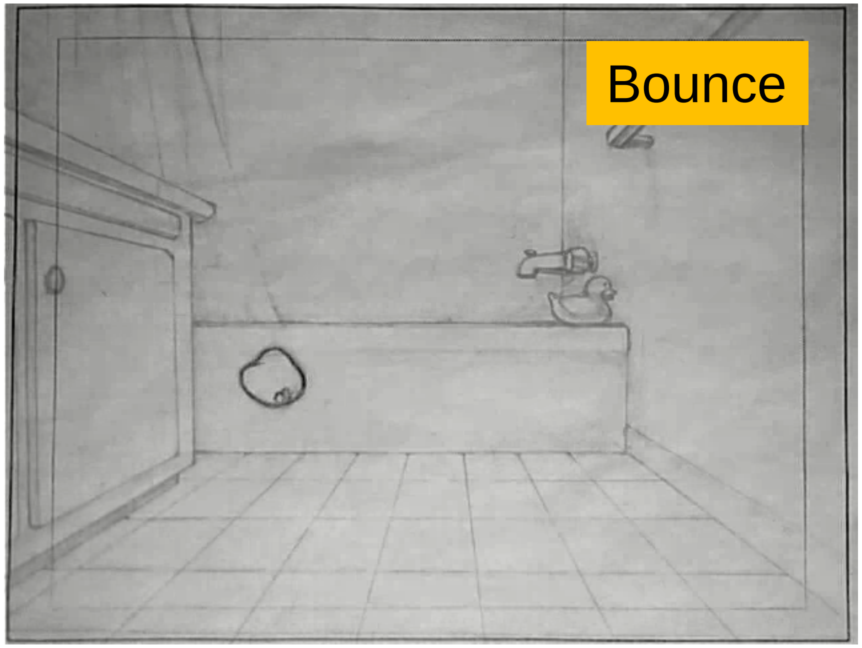
Compressibility & Elasticity

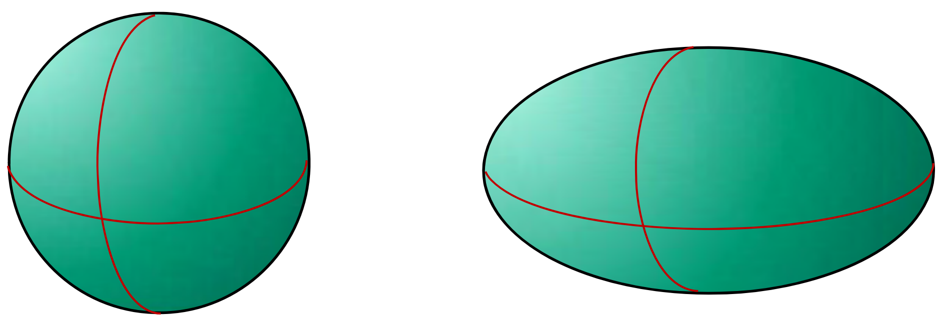
Water Balloon Bounce

The fluid squash and stretch of the balloon continues through the bounce.



