Electrical Circuits

I. Current and Resistance
- Ohm's Law

II. Resistivity
- resistance factors
- conductivity
- drift velocity & current density

III. Electrical Power

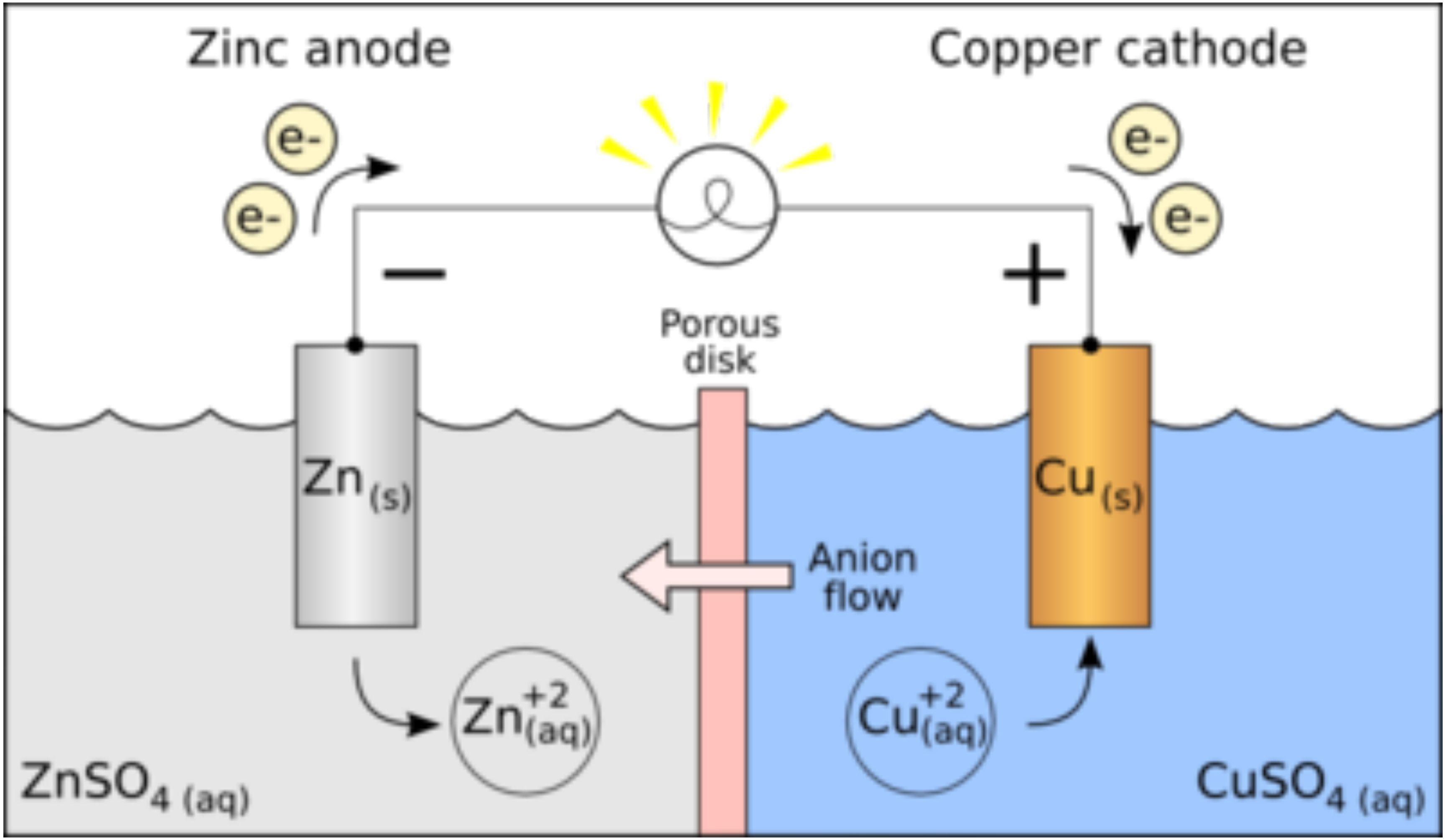
IV. Circuits
- series and parallel
- Kirchoff's Laws

V. Batteries and Meters
- internal resistance

	The student will be able to:	HW:
1	Define current and the ampere, conventional positive current flow, and solve related problems, including those with both positive and negative charge carriers. ✓	1 – 3
2	Define resistance and the ohm, state Ohm's Law, and solve related problems involving ohmic and/or nonohmic devices. ✓	4 – 7
3	Describe and explain factors influencing resistance, state mathematical relation between resistance, length, area, and resistivity or conductivity, and solve related problems. ✓	8 – 13
4	Solve problems involving current density, electric field, resistivity, drift velocity and/or use these concepts to explain the nature of resistance. ✓	14 – 16
5	Solve problems involving electric power. ✓	17 – 21
6	Determine effective resistance of a network of series and/or parallel resistors. ✓	22 – 24
7	Solve for voltage, current, resistance, and power in DC circuits using Kirchoff's Laws and/or effective resistance. ✓	25 – 38
8	Model a cell or battery as an ideal voltage source or as an EMF with internal resistance and a certain terminal voltage, and solve related problems.	39 – 43
9	Understand operation and properties of voltmeters and ammeters and illustrate proper connections thereof, and solve related problems.	44 – 46

Cells & Batteries

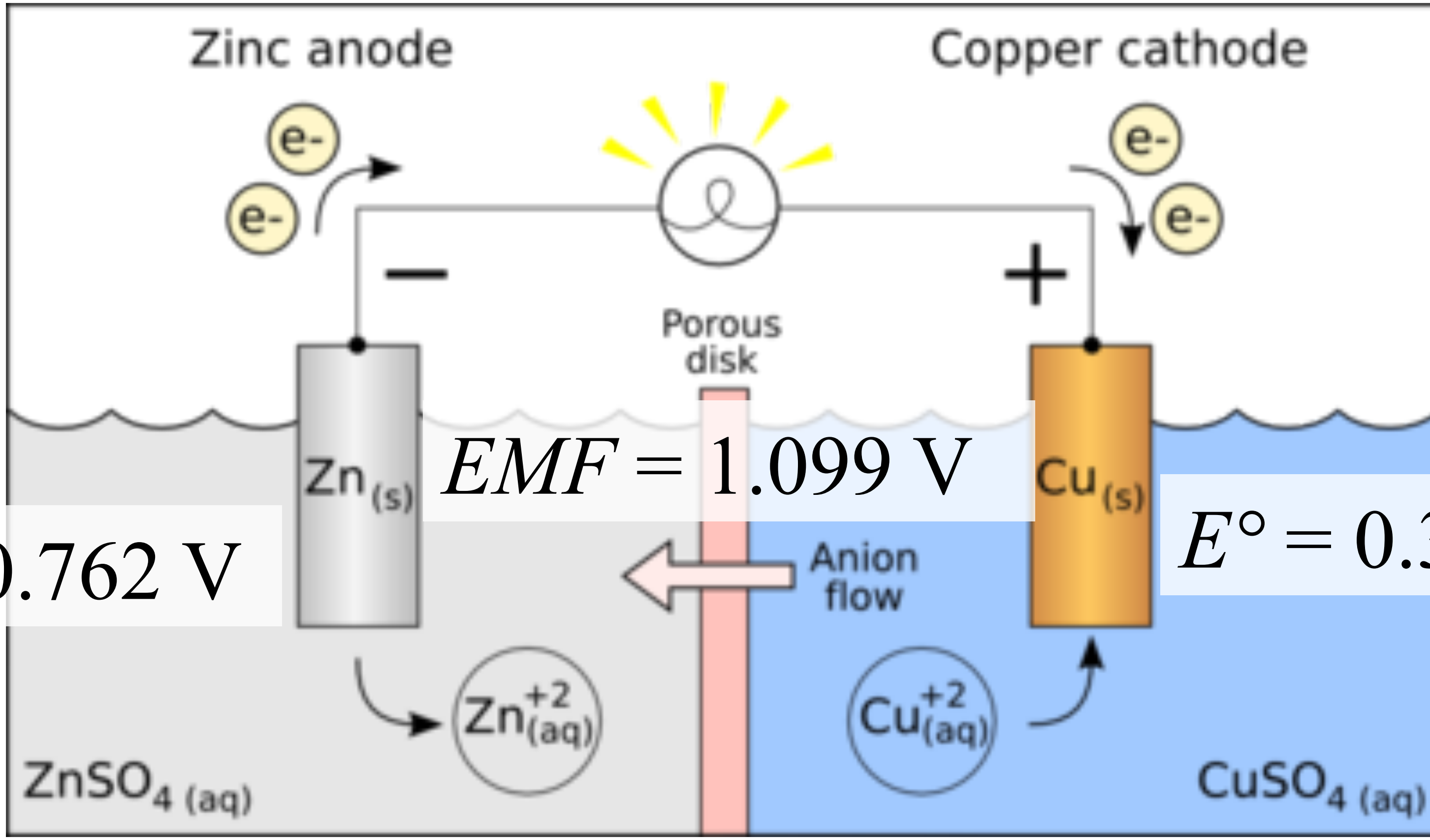
- A voltaic (or galvanic) cell is a single container of chemicals with two electrodes: an anode and a cathode.
- Properly speaking a "battery" is a collection of multiple cells connected in series.
- Energy is "stored" in chemical form until a current is drawn from the battery, at which point oxidation occurs at the anode and reduction occurs at the cathode.



