An Incomplete Manual for Building a
BASIC OBSERVATION BUOY (BOB) BASICS

INTRODUCTION

A Basic Observation Buoys (BOB) are anchored in shallow, protected areas of the Bay. FLO (Fixed Local Observations) is a device that is fixed to a piling or dock structure. Flo's are problematic because the length of cable between the sensor and the data logger cannot be too long. Data transmission between the sensor and the logger is less efficient with increasing cable length. Presently, the limit is about 4 meters (12 ft).

BOBs and FLOs are designed to collect a variety of weather and water quality data. Presently, the data logger does not allow for automated data uploading. The data collected by these devices must be manually retrieved, evaluated, and then uploaded to a local computer. In the future the data will be telemetered to a remote computer or Internet site for automatic archival. The data quality is dependent on the sensor system used to collect the data and the rigor and protocol used to calibrate the sensors. The data collected from BOB utilizes a Pasco GLX data logger (www.Pasco.com) and is

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compatible with PASCO software DataStudio. It has not been evaluated with regards to meeting National Data Buoy Center (NDBC) standards.

A goal of the BOB design is to be able to collect quality data for two weeks without maintenance, and infrequent need for additional sensor calibration. This goal has not yet been achieved.

A Pasco GLX data logger is presently being used on BOB/FLO. A list of sensors that can be deployed with BOB are being tested (Table 1). Appendix 1 shows a picture, the model number, cost, and a brief description of the parameters measured by the sensor.

BOB Sensors

1.	Water Quality Sensor	Temp, pH,DO*,Conductivity
2.	Weather Sensor*	Everything but wind speed (see 8)
3.	Thermocline Sensor	Water Temp, Water Depth
4.	Flow Rate & Temp	Current Velocity, but not direction

Additional Sensors that add to the data stream

5.	Light Sensor	Cloud Cover Monitoring
6.	Sound Level	Ambient sound levels
7.	3-Axis Accelerometer	Small Wave Measurement
8.	Weather/Wind Speed	Temp, Pressure, Humidity, Dew Point, Wind Chill

Accessory Sensors that do not necessarily add to the data stream.

9.	GPS Position	Records position of sample point

Water Quality Parameters that can be measured at the site, but not by BOB/FLO

10.	Colorimeter	Titrations for Ammonia, Nitrate, Phosphates
11.	Wind Speed & Direction	Not for buoy system and not weather proof
12.	Turbidity Sensor	Not flow through – Measures water clarity

The PASCO Dissolved Oxygen Calibration is not yet accurate when measurements are more than one hour apart.

THE BOB BUOY KIT

Students build the BOB/FLO, install and calibrate the sensors, and get them ready for deployment. Initial deployment of the systems can be supported by a dedicated field crew, i.e. a local river keeper or marina operator. Station crews (the schools/community programs that built them) are trained to calibrate the data systems, troubleshoot problems, and learn the steps necessary to swap out sensor modules and data storage

units. Both BOBs and FLOs are designed as modular kits. Each system can be fitted with the sensors that fit the need and budget for the water body being investigated. BOB consists of 3 main assemblies; the Buoy Body, the Sensor Cage, and the Mast.

The Buoy Base – Or "What makes it float?"

The **buoy body** floats on a 24" square of 4" PVC pipe. These pieces are sealed with calk to prevent leakage. Three additional, sealed, floatation "tubes" are placed between the float "square" to provide more floatation and help keep the buoy floating if sections of the floatation leak.

Note: A 10ft section of 4", Schedule 40, PVC pipe is cut into 8, 15" pieces.

Using a power miter saw, sometimes referred to as compound miter saw, cut the pipe into 8 - 15" pieces. Four pieces will be used to make the outer ring, or square, of the buoy. Three will be used to make the inner float. There will be one extra 15" piece of 4" pipe left over.

4 pieces of 4" Schedule 40 PVC pipe cut into 15" sections.

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4 - 90^{o} 4” Schedule 40 PVC elbows.

Assemble the outer ring by inserting the 15” straight pieces between the elbows.

Create the square outer “ring” of the Buoy. Apply a relatively slow drying glue to the pipe end pieces. It is not recommended to use the Oatey PVC Cement. This glue sets almost immediately and fuses the PVC pieces together. When the external buoy ring is built its important that it lies flat. This can be achieved by putting the four sides and elbows together and (carefully) standing on the opposite corners. This makes certain that the buoy ring structure is flat (i.e. does not rock on a flat surface).

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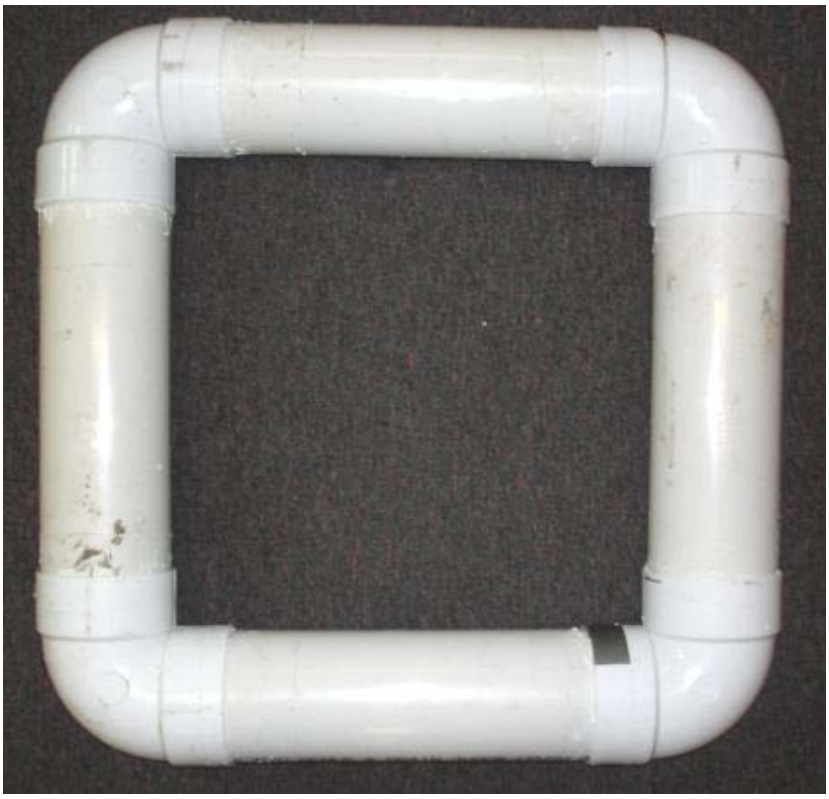

The inner floatation system has a couple of purposes. One is to add to the buoyancy of the buoy allowing more payload. Second, because this series of floatation devices are sealed and independent, it offers added security if one of the other cylinders or the external buoyancy ring leaks.

The auxiliary floats are closed cylinders 15” in length. Take three of your 15” lengths and install the pipe caps on either end. You can use a glue and/or calk to minimize the chance of leaks.

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Prepare Three Auxiliary Floats

Cut two 60” lengths of the Oatey 33927 ¾” x 100’ Plastic Hanger Strap. Wrap the strap around the three auxiliary floats making certain that the loop is inside the end caps. Put a nail through the small holes in the strap to hold it in place and drill out the holes on either side (use a 3/8” drill, or a size that a little larger than the plastic cable tie)

This is a close up of the nail in the strap. The holes in the strap on either side of the nail have been marked for drilling. By enlarging the holes plastic cable ties can be used to create the loop in the straps.

Pull the strap ends taught so they form a loop around the three auxiliary floats. Don’t worry too much about them being tight. We’ll take care of that in the next step. Thread two cable ties through the strap ends to secure the loop that keeps the auxiliary floats together.

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Note the whitish cable tie end between the two blue ones. “Double-up” the cable ties so you have one long one that will reach around the lower and upper loop of the pipe strap. Cinch the cable tie end making the strap that circles the 3 auxiliary floats taught so that the end caps are held together tightly.

In this view you can see the white plastic cable tie “cinching” the bottom and top strap. This will keep the three auxiliary floats together. Do the same for the strap on the lower part of the Auxiliary Float system. You’ll come up with an assembly that looks like the picture below.

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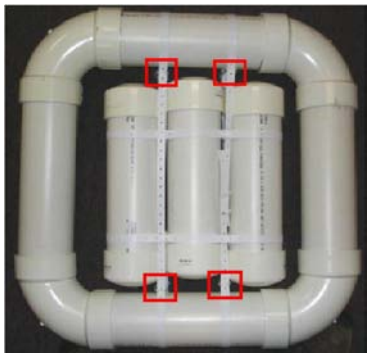
Now we'll attach this to the larger float ring.

Put the auxiliary float system inside the external float "square". Cut 72" lengths of the Oatey 33927 ¾" x 100' Plastic Hanger Strap. Weave this longer strap through the center buoyancy system and around the outer ring. Note that this strap is tucked under the system that you constructed earlier to hold the three auxiliary floats together. Follow the same procedure to secure the ends of this strap. Then, again, double up on the cable ties and "cinch" the strap in the four spots shown on the overall image.



