BL.EN.U4CSE20137
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ASSIGNMENT – 1

Bisection Method

Let a and b is the interval in which solution is said to be present for a function f(x). Let x be the middle point of both a and b. then by using IVM, we need to justify whether the root is present in the set a,c or b,c, if the solution is present in between a and c then assign the value of c in b variable or vice versa and repeat this process until the termination.

Use Bisection Method to find the root of the $\cos(x) - xe^{x} = 0$ where one of the roots lie in between 0.4 and 0.6, -1 and -2.

C++ CODE:

```
#include <iostream>
#include <math.h>
#include <iomanip>
using namespace std;
double check(double, double, double);
double eq(double);
double mod(double);
int main(void)
{
    double a,b,y;
    double x;
    cout << "Enter the value of a : ";
    cin >> a;
    cout << "Enter the value of b : ";
    cin >> b;
    int i=0;
    if(eq(a)*eq(b) < 0)
    {
        do
        {
            x=(a+b)/2;
            y=check(a,b,x);
```

```
            if(y==0)
            {
                b=x;
            }
            else
            {
                a=x;
            }
            if(y==2)
            {
                x=a;
                break;
            }
            if(y==3)
            {
                x=b;
                break;
            }
            if(y==4)
            {
                break;
            }
            i++;
            cout << setprecision(7) << x << endl;
        }while(mod(eq(x)) > 0.001);
        cout << "The root is : " << setprecision(3) << x <<
endl;
        cout << "Number of iterations : " << i << endl;
    }
    else
    {
        cout << "The given intervel has no roots or even
number of roots" << endl;
    }
```

```
}
inline double eq(double x)
{
    return cos(x)-x*exp(x);
}
double check(double a, double b, double x)
{
    if(eq(a)!=0 && eq(b)!=0 && eq(x)!=0)
    {
        if(eq(a)*eq(x) < 0)
        {
            return 0;
        }
        else
        {
            return 1;
        }
    }
    else
    {
        if(eq(a)==0)
        {
            return 2;
        }
        if(eq(b)==0)
        {
            return 3;
        }
        else
        {
            return 4;
        }
    }
}
```

```
double mod(double ans)
{
    if(ans < 0)
    {
        return -(ans);
    }
    else
    {
        return ans;
    }
}
```

1. Let a = 0.4 and b = 0.6

OUTPUT

```
Windows PowerShell
PS C:\Users\madhu\Desktop\Numerical Methods> g++ bi.cpp ; ./a
Enter the value of a : 0.4
Enter the value of b : 0.6
0.5
0.55
0.525
0.5125
0.51875
0.515625
0.5171875
0.5179688
The root is : 0.518
Number of iterations : 8
```

Here, we can observe that while taking 0.4 and 0.6 as the interval, the convergence takes place from 8th iteration (Rounding off to 3 decimals).

The Order of Convergence is linear.

So, the root for the function $\cos(x) - xe^{x} = 0$ is 0.518.

2. Let a=-2 and b=-1

OUTPUT

```
Windows PowerShell
PS C:\Users\madhu\Desktop\Numerical Methods> g++ bi.cpp ; ./a
Enter the value of a : -2
Enter the value of b : -1
-1.5
-1.75
-1.875
-1.8125
-1.84375
-1.859375
-1.8671875
-1.8632812
-1.8652344
-1.8642578
-1.8637695
-1.8640137
The root is : -1.864
Number of iterations : 12
```

Here, we can observe that while taking -2 and -1 as the interval, the convergence takes place from 12th iteration (Rounding off to 3 decimals).

The Order of Convergence is linear.

So, the root for the function $\cos(x) - xe^{x} = 0$ is -1.864.

Use Bisection Method to find the root of the $x^3 - 10x^2 + 5 = 0$ where one of the roots lie in between 0.6 and 0.8.

C++ Code

In the above code, the eq(double) function need to be swapped by below function:

```
inline double eq(double x)
{
    return (x*x*x)-10*(x*x)+5;
}
```

OUTPUT:

Let a=0.6 and b=0.8

```
PS C:\Users\madhu\Desktop\Numerical Methods> g++ bi.cpp ; ./a
Enter the value of a : 0.6
Enter the value of b : 0.8
0.7
0.75
0.725
0.7375
0.73125
0.734375
0.7359375
0.73515625
0.73476562
0.73457031
The root is : 0.7346
Number of iterations : 10
```

Here, we can observe that while taking 0.6 and 0.8 as the interval, the convergence takes place from 10th iteration (Rounding off to 4 decimals).

