5. PROBLEM № 11: WATER DROPLETS

SOLUTION OF NEW ZEALAND

Problem № 11: Water Droplets
/Power Point Presenmtation/

The problem

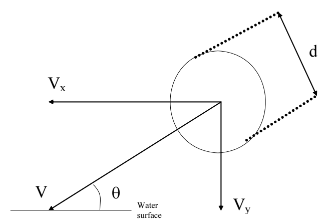
- *If a stream of water droplets is directed at a small angle to the surface of water in a container, droplets may bounce off the surface and roll across it before merging with the body of water. In some cases the droplets rest on the surface for a significant length of time. They can even sink before merging. Investigate these phenomena.*

Definition of question

- **Droplets**; spherical balls of water
- **Bounce**; the droplets, after impact with the water surface must rebound off.
- **Roll**; the droplets don't coalesce with the water surface as they float on the surface while rotating.
- **Merging**; when the droplet coalesces with the water in the container.
- **Investigate**; Explore the nature as to why these phenomena happen and what will affect these phenomena.

Parameters of the problem

Diagram of a droplet

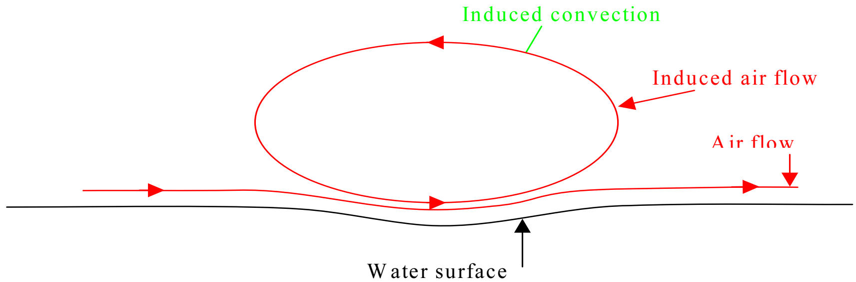


- Droplet diameter (d)
- Impact velocity (V)
- Vertical component of V (V_y)
- Horizontal component of V (V_x)
- Bounce height (b)
- Incident angle (θ)

Theory (why the droplet doesn't mix with the water surface)

- The droplet doesn't coalesce with the water surface.
- The reason for this non-coalescence is because of gas lubrication.
- This is when a very thin layer of air is trapped between the interface.

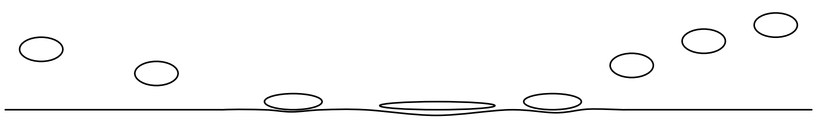
Diagram of gas lubrication



Theory (bouncing)

- The effect of gas lubrication has to be sufficient to maintain separation.
- The downwards momentum makes droplet spread out, creating a dimple in the water surface.
- They recoil to their original states, if this is forceful enough, the droplet will rebound of the water surface.

Sequence of droplet bounce



Theory (rolling)

- If V_x is large enough to maintain sufficient gas lubrication, the droplet won't coalesce.
- But if V_y is too small the droplet doesn't exert a large enough force on the water surface.
- So it will instead roll across the surface until V_x becomes to small.
- Then it will coalesce.

Theory of sinking droplets

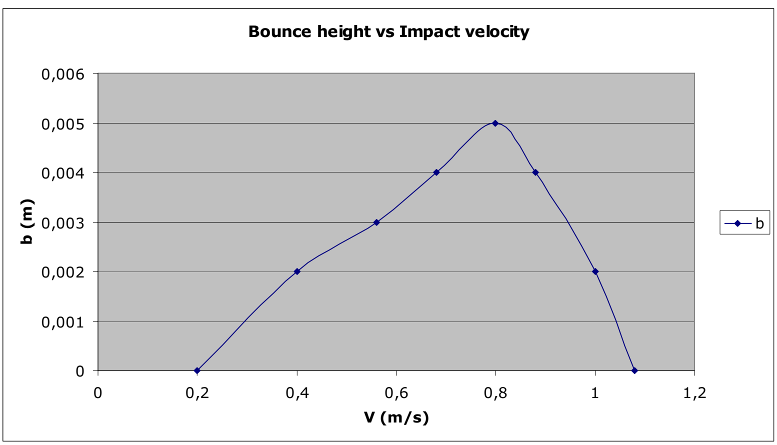
- Heat capacity of a droplet is very small.
- This causes the density to drop.
- It also increases the surface tension of the droplet.
- The droplet must break the surface.
- This can be done be weight (>4mm d) or downwards momentum.

