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COMPUTATIONAL DYNAMICS OF AN IMPROVED INCLINED PLATE WITH VARIABLE TEMPERATURE AND VARIABLE MASS DIFFUSION IN THE EXISTENCE OF THERMAL CONVECTION EFFECTS

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ABSTRACT

This study examines the movement of an inert liquid (water or oil) over an inclined surface subjected to increasing temperature over time. Using the Laplace-transform approach, we simplify the analysis of the system's dynamic behavior. The non-dimensional governing equations derived describe variations in velocity (S), temperature (θ), and intensity (R) within the system. The key physical factors considered include the Schmidt number (Sc), Prandtl number (Pr), Grashof number (Gr), angle of inclination, and experiment duration. Our findings reveal that an increase in Grashof number (Gr) and Prandtl number (Pr) leads to higher fluid velocity, suggesting the enhancement of fluid motion due to greater temperature differentials and thermal diffusivity. Conversely, a decrease in the H parameter**,** Sherwood number (Sh), and experiment duration results in an increased fluid velocity, which indicates the influence of surface roughness, mass transfer efficiency, and experiment duration on fluid flow. Furthermore, increasing the Prandtl number correlates with a rise in the Nusselt number, demonstrating enhanced heat transfer. These insights into the effects of varying physical parameters on liquid movement over inclined surfaces have implications for applications in heat exchangers, cooling systems, and industrial processes where fluid flow and temperature control are critical. The novelty of the present work lies in the extension of the mass transfer effect investigation on an inclined plate. Previously, the plate had a uniform temperature and mass diffusion or a variable temperature and uniform mass diffusion. In this study, the plate has both variable temperature and variable mass diffusion.

Keywords: heat transfer, inclined plate, linear acceleration, inconsistent temperature, mass diffusion, skin friction, nusselt number.

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INTRODUCTION

There are numerous uses for inclined plates in the processing of materials, heat transfer, and fluid dynamics. Their inclination has a big impact on chemical reactions, heat transfer, and fluid flow. The applications include heat exchangers, heat transmission in industrial cooling, and automotive radiators. Solar collectors maximize the solar energy absorption for producing electricity and hot water. Also, the wing tilt and airfoil design can influence an aircraft's lift and drag. Fluid flow control is the creation of turbulence to improve mixing in chemical reactors and wastewater treatment. The catalytic converter mass transfer can be improved in chemical reactors to lower emissions. Increasing the settling area during wastewater treatment for solid-liquid separation is known as sedimentation.

Fujii and Imura [1] demonstrated spontaneous convective thermal transmission from an adjustable tilt plate. Gupta *et al*. [2] researched the unconstrained convective implications on flow through an advanced perpendicular panel in an incompressible diffusive liquid, while Soundalgekar analyzed the effects of mass transmission on the flow of fluid around a uniformly positioned vertical surface [3]. Singh and Raptis examined the unrestricted convection flow of Magneto-Hydro-Dynamic via a complex perpendicular surface [4]. [5] Several investigators analyzed the spontaneous convective boundary layer movement over a hot slab with a slope. [6] Basanth Kumar Jha and Ravindra Prasad investigated the consequences of free convection plus material transference on the passage through a propelled vertical plate containing heating elements. The Magneto-Hydro-Dynamic heat dispersion implications on unrestricted convection, as well as material transmission movement across an endless perpendicular movable surface, were researched by Kafoussias [7]. [8] Muthucumaraswamy and Ganesan investigated the first category chemical reactions on the circulation past an impulsively initiated vertical panel with consistent thermal and mass fluctuation. [9] Chamkha and

Khaled investigated the comparable approaches for Magneto-Hydro-Dynamic thermal as well as material transmission over a slanted panel with thermal output or assimilation. [10] Takhar *et al*. researched the effects of non-consistent barrier degree or material propagation in delimited parts of an inclined panel on the Magneto-Hydro-Dynamic inherent convection circulation in a temperature-segregated high-porosity environment. Molla *et al*. [11] studied the spontaneous convection circulation over a perpendicular undulating substrate with thermal iteration. [12] Alam *et al*. demonstrated a Magneto-Hydro-Dynamic free convective HMT circulation through a sloping surface with thermal output. [13] Deka investigated the Hall phenomena in a rapid MHD movement.

Sundar Raj *et al*. [14] studied the influences of thermal and material transfer on an expedited linear exterior with thermal flow and variable mass dispersion. Nagarajan *et al.* [15] examined the MHD implications on an undulating vertical panel in the existence of a 1st level synthetic response. Kumar &Varma [16] analyzed the consequences of radioactivity on MHD movement past a spontaneously initiated continuously advanced vertical surface with changeable temperature in the vicinity of thermal production. Singh [17] explored the thermal & mass transmission in an MHD boundary-level circulation across an inclined surface with viscous dispersion in a perforated environment. The thermal and mass transmissions in an MHD unlimited convective circulation over an inclined surface with Hall Potential were explored by Mohammad Shah Alam *et al*. [18]. Sandeep and Sugunamma [19] investigated the radiation impacts as well as inclined magnetic fields on a transient hydromagnetic unlimited convective circulation through an impetuously sliding directional panel in a perforated environment. The stepped temperature impact on intermittent MHD spontaneous circulation across an unbounded slanted exterior in the emission vicinity was researched by Narahari *et al*. [20]. Muthucumaraswamy and Jeyanthi [21] conducted a study on the influence of Hall effects in a magneto-hydrodynamic flow around an infinite vertical plate. Their investigation focused on a scenario involving a revolving liquid with variations coupled with a 1stlevel response. The Hall Current, radiation implications on magnetohydrodynamic spontaneous convective thermal, as well as mass transmission movement across an expedited slanted perforated surface with thermal dispersion, were given by Sidda Reddy and Raju [22].

