g-JITTER UNSTEADY FREE CONVECTION FLOW IN A THREE DIMENSIONAL BODY NEAR A STAGNATION POINT REGION WITH HEAT GENERATION

FAKHRU RIDHWAN BIN HAMDAN

A dissertation submitted in fulfilment of the
requirements for the award of the degree of
Master of Science

Faculty of Science
Universiti Teknologi Malaysia

JANUARY 2019

To

my beloved mother, father,

sisters and brothers

who have always given me love,

care and cheer

and whose prayers have always been a source of great inspiration

for me.

May Allah bless you all…

ACKNOWLEDGEMENT

Primarily and foremost, all praise for Almighty ALLAH, who blessed me, the ability to fulfil the requirement for this thesis. I offer my humblest words of thanks to the Holy Prophet Mohammed (Peace be upon Him) who is forever a torch of guidance for humanity.

I would like to express my sincere appreciation and gratitude to my supervisor, Assoc. Prof. Dr. Sharidan Shafie who guided me through this challenging year with amazing patience and perseverance.

I wish to thank the academic and support staff at the Department of Mathematical Science, Universiti Teknologi Malaysia for their kind assistance.

I also wish specially thank my dedicated parents Hamdan bin Awang and Noraini binti Samion and dearest family who either directly or indirectly involved in bringing this successful. I am grateful for their support, assistance and ideas in completing this thesis.

Finally, to all my friends who gave moral support especially Mohamad Hidayad bin Ahmad Kamal, Noraihan, Qushairi, Saiful Adham, Aizat, and Rahman.

ABSTRACT

The three-dimensional axisymmetric stagnation point flow have applications in many manufacturing processes in industry such as the boundary layer along material handling conveyers, the aerodynamic extrusion of plastic sheet, and the cooling of an infinite metallic plate in cooling bath. Therefore in this thesis, unsteady free convection flow of a three-dimensional body near the stagnation point region is studied. The effect of g-jitter and heat generation are also considered. The governing equations which consist of coupled nonlinear partial differential equations are solved numerically through an implicit finite difference scheme known as the Keller-box method. The parameter involved are curvature ratio, c, oscillation frequency, Ω, Prandtl number $\mathrm{Pr} = 0.72$ and g-jitter amplitude, ε. The results presented include mean skin friction and mean heat flux, the skin frictions and heat flux as well as the velocity and temperature profiles in various conditions. The results obtained show that the effect of heat generation, Q gives rises to the skin friction and heat flux as curvature ratio and oscillation frequency increases.

ABSTRAK

Aliran titik genangan tiga matra simetri sepaksi mempunyai pelbagai aplikasi dalam proses pembuatan di industri seperti lapisan sempadan di sepanjang pengawal pengolaan bahan-bahan penghantaran, penyemperitan aerodinamik kepingan plastik, dan penyejukan plat logam tak terhingga dalam penyejuk mandian. Oleh itu di dalam tesis ini, perolakan bebas tak mantap dari badan tiga matra berdekatan dengan kawasan titik genangan dikaji. Kesan ketar-g dan penjanaan haba dipertimbangkan. Persamaan menakluk yang terdiri daripada persamaan terbitan separa yang tak linear diselesaikan secara berangka menggunakan skema beza terhingga tersirat yang dikenali sebagai kaedah kotak Keller. Parameter yang terlibat adalah nisbah lengkungan, c, kekerapan hayunan, Ω, nombor Prandtl $\mathrm{Pr} = 0.72$ dan amplitud ketar-g, ε. Keputusan yang dikemukakan termasuk purata geseran kulit dan fluks haba, pergeseran kulit dan pemindahan haba serta profil halaju dan suhu dalam pelbagai keadaan. Hasil yang diperoleh menunjukkan bahawa kesan penjanaan haba, Q memberikan peningkatan kepada geseran kulit dan fluks haba apabila nisbah lengkung dan frekuensi ayunan meningkat.

