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Dislocated Metric Spaces

An Amazing Result Involving

Highlights

Study the Ecological Processes

Application of Hankel Transform

Discovering Thoughts, Inventing Future

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A Summation Formula in the Light of Special Functions

By Salahuddin, M. P. Chaudhary & Sangeeta Chaudhary

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Abstract- The main objective of the present paper is to derive a summation formula involving certain special functions.

Keywords: *gauss second summation theorem, recurrence relation, prudnikov.*

GJSFR-F Classification : *MSC 2010: 40A25, 11B37*



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Notes

A Summation Formula in the Light of Special Functions

Salahuddin [α], M. P. Chaudhary [σ] & Sangeeta Chaudhary [ρ]

Abstract- The main objective of the present paper is to derive a summation formula involving certain special functions.

2010 MSC NO : 33C05 , 33C20 , 33D15 , 33D50 , 33D60

Keywords: *gauss second summation theorem, recurrence relation, prudnikov.*

I. Introduction

a) Generalized Hypergeometric Functions

A generalized hypergeometric function ${}_pF_q(a_1, ..., a_p; b_1, ..., b_q; z)$ is a function which can be defined in the form of a hypergeometric series, i.e., a series for which the ratio of successive terms can be written

$$\frac{c_{k+1}}{c_k} = \frac{P(k)}{Q(k)} = \frac{(k+a_1)(k+a_2)...(k+a_p)}{(k+b_1)(K+b_2)...(k+b_q)(k+1)}\ z. \tag{1}$$

Where $k+1$ in the denominator is present for historical reasons of notation[Koepf p.12(2.9)], and the resulting generalized hypergeometric function is written

$${}_pF_q\left[\begin{array}{ccc} a_1, a_2, \cdots, a_p & ; & \\ & & z \\ b_1, b_2, \cdots, b_q & ; & \end{array}\right] = \sum_{k=0}^{\infty} \frac{(a_1)_k (a_2)_k \cdots (a_p)_k z^k}{(b_1)_k (b_2)_k \cdots (b_q)_k k!} \tag{2}$$

or

$${}_pF_q\left[\begin{array}{ccc} (a_p) & ; & \\ & & z \\ (b_q) & ; & \end{array}\right] = \sum_{k=0}^{\infty} \frac{((a_p))_k z^k}{((b_q))_k k!} \tag{3}$$

where the parameters $b_1, b_2, \cdots, b_q$ are positive integers.

The ${}_pF_q$ series converges for all finite z if $p \leq q$, converges for $|\ z\ | < 1$ if $p = q+1$, diverges for all z , $z \neq 0$ if $p > q+1$[Luke p.156(3)].

The function ${}_2F_1(a, b; c; z)$ corresponding to $p = 2, q = 1$, is the first hypergeometric function to be studied (and, in general, arises the most frequently in physical problems), and so is frequently known as "the" hypergeometric equation or, more explicitly, Gauss's hypergeometric function

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[Gauss p.123-162]. To confuse matters even more, the term "hypergeometric function" is less commonly used to mean closed form, and "hypergeometric series" is sometimes used to mean hypergeometric function.

The hypergeometric functions are solutions of Gaussian hypergeometric linear differential equation of second order

$$z(1-z)y'' + [c-(a+b+1)z]y' - aby = 0 \tag{4}$$

The solution of this equation is

$$y = A_0\Big[1 + \frac{ab}{1!\ c}z + \frac{a(a+1)b(b+1)}{2!\ c(c+1)}z^2 + \cdots\cdots\Big] \tag{5}$$

This is the so-called regular solution, denoted

$${}_2F_1(a,b;c;z) = \Big[1 + \frac{ab}{1!\ c}z + \frac{a(a+1)b(b+1)}{2!\ c(c+1)}z^2 + \cdots\cdots\Big] = \sum_{k=0}^{\infty}\frac{(a)_k\ (b)_k z^k}{(c)_k k!} \tag{6}$$

which converges if c is not a negative integer for all $\mid z \mid < 1$ and on the unit circle $\mid z \mid = 1$ if $R(c-a-b) > 0$.

It is known as Gauss hypergeometric function in terms of Pochhammer symbol $(a)_k$ or generalized factorial function.

Many of the common mathematical functions can be expressed in terms of the hypergeometric function. Some typical examples are

$$(1-z)^{-a} = z\ {}_2F_1(1,1;2;-z) \tag{7}$$

$$\sin^{-1} z = z\ {}_2F_1(\frac{1}{2},\frac{1}{2};\frac{3}{2};z^2) \tag{8}$$

Gauss' Relations for Contiguous Functions:

The six functions $F(a\pm1,b;c;z), F(a,b\pm1;c;z), F(a,b;c\pm1;z)$ are called contiguous to $F(a,b;c;z)$. Relation between $F(a,b;c;z)$ and any two contiguous functions have been given by Gauss.
[Abramowitz p.558(15.2.14)]

$$(a-b)\ {}_2F_1\left[\begin{matrix} a,\ b\ ; \\ c\ ; \end{matrix}\quad z\right] = a\ {}_2F_1\left[\begin{matrix} a+1,\ b\ ; \\ c\ ; \end{matrix}\quad z\right] - b\ {}_2F_1\left[\begin{matrix} a,\ b+1\ ; \\ c\ ; \end{matrix}\quad z\right] \tag{9}$$

Gauss second summation theorem is defined by [Prudnikov., 491(7.3.7.5)]

$${}_2F_1\left[\begin{matrix} a,\ b\ ; \\ \frac{a+b+1}{2}\ ; \end{matrix}\quad \frac{1}{2}\right] = \frac{\Gamma(\frac{a+b+1}{2})\ \Gamma(\frac{1}{2})}{\Gamma(\frac{a+1}{2})\ \Gamma(\frac{b+1}{2})} \tag{10}$$

$$= \frac{2^{(b-1)}\ \Gamma(\frac{b}{2})\ \Gamma(\frac{a+b+1}{2})}{\Gamma(b)\ \Gamma(\frac{a+1}{2})} \tag{11}$$

In a monograph of Prudnikov et al., a summation theorem is given in the form [Prudnikov., p.491(7.3.7.8)]

$${}_2F_1\left[\begin{matrix} a,\ b\ ; \\ \frac{a+b-1}{2}\ ; \end{matrix}\quad \frac{1}{2}\right] = \sqrt{\pi}\left[\frac{\Gamma(\frac{a+b+1}{2})}{\Gamma(\frac{a+1}{2})\ \Gamma(\frac{b+1}{2})} + \frac{2\ \Gamma(\frac{a+b-1}{2})}{\Gamma(a)\ \Gamma(b)}\right] \tag{12}$$

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Now using Legendre's duplication formula and Recurrence relation for Gamma function, the above theorem can be written in the form

$$ {}_2F_1\left[\begin{matrix} a,\ b \\ \frac{a+b-1}{2}\end{matrix};\quad \frac{1}{2}\right] = \frac{2^{(b-1)}\ \Gamma(\frac{a+b-1}{2})}{\Gamma(b)}\left[\frac{\Gamma(\frac{b}{2})}{\Gamma(\frac{a-1}{2})}+\frac{2^{(a-b+1)}\ \Gamma(\frac{a}{2})\ \Gamma(\frac{a+1}{2})}{\{\Gamma(a)\}^2}+\frac{\Gamma(\frac{b+2}{2})}{\Gamma(\frac{a+1}{2})}\right] \tag{13} $$

Recurrence relation is defined by

$$ \Gamma(\zeta+1) = \zeta\ \Gamma(\zeta) \tag{14} $$

II. Main Summation Formula

$$ {}_2F_1\left[\begin{matrix} a,\ b \\ \frac{a+b+47}{2}\end{matrix};\quad \frac{1}{2}\right] = \frac{2^b\ \Gamma(\frac{a+b+47}{2})}{(a-b)\ \Gamma(b)\Big[\prod_{\Xi=1}^{23}\{a-b-(2\Xi-1)\}\Big]\Big[\prod_{\Upsilon=1}^{23}\{a-b+(2\Upsilon-1)\}\Big]} $$

$$ \Big[\frac{\Gamma(\frac{b}{2})}{\Gamma(\frac{a+1}{2})}\Big\{4194304(a^{24}+a^{23}(-529+1034b)+23a^{22}(5731-7567b+7050b^2)+253a^{21}(-81305+176908b $$
$$ -61617b^2+36378b^3)+253a^{20}(8912547-15301555b+15087141b^2-2370633b^3+994332b^4) $$
$$ +253a^{19}(-729562323+1675642026b-883014850b^2+537100960b^3-47645075b^4+15080702b^5) $$
$$ +437a^{18}(26795032319-51826502991b+52675187208b^2-13398724750b^3+5687164735b^4 $$
$$ -322080707b^5+79712282b^6)+437a^{17}(-1349398815215+32010264875686-205198332754 5b^2 $$
$$ +12651196097 82b^3-1888174322 25b^4+596271070 44b^5-232698546 3b^6+45987855 0b^7) $$
$$ +7429a^{16}(3224471854274-6691057943825b+6910962796281b^2-2224676333517b^3+944086166793b^4 $$
$$ -921360460 35b^5+224512708 11b^6-63463239 9b^7+10117328 1b^8)+874a^{15}(-907619931345281 $$
$$ +2196439780017778b-1583061524809980b^2+978474032814608b^3-189247186989894b^4 $$
$$ +589795055727 24b^5-402356940966 0b^6+77141867491 2b^7-1628889824 1b^8+209091447 4b^9) $$
$$ +46a^{14}(468566121314958303-1017824993014405123b+1057739894293651278b^2 $$
$$ -392620567074002300b^3+164887334296881130b^4-21145413880972458b^5+50110888414065 36b^6 $$
$$ -24892398130110 0b^7+3771082289353 5b^8-601137911275b^9+6063651974 6b^{10}) $$
$$ +46a^{13}(-1048079981530687 9695+2565019172638596 5388b-1995968113819992 9643b^2 $$
$$ +1225008172011414 3878b^3-2771196216002273550b^4+842260723772929616b^5 $$
$$ -75877233063158814b^6+13859663123661012b^7-509900689579875b^8+59821063101140b^9 $$
$$ -6973199770 79b^{10}+4961169797 4b^{11})-46a^{12}(-1930761936640527 3361+4322429289072576 86205b $$
$$ -4479864430197681835 83b^2+1823831590147716020 43b^3-7493769426189041405 8b^4 $$
$$ +1129599081152182381 0b^5-2557424283239432542b^6+166286552352776310b^7 $$
$$ -230836849674189 33b^8+611932225724702 5b^9-50055447050323b^{10}+32247603683 1b^{11}) $$
$$ -46a^{11}(2922906805676735359009-7179158161708177901366b+5874213600004333972050b^2 $$
$$ -3541062392770959869904b^3+8833843368054086005 91b^4-2572969972899907315 02b^5 $$

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$$+27004281748591247100b^6 - 453226356607018737 6b^7 + 2082811939283596 95b^8$$
$$-198673779670466 10b^9 + 287720286194770b^{10} - 322476036831b^{12} + 49611697974b^{13})$$
$$-506a^{10}(-3289323182409779776423 + 74961591211971345007 99b - 7670199805287410414916b^2$$
$$+3305843522579583360570b^3 - 1306390804960229398137b^4 + 2152791296718658055 33b^5$$
$$-4491836776999472381 0b^6 + 3246913411866939100b^7 - 367469311611014041b^8$$
$$+90895282647642 33b^9 - 26156389654070b^{11} + 45504951863 93b^{12} - 63392725189b^{13} + 5512410886b^{14})$$
$$-506a^9(3302934488838793729973 5 - 807162382901211395771 60b + 6790867576251342945376 5b^2$$
$$-3954892430001389431122 2b^3 + 1035988117542724869217 5b^4 - 2790368186666261220084b^5$$
$$+3055366645891453087 09b^6 - 419286570645138485 38b^7 + 160012685301850452 5b^8$$
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$$+1339441607490051028963871 0b - 1332254741495023876699635 0b^2$$
$$+5862527517289620649481 846b^3 - 2151132892496025940533226b^4 + 3553190515262651013866 70b^5$$
$$-6081438750420582816547 8b^6 + 3426198156496859682510b^7 - 3520279076640709955 0b^9$$
$$+8084324855442308902b^{10} - 4165623878567193 90b^{11} + 461673699348378 66b^{12}$$
$$-101980137915975 0b^{13} + 75421645787070b^{14} - 618978133158b^{15} + 32678969763b^{16})$$
$$-23a^7(3713410653113709527978 7603 - 8910139947324650080388571 0b$$
$$+7496115881356316366205956 0b^2 - 4075010141095135505307676 8b^3$$
$$+1040923470820999351792437 2b^4 - 2308469208507693358304248b^5$$
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$$+2771932624732202 4b^{13} - 497847962602200b^{14} + 29313909646656b^{15} - 204986264877b^{16}$$
$$+8737692450b^{17}) - 23a^6(-1816365075503293031147866 71 + 4095244688990857455538961 55b$$
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$$-1516371020452226580169089924b + 1202265485968967736276728367b^2$$
$$-5442185725886156463246000 54b^3 + 9938693744195790422182862 0b^4$$
$$-5890553184666820563182180b^6 + 2308469208507693358304248b^7$$
$$-3553190515262651013866 70b^8 + 6138810010665774684184 8b^9 - 4736140852781047721726b^{10}$$
$$+5145939945799814630 04b^{11} - 2259198162304364762 0b^{12} + 1684521447545859232b^{13}$$

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$$-42290827761944916b^{14}+2241221211763512b^{15}-297599428693056b^{16}+11329150338366b^{17}$$
$$-611953343338b^{18}+16588772219b^{19})-23a^4(-17141664735601324619166101250$$
$$+3618638378432052200750621925b-2849793884317255245197831595b^2$$
$$+845506576871181679688191719b^3-9938693744195790422182862056b^5$$
$$+4892487679615828114006650066b^6-1040923470820999351792437226b^7$$
$$+2151132892496025940533226b^8-22791738585939947122785096b^9+28740597709125046759014b^{10}$$
$$-17667686736108172011826b^{11}+14987538852378028811626b^{12}-5542392432004547100b^{13}$$
$$+329774668593762260b^{14}-7191393105615972b^{15}+3049398318741396b^{16}-358753121227556b^{17}$$
$$+10805612996556b^{18}-524095825b^{19}+10937652b^{20})-23a^3(2910996690958124489461348125$$
$$-5746357719280004177264775750b+3191889854580266346156760950b^2$$
$$-845506576871181679688191719b^4+5442185725886156463246000546b^5$$
$$-1611782725886751431857722806b^6+4075010141095135505307676856b^7$$
$$-5862527517289620649481846b^8+8700763346003056748468846b^9-7272855749675083393254060b^{10}$$
$$+7082124785541919739808b^{11}-3647663180295432040866b^{12}+2450016344022828775656b^{13}$$
$$-785241134148004600b^{14}+37182013246955104b^{15}-7185704557259916b^{16}+240372725858586b^{17}$$
$$-2545757702506b^{18}+59081105606b^{19}-260769636b^{20}+4001586b^{21})$$
$$+a^2(6469153378001424769439217937556-96833027583613230625570719375b$$
$$+7341346665534612596160550185056b^3-6554525933929687063955012668556b^4$$
$$+2765210617728625793436475244156b^5-8812824524227007154808308870b^6$$
$$+1724106652711952764227369880b^7-3064185905438554916409160506b^8$$
$$+3436178993583179530360509006b^9-3881121101475429669947496b^{10}$$
$$+2702138256001993627143006b^{11}-2060737637890933644481856b^{12}+9181453323571967635786b^{13}$$
$$-4865603513750795878856b^{14}+1383595772683922520b^{15}-5134154261357154956b^{16}$$
$$+896716714137165b^{17}-230190568098966b^{18}+23402757050b^{19}-3817046673b^{20}+155891016b^{21}$$
$$-162150b^{22})+a(-2537379133562625794765760937556+96833027583613230625570719375b^2$$
$$-1321662275434400960770898422506b^3+8322868270393720061726430427556b^4$$
$$-3487653347040121134388906825256b^5+9419062784678972147739611565b^6$$
$$-2049332187884669518489371330b^7+3080715697227117366616903306b^8$$
$$-4084241657480129662604296006b^9+3793056515325750057404294b^{10}$$
$$-3302412754385761834628366b^{11}+1988317472973385356543006b^{12}-1179908819413754407848b^{13}$$
$$+468199496786626356586b^{14}-191968836773553729726b^{15}+49707869464675925b^{16}$$
$$-1398848575067216b^{17}+22648181807067b^{18}-4239374325786b^{19}+38712934156b^{20}-44757724b^{21}$$
$$+174041b^{22}-1034b^{23})-b(-2537379133562625794765760937556+64691533780014247694392179375b$$
$$-6695292389203686325761100687556b^2+3942582889188304662408203287556b^3$$

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$$-1523356975295571204226031962 5b^4+41776396736575739716400934 33b^5$$
$$-8540844502161531914351148 69b^6+13454156980400467415719658 1b^7$$
$$-1671284851352429627366591 0b^8+16643975302993485668700 38b^9$$
$$-1344537130611298265144 14b^{10}+88815050328546425746 06b^{11}-48211679150411646597 0b^{12}$$
$$+2155404158048808193 8b^{13}-7932598199957755 94b^{14}+23954601405401 546b^{15}$$
$$-589687282248955b^{16}+11709429123403b^{17}-184579267719b^{18}+22548743 91b^{19}-20570165b^{20}$$
$$+131813b^{21}-529b^{22}+b^{23}))\Big\}-\frac{\Gamma(\frac{b+1}{2})}{\Gamma(\frac{a}{2})}\Big\{16777216(23a^{23}+23a^{22}(-176+329b)$$
$$+253a^{21}(5215-3008b+2679b^2)+253a^{20}(-452960+879605b-182736b^2+103071b^3)$$
$$+253a^{19}(60311301-52865600b+47979950b^2-5173760b^3+2071525b^4)+437a^{18}(-1866667344$$
$$+36857734 17b-12414016 00b^2+70381325 0b^3-4640216 0b^4+1400350 9b^5)+437a^{17}(136919748025$$
$$-147120185088b+134215406415b^2-24378110400b^3+9700951575b^4-429551424b^5+101173281b^6)$$
$$+7429a^{16}(-288016551040+571859066695b-244761992496b^2+138065017179b^3-157104456 00b^4$$
$$+4662174165b^5-147161136b^6+27592713b^7)+874a^{15}(110646186438247-134786297605760b$$
$$+12250447143978 0b^2-28930053259008b^3+1133880679357 8b^4-87994404672 0b^5+20142680490 0b^6$$
$$-4709156352b^7+708212967b^8)+46a^{14}(-52099555819934768+1032250688552821 01b$$
$$-51223939 3194057600b^2+28510225961592100b^3-427891052630448 0b^4+123647142089424 6b^5$$
$$-689302761024 00b^6+12367973723700b^7-218534286960b^8+261364309 25b^9)$$
$$+46a^{13}(152327599806239 8905-202068931312177066 88b+181592109102607534 1b^2$$
$$-5041150769377504 00b^3+19279782772679085 0b^4-19872507249052416b^5+43624112180304 18b^6$$
$$-1797426115104 00b^7+252047936291 25b^8-33454631584 0b^9+3031825987 3b^{10})$$
$$+26a^{12}(-46738665698539844640+91784298587795117985b-5029235764992703988 8b^2$$
$$+2737683074002368791 1b^3-48618706808163808 00b^4+13503250669018219 30b^5$$
$$-997229847532605 12b^6+16721579297625870b^7-5088611341176 00b^8+53344455517925b^9$$
$$-485092157968b^{10}+24805848987b^{11})+a^{11}(233377576555386053564 18-3285539922195769807296 0b$$
$$+2895225481822991002966 8b^2-8932261695719974004224b^3+3291278251514442174622b^4$$
$$-4002494928253082227 20b^5+8230294158594605042 4b^6-4388608849494744576b^7$$
$$+5406889887128515 50b^8-1112500318694336 0b^9+651114949032548b^{10}-644952073662b^{12})$$
$$-22a^{10}(127478100858749242841 44-2462339511003340640719 9b+1441474844926881420864 0b^2$$
$$-7580198303956038791706b^3+14914415029411012808 16b^4-3889815295907376004 13b^5$$
$$+3310206141763042496 0b^6-4888486075362902428b^7+17324552137805140 8b^8$$
$$-1175770240674615 3b^9+29596134046934b^{11}-57329073214 4b^{12}+6339272518 9b^{13})$$
$$-22a^9(-15917461640262849730445 5+23300087479170304526912 0b-19896213090319681897264 5b^2$$
$$+6538018277347963322592 0b^3-22683573168494062454175b^4+29845440523874190849 92b^5$$

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$$-5418708301593339957496^6+29956051044652120960b^7-23952365393365945256^8$$
$$+117577024067461536^{10}-505681963042880b^{11}+630434474302756^{12}-69950593312006^{13}$$
$$+546489010256^{14})-2a^8(14135533727749076201623360-26559464424078244741968715b$$
$$+161212438980987600274274406^2-80069216771815661324508436^3$$
$$+16385936016992051901768006^4-37835926800210021224600556^5+31339943343045174503952b^6$$
$$-30113940382190972886156^7+263476019327025397756^9-19057007351585654886^{10}$$
$$+2703444943564257756^{11}-6615194743528800b^{12}+5797102534698756^{13}-502628860008006^{14}$$
$$+309489066579b^{15})+a^7(22087931964538478863780680 3-32883940888284264918356096 0b$$
$$+2661862282876559483733725846^2-8857380645642457006374758 4b^3$$
$$+2728934142778048237581429 2b^4-3359674931126195881854720b^5$$
$$+3979584463542500106343926^6-6022788076438194577230b^8+6590331229823466611206^9$$
$$-1075466936579838534166^{10}+4388608849494744576b^{11}-434761061738272620b^{12}$$
$$+8268160129478400b^{13}-568926791290200b^{14}+4115802651648b^{15}-2049862648776^{16})$$
$$+a^6(-1125939521154262717909258128+2015056862560521162160964955b$$
$$-1215154200556285221697944320b^2+5378488099323801650020522166^3$$
$$-1002744790663857544331126406^4+1515073722316320969292106 0b^5$$
$$-3979584463542500106343926^7+6267988668609034900790 4b^8-1192115826350534790647 8b^9$$
$$+7282453511878693491206^{10}-8230294158594605042 4b^{11}+259279760358477331 2b^{12}$$
$$-200670916029399228b^{13}+3170792700710400b^{14}-1760470274826006^{15}+109326007934 4b^{16}$$
$$-44212723797b^{17})+a^5(5066968478525294055658370415-7393789471350456781405463232b$$
$$+5357661269531597371164089007b^2-1593656779593915351419429120b^3$$
$$+3223875454257754131549611006^4-1515073722316320969292106 0b^6$$
$$+3359674931126195881854720b^7-7567185360042004244921106^8+6565996915252321986982 4b^9$$
$$-8557593650996227209086b^{10}+4002494928253082227206^{11}-3510845173944737018 0b^{12}$$
$$+9141353334564111366^{13}-5687768536113531 6b^{14}+769071096833280b^{15}-346352918717856^{16}$$
$$+187713972288b^{17}-6119533433b^{18})+a^4(-1441167509289801442673939760 0$$
$$+2323472231289630313380266536 5b-1235874724062886664113237704 0b^2$$
$$+3606933776254835213741125479b^3-3223875454257754131549611006^5$$
$$+1002744790663857544331126406^6-2728934142778048237581429 2b^7$$
$$+3277187203398410380353600b^8-4990386097068693739918506^9+3281171306470422817795 2b^{10}$$
$$-3291278251514442174622b^{11}+1264086377012259008006^{12}-8868700075432379100b^{13}$$
$$+1968298842100060806^{14}-9910117137587172b^{15}+116712900362400b^{16}-4239315838275b^{17}$$
$$+20277743920b^{18}-524095825b^{19})+a^3(3107723477643850851671872 9725$$
$$-3967288204421512256708630304 0b+1906606151437531286390544667 8b^2$$

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$$-360693377625483521374112547 9b^4+159365677959391535141942912 0b^5$$
$$-537848809932380165002052216b^6+885738064564245700637475 84b^7$$
$$-160138433543631322649016 86b^8+143836402101655193097024 0b^9-166764362687032853417532b^{10}$$
$$+893226169571997400422 4b^{11}-711797599240615885686b^{12}+231892935391365184 00b^{13}$$
$$-131147039423323660 0b^{14}+25284866548372992b^{15}-1025685012622791b^{16}+106532342448 00b^{17}$$
$$-307566390250b^{18}+1308961280b^{19}-26076963b^{20})+a^2(-362922408827921482632568980 00$$
$$+391685584588234741575464132 25b-190660615143753128639054466 78b^3$$
$$+123587472406288666411323770 40b^4-535766126953159737116408900 7b^5$$
$$+121515420055628522169794432 0b^6-266186228287655948373372584b^7$$
$$+322424877961975200548548 80b^8-437716687987033001739819 0b^9+317124465883913912590080b^{10}$$
$$-289522548182299100296 68b^{11}+130760129889810303708 8b^{12}-835323701871994656 86b^{13}$$
$$+235627608692664960 0b^{14}-107068908038367720b^{15}+181833684225278 4b^{16}-586521326033 55b^{17}$$
$$+542492499200b^{18}-12138927350b^{19}+46232208b^{20}-677787b^{21})+a(2020420115815121077828833562 5$$
$$-391685584588234741575464132 25b^2+396728820442151225670863030 40b^3$$
$$-232347223128963031338026653 65b^4+739378947135045678140546323 2b^5$$
$$-201505686256052116216096495 5b^6+328839408882842649183560960b^7$$
$$-531189288481564894839374 30b^8+512601924541746699592064 0b^9-541714692420734940958378b^{10}$$
$$+328553992219576980729 60b^{11}-238639176328267306761 0b^{12}+92951700036014507648b^{13}$$
$$-474835316734297664 6b^{14}+117803224107434240b^{15}-424834100647715 5b^{16}+642915208834 56b^{17}$$
$$-1610682983229b^{18}+13374996800b^{19}-222540065b^{20}+761024b^{21}-7567b^{22})$$
$$+b(-2020420115815121077828833562 5+362922408827921482632568980 00b$$
$$-310772347764385085167187297 25b^2+144116750928980144267393976 00b^3$$
$$-506696847852529405566 83704 15b^4+112593952115426271790925812 8b^5$$
$$-220879319645384788637806803b^6+282710674554981524032467 20b^7$$
$$-350184156085782694069801 0b^8+280451821889248334251168b^9-233377576555386053564 18b^{10}$$
$$+121520530816203596064 0b^{11}-700706959108703496 30b^{12}+23965795677169993 28b^{13}$$
$$-96704766947027878b^{14}+21396749576761 60b^{15}-5983392988692 5b^{16}+81573362932 8b^{17}$$
$$-152587591 53b^{18}+114598880b^{19}-1319395b^{20}+4048b^{21}-23b^{22}))\Big\}\Big] \qquad (15)$$

III. Derivation of the Summation Formula

Substituting $c=\frac{a+b+47}{2}$ and $z=\frac{1}{2}$ in equation (9), we get

$$(a-b)\ {}_2F_1\left[\begin{matrix}a,\ b\\ \frac{a+b+47}{2}\end{matrix};\ \frac{1}{2}\right]=a\ {}_2F_1\left[\begin{matrix}a+1,\ b\\ \frac{a+b+47}{2}\end{matrix};\ \frac{1}{2}\right]-b\ {}_2F_1\left[\begin{matrix}a,\ b+1\\ \frac{a+b+47}{2}\end{matrix};\ \frac{1}{2}\right]$$

Now involving the derived formula [Salahuddin et. al. p.12-41(8)], the summation formula is obtained.

