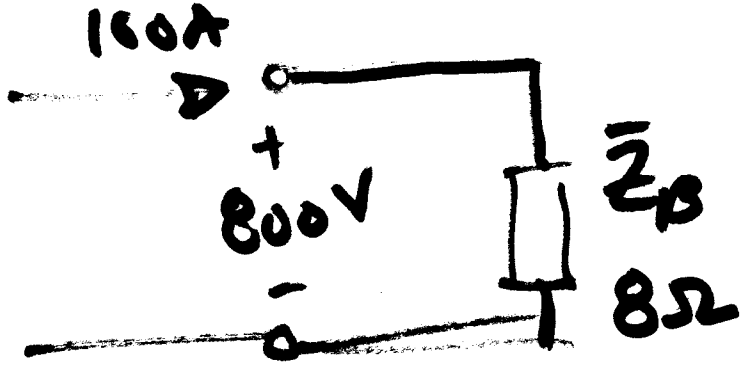
EE 5223 - Lecture 11 Wed Feb 1, 2023

Ongoing List of Topics:

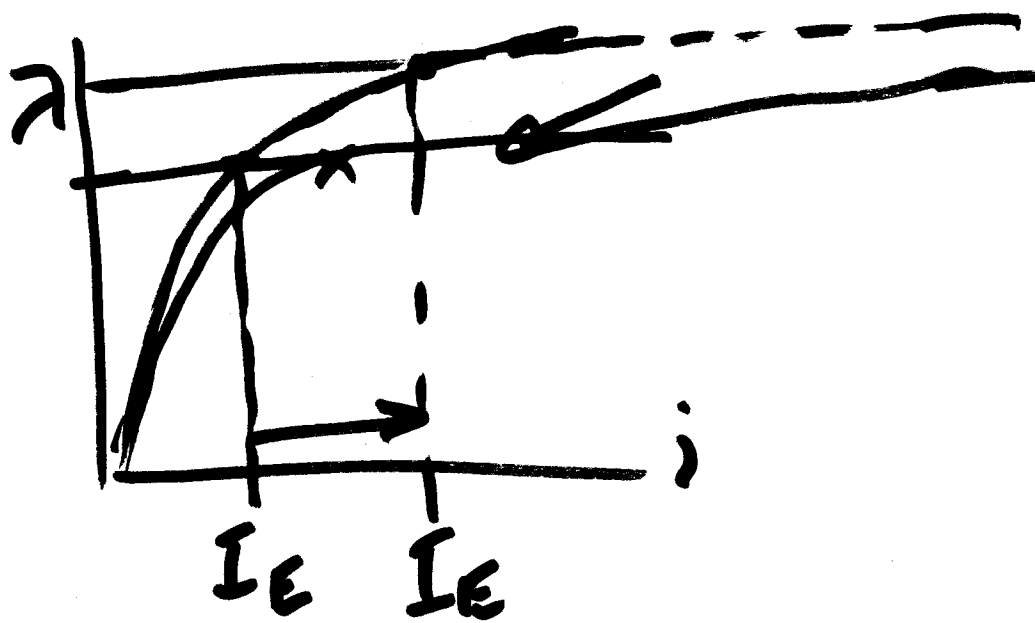
- URL: http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm
- Labs - EE5224 no labs during WC week.
- Term Project - guidance after WC break.
- Software - Aspen V15.6. remote.mtu.edu : confirm operation.
- Team pre-req homework 3B - due Feb 21st. Short circuit calcs!
- CT ratios, MR (multi-ratio) CTs - look at IEEE stds.
  - X/R ratio, dc offset, decay of dc offset
- Calculation of measurement error for given ratio & burden.
- Print out MOCT & CCVT handout from web page
- MOCTs - Magneto-Optic Current Transformers
  - Faraday effect, “faraday rotators,” Verdet constant
  - shift of polarization angle due to strength of H-field
  - Design kept to low near-linear range
- Linear Couplers, Rogowski Coils
- CCVTs
- Voltage & Current relationships during faults, §3.5-3.10
  - relative angles and magnitudes of all Vs & Is during fault

