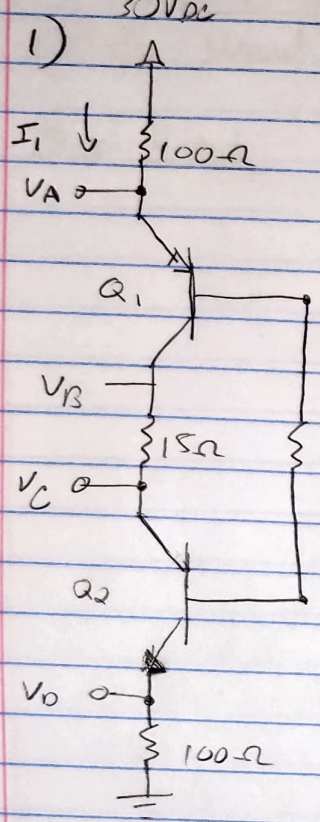
Electronics Extra Credit

1)



	β	V_{BE}	λ
Q_1	70	0.7	0.0
Q_2	120	0.7	0.0

So

KVL

$30 - 100 I_{E_1} - V_{EB_1} - 1K I_{B_2} - V_{BE_2} - \ldots$
$\ldots - 100 I_{E_2} = 0$

by the figure,

$I_{B_1} = I_{B_2}$

$i_{e_1} = i_{e_2}$

$I_{B_1} = \frac{i_{e_1}}{1+\beta_1} = \frac{I_{E_1}}{71}$ $\quad I_{B_2} = \frac{i_{e_2}}{1+\beta_2} = \frac{I_{E_2}}{121}$

then, $\frac{i_{e_1}}{1+\beta_1} = \frac{i_{e_2}}{1+\beta_2}$

$i_{e_2} = \frac{(1+\beta_2)}{(1+\beta_1)} i_{e_1}$

$i_{e_2} = \frac{(1+120)}{(1+70)} i_{e_1} \Rightarrow I_{e_2} = \frac{121}{71} I_{e_1}$

$30 = 100 I_{E_1} + V_{EB_1} + 1K I_{B_2} + V_{BE_2} + 100 I_{E_2}$

$30 = 100 I_{E_1} + 0.7 + 1K\left(\frac{I_{E_1}}{71}\right) + 0.7 + 100\left(I_{E_1}\frac{121}{71}\right)$

$30 = 1.4\, I_{E_1}\left(100 + \frac{1K}{71} + \frac{12100}{71}\right)$

$28.6 = I_{E_1}(284.5070422)$

$I_{E_1} = 0.100524\,A$

$V_A = 30 - I_{E_1} \cdot 100$

$V_A = 30 - 100(0.100524)$

$V_A = 19.9475\,V$

$V_B = 30 - I_{E_1}(100) - V_{EB}$

$V_B = 19.9475 - 0.2 = 19.7475\,V$

$V_C = V_B - I_{E_1} \cdot 15\Omega$

$V_C = 19.7475 - \left(\frac{\beta}{1+\beta} I_{E_1}\right) 15$

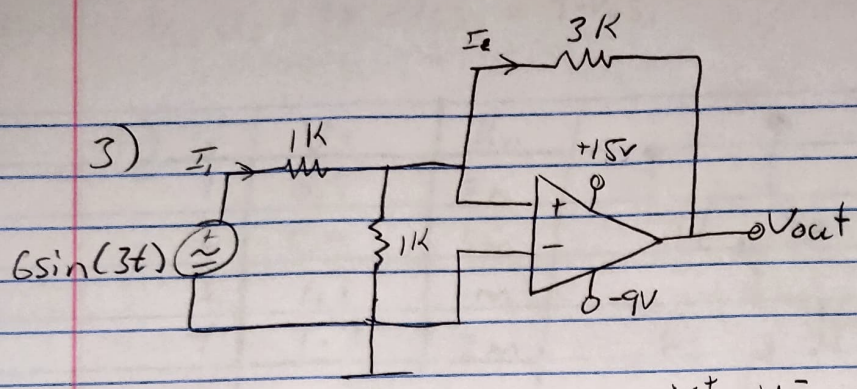
$V_C = 19.7475 - 1.4866$

$V_C = 18.260866\,V$

$I_{R15} = \frac{V_B - V_C}{15} = \frac{19.7475 - 18.260866}{15}$

$I_{R,C} = 99.1089\,mA$ two small, A?

