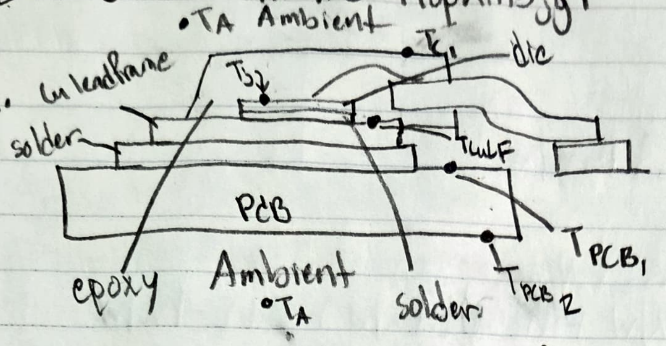
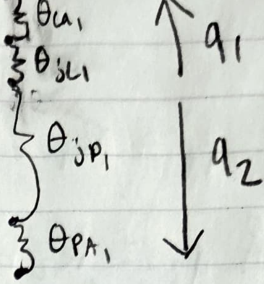
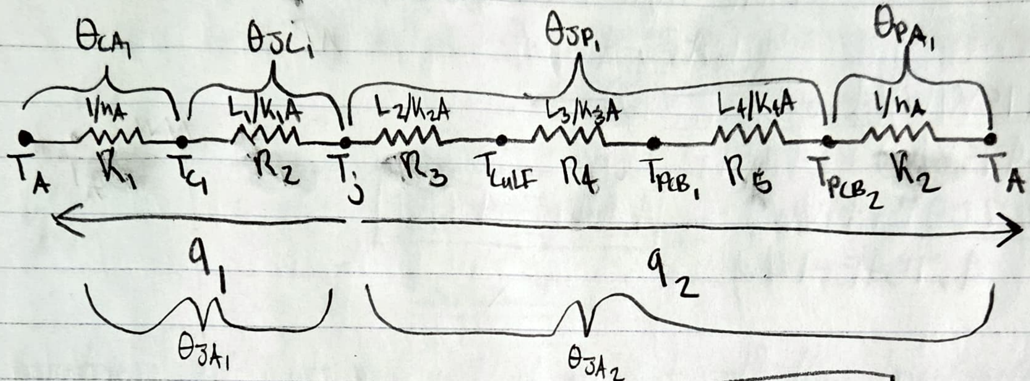
ECE 5224 HW #3 Hopkins, jgl

1. a.

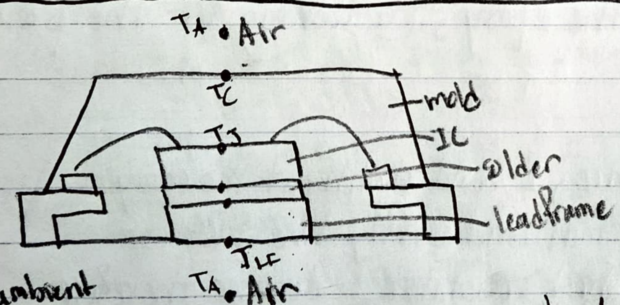






b. $$\theta_{JA} = \frac{(\theta_{CA_1}+\theta_{JL_1})(\theta_{JP_1}+\theta_{PA_1})}{(\theta_{CA_1}+\theta_{JL_1})+(\theta_{JP_1}+\theta_{PA_1})} = \boxed{\frac{\theta_{JA_1}\theta_{JA_2}}{\theta_{JA_1}+\theta_{JA_2}}}$$

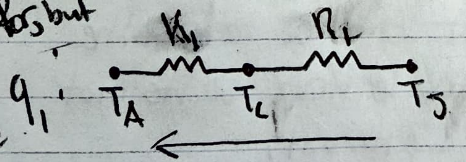
2.



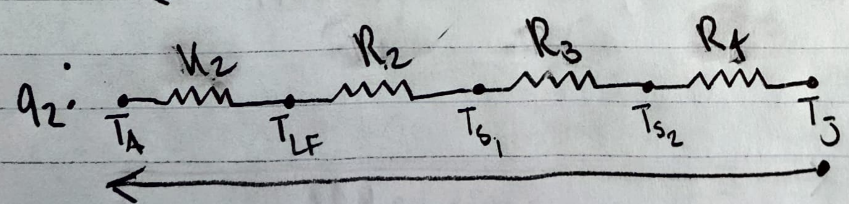
$\left.\begin{matrix}A_{die} \text{ and } A_{LF} \\ \text{and } A_s\end{matrix}\right\} = 4\,mm \cdot 4\,mm = 16\,mm^2 = \underline{.016\,m^2}$

