Chapter 5

NEWTON'S THIRD LAW OF MOTION

From previous weeks …

- Newton’s 1st Law of Motion (Law of Inertia)

 - Every object continues in a state of rest or of uniform speed in a straight line unless acted on by a nonzero net force.

- Newton’s 2nd Law of Motion

 - The acceleration of an object is directly proportional to the net force acting on the object, is in the direction of the net force, and is inversely proportional to the mass of the object. $F = ma$

Objectives- Chapter 5

- Forces and Interactions
- Newton’s Third Law of Motion
- Summary of Newton’s Laws
- Vectors

Forces and Interactions

Interaction

- is between one thing and another.
- requires a pair of forces acting on two objects.

Example: interaction of hand and wall pushing on each other

Force pair—you push on wall; wall pushes on you.

Forces occur in pairs.

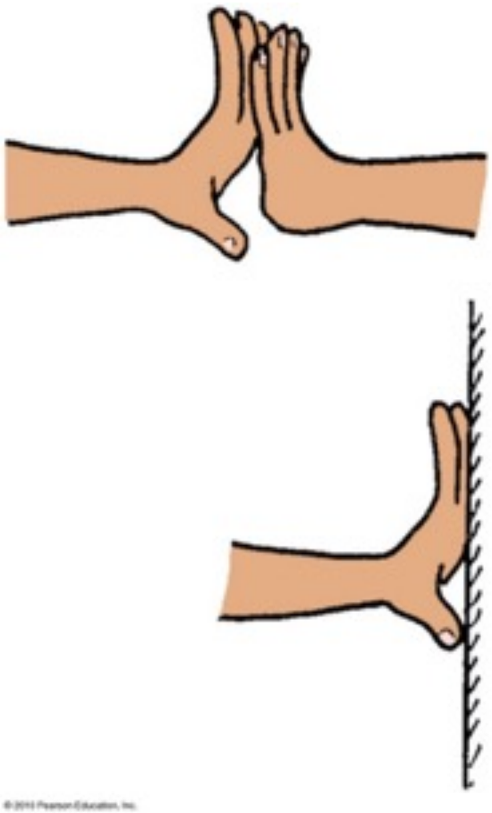
Force Pairs

Every force is a part of an interaction between two objects.

Forces come in pairs.

These forces are equal in magnitude (have the same strength) and opposite in direction.

An interaction requires a *pair* of forces acting in *two separate objects*.



Newton’s Third Law of Motion

Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.

A soccer player kicks a ball with 1500 N of force. The ball exerts a reaction force against the player's foot of

A. somewhat less than 1500 N.
B. 1500 N.
C. somewhat more than 1500 N.
D. None of the above.

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Newton’s Third Law of Motion

Action and reaction forces

- one force is called the action force; the other force is called the reaction force.
- are co-pairs of a single interaction.
- neither force exists without the other.
- are equal in strength and opposite in direction.
- always act on *different* objects.

Newton’s Third Law of Motion

- Reexpression of Newton’s third law: **To every action there is always an opposed equal reaction.**

Example: Tires of car push back against the road while the road pushes the tires forward.

Action: tire pushes on road   Reaction: road pushes on tire

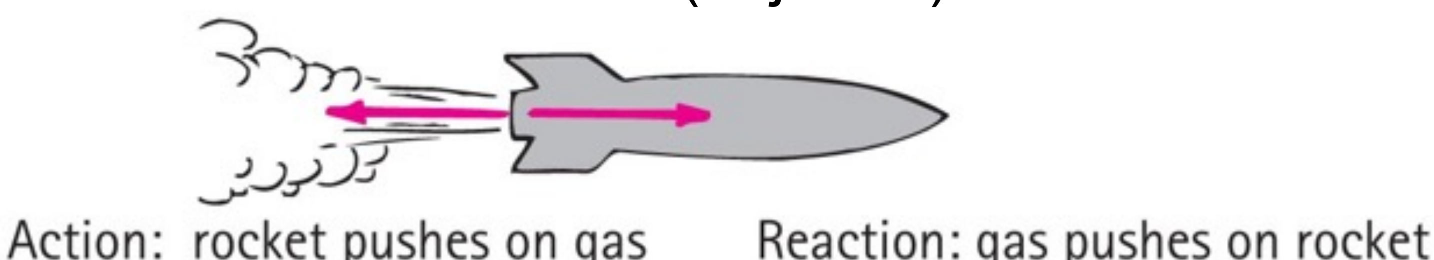
Newton’s Third Law of Motion

Simple rule to identify action and reaction

- Identify the interaction—one thing interacts with another
  - Action: Object A exerts a force on object B.
  - Reaction: Object B exerts a force on object A.