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Application of Hankel Transform of I-function of one Variable for Solving Axisymmetric Dirichlet Potential Problem

By Reema Tuteja, Shailesh Jaloree & Anil Goyal

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Abstract- In the present paper we have solved the well known Axisymmetric Dirichlet problem for a half-space using the Hankel transform of I-function of one variable. Hankel transform is much effective tool for solving the boundary value problems involving cylindrical coordinates. Here we have considered the Axisymmetric Dirichlet problem for a half-space which is mathematically characterized by

$$u_{xx} + (\tfrac{1}{x})u_x + u_{zz} = 0,\ 0 < x < \infty,\ z > 0$$

Boundary conditions are

$$u(x,0) = f(x),\ 0 < x < \infty$$

$$u(x,z) \to 0 \text{ as } \sqrt{(x^2+z^2)} \to \infty,\ z > 0$$

Our main result is believed to be general and unified in nature. A number of known and new results can be obtained by specializing the coefficients and parameters involved in the kernel.

Keywords and Phrases: *potential problem, hankel transform, saxena's I- function of one variable, fox's H-function of one variable.*

GJSFR-F Classification : *MSC 2010: 47B35*



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Notes

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Abstract- In the present paper we have solved the well known Axisymmetric Dirichlet problem for a half-space using the Hankel transform of I-function of one variable. Hankel transform is much effective tool for solving the boundary value problems involving cylindrical coordinates. Here we have considered the Axisymmetric Dirichlet problem for a half-space which is mathematically characterized by

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I. Introduction

Our aim is to find out the solution of boundary value problem involving cylindrical co-ordinates using Hankel transform of order zero.the most important partial differential equation in mathematicalphysics is the Laplace's equation or potential equation i.e.

$$\nabla^2 u = 0 \tag{1.1}$$

regardless of the co-ordinate system.

Laplace's equation arises in steady state heat conduction problems involving homogeneous solids. this same equation is satisfied by the gravitational potential in free space, the electrostatic potential in a uniform dielectric, the

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magnetic in the steady flow of currents in solid conductors, and the velocity potential of inviscid, irrotational fluids.The mathematical formulation of all potential problems is same despite the physical differences of the applications. Because of this, all solutions of the potential equations are collectively called potential functions, and the study of the many properties associated with these functions forms that branch of mathematics known as potentail theory. Here we have considered Axisymmetric Dirichlet problem for a half-space from the book by Andrews and Shivamoggi[1].

The Hankel transform arise naturally in solving boundary vaue problems formulated in cylindrical co-ordinates. They also occur in other applications such as determining the oscillations of a heavy chain suspended from one end, first treated by D. Bernoulli. This later problem is of some special historical significance since it was in this analysis of Bernoulli in 1703 that the Bessel function of order zero appeared for the first time.

The Hankel transform of order ν of a function $f(x)$ denoted by $H_\nu\{f(x);\rho\}$ is defined as

$$H_\nu\{f(x);\rho\} = \int_0^\infty xJ_\nu(\rho x)f(x)dx = g(\rho), \rho > 0, \nu > -\frac{1}{2} \tag{1.2}$$

The inverse Hankel transform is given by

$$f(x) = \int_0^\infty \rho J_\nu(x\rho)\, g(\rho)d\rho, \Re(\nu) > -1 \tag{1.3}$$

I-function of one variable introduced by Saxena V.P.[6] is defined as

$$I^{m,n}_{p_i,q_i:r} = I^{m,n}_{p_i,q_i:r}\left[x\,|^{\{(a_j,\alpha_j)_{1,n}\},\left\{(a_{ji},\alpha_{ji})_{n+1,p_i}\right\}}_{\{(b_j,\beta_j)_{1,m}\},\left\{(b_{ji},\beta_{ji})_{m+1,q_i}\right\}}\right]$$

$$= \frac{1}{2\pi\omega}\int_L \theta(s)x^s ds \tag{1.4}$$

where $$\theta(s) = \frac{\prod_{j=1}^m \Gamma(b_j-\beta_j s)\prod_{j=1}^n \Gamma(1-a_j-\alpha_j s)}{\sum_{i=1}^r [\prod_{j=m+1}^{q_i}\Gamma(1-b_{ji}+\beta_{ji}s)\prod_{j=n+1}^{p_i}\Gamma(a_{ji}+\alpha_{ji}s)]}$$

Here $\omega = \sqrt{-1}$, $p_i(i = 1...r)$, $q_i(i = 1...r)$, m , n are integers satisfying $0 \le n \le p_i$; $0 \le m \le q_i$; r is finite. α_j, β_j, α_{ji}, β_{ji} are real and positive; $a_j, , b_j, a_{ji}, b_{ji}$ are complex numbers. L is the Mellin-Barne's type of contour integral which runs from $-\omega\infty$ to $+\omega\infty$ with indentations.

II. Required Results

In this section we are mentioning the results required for the evaluation of the transform and the solution of the boundary value problem.

a) First Result

Hankel transform of x^μ given in Erdélyi[3] is

$$H_\nu\{x^\mu\} = \int_0^\infty (\rho x)^{\frac{1}{2}} J_\nu(\rho x)x^\mu dx$$

Ref
[1] Andrews Larry C,Shivamoggi Bhimsen K(2009)*Integral Transforms for Engineers*.PHI Learning Pvt Ltd,India,pp 274-285

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$$= 2^{(\mu+\frac{1}{2})}\rho^{-\mu-1}\frac{\Gamma(\frac{\mu}{2}+\frac{\nu}{2}+\frac{3}{4})}{\Gamma(\frac{\nu}{2}-\frac{\mu}{2}+\frac{1}{4})} \tag{2.1}$$

$$\text{where } \rho>0, -\Re(\nu)-\tfrac{3}{2}<\Re(\mu)<-\tfrac{1}{2}$$

b) Second Result

The following result is taken from Erdélyi[3]

$$M\left\{e^{-ax}J_\nu(\beta x)\right\} = \int_0^\infty x^{s-1}e^{-ax}J_\nu(\beta x)dx$$

$$= \frac{\beta^\nu\Gamma(s+\nu)}{2^\nu a^{s+\nu}\Gamma(1+\nu)}{}_2F_1\left[\frac{s+\nu}{2},\frac{s+\nu+1}{2};\nu+1;\frac{-\beta^2}{a^2}\right] \tag{2.2}$$

$$\text{where } \Re(\alpha)>|Im(\beta)|, \Re(s)>-\Re(\nu)$$

c) Third Result

It is a well known result from Rainville[5]

$$(a)_n = \frac{\Gamma(a+n)}{\Gamma(a)} \tag{2.3}$$

III. Hankel Transform of I-function of one Variable

For $\rho,\nu,\alpha\in C, \sigma>0, \rho>0, \alpha>0$ satisfying the condition

$$\Re(\rho)+\Re(\nu)+\sigma_{1\le j\le m}^{min}\left[\frac{\Re(b_j)}{\beta_j}\right]>-\frac{3}{2}$$

and

$$\Re(\rho)+\sigma_{1\le j\le n}^{max}\left[\frac{1-\Re(a_j)}{\alpha_j}\right]<-\frac{1}{2}$$

Then there holds the formula

$$H_\nu\left\{\left(\frac{\rho}{x}\right)^{\frac{1}{2}}I_{p_i,q_i:r}^{m,n}\left[\alpha x^\sigma\,\Big|^{\{(a_j,\alpha_j)_{1,n}\},\left\{(a_{ji},\alpha_{ji})_{n+1,p_i}\right\}}_{\{(b_j,\beta_j)_{1,m}\},\left\{(b_{ji},\beta_{ji})_{m+1,p_i}\right\}}\right]\right\}$$

$$= \frac{2^{\frac{1}{2}}}{\rho}I_{p_i+2,q_i:r}^{m,n+1}\left[\alpha\left(\frac{2}{\rho}\right)^\sigma\,\Big|^{(\frac{1}{4}-\frac{\nu}{2},\frac{\sigma}{2}),\{(a_j,\alpha_j)_{1,n}\},\left\{(a_{ji},\alpha_{ji})_{n+1,p_i}\right\},(\frac{1}{4}+\frac{\nu}{2},\frac{\sigma}{2})}_{\{(b_j,\beta_j)_{1,m}\},\left\{(b_{ji},\beta_{ji})_{m+1,p_i}\right\}}\right] \tag{3.1}$$

Proof: Applying the definition of Hankel transform from eq.(1.2) to the left-hand side of eq.(3.1) and expressing the I-function in Mellin-Barne's type of contour integral, we get

$$= \int_0^\infty(\rho x)^{\frac{1}{2}}J_\nu(\rho x)\left\{\frac{1}{2\pi\omega}\int_L\theta(s)\alpha^s x^{\sigma s}ds\right\}dx$$

Changing the order of integration permissible under the conditions mentioned and using the result (2.1), we obtain

$$= \frac{1}{2\pi\omega}\int_L\theta(s)\alpha^s 2^{\sigma s+\frac{1}{2}}\rho^{-\sigma s-1}\frac{\Gamma(\frac{\sigma s}{2}+\frac{\nu}{2}+\frac{3}{4})}{\Gamma(\frac{\nu}{2}-\frac{\sigma s}{2}+\frac{1}{4})}$$

Rearranging the terms and expressing the integral in I-function of one variable, we get the right-hand side of eq.(3.1).

Ref

[3] Erdelyi A, Magnus W, Oberhettinger F,Tricomi FG(1954)*Table of integral transforms Vol I,II*.Mc-Graw-Hill,Newyork

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Substituting $\nu = 0$, we obtain the Hankel transform of order zero as

$$H_0\left\{(\tfrac{\rho}{x})^{\frac{1}{2}} I^{m,n}_{p_i,q_i:r}\left[\alpha x^{\sigma}\,|^{\{(a_j,\alpha_j)_{1,n}\},\left\{(a_{ji},\alpha_{ji})_{n+1,p_i}\right\}}_{\{(b_j,\beta_j)_{1,m}\},\left\{(b_{ji},\beta_{ji})_{,m+1,p_i}\right\}}\right]\right\}$$

$$= \frac{2^{\frac{1}{2}}}{\rho} I^{m,n+1}_{p_i+2,q_i:r}\left[\alpha\left(\frac{2}{\rho}\right)^{\sigma}|^{(\frac{1}{4},\frac{\sigma}{2}),\{(a_j,\alpha_j)_{1,n}\},\left\{(a_{ji},\alpha_{ji})_{n+1,p_i}\right\},(\frac{1}{4},\frac{\sigma}{2})}_{\{(b_j,\beta_j)_{1,m}\},\left\{(b_{ji},\beta_{ji})_{,m+1,p_i}\right\}}\right] \tag{3.2}$$

where $\rho, \alpha \in C, \sigma > 0, \rho > 0, \alpha > 0$ satisfying the conditions

$$\Re(\rho) + \sigma^{min}_{1\le j\le m}\left[\frac{\Re(b_j)}{\beta_j}\right] > -\frac{3}{2} \text{and } \Re(\rho) + \sigma^{max}_{1\le j\le n}\left[\frac{1-\Re(a_j)}{\alpha_j}\right] < -\frac{1}{2}$$

IV. Axisymmetric Dirichlet Potential Problem

Consider the Axisymmetric Dirichlet problem for a half space which is mathematically characterized by

$$u_{xx} + \frac{1}{x}u_x + u_{zz} = 0, 0 < x < \infty, z > 0 \tag{4.1}$$

Boundary conditions are

$u(x,0) = f(x), 0 < x < \infty$

$u(x,z) \to 0$ as $\sqrt{(x^2+z^2)} \to \infty$, $z > 0$

If we apply Hankel transform of order zero to the variable x in (4.1), we obtain the transformed problem as

$$U_{zz} - \rho^2 U = 0, z > 0 \tag{4.2}$$

Boundary conditions are

$U(\rho,0) = F(\rho)$

$U(\rho,z) \to 0$, as $z \to \infty$

where

$$H_0\{u(x,z); x \to \rho\} = U(\rho,z) \tag{4.3}$$

$$H_0\{f(x); \rho\} = F(\rho) \tag{4.4}$$

The solution of (4.2) is

$$U(\rho,z) = F(\rho)e^{-\rho z} \tag{4.5}$$

Integrating eq.(4.5) by means of Hankel inversion formula,we have

$$u(x,z) = H_0^{-1}\left[F(\rho)e^{-\rho z}; \rho \to x\right] = \int_0^{\infty} \rho F(\rho)e^{-\rho z}J_0(\rho x)d\rho \tag{4.6}$$

V. Solution of Axisymmetric Dirichlet Potential Problem

For $\rho, \alpha \in C, \sigma > 0, \rho > 0, \alpha > 0, \Re(z) > |Im(x)|$ satisfying the conditions

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$$\sigma_{1\leq j\leq m}^{min}\left[\frac{\Re(b_j)}{\beta_j}\right]>1 \qquad \text{and} \qquad \sigma_{1\leq j\leq n}^{max}\left[\frac{1-\Re(a_j)}{\alpha_j}\right]<-\frac{1}{2}$$

$$u(x,z)=\frac{2^{\frac{1}{2}}}{z}\sum_{k=0}^{\infty}\frac{1}{(n!)^2}\left(-\frac{x^2}{z^2}\right)^n$$

$$\times I_{p_i+4,q_i+3:r}^{m+3,n+1}\left[\alpha(2z)^{\sigma}\,\Big|_{(\frac{1}{2}+n,\frac{\sigma}{2}),(1+n,\frac{\sigma}{2}),(1,\sigma),\{(b_j,\beta_j)_{1,m}\},\left\{(b_{ji},\beta_{ji}),_{m+1,p_i}\right\}}^{(\frac{1}{4},\frac{\sigma}{2}),\{(a_j,\alpha_j)_{1,n}\},\left\{(a_{ji},\alpha_{ji})_{n+1,p_i}\right\},(\frac{1}{4},\frac{\sigma}{2}),(\frac{1}{2},\frac{\sigma}{2}),(1,\frac{\sigma}{2})}\right] \qquad (5.1)$$

Proof: Substitute

$$f(x)=(\tfrac{\rho}{x})^{\frac{1}{2}}I_{p_i,q_i:r}^{m,n}\left[\alpha x^{\sigma}\,\Big|_{\{(b_j,\beta_j)_{1,m}\},\left\{(b_{ji},\beta_{ji}),_{m+1,p_i}\right\}}^{\{(a_j,\alpha_j)_{1,n}\},\left\{(a_{ji},\alpha_{ji})_{n+1,p_i}\right\}}\right] \text{ in eq. (3.1)}$$

Then the Hankel transform of order zero of $f(x)$ from eq. (3.2) is

$$F(\rho)=\frac{2^{\frac{1}{2}}}{\rho}I_{p_i+2,q_i:r}^{m,n+1}\left[\alpha\left(\frac{2}{\rho}\right)^{\sigma}\,\Big|_{\{(b_j,\beta_j)_{1,m}\},\left\{(b_{ji},\beta_{ji}),_{m+1,p_i}\right\}}^{(\frac{1}{4},\frac{\sigma}{2}),\{(a_j,\alpha_j)_{1,n}\},\left\{(a_{ji},\alpha_{ji})_{n+1,p_i}\right\},(\frac{1}{4},\frac{\sigma}{2})}\right]$$

Substituting the value of $F(\rho)$ in eq. (4.4), we get

$$u(x,z)=\int_0^{\infty}\rho e^{-\rho z}J_0(\rho x)$$

$$\times\frac{2^{\frac{1}{2}}}{\rho}I_{p_i+2,q_i:r}^{m,n+1}\left[\alpha\left(\frac{2}{\rho}\right)^{\sigma}\,\Big|_{\{(b_j,\beta_j)_{1,m}\},\left\{(b_{ji},\beta_{ji}),_{m+1,p_i}\right\}}^{(\frac{1}{4},\frac{\sigma}{2}),\{(a_j,\alpha_j)_{1,n}\},\left\{(a_{ji},\alpha_{ji})_{n+1,p_i}\right\},(\frac{1}{4},\frac{\sigma}{2})}\right]d\rho$$

Expressing the I-function in Mellin-Barne's integral and changing the order of integration permissible under the specified conditions, we have

$$=2^{\frac{1}{2}}\frac{1}{2\pi\omega}\int_L\alpha^s\theta(s)2^{\sigma s}\frac{\Gamma(\frac{3}{4}+\frac{\sigma s}{2})}{\Gamma(\frac{1}{4}-\frac{\sigma s}{2})}\left\{\int_0^{\infty}\rho^{-\sigma s}e^{-\rho z}J_0(\rho x)d\rho\right\}ds$$

Using the result(2.2), we obtain

$$=2^{\frac{1}{2}}\frac{1}{2\pi\omega}\int_L\alpha^s\theta(s)2^{\sigma s}\frac{\Gamma(\frac{3}{4}+\frac{\sigma s}{2})}{\Gamma(\frac{1}{4}-\frac{\sigma s}{2})}\left\{\frac{\Gamma(1-\sigma s)}{z^{(1-\sigma s)}}{}_2F_1\left[\frac{(1-\sigma s)}{2},\frac{(2-\sigma s)}{2};1;-\frac{x^2}{z^2}\right]\right\}ds$$

Expanding ${}_2F_1$and using the result(2.3) then rearranging the terms, we obtain the right-hand side of eq.(5.1)

VI. Special Cases

Many special cases can be found by suitably specializing the parameters. One of the special case of our result is mentioned below.

Substituting $r=1$, I-function of one variable reduces to Fox's H-function of one variable assuming $a_{j1},\alpha_{j1},b_{j1},\beta_{j1}$ as a_j,α_j,b_j,β_j respectively.

For $\alpha\in C,\sigma>0,\alpha>0,\Re(z)>|Im(x)|$ satisfying the conditions

$$\sigma_{1\leq j\leq m}^{min}\left[\frac{\Re(b_j)}{\beta_j}\right]>1 \qquad \text{and} \qquad \sigma_{1\leq j\leq n}^{max}\left[\frac{1-\Re(a_j)}{\alpha_j}\right]<-\frac{1}{2}$$

$$u(x,z)=\frac{2^{\frac{1}{2}}}{z}\sum_{k=0}^{\infty}\frac{1}{(n!)^2}\left(-\frac{x^2}{z^2}\right)^n$$

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$$\times H_{p+4,q+3}^{m+3,n+1}\left[\alpha(2z)^{\sigma}\ \Big|^{(\frac{1}{4},\frac{\sigma}{2}),\{(a_j,\alpha_j)_{1,p}\},(\frac{1}{4},\frac{\sigma}{2}),(\frac{1}{2},\frac{\sigma}{2}),(1,\frac{\sigma}{2})}_{(\frac{1}{2}+n,\frac{\sigma}{2}),(1+n,\frac{\sigma}{2}),(1,\sigma),\{(b_j,\beta_j)_{1,q}\}}\right] \tag{6.1}$$

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Effect of Magnetic Field on Oscillatory Flow Past Parallel Plates in a Rotating System with Heat and Mass Transfer

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Abstract- This communication investigates the effect of magnetic filed on oscillatory flow with the combined effects of fluctuating heat and mass transfer past vertical parallel porous flat plates. It is assumed that vertical channel is rotating with angular velocity Ω. The periodic suction velocity is assumed at the plate and other plate oscillating with periodic free stream velocity. The governing equations are solved by adopting complex variable notations. The analytical expressions for velocity and temperature fields are obtained using perturbation technique. The effects of various parameters on mean primary, mean secondary velocity, mean temperature, mean concentration, transient velocity, transient temperature, transient concentration and rate of heat and mass transfer in terms of amplitude and phase differences have been discussed and shown graphically.

Keywords: *MHD, porous medium, incompressible fluid, natural convection, heat and mass transfer.*

GJSFR-F Classification : *MSC 2010: 00A69*



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Effect of Magnetic Field on Oscillatory Flow Past Parallel Plates in a Rotating System with Heat and Mass Transfer

Pawan Kumar Sharma [α] & Sushil Kumar Saini [σ]

Abstract- This communication investigates the effect of magnetic filed on oscillatory flow with the combined effects of fluctuating heat and mass transfer past vertical parallel porous flat plates. It is assumed that vertical channel is rotating with angular velocity Ω. The periodic suction velocity is assumed at the plate and other plate oscillating with periodic free stream velocity. The governing equations are solved by adopting complex variable notations. The analytical expressions for velocity and temperature fields are obtained using perturbation technique. The effects of various parameters on mean primary, mean secondary velocity, mean temperature, mean concentration, transient velocity, transient temperature, transient concentration and rate of heat and mass transfer in terms of amplitude and phase differences have been discussed and shown graphically.

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I. Introduction

Magnetohydrodynamics (MHD) (magneto fluid dynamics or hydromagnetics) is the study of the dynamics of electrically conducting fluids. Examples of such fluids are include plasmas, liquid metals, and salt water or electrolytes. The word magnetohydrodynamics (MHD) is derived from magneto- meaning magnetic field, hydro- meaning liquid, and -dynamics meaning movement. The fundamental concept behind MHD is that magnetic fields can induce currents in a moving conductive fluid, which in turn creates forces on the fluid and also changes the magnetic field itself. The set of equations which describe MHD are a combination of the Navier-Stokes equations of fluid dynamics and Maxwell's equations of electromagnetism. MHD applies quite well to astrophysics, content of the universe is made up of plasma, including stars, the interplanetary medium (space between the planets), the interstellar medium (space between the stars), the intergalactic medium, nebulae and jets. Sunspots are caused by the Sun's magnetic fields, the solar wind is also governed by MHD. However, magnetohydrodynamic effects transfer the Sun's angular momentum into the outer solar system, slowing its rotation. MHD is related to engineering problems such as plasma confinement, liquid-metal cooling of nuclear reactors, and electromagnetic casting. The working principle involves electrification of the propellant (gas or water) which can then be directed by a magnetic field, pushing the vehicle in

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the opposite direction. An important task in cancer research is developing more precise methods for delivery of medicine to affected areas. One method involves the binding of medicine to biologically compatible magnetic particles (e.g. ferrofluids), which are guided to the target via careful placement of permanent magnets on the external body.

The flow problems of an electrically conducting fluids under the influence of magnetic field have attracted the interest of many authors in view of its applications to geophysics, astrophysics, engineering, and to the boundary layer control in the field of aerodynamics. On the other hand in view of the increasing technical applications using magnetohydrodynamics effect, it is desirable to extend many of the available viscous hydrodynamic solution to include the effects of magnetic field for those cases when the viscous fluid is electrically conducting. Rossow [1], Greenspan and Carrier [2] have studied extensively the hydromagnetic effects on the flow past a plate with or without injection/suction. The hydromagnetic channel flow and temperature field was investigated by Attia and Kotab [3]. Hossain et al. [4] have studied the MHD free convection flow when the surface kept at oscillating surface heat flux.

In view of applications of the flow through porous medium with the effect of magnetic field, attract attention of a number of scholars. Aldoss et al [5], Helmy [6] and Kim [7] studied the magnetohydrodynamic mixed convection from a vertical plate in a porous medium. Unsteady free convection flow with the combined effect of thermal and mass diffusion in the presence of magnetic field and Hall effect is investigated by Takhar et.al [8]. Ahmed et al [9] studied the thermal diffusion effect on a three-dimensional MHD free convection with mass transfer flow from a porous vertical plate and Chamkha [10] also investigates MHD flow of a uniformly stretched vertical permeable surface in the presence of heat generation/absorption and a chemical reaction. The MHD flow between two parallel horizontal porous plate also investigated by Chaudhary et al [11]. Sharma [12] studied the simultaneous thermal and mass diffusion in three dimensional mixed convection flows in the presence of porous medium. Singh et.al [13] and Lai and Kulacki [14] heve been studied the free convective flow past vertical wall. Nield [15] studied convection flow through porous medium with inclined temperature gradient. Kelleher et al. [16] studied the heat transfer response of laminar free convection boundary layers along vertical heated plates to surface temperature oscillations. Sharma et al [17] studied the unsteady free convection oscillatory flow through porous medium with periodic temperature variation. Also the oscillatory Couette flows in a rotating system have been studied by Jana and Datta [18] Muzumder [19], and Ganapathy [20]. Raptis and Peridikis [21] also studied the oscillatory flow through porous medium in the presence of convection.

