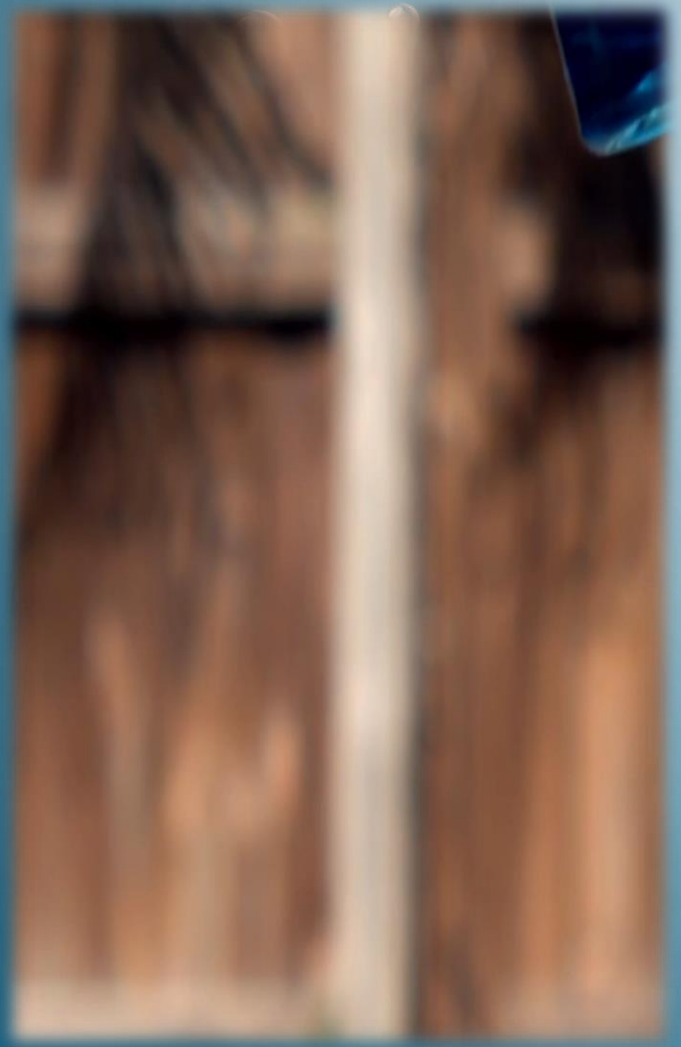


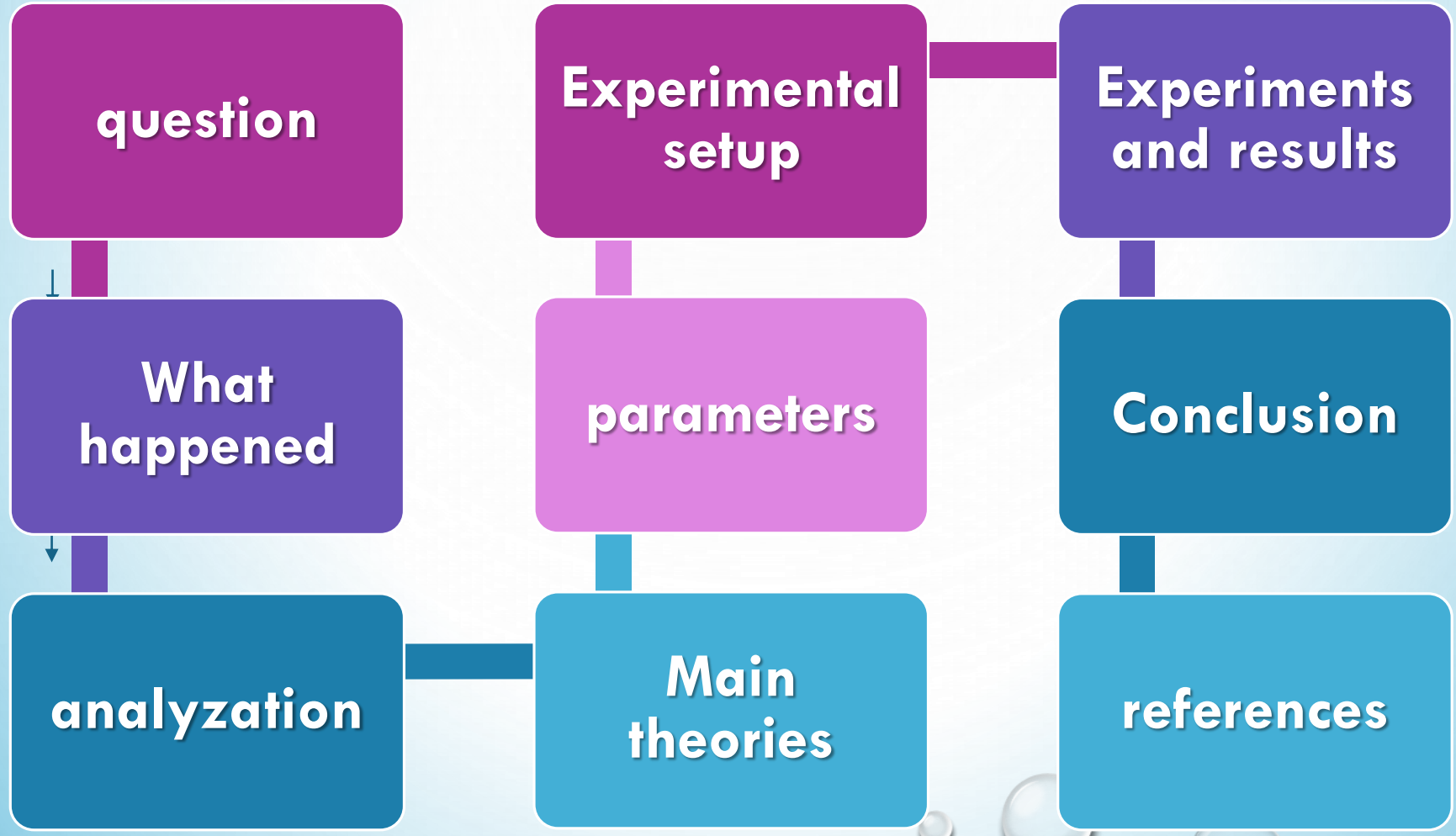
PROBLEM NO.17

WATER BOTTLE

farzanegan3 high school

–

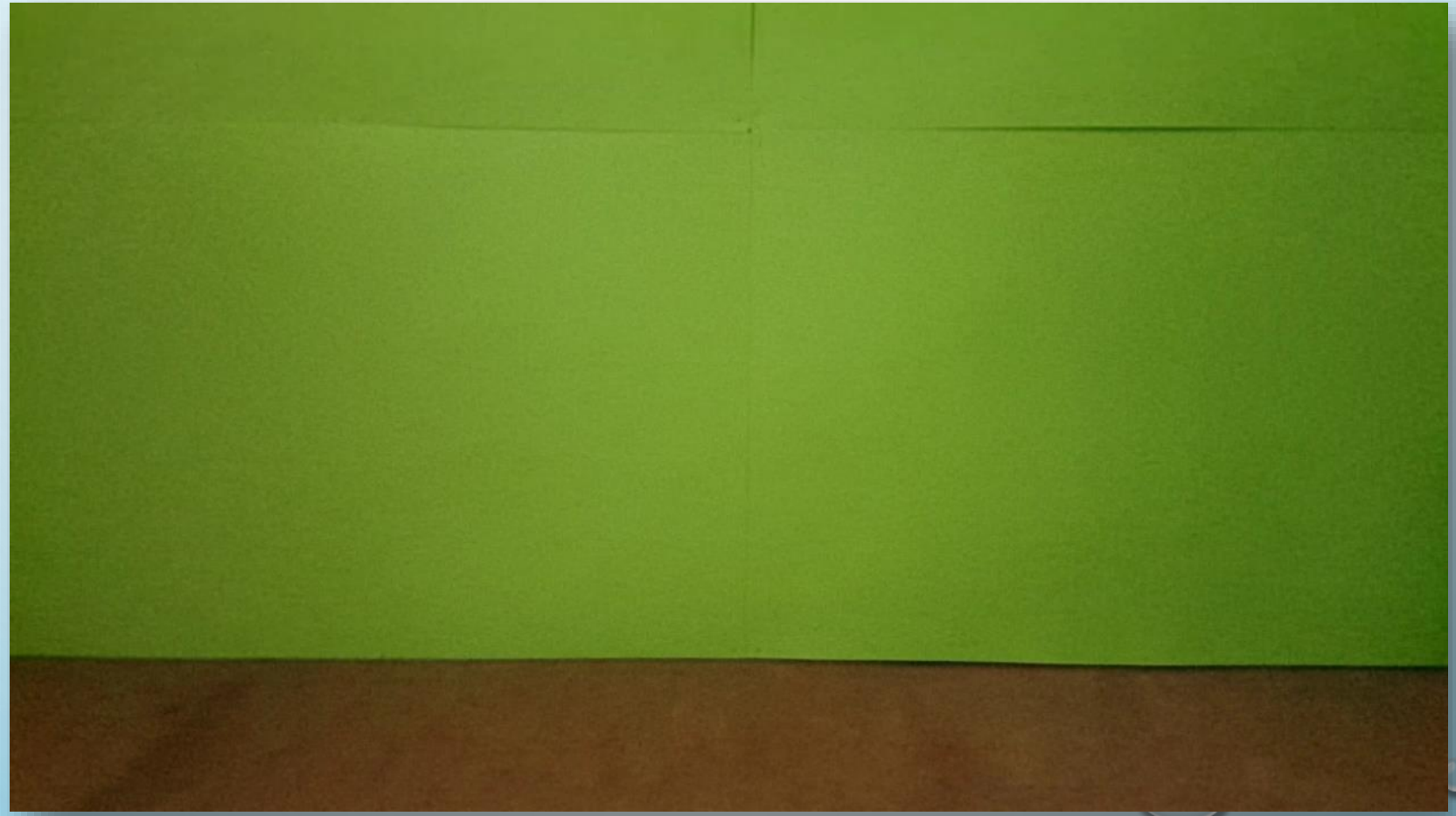
❖ Main approach:



Q.17:Water Bottle

- THE CURRENT CRAZE OF **WATER BOTTLE** FLIPPING INVOLVES LAUNCHING A **PARTIALLY FILLED** PLASTIC BOTTLE INTO THE **AIR** SO THAT IT PERFORMS A **SOMERSAULT** BEFORE LANDING ON A **HORIZONTAL** SURFACE IN A **STABLE, UPRIGHT** POSITION. INVESTIGATE THE PHENOMENON AND DETERMINE THE PARAMETERS THAT WILL RESULT IN A SUCCESSFUL FLIP.

Initial Observation



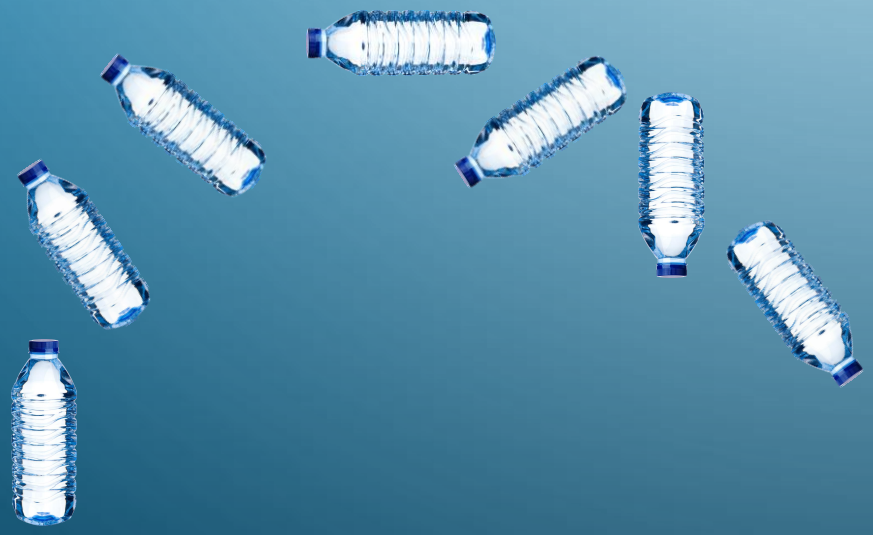
ANALYZATION

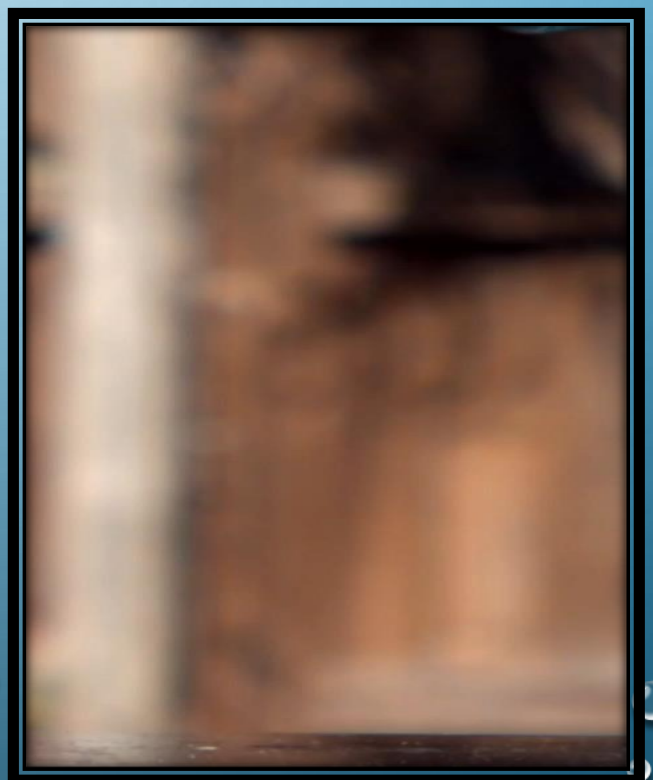
What happened

The flip is made by the flick of wrist, the motion of the water inside the bottle and the force of gravity. The flip could be from neck or cap area.

when the performance is successfully it will land in a stable upright position .

And if it is not successfully it will fall.





What happened

- The increase in the amount of the water causes the bottle to go into free fall in upright position .

Angular momentum

Fluid dynamics

Centripetal force

Gravity

Complex Physics

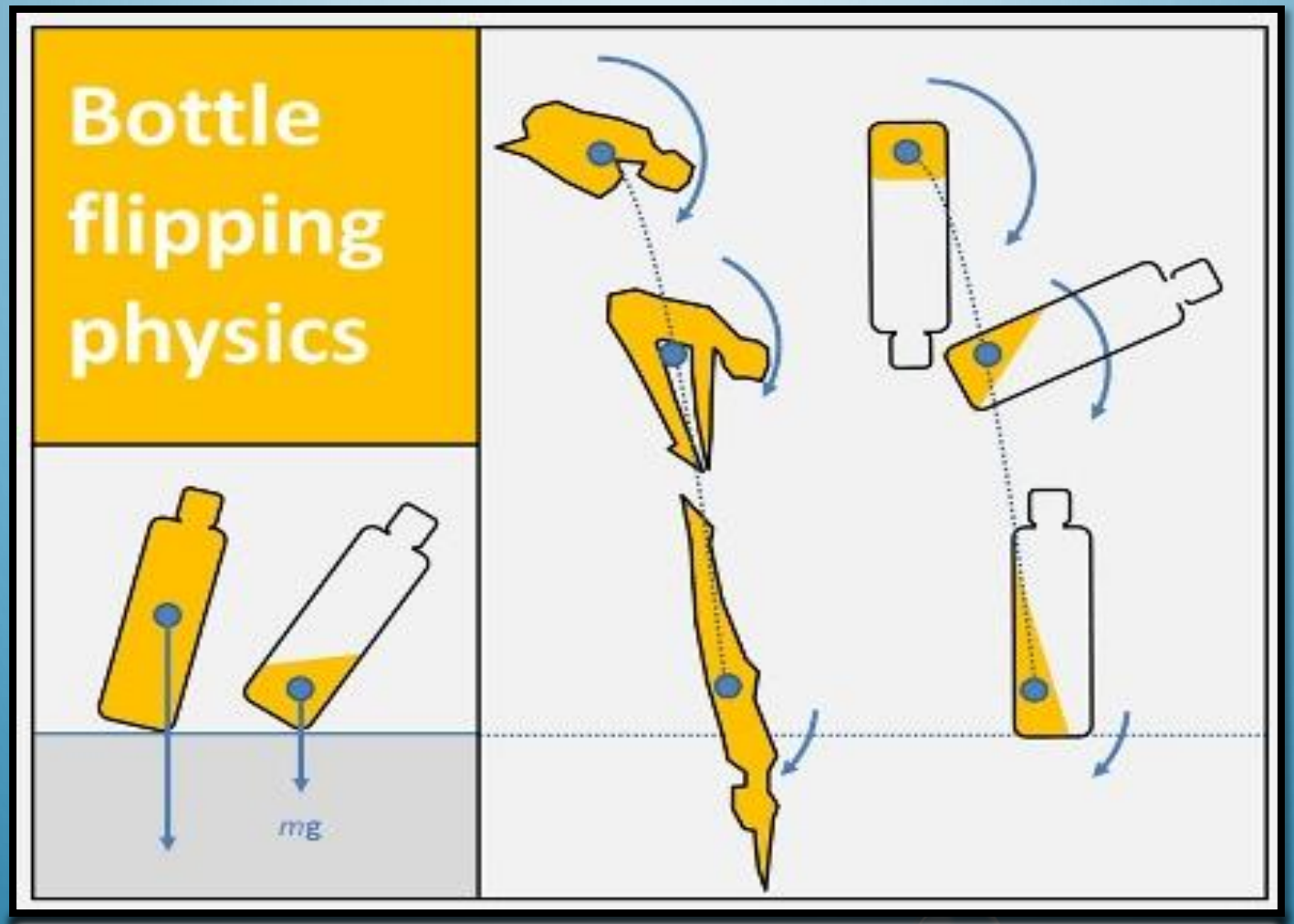
Amount of Fluid and Shape of Water Bottle

