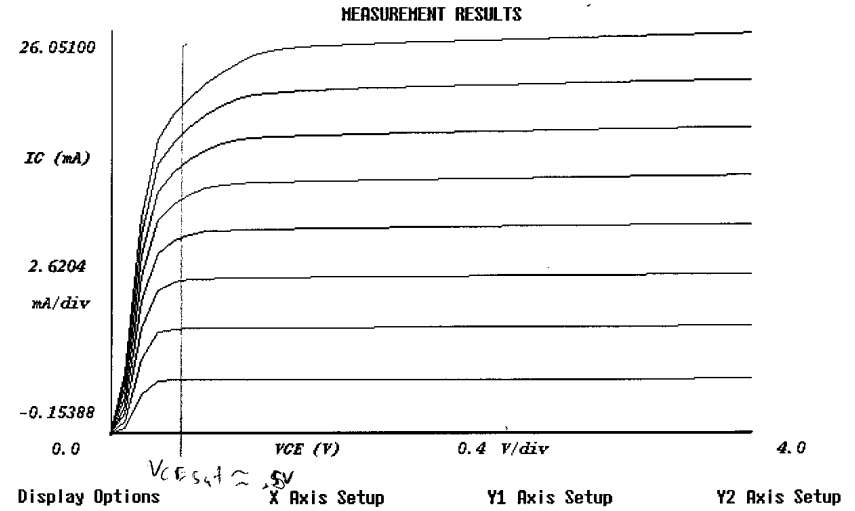
Pset #8 - 6.012

$I_S = 2.39 \text{ fA}$ using $I_S = \frac{I_C}{e^{\beta(V_{BE}/V_{TH})}}$

in constant current region

$\beta_R = 3.8$ (see plot)
$\beta_F = 175$ (see plot)
$V_{AF} = 136$ (see plot)

Output

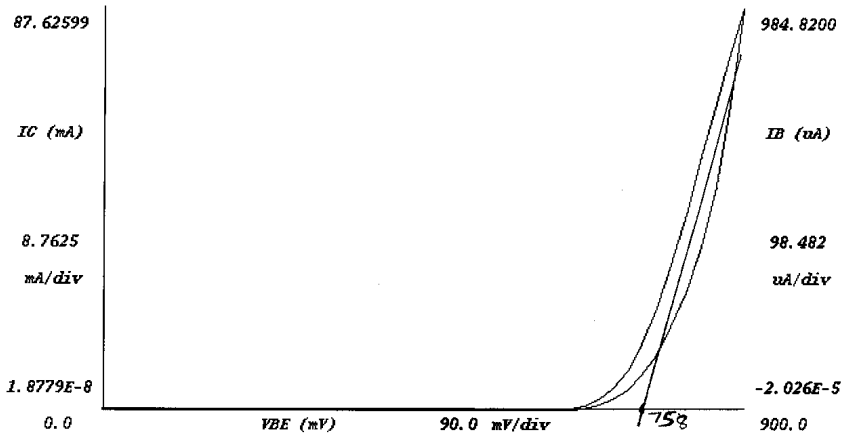


Display Options	X Axis Setup	Y1 Axis Setup	Y2 Axis Setup
Auto Scale	Variable VCE	Variable IC	Variable None
Y1 Axis Disp.	Max. 4.0	Max. 26.051	Max. 1.0
Accent Points	Min. 0.0	Min. -0.15388	Min. -1.0
See Data	Units ----	Units milli	Units Tera
Download Data	Scale Linear	Scale Linear	Scale Linear
Close Window	Value: ---	Value: ---	Value: ---

