UTeach Outreach The University of Texas at Austin

# Forces and Motion

**Time of Lesson:** 50- 60 minutes

**Content Standards Addressed in Lesson:**

TEKS6.8B identify and describe the changes in position, direction and speed of an object when acted upon by unbalanced forces (Reporting Category 2 – Supporting Standard)

TEKS8.6A demonstrate and calculate how unbalanced forces change the speed or direction of an object's motion (Reporting Category 2 – Readiness Standard)

TEKS8.6C investigate and describe applications of Newton's law of inertia, law of force and acceleration, and law of action-reaction such as in vehicle restrains, sports activities, amusement park rides, Earth's tectonic activities and rocket launches (Reporting Category 2 – Readiness Standard)

NSES (1996) **Grades 5-8 – Content Standard B**

- The motion of an object can be described by its position, direction of motion, and speed.
- An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.
- If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

**Scientific Investigation and Reasoning Skills Addressed in Lesson:**

TEKS6.2E and 8.2E analyze data to formulate reasonable explanations, communicate valid conclusions supported by data and predict trends

TEKS6.3A and 8.3A in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing

TEKS6.3B and 8.3B use models to represent aspects of the natural world such as an atom, a molecule, space, or a geologic feature

TEKS6.3C and 8.3C identify advantages and limitations of models such as size, scale, properties, and materials

TEKS6.3D and 8.3D relate the impact of research on scientific thought and society, including the history of science and contributions of scientists as related to the content

TEKS8.4A use appropriate tools to collect, record and analyze information, including computers

NSES (1996) **Grades 5-8 – Content Standard A**

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.

## I. Student Prerequisite Skills/Understandings

1. A basic understanding of balanced and unbalanced forces.
2. The ability to distinguish between velocity, position, acceleration and speed.
3. Knowledge of friction being a force that opposes the motion of an object.

## II. Objectives: Students will be able to

1. Identify when an object is being acted upon by unbalanced forces.
2. Predict the change in motion when a force is applied to an object.
3. Demonstrate an understanding of how unbalanced forces relate to the total force applied to an object.
4. Utilize Newton's Law of Inertia (velocity remains constant unless acted upon by an unbalanced force) to describe the motion of an object when acted upon by an unbalanced force.
5. Identify the advantages and limitations of using the "Force and Motion" PhET simulation.
6. Identify the contributions of Galileo Galilei and Isaac Newton to the study of motion.

## III. Supplies Needed

Experiment 1: per class (if using as a demo) or per pair of students
1 plastic cup
1 penny
1 playing card

Explore: per pair of students
1 computer

Elaborate: per pair of students
30 blocks
Piece (12 inches x 12 inches) of cardboard

# 5E Organization

## Engage (5 minutes)

**Content Focus:** A force is a push or a pull.

Teacher shows three video clips to students and asks students to share their observations. Bow and Arrow: http://youtu.be/BWZ4WJQ-624 Triple Jump: http://youtu.be/zCvFz1oCNQ4 Motorcycle Coming to Stop: http://youtu.be/Mk7b2oWQPR0. The teacher guides the students to define a force as a push or a pull .

| Questions to guide students' learning and thinking | Questions to gather information about students' understanding and learning |
|---|---|
| • What did you observe in each video clip?<br>• What did the person do in each clip? | • What did the archer provide when he pulled the bow?<br>• When the motorcyclist stopped what did the breaks provide?<br>• What did the jumper's legs do to the ground? |

Teacher introduces the **Question of the Day**: "How can forces affect the motion of an object?

- ✓ **Checkpoint:** Students can describe their observations and explain that a force is a push or a pull.

## Explore – Brief History (15 minutes)

**Content Focus:** Gravity is a force that pulls objects towards the center of the Earth.
**Reasoning Skills:** relate the impact of research on scientific thought and society, including the history of science and contributions of scientists as related to the content

Teacher begins a discussion on history and introduces that Galileo discovered the idea that objects fall at the same rate. Teacher explains that Galileo thought that gravity was unique to earth. Teacher discusses how Newton believed that gravity was not unique to earth.

| Questions to guide students' learning and thinking | Questions to gather information about students' understanding and learning |
|---|---|
| • Where have you heard of Galileo before?<br>• What is Newton famous for? | • What do you think it would mean if gravity was unique to earth?<br>• Drop an object. What force was responsible for pulling the object to the ground?<br>• Why don't objects keep falling when dropped? |

