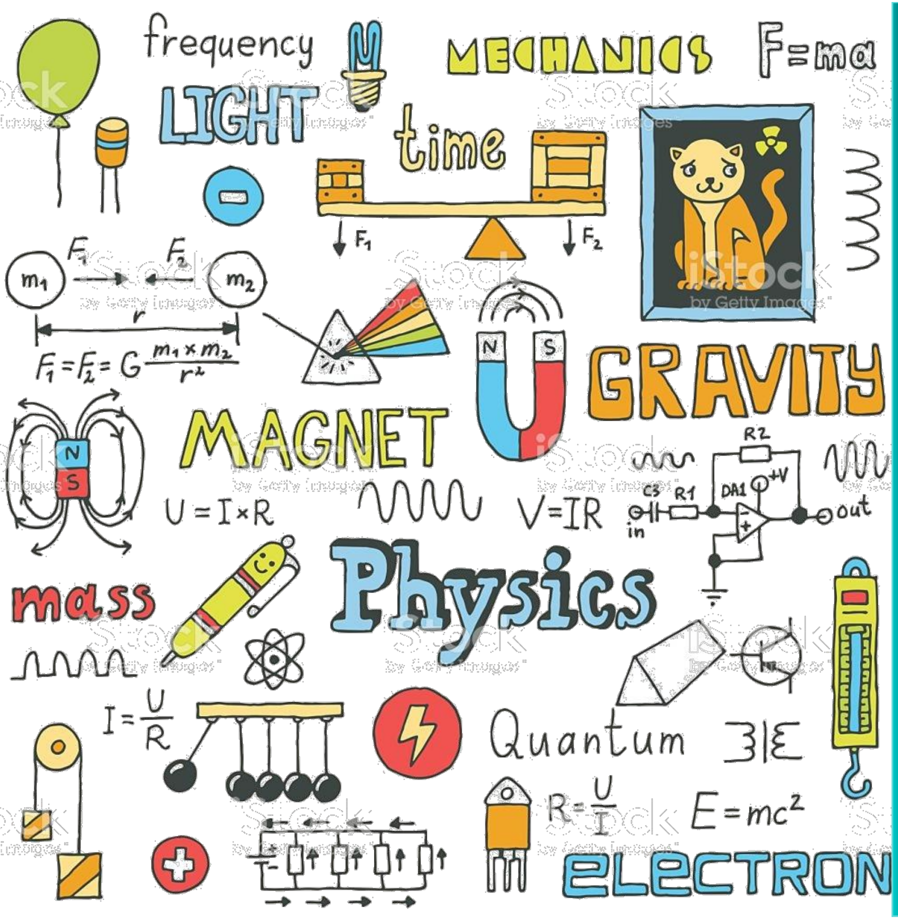


Physics

L4

Wiam Al Drees

Al-imam Muhammad Ibn Saud Islamic University

What are we going to talk about today?

Ch3 : Newton's laws of motion

- 3.1 Force and weight.
- 3.3 Newton’s 1st law.
- 3.5 Newton’s 3rd law.
- 3.6 Newton’s 2nd law.
- 3.8 Some Examples of Newton’s Laws.

Isaac Newton
English physicist and mathematician
(1642–1727)

Mechanic

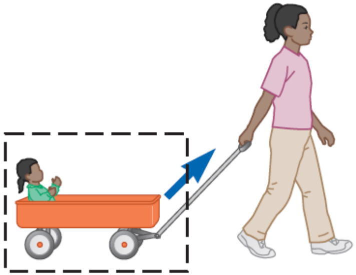
Kinematics describes HOW objects move

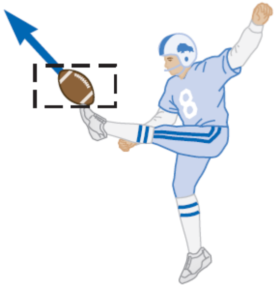
Dynamics shows WHY objects move

What is a force?