Gravity

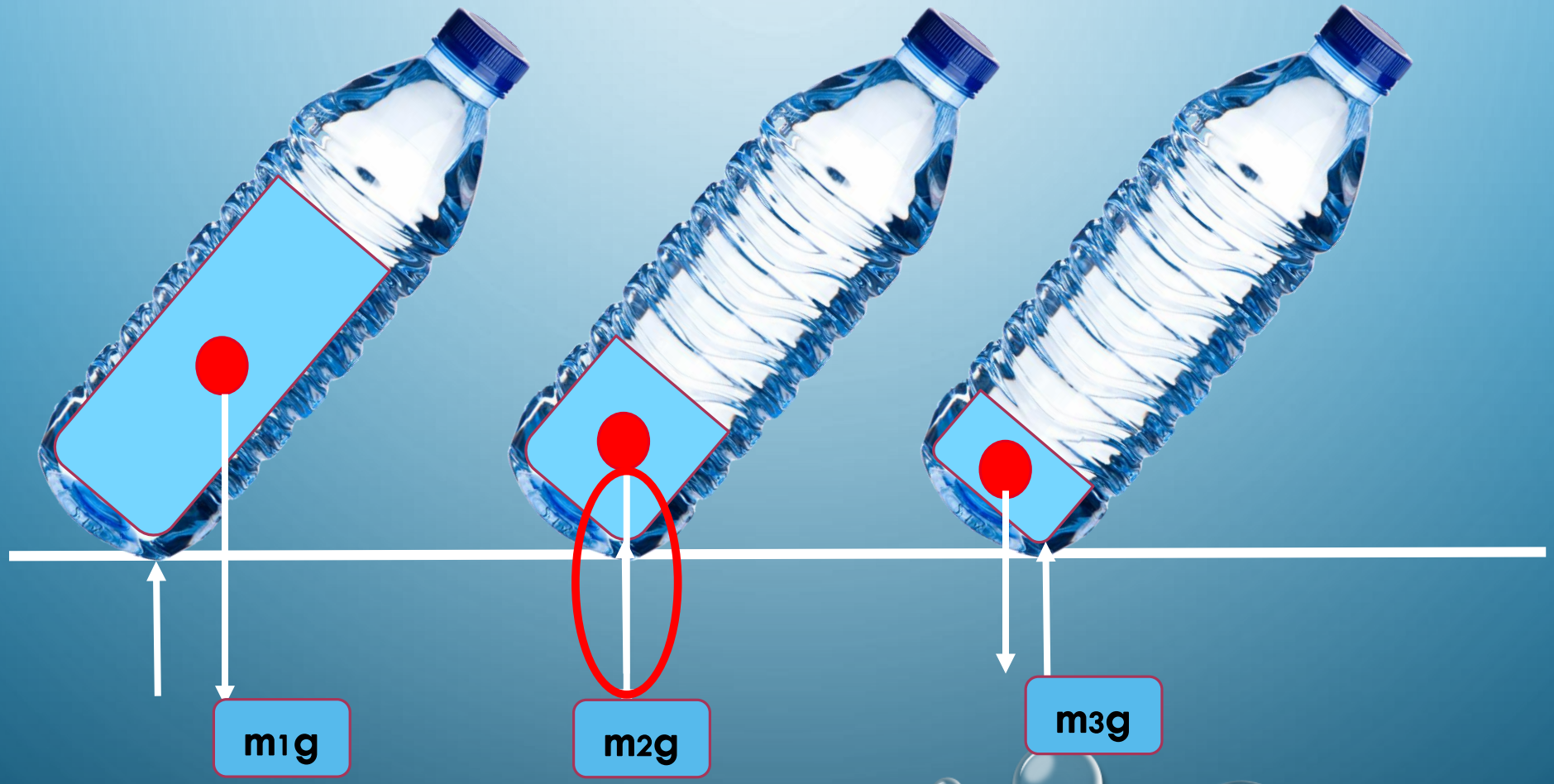
Rotation

Center of mass

Equilibrium



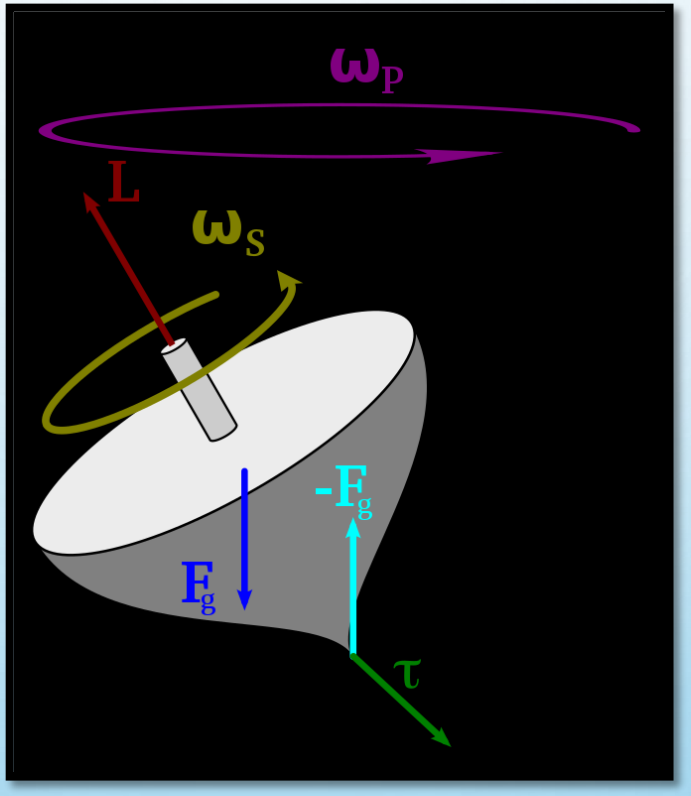
Equilibrium

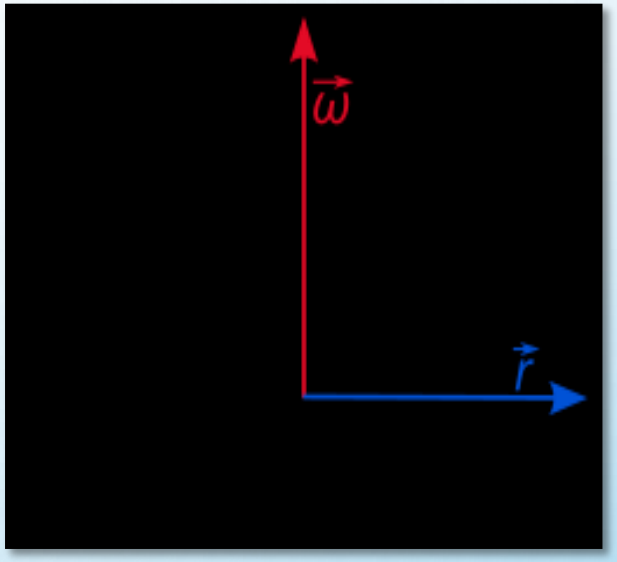


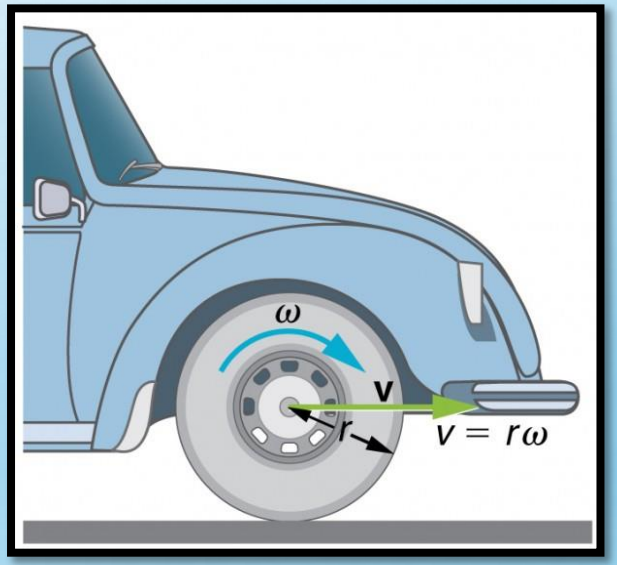
2. BASIC THEORIES

ANGULAR VELOCITY

- Angular velocity of a particle is the time rate of change of its angular position relative to the origin.



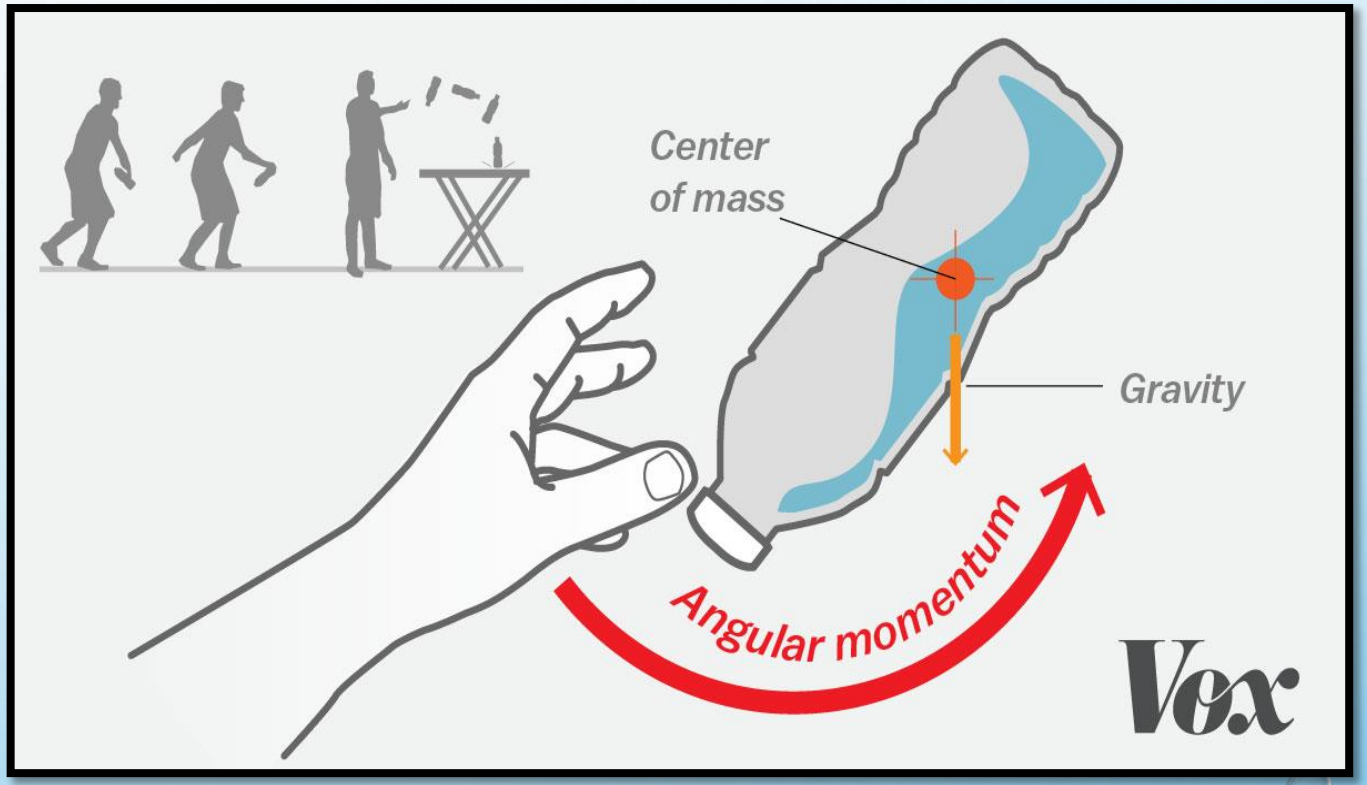


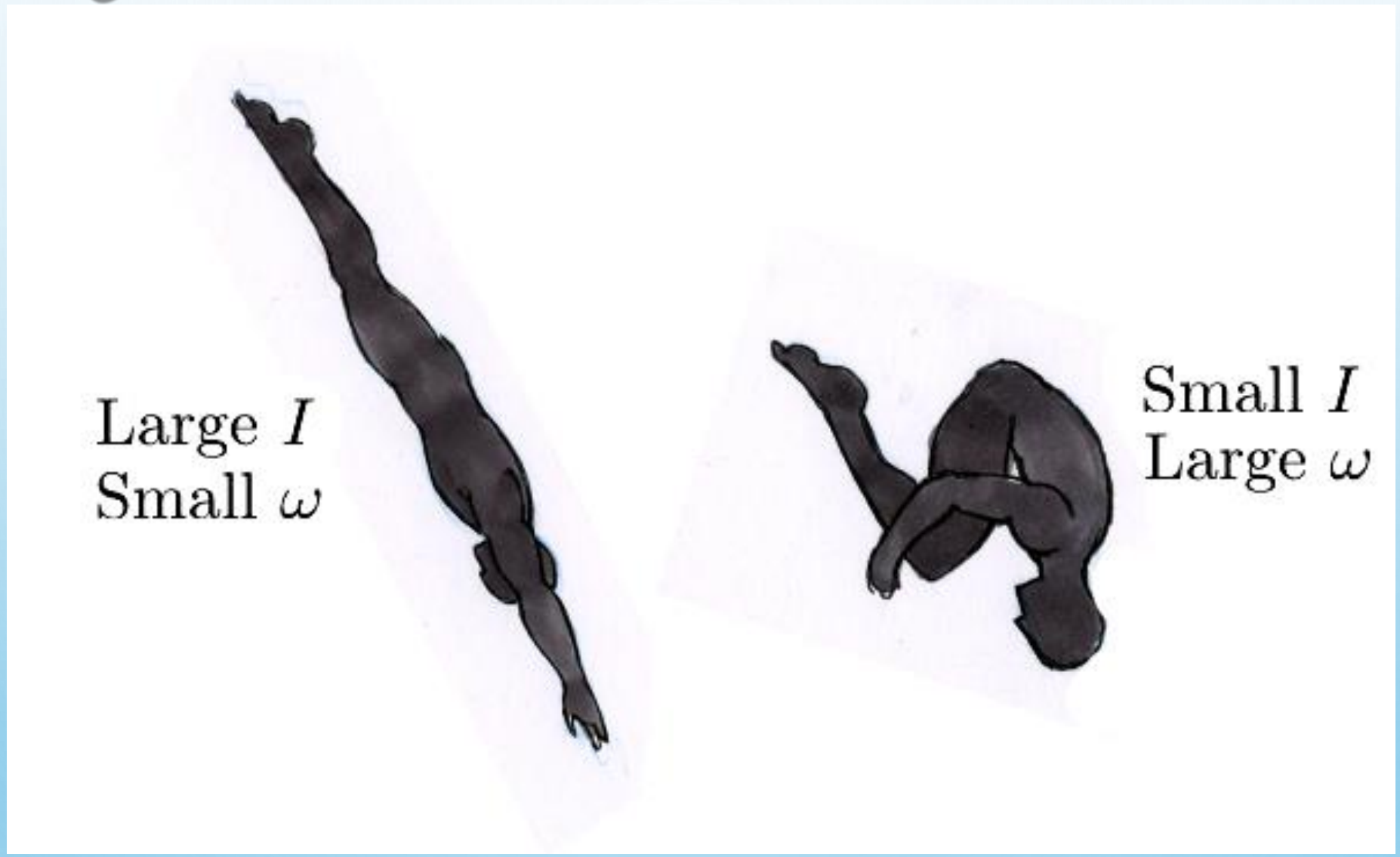


ANGULAR MOMENTUM

- ANGULAR MOMENTUM IS THE QUANTITY OF ROTATION OF A BODY, WHICH IS THE PRODUCT OF ITS MOMENT OF INERTIA AND ITS ANGULAR VELOCITY.

$$L = I\omega$$




Large I
Small ω
Small I
Large ω

3. PARAMETERS

❖ PARAMETERS THAT AFFECT THE FLIP:

- volume of bottle
  - level of water
  - center of mass
  - Height & width of bottle
  - weight of bottle
  - subsurface of the bottle
- initial speed of throwing
- initial angular velocity
- impact angular velocity

And also:

- distance of throwing and landing the bottle
- angular momentum
- height of throwing

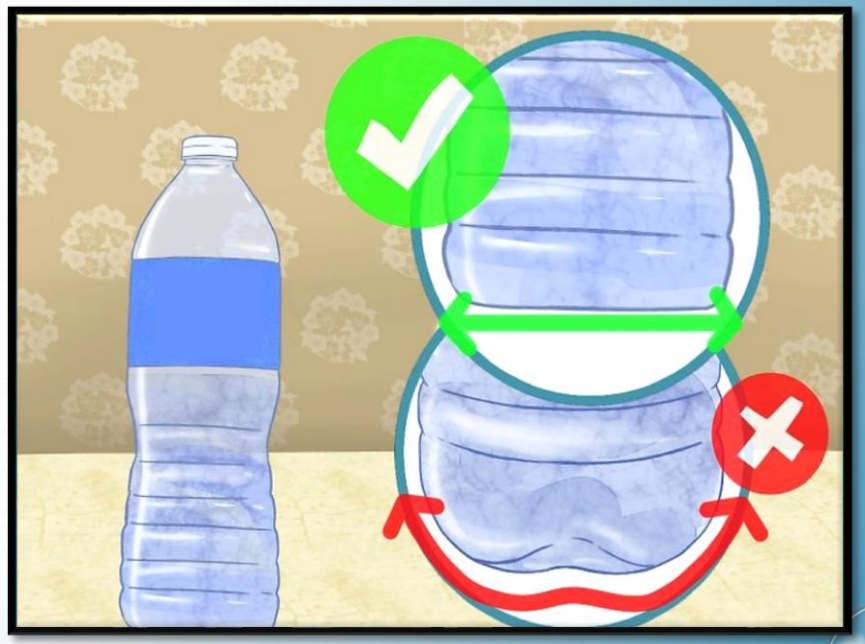
❖ SHAPE OF THE BOTTLE

A plastic bottle with a flat bottom, not a rounded one makes a better flip.

A plastic bottle with a big bottom, is stable & makes good flips.

SHAPE of BOTTLE:

- Bottom of bottle
- Height of bottle
- Area of the bottom
- Width of the body
- Shape of the body



❖ Elimination of some parameters

Air density practically does not affect, it's the same in the vacuum.

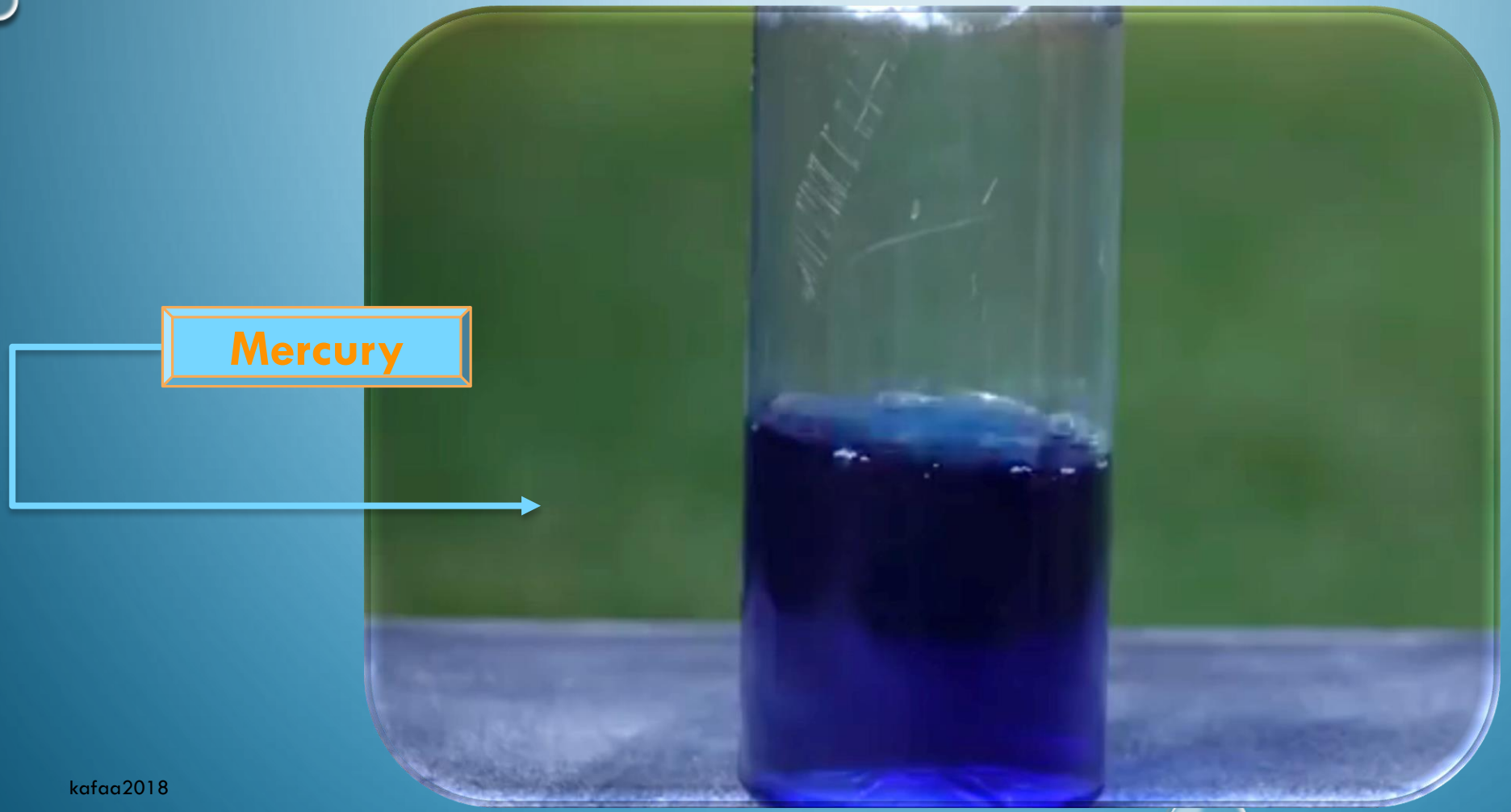
The **friction of air** does not seem to affect rotation or we can eliminate it.

Water density is not logical at the moment, because there is a lot of power to condense water.

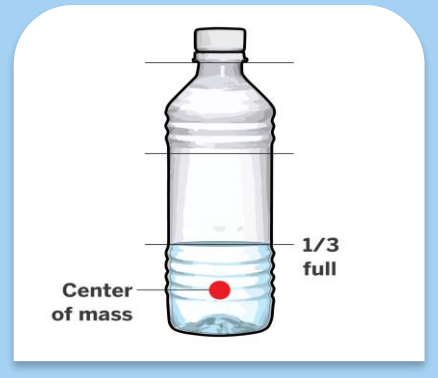
The **gravity** of the Earth is also weighted and it is partially the same in the vacuum.

