Answers for Tutorial 1:

Note: Vt = kT/q is assumed to be 26 mV for these answers.

1. 38.5 uA.
2. If Vd is the voltage across the series combination of the two diodes, Vt is kT/q, then:
   Id = sqrt(I_S1 I_S2) exp(Vd/(2Vt)).
3. A 50 Hz, 5 V amplitude source is to be used. The full wave bridge rectifier should have a load resistance of 6.5 Ohm, with a capacitor in shunt with the load. The cap should be at least 1.4 mF.
4. At steady state, output will be a constant voltage of 2V_in. (V_in was the amplitude of the input sinusoid.)
5. 0.25 mA.

Answers for tutorial 2:

Note: VT = kT/q is assumed to be 26 mV for these answers. Further I_C = I_S exp(V_BE/VT).

1. Units of alpha: A^2/V^2; beta: A/V; gamma: V/A; delta: V/A.
   r_bc = dVBC/dIB; K_bc = dVBC/dVAC; beta_ac = dIC/dIB; r_ac = 1/(dIC/dVAC).
   Small signal circuit has series combination of resistor r_bc and VCVS of K_bc times V_AC, between B and C. Between A and C there is the shunt combination of resistor r_ac, and CCCS of beta_ac times (-I_B).
2. 399 V.
3. V_BE is 0.833 V, I_B is 16.67 uA. I_C is 1.667 mA. RC should be 1.12 kOhm.
4. Gain of -72.
5. Input impedance of 1.54 kOhm. Output impedance of 1.12 kOhm.

Answers for tutorial 3:

Note: VT = kT/q is assumed to be 26 mV for these answers. Further I_C = I_S exp(V_BE/VT).

1. Min R_B is 7.4 kOhm (accurate), 7.7 kOhm (approx). If beta becomes 200, then for the same R_B, 1.8 V of collector-base forward bias will try to appear. Of course this will not happen and the maximum forward bias will be 0.7 V (V_C will never go below V_E, right?).
2. Min R_1 is 52.3 kOhm, R_2 is 23.6 kOhm. Max voltage at collector is 2.5 V. Min voltage at collector is 0.76 V.
3. R_1 of 35 kOhm, R_2 of 15 kOhm will make sure that the base current is 20x smaller than the current through R_1, R_2. Change in I_C is 5%.
4. Max R_2 is 20.3 kOhm.
5. Base of Q1 is at 1.51 V, emitter of Q1 is at 0.75 V, ICQ of Q1 is 1.58 mA, collector of Q1 is at 2.34 V. Base, collector of Q2 are at 0.75 V, emitter at 0 V, ICQ of Q2 = ICQ of Q1 = 1.58 mA.
6. R_B is 74 kOhm.

Answers for tutorial 4:

1. R_E = 940 Ohm, R_C = 4.7 kOhm, R_1 = 8.2 kOhm, R_2 = 51.8 kOhm.
2. Gain = 0.995. Max at emitter is 11.3 V, min at emitter is 0, quiescent is at 5.17 V. Max symmetric swing is between 0 and 10.34 V.
3. Gain = -1.9425. Max at collector is 12 V, min at collector is 7.1 V, quiescent is at 9.45 V. Symmetric swing is from 7.1 V to 11.8 V.
4. Gain = -119. If cap across 3.3 kOhm had not been there, the gain would be approximately -0.9. If R_C had been an inductor instead, V_E is needed for computing the gain. Assuming V_E of 10 V, the voltage gain would be -39600.

