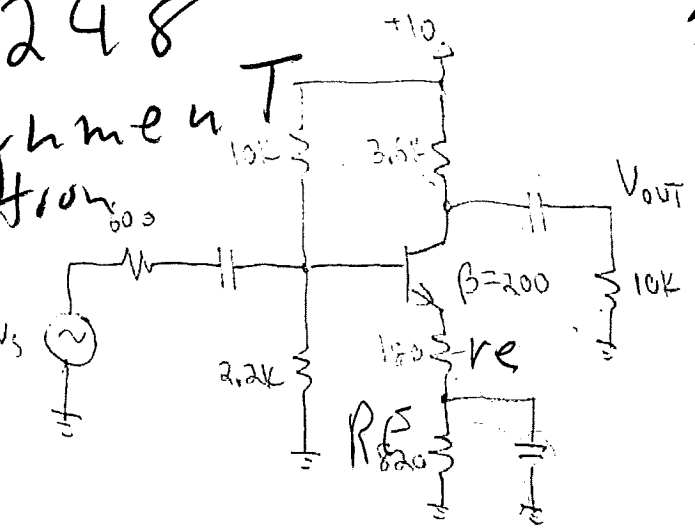
8.W (+16)

ECE248 Assignment 5 solution

STEP 1 Q-Point



- Stiff divider: $10K \,//\, 2.2K = 1.8K$

$\frac{201}{100} \cdot 1K = 2.01K$

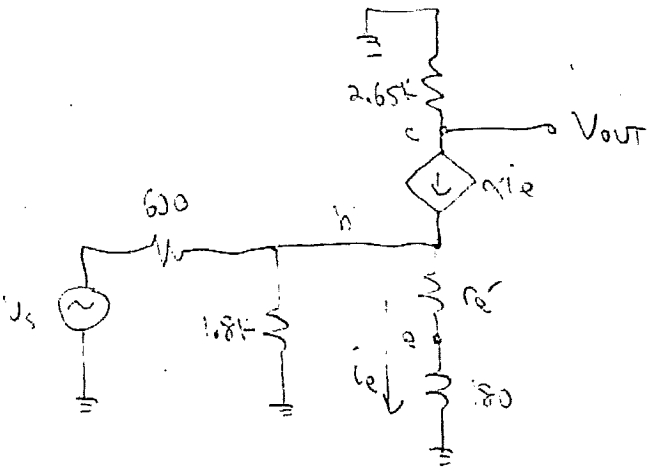
- $V_{BB} = 10 \frac{2.2K}{2.2K + 10K} = 1.8V$

$I_{EQ} = \frac{1.8 - 0.7}{1K} = \boxed{1.1mA}$ $\quad \alpha = \frac{200}{201} = 0.995$

- $V_C = 10 - .995\,(1.1mA)(3.6K) = 6.06V$ $\quad I_{CQ} = \frac{10 - 6.06}{3.6} = 1.094mA$

$V_{CEQ} = 6.06 - 1.1V = \boxed{4.96V}$

STEP 2 AC analysis



$r_c = 3.6K \,//\, 10K = 2.65K$

- $v_{out} = -i_c r_c = -\alpha i_e r_c$

$\boxed{i_e = -\frac{v_{out}}{\alpha r_c}}$

- $v_{ce} = v_c - v_e = v_{out} - i_e R_e = v_{out} - \left(\frac{-v_{out}}{\alpha r_c}\right) R_e = \boxed{v_{out}\left(1 + \frac{R_e}{\alpha r_c}\right)}$

STEP 3 Cut-off vs. Saturation

cut-off: $i_e = -I_{EQ} \Rightarrow \frac{-v_{out}}{\alpha r_c} = -I_{EQ} \rightarrow v_{out} = \alpha I_{EQ} r_c = .995\,(1.1mA)(2.65K) = \underline{2.9V}$

