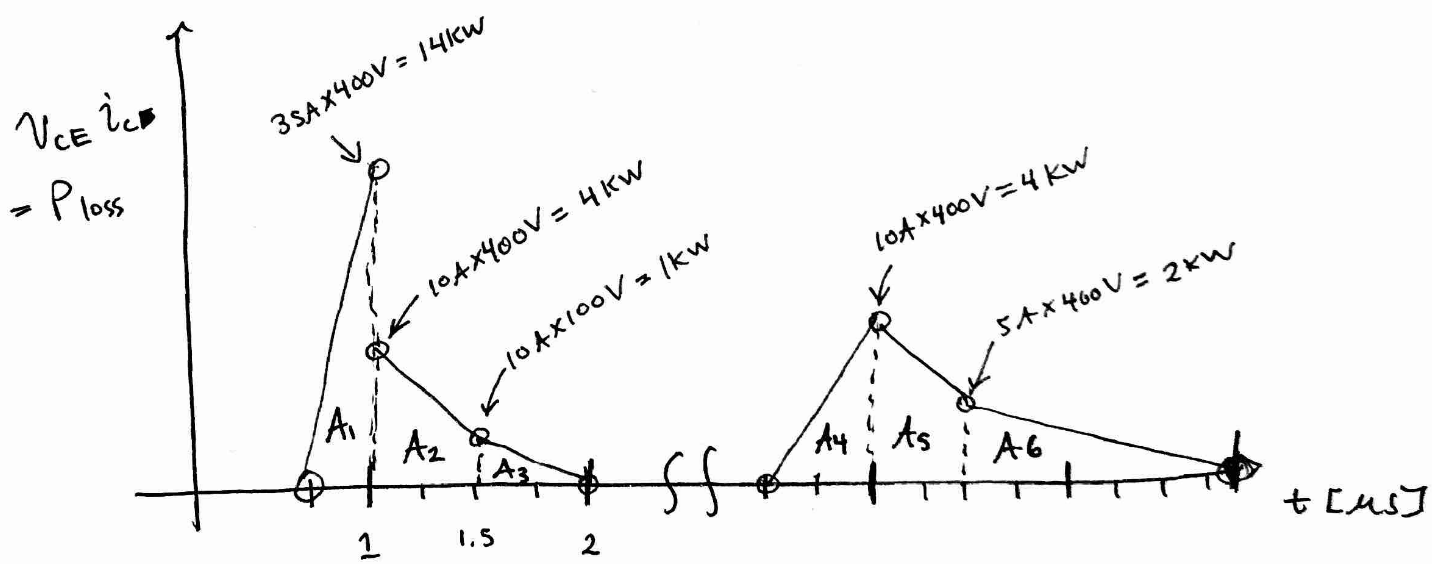
Homework #4 Solutions

Problem #1

1a) - Look @ $v_{CE}(t)$ & $i_c(t)$ waveforms to compute power loss.

- Multiply $v_{CE}(t)$ & $i_c(t)$ @ transition points on waveforms, then connect the dots using straight line approximations where needed.



- Slice up into 6 regions & calculate areas. $\frac{1}{2}$ base × height works for A_1, A_3, A_4, A_6 directly. For A_2 & A_5, its convenient to break those up into a rectangle on the bottom + triangle sitting on top.

$$E_{loss} = A_1 + A_2 + A_3 + A_4 + A_5 + A_6$$

$A_1 = \frac{1}{2} \times 0{,}25\mu s \times 14KW$

$A_2 = \underbrace{0.5\mu s \times 1KW}_{\square \text{ on bottom}} + \underbrace{\frac{1}{2}\, 0.5\mu s \times 3KW}_{\Delta \text{ on top}}$

$A_3 = \frac{1}{2} \times 0.5\mu s \times 1KW$

$A_4 = \frac{1}{2}\, 0.5\mu s \times 4KW$

$A_5 = \underbrace{0.5\mu s \times 2KW}_{\square \text{ on bottom}} + \underbrace{\frac{1}{2} \times 0.5\mu s \times 2KW}_{\Delta \text{ on top}}$