Therefore the object of the present paper is to investigate the oscillatory flow through rotating porous vertical channel in the presence of magnetic field with fluctuating thermal and mass diffusion assuming periodic suction velocity at the plate and other plate which is also fluctuating with periodic free stream velocity about a non zero constant mean. The analytical solutions for mean primary, mean secondary velocity, transient velocity, transient temperature and concentration are obtained using regular perturbation technique. The effect of various parameters on flow characteristic are discussed and shown graphically.

II. Mathematical Formulation of the Problem

Consider an oscillatory free convective flow of a conducting viscous incompressible fluid through highly porous medium bounded between two infinite vertical porous plates distance d

Ref

1. V. J. Rossow, On flow of electrically conducting fluids over a flat plate in the presence of a transverse magnetic field, N. A. C. A., Rept., (1958), 1358.

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apart. The periodic suction velocity is applied at the stationary plate $z^*=0$ and other plate at $z^* = d$, which is oscillating in its own plane with a velocity U^* about a non zero constant mean velocity U_0. The origin is assumed to be at the plate $z^*=0$ and the channel is oriented vertically upward along the x^*-axis. The channel rotates as a rigid body with uniform angular velocity Ω^* about z^* -axis, which is perpendicular to the vertical plane confined with a viscous fluid occupying the porous region. Since the plates are infinite in extent, all the physical quantities except the pressure, depend only on z^* and t^*. Denoting the velocity components u^*, v^*, w^* in the x^*, y^*, z^* directions, respectively, temperature by T^* and concentration by C^*. The flow in porous medium involves small velocities permitting the neglect of heat due to viscous dissipation in governing equation. A magnetic filed of constant intensity is applied perpendicular to the channel.

The basic equation of magnetofluiddynamics and conventional fluid dynamics are different by only additional force term due to electromagnetic field. The Maxwell's equations have to be satisfied in the entire field. In order to derive the basic equations for the problem under consideration, the following assumptions are made:

1. The flow is steady and laminar and the magnetic field is applied perpendicular to the plate.
2. The fluid under consideration is viscous, incompressible and finitely conducting with constant physical properties.
3. The magnetic Reynolds number is taken to be small enough so that the induced magnetic field is neglected.
4. Hall Effect, electrical and polarization effects are neglected.

The equation expressing the conservation of mass and energy transfer in rotating frame of reference are given by

$$w^* = -w_0 (1+\varepsilon \cos \omega^* t^*), \tag{1}$$

$$\frac{\partial u^*}{\partial t^*} + w^* \frac{\partial u^*}{\partial z^*} - 2\Omega^* v^* = -\frac{1}{\rho}\frac{\partial p^*}{\partial x^*} + g\beta(T^* - T_d^*) + g\beta_c (C^* - C_d^*) + \nu \frac{\partial^2 u^*}{\partial z^{*2}} - \frac{\nu u^*}{k^*} - \frac{(\vec{J}\times\vec{B})}{\rho}, \tag{2}$$

$$\frac{\partial v^*}{\partial t^*} + w^* \frac{\partial v^*}{\partial z^*} + 2\Omega^* u^* = -\frac{1}{\rho}\frac{\partial p^*}{\partial y^*} + \nu \frac{\partial^2 v^*}{\partial z^{*2}} - \frac{\nu v^*}{k^*} - \frac{(\vec{J}\times\vec{B})}{\rho}, \tag{3}$$

where the fourth term on the right hand side of equations (2-3) is the Lorentz force due to magnetic field $\vec{B}$, and is given by

$$\vec{J}\times\vec{B} = \sigma(\vec{v}\times\vec{B})\times\vec{B} \tag{4}$$

Using (4) in equations (2) and (3), we have

$$\frac{\partial u^*}{\partial t^*} + w^* \frac{\partial u^*}{\partial z^*} - 2\Omega^* v^* = -\frac{1}{\rho}\frac{\partial p^*}{\partial x^*} + g\beta(T^* - T_d^*) + g\beta_c (C^* - C_d^*) + \nu \frac{\partial^2 u^*}{\partial z^{*2}} - \frac{\nu u^*}{k^*} - \frac{\sigma B^2}{\rho} u^* \tag{5}$$

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$$\frac{\partial v^*}{\partial t^*} + w^* \frac{\partial v^*}{\partial z^*} + 2\Omega^* u^* = -\frac{1}{\rho}\frac{\partial p^*}{\partial y^*} + \nu \frac{\partial^2 v^*}{\partial z^{*2}} - \frac{\nu v^*}{k^*} - \frac{\sigma B^2}{\rho} v^*, \quad (6)$$

$$\frac{\partial T^*}{\partial t^*} + w^* \frac{\partial T^*}{\partial z^*} = \frac{\kappa}{\rho c_p} \frac{\partial^2 T^*}{\partial z^{*2}}, \quad (7)$$

$$\frac{\partial C^*}{\partial t^*} + w^* \frac{\partial C^*}{\partial z^*} = D \frac{\partial^2 C^*}{\partial z^{*2}}. \quad (8)$$

where g is the acceleration due to gravity, β is the volumetric coefficient of thermal expansion, β_c is the volumetric coefficient of expansion for concentration, T* is the temperature, T_d^* is the temperature in free stream, ν is the kinematic viscosity, Ω^* is the angular velocity, k^* is the permeability, C_p is the specific heat at constant pressure, p* is the pressure, ρ is the density, t* is the time and κ is the thermal conductivity, ω^* frequency of fluctuations.

The boundary conditions of the problem are

$$\left.\begin{aligned} z = 0: u^* = 0, \quad v^* = 0, \quad T^* = T_0^* + \varepsilon (T_0^* - T_d^*)\cos \omega^* t^*, \\ C^* = C_0^* + \varepsilon (C_0^* - C_d^*)\cos \omega^* t^* \\ z = d: u^* = v^* = U^* = U_0 (1 + \varepsilon \cos \omega^* t^2), \; T^* = T_d, C^* = C_d. \end{aligned}\right\} \quad (9)$$

Considering u + iv = U and eliminating the pressure gradient from (5) and (6), we have

$$\left.\begin{aligned} \frac{\partial U^*}{\partial t^*} + w^* \frac{\partial U^*}{\partial z^*} + 2i\Omega^* U^* = g\beta (T^* - T_d^*) \\ + g\beta_c (C^* - C_d^*) + \nu \frac{\partial^2 U^*}{\partial z^{*2}} - \frac{\nu U^*}{k^*} - \frac{\sigma B^2}{\rho} U^*, \end{aligned}\right\} \quad (10)$$

We introduce the following non-dimensional quantities as:

$$z = \frac{z^*}{d}, \; u = \frac{u^*}{U_0}, \; v = \frac{v^*}{U_0}, \; \omega = \frac{d^2 \omega^*}{\nu}, \; \theta = \frac{(T^* - T_d^*)}{(T_0^* - T_d^*)},$$

$$k = \frac{k^*}{d^2}, \quad t = \omega^* t^*, \quad \lambda (\text{Suction parameter}) = \frac{d\, w_0}{\nu},$$

$$\alpha (\textit{Thermal diffusivity}) = \frac{\kappa}{\rho C_p},$$

$$M (\text{Hartmann Number}) = \sqrt{\frac{\sigma B^2 d^2}{\rho \nu U_0}}, \quad Sc (\text{Schmidt Number}) = \frac{\nu}{D},$$

$$Gr (\text{Grashof number}) = \frac{g\beta (T_0^* - T_d^*) d^2}{\nu U_0}, \; Pr (\text{Prandtl number}) = \frac{\nu}{\alpha},$$

$$C = \frac{(C^* - C_d^*)}{(C_0^* - C_d^*)},$$

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Notes

$$\text{Gc (modified Grashof number)} = \frac{g\beta_c (C_0^* - C_d^*) d^2}{\nu U_0}$$

Substituting these non-dimensional quantities in equations (7), (8) and (10), we get

$$\omega \frac{\partial U}{\partial t} - (1+\varepsilon \cos t)\lambda \frac{\partial U}{\partial z} + 2i\,RU = Gr\,\lambda^2 \theta + Gc\,\lambda^2 C + \frac{\partial^2 U}{\partial z^2} - \frac{U}{k} - M^2 U, \quad (11)$$

$$\omega \frac{\partial \theta}{\partial t} - (1+\varepsilon \cos t)\lambda \frac{\partial \theta}{\partial z} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial z^2}, \quad (12)$$

$$\omega \frac{\partial C}{\partial t} - (1+\varepsilon \cos t)\lambda \frac{\partial C}{\partial z} = \frac{1}{Sc}\frac{\partial^2 C}{\partial z^2}, \quad (13)$$

The corresponding boundary conditions (9) become

$$\left.\begin{aligned} z = 0: U = 0, \quad \theta = 1+\varepsilon \cos t, \; C = 1+\varepsilon \cos t \\ z = d: U = 1+\varepsilon \cos t, \quad \theta = 0, \quad C = 0. \end{aligned}\right\} \quad (14)$$

III. Solution of the Problem

In order to solve the problem, we assume the solutions of the following form because amplitude ε (< < 1) of the variation of temperature is very small

$$\left.\begin{aligned} U(z,t) = U_0(z) + \varepsilon U_1(z)\, e^{-it} + ... \\ \theta(z,t) = \theta_0(z) + \varepsilon \theta_1(z)\, e^{-it} + ... \\ C(z,t) = C_0(z) + \varepsilon C_1(z)\, e^{-it} + ... \end{aligned}\right\} \quad (15)$$

Substituting (15) in equations (11), (12) and (13), and equating the coefficient of identical powers of ε and neglecting those of ε^2, ε^3 etc., we get

$$U_0'' + \lambda U_0' - 2iR\,U_0 - \frac{U_0}{k} - M^2 U_0 = -Gr\,\lambda^2 \theta_0 - Gc\,\lambda^2 C_0, \quad (16)$$

$$U_1''' + \lambda U_1' - 2iR\,U_1 + i\omega U_1 - \frac{U_1}{k} - M^2 U_1 = -Gr\,\lambda^2 \theta_1 - Gc\,\lambda^2 C_1 - \lambda U_0', \quad (17)$$

$$\theta_0'' + \lambda Pr\,\theta_0' = 0, \quad (18)$$

$$\theta_1''' + \lambda Pr\,\theta_1' + i\omega\, Pr\,\theta_1 = -\lambda Pr\,\theta_0' \quad (19)$$

$$C_0'' + \lambda Sc\,C_0' = 0, \quad (20)$$

$$C_1''' + \lambda Sc\,C_1' + i\omega\, Sc\,C_1 = -\lambda Sc\,C_0' \quad (21)$$

The corresponding boundary conditions (14) reduce to

$$\left.\begin{aligned} z = 0: \; U_0 = 0, \; U_1 = 0, \; \theta_0 = 1, \; \theta_1 = 1, \; C_0 = 1, \; C_1 = 1 \\ z = d: \; U_0 = 1, \; U_1 = 1, \; \theta_0 = 0, \; \theta_1 = 0, \; C_0 = 0, \; C_1 = 0. \end{aligned}\right\} \quad (22)$$

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Solving equations (16) to (21) under corresponding boundary conditions (22), we get

$$U_0(z) = n_{17}\, e^{n_{11} z} + n_{16}\, e^{n_{12} z} + n_{13}\, e^{-\lambda \Pr z} + n_{14}\, e^{-\lambda Sc z} + n_{15} \tag{23}$$

$$\begin{aligned} U_1(z) = {} & n_{31}\, e^{n_{18} z} + n_{30}\, e^{n_{19} z} + n_{20}\, e^{n_{11} z} + n_{21}\, e^{n_{12} z} + n_{22}\, e^{-\lambda \Pr z} \\ & + n_{23}\, e^{-\lambda Sc z} + n_{24}\, e^{n_2 z} + n_{25}\, e^{n_1 z} + n_{26}\, e^{n_7 z} + n_{27}\, e^{n_6 z} \end{aligned} \tag{24}$$

$$\theta_0(z) = \frac{1}{(1 - e^{-\lambda \Pr})}\left(e^{-\lambda \Pr z} - e^{-\lambda \Pr}\right) \tag{25}$$

$$\theta_1(z) = n_4\, e^{n_2 z} + n_5\, e^{n_1 z} + n_3\, e^{-\lambda \Pr z} \tag{26}$$

$$C_0(z) = \frac{1}{(1 - e^{-\Lambda Sc})}\left(e^{-\lambda Sc z} - e^{-\lambda Sc}\right) \tag{27}$$

$$C_1(z) = n_9\, e^{n_7 z} + n_{10}\, e^{n_6 z} + n_8\, e^{-\lambda Sc z} \tag{28}$$

where

$$n_1 = \frac{1}{2}\left[-\lambda \Pr + \sqrt{\lambda^2 \Pr^2 - 4 i \omega \Pr}\right]$$

$$n_2 = \frac{1}{2}\left[-\lambda \Pr - \sqrt{\lambda^2 \Pr^2 - 4 i \omega \Pr}\right]$$

$$n_3 = \frac{\lambda^2 \Pr}{i(1 - e^{-\lambda \Pr})\omega}$$

$$n_4 = \frac{e^{n_1} - n_3\left(e^{n_1} - e^{-\lambda \Pr}\right)}{\left(e^{n_1} - e^{n_2}\right)}$$

$$n_5 = -\left[\frac{e^{n_2} - n_3\left(e^{n_2} - e^{-\lambda \Pr}\right)}{\left(e^{n_1} - e^{n_2}\right)}\right]$$

$$n_6 = \frac{1}{2}\left[-\lambda Sc + \sqrt{\lambda^2 Sc^2 - 4 i \omega Sc}\right]$$

$$n_7 = \frac{1}{2}\left[-\lambda Sc - \sqrt{\lambda^2 Sc^2 - 4 i \omega Sc}\right]$$

$$n_8 = \frac{\lambda^2 Sc}{i(1 - e^{-\lambda Sc})\omega}$$

$$n_9 = \frac{e^{n_6} - n_8\left(e^{n_6} - e^{-\lambda Sc}\right)}{\left(e^{n_6} - e^{n_7}\right)}$$

$$n_{10} = -\left[\frac{e^{n_7} - n_3\left(e^{n_6} - e^{-\lambda Sc}\right)}{\left(e^{n_6} - e^{n_7}\right)}\right]$$

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$$n_{11} = \frac{1}{2}\left[-\lambda + \sqrt{\lambda^2 + 4(2iR + \frac{1}{k} + M^2)}\right]$$

$$n_{12} = \frac{1}{2}\left[-\lambda - \sqrt{\lambda^2 + 4(2iR + \frac{1}{k} + M^2)}\right]$$

$$n_{13} = -\frac{Gr\,\lambda^2}{(1-e^{-\lambda \Pr})[\lambda^2 \Pr^2 - \lambda^2 \Pr - (2iR + \frac{1}{k} + M^2)]}$$

$$n_{14} = -\frac{Gc\,\lambda^2}{(1-e^{-\lambda Sc})[\lambda^2 Sc^2 - \lambda^2 Sc - (2iR + \frac{1}{k} + M^2)]}$$

$$n_{15} = -\frac{Gr\,\lambda^2\, e^{-\lambda \Pr}}{(1-e^{-\lambda \Pr})\,(2iR + \frac{1}{k} + M^2)} - \frac{Gc\,\lambda^2\, e^{-\lambda Sc}}{(1-e^{-\lambda Sc})\,(2iR + \frac{1}{k} + M^2)}$$

$$n_{16} = \frac{1 + (n_{13} + n_{14} + n_{15})\,e^{n_{11}} - n_{13}\,e^{-\lambda \Pr} - n_{14}\,e^{-\lambda Sc} - n_{15}}{e^{n_{12}} - e^{n_{11}}}$$

$$n_{17} = -n_{16} - n_{13} - n_{14} - n_{15}$$

$$n_{18} = \frac{1}{2}\left[-\lambda + \sqrt{\lambda^2 - 4(i\omega - 2iR - \frac{1}{k} - M^2)}\right]$$

$$n_{19} = \frac{1}{2}\left[-\lambda - \sqrt{\lambda^2 - 4(i\omega - 2iR - \frac{1}{k} - M^2)}\right]$$

$$n_{20} = -\frac{\lambda\, n_{11}\, n_{17}}{n_{11}^2 + \lambda\, n_{11} + (i\omega - 2iR - \frac{1}{k} - M^2)}$$

$$n_{21} = -\frac{\lambda\, n_{12}\, n_{16}}{n_{12}^2 + \lambda\, n_{12} + (i\omega - 2iR - \frac{1}{k} - M^2)}$$

$$n_{22} = \frac{\lambda^2\, n_{13} \Pr}{\lambda^2 \Pr^2 - \lambda^2 \Pr + (i\omega - 2iR - \frac{1}{k} - M^2)} - \frac{\lambda^2\, n_3\, Gr}{\lambda^2 \Pr^2 - \lambda^2 \Pr + (i\omega - 2iR - \frac{1}{k} - M^2)}$$

$$n_{23} = \frac{\lambda^2\, n_{14}\, Sc}{\lambda^2 Sc^2 - \lambda^2 Sc + (i\omega - 2iR - \frac{1}{k} - M^2)} - \frac{\lambda^2\, n_8\, Gc}{\lambda^2 Sc^2 - \lambda^2 Sc + (i\omega - 2iR - \frac{1}{k} - M^2)}$$

$$n_{24} = -\frac{Gr\,\lambda^2\, n_4}{n_2^2 + \lambda\, n_2 + (i\omega - 2iR - \frac{1}{k} - M^2)}$$

$$n_{25} = -\frac{Gr\,\lambda^2\, n_5}{n_1^2 + \lambda\, n_1 + (i\omega - 2iR - \frac{1}{k} - M^2)}$$

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$$n_{26} = -\frac{Gc\,\lambda^2\, n_9}{n_7^2 + \lambda n_7 + (i\omega - 2iR - \frac{1}{k} - M^2)}$$

$$n_{27} = -\frac{Gc\,\lambda^2\, n_{10}}{n_6^2 + \lambda n_6 + (i\omega - 2iR - \frac{1}{k} - M^2)}$$

$$n_{28} = n_{20} + n_{21} + n_{22} + n_{23} + n_{24} + n_{25} + n_{26} + n_{27}$$

$$n_{29} = 1 - n_{20}\, e^{n_{11}} - n_{21} e^{n_{12}} - n_{22} e^{-\lambda \Pr} - n_{23} e^{-\lambda Sc} - n_{24}\, e^{n_2} - n_{25}\, e^{n_1} - n_{26} e^{n_7} - n_{27} e^{n_6}$$

$$n_{30} = \frac{n_{29} + n_{28}\, e^{n_{18}}}{e^{n_{19}} - e^{n_{18}}}, \quad n_{31} = -n_{30} - n_{28}.$$

IV. Discussion and Conclusions

a) Steady Flow

We take $U_0 = u_0 + i\, v_0$ in equation (23) and subsequent comparison of the real and imaginary parts gives the mean primary velocity u_0 and mean secondary velocity v_0. The mean primary velocity is presented in Fig. 1 for fixed values of Gr, Gc and Sc=0.60 (for CO_2) in air (Pr = 0.71). The graph reveals that velocity increases with increasing suction parameter λ and reverse effect is observed for R (rotation parameter) and k (permeability of porous medium). This shows that the porosity and rotation of porous medium exert retarding influence on the primary flow. Fig.2 also shows mean primary velocity for different values of Gr (Grashof Number), Gc(Modified Grashof Number) and Sc(Schmidt Number). It is observed from the figure that the mean primary velocity increases rapidly with increasing either Gr or Gc. The magnitude of velocity is lesser in case of Sc=0.78 (NH_3) than that of Sc=0.60 (CO_2). Furthermore the mean primary velocity increases in the vicinity of the plate. It is interesting to note that if we increase magnetic field parameter M (Hartmann Number) , i.e. medium become conducting then the mean primary velocity become fluctuate sinusoidally.

The mean secondary velocity profiles is shown in Fig. 3 for the fixed values of Gr, Gc Sc and Pr=0.71(air). It is observed that it increases with increasing R while reverse phenomena is observed for λ. It is interesting to note that mean primary velocity increases while mean secondary velocity decreases with R and λ. It is also observed that due to increase in k mean secondary velocity decreases upto middle half of the channel then it increases. Fig.4 also showed the mean secondary velocity for different values of parameters. It is observed that it decreases with increasing either Gr, Gc and Sc. The magnitude is lower in case of NH_3 than that of CO_2. The amount of secondary velocity is much lower for Gc than that of Gr. Also due to increase intensity of magnetic field the mean secondary velocity fluctuating.

The mean temperature and concentration is presented in Fig.9. It is observed that both decreases with increasing λ. The mean temperature and concentration decreases exponentially, the magnitude of concentration is less in case of NH_3 than that of CO_2

Notes

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b) Unsteady Flow

Replacing the unsteady parts

$U_1(z,t)=M_r+iM_i$, $\theta_1(z,t)=T_r+iT_i$, *and* $C_1(z,t)=C_r+iC_i$ respectively in equations (24), (26) and (28) we get

$$[U(z,t),\theta(z,t),C(z,t)]=[U_0(z),\theta_0(z),C_0(z)] + \varepsilon e^{-it}[(M_r+iM_i),(T_r+iT_i),(C_r+iC_i)] \quad (29)$$

The primary, secondary velocity fields, temperature and concentration in terms of the fluctuating components are

$$u(z,t)=u_0+\varepsilon(M_r\cos t+M_i\sin t) \quad (30)$$

$$v(z,t)=v_0+\varepsilon(M_i\cos t-M_r\sin t) \quad (31)$$

$$\theta(z,t)=\theta_0+\varepsilon(T_r\cos t+T_i\sin t) \quad (32)$$

$$C(z,t)=C_0+\varepsilon(C_r\cos t+C_i\sin t) \quad (33)$$

Taking $t=\frac{\pi}{2}$ in equations (30) to (33) we get the expression for transient primary velocity, transient secondary velocity transient temperature and concentration as

$$u\left(z,\frac{\pi}{2}\right)=u_0(z)-\varepsilon M_1(z), \quad (34)$$

$$v\left(z,\frac{\pi}{2}\right)=v_0(z)+\varepsilon M_r(z), \quad (35)$$

$$\theta\left(z,\frac{\pi}{2}\right)=\theta_0(z)-\varepsilon T_i(z) \quad (36)$$

$$C\left(z,\frac{\pi}{2}\right)=C_0(z)-\varepsilon C_i(z) \quad (37)$$

The transient primary velocity component is shown in Fig.5 for fixed values of Pr, Gr, Gc, Sc and ω. It is observed that it decreases with increasing either R and k while transient primary velocity increases with increasing suction parameter λ. It is interesting to note that initially there is decrease in transient primary and than it increasing near the other plate which is fluctuating with free stream velocity. The transient primary velocity shift from positive to negative due to increase in intensity of magnetic field. Fig.6 also shows that due to increase in Gr and Gc the transient primary velocity increases. An increase in ω, the frequency of fluctuation transient velocity behave sinusoidally. The transient primary velocity increases with increasing Sc near the plate upto z<0.6 than it decreases. It is interesting to note that due to increase in M, transient velocity is fluctuating sinusoidally.

The transient secondary velocity profiles is given in Fig.7 for different values of R, k and λ. It is observed that transient secondary velocity increases with increasing either R and k, while it decreasing with increase in λ. The amount of decrease in velocity is much lower due to increase in permeability of the porous medium. Physically this is true because the porous material offers resistance to the flow, so velocity decreases in porous medium. Fig.8 also represented transient secondary velocity for different values of Gr, Gc, Sc and ω. The graph reveals that transient secondary velocity decreases with either Gr and Gc. It is interesting to note that value of

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transient secondary velocity is greater in case of NH_3 than that of CO_2. Furthermore velocity decreases rapidly in the vicinity of the plate with ω than it increases near the other the plate which is fluctuating with free stream velocity. The transient secondary velocity Fig.7-8, become fluctuating with increasing M.

Transient temperature and transient concentration are given in Fig.10. It is observed that transient temperature and concentration both are decreasing with suction parameter. The temperature and concentration are decreasing exponentially with distance apart vertical channel.