TABLE OF CONTENTS

		TITLE	PAGE
		DECLARATION	ii
		DEDICATION	iii
		ACKNOWLEDGEMENT	iv
		ABSTRACT	v
		ABSTRAK	vi
		TABLE OF CONTENTS	vii
		LIST OF TALBES	ix
		LIST OF FIGUREs	x
		LIST OF SYMBOLS	xii
CHAPTER	**1**	**INTRODUCTION**	1
	1.1	Research Background	1
	1.2	Problem Statement	3
	1.3	Objectives of the Study	4
	1.4	Scope of Study	4
	1.5	Significance of Research	4
CHAPTER	**2**	**LITERATURE REVIEW**	7
	2.1	Introduction	7
	2.2	The effect of g-Jitter on Heat Transfer	7
	2.3	The effect of g-Jitter on Double Diffusion	12
	2.4	Heat Generation effect on Heat Transfer and Double Diffusion	14

CHAPTER 3 DERIVATION OF EQUATIONS 21

3.1 Introduction 21
3.2 The Continuity Equation 21
3.3 The Momentum Equation 25
3.4 The Energy Equation 38
3.5 Boundary Layer Equation 52

CHAPTER 4 NUEMRICAL PROCEDURE 65

4.1 Basic Equation 65
4.2 Keller-box Method 74
4.2.1 Finite Difference Method 75
4.2.2 Newton's Method 81
4.2.3 Block-elimination Method 88

CHAPTER 5 RESULTS AND DISCUSSION 99

5.1 Introduction 99
5.2 Mean Skin Frictions and Heat Transfer Rates 99
5.3 Reduced Skin Frictions and Heat Flux 103
5.4 Velocities and Temperatures Profile 112

CHAPTER 6 CONCLUSION 115

6.1 Introduction 115
6.2 Summary of Research 115
6.3 Suggestion for Future Research 116

REFERANCES 117
Appendix 123

LIST OF TABLES

TABLE NO.	TITLE	PAGE
Table 3.1	The net rate of surface force on various faces in *y*-direction.	29
Table 3.2	The net rate of surface forces on various faces in *x*-direction.	31
Table 3.3	The net rate of surface forces on various faces in *z*-direction.	31
Table 3.4	The net rate of work done by forces on various faces in *x*-direction.	43
Table 3.5	The net rate of work done by forces on various faces in *y*-direction.	43
Table 3.6	The net rate of work done by forces on various faces in *z*-direction.	43
Table 5.1	The mean skin friction rate $F''(0)$ and the mean heat transfer rate $\Theta'(0)$ for Pr=0.72 and C=0.	100
Table 5.2	The mean skin friction rate $F''(0)$ and the mean heat transfer rate $\Theta'(0)$ for Pr=0.72 and C=0.5.	101
Table 5.3	The mean skin friction rate $F''(0)$ and the mean heat transfer rate $\Theta'(0)$ for Pr=0.72 and C=1.	101
Table 5.4	Comparison of reduced skin frictions $f''(0)$, $h''(0)$ and heat transfer rate $\theta'(0)$ for ε=1(final steady-state), Pr=0.72, Ω=0.2 and various value of C.	102

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
Figure 3.1	A diagram of mass fluxes through the various faces of the element	22
Figure 3.2	The force acting on y-direction	27
Figure 3.3	Energy fluxes acting on y-direction	40
Figure 4.1	Physical model and coordinate system.	65
Figure 4.2	Net rectangle for difference approximations	76
Figure 5	Comparison of the skin friction coefficients $f''(0)$ and $h''(0)$, and heat transfer from the surface of the body $\theta'(0)$ for the steady flow case (ε=1) when Pr=0.72 and Ω=0.2	102
Figure 5.1	The variation of reduced skin friction f'' and heat flux -θ' when C=0, Ω=0.2 with different values of Q=0, 1 and 2	104
Figure 5.2	The variation of reduced skin friction f'' and heat flux -θ' when C=0, Ω=5 with different values of Q=0, 1 and 2.	105
Figure 5.3	The skin friction h'' of $C=0$.	106
Figure 5.4	The variation of skin friction, f'', skin friction h'' and heat flux -θ' when C=0.5, Ω=0.2 with different values of Q=0, 1 and 2.	108
Figure 5.5	The variation of skin friction f'', skin friction h'' and heat flux -θ' when C=0.5, Ω=5 with different values of Q=0, 1 and 2.	109
Figure 5.6	The variation of skin friction f'', skin friction h'' and heat flux θ' when C=1, Ω=0.2 with different values of Q=0, 1 and 2.	110

