KNOW BEFORE YOU FLY

Student Drone Kit
Unit of Study

KNOW BEFORE YOU FLY

STUDENT DRONE KIT UNIT OF STUDY

An educational experience designed for students in grades 9-12
Next Generation Science Standards-compliant

Special thanks to Rick Crosslin for his input on this drone unit of study.

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This unit of study includes the following sections:

KNOW BEFORE YOU FLY

STUDENT DRONE KIT UNIT OF STUDY

INTRODUCTION

Welcome to the Know Before You Fly Student Drone Kit unit of study! We're excited that you have chosen to incorporate these kits into your lesson plan. No previous experience or training with drones is necessary to successfully teach this unit. This guide will help you safely and effectively utilize these advanced drones with your students.

This unit of study is part of a suite of resources to support the drone kit including videos, webinars, and more that can be found at the Student Drone Kit - Know Before You Fly website (https://knowbeforeyoufly.org/resources/studentdronekit). The kit is meant to provide students with hands-on, technical experience that meets science standards while also bolstering career readiness.

Know Before You Fly Student Drone Kit

We hope you will review this unit and implement whatever sections are applicable to your students and educational structure. We look forward to hearing how you use these kits in your unique learning environment! Be sure to complete the survey found through the Student Drone Kit - Know Before You Fly website (https://knowbeforeyoufly.org/resources/studentdronekit) once you have completed the unit of study. This will help us learn from you and provide even better resources based on your feedback.

Recreational UAS Safety Test (TRUST)

Students will study drones to:

- Know how to safely build and fly a drone.
- Understand the forces and motion of drone flight.
- Collect and analyze data.
- Identify pathways to aviation.
- Work in shared team approach.

RESEARCH MORE ABOUT DRONES by visiting these helpful links:

- Student Drone Kit website: Student Drone Kit - Know Before You Fly (https://knowbeforeyoufly.org/resources/studentdronekit)
- Radio frequency: 5.8GHz FPV Channels & Frequency Chart on page 16
- TRUST certification: The Recreational UAS Safety Test (TRUST) (https://www.modelaircraft.org/trust)
- FAA Drone Zone: https://faadronezone.faa.gov/

FAA Drone Zone

Special note: this symbol indicates a technical career skill!

BACKGROUND INFORMATION

Let's begin with some common terms that surround drones and are utilized in this unit of study:

DRONE VOCABULARY

- **Academy of Model Aeronautics (AMA):** The AMA is a membership organization and FAA-recognized community-based organization (CBO). The AMA is a nonprofit community of enthusiasts who come together to celebrate model aviation.
- **Drone:** A craft that operates without direct physical control from a carried crewperson.
- **Unmanned Aircraft System (UAS):** An unmanned aircraft system is an unmanned aircraft and the equipment necessary for the safe and efficient operation of that aircraft. An unmanned aircraft is a component of a UAS. It is defined by statute as an aircraft that is operated without the possibility of direct human intervention from within or on the aircraft (Public Law 112-95, Section 331(8)).
- **Unmanned Air Vehicle (UAV):** An aircraft piloted by remote control or onboard computers.
- **First-Person View (FPV):** The ability of the user to see from an onboard camera mounted to a UAS which provides visual perspective of that aircraft, rather than from his/her own location.
- **Student Drone Kit (SDK):** A drone kit that includes hardware and resources that enable the safe building and operation of an advanced drone. Also includes learning resources for use within an educational setting.
- **Remote Pilot in Command (RPIC):** The responsible party for the operation of a UAS.
- **Return to Landing/Launch (RTL): A** command used on some UAS that initiates a return to launch or return to specified landing location with little or no further control inputs from the RPIC.
- **Federal Aviation Administration (FAA):** Its continuing mission is to provide the safest, most efficient aerospace system in the world.
- **Know Before You Fly (KBYF):** An education campaign organized by the AMA, the Association for Uncrewed Vehicle Systems International (AUVSI), and the Consumer Technology Association (CTA), in partnership with the FAA. Their shared goal is to educate prospective users about the safe and responsible operation of drones.
- **Line of sight (LOS):** The ability of the pilot of an UAS to maintain visual contact with the aircraft and determine its orientation and operation without enhancements other than corrective lenses.

RESOURCE

Next Generation Science Standards - High School Physics

The Big Idea: Building and Flying Drones - Understanding Force and Motion

Next Generations Science Standards (NGSS) & Common Core State Standards (CCSS)	
Enduring Understanding	**Essential Questions**
• The change of the position and the change in speed of an object determines its motion. • In order for motion to change, an unbalanced force must be applied. • All physical objects in the universe interact with one another. Each interaction happens as a result of some type of force. • Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) • Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2), (HS-PS2-3)	• How can we describe the motion of a drone in the world around us? • How can one predict a drone's continued motion, changes in motion, or stability? • How can we describe force in the world around us? • What is the effect of forces on a drone and a drone's motion?

Student Learning Objectives	**Disciplinary Core Ideas (DCI) With Extended Knowledge** **Students will know:**	**Science & Engineering Practices With Additional Skills** **Students will be able to:**	**Cross-Cutting Concepts** **Students will apply:**
• Given a graph of position or velocity as a function of time, recognize in what time intervals the position, velocity and acceleration of an object are positive, negative, or zero and sketch a graph of each quantity as a function of time. HS.PS2.A *[Clarification statement: Students should be able to accurately move from one representation of motion to another.]* • Represent forces in diagrams or mathematically using	**PS2.A: Forces and Motion** • Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) • Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the	**Planning and Carrying Out Investigations** Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models. • Plan and investigate individually and collaboratively to produce data to serve as the basis for evidence. In the design,	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4) **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1), (HS-PS2-5)

Student Learning Objectives	Disciplinary Core Ideas (DCI) With Extended Knowledge Students will know:	Science & Engineering Practices With Additional Skills Students will be able to:	Cross-Cutting Concepts Students will apply:
appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. HS.PS2.A • Understand and apply the relationship between the net force exerted on an object, its interior mass, and its acceleration to a variety of situations. HS.PS2.A • Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. HS-PS2-1 *[Clarification statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.]* *[Assessment boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]*	momentum of objects outside the system. (HS-PS2-2), (HS-PS2-3) **PS2.B: Types of Interactions** • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4), (HS-PS2-5) • Attraction and repulsion between electric charges at the atomic level. Explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-6), *(secondary to HS-PS1-1), (secondary to HS-PS1-3)*	decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5) **Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions	• Systems can be designed to cause a desired effect. (HS-PS2-3) **Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) ***Connections to Nature of Science*** **Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6) **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories and laws provide explanations in science. (HS-PS2-1) • Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1)

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<th>Student Learning Objectives</th>
<th>Disciplinary Core Ideas (DCI) With Extended Knowledge

Students will know:</th>
<th>Science & Engineering Practices With Additional Skills

Students will be able to:</th>
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Predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted. HS.PS2.A
Use mathematical representation to support the claim that the total momentum of a system objects is conserved when there is no net force on the system. HS-PS2-2

[Clarification statement: Emphasis is on the quantitative conservation of momentum in the interactions and the qualitative meaning of this principle.]

