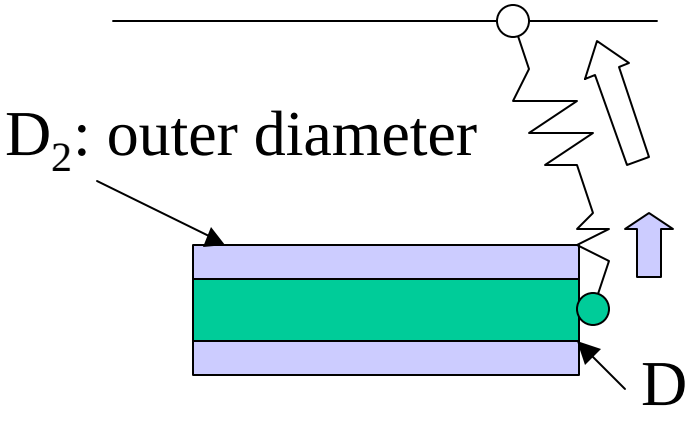
Shape Factor Example

The shape factor can be modeled as thermal resistance as $R_t=1/kS$, Therefore, it can be integrated with the electric circuit analog concept we learned earlier. As an example, let us place a thick insulation layer with a thickness of 10 cm around the pipe line. Now, determine the heat loss. (Caution: the following calculation will be an approximation only since after we put on insulation the outer surface of the insulation will not be constant temperature anymore. Accordingly, the assumption of isothermal surfaces when we derive the shape factor is not valid. However, this is still a reasonable good assumption if the temperature variation is not very large. If we accept this, we can model the heat transfer as two-step process. First, from the pipe through the insulator and followed by the second stage that is from the outer surface of the insulator to the ground.

Shape Factor Example (cont.)



$R_{soil}=1/kS$

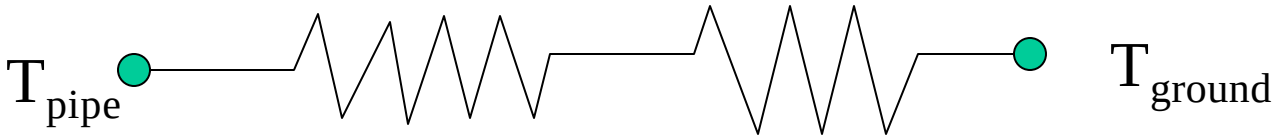
Insulator through the soil to the ground

Pipe through insulator $R_{insulator} = \dfrac{\ln(r_2 / r_1)}{2pk_{insulator}L}$

The thermal resistance from the insulator to the ground is

$$R_{soil} = \frac{1}{k_{soil}S} = \frac{1}{k_{soil}\left(2pL \Big/ \ln(4z/D_2)\right)} = \frac{1}{0.5\left(\dfrac{2p.1}{\ln(4/0.7)}\right)} = 0.555(°C/W)$$

$$R_{insulator} = \frac{\ln(r_2/r_1)}{2pk_{insulator}L} = \frac{\ln(0.35/0.25)}{2p(0.05).1} = 1.07(°C/W)$$



Shape Factor Example (cont.)

$$q = \frac{T_{pipe} - T_{ground}}{R_{insulator} + R_{soil}} = \frac{100 - (-20)}{(0.555 + 1.07)} = 73.85(W)$$

- The heat loss is significantly lower than that without the insulator (q=181.2 W)
- Although the shape factor assumption is not exactly valid, but the approximation should be good enough for most applications. Especially in cases where only a first-order estimation is needed.