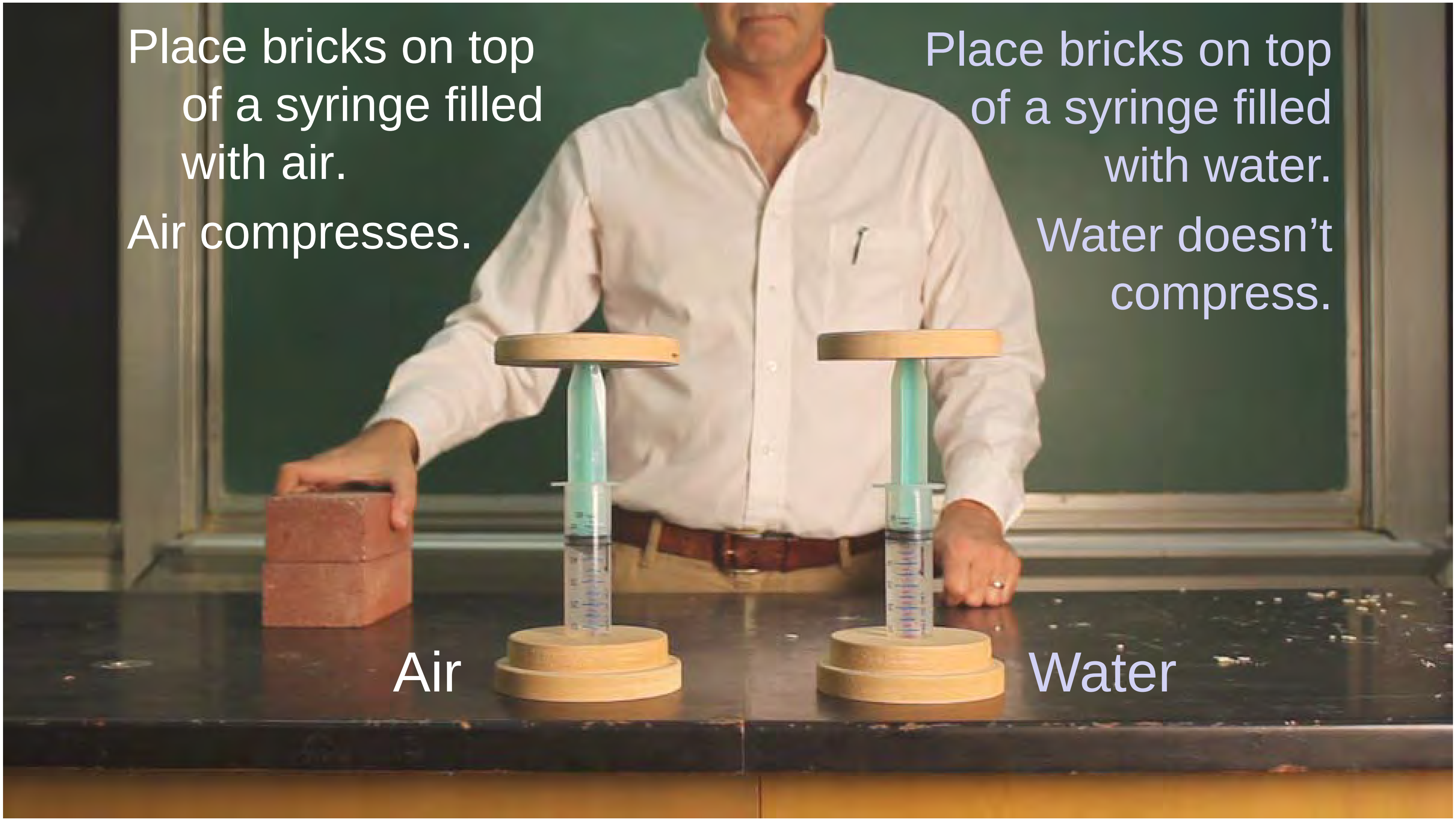
Compressibility

Most solids and liquids are almost *incompressible*, that is, it takes an enormous force to change their volume.



Water balloon easily changes shape since it's mostly liquid but its volume does *not* change.

Incompressibility of Water



Young’s Modulus

Young’s modulus indicates amount of force required to compress or stretch a material.

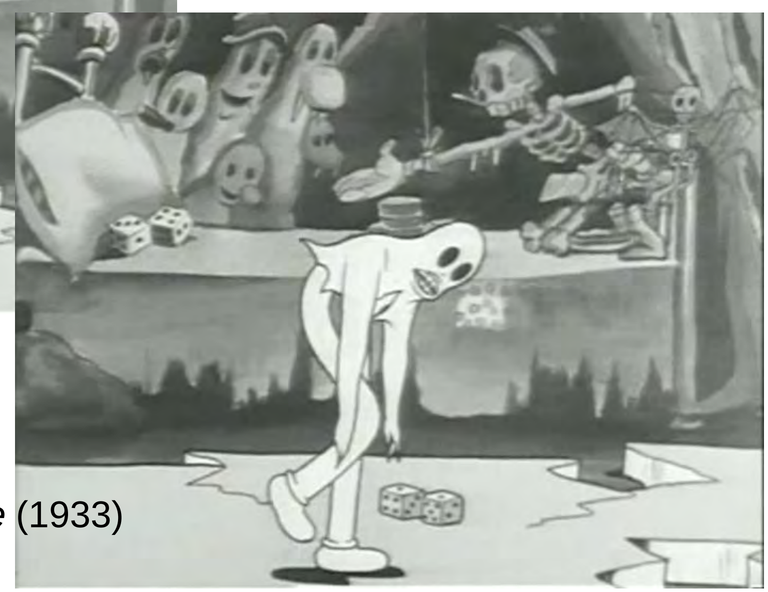
Material	Young’s Modulus (GPa)
Rubber	0.01 to 0.1
Water	7
Wood / Bone	9 to 11
Concrete	30
Steel	200

Rubber is compressible but water is almost as incompressible as wood!

Rubber Hose Animation

In the “rubber hose” style of animation the characters’ bodies stretch and compress as if they’re made of rubber.

