad \eta = 0 \\ f' = 1\;;\;\; \theta = 0;\;\; \phi = 1 \quad as \;\; \eta \to \infty, \end{gathered} \tag{12}$$

and Sakiadis boundary condition

$$\begin{gathered} f = 0\;;\;\; f' = 1\;;\;\; \theta' = -\varepsilon[1 - \theta(0)] \quad at \;\; \eta = 0 \\ f' = 0\;;\;\; \theta = 0;\;\; \phi = 1 \quad as \quad \eta \to \infty. \end{gathered} \tag{13}$$

where,

$$M_x = \frac{\sigma B_0^2 x}{\rho U};\;\; Gr_x = \frac{g\beta x(T_w - T_\infty)}{U^2};\;\; Gc_x = \frac{g\beta^* x(C_w - C_\infty)}{U^2};\;\; Pr = \frac{\upsilon}{\alpha};\;\; Q_x = \frac{qx}{\rho c_p U};$$

$$Ec = \frac{U^2}{c_p(T_w - T_\infty)};\;\; D_f = \frac{Dk_t}{c_p c_s \alpha}\frac{(C_w - C_\infty)}{(T_w - T_\infty)};\;\; k_0 = \frac{3N_R}{3N_R[1 + \theta\varepsilon] + 4};\;\; \varepsilon = \gamma[T_w - T_\infty];$$

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$$Sc = \frac{\upsilon}{D};\ \ Sr = \frac{Dk_t}{\upsilon T_m}\frac{T_w - T_\infty}{C_w - C_\infty}$$

are the local magnetic field parameter (M_x), local Grashof number (Gr_x), local Solutal number (Gc_x), Prandtl number (Pr), local Heat release parameter (Q_x), Eckert number (Ec), Dufour number (D_f), thermal radiation parameter (k_0), variable thermal conductivity parameter (ε), Schmidt number (Sc) and Soret number (Sr) respectively. The local parameters M_x, Gr_x, Gc_x and Q_x in Eqs. (9) – (12) are functions of x.

3 | NUMERICAL RESULTS AND DISCUSSIONS

Numerical solutions to the dimensionless Eqs. (9) – (13) are obtained using the Runge-Kutta-Gills method with the shooting technique and the embedded parameters are varied to study their effects on the dimensionless velocity (f'), temperature (θ) and concentration (ϕ) functions. Numerical results are obtained for the local skin-friction coefficient $f''(0)$, local Nusselt number $-\theta'(0)$, local Sherwood number $-\phi'(0)$ and results displayed in Tables (1) – (3).

3.1 | EFFECTS OF VARIOUS PARAMETERS ON VELOCITY PROFILES

The influence of the flow parameters on velocity profiles are illustrated in Figures (1) to (6). Figure 1 (a-b) shows that Dufour number (D_f) has similar effect on the velocity profile of both Blasius flow and Sakiadis flow. It is observed that the velocity profile decreases with increase in D_f for both the Blasius and the Sakiadis flows. As can be seen from Figure 2 (a-b), Eckert number (Ec) has opposite effects on the velocity profiles of Blasius and Sakiadis flows. For Blasius flow, the velocity profile decreases with increase in Ec whereas, the velocity profiles increase in Sakiadis flow with increase in Ec. Effect of the local Grashof number (Gr_x) on the velocity profiles is shown in Figure 3 (a-b) and it is observed that the velocity profiles increase with increase in the Grashof number (Gr) for both the Blasius flow and the Sakiadis flow. In Figure 4 (a-b), we observed that increase in the local magnetic field parameter (M_x) causes a decrease in the velocity profile for both the Blasius flow and the Sakiadis flow due to the presence of Lorentz force which acts against the flow and Schmidt number due to low molecular diffusivity. Figure 5 (a-b) shows the influence of Prandtl number (Pr) on the velocity profiles and it is observed that the velocity profile increases with increase in Pr for both the Blasius flow and the Sakiadis flow. The influence of Soret number (Sr) is illustrated in Figure 6 (a-b). Soret number (Sr) has opposite effects on the Blasius and Sakiadis flows such that velocity profile decreases with increase in Sr for the Blasius flow but increase for the Sakiadis flow.

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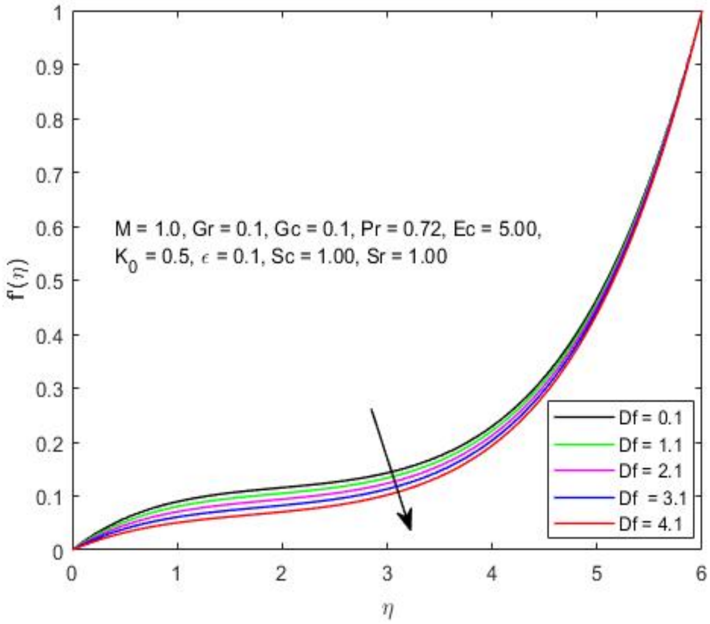
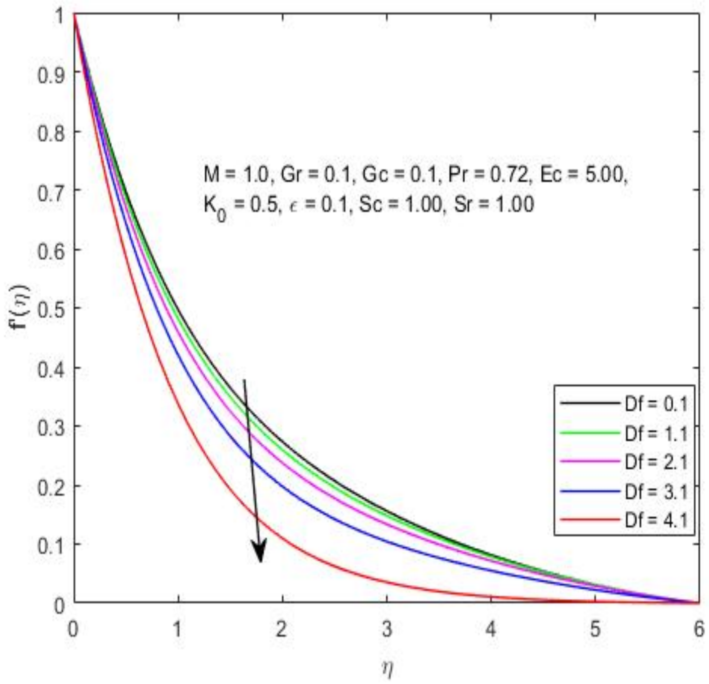


(a) Blasius flow



(b) Sakiadis flow

Figure 1 Effect of various values of Du on the velocity profiles

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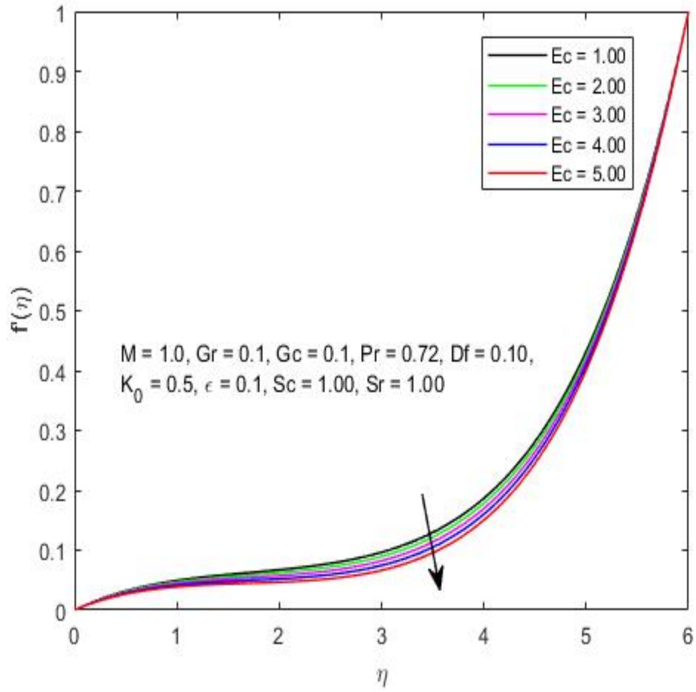
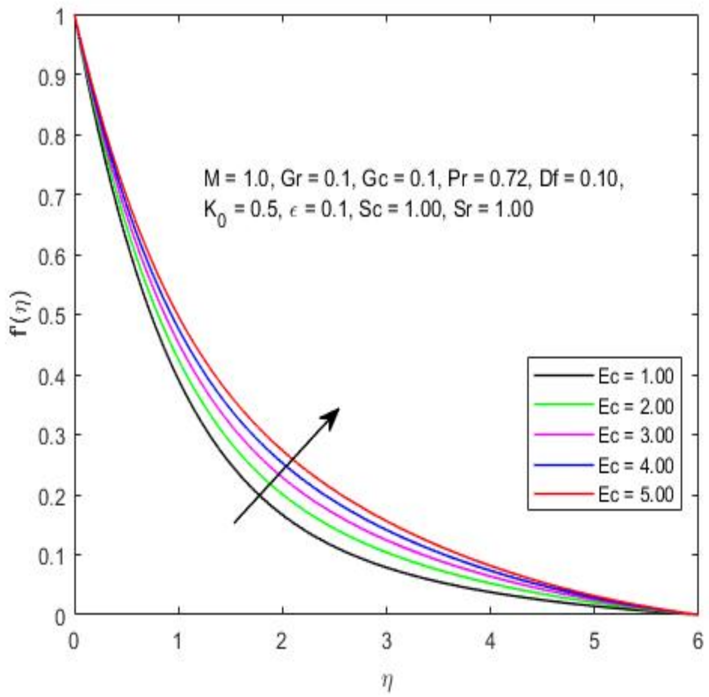