Example: Action—rocket (object A) exerts force on gas (object B).

Reaction—gas (object B) exerts force on rocket (object A).



When you step off a curb, Earth pulls you downward. The reaction to this force is

A. a slight air resistance.
B. nonexistent in this case.
C. you pulling Earth upward.
D. None of the above.

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When you step off a curb, Earth pulls you downward and you pull the force upward. Why do you not sense Earth moving upward toward you?

A. Earth is fixed, so it cannot move.
B. Earth can move, but other objects on it prevent it from moving.
C. It moves, but a very small amount that you cannot see.
D. None of the above.

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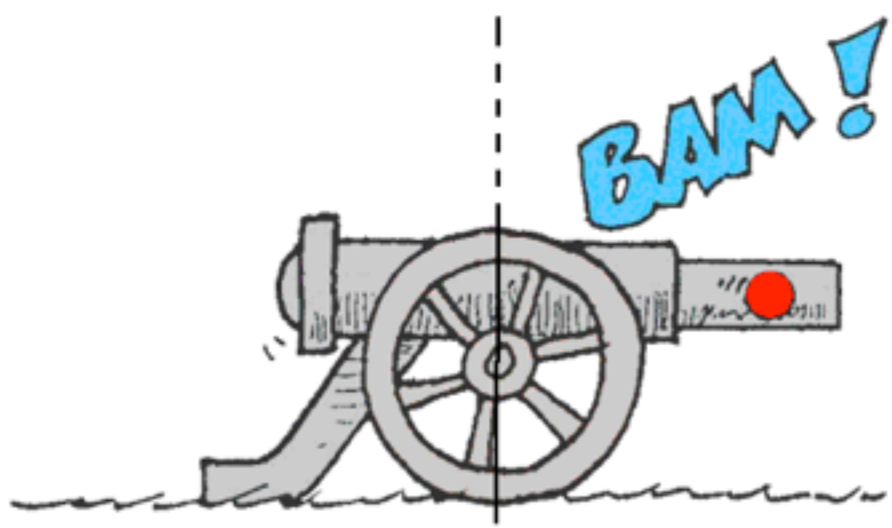
Explanation:
You exert a force on Earth that is equal to the force it exerts on you. But you move more than the Earth does, because its mass is so great compared to your mass that it moves very little and you do not notice it.

When a cannon is fired, the accelerations of the cannon and cannonball are different because the

A. forces don’t occur at the same time.
B. forces, although theoretically the same, in practice are not.
C. masses are different.
D. ratios of force to mass are the same.



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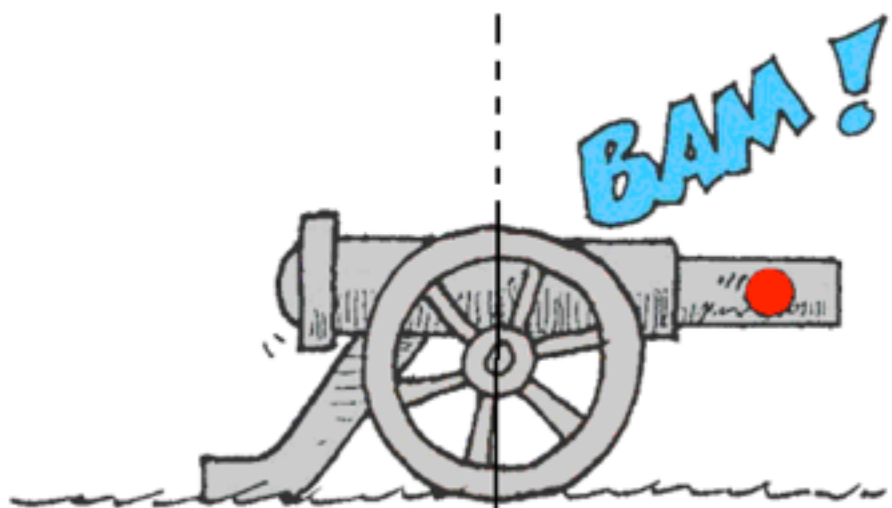
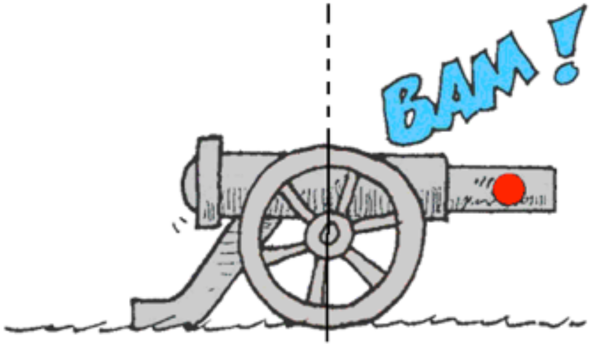