Unsigned Java Applet Window

Transfer

HEASUREMENT RESULTS

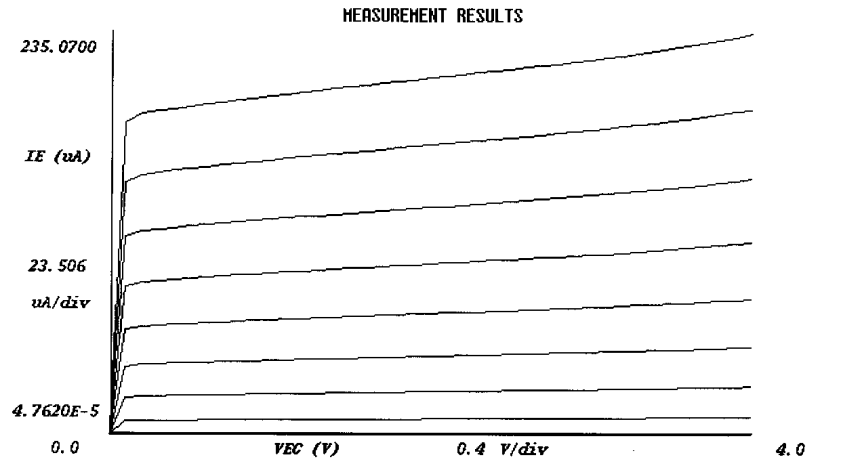


Display Options	X Axis Setup	Y1 Axis Setup	Y2 Axis Setup
Auto Scale	Variable VBE	Variable IC	Variable IB
Y1 Axis Disp.	Max. 900.0	Max. 87.62	Max. 984.8
Accent Points	Min. 0.0	Min. 1.878E-8	Min. -2.026E-5
See Data	Units milli	Units milli	Units micro
Download Data	Scale Linear	Scale Linear	Scale Linear
Close Window	Value: ---	Value: ---	Value: ---

Unsigned Java Applet Window

$V_{BE_{on}} = 758mV$

Reverse Output

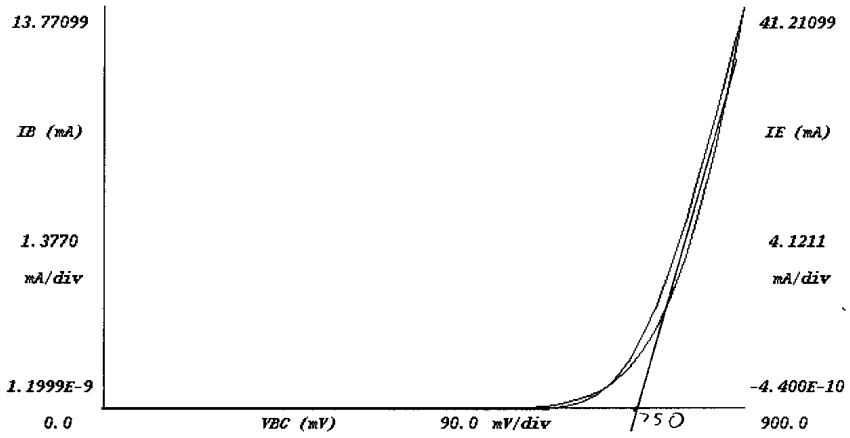


Display Options	X Axis Setup	Y1 Axis Setup	Y2 Axis Setup
Auto Scale	Variable VEC	Variable IE	Variable None
Y1 Axis Disp.	Max. 4.0	Max. 235.07	Max. 235.07
Accent Points	Min. 0.0	Min. 4.762E-5	Min. 4.762E-5
See Data	Units ----	Units micro	Units micro
Download Data	Scale Linear	Scale Linear	Scale Linear
Close Window	Value: ---	Value: ---	Value: ---

Unsigned Java Applet Window

Reverse Transfer

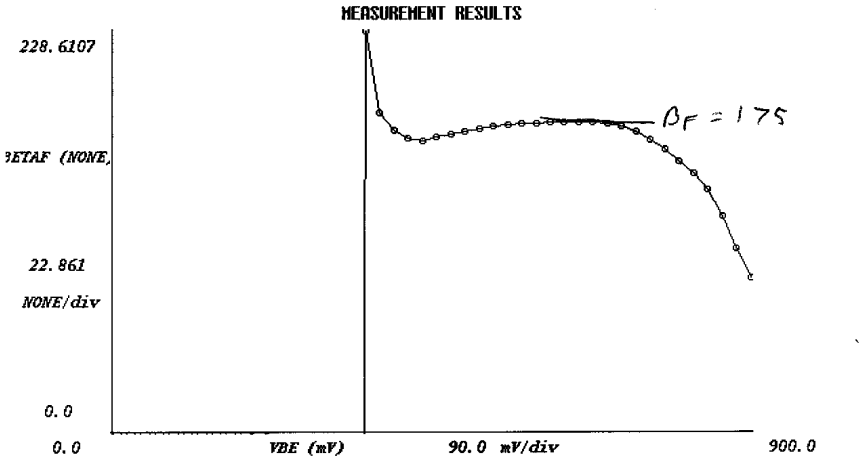
MEASUREMENT RESULTS



Display Options	X Axis Setup	Y1 Axis Setup	Y2 Axis Setup
Auto Scale	Variable VBC	Variable IB	Variable IE
Y1 Axis Disp.	Max. 900.0	Max. 13.771	Max. 41.211
Accent Points	Min. 0.0	Min. 1.2E-9	Min. -4.4E-10
See Data	Units milli	Units milli	Units milli
Download Data	Scale Linear	Scale Linear	Scale Linear
Close Window	Value: ---	Value: ---	Value: ---

