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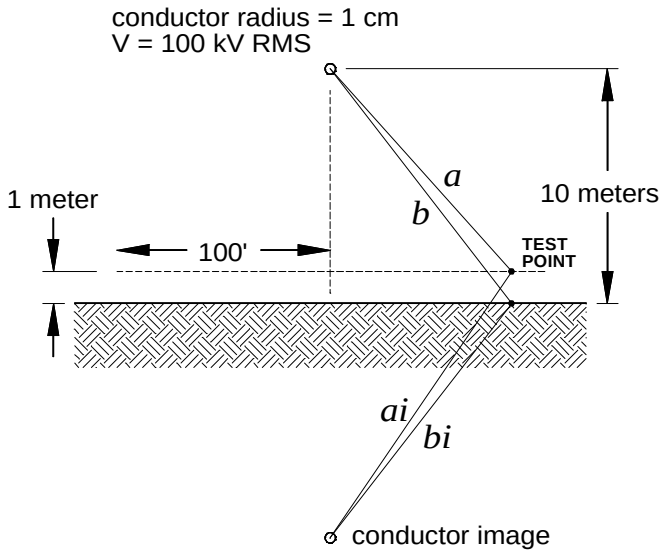
EE368 Electrical Power Transmission and Distribution
Homework 3, 2/15/99

Problem:

Given a single conductor 10 meters above ground with a radius of 1 cm carrying a voltage of 100 kV_{RMS}: Calculate and plot V_{RMS} and E_{RMS} along a line one meter above ground level extending 100' to either side of the right-of-way centerline.



Matlab Program:

```
% *************  GIVEN VALUES  ***************************************

format short                % Instruction to display 5-digit results
LineVoltage = 100000        % Line Voltage RMS
LineHeight = 10;            % Line height above ground [meters]
TestHeight = 1;             % Height above ground of test area [meters]

Radius = .01                % Conductor Radius [meters]
WidthROW = 100              % Half-width of right-of-way [feet]
Epsilon = 8.85e-12;         % Permittivity of free space constant [F/m]


% **********  ADDITIONAL VARIABLES  **********************************

Ql = 0;                     % Line charge [C/m]
Vab = 0;                    % Voltage from a to b [V]
Eq = 0;                     % Electric field due to Ql [V/m]
a = 0;                      % Distance from line to a [meters]

ai = 0;                     % Distance from image to a [meters]
Xn = -100;                  % Incremental x-value along test line [feet]
Vn = 0;                     % Incremental y-value for voltage
En = 0;                     % Incremental y-value for electric field

x = [];                     % matrix of x-axis values
E = [];                     % matrix of y-axis values (electric field)
V = [];                     % matrix of y-axis values (voltage)
Output = [];                % matrix for columnar results
```

```
% ************  CUSTOM FUNCTIONS  ************************************

% Efield_1Lin(Distance in meters,Lineal charge in C/m)
%   Returns the electric field due to a single conductor
%   in volts/meter as a function of distance [meters],
%   from a lineal charge [C/m].
%   function Result = Efield_1Lin(x,Q);
%   Result = Q/(2*pi*8.85*10^(-12)*x);

% Vag_1Lin(Line charge in C/m,Line height in meters,height
%   above ground in meters,distance from center in feet)
%   Returns the voltage to ground due to a single overhead
%   line as a function of line charge [C/m], line height [meters],
%   height above ground of the test point [meters], and horizontal
%   distance from center [feet].
%   function Result = Vag_1Lin(Q,Lh,h,d);
%   ai = 0; a = 0;
%   d = d * .3048;              % convert feet to meters
%   %  Find a and ai by Pythagorean's theorem
%   a = ((Lh-h)^2+d^2)^.5; ai = ((Lh+h)^2+d^2)^.5;
%   Result = log(ai/a)*Q/(2*pi*8.85*10^(-12));


% ************  CALCULATE CAPACITANCE AND CHARGE  *********************

Capacitance = 2*pi*8.85*10^(-12)/log(2*LineHeight/Radius)
Ql = Capacitance * LineVoltage          % Line charge in Coulombs/meter


% ********  CREATE PLOTS FOR VOLTAGE AND ELECTRIC FIELD  **************

newplot
axis([-100 100 0 100]); Xn = -100; x = [];
while Xn <= 100                         % Calculate the voltage
  Vn = Vag_1Lin(Ql,LineHeight,TestHeight,Xn);
  x = [x Xn]; V = [V Vn]; Xn = Xn + .1; % Append values & increment
end
plot(x,V,'k-'); grid on                 % Plot voltage
xlabel('Horizontal Distance in Feet')   % label the x-axis
ylabel('Voltage @ 1 meter AGL in Volts')% label the y-axis

figure; newplot;                        % Opens new window for plot
axis([-100 100 0 100]);  Xn = -100; x = [];
while Xn <= 100                         % Calculate electric field
  En = Efield_1Lin((((LineHeight-TestHeight)^2)+(Xn^2))^(.5),Ql);
  x = [x Xn]; E = [E En]; Xn = Xn + .1; % Append values & increment
end
plot(x,E,'k-'); grid on                 % Plot electric field
xlabel('Horizontal Distance in Feet')   % label the x-axis
ylabel('Electric Field @ 1 meter AGL in Volts/Meter') % label the y-axis
```

```
% **********  CREATE MATRIX OF VALUES FOR DATA SHEET  ****************

Xn = -100;                              % Counter (feet)
x = []; V = []; E = [];                 % Reset matrices
while Xn <= 100                         % Calculate voltage and e-field
  Vn = Vag_1Lin(Ql,LineHeight,TestHeight,Xn);
  En = Efield_1Lin((((LineHeight-TestHeight)^2)+(Xn^2))^(.5),Ql);
  x=[x;Xn]; E=[E;En]; V=[V;Vn];         % Append results to matrices
  Xn = Xn + 1;                          % Increment the counter
end
format bank                             % Results to 2 decimal places
Output = [x V E]                        % Combine and display results
```