4. EXPERIMENTS & RESULTS

❖ OBSERVATION WITH MERCURY



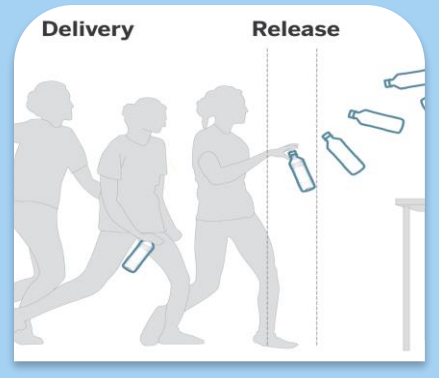
EXPERIMENTS



Changing the **level of water**

Changing the **shape of bottle**

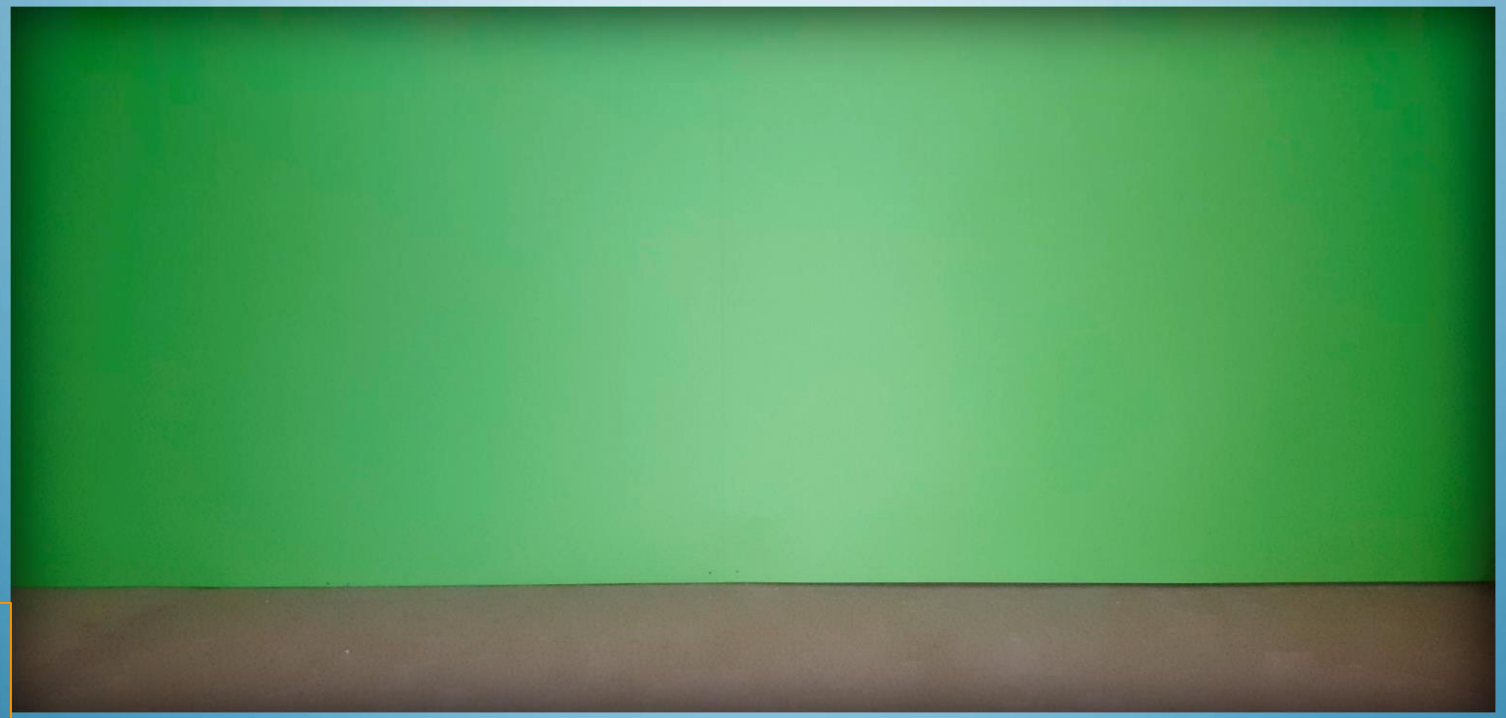
Changing the **volume of bottle**



Changing the **height and distance of throwing**

EXPERIMENTS

- My **testing environment** for doing experiments



Distance:
Max=2 meters
Min=0.5 meters

Height:
Max=2 meters
Min=0.5 meters

EXPERIMENTS

- Some of my **ideal water bottles** for doing experiments

1750 ml	1700 ml	1650 ml	1000 ml	1000 ml	975 ml	975 ml	550 ml	500 ml	350 ml

❖ EXPERIMENTS

- Some of my bottles for the **initial experience**

1700 ml

1000 ml

985 ml

500 ml

340 ml

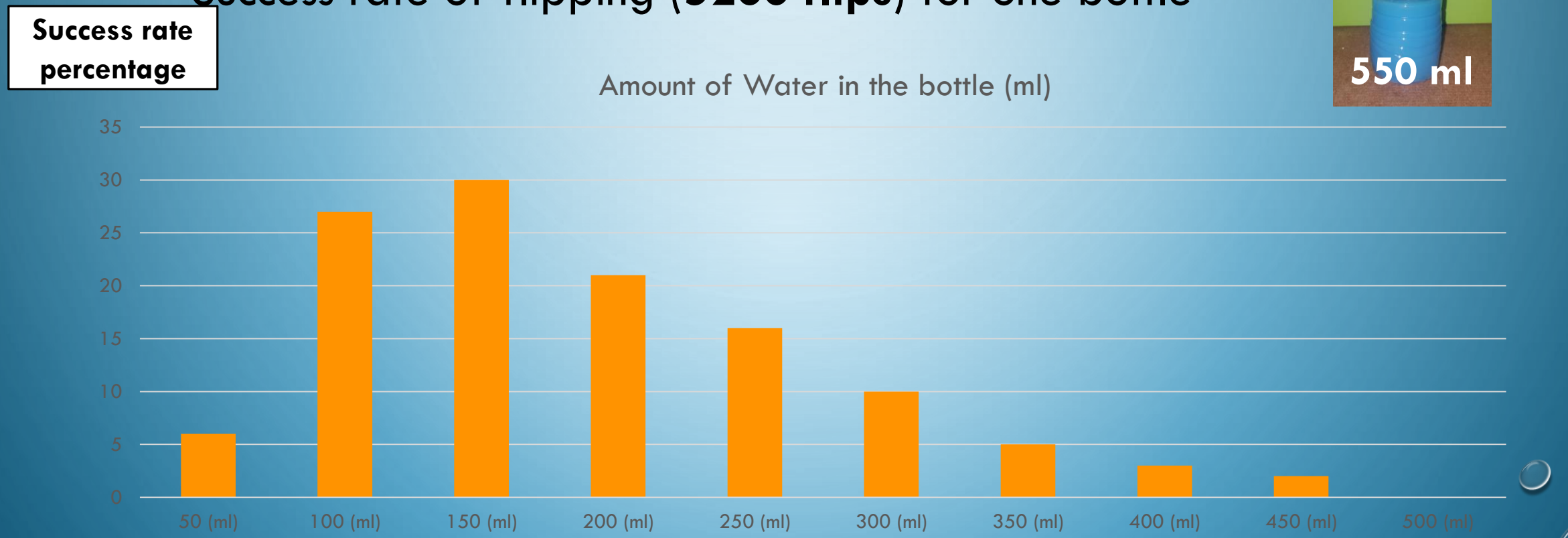
EXPERIMENTS

- Released from different b bottle size landing (**100 flips** for each bottle)

kafaa2018

EXPERIMENTS

- Success rate of flipping (**5200 flips**) for one bottle



Back

EXPERIMENTS

- Some of my bottles for the **ultimate experience**

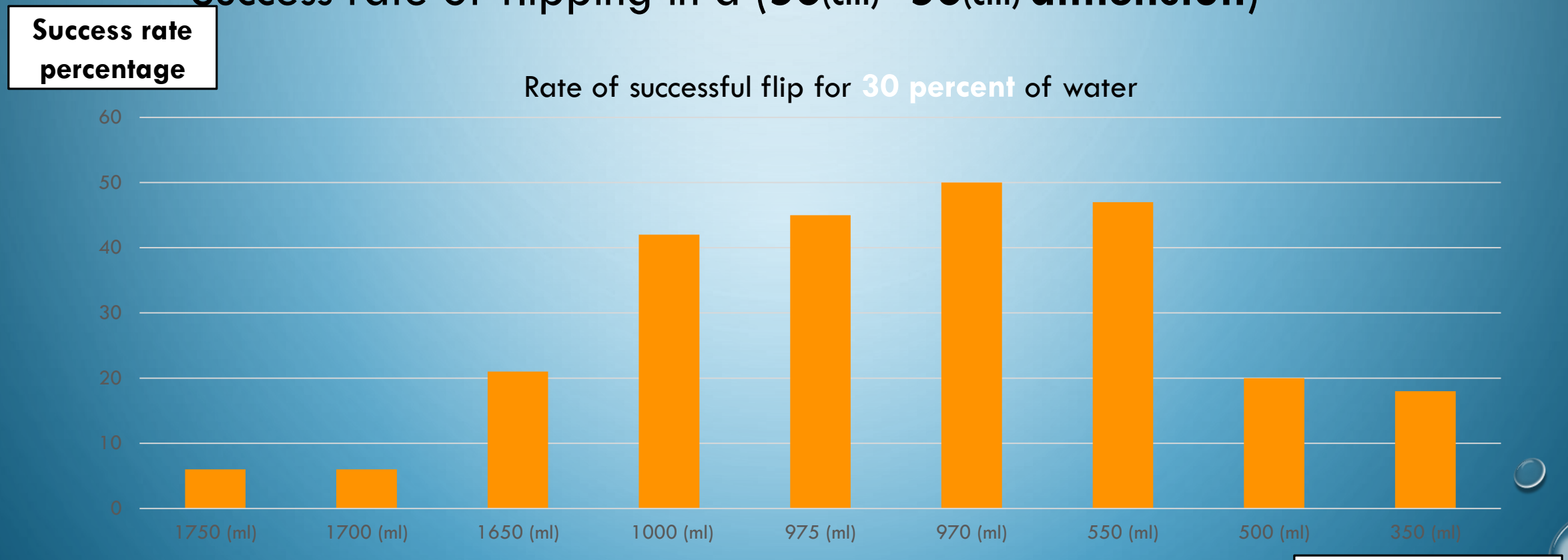
1750 ml	1700 ml	1650 ml	1000 ml	975 ml	975 ml	550 ml	500 ml	350 ml

Back

EXPERIMENTS

height **distance**

- Success rate of flipping in a (**50**(cm) *50(cm) **dimension**)

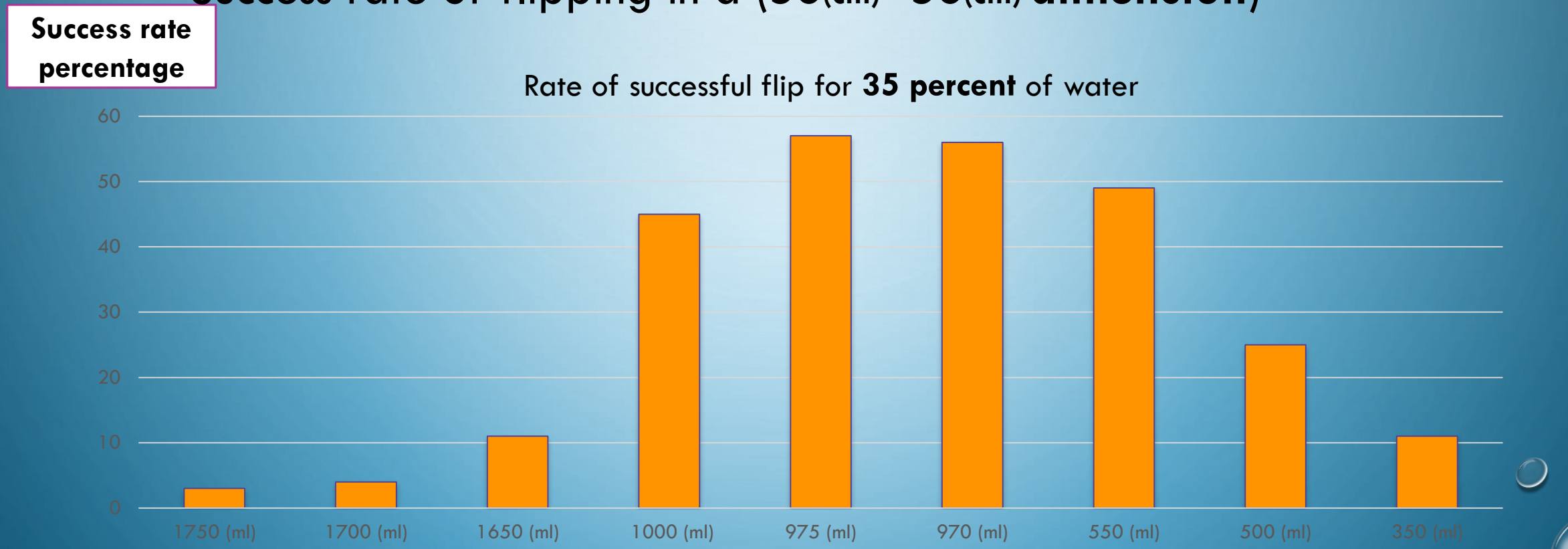


kafaa2018

EXPERIMENTS

height **distance**

- Success rate of flipping in a (**50**(cm) *50(cm) **dimension**)

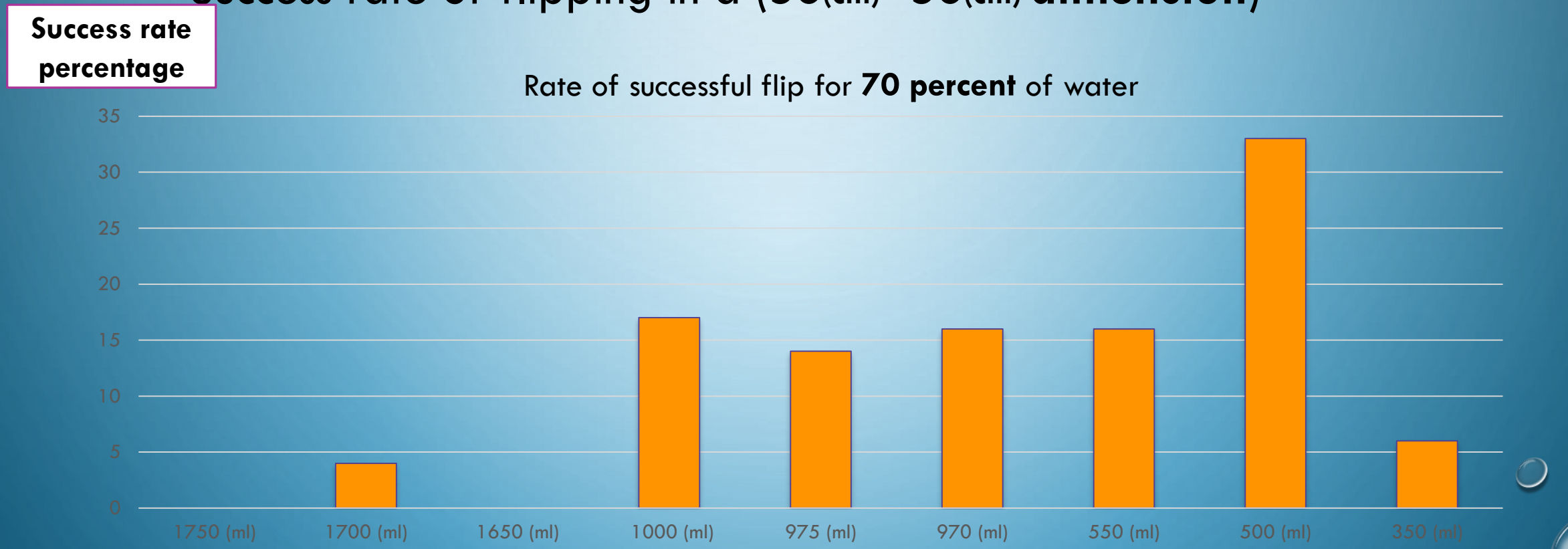


kafaa2018

EXPERIMENTS

height **distance**

- Success rate of flipping in a (**50**(cm) *50(cm) **dimension**)

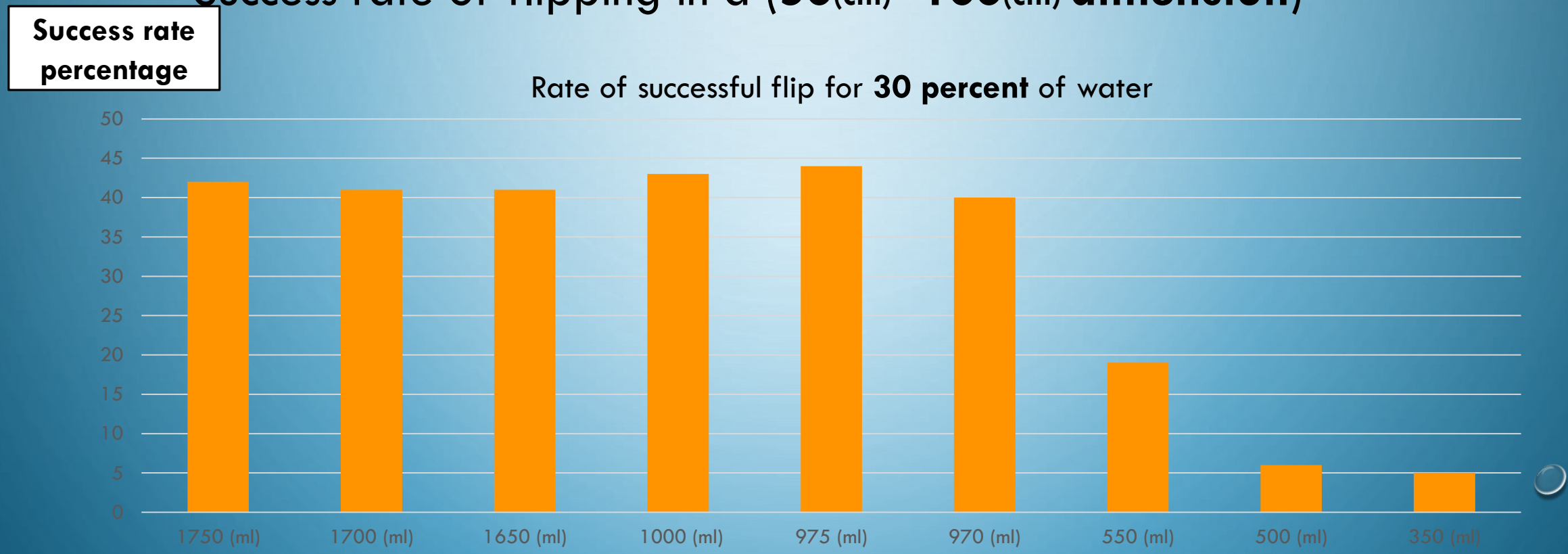


kafaa2018

EXPERIMENTS

height **distance**

- Success rate of flipping in a (**50**(cm) *100(cm) **dimension**)

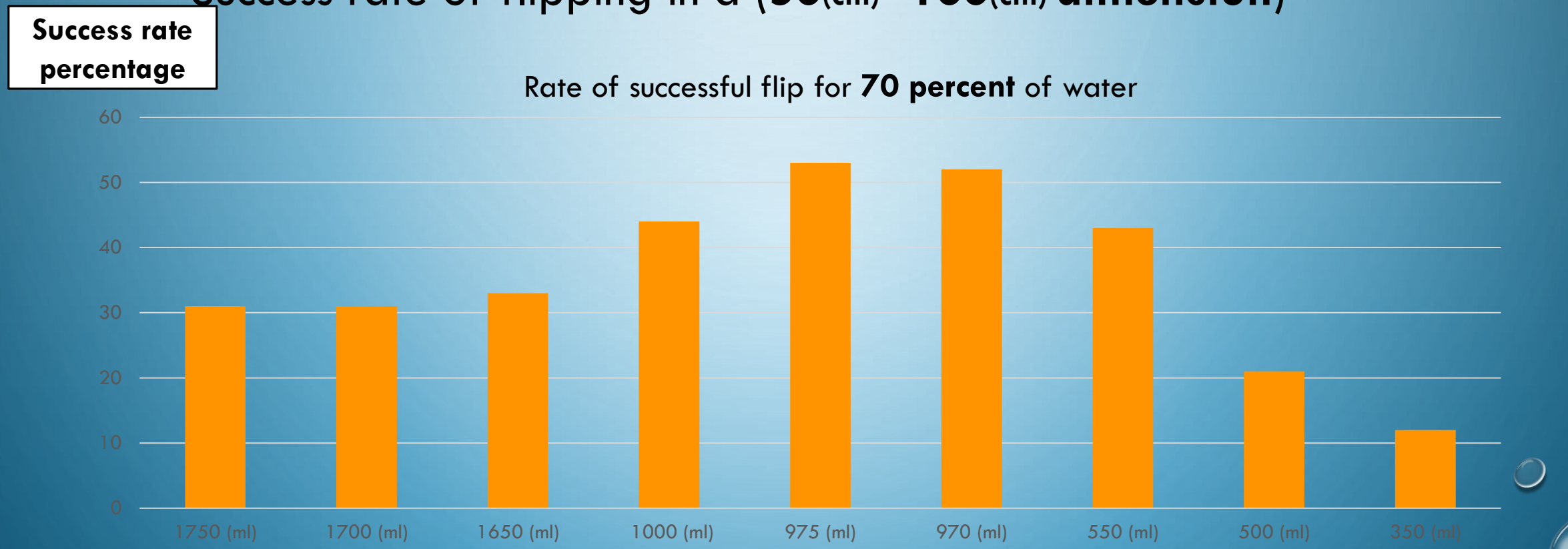


Back

EXPERIMENTS

height **distance**

- Success rate of flipping in a (**50**(cm) *100(cm) **dimension**)



kafaa2018

Conclusion: The optimum amount of water to execute a bottle flip is when the bottle is filled with an amount of water between **25%** and **50%** of it's total capacity.

