Arbor Scientific
Air Puck Lab 2

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Teaching Motion with the Air Puck

Objective:

In studying motion of objects, many times it is difficult to quantitatively measure objects on Earth because of ever-present friction issues. Often, our data and results are skewed due to these factors and generalization of the data is required in order to reach successful conclusions. The ability to minimize friction is a constant problem throughout the Physics lab; using "frictionless" carts or cars with "frictionless" ball-bearings frequently do not ease the errors that occur during any motion experiment. By using the Arbor "mini" Air Puck, many of the experiments that are performed in the lab requiring accurate data readings and results can now be attained. Using the Air Puck which can best simulate a "frictionless" surface, you and your partner can investigate and determine the following in a 4 part series of experiments:

1. Newton's Laws of Motion
2. Significant Figures and Units for Motion
3. Initial Velocity, Final Velocity & Average Velocity
4. Acceleration

Helpful Equations:

$$\bar{v} = \frac{\Delta d}{\Delta t} \qquad a = \frac{\Delta v}{\Delta t} \qquad F_{net} = m\,a \qquad F_f = \mu\, F_n$$

$$\bar{v} = {}^{1}/_{2}\,(v_i + v_f)$$

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Part I: Newton's 1st Law… The Law of Inertia

For Part I, you and your team will need…

- **Air Puck**
- **Smooth surface (example tile floor)**

Using one of the "mini" Air Pucks, turn on the Air Puck and give it a slight push.

1. During the push, what happened to the speed of the puck?

   a) Quickly slows down
   b) Speeds up
   c) Maintains a steady speed

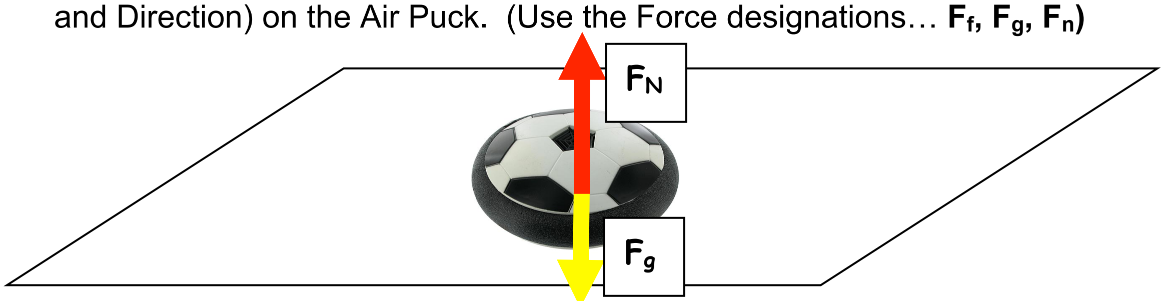
2. After the push, what happened to the speed of the puck?

   a) Quickly slows down
   b) Speeds up
   c) Maintains a steady speed

3. What are the Forces on the puck as it is traveling on the floor?

The only Force acting on the Air Puck is the Force of Gravity (Fg.. the puck's weight). Once set into motion, the puck experiences NO other forces. (Other than a SLIGHT friction force due to fluid friction/air.)

4. Using the diagram below, draw ALL the **Forces** on the Air Puck while AT REST on the tile floor. Use properly drawn and labeled vectors (Magnitude and Direction) on the Air Puck. (Use the Force designations… **F_f, F_g, F_n**)



5. Using the diagram below, draw ALL the **Forces** on the Air Puck while IN MOTION (after the push). Use properly drawn and labeled vectors (Magnitude and Direction) on the Air Puck. (Use the Force designations… **F_f, F_g, F_n**)

If Friction is neglected, then the Ff force vector would NOT be drawn. Ideally, there is considered to be NO friction with this experiment so BOTH diagrams (#4 & #5) would be the same!

