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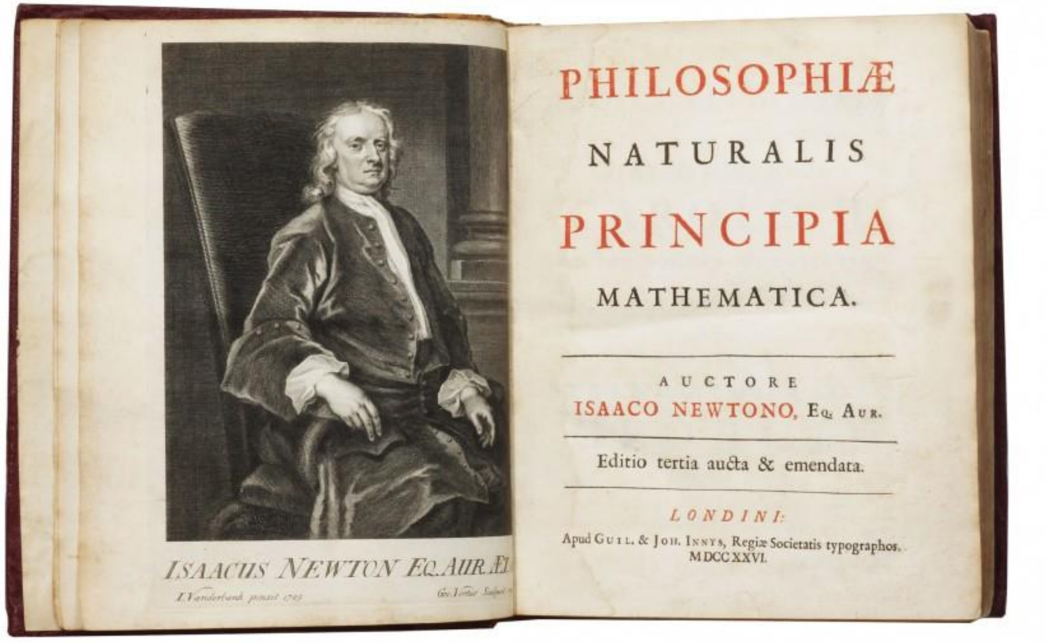
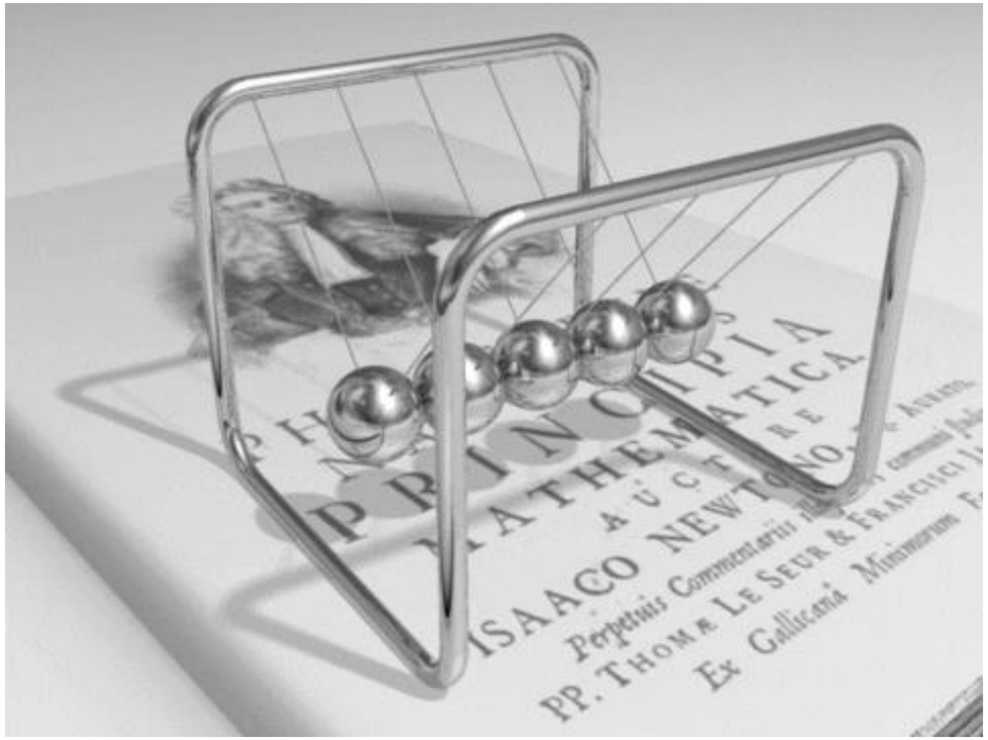
Latin

Newton's Laws
Introduction Chapter 4





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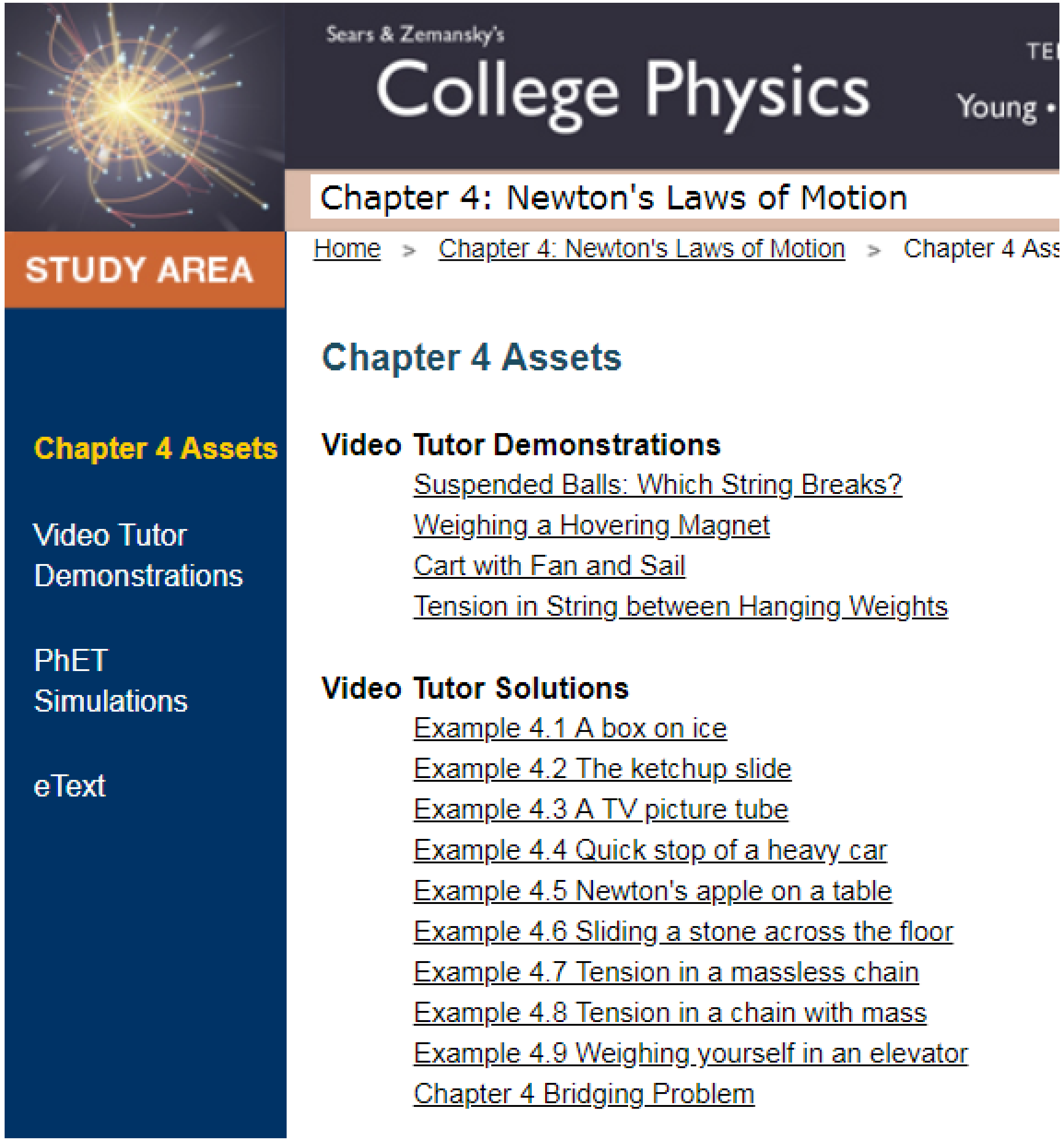
Use the study area as we go through the slides

VTD Suspended balls. Which string breaks

VTS Ex 4.1

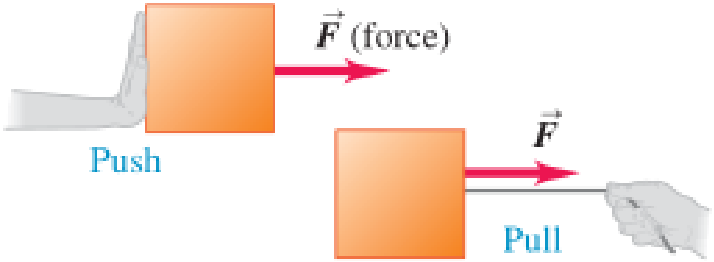


Goals for Chapter 4

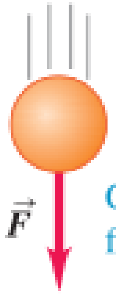
- To understand force – either directly or as the *net force* of multiple components.
- To study and apply Newton's first law.
- To study and apply the concept of mass and acceleration as components of Newton's second law.
- To differentiate between mass and weight.
- To study and apply Newton's third law & identify two forces and identify action-reaction pairs.
- To draw a free-body diagram representing the forces acting on an object.