The amount of water	Total ☺	Total ☹	Total attempts (percentage)
0/8 full	0	900	0
1/8 full	45	855	5
2/8 full	630	270	70
3/8 full	540	460	60
4/8 full	450	550	50
5/8 full	270	630	30
6/8 full	180	720	20
7/8 full	90	810	10
8/8 full	45	855	5

550 ml

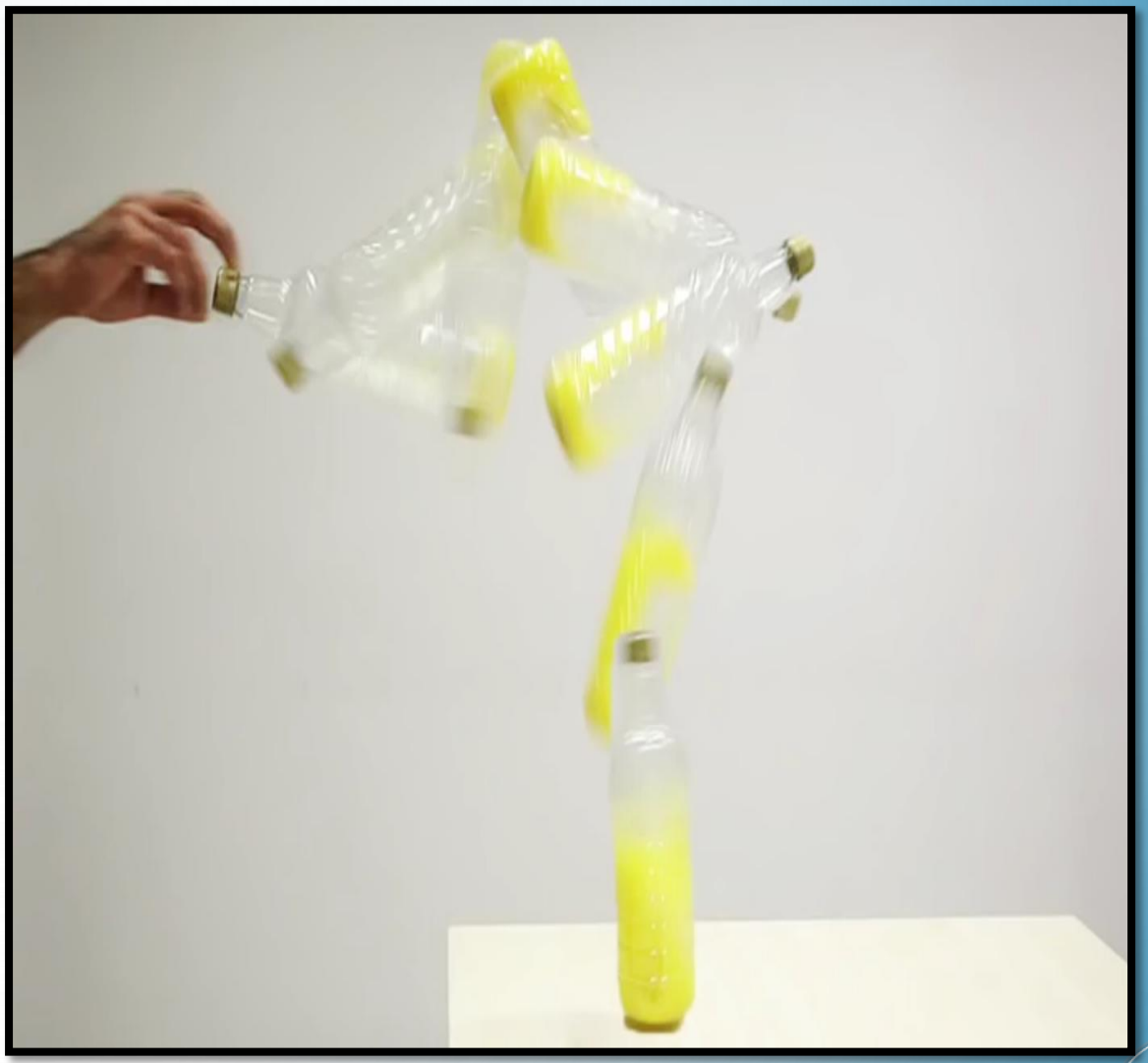
Total 900 flips for the bottle water

5. RESOURCES

RESOURCES:

- HTTP://WWW.IOPBLOG.ORG/ITSFLIPPING-GREAT-TO-THINK-LIKE-A-PHYSICIST/
- HTTP://WWW.IOP.ORG/RESOURCES/TOPIC/ARCHIVE/WATER-BOTTLEFLIP/PAGE_68405.HTML
- HTTPS://WWW.VOX.COM/2016/5/26/11785562/WATER-BOTTLE-FLIP-PHYSICS
- HTTPS://MAKEZINE.COM/2017/03/19/THIS-WEEK-IN-MAKING-LEGO-TAPEBOTTLE-FLIPPING-ROBOT-LAB-GROWN-CHICKEN-STRIPS-AND-MORE/
- HTTPS://YOUTU.BE/GDUVTEEG9I4

- HTTPS://YOUTU.BE/FBAB8SSE3YA
- HTTPS://YOUTU.BE/P8V_BX0L4RY
- HTTPS://YOUTU.BE/H33XCSAGFPG
- HTTPS://YOUTU.BE/G9P2IUS2OFE
- HTTPS://YOUTU.BE/9XOCUAY9QVW
- HTTPS://YOUTU.BE/0TWUMIWCRCU
- HTTPS://YOUTU.BE/IQBV06BBQY
- HTTPS://YOUTU.BE/AMIDFQ-NG8U
- HTTPS://YOUTU.BE/C8GGM1QXSPA
- HTTPS://YOUTU.BE/70CVLVX0NX0
- HTTPS://YOUTU.BE/LQATZBGMJK8



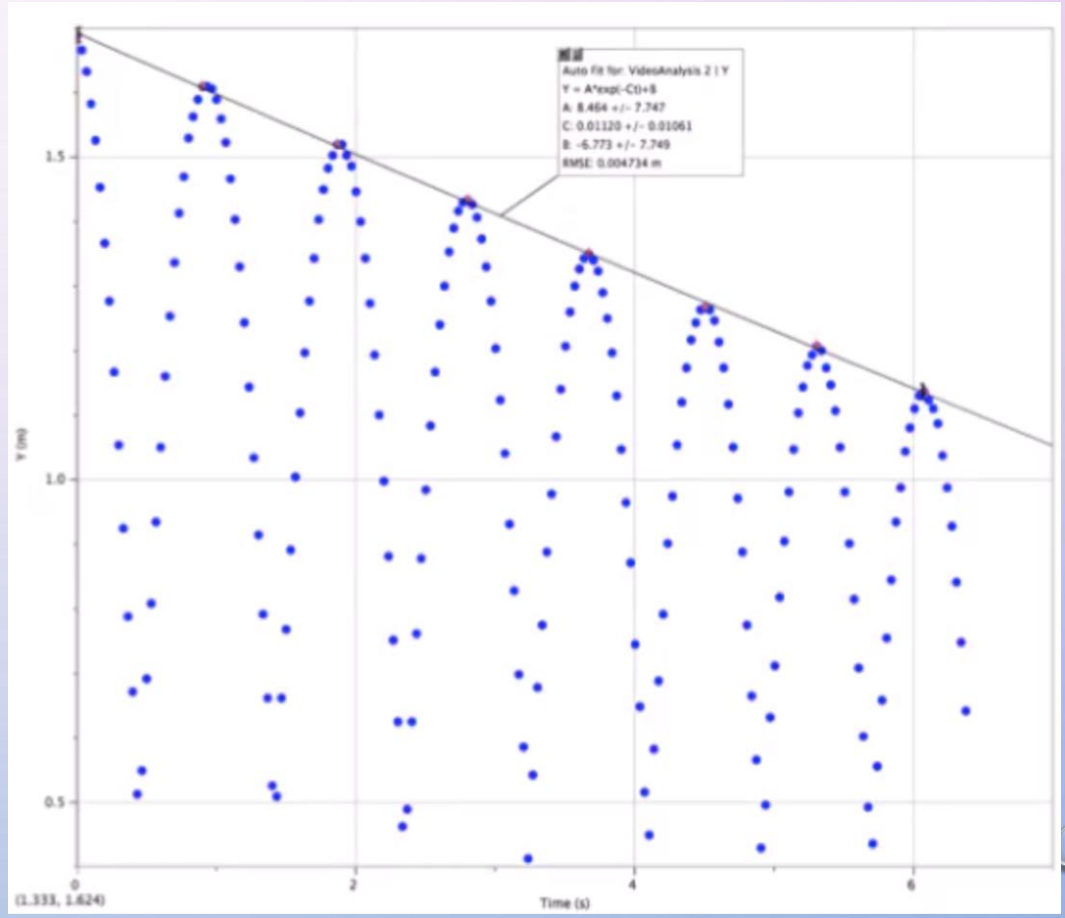
• EXTRA INFORMATION FOR DISCUSSION

$$\vec{L} = m\,\vec{r} \times \vec{v}$$

$$L = I\omega$$

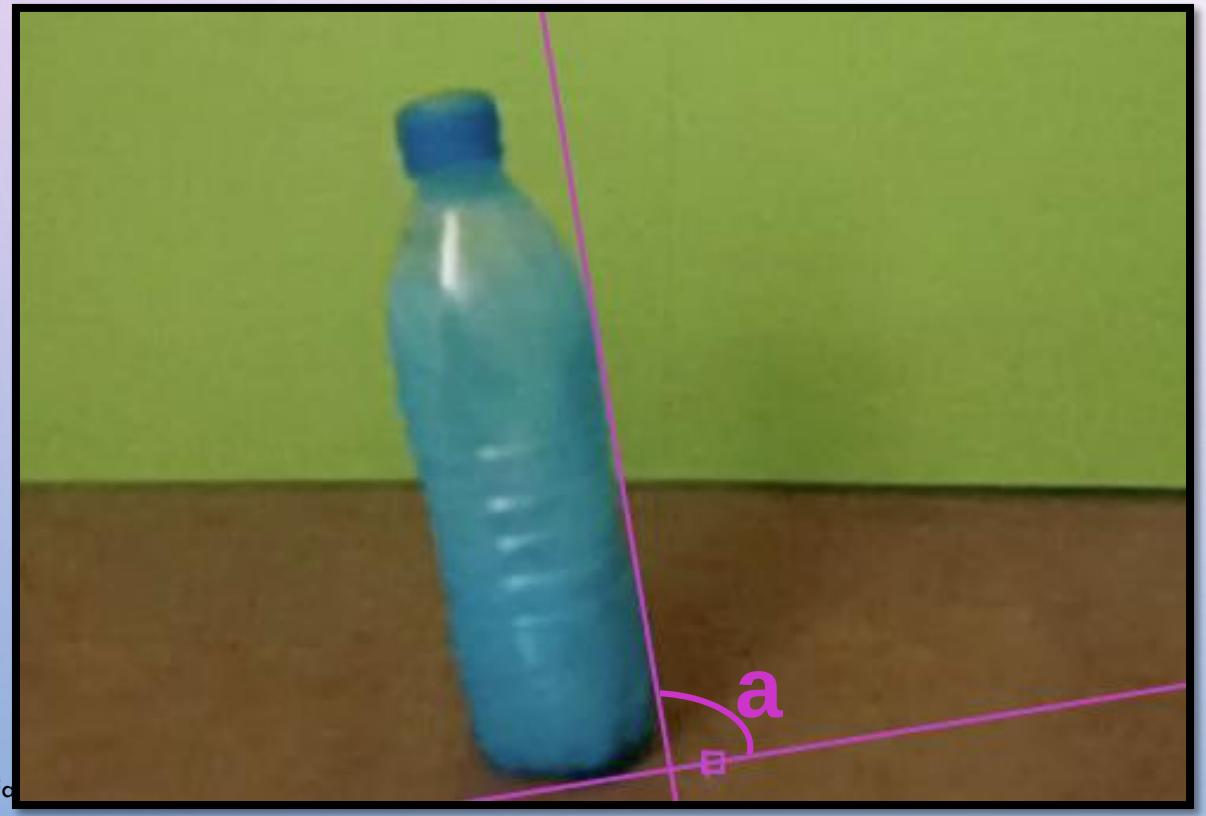
Angular momentum formula

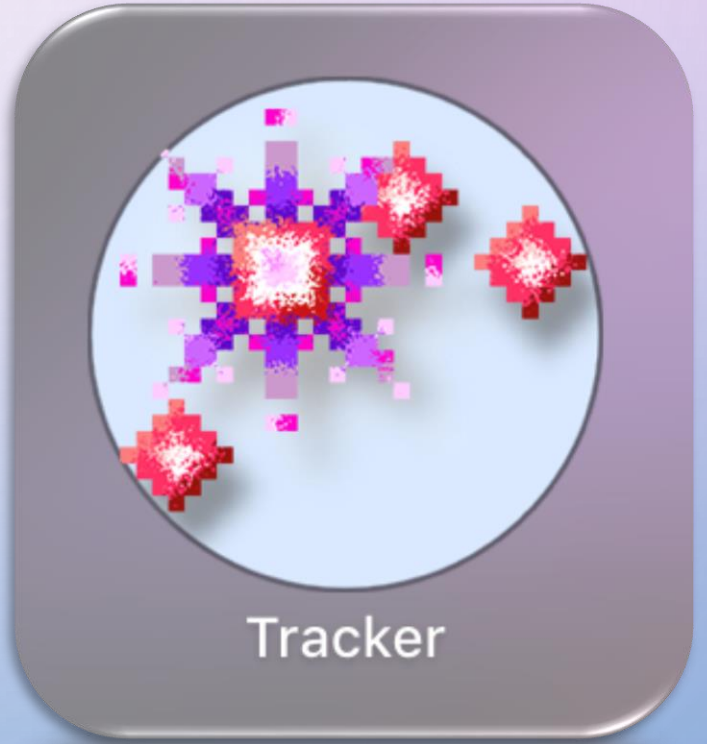
The formation of motion of the bottle in the air is like parabola chart that we can calculate the summit of the chart.

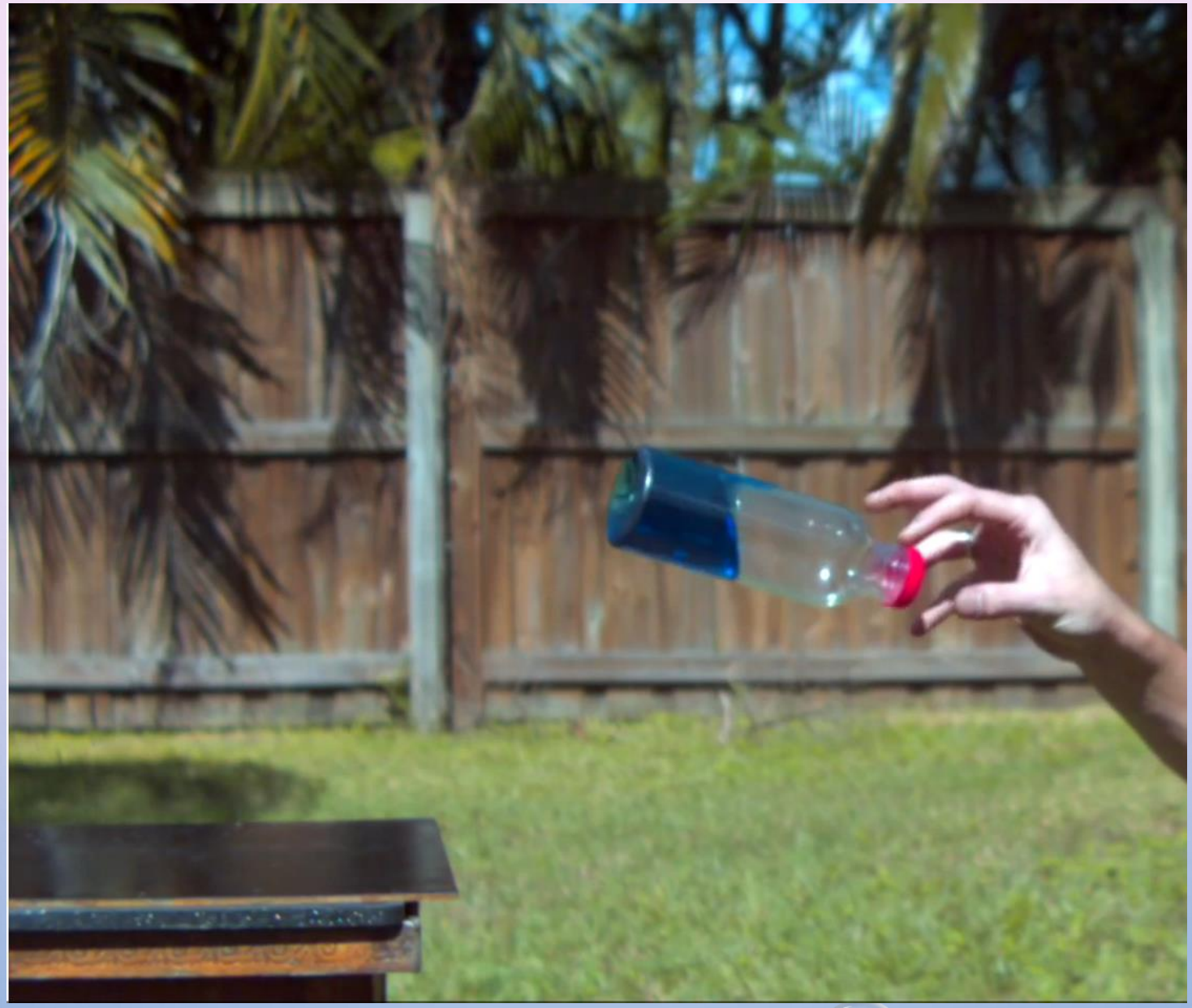


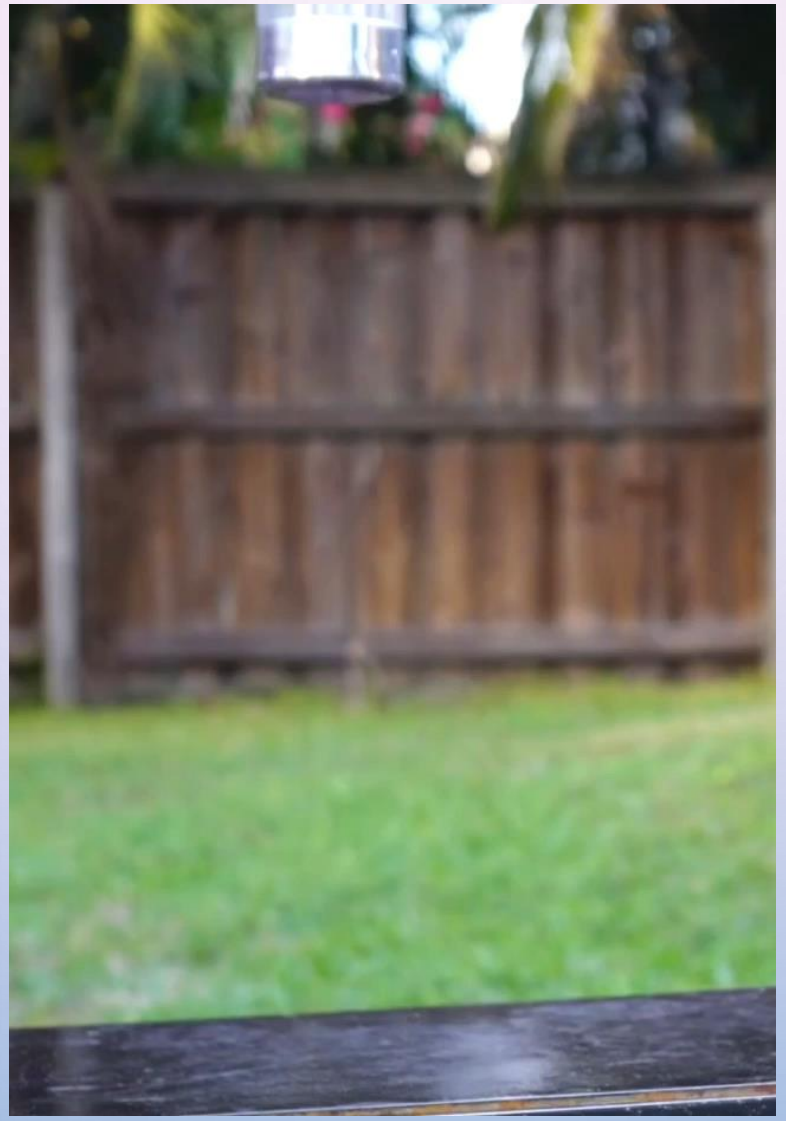
❖ ANGLE OF IMPACT

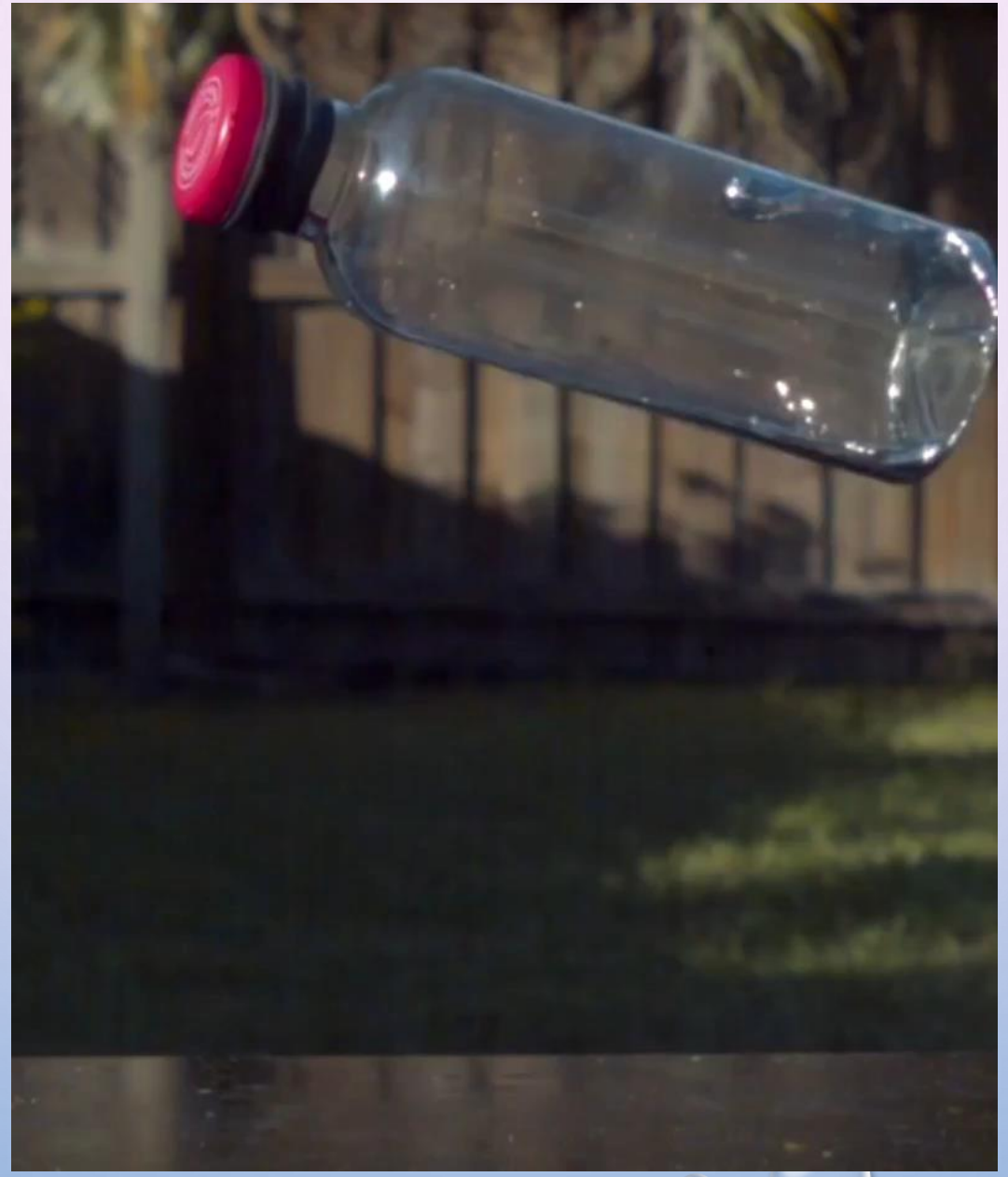
A plastic bottle with an impact angle, almost 90°, has more chance to land upright.