The chemical synthesis influence on an intermittent MHD circulation via a spontaneously initiated undulating slanted surface with evolving temperature, as well as material dispersion in the vicinity of H, C, was investigated by Rajput and Gaurav Kumar [23]. Anjali Devi and Suriyakumar [24] expanded on their previous research on a hydromagnetic blended convective nanofluid slippage movement through a sloped stretchable panel in the existence of interior thermal absorption as well as suction. Setha *et al*. [25] showed the occurrence of unrestricted convective movement driven by magnetohydrodynamics on a moving plate orthogonal to the direction of movement. This circulation was achieved by modulating the heat circulation using an impermeable material in the presence of an angled magnetic field. Pattnaik *et al*. [26] evaluated the consequences of radiative and mass transmission on Magneto-hydro-dynamic circulation through a permeable medium through an infinitely propelled angled surface with differing temperatures. Thirupathi Thumma *et al*. [27] explored the FEA of MHD nanofluid flow across an alternating tilted panel with radiant supply, thermal input, and variable temperature consequences. Shankar Goud *et al*. [28analyzed thehe influence of HC as well as emission on Magneto-hydro-dynamicunlimited convective flow across an oriented parabolic advanced panel with dynamic temperature in a permeable medium. The thermal transmission, as well as slanted magnetism field influences on MHD circulation across a continuously propelled sloped slab in a permeable environment with varying temperatures were hypothesizedzed by Mehari Fentahun Endalew and Anita Nayak [29]. Sameh *et al*. [30] investigated the numerical simulation of heat transfer enhancements through magnetohydrodynamic natural convection over an inclined, semi-infinite, non-reflecting, ideally transparent plate embedded in a variable-porosity, heat-generating porous medium. They utilized nanofluid while considering the presence of solar radiation effects.

THE INFLUENCE OF MAGNETO-HYDRO-DYNAMIC

Streaming via an immensely oriented vertical surface with first-level synthetic activity with variable material disposal and thermal emission was expanded by Usharani *et al*. [31]. Prusty and Senapati [32] investigated the unsteady Magneto-Hydro-Dynamic HMT circulation of an emissive liquid across an expedited slanted perforated panel with chemical interaction. Praveen Kumar Dadheech *et al*. [33] conducted an entropy analysis for radiation-angled MHD slipping movement thermal supply in a porous medium utilizing 2 distinct fluids. Azhar Ali Zafar *et al*. [34] investigated the convection movement of a liquid with a certain rate over an inclined exterior, without the influence of a magnetic field. The investigation also included the implications of temperature and particulate supply. Shamshuddin *et al*. [35] assessed the thermal and solubility effectiveness of Cu/CuO NPs on a non-linear bilaterally expanding interface with a heated source/sink and different synthesized reactivity effects. Manjula & Muthucumaraswamy [36] investigated the influence of thermal as well as material transference on an orthogonal exterior in the vicinity of hall current and heat emission with changeable temperature. Nazish Iftikhar *et al*. [37] conducted a review on HMT via a spontaneous convective chilling circuit with a sloping magnetized gradient utilizing variational controllers. Swain *et al.* [38] evaluated the influence of MWCNT/Fe_3O_4 hybrid nano-particles on an exponentially permeable decreasing membrane exposed to

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synthetic processes and slip barrier circumstances. Shankar Goud Bejawada *et al*. [39] analyzed the influence of irradiation on Magneto-Hydro-Dynamic Casson liquid movement over a sloped non-linear barrier with synthetic reactivity in a Forchheimer permeable material. Preeti Kaushik and Upendra Mishra [40] investigated the quantitative resolution of unrestricted streaming Magneto-Hydro-Dynamic circulation with velocity slip constraint from a slanted perforated exterior. Nagarajan *et al*. [41] investigated the influence of thermodynamic extension on the circulation around an angled quickening segmented slab with continual material dispersion. Sivakumar and Muthucumaraswamy [42] examined the influence of emission on the circulation of a conical configuration across a perpendicular slab that has an unlimited length and maintains a consistent degree. Muhammad Ramzan *et al*. [43] thoroughly examined the dynamics of unsteady free convection flow involving a fractionalized viscous fluid over an oscillating vertically inclined plate. They integrated exponential heating to account for the thermal characteristics of the inclined plate and also considered additional factors like thermal diffusion and slip within their model. Notably, they employed the Caputo fractional derivative in their analysis. A key aspect of their research was investigating how the angle of inclination impacted flow phenomena. Furthermore, they enhanced the model's applicability by incorporating principles from Fourier's and Fick's laws.

[44] Sundar Raj *et al.* investigated the flow instability of a non-steady stream over an inclined plate with constant temperature and mass diffusion. Furthermore, he has also examined [45] the influences of chemical reactions on an inclined isothermal vertical plate.

