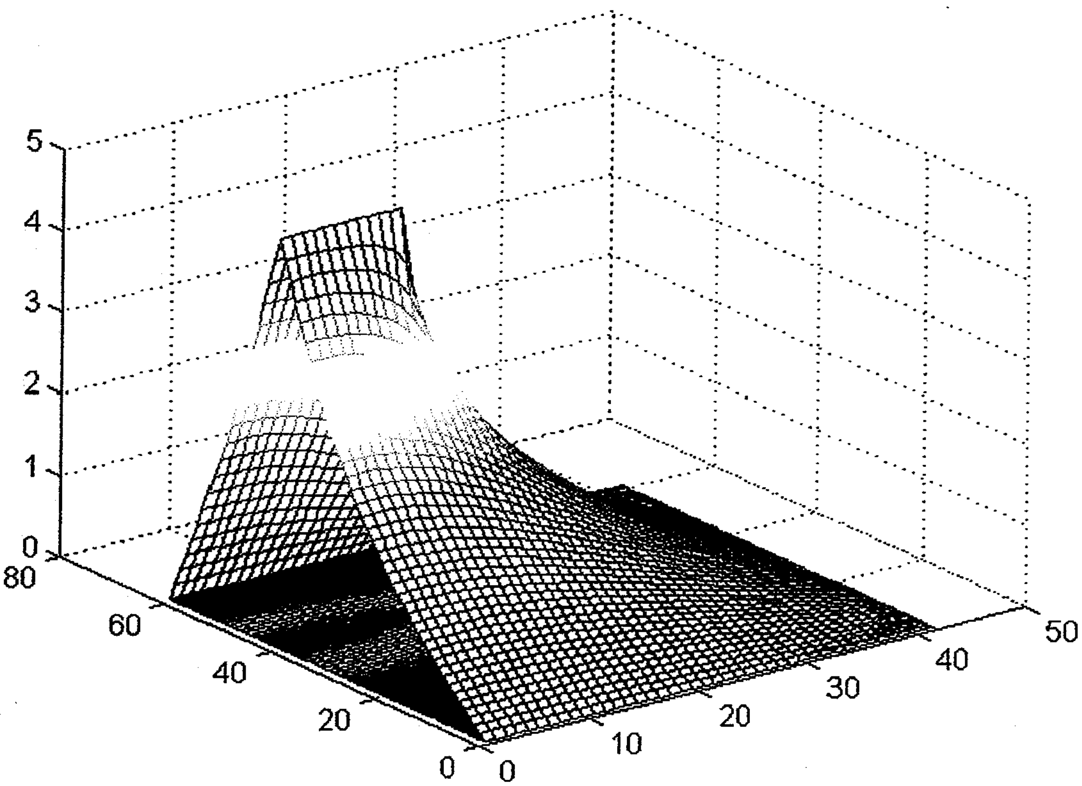
Finite Difference Frequency Domain (FDFD)



Andrew Austin
ECE 5130
Project #1
February 16, 1999

Andrew Austin

PROJECT #1

[Due] Tuesday after VACATION
Tuesday Feb. 16th

* It's o.k. to put this on the WEB.

Feb 26-27 Tours in Salt Lake City
SWE

ECE 5130 FINITE DIFFERENCE FREQUENCY DOMAIN (FDFD)

1. Write a program to compute the 1st and 2nd derivatives using the central difference method.

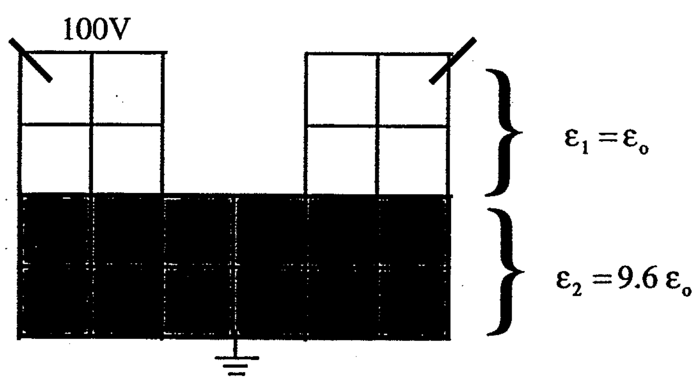
   Use your program to compute df/dx and df^2/dx^2 where f(x) = sin(x). Compute these derivatives in the range $0 \le x \le 2\pi$. Plot the values of the numerical derivatives against the analytical values using n=5, 10,20,1000 divisions ($h= 2\pi/n$). Plot all the first derivatives on one plot, and all of the second derivatives on another, so that you can make comparisons between the derivatives calculated with different resolutions.

2. Do problem 3.7 in the handout (answer given).

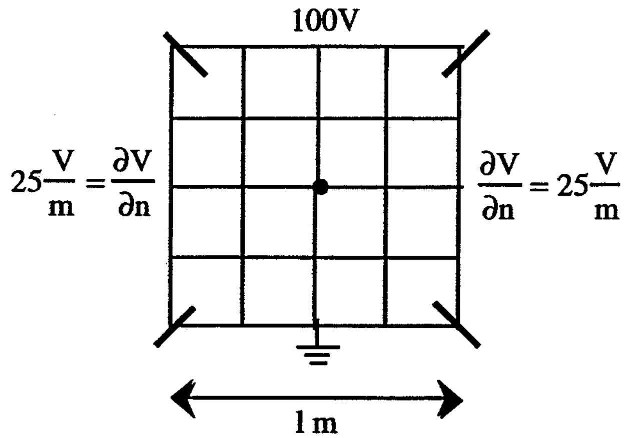
   a. Write the matrix without using symmetry, and solve.

   b. Rewrite the matrix using symmetry and solve again.

