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Transient Heat Transfer Flow by Induced Magnetic Fieldalonga Vertical Plate

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ABSTRACT- In the field of geophysical and astrophysical engineering, the thermal instability in nature, in chemical processes, in separationprocesses and in industrial applications the effect of thermal diffusion on the MHD heat transfer in an unsteady flow past through verticalplate is very much important. It has been investigated numerically under the action of a strong applied magnetic field takinginto accountthe induced magnetic field. This study is performed for cooling problem with lighter and heavier particles. Numerical solutions for thevelocity field, induced magnetic field and temperature distribution are obtained for associated parameters using the explicit finite differencemethod. The obtained results are discussed with the help of graphs using Fortran programming as well as Techplot to observe the effectsofvariousparametersontheabovementionedquantities.Finally,theimportantfindings oftheinvestigationareconcluded.

Keywords-
Transientheat,MagneticDiffusivity,inducedmagneticfield,thermaldiffusion,viscousdissipation

INTRODUCTION:

Heat transfer plays an important role in fluids condensingor boiling at a solid surface. The heat transfer considerationarises due to buoyancy forces caused by thermal diffusions.Condensing and boiling are characteristic for many separationprocessesinchemicalengineeringasdrying,evaporation,distillation,condensation,rectificationandabsorptionofafluid. [5] Peraand Gebhart(1971) was first author to investigatethe combined buoyancy effects of thermal and mass diffusionson natural convection flow. [9] Lin and Wu(1997) have studiedsimultaneous heat and mass transfer model with the entirerange of buoyancy ratio for most practical chemical species indilute and aqueous solutions. [4] Chen(2004)haveobservedtheMHDcombinedheatandmasstransferinnaturalconvectionadjacenttoa vertical surface.

Alongwiththesestudies,theeffectofthermaldiffusionon MHD free convection and mass transfer flows have alsobeenconsideredbymanyinvestigatorsduetoitsimportantroleparticularlyinisotopeseparationandinmixturesbetweengaseswithverylightmolecularweight(incompressibleviscousfluidpastacontinuouslymoving**surface**underonlytheactionoftransversemagneticfieldwithorwithoutthermaldiffusion.Buttheflowunder theactionofastrongmagneticfieldthatinducedanothermagneticfieldhaveofgreatinterestingeophysicsandastrophysics.[3] ChaudharyandSharma(2006)haveanalyticallyanalyzedthesteadycombinedheatandmasstransferflowwithinducedmagneticfield.Thereareanalyticalsolutionrestrictionsintheirstudies.Quiterecently,anumericalstudyofsteadycombinedheatandmasstransferbymixedconvectionflowpastacontinuouslymovinginfiniteverticalporousplateundertheactionofstrongmagneticfieldwithconstantsuctionvelocity,constantheatandmassfluxeshavebeeninvestigatedby[11]Alamet.al.(2008).For unsteadytwodimensionalcase,theaboveproblembecomesmorecomplicated. These type of problems play a special role innature, inmany separationprocesses asisotope separation,inmixturesbetween gases, inmany industrialapplicationsassolidificationofbinaryalloyaswellasinastrophysical

H_2,
H_e)andmediummolecularweight(N_2,air)(Eckert
andgeophysicalengineering.

andDrake,1972).Recently,[11]Alametal.(2006)havenumericallyinvestigatedthemasstransferflowpastaverticalporous mediumwithheatgenerationandthermaldiffusiononthecombinedfree-forcedconvection undertheinfluenceoftransverselyappliedmagneticfield.
Inallthepaperscitedearlier,thestudiesconcentratedonMHDfreeconvectionandmasstransferflowofan

1 MathematicalModel

AflowmodeloftransientMHDheattransferofanelectrically conducting incompressible viscous fluid past anelectricallynon-conductingcontinuouslymovingsemi-infiniteverticalplatewiththermaldiffusionisconsidered.IntroducingtheCartesiancoordinatesystem,thex-axisis chosenalongtheporousplateinthedirectionofflowandthe y-axis is normal to it. A strong uniform magnetic field isapplied normal to the flow region. Because of the magneticReynoldsnumbertheflowisnottakentobesmallenough, theinducedmagneticfieldisnotnegligible.Theinduced

Continuityequation

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

Momentumequation

(1)

magneticfieldisoftheform$(H_x, H_y, 0)$.Thedivergence

$\partial u \;\; \partial u$
$\partial \, u$

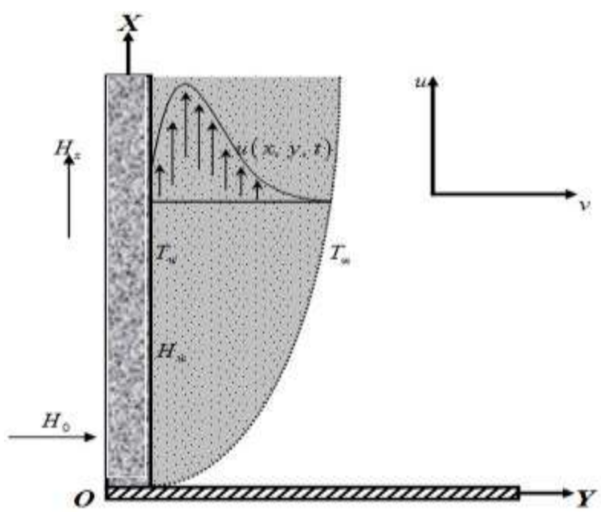


Fig.1 Physical configuration and coordinate system.

 v u
 g T T
 2u

 eH

 Hx u

(2)
 t x y
 y2
 0 y k'

Magneticinductionequation

 H H H
 u u
1 2H
x u x v x Hx
 H0
 x
(3)
 t x y
 x y
  e y
2

Energyequation

 T T T   2T
1   H 2
   u 2
 u v

 x
  (4)
 t x y c y2 c y c y
p p p
withthecorrespondinginitialandboundaryconditionsare
t 0,
u 0,
v 0,
Hx 0,
TT
everywhere (5)
t0,
u 0,
v 0,
Hx 0,
T T
atx 0
u 0,
v 0,