source: Wikipedia, Ohiostandard

EMF

- The energy associated with the chemical reaction can be quantified by *EMF* ("electromotive force"), which is a measure of energy per charge.
- For a given chemical reaction there is a characteristic *EMF*, which is independent of the quantity of reactants and can be determined by standard electric potentials of the corresponding half-reactions.



source: Wikipedia, Ohiostandard

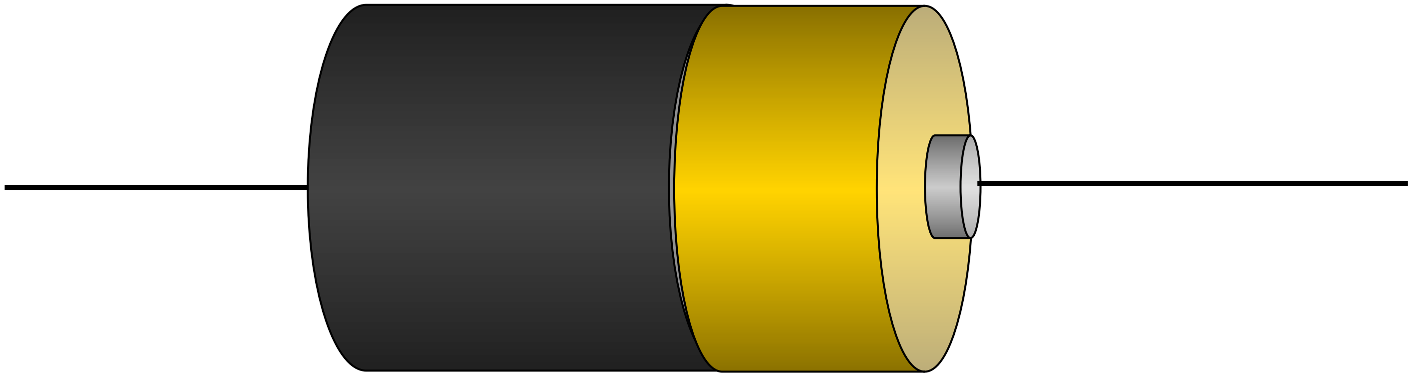
The potential or *EMF* (electromotive force) is the combination of the half-potentials of the reactions. For this particular combination of reactions:

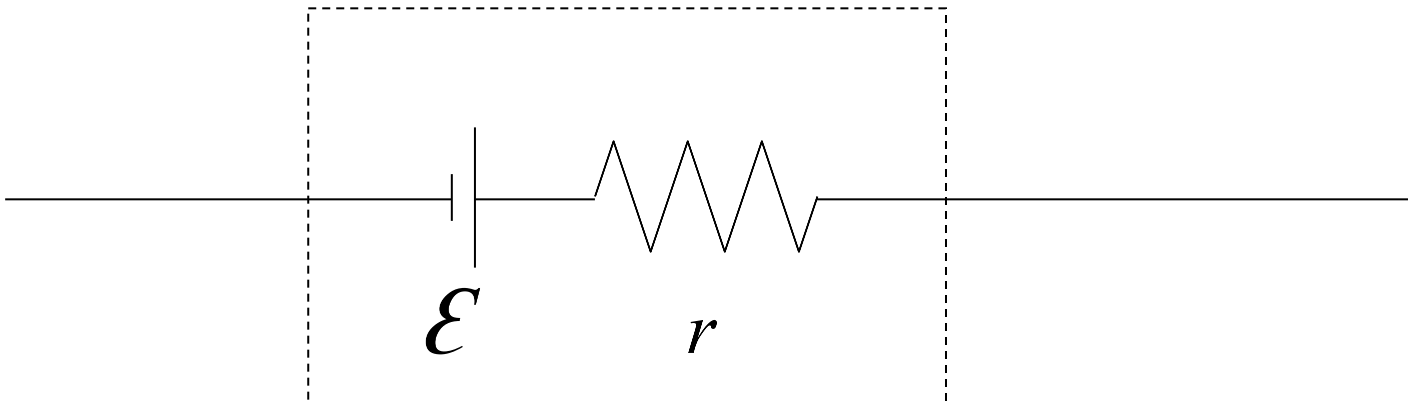
$$EMF = 0.762 + 0.337 = 1.099 \text{ V}$$

Terminal Voltage and Internal Resistance

- A battery’s voltage has a *tendency* to be *relatively constant*. However it is the EMF of the chemical reaction that should be constant.
- The voltage measured at the terminals of the battery is variable depending on the current. The greater the current leaving the positive terminal, the less the terminal voltage.
- The variance in terminal voltage is a result of internal resistance associated with the flow of charge through the battery.

Modeling the Behavior of a Cell or Battery

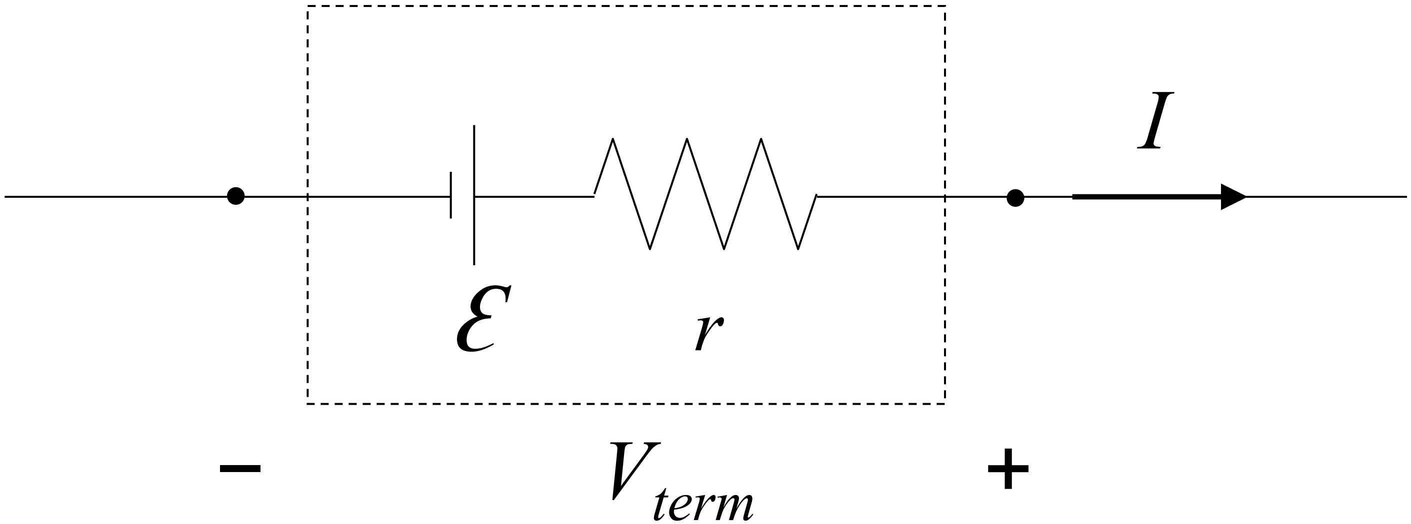




where: $\mathcal{E}$ = emf

r = internal resistance

Modeling the Behavior of a Cell or Battery



Note: in spite of the commonly used schematic of this model there is <u>not</u> an actual resistor inside a battery. The resistor symbol shown here represents the resistance that "occurs" throughout the battery as charge passes from one terminal to the other.

