Version 6

Pressure and Ideal Gases

This worksheet will take you through an exploration of the properties of an ideal gas: temperature, pressure, and microscopic representation. It will build on what you have been learning in class about collisions, forces, and energy, and on the following model of an ideal gas.

* **Ideal Gas Model:**
* The molecules move in random directions in straight lines until they hit the container walls or each other. The collisions with objects are responsible for the pressure of the gas.
* The gas molecules do not interact with each other except when they collide. They can be modeled as small, hard spheres.
* The temperature of the gas is proportional to the Pressure and Volume of the Gas

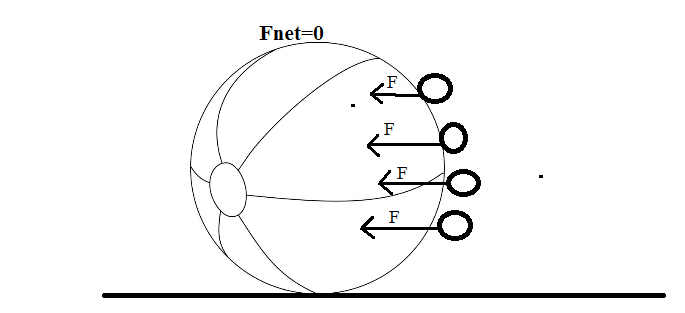
PV = NkT

1. Pressure and Collisions

Playing with beach balls: Imagine that you have one large beach ball and four smaller tennis balls. The large beach ball is initially at rest, and you toss the small tennis balls at it.

* 1. (5 pts) Describe and/or sketch a situation where four bouncy balls hit the beach ball, but the beach ball remains stationary. What is the direction of the net force on the beach ball in this case (to the left, to the right, or zero)? **This describes the situation when the pressure is equal on all sides of an object.**

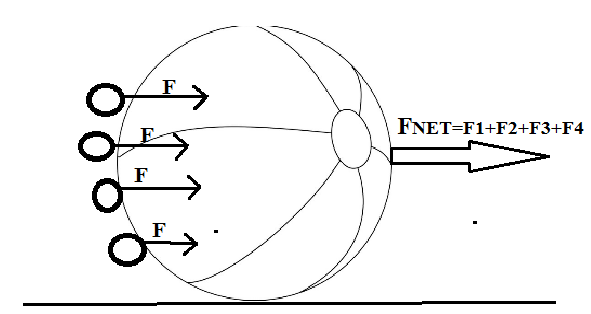
**the small four bouncy balls will hit the beach ball and it still stays stationary because the beach ball has a bigger area and the amount of force the fancy balls are hitting it with is not enough so it causes low pressure on the beach ball**



**The direction of the ball will remain a zero**

* 1. (5 pts) Describe and/or sketch a situation where four bouncy balls hit the beach ball and make the beach ball move to the right fairly quickly. What is the direction of the net force on the beach ball in this case (to the left, to the right, or zero)? **This describes the situation when the pressure is unequal on an object.**

**Because the beach ball has a bigger area it needs a bigger pressure for it to start moving this can be possible when the net force of the small fancy balls is big enough to produce a large pressure( pressure is directionally proportional to force so the bigger the force the bigger the pressure)**

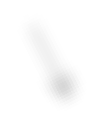
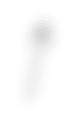
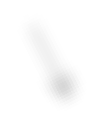
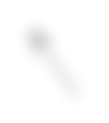
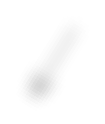
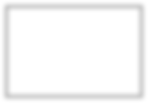


