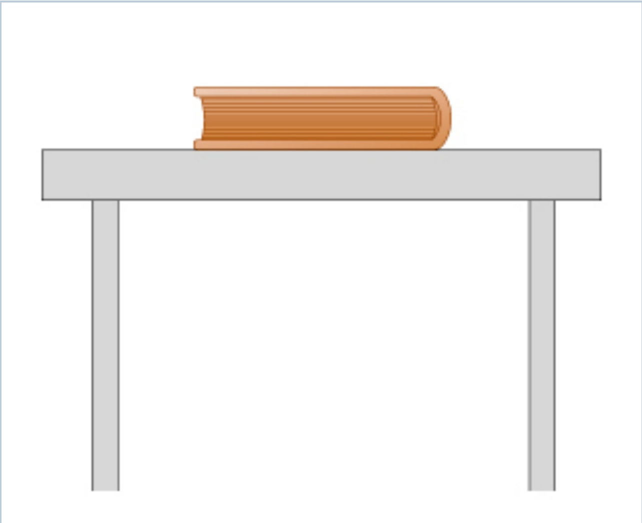
#11 Mass and Weight, Newton's 3rd Law Pre-class

Due: 11:00am on Monday, September 17, 2012

Note: You will receive no credit for late submissions. To learn more, read your instructor's Grading Policy

A Book on a Table

A book weighing 5 N rests on top of a table.



Part A

A downward force of magnitude 5 N is exerted on the book by the force of

ANSWER:

- the table
- gravity .
- inertia

Correct

Part B

An upward force of magnitude _____ is exerted on the _____ by the table.

ANSWER:

- ○ 6 N / table
- ○ 5 N / table
- ◉ 5 N / book
- ○ 6 N / book

Correct

Part C

Do the downward force in Part A and the upward force in Part B constitute a 3rd law pair?

Hint 1. The force of gravity

The force of gravity is another name for the force exerted by the earth (or any astronomical object) on objects near its surface.

Hint 2. Exploring Newton's 3rd law

Indicate whether the following statements about Newton's 3rd law are true, false, or indeterminate.

1. According to Newton's 3rd law, every real force has a unique pair force.
2. The pair force is called a "fictitious force."

3. The force and pair force must act on different point masses.
4. The force and the pair force must always have the same magnitude and must also act in exactly opposite directions.

Enter t for true, f for false, or i for indeterminate for each statement, separating the answers with commas (e.g., if all but the first statement were true, you would enter f,t,t,t).

ANSWER:

t, f, t, t

ANSWER:

- yes
- no

Correct

Part D

The reaction to the force in Part A is a force of magnitude _____, exerted on the _____ by the _____. Its direction is _____ .

Hint 1. The force of gravity

The force of gravity is another name for the force exerted by the earth (or any astronomical object) on objects near its surface.

ANSWER:

- ◉ 5 N / earth / book / upward
- ○ 5 N / book / table / upward
- ○ 5 N / book / earth / upward
- ○ 5 N / earth / book / downward

Correct

Part E

The reaction to the force in Part B is a force of magnitude _____, exerted on the _____ by the _____. Its direction is _____.

ANSWER:

- ○ 5 N / table / book / upward
- ○ 5 N / table / earth / upward
- ○ 5 N / book / table / upward
- ◉ 5 N / table / book / downward
- ○ 5 N / earth / book / downward

Correct

Part F

Which of Newton's laws dictates that the forces in Parts A and B are equal and opposite?

ANSWER:

- Newton's 1st or 2nd law
- Newton's 3rd law

Correct

Since the book is at rest, the net force on it must be zero (1st or 2nd law). This means that the force exerted on it by the earth must be equal and opposite to the force exerted on it by the table.

Part G

Which of Newton's laws dictates that the forces in Parts B and E are equal and opposite?

ANSWER:

- Newton's 1st or 2nd law
- Newton's 3rd law

Correct

Newton's 3rd Law Discussed

Learning Goal:

To understand Newton's 3rd law, which states that a physical interaction always generates a *pair* of forces on the two interacting bodies.

