12000 Air Table

Purpose:

The air table provides a frictionless, two dimensional surface for the study of mechanics. With the proper accessories, studies can be conducted in velocity, acceleration, Newton's Laws, center of mass, elastic and inelastic collisions, linear and angular momentum, conservation of momentum, moment of inertia, centripetal force, simple and complex harmonic motion.

Contents:

One	(1)	Air Table	
Four	(4)	Corner screw assemblies	
each consisting of			
		(1)	screw
		(1)	spring
		(1)	spacer
Three	(3)	Leveling feet	
Six	(6)	Pucks	
Two	(2)	Coil springs	
Two	(2)	Velcro strips	
Two	(2)	Machine Screws *	
		String	

* Longer machine screw replace those already in pucks when they are to be connected to springs.

Additional useful accessories include, a stop watch, Polaroid camera, compression spring, pulley attachment, and small weights.

Optional Accessories:

Optional accessories that can enhance the use of the air table include:

Puck Launcher #12010
Magnetic Puck Set #12015

Assembly:

1) Install the leveling feet by first locating the three threaded inserts in the bottom of the table. Screw one leveling foot into each hole.

2) Your Air Table is assembled upon receipt. If you should need to reassemble, attach the corner screw assemblies (screw assembly - slide one end of the spring onto the screw. Next slide a spacer onto the screw. Attach the screw to the unit.) to the top of the table by first locating the holes in each corner of the table top. Next run the string thru the free loop of each spring and tie the string to itself.

Operation:

Plug in the table and turn on the blower. Wipe the surface of the air table clean using a damp cloth. The pucks will not float properly if the table is covered with dirt, especially grit. **Place a puck on the running table and let it float to test levelness.** The levelness of the table can be achieved by working with the three leveling screws in the base. The table needs to be level before beginning to collect quantitative data.

Maintenance:

Proper care of the air table is essential for long life and maintaining a flat surface. When the table needs cleaning, first turn on the air. Dust can now be removed by gently wiping with a clean damp cloth. Fore more serious problems use a little water and a mild detergent. For long term storage it is advisable to cover the table and stand it on end against a wall to avoid any accidental marring of the surface. It is advisable to retain some or all of the shipping carton for this purpose.

Feedback:

If you have a question, a comment, or a suggestion that would improve this product, you may call our toll free number.

To the Student:

The Air Table provides you with a powerful tool for performing a large number of experiments. This laboratory guide is designed to help you use the Air Table effectively. It provides instructions for performing many experiments. The instructions have been written in an open ended fashion, omitting a great deal of detail so that you have an opportunity to do your own thinking. A great many questions are asked. Finding the answer will require you to pull together information from your text book, your classes, and other books that are available to you plus using your own ingenuity. If something puzzles you, devise your own experiment to solve the puzzle.

Measuring Techniques:

There are three principle measuring techniques for acquiring data in Air Table experiments. The first uses an ordinary stop watch (or an electronically triggered stop clock) to determine the time it takes for the puck to move from one position to another.

The second commonly used method for collecting data is strobe photography. Strobe photography can be done using a variety of methods. First, a light chopper (a rotating disk with slots cut radially around the perimeter) can be mounted in front of the camera. This allows you to use existing room light to make your photographic exposure. Second, a strobe light can be used to illuminate the entire Air Table during which time the experiment is photographed. Third, and most conveniently, a small blinking lamp can be mounted on one or more pucks and then photographed. Whichever strobe method you choose to use, you must be able to adjust the frequency of the strobe effect to suit your needs in any particular experiment; faster strobe rates are required for experiments that involve rapid motion, and slow strobe rates for more slowly moving experiments. Any of the strobe techniques will require a camera mounted on a tripod to record the motion in each experiment. This camera should be mounted at least one and one half times the diagonal length of the Air Table surface directly above the center of the Air Table. Adjust the camera so that the middle of the camera's field of view is aligned with the center of the Air Table. In this configuration, the camera's optical axis is perpendicular to the motion of the pucks on the Air Table and the motion recorded by the photograph will have a uniform scale.

An instant camera mounted on a tripod can be used to photograph the 'blinky' as it moves along the Air Table. Most instant cameras utilize a photocell to determine the proper exposure. However, for strobe photography, an extended exposure is required. We can fool the camera into making extended exposures by covering the camera's photocell while the experiment is under way. Using a dark background behind the Air Table often improves the quality of the photograph.