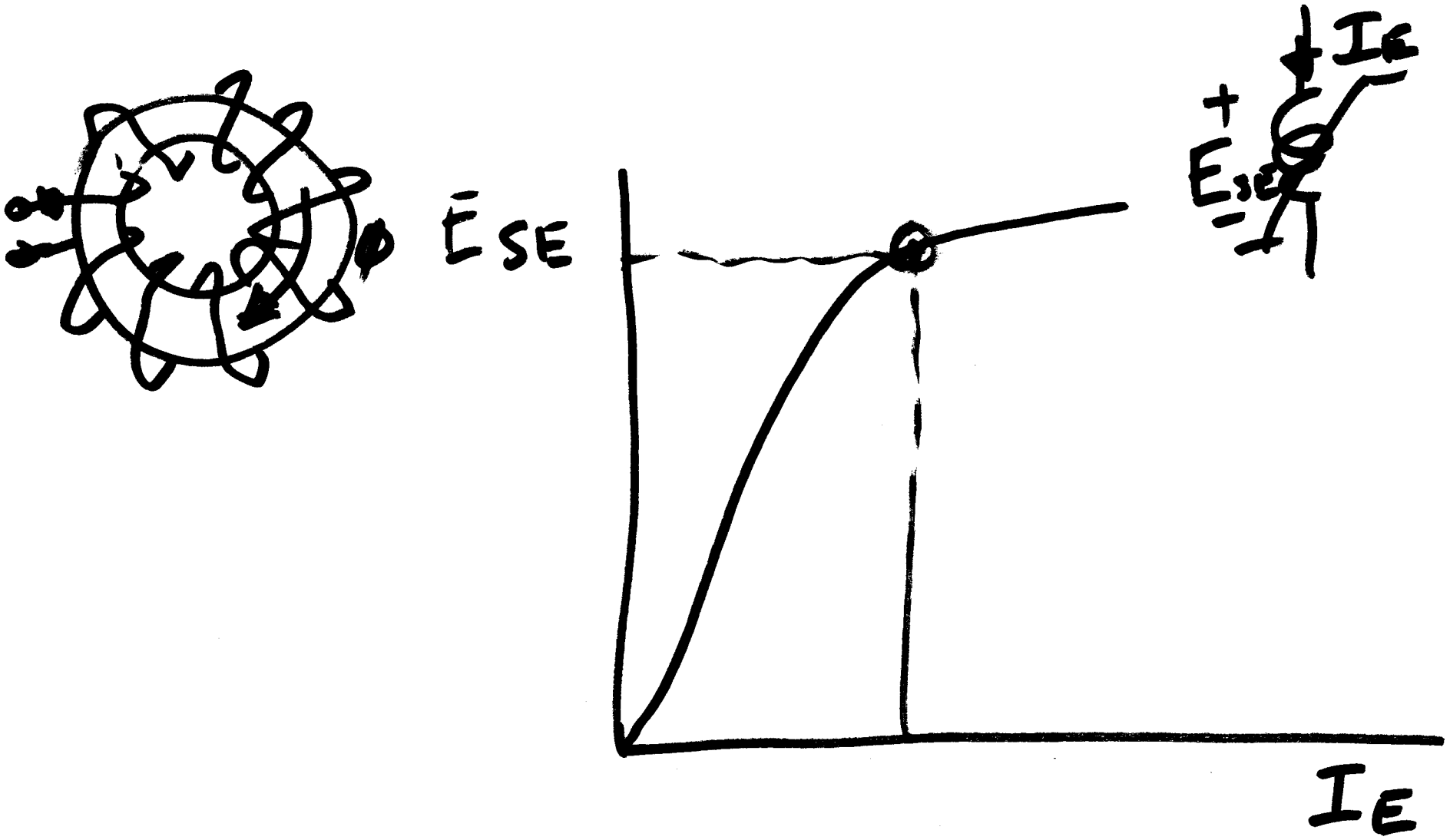


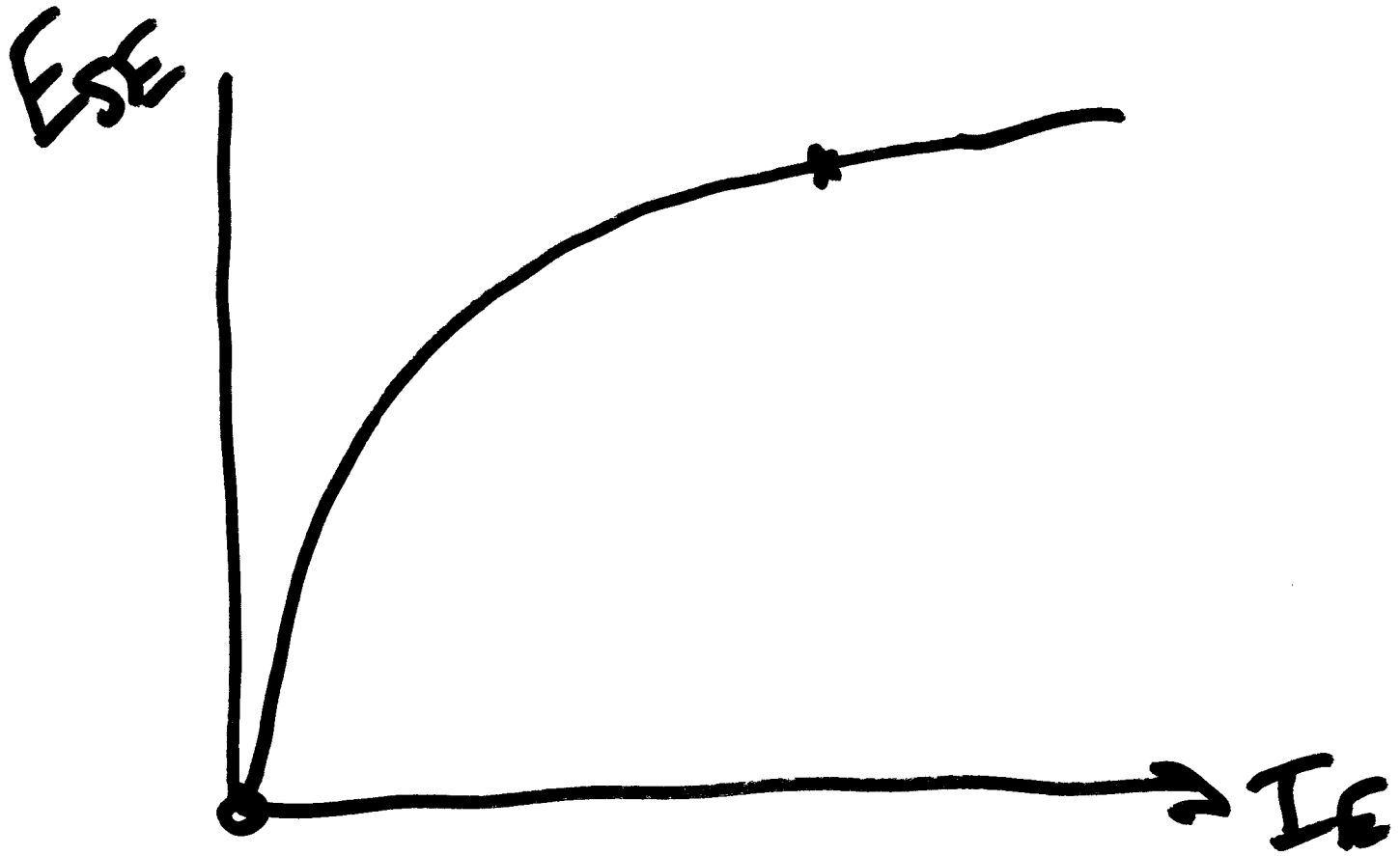
$|\bar{Z}_B| < 8\Omega \Rightarrow$ Error < 10%

$|\bar{Z}_B| > 8\Omega \Rightarrow$ Error > 10%

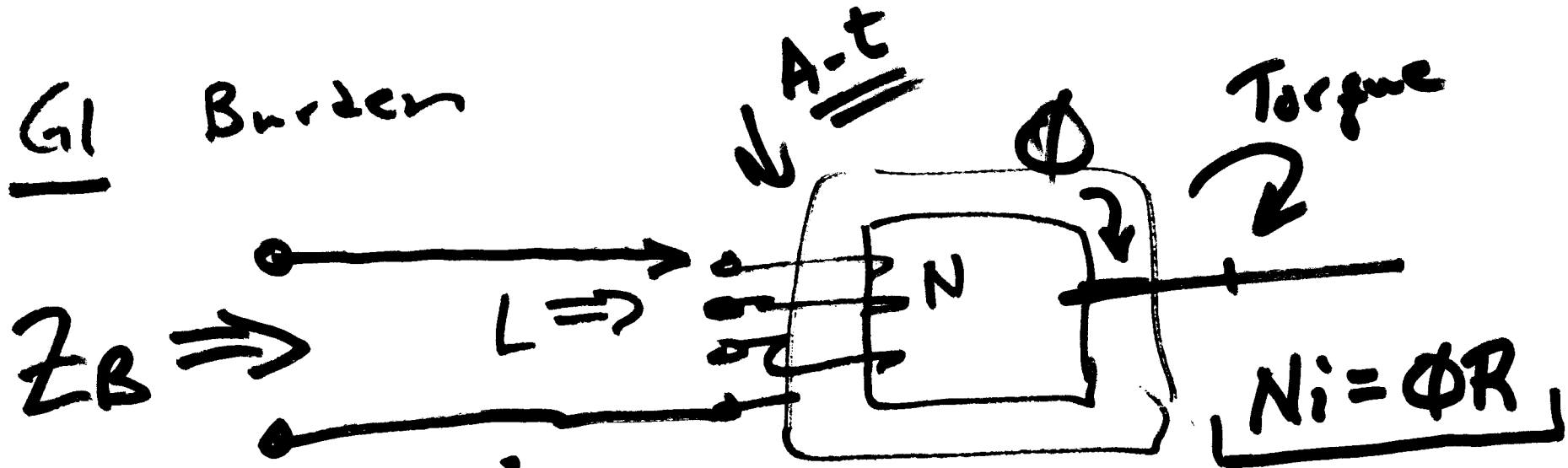
$$e = \frac{d\lambda}{dt} = N\frac{d\phi}{dt}$$