Figure 5.7	The variation of skin friction f'', skin friction h'' and heat flux θ' when C=1, Ω=5 with different values of Q=0, 1 and 2.	111
Figure 5.8	The variation of skin friction f'', skin friction h'' and heat flux θ' when C=0.5, Ω between 0.2 and 5, with fixed ε=0.3 and Q=0, 1 and 2.	112
Figure 5.9	The variation of velocity profiles f' and h' and temperature profiles θ with fixed C=0, ε=0.3, Pr=0.72, Ω=0.2 and 5 and Q=0, 1 and 2.	113
Figure 5.10	The variation of velocity profiles f' and h' and temperature profiles θ with fixed C=0.5, ε=0.3, Pr=0.72, Ω=0.2 and 5 and Q=0, 1 and 2.	113
Figure 5.11	The variation of velocity profiles f' and h' and temperature profiles θ with fixed C=1, ε=0.3, Pr=0.72, Ω=0.2 and 5 and Q=0, 1 and 2.	114

LIST OF SYMBOLS

$\mathbf{a}$	-	Acceleration
$\mathbf{a_1}, \mathbf{a_2}$	-	Unit vector
a_x, a_y, a_z	-	Scalar acceleration in *x*-, *y*- and *z*-
a, b	-	Principle curvature in *y*- and *x*-planes
C	-	Curvature parameter
c_p	-	Heat at constant pressure
e	-	Internal energy
$\mathbf{f}$	-	Body force
f_x, f_y, f_z	-	Body force in *x*-, *y*- and *z*-components
$\mathbf{F}$	-	Force
$\mathrm{F}_x, \mathrm{F}_y, \mathrm{F}_z$	-	Scalar in *x*-, *y*- and *z*-components
g	-	Gravity acceleration
g_0	-	Gravity acceleration at initial time
$\mathbf{H}$	-	Arbitrary vector
$\boldsymbol{H}$	-	Microrotation vector
H_x, H_y, H_z	-	Microrotation component along *x*- and *y*-axis
j	-	Microenertia density
J_σ	-	Surface curvature
k	-	Fluid conductivity
K	-	Material parameter
m	-	Mass
$\mathbf{n}$	-	Unit normal
n	-	Index point on
N	-	Nodal stagnation point
p	-	Pressure
p_D	-	Dynamic pressure
Q	-	Heat generation
$\mathbf{R}$	-	Vector position
$\mathbf{r}$	-	Surface of body S

S	-	Body surface
t	-	Time
T	-	Fluid temperature
T_w	-	Wall temperature
T_∞	-	Ambient temperature
u, v, w	-	Velocity components along *x*- and *y*-axis
$\mathbf{V}$	-	Velocity vector
x, y, z	-	Cartesian coordinates
y_s	-	Typical variable
α	-	Thermal diffusivity
β	-	Thermal expansion
∇	-	Gradient operator
μ	-	Dynamic viscosity
v	-	Kinematic viscosity
∇_S	-	Surface gradient operator
ω	-	Frequency of g-jitter oscillation
Ω	-	Non-dimensional frequency
τ	-	Dimensionless parameter
τ_{yx}, τ_{yz}	-	Viscous stress and shear stress
τ_{yy}	-	Normal stress
θ	-	Dimensionless parameter
ρ	-	Density
σ	-	surface
‘	-	Differentiation with respect to η
s	-	Steady-state flow
w	-	Wall condition
∞	-	Far field condition
C_{fx}	-	Skin friction coefficient in *x*-direction
C_{fy}	-	Skin friction coefficient in *y*-direction
Gr	-	Grashof number
Nu	-	Nusselt number
Pr	-	Prandtl number

