ƘƒƧƠƵƖ! ƴƼƧ!ƒ ƖĂƥ ǏǼƵ ýŏƬĂk!ƒ ƗƖƑƠƼ!ƒ ƘƠƼƼdž!ƒĂ Ɨǂƚ!ƒ ƖƥƠdž ƧŏƛƋk ŎƚŏƵƠǴƚƶdž!ƒ Ƨ ŏĂƵƠk!ƒ ƘƒƦ

ǏƼƵƠƬdž ƥĂdžơdž ƊƠƚƛ .ƥ

ýƬĂdž!ƒ ƗƶdžƠƞ - ƊĂǼƶ!ƒ ƗŏǼǂ - CƠŏƨŏƽ!ƒ Ɗǂƚƥ

ƒ PǼdž!ƒ

yû5Ƨ!ƒ ƖĂùƥ ǏùǼƵ ýŏƬĂk!ƒ ƗƖƑƠƼ!ƒ ƘƠƼƼdž!ƒĂ Ɨǂƚ!ƒ ƖƥƠdž ƧŏƛƋk YĂưĂdž ƗƚƒƧƥ Ɨơ!ƒ ƒRNj Ŏ5 Ɗĩk ƖĂù!ƒ ƥùŏ!Ăk! ýŏùƬĂk!ƒ Ɨù!ƖƑƼ!ƒ ƘƠƼƼdž!ƒ ǏǼƵ ƨŏǂƧk!ƒ Ɗĩk Ɨŏơ .ŎƚŏƵƠǴƚƶdž!ƒ Ƨ ŏĂƵƠk!ƒ ƘƒƦ ƘƒƧƠƵƖ! yû5Ƨ ƖĂ!ƛ UƠƽkơŮƒ yđž ƘƒƧƠƵƖ!ƒ ƚjRNj ýƛdž Ŏ5 Ƨŏ!ƛǂ! ƧƠŏk!ƒ ýŏǼ!k Ư Ƨƶ!Ă .ƧƠƵƖ! Ɨƶ5ƒ2!ƒ Ɨŏƚƚŏ ƵƠǴƚƶdž!ƒ ƊĩƲƶdž LJdž ƥƠƽkƚŮƒ LJǂdžŏ Ɨŏơ!ƛ ĭƧƠƵǧ Ƨ Ǽdž ýǂTƛ ýŏƬĂk!ƒ ƗƖƑƠƼ!ƒ ƘƠƼƼdž!ƒ ƥŏƥƞ Ɗĩŏdž Ƭk Ɗĩk ƥ!5 ÜƗŏ!ƠƶZ ƥùƚƶ5ƒ2 Ɨŏƚƚŏ ƵƠǴƚƶdž ƖĂƥ Nŏ5 ƥ!ĂkkƯŏ2Z Ŏƚƥƶdž ƵŏƧT LJZ ƖƧƛƲZ ƠƚNj Ǽ!ƚ .ƗƛƧƶ!ƒ ƥƵZƠƥ ƗơƠƚdž LJƊ LJù!ƗdžŏŎùk!ƒ ƥƒĂùdžǼ! ƗǼƬƶdž Ɨƚƒƨƥ Ɨơ!ƒ ýĂƠƚk .ƗƶƧƚ!ƒ ƥƵƠƨƛ ƥƒƥƨk Ŏk!ƒĂ Nŏ5ǼZ ΣŏƵƠǴƚƶdž Ǽ!ƨơ ÜƗù!ƥkƶdž!ƒ ƠdžnjkƶǼ!Ă Ɨŏ!Ơƶ!ƒ ƠdžnjkƶǼ!ƬĂk! ĐĂŏƚjđž!ŪƒĂ ΣƠơƚ!ƒ Ŏƚƥƶdž! yƧƼ!ƒ ƖĂƥ ƘƚƧƥ Ɨŏơ Ⅱ!ƚ!ǂ ĐƵPƘƚk -ΣƠùơƚ!ƒ Ǽ!ƛŏƛƚù! ƳƠƚùơ!ƒ Đùk ƥ!5 ÜĐĂŏƚjđž!ŪƒĂ ΣƠơƚ!ƒ Ⅱ ƑƛƚƚLJdž Ư ƶƛ! yƼ!ƒ ƖĂƥ ƳƠƚơ Ɗĩk Ⅱ!Rǂ yû5Ƨ!ƒ ƖĂùƥ ƗƚƧƥ Ɗĩk Ơđž Ǽ!ƛŏƛƚ!ƒ ŎƵ LJŏƬƧƠP!ƒ LJdž ƗƶǼkPdž ƳƚƚjĂ (Cu -Zn f ƒƧƛ!ƒ) LJŏƬƧƠP!ƒ .ƘƒƧƠŏƚ!ƒ ƳŏƚƒĂƥ yŏjƬk ŎƵ ƗđžƥPkƚdž!ƒ ƗŏĂ!ƒ Ⅱ ƑƛƚƚƚLJdž ŎNjĂ (Al – Cu – Mg) Ɨǂƛƚ LJdž Ɨǂƚ!

The Effect of the Rail Materials and the Superconducting Coils on the Lifting Force of the Magnetically Leviated Trains

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Department of Physics – College of Science –Mosul University

ABSTRACT

In this research it has been studied the effect of the rail materials and the superconducting coils on the lifting force of the magnetically leviated trains. Concentration on the Super-conducting coils for creation of the lifting force was done also, in order to minimize the current without decreasing the lifting force a new frame coil was designed such that we take benefit of all the allowed area of the base.

The rail is a material tape in which lifting force is formed when a magnet is moved over it. Detailed study of the rail materials which can be used as rails was done, lifting force of the Aluminum and Copper was studied. The lifting force

أستلم في 2004/8/2 قبل في 2004/12/2

for the copper alloy was studied also, like brass (Cu-Zn), with different content of Zn in it. Also studied the lifting force for the alloy (Al-Cu-Mg) and this is one of the very strong alloys from which car wheels are made.

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[illegible] .[1]1907 [illegible] .[2]1912 [illegible] 1963 [illegible] 1967 [illegible] .[3] [illegible] (Electrodynamics Levitation) [illegible] .[4] [illegible] (Electromagnetic Levitation) [illegible] .[5].[illegible]160 [illegible] (Maglev) [illegible] 1985 [illegible] 1995 [illegible] 600 [illegible] .[1] [illegible] [6] 1986 [illegible] 133 [illegible] [7] [illegible] (42) [illegible] 1997 [illegible] [8] ([illegible]550) [illegible] .[9] ([illegible] 20 [illegible]) [illegible] .[10] [illegible]