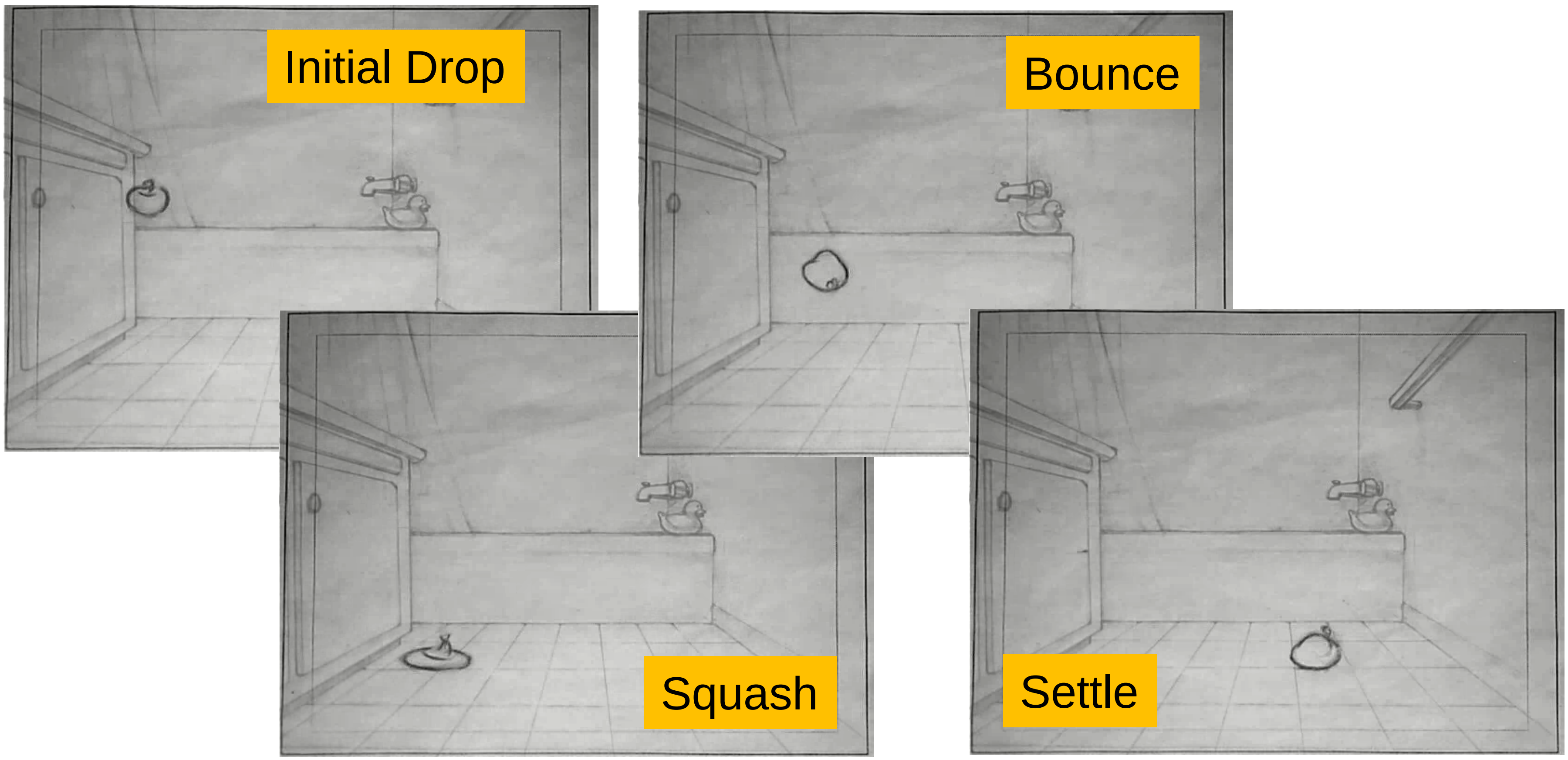
Volume is *not* constant.



Betty Boop’s *Snow White* (1933)

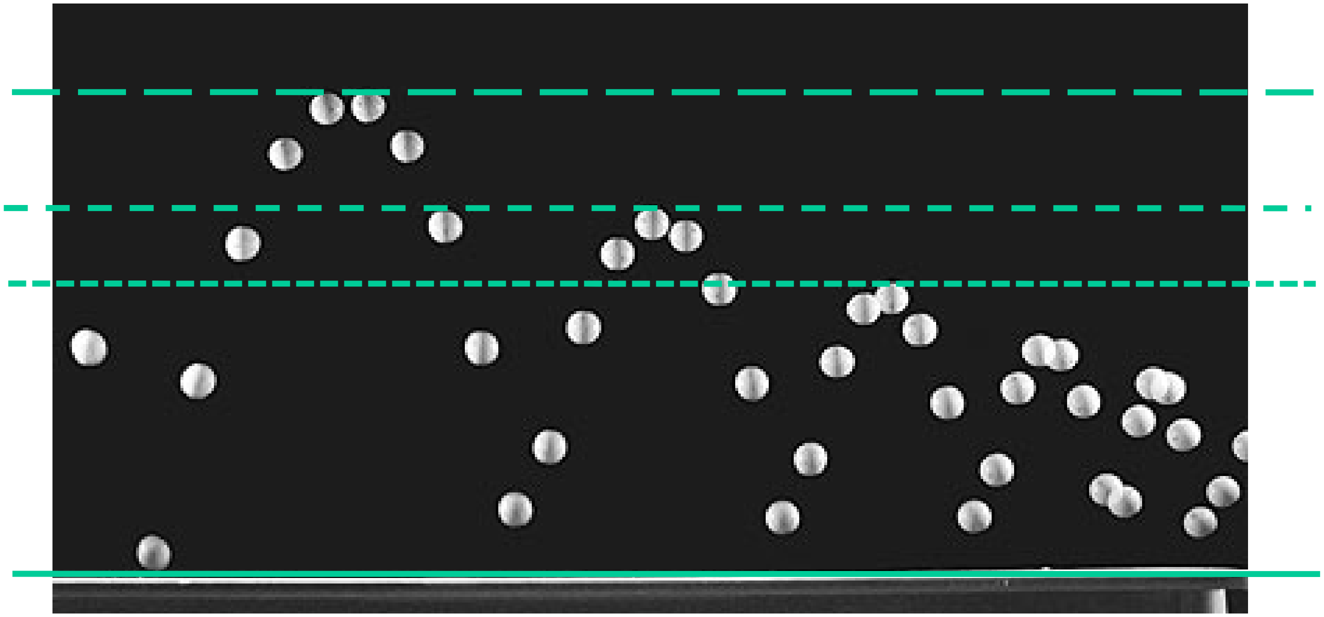
Staying on Model

The volume of the water balloon needs to stay constant throughout the shot to stay on model.



