I wish we had a day off for exams that would be fantastic

WE SHOULD NOT HAVE HAD CLASS TODAY!!!!! BOOOOOOOo!!!

I have three midterms this week; specifically, two tomorrow. I am studying for chemistry and calculus tonight.

The concept seemed easy but the applications seemed rather hard.

I'm really having trouble grasping the pre-lecture problem asking about the current between points a and b.

The charges flowing in clockwise direction made my head spin for a while, the signs changing is confusing.

Can you explain the blue wire and how you can tell the current across it?

You know Watt? The Current amount of electricity puns is Shockingly low. We need to Amp it up. Yes, there will be Resistance to such tom-foolery, some may even be reVolted by its childishness, but there's no reason for assault and Battery on their part. Come on, I believe we Conduit.
Today’s Concept:

Kirchhoff’s Rules
Usually can’t supply too much current to the load without voltage “sagging”
Resistors in series:

Current through is same.
Voltage drop across is $IR_i$

Resistors in parallel:

Voltage drop across is same.
Current through is $V/R_i$

Solved Circuits
**New Circuit**

How Can We Solve This One?

**THE ANSWER:** Kirchhoff’s Rules
Kirchhoff’s Voltage Rule

\[ \sum \Delta V_i = 0 \]

Kirchhoff's Voltage Rule states that the sum of the voltage changes caused by any elements (like wires, batteries, and resistors) around a circuit must be zero.

WHY?

The potential difference between a point and itself is zero!
Kirchhoff's Current Rule states that the sum of all currents entering any given point in a circuit must equal the sum of all currents leaving the same point.

\[ \sum I_{in} = \sum I_{out} \]

**WHY?**

Electric Charge is Conserved
Applying Kirchhoff’s Laws in 5 easy steps

1) Label all currents
   Choose any direction

2) Label +/− for all elements
   Current goes + ⇒ − (for resistors)
   Long side is + for battery

3) Choose loop and direction
   Must start on wire, not element.

4) Write down voltage drops
   First sign you hit is sign to use.

5) Write down node equation $I_{\text{in}} = I_{\text{out}}$
   We’ll do calculation today
   It’s actually the easiest thing to do!

\[-E_1 + I_1 R_1 + E_3 - I_4 R_4 + I_5 R_5 = 0\]
Check Point 1

How many potentially different currents are there in the circuit shown?

Look at the nodes!

**Top node:** \( I_1 \) flows in, \( I_2 \) and \( I_3 \) flow out

**Bottom node:** \( I_2 \) and \( I_3 \) flow in, \( I_1 \) flows out

That’s all of them!
If we are to write Kirchoff’s voltage equation for this loop in the clockwise direction starting from point a, what is the correct order of voltage gains/drops that we will encounter for resistors R1, R2 and R3? 

- A. drop, drop, drop
- B. gain, gain, gain
- C. drop, gain, gain
- D. gain, drop, drop
- E. drop, drop, gain

With the current ➔ VOLTAGE DROP
Against the current ➔ VOLTAGE GAIN
Conceptual Analysis:
- Circuit behavior described by Kirchhoff’s Rules:
  - KVR: $\sum V_{\text{drops}} = 0$
  - KCR: $\sum I_{\text{in}} = \sum I_{\text{out}}$

Strategic Analysis
- Write down Loop Equations (KVR)
- Write down Node Equations (KCR)
- Solve

In this circuit, assume $V_i$ and $R_i$ are known.

What is $I_2$?
In this circuit, assume $V_i$ and $R_i$ are known.

What is $I_2$?

1) Label and pick directions for each current
2) Label the $+$ and $-$ side of each element

This is easy for batteries Long side is $+$
For resistors, the “upstream” side is $+$

Now write down loop and node equations
In this circuit, assume $V_i$ and $R_i$ are known.

What is $I_2$?

How many equations do we need to write down in order to solve for $I_2$?

A) 1  B) 2  C) 3  D) 4  E) 5

Why?

– We have 3 unknowns: $I_1$, $I_2$, and $I_3$
– We need 3 independent equations to solve for these unknowns

3) Choose Loops and Directions
In this circuit, assume $V_i$ and $R_i$ are known.

What is $I_2$?

Which of the following equations is NOT correct?

A) $I_2 = I_1 + I_3$

B) $-V_1 + I_1R_1 - I_3R_3 + V_3 = 0$

C) $-V_3 + I_3R_3 + I_2R_2 + V_2 = 0$

D) $-V_2 - I_2R_2 + I_1R_1 + V_1 = 0$

Why?

