Indian Institute of Technology, Kanpur
Department of Electrical Engineering

ESC 201A

Endsem Examination
Monday, 30th April, 2022

- Maximum time: 180 minutes.
- Feel free to make appropriate approximations in your calculations or assumptions in your analysis. But be sure to mention them clearly in your answer paper.
- Draw the circuit wherever it will help you solve the problem or explain the concept.
- Derive the results analytically as far as possible before plugging in the values.

Q1. For the Flip-flop with two inputs A and B whose characteristic table is shown below, determine first the excitation table **[6]**

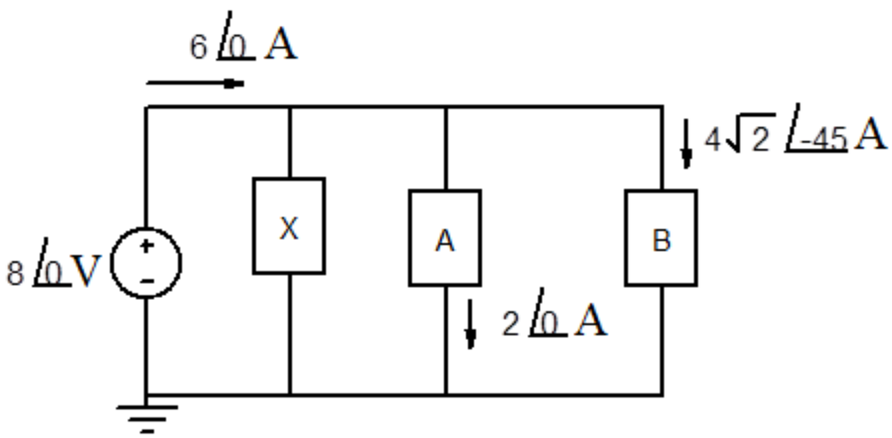
A B	Q(t+1)	State
0 0	1	Set
0 1	$\overline{Q}(t)$	Toggle
1 0	0	Reset
1 1	Q(t)	Hold

Solution:

Excitation table **[6 marks: 1.5 marks for each entry]**

Q(t)	Q(t+1)	A B
0	0	1 X
0	1	0 X
1	0	1 0 , 0 1
1	1	1 1 , 0 0

Q2 (a). Determine the impedance of element X for the given currents and voltages in the circuit shown below and state the type of element X. **[4]**



$$6\angle 0A = i_x + 2\angle 0 + 4\sqrt{2}\angle -45$$
$$\therefore 6\angle 0A = i_x + 2 + 4 - 4j$$

[2 marks]

