4.25 Use the equations in the book or the computer program of this chapter. Find the radiation efficiency of resonant linear electric dipoles of length $l = 0.1\lambda$

Assume that each dipole is made out of copper [$\sigma = 5.7 \times 10^7$ S/m], has a radius of $10^{-4}\lambda$, and is operating at $f = 10$ MHz. Use the computer program **Dipole** of this chapter to find the radiation resistances.

- As part of your solution, compute radiation R_r and loss R_L resistances using equations from text and again using NEC (show input file and relevant part of output). Compare answers. You do not need to use program **Dipole**.

A dipole of length $\ell = 0.1\lambda$ is considered a small dipole (section 4.3 of text).

Per (4-37), $R_r = 20\pi^2(\ell/\lambda)^2 = 20\pi^2(0.01)$

$$R_r = 1.97392\ \Omega$$

Per (2-90b), $R_{hf} = \frac{\ell}{p}\sqrt{\frac{\omega\mu_0}{2\sigma}}$

For a triangular current distribution,

$$R_L = \frac{R_{hf}}{3} = \frac{0.1\lambda}{3(2\pi)10^{-4}\lambda}\sqrt{\frac{2\pi(10\times10^6)4\pi\times10^{-7}}{2(5.7\times10^7)}}$$

$$R_L = 0.044151\ \Omega$$

Per (2-90) $e_{cd} = \frac{R_r}{R_r + R_L} = \frac{1.97392}{1.97392+0.04415}$

$$e_{cd} = 0.9781 = 97.81\%$$

From NEC-2, see attached page

$$e_{cd} = 97.83\%$$

⇒ Excellent agreement!!

NEC-2 input file

```
CM EE 483 Problem 4.25 (4_25_01l.txt)
CM This file is used to determine the efficiency of a
CM 0.1 lambda copper dipole antenna (sigma = 5.7*10^7 S/m)
CM center driven at 10 MHz (lambda = 29.98 m).
CM radius = a = 0.0001(lambda) = 0.002998 m
CM length = l = 0.1 lambda = 0.1*29.98 = 2.998 m
CM Used 63 segments (del/a= 16).  DRIVEN SEGMENT IS #32.
CE
GW 1 63 0.0 0.0 -1.499 0.0 0.0 1.499 0.002998
GE 0
EK 0          ! Use extended kernel in simulation
FR 0 1 0 0 10.0 0.0
EX 0 1 32 00 1.0 0.0
LD 5 0 0 0 5.7e7
XQ 0
EN
```

NEC-2 output file excerpt

```
FREQUENCY= 1.0000E+01 MHZ
WAVELENGTH= 2.9980E+01 METERS
<snip>
     - - - STRUCTURE IMPEDANCE LOADING - - -
LOCATION RESISTANCE INDUCTANCE CAPACITANCE IMPEDANCE(OHMS) CONDUCTIVITY TYPE
ITAG FROM THRU OHMS  HENRYS       FARADS    REAL   IMAGINARY    MHOS/METER
      ALL                                              5.7000E+07    WIRE
<snip>
- - - ANTENNA INPUT PARAMETERS - - -

TAG SEG. VOLTAGE(VOLTS) CURRENT(AMPS) IMPEDANCE(OHMS) ADMITTANCE(S) POWER
NO. NO. REAL IMAG.   REAL  IMAG.  REAL    IMAG.   REAL  IMAG.  (WATTS)
1   32   1.0  0.0 5.29072E-07 5.25505E-04 1.91584E+00-1.90293E+03 5.29072E-07
5.25505E-04 2.64536E-07
<snip>
- - POWER BUDGET - - -
INPUT POWER   = 2.6454E-07 WATTS
RADIATED POWER= 2.5881E-07 WATTS
STRUCTURE LOSS= 5.7284E-09 WATTS
NETWORK LOSS  = 0.0000E+00 WATTS
EFFICIENCY    =  97.83 PERCENT
```

From NEC info, $\bar{I}_{in} = 0.000529 + j0.525505 \text{ mA} = 0.525505\angle 89.94° \text{ mA}$.

$$(2\text{-}76) \qquad R_r = \frac{P_{\text{rad}}}{0.5\,|\bar{I}_{\text{in}}|^2} = \frac{2.5881\text{E}-07}{0.5(0.000525505)^2} \quad \Rightarrow \quad \underline{R_r = 1.8744\ \Omega},$$

$$(2\text{-}77) \qquad R_L = \frac{P_{\text{loss}}}{0.5\,|\bar{I}_{\text{in}}|^2} = \frac{5.72840E-09}{0.5(0.000525505)^2} \quad \Rightarrow \quad \underline{R_L = 0.04149\ \Omega}.$$

- NEC R_r of 1.8744 Ω is slightly smaller than the 1.9739 Ω from theory.
- NEC R_L of 0.04149 Ω is slightly smaller than the 0.04415 Ω from theory.