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JIF = 1.500	SJIF (Morocco) = 2.031	

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SECTION 2. Applied mathematics. Mathematical modeling.

THE DEVELOPMENT OF A LIBRARY OF MAPLE FOR THE SOLUTION OF TRANSCENDENTAL EQUATIONS

Abstract: When solving transcendental equations arise some problems with the use of built-in functions in Maple. More precisely CAS could not solve these equations, even numerically. This work proposes algorithms and developed the library for the CAS for the numerical solution of transcendental equations in a given interval.

Key words: Maple, equation, library.

Language: Russian

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РАЗРАБОТКА БИБЛИОТЕКИ MAPLE ДЛЯ РЕШЕНИЯ ТРАНСЦЕНДЕНТНЫХ УРАВНЕНИЙ

Аннотация: При решении трансцендентных уравнений возникают определенные сложности с применением встроенных функций Maple. Точнее сказать СКА не может решать подобные уравнения, даже численно. В данной работе предлагаются алгоритмы и разработанная библиотека для СКА для численного решения трансцендентных уравнений в заданном промежутке.

Ключевые слова: Maple, уравнение, библиотека.

Introduction

Рассмотрим трансцендентное уравнение

$$e^x = \sin(x^2 + x)$$

Решим его в Системе компьютерной алгебры – Maple.

```
> restart;  
f:=exp(x)=sin(x^2+x);  
solve(f,x);
```

$$f := e^x = \sin(x^2 + x)$$
$$\text{RootOf}(-\text{RootOf}(_Z - \ln(\sin(_Z))^2 - \ln(\sin(_Z))) + _Z^2 + _Z)$$

Как видим СКМ отказывается решать данное уравнение.

Зададим поиск численного решения уравнения:



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GIF (Australia) = 0.564	ESJI (KZ) = 4.102	IBI (India) = 4.260
JIF = 1.500	SJIF (Morocco) = 2.031	

```
> restart;  
f:=exp(x)=sin(x^2+x);  
fsolve(f,x);
```

$$f := e^x = \sin(x^2 + x)$$
$$\text{fsolve}(e^x = \sin(x^2 + x), x)$$

Результат остался прежним.
Изменим функцию на

$$e^x = \sin(x^3)$$

чтобы показать, что решение все таки возможно
для более простых функций.

```
> restart;  
f:=exp(x)=sin(x^3);  
fsolve(f,x);
```

$$f := e^x = \sin(x^3)$$
$$-212.0788800$$

Как видим Maple предлагает решение
уравнения

$$-212.0788800$$

в качестве единственно возможного.

Хотя даже при самом простом анализе
данного уравнения виден совсем другой

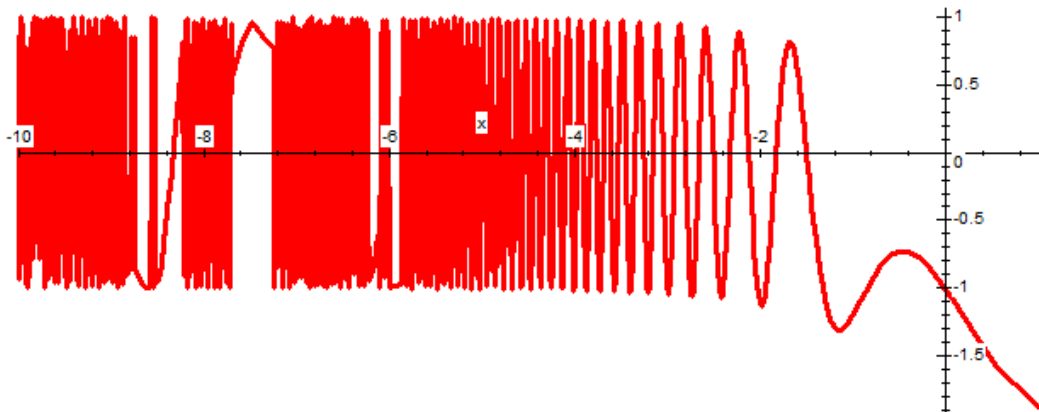
результат. Перенесем обе части в одну сторону и
найдем точки пересечения полученной функции с
осью Oх.

$$y = \sin(x^3) - e^x$$

Построим график данной функции:

```
> y:=rhs(f)-lhs(f);  
  
> plot(y,x=-10.0008..1,thickness=3);
```

$$y := \sin(x^3) - e^x$$



Очевидно, что количество решений
стремится к бесконечности.

