ENEL 469: Analog Electronic Circuits
Quiz-4, Fall 2023
Total marks: 31;   Time: 11:00 am – 12:15 pm

ID (Optional)	First Name (PRINT)	Last Name (PRINT)

1. [**Total 2 x 8 = 16**] Circle the correct answer.
   a) Is the following statement true or false? A power amplifier connected to a speaker needs more voltage amplification than the current amplification at its output stage.
   True / False

   b) Which of the following statements is/are correct? Circle the correct answer or answers if more than one is correct.
      i) For a class-B amplifier, the operating point must be set at the boundary between the saturation and active regions.
      ii) For better accuracy in a class-B amplifier, the operating point is always set at the boundary between the active and cut-off regions, though class-B operation can be performed by setting the operating point at the boundary between the saturation and active regions.
      iii) For better accuracy in a class-B amplifier, the operating point is always set at the boundary between the saturation and active regions, though class-B operation can be performed by setting the operating point at the boundary between the active and cut-off regions.
      iv) All the above statements (i.e., I, ii and iii) are correct.
      v) None of the above statements (i.e., I, ii, iii or iv) is correct.

   c) Which of the following statements is correct?
      i) Class A amplifiers with the collector resistor R_C have the highest efficiency among all classes of amplifiers.
      ii) Class A amplifiers with an inductor at the collector instead of a resistor, have the highest efficiency among all classes of amplifiers.
      iii) Class B amplifiers have the highest efficiency among all classes of amplifiers.
      iv) Class B push-pull amplifiers have the highest efficiency among all classes of amplifiers.

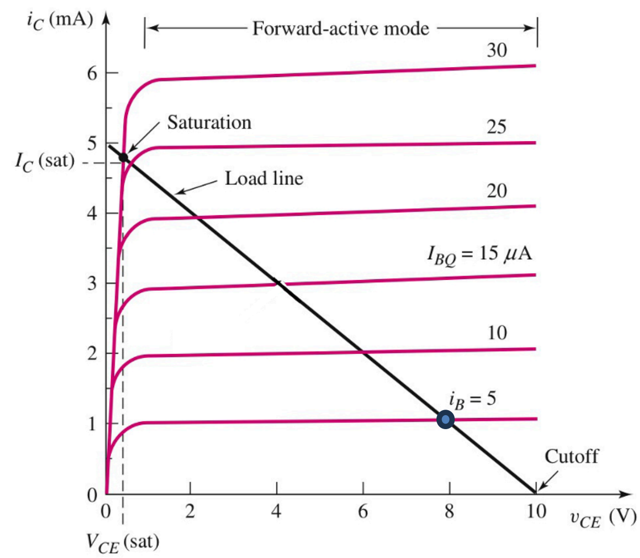
d) In the following load-line, the operating point is set at approximately V_{CE} = 8 V and I_C = 1 mA. Which of the following statements is correct?

i) This amplifier performs class-A operation but no other classes of operations.

ii) This amplifier performs class AB operation but no other classes of operations.

iii) This amplifier performs class C operation but no other classes of operations.

iv) None of the above statements (i.e., i, ii or iii) is correct.



e) Is the following statement true or false?

The power transistors generally have larger β values.

True / False

f) A power transistor's current and voltage limits are given by $I_{C(max)}$ = 2 A and $V_{CE(max)}$ = 60 V. is the following statement true or false?

The power transistor can deal with a maximum of 120 W.

True / False

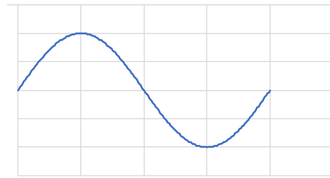
g) Is the following statement true or correct?

A small-signal amplifier converts DC to AC, in accordance to the AC signal applied to its input terminal.