Contact force

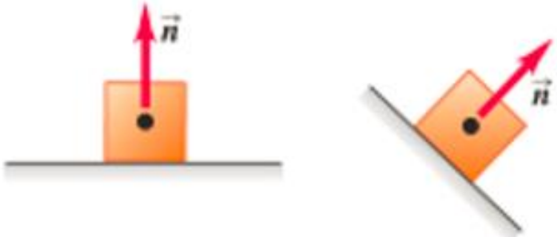
- A force is a push or a pull.
- A force is an interaction between two objects or between an object and its environment.
- A force is a vector quantity, with magnitude and direction.



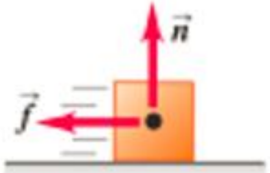
Non-contact force



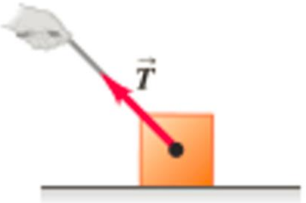
Gravity is an example of a force that acts over a distance.



Normal force $\vec{n}$: When an object rests or pushes on a surface, the surface exerts a push on it that is directed perpendicular to the surface.



Friction force $\vec{f}$: In addition to the normal force, a surface may exert a frictional force on an object, directed parallel to the surface.



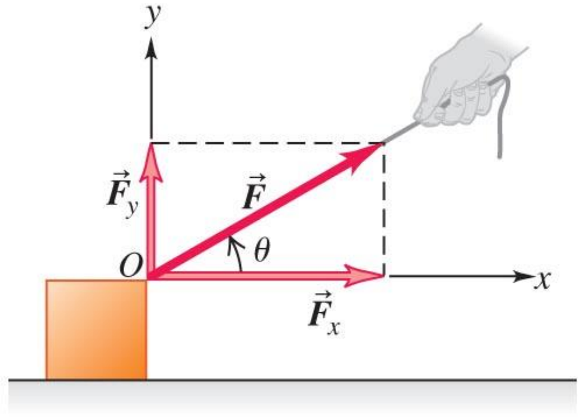
Tension force $\vec{T}$: A pulling force exerted on an object by a rope, cord, etc.

Weight $\vec{w}$: The pull of gravity on an object.

A Force May Be Resolved Into Components

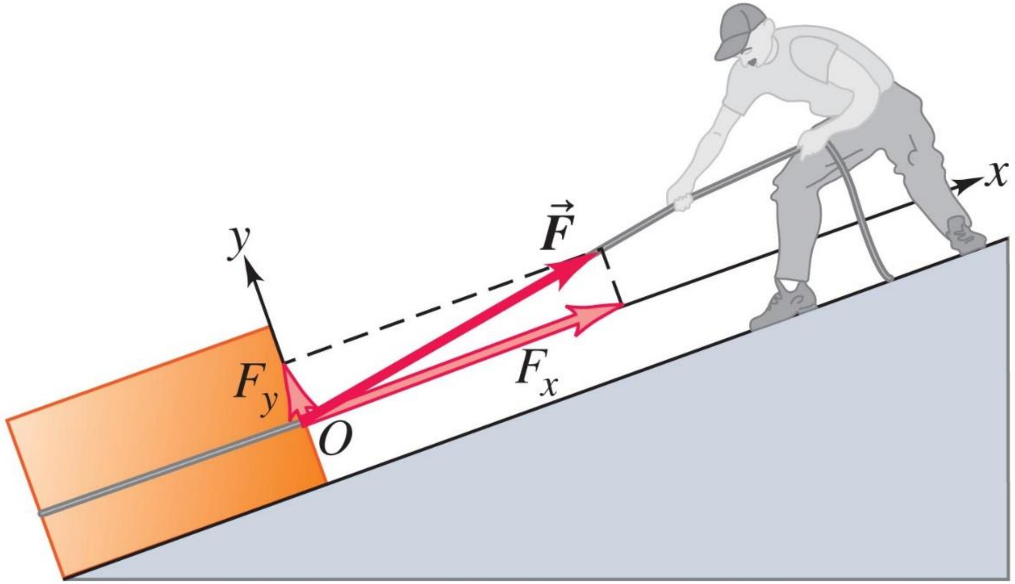
$$F_x = F\cos\theta$$

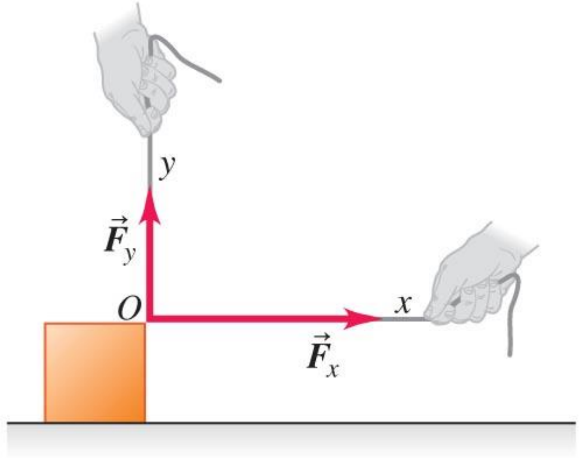
$$F_y = F\sin\theta$$



(a) Component vectors: $\vec{F}_x$ and $\vec{F}_y$
Components: $F_x = F\cos\theta$ and $F_y = F\sin\theta$

- The *x*- and *y*-coordinate axes don't have to be vertical and horizo

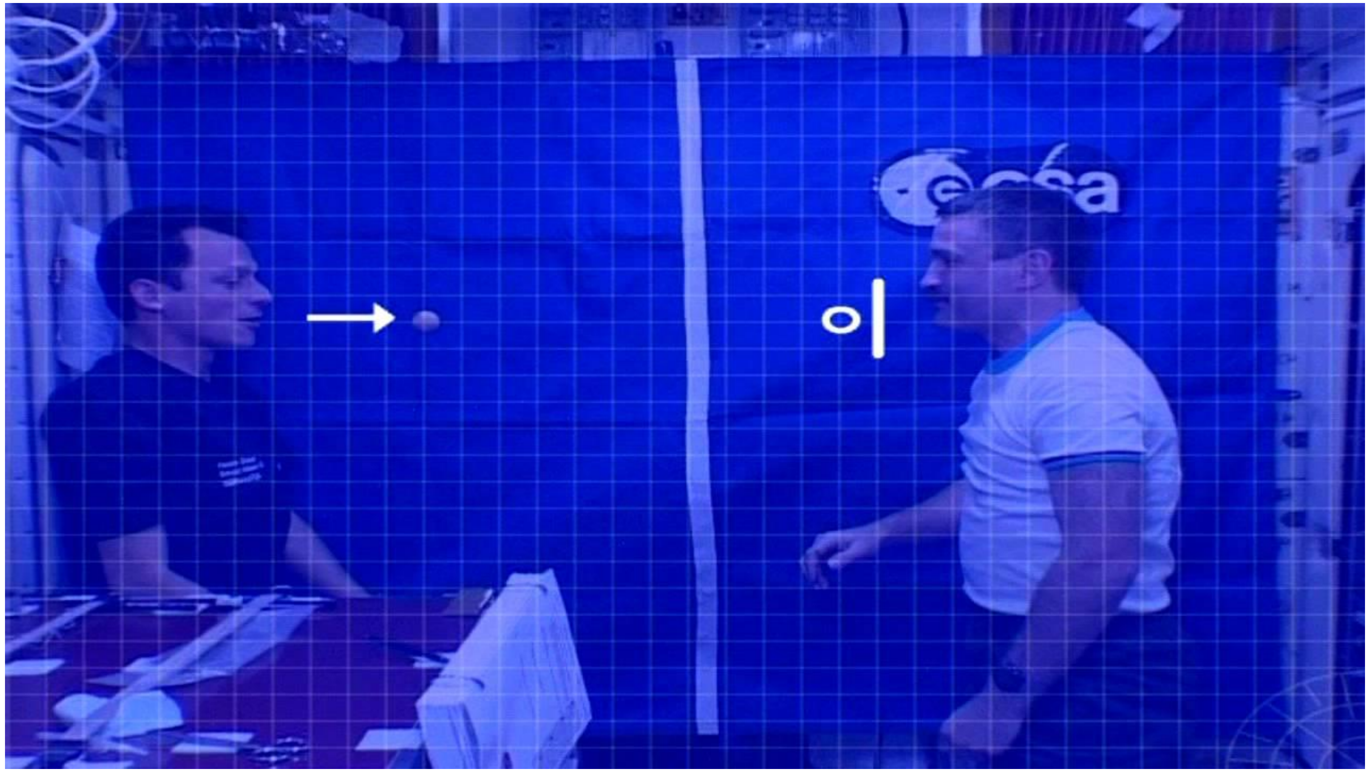




(b) Component vectors $\vec{F}_x$ and $\vec{F}_y$ together have the same effect as original force $\vec{F}$.

Newton's first law video

http://www.youtube.com/watch?v=QoWz5PoJdeU



Newton’s first law

Every object continues either at rest or in constant motion in a straight line, unless it is forced to change that state by forces acting on it.