Heat Transfer: In the dynamics of viscous fluid one is not much interested to know all the details of the velocity and temperature fields but would certainly like to know quantity of heat exchange between the body and the fluid. Since at the boundary the heat exchanged between the fluid and the body is only due to conduction, according to Fourier's law, we have

$$q_w^* = -\kappa \left(\frac{\partial T^*}{\partial z^*}\right)_{z^*=0} \tag{38}$$

where z* is the direction of the normal to the surface of the body. We can calculate the dimensionless coefficient of heat transfer in terms of Nusselt Number as follows

$$Nu = -\frac{q_w^* d}{\kappa\,(T_0^* - T_d^*)} = \left(\frac{\partial \theta}{\partial z}\right)_{z=0} = \left(\frac{\partial \theta_0}{\partial z}\right)_{z=0} + \varepsilon\, e^{-it} \left(\frac{\partial \theta_1}{\partial z}\right)_{z=0} \tag{39}$$

In terms of the amplitude and phase the rate of heat transfer can be written as:

$$Nu = \left(\frac{\partial \theta_0}{\partial z}\right)_{z=0} + \varepsilon \left|H\right| \cos(\phi - t) \tag{40}$$

where

$$H = H_r + i\,H_i = coefficient\ of\ \varepsilon e^{-it}\ in\ equation\,(40)$$

$$\left|H\right| = \sqrt{Hr^2 + Hi^2}\quad ,\quad \tan\phi = H_i / H_r\,.$$

Mass Transfer: According to Fick's Law the dimensionless coefficient of mass transfer at the plate in terms of Shearwood Number is given as follows

$$Sh = \left(\frac{\partial C}{\partial z}\right)_{z=0} = \left(\frac{\partial C_0}{\partial z}\right)_{z=0} + \varepsilon\, e^{-it} \left(\frac{\partial C_1}{\partial z}\right)_{z=0} \tag{41}$$

In terms of the amplitude and phase the rate of mass transfer can be written as:

$$Sh = \left(\frac{\partial C_0}{\partial z}\right)_{z=0} + \varepsilon \left|S\right| \cos(\varphi - t) \tag{42}$$

where

$$S = S_r + i\,S_i = coefficient\ of\ \varepsilon e^{-it}\ in\ equation\,(42)$$

$$\left|S\right| = \sqrt{Sr^2 + Si^2}\quad ,\quad \tan\varphi = S_i / S_r\,.$$

The amplitudes of rate of heat and mass transfer in presented in Fig.11. The graph reveals that both are increases with increasing ω the frequency of fluctuations upto λ <0.8 than they decreases for higher values of suction parameter. It is also observed that amplitude of mass transfer is higher in case of NH_3 than that of CO_2.

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Fig.12 shows the phases of rate of heat and mass transfer. It is observed from the figure that phases of heat and mass transfer increases with increasing ω. The phase of mass transfer increases with increase in Sc. The magnitude is higher for NH_3 than that of CO_2. It is also observed from the figure that phases of heat and mass transfer increases for $\lambda<0.5$ than they decreases and become negative for small values of ω.

Notes

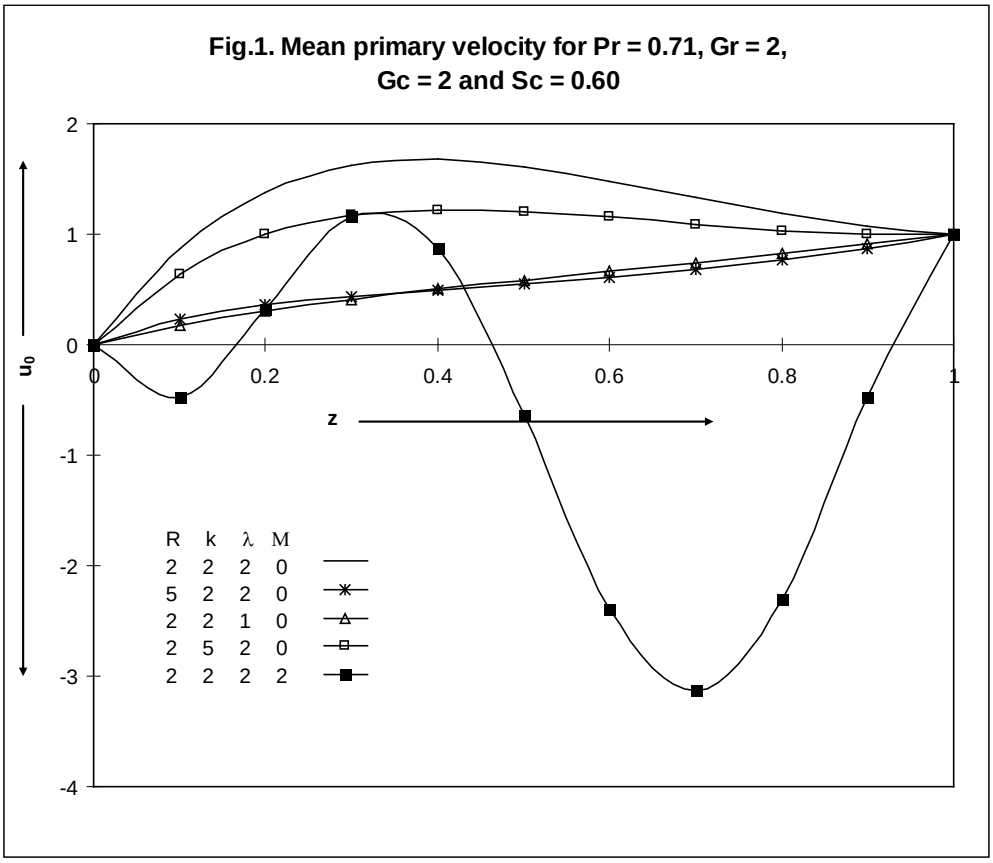
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Fig.1. Mean primary velocity for Pr = 0.71, Gr = 2, Gc = 2 and Sc = 0.60



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Notes

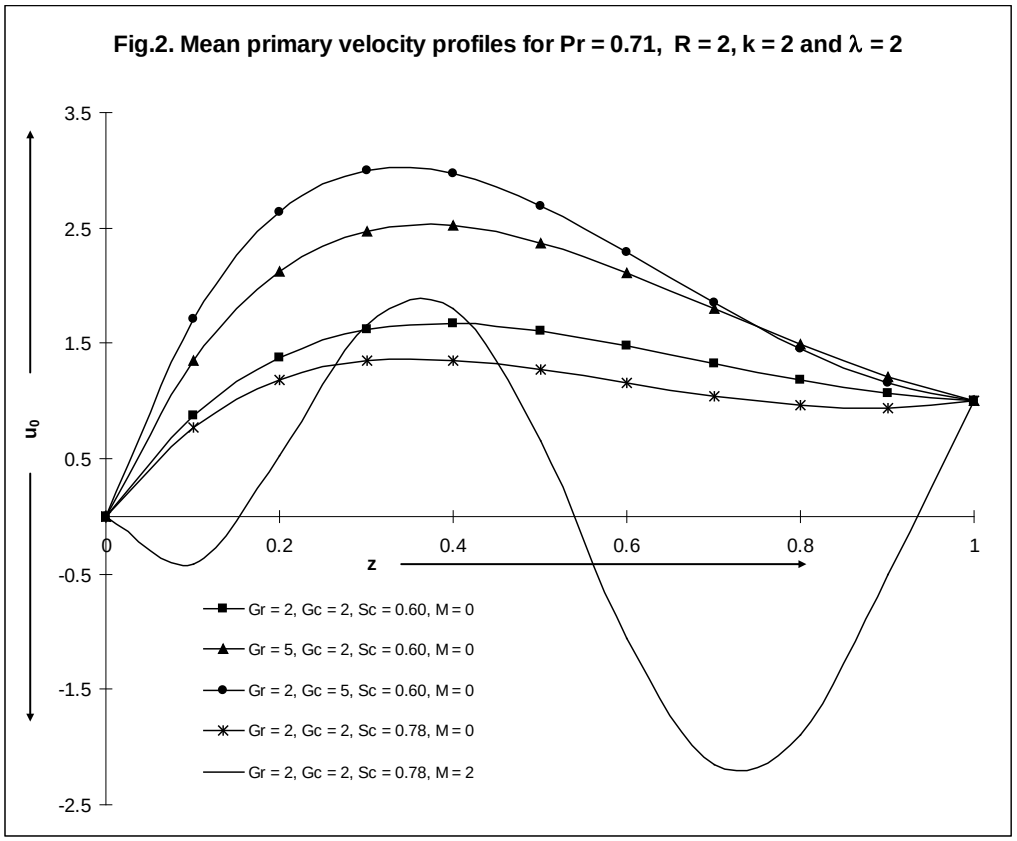


Fig.2. Mean primary velocity profiles for Pr = 0.71, R = 2, k = 2 and λ = 2

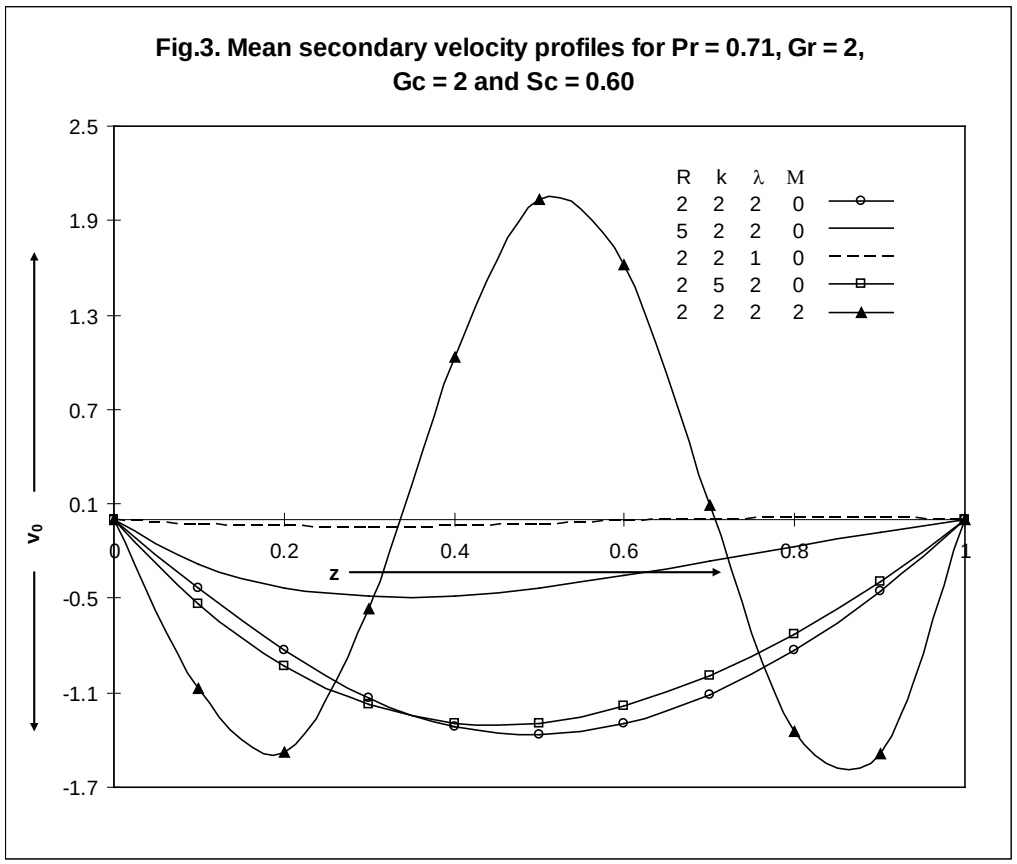


Fig.3. Mean secondary velocity profiles for Pr = 0.71, Gr = 2, Gc = 2 and Sc = 0.60

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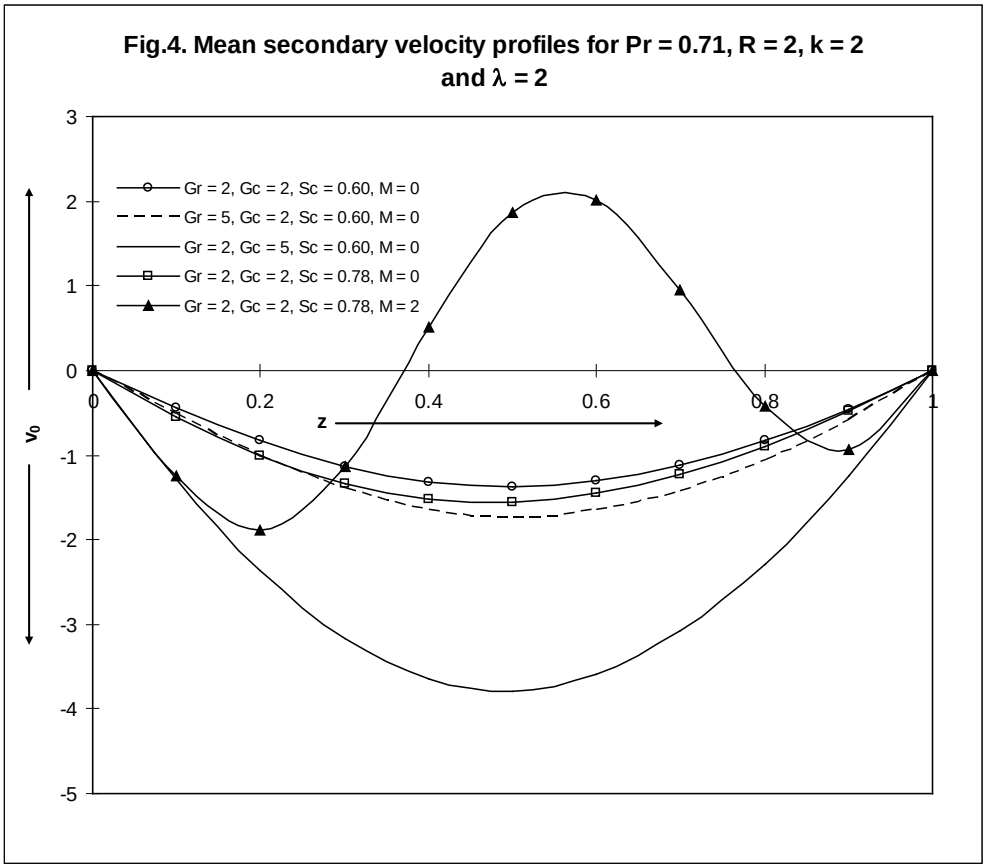


Fig.4. Mean secondary velocity profiles for Pr = 0.71, R = 2, k = 2 and λ = 2

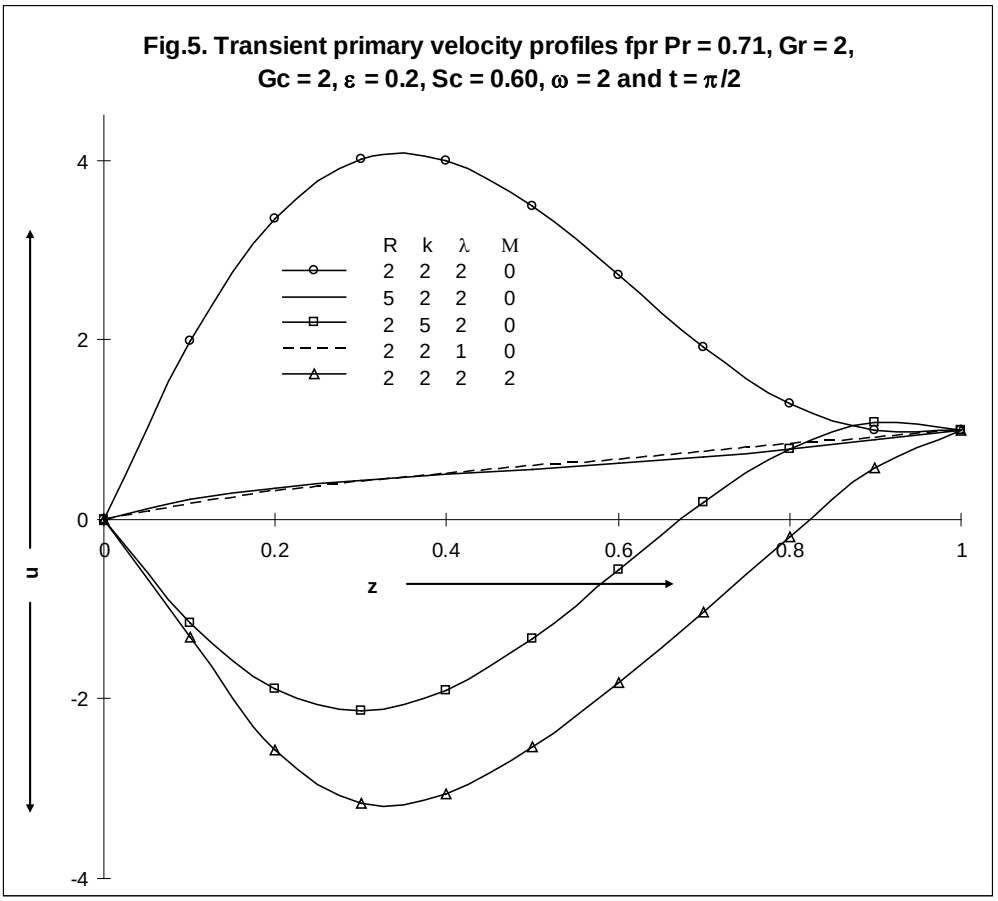


Fig.5. Transient primary velocity profiles fpr Pr = 0.71, Gr = 2, Gc = 2, ε = 0.2, Sc = 0.60, ω = 2 and t = π/2

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Notes

Fig.6. Transient primary velocity profiles for Pr = 0.71, R = 2, k = 2, ε = 0.2, λ = 2 and t = π/2

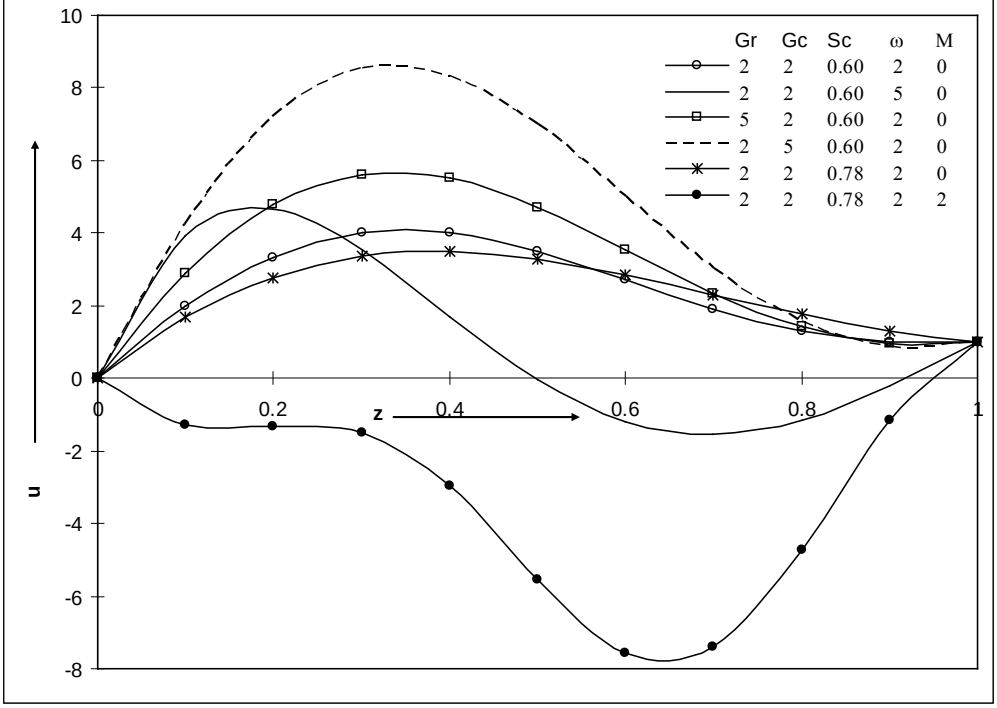
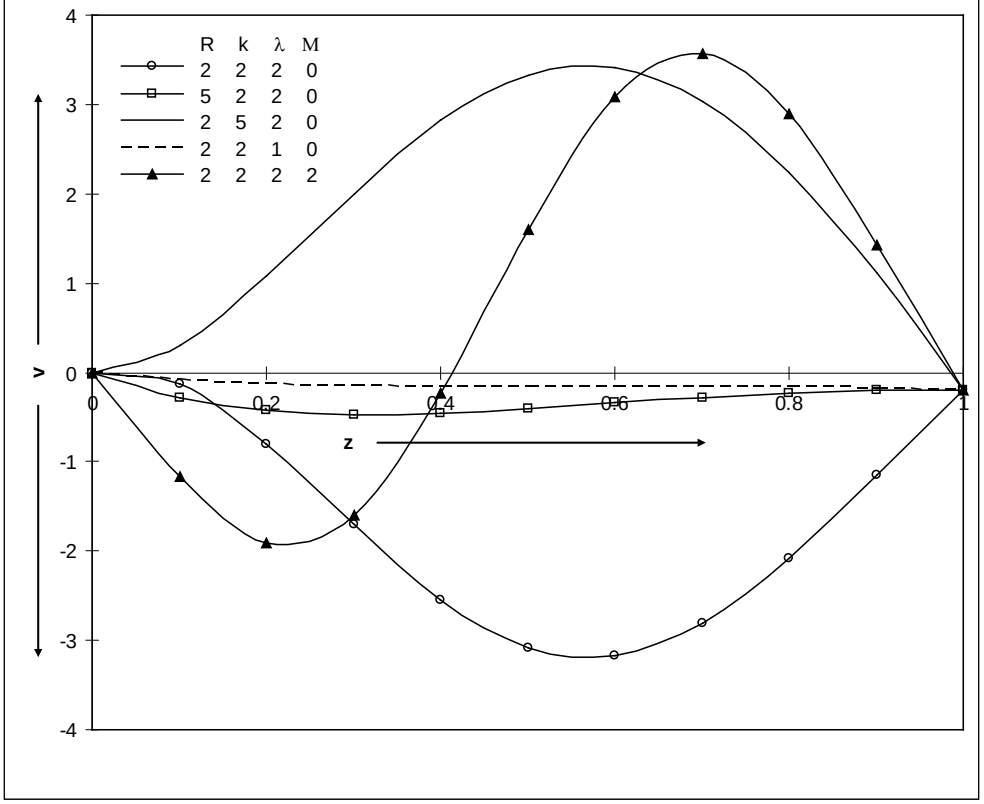


Fig.7. Transient secondary velocity profiles fpr Pr = 0.71, Gr = 2, Gc = 2, ε = 0.2, Sc = 0.60, ω = 2 and t = π/2



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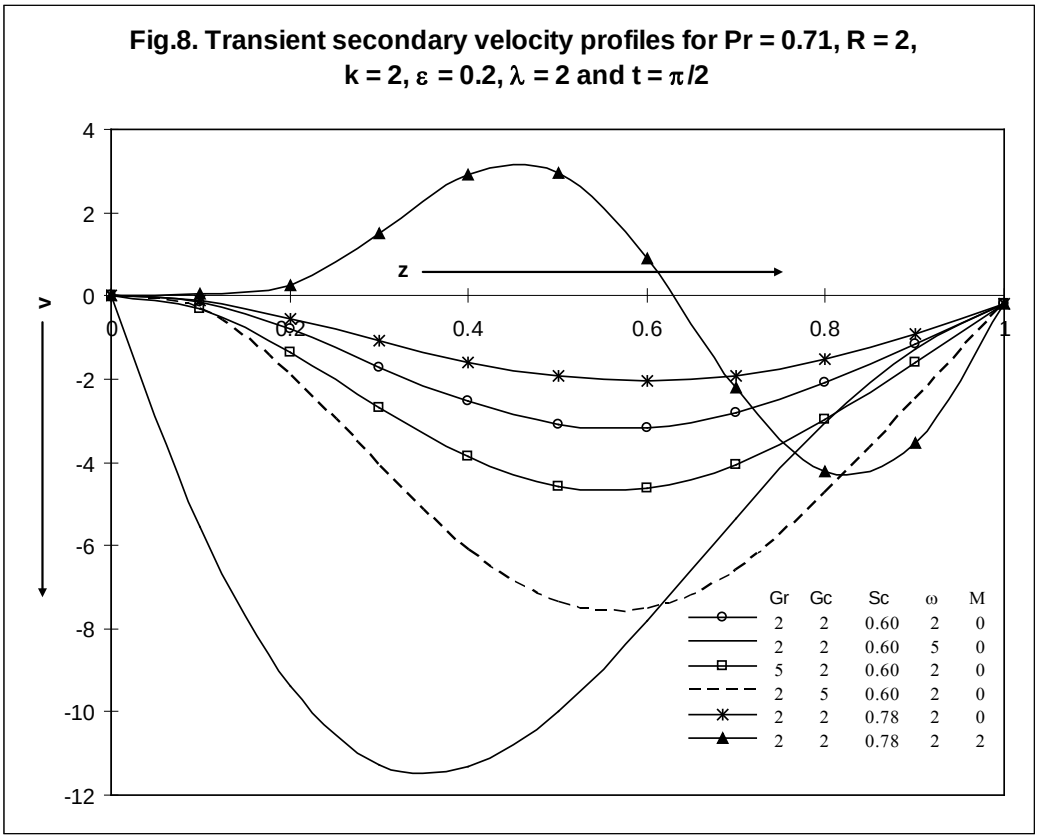


Fig.8. Transient secondary velocity profiles for Pr = 0.71, R = 2, k = 2, ε = 0.2, λ = 2 and t = π/2