$A_6 = \frac{1}{2} \times 1.5\mu s \times 2KW$

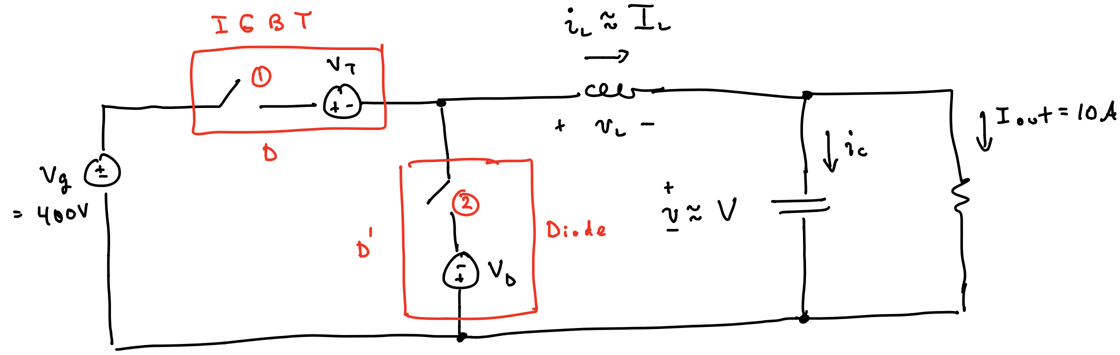
↳ Crunch numbers & total up

$\boxed{E_{loss} = 7.2\ mJ}$ $\boxed{1a}$

& average power loss due to switching is

$P_{sw_{loss}} = F_s\, E_{loss}$

(b) Draw ckt:



Where $V_T = 2.5\,V$, $V_D = 1.5\,V$.

– Conduction loss from diodes only is given by

$$P_{\substack{cond\\loss}} = \underset{?}{D}\,\overbrace{(V_T\ I_L)}^{IGBT} + \underset{?}{D'}\,\overbrace{(V_D\ I_L)}^{diode} \qquad (1)$$

$I_L = 10A$ from plot

D is only unknown. Obtain it from balance eqn.

$$\langle v_L \rangle = 0 = D(V_g - V_T - V) + D'(-V_D - V) \qquad (2)$$

$$\langle i_c \rangle = 0 = \underbrace{D(I_L - I_{out})}_{\text{config ①}} + \underbrace{D'(I_L - I_{out})}_{\text{config ②}} \qquad (3)$$

(2) confirms that $I_L = I_{out} = 10A$.

Use (1) to solve for D

$$\Rightarrow \quad 0 = D(V_g - V_T - V) + \overbrace{D'}^{1-D}(-V_D - V)$$

$$= D(V_g - V_T) - \cancel{DV} - V_D - V + DV_D + \cancel{DV}$$

* collect terms w/ D factor

$$= D\,(V_g - V_T + V_D) - V_D - V$$

$$= 0$$

$$\Rightarrow \quad D = \frac{V_D + V}{V_g - V_T + V_D} \qquad (4)$$

$$= \frac{1.5V + 200V}{400V - 2.5V + 1.5} = 0.505 = D$$

(4) -> (1) gives:

$$P_{\substack{cond\\loss}} = \text{all conduction loss in forward drops}$$

$$= \underbrace{0.505}_{D}\,(V_T I_L) + \underbrace{(1 - 0.505)}_{1-D}\,(V_D I_L)$$

$$\approx 20.05\ W \qquad 1(b)$$

1c) Look @ efficiency

Know

$$P_{out} = VI = (200V)(10A) = 2\,kW$$

Efficiency definition is

$$\eta = \frac{P_{out}}{P_{in}}$$

$$*\ \text{recall} \quad P_{out} = P_{in} - \overbrace{P_{\substack{sw\\loss}} - P_{\substack{cond\\loss}}}^{\text{losses}} \Rightarrow P_{in} = P_{out} + P_{sw} + P_{cond}$$

$$= \frac{P_{out}}{P_{out} + \underbrace{f_s E_{loss}}_{\substack{\text{from}\\\text{part a}}} + P_{\substack{cond\\loss}}}$$

$$\approx \frac{2\,kW}{2\,kW + f_s\,(7.2\,mJ) + 20.05\,W}$$

$$= \eta$$

$\boxed{1c}$

easy to plot on computer