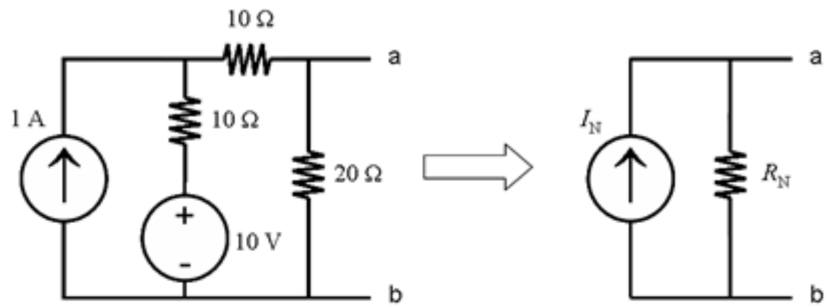
$$\therefore i_x = 4j$$

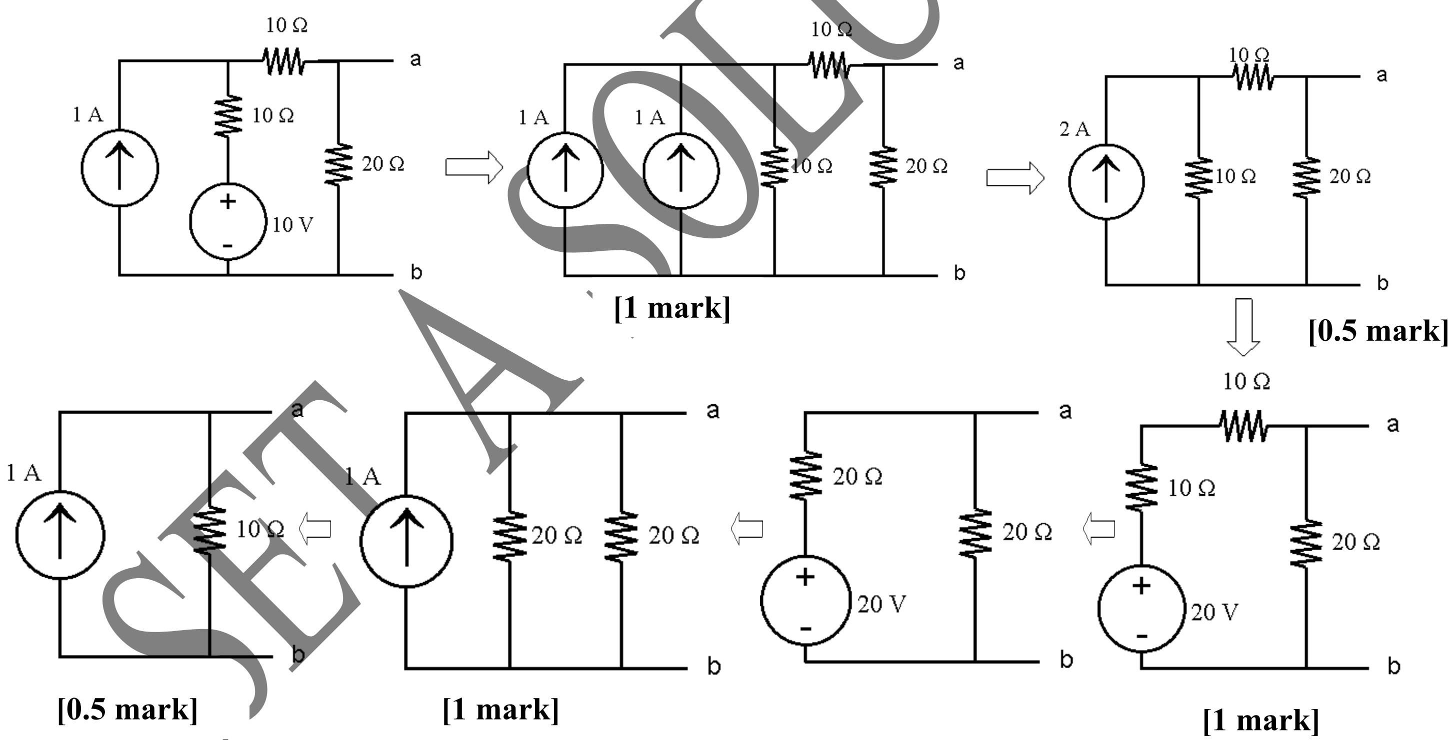
$$\Rightarrow Z_X = \frac{8}{4j} = -2j$$

[1 mark]

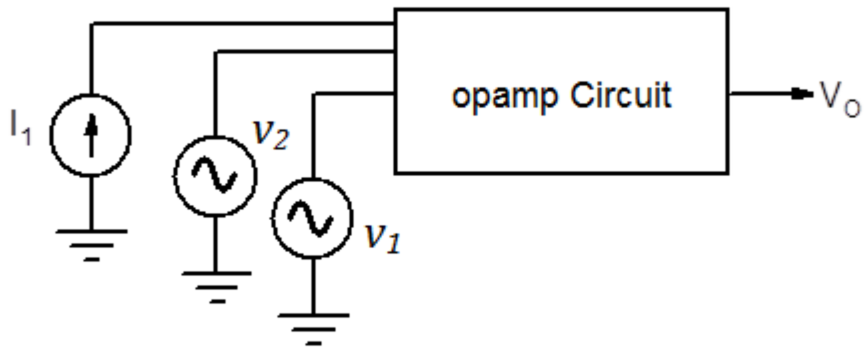
Element X is a capacitor **[1 mark]**

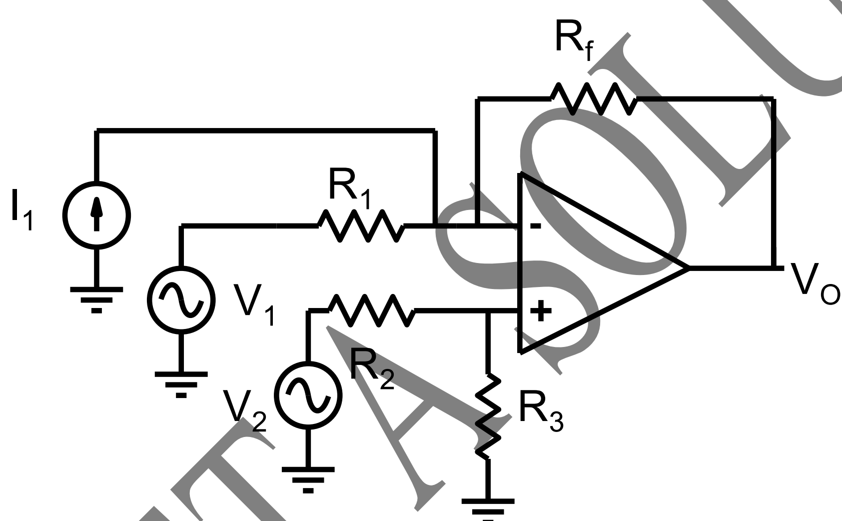
Q2 (b) <u>Using source transformations</u> only, show that the circuit below on the left can be transformed into the equivalent circuit shown on the right. Determine I_N and R_N. **[4]**