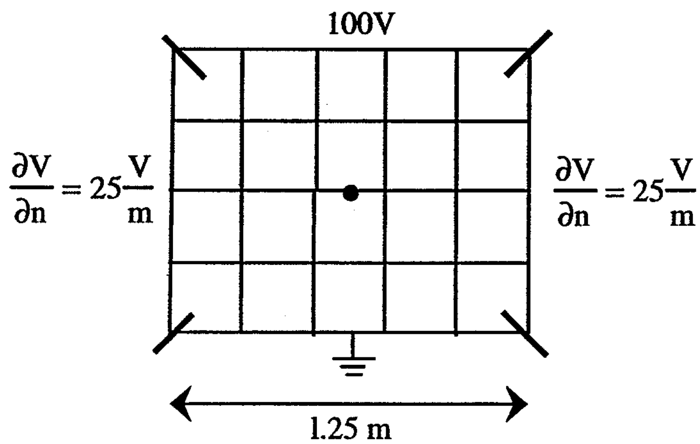
3. Repeat for the case below (with symmetry)



4. Find the potential at the center. Let $h = 0.25$ m



5. Find the potential at the center



6. Write a program to calculate the impedance of a microstripline. Allow the user to input the dimensions (w and h) of the microstrip and the dielectric properties of the substrate, then compute the impedance.

Hand in: All calculations used to compute matrices, including how you numbered the nodes.

Hand in: Matrix equations to be solved (print out matrix $\bar{A}$ and vector $\bar{b}$).

Hand in: Solution, and tell what method you used to solve $\bar{A}\,\bar{x} = \bar{b}$ (i.e. Mathab, Linpack, your gaussian elimination code).

Your grade:

Problem 1	8	/ 10
Problem 2a	10	/ 10
Problem 2b	10	/ 10
Problem 3	10	/ 10
Problem 4	10	/ 10
Problem 5	10	/ 10
Problem 6	30	/ 30
Conclusions	10	/ 10

[illegible] Z error 10-20%

Total 98 100

```
%Andrew Austin
%Project #1 -          Filename: ECE_5130\dt_1.m
%ECE 5130
%Jan. 199
%
%function [index, derivative] = dt_1(F_x,begin_x,end_x,n)
%"dt_1" is a function that returns the first derivative of a number
%of data points.
%The various input VARIABLES are defined as:
%
%F_x        =      the function representing the data points i.e. sin(x)
%begin_x    =      lower bound of x
%end_x      =      upper bound of x
%n          =      degree of resolution per integer

function [index, derivative] = dt_1(F_x,begin_x,end_x,n)

increment = (end_x - begin_x)/n;     %overall increment value - h

points = zeros(n+1,1);               %initialize "points" array

x = begin_x;                         %starting value of x array
for i=1:n+1                          %calculates an array of points
   points(i) = eval(F_x);            %evaluates the function f(x)
   x = x + increment;
end

derivative = zeros(n,1);            %initialize "derivative" array
for j=1:n
   derivative(j) = (points(j+1)-points(j))/increment;
end                                  %calculates derivative (slope)
                                     %outputs array of points

index = zeros(n,1);           %In order to plot we need an index (x-values)
index_value = begin_x;               %set starting point for index

for a=1:n
   index(a)= index_value;
   index_value = index_value + increment;
end

%-------------------------- OUTPUT ----------------------------------------
%» F_x = 'sin(x)';
%» [index,derivative]=dt_1(F_x,0,2*pi,5);
%» plot(index,derivative);
%» title('F`(x)');
%» [index,derivative]=dt_1(F_x,0,2*pi,10);
%» hold
%Current plot held
%» plot(index,derivative,'r');
%» [index,derivative]=dt_1(F_x,0,2*pi,20);
%» plot(index,derivative,'g');
%» [index,derivative]=dt_1(F_x,0,2*pi,1000);
%» plot(index,derivative,'k');
```

```
%Andrew Austin
%Project #1 -          Filename: ECE_5130\dt_2.m
%ECE 5130
%Jan. 199
%
%function [index, derivative_2] = dt_2(F_x,begin_x,end_x,n)
%"dt_1" is a function that returns the first derivative of a number
%of data points.
%The various input VARIABLES are defined as:
%
%F_x        =      the function representing the data points i.e. sin(x)
%begin_x    =      lower bound of x
%end_x      =      upper bound of x
%n          =      degree of resolution per integer

function [index, derivative_2] = dt_2(F_x,begin_x,end_x,n)

h = (end_x - begin_x)/n;    %overall increment value - h

points = zeros(n+1,1);              %initialize "points" array

x = begin_x;                        %starting value of x array
for i=1:n+1                         %calculates an array of points
   points(i) = eval(F_x);           %evaluates the function f(x)
   x = x + h;
end

derivative_2 = zeros(n-1,1);           %initialize "derivative" array
for j=1:n-1
   derivative_2(j) = (points(j+2) - 2*points(j+1)+ points(j))/(h*h);
end                                 %calculates 2nd derivative
                                    %outputs array of points

index = zeros(n-1,1);           %In order to plot we need an index (x-values)
index_value = begin_x + h;             %set starting point for index

for a=1:n-1
   index(a)= index_value;
   index_value = index_value + h;
end
```

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Feb. 1999
Project #1, problem 1

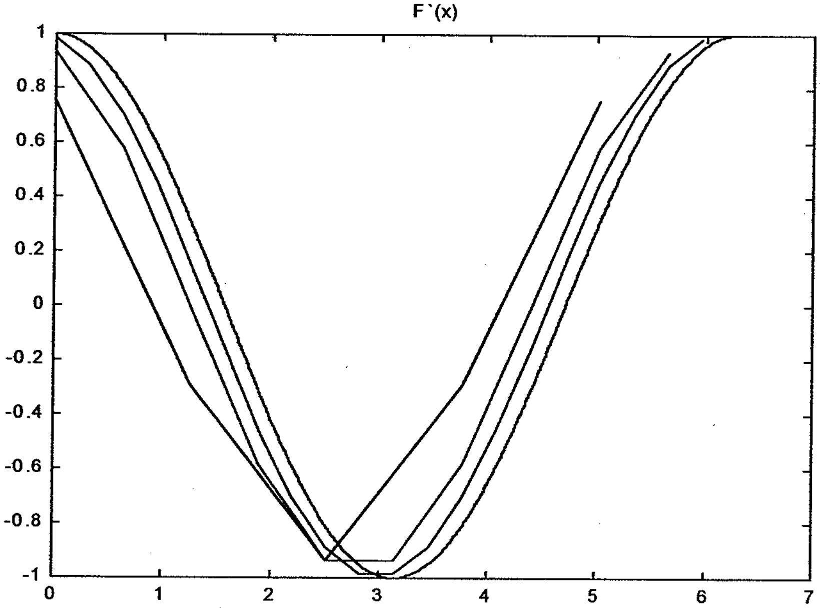
The following derivative plots were made in Matlab and were calculated using the central difference method.

