Computational Electromagnetics

Hw3

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Q-3.24:

3.24 Modify the program in Figure 3.21 or write your own program to calcul
for the microstrip line shown in Figure 3.54. Take $a = 2.02$, $b = 7.0$, $h = 1.$
$t = 0.01$, $\epsilon_1 = \epsilon_0$, $\epsilon_2 = 9.6\epsilon_0$.

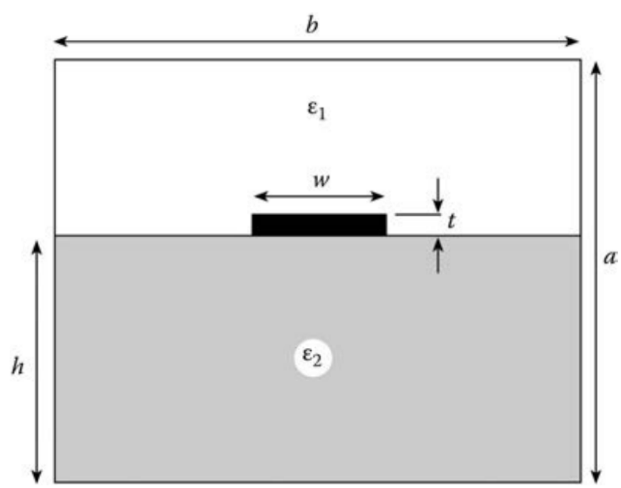
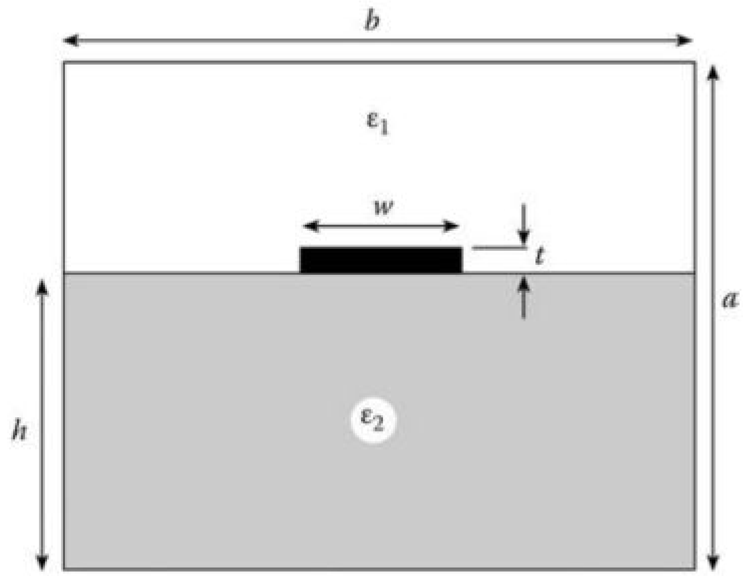
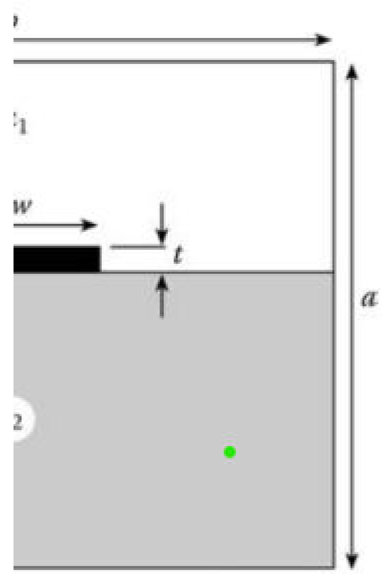


FIGURE 3.54
For Problem 3.24.

we can use symmetry in this problem and consider the right half of this geometry -->






```
clear; clc;
eps0 = 8.854178128e-12 ; % Vacuum Permitivity   [F.m-1]
a=2.02;
b=7.0;
h=1.0;
w = h;


t=0.01;

eps1 = eps0;
eps2 = 9.6*eps0;
```

```
H = 0.001;
NT = 30000;

A  = a; B=b/2; D=h; W=w/2;

ER = 9.6 ;
EO = 8.81e-12;
U = 3.0e+8;

NX  = round(A/H);
NY  = round(B/H);
ND  = round(D/H);
NW  = round(W/H);
VD  = 100.0;
```

