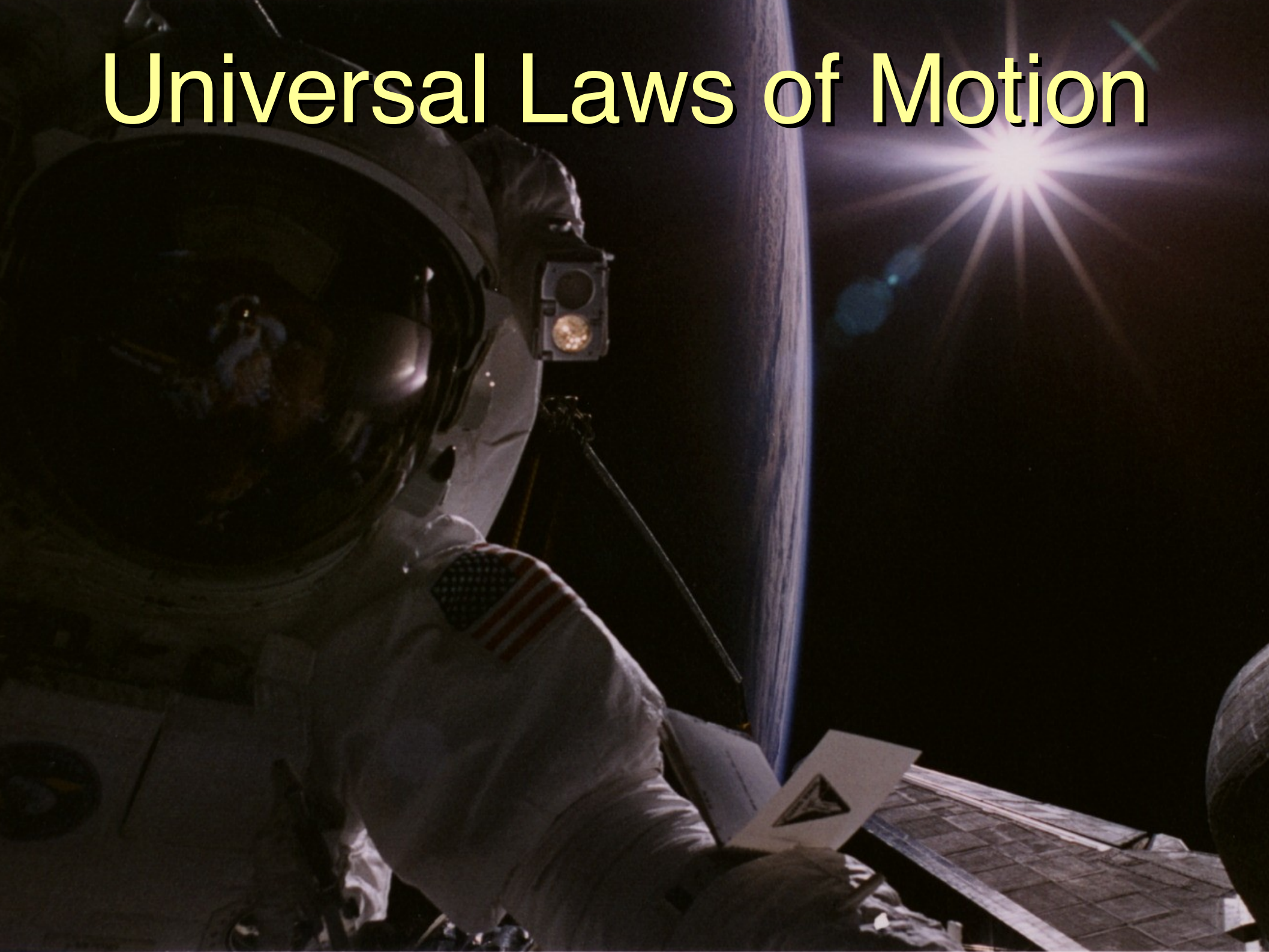
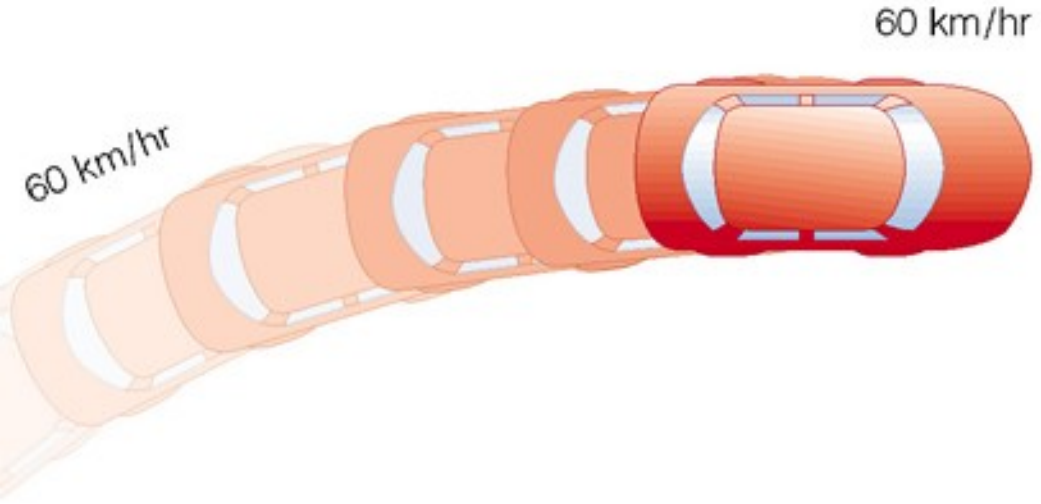
Universal Laws of Motion

