Fluid Pressure and Flow
and
Under Pressure

Design Document

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See to do document here:
https://docs.google.com/document/d/13Jhs-xwKCPvavt13zgPLI1_OdRvQPG0bHZ-1mfxhhUk/edit?hl=en_US

##
Tab 1: Pressure
###################

LEARNING GOALS
pressure at depth h is given by: p = p0 + rho g h
water pressure increases linearly with depth
air pressure decreases with altitude
water pressure at the top of water equals air pressure at the same
pressure doesn't change as you move horizontally through a fluid
water pressure increases linearly with fluid density
water pressure increases linearly with gravity

DISCUSSION ITEMS:
Handle sea-level pressure and pressure vs height for other planets or interpolates?
This would be confusing because it would make the water pressure change primarily based on p0 instead of based on rho g h.

POTENTIAL IMPROVEMENTS
multiple pressure gauges, drag from a toolbox? Add pressure sensor button?
differential pressure gauge
JO: this could be confusing to the user
SR: what about pressure readouts at the top and bottom of the ruler?

pressure sensor on p445 of halliday and resnick or some other way to indicate the meaning (or mechanism) of pressure
Ruler shouldn't be able to overlap ground.

##
Tab 2: Flow
###################
LEARNING GOALS
p + 0.5 rho v^2 + rho g y = constant (16-17 = bernoulli's equation)
Objects move faster when passageway is constricted
Pressure is lower when passageway is constricted
Fluid is conserved, just redistributed based on container dimensions (continuity equation)
Learning goals from Tab 1 still apply under fluid flow

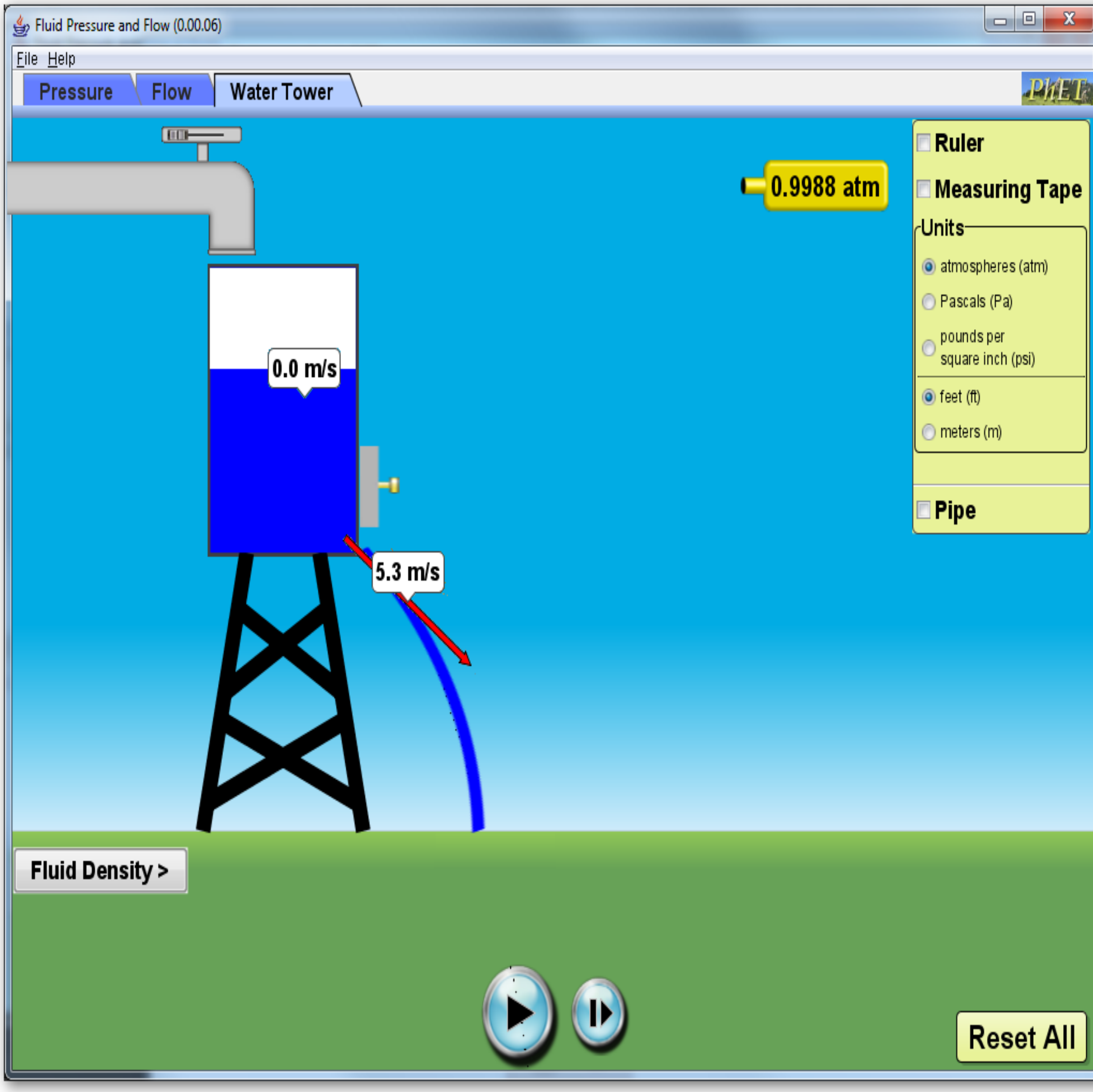
POTENTIAL IMPROVEMENTS:
Visualize pressure as a function along the pipe by gradient highlighting?
Visualize velocity field with vector field?
Visualize velocity field with gradient highlighting?
Option to show streamlines?
Have to make sure comparing pressures at same y-value to see correlation with velocity
Improve location of fluid density control? Move to bottom right?

