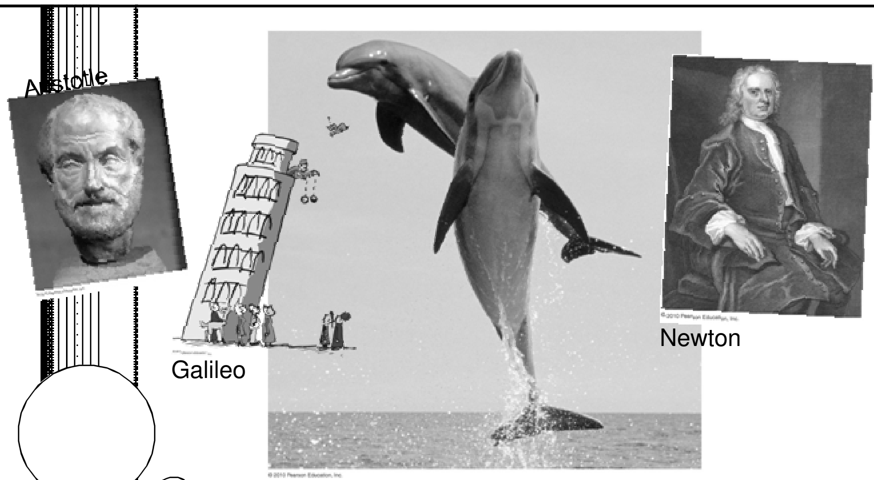
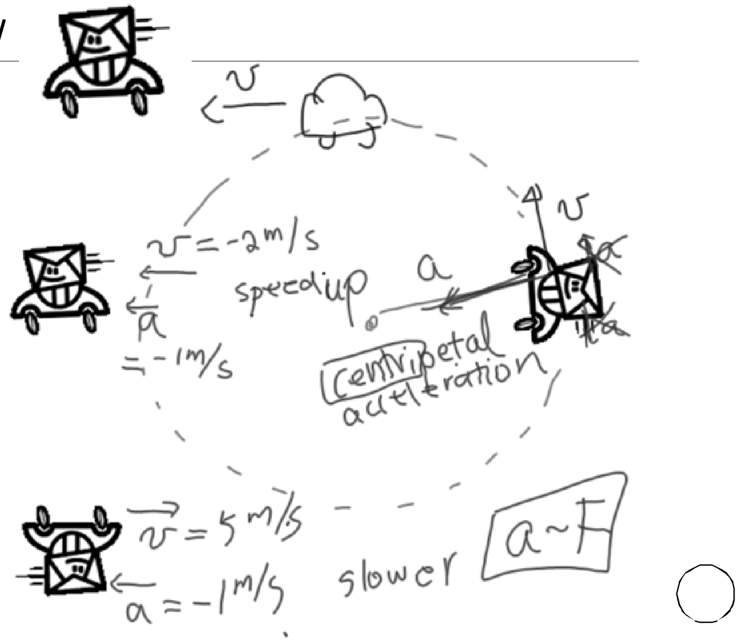


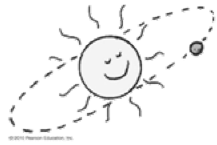
THE LAW OF INERTIA

REVIEW



MOTION IS RELATIVE

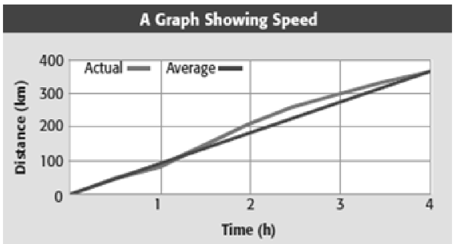
- We are moving 0 m/s and 30km/s



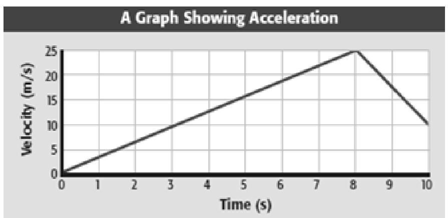
- Find the resultant velocities

MOTION IS RELATIVE

- Position versus Time Graph. Explain how the car is moving.



- Velocity versus Time Graph. Explain how the car is moving.