Calculate charge with and without DIELECTRIC

```
ERR = 1.0; % without DIELECTRIC
for L=1:2
    E1 = EO;
    E2 = EO*ERR;

% INITIALIZATION

    V = zeros(NX+2,NY+2);

% Set POTENTIAL ON INNER CONDUCTOR (FIXED NODES) EQUAL TO VD
    V(2:NW+1,ND+2)  =VD; % On the strip line --> the conductor

% CALCULATE POTENTIAL AT FREE NODES  <MAIN Part of the Programm>

    P1 = E1/(2*(E1+E2));
    P2 = E2/(2*(E1+E2));
    for K=1:NT
        for I=0:NX-1
            for J=0:NY-1
                if( (J==ND)&(I<NW)  )
                    % do nothing
                elseif (J==ND) % The Line Between 2 materials
                    % IMPOSE BOUNDARY Condition at the Interface --> the
                    % Line between 2 materials (DIELECTRICS)
                    V(I+2,J+2) = 0.25*( V(I+3,J+2) +  V(I+1,J+2)   )  + P1*V(I+2,J+3) + P2*V(I-

                elseif (I==0) % The Left Side --> Symmetry --> rond/rond x V = 0 -->
                    % IMPOSE Symmetry COndition Along with Y-AXIS
                    V(I+2,J+2) = ( 2*V(I+3,J+2) + V(I+2,J+3) + V(I+2,J+1)   )/4.0;
                %elseif (J==0)
```