Unsigned Java Applet Window

$V_{BC\,on} = 750$ mV

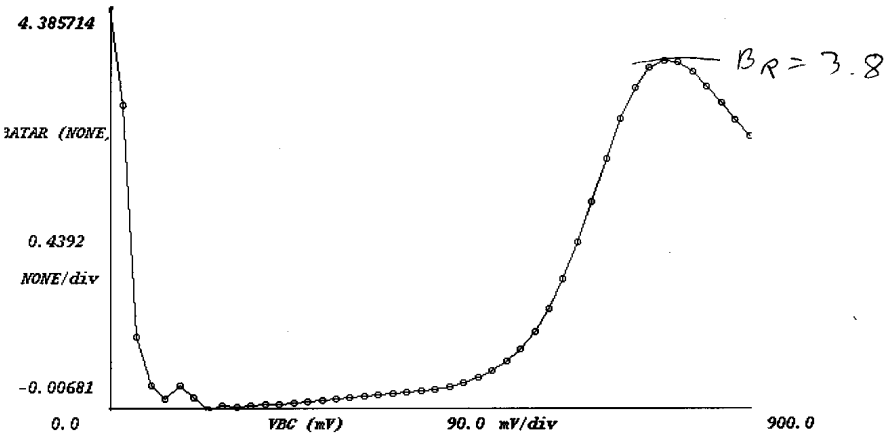


Display Options	X Axis Setup	Y1 Axis Setup	Y2 Axis Setup
Auto Scale	Variable VBE	Variable BETAF	Variable None
Y1 Axis Disp.	Max. 900.0	Max. 228.6108	Max. 986.96
Accent Points	Min. 0.0	Min. 0	Min. -2.365E-5
See Data	Units milli	Units ----	Units micro
Download Data	Scale Linear	Scale Linear	Scale Linear
Close Window	Value: ---	Value: ---	Value: ---

Unsigned Java Applet Window

using function $\beta_F = \frac{I_C}{I_B}$

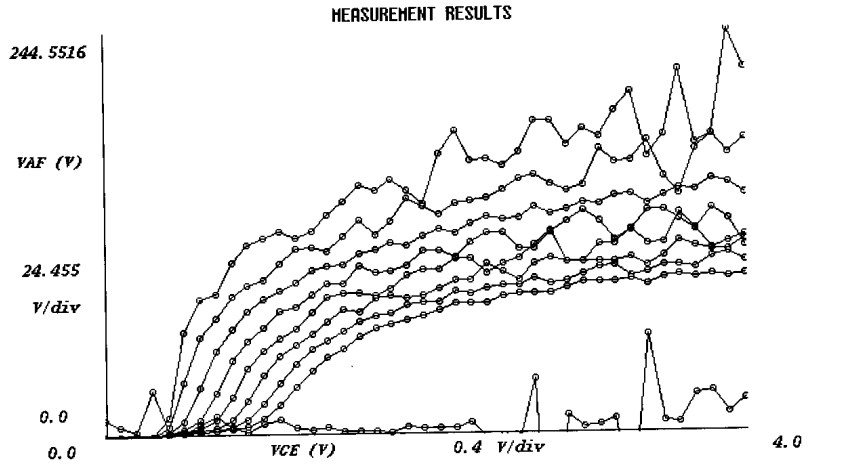
MEASUREMENT RESULTS



Display Options	X Axis Setup	Y1 Axis Setup	Y2 Axis Setup
Auto Scale	Variable VBC	Variable BATAR	Variable None
Y1 Axis Disp.	Max. 900.0	Max. 4.385714	Max. 41.211
Accent Points	Min. 0.0	Min. .006818534	Min. -4.4E-10
See Data	Units milli	Units ----	Units milli
Download Data	Scale Linear	Scale Linear	Scale Linear
Close Window	Value: ---	Value: ---	Value: ---