Theory of sinking droplets

- For this to occur the droplet cannot be allowed to coalesce.
- This non-coalescence occurs again because of gas lubrication.
- Initial air flow under the droplet causes the droplet to rotate.
- A layer of air will fully enclose the droplet and circulate around it maintaining separation.

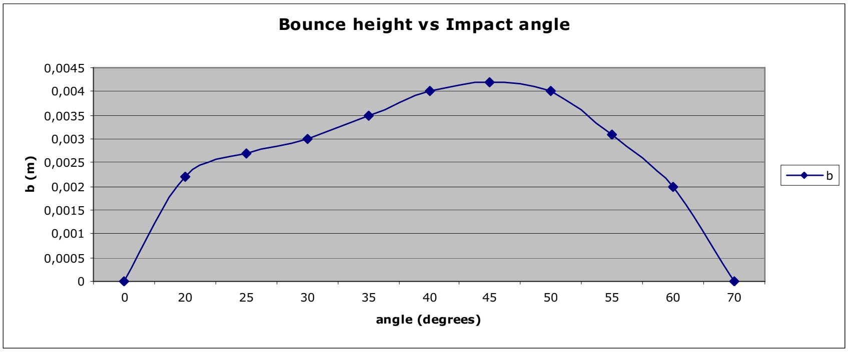
Theory (V)

- The more kinetic energy it has the more kinetic energy can be converted into potential energy.
- Therefore the higher it can bounce.
- The greater V the longer the collision time.
- The more energy loss.
- The lower the bounce height.
- There will be optimum V for any given θ.



Theory (θ)

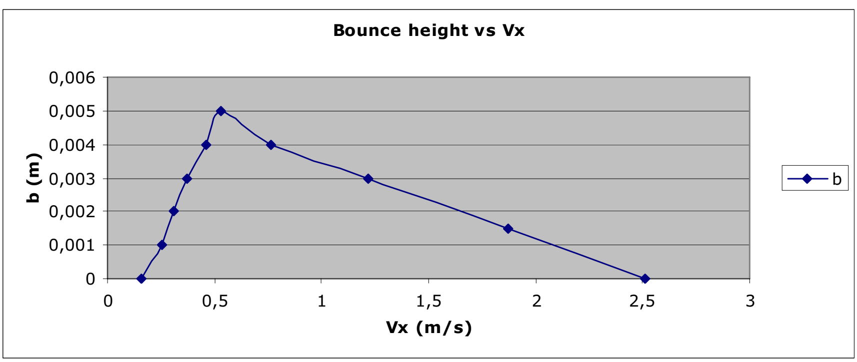
- The less θ is the greater V_x is in relation to V_y.
- The greater θ is the more force the droplet can apply to the surface
- So there is also an optimum θ for a given V.
- At a lower V a greater θ is better and at a higher V a smaller θ is better.



Theory (V_x)

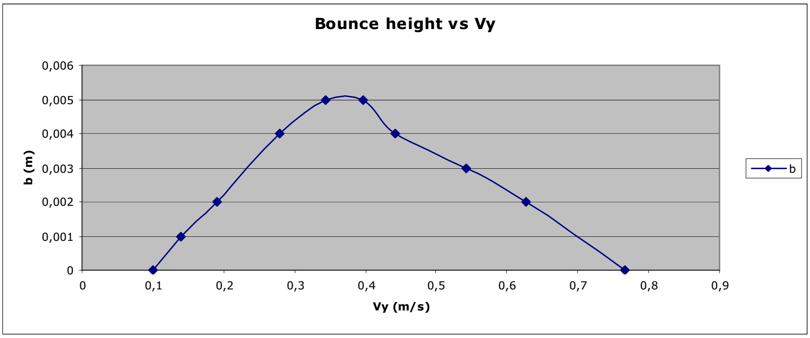
- Greater V_x means better gas lubrication.
- Hence more downwards force it can overcome.
- Hence the higher it can bounce.
- Greater V_x also means greater V hence a longer the collision time.
- Therefore the more energy

loss there is.



Theory (V_y)

- Greater V_y means more downwards force exerted by the droplet.
- The effect of gas lubrication has to also increase to cope with the extra downwards force.
- Greater V also means a longer collision time.



Theory (d)

- Smaller d means a higher ratio of surface tension to volume.
- Therefore the more robust the droplet is.
- Therefore the higher V the droplet can withstand and not break up.
- Also the more efficient the collisions are.

Video of small/large droplets

Conclusion

- The smaller the droplet diameter the higher it bounces
- There will be an optimum impact velocity (V) for any given angle (θ).
- To gain the highest bounce an increase in V_y must have an increase in V_x .
- For the longest roll time a large V_x is needed with a small V_y and if possible a forwards spin.
- For sinking the faster the spin and the larger the droplet (assuming it stays spherical) the better.

Presentation is supported by the Royal Society of New Zealand