



# The Physics of Sailing



Photos by Chris Ray

Project Based Learning

## **Curriki**

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Special Thanks to Chris Ray for generously donating his photographs.

## **Our Team**

Curriki Geometry would not be possible if not for the tremendous contributions of the content contributors, editors, and reviewing team.

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# Section 1

## Introduction and Project Resources



Photos by Chris Ray

# Introduction to the Physics of Sailing

## Welcome!

Welcome to the Physics of Sailing Project, a six-week high school Physics project designed in a project-based learning (PBL) format. The project focuses on the application of Newton's Laws in sailboat design. Over a six-week period, this project mixes team-based student inquiry, direct instruction, and teacher- or student-directed activities.

## Project Timeline and Duration:

6 weeks

## Rating:

Advanced

**Project Description:** In this project, students use their knowledge of physics concepts and Newton's Laws to design a sail and keel for a racing sailboat. The design culminates in a digital model or poster that shows how the sailboat will be fast, but stable, the two constraints in race boat design. The project may end with a competition judged by knowledgeable designers, if available. Ideally, the presentation will be digital, in the form of a Google Sketch Up or AutoCAD design (free for education). If technology is not available, students can create posters to illustrate their designs. The plans that accompany the model must include key physics information showing that students understand how physics influences the forces on a keel and sails.

**The Scenario and Challenge:** The challenge in this project is for students to apply their knowledge of physics to a real-world design of a racing sailboat by showing that they understand how a keel and sail affect speed and stability.

**The Driving Question:** How can we apply our knowledge of Newton's Laws and sailboat design to design a racing sailboat?

**Project Focus:** This project focuses on the ability of students to apply physics concepts to physical models and constructions.

The project addresses Next Generation Science (NGSS) and Engineering for Physics, as well as Common Core State Standards (CCSS) for collaboration and communication. The project is not intended for students to meet the full expectations of the course-level standards through this one project.

The project also encourages students to use online resources to research and examine the sailboat racing industry and the technology issues associated with racing design.

## **Suggested Priority Standards for the Project**

**Next Generation Science Standard HS-PS2-1:** 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.

**Next Generation Science Standard GSS HS-ETS1-2:** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**English Language Arts Common Core State Standard SL.11-12.1 through SL.11-12.6.** These six standards identify performance goals for speaking, listening, presenting information, and making strategic use of digital resources.

## **Project Assessment**

This project includes a suggested overall 21<sup>st</sup> Century Skills & Product Rubric for the project. This rubric can be used as a stand-alone rubric to assess Teamwork, Presentations, Critical Thinking, Work Ethic, and the final sailboat design.

Separate rubrics for teamwork, presentation & communication, critical thinking, and creativity can also be used as the teacher discretion. These are included under the [Rubrics](#) section.

As an option, the project also includes a rubric for assessing the eight Mathematical Practices recommended in the Common Core State Standards. These practices encourage inquiry, problem solving, and mastery of mathematical methods.

All rubrics can be used to generate a score point for grading. The Overview of Assessment contains assessment details for the project. The Rubrics section contains the rubrics designed for the project. If you are new to PBL or would like more information, please refer to the Overview of Assessment in [Appendix D](#).

## **Teaching Guide & Calendar**

The [Teaching Guide](#) and [Calendar](#) offer day-by-day suggestions and guidance for completing the project. Remember, this is only a suggestion, as the educator, you can adapt the schedule to your needs. As much as practical throughout each project, intersperse instruction with team discussions rather than whole class discussion.

The format of this project has some interesting aspects to highlight. Students will engage in both individual work and work in collaborative teams to allow students time to think and work independently as well as share their ideas and build their projects with classmates. There are also built-in checkpoints for the teacher to ensure students have correct understanding as they progress through their project development.