H_X □ H_W,
T□ T_W
aty□ 0
u□ 0, v□ 0, H_X□ 0, T□ T□ asy□ □ (6)
equation□ **H** □ 0ofMaxwell'sequationforthemagneticfieldgivesH_y□ H_0.
wherex , yareCartesiancoordinatesystem;u ,varex ,ycomponent of flow velocity respectively; g is the localaccelerationduetogravity;□ isthethermalexpansion
coefficient;□ isthekinematicviscosity;$□_e$isthemagnetic
permeability; □isthedensityofthefluid; H_0isthe
constantinducedmagneticfield;H_X bethe x-component
Initiallyweconsiderthattheplateaswellasthefluidareat the same temperature T□ T□everywhere in the fluid issame. Also it is assumed that the fluid and the plate is at restafterthattheplateistobemovingwithaconstantvelocity
inducedmagneticfield;□ istheelectricalconductivity;□
isthethermalconductivity;c_p isthespecificheatatthe
constantpressureandH$_W$ istheinducedmagneticfieldat
U_0in its own plane andinstantaneously at time t >0 , thetemperatureofthe plateisraisedtoT$_W$□ T□,whichis thereafter maintained constant, whereT$_W$is the temperatureat the wall and T□is the temperature of the species far awayfromthe plate respectively.
Thephysicalmodelofthisstudyisfurnishedinthe
followingfigure.
Alsotheanalysisisbasedonthefollowingassumptions:
i. Allthephysicalpropertiesofthefluidareconsideredtobeconstantexcepttheinfluenceofvariationsofdensitywith thewall.

1 MathematicalFormulation

Sincethesolutionsofthegoverningequations(1)to(4)undertheinitial(5)andboundary(6)conditionswillbebased on the finite differencemethod itisrequired to makethe said equations dimensionless. For this purpose we nowintroducethefollowingdimensionlessquantities;
temperatureareconsideredonlyonthebodyforceterm,in
accordancewiththeBoussinesq'sapproximation.
ii. Thereisnochemicalreactiontakingplacebetweentheforeignmassandthefluid.
iii. The equationof conservationof electric charge,□ **J**□ 0

X□ $\frac{xU_0}{}$,Y□ $\frac{yU_0}{}$,
□ υ
H_X $\sqrt{\frac{\mu_e}{\rho}}$
2
U□ $\frac{u}{U_0}$,V□ $\frac{v}{U_0}$,□ □$\frac{tU_0}{□}$,
T□ T□

givesJ_y
 constantwhere the current density
H_x ,AndT
0
T_w T

U

J (J_x,J_y,J_z),becausethedirectionofpropagationisconsideredonlyalongthey-axisand**J**doesnot haveanyvariationalongthey-axis. Sincetheplateiselectrically non-conducting, the constant is zero i.e.J_y 0 attheplate andeverywhere.

Fromtheabovedimensionlessvariablewehave

u U_0U,v U_0V,H_x U_0

H_x,and
e
$\sqrt{\mu}$

  ^{2}
 'U^2
0
T T T_w T T.
Alsotheassociatedinitial(5)andboundary(6)conditionsbecome
Usingtheserelationswehavethefollowingderivatives
 0,
U 0,
V0,

$\bar{H}_x$ 0,

$\bar{T}$ 0
everywhere(11)

 u U^3 U u U^2 U u U^2 U

0 ,
0 ,
0 ,
  0,
U 0,
V 0,
H 0,
T 0
atX 0
 t
 x   X y
  Y x

^{2}u

U^3^{2}U

= , 0

□ v □

U^2□ V

□ H U^3

, x□0

□ H x

,

$\sqrt{\frac{\rho}{\mu_e}}$

U□0,

U□ 0,

V□ 0,

V□ 0,

H_X□ 1,

H□ 0,

T□ 1atY□ 0

T□ 0asY□ □ (12) 0

□ y^2

□ 2 □Y^2 □y

□ □ Y □ t □ □ □ x

□ H U^2

x□0

□ H x $\sqrt{\frac{\rho}{\mu_e}}$

, □ H U^2

x□0

□ H x

,

$\sqrt{\frac{\rho}{\mu_e}}$

1 NumericalSolutions

□ x □

□^{2}H U^3

□ X □ y □ □ Y

□^{2}H $\sqrt{\frac{\rho}{\mu_e}}$ □ T U^2□T□ T□ □ T =

Theexplicitfinitedifferencemethodhasbeenusedtosolveequations(7)to (10)subjecttothe conditionsgiven by (11)and

x□0

x,
0 w □
,
□ y² □²
□ Y²

□ t □ □ □

(12).Toobtainthedifferenceequationstheregionoftheflow
isdividedintoagridormeshoflinesparalleltoXandYaxes
□T □ U0□Tw□T□ □□T □T
,
□ U0□Tw□T□ □□T
,
whereX-axisistakenalongtheplateandY-axisisnormalto
□ x
□²T
□
U²□T
□ X □ y
□ T□ □²T
□ □ Y
theplate.
Hereweconsiderthattheplateofheight
X_{max}□ □100□i.e.X
= 0 w
□ y² □²
□

□ Y².
variesfrom0to100andregardY_{max}□ □25□ascorresponding
□ □ □ X □ Y r □ Y² □ Y
□ H □ H □ H □ U □ U 1□²H
x□ U x□ V x□ Hx □ M
□ x
(9)
□ □ □ X □ Y
□ X □ Y P_m
□ Y²

□ T □ T

□ T 1□²T E□ □ H□²
□□ U□²
□ U □ V

c x

\+ E_c

(10)

X

Y P Y^2 P Y

Y

r m

g T_w T

where

G_r 3 U

0

(**GrashofNumber**),

H_0 e

M (**MagneticForceNumber**),

U_0

P_m e (**MagneticdiffusivityNumber**),

c_p

shownin**Fig.2.**

Itisassumedthat X, YareconstantmeshsizesalongX

P_r (**PrandtlNumber**),

U^2

andYdirectionsrespectivelyandtakenasfollows,

X 0.8 0 x 100

E c 0
(c)
c p T w T
(**EckertNumber**)and
Y 0.2 0 y 25
withthesmallertime-step, 0.005

