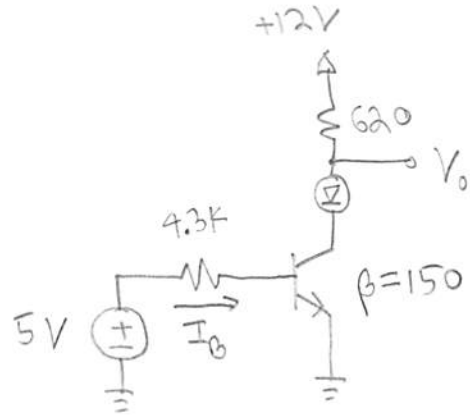
ECE 363
HW #1 Solns

Total = 100 pts



(1) (+10)

(a) $I_B = \frac{5-0.7}{4.3K} = \boxed{1\,mA}$

$I_c = \frac{12-(V_{CE,sat}+V_F)}{620\Omega}$

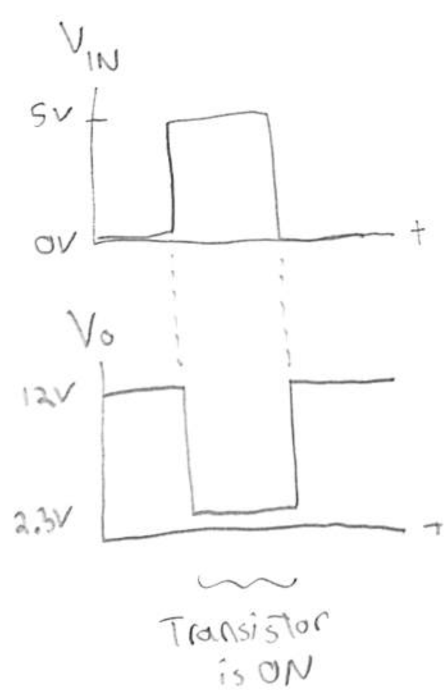
$= \frac{12-(0.3+2)}{620} = .0156\,A = \boxed{15.6\,mA}$

$V_o = 12-(.0156A)(620) = \boxed{2.3V}$

(b) $\frac{I_c}{I_B} = \frac{15.6\,mA}{1\,mA} = 15.6 \approx \underbrace{0.1 \times 150}_{15}$ — close enough

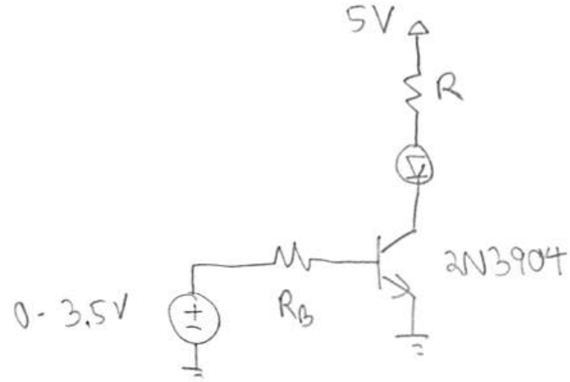
YES, hard saturation

(c)



(2) (+10)

(a) First choose R:



$$5 - (.010)R - 2.5 - V_{CE,sat} = 0$$

$V_{CE,sat}$ ↑ (0.2V)

$$R = \frac{5 - 2.5 - 0.2}{.010} = 230\Omega$$

Choose $\boxed{R = 220\Omega}$

Determine R_B by hard saturation:

$$I_B = \frac{3.5 - V_{BE,sat}}{R_B} \sim \frac{.010A}{0.1\,\beta_{min}}$$

$V_{BE,sat}$ ↑ (0.85V); β_{min} ← (100)

$$R_B \sim (3.5 - 0.85)\,\frac{0.1 \times 100}{.010A} = 2650\Omega$$

Choose $\boxed{R = 2.7K}$

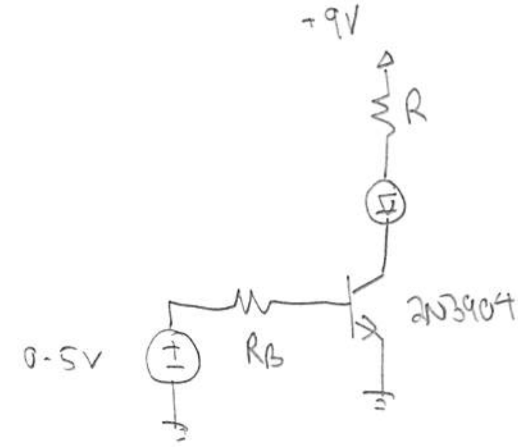
(2.4K is also OK)

