# 8.Bubbles

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New Zealand

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# The Problem

- Is it possible to float on water when there are a large number of bubbles present? Study how the buoyancy of an object depends on the presence of bubbles.

# Presentation Structure

- Definitions
- Initial hypothesis
- Observations
- Theory
- Further experiments
- Conclusion

# Floating

1. Material less dense than water e.g. wood
2. Hollow shape makes the object less dense than water e.g. Titanic
3. Surface tension e.g. drawing pin, aluminium foil

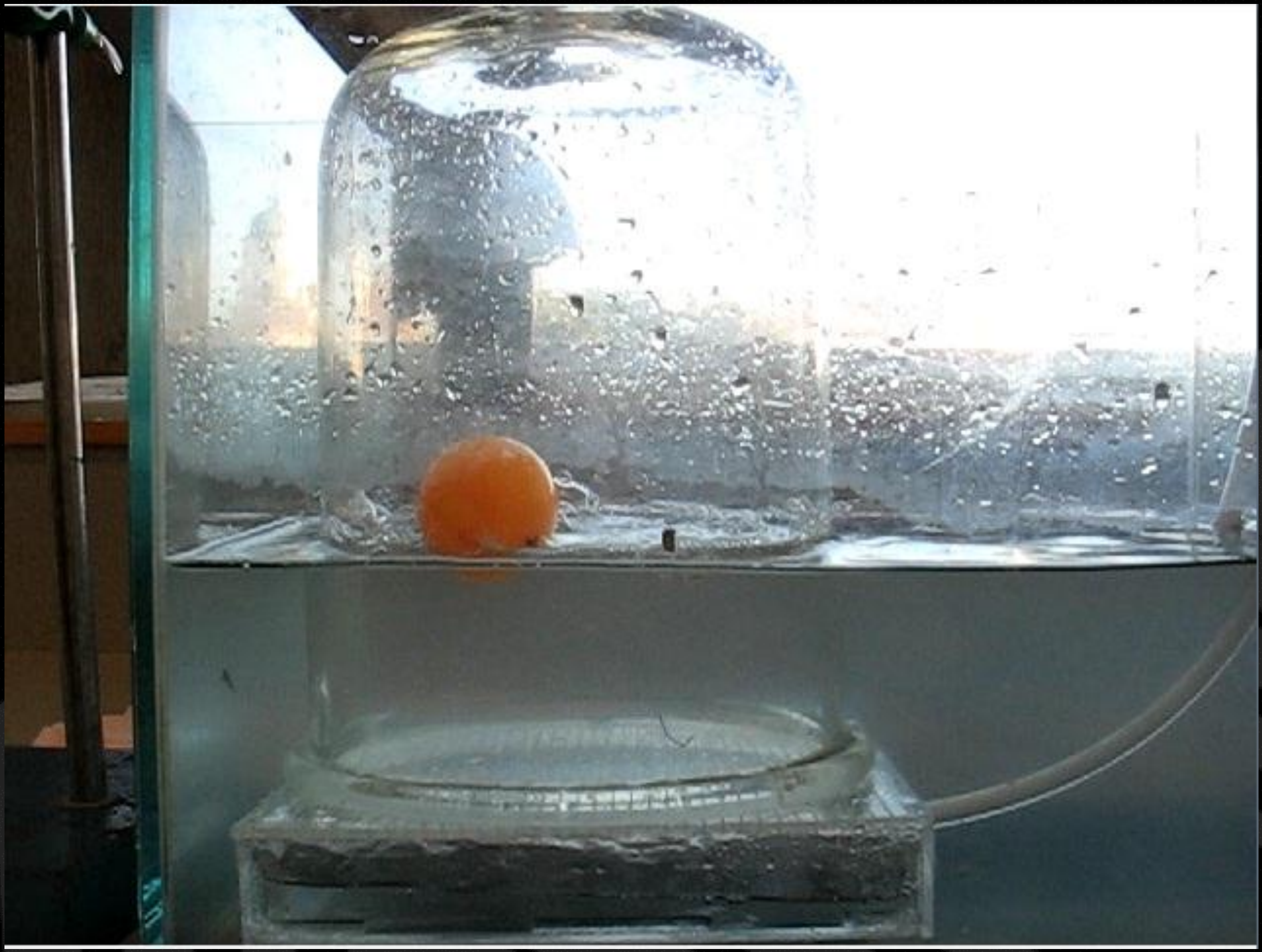
# Initial Hypothesis

- Bubbles of air lower the overall density of the water, reducing buoyancy force – possibly causing object to sink

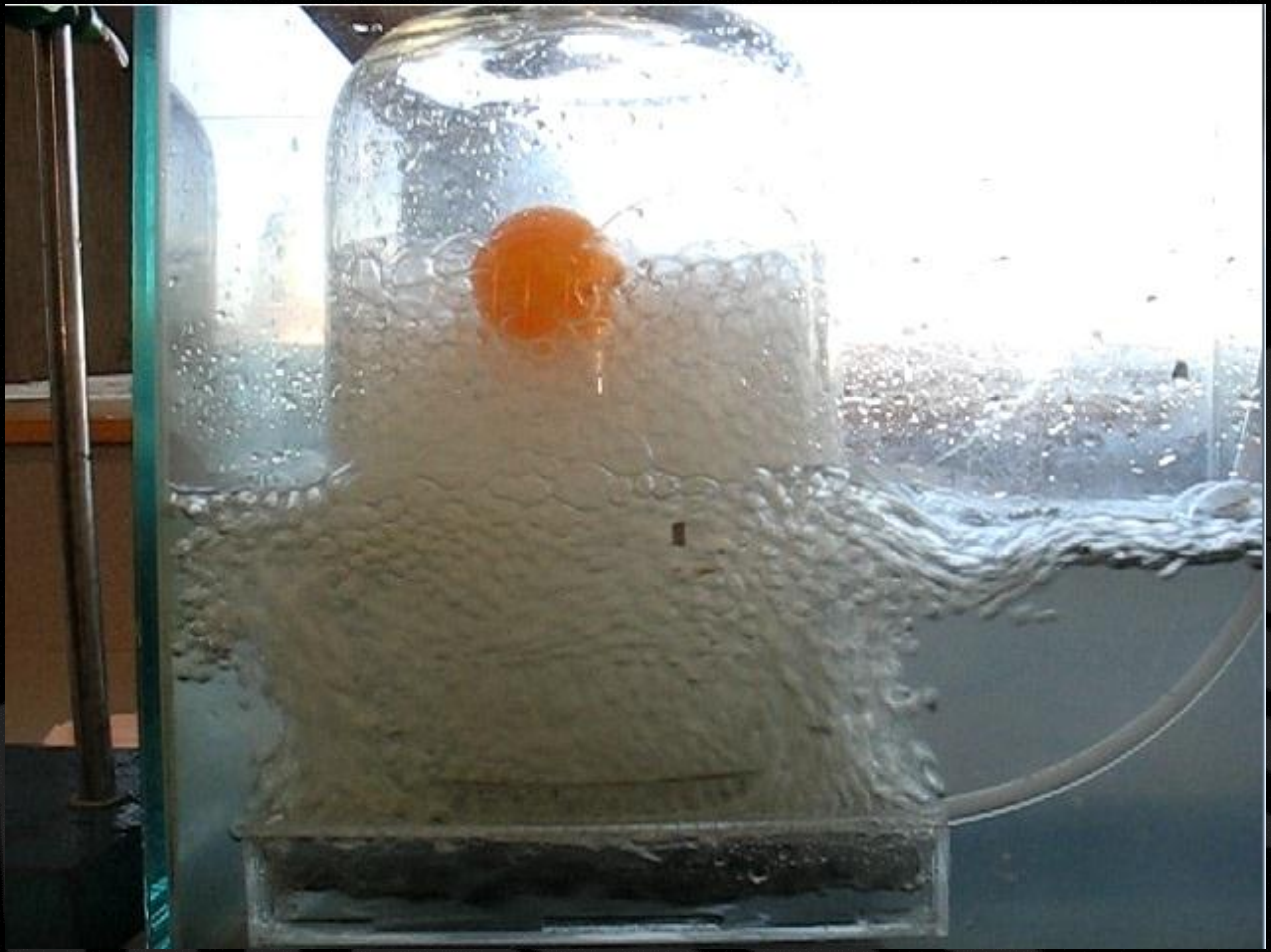
# 1. Open Water

# 2. Containers

# 2. Containers



# 2. Containers



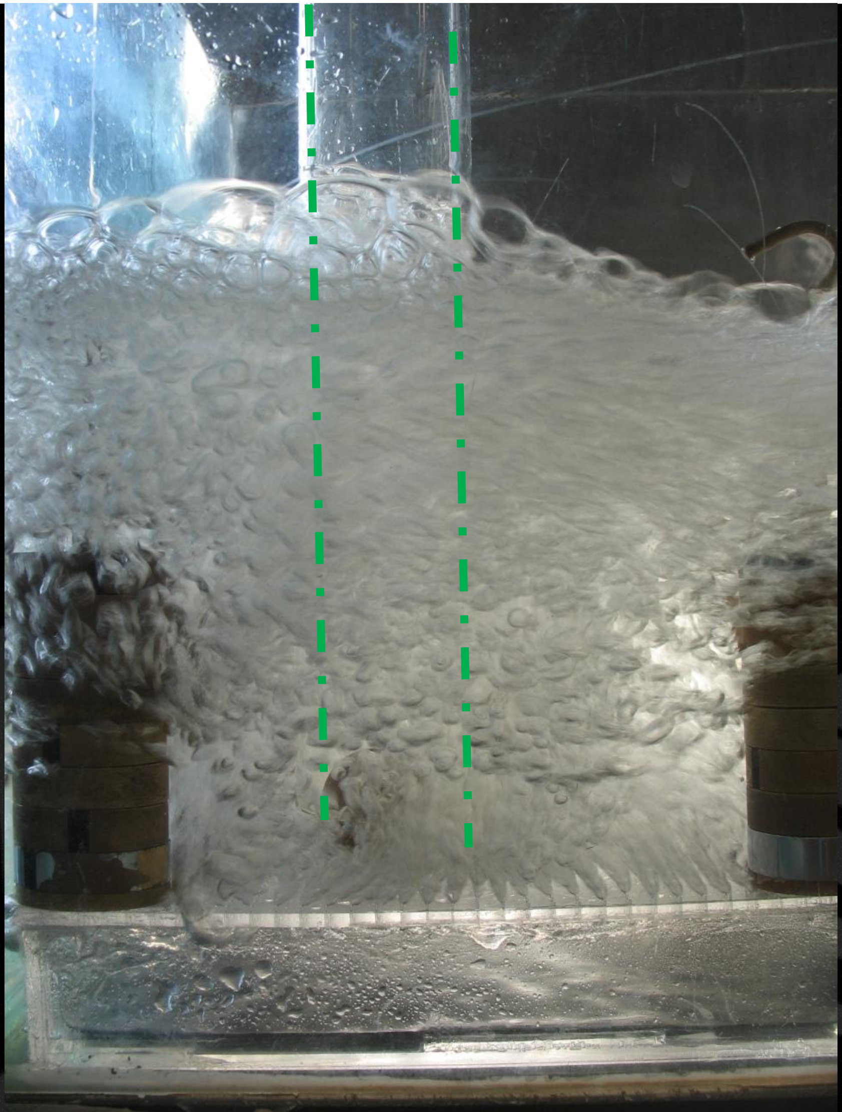
Yes, in many cases it is possible to float: density very low

# 2. Containers

Injected water into the ball
Note 1. Chaotic Motion
2. Hard to see ball, making measurements difficult

# 2. Containers

Ball is stable at the bottom



# Observations - Ball

- Balls with very low density will not sink
- Too few bubbles have no effect
- If number of bubbles is large, more dense balls will begin to sink
- Wide tubes give unpredictable movement
- Narrow tube – sinks and stays down

# Modelling

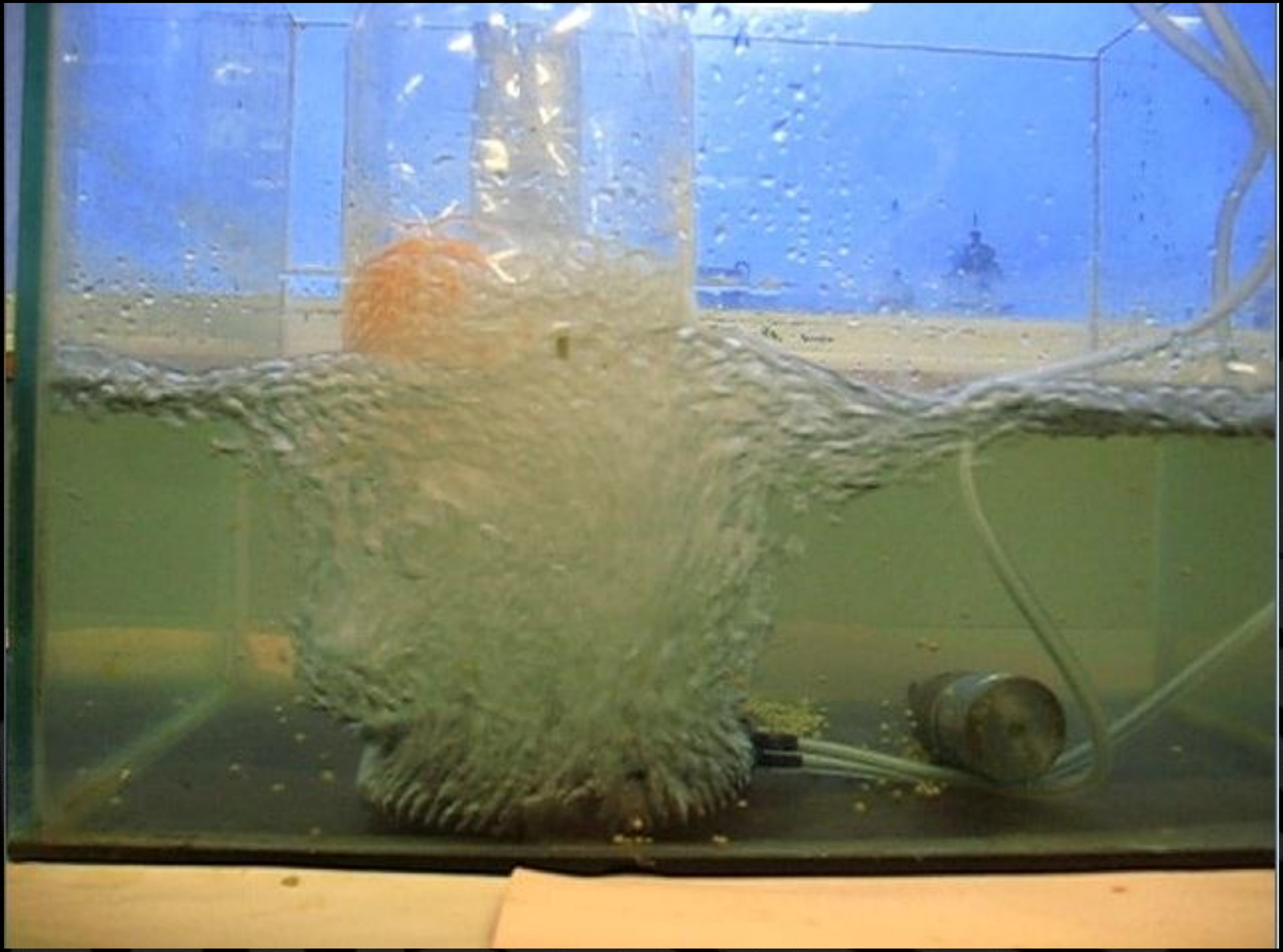
- Turbulent flow.
- Ball is difficult to see: tried several methods of tracking position and force on the ball

Tried to test a number of parameters – density, aeration rate, water depth – no definite quantitative data, but plenty of qualitative data, because of these difficulties. Main focus today will be explanation of phenomenon.