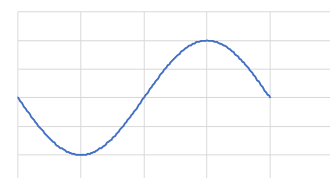
True / False

h) Consider a push-pull amplifier with an input voltage represented by v(t) = 2 sin (ωt) V, i.e., a sine wave. Ignore the magnitude but consider the phases to answer this question. Which of the following waveshapes will appear at the output?

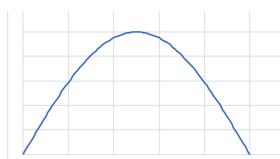
i) A sine wave with 180° conducting angle and with no phase difference between the input and output, as shown below.



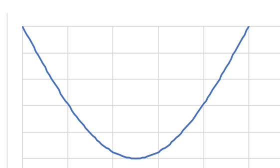
ii) A sine wave with 180° conducting angle but with 180° phase difference between the input and output, as shown below.



iii) The positive half cycle of the sine wave as shown below.



iv) The negative half cycle of the sine wave as shown below.

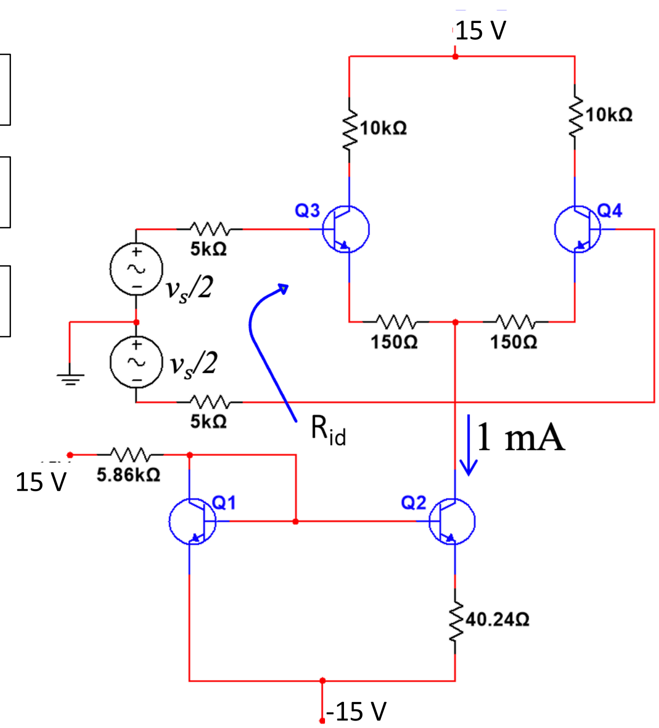


2. [**Total = 7**] Consider the following circuit where V_A = 100 V, β = 100, and $|V_{BE}|$ of Q1, Q3, and Q4 is 0.7 V. Determine the following parameters.
   a) [**3**] The input differential resistance, R_{id},
   b) [**2**] The worst-case A_{cm} if R_C has $\pm$1% tolerance, and
   c) [**2**] The input common-mode resistance, R_{icm}.