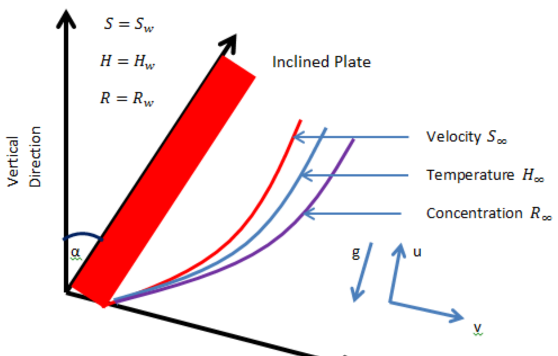
The effects of thermal radiation on the time-dependent flow of a Casson fluid induced by an exponentially accelerated inclined surface were analyzed by Endalew and Subharthi Sarkarz. [46] Their analysis also incorporates convective boundary conditions for both thermal and solutal aspects. The numerical simulation of an incompressible micropolar dusty fluid (fluid-particle suspension) was proposed for three types of flows in an inclined channel by Chandrawat *et al*. [47]. Bharathi *et al*. [48] examined the features of natural convection flow affected by variable thermal conductivity and electro-osmosis along an infinite vertical plate. The dynamics of fluid flow characterized by unsteady, magneto hydrodynamic (MHD) natural convection was examined by Obulesu Mopuri *et al*. [49]. Their study focused on a viscous, incompressible fluid exhibiting non-Newtonian behavior according to the Jeffery model. This fluid flowed over a semi-infinite inclined plate, which was both permeable and moving, and was situated within a porous medium. The investigation incorporated various additional factors, such as thermal radiation, heat absorption, thermal diffusion, and heat and mass transfer phenomena. Mosharrof Hossain *et al*. [50] examined how viscous dissipation influenced the convective transport of an unstable magneto-porous micropolar binary fluid near an inclined surface. The investigation also took into account the effects of thermal radiation alongside viscous dissipation. Nagarajan *et al*. [51] investigated the impact of chemical processes on a sloped surface, focusing on how variations in mass and a constant temperature influence the system. Sundar Raj *et al*. [52] conducted a study on the effects of a magnetic field on fluid flow over an inclined isothermal vertical plate, considering heat transfer and varying mass diffusion.

As a consequence, it is proposed that the influences of circulation through a consistently advanced inclined surface with varying temperature and mass dispersion could be investigated. To resolve dimensionless numerical solutions, the Laplace-transform approach is utilized. The answers are shown as exponential and complement incorrect functional.

MATHEMATICAL ANALYSIS

The erratic movement (unsteady flow)of a viscid incompressible liquid through a slanted surface with changeable temperature, as well as mass dispersion, was explored. When a plate is inclined at an angle α from the x-axis (vertical direction), the flow dynamics are influenced by both the inclination angle and any erratic movements, such as turbulence. The inclination affects the gravitational component along the plate, altering the buoyancy forces and flow patterns.

The surface and liquid are both. (H_∞) and (R_∞) at the same duration $t_1 \le 0$. At $t > 0$, the surface is expedited with $u = \frac{u_0^3 t'}{\nu}$ in its surface, and H_∞ rises linearly over t, as does Adjacent to the surface. The unsteady flow is then regulated by the subsequent formulations under Boussinesq's approximation:



Physical Model

ARPN Journal of Engineering and Applied Sciences

$$\frac{\partial u}{\partial t'} = g\beta\cos\alpha\,(H - H_\infty) + g\beta^*\cos\alpha\,(R' - R'_\infty) + \nu\frac{\partial^2 u}{\partial y^2} \quad (1)$$

$$\rho R_p \frac{\partial H}{\partial t'} = k\frac{\partial^2 H}{\partial y^2} \quad (2)$$

$$\frac{\partial R'}{\partial t'} = D\frac{\partial^2 R'}{\partial y^2} \quad (3)$$

with the appropriate boundary conditions listed below:

$$\begin{aligned} & u = 0, H = H_\infty, R' = R'_\infty \;\; for\, all\;\; y, t' \le 0 \\ & when,\; t' > 0, \\ & u = \frac{u_0^3 t'}{\nu\;_4}, H = H_\infty + (H_\omega - H_\infty)\,A\,t', R' = R'_\infty + (R'_\omega - R'_\infty)A\,t' \\ & \qquad at\;\; y = 0 \\ & u \to 0,\; H \to H_\infty, R' \to R'_\infty,\; as\;\; y \to \infty \end{aligned} \quad (4)$$

where $A = \frac{u_0^2}{\nu}$.

the dimensionless parameters are established:

$$S = \frac{u}{u_0}, t = \frac{u_0^2\, t'}{\nu}, Y = \frac{y u_0}{\nu^2},$$
$$\psi_1^* = \frac{H - H_\infty}{H_\omega - H_\infty}, Gr = \frac{g\nu\beta(H_\omega - H_\infty)}{u_0}, R = \frac{R' - R'_\infty}{R'_\omega - R'_\infty}, \quad (5)$$
$$Gc = \frac{g\nu\beta^*(R'_\omega - R'_\infty)}{u_0}, P_r = \frac{\mu R_p}{k}, S_c = \frac{\nu}{D}$$

in calculations, Equation (1) to Equation(4), results in Applying boundary conditions (4) to equations (1) through (3) and utilizing dimensionless parameters, we obtain

$$\frac{\partial S}{\partial t} = Gr\cos\alpha\,\psi_1^* + Gc\cos\alpha\,R + \frac{\partial^2 S}{\partial Y^2} \quad (6)$$

$$\frac{\partial \psi_1^*}{\partial t} = \frac{1}{P_r}\frac{\partial^2 \psi_1^*}{\partial Y^2} \quad (7)$$

$$\frac{\partial R}{\partial t} = \frac{1}{S_c}\frac{\partial^2 R}{\partial Y^2} \quad (8)$$