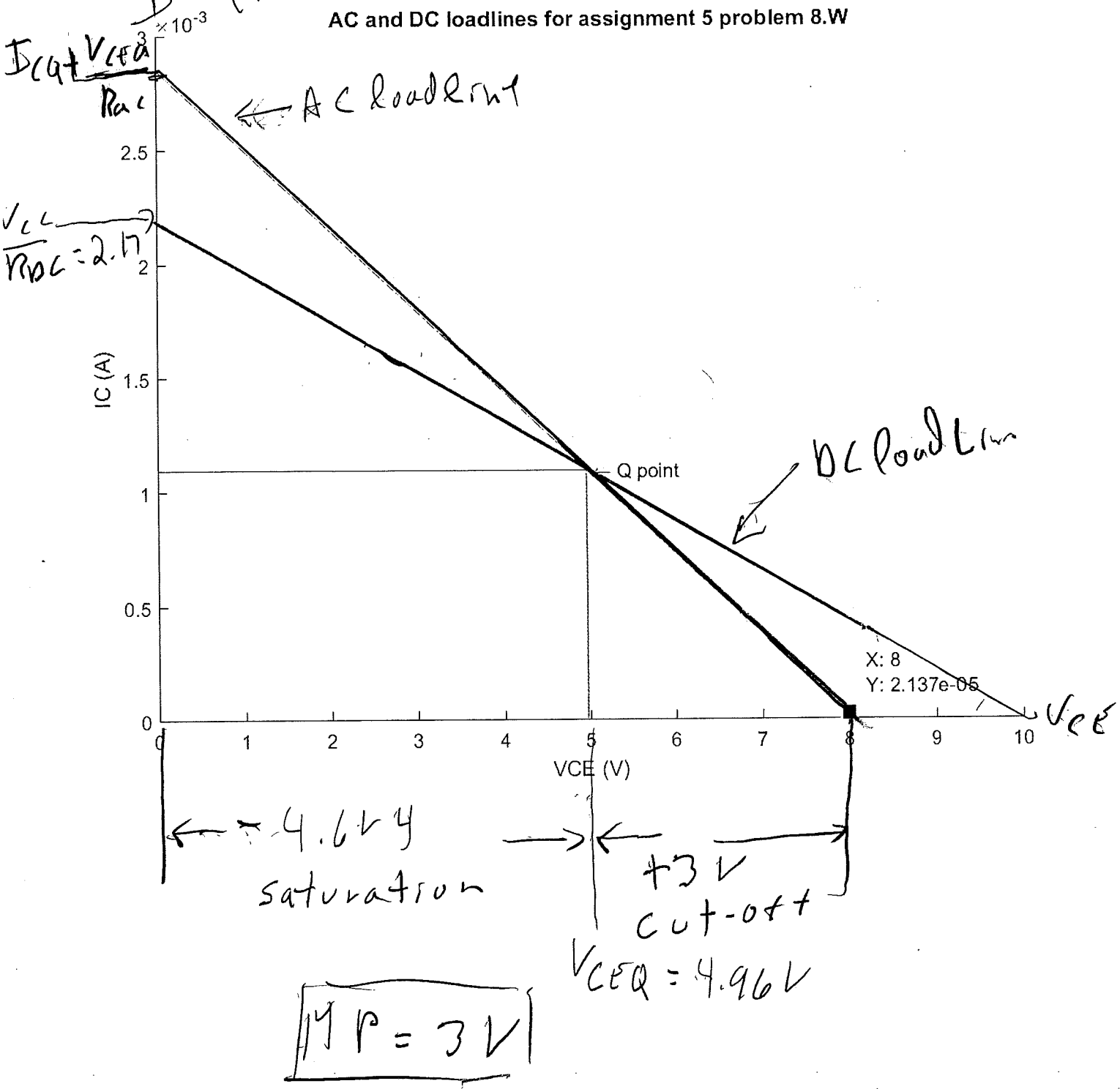
saturation: $v_{ce} = -V_{CEQ} \Rightarrow v_{out}\left(1 + \frac{R_e}{\alpha r_c}\right) = -V_{CEQ}$

