FORCE

Newton's Contributions

- Calculus
- Light is composed of rainbow colors
- Reflecting Telescope
- Laws of Motion
- Theory of Gravitation

Newton's First Law
(law of inertia)

An object at rest tends to stay at rest and an object in motion tends to stay in motion unless acted upon by an unbalanced force.

1st Law

- Unless acted upon by an unbalanced force, this golf ball would sit on the tee forever.

1st Law

- Once airborne, unless acted on by an unbalanced force (gravity and air – fluid friction)
- it would never stop!

Examples

Card, cup, and coin

Fixing a Hammer

Demo - Coins on elbow

Demo - Table setting

Inertia

Balanced Force

Equal forces in opposite directions produce no motion

Constant Velocity Motion – No Forces

- If no external forces are acting, velocity is constant
- Position changes, at a steady (constant) rate

t=0 sec 1 sec 2 sec 3 sec 4 sec 5 sec 6 sec

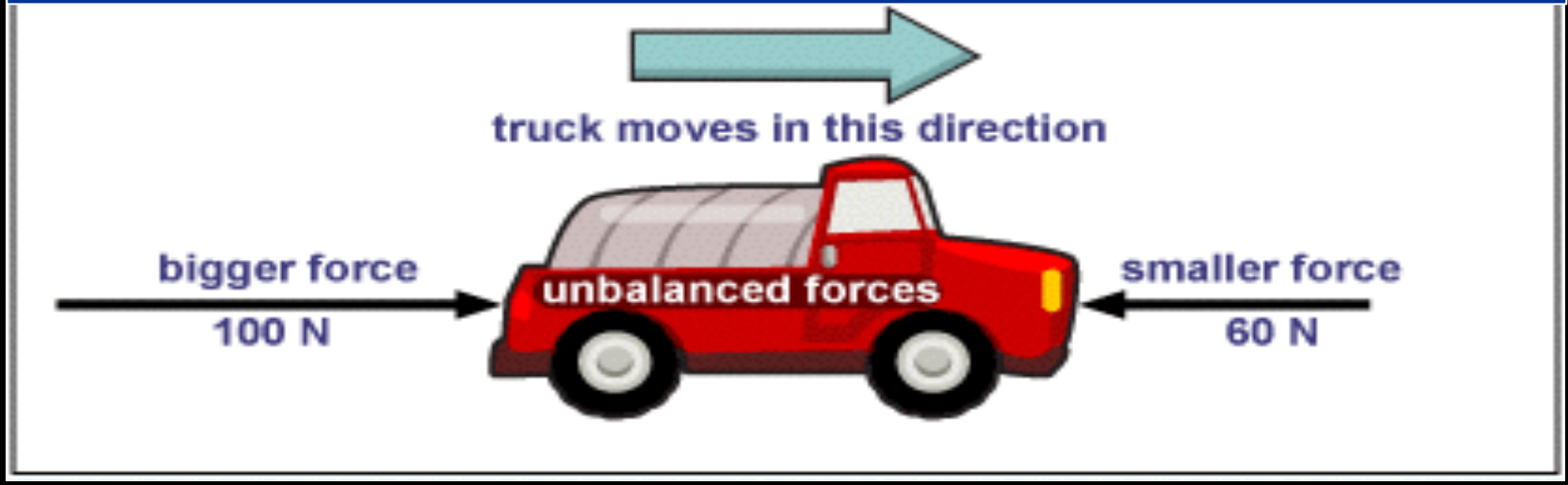
x =1 m 2 m 3 m 4 m 5 m 6 m 7 m

v= 1 m/s 1 m/s 1 m/s 1 m/s 1 m/s 1 m/s ***to right***

How does determination of velocity depend on choice x=0 and t=0?

Unbalanced Forces

Unequal opposing forces produce an unbalanced force causing motion



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If you throw a ball upwards it will eventually slow down and fall because of the force of *gravity*.

Newton's First Law (law of inertia)

