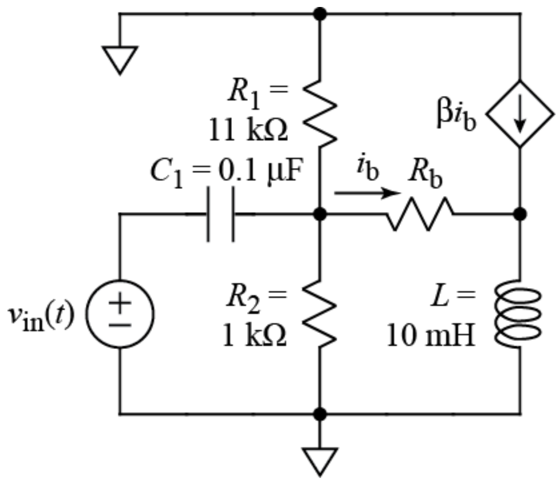
Homework 17

1. The circuit shown below is the small-signal model of an emitter follower incorporating an npn transistor (modeled by R_b and source βi_b). The input voltage in practice would be something like a music waveform. The capacitor couples the input to the input of the transistor, which is biased by R_1 and R_2 and a DC power supply that disappears in the small-signal model, (think superposition). The L represents a speaker coil (which has an impedance value that will look familiar to those who have worked with audio systems).



Note: $v_{in}(t) = 300\cos(800t)\,\text{mV}$

a) The value of R_b for the small-signal model is found by linearizing the current-versus-voltage curve for a diode in the npn transistor. The equation for the diode is as follows:

$$i_D = I_0\left(e^{v_D/v_T} - 1\right)$$

where $I_0 = 0.010$ pA is the reverse saturation current of the diode

$v_T = kT/q = 26$ mV at room temperature

$v_D =$ voltage across diode

$i_D =$ current in diode

The above values are deduced from a data sheet for a standard 1N914 diode (rather than an npn transistor). The URL for the diode data is http://www.mouser.com/ds/2/149/1N914-192459.pdf.

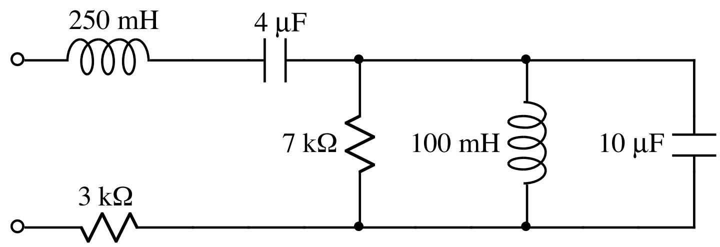
The formula for R_b is based on the slope of the nonlinear diode equation at an operating point of 0.7 V across the diode:

$$R_b = \frac{1}{\left.\frac{di_D}{dv_D}\right|_{v_D=0.70\,\mathrm{V}}}$$

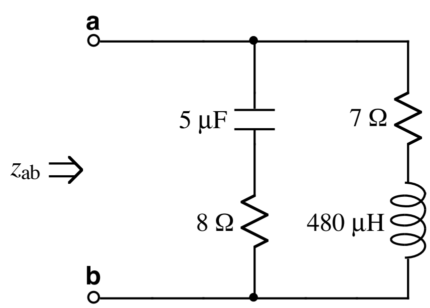
Using the above formula, find the value of R_b.

b) Draw the frequency-domain circuit diagram (with numerical values for impedances and phasors [except the dependent source which is a multiple of the dependent variable]) for the circuit shown above.

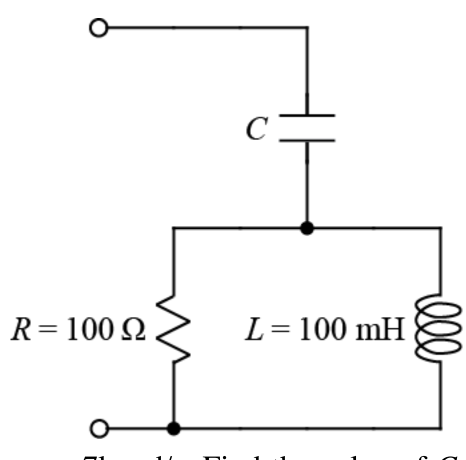
2. a) Find the total impedance of the circuitry shown below if $\omega = 1000$ rad/s.



b) Given $\omega = 50$ k rad/s, find z_{ab}.

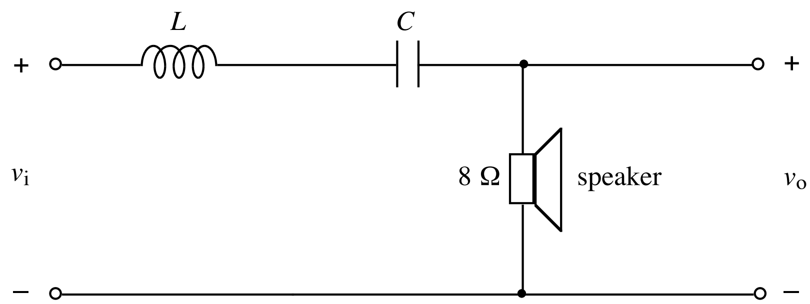


3.



