Lecture 20: 03/28/2024

- Announcements
  Exam 2 in April 2 (Next Tuesday)
  Lab next week, electrons in magnetic field
  Midterm grades – Email me w/ questions

- Last Time
  Intro to magnetism

- Today
  Some review
  Potential
  Resistance and resistivity
  Circuit analysis
  Intro to magnetism

Problem

- What is the resistance of a piece of wire given the material, length, and diameter?

$$R = \rho \frac{L}{A} = \frac{L}{\sigma A}$$

- How much power does it dissipate?

$$P = IV = I^2 R = \frac{V^2}{R}$$

Problem 11: A piece of *14*-gauge copper wire has a length of *7.25* m. The tables provided may be a convenient source of data.

Wire diameter d for select gauges in the AWG (American Wire Gauge) system.

gauge	0	2	4	6	8	10	12	14	16	18	20
d (mm)	8.251	6.544	5.189	4.115	3.264	2.588	2.053	1.628	1.291	1.024	0.812

Conductivity (σ), resistivity (ρ), and temperature coefficient of resistivity (α) at 20°C for select materials.

material	σ $(1/(\Omega \cdot \mathrm{m}))$	ρ $(\Omega \cdot \mathrm{m})$	α $(^\circ\mathrm{C}^{-1})$
conductors			
silver	6.29×10^7	1.59×10^{-8}	3.8×10^{-3}
copper	5.95×10^7	1.68×10^{-8}	3.9×10^{-3}
gold	4.10×10^7	2.44×10^{-8}	3.4×10^{-3}
aluminum	3.77×10^7	2.65×10^{-8}	3.9×10^{-3}

Ampacity Charts | Wire Gauge Chart

Wire Size & Amp Ratings

	Copper			Aluminum	
Wire Gauge Size	60°C (140°F) NM-B, UF-B	75°C (167°F) THW, THWN, SE, USE, XHHW	90°C (194°F) THWN-2, THHN, XHHW-2, USE-2	75°C (167°F) THW, THWN, SE, USE, XHHW	90°C (194°F) XHHW-2, THHN, THWN-2
14	15	20	25	---	---
12	20	25	30	20	25
10	30	35	40	30	35
8	40	50	55	40	45
6	55	65	75	50	55

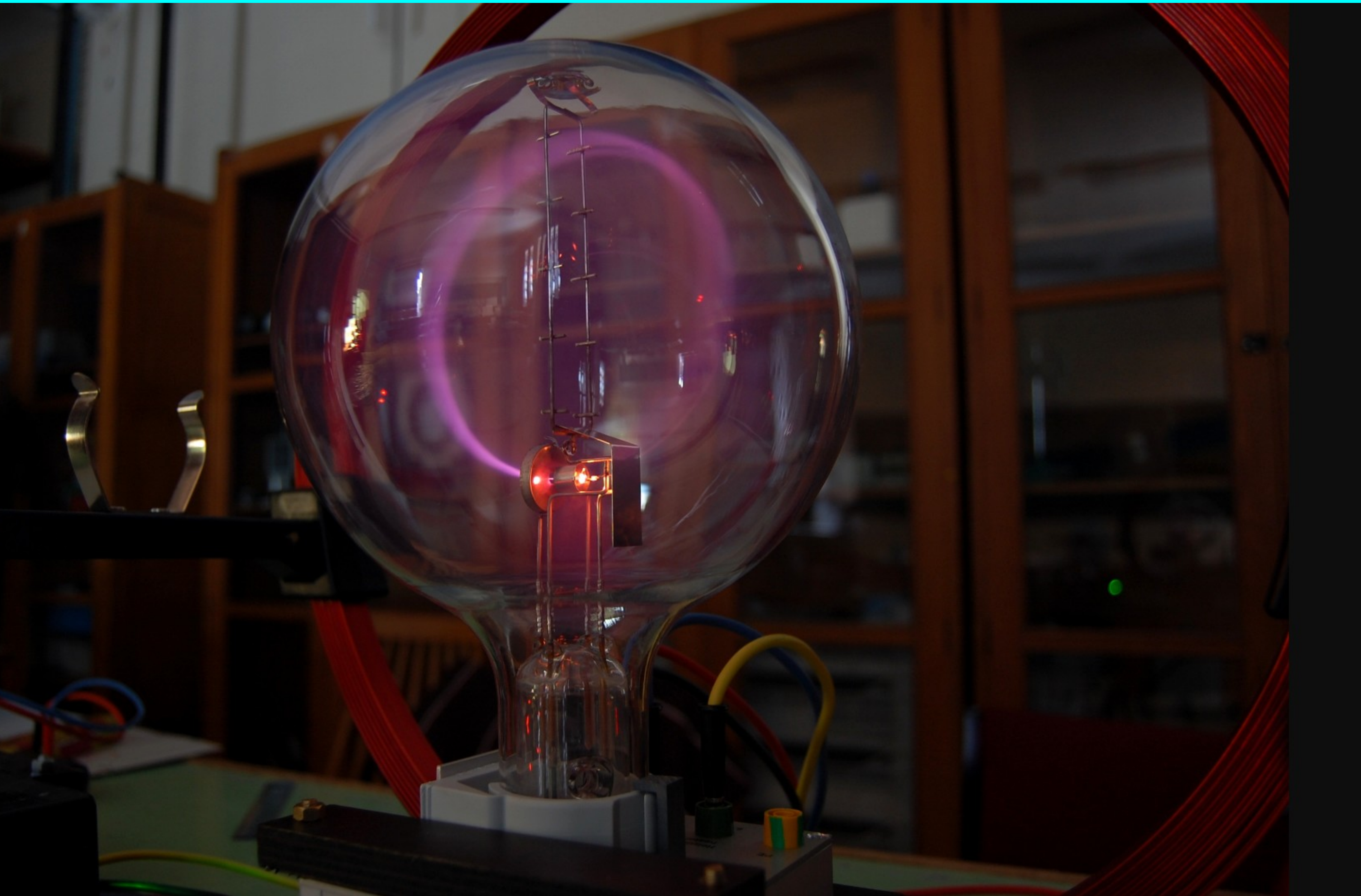
Problem

- An electron begins at 1000 m/s and then crosses a 2000 V potential drop.
- What is its final speed?