The third and most sophisticated method of data collection employs ultrasonic transducers and an associated computer interface. This is by far the most accurate and flexible method of recording experimental data. Because it is computer based, many of the acquisition programs give immediate access to graphing and numerical analysis programs that present the acquired data in a clearer manner with much less time spent on the mundane task of data manipulation. Some users prefer to use a video capture card in the computer along with a digital camera

The Difference Table:

If you are collecting your data by hand, record it in a "Difference Table" and use it to calculate the puck's velocity and acceleration as a function of time. It is not necessary to record every point of your data, instead, you may wish to use every other point or every third point as a convenient time interval. Avoid using the data near the beginning of the trial run because these points will be too closely spaced to accurately measure, and avoid those points near the end of the run where the force on the puck may no longer be constant (for example, when the puck strikes the wire fence around the table).

Difference Table

$\Delta T = T_2 - T_1$

Time	Disp.	Velocity	Acceleration
T_1=___	X_1=___		
		$V_1 = (X_2-X_1)/\Delta T$	
T_2=___	X_2=___		$A_1 = (V_2-V_1)/\Delta T$
		$V_2 = (X_3-X_2)/\Delta T$	
T_3=___	X_3=___		$A_2 = (V_3-V_2)/\Delta T$
		$V_3 = (X_4-X_3)/\Delta T$	
T_4=___	X_4=___		$A_3 = (V_4-V_3)/\Delta T$
		$V_4 = (X5-X_4)/\Delta T$	
T_5=___	X_5=___		$A_4 = (X_5-X_4)/\Delta T$
		$V_5 = (X_6-X_5)/\Delta T$	
T_6=___	X_6=___		$A_5 = (X_6-X_5)/\Delta T$
		$V_6 = (X_7-X_6)/\Delta T$	
T_7=___	X_7=___		$A_6 = (X_7-X_6)/\Delta T$
		$V_7 = (X_8-X_7)/\Delta T$	
T_8=___	X_8=___		

Using graph paper, plot the puck's position, velocity, and acceleration as a function of time to get a clearer mental picture of what the puck is really doing.

Linear Graphs: How to read them.

When you collect data, it is often easier to interpret your results if you plot the data on graph paper and inspect the shape of the best fit line (or curve). The most common type of curve that you will encounter is the straight line. Mathematically a straight line is described by the equation:

$y = mx+b$

where

y	=	the dependent variable (plot this on the vertical axis)
x	=	the independent variable (plot this on the horizontal axis)
m	=	the slope of the line ($\Delta y/\Delta x$)
b	=	the point of intersection between the vertical axis and the line.

For example, if you consider the familiar equation

$\mathbf{F} = m\mathbf{a}$

You can see that the mass of an object could be found by collecting data relating the force applied to an object to the resulting acceleration of the object. After plotting your data with the applied force on the vertical axis and the resulting acceleration on the horizontal axis, calculate the slope of this line to determine the mass of the object under investigation.

Tuning the Air Table:

Before any experiment can be done using the Air Table, it must be leveled first. This can be done most accurately by floating a puck on the surface of the table and watching its motion. Roughly level the Air Table by eye and then turn on the blower. Place a puck near the center of the table, steady it, then gently release it. If the puck drifts to one end of the table or the other you'll need to raise the low end (the end where the puck comes to rest). The faster the puck drifts to one end, the more you will need to raise it. The puck will always have a tendency to drift slightly to one side or the other due to air currents or other disturbances but this slow drifting will have negligible effects on your experiment.

Coil springs are provided with the Air Table pucks to perform a variety of coupling experiments. These springs can be stretched many times their normal length without exceeding their elastic limit.

Threaded holes are provided in the pucks and at various locations on the table's surface for screws that can be used to attach numerous accessories for a variety of experiments.

A puck launcher may be improvised by attaching two screws to the table top and stretching a rubber band between them. A more versatile and reliable device is The Puck Launcher #12010.

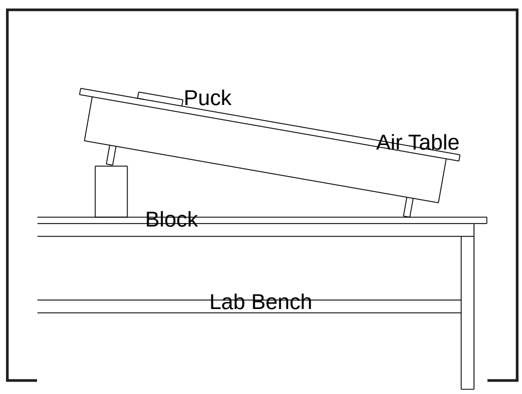
Velcro tape is provided with your Air Table. The tape may be cut to any convenient length. It may be easily attached to the Air Table pucks to provide perfectly inelastic collisions in your experiments. When attached to pucks, make sure the velcro does not drag on the table's surface.

It is useful to have available a set of blocks of various known thicknesses to provide an easily reproducible tilt to the Air Table.

In any experiment where increasing masses are required, the puck masses may be increased by connecting additional pucks or by adding washers to a single puck using the screws supplied. If double or triple mass pucks are required, use a balance and washers to verify that the correct multiple is arrived at.