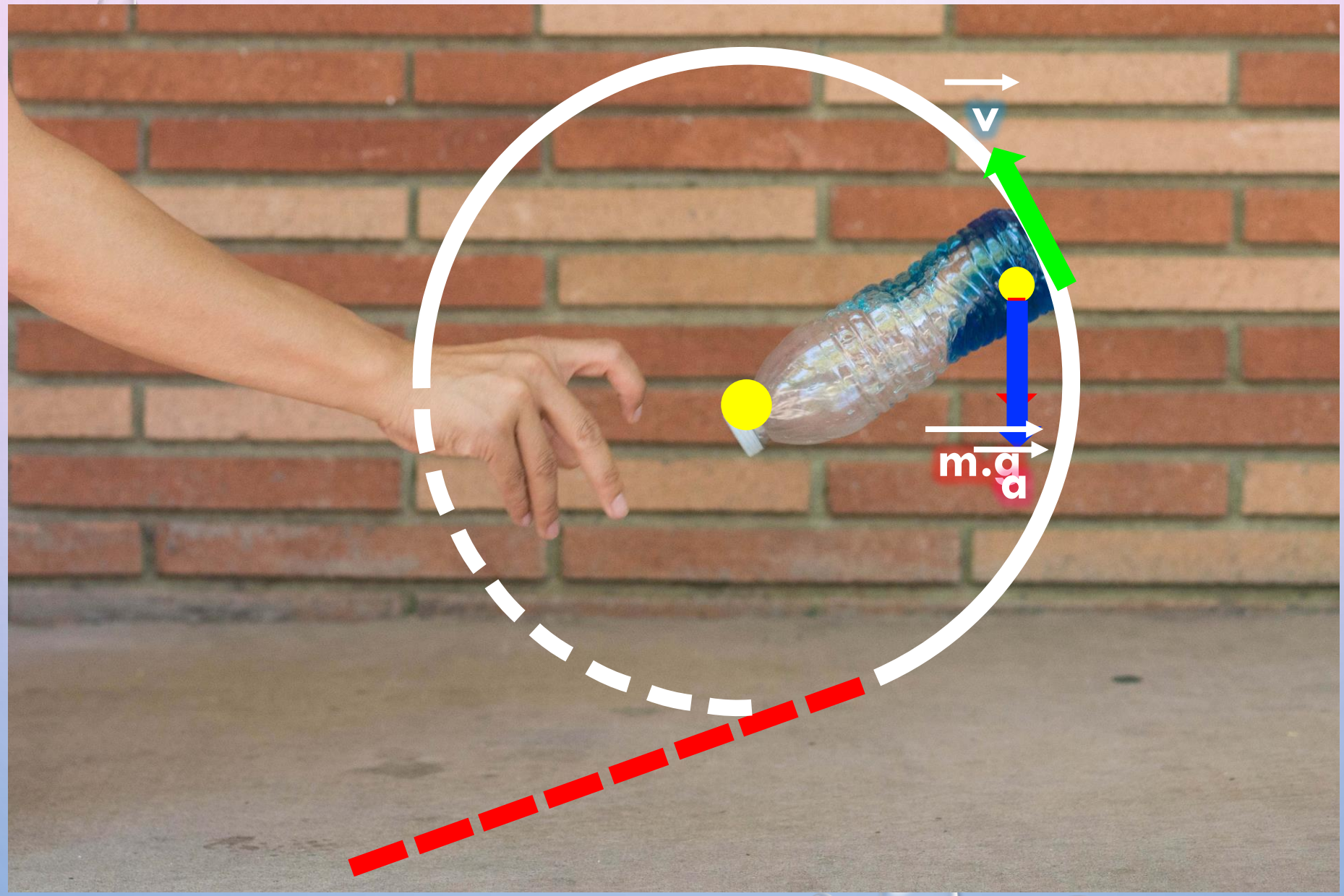







Bottle
filled
1/3
With any water bottle at your disposal. Fill or leave around 1/3 amout of water in the bottle. Spinning the bottle with a third full allows the water to adjust easier to the angular momentum because it can move around.
Hold the bottle from the top. Adjust your fingers so when tossing it upward, the bottle will be able to easily be released from your grab. The water and center of gravity rest in the base of the bottle.
youness amrani
When tossing the bottle with a flick of the wrist, get the bottom to go outward away from you at a 180 degree spin. The water is free to flow, the fluid does not all rotate with the bottle. Instead, it sloshes around and slows the rate of rotation. Consistency is key to accomplish the flip of the bottle.
As the light bottle spins, the angular momentum is transferred to the heavier water. The bottle's spin is slowed down, bringing it back down with gravity and lands straight upright on the table or ground.


Nutrition Facts
Valeur nutritive
RETURN FOR REFUND
CONSIGNE

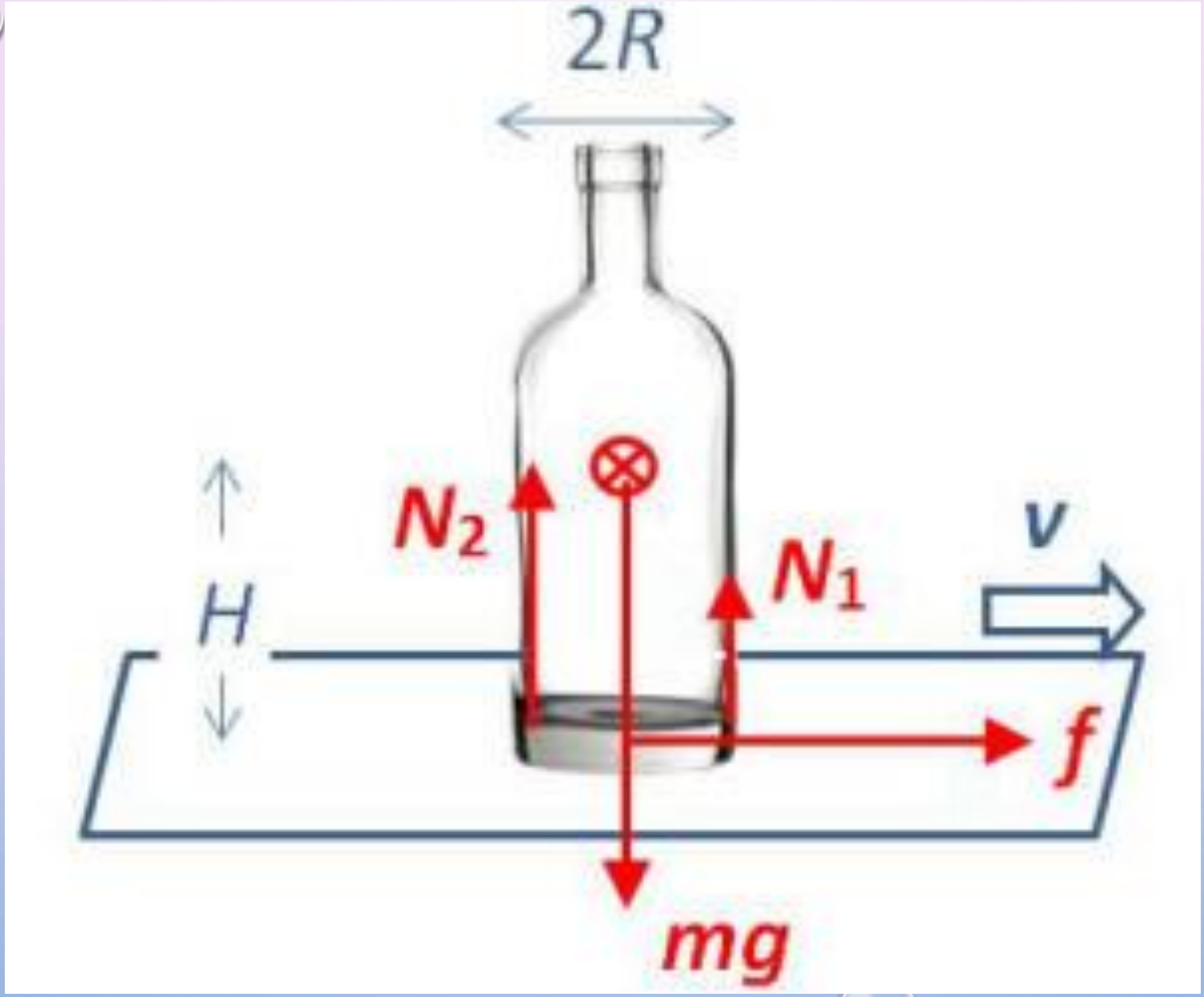

v
m.g
a

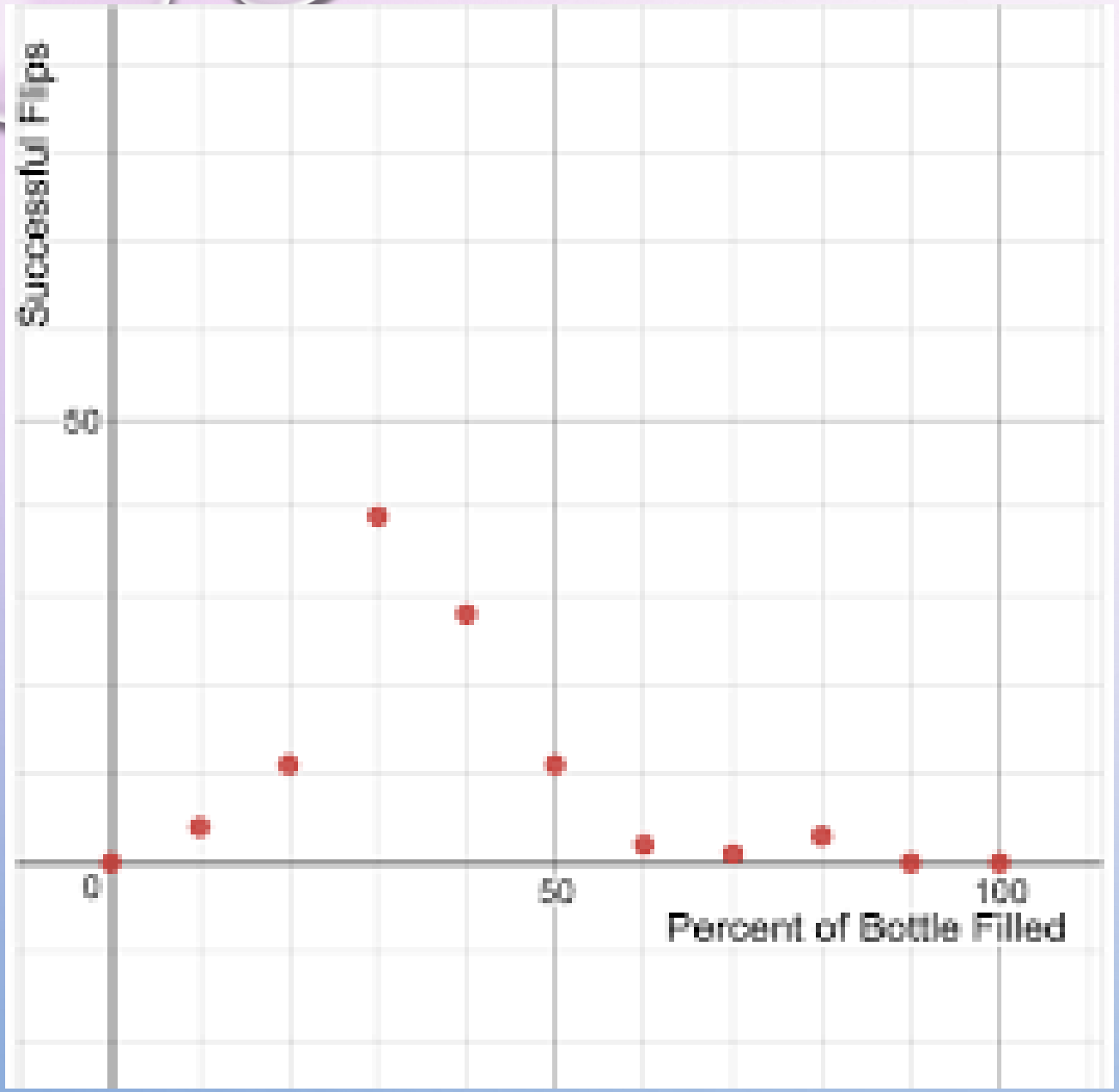

STEP 2
Throw it forwards, making it back-flip with your wrist.
STEP 3
When the bottle leaves your hand it is spinning but the water isn't. As the water starts to turn too, the spinning slows.
STEP 1
Use a bottle one-third full of water to keep centre of gravity low. Hold it at the neck.
STEP 4
The bottle is now barely spinning and the water is at the bottom - so it falls with gravity and lands upright

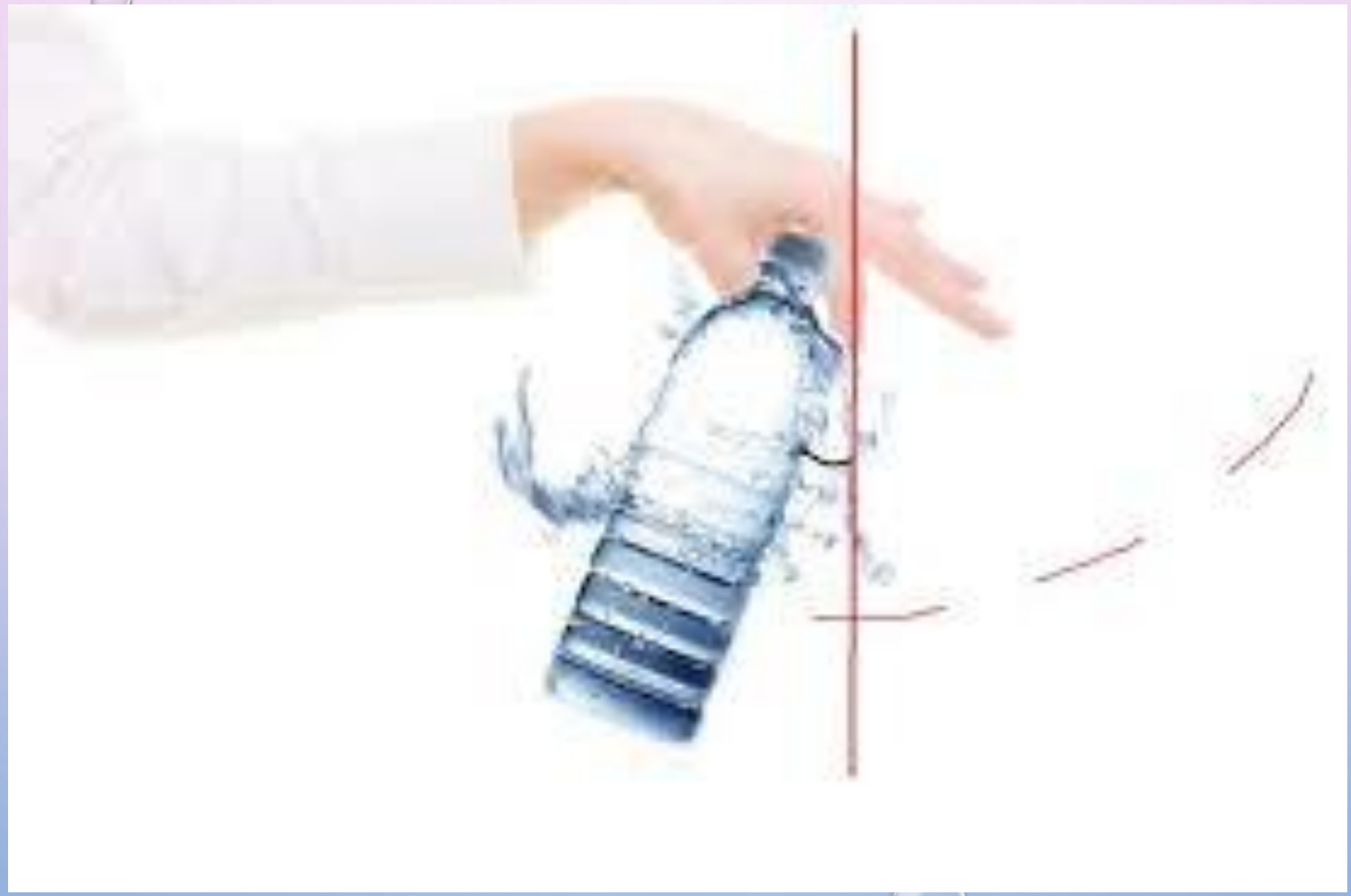
RE = 0

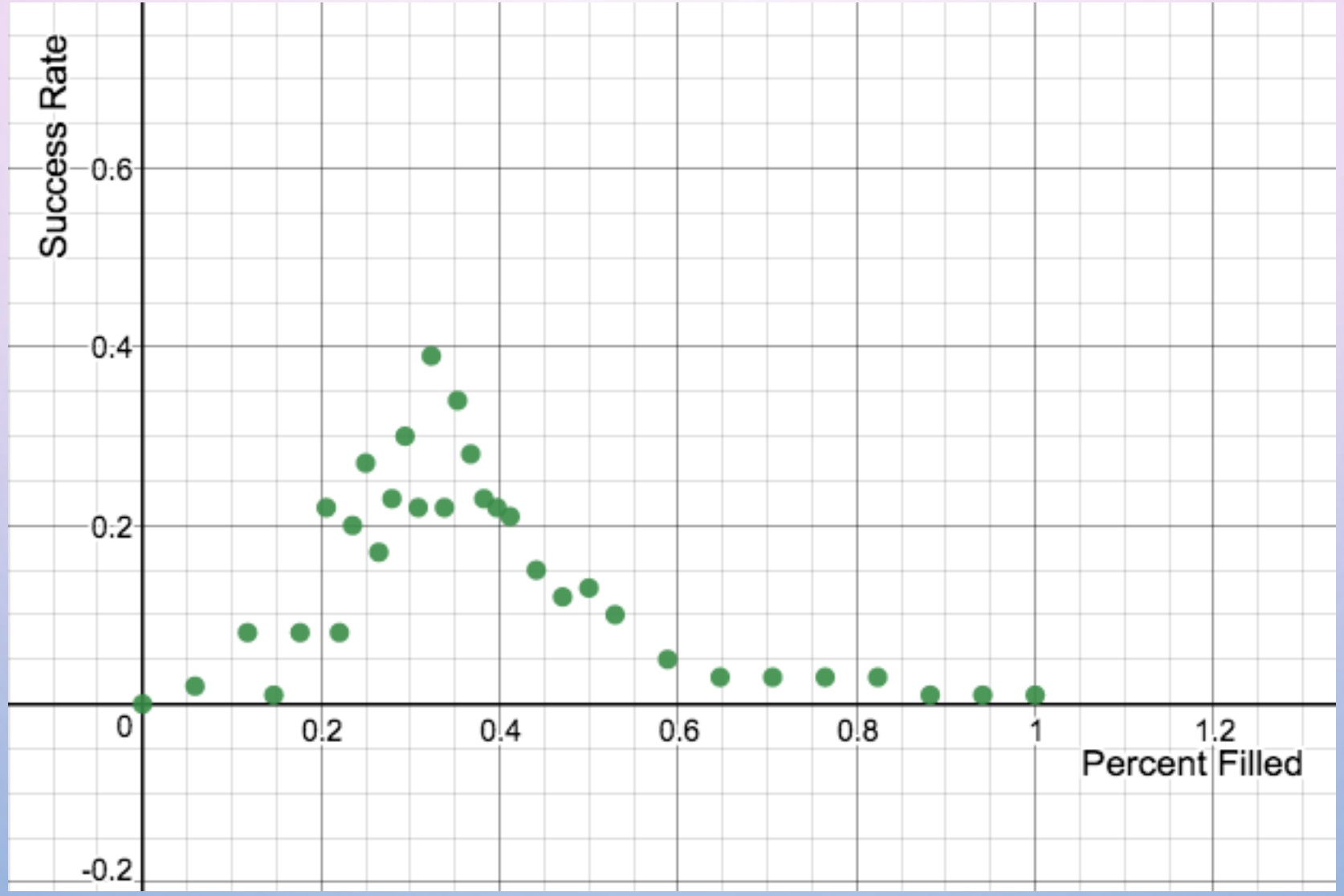
PE = mgh

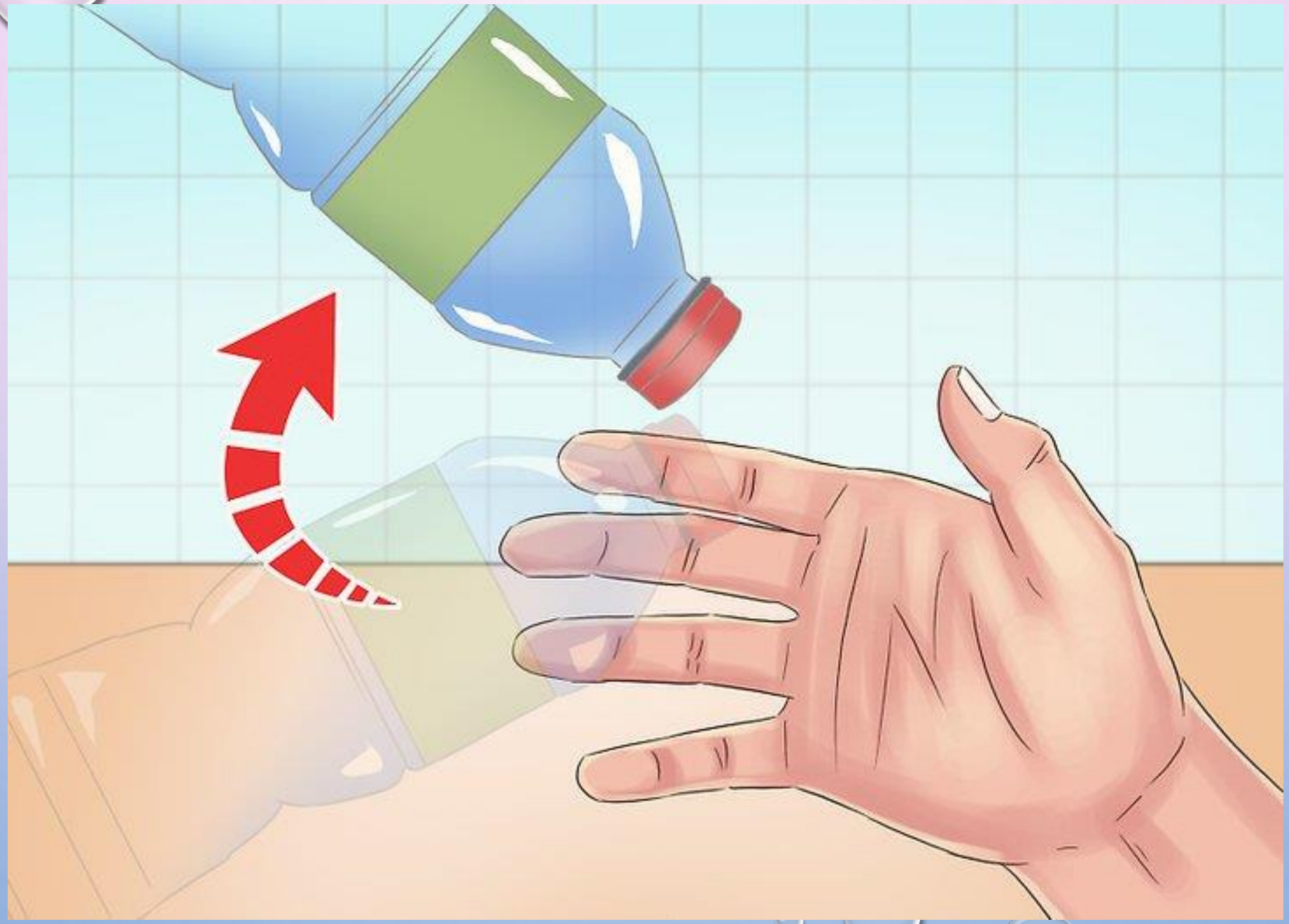

http://www.talkphysics.org
The Physics of the Bottle Flip
Spinning objects have angular momentum.
Angular momentum is always conserved, but can be transferred from one object to another.
If a spinning object expands, its rate of rotation will slow down.
As the water spreads out it slows the rate of spin.
Landing:
Objects fall over if the center of mass of the object is above the base (why tall buses are more likely to fall over).
Having a small amount of water lowers the centre of mass.
Some materials are bouncier than others.
How well two objects will bounce together is called the coefficient of restitution.
A coefficient of restitution of 1 means it will bounce back to the same height, 0 means it will not bounce at all.
So how does this help when you flip your bottle?
As the water 'sloshes out' it reduces the spin.
Angular momentum is conserved.
A low centre of mass makes the bottle more stable.
Not very bouncy. Low coefficient of restitution.