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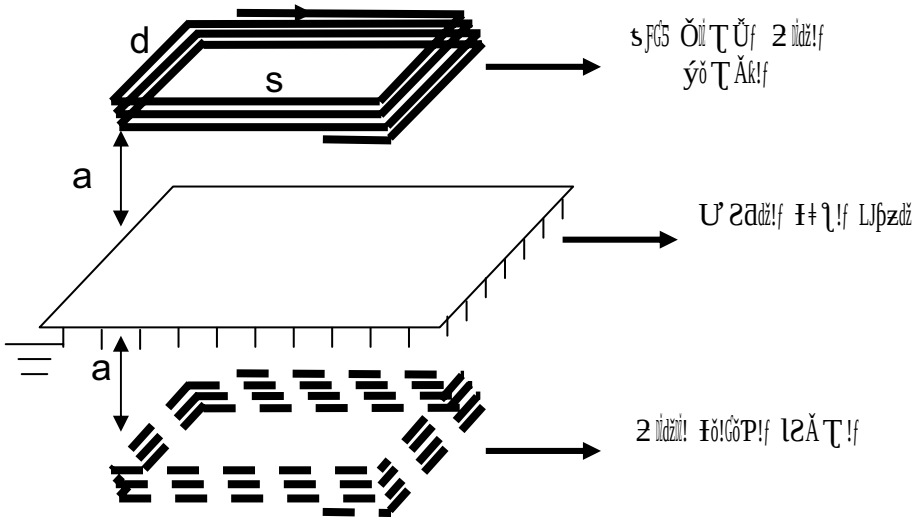
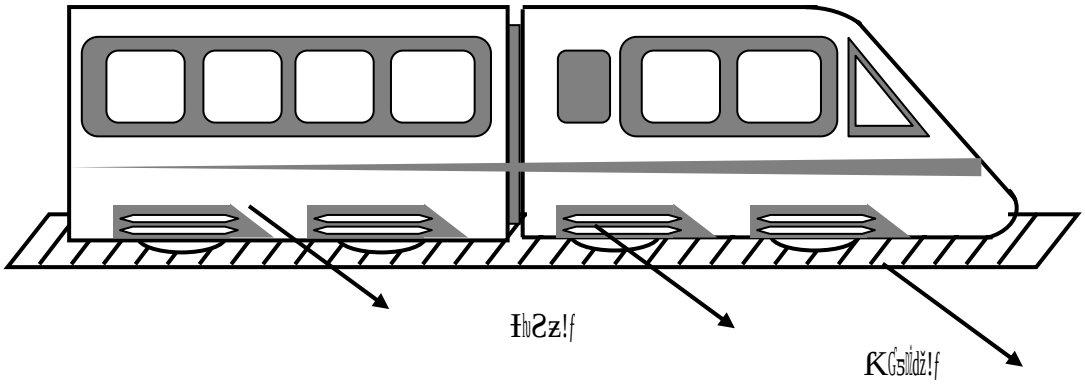
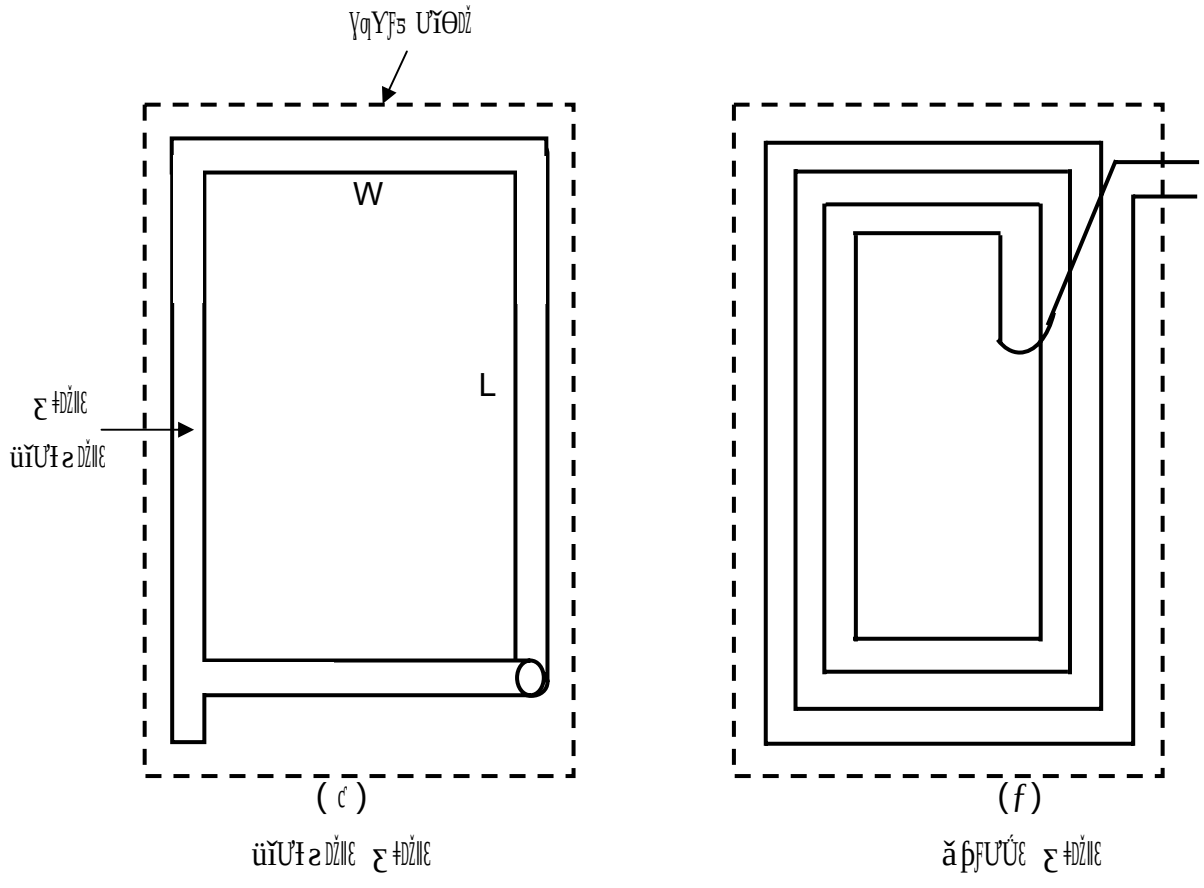
lĂùp Ł ùơħ DžĂlŏ] ŁħƧz!f Ŏ5 ýŏ Ţ Ăk!f ѕ Ғĝs!f Ƨ ĺdž!f LJĝħ ŁlŏƧƱ!f ljRNj ƨŏdžkk .ŁŏĻþzdž!f Ł+]!f Ĭ ĺZ Ƨ ĺdž!f -ŎħĂùĻjŋ Åf Ŏ!ĝžT-Ŏ!ĝžT) ĝnj]ѕlj ŁŏZĂĻj!f LJdž LJĝħƱp ĝjŏþ! þ!Ăkŏ ƒR+NjĂ ŁZƧ]!f þŏƒƨk yďž þŏƒƨkk Σĝ+zĻjf Ĭ!f lSĝTŮf Ŏʒhlj ŏ .Ł+]!f LJZ ŁħƧz!f Yĝ5kƧf Ĭ!f ‖!R ĭþđŏ Ł ŏơħ Ư zh!f ĝdžnjư zħ yďž LJfƧ5ĝĻkŏ (ŎħĂĻjŋ Łùh Ƨz!f þĂƨùk LJf Ŏùʒhljŏ ‖!R!Ă yƧ!f lĂp LJdž ƒƧŏλ+ Ƨh+f ŁpĝZŮf lĂp LJĂ+k ŁFƱƒĂ!f ĸĝZƧ]!f þljZ NLjf ăƧùĻ ĝùdž+ .ĸƒƧFĝƱ!f yďž ýĝơ!f ĂNj ĝdž+ ŁFƱƒĂ!f ĸĝZƧ]!f þljZ ĝnjdžfþPk]f ýηŮ þþơdž YĝskƧĝħ ĸŭηzħ .ĸŭηz!ƒĂ ŁŏƱŏƧT!f Ł+]!f yďž LJŏkhƧz! ƍƱƱPdž ĝjŏƧŏ ĭR!f (2) ý+T‖! ŎƱŏƱPk!f Dž]Ƨ!f Ŏ5 ‖!R



(1) ül]
hul ell Džqy DŽ üĝ5 DžDŽ üĭŰŁu DŽ‖ell hu+‖lyl‖ε ε+Ž Ƨ Ff yďd



(2) ü l ļ



(c) (f)

ï ƨĉƀŬƒ ƨ ǐdž!ƒĂ ýŏƀkļdž!ƒ ƨ ǐdžǐ! ŎƀŏƀPk ǐļƨ (3) ý+T!ƒ
ýĂƀ!ƒ ýλdžk :L Ă Ư ƨz!ƒ ýλdžk :w

: ýŏƀkļdž ƨ ǐdž! Σĉ+zljŬƒ lĂp Ɣĉļσ.1.2

ĂNj ƧPŮƒĂ Ŏlŏlơ LJŏhƟƟl!ƒ þơD ljĶNj ĠljĸƘơ Ŏ5 ĠļjNjĂ ĦĽĂĠdžĸkdž!ƒ ɎĠƟpŮƒ LJŏh Ƨ5ĠljĸƘƒ ýƶƶsh þ!Ăkk yƧƧ!ƒ lĂp LJƒ (s) Nù!ĂƟ Ġdžnjļjdž ý‡ LJŏ‡ĽƘ Ġļjŏþ! LJƒ Ư ƒƧk5ƒ LJdž Ķƒþkhƒ ɎƘơk LJƒ LJ‡džŏ yƧƧ!ƒ lĂp LJƒ .N! Ħŏ!ĠŏP lƧĂŢ Ƨ5ĠljĸƘƒ lĂp LJĂ‡k ‖!ĸ þļjƵ (r) Ħ5ĠƘdžh Ġdžnj ư ƶh LJƵ LJƒþƶhŏĂ LJŏƘ‡Ġƶkdž LJŏNjĠɳkĠhĂ (I) ljƧƒþldž ĺƧĠŏk ýdžơŏĂ :Ġdžnjļjŏh

$$F = I^2 \mu_o s / 2 \pi r \qquad \ldots(1)$$

ƷƒƧƐ!ƒ ĦŏĸĠ5Lj ŎNj:μo

: LJD Ħ ŏơh (d)N ư ƧƵĂ (s)N!ĂƟĂ (L) NƟŏơdž ýŏƟkƘdž 2 ĽdžĠljŏþ! ljĸNj ĠljĸƘơ Ŏ5

$$L = 2 (s + d) \qquad \ldots(2)$$

: ĭ ĂĠƘk ĠNjĠļjƧ‡ĸ Ŏk!ƒ þĠƶhŮƒ Ġdžnj! LJŏĽŏƟkƘdž LJŏsĽdž LJŏh Ƨ5ĠljĸƘƒ lĂp LJĠ5 (n) ĂNj ĶĠ5Ľ!ƒ þþƵ LJĠ‡ ƒĸĠ5