$\bar{E}_{SE}$
I_E
+
E_{SE}
I_E


ESE
I_E

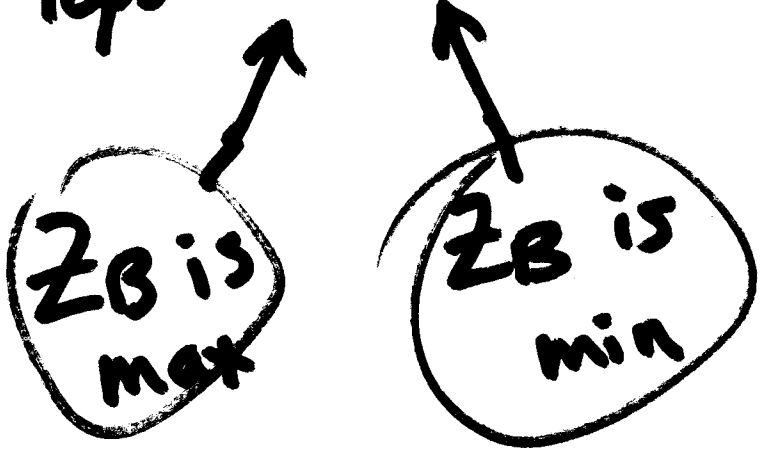
G1 Burden



$$L = \frac{N^2}{R}$$

$\Rightarrow$ Low tap settings have highest Z_{Burden}!

(51) Taps: 4 - 12 A



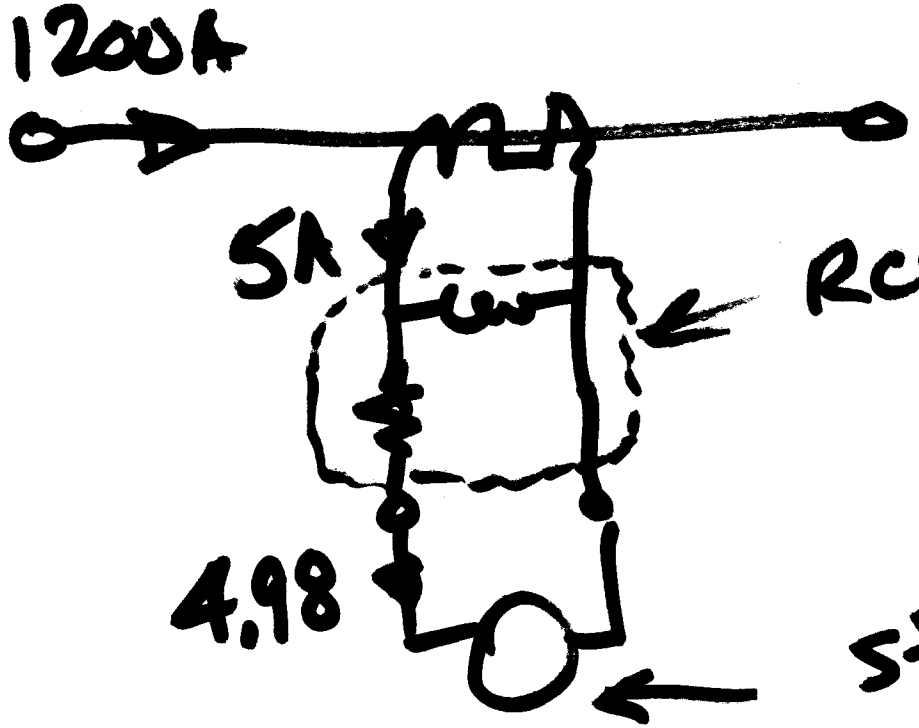
G2 & G3 relays: much smaller Z_B

But: Look at I.L.!

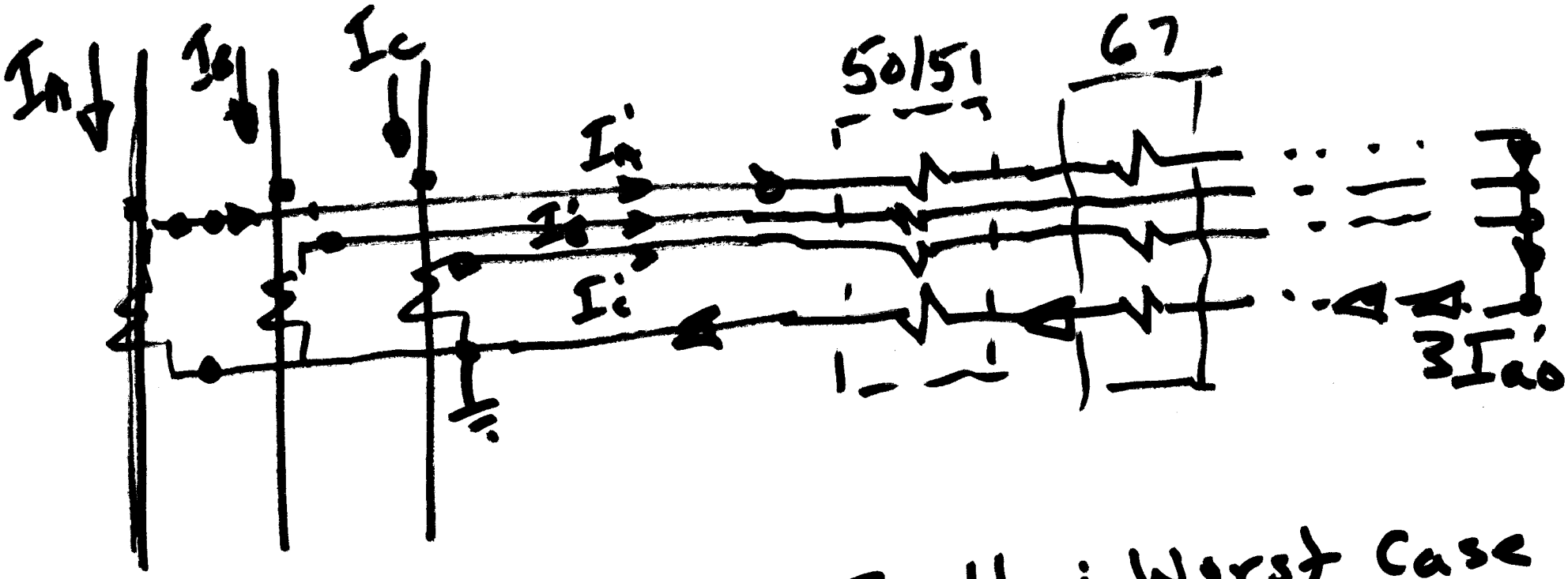
$$\left(\frac{1200}{5}\right) \times RCF =$$

