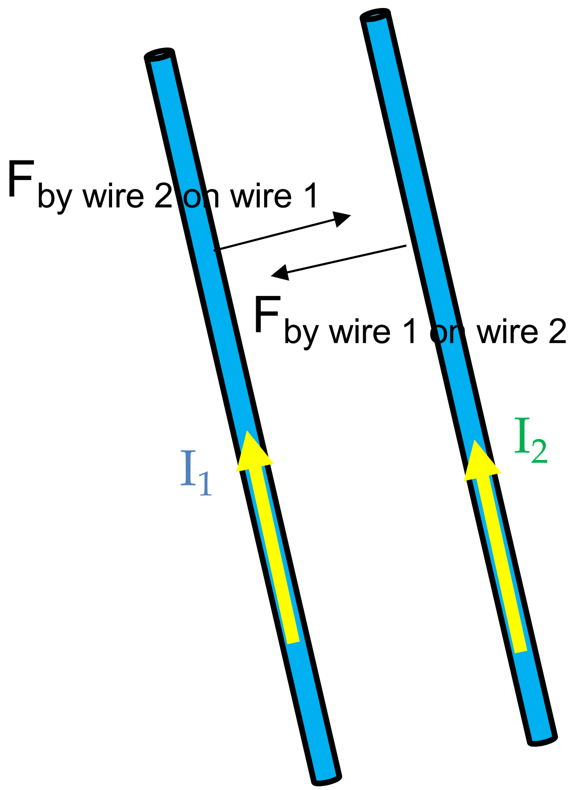
Two wires

What if there are two current-carrying wires close to each other, with no other external B field? Will anything happen?



Wire 1 will produce a magnetic field around it that is going into the page at the location of wire 2. This will exert a force on wire 2 towards wire 1.

Wire 2 will produce a magnetic field around it that is coming out of the page at the location of wire 1. This will exert a force on wire 1 towards wire 2.

Thus, the two wires will **attract each other** if the currents are in the same direction.

What if the currents are opposite directions? (They'll **repel each other**).

Force between two wires

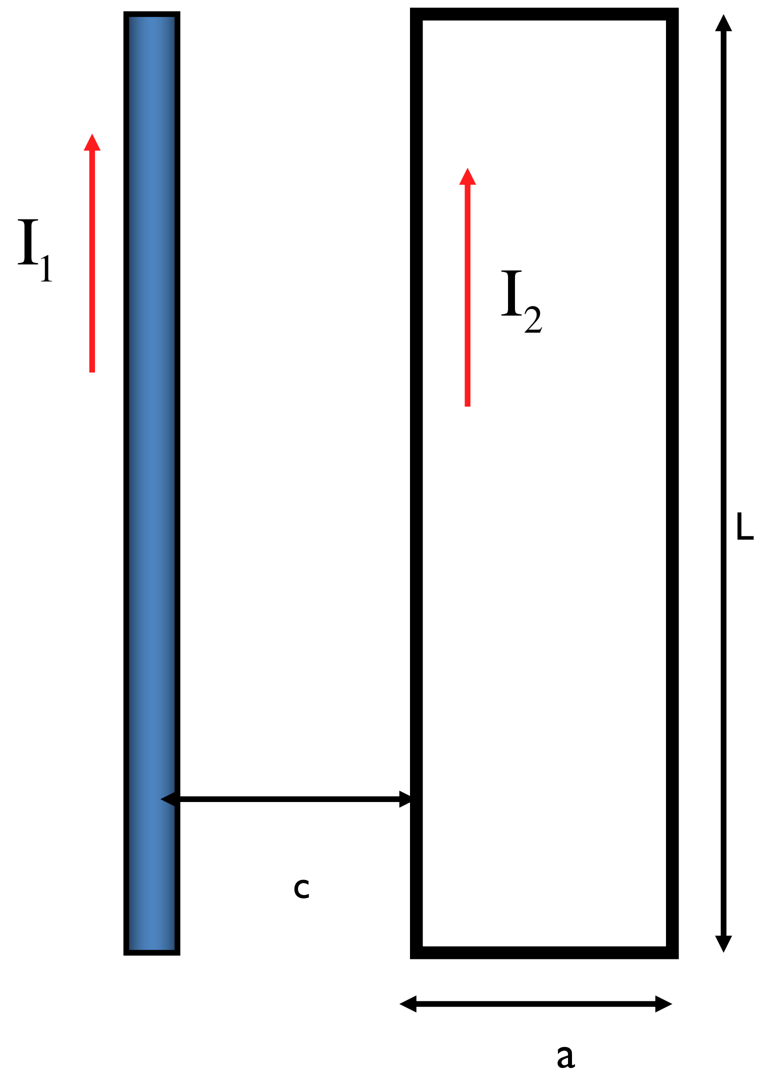
- Mathematically:
  - The field by wire 1 at the location of 2 can be found by $B_1 = \frac{\mu_0 I_1}{2\pi r}$
  - The force on wire 2 due to that magnetic field is $F_2 = I_2 L B_1$
  - Combining those, and thinking about force per unit length, we get:

$$\frac{F_2}{L} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

  - Note:
    - The force is dependent on both currents -- makes sense, as a force requires 2 objects
    - If we looked at the force on wire 1 due to wire 2, we'd get the <u>same relationship</u>
    - This means that the attractive or repelling forces between two current-carrying wires are equal and opposite - Newton's Third Law pairs!

Problem 19.58

If the left wire current is 5 amps and the loop current is 10 amps, what is the magnitude and direction of the force exerted on the loop by the wire, assuming that a=0.15 meters, c = 0.1 meters and L=0.45 meters?