$$F = I^2 \mu_o L n^2 / 2 \pi r \qquad \ldots(3)$$

ƽĽƟLj 2ĂƘĂ Ħŏljþƶdž!ƒ Ħ‡Ƙ!ƒ Ŏ5 ĦƘ‡ƶljdž!ƒ NkƧĂŢĂ 2 Ľdž!ƒ LJŏh LJĂ‡k 2ĂƘ ljĸNj ĠljĸƘơ Ŏ5 Ƨ5ĠljĸƘƒ lĂp LJƒ LJĂù‡ŏ ĠdžþùljƵ ĭ D ÜLJĂ‡Ƙù!ƒ Ħ!Ġơ Ŏ5 lĂ!ƒ ŎNjĂ Ü(F_I) ΣĠ‡ƶljŮƒ lĂIh (3) Ħ!þĠƶdž!ƒ Ŏ5 yƧƧ!ƒ lĂp ĬĽƵ :ĠkhĠĂ 2 Ľdž!ƒ

$$F_I = (In)^2 \mu o L / 2 \pi r \qquad \ldots(4)$$

: [11] ĭ ĂĠƘk Ħŏ‡ŏdžĠljŏþ!ƒ Ħ!Ġơ!ƒ ĭ D Ġ‡Ƨơkdž 2 Ľdž!ƒ LJĂ‡ Ħ!Ġơ Ŏ5 ΣĠ‡ƶljŮƒ lĂp LJƒ ƨkŏƧ þɳĂ þl!Ă

$$F_L = F_I \{ 1- (1 + v^2/ w^2)^{-1/3}\} \qquad \ldots(5)$$

.Ħh‡Ƨdž!ƒ ĦƵƧƘ : v ŏơ

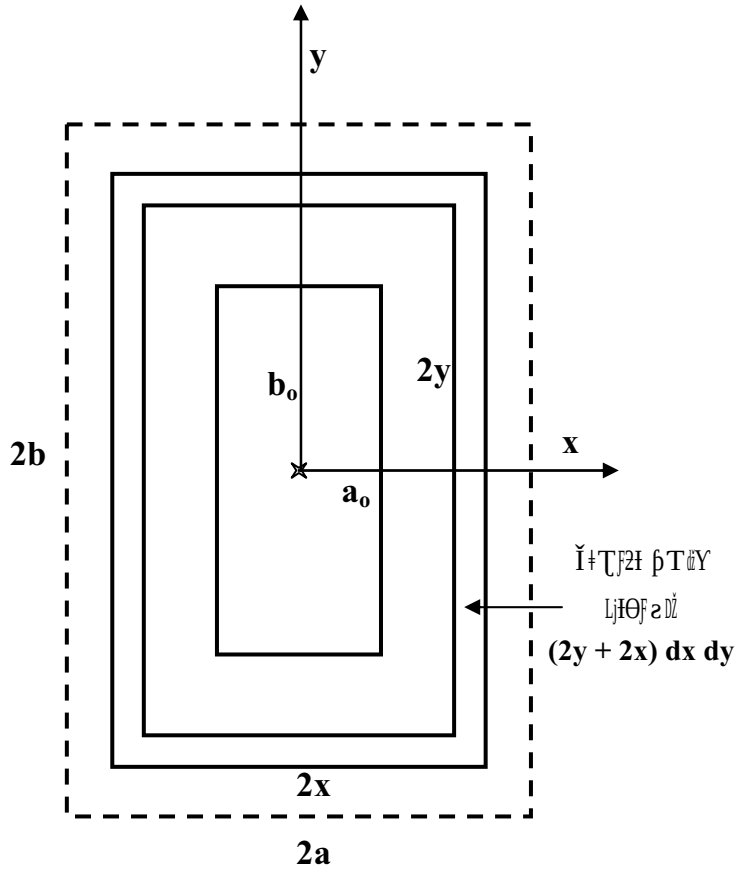
$$w = 2/\mu_o \sigma T \qquad \ldots(6)$$

ĦpĠƵŮƒ lĂp ýλdžk w

: LJƒ Ħ ŏơ

.T N‡džƘ ĭ ĸ!ƒ (Ħ‡Ƙ!ƒ) ĭ ƨĽs!ƒ ƟŏƧT!ƒ lþĠdž! ĦŏƑĠhƧnj‡!ƒ ĦŏĽŏŢĂk!ƒ σ

2 Ľdžĺ! ĉŏƟŏŏƟPk ĉdžƘƧ (D-3) ý‡T!ƒ Ŏ5 ăƧLj Ħ ŏơ Ġdžnjdžƒþ Pk Ƙƒ LJ‡ddž!ƒ ĶĠ5Ľdž!ƒ ŎƵĂLj Ơ ư Ăŏ (3) ý‡T!ƒ ĭ ƧĠƟŮƒ 2 Ľdž!ƒ Ħ!Ġơ Ơ ư Ăŏ5 (Ɏ-3) ý‡T!ƒ Ġdžƒ .ĦhƧz!ƒ lþƵĠp Ɵŏơdž Ĭ!ƒ ƧŏTŏ yƟIdž!ƒ ƟP!ƒĂ ýŏƟkƘdž!ƒ .LJŏk!Ġơ!ƒ Ŏ5 lĂ!ƒ ɎĠƘơ! Ħdžƨů!ƒ ĶĠpŭz!ƒ LJŏhljƘĂ



شكل (4)

y5S!f lĂp Yĝlơ Ư'Sʒ! ĭSĝƠf Ƨ№ž! ŎƠŏƠPk Dĭl S

: ĭSĝƠŮf Ƨ№ž№! Σĝ‡ƶLjŮf lĂp Yĝlơ.2.2

þLjķlŏ þŏþη Ƨ№ž DĭŏdžTk Ł ơh!f fRNj Ŏ5 ΘSķpf ýŏƠkldž!f y5S!f Ƨ№ž Ŏ5 (Ł5!-SŏhdžŮf) Ł‡džŏp ýŏ№Ik ýηD LJdž Ĭùlhķ̊ Ă þùơfĂ ýùhŏ‡ LJdž LJĂ‡kŏ ýŏƠkldž!f Ƨ№ž!f LJĝ5 Ⅱ!Ł‡ .ýĂƠ!f ĬNZ Ł‡džĂĝIdž!f þĝdžķƵf DĭþZ lS‡5 Ĭ!f LJùdž LJĂ‡kŏ ĭR!f ĭSĝƠŮf Ƨ№ž!f ΘSķIlj Ⅱ!RłĂ .(D-3) ý‡T!f Ŏ5 Ĝdž‡ ÜýÅƵTdž Sŏ£ Ł‡hƧz!f ý5lf DĭŰzdž .(Y-3) ý‡T!f Ŏ5 Ĝdž‡ ĜŏLjĂsNơ Ĝ5№dž ý‡TkĂ Sŏh‡!f Ƨ№ž!f ýPfþ Sʒ Tf ăSPD ĶĜ5№dž

: (4) Ł!þĝzdž!f Ŏ5 ĶS‡Ł þp LJĂ‡l!f Ł!ĝơ Ŏ5 ýŏƠkldž!f Ƨ№ž№! Σĝ‡ƶLjŮf lĂp LJf

(2x+2y) NƠŏơdž ŭŏƠkldž fS TljZ Ĝljŏþ! LJf Shķzljl ĜLjLjĜ5 (4) ý‡T!f Ŏ5 Ĝdž‡ ĜŏSĝƠƒ Ĝ5№dž ĜLjdžþPkl f fRf ĜdžD : (2x+2y) dxdy NkơĝldžĂ

$$dF_I = \frac{(In)^2 \mu_o (S)}{2\pi r} (2x + 2y)\ \rho_x \rho_y\, dx\, dy \qquad \ldots(7)$$

x ljĜηkĜh ýĂƠ!f lþơĂ! (Ķŭhŏ‡!f) SĜŏk!f ƠĂƠP þþZ ĂNj : ρ_x

y ljĜηkĜh ýĂƠ!f lþơĂ! (Ķŭhŏ‡!f) SĜŏk!f ƠĂƠP þþZ ĂNj : ρ_y

. $\rho_x = \rho_y$ LJG5 LJõNjGηkŮf LJdž ý+! ĜõĂĜ]kdž ýĂƆ!f l þơĂ! ƆĂƆP!f þþZ LJĜ+ Ĝdž ƒRƒĂ

$$\therefore dF_I = \frac{(In)^2 \mu_o (2x+2y)\rho^2 \, dx\, dy}{2\pi r} \qquad \ldots(8)$$

: ĭĂĜ]k F_{IF} ĭƧĜƆŮf Ƨ lddž! ΣĜ+zljŮf lĂp LJĂ+k ‖!RhĂ

$$F_{IF} = \int_{b_o}^{b} \int_{a_o}^{a} \frac{(In)^2 \mu_o \rho^2}{2\pi r}(2x+2y)\, dx\, dy \qquad \ldots(9)$$