If needed, teacher defines "at rest" and "in motion" while giving examples. Students relate at rest and in motion to balanced and unbalanced forces. The terms net force and total force are introduced. Students describe balanced and unbalanced forces in terms of net force and total force.

| Questions to guide students' learning and thinking | Questions to gather information about students' understanding and learning |
|---|---|
| • What are a few objects around the room that are at rest?<br>• When an object is at rest are the forces balanced or unbalanced? | • How would you define at rest?<br>• If there are balanced forces on an object, what would we get if we added up all the forces?<br>• What does that tell you about an object that is at rest, what is the sum of its forces?<br>• If the net force is zero, are the forces balanced or unbalanced? How do you know? |

✓ **Checkpoint:** Students can identify the contributions of Galileo Galilei and Isaac Newton to the study of motion. Students explain what the total force of an object is and how it relates to forces being balanced or unbalanced.

## Explore – *Experiment 1 Penny Flick* (10 minutes)

**Content Focus:** identify and describe the changes in position, direction and speed of an object when acted upon by unbalanced forces, demonstrate how unbalanced forces change the speed or direction of an object's motion, investigate and describe applications of Newton's law of inertia,
**Investigation Skills:** use appropriate tools to collect, record and analyze information

Teacher passes out materials to pairs of students and Forces and Motion Experiment Sheet. Teacher demonstrates how to put penny on top of playing card, which is resting on top of cup. Teacher or students flick the playing card. Teacher allows students to answer questions on sheet. Teacher leads discussion on when the penny experienced balanced and unbalanced forces and relates experiment to Newton's First Law of Motion.

| Questions to guide students' learning and thinking | Questions to gather information about students' understanding and learning |
|---|---|
| • What observations can you make about the penny resting on the playing card?<br>• What happened during your experiment?<br>• When the playing card is flicked, what do you apply to the card?<br>• What force acted on the penny?<br>• What was at rest? When?<br>• What was in motion? When? | • Are the forces acting on the penny balanced or unbalanced before you flick the card?<br>• When a force is applied, by flicking the playing card, are the forces acting on the playing card balanced or unbalanced, why?<br>• What is the net force on the penny before I flick the playing card? As it falls into the cup?<br>• Define first law of motion. How does Newton's first law relate to what we just saw with the playing card? |

Teacher points out that the penny does move slightly forward but gravity was the more significant force and pulled the penny into the cup.

✓ **Checkpoint:** Students can explain the results of their investigation relating their observations to Newton's first law of motion.

## Explore –*Forces and Motion* PhET Simulation (30 minutes)

**Content Focus:** identify and describe the changes in position, direction and speed of an object when acted upon by unbalanced forces, demonstrate how unbalanced forces change the speed or direction of an object's motion, investigate and describe applications of Newton's law of inertia,
**Investigation and Reasoning Skills:** analyze data to formulate reasonable explanations, communicate valid conclusions supported by data and predict trends, analyze scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, use models to represent aspects of the natural world, identify advantages and limitations of models, use appropriate tools to collect, record and analyze information, including computers

Teacher explains that the students will now begin an investigation using a computer simulation. Teacher gives the students five minutes to play with the simulation then collects students' attention to front of class. Simulation is projected in front of class and teacher selects a few students to point out what they have discovered. Students receive the Forces and Motion PhET Simulation Sheet and are given 30 minutes to complete the activity in pairs.

| **Questions to guide students' learning and thinking** | **Questions to gather information about students' understanding and learning** |
|---|---|
| • How can you clear the screen?<br>• How can you move the box?<br>• How do you think friction affects the motion of an object?<br>• How does the size of the push relate to the motion of the crate?<br>• How does the motion of the crate change on different surfaces? | • How is the simulation similar/different from real life?<br>• What are a few limitations of the simulation?<br>• If you wanted to push something very far with little force, what surface would you prefer? Why?<br>• How does the size of the push relate to the acceleration of the crate?<br>• When do you think simulations are useful for scientists?<br>• How could you design an experiment to test what you see in the simulation? |

✓ **Checkpoint:** Students have completed their investigation sheets.