F(x) = sin(x)

Color code for both:
blue n = 5
red n = 10
green n = 20
black n = 1000

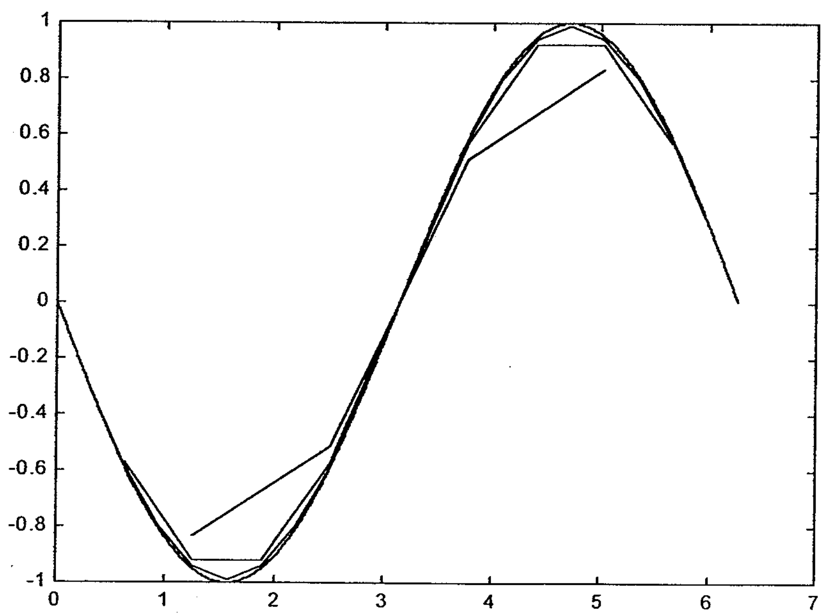
Conclusion:
As you can clearly see, the number of divisions makes a huge difference in the accuracy of the plots. The upper plot is of the derivative of sin(x) and its solution is cos(x) as would be expected. The lower plot is the second derivative of sin(x) and its solution is -sin(x) as expected.

F`(x)



→ shift by $\frac{\Delta x}{2}$ because of -2 location where you take central difference

F``(x)



✓

ECE 5730

3.7 **For a long hollow conductor with a uniform U-shape cross-section shown in Fig. 3.48, find the potential at points A, B, C, D, and E.**

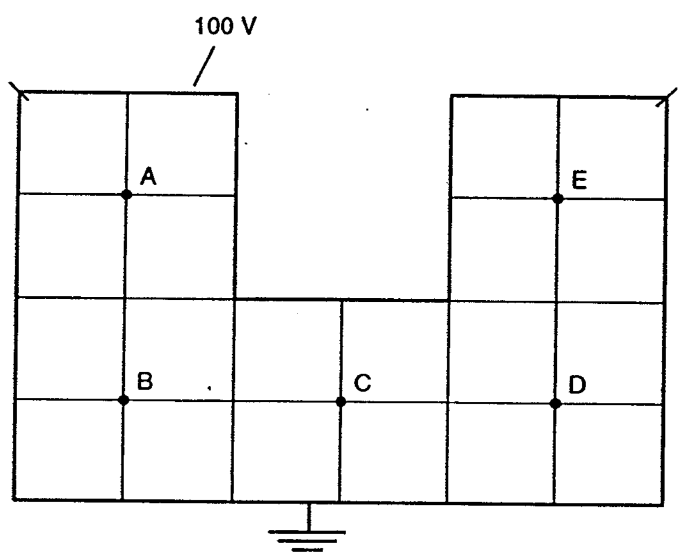
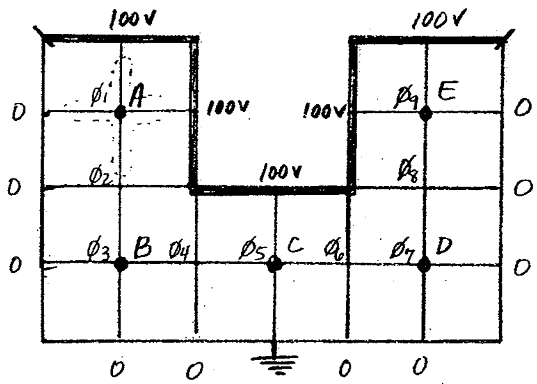


Figure 3.48 For Problem 3.7.

2.a)



$$0 + \phi_2 + 100 + 100 - 4\phi_1 = 0$$

$$\Rightarrow -4\phi_1 + \phi_2 = -200$$

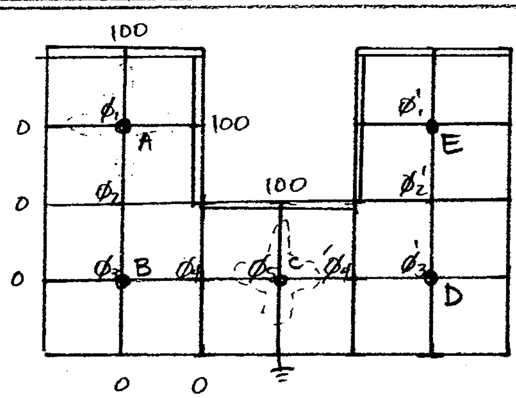
$$\begin{bmatrix} -4 & 1 & & & & & & & \\ 1 & -4 & 1 & & & & & & \\ & 1 & -4 & 1 & & & & & \\ & & 1 & -4 & 1 & & & & \\ & & & 1 & -4 & 1 & & & \\ & & & & 1 & -4 & 1 & & \\ & & & & & 1 & -4 & 1 & \\ & & & & & & 1 & -4 & 1 \\ & & & & & & & 1 & -4 \end{bmatrix} \begin{bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \\ \phi_6 \\ \phi_7 \\ \phi_8 \\ \phi_9 \end{bmatrix} = \begin{bmatrix} -200 \\ -100 \\ 0 \\ -100 \\ -100 \\ -100 \\ 0 \\ -100 \\ -200 \end{bmatrix}$$

$A\phi = b \rightarrow \phi = a \backslash b$

Solved in matlab

ans =
$A = \phi_1 = 61.4641$
$B = \phi_3 = 21.9613$
$C = \phi_5 = 45.9945$
$D = \phi_7 = 21.9613$
$E = \phi_9 = 61.4641$ ✓