**The net force of the ball is to the right**

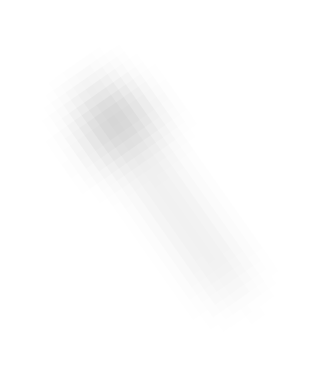
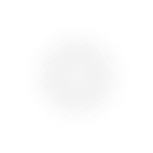
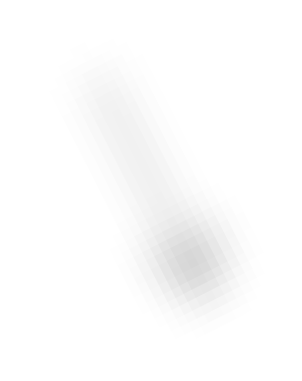
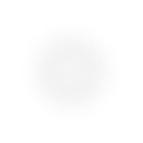
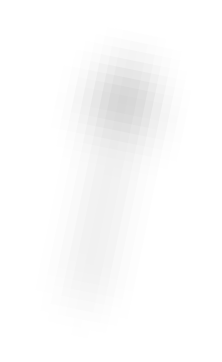
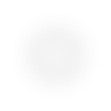
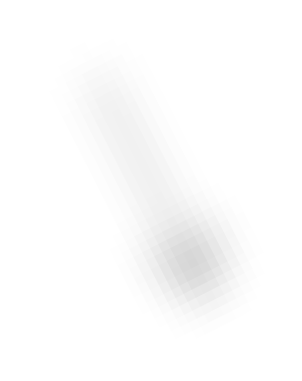
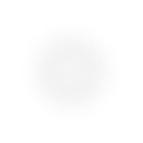
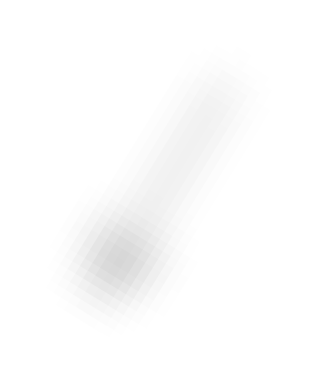
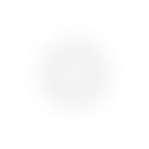
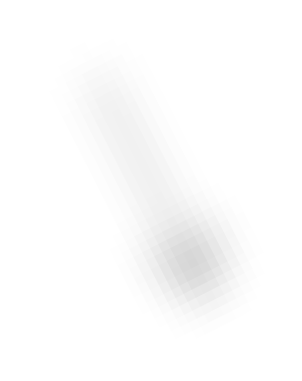
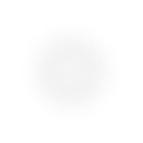
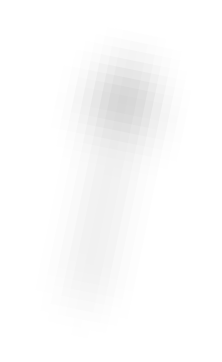
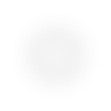
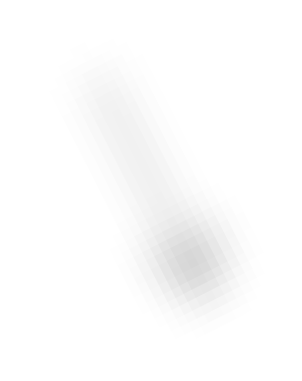
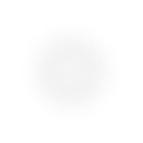
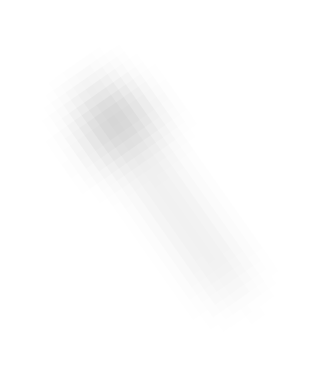
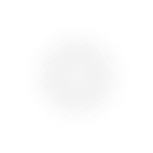
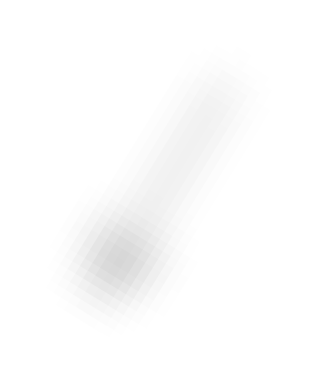
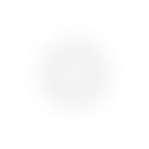
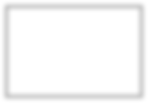
**Key Idea:** Ideal gas molecules exert pressure (pressure=force/area) on their containers by colliding with the walls of the container (just as the bouncy balls collided with the beach ball). *Increasing the strength of the collisions and/or the frequency of collisions will increase the pressure on the walls.*

