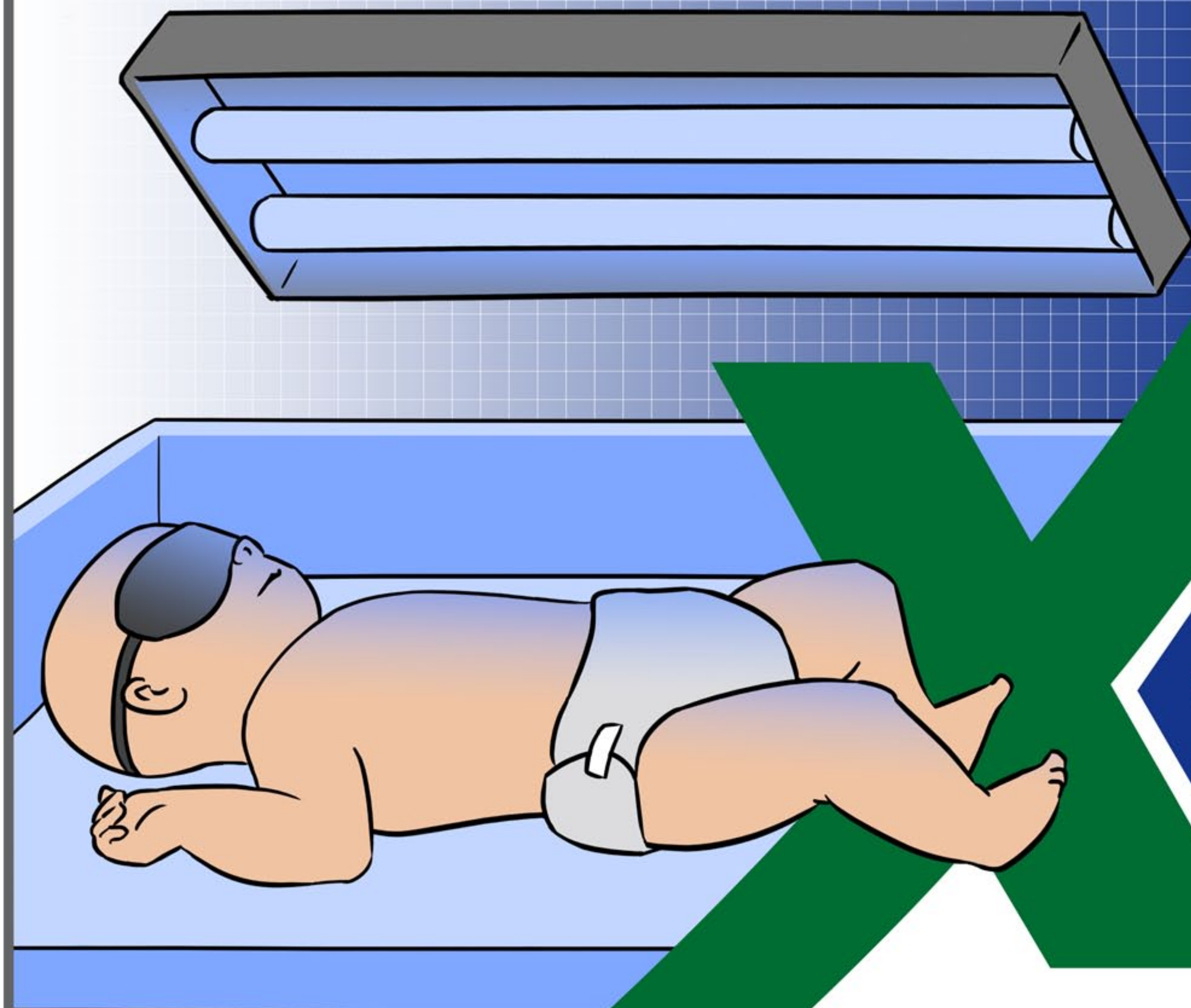


Medical Technology for the Developing World

TechXcite Discover Engineering

Youth Handouts

Common Challenges in Resource-Poor Settings

Unsustainable standards

- Around 80% of the world's population spends less than US$100 per person per year on health
- Vast majority of medical equipment is developed in countries that can spend over $2000 per person per year on health
- Standards and technologies set by the latter are not sustainable for over 80% of the world's population