Q3 (a). Design an opamp circuit that would produce the output voltage $V_o = -2 \times 10^3 I_1 - 2v_1 + v_2$ where I_1, v_1 and v_2 are input current and input voltages respectively as shown below. Assume ideal opamp characteristics and use only one opamp. Specify values of components used. **[6]**





0.5 mark⟶-ve feedback
0.5 mark⟶ I_1
0.5 mark⟶ v_1 and R_1
0.5 mark⟶ v_2 and R_2
0.5 mark⟶ R_F
0.5 mark⟶ R_3

Output voltage due to current source:

$$V_{o1} = -I_1 R_F \Rightarrow R_F = 2k\Omega \quad [\mathbf{1\ mark}]$$

Output voltage due to source v_1:

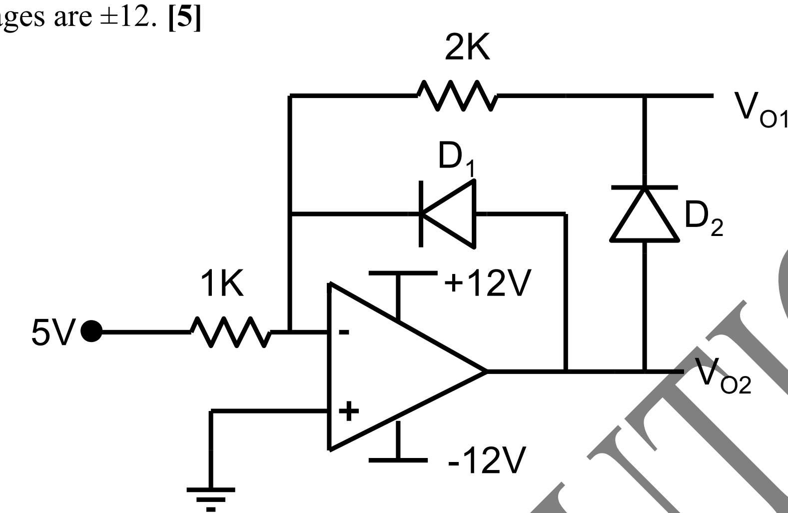
$$V_{o2} = -\frac{R_F}{R_1} v_1 = -2v_1 \Rightarrow R_1 = 1k\Omega \quad [\mathbf{1\ mark}]$$

Output voltage due to source v_2:

$$V_{o3} = \left(1 + \frac{R_F}{R_1}\right)\frac{R_3}{R_2 + R_3} v_2 = v_2 \Rightarrow \frac{R_2}{R_3} = 2 \ \ [\mathbf{1\ mark}]$$

Let R3 = 1K and R2 = 2K

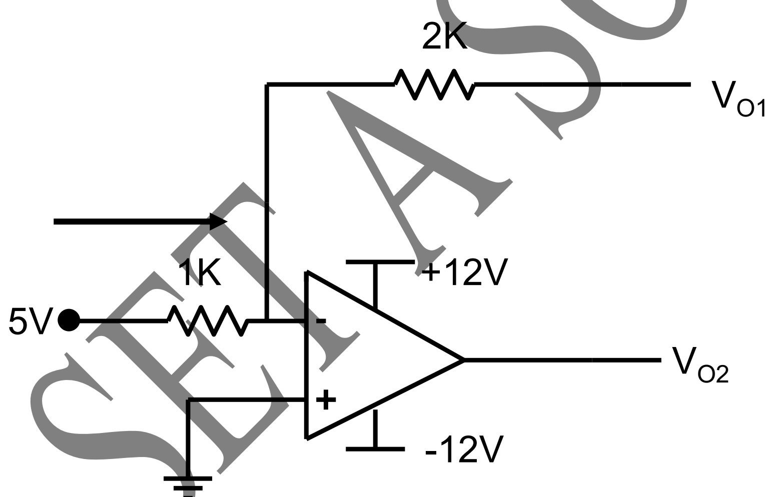
Q3 (b). Assuming ideal opamp and ideal diodes, determine output voltage V_{o1} and V_{o2}. Note that opamp supply voltages are ±12. **[5]**



5V input would try to force the current in the indicated direction but because of the polarity of the diodes, this current cannot flow. Hence current is zero and diodes are reverse biased.