[Assessment boundary: Assessment is limited to qualitative evaluation and/or algebraic manipulations.]
Make qualitative predictions about natural phenomena based on conservation of momentum and restoration of kinetic energy in elastic collisions. HS.PS2.A
Apply scientific engineering ideas to design, evaluate, and refine a device that minimizes the force on

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PS3.A: Definitions of Energy

“Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5)

ETS1.A: Defining and Delimiting an Engineering Problem

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)

ETS1.C: Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS2-3)

Knowledge

Speed is defined as the distance traveled divided by the time

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including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

Use mathematical representations of phenomena to describe explanations. (HS-PS2-2), (HS-PS2-4)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6)

Additional Skills

Create a graph of position vs. time.
Interpret a graph of position vs. time.
Make a prediction regarding motion based on graphs.
Draw strobe photos to represent motion.
Use v=d/t to calculate velocity, distance, or time.
Apply understanding of speed and velocity to authentic situations.
Create a graph of speed vs. time.
Interpret a graph of speed vs. time.

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Student Learning Objectives	Disciplinary Core Ideas (DCI) With Extended Knowledge Students will know:	Science & Engineering Practices With Additional Skills Students will be able to:
a macroscopic object during collision HS-PS2-3 *[Clarification statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples could include a football helmet or a parachute.]* *[Assessment boundary: Assessment is limited to qualitative evaluation and/or algebraic manipulations.]*	it took to travel that distance and is measured in m/s. (v=d/t) • Velocity incorporates speed and direction. • Acceleration is defined as the change in velocity divided by the time it took to change that velocity and is measured in m/s2. (a = v/t) • Newton's first law of motion states that an object at rest will remain at rest or an object in motion will remain in motion unless an unbalanced force is applied. • Inertia is an object's natural tendency to remain in its current state (at rest or in motion) and is directly related to an object's mass. • Newton's second law of motion states that an object's acceleration is directly proportional to the force applied to it and inversely proportional to the mass of the object. • The direction of the acceleration is the same as the direction of the unbalanced force. (F=ma)	• Make a prediction regarding motion based on graphs. • Use a=v/t to calculate acceleration, velocity, or time. • Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values. • Apply understanding of acceleration to authentic situations. • Draw force diagrams. • Interpret force diagrams. • Apply Newton's first law to predict the motion of an object based on the forces applied. • Compare the inertia of two objects. • Create simple models to demonstrate the benefits of seatbelts using Newton's first law of motion. • Apply understanding of inertia to authentic situations. • Use F=ma to explain Newton's second law of motion. • Use F=ma to calculate force, mass, or acceleration. • Use Fg=mg to explain and distinguish between weight and mass. • Measure and describe the relationship between force acting on an object and the resulting acceleration. • Compare an object's weight in different gravitational environments. • Apply understanding of Newton's second law of motion to authentic situations. • Explain Newton's third law of motion in student's words. • Apply Newton's third law of motion to authentic situations. • Construct momentum charts. • Identify initial and final states of systems. • Learn to imply the ideas of impulse and momentum to the world around us. • Use p=mv to solve for momentum, mass, and velocity.

Disciplinary Core Ideas (DCI) With Extended Knowledge Students will know:	Science & Engineering Practices With Additional Skills Students will be able to:
• Friction is a force that opposes motion because of the types of surfaces interacting. • Mass is the amount of matter an object has and is measured in grams. • Weight is the amount of gravitational pull on an object and is measured in Newton (n). (Fg=mg) • All objects exert a gravitational pull on one another. This pull is relative to the mass of the object and the distance between them. • Newton's third law of motion states that every force has an equal and opposite reactive force. • Momentum is equal to the object's mass times the object's velocity. (p=mv) • The total momentum of a system remains constant unless an external force is exerted on the system.	***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories and laws provide explanations in science. (HS-PS2-1), (HS-PS2-4) • Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1), (HS-PS2-4)

KNOW BEFORE YOU FLY

Connections to other DCIs in this grade level:
***HS.PS3.A** (HS-PS2-4),(HS-PS2-5); **HS.PS3.C** (HS-PS2-1); **HS.PS4.B** (HS-PS2-5); **HS.ESS1.A** (HS-PS2-1),(HS-PS2-2),(HS-PS2-4); **HS.ESS1.B** (HS-PS2-4); **HS.ESS1.C** (HS-PS2-1),(HS-PS2-2),(HS-PS2-4);**HS.ESS2.A** (HS-PS2-5); **HS.ESS2.C** (HS-PS2-1),(HS-PS2-4); **HS.ESS3.A** (HS-PS2-4),(HS-PS2-5)*

Articulation of DCIs across grade bands:
***MS.PS1.A** (HS-PS2-6); **MS.PS2.A** (HS-PS2-1), (HS-PS2-2), (HS-PS2-3); **MS.PS2.B** (HS-PS2-4), (HS-PS2-5), (HS-PS2-6); **MS.PS3.C** (HS-PS2-1), (HS-PS2-2), (HS-PS2-3); **MS.ESS1.B** (HS-PS2-4), (HS-PS2-5)*

Common Core State Standards Connections:

ELA/Literacy -	
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-PS2-1), (HS-PS2-6)*
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. *(HS-PS2-1)*
WHST.11-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-PS2-6)*
WHST.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. *(HS-PS2-3), (HS-PS2-5)*
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. *(HS-PS2-5)*
WHST.11-12.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS2-1), (HS-PS2-5)*
Mathematics -	
MP.2	Reason abstractly and quantitatively. *(HS-PS2-1), (HS-PS2-2), (HS-PS2-4)*
MP.4	Model with mathematics. *(HS-PS2-1), (HS-PS2-2), (HS-PS2-4)*
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *(HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5), (HS-PS2-6)*
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5), (HS-PS2-6)*
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. *(HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5), (HS-PS2-6)*
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context. *(HS-PS2-1), (HS-PS2-4)*
HSA.SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. *(HS-PS2-1), (HS-PS2-4)*
HSA.CED.A.1	Create equations and inequalities in one variable and use them to solve problems. *(HS-PS2-1), (HS-PS2-2)*
HSA.CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. *(HS-PS2-1), (HS-PS2-2)*
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS2-1), (HS-PS2-2)*
HSF-IF.C.7	Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. *(HS-PS2-1)*
HSS-ID.A.1	Represent data with plots on the real number line (dot plots, histograms, and box plots). *(HS-PS2-1)*