$$V_{term} = \mathcal{E} - Ir$$

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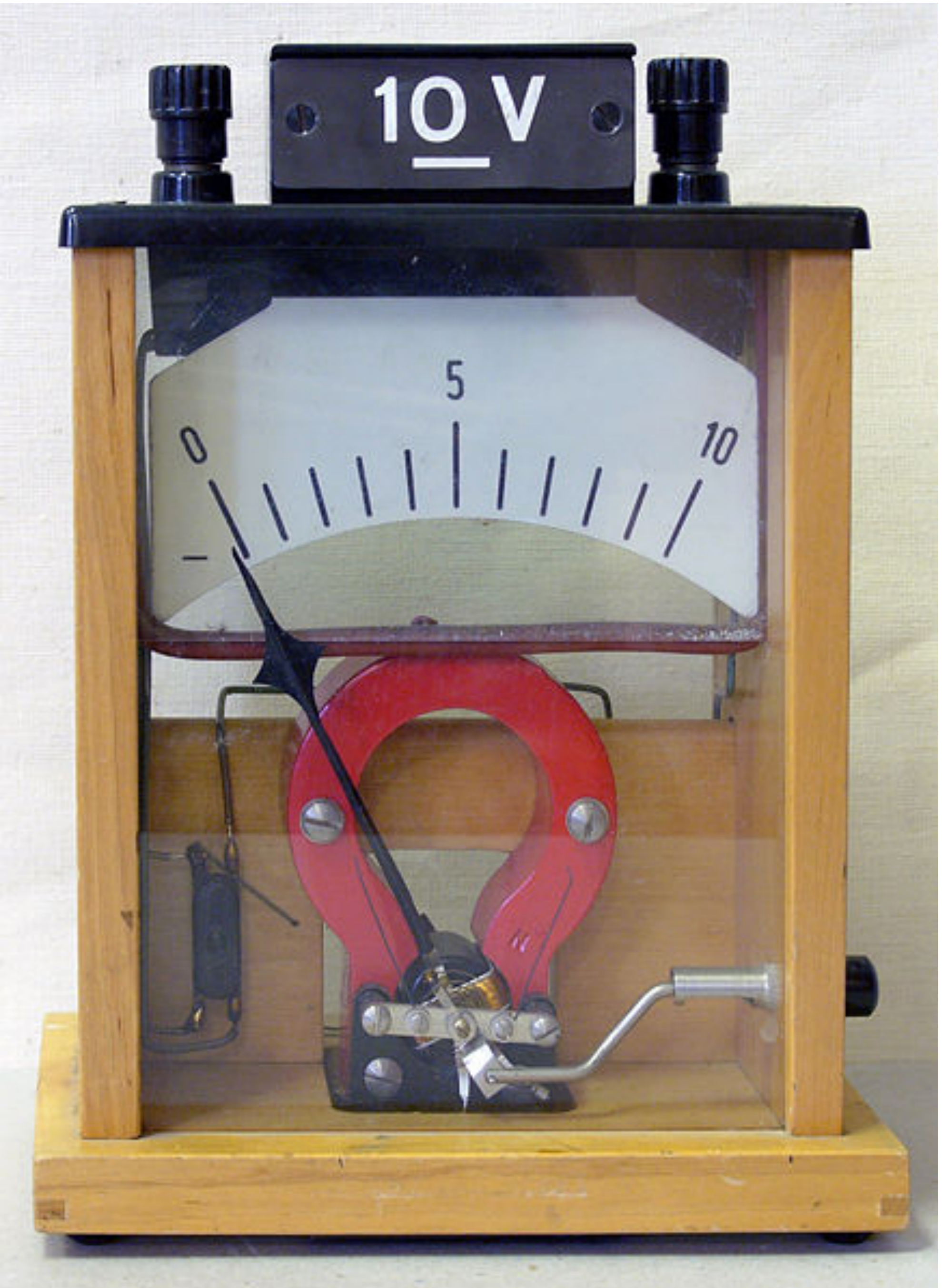
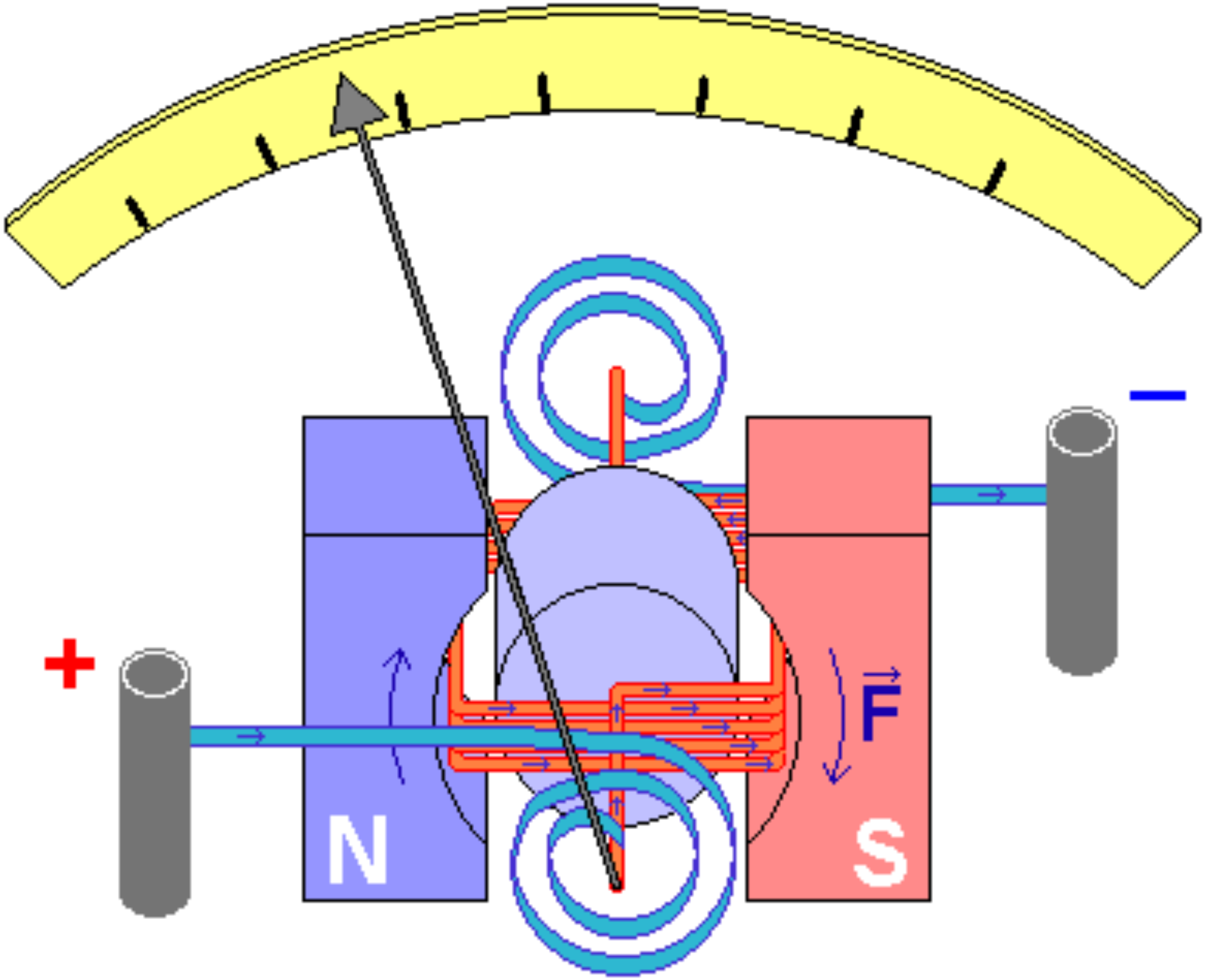
Electrical Meters

- When measuring a voltage or current it is inevitable that the circuit under consideration will be altered!
- It is useful to understand the properties of voltmeters and ammeters and their effect on a circuit…
- We will consider the "old school" technology of analog meters…



Deflection of the needle is proportional to the current in the coil (interacts with permanent magnet).