[1 mark +1 mark for reason]

The circuit reduces to the following **[1 mark for circuit]**



$$V_- = 5V \Rightarrow V_{O1} = 5V$$ **[1 mark]**

The opamp acts as a comparator and thus V_{o2} = -12V [1 mark]

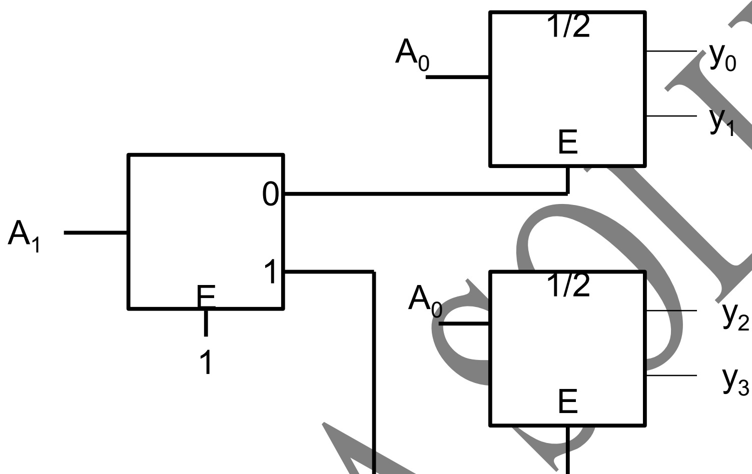
Q4 (a). Prove using basic postulates of Boolean algebra that $x + \bar{x} \cdot y = x + y$ **[4]**

Solution:

$$x + \bar{x} \cdot y = x \cdot (1 + y) + \bar{x} \cdot y \text{ [1 mark]}$$
$$= x + x \cdot y + \bar{x} \cdot y \text{ [1 mark]}$$
$$= x \cdot x + x \cdot \bar{x} + x \cdot y + \bar{x} \cdot y \text{ [1 mark]}$$
$$= (x + \bar{x}) \cdot (x + y) = 1 \cdot (x + y) = x + y \text{ [1 mark]}$$

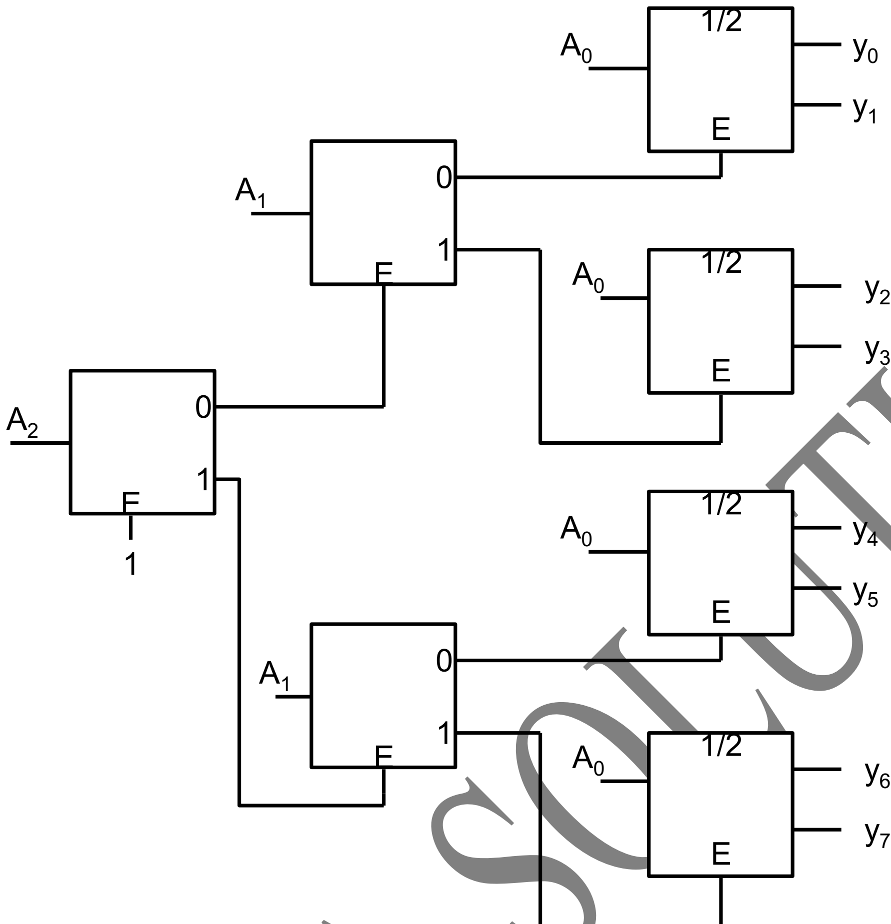
Q4 (b) Implement a 3 to 8 decoder using only 1 to 2 decoders. Assume that each decode has an enable signal. Label all the input and output lines. **[5]**

