Teacher Answer Key: Follow the Guidelines
Introduction to Mobile Robotics > Follow the Guidelines

Construct: Find the Threshold

Check your understanding:

1. What is the robot looking for?  
The robot is looking for Light Sensor readings, and is comparing them against a set threshold. It wants to see if the readings are above or below the threshold number. If the readings are above the threshold, it categorizes them as "light." If they are below the threshold, it calls them "dark."

2. Which way should it go when it sees light? Why?  
To the right. Since we are tracking the left side of the line, if the robot is seeing "light," then it is hopefully to the left of the line, so it needs to go to the right.

3. Which way should it go when it sees dark? Why?  
To the left. Since we are tracking the left side of the line, the robot is only going to see "dark" if it is on the line, so it needs to go to the left.

Construct: Find the Threshold

Record and check:

4. The threshold value you calculated.  
This will differ for each student. Threshold values can be very low or very high, depending on the lighting in the room and the table and tape reflective properties. Make sure that students calculate it by taking the "dark" value and adding it to the "light" value, and then dividing the sum by 2.

5. Classify each of the following light sensor values as "light" or "dark", using the threshold value you calculated for your l sensor.  
Again, the answers will differ for each student, depending on their calculated threshold. Sample answers are in magenta. Note that if the reading is exactly at the threshold (say the threshold is 45 and the reading is 45) then the sensor will consider that number to be "above" the threshold, and it would be considered "light." Students will not know this on their own, though, so it may be a good idea to share this information with them.

My Threshold Value = _________45______

i. 34 Dark
ii. 78 Light
iii. 51 Light
iv. 40 Dark
Construct: Create your Program

Check your understanding:

6. Sketch either a filled sun (light) or an empty sun (dark) to show which half of the Switch block the program will run for each of the following values (if the Switch Block threshold is 45).

   i.  91  filled sun  
   ii. 36  empty sun  
   iii. 5  empty sun  
   v.  20  empty sun

Construct: Control the Motors

Check your understanding:

7. Using your own calculated threshold, describe the motion that the robot will make when the light sensor reads:

   Based on the sample threshold value of 45

   i.  27  Dark - Turns Left  
   ii. 38  Dark - Turns Left  
   iii. 91  Light - Turns Right  
   vi. 45  Light - Turns Right

Contemplate

8. The line tracking behavior is built by organizing several smaller behaviors to run at certain times. Identify two of these smaller behaviors, and explain what they do in the program and when they are used.

   Some of the simple behaviors in the line tracking behavior are:

   **Check Light Sensor value** – This behavior is part of the Switch Block, and comes into play at the beginning of the Switch Block, before the program decides which path to take. It is because of this behavior that the Switch can decide which path to take at all.

   **Compare Light Sensor value to threshold** - This behavior is part of the Switch Block, and also comes into play at the beginning of the Switch Block, so that the program can decide which path to take.

   **Go right** – This behavior is in the upper path of the Switch Block. It is made up of the even smaller behaviors “Turn on Motor C for an unlimited amount at 25%” and “Make sure Motor B is stopped.” This behavior happens when the Light Sensor sees a number above the threshold. It is used to make the robot go towards the right, which would presumably be where the left side of the line is.

   **Go left** – This behavior is in the lower path of the Switch Block. It is made up of the even smaller behaviors “Turn on Motor B for an unlimited amount at 25%” and “Make sure Motor C is stopped.” This
behavior happens when the Light Sensor sees a number below the threshold. It is used to make the robot go towards the left, which would presumably be where the left side of the line is.

**Loop** – The Loop block makes the behavior repeat, so that the robot can actually track the entire line. It is set to repeat the behavior for 10 seconds. This does not set how many times it will loop through the behavior. It will loop as many as it needs to to fill 10 seconds worth of time.

9. Mele writes this program one afternoon, tests it, and finds that it tracks a line well. However, when she comes back the next morning, it doesn’t work! She places her robot on the line and runs the program, but to her surprise, the robot only swing turns to the right in a circle the whole time.

Explain what the cause of this problem is, your reasoning for why this is the case, and what needs to be done to fix it. If you don’t have any idea what could be wrong, explain instead what steps you would take to help Mele find and fix the issue. For each step, explain how and why you would take that step.

Mele’s problem is most likely that her threshold is no longer correct for the environment on the second day. If both the table and line give readings above the threshold, then the robot will only perform the “light” behavior the whole time, resulting in a slow swing turn to the right. To fix the problem, Mele needs to recalculate her threshold for the new lighting conditions, change the value in her program, and download & run the program again.

Students may not yet have the experience or familiarity with thresholds to come to this conclusion. This is fine, and gives a good opportunity to gain some insight into their reasoning and troubleshooting processes. Students who do not have an immediate suspicion about the cause of the problem should come up with an organized and systematic series of steps for determining what the problem is.