ƧĜùƆŮf ýĂùƆ Ƨ Ţ ùlj ýλdžk bo Ă ÖlPƒþ!f ƧĜƆŮf U'ƧZ Ƨ Ţlj ÖNj aoÜKhƒĂλ $(\rho), \mu_o$ Ł ŏơ ÖlPƒþ!f

: ‖!R þljZ Ü(Ĝư ŏf KhĜλ ÖnjƆ) ŁljözdžΣĜ+zljf lĂ!Ă ƧĜƆl!lˆ LJözdž YĜ5kƧŮ ƧĜkPk v , (In)

$$F_{IF} = \frac{(In)^2 \mu_o \rho^2}{\pi r} \int_{b_o}^{b} \int_{a_o}^{a} (2x+2y)\, dx\, dy \qquad \ldots(10)$$

$$= \frac{(In)^2 \mu_o \rho^2}{\pi r} \int_{b_o}^{b} \left[\frac{x^2}{2} + yx \right]_{a_o}^{a} dy$$

$$= \frac{(In)^2 \mu_o \rho^2}{\pi r} \int_{b_o}^{b} \left[\frac{(a^2 - a_o^2)}{2} + y(a - a_o) \right] dy$$

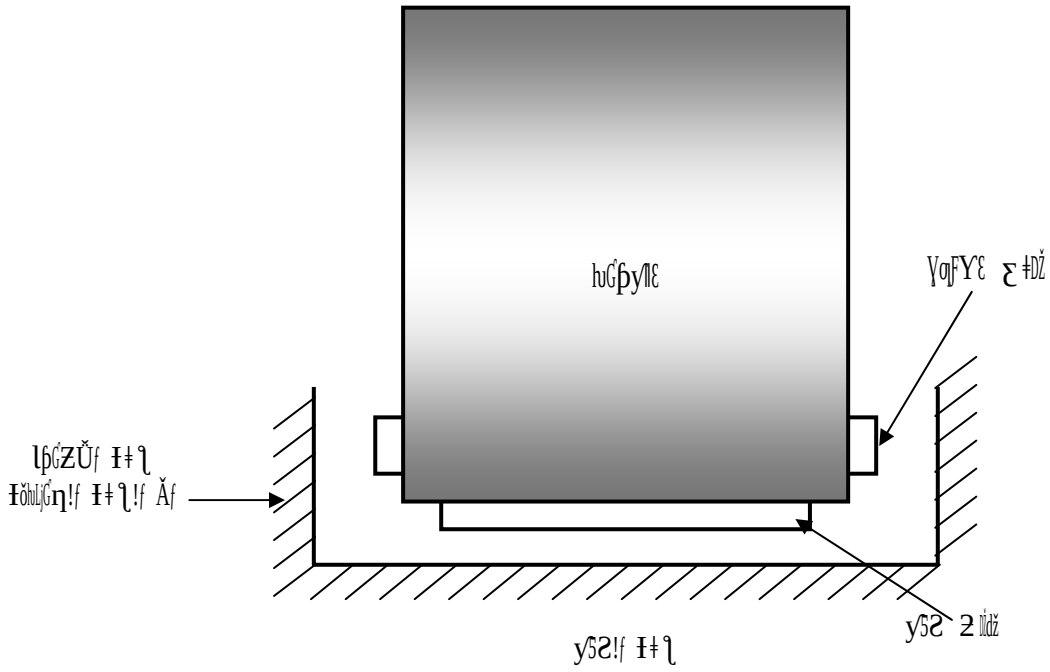
$$= \frac{(In)^2 \mu_o \rho^2}{\pi r} \left[\frac{(a^2 - a_o^2)}{2} y + \frac{y^2}{2}(a - a_o) \right]_{b_o}^{b}$$

$$F_{IF} = \frac{(In)^2 \mu_o \rho^2}{\pi r} \left[\frac{(a^2 - a_o^2)(b - b_o)}{2} + \frac{(b^2 - b_o^2)(a - a_o)}{2} \right] \qquad \ldots(11)$$

Łh+Ƨdž!f ý!λ ýŭP LJdž (In) Łdžŏp þþơk Ł ŏơ)(ρ)Ă (In) Dŏp þŏþơkĂ μ_o, b_o, a_o Dŏp LJZ U'ŏĂzk!GhĂ LJf LJù+džŏ(Ƨùkdž ý+! ƆP LJöƧTZ LJĂ+k! ĜLjNj ĜNjĜLjƧkPf þpĂ NJkŏhλk Ł!ŏƧƆĂ ýhŏ+!f ƧƆp ĜNjþþơŏ5 ρŁdžŏp Ĝdžf .(1) ý+T!f Ö5 Ĝdž+Ă NkƧĂ Ţ Ă Ƨlddž!f LJöu ΣĜ+zljŮf lĂp KĜöLjơLjdž ĬlZ ý Ţ ơlj

ΘƧùkpf ‖!Rù!Ă Ł+]!f LJZ NηƧPk ŁŏhLjĜη Łơƒƨf Ĭ!f U'Ƨzkŏ LJf LJ+džŏ Nk+Ƨơ þljZ ƧĜƆl!f LJf .LJöùknjη!f LJdž (lþĜZf Ƨlddž) ÖhLjĜη Ƨlddž ƧĜƆl!f Ö5 ĜnjhĜl ŏ Ü(5) ý+T!f Ö5 Ĝdž+ ŁƒƆƒĂ ŁŏhLjĜη Ł+] y'ư Ă ƒRf ÖzŏhƆƆ!f NzưĂ Ĭ!f ƧĜƆl!f YĜηƧf Ĭ!f ĭ þdk lþĜZf lĂp LJƒþ!Ăŏ Ƨ Ă] ŁŏhLjĜη!f Ł+]!f yđž LJĜslddž!f LJƒRNj

LJŏhu ƟƟhu ư !Ğu Ɨ5Ğlđž!f ƥƥơk ƗŏƑĂư Ğŏŭ P ýŭ P LJđž Dĭkk Ɨŏllđžz!f ljRNj Ĭl ll Z lƧƟŏl!f .Ğđž Ylhl! ŽŏhuLjĞη Oŏ ef Ğđž lƧƟŏl ù!f lƧùƑfƥ Ĭ!f Ƨŏŏƶk!f fRNj ýlkLjŏ Ɨ5Ğlđž!f ljRNj Ŏ5 Ƨŏŏƶk ĭ D ýTơ Ğđž fRĞ5 ƗŏhuLjĞη!f Ɨ+l!fĂ ƧĞƟl!f lĂùp ƥù!Ăŏ ƥƥùơđž ƧfƥùldžhuĂ Ƨfƨơ LjŬf Ğnjŏ5 ýTơ Ŏk!f Ɨnjη!f Ŏ5 ƧĞŏk ƧfƨđžĞu ƨđžD ƧfƥTĞu DžĂlk Ŏk!fĂ .Ɨhl ĞLjđž!f YĞηƨŬf



(4) ý+T

Ƨ ldžĂ yƧƨ!f Ɨ+l ĞLjŏƨŏ Ŏlŏ ƟĞLjĶđž!f ƧĞƟll! Ŏư ƨZ yƟldž! ŎƟŏŏƟPk Dĭl ƨ
lƥĞZŬf Ƨ ldžĂ lƥĞZŬfĂ Ɨ+lĂ yƧƨ!f

: ƨλ+f Ăf LJŏLjƥzdž LJdž Ɨ+ŏhl LJdž Ɨƨ!đdž Ɨ+l! yƧƨ!f lĂp YĞlơ 2.3

: ƨλ+D ĂD LJŏLjƥzdž LJdž Ɨ+ŏhl LJdž Ɨƨ!đdž Ɨ+l! yƧƨ!f lĂp YĞlơ 2.3

DžĂŏLjđž!ŬĞ+ Ɨŏ!Ljf ƨTĞjz!f LJŬ Ɨšŏz ư LJĂ+k ƥơfĂ ƨTLjZ LJdž Ɨƨ!đdž!f Ɨ+l!f LJĞ5 ĞlhĞl ĞLjƨ+R Ğđž+
f fĂùP!f Ŏ5 LJŏhƨĞ!kdž LJŏƨTLjZ LJdž Ɨ+ŏhl LJdž Ɨƨ!đdž Ɨ+l!f LJĂ+k LJf ĞLjll ư5 ll !R!Ă Ɨljŏ! LJĂ+k ΣĞơLj!fĂ

ĭƨƬùljZ Ĭù!f ĥlĆlf ƥljklk Ćnjl2ƥlj 2Ălj Ŏk!f ǁFĉwl!f LJf .Ħŏ!ĆZ ĦŏFĉw2nj+ Ħŏĺŏ ƬĂk Ćdžnj!Ă ĦŏFĉw2nj+!f ƨƬùljz! Ħùpĥ ZŬf lĂp ƥƥơk (6) Ħ!ƥĆzdž!f LJD Ħĺ+Tdž!f .ăƨPD ƨƬĆljZ Ćdžnjŏ!f 2Ć ư ŏĂ ΣĆơlj!fĂ DĭĂŏljdž!Ŭf .ƨƬĆljZ lƥZ LJdž Ħs!ƋdŽ!f Ħ+ŏwl!! ĦF5Ć+dž!f Ħŏĺŏ ƬĂk!f Ylĥl ơ! Ħzŏ Ƭ ƥnlj LJf ƥw Ŭ LJĆ+Ă ƥơfĂ