In *Principia*, Newton wrote:
To every action there is always opposed an equal reaction: or, the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

(translation by Cajori)

The phrase after the colon (often omitted from textbooks) makes it clear that this is a statement about the nature of force. The central idea is that physical interactions (e.g., due to gravity, bodies touching, or electric forces) cause forces to arise between *pairs* of bodies. Each pairwise interaction produces a *pair* of opposite forces, one acting on each body. In summary, each physical interaction between two bodies generates a *pair* of forces. Whatever the physical cause of the interaction, the force on body A from body B is equal in magnitude and opposite in direction to the force on body B from body A.

Incidentally, Newton states that the word "action" denotes both (a) the force due to an interaction and (b) the changes in momentum that it imparts to the two interacting bodies. If you haven't learned about momentum, don't worry; for now this is just a statement about the origin of forces.

Mark each of the following statements as true or false. If a statement refers to "two bodies" interacting via some force, you are *not* to assume that these two bodies have the same mass.

Part A

Every force has one and only one 3rd law pair force.

ANSWER:

- (selected) true
- false

Correct

Part B

The two forces in each pair act in opposite directions.

ANSWER:

- ◉ true
- ○ false

Correct

Part C

The two forces in each pair can either both act on the same body or they can act on different bodies.

ANSWER:

- ○ true
- ◉ false

Correct

Part D

The two forces in each pair may have different physical origins (for instance, one of the forces could be due to gravity, and its pair force could be due to friction or electric charge).

ANSWER:

- true
- false (selected)

Correct

Part E

The two forces of a 3rd law pair *always* act on different bodies.

ANSWER:

- true (selected)
- false

Correct

Part F

Given that two bodies interact via some force, the accelerations of these two bodies have the same magnitude but opposite directions. (Assume no other forces act on either body.)

Hint 1. $\vec{F} = m\vec{a}$

Remember $\vec{F} = m\vec{a}$: If the forces are equal in magnitude, must the accelerations also be of equal magnitude?

ANSWER:

- true
- false (selected)

Correct

Newton's 3rd law can be summarixed as follows: A physical interaction (e.g., gravity) operates between two interacting bodies and generates a *pair* of opposite forces, one on each body. It offers you a way to test for real forces (i.e., those that belong on the force side of $\Sigma\vec{F} = m\vec{a}$)--there should be a 3rd law pair force operating on some other body for each real force that acts on the body whose acceleration is under consideration.

Part G

According to Newton's 3rd law, the force on the (smaller) moon due to the (larger) earth is

ANSWER:

- greater in magnitude and antiparallel to the force on the earth due to the moon.
- greater in magnitude and parallel to the force on the earth due to the moon.
- equal in magnitude but antiparallel to the force on the earth due to the moon. (selected)
- equal in magnitude and parallel to the force on the earth due to the moon.
- smaller in magnitude and antiparallel to the force on the earth due to the moon.
- smaller in magnitude and parallel to the force on the earth due to the moon.

Correct

Lifting a Bucket

A 6-kg bucket of water is being pulled straight up by a string at a constant speed.

Part A

What is the tension in the rope?

ANSWER:

- about 42 N
- about 60 N
- about 78 N
- 0 N because the bucket has no acceleration.

Correct

Part B

At a certain point the speed of the bucket begins to change. The bucket now has an upward constant acceleration of magnitude 3 $\mathrm{m/s^2}$. What is the tension in the rope now?

ANSWER:

- about 42 N
- about 60 N
- about 78 N
- It is increasing as the speed increases.

Correct

Now assume that the bucket has a downward acceleration, with a constant acceleration of magnitude 3 $\mathrm{m/s^2}$.

Part C

Now what is the tension in the rope?

ANSWER:

- (selected) about 42 N
- about 60 N
- about 78 N
- It is decreasing as the speed increases.

Correct

Note that the force of tension is not related to the direction or the magnitude of the bucket's *velocity*: Only the *acceleration* matters.