Untrained technicians

- Often times handymen are utilized as technicians i.e. no formal training
- Perform do-it-yourself repairs
- Incorrect radiation/infusion amounts and doses (e.g. CT, infusion pump)

Cross-contamination

- Disposables being reused
- Rushed reprocessing
- Faulty sterilization units
- Often missing cleaning/disinfecting protocols, guidelines and manuals
- High incidence of infections

Lack of consumables

- Disposables being incorrectly sterilized and reused
- In short supply and shut down equipment due to lack of local supply outlets
- Damaged or faulty equipment in service → inaccurate diagnoses → wrong treatment

Spare parts

- No supplies and frequent repairs means substitution with hopefully equivalent (not always) parts

Service literature

- Difficult to find or non-existent
- Language barriers when available

Power

- Poorly regulated, often unreliable, generators and batteries are over run
- Grounding, isolation, and monitoring frequently poor

Potable (drinking) water

- Hard to come by. Options limited to bottled water or water from a distillation unit
- Reverse osmosis (RO) not often available

Environmental challenges

- Often a lack of temperature and humidity control which adversely affects equipment

Common Challenges in Resource-Poor Settings

Compressed gas hazards

- Frequently bottles only and non-standard connectors. Oxygen might be from oxygen concentrators only
- Old bottles may leak and catch a spark (surgical fire)
- Free standing in rooms/ORs. Missile or explosion waiting to happen!

Alarm hazards

- Alarm fatigue: staff become overwhelmed with amount of alarms; alarm desensitization
- Inability to distinguish the urgency of alarms
- Alarms not being restored to active setting after being put on standby
- Alarms not being properly relayed to pager, wireless phone etc.
- Lack of alarm response protocols

Poor usability of home-use medical devices

- Caregiver knowledge
- Environmental unpredictability
- Device usability

Other challenges/hazards

- Calibration basically unavailable; no metrology labs nor standards
- Inadequate pre-use inspection of anesthesia units
- Misconnected breathing units, ventilator leaks, empty gas cylinders etc.
- Dosimeter and industrial hygiene often not available
- Biologically safe disposal of waste not a given; disposal in a single stream and not sterilized before removed from clinical setting

Activity 1: Reusable Electrodes

Name: ____ Date: ___________________

Materials List

- Conductive gel
  - Option 1 (Recommended):
    - Gel body wash or liquid soap
  - Option 2:
    - Small cup
    - Spoon
    - 1 Teaspoon salt
    - ½ Teaspoon flour
    - Small amount of water
- 2 Bottle cap liners
- 2 Nickel-plated brass sewing snap, size 3
- 2 Alligator wires
- 2 Medical-grade disposable electrodes
- Medical tape
- Paper towels
- Water
- Multimeter

Procedure

1. To measure resistance, set the multimeter to 2MΩ. This means the meter can measure up to 2 million ohms (or 2000 kΩ).
2. First, measure body resistance without electrodes. Place the leads approximately 3 inches apart on your wrist. Use the photo to the right as a guide.
3. Take and record measurements of your wrist resistance below. You will need your partner to help. Be careful not to touch the metal part with your fingers (it won't hurt, it will just mess up the measurement). Also, be aware that the measurements will probably move around.

   Wrist resistance: ________ MΩ (No electrodes)
4. To make low-cost, reusable electrodes:
   a. Push a pin through a bottle cap liner or plastic sheet and use the tip of a pen to enlarge the hole.
   b. Place a sewing snap through the hole.

Activity 1: Reusable Electrodes

5. Now measure your skin resistance using reusable electrodes. Tape the electrodes to your forearm about 3 inches apart and attach the leads. To be consistent, take and record each resistance value about 5 seconds after connecting the leads. Hint: If the multimeter is not showing a measurement, try to apply some pressure to the electrode.

