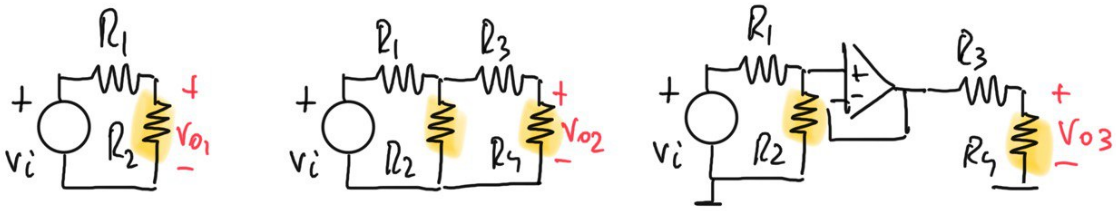
Circuit Theory
Mid-semester examination. April 26, 2022

Time limit: 1 hour 45 minutes.

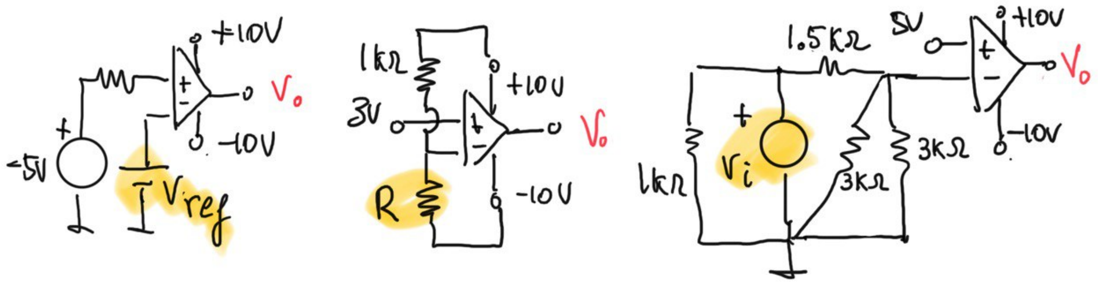
1 Short Questions (50%)

Each equation, or group of equations, **must be preceded by a brief explanation** of what you want to do.

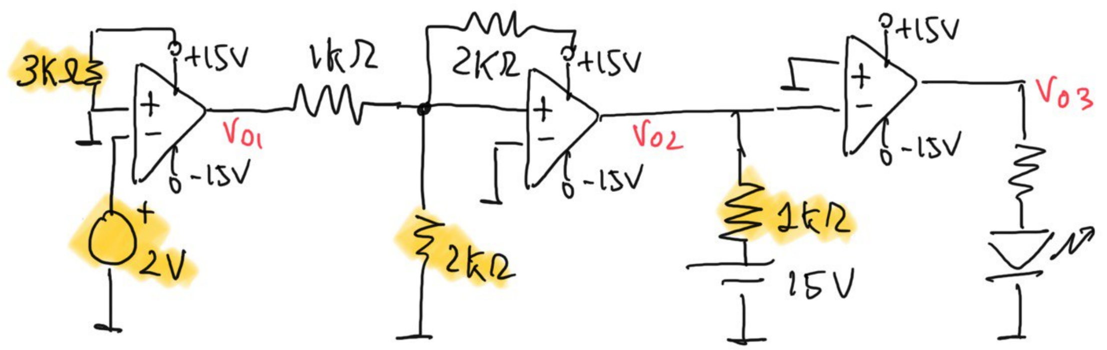
a) Determine the voltage in red of the following circuits and the power consumed by the elements in yellow.



b) Compute the range of values of the elements in yellow that saturate the output of each comparator to a positive value.



c) Compute the power consumed by the elements in yellow. Comment on the results if the maximum power of the resistors is 1/4 W. Will the LED be turned on? Compute the value of R_L if $V_{threshold} = 1.5\,\mathrm{V}$ and the desired current is $i_{LED} = 15\,\mathrm{mA}$.



2 Problem: the Wheatstone bridge (20 %)

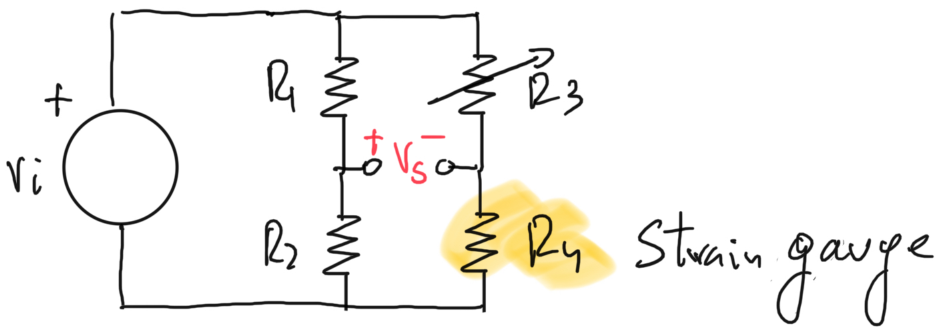
The following circuit shows a *Wheatstone bridge* in which R_4 is a *strain gauge*, a resistance whose value changes when it is deformed in a specific direction. To simplify the problem, we could say that $R_4 = R_0(1 + dx)$, where R_0 is the value of R_4 when there is no deformation, and dx is the deformation in micrometers. The resistance R_3 is adjusted to achieve $v_s = 0$ when there is no deformation, i.e $dx = 0$. When the resistance R_4 undergoes a deformation, $v_s \neq 0$. In the following, consider $v_i = 9\,\text{V}$, $R_1 = 1\,\text{k}\Omega$, $R_2 = 2\,\text{k}\Omega$ and $R_0 = 4\,\text{k}\Omega$.

a) Comment on the number and type of equations needed to determine the voltage and current of all the elements in the circuit. Hint: number of KCLs and its relationship to the number of nodes...

b) Compute v_s as a function of v_i, R_1, R_2, R_3 and R_4.

c) Adjust R_3 to get $v_s = 0$ when there is no deformation.

d) Compute v_s when the deformation is $1\,\mu\text{m}$, i.e $dx = 1$.



3 Problem: the inverting Schmitt trigger (30 %)

We want to design and inverting Schmitt trigger (the comparator with hysteresis that we have studied during the course) whose output v_o turns on a LED when the deformation of the previous strain gauge is greater than $1.5\,\mu\text{m}$, and turns it off when it is lesser than $1\,\mu\text{m}$. Use a rail-to-rail operational amplifier with a power supply of $\pm 9\,\text{V}$.

a) Compute the values of v_s of the previous circuit (the Wheatstone bridge) for the two values of dx that limit the hysteresis cycle.

b) Draw the relationship v_o versus v_s.

c) Design the comparator with hysteresis using two resistors and an extra voltage source.

d) Design the comparator with hysteresis using no extra voltage source.

e) Draw the complete design including the Wheatstone bridge and the LED.