For example:
1. Make sure the port number in the program matches the port that Mele has the sensor plugged into.
2. Make sure her motors are plugged in correctly.
3. Double-check that Mele is running the right program. Download her code again to be sure.
4. If that doesn’t work, then maybe the problem is with the Light Sensor instead. Check the Light Sensor values in the View mode to make sure her Light Sensor is working.
5. If the Light Sensor is working, then check to see if maybe her threshold value is set wrong. Take new readings for light and dark and calculate the threshold again.
6. If nothing works, try loading the program on another robot, or loading someone else’s program on Mele’s robot to see if that works.
7. Ask a teacher if it still doesn’t make sense.

The exact steps are not as important as the strength of the problem solving/troubleshooting methodology that students use. Steps should be:

- **Precisely described**
  
  Good: “Check the Light Sensor values in View Mode to make sure her Light Sensor is working”
  
  Too vague: “See if something is wrong with the Light Sensor”

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1 “Obsolete” threshold values are a common problem in classrooms or other settings where daylight changes the lighting conditions. In Mele’s case, it is likely that the amount of light coming from the sun has changed such that the dark line on the table no longer gives a value that is below the threshold. This could happen, for instance, if the sun shines directly on the table during the morning, causing both the light and dark areas to give far higher light readings than they would have in the afternoon, when the original threshold was set. Consequently, the robot would only see “light”, and therefore perform the “light” behavior, making the robot swing turn to the right the whole time.
- **Meaningfully motivated**
  
  **Good:** “Double-check that Mele is running the right program. Download her code again to be sure.”
  
  **Unclear motivation:** “Take the NXT off and put it back on.”
  
  **Poorly motivated:** “The problem might be that Mele is bad luck, so have someone else run the robot instead.”

- **Systematic breakdown and sequence of steps**
  
  **Good:** Make sure that each component in the robot system (sensor, NXT, program, etc.) is functioning correctly on its own, then see if they are correctly matched to each other (ports, etc.)
  
  **Good:** Try to address the quickest, most common problems first, and if they don’t work, check progressively harder and more time-consuming possibilities
  
  **Unorganized:** Check a lot of different things with no clear pattern or plan.

10. Imagine that instead of dark tape on a light surface, your classroom has dark surfaces with light tape on them.

   i. Would the robot be able to follow the line using your same program?

      **Yes, the robot would still be able to follow this line,** as long as the threshold that was calculated before is still applicable. The program is simply looking for the difference between light and dark, and with the light line on the dark surface, we still have that in this case. You just have to be sure that the light and dark values are still on either side of the threshold, or else the robot will always spin in one direction or another.

   ii. Would it behave exactly the same, or slightly differently? Explain.

      **The robot will now track the right side of the line.** It still thinks that “light” is to the left of the line and “dark” is to the right of it. So when it sees “light,” meaning that it is on top of the line, it will go to the right until it sees “dark.” Therefore, it will work its way toward the right side of the line.

11. Now think about the physical placement of your Light Sensor on the robot.

   i. Is the placement of the Light Sensor important?

      **The sensor placement is very important!** It determines the amount of light that the sensor ‘sees,’ which, in turn, determines the threshold and all of the light values.

   ii. What happens if you raise or lower the Light Sensor?

      **If you put the sensor lower to the ground, it will read different values.** Light surfaces may have a higher sensor value, but so also may dark surfaces, because the sensor is actually reading the light reflected from its own red floodlight (which is the red light you see on the front of the sensor). If the red floodlight is closer to the ground, more of it will reflect back up into the Light Sensor, even on dark surfaces, making the sensor reading higher.

      If the Light Sensor is farther from the ground, then the difference that the sensor reads between light and dark surfaces will be less, because more ambient light will interfere with the sensors readings.

   iii. What happens if you place it in the rear of the robot instead of the front, but don’t change your program?

      Attempting to line track with the sensor behind the robot may seem like a good idea, but in effect, it’s like trying to drive down a highway by lining up the road in your rear view mirror. If the road is straight, it might seem to work, but as soon as you hit a curve, there’s no way you can know which way to go.

      **Common Confusion:** Ultimately, placing the Light Sensor on the rear of the robot will prove to be a valuable strategy (see Exploration activity), because it places the sensor closer to the turning center of the robot; however, the robot must line track **while moving backwards** in order for this to work. Thus the line sensor would still be “in front” of the robot as it moves. This is not the same program or strategy as what this question is proposing.
12. Why does this behavior track the right side of the line instead of the left?
Now that we have switched the two behaviors, the robot will reverse what it does and when. When it sees light, it now turns left. When it sees dark, it now turns right. Put that together and you get line tracking on the other side of the line!

13. When might this behavior be useful?
This might be useful if you have to track the side of a large area and there isn’t enough space for the robot to travel on the left side of it, like the edge of a pool or the difference between two different kinds of flooring.
It can also come in handy if you have a line that branches off to the left, but you want to follow the right-most branch. By tracking the right side of the line the entire way, you ensure that the robot will follow the right side of any branch.