Problem 1 – (30 points)

Solution

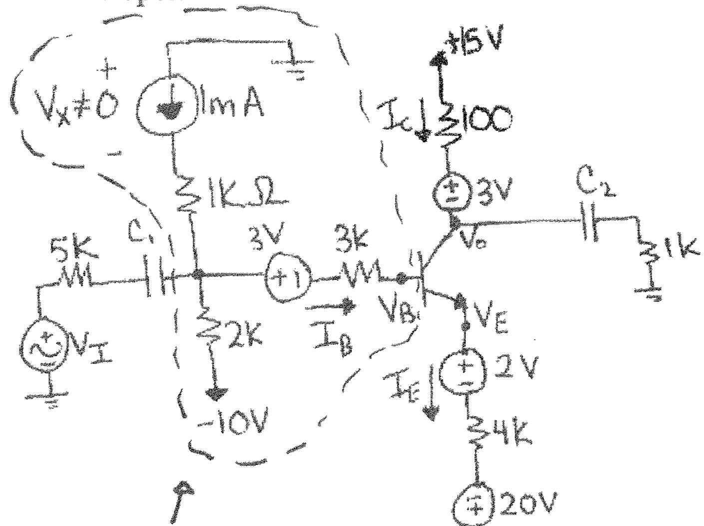
Use: **ignore r_o, $|V_{BE}|=0.7$, $\beta=100$**
$V_I = 20+0.001\sin(20t)$
For DC analysis, assume that the capacitors are open

(a) Solve for the DC currents:
  a. $I_B = 15.6\mu A$
  b. $I_E = 1.58mA$
  c. $I_C = 1.56mA$

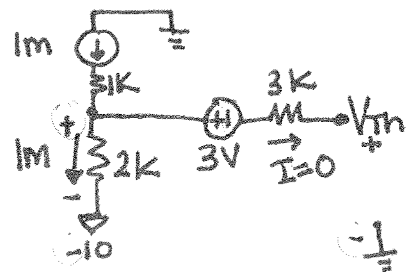
(b) Solve for the DC voltages:
  a. $V_B = -11.08V$
  b. $V_E = -11.78V$
  c. $V_o = +11.8$

(c) What region of operation is this transistor acting? ACTIVE

(d) Sketch the total instantaneous waveform observed for Vo if Vo/V$_I$=5V/V.



Take Thevenin at the base

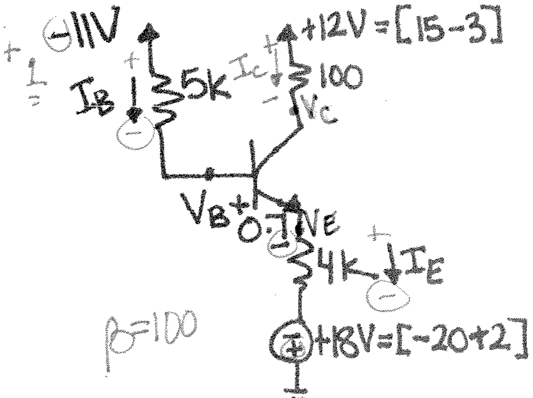


$$-10 + I(2K) - 3 - V_{Th} = 0$$

$$V_{Th} = -13 + 1m(2K) = -11V$$

$$R_{Th} = 3K + 2K = 5K$$

(Note that 1mA becomes an open)



$$-11 - I_B(5k) - 0.7 - I_E(4k) + 18 = 0$$

$$I_B = \frac{I_E}{\beta+1}$$

$$\frac{(+18-11.7)}{\frac{5K}{101}+4K} = I_E \approx \frac{6.3}{4k} \approx 1.58mA$$

