Praveen Kumar Yadav

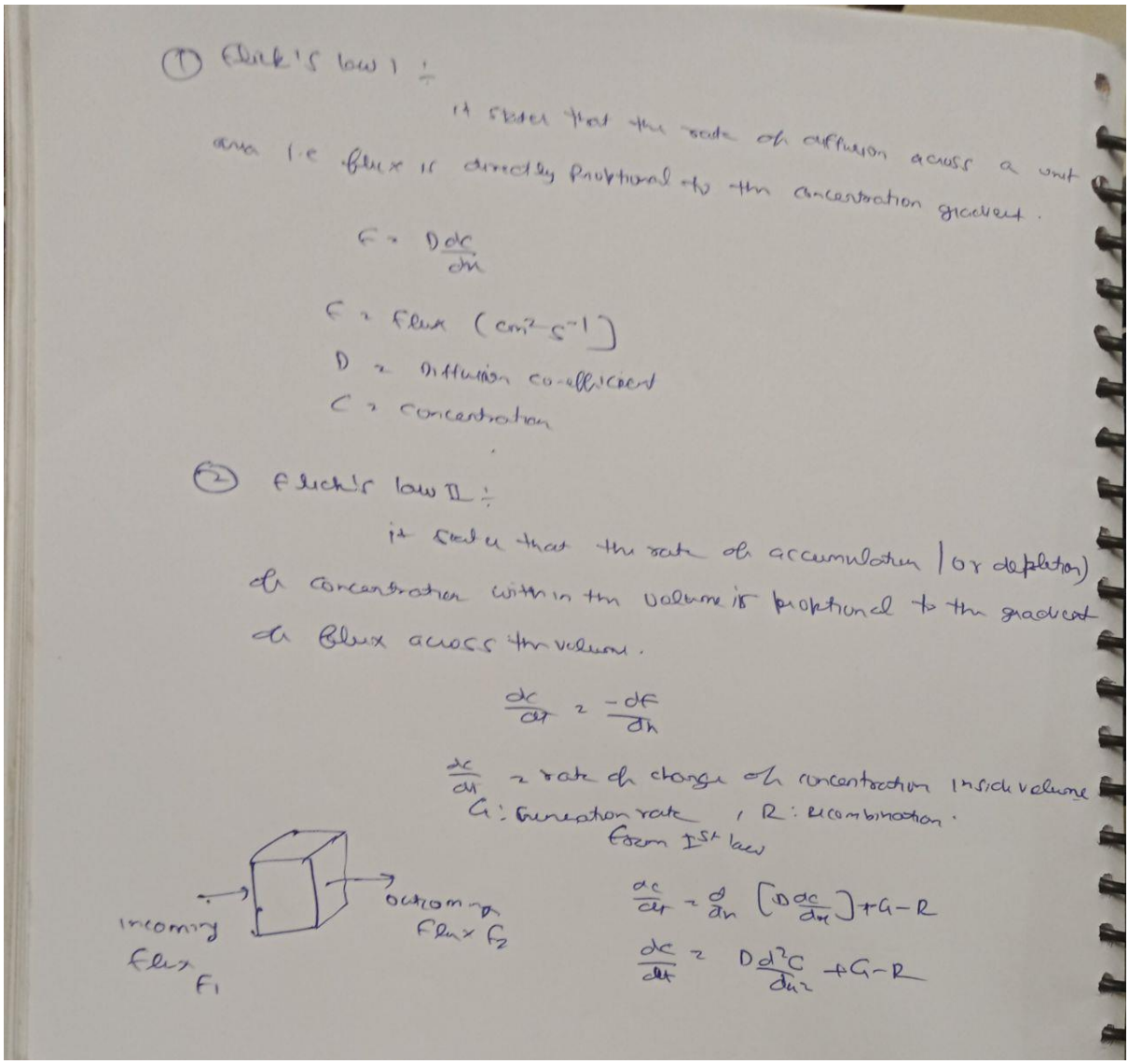
(MTech VLSI Sem 1, EE22M308)

Lab no. : 6

Used version: Matlab 2022

1) State the Fick's laws of diffusion and the continuity equation.