## Explain (15 minutes)

**Content Focus:** identify and describe the changes in position, direction and speed of an object when acted upon by unbalanced forces, demonstrate how unbalanced forces change the speed or direction of an object's motion, investigate and describe applications of Newton's law of inertia

**Reasoning Skills:** analyze data to formulate reasonable explanations, communicate valid conclusions supported by data and predict trends, analyze scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, identify advantages and limitations of models

Teacher leads class discussion on the students' results from their exploration. Teacher introduces the concept of positive and negative forces allowing the students to use their simulation sheets as evidence. Teacher defines friction as a force that opposes the motion of an object. Teacher allows students to explain how balanced and unbalanced forces relate to the motion of the object. Students describe how the total force relates to the motion of an object and what contributes to the total force when friction is and is not present. Students discuss the advantages and limitations of the simulation in pairs.

| **Questions to guide students' learning and thinking** | **Questions to gather information about students' understanding and learning** |
|---|---|
| • What did you notice appeared on the screen as you attempted to push the box?<br>• As you pushed the crate to the right, did positive or negative values appear in the force dialog box?<br>• How about as you pushed the crate to the left?<br>• How did the arrows change as the crate moved?<br>• How does the direction of the total force arrow relate to the direction the crate moves?<br>• When the surface is ice what force is missing from when the surface was wood?<br>• How was the motion of the crate different when ice is the surface?<br>• Why is there a small change in speed when a small force is applied? What evidence do you have?<br>• Why is there a big change in speed with a larger push? What evidence do you have?<br>• What are a few advantages/disadvantages of using a simulation? | • Why do you think scientists use positive and negative values to represent forces?<br>• What did you notice about the length of the arrows once you've applied enough force to push the crate? What does that tell you about how the applied force and friction force relate to the motion of an object?<br>• Are the forces in balance or unbalanced when the crate moves? How do you know?<br>• What general statement can we make about the relationship between the applied force and how fast an object changes speed?<br>• How would you change the simulation so that it has fewer limitations? |

✓ **Checkpoint:** Students are able to explain the results of their investigation using terms, such as, total force, balanced and unbalanced forces and acceleration. Students can identify the advantages and limitations of using the simulation.

## Elaborate (10 minutes)

**Content Focus:** relate a real world example to laboratory experiences

Teacher discusses the October 23, 2011 earthquake in Turkey using a PowerPoint. Students hypothesize what the job responsibilities of an earthquake engineer are. Students complete a hands-on investigation where students build a tower out of wooden blocks to represent buildings and a cardboard box top represents the earth. Teacher instructs students to shake the cardboard and students make observations using newly acquired terms from their previous exploration.

| Questions to guide students' learning and thinking | Questions to gather information about students' understanding and learning |
|---|---|
| • What do you think causes earthquakes?<br>• [using map on Slide 3] What two plates on this map could have been responsible for the earthquake in Turkey?<br>• [using Slide 5] What do you think the different colors represent?<br>• What do you think an earthquake engineer does?<br>• What did you notice about how the size of the tower relates to the movement of your tower? | • When are the forces balanced and unbalanced during your earthquake?<br>• What forces are acting on the tower before and after you shake the cardboard?<br>• How is this model similar/different from a real earthquake?<br>• What changes could you make to this model to make it a better representation of the natural world? |

- ✓ **Checkpoint**: Students can describe their hands-on investigation using terms from their previous exploration.

## Evaluate

Use evaluations in attached documents.

Name: ______________________

## Forces and Motion Experiment

### Materials

- 1 playing card
- 1 cup
- 1 penny

### Procedure

1. Set the playing card on top of the cup.
2. Set the penny on top of the playing card.
3. Flick the playing card.
4. Observe what happens!

### Questions

1. What force(s) acted on the playing card?

2. What force(s) acted on the penny?

3. In this experiment, what was at rest?

4. In this experiment, what was in motion?

5. Why didn't the penny move sideways as much as the card?

Newton's 1st Law:

*An object at rest remains at _______ unless acted upon by an ______ force and an object in motion remains in _______ unless acted upon by an ______ force.*

Name: _________________________

### *Forces and Motion Basics* PhET Simulation

1) Fill in the following blanks with your partner.

a) The **total force** is the _______________ of all the forces.

b) An object's **acceleration** is an object's _____________ in speed.

c) **Friction** is a force that ________ the motion of an object.

2) **Play** with the simulation for five minutes. Be prepared to share what you have discovered!