Formulas Used:

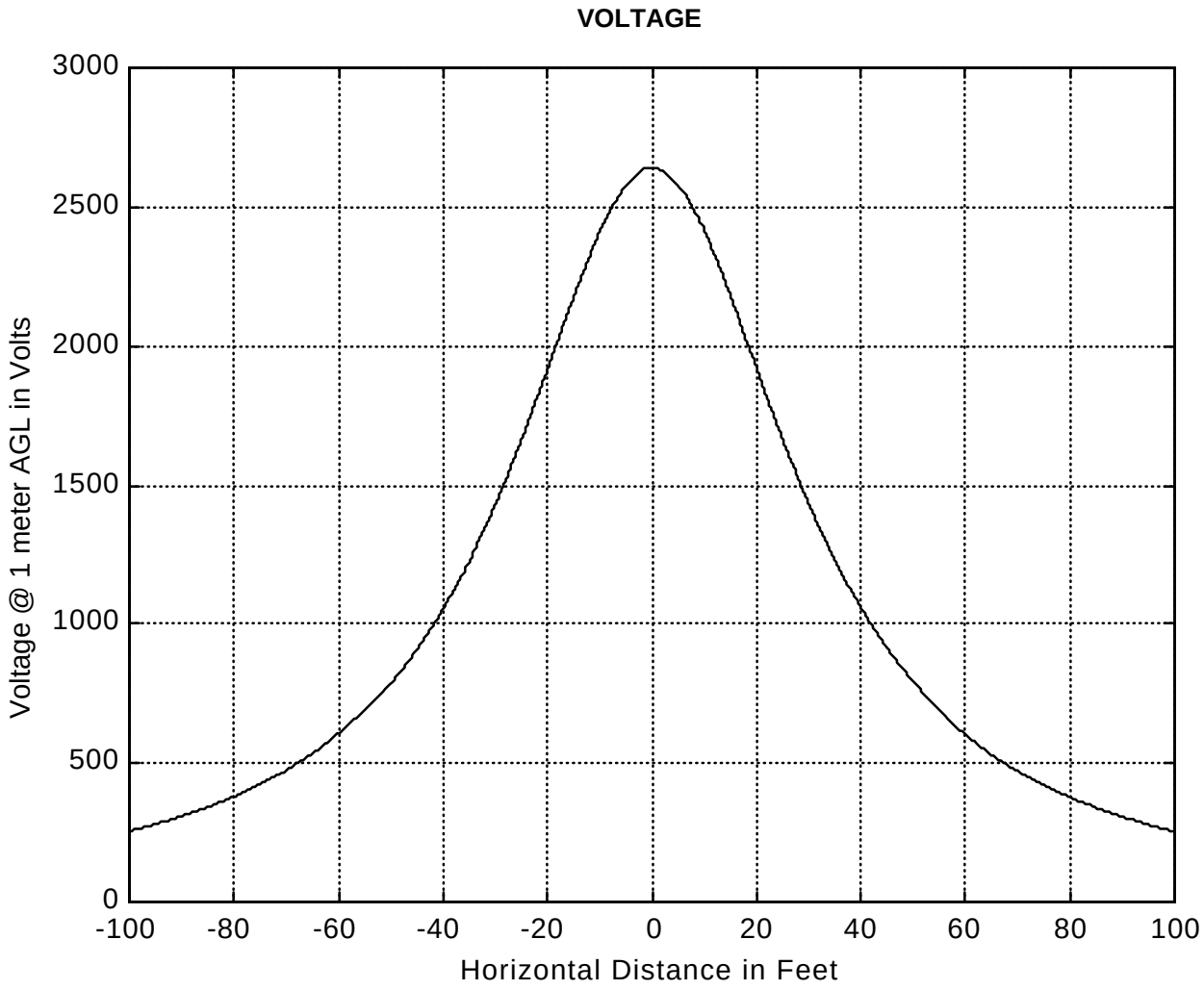
$C_l = \frac{2\pi\varepsilon_0}{\ln\frac{2h}{r}}$	C_l = capacitance per unit length [F/m]
	ε_0 = Permittivity of free space 8.85×10^{-12} [F/m]
	h = height of transmission line [m]
	r = radius of the conductor [m]
$q_l = C_l V$	q_l = charge per unit length [coulombs/meter]
	V = line voltage [V]
$V_{ag} = \frac{q_l}{2\pi\varepsilon_0}\ln\left(\frac{ai}{a}\right)$	V_{ag} = voltage from point a to ground [V]
	ai = distance from image to test point [m]
	a = distance from conductor to test point [m]
$E_{ql} = \frac{q_l}{2\pi\varepsilon_0 a}$	E_{ql} = Electric field due to line charge q_l [V/m]

