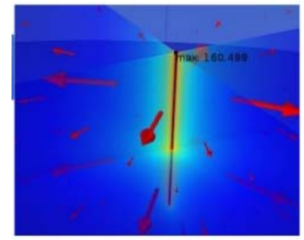
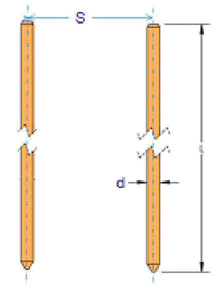
RESISTANCE OF GROUND ROD:



- **One ground rod:** $R_1(L,a,\rho) := \dfrac{\rho}{2\pi \cdot L}\cdot\left(\ln\left(\dfrac{4L}{a}\right)-1\right)$

Where:
R = resistance in Ω
ρ = resistivity in Ω.cm
d = distances - in cm
S = space between rods (cm)
a= rod radius (cm)
L= Rod length (cm)



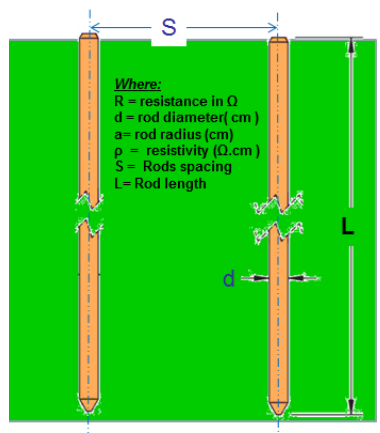
- **Two ground rods:**

a) For $S > L$: $$R_2(L,S,a,\rho) := \frac{\rho}{4\pi \cdot L}\cdot\left(\ln\left(\frac{4L}{a}\right)-1\right)+\frac{\rho}{4\pi \cdot S}\cdot\left(1-\frac{L^2}{3S^2}+\frac{2L^4}{5S^4}\right)$$

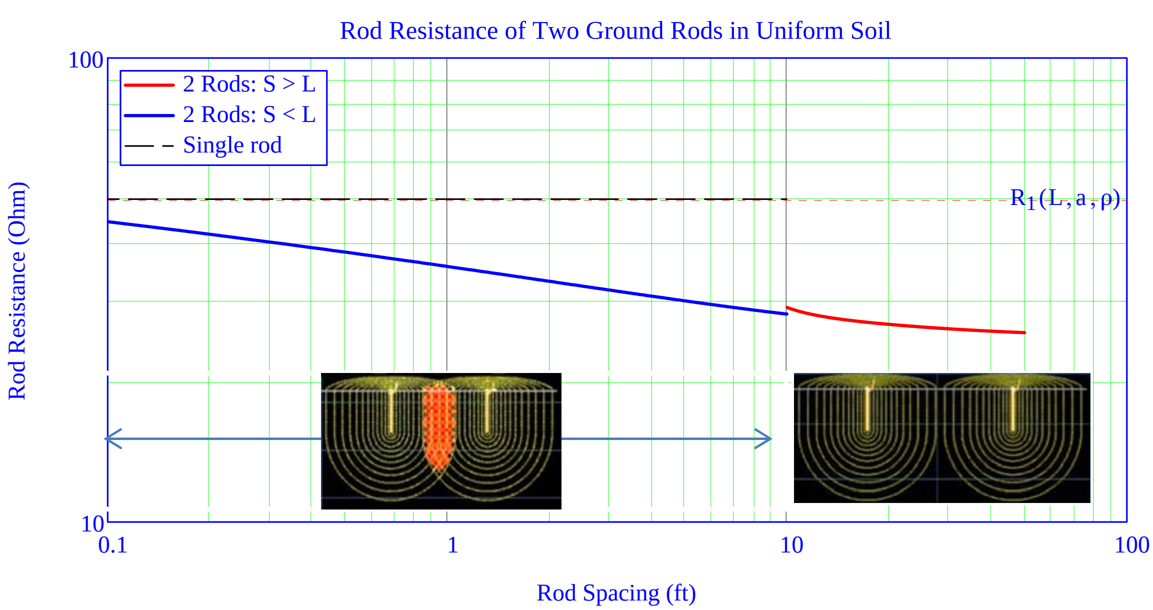
b) For $S < L$: $$R_3(L,S,a,\rho) := \frac{\rho}{4\pi \cdot L}\left[\ln\left(\frac{4L}{a}\right)+\ln\left(\frac{4L}{S}\right)-2+\frac{S}{2L}-\left(\frac{S^2}{16L^2}\right)+\frac{S^4}{256L^4}\right]$$

