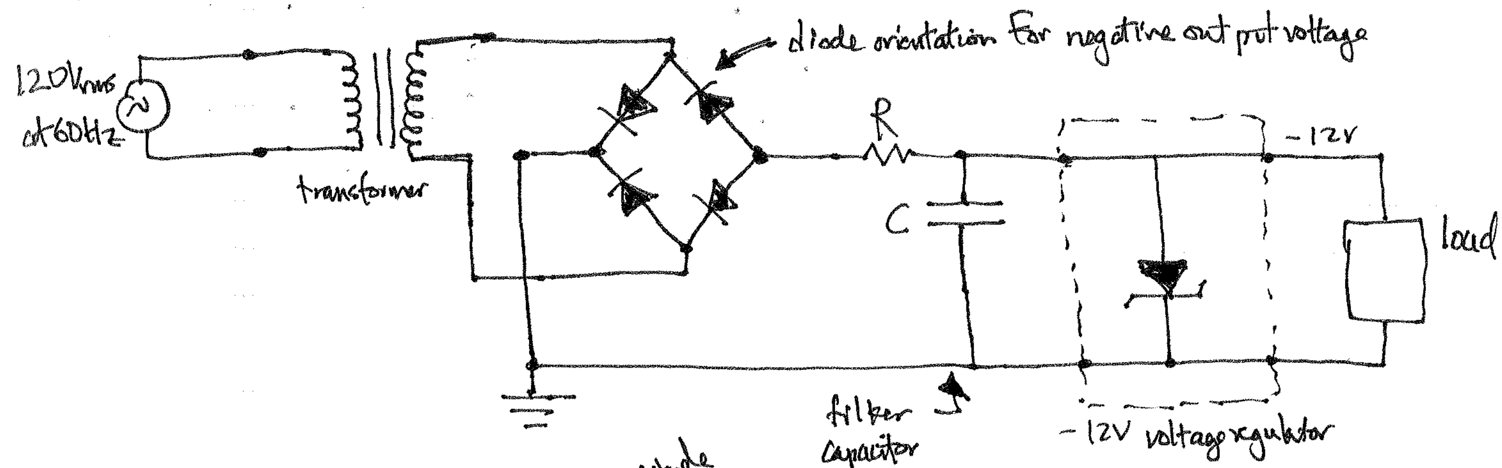
PHYSICS 220 : Physical Electronics   Problem Set #3   SOLUTIONS

Simpson Ch.4 : 23, 25, 26, [redacted],   Ch.5 : 8, 10, 11, 12

Simpson, chapter 4 :

[23] Sketch a full-wave rectifier circuit to produce a −12 V DC. output.



• This ~~input~~ primary voltage amplitude on the transformer is $V_p \sim 120\text{V}\cdot\sqrt{2} = 170\text{ V}$

We want the secondary to be $V_s \gtrsim 12\text{V} + 2\times 0.6\text{V} = \underline{13.2}\text{ V}$

↑ Since there are two forward-biased diodes between output and ground in each half cycle.

So... the turns ratio on the transformer should be about...

$$\frac{N_s}{N_p} > \frac{13.2}{170} = 0.0776 \quad \text{or...} \quad \frac{N_p}{N_s} \lesssim 12.9$$

Choose $\boxed{\frac{N_p}{N_s} = 12}$ or $\frac{N_s}{N_p} = 0.0833$

• The filter capacitor has to be big enough to reduce the ripple to acceptable levels under load conditions. If, for example, we want to draw 100 mA, then in $\frac{1}{120\text{Hz}} = 8.3\text{ ms}$ (the [redacted] period of the ripple), the voltage on the filter capacitor will decrease by approximately...

$\Delta V = \frac{I_{load}\,\Delta t}{C}$. For the ripple to be less than 5% of the DC output level under loaded conditions... we need

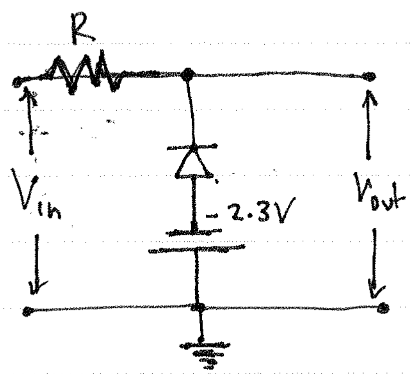
$$C > \frac{I_{load}\,\Delta t}{0.05\,V_{DC}} = \frac{0.1\text{A}}{0.05\cdot 12\text{V}}\cdot\frac{\text{s}}{120} = \underline{\underline{1.4\times10^{-3}\text{F}}}$$

$\boxed{14{,}000\,\mu\text{F}}$

• The filter resistor R should be small so the DC output does not droop under loaded conditions $V_{out} = \frac{R_{load}}{R+R_{load}}\cdot V_{in}$

If $\frac{V_{out}}{V_{in}} = 0.95$, then... $\frac{R}{R_{load}} + 1 \leq \frac{1}{0.95}$ or $R < 0.053\,R_{load} = 0.053\,\frac{12\text{V}}{.1\text{A}} = \underline{\underline{6.3\,\Omega}}$

25 Diode clipping circuit to clip off negative-going pulses at −3.0 V.



When the input goes more negative than −3.0 V, the diode is forward-biased and current flows so that the portion of Vin that is more negative than −3 V appears across the resistor R, and <u>not</u> across the output.

