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PHY121 Physics 1

Chapter 5 Force and Motion 1

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Bölüm 5 Kuvvet ve Hareket 1

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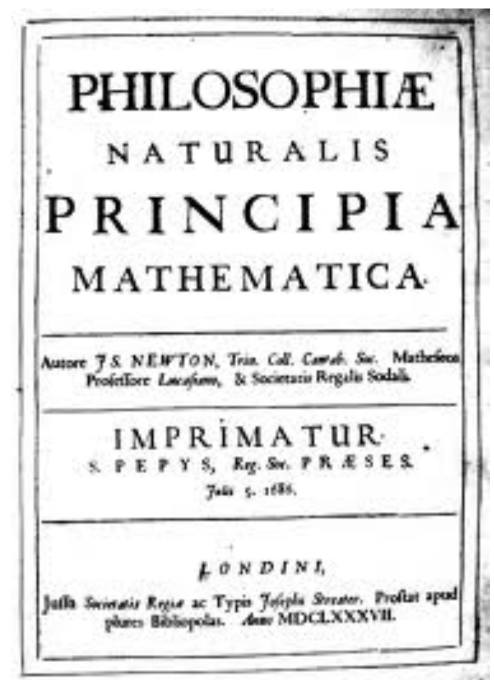


PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore J S. NEWTON, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,
Jussu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.

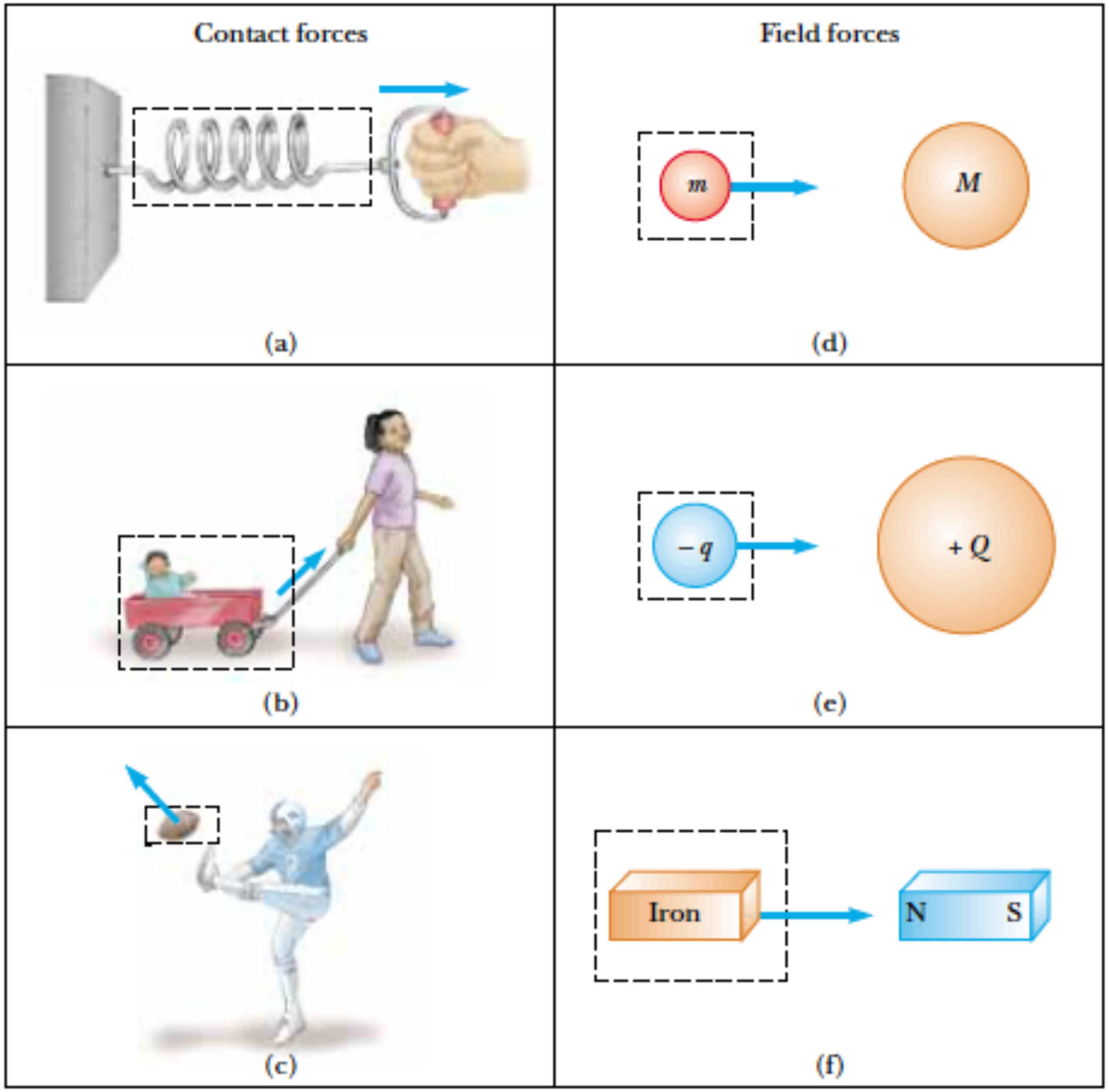
5.1. The Concept of Force

Examples:

- **You exert a force on a ball when you throw or kick it**
- **The force, that keeps objects bound to the Earth and the planets in orbit around the Sun.**
- **The force of a magnet, that attracts a piece of iron.**
- **Frictional force, that stops a sliding book on table**

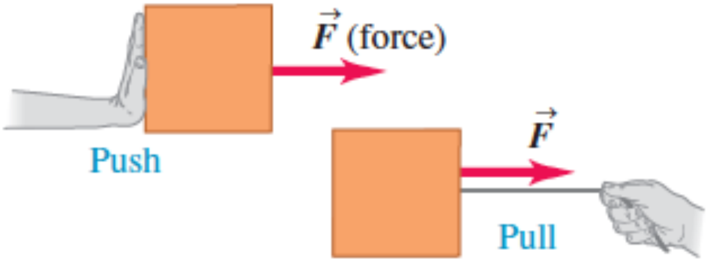
A force is an interaction between two bodies or between a body and its environment

+ 5.1. The Concept of Force



5.1. The Concept of Force

A force is a vector quantity, with magnitude and direction.