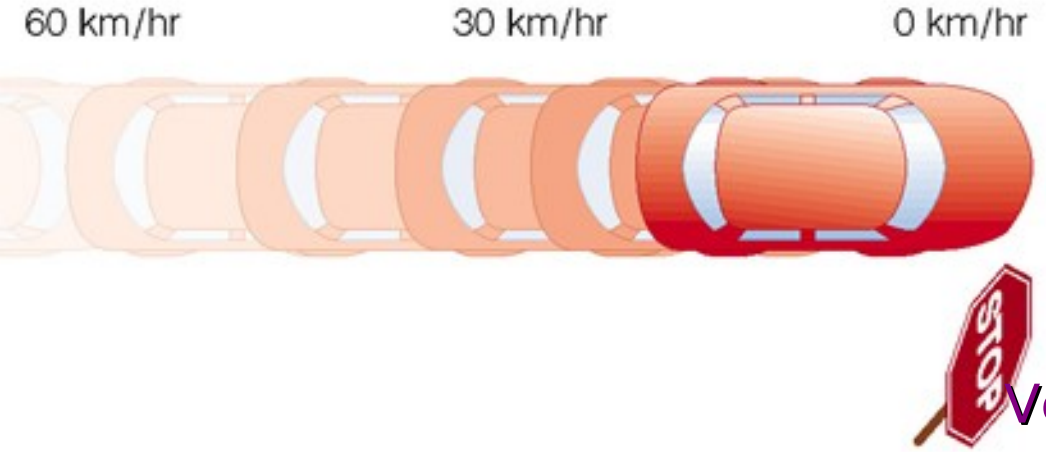


Speed, Velocity and Acceleration

Velocity accelerating



Speed constant
Velocity accelerating



Velocity decelerating

Velocity: distance travelled per time
(speed: the magnitude of velocity)
Acceleration: velocity changed per time

Newton's Laws of Motion (foundation for physics)

1. No Force, Velocity Constant

there is no spontaneous motion.

This is also called 'conservation of momentum'

where momentum = mass x V

everyday life there is usually friction

but we can see the 1st law when friction small

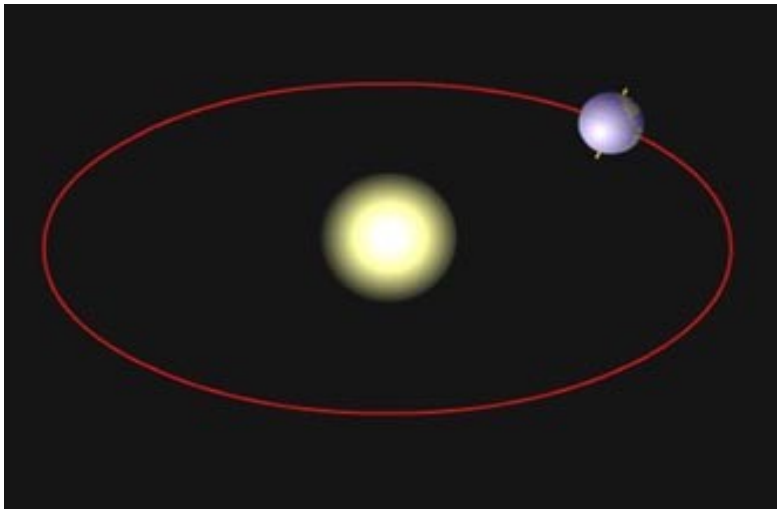
e.g., rolling car, a skater, air-hockey table puck