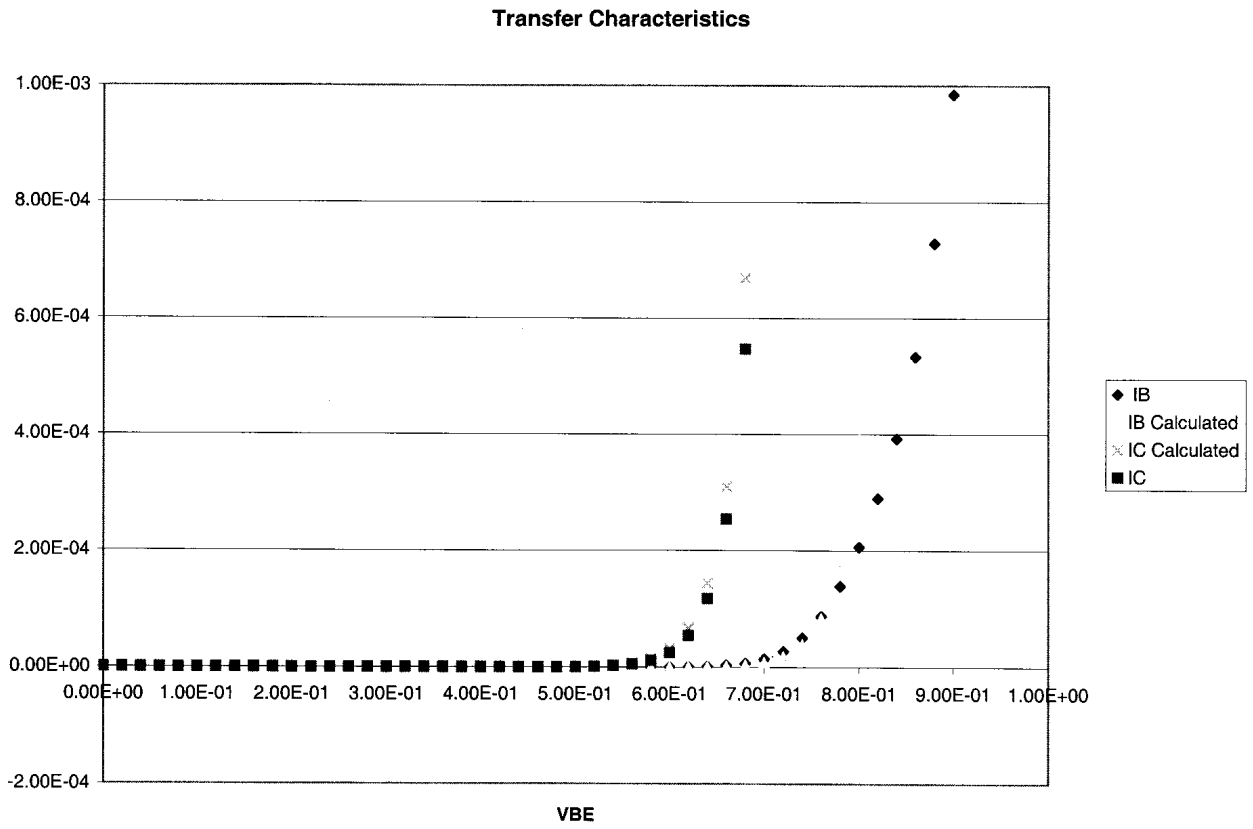
Unsigned Java Applet Window

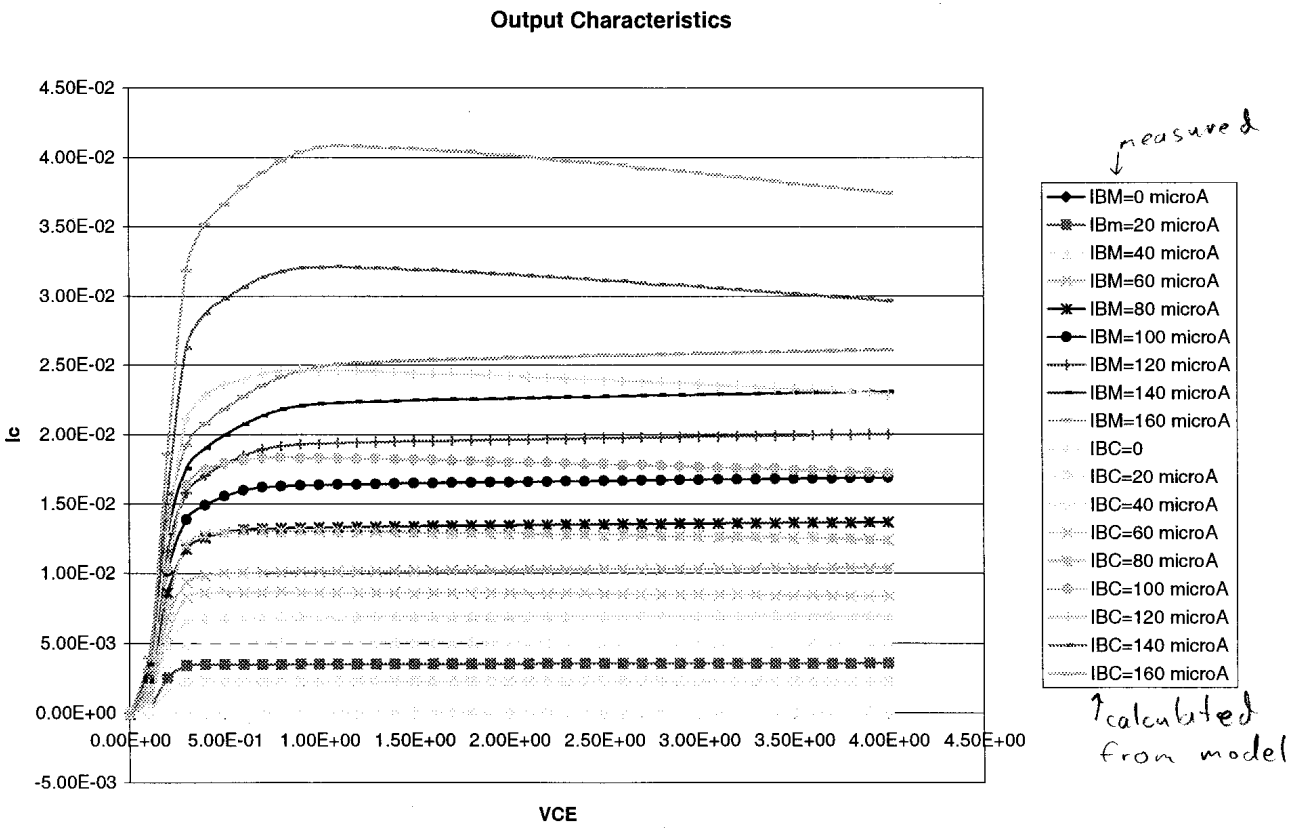
using function $\frac{I_E}{I_B}$



VAF = 136

Using Function $VAF = \frac{Ic}{\frac{\partial Ic}{\partial Vce}}$


Transfer Characteristics
1.00E-03
8.00E-04
6.00E-04
4.00E-04
2.00E-04
0.00E+00
-2.00E-04
0.00E+00
1.00E-01
2.00E-01
3.00E-01
4.00E-01
5.00E-01
6.00E-01
7.00E-01
8.00E-01
9.00E-01
1.00E+00
VBE
IB
IB Calculated
IC Calculated
IC


Output Characteristics
4.50E-02
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
-5.00E-03
Ic
0.00E+00 5.00E-01 1.00E+00 1.50E+00 2.00E+00 2.50E+00 3.00E+00 3.50E+00 4.00E+00 4.50E+00
VCE
measured
IBM=0 microA
IBm=20 microA
IBM=40 microA
IBM=60 microA
IBM=80 microA
IBM=100 microA
IBM=120 microA
IBM=140 microA
IBM=160 microA
IBC=0
IBC=20 microA
IBC=40 microA
IBC=60 microA
IBC=80 microA
IBC=100 microA
IBC=120 microA
IBC=140 microA
IBC=160 microA
↑calculated from model

Problem #2:

a) $V_{GS} = V_{Bias} - V_{SS}$

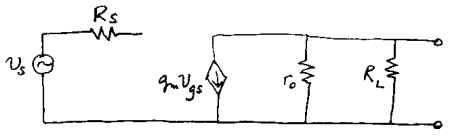
$$I_D = \frac{1}{2}\frac{W}{L}\mu_n C_{ox}\left(V_{GS} - V_{Tn}\right)^2 = I_{sup}$$

$$V_{GS} = V_{Tn} + \sqrt{\frac{2}{\mu_n C_{ox}}\frac{L}{W} I_{sup}} = 0.7 + \sqrt{\frac{2}{50\times10^{-6}}(0.01)(250\times10^{-6})}$$

$V_{GS} = 1.02$ Volts.