   Wrist resistance: ________ MΩ (Reusable electrodes, no gel)

6. Add a bit of your chosen gel to the bottom of each pad and repeat the previous measurement. This is supposed to replace commercial electrode gel.

   Wrist resistance: ________ MΩ (Reusable electrodes with gel)

7. Now we'll compare the results with commercial electrodes. Repeat step 5 with just the commercial disposable electrode.

   Wrist resistance: ________ MΩ (Commercial disposable electrodes)

8. Finally, measure the resistance of your forearm with some of your conductive gel on the skin and NO pad.

   Wrist resistance: ________ MΩ (Gel only)

9. Fill out the table below with the data collected from the measurements in this activity and, in the blank spaces, any additional experiments you want to try.

Measurement Type	Resistance (MΩ)
No electrode	
Reusable EWH electrode, no gel	
Reusable EWH electrode with gel	
Commercial disposable electrode	
Gel only (no electrode)	

10. Rank the measurement techniques from best to worst (1 to 5) in the chart below. Note: the smaller the resistance, the better the measurement quality.

Activity 1: Reusable Electrodes

Rank	Measurement Type
1	
2	
3	
4	
5	

Exploration Questions

1. What were the advantages and disadvantages of the commercial disposable electrode?

2. What were the advantages and disadvantages of the reusable electrode?

3. Did the gel (body wash, liquid soap, etc.) lower the resistance? Why? What are some other ways to lower the resistance?

Activity 1: Reusable Electrodes

4. Why are the leads attached to the body with tape?

5. The two acronyms for electrocardiogram—ECG and EKG—can be used interchangeably, and in many places, EKG is actually more common. Why?

Activity 2: Low-Cost Stethoscope

Name: ______________________________ Date: ______________

Materials List

- Plastic tubing (2 ft, 7/16-inch outer diameter)
- Medium funnel
- Balloon
- Stopwatch
- Scissors
- Masking tape

Procedure

Part A: Calculating Heart Rate Manually

1. Place your index and middle finger on either your radial artery (inside the wrist) or carotid artery (side of the neck) and locate your pulse.
2. When your instructor tells you to begin, start counting your pulse. After 10 seconds you will be asked to stop.
3. Record this number below and multiply it by 6. This is your resting beats per minute (BPM).

Resting Pulse: ___________ X 6 = _________ BPM
Resting Beats (10s) *Resting Beats (60s)*

4. Now stand up and get your heart beating fast! Run in place or do jumping jacks for 15-20 seconds. Be careful not to hurt yourself or anyone around you.
5. Sit down and measure your pulse again for 10 seconds. Record this number and multiply it by 6. This is your active BPM.

Active Pulse: __________ X 6 = _________ BPM
Active Beats (10s) *Active Beats (60s)*

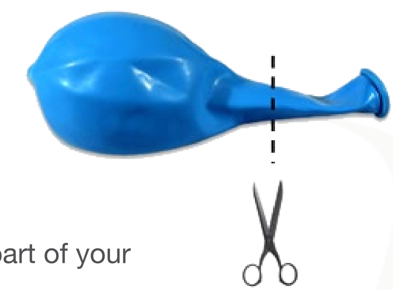
6. Compare your results with other members of your group. Did everyone have the same BPM? Probably not! This is because our hearts are all different and BPM is influenced by factors like the ones listed below. In the table, write "high" next to the factors you think will cause you to have a higher heartbeat, and write "low" next to the ones you think cause you to have a lower one.

Activity 2: Low-Cost Stethoscope

Factor	Heartbeat
Exercising	
Stress	
Sleeping	
Being overweight	
Being healthy	

Part B: Stethoscope

7. Now we will build a low-cost stethoscope. First, cut out a piece of the balloon large enough to fit over the opening of the funnel (cut about ¼ of the balloon from the end).



8. Completely cover the large opening of the funnel with the balloon and make sure it is tight!
9. Fit one end of the rubber tubing over or insert into (depending on the type of funnel you have) the narrow end of the funnel. It should fit very snugly. You can use tape to help hold it better.
10. Take the large, balloon-covered end of the funnel, and place it on the left part of your chest, slightly centered.
11. Place the narrow end of the tube into your ear, being careful not to stick it in too deep. Can you hear a thumping noise? That's your heartbeat!

