Lesson 1 Handout: How a Drone Flies

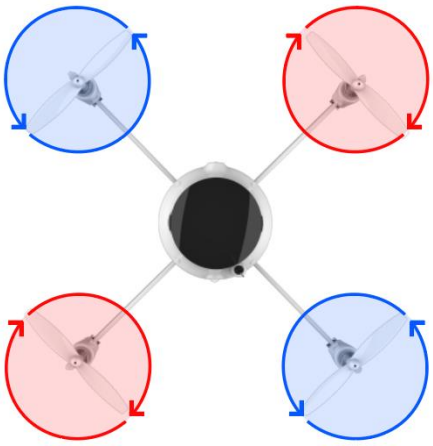
How to Make a Drone Go Up

On an airplane, the propellers face forward and push the plane in the forward direction. On a drone, the propellers point upwards and push the drone in the upward direction. The spinning blades of a drone push air downward. As **Newton's third law** states, for every action, there is an equal and opposite reaction. As the drone propellers push air down, air pushes up on the propellers creating **lift**, the force that opposes gravity. The faster the speed of the propellers, the more lift is created and the faster the drone goes up.

Summary:

- To make a drone go up, the force of lift needs to be greater than the force of gravity. If the force of lift is less than the force of gravity, the drone goes down. When the forces of lift and gravity are equal, the drone hovers in place.

How to Make a Drone Turn



Your Circuit Scribe Drone has two sets of propellers rotating in opposite directions. In the image to the right, the top left and bottom right are spinning in the counterclockwise direction while the top right and bottom left are spinning in the clockwise direction. When the drone is stationary in the air, the propellers are all going at the same speed. (Remember, speed is a **scalar quantity**, meaning that each propeller moves at the same rate. Scalar quantities do not take into account the direction an object moves.)

One set of propellers has a negative angular momentum and the other set have a positive angular momentum. However, the net angular momentum at the drone body is zero.

To make a drone turn in a certain direction, the net angular momentum at the drone body should not equal zero. This happens when one set of propellers spins faster while the other set spins slower by the same factor. By increasing the speed of one set at the same rate that the other set is decreased, the overall upwards force remains the same. This ensures that while the drone rotates, it does not move up or down in the air.

Summary:

- To rotate the drone clockwise, increase the speed of the motors going clockwise and decrease the speed of the motors going counterclockwise. This will make the angular momentum of the drone body point in the clockwise direction.

- To rotate the drone counterclockwise, decrease the speed of the motors going clockwise and increase the speed of the motors going counterclockwise. This will make the angular momentum of the drone body point in the counterclockwise direction.

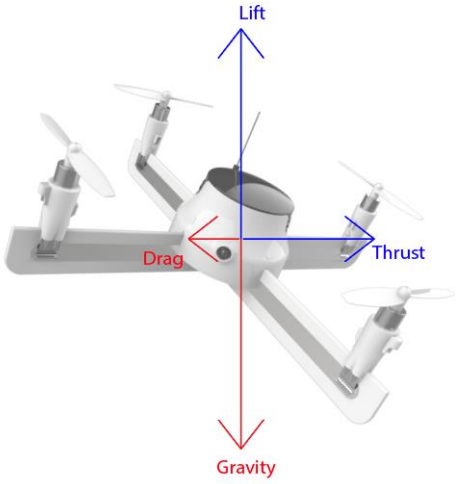
As your Circuit Scribe Drone flies, its propellers move at a certain speed and spin in a certain direction. The image to the right demonstrates that the top left and bottom right propellers are spinning in the counterclockwise direction, while the top right and bottom left propellers are spinning in the clockwise direction. When the drone is stationary in the air, the propellers are all going at the same speed. For the drone to turn clockwise, the clockwise propellers must move at a faster speed than the counterclockwise set. For the drone to turn counterclockwise, the counterclockwise propellers must move at a faster speed than the counterclockwise set.

Summary:

- To rotate the drone clockwise, increase the speed of the motors going clockwise and decrease the speed of the motors going counterclockwise. To rotate the drone counterclockwise, increase the speed of the motors going counterclockwise and decrease the speed of the motors going clockwise.
- To keep the drone from moving upward or downward while you are rotating it, ensure that, as the speed of one set of propellers increases, the other set is decreased. This keeps the overall lift force the same, as the amount of air being pushed down by the propellers remains constant.

How to Make a Drone Move Horizontally

For a drone to move in any direction, it needs **thrust**, a forward force. Below is a drone's free body diagram, or a picture representing the forces on the drone, as it moves to the right. The blue arrows, thrust and lift, are the forces applied by the motors. The red arrows, drag and gravity, oppose the force created by the motors. In particular, gravity is a naturally-occurring force that points in the direction opposite to lift and drag is a force of friction that points in a direction opposite to thrust. The arrows in the free body diagram represent the net force in that direction as a result of all four motors. In reality, each motor applies ¼ of the total thrust and lift.



Moving the drone in any direction is a balancing act. The total lift needs to remain the same as the weight of the drone to keep it at the same height. The total angular momentum needs to remain at zero so the drone doesn't rotate/the speed of all propellers need to remain the same so the drone doesn't rotate. For the drone to move in a horizontal direction, it needs a forward component of thrust from the propellers. This can be accomplished by reducing the speed of two adjacent motors and increasing the speed of the other two motors by the same factor. For example, if you wish to move the drone to the right as pictured in the free body diagram above, the speed of the two motors on the left should be increased and the two motors on the right should be decreased.