Assignment 7

Group Number 32

Software used: **Matlab**

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a. Forward in time backward in space(FTBS)

The following scheme is not stable but consistent. So the roundoff errors are not allowing the solution to converge. The following stability analysis is been provided here.

1) Backward Scheme in Space

$$f''(x) = \frac{u_i^n - 2 \cdot u_{i-1}^n + u_{i-2}^n}{\Delta x^2}$$

2) Forward Scheme in time

$$\frac{u_i^{n+1} - u_i^n}{\alpha \cdot \Delta t}$$

3) Assumption for 'r'

$$r = \frac{\alpha \cdot \Delta t}{\Delta x^2}$$

4) Simplification gives

$$u_i^{n+1} = (1+r) \cdot u_i^n - 2 \cdot r \cdot u_{i-1}^n + r \cdot u_{i-2}^n$$

5) Making substitution

$$u_m^n = g_n \cdot e^{i \cdot m\Theta}$$

$$with \quad |g| \leq 1 \quad CFL\, condition$$

6) Expression for 'g'

$$g = 1 + 2 \cdot r + 2 \cdot r\cos\Theta - r\cos 2\Theta \;\; + \ldots\ldots + \;\; higher\ order\ terms$$

Which is unstable for all values of 'r' and 'Θ'

b. Du-Fort Frenkel Scheme

Code

```
clearvars
clc
fprintf('\nDu-Fort Frankel Scheme applied to 1-D heat conduction problem\n')
%Endpoints of rod such that b-a=Length of rod
a=0;
b=1;
% for Ut=alp*Uxx form
alp=400/(385*8000);

% dx and dt are grid differences
dx=input('\nUnit Grid Size dx: ');
dt=input('\nInput Time Step dt: ');
%dx=0.25;
%dt=2;
x=a:dx:b;
t=0:dt:900;
%Calculation for size of x and t points
[sizx,sizx]=size(x);
[sizt,sizt]=size(t);
u= zeros(sizt,sizx);
%formula for r
r=alp*dt/(dx^2);

%Initial Condition
u(1,:)=25;


%Rod is maintained at 400 C.
%Thus setting Boundary conditions
u(2:sizt,1)=400;
u(2:sizt,sizx)=400;

%Formula is worked out for Du-Fort Frankel Scheme
%Format U(i+1,j)=F(U(i,j+1),U(i,j-1),U(i,j))
%Here 'i' represents time step
%And 'j' represents spatial variation
%Loop is written to get iteration values

%For deifining TDMA
A=zeros(sizx-2,sizx-2);
```

Output

a. **dy = 0.1m , dt = 1s**

Du-Fort Frankel Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.1

Input Time Step dt: 1

Middle length reaches 200 C at t = 678.000000s

b. **dy = 0.2m , dt = 1s**

Du-Fort Frankel Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.2

Input Time Step dt: 1

Middle length reaches 200 C at t = 634.000000s

c. **dy = 0.5m , dt = 1s**

Du-Fort Frankel Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.5

Input Time Step dt: 1

Middle length reaches 200 C at t = 606.000000s

d. **dy = 0.1m , dt = 0.5s**

Du-Fort Frankel Scheme applied to 1-D heat conduction problem

```
for i=2:sizt

    %Now based of formula we will write TDMA matrix
    %a represents 1st diagonal below main diagonal
    %b represents main diagonal
    %c represents 1st diagonal above main diagonal


for j=1:sizx-3
   a(1,j)=0;
   c(1,j)=a(1,j);
   A(j+1,j)=a(1,j);
   A(j,j+1)=c(1,j);

end

for j=1:sizx-2
    b(1,j)=(1+2*r);
    A(j,j)=b(1,j);
    if i==2
       d(j,1)=2*r*u(i-1,j)+(1-2*r)*u(i-1,j+1)+2*r*u(i-1,j+2);
    else
       d(j,1)=2*r*u(i-1,j)+(1-2*r)*u(i-2,j+1)+2*r*u(i-1,j+2);
    end
end

%For identifying the size of matrix
[n,j]=size(d);

%Definition taken from Atkinson
beta(1)=A(1);
g(1)=d(1);

%TDMA triangular matrix solution for Lg=b form where
g=UX
for l=2:n

%Definition taken from Atkinson
alpha(l)=A(l,l-1)/beta(l-1);
beta(l)=A(l,l)-alpha(l)*A(l-1,l);
g(l)=d(l)-alpha(l)*g(l-1);

end

%Back substitution for solving g=UX
xu(n)=g(n)/beta(n);
for l=n-1:-1:1
xu(l)=(g(l)-A(l,l+1)*xu(l+1))/beta(l);
end
xu;

%Updating thevalue of u
u(i,2:sizx-1)=[xu];

end
```

Unit Grid Size dx: 0.1

Input Time Step dt: 0.5

Middle length reaches 200 C at t = 678.000000s

e. **dy = 0.2m , dt = 0.5s**

Du-Fort Frankel Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.2

Input Time Step dt: 0.5

Middle length reaches 200 C at t = 633.500000s

f. **dy = 0.5m , dt = 0.5s**

Du-Fort Frankel Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.5

Input Time Step dt: 0.5

Middle length reaches 200 C at t = 605.500000s

g. **dy = 0.1m , dt = 0.1s**

Du-Fort Frankel Scheme applied to 1-D heat conduction problem

```
%y represents all the values of temperature which
change for t>0 at mid
%midlen
y=u(:,round(sizx/2));
figure
subplot(2,1,2);
plot(t,y,'-r')
title('Graph of temperature vs time at mid-length')
xlabel('Time')
ylabel('Temperature')
legend(['dx = ',num2str(dx),'  dt =
',num2str(dt)],'Location','north')

%Additional information
y=u(sizt,:);
%represents temperature variation in bar at 900s
subplot(2,1,1);
plot(x,y,'-ro')
title('Graph of temperature vs length at t = 900s ')
xlabel('Length')
ylabel('Temperature')
legend('Du-Fort Frankel Scheme','Location','north')
grid on

%'k' Finds the values where we get 200 C
k = find(round(u(:,round(sizx/2)))==200 & (abs(200-
u(:,round(sizx/2)))< 1));
if isempty(k) == 1
   fprintf('\nMethod is stable but not consistent\n');
   fprintf('\nThis scheme will not reach to 200 C for
interval %d to %ds\nMiddle length temperature is %f C
at %ds\n\n',t(1),t(sizt),u(sizt,round(sizx/2)),t(sizt));
else
%Some values might be repeated when grid size is small
%Thus median is taken as rod has symmetric condition
k=round(median(k));
%t200 represents time when mid-section is at 200 C
t200=t(k);
fprintf('\nMiddle length reaches 200 C at t =
%fs\n\n',t200)
%u(k,round(sizx/2)) is actual value close to 200 C
end
```

Unit Grid Size dx: 0.1

Input Time Step dt: 0.1

Middle length reaches 200 C at t = 677.700000s

h. **dy = 0.2m , dt = 0.1s**

Du-Fort Frankel Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.2

Input Time Step dt: 0.1

Middle length reaches 200 C at t = 632.900000s

i. **dy = 0.5m , dt = 0.1s**

Du-Fort Frankel Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.5

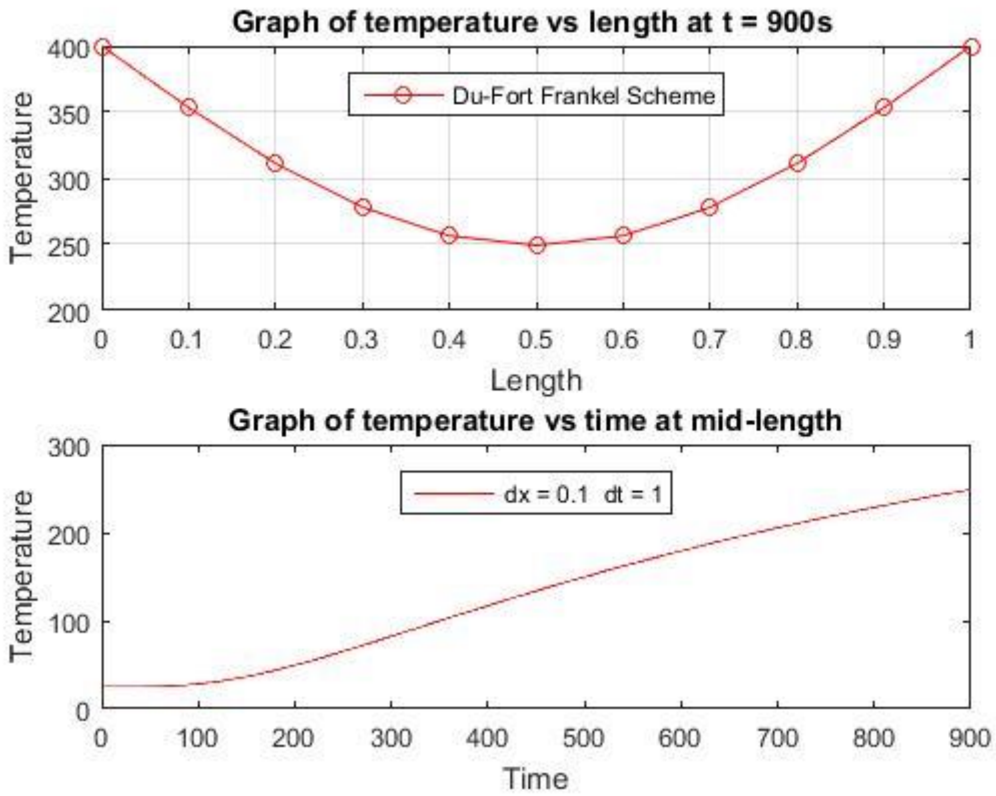
Input Time Step dt: 0.1

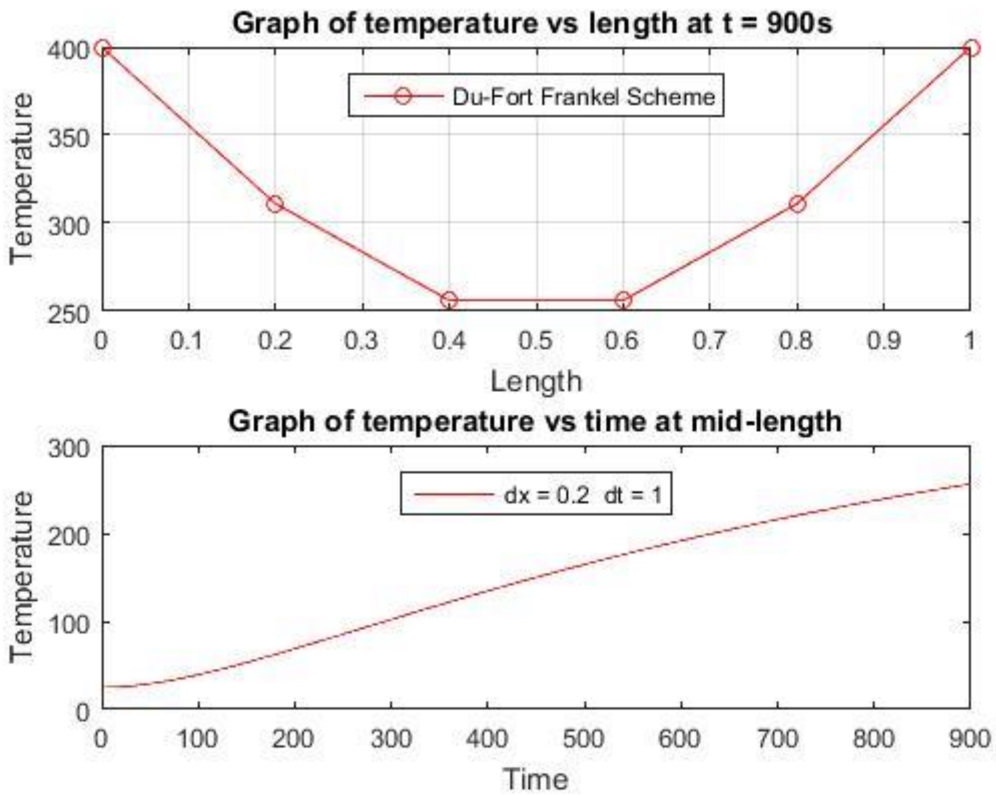
Middle length reaches 200 C at t = 605.200000s