Ans:



2) For each of the cases listed below, provide the analytical solutions, and compare them with numerical solutions. Assume steady state and D=30 cm2

/s

(a) Consider diffusive transport of particles between two points A & B separated by

100 µm. The concentration of particles at A is 1012 cm-3 & at B is 0 cm-3. Assume τ=∞.

Find the concentration profile for particles from A to B. What is the particle flux from

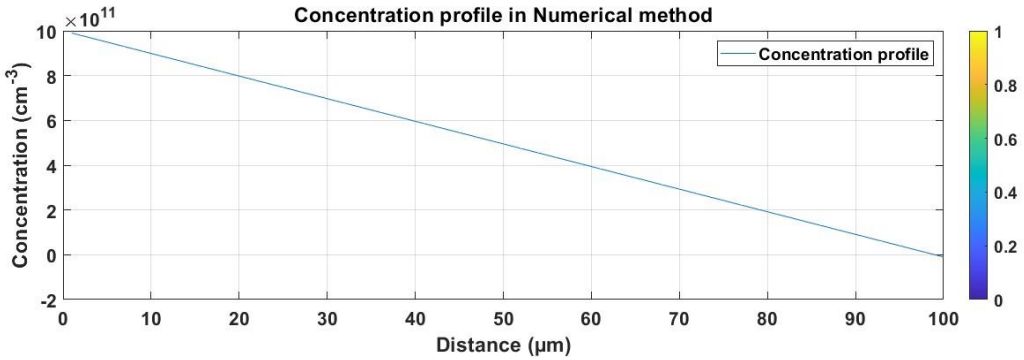
A to B?

Ans:

Concentration: Numerical method

```
clc;
N=100;
Ca=-10^(12);
Cb=0;
C=zeros(1,N);
C(1)=Ca;
C1=C';
for i=1:N-1
    M(i,i)=-2;
end
for i=1:N-1
    M(i,i+1)=1;
end
for i=1:N-1
    M(i+1,i)=1;
end
Cf=inv(M)*C1;
i=1:100;
plot(i,Cf)
grid on;
xlabel('Distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Numerical method')
```

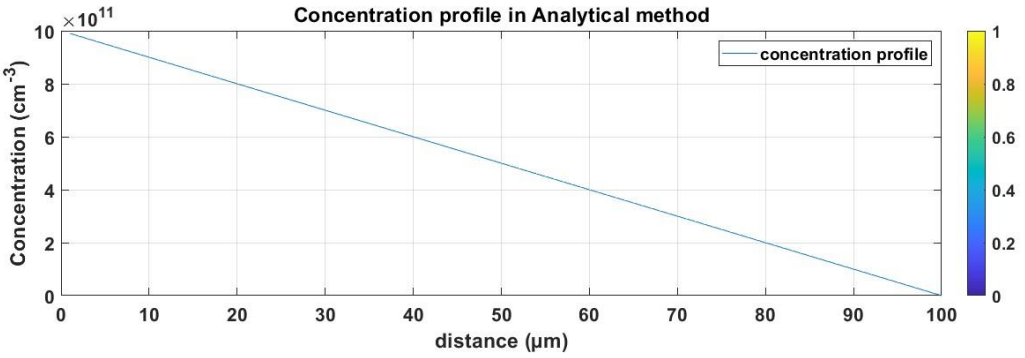
A



Analytical:

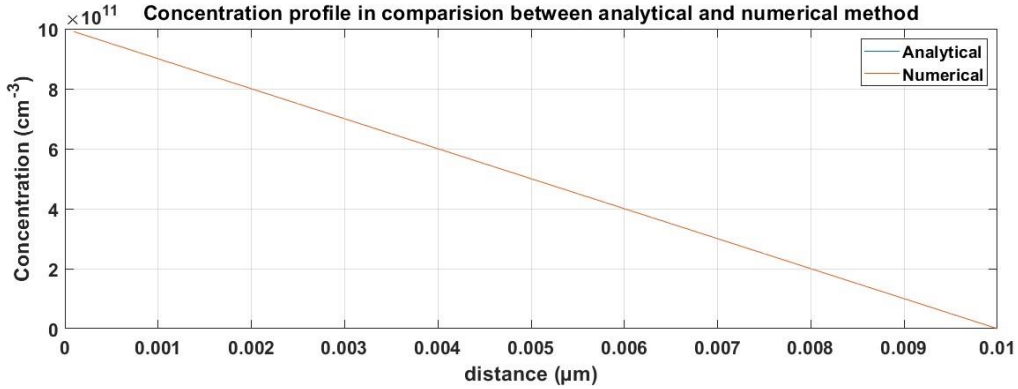
```
clc;
x=1:100;
c=(-(10^14)*x)+(10^12);
```

```
plot(x,c);
grid on;
xlabel('distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Analytical method')
```



Comparision:

```
clc;
q=1.6*(10)^(-19);
a=100*10^(-4);
h=a/100;
N=100;
Ca=-10^(12);
Cb=0;
C=zeros(1,N);
C(1)=Ca;
C1=C';
D=30;
for i=1:N-1
    M(i,i)=-2;
end
for i=1:N-1
    M(i,i+1)=1;
end
for i=1:N-1
    M(i+1,i)=1;
end
Cf=inv(M)*C1;
i=1:100;
z=i*10^-4;
grid on;
xlabel('distance (µcm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Numerical method')
x=1:100;
z=x*10^-4;
c=(-(10^14)*z)+(10^12);
plot(z,Cf,z,c);
grid on;
xlabel('distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in comparision between analytical and numerical
method')
```

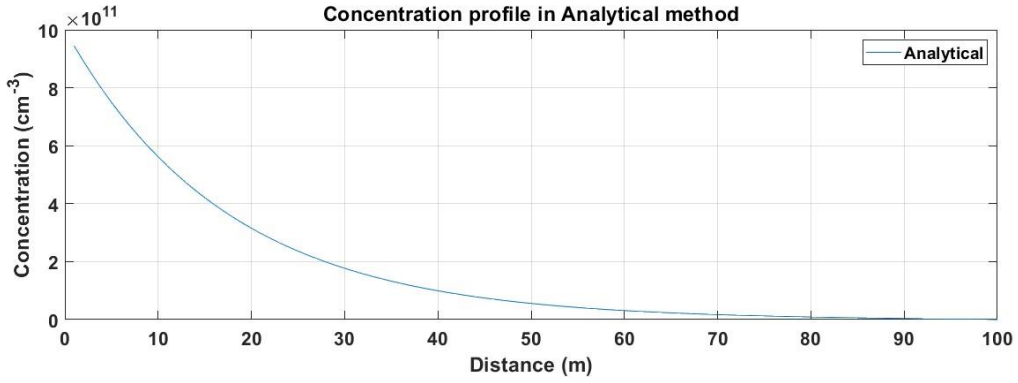


(b) Solve (a) with τ=10-7 s and other conditions remaining the same.

ANS:

ANALYTICAL:

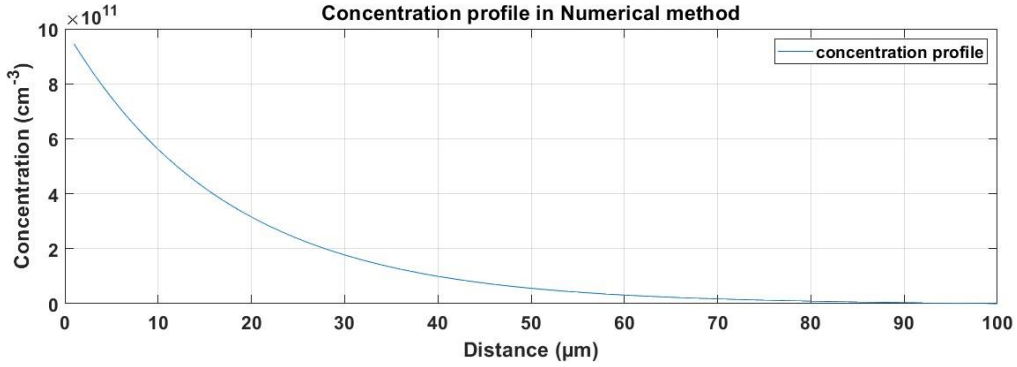
```
clc
N=1000;
h=(100*(10^-4))/N;
D=30;
tau=10^-7;
j=(D*tau)^-0.5;
A=-10^7;
B=10^12;
i=1:100;
y=i*(10^-4);
c=(A*exp(j*y))+(B*exp(-j*y));

plot(i,c)
grid on
xlabel('Distance (m)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Analytical method')
```



