

```
In[*]:= << c:\femm42\mathfemm\mathfemm.m
```

```
MathFEMM loaded at Sun 17 Apr 2022 21:37:32
```

```
In[*]:= OpenFEMM[1];
```

```
In[*]:= myAWG = 20;  
myFill = 0.5;  
myKi = 0.26;  
myKc = 398;  
myKp = 1;
```

```
In[*]:= dw[awg_] := (1 / 200) * 92^((36 - awg) / 39)
```

```
In[*]:= myKw[kc_, ki_, R_, d_] :=  
ki (2 kc R^2 + (2 R d + d^2) (kc + ki)) / (2 ki R^2 + (2 R d + d^2) (kc + ki))
```

```
In[*]:= myKe[kc_, ki_, kp_, R_, d_, vc_] := Module[{kw, vw}, kw = myKw[kc, ki, R, d];  
vw = vc * ((R + d) / R)^2;  
kp * (kp * (1 - vw) + kw * (1 + vw)) / (kp * (1 + vw) + kw * (1 - vw))]
```

```
In[*]:= MaxFill[awg_] := Module[{R, d},  
R = (1 / 2) * dw[awg];  
d = (28.3357 - 0.250092 * awg - (0.133567 * awg)^2 + (0.0623628 * awg)^3) / (0.0254 * 10^6);  

$$\frac{\pi R^2}{4 (d + R)^2}$$
  
]
```

```
In[*]:= GetKw[awg_, vc_, kc_, ki_, kp_] :=  
Module[{R, d, Rtot, w, Inch, xm, F, G, femmKe, Ke, Thi, Tlo, mesh},  
R = (1 / 2) * dw[awg];  
d = (28.3357 - 0.250092 * awg - (0.133567 * awg)^2 + (0.0623628 * awg)^3) / (0.0254 * 10^6);  
Rtot = R + d;  
w = Sqrt[Pi * R^2 / vc] / 2;  
Inch = 0.0254;  
Thi = 1;  
Tlo = 0;  
mesh = d;  
NewDocument[2];  
HIDrawArc[R, 0, 0, R, 90, 1];  
HIDrawArc[Rtot, 0, 0, Rtot, 90, 1];  
HIDrawRectangle[0, 0, w, w];  
HIAddMaterial["Kc", kc];  
HIAddMaterial["Ki", ki];  
HIAddMaterial["Kp", kp];  
xm = R / 2;  
HIAddBlockLabel[xm, xm];  
HISelectLabel[xm, xm];  
HISetBlockProp["Kc", 0, mesh, 0];
```

```

HIClearSelected[];
xm = (R + d / 2) / Sqrt[2];
HIAddBlockLabel[xm, xm];
HISelectLabel[xm, xm];
HISetBlockProp["Ki", 0, mesh, 0];
HIClearSelected[];
xm = w - d;
HIAddBlockLabel[xm, xm];
HISelectLabel[xm, xm];
HISetBlockProp["Kp", 0, mesh, 0];
HIClearSelected[];
HIAddBoundProp["Thi", 0, Thi];
HISelectSegment[w / 2, w];
HISetSegmentProp["Thi", 0, 1, 0, 0, "<None>"];
HIClearSelected[];
HIAddBoundProp["Tlo", 0, Tlo];
HISelectSegment[R / 2, 0];
HISelectSegment[R + d / 2, 0];
HISelectSegment[w - 10-6, 0];
HISetSegmentProp["Tlo", 0, 1, 0, 0, "<None>"];
HIClearSelected[];
HISaveAs["c:\\temp\\temp.feh"] × HIANalyze[1];
HILoadSolution[];
HOGroupSelectBlock[0];
F = HOBBlockIntegral[3];
G = (Tlo - Thi) / (w * Inch);
femmKe = F[[2]] / G;
Ke = myKe[kc, ki, kp, R, d, vc];
HOClose[];
HIClose[];
{Ke, femmKe}
]

```

In[]:= GetKw[myAWG, myFill, myKc, myKi, myKp]

Out[]:= {2.26095, 2.27424}

In[]:= Table[k, {k, 14, 44, 6}]