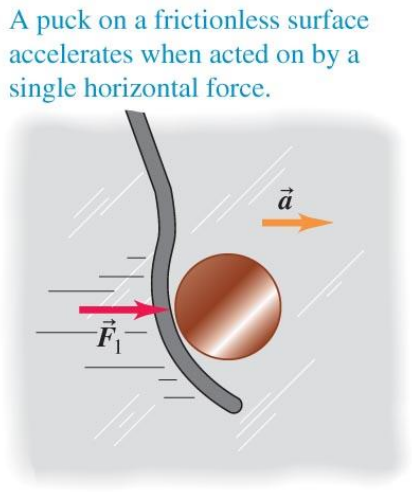
Newton's First Law: Vector form

$$\sum \vec{F} = 0 \qquad \vec{a} = 0$$

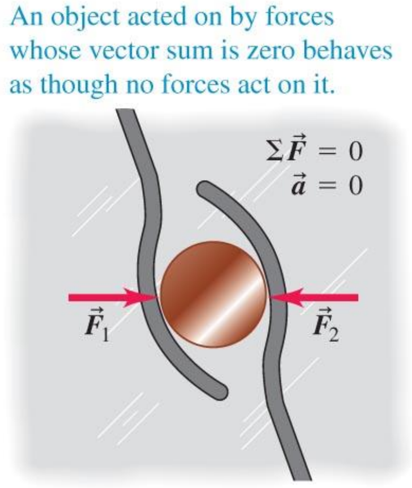
$$\Delta\vec{v} = 0$$

$$\vec{v} = \text{constant}$$

We Determine Effect with the Net Force



(a)



(b)

- The top puck responds to a non-zero net force (resultant force) and accelerates.
- The bottom puck responds to two forces whose vector sum is zero:

$$\vec{R} = \vec{F}_1 + \vec{F}_2 = \sum \vec{F} = 0$$

$$\text{where} \begin{cases} R_x = \sum F_x = 0 \\ R_y = \sum F_y = 0 \end{cases}$$

- The bottom puck is in **equilibrium,** and does NOT accelerate.

Inertia

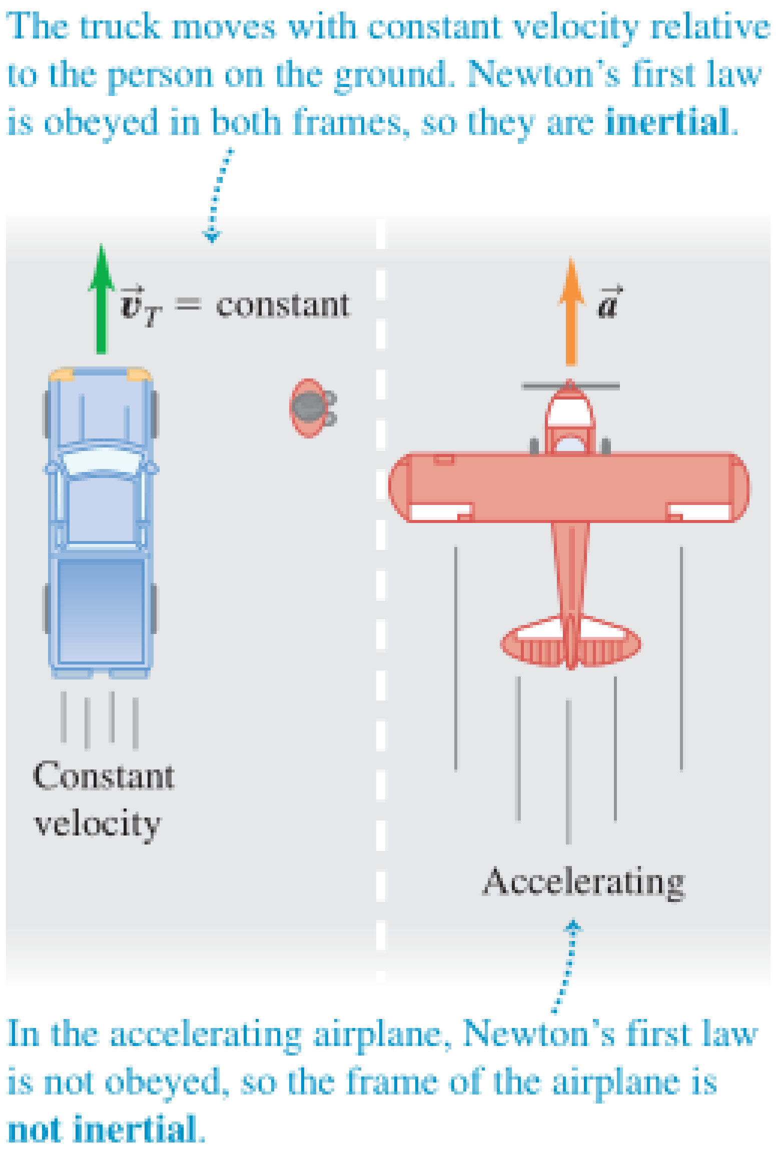
- Every object has **inertia**; the tendency of a body to resist change in motion.
- The **mass** of the body is a measure of its inertia.
- Newton's 1st law is also known as the law of inertia.

Most large tankers turn off their engines about 15 miles (25 km) away from their stop point

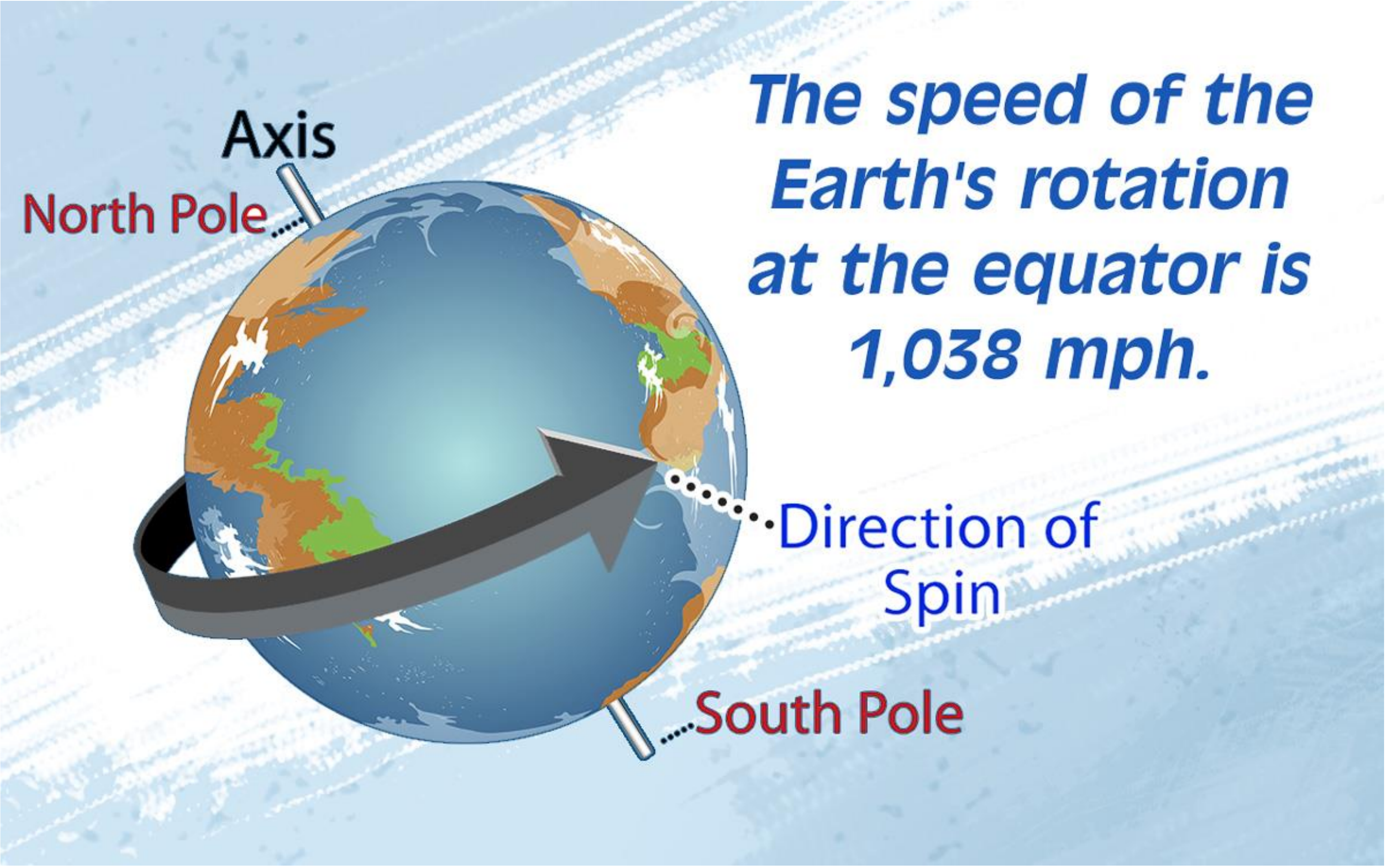

VIA 9GAG.COM
INERTIA
Your truck has brakes...the massive hunk of stone doesn't.

▶ Application **Objects at rest?** This trick photo was taken an instant after a super-smooth table was very rapidly yanked out from underneath the dinner setting. The table was removed so rapidly that it exerted a force on the place setting only for a very short time. We can visualize the concept of inertia as described by Newton's first law. The objects at rest tend to stay at rest—but the force of gravity causes them to accelerate rapidly downward!

A frame of reference in which Newton's first law is valid is called an **inertial frame of reference.** The earth is approximately an inertial frame of reference, but the airplane is not.



▲ **FIGURE 4.9** Inertial and non-inertial frames of reference.



We experience the effects of acceleration but not velocity.

