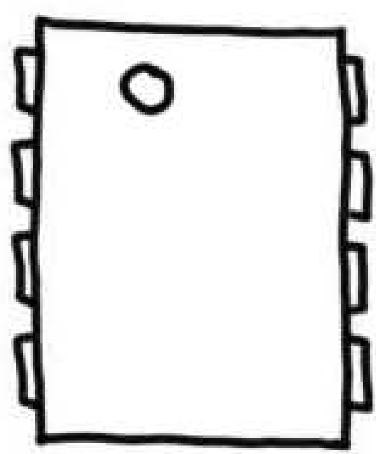
Operational Amplifiers: Operational amplifiers, or "op amps", are extremely versatile and useful elements. This is the first instance in which you see a circuit element that is not an ideal basic circuit element. The op-amp is an "integrated circuit" or IC, in the jargon used by electrical engineers.

Typical op-amps have 8 terminals, which are points of connection to the rest of the circuit. For the sake of definiteness, assume the op-amps used in the worksheet are the LM741's. Keep in mind that other types of op-amps exist and will have different properties, but the LM741 are very representative of op-amps and are good general purpose op-amps.

Op-Amp Terminals: Given the top-down view of the op-amp, label the terminals numerically from 1 to 8 and state the function of each terminal.



Properties of an Ideal Operational Amplifier:

1) Write down the *voltage transfer characteristic* of an operational amplifier in both equation and graphical form. Define all variables involved. In particular, define *A* and how large it is.

   a) Answer: Equation

b) Answer: Graph. Carefully label each section of the graph

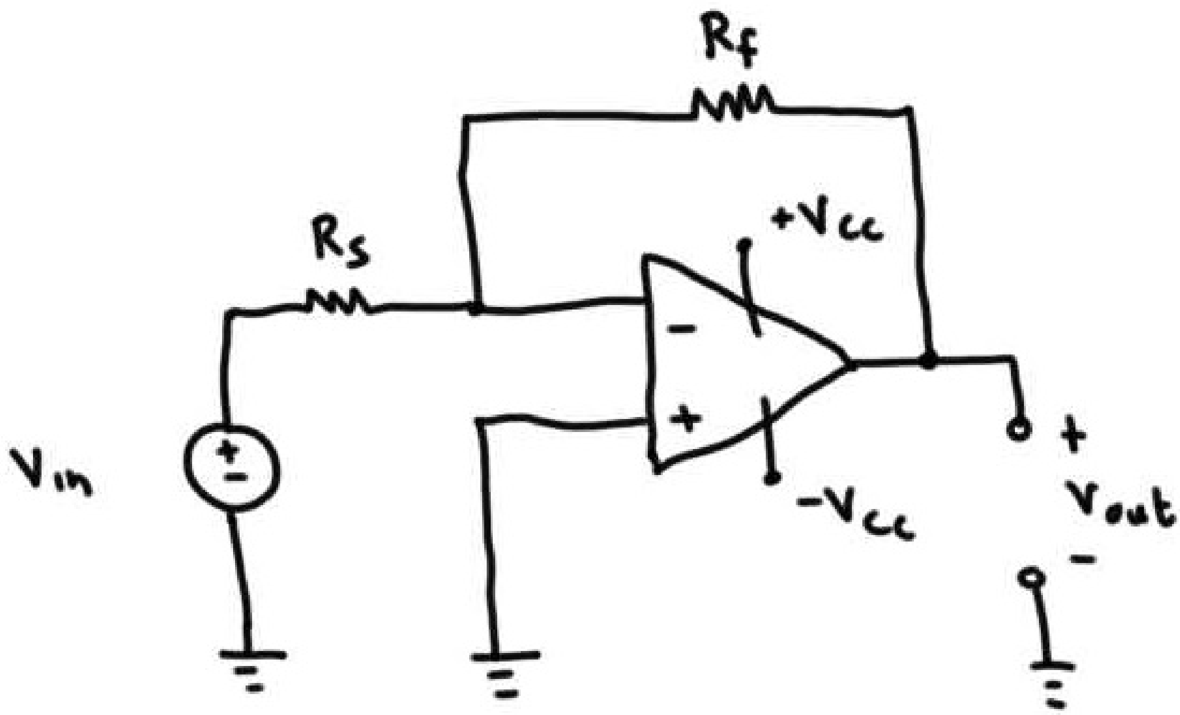
2) **Saturation:** What are the maximum and minimum values that any circuit with an ideal op amp can take on?