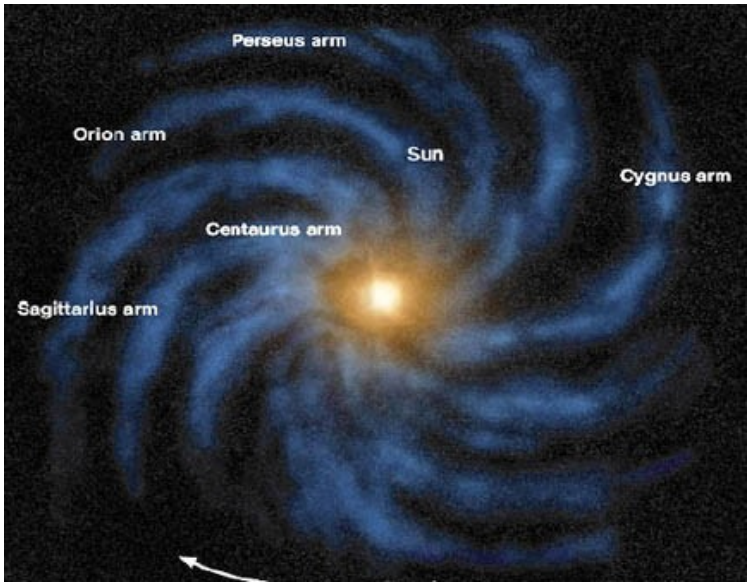
2. Force = Mass x Acceleration

3. Action = Reaction

Conservation of momentum

Conservation of Momentum?





The Moon runs around the Earth,
the Earth runs around the Sun,
the Sun runs around the Galactic center...

do they conserve their momentum?

Newton's Laws of Motion

1. No Force, Velocity Constant

2. Force = Mass x Acceleration

. if something is pushed, its velocity changes

(either in value or in direction)

. the harder it is pushed, the quicker its velocity changes

. the heavier it is, the slower its velocity changes

(inertia)

3. Action = Reaction

Newton's Law of gravity:

$$F_g = G\frac{M_1 M_2}{d^2}$$

. an attractive force, called gravity, exists between any two objects

. the more massive, the greater the attraction

. the further the distance, the weaker the attraction

. in everyday life, we call this gravitational force 'weight'

What is the difference between Mass and Weight?

Newton's Law of Gravity + 2nd Law of Motion

$$F_g = G\frac{M_1 M_2}{d^2}$$

Force= mass x acceleration

Your acceleration (due to gravity) does not depend on your mass.

This means: if mass of the Earth is suddenly increased by a factor of 2, it will still happily go on its current orbit. NO CHANGE!

... which is fortunate considering that otherwise...
the Moon and the Earth will be diverging on their motion around the Sun;
the orbit of each satellite will depend on how many germs got abroad...