Numerical:

```
clc;
a=100*10^(-4);
h=a/100;
N=100;
Ca=-10^(12);
Cb=0;
C=zeros(1,N);
```

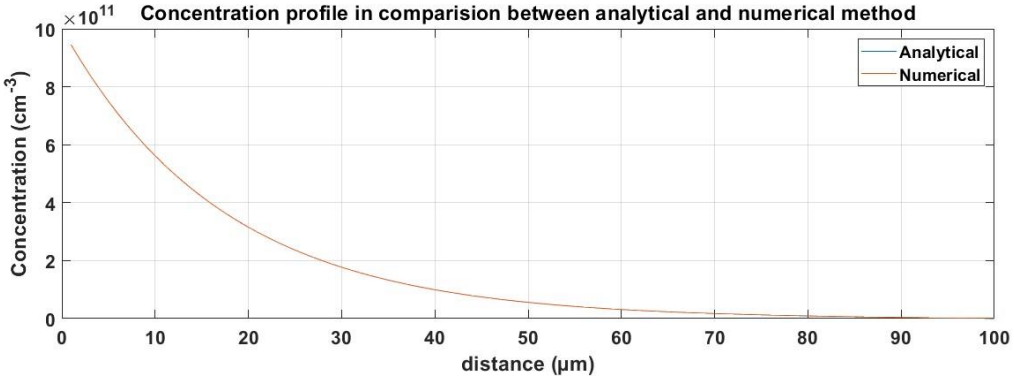
```
C(1)=Ca;
C1=C';
Tau=10^(-7);
D=30;
for i=1:N-1
    M(i,i)=-(2+(((h)^2)/(D*Tau)));
end
for i=1:N-1
    M(i,i+1)=1;
end
for i=1:N-1
    M(i+1,i)=1;
end
Cf=inv(M)*C1;
i=1:100;
plot(i,Cf);
grid on;
xlabel('Distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Numerical method')
```



Comparision:

```
clc
N=100;
h=(100*(10^-4))/N;
D=30;
tau=10^-7;
j=(D*tau)^-0.5;
A=-10^7;
B=10^12;
i=1:100;
y=i*(10^-4);
c=(A*exp(j*y))+(B*exp(-j*y));
Ca=-10^(12);
Cb=0;
C=zeros(1,N);
C(1)=Ca;
C1=C';
for i=1:N-1
    M(i,i)=-(2+(((h)^2)/(D*tau)));
end
for i=1:N-1
    M(i,i+1)=1;
end
for i=1:N-1
    M(i+1,i)=1;
```

```
end
Cf=inv(M)*C1;
i=1:100;
plot(i,Cf,i,c);
grid on;
xlabel('distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in comparision between analytical and numerical
method')
```



(c) For the configuration in part (a), assume that the boundary condition at B is such

