NEWTON'S LAWS OF MOTION I

PHYS1112

Lecture 2

Objectives

1. Understand the concept of frame of reference and relative velocity
2. Use the Newton’s three laws of motion to solve problems.
3. Understand the concept of inertial frame of reference.
4. Understand the meanings of apparent weight and weightlessness.

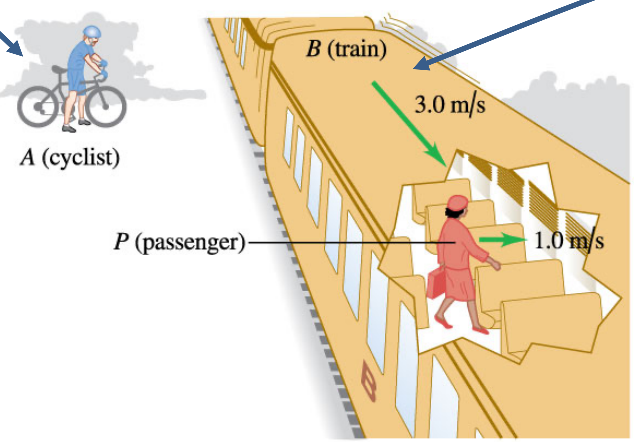
Relative velocity – concerning more than one observer

An observer making observation/measurement forms a <u>reference frame</u>

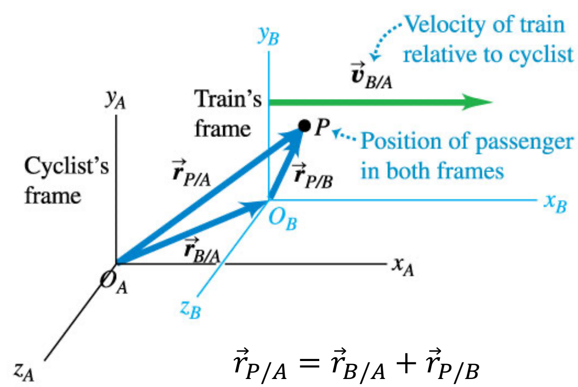
<u>Reference Frame A</u>
1st observer A, standing still on the platform

<u>Reference Frame B</u>
2nd observer B, sitting still inside the train

(a)



(b)



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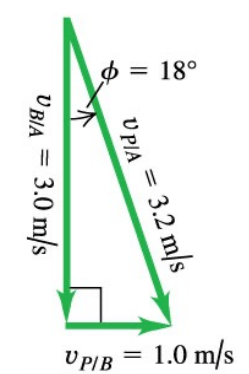
(c) Relative velocities (seen from above)



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$$\vec{r}_{P/A} = \vec{r}_{B/A} + \vec{r}_{P/B}$$

$$\Rightarrow \vec{v}_{P/A} = \vec{v}_{B/A} + \vec{v}_{P/B}$$

velocity of P measured in frame A

velocity of frame B measured in frame A

velocity of P measured in frame B

Q3.12

The pilot of a light airplane with an airspeed of 200 km/h wants to fly due west. There is a strong wind of 120 km/h blowing from the north.

If the pilot points the nose of the airplane north of west so that her ground track is due west, what will be her ground speed?

A. 80 km/h

B. 120 km/h

C. 160 km/h

D. 180 km/h

E. It would impossible to fly due west in this situation.

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Newtons' first law of motion

A body acted on by no net force moves with constant velocity

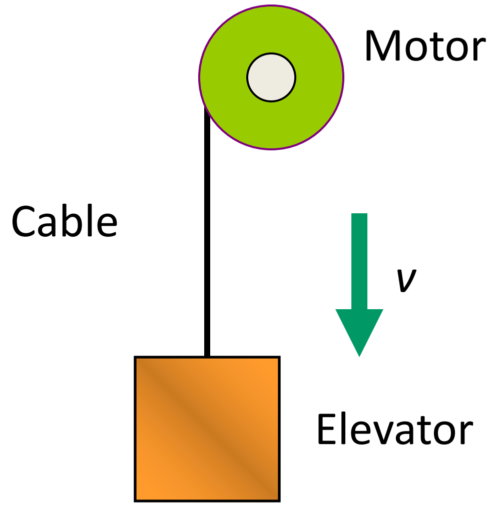
$$\sum \vec{F} = 0$$

body in equilibrium

Q4.6

An elevator is being lowered at constant speed by a steel cable attached to an electric motor. There is no air resistance, nor is there any friction between the elevator and the walls of the elevator shaft.