Bounce Height

Objects lose energy with each impact so their speed after impact is less than speed before impact.



Because of this loss of speed, each bounce is lower.

Elasticity

Rubber ball is elastic; it bounces high when dropped on a hard surface.

Steel ball and a golf ball also elastic, even though they are very incompressible.

Clay ball or flour sack are inelastic since they lose almost all energy on impact.

Elastic

Inelastic

Water is Elastic

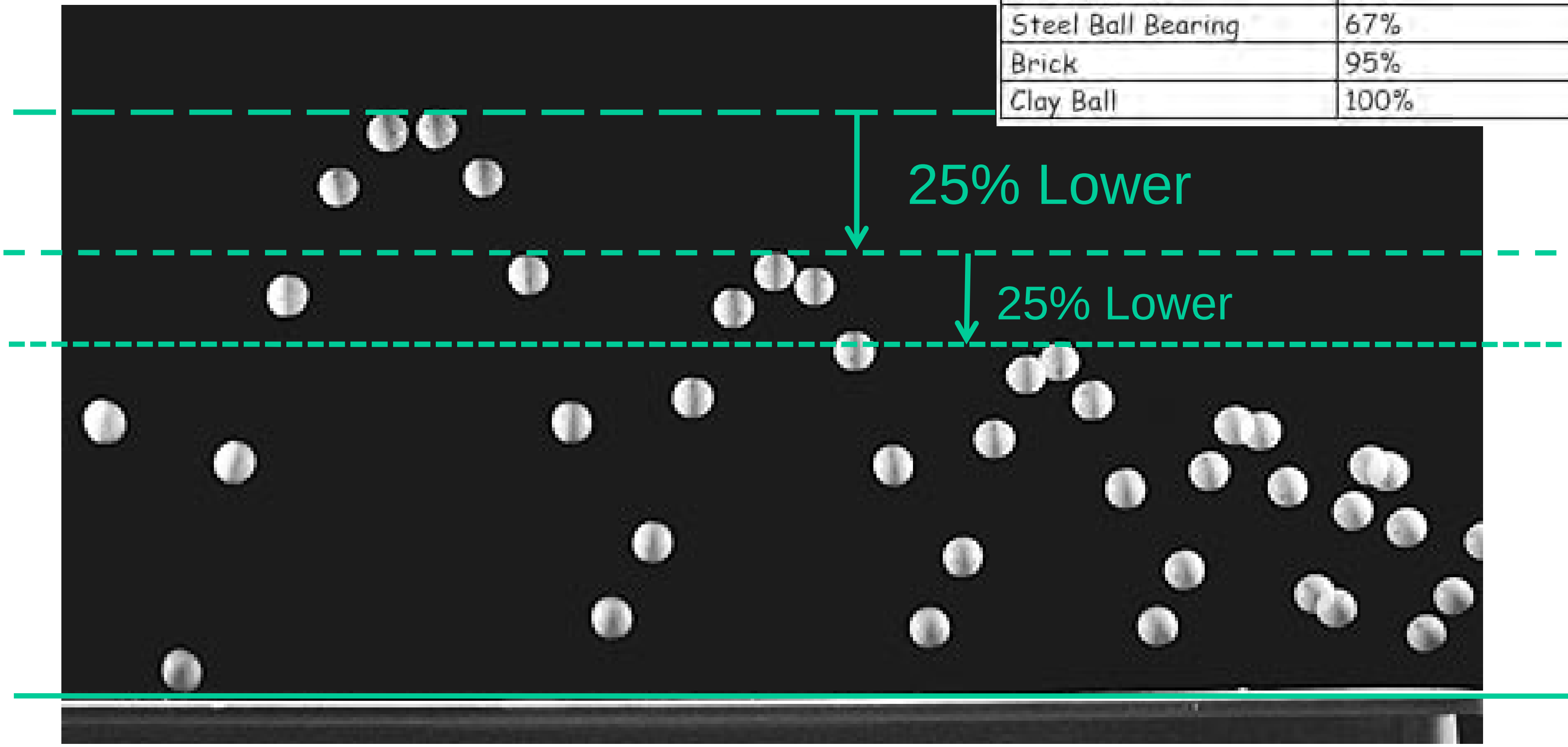
Water is elastic, as can be seen by the height of splashes and from the fact that you can skip a stone off the surface.