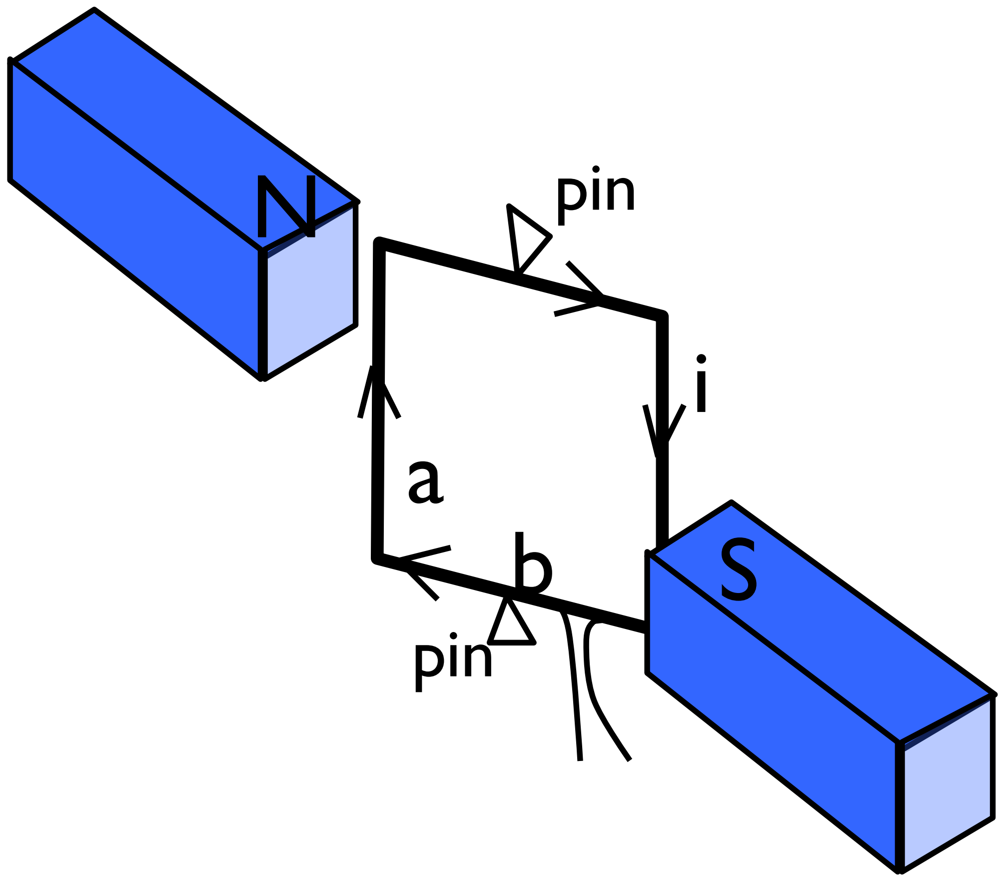


Solution is posted on class Website

Galvanometer

Remember our circuits labs? We used a **galvanometer** to measure the current. Here's how that works:

Set-up for the galvanometer. Below is a coil pinned in a magnetic field. When current passes through the coil, its sides feel forces which make it want to rotate about the pin.

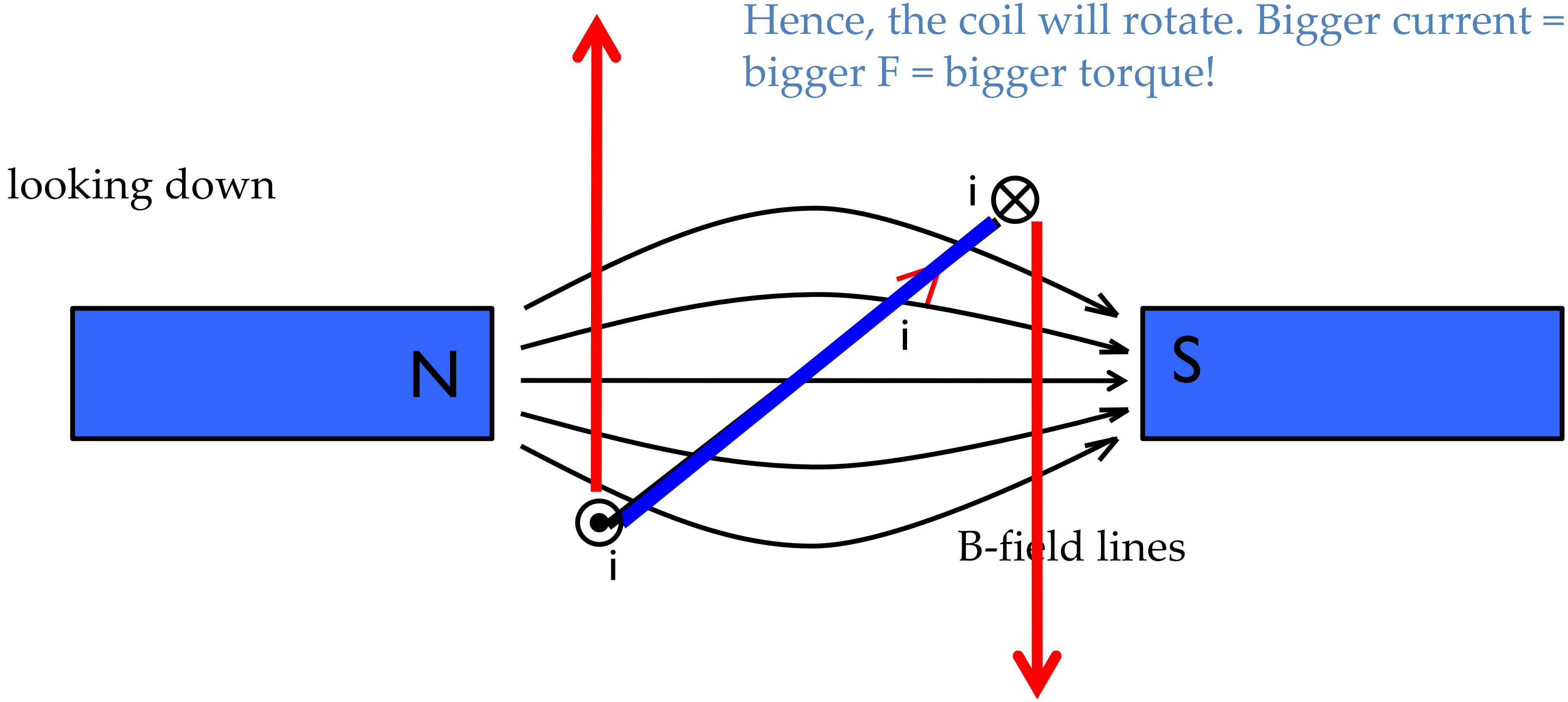


Thanks, Mr. Fletcher, for these slides!