Experiment 1: Motion in a Straight Line

Always begin each experiment by carefully leveling the Air Table. Once the Air Table is leveled, propel a puck along the table and record its motion. From this record of its motion, determine the puck's velocity and acceleration.

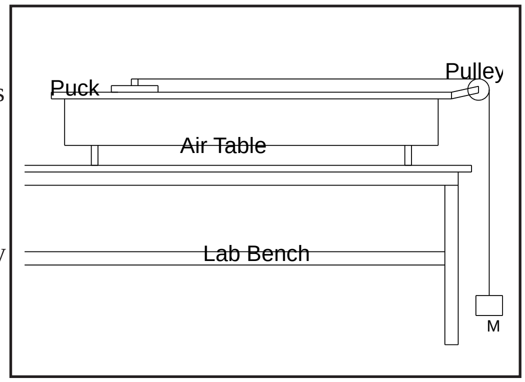


Place a small block 2 or 3 cm in thickness under the single foot of the Air Table. Without giving it a push, release the puck from the raised end of the table. Using a stopwatch or other timer, how long did it take the puck to reach the other end of the table? What is the distance the puck traveled? What was the average speed of the puck? Repeat this experiment three more times. How do the average speeds for each trial compare? Did the puck accelerate during its trip from one end of the table to the other? How do you know?

How does the weight of a puck affect its acceleration? We can test this by placing a puck on the raised end of the table so that its front (down hill) edge is 30 centimeters from the end of the table. Release the puck and record its motion until it reaches the opposite end of the table. Repeat this experiment three more times. Now double the puck's mass by attaching additional masses. Repeat this experiment four more times using the heavier puck. From your recorded data, determine the accelerations for each trial. How does the acceleration of the unloaded puck compare with that of the loaded puck? Are you surprised with your results? Can you explain them? Can you relate this experiment to Galileo's famous experiment when he dropped balls of various masses from the leaning tower of Pisa? Repeat the experiment moving the puck down hill in increments of 30 cm. Make a table of average speed and distance traveled. Can you determine the acceleration of the puck from your data? Try the experiment with a triple mass puck.

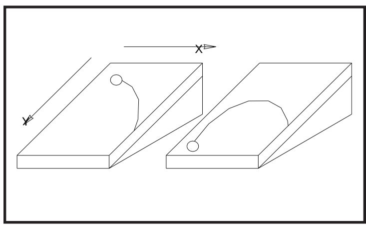
With the Air Table still inclined, launch an unloaded puck from the low end of the table so that it travels up the incline but does not quite touch the bumper at the top of the table. Record the motion of the puck. From the recorded data, what is the average speed of the puck as it moves up the incline? What is its acceleration? If you launch the puck with different initial velocities will the average velocity change? Will the acceleration change?

In the last two experiments a component of the puck's weight provided the accelerating force. In this experiment an external weight will be used to provide the accelerating force. Carefully level the Air Table. Attach a pulley to the edge of the lab table so that a string can be run from the puck on the Air Table horizontally over the pulley then down to a weight hanger (see figure 3). Hold the puck in place until you are ready to record its motion. When everything is ready, release the puck. Calculate the average speed from the recorded motion. Where was the speed the greatest? Calculate the puck's acceleration. How does this acceleration compare with the acceleration of the puck sliding down the inclined table? If there is any difference, can you explain it?



Experiment 2: Motion in Two Dimensions

In experiment 1 your studied the motion of an object moving in a straight line. This was linear motion or motion in one dimension. In this experiment you will study the motion of an object moving in two dimensions.



On a level Air Table, launch a puck across the table using the puck launcher. Determine the velocity imparted to the puck at this setting of the puck launcher. What is the acceleration of the puck after it leaves the launcher? What is the resultant force acting on the puck as it moves across the table?

Raise one end of the Air Table about 2 or 3 centimeters. Release a puck from the raised end of the table so that it slides straight down in the Y direction. Determine the acceleration of the puck. Use the same puck launcher setting as you did when the table was flat and launch the puck up the inclined table. How high will it travel before it stops and begins to return to the starting point. What effect would changing the angle of tilt of the table have on the "height" to which the puck travels assuming the same launch velocity is used? What happens if you change the puck launcher setting while keeping the tilt angle constant? Explain your answer.

Keeping the table tilt and puck launcher setting constant, project a puck horizontally across the table as shown in figure 3A. Record the motion of the puck. After the puck is launched what force or forces act on the puck? Think about this as you analyze the photographic data. What is the acceleration component of the puck in the Y direction? How does this compare with the acceleration you determined in the previous section, part 2. What is the component of

acceleration in the X direction? How does this compare with the acceleration of the puck in part 1? What would be the effect on the motion of the puck if the angle of tilt was kept constant while the launch velocity was varied?