Materials and Methods

Разработаем библиотеку для Maple
позволяющую для любого трансцендентного
уравнения получать численное решение с
заданной точностью на заданном промежутке:

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JIF = 1.500	SJIF (Morocco) = 2.031	

```

> restart;
      trans:=proc (sn, an, bn, epsn, opt)
local a, b, c, d, fa, fb, fc, a0, yy, y, x, s, dh;
s:=sin(x^2)=exp(x):
yy:=rhs(s)-lhs(s):
y:=x->exp(x)-sin(x^2):

if opt=0 then plot([y(x)], x=an..bn, color=[green, red, blue]);fi;
b:=bn:
dh:=.001;

while b>an do
d:=.001:
a:=b-d:
fa:=evalf(y(a)):
fb:=evalf(y(b)):
while fa*fb>0 do
d:=d+dh:
a:=b-d:
fa:=evalf(y(a)):
od:
if opt=1 then print([a, b], [fa, fb]);fi;
a0:=a:
Уточнение корня методом половинного деления
while b-a>epsn do
c:=(a+b)/2:
fa:=evalf(y(a)): fb:=evalf(y(b)): fc:=evalf(y(c)):
if fa*fc>0 then a:=c:fi;
if fc*fb>0 then b:=c:fi;
od:
c:=(a+b)/2:
fc:=evalf(y(c)):
if opt=2 then print(c, fc);fi;

b:=a0:
od:
end:

```

Приведем пример использования разработанной библиотеки Trans()

```

q:=sin(x^2)=exp(x);
trans(q, -10, 1, 0.00001, 2);

```

$$q := \sin(x^2) = e^x$$

Результатом работы библиотеки будет набор решений которым удовлетворяет данное трансцендентное уравнение:



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GIF (Australia) = 0.564	ESJI (KZ) = 4.102	IBI (India) = 4.260
JIF = 1.500	SJIF (Morocco) = 2.031	

-0.7149705601, -0.27623 10⁻⁵
-1.720965463, -0.88427 10⁻⁵
-2.522599223, .00001555154
-3.062353182, .00002359010
-3.548959214, .00001762246
-3.960921419, -.00001806580
-4.343102932, .934606 10⁻⁵
-4.688491998, .9324435 10⁻⁵
-5.013915697, .000035489984
-5.316902911, .000030637538
-5.605316486, .000031890221
-5.878329333, .000036022362
-6.140132480, .000039612807
-6.390538424, -.000045792984
-6.632014071, .4017495 10⁻⁵
-6.864607058, -.000015651009
-7.089872973, .0000171907637
-7.307970064, .0000215251058
-7.519919131, .0000262010485
-7.725921419, .0000425918900
-7.926677965, -.95045722 10⁻⁵
-8.122386905, .0000201239526
-8.313559925, .49186800 10⁻⁵
-8.500380817, .0000463883349
-8.683226522, -.0000297402432
-8.862259814, -.0000256951098
-9.037783708, -.65227495 10⁻⁵
-9.209934388, -.0000101763176
-9.378951007, -.00004320570644
-9.544951875, -.909249922 10⁻⁵
-9.708131655, .00002016487329
-9.868604494, .00003417364686
-10.02651302, .00004582693052
-10.027