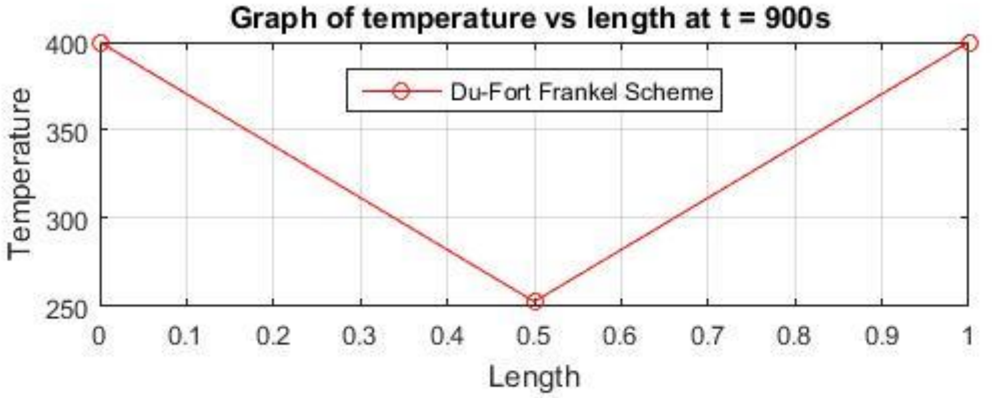
- **Results**

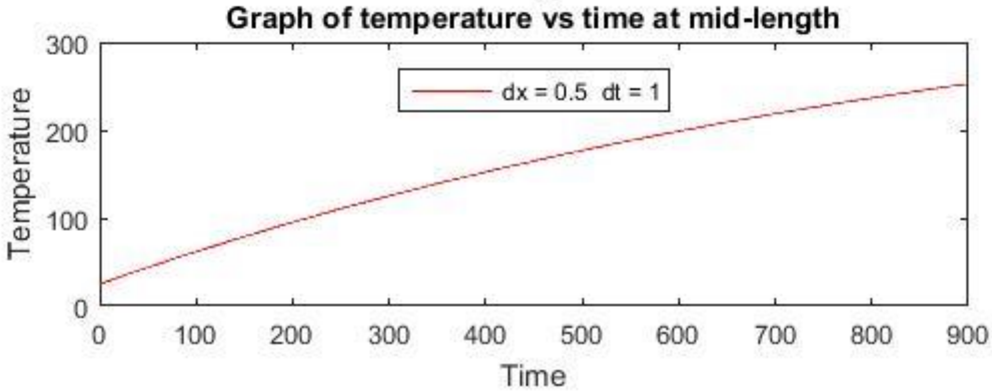
  The time required to reach 200 is mention in the table. The graph is plotted for variation of middle length from 0 – 900 s. Also the graph is plotted for temperature at 900 time step.

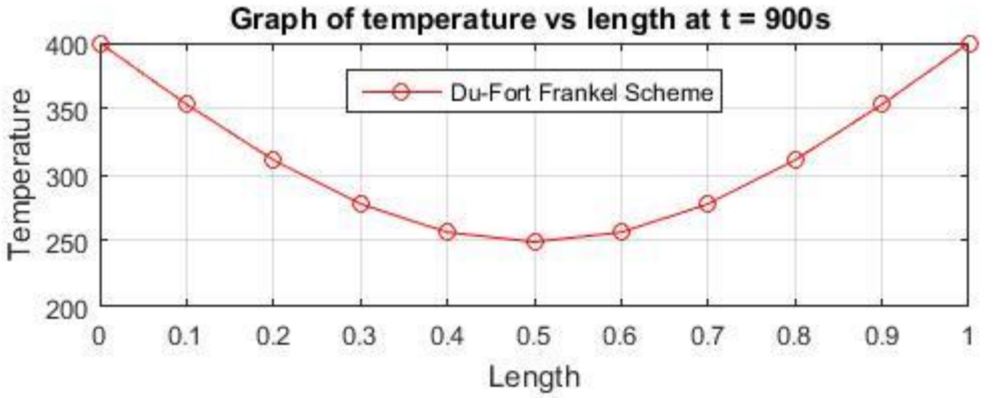
	dy = 0.1m	dy = 0.2m	dy = 0.5m
dt = 1s	678.000000s	634.000000s	606.000000s
dt = 0.5s	678.000000s	633.500000s	605.500000s
dt = 0.1s	677.700000s	632.900000s	605.200000s

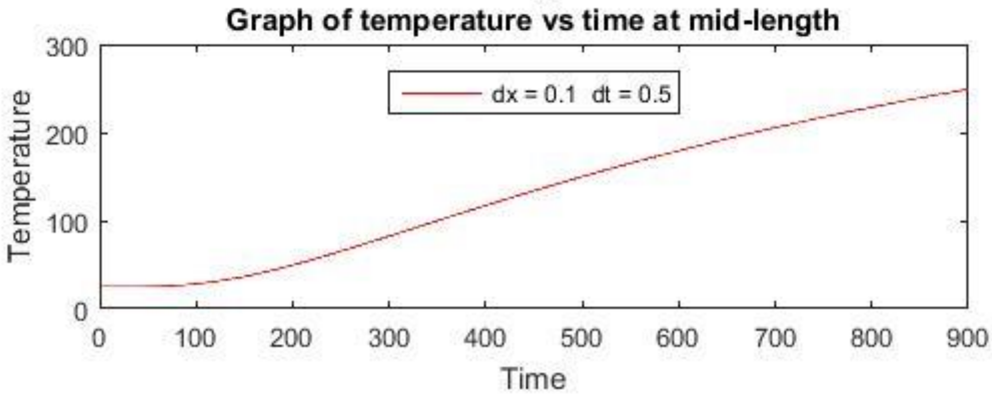

Graph of temperature vs length at t = 900s
Du-Fort Frankel Scheme
Temperature
Length
Graph of temperature vs time at mid-length
dx = 0.1 dt = 1
Temperature
Time

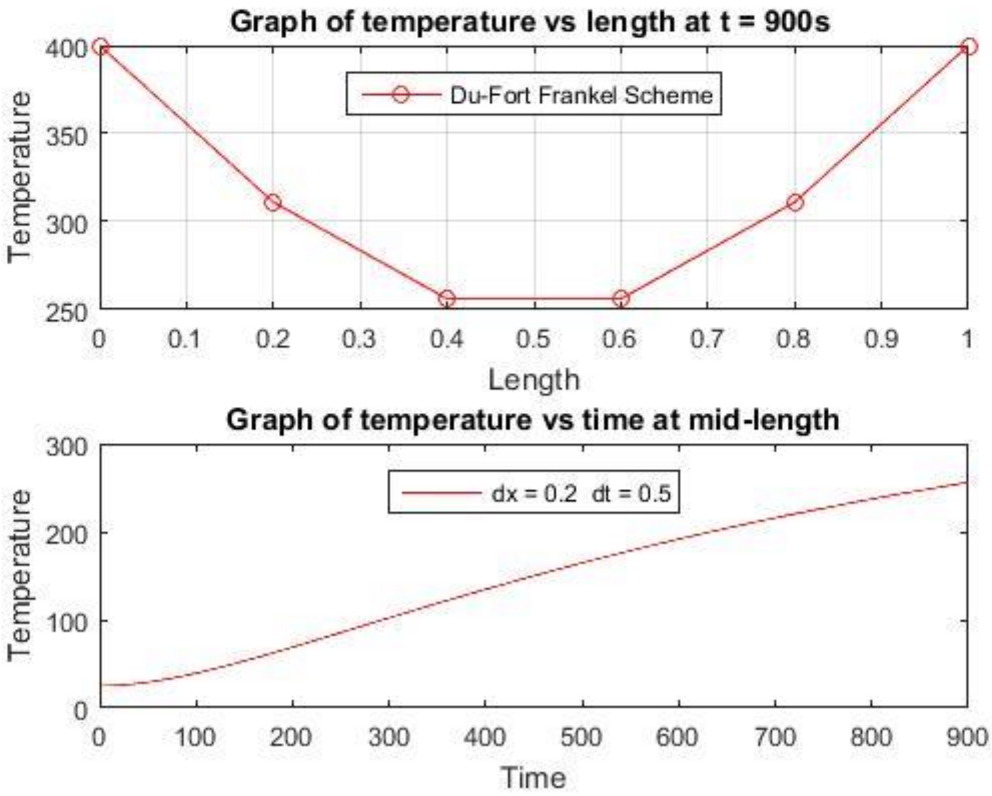

Graph of temperature vs length at t = 900s
Du-Fort Frankel Scheme
Temperature
Length
Graph of temperature vs time at mid-length
dx = 0.2 dt = 1
Temperature
Time

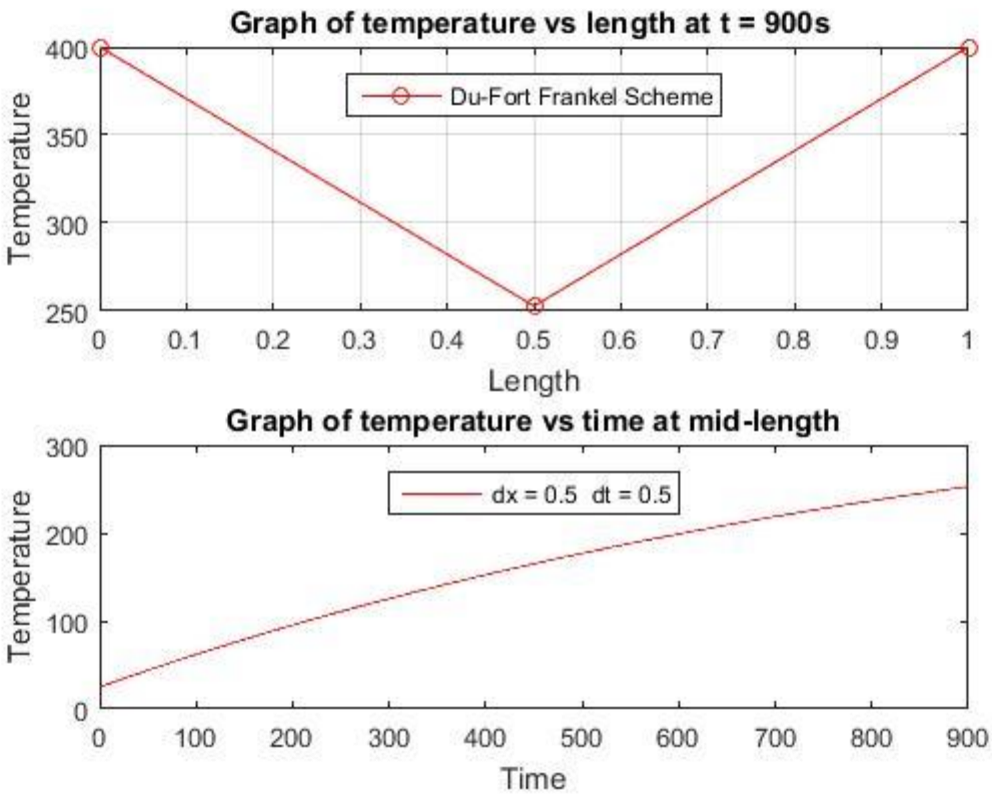

Graph of temperature vs length at t = 900s
Du-Fort Frankel Scheme
Temperature
Length
400
350
300
250
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