In this experiment, you will launch the puck at an angle with the X axis from the lower end of the table. Set up your table as shown in figure 3B. Project the puck up the incline. Vary the launch angle while keeping the launch velocity constant. Determine the angle that will allow the puck to reach the greatest height on the Air Table (maximum in the Y direction). Determine the angle that produces the greatest range for the puck (maximum in the X direction) when it returns to the same level from which it was launched. Keep the launch angle constant and vary the launch velocity. How does this effect the maximum in the X and Y directions?

Experiment 3: Measuring the Acceleration due to Gravity.

First, level the Air Table, then raise one end of the table until it is inclined by 10o. Place a puck on the table and record its motion. From your data determine its acceleration. Repeat the experiment for four or five additional angles, increasing the incline from 10o to 60o. For steep angles, the final velocity of the puck will be high. To avoid damage to the puck, catch it before it strikes the bottom of the table. Graph the acceleration of the puck vs. angle of incline for each trial. Can you determine by extrapolation the acceleration for a 90o angle?

Experiment 4: Inertial and Gravitational Mass.

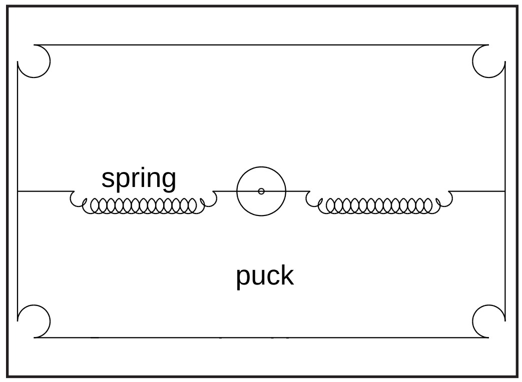
Every object tends to resist any change in its current state of motion. If an object is sitting still, it resists being moved. If an object is in motion, it resists being stopped. This resistance is called inertia. The inertial mass of an object is a measure of the object's resistance to change its state of motion. In the equation

$\mathbf{F} = m\mathbf{a}$

the proportionality constant, m, is a measure of the inertial mass. If we apply the same force to two different objects and their accelerations are measured to be the same, then their inertial masses are equal. To measure the inertial mass of an object we apply a force to it and measure its acceleration. Gravity is not a factor; we would obtain the same results anywhere in the universe.

Gravitational mass, on the other hand, is a measure of the attractive force between two objects, for example, you and the earth. To measure gravitational mass we use a balance which compares the gravitational forces on two objects. If the gravitational forces are equal then the gravitational masses are equal.

In this experiment, you will measure the inertial and gravitational masses of the Air Table pucks and attempt to determine the relationship between these two types of mass.



To set up this experiment, use two of the weak coil springs from the Air Table accessory package. Carefully level the Air Table. Attach one spring to each end of the Air Table. Place a single mass puck on the Air Table and attach the remaining free end of each spring to the puck (see figure 5). Let the puck settle down. The point where the puck comes to rest is the equilibrium point. When it is at rest at the equilibrium point, each spring is pulling on the puck with an equal amount of force. Displace the puck about 30 cm from its equilibrium point and release it. Measure the time required for the puck to complete five oscillations. Divide this time by five to find the period of one oscillation. Why did we time five oscillations and then divide by five to get the time of one period when we could have measured a single period directly? Record your data in table that lists the period of oscillation, the inertial mass, and the gravitational mass. Continue the experiment by adding additional masses to the puck. From your data, plot the period of the oscillations as a function of mass.

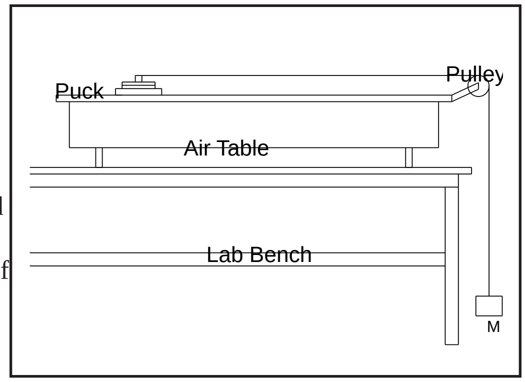
Repeat this experiment several more times using "unknown" masses (washers or other masses that can be easily attached to the puck). After the period of oscillation has been determined, refer to your graph of period as a function of inertial mass. Knowing the period of oscillation, determine the inertial mass from this graph (don't forget to account for the mass of the puck!). To determine the gravitational mass of these objects, use a standard laboratory balance. How do the gravitational mass and inertial mass compare? What is the relationship between inertial and gravitational mass? If the above experiment were performed on another planet would the results be the same? Explain.