NEWTON'S 1ST LAW OF MOTION:
THE LAW OF INERTIA

NEWTON'S FIRST LAW OF MOTION: THE LAW OF INERTIA

- An object at rest stays at rest, and an object in motion remains in motion (at a constant velocity, in a straight line), unless acted on by a nonzero net force.
- Demo: PASCar, truck and marble

INERTIA?

- Play catch with a basketball or a bowling ball.
- Which is harder to throw?
- Which is harder to catch?

INERTIA?

- Play catch with a basketball or a bowling ball.
- Which is harder to throw?
- Which is harder to catch?

- The bowling ball. It’s more resistant to changes in velocity. The bowling ball has more inertia and more mass.

INERTIA IS…

- Laziness, stubbornness of an object
- Resistance to a change in motion
- A property of matter

ON YOUR PAPER, ANSWER THIS QUESTION…

- Aristotle: The Earth is the center of the universe. The stars we see in the sky must revolve around us.
- Galileo: No! The Earth revolves around the sun!
- Aristotle: That is impossible! The Earth is so big. How can there be such a force to keep pushing the Earth around the sun.
- Galileo: (how would you reply???)

THE LAW OF INERTIA

The Key:

Acceleration
⇔
An Unbalanced Force!

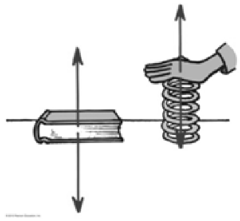
NEWTON'S FIRST LAW OF MOTION

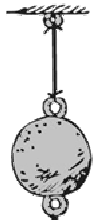
- A force is not necessary to keep an object in motion once it's already moving.
  - You can push the book once in space, and it will move in a straight line forever.
  - In the classroom, the book eventually stopped because of friction, but during the time it was moving, I did not do anything besides the initial push.

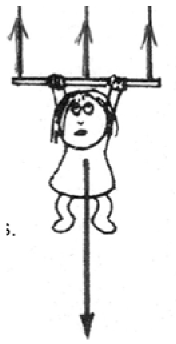
STATIC EQUILIBRIUM

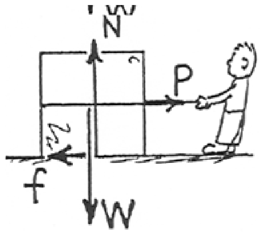
$\Sigma F = 0$

- Names of forces?



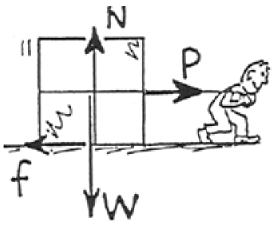


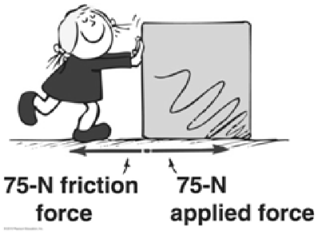


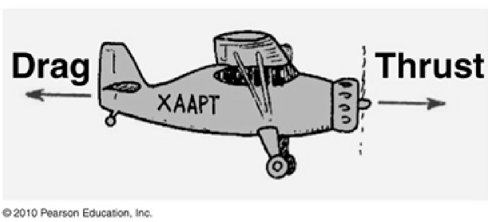


DYNAMIC EQUILIBRIUM

- Book in space

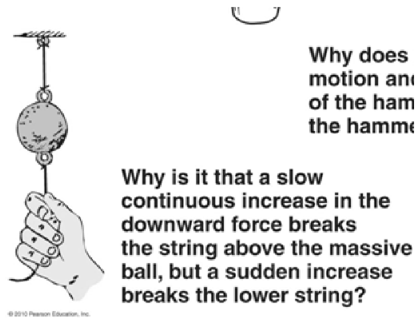






EXAMPLES OF INERTIA

- Figure 2.9.