- (D) is an attempt to write down KVR for the top loop
- Start at negative terminal of $V_2$ and go clockwise
  $V_{gain} (-V_2)$ then $V_{gain} (-I_2R_2)$ then $V_{gain} (-I_1R_1)$ then $V_{drop} (+V_1)$
We have the following 4 equations:

1. \( I_2 = I_1 + I_3 \)
2. \(- V_1 + I_1R_1 - I_3R_3 + V_3 = 0\)
3. \(- V_3 + I_3R_3 + I_2R_2 + V_2 = 0\)
4. \(- V_2 - I_2R_2 - I_1R_1 + V_1 = 0\)

Why?

- We need 3 INDEPENDENT equations
- Equations 2, 3, and 4 are NOT INDEPENDENT

Eqn 2 + Eqn 3 = − Eqn 4

- We must choose Equation 1 and any two of the remaining (2, 3, and 4)

We need 3 equations:
Which 3 should we use?

A) Any 3 will do
B) 1, 2, and 4
C) 2, 3, and 4

In this circuit, assume \( V_i \) and \( R_i \) are known.

What is \( I_2 \) ?
In this circuit, assume $V_i$ and $R_i$ are known.

What is $I_2$?

We have 3 equations and 3 unknowns.

$$I_2 = I_1 + I_3$$
$$V_1 + I_1R_1 - I_3R_3 + V_3 = 0$$
$$V_2 - I_2R_2 - I_1R_1 + V_1 = 0$$

Now just need to solve 😊

The solution will get very messy!

Simplify: assume $V_2 = V_3 = V$

$$V_1 = 2V$$
$$R_1 = R_3 = R$$
$$R_2 = 2R$$
In this circuit, assume $V$ and $R$ are known. What is $I_2$?

We have 3 equations and 3 unknowns.

\[
I_2 = I_1 + I_3 \\
-2V + I_1R - I_3R + V = 0 \quad \text{(outside)} \\
-V - I_2(2R) - I_1R + 2V = 0 \quad \text{(top)}
\]

With this simplification, you can verify:

\[
I_2 = \left(\frac{1}{5}\right) \frac{V}{R} \\
I_1 = \left(\frac{3}{5}\right) \frac{V}{R} \\
I_3 = \left(-\frac{2}{5}\right) \frac{V}{R}
\]
We know:

\[ I_2 = (\frac{1}{5}) \frac{V}{R} \]
\[ I_1 = (\frac{3}{5}) \frac{V}{R} \]
\[ I_3 = (-\frac{2}{5}) \frac{V}{R} \]

Suppose we short \( R_3 \): What happens to \( V_{ab} \) (voltage across \( R_2 \)?)

A) \( V_{ab} \) remains the same
B) \( V_{ab} \) changes sign
C) \( V_{ab} \) increases
D) \( V_{ab} \) goes to zero

Why?

Redraw:

Bottom Loop Equation:
\[ V_{ab} + V - V = 0 \]
\[ V_{ab} = 0 \]
Is there a current flowing between \( a \) and \( b \)?

**A)** Yes

**B)** No

\( a \) & \( b \) have the same potential

No current flows between \( a \) & \( b \)

Current flows from battery and splits at \( a \)

Some current flows down

Some current flows right
Consider the circuit shown below. Note that this question is not identical to the similar looking one you answered in the prelecture.

Which of the following best describes the current flowing in the blue wire connecting points a and b?

A. Positive current flows from a to b
B. Positive current flows from b to a
C. No current flows between a and b

\[ I_1 R - I_2 (2R) = 0 \quad \Rightarrow \quad I_2 = \frac{1}{2} I_1 \]

\[ I_4 R - I_3 (2R) = 0 \quad \Rightarrow \quad I_4 = 2 I_3 \]

\[ I = I_1 - I_3 \]

\[ I + I_2 = I_4 \quad \Rightarrow \quad I_1 - I_3 + \frac{1}{2} I_1 = 2I_3 \]

\[ I_1 = 2I_3 \]

\[ I = +I_3 \]
What is the same? Current flowing in and out of the battery.

What is different? Current flowing from a to b.
Current will flow from left to right in both cases.

In both cases, \( V_{ac} = V/2 \)

\[
I_{2R} = 2I_{4R}
\]

\[
I_A = I_R - I_{2R} = I_R - 2I_{4R}
\]

\[
I_B = I_R - I_{4R}
\]