    Tip: If you have a sweatshirt on, you may want to remove it first so you can hear your heart better. If you still can't hear anything, do 10 jumping jacks and try again.

Activity 2: Low-Cost Stethoscope

Exploration Questions

1. Try using the medical stethoscope to listen to your heart. What differences do you notice?

2. Do doctors face any challenges using stethoscopes in resource-poor environments that are not faced by doctors in western hospitals?

Activity 3: Building a Bili-meter

Name: ______________________________ Date: ______________

Materials List

- Phototherapy test light:
  - 1 Breadboard
  - 1 Battery (9 V)
  - 1 Battery snap
  - 2 Resistors (1 kΩ)
  - 1 Blue LED
  - 1 White LED
  - 10 Jumper wires
  - 2 Alligator leads
- Bili-meter:
  - 1 Blue glass filter
  - 1 Solar cell
  - 1 Piece of black construction paper
  - 1 Roll of clear tape
- 1 Yard stick or tape measure
- 1 Multimeter
- 1 Pair of scissors

Procedure

Part A: Build a Bili-meter

1. Trace the outline of the blue filter in the center of the construction paper with a pen or pencil and cut out the hole. There must not be any gaps between the blue filter and the paper, so it is recommended to cut along the inside of the traced line.
2. Place the black construction paper over the solar cell and secure it with clear tape.
3. Place the blue filter inside the cut-out and tape it to the solar cell.
4. Connect the solar cell wires to the multimeter and make sure the dial is turned to 200μA (microamps).

Part B: Test the Bili-meter

5. Set up the breadboard by connecting the top red line (TRL) to the bottom red line (BRL) and connecting the top blue line (TBL) to the bottom blue line (BBL). The red line will be plugged into the positive side of the battery and the blue line will be plugged in the negative side of the battery.

   Note: This will make it easier to wire more complicated circuits later in the activity so do not remove these wires when designing your circuits.
6. Create a simple light circuit using a 9V battery, a blue LED, and a resistor (see circuit diagram and wiring tables below).