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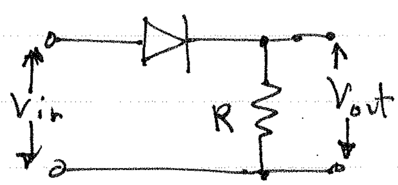
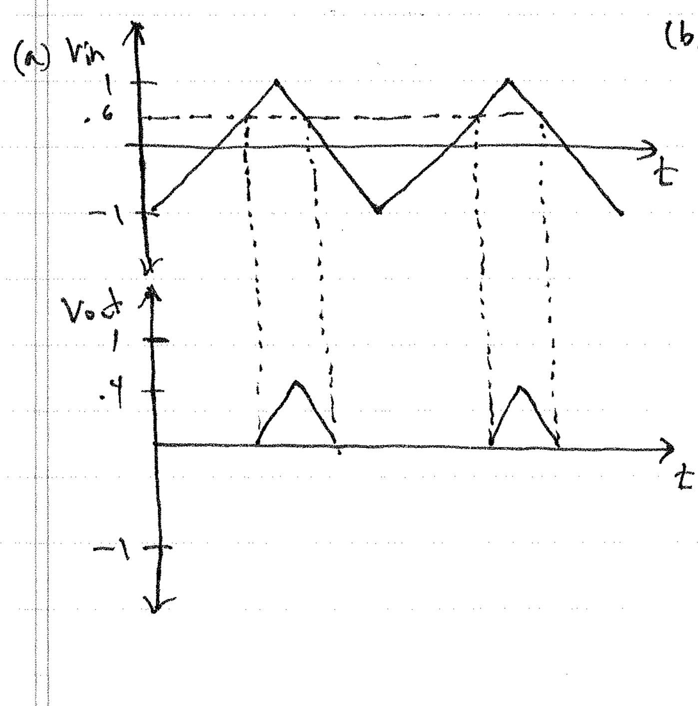
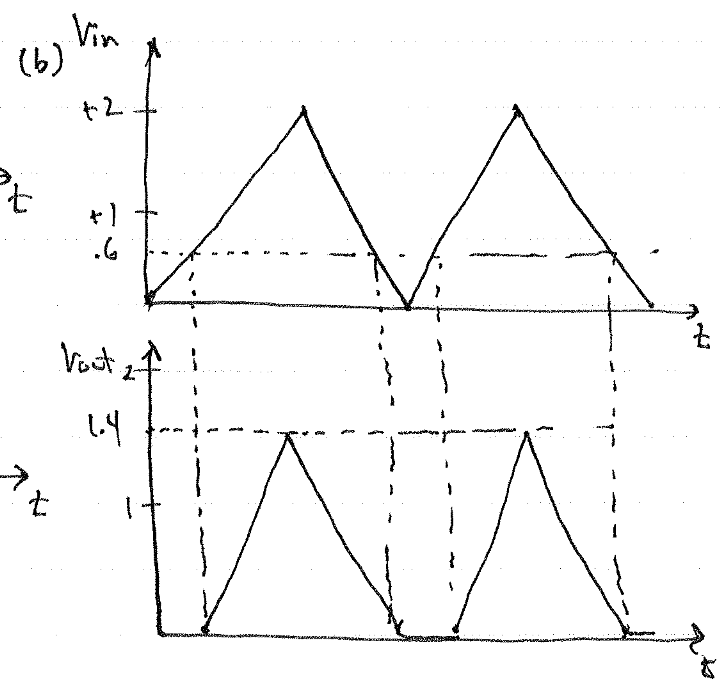
26 Sketch the output voltage, ~~when~~ for the following circuit and input waveforms.



