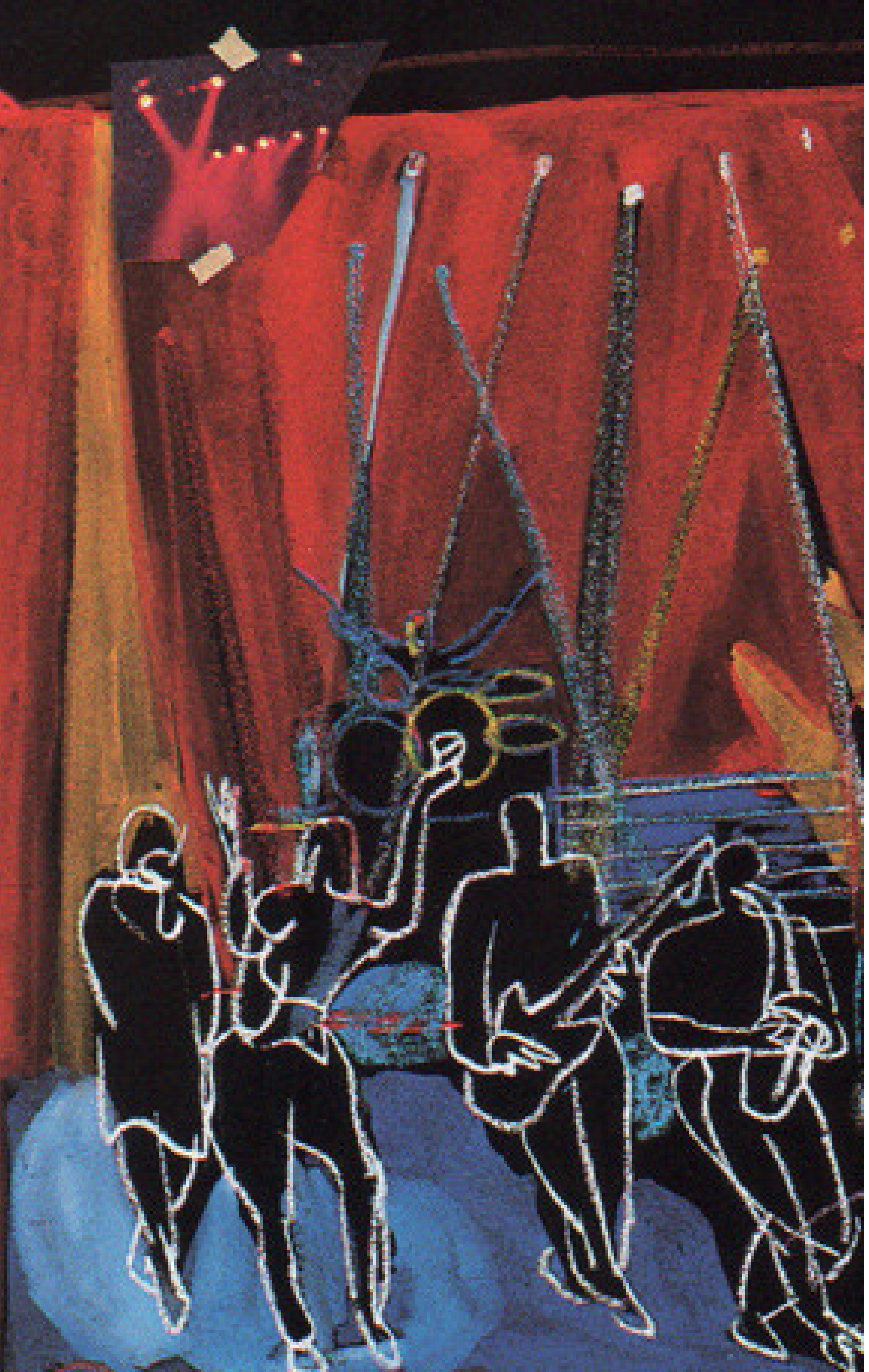


PHY-141

Newtonian Mechanics

Luis Anchordoqui

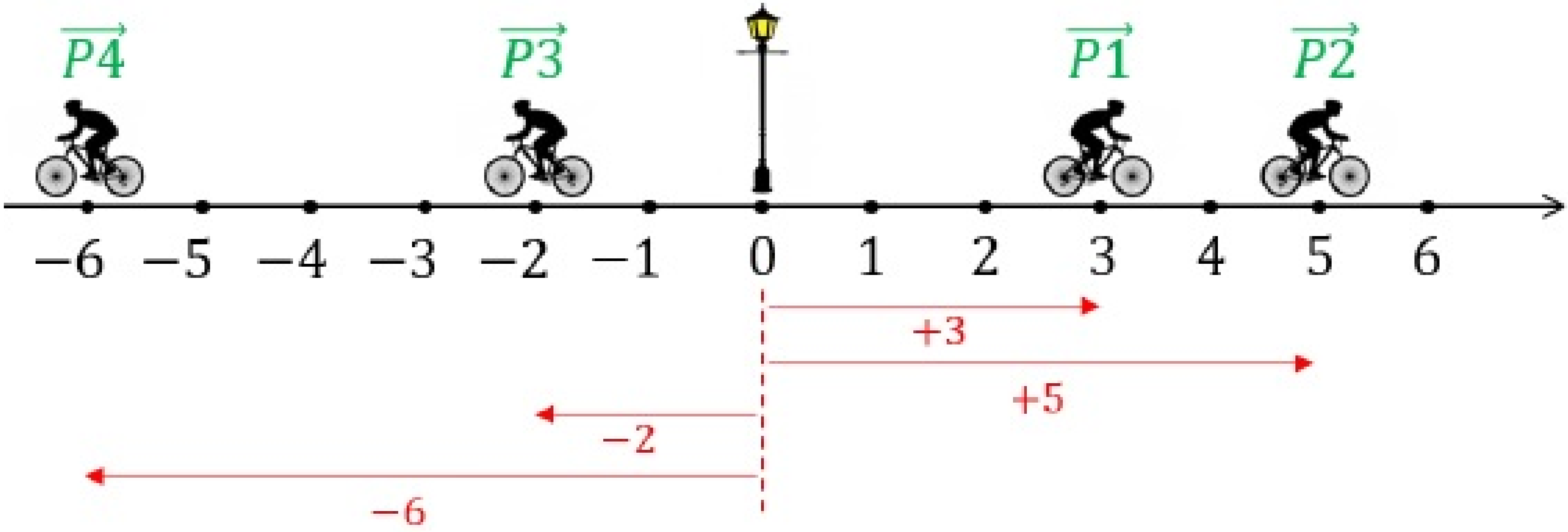
Outline

- Newtonian mechanics is a branch of classical physics that describes the motion of macroscopic objects using concepts of force, mass, and acceleration, based on principles formulated by Isaac Newton in 1687

- It acts as a foundational, predictive model for everyday objects moving at speeds much slower than the speed of light