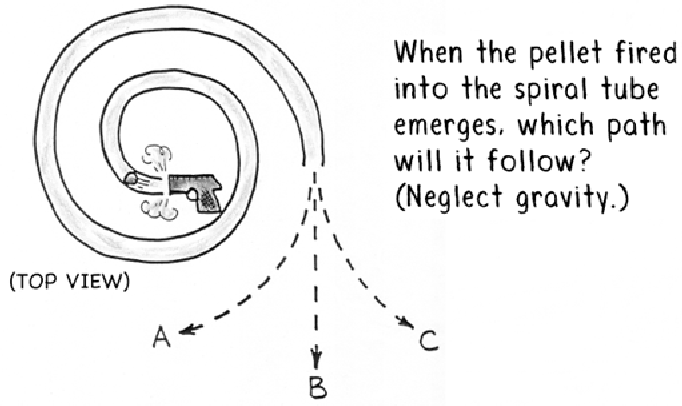
  - Pull quickly: *The ball wants to stay at rest*
  - Pull slowly: *The ball wants to stay in motion*

NEWTON'S FIRST LAW OF MOTION: THE LAW OF INERTIA

- From Aristotle to Galileo
  - It took 2000 years for humankind to develop the current laws of motion.
  - The main concept is **inertia**, first discovered by Galileo and later developed by Newton.
- **Force** = a push or a pull (vector)
- **Inertia** = resistance to change in motion
  - Innate property of an object
  - Like a habit:

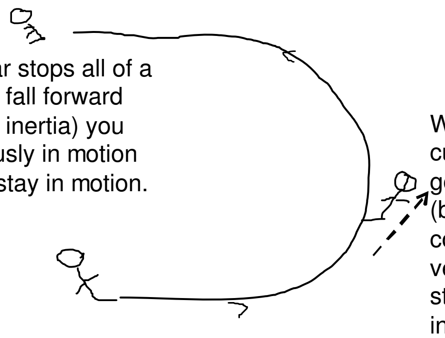
    An object at rest (not moving) wants to stay at rest

    An object in motion wants to stay in motion (at constant velocity)



EXAMPLES OF INERTIA

- Riding in a car.



When the car stops all of a sudden, you fall forward because (by inertia) you were previously in motion and tend to stay in motion.

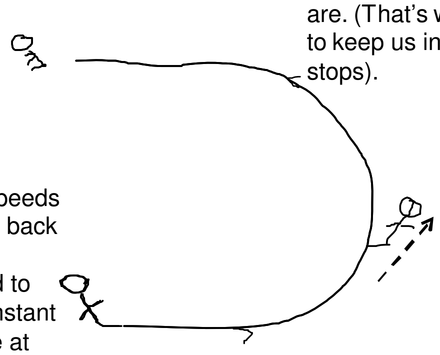
When the car rounds a curve, you feel yourself going sideways because (by inertia) you want to continue at the same velocity (same speed, straight line). It's the friction in the seat that keeps you seated.

When the car starts moving, you fall back in your seat because you were previously at rest and (by inertia) tend to stay at rest.

EXAMPLES OF INERTIA

- Riding in a car.

When the car slows down, you also fall forward. By inertia, you want to continue at the constant speed you were at before, but now the seat travels slower than you are. (That's why we need seatbelts to keep us in our seats at abrupt stops).

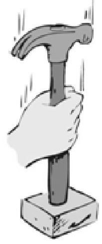


When the car speeds up, you also fall back in your seat. By inertia, you tend to move at the constant speed you were at before (which is slower than the back of your chair, so the chair pushes you forward now).

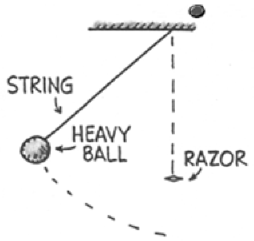
EXAMPLES OF INERTIA: FIGURE 2.8

Check your thinking Pg. 26

Why does the downward motion and sudden stop of the hammer tighten the hammerhead?

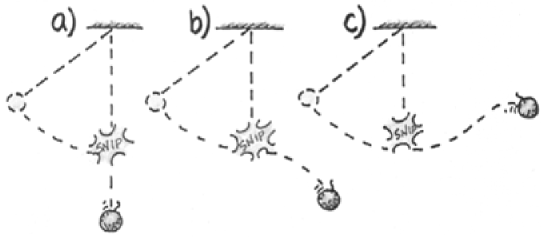


Why will the coin drop into the glass when a force accelerates the card?