An interaction between TWO objects. For example, pushes and pulls are forces:

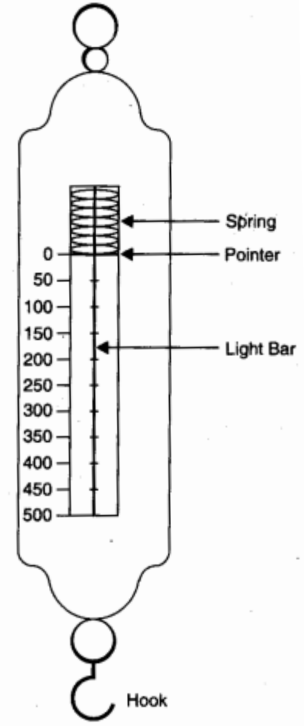
- When a stationary cart is pulled, the cart moves.
- When a football is kicked, it is both deformed and set in motion.



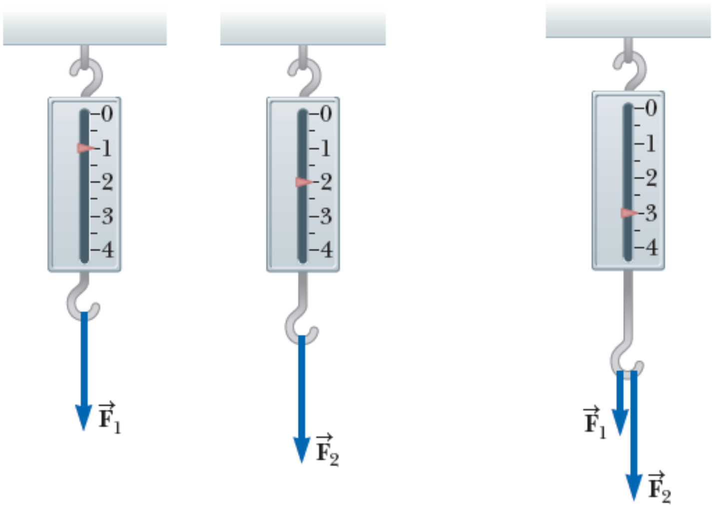


What is a force?

- Forces have both magnitude and direction, so we can add and subtract it as vectors quantities.
- The unit of force is **Newton (N)**, and represented by the symbol $\vec{F}$
- A Force can be measured using a spring balance, the pointer of the spring balance will be at zero (0) when nothing is hung from the hook

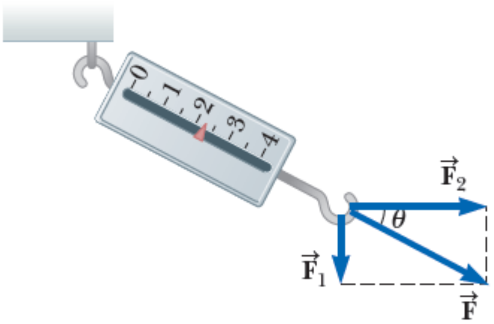


For Example : Addition of Forces



If we have two forces $\vec{F}_1 = -1\text{N}\,\hat{x}$ and $\vec{F}_2 = -2\text{N}\,\hat{x}$, the resultant of these force is: $\vec{F}_{net} = -3\text{ N}\,\hat{x}$ (or $F_{net} = 3\text{ N}$)

If we have two forces $\vec{F}_1 = -1\text{N}\,\hat{y}$ and $\vec{F}_2 = 2\text{N}\,\hat{x}$, the resultant of these force is: $F_{net} = \sqrt{{F_1}^2 + {F_2}^2} = 2.24\text{ N}$

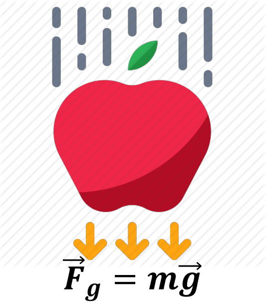


3.1 Force and weight

Gravitational Force

The gravitational force $\vec{F}_g$ is defined as a force that exerted by the earth on an object of mass m.

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



- The gravitational force always acts downward, toward the center of the earth.