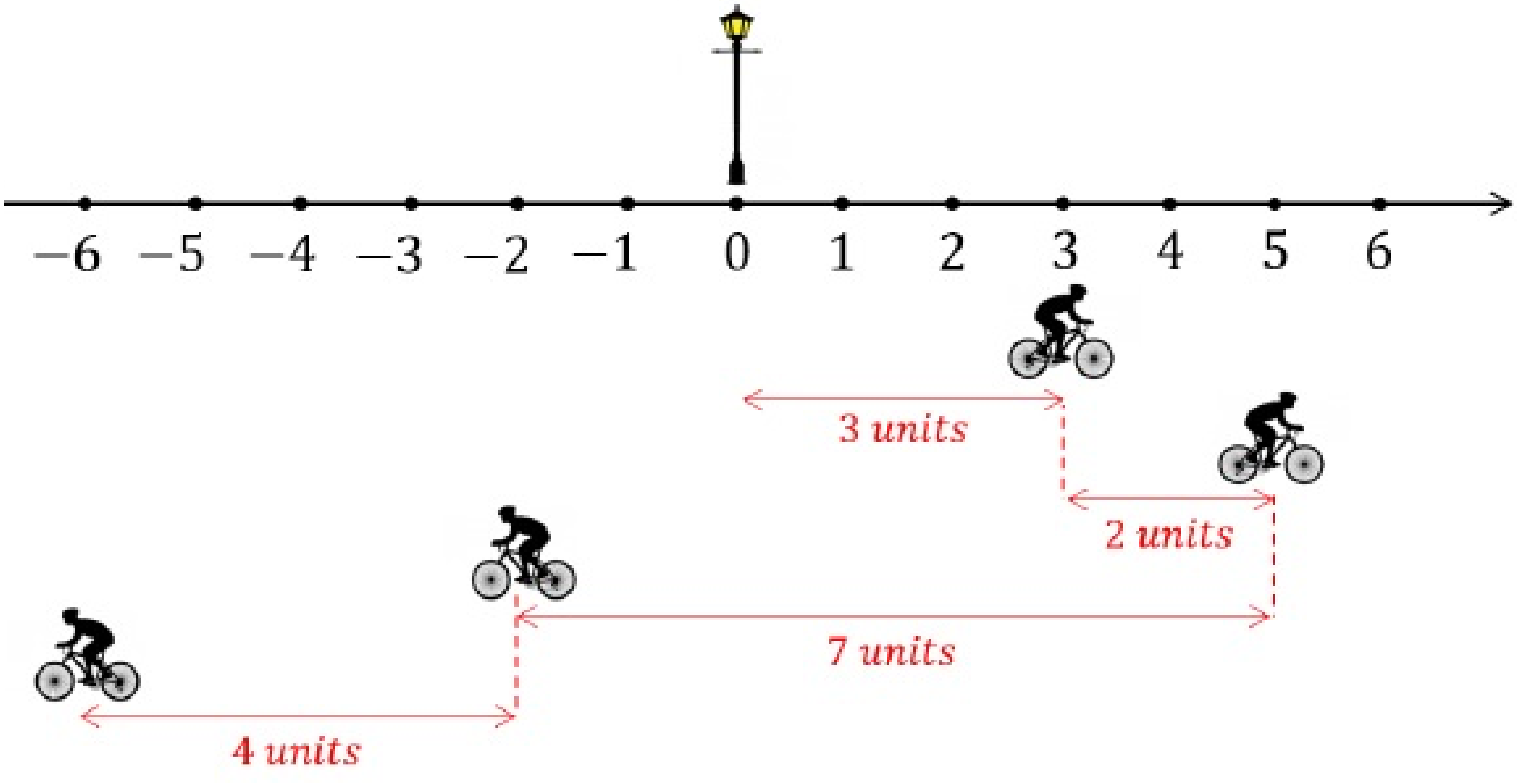
- In today's class we will summary its basic concepts

- Position can be understood as the location of an object with respect to a reference point
- It is expressed as a position vector



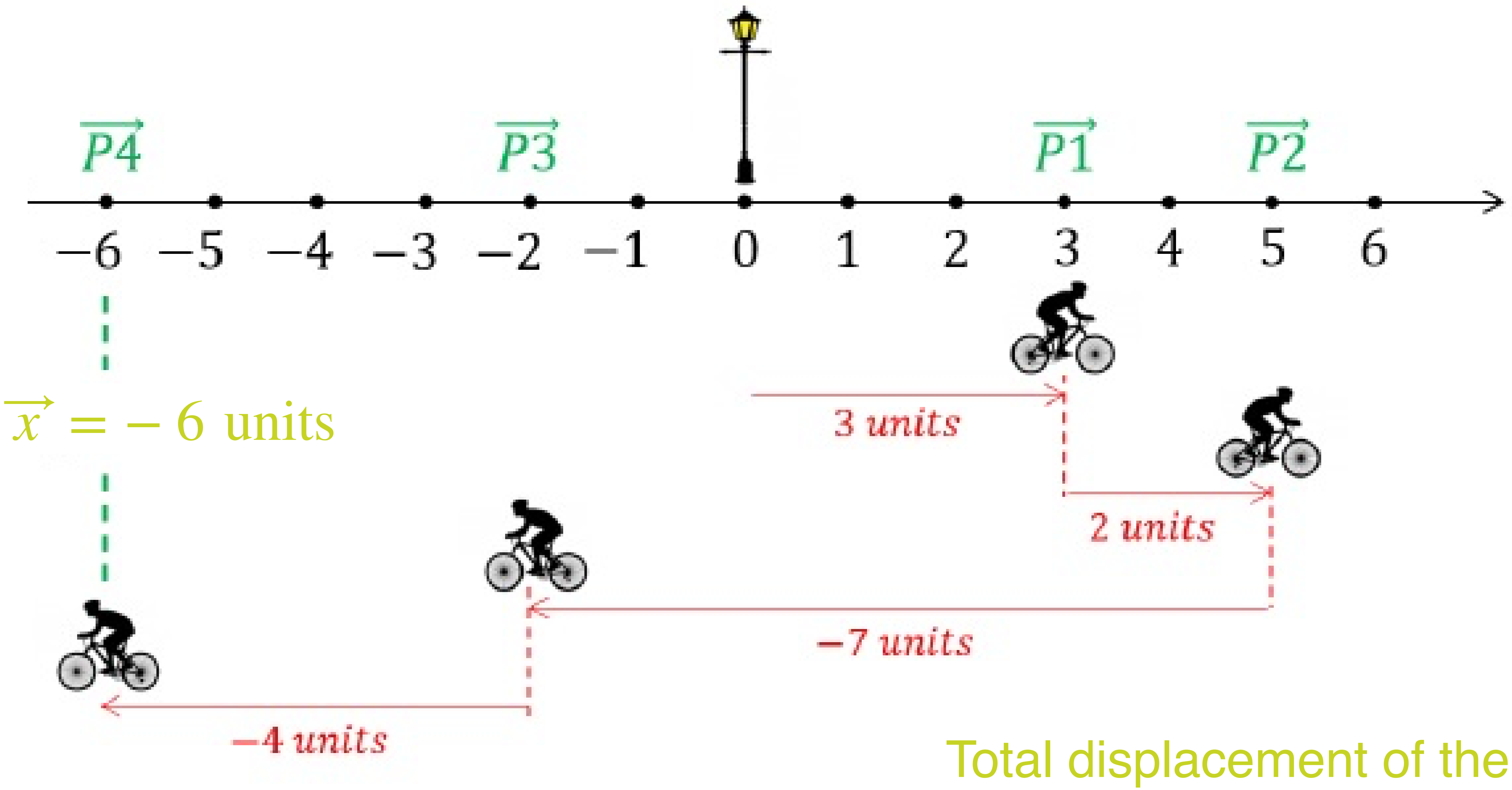
- A vector is a quantity that has both a magnitude (a size or length) and a direction
- It can be represented by a direct line segment, with the arrow's length showing the magnitude and the arrow's point showing the direction