3) a) **Explore** how the **"Applied Force"** and **"Friction Force"** arrows change as you apply different amounts of force.
b) Use the table to record your observations.

| How much force is applied? | Is the applied force **larger**, **smaller** or **equal** to the friction force? | The forces on the crate are… **(circle one)** | Observations – what evidence do you have for your selections? |
|---|---|---|---|
| | | balanced<br>unbalanced | |
| | | balanced<br>unbalanced | |
| | | balanced<br>unbalanced | |

4) a) **Explore** how the **"Total Force"** arrow depends on how the crate moves.
b) As the object moves, what happens to the total force arrow?

______________________________________________________________________

______________________________________________________________________

5) a) **Explore** what happens when you **change the surface**.
b) Fill in the table with your observations.

| **Surface** | **Observations** |
|---|---|
| Ice (no friction) | |
| Friction | |

c) The simulation assumes that ice is a frictionless surface. To have a truly frictionless environment what else would you need to consider?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

6) a) **Explore** how the crate's speed changes as you apply more and less force to the crate.
b) Fill in the table with your observations.

| Size of push | Amount of change in speed **(circle one)** |
|---|---|
|  | large change in speed<br>small change in speed |
|  | large change in speed<br>small change in speed |

c) What can you say about how the amount of force applied affects an object's **acceleration**?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

Name: ___________________________

## Forces and Motion Evaluation Questions

1. When the forces on an object are balanced, what is the total force?
   a) 1 Newton to the left.
   b) 1 Newton to the right.
   c) Unable to determine without knowing the forces involved.
   d) 0 Newtons.

2. An object experiences a force of 5.0 Newtons pushing towards the left and a force of 5.0 Newtons pushing towards the right. These forces are
   a) balanced.
   b) unbalanced.
   c) complimentary.
   d) inverse.

3. An object is initially at rest on a **frictionless** surface. We apply a force of 1.0 Newton to the right. What happens?
   a) The object was not moving, so it starts moving to the right.
   b) The object pushes back with a force of 1.0 Newton, so nothing happens.
   c) The object moves to the right and will continue to move to the right at a constant speed.
   d) The object slows down while moving to the right.

4. The table below shows the acceleration of a 50kg crate in response to applied forces. Identify which acceleration should be used in the missing spot.

   a) 0 m/s$^2$
   b) 0.67 m/s$^2$
   c) 7.02 m/s$^2$
   d) 1.33 m/s$^2$

| Applied Force (N) | Acceleration (m/s$^2$) |
|---|---|
| 0.5 | ? |
| 1.0 | 2.67 |
| 2.0 | 5.33 |
| 3.0 | 8 |

5. To test how an object moves without friction, you must
   a) make sure the object does not touch anything (including air).
   b) put the object on ice.
   c) take away friction by lubricating the surface the object is on.
   d) make the object move very fast to reduce the effect of friction.

6. How did Galileo’s study of motion differ from Newton’s? Why do we use Newton’s physics today instead of Galileo’s?

Name: _________KEY_________

## Forces and Motion Experiment

### Materials

- 1 playing card
- 1 cup
- 1 penny

### Procedure

1. Set the playing card on top of the cup.
2. Set the penny on top of the playing card.
3. Flick the playing card.
4. Observe what happens!

### Questions

1. What force(s) acted on the playing card?

   Gravity, my hand.

2. What force(s) acted on the penny?

   Gravity, the playing card transmitted a small part of the force from my hand.

3. In this experiment, what was at rest?

   The cup, playing card and penny before I flicked, the cup when I flicked the playing card, and the cup, playing card and penny after they fall.

4. In this experiment, what was in motion?

   When I flicked the playing card, the card and penny were in motion. They stayed in motion until they hit the ground.

5. Why didn't the penny move sideways as much as the card?

   The friction between the penny and card was small, so only a small amount of the force of my hand was transmitted. Since it was a small amount of force, the penny only moved a little.

Newton's 1st Law:

*An object at rest remains at _rest__ unless acted upon by an _unbalanced_ force and an object in motion remains in _motion_ unless acted upon by an _unbalanced_ force.*

Name: ___________KEY_______________

## *Forces and Motion Basics* PhET Simulation

1) Fill in the following blanks with your partner.

a) The **total force** is the ____sum________ of all the forces.

b) An object's **acceleration** is an object's ____change____ in velocity.

c) **Friction** is a force that _reduces_ the motion of an object.