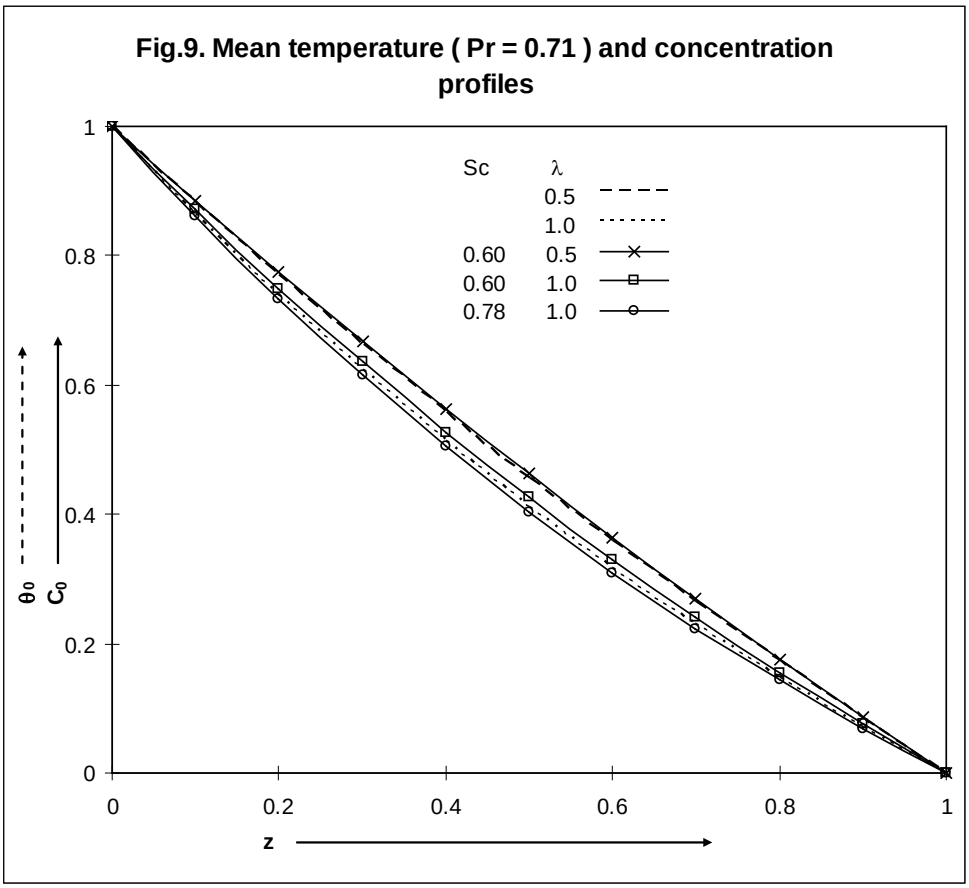
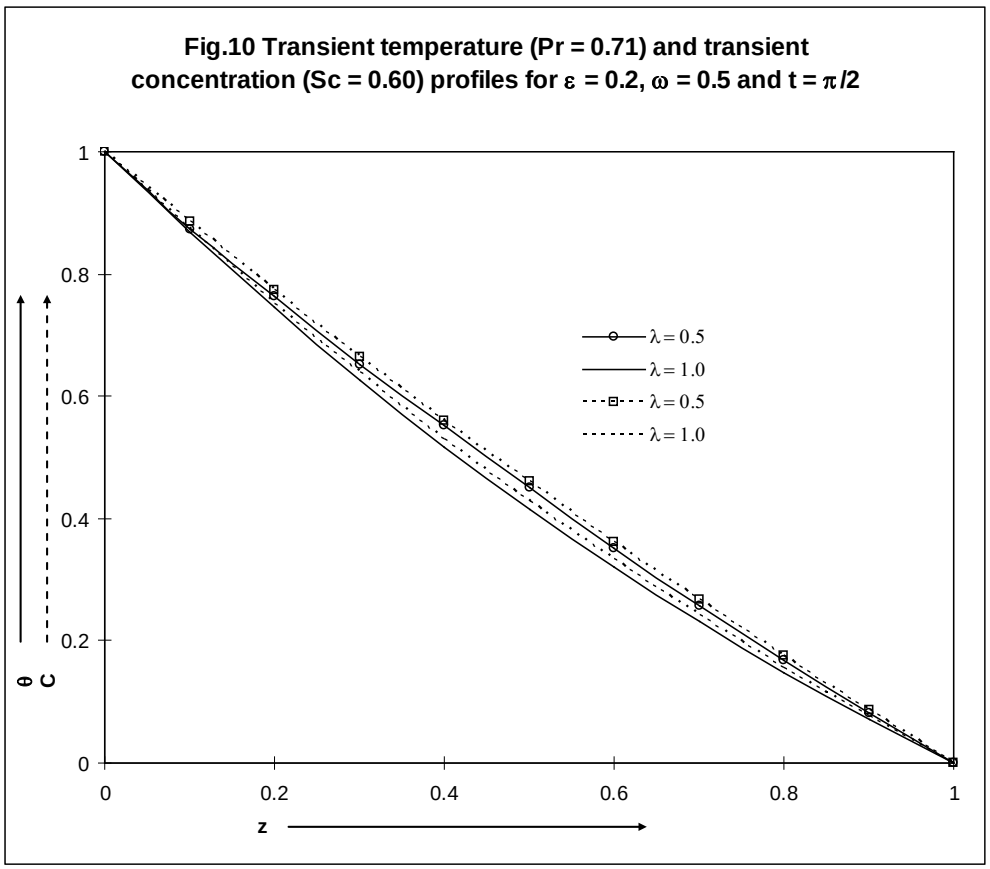
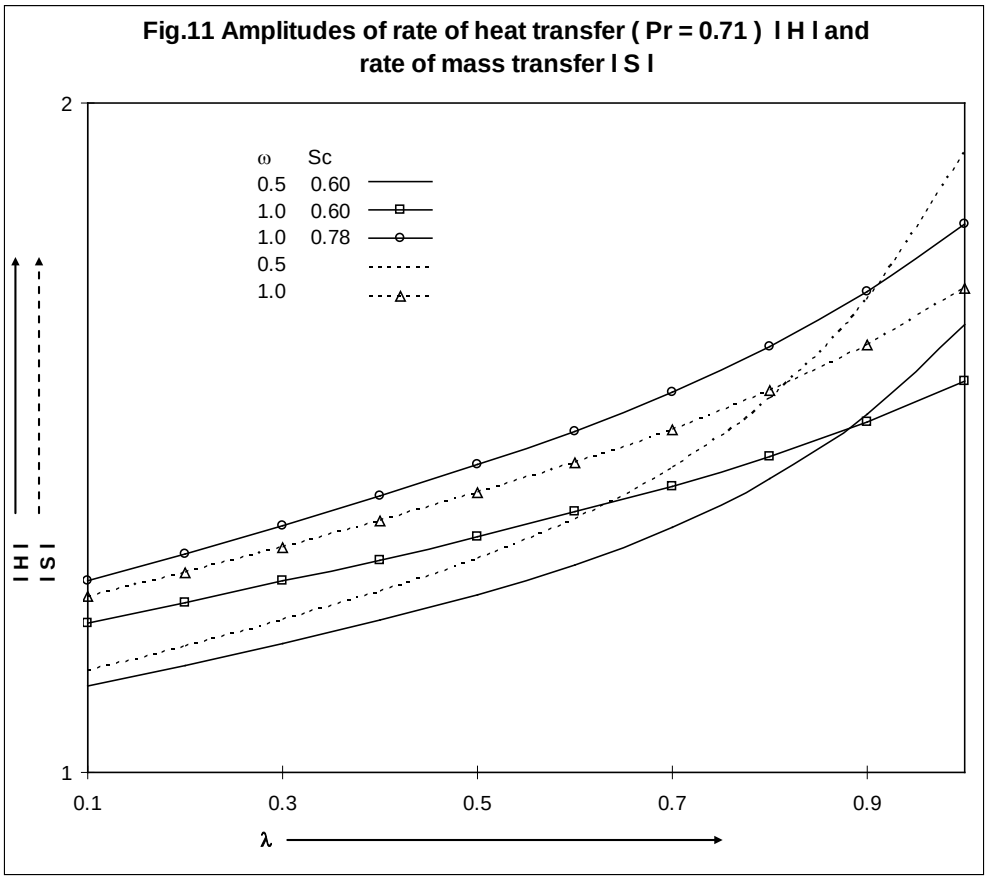


Fig.9. Mean temperature (Pr = 0.71) and concentration profiles

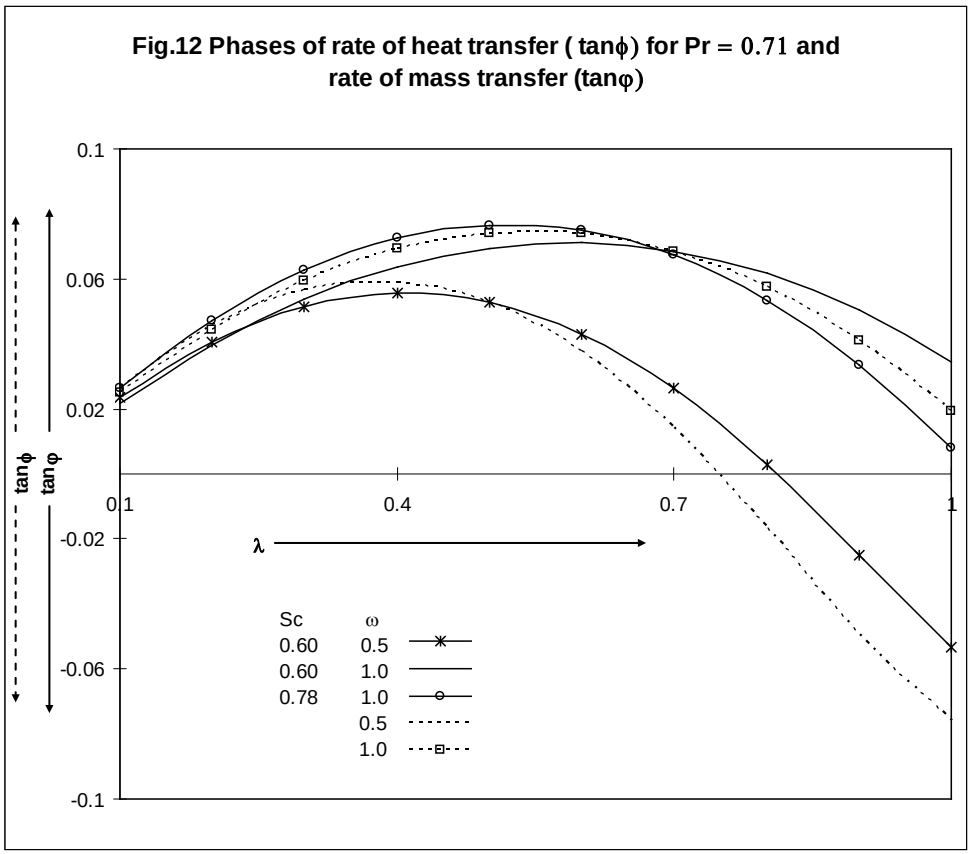
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GEOMATIC Techniques to Study the Ecological Processes of Field Data

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Keywords: *GEOMATIC techniques, spatial pattern analysis, canonical correspondence analysis.*

GJSFR-F Classification : *MSC 2010: 92D40*



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GEOMATIC Techniques to Study the Ecological Processes of Field Data

Imteaz Husain [α], Nasiruddin Khan [σ] & Syed Shahid Shaukat [ρ]

Abstract- Geometic techniques are widely applied in landscape ecology to quantify the spatial patterns exhibited within species and its associated root fungi. Several analyses have been developed and modified to improve the ability to detect and characterize the patterns by the growth of species and population in various scale. Analysis of spatial pattern for disease and pathogen are of interest for the understanding and management plan to control the increase or spread within plant populations due to the numerous shared channels. Mathematical approaches encounter and give quantitative information of infections caused by many soilborne plant pathogens which are generally found in clusters of patches. Reliable approach for the use of spatial data can be established either by the research objective or by the measurement types and sampling designs procedures. We applied several mathematical tools to quantify the quantitative nature of Meloidogyne javanica and its associated soil fungi and soil characteristics in the development of nematode populations in the tomato grown field.

Keywords: GEOMATIC techniques, spatial pattern analysis, canonical correspondence analysis.

I. Introduction

Plant parasitic nematodes are well known parasites worldwide and utilize all parts of the host, and affect virtually every crop within their domain. Root-knot nematode species (*Meloidogyne*), are the most important plant-parasitic nematodes, infecting a wide range of cultivated plants, and are responsible for billions of dollar crop losses annually[1,2]. Since nematodes (saprotrophs or parasites) are more abundant in the rhizosphere, it is not surprising that their natural enemies will also be more numerous in such a habitat. The fungal antagonists of nematodes consist of a wide array of organisms, which include the nematode-trapping or predaceous fungi, endoparasitic fungi, parasites of nematode eggs and fungi, which produce metabolites toxic to nematodes[3]. In view of the long co-evolution of nematodes and fungi, which obviously occurred in the close confines of the soil habitat, it is a great variety of interrelationships have developed between two groups.

There are two important factors whereby environmental forces impact nematode community structure i.e., the community composition of nematode[45], and land management practices[6], mineral fertilizers[7], and toxic substances such as pesticides[8], affect nematode community composition. Most of these factors also influence the survival and proliferation of other micro-inhabitants including fungi in the rhizosphere.

Plant-parasitic nematodes generally have aggregated spatial distribution in an area, such as an agricultural field, with frequency distributions generally described by negative binomial function[9,10]. Taylor's Power Law[11] , which empirically expresses the relation between variance and mean, has also been used to measure the distribution and to develop sampling strategies for nematodes[12,13]. While the soil sampling strategy often required is a systematic sampling over large areas, the studies usually report average values of nematode densities for the entire area field[14]. In the absence of information on spatial variation, site-

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specific management strategies can not be formulated. Vast expanses involved in obtaining and analyzing soil/nematode samples makes it imperative that techniques of assessing spatial variability of root-knot nematode populations be highly efficient. Increased efficiency can be attained through robust sampling designs or by relating root-knot nematode populations to readily measured properties, such as soil pH, soil texture and organic matter that are expected to exhibit some degree of spatial pattern in the field[15].

Mathematical techniques enable us to assess the quantitative relationship of population dynamics of pathogens and has key role for the development of simulation models. It is also used for the design of experimental research[16,17].

Mathematical approach of canonical correspondence analysis (CCA) is a relatively recent technique that exposes the joint structure of populations and the associated environmental data[18]. In terms of a linear model, CCA is based on a weighted multivariate regression of transformed species data on the covariable environmental data set. Our central goal is to determine the causes by which environmental factors within human management practice change the community composition of nematode. In this regard, published data only reported control plot or laboratory experimentation. Assessing the quality of soil at various scales depends on several factors and community composition[19].

Present study applied to check the non-randomness and analyze the spatial pattern of root-knot disease incited by *Meloidogyne javanica* (the root-knot nematode) in tomato grown field, nematode populations (in soil and roots), as well as colonies of the colonization incidence of three soilborne root-infecting fungi, *Fusarium solani*, *Paecilomyces lilacinus* and *Aspergillus* spp. to observe the relationship among nematode population with fungus in the study area.

II. Materials and Methods

A field plot located at Gharo (approximately 50 km from Karachi city) was selected for sampling. The field chosen for the study is a cultivated field where generally tomato (*Lycopersicon esculentum* Mill.) and guar (*Cyamopsis tetragonoloba* L.) are grown in rotation for the last 10 years. For the purpose of sampling, a 14.4 × 14.4 meter square grid matrix was designed in the field. The grid matrix was divided into hundred and forty-four 1.2 m × 1.2m contiguous grids (quadrats). Each grid was sampled for *Meloidogyne javanica* (Treub.) Chitwood and fungi occurs in the soil and the rhizosphere. A number of microfungi were recorded but the analysis was restricted to only the abundant ones in the soil or nematode eggs; these included *Fusarium solani*, *Paecilomyces lilacinus*, *and Aspergillus* spp. Each grid unit arranged three tomato plants in two rows each row separated 60 cm apart and plant-to-plants distances were kept approximately 40 cm. A steel corer of 13 mm diam. × 189 cm deep is used to collect the six replicate cores near to the roots of selected field plot. The replicate soil samples from each grid were pooled to obtain composite samples. We used different mathematical techniques to analyze our data obtained from the field plot. Data matrix is further divided in four classes for the simplicity to compare the results. In First class (C1), we have taken 1x1 matrix grid (1 block), i.e., 12 rows and 12 columns, total 144 grids. In second class (C2), designed by dividing the whole field plot in terms of 2 x 2 matrix grid (4 blocks), i.e., each matrix consists 6 rows and 6 columns, total 36 grids . Third class (C3), designed by dividing whole field plot in terms of 3x3 matrix grid (3 blocks), i.e., 4 rows and 4 columns, total 16 grids. Fourth class (C4), designed by dividing whole field plot into 4 x 4 matrix grid (4 blocks), i.e., 3 rows and 3 columns, total 9 grids (Table-1).

III. Mathematical Techniques

a) Aggregation Indices

To analyze the spatial pattern of nematode population, rhizosphere and egg parasitic fungi and the associated soil characteristics, an index of pattern detection, which is not affected by the changes in density caused by random thinning, is required[20] . Therefore, aggregation indices including Lloyd's[21] index of patchiness (c) and Morisita[22] index (I_δ) were employed because they are insensitive to changes in density. First mean crowding m* was calculated as:

$$m^* = \frac{1}{N}\sum_{i=1}^{Q} X_i\left(X_i - 1\right) \qquad [1]$$

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X_i represents nematodes soil population (or colonization frequency by the fungi) in the *i*th quadrate, whereas, number of quadrats is denoted by Q, with $N = \sum X_i$. While $c = \frac{m}{\lambda}$, such that λ is almost equals to average density in each quadrat. Indices for Lloyd's and Morisita's were determined by the formula:

$$I_d = \frac{Q\sum X_i(X_i - 1)}{N(N-1)} \quad [2]$$

Morisita's index 1indicate the random distribution whereas, greater than 1 indicate for aggregated pattern of root-knot nematode soil population. The variance/mean ratio[23] for each variable (dependent and independent) was applied to measure the non-randomness. Indices for Lloyd's and Morisita's were also calculated in different blocks such as 1 × 1, 2 × 2, 3 × 3 and 4 × 4 simultaneously.

b) Spatial Autocorrelation

We applied spatial autocorrelation method by using Moran's[24] *I* statistics for continuous variables as opposed to binary variables. As this technique is closely associated to the spatial autocorrelation coefficient. Therefore, a strong positive spatial autocorrelations may determine if Moran's *I* gives a relatively larger value. We can depict spatial information by using Moran's *I* test for content of the field sampling by utilizing information on the location of each sample point[25]. Thus, spatial autocorrelation was employed to determine autocorrelation of the nematode, soil-borne fungi and some soil factors among the quadrates. The statistic was computed as follows:

$$I = \frac{\left(\frac{1}{W}\right)\sum_{i=1}^{Q}\sum_{j=1}^{Q}\left[W_{ij}(x_i - x_m)(x_j - x_m)\right]}{\left[\frac{1}{Q}\sum_{i=1}^{Q}(x_i - x_m)^2\right]} \quad [3]$$

X_m represent the mean, W_{ij} is the weight assigned to the join between quadrats *i* and *j*, and *W* is the sum of all weights. There is no trend detected if Moran's *I* statistic is approximately equal to zero in the spatial pattern. Spatial autocorrelation is tested against the null hypothesis that sample *I* do not differ from the expected value:

$$E(I) = \frac{-1}{Q-1} \quad [4]$$

Randomization of null hypothesis is used to check the significance of Moran's *I* whereas, a wide range of pattern detection indices techniques were used in research because they measure slightly different aspects of pattern[23].

c) Canonical Correspondence Analysis

The canonical correspondence analysis (CCA)[26] is employed here to expose the correlation structure between the species data set (nematode and fungi) and the environmental data set (i.e., soil variables). CCA has been widely used in community ecology to unravel the interrelationships between species populations and environmental characteristics. In CCA, nematode and fungal species and associated environmental factors are arranged in multidimensional space, with the restriction that the ordination axes must be linear combinations of the specified environmental variables. CANOCO, version 4.5[27] was used to accomplish canonical correspondence analysis. Data on the abundance of fungal species were log-transformed to dampen the influence of dominant species.

IV. Results

Field plot design for analysis are given in Table-I. Results of Lloyd's index (m^*), Morisita's index (I_δ), variance mean ratio and Moran's index for autocorrelation for number of root-knot nematode eggs root and

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juvenile population density in soil, egg parasitism by *F. solani*, *P. lilacinus* and *Aspergillus* spp are presented in Table-II. Generally, mean crowding (the clumping together of individuals within a quadrat) for nematode eggs per root system increased with the increase in block size. By contrast, mean crowding of nematode juveniles, egg parasitism by fungi and rhizosphere population of fungi decreased if we increased the size of blocks (quadrats). In most cases, variances of Morisita's index were found relatively low as compare to the variance of Lloyd's index. The variance/mean ratios were much higher than unity in every instance, implying aggregation of root-knot nematodes and associated soil-borne fungi. The variances of Lloyd's index for different organisms, in general, increased with increasing of block size. Morisita's index for *F. solani* and *Aspergillus* spp. generally increased with increasing block size but for other organisms it varied. Moran's *I* statistic for spatial autocorrelation was found significantly greater than the expected value *E(I)* for the nematode population in soil ($p<0.05$), and rhizosphere colonization by *F. solani* ($p<0.001$) and *P.lilacinus* ($p<0.01$) and egg-parasitism by fungi ($p<0.001$). In comparison of the results of Lloyd's and Morisita's index, the characteristics of mean crowding values found to be independent of block size (quadrat). In this regard, if the value of Morisita's index varies with the increase or decrease of block size may reflect the scale and pattern intensity. However, index value larger than 1 (expected value for random distribution) in Morisita's index showed significantly at various block sizes with the exception of block size 4×4 for *P. lilacinus* ($p<.001$).

The frequency of eggs produced by *M. javanica* was significantly positively correlated at small block sizes i.e., 1×1 ($p<0.001$) and 2×2 ($p<0.01$). The rhizosphere colonization frequency of the fungi (*F. solani*, *P.lilacinus* and *Aspergillus* spp.) showed negative correlation with number of eggs produced by *M. javanica* intensity at all block sizes. However, total numbers of eggs were found correlated with parasitism by fungi only at smaller block sizes (1 x 1 and 2 x 2).

A perusal of CCA ordination discloses that the quadrats (grid units) are distributed in almost the entire ordination plane but they exhibit clustering at low values of the first CCA axis and low to middle values of the second canonical axis (Figure-1). These quadrats generally belong to the lower left side of the sampled grid. The total variation of species composition data set was 0.193, and sum of all canonical eigenvalues (total explained variation) was 0.174 (Table-3). The Monte Carlo permutation test (499 permutations) showed that a significant relationship between quadrat to quadrat variation in fungal and nematode populations and the environmental (soil) variables ($F=1.815$, $P=0.0220$). The first two CCA axes were also significant based on the Monte Carlo permutation test with 499 permutations. For the first canonical axis the eigenvalues was 0.097 corresponding to second axis was 0.042 ($p<0.01$) (Table-4).

V. Discussion

Our results showed lowest I_δ value or small plot size (4 x 4) and greater values in plot size (3 x 3). In this regard sampling was consider more reliable if I_δ value could be minimized[22], and selection of appropriate plot size for sampling could have significant bearing on sampling efficiency[17]. Lowest I_δ value in block size (4 x 4) elaborate that highest sampling precision can be achieved. The sampling intensity must be greater enough to measure the populations so that the management decisions can be made at an acceptable level of risk[14]. Not surprisingly, the frequency of eggs produced by *M. javanica* was positively correlated ($p<0.001$) with nematode densities in the soil, particularly at larger block sizes *i.e.*, 1×1 and 2×2. However, such relationships were not recorded at smaller block sizes *i.e.*, 3×3 and 4×4. The colonization frequency of the fungi (*F. solani*, *P .lilacinus* and *Aspergillus* spp.) indicates significantly positive correlation with egg masses intensity relatively (3 x 3) or (4 x 4) blocks reflecting their interaction at a small spatial scale. Relationship among root-knot nematode and their associated root-infecting fungi is in the cultivation field is very familiar and often ignored to measure their interaction at different scales. After analyzing two data sets, the spatial pattern of nematode population has found to be direct effects of management practices. Ordination of sites and genera for each dataset were performed separately most of them influence in structuring nematode populations, i.e., soil moisture, and pH[28]. Environmental class variables (i.e., Soil moisture, Organic matter, pH, and calcium carbonate, Nitrate, Phosphorus and Potassium) were coded as nominal variables. Log transformation were applied to normalize the data of nematode abundance prior to

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application of CCA[29]. Responses of nematode populations to indirect effects were estimated using partial CCA[26] ordinations. CCA biplots indicate relative importance of a vector is its length; the angle indicates correlation with other vectors and CCA axes and triplot from a CCA of the root-knot nematode and soil fungi of tomato egg plants are shown in Figure-2. Environmental variables are represented by. Eigenvalues for CCA axes indicate the importance of the axes in explaining relationships in the genera-environment data matrices. The total variation of species composition dataset was 0.193, and sum of all canonical eigenvalues (total explained variation) was 0.174 (i.e., 17.4% of variation in species distribution was explained by the seven (environmental) variables. However, results of canonical correlations and corresponding eigenvalues shows the cumulative percentage of variance of species-environmental relations for first axis was 56.2% and for the first two axes nearly 80.1% are indicating high degree of environmental variables control of nematode and fungi populations . Significance of canonical correlation was verified by Monte Carlo test and showed that a significant relationship between quadrat to quadrat variation in fungal and nematode populations and the environmental (soil) variable at P=0.022. The first two CCA axes were also found to be significant, the first canonical axis the eigenvalues was 0.097 corresponding to second axis was 0.042 ($p < 0.01$). The F-ratio for the first canonical axis (eigenvalues=0.097) was 1.024 (p=0.004) while the F-ratio for all canonical axes (all eigenvalues, trace=0.174) was 1.815 (p=0.022).

VI. Conclusion

Plant parasitic nematodes (*Meloidogyne javanica*) largely damaged vegetation of cultivation field used in traditional method to design the plot. However, our mathematical technique to design the field in terms of matrix model in various block sizes (i.e., 1 x 1, 2 x 2, 3 x 3 and 4 x 4) before the vegetation of crops give more reliable results in the prevention of root-knot nematode disease. Moreover, our study also suggested that in small block sizes, disease frequency of root-knot nematode in tomato plants found significantly low, at the same time nematode were controlled by their root infected fungi (*Paecilomyces lilacinus*) as a biocontrol in small blocks.

