Electrical Engineering Workshop (ইলেকিট্রিকাল ইঞ্জিনিয়ারিং) 3 hours/day

Week 1: From Electrons to Circuits (ইলেক্ট্রন থেকে সার্কিট)

Lesson 1.1: Fundamentals of Electricity: Wires, Ohm’s Law, Resistors, LED’s (ইলেক্ট্রিসিটির মূলসূত্র)

****Note: for many of the GUIDE segments, pick a student (and/or ask for volunteer) to come up to the board and write their thoughts about certain questions you pose (when there’s not time for a group thinking activity)****

• **GREET:** Everyone at the door as they enter!	
• **QUICK SELF INTRO:** Say my name and short intro	• 2 m
• **STUDENT INTROS:** Go around and everybody introduce themselves with name (everyone has a nametag as well) & one thing about you that you’re proud/happy about (keep notes on the students’ names, where they’re sitting, + little tidbit about them)	• 5 m
• **NEW CONCEPT:** This class is not going to be like your normal classes. For this workshop, **you guys will be little engineers.** Not only will you engineer your own heartbeat monitor by the end of the class, you will also help engineer how this class will work! You guys will help me build how this class is taught!	• 15 m
○ **MY IDEA:** Talk a little bit about how I believe a class should be taught: constant student involvement/engagement	
○ **Student-driven classroom:** I want to teach some things, but I won’t just tell you; you as the student should be allowed to think and explore.	
○ **Inquiry-based learning:** So I will ask you questions to stimulate your thought. And you will think individually or in groups about your answers to those questions.	
○ **Constantly sharing ideas/thoughts:** And then you should all share your ideas to help everyone in the classroom understand the material together.	
○ **Trashing lectures:** I think that it’s important that you students feel confident in your ability to learn and your knowledge, and I don’t think that me lecturing at you and you memorizing information is good for that.	
○ **Growth mindset:** So in this classroom we will praise how hard you work, how much effort you put into what you’re doing. Not necessarily what you can do. But by the end of it, you will be excited to see that by putting in a lot of effort, you are able to accomplish a lot!	
○ **Establishing comfort asking questions:** And I also think it’s super important that you guys feel comfortable asking me questions at any time. If you have a question, raise your hand and I will get to you as soon as possible. There are no wrong questions!)	
○ **Hands-on learning:** Students should actively create something every day. In this class, you will be making circuits every day!	
○ **Constant student input:** What do you think?	
○ **WHAT ARE YOUR IDEAS?** Ask students: Think of this class as an experiment. Right now, think about everything you know about how a class is taught. And now throw it out the window. Burn it in your head. Nothing is right, nothing is wrong. Now tell me: How do you want a classroom to work? What kind of learning style would you like to try out or explore? Which of the ideas I mentioned do you like best? There are no wrong answers.	
○ **CHOOSE:** Maybe put up some options on the board (things you mentioned above, plus some more traditional options like lecture, homework,) and have all the students come up and put a check mark by the option they think is best.	
○ RECONVENE: Talk about the ideas and ask students to volunteer and talk about why they chose the teaching/learning method that they did.	
• **NEW CONCEPT:** Since we talked about what teaching/learning styles we would like to explore in this workshop, **what kind of culture do we want to build in this classroom?**	
○ **LIST QUESTIONS ON BOARD:** Questions to discuss (How should we work in groups? When should students be expected to share their ideas? How can we encourage and value others’ ideas, even if they are not necessarily correct? How can we respect everyone in the classroom?)	• 10 m
○ **ASK:** Every student to go up to the board and write down some ideas under each question	

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<li style="list-style-type:circle">DISCUSS and WRITE UP: Write up a document live that combines ideas that students wrote down as we discuss them (project it so everyone sees)
<li style="list-style-type:circle">CLASS CONTRACT: This will be our class contract, guys! We will return to it during every class and refer to its ideas.