- **MASS is the measure of the amount of matter in an object.**

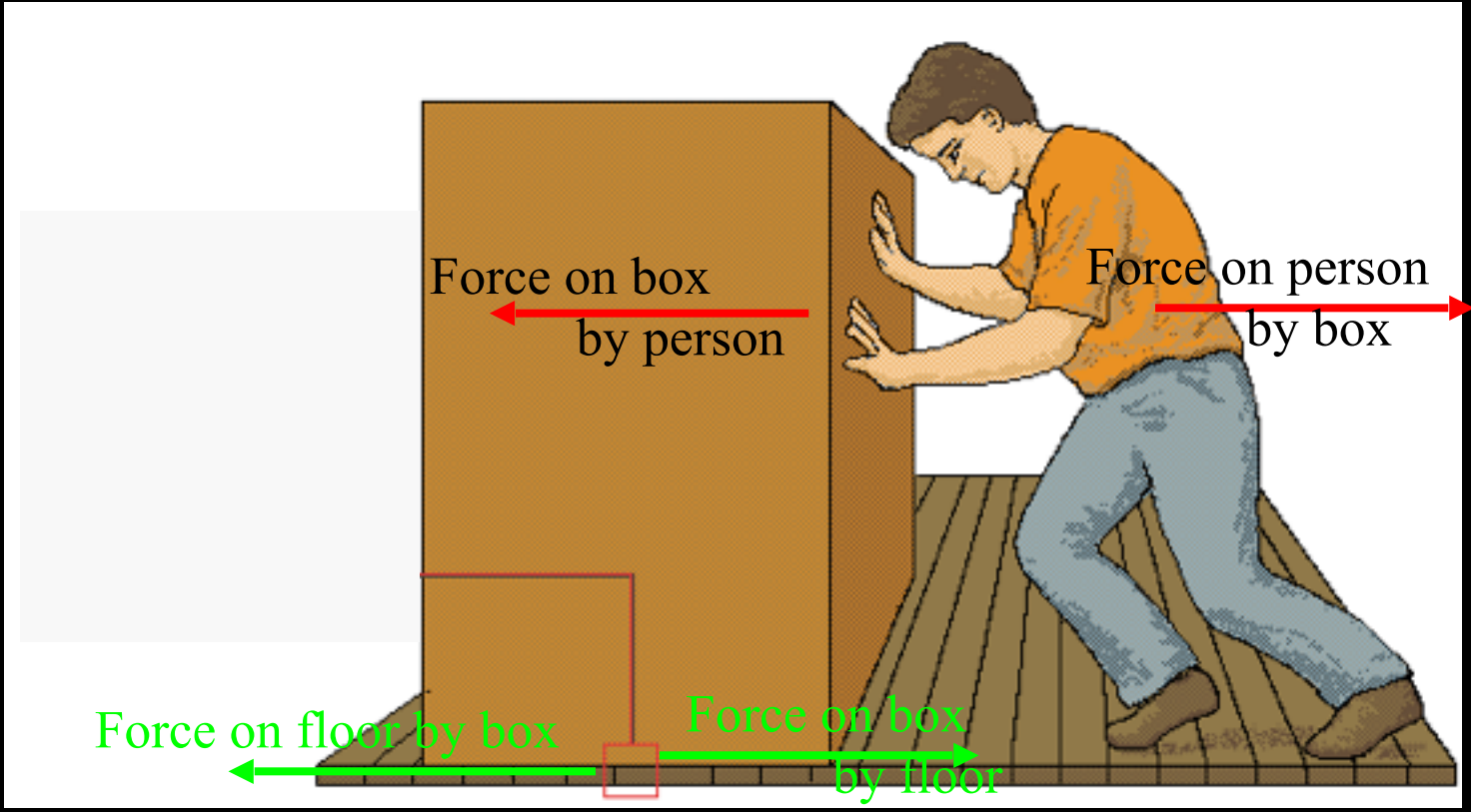
- **It is measured in Kilograms**

What is this unbalanced force that acts on an object in motion?

Friction!

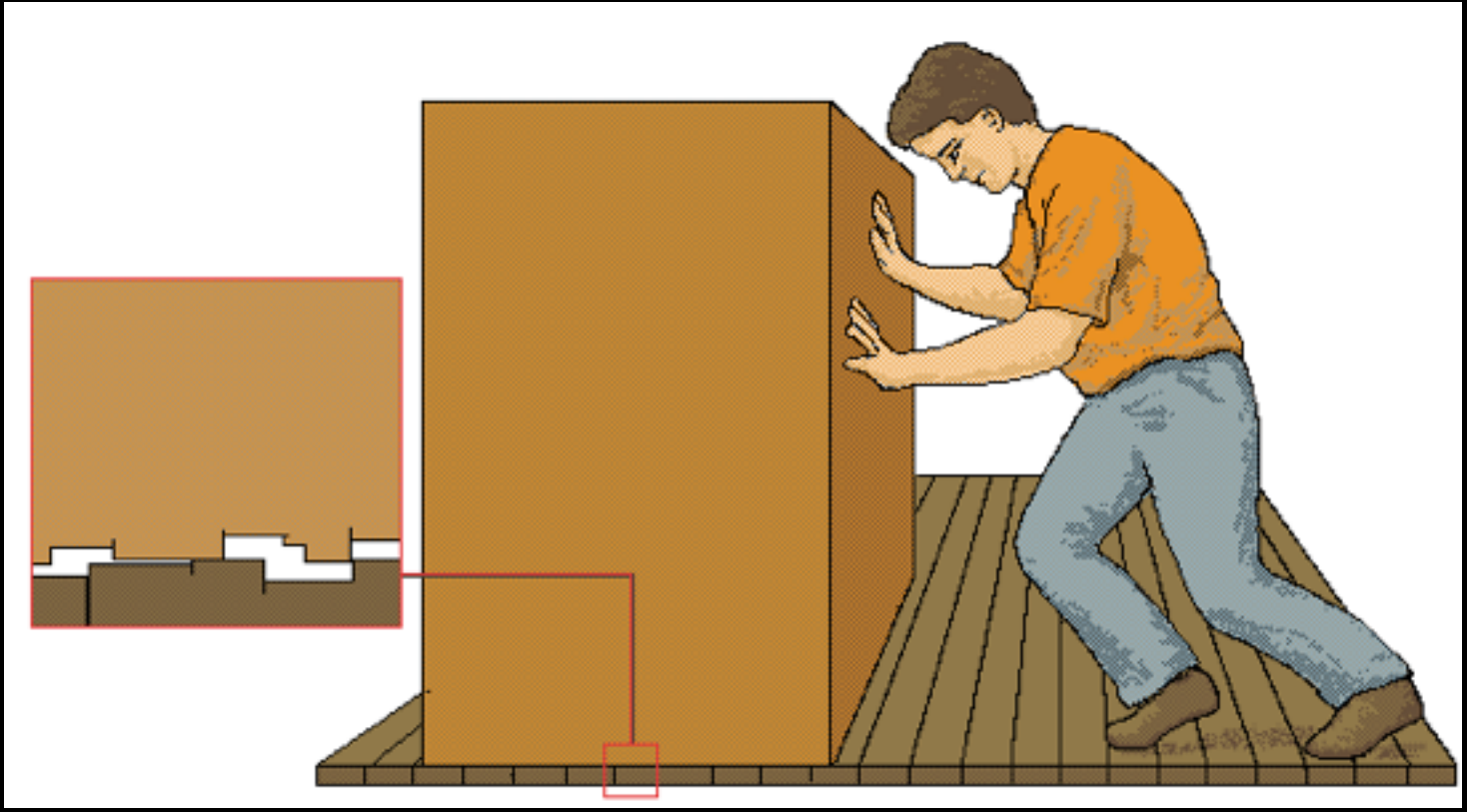
- **There are four main types of friction:**
  - **Sliding friction: ice skating or tires stopping**
  - **Rolling friction: bowling or tires rolling**
  - **Fluid friction (air or liquid): air or water resistance**
  - **Static friction: initial friction when moving an object**

Friction is a Force



It's the sum of all the forces that determines the acceleration.
Every force has an equal & opposite partner.