Water balloon is elastic because water and rubber are both elastic so it has a noticeable bounce

Coefficient of Restitution

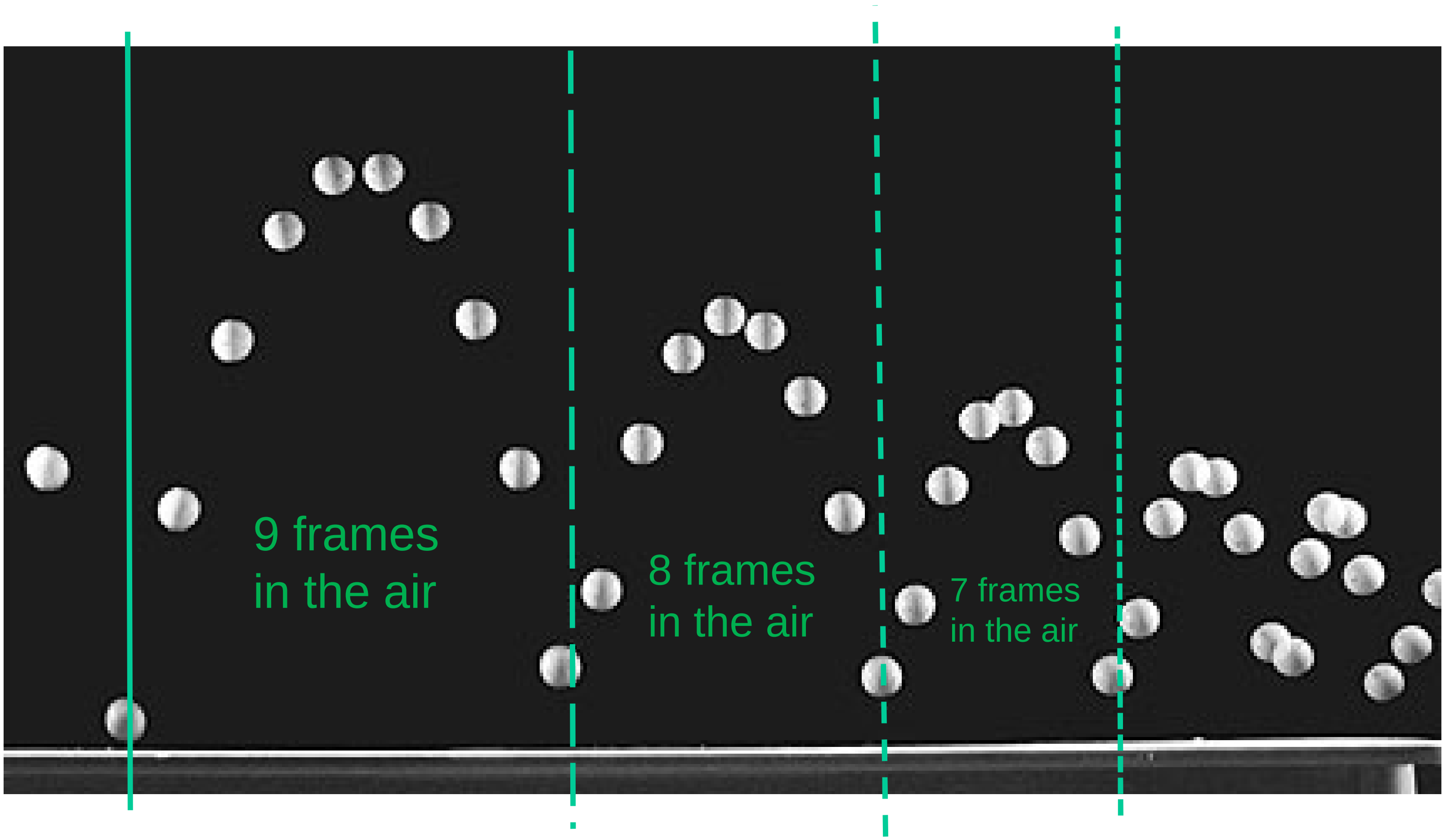
Each bounce is lower by roughly the same fractional amount.

Bouncing Object	Percent of height lost per bounce
Golf Ball	33%
Billiard Ball	40%
Hand Ball	50%
Tennis Ball	50%
Glass Marble	60%
Steel Ball Bearing	67%
Brick	95%
Clay Ball	100%



Bouncing Range

Decreasing distance covered with each bounce since time in the air decreases.



