A) **Estimate the value of R1** so that $V_o = 0$. Assume that all transistors have $V_{BE} = 0.7$, and Beta = infinity. (Hint: It is sufficient to find R1 so that $V_{BE5} = 0.7$)

B) Given Beta = infinity, $V_{BE} = 0.7$, and $V_o = 0$, find $I_c5$.

C) **Find the gain of the OP AMP**. $GAIN = \frac{V_o}{V_{in}}$. (Hint: You will need to find the $g_m$'s of the transistors first.)

**Assume $\beta = 50$ for all transistors in part C**
2) Show below is a differential amplifier. Q1, Q2 and Q5 form the amplifier, while Q3 acts as an emitter follower. Current is supplied to Q3 by Q6. The diodes are added to provide a voltage drop of 1.4 volts so that the quiescent output voltage, $V_o(t)$, can be set to 0 volts. Q4, Q5 and Q6 form current mirrors.

**SPECIFICATIONS:**

- $V_{CC} = 10 \text{ V}$
- $V_{EE} = -10 \text{ V}$
- $I_{CC} = 6 \text{ mA}$
- $V_o$ (quiescent voltage) = 0 V
- All transistors are in their **ACTIVE REGION**

A) Find $R_R$ ($\text{Assume } B = \infty$)
B) Find $R_c$
C) Find gain $= \frac{V_o}{V_i}$ ($\text{midband}$)
D) Find the common mode voltage range. The answer is approximate. Justify your answer either with equations or words.