Weight

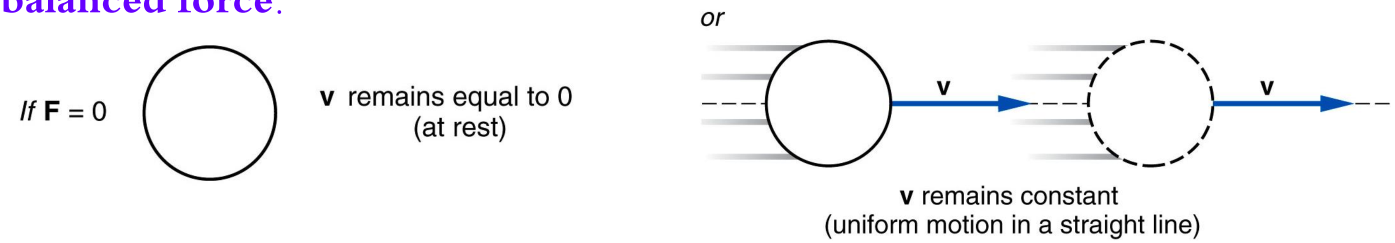
The weight defined as the magnitude of the gravitational force $\vec{F}_g$

$$\text{Weight} = \left|\vec{F}_g\right| = \text{m}\ |\vec{g}|$$
$$\text{W} = \text{m g}$$

- As the mass of a body increases, its' weight increases proportionally.

3.3 Newton's 1st law

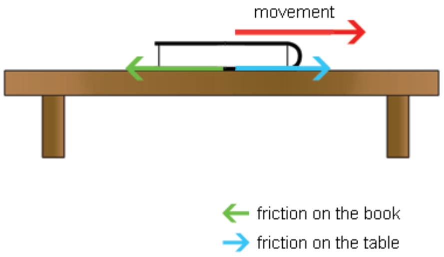
Newton's First Law: An object at rest remains at rest and an object in motion remains in motion at constant speed in a straight line unless acted on by an unbalanced force.



Why don't moving objects keep moving forever?

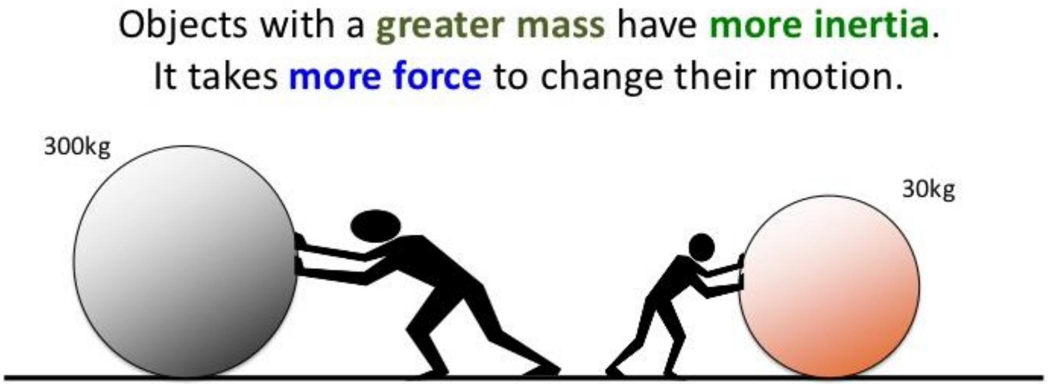
Things don't keep moving forever because there's almost always an unbalanced force acting upon it.

A book sliding across a table slows down and stops because of the force of friction.



3.3 Newton’s 1st law

- Newton's first law is also called the law of inertia.
- Inertia means resistance of object to change in state of motion. It is dependent on object’s mass.



Examples of Inertia

- This law explains why the pencil stay at place when a force accelerates the paper, Because of Inertia, the pencil at rest wants to remains at rest.

- This law explains why you fly forward in a car when someone slams on the brakes. Because of Inertia, your body wants to keep moving at the same speed as the car.