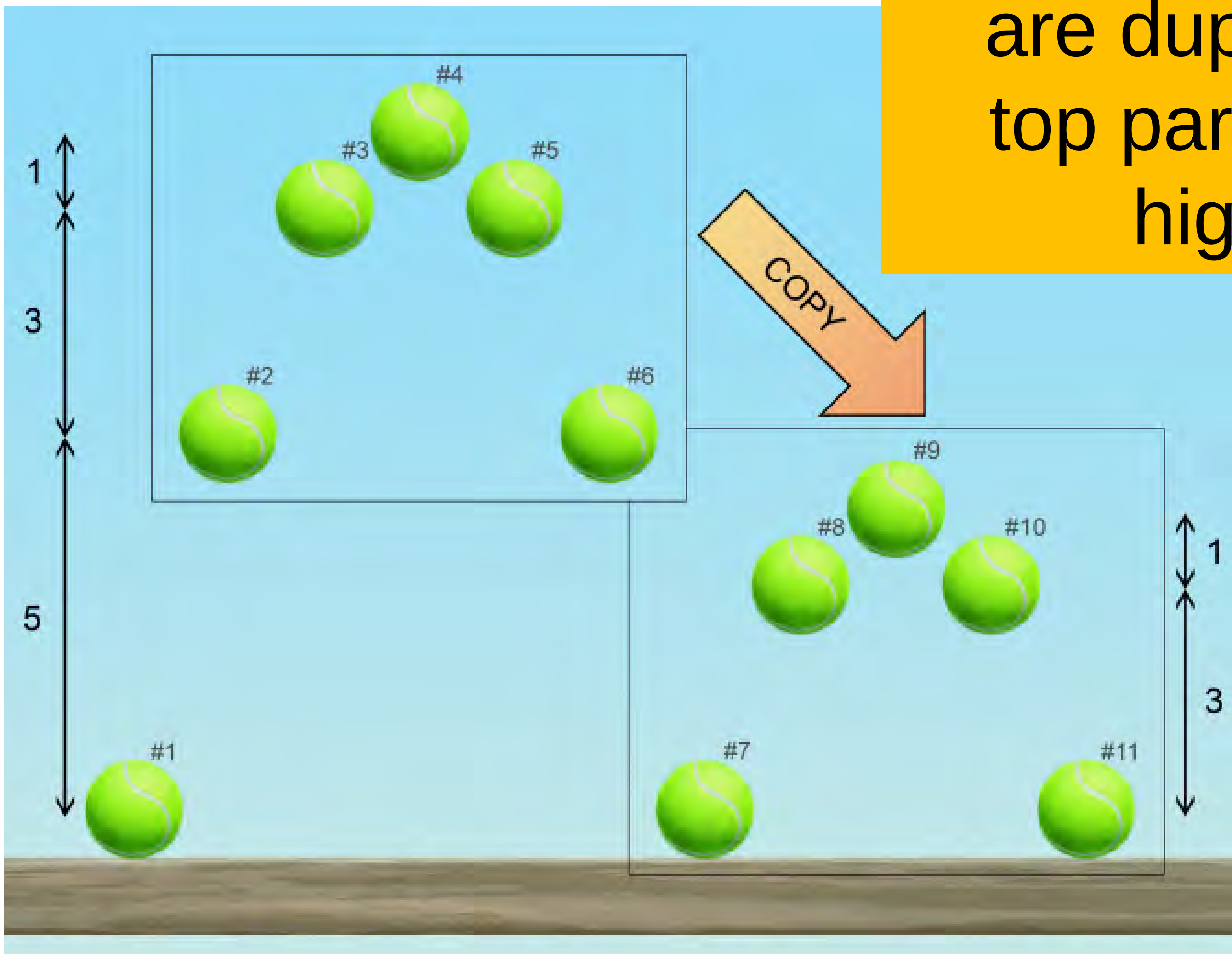
Enhanced Bouncing

Bounce height can be restored to a ball if it hits a moving surface or if the ball has a lot of spin.

A character can also add energy by pushing down with the right timing.

Path of Action Arcs in Bounces

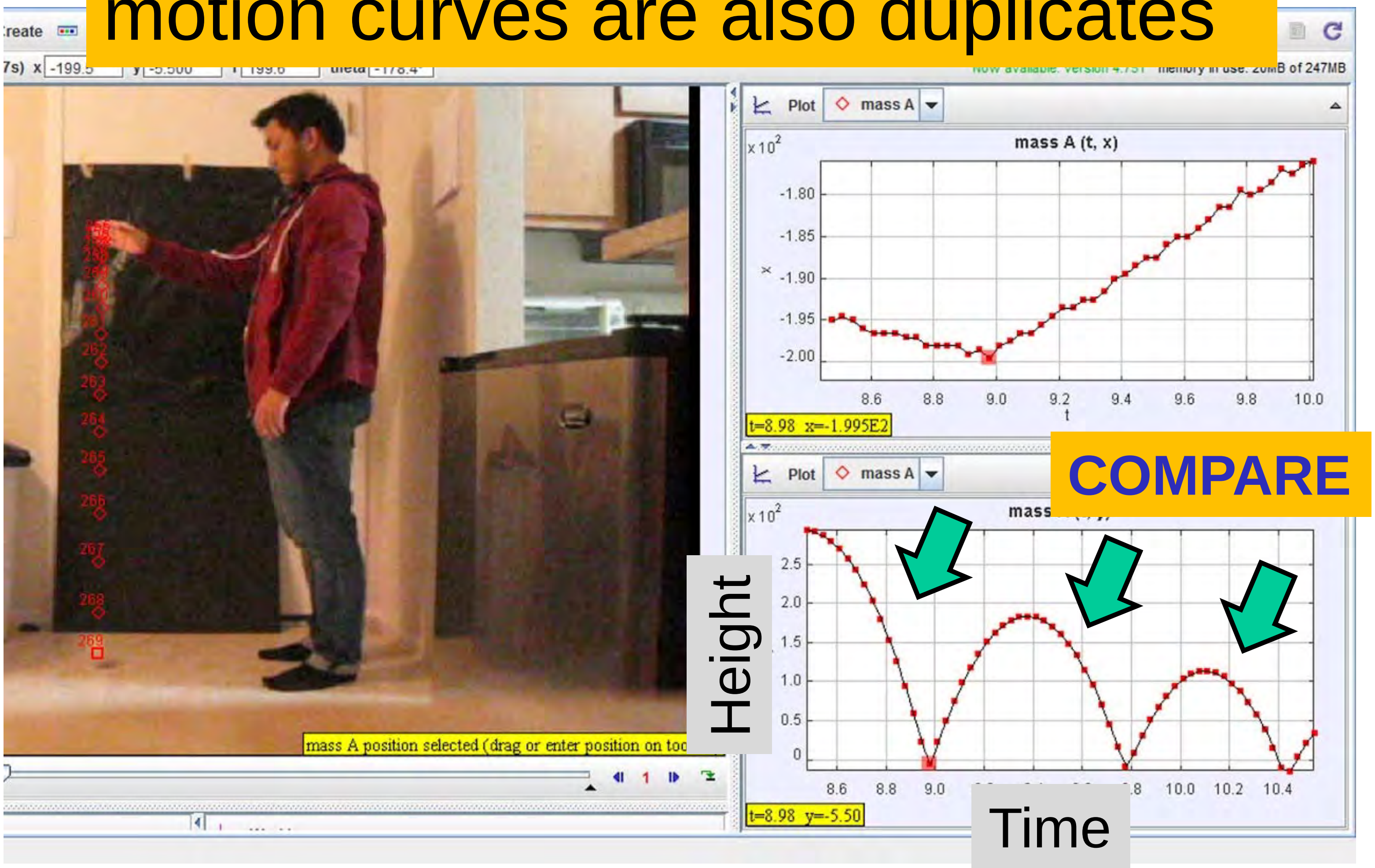
Arcs of lower bounces are duplicates of the top part of the arc of higher bounces.