Galvanometer

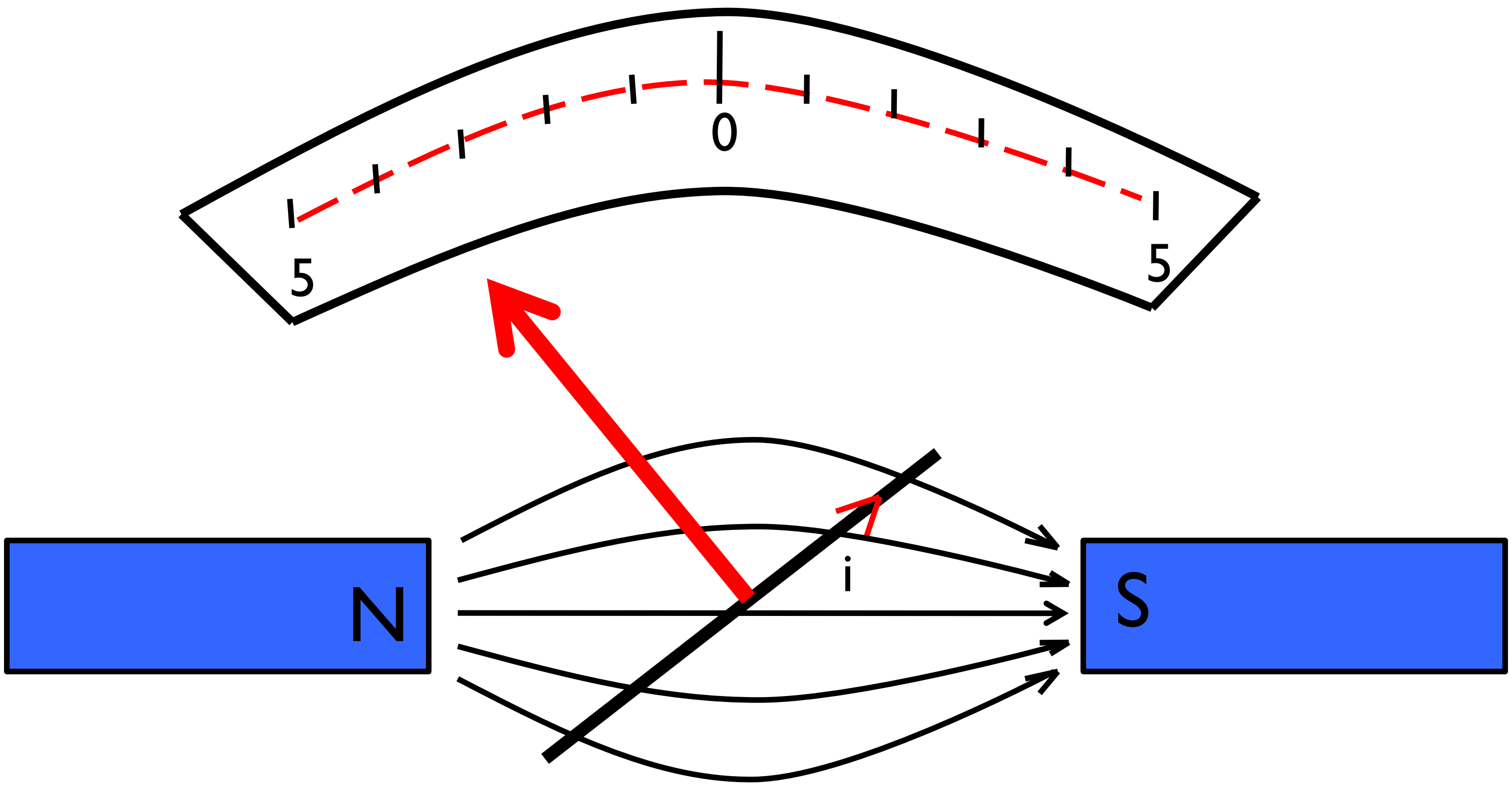
Looking from above, the current is passing across the top side of the coil while the magnetic field is pointed to the right.

The current in the sides of the coil is in/out of the page producing the forces shown in red. What does that produce? A **torque**! Hence, the coil will rotate. Bigger current = bigger F = bigger torque!