3) **Assumptions of an ideal op amp:**

a) State the input voltage constraint of an ideal op amp in equation form
Answer:

b) State the input current constraint of an ideal op amp in equation form
Answer:

Inverting Amplifier Circuit: Assume the op amp in the circuit below is ideal. Calculate the output voltage, v_{out}, as a function of the input voltage, v_{in}, and the rest of the components in the circuit. The answer should be an equation.



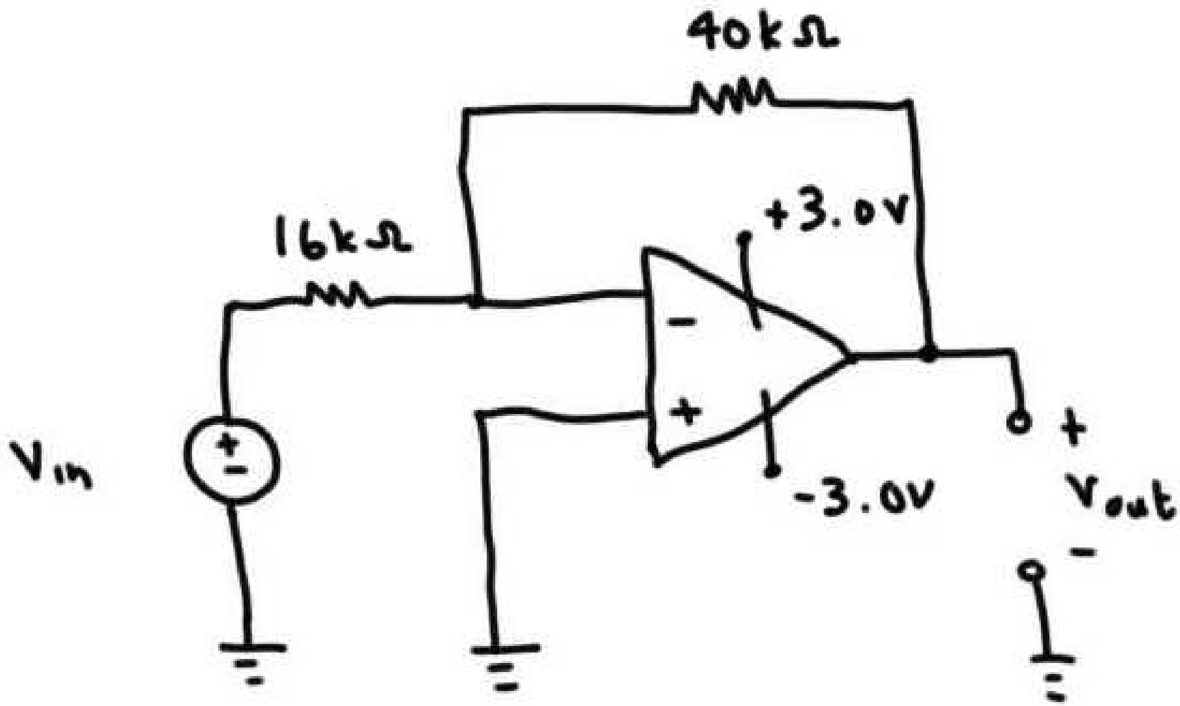
Answer: This should be an equation

$v_{out} =$