2b)



$\phi_1 = \phi_1'$, $\phi_2 = \phi_2'$ etc...

use $\phi_1 - \phi_5$

$$\begin{bmatrix} -4 & 1 & & & \\ 1 & -4 & 1 & & \\ & 1 & -4 & 1 & \\ & & 1 & -4 & 1 \\ & & & 2 & -4 \end{bmatrix} \begin{bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \end{bmatrix} = \begin{bmatrix} -200 \\ -100 \\ 0 \\ -100 \\ -100 \end{bmatrix}$$

Solved in MATLAB

$A = E = \phi_1 = \phi_1' = 61.4641$

$B = D = \phi_3 = \phi_3' = 21.9613$

$C = \phi_5 = \longrightarrow 45.9945$ ✓

$-4\phi_5 + \phi_4 + \phi_4' + 100 + 0 = 0$

$-4\phi_5 + 2\phi_4 = -100$

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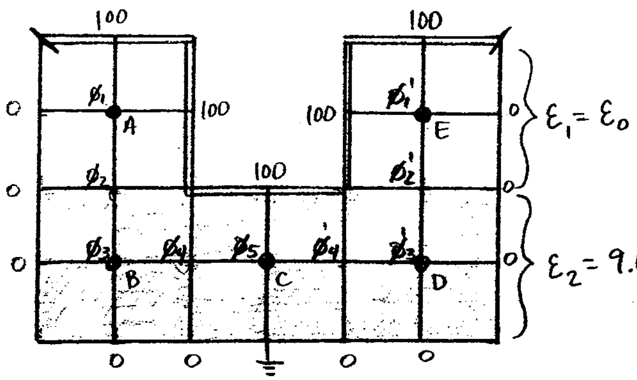
3.) Repeat 3.7 for the case below (with symmetry)



ϕ_2 & $\phi_2' = \frac{\varepsilon_1 + \varepsilon_2}{2}$

$\phi_1, \phi_1' = \varepsilon_1$

$\phi_3, \phi_4, \phi_5, \phi_4', \phi_3' = \varepsilon_2$

	1	2	3	4	5
1	-4	1			
2	1	-4(5.3) (21.2)	~~9.6~~ 1		
3		1	-4	1	
4			1	-4	1
5				2	-4

$$\begin{bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \end{bmatrix} = \begin{bmatrix} -200 \\ -530 \\ 0 \\ -100 \\ -100 \end{bmatrix}$$

$$-4\phi_2\left(\frac{9.6+1}{2}\right)^{5.3} + (1)\phi_1 + 9.6\,\phi_3 + 100(5.3) = 0$$

$$-4\phi_5 + \phi_4 + \phi_4' + 100 = 0$$

~~$\phi_1 = \phi_1' = A, E = 59.1518$~~

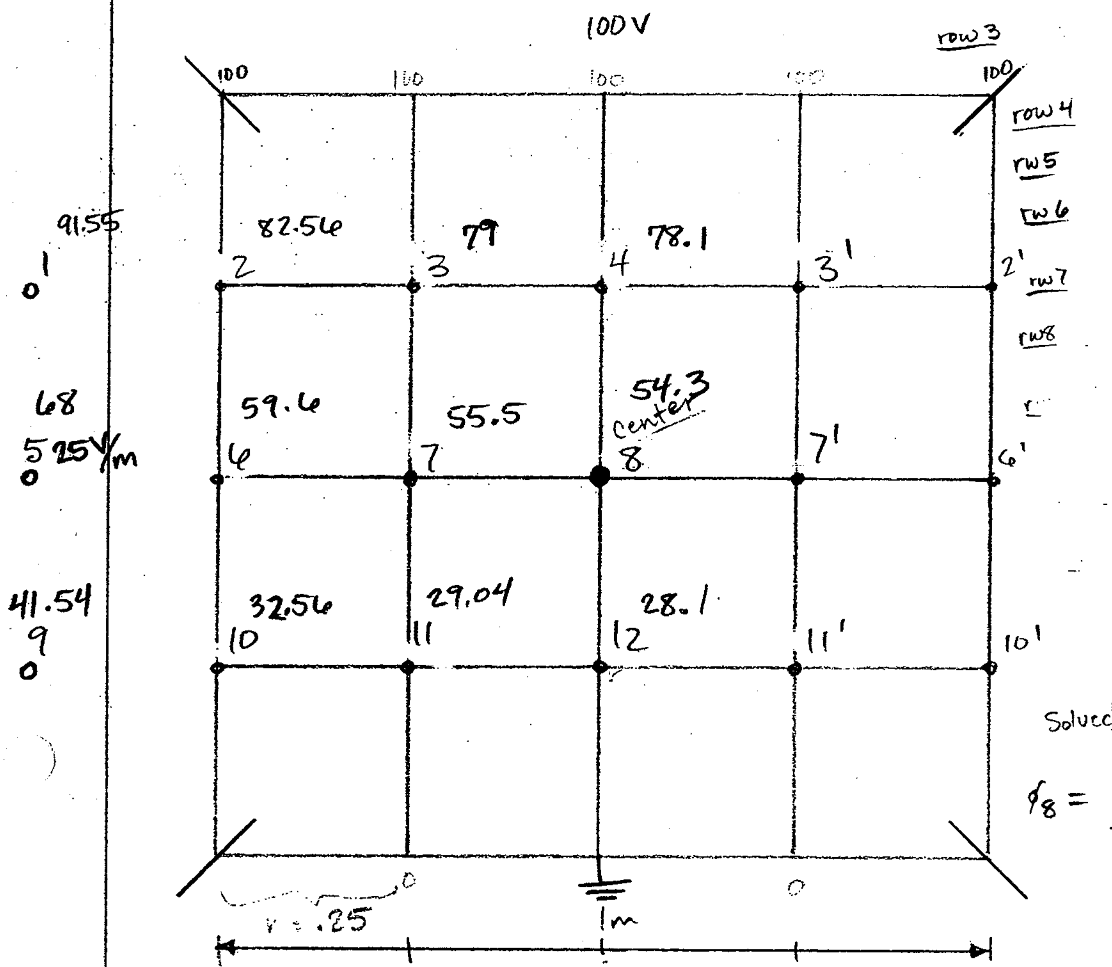
~~$\phi_3 = \phi_3' = B, D = 19.4712$~~

~~$\phi_5 = C = 45.6387$~~

4. Solve for the potential at the center. row1 $\frac{\phi_1 - \phi_7}{2h} = 25$

$2h = .5$

row2 $-4\phi_4 + \phi_7 + \phi_1 + \phi_5 = -100$



Solved in MATLAB

$\phi_8 = \underline{54.3067\ V}$ ✓

	1	2	3	4	5	6	7	8	9	10	11	12
1	1											
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												