Action and Reaction on Different Masses

Cannonball: $$\frac{F}{m} = a$$

Cannon: $$\frac{F}{m} = a$$

- The same force exerted on a small mass produces a large acceleration.
- The same force exerted on a large mass produces a small acceleration.



Consider a high-speed bus colliding head-on with an innocent bug. The force of impact splatters the unfortunate bug over the windshield.
Which is greater, the force on the bug or the force on the bus?

A. Bug
B. Bus
C. Both are the same.
D. Cannot say

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Two people of equal mass on slippery ice push off from each other. Will both move at the same speed in opposite directions?

A. Yes
B. Yes, but only if both push equally
C. No
D. No, unless acceleration occurs

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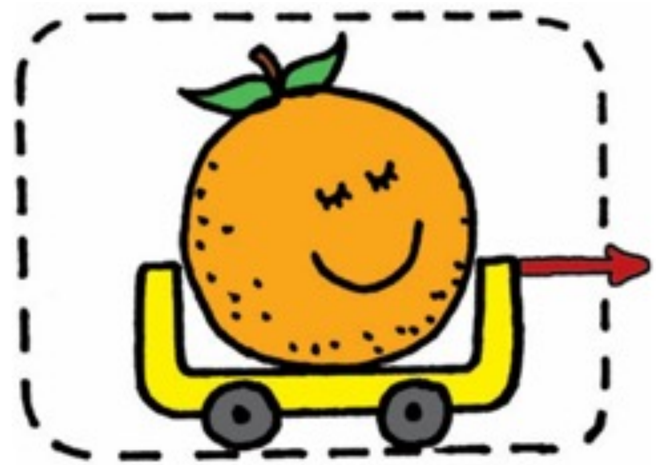
Explanation:

However they push, the result is equal-magnitude forces on equal masses, which produces equal accelerations; therefore, there are equal changes in speed.