### **Prior Knowledge**

Students should have prior knowledge of [NGSS Middle School Forces and Interactions.](#)

PS2.A: Forces and Motion: For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)

The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)

All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

### **Differentiating Instruction**

The Teaching Guide is designed for a typical student. For students who may struggle in a project, consider:

- Scaffolding skills by breaking them down into steps, such as the ability to listen or to resolve conflicts as steps to becoming a better team member. The scaffolds can be taught prior to the project.
- Adjusting the complexity of the task to fit the ability level or background knowledge of the student.
- Setting up a buddy system in which an advanced student on the team assists his or her teammate. This is particularly useful if students are struggling with language acquisition challenges.
- Offering more ongoing coaching support. In PBL, individual student needs will vary.

For advanced students, consider:

- Encouraging students to develop a set of personal goals that exceed the normal demands of the project or that meet college and career readiness goals.
- Putting advanced students in leadership roles in the team.
- Discussing performance that meets the criteria for breakthrough, the category on the rubrics that exceeds mastery of academic content and indicates a high level of critical thinking or creativity.

# What is Project-Based Learning?

## **What Is Project-based Learning (PBL)?**

"In PBL, students go through an extended process of inquiry in response to a *complex* question, problem, or challenge. While allowing for some degree of student "voice and choice," rigorous projects are carefully planned, managed, and assessed to help students learn key academic content, practice 21st Century Skills (such as collaboration, communication & critical thinking), and create high-quality, authentic products & presentations." – BIE, The Buck Institute for Education.

## **For more information on PBL:**

See [video examples](#) of PBL. There are many examples available; use the search box to the left of the videos to locate videos on physics, including these:  
*How does PBL work in a Physics course at Harvard?*  
*How physics is used in music.*

## Tools and Resources

These resources may be useful in the Physics of Sailing project. However, they are also useful for other projects or for general classroom instruction.

### Content & Organization Resources

Resource	Description	Best Use
<a href="#">Curriki</a>	Curriki has over <b>15K</b> searchable resources for Physics and Math.	Search by topic to find problems, exams, or lesson plans that fit your needs for this project or other projects and lessons.
<a href="#">The Khan Academy</a>	The Khan Academy offers teaching suggestions and materials for math and physics.	Physics and Math assessments.
<a href="#">Math for America</a>	Offers resources and links to high quality math instruction.	Use this site to help students improve math proficiency.
<a href="#">Analyze Math</a>	Sample lessons in all math subjects. Solutions and detailed explanations to problems that make your teaching more active and engaging.	Use this site to help students improve math proficiency.
<a href="#">Quizlet</a>	This is an online quiz creator for teachers.	Use this site when you need to create quizzes. This is also a student-friendly tool that helps students design their own quizzes as study tools.
<a href="#">Visuwords</a>	This is an online quiz creator for teachers.	Use this site when you need to create quizzes.
<a href="#">Three Ring</a>	This is an online tool for vocabulary.	This is an excellent tool for building students' vocabulary and knowledge of origins and relationships between words.
<a href="#">Google Classroom</a>	Classroom weaves together Google Docs, Drive and Gmail to help students organize their work.	This supports project-based learning.

### Presentation and Communication Tools

Resource	Description	Best Use
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<a href="#"><u>Prezi</u></a>	This is a flexible, creative visual presentation tool that allows students to tell detailed stories about their work.	Prezi is free, but requires students to create an account.
<a href="#"><u>Microsoft Office Mix</u></a>	A PowerPoint 2013 add-on that turns presentations <a href="#"><u>into interactive online lessons</u></a> loaded with audio, video, quizzes and whiteboard-type drawings.	Good tool for students to use to make their team presentations interactive and record the presentations.
<a href="#"><u>Doceri</u></a>	This is an iPad interactive whiteboard and screencast recorder with sophisticated tools for hand-drawn graphics and built-in remote desktop control.	Doceri works well in a 1-to-1 classroom.
<a href="#"><u>Padlet</u></a>	Padlet is an Internet application that works like an online sheet of paper where students can put any content (e.g. images, videos, documents, text) anywhere on the page, together with anyone, from any device.	Think of it like a multi-media friendly, free-form, real-time wiki.
<a href="#"><u>Haiku Deck</u></a>	Haiku Deck is a free presentation software tool that makes it easy to integrate graphics and pictures into creative presentations.	Haiku Deck requires an iPad.
<a href="#"><u>Trello</u></a>	This is the perfect tool for organizing a group project and group work. Working on iOS, Android, Windows 8, and the web, it allows you to brainstorm ideas, set to-do lists, add photos, monitor progress, and keep everyone informed with the latest details.	Ideally suited for project-based learning activities.
<a href="#"><u>AutoCAD for Education</u></a>	Free for education, students can create 3D designs and connect with the cloud to collaborate on designs.	This is free for education and a great tool for creating project designs.
<a href="#"><u>Blogster</u></a>	This is a mainstream blogging site that students can use to create and post blogs.	This site may require monitoring.
<a href="#"><u>Google SketchUp</u></a>	This is free, downloadable software for creating 3D presentations.	This is easy to learn and is integrated with Google Maps.