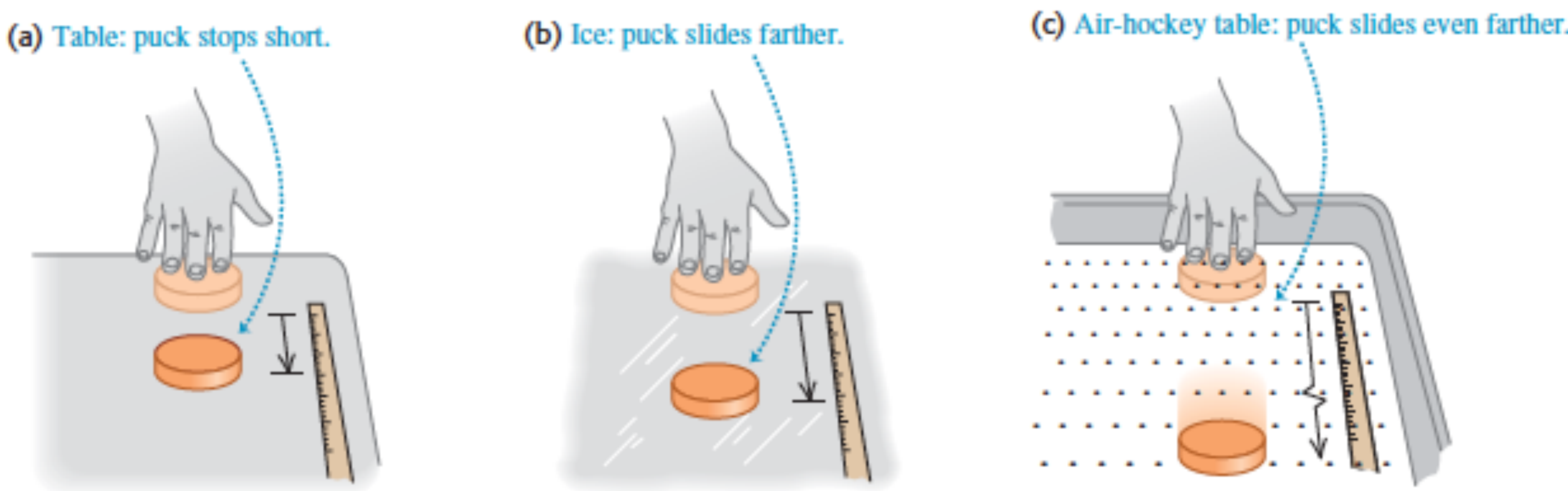


When two or more forces act on a body, we can find their net force, or resultant force, by adding the individual forces vectorially.

There may be multiple forces acting on a body, but if their net force is zero, the body cannot accelerate.

5.2. Newton's 1. Law

How do the forces that act on a body affect its motion? What happens when the net force on a body is zero.



Newton's 1. Law:

If no net force acts on a body, the body's velocity cannot change; that is, the body cannot accelerate.

5.3. Mass

Put a tennis ball and a bowling ball on the floor and give both the same sharp kick. Which one has more acceleration ?

Mass is that property of an object that specifies how much resistance an object exhibits to changes in its velocity.

A force acting on an object of mass m_1 produces an acceleration a1, and the same force acting on an object of mass m_2 produces an acceleration a_2. The ratio of the two masses is defined as the inverse ratio of the magnitudes of the accelerations produced by the force

$$\frac{m_1}{m_2} \equiv \frac{a_2}{a_1}$$

5.4. Newton's 2. Law

How do the forces that act on a body affect its motion?

- **The acceleration of an object is directly proportional to the force acting on it.**

$$F \Rightarrow a$$

$$2F \Rightarrow 2a$$

- **The acceleration of an object also depends on its mass,**

$$m \Rightarrow a$$

$$3m \Rightarrow a/3$$

Newton's 2. Law:

When viewed from an inertial reference frame, the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

$$\vec{a} = \frac{\sum \vec{F}}{m} \Rightarrow \qquad \boxed{\sum \vec{F} = m\vec{a}}$$

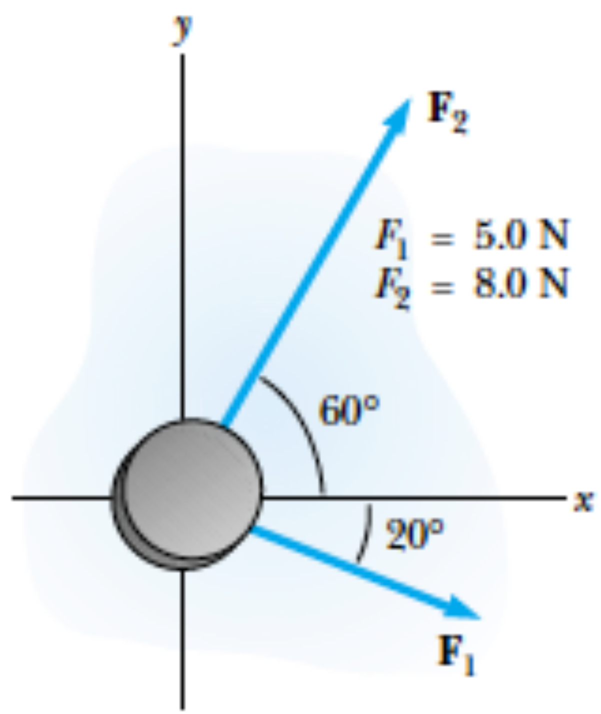
Sı Units: 1 N= 1 kgm/s^2

$$\boxed{F_x = ma_x ; F_y = ma_y ; F_z = ma_z}$$

5.4. Newton's 2. Law

Example:1

A hockey puck having a mass of 0.30 kg slides on the horizontal, frictionless surface of an ice rink. Two hockey sticks strike the puck simultaneously, exerting the forces on the puck shown in Figure. The force F_1 has a magnitude of 5.0 N, and the force F_2 has a magnitude of 8.0 N. Determine both the magnitude and the direction of the puck's acceleration.



5.5. Some Particular Forces

Gravitaional Force

The attractive force exerted by the Earth on an object is called the gravitational force F_g. To find the magnitude of this force, we apply Newton's 2. Law:

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

$$\vec{F}_g = m\vec{g}$$

$$-F_g\hat{j} = mg(-\hat{j})$$

$$-F_g = m(-g)$$

$$F_g = mg$$

+ 5.5. Some Particular Forces

Weight

To keep a ball at rest in your hand while you stand on the ground, you must provide an upward force to balance the gravitational force on the ball from Earth.