that the particle flux F there is equal to kC, where k=103

cm/s and C is the

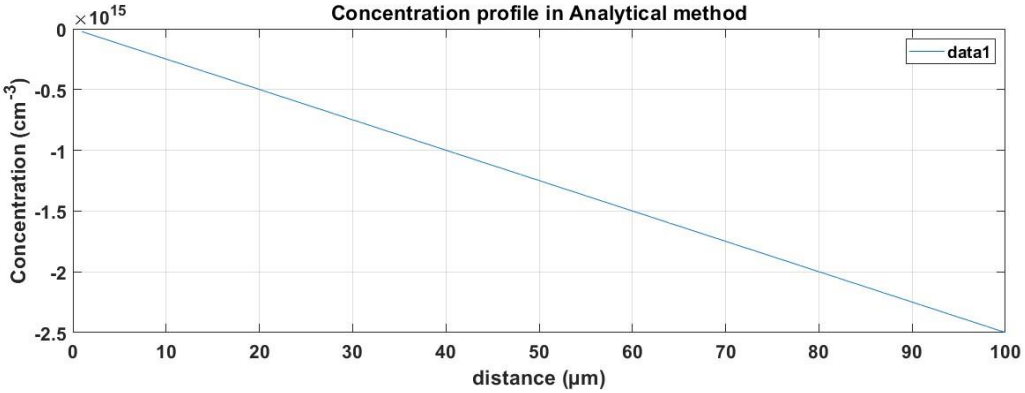
concentration there. Assume τ=∞. Find the concentration profile for particles from A

to B.

ans

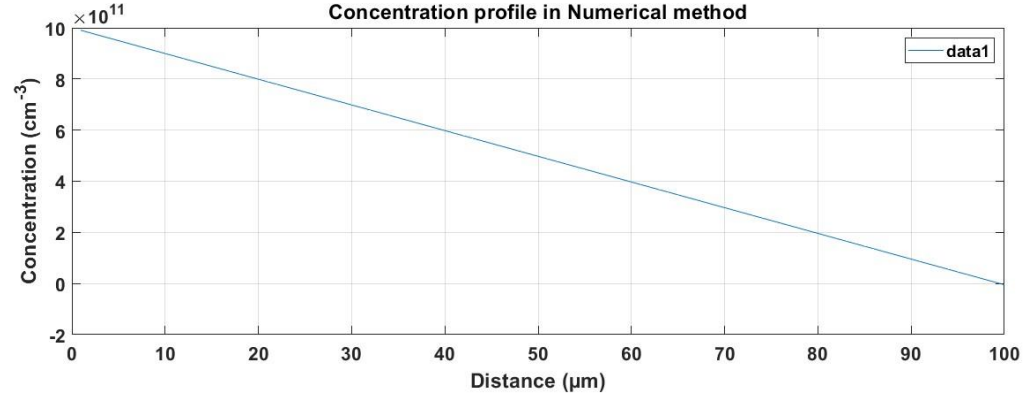
analytical

```
clc;
x=1:100;
c=(-(10^14)*x)+(10^12);
plot(x,c);
grid on;
xlabel('distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Analytical method')
```



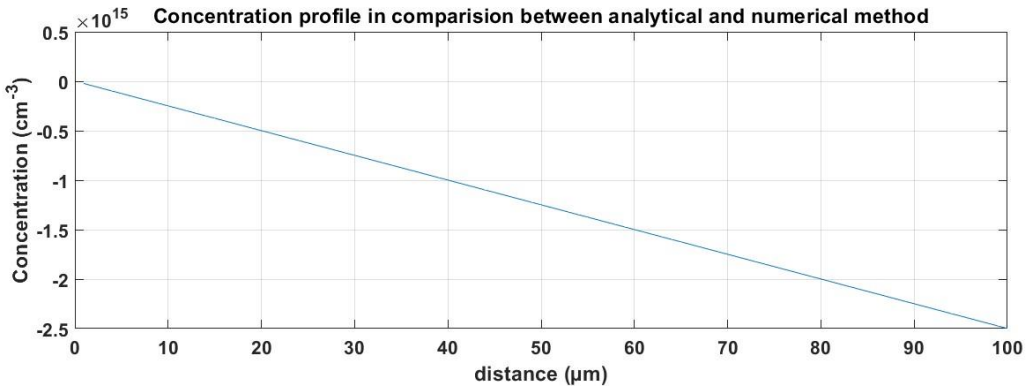
Numerical:

```
clear all;
clc;
a=100*10^(-4);
h=a/100;
N=100;
Ca=-10^(12);
Cb=0;
C=zeros(1,N);
C(1)=Ca;
C1=C';
D=30;
for i=1:N-1
    M(i,i)=-2;
end
for i=1:N-1
    M(i,i+1)=1;
end
for i=1:N-1
    M(i+1,i)=1;
end
M(N,N-1)=(-(D/h)+(10^3));
M(N,N)=(-(D/h));
Cf=inv(M)*C1;
plot(Cf)
grid on;
xlabel('Distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Numerical method')
```