$v_{out} = \frac{-4.96V}{1 + \frac{.18K}{.995 \cdot 2.65K}} = \underline{-4.64V}$

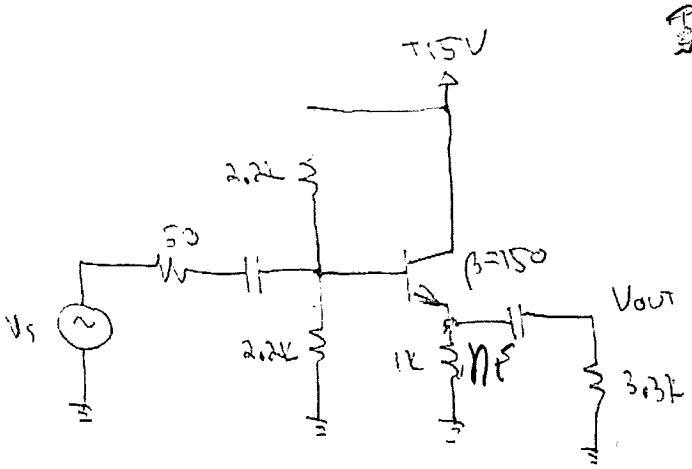
$\boxed{MP = 2.9V}$

Due to cut-off on (+) side

Load lines for Problem 8W



9,X (+16)



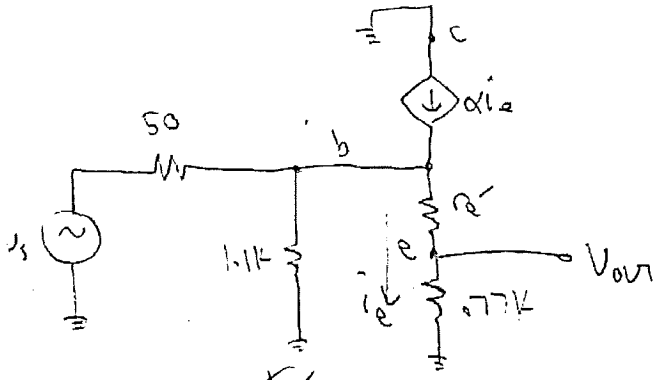
STEP 1 Q-Point

- Stiff divider? $2.2k // 2.2k = 1.1k$

  $\frac{151}{100} \times 1k = 1.51k$ ✓

- $V_{BB} = 15 \cdot \frac{2.2k}{2.2k + 2.2k} = 7.5V \rightarrow I_{EQ} = \frac{7.5 - 0.7}{1k} = \boxed{6.8mA}$