LetU ,V ,
x x

H andT denotethevaluesof U,V,H

U i,j 1

U i,j

1 H x i,j 1

2H

x i,j

H x i,j 1

andT attheendofatime-steprespectively.Usingthe M
explicitfinitedifferenceapproximationwehave,

Y P m

Y 2
(15)

U
U U

U
U U

T i ,j T i,j U T i,j T i 1,j V

T i,j 1 T i,j 1 T i,j 1 2T i,j T i,j 1

i,j i,j
,
i,j i 1,j
,
i,j
X

i,j

Y P Y 2

r

i, j

X =

i,j X

U

∂Y

i,j

U i,j 1 U i,j

,

Y

E H x i,j 1 H x i,j

+

2

U U 2

i,j 1 i,j

E

c

c

(16)

Pm Y Y

V

V i,j V i,j 1 $\partial\tau$

H x

Hx H x

i,j i,j

i,j ∂Y ΔY

,

i,j

,

andtheinitialandboundaryconditionswiththefinite differenceschemeare

H H

$\bar{U}^0=0,\quad \bar{V}^0=0,\quad \bar{H}^0=0,\quad \bar{T}^0=0$

(17)

H x

x i,j x i 1,j

i,j i, j xi,j i,j

X

,

X

U^n=0, V^n=0, H^n=0,

T^0=0

i,j

0, j

0,j x0,j

0, j

H H

U^n

=0,

V^n=0,

H^n=1,

T^n= 1

H x

xi,j 1 x i,j

T

Ti,j Ti,j

i,0

i,0

xi,0

i,0

Y

,

Y

,

U^n=0, V^n=0, H^n=0, T^n=0

i,j

i,j

i,L i,L xi,L i,L

T

X

$(\quad)_{i,j}$

$(\partial^2 U)$

Ti,j Ti 1j

X

$)_{i,j}$

$U_{i,j+1}-2U_{i,j}+U_{i,j-1}$

T

, Y

$T_{i,j}$ 1 $T_{i,j}$,

Y

whereL . (18)

^{2}T

i,j $\partial^2 Y$

$T_{i,j}$ 1 2$T_{i,j}$ $T_{i,j}$ 1

Y ^{2}

Herethesubscripts*i*and *j*designatethegridpointswith *x*and*y*coordinatesrespectivelyandthesuperscript*n* aretreatedasconstants.Thenattheendofanytime-step

, the new temperatureT, the new velocity U , the newinducedmagneticfield H andV atallinteriornodal

From the system ofpartial differential equations (7) to (10)with substituting the above relations into the correspondingdifferentialequationwe obtainanappropriatesetof finite

pointsmaybeobtainedbysuccessiveapplicationsofequations (16), (14), (15) and (13) respectively. This process isrepeatedintimeandprovidedthetime-stepissufficiently

differenceequations,

small,U,V,

$H_x$andTshouldeventuallyconvergeto

U U V V

valueswhich approximate the steady-state solution of

i,j i 1,j

X

U_i ,j $U_{i,j}$ U

i,j i,j 1 0

Y

$U_{i,j}$ U_i 1,j V

(13)

$U_{i,j}$ 1 $U_{i,j}$

GT

equations(7)to(10).Theseconvergedsolutionsareshowngraphicallyin Figs.3to38.

Forthepurposeofdiscussingtheresultsoftheproblem,theapproximatesolutionsareobtainedforvariousparameters

  i,j X
U i,j 1 2U i,j U i,j 1
i,j
 Y

H x i,j 1 H x i,j
ri,j

withsmallvaluesofEckertnumber.Inordertoanalyzethe
physicalsituationofthemodel,wehavecomputedthesteady
statenumericalvaluesofthenon-dimensionalvelocityU,

 2
 Y
 M
 Y
 U i,j
(14)

inducedmagneticfield

H x andtemperatureTwithinthe
H x H x

H x H x

H x H x
U U

boundarylayerfordifferentvaluesofmagneticparameter

i,j i,j U i,j i 1,j V
i,j 1
i,j H
i,j i 1,j
M ,magneticdiffusivity P ,Grashofnumber G ,

  i,j X
i,j
 Y
x i,j
 X
m r
Prandtalnumber P_r andEckertnumber E_c .

Togetthesteadystatesolutions,thecomputationshavebeencarriedoutupto 80
.Weobservedthattheresultsofthecomputations,however,shownovisiblechangesafter
 40 . Thus the solution for 40are essentially steadystatesolutions.
Becauseofthespecialimportanceofcoolingprobleminnuclearengineeringinconnectionwiththecoolingofreactors,thevalueoftheGrashofnumberforheattransferis
takentobepositive G_r 0 andthepresentstudyhas
considered G_r 1.0,1.2and1.4.Sincethemostimportantfluidsareatmosphericair,saltwaterandwatersothe
resultsarelimitedto P_r 0.71(Prandtlnumberforairat

20◦C),P 1.0(Prandtlnumberforsaltwaterat20◦C)