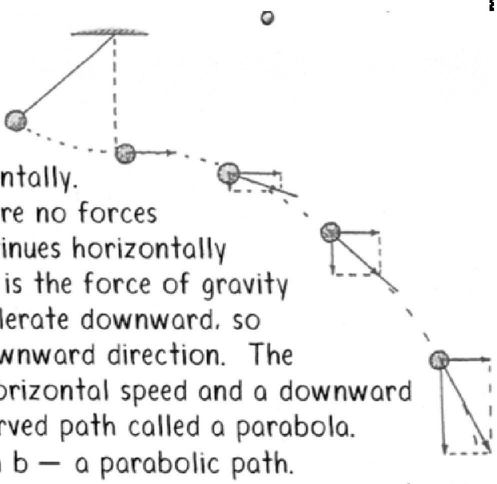
When the ball at the end of the string swings to its lowest point, the string is cut by a sharp razor.

Which path will the ball then follow?



Answer: b

At the moment the string is cut, the ball is moving horizontally. After the string is cut there are no forces horizontally, so the ball continues horizontally at constant speed. But there is the force of gravity which causes the ball to accelerate downward, so the ball gains speed in the downward direction. The combination of a constant horizontal speed and a downward gain in speed produces the curved path called a parabola. The ball continues along path b — a parabolic path.



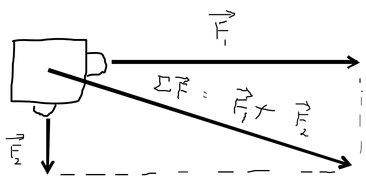
NET FORCE ΣF

- Net Force = Sum of all forces on an object.
- It is the ***net force*** that changes an object's state of motion.

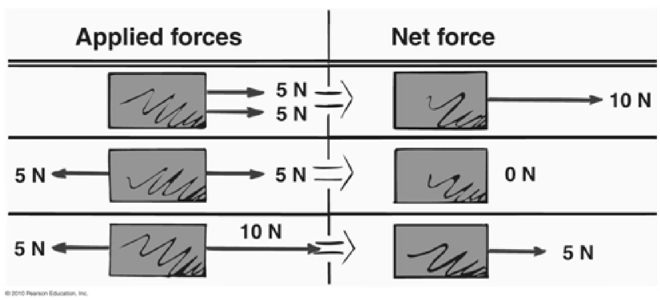
  ("change in state of motion": start moving or change in speed or direction)
- The unit of force is the Newton (N)

EXAMPLES OF NET FORCE

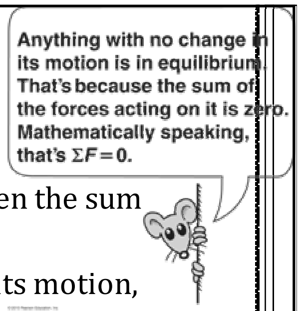
- Suitcase



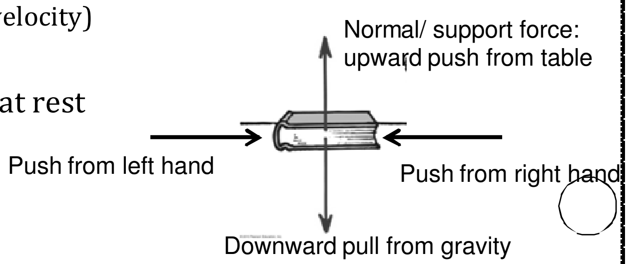
- Figure 2.10



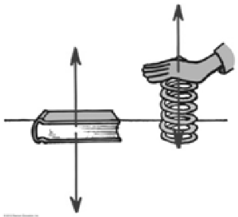
EQUILIBRIUM $\Sigma F = 0$



- An object is in mechanical equilibrium when the sum of all forces (the net force) is zero.
- An object in equilibrium has no change in its motion, which means it must be either:
  - (1) Not moving at all (at rest)
  - (2) Moving at constant speed and in a straight line (constant velocity)
- Example: Book at rest



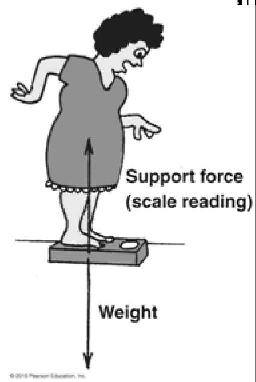
(1) EQUILIBRIUM FOR AN OBJECT AT REST $\Sigma F = 0$

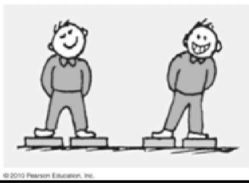


- Gravity pulls everything down. Figure 2.14
  - Gravity pulls the book down.
  - The table pushes the book up. The table exerts a "**normal force**" or "**support force**" on the book.
    - "normal" means perpendicular, at right angles (to the Earth's surface).
    - Without the normal force, the book would fall through the table.

