



Hot Air Balloons  
Balloons and Buoyancy PhET Simulation

**Length of Lesson:** PhET simulation: 50 minutes – 1 hr; Balloon construction: 30 minutes; Balloon launch: 30 minutes

**Content Standards Addressed in Lesson:**

TEKS6.9A investigate methods of thermal energy transfer, including conduction, convection, and radiation

TEKS6.9B verify through investigations that thermal energy moves in a predictable pattern from warmer to cooler until all the substances attain the same temperature such as an ice cube melting

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 restraints, sports activities, amusement park rides, Earth's tectonic activities and rocket launches

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

- A substance has characteristic properties, such as **density**, a boiling point, and solubility, all of which are independent of the amount of the sample.
- Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

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

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

TEKS6&8.3A in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student

TEKS6&8.3B use models to represent aspects of the natural world such as a model of Earth's layers

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

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**

- Students have a conceptual understanding of density.
- Students have a basic understanding of the units atmosphere and Kelvin.

### **II. Objectives: Students will be able to**

1. Describe how hot air balloons rise and determine the conditions necessary to keep a balloon afloat by using a computer simulation (*Balloons and Buoyancy* PhET).
2. Explain the principle that warm air expands when heated and how heat is transferred through convection.
3. Construct and launch a hot air balloon.
4. Generalize the relationships between temperature, volume and pressure.

### **III. Supplies Needed**

Per pair

- 1 computer
- 1 glue stick
- a few meters of string
- 12 sheets of large non-flammable tissue paper
- templates/patterns (petal shaped)
- 1 manila folder or similar weighted paper

Per class

- Hot air balloon launcher
- Hand-held blow dryer
- Ping-Pong ball

### **IV. Advanced Preparation**

- Have hot air balloon templates cut
- Have teacher and student computers set up to <http://phet.colorado.edu/en/simulation/balloons-and-buoyancy>
- Record current air pressure and temperature for launch area

# 5E Organization

## Engage (5 minutes)

**Content Focus:** Air can move things. Air pushes on objects.

Show a brief demonstration with a Ping-Pong ball and a hair dryer. Students are asked what they think will happen when the hair dryer is turned on and the Ping-Pong ball is placed over the mouth of the hair dryer. Turn on the hair dryer and ball should “float.” Students discuss what their observations tell them about air (i.e. air pushes, air can move things). Introduce Question of the Day, “How does a hot air balloon stay in the air?”

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
<ul style="list-style-type: none"><li>• What do you predict will happen when the hair dryer is turned on?</li><li>• What is happening?</li></ul>	<ul style="list-style-type: none"><li>• Why do you think the ball is being held in the air by the hair dryer?</li><li>• Based on what you just observed with the Ping-Pong ball, what information do you know about air?</li></ul>

✓ **Checkpoint:** Students can describe their observations and Question of the Day is introduced.

## Explore – Part 1 Balloon Construction (30-35 minutes)

Students take ownership of the lesson by constructing their own hot air balloons. Form groups of three and passes out materials to each group. Demonstrate steps, as needed. Emphasize that the students should work as a team to complete the task

✓ **Checkpoint:** Students have completed construction of their hot air balloons.

## Explore – Part 2 *Balloons and Buoyancy* PhET Simulation (30-35 minutes)

**Content Focus:** investigate methods of thermal energy transfer, including conduction and convection, verify through investigations using the PhET simulation that thermal energy moves in a predictable pattern from warmer to cooler until all the substances attain the same temperature such as an ice cube melting

**Investigation Skills:** analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends, use models (PhET simulation) to represent aspects of the natural world such as a model of Earth's layers, identify advantages and limitations of models such as size, scale, properties, and materials

Explain that the students that they will be using a computer simulation titled “Balloons and Buoyancy” to explore how the air particles inside and outside of their hot air balloon will behave. Group students into pairs and assign each a role of either Driver or Navigator. Discuss

responsibilities of each role. Pass out laptops and allow students five minutes for “open-play.” Discuss how the simulation is different from the demo with the Ping-Pong ball (i.e. you can see the air particles, etc). Collect students’ attention using “half-mast” or “acute angles” method. Allow a few students to demonstrate what they have observed using the teacher projected computer. Pass out the “Balloons and Buoyancy” PhET Sheet and give students the temperature and atmospheric pressure present at their launch for them to use in the final challenge. Write these values on the board so the students can reference them later. Give students 30 minutes to complete their investigations.

