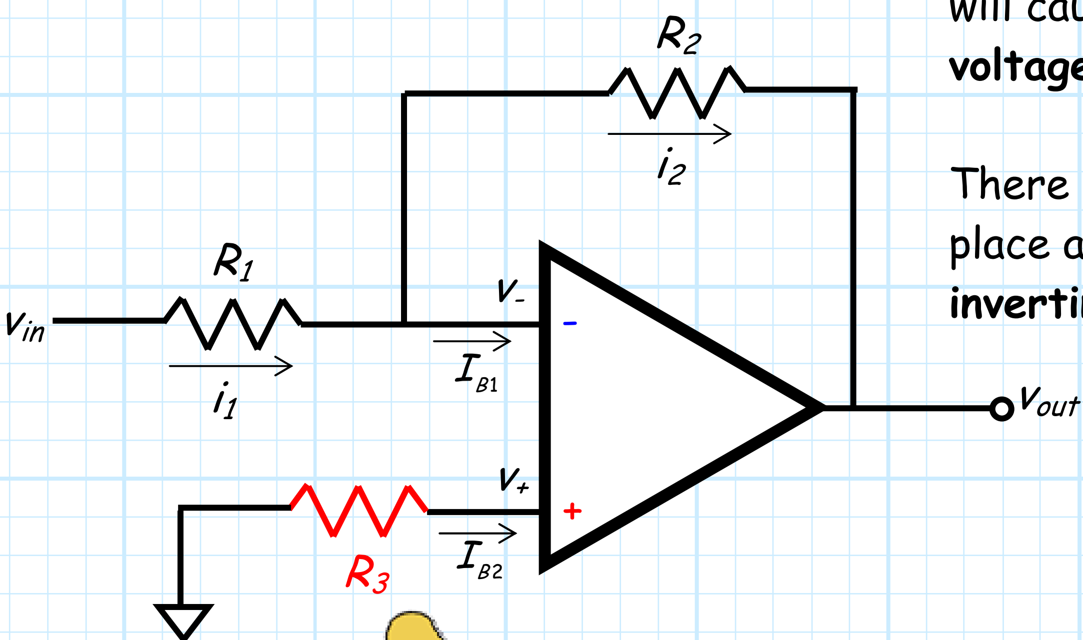
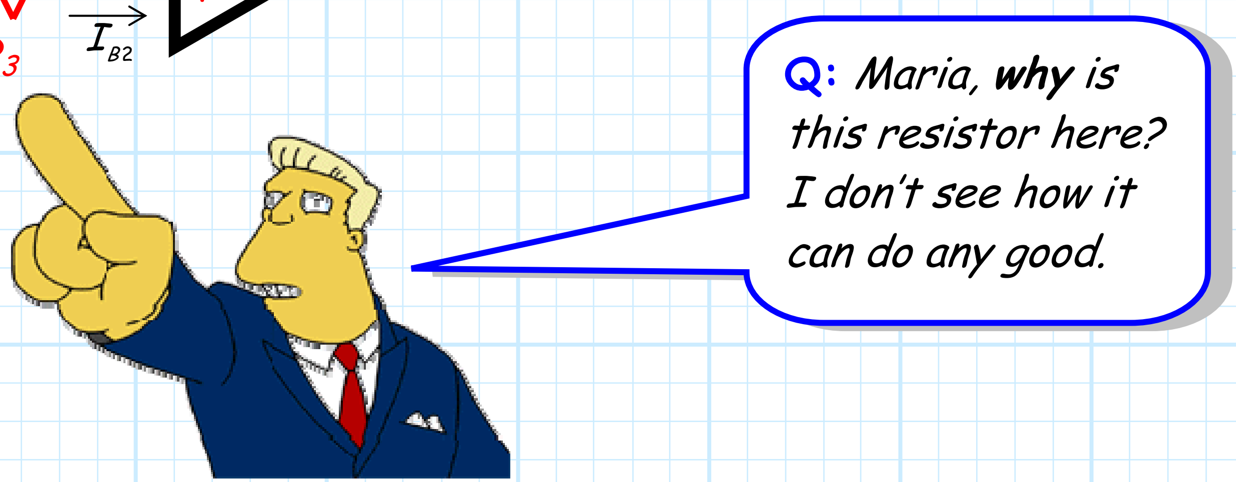
Reducing the Effect of Input Bias Current

We found that the input bias current will cause an **offset** in the **output voltage**.