Out[]:= {14, 20, 26, 32, 38, 44}

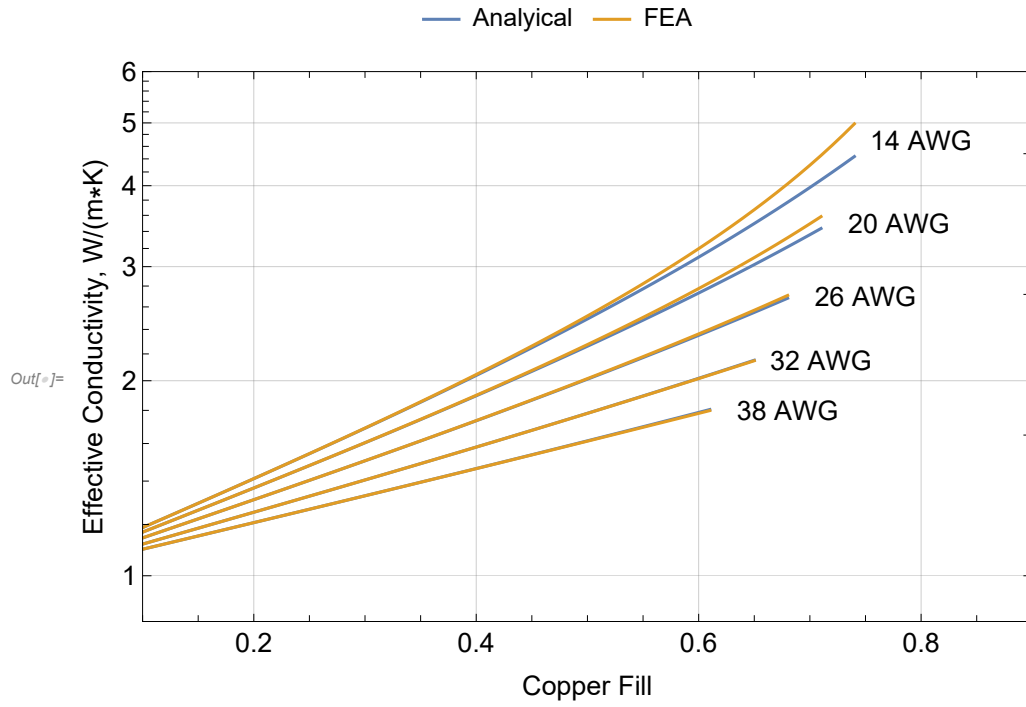
```
In[ ]:= myData = {};  
For[awg = 14, awg ≤ 44, awg += 6,  
  z = {};  
  Print[awg];  
  For[fill = 0.1, fill < MaxFill[awg], fill += 0.01,  
    z = Append[z, Join[{fill}, GetKw[awg, fill, myKc, myKi, myKp]]]  
  ];  
  myData = Append[myData, z]  
]  
14  
20  
26  
32  
38  
44
```

```
In[ ]:= u = {{1, 0}, {0, 1}, {0, 0}};  
v = {{1, 0}, {0, 0}, {0, 1}};
```

```

In[ ]:= Show[ListLogPlot[{myData[[1]].u, myData[[1]].v}, Joined → True,
  Frame → True, GridLines → Automatic, PlotRange → {{0.1, 0.9}, {0.85, 6}},
  ImageSize → 500, BaseStyle → {FontFamily → "Arial", FontSize → 14},
  PlotLegends → Placed[{"Analytical", "FEA"}, Above],
  FrameLabel → {"Copper Fill", "Effective Conductivity, W/(m*K)"},
ListLogPlot[{myData[[2]].u, myData[[2]].v},
  Joined → True, Frame → True, PlotRange → {{0.1, 0.9}, {0.85, 6}},
  ImageSize → 500, BaseStyle → {FontFamily → "Arial", FontSize → 14},
  FrameLabel → {"Copper Fill", "Effective Conductivity, W/(m*K)"},
ListLogPlot[{myData[[3]].u, myData[[3]].v},
  Joined → True, Frame → True, PlotRange → {{0.1, 0.9}, {0.85, 6}},
  ImageSize → 500, BaseStyle → {FontFamily → "Arial", FontSize → 14},
  FrameLabel → {"Copper Fill", "Effective Conductivity, W/(m*K)"},
ListLogPlot[{myData[[4]].u, myData[[4]].v},
  Joined → True, Frame → True, PlotRange → {{0.1, 0.9}, {0.85, 6}},
  ImageSize → 500, BaseStyle → {FontFamily → "Arial", FontSize → 14},
  FrameLabel → {"Copper Fill", "Effective Conductivity, W/(m*K)"},
ListLogPlot[{myData[[5]].u, myData[[5]].v},
  Joined → True, Frame → True, PlotRange → {{0.1, 0.9}, {0.85, 6}},
  ImageSize → 500, BaseStyle → {FontFamily → "Arial", FontSize → 14},
  FrameLabel → {"Copper Fill", "Effective Conductivity, W/(m*K)"},
Graphics[{Text["38 AWG", {0.68, Log[1.8]}],
  Text["32 AWG", {0.71, Log[2.15]}],
  Text["26 AWG", {0.75, Log[2.7]}],
  Text["20 AWG", {0.78, Log[3.5]}],
  Text["14 AWG", {0.8, Log[4.7]}]
}]
]