$$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$$

$$U = QV$$

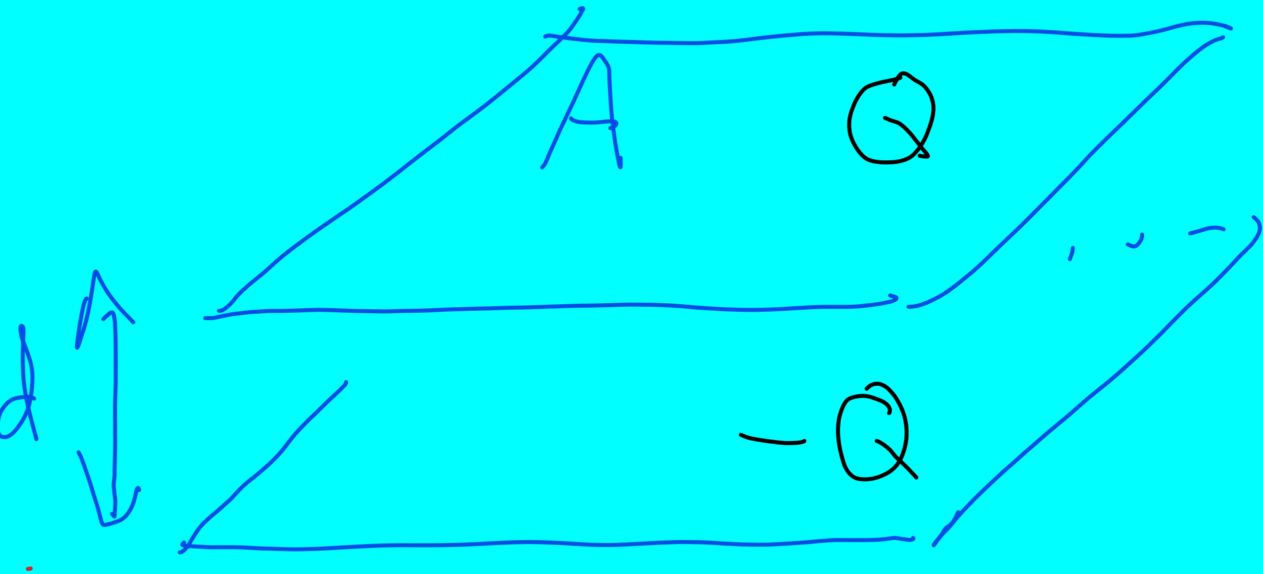
Next Week's Lab



Problem

- What is the capacitance of the Earth?

$$R_e = 6400 \quad \text{km}$$
$$Q = CV$$



$$E = \frac{Q}{A\epsilon_0}$$

$$E = \frac{\sigma}{\epsilon_0}$$

$$Q = CV$$

$$E = \frac{Q}{A\epsilon_0}$$

$$V = E\Delta z$$

$$V = Ed = \frac{Q}{A\epsilon_0} d$$

$$\Delta z = d$$

$$E = V/d$$

$$Q = \frac{A\epsilon_0}{d} V$$

Problem 3: Suppose you have a 9.00 V battery, a *2.6* μF capacitor, and a *8.25* μF capacitor.

Part (a) Find the total charge stored in the system if the capacitors are connected to the battery in series in C.
Numeric : A numeric value is expected and not an expression.
Q = ____

Part (b) Find the energy stored in the system if the capacitors are connected to the battery in series in J.
Numeric : A numeric value is expected and not an expression.
U_s = ____

Part (c) Find the charge if the capacitors are connected to the battery in parallel in C.
Numeric : A numeric value is expected and not an expression.
Q = ____

Part (d) Find the energy stored if the capacitors are connected to the battery in parallel in J.
Numeric : A numeric value is expected and not an expression.
U_p = ____

Problem 3: Suppose you have a 9.00 V battery, a ***2.6*** μF capacitor, and a ***8.25*** μF capacitor.

$V_B = 9\text{ V}$

$C_1 = 2.6\,\mu F$

$C_2 = 8.25\,\mu F$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

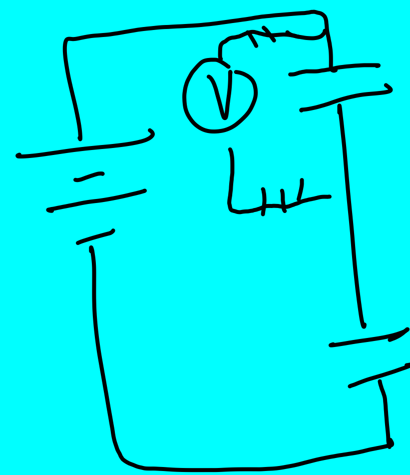
$$\frac{1}{C} = \frac{1}{2.6} + \frac{1}{8.25}$$

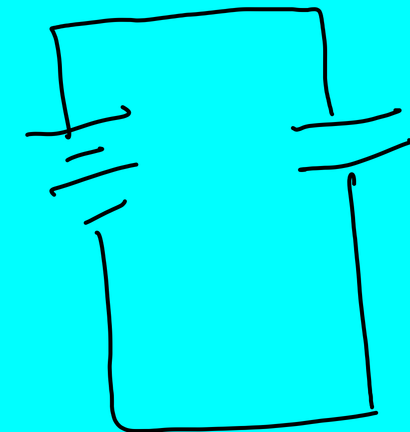
$= .384 + .121 = .505 = \frac{1}{C}$

$= .384$

$C = 1.97\,\mu F$

$Q = CV$





$Q = C_{eq} V$

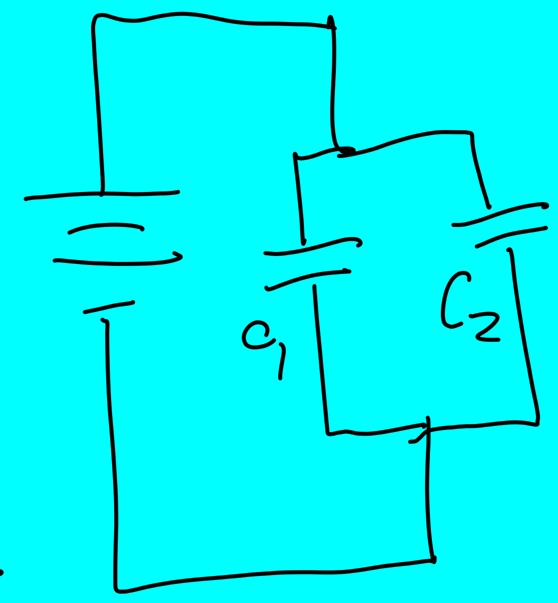
$(1.97\times 10^{-6})(9)$

$Q \approx 18\,\mu C$

Problem 3: Suppose you have a 9.00 V battery, a ***2.6*** μF capacitor, and a ***8.25*** μF capacitor.