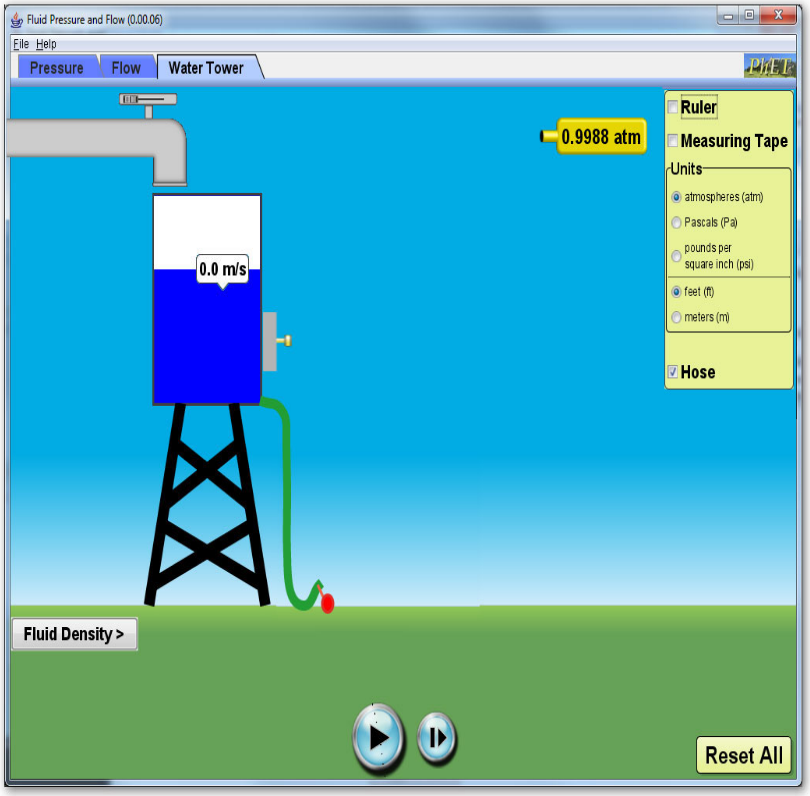
http://physics.bu.edu/~duffy/py105/Bernoulli.html

##
Tab 3: Water Tower
###################
LEARNING GOALS:
1. torricelli's theorem v = sqrt(2gh), see http://mysite.du.edu/~jcalvert/tech/fluids/bernoul.htm
   See also http://en.wikipedia.org/wiki/Torricelli's_law
   This learning goal also includes the subgoals v = f(g,h) and v!=f(rho, y)

2. p + 0.5 rho v^2 + rho g y = constant (16-17 = bernoulli's equation), mostly as it pertains to torricelli's theorem

Mock-

ups: 
Fluid Pressure and Flow (0.00.06)
File Help
Pressure
Flow
Water Tower
0.9988 atm
Ruler
Measuring Tape
Units
atmospheres (atm)
Pascals (Pa)
pounds per square inch (psi)
feet (ft)
meters (m)
Pipe
0.0 m/s
5.3 m/s
Fluid Density >
Reset All



UI Elements:

1. The user can change the water level by turning on and off the input pipe. Turning the spigot slider (as in Farady's generator tab) all the way to the left turns the input water flow completely off. Turning the spigot slider all the way to the right maximizes the input flow, equal to the maximum possible output flow. This setting will maintain the current height of the water in the water tower. The flow is depicted as a solid rectangle of water, as in Faraday's generator tab.

Note: we will need to verify that students don't correlate the velocity of the input flow water with the velocity of the output flow water. That is partly why we chose this faucet analogy, having an input pipe might exacerbate this problem.

NP: we'll need radio buttons for "auto/manual", auto keeps the constant level

2. The user can drag the body of the water tower to change its height. In "water tower hole" mode, this will help the user see that only delta h is relevant in torricelli's theorem. In "output pipe" mode, it will allow the user to change the delta h value.

NP: Add a handle like from states of matter or the ramp, cursor turns to a hand.

3. The user can unplug a hole in the water tower, using a covering control like in Gas Properties. The covering control should always be entirely covering the hole or entirely off the hole, so the confounding factor of differing output sizes does not enter in to the sim. Having the hole covered when the sim starts up is also how we have the sim start up with nothing happening. This control should be made easy to see since it should be the first thing that students use when they get to this tab, if students don't see it right away, we could put a double-headed arrow to indicate that it's draggable.

The sim should allow multiple output water segments for the case in which the user covers and uncovers the hole rapidly. The flowing out water should use the same strategy as the deformable red dye in the Flow tab, by using sample particles to set the end boundaries, but rendering as a solid block.