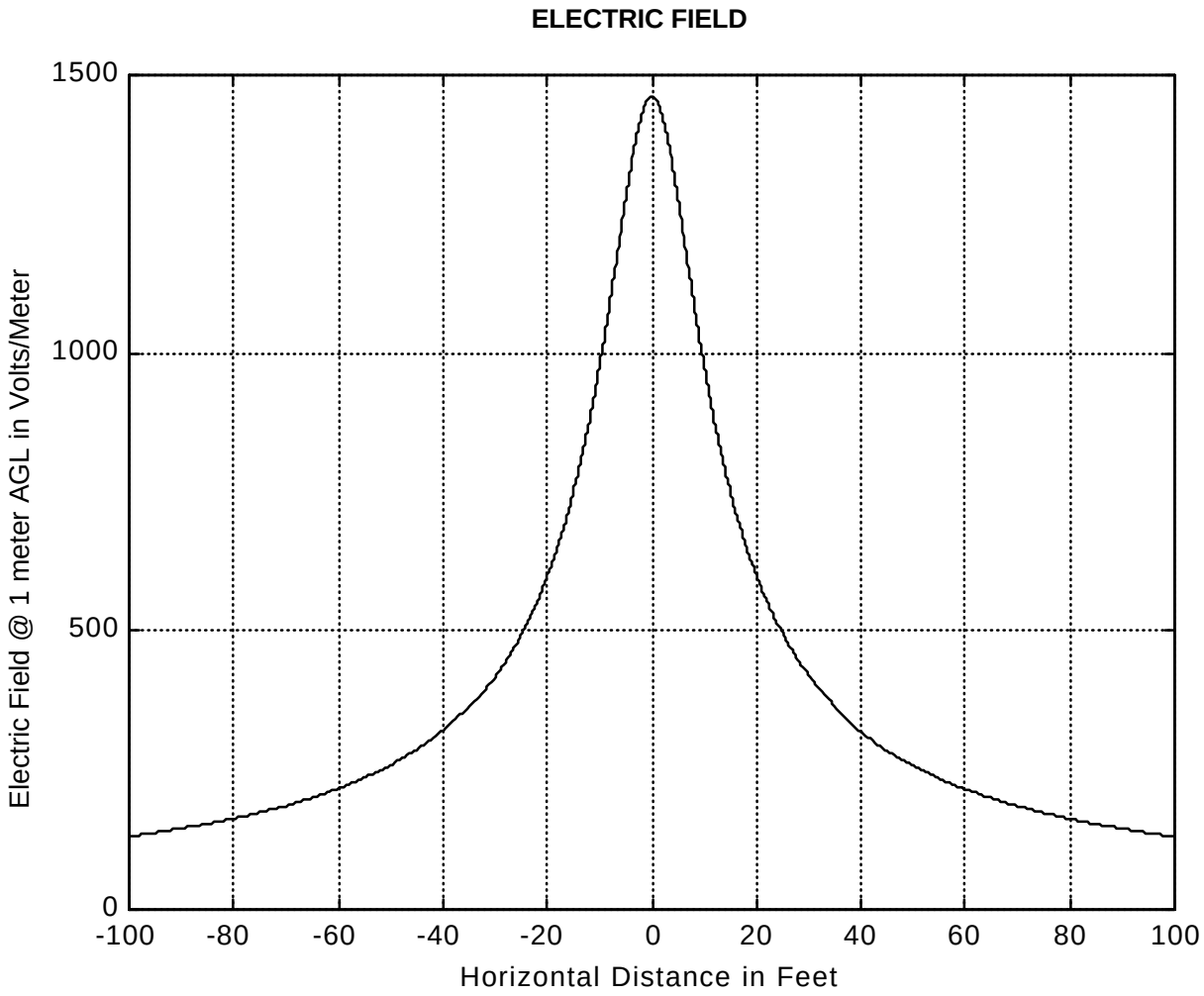
Initial Program Output:

LineVoltage = 100000
Radius = 0.0100
WidthROW = 100
Capacitance = 7.3157e-012
Ql = 7.3157e-007

(Description of variables is on page 1.)

Plots of Voltage and Electric Field:




ELECTRIC FIELD
1500
1000
500
0
Electric Field @ 1 meter AGL in Volts/Meter
-100
-80
-60
-40
-20
0
20
40
60
80
100
Horizontal Distance in Feet

Voltage and Electric Field Data:

FEET FROM R.O.W. CENTERLINE	VOLTAGE @ 1 METER A.G.L. [V]	ELECTRIC FIELD @ 1 METER A.G.L. [V/m]
-100.00	255.49	131.03
-99.00	260.16	132.35
-98.00	264.95	133.69
-97.00	269.88	135.05
-96.00	274.93	136.45
-95.00	280.13	137.87
-94.00	285.47	139.32
-93.00	290.95	140.81
-92.00	296.59	142.32
-91.00	302.38	143.87
-90.00	308.34	145.46
-89.00	314.47	147.07
-88.00	320.78	148.73
-87.00	327.26	150.42
-86.00	333.94	152.15
-85.00	340.81	153.92
-84.00	347.89	155.73
-83.00	355.18	157.59
-82.00	362.69	159.49
-81.00	370.42	161.43
-80.00	378.39	163.42
-79.00	386.60	165.47
-78.00	395.07	167.56
-77.00	403.81	169.71
-76.00	412.81	171.91
-75.00	422.11	174.17
-74.00	431.70	176.49
-73.00	441.59	178.87
-72.00	451.81	181.32
-71.00	462.36	183.83
-70.00	473.26	186.41
-69.00	484.52	189.07
-68.00	496.15	191.80
-67.00	508.18	194.62
-66.00	520.61	197.51
-65.00	533.46	200.49
-64.00	546.75	203.56
-63.00	560.50	206.73
-62.00	574.73	210.00
-61.00	589.45	213.37
-60.00	604.69	216.85
-59.00	620.46	220.44
-58.00	636.80	224.15
-57.00	653.71	227.99
-56.00	671.23	231.96
-55.00	689.39	236.07
-54.00	708.19	240.32
-53.00	727.68	244.73
-52.00	747.88	249.30
-51.00	768.81	254.04

FEET FROM R.O.W. CENTERLINE	VOLTAGE @ 1 METER A.G.L. [V]	ELECTRIC FIELD @ 1 METER A.G.L. [V/m]
-50.00	790.51	258.96
-49.00	813.00	264.08
-48.00	836.32	269.40
-47.00	860.49	274.93
-46.00	885.55	280.69
-45.00	911.52	286.69
-44.00	938.45	292.94
-43.00	966.35	299.47
-42.00	995.27	306.29
-41.00	1025.23	313.42
-40.00	1056.27	320.89
-39.00	1088.41	328.70
-38.00	1121.67	336.90
-37.00	1156.10	345.50
-36.00	1191.70	354.54
-35.00	1228.51	364.05
-34.00	1266.53	374.07
-33.00	1305.77	384.63
-32.00	1346.25	395.78
-31.00	1387.97	407.57
-30.00	1430.91	420.05
-29.00	1475.05	433.28
-28.00	1520.38	447.33
-27.00	1566.85	462.27
-26.00	1614.42	478.18
-25.00	1663.02	495.15
-24.00	1712.56	513.28
-23.00	1762.95	532.68
-22.00	1814.08	553.49
-21.00	1865.80	575.84
-20.00	1917.96	599.88
-19.00	1970.38	625.78
-18.00	2022.85	653.74
-17.00	2075.14	683.97
-16.00	2127.01	716.67
-15.00	2178.17	752.10
-14.00	2228.34	790.49
-13.00	2277.19	832.08
-12.00	2324.39	877.09
-11.00	2369.59	925.68
-10.00	2412.44	977.90
-9.00	2452.59	1033.66
-8.00	2489.67	1092.57
-7.00	2523.35	1153.89
-6.00	2553.29	1216.30
-5.00	2579.19	1277.86
-4.00	2600.79	1335.82
-3.00	2617.83	1386.80
-2.00	2630.15	1427.00
-1.00	2637.60	1452.87