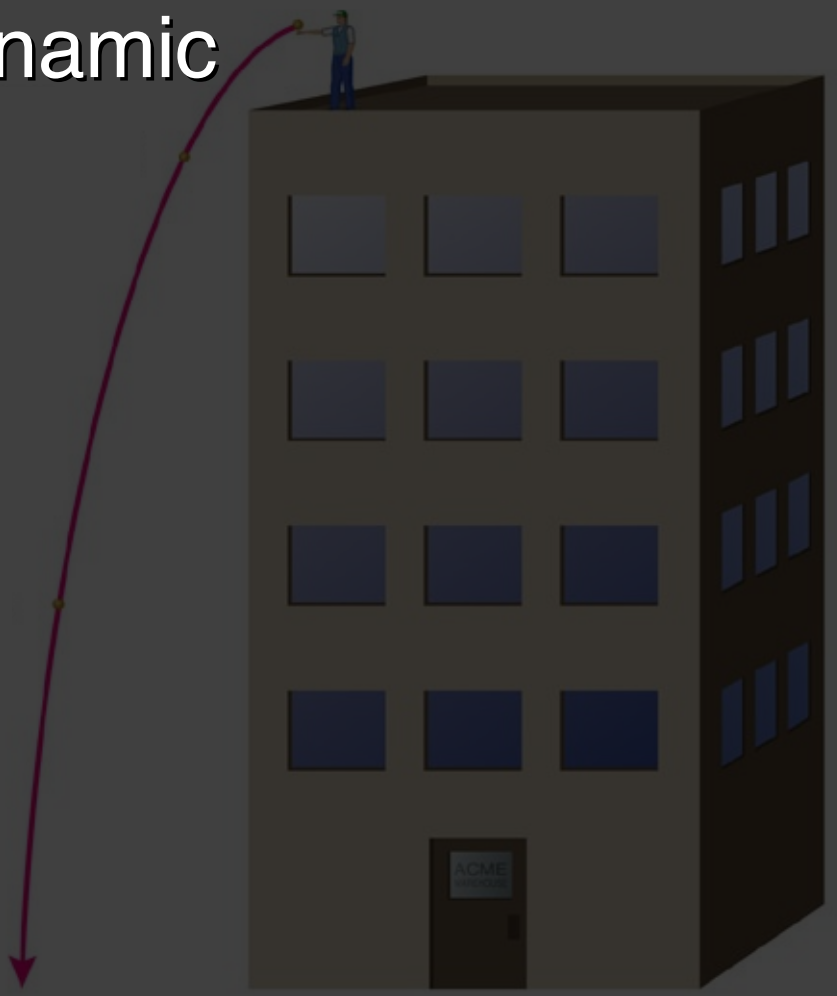
On the Moon, what falls faster, a hammer or a feather?

Feather falls faster,
as it is more aerodynamic

Both fall equally fast

Feather falls slower,
as it weighs less

Feather falls slower,
due to air drag

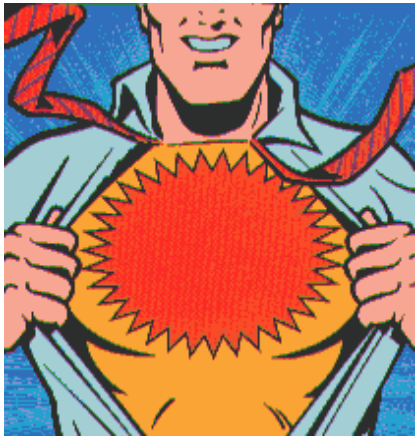


Apollo 15 experiment:

Dropping a feather and a hammer on the Moon.

Also notice their jumpy movement on the Moon.

--- an astronaut has the same mass everywhere,
but on Moon, his/her weight is 6 times less.



How to become a superman...