Solution:
Construct a 2 to 4 decoder first:



[2 mark]

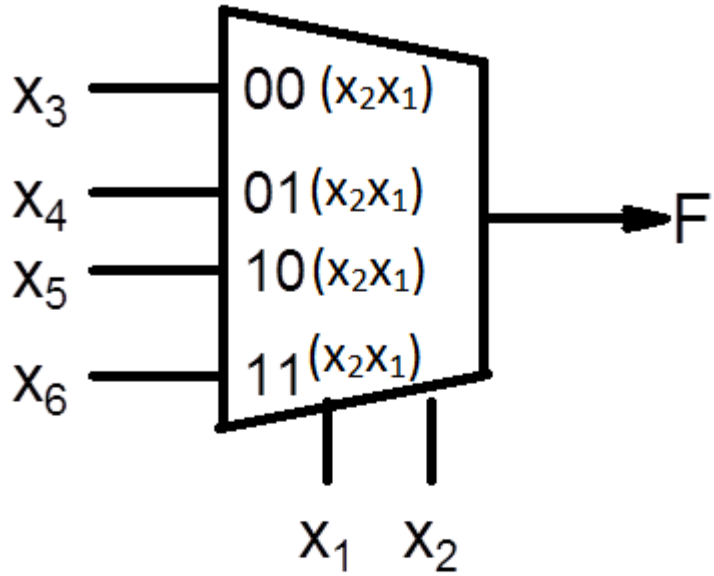
Use two 2 to 4 decoders to construct a 3 to 8 decoder:



[3 marks]

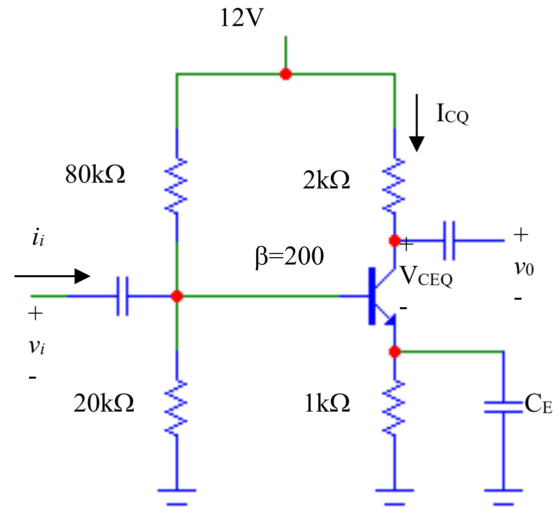
Q4 (c) Show how one can use a 4 to 1 multiplexer to implement the following 6-variable Boolean expression: $F = \overline{x_1} \cdot \overline{x_2} \cdot x_3 + x_1 \cdot \overline{x_2} \cdot x_4 + \overline{x_1} \cdot x_2 \cdot x_5 + x_1 \cdot x_2 \cdot x_6$ **[6]**

Solution:



[1 mark for labelling each input and select line]

Q5 For the following common emitter amplifier circuit:
(a) Calculate V_{CEQ} and I_{CQ}. **[6]**

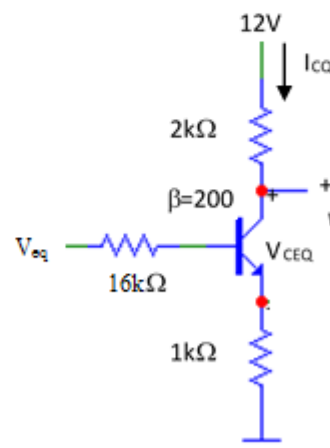


Solution: DC Analysis

$$V_{eq} = \frac{20 \times 12V}{100} = 2.4V \;\; [\mathbf{1\ mark}]$$

Also,

$$80k||20k = 16k \;\; [\mathbf{1\ mark}]$$



[1 mark for circuit]