- The path length (or distance) is the total length of the path covered by the moving



- The displacement is the shortest distance between the initial and final positions

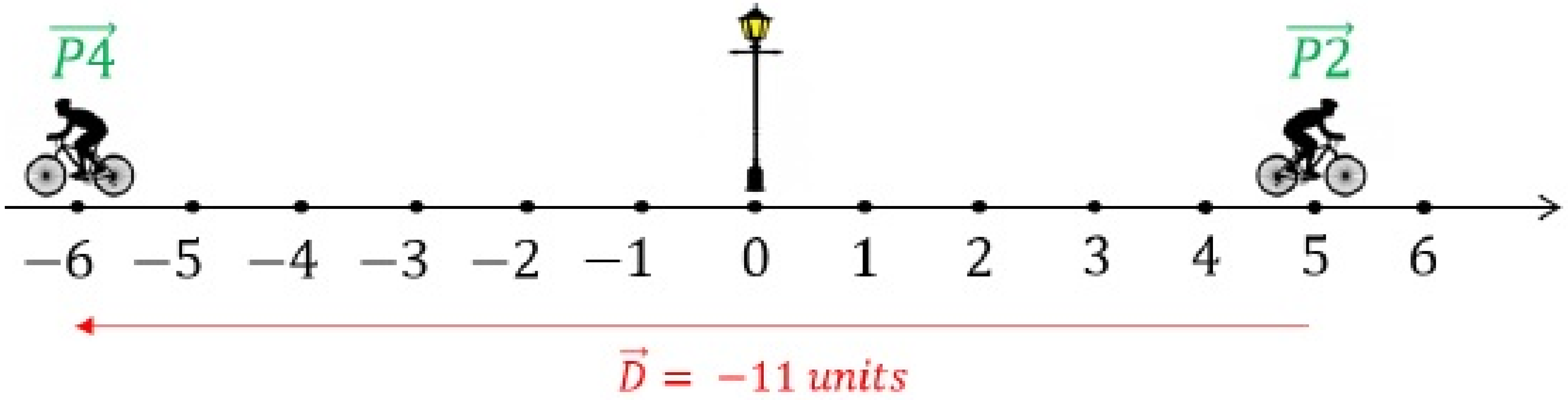
$$\Delta \vec{x} = \text{final position} - \text{initial position}$$



$$\Delta \vec{x} = -6 \text{ units}$$

Total displacement of the cyclist

- The magnitude of the displacement may or may not be equal to the distance traveled
- If the object does not change direction during motion, then the distance is equal to the magnitude of the displacement
- If the object changes direction during motion, then the distance is always greater than the displacement



- Displacement of the cyclist between position P2 and position P4

TIME

- Time is the ongoing sequence of events from the past, through the present, and into the future
- While it is a fundamental part of existence, its definition varies significantly across different fields of study
- In Newtonian physics, time is defined as an absolute, universal entity that exists independently of space and any physical observer
- Often referred to as *absolute time*, it is conceptualized as a continuous and unchanging *flow* that serves as the fixed backdrop for all physical events

TIME

- Absoluteness: Newton described time in his Principia as *absolute, true, and mathematical time* that *flows equably without regard to anything external*

- Universality: Time passes at the same constant rate everywhere in the universe

- Reversibility: Most fundamental Newtonian laws are time-symmetric, meaning they do not mathematically distinguish between the future and the past.

- Independence: Unlike in Einstein’s theory of relativity, Newtonian time is not linked to space; they are distinct, separate containers where space is the *where* and time is the *when*

ARROW OF TIME

- Unlike spatial dimensions where one can move in any direction, time appears to move in only one direction: from past to future

- This is the so-called *arrow of time* that is often explained by the second law of thermodynamics, which states that the universe's total disorder, or entropy, always increases

- Units of time can be seconds (s), hours (hr), years (yr), eons

VELOCITY

- In Newtonian physics, velocity is a vector quantity representing the rate of change of an object's position with respect to time, encompassing both its speed (magnitude) and direction of motion

- It is defined as the displacement divided by the time interval

$$\vec{v} = \frac{\text{final position} - \text{initial position}}{\text{final time} - \text{initial time}} = \frac{\Delta \vec{x}}{\Delta t}$$

- Unlike speed, velocity changes if direction changes, even if the speed is constant