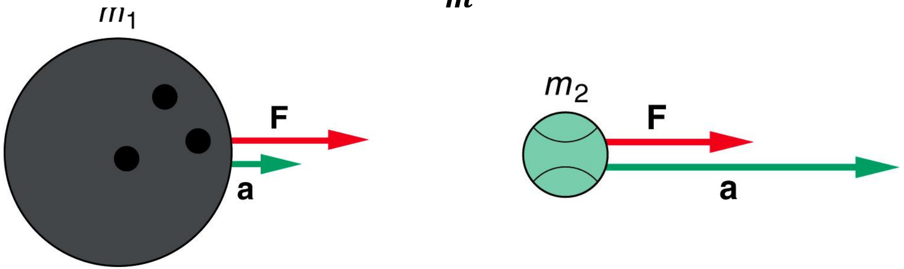
3.3 Newton's 1st law: https://www.youtube.com/watch?v=6gzCeXDhUAA

3.6 Newton's 2nd law

When a NET external force F acts on an object of mass m, the acceleration a that results is:

1– Directly proportional to the net force $a \propto F$

2– Inversely proportional to the mass $a \propto \frac{1}{m}$



It can be expressed the relationship between force, mass, and acceleration as a mathematical equation:

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

Newton's Second Law

3.6 Newton's 2nd law

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

Newton's Second Law

$\sum \vec{F}$: The sum of all the forces acting on an object.

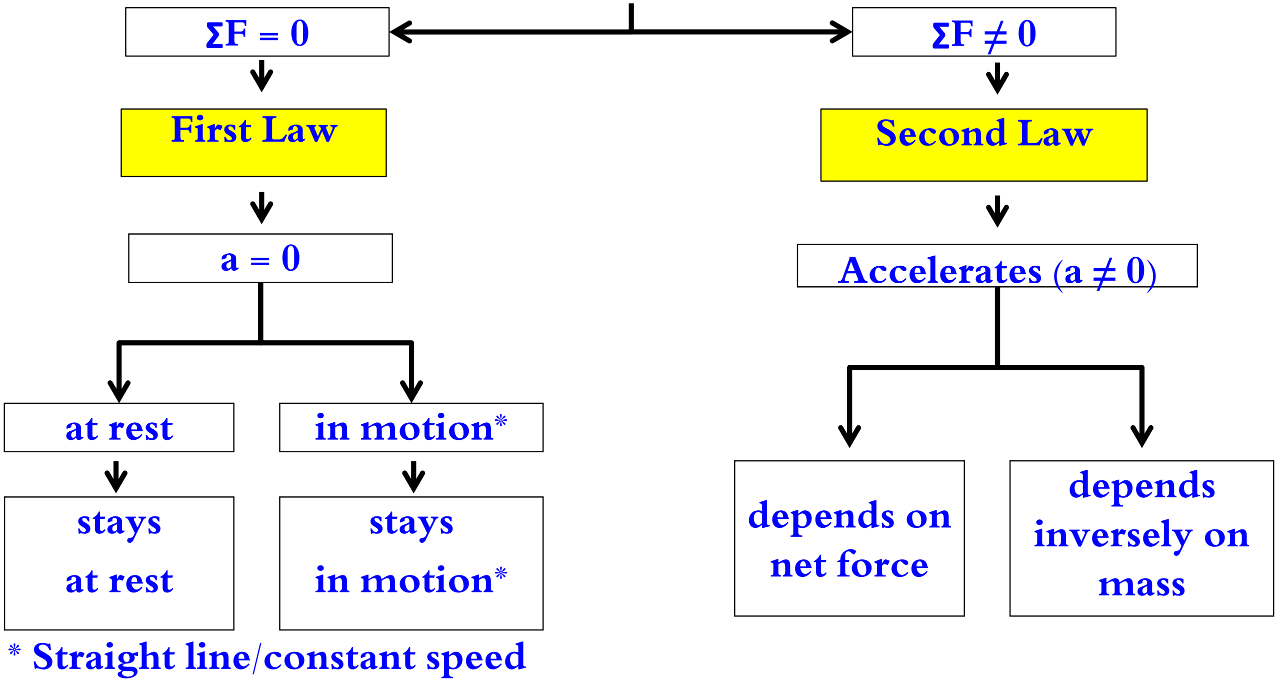
The net force $\sum \vec{F}$ always in the direction of acceleration $\vec{a}$

- Force is a vector quantity.
- Force Can be negative, positive
- Force has a dimensions of $M \times \frac{L}{T^2}$
- Force has SI unit Newton $[N = kg\ m/s^2]$

Equilibrium: If the net force on the object is zero $\sum \vec{F} = 0$ (even though two or more forces act upon it). In this case the object is said to be in equilibrium.