$$U = \frac{1}{2}QV = \frac{1}{2}CV^2$$

$$U = \left(\frac{1}{2}\right)(1.97\,\mu F)(9\,V)^2$$

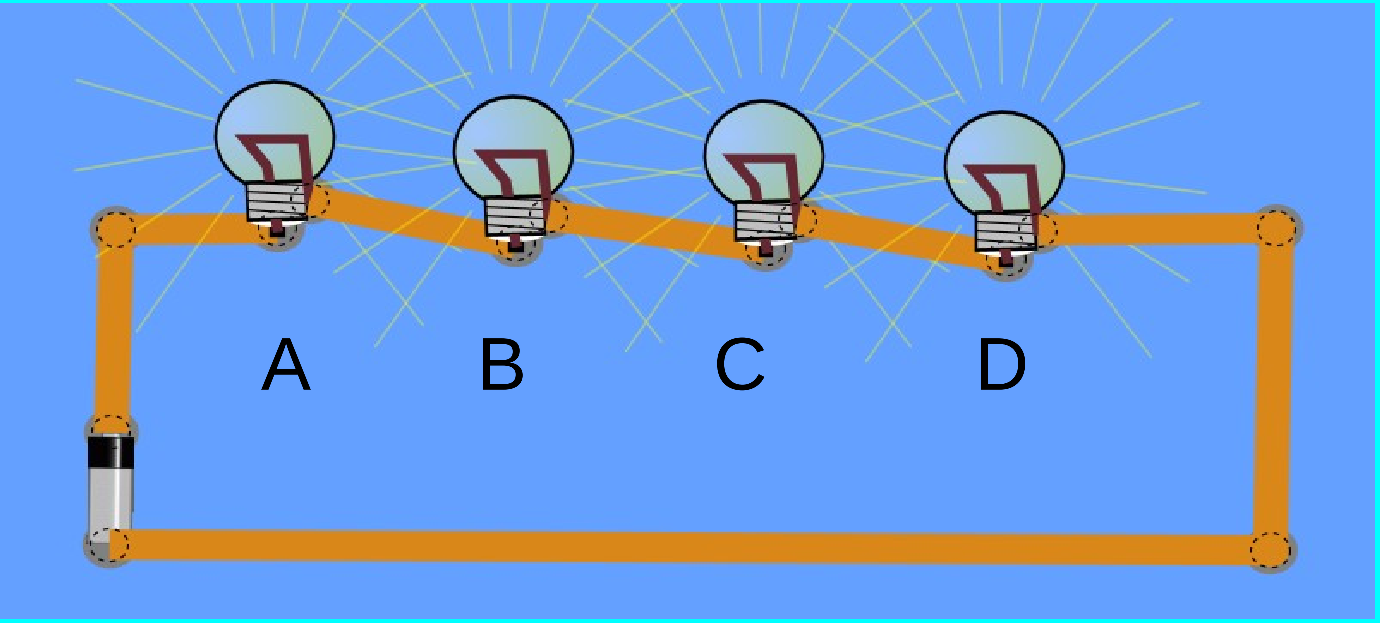


$$Q = CV \qquad C_{eq} = C_1 + C_2 = 10.85\,\mu F$$

$$Q = (10.85\,\mu F)(9)$$

$$Q = 97.6\,\mu C$$

Problem 3: Suppose you have a 9.00 V battery, a ***2.6*** μF capacitor, and a ***8.25*** μF capacitor.



Four light bulbs are in series as shown. Light bulb “C” Is removed. What happens?

A. Bulbs “A” and “B” and “D” remain lit the same brightness

B. Bulbs “A”, “B”, and “D” remain lit and get brighter

C. Bulbs “A” and “B” get brighter, and bulb “D” goes out

D. Bulbs “A” and “B” remain lit the same brightness, and bulb “D” goes out

E. Bulbs “A”, “B” and “D” go out.

Equivalent Resistors

If you replace resistors with an equivalent resistor then:

1) The current through the equivalent resistor is the same as the TOTAL current through the original circuit.

2) The power used by the equivalent resistor is the same as the TOTAL power used by the original circuit.

3) The sum of the power used at each original resistor equals the power used by the equivalent resistor.

4) The sum of the currents thru all parallel legs is the same as the current through the equivalent resistor.

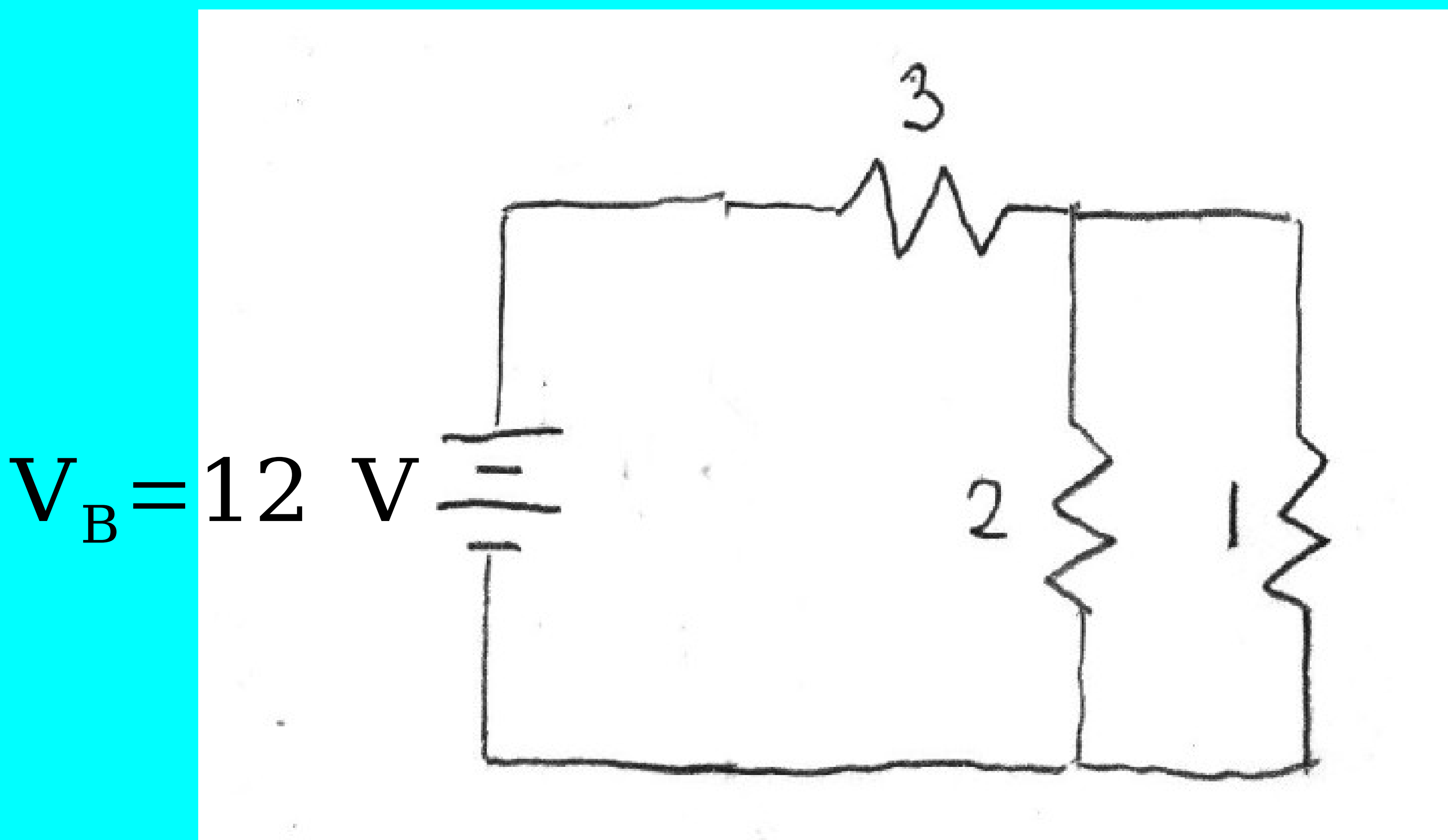
Equivalent Capacitors

If you replace capacitors with an equivalent capacitor then:

1) The charge on the equivalent capacitor is the same as the charge on any series capacitor in the original circuit.

2) The sum of the charges on all parallel legs is the same as the charge on the equivalent capacitor.

What is the equivalent resistance of this circuit?
What is the voltage across the 2-Ohm resistor?
What is the voltage across the 3-Ohm resistor?