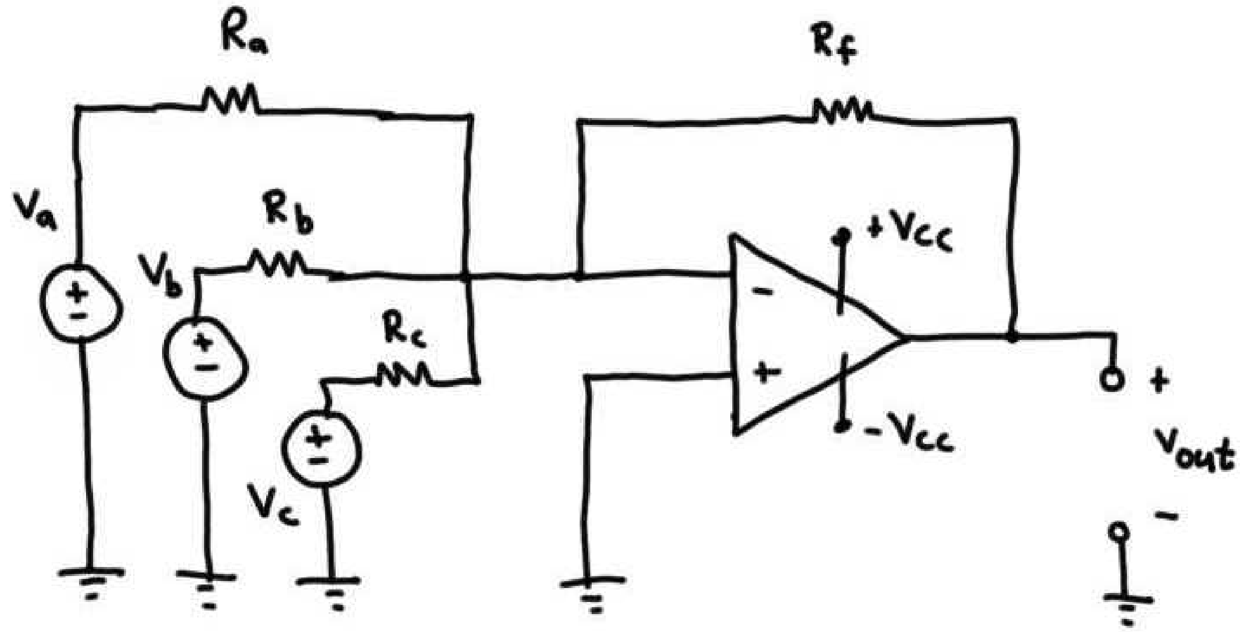
Problem #1: The op amp in the circuit shown below is ideal.

a) Calculate v_{out} for the following values of v_s:
$0.2\ V, 1.0\ V, 1.75\ V, -0.3\ V, -0.8\ V, -1.2\ V$

b) What is the operating range for v_s needed to avoid saturation?



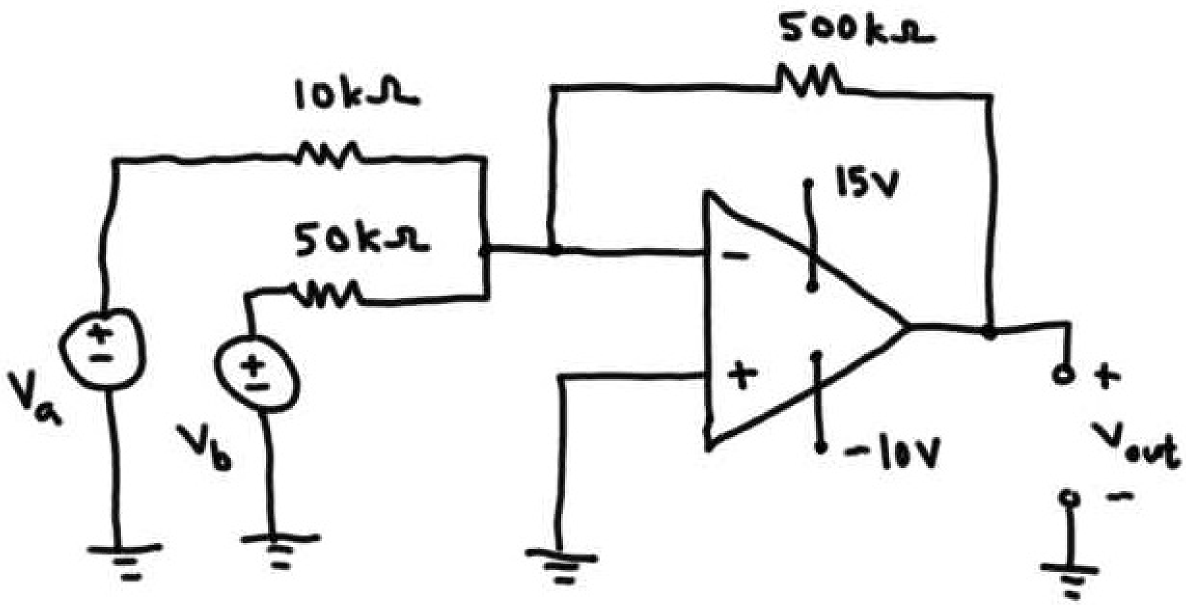
Summing Amplifier Circuit: Assume the op amp in the circuit below is ideal. Calculate the output voltage, v_{out}, as a function of the input voltages, v_a, v_b, v_c, and the rest of the components in the circuit. The answer should be an equation.