The earth moves at a constant velocity, as an inertial frame of reference

VTD Suspended balls. Which string breaks

https://www.khanacademy.org/science/physics/forces-newtons-laws/newtons-laws-of-motion/v/newton-s-1st-law-of-motion

Newton's Second Law

$$\Sigma\vec{F} = m\vec{a}$$

http://www.youtube.com/watch?v=WzvhuQ5RWJE

Newton's Second Law

- **The net force acting on an object is equal to its mass times its acceleration**

Vector form

$$\Sigma \vec{F} = m\vec{a}$$

Component form

$$\Sigma F_x = ma_x \qquad \Sigma F_y = ma_y$$

Illustration – a 1-D problem

- At a certain moment, the engine of a 2000-kg car produced a forward force of 4000 N. the air resistance is 800 N . Calculate the acceleration of the car.

$$\Sigma\vec{F} = m\vec{a}$$

Ans=1.6 m/s^2

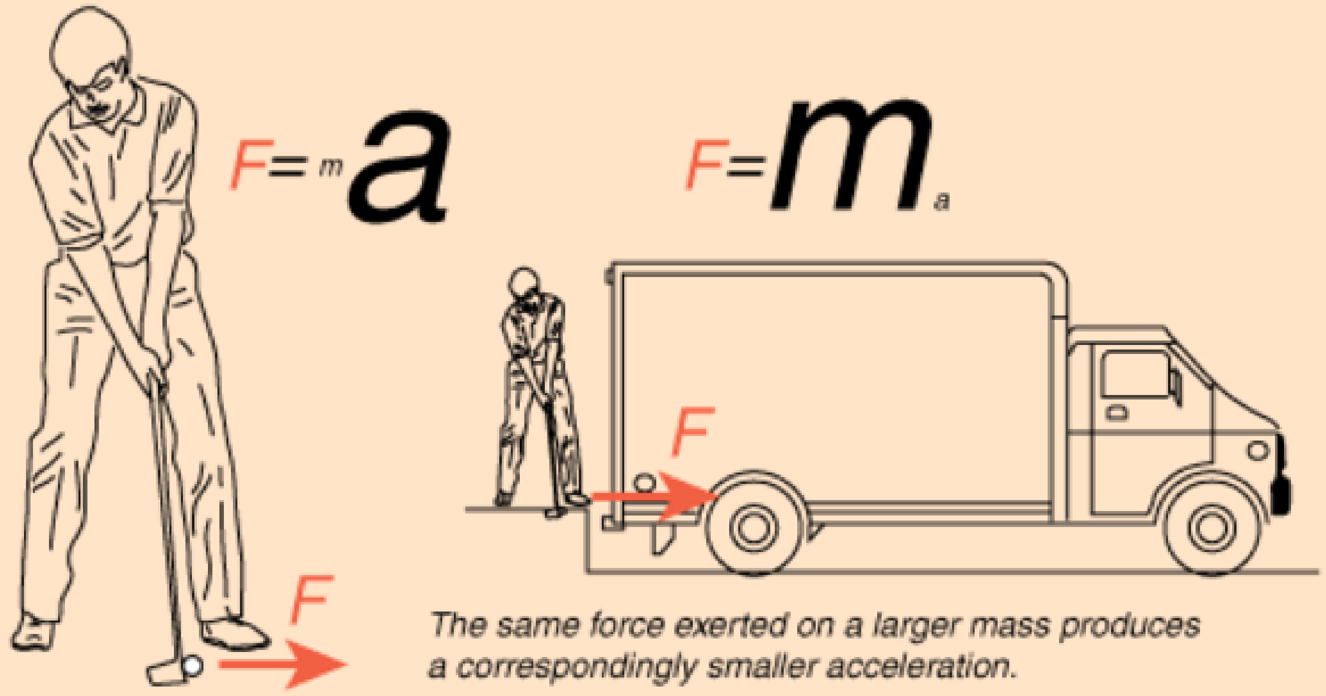
Mass and Weight

- Weight is the gravitational force acting on a mass.
- The gravitational acceleration ***g*** is assumed constant near the surface of the Earth (unless otherwise is stated)
- ***g*** varies from a planet to another, so weight changes, but mass does not change.

$$W = mg$$

Newton's Second Law Illustration

Newton's 2nd Law enables us to compare the results of the same force exerted on objects of different mass.



Contact Forces

- When an object rests or slides on a surface, the surface exerts a **contact force** on the object.
- The contact force has two components:
  - Normal force $\vec{n}$: perpendicular to the surface
  - Friction force $\vec{f}$: parallel to the surface
    - Static friction $\vec{f_s}$: no relative motion exists
    - Kinetic friction $\vec{f_k}$: there is relative motion between object and surface

4.3 Mass and Newton's Second Law

6. • A box rests on a frozen pond, which serves as a frictionless horizontal surface. If a fisherman applies a horizontal force with magnitude 48.0 N to the box and produces an acceleration of magnitude 3.00 m/s^2, what is the mass of the box?

4.6. Set Up: Let $+x$ be the direction of the force and acceleration. $\sum F_x = 48.0$ N.

Solve: $\sum F_x = ma_x$ gives $m = \dfrac{\sum F_x}{a_x} = \dfrac{48.0\text{ N}}{3.00\text{ m/s}^2} = 16.0\text{ kg}$.

https://www.khanacademy.org/science/physics/forces-newtons-laws/newtons-laws-of-motion/v/newton-s-second-law-of-motion

Newton’s third law

- **For every action (force) there is a reaction (force) equal in magnitude and opposite in direction.**

$$\vec{F}_{AonB} = -\vec{F}_{BonA}$$
$$\vec{F}_{AB} = -\vec{F}_{BA}$$

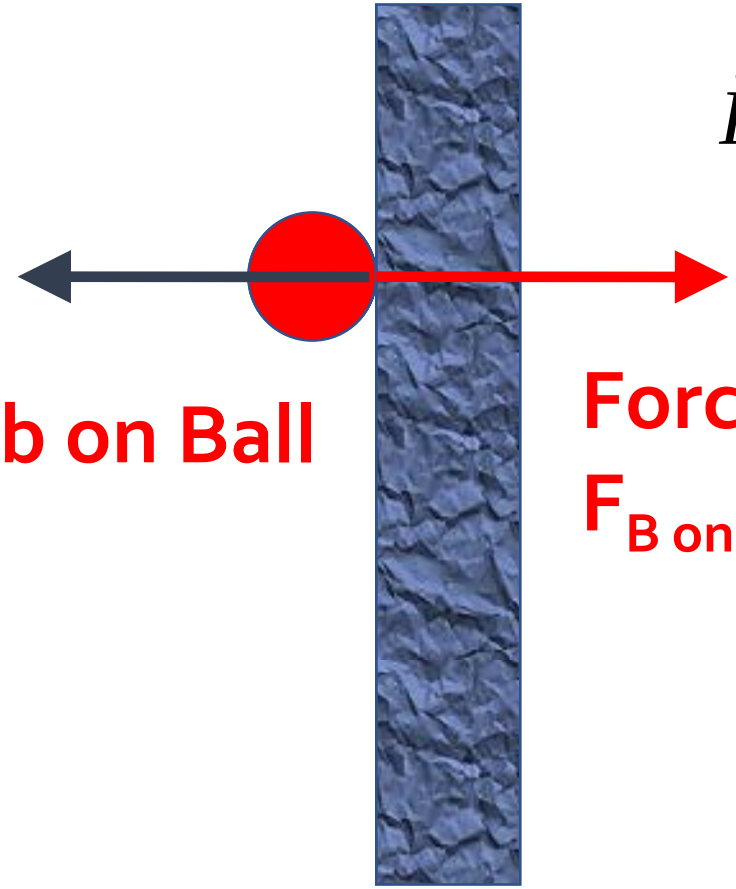
- Forces always act in pairs (of action and reaction)

Newton's 3rd law of motion

http://www.youtube.com/watch?v=cP0Bb3WXJ_k

A ball moving horizontally strikes a vertical slab of concrete. What are the forces in this interaction? How are these forces related?

$$\vec{F}_{BonS} = -\vec{F}_{SonB}$$



Force of Slab on Ball

$F_{S\ on\ B}$

Force of Ball on Slab

$F_{B\ on\ S}$

Gravitational Force

- The earth pulls an apple down with a force W. What is the reaction?