Source: Wikipedia, Panther

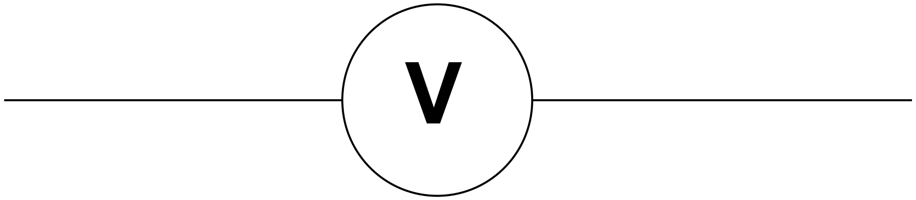
A **galvanometer** is little more than the coil/ needle/magnet apparatus. A relatively small current through the coil will cause the needle to deflect.

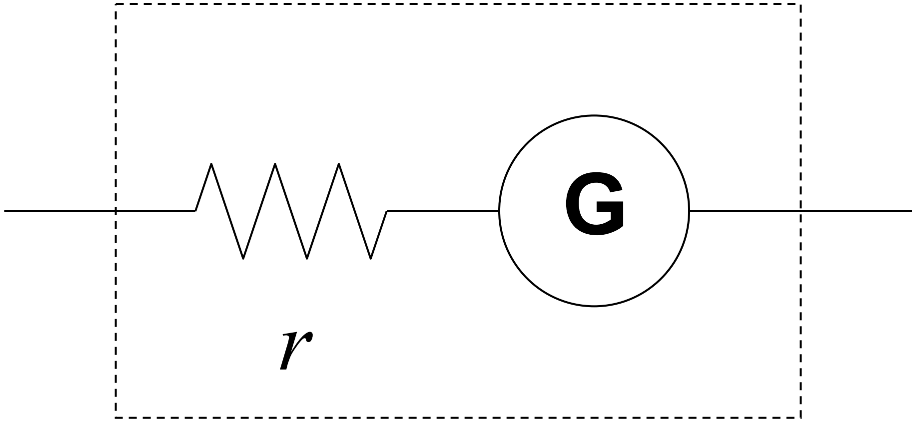
A **galvanometer** is characterized by its internal resistance (that of the coil) and its "full scale current" – enough to cause the needle to deflect to the end of the scale.

Voltmeter

- A **voltmeter** can be formed by connecting a galvanometer in series with a resistor.
- Typically a resistor of very large resistance is required to prevent overloading the coil.
- An "ideal voltmeter" would have *infinite* resistance and draw *zero* current. In reality an actual voltmeter has very large resistance and draws very little current.

Voltmeter Design

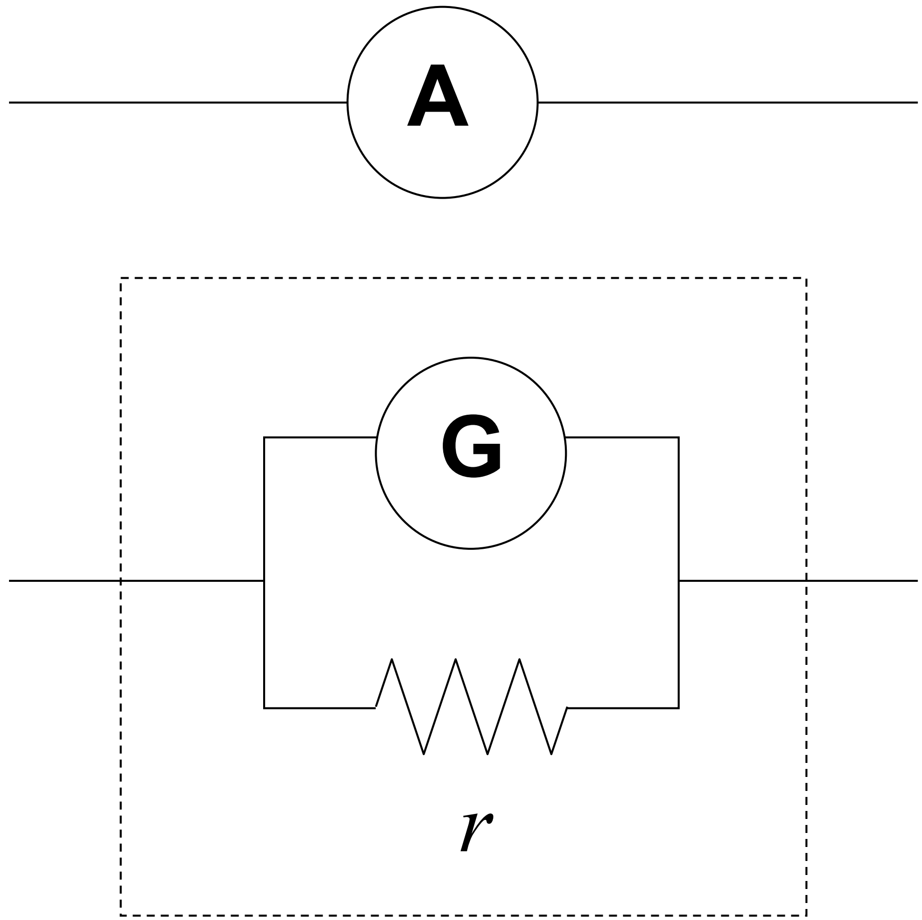




Ammeter

- An **ammeter** can be formed by connecting a galvanometer in parallel with a resistor.
- Typically the resistor must have very small resistance providing a "shunt" to prevent overloading the coil.
- An "ideal ammeter" would have *zero* resistance and not affect current. In reality an actual ammeter has very small resistance and may reduce current slightly.