In non-dimensional measurements, the subject of the BC's are

$$\begin{aligned} t \le 0: &\quad S = 0, \quad \psi_1^* = 0, \quad R = 0 \quad for\, all \quad Y \\ t > 0: &\quad S = t, \quad \psi_1^* = t, \quad R = t \quad at \quad Y = 0 \\ &\quad S \to 0, \quad \psi_1^* \to 0, \quad R \to 0 \quad as \quad Y \to \infty \end{aligned}$$

(9)

WORKING PROCEDURE

Nondimensional mathematical expressions Equation (6) to Equation (8), are solved using the standard Laplacian technique, and the answers are obtained as follows, corresponding to the preliminary BC's, Equation (9):

$$\psi_1^* = t\left[(1 + \frac{Y^2 P_r}{2t})\, erfc\,(\frac{Y\sqrt{P_r}}{2\sqrt{t}}) - \frac{Y\sqrt{P_r}}{\sqrt{t\,\pi}}\exp(-\frac{Y^2 P_r}{4t})\right] \quad (10)$$

$$R = t\left[(1 + \frac{Y^2 S_c}{2t})\, erfc\,(\frac{Y\sqrt{S_c}}{2\sqrt{t}}) - \frac{Y\sqrt{S_c}}{\sqrt{t\,\pi}}\exp(-\frac{Y^2 S_c}{4t})\right] \quad (11)$$

$$\begin{aligned} S = {} & t\left[(1 + 2\eta^2)\, erfc(\eta) - \frac{2\eta}{\sqrt{\pi}} e^{(-\frac{y^2}{4t})}\right] \\ & - \frac{Gr\cos\alpha\, t^2}{6(1 - P_r)}\left[\begin{aligned} & (3 + \frac{3y^2}{t} + \frac{y^4}{4t^2}) erfc(\eta) - (3 + 12\eta^2 P_r \\ & + 4\eta^4 (P_r)^2) erfc(\eta\sqrt{P_r}) - \frac{\eta}{\sqrt{\pi}}(10 + 4\eta^2)\exp(-\eta^2) \\ & + \frac{\eta\sqrt{P_r}}{\sqrt{\pi}}(10 + 4\eta^2 P_r)\exp(-\eta^2 P_r) \end{aligned}\right] \\ & - \frac{Gc\cos\alpha\, t^2}{6(1 - S_c)}\left[\begin{aligned} & (3 + \frac{3y^2}{t} + \frac{y^4}{4t^2}) erfc(\eta) \\ & - (3 + 12\eta^2 S_c + 4\eta^4 (S_c)^2) erfc(\eta\sqrt{S_c}) \\ & - \frac{\eta}{\sqrt{\pi}}(10 + 4\eta^2)\exp(-\eta^2) \\ & + \frac{\eta\sqrt{S_c}}{\sqrt{\pi}}(10 + 4\eta^2 S_c)\exp(-\eta^2 S_c) \end{aligned}\right] \end{aligned} \quad (12)$$

Where, $\eta = \frac{Y}{2\sqrt{t}}$.

Skin-Friction (τ)

The non-dimensional plate friction factor seems to be

$$\tau = -\left[\frac{\partial S}{\partial y}\right]_{y=0} = -\frac{1}{2\sqrt{t}}\left[\frac{dS}{d\eta}\right]_{\eta=0}$$

ARPN Journal of Engineering and Applied Sciences

$$\tau = \frac{2\sqrt{t}}{\sqrt{\pi}} + \frac{4G_r \cos\alpha\, t\sqrt{t}}{3(1-P_r)\sqrt{\pi}}(-1+\sqrt{P_r}) + \frac{4G_c \cos\alpha\, t\sqrt{t}}{3(1-S_c)\sqrt{\pi}}(-1+\sqrt{S_c})$$

Sherwood number (S_h)

S_h is given by $S_h = -\left[\frac{dR}{dy}\right]_{\eta=0} = \frac{2\sqrt{t}\sqrt{S_c}}{\sqrt{\pi}}$

Nusselt number (N_u)

$$N_u = -\left[\frac{d\psi_1^*}{dy}\right]_{\eta=0} = \frac{2\sqrt{t}\sqrt{P_r}}{\sqrt{\pi}}$$

Table-1. Skin-Friction for different parameters.

α (in degrees)	t	P_r	Gr	Gc	S_c	τ
30	0.2	0.71	2	2	0.16	0.4406
45	0.2	0.71	2	2	0.6	0.4917
60	0.2	7.0	2	2	0.3	-0.1811
30	0.4	0.71	2	5	2.01	0.5042
45	0.4	7.0	2	5	0.16	-2.2830
60	0.4	0.71	2	5	0.6	0.6621
30	0.6	7.0	5	5	0.3	-14.5541
45	0.6	0.71	5	5	2.01	0.2961
60	0.6	7.0	5	5	0.16	-7.8313
90	0.2	0.71	2	2	0.6	0.5046

Table-2. Sherwood quantity for different parameters.

t	S_c	S_h
0.2	0.16	0.2019
0.4	2.01	1.0118
0.6	2.01	1.2392
0.2	0.6	0.3909
0.4	0.16	0.2855
0.6	0.3	0.4788

Table-3. Nusselt quantity for different parameters.

t	P_r	N_u
0.2	0.71	0.4252
0.4	0.71	0.6013
0.6	0.71	0.7365
0.2	7.0	1.3351
0.4	7.0	1.8881
0.6	7.0	2.3125

RESULTS AND DISCUSSIONS

To obtain a corporeal understanding of the issue, mathematical calculations for numerous tangible criteria, as well as the essence of the surge and transit, are performed. It is assumed to be 0.3. In addition, the P_r values are selected to identify air ($P_r = 0.71$). The various outcomes are evaluated for various physical parameters.