In this experiment you will attempt to measure the mass of an object using an inclined Air Table. First level the Air Table and then slip a 2 or 3 cm block under the table's single leg. In the previous experiment the springs provided the forces which caused the acceleration. What force or forces produce the acceleration in this experiment? What kind of mass are we determining, inertial or gravitational? Allow a puck to move down the table. Make the necessary measurements and compute its acceleration. Repeat the experiment four additional times; each time adding more mass to the puck. From your data plot a graph of mass vs. acceleration. Account for the shape of the graph. Can you determine the mass of an unknown object from the graph? Remember Galileo's experiment at the leaning tower of Pisa?

Experiment 5: Force and Motion.

Carefully level the Air Table. With your hand or the puck launcher, project a puck along the table and record its motion. Catch the puck before it strikes the opposite end of the table. From your recorded data, graph the puck's velocity as a function of time. What is the velocity of the puck as it moves along the table? Is there any point in its motion where an un balanced force acts on the puck? From your graph, determine the distance traveled by the puck and compare this with actual measurements of the distance. Do the two values agree? On a separate sheet of graph paper, plot the puck's acceleration as a function of time. What is the average acceleration of the puck?

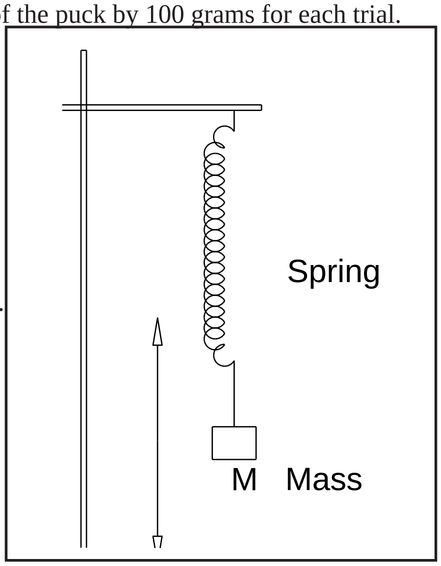
We know from experience that it requires an unbalanced force to make an object accelerate. In the first part of this experiment,



a force was applied briefly to accelerate the puck and then removed. In this experiment you will investigate the effect of a constant force acting on the puck. In all experiments it is extremely important to deal with only one variable at a time. Therefore, in this experiment, the mass of the puck system (puck + string + weights) must be kept constant while the force is varied. Because the puck, string, and mass hanging from the string are all physically connected, they are part of the same system and will accelerate at the same rate. Therefore, the mass that is being accelerated is the sum of the puck and string and masses hanging from the string. Would it be possible for the mass hanging from the string to accelerate faster than the puck, assuming the string does not stretch? If this situation did occur, what would be the fate of the string?

Select four small, equal masses (somewhere in the range of 5 to 10 grams each) for the experiment. To begin the experiment, attach three of the masses to the puck and one to the end of the string which passes over a pulley as shown in figure 6. The mass hanging from the string will supply the necessary force to accelerate the puck. Hold the puck in place until you are ready to begin the experiment. Release the puck and record its motion. From the record of the motion, plot the distance as a function of time for the puck. On a separate sheet of graph paper, plot a velocity as a function of time. And finally, from the velocity vs. time graph determine the puck's acceleration. Is this acceleration constant or variable? What experimental conditions would produce a variable acceleration? Repeat the experiment three additional times, each time transferring one mass from the puck to the end of the string. Using the data from each of the four trials, plot a graph of acceleration vs. force. Can you determine a relationship between force and acceleration from you graph?

In the previous experiment, the mass of the system was held constant while the force was varied. This next experiment will examine the effects of a constant force on various masses. To begin, set up the experiment as you did in the previous experiment, except begin with only one mass hanging from the string and no extra mass attached to the puck. Release the puck and record the motion. From the recorded data, determine the acceleration of the puck. For the next trial, attach 100 grams to the puck and repeat the experiment. Determine the puck's acceleration. Repeat the experiment two more times increasing the mass of the puck by 100 grams for each trial. Using the acceleration data from each trial, plot a graph of acceleration as a function of mass. Can your determine a relationship between acceleration and mass?

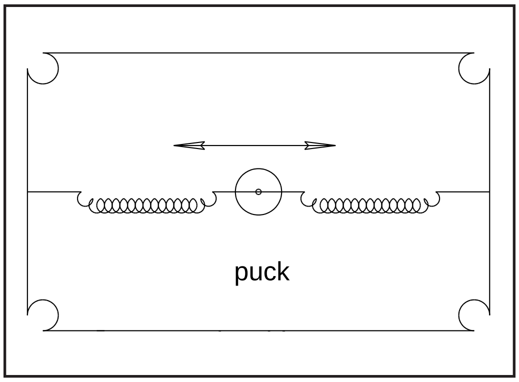


Experiment 6: Oscillations.

