

# BUILD A SPECTROPHOTOMETER

## STEP-BY-STEP INSTRUCTIONS

To get started building the spectrophotometer we recommend watching the video *Building a Spectrophotometer* on Teach.Genetics.utah.edu to get yourself acquainted with the steps involved. Use this guide to step through the process. For a full list of materials see the *Shopping List* PDF in the downloads section on the *Build a Spectrophotometer* webpage.

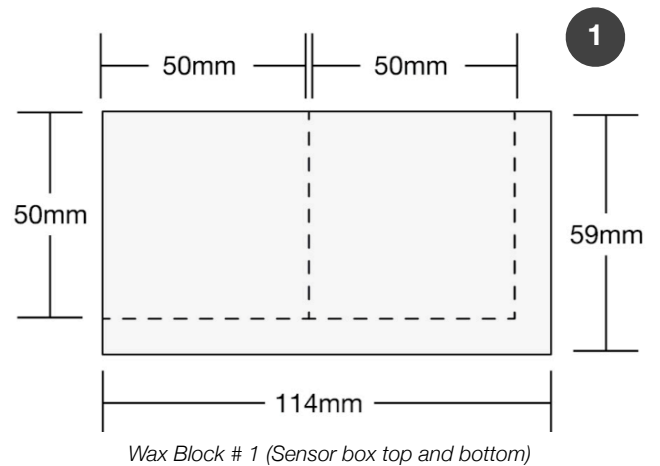
### STEP 1: Preparing the Sensor Box and Spacers

#### Cut Sensor Block

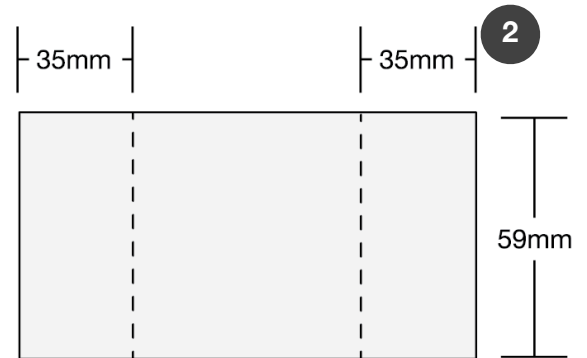
1. Remove two blocks of wax from the package.
2. One block (block #1) will be used to make the sensor box top and bottom.
3. The other (block #2) will be used to make the spacers.
4. Mark a 50 mm x 50 mm square on block #1.
5. Using your bread knife, cut out the square.

*The piece may break off before it is completely cut, leaving a raised amount of material. Use your bread knife to shave excess material off so the side is clean and flat.*

6. Repeat this process to cut out another 50 mm x 50 mm square from block #1.
7. Measure both squares again to make sure both are the same length and width. Shave around the edges as needed if they are a little off and don't quite match in size.



Wax Block # 1 (Sensor box top and bottom)



Wax Block # 2 (Spacers)

#### Cut And Fit Spacers\*

1. Mark two lines 35 mm from the short edges of block #2 and use your bread knife to cut the pieces off.

*The spacers will be slightly wider than you will need them to be so that you can shave them down to create an exact fit.*

2. Place your sensor box top and bottom in the wooden box.
3. Place one of the spacers on the right side of the sensor box top and bottom.

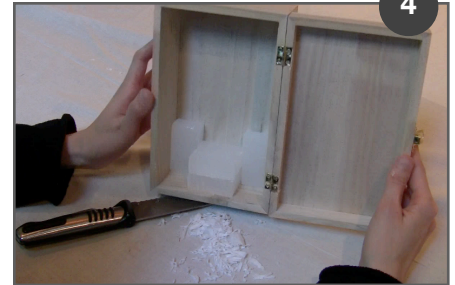


#### \*NOTE

*If your wood craft box is a different size than this one, you may need to adjust the measurements of the spacers and horizontal bamboo skewers. The goal is to cut spacers that hold the sensor box snugly in the center of the wood craft box.*