In Figure-1, we observe a depiction of tilt angles (60°, 45°, 30°) alongside Schmidt number (Sc) of 0.3, Prandtl number (Pr) of 0.71, and at a specific time point, t = 0.4. Notably, there's a discernible pattern: as the velocity increases, there's a corresponding reduction in the tilt angle. This relationship suggests that higher velocities are associated with a decrease in tilt angle, indicating a potential inverse correlation between velocity and tilt angle within the observed parameters.

Figure-2 illustrates the impact of different Grashof numbers (Gc = 5, 10, 50, 100) under specific conditions: time t = 0.4, Prandtl number (Pr) = 0.71, Schmidt number (Sc) = 0.3, Grashof number (Gr) = 2, and a fixed angle parameter of 45 degrees. Notably, there's a clear trend observed: as the Grashof number (Gc) increases, there's a corresponding rise in velocity. This relationship suggests that higher Grashof numbers are associated with increased velocity, implying a positive correlation between Gc and velocity within the given parameters.

In Figure-3, the impacts of several factors: Gr (Grashof number), Pr (Prandtl number), Sc (Schmidt number), and Gc (Grashof number), at a specific time point of 0.4, and an angle parameter set at 45 degrees are examined. The relationship stated indicates that Gr is directly proportional to velocity V. This phenomenon is crucial because a higher Grashof number leads to buoyancy effects, which consequently induces more flow within the system.

In Figure-4, the influence of the variable v across different values of Sc (Schmidt number), Gr (Grashof number), and Gc (Grashof number), at a given time and angle parameter, is explored. The observation made in this context is that there exists an inverse relationship between Sc and v. This means that as the Schmidt number increases, the velocity v decreases, and vice versa. This inverse proportionality suggests that the changes in the Schmidt number might have a significant impact on the velocity v within the system under consideration.

Figure-5 illustrates velocity contours across a range of durations (t), Gr (Grashof number), Gc (Grashof number), Pr (Prandtl number), Sc (Schmidt number), and different angle parameter values. An observation from this depiction is that with increasing durations (t), there is a corresponding escalation in velocity. This indicates a direct correlation between the duration of the process and the velocity within the system. As time progresses, the velocity tends to elevate, suggesting a progressive intensification of flow dynamics or mass transfer phenomena.

In Figure-6, the effects of different Gc values: 5, 10, 50, and 100, while keeping other parameters constant at time 0.6, Pr = 0.71, Sc = 0.6, Gr = 5, and an angle parameter of 30 degrees are examined. Additionally, an important observation is made: The Gc exhibits a direct proportionality to the velocity v.

In Figure 7, the effects of different Gr values: 5, 10, 50, and 100, while maintaining other parameters constant at time 0.6, Pr = 0.71, Sc = 0.6, Gc = 2, and an angle parameter of 60 degrees were examined. Additionally, an important observation is made: Gr exhibits a direct proportionality to the velocity v.

In Figure-8, the influence of different Sc values, including 0.16, 0.3, 0.6, and 2.01, is examined alongside Gr and Gc set to 2, at a time of 0.6, with Pr = 0.71, and an angle parameter of 30 degrees. The notable observation is the inverse relationship between Sc and velocity v. This implies that as the Schmidt number (Sc) increases, the velocity v decreases. This inverse proportionality indicates that the changes in Sc have a significant impact on the velocity within the system.

In Figure-9, the velocity contours are illustrated for different durations (t = 0.2, 0.4, 0.6, 0.8), with Gr and Gc both set to 2, Pr = 0.71, Sc = 0.6, and an angle parameter of 30 degrees. An important observation from this depiction is that as the duration (t) increases, there is a corresponding increase in velocity. This suggests a direct correlation between the duration of the process and the velocity within the system.

In Figure-10, we examine the effects of different values for Gr (Grashof number) and Gc (geometry factor), with Gr ranging from 2 to 5 and Gc ranging from 2 to 5. Additionally, Sc is set at 0.3, Pr is set at 0.71, the angle parameter is fixed at 45 degrees, and the velocity is observed at a specific time, t = 0.2. A significant observation from this analysis is that as either Gr or Gc increases, there is a corresponding increase in velocity v. This suggests a direct relationship between these parameters and velocity, indicating that changes in Gr or Gc lead to changes in the velocity within the system.

In Figure-11, we explore the effects of different values for the Prandtl number (Pr), with Pr 0.71 and 7.0. Other parameters include a fixed angle of 45 degrees, a specific time point of t = 0.4, and constant values for Sc (0.3) and Gr set to 5. A notable observation from this analysis is that as the Prandtl number increases, there is a proportional increase in velocity. This indicates a direct relationship between the Prandtl number and velocity within the system under consideration.

Figure-12 illustrates the influence of assimilation profiles at different Schmidt numbers (Sc) at a fixed time of 0.6. Control over deliberation is notably important in this field. The magnitude consistently decreases from the outermost area to a point where the variable reaches zero in unconfined flows across all configurations. Additionally, there's an observation that the wall focus increases as the Schmidt number decreases.