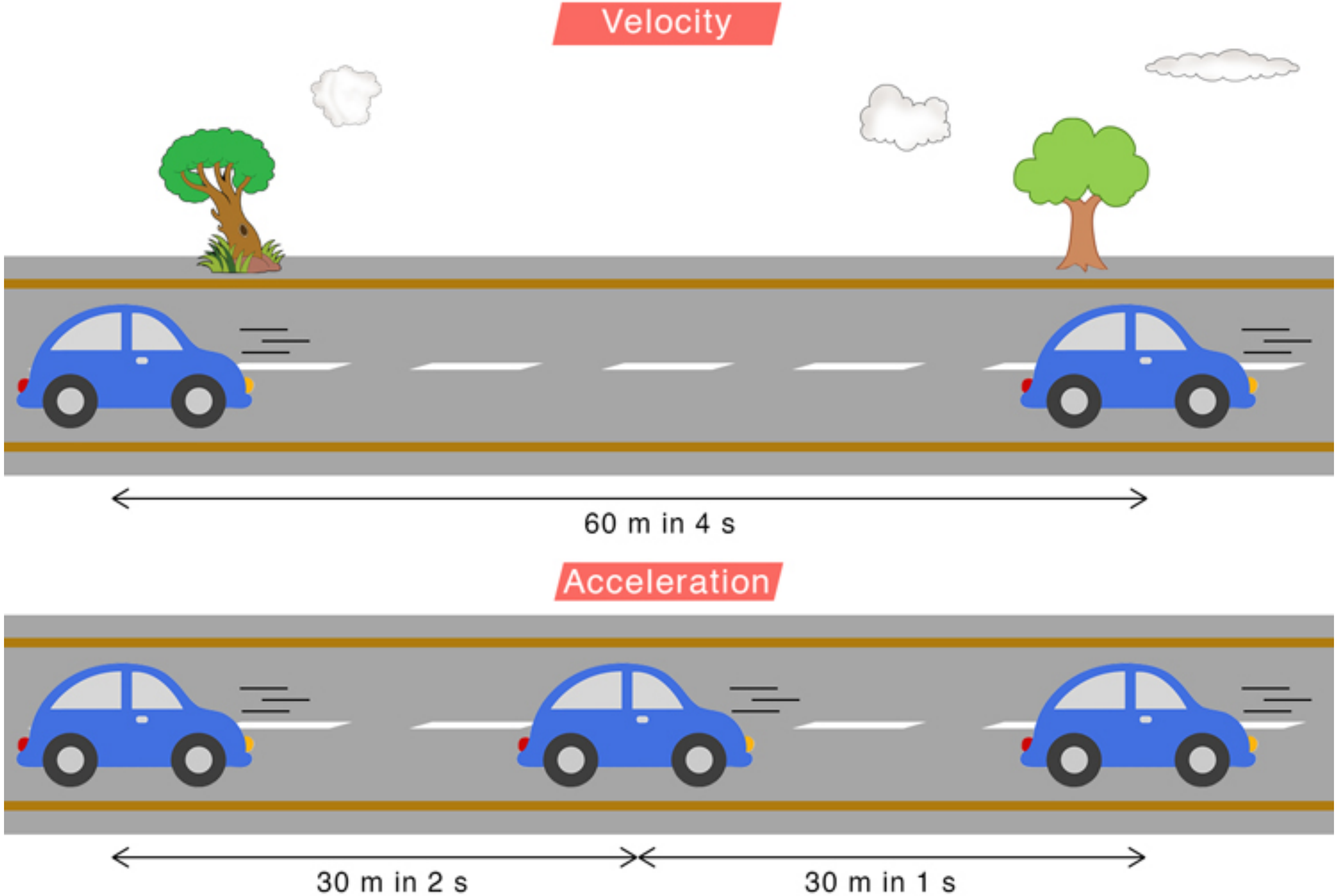
ACCELERATION

- In Newtonian physics, acceleration ($\overrightarrow{a}$) is the vector rate of change of an object's velocity with respect to time, involving changes in speed, direction, or both

- Defined as $\overrightarrow{a} = \dfrac{\text{final velocity} - \text{initial velocity}}{\text{final time} - \text{initial time}} = \dfrac{\Delta \overrightarrow{v}}{\Delta t}$

- Near the Earth's surface, the acceleration due to gravitational attraction is approximately $g \simeq 9.8\ \mathrm{m/s^2}$ (or equivalently $32.2\ \mathrm{ft/s^2}$)

VELOCITY Vs.ACCELERATION



TIME AS THE 4TH DIMENSION

- We can now provide a more accurate characterization of the universality property of Newtonian time

- Time passes at the same constant rate everywhere in the universe

- All observers, regardless of their location or velocity, will agree on the duration of an interval and the simultaneity of events

- According to Einstein's theory of relativity, however, time is not absolute but relative

- It can *slow down* or dilate depending on an observer's speed or the strength of a nearby gravitational field

MASS

- In Newtonian physics, mass m is an intrinsic scalar property representing the quantity of matter in an object, its inertia (i.e. its resistance to changes in motion), and its strength in gravitational interactions

- Newton originally defined it as the *quantity of matter* arising from its density and volume combined

- In the International System of Units (SI) mass is measured in kg

FORCE

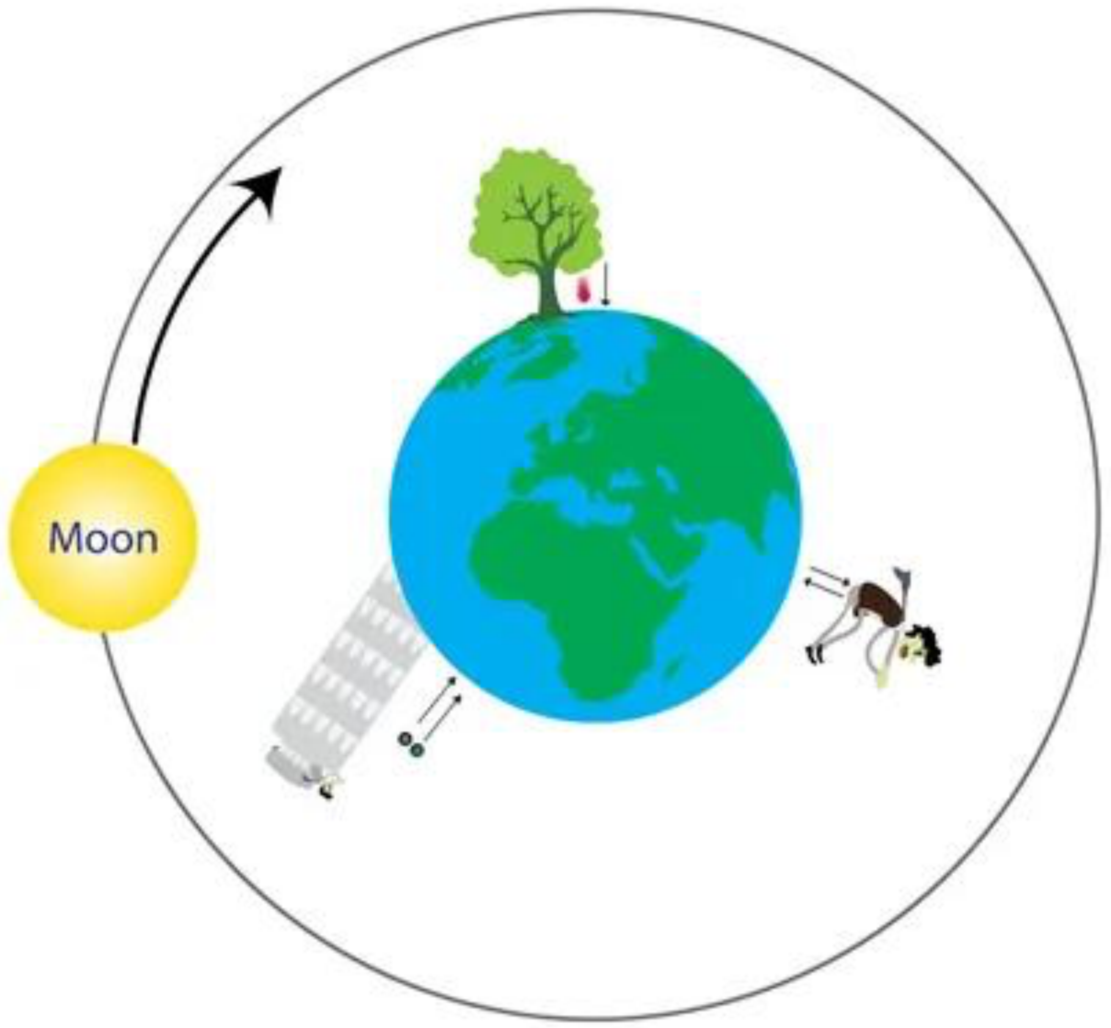
- In Newtonian physics, a force ($\overrightarrow{F}$) is a vector quantity – possessing both magnitude and direction – that acts as a push or pull on an object resulting from its interaction with another object