(a) Blasius flow



(b) Sakiadis flow

Figure 2 Effect of varying Eckert number (Ec) on the velocity profiles

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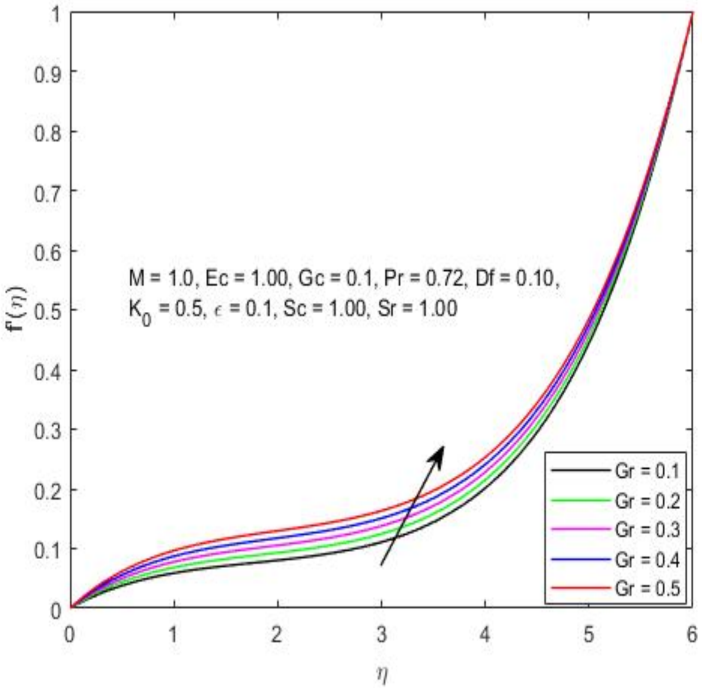
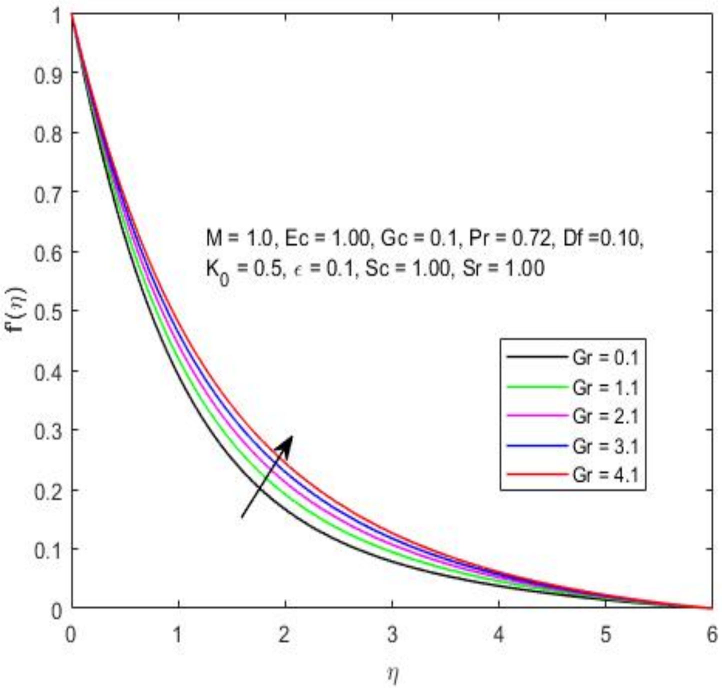


(a) Blasius flow



(b) Sakiadis flow

Figure 3 Effect of various values of Gr_x parameters on velocity profiles

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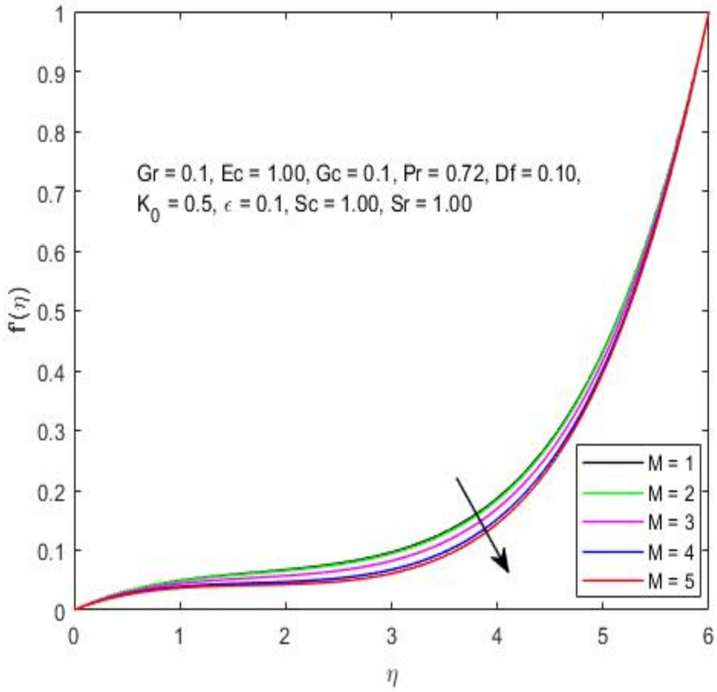
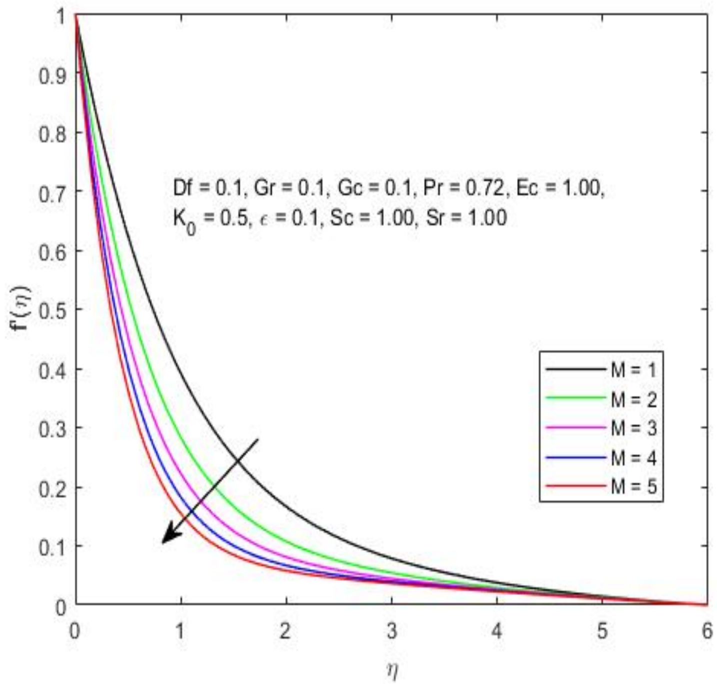