The upward force exerted on the elevator by the cable has the same magnitude as the force of gravity on the elevator, but points in the opposite direction. Why?



A. Newton's first law

B. Newton's second law

C. Newton's third law

A4.6

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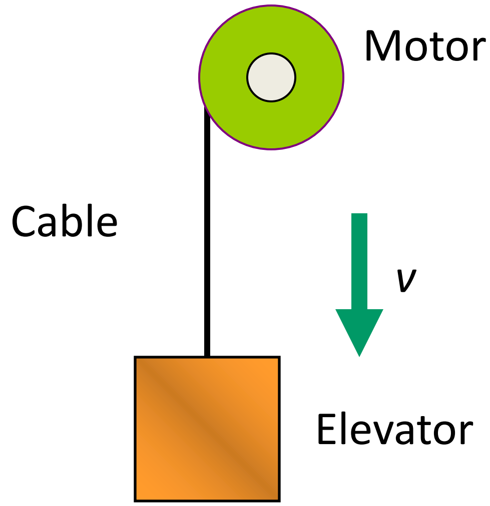

A. Newton's first law

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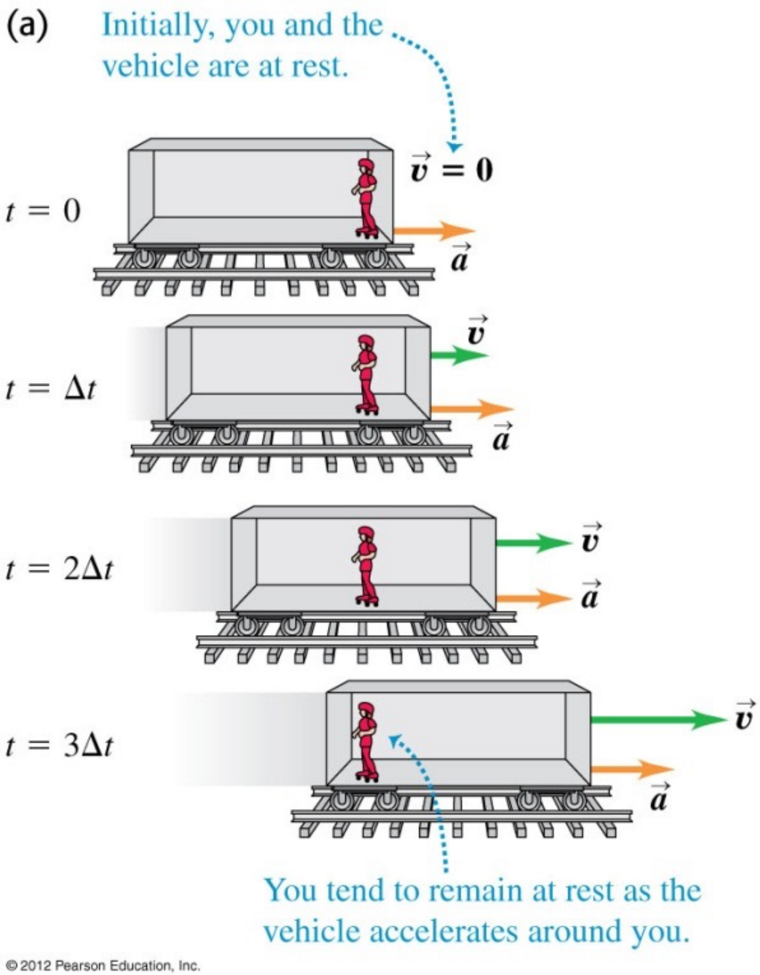
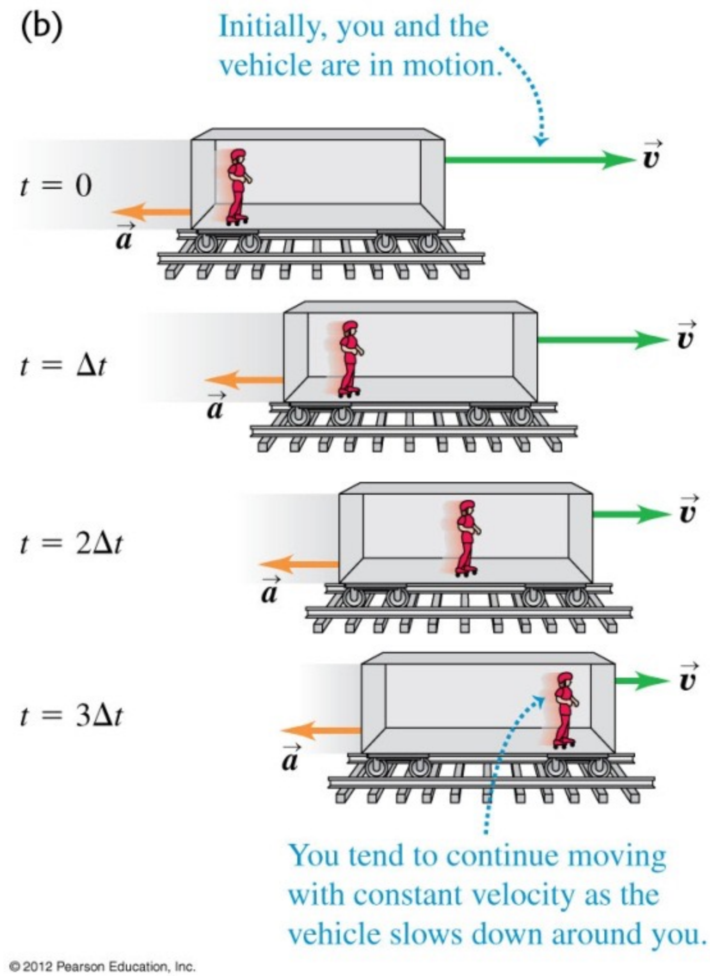
Inertial Frame of Reference