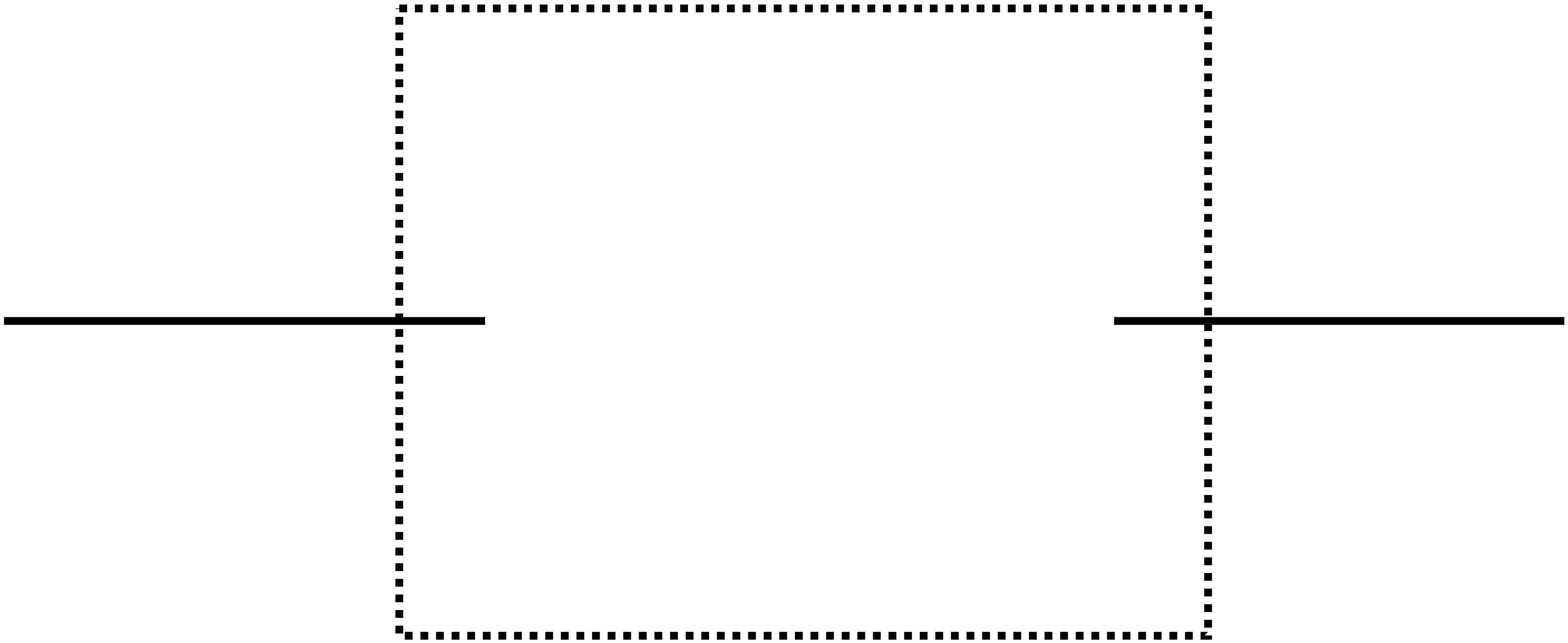
Galvanometer

Attach a pointer to the rotating coil, and put a scale under the pointer, and you have a meter.



Our galvanometers show maximum deflection with a current of 5×10^{-4} amps.

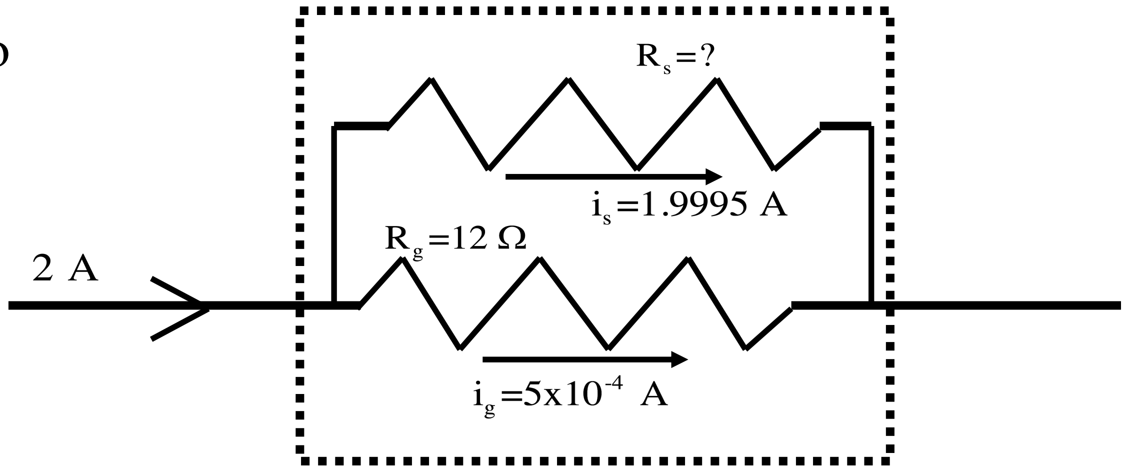
Ammeter



Example: Create a 2 amp ammeter (meaning 2 A flows through the entire ammeter) starting with the frame provided above (i.e., put in the circuit and determine any extraneous resistances). You may assume the galvanometer's resistance is 12 ohms.

Ammeter

For the galvanometer to go full deflection--something you want it to do when 2 amps flow into it--you need to shunt some of the current away from the galvanometer. The current that does not flow into the galvanometer flows through the shunt resistor. In this case, that will be 2 - .0005 = 1.9995 amps. The two resistances are in parallel, so the voltage across each will be the same. As such, we can write:



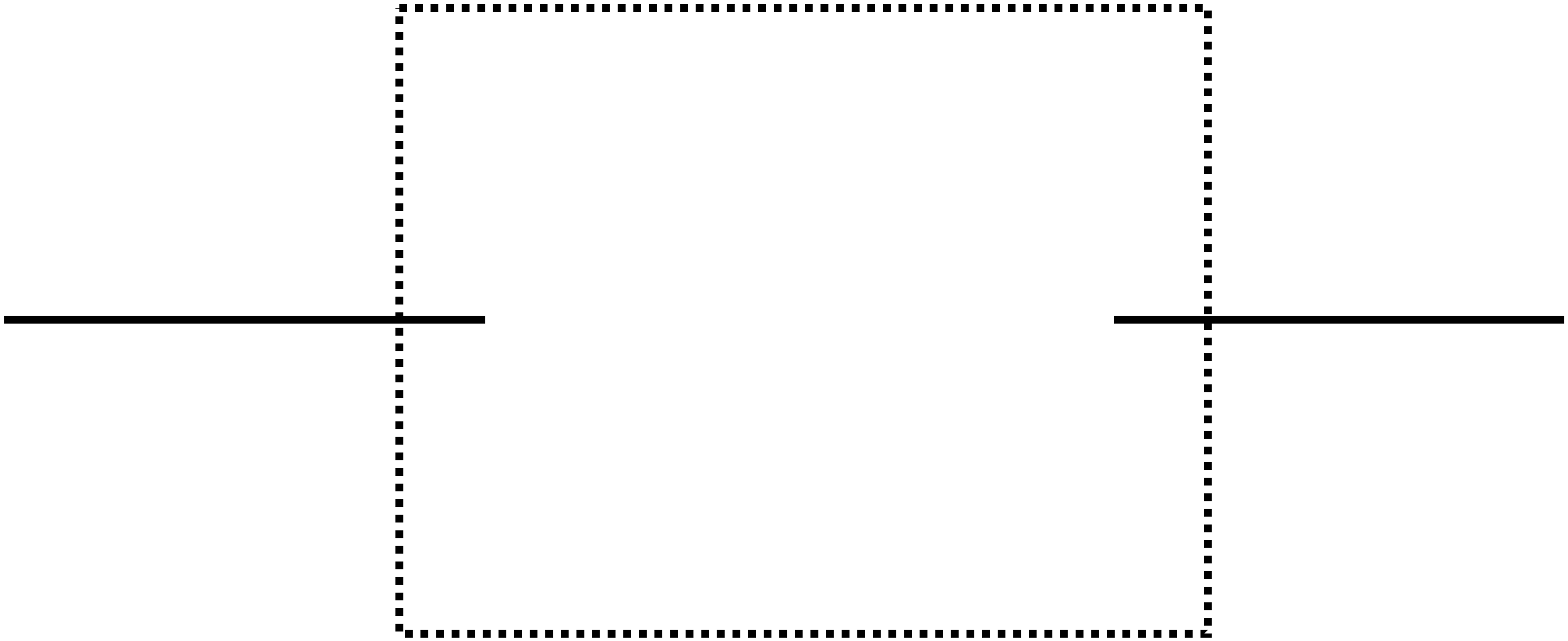
$$i_g R_g = i_s R_s$$

$$\Rightarrow \quad (5x10^{-4}\,A)(12\ \Omega) = 1.9995(R)$$

$$\Rightarrow \quad R \approx 3x10^{-3}\Omega$$

Note: A short wire across the galvanometer's terminals will give us this resistance. Also, the equivalent resistance of a parallel combination of resistors is smaller than the smallest resistor in the combination. That means the equivalent resistance of this ammeter is less than three thousandths of an ohm. That is what we expected. Ammeters have little net resistance to charge flow (hence current is not impacted by putting one directly into a circuit).

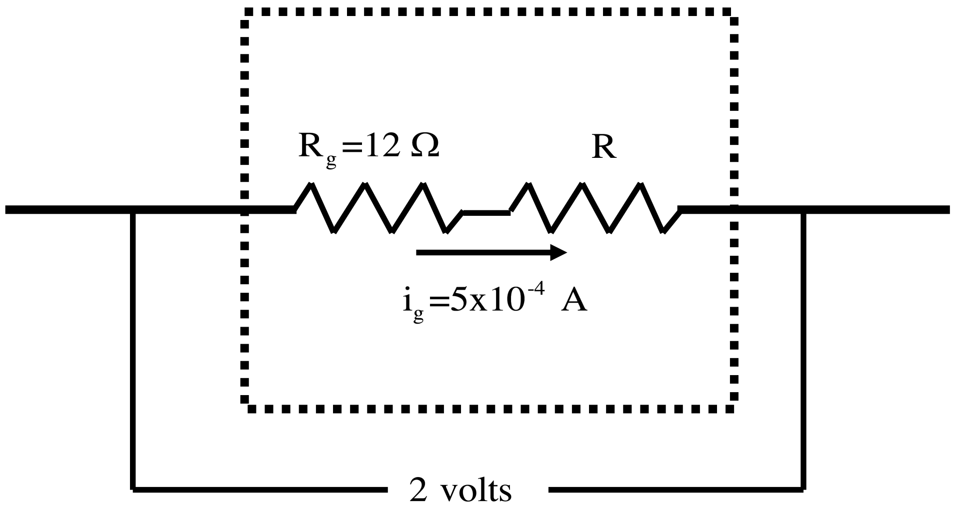
Voltmeter



Example: Create a 2 volt voltmeter starting with the frame provided above (i.e., put in the circuit and determine any extraneous resistances). You may assume the galvanometer's resistance is 12 ohms.

Voltmeter

For the galvanometer to go full deflection--something you want it to do when 2 amps flow into it--you to have a half milliamp flow through it. Two volts across a 12 ohm galvanometer will produce a huge current, so you have to cut the current down some. You do that by putting a resistor in series with the galvanometer. Remembering that the current through resistors in series is the same, we can write:



$$V = i_g R_g + i_g R$$

$$\Rightarrow \quad 2 = \left(5\text{x}10^{-4}\text{ A}\right)\left(12\ \Omega\right) + \left(5\text{x}10^{-4}\text{ A}\right)\left(R\right)$$