The Order of Convergence is linear.

So, the root for the function $x^3 - 10x^2 + 5 = 0$ is 0.7346.

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False Position Method

Let a and b be the interval in which the root is present for a function f(x). Let c be a point where the secant of a and b cuts the x-axis, then by using IVM find the pair in which the root is present. if the root is present in between a and c then assign the value of c in b variable or vice versa and repeat this process until the termination.

Use False Position Method to find the root of the $3x^2 + 1 - e^x = 0$ where one of the roots lie in between 0.4 and 0.5, 3.6 and 3.8.

C++ CODE

```
#include <iostream>
#include <iomanip>
#include <math.h>
using namespace std;
double eq(double);
double val(double, double);
double mod(double);
double check(double, double, double);
int main(void)
{
    double a,b,c,t;
    cout << "Enter the value of a : ";
    cin >> a;
    cout << "Enter the value of b : ";
    cin >> b;
    int i=0;
    do
    {
        c = val(a,b);
        if(eq(a) != 0 && eq(b) != 0 && eq(c) != 0)
        {
            if(eq(a) * eq(c) < 0)
            {
```

```
                b=c;
            }
            else
            {
                a=c;
            }
        }
        else
        {
            if(eq(a) == 0)
            {
                    c=a;
                    break;
            }
            else if(eq(b) == 0)
            {
                    c=b;
                    break;
            }
            else
            {
                break;
            }
        }
        i++;
        cout << setprecision(9) << c << endl;
    } while(mod(eq(c)) > 0.0001);
    cout << "Root : " << setprecision(3) << c << endl;
    cout << "Number of iterations : " << i << endl;
}
inline double eq(double x)
{
    return 3*(x*x)-exp(x)+1;
}
```

```
inline double val(double a, double b)
{
    return (b - eq(b) * ( (b - a) / (eq(b) - eq(a)) ));
}
double mod(double x)
{
    if(x < 0)
    {
        return -x;
    }
    else
    {
        return x;
    }
}
```

1.Let a=0.4 and b=0.5

OUTPUT

```
PS C:\Users\madhu\Desktop\Numerical Methods> g++ fp.cpp ; ./a
Enter the value of a : 0.4
Enter the value of b : 0.5
0.410454765
0.412260046
0.412564002
Root : 0.413
Number of iterations : 3
```

Here, we can observe that while taking 0.4 and 0.5 as the interval, the convergence takes place from 3th iteration (Rounding off to 3 decimals).

The Order of Convergence is linear.

So, the root for the function $3x^2 + 1 - e^x = 0$ is 0.413.

2.Let a=3.6 and b=3.8

OUTPUT

```
PS C:\Users\madhu\Desktop\Numerical Methods> g++ fp.cpp ; ./a
Enter the value of a : 3.6
Enter the value of b : 3.8
3.77918702
3.78227185
3.78232021
Root : 3.782
Number of iterations : 3
```

Here, we can observe that while taking 3.6 and 3.8 as the interval, the convergence takes place from 3th iteration (Rounding off to 3 decimals).

The Order of Convergence is linear.

So, the root for the function $3x^2 + 1 - e^x = 0$ is 3.782.

Use False Position Method to find the root of the $x^3 - 10x^2 + 5 = 0$ where one of the roots lie in between 0.6 and 0.8.

C++ CODE

In the above code, the eq(double) function need to be swapped by below function:

```
inline double eq(double x)
{
    return (x*x*x)-10*(x*x)+5;
}
```

OUTPUT

Let a=0.6 and b=0.8

```
PS C:\Users\madhu\Desktop\Numerical Methods> g++ fp.cpp ; ./a
Enter the value of a : 0.6
Enter the value of b : 0.8
0.72907348
0.73439681
0.73459581
0.73460322
0.7346035
Root : 0.7346
Number of iterations : 5
```

Here, we can observe that while taking 0.6 and 0.8 as the interval, the convergence takes place from 5th iteration (Rounding off to 4 decimals).