# Density Hypothesis

- Flotation depends on a density difference

# Volume Fraction



Measured the volume fraction of air: 2%-3%

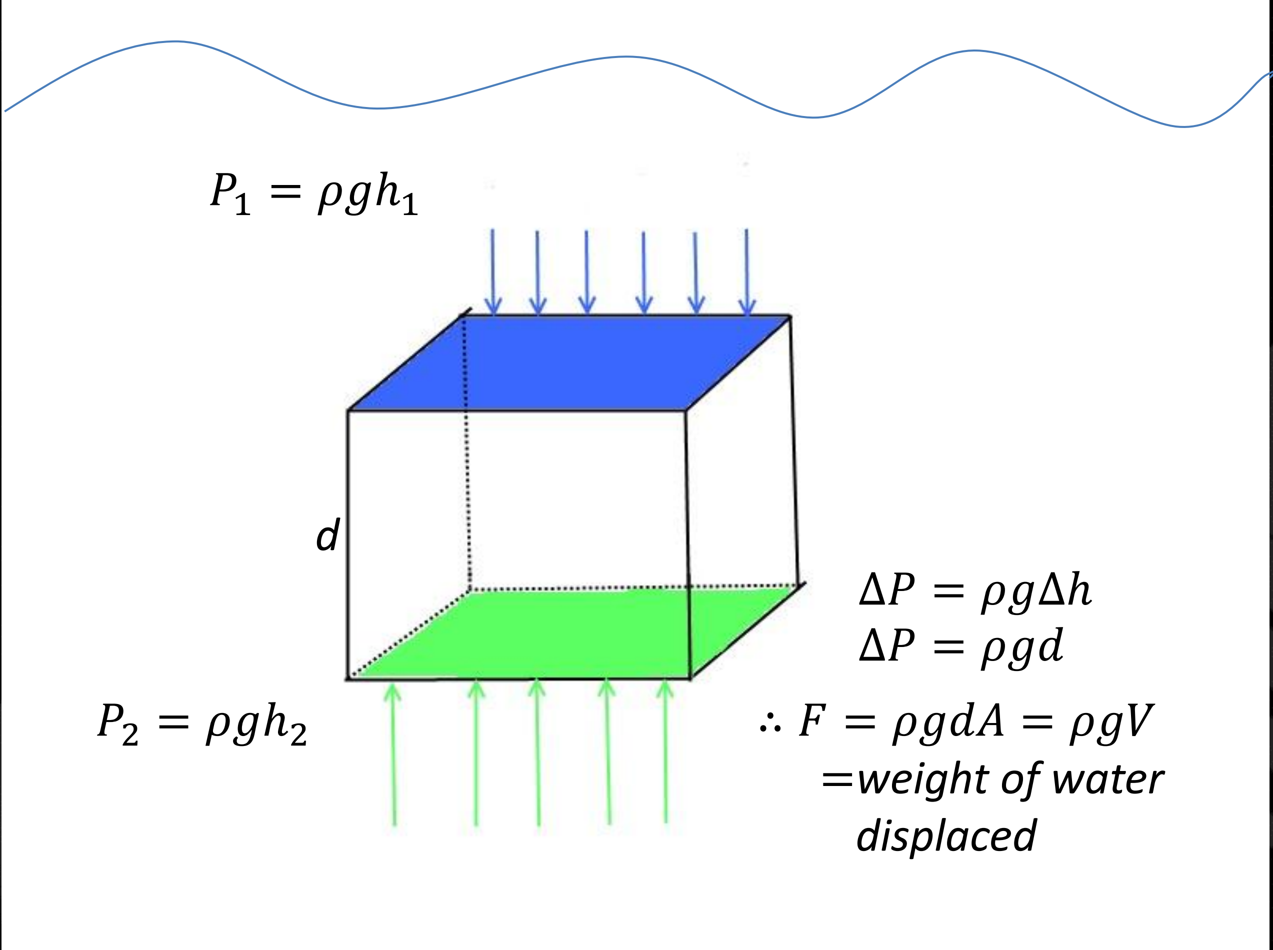
# Volume Fraction

It might look like there is more than 3%, but the photo has z-axis depth. The bubbles are actually spread out – see them moving over hand

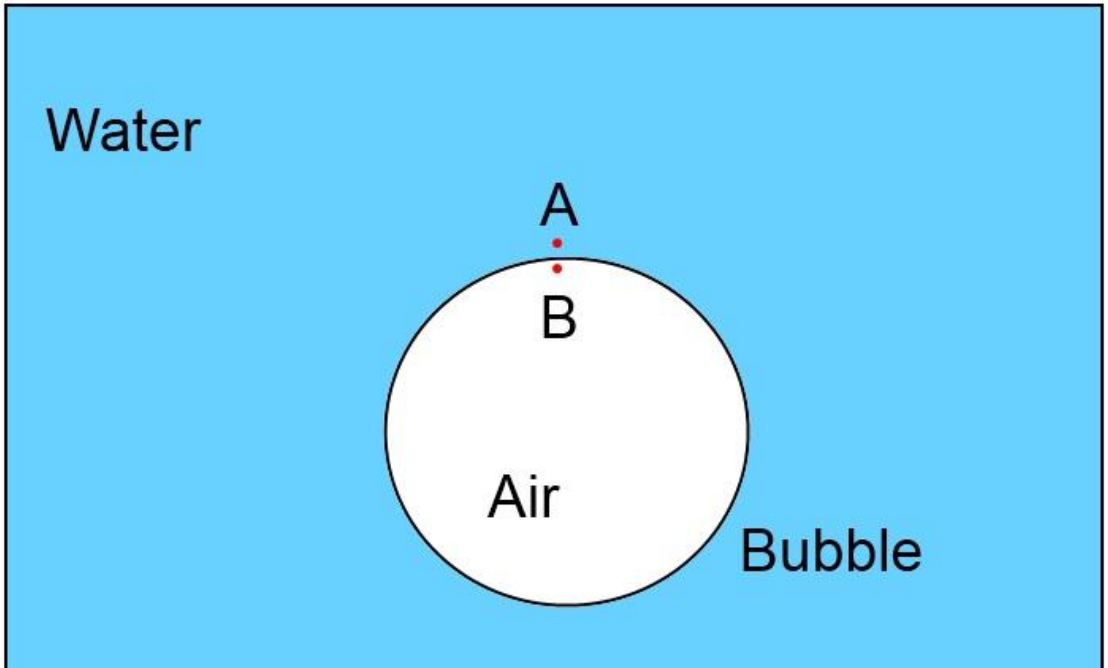
# Volume Fraction

- Weight force = mg = 7.95$\times 10^{-3} \times 9.81 = 77.99 \times 10^{-3} N$
- Buoyancy force = V$\rho g = 8.419 \times 10^{-6} \times (1000 \times 0.97 + 1.2 \times 0.03) \times 9.81 = 80.12 \times 10^{-3} N$
- Net force = $80.12 - 77.99 = 2.13 mN$ <u>upwards</u>
- But ball moves downwards

# Buoyancy Origin

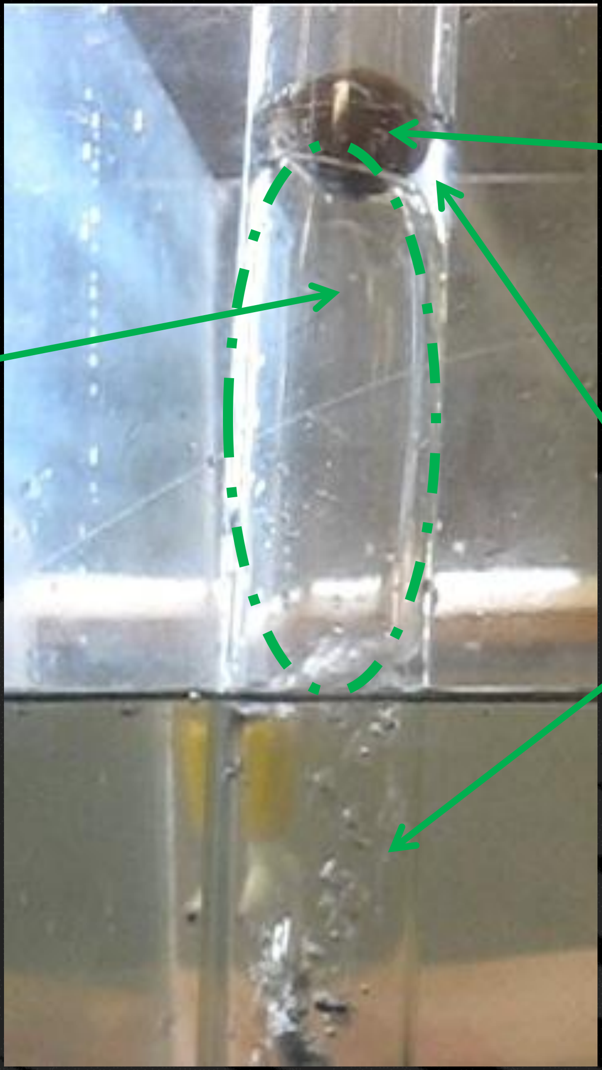


# Buoyancy Origin




$$Pressure_A \cong Pressure_B$$

# Buoyancy Origin



# Netting

- The density hypothesis is disproved.
- The change in density caused by bubbles does not cause the ball to sink.

# Ring

# Ring

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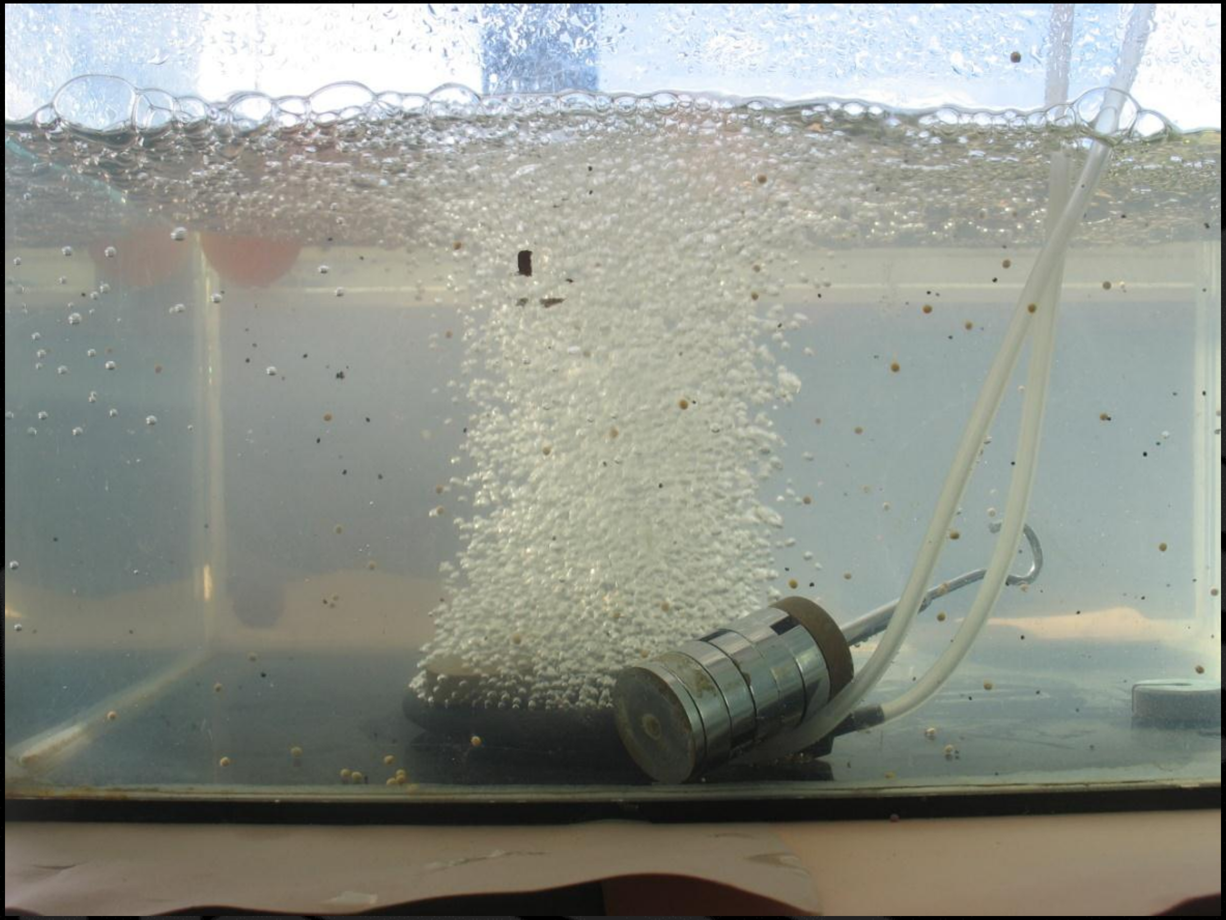
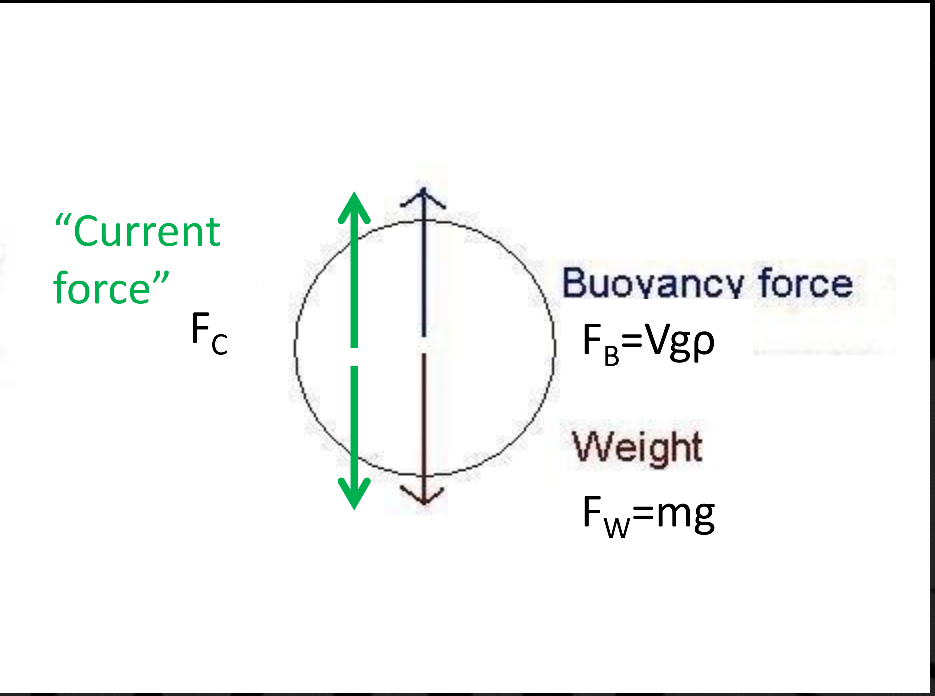
The ball sinks but is not in a bubble stream! This suggests currents are the cause of the sinking. We visualised currents with mustard seeds.

