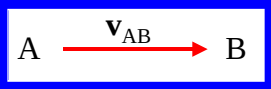
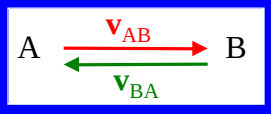
Relative Velocity

Rules of relative velocity

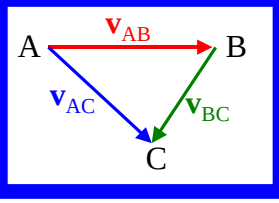
- relative velocity $\mathbf{v}_{AB}$ is a vector
- graphically, $\mathbf{v}_{AB}$ is pointing from A to B representing the velocity of A relative to B

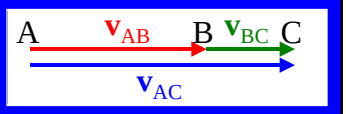


- $\mathbf{v}_{BA} = -\mathbf{v}_{AB}$

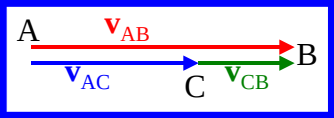


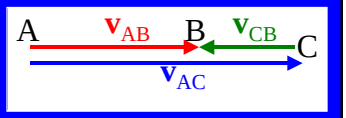
- $\mathbf{v}_{AC} = \mathbf{v}_{AB} + \mathbf{v}_{BC}$





- $\mathbf{v}_{AC} = \mathbf{v}_{AB} - \mathbf{v}_{CB}$



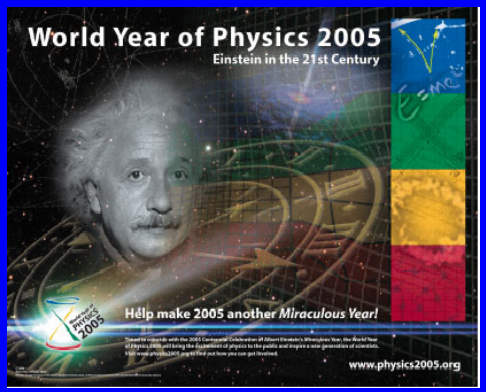


Do Concept Simulation 3.3

Relative Velocity

Relative velocity and Relativity

- the rule $\mathbf{v}_{AC} = \mathbf{v}_{AB} + \mathbf{v}_{BC}$ no longer works in Einstein's special relativity since the speed of light *c* is a constant
- it works if the magnitude of both $\mathbf{v}_{AB}$ and $\mathbf{v}_{BC}$ are much less than *c*
- however, the principle of relativity still works within classical physics, i. e., two observers moving relative to each other should still observe same physical events.



Newton's Laws of Motion

What causes an object to accelerate (decelerate)?

- With the equations of kinematics, we know how to describe the motion of an object once its acceleration vector is given.
- We still need to know how to determine its acceleration.
- Newton's Laws of Motion relate the acceleration of an object to two other physical quantities: its mass and the force acting on it.

Newton's Laws of Motion

Newton's First Law of Motion

- "An object continues in a state of rest or in a state of motion at a straight line, unless compelled to change that state by a net force."
- example: a person can stand on the floor without falling through it because the floor applies a normal force that balance that person's weight so that the net force is zero.
- example: a person inside a car moving in constant velocity can be moving in high speed relative to the road without the help of any net force. However, if the car stops suddenly, a net force will be needed for that person to stop the forward motion (that is why a seatbelt is so important!).

Newton's Laws of Motion

Inertia and Mass

- "Inertia is the natural tendency of an object to remain at rest or at a constant speed along a straight line. The mass of an object is a quantitative measure of inertia."
- SI unit of inertia: kilogram (kg)
- mass and weight are different concepts.

Newton's Laws of Motion

Inertial reference frame

- A reference frame is a three dimensional spatial coordinate system that can be used to describe the motion of objects.
- Different reference frames can be moving relative to each other. E. g., a car moving on a road can be described by using the road as a reference frame. At the same time, an object moving inside the car is most conveniently described by using the car as a reference frame. These two reference frames are moving relative to each other.
- "An inertial reference frame is one in which Newton's first law (law of inertial) is valid. E. g. a decelerating car is NOT an inertial frame because an object inside it will have a tendency of moving forward which is due to its inertial, not by a net force.
- Sometimes the concept of inertial force is introduce in a non-inertial reference frame.
- A reference moving with a constant velocity relative to an inertial reference frame is also an inertial reference frame.
- The Earth is approximately an inertial reference frame.