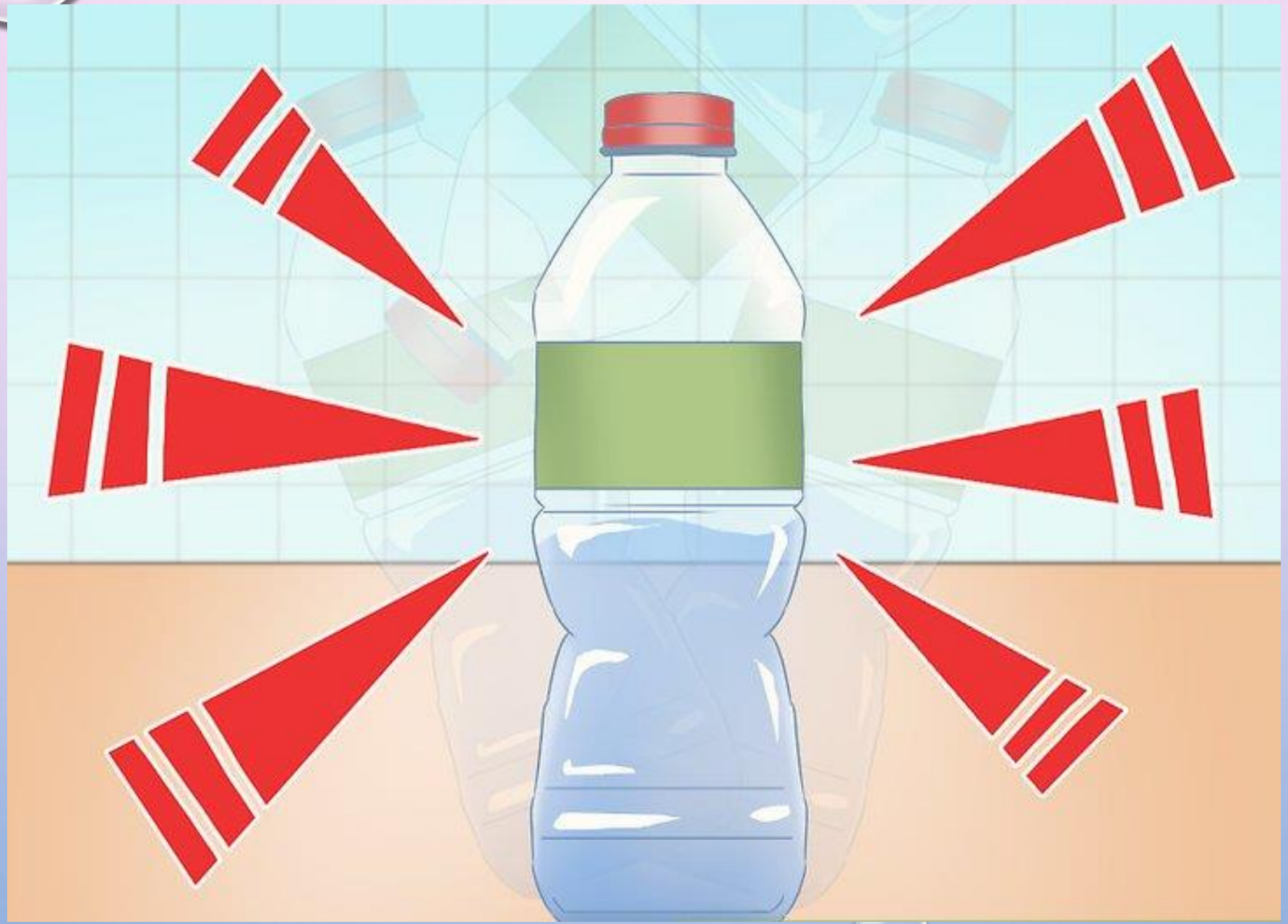

2R
N2
N1
v
H
f
mg

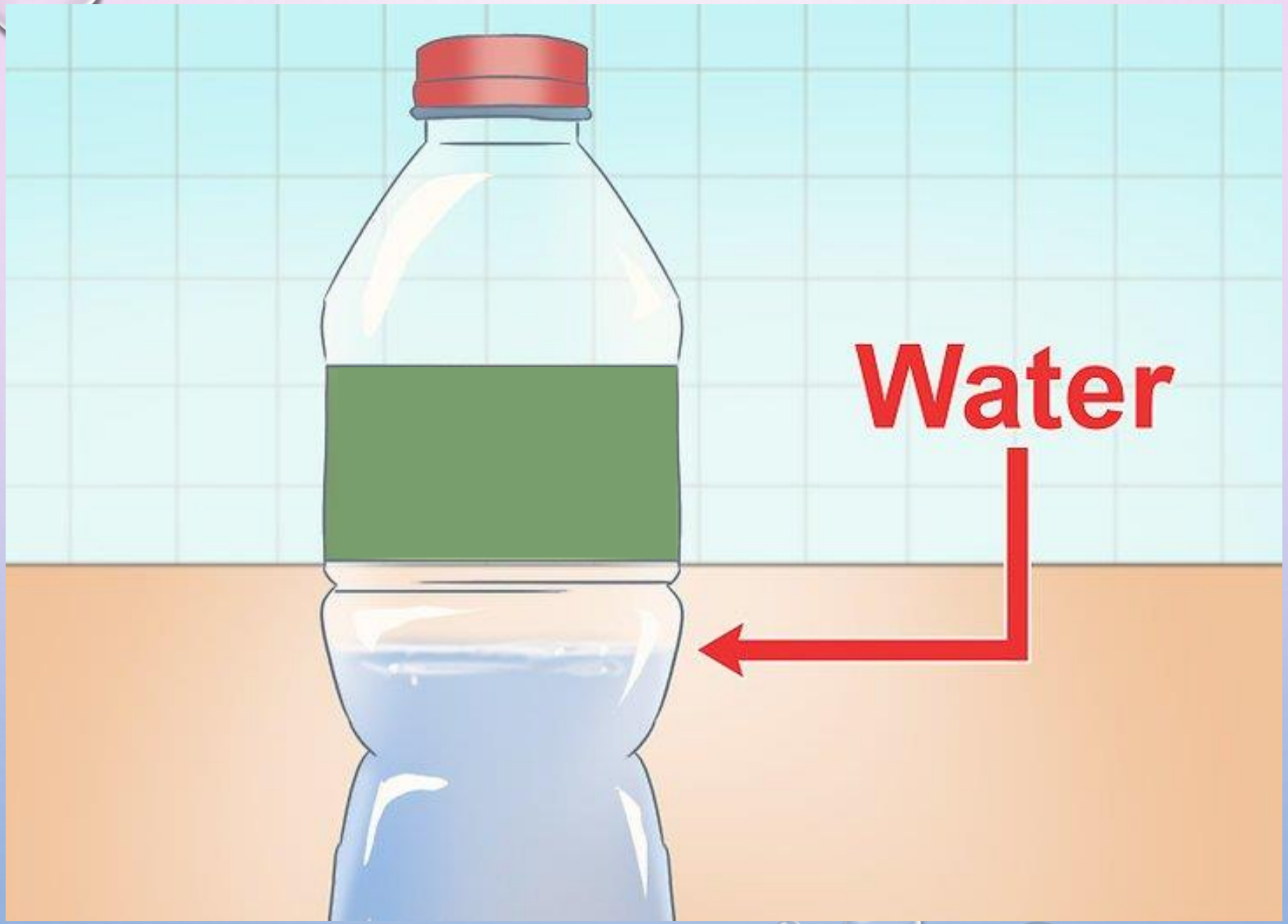

Successful Flips
50
0
50
100
Percent of Bottle Filled

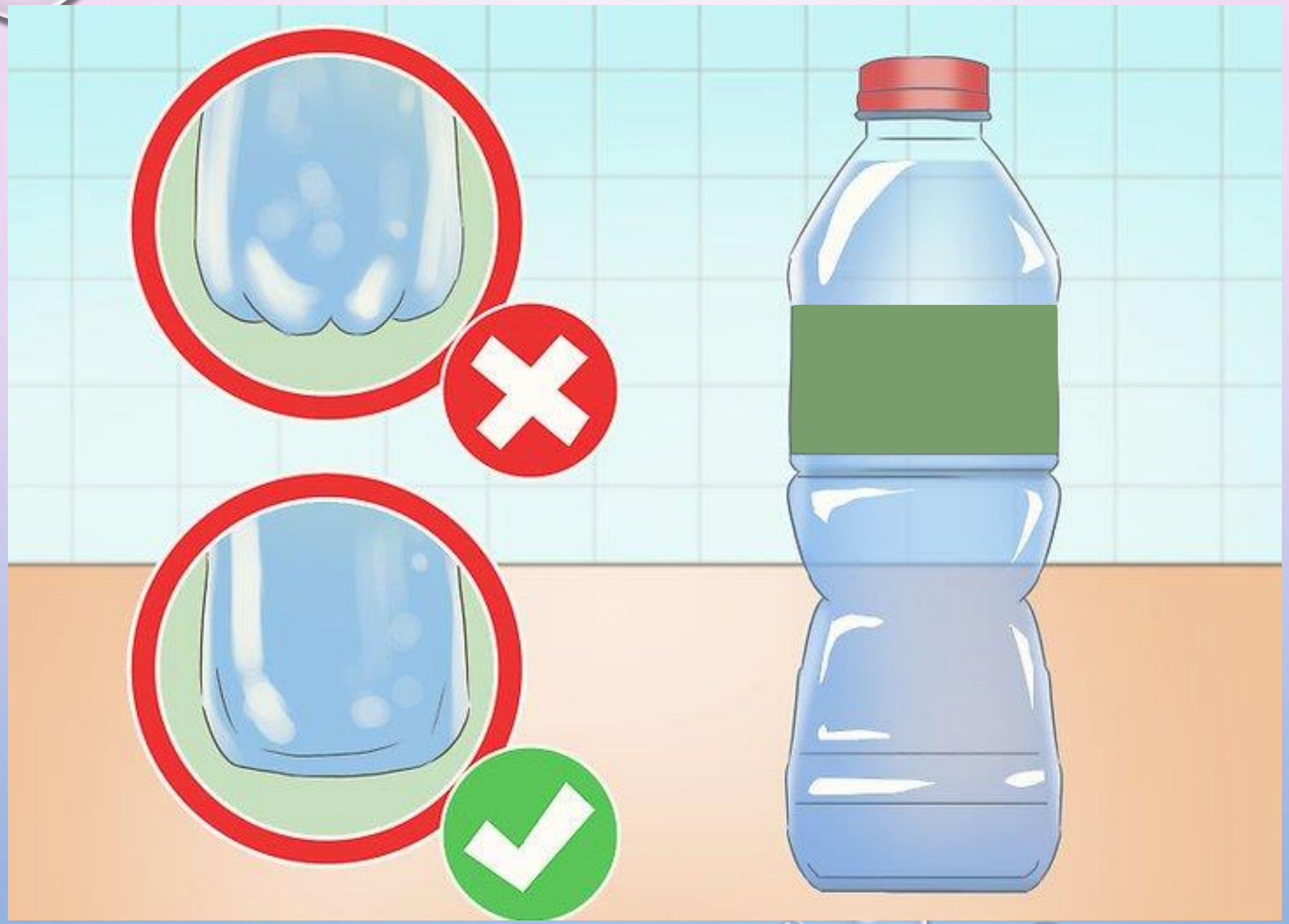



Success Rate
0.6
0.4
0.2
0
-0.2
0.2
0.4
0.6
0.8
1
1.2
Percent Filled





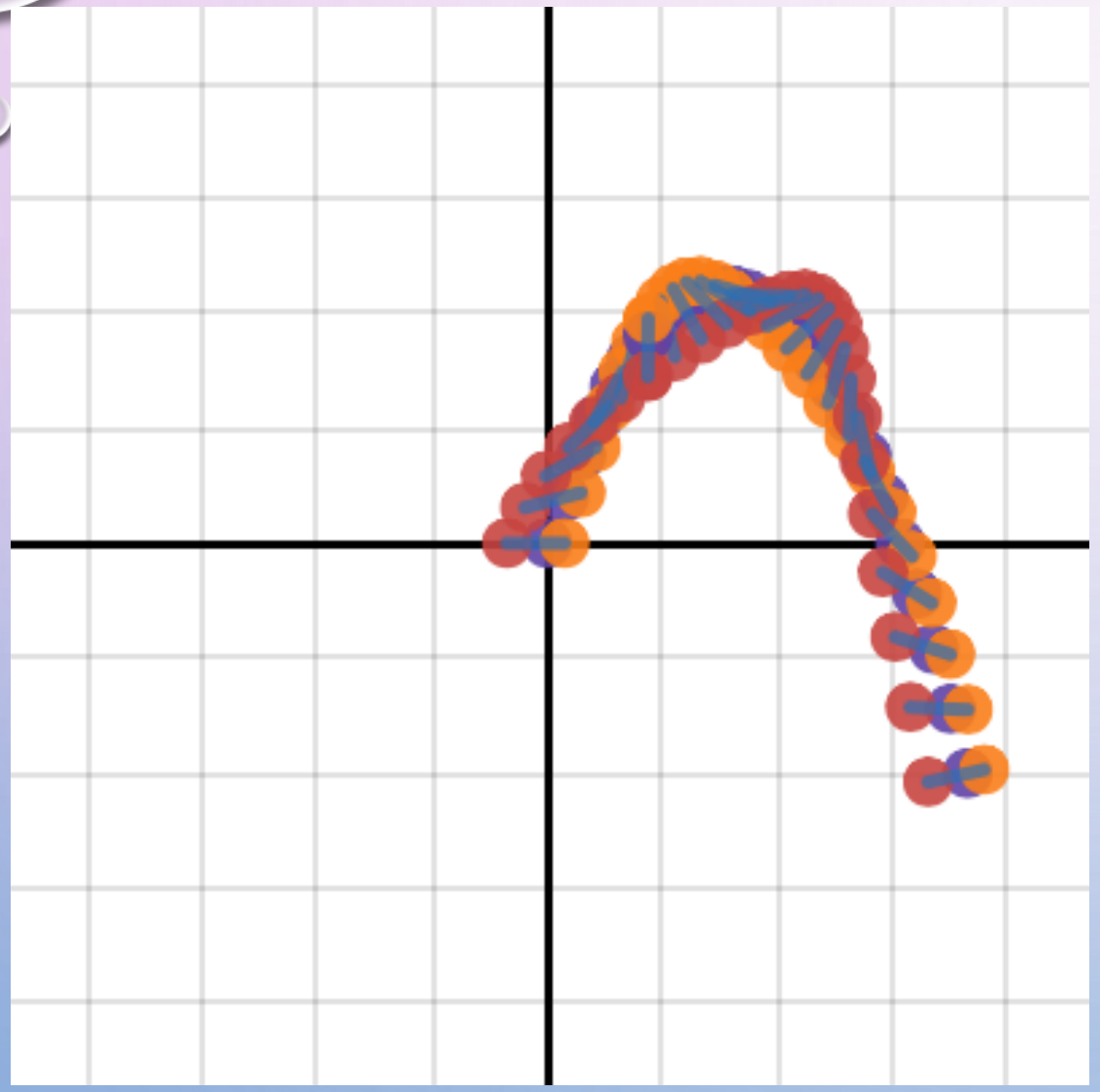

Water

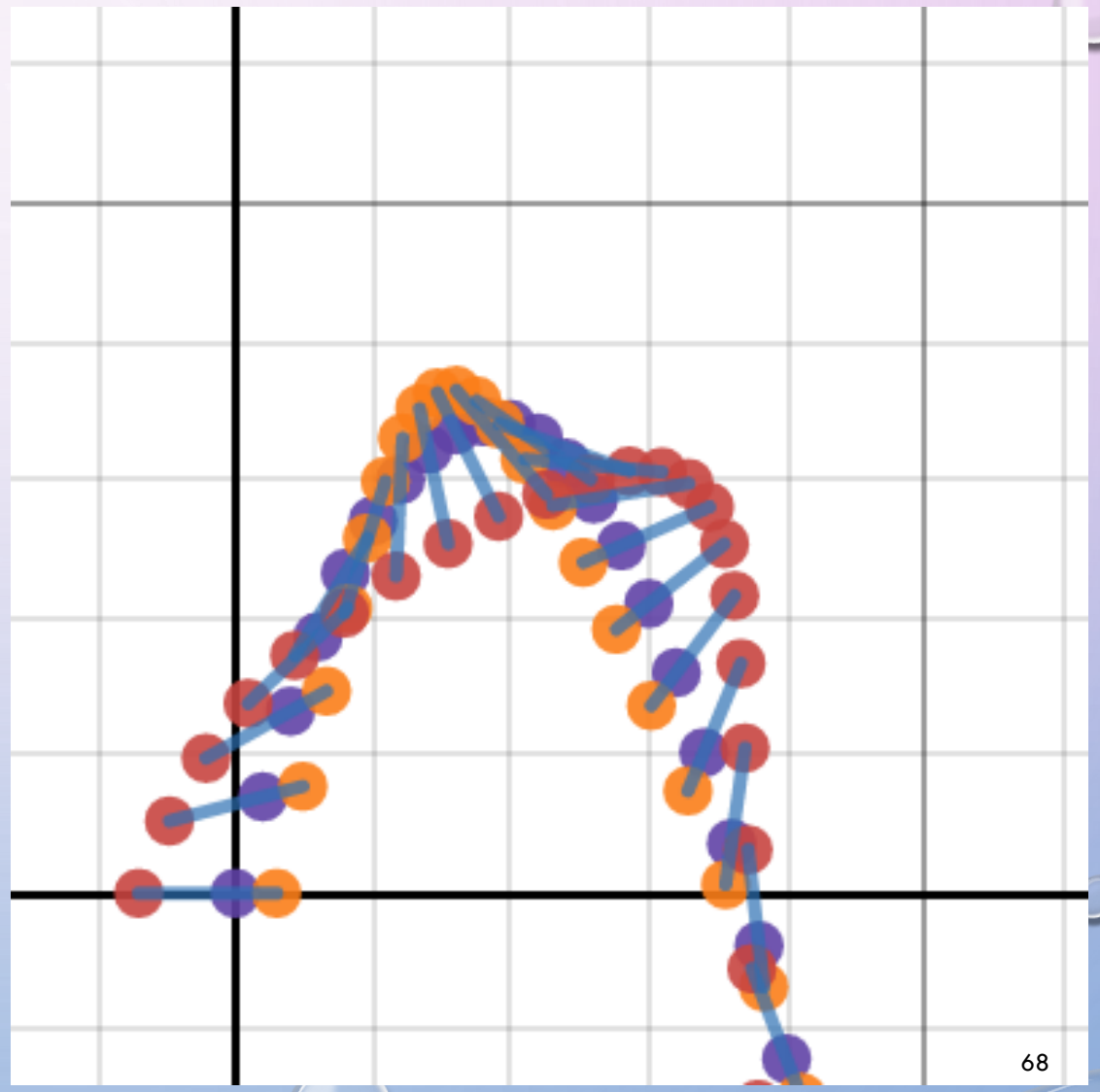


Bottle flipping comes down to physics—having the right amount of **water** in a **bottle** that's given just enough **force** when tossed into the air. ... But the **water** in the **bottle** is much heavier than the **bottle** itself—it has more mass. The **water** slows the angular momentum of the bottom of the **bottle** down.

Use a **water bottle** that's about a quarter full (eyeball it). Hold the **bottle** from its neck-and-cap area. Apply force and give it a little flick with the bottom of the **bottle** out and rotating away from you. May 26, 2016

Model of a flipping water bottle. Red is the "cap", orange is the "base" and purple is the center of mass.





