ID:	Name:

Brac University

Semester: Spring 2024
Course Code: CSE251
Electronic Devices and Circuits
Section: 01-23

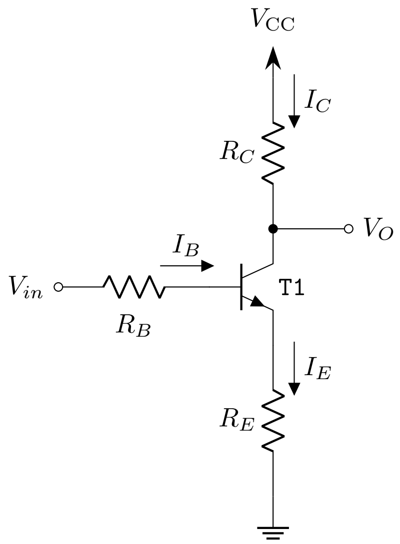
Set **A**

Assessment: *Final Examination*
Duration: 1 hour 30 minutes
Date: 07 May, 2024
Full Marks: 30

Instructions: Answer **any 3 out of 5** questions.

■ Question 1 of 5 *[CO1, CO2, CO3] [10 marks]*

Andrew and Nicole found the adjacent circuit built in a trainer board. From the transistor model, they knew it had a gain of $\beta = 80$. They also saw $V_{CC} = 5\,\text{V}$, $R_B = 2\,\text{k}\Omega$, and $R_C = 3\,\text{k}\Omega$. However, the R_E resistor was an unknown one. So, they provided an input of $V_{in} = 2\,\text{V}$ and measured the output to be $V_0 = 2.2\,\text{V}$. Nicole said, "In this condition, the transistor is in **active** mode". But, **Andrew disagreed**.



(a) **[CO1] Illustrate** the Voltage Transfer Characteristic curve of a MOSFET driven inverter with proper labeling. [1.5]

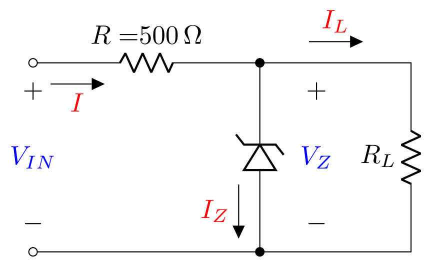
(b) **[CO3] Design** the circuit, i.e., determine the value of R_E, using what Nicole said about the mode of the transistor. [4]

(c) **[CO2]** Use the calculations in (b), and **determine** who is right between Andrew and Nicole. [1.5]

(d) **[CO2]** Using the value of R_E obtained from (b), **determine** who will be right if $V_{in} = 4\,\text{V}$. [3]

■ Question 2 of 5 *[CO1, CO2, CO3] [10 marks]*

A Zener diode in the adjacent circuit is specified to have a voltage of 3.8 V when the current through it is 5 mA and a V_{ZO} of 3.7 V. The zener diode has a zener knee current of $I_{ZK} = 2\,\text{mA}$. The supply voltage V_{IN} is nominally 10 V but can vary by $\pm$ 1 V.



(a) **[CO1] Explain** in short, why a zener diode is a better voltage regulator than a regular diode. [1]

(b) **[CO1]** The breakdown region of a zener diode is modeled by a constant voltage drop (V_{ZO}) in series with a resistor (r_z). **Determine** the model parameters - V_{ZO} and r_z - for the given zener diode. [2]

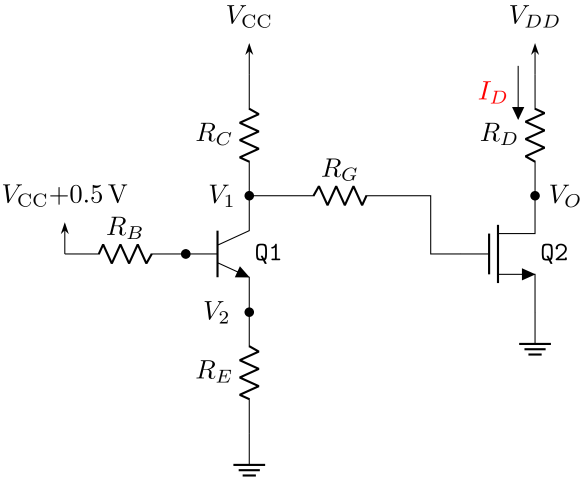
(c) **[CO2]** Assume, $R = 500\,\Omega$. **Determine** the highest load current $I_{L_{\max}}$ that the zener diode can support, above which it fails to function as a regulator. Determine R_L for this case. [3]

For the next question, consider that the voltage regulator supply voltage V_{IN} suddenly becomes half of its initial value, i.e., 5 V with a variation of ± 0.5 V.