Given $\omega = 7$k rad/s, Find the value of C that makes the total impedance of the above circuit real. You may round off the value of C to the nearest standard value.

4.



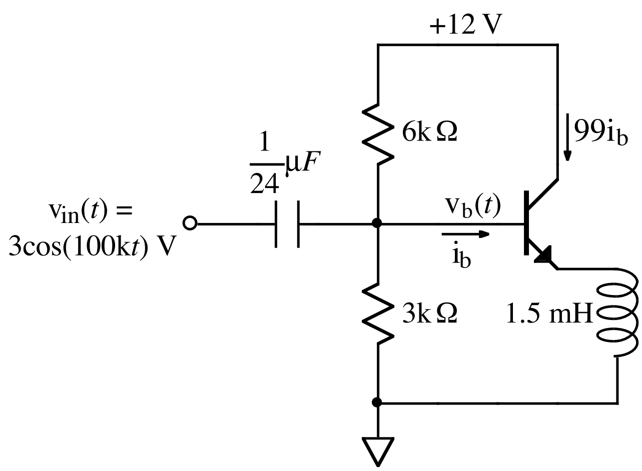
The above circuit is part of a simple crossover network for driving a midrange speaker having an impedance of 8Ω. The circuit is described at the following web site: http://www.termpro.com/articles/xover2.html. A more in-depth discussion of crossover networks may be found at http://sound.westhost.com/lr-passive.htm.

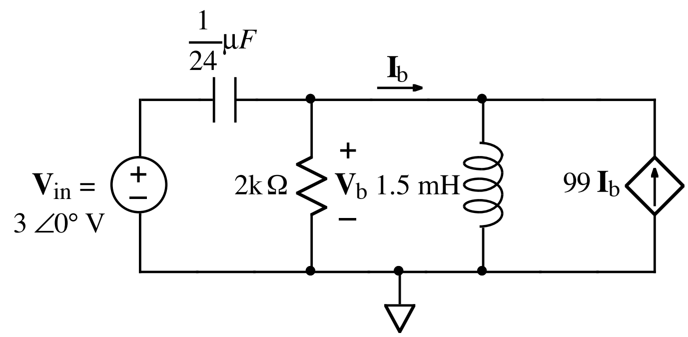
The web site describing the above bandpass filter suggests using cutoff frequencies of f_{C1} = 130 Hz and f_{C2} = 4 kHz. This results in the following values of L and C.

L = 330 μH $\qquad\qquad$ C = 150 μF

Plot $|V_o/V_i|$ versus ω.

5.





The above circuit diagrams show an emitter-follower amplifier and its high-frequency equivalent circuit. Find $v_b(t)$.

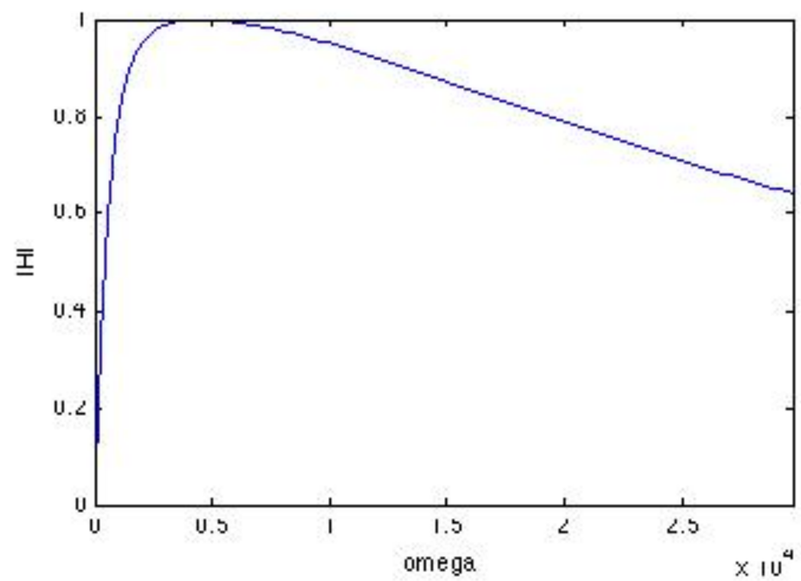
Answers:

1.a) $R_b = 5.28\ \Omega$ b) $z_C = -j12.5\text{k}\ \Omega$, $z_L = j8\ \Omega$, $\mathbf{V}_{in} = 300\angle 0°\,\text{mV}$

2.a) $z_{tot} = 10\ \text{k}\Omega$ b) $z_{ab} = 4\sqrt{5}\angle -6°\,\Omega$

3. $C = 10\ \mu\text{F}$

4.



5. $v_b(t) \approx 3\cos(100\text{k}t + 7°)$ V