$[\phi_1, \phi_2, \ldots] = [\ ]$

```
%Andrew Austin
%ECE 5130   Project #1          Filename: ECE_5130\sor.m
%Feb. 11, 1999
%
%This program computes the potentials of a specified box using the "Successive
%Over Relaxation" Method of numerical analysis
width = input('Enter width of box: \n');
height = input('Enter height of box: \n');
voltage = input('Enter dc voltage on the top of the box (V): \n');
volts_meter = input('Enter variable voltage on sides (V/m): \n');
h = input('Specify resolution (h): \n');
maxit = input('Specify number of iterations to compute: \n');
done_early_flag = 0;

x_cells = width/h;
y_cells = height/h;

test_odd = mod(x_cells,2);
if(test_odd == 1)                  %x_cells is an odd number
   jmax = x_cells/2 + 2.5;         %add .5 to make jmax an integer
else
   jmax = x_cells/2 + 3;           %Vertical symmetry
end
imax = y_cells + 1;

phi = zeros(imax, jmax);           %initializes the array of potentials to zero

for j=1:jmax
   phi(1,j) = voltage;              %initializes dc voltage boundary condition
end

ww = 1.5;                          %overrelaxation constant
delta_phi = 1e-6;                  %maximum change in phi

for k=1:maxit
   error = 1e6;                    %initializes error

   for i=2:imax-1
      for j=2:jmax-1
         Rij = 0.25*(phi(i+1,j)+phi(i-1,j)+phi(i,j+1)+phi(i,j-1)-4.0*phi(i,j));
         phi_k = phi(i,j);
         phi(i,j) = phi_k + ww*Rij;
         error = min(error,abs(phi(i,j) - phi_k));
      end
   end

   %------------------------------Force BOUNDARY CONDITIONS
   for i=1:imax
      phi(i,1) = volts_meter*2*h  + phi(i,3);
   end

   %------------------------------Force SYMMETRY PLANE
   if(test_odd == 1)
      for i=1:imax
         phi(i,jmax) = phi(i,jmax-1);  %symmetry plane inbetween points
      end
   else
      for i=1:imax
           phi(i,jmax) = phi(i,jmax-2);  %symmetry plane lies on points
      end
   end


   if (error < delta_phi)
      disp(['The solution is complete:']);
      disp(['The number of iterations used was: ',num2str(k)]);
      done_early_flag = 1;
      break
   end
end

if (done_early_flag == 1)
   disp(['The maximum change in phi = ',num2str(error)]);
  else
     disp(['The maximum number of iterations were reached:']);
     disp(['The maximum change in phi = ',num2str(error)]);
end
```

```
%Andrew Austin   ECE 5130 - Project #1
%Problem: 2a

» A = [ -4 1 0 0 0 0 0 0 0
    1 -4 1 0 0 0 0 0 0
    0 1 -4 1 0 0 0 0 0
    0 0 1 -4 1 0 0 0 0
    0 0 0 1 -4 1 0 0 0
    0 0 0 0 1 -4 1 0 0
    0 0 0 0 0 1 -4 1 0
    0 0 0 0 0 0 1 -4 1
    0 0 0 0 0 0 0 1 -4]

A = -4     1     0     0     0     0     0     0     0
     1    -4     1     0     0     0     0     0     0
     0     1    -4     1     0     0     0     0     0
     0     0     1    -4     1     0     0     0     0
     0     0     0     1    -4     1     0     0     0
     0     0     0     0     1    -4     1     0     0
     0     0     0     0     0     1    -4     1     0
     0     0     0     0     0     0     1    -4     1
     0     0     0     0     0     0     0     1    -4

» b = [-200;-100;0;-100;-100;-100;0;-100;-200]
b =
  -200
  -100
     0
  -100
  -100
  -100
     0
  -100
  -200

» A\b        %Solve MATRIX

ans =
    61.4641  % = A
   45.8564
   21.9613  % = B
   41.9890
   45.9945  % = C
   41.9890
   21.9613  % = D
   45.8564
   61.4641  % = E
%----------------------------------------------------------------------
%Problem: 2b   (Solve 3.7 using symmetry)

  » A = [ -4 1 0 0 0
   1 -4 1 0 0
   0 1 -4 1 0
   0 0 1 -4 1
   0 0 0 2 -4]

A = -4     1     0     0     0
     1    -4     1     0     0
     0     1    -4     1     0
     0     0     1    -4     1
     0     0     0     2    -4
» b = [-200;-100;0;-100;-100]
b =
  -200
  -100
     0
  -100
  -100

» A\b

ans =
   61.4641  % = A,E
   45.8564
   21.9613  % = B,D
   41.9890
   45.9945  % = C
```