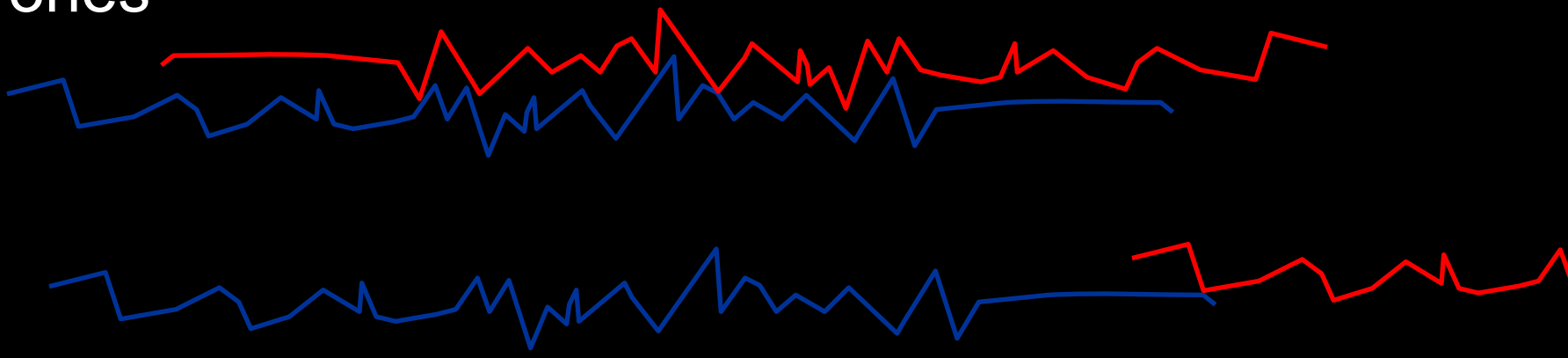
Friction Mechanism



Corrugations in the surfaces grind when things slide. Lubricants fill in the gaps and let things slide more easily.

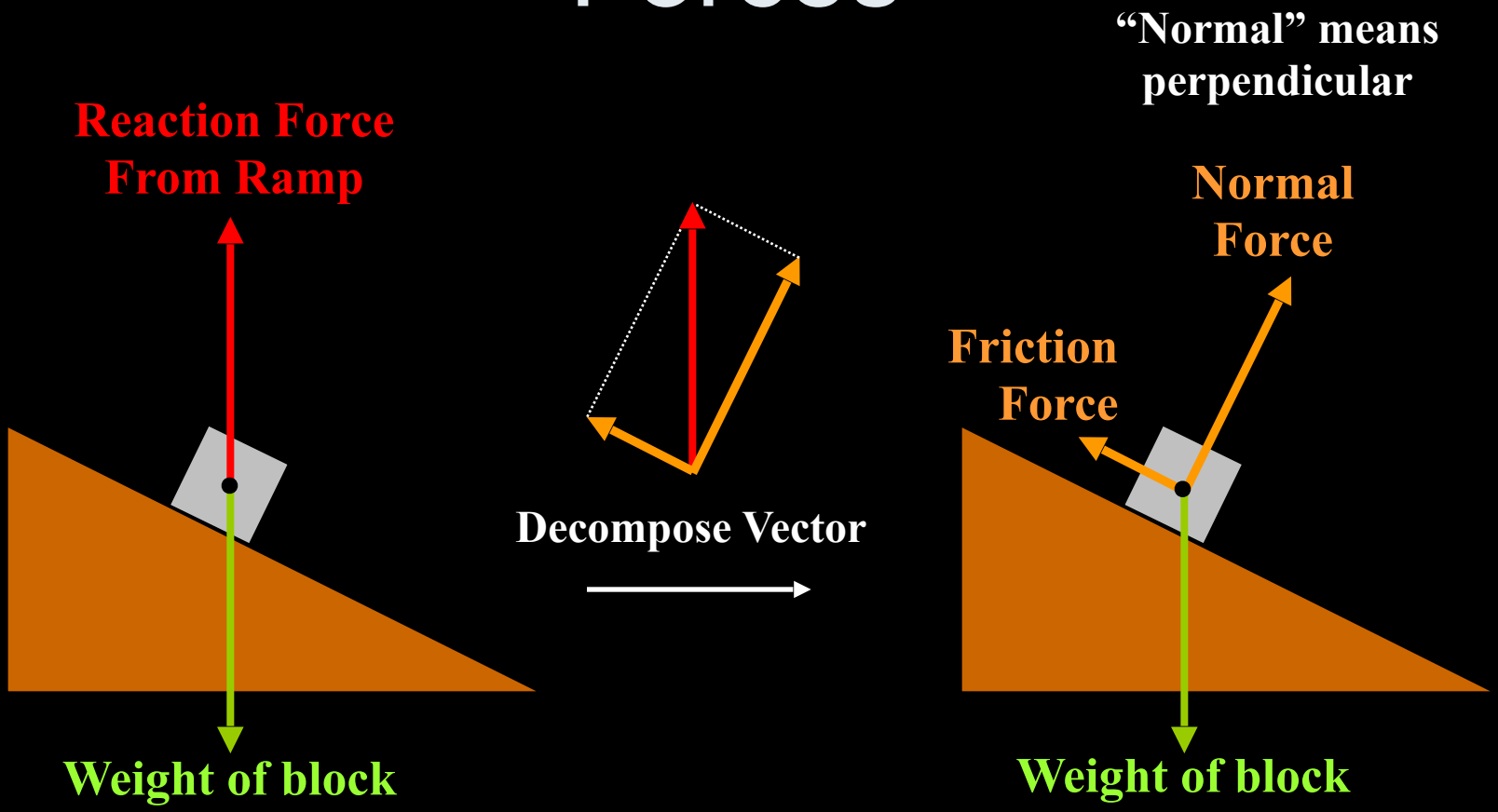
Static and Sliding (Dynamic) Friction

- Static frictional force: when nothing is sliding
- Sliding frictional force: when surfaces are sliding
- Static frictional forces always greater than sliding ones