Answer: This should be an equation

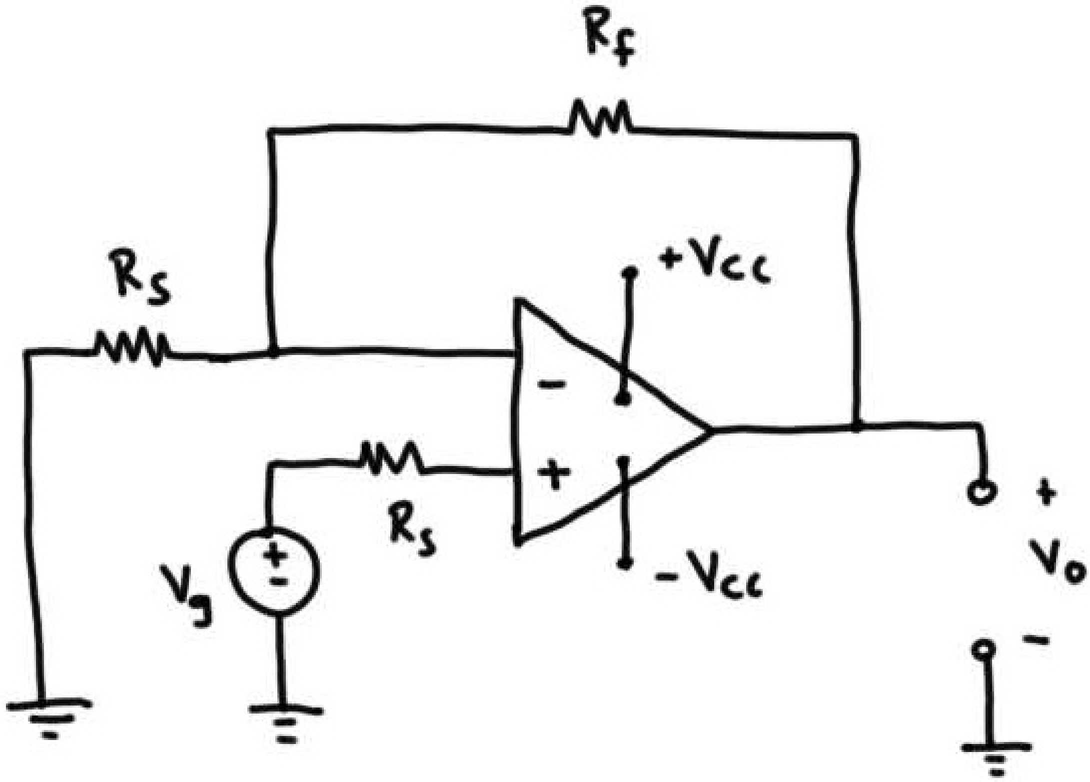
$v_{out} =$

Problem #2: The op-amp in the circuit shown below is ideal.



a) If $v_a = 0.2\ V$ and $v_b = 0.50\ V$ then find the output voltage, v_{out}.
b) If $v_b = 0.25\ V$, then how large can v_a become before the op amp saturates?
c) If $v_a = 0.1\ V$, then how large can v_b become before the op amp saturates?
d) Repeat parts (a), (b), and (c) if the polarity of v_b is reversed.