RCF ↑ 1.004

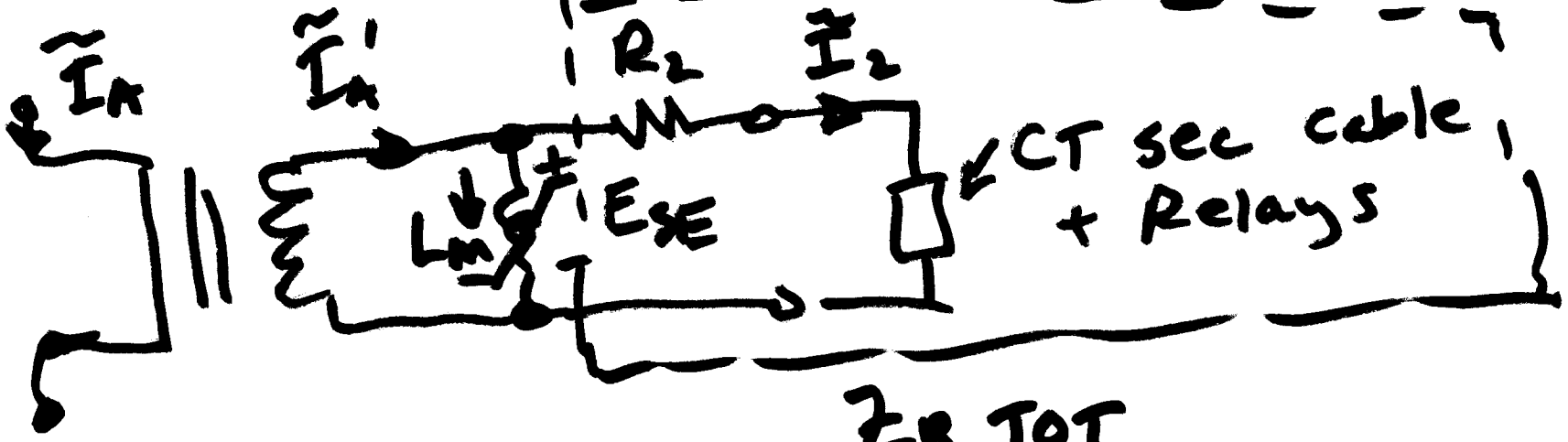
$$240 \times 1.004 = \underline{240.96}$$



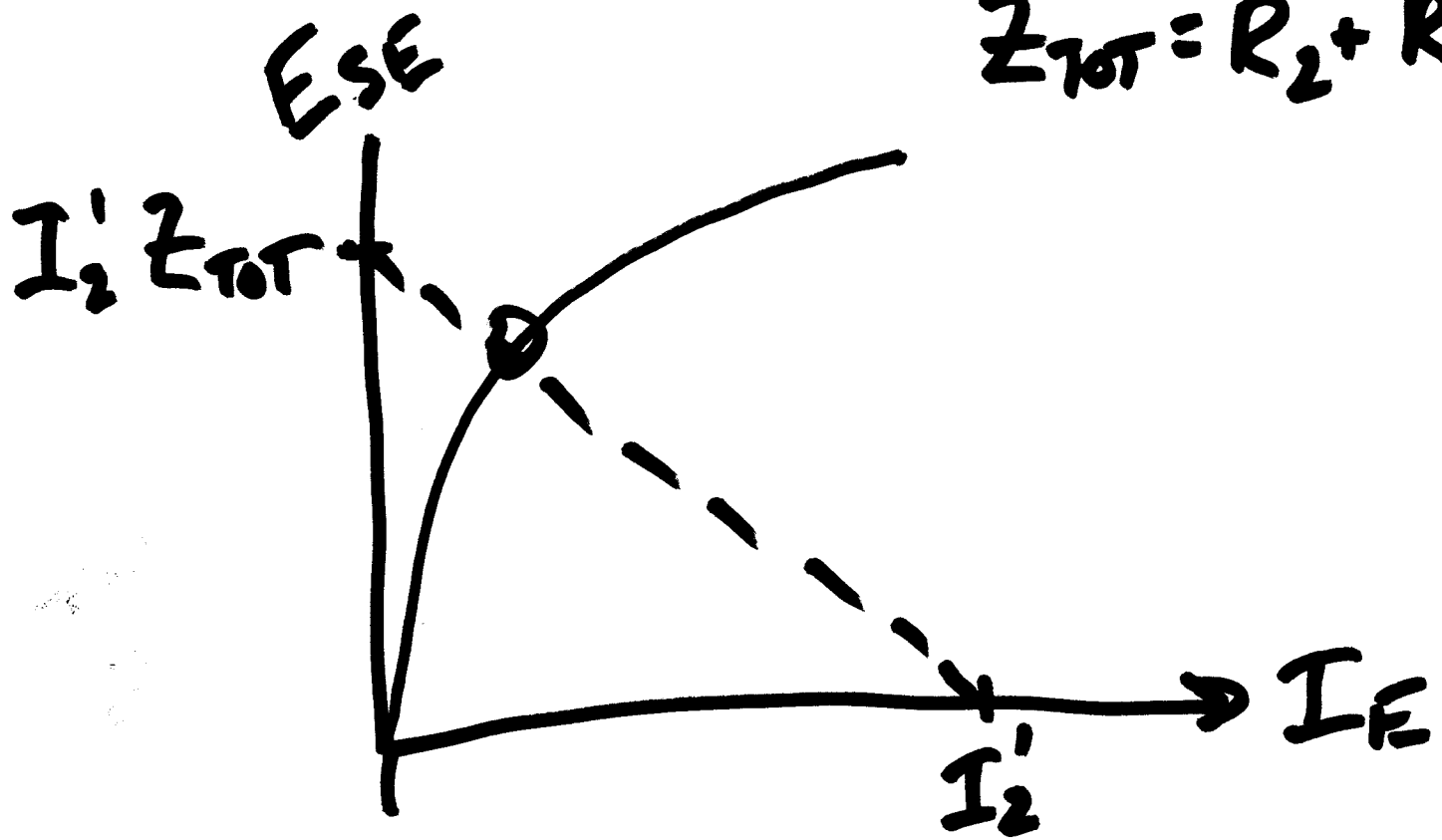
B-8 Burden!