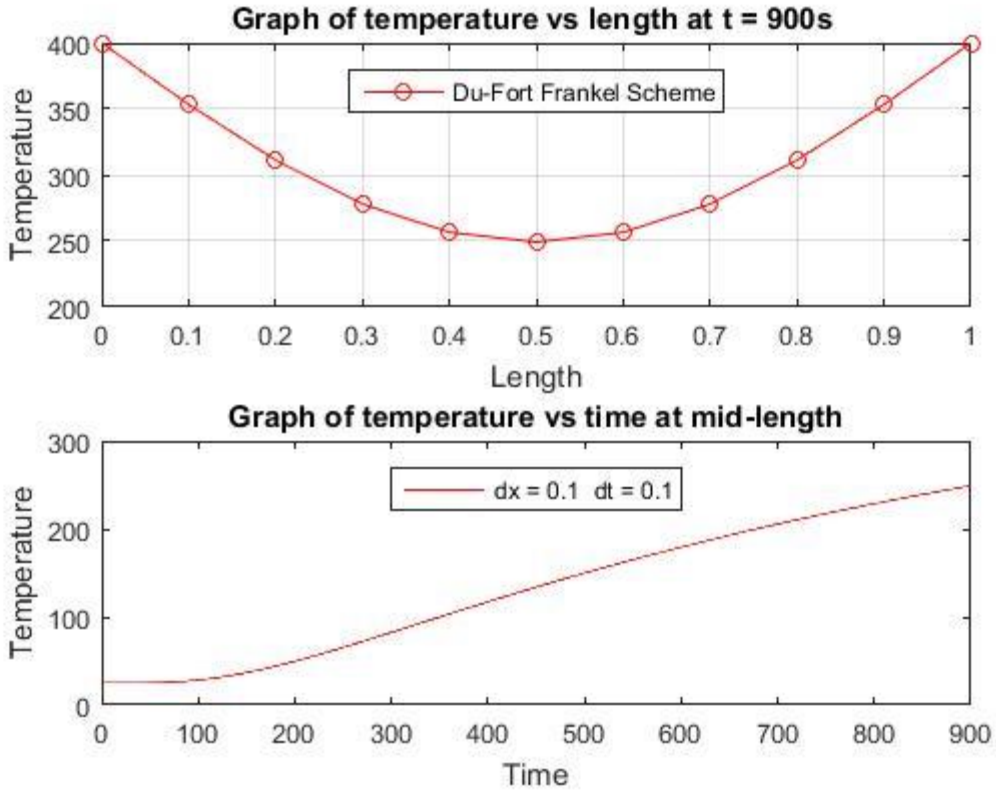

Graph of temperature vs time at mid-length
dx = 0.5 dt = 1
Temperature
Time
300
200
100
0
0
100
200
300
400
500
600
700
800
900

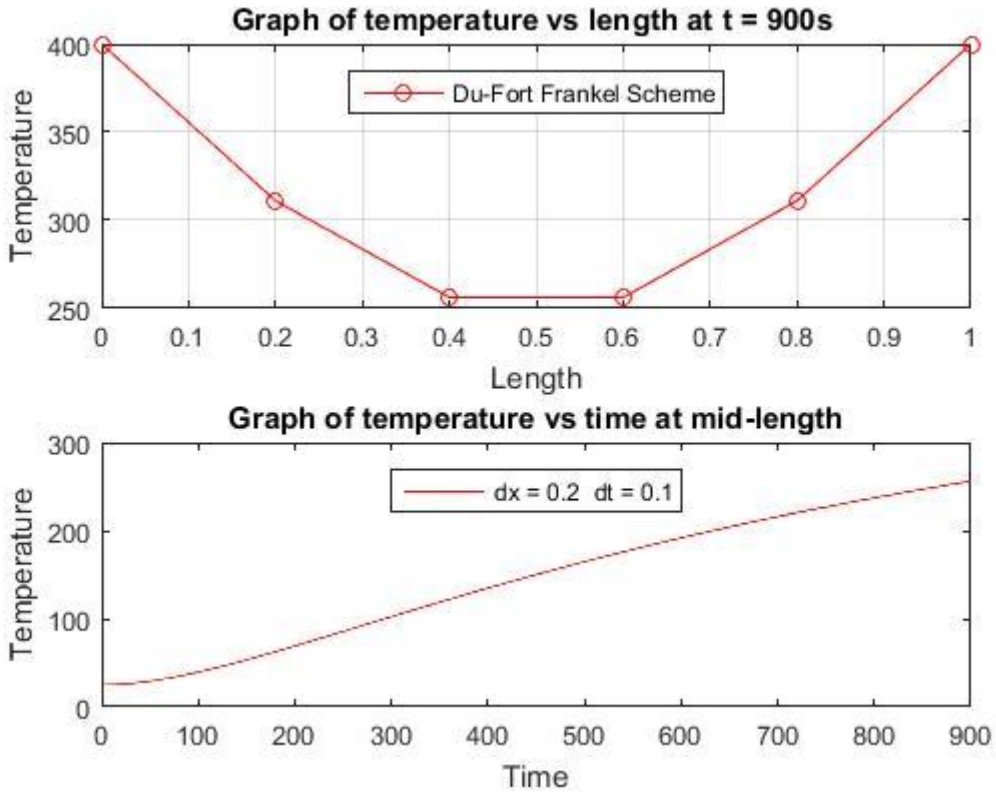

Graph of temperature vs length at t = 900s
Du-Fort Frankel Scheme
Temperature
Length
400
350
300
250
200
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

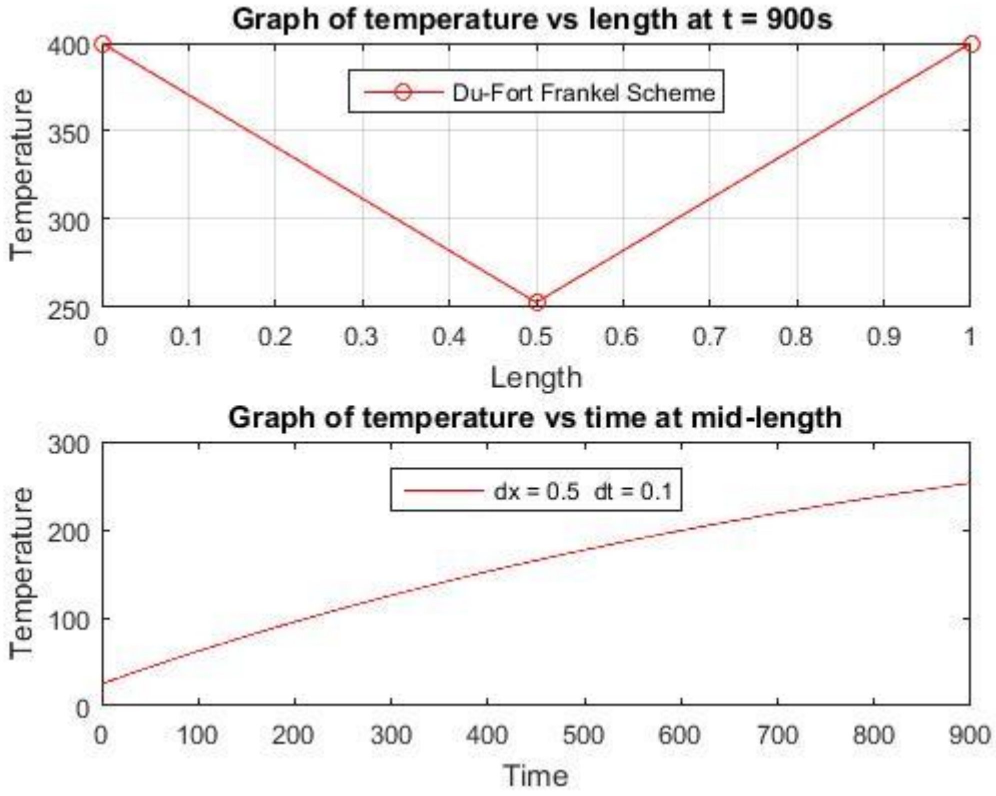

Graph of temperature vs time at mid-length
dx = 0.1 dt = 0.5
Temperature
Time
300
200
100
0
0
100
200
300
400
500
600
700
800
900


Graph of temperature vs length at t = 900s
Du-Fort Frankel Scheme
Temperature
Length
Graph of temperature vs time at mid-length
dx = 0.2 dt = 0.5
Temperature
Time


Graph of temperature vs length at t = 900s
Du-Fort Frankel Scheme
Temperature
Length
Graph of temperature vs time at mid-length
dx = 0.5 dt = 0.5
Temperature
Time


Graph of temperature vs length at t = 900s
Du-Fort Frankel Scheme
Temperature
Length
400
350
300
250
200
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Graph of temperature vs time at mid-length
dx = 0.1 dt = 0.1
Temperature
Time
300
200
100
0
0
100
200
300
400
500
600
700
800
900


Graph of temperature vs length at t = 900s
Du-Fort Frankel Scheme
Temperature
Length
400
350
300
250
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Graph of temperature vs time at mid-length
dx = 0.2 dt = 0.1
Temperature
Time
300
200
100
0
0
100
200
300
400
500
600
700
800
900



Graph of temperature vs length at t = 900s
Du-Fort Frankel Scheme
Temperature
Length
Graph of temperature vs time at mid-length
dx = 0.5 dt = 0.1
Temperature
Time

c. Fully Explicit Scheme

<table>
<tr><th>Code</th><th>Output</th></tr>
<tr><td>

```
clearvars
clc
fprintf('\nFully Implicit Scheme applied to 1-D heat
conduction problem\n')
%Endpoints of rod such that b-a=Length of rod
a=0;
b=1;
% for Ut=alp*Uxx form
alp=400/(385*8000);

% dx and dt are grid differences
dx=input('\nUnit Grid Size dx: ');
dt=input('\nInput Time Step dt: ');
%dx=0.25;
%dt=2;
x=a:dx:b;
t=0:dt:900;
%Calculation for size of x and t points
[sizx,sizx]=size(x);
[sizt,sizt]=size(t);
u= zeros(sizt,sizx);
%formula for r
r=alp*dt/(dx^2);

%Initial Condition
%This array has ghost value included
u(1,:)=25;


%Rod is maintained at 400 C.
%Thus setting Boundary conditions
u(2:sizt,1)=400;
u(2:sizt,sizx)=400;

%Formula is worked out for Fully Implicit
%Format U(i+1,j)=F(U(i,j+1),U(i,j-1),U(i,j))
%Here 'i' represents time step
%And 'j' represents spatial variation
%Loop is written to get iteration values

%For deifining TDMA
A=zeros(sizx-2,sizx-2);
```

</td><td>

a. **dy = 0.1m , dt = 1s**

Fully Implicit Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.1

Input Time Step dt: 1

Method is stable but not consistent

This scheme will not reach to 200 C for interval 0 to 900s
Middle length temperature is 10.061277 C at 900s

b. **dy = 0.2m , dt = 1s**

Fully Implicit Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.2

Input Time Step dt: 1

Method is stable but not consistent

This scheme will not reach to 200 C for interval 0 to 900s
Middle length temperature is 9.591897 C at 900s

c. **dy = 0.5m , dt = 1s**

Fully Implicit Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.5

Input Time Step dt: 1

Method is stable but not consistent

This scheme will not reach to 200 C for interval 0 to 900s
Middle length temperature is 9.818774 C at 900s