(a) Blasius flow



(b) Sakiadis flow

Figure 4 Effect of variable M_x on velocity profiles

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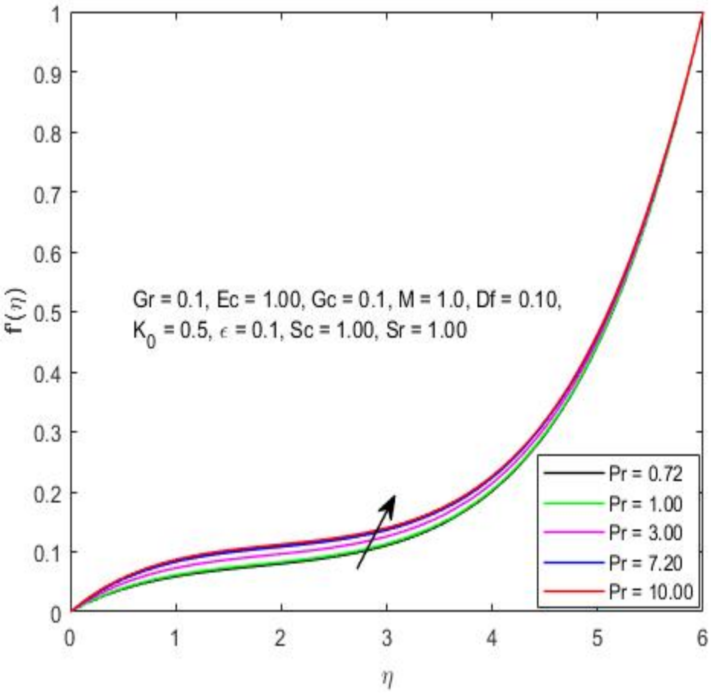
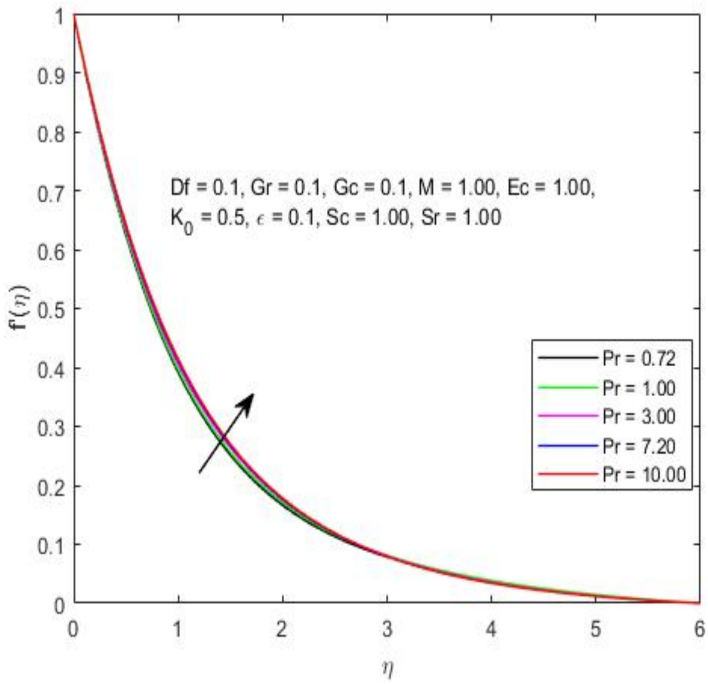


(a) Blasius flow



(b) Sakiadis flow

Figure 5 Effect of varying values of Pr on velocity profiles

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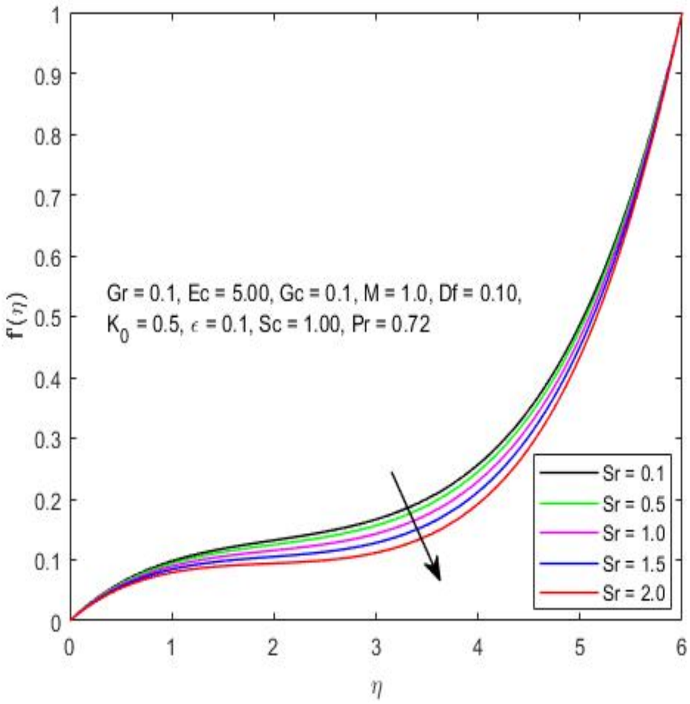
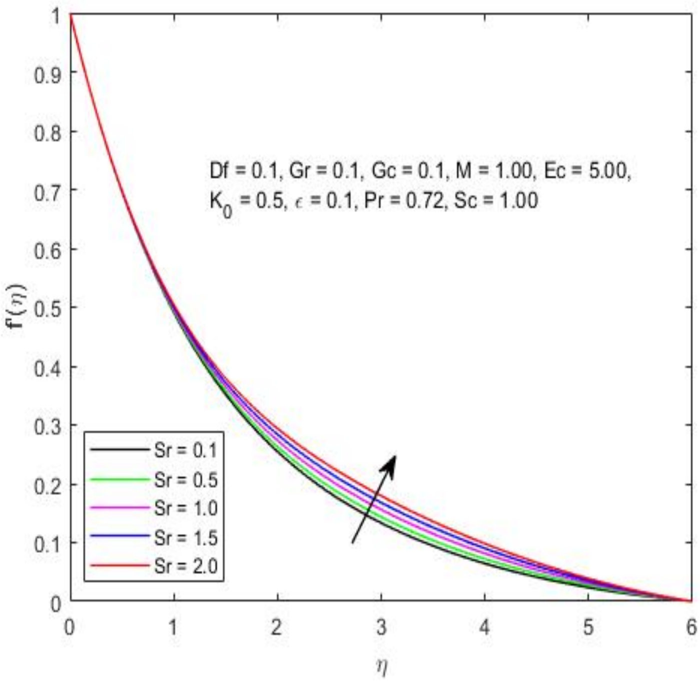


(a) Blasius flow



(b) Sakiadis flow

Figure 6 Effect of variable values of Sr on velocity profiles

3.2 | EFFECTS OF VARIOUS PARAMETERS ON TEMPERATURE PROFILES

This section considers the influence of the flow parameters on temperature profiles and illustrated in Figures (7) to (12). D_f has the same effect on both the Blasius and Sakiadis flows as shown in Figure 7 (a-b). The temperature profiles decreases with increase in D_f for

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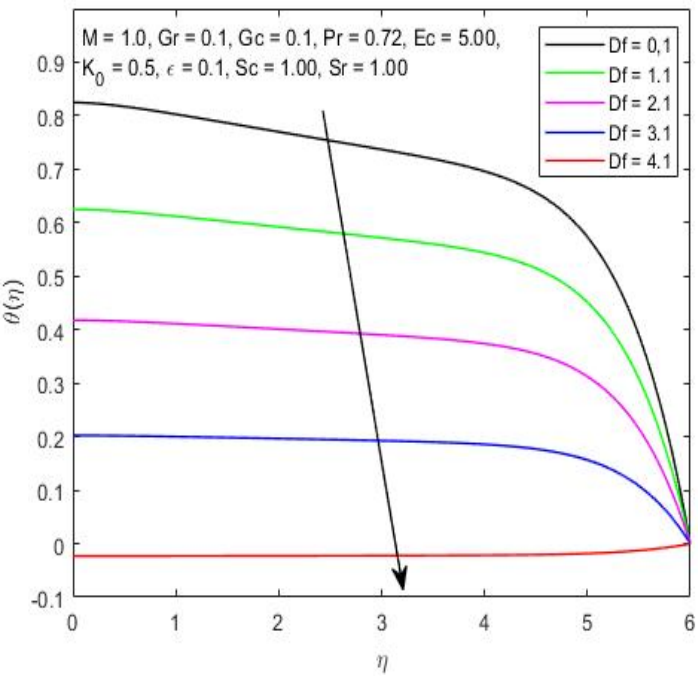
both the Blasius flow and the Sakiadis flow. Figure (8) and (10) show that Ec and local magnetic field parameter (M_x) have similar effect on the temperature profile of both Blasius and Sakiadis flows. Temperature profiles increase for both the Blasius and the Sakiadis flows with increase in Ec and M_x. Figure (9) shows that the temperature profiles decrease with increase in the local Grashof number (Gr_x) for both the Blasius flow and the Sakiadis flow while, in Figure (11) the influence of varying values of Pr on temperature profiles increases greatly in the Blasius flow as Pr increases but experiences a dual effect in Sakiadis flows as Pr increases. As Pr increases, the temperature profiles increases close to the boundary layer but decreases in the free stream. Figure (12) shows the influence of Sr on the temperature profiles and it is observed that the temperature profile increases with increase in the Sr for the Blasius flow but decreases for Sakiadis flow.