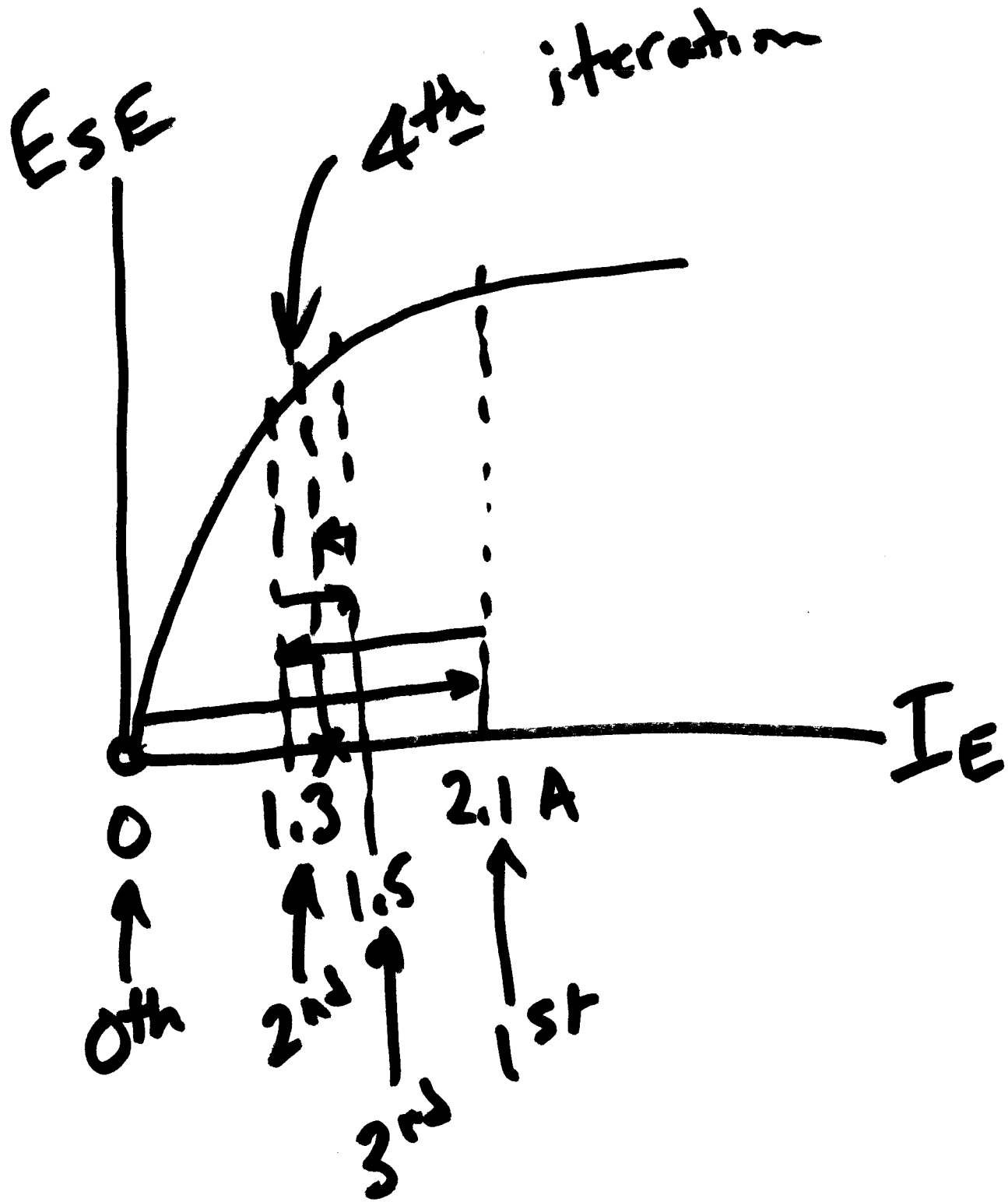


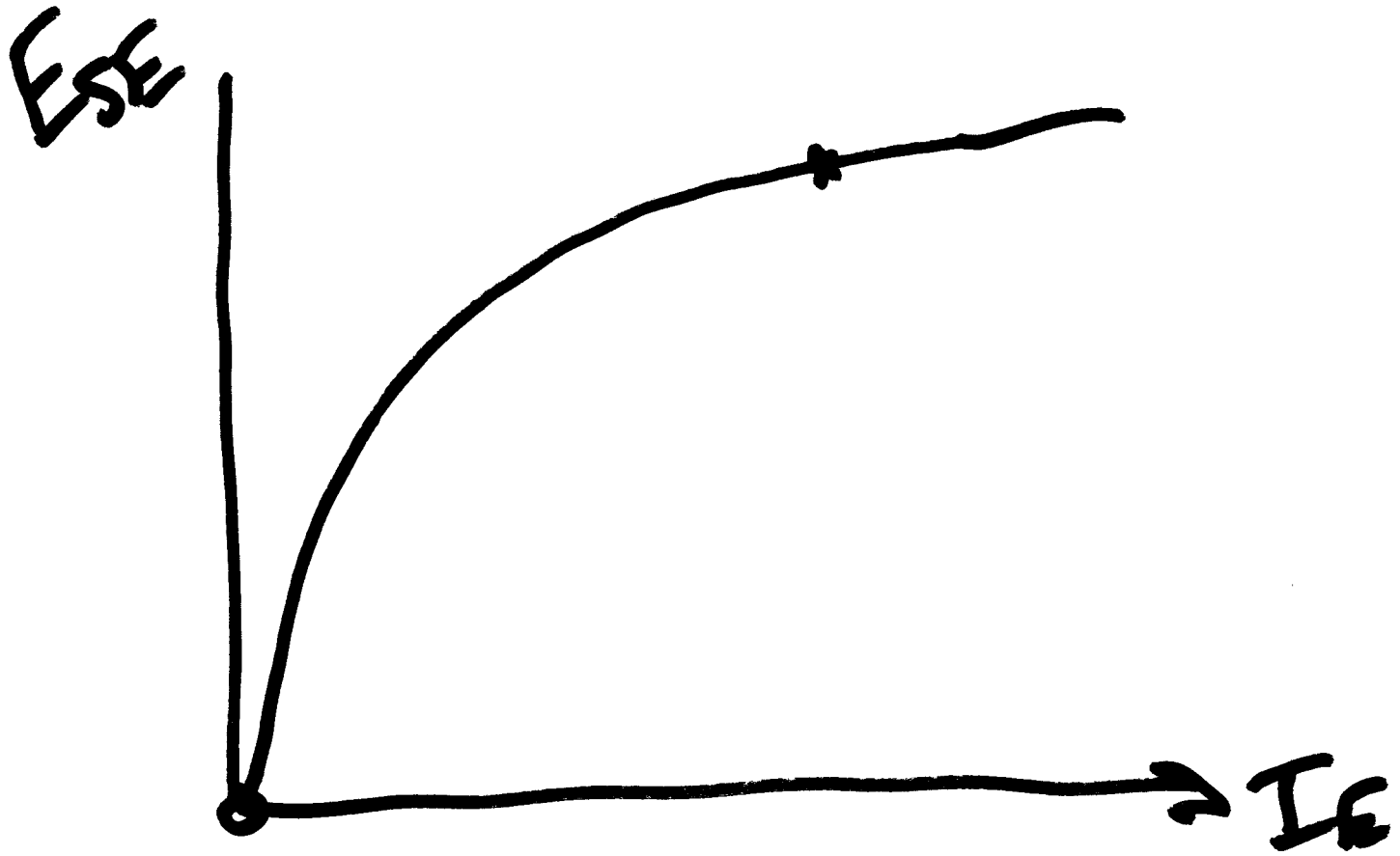
ϕA-G Fault : Worst Case Burden.