```



```
In[ ]:= X = 100 * Flatten[Table[Abs[(myData[[k]].{0, -1, 1}) / (myData[[k]].{0, 0, 1})], {k, 1, 5}]]
```

```
Out[ ]:= {0.00173313, 0.00199379, 0.00241975, 0.00282911, 0.00342099, 0.0042402, 0.00521434,
0.00640744, 0.00788296, 0.00978764, 0.0119053, 0.0146028, 0.0179328, 0.0218212,
0.0264311, 0.0318816, 0.0382736, 0.0457178, 0.0544858, 0.0642616, 0.0757823, 0.0888904,
0.104136, 0.121394, 0.14112, 0.163466, 0.188671, 0.216957, 0.249003, 0.284868,
0.324947, 0.369829, 0.419794, 0.475341, 0.536955, 0.605034, 0.680592, 0.76383,
0.855849, 0.957372, 1.06893, 1.1916, 1.32619, 1.47398, 1.6358, 1.8132, 2.00703,
2.21939, 2.45111, 2.70462, 2.98137, 3.2834, 3.61314, 3.97336, 4.36618, 4.79517,
5.26351, 5.77458, 6.33284, 6.94288, 7.6097, 8.33911, 9.13772, 10.0128, 10.9725,
0.00384656, 0.00405743, 0.00420052, 0.00446165, 0.00473846, 0.00521573, 0.00574644,
0.00637761, 0.00723527, 0.00821802, 0.00939703, 0.0108695, 0.0125591, 0.0148458,
0.0172915, 0.0203204, 0.0239092, 0.0280892, 0.0328765, 0.0384826, 0.044902, 0.0523149,
0.0607326, 0.0705376, 0.0814179, 0.0938472, 0.107797, 0.123525, 0.141287, 0.161025,
0.183018, 0.207672, 0.234961, 0.265164, 0.298677, 0.33565, 0.376565, 0.421371,
0.470904, 0.525137, 0.584639, 0.649858, 0.721093, 0.798842, 0.883677, 0.976221,
1.07682, 1.18631, 1.30559, 1.43298, 1.57316, 1.72536, 1.88916, 2.06772, 2.26109,
2.47019, 2.6964, 2.94092, 3.20524, 3.49101, 3.79899, 4.13175, 0.00298602, 0.00320702,
0.00329874, 0.00334426, 0.00354684, 0.00377807, 0.0039794, 0.00425166, 0.0045997,
0.00497621, 0.0054977, 0.00604797, 0.00666203, 0.00750143, 0.00842825, 0.00951126,
0.0108265, 0.01237, 0.0139619, 0.0159444, 0.0181847, 0.0208389, 0.0237306, 0.027059,
0.0307663, 0.034965, 0.0397802, 0.0452486, 0.0513156, 0.057979, 0.0654078, 0.0736607,
0.0827096, 0.0928198, 0.103999, 0.116245, 0.129719, 0.144432, 0.160555, 0.178181,
0.197427, 0.218502, 0.241365, 0.266188, 0.293042, 0.322387, 0.353514, 0.387483,
0.424203, 0.464034, 0.506614, 0.55277, 0.602454, 0.655236, 0.7125, 0.772752, 0.838543,
0.909023, 0.984336, 0.00260859, 0.00280602, 0.00292501, 0.00296572, 0.00310625,
0.00315763, 0.00331798, 0.003388, 0.00349128, 0.00350421, 0.00357633, 0.00357664,
0.00350589, 0.00353085, 0.00354779, 0.00343121, 0.00332912, 0.00317383, 0.00299773,
0.00273602, 0.00238061, 0.00198711, 0.00155858, 0.00102021, 0.000249695, 0.000396958,
0.00125841, 0.00214481, 0.00314398, 0.0044558, 0.00581311, 0.00730953, 0.00904272,
0.0109455, 0.0130011, 0.0155098, 0.0182205, 0.0213393, 0.0247113, 0.0279994, 0.0319679,
0.0362279, 0.0411639, 0.0462676, 0.0525725, 0.0591858, 0.0662008, 0.0741077, 0.0830237,
0.0922026, 0.102268, 0.112929, 0.124795, 0.137997, 0.15228, 0.16972, 0.00289929,
0.00305862, 0.00319699, 0.00324288, 0.00326789, 0.00346545, 0.00361867, 0.00370547,
0.00364534, 0.00376002, 0.0034445, 0.00334106, 0.00296002, 0.00262942, 0.00219882,
0.00165029, 0.000979415, 0.0000189117, 0.000943303, 0.00212863, 0.00350825,
0.00519054, 0.00724438, 0.00926185, 0.0118531, 0.0146755, 0.0179432, 0.0214711,
0.0254154, 0.0298985, 0.0348168, 0.0403139, 0.04632, 0.0531976, 0.0605882, 0.0686174,
0.0775454, 0.0873952, 0.0983525, 0.110219, 0.1233, 0.137888, 0.153186, 0.170082,
0.188489, 0.208642, 0.230235, 0.253968, 0.279985, 0.307838, 0.338237, 0.371544}
```

```
In[ ]:= Max[X]
```

```
Out[ ]:= 10.9725
```

```
In[ ]:= Sqrt[X.X / Length[X]]
```

```
Out[ ]:= 1.67351
```

```
In[ ]:= Pi / 4.
```

```
Out[ ]:= 0.785398
```

```
In[ ]:= Pi / (2 Sqrt[3.])
```

```
Out[ ]:= 0.9069
```