# Currents

- Mustard seeds



# Theory - Forces




$$Net\ force = F_B - F_W + F_C$$

# Boats

# Surface Tension

# The Problem

- Is it possible to float on water when there are a large number of bubbles present? Study how the buoyancy of an object depends on the presence of bubbles.

# Conclusions

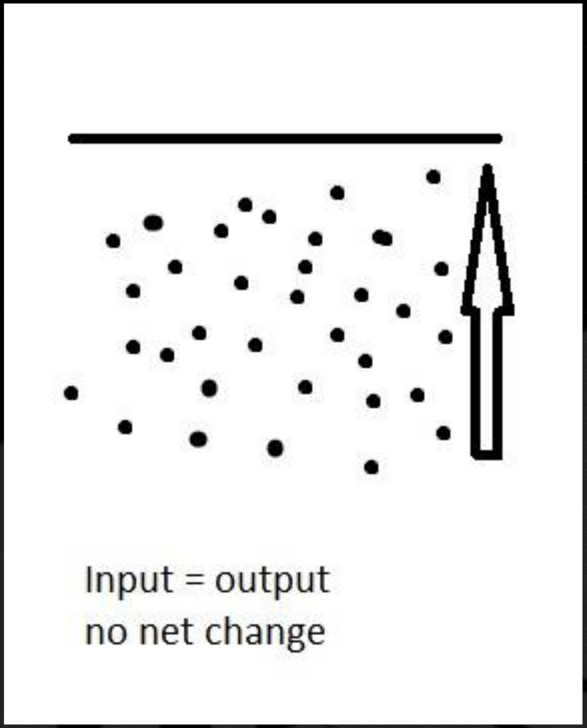
- Yes: definitely possible to float in many cases
- Buoyancy force is almost totally unaffected
- When large number of bubbles present, objects may sink
- This is due mainly to currents – density change is insignificant
- A ball must be reasonably dense, so that the current can overcome buoyancy force
- Both solid fields and ring-shaped ones work
- Bubbles easily disrupt flotation by surface tension
- Presence of a container increases the effect of downward currents
- Size of the container affects the currents' shape

# Thank you for listening

# Experiment 4: volume fraction

- Easy to measure air flow rate: downward displacement of water
- But this doesn't tell us how much air is in the water at a given moment in time (% by volume in the body)

# Experiment 4: volume fraction



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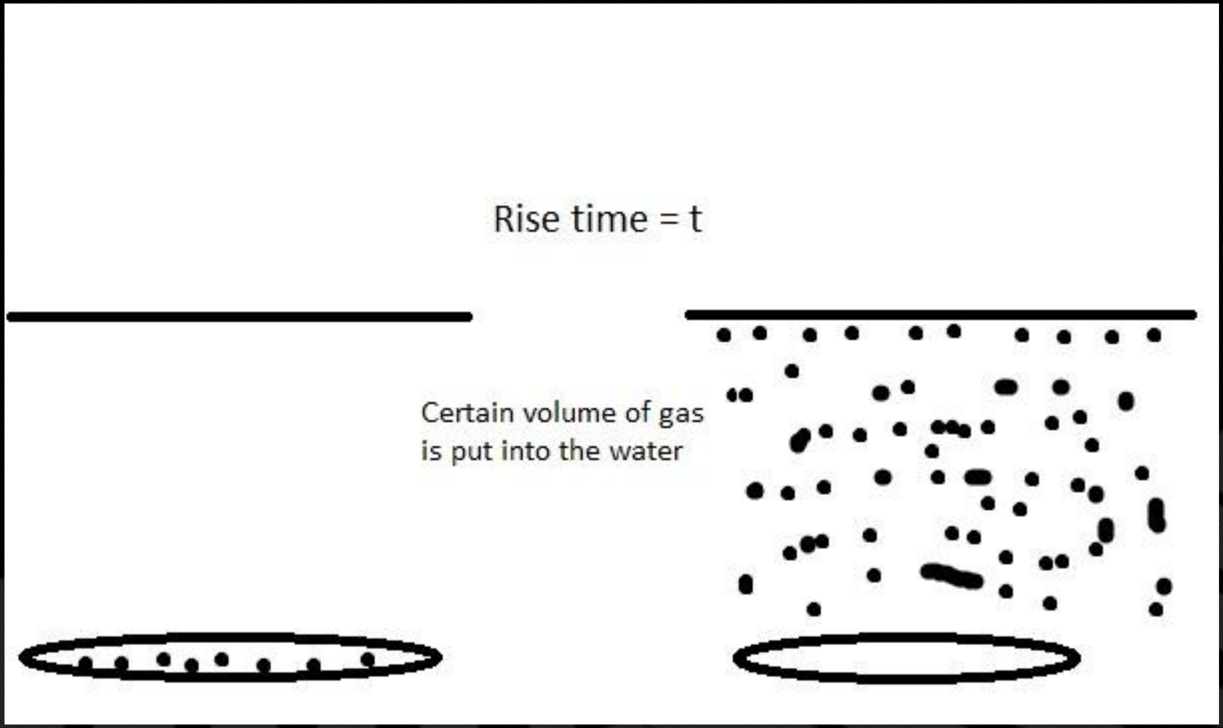

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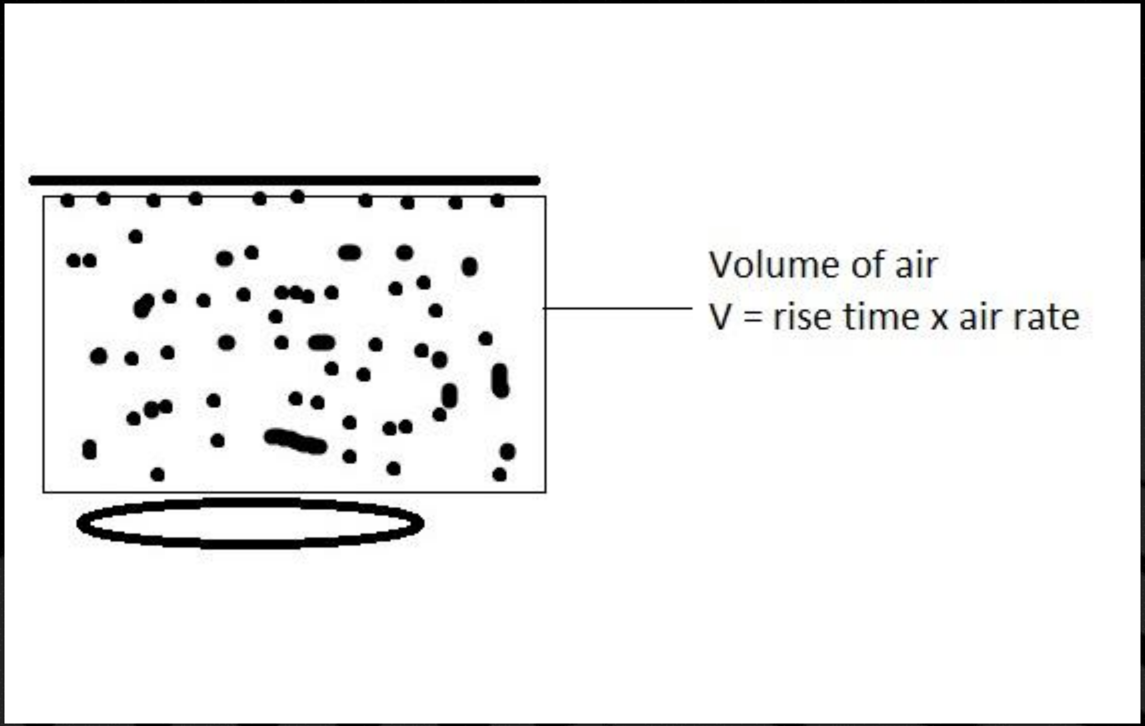

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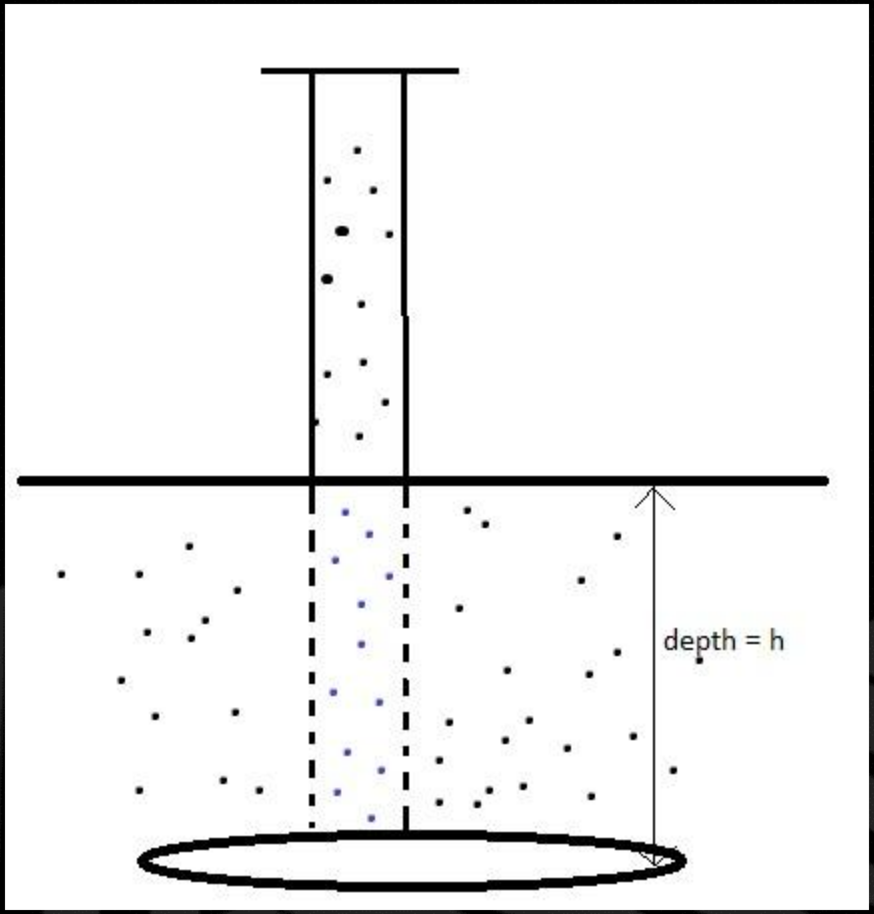