Ideal Gas in a Rigid Container: Now we consider collisions of an ideal gas with a rigid container. For each of the following instances described in the box provided, choose the appropriate answer. For each situation, only one variable is changed from the original situation. The length of the arrow represents the velocity where longer arrows indicate a larger velocity.

Original situation, an ideal gas in a container:



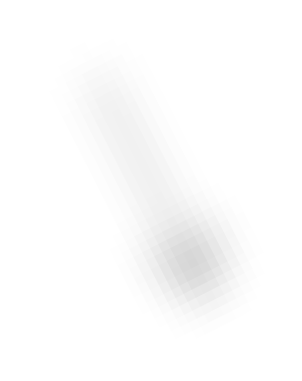
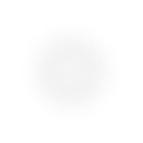
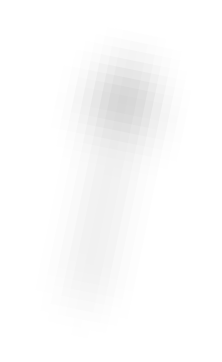
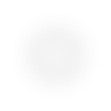
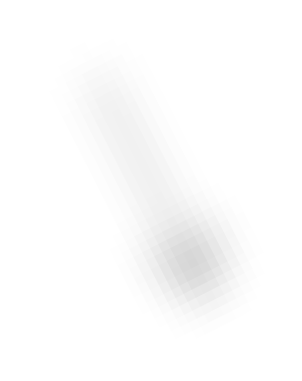
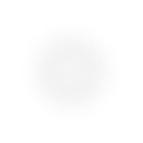
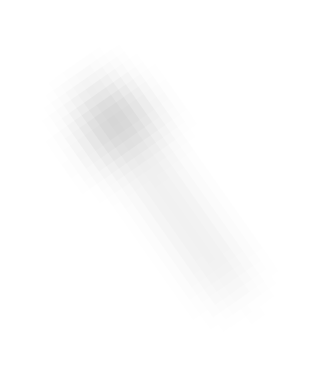
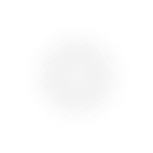
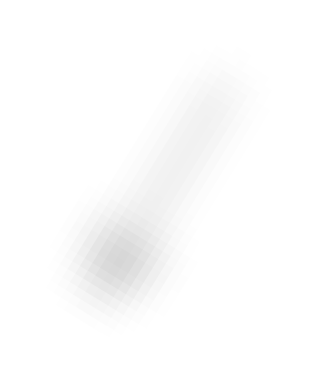
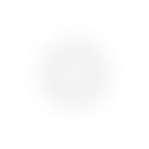
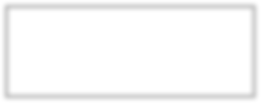
* 1. **(5pts) Increasing the number of gas molecules** will (Increase/Decrease/Not Change) the pressure. **Explain your reasoning.**



**Increasing the number of molecules will increase the pressure in the container because**

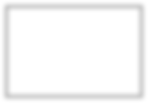
**The number of collisions will increase on the walls of the container which causes an Increase in pressure**

* 1. **(5pts) Increasing the volume of the container** will (Increase/Decrease/Not Change) the the pressure. **Explain your reasoning.**