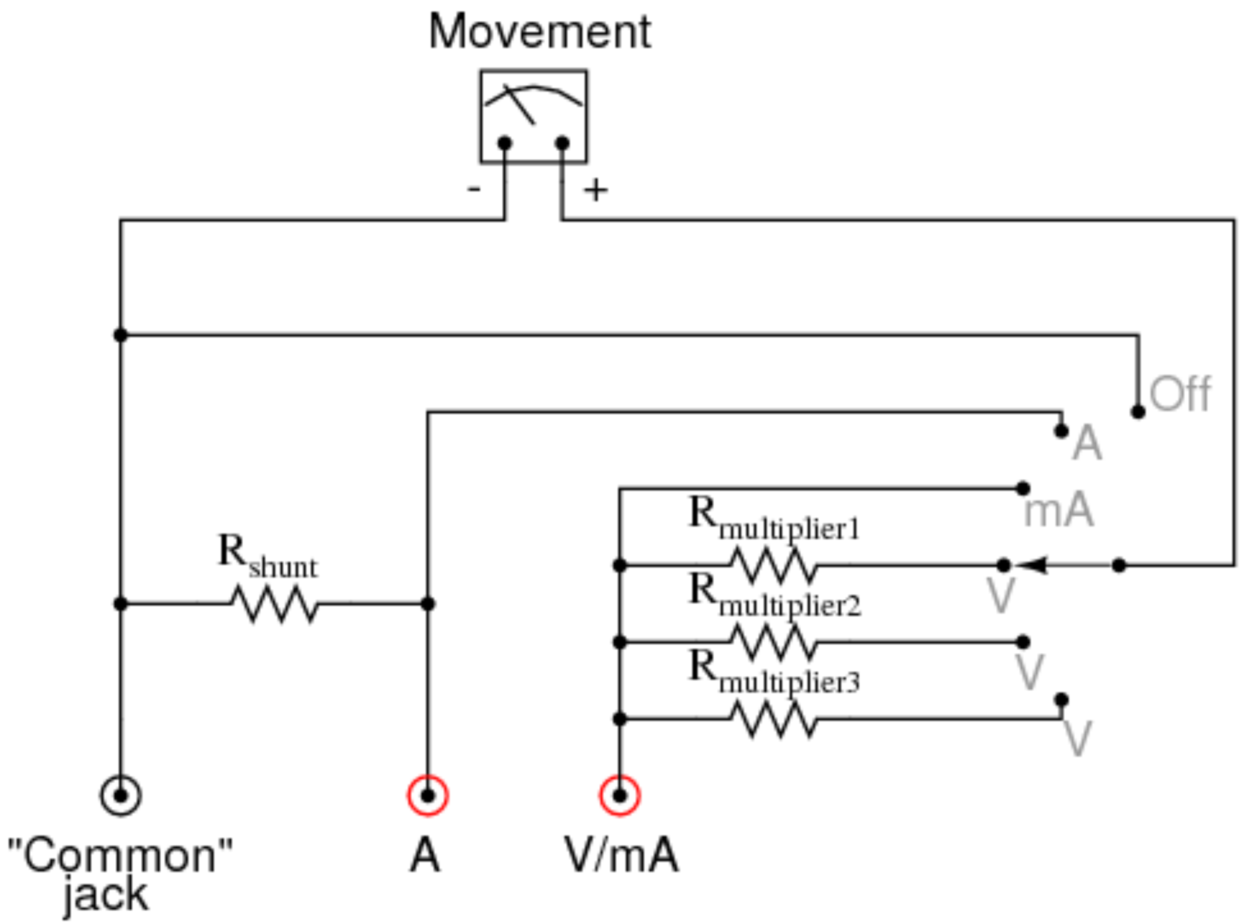
Ammeter Design



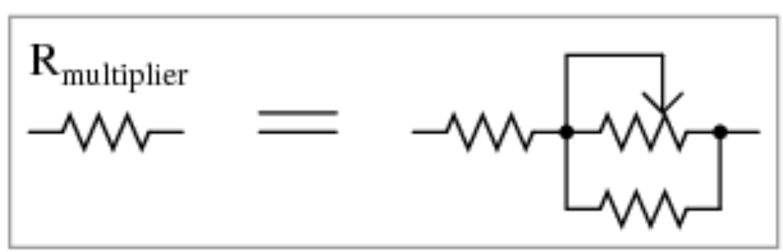
Multimeters

Analog

Digital



"$R_{multiplier}$" resistors are actually rheostat networks




TRIPLETT
9005
R47
U3
D6
R22
R23
R21
R10
R63
C18
D7
R46
C5
Q4
R20
D1
R12
R13
R14
R15
R17
R16
R59
U2
JRC
D4
D5
D2
D3
R2
R24
R25
hFE
R26
R27
PTC
F 2A/250V
10A
A
R19
V/OHM