A regular back and forth motion is called a vibration or oscillation. In an oscillating system energy is continually changing from potential energy to kinetic energy. If an object is acted upon by a restoring force whose magnitude is directly proportional to the object's displacement, it will undergo a series of oscillations. This type of oscillation is called simple harmonic motion.

To investigate simple harmonic motion you must choose two springs of equal length from the accessory kit. Suspend one spring from a suitable support. Hang a small weight from the end of the spring and record the spring extension on the y-axis of a graph and the force applied to it by the weight hanging from its end on the x-axis. Repeat this measurement several times, each time incrementing the weight hung from the spring. From your graph of the applied force as a function of the spring extension, determine the spring constant. Repeat this procedure for the second spring. Using your graph, predict the force required to produce an extension of 20 cm.

Suspend one spring and hang a 20 gram mass from its free end. Pull the mass down 10 cm. and release it. Time each oscillation to find out if the time for each complete oscillation (period) is the same or different. Can you explain your results? Pull the mass down 20 cm and release it. How does the period compare with that in the previous example? Try several different displacements until you can determine the relationship between the period of oscillation and the initial displacement.



Next, vary the mass hanging from the spring. Time the period of oscillation for several different masses to determine the relationship between mass and period. In all the above experiments what forces were acting on the mass? Draw a vector force diagram of the forces acting on the mass at its maximum displacement in the downward direction, another for its maximum displacement in the upward direction, and at its equilibrium position (midpoint).

To produce vertical oscillations, only one spring was required. To produce oscillations in the absence of gravity (or horizontally) two springs are required. Why? In this experiment we will need two springs to produce oscillations in a plane parallel to the surface of the earth. Do you think the same basic principles that applied to vertical oscillations will also apply to horizontal oscillations? Attach one spring to each end of the Air Table. Place a puck on the table and attach the free end of each spring to the puck (see figure 8). Displace the puck and determine the period. Determine the period for several different displacements. How is the period affected by varying the puck displacement? How does this compare to your experiments with vertical oscillations?

Next, vary the mass of the puck while keeping the displacement constant. Determine the period for several different puck masses. How is the period affected by varying the puck mass. How does this compare to your experiments with vertical oscillations?

In this next experiment You'll attempt to determine the velocity and acceleration of the puck at several positions during one half an oscillation. This can be a little tricky if you intend to use strobe photography; a computer interface to an ultrasonic ranger makes this experiment a piece of cake. If you're using strobe photography, be careful not to photograph any more than one transit of the puck from maximum displacement to maximum displacement. If the exposure is longer than this, the image of the puck will be passing back and forth over itself and the resulting data will be nearly impossible to resolve.

After you have recorded the experiment, determine the velocity and acceleration of the puck at the midpoint, and at the end points of the motion. Where is the velocity a maximum? Where is it a minimum? Repeat this experiment on a tilted table. What force is introduced? What affect does it have? Before doing the experiment, make some predictions using the same two springs and puck. Can you predict the period of motion? Will the equilibrium position be in the same place on the table? What would happen (don't do it!) if the table were tilted 90^o with respect to the horizontal? Can you predict the period?

Experiment 7: Momentum Changes in Explosion.

In this experiment, we will study the effects of an explosion between two pucks. We can define and explosion as a sudden force pushing the pucks apart. We will be concerned primarily with the momentum of the two puck system. Place two pucks on the Air Table with a compression spring between them. Compress the spring by pushing the pucks together and then release them. Record their motion. What is the momentum of puck **A** before the explosion? What is the momentum of puck **B** before the explosion? What is the vector sum of the momenta of the two pucks? What is the momentum of puck **A** after the explosion? What is the momentum of puck **B** after the explosion? What is the vector sum of their momenta after the explosion?

Repeat the above experiment using two equal mass pucks except compressing the springs a little more or a little less than in the previous experiment. Does the momentum of each puck before and/or after the explosion depend upon the strength of the explosion? Repeat the experiment except add 100 grams to puck **A**. Continue to repeat the experiment, each time adding mass to puck **A** until you have obtained enough data to answer the following questions. How does the total momentum of the system before an explosion compare with the total momentum after an explosion? What if you did the experiment on a tilted Air Table? How would this affect your experiment? Make some predictions then try it.

What if we push puck **A** against the bumper wire of the Air Table and then release it? Is momentum conserved in this case? We see the puck moving in one direction but nothing appears to move in the opposite direction. Can you explain what's happening.

Experiment 8: Collisions (elastic).

In the previous experiment we analyzed the momentum changes in pucks which were "exploded". Since both pucks were initially at rest the total initial momentum of the system was zero. In this experiment we will study two pucks moving toward each other so that the initial momentum of the system is non-zero.