NP: the decrease in volume of the water tower should be proportional to the velocity at the output hole

4. When the hole in the water tower is unplugged, the user can alternatively plug in a J-shaped pipe. The pipe can have its height and output angle changed. This will allow the user to set up a trajectory of the output water that is directly up, or at any angle between 90 degrees and 0 degrees. The output pipe has cross sections the exact same shape as the hole in the water tower so that compressing flow lines are not a consideration. The output pipe is not available by default, but is toggled on and off through a check box in the control panel.

NP: this should be a garden hose. How will the user change the angle?

NP: A red lollipop off the end of the hose for rotation.

NP: grabbing the hose anywhere and dragging up and down just moves the output point up and down, can't move hose left and right

NP: should be able to move the output point above the water tower input point.

start without drag handles on ,add them later if interviews necessary.

NP: use radio button for hose on off

NP: can't turn water off to hose, we'll see if this is okay

5. Vertical ruler is available (with a checkbox) to help the user measure delta h values. The ruler needs to be big enough to compute delta H values for both water-hole and output-pipe modes.

6. Measuring tape is available (with a check box) to enable the user to compute horizontal distances (for water projectile motion calculations), or to compute another distance at the same time as the ruler is being used elsewhere.

7. The user can drag a velocity meter (as in the "flow" tab) to inspect the velocity of water flow at any point. This will be used to show that v=root(2gh) at the output spigot, that water speeds up as it accelerates under gravity's influence. There is no terminal velocity. The velocity meter should also show v=0 throughout the water in the water tower.

8. The sim can be paused so the user can inspect trajectories and heights.

9. There is a Fluid Density control as in the other tabs, so the user can see that the behavior is independent of the fluid density.

10. As in the other tabs, pressure sensor allows the user to measure pressure at any location. pressure of falling water is air pressure. Air pressure can also be measured as in the air as in tab 1,

Other notes:
The value for g should be 9.8m/s^2, but not depicted or measurable in the sim, so that students could use measurements of v and delta H to determine g.

To Discuss:
To mitigate the possibility that students will think the water faucet is adding to the velocity of the output water hole, should we show some water bubbles in the tower to indicate the velocity field? This would show that things near the top aren't moving very quickly at all, and there would be some motion near the output water hole. We have a similar control in one of our chemistry sims.

Issues that were considered but discarded
User could change the height of the water tank with a green double-arrow drag handle
User can change the water level within the tower with a green double-arrow drag handle
Add a rotatable spigot off the side of the water tower

##
Discussion issues
###################

- Might be neat to have an air balloon that expands or contracts as it is moved around to different pressure areas. Would make a concrete anchor for what it "feels like" to be at different pressure. (Maybe two balloons so users can do comparisons?)

SR: Can use boyle's law for correct values: http://home.flash.net/~table/gasses/boyle1.htm

SR: correct values are impossible to see at this depth, just 1-2 pixels difference in the radius. I think we should remove this feature or add a zoom-out function or a deeper well tab.

Add units selection to the ruler, not in control panel

SR: CM commented that it is nice to keep all units together. Also, it changes the pool readout too, not just the kind of ruler, so I think we should leave this in the control panel.

Responses to NP:
NP: Seems like we should use SI units, but maybe this isn't appropriate for middle school?

SR: That's why I defaulted to "atm" but allowed SI as an option.

- It would be awfully cool to be able to place various shaped objects in the flow path (sphere, air foil, car, etc.)...but have to think about how expensive this would be, and whether it is a learning goal.

SR: sounds like a different sim or tab

- Left pipe overlaps the "fluid density" control when moved down. Not sure of a good solution to this, since this seems to be the ideal location for the density control.

SR: I'll leave it for now

what about adding a balloon or other force-able object to show pressure?

Turns out that the change in volume of a balloon is imperceptible at the sim's scale.

##
Issues for all tabs that have been decided against

##################
CM: add tick marks from buoyancy. I tried this but bailed, because it looked like the “10 ft” label was associated with the tick mark half-way down the pool. Should 10 be the top or bottom tick? Which ticks should be labeled? Or should we forget about this?

CM: Since this would add a lot of text to the screen if we label all ticks (and move the 10’ label elsewhere), we decided just to leave this alone.

###
Interview issues
##################
Tell NP: “Match leakage” verbiage made sense to Rachel
Tell NP: RP Didn’t play with arrow
Tell NP: RP Didn’t play with fluid density control

###########################
Design Decisions (from to-do doc)

Archived discussion (to be moved to design doc):