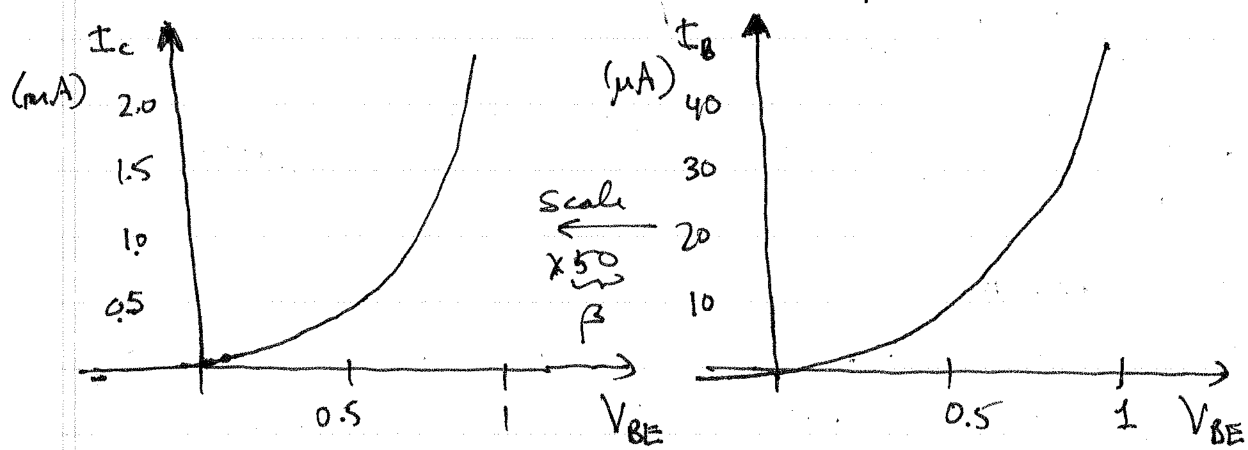




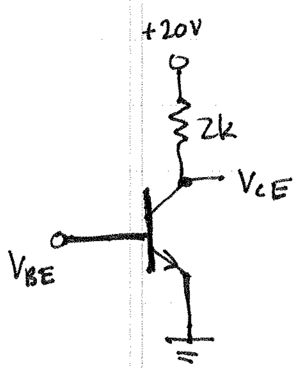
Simpson, chapter 5 :

8 Sketch a graph of collector current vs. base-emitter voltage for a silicon transistor. Repeat for base current vs. base-emitter voltage. Use $\beta = 50$.

The base-emitter is a pn junction ... so I_B vs. V_{BE} looks like a diode.
And the transistor maintains (approximately) $I_c = \beta I_B$ so...



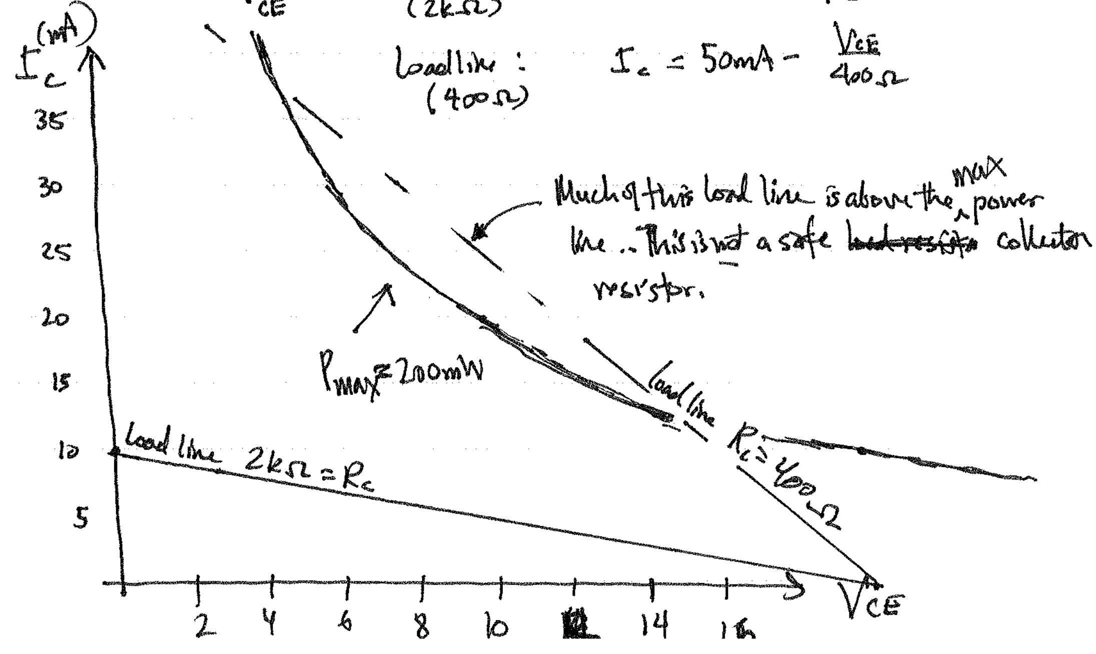
10 Consider a transistor with $P_{max} = 200\,mW$ and a 20 V power supply. Plot the max power curve on a graph of I_c vs. V_{CE}. Also draw the load line for a $2\,k\Omega$ collector resistor.