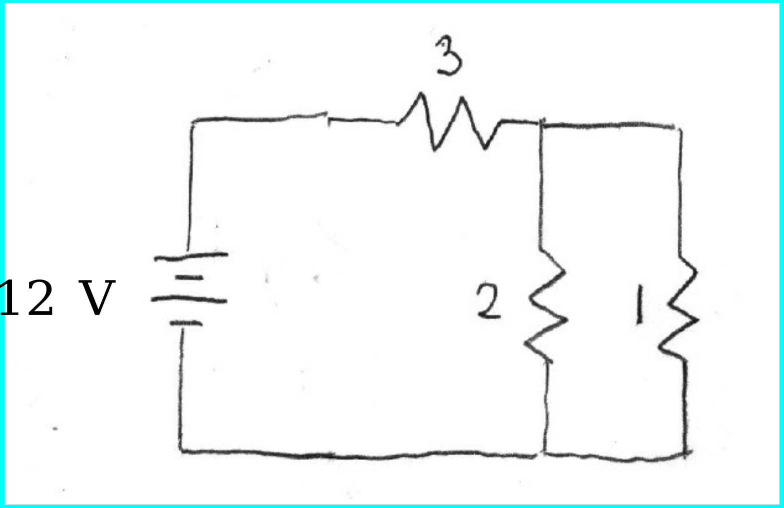


$R_{eq}=?...$

$\Delta V_2=?...$

$\Delta V_3=?...$

$V_B=12$ V



Solving resistor network problems

1) Redraw the circuit as needed to see what parts are in series and what parts are in parallel.

2) Replace each section with an equivalent resistor for that section.

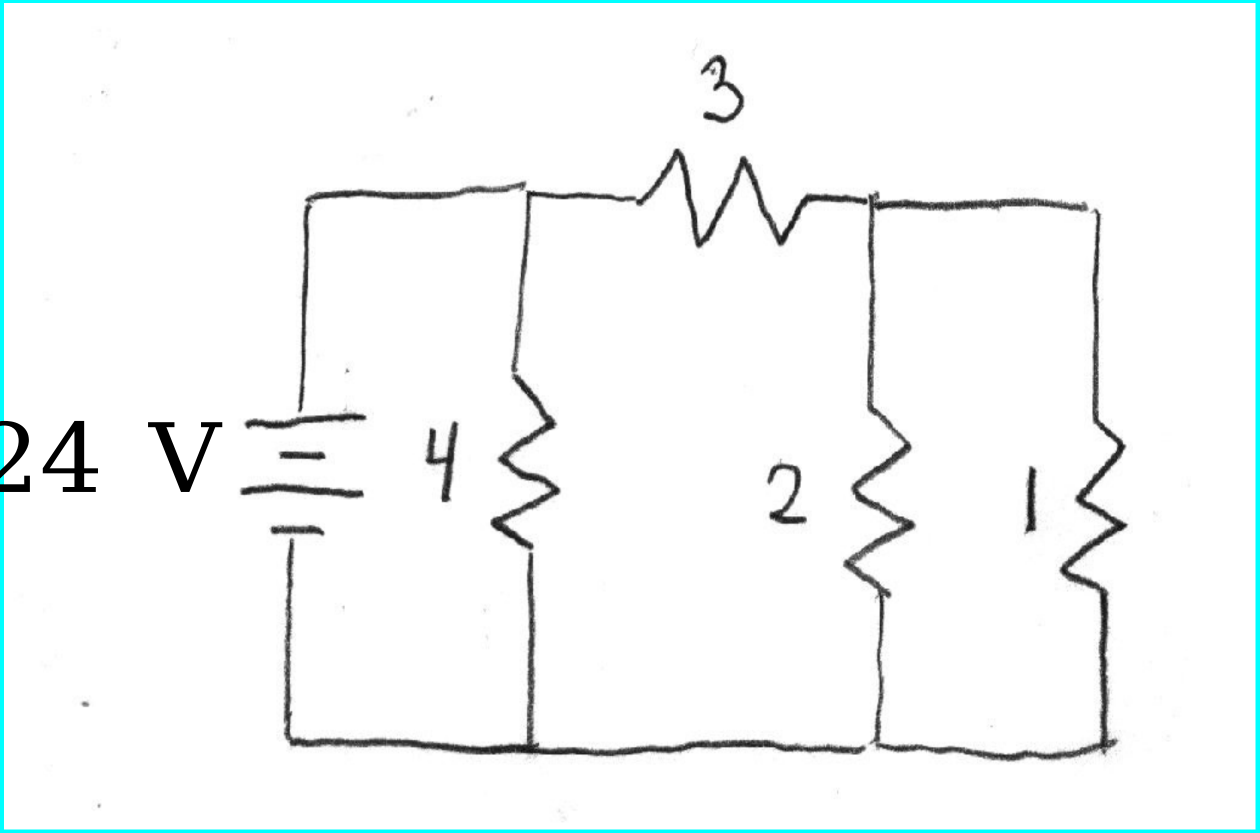
3) Combine equivalent resistors to get down to a single resistor. Get total current.

4) Apply current to all series sections to get voltage drop.

5) Apply voltage drop to all parallel sections to get current.

What is the equivalent resistance of this circuit?
What is the voltage across the 2-Ohm resistor?
What is the voltage across the 3-Ohm resistor?

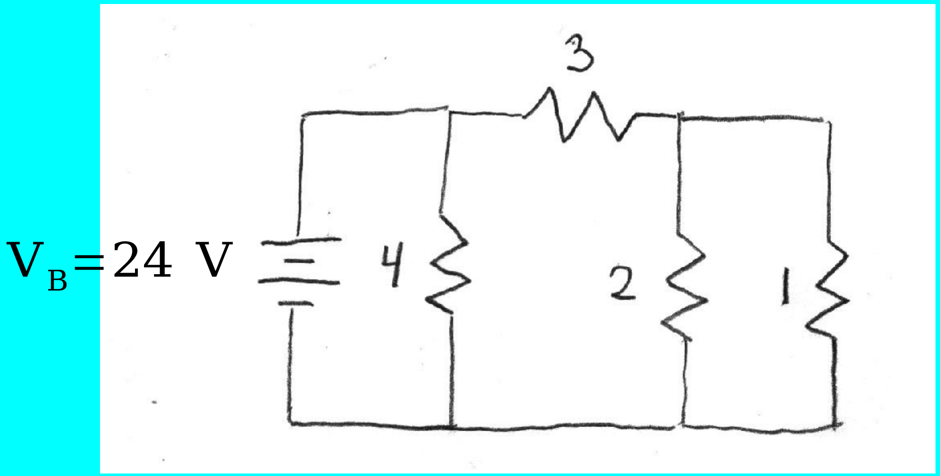
$V_B = 24\ V$



$R_{eq}=?...$

$\Delta V_2=?...$

$\Delta V_3=?...$

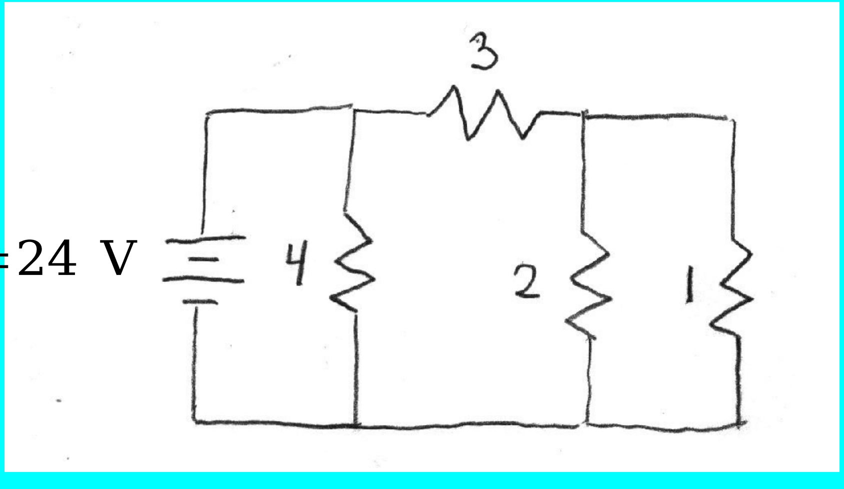


$R_{eq} = ?...$

$\Delta V_2 = ?...$

$\Delta V_3 = ?...$

$V_B = 24\ V$



Redraw this circuit to show parallel/series combos better.
Given V = 11 Volts. Example of Kirchhoff's Voltage law.