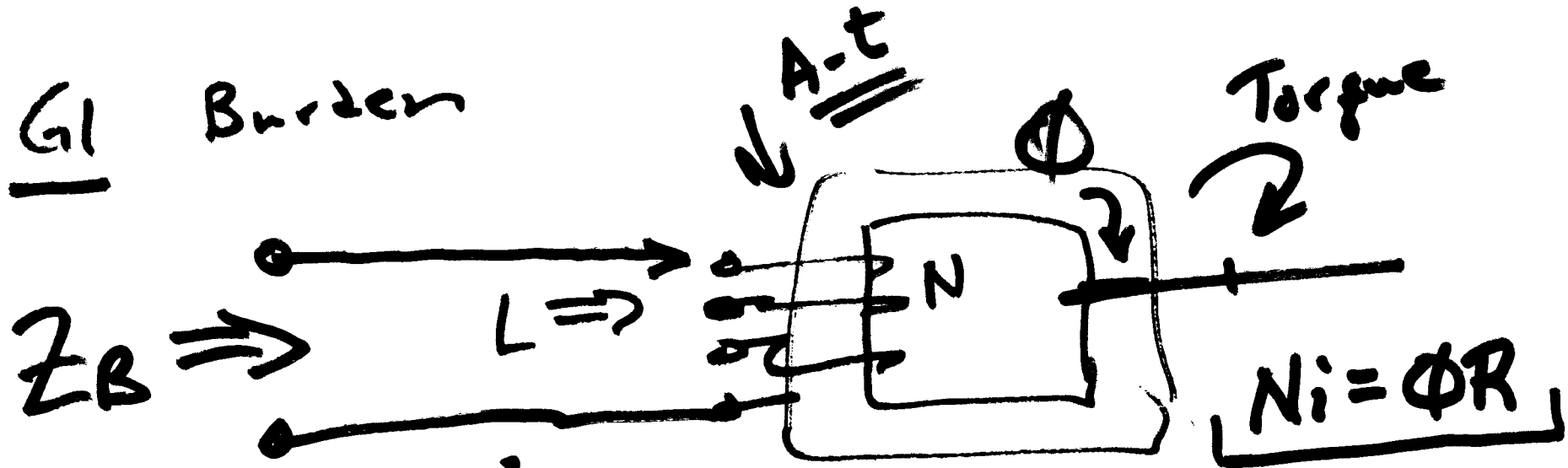
$Z_{TOT} = R_2 + R_{cond} + R_{Relays}$




ESE
4th iteration
IE
0
1.3
2.1 A
1.5
0th
2nd
3rd
1st


ESE
I_E

G1 Burden



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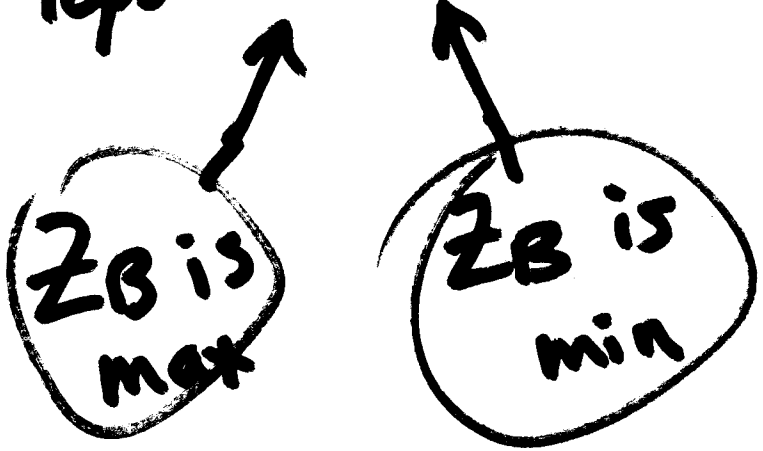