</td></tr>
</table>

```
for i=2:sizt

   %Now based of formula we will write TDMA matrix
   %a represents 1st diagonal below main diagonal
   %b represents main diagonal
   %c represents 1st diagonal above main diagonal


for j=1:sizx-3
  a(1,j)=r;
  c(1,j)=r;
  A(j+1,j)=a(1,j);
  A(j,j+1)=c(1,j);

end

for j=1:sizx-2
   b(1,j)=-(1+2*r);
   A(j,j)=b(1,j);
   d(j,1)=-u(i-1,j+1);
end

%For identifying the size of matrix
[n,q]=size(d);

%Definition taken from Atkinson
beta(1)=A(1);
g(1)=d(1);

%TDMA triangular matrix solution for Lg=b form where g=UX
for l=2:n

%Definition taken from Atkinson
alpha(l)=A(l,l-1)/beta(l-1);
beta(l)=A(l,l)-alpha(l)*A(l-1,l);
g(l)=d(l)-alpha(l)*g(l-1);

end

%Back substitution for solving g=UX
xu(n)=g(n)/beta(n);
for l=n-1:-1:1
xu(l)=(g(l)-A(l,l+1)*xu(l+1))/beta(l);
end
xu;

%Updating thevalue of u
u(i,2:sizx-1)=[xu];

end
```

d. **dy = 0.1m , dt = 0.5s**

Fully Implicit Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.1

Input Time Step dt: 0.5

Method is stable but not consistent

This scheme will not reach to 200 C for interval 0 to 900s
Middle length temperature is 10.057641 C at 900s

e. **dy = 0.2m , dt = 0.5s**

Fully Implicit Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.2

Input Time Step dt: 0.5

Method is stable but not consistent

This scheme will not reach to 200 C for interval 0 to 900s
Middle length temperature is 9.588616 C at 900s

f. **dy = 0.5m , dt = 0.5s**

Fully Implicit Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.5

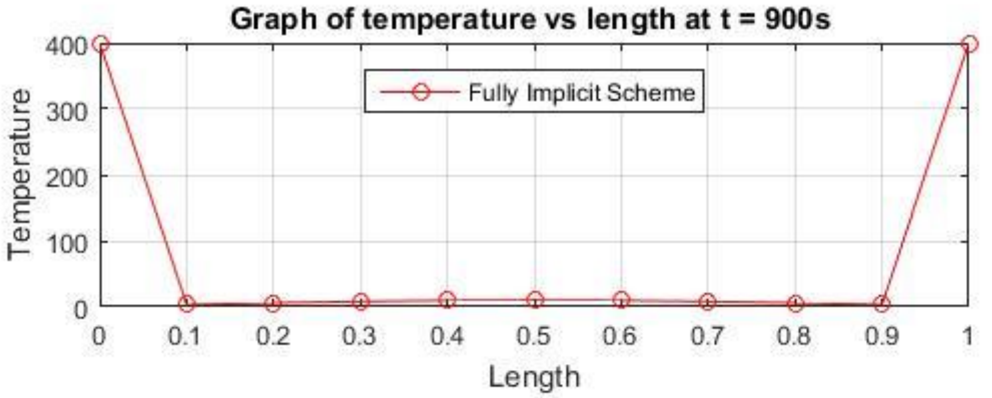
Input Time Step dt: 0.5

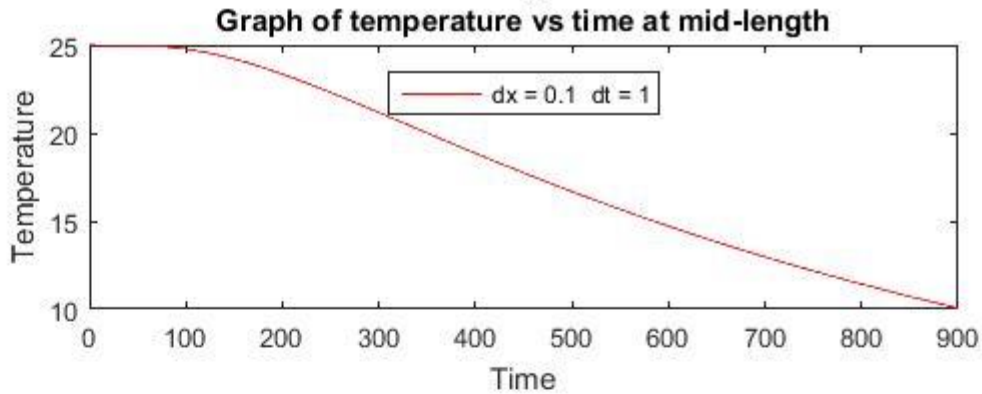
Method is stable but not consistent

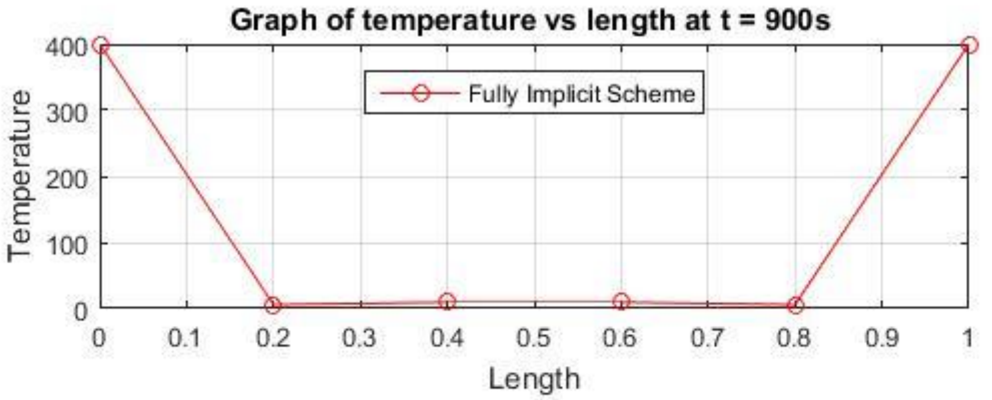
This scheme will not reach to 200 C for interval 0 to 900s
Middle length temperature is 9.816392 C at 900s

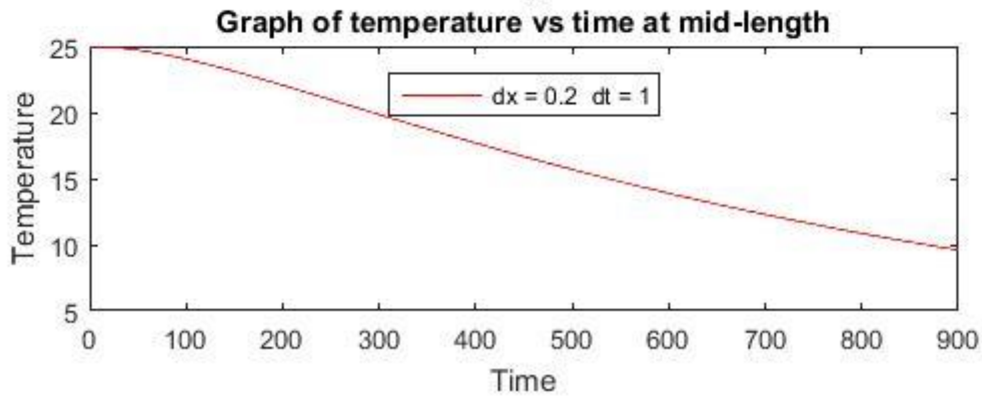
<pre>%y represents all the values of temperature which
change for t>0 at mid
%midlen
y=u(:,round(sizx/2));
figure
subplot(2,1,2);
plot(t,y,'-r')
title('Graph of temperature vs time at mid-length')
xlabel('Time')
ylabel('Temperature')
legend(['dx = ',num2str(dx),' dt =
',num2str(dt)],'Location','north')
 	
%Additional information
y=u(sizt,:);
%represents temperature variation in bar at 900s
subplot(2,1,1);
plot(x,y,'-ro')
title('Graph of temperature vs length at t = 900s ')
xlabel('Length')
ylabel('Temperature')
legend('Fully Implicit Scheme','Location','north')
grid on
 	
%'k' Finds the values where we get 200 C
k = find(round(u(:,round(sizx/2)))==200 & (abs(200-
u(:,round(sizx/2)))< 0.05));
if isempty(k) == 1
   fprintf('\nMethod is stable but not consistent\n');
   fprintf('\nThis scheme will not reach to 200 C for
interval %d to %ds\nMiddle length temperature is %f C
at %ds\n\n',t(1),t(sizt),u(sizt,round(sizx/2)),t(sizt));
else
%Some values might be repeated when grid size is small
%Thus median is taken as rod has symmetric condition
k=round(median(k));
%t200 represents time when mid-section is at 200 C
t200=t(k);
fprintf('\nMiddle length reaches 200 C at t =
%fs\n\n',t200)
%u(k,round(sizx/2)) is actual value close to 200 C
end</pre>
	g. **dy = 0.1m , dt = 0.1s**
	
	Fully Implicit Scheme applied to 1-D heat conduction problem
	
	Unit Grid Size dx: 0.1
	
	Input Time Step dt: 0.1
	
	Method is stable but not consistent
	
	This scheme will not reach to 200 C for interval 0 to 900s
	Middle length temperature is 10.054730 C at 900s
	
	h. **dy = 0.2m , dt = 0.1s**
	
	Fully Implicit Scheme applied to 1-D heat conduction problem
	
	Unit Grid Size dx: 0.2
	
	Input Time Step dt: 0.1
	
	Method is stable but not consistent
	
	This scheme will not reach to 200 C for interval 0 to 900s
	Middle length temperature is 9.585989 C at 900s
	
	i. **dy = 0.5m , dt = 0.1s**
	
	Fully Implicit Scheme applied to 1-D heat conduction problem
	
	Unit Grid Size dx: 0.5
	
	Input Time Step dt: 0.1
	
	Method is stable but not consistent
	
	This scheme will not reach to 200 C for interval 0 to 900s
	Middle length temperature is 9.814486 C at 900s

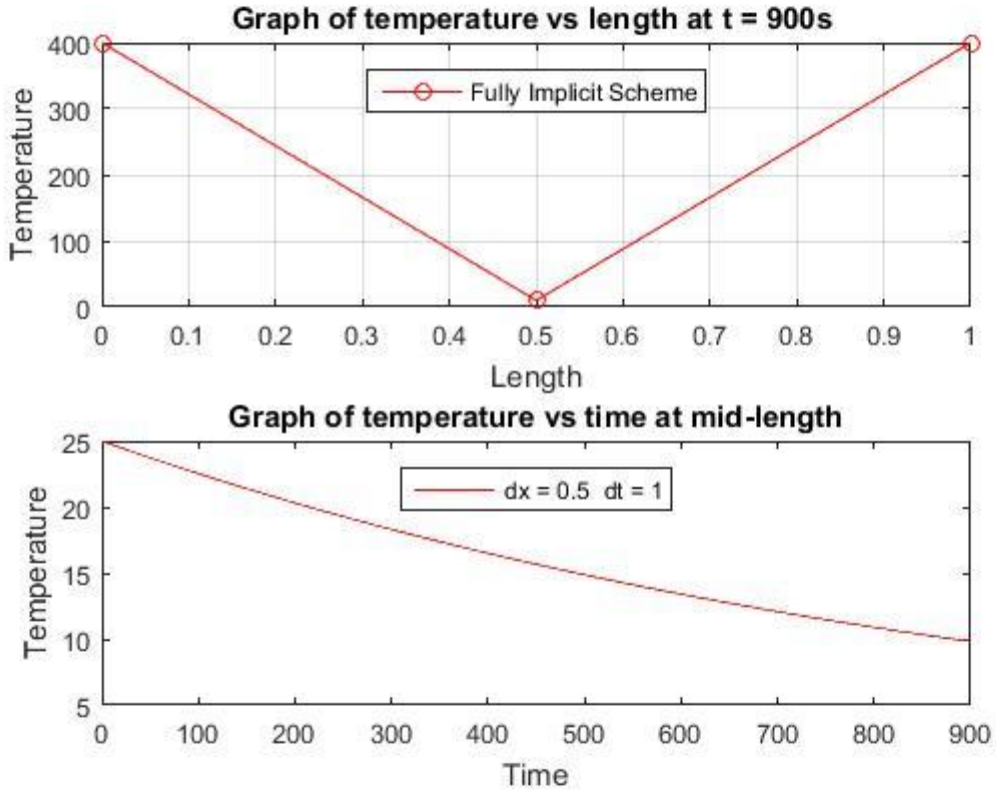
- **Results**
  For any values of dt and dy mentioned the solution will be erroneous as the method is inconsistent.