- **Lubrication provides microscopic rollers between surfaces**

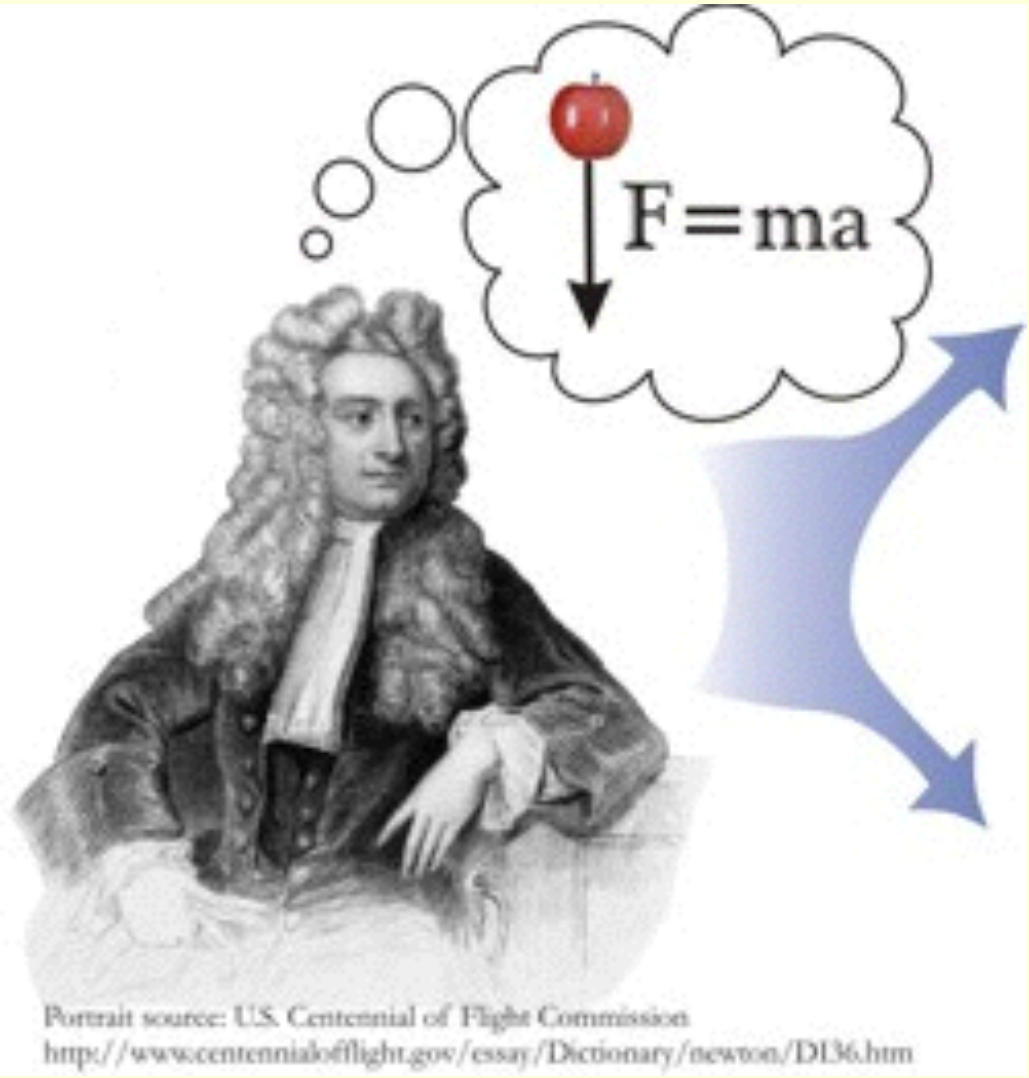
“Normal” Forces and Frictional Forces



Friction Force = Normal Force × (coefficient of friction)

$$F_{friction} = \mu \cdot F_{normal}$$

Newton's Second Law



Force equals mass times acceleration.

F = ma

Newton's Second Law

- **Force = Mass x Acceleration**
- **Force is measured in Newtons**

ACCELERATION of GRAVITY(Earth) = 9.8 m/s^2

- Weight (force) = mass x gravity (Earth)

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Moon's gravity is 1/6 of the Earth's

If you weigh **420** Newtons on earth, what will you weigh on the Moon?

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If you weigh **420** Newtons on earth, what will you weigh on the Moon?

70 Newtons

If your mass is 41.5Kg on Earth what is your mass on the Moon?

The acceleration of an object is directly proportional to the net force acting on the object…

…and inversely proportional to the mass of the object.

Newton's Second Law

When Acceleration Is Zero...

- …we say the object is in Mechanical Equilibrium.
- …the net force is zero.
- For Static Equilibrium the velocity is *zero*.
- For Dynamic Equilibrium the velocity is *constant*.

Acceleration Is Less Than g...

- …the object is not in Free Fall.
- In this case there is a force other than gravity.
- That force is air resistance.
- Air resistance depends on size and speed.

Terminal Velocity

$$a = \frac{F_{net}}{m}$$

$$a = \frac{1000\ N}{100\ kg}$$

$$a = 10.0\ m/s^2$$

(down)

Summary

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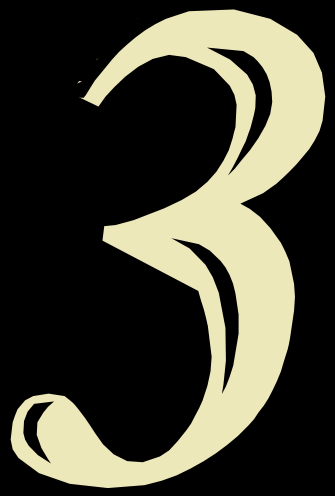
- *Mass* is a property of objects, producing a reluctance to accelerate, called *inertia*
- *Velocity* refers to both speed *and* direction
- *Acceleration* means a change in velocity (either magnitude, *or* direction *or both*)
- If an object is accelerating, it is being acted upon by a force, and $\boldsymbol{F} = m\boldsymbol{a}$. No exceptions.