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	JIF = 1.500	SJIF (Morocco) = 2.031	

```
> q:=sin(x^2)=exp(x);
trans(q,-10,1,0.00001,1);
```

$$q := \sin(x^2) = e^x$$

```
[-.715, 1], [-.0000538806, 1.876810843]
[-1.721, -.715], [.0001019374, -.0000538806]
[-2.523, -1.721], [-.00203207971, .0001019374]
[-3.063, -2.523], [.00395135629, -.00203207971]
[-3.549, -3.063], [-.00027292953, .00395135629]
[-3.961, -3.549], [.00060283817, -.00027292953]
[-4.344, -3.961], [-.00779409674, .00060283817]
[-4.689, -4.344], [.004768316774, -.00779409674]
[-5.014, -4.689], [-.000810429245, .004768316774]
[-5.317, -5.014], [.001062581191, -.000810429245]
[-5.606, -5.317], [-.007633480057, .001062581191]
[-5.879, -5.606], [.007919369577, -.007633480057]
[-6.141, -5.879], [-.01061604015, .007919369577]
[-6.391, -6.141], [.005853069975, -.01061604015]
[-6.633, -6.391], [-.01307514440, .005853069975]
[-6.865, -6.633], [.005378865027, -.01307514440]
[-7.090, -6.865], [-.001784142208, .005378865027]
[-7.308, -7.090], [.0004590449998, -.001784142208]
[-7.520, -7.308], [-.001190101951, .0004590449998]
[-7.726, -7.520], [.001256787117, -.001190101951]
[-7.927, -7.726], [-.005115033445, .001256787117]
[-8.123, -7.927], [.009979760700, -.005115033445]
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[-8.501, -8.314], [.01057304658, -.007312487246]
[-8.684, -8.501], [-.01346261899, .01057304658]
[-8.863, -8.684], [.01309382792, -.01346261899]
[-9.038, -8.863], [-.003916187501, .01309382792]
[-9.210, -9.038], [.001198386898, -.003916187501]
[-9.379, -9.210], [-.0009622196551, .001198386898]
[-9.545, -9.379], [.0009096039588, -.0009622196551]
[-9.709, -9.545], [-.01683985323, .0009096039588]
[-9.869, -9.709], [.007840414424, -.01683985323]
[-10.027, -9.869], [-.009719739448, .007840414424]
-10.027
```



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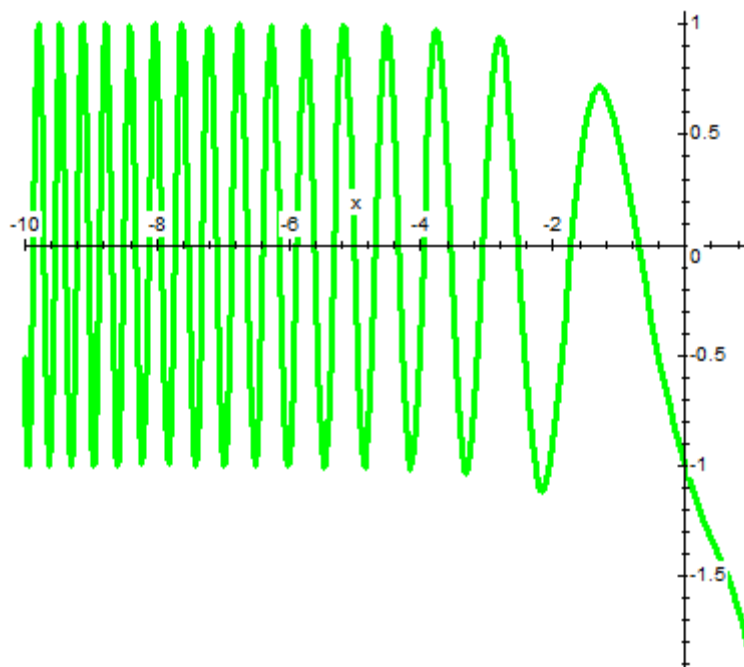
В библиотеке предусмотрена возможность вывода решений как в приближенном виде так и в виде интервалов изоляции на которых