Passenger (in roller skate) accelerates inside the train, but the net force is zero.
Violate Newton's first law?? The train with non-zero acceleration is not an inertial frame.

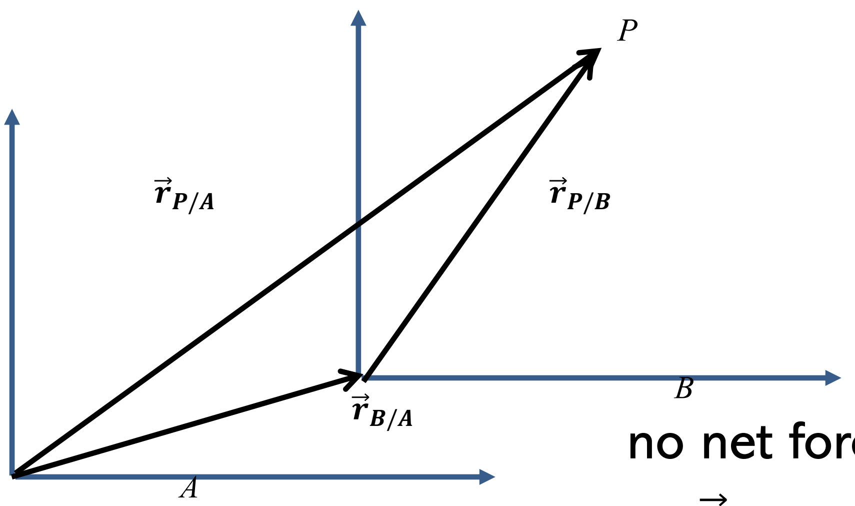
Inertial Frame

A frame of reference in which Newton's first law is valid is called an *inertial frame.*