Newton's Third Law



For every action there is an equal and opposite reaction.

Newton's 3rd Law

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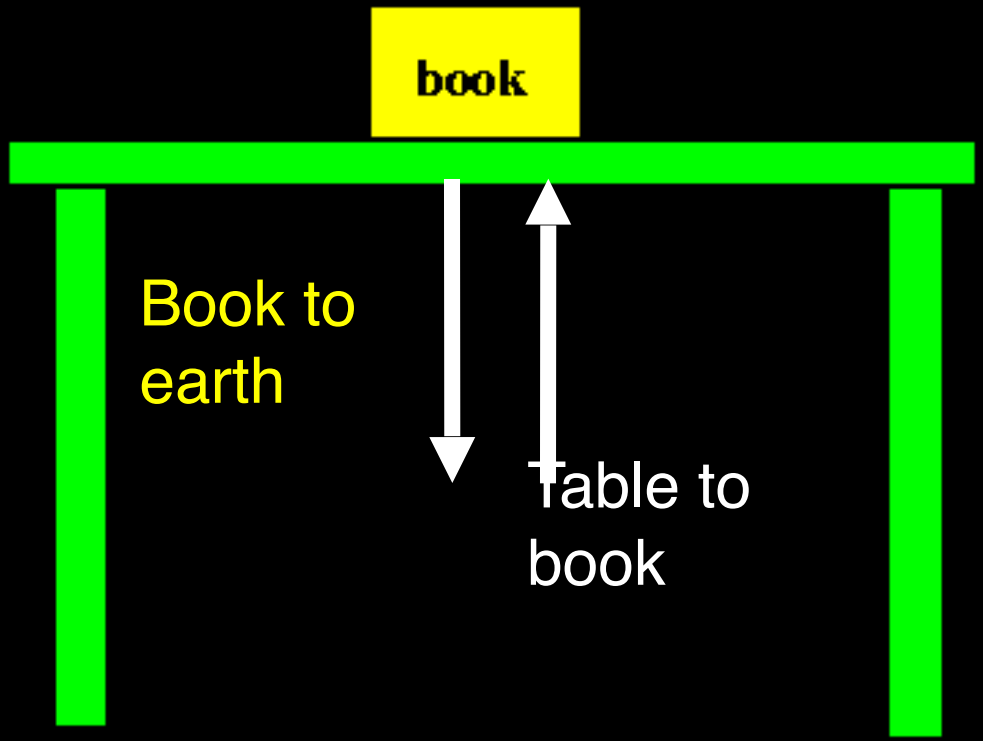

Think about it . . .

What happens if you are standing on a skateboard or a slippery floor and push against a wall? You slide in the opposite direction (away from the wall), because you pushed on the wall but the wall pushed back on you with equal and opposite force.

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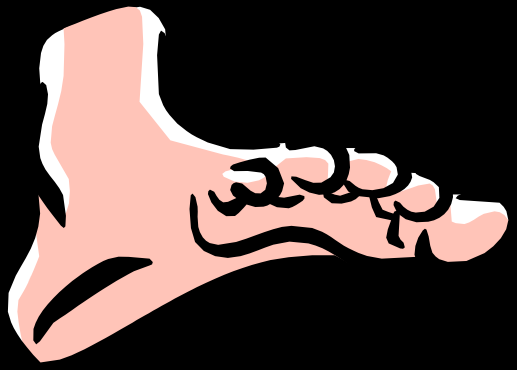


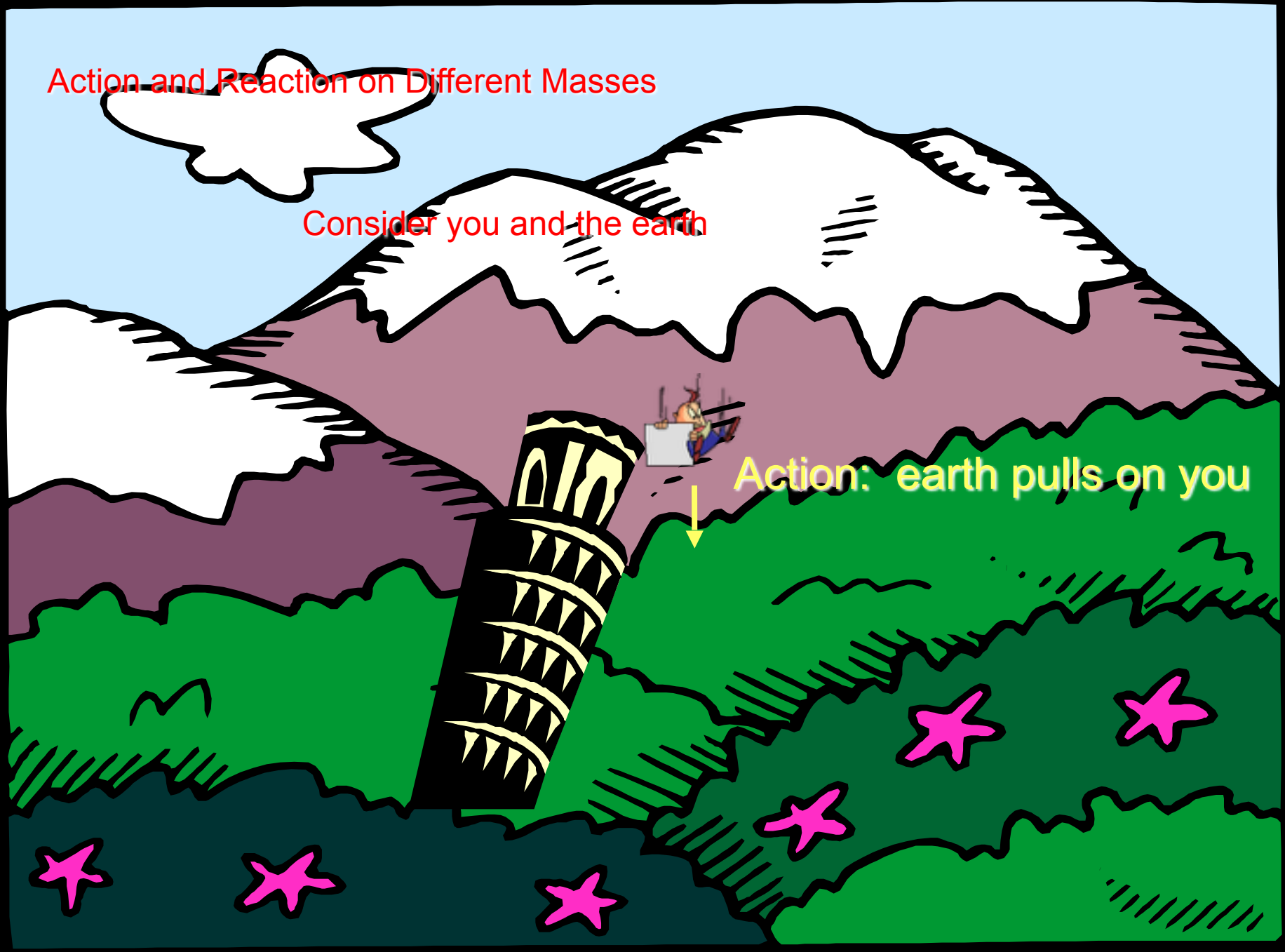
Why does it hurt so much when you stub your toe? When your toe exerts a force on a rock, the rock exerts an equal force back on your toe. The harder you hit your toe against it, the more force the rock exerts back on your toe (and the more your toe hurts).