Place an unloaded puck, **A**, at the center of the table. There may be some slight drift but this will not affect the results. Launch a second unloaded puck, **B**, from the end of the table. What is the momentum of **A** before the collision? What is the momentum of **B** before the collision? What is the total momentum (vector sum) of the system before the collision? What is the momentum of **A** after the collision? What is the momentum of **B** after the collision? What is the total momentum (vector sum) of the system after the collision? How does the momentum before the collision compare with the momentum after the collision?

Repeat the experiment except add 100 grams mass to the stationary puck **A** and record the system's motion. Remove the 100 grams mass from the stationary puck **A** and place it on the moving puck **B** and repeat the experiment. Record the system's motion. Place an unloaded puck in the center of the table and launch pucks of varying mass at it. For each situation; What is the momentum of **A** before the collision? What is the momentum of **B** before the collision? What is the total momentum (vector sum) of the system before the collision? What is the momentum of **A** after the collision? What is the momentum of **B** after the collision? What is the total momentum (vector sum) of the system after the collision? How does the momentum before the collision compare with the momentum after the collision?

In the previous experiment, one puck was stationary at the start of the experiment. In this experiment you will work with two moving pucks. Place one puck (with no additional mass) at each end of the table and launch them toward each other at low velocities. From the record of the pucks' motion determine the velocities (and momentum) of each puck both before and after the collision. Increase the mass of one puck and repeat the experiment. Is momentum conserved?

Experiment 9: Collisions (inelastic).

So far, the experiments involving collisions have all been elastic. The next experiment involves inelastic collisions. Place a strip of hook velcro on one puck and pile velcro on the other. Now, when the pucks are launched at each other they will stick when they strike and become one object after the collision.

Place an unloaded puck, **A**, at the center of the table. Launch a second unloaded puck, **B**, from the end of the table. What is the momentum of **A** before the collision? What is the momentum of **B** before the collision? What is the total momentum (vector sum) of the system before the collision? What is the momentum of **A** after the collision? What is the momentum of **B** after the collision? What is the total momentum (vector sum) of the system after the collision? How does the momentum before the collision compare with the momentum after the collision?

Repeat the experiment except add 100 grams mass to the stationary puck **A** and record the system's motion. Remove the 100 grams mass from the stationary puck **A** and place it on the moving puck **B** and repeat the experiment. Record the system's motion. Place an unloaded puck in the center of the table and launch pucks of varying mass at it. For each situation; What is the momentum of **A** before the collision? What is the momentum of **B** before the collision? What is the total momentum (vector sum) of the system before the collision? What is the momentum of **A** after the collision? What is the momentum of **B** after the collision? What is the total momentum (vector sum) of the system after the collision? How does the momentum before the collision compare with the momentum after the collision?

In the previous experiment, one puck was stationary at the start of the experiment. In this experiment you will work with two moving pucks. Place one puck (with no additional mass) at each end of the table and launch them toward each other at low velocities. From the record of the pucks' motion determine the velocities (and momentum) of each puck both before and after the collision. Increase the mass of one puck and repeat the experiment. Is momentum conserved?

In these experiments involving collisions, you have studied only the momentum of the system. No analysis has been made of the energy of the system. Is energy conserved in these experiments? Using the data you have collected, answer the following questions: What is the kinetic energy of each puck before and after the collision? What is the total kinetic energy of the system before and after the collision? Is energy conserved in these collisions?

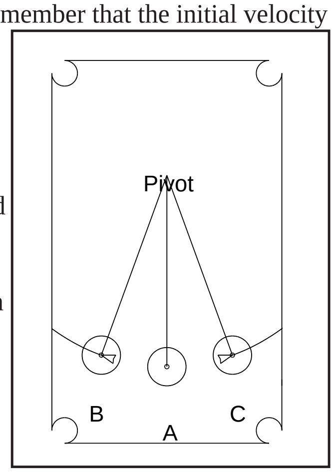
Experiment 10: Energy

Level the Air Table as usual and then raise one end of the table 2 or 3 centimeters. Release a puck from the raised end of the table so that it moves down the table. Record its motion until it strikes the bottom bumper. Compute the potential and kinetic energy of the puck at six points along its path. Calculate the sum of the potential and kinetic energy at each point. Can you draw any conclusions from your results? Repeat this experiment for various angles of table tilt.

Repeat the previous experiment except this time launch the puck up the incline with the puck launcher. Remember that the initial velocity is not zero as it was in the previous experiment.

Experiment 11: The Pendulum

In this section, you will study the motion of the pendulum. Normally one constructs a pendulum using a mass hung from a long thin string. We will duplicate these conditions using a puck as the mass tied to a heavy piece of thread as shown in figure 9.



