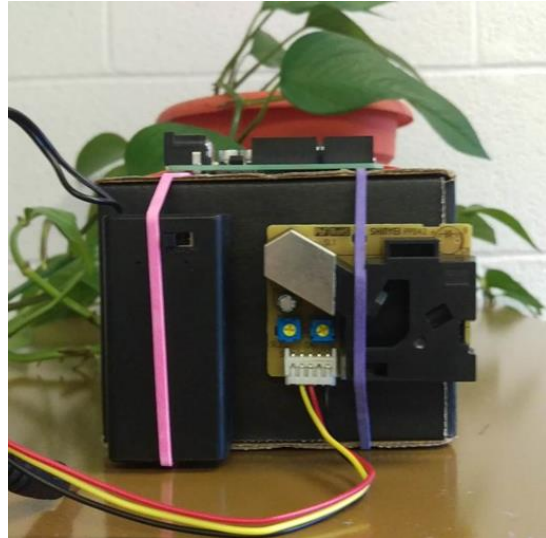# Instructions for Shining Light on Pollution – Build Your Own Particle Sensor

Step 1: Organize the Components and Prepare the Mounting Box for the PM detector

Materials:

- Cardboard box
- Rubber bands
- 1 Arduino
- 1 PM sensor
- 6 short wires
- 1 long wire
- 3 LEDs (red, 5.5 mm)
- 3 resistors (1K Ohm or brown, black, red, and gold)
- 1 half breadboard
- Battery clip w/ 9 volt battery

Prepare the Mounting Box

1. Use a big rubber band to attach the PM sensor to the left (your left) side of the box. The sliver part of the PM sensor should be on top and it may be helpful to mount it close to the edge of the box near you.
2. Use another big rubber band to attach the battery clip (make sure it is OFF) next to the PM sensor. Make sure the switch is facing out and the wire is on top.
3. Use a thin rubber band to attach the Arduino to the top of the box next to the PM sensor. It will be easier to work with if you orient the Arduino so the silver USB plug is on "top".
4. Use another rubber band to attach the half bread board to the top of the box. Try to place the bread board close to the Arduino so it will be easy to connect the wires. Orient the breadboard so that the letters across the top and bottom are right-side up.

NOTE: You can use a wide range of materials to mount the sensors. The original activity developed by the US EPA used children's building toys and Velcro. You can also attaching the components in different orientations. However, it is helpful to have the Arduino, power source, PM sensor and breadboard close to each other so that the wires will reach easily.

Step 2: Assemble the LED circuits

1. Notice that the breadboard is labeled a-j across the top and bottom and 1-3 down the sides.
2. Take the first **LED** and plug the long end (the positive + end) into **E3** on the breadboard. Plug the short end (the negative – end) into **F3**.
   a. Plug in the second LED: use **E15** for the long end and **F15** for the short end.
   b. Plug in the second LED: use **E28** for the long end and **F28** for the short end.
3. Take a **resistor** and plug one end into **H3** and the other end in **any blue (negative)** space on the right.
   a. Add resistors to the second and third LED circuits
   b. NOTE: it does not matter which direction you plug the resistors in because they are non-polar, but you do need to make sure one end is in the negative column.

4. Take the **blue** wire and plug one end into **A3** and leave the other end hanging.
   a. Plug one end of the **orange** wire into **A15** and leave the other end hanging.
   b. Plug one end of the **white** wire into **A28** and leave the other end hanging.
5. Take the long (**green**) wire and plug it into any pin in the **blue (negative)** column on the right side of the breadboard. Leave the other end hanging.
6. Check all the wires on the breadboard to make sure they are in the correct location and pressed in firmly.
   a. Think about making sure that all of the components (wire, both sides of the LED, and first side of the resistor) are connected in the same row. When we connect the blue wire to the Arduino (with the battery plugged in) this completes the circuit.