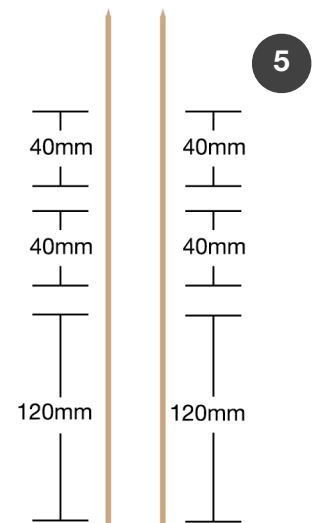
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4. Hold the other spacer over the area to the left side of the sensor box pieces and estimate how much material you will need to shave off. (Figure 3)
5. Use your bread knife to shave down the long side of the spacer.
6. Test it in the box.
7. Shave and test again, repeating until the spacer fits snugly, but can still be removed easily. (Figure 4)



## Cut Bamboo Skewers

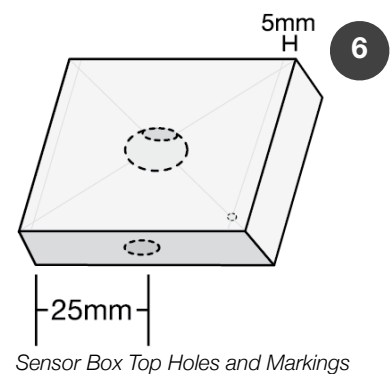
1. Using your wire stripper/crimper cut a 120 mm piece of the bamboo skewer from the blunt end. (Figure 5)
2. Slide it horizontally into the box above the spacers to help hold them in place.
3. Cut another 120 mm piece from the other bamboo skewer.
4. Slide it horizontally into the box in front of the bottom of the sensor box to help hold it in place.
5. Cut four 40 mm pieces from the remaining pieces of bamboo skewer and cut down any pointy ends. These will form the stilts for the sensor box.



## Prepare Sensor Box Top And Bottom

1. Use your paring knife to lightly mark an X from corner to corner on both sides of the top and bottom of the sensor box wax squares. (Figure 6)
2. Measure in from the sides and lightly draw a line 5mm in from the left and right side.

*The intersection of these lines marks where the stilt holes will be drilled later on.*



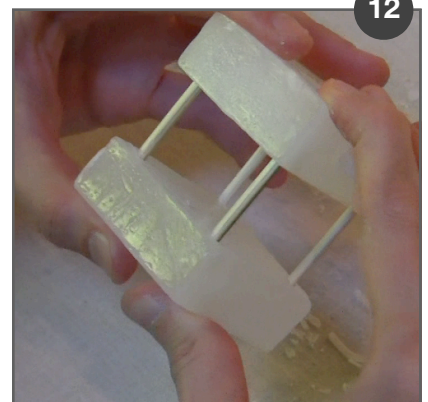
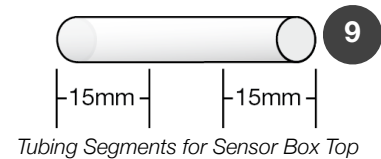
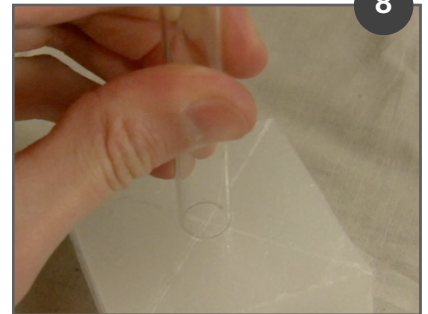
Sensor Box Top Holes and Markings

3. On the side of one wax square measure 25 mm from the side and mark in the center. (Figure 6)
4. Use your #2 flat-bladed screwdriver to carefully drill straight into the wax where you marked. (Figure 7)
5. Make sure to keep the screwdriver as straight as possible as it turns. Stop frequently to clean the wax bits off your tool.