Questions to guide students’ learning and thinking	Questions to gather information about students’ understanding and learning
<ul style="list-style-type: none"> <li>• What does the driver of a car do?</li> <li>• What do you think the job role of Driver will do today with the computers?</li> <li>• What does a navigator do?</li> <li>• What do you think the job role of Navigator will do today with the computers?</li> <li>• What is happening when you pump the handle? What is different?</li> <li>• What patterns do you observe about the balloon’s movement?</li> <li>• What changes do you observe when you add heat?</li> <li>• When heat was added what happened to the pressure?</li> <li>• What is happening to the dials as you change the volume of the container?</li> <li>• What do you notice when you move the “Layer tool” up and down?</li> <li>• What happens when you add heat to the balloon?</li> <li>• What changes do you observe in the balloon as you add heat?</li> </ul>	<ul style="list-style-type: none"> <li>• What does the computer simulation show that is different from the demonstration with the Ping-Pong ball?</li> <li>• What is changing inside of the container when you pump the handle?</li> <li>• What can you infer about air based on the movement of the balloon?</li> <li>• If as the temperature rises, the pressure rises, what does that tell you about the relationship between temperature and pressure?</li> <li>• What changes do you observe when you change the volume of the container? What does this tell you about how volume affects temperature and pressure?</li> <li>• What parameter is responsible for making the lid pop off? Why?</li> <li>• Is it possible to get a high temperature without a high pressure? How?</li> <li>• Where are most of the particles? Why do you think this is so?</li> <li>• How does the particles’ behavior inside the balloon change as heat is increased? Decreased? Why?</li> <li>• What happens to the energy inside the balloon as heat is added/removed?</li> <li>• What types of energy are present in this simulation?</li> </ul>

✓ **Checkpoint:** Students have completed their investigations using the computer simulation.

### Explain (10 minutes)

**Content Focus:** investigate methods of thermal energy transfer, including conduction and convection

**Investigation and Reasoning Skills:** in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student

Begin a class discussion on students' findings from Explore Part 2. Discuss the following topics relating the students' experiences to new/reviewed concepts: the movement of the air particles as heat is increased/decreased; how the addition/removal of heat contributes to the kinetic energy of the air particles; connections between pressure, volume and temperature; how the density of the air changed as it was heated and cooled; buoyant force; convection currents and thermal energy.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
<ul style="list-style-type: none"> <li>• How does the movement of air particles change when it is heated up?</li> <li>• How did the pressure and volume change as the balloon was heated up?</li> <li>• In what direction does gravity always pull on the Earth?</li> <li>• What did you notice about the particles <i>inside</i> the balloon when you added heat?</li> <li>• What do you think of when you hear the word buoyancy?</li> <li>• How do the particles interact with each other?</li> <li>• How could we make the balloon come down?</li> </ul>	<ul style="list-style-type: none"> <li>• If the movement of the particles changes, what can you infer about the kinetic energy of the particles?</li> <li>• What happened to the density of the air particles as the particles were heated? Use your understanding of the formula for density to explain your observations. Keep in mind that the mass of the particles in the container only changes when you add more particles.</li> <li>• What conclusions can we form about the density of the air <i>inside</i> the balloon when it is heated?</li> <li>• What keeps the balloon at the bottom of the container before you add heat?</li> <li>• What fluid is our balloon floating in?</li> <li>• If the balloon rises, what does that tell us about the forces present?</li> <li>• How did having a hole in the balloon affect how it floats?</li> <li>• When was the balloon the least dense? At the top of the container or the bottom? How do you know?</li> <li>• What type(s) of energy are present in the balloon? In the container?</li> <li>• What type of heat transfer happens in our hot air balloon?</li> <li>• Why is it important to learn about air? Convection currents? Hot air balloons?</li> </ul>

✓ **Checkpoint:** Students have related their experiences with the simulation to new content learned.