Inertial Frame

1. Is the earth an inertial frame? Only approximately

2. Any frame moving with a constant velocity related to a given inertial frame is also an inertial frame.



$$\vec{v}_{P/A} = \vec{v}_{P/B} + \vec{v}_{B/A}$$

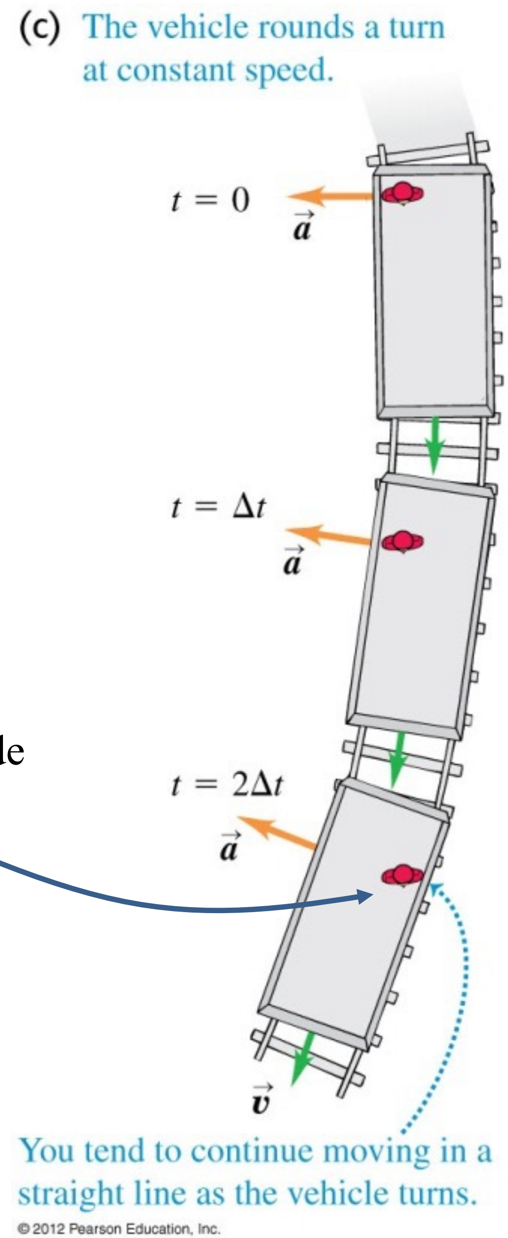
no net force

$\Rightarrow$ $\vec{\mathrm{v}}_{\mathrm{P/A}}$ constant

$\Rightarrow$ $\vec{\mathrm{v}}_{\mathrm{P/B}}$ constant provided $\vec{\mathrm{v}}_{\mathrm{B/A}}$ constant

In a non-inertial frame of reference, may feel like being acted on by a (non-existing) force.

feel like a force
pushing you aside



Question

- In which of the following situations is there zero net force on the body?
  a) an airplane flying due north at a steady speed and at a constant altitude, assuming that the earth is flat and is an inertial frame;
  b) a car driving straight up a hill at constant speed;
  c) a hawk circling at constant speed and constant height above an open field;
  d) a box with slick, frictionless surfaces in the back of a truck as the truck accelerates forward on a level road at constant acceleration.


RELATIVE MOTION
TRACK

Newton's second law

If a net external force acts on a body, the body accelerates according to

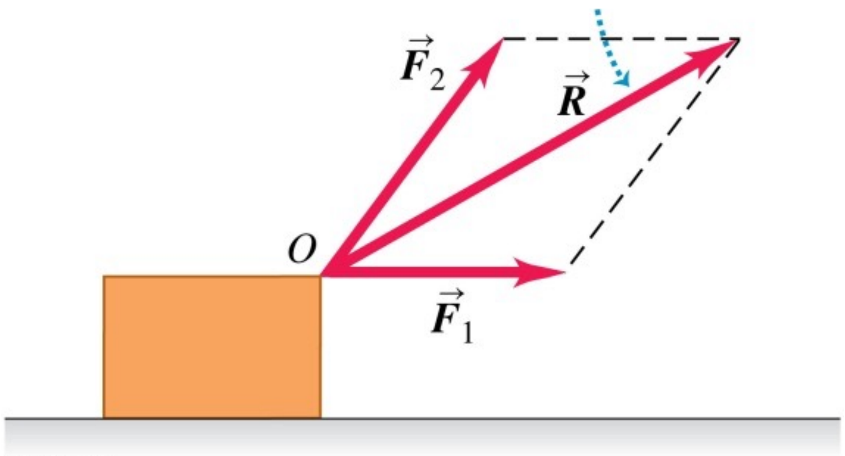
$$\sum \vec{\boldsymbol{F}} = m\vec{\boldsymbol{a}}$$

<u>inertial mass</u>

– how reluctant the body is to change its velocity

Forces are vectors and can be added up (superposition of forces)