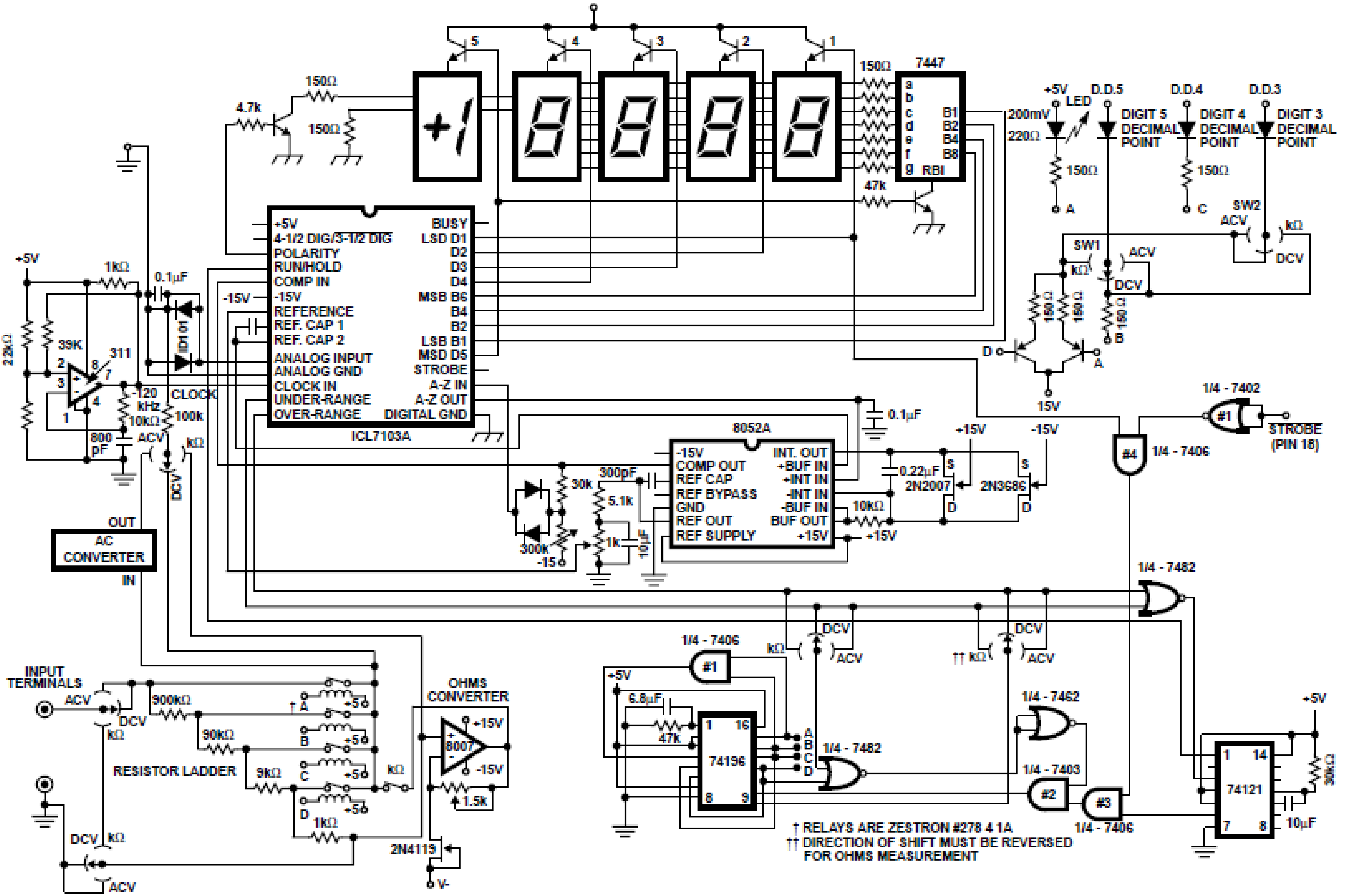
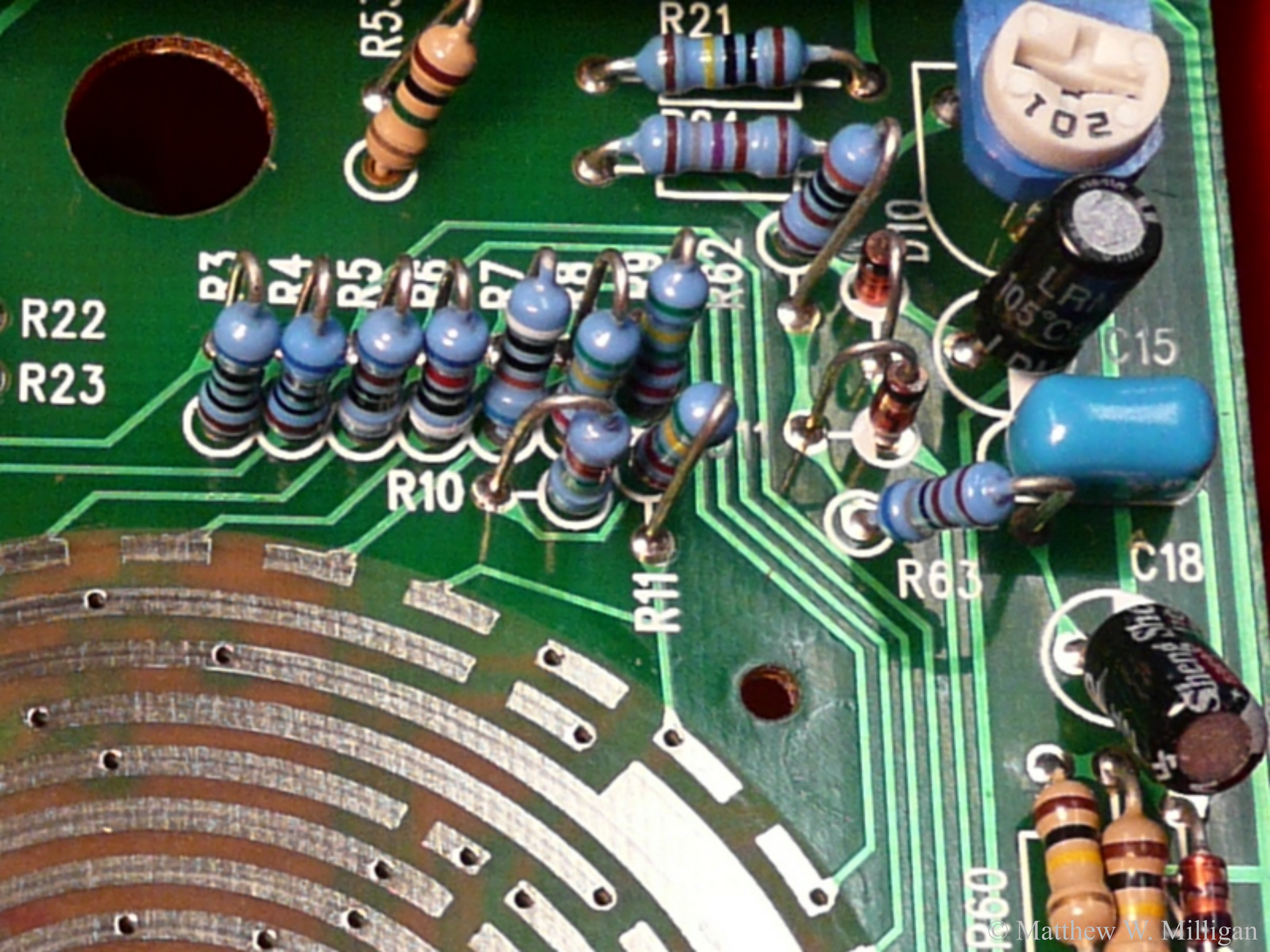
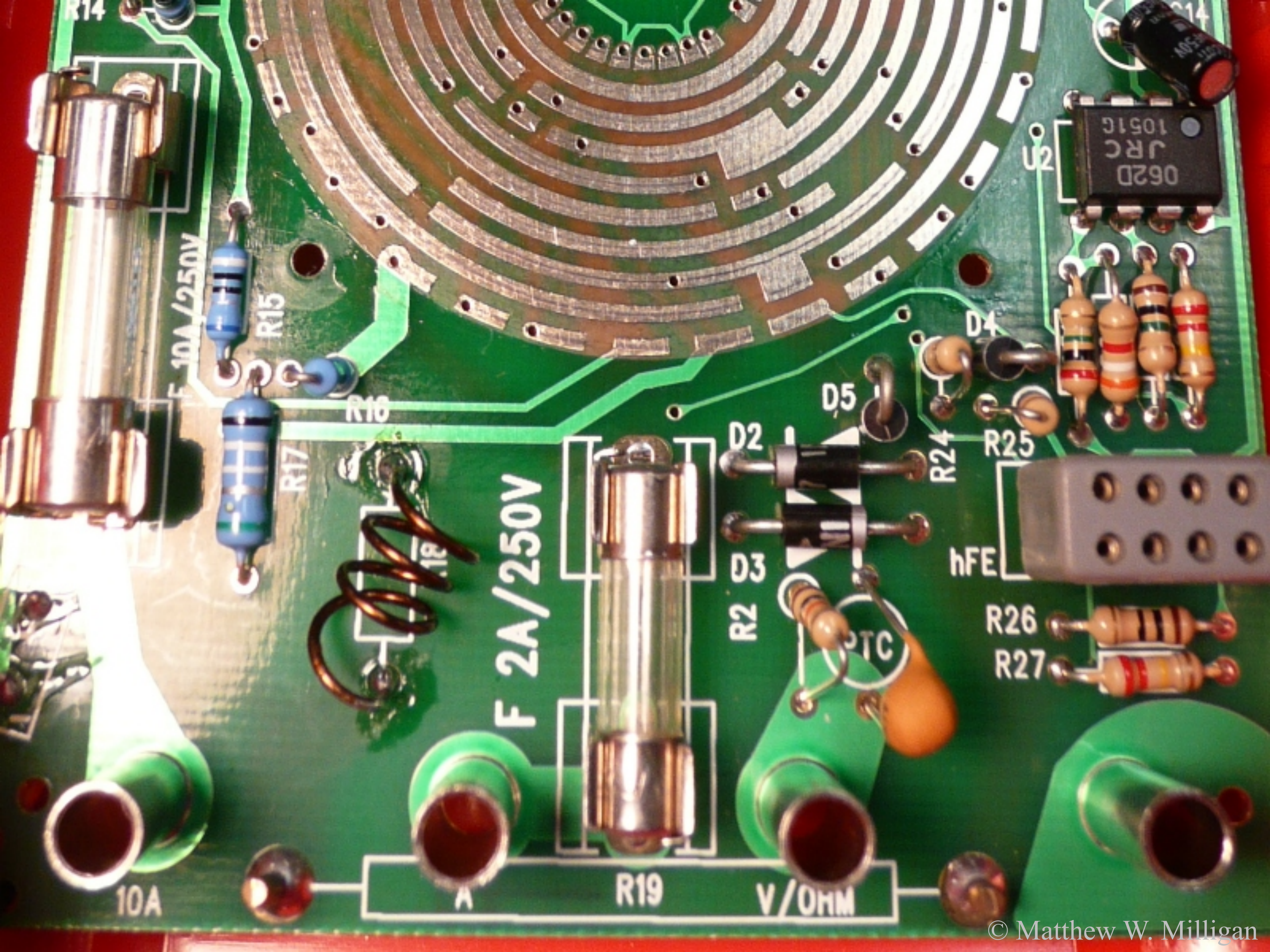
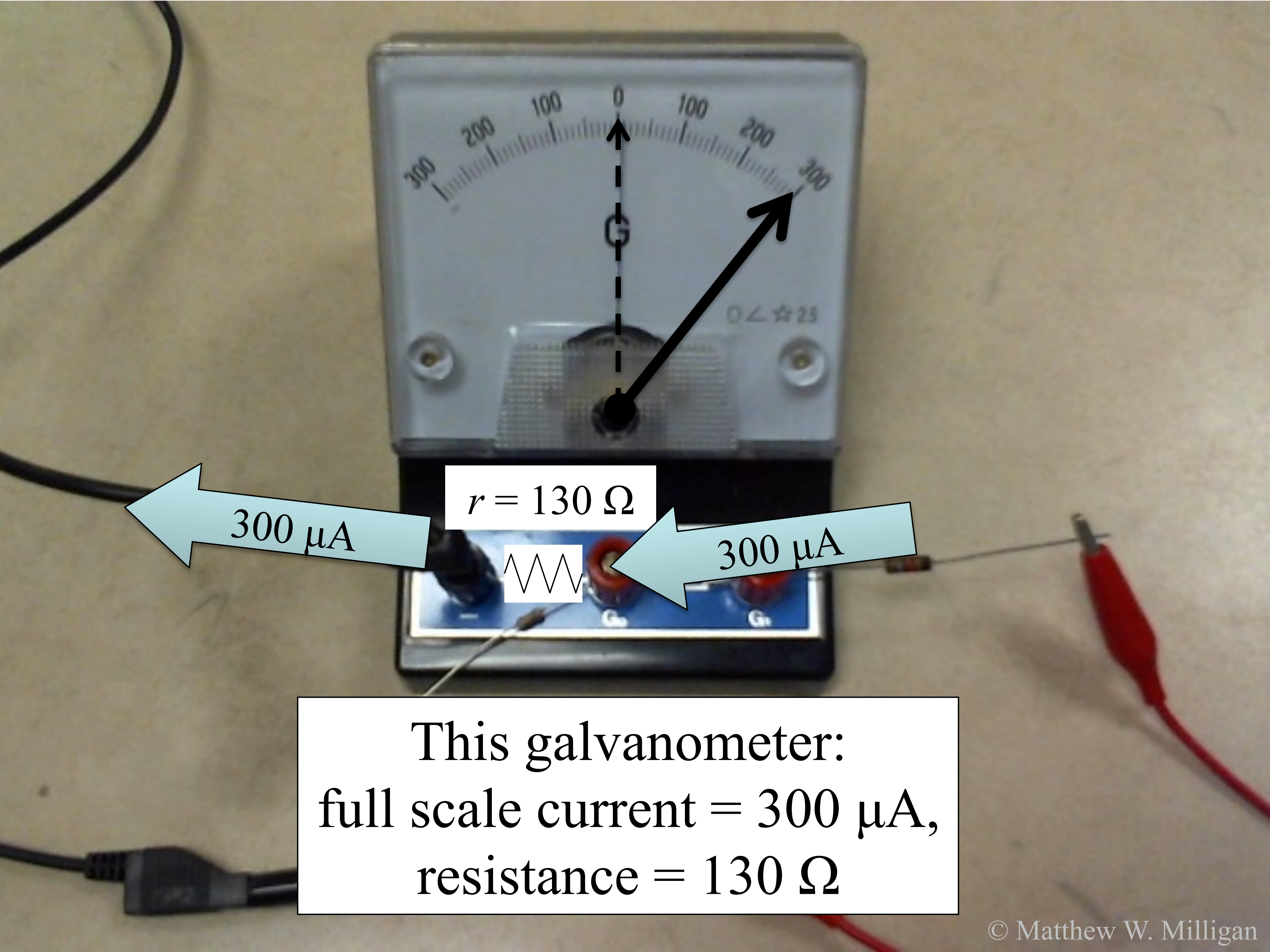