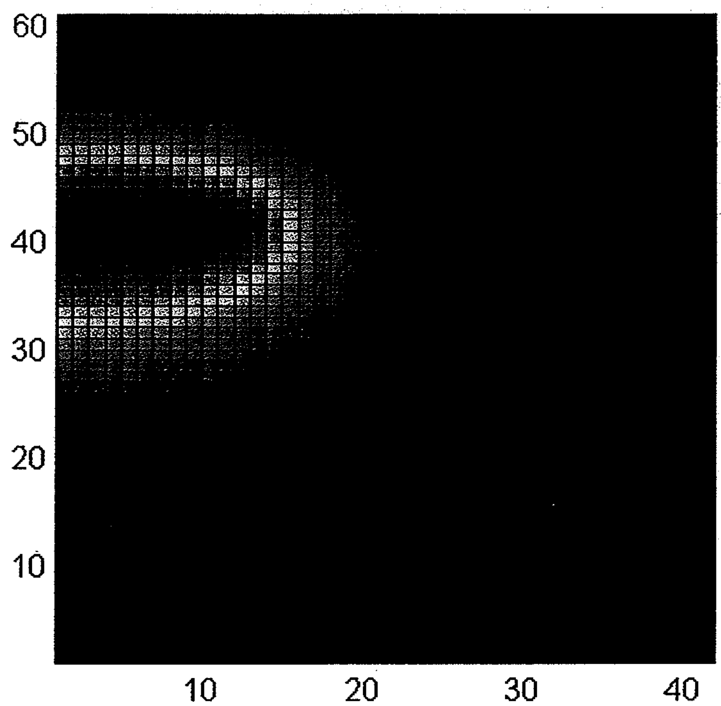
```
%---------------------------------------------------------------------------
%Problem 3:

A =
   -4.0000    1.0000         0         0         0
    1.0000  -21.2000    9.6000         0         0
         0    1.0000   -4.0000    1.0000         0
         0         0    1.0000   -4.0000    1.0000
         0         0         0    2.0000   -4.0000

» A\b

» b=[-200;-530;0;-100;-100]

b =
  -200
  -530
     0
  -100
  -100

ans =
    59.1518 % = A,E
   36.6073
   19.4712 % = B,D
   41.2775
   45.6387 % = C

%---------------------------------------------------------------------------
%Problem 4:

A =
     1     0    -1     0     0     0     0     0     0     0     0     0
     1    -4     1     0     0     1     0     0     0     0     0     0
     0     1    -4     1     0     0     1     0     0     0     0     0
     0     0     2    -4     0     0     0     1     0     0     0     0
     0     0     0     0     1     0    -1     0     0     0     0     0
     0     1     0     0     1    -4     1     0     0     1     0     0
     0     0     1     0     0     1    -4     1     0     0     1     0
     0     0     0     1     0     0     2    -4     0     0     0     1
     0     0     0     0     0     0     0     0     1     0    -1     0
     0     0     0     0     0     1     0     0     1    -4     1     0
     0     0     0     0     0     0     1     0     0     1    -4     1
     0     0     0     0     0     0     0     1     0     0     2    -4

» b

b=
   12.5000
 -100.0000
 -100.0000
 -100.0000
   12.5000
         0
         0
         0
   12.5000
         0
         0
         0

» A\b

ans =             %The center potential is at node #8.
   91.5441
   82.5630
   79.0441
   78.0987
   68.0147
   59.6639
   55.5147
   54.3067  %<------- Center Potential (54.3067 volts    )
   41.5441
   32.5630
   29.0441
   28.0987
```

```
%-----------------------------------------------------------------------
%Problem 4: Find the potential at the center

» sor
Enter width of box:
1
Enter height of box:
1
Enter dc voltage on the top of the box (V):
100
Enter variable voltage on sides (V/m):
25
Specify resolution (h):
.25
Specify number of iterations to compute:
25
%----ANSWER------
The solution is complete:
The number of iterations used was: 23
The maximum change in phi = 1.9602e-007
» phi

phi =

  112.5000  100.0000  100.0000  100.0000  100.0000
   91.5441   82.5630   79.0441   78.0987   79.0441
   68.0147   59.6639   55.5147   54.3067   55.5147
   41.5441   32.5630   29.0441   28.0987   29.0441
   12.5000         0         0         0         0

%By inspection the center potential is at cell phi(3,4) = 54.3067

%-----------------------------------------------------------------
%Problem 5:  Find the potential at the center.

» sor
Enter width of box:
1.25
Enter height of box:
1
Enter dc voltage on the top of the box (V):
100
Enter variable voltage on sides (V/m):
25
Specify resolution (h):
.25
Specify number of iterations to compute:
100
%--------------ANSWER---------------------------
The solution is complete:
The number of iterations used was: 16
The maximum change in phi = 1.4336e-007

phi =

  112.5000  100.0000  100.0000  100.0000  100.0000
   91.0618   82.1909   78.5618   77.2177   77.2177
   67.3387   59.1398   54.8387   53.0914   53.0914
   41.0618   32.1909   28.5618   27.2177   27.2177
   12.5000         0         0         0         0

%By inspection the center potential is between phi(3,4) & phi(3,5),
%both of which have a potential of 53.0914, and obviously the average
%of the two = 53.0914;
```

Andrew Austin ECE 5130
Project #1, problem 6:

To the left is the graph of half of a microstrip line and the voltage potential distribution from the 5 V plate. The matrix is inverted horizontally for convenience in matrix numbering. The origin I used would be (0,60) on this graph. This only shows the left hand portion of symmetry for the microstrip line. The ground plane used in this model would be the top in this picture.

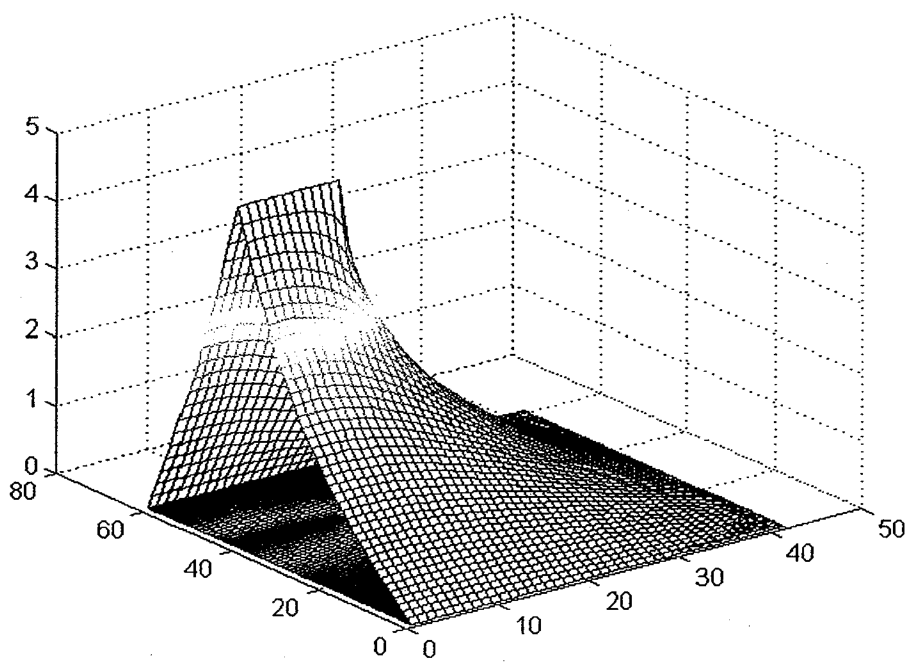
The **specifications** are as follows:
width = 2m
height = 2m
h = .1 (resolution 10 partitions/m)
iterations = 500
e1 = 1, e2 = 1 (air)