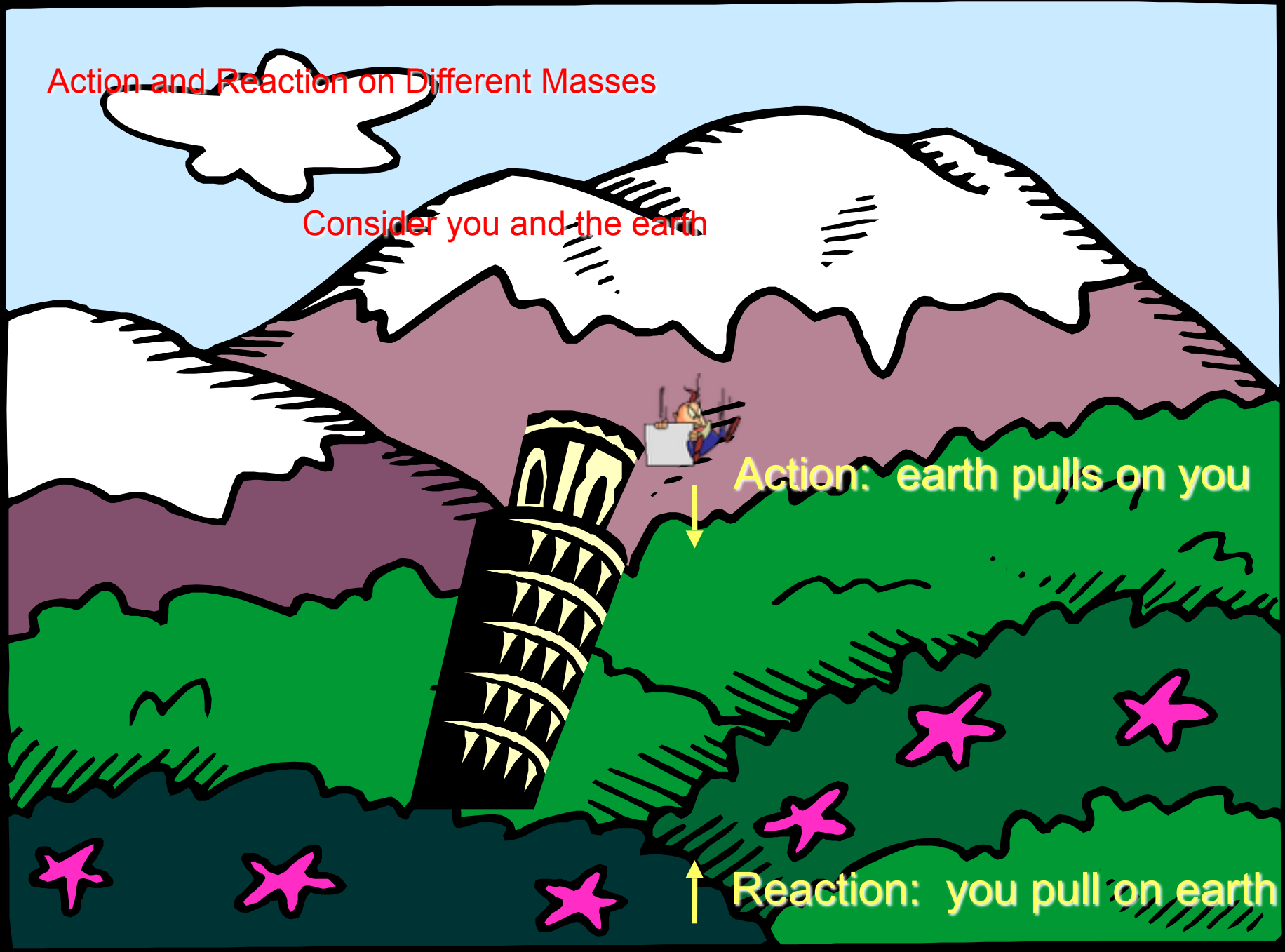
Newton's Third Law

- A bug with a mass of 5 grams flies into the windshield of a moving 1000kg bus.
- Which will have the most force?
- The bug on the bus
- The bus on the bug

Newton's Third Law

- **The force would be the same.**
- **Force (bug)= m x A**
- **Force (bus)= M x a**


Action and Reaction on Different Masses
Consider you and the earth
Action: earth pulls on you


Action and Reaction on Different Masses
Consider you and the earth
Action: earth pulls on you
Reaction: you pull on earth