### Explore – Part 3 Hot Air Balloon Launch (30 minutes)

**Content Focus:** investigate methods of thermal energy transfer, including conduction and convection, verify through investigations that thermal energy moves in a predictable pattern from warmer to cooler until all the substances attain the same temperature such as an ice cube melting, investigate and describe applications of Newton’s law of inertia, law of force and acceleration, and law of action-reaction

**Investigation and Reasoning Skills:** analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends

Students launch their hot air balloons. Monitor balloon launches and ask probing questions relating the simulation to the hands-on experiment. Reintroduce the Question of the Day and allow students to develop an answer based on their observations/evidence in both experiments.

Questions to guide students’ learning and thinking	Questions to gather information about students’ understanding and learning
<ul style="list-style-type: none"> <li>• What could happen if there was a hole in the top of the hot air balloon? How would that affect its flight?</li> <li>• What is the difference between room temperature air and hot air?</li> <li>• Recall what we saw with the simulation, when heat was added, what happened to the location of the air particles?</li> <li>• How are our hot air balloons different from a larger hot air balloon?</li> <li>• How does the volume of an object affect its density?</li> </ul>	<ul style="list-style-type: none"> <li>• What happens to the average speed of the air particles as they are heated up?</li> <li>• What happens to the energy of the air particles when they are heated? Why?</li> <li>• Why is hot air used to launch our balloons?</li> <li>• What makes hot air different from colder air?</li> <li>• How could this be an advantage for our hot air balloon launch?</li> <li>• How would the flight of the hot air balloon change if we launched our balloons on a windy day?</li> <li>• How is gravity affecting the motion of our balloon?</li> <li>• What changes in our launch conditions would we have to make if we wanted to launch a heavier hot air balloon?</li> <li>• What causes our balloon to sink after it has been in flight for a while?</li> <li>• What makes a hot air balloon stay in the air?</li> </ul>

✓ **Checkpoint:** All students have launched their balloons and connections were made between the simulation and the hands-on investigation.

### Elaborate (5-10 minutes)

**Content Focus:** The affects of buoyancy are different in different environments.

Discuss how there is little air over the Himalayas. Have the students predict what changes they would have to make to the launching of their balloon if it was launched over the Himalayas. Use the simulation to verify their predictions. Ask students if their balloon could be launched on the Moon.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
<ul style="list-style-type: none"><li>• What do we know about air?</li><li>• What characteristics make the Moon different from Earth?</li></ul>	<ul style="list-style-type: none"><li>• Could you use a hot air balloon to fly over the Himalayas where there is very little air? Explain</li><li>• What about on the Moon? The Moon does not have an atmosphere, so would a hot air balloon fly? Why or why not?</li></ul>

- ✓ **Checkpoint:** Students have discussed the conditions necessary to launch their balloon on the Moon or over the Himalayas.

## Evaluate

Use evaluations in attached documents.

Question of the Day

What makes  
a hot air  
balloon stay  
in the air?



Name: \_\_\_\_\_

**Balloons and Buoyancy PhET Sheet**

**Important Terms:**  
**Kelvin (K):** a unit for measuring temperature  
**Atmosphere (atm):** a unit for measuring pressure

1) What is the initial air pressure? What does that tell you?

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2) **Make the lid pop off** and use the table below to record your findings.

Trial #	Pressure at time of lid popping off (atm)	Did you increase or decrease the size of the box?	Temperature at time of lid popping off (K)	What was your method?
1		stayed the same increased decreased		
2		stayed the same increased decreased		
3		stayed the same increased decreased		

2) a) Find three ways to make the temperature increase inside the simulation, if the **same amount of air particles are present**.

How can you make sure the same amount of air particles are present?

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What did you do?	As temperature increased pressure....	As temperature increased the density of the air....
	stayed the same increased decreased	stayed the same increased decreased
	stayed the same increased decreased	stayed the same increased decreased

	stayed the same increased decreased	stayed the same increased decreased
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b) In a complete sentence summarize what happens the temperature increases in the simulation

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3) **Challenge:** Now, the simulator is your hot air balloon! In our experiment, we will be heating the inside of the hot air balloon. You want to make sure that your balloon floats above the bottom of the container. You **DO NOT** want your balloon to touch the ceiling. Use the *stopwatch* and make sure your balloon can float for 30 pico-seconds. Think about how you can keep the simulation to have similar conditions to Earth (\*\*hint\*\*) Does gravity change on Earth?)