$V_{Bias} = V_{GS} + V_{SS} = 1.02 - 2.5 =$ **-1.484 volts**

b)



$R_{in} = \infty$

$R_{out} = r_o // R_L = 8.57\ k\Omega$

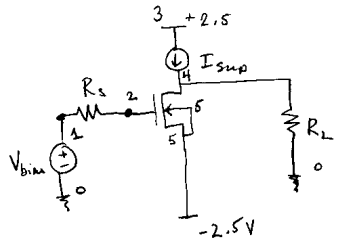
$A_{v_o} = -g_m(r_o) = -94.33$

$$r_o = \frac{1}{\lambda_n I_D} = \frac{1}{(0.067)(250\times10^{-6})} = 59.7\ k\Omega$$

$$g_m = \sqrt{2\mu_n C_{ox}\frac{W}{L} I_D} = \sqrt{2(50\times10^{-6})(100)(250\times10^{-6})} = 1.58\times10^{-3}\ S$$

c) $A_v = \frac{v_{out}}{v_s} = -g_m R_{out} = \underline{-13.54}$

d)

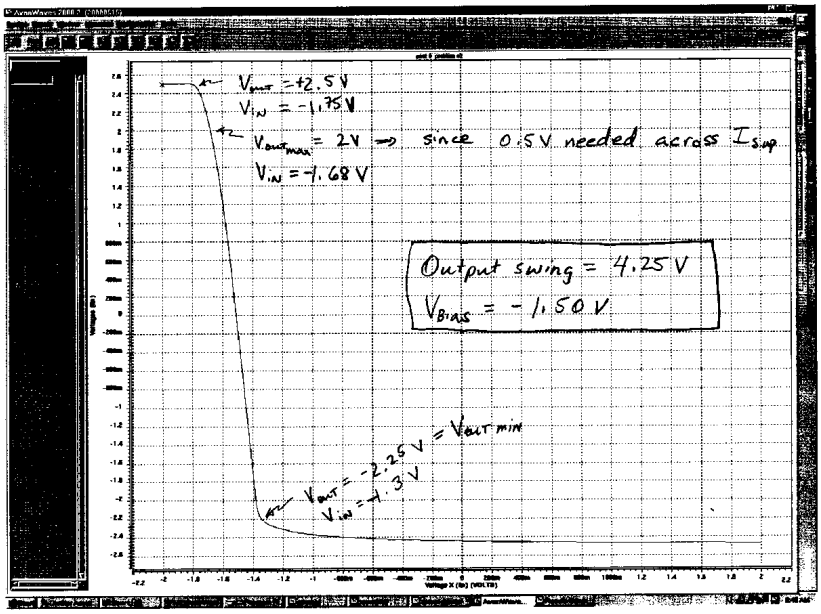


$V_{out_{max}} = 2.0$ V ← limited by 0.5 V across I_{sup}.

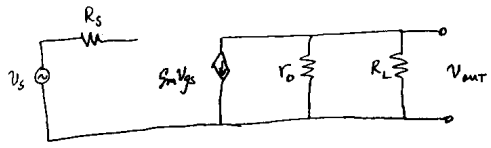
$V_{out_{min}} \sim -2.5$

Swing ~ 4.5 V

(e)



(f)



$V_{GS} = -1.50 + 2.5 = 1\ V$

$I_D = \frac{1}{2}\frac{W}{L}\mu_n C_{ox}\left(V_{GS} - V_{TN}\right)^2$

$I_D = \frac{1}{2}(100)(50\times10^{-6})(0.3)^2 = 225\,\mu A$

$g_m = \sqrt{2\mu_n C_{ox}\frac{W}{L} I_D} = 1.5\ mS$

$A_v = -g_m(r_o \| R_L) = \underline{-12.86}$