- $V_{CEQ} = V_C - V_E = 15 - 6.8V = \boxed{8.2V}$

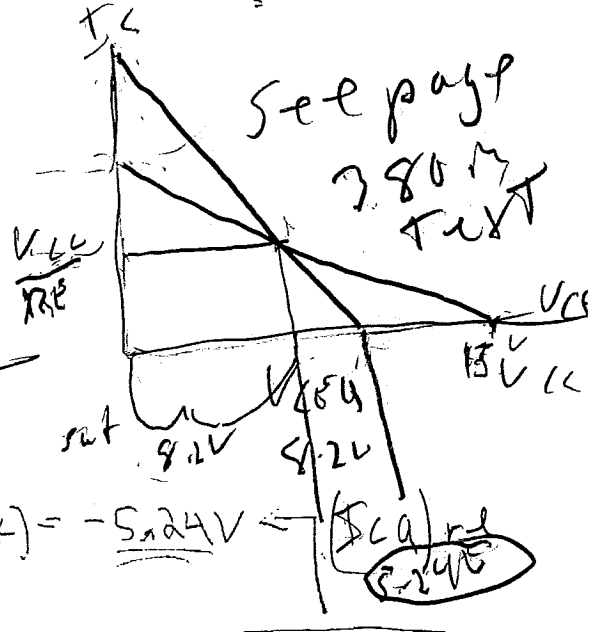


STEP 2 AC analysis

$r_e = 1k // 3.3k = 0.77k$

- $V_{out} = i_e r_e \rightarrow \boxed{i_e = \frac{V_{out}}{r_e}}$

- $V_{ce} = V_c - V_e = 0 - V_{out} = \boxed{-V_{out}}$ ✓



STEP 3 Cut-off vs. saturation

Cut-off: $i_e = -I_{EQ} \Rightarrow \frac{V_{out}}{r_e} = -I_{EQ}$

Max $V_{out} = -(6.8mA)(0.77k) = -5.24V$

Saturation: $V_{ce} = -V_{CEQ} \Rightarrow -V_{out} = -V_{CEQ}$

Max $V_{out} = 8.2V$

$\boxed{MP = 5.24V}$

Due to cut-off on (-) side

9.4 (10)

$$V_{LOAD} = V_G \frac{Z_{IN}}{Z_{IN} + Z_S} A$$

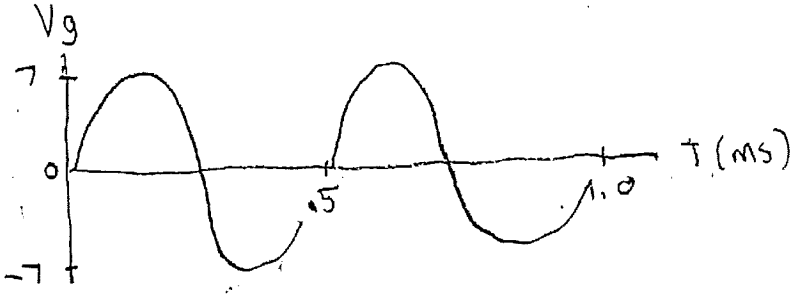
$$r_e' = \frac{.026}{6.8mA} = .0038K$$

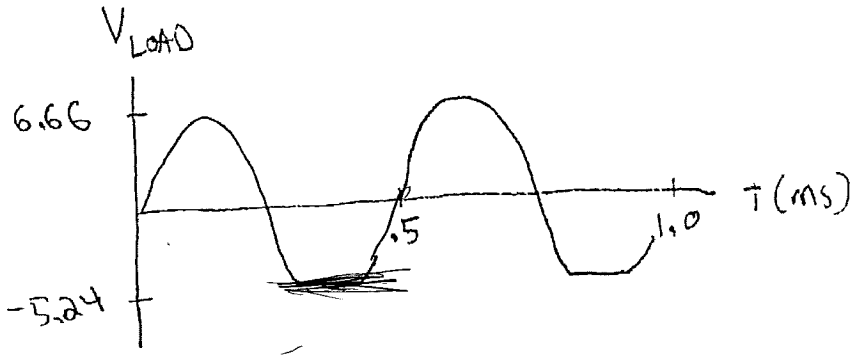
$$\frac{r_e}{r_e + r_e'} = \frac{.77K}{.77K + .0038K} = 0.995$$

$$Z_{IN} = 2.2K // 2.2K // (151)(.0038K + .77K) = \underline{1.09K}$$

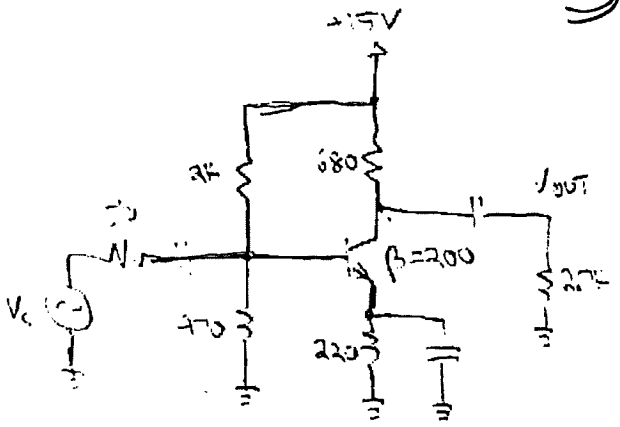
$$V_{LOAD} = (7V_p) \frac{1.09K}{1.09K + .050K} \times .995 = \underline{6.66V_p}$$