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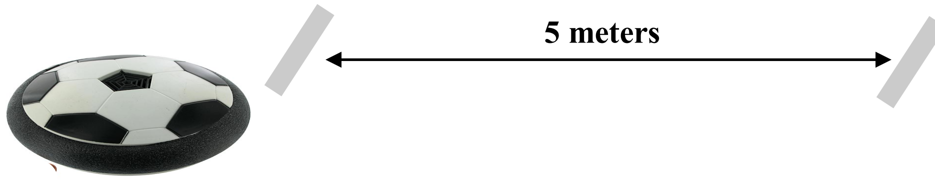
Part II: Determining Average Velocity

For Part II, you and your team will need…

- **Calculator**
- **Measuring Tape or Meter Stick**
- **Masking tape**
- **Air Puck**
- **stopwatch**



1. As in the diagram above, place one of the "mini" Air Pucks on the tile floor. If your floor does NOT have tiles, you will be able to perform this station as long as the floor has a smooth surface.
2. Place a piece of tape at the "Starting Line" and measure **5.0 meters** from that line. Place another piece of masking tape on the floor as the "Finish Line".
3. Turn on your Air Puck and beginning BEHIND the starting line, initially slide the Air Puck along the floor so that it has enough speed to pass between the Start and Finish lines and continue on PAST the Finish Line. (The Air Puck MUST move through the entire 5 meters and NOT stop within that distance.
4. Have your partner record the time from when the Air Puck passes the Start line to the instant it passes the Finish line. Record the time to the nearest **0.01 seconds**.
5. Find the **Average Velocity** of the Air Puck from the **Start Line to the Finish Line**.
6. Use Significant Figure rules when calculating Average Velocity. **Remember your Units!**

	Time(t)	Distance(d)	Average Velocity (v)
Average Velocity Trial	*7.43 seconds*	*5.0 meters*	*0.67 m/sec*

- ***REMEMBER…Measure 1st, THEN Significant Figures!***

CALCULATIONS

Remind your students of the significant figure operation rules. They should take their measurements to the best precision possible with the measuring device they are using, calculate their answer, THEN apply the Sig. Fig. rules. For multiplication & division, your answer MUST be expressed to the least # of significant digits in your operation!

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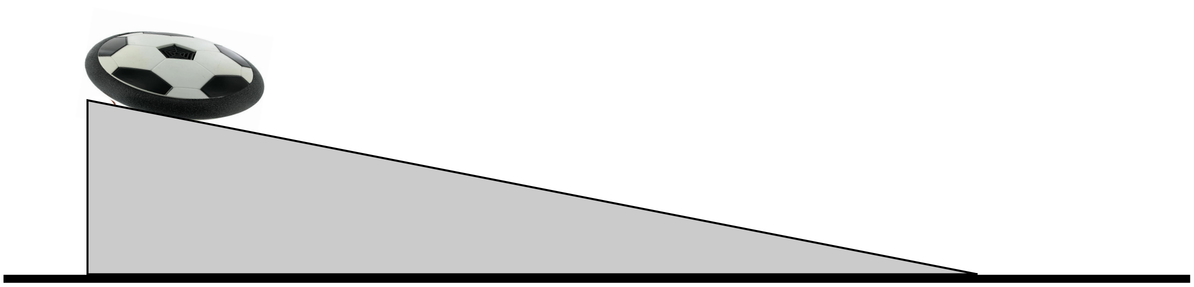
Part III: Determining Initial Velocity, Final Velocity, Average Velocity, and Acceleration

For Part III, you and your team will need…

- **Calculator**
- **Measuring Tape or Meter Stick**
- **Air Puck**



1. As in the diagram above, secure a ramp from your Physics teacher and place it on a stack of physics textbooks or secured to a ringstand.
2. Measure the distance from the top of the ramp to the end of the ramp. Be certain to **measure the distance** to the nearest **0.1 cm.**
3. Set your ramp at 15^o to the horizontal by measuring with a protractor.
4. Hold your Air Puck at the top of the ramp.
5. Upon release have your partner record the time from when the Air Puck begins its motion to when it strikes the bottom of the ramp. Record the time to the nearest **0.01 seconds**. Make certain to stop timing the moment the car exits the ramp!
6. Using your Physics Reference Table of Motion equations, calculate the **Initial Velocity, Final Velocity, Average Velocity & Acceleration** for your Air Puck.
7. Record your measurements in the table below. Show all your calculations.
8. Repeat the experiment with the ramp set at 30^o and at 45^o. Calculate the **Initial Velocity, Final Velocity, Average Velocity & Acceleration** for your Air Puck for EACH trial.
9. Use Significant Figure rules when calculating your results. **Remember your Units!**

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**** REMEMBER…Measure 1st, THEN Significant Figures!***

	t (time)	**d (distance)**	V_{ave}	V_i	V_f	a
Ramp Trial #1 15°	5.84 sec	2.50 m	0.428 m/s	0 m/s	0.856 m/s	0.147 m/s^2
Ramp Trial #1 30°	2.95 sec	2.50 m	0.847 m/s	0 m/s	1.70 m/s	0.576 m/s^2
Ramp Trial #1 45°	1.43 sec	2.50 m	1.75 m/s	0 m/s	3.50 m/s	2.45 m/s^2