Newton’s Third Law of Motion

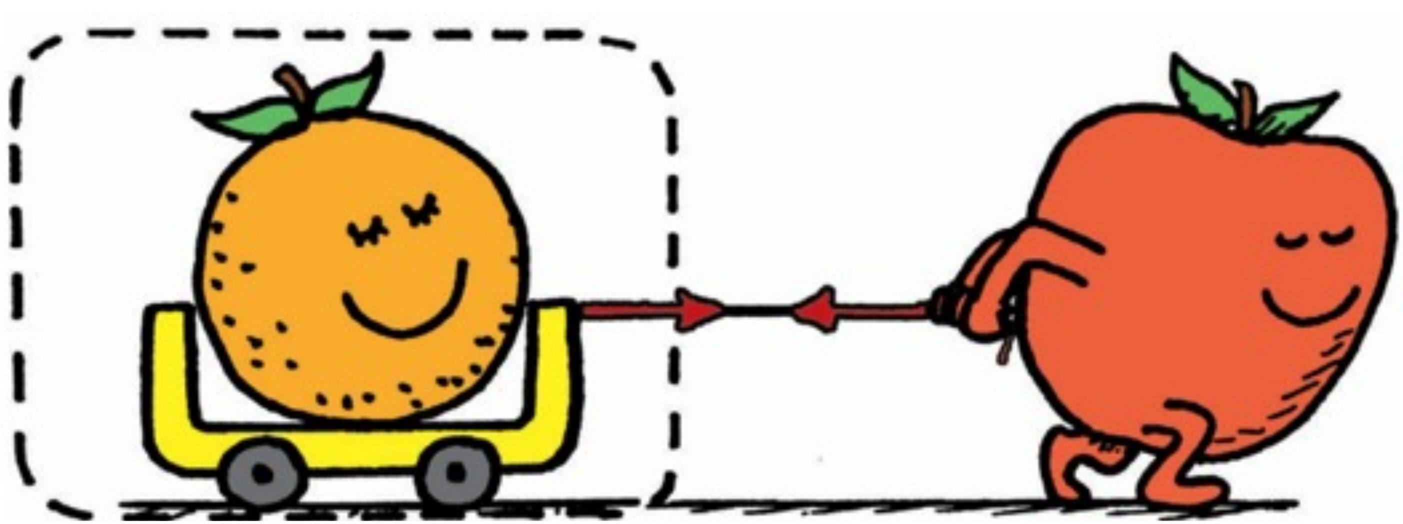
Defining Your System

- Consider a single enclosed orange.
  - Applied external force causes the orange to accelerate in accord with Newton’s second law.
  - Action and reaction pair of forces is not shown.



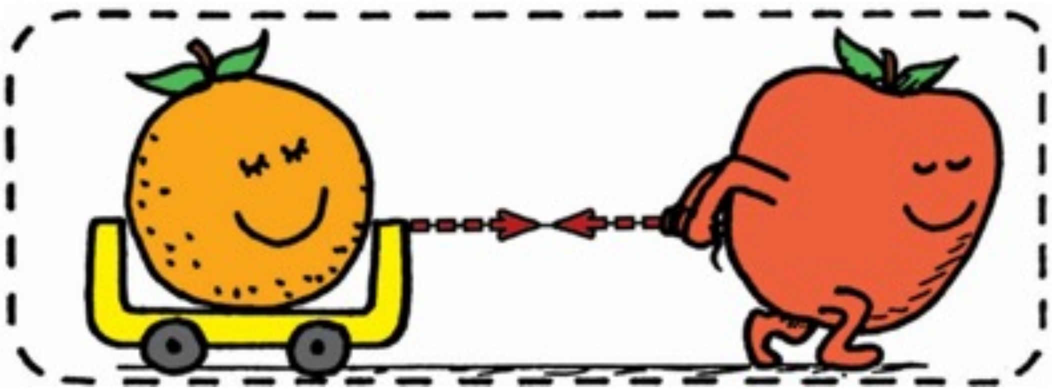
Newton's Third Law of Motion

- Consider the orange and the apple pulling on it.
  - Action and reaction do not cancel (because they act on different things).
  - External force by apple accelerates the orange.



Newton's Third Law of Motion

- Consider a system comprised of both the orange and the apple
  - The apple is no longer external to the system.
  - Force pair is internal to system, which doesn't cause acceleration.
  - Action and reaction within the system cancel.
  - With no external forces, there is no acceleration of system.



Newton’s Third Law of Motion

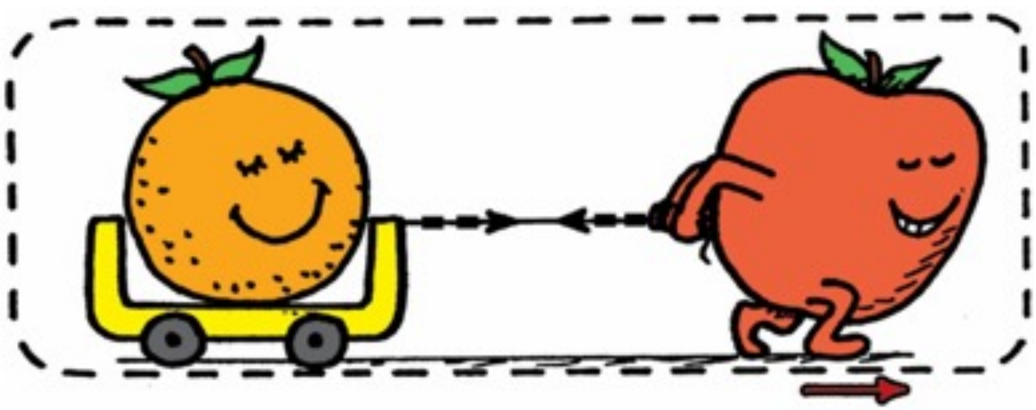
- Consider the same system, but with external force of friction on it.
  - Same internal action and reaction forces (between the orange and apple) cancel.
  - A second pair of action-reaction forces (between the apple’s feet and the floor) exists.