NP: wasn't clear to me why you would want to turn off the atmosphere

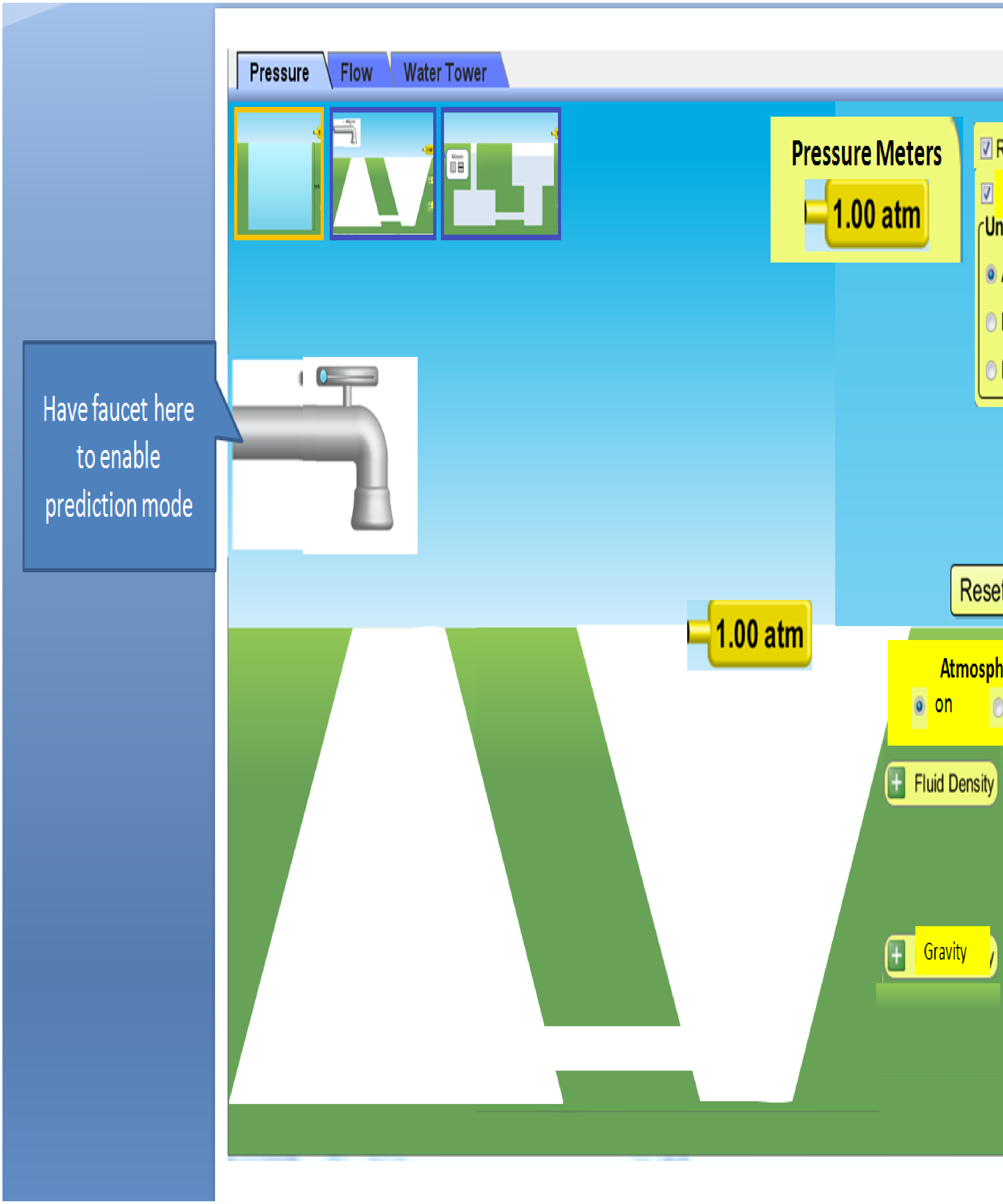
KP: If you are trying to develop the idea of the pressure due to the weight of the water, having the constant of the atmosphere complicates things and makes the relationships a bit harder to see. So it's nice to be able to turn it off and just focus on the water. It also emphasizes that the reason that p is not zero at the top of the water IS the atmosphere.

AP: I think KP's original suggestion of having weights on only one side would be best. Thinking about hydraulics is fertile enough ground for another sim completely, and I think best not handled here. I also agree masses/weights vs. Pistons.