CHAPTER 1

INTRODUCTION

1.1 Research Background

The stagnation point is defined as the point on the surface of objects in the flow field where the fluid is brought at rest by the object. The problem of flow and heat transfer at a general three-dimensional stagnation-point region has important applications in many manufacturing processes in petrochemical industries, the aerodynamic of plastic sheet, solar central receivers exposed to wind currents, and so forth. Poots (1964) formulated the boundary-layer equations for the free convection flow at three-dimensional lower stagnation point on a general curved isothermal surface. Banks (1974) concluded that the three-dimensional solution can be exhibited at a two-dimensional stagnation point for a Prandtl number Pr=0.72. Further the author investigated at infinitely large Prandtl number on the three-dimensional problem which can be reduced to the two-dimensional case.

A well-understood problem in buoyancy-driven convection is the flow induced in a Boussinesq fluid by a heated body in the presence of a constant downward gravitational field. Recently, there has been a great deal of interest in the study of the effect of complex body forces on fluid motion. Such forces can arise in a number of ways, for example when a system with density gradients is subject to vibrations. The resulting buoyancy forces, which are produced by the interaction of density gradients with the acceleration field, have a complex spatio-temporal structure depending on both the nature of density gradients and the spatial and frequency distribution of the vibration-induced acceleration field. The effect of such forces on fluid motion is known as gravity modulation or g-jitter induced flow.

g-Jitter can be defined as the inertia effects due to quasi-steady, oscillatory or transient accelerations arising from crew motions and machinery vibrations in parabolic aircrafts, space shuttles or other microgravity environments. g-Jitter characterizes a small fluctuating gravitational field, very irregular in amplitude, random in direction, and contains a broad spectrum of frequencies (Schneider and Straub, 1989; Alexander et.al., 1991; Nelson, 1991). Its effects may be negligible in earthbound situations, but in a low-gravity environment, where heat and mass transfer in a fluid medium, in the absence of radiation, is expected to be affected only by pure diffusion, g-jitter can give rise to significant convective motions.

Experiment based on microgravity need an environment that were suitable such as International Space Station (ISS), and microgravity facilities on earth namely Drop Tower, Parabolic Flights, Sounding Rockets, and Orbiting Spacecrafts (Mell et. al., 2001; Yoshiaki et. al., 2000). Performing an experiment in g-jitter effect can reduce the effect of gravity on convection and sedimentation which help supress unwanted convective flows to effect the experiments.

In experiments, the most basic investigation that every scientist can conduct are three fundamental states of matter which were solid, liquid and gas. Solidified and melting process for crystal process was an example of process which will be effected by intense convective flows.

Magnitude and frequency of g-jitter and alignment of gravitational field with respect to the growth direction or the direction of the temperature gradient were related to study of g-jitter effect on convection in microgravity environments. g-Jitter gives additional effect on material processing in microgravity environment which interact the density gradient and result in both fluid flow and solute segregation.

Convection is defined as movement of fluid without needed to mind about the cause in fluid mechanic. Another definition is a transfer of heat through a fluid which are either liquid or gas caused by molecular motion. There are two major of heat convection that likely used in research that are forced convection and natural convection or free convection. By using external force to force the fluid to flow is the definition of external force and fluid flow causes by the density difference related to temperature in the fluid is the definition of free convection

A large number of physical phenomena involve natural convection driven by heat generation. The study of heat generation in moving fluids is important in several physical problems dealing with chemical reactions and those concerned with dissociating fluids. Possible heat generation effects may alter the temperature distribution and therefore, the particle deposition rate. In addition, understanding of the effects of internal heat generation also significant in numerous applications that include reactor safety, analysis, metal waste, spent nuclear fuel, fire and combustion studies and strength of radioactive materials.