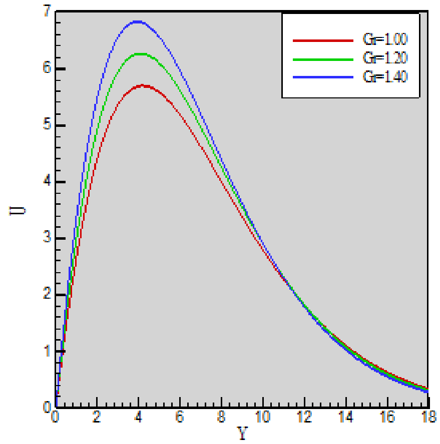


Fig.4 VelocityprofilesfordifferentvaluesofG_r

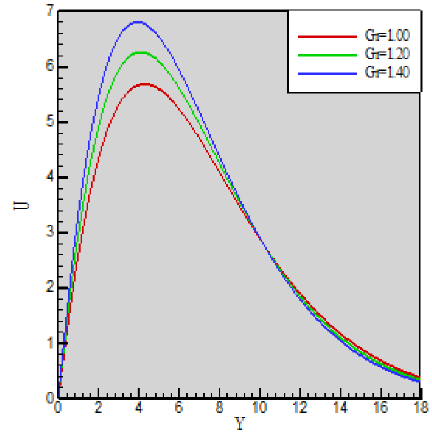
r

andP 7.0(Prandtlnumberforwaterat20◦C).However
where M 0.10,P_m 1.00, P_r 0.71 and

r

thevaluesofanotherparameters M, P_m and E_c are
E_c 0.01attime 30.
chosenarbitrarilyas M=0.10,0.20and0.30;
and2.0;E_c=0.01,0.02and0.03.
P_m=1.0,1.5

Alongwiththeobtainedsteadystatesolutions,theflowbehaviorsincaseofcoolingproblemarediscussedgraphically.Thepro filesofthetransientvelocity,inducedmagnetic field and temperature versusYare illustrated in**Figs.3to38.**



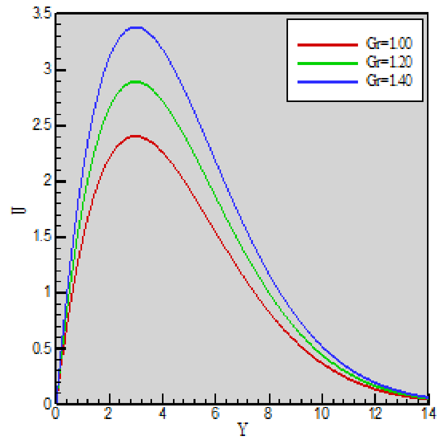


Fig.5 VelocityprofilesfordifferentvaluesofG$_r$

where
M□ 0.10,
P$_m$□ 1.00,
P$_r$□ 0.71
and

E$_c$□ 0.01attime□ □ 40.

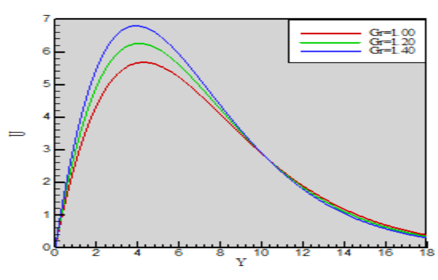


Fig.3 VelocityprofilesfordifferentvaluesofG$_r$

where
M□ 0.10,
□ □ 10.
P_m□ 1.00,
P_r□ 0.71
and
E_c□ 0.01
attime

Fig.6 VelocityprofilesfordifferentvaluesofG_r **Fig.9**InducedmagneticfieldsfordifferentvaluesofG_r
where M□ 0.10,P_m□ 1.00, P_r□ 0.71
and
whereM□ 0.10,P_m□ 1.00,P_r□ 0.71andE_c□ 0.01
E_c□ 0.01attime□ □ 50.

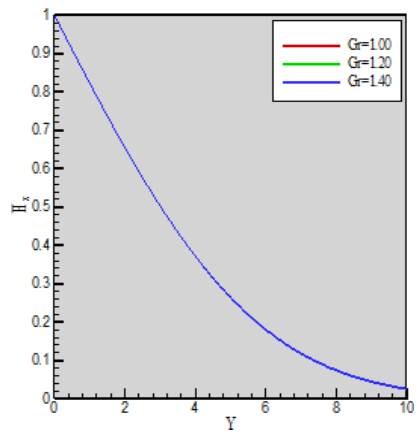


Fig. 7 Induced magnetic fields for different values of$G_r$whereM□ 0.10,P_m□ 1.00,P_r□ 0.71andE_c□ 0.01at time□ □ 10.
attime□ □ 40.

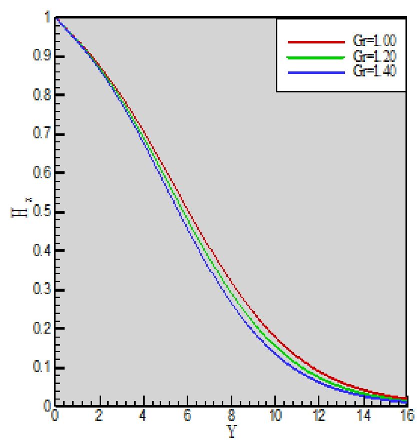
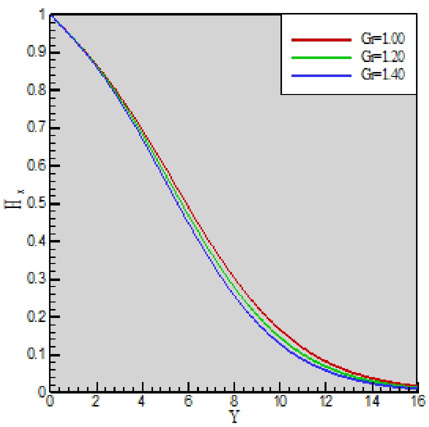


Fig. 10 Induced magnetic fields for different values of$G_r$whereM□ 0.10 ,P_m□ 1.00,P_r□ 0.71 andE_c□ 0.01attime□ □ 50.

Fig. 8 Induced magnetic fields for different values of$G_r$whereM□ 0.10,P_m□ 1.00,P_r□ 0.71andE_c□ 0.01attime□ □ 30.
Fig.11 Temperatureprofilesfordifferentvaluesof$G_r$where
M□ 0.10,P_m□ 1.00,P_r□ 0.71andE_c□ 0.01attime
□ □ 10.