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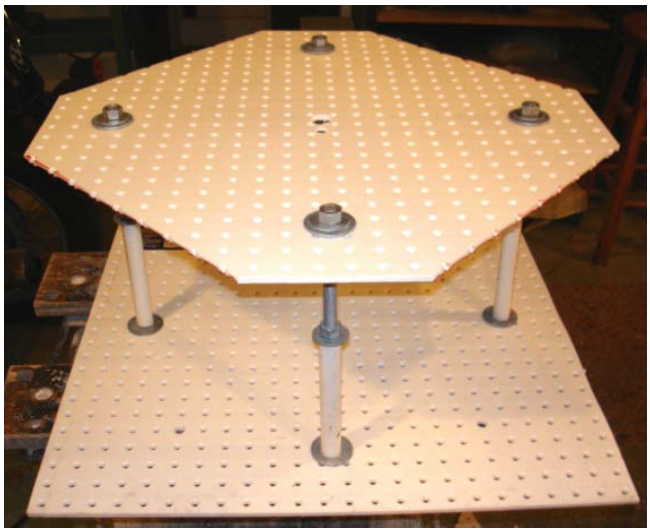
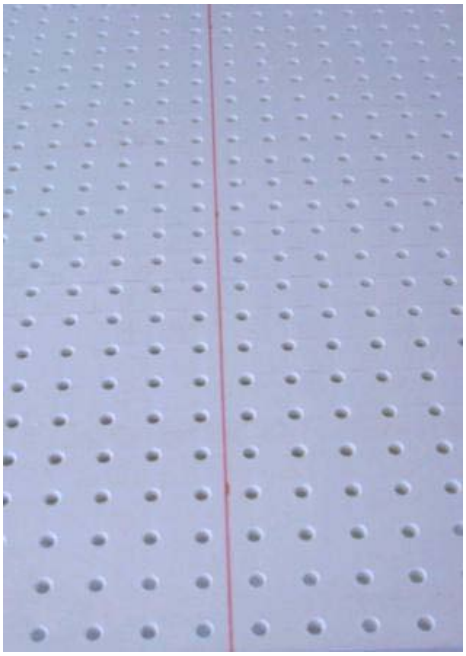
This is the completed Base of the Basic Observation Buoy. The mathematical solutions for determining the buoyancy of this structure can be found in Appendix II.

Building the Buoy Platform

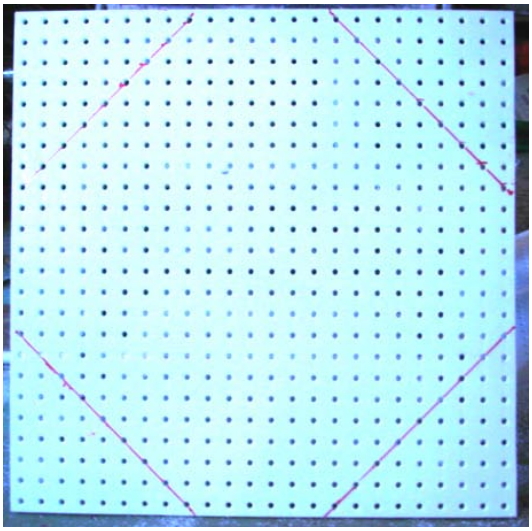


In this stage of BOB construction we'll be creating the platforms that the data logger and sensors are then installed in and on. The Buoy Body consists of two pieces of plastic pegboard. The bottom platform is fastened to the floats with plastic cable ties. The upper platform is attached, and separated from the bottom platform by a set of 4 12" galvanized or stainless steel bolts.

Get the 2’ x 4’ sheet of plastic peg board out. We’ve got to measure and mark it for cutting.



Mark the 2’ x 4’ piece of PegMaster so you cut it in half, creating two pieces that are 2’ x 2’. Cut it with a jig saw.



Make sure you follow safety procedures before cutting. Use eye protection and ear protection. Know where the cord is so that you don’t cut through it. In the end you’ll have two pieces of the plastic peg board. We will cut the corners off of what will become the upper platform.

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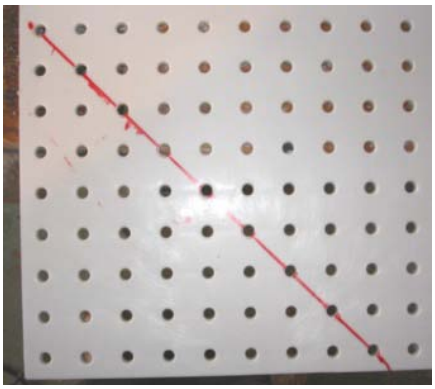
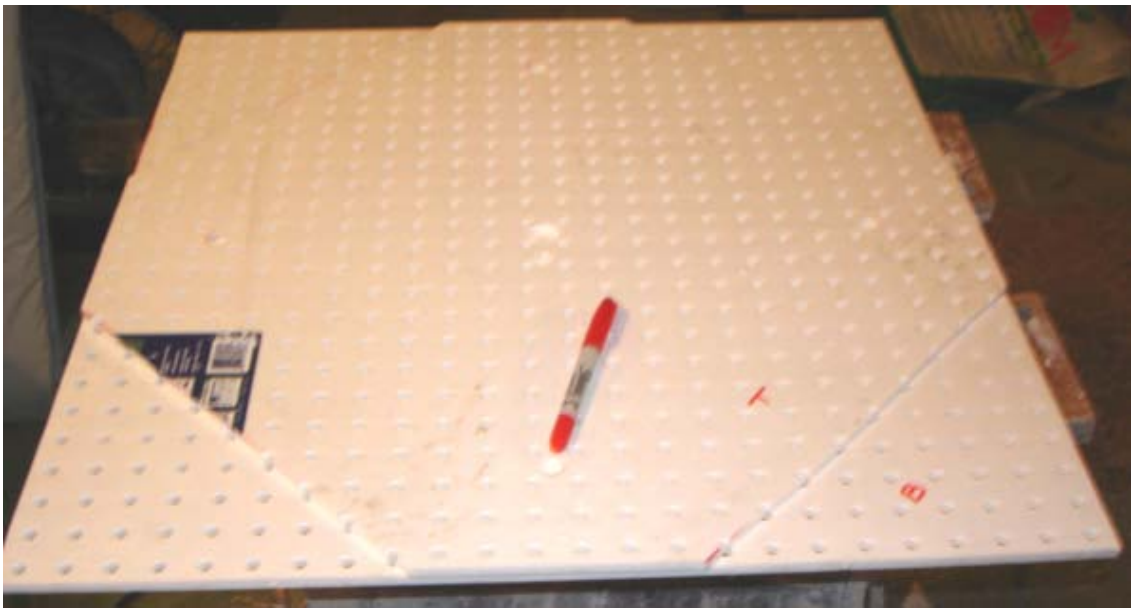
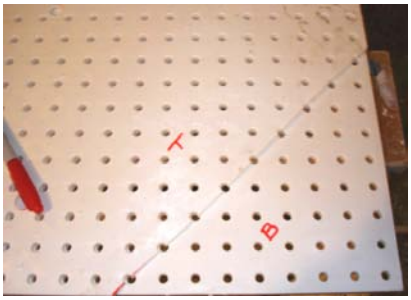
The diagonal cuts of the corners run 9 holes in the x & y direction. Then “connect” the dots. Do this for all four corners.



You’ll end up with a bottom and top platform for the buoy. When the top piece is placed over the bottom piece you’ll have an overlap that reveals the corners of the lower platform (that looks like what’s in the image below). in the next image you see this individual corner in more detail.





In this frame, the “T” represents the top platform, and the “B” the bottom platform.

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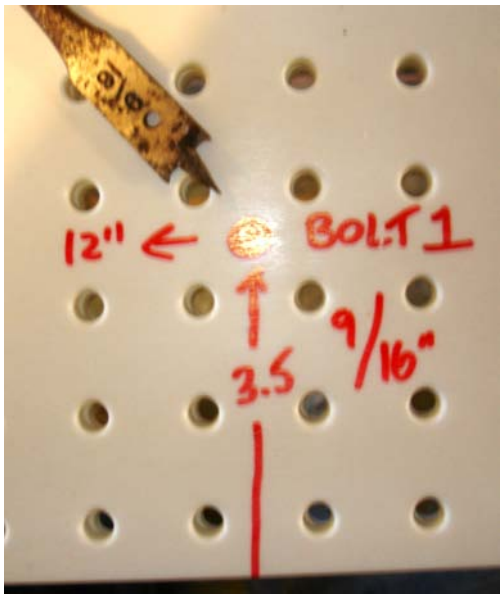
So, now you have a lower and an upper buoy platform. Now we'll connect them with a series of bolts.

For the lower part of platform, you will need to prepare four (4) sets of these; One 12" long bolt, 3 flat washers, 1 6" piece of ½" PVC Schedule 40 pipe, and a 5/8" nut.

Now, get the two platform pieces and get them ready to drill the holes that the bolts will be inserted through.



It's a little hard to tell from the glare, but the four platform bolt holes are positioned 12" from either edge and 3.5" from the platform edge. Or, you can measure 12" from the edge and put the hole between the third and forth pegboard holes, as was done here. I use a 9/16" wood bit to drill cleanly through the plastic.