2KHz ⇒ 1 cycle = .5 ms





10.3 (+16)



STEP 1 Q-Point

- Strict divider: 2K // 47K = 0.38K

$\frac{20}{100} \cdot 22K = 0.44K$ ✓

- $V_{BB} = 15 \frac{.47K}{.47K + 2K} = 2.85V$

$\rightarrow I_{EQ} = \frac{2.85 - 0.7}{220} = \boxed{.0098A}$

$\alpha = \frac{200}{201} = .995$

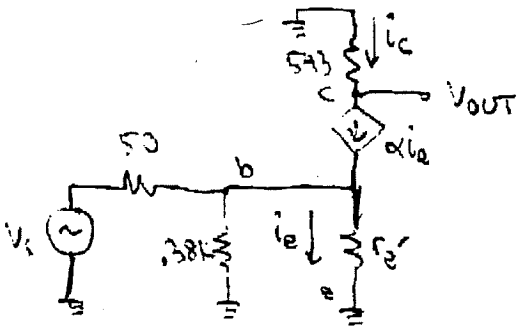
- $V_c = 15 - 0.995\,(.0098A)(680\Omega) = 8.37V$

$V_E = 2.15V$

$\therefore V_{CEQ} = 8.37 - 2.15$

$= \boxed{6.22V}$

STEP 2 AC analysis



$r_c = 680 // 2700 = 543\Omega$

- $V_{OUT} = -i_c r_c = -\alpha i_e r_c$

$\boxed{i_e = -\frac{V_{OUT}}{\alpha r_c}}$

- $V_{ce} = V_c - V_e = V_{OUT} - 0 = \boxed{V_{OUT}}$

STEP 3 Cut-off vs Saturation

Cut-off: $i_e = -I_{EQ} \rightarrow -\frac{V_{OUT}}{\alpha r_c} = -I_{EQ} \rightarrow$ Max $V_{OUT} = \alpha I_{EQ} r_c$

$= .995\,(.0098A)(543\Omega)$

$= 5.3V \leftarrow$ MP

Saturation: $V_{ce} = -V_{CEQ} \rightarrow V_{OUT} = -V_{CEQ} \rightarrow$ Max $V_{OUT} = -6.22V$ ← cut-off on (+) side

$\boxed{MPP = 10.6V_{pp}}$

10.2 (+10)

$V_{OUT} = V_g \frac{Z_{IN}}{Z_{IN} + Z_s} A$ ← $A = -\alpha \frac{R_c // R_L}{r_e'}$

$\alpha = \frac{200}{201} = .995$

$680 // 2700 = 543.2\Omega$

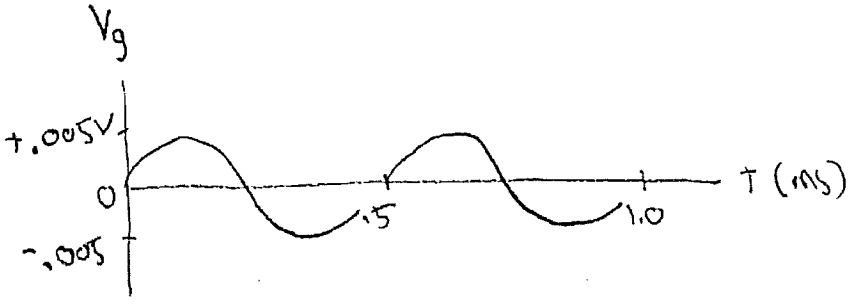
$r_e' = \frac{.026V}{.0098A} = 2.65\Omega$