Assume transistor in forward-active mode.
Applying KVL:

$$2.4 - (16 \times 10^3)I_B - 0.7 - 10^3 I_E = 0$$

$$\Rightarrow 2.4 - (16 \times 10^3)\frac{I_{CQ}}{\beta} - 0.7 - 10^3\frac{I_{CQ}}{\beta}(\beta + 1) = 0$$

$$\Rightarrow I_{CQ} = 1.57mA \;\; [\mathbf{1.5\ mark}]$$

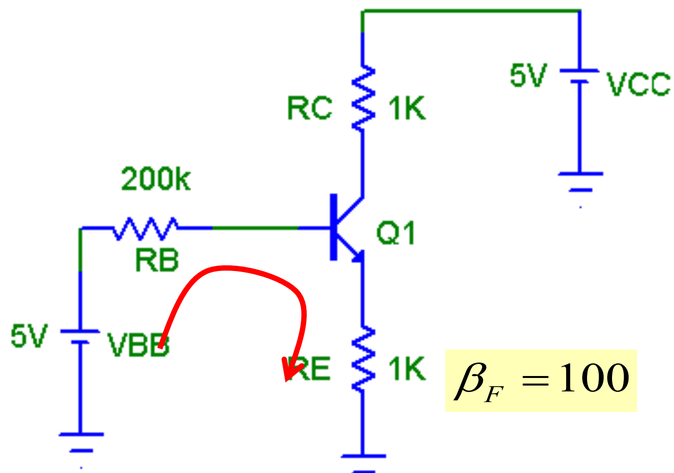
Applying KVL:

$$12 - (2 \times 10^3)(1.57 \times 10^{-3}) - V_{CEQ} - 10^3\frac{1.57 \times 10^{-3}}{200}201 = 0$$

$$\Rightarrow V_{CEQ} = 7.28V > 0.2V \;\; [\mathbf{1.5\ mark}]$$

So forward-active assumption is correct.

Q6: For the following circuit, calculate I_C (the current flowing through the resistor RC) and V_{CE}. **[4]**



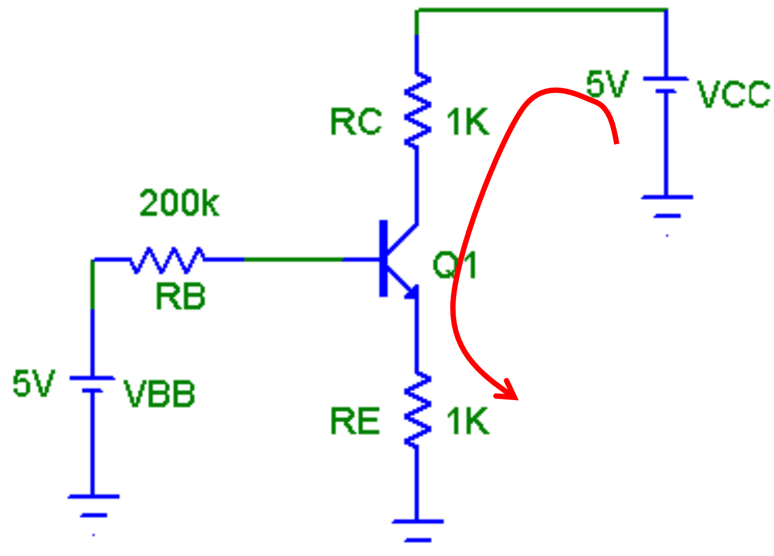
Assuming the transistor is in forward active region

$$-V_{BB} + I_B R_B + 0.7 + I_E R_E = 0$$ **[1 mark]**

$$I_E = (\beta + 1) I_B$$

$$I_B = \frac{V_{BB} - 0.7}{R_B + (1+\beta) R_E} = 14.29 \mu A$$

$$I_C = \beta_F I_B = 1.429 mA$$ **[1 mark]**



$$I_E = (\beta_F + 1) I_B = 1.443mA$$

$$-V_{CC} + I_C R_C + V_{CE} + I_E R_E = 0$$

[1 mark]

$$V_{CE} = 2.129V$$

Since VCE > 0.2 V, our assumption is correct, and the transistor is in forward active region. **[1 mark]**