4.

a) $P_{elec}(s) = \dfrac{V_s(s)}{V_c(s)} = \dfrac{V_a}{V_c} \cdot \dfrac{I_c}{V_a} \cdot \dfrac{V_s}{I_c}$

$$\frac{V_a}{V_c} = 5 \qquad \frac{V_s}{I_c} = 5 \cdot R_s = 1$$

$$I_c = \frac{V_a - V_{emf}}{L_c s + R_c}$$

$V_{emf} = K_f X s$

$$F = K_f I_c = bXs + k_1 x + mXs^2$$

$$X = \frac{K_f I_c}{ms^2 + bs + k_1} \qquad \text{so, } V_{emf} = \frac{K_f^2 I_c s}{ms^2 + bs + k_1}$$

Thus, $\dfrac{I_c}{V_a} = \dfrac{1}{(L_c s + R_c)\left(1 + \dfrac{K_f^2 s}{(ms^2 + bs + k_1)(L_c s + R_c)}\right)}$

$$\boxed{\frac{V_s}{V_c} = \frac{5}{(L_c s + R_c)\left(1 + \dfrac{K_f^2 s}{(ms^2 + bs + k_1)(L_c s + R_c)}\right)}}$$

b) $P_{elec} = \dfrac{V_s}{V_c} = \dfrac{V_a}{V_c} \cdot \dfrac{I_c}{V_a} \cdot \dfrac{V_s}{I_c}$

$$= 5 \cdot \frac{1}{L_c s + R_c} \cdot 1$$

$$= \boxed{\frac{5}{L_c s + R_c}}$$

c) At high frequencies, both transfer functions will be the same because $\lim_{s \to \infty} \dfrac{K_f^2 s}{(ms^2 + bs + k_1)(L_c s + R_c)} = 0$

Thus, any affect $V_{back\,emf}$ has disappears

d) To obtain DC gain of $G_u = -0.5$ A/V, set $s=0$ for C.L. TF

so,

$$\frac{-R_2}{R_1} \cdot \frac{1}{1+L} \cdot 5R_s \Rightarrow \frac{R_2}{10{,}000} \cdot 0.2 = \frac{1}{10}$$

$$\boxed{R_2 = 5{,}000\,\Omega}$$

To obtain a gain cross over frequency of $w_c = 6\times10^5$ rad/sec, we set the zero of C_{elec} a decade before desired w_c and the pole of C_{elec} a decade after desired w_c.

Therefore,

$$\boxed{\begin{aligned} R_3 &= 121{,}000\ \Omega \\ C_1 &= 1.3\times10^{-9}\ F \\ C_2 &= 1.3\times10^{-12}\ F \end{aligned}}$$