Problem 1

Amp A: pretend $R_2$ is two $2R_2$ resistors in parallel.

$$G_m = \frac{g_m}{1 + g_m Z R_2} = \frac{1}{2 R_2} \quad R_0 = R_1,$$

so

$$A_{vdm} = -\frac{g_m Z R_1}{2}.$$

Amp B: Now instead of $R_{hi} = R_2$, it's $R_{o3}$

$$G_m = \frac{g_m}{1 + g_m Z R_{o3}} = \frac{1}{2 R_{o3}}$$

And we have a more complete expression for $V_{out}$:

$$V_{out} = V_{up} || V_{down} = \frac{V_{o3}}{2} \left(\frac{s}{s + \frac{1}{\tau_{o3}}} + \frac{g_{m3} Z R_{o3}}{g_{m3} Z R_{o3} + g_{m3} Z R_{o3} + g_{m3} Z R_{o3}}\right)$$

$$= \frac{V_{o3}}{2} \frac{1}{R_{o3}} = \frac{2}{8} V_{o3}.$$

Assuming all $g_m$ and $R_0$ values are equal...

$$A_{vcm} = -G_m R_0 = \frac{1}{2 R_{o3}} = \frac{2}{3} R_0 = \frac{1}{3}.$$

In differential mode, $G_m = \frac{g_m}{2}$ again and $R_0 = \frac{2}{3} R_0$

so

$$A_{vdm} = -\frac{1}{3} g_m R_0.$$
Amp C: \[ \text{Aucm} = \infty \] : ideal current source.

Now, MI\$'s degeneration impedance isn't just \( g_m \).

It will be \( Z = \frac{R_o + R_2}{g_m R_o} = \frac{2}{g_m} \).

So, \( G_m = \frac{g_m}{1 + g_m R_o} = \frac{g_m}{g_m + \frac{1}{2}} \).

And \( R_{out} = R_o \left( \frac{1}{R_m^2 + \frac{g_m^2}{2}} \right) \).

\[ R_{out} = \frac{R_o}{3 R_o} = \frac{2}{3} \]

\[ \text{Aucm} = -G_m R_o = \frac{g_m}{3} \cdot \frac{2}{3} R_o = \frac{2}{9} \frac{g_m}{R_o} \]

Amp D: It is common mode, the current mirror will enforce equal current in each side but that was true already. We can write directly: \( G_m = \frac{1}{R_o} \).

Output resistance we know from \( H_2 \) a \( R_2 \) already: \( \frac{R_o}{2} \).

So \( \text{Aucm} = -\frac{1}{R_o} \cdot \frac{R_o}{2} = -\frac{1}{2} \).

In differential mode, \( G_m = g_m \) thanks to the mirror. \( R_2 \) is the same. So, \( \text{Aucm} = -g_m R_2 \).
Problem 2: first part:

$V_0_1$ will result in a $V_0_2$ according to $A_{V_2}$.  
$V_0_2$ will result in a current through $C_c$, $V_2 - sC_c$.  
This current will be mirrored into $i_c$ in $I_1$.

$$i_c = V_0_1 \cdot A_{V_2} \cdot sC_c = -V_0_1 \cdot g_m \cdot R_{o_2} \cdot sC_c$$

Second part: Adding another current mirror stage flips the current direction with respect to $i_c$, so the new current is:

$$i_c = +V_0_1 \cdot g_m \cdot R_{o_2} \cdot sC_c.$$

$V_0_1$ experiences current draw proportional to $A_{V_2}$ and $sC_c$  
so it will still see a load that splits poles.

The RHP zero is eliminated.
Problem 3

The zero in the transfer function comes from the current through the compensation cap at some frequency, equaling, and canceling, the current generated by the second stage's gain.

In Fig. 9.21, the forward current remains to load the first stage like \( (1-A_{02})C_c \) but that current is kept from \( V_{O2} \) and thus doesn't interfere with \( g_{m2} \).