COMPARISION:

```
clear all;
clc;
a=100*10^(-4);
h=a/100;
N=100;
Ca=-10^(12);
Cb=0;
C=zeros(1,N);
C(1)=Ca;
C1=C';
y=[];
D=30;
for x=1:100
c=(-(0.25*(10^14)*x)+(10^12));
y=[y c];
end
x=1:100;

for i=1:N-1
    M(i,i)=-2;
end
for i=1:N-1
    M(i,i+1)=1;
end
for i=1:N-1
    M(i+1,i)=1;
end
M(N,N-1)=(-(D/h)+(10^3));
M(N,N)=(-(D/h));
Cf=inv(M)*C1;


plot(x,y,i,Cf)
grid on;
xlabel('distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in comparision between analytical and numerical
method')
```

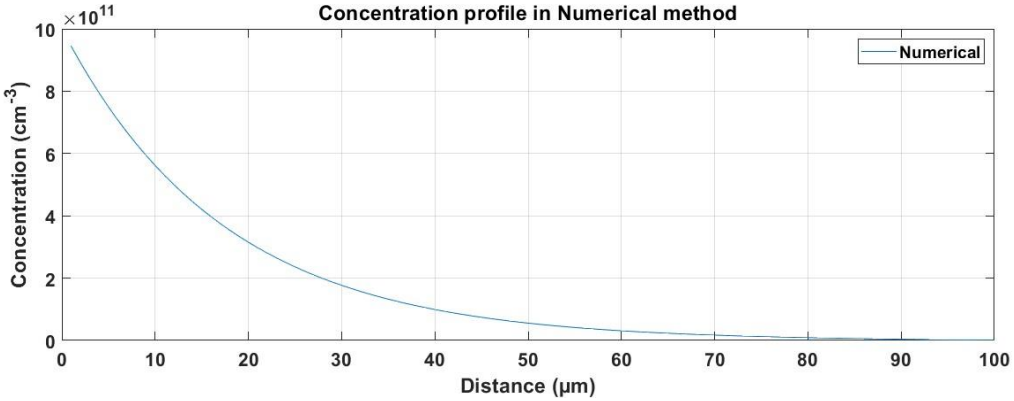


(d) Solve (c) with τ=10-7 s and other conditions remaining the same.

ANS

NUMERICAL

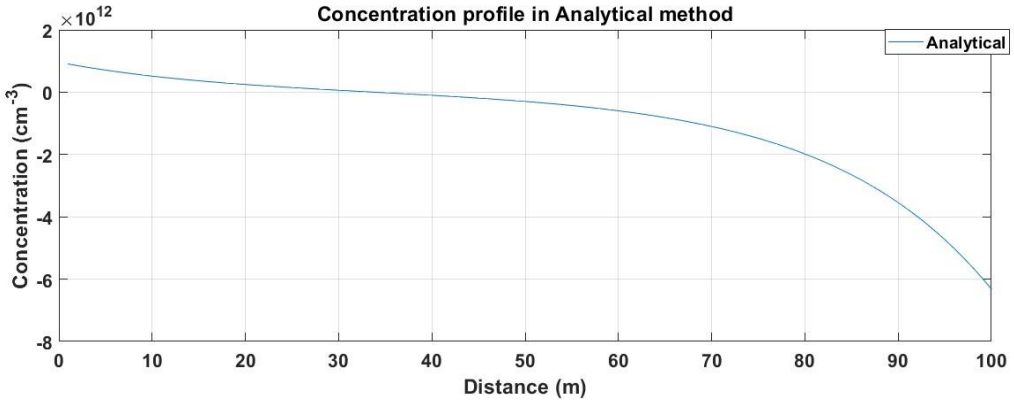
```
clear all;
clc;
a=100*10^(-4);
h=a/100;
N=100;
Ca=-10^(12);
Cb=0;
C=zeros(1,N);
C(1)=Ca;
C1=C';
D=30;
Tau=(10^(-7));
for i=1:N-1
    M(i,i)=-(2+((h^2)/(D*Tau)));
end
for i=1:N-1
    M(i,i+1)=1;
end
for i=1:N-1
    M(i+1,i)=1;
end
M(100,99)=((10^3));
M(100,100)=(-2*(10^3)-(h^2)/(D/Tau));
Cf=inv(M)*C1;
plot(Cf)
grid on;
xlabel('Distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Numerical method')
```