<a href="#"><u>Movenote</u></a>	Movenote works with Google Drive, Microsoft mail, Gmail, and Google Docs and on any device. Students open Movenote inside their email program, prompting their camera to automatically be activated. They then add their content (from any document type) and begin recording themselves talking through the information.	This is a wonderful tool for the flipped classroom and for having students showcase what they've learned in a particular unit of study.  Free registration with an email account is required. If you are a Google Apps for Education district, there is a simple add-on available in Google Drive. There is also an app for iOS devices.
<a href="#"><u>Adobe Storytelling iPad App</u></a>	A free app that helps embed images, music, voiceovers and special effects.	Users begin by choosing from a preset story template that helps outline the structure of their video. They can then import their own photos, draw from the app's library of 25,000 icons or search the web for their own images.

# Physics of Sailing Project Glossary

The following terms are used throughout the project and represent the core vocabulary and concepts that students should know to meet the identified Next Generation Science Standards and Common Core State Standards.

Term	Definition
<b>Force</b>	Push or pull upon an object resulting from the object's interaction with another object
<b>Contact force</b>	Force that results when the two interacting objects are perceived to be physically contacting each other
<b>Newton</b>	Standard metric unit used to measure quantity of force $1 \text{ Newton} = 1 \text{ kg} \cdot \text{m/s}^2$
<b>Vector</b>	Quantity that is fully described by both a magnitude and a direction; represented by an arrow
<b>Net force</b>	The vector sum of all the forces that act upon an object
<b>Newton's 1st Law of Motion</b>	An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.
<b>Newton's 2nd Law of Motion</b>	The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object $F_{\text{net}} = m \cdot a$
<b>Free body diagram (Force diagram)</b>	Diagram used to show the relative magnitude and direction of all forces acting upon an object in a given situation
<b>Starboard</b>	The right side of a boat, facing forward
<b>Port</b>	The left side of a boat, facing forward
<b>Aft</b>	The back of a ship
<b>Bow</b>	The front of a ship
<b>Points of sail</b>	Sailing positions, relating to the angle between a sailboat's heading, or course, and the direction of the wind
<b>Close Hauled</b>	Point of sail, sailing as close to the wind as possible; also known as beating
<b>Close reach</b>	Point of sail between close hauled and a beam reach
<b>Beam reach</b>	Point of sail with wind coming over the beam
<b>Broad reach</b>	Point of sail with the wind coming over the boat's quarter
<b>Running</b>	Point of sail directly downwind
<b>Keel</b>	An extension of the hull that goes deeper into the water and provides stability from heel and sideways resistance to wind

# Section 2

## Teaching and Learning Guide



Photos by Chris Ray

# Teaching Guide

Over a six-week period, this project mixes team-based student inquiry, direct instruction, and teacher- or student-directed activities. The Teaching Guide is a pacing guide that offers a suggested sequence for the Physics of Sailing project, but the final calendar and sequence remain up to you. For example, the Guide allows 6 days for the final design, but this can be shortened.

It may be necessary to modify the project based on your circumstances, the needs of students, or the tools and technology available to you. The project can easily be done with designs created on posters. However, this guide contains many suggestions for using the wide array of digital resources available online.

## Preparing for the Project

### 0 Teacher Preparation

A successful project requires that teachers prepare, plan and communicate before the project begins. So, prior to beginning the project with students, review this entire document, examine the rubrics and student project tools found in the Appendices, and modify the calendar if necessary.