2) **Play** with the simulation for five minutes. Be prepared to share what you have discovered!

3) a) **Explore** how the **"Applied Force"** and **"Friction Force"** arrows change as you apply different amounts of force.
b) Use the table to record your observations.

| How much force is applied? | Is the applied force **larger**, **smaller** or **equal** to the friction force? | The forces on the crate are… **(circle one)** | Observations – what evidence do you have for your selections? |
|---|---|---|---|
| 200 Newtons | Equal to the friction force, in the opposite direction. | [✓ balanced]<br>unbalanced | The box doesn't move, and the total force arrow is zero. |
| -400 Newtons | Equal to the friction force, in the opposite direction. | [✓ balanced]<br>unbalanced | The box doesn't move, and the total force arrow is zero. |
| 500 Newtons | Greater than the friction force, in the opposite direction. | balanced<br>[✓ unbalanced] | The box moves, and the total force arrow points to the right. |

4) a) **Explore** how the **"Total Force"** arrow depends on how the crate moves.
b) As the object moves, what happens to the total force arrow?
__If the crate isn't moving, the total force arrow is zero. The force arrow points to the right if a positive force is applied and the object is moving. It points to the left if a negative force is applied and the object is moving. When we stop applying the force, the force arrow points in the opposite direction of motion, and is the same size all the time.________________________________________

5) a) **Explore** what happens when you **change the surface**.
b) Fill in the table with your observations.

| **Surface** | **Observations** |
|---|---|
| Ice (no friction) | Any force will cause the crate to move and it only stops if it collides with something else. |
| Friction | The crate must get a certain amount of force to start moving and when the force stops, friction causes the crate to slow down. |

c) The simulation assumes that ice is a frictionless surface. To have a truly frictionless environment what else would you need to consider?

__The object touches nothing.____________________________________________

______________________________________________________________________

6) a) **Explore** how the crate's speed changes as you apply more and less force to the crate.
b) Fill in the table with your observations.

| Size of push | Amount of change in speed **(circle one)** |
|---|---|
|  | [✓ large change in speed]<br>small change in speed |
|  | large change in speed<br>[✓ small change in speed] |

c) What can you say about how the amount of force applied affects an object's **acceleration**?

__The greater the unbalanced force applied on an object, the greater the acceleration of the object.______________________________________________

______________________________________________________________________

Name: ___________________________

# Forces and Motion Evaluation Questions

Key – numbers reference learning goal #

1. When the forces on an object are balanced, what is the total force? (3)
   a) 1 Newton to the left.
   b) 1 Newton to the right.
   c) Unable to determine without knowing the forces involved.
   d) 0 Newtons.

2. An object experiences a force of 5.0 Newtons pushing towards the left and a force of 5.0 Newtons pushing towards the right. These forces are (1)
   a) balanced.
   b) unbalanced.
   c) complimentary.
   d) inverse.

3. An object is initially at rest on a frictionless surface. We apply a force of 1 Newton to the right. What happens? (2, 4)
   a) The object was not moving, so it starts to move towards the right.
   b) The object pushes back with a force of 1 Newton, so nothing happens.
   c) The object moves to the right and will continue to move to the right at a constant speed.
   d) The object slows down while moving to the right.

4. The table below shows the acceleration of a 50kg crate in response to applied forces. Identify which acceleration should be used in the missing spot.

   a) 0 $m/s^2$
   b) 0.67 $m/s^2$
   c) 7.02 $m/s^2$
   d) 1.33 $m/s^2$

| Applied Force (N) | Acceleration ($m/s^2$) |
|---|---|
| 0.5 | ? |
| 1.0 | 2.67 |
| 2.0 | 5.33 |
| 3.0 | 8 |

5. To test how an object moves without friction, you must (5)
   a) make sure the object does not touch anything (including air).
   b) put the object on ice.
   c) take away friction by lubricating the surface the object is on.
   d) make the object move very fast to reduce the effect of friction.

6. How did Galileo's study of motion differ from Newton's? Why do we use Newton's physics today instead of Galileo's? (6)
   Galileo thought the gravity he measured on Earth was unique; Newton showed that the force of gravity could be calculated for any place in the universe. Newton's physics applies to more situations, which is why we use it.