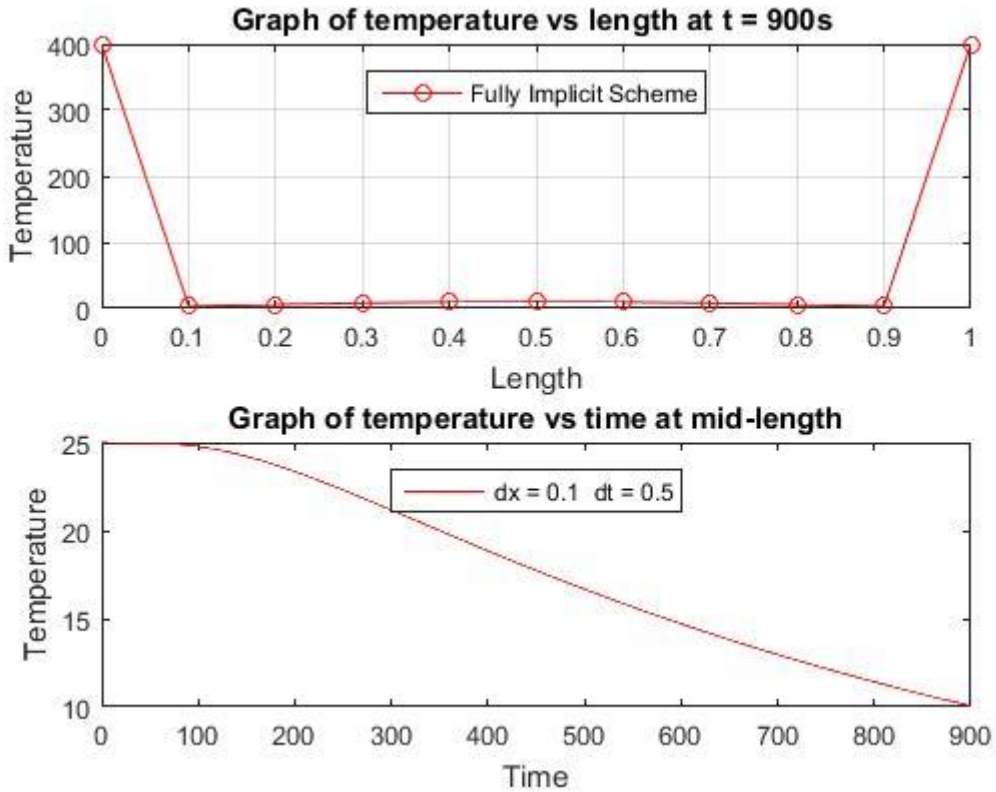

Graph of temperature vs length at t = 900s
Fully Implicit Scheme
Temperature
Length
0
100
200
300
400
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

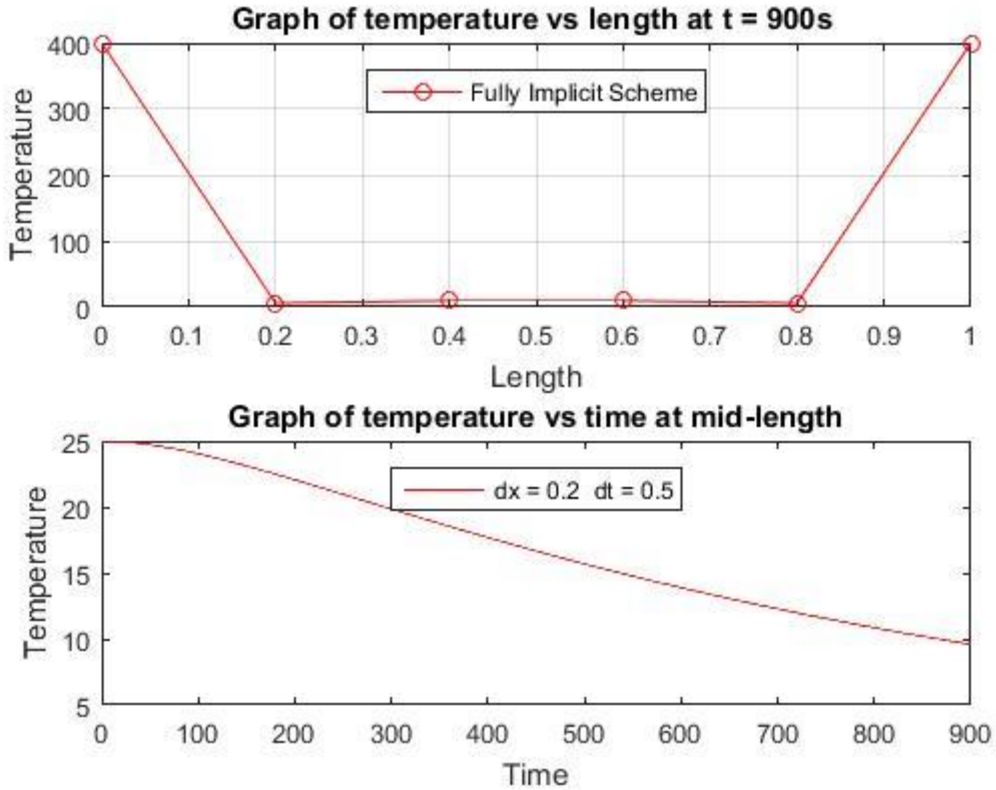

Graph of temperature vs time at mid-length
dx = 0.1 dt = 1
Temperature
Time
10
15
20
25
0
100
200
300
400
500
600
700
800
900

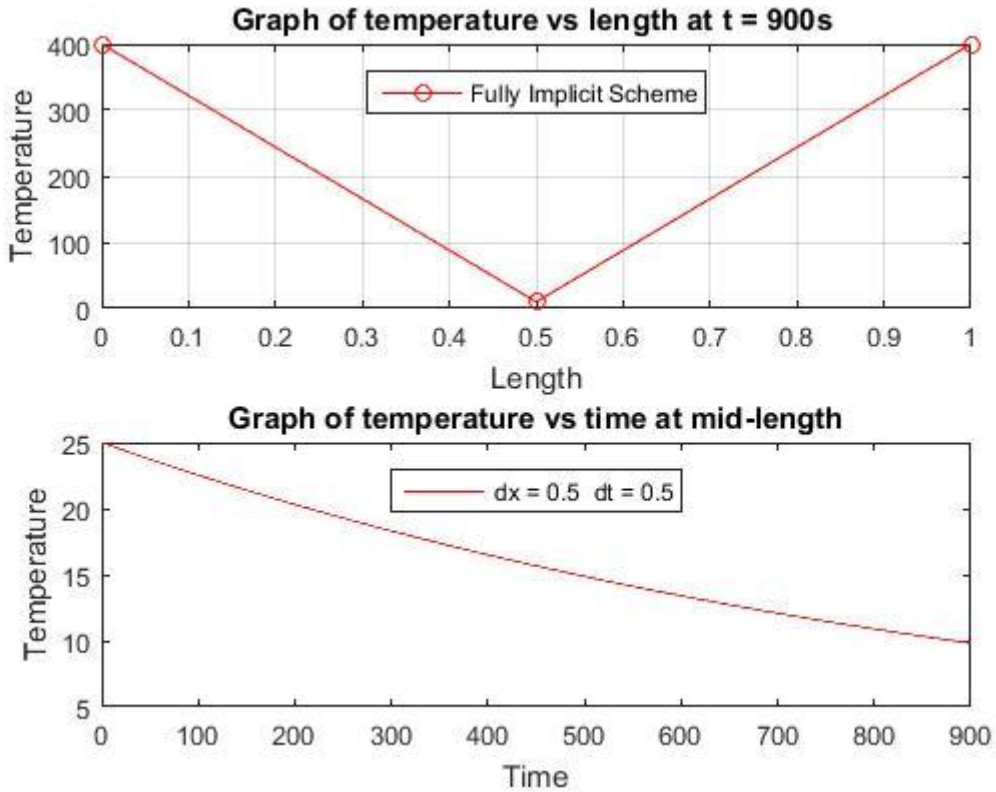

Graph of temperature vs length at t = 900s
Fully Implicit Scheme
Temperature
Length
0
100
200
300
400
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Graph of temperature vs time at mid-length
dx = 0.2 dt = 1
Temperature
Time
5
10
15
20
25
0
100
200
300
400
500
600
700
800
900


Graph of temperature vs length at t = 900s
Fully Implicit Scheme
Temperature
Length
Graph of temperature vs time at mid-length
dx = 0.5 dt = 1
Temperature
Time


Graph of temperature vs length at t = 900s
Fully Implicit Scheme
Temperature
Length
Graph of temperature vs time at mid-length
dx = 0.1 dt = 0.5
Temperature
Time


Graph of temperature vs length at t = 900s
Fully Implicit Scheme
Temperature
Length
400
300
200
100
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Graph of temperature vs time at mid-length
dx = 0.2 dt = 0.5
Temperature
Time
25
20
15
10
5
0
100
200
300
400
500
600
700
800
900