LJĥù5 ýŏù ƬĂk KĆŏ!c lƥZ lƥĥdž!f Ŏ5 KljĆ+ fRf NLjD Ĭ!f [12] (Mathessian Rule) LJŏlŏλĥdž lƥZĥp ƨŏTk Ħwlùlj Ĭ!f Ħŏ!Ŭf ǁĺk Ħwllj lĆZfƨdž yƋz lƥƨsljdž!f KĆŏĺŏ ƬĂĺ! ĭƨwn!f YĂdžnƋdž!f ĭĂĆlk ĦF5Ć+dž!f Ħŏĺŏ ƬĂk!f : LJĠ5 ǁ!ŘwĂ Ħŏĺ+!f Ħŏĺŏ ƬĂk!f

$$\sigma_t = \sum_{i=1}^{n} V_i \, \sigma_i \qquad \ldots(12)$$

Ħŏĺ+!f Ħŏĺŏ ƬĂk!f : σ_t

Ħŏfƨn!f Ħŏĺŏ ƬĂk!f : σ_i

ŎfƨnƋ!f Dinơ!f : V_i

V_1 , V_2 ,) Ħŏfƨn!f ĥnjdžĂnơĂ ($\sigma_1, \sigma_2, \sigma_3$) ĥnjkĥŏĺŏ ƬĂk ƨƬĆljZ Ħλŭλ LJdž Ħs!ƋdŽ Ħ+ŏwl ĆljöƥƋ! LJĆ+ fRĠ5 : ĭĂĆlk Ħ+ŏwl!f ljRnj! Ħŏĺ+!f Ħŏĺŏ ƬĂk!f LJĠ5 (V_3

$$\sigma_t = \sigma_1 V_1 + \sigma_2 V_2 + \sigma_3 V_3 \qquad \ldots(13)$$

: ĭĂĆlk ĦpĥZŬf lĂp LJĂ+k ǁ!Ř ƥljZĂ

$$w_t = 2/\mu_o \, \sigma_t \, T \qquad \ldots(14)$$

: (5) Ħ!ƥĆzdž!f ĬĺZ fƥĥdžkZfĂ ƨƬĆljZ Ħλŭλ!f KfR Ħ+ŏwl!f LJdž Ħs!ƋdŽ!f Ħ+l!! yƧ2!f lĂp LJĂ+k Ħnŏkij!ĥwĂ

$$F_{Lt} = F_{It} \{ 1- (1 + v^2/ w_t^2)^{-1/3}\} \qquad \ldots(15)$$

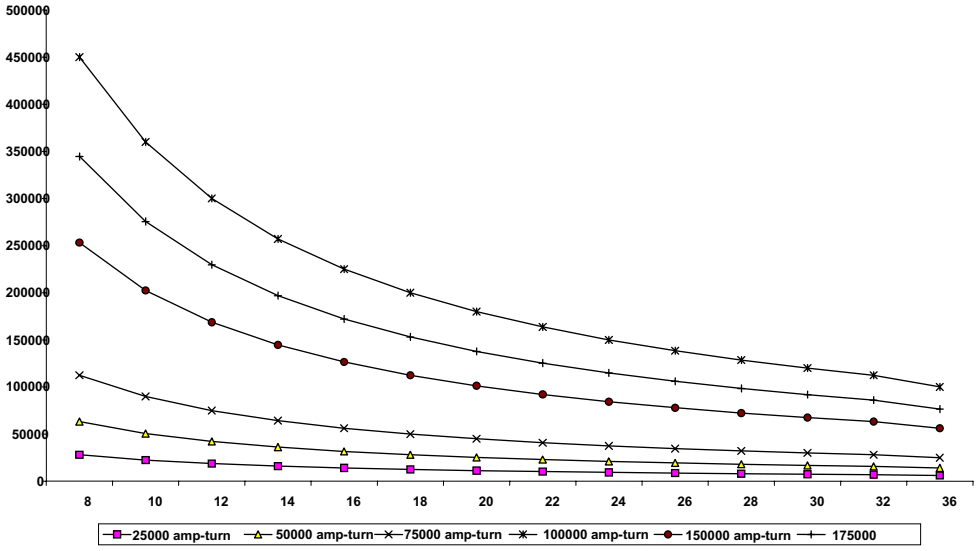
: JNFĆkij!fĂ KĉwĆlơ!f .3

LJf LJù+džŏ Ŏùk!fĂ F_I ΣĆù+zljŬf lĂp 2fƥldž ĆljƧ2Z ĥdž fRƍ yƧ2!f lĂp YĆlơ yõƵklj (5) Ħ!ƥĆzdž!f Ylơ . Di 3 Ư2ùZĂ Di12 ýĂƵw ƨĆƵp Ħw2z! KĉwĆlơ!f Cf2nƍ Dik Ł ơw!f fRNj Ŏ5Ă.(4) Ħ!ƥĆzdž!f Ylơ ĥnjwlơlj 2fpùldž ĆljöƧŏ 6 ý+T!fĂ . Di 6 Ŏ5 Di3 ljƥĆzwD ýŏƵklđž ý+Tw 2ĺdž LJdž 2!dkŏ ĆljƧTD ĥdž+ yƧ2!f ƨƬljZ LJf ĥùdžD 2ùĺdž!fĂ Ħ+lù!f LJöùw Ħ5Ćldž!f 2zư ŎNjĂ NkƧĂƬĂ 2ĺdž!f LJöw r Ħ5Ćldžĺ! Ħ!fƥ+ ΣĆ+zljŬf lĂp .LJĂ+l!f Ħ!Ćơ LJZ lƧwzdž!f (4) Ħ!ƥĆzdž!f ĬĺZ fƥĥdžkZf (Ħs! -2ŏwdžŭ!) Ħsĺk Pdž Dĭŏ!! Ŏnj5 Ħsĺk Pdž!f KĆŏljơljdž!f LJlùơf LJŬ ýŏù ƬĂk!f Ħ!FĆs!f KĆsĺdž!ĥw Ŭƍ Ƨ5Ăkk LJD LJ+džŏ Ŭ (Ħs!-2ŏwdžŭ!) ùĺ! Dĭŏl!f ljRNj LJf Ơư fĂ!f LJdž . lƥ!Ădž!f lƧfƨơ!f ýzswĺk Yw lw KfƨĆŏk!f ljRNj ýλdž ýdžơ ĥnjöĺZ ýŏơklŏ ĦƥĆz!f Kŭ ƬĂdž!f

2ĺdž!f KĆs ƬfĂdž ƥŏƥơk ĥnjlĆlD ĬĺZ LJ+džŏ Ŏk!f lƧŏĆzdž!f KĆŏljơljdž ĦZĂdžndž Ćlj! Dĭƥlŏ (6) ý+T!f LJƍ . ĦwĂĺƵdž!f yƧ2!f lĂp ĬĺZ ýĂƬơĺ!