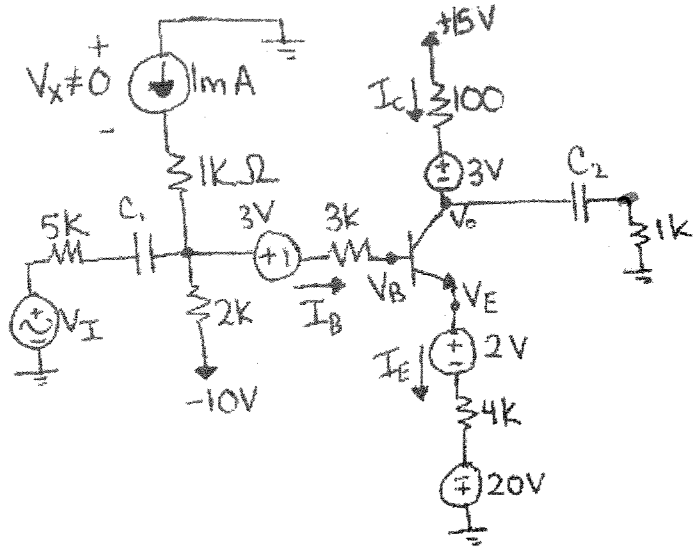
$$I_B = \frac{I_E}{101} = \frac{1.58m}{101} \approx 15.6\mu A$$

$$I_C = \beta I_B = 1.56mA$$

Problem 1: (extra page)

$-11 - I_B(5K) - V_B = 0$

$V_B = -11 - I_B(5K) = \underline{-11.08V}$



$V_E = V_B - 0.7 = \underline{-11.78V}$

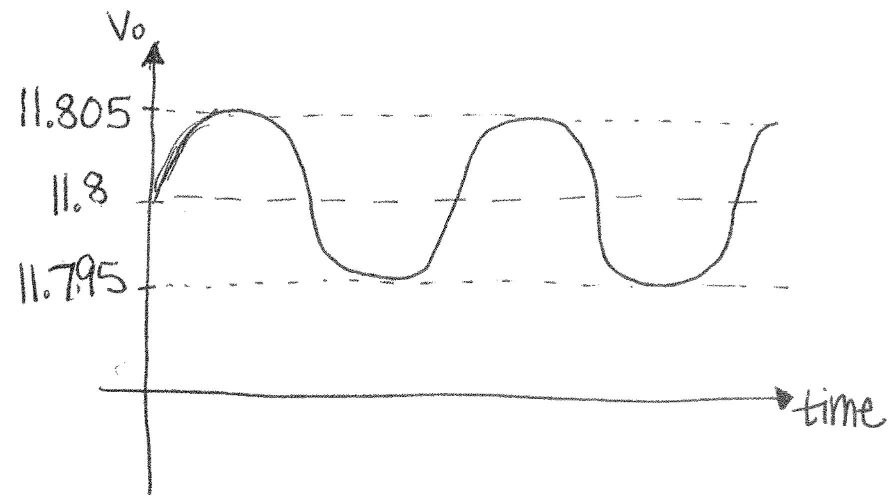
$V_C = +12 - I_C(100) = \underline{+11.8V}$