In Fig. 9.22, the first stage still receives \( C_c \) current through \( M11 \) but the block is on the 1st stage side; \( C_c \) current can flow back to \( V_1 \), but current from \( V_1 \) sees high-importance nodes so feed-forward again won't reach \( V_{O2} \).

In Fig. 9.23, feed-forward current again sees high-\( Z \) while \( C_c \) current can be easily added to \( V_{O1} \)'s path via the cascode node instead of at the 1st stage output.
Problem 4

If \( g m_3 = g m_7 = g m \) and \( C_e = 10 C_L \),
to get 90° phase margin, we want the amplifier's second pole to be at least 1 decade away from \( \omega_m \), so its phase effects are far away.

\[ \beta = \frac{g_m}{C_e} \]

Note: \( \beta' \) is feedback factor \( f \).

\[ C_e > 3 \]

\[ f \approx \frac{1}{10 \, R_{o2} \, C_L} \]

Assume \( 1 - A_v = 2 - A_v > g_m \, R_{o2} \):

\[ \frac{1}{C_e \, g_m \, R_{o2}} \approx \frac{1}{(10 \, R_{o2} \, C_L)} \rightarrow f \approx \frac{C_e}{10 \, C_L} = \frac{10 \, C_L}{10 \, C_L} = 1 \]

Codas like if \( g m_3 = g m_7 \) and \( C_e = 10 \, C_L \), then compensated amp should have PM = 90° when \( f = 1 \).
Problem 5

(a) If 1 diode passes 10 mA at 0.7 V, 10 diodes will pass 100 mA each at 0.90 V less or 0.90 - V.

(b) The voltage across T2 will be the same as the voltage difference between the two diodes: 0.90 V.

(c) $V_{D1}$ and $V_{D10}$ will trend as $-1.5 mV/K$, and the difference between them will end up as $V_T x (N) = \frac{kT}{q} \ln (i_0)$. Temp range is -33°C to +87°C, but just ±60°C is enough.

2. Room temp, $V_{D1} > 720 mV$, $V_{D10} > 640 mV$.

   $\rightarrow + 15 mV/10$ degrees Celsius, or $\pm 90 mV \approx 760 mV$.

   $V_T = \frac{kT}{q} \ln (i_0) = \frac{0.2 mV}{K}$

   $V_R = \frac{60 mV}{60 mV}$

2. Temp estimator, $V_T = 0.2 mV \cdot (300 - 60)$

   $= 72 mV \to 48 mV.$
Problem 6 (a)

We know $V_{ou} = 200\text{mV}$ and $V_{T} = 0.5\text{V}$, so, for M1A, $V_{gs} = V_{ds} = 700\text{mV}$. The current mixer will make currents in each branch equal, so we can guess is the same as M1A.

$V_{gs}$ for M2A is also 700mV, so that top-right node is $300\text{mV}$.

$$M1B = 4\times M1A; \text{ if current is the same then } V_{ou} \text{ is } \frac{5}{4} \text{v} \text{ or } 200\text{mV} \text{ less, or } 180\text{mV}. \text{ So we can conclude it } V_{gs} = 700\text{mV}, \text{ Vgs must be } 180\text{mV}.$$

(b) if $V_{r} = (100\text{mV})$ and $R = 10\text{k}\Omega$, $I_{z} = 10\text{mA}$, EES the current mixer will enforce $I_{t} = I_{z}$.

(i) $g_{m} = \frac{2I_{z}}{V_{gs}} = \frac{2 \times 10\text{mA}}{200\text{mV}} = 0.1\text{mS}$ (also $\frac{1}{2}$)

(d) $g_{m} = \frac{2 \times 10\text{mA}}{100\text{mV}} = 0.2\text{mS}$.

(e) As we reduce $V_{DD}$, $g_{m}$ of M1A will stay constant, so its $V_{ds}$ will stay at $700\text{mV}$. $V_{D}$ of M1B will also stay stuck at $200\text{mV}$. If we assume we need $V_{ou} \geq 100\text{mV}$ for strong inversion, $V_{DD}$ can be as low as 0.8V.

$V_{ou}$ before M2A drops out of saturation.