- The apple pulls up on the earth with the same force

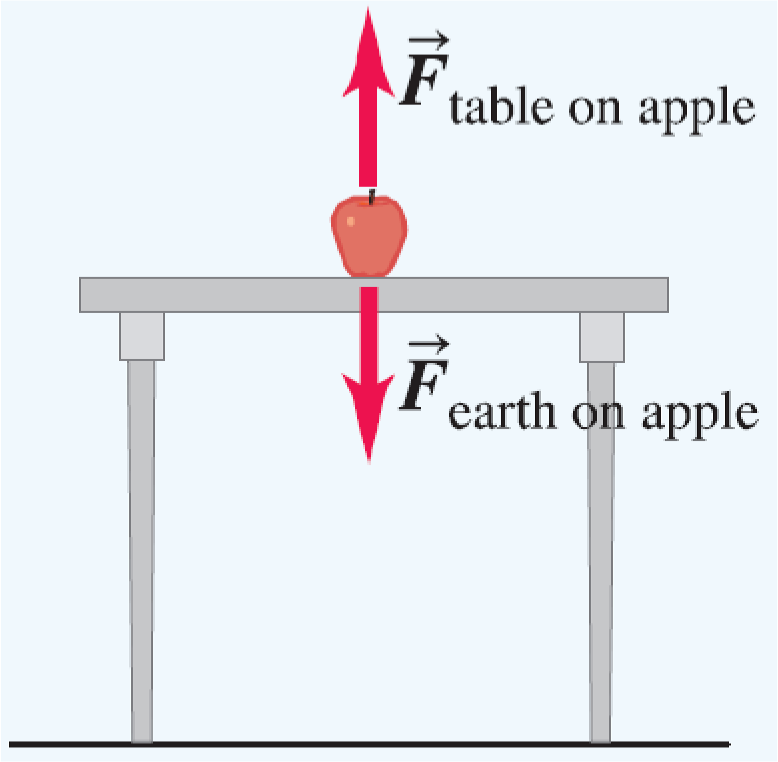
VTD Weighing a hovering magnet

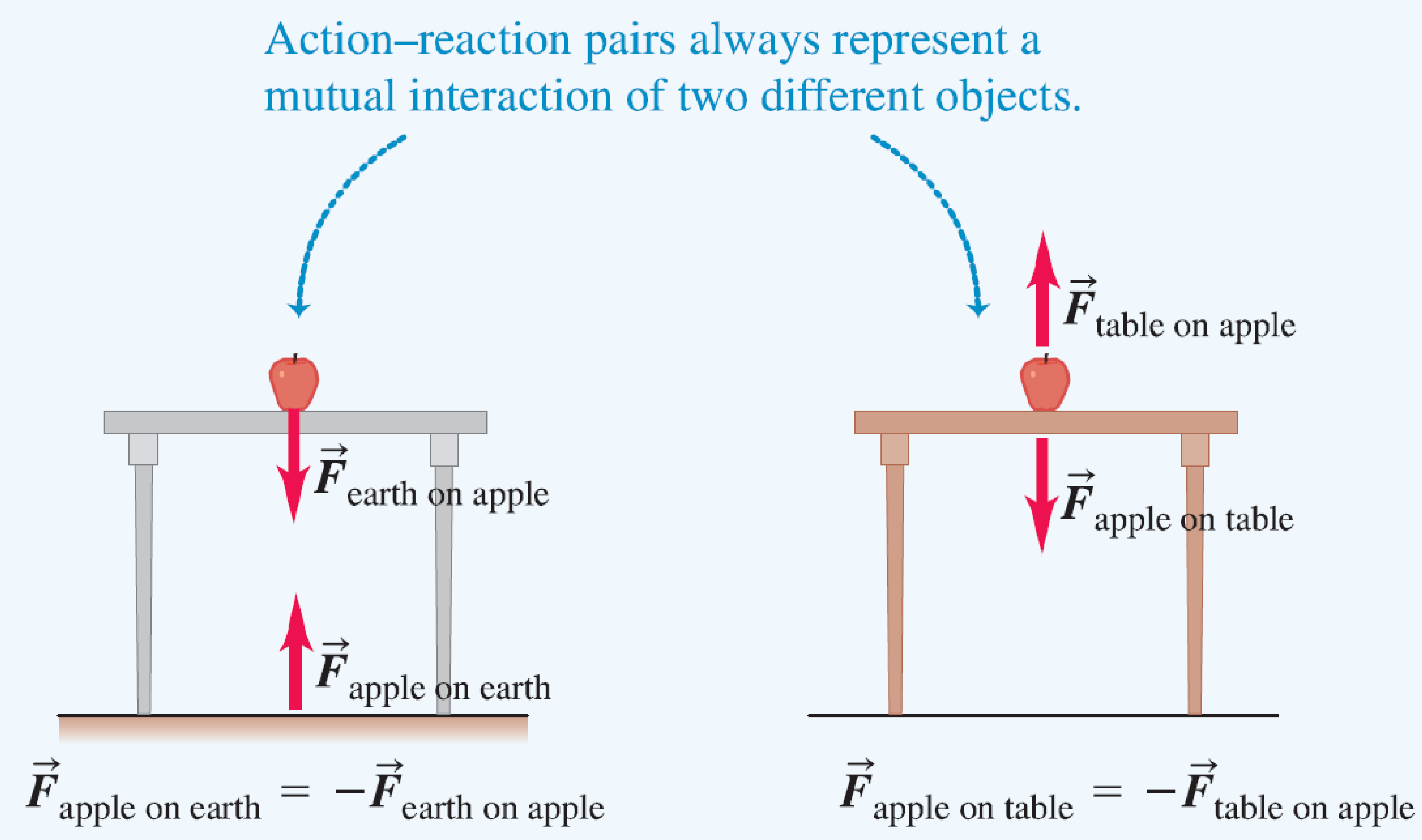
VTD Cart with fan and sail

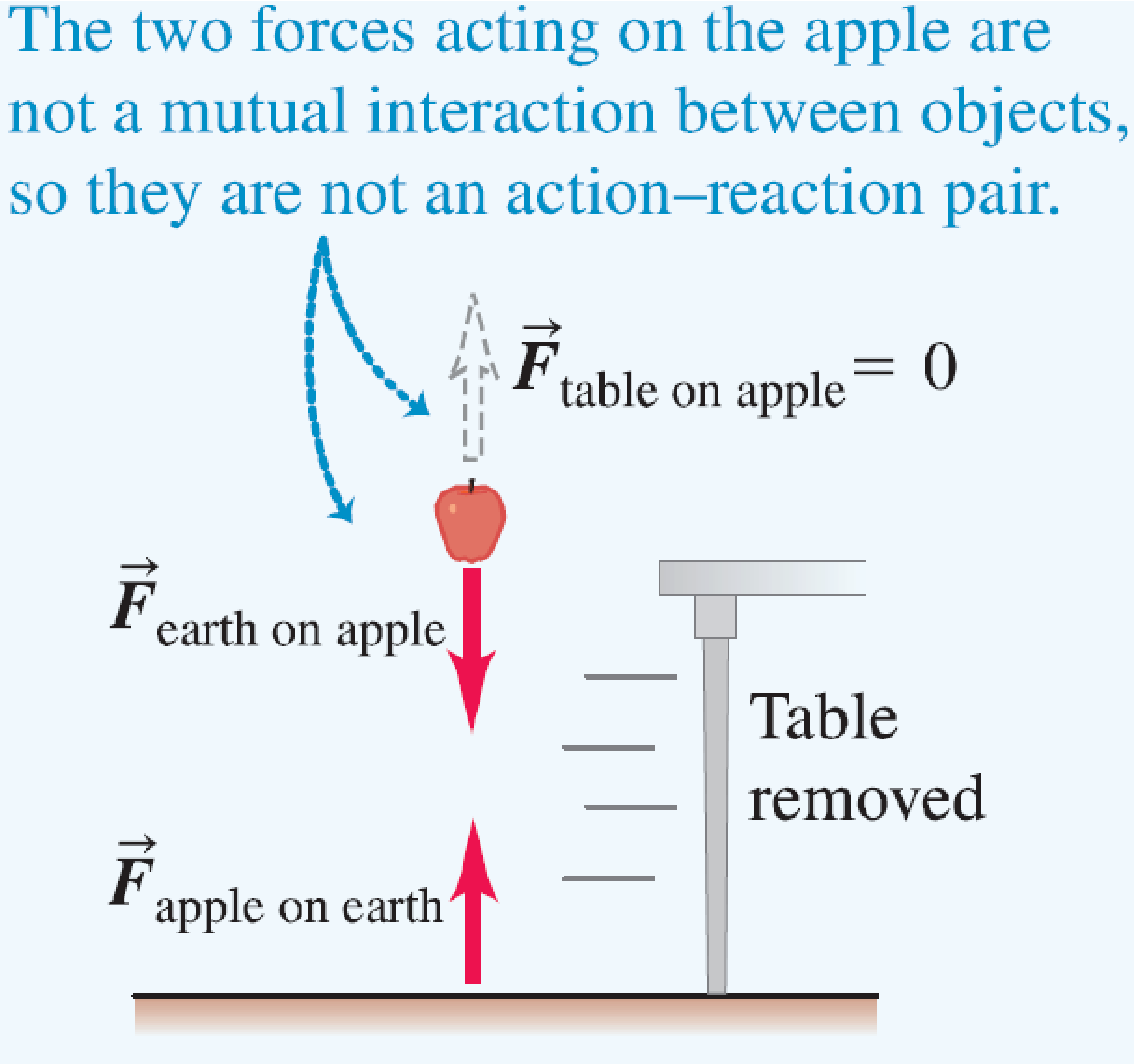
VTD Tension in spring between hanging weights

Find the pairs

VTS Ex 4.5



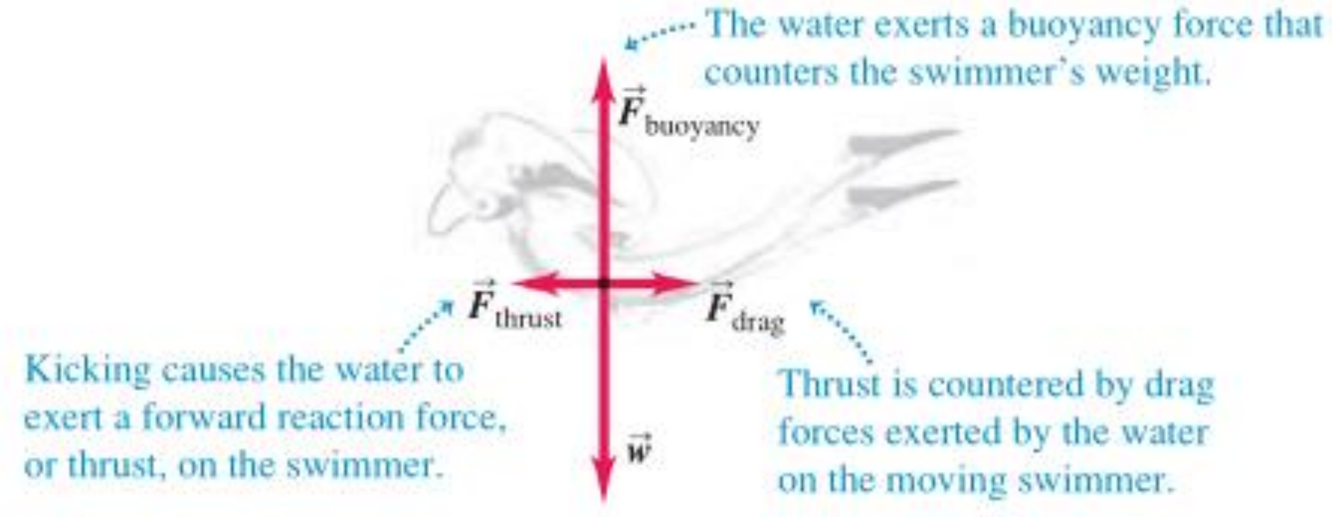

Action–reaction pairs always represent a mutual interaction of two different objects.
$\vec{F}_{\text{earth on apple}}$
$\vec{F}_{\text{apple on earth}}$
$\vec{F}_{\text{table on apple}}$
$\vec{F}_{\text{apple on table}}$
$\vec{F}_{\text{apple on earth}} = -\vec{F}_{\text{earth on apple}}$
$\vec{F}_{\text{apple on table}} = -\vec{F}_{\text{table on apple}}$