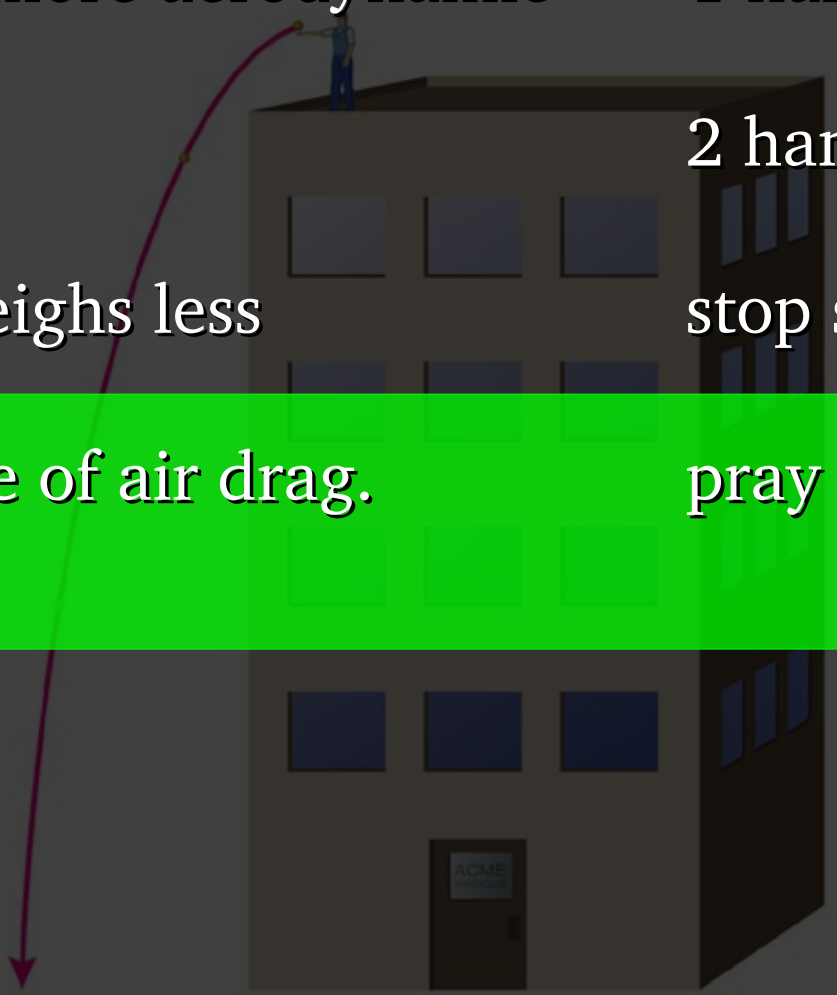
$$F_g = G\frac{M_1 M_2}{d^2}$$

Everyone knows that Superman is a being from another Planet (Krypton), unburdened by the vastly weaker gravity of Earth.

But not everyone understands how gravity affects strength! If you were on a world smaller than ours, you could jump over high buildings, lift enormous weights . . . and thus duplicate some of the feats of the Man of Steel!

On Earth, what falls faster, a hammer or a feather?

Feather falls faster, as it is more aerodynamic	1 hand up
Both fall equally fast	2 hands up
Feather falls slower, as it weighs less	stop sign
Feather falls slower, because of air drag.	pray sign



Suppose the Sun shrank in size (but kept the same mass), what would happen to Earth's orbit?

It would expand and it would take more time to go around — 1 hand up

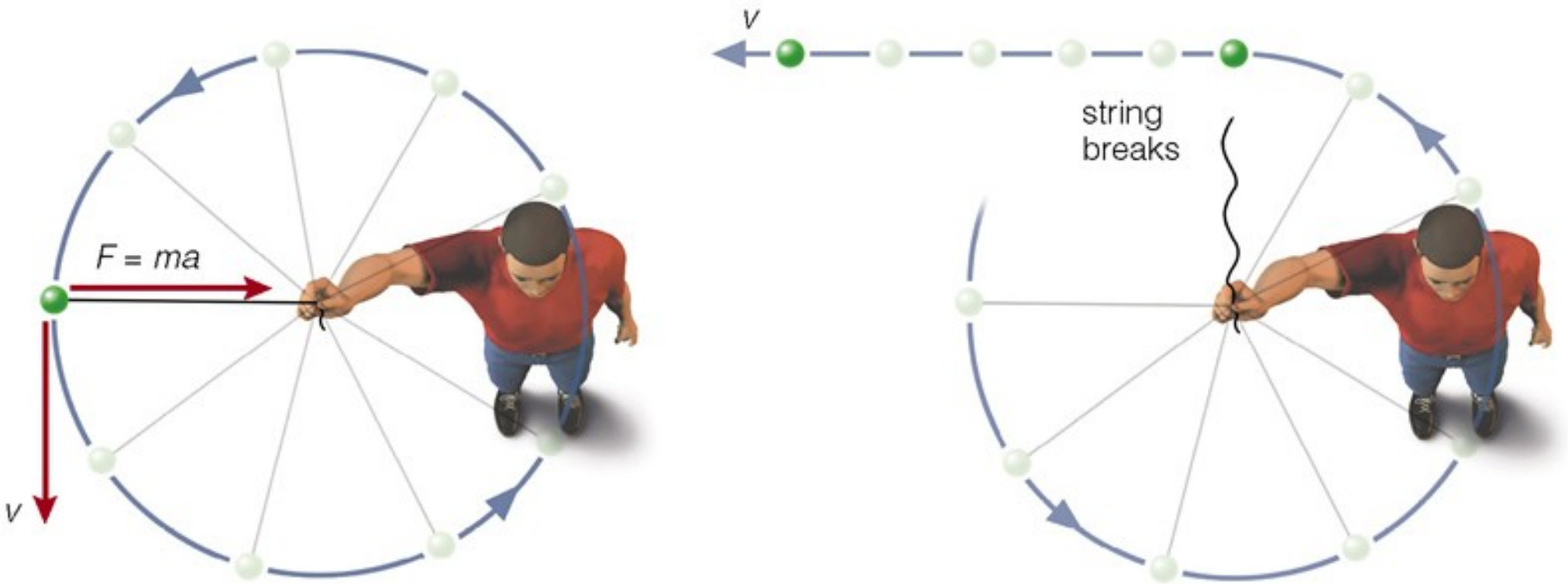
It would shrink and it would take less time to go around — 2 hands up