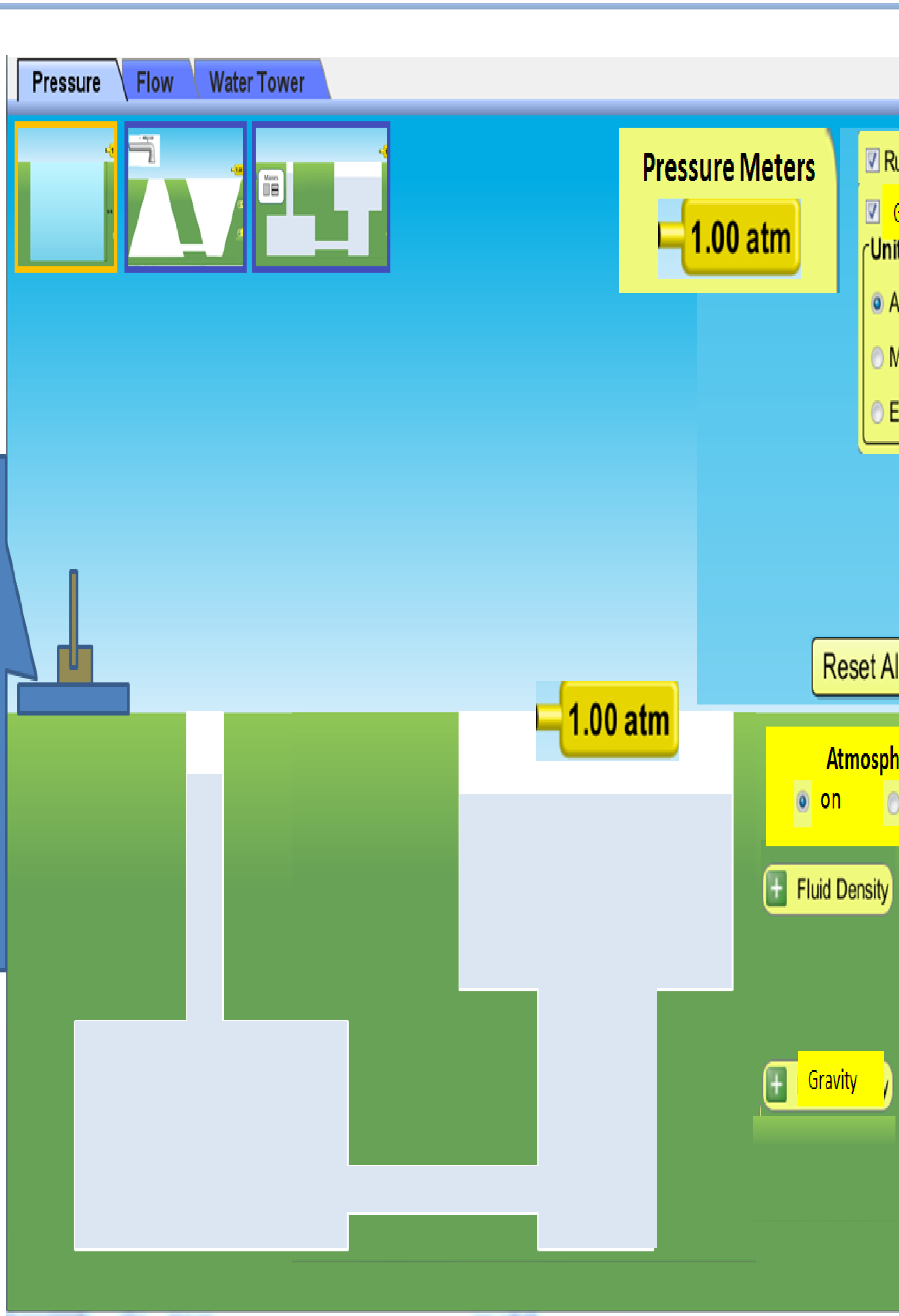
KP: I'm thinking its either masses or a piston - not sure which is better but leaning towards masses, because you can have discrete units -- like I double the mass (etc) whereas a finger is harder to say how much force you are exerting. Having them sit above ground is OK with me - I was hoping to get a label in there as "masses" somewhere

When changing scenes, everything else stays the same (ruler, grid, pressure meters)

Prediction mode: Allow an instructor or a student to question how the pressures will be affected before the tank or tanks are filled.


Pressure
Flow
Water Tower
Pressure Meters
1.00 atm
Have faucet here to enable prediction mode
1.00 atm
Reset
Atmosph
on
Fluid Density
Gravity

Here idea is that you can push down on one side and see what happens to water pressure ... could use piston or weights



SR: Nonlinear fill when passing the passage?

SR: No, I think it looks fine without this

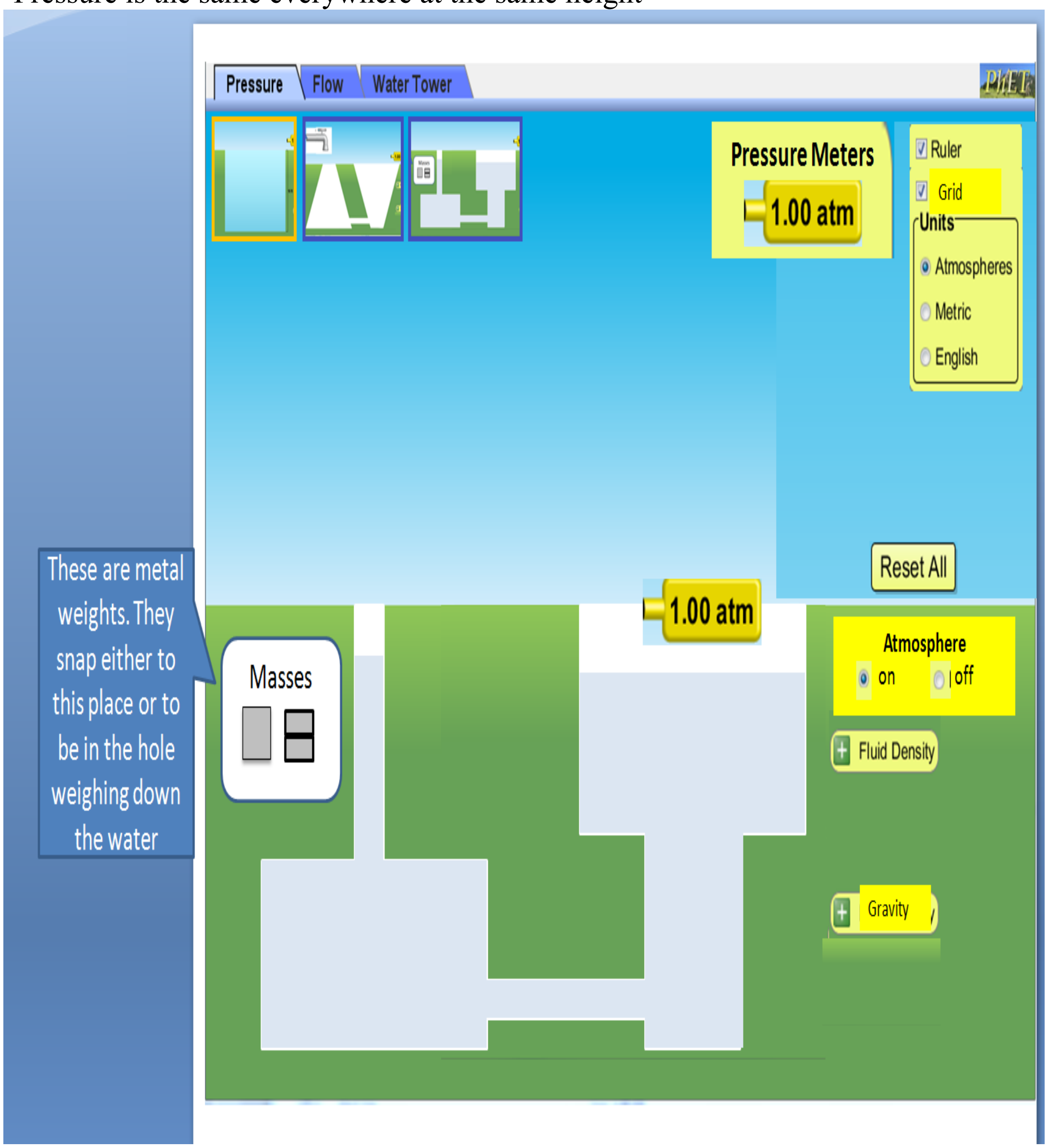
How to implement model for new shapes? Do we need analytic model for them? How about providing Range[] as a function of y? Or build on primitives, such as quadrilateral?