$\rightarrow A = -.995 \frac{543.2}{2.65} = \underline{\underline{-204}}$

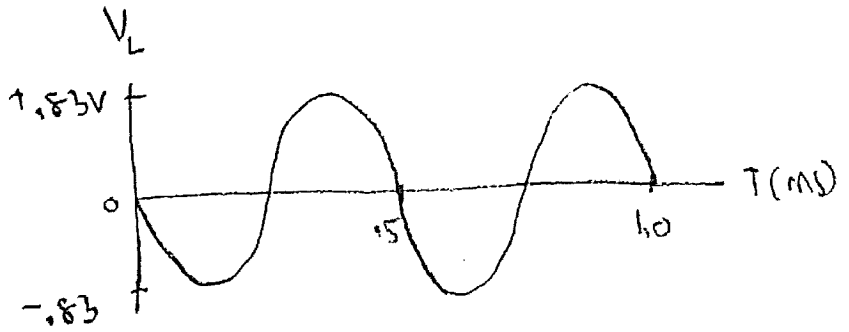
$Z_{IN} = 2000 // 470 // (201)(2.65) = \underline{\underline{222\Omega}}$

So, $V_{OUT} = (.005V_p) \frac{222}{222 + 50} (-204) = \underline{\underline{-0.83V_p}}$ ←

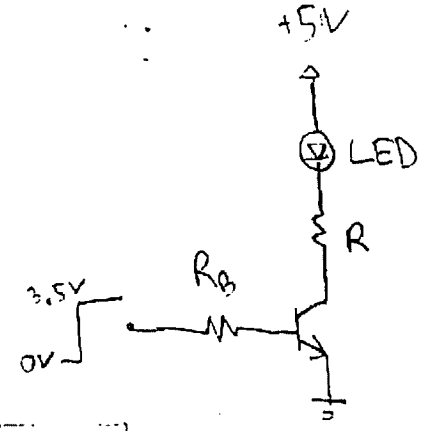
less than MP!



2kHz → .5ms per cycle



6.X (+8)



- Load properties: LED has $V_F = 3.5V$ @ 25mA

- Saturated BJT: $5 - V_{LED} - I_{LED}R - V_{CE,sat} = 0$

  (V_{LED} = 3.5V, I_{LED} = .025A, $V_{CE,sat}$ = 0V)

$$\Rightarrow R = \frac{5 - 3.5V}{.025A} = 60\Omega$$

For $I_{LED} < 25mA$, choose $\boxed{R = 62\Omega}$ ← [68Ω is probably safer, but 62Ω is OK]

$$I_{LED} = \frac{5 - 3.5V}{62\Omega} = \underline{24.2mA}$$

- Base current: $I_B \sim \frac{I_C}{10}$ (Hard saturation)

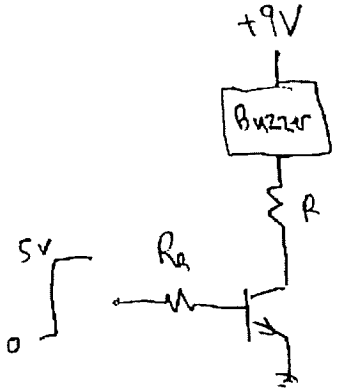
$$\frac{3.5 - 0.7}{R_B} \sim 2.42mA$$

$$\Rightarrow R_B = \frac{3.5 - 0.7V}{.00242A} = 1157\Omega$$

Choose $R_B = 1.2K$

(1.1K also OK)

6.Y (+8)



- Load: $V_L = 6V$ @ 120mA

- Saturated BJT:

$$9 - V_{LOAD} - I_{LOAD}R - V_{CE,sat} = 0$$

(V_{LOAD} = 6V, I_{LOAD} = .12A, $V_{CE,sat}$ = 0V)

$$R = \frac{9-6V}{.12A} = 25\Omega \Rightarrow \text{Choose } \boxed{R = 27\Omega} \leftarrow I = \frac{9-6}{27\Omega} = .11A$$