Note: Horizontal spacings may change if there's spin on the ball.

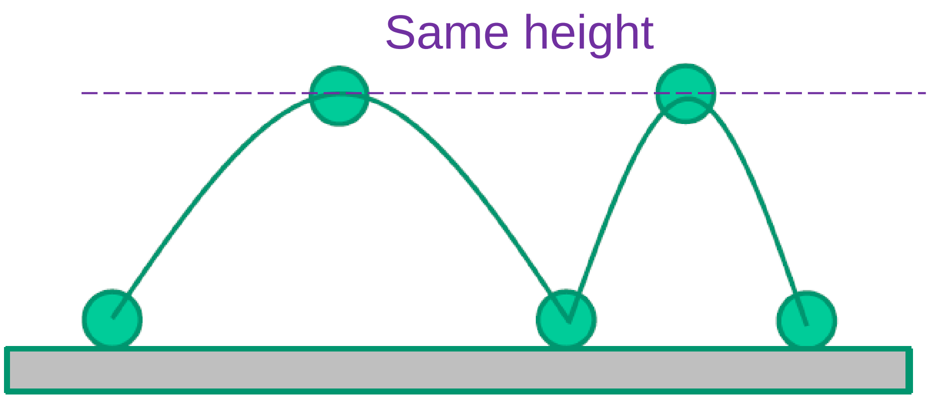
Motion Graph Arcs for Bounces

Parabolic arcs in the graph editor's motion curves are also duplicates

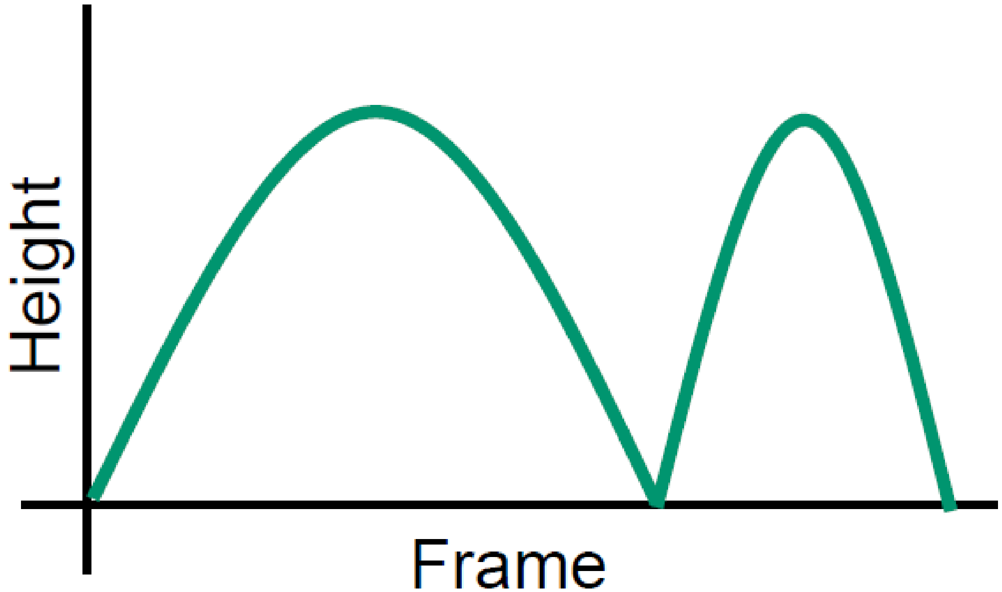


Path of Action vs. Motion Curve

An ball with spin happens to bounce like this →



Does the motion curve of height look like this? →

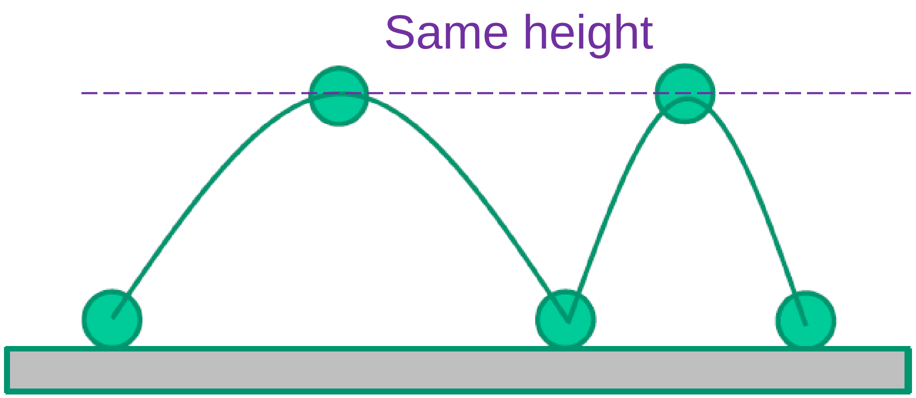


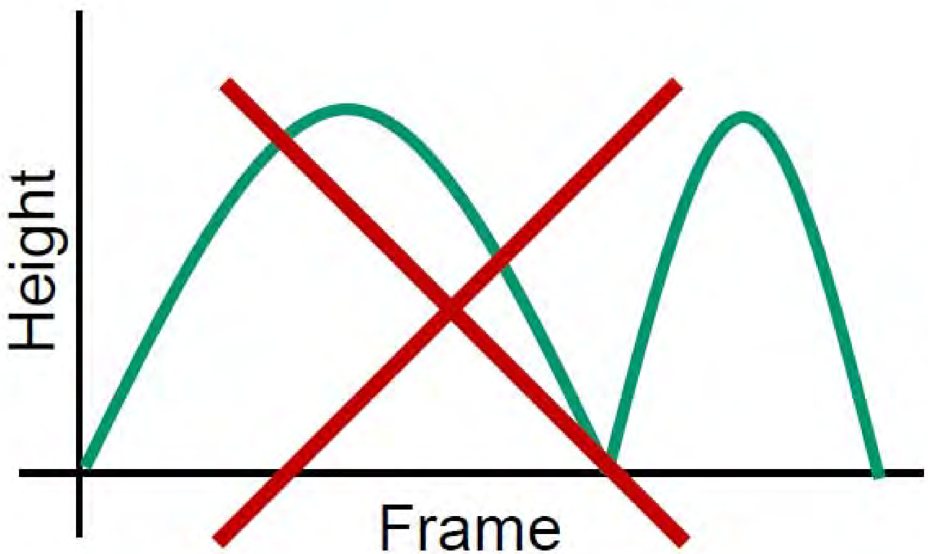
A) Yes B) No
C) Maybe yes, maybe not.

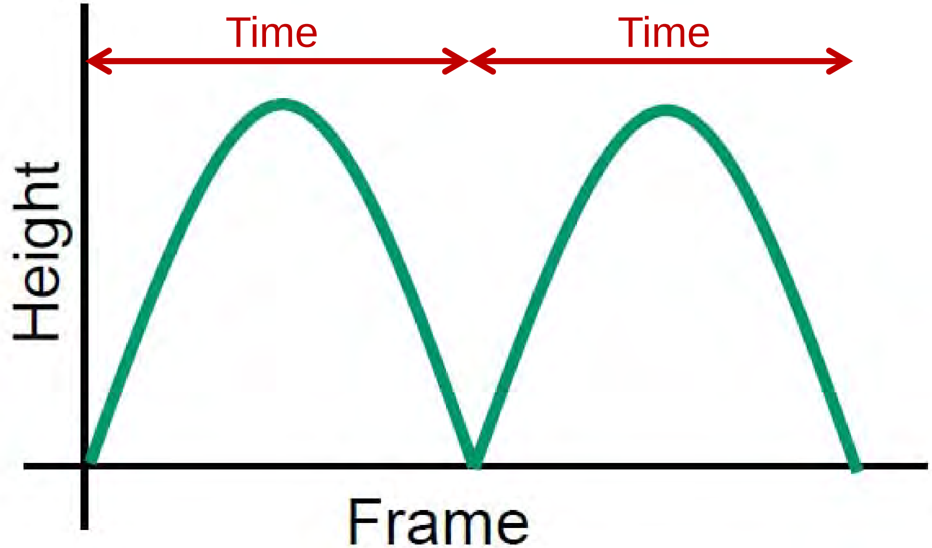
Path of Action vs. Motion Curve

B) No

The heights are the same so the time in the air is the same.







Summary

- Most liquids and solids are very incompressible.
- Rubber is compressible; when an object or a character’s volume changes it looks rubbery.
- Elasticity does not imply compressibility.
- Elastic objects bouncing on a hard surface retain much of their energy after the impact with each bounce lower by the same percentage.
- The vertical spacings in the parabolic path of action for each bounce are the same.
- The parabolic arc of the motion curve for each bounce is the same shape.