$\overrightarrow{R}$ is called the net or resultant force



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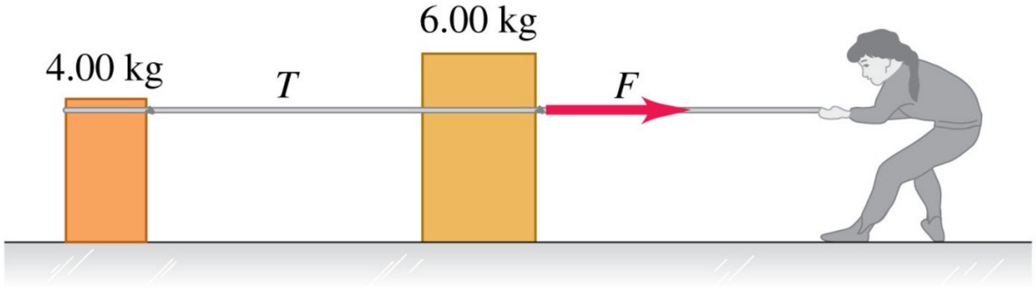
The SI unit of force is newton,
1 N = 1 kg m/s^2

Q4.12

A woman pulls on a 6.00-kg crate, which in turn is connected to a 4.00-kg crate by a light rope. It is given that both crates have non-zero accelerations and the light rope remains taut.



Compared to the 6.00-kg crate, the lighter 4.00-kg crate

A. is subjected to the same net force and has the same acceleration.

B. is subjected to a smaller net force and has the same acceleration.

C. is subjected to the same net force and has a smaller acceleration.

D. is subjected to a smaller net force and has a smaller acceleration.

E. none of the above

A4.12

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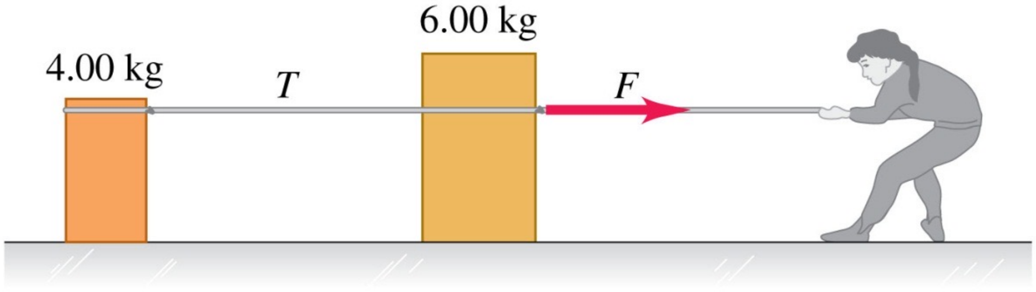

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C. is subjected to the same net force and has a smaller acceleration.

D. is subjected to a smaller net force and has a smaller acceleration.

E. none of the above

Question

- Suppose an astronaut landed on a planet where $g = 19.6$ m/s^2.
- Compared to earth,
  - it would be (easier / harder / just as easy) for her to walk around;
  - it would be (easier / harder / just as easy) for her to catch a ball that is moving horizontally at 12 m/s.

Newton’s third law of motion

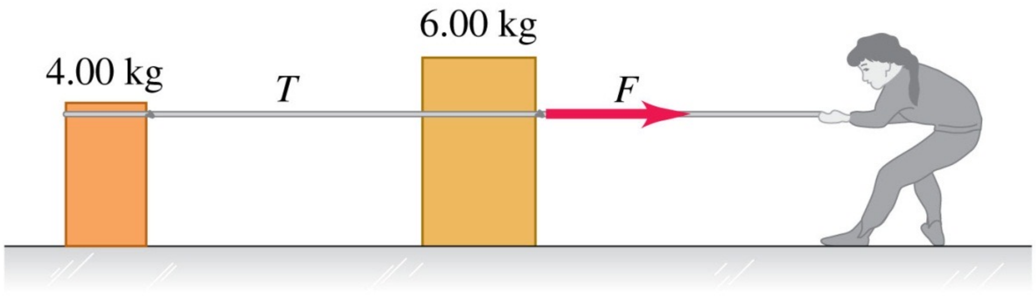
- If body A exerts a force on body B (an “action”), then body B exerts a force on body A (a “reaction”).
- These two forces have the same magnitude but are opposite in direction.
- These two forces act on different bodies.