There is a **solution** to this problem—place a **resistor** (R_3) on the **non-inverting input**!





The voltage v_+ is non-zero!

A: Let's **analyze** this circuit to determine how this new resistor helps.

First, notice that the voltage at the **non**-inverting terminal is now **non-zero**!

The bias current I_{B2} means that, by virtue of KVL:

$$v_+ = 0 - R_3 I_{B2} = -R_3 I_{B2}$$

Now, because of the **virtual short**:

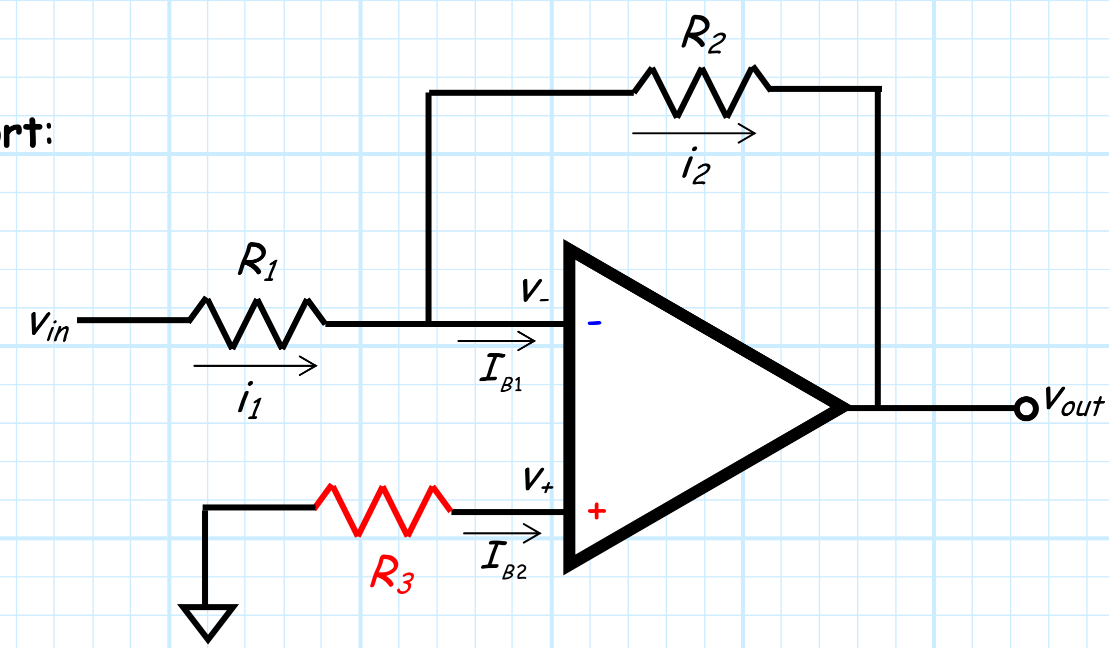
$$v_- = v_+ = -R_3 I_{B2}$$

And from KCL:

$$i_1 = i_2 + I_{B1}$$

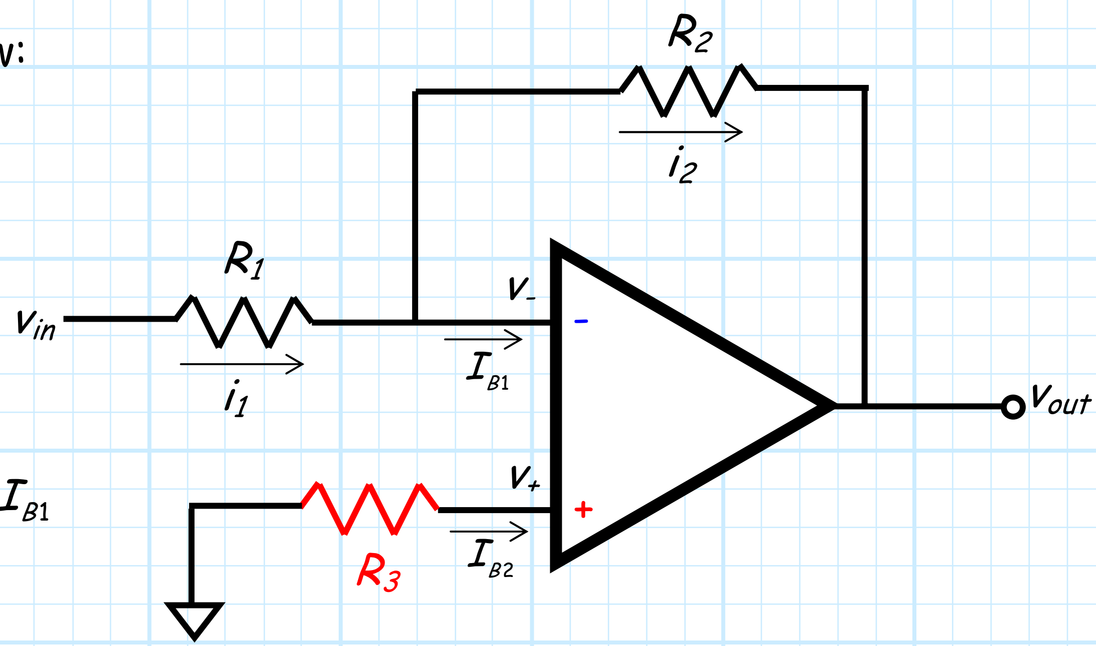
where from KCL and Ohm's Law:

$$i_1 = \frac{v_{in} - v_-}{R_1} = \frac{v_{in} + R_3 I_{B2}}{R_1}$$



It seems like this just made the offset even larger

And also from KCL and Ohm's Law:



$$i_2 = \frac{v_{in} - v_{out}}{R_2} = \frac{-\left(R_3 I_{B2} + v_{out}\right)}{R_2}$$

Combining these results:

$$\frac{v_{in} + R_3 I_{B2}}{R_1} = \frac{-\left(R_3 I_{B2} + v_{out}\right)}{R_2} + I_{B1}$$

Performing the usual algebraic gymnastics, we **rearrange** this result and find that the **output voltage** is:

$$v_{out} = \left(-\frac{R_2}{R_1}\right) v_{in} - \left(R_3 I_{B2} + \frac{R_2 R_3}{R_1} I_{B2} - R_2 I_{B1}\right)$$

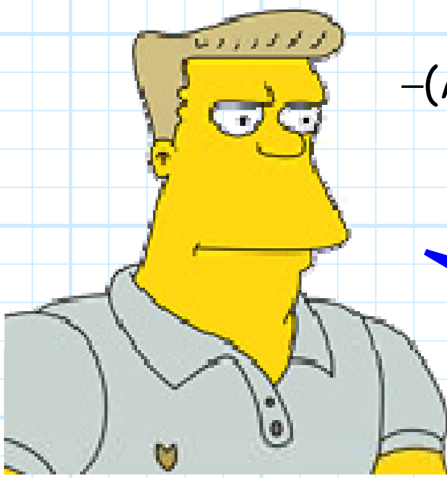
Awl be baak

Again we find the output consists of **two** terms. The first term is the **ideal** inverting amplifier result:

$$-\frac{R_2}{R_1} v_{in}$$

and the second is an output **D.C. offset**:

$$-\left(R_3 I_{B2} + \frac{R_2 R_3}{R_1} I_{B2} - R_2 I_{B1}\right)$$



Q: *Resistor R_3 was supposed to **reduce** the D.C. offset, but it seems to have made things even **worse**. Fix this or I shall be forced to pummel you.*

We must choose the proper value of R_3…

A: Say we **set** the value of resistor R_3 to equal $R_3 = R_1 \| R_2$, i.e.:

$$R_3 = \frac{R_1 R_2}{R_1 + R_2}$$

In this case, the **D.C. offset** becomes:

$$\begin{aligned}
&-\left(\frac{R_1 R_2}{R_1 + R_2} I_{B2} + \frac{R_2^{\,2}}{R_1 + R_2} I_{B2} - R_2 I_{B1}\right) \\
&= -\left(\frac{(R_1 + R_2) R_2}{R_1 + R_2} I_{B2} - R_2 I_{B1}\right) \\
&= R_2 (I_{B1} - I_{B2}) \\
&= R_2 I_{os}
\end{aligned}$$

Typically, the bias currents I_{B1} and I_{B2} are approximately equal, so that **offset current** $I_{B1} - I_{B2} = I_{os}$ is very **tiny**.