Newton’s Third Law of Motion

– One of these acts by the system (apple on the floor) and the other acts on the system (floor on the apple).

– External frictional force of floor pushes on the system, which accelerates.

– Second pair of action and reaction forces do not cancel.



When lift equals the weight of a helicopter, the helicopter

A. climbs down.
B. climbs up.
C. hovers in midair.
D. None of the above.

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A bird flies by

A. flapping its wings.
B. pushing air down so that the air pushes it upward.
C. hovering in midair.
D. inhaling and exhaling air.

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Compared with a lightweight glider, a heavier glider would have to push air

A. downward with greater force.
B. downward with the same force.
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Explanation:

The force on the air deflected downward must equal the weight of the glider.

Summary of Newton’s Three Laws of Motion

- Newton’s first law of motion (the law of inertia)
  - An object at rest tends to remain at rest; an object in motion tends to remain in motion at constant speed along a straight-line path.
- Newton’s second law of motion (the law of acceleration)
  - When a net force acts on an object, the object will accelerate. The acceleration is directly proportional to the net force and inversely proportional to the mass.
- Newton’s third law of motion (the law of action and reaction)
  - Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.

Vectors

Vector quantity

- has magnitude and direction.
- is represented by an arrow.

Example: velocity, force, acceleration

Scalar quantity

- has magnitude.

Example: mass, volume, speed

Vectors

Resultant

- The sum of two or more vectors
  - For vectors in the same direction, add arithmetically.
  - For vectors in opposite directions, subtract arithmetically.
  - Two vectors that don’t act in the same or opposite direction:
    - use parallelogram rule.
  - Two vectors at right angles to each other
    - use Pythagorean Theorem: $R^2 = V^2 + H^2$.

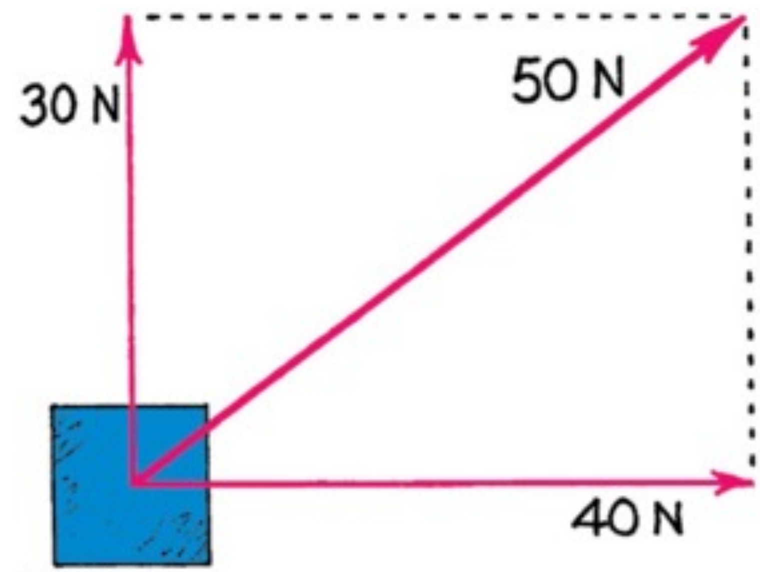
Referring to the figure, which of the following are true statements?

A. 50 N is the resultant of the 30- and 40-N vectors.

B. The 30-N vector can be considered a component of the 50-N vector.

C. The 40-N vector can be considered a component of the 50-N vector.

D. All of the above are correct.



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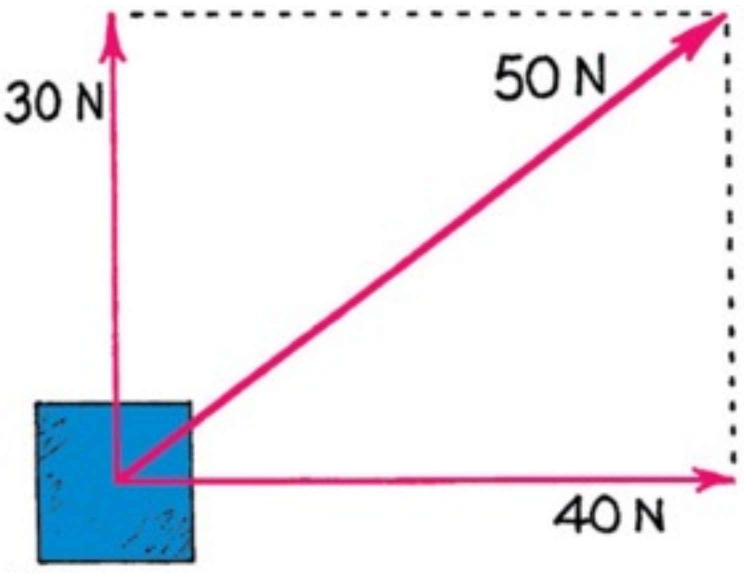

Referring to the figure, which of the following are true statements?