Okay, now let’s get started on the content!
GROUP THINKING EXERCISE: What do you think electricity is? How do you think you get power in your house for lightbulbs, cooking, etc.? (multiple choice) Talk about it in groups of four.

RECONVENE: each group share their thoughts
EXPLAIN: Correct answer (tiny bits moving around, providing energy)

NEW CONCEPT: Everything is made of tiny little particles called atoms. You’re made of billions of atoms (explain how big billions is if they don’t know – Bangladesh 160 million people, Dhaka 9 million people) – and these atoms have tiny little particles inside them called charges (including electrons, which have a negative charge)

EXAMPLE: Consider this metal plate. It’s full of atoms that look like:
DRAW: crystal structure of atoms in metals (do not have to explain crystal structure. Just show how there are a bunch of atoms all arranged together like blocks, maybe bring in legos to help show). And one of these atoms looks like this:
DRAW: atom with electron cloud

Electrons in metals move freely across crystal structure.

Show in crystal structure drawing the free movement of electrons
GROUP THINKING EXERCISE: What do you think happens when a bunch of electrons in this crystal structure move in one direction? Traffic jokhon move hoye tokhon ki, ekta flow hoye na? (give options with analogies to choose from)
RECONVENE: each group shares their thoughts
TIE BACK: This is where we get electricity: these tiny little bits moving in one direction makes usable energy that can make light for example.

VOCABULARY: When a lot of electrons start to move in the same direction, we call that a current. Let’s explore together how a current flows.
When an electron moves from one spot to an empty spot (hole), it also leaves behind an empty spot (also a hole).

GAME TIME: Demonstrate how electrons and holes move: Line up your n students so they are all facing forward (they see the back of the person in front of them). Give n-1 students each one ball. Every student gets a ball except for the student first in line. Tell this student to get in position to catch the ball. Tell the second student to turn around and throw the ball to the first person, and immediately turn around so that the third person can throw the third ball to him. Then the third person immediately turns around and receives the first ball. Do this all the way along the line until the last person in line throws his ball.
ASK THE STUDENTS: (expecting responses in unison) Which direction did the balls move? Did they all move in the same direction? Where was the empty hand (hole) at the beginning? Where was it at the end? Did the hole move? How far did the hole move? How far did each ball move? What did you have to do in order to get the balls and the holes to move?
PREPARE TO GUIDE THEM INTO KNOWING: Each ball (electron) only moves a very small distance, but all in the same direction. But the hole moves all the way across the line. So this movement of holes is formally called current, I. And you had you use force to push the ball forward to the person in front of you right? This force or ENERGY represents voltage, V.
ASK THE STUDENTS: What would happen if I put a large barrier with a hole cut out after every person? Would the movement of the hole slow down, speed up, or not change? Explain that their thoughts constitute a hypothesis.
TEST THEIR HYPOTHESIS: Explain that now we have to test our hypothesis with an experiment. Do the experiment of throwing the balls down the line again.

