Problem 1 (20 points)

You must show your detailed work to get full credit.

For the Wheatstone bridge circuit shown in Fig.1, solve the following problems:

(a) Express I_a, the reading on the ammeter, as a function of all the circuit elements R_1, R_2, R_3, R_x, R_a and V_0.

(b) If $R_1 = 1\Omega$, $R_2 = 2\Omega$, and $R_x = 3\Omega$, to what value should R_3 be adjusted so as to achieve a balanced condition, that is, $I_a = 0$?

(c) Further, if $V_0 = 6\text{V}$, $R_a = 0.1\Omega$, and R_x were then to deviate by a small amount to $R_x = 3.01\Omega$, what would be the reading on the ammeter?

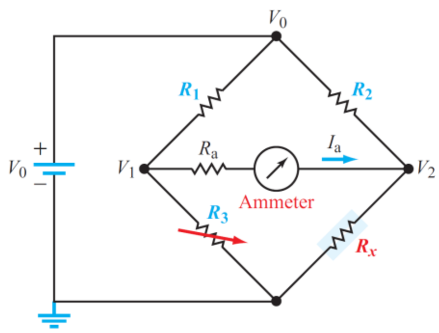

Fig. 1 for Problem 1.

Problem 2 (15 points)

You must show your detailed work to get full credit.

The circuit shown in Fig. 2 contains a variable load R_L.

(a) Choose R_s so that I_L never exceeds 4mA, regardless of the value of R_L.

(b) Given that choice, what is the maximum power that R_L can extract from the circuit?

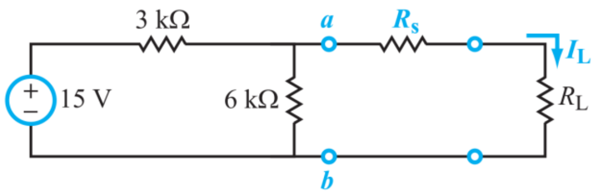

Fig. 2 for Problem 2.

Problem 3 (20 points)

You must show your detailed work to get full credit.

For the circuit shown in Fig. 3, assume the op amp is ideal. Given $v_{\text{in}} = A\,u(t)$, $A = 6\text{V}$, $R_1 = 10\ \text{k}\Omega$, $R_2 = 5\ \text{k}\Omega$, $R_f = 50\ \text{k}\Omega$, and $C_1 = C_2 = 1\ \mu F$, determine $v_{out}(t)$ for $t \geq 0$.
Hint: There is no energy stored in the two capacitors at time $t = 0$.

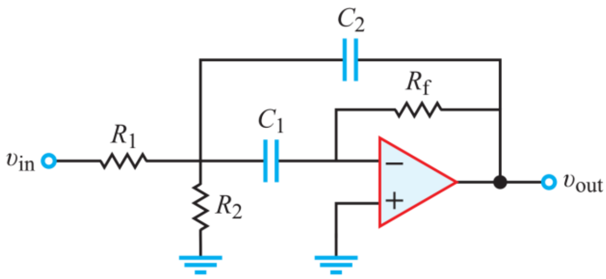

Fig. 3 for Problem 3.

Problem 4 (15 points)

You must show your detailed work to get full credit.

Determine the amount of average power delivered to R_L in the circuit shown in Fig. 4. Assume that the op amp is ideal and $v_{\text{in}}(t) = 0.5\cos 2000t$ V, $R_1 = 1$ kΩ, $R_2 = 10$ kΩ, C $= 0.1$ μF, $R_L = 1$ kΩ and $L = 0.2$ H.

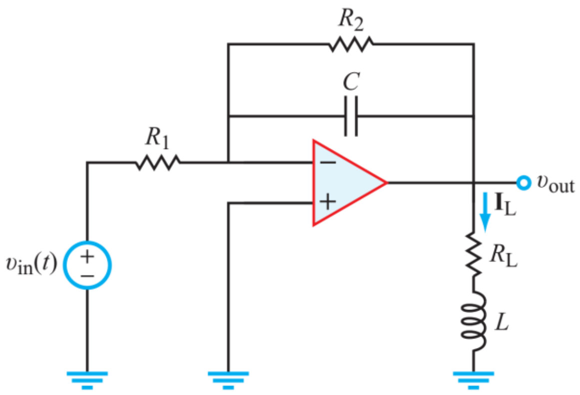

Fig. 4 for Problem 4.

Problem 5 (15 points)

You must show your detailed work to get full credit.

For the circuit shown in Fig. 5,

a) Find the steady-state expressions for the currents i_g and i_L when $v_g = 168\cos 800t$ V.

b) Find the coefficient of coupling $k = \frac{M}{\sqrt{L_1 L_2}}$.

c) Find the total energy stored in the magnetically coupled coils at time $t = 1250\pi$ μs.

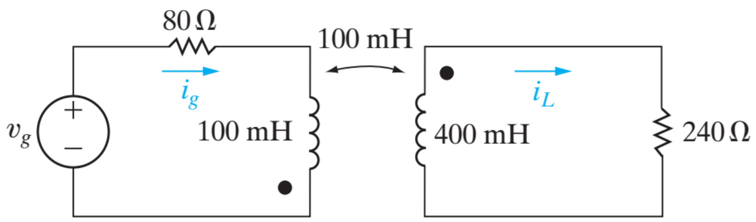

Fig. 5 for Problem 5.

Problem 6 (15 points)

You must show your detailed work to get full credit.

For the series RLC circuit of Fig. 6, $R = 5\ \Omega$, $L = 20$ mH, $C = 0.5$ μF.

(a) Obtain an expression for the transfer function $\mathrm{H}(\omega) = \mathrm{V_R}/\mathrm{V_s}$.

(b) What are the values of the resonant frequency ω_0 and quality factor Q?

(c) What are the values of half-power frequencies ω_{c1} and ω_{c2}?

(d) Is it possible to double the magnitude of Q by changing the values of L and/or C, while keeping ω_0 and R unchanged? If yes, propose such values, and if no, explain why.

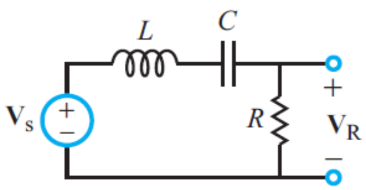

Fig. 6 for Problem 6.