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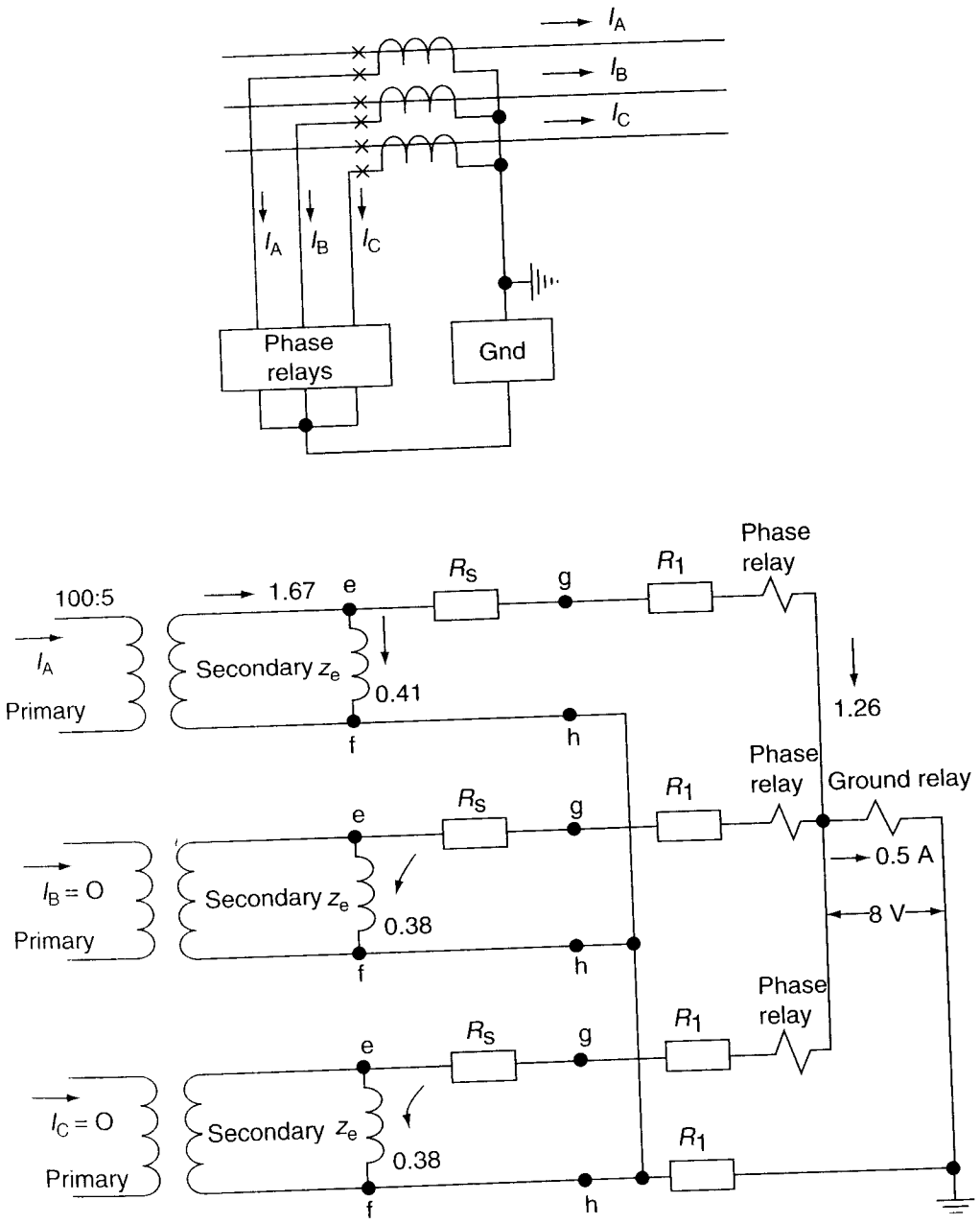
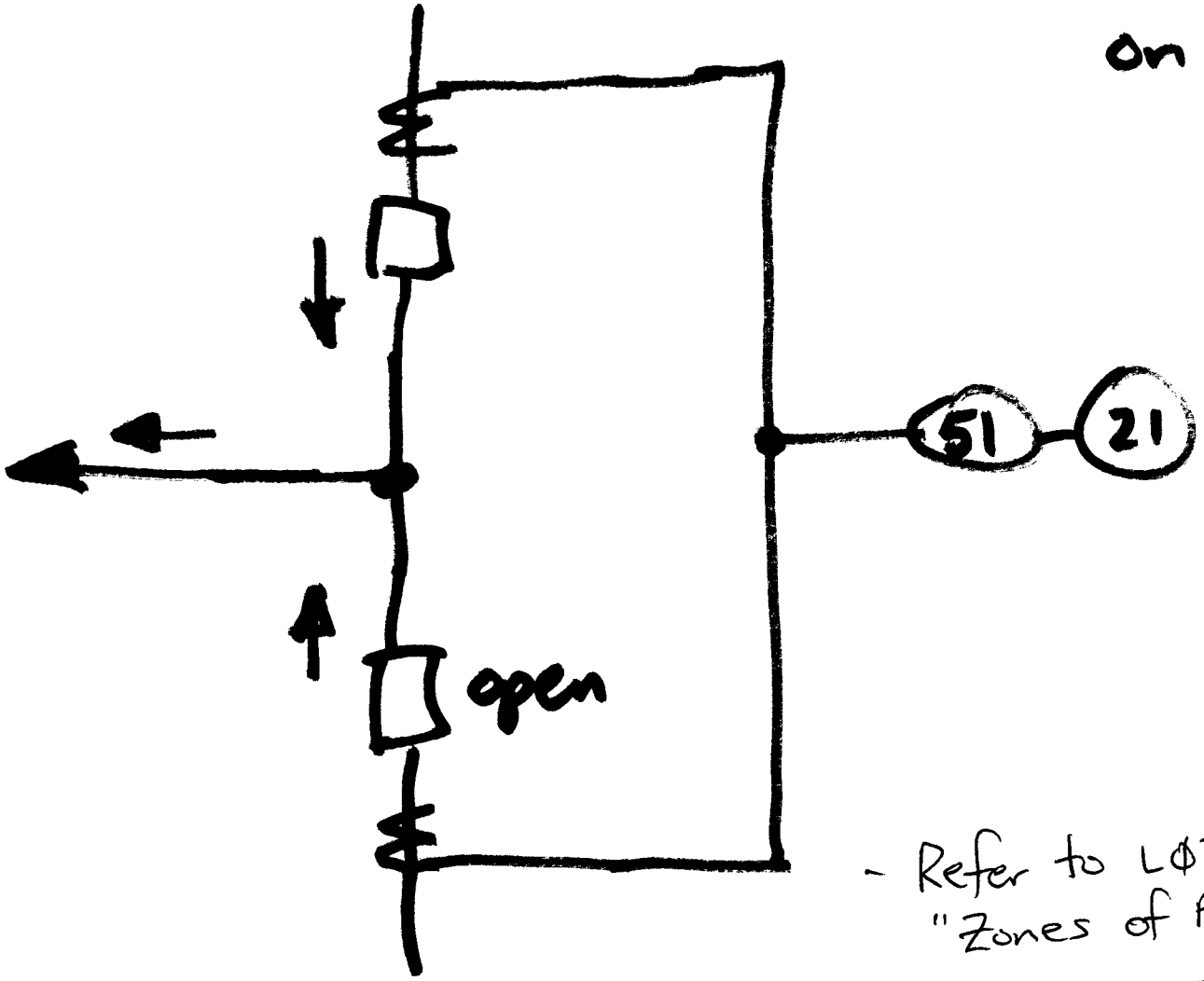


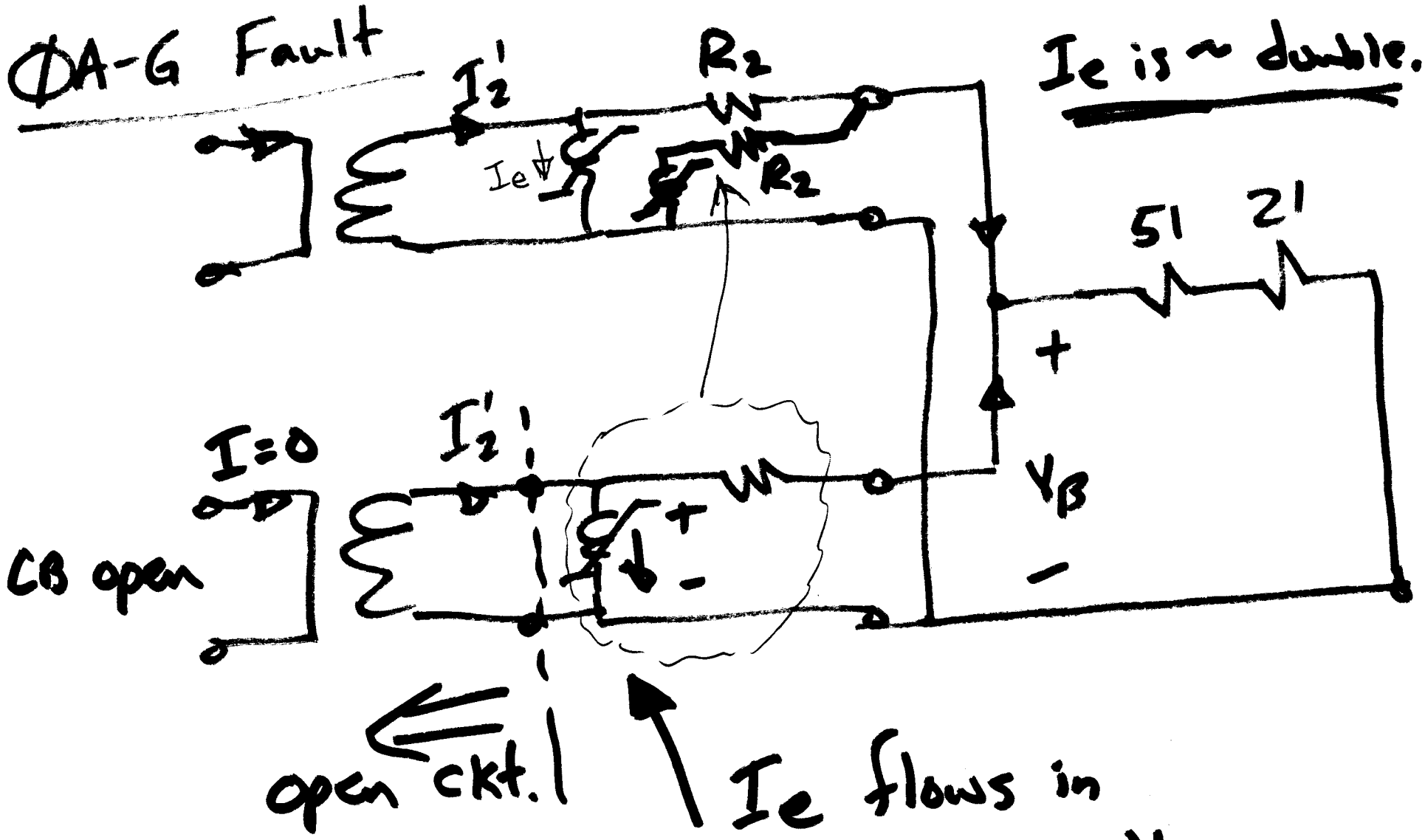
FIGURE 5.12 Phase-and-ground relays for the protection of a circuit and the current distribution for a phase-and-ground fault.