If your students have no or little experience with Project Based Learning, you may have to begin the first day by explaining the process. They can also choose and watch an explanatory [video](#) on PBL.

### A Few Tips on Project Management

Managing a project differs from classroom management. Primarily, PBL requires that the teacher gives equal attention to the process of learning as well as to the delivery of content. You can expect to facilitate student problem solving by helping them ask questions, formulate solutions, test hypotheses, and design products and presentations.

Project management can be broken down into five categories. For each category, we offer resources to meet the challenge. These resources represent a set of best practices for PBL that have been tested and refined by PBL teachers.

- 1. Forming and Managing Effective Student Teams.** The resources in [Appendix B: Teams and Grouping](#) provide tools such as conflict resolution assistance and team building activities.
- 2. Maintaining quality throughout the project.** [Appendix C: Visible Thinking Routines](#) offers links to dozens of student-to-student protocols for effective interaction between students.
- 3. Supporting different ability levels of students.** [Appendix B: Teams and Grouping](#) contains resources and activities for coaching team members. These methods allow teachers to provide individual support to ELL or Special Education students.
- 4. Completing the project in a positive manner.** This project includes a [Teaching Guide](#) to allow sufficient time for students to solve problems, create the final product, and prepare for presentations. Use rubrics often as feedback tools on performance throughout the project. Plan to re-teach key concepts and standards, if necessary.
- 5. Reflecting on the project to anchor learning and retention.** At the end of the project see the Reflection resources for tools such as lists for project milestones or methods for reflection. The [Reflection Matrix](#) is your key tool.

## Launching the Project

- 1 Introduce the project and generate interest.**

### Entry Event:

Generate interest with the [Oracle TEAM USA – Racing on the Bay Video](#), the [Exploratorium Science At America's Cup: "Sailing 101"](#) video, or [KQED's Physics of Sailing](#) video.

### **Oracle TEAM USA – Racing on the Bay Video**



*Click image to link to video. It will open in your browser*

**Introduce the challenge:** The challenge in this project is for students to use their knowledge of forces in physics to design a keel and sail for a racing sailboat that balances the need for both speed and stability. Working in teams, students will use an existing hull and a choice of sail and keel types to design a fast, stable sailboat. They must be able to justify their design choices in terms of Newton's Laws. The project will culminate in a digital sketch or poster that shows their final design product. Teams will give a brief presentation of their design.

**Frame the task with the Driving Question:** How can we apply our knowledge of Newton's Laws and sailboat design to design a racing sailboat?

After discussion, have them share an initial brainstorm on the Driving Question using [www.padlet.com](http://www.padlet.com), in classroom whiteboard, or other tools at your disposal.

If your or students would like to change or refine the Driving Question, use this guide to [Refining the Driving Question](#) in Appendix D and [Tools and Resources](#) section.

**Set up the project.** Students will create a basic model sketch in Force Diagram format, along with a 10 minute presentation as their final products. Students must show that they can answer the Driving Question by demonstrating that their final design demonstrates that the keel and sail will make the boat fast and stable. The model can be drawn digitally on Google SketchUp, AutoCAD, or with other materials such as a poster.

**Describe the physics standards and concepts that students will learn as they complete the project.**

Students are expected to calculate the effect of forces on objects, including the law of inertia, the relationship between force and acceleration, and the nature of force pairs between objects, and will develop and interpret free-body force diagrams.

[NGSS Disciplinary Core Idea: PS2.A](#): Forces and Motion. Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)

[Next Generation Science Standard HS-PS2-1](#): 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.

[Next Generation Science Standard GSS HS-ETS2](#): Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Note: The project addresses, but does not assess, [English Language Arts Common Core State Standard SL.11-12.1 through SL.11-12.6](#). These six standards identify performance goals for speaking, listening, presenting information, and making strategic use of digital resources.

Note: The project addresses, but does not directly assess, four standards for digital literacy developed by the [International Society for Technology in Education](#): (1) Creativity and innovation; (2) Communication and collaboration; (3) Research and information fluency; and (4) Critical Thinking, problem solving, and decision making.