1.2 Problem Statement

The study will explore on the effect of g-jitter unsteady free convection flow near a stagnation point region of a three dimensional body with heat generation. The problem statement that can be obtain based on How to get the basic equation (continuity, momentum and energy equations)? What term that can be used to reduce the number of variables on the governing equation that can satisfy numerical approach? What will happen when the effect of heat generation to the skin friction and heat flux and also the effect of velocity and temperature profiles?

1.3 Objectives of the Study

The objectives of the study can be shown below:

i. To derive the mathematical models consisting of continuity, momentum and energy equation.
ii. To solve the obtained governing equation numerically using Keller box method.
iii. To analyse the numerical results consist of reduced skin frictions and heat flux also velocity profiles and temperature profiles obtained with different parameter values based on the plotted graph.

1.4 Scope of Study

This study focus on g-jitter free convection flow near a stagnation-point region of a three dimensional body involve with heat generation. The problem occured in different level of curvature ratio, force frequency of g-jitter oscillation, force amplitude, heat generation and fixed Prandtl number. The governing equation of continuity equation, momentum equation, energy equation are solved numerically using Keller-Box method.

1.5 Significance of Research

The results obtained from this project are being significant because of the following reasons.

I. Stagnation point flow have significant impact on the technology application such as spacecraft manoeuvres which can be explained using boundary layer flow near stagnation point theory.
II. Calculation of the skin friction can be used on body as it is moved through types of fluid
III. The study of heat generation is important in viewing several physical problem such as dealing with chemical reactions.

REFERENCE

Alexander, J.I.D., Amiroudine, S., Ouazzani, J. and Rosenberger, F., 1991. Analysis of the low gravity tolerance of Bridgman-Stockbarger crystal growth II. Transient and periodic accelerations. *Journal of crystal growth*, *113*(1-2), pp.21-38.

Amin, N. (1988). The effect of g-jitter o heat transfer. *Proceedings of Royal Society*. A 419:151-172.

Banks, W.H.H., 1972. Three-dimensional free convection flow near a two-dimensional isothermal surface. *Journal of Engineering Mathematics*, *6*(2), pp.109-115.

Banks, W.H.H., 1974. Laminar free convection flow at a stagnation point of attachment on an isothermal surface. *Journal of Engineering Mathematics*,*8*(1), pp.45-56.

Bhadauria, B.S. and Singh, A., 2017. Throughflow and G-jitter effects on chaotic convection in an anisotropic porous medium. *Ain Shams Engineering Journal*.

Biringen, S. and Peltier, L. J. (1990). Computational study of 3-D Benard convection with gravitational modulation. *Physics Fluid*. A2:279-283.

Biringen, S. and Danabasoglu, G. (1990). Computational of convection flow with gravity modulation in rectangular cavities. AIAA *Journal of Thermophys Heat Transfer*. 4:357-365.

Chamkha, A.J. and Issa, C., 2000. Effects of heat generation/absorption and thermophoresis on hydromagnetic flow with heat and mass transfer over a flat surface. *International Journal of Numerical Methods for Heat & Fluid Flow*, *10*(4), pp.432-449.

Damseh, R.A., Al-Odat, M.Q., Chamkha, A.J. and Shannak, B.A., 2009. Combined effect of heat generation or absorption and first-order chemical reaction on micropolar fluid flows over a uniformly stretched permeable surface. *International Journal of Thermal Sciences*, *48*(8), pp.1658-1663.

Doi, T., Prakash, A., Azuma, H., Yoshihara, S. and Kawahara, H., 1995. Oscillatory convection induced by g-jitter in a horizontal Liquid Layer. In *33rd Aerospace Sciences Meeting and Exhibit* (p. 269).

Ferdousi, A. and Alim, M.A., 2010. Natural convection flow from a porous vertical plate in presence of heat generation.