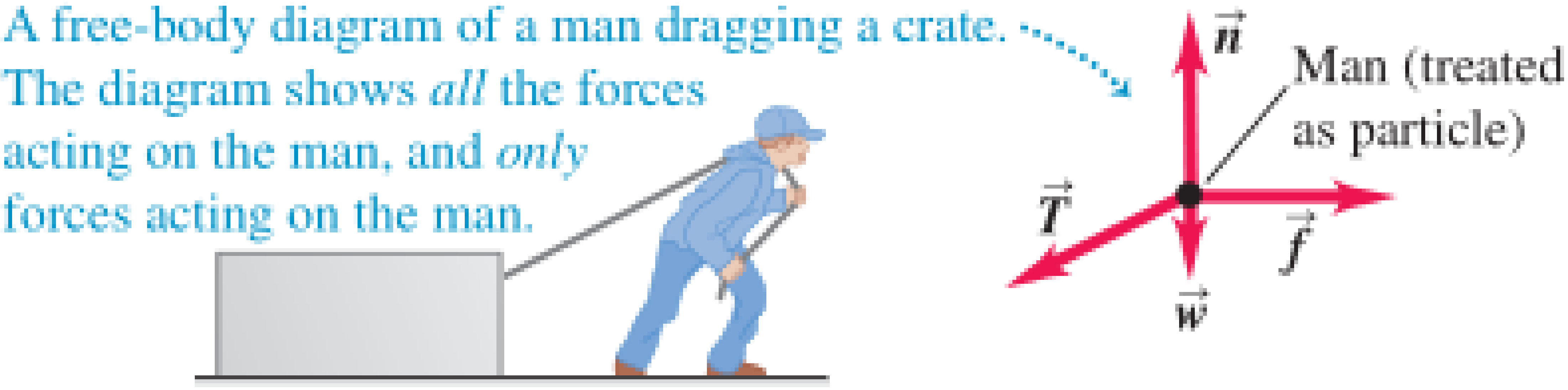

The two forces acting on the apple are not a mutual interaction between objects, so they are not an action–reaction pair.
$\vec{F}_{\text{table on apple}} = 0$
$\vec{F}_{\text{earth on apple}}$
$\vec{F}_{\text{apple on earth}}$
Table removed

To help identify the relevant forces, draw a **free-body diagram**. What's that?
It is a diagram showing the chosen object by itself, "free" of its surroundings, with vectors drawn to show the forces applied to it by the various other objects that interact with it.

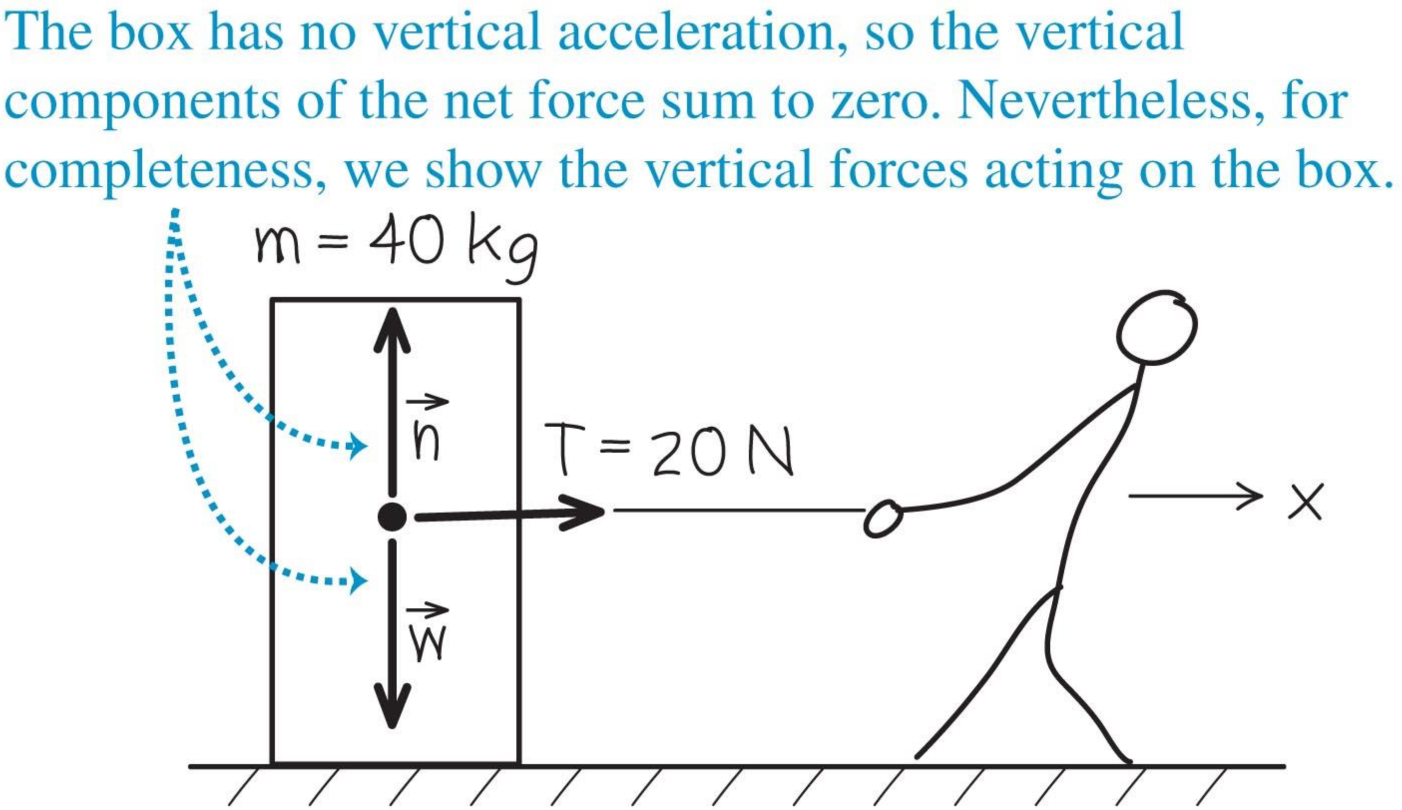
Be careful to include all the forces acting on the object, but be equally careful not to include any forces that the object exerts on any other object. In particular, the two forces in an action–reaction pair must never appear in the same free-body diagram, because they never act on the same object.

ONLY SHOW FORCES ACTING ON THE OBJECT





ONLY SHOW FORCES ACTING ON THE OBJECT

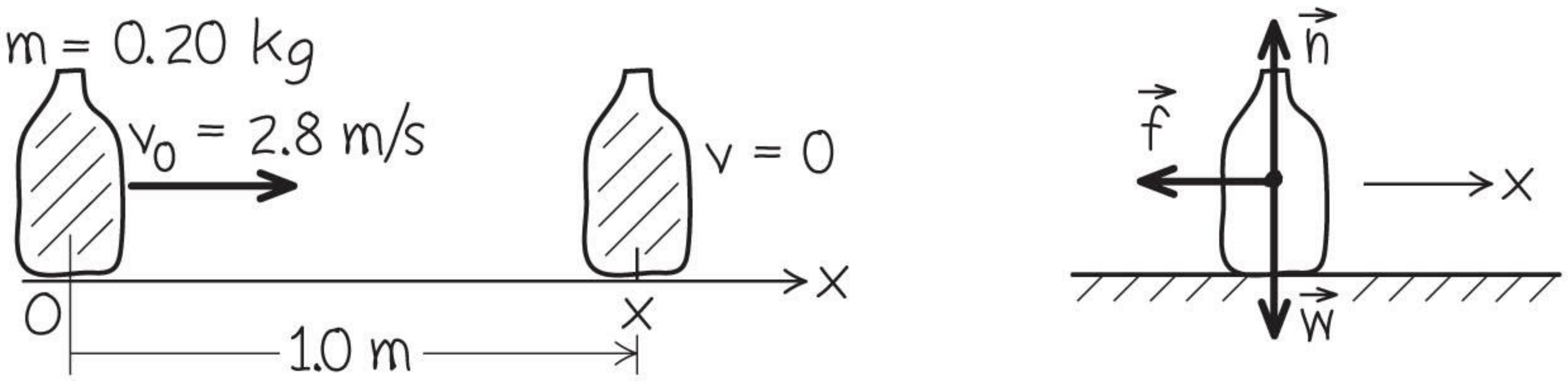


- The vertical forces are in **equilibrium** so there is no vertical motion.
- But there is a net force along the horizontal direction, and thus acceleration.

VTS Ex 4.1

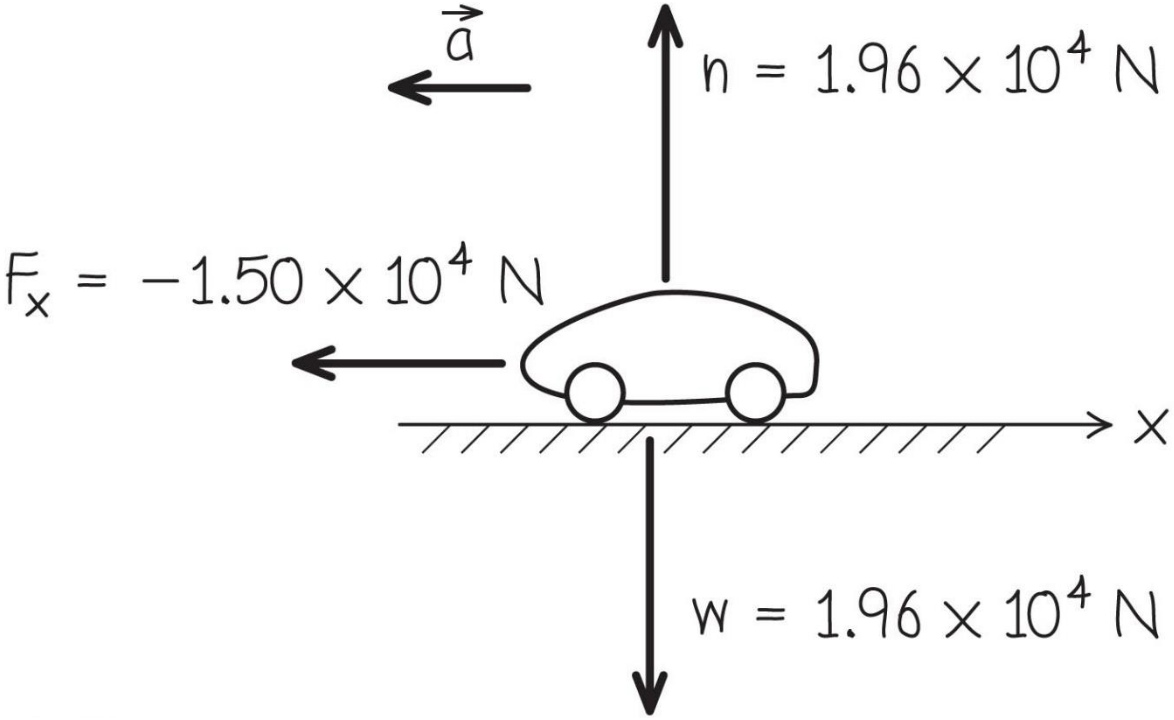
- Again, in this case, the net horizontal force is unbalanced.
- In this case, the net horizontal force opposes the motion and the bottle slows down (decelerates) until it stops.
- What is the frictional force?