находится решение. А также непосредственно графика.

```
> q:=sin(x^2)=exp(x);  
trans(q,-10,1,0.00001,0);
```

$$q := \sin(x^2) = e^x$$

-10.027



Приведем примеры использования библиотеки для некоторых других уравнений

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```
q:=sin(x^2+x)=exp(x);  
trans(q,-10,1,0.00001,2);
```

$$q := \sin(x^2 + x) = e^x$$

-0.7149705601, -0.27623 10⁻⁵
-1.720965463, -0.88427 10⁻⁵
-2.522599223, .00001555154
-3.062353182, .00002359010
-3.548959214, .00001762246
-3.960921419, -.00001806580
-4.343102932, .934606 10⁻⁵
-4.688491998, .9324435 10⁻⁵
-5.013915697, .000035489984
-5.316902911, .000030637538
-5.605316486, .000031890221
-5.878329333, .000036022362
-6.140132480, .000039612807
-6.390538424, -.000045792984
-6.632014071, .4017495 10⁻⁵
-6.864607058, -.000015651009
-7.089872973, .0000171907637
-7.307970064, .0000215251058

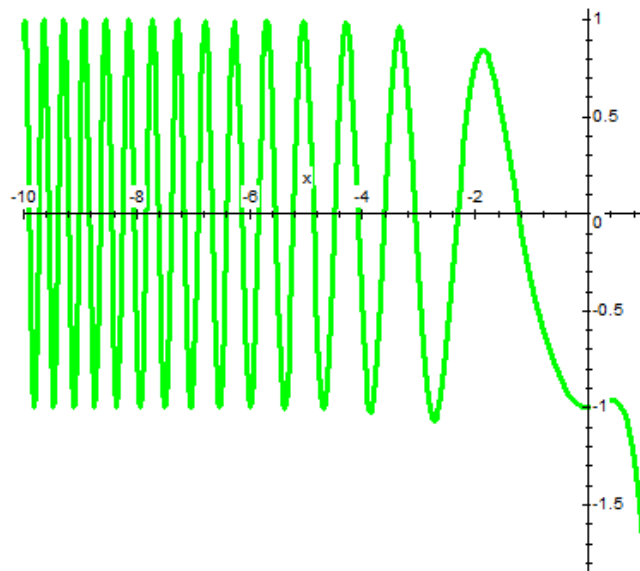


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-7.519919131, .0000262010485
-7.725921419, .0000425918900
-7.926677965, -.95045722 10⁻⁵
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-8.313559925, .49186800 10⁻⁵
-8.500380817, .0000463883349
-8.683226522, -.0000297402432
-8.862259814, -.0000256951098
-9.037783708, -.65227495 10⁻⁵
-9.209934388, -.0000101763176
-9.378951007, -.00004320570644
-9.544951875, -.909249922 10⁻⁵
-9.708131655, .00002016487329
-9.868604494, .00003417364686
-10.02651302, .00004582693052
-10.027

```
> plot([sin(x^2+x)-exp(x)],x=-10..1,color=[green,red,blue],thickness=3);
```



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	JIF = 1.500	SJIF (Morocco) = 2.031	