(1) EQUILIBRIUM FOR AN OBJECT AT REST $\Sigma F = 0$

- **Weight** = *Gravitational* ***Force*** = how hard the Earth is pulling down on you.
- For a spring scale, the reading is from how much the spring is compressed. (The provides the upward support force). So the scale reading is really a measure of the upward support force. Figure 2.15
  - The scale pushes up on the person as hard as the person presses down on the scale.
- Check Your Thinking Pg. 31

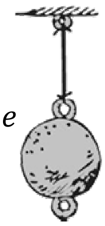




(1) EQUILIBRIUM FOR AN OBJECT AT REST $\Sigma F = 0$

- Object hanging on a string. Gravity pulls down on it. Why doesn't the object fall?

  Because the string is holding the object up. Consider the string as having an upward pull, the tension.



- **Tension** of a string = the "stretching force" of the string.
- Tug-of-war

(1) EQUILIBRIUM FOR AN OBJECT AT REST $\Sigma F = 0$

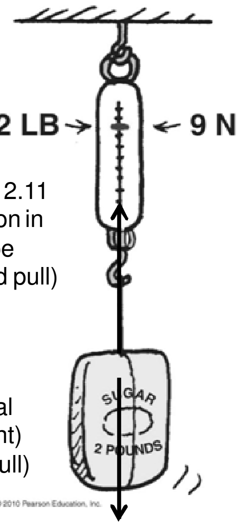
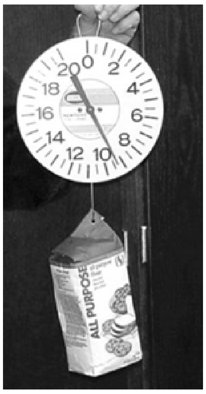


Figure 2.11
Tension in rope
(upward pull)

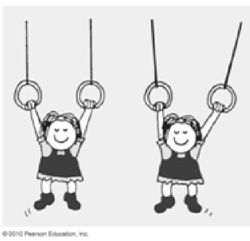
Gravitational Force (weight)
(downward pull)



The upward tension = the downward pull from gravity
→ the bag of sugar remains at rest.
(in equilibrium)

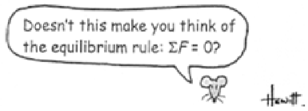
(1) EQUILIBRIUM FOR AN OBJECT AT REST $\Sigma F = 0$

- Check your thinking Pg. 29
  Practice Book Pg. 5



(1) EQUILIBRIUM FOR AN OBJECT AT REST $\Sigma F = 0$

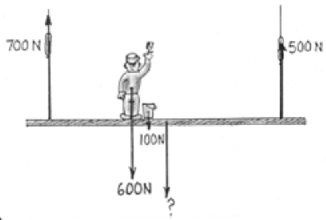
Note the readings on the scales.
Burl the painter has a weight of 600 N, and carries a 100-N bucket of paint.
What is the weight of the scaffold?



(1) EQUILIBRIUM FOR AN OBJECT AT REST $\Sigma F = 0$

Answer: 500 N

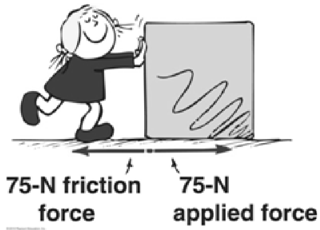
The scaffold is in equilibrium, so we see that in accord with $\Sigma F = 0$, the net force on the scaffold is zero. That means that the sum of the upward forces must be equal in magnitude to the sum of the downward forces. Note the scale readings add to 1200 N, the total force upward. The total force downward must then also be 1200 N. We see that Burl and his bucket of paint weigh 700 N. So the weight of the scaffold is 1200 N − 700 N = 500 N.