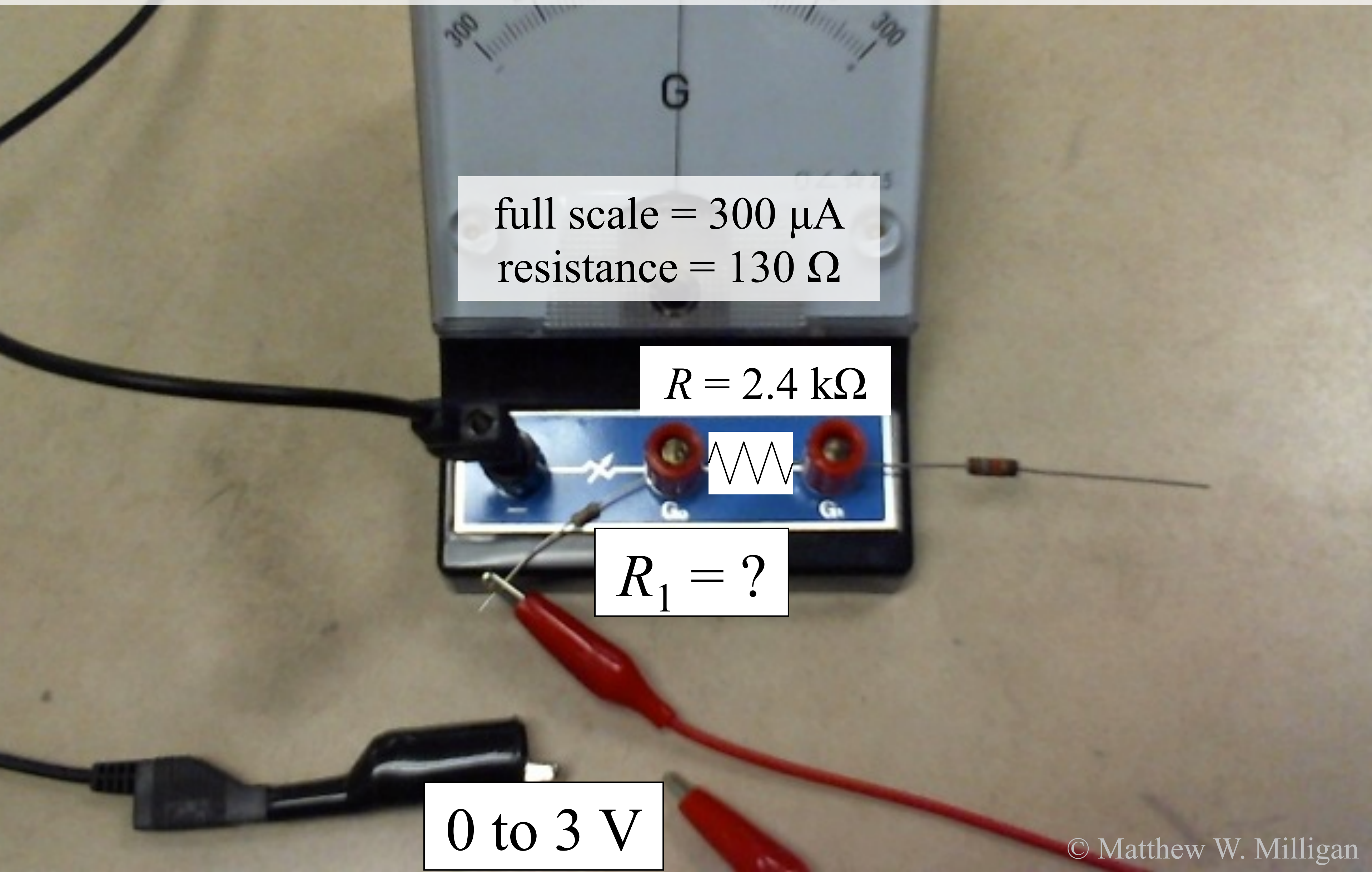
FIGURE 5. AUTO-RANGING SCHEMATIC #1


R21
102
R22
R23
R3
R4
R5
R7
R62
D10
C15
R10
R11
R63
C18


R14
F 10A/250V
R15
R16
R17
F 2A/250V
D2
D3
D4
D5
R2
PTC
R24
R25
U2
hFE
R26
R27
10A
A
R19
V/OHM


100
0
100
200
200
300
300
G
r = 130 Ω
300 μA
300 μA
This galvanometer:
full scale current = 300 μA,
resistance = 130 Ω

What value resistors would turn the galvanometer into a voltmeter with two ranges:



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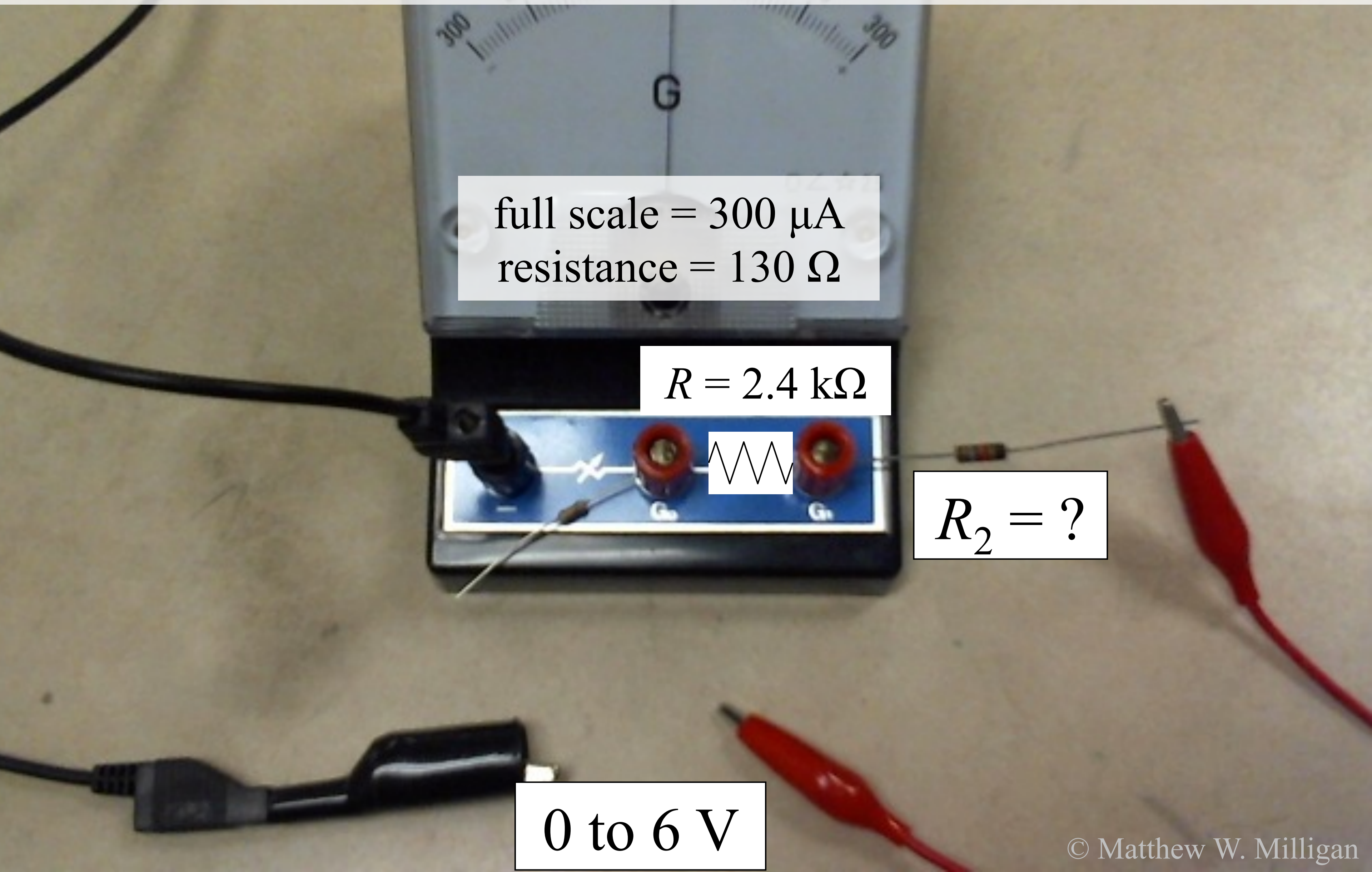