SAFETY AND REGULATORY INFORMATION

Although we recommend learning to fly these drones on a simulator and indoors, it is important to understand the rules and regulations that must be followed to pilot drones outdoors in the National Airspace System (NAS). The United States has the busiest airspace in the world, so these requirements are in place to keep everyone safe. Ask students to read and be prepared to discuss in class the following FAA regulations and requirements:

- Understand the requirement to complete The Recreational UAS Safety Test (TRUST) and carry proof of passage. This is a free, guided knowledge check that takes less than 30 minutes to complete. Learn more, view a study guide and complete the certification here: The Recreational UAS Safety Test (TRUST) (https://www.modelaircraft.org/trust).
- Understand Part 107 licensed operations vs. recreational/educational flights. Learn more here: Certificated Remote Pilots (https://www.faa.gov/uas/commercial_operators).
- Required registration with the FAA if flying an aircraft that weighs more than .55 pounds at FAA Drone Zone (https://faadronezone.faa.gov/). The drone in the KBYF Kit weighs less than this, therefore does not require registration.
- Flying recreationally or for educational purposes within the safety guidelines of a federally recognized Community Based Organization (CBO) (https://www.faa.gov/uas/recreationalfliers/faa-recognized-community-based-organizations).

Understanding the rules that surround aviation leads to a safe and accessible NAS.

Recreational UAS Safety Test (TRUST)

FAA Certificated Remote Pilots

FAA Drone Zone

FAA Community Based Organizations (CBO)

SAFE DRONE FLYING PRACTICES

Modified from the Academy of Model Aeronautics Safety Code

- Keep your aircraft in line of sight at all times. Use an observer to assist if needed or if you choose to fly via FPV.
- Remain well clear of and do not interfere with manned aircraft operations, and you must always see and avoid other aircraft and obstacles.
- Do not fly over unprotected persons or moving vehicles and remain well clear of individuals and vulnerable property.
- Do not fly in adverse weather conditions such as high wind or reduced visibility.
- Do not fly under the influence of alcohol or drugs.
- Ensure that the operating environment is safe and that the operator is competent and proficient in the operation of the UAS.
- Do not fly near or over sensitive infrastructure or property such as power stations, water treatment facilities, correctional facilities, heavily traveled roadways, government facilities, etc.
- Check and follow all local laws and ordinances before flying over private property.
- Do not conduct surveillance or photograph people in areas where there is an expectation of privacy without the individual's permission.
- Recreational drone operators don't need a Part 107 license to fly. You should register your drone before you fly it with the FAA, if it weighs more than .55 pounds. The drone in the KBYF Kit weighs less than this, therefore does not require registration.
- Users of both commercial and recreational UAS should be aware that in remote, rural, and agricultural areas, manned aircraft, including fixed-wing aircraft and helicopters, may be operating very close to ground level. Pilots conducting agricultural, firefighting, law enforcement, emergency medical, wildlife survey operations, and a variety of other services all legally and routinely work in low-level airspace. Operators controlling UAS in these areas should maintain situational awareness, give way to, and remain a safe distance from these low-level, manned airplanes and helicopters.

BUILD THE DRONE(S)

PREPARE

Before building the drones with students, make sure you familiarize yourself with the process by reviewing the kit instruction booklet and watching the video. Confirm that all kits contain the required components. If anything is missing or defective, please contact the manufacturer directly.

TIP: Depending on the group size and skills, we recommend distributing the drone components to students step-by-step at each stage of the building process. This can help prevent students from falling behind or working ahead.

> Building a drone leads to a deeper understanding of the complex systems that enable flight. Certified aviation mechanics understand how to build, maintain, and service these systems to ensure safety within the NAS.

Materials:

- Student drone kit (all contents).
- Computer for showing the build video, if applicable/desired.
- Helpful tools for working with small components, such as tweezers or needle nose pliers.

ACTIVITIES AND INVESTIGATIONS

Divide the class into appropriate groups depending on how many drone kits and students you have. Our recommendation is for each group to build and fly one drone.

IMPORTANT NOTE: These kits must be handled, built, and flown with care.

Use the instruction manual and/or video found through the Student Drone Kit - Know Before You Fly website (https://knowbeforeyoufly.org/resources/studentdronekit) to complete the following with the students:

- Review kit contents.
- Remind students that these small, lightweight components must be handled and assembled with care.
- Review and follow step-by-step assembly instructions as contained in the manual that is packaged within your drone kit. You can also distribute digital versions by visiting the following link:
- Follow specific equipment instructions (found in the manual) for drone system components:
- Batteries/charging
  - Transmitter
  - FPV goggles/monitor
  - Powering on the drone
  - Binding the drone to the transmitter
- **Before you fly the drones,** the transmitter, monitor, and batteries will need to be charged. Charging time can vary based on many factors. Reference the instructions included with the kit to charge the batteries safely and effectively. It is also important to review safety and regulatory information on pages 9-10 with students before flying.

Know Before You Fly
Student Drone Kit

REVIEW

Discussion Prompts

- How did the process of building the drone compare to your expectations?
- Have you ever operated a drone before?

Journal Writing Prompts

- Draw and label some of the major drone components.
- What was the most challenging part of building the drone?

Student Uses of Technology

- Assembling a drone from components.
- Safe battery usage and charging.

Assessment: Evidence of Student Learning

- Students demonstrate correct building techniques with a finished, working drone.

It's important to understand how an aircraft is built and repaired to meet the standards of flight in both UAS and crewed aviation.

FLYING THE DRONES

FREE ONLINE SIMULATOR

The BEST and most economical way to get started with flying a drone is to use a computer-based flight simulator. This allows new pilots to practice flight skills without risking any damage to the drone as they learn. If you have access to a computer, you can do this for free!