CALCULATIONS

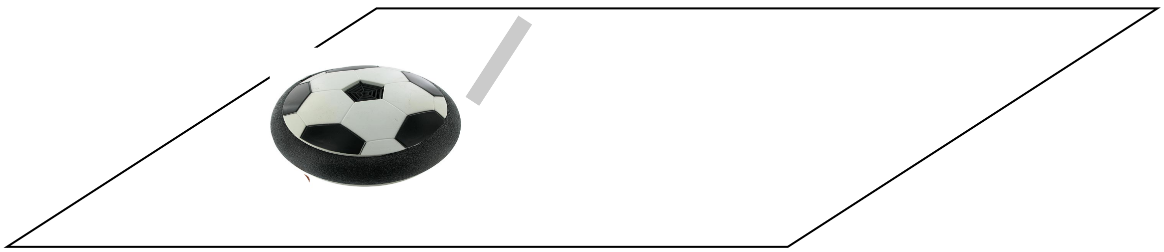
For this section, it would be helpful to use the relationship of $V_{ave} = \frac{V_f + V_i}{2}$

Since the Air Puck's causes a "frictionless" condition, its motion down the ramp will be a CONSTANT ACCELERATION. Therefore, we can use that equation to help students in solving for V_f in this section. Assume the Air Puck starts at a $V_i = 0$ for each trial.

Part IV: Determining Deceleration

For Part IV, you and your team will need…

- **Calculator**
- **Measuring Tape or Meter Stick**
- **Masking tape**
- **Air Puck**
- **Stopwatch**



- As in the diagram above, place one of the “mini” Air Pucks on the tile floor. If your floor does NOT have tiles, you will be able to perform this station as long as the floor is a smooth surface.
- Place a piece of tape at the “Starting Line” and be certain that you have a long hallway, which extends well beyond the Start Line.
- Turn on your Air Puck and beginning <u>BEHIND</u> the starting line, initially slide the Air Puck along the floor so that it has enough speed to pass the Starting line.
- Have your partner record the time from when the Air Puck passes the Start line to the moment that the Air Puck stops. Record the time to the nearest <u>**0.01 seconds**</u>. It will take your Air Puck some time to come to complete stop since the motion is enhanced by a “frictionless” surface.
- Measure the distance your Air Puck traveled from the Start Line to rest (V_f=0).
- Using your Physics Reference Table of Motion equations, calculate the **Initial Velocity, Final Velocity, Average Velocity & Acceleration (Deceleration)** for your Air Puck.
- Record your measurements in the table below. Show all your calculations.
- Use Significant Figure rules when calculating your results. **Remember your Units!**

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**** REMEMBER…Measure 1^st^, THEN Significant Figures!***

	t (time)	**d (distance)**	V_{ave}	V_i	V_f	a
Deceleration Trial	15.25 sec	12.0 m	0.787 m/s	1.57 m/s	O m/s	-0.103 m/s^2

For this section, it would ALSO be helpful to use the relationship of

$$V_{ave} = \frac{V_f + V_i}{2}$$

Since the Air Puck's causes a "frictionless" condition, its motion on the level surface as it slows down will be a CONSTANT DECELERATION. Therefore, we can use that equation to help students in solving for V_f in this section. Assume the Air Puck ends its motion with a V_f = 0 for each trial.
Your students' answers should result in a NEGATIVE acceleration since the Air Puck is Decelerating or slowing down. Many student will have the correct MAGNITUDE (#) but the – sign will be missing because of an error in their equation substitution.

Lab Questions and Analysis

1. An Air Puck or object on a horizontal frictionless surface has been given a push and released, what will happen to the object?

   a) Slowly come to a stop
   b) Continue with constant acceleration
   c) Continue with decreasing acceleration
   d) Continue with constant velocity
   e) Immediately come to a stop

2. How does your experiment in **Part I** compare with the ACTUAL answer to question #1. Does it behave as you predicted?

"The Air Puck eventually slowed down because of small frictional forces acting against its forward motion. Even though the Air Puck should continue at a constant velocity in a perfect Newtonian world, our Air Puck came to a stop."