Step 3: Connect the Sensor and Wires to the Arduino

1. Connect the PM sensor to the Arduino
   a. Find the white connector at the end of the wires connected to the PM sensor.
   b. Take the short yellow wire and plug one end into the white connector: match yellow wire to yellow wire.
   c. Take the short red wire and plug one end into the white connector: match red wire to red wire.
   d. Take the short black wire and plug one end into the white connector: match black wire to black wire.
   e. Plug the **yellow** wire into the **8** on the **right** side of the Arduino
   f. Plug the **red** wire into the **5 V** on the **left** side of the Arduino
   g. Plug the **black** wire into the **GND** on the **left** side of the Arduino
2. Connect the LED circuits to the Arduino
   a. Take the **blue** wire connected to **A3** and plug the other end into the **~5** pin on the **right** side of the Arduino
   b. Take the **orange** wire connected to **A15** and plug the other end into the **4** pin on the **right** side of the Arduino
   c. Take the **white** wire connected to **A28** and plug the other end into the **~3** pin on the right side of the Arduino
   d. Take the long (**green**) wire connected to the blue (negative) column on the **right** side of the breadboard and plug the other end into the **GND** on the **right** side of the Arduino
3. Review your wiring!!!
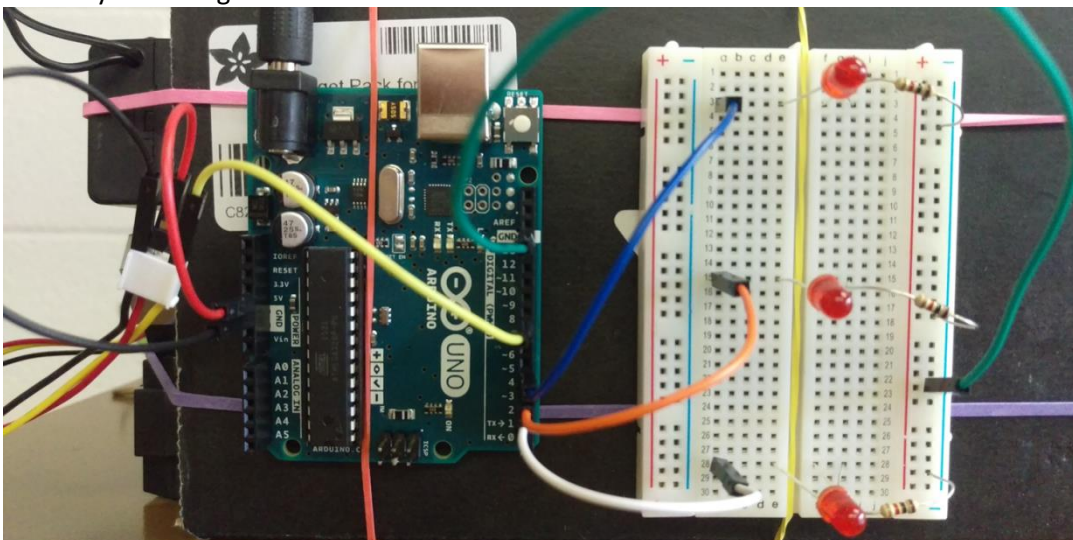
Step 4: Test the PM Detector!

1. Plug in the Battery
   a. Make sure the battery is OFF (some battery clips do not have a switch)
   b. Connect the end of the battery clip into the round black plug at the top of the Arduino.
   c. Turn the switch on the batter clip on.
      i. A yellow and green light should come on and one LED should light up.
      ii. More than one LED will light up depending on the concentration of PM.
   d. NOTE: If your Arduino is still connected to the laptop or tablet, the lights will come on as soon as the circuit is complete. For students, it is important that the Arduinos are NOT connected to a power source while they are tinkering with the wiring.
2. Troubleshoot!
   a. The most common reason for the PM detector to not work is because a wire is not quite in the right place. If lights don't light up, seem to be dim, or are in a strange order turn the power off and check the wiring.
      i. LEDs need to go positive to negative.
      ii. All wires need to be firmly connected.
   b. You can also check to see if the sensor is working by viewing the output on the laptop or tablet.
      i. Connect the Arduino to a laptop or tablet.
      ii. Under the "tools" menu, select "serial monitor." This will allow you to see the values that the sensor is detecting. If you introduce particles directly over the sensor and you only see zeros on the serial monitor, you can assume the sensor is not communicating with the Arduino.
      iii. If the numbers are changing slightly but only one LED lights up, you may need to adjust the sensitivity. An instructor can help with this. OR you can see if you can find the place in the code to change!
3. Explore and Tinker
   a. Remember, the particle sensor works by "counting" the number of particles inside the detector. To see a change in the number of particles detected, you may have to "assist" by providing air flow (i.e. move the sensor around or wave air in front of it).
      i. Try rubbing your hands in front of the detector.
      ii. Take the detector to different rooms in your school.
      iii. Test the detector inside and outside. Which environment appears to have more particles? How does this compare to what we know about indoor versus outdoor (ambient) air pollution?
   b. It is also important to remember that the particle sensor is a pretty simple device and it is not calibrated. This makes a great question or design challenge for students: how could we take this relatively inexpensive sensor (~$60 for all parts) and make it better?