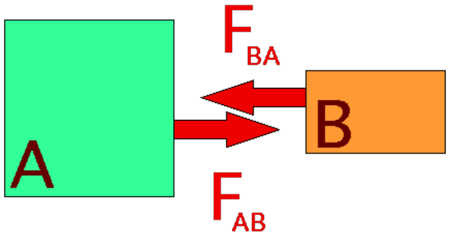
3.6 Newton’s 2nd law

Review of Newton’s Laws of Motion



3.5 Newton's 3rd law

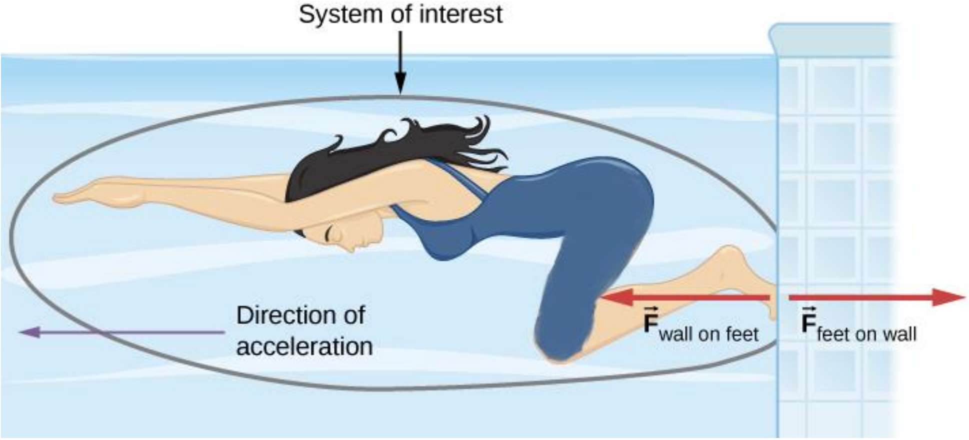
Newton's Third Law : Whenever one object (Object A) exerts a force on another object (Object B), the second object B exerts a force back on the first object A.



- These forces are ALWAYS equal in magnitude $|\vec{F}|_{AB} = |\vec{F}|_{BA}$ (but they point in opposite directions $\vec{F}_{AB} = -\vec{F}_{BA}$).
- Such forces are called "Newton's third law force pairs".
- The forces are on different bodies, so do not add to zero.

What does this mean?

For example: suppose you are at rest in a swimming pool. If you push a wall with your legs, the wall exert a force that propels you further into the pool. The reaction force the wall exerts on you is opposite in direction to the action force you exert on the pool.

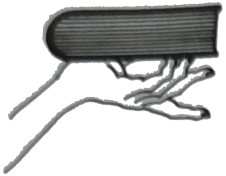


Example 3.5 P54:

A student holds a book so that it does not move, The book weighs 20 N. Find:

(a) The forces acting in the book ? Ans: $\overrightarrow{F_g} = -20\,\hat{y}\,N$ & $\vec{n} = 20\,\hat{y}\,N$

(b) The reaction to those forces ? Ans: $\overrightarrow{F_g} = 20\,\hat{y}\,N$ & $\vec{n} = -20\,\hat{y}\,N$



Using Newton's Laws to Solve Problems

1. **Identify all forces acting on the object:**

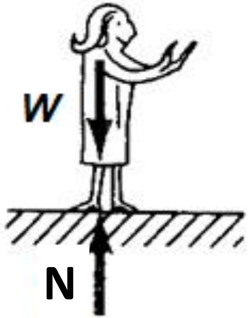
- **Pushes or Pulls**
- **Gravitational Force (W = mg)**
- **Normal forces (action and reaction forces).**