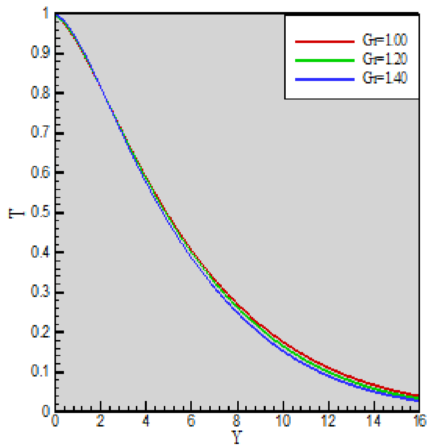


Fig.12 Temperatureprofilesfordifferentvaluesof$G_r$where
M□ 0.10,P_m□ 1.00,P_r□ 0.71andE_c□ 0.01attime
□ □ 30.

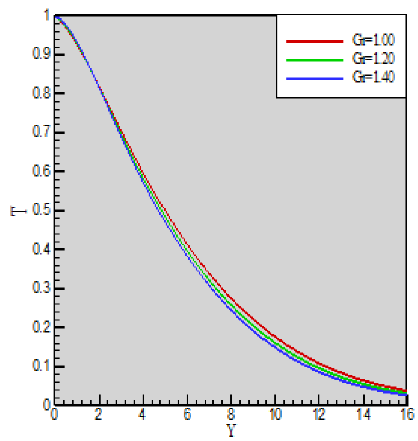


Fig.13 Temperatureprofilesfordifferentvaluesof$G_r$where
M□ 0.10,P_m□ 1.00,P_r□ 0.71andE_c□ 0.01attime
□ □ 40.
Fig.15 Velocityprofilesfordifferentvaluesof$P_r$where
G_r□ 1.00,M□ 0.10,P_m□ 1.00andE_c□ 0.01
attime□ □ 10.

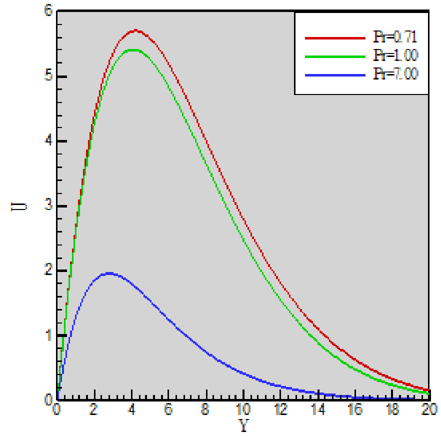


Fig.16 VelocityprofilesfordifferentvaluesofP$_r$where

G$_r$□ 1.00,M□ 0.10,P$_m$□ 1.00andE$_c$□ 0.01

attime□ □ 30.

Fig.17 VelocityprofilesfordifferentvaluesofP$_r$where

Fig.14 TemperatureprofilesfordifferentvaluesofG$_r$where

G□ 1.00,M□ 0.10P□ 1.00andE□ 0.01attime

M□ 0.10,P□ 1.00

P□ 0.71andE□ 0.01 r

, m c

attime□

m , r c

□ 50.

□ □ 40.

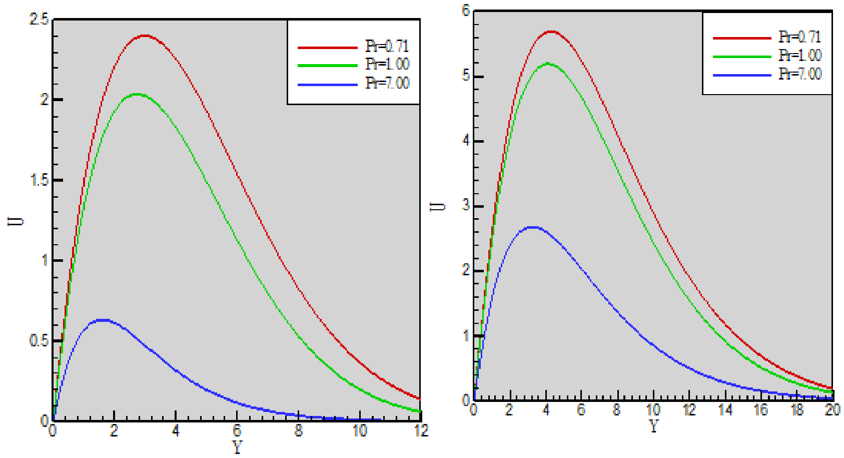


Fig.18 Velocityprofilesfordifferentvaluesof$P_r$where
G_r□ 1.00,M□ 0.10,P_m□ 1.00andE_c□ 0.01attime
□ □ 50.

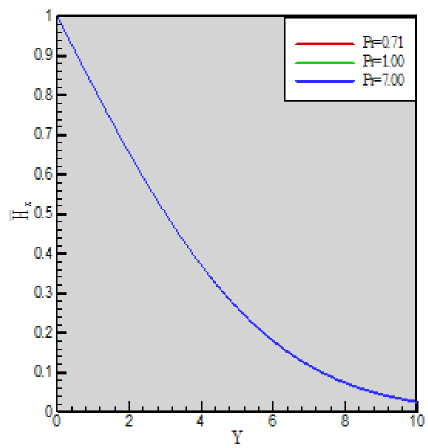


Fig.19 Induced magnetic fields for different values of $P_r$whereG_r□ 1.00,M□ 0.10,P_m□ 1.00andE_c□ 0.01attime□ □ 10.
Fig.21 Induced magnetic fields for different values of $P_r$whereG_r□ 1.00,M□ 0.10,P_m□ 1.00andE_c□ 0.01at time□ □ 40.

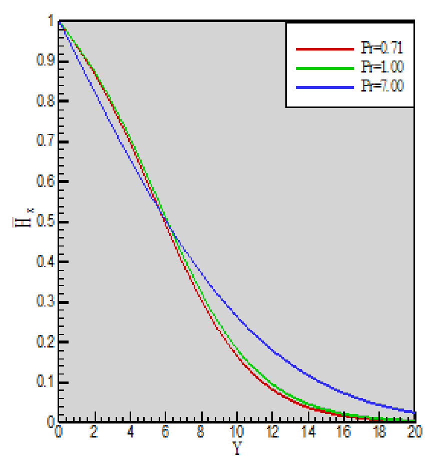


Fig. 22 Induced magnetic fields for different values of $P_r$whereG_r□ 1.00,M□ 0.10,P_m□ 1.00andE_c□ 0.01attime□ □ 50.