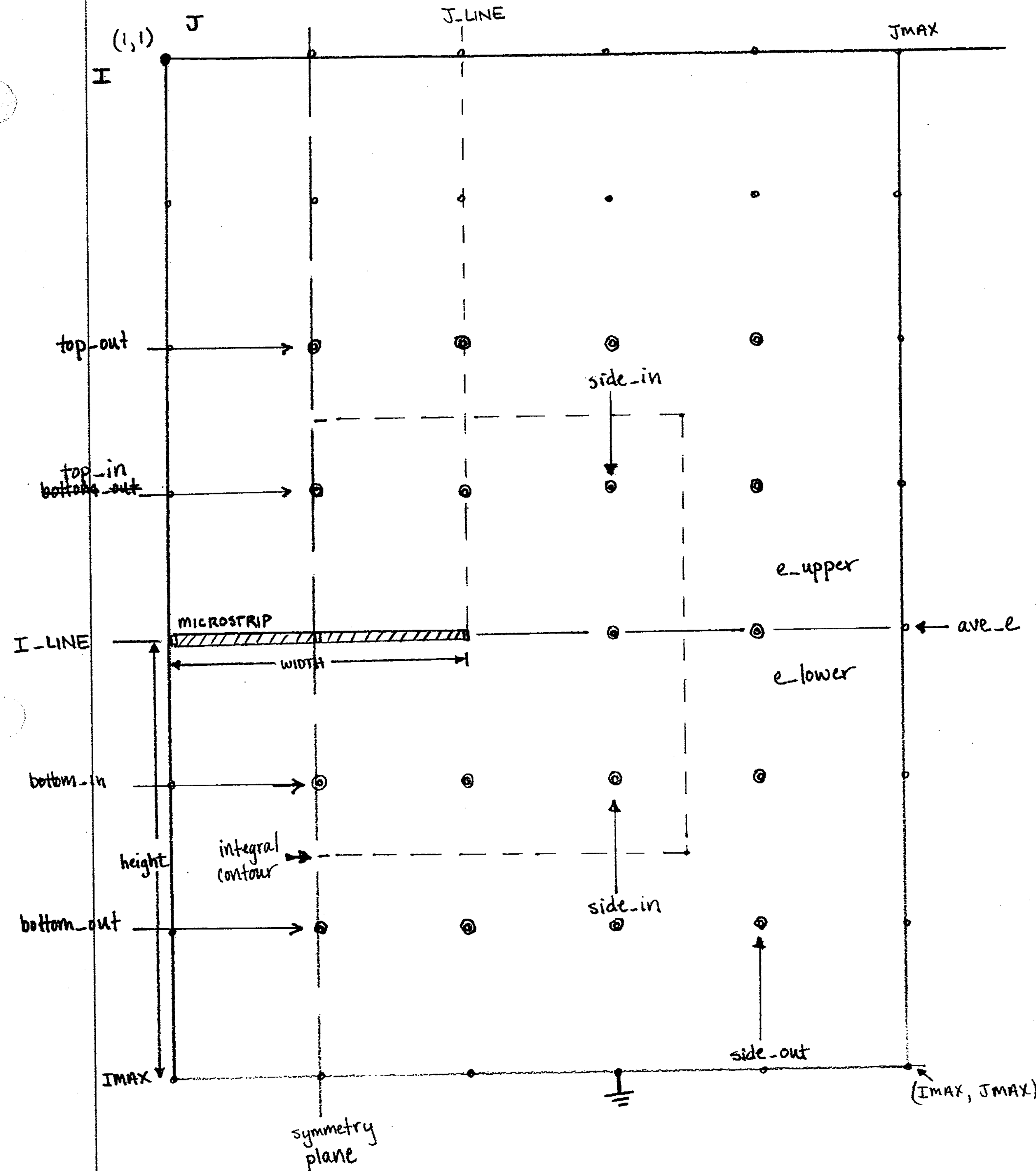


Color Code:

Dark Red = high potential (5V)
Dark Blue = zero voltage
Other shades equal decreasing potentials.