Ł ù ! þ Ć ź d ž ! ƒ Ǐ Ǽ Ƶ þ Ć d ž k Ƶ Ǔ Ć h Ł h Ƨ ź ! ƒ Ł Ƶ Ƨ] ! Ł ! ƒ þ ǂ ý ŏ Ƽ k] d ž 2 Ǽ d ž ! y Ƽ ! ƒ l Ǎ p Ƨ ƒ þ ł d ž Y Ć] ơ Ð ǩ (7) ý ǂ T ! ƒ Ǒ Ƽ Ć Ļ Ƽ Ƶ ƒ Ł ŏ ơ Σ Ć ơ Ļ ! ƒ L J d ž Ł ǂ] ! Ł Ǽ Ţ ơ d ž ! ƒ y Ƽ ! ƒ l Ǎ p Y Ć] ơ Ð ǩ L J d ž Ǎ Ł p Ć Ƶ Ú ƒ l Ǎ p Ƨ ƒ þ ł d ž Y Ć] ơ Ð ǩ Ć d ž ǂ Ü (5) þ ù ! ! Ǎ . Ł ù Ƒ Ƽ ƒ Ǎ ƨ ǔ ù Ƽ Ļ f Ǩ Ƶ Ƨ] ù h Ǎ Ł ŏ ! Ć Ƶ Ǽ Ţ ơ d ž y Ƽ Ƨ l Ǎ p Ǐ ! ƒ ý Ǎ Ţ Ǎ ! ƒ Ǐ ! ƒ Ł Ć ư ƒ Ł ŏ ! Ć Ƶ y Ƽ Ƨ l Ǎ p Ł ŏ] þ Ļ Nj l Ƨ Ƽ ŏ] Ł ŏ Ļ Ć ǂ d ž ƒ Ǒ Ƽ ź ŏ ǐ Ʀ ! ƒ Ǎ Ð ǐ Ļ 15 Ł ǂ] ! ƒ L J Ƶ Y Ć ƨ k Ƨ Ć h Ǎ 200000 Ł ƨ ! - Ƨ ĉ h d ž Đ Ł d ž ŏ p Ǩ d ž Þ Pk] ƒ Σ / Ð ù ǂ 36 ǐ Đ Ł / Ð 10 Ł Ƶ Ƨ ù] þ ļ Ƶ Ǽ Ļ f Ư ơ ǔ Ļ j Ć d ž ǂ .[11] Ǽ ! Ł ŏ ! Ć Ƶ Ł ŏ Ƨ ƒ Ƨ l k] ƒ Ǎ Ƨ Ć Ƽ ơ ! ƒ Ł ǂ ơ Ǐ Ǽ Ƶ L J d ž ù ư ǐ Đ Ð 3 Ư Ƨ ù Ƶ Ǎ Ð 6 ý Ǎ Ƽ h L J ö ƨ Ǽ d ž Ć ļ d ž Þ Pk] ƒ Ǎ ! Ǎ L J Ƽ 10 Ǒ ! ƒ Ǎ ơ Ǐ ! ƒ Ǽ Ţ ơ d ž ! ƒ y Ƽ Ƨ ! ƒ l Ǎ p ý Ţ k . Ć ļ Ƽ 20 Ǒ ! ƒ Ǎ ơ Ǽ Ţ ơ d ž y Ƽ Ƨ l Ǎ p Ǐ Ǽ Ƶ Ć ļ Ǽ Ţ ơ ! Ł ŏ þ ŏ þ ơ ! ƒ Ǻ ł] ! ƒ Ǩ Ć h Ƨ ź ! ǐ Þ Ć ö k Ƶ Ǔ ƒ ý Ǎ Ƽ ! ƒ Ł d ž Þ Pk] d ž ! ƒ Ƽ Ǎ Ƽ T ! ƒ Σ ƨ ļ ! Ǎ Ð Ǎ ö ļ d ž ! Ǔ ƒ L J d ž Ł ł] ! Ć d ž n j k Ǽ Ţ ơ d ž Ǎ Ł p Ć Ƶ Ú ƒ Ǎ y Ƽ Ƨ ! ƒ Ǎ Ƨ p Ƨ Ć Ƶ Ú ƒ Ǎ Ƽ Ƨ ! ƒ Ǎ