FEET FROM R.O.W. CENTERLINE	VOLTAGE @ 1 METER A.G.L. [V]	ELECTRIC FIELD @ 1 METER A.G.L. [V/m]
0	2640.09	1461.81
1.00	2637.60	1452.87
2.00	2630.15	1427.00
3.00	2617.83	1386.80
4.00	2600.79	1335.82
5.00	2579.19	1277.86
6.00	2553.29	1216.30
7.00	2523.35	1153.89
8.00	2489.67	1092.57
9.00	2452.59	1033.66
10.00	2412.44	977.90
11.00	2369.59	925.68
12.00	2324.39	877.09
13.00	2277.19	832.08
14.00	2228.34	790.49
15.00	2178.17	752.10
16.00	2127.01	716.67
17.00	2075.14	683.97
18.00	2022.85	653.74
19.00	1970.38	625.78
20.00	1917.96	599.88
21.00	1865.80	575.84
22.00	1814.08	553.49
23.00	1762.95	532.68
24.00	1712.56	513.28
25.00	1663.02	495.15
26.00	1614.42	478.18
27.00	1566.85	462.27
28.00	1520.38	447.33
29.00	1475.05	433.28
30.00	1430.91	420.05
31.00	1387.97	407.57
32.00	1346.25	395.78
33.00	1305.77	384.63
34.00	1266.53	374.07
35.00	1228.51	364.05
36.00	1191.70	354.54
37.00	1156.10	345.50
38.00	1121.67	336.90
39.00	1088.41	328.70
40.00	1056.27	320.89
41.00	1025.23	313.42
42.00	995.27	306.29
43.00	966.35	299.47
44.00	938.45	292.94
45.00	911.52	286.69
46.00	885.55	280.69
47.00	860.49	274.93
48.00	836.32	269.40
49.00	813.00	264.08

FEET FROM R.O.W. CENTERLINE	VOLTAGE @ 1 METER A.G.L. [V]	ELECTRIC FIELD @ 1 METER A.G.L. [V/m]
50.00	790.51	258.96
51.00	768.81	254.04
52.00	747.88	249.30
53.00	727.68	244.73
54.00	708.19	240.32
55.00	689.39	236.07
56.00	671.23	231.96
57.00	653.71	227.99
58.00	636.80	224.15
59.00	620.46	220.44
60.00	604.69	216.85
61.00	589.45	213.37
62.00	574.73	210.00
63.00	560.50	206.73
64.00	546.75	203.56
65.00	533.46	200.49
66.00	520.61	197.51
67.00	508.18	194.62
68.00	496.15	191.80
69.00	484.52	189.07
70.00	473.26	186.41
71.00	462.36	183.83
72.00	451.81	181.32
73.00	441.59	178.87
74.00	431.70	176.49
75.00	422.11	174.17
76.00	412.81	171.91
77.00	403.81	169.71
78.00	395.07	167.56
79.00	386.60	165.47
80.00	378.39	163.42
81.00	370.42	161.43
82.00	362.69	159.49
83.00	355.18	157.59
84.00	347.89	155.73
85.00	340.81	153.92
86.00	333.94	152.15
87.00	327.26	150.42
88.00	320.78	148.73
89.00	314.47	147.07
90.00	308.34	145.46
91.00	302.38	143.87
92.00	296.59	142.32
93.00	290.95	140.81
94.00	285.47	139.32
95.00	280.13	137.87
96.00	274.93	136.45
97.00	269.88	135.05
98.00	264.95	133.69
99.00	260.16	132.35
100.00	255.49	131.03