### Current Launch Conditions

Today the temperature is \_\_\_\_\_. In Kelvins this is \_\_\_\_\_. The atmospheric pressure is \_\_\_\_\_.

Explain your methods for keeping your balloon floating for 30 picoseconds. Include any issues or problems that you had and what you did to fix them.

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### Fill in the table with your observations

As the hot air balloon was heated the particles moved....	As the hot air balloon was heated the <i>kinetic energy</i> of the particles inside the balloon...	As the hot air balloon was heated the <i>thermal energy</i> of the particles inside the balloon...
at the same speed faster slower	stayed the same increased decreased	stayed the same increased decreased

Name: \_\_\_\_\_

### Hot Air Balloons! Post-lab

#### Important Equations

$$\text{Temperature} = \text{Pressure} \times \text{Volume}$$

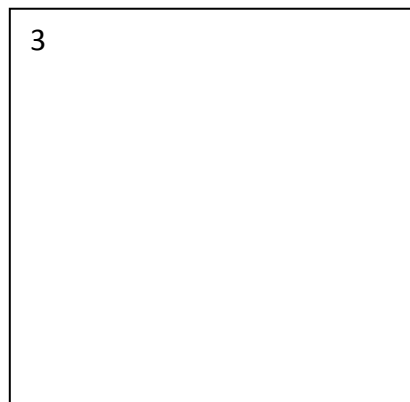
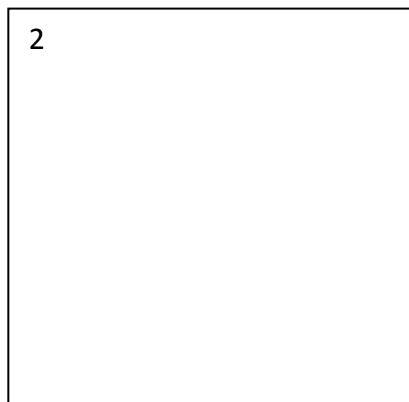
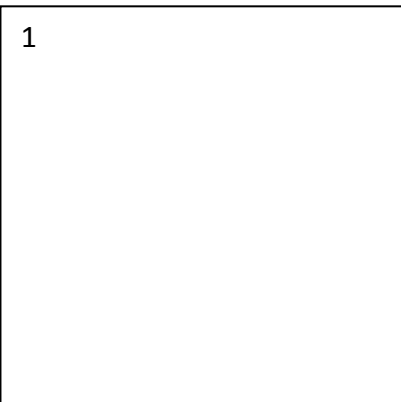
$$\text{Density} = \text{mass}/\text{volume}$$

1. Air is constantly moving.

a) When air heats up, how does the movement of the air particles change?

b) How does the kinetic energy of the air change?

2. Draw diagrams for the three situations below. Show the air by drawing dots representing air particles.



Draw a picture of a rubber balloon before it is blown up.

Draw a picture of a rubber balloon filled with cold air.

Draw a picture of a rubber balloon with the same amount of air, heated up.

3. Let's study **Pictures 2 and 3**.

a) Did the mass of the air in the balloon change?

b) Which balloon has a larger volume?

c) How has the density of the air inside the balloon changed? Hint: look at the equation for density above.

d) How does the pressure, volume and temperature change? Hint: look at the equation for temperature above.

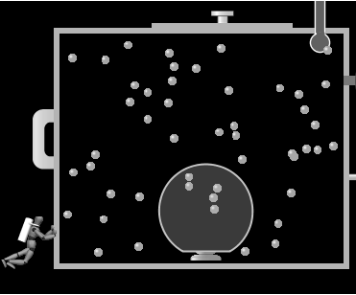
## Our Hot Air Balloon Experiment



1. Imagine a hot air balloon is filled with room temperature air.
  - a) Is there any difference between the air inside and outside the balloon? Explain.
  
  - b) Describe the forces inside and outside the balloon.
  
2. Hot air balloons can't expand once filled. Explain what would happen if we increase the temperature of the air inside of our hot air balloon.
  