(a) Blasius flow

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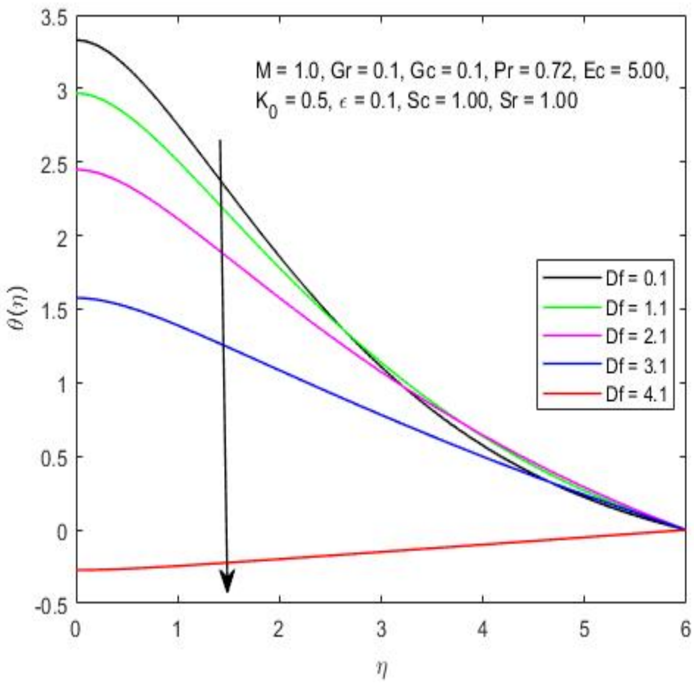
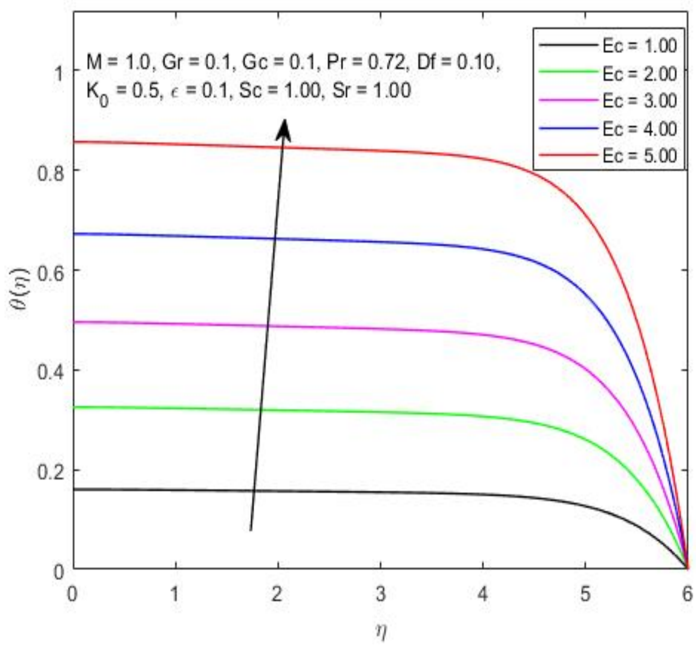


(b) Sakiadis flow

Figure 7 Effect of Dufour number (D_f) on the temperature profiles



(a) Blasius flow

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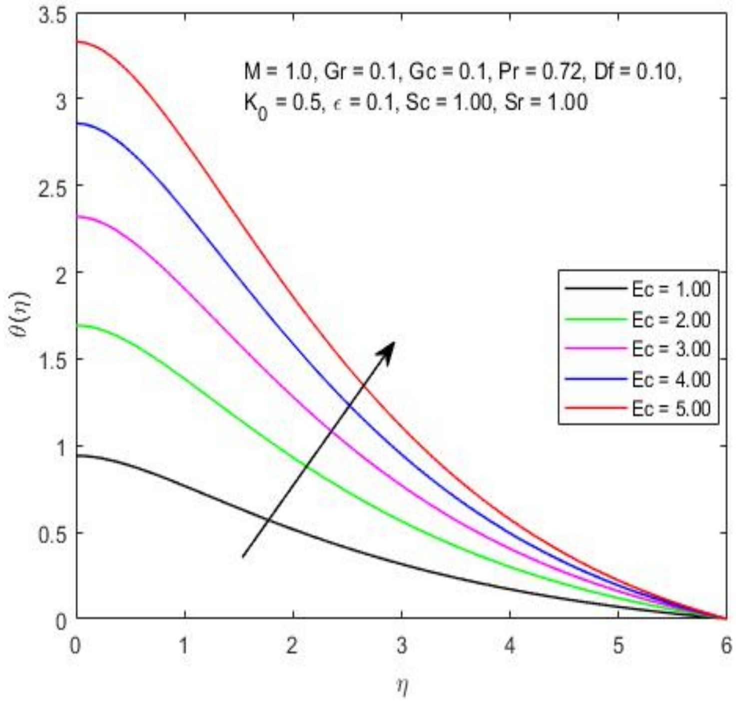
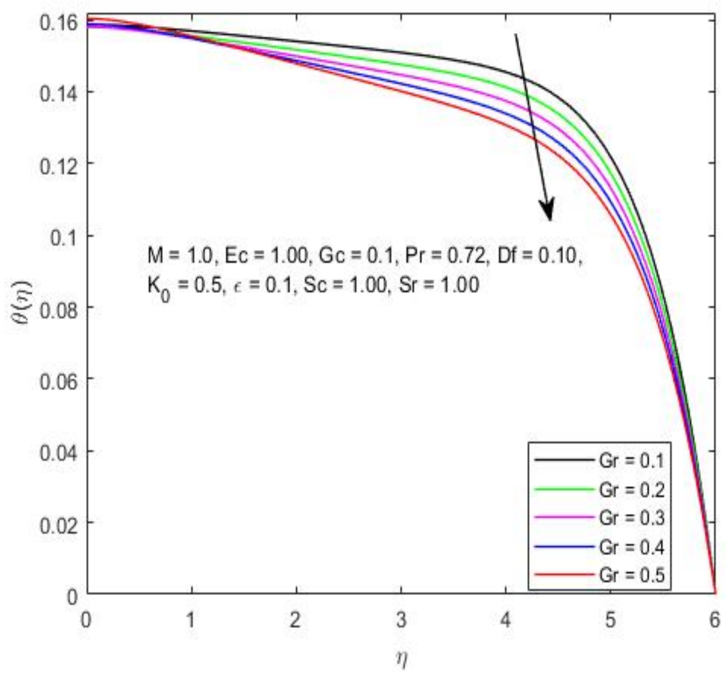


(b) Sakiadis flow

Figure 8 Effect of different values of Ec on temperature profiles



(a) Blasius flow

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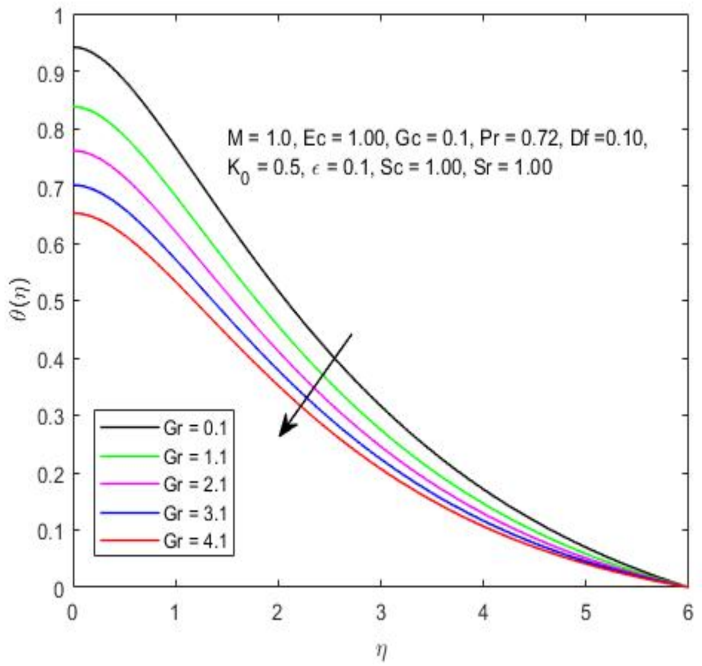
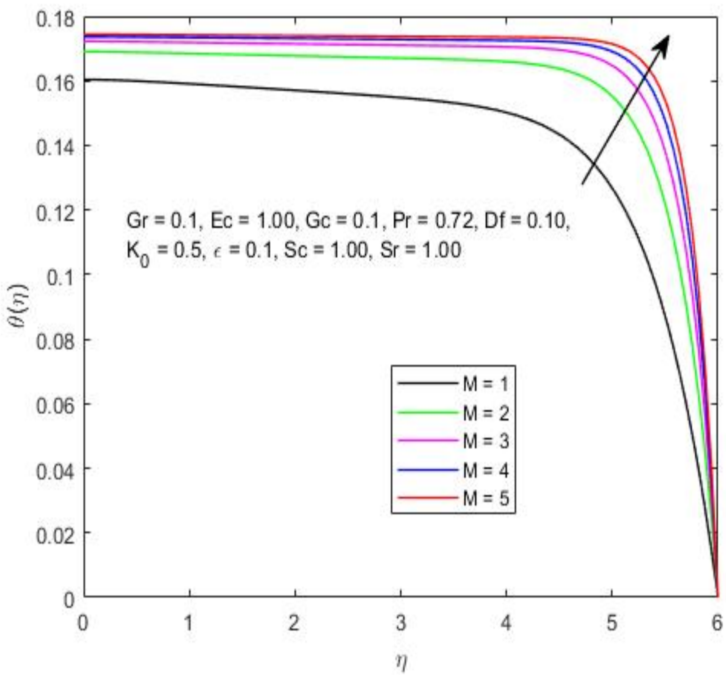