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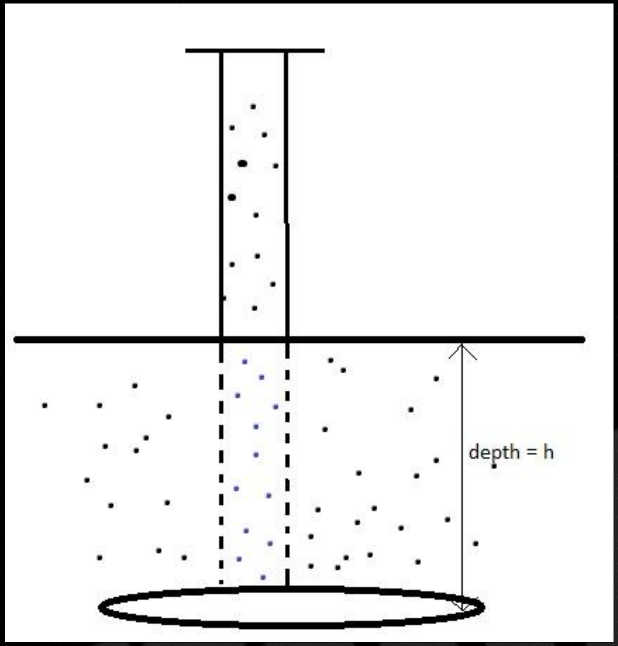



$$\%\ vol\ of\ air = \frac{V\ of\ air}{V\ of\ body}$$

$$\% = \frac{rising\ time\ x\ air\ rate}{\pi r^2 h}$$

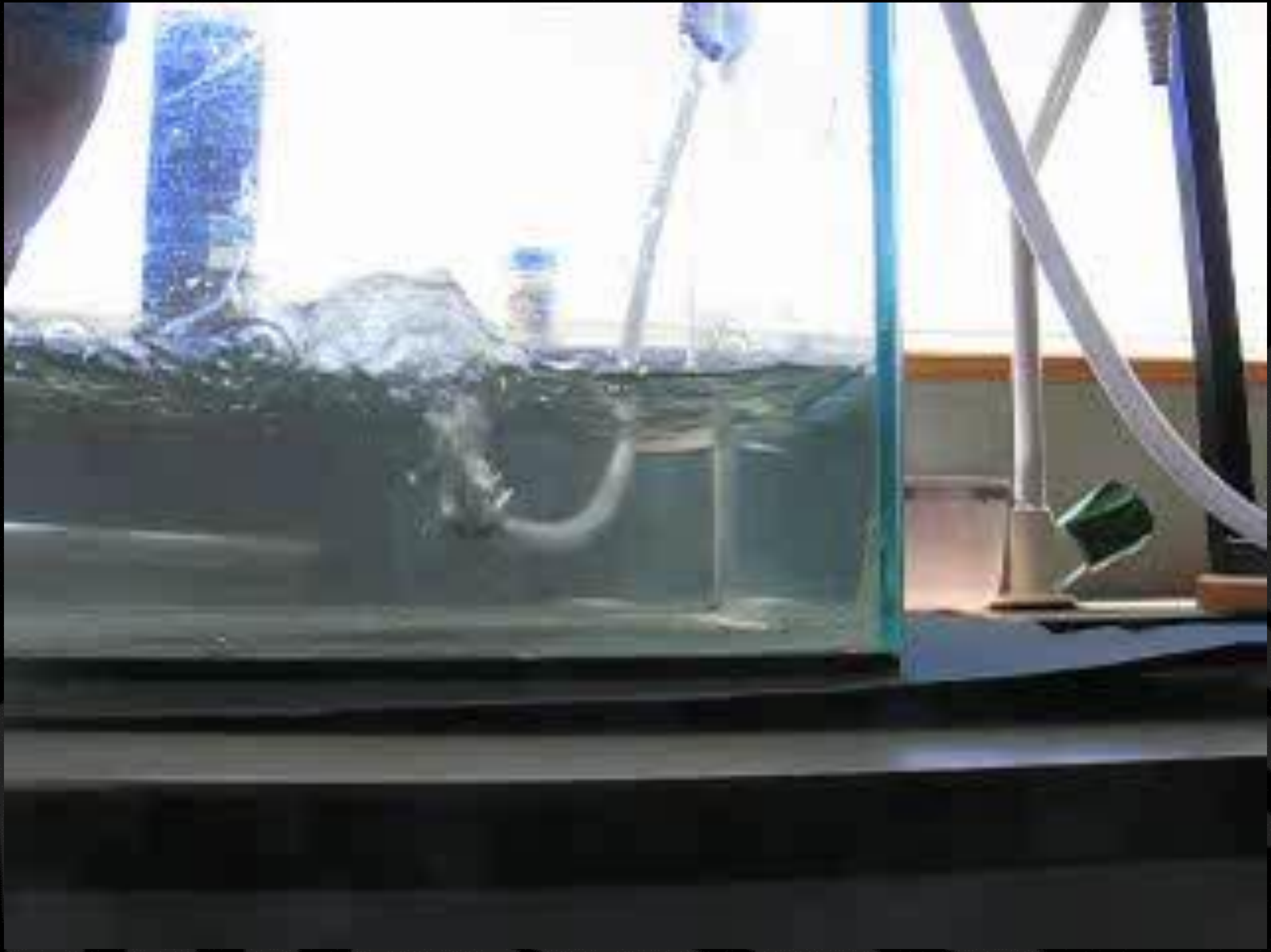
# Experiment 4: volume fraction

- Several trials at high pressures
- 300fps footage to calculate rising time
- Downward displacement of water for 10s

# Setup 1

- Wooden ball in tank of water; bubbles from an air blower through a tube

# Setup 1



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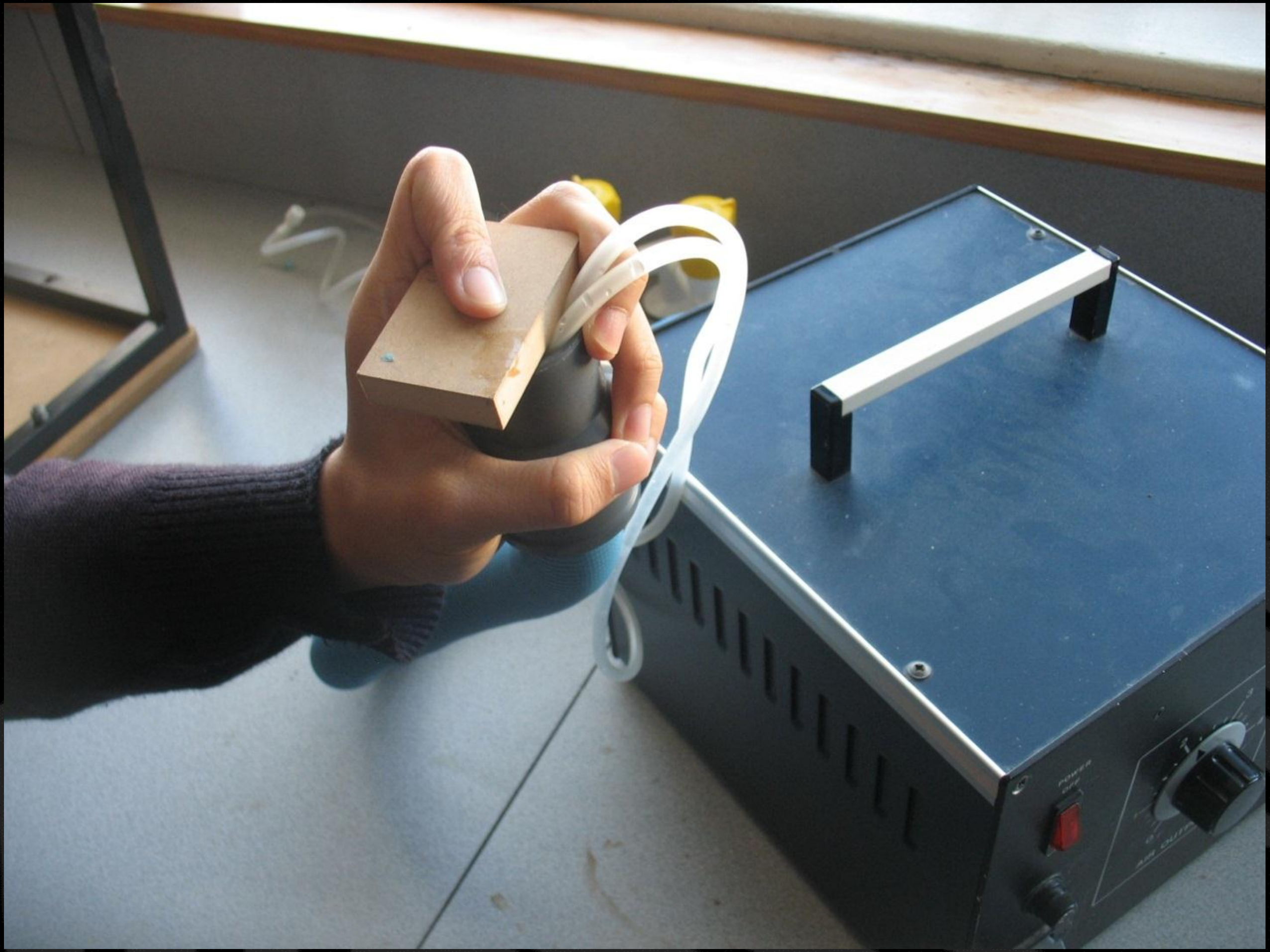

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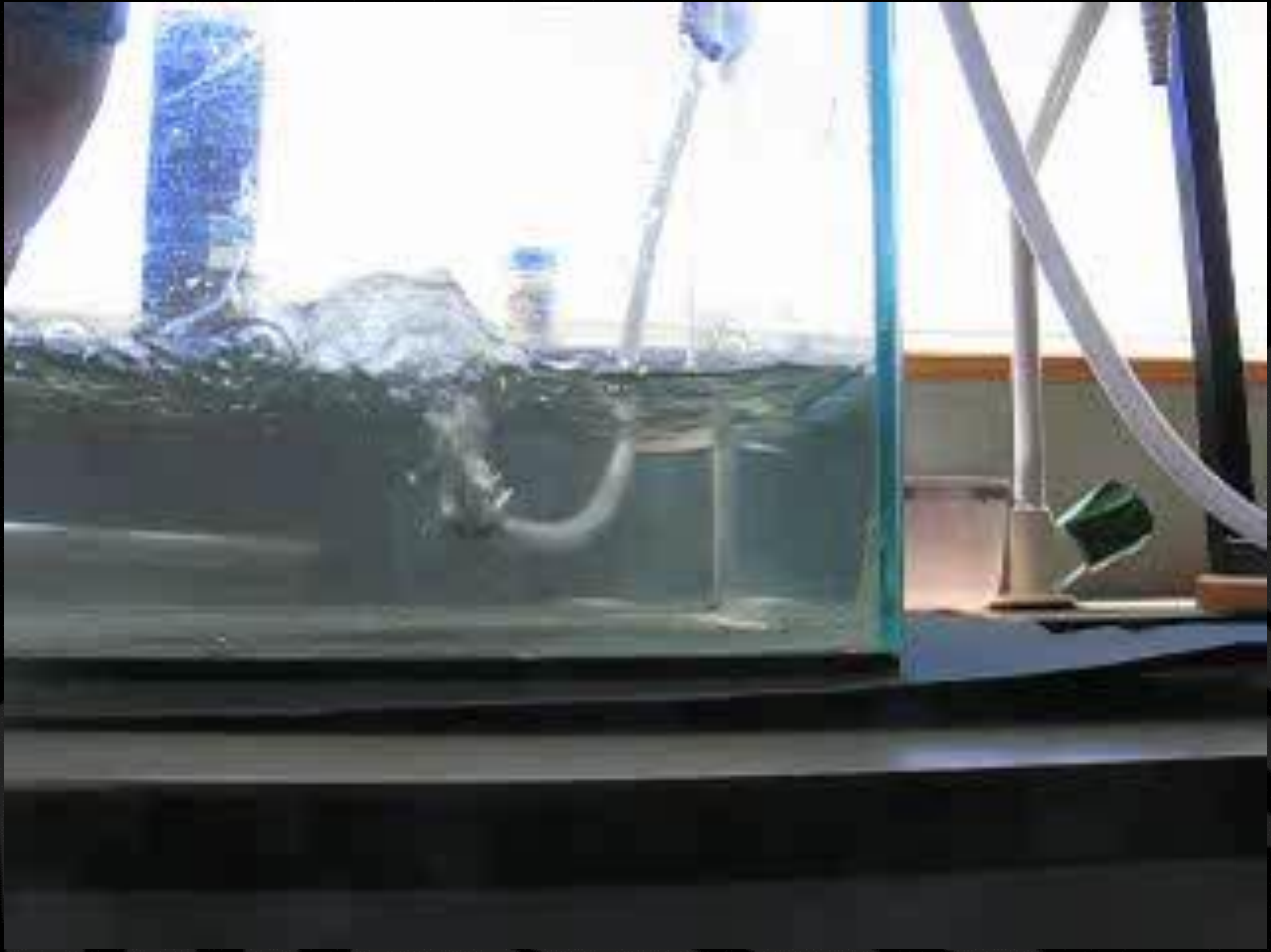
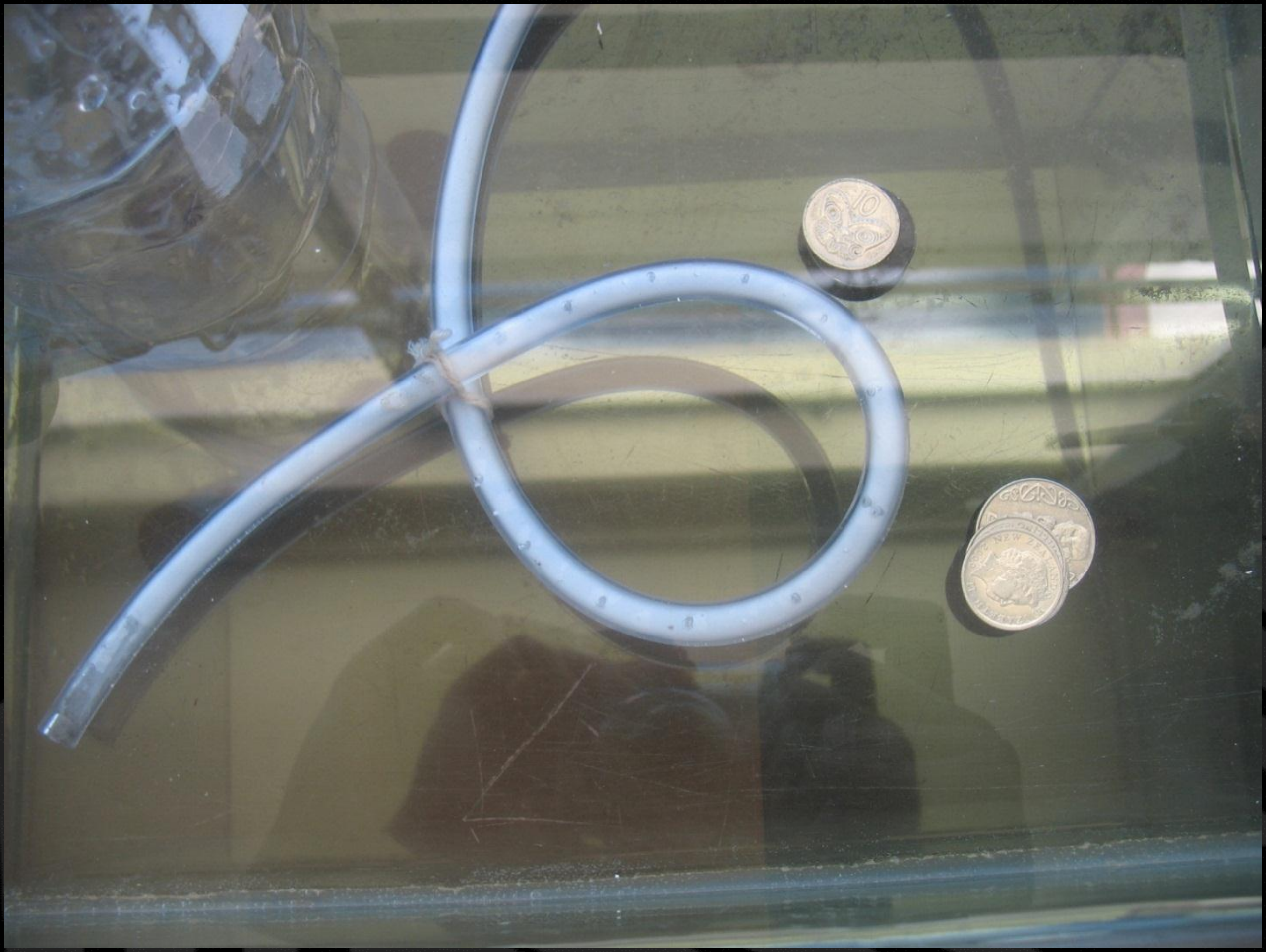