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6. Once you are about half way through, mark the other side where the screwdriver will exit and begin drilling from that side now until you break through.
7. Use the mouth of your test tube to make a circular mark in the center X on the sensor box top. Using this circular mark as a guide, carve out the hole for the test tube using the paring knife. Do the same on the other side of the sensor box top. (Figure 8)
8. Use your wire crimper/stripper to cleanly cut two 15 mm segments of the polyethylene tubing. The tubing will protect the holes where the LED and phototransistor will go. (Figure 9)
9. Use your #2 flat-bladed screwdriver to gently remove wax from the holes until you can easily fit the tubing into the holes. Do not force them in or the wax will break. (Figure 10)
10. In the center of the X on the sensor box bottom, use your paring knife in a sweeping motion to carve out an indentation for the test tube bottom to rest when it is inserted into the sensor box.
11. Place the test tube into the indentation and widen if needed. (Figure 11)



### Add Sensor Box Stilts

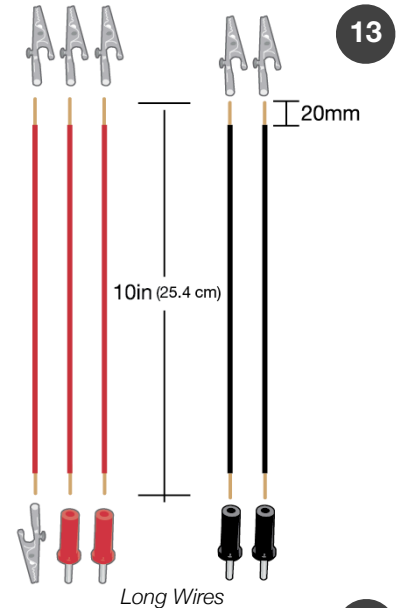
1. Use your mini-screwdriver to gently drill holes a couple millimeters deep at the intersection of the markings you made earlier on both wax squares. There should be eight holes total, four in the top and four in the bottom.
2. Place the stilts into the holes.
3. Place your test tube into the large center hole in the sensor top. If the box rocks back and forth or the test tube leans, you will need to adjust the height of your stilts or the depth of the stilt holes. (Figure 12)

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## STEP 2: Preparing the Wires

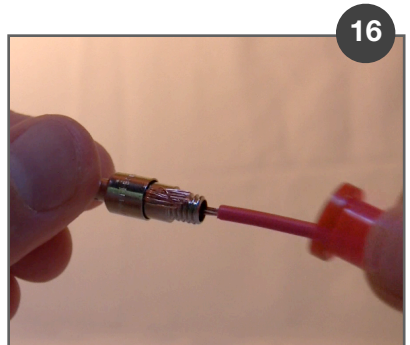
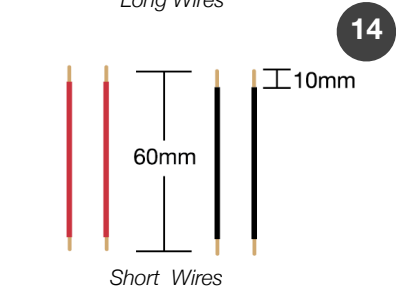
### Cutting And Stripping Wires

1. Use your wire stripper/crimper to cut three 10 inch (25.4 cm) long red wire segments and two 10 inch (25.4 cm) long black wire segments. (Figure 13)
2. Cut two 60 mm long red wire segments and two 60 mm black wire segments. (Figure 14)
3. Use your wire stripper/crimper to strip 20 mm from each end of the 10 inch (25.4 cm) long segments. Make sure to select the proper stripping size on the wire stripper for 18 gauge wire.
4. Strip off 10 mm from each end of the short segments.



### Alligator Clips And Banana Plugs

1. To attach the alligator clips, thread the wire through the small hole inside the clip and out the other side. Pull the wire through and wrap tightly around the screw. Use a screwdriver to tighten the screw. (Figure 15)
2. Add the banana plugs to the long wires as indicated in Figure 13. Add the red plugs to the red wires and the black plugs to the black wires.
3. If you are adding the optional heat shrink tubing, slip this on the wire before adding the banana plug.
4. To attach the banana plugs, unscrew the rounded metal piece over the plug. Unscrew the casing. Slide the casing over the wire. The metal plug portion has a small hole to feed the wire through. Feed the wire through the hole then bend it down. Screw the rounded metal piece back onto the plug. Slide the casing back up and tighten. (Figure 16)