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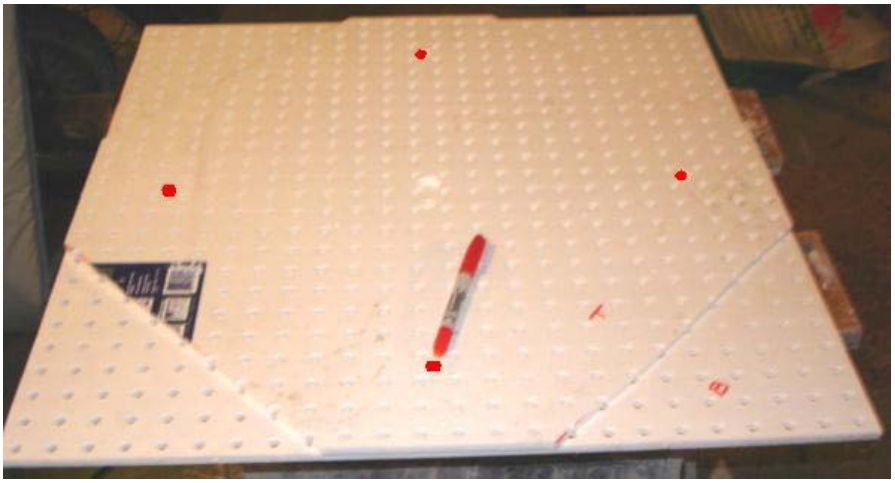
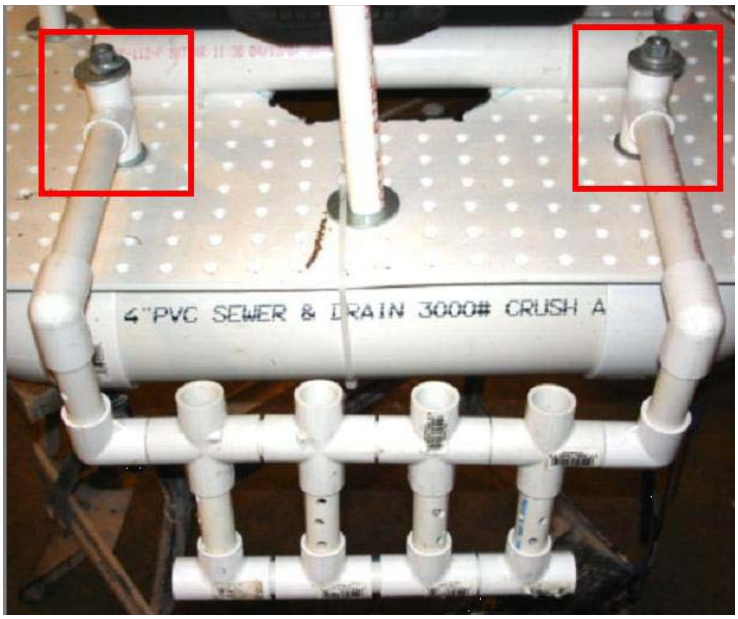
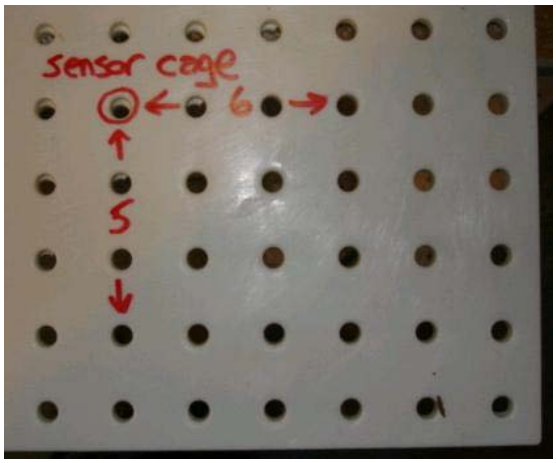


Do this on all four sides and you're ready to install the platform bolts. When I drill these holes, I stack the upper and lower platforms in the orientation that they will be in when the structure is built. This insures that the four bolt holes will be perfectly aligned and the installed bolts will be vertical (not slanted).



While we're at it, we might as well drill the other holes for the sensor cage assembly and the center mast. For the sensor cage assembly, you'll need to drill two holes to accommodate two bolts. The attachment will look like it does in the following picture.



Mark the two spots on the lower square platform piece where the sensor assembly will attach to it. These can be located by counting 6 holes from one edge and 5 from the other, as seen in this picture.

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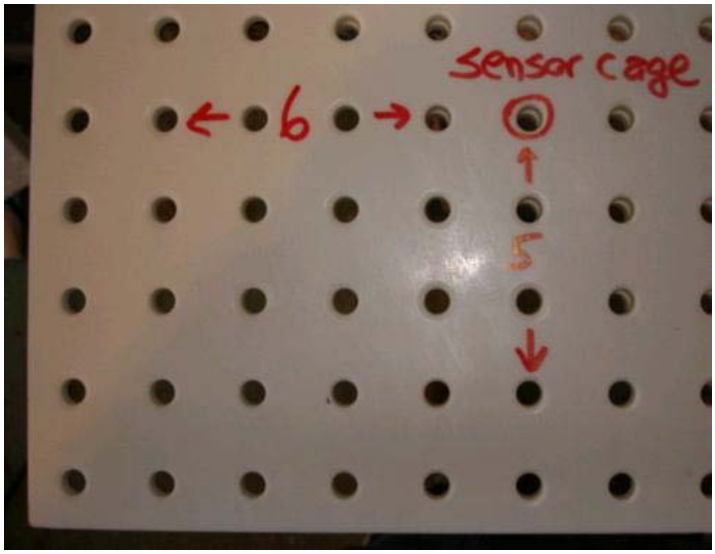

Do the same for the opposite side of the pegboard piece.

Enlarge the hole at the intersection with a 7/16” wood drill bit. When you install the sensor assembly, the bolt will slide right through. Ok.. we’re done here for now..

Once the holes are drilled it’s time to install the platform bolts.

Put a 5/8” washer on a 12” bolt and slide it up under the lower platform.

Where the bolt goes through the lower platform place a 5/8” washer so the platform plastic is sandwiched between the lower bolt head and washer and the washer you just installed. Now, put the 6” PVC sleeve over the washer and the bolt threads. Now, put another flatwasher over the PVC sleeve. Spin a nut down until it is snug against the sleeve and the bold is able to standup. You should have about 6” of additional thread left to work with. Repeat this for each of the four holes.

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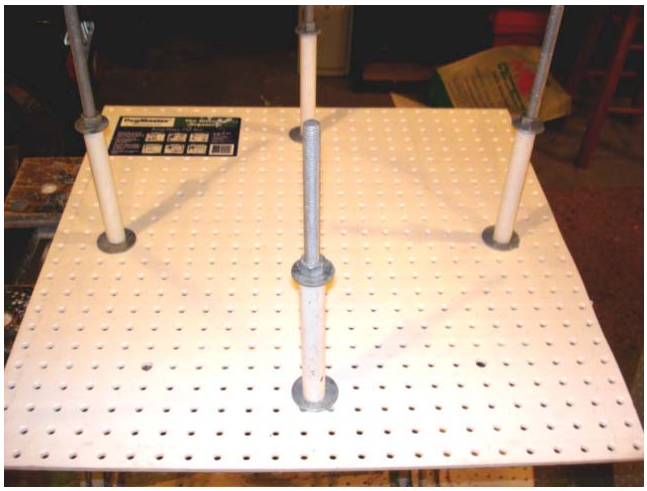

You'll end up with a platform with four bolts to which you'll attach the upper platform.

Now thread a nut down onto the threads leaving about an inch of the bolt end exposed. Slide a 5/8" washer onto the nut. These become the surface on which the upper platform will rest. Repeat this procedure for all four of the platform bolts.

Next, take the upper buoy platform with the drilled holes and slide it over the four bolts The upper platform should rest on the washers above the nut you "staged" on the bolt below. Don't worry about it being level right now. We'll get to that in a minute. Now put another 5/8" washer so it rests on the pegboard, put a 5/8" lock washer over that, and add the final 5/8" inch nut. Finger tighten this for now.

Initially, to make the upper platform level, adjust the nut system just below the platform, and simultaneously tighten the upper nut so that the bolt end is flush with the nut edge. This will give you a working platform that we can attach to the buoy floatation system.

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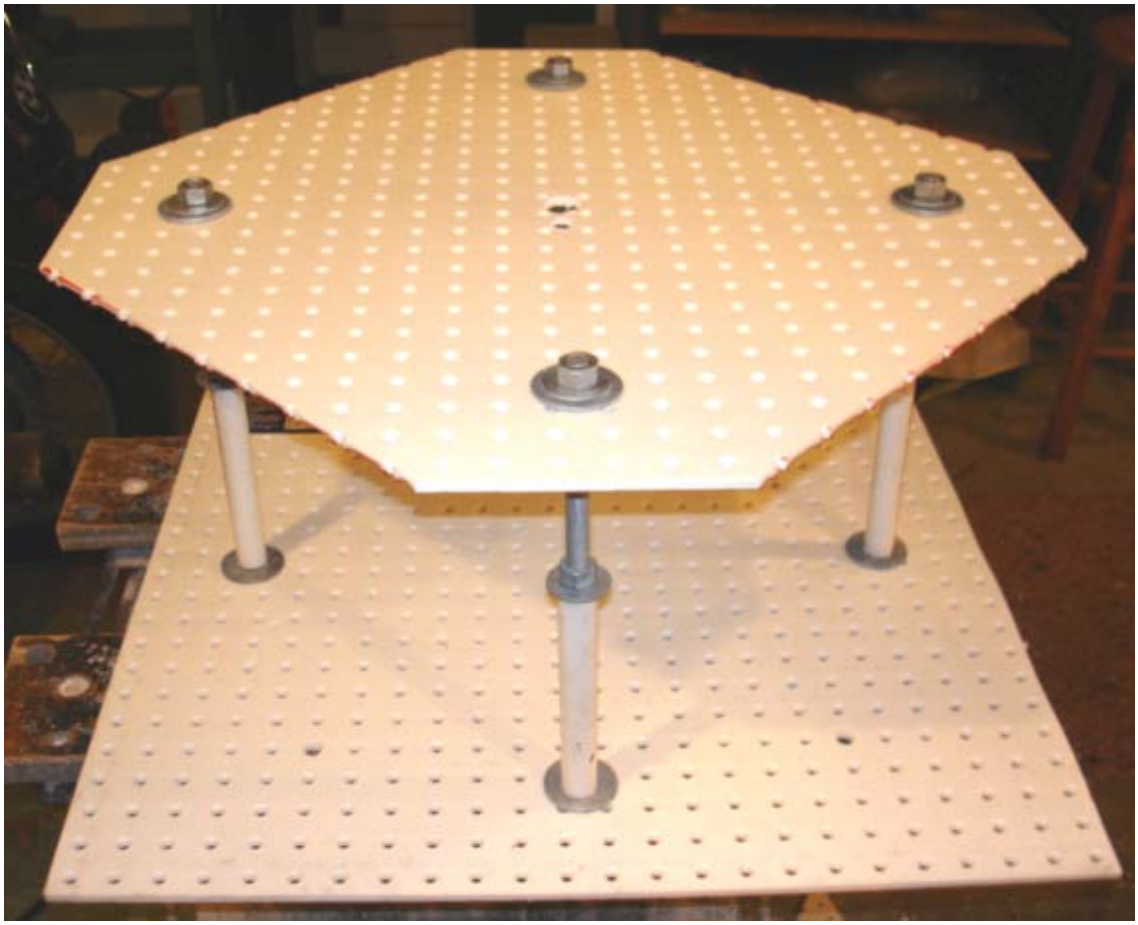
This is the two-stage, buoy platform that we'll affix to the buoy floatation frame.