Reaction: road pushes on tire

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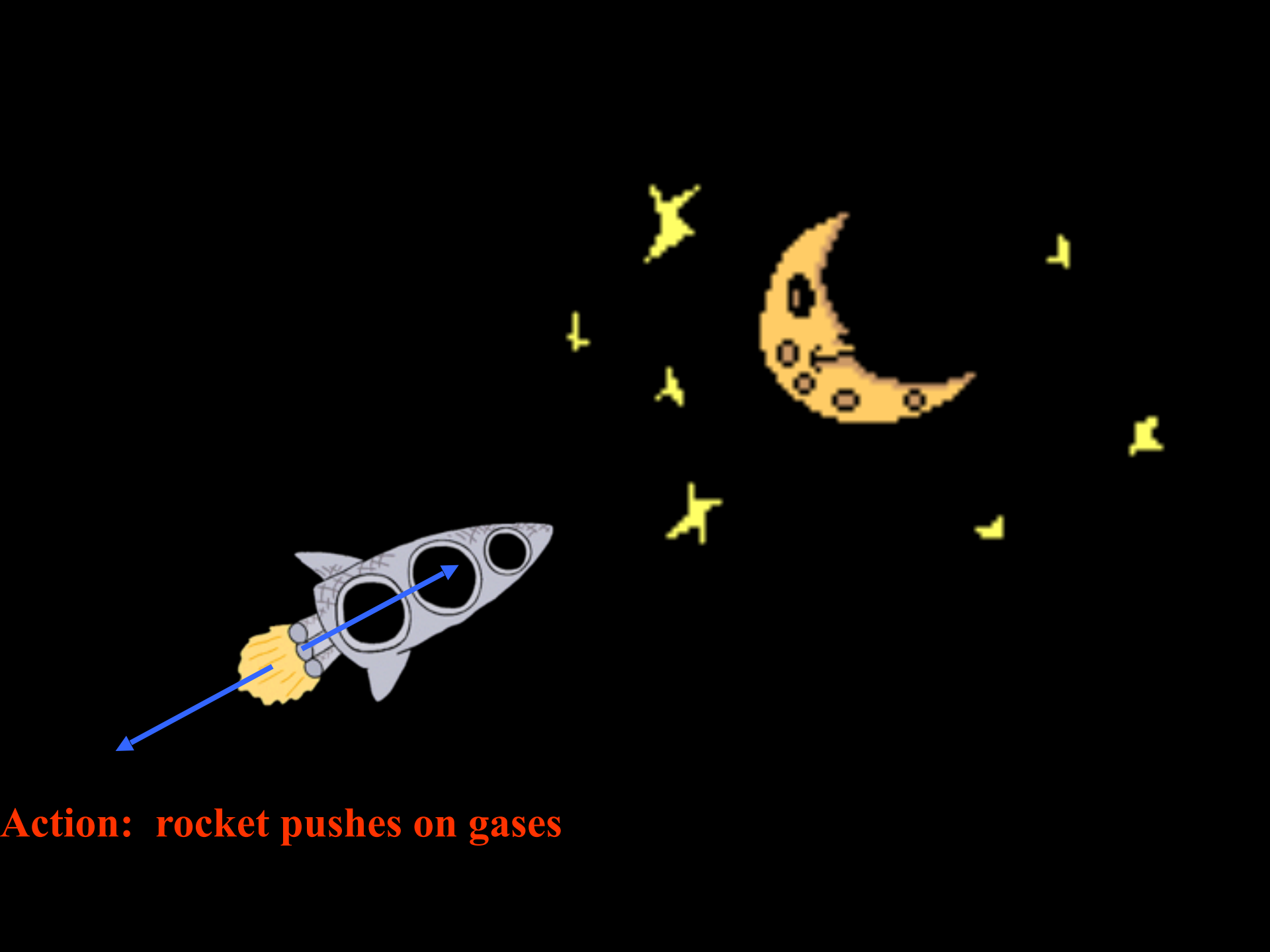
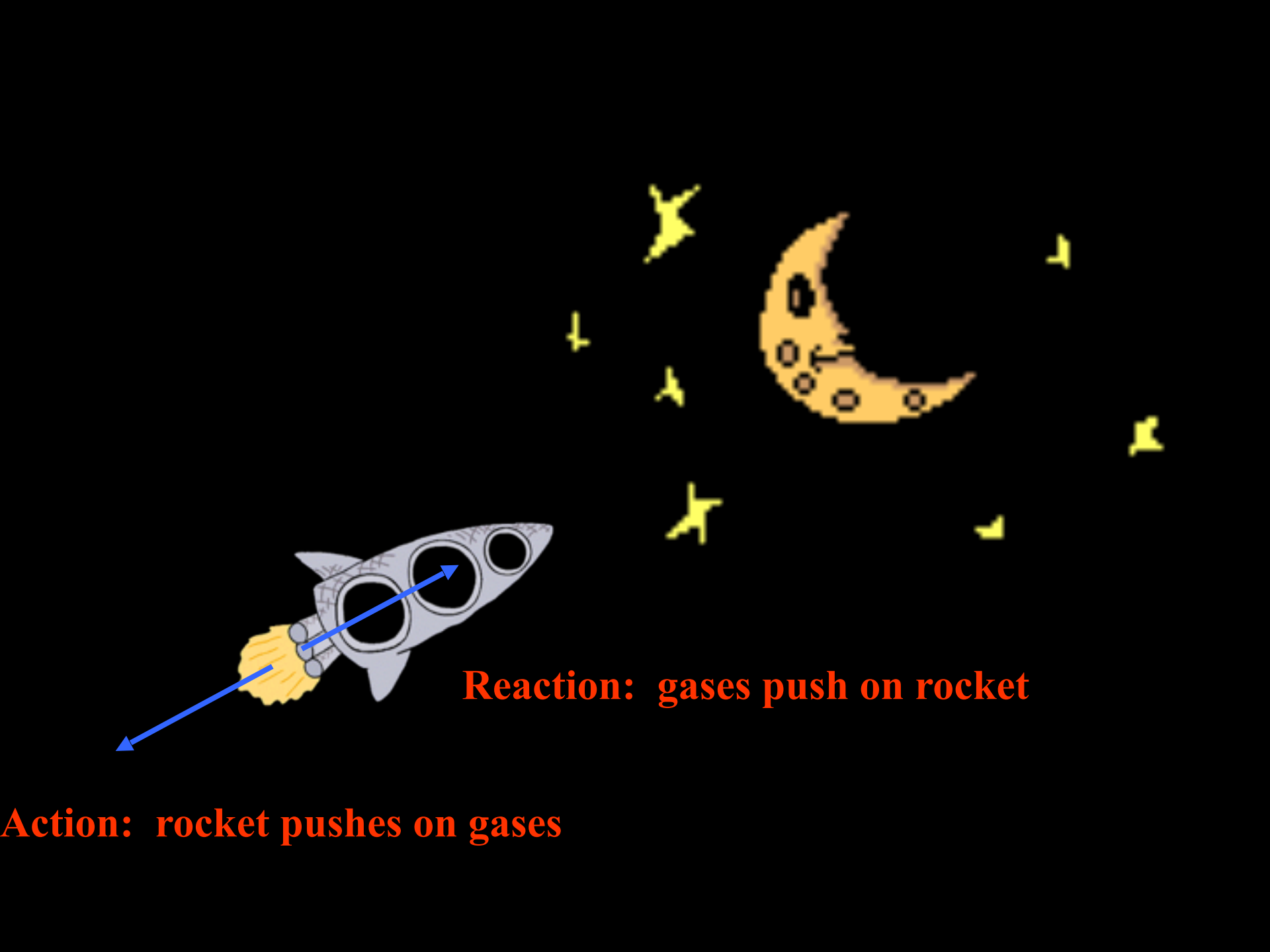
Action: tire pushes on road