Question

- Since action and reaction are equal and opposite, should they cancel each other?

Q4.14

A woman pulls on a 6.00-kg crate, which in turn is connected to a 4.00-kg crate by a light rope. It is given that both crates have non-zero accelerations and the light rope remains taut.



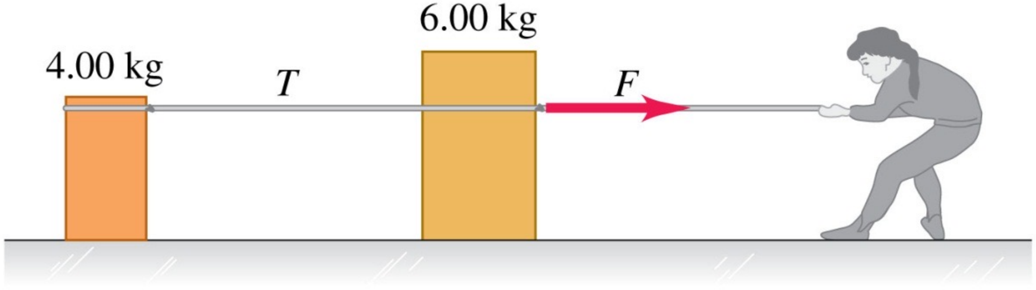
A. the 6.00-kg crate exerts more force on the 4.00-kg crate than the 4.00-kg crate exerts on the 6.00-kg crate.

B. the 6.00-kg crate exerts less force on the 4.00-kg crate than the 4.00-kg crate exerts on the 6.00-kg crate.

C. the 6.00-kg crate exerts as much force on the 4.00-kg crate as the 4.00-kg crate exerts on the 6.00-kg crate.

Q4.14

A woman pulls on a 6.00-kg crate, which in turn is connected to a 4.00-kg crate by a light rope. It is given that both crates have non-zero accelerations and the light rope remains taut.



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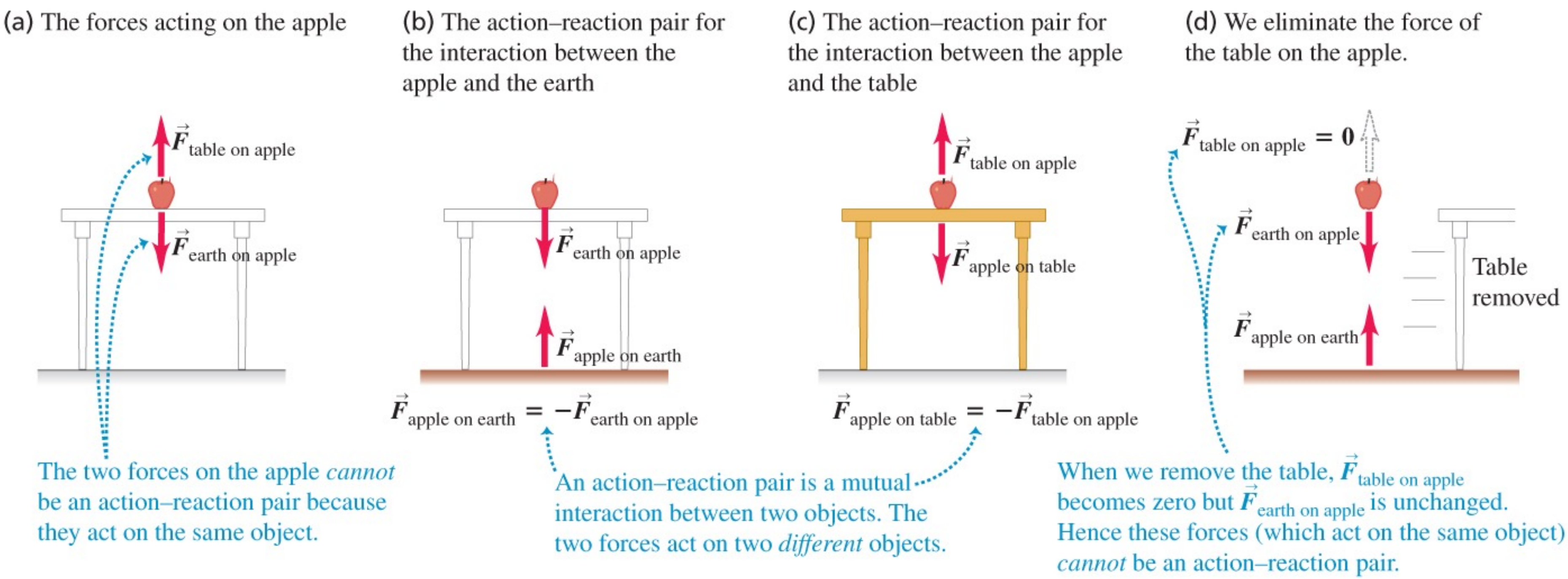
C. the 6.00-kg crate exerts as much force on the 4.00-kg crate as the 4.00-kg crate exerts on the 6.00-kg crate.