Materials

- Computer
- Transmitter from drone kit (charged)
- USB cable from drone kit (USB-C)
- Drone kit instruction manual

Tiny Whoop Go Website

Setting Up the Flight Simulator

- Review and follow the kit instructions for using simulator mode.
- Download a free simulator. We recommend Tiny Whoop Go (https://tinywhoopgo.com/). *This may require assistance from the IT department at your location.*
- Practice using the simulator with the kit's drone transmitter.
- Have students take turns using the simulator to practice flying the drone. The first goal should be to hover successfully, then maneuver through the course and around the virtual obstacles. You may choose to utilize the simulator as a classroom competition by timing the fastest lap for each student.

New Bee Drone Replacement Parts

Tip: Unless you have a computer and transmitter for each student, not all students will be able to fly the simulator at once. If possible, have students who are NOT flying work on another assignment, such as the career pathway research and presentation project on page 17. Then switch out until all students have had the opportunity to fly using the simulator.

FLIGHT INSTRUCTIONS: INDOOR FLYING

Flying drones with students should be fun, but there are potential challenges to consider as well. Read through this section beforehand for valuable information that will help you be as prepared as possible. Remember, crashes are expected and the drone kit is made to endure, but replacement parts are available for purchase from the manufacturer if the need arises. New Bee Drone Replacement Parts (https://newbeedrone.com/collections/kbyf)

Knowing how to safely operate an aircraft is paramount to enjoying a hobby, excelling at competition, and or pursuing an aviation career.

Safety Precautions

Know Before You Fly
Student Drone Kit

- Be sure to read, understand, and follow the safety section of the KBYF SDK manual that is included in your kit. Student Drone Kit - Know Before You Fly website (https://knowbeforeyoufly.org/resources/studentdronekit)
- Safe battery use and charging (read more in the included KBFY SDK manual).
- Review the Safety and Regulatory Information on pages 9-10.
- Fly in a safe manner and location under teacher supervision.
- Wear safety glasses or eye protection.
- Students with long hair may want to tie it back to avoid drone entanglement.
- Designate a flightline. No students may cross this line while aircraft are active.
- Make it clear that safety is the priority, and that any students not following safety rules will lose the privilege of flying.
- We recommend flying indoors to avoid potential weather and airspace restrictions. If you fly outside ensure you follow all local, state, and federal guidelines.

Materials

- Know Before You Fly Student Drone Kits.
- Radio frequency: 5.8GHz FPV Channels & Frequency Chart on page 16.

Where to Fly

Select a large, open indoor space such as a gymnasium, hallway, or empty classroom. Flying indoors will avoid having your flights impacted by the weather, reduce the risk of losing aircraft, and hopefully make it easier to keep an eye on your students. Try to use a flying space that has light-colored walls that make it easier to see the drone.

Tip: Unless you have a drone for each student, not all students will be able to fly at once. If possible, have students who are NOT flying work on another assignment, such as the career pathway research and presentation project on page 17. Then switch out until all students have had the opportunity to fly.

Setup

Label each kit's associated transmitter and FPV goggles, so you know which ones go together. You can use a permanent marker, colored stickers or a label maker. Label "drone 1" on the drone, transmitter, and FPV goggles/monitor that go together.

Charge the batteries, monitors, and transmitters. Set up a charging area near your flying space. Battery life for the drone is approximately 5 minutes per charge. Each kit includes four batteries. It may take several batteries for some people to be able to hover the drone. When you swap out the depleted batteries, put them on the charger so they can be used again.

Procedures are an important task that ensures the processes are in place to identify and solve problems throughout many aviation focused careers.

Plan plenty of time for initial drone flights. Some students will pick it up more quickly than others. If any students are skilled pilots, ask them to help instruct other students during initial flights.

Review the instruction manual to learn about and utilize the following:

- Transmitter
- First flight preparation
- Flight order of operations (pre-flight, flight, post-flight)
- Flight tips

First Flights

- Safety first! Designate a flightline, which no students may cross while any drones are active.
- The first flight skill to master is hovering in place. Have students practice this without the FPV goggles initially.
- Recommend a maximum of four students per drone (this will allow one battery for each of the students to use).

Being aware of safety procedures and complying with them is important in every workplace.

- The video on the FPV goggles is a live feed only and does not record. FPV use *requires* a spotter with a constant Line of Sight (LOS) to the aircraft.
- When multiple pilots are flying their drones simultaneously using the FPV Goggles, you will need to make sure that each drone/goggles pair is on a different VTX channel or the signals will get mixed up. Depending on your location, there are specific channels that may have the best results depending on a variety of factors. These are some of the best FPV channels when flying in groups. They enable six pilots to fly at the same time clearly. You can attempt to fly with up to eight pilots but signals will likely be less clear. Two pilots: R1, R8. Three pilots: R1, R4, R8. Four pilots: R1, R3, R6, R8. Five pilots: R1, R2, F2, F4, E5. Six pilots: 5645 (E4), 5685 (E2), 5760 (F2), 5805 (A4), 5905 (E6), 5945 (E8) Or: R1, R2, F2, F4, R7, R8. (S*ome of these frequencies may be illegal in some countries. Check local regulations before transmitting!)*
- Ensure that all batteries are charged. Allow a depleted battery to cool down then charge it again if needed.
- Once hovering is successful, you can begin to slowly and carefully navigate your airspace.

REVIEW

Discussion Prompts

- If applicable, how did the flight simulator help with flying?
- Compare and contrast LOS flying, FPV flying, and simulator flying.

Journal Writing Prompts

- Draw the forces of flight of a drone.
- Compare and contrast drone and fixed-wing flight controls.
- Draw, label, and explain how a drone maneuvers in flight.

Student Uses of Technology

- Safe battery usage and charging.
- Drone FPV goggles.
- Drone transmitter.
- Tiny Whoop GO flight simulator. [(tinywhoopgo.com)](tinywhoopgo.com)
- Piloting a drone.

Homework: Potential Assignments

- Research drone information - [Know Before You Fly](https://knowbeforeyoufly.org/resources) (https://knowbeforeyoufly.org/resources)
- How do drones fly? Quad motor layout, torque, throttle, yaw, pitch, roll, etc.

It's important to understand how controls correspond to flight in both model aviation and full-scale aviation.

Assessment: Evidence of Student Learning

- Students demonstrate flying techniques with drone.
- Students understand and comply with safe flying practices.