Ans: R_{id} =

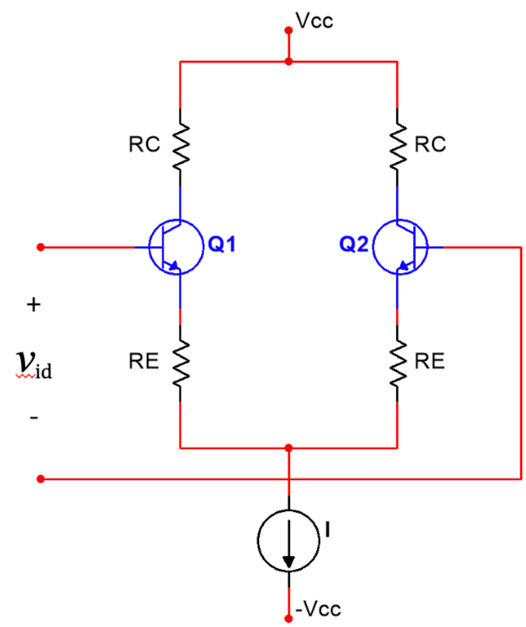
Ans: A_{cm} =

Ans: R_{icm} =



Solution: See the lecture slides

3. [**Total 8**] Consider the following circuit where v_{id} = 0.1V, RE=100 Ω, R_C = 5k, I = 2 mA, α=1, and β=100. $|V_{BE}|$ of the conducting transistor(s) is 0.7V. Determine:
   a) [**2**] i_e and v_{be}, the signal current in emitter and signal voltage between emitter and base.
   b) [**2**] Total emitter current
   c) [**2**] The differential voltage gain ($v_{od} = v_{C1} - v_{C2}$), and
   d) [**2**] The differential input resistance R_{id}.



Solution: See the lecture slides

$\beta = \frac{I_C}{I_B}$ $\alpha = \frac{I_C}{I_E}$ $\beta = \frac{\alpha}{1-\alpha}$ $\alpha = \frac{\beta}{1+\beta}$ $r_0 = \frac{V_A}{I_C}$

$g_m = \frac{I_C}{V_T}$ $r_e = \frac{V_T}{I_E}$ $r_\pi = \frac{V_T}{I_B}$ $r_\pi = \frac{\beta}{g_m}$ $r_e = \frac{\alpha}{g_m}$

$A_{vo} = -g_m \times (R_C||r_o)$ $Voltage\ gain\ = \frac{Total\ resistance\ in\ the\ collector}{Total\ resistance\ in\ the\ emitter}$

$A_{vo} = \frac{g_m R_C}{1+g_m R_E}$ $I_C = I_S e^{V_{BE}/V_T}$ $f_C = \frac{1}{2\pi RC}$ $f_C = \frac{1}{2\pi\sqrt{LC}}$ $|Z_C| = \frac{1}{2\pi f C}$

$\frac{I_o}{I_{REF}} = \frac{1}{1+\frac{2}{\beta}}$ $\frac{I_o}{I_{REF}} = \frac{1}{1+\frac{2}{\beta^2}}$ $R_{in} \approx \frac{1}{g_m}$ $\frac{I_o}{I_{REF}} = \left[\frac{1}{1+\frac{2}{\beta}}\right]\left[\frac{1+\frac{V_{CE2}}{V_A}}{1+\frac{V_{CE1}}{V_A}}\right]$

$R_0 = [1 + g_m(R_E \parallel r_\pi)]r_0$ $I_0 R_E = V_T ln\left(I_{REF}/I_0\right)$ $R_o = \frac{\beta r_o}{2}$

$\frac{i_{c1}}{i_{c1}+i_{c2}} = \frac{1}{1+e^{-\frac{v_{id}}{v_T}}}$ $\frac{i_{c2}}{i_{c1}+i_{c2}} = \frac{1}{1+e^{\frac{v_{id}}{v_T}}}$ $A_d = A_{d1} - A_{d2} = -g_m R_C$

$R_{id} = 2(\beta + 1)(r_e + R_E)$ $R_{iCM} = (\beta + 1)(R_{EE}||\frac{r_0}{2})$ $A_{CM} \approx \frac{\Delta R_C}{2R_{EE}}$

$\text{CMMR} = 20\ log\left|\frac{A_d}{A_{CM}}\right| dB$ $|V_{OS}| = V_T\left(\frac{\Delta R_C}{R_C}\right)$ $|V_{OS}| = V_T\left(\frac{\Delta I_S}{I_S}\right)$

$I_{OS} = I_B\left(\frac{\Delta\beta}{\beta}\right)$ $V_{OS} = \sqrt{\left(\frac{\Delta R_C}{R_C}\right)^2 + \left(\frac{\Delta I_S}{I_S}\right)^2}$ | $A_d = \frac{v_{C1}-v_{C2}}{v_d} = -g_m R_C$

$R_i = (\beta + 1)(r_e + R_E)$ $V_{BB} = V_{BE1}\left(1 + \frac{R_2}{R_1}\right)$ $A_i = \frac{R}{2R_L}(1 + \beta)$