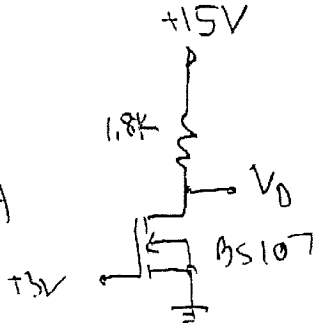
- Base current: $I_B \sim \frac{I_C}{10}$ (Hard saturation)

$$\frac{5-0.7}{R_B} \sim .011A \Rightarrow R_B = 391\Omega \quad \text{Choose } \boxed{R_B = 390\Omega}$$

12.11 (+8)

According to Table 12-1, BS107 has

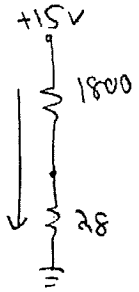
$$V_{GS,ON} = 2.6V, \quad R_{DS,ON} = 28\Omega, \quad I_{D,ON} = 20mA$$



$V_{GS} = 3-0 = 3V > V_{GS,ON} \Rightarrow$ MOSFET is on.

$$I_D = \frac{15-0V}{1800+28\Omega} = .0082A = 8.2mA < 20mA$$

Ohmic ✓



$$\Rightarrow V_D = I_D R_{DS,ON} = (.0082A)(28\Omega) = \boxed{0.23V}$$

OR

$$= 15 - I_D(1800) = 0.24V$$

Discrepancy due to rounding error

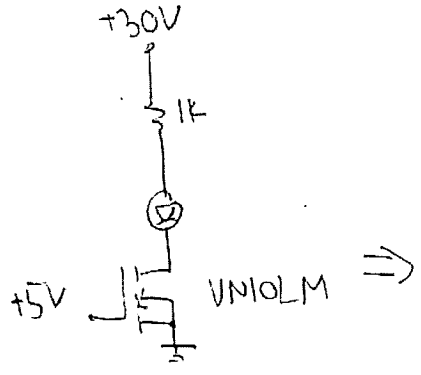
12.14 (+8)

MOSFET is ON since $+5V = V_{GS,ON}$

$V_{GS,ON} = 5V$

$R_{DS,ON} = 7.5\Omega$

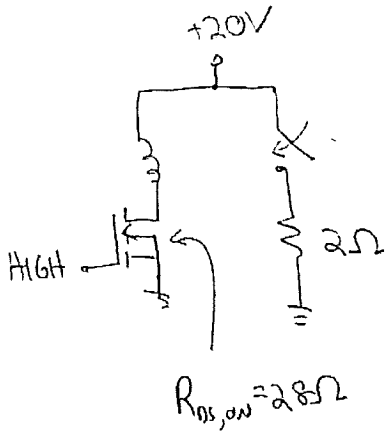
$I_{D,ON} = 200mA$



$$I_D = \frac{30-2V}{1000+7.5} = .0278A$$

$$= \boxed{27.8mA} < 200mA \quad \text{Ohmic} \checkmark$$

12.15 When MOSFET is ON,



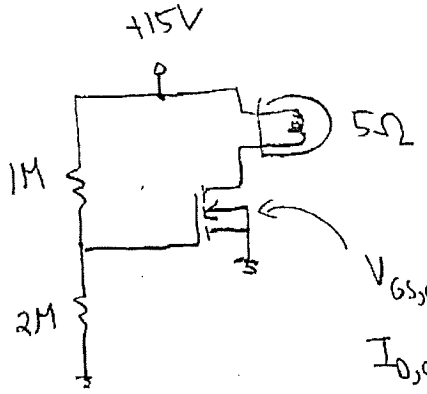
(+8) $I_D = \frac{20-0V}{1000+28\Omega}$

$= \boxed{19.5mA} < 20mA$

ohmic ✓

Load current = $\frac{20V}{2\Omega} = \boxed{10A}$ ← HUGE!