3. Until the time of Galileo, people believed that a **constant force** is required to produce a **constant speed**. What does a constant force produce?

A constant (unbalanced) force applied to any object causes that object to accelerate, NOT move at a constant velocity.

4. What would have to be done in order to have the Air Puck continue with a Constant Acceleration?

   a) push the **Air Puck** harder before release.
   b) push the **Air Puck** longer (for more time) before release.
   *c) push the **Air Puck** continuously with a constant force*.
   d) change the mass of the **Air Puck** (add clay to the Air Puck)
   e) it is impossible cause the Air Puck to accelerate.

5. Jane Equation and Joe Fizziks are arguing in the cafeteria. Joe says that if he flings his chicken nugget with a greater velocity it will have a greater inertia. Jane argues that inertia does not depend upon velocity, but rather upon mass. Who do you agree with? Explain why.

Jane is correct in her argument because Inertia is INDEPENDENT of Velocity. The Inertial of an object is proportional to the object's mass ONLY. Throwing the chicken nugget with a greater speed will increase its momentum, its kinetic energy, its temperature, etc., but not its Inertia (mass).

6. Supposing you were in space in a weightless environment, would it require a force to set an object in motion?

To SET the object in motion, you WOULD need to apply a force to it. Newton's 1st Law of motion states that an object at rest will remain at rest

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unless acted upon by an external force. After the force is applied, no further force would be required to KEEP it moving.

7. For your results in Part III, what effect did the angle have on the acceleration of your Air Puck?
As the angle of the ramp increased, the acceleration of the Air Puck also increased.

8. Johnny is being chased by a rogue elephant which he was attempting to photograph. The enormous mass of the elephant is extremely intimidating. Yet, if Johnny makes a zigzag pattern as his runs away, he will be able to use the large mass of the elephant to his own advantage. Explain this in terms of inertia and Newton's first law of motion.
Since the elephant has a very large mass, its Inertia is also very large. The elephant cannot effortlessly alter its direction because of its large mass. Therefore, your zig-zagging pattern is to your advantage since the elephant cannot follow your path easily. Newton's 1st Law of motion states that an object in motion will remain in motion at a constant velocity in the same direction unless acted upon by an external force.

9. Where do you have **greater INERTIA**: …on **Earth** or on the **Moon**? Explain why?
Inertia is NOT affected by location since it is ~ to mass. By placing you on the Moon, your WEIGHT will change but not your Mass, therefore your Inertial will not change for the same reason.

10. Two closed containers look exactly the same but one is filled with gold and the other is filled with feathers. How will you able to tell the difference between them in a "gravity-free environment?
By shaking the containers, even in a "gravity-free" environment, you would be able to detect a difference in mass. Also, if you could apply the SAME force to each container, the MORE massive gold container would exhibit a lower acceleration than the feather container. Newton's 2nd Law states that if an unbalanced force is applied to a mass, the mass will accelerate. Also, if the two containers were in motion at the same velocity, the gold container would have more momentum therefore it would require a higher Impulse (F·t) to stop it.

11. If you were in a spaceship and fired a cannonball into frictionless, gravity-free space, how much **force** would have to be exerted on the cannonball **to keep it going** at a **constant velocity**?
No force would be required to keep the cannonball moving since Newton's 1st Law of motion states that an object in motion will remain in motion at a constant velocity in the same direction unless acted upon by an external

force

12. Using the acceleration (deceleration) from Part IV calulate the coefficiant of kenetic friction μ_k

Fnet= $F_f = \mu_k F_n$ F_n=-mg
Where g= 9.81m/s^2 ma= μ_k – mg ∴ $\mu_k = \frac{ma}{-mg} = \frac{a}{-g}$

13. When calculating the values for acceleration and deceleration in Parts II and IV, what assumption must be made about the nature of the acceleration of the Air Puck? How did the Air Puck undergo acceleration? Was the acceleration rate constant or did it vary?

The assumption that the Air Puck was moving on a "frictionless" surface means that the puck COULD exhibit CONSTANT Accelerations or CONSTANT Decelerations. Since in Parts III and IV, the Air Puck was acted upon by ***CONSTANT UNBALANCED*** *frictional forces, the puck's acceleration rates were constant.*

Teacher Note: This lab is designed to allow students to investigate motion WITHOUT the use of photogates or electronic measuring devices. All of the stations where stopwatches and meters sticks are used can be adapted for use with a photogate or other motion capturing device.