(2) **EQUILIBRIUM FOR A MOVING OBJECT**
(CONSTANT SPEED IN STRAIGHT LINE
CONSTANT VELOCITY)

$\Sigma F = 0$

- Fig. 2.16 The crate is moving at constant velocity (constant speed, constant direction: straight line)

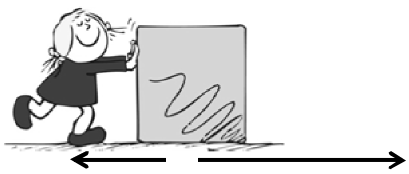


  - The crate is in equilibrium. There is no change in its motion. Why?

    The girl is pushing as hard on the crate as friction is opposing it. She pushes just hard enough to overcome friction.

- If the push is very big (bigger than the friction), then the crate would move faster and faster.

  (not equilibrium. Net force (toward the right) is nonzero.)

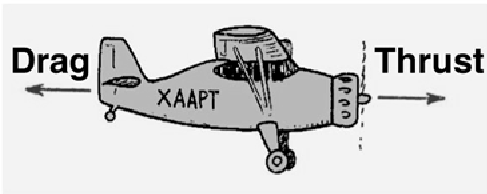


(2) **EQUILIBRIUM FOR A MOVING OBJECT** (CONSTANT SPEED IN STRAIGHT LINE CONSTANT VELOCITY)

$\Sigma F = 0$

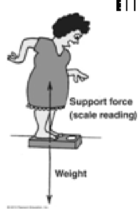
- Check Your Thinking Pg. 31

  The plane is moving at constant velocity. Which force is bigger: drag or thrust?



- Equilibrium: Practice Book Pg. 4

SOME NOTES ON TERMS (REACTIONS)



- **Support Force (Normal Force)**
  - Support Force = Pull of Gravity (until the surface breaks).
  - For a light object, the support force is small. For a heavy object, the support force is big. When the object is too heavy, the surface will break.
- **Tension of a string**
  - Tension = How hard the string is pulled (until the string breaks)
  - For a small pull, the tension is small. If you pull too hard, the string breaks.

- **Friction**

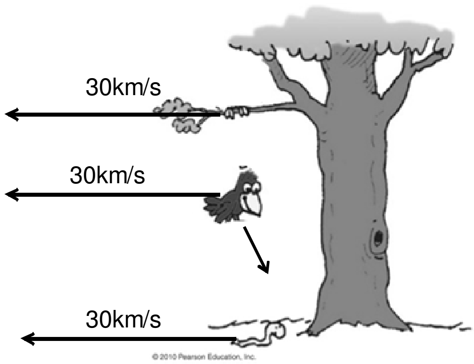
  - Friction = horizontal pull/push if the object is in equilibrium (at rest or moving at constant velocity)
  - Friction depends on the surface, the amount of contact between the surface and object, and how fast the object is sliding.
  - Every surface has a maximum amount of friction possible: Friction cancels out the push or pull, until the push or pull can no longer be counteracted.

EARTH MOVES AROUND THE SUN

- Motion is relative.
- Figure 2.18. The Earth is moving at 30km/s around the Sun. When the bird has left the tree branch, why doesn't the worm and the ground move away? Why is it that the bird can catch the worm?

EARTH MOVES AROUND THE SUN

- Motion is relative. The Earth and everything on it moves together at 30km/s, as viewed if you were standing at the Sun and looking at Earth.
- Figure 2.18. When the bird is in the air, why doesn't the worm and the ground move away?



At the instant the bird's feet left the branch, the bird was moving left at 30km/s. By inertia, the bird continues moving left at 30km/s, with no resistance because the atmosphere is also moving left at 30km/s. **<u>The initial sideways motion is always there, in addition to the bird's own flying</u>**.

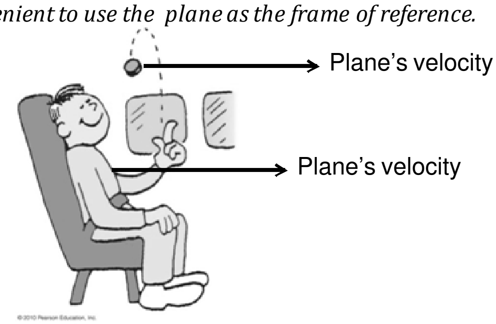
MORE EXAMPLES OF INERTIA

- Check Your Thinking Pg. 33
  - (a) You are on an airplane moving at constant velocity. You toss up a bag of peanuts directly over your feet. Will the bag drop in front of, on, or behind your feet?
  - (b) If the airplane slows down, will the bag drop in front of, on, or behind your feet?
  - (c) If the airplane speeds up, will the bag drop in front, on, or behind your feet?