(b) $P = I^2R = (.010)^2(220\Omega) = .022W = \boxed{22mW}$

(c) 2 × 22mW = 44 mW ← $\boxed{\text{1/8 W resistor is fine}}$

(3) (+10)

(a) First determine R:



$$9 - (.030)R - 3.5 - V_{CE,sat} = 0$$

($V_{CE,sat}$ = .3V)

$$R = \frac{9 - 3.5 - .3}{.030} = 173\,\Omega$$

Choose **R = 160 Ω**

Determine R_B:

$$I_B = \frac{5 - V_{BE,sat}}{R_B} \sim \frac{.030}{0.1\,\beta_{min}}$$

($V_{BE,sat}$ = 0.9V, β_{min} = 80)

$$R_B \sim (5 - 0.9)\,\frac{0.1 \times 80}{.030} = 1093\,\Omega$$

Choose **R_B = 1K**

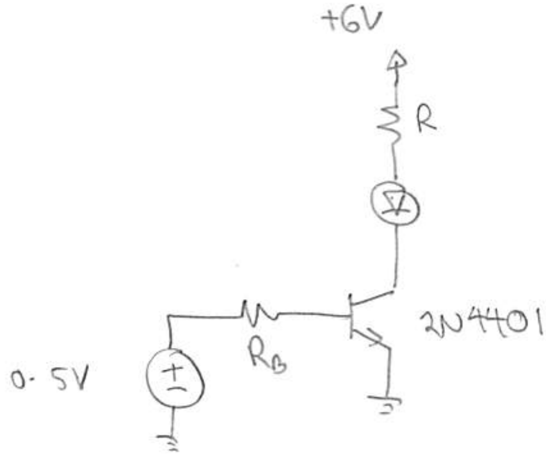
(1.1K is fine)

(b) $P = I^2R = (.030)^2(160) = .144\,W$

$2 \times .144 = .288\,W$ Choose **½W resistor**

(4) +10

(a) Determine R:



$$6 - (.3)R - 3.5 - V_{CE,sat} = 0$$

$V_{CE,sat}$ ~0.6V

$$R = \frac{6 - 3.5 - 0.6}{.3} = 6.33\Omega$$

Choose $\boxed{R = 6.2\Omega}$

Determine R_B:

$$I_B = \frac{5 - V_{BE,sat}}{R_B} \sim \frac{.300A}{0.1\beta_{min}} = .043A$$

$V_{BE,sat}$ ~1.1V; β_{min} ~70

$$R_B \sim (5 - 1.1) \times \frac{1}{.043A} = 91\Omega$$

Choose $\boxed{R_B = 91\Omega}$

(b) $P = I^2R = (.3)^2(6.2) = 0.558W$

$2P = 1.116W$ Choose $\boxed{\text{2W resistor}}$ (safer)

1W is probably OK

Can also add $(.043A)(1.1V) = 47mW$ for base current

(c) $P_{MAX} = 625mW - (5mW/°C)(60 - 25) = \boxed{450mW}$

(d) $P = I_E V_{CE} = (0.3A)(6 - .3 \times 6.2 - 3.5) = 0.192W = \boxed{192mW}$

$(6 - .3 \times 6.2 - 3.5) = 0.64V$

(e) $2P = 384mW < 450mW$

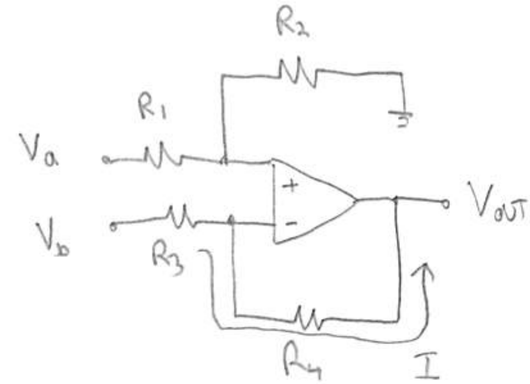
$\boxed{\text{No heat sink needed}}$

If we include base current contribution, $2P = 478mW$

Heat sink may be needed ...