Graph of temperature vs length at t = 900s
Fully Implicit Scheme
Temperature
Length
400
300
200
100
0
0
0.1
0.2
0.3
0.4
0.5
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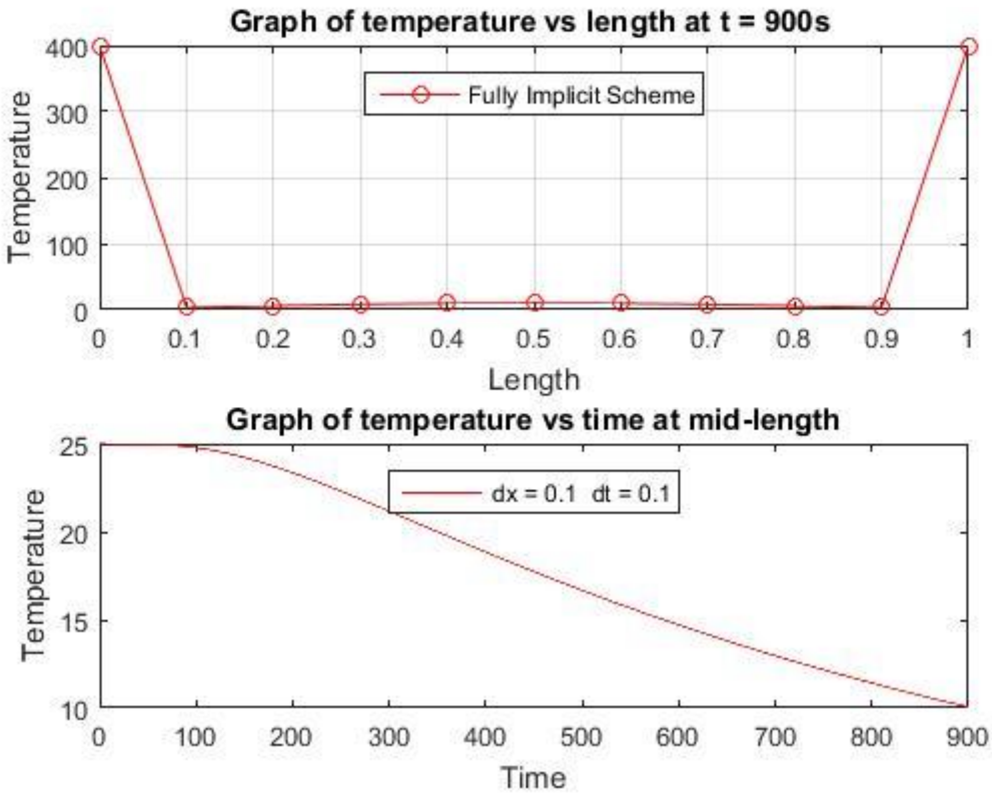
1
Graph of temperature vs time at mid-length
dx = 0.5 dt = 0.5
Temperature
Time
25
20
15
10
5
0
100
200
300
400
500
600
700
800
900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Fully Implicit Scheme
Temperature
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300
200
100
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Graph of temperature vs time at mid-length
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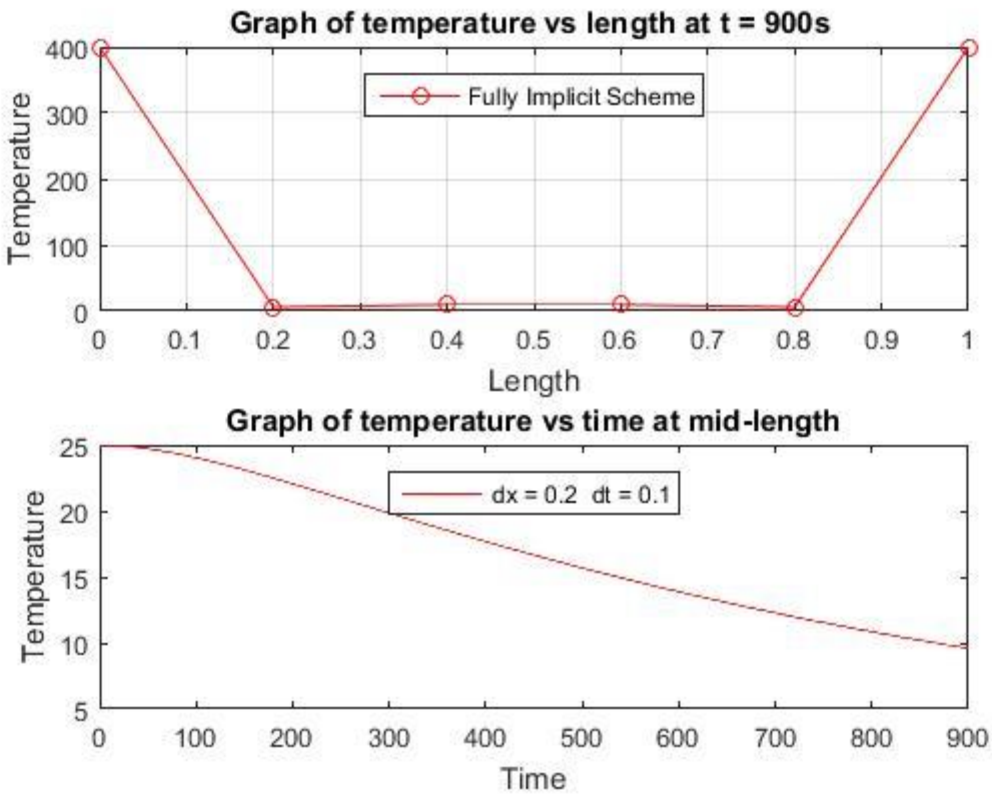
Time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Temperature
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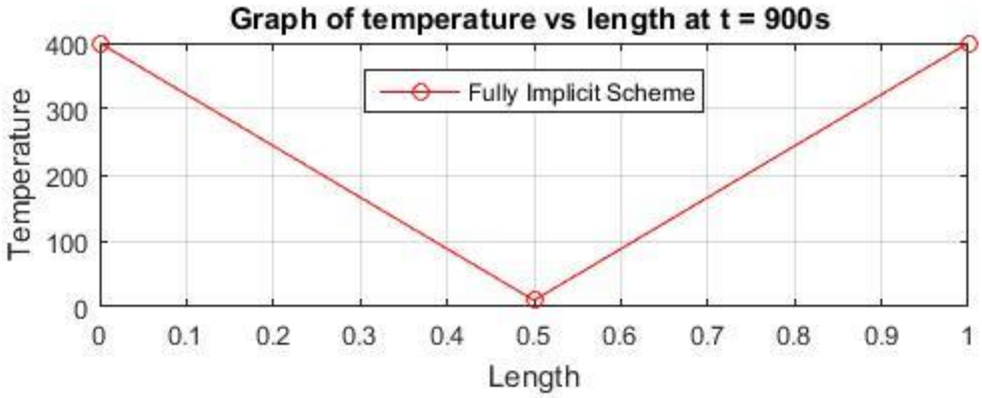
Graph of temperature vs length at t = 900s
Fully Implicit Scheme
Temperature
Length
400
300
200
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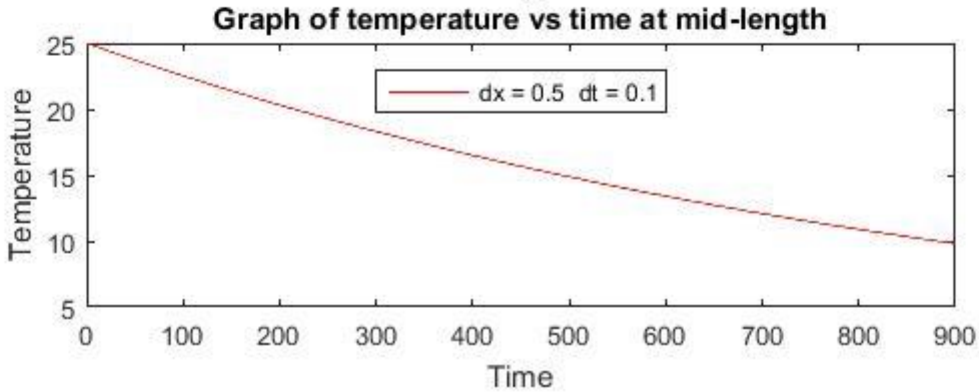
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Graph of temperature vs time at mid-length
dx = 0.5 dt = 0.1
Temperature
Time
25
20
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300
400
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900

d. Crank Nicholson Scheme

Code	Output

``clearvars``
``clc``
``fprintf('\nCrank Nicholson Scheme applied to 1-D heat conduction problem\n')``
``%Endpoints of rod such that b-a=Length of rod``
``a=0;``
``b=1;``
``% for Ut=alp*Uxx form``
``alp=400/(385*8000);``
 	
``% dx and dt are grid differences``
``dx=input('\nUnit Grid Size dx: ');``
``dt=input('\nInput Time Step dt: ');``
``%dx=0.25;``
``%dt=2;``
``x=a:dx:b;``
``t=0:dt:900;``
``%Calculation for size of x and t points``
``[sizx,sizx]=size(x);``
``[sizt,sizt]=size(t);``
``u= zeros(sizt,sizx);``
``%formula for r``
``r=alp*dt/(dx^2);``
 	
``%Initial Condition``
``u(1,:)=25;``
 	
``%Rod is maintained at 400 C.``
``%Thus setting Boundary conditions``
``u(2:sizt,1)=400;``
``u(2:sizt,sizx)=400;``
 	
``%Formula is worked out for Crank Nicholson``
``%Format U(i+1,j)=F(U(i,j+1),U(i,j-1),U(i,j))``
``%Here 'i' represents time step``
``%And 'j' represents spatial variation``
``%Loop is written to get iteration values``
 	
``%For deifining TDMA``
``A=zeros(sizx-2,sizx-2);``
	a. **dy = 0.1m , dt = 1s**
	
	Crank Nicholson Scheme applied to 1-D heat conduction problem
	
	Unit Grid Size dx: 0.1
	
	Input Time Step dt: 1
	
	Method is stable but not consistent
	
	This scheme will not reach to 200 C for interval 0 to 900s
	Middle length temperature is 129.526119 C at 900s
	
	b. **dy = 0.2m , dt = 1s**
	
	Crank Nicholson Scheme applied to 1-D heat conduction problem
	
	Unit Grid Size dx: 0.2
	
	Input Time Step dt: 1
	
	Method is stable but not consistent
	
	This scheme will not reach to 200 C for interval 0 to 900s
	Middle length temperature is 132.813586 C at 900s
	
	c. **dy = 0.5m , dt = 1s**
	
	Crank Nicholson Scheme applied to 1-D heat conduction problem
	
	Unit Grid Size dx: 0.5
	
	Input Time Step dt: 1
	
	Method is stable but not consistent
	
	This scheme will not reach to 200 C for interval 0 to 900s
	Middle length temperature is 131.225428 C at 900s

```
for i=2:sizt

   %Now based of formula we will write TDMA matrix
   %a represents 1st diagonal below main diagonal
   %b represents main diagonal
   %c represents 1st diagonal above main diagonal


for j=1:sizx-3
  a(1,j)=-r;
  c(1,j)=a(1,j);
  A(j+1,j)=a(1,j);
  A(j,j+1)=c(1,j);

end

for j=1:sizx-2
   b(1,j)=2*(1+r);
   A(j,j)=b(1,j);
   d(j,1)=r*u(i-1,j)+2*(1-r)*u(i-1,j+1)+r*u(i-1,j+2);
end

%For identifying the size of matrix
[n,j]=size(d);

%Definition taken from Atkinson
beta(1)=A(1);
g(1)=d(1);

%TDMA triangular matrix solution for Lg=b form where g=UX
for l=2:n

%Definition taken from Atkinson
alpha(l)=A(l,l-1)/beta(l-1);
beta(l)=A(l,l)-alpha(l)*A(l-1,l);
g(l)=d(l)-alpha(l)*g(l-1);

end

%Back substitution for solving g=UX
xu(n)=g(n)/beta(n);
for l=n-1:-1:1
xu(l)=(g(l)-A(l,l+1)*xu(l+1))/beta(l);
end
xu;

%Updating thevalue of u
u(i,2:sizx-1)=[xu];

end
```

d. **dy = 0.1m , dt = 0.5s**

Crank Nicholson Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.1

Input Time Step dt: 0.5

Method is stable but not consistent

This scheme will not reach to 200 C for interval 0 to 900s
Middle length temperature is 129.574063 C at 900s

e. **dy = 0.2m , dt = 0.5s**

Crank Nicholson Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.2

Input Time Step dt: 0.5

Method is stable but not consistent

This scheme will not reach to 200 C for interval 0 to 900s
Middle length temperature is 132.858142 C at 900s

f. **dy = 0.5m , dt = 0.5s**

Crank Nicholson Scheme applied to 1-D heat conduction problem

Unit Grid Size dx: 0.5

Input Time Step dt: 0.5

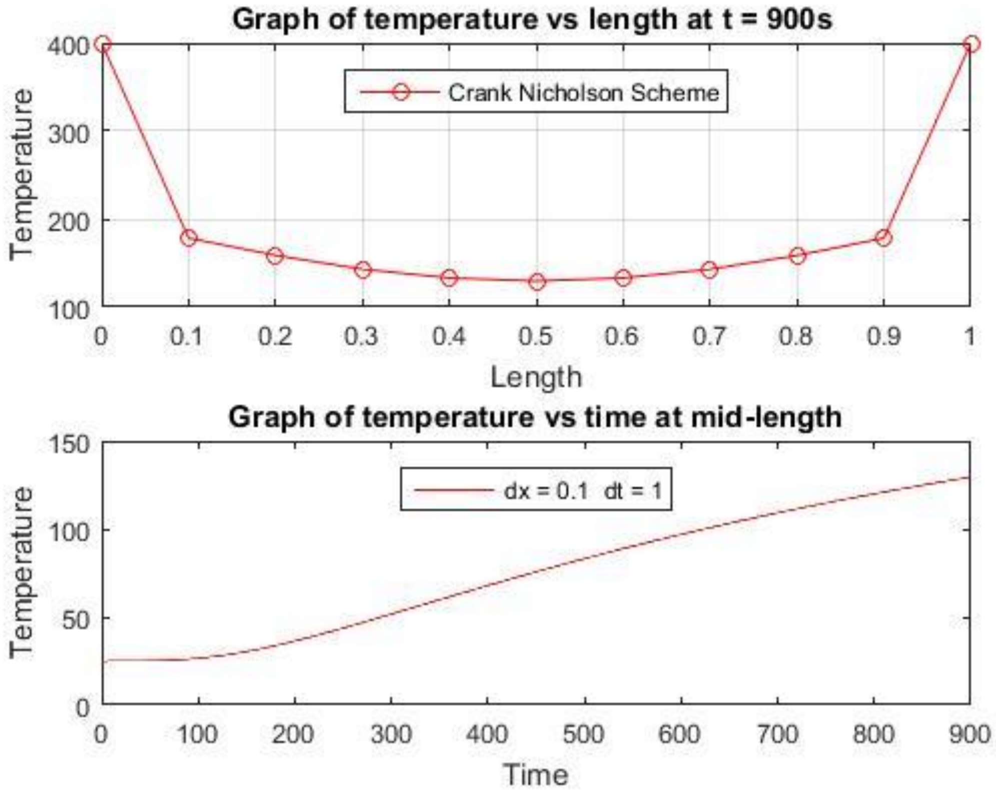
Method is stable but not consistent

This scheme will not reach to 200 C for interval 0 to 900s
Middle length temperature is 131.263690 C at 900s