2. **Draw a "Freebody Diagram": draw the object, show all forces acting on that object as vectors pointing in the correct direction.**
3. **Show the direction of the acceleration.**
4. **Chose a coordinate system.**
5. **Translate the freebody diagram into an algebraic expression based on Newton's second law.**
6. **Apply Newton's second law in component form one in x axis $\sum F_x = ma_x$ and anther for y axis axis $\sum F_y = ma_y$**

3.8 Some Examples of Newton’s Laws

Example 3. 2 P 52:

A woman has a mass of 60 kg . She is standing on a floor and remains at rest. Find the normal force exerted on her by the floor. Ans: 588 N



Example 3.6 P55:

A child pushes a sled across a frozen pond with a horizontal force of $20N$. Assume friction is negligible.

a) If the sled accelerates at $0.5\ m/s^2$ what is its mass? Ans: 40 kg

3.8 Some Examples of Newton's Laws

Example 3.6 P55:

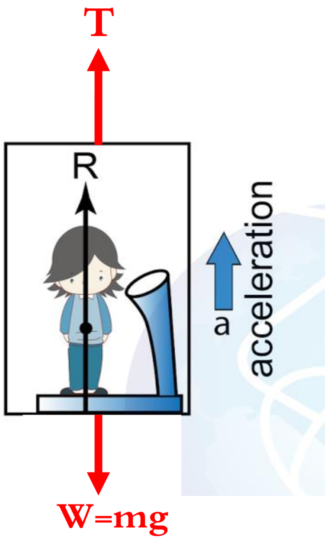
A child pushes a sled across a frozen pond with a horizontal force of $20N$. Assume friction is negligible.

b) Another child with a mass of 60 sits on the sled. What acceleration, the same force produces now? Ans: 0.2 m/s^2

Example 3.7 P57:

An elevator has a mass of 1000 Kg. It accelerates upward at $3m/s^s$.

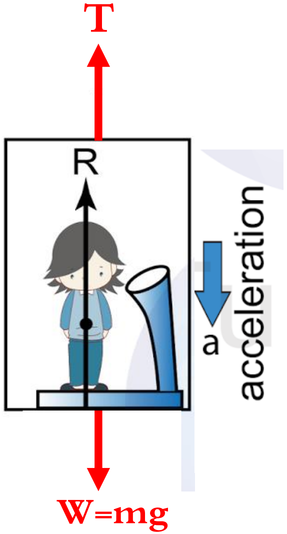
(a) What is the force T exerted by the cable on the elevator? Ans: 12800 N



Example 3.7 P57:

An elevator has a mass of 1000 Kg. It accelerates upward at $3m/s^s$.

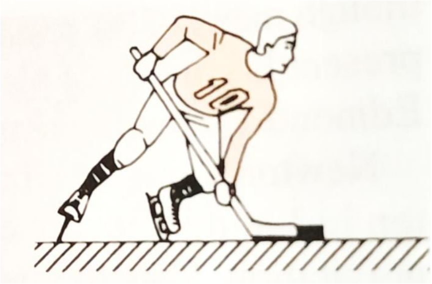
(b) What is the force T if the acceleration is $3m/s^s$ downward ? Ans: 6800 N



Example 3.8 P58:

An ice hockey player strikes a puck of mass 0.17 kg with his stick, accelerating it along the ice from rest to a speed of 20 m/s over a distance of 0.5m. What force must he exert if the frictional force between the puck and the ice is negligible?