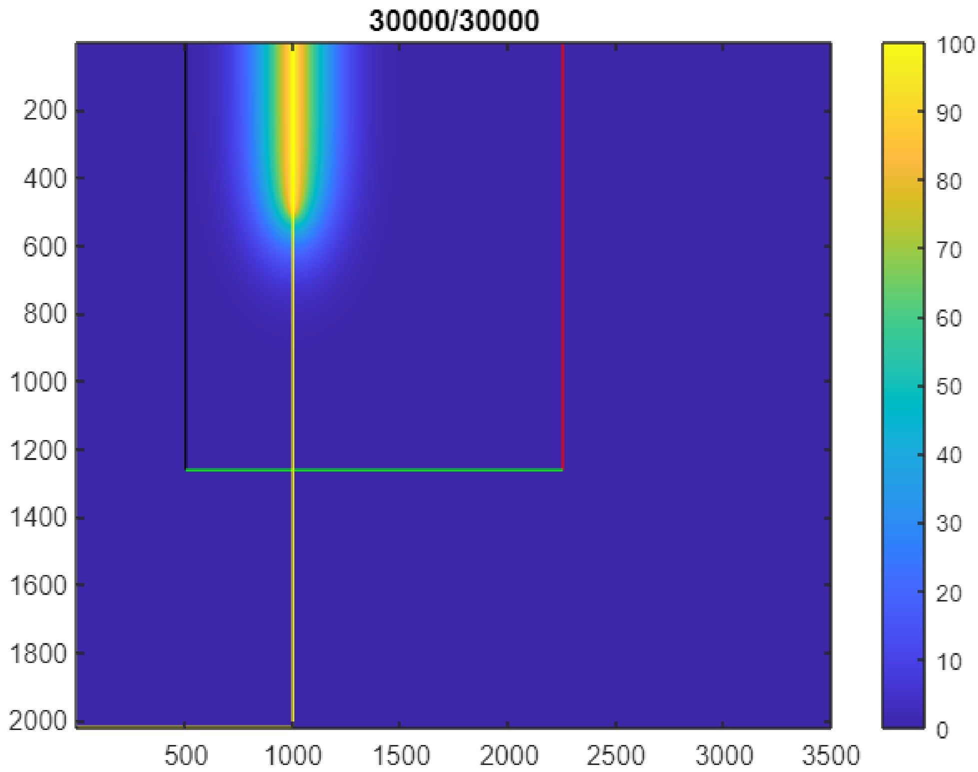
```
                    % IMPOSE BOUNDARY Condition at the Interface of E2 and
                    % the PEC wall
                    % V(I+2,J+2) = ( V(I+3,J+2) + V(I+1,J+2) + V(I+2,J+3)   )/4.0;
                 else
                     V(I+2,J+2) = (  V(I+3,J+2) + V(I+1,J+2) + V(I+2,J+3) + V(I+2,J+1) )/4.0;
                 end
             end
         end
         % ANimation of Calculation
%          figure(1);
%          imagesc(V);
%          colorbar;
%          title([num2str(K),'/' , num2str(NT) ])
%          drawnow


     end


% Now Calculate the TOTAL CHARGE ENCLOSED IN A Rectangular Path Surrounding the Inner CONDUCTOR
     IOUT = round((NX+NW)/2) ;
     JOUT = round((NY+ND)/2) ;
% SUM Potential on Inner and Outer LOOPS:
     for K=1:2
         SUM = E1* sum( V(3:IOUT+1 , JOUT+2)  )  + E1*V(2,JOUT+2)/2 ; % %E2*V(IOUT+2,2)/2; --> F
         for J=round((ND)/2):JOUT-1
             if(J<ND)
                 SUM =SUM + E2*V(IOUT+2,J+2);
             elseif (J==ND)
                 SUM = SUM + (E1+E2)*V(IOUT+2,J+2)/2;
             else
                 SUM = SUM + E1*V(IOUT+2,J+2);
             end
         end

         if (K==2)
         SUM =SUM + sum(E2*V(3:IOUT+2,round((ND+2)/2)+1))  + E2/2*V(2,round((ND+2)/2)+1) ;
         else
         SUM =SUM + sum(E2*V(3:IOUT+2,round((ND+2)/2)))  + E2/2*V(2,round((ND+2)/2)) ;
         end

         if K==1
             SV(1) = SUM;
             V_C0 = V;
         end
         IOUT = IOUT -1;
         JOUT = JOUT -1;
     end
     SUM  = SUM + 2.0* E1* V(IOUT+2,JOUT+2);
     SV(2) =     SUM;
```

```
    Q(L)  = abs(SV(1) - SV(2) ); % Charge
    ERR = ER;

 end
```

```
 % Calculate the Z0:
    C0 = 2.0*Q(1)/VD ;
    C1 = 2.0*Q(2)/VD;
    Z0 = 1.0/( U*sqrt(C0*C1) );

    disp([H,NT,Z0]);
```

```
   1.0e+04 *

    0.0000    3.0000    0.1678
```

```
save("V_"+NT+"_H_"+H+"_12_Nov.mat");

IOUT = round((NX+NW)/2) ;
JOUT = round((NY+ND)/2) ;

figure(2);
imagesc(V);
colorbar;
title([num2str(NT),'/' , num2str(NT) ])
hold on

line( [JOUT+2,JOUT+2],[2,IOUT+2], 'Color', 'r');
line([(ND+2)/2,(ND+2)/2], [2,IOUT+2], 'Color', 'black');
line([(ND+2)/2,JOUT+2], [IOUT+2,IOUT+2], 'Color', 'g');

% line( [JOUT+1,JOUT+1],[2,IOUT+1], 'Color', 'g');
% line([(ND-2)/2,(ND-2)/2], [2,IOUT+1], 'Color', 'b');
% line([(ND-2)/2,JOUT+1], [IOUT+1,IOUT+1], 'Color', 'r');


% Inside The Di-Electric
line([2,ND],[NX,NX], 'Color', 'y');
line( [ND,ND],[NX,2], 'Color', 'y');
hold on
plot(V(2,JOUT+2),'r')
```