MORE EXAMPLES OF INERTIA

- Check Your Thinking Pg. 33 Answer to (a)
  - You are on an airplane moving at constant velocity. You toss up a bag of peanuts directly over your feet. Will the bag drop in front of, on, or behind your feet?

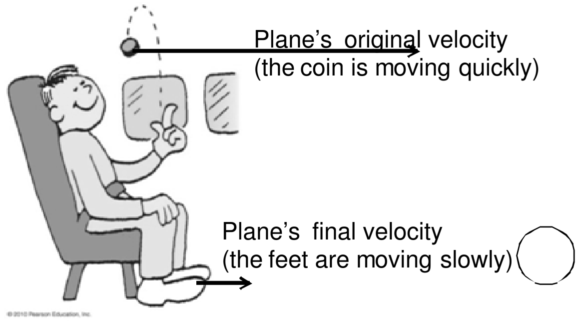
    On your feet. Like the bird, the bag has a sideways velocity when it leaves your hand. Everything in and on the plane has that sideways velocity. It's convenient to use the plane as the frame of reference.



MORE EXAMPLES OF INERTIA

- Check Your Thinking Pg. 33 Answer to (b)
  - If the airplane slows down, will the bag drop in front of, on, or behind your feet?

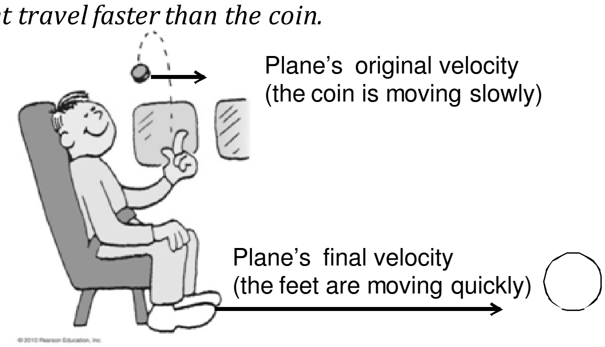
    In front of your feet. By inertia, the coin moves at the same sideways velocity of when it got out of your hand (the original speed of the plane). Now the plane slows down, so you and your feet travel slower than the coin.



MORE EXAMPLES OF INERTIA

- Check Your Thinking Pg. 33 Answer to (c)
  - If the airplane speeds up, will the bag drop in front, on, or behind your feet?

    Behind your feet. By inertia, the coin moves at the same sideways velocity of when it got out of your hand (the original speed of the plane). Now the plane speeds up, so you and your feet travel faster than the coin.