Fig. 20 Induced magnetic fields for different values of $P_r$whereG_r□ 1.00,M□ 0.10,P_m□ 1.00andE_c□ 0.01attime□ □ 30.

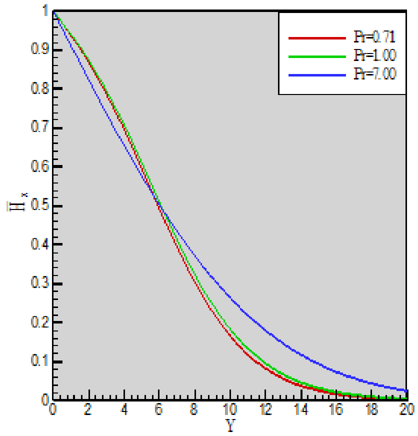


Fig.23 Temperatureprofilesfordifferentvaluesof$P_r$where
G_r□ 1.00,M□ 0.10,P_m□ 1.00andE_c□ 0.01attime
□ □ 10.

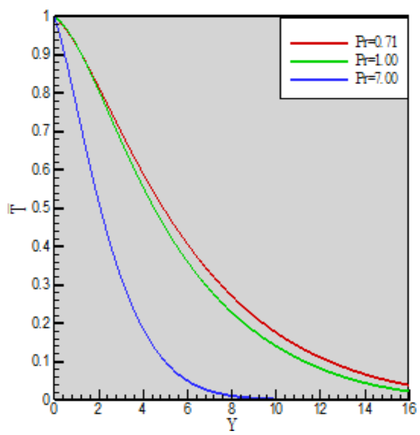


Fig.24 Temperatureprofilesfordifferentvaluesof$P_r$where
G_r□ 1.00,M□ 0.10,P_m□ 1.00andE_c□ 0.01attime
□ □ 30.

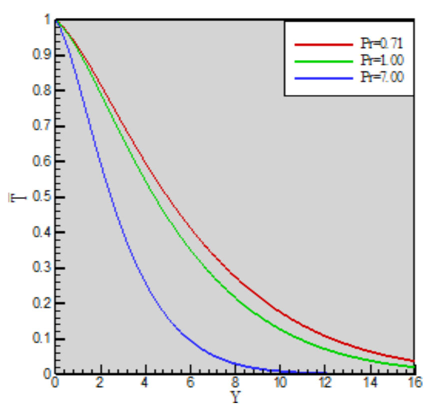


Fig.25 Temperatureprofilesfordifferentvaluesof$P_r$where

Fig.27 VelocityprofilesfordifferentvaluesofE$_c$where
G$_r$□ 1.00,M□ 0.10,P$_m$□ 1.00andP$_r$□ 0.71attime
□ □ 10.

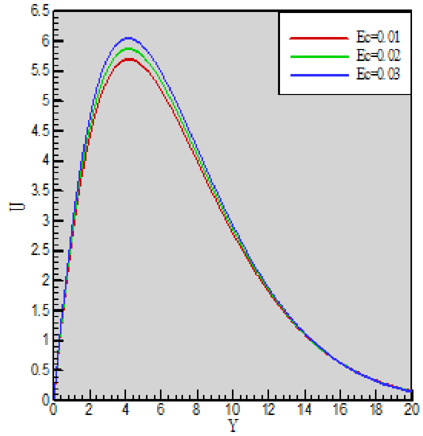


Fig.28 VelocityprofilesfordifferentvaluesofE$_c$where
G$_r$□ 1.00,M□ 0.10,P$_m$□ 1.00andE$_c$□ 0.01attime
G□ 1.00,M□ 0.10P□ 1.00andP□ 0.71attime
□ □ 40.
r
□ □ 30.
, m r

Fig.26 TemperatureprofilesfordifferentvaluesofP$_r$where
G$_r$□ 1.00,M□ 0.10,P$_m$□ 1.00andE$_c$□ 0.01attime
□ □ 50.

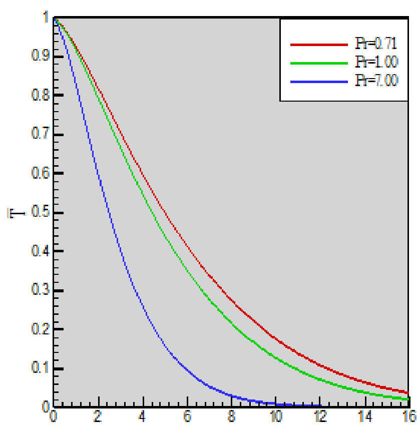


Fig.29 VelocityprofilesfordifferentvaluesofE$_c$where
G$_r$□ 1.00,M□ 0.10,P$_m$□ 1.00andP$_r$□ 0.71attime
□ □ 40.

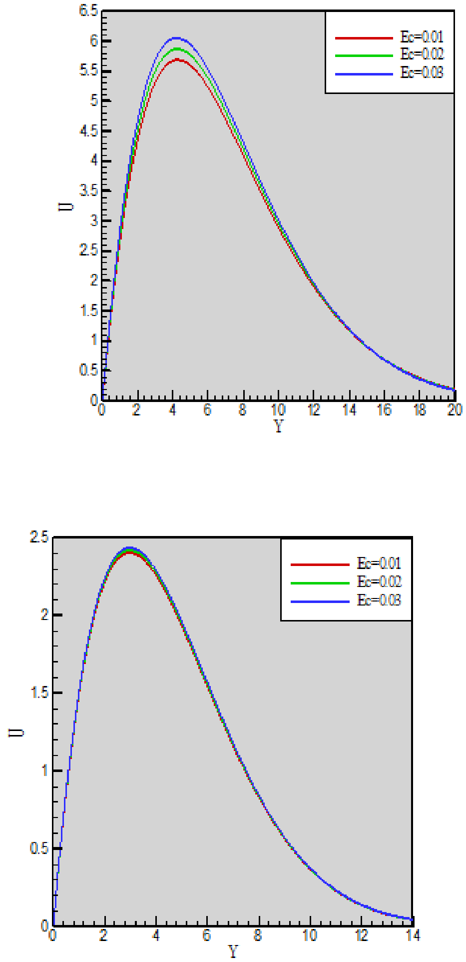


Fig.30 Velocityprofilesfordifferentvaluesof$E_c$where
G_r□ 1.00,M□ 0.10,P_m□ 1.00andP_r□ 0.71attime
□ □ 50.