(b) Sakiadis flow

Figure 9 Effect of different values of Gr_x on temperature profiles



(a) Blasius flow

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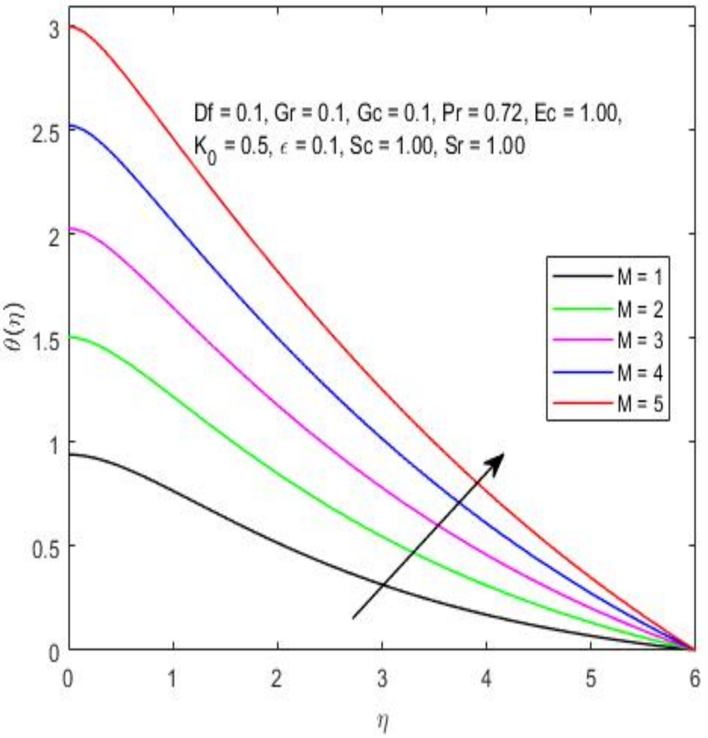
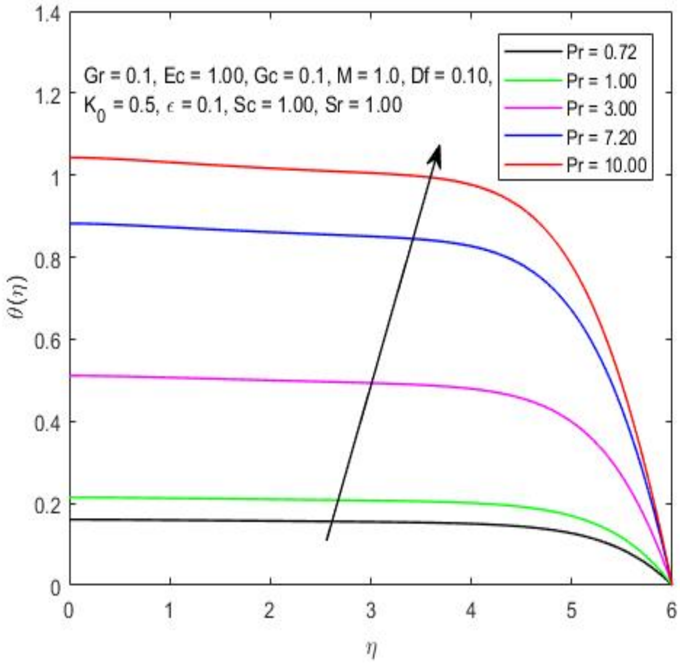


(b) Sakiadis flow

Figure 10 Effect of variable M_x on temperature profiles



(a) Blasius flow

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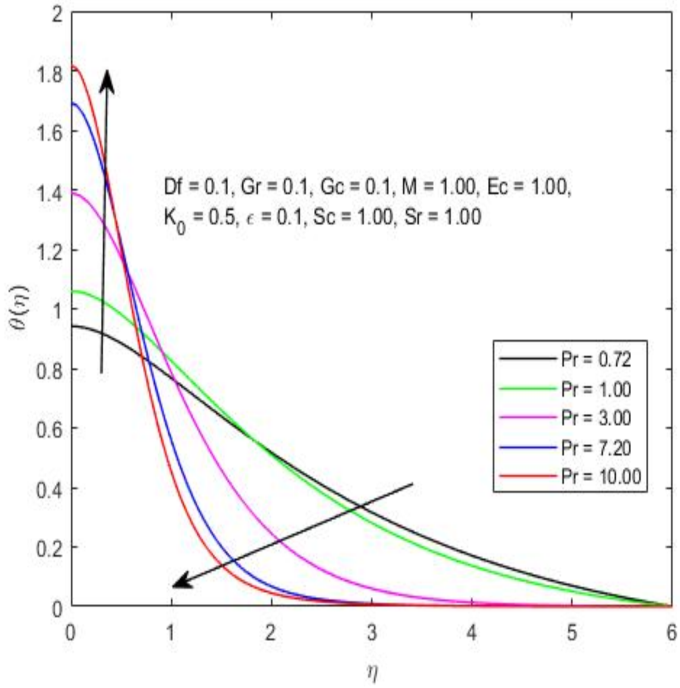
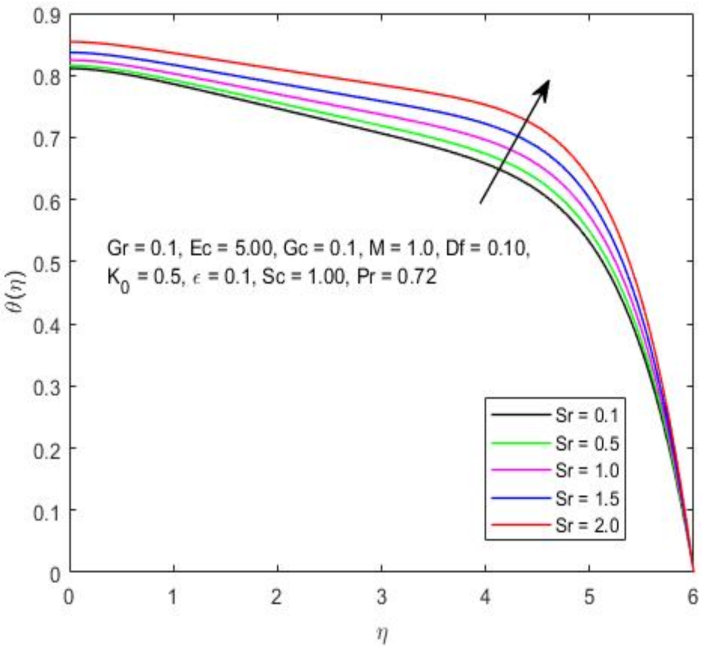


(b) Sakiadis flow

Figure 11 Effect of different values of Pr on the temperature profiles



(a) Blasius flow

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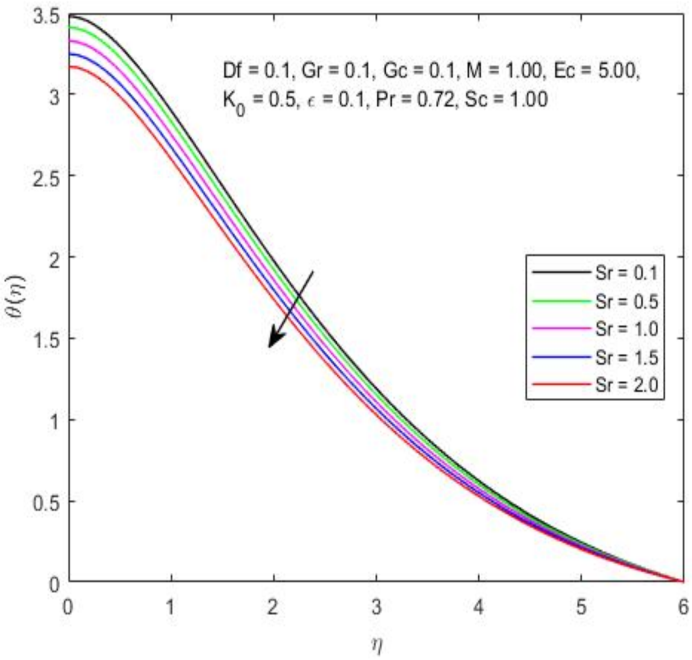

(b) Sakiadis flow

Figure 12 Effect of Soret number on the temperature profiles

3.3 | EFFECTS OF VARIOUS PARAMETER ON CONCENTRATION PROFILES

This section considers the influence of the flow parameters on the concentration profiles and depicted in Figures (13) to (18). Figure (13) shows D_f effects on Blasius and Sakiadis flows. It is observed that concentration profiles increase as D_f increases for Blasius flow but experiences a swirling first effect and then decreases for the Sakiadis flow. Figure (14) shows that increase in Ec decreases for Blasius flow but for Sakiadis flow, the concentration profiles experiences a decrease at the boundary layer and later increases at the free stream. Figure (15) shows that the concentration profiles decrease with increase in Gr_x for Blasius flow and the Sakiadis flow. It can be seen from Figure (16a) that increase in M_x have dual effect on the concentration profiles of Blasius flow. It is observed that concentration profiles increase in the boundary layer but decreases towards the free stream along the boundary layer. While the concentration profiles remains unchanged initially away from the plate, it later increased towards the free stream as M_x increased for Sakiadis flow (see Figure (16b)). Figure (17) shows the influence of Pr on the concentration profiles for Blasius and Sakiadis flows. It is observed that Blasius flow experiences decrease in the concentration profiles with increase in Pr whereas Sakiadis flow experiences increase in the concentration profiles with increasing values of Pr. Figure (18) shows the influence of Sr on the concentration profiles and it is observed that the concentration profiles decreases with increase in Sr for the Blasius flow with dual effect for the Sakiadis flow. These analysed results are in agreement with existing literatures.