Analytical

```
clc
N=1000;
h=(100*(10^-4))/N;
D=30;
tau=10^-7;
j=(D*tau)^-0.5;
A=-19.65*(10^9);
B=.981*(10^12);
i=1:100;
y=i*(10^-4);
c=(A*exp(j*y))+(B*exp(-j*y));

plot(i,c)
grid on
```

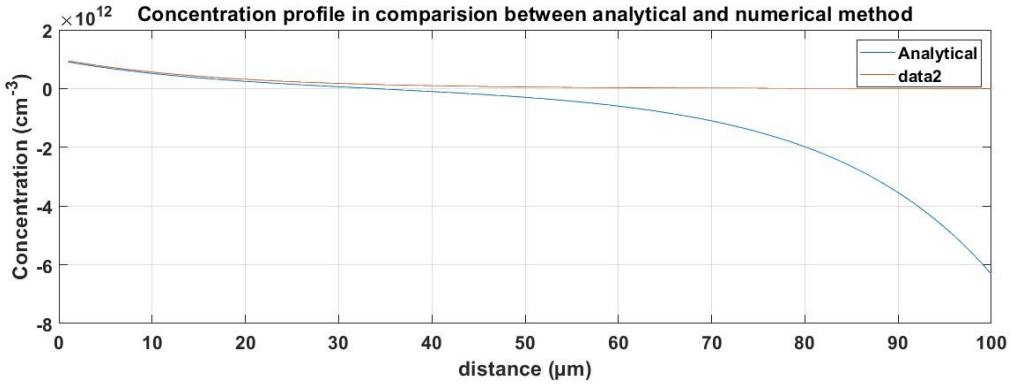
```
xlabel('Distance (m)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Analytical method')
```



Comparision:

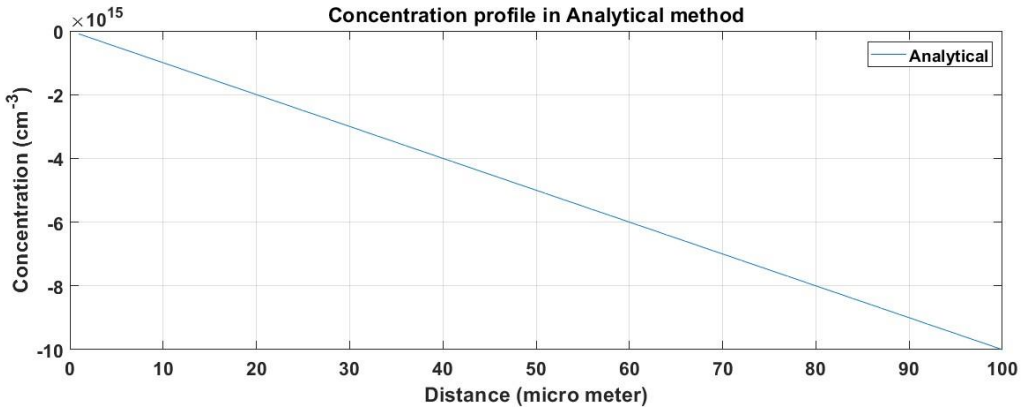
```
clear all;
clc;
a=100*10^(-4);
h=a/100;
N=100;
Ca=-10^(12);
Cb=0;
C=zeros(1,N);
C(1)=Ca;
C1=C';
D=30;
Tau=(10^(-7));
for i=1:N-1
    M(i,i)=-(2+((h^2)/(D*Tau)));
end
for i=1:N-1
    M(i,i+1)=1;
end
for i=1:N-1
    M(i+1,i)=1;
end
M(100,99)=((10^3));
M(100,100)=(-2*(10^3)-(h^2)/(D/Tau));
Cf=inv(M)*C1;

N=1000;
h=(100*(10^-4))/N;
D=30;
tau=10^-7;
j=(D*tau)^-0.5;
A=-19.65*(10^9);
B=.981*(10^12);
i=1:100;
y=i*(10^-4);
c=(A*exp(j*y))+(B*exp(-j*y));

plot(i,c,i,Cf)
grid on;
xlabel('distance (µm)')
ylabel('Concentration (cm^-^3)')
```

```
title('Concentration profile in comparision between analytical and numerical
method')
```