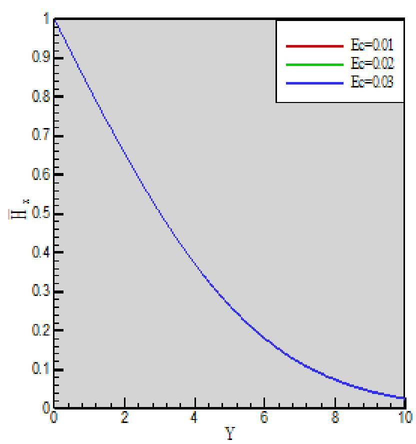


Fig.31 Induced magnetic fields for different values of$E_c$whereG_r□ 1.00 ,M□ 0.10,P_m□ 1.00 andP_r□ 0.71 attime□ □ 10.

Fig.33 Induced magnetic fields for different values of E_c where G_r □ 1.00, M □ 0.10, P_m □ 1.00 and P_r □ 0.71 at time □ □ 40.

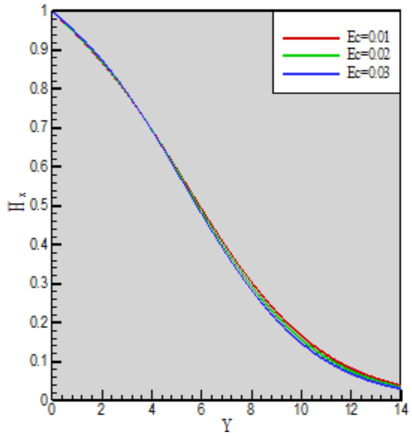


Fig. 34 Induced magnetic fields for different values of E_c where G_r □ 1.00, M □ 0.10, P_m □ 1.00 and P_r □ 0.71 at time □ □ 50.

Fig.32 Induced magnetic fields for different values of E_c where G_r □ 1.00, M □ 0.10, P_m □ 1.00 and P_r □ 0.71 at time □ □ 30.

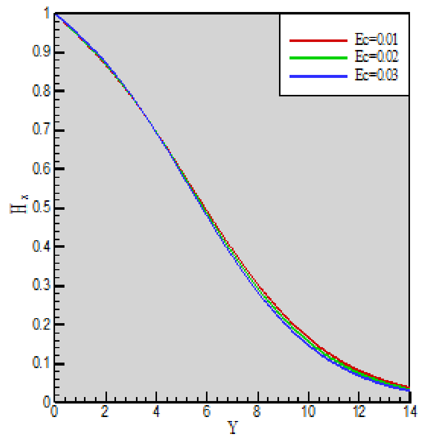


Fig.35 Temperature profiles for different values of E_c where G_r □ 1.00, M □ 0.10, P_m □ 1.00 and P_r □ 0.71 at time □ □ 10.

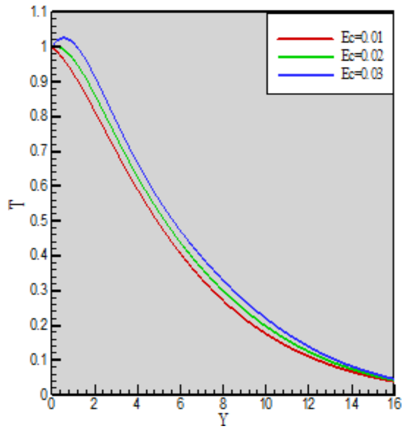


Fig.36 TemperatureprofilesfordifferentvaluesofE$_c$where

valueofG$_r$

increases.Atτ=50theinducedmagneticfield

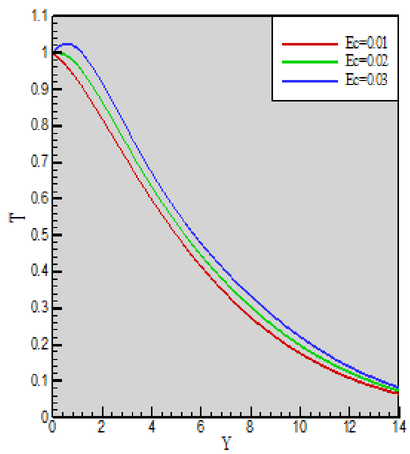
G$_r$ 1.00,M 0.10,P$_m$ 1.00andP$_r$ 0.71attime

30.

profile shows identical graph as τ =40. Also as the value of τincreasesthevelocityprofilesalsoincreaseuptoτ=40.Butatτ=50thevelocityprofileshowssamegraphasτ=40.

Thetemperatureprofile**(Figs.11to14)**remainssameasthe

valueofG$_r$



increasesatτ=10.Butforτ=30,40and50the

temperatureprofiledecreasesasthevalueofG$_r$

increases.

Fig.37 Temperatureprofilesfordifferentvaluesof$E_C$where

G_r□ 1.00,M□ 0.10,P_m□ 1.00andP_r□ 0.71attime

□ □ 40.

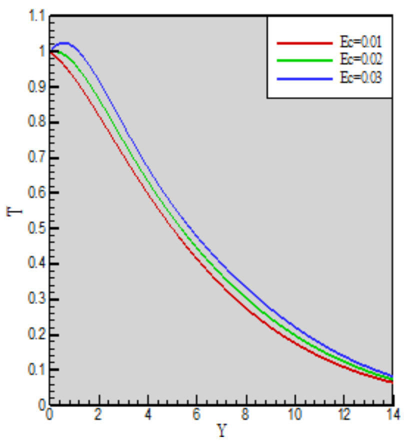
Atτ=50thetemperatureprofileshowsidenticalgraphasτ =40. Also as the value of τ increases the temperature profilesincreaseuptoτ=40.Butatτ=50thetemperatureprofileshowssamegraphasτ=40.