Answers for tutorial 5:

1. I_D is 0.1 mA. V_{DS} (Q) is 3 V. Output impedance of 20 kOhm. Voltage gain of - 20kOhm * 1mS = -20. Minimum voltage drain can go to is 0.2 V. Max voltage drain can go to is 5 V. Quiescent is 3 V. For symmetric swing the limits are 5 V and 1 V.
2. I_D is 0.1 mA; V_{SD} (Q) is 1.9 V. Output impedance of 18 kOhm. Voltage gain of -18. Max voltage at drain is 3.5 V. Minimum voltage at drain is 0. For symmetric swing the limits are 3.5 V and 0.1 V.
3. For R_D of 40 kOhm the device *does not* operate in the flat region.
4. I_D is 0.1 mA; V_{DS} (Q) is 4 V. Output impedance is 4.44 kOhm. Voltage gain is -1.28. Max V_{DS} is 4.39 V. Min V_{DS} is 0.6 V. For symmetric swing the limits are 4.39 V and 3.61 V.
5. I_D is 0.1 mA; V_{SD} (Q) is 1.2 V. Output impedance is 28 kOhm. Voltage gain is -28. Min drain voltage is 0 V. Max drain voltage is 3.52 V. For symmetric swing the limits for the drain voltage are 3.52 V and 2.08 V.
6. I_D is 5.625 mA for both devices, V_{DS} / V_{SD} for both devices is 2.5 V. Output impedance is 889 Ohms. Voltage gain is 13.3. The output cannot swing at all if both devices are to be maintained in their flat regions.

Answers for tutorial 7:

1. $-R2/R1 \frac{1 + s C1 R1}{1 + s C2 R2}$
2. v_E can be written as:
   $v_E = v_{in} \frac{g_m R_E A}{1 + g_m R_E + g_m R_E A}$
   As A tends to ∞, v_E becomes equal to v_{in}. This means current through R_E becomes v_{in}/R_E. Current through R_E is the same as current through R_C. Output voltage is therefore $-v_{in} R_C/R_E$.
3. $v(t) = A \cos(wt + phi)$ where $w = 1/(RC)$. A and phi are arbitrary constants of integration.
4. $A(s) = wu/s$; here the bandwidth can be expressed as $wu/(1+R2/R1)$.
   $A(s) = A/(1 + s/wp)$; here the bandwidth can be expressed as $wp(A + 1 + R2/R1)/(1 + R2/R1)$.
5. DC gain of 600, unity gain bandwidth of 6 MHz.
6. DC gain of 500, unity gain bandwidth of 5 MHz.

Answers for tutorial 8:

1.
    1. $(gm3\ rds3\ rds4) \| (gm2\ rds2\ (rds1 \| R))\ .\ gm1\ .\ (R \| rds1) / (R \| rds1 + 1/gm2)$
    2. $(gm3\ rds3\ rds4) \| (gm2\ (rds2 \| R)\ rds1\ )\ .\ gm1\ .\ rds1 / (rds1 + (R \| 1/gm2))$
    3. $(gm4\ rds4\ rds5) \| (gm3\ rds3\ (rds2 \| rds1))\ .\ gm1\ .\ (rds1 \| rds2) / ((rds1 \| rds2) + 1/gm3)$
    4. Ditto.
2. For the BJT current mirror, the following transcendental equation is to be numerically solved:
   $I_{out} R = v_T \ln (I_0 / I_{out})$
   For the MOS current mirror:
   $I_{out} = \frac{2R\sqrt{I_0 K} + 1 - \sqrt{1+4R\sqrt{I_0 K}}}{2 K R^2}$
3. V_{in} / R
4. $kT/q \ln (m/n)$

Answers for tutorial 9:

1. $- I_0 R_C \tanh(v/v_T)$
2. (a) Differential mode gain is $-gm(R \| rdsn \| rdsp)$
   Common mode gain is approximately $-1/(2\ gmp\ R0)$ where R0 is the output resistance of the current source.
   (b) Differential mode gain is approximately $-rdsp / R$.
   Common mode gain is approximately $-rdsp/(R + 2\ R0)$ where R0 is the output resistance of the current source.
3. $v_{out} / (v_1 - v_2) = gmn\ rdsn \frac{rdsp\ (1 + gmp(1/gmp \| rdsp))}{2\ rdsp + 2\ rdsn}$
   $v_{out} / (v_1 + v_2) = 0$; CMRR = infinite because common mode gain is 0.