Figure-13 displays temperature contours for two different Prandtl numbers: 0.71 and 7.0, at a specific time of 0.6. The illustration suggests that as the Prandtl number decreases, the time increases.

In Table-1, we observe the effects of local skin friction on various parameters. Increasing the incline angle leads to an increase in skin friction. However, this has the opposite effect on the time, thermal, and mass Grashof numbers, causing them to increase instead.

Table-2 illustrates the influence of Schmidt number (Sc) and time (t) on the Sherwood number (Sh). It is observed that an increase in Sc directly correlates with an augmentation in Sh. As Sc increases, the mass transfer represented by Sh also increases in a directly proportional manner.

Table-3 presents the Nusselt number (Nu) for different physical parameters, including Prandtl number (Pr) and time. The table shows that the Nusselt number for air (Pr = 0.71) is lower than that of water (Pr = 7). The reason is that the higher values of Pr decrease the thermal conductivities and hence the heat can diffuse away from the plate and further rapidly.

NOVELTY

The novelty in the present work lies in extending the investigation of mass transfer effects on an inclined plate from the previous study by Sundar *et al*. [41] and [43]. In the prior work, the plate was assumed to have uniform temperature and uniform mass diffusion, and also variable temperature and uniform mass diffusion, whereas, in the current study, the plate exhibits variable temperature and variable mass diffusion. This extension allows for a more comprehensive understanding of the heat and mass transfer phenomena occurring on inclined surfaces, capturing the complexities of real-world scenarios more accurately. By considering variable temperature and mass diffusion, the present study provides insights into how these variations influence the heat and mass transfer processes, offering potentially valuable implications for various engineering applications, such as in heat exchangers, chemical reactors,

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and environmental processes. We have utilized the Laplace transform method to solve. Furthermore, we have harnessed the capabilities of the MATLAB programming platform to obtain graphical representations of our findings.

CONCLUSIONS

We investigated the precise solution of unsteady circulation across a consistently advanced slanted surface in the context of changing heat and mass transfer (HMT).

The following indicators are given:

a) Velocity increases as the angle of inclination, Schmidt number, and time reduces.

b) Velocity elevates when the thermal Grashof number and mass Grashof number rise.

c) Temperature increases with decreasing Pr.

d) Intensity improves when the Sc is reduced.

e) Local skin friction elevates when angle, Pr, Sc increases, and it reduces under elevation of Gr, Gc, t.

f) The thermal transmission is enhanced while Pr increases.

g) The mass transmission elevates when Sc rises.

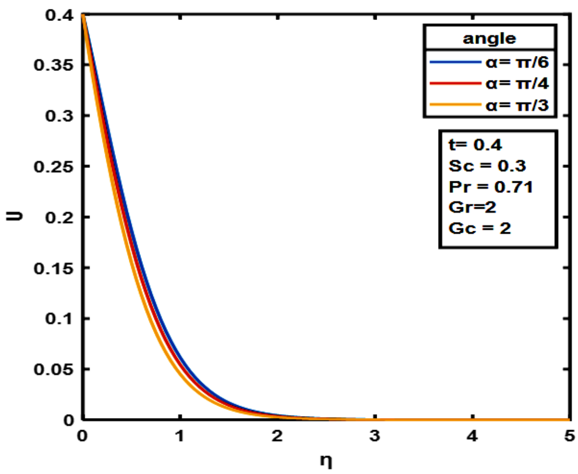

Figure-1. Velocity Profile for different values of angle α.

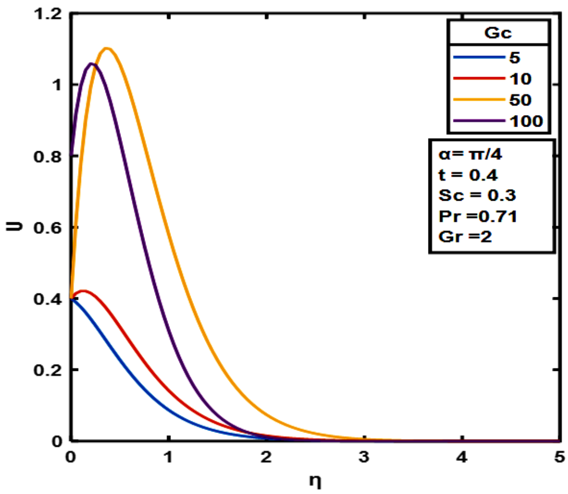

Figure-2. Velocity Profile for different values of Gc.

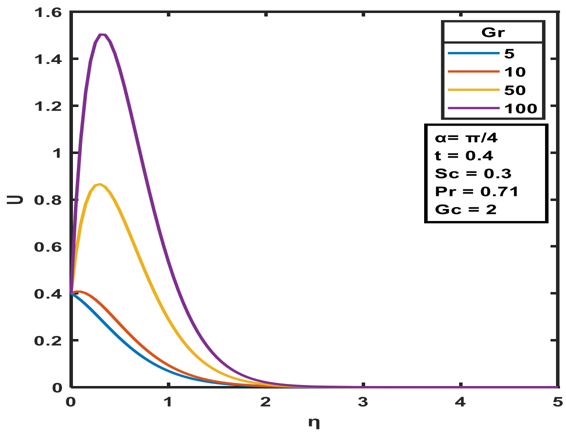

Figure-3. Velocity Profile for different values of Gr.