# Setup 2



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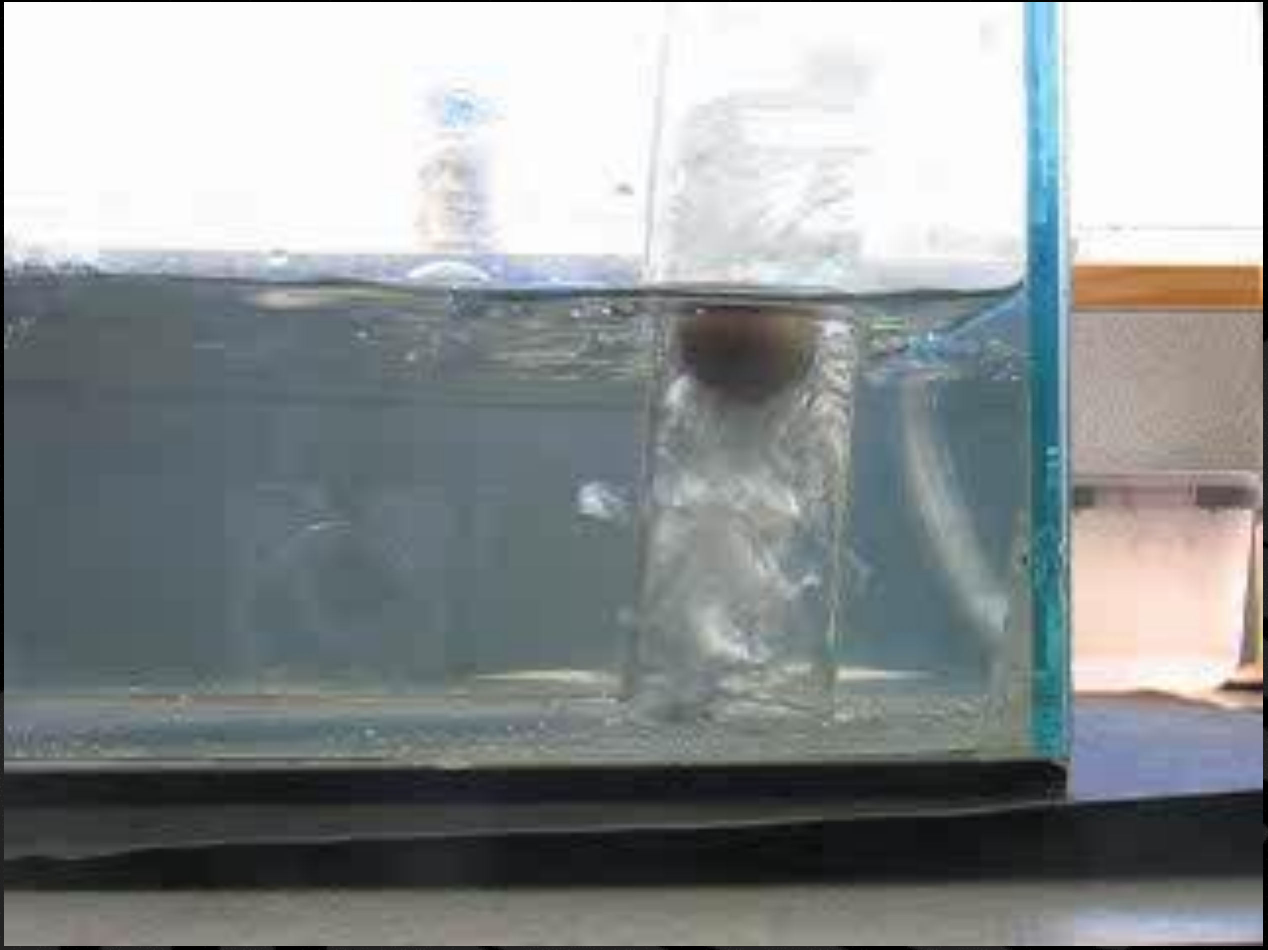

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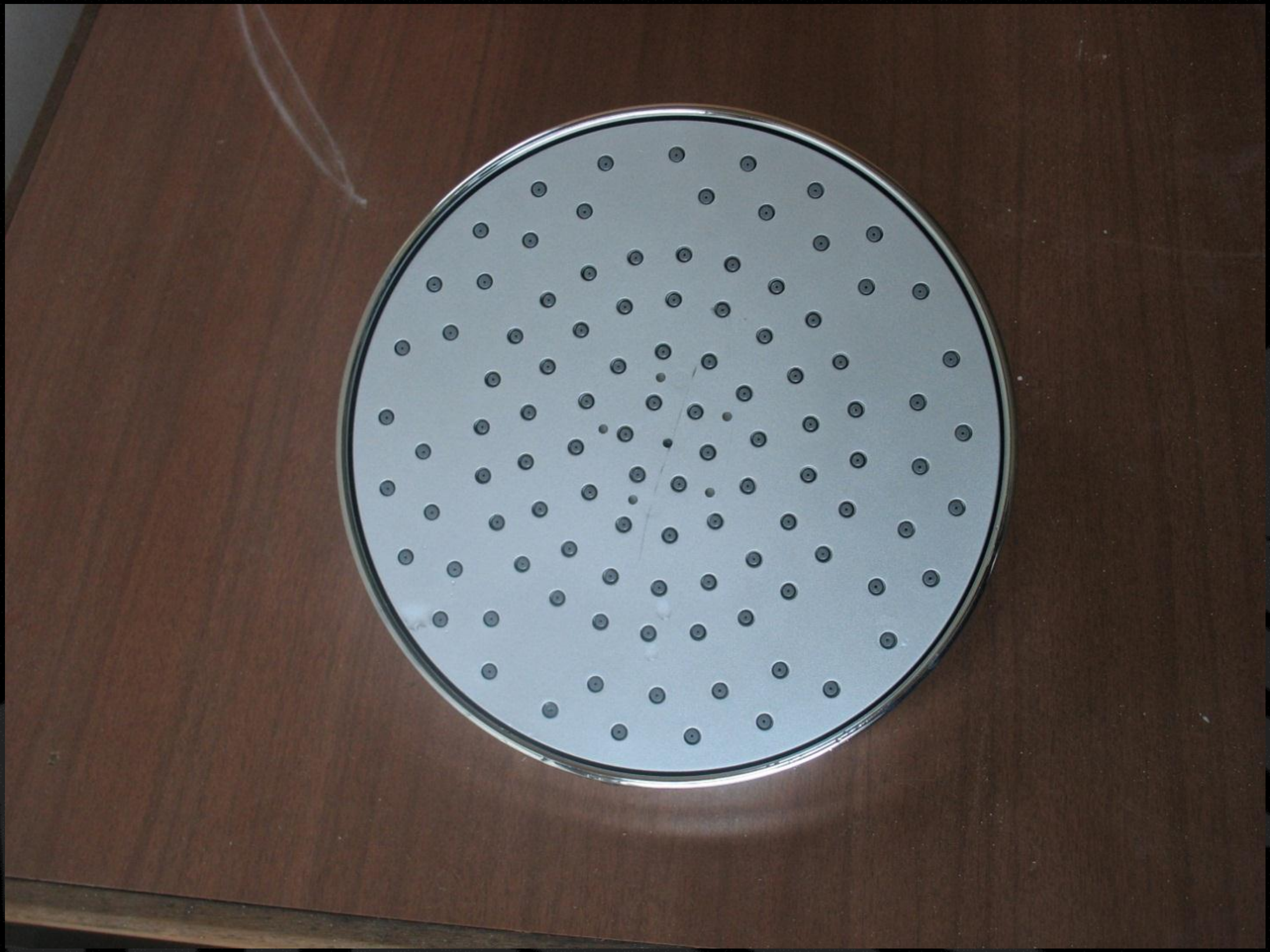


# Setup 3

# Setup 3

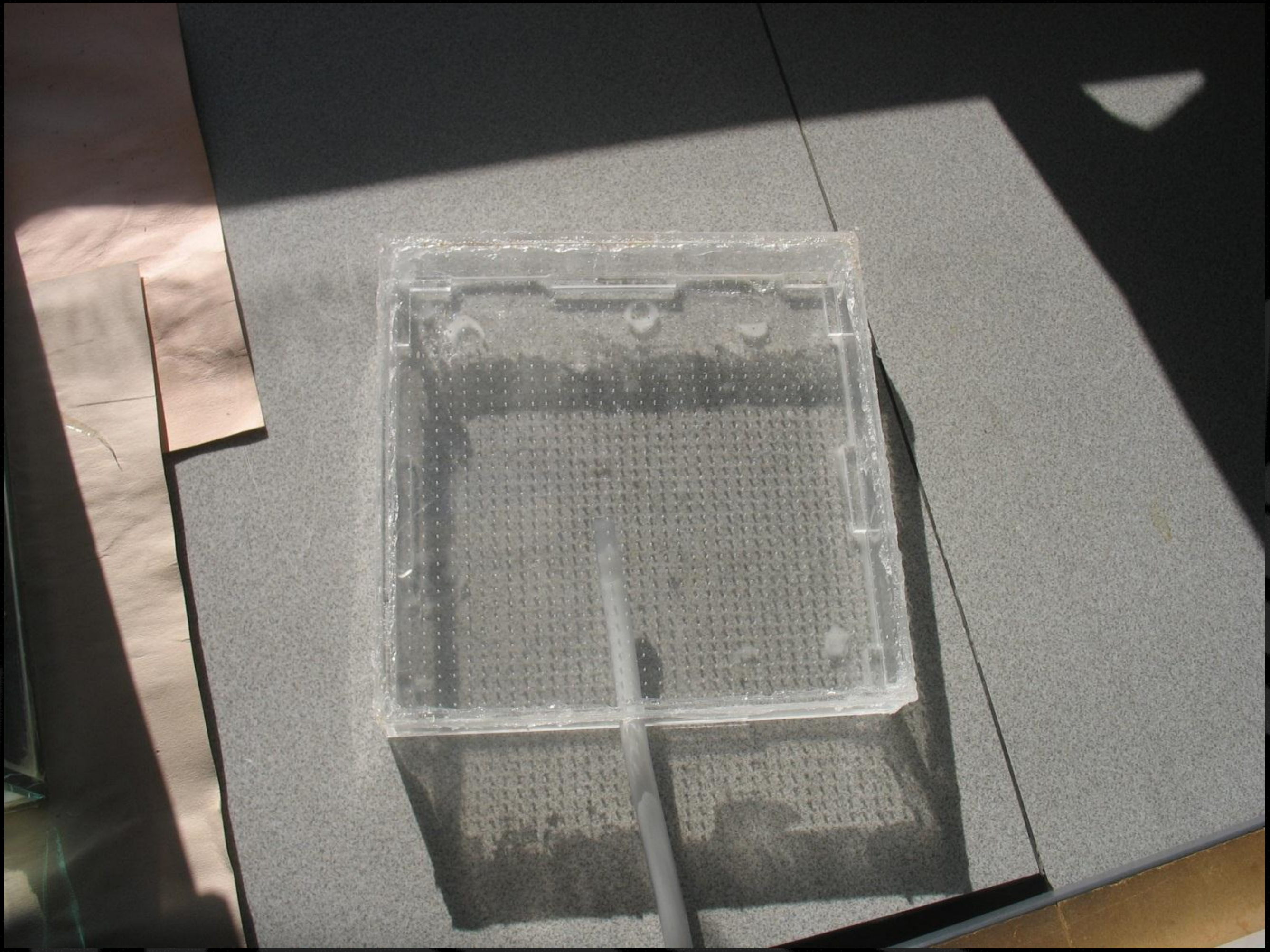
# Setup 3

- Needed uniform bubble field
- Large bubbles not ideal. Choppiness will destroy “Titanic” and “tinfoil”,
  BUT does nothing for wooden ball
- This “wooden” flotation seems the most central idea

# Setup 3

- Wanted fine bubbles, hopefully less turbulence – investigate average density hypothesis
- Strong, steady air supply
- Starfish has a small coverage area – suitable to use only with glass tube
- Black tube gave fine, evenly distributed bubbles – versatile