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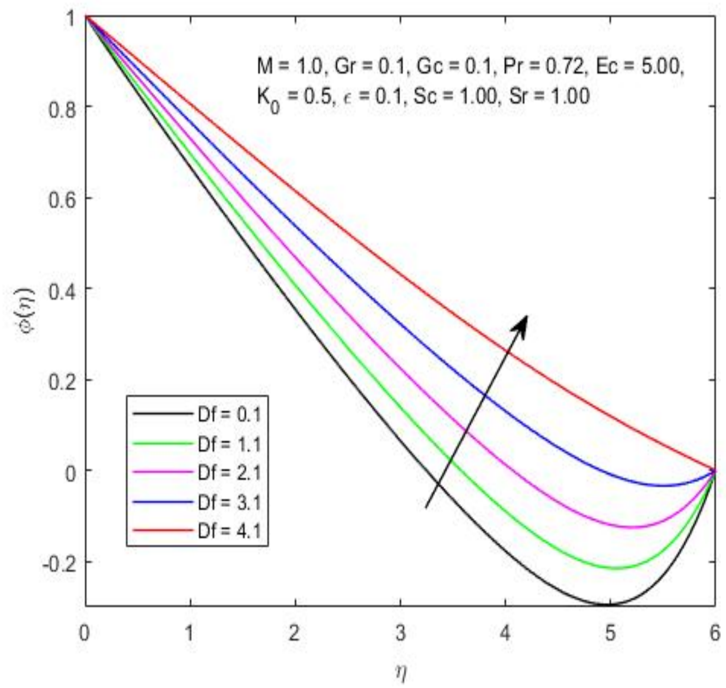
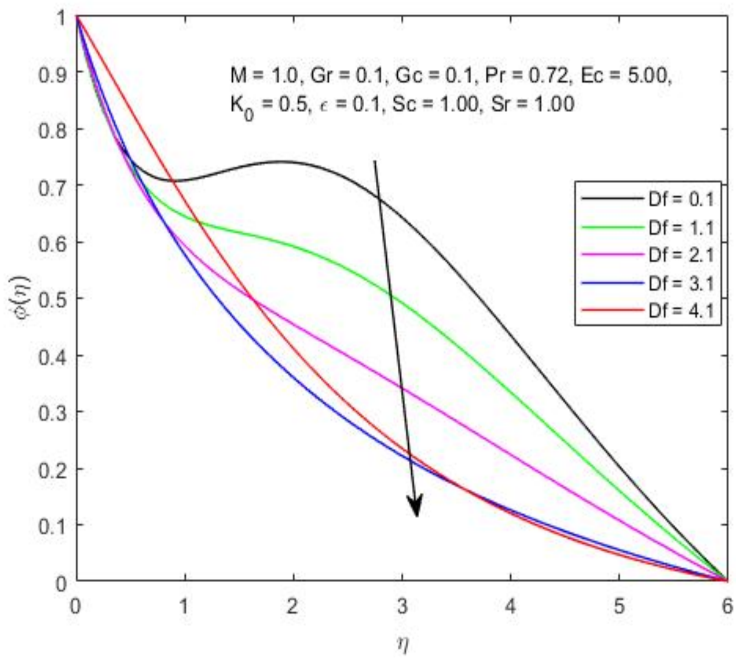


(a) Blasius flow



(b) Sakiadis flow

Figure 13 Effect of different values of D_f on concentration profiles

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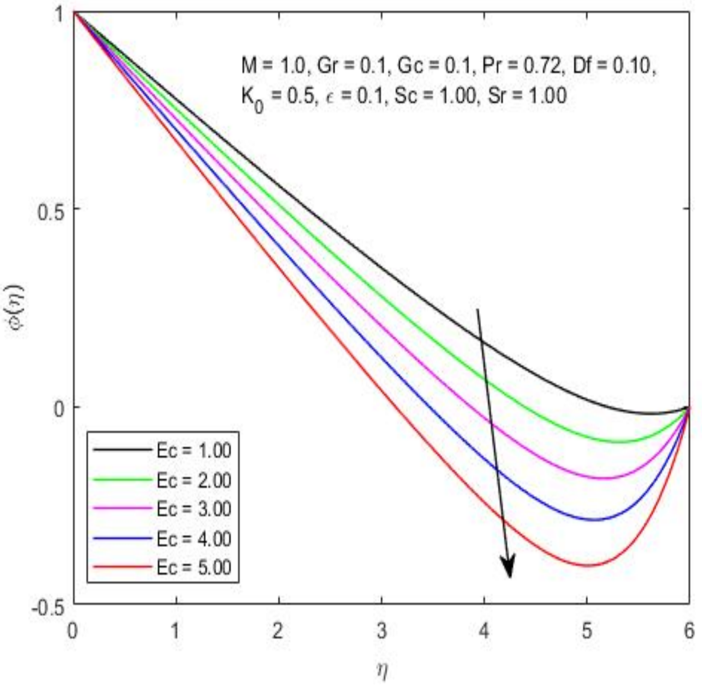
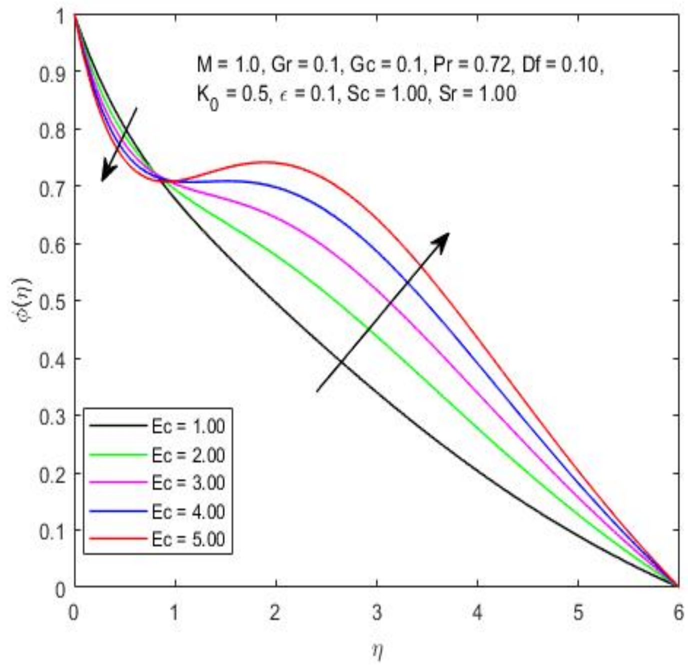


(a) Blasius flow



(b) Sakiadis flow

Figure 14 Effect of different values of Ec on concentration profiles

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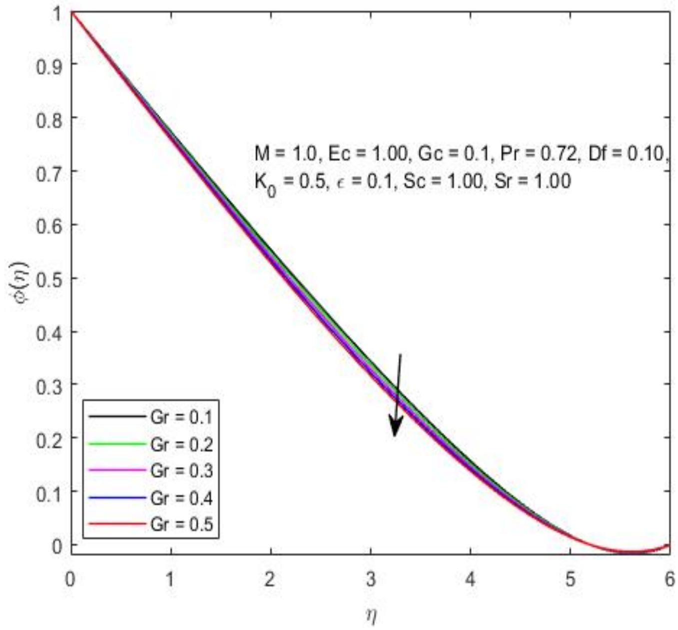
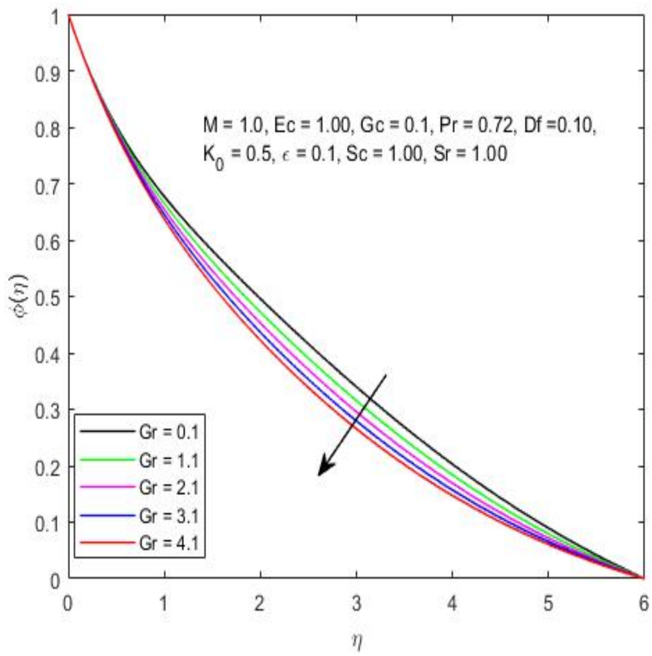