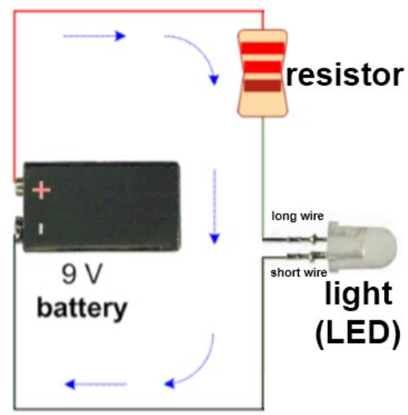
Activity 3: Building a Bili-meter

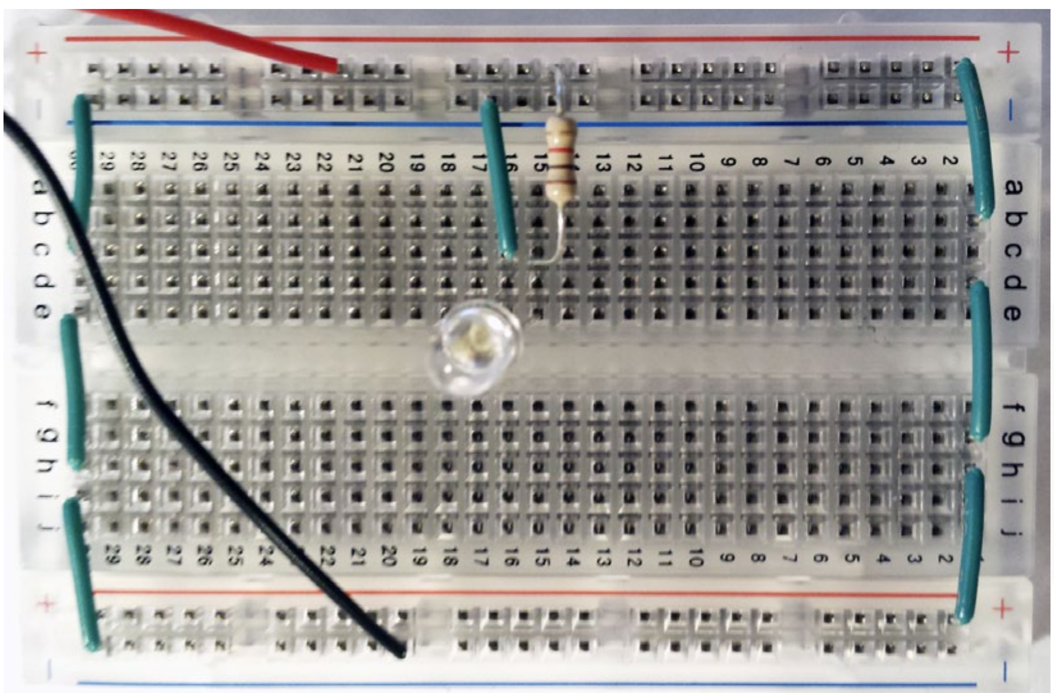
Breadboard Set Up & Simple Circuit

Component	Start	End
Wire 1	TRL	B1
Wire 2	D1	G1
Wire 3	H1	BRL
Wire 4	TBL	C30
Wire 5	E30	H30
Wire 6	I30	BBL

Component	Start	End
Resistor 1	TRL	C15
LED 1	Pos to E15	Neg to E16
Wire 7	C16	TBL
Battery Snap	Red to TRL	Black to BBL

LED Pos = Long Leg
LED Neg = Short Leg
TRL = Top Red Line
BRL = Bottom Red Line
TBL = Top Blue Line
BBL = Bottom Blue Line