**Increasing the volume of the container Will decrease the pressure on the container walls as the is more space inside the container for the molecules to move freely reducing the collisions**

* 1. **(10pts) Decreasing the temperature of the gas molecules** will (Increase/ Decrease/Not Change) the pressure. **Explain your reasoning.**

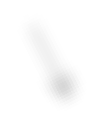
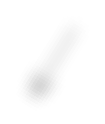
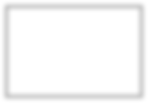
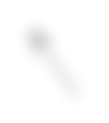
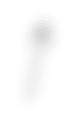
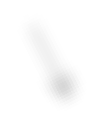


**Decreasing the temperature will decrease the pressure of the container because when**

**When temperature decreases it reduces the energy the molecules have this means the**

**Move more slowly which reduces the number of collisions on the walls**

* 1. **(10pts) Changing the type of gas** from oxygen to helium will (Increase/ Decrease/Not Change) the pressure. Explain your reasoning.



**Changing the type of gas from oxygen to helium will decrease the pressure of the Container because helium has less molecules and it is lighter than oxygen which means less collision with the walls of the container**

**Summary and Preview:** In this section, you explored the idea of pressure as collisions of gas molecules against container walls. In the next section you will apply these ideas to a situation that includes a vacuum.

1. Vacuums and Partial Vacuums
   1. **(5pts)** A vacuum is defined as a region with no molecules whatsoever. Explain how you can move water up a straw, assuming a vacuum at the top of the straw.

**Molecules will move from a place of high density to place of low density, the water molecules move up a strew because the is no molecules prevent them to move meaning no pressure to keep them in their container they freely move at random from their high pressure to the vacuum**

True vacuums do not exist. However, partial vacuums exist, where the number of molecules is far less than typical. For reference, here is a table with values of particle densities and pressures at various regions inside and above the Earth.

|  |  |  |
| --- | --- | --- |
| **Location** | **Num be r / c ubic centimeter** | **Pressure** |
| Gas at standard temperature and pressure | 2.5x1019 | 100,000 Pa |
| Summit of Mount Everest | 1017 | 33,000 Pa |
| Upper atmosphere | 1010 | 0.1 Pa |
| Inside a vacuum chamber | 106 | 1x10-8 Pa |
| Region between Earth and Sun | 11 | ~0 Pa |

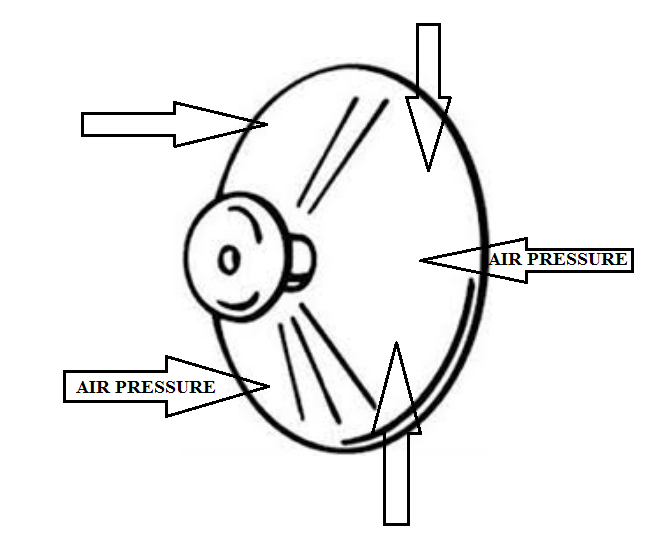
* 1. **(5pts)** Consider a suction cup of the type used to hang ornaments from windows. If possible, locate one in your home, then play around with it, and hang some weight from it. Now explain how it works using ideas about ideal gas and pressure that you have just been discussing. Sketches will likely be very useful here.