$$I_4 = \frac{11}{4} \ \text{A} \qquad R_{eqv_{12}} = \frac{2}{3} \ \Omega \qquad R_{eqv_{123}} = \frac{11}{3} \ \Omega$$

$$I_3 = 3 \ \text{A}$$

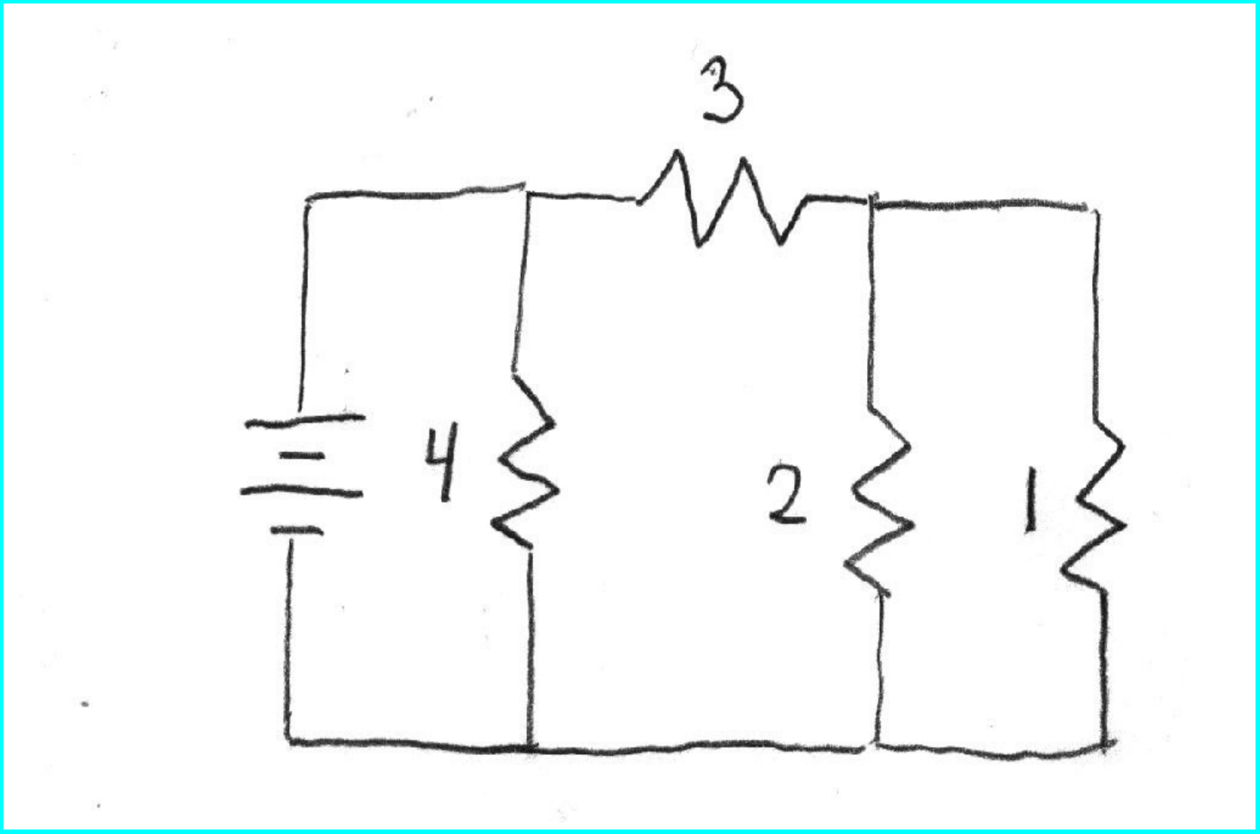
$$I_1 = 2 \ \text{A}$$

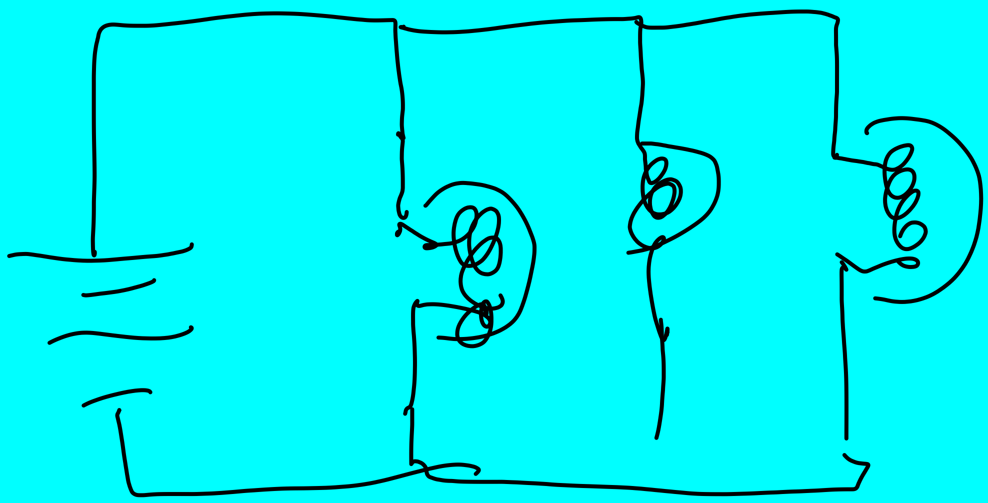
$$I_2 = 1 \ \text{A}$$

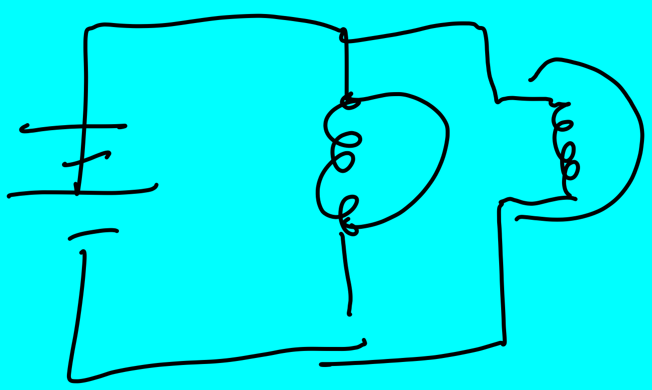
$$V_3 = 9 \ \text{V}$$

$$I_{total} = 5.75 \ \text{A}$$