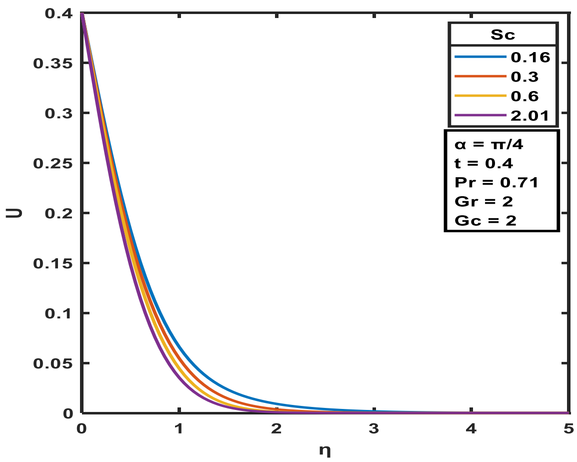

Figure-4. Velocity Profile for different values of S_c.

VOL. 20, NO. 15, AUGUST 2025 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

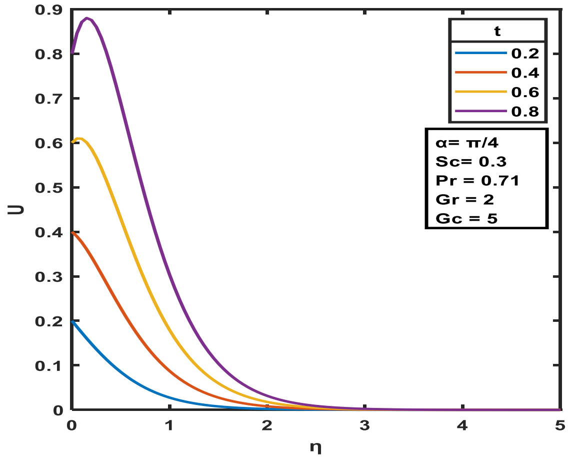

Figure-5. Velocity Profile for different values of t.

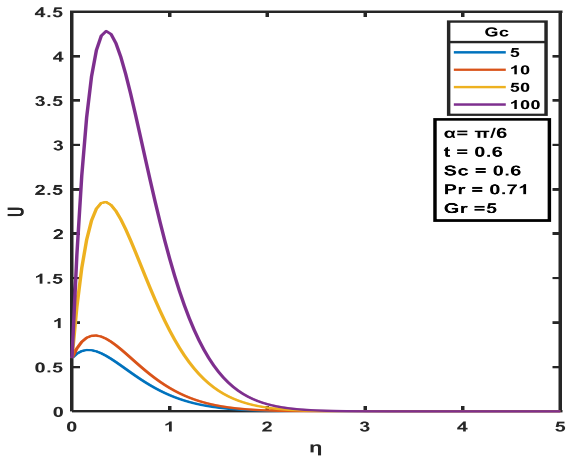

Figure-6. Velocity Profile for different values of Gc.

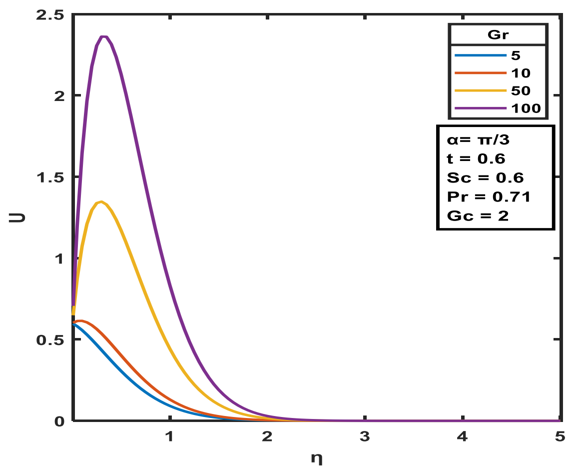

Figure-7. Velocity Profile for different values of Gr.

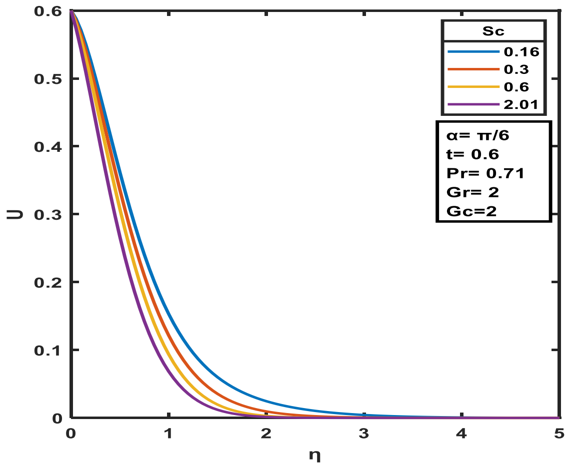

Figure-8. Velocity Profile for different values of S_c.

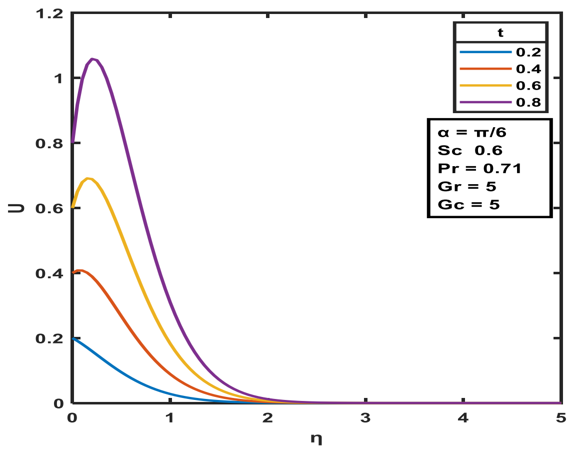

Figure-9. Velocity Profile for different values of t.