Resources

Enduring Understanding:

- The change of the position and the change in speed of an object determines its motion.
- In order for motion to change, an unbalanced force must be applied.
- All physical objects in the universe interact with one another. Each interaction happens as a result of some type of force.
- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)

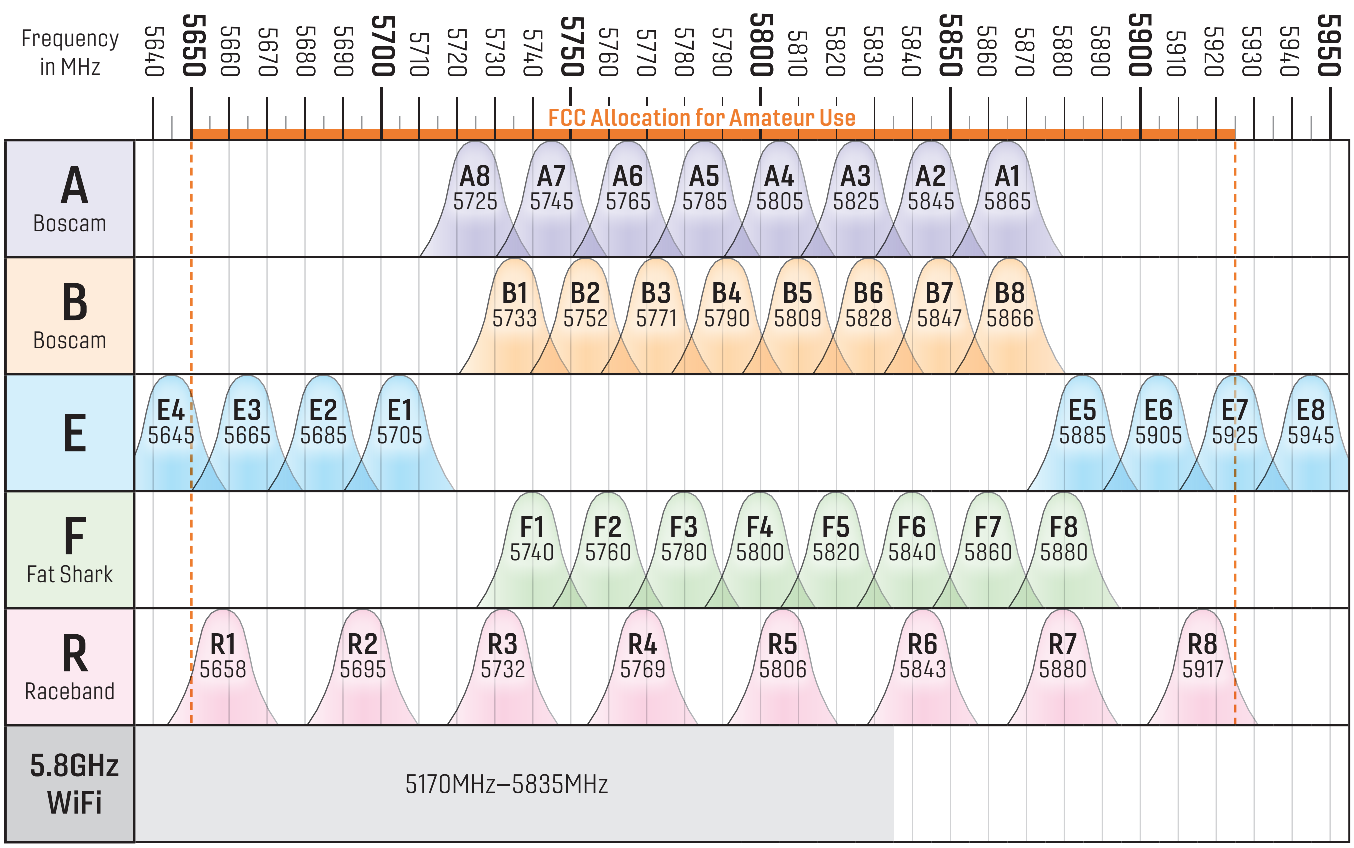
Links

- Student Drone Kit website: [Student Drone Kit - Know Before You Fly](https://knowbeforeyoufly.org/resources/studentdronekit) (https://knowbeforeyoufly.org/resources/studentdronekit)
- FAA Drone Zone: https://faadronezone.faa.gov/.
- AMA Safety Code: [Academy of Model Aeronautics](https://www.modelaircraft.org/safety) (https://www.modelaircraft.org/safety)

AMA Safety Page

FAA Drone Zone

5.8GHZ FPV CHANNELS & FREQUENCY CHART



CAREER PATHWAY INVESTIGATION

PREPARE

Learning to assemble and fly a drone could be the first step toward a career in aviation! This activity gives students the opportunity to investigate different aviation-related careers by doing their own research *and* learning from presentations given by their peers.

TIP: This is a great project to have students work on while they are waiting for their turn to fly the drone!

Materials

- Computer access

> There are many options to pursue careers that are in high demand throughout the aviation workspace. Boeing recently forecasted that "the global aviation industry will need to keep a sharp focus and engage in collective efforts to build a robust, diverse talent pipeline through more educational outreach and recruitment, development of new pathways to aviation careers, investment in early career learning opportunities, and deployment and adoption of more efficient learning methods."

ACTIVITIES AND INVESTIGATIONS

Operating a drone professionally in the United States carries some requirements which students should be aware of. It is important that they review regulations from the FAA as part of this project. Examples:

- Understand the requirement to complete The Recreational UAS Safety Test (TRUST) and carry proof of passage. This is a free, guided knowledge check that takes less than 30 minutes to complete. Learn more, view a study guide, and complete the certification here: The Recreational UAS Safety Test (TRUST) (https://www.modelaircraft.org/trust)
- Understand Part 107 licensed operations vs. recreational/educational flights. Learn more here: Certificated Remote Pilots (faa.gov) (https://www.faa.gov/uas/commercial_operators)
- Required registration with the FAA if flying an aircraft that weighs more than .55 pounds at https://faadronezone.faa.gov/. (The KBYF SDK is less than this weight!)

> Understanding the rules that surround aviation leads to a safe and accessible NAS.

Aviation Career Pathways Research

Assign the following research topics to students or allow them to choose an aviation career that interests them. Topics may include how drones are used in certain industries, as well as other traditional aviation careers.