$$R_{eqv_{total}} = \frac{44}{23} \ \Omega$$



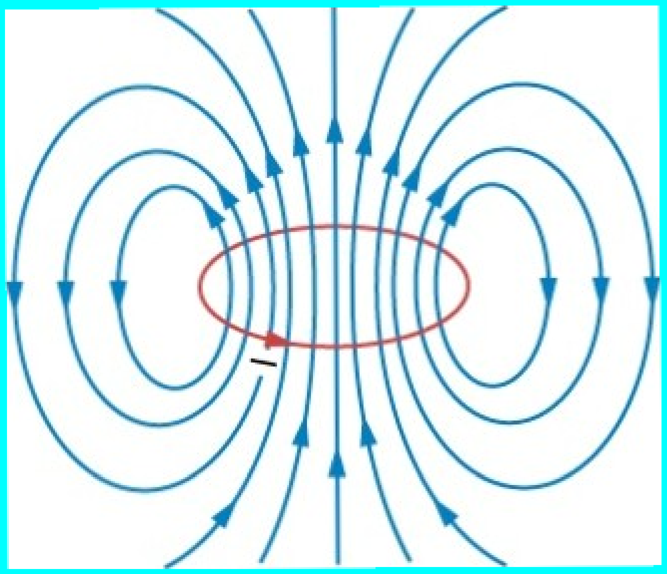


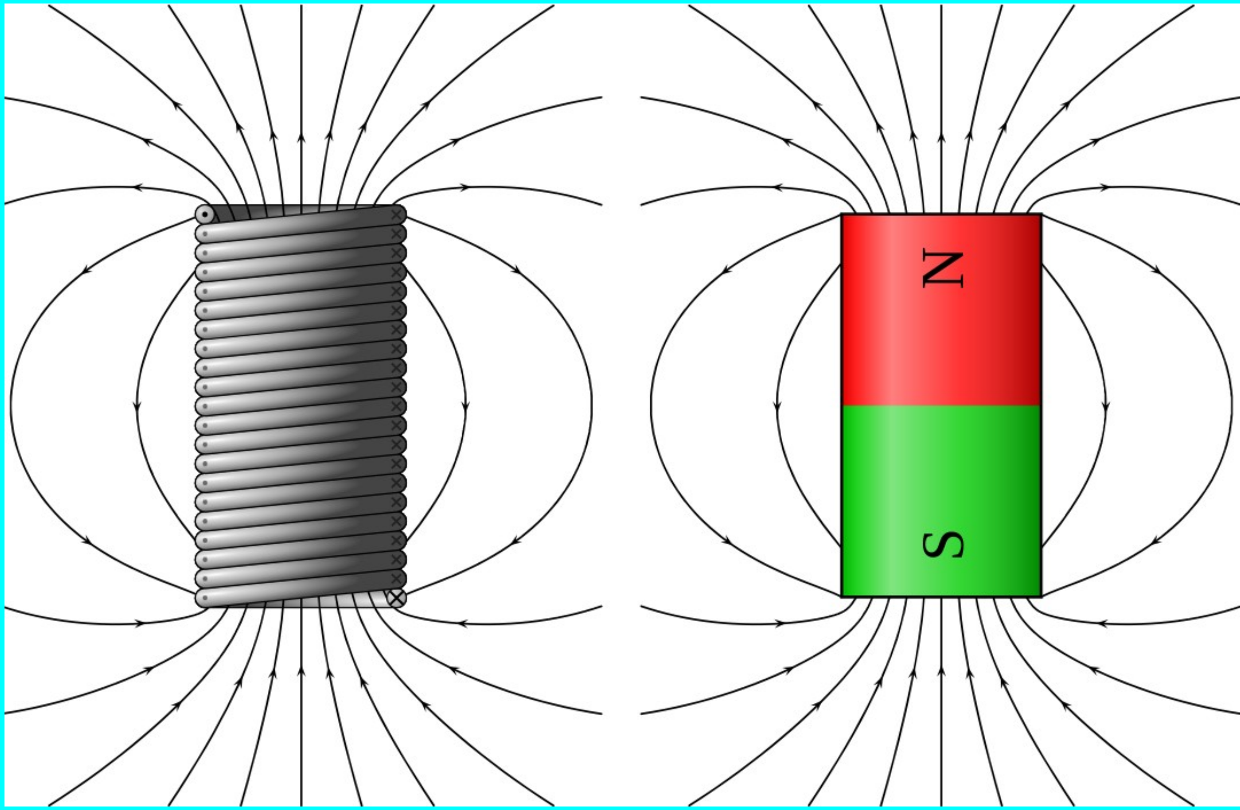


$$P = \frac{V^2}{R}$$

Electromagnets

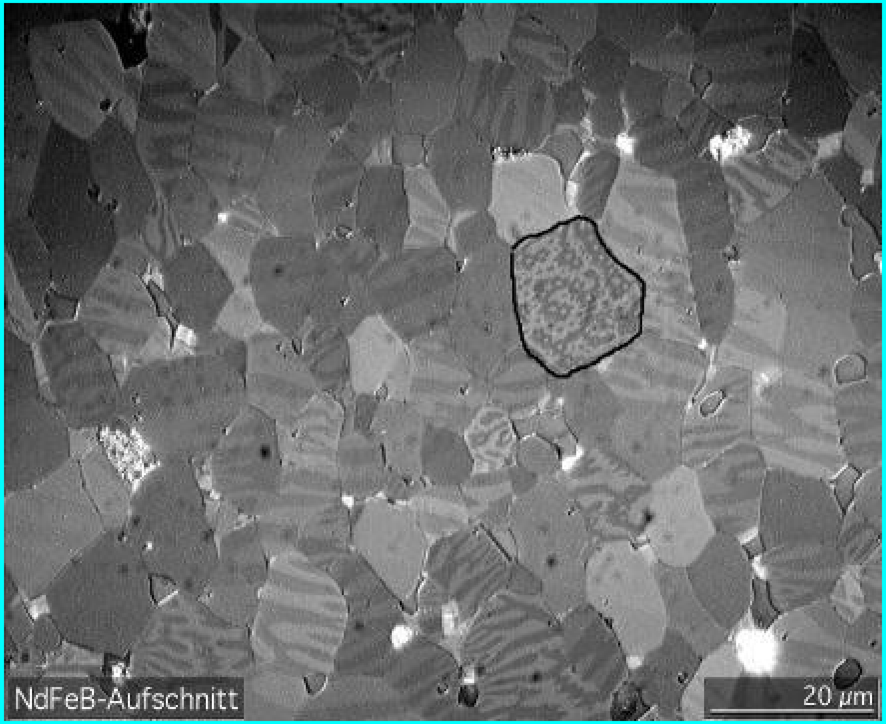
- A loop of wire is a basic electromagnet
- Many loops of wire (a coil or "solenoid") is a better electromagnet.

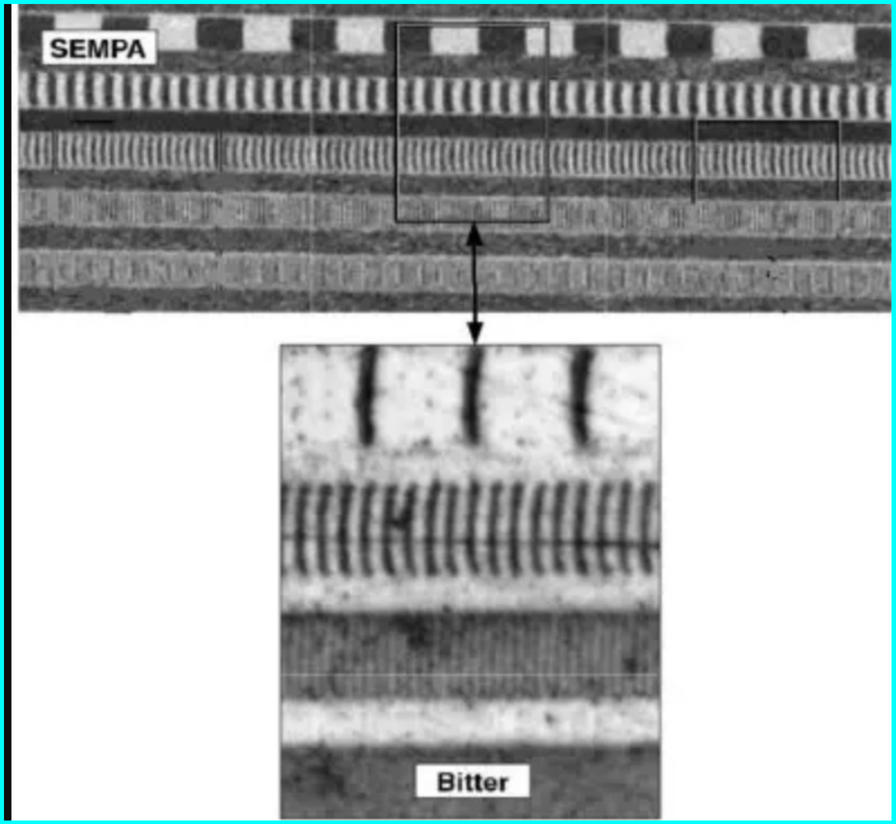




Electromagnets and “Regular magnets”