A. 100 km/h is the resultant of the 80- and 60-km/h vectors.
B. The 80-km/h vector can be considered a component of the 100-km/h vector.
C. The 60-km/h vector can be considered a component of the 100-km/h vector.
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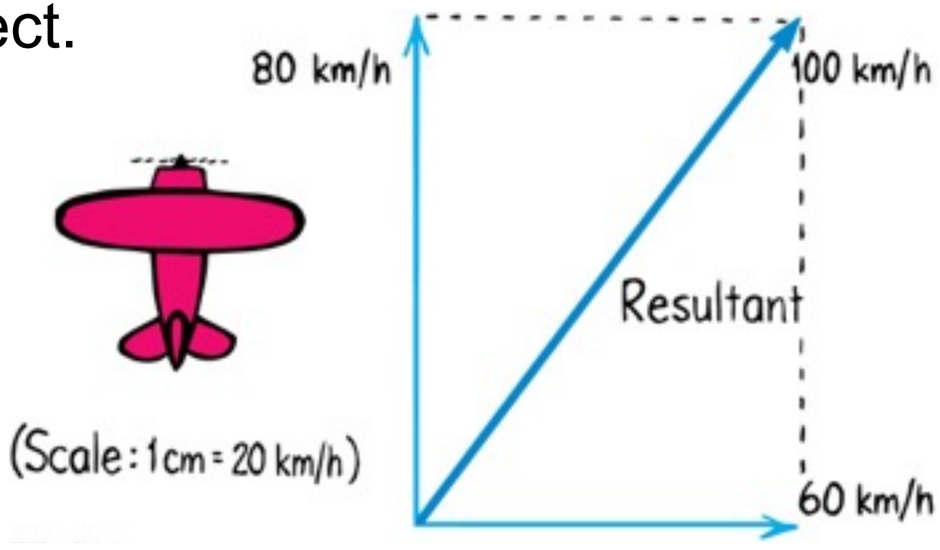