$$\vec{F}_{net,y} = m\vec{a}_y$$

$$W - F_g = 0$$

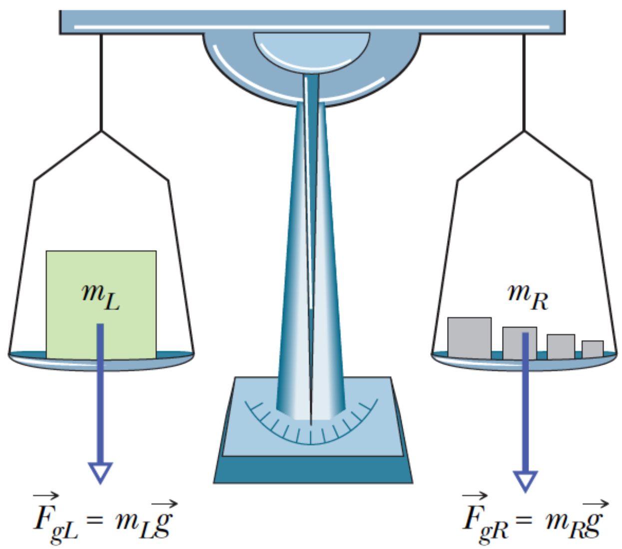
$$W = F_g = mg$$

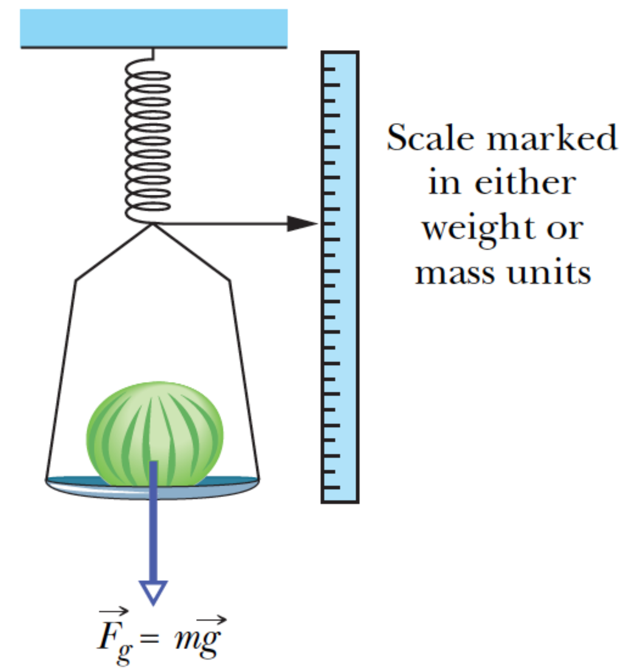
The weight W of a body is equal to the magnitude F_g of the gravitational force on the body.

5.5. Some Particular Forces

Weight

To weigh a body means to measure its weight.





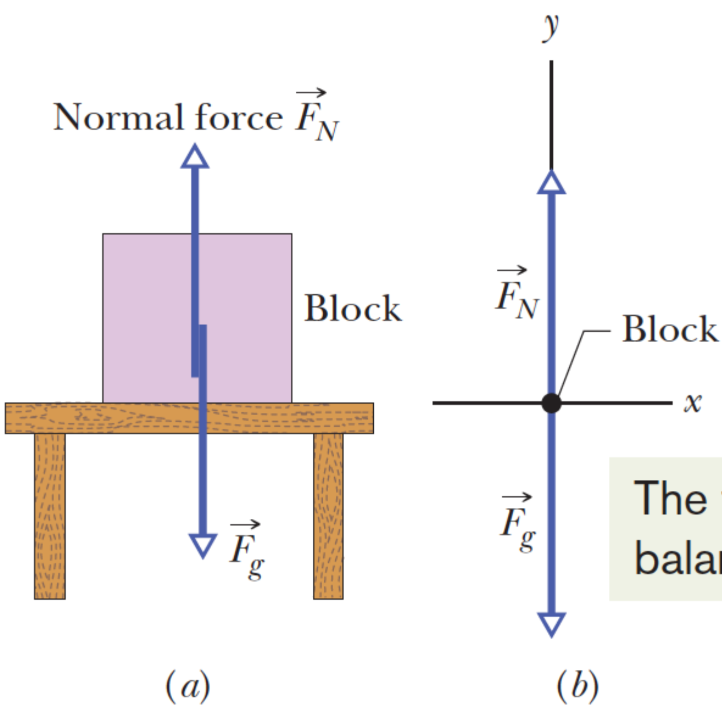
The weight of a body must be measured when the body is not accelerating vertically relative to the ground.

5.5. Some Particular Forces

The Normal Force

The normal force is the force on the block from the supporting table.

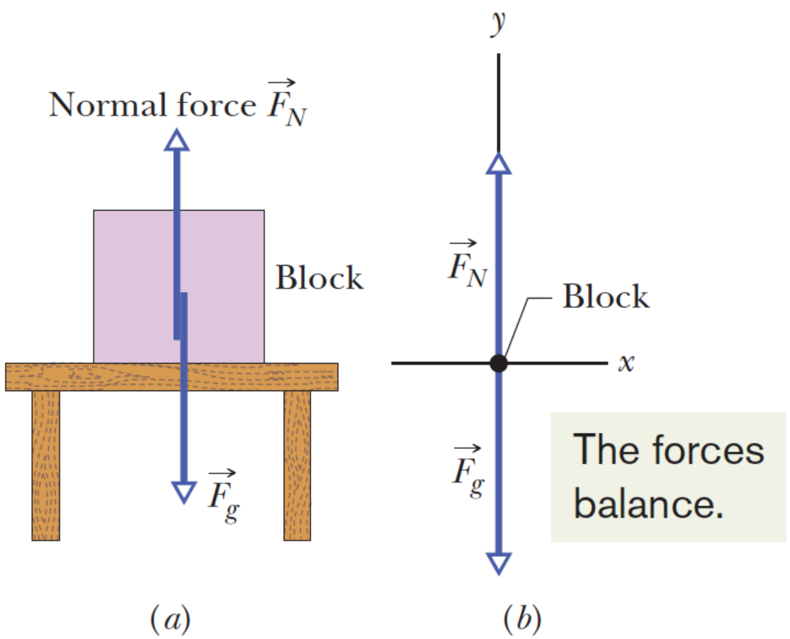
The gravitational force on the block is due to Earth's downward pull.



The forces balance.

5.5. Some Particular Forces

Normal Kuvveti



By applying Newton's 2. Law:

$$\vec{F}_N + \vec{F}_g = m\vec{a}_y$$

$$F_N - mg = ma_y$$

$$\boxed{F_N = m(g + a_y)}$$

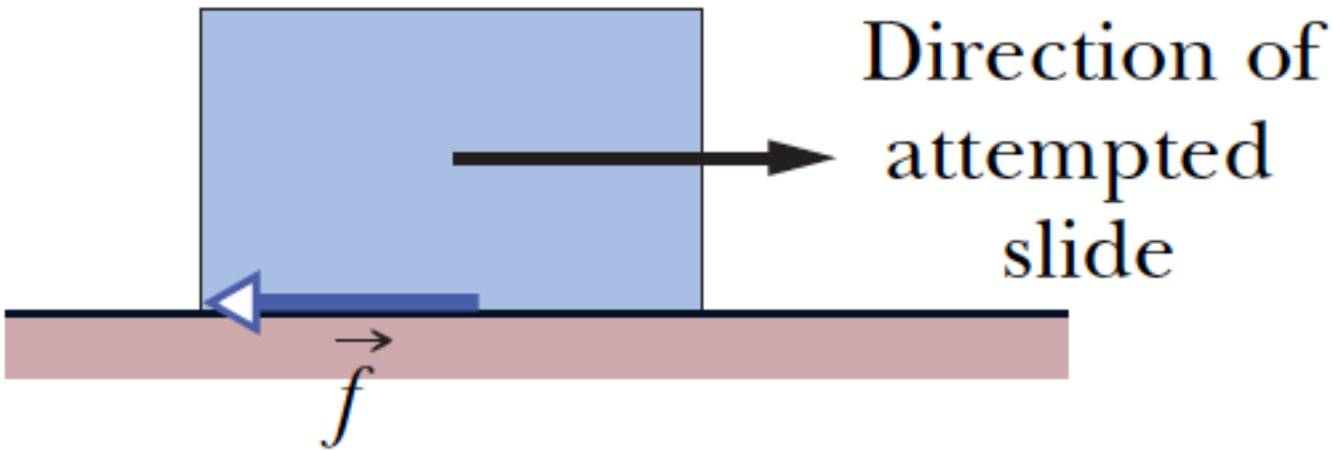
Here ay is th accelaration of box and table (for example they can stand on a elevator). But if the ecceleration is zero, then the magnitude of normal force is given by:

$$\boxed{F_N = mg}$$

5.5. Some Particular Forces

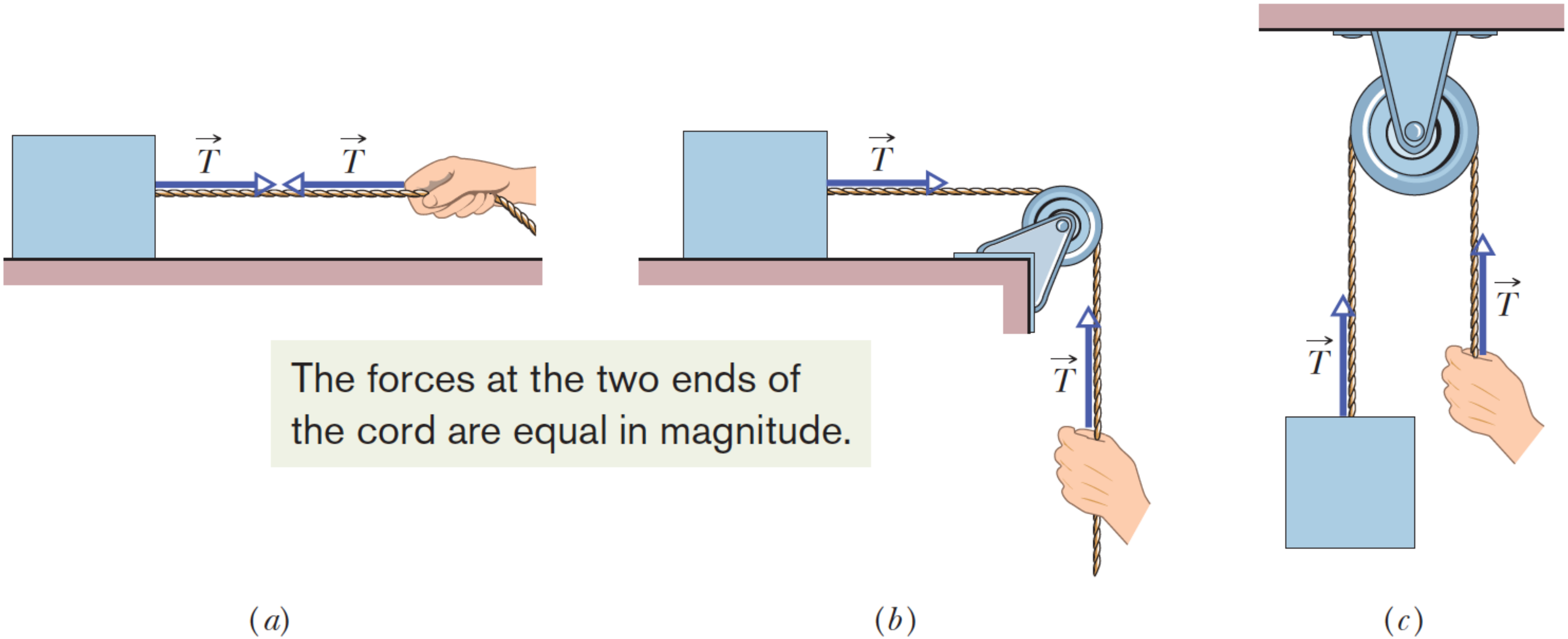
Friction

If we either slide or attempt to slide a body over a surface, the motion is resisted by a bonding between the body and the surface. The resistance is considered to be a single force called either the frictional force or simply friction.



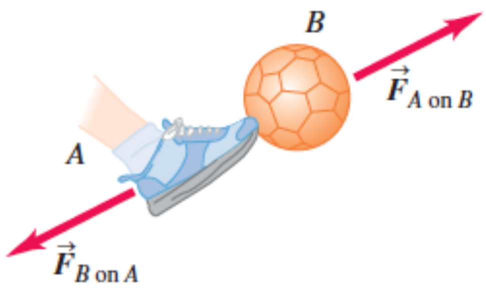
5.5. Some Particular Forces

Tension



5.6.Newton's 3. Law

When you kick a football, the forward force that your foot exerts on the ball launches it into its trajectory, but you also feel the force the ball exerts back on your foot.