We draw one diagram for the bottle's motion and one showing the forces on the bottle.

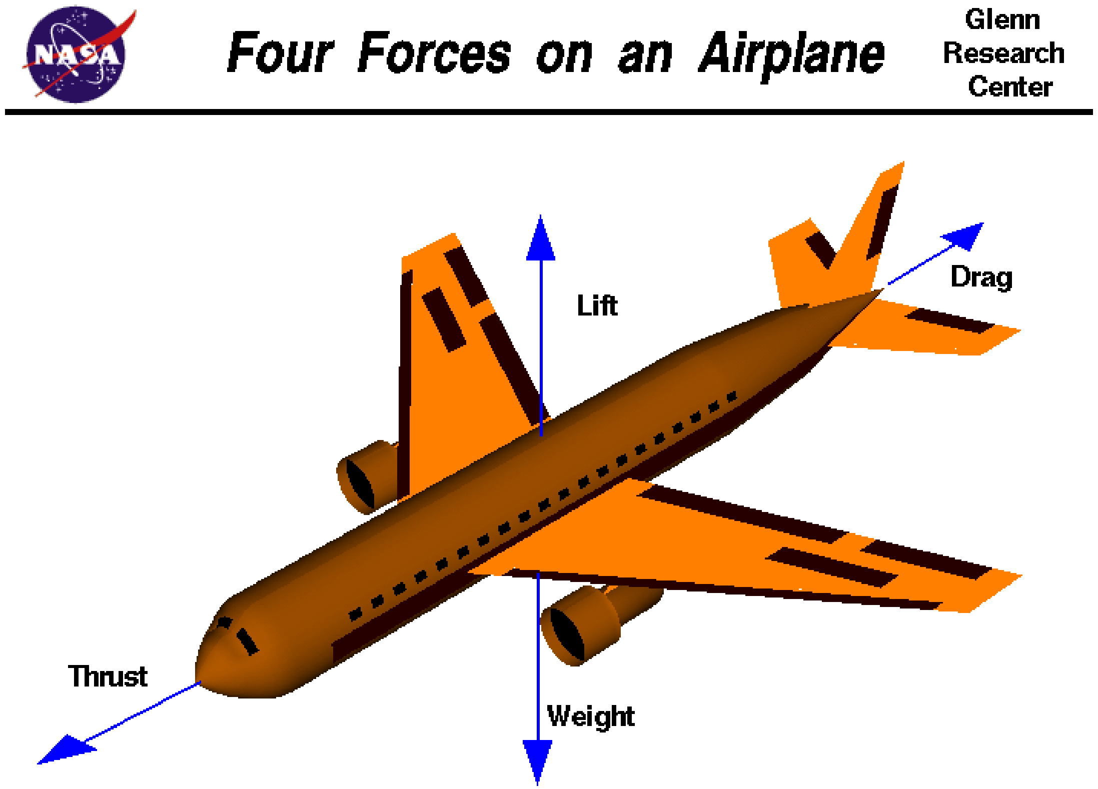


VTS Ex 4.2

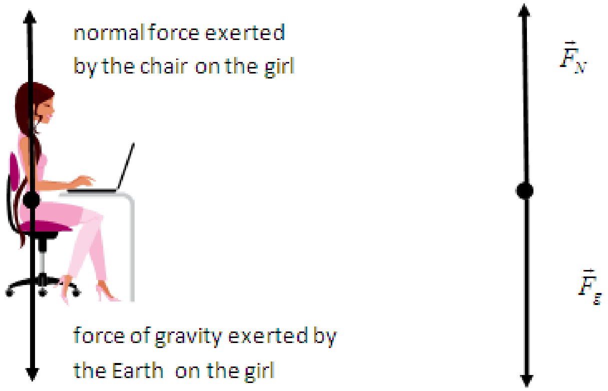
- A car traveling in the +ve x direction breaks
- We can solve for acceleration due to braking.