Do 4.CQ.002-004

Newton's Laws of Motion

Newton's Seconed Law of Motion

• $\mathbf{a} = \Sigma\mathbf{F}/m$, or , $\Sigma\mathbf{F} = m\,\mathbf{a}$, or simply $\mathbf{F} = m\,\mathbf{a}$

• $\Sigma\mathbf{F}$ is the total net force (vector) acting on the object with a mass m. The SI unit of force is newton (N), i. e., kg m/s^2

• $\mathbf{a}$ is the vector acceleration of the object.

• In components, $\Sigma F_x = m\,a_x$, $\Sigma F_y = m\,a_y$

• With two or more forces, must calculate the vector sum to get the net force in order to determine the acceleration. Should draw a free-body diagram to help doing the vector addition of forces.

• Still need to specify how to determine the forces acting on an object. We will see various types of force later.

Newton's Laws of Motion

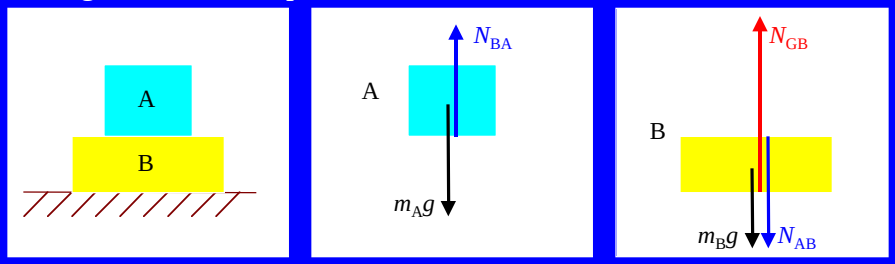
Free-body Diagram

• Isolate different objects in a given problem.

• For each object, draw a separate free-body diagram.

• In each diagram, draw all forces acting on the object (and the locations where the forces are applied), but not forces acting by the object to other objects.

• E. g., a block on top of another block



Newton's Laws of Motion

Free-body Diagram

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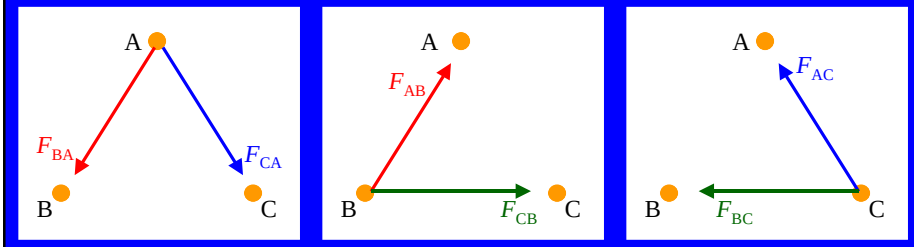
- For each object, draw a separate free-body diagram.
- In each diagram, draw all forces acting on the object (and the locations where the forces are applied), but not forces acting by the object to other objects.
- E. g., a block on top of another block; gravitational forces among three objects.



Newton's Laws of Motion

Free-body Diagram

- Isolate different objects in a given problem.
- For each object, draw a separate free-body diagram.
- In each diagram, draw all forces acting on the object (and the locations where the forces are applied), but not forces acting by the object to other objects.
- E. g., a block on top of another block; gravitational forces among three objects.
- After drawing the forces, a coordinate system can be chosen so as to work in components.

Do Concept Simulation 4.1 , 4.CQ.005

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Newton's Laws of Motion

Newton's Third Law of Motion

- "Whenever one body exerts a force on a second body, the second body exerts an oppositely directed force of equal magnitude on the first body." –– Action-Reaction Law
- example: a block on the floor exerts a force due on the floor due to its weight. At the same time, the floor exerts a normal force on the block that balance the weight of the block so that the net force acting on it is zero and thus it is not moving.
- These two forces are acting on different objects --- they should not be drawn at the same time on the free-body diagram of an object.
- These two forces can produce accelerations of very different magnitude to the two objects.

Do 4.CQ.006