THE physics OF water bottle flipping

PHOTOS | DIVYA ANNAMALAI
ILLUSTRATIONS | SELENA QIAN

1 BOTTLE SELECTION

Hard
- Tall & skinny = harder to find optimal water level
- Pronged bottom = least surface to land on

Medium
- Bendable plastic = deforms so more difficult after multiple flips
- Flat bottom = middle amount of surface to land on

Easy
- Wide = easy to find optimal water level
- Large, flat bottom = most surface to land on

2 OPTIMAL WATER LEVEL

Lower the water level to about one-third of the way up the bottle to move the center of gravity down. This will help the bottle stay upright by keeping the top from tipping over. Applies to all bottle types.

THE GAME THEORISTS YOUTUBE // SOURCE

Pro Tip:
You can test this level without flipping.
1. Hold the bottle at a 45° angle.
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If the level is correct, the bottle should land upright. If not, drink or pour out some of the water.

3a THE THROW: RELEASE ANGLE

Practice until you can reliably get the bottle to release at a 90° angle every time. This makes the center of gravity move upward so the bottle flips perfectly.

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Make sure the throw goes mostly upward rather than forward. If you throw the bottle too far forward, the water will keep moving after landing and then tip the bottle over.

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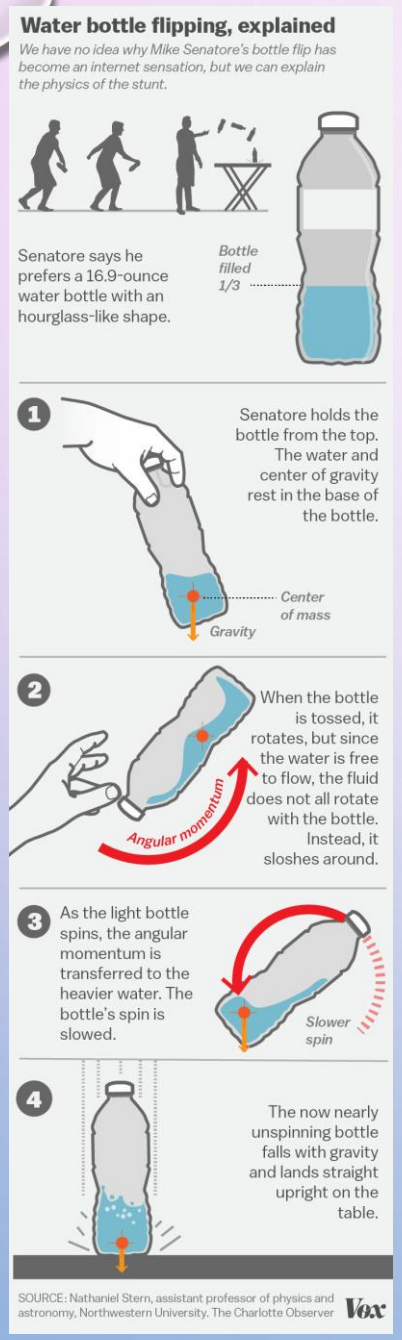
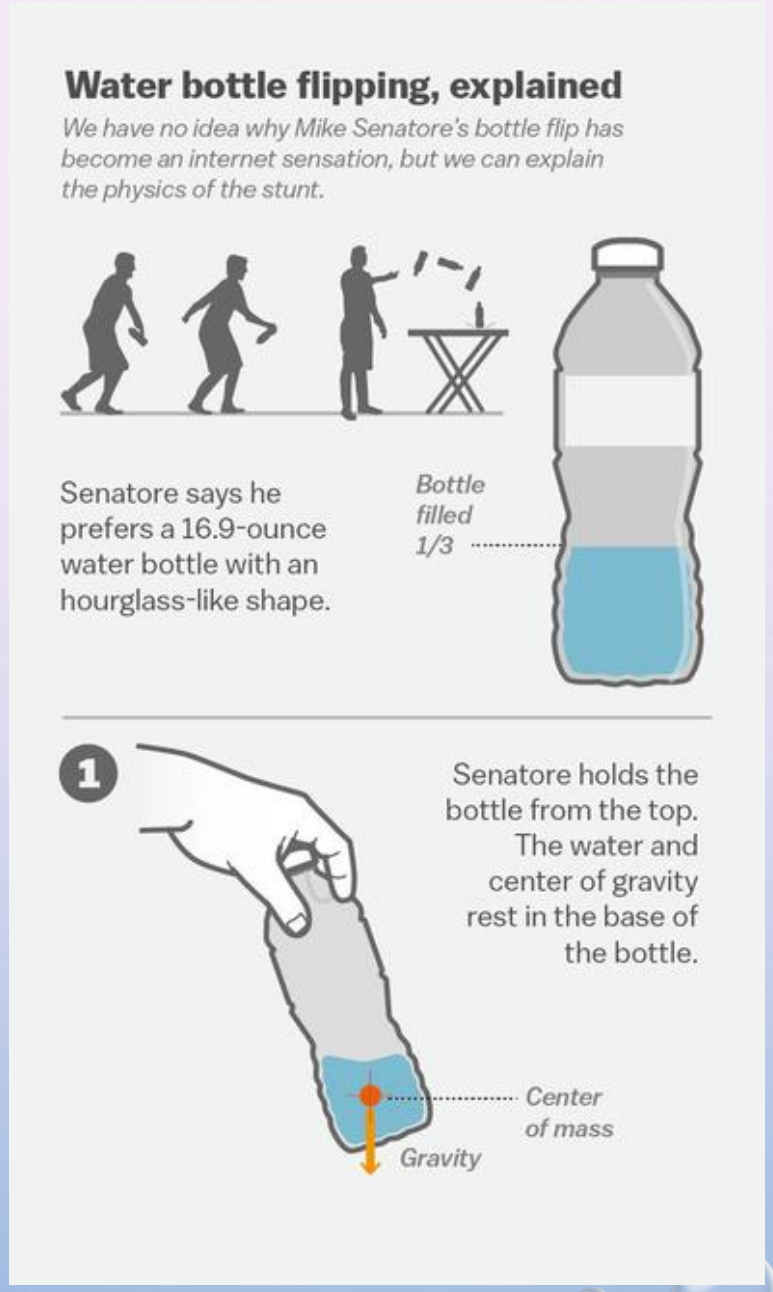

Water bottle flipping, explained
We have no idea why Mike Senatore's bottle flip has become an internet sensation, but we can explain the physics of the stunt.
Senatore says he prefers a 16.9-ounce water bottle with an hourglass-like shape.
Bottle filled 1/3
1
Senatore holds the bottle from the top. The water and center of gravity rest in the base of the bottle.
Center of mass
Gravity
2
When the bottle is tossed, it rotates, but since the water is free to flow, the fluid does not all rotate with the bottle. Instead, it sloshes around.
Angular momentum
3
As the light bottle spins, the angular momentum is transferred to the heavier water. The bottle's spin is slowed.
Slower spin
4
The now nearly unspinning bottle falls with gravity and lands straight upright on the table.
SOURCE: Nathaniel Stern, assistant professor of physics and astronomy, Northwestern University. The Charlotte Observer
Vox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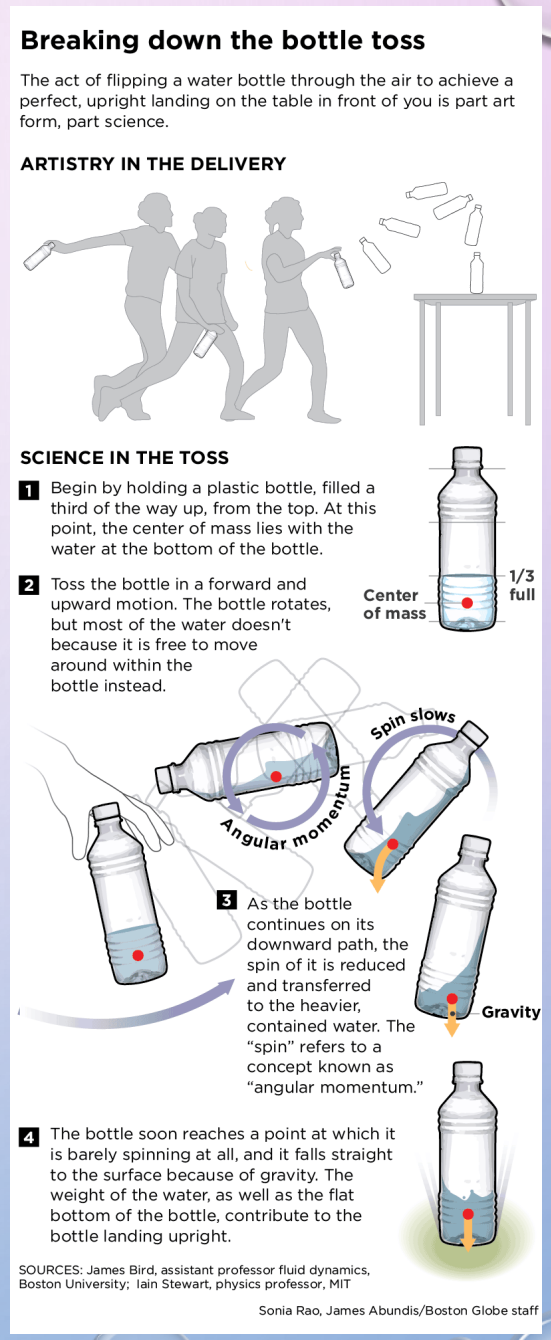
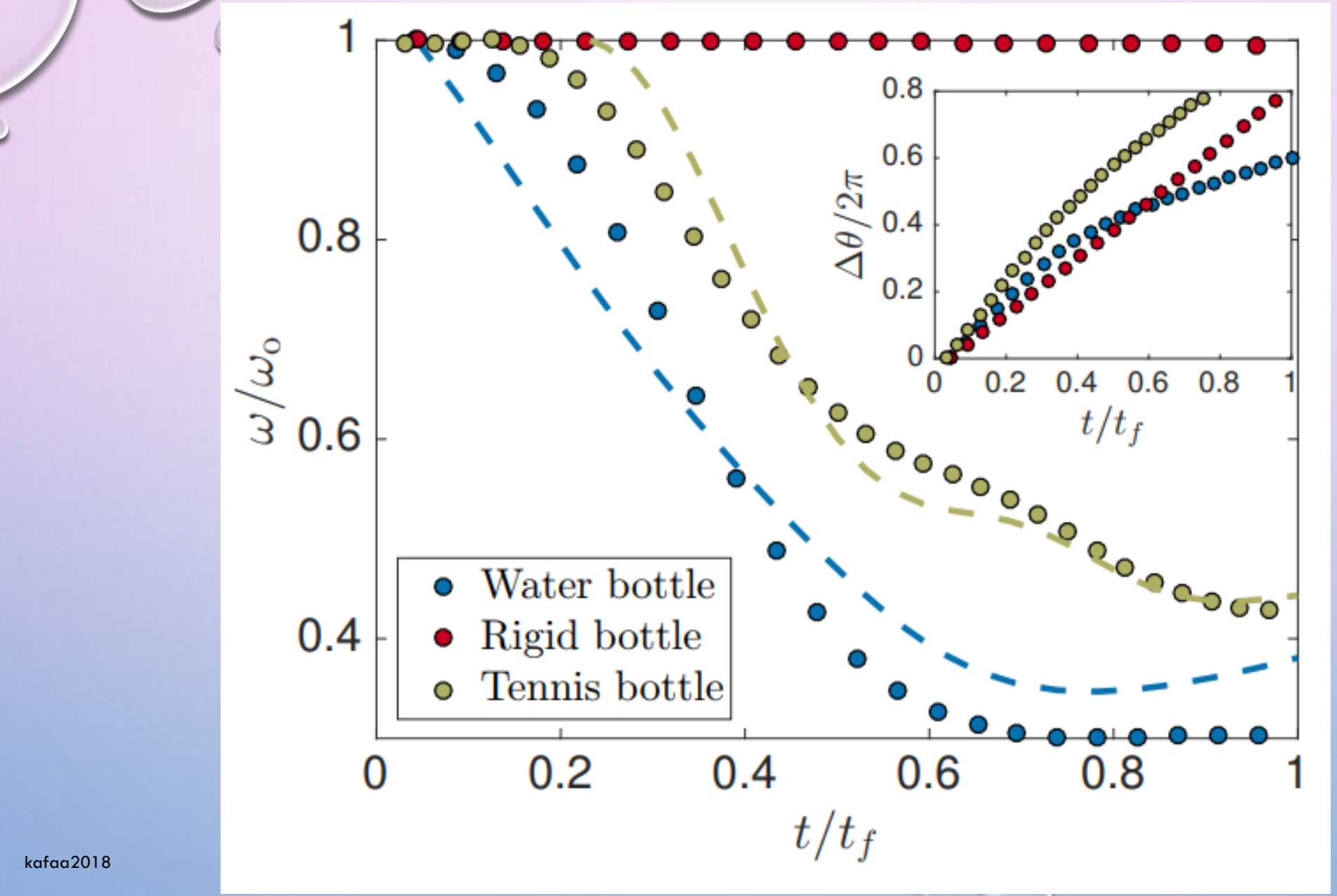
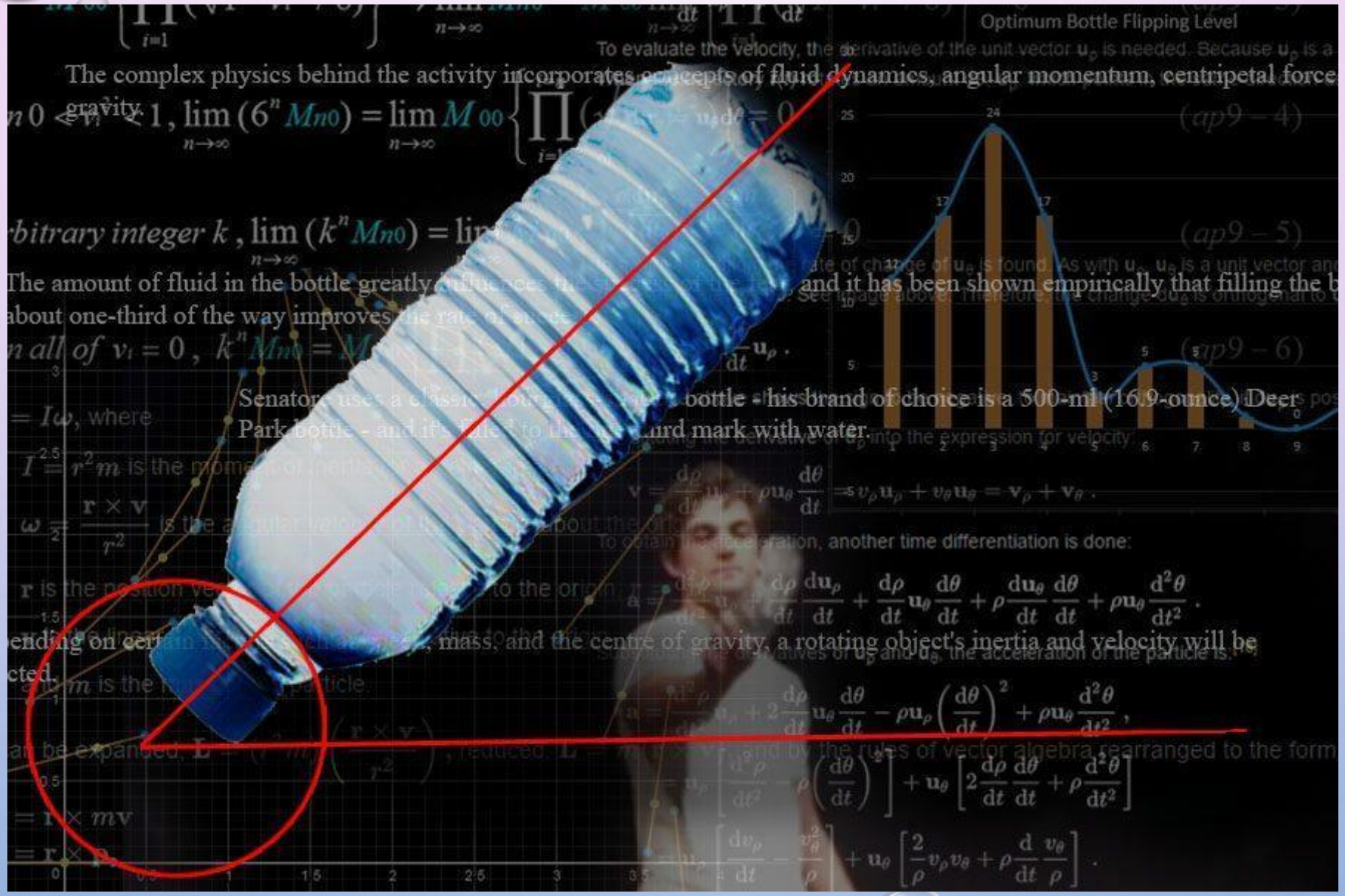

Breaking down the bottle toss
The act of flipping a water bottle through the air to achieve a perfect, upright landing on the table in front of you is part art form, part science.
ARTISTRY IN THE DELIVERY
SCIENCE IN THE TOSS
1 Begin by holding a plastic bottle, filled a third of the way up, from the top. At this point, the center of mass lies with the water at the bottom of the bottle.
Center of mass
1/3 full
2 Toss the bottle in a forward and upward motion. The bottle rotates, but most of the water doesn't because it is free to move around within the bottle instead.
Spin slows
Angular momentum
3 As the bottle continues on its downward path, the spin of it is reduced and transferred to the heavier, contained water. The "spin" refers to a concept known as "angular momentum."
Gravity
4 The bottle soon reaches a point at which it is barely spinning at all, and it falls straight to the surface because of gravity. The weight of the water, as well as the flat bottom of the bottle, contribute to the bottle landing upright.
SOURCES: James Bird, assistant professor fluid dynamics, Boston University; Iain Stewart, physics professor, MIT
Sonia Rao, James Abundis/Boston Globe staff


1
0.8
0.6
0.4
ω/ω_o
0
0.2
0.4
0.6
0.8
1
t/t_f
Water bottle
Rigid bottle
Tennis bottle
$\Delta\theta/2\pi$
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
t/t_f


Optimum Bottle Flipping Level
The complex physics behind the activity incorporates concepts of fluid dynamics, angular momentum, centripetal force, gravity
The amount of fluid in the bottle greatly influences the
about one-third of the way improves the
Senator uses a classic 20-ounce bottle - his brand of choice is a 500-ml (16.9-ounce) Deer Park bottle - and it's fair to the
third mark with water.
ending on certain
cted.

The Physics Behind Water Bottle Flipping

- The amount of water plays a major role in flipping the bottle
- Some Complex physics include:

- Fluid dynamics
- Centripetal force
- Angular Momentum
- Gravity

Fluid dynamics is the flow of liquids and gases that deals with whether there are at rest or in motion interacting with other forces

Gravity is the force that pulls object down to Earth at 9.8 m/s^2

Centripetal force is the force that follows a curved path

Angular momentum is the product of inertia and angular velocity that rotates the body of an object

$$PE_{gravity} = KE_{translational} + KE_{rotational}$$

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

Rotational Motion

Consider an object moving in a circular path. It has velocity, acceleration, kinetic energy and momentum but these are not the simplest variables

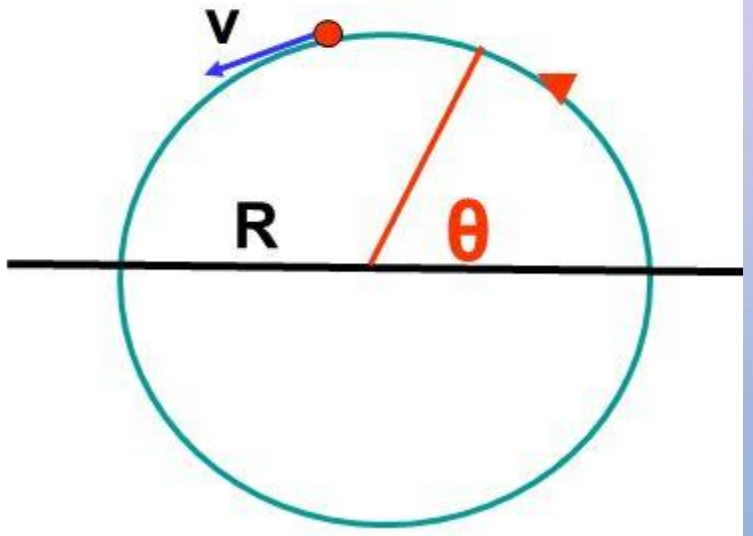
Displacement we use the angle θ measured in radians