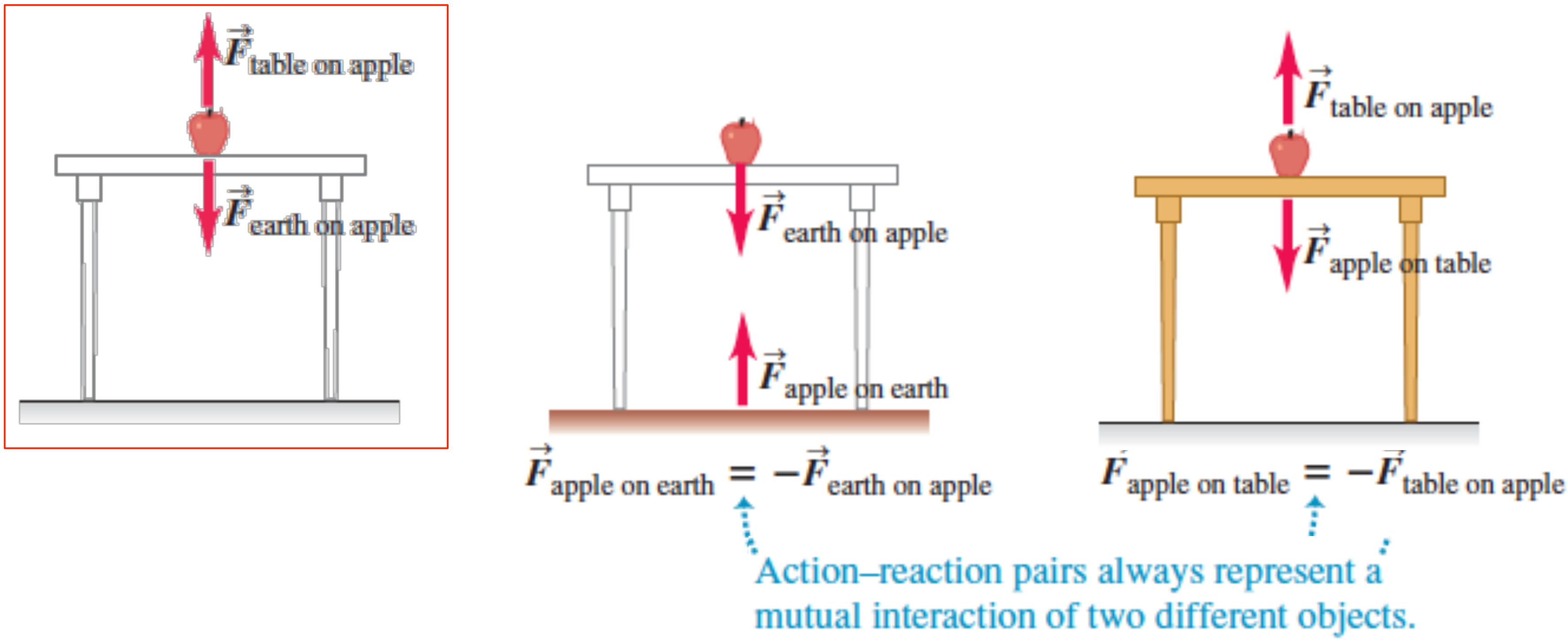
Newton's 3. Law:

If two objects interact, the force F_{12} exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force F_{21} exerted by object 2 on object 1:

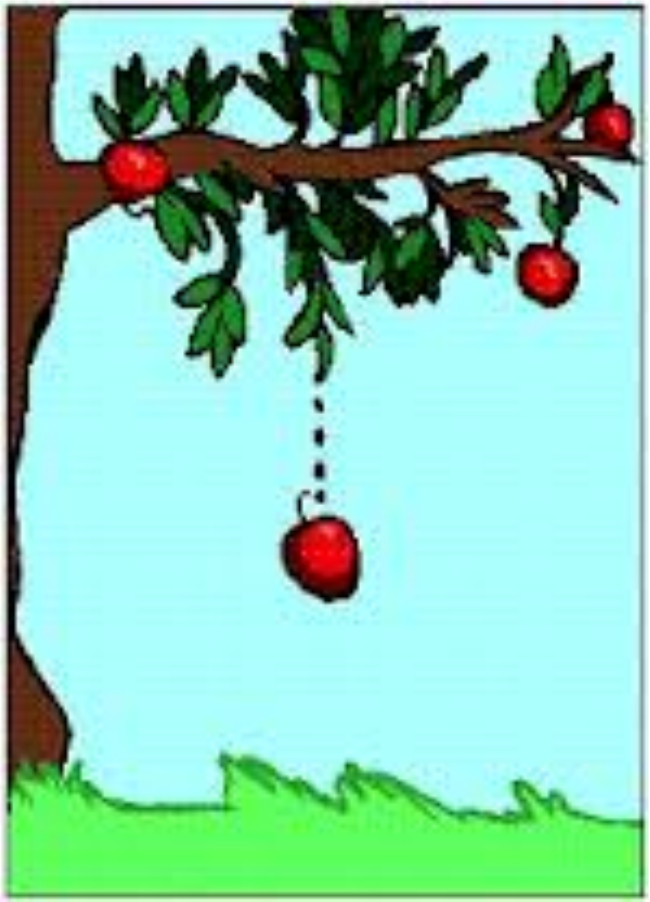
$$\boxed{\vec{F}_{12} = -\vec{F}_{21}}$$

5.6.Newton’s 3. Law

Etki-tepki kuvvetleri aynı cisim üzerine etki etmez !



5.6.Newton’s 3. Law



A free falling apple is under the effect of gravitaional force. Earth exerts a gravitaional force to the apple. Falling apple exerts also a force to the Earth. This force are in same magnitude but in opposite direction.

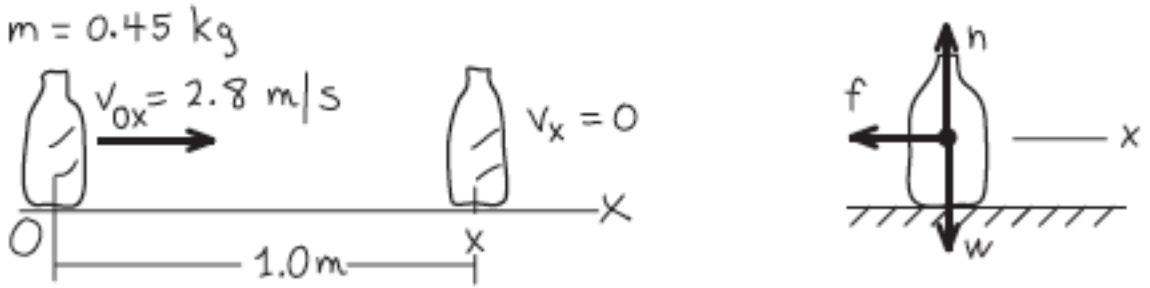
How about the acceleration of apple and Earth ?

Example 2

A bartender shoves a beer bottle with mass 0.45 kg to his right along a smooth, level lunch counter. The bottle leaves his hand moving at 2.8 m/s, then slows down as it slides because of a constant horizontal friction force exerted on it by the countertop. It slides for 1.0 m before coming to rest. What are the magnitude and direction of the friction force acting on the bottle?