```
q:=sin(x^3)=exp(x);
trans(q,-10,1,0.00001,2);
```

```
q := sin(x^3) = e^x
-1.498795044, .0000194738
-1.829350991, -.12346 10^-5
-2.121247011, -.25461 10^-5
-2.318798602, -.00004041545
-2.508736179, .00004775663
-2.658034122, -.00001498343
-2.804238100, -.00009236038
-2.927102878, .00005253529
-3.048176545, .00002967737
-3.153939120, .00004949971
-3.258432832, -.00005699265
-3.352039003, -.00002684903
-3.444643434, -.00002616877
-3.529089510, -.00001212768
-3.612683381, .316051 10^-5
-3.689929506, .00002338446
-3.766421938, -.197154 10^-5
-3.837830996, .00008254402
-3.908553652, .00017143906
-3.975120792, .00013536131
-4.041053347, .00017118062
-4.103519411, .00011309831
-4.165405886, -.00016208128
-4.224341007, .00001763032
-4.282741578, .00010903126
-4.338613770, -.00015639666
-4.393989931, -.00005845479
```



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-4.447166138, -.279321 10⁻⁵
-4.499876222, -.00018312414
-4.550654483, -.00018996003
-4.600996949, .000114203934
-4.649644105, .000140930091
-4.697868166, -.000115013084
-4.744578311, -.000138277640
-4.790896121, .000115378943
-4.835865420, .000191462378
-4.880453433, -.000147869780
-4.923824159, .000161794594
-4.966834657, .000016806214
-5.008746218, .000087676552
-5.050315554, -.000062646404
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-5.131121645, .000123064574
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-5.209462038, .000176048845
-5.247642825, .000301457496
-5.285522219, -.000367967783
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-5.359444461, -.000036137984
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-5.431389161, -.000313938512
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-5.501474489, -.000354395222
-5.535763430, -.000379183258
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-5.603290285, .000229022541
-5.636520633, .000029513655
-5.669222536, .000366043593
-5.701683594, .000158504116
-5.733652344, .000173528818
-5.765394532, -.000125866654
-5.796663210, -.000261942647
-5.827723758, .5252762 10⁻⁵



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-5.858337771, -.000210137899
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-5.948534913, .7354553 10⁻⁵
-5.977932740, -.000275880967
-6.007139406, .000380517578
-6.035976076, -.000334786477
-6.064628298, .000093228274
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-6.729368287, .0002939861310
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-6.775306520, -.000130373750



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	JIF = 1.500	SJIF (Morocco) = 2.031	

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	GIF (Australia) = 0.564	ESJI (KZ) = 4.102	IBI (India) = 4.260
	JIF = 1.500	SJIF (Morocco) = 2.031	

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-7.622951661, -.0000332477627
-7.640925294, .0001142740076
-7.658828615, -.00071110765673
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-7.694362794, .0003460575917
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-7.747063966, .0002580777852
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-7.781804933, .0002964199024
-7.799063966, -.0002747892033
-7.816240481, .0007084887757
-7.833348390, -.0007364042173
-7.850373293, .0007589536671
-7.867331788, -.0005443383771
-7.884207277, -.0000417149271
-7.901024661, -.0004552224601

-7.917761720, .0007342494378
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-8.000417970, -.0003165423736
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-8.033008059, -.0006196871317
-8.049199220, .0004016616495
-8.065332032, -.0001802037279
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	GIF (Australia) = 0.564	ESJI (KZ) = 4.102	IBI (India) = 4.260
	JIF = 1.500	SJIF (Morocco) = 2.031	

-8.129214844, .0005156634264
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-8.192113282, .0003703064632