A World-Class Sprinter

World-class sprinters can accelerate out of the starting blocks with an acceleration that is nearly horizontal and has magnitude $15\ \mathrm{m/s^2}$.

Part A

How much horizontal force F must a sprinter of mass 49kg exert on the starting blocks to produce this acceleration?

Express your answer in newtons using two significant figures.

Hint 1. Newton's 2nd law of motion

According to Newton's 2nd law of motion, if a net external force $F_{\rm net}$ acts on a body, the body accelerates, and the net force is equal to the mass m of the body times the acceleration a of the body:

$$F_{\rm net} = ma.$$

ANSWER:

F = 740 $\rm N$

Correct

Part B

Which body exerts the force that propels the sprinter, the blocks or the sprinter?

Hint 1. How to approach the question

To start moving forward, sprinters push backward on the starting blocks with their feet. Newton's 3rd law tells you that the blocks exert a force on the sprinter of the same magnitude, but opposite in direction.

ANSWER:

- the blocks
- the sprinter

Correct

To start moving forward, sprinters push backward on the starting blocks with their feet. As a reaction, the blocks push forward on their feet with a force of the same magnitude. This external force accelerates the sprinter forward.

A Space Walk

Part A

An astronaut is taking a space walk near the shuttle when her safety tether breaks. What should the astronaut do to get back to the shuttle?

Hint 1. How to approach the problem

Newton's 3rd law tells us that forces occur in pairs. Within each pair, the forces, often called *action* and *reaction*, have equal magnitude and opposite direction.

Which of the actions suggested in the problem will result in the force pushing the astronaut back to the shuttle?

ANSWER:

- Attempt to "swim" toward the shuttle.
- Take slow steps toward the shuttle.
- Take a tool from her tool belt and throw it *away* from the shuttle.
- Take the portion of the safety tether still attached to her belt and throw it *toward* the shuttle.

Correct

As the astronaut throws the tool away from the shuttle, she exerts a force in the direction *away* from the shuttle. Then, by Newton's 3rd law, the tool will exert an opposite force on her. Thus, as she throws the tool, a force directed toward the shuttle will act on the astronaut. Newton's 2nd law stipulates that the astronaut would acquire an acceleration toward the shuttle.

Part B

Assuming that the astronaut can throw any tool *with the same force*, what tool should be thrown to get back to the shuttle as **quickly** as possible?

Hint 1. How to approach the problem

Recall that the force acting on the astronaut is equal in magnitude and opposite in direction to the force that she exerts on the tool.

Hint 2. Newton's 2nd law

Newton's 2nd law states that $F = ma$. If force is held constant, then acceleration is inversely proportional to mass. For example, when the same force is applied to objects of different mass, the object with the largest mass will experience the smallest acceleration.

ANSWER:

- ○ The tool with the smallest mass.
- ◉ The tool with the largest mass.
- ○ Any tool, since the mass of the tool would make no difference.

Correct

The force that acts on the astronaut must equal in magnitude the force that she exerts on the tool. Therefore, if she exerts the same force on any tool, the force acting on her will be independent of the mass of the tool. However, the acceleration that the astronaut would acquire is inversely proportional to her mass since she is acted upon by a constant force. If she throws the tool with the largest mass, the remaining mass (the astronaut plus her remaining tools) would be smallest—and the acceleration the greatest!

Part C

If the astronaut throws the tool with a force of 16.0N , what is the magnitude of the acceleration a of the astronaut during the throw? Assume that the total mass of the astronaut after she throws the tool is 80.0kg .

Express your answer in meters per second squared.

Hint 1. Find the force acting on the astronaut

What is the magnitude of the force F acting *on* the astronaut as she throws the tool?

Express your answer in newtons.

ANSWER:

F = 16.0 N

Hint 2. Newton's 2nd law

An object of mass m acted upon by a net force F has an acceleration a given by $F = ma$.

ANSWER:

a = 0.200 $\mathrm{m/s^2}$

Correct

Score Summary:

Your score on this assignment is 92.2%.
You received 23.05 out of a possible total of 25 points.