It would become unbound; Earth would fly off — stop sign

It would be unaffected — pray sign

The Sun exerts a gravity on the Earth.
Why is the Earth not falling towards the Sun?

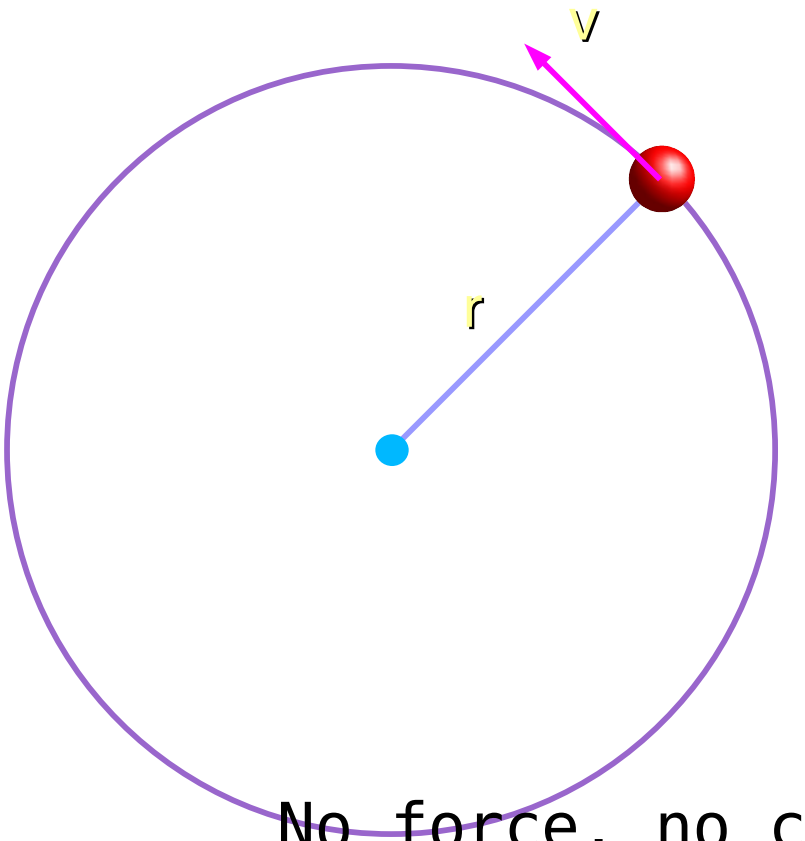
(or the Moon towards the Earth, the Sun towards the centre of the Galaxy...)



Because the tendency for Earth to fly away(due to its momentum)
--- the centrifugal force --- counteracts the gravity from the Sun.
So as we sit on Earth, we do not 'feel' the Solar gravity.