- Meteorology
- Search-and-rescue operations
- Agriculture
- Military
- Construction
- Law enforcement
- Delivery
- Natural disaster support
- Photography
- Filming
- Scientific research
- Wildlife management
- Government/regulatory
- General aviation

- History and development of drone technology
- Drones and artificial intelligence
- Archeology
- Air traffic control
- Space exploration
- Computer programming
- Aircraft maintenance

Recreational UAS Safety Test (TRUST)

REVIEW

Discussion prompts

- What is a drone/UAS?
- What can a drone do that other aircraft cannot?
- What are safe drone flying practices?
- Who regulates drone flying?
- How are drones used?
- How did the flight simulator help with flying?
- What is the difference between recreational and commercial drone use?
- Compare and contrast LOS flying, FPV flying, and simulator flying.
- Identify a process or path to success that begins with the KBYF SDK and leads to an aviation career.

FAA Certificated Remote Pilots

Journal Writing Prompts

- Select an aviation career pathway and prepare a brief presentation for the class.

Aviation Career Pathway Presentations

Allow time for students to make short presentations about the topics they selected for research. Presentations should be brief and make use of visual resources. Schedule time in class for students to conduct their presentations in front of their peers.

Know Before You Fly Resources

Student Uses of Technology

- Computer research and directions

Homework: Potential Assignments

- Research drone information - Know Before You Fly website (https://knowbeforeyoufly.org/resources)
- Research FAA - https://faadronezone.faa.gov/.
- What type of rotors and motors are used in drones? (History, type, etc.)
- How have batteries developed? (History, type, uses, and safety.)
- How do drones fly? (Quad motor layout, torque, throttle, yaw, pitch, and roll.)
- How are drones used?

FAA Drone Zone

Assessment: Evidence of Student Learning

- Students state multiple uses for drones
- Students understand and state how drone use can lead to aviation careers
- Students give oral and/or written presentations as assigned

Resources

Links

- FAA: How to Become a Drone Pilot (https://www.faa.gov/uas/commercial_operators/become_a_drone_pilot)

FAA How to Become a Drone Pilot

DRONE SCIENCE: FORCES AND MOTION

PREPARE

Drones can be an excellent hands-on tool for learning about scientific concepts. This activity focuses on the physics of forces and motion using free body diagrams.

> Understanding the four forces of flight, and the balance of these forces, is a key component to safety in aviation.

Getting Started

Review with the class the information learned by building and flying the drone. Allow time for students to ask and answer questions about the following:

- What did you learn about how drones operate?
- What did you learn about how drones can be used?
- What are the key safety rules to follow when operating drones?

Safety Precautions

- Eye protection.
- Safe battery use and charging.
- Fly in a safe manner and location under teacher supervision.
- Ensure that enough space is available for all drone groups to safely fly.

Materials

- Student journal.
- Drones - all charged for flight.
- Meter stick or tape measure to measure height of the classroom.
- Stopwatch or timing device.

ACTIVITIES AND INVESTIGATIONS

Introduction to the topic of the lesson: *How can drones be used to understand forces and motion?* Tell students that they will be revisiting and reviewing the following concepts and terms:

Properties of a moving object

- D = distance object traveled
- a = acceleration
- t = time elapsed
- Forces = Fn, Fa, Fg
- Vi/Vf = Initial velocity divided by final velocity

Definitions

- Speed: The rate at which an object covers a distance.
- Velocity: The rate at which an object changes its position. It must contain a direction.
- Acceleration: A vector quantity that is defined as the rate at which an object changes its velocity. An object is accelerating if it is changing its velocity.
- Free Body Diagrams: A type of vector diagram that depicts the direction and relative magnitude of a vector quantity by a vector arrow.

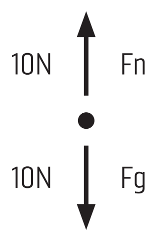
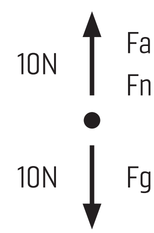
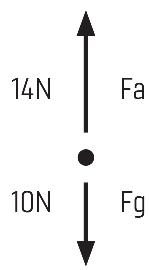
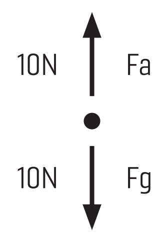
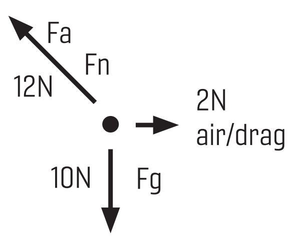
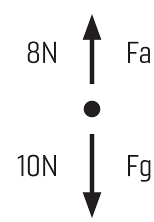
FREE BODY DIAGRAMS WITH A DRONE

Share with the class the following six free body diagrams (A-F). Discuss each diagram as it relates to a drone being flown in the classroom. For each situation, the pressure and temperature are the same. Draw these examples and define the following terms:

- F = Force
- Fn = Force normal (perpendicular)
- Fg = Force gravity
- Fa = Force applied

Ask students to copy each diagram in their journal. Ask the following question for each diagram:

- Is the drone accelerating?
- Is the drone at rest?
- What is the net force?
- Are the forces balanced?

Free Body Diagrams (from above) · N = Newton	
A. Rotors not spinning On table Net force zero, balanced No motion 	**B.** Rotors spinning On table Net force zero, balanced No motion 
C. Rotors spinning Above the table Net force **not** balanced (unbalanced) Accelerating up Motion 	**D.** Rotors spinning Above the table Net force zero, balanced Hover, no motion 
E. Rotors spinning Above the table Net force **not** balanced (unbalanced) Constant velocity forward 	**F.** Rotors spinning Above the table Net force **not** balanced (unbalanced) Descending down motion 

Drone-Free Body Diagram Descriptions

A. On a table, not moving, rotors off, and not spinning.
B. On a table, not moving, rotors on, and spinning.
C. Accelerating from the table up, rotors spinning
D. In the air above the table, hovering, rotors spinning, no vertical movement, horizontal movement, or side movements.
E. Accelerating at a constant velocity forward above the table.
F. Descending back to the table.

Fly the Drones

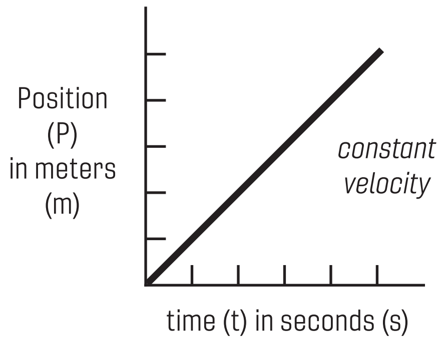
Have students arrange into their drone groups. Ask students to fly the drones in such a manner as to demonstrate each of the six free-body diagrams.