Table 1 : Arrangements of field plot of the study area, data were arranged in four classes before the analyses.

Class 1 (C1)	Class 2 (C2)	Class 3 (C3)	Class 4 (C4)
1 x 1	2 x 2	3 x 3	4 x 4
144 grids	36 grids	16 grids	9 grids
12R x 12C	6R x 6C	4R x 4C	3R x 3C

Table 2 : Jackknife estimates of Lloyd's index, Morisita's index and Moran's index, variance-mean ratio (V:M) with their autocorrelation for nematode and fungi in soil population.

Variables	Blocks	Mean	V:M	Lloyd's index		Morisita's index		Moran's index	
				value	variance	value	variance	I	P(I = E(I))
No. of eggs	1 x 1	74311	30527	104857	3.2	1.410	0.0030	0.005	n.s.
	2 x 2	-	43874	119349	36.2	1..594	0.030	-	-
	3 x 3	-	30581	145894	58.3	1..275	0.015	-	-
	4 x 4	-	29610	166702	111.9	1.234	0.016	-	-
Nematode soil population	1 x 1	4313	2266	6563.2	5570	1.521	2.97	0.014	<0.05
	2 x 2	-	1846	6154.3	2871	1.411	7.54	-	-
	3 x 3	-	2030	5444.0	1096	1.549	3.28	-	-
	4 x 4	-	1415	5117.0	6660	1.325	1.97	-	-
Fusarium solani	1 x 1	27.6	95.02	122.64	299.7	4.38	0.357	0.051	<0.001
	2 x 2	-	74.28	97.32	425.1	4.52	0.683	-	-

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	3 x 3	-	72.67	109.39	3118	6.80	5.157	-	-
	4 x 4	-	29.38	50.43	772.3	6.10	4.105	-	-
Paecilomyces lilacinus	1 x 1	4.08	8.76	11.91	1.73	2.908	0.037	0.031	<0.01
	2 x 2	-	7.09	9.84	11.5	3.102	0.465	-	-
	3 x 3	-	1.383	2..25	1.85	1.50	0.550	-	-
	4 x 4	-	0.252	0.607	0.09	0.483	0.043	-	-
Aspergillus niger	1 x 1	27.6	95.02	122.64	299	4.388	0.357	0.007	n.s.
	2 x 2	-	74.28	97.32	425	4.523	0.683	-	-
	3 x 3	-	17.45	72.67	109	3118	6.80	-	-
	4 x 4	-	29.38	50.43	772	6.10	4.105	-	-
Egg parasitism	1 x 1	10.9	4.68	14.618	0.91	1.334	2.17	0.039	<0.001
	2 x 2	-	3.20	11.668	1.53	1.225	3.54	-	-
	3 x 3	-	2.04	8.3210	1.55	1.133	7.12	-	-
	4 x 4	-	1.39	6.8360	1.29	1.0534	4.08	-	-

Table 3 : Results of canonical correspondence analysis. Eigenvalues, species-environmental correlations, cumulative percentage variance of species data and cumulative percentage variance of species-environment relations.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.097	0.042	0.018	0.016	0.193
Species-environmental correlation	1.000	0.999	0.988	0.997	
Cumulative percentage variance of species data	50.6	72.1	81.3	89.8	
Cumulative percentage variance of species-environmental relation	56.2	80.1	90.3	99.7	
Sum of all Eigenvalues	0.193				
Sum of all canonical eigenvalues	0.174				

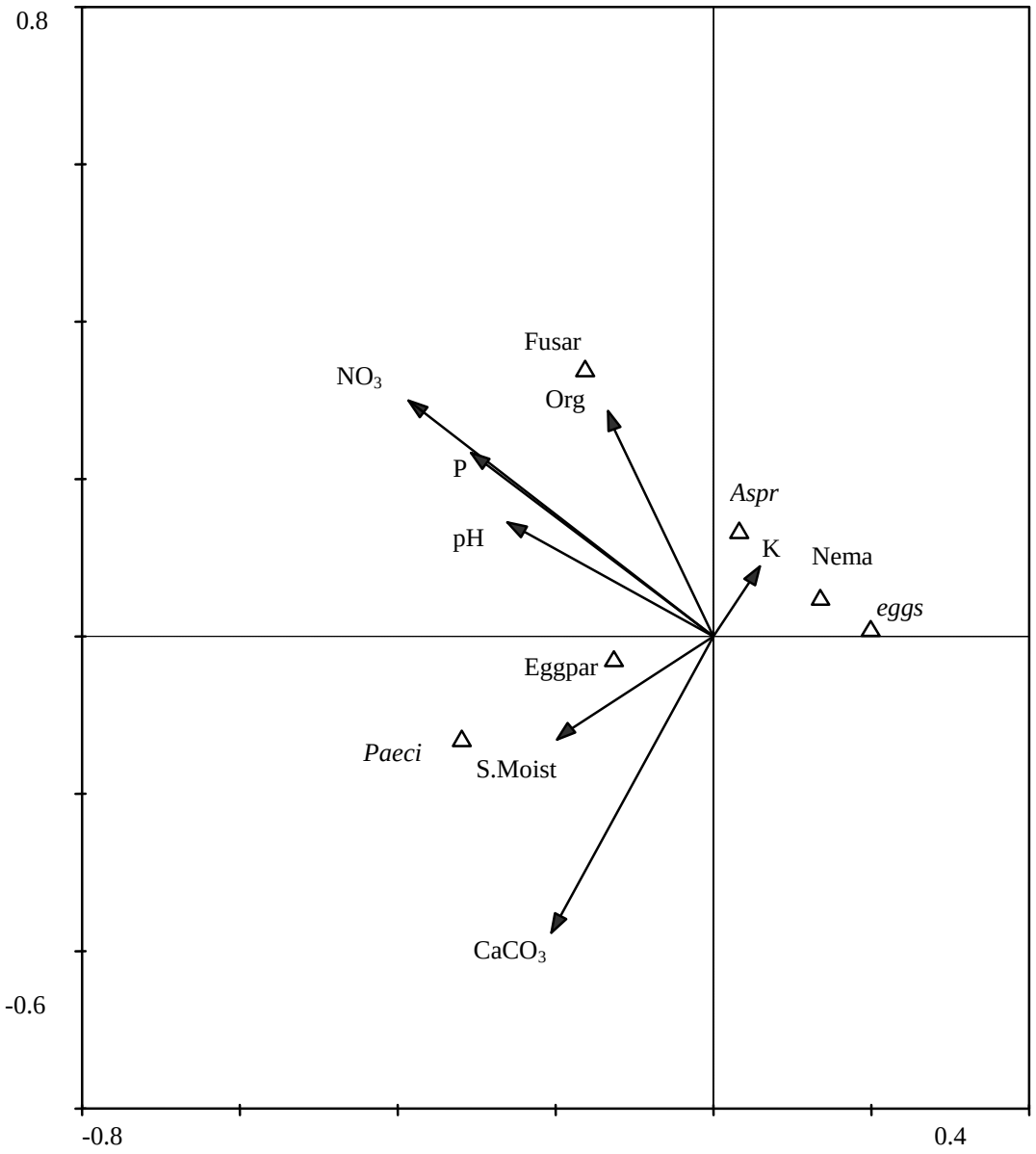
Table 4 : Monte Carlo permutation test, test for significance of first canonical axis.

Eigenvalues	0.097
F-ratio	1.024
P-value	0.004
Trace	0.174
F-ratio	1.815
P-value	0.022

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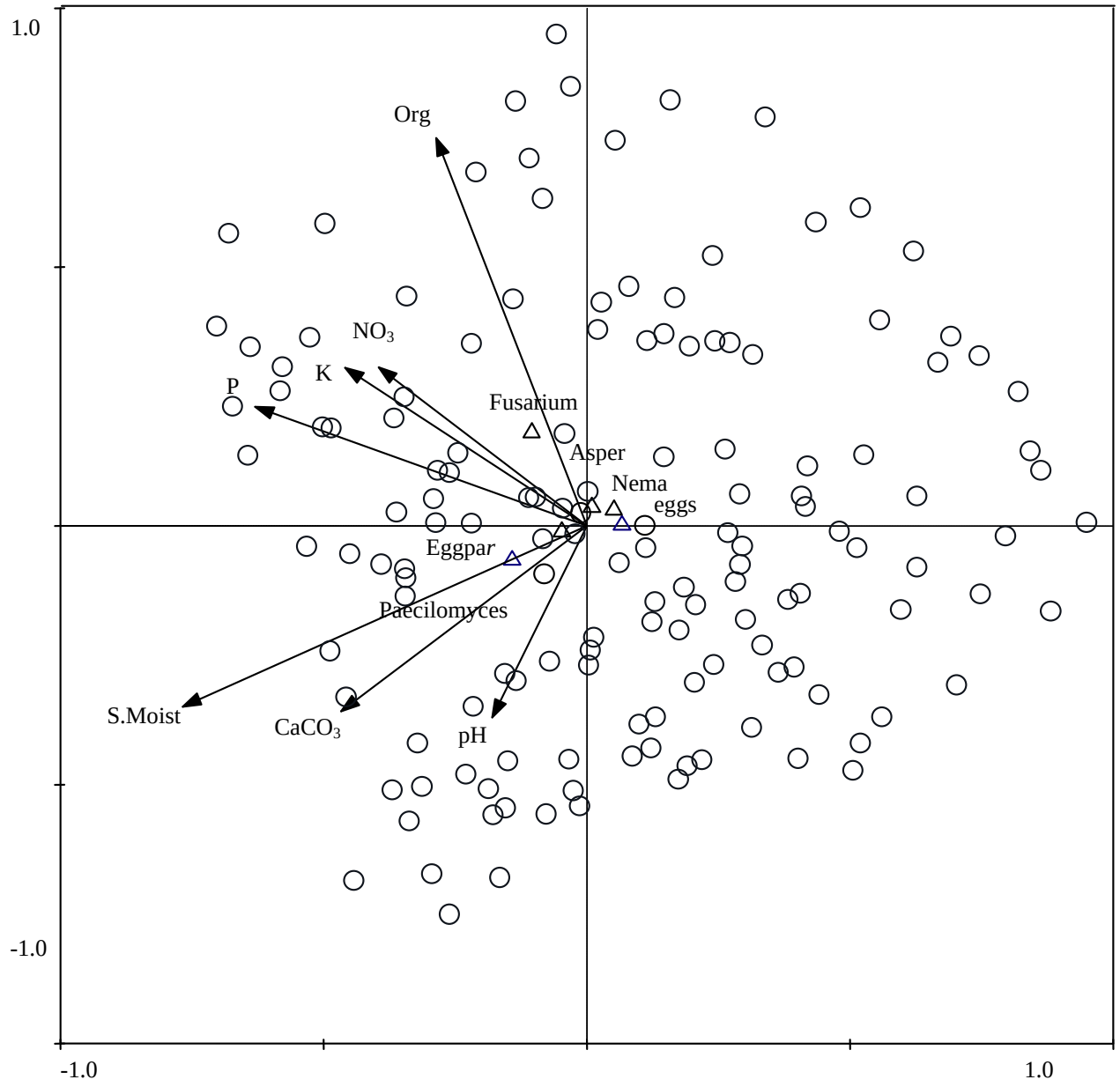
Figure 1 : CCA-ordination diagram of the sampling plots with biological (Δ) and environmental variables (arrows); first axis is horizontal, second axis vertical. The biological variables including root-knot nematode and fungi. The fungi are: A. spp. = Aspergillus spp, Paeci = Paecilomyces lilacinus, Fusar = Fusarium solani. And nema = nematode soil population, eggs = number of eggs, eggpar = egg parasitism.



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Figure 2 : Triplot from a CCA of the root-knot nematode and soil fungi of tomato egg plants. Environmental variables are represented by arrows, samples (quadrats) by small open circles, and species by triangle (Δ). The species are listed by the initial letters of the genus and the specific epithet, they include: A. fumig. = Aspergillus spp., Paeci = Paecilomyces lilacinus, Fusar = Fusarium solani. And nema = nematode soil population, eggs = number of eggs, eggpar = egg parasitism.



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An Amazing Result Involving Contiguous Relation : A Comutational Approach

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Abstract- The main aim of the present paper is to evaluate an amazing summation formula involving recurrence relation of Gamma function and contiguous relation.

Keywords: *gauss second summation theorem, recurrence relation, prudnikov.*

GJSFR-F Classification : *MSC 2010: 33C05, 33C20, 33D15, 33D50, 33D60*



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Notes

An Amazing Result Involving Contiguous Relation : A Comutational Approach

Salahuddin [α] & Vinesh Kumar [σ]

Abstract- The main aim of the present paper is to evaluate an amazing summation formula involving recurrence relation of Gamma function and contiguous relation.

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I. Introduction

Generalized Gaussian Hypergeometric function of one variable is defined by

$$ {}_AF_B\left[\begin{array}{c} a_1, a_2, \cdots, a_A \\ \\ b_1, b_2, \cdots, b_B \end{array} ; \; z \right] = \sum_{k=0}^{\infty} \frac{(a_1)_k (a_2)_k \cdots (a_A)_k z^k}{(b_1)_k (b_2)_k \cdots (b_B)_k k!} \tag{1} $$

where the parameters $b_1, b_2, \cdots, b_B$ are neither zero nor negative integers and $A,\ B$ are non-negative integers and $\mid z \mid = 1$

Contiguous Relation is defined by

[Andrews p.363(9.16), E. D. p.51(10)]

$$ (a-b)\ {}_2F_1\left[\begin{array}{c} a,\ b \\ c \end{array} ; \; z \right] = a\ {}_2F_1\left[\begin{array}{c} a+1,\ b \\ c \end{array} ; \; z \right] - b\ {}_2F_1\left[\begin{array}{c} a,\ b+1 \\ c \end{array} ; \; z \right] \tag{2} $$

Gauss second summation theorem is defined by [Prudnikov., 491(7.3.7.5)]

$$ {}_2F_1\left[\begin{array}{c} a,\ b \\ \frac{a+b+1}{2} \end{array} ; \; \frac{1}{2} \right] = \frac{\Gamma(\frac{a+b+1}{2})\ \Gamma(\frac{1}{2})}{\Gamma(\frac{a+1}{2})\ \Gamma(\frac{b+1}{2})} \tag{3} $$

$$ = \frac{2^{(b-1)}\ \Gamma(\frac{b}{2})\ \Gamma(\frac{a+b+1}{2})}{\Gamma(b)\ \Gamma(\frac{a+1}{2})} \tag{4} $$

In a monograph of Prudnikov et al., a summation theorem is given in the form [Prudnikov., p.491(7.3.7.8)]

$$ {}_2F_1\left[\begin{array}{c} a,\ b \\ \frac{a+b-1}{2} \end{array} ; \; \frac{1}{2} \right] = \sqrt{\pi} \left[\frac{\Gamma(\frac{a+b+1}{2})}{\Gamma(\frac{a+1}{2})\ \Gamma(\frac{b+1}{2})} + \frac{2\ \Gamma(\frac{a+b-1}{2})}{\Gamma(a)\ \Gamma(b)} \right] \tag{5} $$

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Now using Legendre's duplication formula and Recurrence relation for Gamma function, the above theorem can be written in the form

$$ {}_2F_1\left[\begin{array}{c} a,\ b \\ \frac{a+b-1}{2} \end{array};\ \frac{1}{2}\right] = \frac{2^{(b-1)}\ \Gamma(\frac{a+b-1}{2})}{\Gamma(b)}\left[\frac{\Gamma(\frac{b}{2})}{\Gamma(\frac{a-1}{2})} + \frac{2^{(a-b+1)}\ \Gamma(\frac{a}{2})\ \Gamma(\frac{a+1}{2})}{\{\Gamma(a)\}^2} + \frac{\Gamma(\frac{b+2}{2})}{\Gamma(\frac{a+1}{2})}\right] \tag{6} $$

Recurrence relation is defined by

$$ \Gamma(\zeta+1) = \zeta\ \Gamma(\zeta) \tag{7} $$

II. Main Summation Formula

$$ {}_2F_1\left[\begin{array}{c} a,\ \ b \\ \frac{a+b+49}{2} \end{array};\ \frac{1}{2}\right] = \frac{2^b\ \Gamma(\frac{a+b+49}{2})}{(a-b)\ \Gamma(b)\Big[\prod_{\mu=1}^{24}\{a-b-(2\mu-1)\}\Big]\Big[\prod_{\xi=1}^{24}\{a-b+(2\xi-1)\}\Big]} $$

$$ \Big[\frac{\Gamma(\frac{b}{2})}{\Gamma(\frac{a+1}{2})}\Big\{8388608(a^25+a^24(-576+1127b)+4a^{23}(39169-51744b+48363b^2)+92a^{22}(-290928 $$

$$ +634207b-221088b^2+131271b^3)+3542a^{21}(909563-1563264b+1548462b^2-243648b^3 $$

$$ +103071b^4)+3542a^{20}(-82032288+188926633b-99710688b^2+61109118b^3-5432448b^4+1740081b^5) $$

$$ +92a^{19}(221572333763-429292237920b+438974519095b^2-111905902080b^3+48021637825b^4 $$

$$ -27284470008b^5+6861719 41b^6)+1748a^{18}(-652191333552+15528365381 41b-997765722240b^2 $$

$$ +621099121475b^3-93000114480b^4+29813967827b^5-1169334432b^6+236070989b^7) $$

$$ +437a^{17}(118237765837763-245960503305216b+256017026954220b^2-82688287167360b^3 $$

$$ +355774249280 10b^4-34892939450 88b^5+8676948708 12b^6-247230708 48b^7+40561288 11b^8) $$

$$ +437a^{16}(-4391592874255488+106790203701803 65b-7723439928047424b^2+48319865951643 16b^3 $$

$$ -939198292845120b^4+2983356311115 18b^5-205124646061 44b^6+4042994679612b^7-865307479 68b^8 $$

$$ +115674784 61b^9)+1288a^{15}(45681097143081937-99574723999503648b+1045016595425153 43b^2 $$

$$ -389850883775930 88b^3+166613208124536 58b^4-215336310017875 2b^5+523951164774702b^6 $$

$$ -263759847275 52b^7+4156630669317b^8-67988444832b^9+7318200659b^{10}) $$

$$ +1288a^{14}(-1160835982753925712+2858915589700984289b-2236018737076611360b^2 $$

$$ +139373830824965 0165b^3-3177521852599 53120b^4+9900620790652 4274b^5-9037635481929600b^6 $$

$$ +171499371279789 0b^7-647236750298 40b^8+8093019369325b^9-1003638947 52b^{10}+826861632 9b^{11}) $$

$$ +4a^{13}(7885248558387029118799-1774004620025907083 9424b+1862142071806050775 2818b^2 $$

$$ -764051053258276434 3360b^3+3212288577782897155725b^4-4906059343145696762 88b^5 $$

$$ +115216473790726873964b^6-7683233847037257600b^7+1135210887503614425b^8 $$

$$ -320039740076 17920b^9+3027437157819074b^{10}-259303808077 44b^{11}+121548660036 3b^{12}) $$

$$ -4a^{12}(1379711124013245068802 24-3417457558477690912595 81b+2818055233127103092235 84b^2 $$

$$ -1734044138773073335490 10b^3+4382788825476386712441 6b^4-1321746023798862111786 7b^5 $$

$$ +1422491466706905381696b^6-2537122333996822750 36b^7+1239565195762825276 8b^8 $$

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$$-136537559750122230 7b^9+26275970193336864b^{10}-14010508880184 18b^{11}+12154866003 63b^{13})$$
$$-8a^{11}(-99796525552155630163 0937+22908803608053708962084 16b$$
$$-2384783868725789458101993b^2+1041281209707578516441856b^3-4251071255373456297025 97b^4$$
$$+7182452187364449275280 0b^5-1589724846392451112043 7b^6+1221363446491517032704b^7$$
$$-1593642889524313497 87b^8+5235987688270186848b^9-321328557128862283b^{10}$$
$$+7005254440092 09b^{12}-129651904038 72b^{13}+133124722896 9b^{14})$$
$$-88a^{10}(1078858323154473624051792-2668043597373206882428487b$$
$$+22734484231685553621006 72b^2-1363876306485811724341981b^3+3662498492805616459238888b^4$$
$$-1044191221641681174542 39b^5+1214933565445446893155 2b^6-1918719572514798578525b^7$$
$$+9722301194131572446 4b^8-6964630094652459229b^9+292116870117147 53b^{11}$$
$$-119436228151531 2b^{12}+13761077990086 7b^{13}-146896245955 2b^{14}+10711184600 9b^{15})$$
$$-7a^9(-131435064277092371288499193+3044705324899863378209126 40b$$
$$-3106772642136253036388782 80b^2+1401117841930904892188213 76b^3$$
$$-5427455425066842637295 0732b^4+9523746494510523997822464b^5$$
$$-1871972045189388236407 768b^6+1399759836350631784005 12b^7-1190875279984040861181 4b^8$$
$$+8755534976134520173 6b^{10}-59839859294516421 12b^{11}+78021462714355560 4b^{12}$$
$$-182879851472102 40b^{13}+14891155639558 00b^{14}-12509873849088b^{15}+722141155351b^{16})$$
$$-7a^8(1025362604429196125260479168-2506679259033952138613891519b$$
$$+2159784906066357430182552960b^2-1235115440333777196206435368b^3$$
$$+3350471374498566698187395712b^4-8511830124772857828221562 0b^5$$
$$+9261191686825417130273664b^6-9563264150266913438766 96b^7+1190875279984040861181 4b^9$$
$$-1222232150119397678976b^{10}+1821306159456358283 28b^{11}-7083229690073287296b^{12}$$
$$+6486919357163511 00b^{13}-11909156205490560b^{14}+764820043154328b^{15}-54019909802 88b^{16}$$
$$+253218327201b^{17})-4a^7(-1107990220845419349227262 3069+2552200049521438545913453660 8b$$
$$-2498884920995388531015698109 5b^2+1115536243631618874577108531 2b^3$$
$$-3866575614517011321331687540b^4+6173131049168600566149730 56b^5$$
$$-7958805301988469036474343 6b^6+1673571226296709851784218b^8-2449579713613605622008 96b^9$$
$$+4221183059532556872755 0b^{10}-24427268929830340654 08b^{11}+2537122333996822750 36b^{12}$$
$$-7683233847037257600b^{13}+5522279755209205 80b^{14}-8493067082271744b^{15}+4416971687476 11b^{16}$$
$$-2700995490144b^{17}+103163022193b^{18})-4a^6(5289565860371542217733617 7744$$
$$-1255044994845179131204810 96725b+1054246909288081848081182569 92b^2$$
$$-5424855236006234657218757 5205b^3+1312654113224400014927724768 0b^4$$
$$-2195627585159893786910327 620b^5+7958805301988469036474343 6b^7$$
$$-1620708545194447997797891 2b^8+3275951079081429413713594b^9$$

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$$-267285384397998316494144b^{10}+3179449692784902224087 4b^{11}-1422491466706905381696b^{12}$$
$$+115216473790726873964b^{13}-291011862518133120 0b^{14}+168712275057454044b^{15}$$
$$-2240986758221232b^{16}+947956646362 11b^{17}-510999146784b^{18}+15781954643b^{19})$$
$$-2a^5(-377701803640400756305158527625+840006312597078894057676662067 2b$$
$$-7465048361968687087168966105 62b^2+2929820227255507418397781560 96b^3$$
$$-6719102082465699759211352068 9b^4+4391255170319787573820655240b^6$$
$$-1234626209833720113229946112b^7+2979140543670500239877546 70b^8$$
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$$-7624107270017 28b^{17}+260574078807 98b^{18}-125508562368b^{19}+3081683451b^{20})$$
$$-2a^4(95998344090527002729473327 6000-2103824541313062802889734 5547475b$$
$$+1539288905064687878184690274 080b^2-5279010574972727589190535 80818b^3$$
$$+6719102082465699759211352068 9b^5-2625308226448800029855449 5360b^6$$
$$+7733151229034022642663375080b^7-1172664981074498443655884992b^8$$
$$+1899609398773394923053275 62b^9-1611499336834471242065 1072b^{10}$$
$$+1700428502149382518810388b^{11}-8765577650952773424883 2b^{12}+6424577155565794311450b^{13}$$
$$-2046324073074098092 80b^{14}+1072989060322015575 2b^{15}-2052148269866587 20b^{16}$$
$$+77736673467701 85b^{17}-81282100055520b^{18}+2208995339950b^{19}-96208654 08b^{20}+182538741b^{21})$$
$$-28a^3(-1146956770252052436000753393 75+2225153458030773577304777400000b$$
$$-1335454783635714968893883360 075b^2+3770721839266233992278954 1487b^4$$
$$-2092728733753933870284129686 4b^5+7749793194294620938883939315b^6$$
$$-1593623205188026963681583616b^7+3087788600834442990516088 42b^8$$
$$-3502794604827262230470534 4b^9+4286468391812551133646226b^{10}$$
$$-2975089170593081475548 16b^{11}+2477205912532961907843 0b^{12}-1091501504654680620480b^{13}$$
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$$-12905279104334 40b^{17}+387743308692 25b^{18}-367690821120b^{19}+7730303427b^{20}-30821472b^{21}$$
$$+431319b^{22})-28a^2(10949556710701056784228 8930000-1677378798158014617931 91761875b$$
$$+1335454783635714968893883360 075b^3-1099492075046205627274778767 20b^4$$
$$+5332177401406205062263547218 3b^5-1506067013268688354401689385 6b^6$$
$$+3569835601421983615736711585b^7-5399462265165893575456382 40b^8$$
$$+7766931605340632590971957 0b^9-7145123615672602566602112b^{10}$$
$$+6813668196359398451719 98b^{11}-4025793190181575846051 2b^{12}+2660202959722929678974b^{13}$$
$$-1028568619055241225 60b^{14}+4807076338955705778b^{15}-120540830305597296b^{16}$$