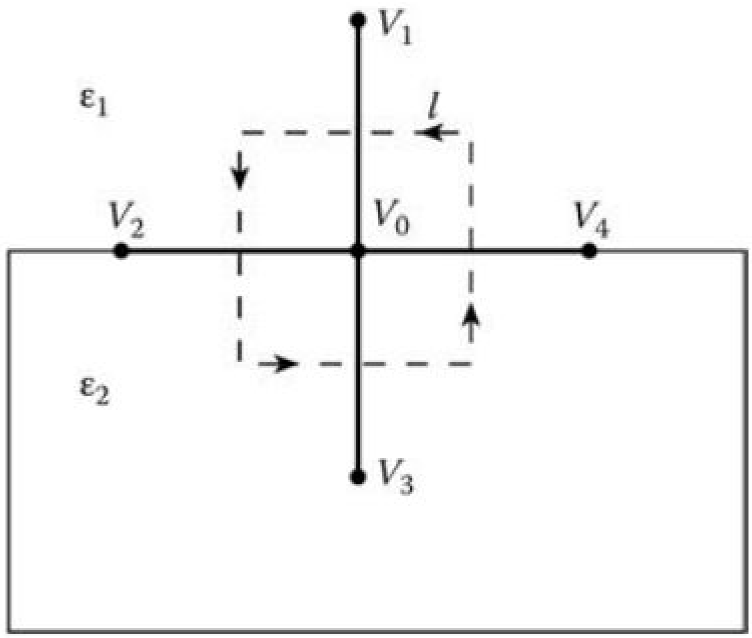
New Q Line:

```
% SUM Potential on Inner and Outer LOOPS:

    SUM1 = E1* sum( V(2:IOUT+2,JOUT+2)  )  ;%+ E1*V(2,JOUT+2)/2 + E2*V(IOUT+2,2)/2;
    for J=round(ND-2)/2:JOUT+2
        if(J<ND)
            SUM1 =SUM1 + E2*V(IOUT+2,J);  % A Parallel Line along Y-Axis from The bottom up.
        else
            SUM1 =SUM1 + E1*V(IOUT+2,J);  % A Parallel Line along Y-Axis from The bottom up.
        end
    end

    %SUM1  = SUM1 + 2.0* E1* V(IOUT+2,JOUT+2);  % Corner Point
    SUM2  = E2* sum( V(2:IOUT+2 , round((ND-2)/2))  ); % + E1*V(2,Nb+2)/2 + E1*V(Na+2,2)/2;
%     for J=1:Nb+2
%             SUM2 =SUM2 + E1*V(Na+2,J+2);  % A Parallel Line along Y-Axis from The bottom up.
%     end
    SUM2  = SUM2 + 2.0* E1* V(IOUT+2,JOUT+2);  % Corner Point

    Q2 = abs(SUM1 - SUM2 );

    V_C1 = V;
    V = V_C0;
% SUM Potential on Inner and Outer LOOPS:
```

```
    SUM1 = E1* sum( V(2:IOUT+2,JOUT+2)  )  ;%+ E1*V(2,JOUT+2)/2 + E2*V(IOUT+2,2)/2;
    for J=round(ND-2)/2:JOUT+2
        if(J<ND)
            SUM1 =SUM1 + E2*V(IOUT+2,J);  % A Parallel Line along Y-Axis from The bottom up.
        else
            SUM1 =SUM1 + E1*V(IOUT+2,J);  % A Parallel Line along Y-Axis from The bottom up.
        end
    end

    %SUM1  = SUM1 + 2.0* E1* V(IOUT+2,JOUT+2);  % Corner Point
    SUM2  = E2* sum( V(2:IOUT+2 , round((ND-2)/2))  ); % + E1*V(2,Nb+2)/2 + E1*V(Na+2,2)/2;
%     for J=1:Nb+2
%             SUM2 =SUM2 + E1*V(Na+2,J+2);  % A Parallel Line along Y-Axis from The bottom up.
%     end
    SUM2  = SUM2 + 2.0* E1* V(IOUT+2,JOUT+2);  % Corner Point

    Q1 = abs(SUM1 - SUM2 );

  % Calculate the Z0:
    C0_2 = 4.0*Q1/VD ;  % *4  --> Due to Symmetry
    C1_2 = 4.0*Q2/VD;
    Z0_method2 = 1/( U*sqrt(C1*C0) );
    disp(Z0_method2) % The Impedance is Equal to:  ---> Which is very close to  43 ohm!
```

```
1.6780e+03
```

$$\boxed{V_0 = \frac{\varepsilon_1}{2(\varepsilon_1+\varepsilon_2)}V_1 + \frac{\varepsilon_2}{2(\varepsilon_1+\varepsilon_2)}V_3 + \frac{1}{4}V_2 + \frac{1}{4}V_4} \tag{3.53}$$