- Forces cause objects to change their velocity (speed and/or direction), or shape

- The SI unit is the Newton (N), where $1 \text{ N} = 1 \text{ kg} \cdot \text{m/s}$

EXAMPLE OF FORCES

➢ Among the most commonly experienced and well-known forces in daily life are: the gravitational force (acting between all objects with mass or energy, drawing them together) and the frictional force (that opposes motion between surfaces in contact)

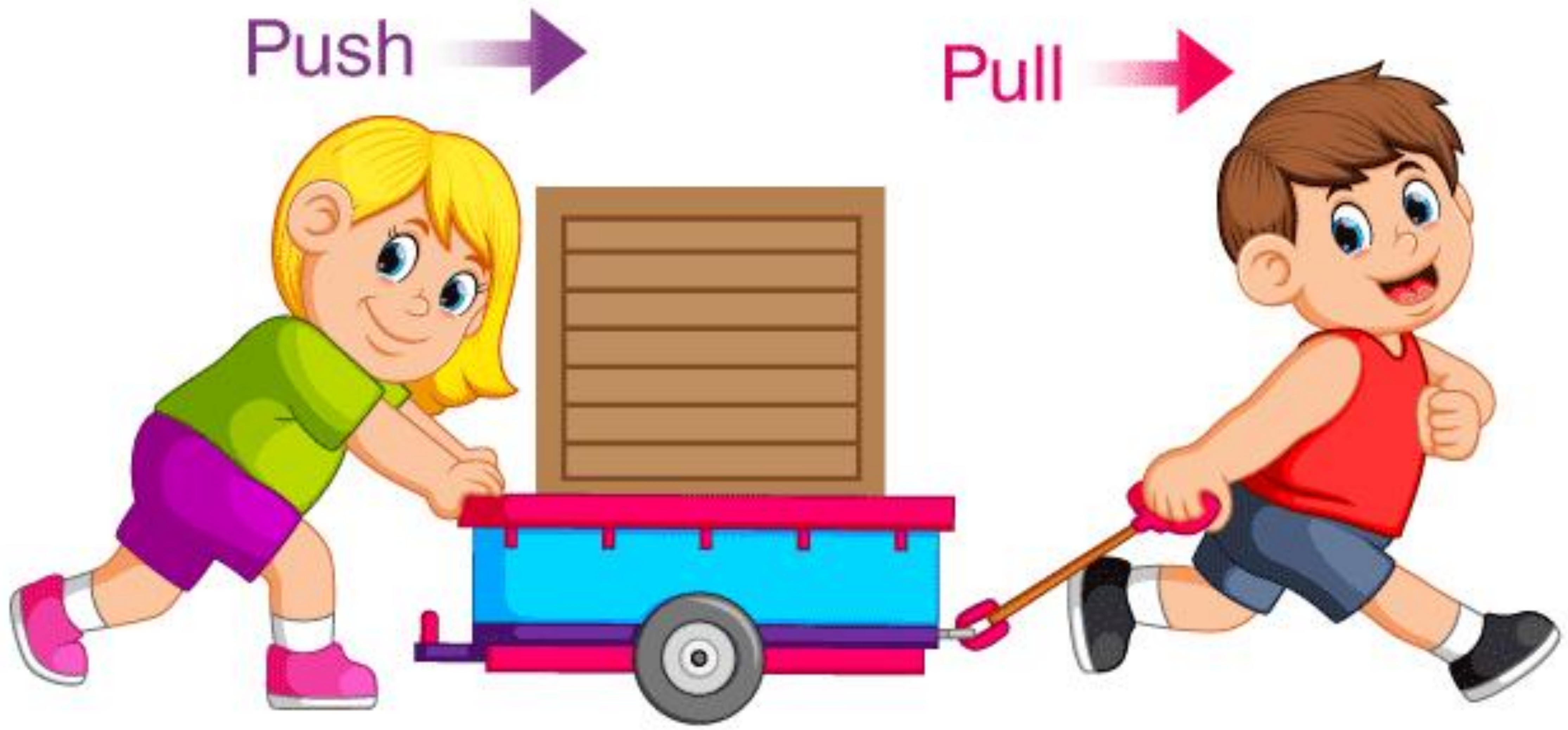


➢ They represent two distinct categories of interaction: non-contact forces (gravity) and contact forces (friction)

NET FORCE

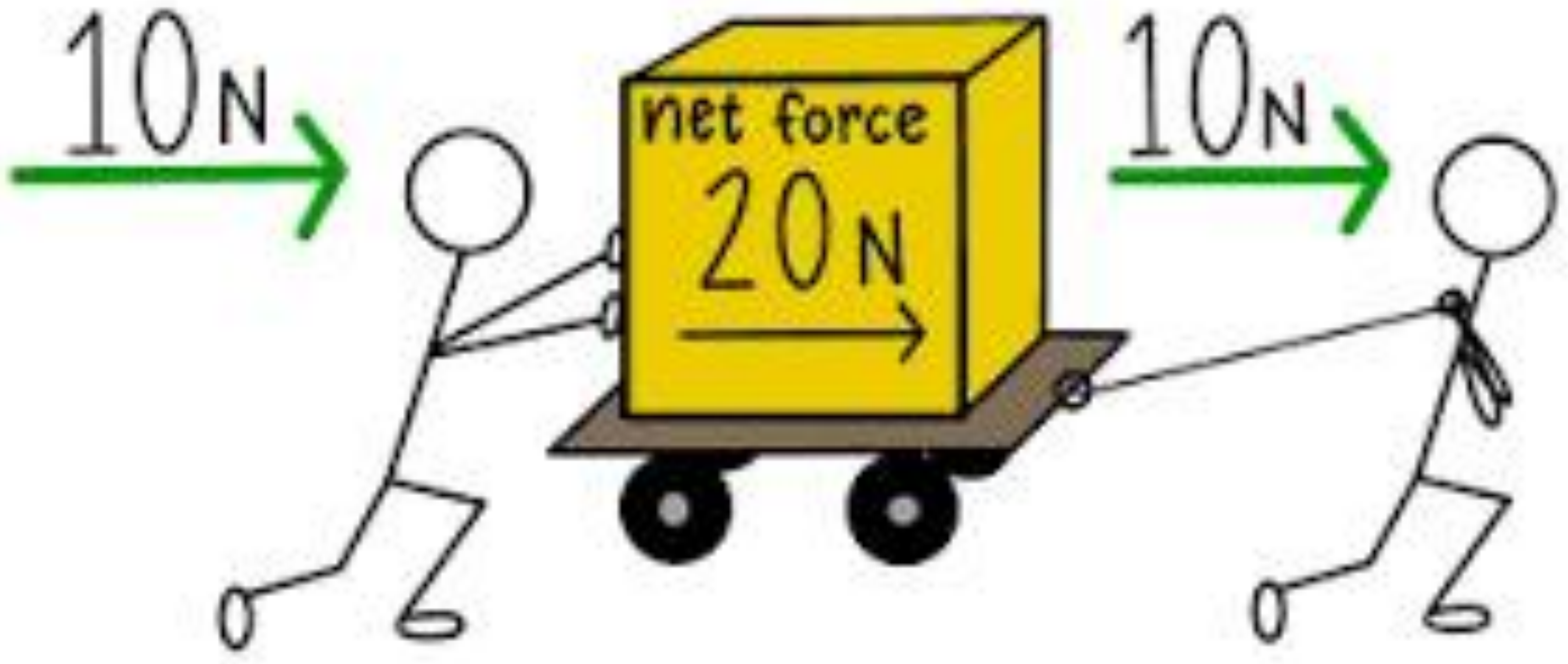
- For a set of forces acting on an object, the net force (or resultant force) is the vector sum of all individual forces