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- PREPARE TO GUIDE THEM INTO REALIZING: When we place barriers that make it harder to throw the ball in the way, then the hole moves a lot slower for that path. This **barrier that makes the speed of electron/hole flow slower (means the current is smaller) is called resistance, R**.
  - **ASK STUDENTS:** If your voltage (force) is fixed, what happens when there is more resistance (balls move slower → less current)? What about if your current HAS to be very fast, but you still have a lot of resistance, what do you need more of (more force and quicker accuracy → voltage)? Explain how **we can now draw conclusions from our experiment.**
- **WORKSHEET:** Write down what you learned. What do voltage, current, and resistance mean in your own words?
- Now we are ready to describe this with math: (derive Ohm's Law w/ them)
  - **DRAW:** voltage source attached to a resistor. Draw arrow with I, voltage source with V, resistance with R.
  - **EXPLAIN:** that **this is a circuit schematic**. And this is how all engineers draw circuits. The wires mean two things are connected. The components each have their own symbol and value.
  - **ASK STUDENTS (answers expected in unison):** Write up an example of types of algebraic equations. How do you think we can write an equation to relate voltage, current, and resistance? Draw an XY plot. Label x axis as R and y axis as I. If voltage is the same (10 V), say we make R bigger (R = 1 ohm now), then what happens to I (10 A)? (gets smaller) What happens if R gets 2x bigger? How much smaller will I get? (5 A) What if the R gets 5x bigger? How much smaller will I get? (2 A) Plot this as the students answer it. Draw a line of fit.
  - **GROUP THINKING:** Based on our exploration just now, which type of algebraic equation do you think can be used to describe the relationships between V, R, and I? (Have multiple choice for types of algebraic equations)
  - **RECONVENE:** Each group share your thoughts
  - **DISCUSS/GUIDE:** Now let's see. Let's multiply I and R. It's always the same, and it equals 10 (Volts)! Whoa! Now how can we use variables to write this? V = IR. It's called Ohm's Law!

- 15 m

- Now draw examples on the board of circuits with V, I, and R. Give two, ask the students: what is the value of the third? Go through 5 such examples, calling on different students each time.
- **WORKSHEET:** Now give them 5 minutes to work on two examples in their worksheets and discuss with their partner. Call on two different students to give the answers at the end. If wrong, discuss. If correct, ask if anyone in the class is confused. If confused, explain.
- **NEW CONCEPT**: Draw the same circuit but with two separate resistors. Introduce the idea of a **node** (any point where two or more circuit elements meet). Each node has a value of voltage. And when we say **voltage across** a resistor, we mean the voltage of the node at one side minus the voltage of the node at the other side (subtract one side voltage from other side voltage).

- 10 m

  - **ASK THE STUDENTS/MINI ACTIVITY:** Now. Give values of V and both R's, what is the current going through the resistors? Guide them through thinking about this. Give analogy of blowing through a coffee straw. Have them each **blow through one coffee straw** and feel the air coming out at the end. Now have them blow through two coffee straws back to back with about the same amount of force as before. Does the air at the end come out faster and stronger or slower and weaker?

- 15 m

  - **ANALOGY:** Think of the coffee straws as resistors, and your mouth as the voltage source. So what happens when we put two resistors back to back (this is called series)? Will the current get bigger, smaller, or stay the same?
  - **GROUP THINKING EXERCISE:** So how can we calculate the current (give them multiple choice: step1: add resistances, subtract, divide, multiply; step2: use ohm's law, not possible to calculate, something else)? Think in groups for 2 minutes.
  - **RECONVENE** and share ideas. If no one gets it – guide them to add the two resistances and treat it like one big resistor (tying back to analogy of coffee straws). Then use V = IR.