5.7. Applying Newton's Laws

Answer:2



$$a_x = \frac{v_x^2 - v_{ox}^2}{2(x - x_o)} = \frac{0-(2.8)^2}{2(1-0)} = -3.9 m/s^2$$

$$\sum F_x = -f = ma_x = (0.45)(-3.9) = -1.8N$$

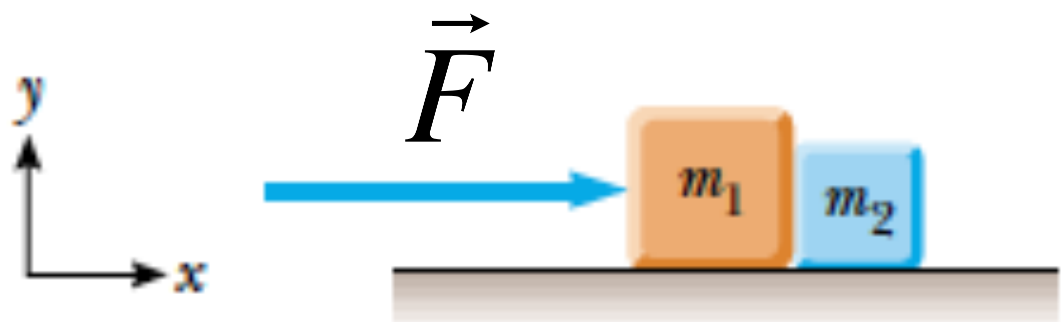
5.7. Applying Newton's Laws

Example:3

A constant horizontal force of magnitude 20 N is applied to block 1 of mass m_1= 15.0 kg, which
pushes against block 2 of mass m_2= 5.0 kg. The blocks slide over a frictionless surface, along an x axis.

(a) What is the acceleration of the blocks?

(b) Determine the magnitude of the contact force between the two blocks.



5.7. Applying Newton's Laws

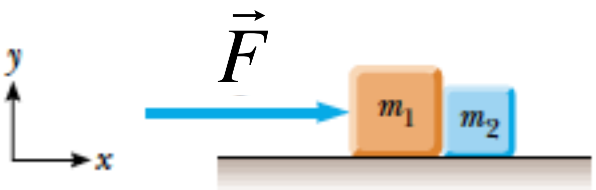
Answer:3

Because the force causes the acceleration of the full two-block system, all systems has to be same acceleration.

$$\vec{F} = (m_1 + m_2)\vec{a}$$

$$F_x = (m_1 + m_2)a_x$$

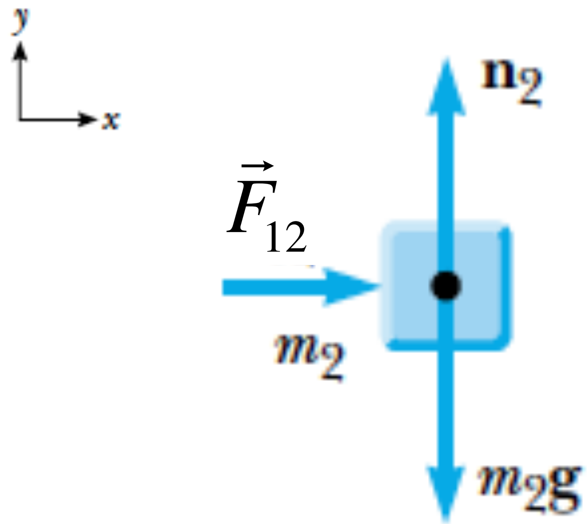
$$a_x = \frac{F_x}{(m_1 + m_2)} = 1m/s^2$$



5.7. Applying Newton's Laws

Answer:3

The force exerted by m_1 on m_2 is F_{12} .



$$\vec{F}_{12} = m_2\vec{a}$$

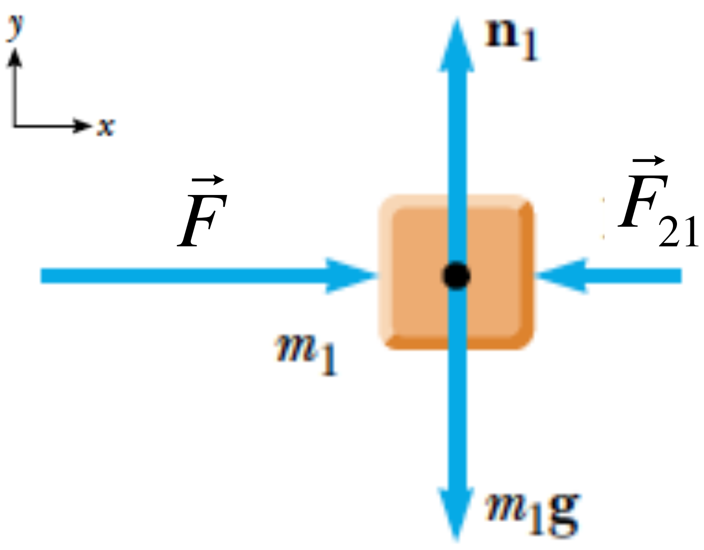
$$F_{12} = m_2 a_x$$

$$F_{12} = 5.1 = 5N$$

5.7. Applying Newton's Laws

Answer:3

The horizontal forces acting on m1 are the applied force F to the right and the contact force F_{21} to the left (the force exerted by m2 on m1).



$$\vec{F} + \vec{F}_{21} = m_1\vec{a}$$

$$F - F_{21} = m_1 a_x$$

$$F_{21} = F - m_1 a_x$$

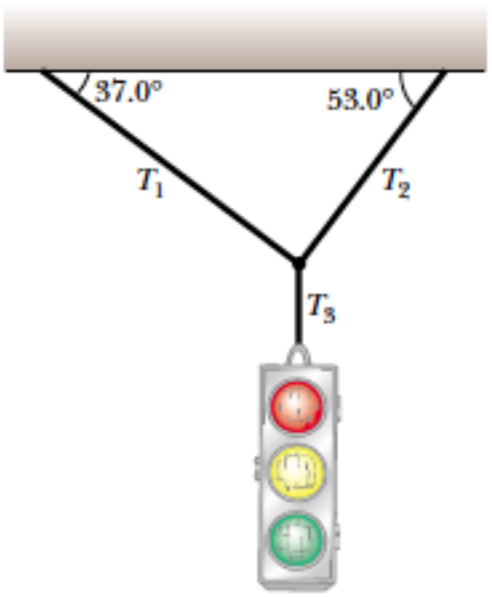
$$F_{21} = 20 - 15.1 = 5N$$

$$\vec{F}_{21} = -\vec{F}_{12}$$

5.7. Applying Newton's Laws

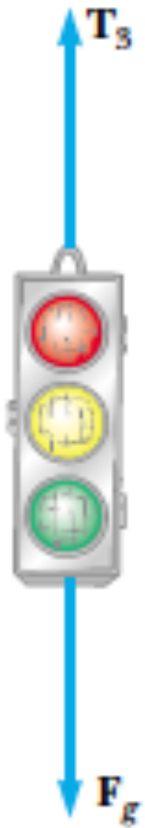
Example:4

A traffic light weighing 122 N hangs from a cable tied to two other cables fastened to a support, as in Figure right side. The upper cables make angles of 37.0° and 53.0° with the horizontal. These upper cables are not as strong as the vertical cable, and will break if the tension in them exceeds 100 N. Will the traffic light remain hanging in this situation, or will one of the cables break?