16 Ω on its 0.5 A tap 68° lag. To pass pickup current through the ground relay, $0.5 \times 16 = 18$ V is required. This voltage, less the small drop through the phase relay circuit, will appear across the phase B and C current transformer secondaries to excite them. The voltage V_{ef} depends on the current that, in turn, depends on the voltage, so the exact determination is a "cut-and-try" process. At the first try, assume that $V_{ef} = 8$ V. From the CT characteristic

L-G fault on Phase A.



- Refer to LØ3 notes on "Zones of Protection"
- Refer to CT notes posted on Week 1 (webpage).

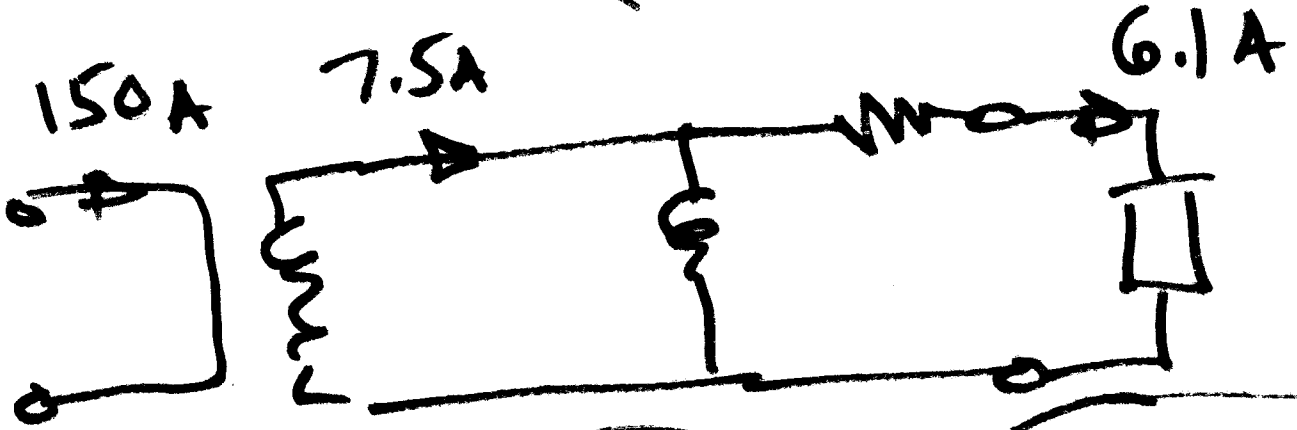

ØA-G Fault
Ie is ~ double.
I_2'
R_2
W
Ie
R_2
5'
2'
+
V_β
−
I=0
I_2'
W
+
−
CB open
open ckt.
Ie flows in CT even though its Pri current is Zero!

RCF:

$$\text{Ratio}_{\text{ACTUAL}} = (\text{Ideal Ratio}) \times \text{RCF}$$

From previous example:

$$\frac{150}{6.1} = \left(\frac{100}{5}\right) \times \text{RCF} \Rightarrow \underline{\text{RCF} = 1.23}$$



Typically, RCF > 1

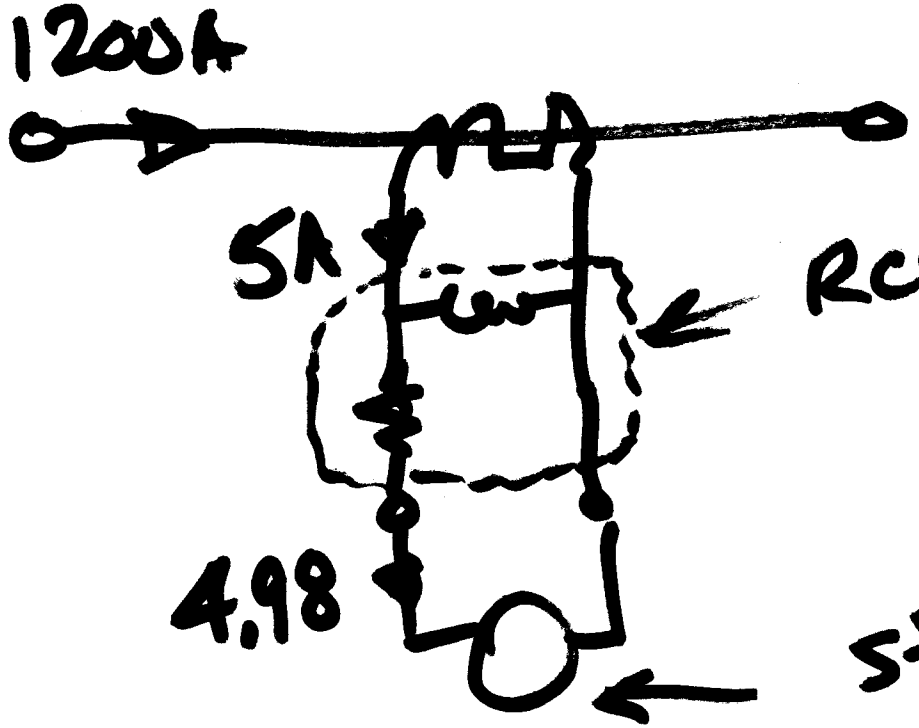
RCF: Keep ≤ 1.1

(10C800)

$$\left(\frac{1200}{5}\right) \times RCF =$$

RCF ↑ 1.004

$$240 \times 1.004 = \underline{240.96}$$



B-8 Burden!