Example:

- Rod lengt: $L := 10\text{ft}$
- Rod diameter: $d := \frac{5}{8}\text{in}$; Radius $a := \frac{d}{2}$
- Soil resistivity: $\rho := 150\Omega \cdot m$
- Number of rods. n
- Rod Spacing: S , Burried depth: $h := 24\text{in}$
- One ground rod: $R_1(L,a,\rho) = 49.634\,\Omega$



Ground Rods in a Uniform Soil



	Hemisphere radius a	$R = \frac{\rho}{2\pi a}$
•	One ground rod length L, radius a	$R = \frac{\rho}{2\pi L}\left(\ln\frac{4L}{a} - 1\right)$
• •	Two ground rods $s > L$; spacing s	$R = \frac{\rho}{4\pi L}\left(\ln\frac{4L}{a} - 1\right) + \frac{\rho}{4\pi s}\left(1 - \frac{L^2}{3s^2} + \frac{2L^4}{5s^4} \cdots\right)$
••	Two ground rods $s < L$; spacing s	$R = \frac{\rho}{4\pi L}\left(\ln\frac{4L}{a} + \ln\frac{4L}{s} - 2 + \frac{s}{2L} - \frac{s^2}{16L^2} + \frac{s^4}{512L^4} \cdots\right)$
—	Buried horizontal wire length $2L$, depth $s/2$	$R = \frac{\rho}{4\pi L}\left(\ln\frac{4L}{a} + \ln\frac{4L}{s} - 2 + \frac{s}{2L} - \frac{s^2}{16L^2} + \frac{s^4}{512L^4} \cdots\right)$
L	Right-angle turn of wire length of arm L, depth $s/2$	$R = \frac{\rho}{4\pi L}\left(\ln\frac{2L}{a} + \ln\frac{2L}{s} - 0.2373 + 0.2146\frac{s}{L} + 0.1035\frac{s^2}{L^2} - 0.0424\frac{s^4}{L^4} \cdots\right)$
⅄	Three-point star length of arm L, depth $s/2$	$R = \frac{\rho}{6\pi L}\left(\ln\frac{2L}{a} + \ln\frac{2L}{s} + 1.071 - 0.209\frac{s}{L} + 0.238\frac{s^2}{L^2} - 0.054\frac{s^4}{L^4} \cdots\right)$
+	Four-point star length of arm L, depth $s/2$	$R = \frac{\rho}{8\pi L}\left(\ln\frac{2L}{a} + \ln\frac{2L}{s} + 2.912 - 1.071\frac{s}{L} + 0.645\frac{s^2}{L^2} - 0.145\frac{s^4}{L^4} \cdots\right)$
✳	Six-point star length of arm L, depth $s/2$	$R = \frac{\rho}{12\pi L}\left(\ln\frac{2L}{a} + \ln\frac{2L}{s} + 6.851 - 3.128\frac{s}{L} + 1.758\frac{s^2}{L^2} - 0.490\frac{s^4}{L^4} \cdots\right)$
✳	Eight-point star length of arm L, depth $s/2$	$R = \frac{\rho}{16\pi L}\left(\ln\frac{2L}{a} + \ln\frac{2L}{s} + 10.98 - 5.51\frac{s}{L} + 3.26\frac{s^2}{L^2} - 1.17\frac{s^4}{L^4} \cdots\right)$
○	Ring of wire diameter of ring D, diameter of wire d, depth $s/2$	$R = \frac{\rho}{2\pi^2 D}\left(\ln\frac{8D}{d} + \ln\frac{4D}{s}\right)$
—	Buried horizontal strip length $2L$, section a by b, depth $s/2$, $b < a/8$	$R = \frac{\rho}{4\pi L}\left(\ln\frac{4L}{a} + \frac{a^2 - \pi ab}{2(a+b)^2} + \ln\frac{4L}{s} - 1 + \frac{s}{2L} - \frac{s^2}{16L^2} + \frac{s^4}{512L^4} \cdots\right)$
	Buried horizontal round plate radius a, depth $s/2$	$R = \frac{\rho}{8a} + \frac{\rho}{4\pi s}\left(1 - \frac{7}{12}\frac{a^2}{s^2} + \frac{33}{40}\frac{a^4}{s^4} \cdots\right)$
	Buried vertical round plate radius a, depth $s/2$	$R = \frac{\rho}{8a} + \frac{\rho}{4\pi s}\left(1 + \frac{7}{24}\frac{a^2}{s^2} + \frac{99}{320}\frac{a^4}{s^4} \cdots\right)$

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