5.7. Applying Newton's Laws

Answer:4



According to free body diagram for traffic light, a force exerts to it in y-direction. Applying Newton's 2. law:

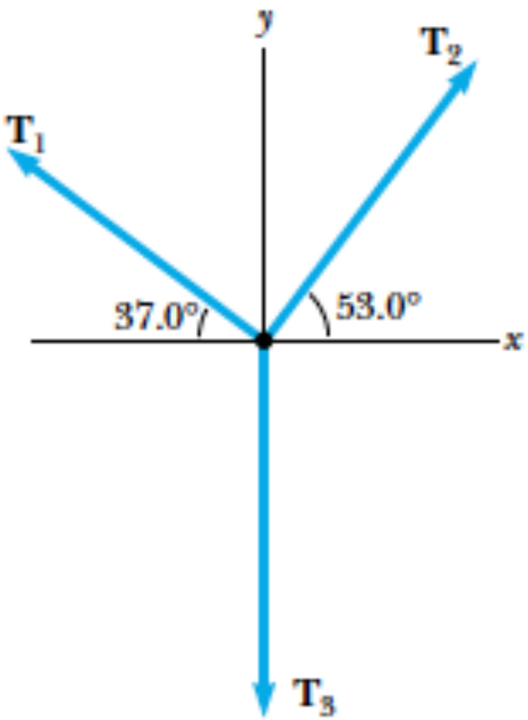
$$\sum F_y = 0$$

$$T_3 - F_g = 0$$

$$T_3 = F_g = 122N$$

5.7. Applying Newton's Laws

Answer:4



we apply the equilibrium condition in the y direction,

$$(1)\ \sum F_x = -T_1 \cos 37 + T_2 \cos 53 = 0$$

$$(2)\ \sum F_y = T_1 \sin 37 + T_2 \sin 53 + (-122N) = 0$$

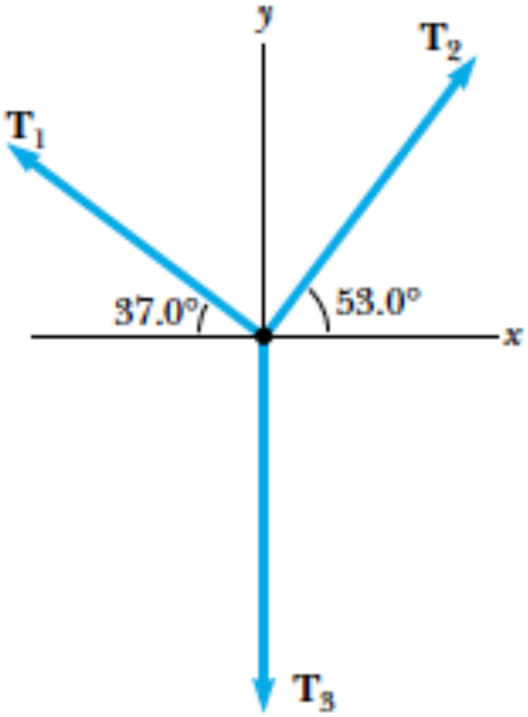
From (1) we can find a value for T_2:

$$T_2 = T_1 \left(\frac{\cos 37}{\cos 53}\right) = 1.33 T_1$$

This value for T_2 is substituted into (2)

5.7. Applying Newton's Laws

Answer:4



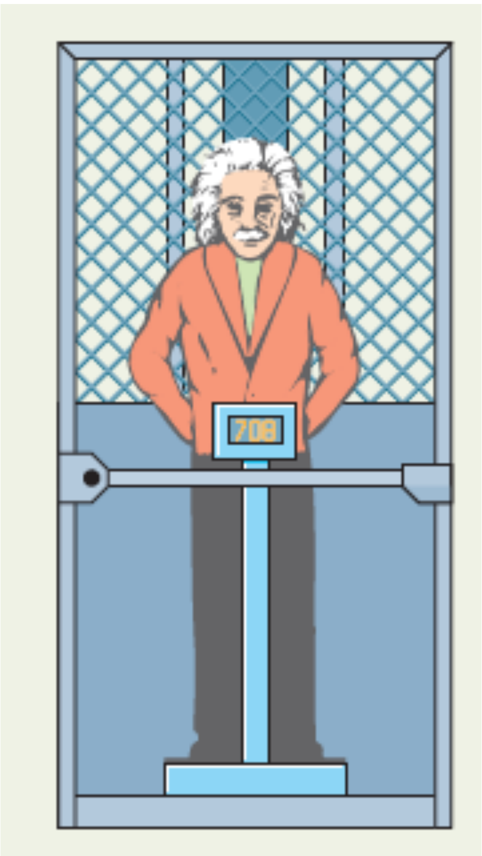
$$T_1 \sin 37 + 1.33 T_1 \sin 53 - 122 = 0$$

$$T_1 = 73.4N$$

$$T_2 = 97.4N$$

5.7. Applying Newton's Laws

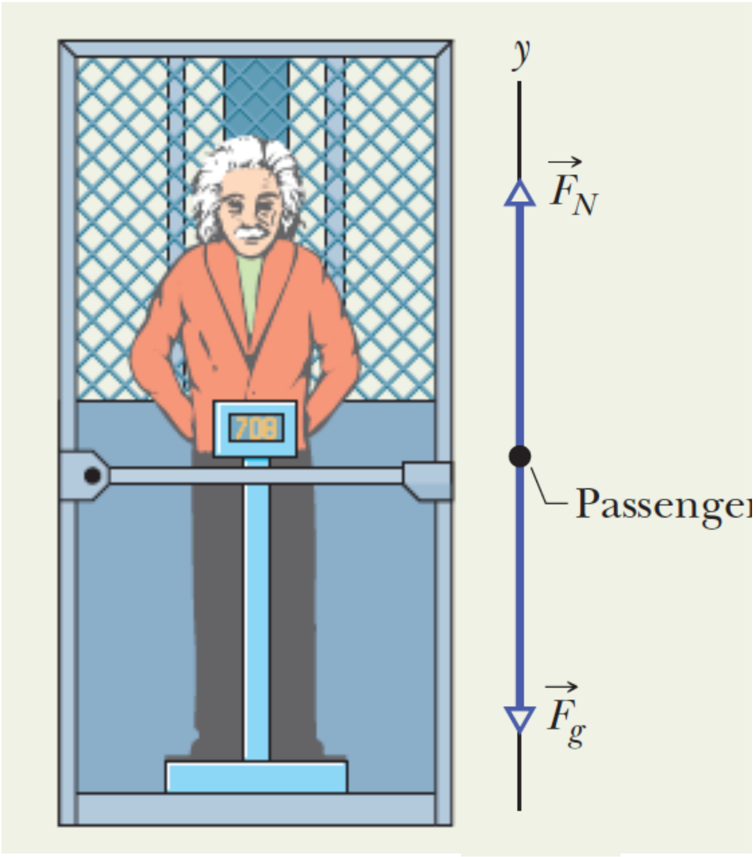
Example:5



A passenger of mass m 72.2 kg stands on a platform scale in an elevator cab. We are concerned with the scale readings when the cab is stationary and when it is moving up or down.