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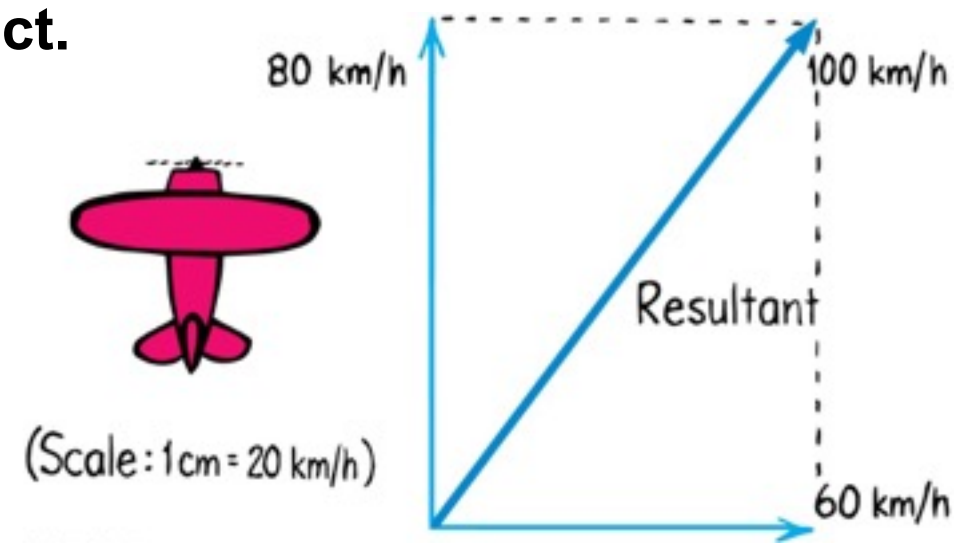
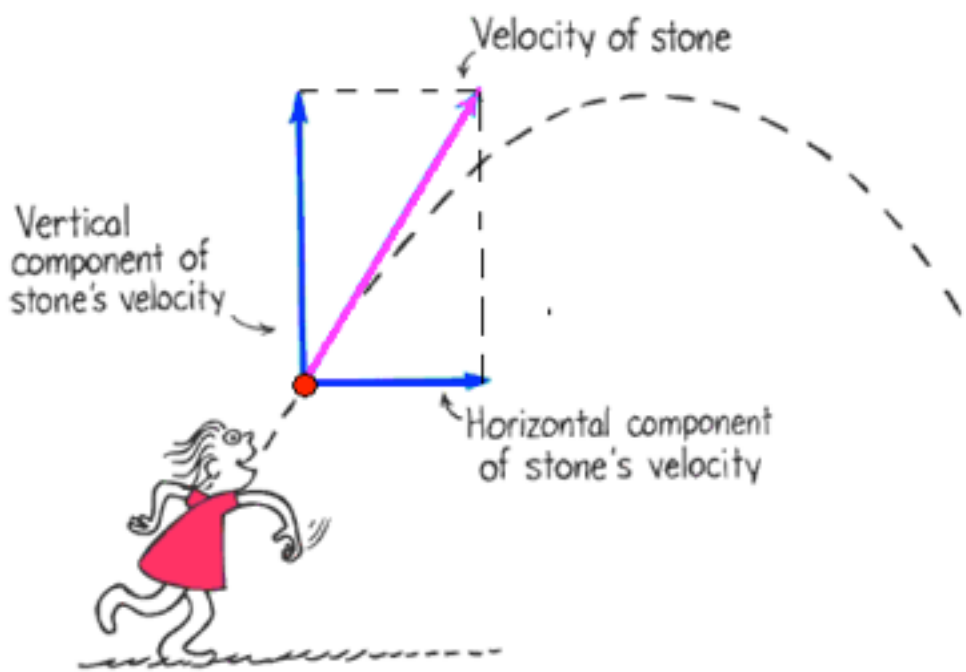


Vectors

Vector components

- Vertical and horizontal components of a vector are perpendicular to each other.
- Determined by resolution.



You run horizontally at 4 m/s in a vertically falling rain that falls at 4 m/s. Relative to you, the raindrops are falling at an angle of

A. 0°.
B. 45°.
C. 53°.
D. 90°.

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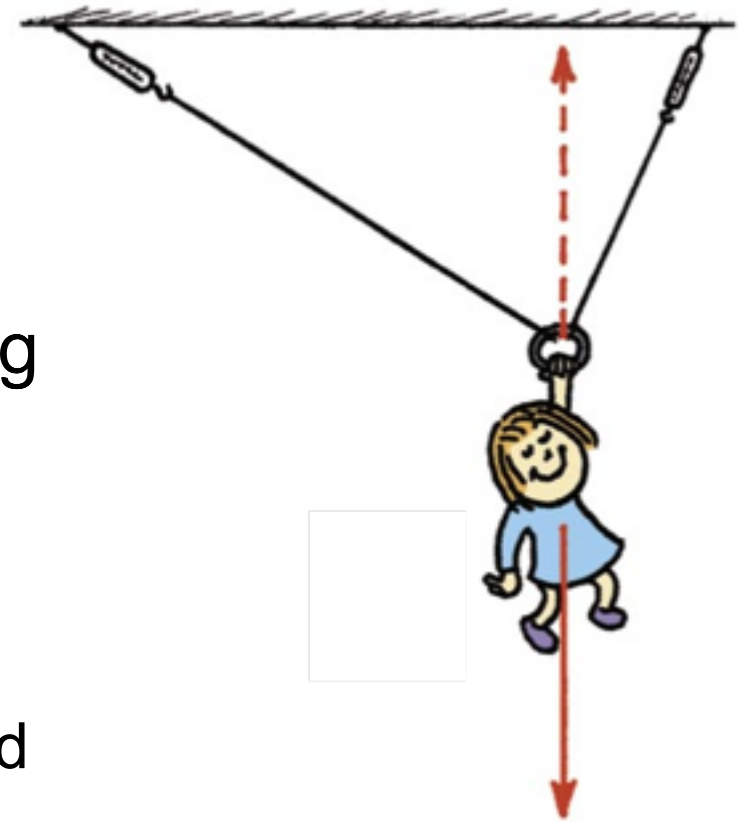
Explanation:
The horizontal 4 m/s and vertical 4 m/s combine by the parallelogram rule to produce a resultant of 5.6 m/s at 45°.