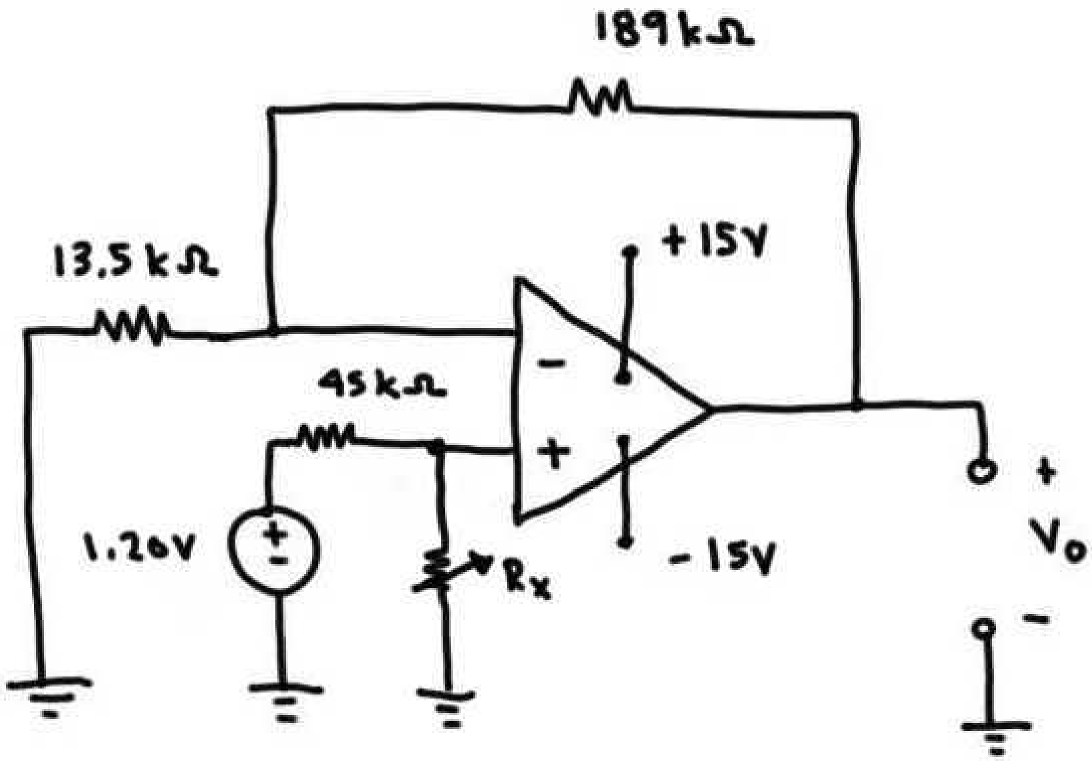
Non-Inverting Amplifier Circuit: Assume the op amp in the circuit below is ideal. Calculate the output voltage, v_{out}, as a function of the input voltage, v_g, and the rest of the components in the circuit. The answer should be an equation.



Answer: This should be an equation

$v_{out} =$

Problem #3: The op-amp in the circuit below is ideal.



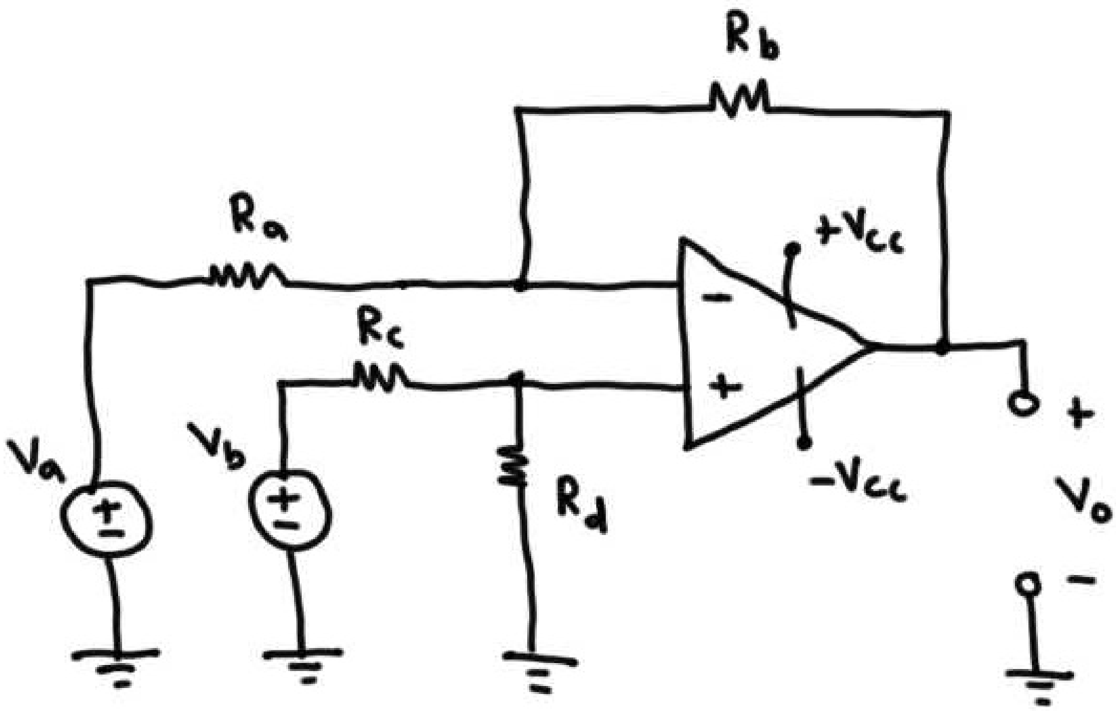
a) If the variable resistor is set to $1.80\ k\Omega$, then find the output voltage.
b) How large can the variable resistor R_x be before the amplifier saturates?