o If we **define GND = 0V at negative terminal of battery** (standard practice). What is the voltage X at the node between the two resistors? Think about it as solving for the voltage across the bottom resistor, because the other node of that resistor is 0V. So X-0 = X. Any ideas? Will this voltage be bigger or smaller than the battery voltage? If none or wrong response, ask them to think back about the ball and hole line, if you add up all the force needed from beginning to end, was the total more or less than the total if you only consider the bottom half of the line? o How do we find X? If none or wrong response, **prod them to thinking about how to apply Ohm's law.** Then solve. o This is called a voltage divider! Because with resistors, we get a voltage smaller than the battery (supply) voltage. • **GUIDE:** them through three examples of voltage dividers. o As a class, derive the equation for calculating the midpoint resistance of a voltage divider. • **WORKSHEET**: Give 5 minutes for them to work on 2 examples of calculating midpoint voltages from voltage dividers on their worksheets. Reconvene and ask for two different students to explain how they did the different problems. • **GUIDE:** them through creating a voltage divider that will give 4.5V from 9V. • **WORKSHEET**: Design 2 voltage dividers on their worksheets. Reconvene and ask for two different examples. • **DEMO:** Now show them how you can make a resistor with just a small piece of paper and rubbing your pencil on it hard. Show them a multimeter and how to measure resistance. Have the students make their own resistors + measure the value of the resistance they made with their LCR meter. • **BUILD:** Use that resistor, batteries, and alligator clips to light up an LED. o **ASK THE STUDENTS (GROUP THINKING + RECONVENE)**: Why do you think that LED is lighting up? What happens if you unhook one of the alligator clips? Is current still flowing? Do LED's need current to flow through them to light up? o **DEMONSTRATION**: Now go through theory of how LED works. Use two students. Have one hold a ball and the other one hand open. Then draw two pieces of metal next to each other. One with electrons. And one with holes. With no current, the balls and holes remain apart. But when there is a current, the ball and the hole combine and they release energy. And this energy in an LED is light! Push the students together to hug to join the ball and the hole. What do they feel? Hotter, right? Heat is also a form of energy! So the LED releases light instead of heat. • **VOCABULARY:** Explain that **LED's need about 2V (forward voltage)** across them and about 30 mA of current in order to light up. • Draw example of V, R, LED circuit. Guide them through calculating the resistance needed to light the LED fully. • **WORKSHEET:** Give students 5 minutes to work through calculating R and I in LED circuits and answer accompanying questions. Reconvene and go over with answers from different students. • **POSE QUESTION (GROUP THINKING + RECONVENE)**: What do you think happens when we put too much current through an LED? How can we answer this? Multiple choice. o **EXPERIMENT**: Everybody put on safety glasses! What happens when we put too much voltage across (3 batteries in series = 27 volts) an LED, but no resistor in between. Ask them what they think will happen and why? If explode, why? Too much current because high voltage and super low resistance. Now let's blow up an LED! Only the teacher does this demo. Students can gather round and watch. • **POSE QUESTION (GROUP THINKING + RECONVENE):** What happens when we put too much current through a resistor? o **EXPERIMENT:** Demonstrate a resistor burning up because it can only handle ¼ W of power. o **NEW CONCEPT:** Power as voltage times current. Maximum power means that the voltage times current can be no more than a certain amount of Watts. Too much power through a component means it will die!	• 10 m • 10 m • 5 m • 10 m • 2 m • 10 m • 10 m

• **BUILD:** Now for the most fun part!!! We're going to make plasma cutters to understand power a little better.
    o We saw with the resistor how when we put a lot of voltage through a very small resistance, we get a very large current right? And that makes sense with V = IR?
    o If we try, we can get such a high current that we can ionize the air, which makes the gases in the air so hot that it changes from a gas to a plasma.
    o This plasma can cut through thin materials.
    o **DEMO:** show demo of plasma cutter cutting aluminum foil and paper.
    o Go through the activity of making a plasma cutter step by step with students (working in partners). **MAKE SURE THEY HAVE SAFETY GLASSES ON.** Have the 4 batteries in series with the wires soldered on ready for them. Have them hook up the alligator clips, the pencil lead, and the aluminum foil in the right way. Each group has a cup of water next to them.
    o WARN THEM: Be careful to ONLY HOLD THE PLASTIC PART OF THE ALLIGATOR CLIP WITH THE PENCIL LEAD. DO NOT TOUCH NOTHING ELSE! And keep the pencil lead above the aluminum foil as best as they can. If they get too deep, it will set the lead on fire. IF THE LEAD IS ON FIRE JUST DROP IT INTO THE **WATER CUP**.
    o **WORKSHEET:** Explain in your own words how a plasma cutter works.
• **EXIT:** Yay that's it! Everyone's exit ticket is a piece of paper with their (1) rating of the class, (2) list of up to three things they liked a lot, and (3) list of up to three things they didn't like and what they would like instead.
	• 10 m
	• 30 m
	• 5 min