The Order of Convergence is linear.

So, the root for the function $x^3 - 10x^2 + 5 = 0$ is 0.7346.

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Secant Method

Let a and b be the interval in which the root is present for a function f(x). Let c be a point where the secant of points f(a) and f(b) cuts the x-axis(step2). Now, assign the value of c in a and repeat the step2 again, now assign the value of c in b and repeat the whole process until termination.

Use Secant Method to find the root $e^x(x^2 - 5x + 6) + 1 = 0$ where one of the roots lie in between 2 and 2.5, 2.5 and 3.

C++ CODE

```
#include <iostream>
#include <iomanip>
#include <math.h>
using namespace std;
double val(double, double);
double eq(double);
double mod(double);
int main(void)
{
    double a,b,c;
    cout << "Enter the value of a : ";
    cin >> a;
    cout << "Enter the value of b : ";
    cin >> b;
    int i=0;
    if(eq(a) != eq(b))
    {
        do
        {
            c=val(a,b);
            if(i%2 != 0)
            {
                a=c;
            }
```

```
            else
            {
                b=c;
            }
            i++;
            cout << setprecision(7) << c << endl;
        } while(mod(eq(c)) > 0.00001);
    }
    else
    {
        cout << "The secant will not cross the x-axis"<<
endl;
    }
    cout << "Root : " << setprecision(4) << c << endl;
    cout << "Number of iterations : " << i << endl;
}
inline double val(double x, double y)
{
    return (x - (eq(x) * (x-y) / (eq(x) - eq(y))));
}
inline double eq(double x)
{
    return exp(x)*((x*x)-5*x+6)+1;
}
double mod(double ans)
{
    if(ans < 0)
        return -(ans)
    else
        return ans;
}
```

1.Let a=2 and b=2.5

OUTPUT

```
PS C:\Users\madhu\Desktop\Numerical Methods> g++ sm.cpp ; ./a
Enter the value of a : 2
Enter the value of b : 2.5
2.16417
2.137403
2.136731
2.136736
Root : 2.137
Number of iterations : 4
```

Here, we can observe that while taking 2 and 2.5 as the interval, the convergence takes place from 4^{th} iteration (Rounding off to 3 decimals).

So, the root for the function $e^x(x^2 - 5x + 6) + 1 = 0$ is 2.137.

2.Let a=2.5 and b=3

OUTPUT

```
PS C:\Users\madhu\Desktop\Numerical Methods> g++ sm.cpp ; ./a
Enter the value of a : 2.5
Enter the value of b : 3
2.83583
3.471958
2.870299
2.894786
2.954202
2.943088
2.944225
2.944251
Root : 2.944
Number of iterations : 8
```

Here, we can observe that while taking 2.5 and 3 as the interval, the convergence takes place from 8^{th} iteration (Rounding off to 3 decimals).

So, the root for the function $e^x(x^2 - 5x + 6) + 1 = 0$ is 2.944.

Use Secant Method to find the root of the $x^3 - 10x^2 + 5 = 0$ where one of the roots lie in between 0.6 and 0.8.

C++ CODE

In the above code, the eq(double) function need to be swapped by below function:

```
inline double eq(double x)
{
    return (x*x*x)-10*(x*x)+5;
}
```

OUTPUT

Let a=0.6 and b=0.8

```
PS C:\Users\madhu\Desktop\Numerical Methods> g++ sm.cpp ; ./a
Enter the value of a : 0.6
Enter the value of b : 0.8
0.72907348
0.73509737
0.73460187
0.73460351
Root : 0.7346
Number of iterations : 4
```

Here, we can observe that while taking 0.6 and 0.8 as the interval, the convergence takes place from 4th iteration (Rounding off to 4 decimals).

So, the root for the function $x^3 - 10x^2 + 5 = 0$ is 0.7346.

NEWTON - RAPHSON METHOD

Calculate $\sqrt{7}$ by NEWTON's Iteration Method, starting from $x_0 = 2$ and Calculating x_1, x_2, x_3, x_4, x_5. and Compare with $\sqrt{7} = 2.645751$.