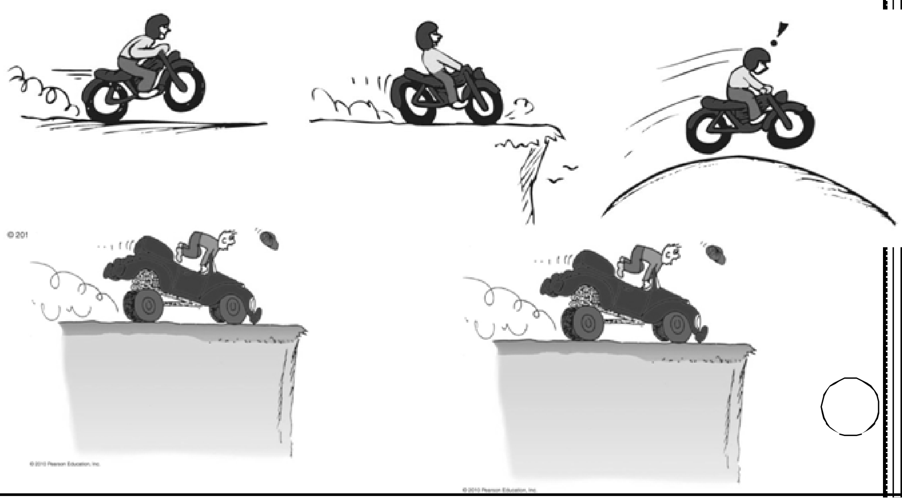


ACCELERATION

- Acceleration =
- Units…
- Demo: PASCar

ACCELERATION

- Draw the acceleration and velocity vectors.
- Draw the net force vector

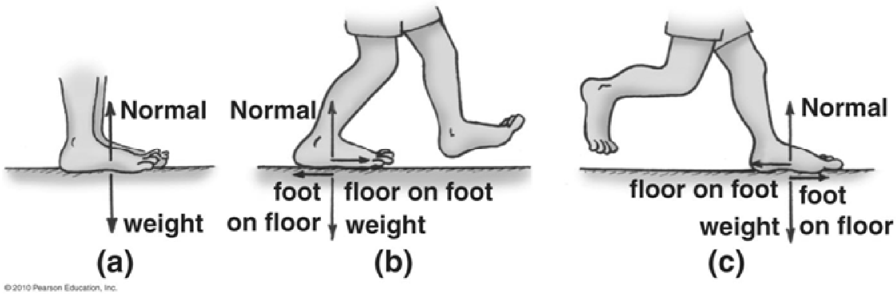


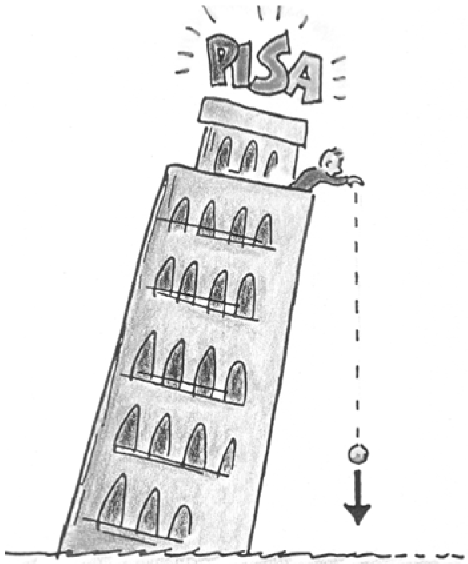
What are Newton’s 3 Laws of Motion?

1.

2.

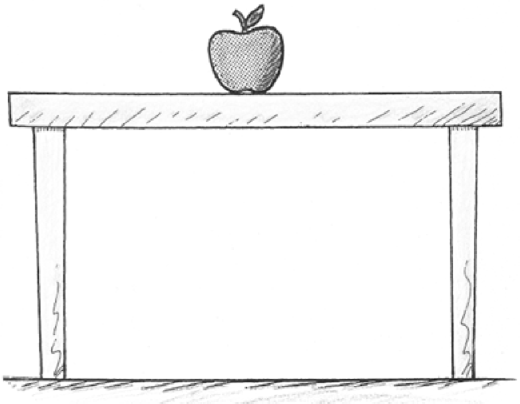
3.
- How does this help with walking? Wheels?
- See CISE Ch. 4

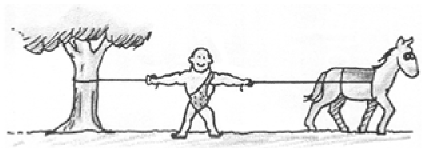




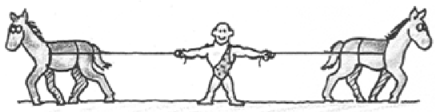
For every force there exists an equal and opposite force. Consider action and reaction forces in the case of a rock falling under the influence of gravity. If action is considered to be the force of gravity on the rock, can you clearly identify the reaction force?

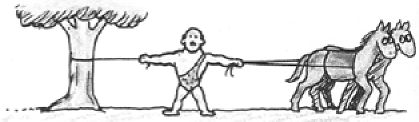
Consider the apple at rest on the table. If we call the gravitational force exerted on the apple *action*, what is the *reaction force* according to Newton's 3rd law?





The strong man can withstand the tension forces exerted by the pair of ropes—one tied to a tree and the other to a horse. No problem. Compare the tension he experiences in two other situations shown to the right—horse and horse, and two horses and a tree.





NEWTON'S THIRD LAW

- See The Apple-Orange Conundrum

- Focus on one object when talking about net force.
- The Third Law involves 2 forces on 2 objects, so they don't cancel!