The Academy of Model Aeronautics ALPHA:

Potential Energy Background Information for the Teacher

When the rubber motor of a model plane is wound it becomes a form of stored **potential energy**. As the rubber band unwinds, this potential energy is converted into **kinetic energy**, the energy of motion. In this system, kinetic energy is expressed in the following way: the propeller spins and the air behind the propeller is pushed back. As a result, the plane moves forward. All of these are forms of motion that are the result of kinetic energy.

As the **ALPHA** moves forward, air molecules flow over the wings that are also a part of the plane. This airflow causes lift that causes the plane to climb. This altitude gain is itself a form of potential energy. When the rubber band completely unwinds, the altitude gained is converted back into kinetic energy in the form of distance or duration as the plane descends as a glider.

In general, in accordance with **Newton's 2nd law (F = ma)**, planes with more turns on the rubber band motor will generate more thrust and will have a greater flight duration in the air. Planes with more turns on the rubber motor typically fly higher and farther and have longer flight times than planes with fewer turns. This student activity tests this hypothesis.

According to **Newton's 3rd law**, every force has an opposing force. In aviation, there are four well-known forces of flight. For a plane to stay in level flight or climb, the thrust produced by a propeller must equal or exceed the drag produced by the plane. In a similar way, lift produced by the wing must exceed the mass of the aircraft, expressed as weight, the force of gravity acting downward on a mass. If the lift is insufficient, the plane will descend because of the force of gravity. Sufficient velocity is needed to generate lift and this is why the propeller is needed to generate thrust.

However, as the plane moves through the air, lift is produced but so is drag. In fact, it is not possible to generate lift without also generating some amount of drag. Flight duration of the aircraft is maximized at the velocity that maximizes the production of lift while minimizing the amount of drag. This velocity is sometimes referred to by aviators as the "best speed to fly." The forces of thrust, drag, lift, and weight are commonly referred to as the "Four Forces of Flight."

As mentioned above, increasing the number of times the rubber band is wound typically will increase the time that the propeller will spin, increasing overall flight duration. However, students may find that increasing the number of turns in the rubber band also makes the propeller spin faster with the effect of increasing thrust and making the plane fly faster. If the plane is trimmed to fly in level flight at low speeds and increased thrust is applied, the plane will tend to climb rather than stay in level flight. Students can experiment with trimming the aircraft to maintain level flight or a slight climb, as they increase the number of turns in the rubber band.

To maximize endurance, the **ALPHA** should be launched at the "best speed to fly" and at the proper pitch, or angle of attack. Pitch refers to the up or down angle that the nose is pointed. With too much nose-up attitude the plane will immediately climb, lose velocity, and with insufficient air going over the wings to generate lift, the wing will "stall." In this condition, gravity will force the plane to descend, and in doing so the aircraft will once again pick up speed, and increased air-flow over the wing may help the plane level out and continue flying. However, flight duration will be reduced because of the stall. Similarly, students that launch with nose-down attitude are essentially pitching the plane toward the ground with high initial velocity, decreasing flight duration and possibly damaging the model. In between these extremes is the best attitude for launch. In general, if students are coached to launch the models with wings-level and nose pointed at the horizon, the angle of attack is sufficiently close to the proper pitch that the flight will be a success.

Students should launch their planes as if they are throwing a dart at a dartboard rather than throwing a curveball. Throwing the plane as a dart minimizes induced drag. Throwing the plane with a twist as a curveball creates roll and yaw, both of which can add drag. Because this lesson is largely about potential and kinetic energy, duration and distance are maximized when both of these types of energy are conserved.

For purposes of this lesson, little can be done about weight, the force of gravity acting on the mass of the plane. To counteract weight, airfoils are designed to maximize lift, which is the science of aeronautical engineering. The **ALPHA** wing design is fixed and this allows students to study different amounts of thrust (as in the number of rubber band windings) to see how stored potential energy is converted to kinetic energy. They can also try to minimize drag by launching correctly to keep the plane from stalling or diving and being damaged. Drag is often considered "the enemy of flight," and this unit allows students to explore the opposing forces of thrust and drag.