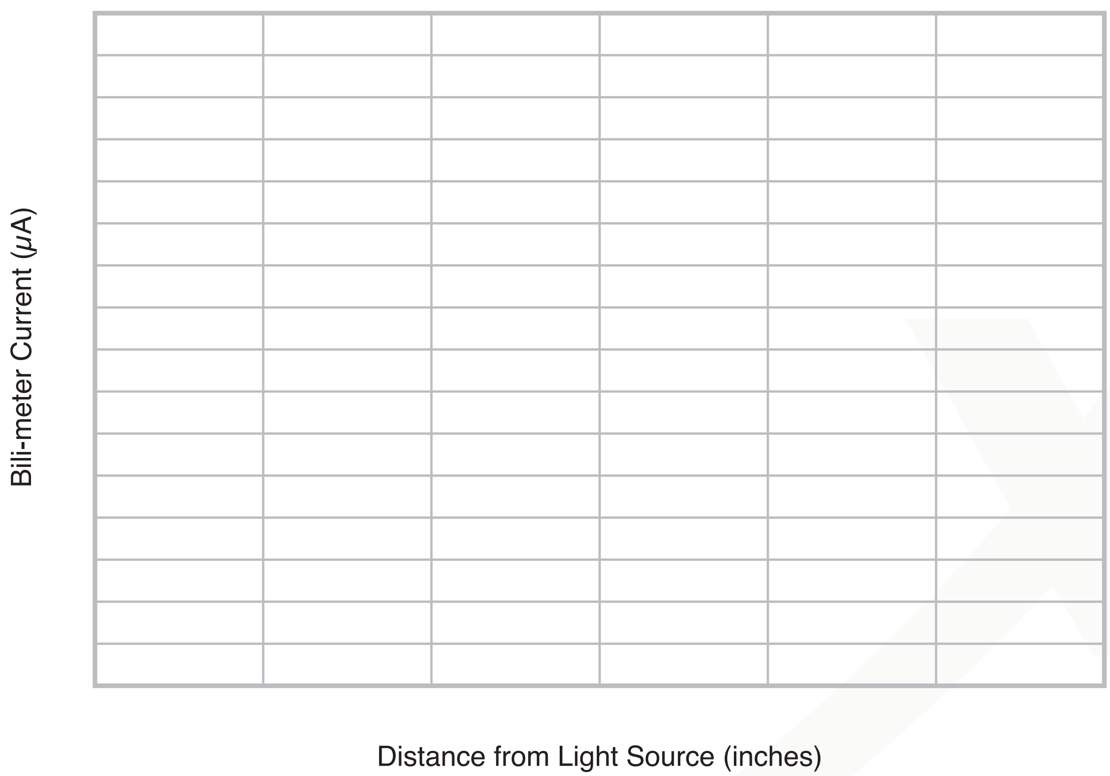


Activity 3: Building a Bili-meter

7. Place your bili-meter 5 inches away from the light and take a current measurement. Record the value in the table below and repeat at 10, 15, 20, and 25 inches away from the light.
8. Plot each value on the graph and connect your plotted points with a **dashed** line.
9. Replace the blue LED with a white LED and repeat step 7.
10. Plot each value on the graph and connect these plotted points with a **solid** line.

Light Intensity vs Distance

Distance (in)	Blue LED (µA)	White LED (µA)
5		
10		
15		
20		
25		

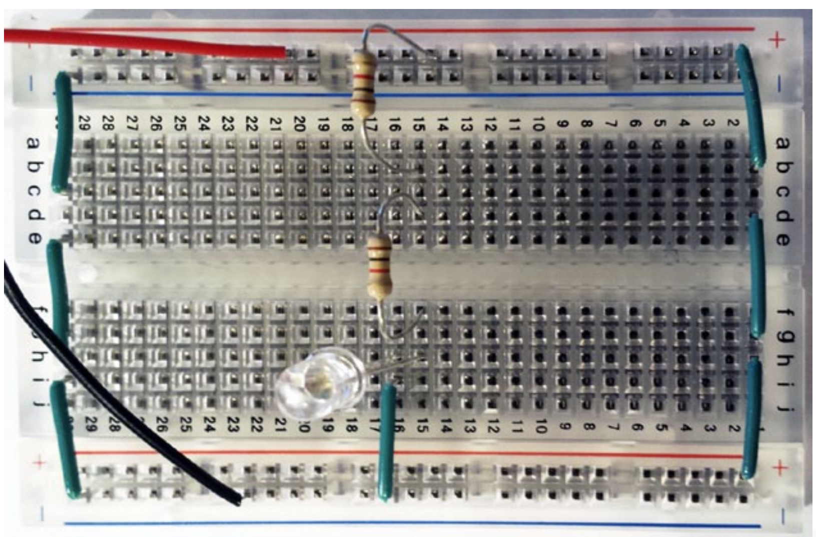


Activity 3: Building a Bili-meter

Part C: Series and Parallel Circuits

11. Build a circuit with one blue LED and **two resistors in series** (see wiring table). Keep the same breadboard set up from the previous circuit.

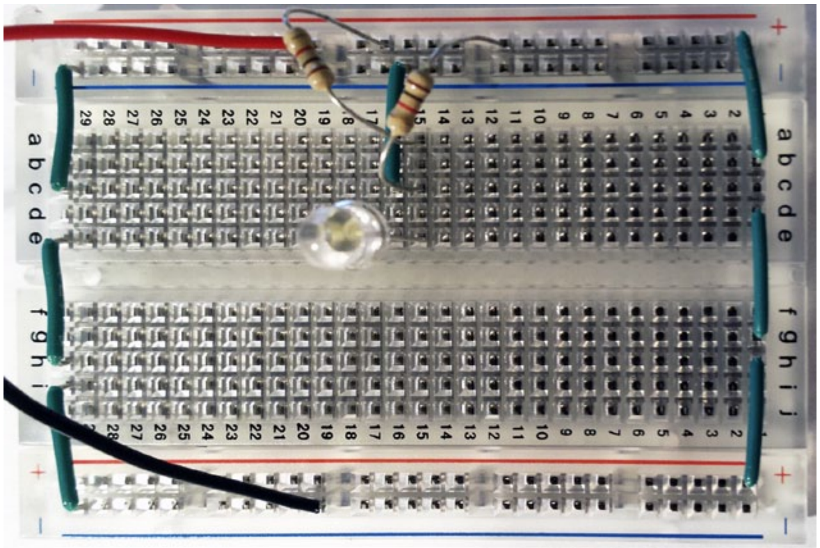
Component	Start	End
Resistor 1	TRL	C15
Resistor 2	D15	F15
LED 1	Pos to H15	Neg to H16
Wire 7	I16	BBL
Battery Snap	Red to TRL	Black to BBL