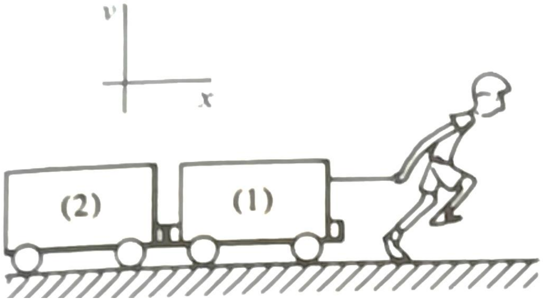
Ans: 68 N



Example 3.9 P58:

A child pulls a train of two cars with a horizontal force F of 10N. Car 1 has a mass m_1=3kg and car 2 has a mass m_2 =1kg. The mass of the string connection the cars is small enough so it can be set equal to zero, and friction can neglected. Find:

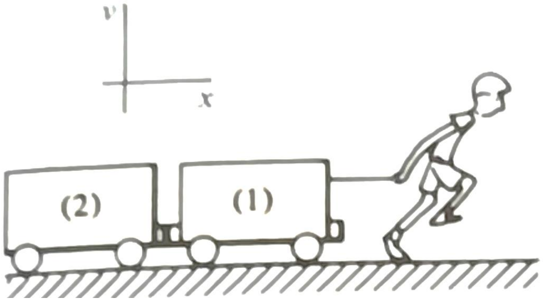
(a) The normal forces exerted on each car by the floor? Ans: $n_1 = 9.80$ N & $n_2 = 29.4$ N



Example 3.9 P58:

A child pulls a train of two cars with a horizontal force F of 10N. Car 1 has a mass m_1=3kg and car 2 has a mass m_2 =1kg. The mass of the string connection the cars is small enough so it can be set equal to zero, and friction can neglected. Find:

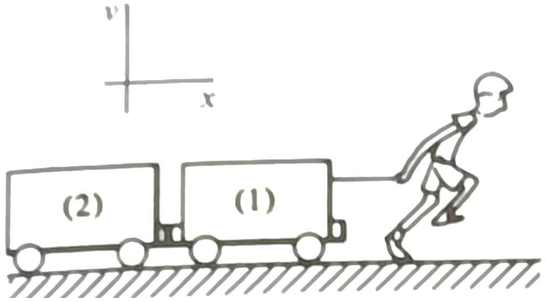
(b) What is the tension in string? Ans: T=2.5 N



Example 3.9 P58:

A child pulls a train of two cars with a horizontal force F of 10N. Car 1 has a mass m_1=3kg and car 2 has a mass m_2 =1kg. The mass of the string connection the cars is small enough so it can be set equal to zero, and friction can neglected. Find:

(c) What is the acceleration of the train? Ans: $2.5\ m/s^2$

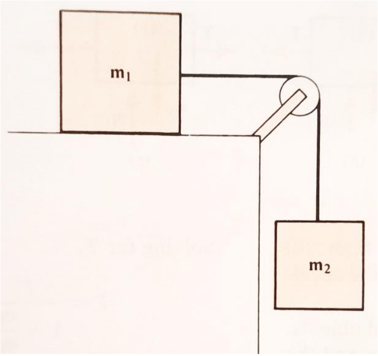


3.8 Some Examples of Newton's Laws

Example 3.10 P59:

A block of mass m_1= 20 kg is free to move on a horizontal surface. A rope, which passes over a pulley, attaches it to a hanging block of a mass m_1=10 kg. Assuming for simplicity that the pulley and rope masses are negligible and that there is no friction. Find:

(a) The forces on the blocks Ans: $T = 65.3\ N$



Example 3.10 P59:

A block of mass m_1= 20 kg is free to move on a horizontal surface. A rope, which passes over a pulley, attaches it to a hanging block of a mass m_1=10 kg. Assuming for simplicity that the pulley and rope masses are negligible and that there is no friction. Find:

(b) Their acceleration. Ans: $3.27 m/s^2$

Example 3.10 P59:

A block of mass m_1= 20 kg is free to move on a horizontal surface. A rope, which passes over a pulley, attaches it to a hanging block of a mass m_1=10 kg. Assuming for simplicity that the pulley and rope masses are negligible and that there is no friction. Find:

(c) If the system is initially at rest, haw far has it moved after 2 s? Ans: $6.54m$

Example 3.10 P60:

A parachutist of weight W strikes the ground with her legs fixed and comes to rest with an upward acceleration of magnitude 3g. Find the force exerted on her by the ground during landing Ans: $F = 4W$