- It represents the combined effect of all pushes and pulls on an object

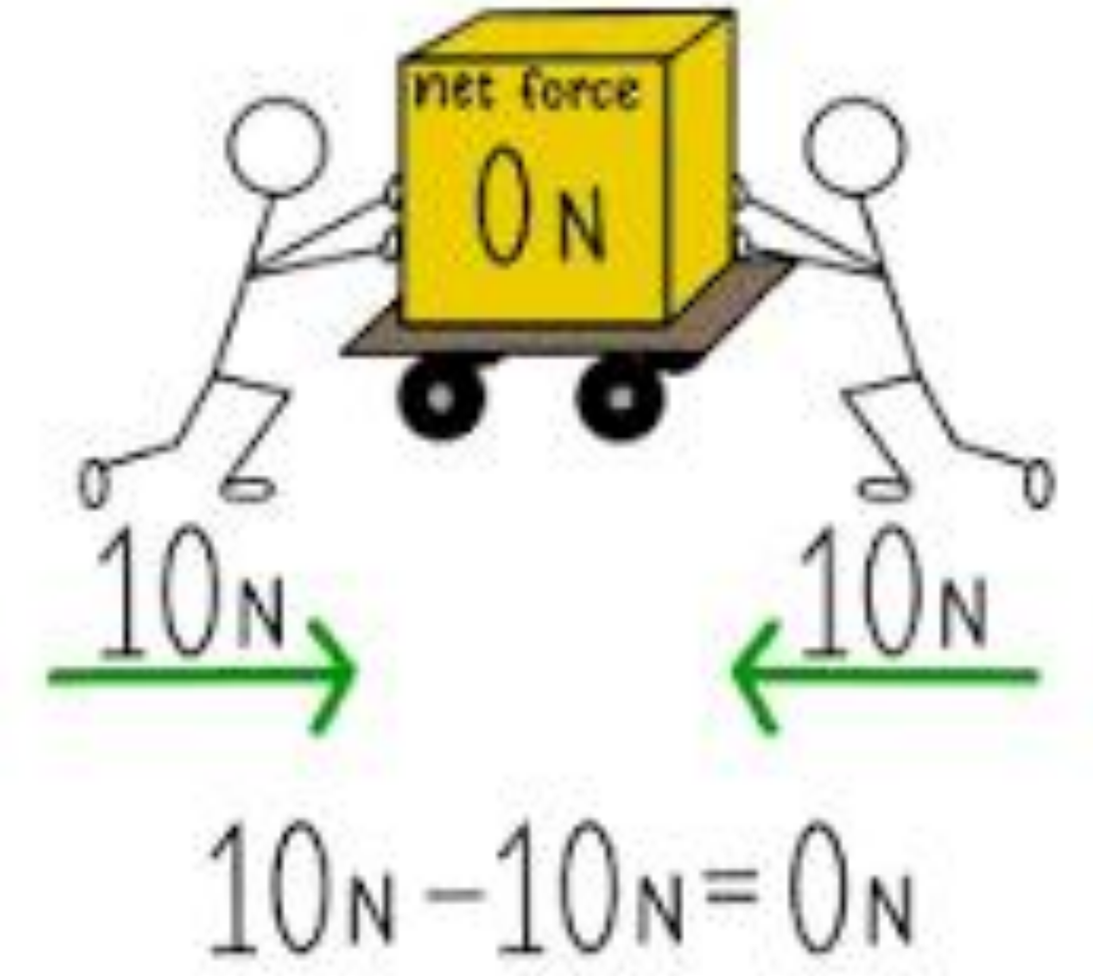


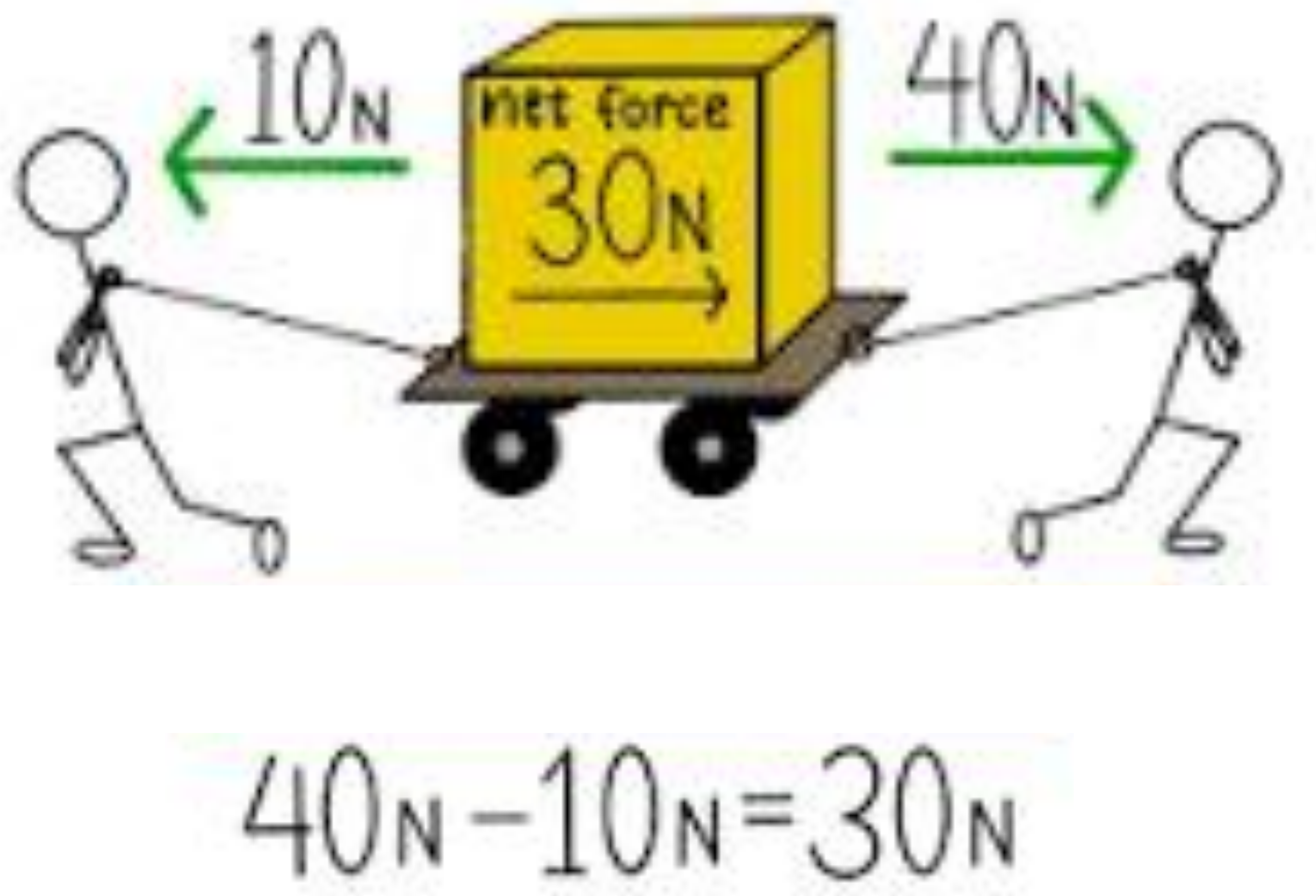
CALCULATING NET FORCE

- If both forces are moving in the same direction, add them together



- If the forces are moving in opposite directions, subtract



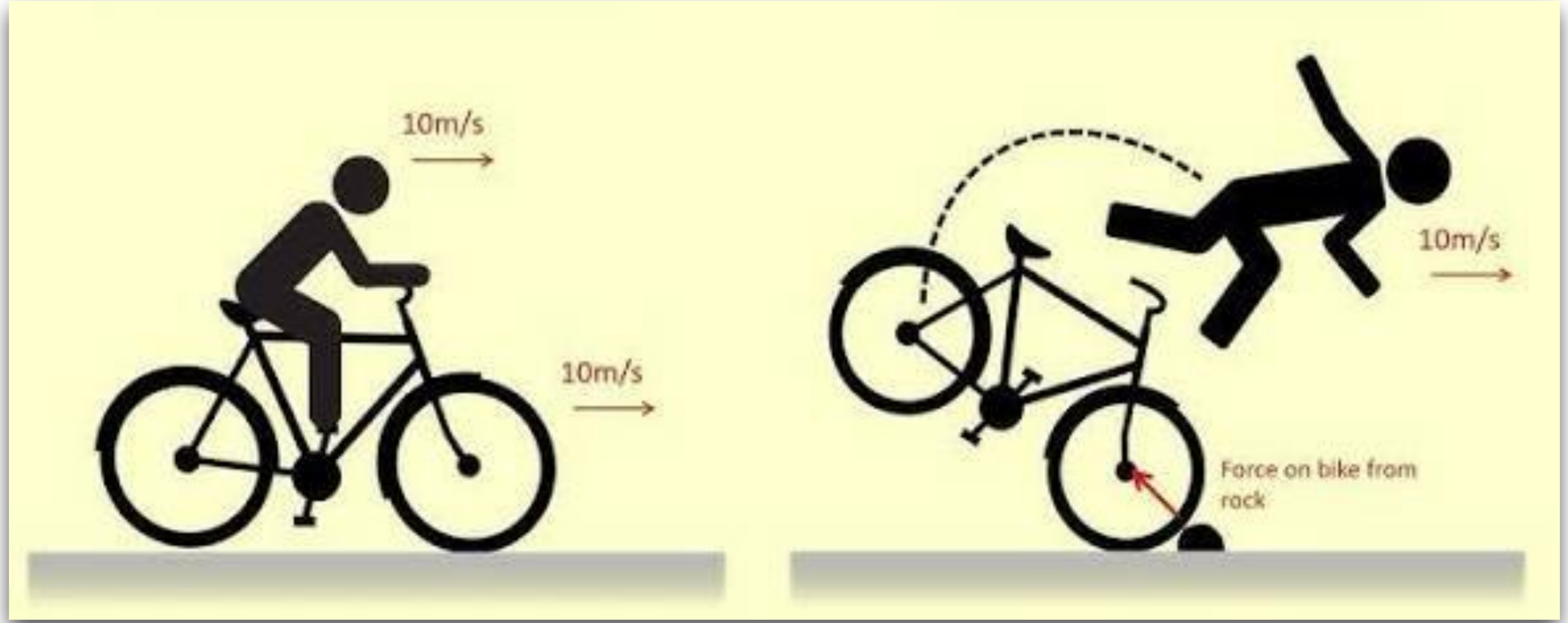


MORE ON NET FORCE

- The summation symbol $\sum$ represents a compact, efficient way to write the sum of a sequence of terms following a pattern
- Example Walkthrough ☛ $\vec{F}_{\text{net}} = \sum_{i=1}^{n} \vec{F}_i = \vec{F}_1 + \vec{F}_2 + \cdots + \vec{F}_n$
- $\sum$ indicates an addition over a set of forces, where the index starts at the lower bound $(i = 1)$ and increases by 1 until the upper bound n is reached, substituting each value into $\vec{F}_i$

NEWTON'S FIRST LAW

- Newton's First Law of Motion, also known as the principle of inertia, states that an object at rest stays at rest, and an object in motion stays in motion with the same speed and in the same direction, unless acted upon by an unbalanced external force