Answer: This should be an equation

a) $v_{out} =$

b) $R_x =$

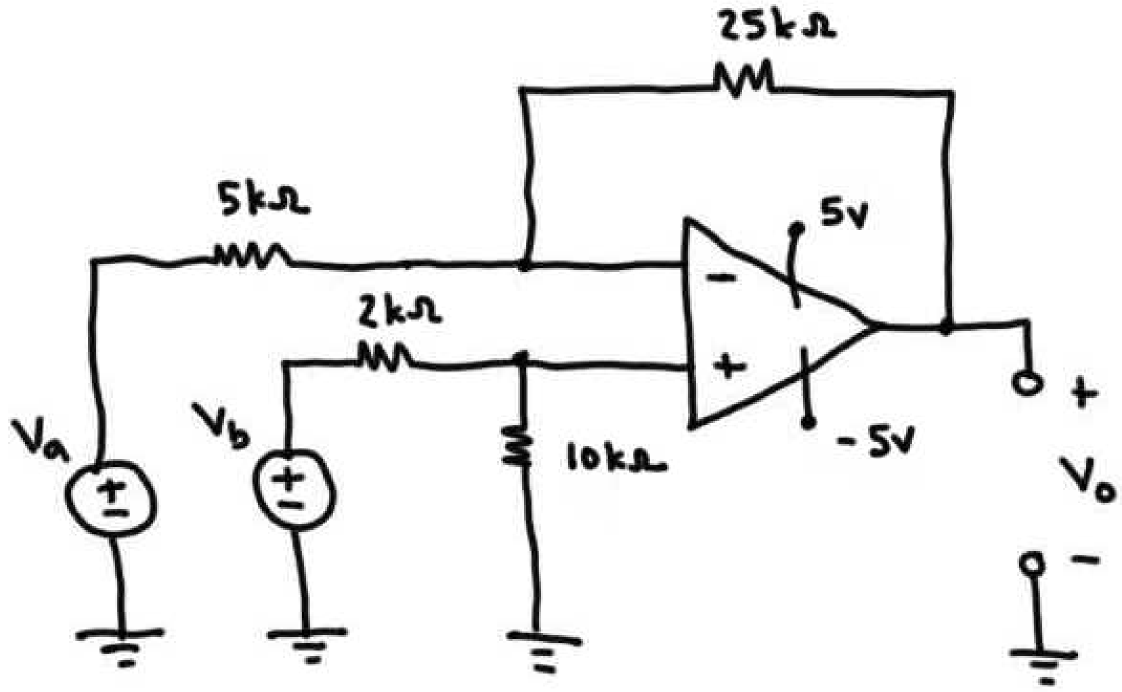
Difference Amplifier Circuit: Assume the op amp in the circuit below is ideal. Calculate the output voltage, v_{out}, as a function of the input voltages, v_a, v_b, and the rest of the components in the circuit. The answer should be an equation.



Answer: This should be an equation

$v_{out} =$

Problem #4: The op-amp in the circuit below is ideal.



a) If $v_b = 2.0\ V$, then what range of values for v_a will result in linear operation?

b) Suppose the $10\ k\Omega$ resistor is replaced with a $4\ k\Omega$ resistor. Repeat question a) above.