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-8.238659426, -.0000249007362
-8.254058594, .0005982929302
-8.269403078, .0003947920366
-8.284688722, .0000706509707
-8.299915774, -.0000212155795
-8.315089844, .0004091018306
-8.330205324, -.0005274379147
-8.345271242, .0005458311345
-8.360278566, -.0005350884796
-8.375241945, -.0005896745252
-8.390139406, -.0000330792605
-8.404989748, .0003778765579
-8.419783938, -.0006486196701
-8.434534913, -.0000325302315
-8.449227296, .0000456765214
-8.463873536, -.0002293038051
-8.478461672, -.0003799981134
-8.493007570, .0001350461029
-8.507497560, -.0004281550005
-8.521948732, -.0007309915269
-8.536337160, -.0003519031289
-8.550688966, -.0003511238047
-8.564982912, -.0003386510874
-8.579234620, .0006178403251
-8.593442872, .0006827918067
-8.607600098, -.0003090093769
-8.621709474, .0003467197075
-8.635770998, .0007440224186



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JIF = 1.500	SJIF (Morocco) = 2.031	

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-8.705422364, .0007321310797
-8.719217286, -.0001017775024
-8.732965090, -.0006997771074
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-8.760347168, .0006306619192
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-8.787552248, .0003663456924
-8.801094240, -.0004890027442
-8.814590577, .0002561671841
-8.828046388, .0004125004513
-8.841463625, .00004922118113
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-8.868176270, .0003069021984
-8.881469972, .0004298902976
-8.894723880, -.0006385936034
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-9.012292238, .0001147885287
-9.025165284, -.0002817970880
-9.038006594, -.0002663989571
-9.050803712, -.0006283503959
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-9.076298586, -.0007568102008
-9.088997071, -.0000889907943
-9.101654054, -.0001340802880
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JIF = 1.500	SJIF (Morocco) = 2.031	

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-9.189298586, -.0003689368311
-9.201680666, -.0000445205372
-9.214031985, .0002316753774
-9.226352540, .0005573140701
-9.238633790, .0007087613092
-9.250885744, -.0007464779688
-9.263108156, .0004410182375
-9.275299806, .0006070987177
-9.287452150, .0006190440095
-9.299581056, .0006736435211
-9.311674806, -.0006639642739
-9.323733400, .00001865380299
-9.335762697, .0005094921721
-9.347762697, -.0002592731344
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-9.371668947, -.0005737392378
-9.383581056, -.0003121123549
-9.395458009, .0002132529463
-9.407305666, .00004392320862
-9.419124026, .0001526021946
-9.430911379, .0003553145398
-9.442668947, -.0006476934382
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-9.466100588, -.0004924364515
-9.477777102, -.0005286432539
-9.489416994, -.0002842282222
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	GIF (Australia) = 0.564	ESJI (KZ) = 4.102	IBI (India) = 4.260
	JIF = 1.500	SJIF (Morocco) = 2.031	

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-9.604311526, -.0004746749442
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-9.847838868, -.001386129491
-9.858632081, -.0005340612450
-9.869390382, -.0006475641626
-9.880132570, -.00009886644061
-9.890848633, .0002234302992
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-9.933481691, .00009410254558
-9.944084231, -.0003431155683

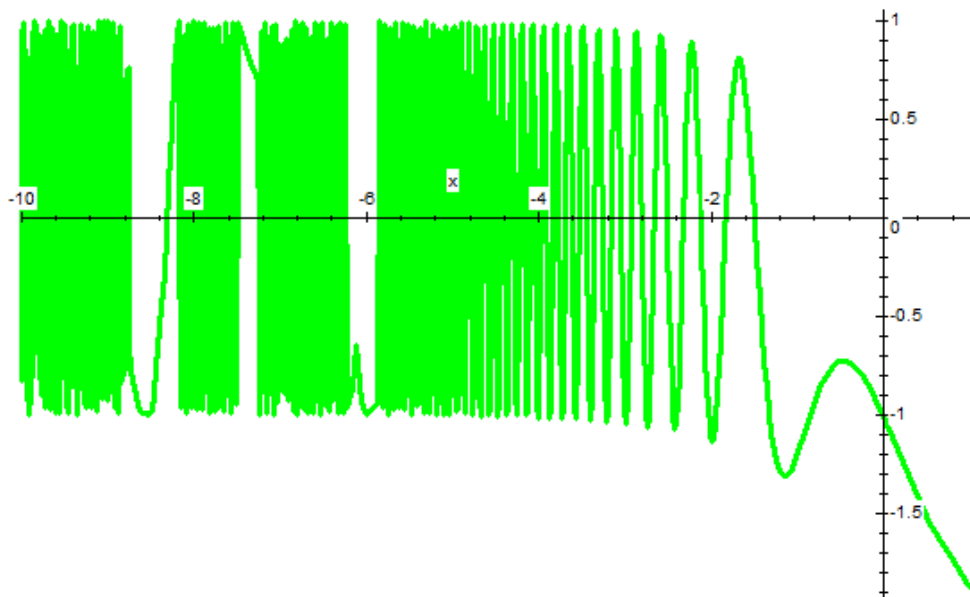


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GIF (Australia) = 0.564	ESJI (KZ) = 4.102	IBI (India) = 4.260
JIF = 1.500	SJIF (Morocco) = 2.031	

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-10.00722389, -.0006314316570
-10.008

```
plot([sin(x^3)-exp(x)],x=-10..1,color=[green,red,blue],thickness=3);
```



Conclusion

Разработанная библиотека апробирована для трансцендентных уравнений которые система Maple не может решить.

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