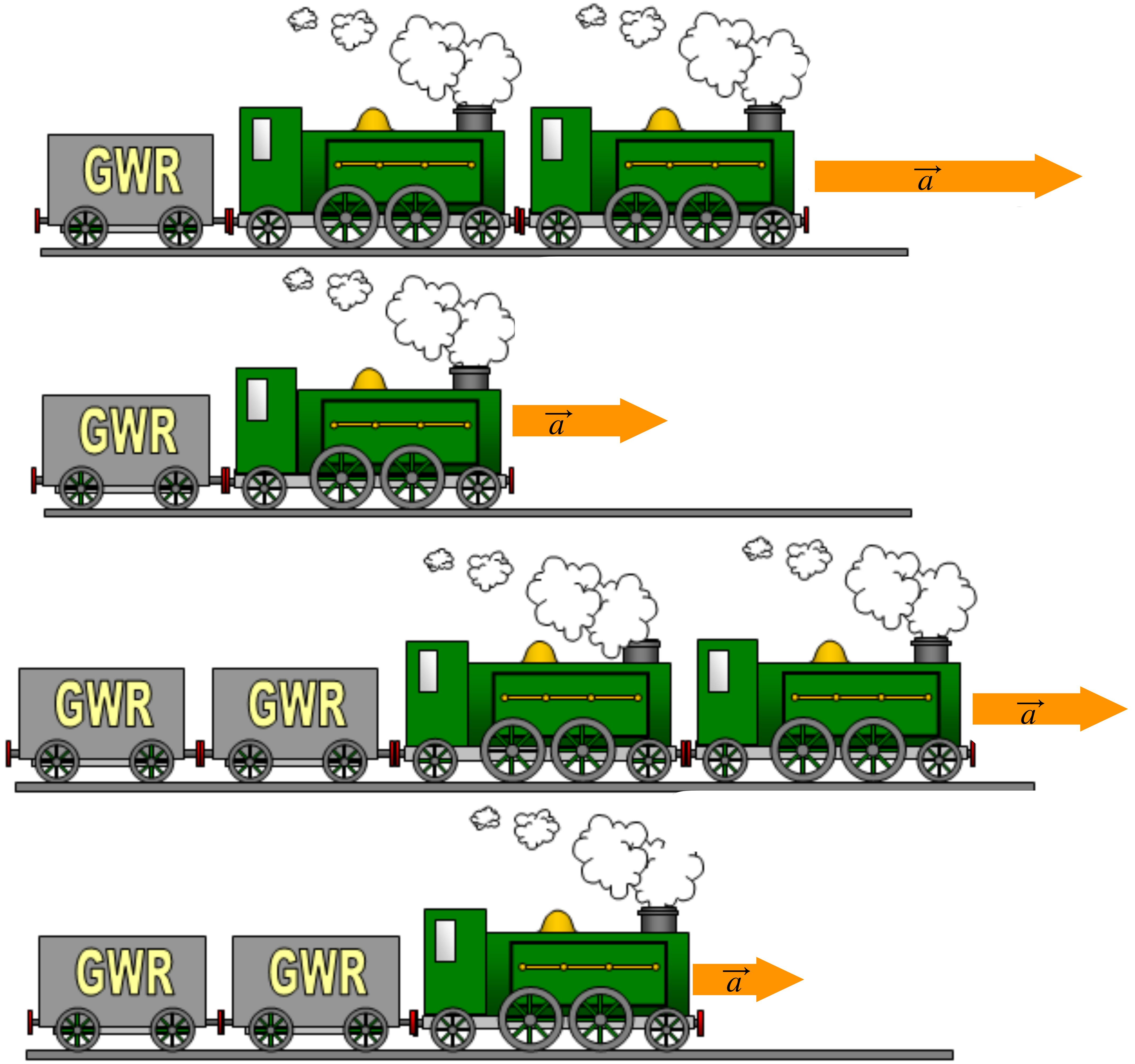
NEWTON'S FIRST LAW

- This means objects resist changes in their state of motion; a stationary object needs a force to start moving, and a moving one needs a force to stop or change direction

- The principle of inertia implies that there is no fundamental physical distinction between being at rest and moving at a constant velocity

NEWTON'S SECOND LAW

- Acceleration is directly proportional to the net external force acting on a body $\vec{F}_{\text{net}}$ and inversely proportional to its mass m, per Newton's Second Law $\vec{F}_{\text{net}} = m\vec{a}$



NEWTON'S THIRD LAW

- Newton's Third Law states that forces always occur in pairs: if one object exerts a force on a second object, the second object simultaneously exerts a force of the same magnitude but in the opposite direction on the first object, acting on different bodies

- A common example is that of a rocket pushing gas down (action) and the gas pushing the rocket up (reaction)

If the net force on an object is zero, what can be concluded about its motion?

A. It must be at rest
B. It is accelerating
C. It is moving with constant velocity or is at rest
D. It is decreasing in speed twice the force wich it was fired

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A ball is dropped from a cliff and experiences no air resistance. As it falls, its speed:

A. Increases by 9.8 m/s during each second

B. Remains constant

C. Decreases

D. Is 9.8 m/s throughout the fall

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A ball is thrown vertically upward, reaches a highest point, and falls back down. At the maximum height, its velocity is:

A. 9.8 m/s downward
B. 9.8 m/s upward
C. 0 m/s
D. Maximum

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Convert a speed of 72 km/hr to m/s

A. 16 m/s

B. 18 m/s

C. 100 m/s

D. 20 m/s

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A. 16 m/s

B. 18 m/s

C. 100 m/s

D. 20 m/s

After a cannonball is fired into frictionless space,

the amount of force needed to keep it going equals

A. zero, since no force is necessary to keep it moving

B. twice the force with which it was fired.

C. one half the force with which it was fired.

D. the same amount of force with which it was fired.

E. one quarter the force with which it was fired

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Which has more mass, a kilogram of feathers or a kilogram of iron?

A. The feathers

B. The iron

C. Neither—they both have the same mass

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A 10-kg brick and a 1-kg book are dropped in a vacuum.

The force of gravity on the 10-kg brick is

A. 10 times as much as the force on the 1-kg book

B. zero

C. the same as the force on the 1-kg book

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A player hits a ball with a bat. The action force is the impact of the bat against the ball. What is the reaction to this force?

A. The force of the ball against the bat

B. The weight of the ball

C. Air resistance on the ball

D. The grip of the player's hand against the bat

E. none of the above

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A person is attracted towards the center of Earth by a 440-N gravitational force. The force with which Earth is attracted toward the person is

A. 440N

B. very very small

C. very very large

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Friction is a force that always acts

A. perpendicular to an object's motion

B. opposite to an object's motion

C. in the same direction as an object's motion

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The law of inertia applies to

A. objects at rest

B. moving objects

C. both moving and nonmoving objects

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C. both moving and nonmoving objects

One object has twice as much mass as another object. The first object also has twice as much

A. velocity

B. gravitational acceleration

C. inertia

D. all of the above

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How does acceleration of an object change in relation to its mass? It is

A. directly proportional

B. Acceleration doesn't depend on mass at all

C. inversely proportional

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A girl pulls on a 10-kg wagon with a constant force of 20 N.

What is the wagon's acceleration?

A. 0.5 m/s2

B. 2 m/s2

C. 10m/s2

D. 20m/s2

E. 200 m/s2

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A force of 3N accelerates a mass of 3kg at the rate of 1 m/s^2.

Acceleration of a mass of 6 kg acted upon by a force of 6 N is

A. twice as much

B. half as much

C. the same

D. none of the above

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Suppose a cart is being moved by a force. If suddenly a load is dumped into the cart so that the cart's mass doubles, what happens to the cart's acceleration?

A. It quarters

B. It halves

C. It stays the same

D. It doubles

E. It quadruples

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You pull horizontally on a 50-kg crate with a force of 450 N and the friction force on the crate is 250 N.

The acceleration of the crate is

A. 2 m/s^2

B. 4 m/s^2

C. 9 m/s^2

D. 14 m/s^2

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B. 4 m/s^2

C. 9 m/s^2

D. 14 m/s^2

According to Newton's third law, if you push gently on something, it will push

A. gently on something else

B. on you only if you aren't moving

C. gently on you

D. on something only under the right conditions

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A box is dragged without acceleration in a straight-line path across a level surface by a force of 13 N. What is the frictional force between the box and the surface?

A. 13N

B. Less than 13 N

C. More than 13 N

D. Need more information to say

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