(a) Blasius flow



(b) Sakiadis flow

Figure 15 Effect of varying Gr_x on concentration profiles

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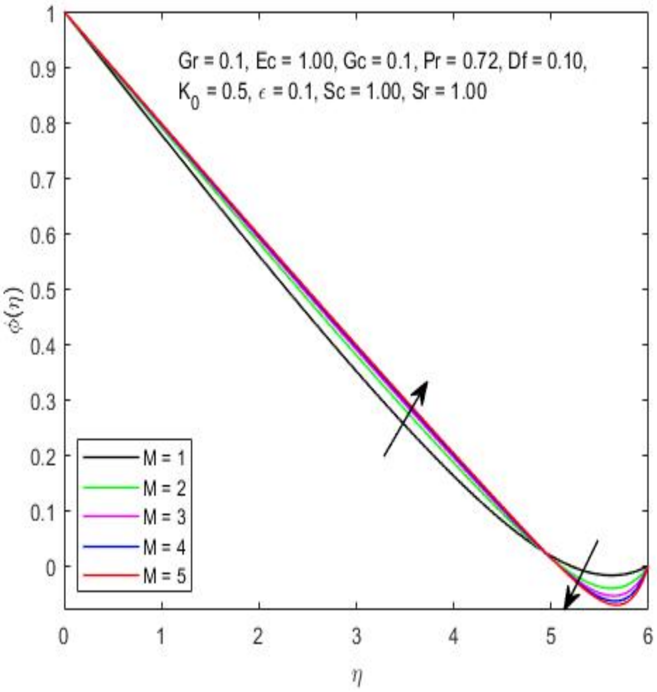
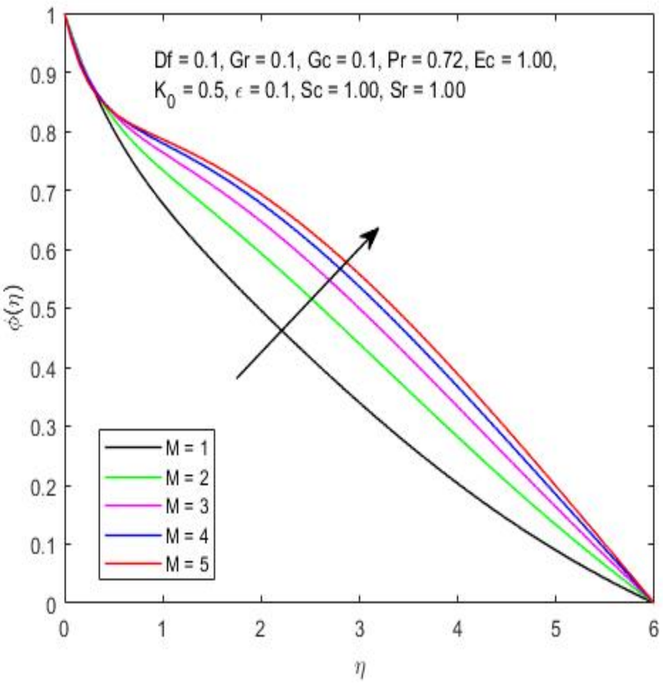


(a) Blasius flow



(b) Sakiadis flow

Figure 16 Effect of varying M_x on concentration profiles

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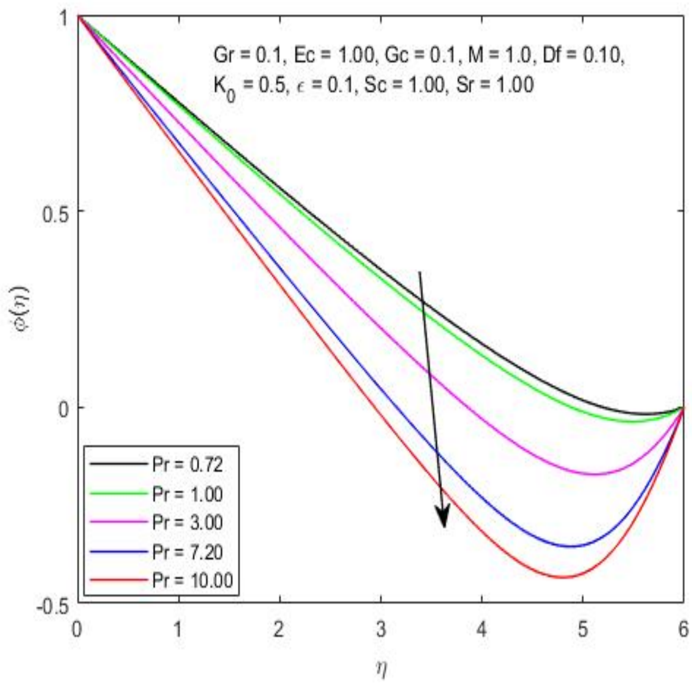
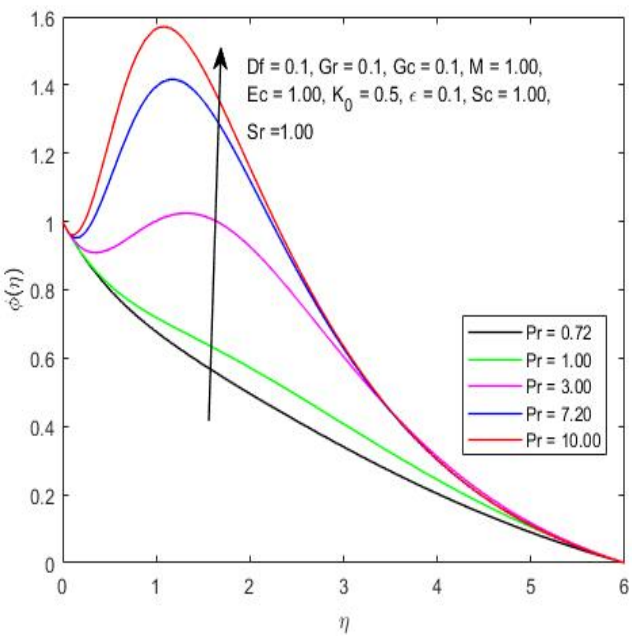


(a) Blasius flow



(b) Sakiadis flow

Figure 17 Effect of various values of Pr on concentration profiles

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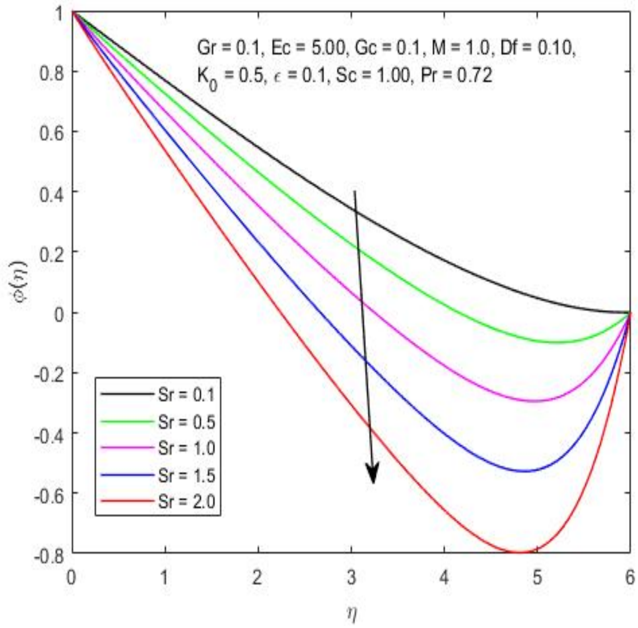
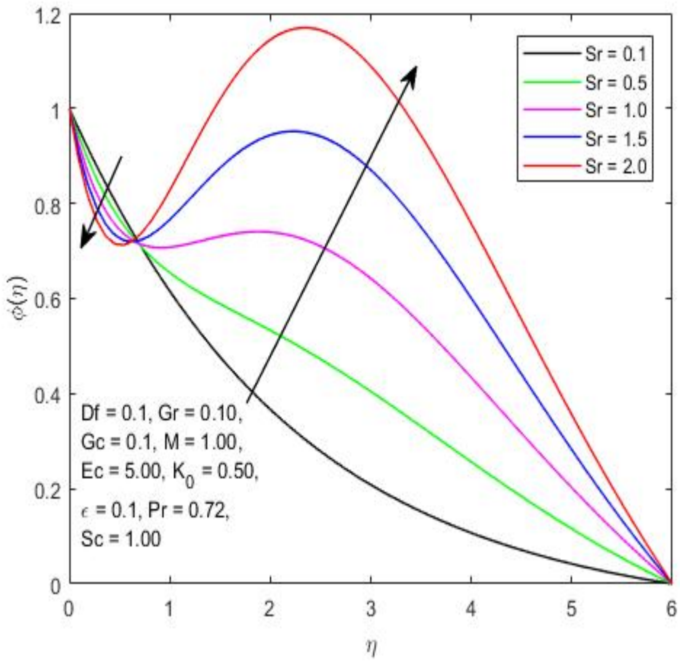