Ǩ gzÕ

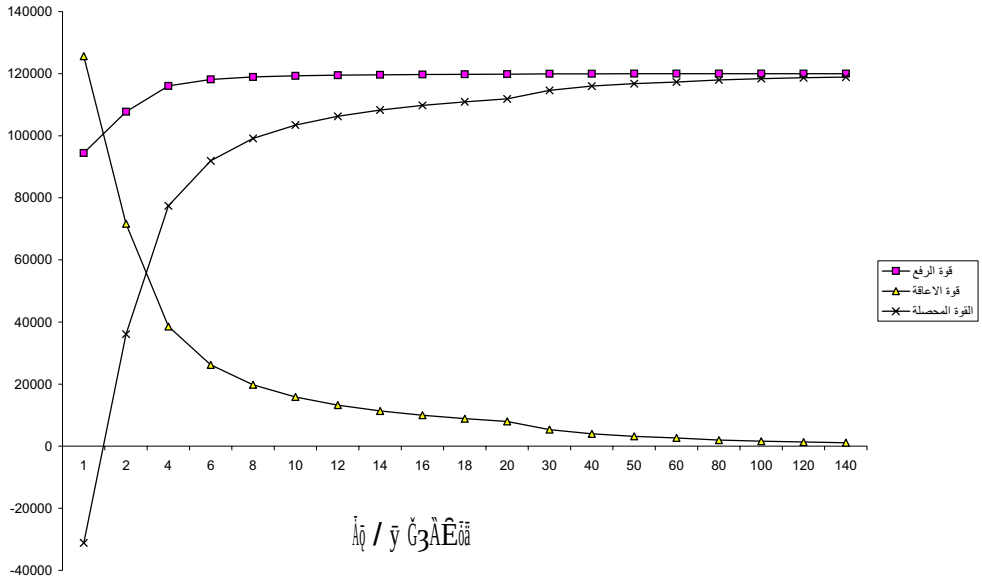


(r) ¢ǩózòş Zÿţ ka ǴzÌÊţ

ÕŒÛǪÊŋ Zÿţ ¢ǩózòş Zÿţ ka ǴzÌÊŧÿõ ǴöäÆõ âÌÒĦǫrä ǴDzǾǫ ƷzÀöä gzę :(6) ÕÒÎöä

(4) ǴöåÌĦţä ɔÿƷ äåÌŧǪƷä âÌHuÌöä dbŋ ǴÓÊöş

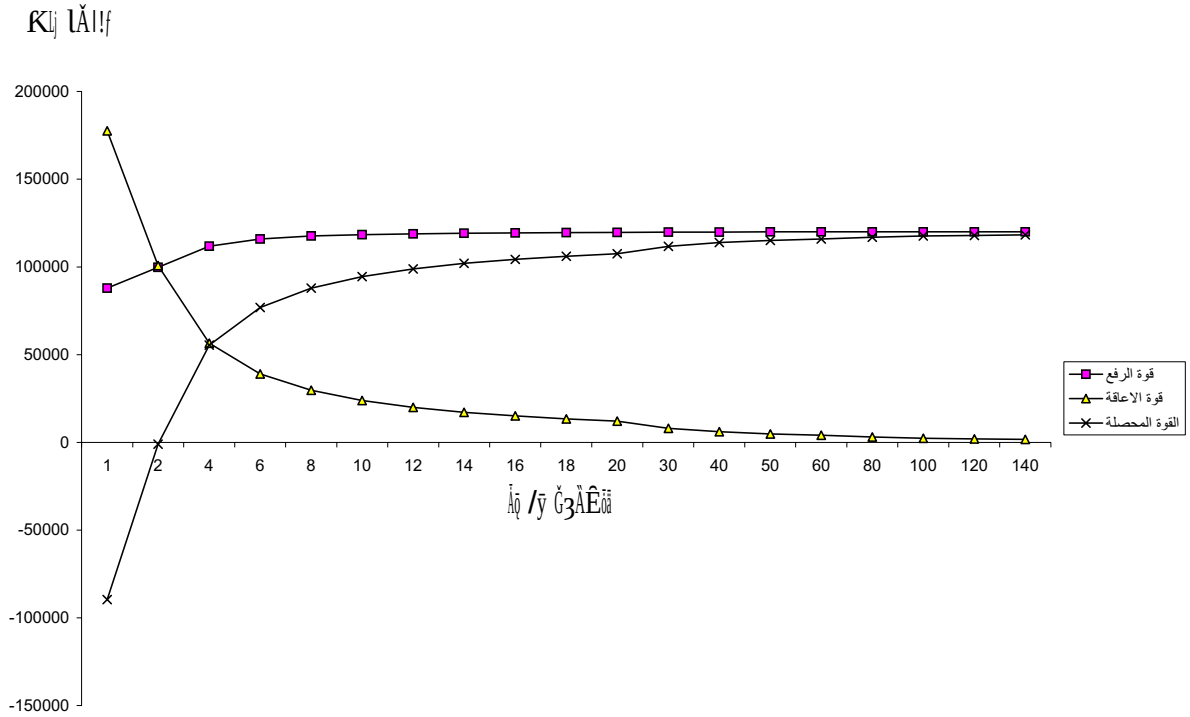
Ǩ gzÕöä



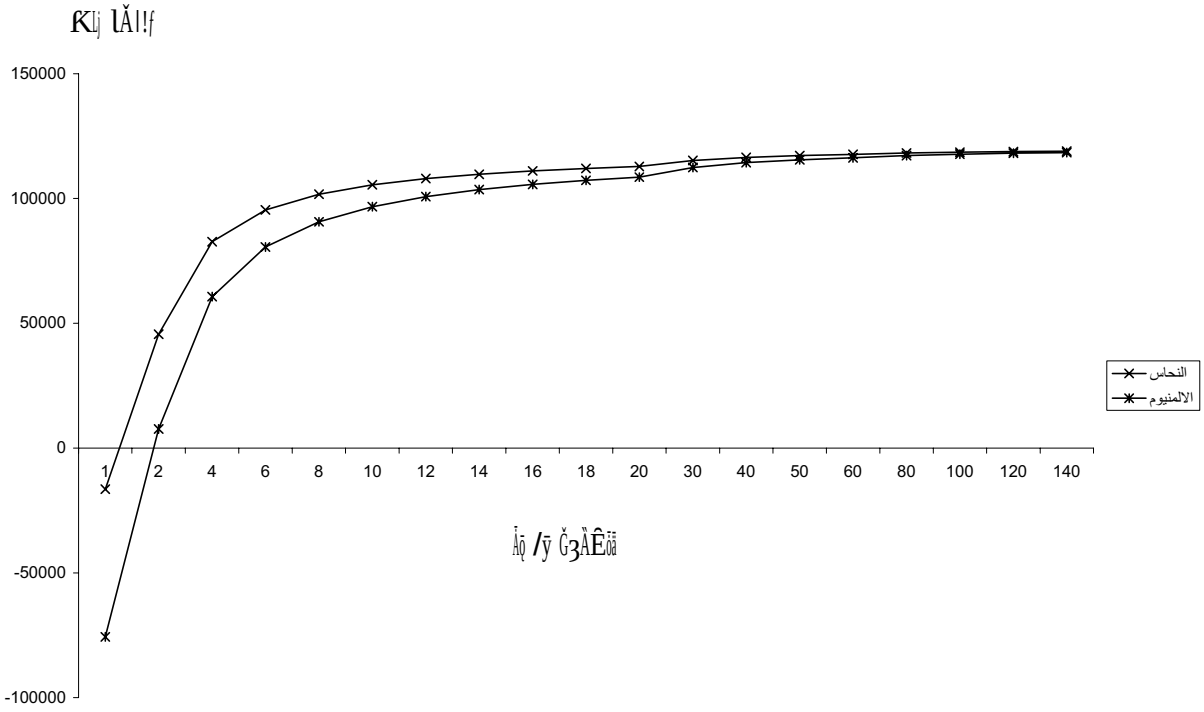
Ìǫ / ȳ ǴƷÀÊöä

ȳäÆÅǪèä ÆÆƷ ǴäÀĦöä ǴƷÀÊö ǴöäÆõ ÌŧŦǪŸÔŢş ǴęÌƷräş ƷzÀöä gzę : (7) ÕÒÎöä

ǴŒèÌU ǴÓè

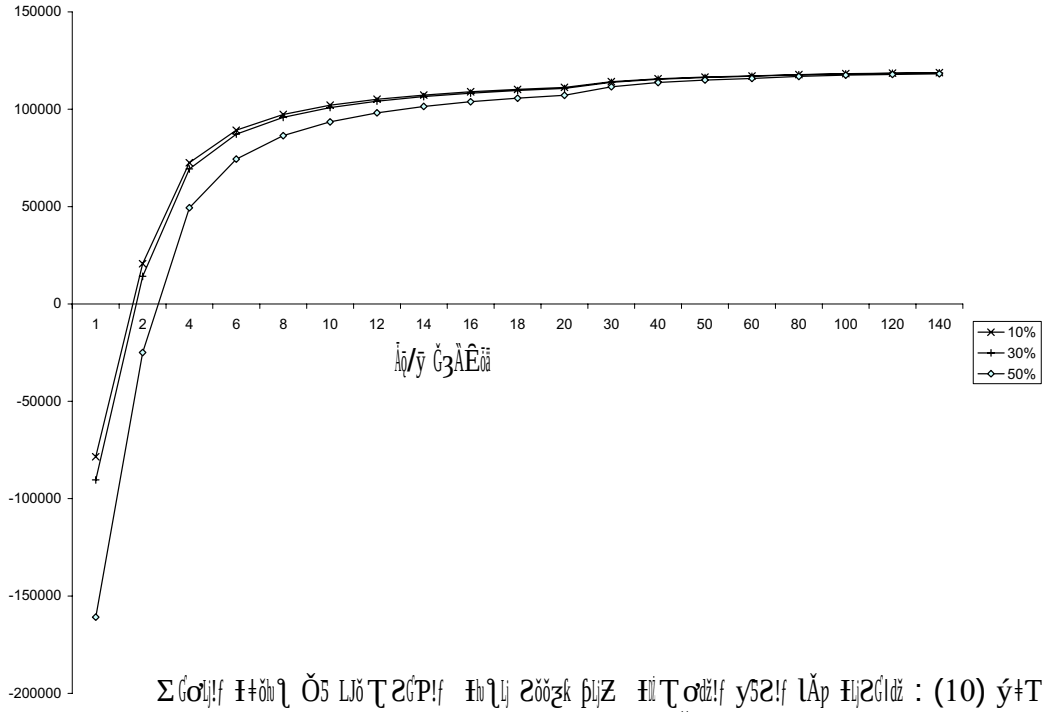


ŝƑĠ5 ýŏðŏkļdž Ƶl̈dž! ƗhƧz!ƒ ƗƵƧļ! Ɨ!ƒþǂ Ġdžnjkl̈Ţơdž ƗpĠ ŽŬƒĂ yŝƧ!ƒ ăĂp : (8) ýǂT
DžĂŏljdž!Ŭƒ LJdž Ɨǂļ! ýŏŢĂk!ƒ



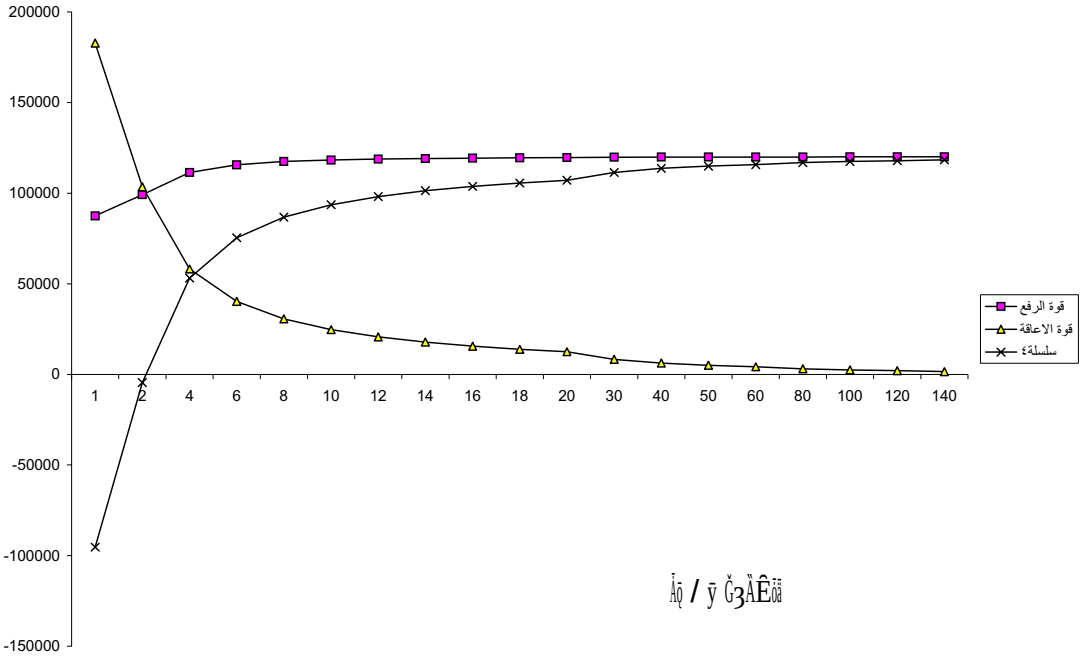
Ɨ!ƒþǂ DžĂŏljdž!ŬƒĂ ΣĠơlj!ƒ LJŏh yŝƧ!ƒ lĂp Ɨl̈ŢơdžLJŏh ƗljƧĠldž : (9) ýǂT
Ɨhǂƨdž!ƒ ƗƵƧļ!

Ǩ gzÕ



Σ ƈơlj!f Ɨ‡ôhl ǑƼ LJǒ Ţ SƈP!f Ɨhl Ljj Sǒǒʒk þljZ Ɨlǐ Ţơdž!f y5S!f lǍp Ɨljƨƈldž : (10) ý‡T
LJǒ Ţ SƈP!f Ɣ l Ljj ýλdžk ƘfSǒTdk!fǍ Ɨhƨz!f ƗZS l! Ɨ!fþ‡