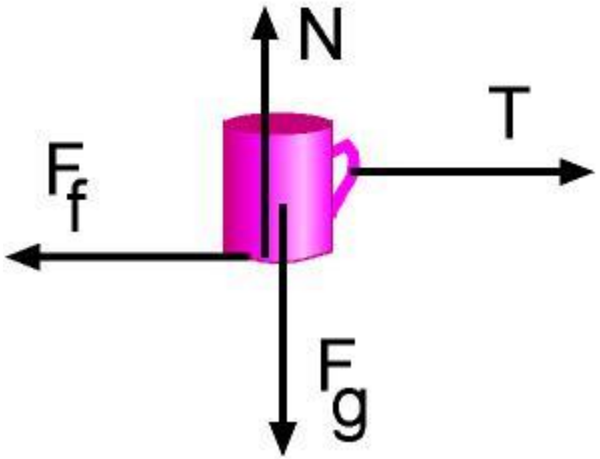


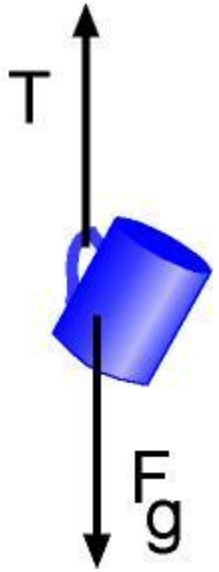
VTS Ex 4.4



ONLY SHOW FORCES ACTING ON THE OBJECT

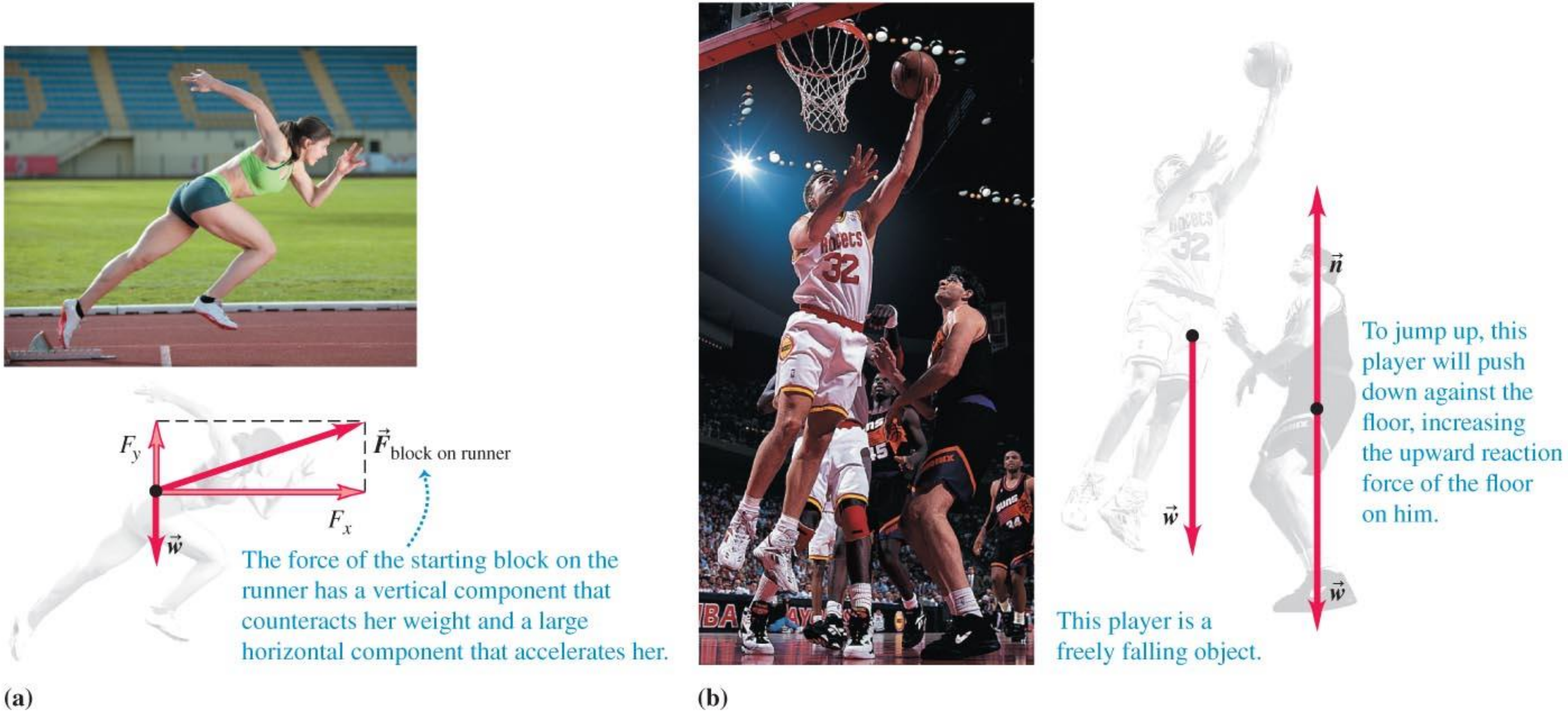






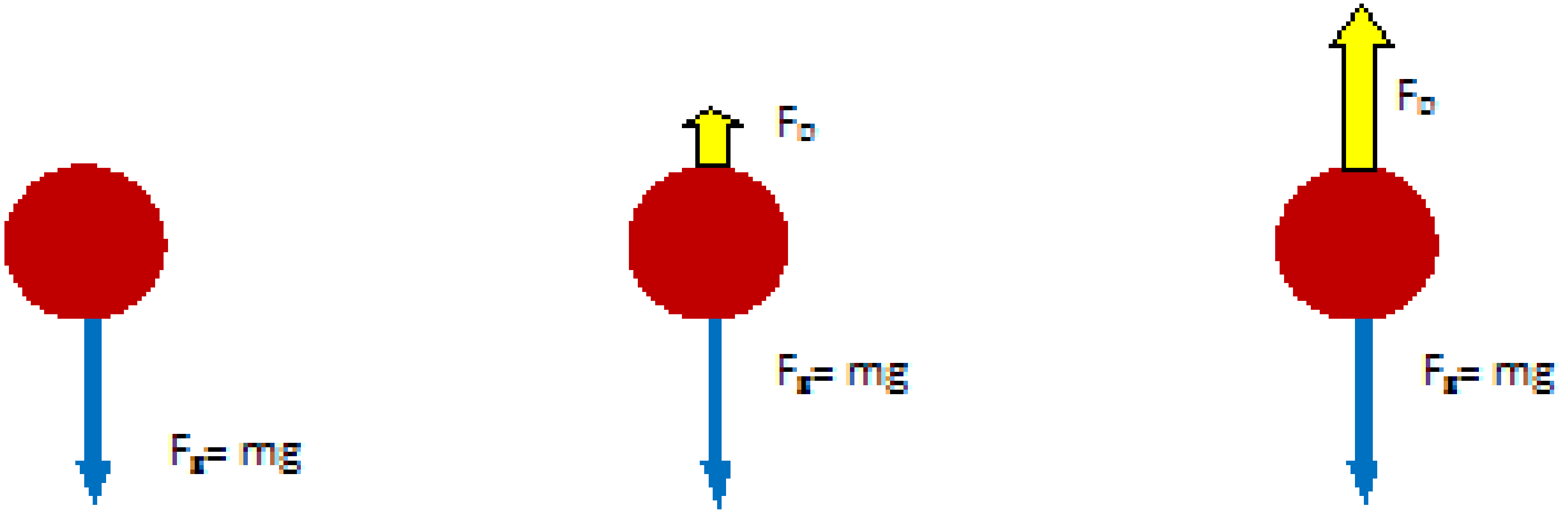
Use Free Body Diagrams In Any Situation

- Find the object of the focus of your study, and collect all forces acting upon it.



https://www.khanacademy.org/science/physics/forces-newtons-laws/newtons-laws-of-motion/v/newton-s-third-law-of-motion

A note on air drag and terminal velocity



Object released from rest (no air drag force yet)

Air drag force increases as the object speeds up

Air drag force is equal to the force of gravity. Object falls at terminal velocity

Newton's first law

Every object continues either at rest or in constant motion in a straight line,
unless it is forced to change that state by forces acting on it.

Newton's Second Law

- **The net force acting on an object is equal to its mass times its acceleration**

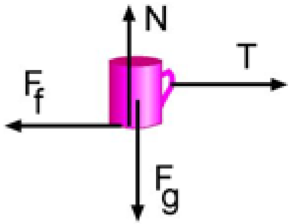
Vector form

$$\Sigma\vec{F} = m\vec{a}$$

Component form

$$\Sigma F_x = ma_x \qquad \Sigma F_y = ma_y$$

1. $\Sigma\vec{F} = 0$
2. $\Sigma\vec{F} = m\vec{a}$
3. $\vec{F}_{AB} = -\vec{F}_{BA}$



Newton's First Law: Vector form

$$\sum\vec{F} = 0 \qquad \vec{a} = 0$$

$$\Delta\vec{v} = 0$$

$$\vec{v} = \text{constant}$$

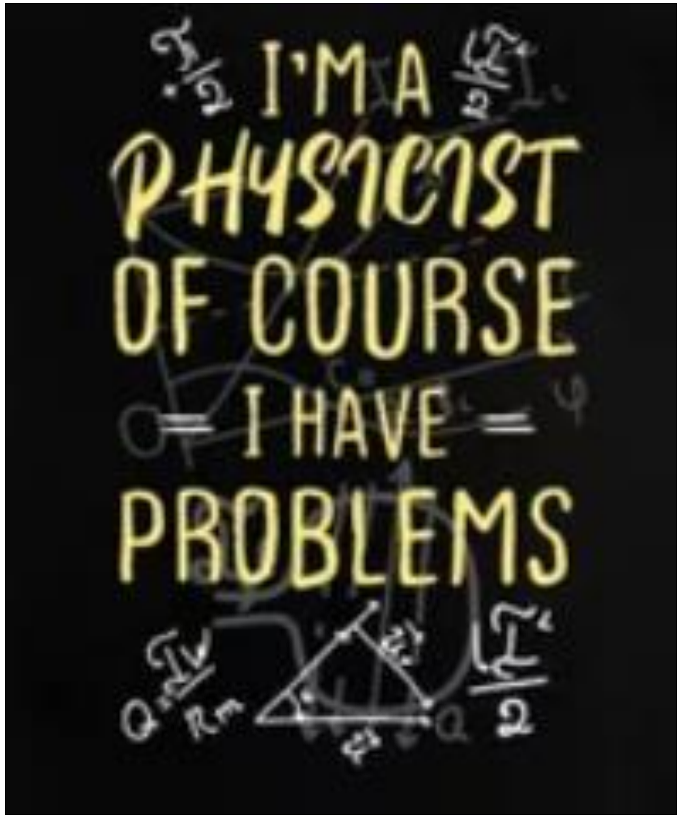
Newton's third law

- **For every action (force) there is a reaction (force) equal in magnitude and opposite in direction.**

$$\vec{F}_{AonB} = -\vec{F}_{BonA}$$
$$\vec{F}_{AB} = -\vec{F}_{BA}$$

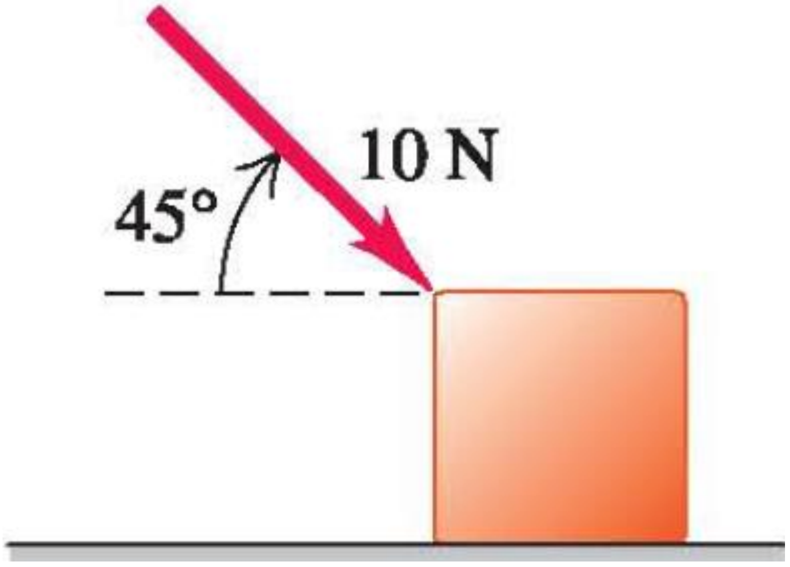
- Forces always act in pairs (of action and reaction)

Problems



Chapter 4 – prob. 1

- A warehouse worker pushes a crate along the floor, as shown in Figure 4.33, by a force of 10 N at 45° below the horizontal. Find the horizontal and vertical components of the push.



- A hockey puck with mass 0.160 kg is at rest on the horizontal, frictionless surface of a rink. A player applies a force of 0.250 N to the puck, parallel to the surface of the ice, and continues to apply this force for 3.00 s. What are the position and speed of the puck at the end of that time?

Ans = position = 7.02 m, velocity = 4.68 m/s

- A 3000-kg car is moving @ 15 m/s under the effect of the 2.0 kN engine and an air resistance of 2.0 kN.

a) Find the horizontal acceleration of the car.
b) What is the velocity of the car after 5.0 s?
c) What is the weight of the car?
d) What is the vertical acceleration of the car?

The normal force is

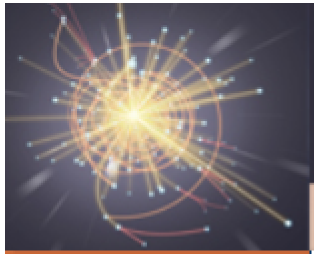
A) Force downwards
B) Force upwards
C) Force perpendicular to the surface
D) Force perpendicular to the object not resting on a surface.

Newtons second law is closest to

A) The force of an accelerating object
B) Objects move in straight lines if there is no force
C) If I push an object it pushes back with the same force

Inertia is closest to

A) An object remains stationary
B) An object has a tendency to stay the same velocity
C) An object can’t change velocity



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Chapter 4: Newton's Laws of Motion

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- Weighing a Hovering Magnet
- Cart with Fan and Sail
- Tension in String between Hanging Weights

Video Tutor Solutions

- Example 4.1 A box on ice
- Example 4.2 The ketchup slide
- Example 4.3 A TV picture tube
- Example 4.4 Quick stop of a heavy car
- Example 4.5 Newton's apple on a table
- Example 4.6 Sliding a stone across the floor
- Example 4.7 Tension in a massless chain
- Example 4.8 Tension in a chain with mass
- Example 4.9 Weighing yourself in an elevator
- Chapter 4 Bridging Problem