Let x be a Square root, then $x = \sqrt{7}$

$$x = \sqrt{7}$$

$$\Rightarrow \quad x^2 - 7 = 0$$

then,

$$f(x) = x^2 - 7$$

$$f'(x) = 2x$$

By the Newton Iteration Method,

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)} \qquad n = 0, 1, 2, 3, 4 \ldots$$

Given $x_0 = 2$

$n = 0$

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}$$

$$x_1 = 2 - \frac{2^2 - 7}{2 \times 2}$$

$$x_1 = 2 + \frac{3}{4}$$

$$x_1 = 2.75$$

$n = 1$

$$x_2 = x_1 - \frac{f(x_1)}{f'(x_1)}$$

$$x_2 = 2.75 - \frac{(2.75)^2 - 7}{2 \times 2.75}$$

$$x_2 = 2.75 - \frac{0.5625}{5.50}$$

$$x_2 = 2.64772727.$$

$n = 2$

$$x_3 = x_2 - \frac{f(x_2)}{f'(x_2)}$$

$$\Rightarrow x_3 = 2.647727 - \frac{(2.647727)^2 - 7}{2(2.647727)}$$

$$\Rightarrow x_3 = 2.6457090$$

Iterations	x_n	Value
0	x_0	2.00
1	x_1	2.75
2	x_2	2.64772727
3	x_3	2.6457090
4	x_4	2.6457513114
5	x_5	2.6457513121278

$\sqrt{7} = 2.645751$

$n = 3$

$$x_4 = x_3 - \frac{f(x_3)}{f'(x_3)}$$

$$\Rightarrow x_4 = (2.6457090) - \frac{(2.6457090)^2 - 7}{2(2.6457090)}$$

$$\Rightarrow x_4 = 2.6457513114$$

$n = 4$

$$x_5 = x_4 - \frac{f(x_4)}{f'(x_4)}$$

$$x_5 = 2.6457513114 - \frac{(2.6457513114)^2 - 7}{2(2.6457513114)}$$

$$x_5 = 2.64575131278.$$

Therefore, If we roundoff upto 6 digits we can observe the n=3 starting, gets converges to a certain value given $\sqrt{7}$ $= 2.645751$.

So, the value for $\sqrt{7} \approx 2.6457\ldots$

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FIND Positive root of the equations $x^4 + 2x + 1 = 0$ and Correct it upto 4 decimals (choose $x_0 = 1.3$)

Given function

$$f(x) = x^4 + 2x + 1$$

$$\Rightarrow f'(x) = 4x^3 + 2$$

By Newton's Iteration Method,

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

$n=0$

$$x_1 = 1.3 - \frac{(1.3)^4 + 2(1.3) + 1}{4(1.3)^3 + 2}$$

$$x_1 = 1.3 - \frac{6.4561}{10.788}$$

$$x_1 = -0.701548016$$

$n=1$

$$x_2 = x_1 - \frac{f(x_1)}{f'(x_1)}$$

$$x_2 = -(0.701548016) - \frac{0.242230933405 - 2(0.701548016) + 1}{4(0.701548016)^3 + 2}$$

$$x_2 = 0.2599304 - 0.701548016$$

$$x_2 = -0.44161758.$$

$n = 2$

$$x_3 = x_2 - \frac{f(x_2)}{f'(x_2)}$$

$$x_3 = -0.44161758 - \frac{(-0.44161758)^4 - 2(0.44161758) + 1}{4(-0.44161758)^3 + 2}$$

$$x_3 = -0.53512452$$

Iteration n	x_n	Value
0	x_0	1.3
1	x_1	-0.71548016
2	x_2	-0.44161758
3	x_3	-0.53512452
4	x_4	-0.543597166
5	x_5	-0.54359716

$n = 3$

$$x_4 = x_3 - \frac{f(x_3)}{f'(x_3)}$$

$$x_4 = -0.53512452 - \frac{(-0.53512452)^4 - 2(0.53512452) + 1}{4(-0.53512452)^3 + 2}$$

$$x_4 = -0.543597166.$$

$n = 4$

$$x_5 = x_4 - \frac{f(x_4)}{f'(x_4)} \Rightarrow x_4 = (-0.5435....) - \frac{(-0.5435..)^4 - 2(0.5351) + 1}{4(-0.543597166)^3 + 2}$$

$$x_5 = -0.54359716$$

while taking $x_0 = 1.3$ (Initial Assumption), after 5 Iterations the Convergence takes place.