`%y represents all the values of temperature which change for t>0 at mid`
`%midlen`
`y=u(:,round(sizx/2));`
`figure`
`subplot(2,1,2);`
`plot(t,y,'-r')`
`title('Graph of temperature vs time at mid-length')`
`xlabel('Time')`
`ylabel('Temperature')`
`legend(['dx = ',num2str(dx),'  dt = ',num2str(dt)],'Location','north')`
 	
`%Additional information`
`y=u(sizt,:);`
`%represents temperature variation in bar at 900s`
`subplot(2,1,1);`
`plot(x,y,'-ro')`
`title('Graph of temperature vs length at t = 900s ')`
`xlabel('Length')`
`ylabel('Temperature')`
`legend('Crank Nicholson Scheme','Location','north')`
`grid on`
 	
`%'k' Finds the values where we get 200 C`
`k = find(round(u(:,round(sizx/2)))==200 & (abs(200-u(:,round(sizx/2)))< 0.05));`
`if isempty(k) == 1`
`   fprintf('\nMethod is stable but not consistent\n');`
`   fprintf('\nThis scheme will not reach to 200 C for interval %d to %ds\nMiddle length temperature is %f C at %ds\n\n',t(1),t(sizt),u(sizt,round(sizx/2)),t(sizt));`
`else`
`%Some values might be repeated when grid size is small`
`%Thus median is taken as rod has symmetric condition`
`k=round(median(k));`
`%t200 represents time when mid-section is at 200 C`
`t200=t(k);`
`fprintf('\nMiddle length reaches 200 C at t = %fs\n\n',t200)`
`%u(k,round(sizx/2)) is actual value close to 200 C`
`end`
	g. **dy = 0.1m , dt = 0.1s**
	
	Crank Nicholson Scheme applied to 1-D heat conduction problem
	
	Unit Grid Size dx: 0.1
	
	Input Time Step dt: 0.1
	
	Method is stable but not consistent
	
	This scheme will not reach to 200 C for interval 0 to 900s
	Middle length temperature is 129.612401 C at 900s
	
	h. **dy = 0.2m , dt = 0.1s**
	
	Crank Nicholson Scheme applied to 1-D heat conduction problem
	
	Unit Grid Size dx: 0.2
	
	Input Time Step dt: 0.1
	
	Method is stable but not consistent
	
	This scheme will not reach to 200 C for interval 0 to 900s
	Middle length temperature is 132.893770 C at 900s
	
	i. **dy = 0.5m , dt = 0.1s**
	
	Crank Nicholson Scheme applied to 1-D heat conduction problem
	
	Unit Grid Size dx: 0.5
	
	Input Time Step dt: 0.1
	
	Method is stable but not consistent
	
	This scheme will not reach to 200 C for interval 0 to 900s
	Middle length temperature is 131.294287 C at 900s

- **Results**

  For any values of dt and dy mentioned the solution will be erroneous as the method is inconsistent.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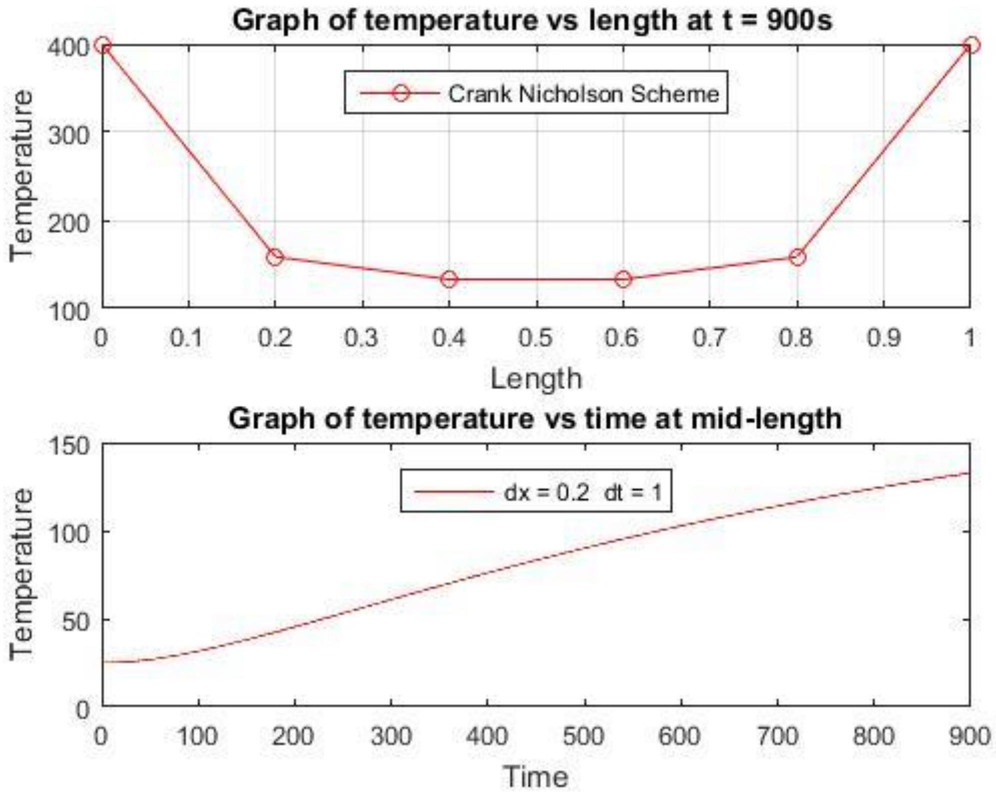
Temperature
400
300
200
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Length
Graph of temperature vs time at mid-length
dx = 0.1 dt = 1
Temperature
150
100
50
0
0
100
200
300
400
500
600
700
800
900
Time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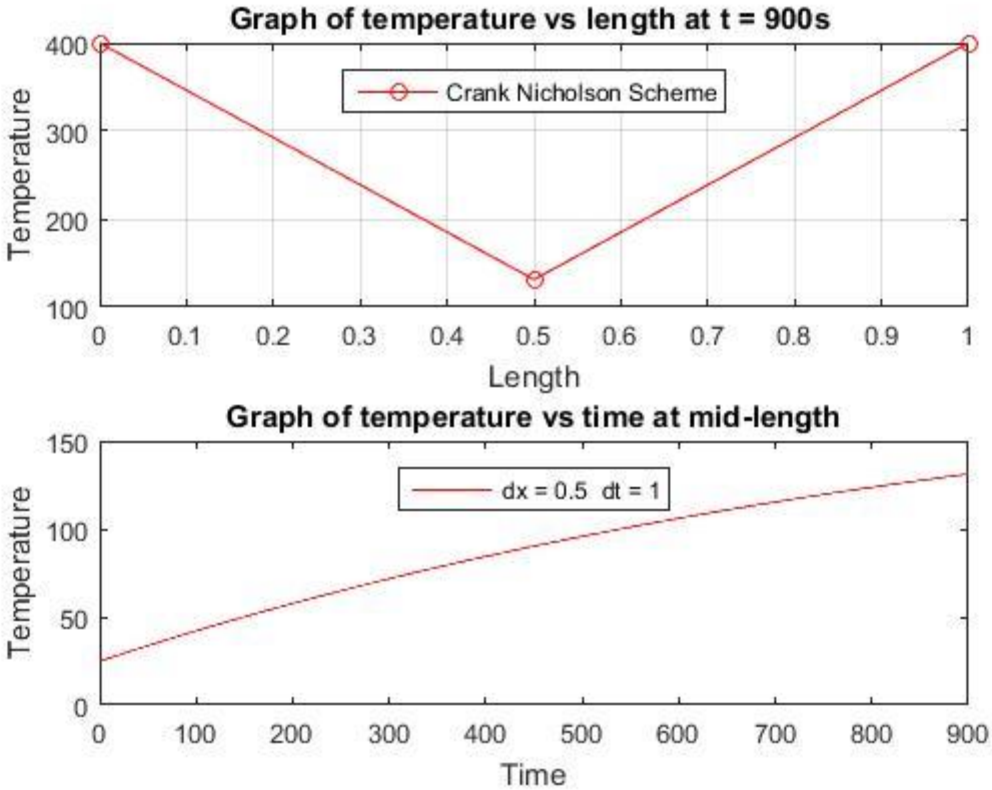
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Crank Nicholson Scheme
Temperature
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300
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0.9
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Length
Graph of temperature vs time at mid-length
dx = 0.5 dt = 1
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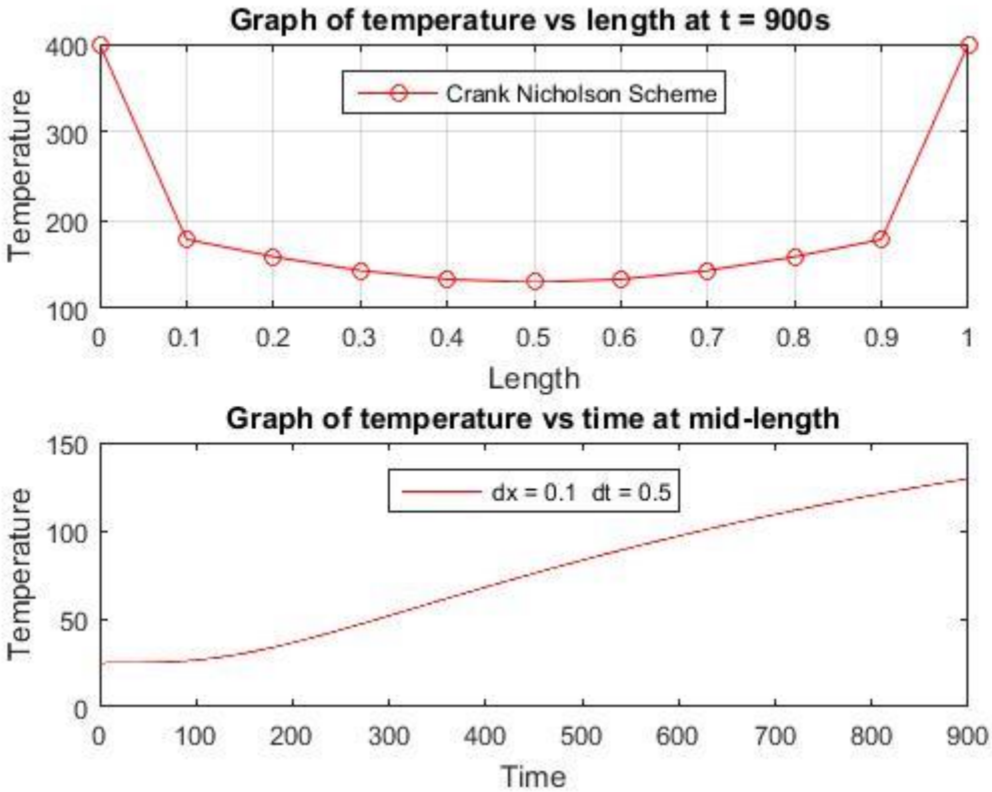
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Crank Nicholson Scheme
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400
300
200
100
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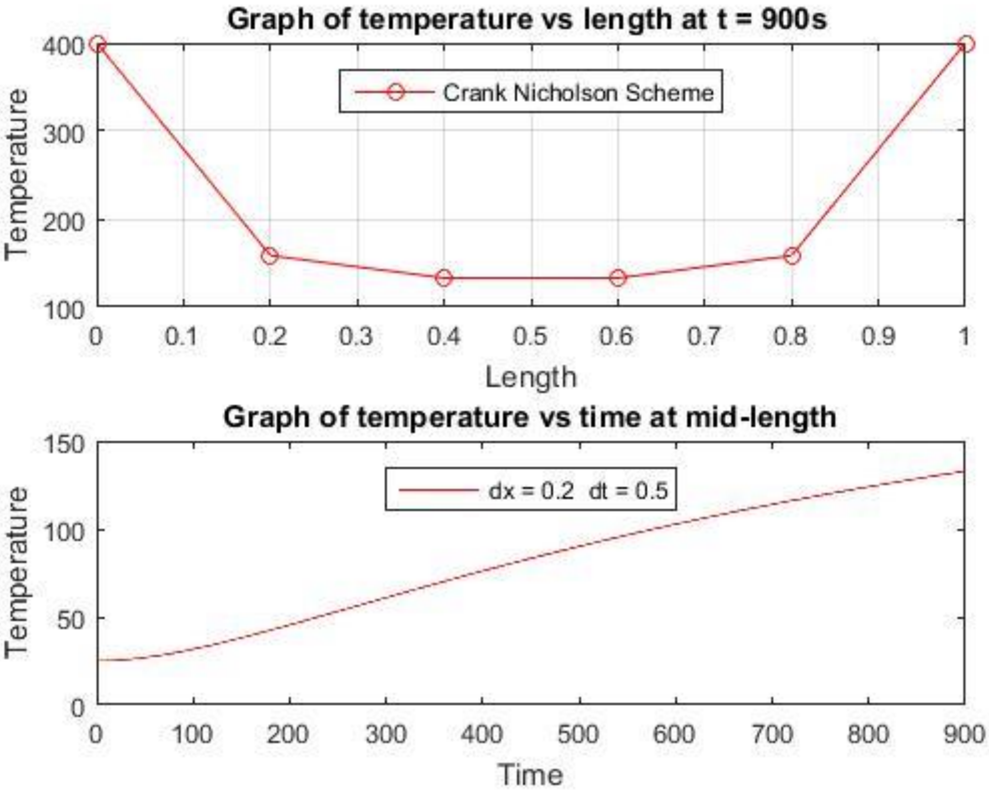
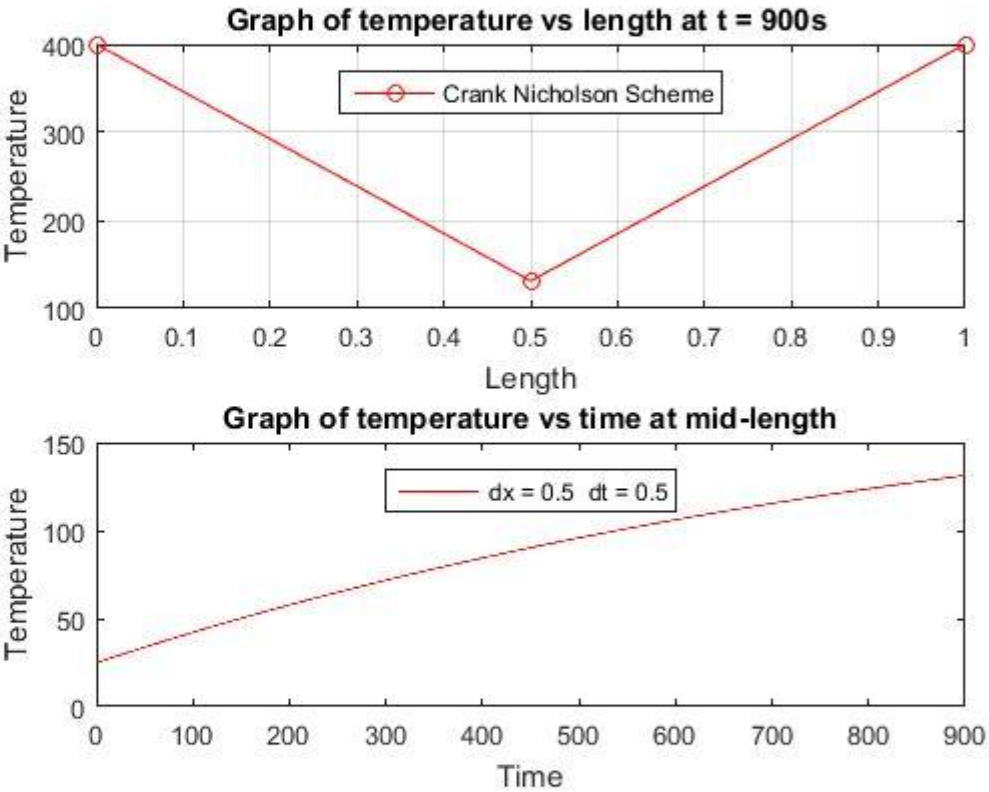