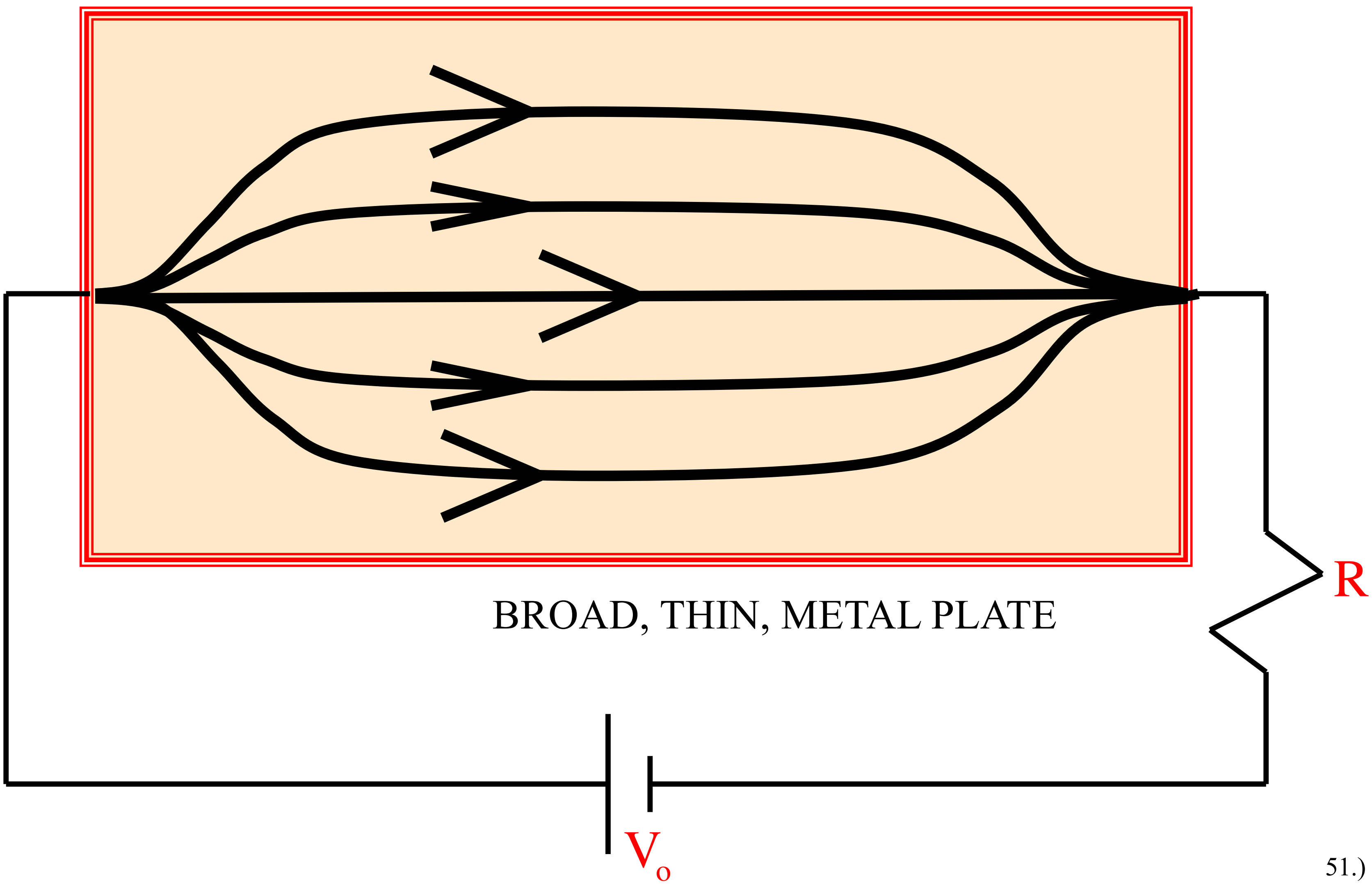
$$\Rightarrow \quad R \approx 4\text{x}10^{3}\Omega$$

Note: The equivalent resistance of a series combination of resistors is larger than the largest resistor in the combination. That means the equivalent resistance of this voltmeter is greater than four thousand ohms. That is exactly what we expected. Voltmeters have huge resistance to charge flow (hence little current passes through them when put in a circuit).

HALL EFFECT

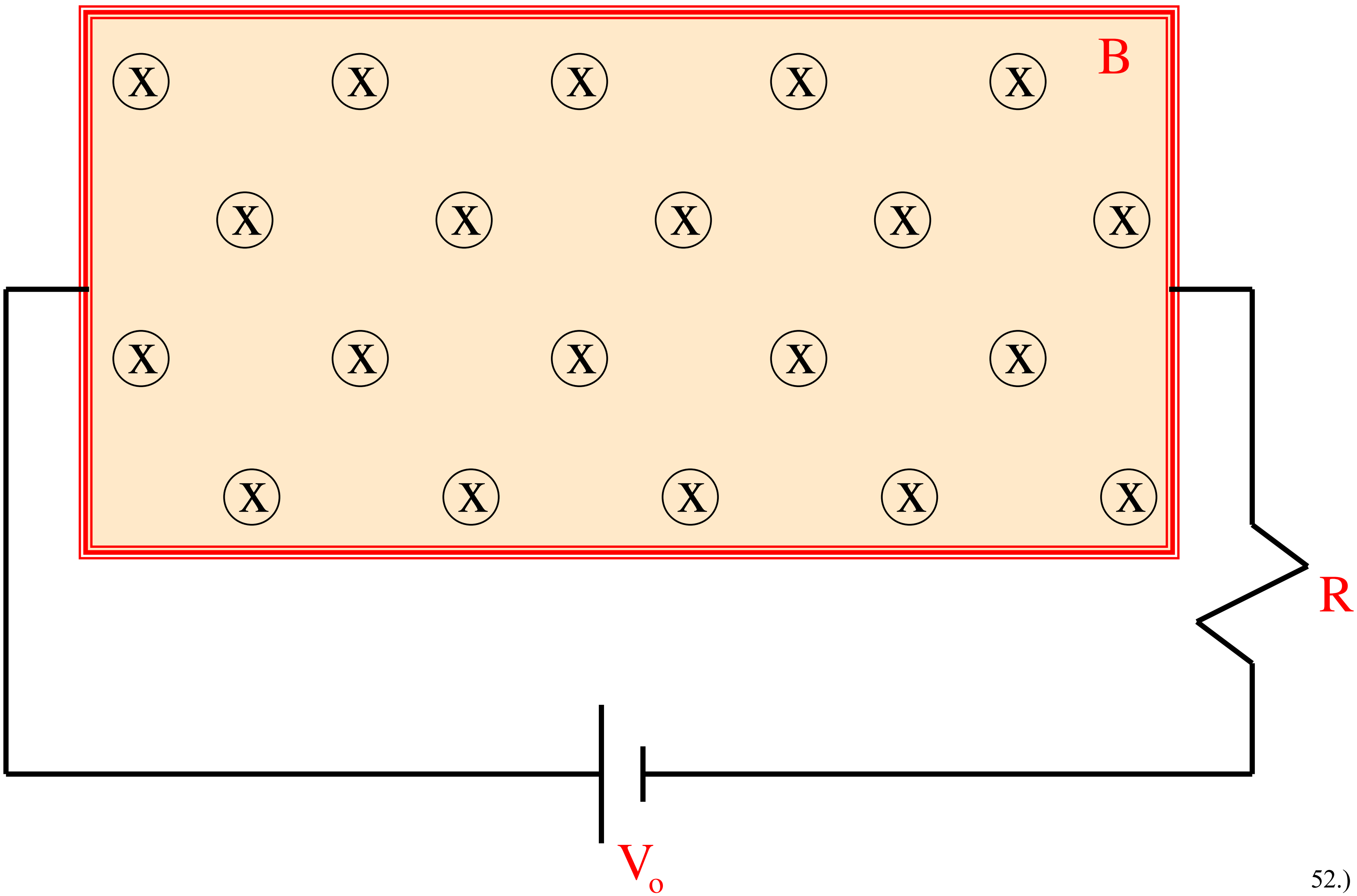
An experiment to prove that *negative charges* moves through electrical circuits when current flows.