+ 5.7. Applying Newton's Laws

Answer:5



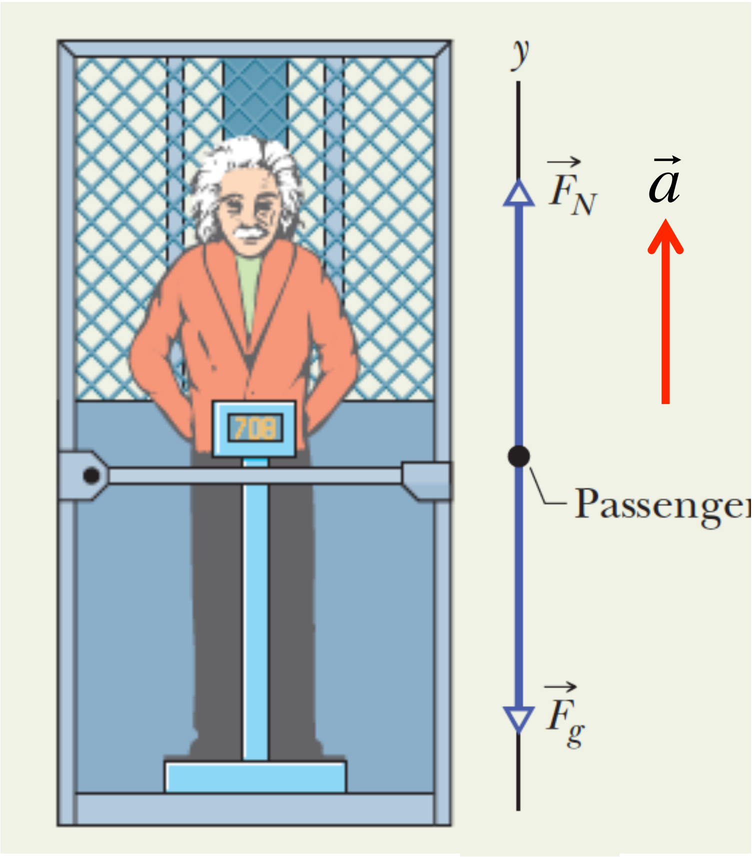
if the cab is stationary,:

$$F_N - F_g = 0$$

$$F_g = F_N = mg$$

5.7. Applying Newton's Laws

Answer:5



When it is moving up

$$F_N - F_g = ma$$

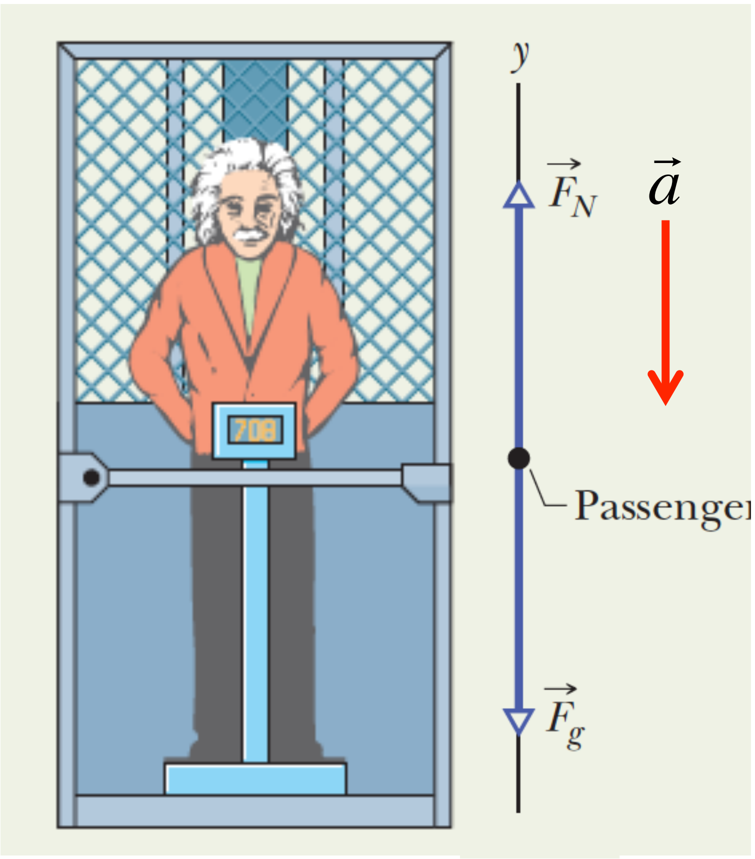
$$F_N - mg = ma$$

$$F_N = m(g + a)$$

The scale reading is greater than the passenger's weight

5.7. Applying Newton's Laws

Answer:s



When it is moving down:

$$F_g - F_N = ma$$

$$mg - F_N = ma$$

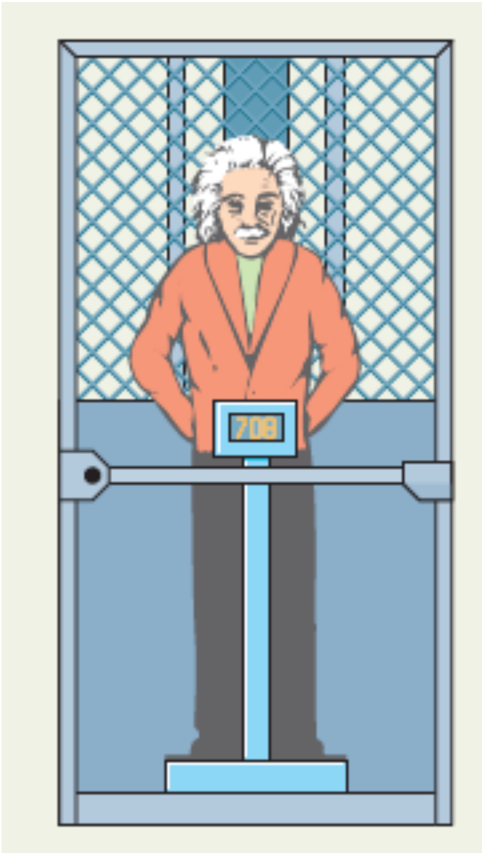
$$F_N = m(g - a)$$

The scale reading is less than the passenger's weight

What if we cut the cable ?

5.7. Applying Newton's Laws

Answer:5



What if we cut the cable ?

$$F_N = m(g-a) = 0$$

He makes a free falling and scale reading exhibits zero !