-If pool fills up while faucet is being dragged, there is a quirk if the user doesn't let go of the mouse

Could this impact other sims?

SR: I fixed the worst part of this problem

-Pressure is the same everywhere at the same height



-SR: How to prevent user from actively pulling the mass down too far?

1. force them to drop at the y=0 opening, could have a text message to say to release, could make it auto-drop
2. prevent the mass from being dragged down too far, could make it auto-drop
3. Show dotted outline of where it can be dropped for the left side

This will work well for the left chamber. Maybe we can get something like this to work for the right side

-Don't let the masses be so heavy that they can push into the 2nd chamber

SR: Actually, this is physically accurate since the pressures are equalized

-The atmosphere has an effect, maybe we should consider showing the grid in the atmosphere too.

No, just showing it underwater signals that it is most important underwater

-Object weights should be in Newtons

SR: Where should we show this? On the masses? Why is it important to be quantitative here?

SR: In case we show a car or something

** Sensors: -how to handle winding number in other tabs?

Not a practical problem for this sim with current values

-force factor will depend on the “into the screen” dimension for the pool. Factor of 6 if constant screen depth, factor of 36 if square. Could add to teacher tips as a “game” for students to measure the screen depth.

SR: I recommend having “into the screen dimension” match the x-dimension so that it is square, to have a more pronounced effect, and more like realistic piston problems

SR: On the other hand, this makes the amount of distance traveled much smaller and hard to see.

SR: Decision: go with squaring it since the increased lifting power and decreased motion are really important. Can tune the opening widths to find a happy medium

-NP: It might also be nice to have more realistic gauges in the first tab. At the very least, a pressure gauge like the one in SOM. Even better might be a mercury type barometer. One of the weird things here is that "more height is less pressure". That might be cued more strongly with a gauge that maps up/down to high/low pressure (so moving the gauge up makes the readout go down, and vice versa).

SR: having something go down as you move it up may be confusing to users. Maybe consider a left/right or needle gauge?

SR: main problem here will be showing the full dynamic range

Grid:

-How to handle grid lines for different scenes? The value is diminished because the top of the water can move

SR: Maybe just disable grid check box for scenes 2-3

-Maybe show a needle/bar gauge as well as an arrow indicating the gradient (pointing toward higher pressure). Could give an impression of the pressure differences--the pressure is changing slowly (but still changing!) when in the atmosphere and lots more when in the fluid. Maybe pointing toward low pressure, since it is like a force.

SR: Maybe the arrow would alleviate the need for switching precision when submerging the sensor

SR: No, I think it still wouldn't replace the value of seeing 1.000001 at one point and 1.000002 at a nearby point.

-On tab 1, make the pressure sensors larger, a factor of 1.2. Feature got dropped when we added toolbox panel for these.

SR: Wait until deciding whether changing sensor representations before working on this

SR: No need to work on this since we are switching to gauge-based pressure meters

** -KP: Have a meter to measure pressure difference between 2 probes?

SR: By visually comparing pressure needle gauges, I think the same effect can be achieved.

SR, no longer needed

**Lifting something in the 2nd chamber:

-NP: could lift something really heavy on the right side, like a car

SR: Let's compute something that has the right size and mass dimensions

-When pushing on both sides, add additional force pressure term

-Maybe just be able to put the same blocks on both sides?