After the table has been leveled, raise one end of the table by about 5 cm. Set up your equipment as shown in figure 9. Pull the puck back to position **B** and release. With a stop watch, time one complete oscillation (the motion from **B** to **C** and back to **B**). Do this several times and find the average time (the period) for a complete oscillation. What happens to the period as we increase the mass hanging from the string? Determine the period of the pendulum for several different puck masses. What effect does changing the mass of the pendulum have on its period?

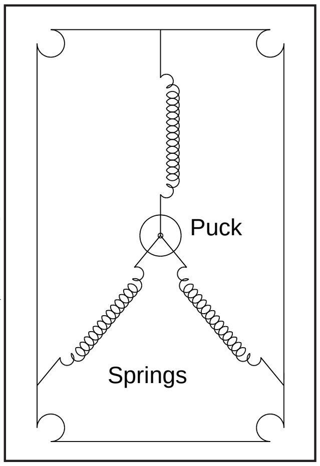
Set up your equipment to answer each of the following questions: What happens to the period if you change the length of the string? What happens to the period if you change the angle of tilt of the table? What happens to the period if you change the amplitude of the motion?

Look up the formula for the period of a pendulum in a physics text. Can you determine the value of 'g' in the formula by performing an experiment on the Air Table? How would you modify this formula so that it would be valid under all conditions on the Air Table. Explain how you could model the behavior of a pendulum on the moon using the Air Table.

Attach a mini strobe or blinky to the end of a string and set up the equipment as shown in figure 9 (or use strobe photography). Take a photograph of the pendulum swinging from **A** to **C**. Determine from the record of the motion the point at which the speed of the pendulum bob (the puck or mini strobe) is a maximum. Determine the point at which the tangential acceleration is a maximum. Determine the point where the speed is a minimum. Determine the point at which the tangential acceleration is a maximum. Where is it a minimum?

Experiment 12: Vectors

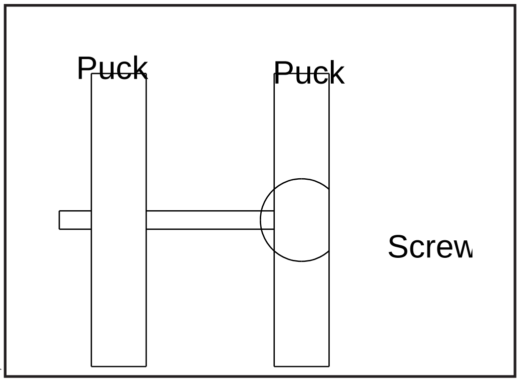
The Air Table may be used as a force table. Calibrate three springs as explained in experiment 6. Using any convenient screw locations, set up the experiment as shown in figure 10. The three springs will stretch to various lengths until equilibrium is attained. Since the system is in equilibrium, the vector sum of all the forces is zero. The force exerted by any spring must be equal to the forces exerted by the other two springs (remember, force is a vector). The magnitude of the force exerted by each spring can be determined from the previous calibrations. The angles may be measured using protractors.



Move the springs to other positions on the table and draw vector diagrams of the forces acting on the puck. How would your results be affected if a more massive puck were used? What would be the effect of carrying out the experiment on a tilted table? Could you carry out this experiment using two springs with gravity as the third force component? Try it.

Experiment 13: Rolling and Sliding

If one disk is released on an incline which is sufficiently tilted so that it will slide down the incline on its flat side and another identical disk is released on end at the same time so that it rolls down the incline, the rolling disk will reach the bottom first. Would the rolling disk reach the bottom first on an Air Table where there is no friction? Explain your answer.



To carry out an experiment to determine whether a rolling or sliding disk would reach the bottom first, you will first need two small size pucks and a stop watch. Raise one end of the Air Table about 2 centimeters. Connect two pucks as shown in figure 11. Use a long screw to connect the pucks. With the air off, allow the pucks to roll down the incline. Next, with the air on, allow the pucks to slide down the incline. Time the motion of the pucks each time.

In which case do the pucks reach the bottom of the table first? Can you explain the results?

Repeat the previous experiment using two large pucks. Compare the time it takes for the large pucks to slide down the incline with the time it took the small pucks to slide in the previous experiment. Is there any difference? Explain. Compare the rolling times for the large double puck and the small double puck. Is there any difference?

With the improved "Ealing" style pucks, a single puck will not roll by itself because of the protruding bumper that makes collisions align with the center of mass of the pucks.

Additional Experiments:

Your Air Table can be used for learning and demonstrating a number of other physics principles. Experiments can be performed in scattering, elastic collisions, moment of inertia, centripetal acceleration, conservation of angular momentum, Newton's third law, the Coriolis effect, the Foucault pendulum, equilibrium, and conservation of momentum.