$V_C = V_o = 11.8 > V_B = -11.08$ ✓

∴ Acting in **Active Mode**

For $\frac{V_o}{V_I} = 5 V/V$ then $V_{oAC} = 1m(5)\sin(20t) = 5m\sin(20t)$

$V_{o\,total} = V_{oDC} + V_{oAC} = 11.8 + 5m\sin(20t)$

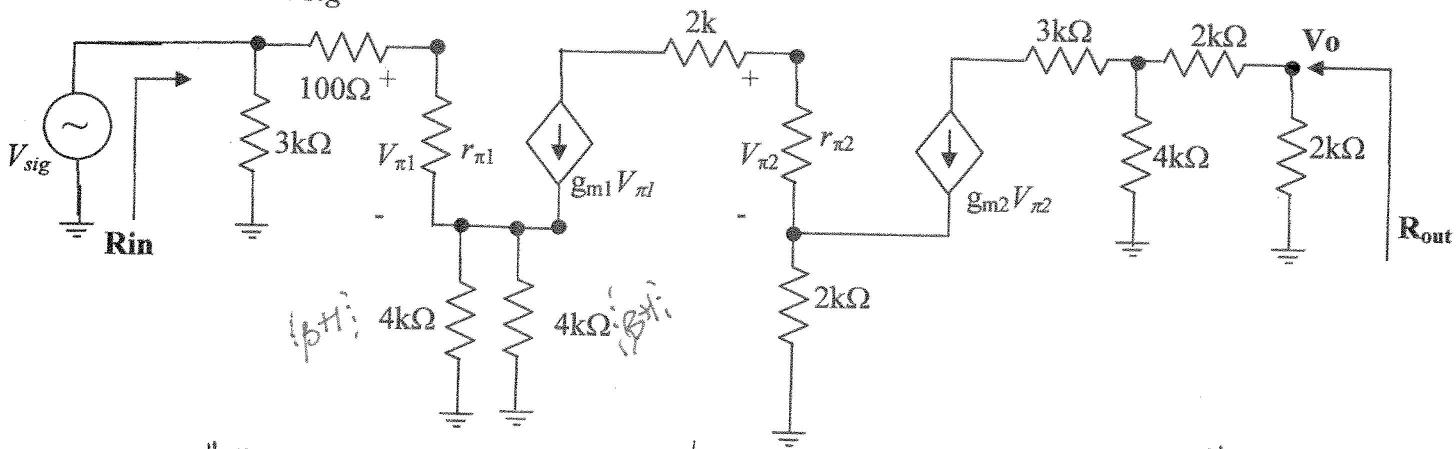


Problem 2 – **(30 points)**

Use: **ignore r_o and r_x, $|V_{BE}|=0.7$, $\beta=100$, $V_T=25mV$** $g_{m1}=\frac{\beta}{r_{\pi 1}}=\frac{100}{1{,}200}=83.3m$
$V_I = 10+0.002\sin(20t)$

$r_{\pi 1}=1{,}200$ $g_{m2}=25mA/V$, and $I_{B2}=$ 6.25μ; $r_{\pi 2}=\frac{\beta}{g_m}=\frac{100}{25m}=4K$ or $r_{\pi 2}=\frac{V_T}{I_B}=\frac{25m}{6.25\mu}$

For the following hybrid-π equivalent circuit below, find the following values:
(a) R_{in} (input resistance –ignore only the input source, Vsig and include all resistors at the base)
(b) R_{out} (output resistance-include **all** resistors at the collector{no load is connected})
(c) midband gain, $\frac{Vo}{Vsig}$



$R_{in}=3K\|[100+r_{\pi 1}+2K(\beta+1)]$
$R_{in}=3K\|203.3K=$ $\boxed{2.96K\Omega}$

$R_{out}=2K\|(2K+4K)=2K\|6K$
$\boxed{R_{out}=1.5K\Omega}$

$V_o=\left[\underbrace{\frac{-g_{m2}V_{\pi 2}(4K)}{4K+4K}}_{I}\right]\cdot 2K=-25m\cdot 1K\, V_{\pi 2}=-25V_{\pi 2}$

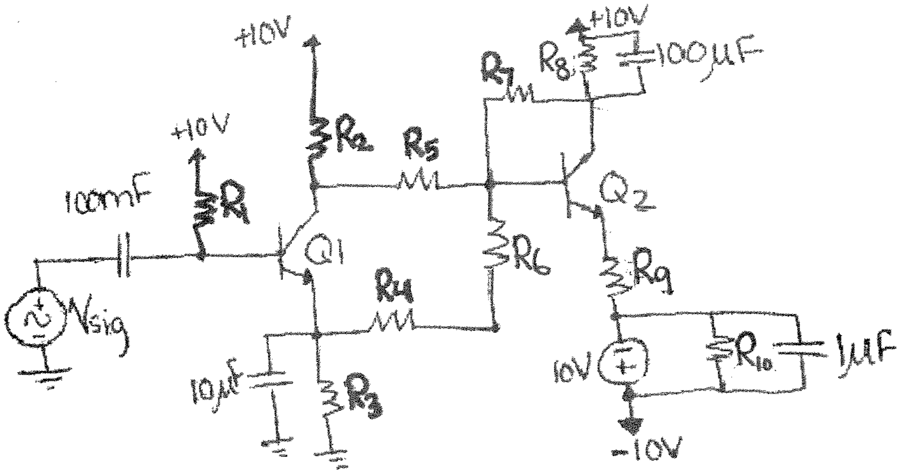
$V_{\pi 2}=-g_{m1}V_{\pi 1}\cdot r_{\pi 2}=-\underbrace{\frac{\beta}{1{,}200}}_{83.3m}\cdot V_{\pi 1}\cdot 4K=-333V_{\pi 1}$

