Physics 4700 HOMEWORK V

Due March 15

Note: All sub-parts are worth 5 points each. Use Mathematica to test your answers for parts c and d. Add your Mathematica work to the solution

1. The following problem is designed to familiarize you with the concept of amplitude modulation. This concept is obviously crucial to the understanding of the AM radio you are about to build. The general expression for an Amplitude Modulated voltage is:

$$V(t) = (1 + acos\omega_m t)(cos\omega_c t)$$

In this expression ω_c is the carrier frequency, ω_m is the modulating frequency and a is the amount of modulation ($0 < a < 1$). For the AM radio example the carrier frequency, ω_c, is high frequency (hundreds of kHz) while the modulating, ω_m, frequency is low frequency (audio frequency, 20-20 kHz).

   a. Make a sketch of V vs. t assuming $\omega_m = 1$ kHz, $\omega_c = 10$ kHz, $a = 1$.

   b. Show that V can be written in the following form which contains 3 different frequencies. Relate ω_1, ω_2, and ω_3 to ω_m and ω_c:

$$V(t) = \cos(\omega_1 t) + \frac{1}{2}\cos(\omega_2 t) + \frac{1}{2}\cos(\omega_3 t)$$

   c. Show that for small voltages (V) the Ebers-Moll (or Diode) equation for current (I) has the form:

$$I = \alpha V + \beta V^2$$

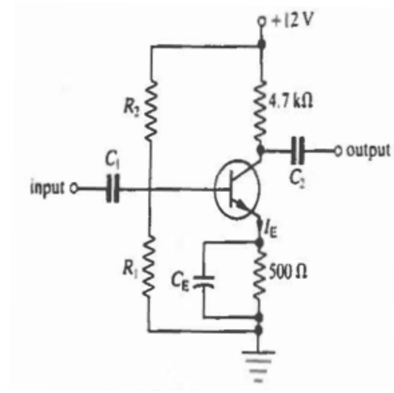
   with α and β constants.

   d. Assume that the current is given by the expression in part c) and the voltage is given by the expression in part b). Show that the resulting current has a term that depends linearly on $\cos\omega_c t$ and a term that depends linearly on $\cos\omega_m t$ (it also has lots of other terms!).

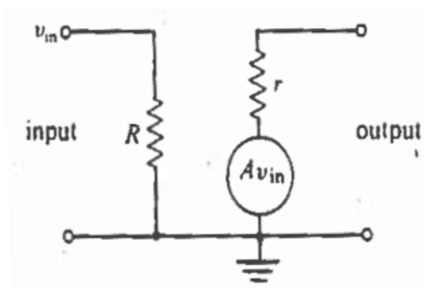
   e. Remembering that the base-emitter junction of a transistor acts like a diode, use the results of part d) to describe how a high frequency AM signal gets demodulated (turned into high and audio frequencies) in the radio you will be building in lab.

   f. Again, considering the AM radio you are to build, what happens to these high frequency and audio terms, i.e. which frequency(s) are amplified and which are filtered out? What component(s) do the filtering?

2. Assume $R_1 = 4\ \text{k}\Omega$ and $R_2 = 31.6\ \text{k}\Omega$,
    a. Calculate the AC voltage gain.
    b. Estimate the input and output impedances.

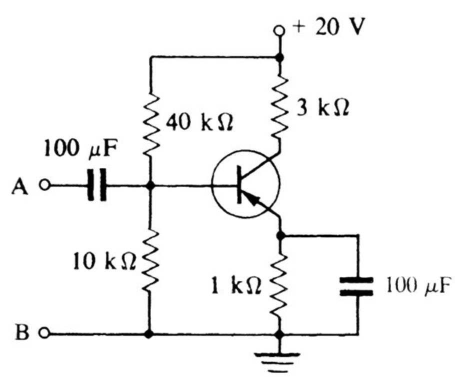


3. In a simple equivalent circuit shown, assume that there is a resistor R_L across the output and calculate
    a. current gain
    b. voltage gain

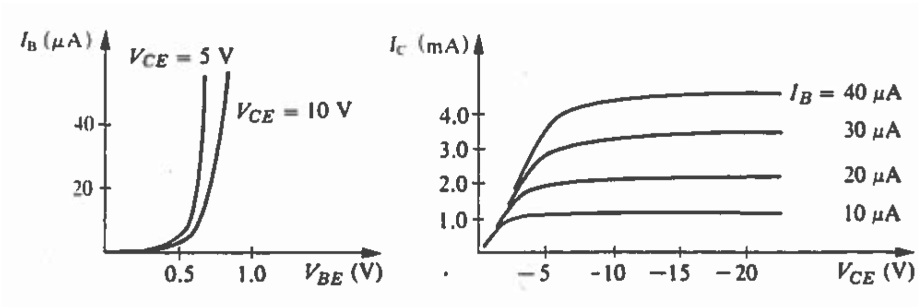


Note: This is a PNP transistor and not a NPN transistor as used in the lab.

4. Calculate the DC and AC voltage gain of the amplifier. Assume $R_L = 1\ \text{M}\Omega$, $h_{ie} = 2\ K\Omega$, $h_{re} = 10^{-4}$, $h_{fe} = 100$, $h_{oe} = 10^{-5}\ mhos$. Note: R_L is not shown in the figure.



5. For the transistor with input and output characteristics curves shown below,
   a. Calculate the four h parameters and β if the DC operating point is $I_c = 2\ mA, V_{CE} = 10\ V$.
   b. As the collector current is increased, how do h_{fe} and h_{oe} change?
   c. Compare h_{fe} with $\beta = \alpha/(1-\alpha)$.
   d. Explain why V_{CE} at the operating point should be greater than (1 mA, 1 V).



6. Simulate the common emitter amp that you built in lab using EasyEDA. Do a transient and an AC analysis on the circuit. How does the simulation's voltage gain compare with the gain of the amp that you actually built? For the transient analysis assume that V_{in} is a sine wave with f = 1 kHz and amplitude 10 mV.