$L_{IC} = 3\,mm - .5\,mm - .5\,mm - .1\,mm = 1.9\,mm = \underline{.0019\,m}$

*I know the ambient was not asked for, but i drew it anyways, I did not use it in my calculations



$$R_1 = L_{IC}/kA = \frac{.0019\,m}{(0.25\,W/mK)(.016\,m^2)} = \underline{.475\,K/W}$$



$$R_4 = \frac{.0005\,m}{(120\,W/mK)(.016\,m^2)} = \underline{2.6E-4\,K}$$

$$R_2 = \frac{.0005\,m}{(390\,W/mK)(.016\,m^2)} = \underline{8.01E-5\,K/W} \qquad R_3 = \frac{.0001\,m}{(50\,W/mK)(.016\,m^2)} = \underline{1.25E-4\,K/W}$$

2 Continued:

Thermal Res of $q_1 = R_1 = .475K/W$

Thermal Res of $q_2 = R_2 + R_3 + R_4$

$= 8.01E\text{-}5K/W + 1.25E\text{-}4K/W + 2.6E\text{-}4K/W$

$= 4.651E\text{-}4K/W$

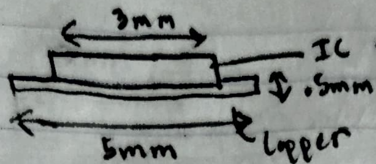
$$\theta_{JC} = \frac{(.475K/W)(4.651E\text{-}4\ K/W)}{(.475K/W) + (4.651E\text{-}4K/W}$$

$$= \frac{2.209E\text{-}4K/W}{4.754E\text{-}1K/W} = \boxed{4.647E\text{-}4\ K/W}$$

a. Most of the heat will flow to the bottom due to the resistance in the leadframe being the lowest and the resistance in the epoxy being significantly higher causing all the heat to push downward. Also since heat isn't spreading in the epoxy, it's looking for the path of least resistance to escape.

b. If I wanted to lower the resistance, I would switch out the epoxy with something w/ a higher thermal conductivity like FR4 or Aluminum. This would cause the highest resistance to decrease therefore decreasing everything. My second solution would be to put the epoxy or better material at the bottom of the leadframe so its not just exposed to air and giving the heat a path out.

3. a-1:



$w_{die} = 3mm \quad A_{die} = 3mm \cdot 3mm = 9mm^2$

$L_{BP} = 0.5mm \quad w_{BP} = 5mm$

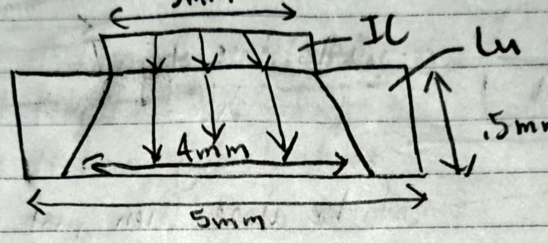
$w_{spread} = (2(.5)+3) = 4mm \leq 5mm$ ✓

$A_{spread} = (2L_{BP} + w_{die})(2L_{BP} + w_{die}) = (2(.5)+3)^2 = 16mm^2$

$A_{eff} = (A_{spread} + A_{die})/2 = (16+9)/2 = 12.5mm^2$

$R_{th,BP} = L_{BP}/(K_{BP}A_{eff}) = .0005m/(390W/mK \cdot .0125m^2)$

$= \underline{1.026E\text{-}4K/W}$



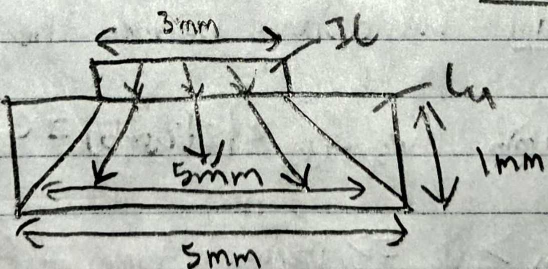
a-2: $w_{die} = 3mm$, $A_{die} = 9mm^2$, $L_{BP} = 1mm$, $W_{BP} = 5mm$