Angular Momentum

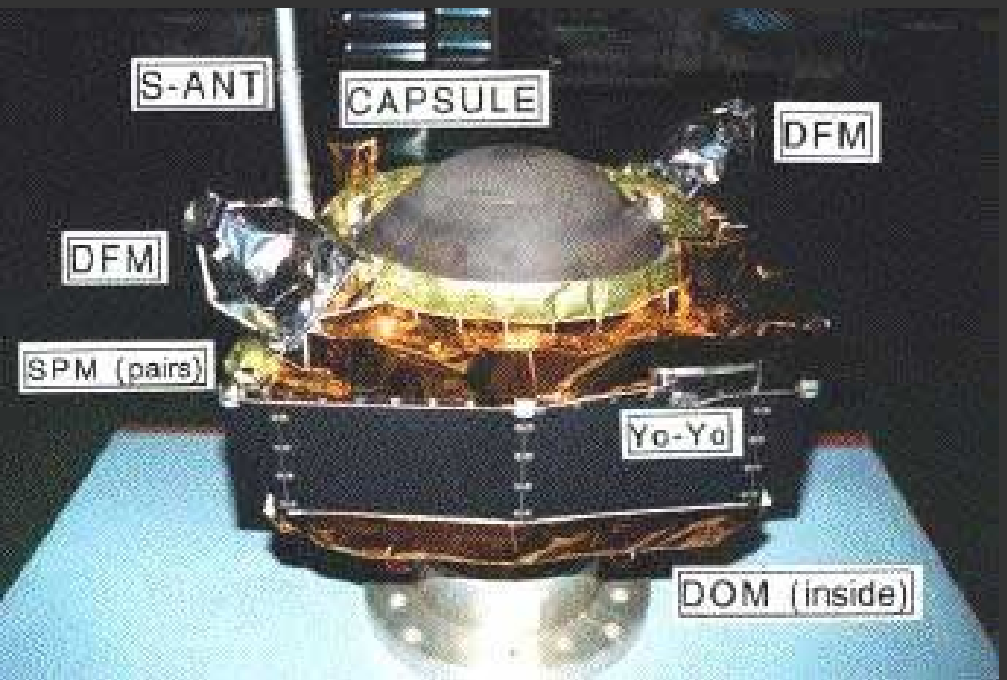
= Radius x mass x Velocity

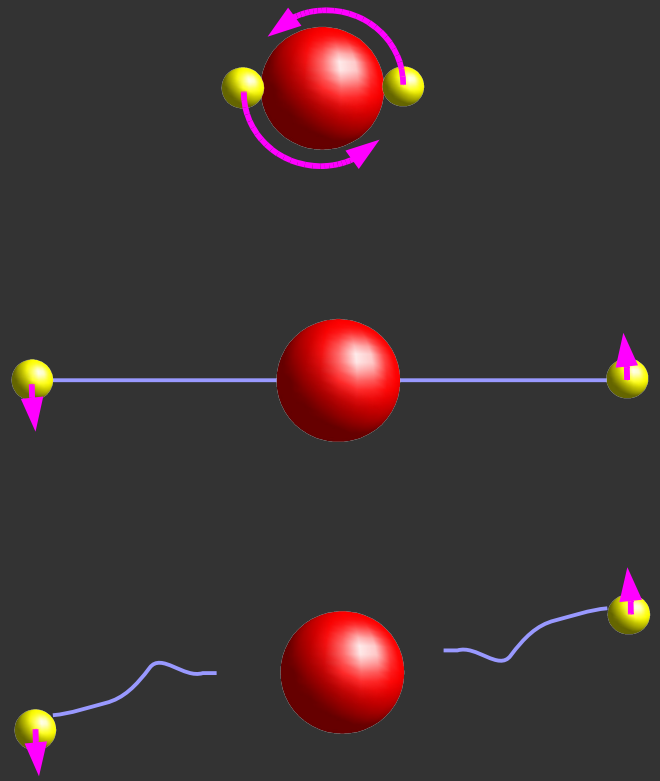


Torque=
Radius x Force

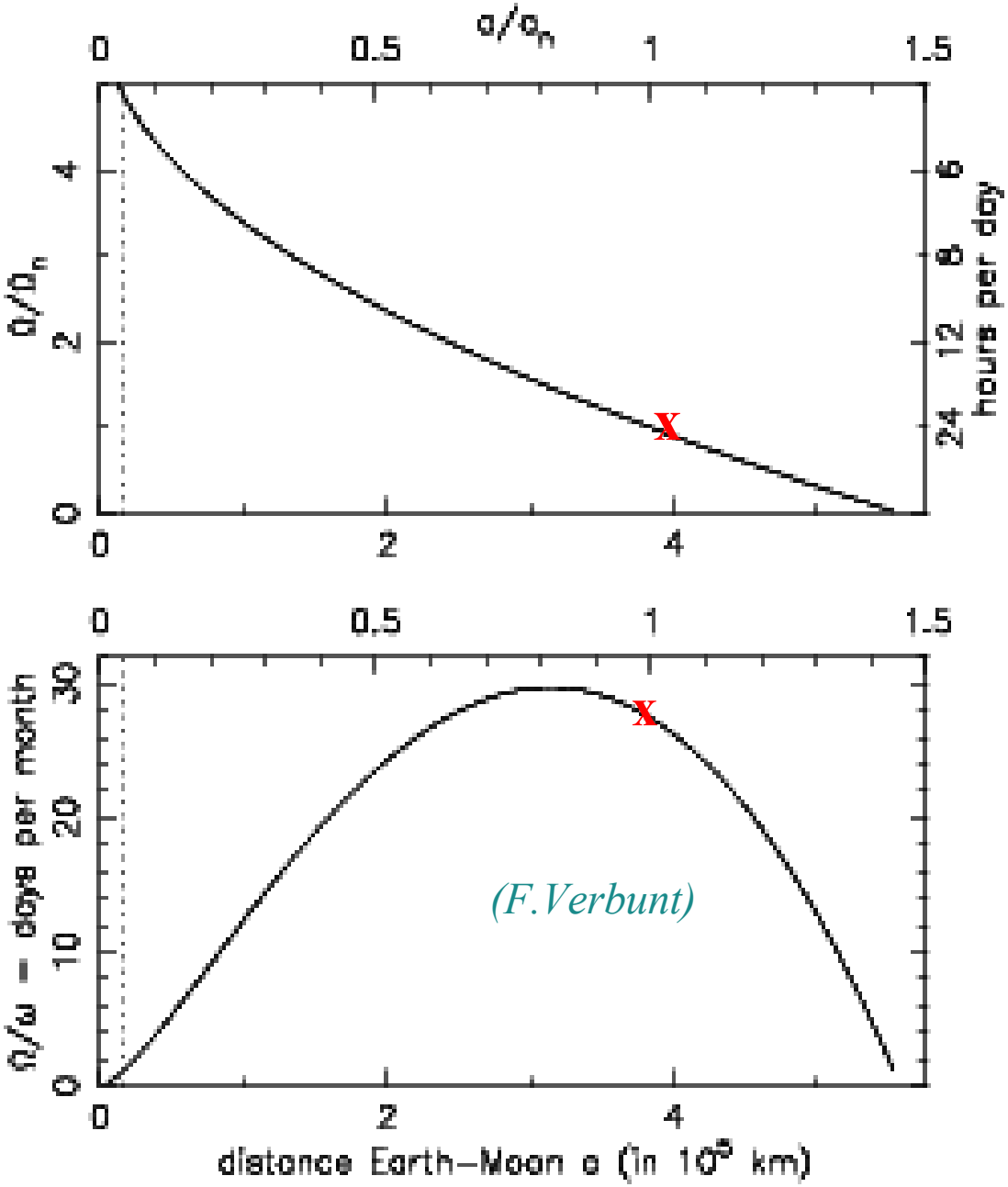
No force, no change in momentum
No torque, no change in angular momentum

Conservation of Angular Momentum





Conservation of angular momentum: Earth-Moon system



As a result of tidal dissipation:

the Moon is moving away from us

--angular momentum transfer--

spinning of Earth is slowing down

Observable Consequences:

lengths of day & month are increasing

number of days in a month is decreasing

Evidences:

laser ranging,
historical eclipse records,
coral & nautilus fossil,
mud deposit

Instant Quiz: Why is an astronaut 'weightless' (not mass-less)?

There is no gravity in space.	1 hand up
There is no atmosphere in space.	2 hands
The astronaut is too far from the Earth.	stop sign
The astronaut is orbiting around the Earth.	pray sign

Question: the Earth is accelerating all the time (spinning, going around the Sun...). Why don't we feel it?

1. Spin of the Earth is rather slow, hard to feel.
   If it is fast... sitting in a merry-go-around

2. Gravity of the Sun is balanced by our motion
   around the Sun (a 'centrifugal force').
   We feel 'weightless' relative
   to the Sun, much like an astronaut feel 'weightless'
   when s/he is orbiting the Earth in a shuttle.

3. Similar argument for our movement around the
   Galaxy, other galaxies...

Newton's Laws of Motion

1. No Force, Velocity Constant

2. Force = Mass x Acceleration

3. Action = Reaction

if you push something, you will be pushed back

examples: airplane flying forward

rocket, skater pushing against a wall

punching someone...

Action = Reaction

Rocket pushes hot air backward, reaction thrusts it forward.