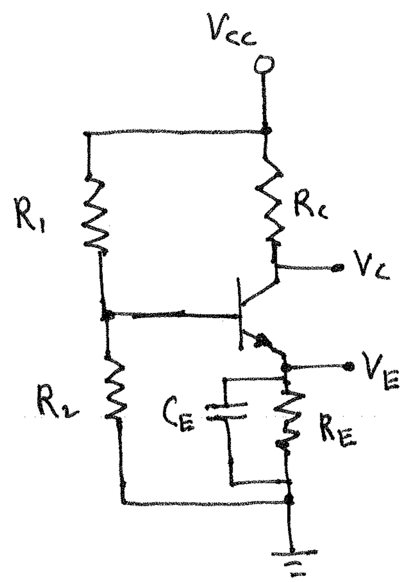
Power: $I_c = \dfrac{P}{V_{CE}}$

Load line (2kΩ): $I_c = \dfrac{V_{cc}}{R_c} - \dfrac{V_{CE}}{R_c} = 10\,mA - \dfrac{V_{CE}}{2\,k\Omega}$

Load line (400Ω): $I_c = 50\,mA - \dfrac{V_{CE}}{400\,\Omega}$



11 Calculate I_c and V_{CE}. The transistor has a β of 100.



- The bypass capacitor on the emitter does not affect the DC quiescent operation of the transistor

- Base voltage is output of a voltage divider

$$V_B = \frac{R_2}{R_1+R_2} \cdot V_{cc} = \frac{1}{5} \cdot 15V = \underline{3.0V}$$

- Emitter is one forward-biased diode drop lower than this

$$V_E = V_B - 0.7V = \underline{2.3V}$$

- The current through the emitter resistor is therefore $I_E = \frac{V_E}{R_E} = \frac{2.3V}{1k\Omega} = \underline{2.3mA}$

- The collector current is approximately equal to the emitter current when $\beta \gg 1$.

$$\boxed{I_c \simeq 2.3 mA}$$

- The collector voltage is $V_c = V_{cc} - I_c R_c = 15V - 2.3mA \cdot 2k\Omega$

$$= 15V - 4.6V$$

$$V_c = 11.4V$$

- So the collector-to-emitter voltage is..

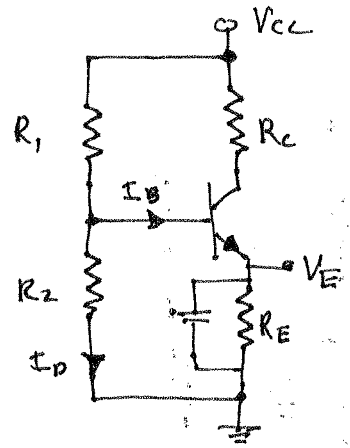
$$V_{CE} = V_c - V_E = 11.4V - 2.3V = \boxed{9.1V}$$

- Check to see that I_B is much less than current in R_2 -- otherwise voltage divider is loaded down...

$$I_B \simeq \frac{I_c}{\beta} \simeq 23\mu A$$

and $I_2 = \frac{V_B}{R_2} = \frac{3.0V}{10k\Omega} = \underline{333\mu A}$ much greater... check ✓

12 Calculate R_1 and R_2 if $I_D = 20 I_B$. The transistor is silicon and has a $\beta = 100$. $V_E = 1V$.



- Knowing that the emitter voltage is 1V, we can find the emitter current.

$$I_E = \frac{V_E}{R_E} = \frac{1V}{500\,\Omega} = 2.0\text{ mA}$$

- Since $\beta >> 1$ $\quad I_C \simeq I_E = 2.0\text{ mA}$

- The base current is, therefore, $I_B = \frac{I_C}{\beta} \simeq 20\mu A$

- The base voltage is $V_B = V_E + 0.7V = 1.7V$

- The current I_D, in resistor R_2 is $I_D = V_B / R_2$ and we want this to be 20X larger than I_B... so...

$$R_2 = \frac{1.7V}{400\mu A} = \boxed{4.25\text{ k}\Omega}$$

- To get $V_B = 1.7$ V from the voltage divider formed from R_1 and R_2, ...

$$V_B = \frac{R_2}{R_1 + R_2} \cdot V_{cc}$$ solve for R_1...

$$\frac{R_1 + R_2}{R_2} = \frac{V_{cc}}{V_B} \quad \text{or} \quad \frac{R_1}{R_2} + 1 = \frac{V_{cc}}{V_B}$$

or... $$R_1 = R_2\left[\frac{V_{cc}}{V_B} - 1\right] = 4.25\text{k}\Omega\left[\frac{15V}{1.7V} - 1\right]$$

$$= \boxed{33.25\text{ k}\Omega}$$