10-105 Fan Cart

Purpose:
To investigate forces and their components as applied to wind driven sails, and the acceleration produced by a constant force.

Required Accessories:
Inclined plane or spring scale
Ultrasonic Motion Probe (optional)

Assembly:
To adjust the angle of the sail, loosen the wingnut, turn the sail to the desired angle and tighten the wingnut again.

Discussion:
How does a sail boat move through the water on a windy day? The wind pushes against the sail resulting in a net force which begins to accelerate the boat through the water. If there is no wind, there will be no force, and the boat will not move. Why not create your own wind? Will the boat move if you stand in the boat and blow air into the sails with a fan? (This is very similar to sitting in a canoe on a calm day and pulling on a rope tied to one end of the canoe. Will you be able to move the boat?) There must be a net force on the boat before it will move. On a windy day this force comes from the wind pushing on the sail and for all practical purposes, is perpendicular to the surface of the sail.

Before going much further, we must explain what a vector is. A vector is a notation that is used to describe a certain value (magnitude) that also has a direction associated with it. An example of a vector would be displacement, its magnitude would be distance, say, 10 meters, but the first question that should come to mind after hearing this is "10 meters in which direction?". We can now associate a direction with the magnitude; for example North East. What can we do with this vector now that we've defined it? A vector does not have to remain in the same place that it was originally drawn, you can "pick it up and move it" anywhere you need to; just keep the length of the vector and its direction the same. We can add vectors graphically by placing the tail of one at the head of another. We can also split a vector up into components and have two or more vectors that will add up to the original vector. Be sure to refer to your text book for a more complete description of vectors and their use.

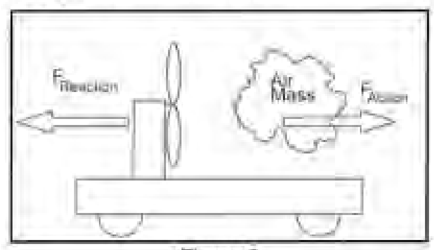

Figure 2

Force diagram of Fan Cart without the sail in place. Will the cart move?

Now back to our sail boat (sail cart) with a fan. If we have no sail and turn the fan on, what will happen to the cart? Will it move? Let's look at a force diagram for the cart (Figure 2).

Consider the forces in the vertical direction. The cart is being pulled downward by the force of gravity and it is being pushed upward by the normal force exerted on the cart by the table top. These two forces are equal in magnitude and opposite in direction. Assuming a frictionless table top, what are the forces in the horizontal direction. There is one force on the cart caused by the air pushing against the fan as it spins around (the opposite force is the fan pushing against the air behind the cart). If we look at the cart alone, there is a net force in the horizontal direction which implies that there will be an acceleration of the cart. The cart will move.

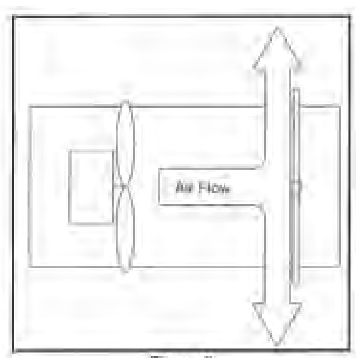

Figure 3

Put the sail back on the cart and position it perpendicularly to the length of the cart so that the fan blows directly into the sail. Place the cart on a flat table top and turn on the fan. What happens this time? Does the cart move?

(Remember that the motion of air is a complex phenomena and your results may vary from one experiment to another depending upon the way you position the sail. You are looking for the outstanding differences between experiments. For example if the cart rolls quickly in one experiment we know there is a large force on the cart. If the cart moves slowly in the next experiment then we know there is a relatively small force on the cart, perhaps near zero. You may find that in certain circumstances, theory states that the net force should be zero and yet you still detect a small acceleration. Observations such as this occur because the theory does not fully account for the complexities of moving air.)

You will find that the cart remains motionless or perhaps moves very slowly compared to the previous experiment that did not use the sail. Why is this? If we draw a force diagram of the cart for this new configuration we find that it looks the same as before except for the moving air mass that strikes the sail. This air mass exerts a force on the sail. The air can be thought of as a very large number of microscopic particles colliding with the sail's surface. Each particle experiences a change of direction, initially perpendicular to the sail then roughly parallel to the sail's surface after impacting (see Figure 3). This collision exerts a force on the sail in a direction opposite to the thrust from the propeller. The net force on the sail cart is zero (or nearly so).

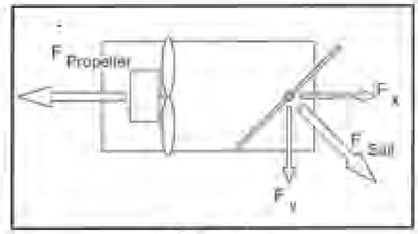

Figure 4

Force diagram for the Fan cart with the sail at an angle.

What happens if you place the sail at an angle to the cart's axis? The net force on the cart can be determined by allowing the cart to push itself up an inclined plane. With this method, you are balancing the thrust of the cart against a component of the cart's weight. The steeper the incline, the greater the net "pushing" force. Try balancing the cart's thrust by gradually increasing the angle of the incline until the cart no longer moves upward. Plot the angle of this incline as a function of the sail angle.

You may wish to modify the shape of the sail by adding cardboard extensions to the sides of the sail. These cardboard shapes can be used to redirect the air that leaves the sail. Try redirecting the wind back toward the motor end of the cart. How does this affect the cart's motion? It is helpful to keep the concept of conservation of momentum in mind when conducting these types of experiments and to think of the air as many microscopic particles.

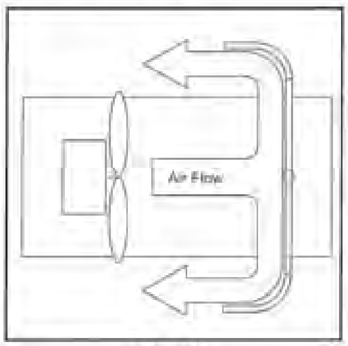

Figure 5

The effect of reversing the direction of the air flow.

Product Improvement Accessory Package:

It is useful to change the force on the cart without changing the mass in order to study the relationship between force and the acceleration produced. The enclosed by-pass conductors (shunts) are to be wrapped under one or two of the AA cells with the paper side facing the cell. This will insulate the cell terminals but complete the series circuit by shunting the battery pack terminals. This gives the cart three different propeller speeds which will provide three different accelerations. Again, the cart can be placed in equilibrium on an inclined plane at each propeller speed, plotting the angle of the incline versus the number of batteries driving the motor as before. An ultrasonic motion probe will return quantitative data for making the measurement of actual cart acceleration at the different propeller speeds.

Time Allocation:

Five minutes is required to prepare this product for service the first time. Individual experiment times will then vary depending on student needs and methods of instruction, but normally will not exceed one class period.

Feedback:

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

Warranty and Parts: We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.