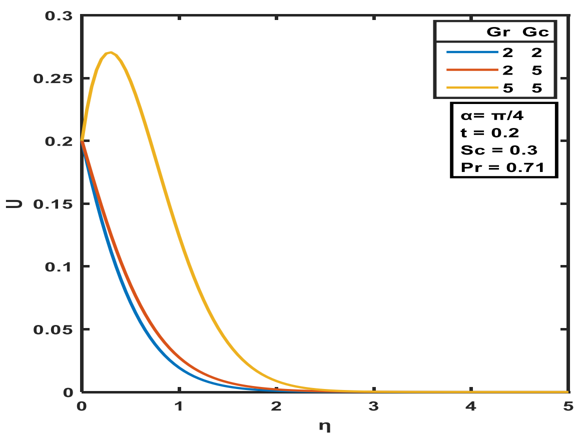

Figure-10. Velocity Profile for different values of Gr and Gc.

VOL. 20, NO. 15, AUGUST 2025 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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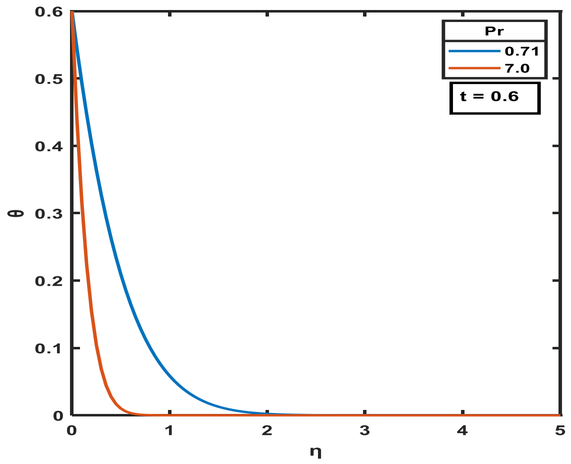

Figure-11. Velocity Profile for different values of Pr .

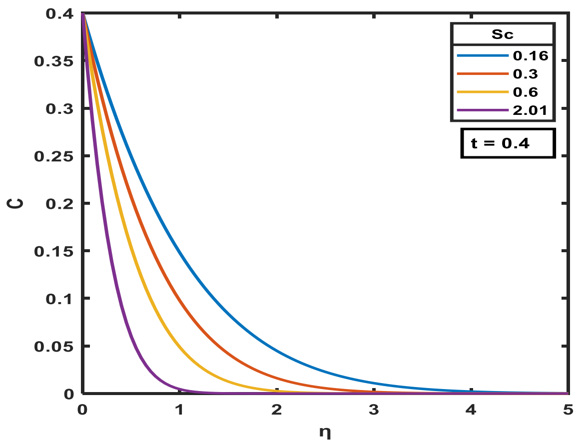

Figure-12. Concentration Profile for different values of S_c .

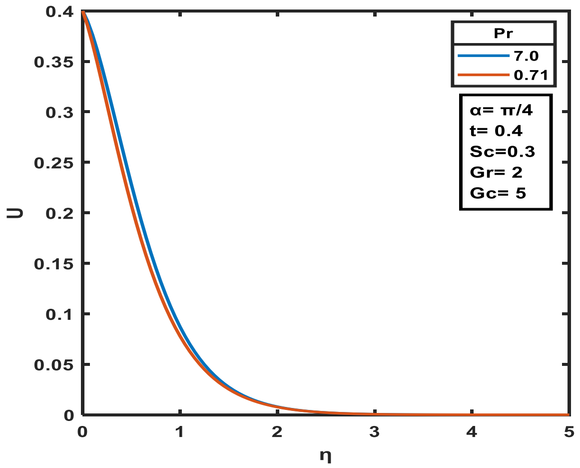

Figure-13. Temperature Profile for different values of P_r .

NOMENCLATURE

A	constant
R'	species concentration in the fluid mol
R, C	non dimensional concentration
R_p	specific heat at constant pressure
D	mass diffusion coefficient
Gc	mass Grashof number
Gr	thermal Grashof number
g	accelerated due to gravity
k	thermal conductivity
P_r	Prandtl number
S_c	Schmidt number
S_h	Sherwoods Number

N_u	Nusselt Number
H, T	temperature of the fluid near the plate
t'	time
t	non-dimensional time
u	velocity of the fluid in the x-direction m
u_0	velocity of the plate
S, V	non-dimensional velocity
x	spatial coordinate along the plate
y'	coordinate axis normal to the plate m
y	non-dimensional axis normal to the plate
x	spatial coordinate along the plate
y'	coordinate axis normal to the plate m

GREEK SYMBOLS

α	Angle of inclination
β	volumetric coefficient of thermal expansion
$\beta*$	volumetric coefficient of expansion with concentration
μ	coefficient of viscosity
υ	kinematic viscosity
ρ	density of the fluid
τ	non-dimensional skin-friction
ψ_1^*	non dimensional temperature
η	similarity parameter
$erfc$	complementary error function

SUBSCRIPTS

ω	conditions at the wall
∞	conditions in the free stream

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