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$$+3995694313535505b^{17}-622890886598 40b^{18}+14423448484 55b^{19}-12613402032b^{20}+195880443b^{21}$$
$$-726432b^{22}+6909b^{23})-b(11925681927744341235399076406 25$$
$$-3065875878996295899584090040000b+32114789567057468208021095025 00b^{2}$$
$$-1919966881810540054589466552000b^{3}+75540360728080151261031705525 0b^{4}$$
$$-2115826344148616887093447109 76b^{5}+4431960883381677396909049227 6b^{6}$$
$$-7177538231004372876823354176b^{7}+9200454499396465990194943 51b^{8}$$
$$-9493953243759367891655769 6b^{9}+7983722044172450413047496b^{10}$$
$$-5518844496052980275208 96b^{11}+3154099423354811647519 6b^{12}-1495156745787056317056b^{13}$$
$$+588372531202895348 56b^{14}-191912608604964825 6b^{15}+5166990367110243 1b^{16}$$
$$-1140030451048896b^{17}+203846547061 96b^{18}-29055836409 6b^{19}+3221672146b^{20}-26765376b^{21}$$
$$+156676b^{22}-576b^{23}+b^{24})-7a(-17036688468206201764855823 4375$$
$$+6709515192632058471727670475 00b^{2}-8900613832123094309219109600000b^{3}$$
$$+6010927260894465151113527272850b^{4}-2400018035991653983021933201 92b^{5}$$
$$+7171685684829595035456062670 0b^{6}-1458400028297964883379116377 6b^{7}$$
$$+2506679259033952138613891519b^{8}-3044705324899863378209126 40b^{9}$$
$$+3354111950983460080767240 8b^{10}-2618148983777566738523904b^{11}$$
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$$-1832174921590867123 2b^{15}+666675985966974215b^{16}-153549628491970 56b^{17}$$
$$+387765466952924b^{18}-56421265555 20b^{19}+9559687629 8b^{20}-791011584b^{21}+8335292b^{22}$$
$$-29568b^{23}+161b^{24}))\Big\}-\frac{\Gamma(\frac{b+1}{2})}{\Gamma(\frac{a}{2})}\Big\{268435456(3a^{2}4+a^{23}(-575+1078b)+23a^{22}(8921-5145b+4606b^{2})$$
$$+253a^{21}(-77095+150388b-31255b^{2}+17766b^{3})+1771a^{20}(1616303-1417115b+1295273b^{2}$$
$$-139825b^{3}+56588b^{4})+161a^{19}(-1046829225+2079583870b-701082550b^{2}+401485280b^{3}$$
$$-26525625b^{4}+8120378b^{5})+437a^{18}(31431018189-33798962505b+31115280280b^{2}-5662501250b^{3}$$
$$+2284103885b^{4}-101504725b^{5}+24361134b^{6})+437a^{17}(-1247763838705+2496774883568b$$
$$-1070526853935b^{2}+611526437130b^{3}-69822872175b^{4}+21096742044b^{5}-669931185b^{6})$$
$$+128765994b^{7}+437a^{16}(63279202335014-772045357279 35b+709727183193 07b^{2}-168144389308 35b^{3}$$
$$+67033537186 35b^{4}-5232162554 85b^{5}+1226704902 57b^{6}-289723486 5b^{7}+450680979b^{8})$$
$$+46a^{15}(-16707727701716125+33427983247486282b-16637832109112620b^{2}+94079193878399 52b^{3}$$
$$-14198049315103 50b^{4}+4197886736968 68b^{5}-2363444137278 0b^{6}+4382164307808b^{7}$$
$$-788691713 25b^{8}+9914981538b^{9})+322a^{14}(79295022194898059-105473963039669 5555b$$
$$+96149741683852070b^{2}-26833902200939900b^{3}+10487574691456690b^{4}-1091431440650250b^{5}$$
$$+247315972449000b^{6}-10375779845100b^{7}+1527762530955b^{8}-21077766875b^{9}+2090914474b^{10})$$
$$+14a^{13}(-35950100218471660065+71474117681249818612b-39360973797993711325b^{2}$$
$$+21863665400825735130b^{3}-39192125790141040 50b^{4}+11221920159007663 84b^{5}$$

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$$-843581541921218 10b^6+148355357816211 00b^7-4690703725181 25b^8+537628070348 60b^9$$
$$-54886504942 5b^{10}+3858687620 2b^{11})-2a^{12}(-55833695107505586 30069$$
$$+7896740167166969665365b-7087705250539547642827b^2+2206545302765470623411b^3$$
$$-8369634849224771527 86b^4+1035712365594097891 70b^5-2230714985768072895 0b^6$$
$$+1235374684159413798b^7-166195491552756393b^8+38370895927213 85b^9-308337748365647b^{10}$$
$$+17557028671 91b^{11})-2a^{11}(7767954491490205996 8025-1524685930591788462004 22b$$
$$+9003262599765487620894 6b^2-4865136170447285597 8832b^3+9737398318034636797639b^4$$
$$-2656016246289983093790b^5+2346585086323402859 48b^6-3778739845058821988 8b^7$$
$$+1501966116788209527b^8-1397583111207343 06b^9+178076703915710 6b^{10}-17557028671 91b^{12}$$
$$+270108133414b^{13})-22a^{10}(-1042470154542718591896 19+1538295744077017471466 55b$$
$$-1346866623313093665911 24b^2+4500373131116898166895 4b^3-1630106382809589220017 3b^4$$
$$+2225837182955034257245b^5-4399714631360725271 14b^6+2726724369142492009 2b^7$$
$$-298475703581515450 9b^8+645997980506929 05b^9-161887912650646b^{11}+280307043968 77b^{12}$$
$$-349277758725b^{13}+30603384574b^{14})-2a^9(1100904826898 93232646399205$$
$$-2114913071990228 5116184280b+1304584752873054391030 5335b^2$$
$$-6750367182363652097461218b^3+1433016625366977190668765b^4-3596063748957993318 58012b^5$$
$$+3337704637132858714221 5b^6-4383400224672365182 286b^7+1453777198143138818 95b^8$$
$$-7105977785576219 55b^{10}+1397583111207343 06b^{11}-38370895927213 85b^{12}+37633964924402 0b^{13}$$
$$-3393520466875b^{14}+228044575374b^{15})-7a^8(-3007430464031790403120 7129$$
$$+4545765290141042983339 6010b-3823429775180270307279 2954b^2$$
$$+1318979998232192913626 6058b^3-4407268569094241056242 846b^4+6076838418146058728829 30b^5$$
$$-9820290302145412296971 4b^6+4766935154986745025714b^7-4153649137551825197 0b^9$$
$$+9380664969704771314b^{10}-4291331762252027 22b^{11}+4748442615793039 8b^{12}$$
$$-938140745036250b^{13}+702770764239 30b^{14}-518283125850b^{15}+28135369689b^{16})$$
$$-7a^7(1902354123976999034366261 25-3525128676354317853734912 18b$$
$$+2201899943972679407179044 08b^2-1054331477522120012962915 52b^3$$
$$+2200062382749398473656913 2b^4-4525707003741997245659016b^5$$
$$+3162387759757828664484 24b^6-4766935154986745025714b^8+1252400064192104337796b^9$$
$$-8569705160162117743 2b^{10}+1079639955731091996 8b^{11}-3529641954741182 28b^{12}$$
$$+296710715632422 00b^{13}-477285872874600b^{14}+28797079737024b^{15}-180870233715b^{16}$$
$$+8038677054b^{17})+a^6(7770470705804151971129199483-1172604234352128024664255 7835b$$
$$+9162223760308066388492093 234b^2-3047575597179067504367633 144b^3$$
$$+8373011297237408128418546 12b^4-8460955066346496713090154 0b^5$$
$$+2213671431830480065138968b^7-6874203211501788607879 98b^8+6675409274265717428443 0b^9$$

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Notes

$$-9679372188993595596508b^{10}+4693170172646805718966b^{11}-4461429971536145790 0b^{12}$$
$$+1181014158689705340b^{13}-796357431285780000b^{14}+10871843031478806b^{15}-536070042423096b^{16}$$
$$+29275992784 5b^{17}-1064581555 8b^{18})+a^5(-2966570297882889037505281 0935$$
$$+5133579117691178465742585949 2b-3048881377533476774161065889 5b^2$$
$$+1204793635702982674588552304 6b^3-1807496481680040996575067820b^4$$
$$+8460955066346496713090154 0b^6-3167994902619398071961311 2b^7$$
$$+4253786892702241110180510b^8-7192127497915986637160 24b^9+4896841802501075365939 0b^{10}$$
$$-5312032492579966187580b^{11}+2071424731188195783 40b^{12}-1571068822261072937 6b^{13}$$
$$+3514409238893805 00b^{14}-193102789900559 28b^{15}+228645503646945b^{16}-92192762732 28b^{17}$$
$$+443575648 25b^{18}-1307380858b^{19})+a^4(9348147412931602914969405 6225$$
$$-1328609778924127295816083356 5b+8608839543451565234630999495 1b^2$$
$$-2030474793207111788176710812 7b^3+1807496481680040996575067820b^5$$
$$-8373011297237408128418546 12b^6+1540043667924578931559839 24b^7$$
$$-3085087998365968739369992 2b^8+2866033250733954381337530b^9$$
$$-3586234042181096284038 06b^{10}+1947479663606927359527 8b^{11}-1673926969844954305572b^{12}$$
$$+5486897610619745670 0b^{13}-337699905064905418 0b^{14}+65311026849476100b^{15}$$
$$-2929365575043495b^{16}+30512595140475b^{17}-998153397745b^{18}+4270625625b^{19}-100217348b^{20})$$
$$+a^3(-1787461689354206481614282735 25+2583796846071016049255514035 10b$$
$$-1077955383205635876511295993 82b^2+2030474793207111788176710812 7b^4$$
$$-1204793635702982674588552304 6b^5+3047575597179067504367633144b^6$$
$$-7380320342654840090740408 64b^7+9232859987625350395386240 6b^8$$
$$-1350073436472730419492243 6b^9+9900820888457175967169 88b^{10}-9730272340894571195766 4b^{11}$$
$$+4413090605530941246822b^{12}-3060913156115602918 20b^{13}+8640516508702647800b^{14}$$
$$-432764291840637792b^{15}+7347909812774895b^{16}-267237053025810b^{17}+24745130462 50b^{18}$$
$$-646391300 80b^{19}+24763007 5b^{20}-4494798b^{21})-7a^2(-3197555457909636476510276 2875$$
$$+3179252608685503934004227 8575b-1539936261722336966444708562 6b^3$$
$$+1229834220493080747804428 4993b^4-4355544825047823963087236985b^5$$
$$+1308889108615438055498870462b^6-2201899943972679407179044 08b^7$$
$$+3823429775180270307279295 4b^8-3727385008208726831515810b^9+4233009387555437235721 04b^{10}$$
$$-2572360742790139320255 6b^{11}+2025058643011299326522b^{12}-7872194759598742265 0b^{13}$$
$$+4422888117457195220b^{14}-109334325288454360b^{15}+443072541507673 7b^{16}-668314621670 85b^{17}$$
$$+1942482497480b^{18}-161248986 50b^{19}+32770406 9b^{20}-1129645b^{21}+15134b^{22})$$
$$+b(1155279578871850810789867706 25-2238288820536745533557193401 25b$$
$$+1787461689354206481614282735 25b^2-9348147412931602914969405 6225b^3$$
$$+2966570297882889037505281 0935b^4-7770470705804151971129199 483b^5$$

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$$+133164788678389932405638287 5b^6 - 2105201324822253282184499 03b^7$$
$$+220180965377864652927984 10b^8 - 2293434339993980902171618b^9 + 1553590898298041199360 50b^{10}$$
$$-111667390215011172601 38b^{11} + 5033014030586032409 10b^{12} - 2553299714675717499 8b^{13}$$
$$+768555474278941750b^{14} - 276530114204011 18b^{15} + 5452727975140 85b^{16} - 137353549485 93b^{17}$$
$$+1685395052 25b^{18} - 28624726 13b^{19} + 19505035b^{20} - 205183b^{21} + 575b^{22} - 3b^{23})$$
$$-7a(165039939838835830112838243 75 - 3179252608685503934004227857 5b^2$$
$$+369113835153002292750787719 30b^3 - 1898013969891611042259440 4795b^4$$
$$+733368445384454066534655135 6b^5 - 1675148906217325749520365 4405b^6$$
$$+352512867635431785373491 218b^7 - 4545765290141042983339601 0b^8$$
$$+604260877711493860462408 0b^9 - 4834643767099197767466 30b^{10} + 4356245515976538462869 2b^{11}$$
$$-225621147633341990439 0b^{12} + 1429482353624996372 24b^{13} - 4851802299824799530b^{14}$$
$$+219669604197766996b^{15} - 481976887330108 5b^{16} + 155870089159888b^{17} - 21100209449 55b^{18}$$
$$+47830429010b^{19} - 358530095b^{20} + 5435452b^{21} - 16905b^{22} + 154b^{23}))\Big\}\Big] \qquad (8)$$

III. Derivation of the Summation Formula

Putting $c = \frac{a+b+49}{2}$ and $z = \frac{1}{2}$ in equation (2), we get

$$(a-b)\ {}_2F_1\left[\begin{matrix} a,\ b \\ \frac{a+b+49}{2} \end{matrix};\ \frac{1}{2}\right] = a\ {}_2F_1\left[\begin{matrix} a+1,\ b \\ \frac{a+b+49}{2} \end{matrix};\ \frac{1}{2}\right] - b\ {}_2F_1\left[\begin{matrix} a,\ b+1 \\ \frac{a+b+49}{2} \end{matrix};\ \frac{1}{2}\right]$$

Now involving the derived formula [Salahuddin et. al. p.12-41(8)], the summation formula is obtained.

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Exact Traveling Wave Solutions for Power law and Kerr law non Linearity Using the Exp(−φ (ξ))-expansion Method

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Abstract- The exp(−φ (ξ))-expansion method is used as the first time to investigate the wave solution of the nonlinear Burger equation with power law nonlinearity, the perturbed non-linear Schrodinger equation with kerr law nonlinearity. The proposed method also can be used for many other nonlinear evolution equations.

Keywords: *exp(−φ(ξ))-expansion method, homogeneous balance, travelling wave solutions, solitary wave solutions, the nonlinear burger equation with power law nonlinearity, the perturbed nonlinear schrodinger equation with kerr law nonlinearity.*

GJSFR-F Classification : *MSC 2010: 35C07*



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Exact Traveling Wave Solutions for Power Law and Kerr Law Non Linearity Using the Exp(−φ (ξ))-expansion Method

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Abstract- The exp(−φ (ξ))-expansion method is used as the first time to investigate the wave solution of the nonlinear Burger equation with power law nonlinearity, the perturbed non-linear Schrodinger equation with kerr law nonlinearity. The proposed method also can be used for many other nonlinear evolution equations.

Keywords: *exp(−φ(ξ))-expansion method, homogeneous balance, travelling wave solutions, solitary wave solutions, the nonlinear burger equation with power law nonlinearity, the perturbed nonlinear schrodinger equation with kerr law nonlinearity.*

I. Introduction

The nonlinear equations of mathematical physics are major subjects in physical science [1]. Exact solutions for these equations play an important role in many phenomena in physics such as fluid mechanics, hydrodynamics, Optics, Plasma physics and so on. Recently many new approaches for finding these solutions have been proposed, for example, tanh - sech method [2]-[4], extended tanh - method [5-7], sine - cosine method [8]-[10], homogeneous balance method [11]and [12], Jacobi elliptic function method [13]-[16], F-expansion method [17]-[19], exp-function method [20]-[21], trigonometric function series method [22], $(\frac{G'}{G})-$ expansion method [23]-[26], the modified simple equation method [27]-[32] and so on.

In the present paper, we shall proposed a new method which is called exp-$\varphi(\xi)$-expansion method to seek traveling wave solutions of nonlinear evolution equations. The main ideas of the proposed method are that the traveling wave solutions of nonlinear evolution equation can be expressed by a polynomial in exp-$\varphi(\xi)$.

The paper is organized as follows: In section 2, we give the description of exp-$\varphi(\xi)$-expansion method. In section 3, we use this method to find the exact solutions of the nonlinear evolution equations pointed out above and some figures of our results are drawn. In section 4, conclusion are given.

II. Description of the Exp(−φ(ξ))-expansion Method

Consider the following nonlinear evolution equation

$$F(u, u_t, u_x, u_{tt}, u_{xx}, ...) = 0, \tag{2.1}$$

where F is a polynomial in $u(x,t)$ and its partial derivatives in which the highest order derivatives and nonlinear terms are involved. In the following,we give the main steps of this method

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Step 1. We use the wave transformation

$$u(x,t) = u(\xi), \qquad \xi = x - ct, \tag{2.2}$$

where c is a positive constant, to reduce Eq.(1)to the following ODE:

$$P(u, u', u'', u''', ...) = 0, \tag{2.3}$$

where P is a polynomial in $u(\xi)$ and its total derivatives,while $' = \frac{d}{d\xi}'$.

Step 2. Suppose that the solution of ODE(2.3) can be expressed by a polynomial in $exp(-\varphi(\xi))$ as follows

$$u(\xi) = \alpha_m \left(exp(-\varphi(\xi))\right)^m + ..., \quad \alpha_m \neq 0, \tag{2.4}$$

where $\varphi(\xi)$ satisfies the ODE in the form

$$\varphi'(\xi) = exp(-\varphi(\xi)) + \mu exp(\varphi(\xi)) + \lambda, \tag{2.5}$$

the solutions of ODE (2.5) are
when $\lambda^2 - 4\mu > 0, \mu \neq 0$,

$$\varphi(\xi) = ln\left(\frac{-\sqrt{\lambda^2 - 4\mu}\ tanh\left(\frac{\sqrt{\lambda^2-4\mu}}{2}(\xi + C_1)\right) - \lambda}{2\mu}\right), \tag{2.6}$$

when $\lambda^2 - 4\mu > 0, \mu = 0$,

$$\varphi(\xi) = -ln\left(\frac{\lambda}{exp\left(\lambda\left(\xi + C_1\right)\right) - 1}\right), \tag{2.7}$$

when $\lambda^2 - 4\mu = 0, \mu \neq 0, \lambda \neq 0$,

$$\varphi(\xi) = ln\left(-\frac{2\left(\lambda\left(\xi + C_1\right) + 2\right)}{\lambda^2\left(\xi + C_1\right)}\right), \tag{2.8}$$

when $\lambda^2 - 4\mu = 0, \mu = 0, \lambda = 0$,

$$\varphi(\xi) = ln\left(\xi + C_1\right), \tag{2.9}$$

when $\lambda^2 - 4\mu < 0$,

$$\varphi(\xi) = ln\left(\frac{\sqrt{4\mu - \lambda^2}\ tan\left(\frac{\sqrt{4\mu-\lambda^2}}{2}\ (\xi + C_1)\right) - \lambda}{2\mu}\right), \tag{2.10}$$

where $a_m, ..., \lambda, \mu$ are constants to be determined later,

Step 3. Substitute Eq.(2.4) along Eq.(2.5) into Eq.(2.3) and collecting all the terms of the same power $exp\left(-m\varphi(\xi)\right)$ and equating them to zero, where the positive integer m can be determined by considering the homogeneous balance between the highest order derivatives and nonlinear terms appearing in ODE(2.3). We obtain a system of algebraic equations, which can be solved by Maple or Mathematica to get the values of α_i.

Step 4. substituting these values and the solutions of Eq.(2.5) into Eq.(2.3) we obtain the exact solutions of Eq.(2.3).

a) Example1. The nonlinear Burger equation with power law nonlinearity.

This equation is well known [33] and has the form:

$$v_t + a(v^n)_x + bv_{xx} = 0, n > 1, \tag{2.11}$$

Ref

[33] M. Hayek, Constructing of exact solutions to the KdV and Burgers equations with power law nonlinearity by the extended $(\frac{G'}{G})$- expansion method, Appl. Math. Comput. 217 (2010) 212-221.

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where a and b are nonzero constants. The solutions of Eq.(2.11) have been discussed, the exact solitary wave solutions, the periodic solutions and the rational function solution are obtaines in [33] by means of the extended $(\frac{G'}{G})$ -expansion method. Let us now solve Eq.(2.11) using the $\exp(-\varphi(\xi))$-expansion method. To this end, we use the wave transformation (2.2) to reduce Eq.(2.11) to the ODE and integrating the equation with zero constant of integration:

$$-cv + av^n + bv' = 0. \tag{2.12}$$

Notes

Balancing v' with v^n yields $m = \frac{1}{n-1}, n > 1$. Using the transformation

$$v = u^{\frac{1}{n-1}}, \tag{2.13}$$

to reduce Eq.(12) to the following equation

$$-c(n-1)u + a(n-1)u^2 + bu' = 0, \tag{2.14}$$

where u is a new function of ξ. Balancing u' with u^2 yields $m = 1$. Consequently, Eq.(2.1) has the formal solution

$$u = \alpha_0 + \alpha_1 exp(-\varphi), \tag{2.15}$$

where α_0 and α_1 are constants to be determined, such that $\alpha_1 \neq 0$. It is easy to see that

$$u' = -\alpha_1 exp(-2\varphi) - \mu\alpha_1 - \lambda\alpha_1 exp(-\varphi), \tag{2.16}$$

substituting Eq.(2.15) and its derivatives in Eq.(2.1) and equating the coefficient of different power's of$exp(-\varphi(\xi))$ to zero, we get

$$a(n-1)\alpha_1^2 - b\alpha_1 = 0, \tag{2.17}$$

$$-v(n-1)\alpha_1 + a(n-1)(2\alpha_0\alpha_1) - b\lambda\alpha_1 = 0, \tag{2.18}$$

$$-c\alpha_0(n-1) + a(n-1)\alpha_0^2 - b\mu\alpha_1 = 0, \tag{2.19}$$

Eqs.(2.1)-(2.19) yield

$$\alpha_0 = \frac{b\lambda}{2a(n-1)} + \frac{v}{2a}, \alpha_1 = \frac{b}{a(n-1)}. \tag{2.20}$$

thus the solution is

$$u = \frac{b\lambda}{2a(n-1)} + \frac{v}{2a} + \frac{b}{a(n-1)} exp(-\varphi) \tag{2.21}$$

Let us now discuse the following case:

Case 1. if $\lambda^2 - 4\mu > 0, \mu \neq 0$. then we deduce from Eq.(2.21) that

$$u(\xi) = \frac{b\lambda}{2a(n-1)} + \frac{v}{2a} + \frac{2b\mu}{a(n-1)\left[-\sqrt{\lambda^2-4\mu}tanh\frac{\sqrt{\lambda^2-4\mu}}{2}(\xi+c_1) - \lambda\right]} \tag{2.22}$$

Case 2. if $\lambda^2 - 4\mu > 0, \mu = 0$. then we deduce from Eq. that

$$u(\xi) = \frac{b\lambda}{2a(n-1)} + \frac{v}{2a} + \frac{2b\mu}{a(n-1)\ [exp(\lambda\xi + c_1) - 1]}. \tag{2.23}$$

Case 3. if $\lambda^2 - 4\mu = 0, \mu \neq 0, \lambda \neq 0$. then we deduce from Eq. that

$$u(\xi) = \frac{b\lambda}{2a(n-1)} + \frac{v}{2a} - \frac{b\lambda^2(\xi + c_1)}{2a(n-1)\left[\lambda(\xi + c_1) + 2\right]}. \tag{2.24}$$

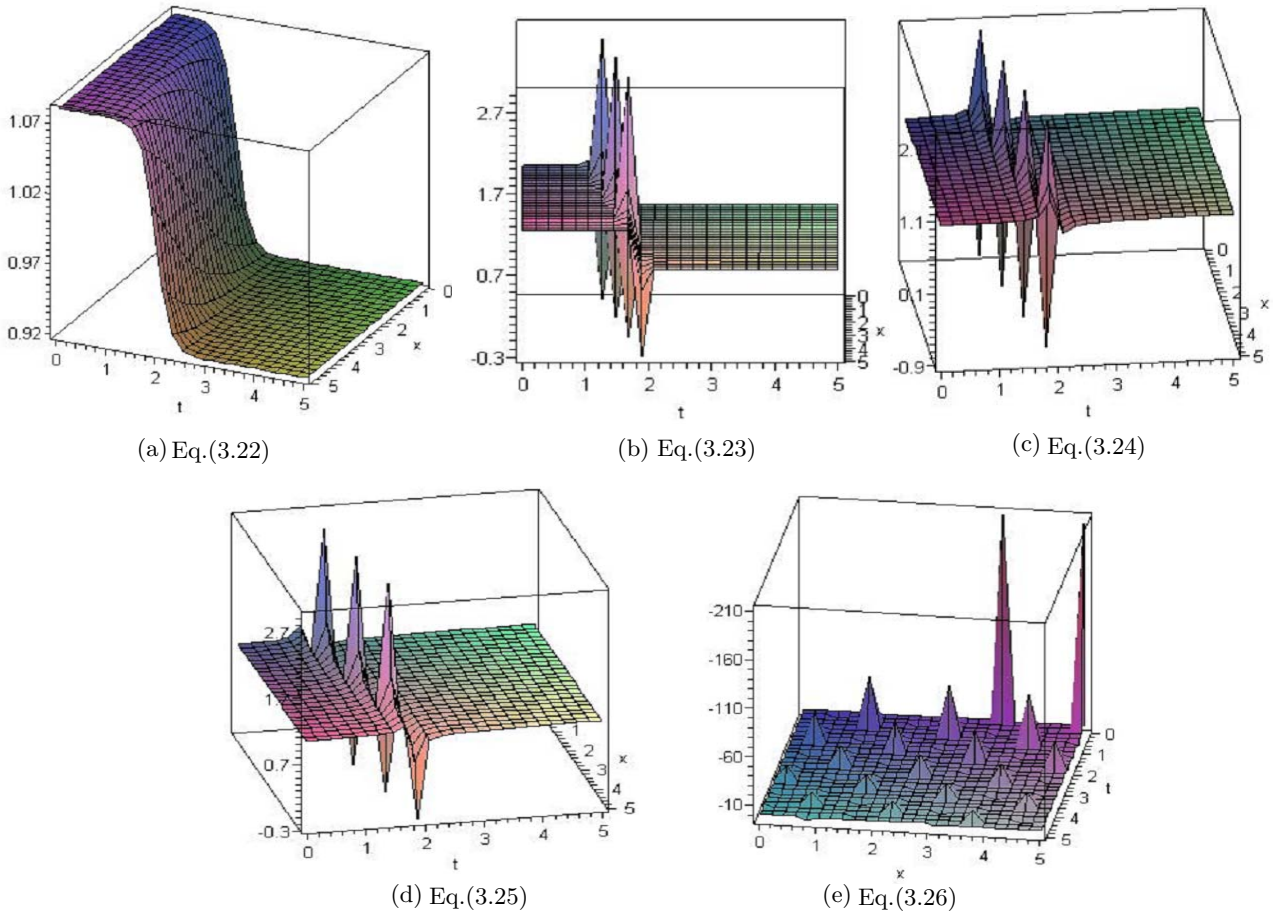
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Case 4. if $\lambda^2 - 4\mu = 0, \mu = 0, \lambda = 0$. then we deduce from Eq. that

$$u(\xi) = \frac{b\lambda}{2a(n-1)} + \frac{v}{2a} + \frac{b}{a(n-1)\left[\xi + c_1\right]}. \tag{2.25}$$

Case 5. if $\lambda^2 - 4\mu < 0$, then we deduce from Eq. that

$$u(\xi) = \frac{b\lambda}{2a(n-1)} + \frac{v}{2a} + \frac{2b\mu}{a(n-1)\left[\sqrt{4\mu-\lambda^2}tan(\frac{\sqrt{4\mu-\lambda^2}}{2}(\xi+c_1)) - \lambda\right]}. \tag{2.26}$$



(a) Eq.(3.22) (b) Eq.(3.23) (c) Eq.(3.24)

(d) Eq.(3.25) (e) Eq.(3.26)

Figure 1 : solution of Eqs.(3.22)-(3.26)

b) Example2. The perturbed nonlinear Schrodinger equation with Kerr law nonlinearity.