Example 4.9
Action and reaction forces acting on an apple sitting on a table



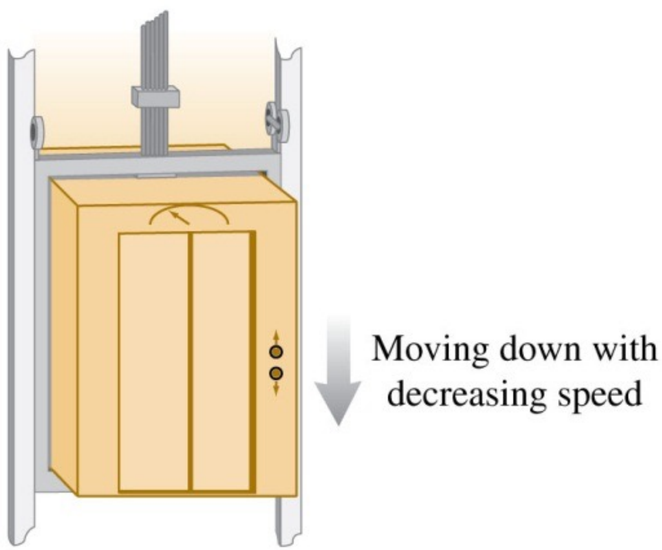
Question

- The buoyance force experienced by a scuba diver is one half of an action-reaction pair.
- What force is the other half of this pair?
  a) the weight of the diver;
  b) the forward thrust force;
  c) the backward drag force;
  d) the downward force that the swimmer exerts on the water.

Example: Tension in an elevator cable

An elevator, mass 800 kg, moving downwards at 10.0 m/s
If it comes to a stop in a distance of 25.0 m

(a) Descending elevator



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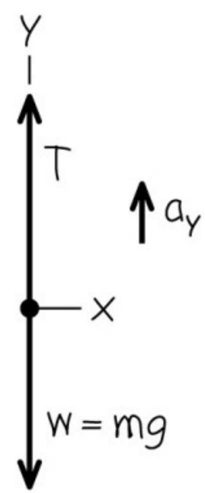
(b) Free-body diagram for elevator



To find deceleration a_y

$$\underset{0\text{ m/s}}{v_y^2} = \underset{-10.0\text{ m/s}}{v_{0y}^2} + 2a_y\underset{-25.0\text{ m}}{(y - y_0)}$$