**Review the [project calendar](#) with students.**

**Anchor the Project Rubrics.** Discuss rubrics to be used in the project to assure understanding and clarity.

It's critical to a good start that students understand the project assessment. Their final presentation will be assessed on (1) Physics content; (2) Presentation skills; and (3) the digital sketch incorporating evidence of the design process, explanation of how Newton's Laws influence their designs, and the answer to the Driving Question. They will also be assessed on teamwork throughout the project.

Other assessments may be included in the project. The 21<sup>st</sup> Century Skills & Product Rubric contains sections on Critical Thinking and Work Ethic. Separate

rubrics for teamwork, presentations, critical thinking or creativity are provided for more in-depth evaluation of those skills.

## 2 Form teams and begin background research.



*Click image to link to video. It will open in your browser*

**Have students view this [video from Oracle Team USA](#),** where Grant Simmer, CEO, talks through many of the concepts the students will need to investigate for this project---sailboat racing and sailboat design. Have students view sites on sailboat racing and sailboat design. Ask: *Can they think outside the box for this project, and how will they do that?* Take this time to initiate a class brainstorming/discussion to generate ideas for the project. This is an open-ended prompt, to which the discussion will vary.

**Generate ideas and questions for the project.** Use either a [Know/Need to Know chart](#) or the [Visible Thinking Routine](#) Think-Puzzle-Explore to begin generating ideas for the project. Record questions and ideas on board or paper.

**Assign or create teams of students to begin project work.** Teams should review the project goals and timeline, and establish a task list following the Project Calendar. This document can be filled out by hand, but will be modified as the project proceeds. See resources in [Appendix B](#) for guidance on forming and managing teams.

***Introduce the [Weekly Work Log](#) and [Weekly Team Meeting Checklist](#).***

If necessary, use team building tools found in the Appendix, to establish effective working teams, such as team roles, conflict resolution speak, or rules for high performance collaboration.

If necessary, introduce the rationale for teamwork: This is a 21<sup>st</sup> century skill essential in the workplace. The teamwork will be tied to ELA Common Core State Standards listed in the above.

Four is a good size for teams; however, this may vary according to class size or teacher discretion.

Have teams review and discuss the teamwork section of the [21<sup>st</sup> Century Skills & Product rubric](#).

The Weekly Work Log and the Weekly Team Meeting Checklist help teams stay on task, meet milestones, and identify gaps in their progress toward designing a high quality final product. The Weekly Work Log can be graded as a formative assessment.

## **Managing the Project**

### **3 Introduce sailing and physics vocabulary.**

**Teach.** Use a workshop method to introduce physics and sailing vocabulary. Key vocabulary for the project can be found in the Project [Glossary](#). The [Workshop Model](#) is a structured blueprint for instruction.

Use videos [1](#) and [2](#) to introduce the parts of a sailboat and Newton's Law as applied to a sailboat.

**Vocabulary activity.** A brief vocabulary activity will help students build vocabulary and use games to practice. Example: For the vocabulary words that apply to the parts of a sailboat, try the following: Give each team a simple drawing of a sailboat and a list of the vocabulary words and ask them to quiz each other by identifying the parts of that sailboat. After about 10 minutes, teams can see how they did when the instructor displays the correct answers on a diagram.

**Homework:** Have students work through one or more of the following videos and tutorials to give them an overview of Newton's Laws. Students can use the [Research/Information Gathering Tool](#) handout to record what they learn from these sites.

[Khan Academy Tutorial on Forces & Laws of Motion](#)

[PS2A - Forces and Motion](#)

**From the Physics Classroom:**

[Newton's 1st Law](#)

[Newton's 2nd Law](#)

[Newton's 3rd Law](#)

[Forces & Motion Simulation](#) (Note: this site requires a flash plug in).

**Homework:** Students view this video on Newton's first law: [Newton's First Law Explained](#)

#### **4      Introduce Newton's Laws.**

**Teach:** Newton's Laws using the Newton's Laws Activity as follows:

As a whole class activity, review what students learned from their homework and work through any points of clarification. Ask students how the laws will apply to their project. If review is needed, try the following lessons:

The following websites may be used to guide the teaching activities.