$w_{spread} = (2(1)+3) = 5mm \leq 5mm$ ✓

$A_{spread} = 5 \cdot 5 = 25mm^2$

$A_{eff} = (25+9)/2 = 34/2 = 17mm^2$

$R_{th,BP} = .001m/(390W/mK \cdot .017m^2) = \underline{1.51E\text{-}4K/W}$



a-3: $w_{die} = 3mm$, $A_{die} = 9mm^2$, $L_{BP} = 3mm$, $W_{BP} = 5mm$

$w_{spread} = (2(3)+3) = 9mm \geq 5mm$ X

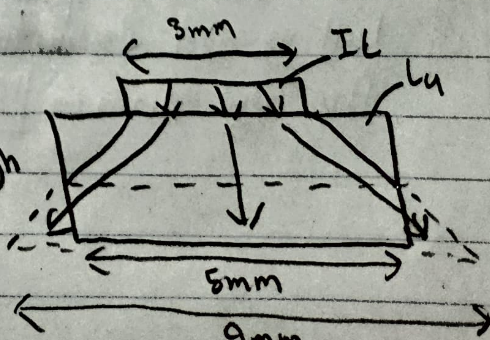
$A_{spread} = 9 \cdot 9 = 81mm^2$

$A_{eff} = (81+9)/2 = 45mm^2$

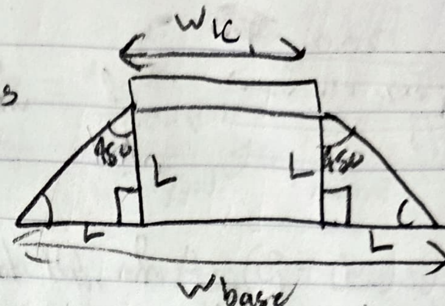
$R_{th,BP} = .003m/(390W/mK \cdot .045m)$

$= \underline{1.71E\text{-}4K/W}$

not enough room!



3. b. The optimal thickness is one that has the heat spread match the base width while adequately cooling, as seen in 3a w/ the 1 mm thickness.



Based on the picture on the right, we can assume the w_{base} is just the w_{IC} along w/ the spreading on each side which can be represented as $2L\tan(\theta)$. θ in this case is 45°. Therefore:

$$w_{base} = w_{IC} + 2L\tan\theta \Rightarrow w_{base} - w_{IC} = 2L\tan\theta$$

$$\Rightarrow \frac{w_{base} - w_{IC}}{2\tan(45°)} = L \Rightarrow \boxed{\frac{w_{base} - w_{IC}}{2} = L}$$

where L in this case should be 1mm as per 3a.

4. a. $w_{die_1} = 2mm$, $A_{die_1} = 4mm^2$, $L_{BP} = 2mm$

$A_{spread} = (2(2)+2)^2 = (6)^2 = 36mm^2$

$\Rightarrow$ meaning its spread is ~6mm

$6mm - 2mm = 4mm/2 = 2mm$ spread on one side

$w_{die_2} = 5mm$, $A_{die_2} = 25mm^2$, $L_{BP} = 2mm$

$A_{spread} = (2(2)+5)^2 = 81mm^2$

$\Rightarrow$ meaning its spread is ~9mm

$9mm - 5mm = 4/2 = 2mm$ spread on one side

$\Rightarrow 2mm + 2mm = \underline{4mm} =$ min distance between the two

b. $w_{spread_1} = (2(2)+2) = 6mm$ $\quad w_{spread_2} = (2(2)+5) = 9mm$

$w_{spread,total} = 6+9 = 15mm > w_{BP} \Rightarrow 15mm + 4mm = \boxed{19mm}$

$\Rightarrow$ The total w_{spread} is 15mm which is the smallest the w_{BP} can be but we must also account for the die distance from part a, so 15+4 gets the new minimum $\boxed{19mm}$

4. c. One negative consequence is the increase in size of the base plate therefore increasing weight and cost.
Another negative effect would be a increase in interconnect lengths which could lead to longer transmission delays or other unneeded consequences.

6. a. $K_{xy} = K_m t_m + k_i (1 - t_m)$

total insulator thickness $= 215\,\mu m \cdot 5 = 1075\,\mu m$

$t_m = \dfrac{t_{cu}}{1075 + t_{cu}}$ $\quad 60\,W/mK = (390\,W/mK)\left(\dfrac{t_{cu}}{1075 + t_{cu}}\right) + 0.25\,W/mK\left(1 - \dfrac{t_{cu}}{1075 + t_{cu}}\right)$

$\Rightarrow 60 = \dfrac{390 t_{cu}}{1075 + t_{cu}} + .25 - \dfrac{.25 t_{cu}}{1075 + t_{cu}} \Rightarrow 60 = \dfrac{389.75 t_{cu}}{1075 + t_{cu}} + .25$

$\Rightarrow 59.75 = \dfrac{389.75 t_{cu}}{1075 + t_{cu}} \Rightarrow 59.75(1075 + t_{cu}) = 389.75 t_{cu}$

$\Rightarrow 0.06423 + 59.75 t_{cu} = 389.75 t_{cu} \Rightarrow \dfrac{0.06423}{330} = \dfrac{330 t_{cu}}{330}$

$\Rightarrow 194.63\,\mu m = t_{cu} \Rightarrow \dfrac{194.63}{4} = 48.66\,\mu m =$ Cu thickness

Verify: $K_{xy} = (390\,W/mK)\dfrac{(48.66\,\mu m \cdot 4)}{(215\,\mu m)(5) + (48.66\,\mu m \cdot 4)} + (.25\,W/mK)\left(1 - \dfrac{(48.66\,\mu m \cdot 4)}{(215)(5) + (48.66 \cdot 4)}\right)$