# Setup 4

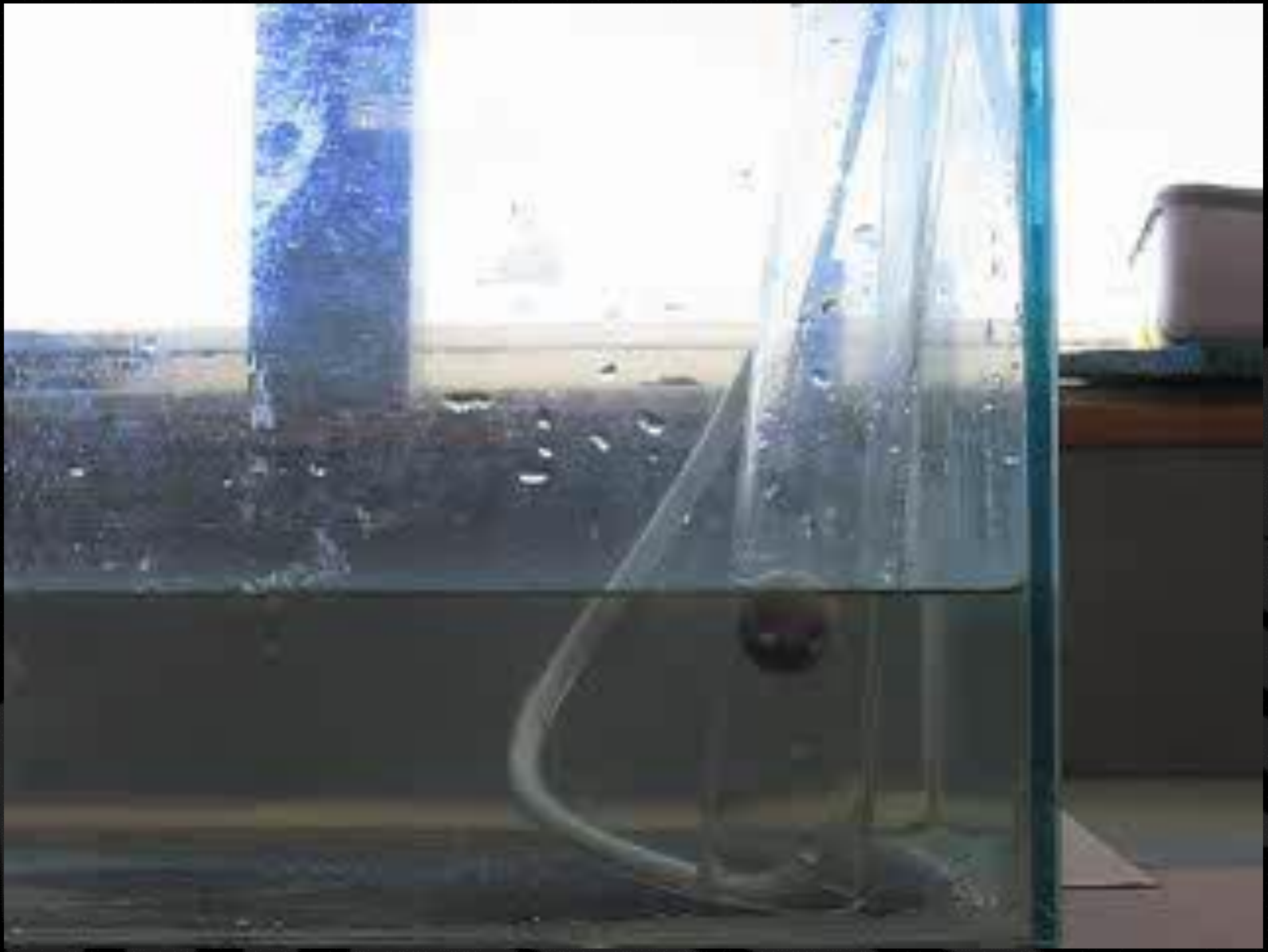


# Different Balls

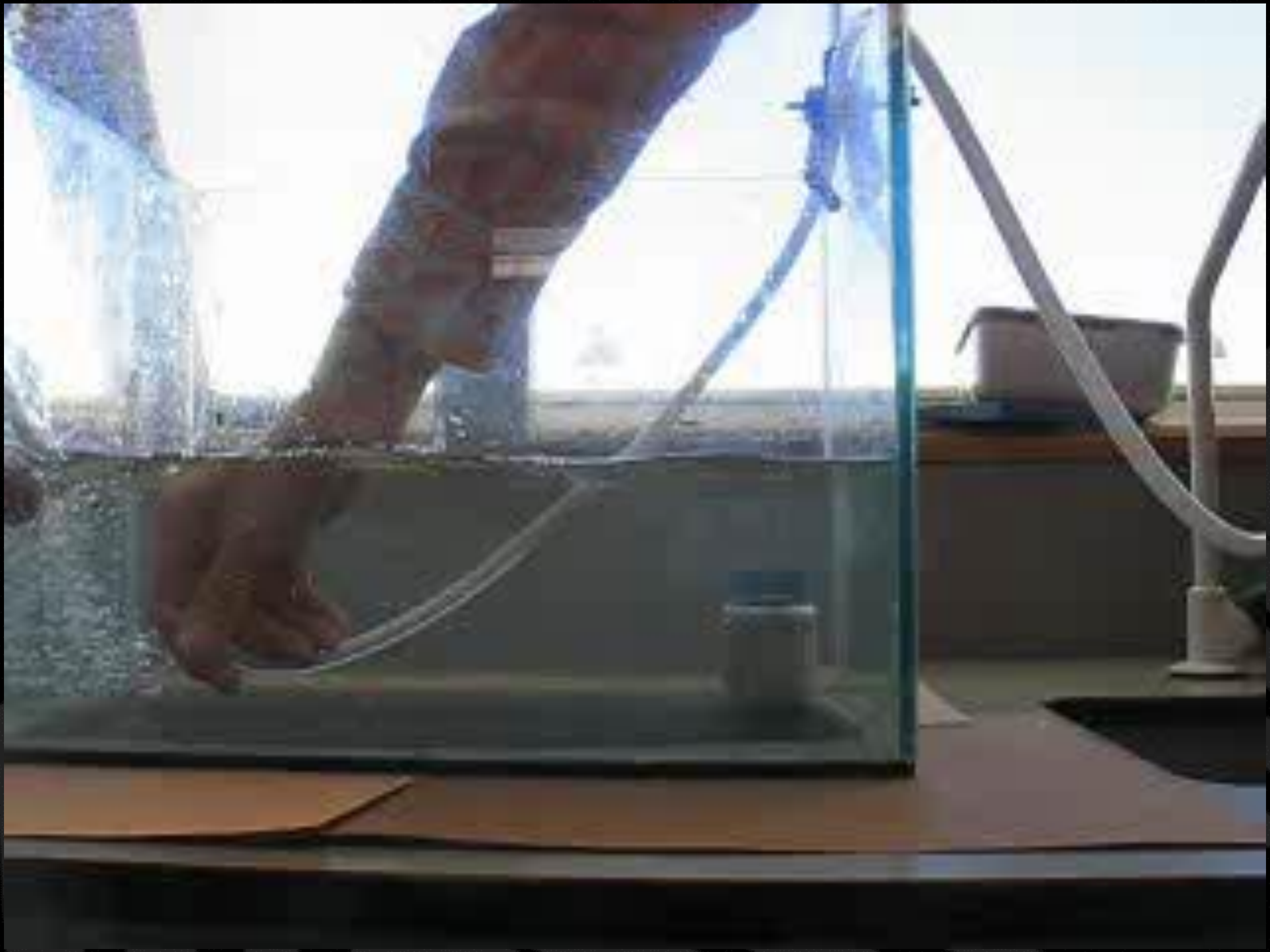
# Bernoulli Effect

- "Faster-flowing fluid has lower pressure"
- Bernoulli equation for incompressible fluid
  $\mathrm{P} + \rho g h + \frac{1}{2}\rho v^2 = constant$
- This might be pulling the ball down

# Bernoulli Effect



# Bernoulli Effect



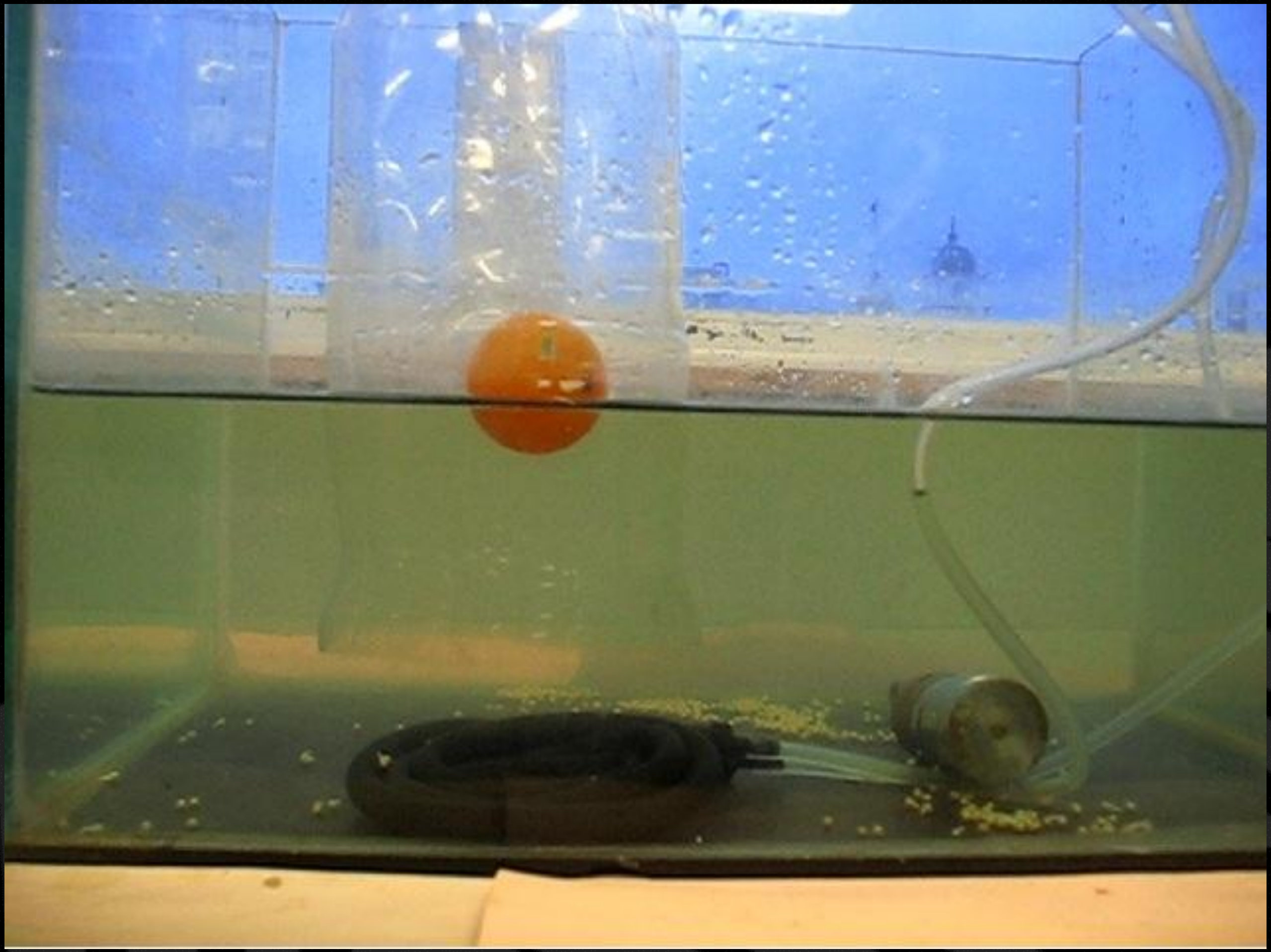
# Bernoulli Effect

- It didn't work in the open tank
- Discarded this hypothesis on further thought: there is no region that remains at higher pressure
- More likely to be water currents flowing downwards

# Density Threshold

- Balls of different densities behave differently
- Only balls above a certain threshold density will sink

# Density Threshold



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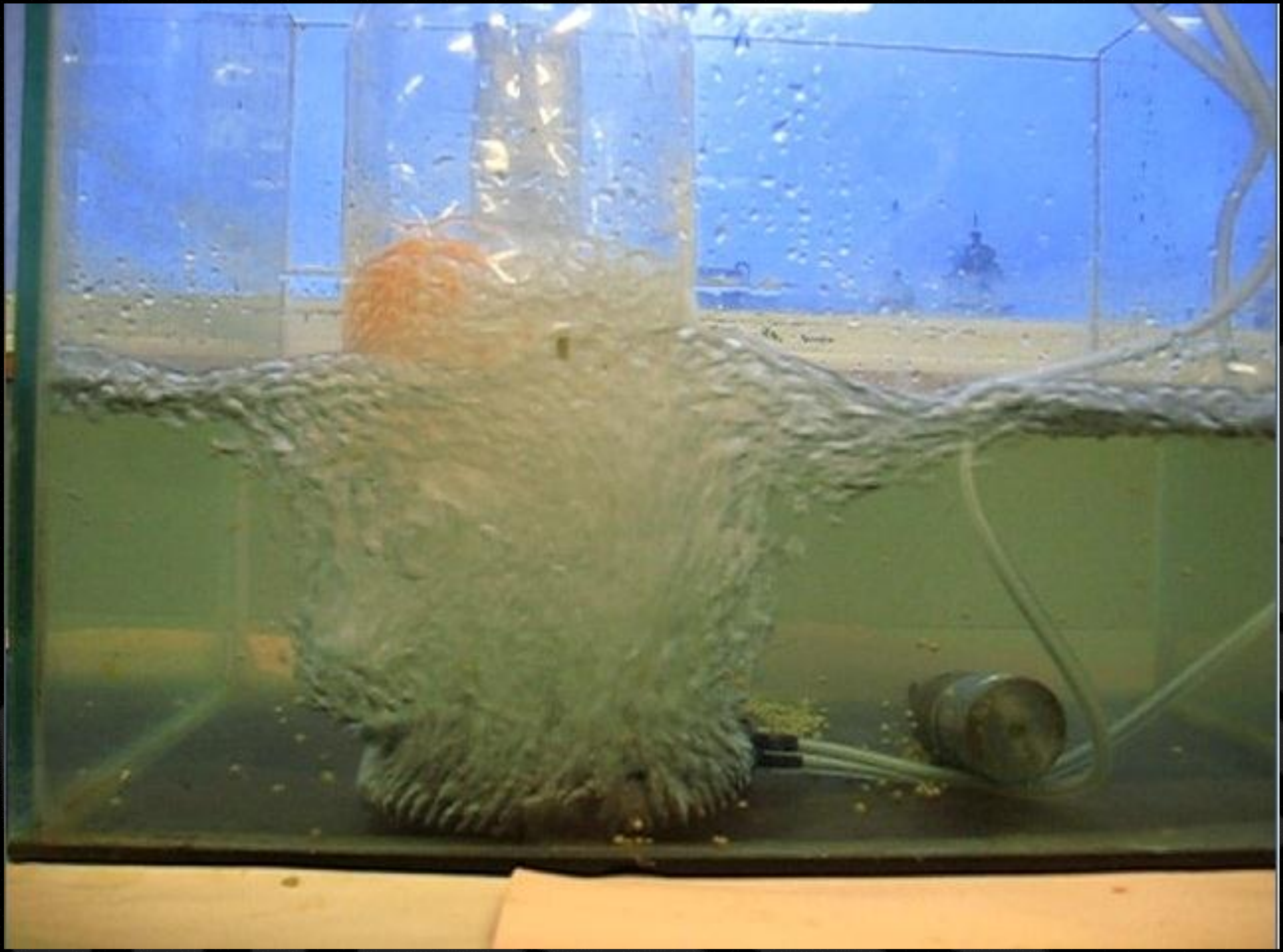