This equation is well-known [34],[35] and has the form:

$$iu_t + u_{xx} + \alpha|u|^2u + i\left\{\gamma_1 u_{xxx} + \gamma_2|u|^2u_x + \gamma_3(|u|^2)_x u\right\} = 0, \tag{2.27}$$

where α, γ_1, γ_2, γ_3 are constants such that γ_1 is the third order dispersion, γ_2 is the nonlinear dispersion, while γ_3 is also a version of nonlinear dispersion [36],[37]. Eq.S1 describes the propagation of optical solitons in nonlinear optical fibers that exhibits a Kerr law nonlinearity. Eq.S1 has been discussed in [35] using the first integral method and in [34] using the modified mapping method and its extended. Let us now solve Eq.S1 using the $\exp(-\varphi(\xi))$-expansion method. To this end we seek its traveling wave solution of the form [34],[35]:

$$u(x,t) = \phi(\xi)exp[i(kx - \Omega t)],\ \xi = x - ct, \tag{2.28}$$

Ref
[35] H. Moosaei, M. Mirzazadeh and A. Yildirim, Exact solutions to the perturbed nonlinear Scrodinger equation with Kerr law nonlinearity by using the first integral method, Nonlinear Analysis: Modelling and Control, 16 (2011) 332-339.

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where k , Ω and c are constants,while $i = \sqrt{-1}$. Substituting S2 into Eq.S1 and equating the real and imaginary parts to zero, we have

$$\gamma_1\phi''' + (2k - c - 3\gamma_1 k^2)\phi' + (\gamma_2 + 2\gamma_3)\phi^2\phi' = 0, \tag{2.29}$$

and

$$(1 - 3\gamma_1 k)\phi'' + (\Omega - k^2 + \gamma_1 k^3)\phi + (\alpha - \gamma_2 k)\phi^3 = 0. \tag{2.30}$$

With reference to [34], the two equations (2.29) and (2.30) can be simplified as follows: Integration Eq.(2.29) and vanishing the constant of integration, we have

$$\gamma_1\phi'' + (2k - c - 3\gamma_1 k^2)\phi + \frac{1}{3}(\gamma_2 + 2\gamma_3)\phi^3 = 0, \tag{2.31}$$

From Eqs.(2.30) and (2.31) we deduce that

$$\frac{\gamma_1}{1 - 3\gamma_1 k} = \frac{2k - c - 3\gamma_1 k^2}{\Omega - k^2 + \gamma_1 k^3} = \frac{\frac{1}{3}(\gamma_2 + 2\gamma_3)}{\alpha - \gamma_2 k}. \tag{2.32}$$

From Eq.(2.32), we can obtain $k = \frac{\omega - \alpha\gamma_1}{3\omega\gamma_1 - \gamma_1\gamma_2}$, $\Omega = \frac{(1-3\gamma_1 k)(2k-c-3\gamma_1 k^2)}{\omega} + k^2 - \gamma_1 k^3$, where $\omega = \frac{1}{3}\gamma_2 + \frac{2}{3}\gamma_3$. Now, Eq.(2.32) is transformed into the following form:

$$A\phi'' + B\phi + \omega\phi^3 = 0, \tag{2.33}$$

where $A = \gamma_1$ and $B = 2k - c - 3\gamma_1 k^2$. Balancing ϕ'' with ϕ^3 yields $m = 1$. Thus, we get the same formulas (2.15). Substituting (2.15) and its derivatives into Eq.(2.33) and equating the coefficients of $exp(-m\varphi)$ to zero, we get

$$2\alpha_1 A + \omega\alpha_1^3 = 0, \tag{2.34}$$

$$3\lambda\alpha_1 A + 3\alpha_0\alpha_1^2\omega = 0, \tag{2.35}$$

$$A\alpha_1(\lambda^2 + 2\mu) + 3\alpha_0^2\alpha_1\omega + B\alpha_1 = 0, \tag{2.36}$$

$$\lambda\mu\alpha_1 A + \omega\alpha_0^3 + B\alpha_0 = 0 \tag{2.37}$$

Eqs.(2.34)-(2.37) yields

$$\alpha_0 = \mp\lambda\sqrt{\frac{-A}{2\omega}}, \alpha_1 = \pm\sqrt{\frac{-2A}{\omega}}. \tag{2.38}$$

thus the solution is

$$u = \mp\lambda\sqrt{\frac{-A}{2\omega}} \pm \sqrt{\frac{-2A}{\omega}}exp(-\varphi) \tag{2.39}$$

Let us now discuse the following case:
Case 1. if $\lambda^2 - 4\mu > 0, \mu \neq 0$. then we deduce from Eq.(2.33) that

$$u(\xi) = \mp\lambda\sqrt{\frac{-A}{2\omega}} \pm \sqrt{\frac{-2A}{\omega}}\left[\frac{2\mu}{-\sqrt{\lambda^2 - 4\mu}\ tanh\frac{\sqrt{\lambda^2-4\mu}}{2}(\xi + c_1) - \lambda}\right], \tag{2.40}$$

Case 2. if $\lambda^2 - 4\mu > 0, \mu = 0$. then we deduce from Eq.(2.33) that

$$u(\xi) = \mp\lambda\sqrt{\frac{-A}{2\omega}} \pm \sqrt{\frac{-2A}{\omega}}\left[\frac{\lambda}{exp(\lambda\xi + c_1) - 1}\right], \tag{2.41}$$

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Case 3. if $\lambda^2 - 4\mu = 0, \mu \neq 0, \lambda \neq 0$. then we deduce from Eq.(2.33) that

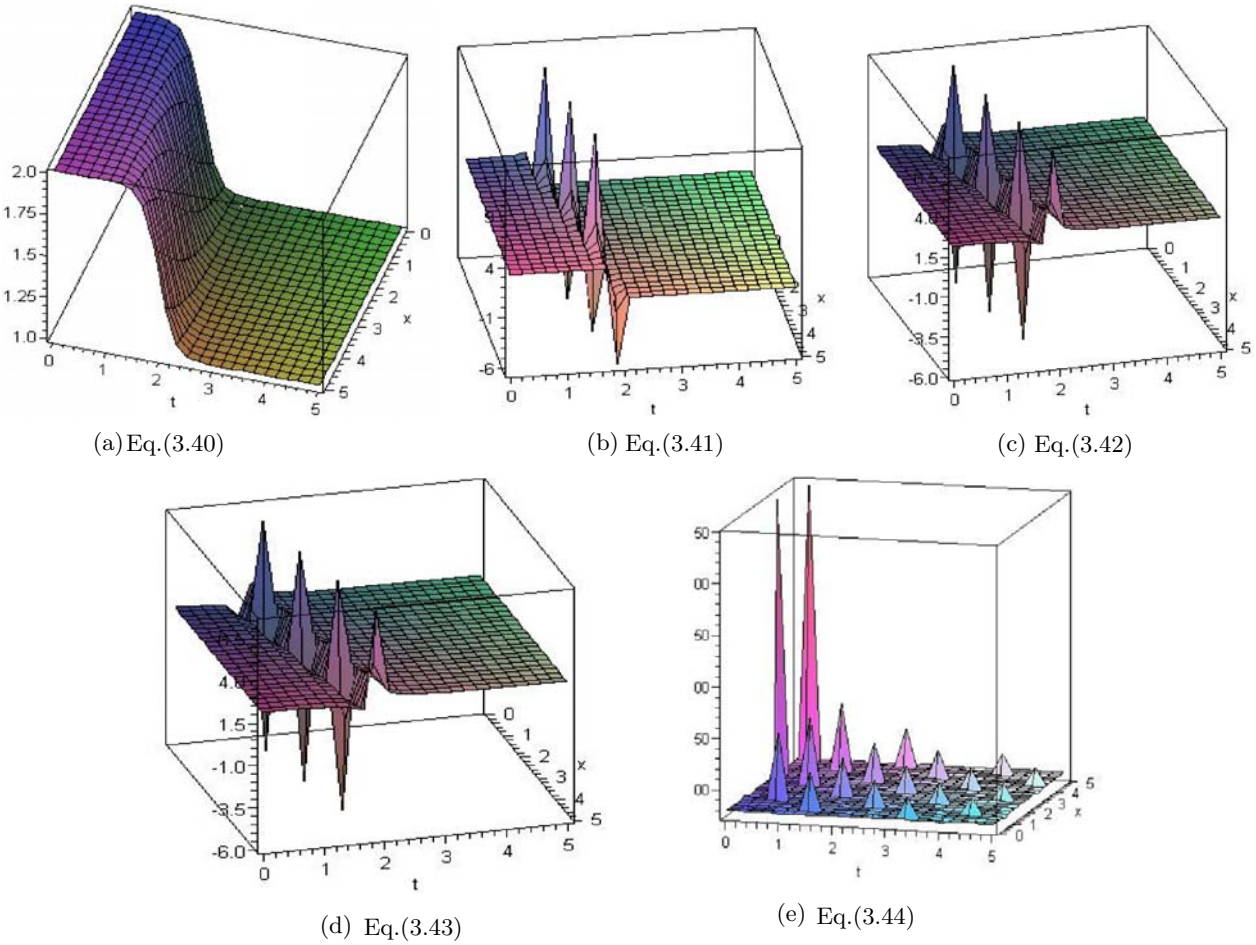
$$u(\xi) = \mp\lambda\sqrt{\frac{-A}{2\omega}} \pm \sqrt{\frac{-2A}{\omega}}\left[\frac{\lambda^2(\xi + c_1)}{2(\lambda(\xi + c_1) + 2)}\right]. \tag{2.42}$$

Case 4. if $\lambda^2 - 4\mu = 0, \mu = 0, \lambda = 0$. then we deduce from Eq.(2.33) that

$$u(\xi) = \mp\lambda\sqrt{\frac{-A}{2\omega}} \pm \sqrt{\frac{-2A}{\omega}}\left[\frac{1}{\xi + c_1}\right], \tag{2.43}$$

Case 5. if $\lambda^2 - 4\mu < 0$, then we deduce from Eq.(2.33) that

$$u(\xi) = \mp\lambda\sqrt{\frac{-A}{2\omega}} + \frac{v}{2a} \pm \sqrt{\frac{-2A}{\omega}}\left[\frac{2\mu}{\sqrt{4\mu - \lambda^2}\ tan(\frac{\sqrt{4\mu-\lambda^2}}{2}(\xi + c_1)) - \lambda}\right]. \tag{2.44}$$



(a) Eq.(3.40) (b) Eq.(3.41) (c) Eq.(3.42)

(d) Eq.(3.43) (e) Eq.(3.44)

Figure 2 : solution of Eqs.(3.40)-(3.44)

III. Conclusions

In this paper, it has been shown that the new exp(−(φ))-expansion method is a powerful tool for the nonlinear evolution equations. we can obtained new and more travelling wave solutions for the equations above , such as, the nonlinear Burger equation with power law nonlinearity, the perturbed nonlinear Schrodinger equation with kerr law nonlinearity.. Otherwise, the general solutions of the ODE have been well known for the researchers. Furthermore, the new method can be used for many other nonlinear evolution equations.

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Fixed Points for Cyclic Contractions in Dislocated Metric Spaces

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Abstract- In this work, we study fixed point theorems for cyclic contractions in dislocated metric spaces. Our results, extension, improve and generalize some recent results in the literature.

Keywords: *dislocated metric spaces, fixed point, d-convergent, d-cyclic contraction.*

GJSFR-F Classification : *MSC 2010: 30L05 , 31E05*



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Fixed Points for Cyclic Contractions in Dislocated Metric Spaces

K. Prudhvi

Abstract- In this work, we study fixed point theorems for cyclic contractions in dislocated metric spaces. Our results, extension, improve and generalize some recent results in the literature.

Keywords: *dislocated metric spaces, fixed point, d-convergent, d-cyclic contraction.*

I. Introduction and Preliminaries

P.Hitzler et.al.[1] have introduced "the notion of dislocated metric space". Recently, Kirk et.al. [4] have introduced "the notion of cyclic contraction and prove fixed point theorems on this contraction". Later on many authors have proved fixed point theorems on cyclic contractions in dislocated metric spaces (see, [3], [5]). In this paper, we obtain, fixed point theorems for cyclic contractions in dislocated metric spaces which improve,extends and generalises results of [3].

The following definitions are needful to prove main results.

Definition 1.1 [1]. Let X be a non empty set and let d: $X \times X \to [0, \infty)$ be a function called a distance function .Consider the following conditions:
(i) $d(x, x) = 0$, for all $x \in X$.
(ii) $d(x, y) = 0$ then $x = y$, for all $x,y \in X$.
(iii) $d(x, y) = d(y,x)$, for all $x,y \in X$.
(iv) $d(x,y) \leq d(x,z) + d(z,y)$, for all $x,y,z \in X$.
If d satisfies (i) to (iv), then it is called metric. If it satisfies (ii) to (iv), then d is called dislocated metric (or simply d-metric).

Definition 1.2 [1]. A sequence $\{x_n\}$ in a d-metric space(X,d) converges with respect to d , if there exists a point $x \in X$ such that $d(x_n, x)$ converges to 0 as $n \to \infty$.

Proposition 1.1 [1]. Limits in d-metric spaces are unique.

Definition 1.3[1]. A sequence $\{x_n\}$ in a d-metric space(X,d) is called a Cauchy sequence , if for each $\varepsilon > 0$ there exists $n_0 \in N$ such that for all $m,n \geq n_0$, we have $d(x_m, x_n) < \varepsilon$.

Proposition 1.2[1]. Every convergent sequence in d-metric spaces is a Cauchy sequence.

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Definition 1.4[1]. A function f: X → X in a d-metric space is called a contraction if there exists $0 \leq \lambda < 1$ such that $d(fx, fy) \leq \lambda\, d(x, y)$ for all $x,y \in X$.

Definition 1.5[4]. Let A and B be two non empty subsets of a metric space (X, d) and T: $A \cup B \to A \cup B$, T is called a cyclic map if $T(A) \subseteq B$ and $T(B) \subseteq A$.

Definition 1.6[4]. Let A and B be two non empty subsets of a metric space (X,d) and a cyclic map T: $A \cup B \to A \cup B$ is said to be a cyclic a cyclic contraction if there exists $k \in (0,1)$ such that $d(Tx, Ty) \leq \lambda\, d(x, y)$ for all $x \in A$ and $x \in B$.

II. Main Results

In this section, we prove fixed point thoerems for cyclic contractions in dislocated metric spaces. Our results improve, extends and generalises the results of [3].

Theorem 2.1 . Let (X, d) be a complete dislocated metric space. Let A and B be two non empty closed subsets of X and $f : A \cup B \to A \cup B$ be such that

$d(fx,fy) \leq \alpha[d(fx, x) + d(fy, y) + d(fy, x) + d(y, fx)]$, where $\alpha \in [0, 1/6)$.

Then f has a unique fixed point in $A \cap B$.

Proof: Let $\{f^n\} \subseteq X$, $\{f^{2n}\} \subseteq A$ and $\{f^{2n-1}\} \subseteq B$. Fix $x \in A$. By above definition there exists $\alpha \in [0, 1/6)$ such that

$$d(f^2x, fx) \leq \alpha\,[d(f^2x, fx) + d(fx, x) + d(fx, fx) + d(x, f^2x)],$$

$$d(f^2x, fx) \leq \alpha\,[d(f^2x, fx) + d(fx, x) + d(fx,x) + d(x, fx) + d(x,fx) + d(fx, f^2x)],$$

$$\leq \alpha\,[2d(f^2x, fx) + 4d(fx, x)],$$

$$(1-2\alpha)\, d(f^2x, fx) \leq 4\alpha d(fx, x)$$

$$d(f^2x, fx) \leq 4\alpha / 1-2\alpha \;\; d(fx,x).$$

Put $k = 4\alpha / 1-2\alpha < 1$.

$$d(f^2x, fx) \leq kd(fx, x).$$

By induction we have,

$$d(f^{n+1}x , f^n x) \leq k^n\, d(fx, x).$$

More generally, for $m > n$ we have,

$$\begin{aligned} d(f^m x,\; f^n x) &\leq d(f^m x,\; f^{m-1}x) + d(f^{m-1} x,\; f^{m-2}x) + \ldots + d(f^{n+1} x,\; f^n x) \\ &\leq (k^{m-1} x + k^{m-2}x + \ldots + k^n x)d(fx,x) \\ &= k^n (1+k+ k^2 + \ldots + k^{m-n-1})d(fx,x). \end{aligned}$$

Since, $k<1$ so as $m,n \to \infty$ we have $k^n (1+k+ k^2 + \ldots + k^{m-n-1}) \to 0$.

Hence, $d(f^m x,\; f^n x) \to 0$.

Therefore, $\{f^n x\}$ is a Cauchy sequence. Since (X,d) is complete, so $\{f^n x\}$ converges to some point $z \in X$.

Since, $\{f^{2n}\} \subseteq A$ and and $\{f^{2n-1}\} \subseteq B$ so $z \in A \cap B$.

We claim that $fz = z$.

$$d(fz,z) = d(fz, f^{2n} x)$$

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$$\leq \alpha\,[d(fz, z) + d(f^{2n}x\,,\ f^{2n-1}x) + d(f^{2n}x\,,\ z) + d(\ f^{2n-1}x,\ fz)]\ .$$

Letting, as $n \to \infty$ we get that,

$$\begin{aligned} d(fz, z) &\leq \alpha\,[d(fz, z) + d(z\,,\ z) + d(z, z) + d(z, z)] \\ &\leq \alpha\,[d(fz, z) + 3d(z\,,z)] \\ &\leq \alpha\,[d(fz, z) + 3d(z\,,\ fz) + 3d(fz\,,\ z)] \\ &\leq 7\alpha d(fz, z)\,, \quad \text{since } \alpha \in [0, 1/6). \end{aligned}$$

$$(1\text{-}7\alpha)\, d(fz, z) \leq 0.$$

Implies , $d(fz, z) = 0$.

Hence, $fz = z$.

Uniqueness, let u and v be two fixed points of f that is, $fu = u$ and $fv = v$. Then,

$$\begin{aligned} d(u,v) = d(fu,fv) &\leq \alpha\,[d(fu,u) + d(fv,v) + d(fv,u) + d(v,fu)] \\ &\leq \alpha\,[d(u,u) + d(v,v) + d(v,u) + d(v,u)] \\ &\leq \alpha\,[d(u,v) + d(u,v) + d(u,v) + d(u,v) + d(v,u) + d(v,u)] \\ &\leq 6\alpha\, d(u,v). \end{aligned}$$

Implies, $(1\text{-}6\alpha)\, d(u,v) \leq 0$. Since, $\alpha \in [0, 1/6)$.

We have, $d(u,v) = 0$. Implies, $u = v$.

Therefore, f has a unique fixed point in $A \cap B$.

Example 2.1. Let $X = R$, $A = [-1, 0]$, $B = [0, 1]$. Define $d(x, y) = |x - y| + 4|x| + 4|y|$ Then d is the dislocated metric.Define $f : A \cup B \to A \cup B$, by $fx = -x/6$, then f is a cyclic mapping. For any two points in A and B, the contractive condition is satisfied and 0 is the unique fixed point of the function f.

Theorem 2.2. Let (X, d) be a complete dislocated metric space. Let A and B be two non empty closed subsets of X and $f : A \cup B \to A \cup B$ be a cyclic mapping satisfying

(i). there exists a number $k \in [0,1/2)$.

(ii) . $d(fx,fy) \leq \max\{ d(x,y), d(x,fx), d(y,fy), d(x, fy), d(y,fx)\}$

for all $x \in A$ and $y \in B$ then f has a unique fixed point in $A \cap B$.

Proof: Let $\{f^n\} \subseteq X$, $\{f^{2n}\} \subseteq A$and $\{f^{2n-1}\} \subseteq B$. Fix $x \in A$ If $f^n x = f^{n+1}x$ for some n, then $f^{n+1}x = f^{n+2}x$ then $\{f^n x\}$ converges to some $z \in X$. So suppose $f^n x \neq f^{n+1}x$. Now by using above contractive condition of the theorem, we have

$$\begin{aligned} d(f^2x, fx) &\leq k \max\{d(fx,x), d(fx, f^2x), d(x, fx), d(fx,fx), d(x, f^2x)\} \\ &= k \max\{d(fx, x), d(fx,fx), d(x, f^2x)\} \\ &\leq k \max\{d(fx,x), d(fx, x) + d(fx, x), d(x,fx) + d(fx, f^2x)\} \\ &\leq k \ \max\ \{d\,(fx,x)\,,\ 2\, d(fx, x)\} \\ &\leq k\, d\,(fx,x) \text{ or } 2k\, d(fx, x) \\ &\leq 2k\, d\,(fx,x) \\ &\leq hd\,(\ fx, x) \text{ where, } h = 2k. \end{aligned}$$

Now by induction we have,

$$d(f^2x, fx) \leq h^n x\, d(fx,x).$$

Following the same process as in the above theorem we show that $\{f^n x\}$ is a cauchy sequence. Since (X,d) is complete, so $\{f^n x\}$ converges to some point $z \in X$. Since $\{f^{2n}\} \subseteq A$ and $\{f^{2n-1}\} \subseteq B$ so $z \in A \cap B$. We claim that $fz = z$.

$$d(fz,f^{2n}x) \leq k \max\{d(z, f^{2\text{-}1}x), d(fz,z), d(f^{2n}\ x,\ f^{2n-1}x), d(z, f^{2n}x), d(f^{2n}\ x,z)\ \}.$$

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Letting, as $n \to \infty$, we have

$$d(fz, z) \leq k \max \{ d(z,z), d(fz, z), d(z, z), d(z, z)\}$$
$$\leq k\, d(fz,z), \text{ which is a contradiction.}$$

Hence, $d(fz,z) = 0$.

$\Rightarrow \quad fz = z$.

Therefore, f has a fixed point.

Uniqueness, Let us assume that there exists fixed points u and v, that is $fu = u$ and $fv = v$.

$$d(fu, fv) \leq k \max \{ d(u,v), d(u,fu), d(v,fv), d(u,fv), d(v,fu)\}$$
$$\leq k \max \{ d(u,v), d(u, u), d(v,v), d(u,v), d(v,u)\}$$
$$= k \max \{ d(u,v), d(u, u), d(v,v), \}$$
$$\leq k\ d(u,v) \text{ or } k\, d(u, u) \text{ or } k\, d(v,v)$$
$$(1-k)\, d(u,v) \leq 0 \text{ or } (1-2k)\, d(u,v) \leq 0.$$

This implies that, $u = v$.

Therefore, f has a unique fixed point in $A \cap B$.

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15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.



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27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

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Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.



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Abstract:

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An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
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- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

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This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.



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Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
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- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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