3-Dimensional view





- VARIABLE DEFINITIONS -

```
%Andrew Austin
%ECE 5130   Project #1          Filename: ECE_5130\z_mix.m
%Feb. 11, 1999
%
%The function 'z_mix' calculates the capacitance of certain dielectrics
%used in a microstrip line.  The 'z' stands for impedance, because when the
%capacitances of air and a certain substrate are found, the impedance can
%be calculated.  The 'mix' means the microstrip is in between two different
%substrates.

function [capacitance]=z_mix()

width = input('Enter width of the microstrip: \n');
height = input('Enter height of the microstrip: \n');
e_upper = input('Enter the upper dielectric substrate constant: \n');
e_lower = input('Enter the lower dielectric substrate constant: \n');
h = input('Specify resolution (h): \n');
maxit = input('Specify number of iterations to compute: \n');

width = width/2;
x_cells = width*4; %-------------------->***Experimental values
y_cells = height*2 + height;
jmax = x_cells*(1/h)+ 2;
imax = y_cells*(1/h) + 1;

phi = zeros(imax, jmax);       %initializes the array of potentials to zero
I_line = height*2*(1/h) + 1;   %distance from origin to the strip length
J_line = width*(1/h) + 2;      %distance from origin to strip width

for j=1:J_line
   phi(I_line,j) = 5;          %initializes microstrip voltage
end

ww = 1.5;                    %overrelaxation constant

ave_e = (e_upper + e_lower)/2;    %average dielectric for boundary

for k=1:maxit
   for i=2:I_line-1               %computes upper dielectric
      for j=2:jmax-1
         Rij = 0.25*(phi(i+1,j) + phi(i-1,j) + phi(i,j+1) +...
            phi(i,j-1) - 4.0*phi(i,j));
         phi_k = phi(i,j);
         phi(i,j) = phi_k + ww*Rij;
      end
   end

   i = I_line;                    %computes along the microstrip row
   for j=J_line+1:jmax-1
      phi(i,j) = ((1/ave_e)*0.25)(phi(i+1,j)*e_lower +...
         phi(i-1,j)*e_upper + phi(i,j+1)*ave_e + phi(i,j-1)*ave_e);
   end

   for i=I_line+1:imax-1          %computes bottom dielectric
      for j=2:jmax-1
         Rij = 0.25*(phi(i+1,j) + phi(i-1,j) + phi(i,j+1) +...
            phi(i,j-1) - 4.0*phi(i,j));
         phi_k = phi(i,j);
         phi(i,j) = phi_k + ww*Rij;
      end
   end
```

```
   %-----------------------------Force BOUNDARY CONDITIONS
   for j=1:J_line
      phi(I_line,j) = 5;          %reset MICROSTRIP VOLTAGE
   end
   %-----------------------------Force SYMMETRY PLANE

   for i=1:imax
      phi(i,1) = phi(i,3);  %symmetry plane lies on the origin
   end

end  %iterations complete

pcolor(phi);                %OUTPUTS color graphic potential distribution
%--------------------IMPEDANCE WAS CALCULATED----------------

diff = imax - I_line;      %finds gap between strip & ground
is_odd = mod(diff,2);
num = (diff)/2;
if (is_odd == 1)
   in = floor(num);         %sets the distance for the contours from strip
   out = ceil(num);
else
   out = num;
   in = out - 1;
end

bottom_out = I_line + out;        %Define integral contours
bottom_in = I_line + in;
side_out = J_line + out;
side_in = J_line +in;
top_out = I_line - out;
top_in = I_line - in;

%-------------BOTTOM----------
b_charge = 0;                           %initialize bottom charge
for j=3:side_in
   b_charge = 2*e_lower*(phi(bottom_out,j) - phi(bottom_in,j)) + b_charge;
end
b_charge = b_charge + e_lower*(phi(bottom_out,2) - phi(bottom_in,2));

%--------------TOP------------
t_charge = 0;
for j=3:side_in
   t_charge = 2*e_upper*(phi(top_out,j) - phi(top_in,j)) + t_charge;
end
t_charge = t_charge + e_upper*(phi(top_out,2) - phi(top_in,2));

%------------SIDES-----------
s_charge = 0;
for i=top_in:I_line -1
   s_charge = 2*e_upper*(phi(i,side_out) - phi(i,side_in)) + s_charge;
end
s_charge = s_charge + 2*ave_e*(phi(I_line,side_out) - phi(I_line,side_in));
for i = I_line+1:bottom_in
   s_charge = 2*e_lower*(phi(i,side_out) - phi(i,side_in)) + s_charge;
end

total_charge = b_charge + t_charge + s_charge;

capacitance = -(total_charge*8.854e-12)/5;    %e_o = 8.854e-1
```

```
%Andrew Austin
%ECE 5130 Project #1
%Problem 6: Output from program 'z_mix.m'
%The function z_mix calculates the capacitance of a dielectric
%and from these capacitances the impedance can be found.


» C_air = z_mix
Enter width of the microstrip:
2
Enter height of the microstrip:
2
Enter the upper dielectric substrate constant:
1
Enter the lower dielectric substrate constant:
1
Specify resolution (h):
.1
Specify number of iterations to compute:
200

C_air =

 3.1030e-011                %calculated capacitance of air

» C_5 = z_mix
Enter width of the microstrip:
2
Enter height of the microstrip:
2
Enter the upper dielectric substrate constant:
1
Enter the lower dielectric substrate constant:
5
Specify resolution (h):
.1
Specify number of iterations to compute:
200

C_5 =

   9.9021e-011              %calculated capacitance of e_0 = 5

% The numerical solution for the impedance is as follows:

% Zo = 1/(2.996e8 * sqrt(31.03e-12*99.021e-12)) =  60.2 ohms

% The analytical value was calculated to be:   67.2 ohms
```

Andrew Austin
ECE 5130 Project #1
Feb. 16, 1999

CONCLUSIONS

The following are the conclusions that I made from the different problems included in Project 1 dealing with FINITE DIFFERENCE FREQUENCY DOMAIN (FDFD).

Problem:

1. Problem one dealt with finding the first and second derivatives of a sine function, and how resolution plays a big part in getting an accurate solution. The programming for this problem was straight forward, and the only tricky part was indexing the array correctly to get the graphs to overlap correctly. To see how resolution has an affect on the derivative accuracy, refer to the graph included in this report. An additional conclusion is attached to the graph.

2. The second problem was to find potentials on a 'U' shaped box that had a 100 V source on the top and a ground plate on the bottom. The matrix equations were calculated by hand and the matrix was entered into Matlab to find the various potentials. My results are attached to my problem sheet. I didn't have any difficulties with this particular problem. Using symmetry gave me the exact same results.

3. Number three was similar to number two except for on the boundary between the two dielectrics. On the dielectric it's necessary to scale the nodes by the substrate constants and the points lying on the line by the average of the two substrates. I found the equations by hand and solved the matrix in Matlab.

4. Number four was a little trickier than the others because varying potentials were applied to the sides of the box. I solved this problem by hand first in order to get a solution to check my program results. After getting an answer from Matlab, I programmed it using the SOR method in Matlab and the program calculated the exact same result to four decimal places at least. This gave me a lot more confidence using the SOR method because that proved to me that it works.

5. I solved number five using my program for number four. I modified the code a little so it could handle both kinds of symmetry using a mod() function that determined whether the amount of sections were even or odd. The code worked perfectly and a logical answer was calculated.

6. Unlike the previous problems that were fairly straight forward to solve, number six was a harder animal to tackle. Although it took a lot more time and effort, I never really got stuck too bad. One hang up that I had was that I had to multiply the charge (q) by Eo (8.854e-12) in order to get capacitance. My original values were way too low, but after that adjustment I was only off by about 7 ohms. This could have been because of a lot of reasons. My integral contours could have been in a more optimal location or I might not have used enough iterations to converge enough. Although I wasn't right on, my impedance results were relatively close considering the error factors that come into play. To get a good idea of how a potential distribution acts around a microstrip line, refer to the 2-D and 3-D graphs included in this project report.

Overall Summary: This project really helped me understand FDFD, after hours and hours in the computer lab it better have helped me. I really feel comfortable with this numerical method and I thought it was very interesting how potentials could be calculated using these different methods. Matlab was a very helpful tool in visualizing what was happening by using some of its various plotting functions. Overall this was a great learning experience for me.