# Density Threshold

- Experimented with changing the density of ping pong balls – injected water into them

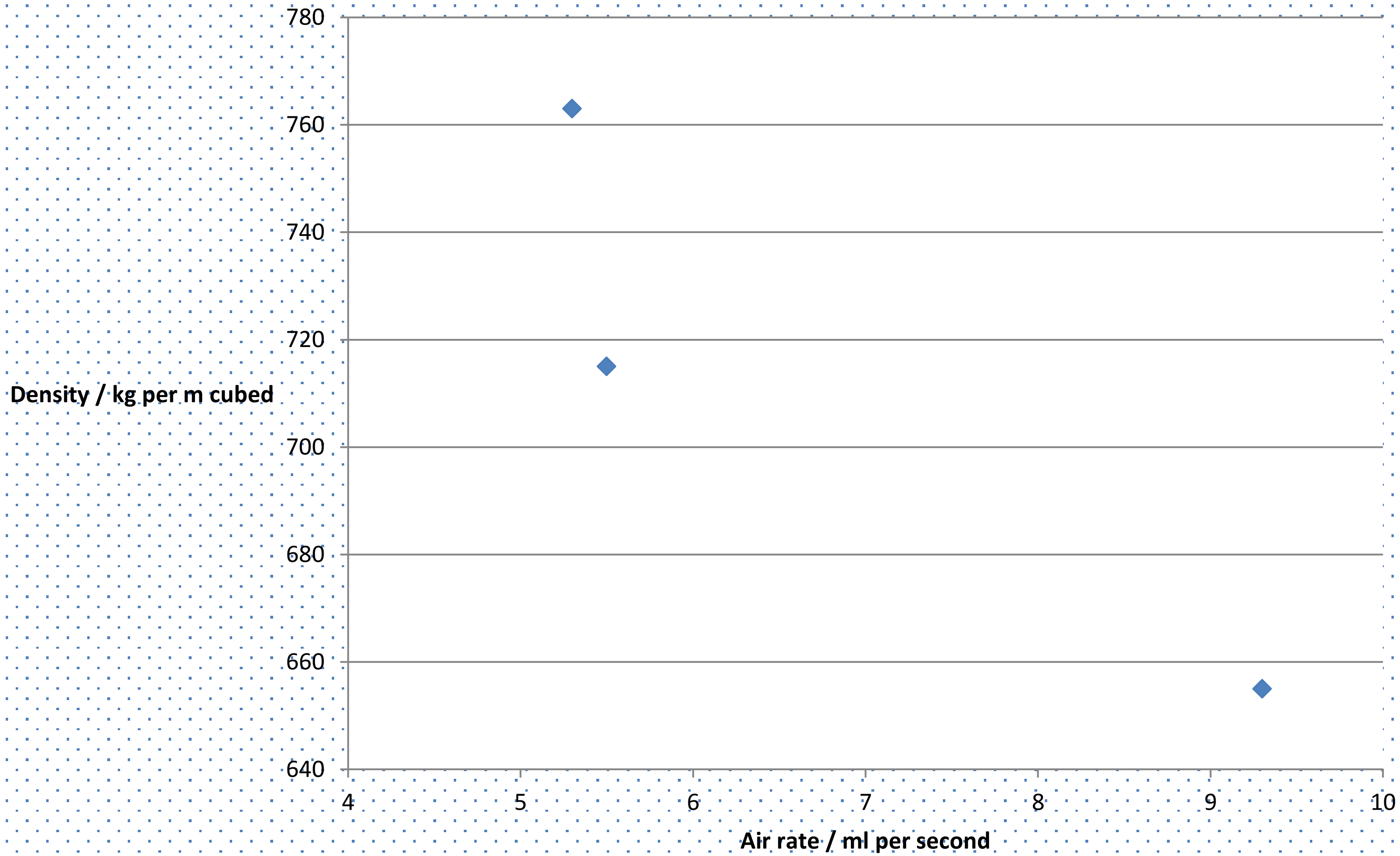
# Density Threshold

| Mass / g | Sink – Yes or No |
|---|---|
| 24.07 | Yes |
| 23.68 | Yes |
| 22.68 | Yes |
| 22.07 | Yes |
| 20.49 | No |

| 21.20 | Yes |
|---|---|
| 20.98 | No |

∴Threshold is in the range 20.98 – 21.20 grams
i.e. $21.09 \pm 0.11$ g

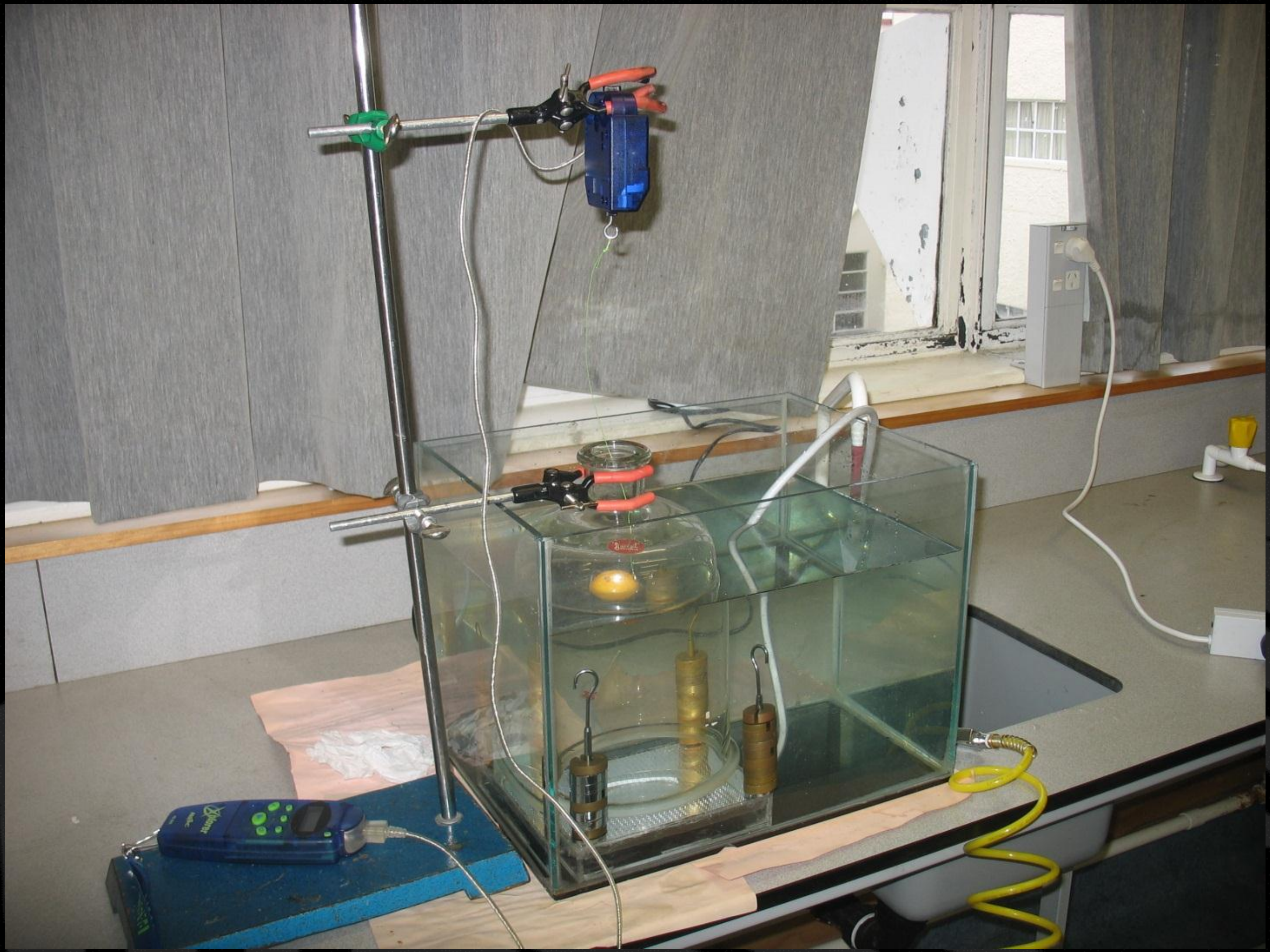
# Threshold Density vs Air Rate



# Density Threshold

- Not much of a trend – only 3 points
- Seems that density required to sink decreases as air rate increases
- As air rate increases, so does current speed – current is more powerful, and better able to overcome buoyancy force

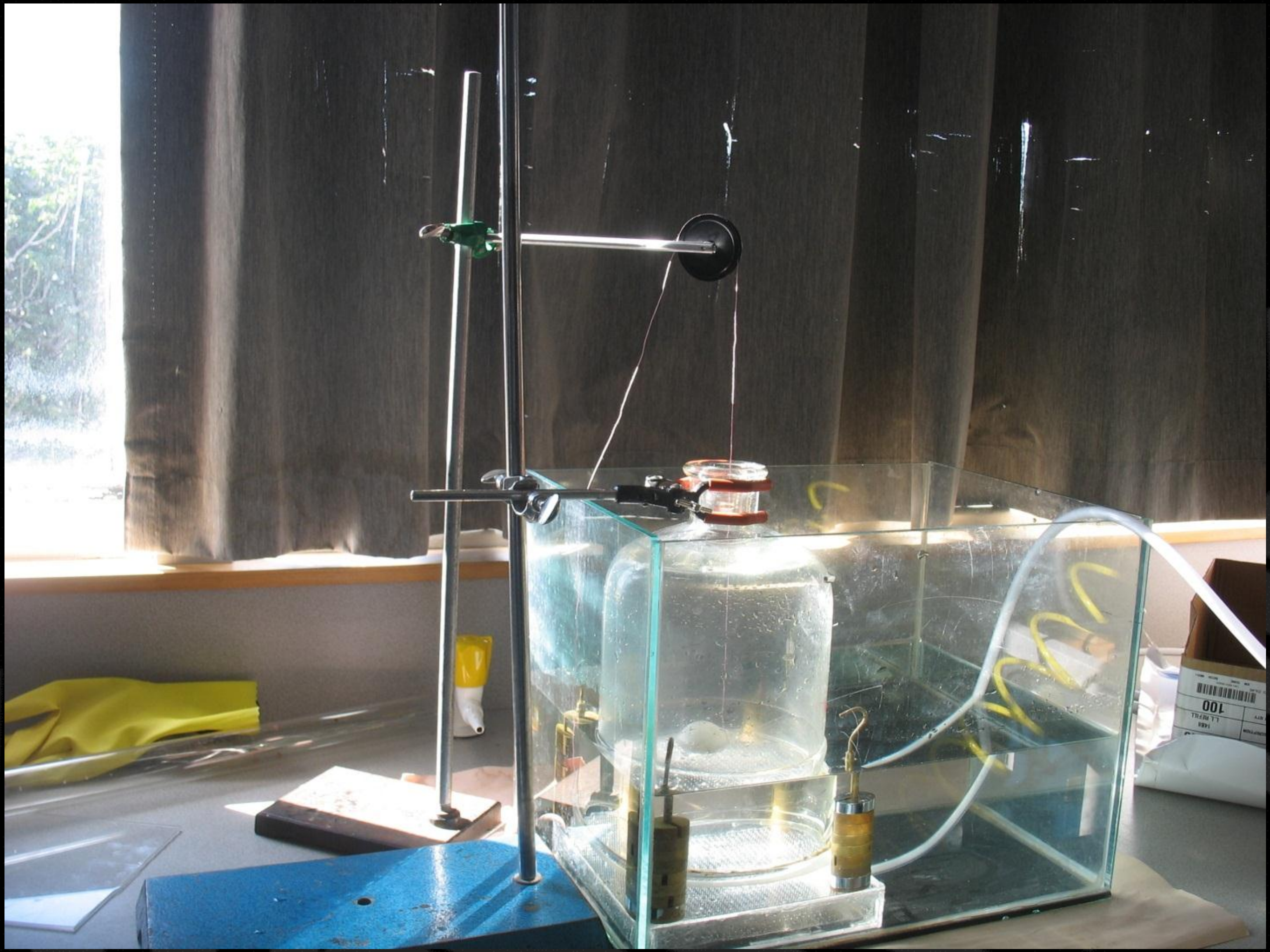
# Forcemeter



# Forcemeter

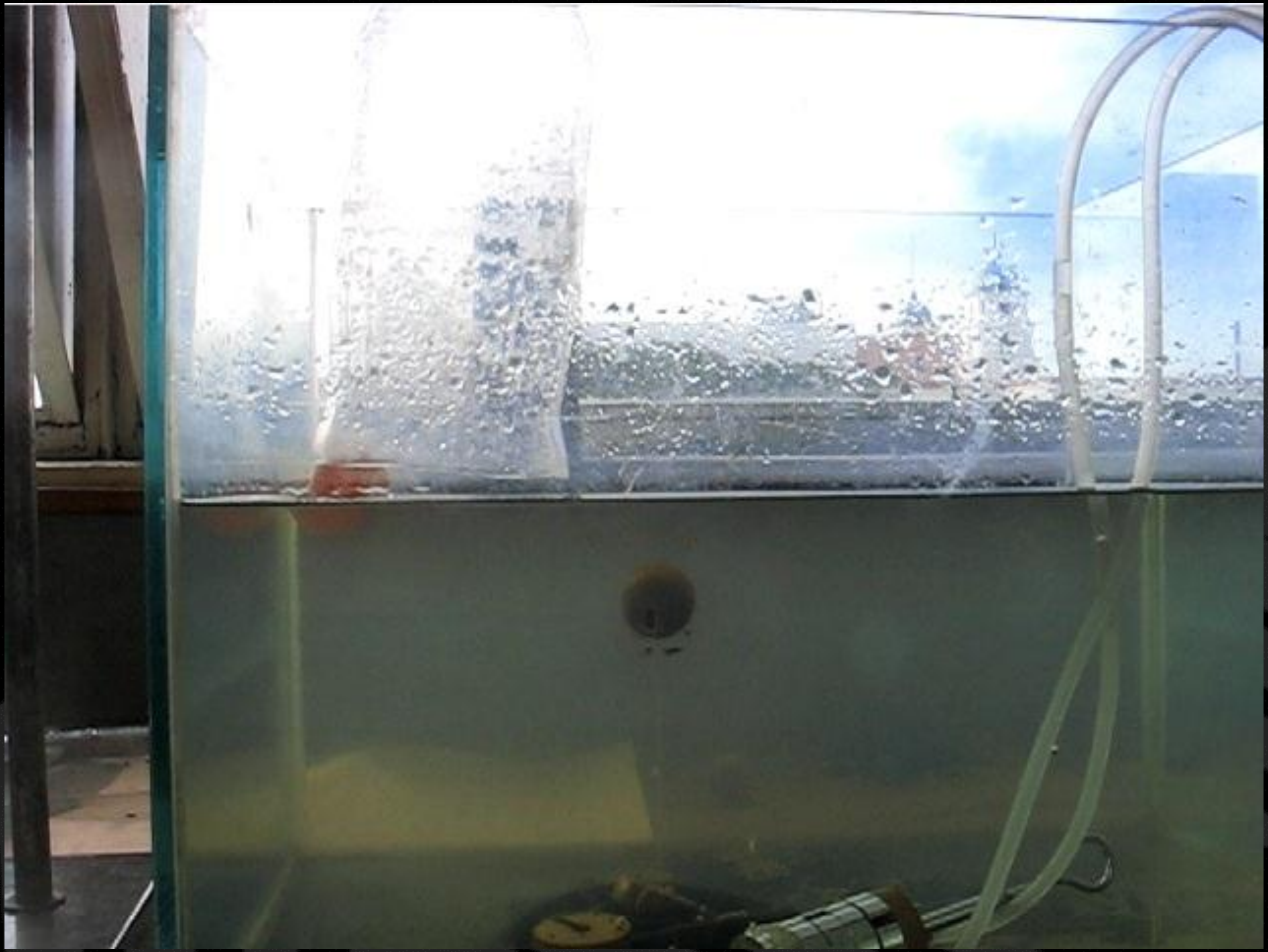
- Not sensitive enough
- Data logger display to the nearest 0.01N
- Sometimes read 0.01N, sometimes 0N