Hence, The Root of the equation $= -0.5436$

USE NEWTON RAPHSON's METHOD to find the root of the function $f(x) = x^3 - 10x^2 + 5$ where $x_0 = 0.8$

Given function

$$f(x) = x^3 - 10x^2 + 5$$

$$f'(x) = 3x^2 - 20x + 0$$

By the Newton Iteration Method,

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

$n = 0$

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}$$

$$x_1 = 0.8 - \frac{(0.8)^3 - 10(0.8)^2 + 5}{3(0.8)^2 - 20(0.8)}$$

$$x_1 = 0.7369318$$

$n = 1$

$$x_2 = x_1 - \frac{f(x_1)}{f'(x_1)}$$

$$x_2 = (0.73\ldots) - \frac{(0.73\ldots)^3 - 10(0.73\ldots)^2 + 5}{3(0.73\ldots)^2 - 20(0.73\ldots)}$$

$x_2 = 0.7346067$

$n = 2$

$$x_3 = x_2 - \frac{f(x_2)}{f'(x_2)}$$

$$x_3 = (0.7346067) - \frac{(0.7346067)^3 - 10(0.73460..)^2 + 5}{3(0.7346067)^2 - 20(0.7346..)}$$

$x_3 = 0.734603$

x_n	Value
x_0	0.8
x_1	0.7369318
x_2	0.7346067
x_3	0.734603

We Can observe that after 3 iterations, the process Converges to 0.7346 while taking Initial assumption as $x_0 = 0.8$

FIXED POINT ITERATION METHOD

FIND Roots of the equation $x - e^{-x} = 0$

Let us Assume $\phi(x) = x$

we have

$$\phi(x) = e^{-x}$$

By the Convergence Condition

$$|\phi'(x)| < 1$$

So, $\Rightarrow \underset{\text{Positive}}{e^{-x}} < \underset{\text{Positive}}{1}$

$$\Rightarrow -x < 0$$

$$\boxed{x > 0}$$

Iteration form: $x_{i+1} = e^{-x_i}$ Let $x_0 = 1.5$

So, $i=0$

$$x_1 = e^{-x_0}$$

$$\Rightarrow x_1 = e^{-1.5}$$

$$\Rightarrow x_1 = 0.22313016$$

$i=1$ $\Rightarrow x_2 = e^{-x_1}$ $\Rightarrow x_2 = e^{-0.2231}$ $\Rightarrow x_2 = 0.80001071$	$i=2$ $\Rightarrow x_3 = e^{-x_2}$ $\Rightarrow x_3 = e^{-0.800017}$ $\Rightarrow x_3 = 0.44932415$	$i=3$ $\Rightarrow x_4 = e^{-x_3}$ $\Rightarrow x_4 = 0.63805923$ ~~$\Rightarrow x_4 =$~~
$i=4$ $x_5 = e^{-x_4}$ $x_5 = e^{-0.6380523}$ $x_5 = 0.52831676$	$i=5$ $x_6 = e^{-x_5}$ $x_6 = e^{-0.52831676}$ $x_6 = 0.58959656$	$i=6$ $x_7 = e^{-x_6}$ $x_7 = e^{-0.58959\ldots}$ $x_7 = 0.55455096$
$i=7$ $x_8 = e^{-x_7}$ $x_8 = e^{-0.55455}$ $x_8 = 0.57433009$	$i=8$ $x_9 = e^{-x_8}$ $x_9 = e^{-0.57433\ldots}$ $x_9 = e^{-0.574} = 0.56308195$	$i=9$ $x_{10} = e^{-x_9}$ $x_{10} = e^{-0.5630\ldots}$ $x_{10} = 0.56945133$
$i=10$ $x_{11} = e^{-x_{10}}$ $x_{11} = 0.56788530$	$i=11$ $x_{12} = e^{-x_{11}}$ $x_{12} = 0.56672261$	$i=12$ $x_{13} = e^{-x_{12}}$ $x_{13} = 0.56738192$

$i=13$

$x_{14} = e^{-x_{13}}$

$x_{14} = 0.56700796$

x_n	Value
x_0	1.5
x_1	0.22313016
x_2	0.80001071
x_3	0.44932415
x_4	0.63805923
x_5	0.52831676
x_6	0.58959656
x_7	0.55455096
x_8	0.57433009
x_9	0.56308195
x_{10}	0.56945133
x_{11}	0.56788530
x_{12}	0.56672261
x_{13}	0.56738192
x_{14}	0.56700496

We can observe that the process converges to 0.567 (rounding off to 3 decimals), after 14 Iterations.