Gresho, P. M. and Sani, R. L. (1970). The effects of gravity modulation on the stability of a heated fluid layer. *Journal of Fluid Mechanics.* 40:783-806.

Jawdat, J.M. and Hashim, I., 2010. Low Prandtl number chaotic convection in porous media with uniform internal heat generation. *International Communications in Heat and Mass Transfer*, *37*(6), pp.629-636.

Jeong, Y.S., Seo, S.B. and Bang, I.C., 2018. Natural convection heat transfer characteristics of molten salt with internal heat generation. *International Journal of Thermal Sciences*, *129*, pp.181-192.

John, D. and Anderson, J.R., 1995. Computational fluid dynamics: the basics with applications. *Mechanical Engineering Series. McGraw-HILL*.

Khoshnevis, A., Ahadi, A. and Saghir, M.Z., 2014. On the influence of g-jitter and prevailing residual accelerations onboard International Space Station on a thermodiffusion experiment. *Applied Thermal Engineering*, *68*(1-2), pp.36-44.

Kumar, A. and Gupta, V.K., 2016. Study of heat and mass transport in couple-stress liquid under g-jitter effect. *Ain Shams Engineering Journal*.

Langbein, D. (1983). *Oscillatory convection in a spherical cavity due to a g-jitter.* ESA *Mater. Sci. under Microgravity, International Organization*, 359-363.

Li, B.Q., 1996. g-Jitter induced free convection in a transverse magnetic field. *International journal of heat and mass transfer*, *39*(14), pp.2853-2860.

Li, B.Q. and De Groh, H.C., 2003. Three-dimensional gravity-jitter induced melt flow and solidification in magnetic fields. *Journal of thermophysics and heat transfer*, *17*(4), pp.498-508.

Magyari, E. and Chamkha, A.J., 2010. Combined effect of heat generation or absorption and first-order chemical reaction on micropolar fluid flows over a uniformly stretched permeable surface: The full analytical solution. *International Journal of Thermal Sciences*, *49*(9), pp.1821-1828.

Mishra, S.R., Khan, I., Al-mdallal, Q.M. and Asifa, T., 2018. Free convective micropolar fluid flow and heat transfer over a shrinking sheet with heat source. *Case studies in thermal engineering*, *11*, pp.113-119.

Mohamed, R.A., 2009. Double-diffusive convection-radiation interaction on unsteady MHD flow over a vertical moving porous plate with heat generation and Soret effects. *Applied mathematical sciences*, *3*(13), pp.629-651.

Mohammadein, A.A. and Subba Reddy Gorla, R., 2001. Heat transfer in a micropolar fluid over a stretching sheet with viscous dissipation and internal heat generation. *International Journal of Numerical Methods for Heat & Fluid Flow*, *11*(1), pp.50-58.

Mohd Arif Admon (2011). *Mathematical Modelling of Unsteady Free Convection Boundary Layer Flow over a Three-Dimensional Stagnation Point*. Master. Universiti Teknologi Malaysia, Skudai

Mell, W.E., Kashiwagi, T., Nakamura, Y., Olson, S.L., Baum, H.R. and McGrattan, K.B., 2001. Multidimensional Effects on Ignition, Transition, and Flame Spread in Microgravity.

Mendez, F. and Trevino, C., 2000. The conjugate conduction–natural convection heat transfer along a thin vertical plate with non-uniform internal heat generation. *International Journal of Heat and Mass Transfer*, *43*(15), pp.2739-2748.

Molla, M.M., Hossain, M.A. and Yao, L.S., 2004. Natural convection flow along a vertical wavy surface with uniform surface temperature in presence of heat generation/absorption. *International Journal of Thermal Sciences*, *43*(2), pp.157-163.

Nelson, E.S., 1991. An examination of anticipated g-jitter on space station and its effects on materials processing, NASA Tech.