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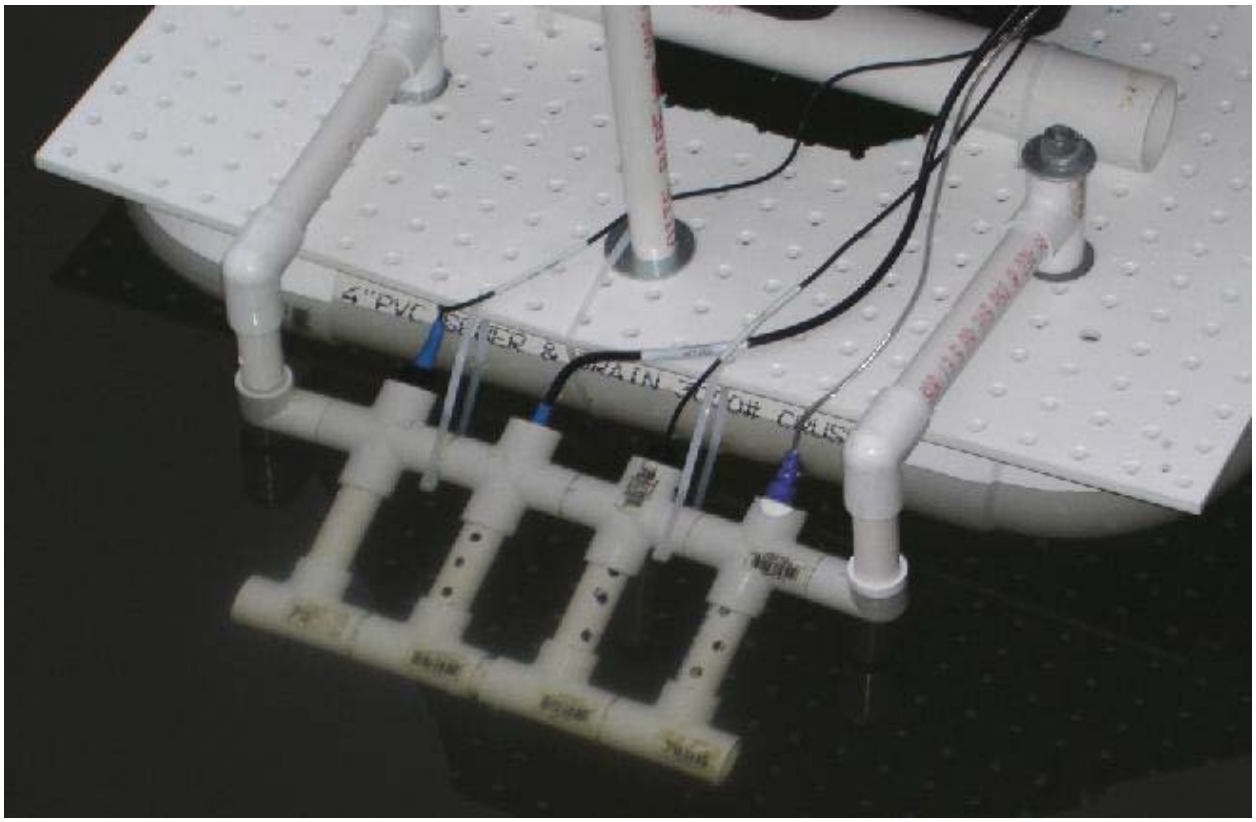
THE SENSOR CAGE

The **sensor cage** is designed to hold 4 water quality sensors provided by Pasco (www.pasco.com). Note in the picture below that the sensor cage can be rotated to an angle so that its low point is above the bottom of the Buoy float. This keeps the sensors from resting on the bottom when low tide empties a site of water.



The Sensor Cage is built using PVC fittings obtained from www.pvcfittings.com. The tilt feature of the cage allows the user to rotate the sensors so that the bottom of the cage will not be in direct contact with bay bottom in the event of a low water, low tide event. This means that you should avoid gluing the joints where the rotation occurs. These joints are highlighted in red in the parts figure.

Putting the cage together is not much different than Legos, with a plan. In the following series of images we'll piece the sensor cage together. Before you glue the pieces together, I recommend building the whole cage and make sure of the fit. This will insure that you end up with a straight sensor cage. Get the feel of what you're going to end up with before you start gluing.

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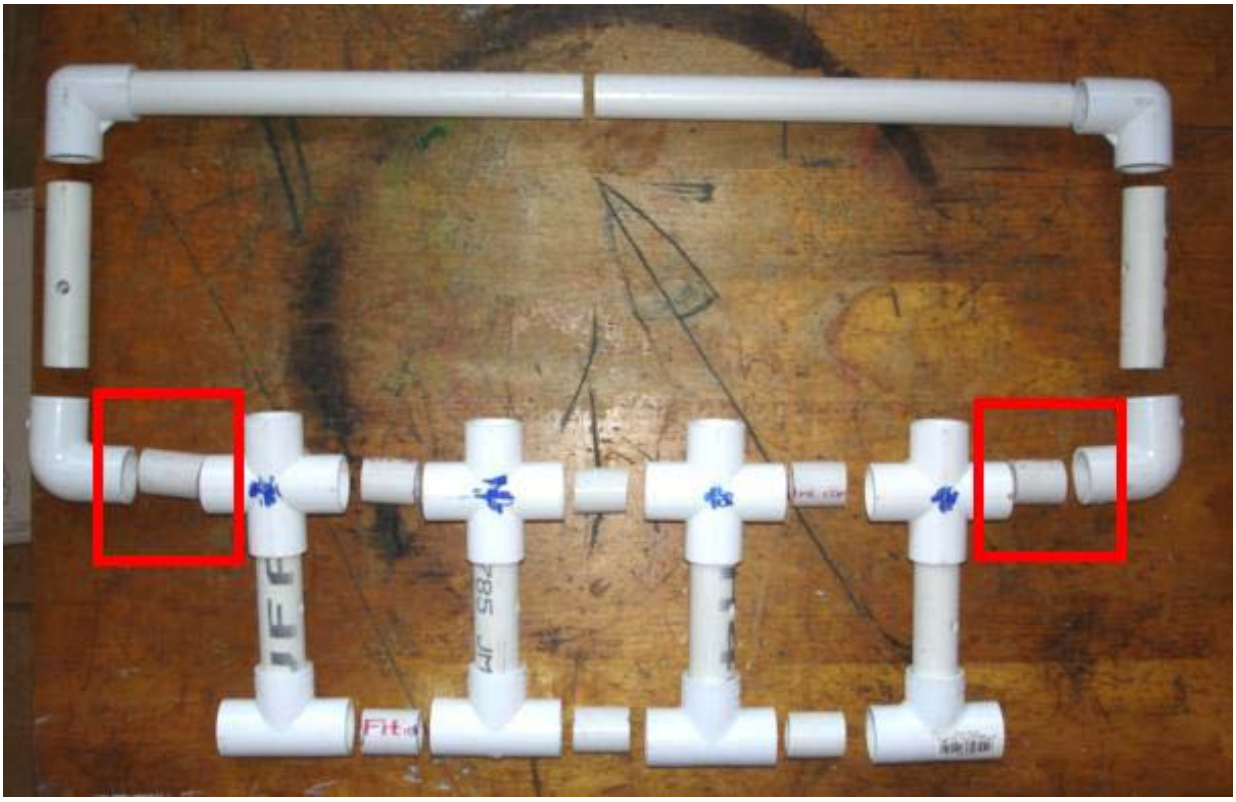
The parts are shown in the figure below and are listed as follows:

2 – 9” lengths of ½” PVC
4 – 90 degree elbows
4 – T fittings
4 – 4-way fittings (be sure that the internal piping is clear of burrs)
8 – 1” pieces of PVC
6 – 3” pieces of PVC - note that there is a hole drilled through these to allow water to circulate for better water quality measurements.



The small 1” pieces are what hold the bigger pieces together.

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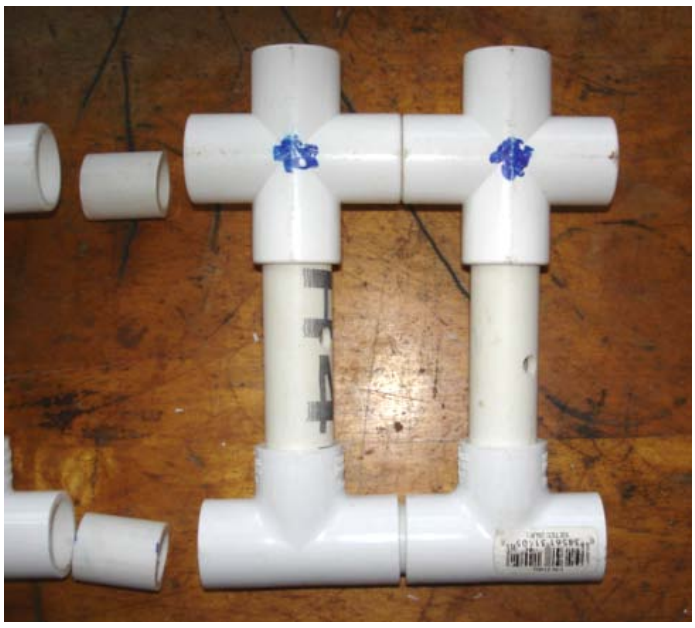
When you're ready, glue the ends and jam them into the adjoining pieces. Use glue that doesn't dry instantly in case you make a mistake.

Start by grabbing a 4-way connector, a 3" section of ½" pvc, and a T. Put together the basic sensor holder. Then put 1" joint pieces in the side of the 4-way and T-joint so we can put four of these assemblies together.



With the 1" joint pieces in place push the sensor holder assembly together.