12.27



(+8) DARK → photodiode is OFF

⇒ ACTs like open circuit

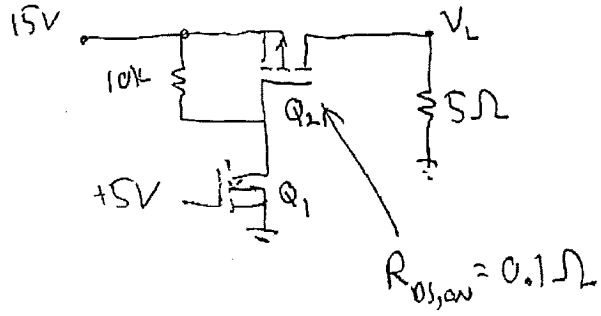
$V_{Gate} = 15\ \frac{2M}{2M+1M} = \underline{\underline{10V = V_{GS,ON}}}$

⇒ MOSFET is ON

$I_D = \frac{15-0V}{5+1.07} = 2.47A < 5A$ ohmic ✓

Lamp power = $I_D^2 R = (2.47A)^2(5\Omega) = \boxed{30.5W}$

12.34



(+8) When Q_1 ON, Q_2's $V_G \approx 0V$

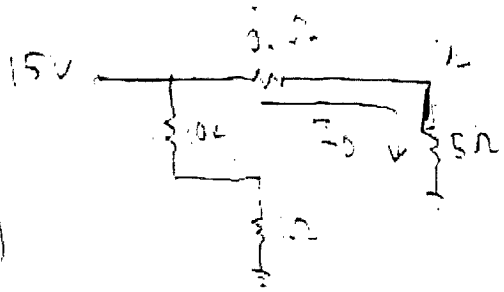
$V_{GS} \approx -15V$

⇒ Q_2 is ON

12-24 continued

$$I_0 = \frac{15V}{.1 + 5\Omega} = 2.94A < 5A$$

ohmic ✓



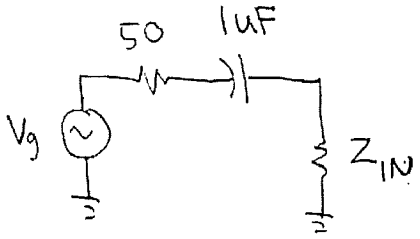
$$P_{ss} = I_0^2 R_{ss,all} = (2.94A)^2 (0.1\Omega)$$

$$= \boxed{0.864\,W}$$

$$P_L = I_0^2 R_L = (2.94A)^2 (5\Omega) = \boxed{43.2\,W}$$

14.33

(+6) $f_1 = \dfrac{1}{2\pi(50 + R_{in})(1\times10^{-6}\,F)}$



$Z_{in} = (10K \,//\, 2.2K) \,//\, 201 r_e'$

- Stiff divider? $10K \,//\, 2.2K = 1.8K$ ✓
  $\frac{201}{100}\,1K = 2.01K$ ✓

$I_{EQ} = \dfrac{10\,\frac{2.2K}{12.2K} - 0.7}{1K} = 1.1mA \Rightarrow r_e' = \dfrac{.026V}{.0011A} = \underline{23.6\Omega}$

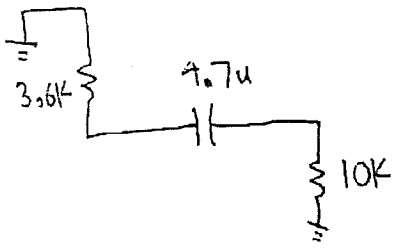
$\Rightarrow Z_{in} = 10000 \,//\, 2200 \,//\, 201(23.6) = \underline{1307\,\Omega}$

$\Rightarrow f_1 = \dfrac{1}{2\pi(50+1307)(10^{-6})} = \boxed{117.3\,Hz}$

14.34

(+3) $f_1 = \dfrac{1}{2\pi(3600+10000)(4.7\times10^{-6})}$

$= \boxed{2.49\,Hz}$



14.35

(+3) $f_1 = \dfrac{1}{2\pi\left[1000 \,//\, (23.6 + 0.24)\right](25\times10^{-6})}$

$= \boxed{273.4\,Hz}$

$\frac{50 \,//\, 1000 \,//\, 2200}{201} = 0.24\,\Omega$