(d) **[CO3]** In this scenario, **design** the regulator circuit, i.e., find an appropriate value of R so that the zener diode does not fall out of regulation. [4]

■ Question 3 of 5 *[CO1, CO2, CO3] [10 marks]*

Answer the questions **(a-d)** based on the circuit shown below. the parameter values of the circuit are given in the adjacent table:



Resistor values in (kΩ)

R_B	R_C	R_E	R_G	R_D
100	1.1	1	3	-

Supply Voltages

$V_{CC} = 5\,\mathbf{V}$
$V_{DD} = 10\,\mathbf{V}$

Transistor Parameters

Q1	Q2
$\beta = 100$	$k_n' = 0.25\,\text{mA/V}^2$
$v_{CE(Sat)} = 0.2\,\text{V}$	$W/L = \frac{0.72\ \mu m}{0.18\ \mu m}$
$v_{BE(Act)} = v_{BE(Sat)} = 0.7\,\text{V}$	$V_T = 1\,\text{V}$

Based on the above scenario, answer the following questions:

(a) **[CO1]** In the Switch Model of BJT, **Determine** in which mode does a BJT operate when it is OFF? Which mode does it operate in when it is ON? [2]

(b) **[CO2]** **Find out** the currents going through the three terminals of the transistor `Q1`. [4]

(c) **[CO2]** **Determine** the the value of V_1 and V_2. [1]

(d) **[CO3]** **Design** the circuit, i.e. find an appropriate value of R_D, such that `Q2` remains at the edge of saturation, i.e., when $V_{DS} = V_{GS} - V_T$. [3]

■ Question 4 of 5 *[CO1, CO2, CO3] [10 marks]*

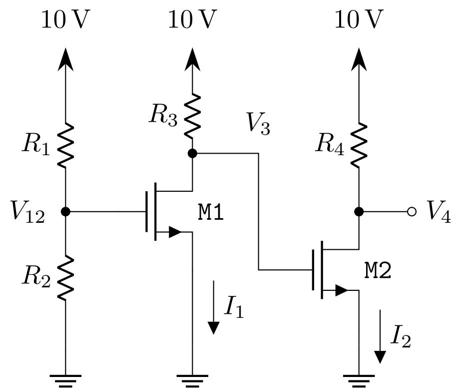
Relevant information for the circuit configuration on the right is given in the tables below:

Resistor values in **(kΩ)**

R_1	R_2	R_3	R_4
3	5	2	4

Transistor Parameters

$k_n = 2\,\text{mA/V}^2$
$V_T = 1\,\mathbf{V}$



(a) **[CO1]** **Draw** the IV-characteristics of a MOSFET using S-model with proper labeling. [1]

(b) **[CO2]** **Determine** the value of V_{12}. [1]

(c) **[CO2]** **Calculate** the value of drain-to-source voltage of the transistor `M1`. In the process, determine the operating mode of `M1`. [3.5]

(d) **[CO2]** **Determine** which one of the four resistors will consume the least amount of power. [**Hint**, Power $= I^2R$] [3]

(e) **[CO2]** **Determine** how the operating mode of `M2` would change if R_2 were set to zero. [1.5]

■ Question 5 of 5 *[CO1, CO2, CO3] [10 marks]*

CRAB University has installed Air Conditioning systems in its classrooms. The system monitors the signals from two temperature sensors `T1` and `T2`. A temperature sensor is supposed to turn **HIGH** if the temperature of a classroom exceeds 25° Celsius. The system uses the signals from 2 sensors so that it is more reliable.

However, due to the incompetence of CRAB University's administration, they have installed a defective AC system. The AC **turns ON** if any one of the sensors turn **HIGH**, but unfortunately, the AC **turns OFF** if both the sensors become **HIGH**. As a result, in some cases of extreme heat, the AC **turns off** which causes a lot of suffering to both teachers and students during class hours.

(a) [**CO1**] There are 3 modes of operation of a MOSFET - Cutoff, Triode, and Saturation. In the Switch Model of MOSFET, **determine** in which mode does a MOSFET operate when it is OFF? Which mode does it operate in when it is ON? [1]

(b) [**CO3**] **Design** a logic circuit with MOSFETs to implement the logic function $\mathbf{f} = \mathbf{A}.\overline{\mathbf{B}}$ (Use the switch model of MOSFETs.) [2]

(c) [**CO1**] **Write** down the Truth Table of the function, $\mathbf{f} = \mathbf{A}.\mathbf{B} + \overline{\mathbf{A}}.\overline{\mathbf{B}}$ [1]

(d) [**CO2**] **Analyze** the defective Air-conditioning system above and **implement** the Truth Table relating the logic signals `T1`, `T2` and AC. Is there any relation of this Truth Table to that in (c)? [2]

(e) [**CO2**] **Write** down the logic function relating the signals `T1`, `T2` and the AC. [1]

(f) [**CO3**] **Construct** the logic circuit that the (defective) Air Conditioning system uses by implementing the logic function of (e), using MOSFETs. [3]

Current equations for MOSFET

Cut-off: $I_D = 0$

Triode: $I_D = k\left[(V_{GS} - V_T)\,V_{DS} - \frac{1}{2}V_{DS}^2\right]$

Saturation: $I_D = \frac{1}{2}k\,(V_{GS} - V_T)^2$