-Dotted outline/drop will work well for the left chamber. Maybe we can get something like this to work for the right side

SR: Maybe discuss this with team before proceeding. main questions:

(a) will it be confusing to put a thin sheet on the right hand side?

(b) reuse blocks from left side to put on the right side?

(c) maybe this is already rich enough and hydraulic lift should be reserved for later?

no hydraulics for me

Team decision 4/5/2012: No hydraulics/forces in this sim, leave it for another one

** -Don't change sensor resolution when going underwater

-adding a needle gauge may make it unnecessary to drop resolution in digits

SR: I should ask about that, because showing the reduced resolution does have some benefits, at least for atm units

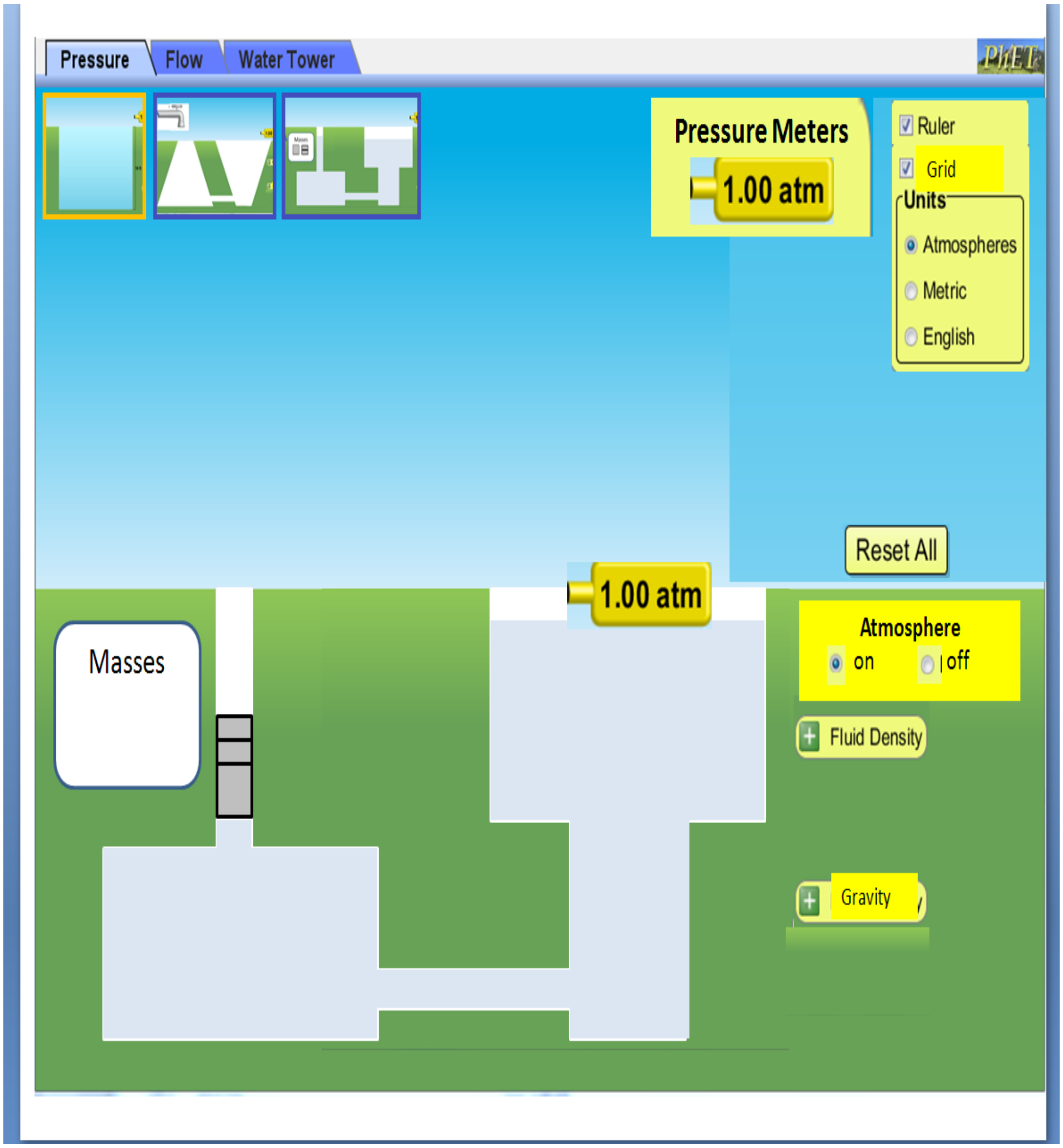
Meeting notes: keep this feature

Scene 3 Physics:

** Make containers square so that ratios go as the square

SR: This makes the motion on the right side too small. Could fix this by changing the size of the masses and the left opening.

AP: Either way is okay because the main learning goal is equal pressure at equal depths.



Discussions 4/30/2012

- The speed reader tool can be a bit "jumpy" if placed near the edge of the water stream (it will flicker back and forth between the speed value and the "null" value. Perhaps have it "snap" to the center of the water stream, with some reasonable acceptance distance?

    SR: This seems tricky--maybe easier to put some time averaging on the display value.

    SR: Water stream passing by the speed sensor doesn't trigger it--it should.

    SR: this problem would be reduced if the speed sensor didn't change size as the readout changed.