Graph of temperature vs length at t = 900s
Crank Nicholson Scheme
Temperature
Length
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
100 200 300 400
Graph of temperature vs time at mid-length
dx = 0.2 dt = 0.5
Temperature
Time
0 100 200 300 400 500 600 700 800 900
0 50 100 150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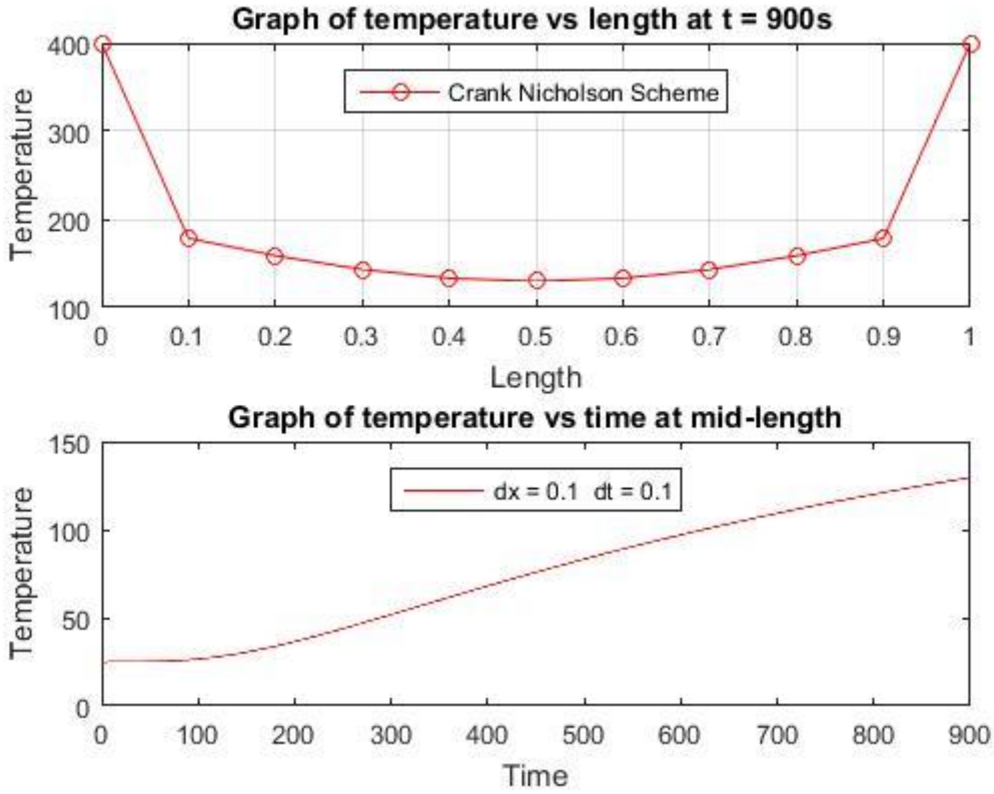
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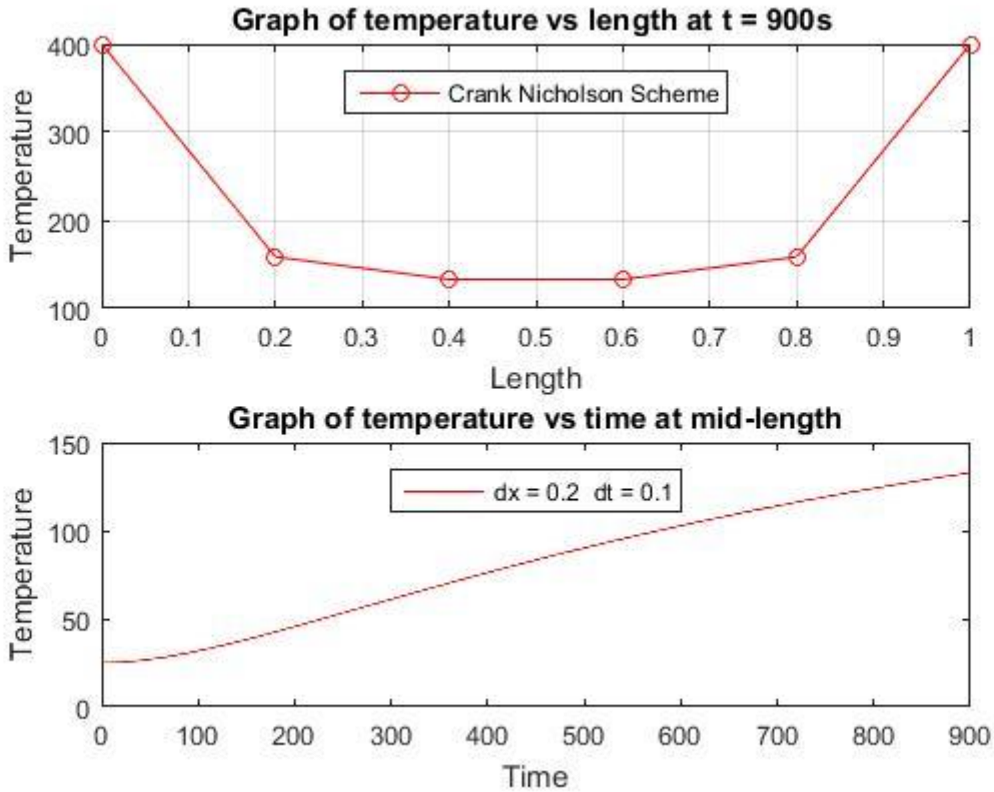
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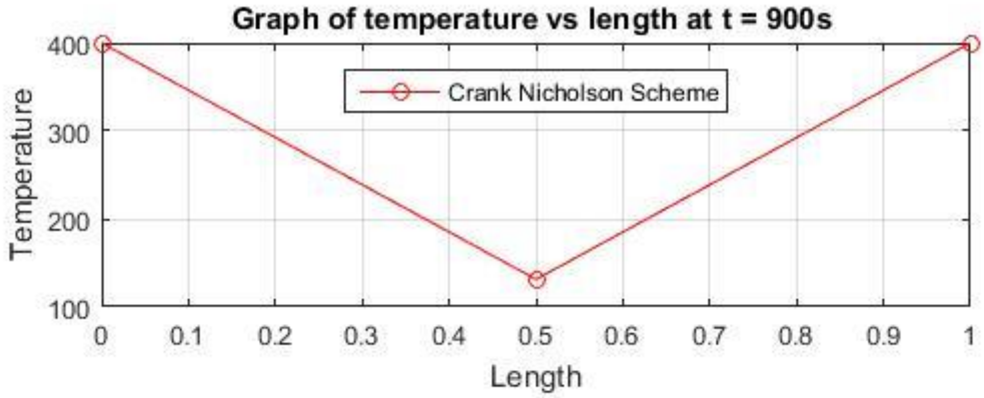

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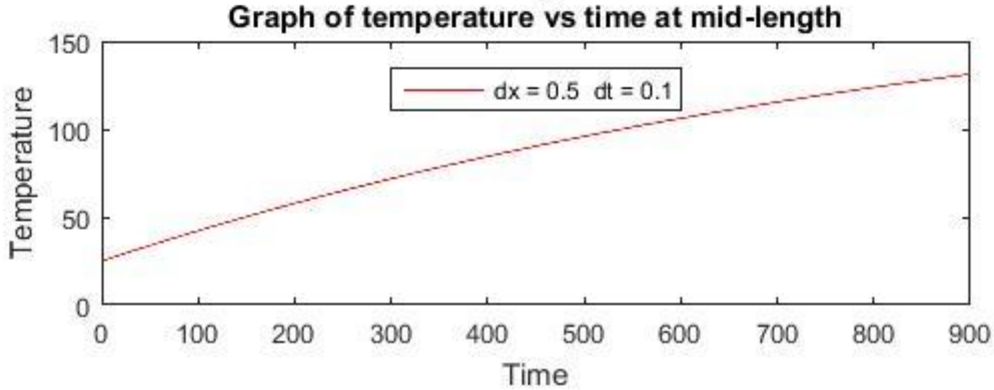

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