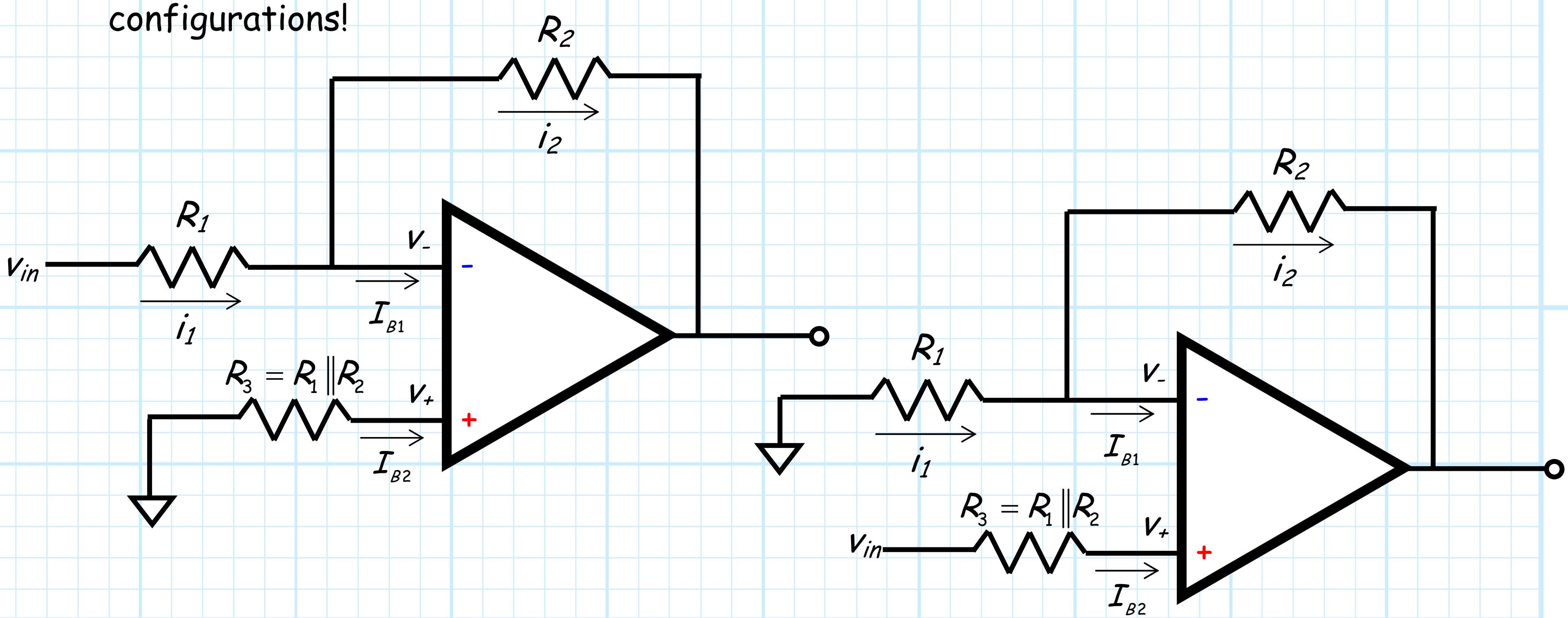
Therefore, the resulting output **offset voltage** is likewise very **tiny**!

...and this is that proper value

Therefore, when designing an amplifier with **real** op-amps, **always** include a resistor R_3 equal to the value:

$$R_3 = R_1 \| R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

This is true **regardless** of whether we use the **inverting** or **non**-inverting configurations!



This is just the type of subtle point that shows up on an exam

If the impedances are **complex** (i.e., $Z_1(\omega)$ and $Z_2(\omega)$), then set the resistor R_3 based on the D.C. values of the impedances:

$$R_3 = Z_1(\omega = 0) \| Z_2(\omega = 0)$$

In other words, set the **capacitors** to **open** circuits and **inductors** to **short** circuits.