(e) For the configuration in part (a), assume that a particle flux is introduced at x=30
µm at the rate of 1012 cm-2/s. Assume that the particle density at A & B are held constant at 0 and τ=∞. Find the concentration profile for particles from A to B.
ans
analytical:

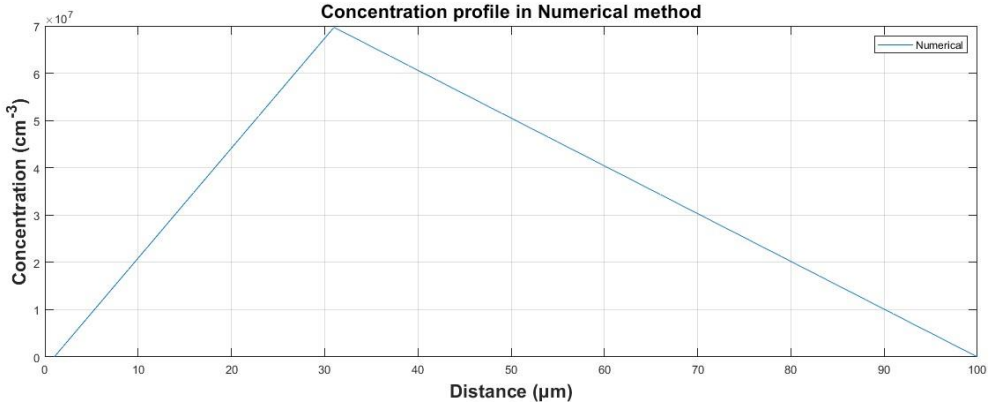
```
y=[];
for i=0:30
    x=(7/3)*10^6*i;
    y=[y x];
end
for i=31:100
    x=-(i-100)*10^6;
    y=[y x];
end
i=0:100;
k=i*10^-4;
plot(k,y);
grid on
xlabel('Distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Analytical method')
```



NUMERICAL:

```
clc;
q=1.6*(10)^(-19);
a=100*10^(-4);
h=a/100;
N=100;
D=30;
k=10^12;
```

```
C=zeros(1,N);
C(31)=-((h*k)/D);
C1=C';
for i=1:N-1
    M(i,i)=-2;
end
for i=1:N-1
    M(i,i+1)=1;
end
for i=1:N-1
    M(i+1,i)=1;
end
M(1,1)=1;
M(1,2)=0;
M(N,N)=1;
M(N,N-1)=0;
Cf=M\C1;
plot(Cf);
grid on;
xlabel('Distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in Numerical method');
```




```
Comparision:
clc;
q=1.6*(10)^(-19);
a=100*10^(-4);
h=a/100;
N=101;
D=30;
k=10^12;
C=zeros(1,N);
C(31)=-((h*k)/D);
C1=C';
for i=1:N-1
    M(i,i)=-2;
end
for i=1:N-1
    M(i,i+1)=1;
end
for i=1:N-1
    M(i+1,i)=1;
end
M(1,1)=1;
M(1,2)=0;
M(N,N)=1;
M(N,N-1)=0;
```

```
Cf=M\C1;
y=[];
for i=0:30
    x=(7/3)*10^6*i;
    y=[y x];
end
for i=31:100
    x=-(i-100)*10^6;
    y=[y x];
end
i=0:100;

plot(i,y,i,Cf);
grid on;
xlabel('distance (µm)')
ylabel('Concentration (cm^-^3)')
title('Concentration profile in comparision between analytical and numerical
method')
```