Student Data Sheet

Background: When you wind the rubber motor of a model plane, you are storing potential energy. This energy is transformed into kinetic energy when you launch the plane. In general, according to **Newton's 2nd law (F = ma)**, planes with more turns on the rubber motor will generate more thrust and accelerate faster than models with less thrust. As thrust accelerates the plane forward, the wings of the plane generate lift. Drag, the resistance to forward motion, is a by-product of the plane's passage through the air. As the plane's velocity increases, drag increases. Planes with more potential energy have the opportunity to generate thrust over a longer period of time and will have greater time aloft. Planes that minimize drag also can extend flight times by reducing the energy needed to maintain level flight.

Directions: You will study how increasing the turns in a rubber motor will affect a plane's time aloft. Work with your partner or group and choose one plane to study.

1) Finish this hypothesis: If thrust increases, then…

2) List at least three variables you should keep the same every time you test your plane.

Flying the AMA **ALPHA** with **600** turns on the rubber motor:

Adjust your wing to establish the correct center of gravity (CG). Mark the wing position with a pen. Use a winder to put **600** turns on your rubber motor.

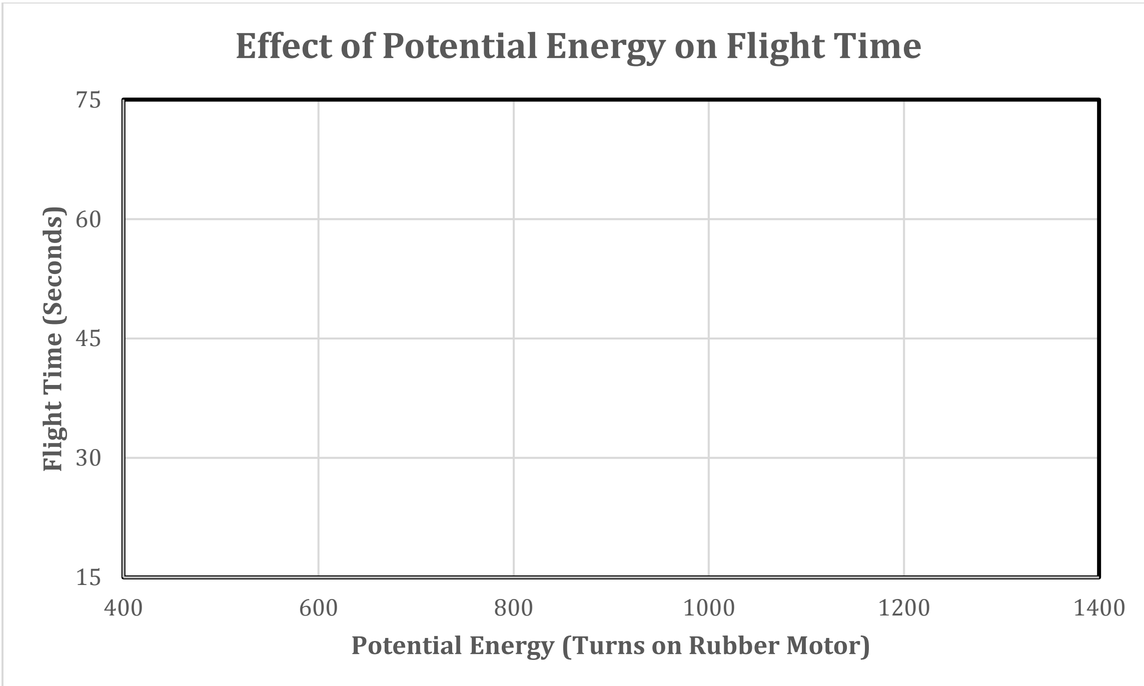
Flying the **ALPHA** with **800** turns on the rubber motor:

- Move your wing to the mark. Use a winder to put **800** turns on your rubber motor.
- Collect data using the same procedure as before.

ALPHA time aloft with 800 Turns ___________

ALPHA time aloft with 1000 Turns___________

Graph your data for _____, ________, and _________turns:



How did changing the number of turns on the rubber motor affect time aloft?