- A loop of wire is a basic electromagnet
- Many loops of wire (a coil or “solenoid”) is a better electromagnet.
- Atoms with orbiting unpaired electrons are quantum electromagnets.
- They have magnetic “moments”
- Groups of atoms get together and make magnetic “domains”
- You “magnetize” iron by lining up its domains by exposing it to a strong magnet or by wrapping wire around it.


NdFeB-Aufschnitt
20 µm


SEMPA
Bitter

Equations of Magnetism

$\vec{F} = Q\,\vec{v} \times \vec{B}$ Force on charge Q

$\vec{F} = I\,\vec{L} \times \vec{B}$ Force on current I

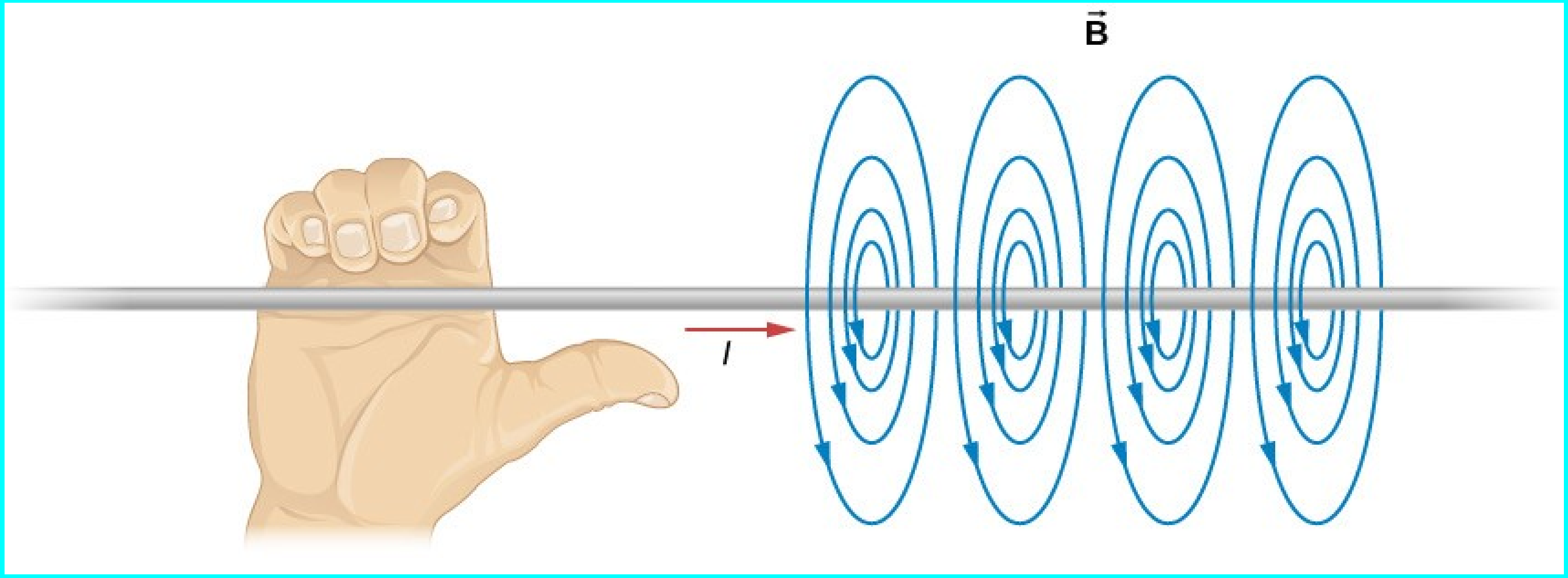
$\vec{B} = \dfrac{\mu_0 I}{2\pi r}\hat{\phi}$ Field of Infinite wire

$\vec{B} = \dfrac{\mu_0 I}{2a}\hat{z}$ Field in center of wire loop

$\vec{B} = \mu_0 n I \hat{z}$ Field of an infinite coil (solenoid)

Problem

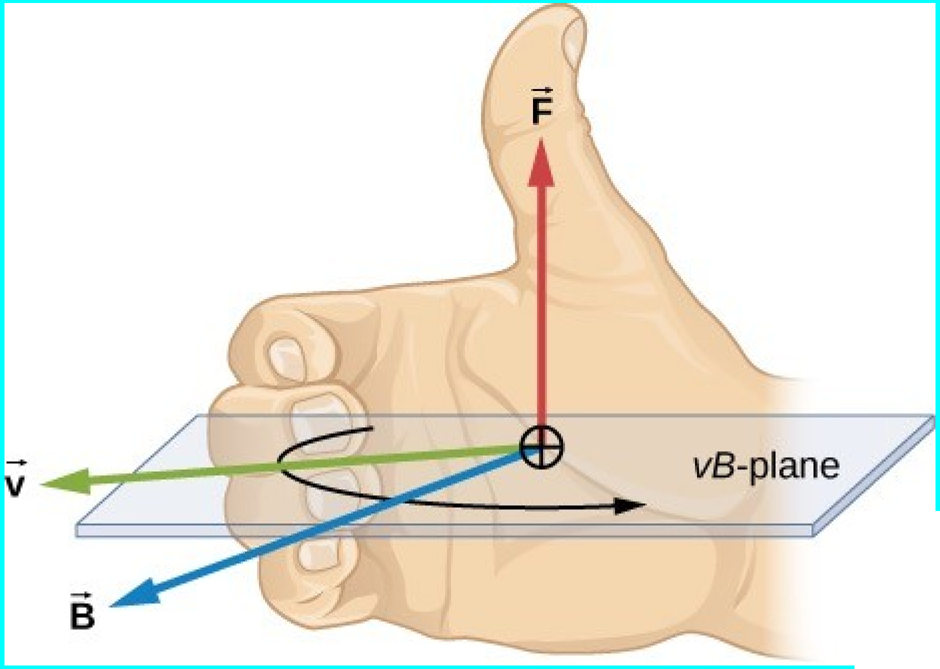
- Two horizontal wires 3 meters long carry 15 Amperes directed to the right. They are separated by 1 cm.
- What is the magnetic field one cm above the bottom wire?
- What is the force on the top wire?