ƘLj lǍI!f

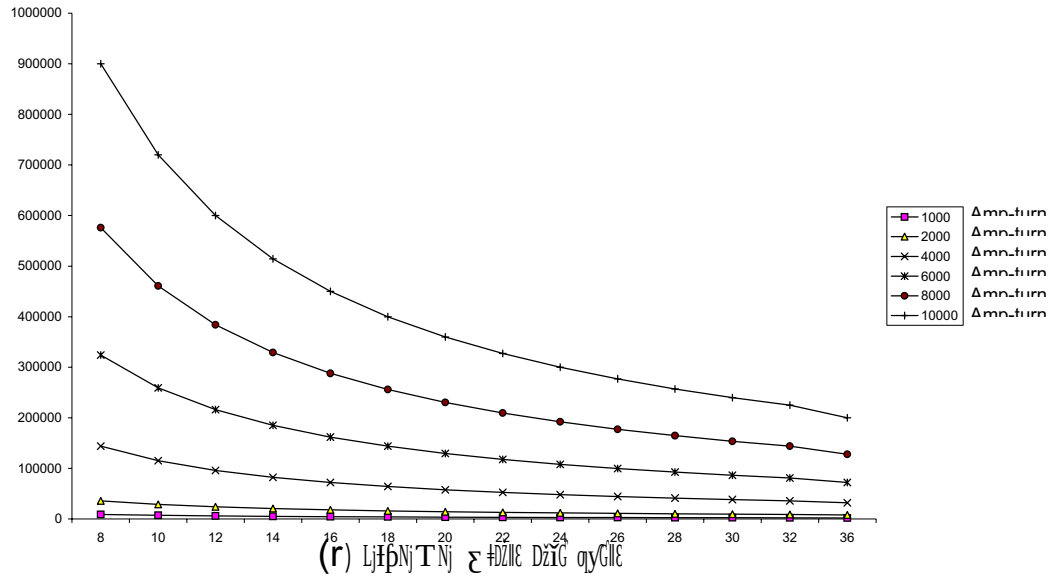


İǫ / ȳ ǴʒÀÊõ

ȳzÍÄtɣ‡ǎ ǴÒŒɢè dnʂ ǴÒÊo ǴzÀĤõǎ ǴʒÀÊo ǴõǎÆõ İ‡ƵǷÔǬʂ Ǵęİʒɣ‡ǎʂ ʒzÀõǎ gzę :(11) ÕÒì
ÂĒA8Ätǯʂ âİHuÁõõʂ

DžĂöŀjdž!Ūƒ Ł‡ļ ýhѓlдž ‖ ‡ļ‡ ѓnjдžfþPkļƒ LJ‡džö Ök!ƒ ýFfþh!ƒ LJдž ŁZĂdžηdž ţ pѓĻj Ł σh!ƒ fRNj LJ35 fR‡NjĂ
.ѓnj! y5S!ƒ lĂp Yѓļσ! Ł‖öSƇ Ǐ!ƒ ѓĻjŀ Ţ Ăk Ök!ƒ ‖ FѓhļƒĂ . Ł Ăσh!ƒ Ö5 ѓnjö!D SѓTdž!ƒ
LJдž lpѓ5kļÚѓh Ł‖Ţσdž!ƒ y5S!ƒ lĂp lpѓöѕĂ Łö!ѓz!ƒ Kƒ Sѓök!ƒ ýöŀ‖k ŁļfSþ Ł σh!ƒ ýĂѓơ Łöļѓλ Łöơѓļj LJдž
Ƨ ŀdž LJöĂ‡k! SPŪƒ ýPfþ þơƒĂ!ƒ Ł‖öƇkļdž KѓsŀdžDžfþPkļѓh ѓļSTD ѓdž‡Ă Üýö Ţ Ăk!ƒ Ł|Fѓs!ƒ þfĂdž!ƒ f ƒĂP
ѓļjöSöĂ .(4) ý‡T!ƒ Ö5 ѓdž‡Ă Łh Sƨ!ƒ lpŽѓp LJдž lS5Ăkdž!ƒ Łơѓ‖dž!ƒ YļơĂ ĭ Sѓƈ9
(Kŭhö‡) Sѓök ƇĂƇP Ł5ѓλ‡hĂ Dž 1 Ư Sƨh ĭ Sѓƈ Úƒ Ƨ ŀdžž! Σ ѓ‡ƨljŪƒ lĂp Kѓöljơljдž (12) ý‡T!ƒ
þþZ LJƒ ăSljĂ .(11) Džþ Ł!þѓƨdž!ƒ YļơĂ ĭ SUlj!ƒ Cƨη!ƒ Ö5 N! y5S!ƒ lĂp ѕѓlkTƒ Džk Ök!ƒĂ Dž/ ƇP 20
lSöѓƨdž Kѓöljơljдž (12) ý‡T!ƒ Džþlöà .þöη ƨѓηljg ѓljSĂŢk Ö5 ĂNjĂ lSдž 100 Ö!ƒĂσh ýp Ł5!– Söhdžŭƒ
.LJĂ‡ļ!ƒ Ł!ѓơ!Ă ŁhĂŀƇdž!ƒ y5S!ƒ lĂp Sƒþlдžà Džödžѓ Ţk!ƒ Yļơ

Ǩ â ÒĤ ŗ ĝ gzę



(r) LjŁÞNjT Nj ε ŁDŽlłε DžĭĞ qyѓlłε

Ł ļ fSþ!ƒ NJkơSkpf ĭ R!ƒ ĭ SѓƇ Ŭƒ YĂlj!ƒ LJдž ýö Ţ Ăk!ƒ ѕƒѓs!ƒ ýöƇkļdž!ƒ Ƨ ŀdžž! Σ ѓ‡ƨljŪƒ lĂp : (12) ý‡T
Ł5! - Söhdžƒ ýѓh ÖNj Kѓöljơljdžŀ! lpƒFѓz!ƒ DžѓpSŬƒ NJkSĂŢĂ Ƨ ŀdž!ƒ LJöh þƨhŀ! Ł!ƒþ‡ y5S!ƒ lĂp lpѓöѕ!

: lƒШFH#ЁHsÚ€

- ÅùNj þƒÅdž!ƒ LJlσƒ LJD Ǐ!ƒ Ɨσh!ƒ Ǒ5 ĠЏǗÅk þl!Å y5S!ƒ lÅp Sõ5Åk Ǒ5 Ɨʒ!Ġu ƗðžNjD Ġnj! Ɨ‡l!ƒ lþĠdž LJD ĺùdžŻ ǑùlldžZ ý‡Tùlu DžþPklùk LJD LJ‡džõ Ǒk!ƒÅ DžÅöljdž!Ūƒ NõǏõÅ y5S Ǐ Ǘpd S5Åõ ǐR!ƒ Σ Ġσlj!ƒ .ĠǏldžŻ DžþPklдž DžÅöljdž!Ūƒ
- yùkdžkk Ů Ɨõllj!ƒ LJþĠzdž!ƒ LJÅ‡ ydž ĠǗÅǗP Ɨõ5ÅS ư ýFƒþh‡ ΣĠσlj!ƒÅ DžÅöljdž!Ūƒ ‖FĠhl ΘSƱ Ɨσh!ƒ ƗZÅljǗdž Ɨ‡l! y5S!ƒ lÅp ϒĠlσ! ƗlõSƱ þĠηǒǫ DžkÅ . ý‡Dk!ƒ ÅD DþǗ!ƒ ƗdžÅĠlдž ÅD Ɨõ‡öljĠ‡ödž!ƒ ƗljĠkdž!Ġh . Ɨ‡öhl!ƒ ЌĠljÅ‡dž LJdž Ɨhljl Ɨõ Ū y5S!ƒ lÅp ϒĠlσ LJ‡džõ Ɨõσh ĠnjljdžŻ
- Ɨùödž‡!ƒ ýùlllõ LJD LJ‡džõ ǐR!ƒ ǐSĠƱÚƒ Zlldž!ƒ ÅNj ýõǗÅk!ƒ ѕFĠs!ƒ Zlldžll! ƒþõþη ĠdžõdžǗk Ɨσh!ƒ Džþp .y5S!ƒ lÅp þĠõþsƒ ydž lSdž ƗFĠdž Ǒ!ƒÅσh (Ɨsll!ƒ — Sõhdž Ū ƒ)
- lþözdž lÅp Sõ5Åk! YĠskSŮƒ ƗFƱƒÅ Ɨõhljǵη Ɨ‡l yϖÅh ƒSĠlõ ÅD ĠljödžõZ ƒSσljŮƒ ǏllŻ lSƱõl!ƒ LJ‡džõ lSƱõlù!ƒ Džkùŏ Ǒk!ƒ lþĠZŮƒ ЌĠsldž ýŭP LJdž Džkk lSƱõl!ƒÅ Z Sσljƒ Å! Ġdžõ5 ljSĠldž Ǐ!ƒ SĠƱl!ƒ þözk .ƗõljÅSk‡!ƒ Ɨlõ SƱh ĠnjöllŻ
- Ɨùöldž S!ƒ Ư SŮƒ Ɨùzöh Ʊ! ƒSùUlj ѕƒSz!ƒ Ǒ5 ѕöhƱkl! ýhĠp Ɨõlõ ƱĠljʒdž!ƒ lþĠlÅ!ƒ SĠƱp YÅSTdž LJƒ lSÅùƱkdž ĠõηÅ!Ålj‡k Ǐ!ƒ ЩĠkơk Ů Ǒk!ƒ Ɨ‡l!ƒ ljRNj ýλdž yõljǗk Ɨ!Ånjl!Å Ɨõlõ ƒS!ƒ NUþdž LJõh ЌƒR!ĠhÅ .ѕƒSz!ƒ ýPƒþ Ölhlkldž!ƒ ýllj!ƒ yõSĠTdž þσƒ YÅSTdž!ƒ ƒRNj LJÅ‡ö LJƒ ýdžD

: þσqƒøøøTDŽll€

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