3)



Find Vout over 1 full cycle

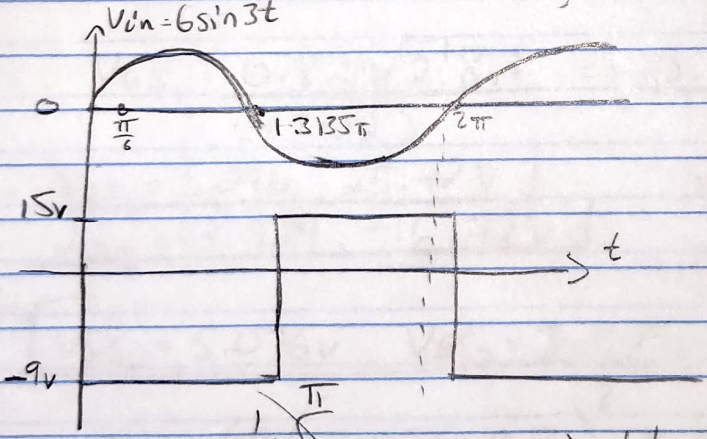
$V^+ = V^- = 0$

$I_1 = \frac{6\sin(3t)}{1K} = I_2$

$V_{out} = -3K\, I_2 = -3(6\sin(3t)) \Rightarrow V_{out} = -18\sin(3t)$

1) $V_o = 15 = -18\sin(3t)$, $\omega t = 3t = -56.44^\circ = 1.3135\pi$

2) $V_o = -9v = -18\sin(3t)$, $\omega t = 3t = 30^\circ = \frac{\pi}{6}$



$V_{out(AVG)} = \frac{15+(-9)}{2}$

$V_{out} = 3V_{avg}$

2) a) 4.488 V_{avg}

$V_{out_{avg}} = \frac{1}{2\pi}\int_0^{\pi} -18\sin(3t)\,dt$

$\frac{18}{2\pi} = \frac{9}{\pi}\cdot 3$

$\frac{27}{\pi}$

$= -\frac{18}{2\pi}\,3\cos(3t)\Big|_0^{\pi}$

$= -\frac{27}{\pi}\cos(\pi) + \frac{27}{\pi}\cos(0)$

$= +\frac{27}{\pi} + \frac{27}{\pi}$

$= 5.4/\pi$

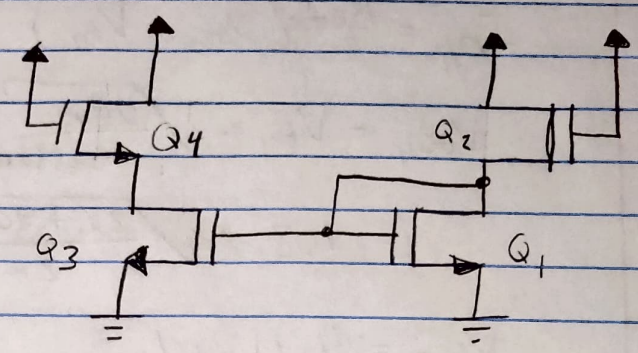
$= 1.7188\ V_{avg}$

$V_{GS}\,Q_4 = 12v = V_{GS4}$

$V_{GS}\,Q_2 = 9v = V_{GS_2} = 9 - V_{GS_1}$

4)

Q	V_T	K_n
1	0.8	2m
2	0.9	4m
3	1.1	1m
4	1.3	2m
I_2		
V_2		



$$I_{D_1} = I_{D_2} \Rightarrow \frac{K_{n_1}}{2}(V_{GS_1} - V_{t_1})^2 = \frac{K_{n_2}}{2}(V_{GS} - V_{t_2})^2$$

$$\frac{2m}{2}(V_{GS_1} - 0.8)^2 = \frac{4m}{2}(9 - V_{GS_1} - 0.9)^2$$

$$(V_{GS_1} - 0.8)^2 = 2(8.1 - V_{GS_1})^2$$

$$V_{GS_1} - 0.8 = \pm\sqrt{2}(8.1 - V_{GS_1})$$

$$V_{GS_1} = \frac{0.8 \pm \sqrt{2}\,8.1}{(1 \pm \sqrt{2})} = \frac{0.8 \pm 11.455}{1 \pm \sqrt{2}}$$

$V_{GS_1} = 5.076,\ 25.72\,V$

$V_{GS_2} = 3.924,\ -16.72\,V$

for NMOS $V_{GS} \geq V_t$

So, $V_{GS_1} = 5.076v,\ V_{GS_2} = 3.924v$

$$I_{D_1} = I_{D_2} = \frac{2m}{2}(5.076 - 0.8)^2 = 18.286\,mA$$

2_3 and 2_4 form a current mirror w/ 2_1 and 2_2

$$I_{D_3} = I_2 = \frac{K_{n_3}}{2}(V_{GS_3} - V_{t_3})^2$$

$$I_2 = \frac{1m}{2}(5.076 - 1.1)^2$$

(4) $I_2 = 7.905\,mA$

5 on back

$$I_{D4} = \frac{K_{n4}}{2}(V_{GS4} - V_{t4})^2$$

$$V_{GS4} = V_{t4} + \sqrt{\frac{2I_{D4}}{K_{n4}}}$$

$$= 1.3 + \sqrt{\frac{2(7.905mA)}{2m}}$$

$$V_{GS4} = \underline{4.112V}$$

$$V_2 = V_{G4} - V_{GS4} = 12 - 4.112V$$

$$\boxed{V_2 = 7.888V}$$