How normal current flows through the plate.



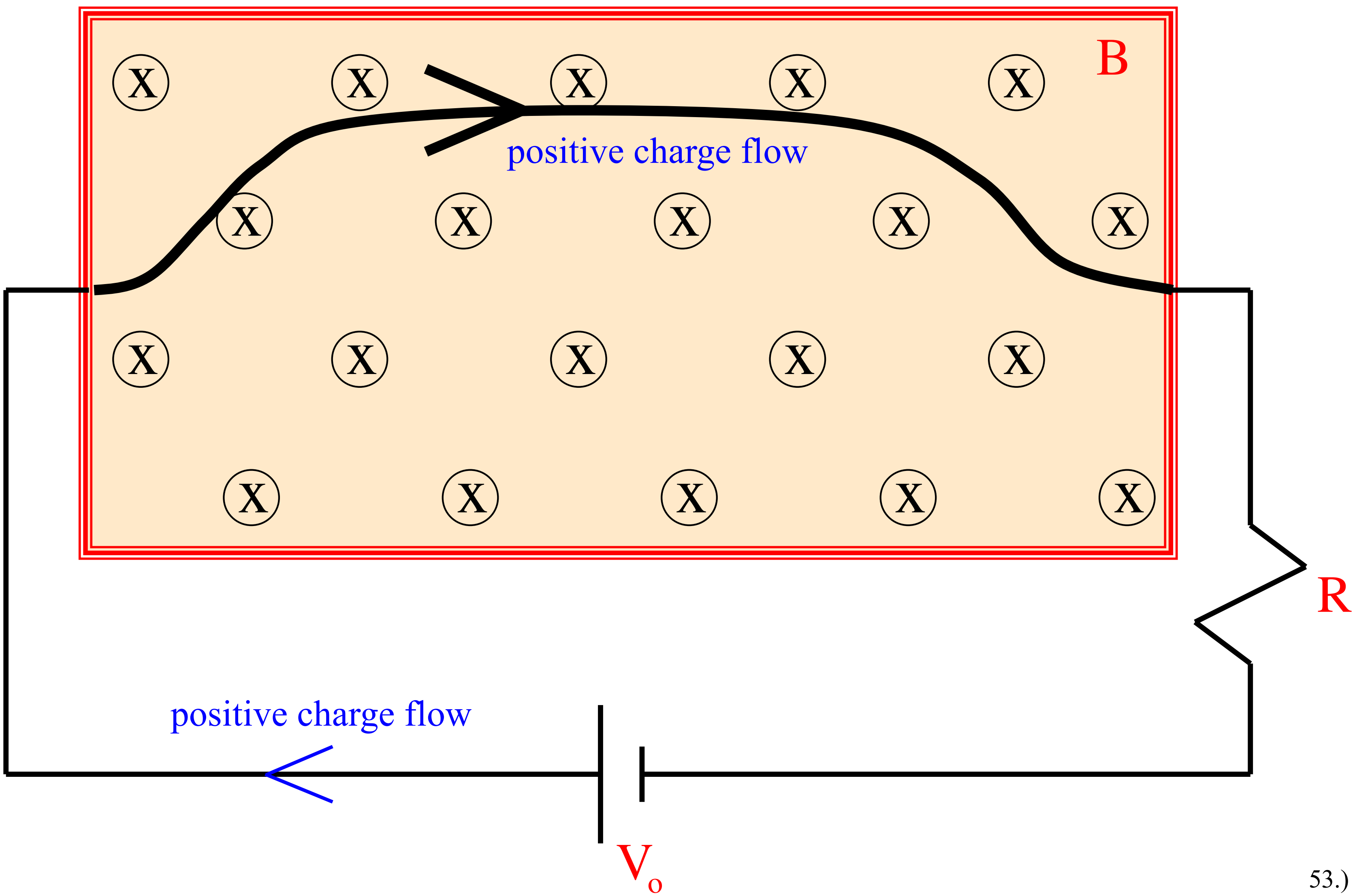
What happens when the plate is permeated by *B-fld*.