3. Pressure is a force applied to an area.
  - a) Does the area of our balloon change?
  
  
  - b) How is the force of the hot air inside our balloon different from the force of the air outside of our balloon?
  
4. All objects (air included) tend to move towards a state of balanced forces.
  - a) What is the difference between a balanced and an unbalanced force?
  
  
  - b) What can we expect to happen for pressure of the air inside and outside the balloon?
  
5. Since the hot air balloon is open at the bottom, the air can move into and out of the balloon.
  - a) How would the air move in our hot air balloon after it is removed from the fan?
  
  
  - b) What has happened to the amount of the air in the balloon by heating it?
  
6. How has the density of the air inside the balloon changed by heating it?

Name: \_\_\_\_\_

## Show off what you know!

1. If you heat up the air inside a hot air balloon, the particles inside
    - a) speed up and move closer together.
    - b) slow down as they heat up.
    - c) speed up and move further apart.
    - d) all move upwards.
  
  2. The buoyant force, which causes a balloon to rise, opposes what force?
    - a) Gravity
    - b) Friction
    - c) Static Electricity
    - d) Weak force
  
  3. There are many examples of convection besides hot air balloons. Which of the following is an example of convection?
    - a) Placing a frying pan on the stove.
    - b) Electromagnetic waves traveling through space.
    - c) Heated air in the atmosphere expanding and becoming less dense then being replaced by cooler air.
    - d) Sunlight.
  
  4. In the picture on the right, what force is stronger gravity or buoyancy?
    - a) Gravity.
    - b) Buoyancy.
    - c) They are the same.
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5. Why do we have hot air balloons instead of cold air balloons?

Name: KEY

### Balloons and Buoyancy PhET Sheet

**Important Terms:**  
**Kelvin (K):** a unit for measuring temperature  
**Atmosphere (atm):** a unit for measuring pressure

1) What is the initial air pressure? What does that tell you?

0, that there is nothing in the chamber

2) **Make the lid pop off** and **use the table** below to record your findings. Be sure to work as a team!

Trial #	Pressure at time of lid popping off (atm)	Did you increase or decrease the size of the box?	Temperature at time of lid popping off (K)	What was your method?
1	6.04	stayed the same increased decreased	556	Added light particles and heated
2	7.01	stayed the same increased decreased	1012	Added heavy particles and heated
3	6.00	stayed the same increased decreased	552	Expanded the volume, added heavy and light particles of gas and heated

3) a) Find three ways to make the temperature increase inside the simulation, if the **same amount of gas particles are present**.

How can you make sure the same amount of air particles are present

Pump same amount of times, use the tool to adjust to the same amount of particles

What did you do?	As temperature increased pressure....	As temperature increased the density of the air....
Added heavy particles, added heat	stayed the same increased decreased	stayed the same increased decreased
Decreased the volume	stayed the same increased decreased	stayed the same increased decreased
Changed particles from light to heavy, but kept total number the same	stayed the same increased	stayed the same increased

	decreased	decreased
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b) In a complete sentence summarize what happens when the temperature increases in the simulation.

As temperature increases the pressure increases until the lid pops off.

4) **Challenge:** Now, the simulator is your hot air balloon! In our experiment, we will be heating the inside of the hot air balloon. You want to make sure that your balloon floats above the bottom of the container. You **DO NOT** want your balloon to touch the ceiling. Use the *stopwatch* and make sure your balloon can float for 30 pico-seconds. Think about how you can keep the simulation to have similar conditions to Earth (\*\*hint\*\* Does gravity change on Earth?)

### Current Launch Conditions

Today the temperature is 100 F. In Kelvins this is 311. The atmospheric pressure is 1 atm.

Explain your methods for keeping your balloon floating for 30 picoseconds. Include any issues or problems that you had and what you did to fix them.

I decreased the amount of particles in the box, cooled the box, and expanded the volume to bring my conditions close to that of the launch conditions

### Fill in the table with your observations

As the hot air balloon was heated the particles moved....	As the hot air balloon was heated the <i>kinetic energy</i> of the particles inside the balloon...	As the hot air balloon was heated the <i>thermal energy</i> of the particles inside the balloon...
at the same speed faster slower	stayed the same increased decreased	stayed the same increased decreased