1. A Trans-Impedance Amplifier

Above is a picture of the equivalent circuit of an op-amp. Consider the following circuit with an ideal op amp in negative feedback:

(a) Use the golden rules to calculate $v_{out}$ as a function of $I_s$ and $R$.

(b) Use the golden rules to implement the same behavior as the above circuit (with a current source), but use instead a voltage source and resistor.

2. Op-Amp Golden Rules

On the left is the picture of the equivalent circuit of an op-amp for reference.
(a) What are the currents flowing into the positive and negative terminals of the op amp? I.e., what are $I^+$ and $I^-$? What are some of the advantages of your answer with respect to using an op amp in your circuit designs?

(b) Suppose we add a resistor of value $R_L$ between $v_{out}$ and ground. What is the value of $v_{out}$? Does your answer depend on $R_L$? In other words, how does $R_L$ affect $A_{vin}$? What are the implications of this with respect to using op amps in circuit design?

(c) Now consider the circuit on the right. Assuming this is an ideal op amp, what is $v_{out}$?

(d) Assume for the op-amp that $R_{in} \to \infty$ and $R_{out} \to 0$. Draw the equivalent circuit for this op-amp and calculate $v_{out}$ in terms of $A$, $V$ and $R_L$. Does $v_{out}$ depend on $R_L$? What is $v_{out}$ in the limit as $A \to \infty$?

3. Op-amps as Comparators

For each of the circuits shown below, plot $V_{out}$ for $V_{in}$ ranging from $-10V$ to $10V$ for (a) and from $0V$ to $10V$ for (b). Let $A = 100$ for your plots.
\[ V_{in}^{+} \quad \begin{array}{c} \downarrow \quad 1k\Omega \quad \downarrow \quad 2k\Omega \quad \downarrow \quad 2V \quad \downarrow \quad + \end{array} \quad 5V \quad \begin{array}{c} \downarrow \quad - \quad \downarrow \quad V_{out} \quad \downarrow \quad + \end{array} \]