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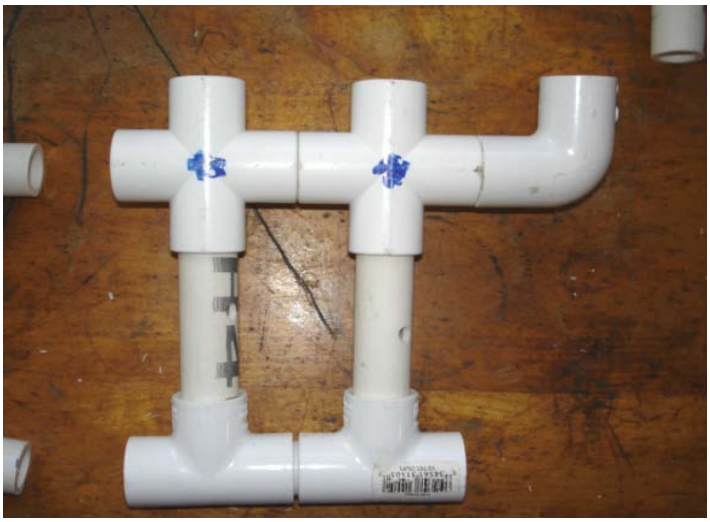
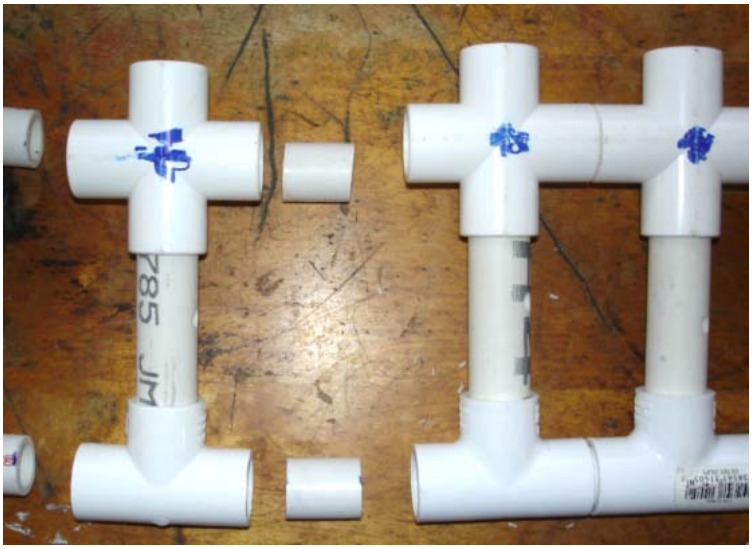
With the 1” joint piece in place add the 90 degree elbow to the sensor cage end.



The sensor cage should lie flat with this piece connected, i.e. It should point vertically (not angled).



Prepare to add the third and fourth sensor holder by adding the 1” joint pieces to the crosses and the T’s.

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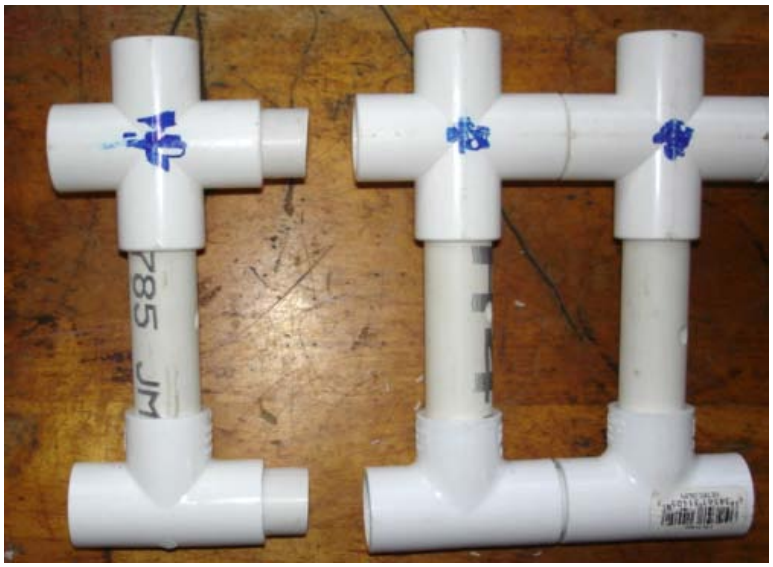
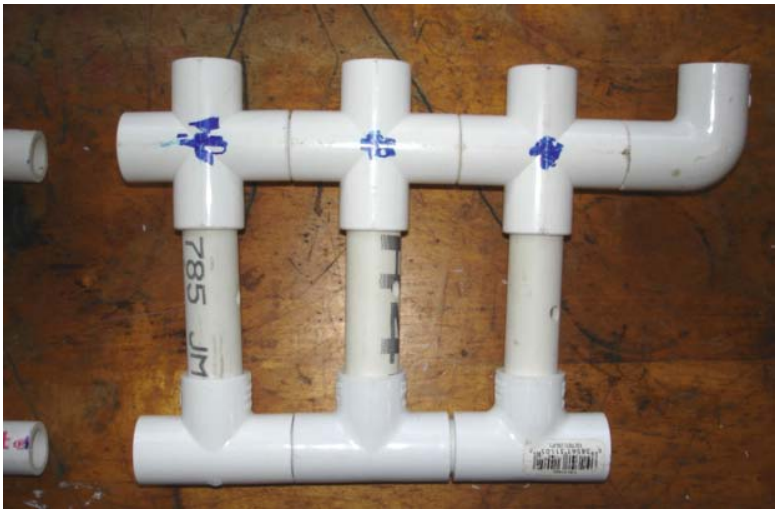
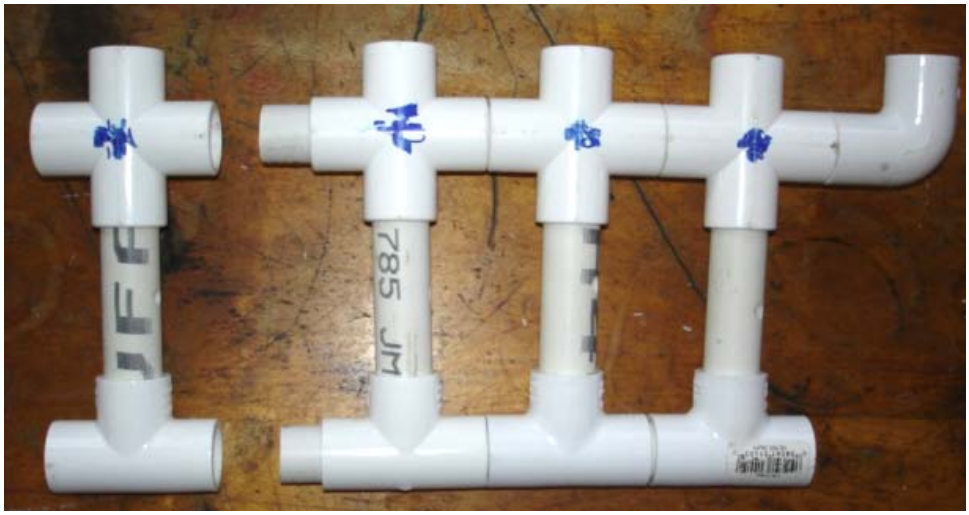


The third section is ready to be added.



The third section is added.



Prepare to add the fourth sensor holder.

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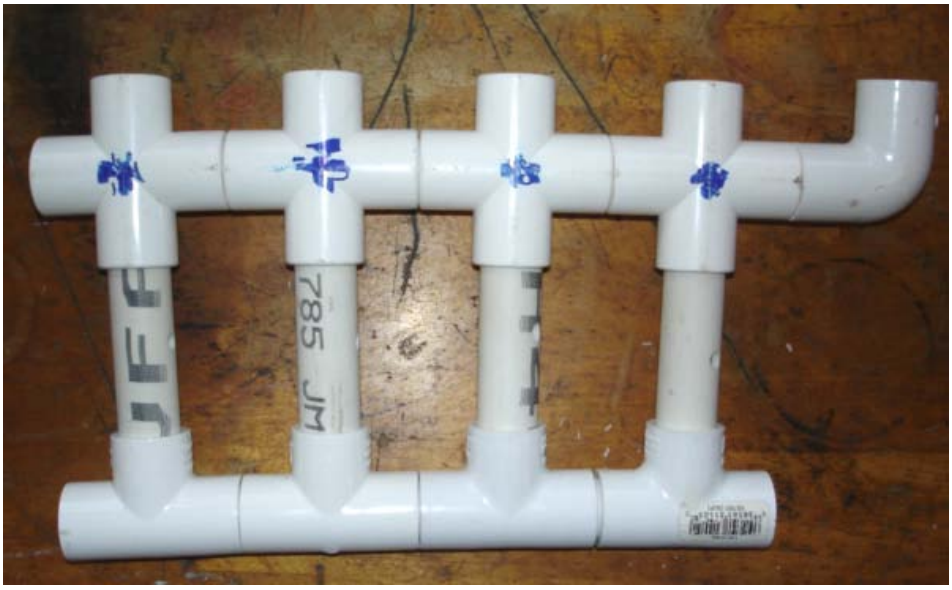
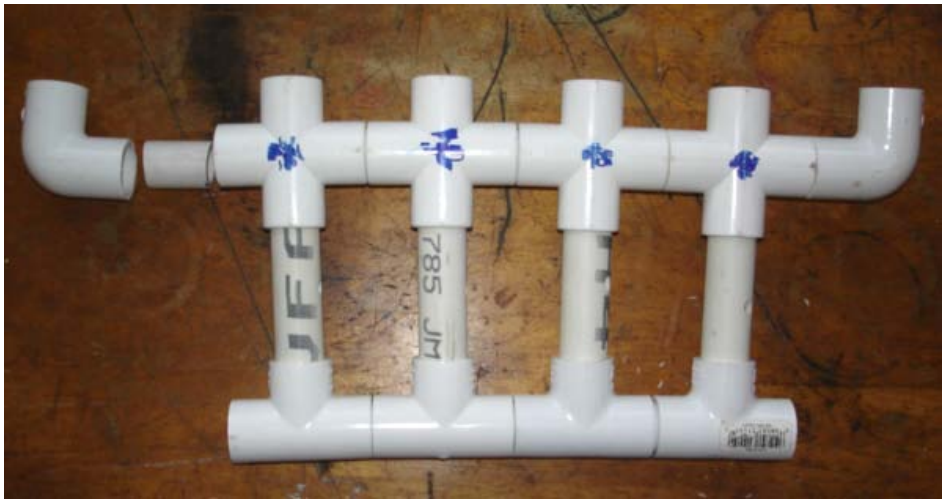
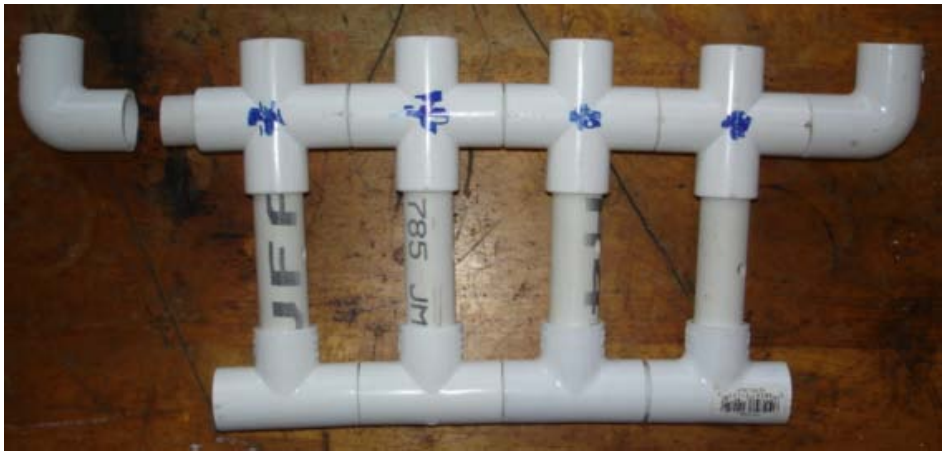