Vectors

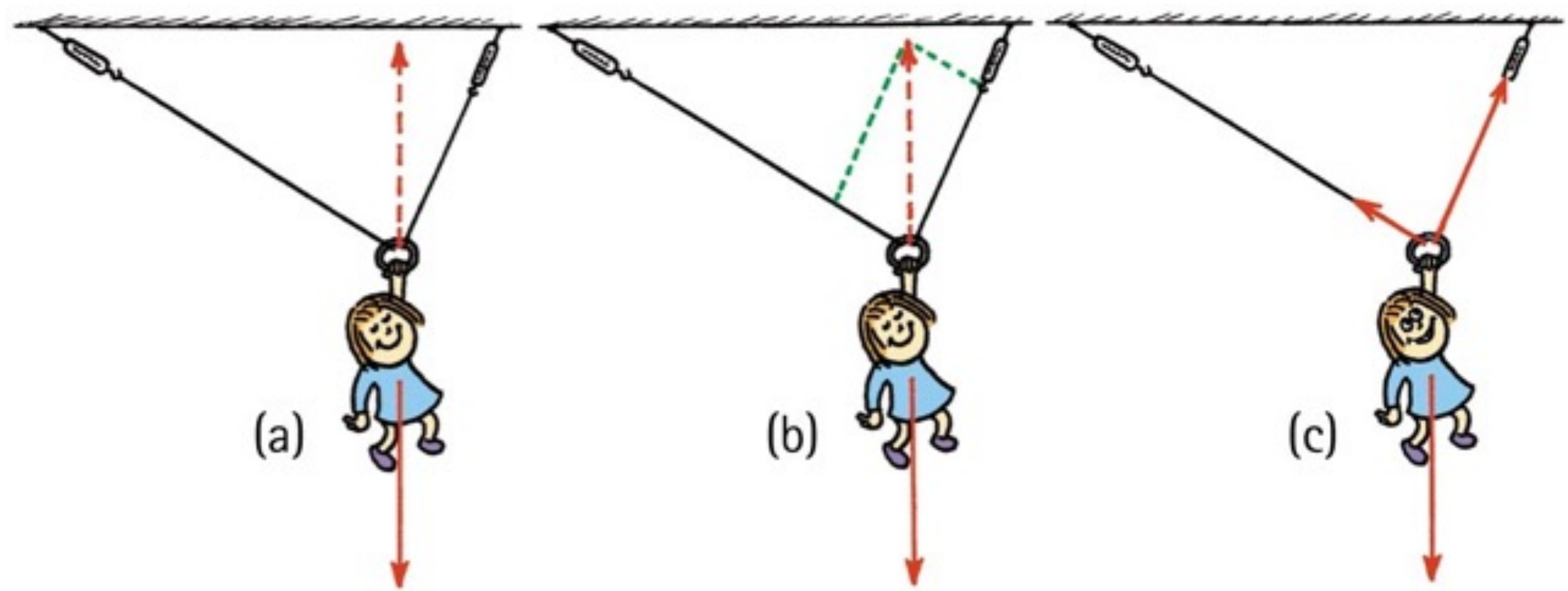
Nellie Newton hangs from a rope as shown.

- Which side has the greater tension?
- There are three forces acting on Nellie:
  - her weight,
  - a tension in the left-hand side of the rope,
  - and a tension in the right-hand side of the rope.



Vectors

- Because of the different angles, different rope tensions will occur in each side.
- Nellie hangs in equilibrium, so her weight is supported by two rope tensions, adding vectorially to be equal and opposite to her weight.
- The parallelogram rule shows that the tension in the right-hand rope is greater than the tension in the left-hand rope.



Chapter 5 Problems

2. If you stand next to a wall on a frictionless skateboard and push the wall with a force of 40 N, how hard does the wall push on you?

   The wall must exert an equal and opposite force or **40N**

   If your mass is 80 kg, show that your acceleration is 0.5 m/s

   .

   a = F/m = 40 N / 80 kg = 40 kg m/s^2 / 80 kg = **0.5 m/s^2**.

Homework

- Read Chapter 5 in Detail.
- Do Exercises 13, 16, 24, 44
- Do Problem 2.

Homework due: Jun 04