(a) Blasius flow



(b) Sakiadis flow

Figure 18 Effect of different values of Sr on concentration profiles

The numerical computations have been done for different parameters and we selected the following values: Prandtl number (Pr) is taken to be 0.72 which corresponds to air and positive value of the buoyancy parameters $Gr_x > 0$, which corresponds to the cooling problem, the local magnetic field parameter $(M_x = 1, 2, 3, 4, 5)$, local Grashof number $(Gr_x = 0.1, 0.2, 0.3, 0.4, 0.5)$, Eckert number $(Ec = 1, 2, 3, 4, 5)$, Prandtl number $(Pr = 0.72, 1, 3, 4, 5)$, Dufour number $(D_f = 0.1, 1.1, 1.2, 1.3, 1.4)$, Soret number $(Sr = 1.00)$, Schmidt number $(Sc = 1.00)$, local Solutal Grashof number $(Gc_x = 0.1)$, variable thermal conductivity parameter $(\varepsilon = 0.1)$ and thermal radiation parameter $(k_0 = 0.5)$ respectively.

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The effects of Gr_x, M_x, Ec, Pr and D_f on local skin-friction coefficient, local Nusselt number and local Sherwood number are shown in Tables (1) – (3).

Table 1 shows the influence of the flow parameter on skin-friction coefficient for Blasius and Sakiadis flow. Increase Gr_x, Ec and Pr brings an increase in skin-friction coefficient as increase in M_x and D_f results in the decrease of skin-friction coefficient for Blasius and Sakiadis flow respectively. Table (2) and (3) shows the flow parameters influence on the Nusselt and Sherwood numbers. Increase in local Grashof number (Gr_x) results in the increase of both Nusselt and Sherwood numbers for Blasius flow but decreases for Sakiadis flow. Increase in Eckert number (Ec) brings an increase in Nusselt and Sherwood numbers for both Blasius and Sakiadis flow. But decreases in Nusselt and Sherwood number for Blasius-Sakiadis flow with increasing values of Dufour number (D_f).

From Tables (2) and (3), increasing values of M_x and Pr, results in increasing values of Nusselt and Sherwood numbers both for Blasius and Sakiadis flow. Increase in M_x brings a decrease in both Nusselt and Sherwood numbers for Blasius-Sakiadis flow which are in agreement with the observations of Gangadhar (see Table (3)).

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Table 1 Computation of skin-friction coefficient $f''(0)$ for several values of the varying governing parameters

Gr	M	Ec	Df	Pr	$f''(0)$ (Blasius)	$f''(0)$ (Sakiadis)
0.1	1	1	0.1	0.72	0.1004	-0.9349
0.2	1	1	0.1	0.72	0.1157	-0.877
0.3	1	1	0.1	0.72	0.1309	-0.8291
0.4	1	1	0.1	0.72	0.1462	-0.788
0.5	1	1	0.1	0.72	0.1618	-0.7519
0.1	1	1	0.1	0.72	0.1004	-0.9349
0.1	2	1	0.1	0.72	0.0727	-1.3218
0.1	3	1	0.1	0.72	0.0608	-1.6245
0.1	4	1	0.1	0.72	0.0535	-1.8815
0.1	5	1	0.1	0.72	0.0484	-2.1085
0.1	1	1	0.1	0.72	0.1004	-0.9349
0.1	1	1	0.1	1	0.1047	-0.9254
0.1	1	1	0.1	3	0.1255	-0.9027
0.1	1	1	0.1	4	0.144	-0.8851
0.1	1	1	0.1	5	0.1505	-0.8778
0.1	1	1	0.1	0.72	0.1004	-0.9349
0.1	1	2	0.1	0.72	0.1137	-0.872
0.1	1	3	0.1	0.72	0.1272	-0.8195
0.1	1	4	0.1	0.72	0.1411	-0.7744
0.1	1	5	0.1	0.72	0.1554	-0.7349
0.1	1	5	0.1	0.72	0.1554	-0.7349
0.1	1	5	1.1	0.72	0.1389	-0.7647
0.1	1	5	2.1	0.72	0.1218	-0.8081
0.1	1	5	3.1	0.72	0.104	-0.8815
0.1	1	5	4.1	0.72	0.0853	-1.0365

Table 2 Computation of heat transfer coefficient $-\theta'(0)$ for several values of the embedding parameters

Gr	M	Ec	Df	Pr	$\theta'(0)$ (Blasius)	$\theta'(0)$ (Sakiadis)
0.1	1	1	0.1	0.72	-0.08412	-0.00583
0.2	1	1	0.1	0.72	-0.0842	-0.01619
0.3	1	1	0.1	0.72	-0.08419	-0.02386
0.4	1	1	0.1	0.72	-0.08411	-0.02986
0.5	1	1	0.1	0.72	-0.08396	-0.03475
0.1	1	1	0.1	0.72	-0.08412	-0.00583
0.1	2	1	0.1	0.72	-0.08327	0.05061
0.1	3	1	0.1	0.72	-0.08291	0.10289
0.1	4	1	0.1	0.72	-0.08274	0.15244
0.1	5	1	0.1	0.72	-0.08265	0.20014
0.1	1	1	0.1	0.72	-0.08412	-0.00583
0.1	1	1	0.1	1	-0.07897	0.00596

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0.1	1	1	0.1	3	-0.05381	0.03896
0.1	1	1	0.1	4	-0.03148	0.0692
0.1	1	1	0.1	5	-0.02346	0.08186
0.1	1	1	0.1	0.72	-0.08412	-0.00583
0.1	1	2	0.1	0.72	-0.06807	0.06939
0.1	1	3	0.1	0.72	-0.05172	0.13212
0.1	1	4	0.1	0.72	-0.03493	0.18591
0.1	1	5	0.1	0.72	-0.01755	0.23297
0.1	1	5	0.1	0.72	-0.01755	0.23297
0.1	1	5	1.1	0.72	-0.0375	0.19684
0.1	1	5	2.1	0.72	-0.05821	0.14493
0.1	1	5	3.1	0.72	-0.07976	0.05765
0.1	1	5	4.1	0.72	-0.10231	-0.12734

Table 3 Computation of Sherwood number $-\phi'(0)$ for several values of the varying parameters

Gr	M	Ec	Df	Pr	$-\phi'(0)$ (Blasius)	$-\phi'(0)$ (Sakiadis)
0.10	1.00	1.00	0.10	0.72	0.2286	0.5189
0.20	1.00	1.00	0.10	0.72	0.2331	0.5140
0.30	1.00	1.00	0.10	0.72	0.2375	0.5111
0.40	1.00	1.00	0.10	0.72	0.2420	0.5092
0.50	1.00	1.00	0.10	0.72	0.2465	0.5080
0.10	1.00	1.00	0.10	0.72	0.2286	0.5189
0.10	2.00	1.00	0.10	0.72	0.2135	0.5684
0.10	3.00	1.00	0.10	0.72	0.2082	0.6297
0.10	4.00	1.00	0.10	0.72	0.2055	0.6955
0.10	5.00	1.00	0.10	0.72	0.2038	0.7635
0.10	1.00	1.00	0.10	0.72	0.2286	0.5189
0.10	1.00	2.00	0.10	0.72	0.2589	0.6362
0.10	1.00	3.00	0.10	0.72	0.2900	0.7332
0.10	1.00	4.00	0.10	0.72	0.3222	0.8157
0.10	1.00	5.00	0.10	0.72	0.3557	0.8872
0.10	5.00	5.00	0.10	0.72	0.3557	0.8872
0.10	5.00	5.00	1.10	0.72	0.3173	0.8405
0.10	5.00	5.00	2.10	0.72	0.2777	0.7700
0.10	5.00	5.00	3.10	0.72	0.2369	0.6385
0.10	5.00	5.00	4.10	0.72	0.1946	0.3214
0.10	1.00	5.00	4.10	0.72	0.2286	0.5189
0.10	1.00	5.00	4.10	1.00	0.2383	0.5339
0.10	1.00	5.00	4.10	3.00	0.2856	0.5994
0.10	1.00	5.00	4.10	4.00	0.3281	0.7020
0.10	1.00	5.00	4.10	5.00	0.3438	0.7504

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3.4 | CONCLUSION

In this paper, we have theoretically studied the effects of variable parameters on Blasius and Sakiadis fluid flow about a flat plate in the presence of Dufour and Soret effects. The dimensionless differential Eqs. (9) – (13) were solved numerically to identify the effects of various variational parameters on the flow structure. The local magnetic field has shown that flow is retarded in the boundary layer but enhances temperature and concentration distributions. Dufour effects are influenced by increase in concentration but reduce both in velocity and temperature boundary layer thicknesses as the concentration field is appreciably influenced by the Soret effects [7, 12]. Further studies on the transient effects will be researched and communicated soonest.

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