The fourth sensor holder is added.



With the sensor cage complete we'll now add the elbow on the other side.



The elbow is ready to be attached to the sensor cage. Don't glue the elbows on if you want to be able to rotate the sensor cage.

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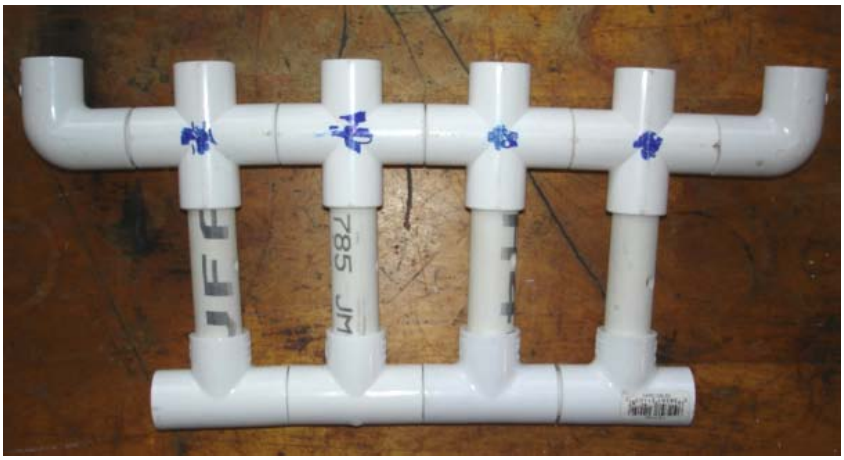
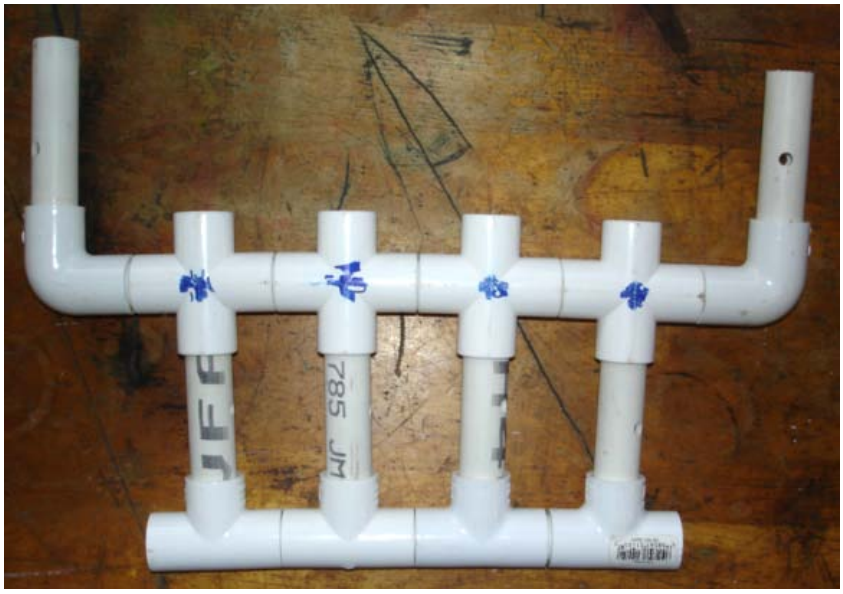
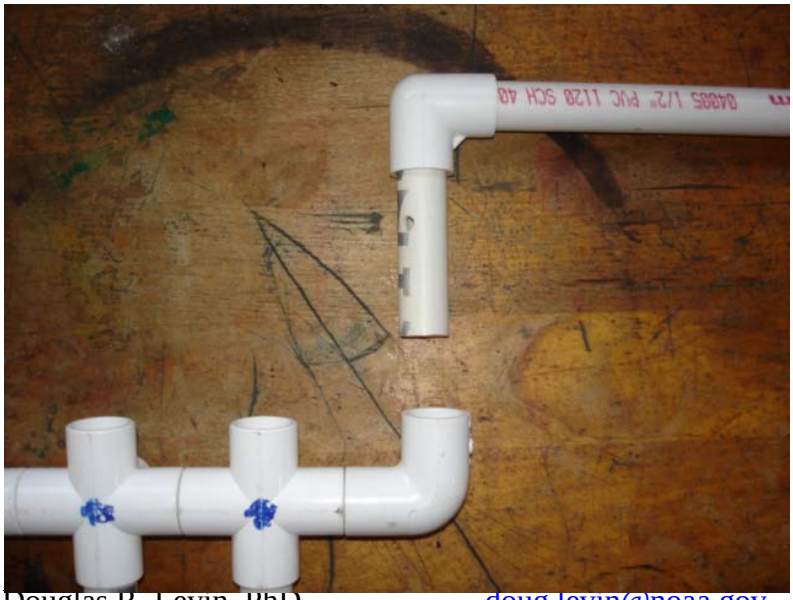


The elbow attached to the completed sensor cage.



The complete 4-sensor sensor cage. 3” pvc extenders have been inserted into the elbows. The completed structure is almost ready to be hung from the buoy platform.



Attach the upper elbow to the 3” ½” PVC piece. Then attach the 9” ½” PVC piece to the other opening of the elbow.

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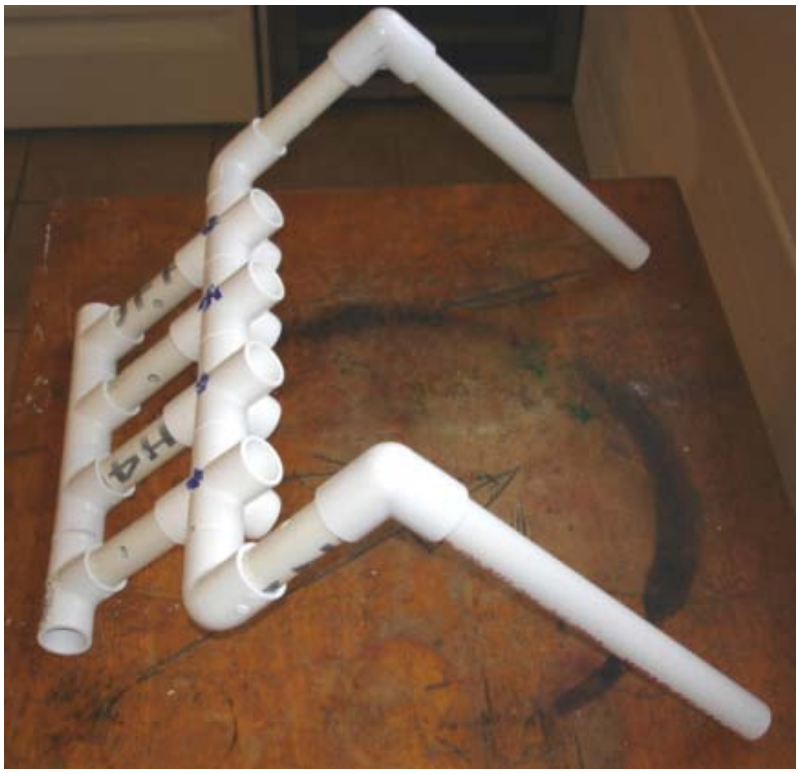
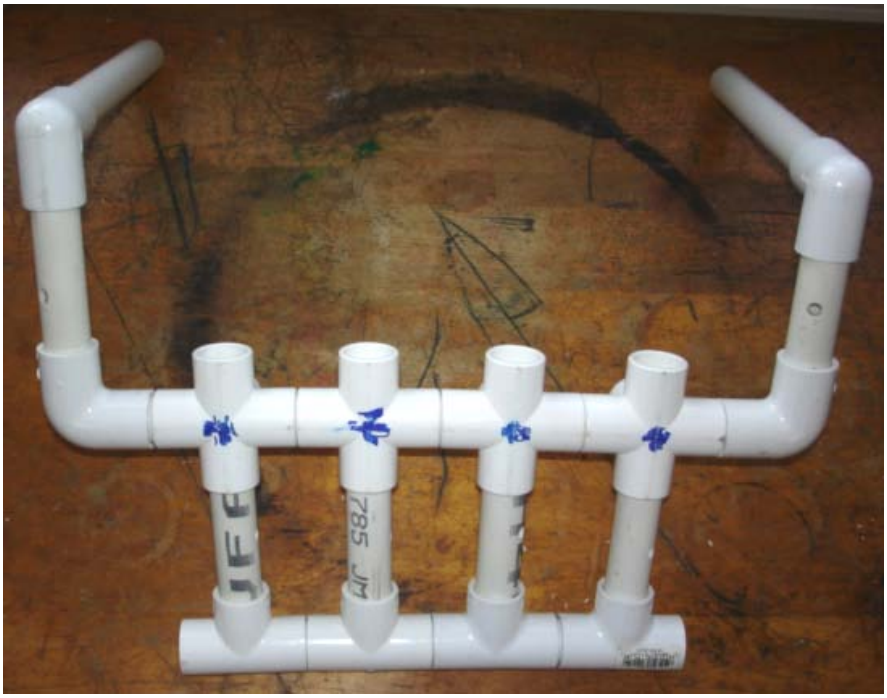


This image is what the finished sensor cage looks like from the side.