### Prepare The IR LED And Phototransistor

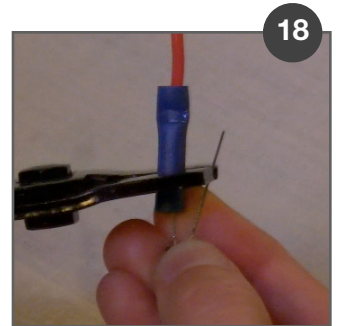
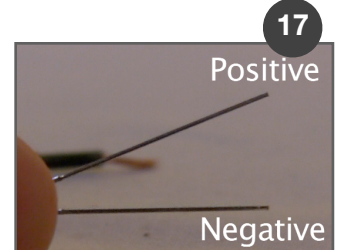
*Notice that both the IR LED and Phototransistor have a short wire and a long wire. The long wire is positive and the short wire is negative. (Figure 17)*

1. Crimp the red 60 mm wire to the positive wire of the IR LED and

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the black 60 mm wire to the negative wire of the IR LED.  
To crimp, slide the LED wire into one end of a blue crimp connector.  
Slide the 60 mm 18 gauge wire into the other end. (Figure 18)

2. Leave as much diode wire as possible coming out of the connector. This will give you some wiggle room later on when you put it into the box.
3. Once you have crimped both wires, tug the LED. If it pulls out or is loose, crimp it more until it's secure.
4. Repeat to connect the red and black 60 mm wires to the Phototransistor.



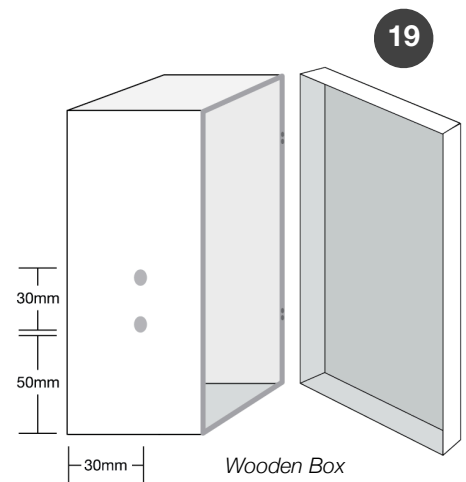
## Test The IR LED

*Infrared light is invisible to the naked eye, but most digital cameras, including cell phone cameras, can detect it.*

1. Set up your camera so that the IR LED is viewable in the camera viewfinder.
2. Place your D-cell battery into the battery holder. Hold the black wire of the battery holder to the short black wire attached to the IR LED and the red end of the battery to the red wire. You should see the LED light up in the camera viewer.

## STEP 3: Preparing the Wooden Box

1. Use your phillips head screwdriver to remove the lid; set it aside.
2. Turn the box so that the door swings out toward you as shown in Figure 19. This will be the orientation when the spectrophotometer is in use.
3. You will mark points for two holes on both the left and right side of the wooden box, four holes total. Mark one point 50 mm from the bottom and 30 mm from the back edge. Mark a second point 80 mm from the bottom and 30 mm from the side. (Figure 19)
4. Using your metal skewer as a drill, turn and push it through each point to make two holes on each side of the box. Alternatively you can use an awl, but it is more likely to split the wood.

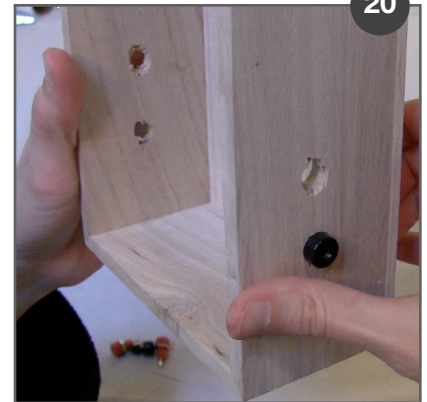




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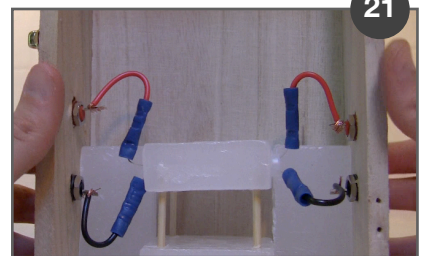
## Adding The Banana Jacks

1. Use your paring knife to gently widen the holes enough to slide in the banana jacks.
2. Remove the nut and washer from the black banana jack and slip it into the bottom hole. Screw on the nut and washer on the end of the banana jack inside the box. (Figure 20)
3. Repeat for the other banana jacks and make sure red is in the top hole on both sides of the box.