12. Build another circuit with one blue LED and **two resistors in parallel** (see wiring table).

Component	Start	End
Resistor 1	TRL	C15
Resistor 2	TRL	A15
LED 1	Pos to E15	Neg to E16
Wire 7	C16	BBL
Battery Snap	Red to TRL	Black to BBL

Activity 3: Building a Bili-meter



13. Use your bili-meter to compare the intensity of both circuits, one at a time. You can do so by placing your bili-meter a few inches away from light. Record the multimeter reading below. Make sure to take your measurements at the same distance each time!

    Distance: __________ inches

    Series Circuit: __________ mA

    Parallel Circuit: __________ mA

    Which of the arrangements has a stronger light intensity, parallel or series?

Activity 3: Building a Bili-meter

Exploration Questions

1. What do you notice from these experiments? Which light produces the lowest bili-meter readings? Why?

2. Do your plotted points produce a straight line or a curved line? Why?

3. Why do you think the engineers of the bili-meter pictured below chose to use a green and red gauge rather than a digital readout like the multimeter?

Activity 4: Phototherapy Design Challenge

Name: ______________________________ Date: ______________

Materials List

- Phototherapy light:
  - 1 Breadboard
  - 1 Battery (9 V)
  - 1 Battery snap
  - Resistors (1 kΩ)
  - 6 Blue LEDs
  - Jumper wires
  - 2 Alligator leads
- Bili-meter (from Activity 3)
- Multimeter
- 12” String

Engineering Design Challenge

Design a phototherapy unit that distributes the maximum intensity of blue light over the entire baby for the lowest price.

Design Constraints

- Only use the materials provided
- Maximum of 6 blue LEDS per phototherapy unit
- Maximum of 3 resistors in parallel
- Phototherapy unit must be held at least 12 inches away from the bili-meter
- No square on the baby grid should measure a light intensity rating less than 25µA for Jameco blue LEDs or 35µA for Mouser blue LEDs (if you don’t know the brand ask your instructor)

Material Costs

Item	Cost per Unit
Resistors	$1.00
Jumper wires	$0.80
LEDs	$3.40

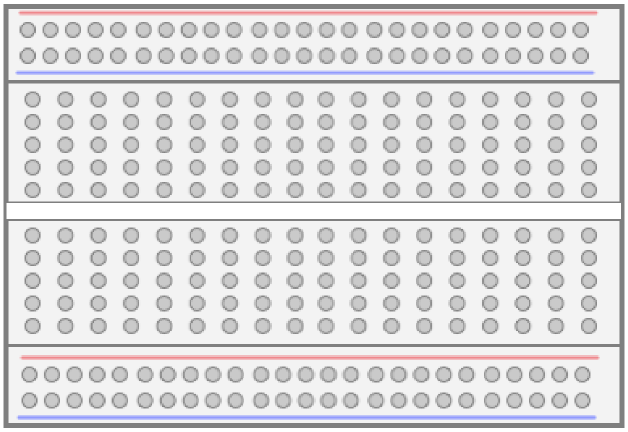
Notes

- Current will only travel through LEDs in one direction. They will not work if installed backwards.
- Always have at least one resistor in the circuit between the positive side of the battery and the positive leg of the LED. If there are no resistors, the LED will burn out.
- NEVER use more than 3 resistors in parallel with a LED. This will cause the LED to burn out.

Activity 4: Phototherapy Design Challenge

Use the breadboard template below to design your phototherapy unit. You may wish to brainstorm several options within your group and draw them on a separate sheet of paper before deciding on your final design.