This is a front view of the completed sensor cage. It's ready to be attached to the buoy.

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Attaching the Sensor Cage to the Buoy Platform

Now we'll put together the system used to affix the sensor cage to the lower buoy platform. It consists of the following pieces:

2 – 3" 3/8" Galvanized or Stainless Steel Bolts
6 – 3/8" Flat washes
2 – 3/8" Lock washers
2 – 3/8" Nuts
2 – ½" PVC T's

I

t attaches to the lower platform of the buoy in a manner similar to the way we put the bigger platform bolts in. In an earlier stage you drilled the holes that these bolts would attach to.

Take the assembly apart. Slide a 3/8" flat washer onto the bolt and then through the pegboard of the lower platform.

On the top side of the bolt, sandwich the plastic platform with another 3/8" flat washer and slide the "T" fitting over the bolt. The threads should (better) come out the top of the fitting. Now, put another 3/8" flat washer over the top of the T, as shown, a lock washer, as shown, and top it off with the 3/8" nut, as shown. Tighten these nuts down.

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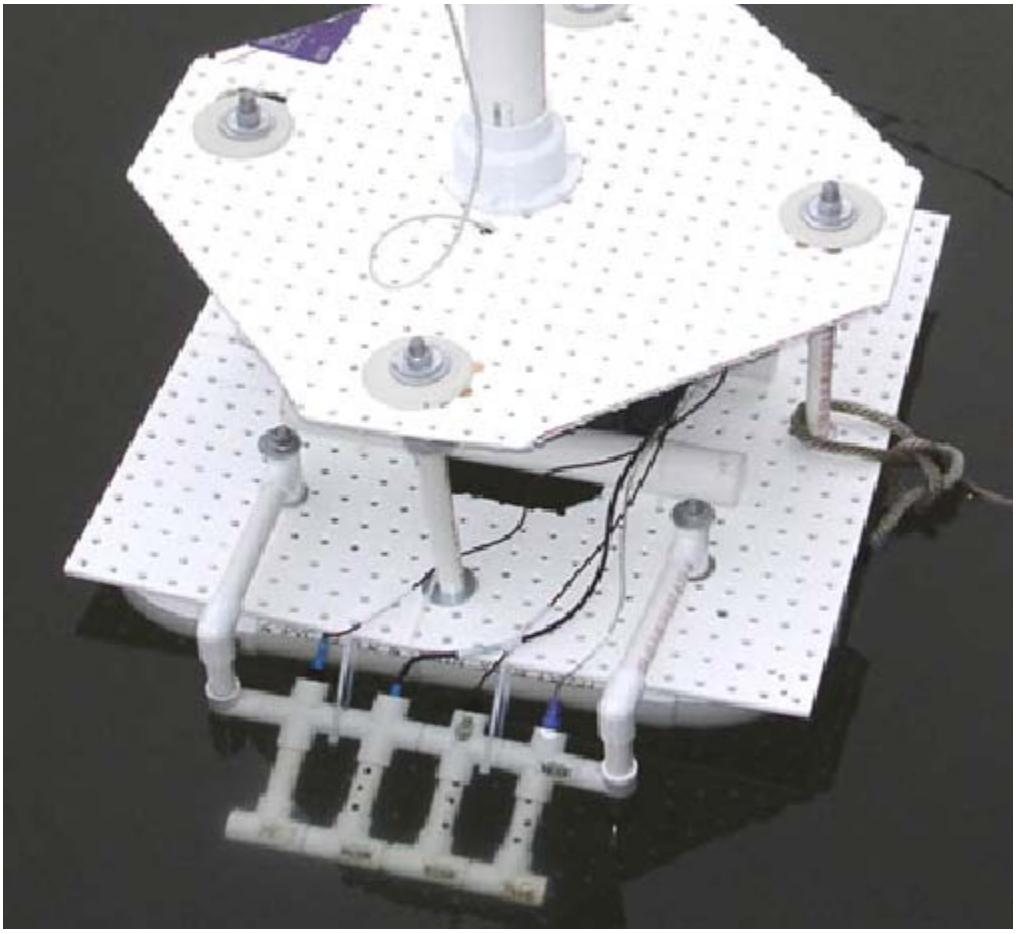
The Sensor Cage Structure can now be attached to the Buoy. Attach it by pushing the extensions of the sensor cage into the T-fitting of the bolt you've attached to the buoy platform.



The Data Logger Nest

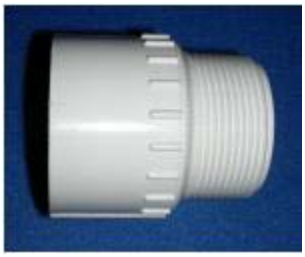
The Data Logger is housed inside a small plastic case.

The Mast Options.

To say that the **mast** design is imperfect is an understatement. There is some debate that simply adding a mast that collects air temperature 1m off of the water surface is enough. If this is elected for BOB, then the following instructions will suffice. In the event your group has chosen to add a more substantial meteorological monitoring component, jump to the second mast design.

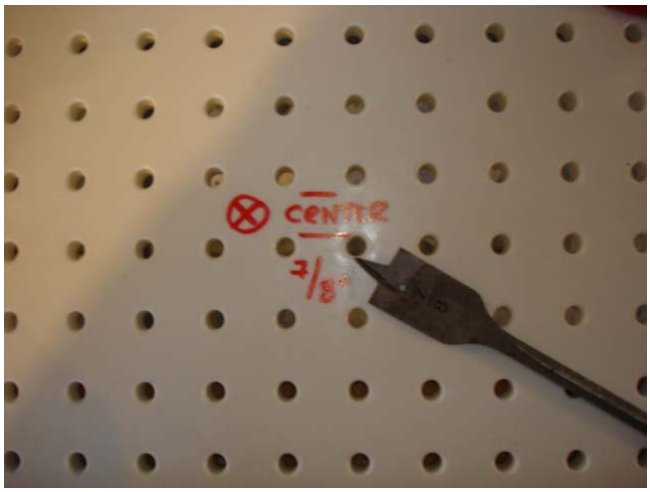
For simply adding a mast to attach an air temperature sensor above the water surface, you'll need to drill a hole in the center of the upper platform and gather the following parts.

1- 1m length of ½" PVC

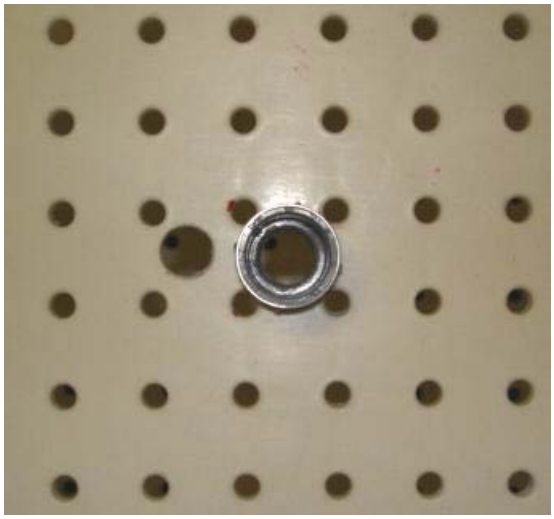


1- Lasco Pt No 436-005 – check to make sure that a ½" PVC goes into the non threaded end.

1-1/2" Rigid conduit Locknut



Drill a 7/8" hole, using a wood bit, in the center of the upper platform. Drill another ½" hole about 2" to the side of



the center hole.

Thread the lasco 1/2" male adapter through the mast, with the threads to the bottom. Fasten it in place by, again, sandwiching the plastic pegboard with the conduit nut on the top side of the buoy platform.

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In the case where a simple temperature sensor is going to be deployed on the mast, it is possible that the sensor cabling can be “fished” or threaded through the mast PVC. The second hole that was drilled can also be used to thread sensor cables from the data logger below.

This is what the Basic Observation Buoy with the simple temperature recording mast option.

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Installing a more substantial mast for weather data recording

A crudely engineered mast has been designed that accommodates a more sophisticated weather measuring system. What it lacks most is an ability to accurately measure wind speed and direction. There is no easy way to measure wind direction on a rotating buoy, so we're limited to measuring wind speed.

The pieces required to build this are:

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APPENDIX 1
Datalogger & Sensors for BOB/FLO

Data Logger

PS-2002 Pasco GLX $329

- Large backlit LCD -- visible in both sunlight and low light
- Stand-Alone or Computer Interface
- 4 universal sensor ports
- 4 built-in sensors (2 temperature, sound, voltage)
- Collect Data in the Classroom or the Field
- Graphs, tables, digits, and meter displays
- Prints graphs and data directly to printers

Sensors

The following sensors offered with the GLX can be installed onto a BOB/FLO.