The suction cup works by principle of pressure differences, the part of the suction cup that

Sticks to the window needs to be pressed against the window so it removes air molecules

Cause a bit of a vacuum which causes the pressure from the outside to apply a force on the

Suction cup that’s why it sticks to the window



* 1. **(5pts)** You are an engineer working for NASA. Your team has been assigned the task of coming up with a way of making space walks safer for astronauts. A fellow engineer proposes giving the astronauts suction cups, so they can “stick” to the outside of the space station. Will this work? Discuss in your group and **explain** why it will or will not work.

**No it will not work because suction cups rely on pressure differences from the outside of**

**The suction cup and since in space the is very little pressure it will not stick**

1. Application of ideal gas ideas
   1. (10 pts) Watch the video at https://[www.stevespanglerscience.com/lab/](http://www.stevespanglerscience.com/lab/) experiments/incredible-can-crusher/ When the can was ﬂipped over in a tub of water, the can collapsed. What was the purpose of pouring some water into the can before heating? Discuss this amongst your group and **explain** why the can was crushed.

**The purpose of pouring water in the can is to force the air inside the can to leave the can when the water starts boiling by using the water vapor leaving the can this causes a low pressure inside the can and when it is flipped inside the cold water the water condenses quickly and creates a vacuum which makes high air pressure molecules outside to try to enter the vacuum which apply a force on the outside that crushes the can**

* 1. The New England Patriots were once accused of cheating by reducing the pressure of their footballs in an AFC Championship game. The league requires the balls to be between 12.5 and 13.5 PSIg (gauge pressure). At half-time, on the field the ball pressure was measured to be about 11.5 PSIg. For this problem, you can assume that the balls started in the locker room at around 72° F before the game, and that the half-time temperature on the field —where the ball pressure was later measured— was 45°F. Initially there were reports that the ball pressure on the field was 10.5 PSIg, but that turned out to be inaccurate.

# Useful information :

We can use the ideal gas law PV=NkT to investigate this:

In the locker room **Pi V = Nk Ti**

and on the field **Pf V = Nk Tf**

So we can conclude that **Pf = (Tf/Ti ) Pi**

**Note that we must use absolute pressure and absolute Temperature here. Gauge pressure** is the pressure diﬀerence from 1 atm.

**Absolute pressure** is the pressure measured with respect to perfect vacuum. PSI stands for “Pounds per Square Inch” and is a common unit of pressure.

To discriminate between **Gauge and Absolute pressure** the letter “g” or “a” is sometimes added to the end of the pressure unit. For example, “PSIg” or “PSIa”.

So 1 Atm = 101.3 kPa

= 14.7 PSIa

= 0 PSIg

In other words, to get from PSIg to PSIa, you need to add the oﬀset of 14.7 Example :convert 100 PSIg to PSIa:

P = 100 +14.7 = 114.7 PSIa*.*

Example : convert 33 PSIa to PSIg: P= 33 - 14.7 = 18.3 PSIg

***Please keep the diﬀerence between gauge and absolute pressure in mind when solving the following problem.***

* 1. (10 pts) In response to the allegations of cheating, based on the initial rumors of

10.5 PSIg, it was incorrectly concluded that “the pressure dropped from 12.5 PSIg to around 10.5 PSIg, which is a relative drop of 16%. Explain what is wrong with this statement.

**16% is not a relevant drop the pressure cannot drop that much from just a**

**Temperature drop a relevant is a very small percentage, this percentage is a**

**Deflated pressure percentage**

* 1. (20 pts) Calculate what the Gauge pressure in PSIg of a football would be when it has cooled down to 45° F, if it was at 12.5 PSIg when at 72° F. **You will need to use absolute pressure and temperature in your calculations, but in the end convert back to gauge pressure!**

* 1. (5 pts) The Patriots’ footballs were measured to be at 11.5 PSIg (average) at half- time just after being outside for hours on a rainy, 45° F day. Based on your calculations above, can you conclude that they were illegally deﬂated? Discuss.

**Yes from the calculations it proofs that the balls were illegally deflated because the amount of pressure is way below the calculated amount**