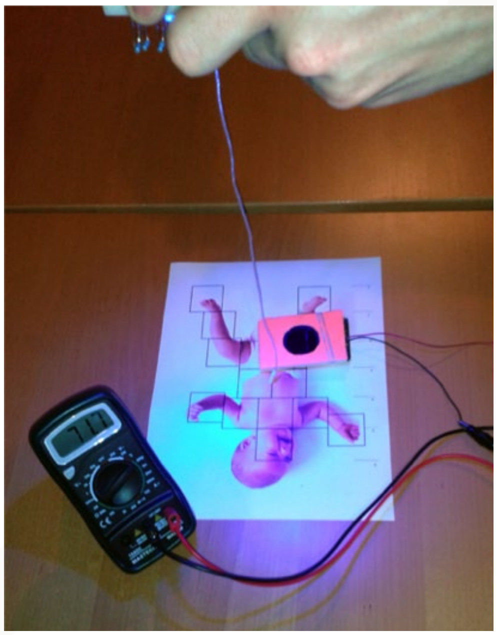
Note: Engineers normally use the ⊗ symbol for light bulbs, but you are welcome to use any other symbol. You should also draw in the jumper wires and resistors as well.



Testing Procedure

1. IMPORTANT: TURN OFF THE CEILING LIGHTS IN THE ROOM BEFORE TAKING ANY MEASUREMENTS! AMBIENT LIGHT WILL PRODUCE HIGHER/INCONSISTENT BILI-METER READINGS!
2. Tape a 12” string to the breadboard of your phototherapy unit. This will hang from the unit as you hold it above the “baby” and allow you to keep a consistent distance from the paper. If the string isn’t straight, you may wish to wrap a small piece of tape to the end to weigh it down.
3. Have one person in your group hold the phototherapy unit 12 inches above the baby grid. Once you decide where the unit should be placed and start taking measurements, do not move it around.

   Note: The LEDs do not emit light in a uniform cone. In other words, your LEDs will produce a different array of light on the baby when rotated 90 degrees. You must choose the best orientation.
4. Place the bili-meter such that the sensor (blue filter) is centered in square #1 of the baby grid. Record the current reading in the *Bili-Meter Measurements* table.
5. Repeat step 4 for each of the baby grid squares.
6. Determine if your LED layout meets the minimum testing requirements. If not, try modifying it. You also may wish to try a different circuit design just for comparison. Keep rebuilding and testing until you find the design you think works best.



Activity 4: Phototherapy Design Challenge

7. Calculate the average light intensity over the entire baby grid.
8. Record the cost of your phototherapy unit in the *Expenses* table and calculate the total.
9. Calculate the overall performance of your phototherapy unit using the formula below. Record each group's data and performance score on the *Overall Performance* table. The higher the performance score, the better.

$$\text{performance} = \frac{\text{average light intensity}}{\text{total cost}}$$

Bili-Meter Measurements

Baby Grid	Light Intensity (μA)		
	Trial 1	Trial 2	Trial 3
#1			
#2			
#3			
#4			
#5			
#6			
#7			
#8			
#9			
#10			
#11			
#12			
#13			
#14			
AVERAGE			

Activity 4: Phototheraphy Design Challenge

Expenses

Item	Cost per Unit	Units	Cost
Resistors	$1.00		
Jumper wires	$0.80		
LEDs	$3.40		
		TOTAL COST	

Overall Performance

Group	Average Intensity (μA)	Total Cost ($)	Performance Score
Example	*70*	*30*	*2.5*

Activity 4: Phototheraphy Design Challenge

Exploration Questions

1. You've just learned that a filtered solar panel can be used to test a phototherapy unit and that you can build a phototherapy unit out of basic inexpensive parts. What else would you need for these to be effective devices in a hospital?

2. What needs of a resource-poor setting does the bili-meter meet? What kinds of problems can it detect?

3. Could babies with neonatal jaundice be treated simply by placing them in direct sunlight?

Activity 4: Phototherapy Design Challenge