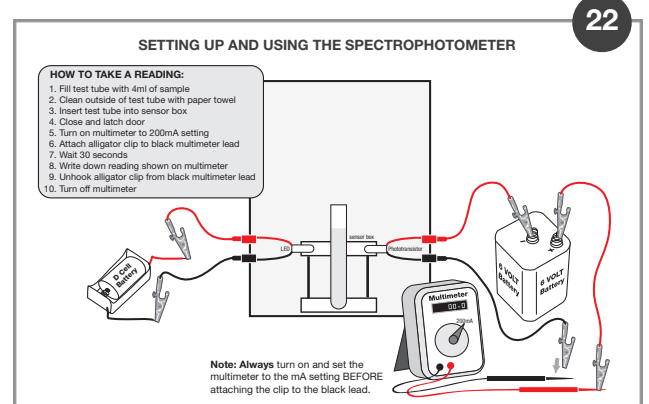
## Adding The IR LED And Phototransistor

1. The IR LED will go on the left and the phototransistor will go on the right.
2. If you are adding the optional heat shrink tubing, you will want to slip these pieces onto the wires before connecting the diodes to the banana jacks. (heat shrink tubing not shown in figure 21)
3. Feed the red wire into the small hole on the red banana jack. Do the same for the other wires as shown in Figure 21.
4. Put the sensor box into the wooden box. Fit the diodes into the tubing in the sensor box holes, then slide in the spacers.
5. Slide in the two 120 mm horizontal bamboo sticks to hold in the spacers on the top and sensor box on the bottom.



## STEP 4: Testing the Spectrophotometer

1. Refer to the Setting Up and Using the Spectrophotometer PDF (available in the downloads section on the Build a Spectrophotometer webpage) to hook up the wires and batteries on the spectrophotometer to test whether your phototransistor is detecting the IR LED. (Figure 22)



Setting Up and Using the Spectrophotometer half-page printout



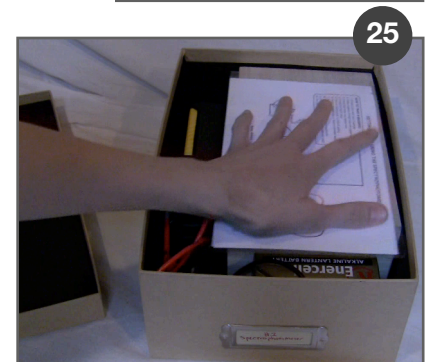
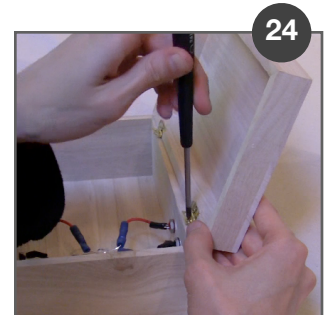
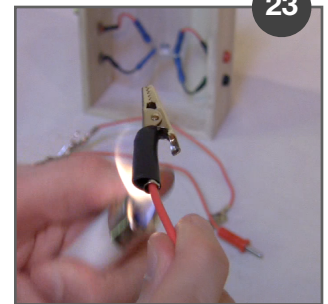
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## Troubleshooting

- Make sure all your alligator clips, banana plugs and banana jacks are all wired tightly.
- Make sure nothing is blocking the holes in the sensor box.
- Install a new fuse in the multimeter.
- Use a digital camera to see if the IR LED is on.
- Use your multimeter to check whether both batteries are working.

## STEP 5: Finishing Touches

1. Slide the tubing over the wires and gently heat the optional heat shrink tubing to secure it in place. (Figure 23)
2. Screw the lid back onto the wooden box. (Figure 24)
3. Assemble the spectrophotometer kit using the photo storage box:
  - Pack the wires and D-cell battery into the wooden box.
  - We recommend keeping the test tube you used to build the spectrophotometer in the kit since the sensor box was custom fitted for it.
  - Slide the 6 volt battery and the multimeter into the photo storage box.
  - Add a laminated copy of Setting Up and Using the Spectrophotometer. (Figure 25)



**Your spectrophotometer kit is now complete!**

## FUNDING

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