$$\Longrightarrow a_y = 2.00\ \text{m/s}^2$$

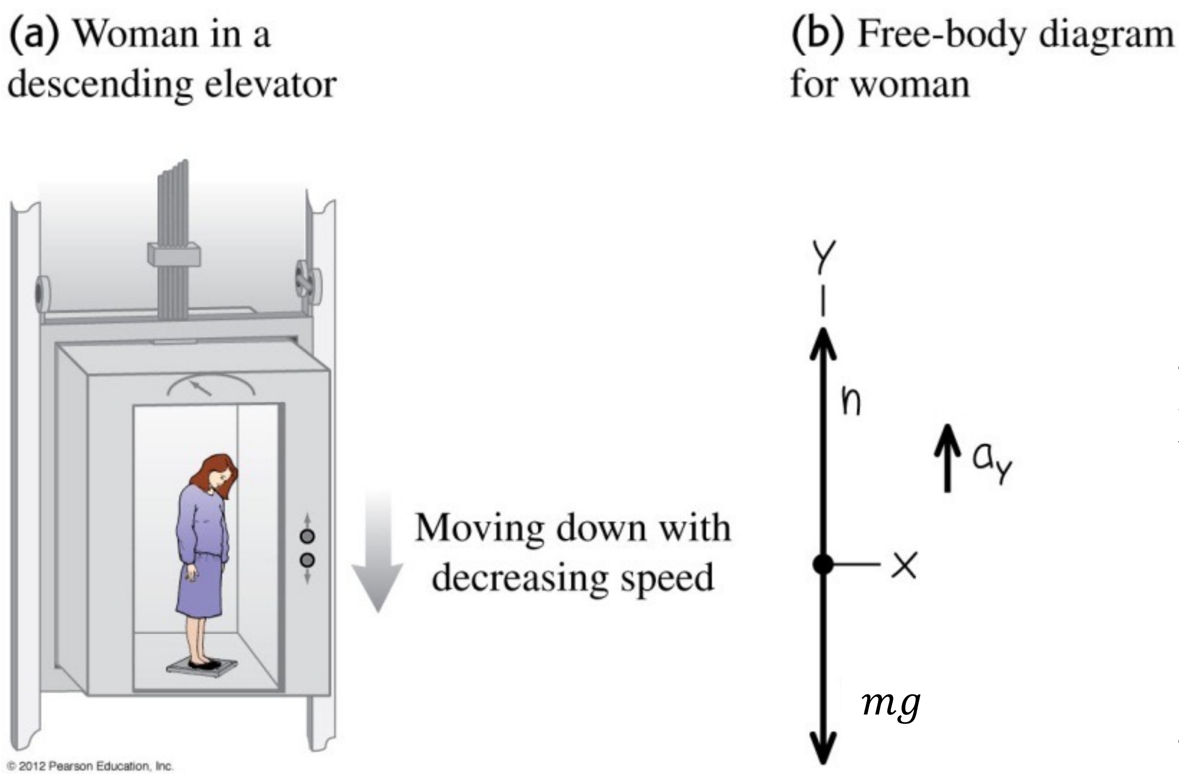
Tension in the cable

$$\sum F_y = T - w = ma_y$$

$$\Rightarrow \quad T = m(g + a_y) = 9440\ \text{N}$$

Apparent weight and weightlessness

A person standing on a scale in an elevator, reading of the scale is n



$\sum F_y = n - mg = ma_y$

$\Rightarrow \quad n = m(g + a_y)$

apparent weight of the person

What if free falling, i.e., $a_y = -g, n = 0$

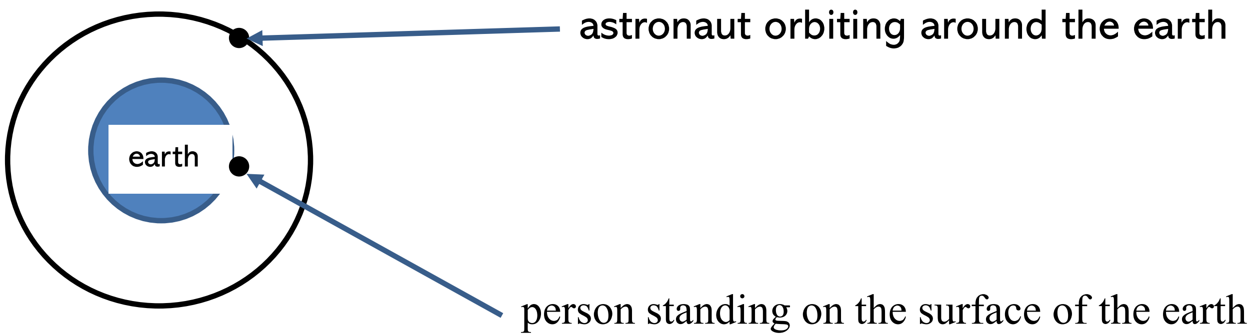
apparent weightlessness

Her feet effectively lose contact with the floor

Question

- One of your very clever classmates says, “If your elevator has a broken cable and is falling freely to the ground, you can save yourself by jumping up at the instant the elevator hits the ground.” Will this work?

Question



Both are under the gravitational attraction of the earth. Why does the person has weight but the astronaut is weightless?