plate permeated by *B-fld*



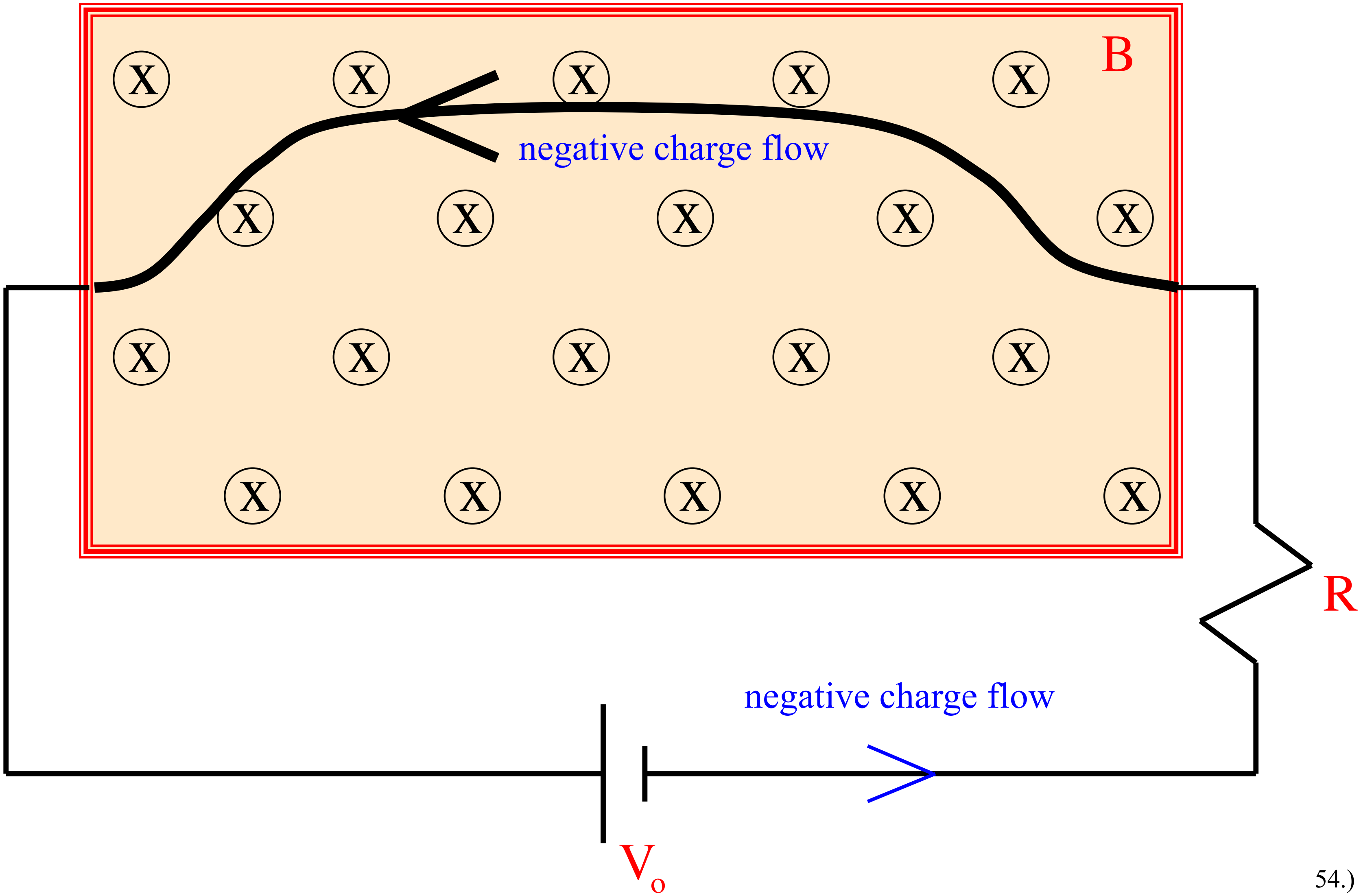
. . . *if POSITIVE charge* is assumed to flow through circuit?

positive charge flow suggests upper side of plate will be high voltage side

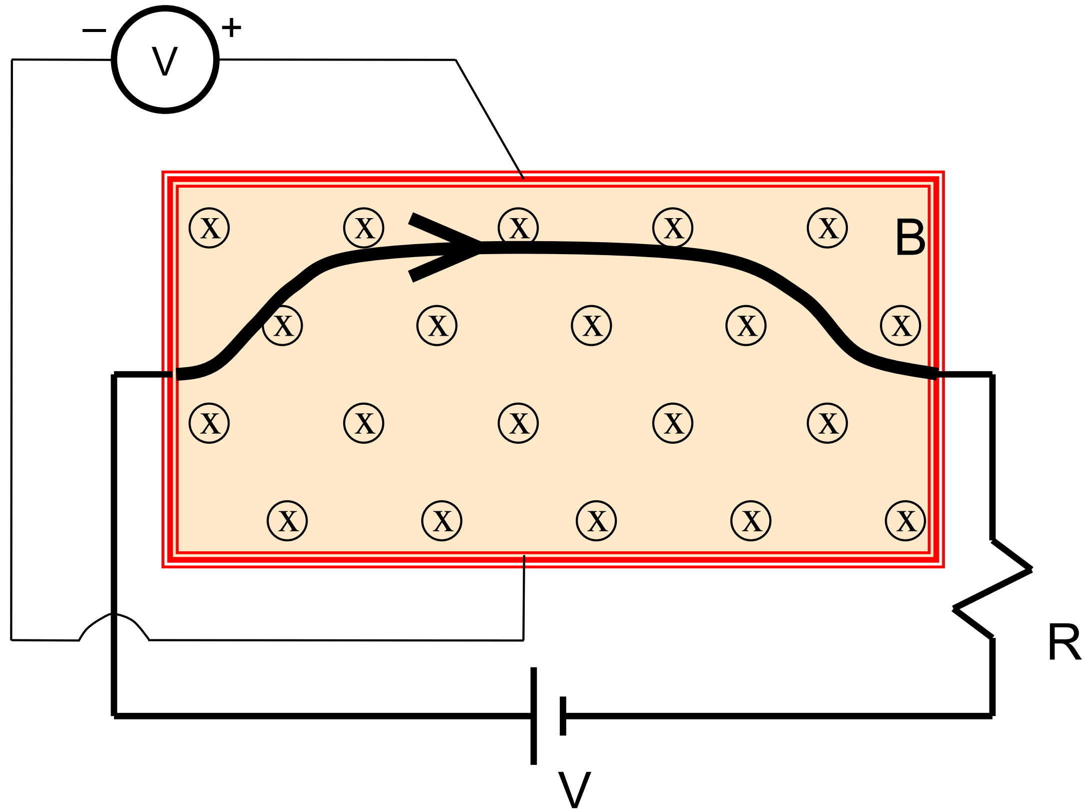


. . . *if NEGATIVE charge* is assumed to flow through circuit?

negative charge flow suggests upper side of plate will be low voltage side



So back to the positive charge-flow assumption:



If there exists a predominance of positive charge on the upper side of the plate making that side of the plate higher voltage than the bottom side, then placing a voltmeter with its + and – terminals as positioned would produce a meter reading *that was sensible* (that is, the needle would swing in the appropriate direction).

In fact, if this experiment was done, the needle would swing in the *wrong direction*. In other words, the the meter is hooked up wrong. What are accumulating on the upper side of the plate are not positive charges, they are NEGATIVE charges.

In short, it is *negative charge* that flows through circuits.