$\Rightarrow 390(0.153303) + .25(1 - 0.153303) = 59.99 \approx 60 \checkmark$

$\Rightarrow$ Cu thickness is $48.66\,\mu m$

HW3_Part5

March 7, 2025

Problem 5

Equations Used:

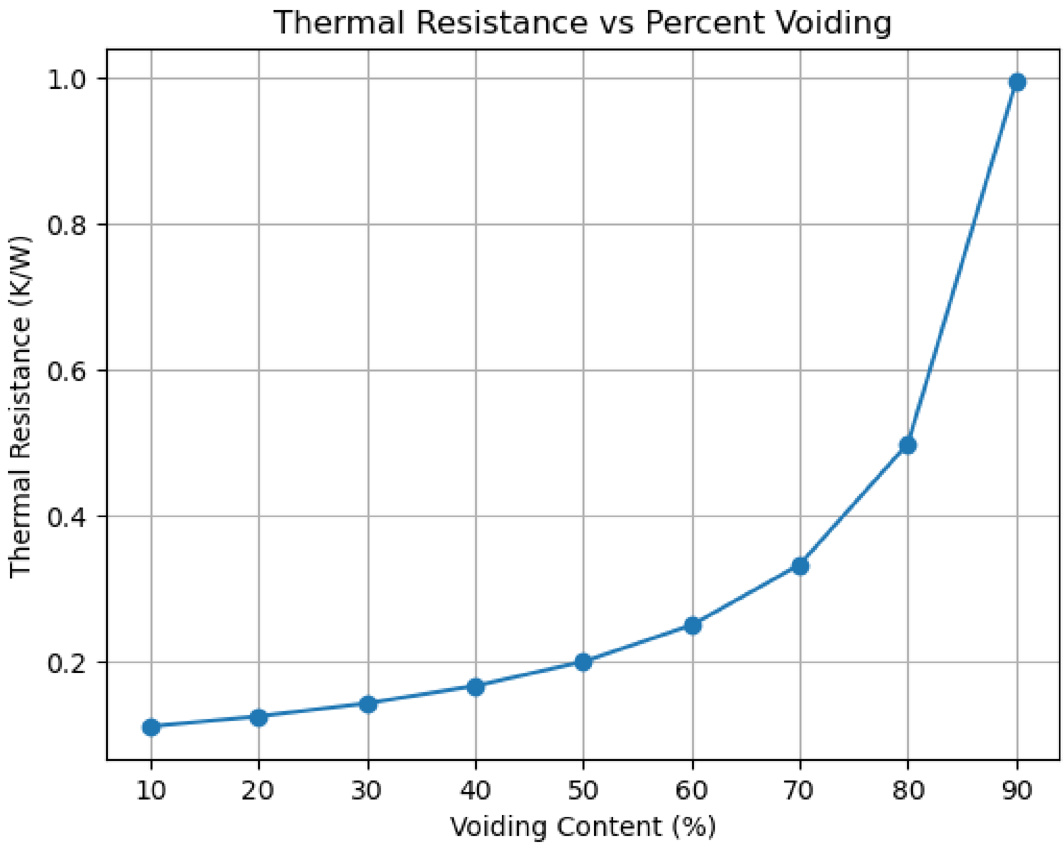
$R_s = \frac{\delta}{k_s((1-\%)*A)}$
$R_v = \frac{\delta}{k_v(\%*A)}$
$R_{int} = (\frac{1}{R_s} + \frac{1}{R_v})^{-1}$

[30]:
```
# Import libraries
import numpy as np
import matplotlib.pyplot as plt
```

[31]:
```
# Define Constants in terms of meters
percentVoids = np.array([0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9])
A = 20E-6 # This was converted from mm^2 to m^2
delta = 100E-6
k_1 = 50
k_f = 0.024

# Calculate resistances
R_1 = []
R_v = []
for x in range(len(percentVoids)):
    R_1.append(delta / (k_1 * ((1 - percentVoids[x]) * A)))
    R_v.append(delta / (k_f * (percentVoids[x] * A)))

R_int = []
for x in range(len(R_1)):
    R_int.append(((1/ (R_1[x])) + (1/R_v[x])) ** -1)
```

[32]:
```
# Plot
fig, ax = plt.subplots()

ax.plot(percentVoids*100, R_int, marker='o', linestyle='-')

ax.set(xlabel='Voiding Content (%)', ylabel='Thermal Resistance (K/W)',
       title="Thermal Resistance vs Percent Voiding")
```

```
ax.grid()
```


Thermal Resistance vs Percent Voiding
Thermal Resistance (K/W)
1.0
0.8
0.6
0.4
0.2
10
20
30
40
50
60
70
80
90
Voiding Content (%)