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SR: Water stream passing by the speed sensor doesn't trigger it--it should.

Not exactly a problem, may be conflated with other problem.
SR: Is my fix good enough for this? I think that having the stream move past the velocity sensor is enough of a learning goal that the speedometer shouldn't track with the water. (But we could add an "average speed" readout).
April 2012 Decided that fixing the hot spot jumping problem resolved the problem

- There is a bug in the inputs for Fluid density and gravity. When the slider has been put to the extremes, the input box does not seem to accept higher or lower inputs then the limits. This feature works properly on the other tabs, for instance, if the density is input at 10000, it accepts and just goes to the highest limit allowed by the sim.
SR: I asked about this.
SR: I think what you observed is actually a bug that on the 2nd tab for the flow rate slider/ text box you can type in an out-of-range value for the slider (which does not update the model).
Fixed

############################
Discussion from 5/10/2012

Just a pressure sim?
pro: for students doing just pressure, no distractions

Pressure pool? Needs a nice title.

p=rho g h
Pascal's Law

"Under Pressure"
"Hydrostatic Pressure"
Air and water pressure
Pressure Pool
Swimming Pool Pressure
Pool Pressure
Fluid Statics
Pascal's Pool

##############################
Interviews:

Fluid Pressure and Flow (0.00.32)
Interview 1, October 3, 2011

Student Background
Senior Male IPHY major currently taking physics 2010, no previous physics experience and had seen one sim previously.
Priority Fixes:

In the 2nd tab, the handles have a color that closely matches the pipe. The student had difficulty realizing the handles could be manipulated. The handle color should be changed for contrast and ideally the handle image made more “handle like”
In the 2nd tab if the right hand pipe opening is made to full width it visually interferes with the “fluid density” control box.
For Discussion:
The “line” of ink in the 2nd tab appeared to be somewhat confusing when the pipe was highly distorted. It would be good if we could work on a somewhat “smoother” visual aid, but only if there is an easy fix.
Reflections:
Overall the sim was very engaging and clear for a student that was quite unfamiliar with the topic. He found all controls easily (except for the handles to manipulate the pipe in the second tab), manipulated the sim with ease, and specifically commented on its coolness. The student appeared to notice the pause and play buttons (paused the cursor over them momentarily), but I have yet to see a student use these controls in any interview except with Normal Modes. It seems only a few more minor tweaks will be necessary for the sim to go to publication.

Fluid Pressure and Flow (0.00.32)
Interview 2, October 3, 2011

Student Background
Freshman Male engineering major (likely geology) currently taking physics 1110, had taken physics in high school and used CCK, Lunar Lander, and ESP
Priority Fixes:
In the 2nd tab there appears to be a bug in which the pressure meter reads a “negative” pressure at a very tight constriction of the tube
“Ghosting” occurs with the ruler in the 3rd tab…a similar problem occurred in Balancing Act with the bricks John B. drew.
The handles for the pipe in the 2nd tab should be changed.
For Discussion:
Sam suggested that perhaps constraining the pipe in the 2nd tab to have a larger minimum diameter might fix both the negative pressure problem and make the “line” feature remain smoother.
Reflections:
Again, the student was quite engaged by this sim and found most controls with ease (including the play/pause buttons!...the first student I have seen use these buttons). The handles in the 2nd tab took a bit for him to find, but once he did, he manipulated them with ease and used all the various measurement tools to understand the system. For instance, he used the speed sensor to verify that with friction, the speed of fluid flow was less near the walls of the pipe. It seems with the minor bug fixes the sim will only require a couple more interviews to verify it is ready for publication.

Fluid Pressure and Flow (0.00.32)
Interview 1, October 3, 2011

Student Background
Senior Male IPHY major currently taking physics 2010, no previous physics experience and had seen one sim previously.
Priority Fixes:
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Fluid Pressure and Flow (0.00.54)
April 20, 2012

Student Background
College freshman, male, Pschology/Iphy major, some PhET experience (high school and phys1110)

Priority Fixes:

Tab 1:
- Remove plant, and begin "scene 1" with an empty water basin. Add a faucet and a drain.
- Set "metric" as default units, and move metric to 1st radio button
- There is a bug in the inputs for Fluid density and gravity. When the slider has been put to the extremes, the input box does not seem to accept higher or lower inputs then the limits. This feature works properly on the other tabs, for instance, if the density is input at 10000, it accepts and just goes to the highest limit allowed by the sim.

Tab 2:
- Move the fluid density floating control slightly up and to the left. It has not negative

space from the bottom corner of the sim currently

For Discussion:
Tab 3:
- The speed reader tool can be a bit “jumpy” if placed near the edge of the water stream (it will flicker back and forth between the speed value and the “null” value. Perhaps have it “snap” to the center of the water stream, with some reasonable acceptance distance?

Reflections:

The sim seems to be in overall very good shape, and with the changes above should be ready to publish. I do not think further interviews are necessary. The student used all controls with ease. In addition, the student generally engaged with the learning goals of the sim. However, he was at first confused with what scene 1 on tab 1 represented (this has been a common confusion in interviews). Since we have added the functionality of a faucet and a drain to scene 2, it seems natural to add this feature to scene 1, making it clear that the basin is filled with water and making the scene more interactive.