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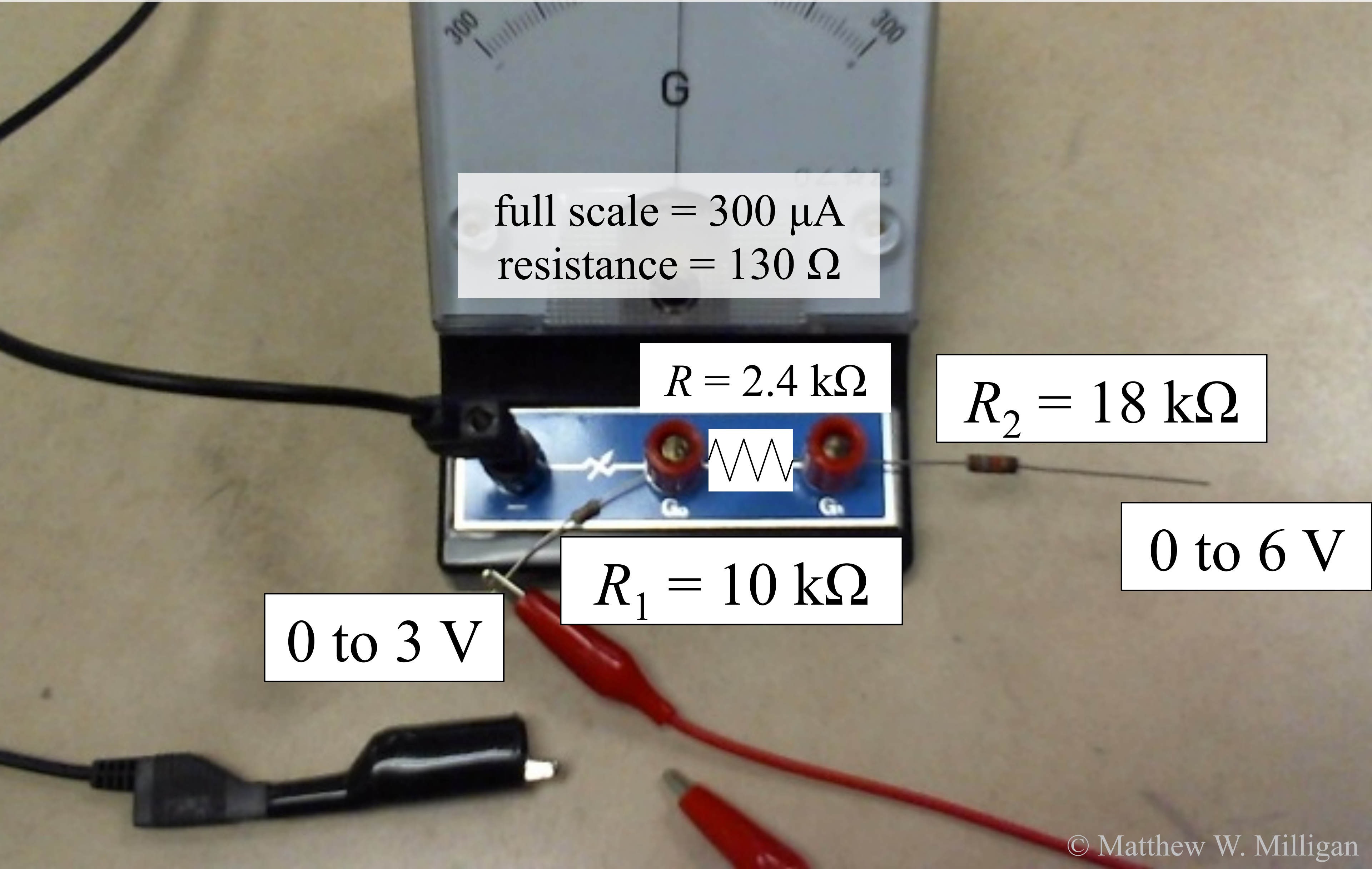
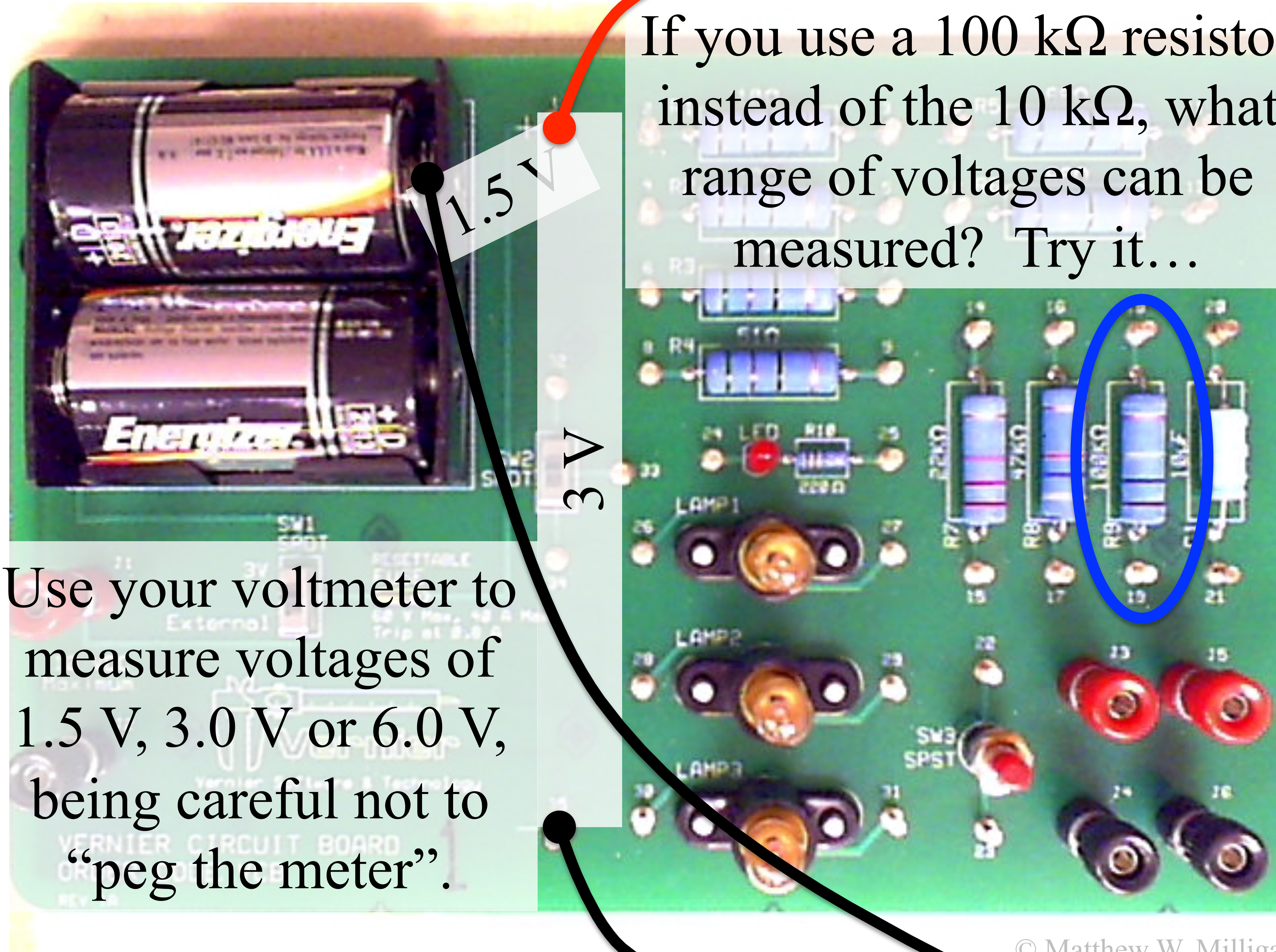


If you use a 100 kΩ resistor instead of the 10 kΩ, what range of voltages can be measured? Try it…



Use your voltmeter to measure voltages of 1.5 V, 3.0 V or 6.0 V, being careful not to “peg the meter”.