And for calculation of Charges enclosed in a rectangular shape:

$$Q = \oint_\ell \mathbf{D} \cdot d\mathbf{l} = \oint_\ell \varepsilon \frac{\partial V}{\partial n} d\ell$$

$$= \varepsilon\left(\frac{V_P - V_N}{\Delta x}\right)\Delta y + \varepsilon\left(\frac{V_M - V_L}{\Delta x}\right)\Delta y + \varepsilon\left(\frac{V_H - V_L}{\Delta y}\right)\Delta x$$

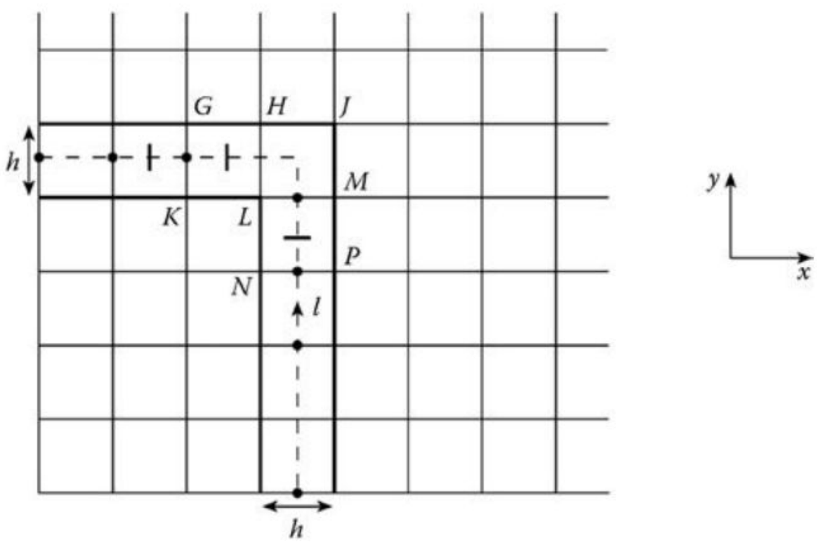
$$+ \varepsilon\left(\frac{V_G - V_K}{\Delta y}\right)\Delta x + \cdots \quad (3.61)$$

Since $\Delta x = \Delta y = h$,

$$Q = (\epsilon V_P + \epsilon V_M + \epsilon V_H + \epsilon V_G + \cdots) - (\epsilon V_N + 2\epsilon V_L + \epsilon V_K + \cdots)$$

or

$$\begin{aligned} Q = \varepsilon_o \Big[\sum \varepsilon_{ri} V_i \quad &\text{for nodes } i \text{ on outer rectangle GHJMP} \\ &\text{with corners (such as J) not counted}\Big] \\ - \varepsilon_o \Big[\sum \varepsilon_{ri} V_i \quad &\text{for nodes } i \text{ on inner rectangle KLN} \\ &\text{with corners (such as L) counted twice}\Big], \end{aligned} \quad (3.62)$$



Convergence:

Although, we did everything to reach the correct answer which is 43 ohm, we are not satisfied with results! --> Convergence never happend! --> Tried debugging the code but failed -->

Step 1:

H = 0.1 0.1 0.01 0.01 0.01 0.01 0.001
0.001

NT = 1000 5000 1000 5000 10000 30000 10000
30000

Z0 = 56.15 56.1581 145.6462 64.5268 56.9608 53.2661 5523000 1678

```
% My Code Did not Converge Properly! --> a  partial COnvergence can be
% observed --> maybe with increase in NT we face better results!
```