Water Quality PS-2169 $369

- Temperature (water and/or air)
- pH $ 79**
- Dissolved Oxygen $225**
- Conductivity (note that conductivity & temperature = salinity) $108**

** If purchased separately

Thermocline Sensor PS-2151 $269

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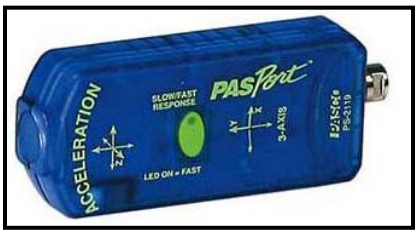
- Measures water depth changes
- Measures water temperature (at depth)

3-Axis Acceleration Sensor PS-2119 $185



- For measuring small waves
- (This sensor has not been tested on BOB)

Weather/Anemometer PS-2174 $179

- Temperature
- Barometric Pressure
- Relative and Absolute Humidity
- Dew Point
- Wind Speed* (not direction)
- Wind Chill
- Installation method still in design phase

Water Quality Colorimeter PS-2179 $129

- Not an in-situ measurement
- Used w/titration kits
- Analyze for ammonia, nitrate, phosphates

Flow Rate and Water Temperature PS-2130 $129

- An impeller on a stick

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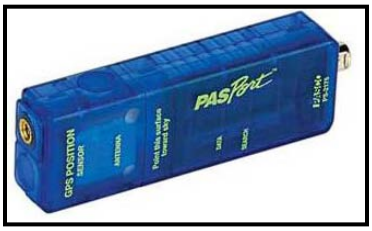
- Current Velocity Measurements (w/o direction)
- Requires a vane to point in direction of current

GPS Position PS-2175 $159



- Automatically records position of sample
- Not necessary for BOB/FLO in fixed location.
- Position can be measured once by a "loaner" GPS.

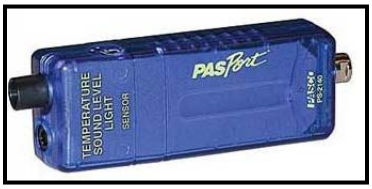
High Sensitivity Light Sensor PS-2176 $133

- Study cloud cover

Light Sensor PS-2106A $59

- Study cloud cover w/ less accuracy than 2176

Temperature/Sound Level/Light PS-2140 $98



- Combination, air temp, cloud cover, ambient sound

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Turbidity Sensor PS-2122 $125

- Not a flow through sensor
- Measure water clarity

Weather Sensor PS-2154A $109

- Barometric Pressure
- Absolute & Relative Humidity
- Dew Point
- Temperature
- Relative Altitude
- No wind so orientation is not an issue

Wind Velocity Accessory ME-6812 $99

- Wind Velocity & Direction from a dock
- Not for a buoy system
- Not weather proof

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Appendix II

Calculations of Buoy Buoyancy and Payload Size Considerations

The objective is to determine how much water (in weight) the buoy displaces. So, first, calculate its volume. Then, using the specific weight of water (62 lb. per cubic foot) determine how much weight of water would be displaced if the structure was completely submerged. Then, subtract from that the actual air weight of the object. This gives give you its reserve buoyancy, or an amount of payload you can add to it before it sinks.

So, why don't we fill the floats with foam? Even if you were to fill the tubes with foam, it doesn't increase the buoyancy. In fact, it decreases it slightly by the weight of the foam. However, the upside is that the foam displaces airspace that would fill up with water in the event of a leak, which would quickly subtract from any reserve buoyancy available (assuming the foam wasn't absorbent).

Mathematically, the equation for buoyancy is calculated by determining the volume of the object and subtracting the air weight of the object (put it on a scale). The resultant number is the reserve buoyancy.

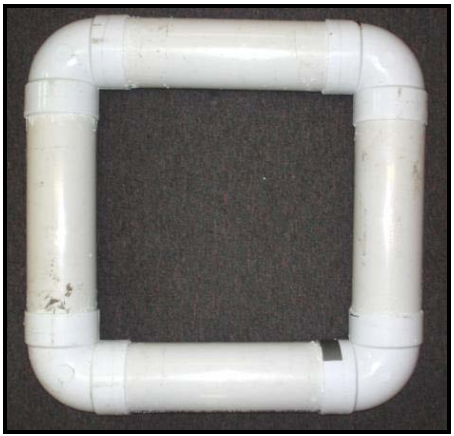
The equation is

(Vol of air inside the object (ft^3) x 62 lb/ft^3 – (air weight of object in lbs) = Reserve Buoyancy

The volume of a cylinder equals the (area of the base)*height = $\P r^2 h$
where = ¶ = Pi, or 3.14
r = the radius of the cylinder's inner wall.
h= the height of the cylinder

An online cylinder volume calculator can be found by "googling" cylinder volume calculator or going directly to
http://referencedesigner.com/calc/cal_07.php

Here are the calculations for the buoy base:



Each side of the external ring is 20". The inside wall of the Schedule 40 is 4".

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The volume of each side = 0.134 ft ^{3}

The volume of the whole external ring = 0.536 ft^{3}

The volume of air inside the external ring = 0.536 ft^{3} x 62 lb/ft ^{3} = 33.23 lbs.

The buoyancy of the external ring is 33.23 lbs.

The air weight of the external ring is 15 lbs.

The reserve buoyancy for the external ring is 33.23 – 15 = 18.23 lbs

Each auxiliary float is 15” long. The inside wall of the Schedule 40 is 4”.

The volume of each 15” float = 0.101 ft^{3}

The buoyancy of each auxiliary float = 0.101 ft^{3} x 62 lb/ft^{3} = 6.26 lbs.

The added buoyancy of 3 auxiliary floats =

3 x 6.26 = 18.78 lbs

he air weight of the auxiliary float structure is 8.1 lbs.

The reserve buoyancy for the auxiliary float structure is:

18.78 – 8.1 = 10.68

The summed buoyancy of the external ring and three auxiliary floats is:

10.68 + 18.23 = 28.9 lbs.

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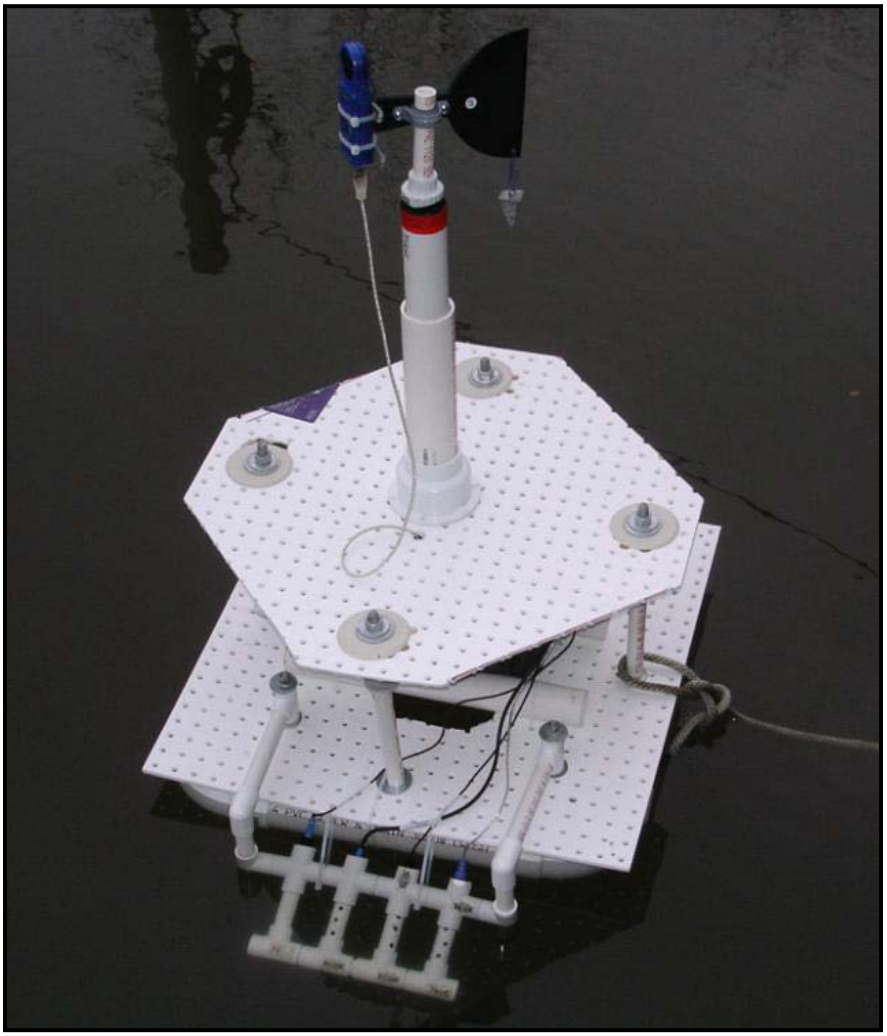

The weight of the buoy platform, data logger, protective case, and sensors is: 12 lbs.

The reserve buoyancy on BOB after subtracting the platform is:

28.9 – 12 = 16.9 lbs.

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Appendix III

Qty	Description
Buoy Body Parts	
4	12" 1/2" Galvanized Bolts
20	5/8" Flat Washers Galvanized
8	1/2" Flat Washers
4	5/8" Locknut Galvanized
12	3/4" Nut Galvanized
1	Plastic Peg (Pegmaster) Board 2' x 4'
4	4" 90' Elbows
7	15" Lengths 4" PVC Sch 40 PVC Pipe
6	4" End Caps for Auxiliary Floats
2	15" Lengths 1 1/2" PVC Lengths
1 roll	Oatey Pipe Strap
Sensor Cage	
2	3" 3/8" Galvanized Bolts
6	3/8" flat washers
2	3/8" lock washers
2	3/8" Nut Galvanized
6	1/2" PVC T's
4	1/2" PVC Elbows (90')
4	1/2" PVC Cross
2	1/2" PVC 9" lengths
6	1/2" PVC 3" lengths
8	1/2" PVC 1" lengths
Mast Assembly	**With Meteorological Sensor (see manual for w/o Met Sensor)**
1	Lasco D2466 2" x1/2" Sch 40
1	2" PVC Sch 40 10" Length
1	15" Length 1 1/2" PVC Lengths
1	4" length 1/2" PVC
1	11" length 1/2" PVC
1	1/2" coupling assembly
1	1/2" Conduit Clamp
1	4" length Temflex Rubber Tape

2	1" stainless or galvanized machine screws, washers, nuts
1	Stainless U-Bolt no. 132
1	6" Plastic Putty Knife