AsthevalueofPrincreasesthevelocityprofile**(Figs. 15to 18)**decreases at τ =10, 30 and 40. But atτ =50 the velocityprofileshowssamegraphasτ=40.Onetheotherhand,asthevalueofτincreasesthevelocityprofilesalsoincreaseuptoτ =40.Butatτ=50thevelocityprofileshowssamegraphasτ=40.

The induced magnetic field profile **(Figs. 19 to 22)** remainssame as the value ofPrincreases at τ =10. But for τ =30, 40and 50 the induced magnetic field profile initially decreasesandaftercertainamountofYitincreasesasthevalueofPr increases. At τ =50 the induced magnetic field profile showsidentical graph as τ =40. Also as the value of τ increases theinducedmagneticfieldprofilesalsoincreaseuptoτ=40.Butatτ=50theinducedmagneticfieldprofileshowssamegraphasτ =40.

As thevalue ofPrincreases thetemperatureprofile**(Figs.23 to 26)**decreases at τ =10, 30 and 40. But atτ =50 thetemperatureprofileshowssamegraphasτ=40.Onetheotherhand,asthevalueofτincreasesthetemperatureprofilesalsoinc reaseuptoτ=40.Butatτ=50thetemperatureprofileshowssamegraphasτ=40.

Fig.38 TemperatureprofilesfordifferentvaluesofE_C



where

AsthevalueofE_C

increasesthevelocityprofile**(Figs.27to**

G_r□ 1.00,M□ 0.10,P_m□ 1.00andP_r□ 0.71attime

□ □ 50.

Foravoidingthecomplexityhereweshowthevariationsfor

τ=10,30,40and50.ForthechangeofG_r,thevelocity

30)alsoincreasesatτ=10,30and40.Butatτ=50thevelocity profile shows same graph as τ =40. One the otherhand,asthevalueofτincreasesthevelocityprofilesalsoincrease upto τ =40. But atτ =50 the velocity profile showssamegraphasτ=40.

profileisshownin(**Figs.3to6).**Fromthese Fig.wesee Theinducedmagneticfieldprofile**(Figs.31to34)**remains

that,asthevalueofG_r
increasesthe velocityprofilealso
sameasthevalueofE_c
increasesatτ=10.Butforτ=30,40

increasesatτ=10,30and40.Butatτ=50thevelocityprofile and50theinducedmagneticfieldprofiledecreasesasthe

showssamegraphasτ=40.Onetheotherhand,asthevalue
valueofE_c
increases.Atτ=50theinducedmagneticfield

ofτincreasesthevelocityprofilesalsoincreaseuptoτ=40.
Butatτ=50thevelocityprofileshowssamegraphasτ=40.Theinducedmagneticfieldprofile**(Figs.7to10)**remainssameasthe valueofG_r increasesatτ=10.Butforτ=30,40
profile shows identical graph as τ =40. Also as the value of τincreasesthevelocityprofilesalsoincreaseuptoτ=40.Butatτ=50thevelocityprofileshowssamegraphasτ=40.
Asthevalueof$E_c$increasesthetemperatureprofile**(Figs.** and50theinducedmagneticfieldprofiledecreasesasthe
35to38) increasesatτ=10,30and40.Butat τ=50the

temperatureprofileshowssamegraphasτ=40.Onetheotherhand,asthevalueofτincreasesthetemperatureprofilesalsoincreaseuptoτ=40.Butatτ=50thetemperatureprofileshowssamegraphasτ=40.

CONCLUSIONS

Atransientheattransferflowthroughanelectricallyconducting incompressible viscous fluid past an electricallynonconductingcontinuouslymovingsemi-infiniteverticalplateundertheactionofstrongmagneticfieldtakingintoaccounttheinducedmagneticfieldconstantheatisinvestigated in this work. The resulting governing system ofdimensionlesscouplednon-linearpartialdifferentialequationsarenumericallysolvedbyanexplicitfinitedifferencemethod.Theresultsarediscussedfor differentvaluesofimportantparametersasmagneticparameter,magneticdiffusivitynumbers,Grashofnumber,Prandtalnumber and Eckert number. Some of the important findingsobtainedfromthegraphicalrepresentationoftheresultsare listedherewith;

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Av.287, p.123-141, 1965.

1. Thevelocityincreaseswiththeincreaseof $E_c$orG_r whileitdecreaseswiththeincreaseofP_r.
2. Themagneticinductiondecreaseswiththeincrease of G_r, E_c.Moreover, the magnetic induction initiallydecreases and later increases with the increaseof P_r.Particularly,theinducedmagnetic

[9]LinandWu,*"Combinedheatandmasstransferbylaminar naturalconvectionfromaverticalplatewithuniformheatfluxandconcentration"*Int.J.HeatMassTransfer,v.32,p. 293-299,1997.

[10]MichaelFaraday,*"ElectromagneticForceField,Particle/Field Duality"*v.2,p.525-1333,1832.

[11]M.M.Alam,M.R.Islam,F.Rahman,*"Steadyheatandmass transferbymixedconvectionflowfromaverticalporousplate*

fieldisgreaterforheavierthanlighterparticles.

3. The temperature increases with the increase of$E_c$while it decreases with the increase of$G_r$orP_r .Particularly,thefluidtemperatureismoreforairthanwateranditislessforlighterthanheavier particles.

As the basis for many scientific and engineering applicationsfor studying more complex vertical problems involving theflowofelectricallyconductingfluids,itishopedthatthepresent investigation of the study of applied physics of flowoveraverticalsurfacecanbeutilized.Inthemigrationofunderground water or oil as well as in the filtration and waterpurification processes, the findings may be useful for study ofmovement of oil or gas and water through the reservoir of anoil or gas field. The results of the problem are also of greatinterestingeophysicsandastrophysicsinthestudyofinteractionofthegeomagneticfieldwiththefluidingeothermalregion.

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