UNDERSTANDING MOTION WITH VECTORS

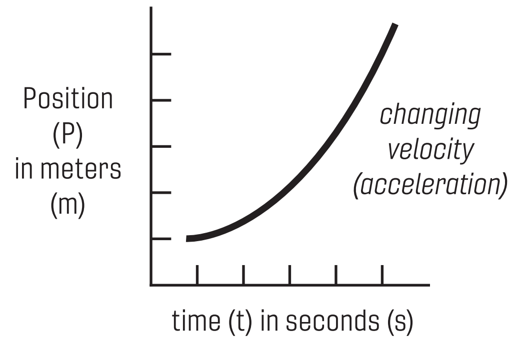
Share the following vector diagrams with the class. Each diagram shows a different vector. Discuss what the vector drawings represent, compared with a drone flight path. Have each group attempt to demonstrate each vector by flying the drone as described.

The Meaning of the Shape of a Position (P) and Time (t) Graph

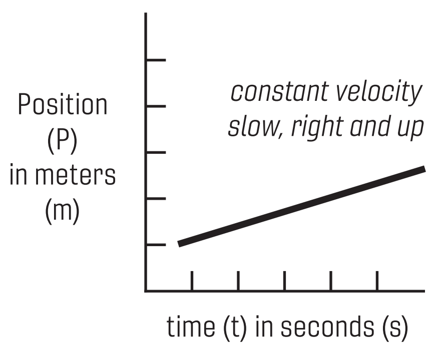
Positive Velocity(+)



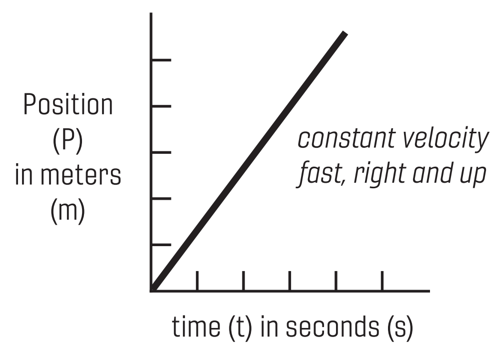
Positive Velocity(+)



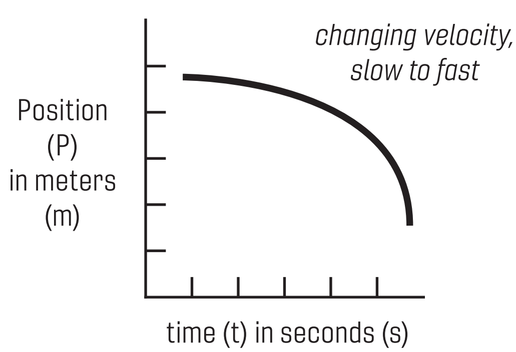
Positive Velocity(+)



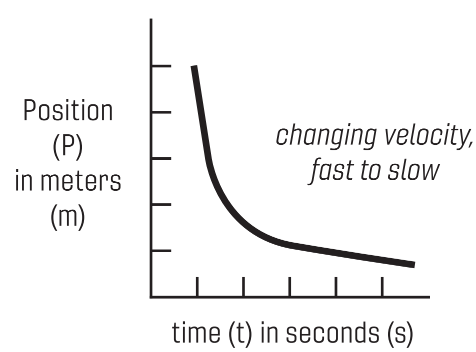
Positive Velocity(+)



Negative Velocity(-)



Negative Velocity(-)



REVIEW

Journal Writing Prompts

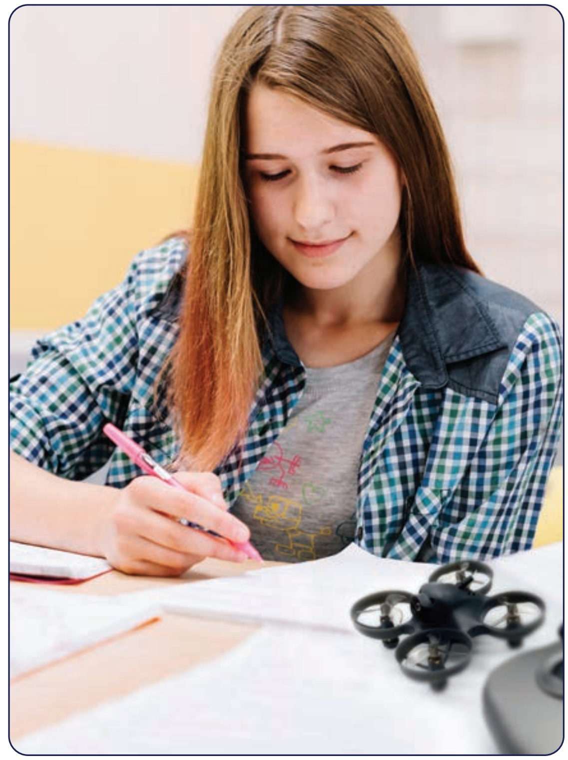
- What is the difference between acceleration and velocity?
- Draw and label three or more free body diagrams of class drone flights
- Draw and label three or more time and position vector diagrams.

Student Uses of Technology

- Battery safe usage and charging.
- Drone transmitter.
- Piloting a drone.

Assessment

- Check student journals for understanding.
- Check for understanding of free body diagrams and vector drawings by observing flights.



Resources

Formulas

- Newton's second law: force, mass, acceleration F=ma
- Mass vs. gravity F_g=mg
- Velocity, distance, time v=d/t
- Acceleration, velocity, distance, time a=v/t
- SDK drone specifications: 21 grams, LiPo battery: 7 grams

Enduring Understanding

- The change of the position and the change in speed of an object determines its motion.
- For motion to change, an unbalanced force must be applied.
- All physical objects in the universe interact with one another. Each interaction happens as a result of some type of force.
- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)

Essential Questions: How do drones help us understand forces, motion, and flight?

- How can we describe the motion of a drone in the world around us?
- How can one predict a drone's continued motion, changes in motion, or stability?
- How can we describe force in the world around us?
- What is the effect of forces on a drone and a drone's motion?

DESIGNING AND FLYING A DRONE OBSTACLE COURSE

PREPARE

In this activity, students will engineer an obstacle course to specifications and pilot the drones in a timed challenge. You choose whether your student groups will complete separate time trials or combine the entire class into a racing tournament!

Getting Started

- Verbally review safe flying practices for drone flying with students.
- Allow drone flying practice: LOS, FPV, and/or simulator.

