a) At low frequencies $C_L$ sees $R_{out}$ and the $C_p$ at the source of $V_g$ sees a resistance on the order of $r_0$.

Since $R_{out} \gg r_0$ (and since it is reasonable to assume $C_L \gg C_p$), the dominant pole will be $P_d = \frac{1}{C_L R_{out}}$.

At frequencies well beyond the dominant pole frequency, the resistance at the source of $V_g$ and $V_f$ looks like $\frac{1}{j \omega C_p}$.

The output will be shorted by $C_L$.

$\Rightarrow P_{nd} = \frac{\sqrt{\mu r_0}}{C_p}$
b) The total phase as a function of frequency, well beyond the dominant pole, is given by:

\[ -90° - \tan \frac{w}{\text{dominant pole}} \]

For \( w = GBW = \omega_d \cdot A_0 \cdot f = \frac{1}{C_L \cdot R_{out}} \cdot f \cdot \frac{g_{m2}}{C_L} \)

This phase is also equal to

\[ -180° + PM \]

(Where PM is the phase margin)

(Strictly speaking, the GBW is only the approximate frequency at which the (loop) gain becomes unity, but we will ignore the difference)

\[ \tan \ PM = \frac{\omega_d}{GBW} \]

So for \( PM > 60° \), \( \frac{\omega_d}{GBW} \geq \sqrt{3} = 1.73 \)
\[ A = \frac{1}{f} \frac{g_{u_{1,2}}} {g_{u_{1,2}}} \frac{C_L}{C_P} \geq \sqrt{3} = 1.73 \]

c) \[ A(s) = \frac{A_0}{(1 + \frac{s}{p_d})(1 + \frac{s}{p_{ud}})} \]

Closed loop gain \( a(s) = \frac{A(s)}{1 + f \cdot A(s)} \)

\[ a(s) = \frac{A_0}{1 + A_0 f} \frac{1}{1 + \frac{s}{(1 + fA_0)p_d} + \frac{s}{(1 + fA_0)p_{ud}}} + \frac{s^2}{(1 + fA_0)p_d p_{ud}} \]

\[ a(s) \propto \frac{A_0}{1 + A_0 f} \frac{1}{1 + \frac{s}{GBW} + \frac{s^2}{GBW \cdot p_{ud}}} \]

For \( PM = 60^\circ \): \( p_{ud} = \sqrt{3} \cdot GBW \)

And \( a(s) = \frac{A_0}{1 + A_0 f} \frac{1}{1 + \frac{s}{GBW} + \frac{s^2}{\sqrt{3} \cdot GBW}} \)
d) we can reformulate the closed loop gain as

\[ a(s) = \frac{a_0}{1 + \frac{\sqrt{3}}{\omega_u} s + \frac{s^2}{\omega_u^2}} \]

where \[ a_0 = \frac{A_0}{1 + f A_0} = \frac{1}{f} \left( 1 - \frac{1}{1 + A_0 f} \right) \]

\[ \omega_u = \sqrt{3} \; \text{GBW} \]

\[ s = \frac{1}{2} \; \sqrt{3} \; \omega_u < 1 \rightarrow \text{underdamped system} \]

\[ \Rightarrow \text{step response} \; (= L^{-1} \left( \frac{a(s)}{s} \right)) \]

\[ = \frac{1}{f} \left( 1 - \frac{1}{1 + A_0 f} \right) \left( 1 - \frac{e^{-\frac{\sqrt{3}}{2} \omega_u t}}{\sqrt{1 - \frac{3}{2} \omega_u^2}} \sin\left( \sqrt{1 - \frac{3}{2} \omega_u^2} \omega_u t + \varphi \right) \right) \]

\[ = \frac{1}{f} \left( 1 - \varepsilon_{\text{static}} \right) \left( 1 - \varepsilon_{\text{dynamic}} \right) \]

ideal closed loop gain

static error, due to finite loopgain at low frequencies

dynamic error, due to incomplete linear settling
\[ E_d = \frac{e^{-3\omega_n t}}{\sqrt{1-\delta^2}} \sin(\sqrt{1-\delta^2} \omega_n t + \phi) \]

\[ |E_d| \leq \frac{e^{-3\omega_n t}}{\sqrt{1-\delta^2}} = \frac{e^{-t \tau}}{\sqrt{1-\delta^2}} \]

\[ \tau = \text{time constant of the envelope of the settling error} \]

\[ = \frac{1}{3\omega_n} = \frac{2}{\sqrt{3} \text{ GBW}} \geq \frac{1}{\text{GBW}} \]