Action: rocket pushes on gases


Reaction: gases push on rocket
Action: rocket pushes on gases

Newton's 3rd Law

- Suppose you are taking a space walk near the space shuttle, and your safety line breaks. How would you get back to the shuttle?

Newton's 3rd Law

- The thing to do would be to take one of the tools from your tool belt and throw it is hard as you can directly away from the shuttle.

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- As you throw the tool, you push against it, causing it to accelerate.
- At the same time, by Newton's third law, the tool is pushing back against you in the opposite direction, which causes you to accelerate back towards the shuttle, as desired.

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Air Resistance

- We’re always “neglecting air resistance” in physics
  - Can be difficult to deal with
- Affects projectile motion
  - Friction force opposes velocity through medium
  - Imposes horizontal force, additional vertical forces
  - Terminal velocity for falling objects
- Dominant energy drain on cars, bicyclists, planes

“Free” Fall

- Terminal velocity reached when

$$F_{drag} = F_{grav} \; (= mg)$$

- For 75 kg person that is 0.5 m^2,

$$v_{term} = 50 \text{ m/s, or } 110 \text{ m.p.h.}$$

in about 5 seconds, over 125 m of fall

  - actually takes slightly longer, because acceleration is reduced from the nominal 9.8 m/s^2 as you begin to encounter drag

- Free fall only lasts a few seconds, even for skydivers

What Laws are represented?

Review

Newton's First Law:

Objects in motion tend to stay in motion and objects at rest tend to stay at rest unless acted upon by an unbalanced force.

Newton's Second Law:

Force equals mass times acceleration (F = ma).

Newton's Third Law:

For every action there is an equal and opposite reaction.

Newton's Laws

1st law: Homer is large and has much mass, therefore he has much inertia. Friction and gravity oppose his motion.

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2nd law: Homer's mass x 9.8 m/s/s equals his weight, which is a force.

3rd law: Homer pushes against the ground and it pushes back.

Which is an example of Newton's 1st Law?

A. Fixing a hammer

B. running

C. Table throwing

D. weights

Which is a balanced force?

A. 100 N West and 100 N East

B. 50 N South and 50 N East

C.120 N East and 125 N West

D. 75 N West and 65 N South

Object	Mass (kg)	Speed (m/s)
A	4	6
B	6	5
C	8	4
D	10	1.5

Which object has the greatest inertia?

(A) *A*
(B) *B*
(C) *C*
(D) *D*

Quiz

Which is not the formula for force?

A. F= ma

B. m=F/a

C. a=F/m

D. f=mV

Quiz

When the acceleration is less than g…

A. the object is experiencing free fall.

B. the object is not in free fall

C. the acceleration is faster than it was before

D. the acceleration is slower than it was before.

Quiz

Force experienced on an object is air resistance when

A. the acceleration is greater than g
B. when the object is in free fall
C. when the object is on an incline.
D. the acceleration is less than g

What is the weight of a 3.00-kilogram object on the surface of Earth?

(A) 7.36 N
(B) 3.00 N
(C) 9.81 N
(D) 29.4 N

A 35-N horizontal force northward and a 45-N horizontal force southward act concurrently on a 15-kg object on a frictionless surface. What is the magnitude of the object's acceleration?

(A) 0.67 m/s^2
(B) 1.7 m/s^2
(C) 2.3 m/s^2
(D) 4.0 m/s^2

A 60-kg physics student would weigh 1560 N on the surface of planet X. What is the magnitude of the acceleration due to gravity on the surface of planet X?

(A) 0.038 m/s^2
(B) 6.1 m/s^2
(C) 9.8 m/s^2
(D) 26 m/s^2

Consider hitting a baseball with a bat. If we call the force applied to the ball by the bat the *action force*, identify the *reaction force*.

(a) the force applied to the bat by the hands
(b) the force applied to the bat by the ball
(c) the force the ball carries with it in flight
(d) the centrifugal force in the swing

What is Newton's 3rd Law?

A. Everything has one reaction
B. Force pushed on any object is in one direction
C. Every force has an equal and opposite reaction.

Which is the relationship between you and the Earth?

A. The earth is pulling you
B. You pull on the earth
C. None of the above
D. A and B

If you punch a wall, what happens according to Newton's 3rd Law?

1. The force is exerted on the other side of the wall
2. The force is lost in the wall
3. The wall sends the force back into your hand
4. You will hurt your hand.