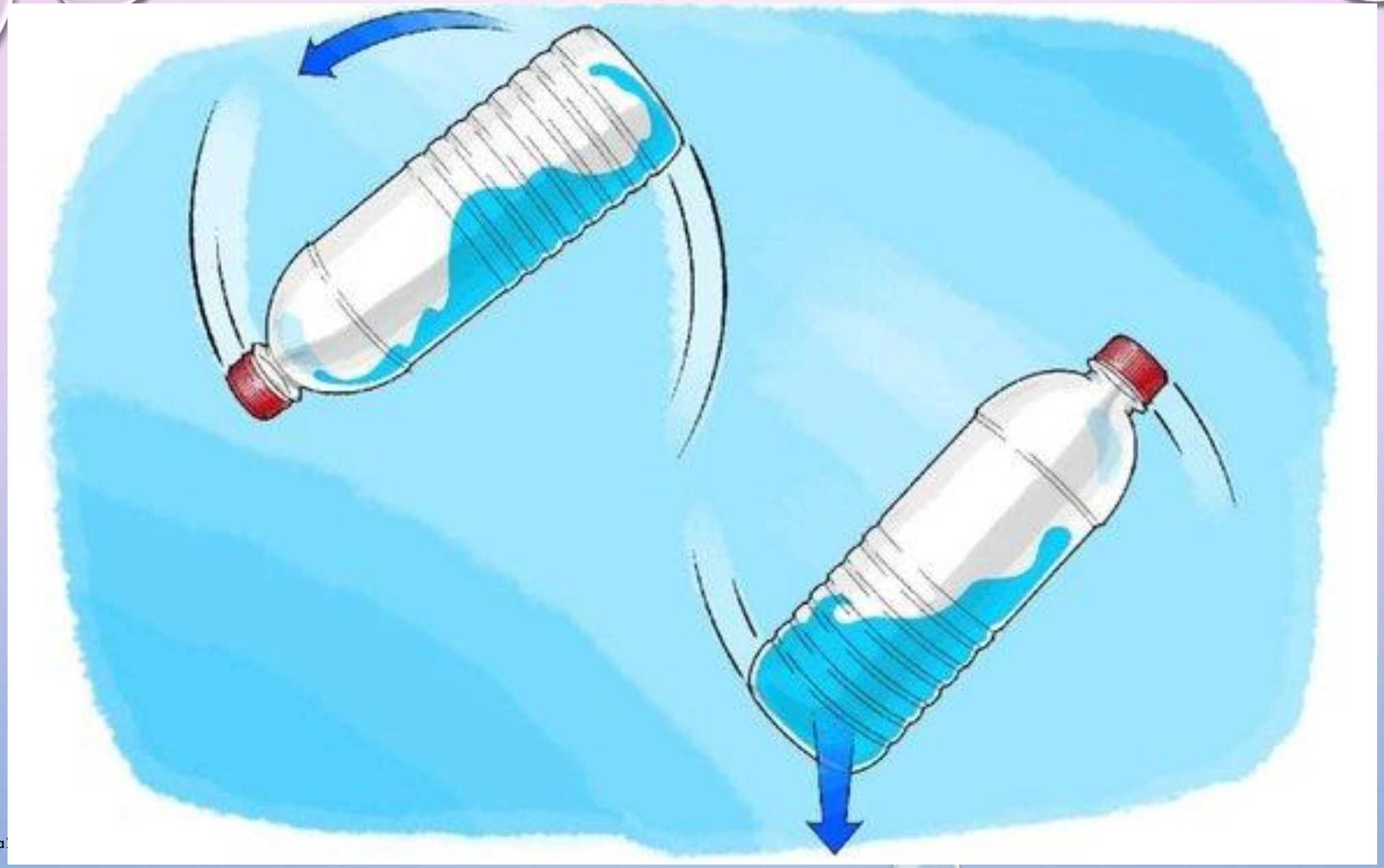
Angular velocity $\omega = \Delta\theta/\Delta t$

Angular acceleration $\alpha = \Delta\omega/\Delta t$

1 revolution/sec = 2π radians/sec
Since the time for one revolution is
$2\pi r/v = 2\pi/\omega$ then $v = r\omega$
so $\Delta v = r\Delta\omega$ and $\Delta v/\Delta t = r\Delta\omega/\Delta t$
and $a = r\alpha$

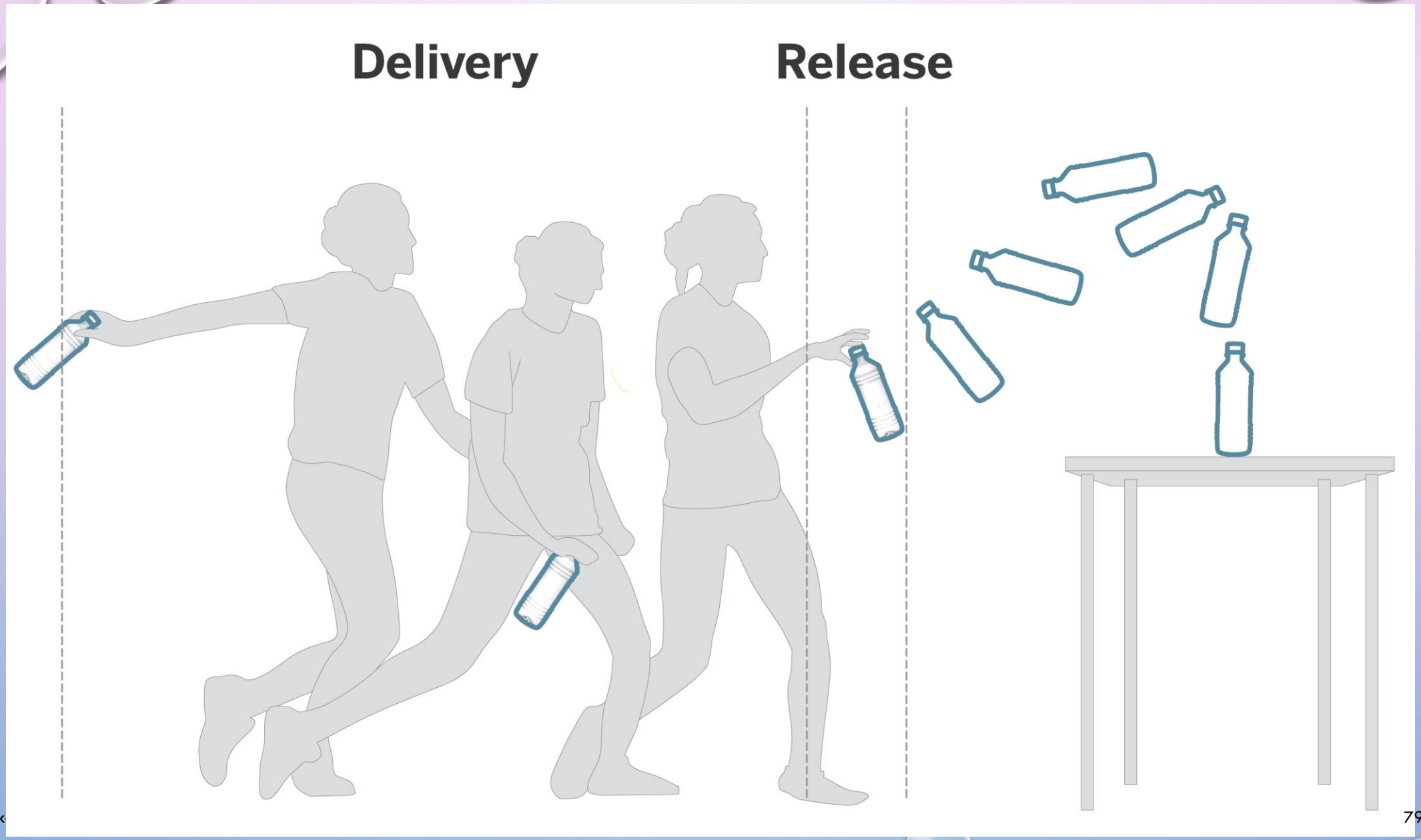
All parts of a rotating wheel have the same ω but
The further from the center the bigger is v



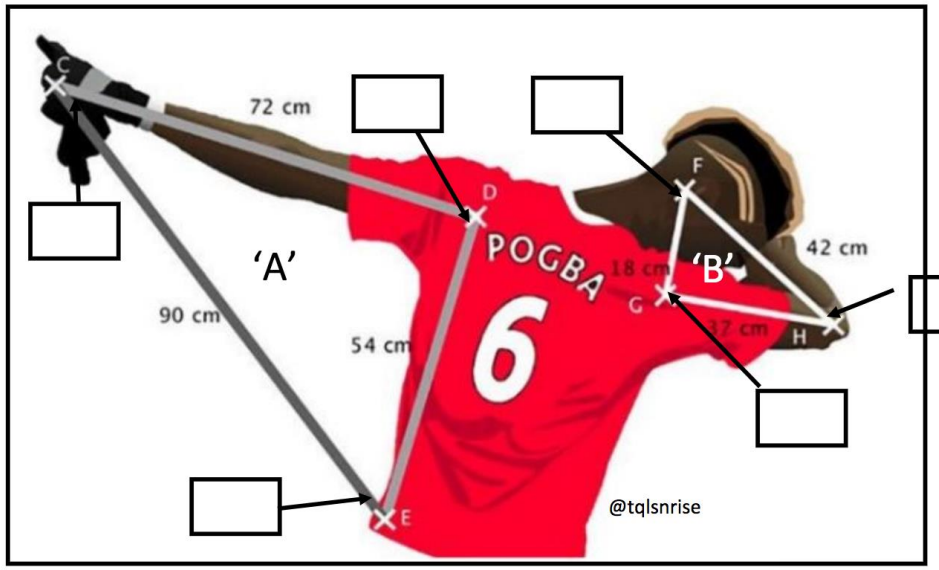


The Water Bottle Flip Challenge

Hold the **bottle** from its neck-and-cap area. Apply force and give it a little flick with the bottom of the **bottle** out and rotating away from you. Give it enough arc so that as the rotation is being completed,
the **water** slushes back to the bottom,
allowing the **bottle** to fall straight down.
That's how you **bottle flip**.


Delivery
Release

Dab and Bottle Flip Maths.



Measure each angle and place in the boxes.

Which angles are there? Write the correct number in the box.

Right angle ☐

Acute angle ☐

Obtuse angle ☐

What is the perimeter of triangle 'A'? ☐

What is the perimeter of triangle 'B'? ☐

Which angles are there? Write the correct number in the box.

Right angle ☐

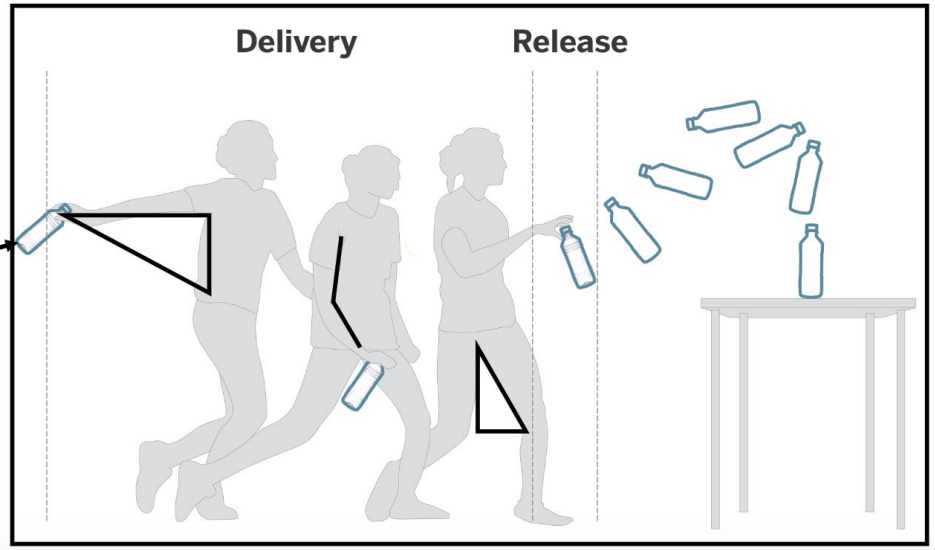
Acute angle ☐

Obtuse angle ☐

How many degrees will the bottle rotate from

To landing on the table?

The best way to have a successful flip is to fill the bottle a third full of water - can you draw a line at about a third full on this bottle?



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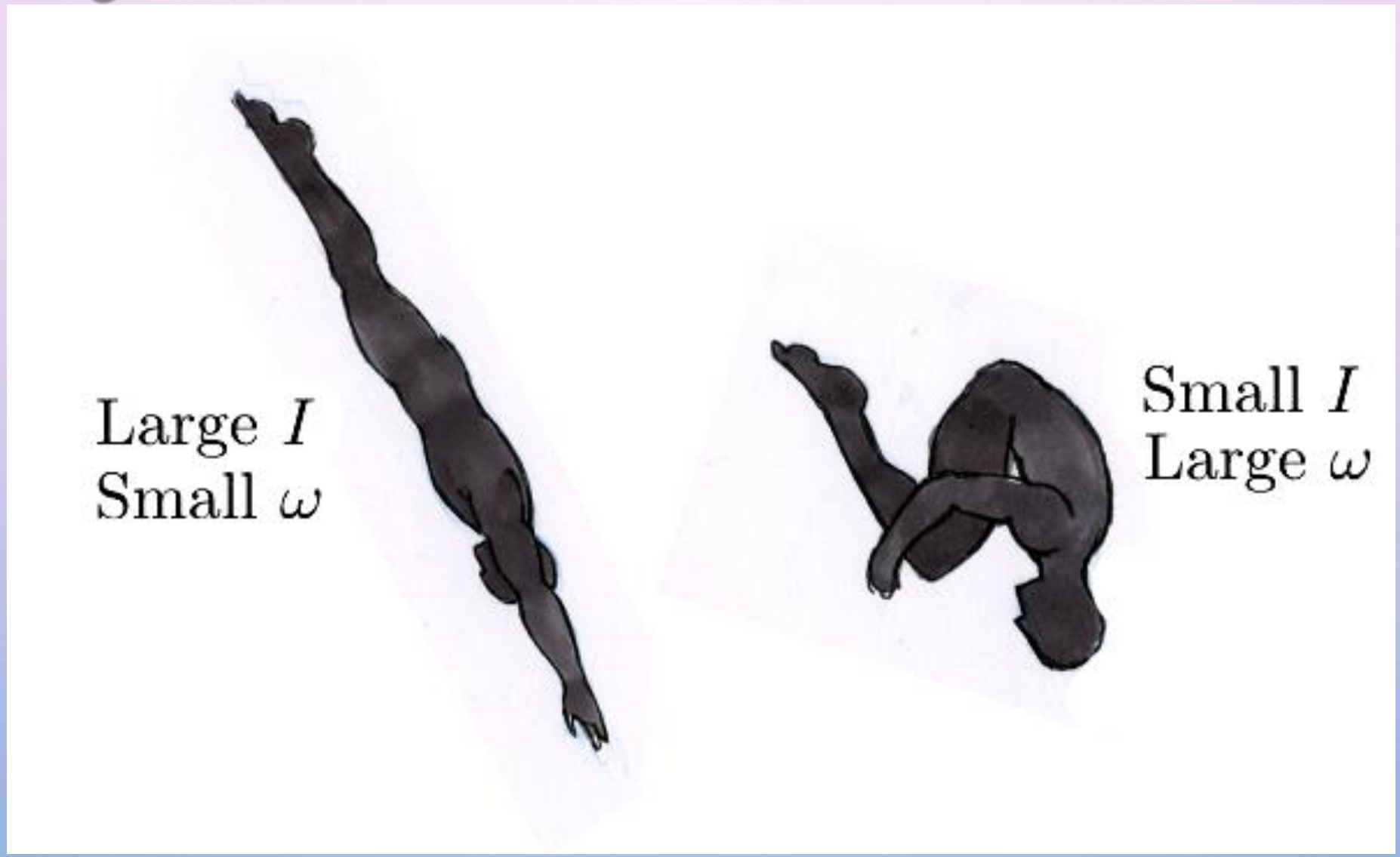
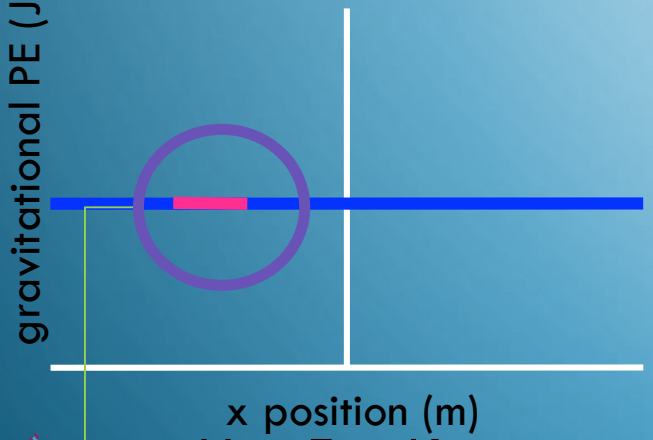

Large I
Small ω
Small I
Large ω

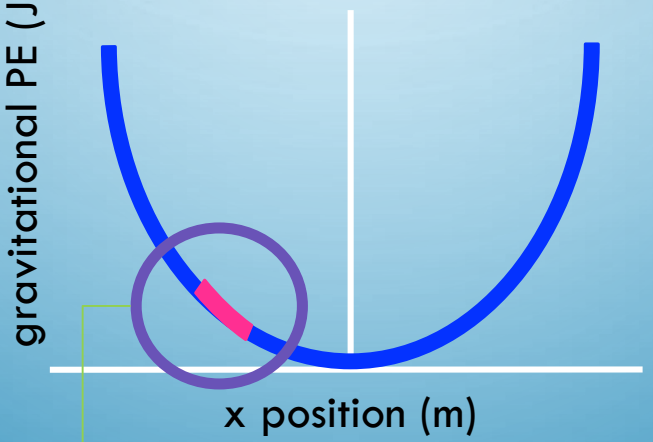
❖ EQUILIBRIUM

Neutral

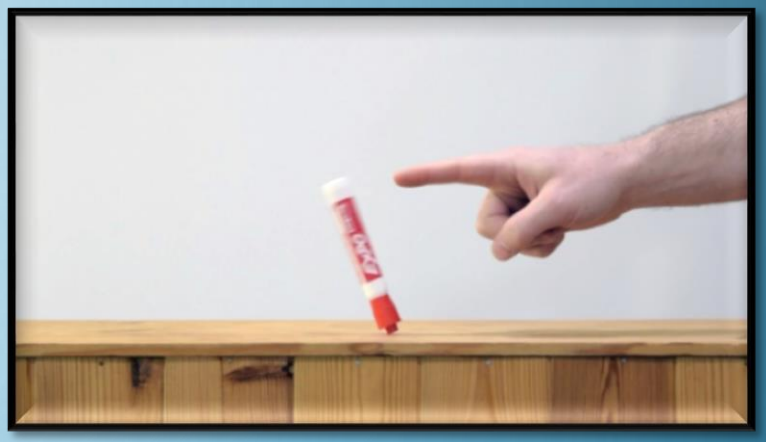


$U = E + K = cte.$

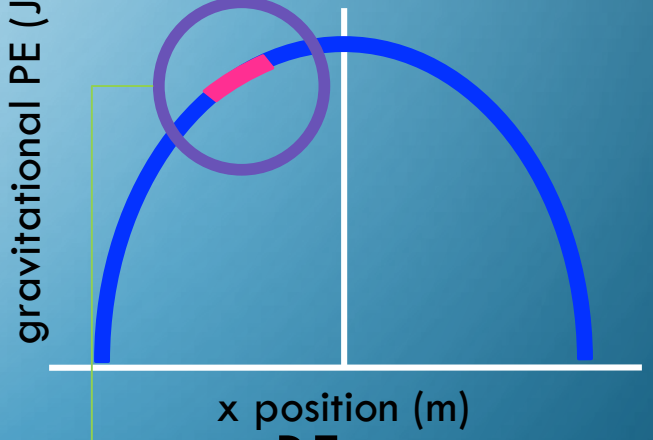
Stable



$P.E. = -dU/dx = 0$



Unstable

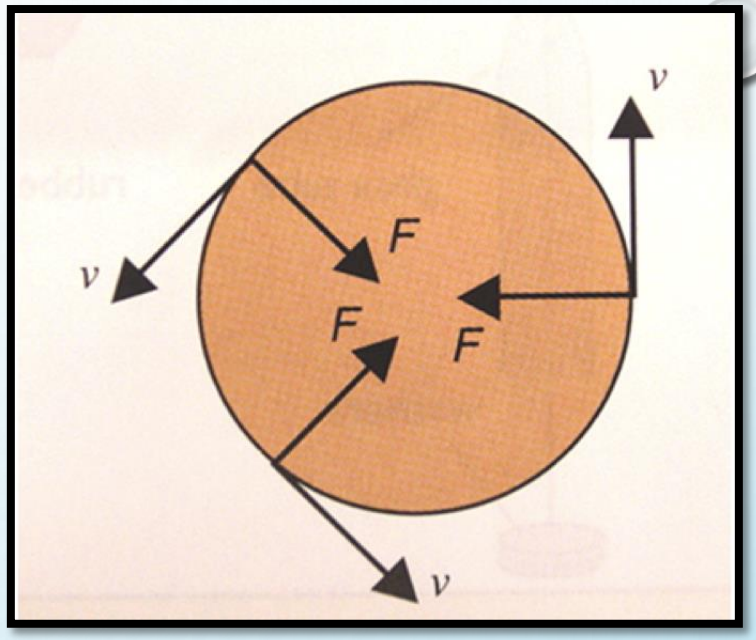


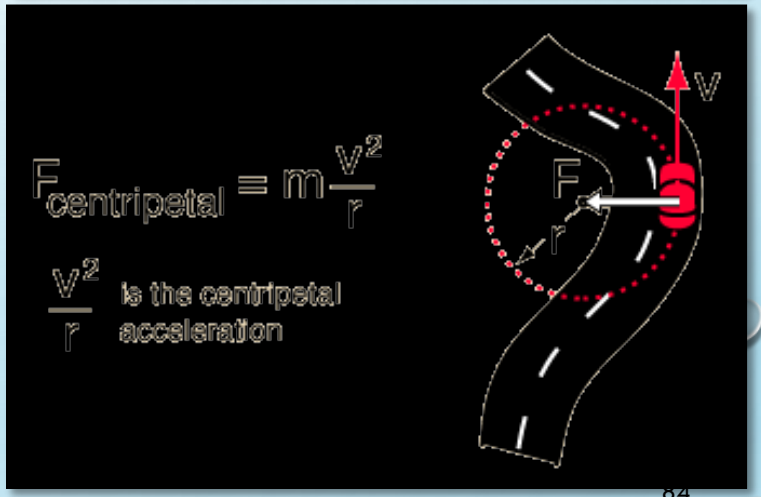
$P.E. = +dU/dx$

Back

❖ CENTRIPETAL FORCE

- Acceleration is caused by Force (F=ma).
- Force must be in the same direction as acceleration.
- Centripetal Force acts towards the center of the circle.
- Force is provided by some external force – e.g. friction.





ANGLE OF IMPACT RESULTS

Best angle for bottles with less level of ideal water level

Between 60° to 120°

Best angle for ideal level of water

Between 80° to 100°

Best angle for bottles with higher level of ideal water level

Almost 90°

Back