# String

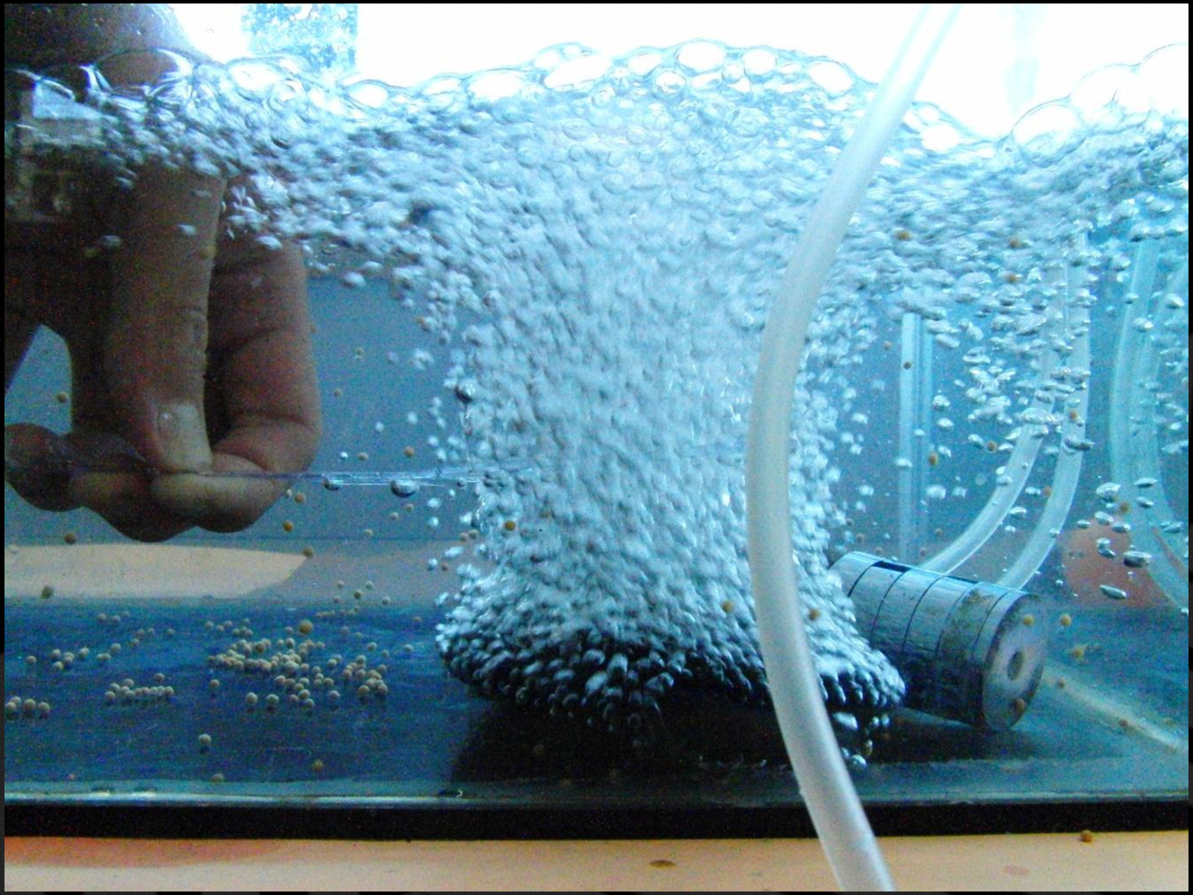


# String

# Upthrust



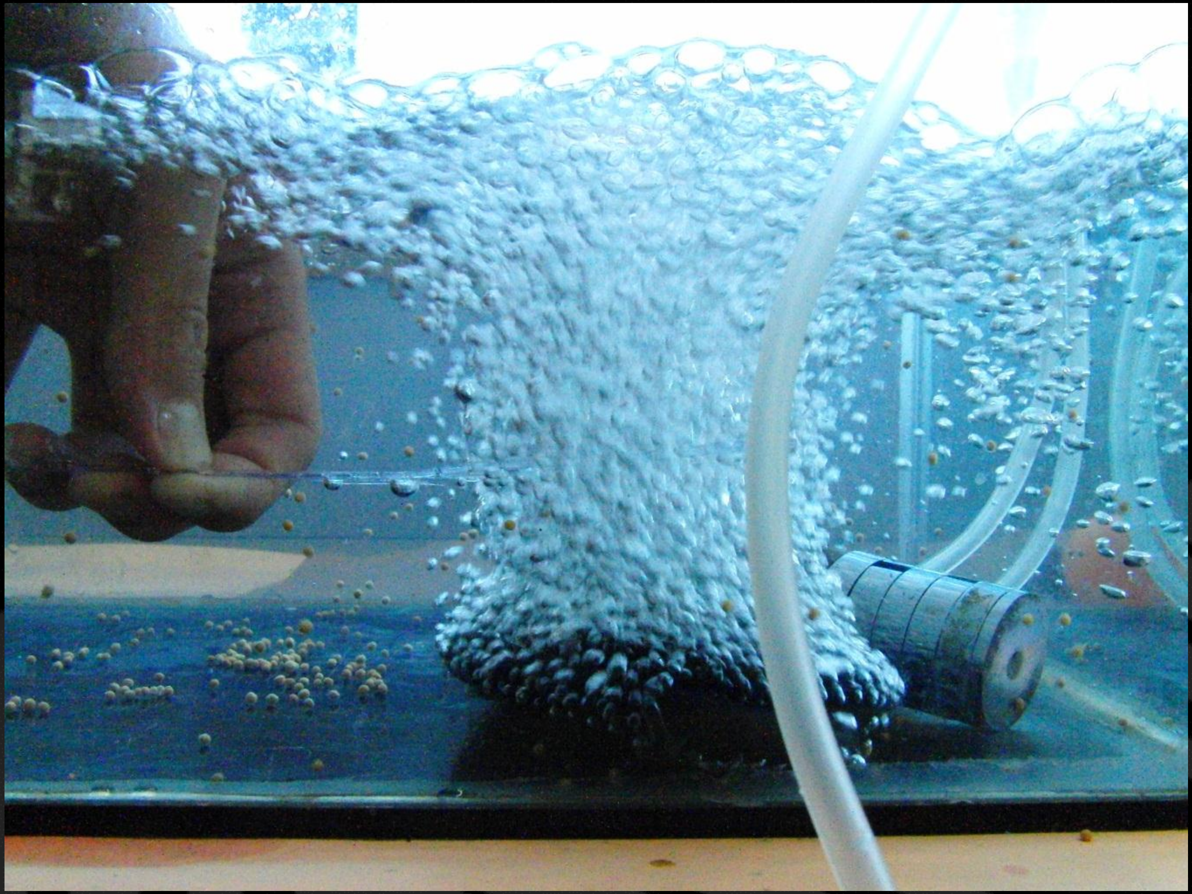
# Upthrust



# Current

- As fluid flows past the ball,
  a force is caused by the **change in momentum of the water and/or air** – both bubbles and water are rising in the centre
- Fluid has to slow down / change its path (i.e. velocity) to go around the ball
- Force known as drag

# Current



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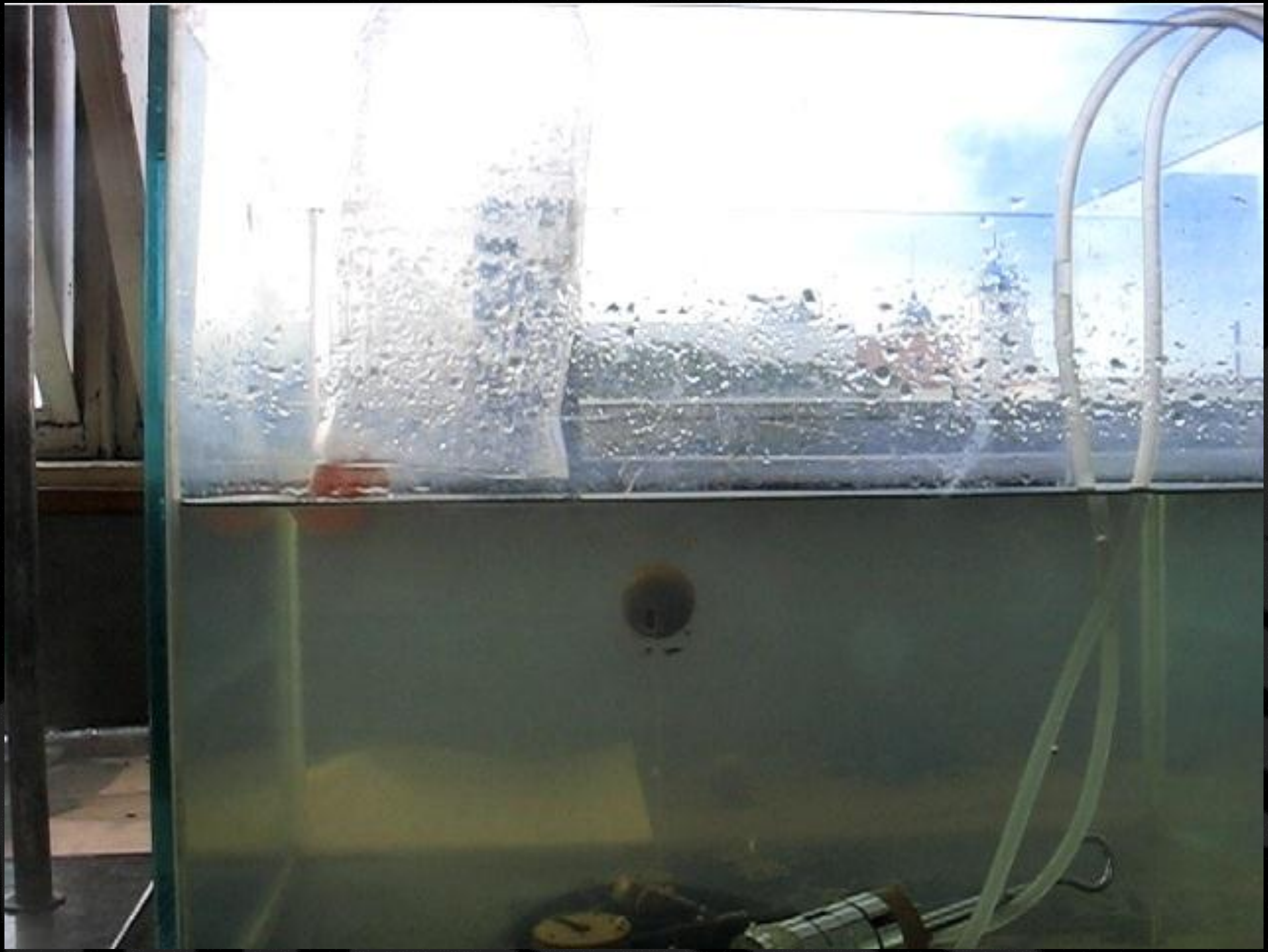

# Unanswered Questions

- What is the effect of bubbles on a boat shaped object?
- Why is the current so different in different-sized containers?
- What is the effect of container shape?
- More detailed investigation on the effect of bubble size – finer/wider range
- What happens in an “ocean” scenario?
- Investigate other “surface tension” materials
- Carbonated water

# Drag

$$F_D = \frac{1}{2}\rho v^2 A C_d$$

$F_D$ is the force of drag

$\rho$ is the density of the fluid

V is the relative speed of object and fluid

A is the cross-sectional area

$C_d$ is the drag coefficient

College Physics, Vol 1. Nicholas Giordano. Cengage Learning.

# Bubble Momentum

*Momentum equation for the gas phase*

$$\frac{\partial\left(\alpha_g \rho_g \boldsymbol{v}_g\right)}{\partial t} + \nabla\cdot\left(\alpha_g \rho_g \boldsymbol{v}_g \boldsymbol{v}_g\right) = -\alpha_g \nabla p_g$$

$$+\nabla\cdot\left[\alpha_g\left(\boldsymbol{\mathcal{T}}_g^{\mu} + \boldsymbol{\mathcal{T}}_g^{T}\right)\right] + \alpha_g \rho_g \boldsymbol{g}$$

$$+\Gamma_g \boldsymbol{v}_{gi} + \boldsymbol{M}_{ig} - \nabla\alpha_g \cdot \boldsymbol{\mathcal{T}}_{gi} + \left(p_{gi} - p_g\right)\nabla\alpha_g$$

Thermo-Fluid Dynamics of Two-Phase Flow. M. Ishii, T. Hibiki