Pan B, Shang DY, Li BQ, De Groh HC. Magnetic field effects on g-jitter induced flow and solute transport. International journal of heat and mass transfer. 2002 Jan 1;45(1):125-44.

Poots G., 1964. Laminar free convection near the lower stagnation point on an isothermal curved surface. *International Journal of Heat and Mass Transfer*, *7*(8), pp.863-874.

Postelnicu A. and Pop, I., 1999. Similarity solutions of free convection boundary layers over vertical and horizontal surfaces in porous media with internal heat generation. *International communications in heat and mass transfer*, *26*(8), pp.1183-1191.

Rajvanshi S.C., Saini B.S. and Bhawn J.E.E.T., 2013. Effect of radiation and gravity modulation on unsteady MHD free convection flow through porous medium in slip-flow regime with entropy. *Walailak Journal of Science and Technology (WJST)*, *11*(3), pp.225-242.

Ramos, J.I., 2000. Heat and mass transfer in annular liquid jets: II. g-jitter. *Applied mathematics and computation*, *110*(2-3), pp.165-183.

Rawi, N.A., Kasim, A.R.M., Isa, M. and Sharidan, S., 2014. g-Jitter Induced Mixed Convection Flow of Heat and Mass Transfer past an Inclined Stretching Sheet. *Jurnal Teknologi*, *71*(1), pp.27-31.

Rees, D.A.S. and Pop, I., 2000. The effect of g-jitter on vertical free convection boundary-layer flow in porous media. *International communications in heat and mass transfer*, *27*(3), pp.415-424.

Rees, D.A.S. and Pop, I., 2000. Vertical free convection in a porous medium with variable permeability effects. *International journal of heat and mass transfer*, *43*(14), pp.2565-2571.

Rees, D.A.S. and Pop, I., 2003. The effect of large-amplitude g-jitter vertical free convection boundary-layer flow in porous media. *International journal of heat and mass transfer, 46*(6), pp.1097-1102.

Schneider, S. and Straub, J., 1989. Influence of the Prandtl number on laminar natural convection in a cylinder caused by g-jitter. *Journal of Crystal Growth*, *97*(1), pp.235-242.

Shafie, S., Amin, N. and Pop, I., 2005. The effect of g-jitter on double diffusion by natural convection from a sphere. *International journal of heat and mass transfer*, *48*(21-22), pp.4526-4540.

Shafie, S., Amin, N. and Pop, I., 2007. g-Jitter free convection flow in the stagnation-point region of a three-dimensional body. *Mechanics Research Communications*, *34*(2), pp.115-122.

Shi Z, Luo L, Lei M, Su T. A model for the jitter of a ring oscillator under sinusoidal interference on the power supply. Microelectronics Journal. 2018 May 31;75:41-51.

Shu, Y., Li, B.Q. and De Groh, H.C., 2001. Numerical study of g-jitter induced double-diffusive convection. *Numerical Heat Transfer: Part A: Applications*, *39*(3), pp.245-265.

Shu, Y., Li, B.Q. and III, H.D.G., 2002. Magnetic damping of g-jitter induced double-diffusive convection. *Numerical Heat Transfer: Part A: Applications*, *42*(4), pp.345-364.

Turkyilmazoglu, M., 2018. Heat transfer from moving exponential fins exposed to heat generation. *International Journal of Heat and Mass Transfer*, *116*, pp.346-351.

Vadasz, P. and Olek, S., 1999. Weak turbulence and chaos for low Prandtl number gravity driven convection in porous media. *Transport in Porous Media*, *37*(1), pp.69-91.

Vajravelu, K. and Hadjinicolaou, A., 1993. Heat transfer in a viscous fluid over a stretching sheet with viscous dissipation and internal heat generation. *International Communications in Heat and Mass Transfer*, *20*(3), pp.417-430.

Vajravelu K, Hadjinicolaou A. Heat transfer in a viscous fluid over a stretching sheet with viscous dissipation and internal heat generation. International Communications in Heat and Mass Transfer. 1993 May 1;20(3):417-30.