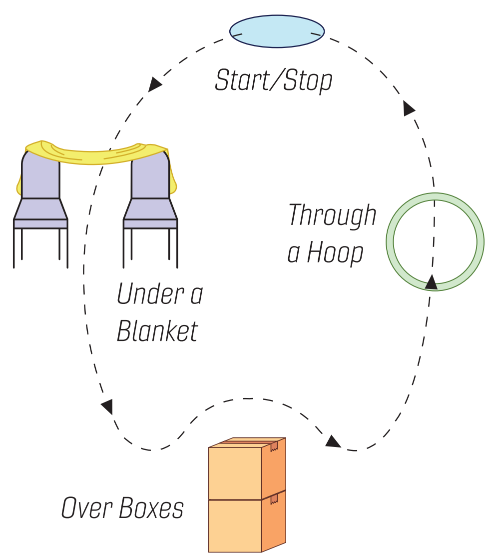
Safety Precautions

- Eye protection.
- Safe battery use and charging.
- Fly in a safe manner and location under teacher supervision.
- Ensure that enough space is available for all drone groups to fly.

Materials

- Drones: all charged for flight.
- Meter stick or measurement tape.
- Construction materials: cardboard boxes, hoops, tape, blankets (crash barriers), etc.
- Stopwatch.
- Large flight space.

Example of a Simple Obstacle Course



ACTIVITIES AND INVESTIGATIONS

Design a Drone Obstacle Course

Pose an engineering problem to the class: How do we design a safe, fun, and achievable obstacle course for a drone flying tournament?

Obstacle course design constraints should include:

- Classroom space.
- All line of sight (possible FPV at a later event).
- Safety measures: protect students and materials.

Obstacle Course design *may* include the following elements. Be sure to limit the difficulty of the courses based on the skills of your students. *NOTE: Most often, initial course designs are overly complex. Keep this in mind as you guide students through their obstacle course layout.*

- Turns
- Fly-through obstacle(s)
- Over or under obstacle(s)
- Distance traveled

Each student makes a final drawing with labels and measurements of the course in his/her journal.

Build and Fly the Obstacle Course

You can allow each team to construct and fly their own course using time trial selection. Additionally, you may select one course design to build and hold a class racing tournament.

Time Trial Selection

Determine whether the trials should include *one* pilot for each group or a cumulative time of *all* the students in the group to fly the course. (NOTE: Time and equipment constraints should be considered.) Each team should:

- Determine a team name.
- Determine the rules of their course.
- Charge batteries for the event.
- Have practice time on the course.

Once prepared, have a student fly the course while another keeps track of the time. Another student may act as a course judge, observing the aircraft to make sure that every obstacle is being properly cleared. For each obstacle missed, the pilot receives a pre-determined time penalty. Make observations and take notes to build strategies for the final races.

Racing Tournament

Have students review the obstacle course designs. Select one to build and then hold a race, tournament style!

1. Select a tournament marshal to provide final judgment on any disputes.
2. Will the tournament be individual pilots trying to complete the course in the fastest time, *or* will the challenge be a race between two (or more) pilots who are flying the course at the same time?
3. Review safety rules.
4. Select six qualifying heats.
5. Begin qualifications.
6. Complete the race tournament.

REVIEW

Discussion Prompts

- What criteria should be used to build the drone obstacle course?
- What criteria should be used to select the race pilot for your group?
- What criteria should be used to determine the trials? Best pilot time on the course? Cumulative course time for all team members?
- What are the fairest racing rules?
- How can we improve drone racing?

Journal Writing Prompts

- Draw and label the drone obstacle course.
- Make observations and take notes on different aspects of the course for planning and strategy.
- Make observations and take notes on the practice and time trials selected for the event.
- What did you learn from the drone racing tournament?
- How would you design the obstacle course differently?
- How would you design the drone racing tournament differently?

Student Uses of Technology

- Simple construction tools and materials: tape, cardboard, plastic, etc.
- Stopwatch or timing device.
- Meter stick or measurement tape.
- Battery safe usage and charging.
- FPV goggles.
- Drone transmitter.
- Tiny Whoop Go flight simulator.
- Piloting a drone.

Homework

- Ask students to research drone racing to look for strategies and flying tips.

Assessment

- Students design and construct a safe drone obstacle course that meets stated criteria.
- Students practice flying the drone obstacle course and determine team pilot for flights.

Resource

- **Student Drone Kit** website: Student Drone Kit - Know Before You Fly website (https://knowbeforeyoufly.org/resources/studentdronekit)

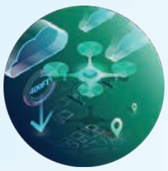
Know Before You Fly
Student Drone Kit

INFORMATION FOR

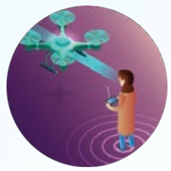
RECREATIONAL FLYERS

WWW.KNOWBEFOREYOUFLY.ORG

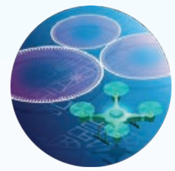
KNOW BEFORE YOU FLY



FLY YOUR DRONE at or below 400 feet



KEEP YOUR DRONE within your line of sight



CHECK FOR FAA airspace restrictions

NEVER FLY NEAR other aircraft, especially near airports

NEVER FLY OVER groups of people or public events

NEVER FLY NEAR emergencies such as wildfires or hurricane recovery efforts

DOs

- **REGISTER** your drone
- **FLY** your drone at or below 400 feet, and in controlled airspace be sure to have an approved airspace authorization for your flight
- **KEEP** your drone within your line of sight
- **CHECK** for FAA airspace restrictions
- **RESPECT** privacy

WHETHER YOU'RE A NOVICE DRONE PILOT OR HAVE MANY YEARS OF AVIATION EXPERIENCE, RULES AND SAFETY TIPS EXIST TO HELP YOU FLY SAFELY IN THE NATIONAL AIRSPACE. THINK OF THESE TIPS AS A PRE-FLIGHT CHECKLIST TO HELP YOU FLY SAFELY.

DON'Ts

- **NEVER FLY** near other aircraft, especially near airports
- **NEVER FLY** over groups of people, public events, or stadiums full of people
- **NEVER FLY** near emergencies such as fires or hurricane recovery efforts
- **NEVER FLY** under the influence of drugs or alcohol

www.knowbeforeyoufly.org

AUVSI

YOUR PASSION. YOUR HOBBY. ONE COMMUNITY. AMA

Consumer Technology Association

Federal Aviation Administration