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USE FIXED POINT ITERATION METHOD, To find the Root of the equation $x^3 - 10x^2 + 5 = 0$ where $x_0 = 0.8$

Given function

$$f(x) = x^3 - 10x^2 + 5$$

$$f'(x) = 3x^2 - 20x$$

Let $\phi(x) = x$

By the Convergence Condition

$|\phi'(\bar{x})| < 1$ where $\bar{x}$ be the root of $f(x)$

$$x = 10 - \frac{5}{x^2}$$

$$x = 10 - 5x^{-2}$$

$$x_{n+1} = 10 - 5(x_n)^{-2}$$

$$x_0 = 0.8$$

$$x_1 = 10 - 5(0.8)^{-2}$$

$$x_1 = 2.1875$$

$$x_2 = 10 - 5(2.1875)^{-2}$$

$$x_2 = 8.95510$$

$$x = \frac{x^3 - 5}{10x^2}$$

$$x = \frac{x}{10} - \frac{1}{2}x^{-2}$$

$$x_{n+1} = \frac{x_n}{10} - \frac{1}{2}(x_n)^{-2}$$

$$x_0 = 0.8$$

$$x_1 = \frac{0.8}{10} - \frac{1}{2}(0.8)^{-2}$$

$$x_1 = -0.70125$$

$$x_2 = \frac{-0.70125}{10} - \frac{1}{2}(-0.70125)^{-2}$$

$$x_2 = -1.0868985$$

Both Diverge.

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Take $x = \sqrt{\frac{5}{10-x}} \Rightarrow x_{n+1} = \sqrt{\frac{5}{10-x_n}}$

$n = 0$

$x_1 = \sqrt{\frac{5}{10-(0.8)}} \Rightarrow x_1 = 0.73720978$

$n = 1$

$x_2 = \sqrt{\frac{5}{10-x_1}} \Rightarrow x_2 = 0.73470684.$

$n = 2$

$x_3 = \sqrt{\frac{5}{10-x_2}} \Rightarrow x_3 = 0.73460760$

$n = 3$

$x_4 = \sqrt{\frac{5}{10-x_3}} \Rightarrow x_4 = 0.73460367.$

$\therefore$ It Converges to 0.7346 (4 decimals)

we can observe that the process Converges, after 3 Iterations, to 0.7346 (rounding off upto 4 decimals.)

x_n	Value
x_0	0.8
x_1	0.73720978
x_2	0.73470684
x_3	0.73460760
x_4	0.73460367

We can observe that the process converges to 0.7346 (rounding off to 3 decimals), after 4 Iterations.

Summary

- In Bisection Method, it can be observed that the solution will surely converge to a point, despite of being very slow convergence (The rate of Convergence is linear).
- Like Bisection Method, Regula falsi Method method also has the limitation of finding multiple roots in a given interval.
- Secant method may or may not converge and if f'(a)=0 which implies a tangent drawn to the graph y=f(x) at x=a.
- Unlike previous methods, Newton-Raphson Method and Fixed-Point Iteration method are open methods which means some point x_0 is chosen and then the iterative procedure starts.
- Newton-Raphson Method may get some issues with infection point and gets diverge. (Like f'(c)=0)
- In Fixed-Point Iteration method, the main problem comes while choosing **ϕ(x)=x,** because most of the equations may diverge.

$$x^3 - 10x^2 + 5 = 0$$

Root : 0.7346…

Methods	Number of Iterations
Bisection	10
Regula Falsi	5
Secant	4
Newton-Raphson	3
Fixed-Point Iteration	4

Bisection Method converges slowly.

Newton Raphson Method converges quickly.