$V_{\pi 1}=\frac{Vsig\,(r_{\pi 1})}{100+r_{\pi 1}+2K(\beta+1)}=\frac{Vsig\,(1{,}200)}{203.3K}=5.9m\,Vsig$

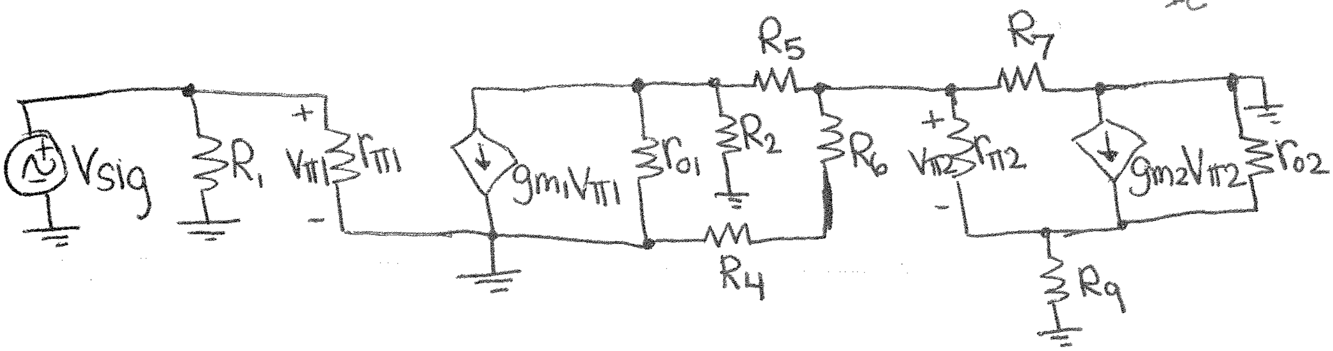
$\frac{V_o}{Vsig}=-25(-333)(5.9m)\,Vsig\cong\boxed{+49V/V}$

Problem 3 – (15 points)

For the circuit shown below, **draw** the AC small-signal equivalent circuit(use hybrid-π or model T). Make sure that everything is labeled in terms of the transistor number. (e.g. g_{m1}, $v_{\pi 2}$, etc.). **Include r_o for all transistors.** v_{sig}=0.001sin(10t) AC. Assume that the capacitors act as a short.

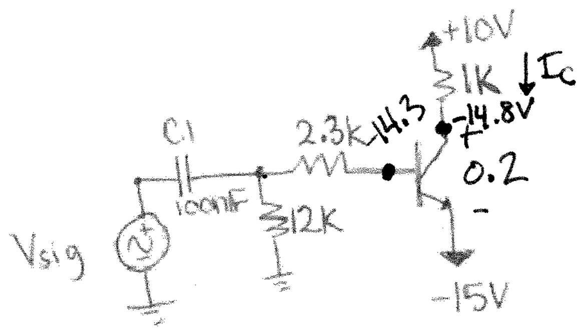


$r_o = \frac{V_A}{I_c}$



Problem 5

$|V_{BE}|=0.7$, $\beta=100$, $V_T=25mV$, ignore r_o, and r_x, $v_{sig}=\{2+0.1\sin(\omega t)\}$ Volts. Assume that the capacitor acts as an open for DC operation and short for AC operation. Does this circuit operate as a **linear** AC amplifier? If so, what is the gain, $\frac{Vo}{Vsig}$, of the following circuit? **If not, explain why**. Assume output is taken at collector of transistor. If in saturation, use the datasheet values to determine β_{forced}. $V_{CESAT}=0.2V$



$I_c = 100m = \beta I_B$

$I_B = \frac{14.3}{14.3K} = 1m$

$V_c = 10 - 1k(100m) = -90V.$!

$V_c < V_B$ ∴ Not ACTIVE

$I_B = 1m$, $V_B = -14.3V$

$I_c = \frac{10-(-14.8)}{1K} = \frac{24.8}{1K} = 24.8m$

$\beta_{forced} = \frac{I_C}{I_B} = \frac{24.8m}{1m} = 24.8 < 100$

∴ SAT