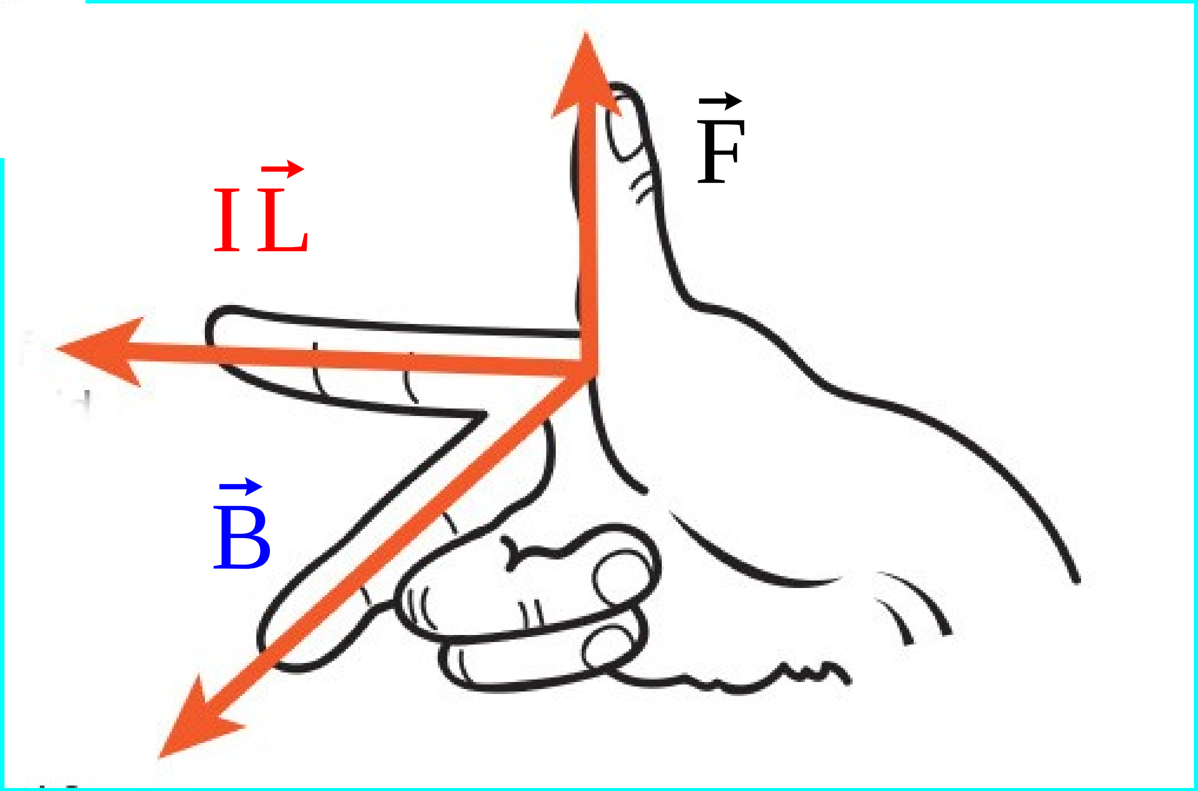
Problem

- Two horizontal wires 3 meters long carry 15 Amperes directed to the right. They are separated by 1 cm.

- What is the magnetic field one cm above the bottom wire?



$$\vec{F} = I\vec{L} \times \vec{B}$$

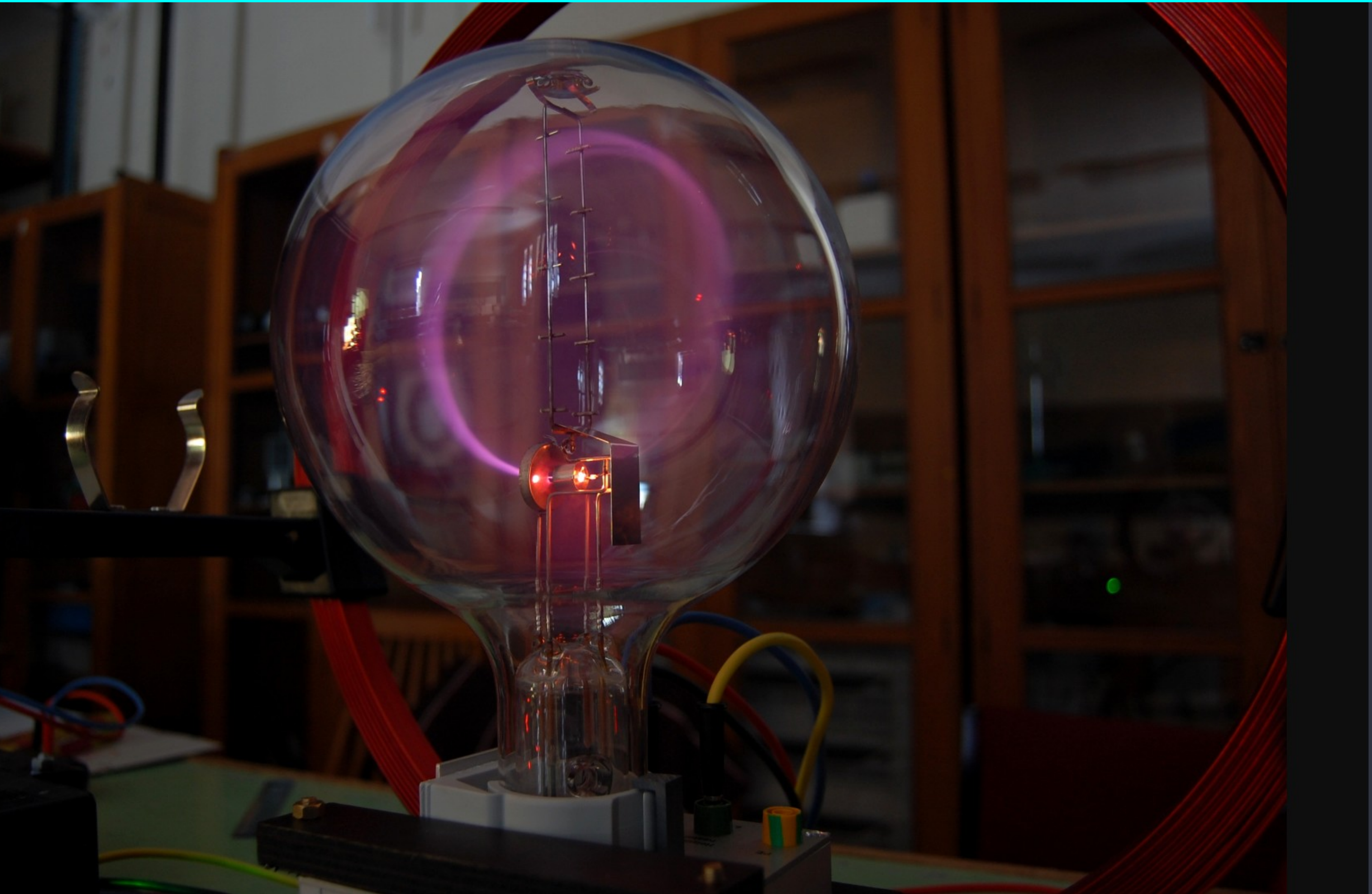


Problem

- Two horizontal wires 3 meters long carry 15 Amperes directed to the right. They are separated by 1 cm.

- What is the force on the top wire?

Next Week's Lab



Problem

- A uniform magnetic field of one milliTesla is in the z-direction
- An electron goes through a 1000 V potential drop.
- What path does the electron make in the field?
- What is the radius of the circle that it makes?