(5) (+10)

(a) $V_+ = V_a \frac{R_2}{R_1+R_2}$



$I = \frac{V_b - V_-}{R_3} = \frac{V_- - V_{OUT}}{R_4}$

$\frac{R_4}{R_3} V_b - \frac{R_4}{R_3} V_- = V_- - V_{OUT}$

$V_{OUT} = V_-\left(1 + \frac{R_4}{R_3}\right) - \frac{R_4}{R_3} V_b$

Since $V_- = V_+$:

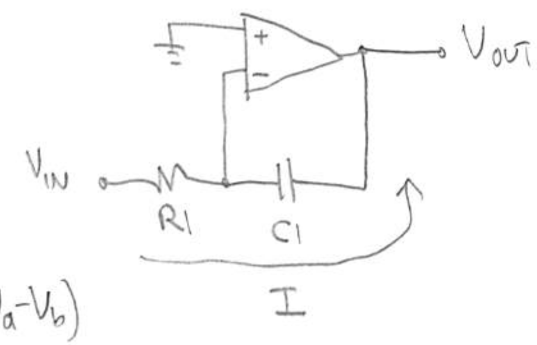
$$\boxed{V_{OUT} = V_a \frac{R_2}{R_1+R_2}\left(1+\frac{R_4}{R_3}\right) - \frac{R_4}{R_3} V_b}$$

(b) $R_3 = R_1$ and $R_4 = R_2$: $V_{OUT} = V_a \frac{R_2}{R_1+R_2}\left(1+\frac{R_2}{R_1}\right) - \frac{R_2}{R_1} V_b$

$= V_a \frac{R_2}{R_1} - \frac{R_2}{R_1} V_b = \boxed{\frac{R_2}{R_1}(V_a - V_b)}$

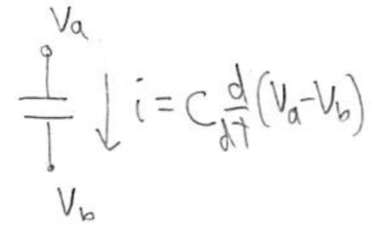
(6) (+10)

(a) $V_+ = 0$
$\to V_- = 0$



$I = \frac{V_{IN} - 0}{R_1}$

For capacitor,

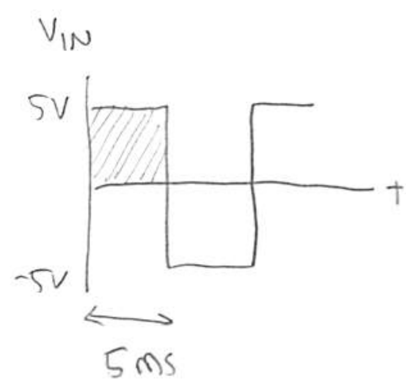


So, $I = \frac{V_{IN}}{R_1} = C_1 \frac{d}{dt}(0 - V_{OUT})$

$$\frac{dV_{OUT}}{dt} = -\frac{1}{R_1 C_1} V_{IN}$$

$$\boxed{V_{OUT} = -\frac{1}{R_1 C_1} \int V_{IN}\, dt}$$

(b) $R_1 C_1 = (10^5 \Omega)(10^{-7} F) = .01$

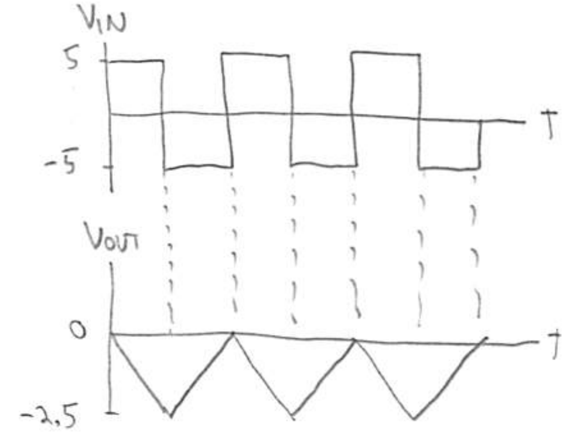


$$V_{OUT} = -\frac{1}{.01} \int V_{IN} dt = -100 \int V_{IN} dt$$

100Hz ⇒ T = .01s = 10ms

For $0 < t < 5ms$, $\int V_{IN} dt$ is a ramp
(const)

$$\int_0^{.005} 5\, dt = 5 \times .005 = .025$$



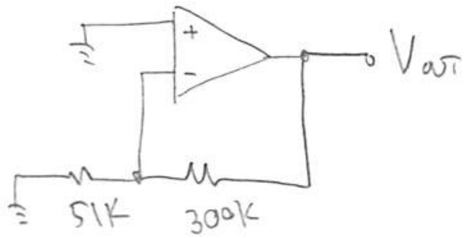
$\to V_{OUT} = -100 \times .025$

$= \underline{-2.5V}$

(7) +10

(a) $R_{IN} = 51K$

(b) For 741C op amp:



$I_{IN(BIAS)} = 500\,nA$

$I_{IN(OFFSET)} = 200\,nA$

$V_{IN(OFFSET)} = 6\,mV$

$G = -\frac{300K}{51K} = -5.88$

$R_{TH(+)} = 0$

$R_{TH(-)} = 51K \,//\, 300K = 43.6K$

Input bias current: $\Delta V_{IN} = (500nA)(43.6K - 0) = .0218V$

$\Delta V_{OUT} = 5.88\,(.0218) = 0.128V$

Input offset current: $\Delta V_{IN} = (200nA)\left(\frac{43.6K + 0}{2}\right) = .0044V$

$\Delta V_{OUT} = 5.88\,(.0044) = .026V$

Input offset voltage: $\Delta V_{OUT} = 5.88\,(.006) = .035V$

(c) Main source of error is input bias current

(d) Worst case ΔV_{OUT}: $.128 + .026 + .035 = 0.189V$

(8) +10

(a) $R_{IN} = 51K$

(b) $I_{IN(BIAS)}$: $\Delta V_{OUT} = 5.88 \times (400pA)(43.6K - 0) = 103\ \mu V$

$I_{IN(OS)}$: $\Delta V_{OUT} = 5.88 \times (200pA)\left(\frac{43.6K + 0}{2}\right) = 26\ \mu V$

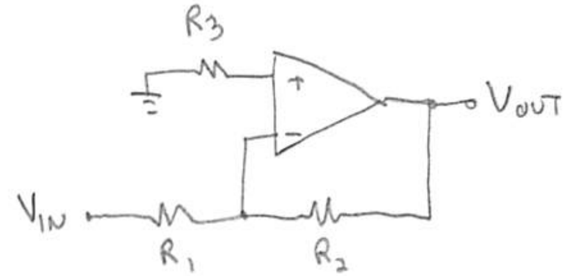
$V_{IN(OS)}$: $\Delta V_{OUT} = 5.88 \times .015 = 88\ mV$

(c) Main source of error is input offset voltage

(d) worst case $\Delta V_{OUT} = 0.103\ mV + 0.026\ mV + 88\ mV = 88.129\ mV$

(9)

(+10) (a) $G = -\frac{R_2}{R_1} = -50$



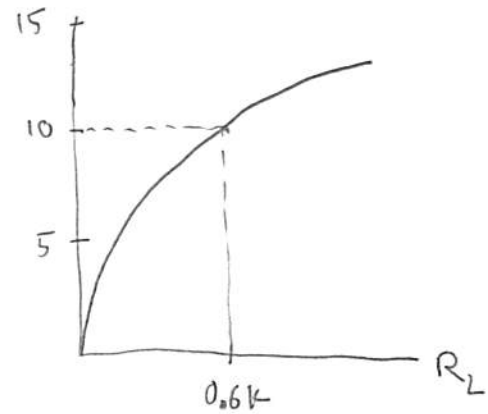
Many combinations of R_1 and R_2 are OK.

Let $R_1 = 20K$, $R_2 = 1M$

(b) $R_3 = R_1 // R_2 = 20K // 1M = 19.6K$

Choose $R_3 = 20K$

(c) $V_{OUT} = -50 \times (-0.2V) = \underline{10V}$

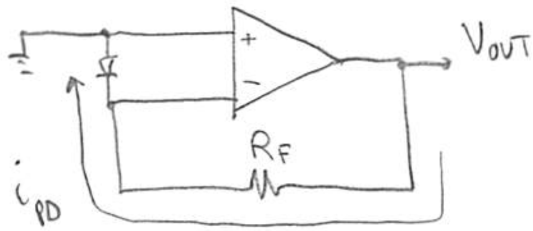


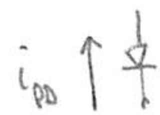
According to plot of output voltage swing, $R_L \geq 0.6K$

(10)

(+10)

(a) Choose the left circuit because photocurrent always flows from cathode to anode.





Therefore, $V_{OUT} > 0$ for above circuit.

(b) According to plot, $I_{PD} \sim 3.5\mu A$

so, $(3.5\mu A) \times R_F \geq 5V$

$$R_F \geq \frac{5V}{3.5\mu A} = 1.43M$$

choose $\boxed{R_F = 1.5M}$

(c) $R_{TH(+)} = 0$

$R_{TH(-)} = R_F = 1.5M$

$$\Delta V_{OUT} = (400pA)(1.5M - 0) + (200pA)\left(\frac{1.5M + 0}{2}\right) + .015$$

$$= .0006 + .00015 + .015$$

$$= .01575 V = \boxed{15.75 mV}$$ ← Pretty small

voltage gain is effectively equal to 1