**Bozeman Science:** [Newton's Three Laws of Motion](#)

Mr. Andersen defines Newton's three laws of motion. He describes how the first law relates to inertia, how the second law relates to mass and acceleration, and how the third law allows a rocket to launch.

[Newton's Laws Gallery](#)

Open the gallery and have students discuss as a class what is going on in the photos, if they recognize or have personal experience with the scenario in the photos, etc. Discussions will vary based on students' prior knowledge and experience.

**Bozeman Science Video:** [Speed, Velocity, and Acceleration](#)

Mr. Andersen explains the basic quantities of motion. Demonstration videos and practice problems are also included. The difference between scalar and vector quantities is also discussed.

[Newton's Laws Problem Set](#)

Allow students to open the problem set link. Monitor students' progress as they work through the problems. The teacher may choose to complete the first problem(s) in front of the class to get them started, or the entire set may be assigned as independent practice. The answers are provided for feedback.

Regard this day as a first milestone for checking team effectiveness. If teams are not showing signs of cohesion, take time to discuss or intervene.

### **Homework:**

**Have students view the following video:** [Launchpad: Newton's Laws On-Board the International Space Station](#)

Join astronauts on-board the International Space Station to learn more about Newton's laws. Learn about the inverse relationship between mass and acceleration when calculating force and see what the equation  $f=ma$  has to do with rockets.

### **5 Introduce digital resources.**

**Teach.** Introduce any digital resources you have decided to use, such as blog, Padlet, AutoCAD, or Google Sketchup. See [Tools and Resources](#) section for info.

**Teach.** If using Google Sketchup, use these [Google SketchUp Tutorial videos](#) to introduce and practice design software.

If students use personal devices or log into a Learning Management System, teams should use this day to set up folders, team products, etc

### **6 Quiz on Newton's Laws.**

**Quiz.** Vocabulary & Newton's Laws. Have students complete this self-assessment on [Newton's Laws](#).

**Milestones.** Have teams fill out [Weekly Work Log](#). Students should open the weekly work log at the beginning of class and spend 5-10 minutes deciding tasks for the day. At the end of class, the team tasks should be checked off. There should be daily notes or observations recorded regarding their progress, upcoming deadlines, etc.

### **7 Review of sailing and sailboat design.**

**Workshop:** The [Points of Sail](#) entry in Wikipedia describes a sailing boat's course in relation to the wind direction. The [Points of Sail diagram](#) provides a visual orientation of the boat and sail at each point of sail. Have students watch the Points of Sail [video](#), examine this helpful site with an animation, article and

video. Teams should record the information learned in the Research/Information Gathering Tool handout.

From [Wikipedia](#):

The point of sail describes a sailing boat's course in relation to the wind direction.

No sailboat can sail directly into the wind (known as being "in irons"), and for a given boat there is a minimum angle that it can sail relative to the wind; attempting to sail closer than that leads to the sails luffing and the boat will slow down and stop. This "no-go zone" (shown shaded in accompanying figure) is about 45° either side of the true wind for a modern sloop.

There are 5 main points of sail. In order from the edge of the no-go zone (or "irons") to directly downwind they are:

- close haul (the minimum angle to the wind that the boat and its rig can manage - typically about 45° )
- close reach (between close hauled and a beam reach)
- beam reach (approximately 90° to the wind)
- broad reach (between a beam reach and running)
- running (close to directly downwind)

The sail trim on a boat is relative to the point of sail one is on: on a beam reach sails are mostly let out, on a run sails are all the way out, and close hauled sails are pulled in very tightly. Two main skills of sailing are trimming the sails correctly for the direction and strength of the wind, and maintaining a course relative to the wind that suits the sails once trimmed.

Students should enter day's observations in Work logs.

**Homework:** Have students watch this video on [How Sails Work](#) and record what they've learned in a Research/Information Gathering Tool handout.

## 8      Sails and Keel activity.

**Workshop:**

**Sail & Keel Activity:** In this activity, students will conduct research on how sails and keels work and the design of sails and keels.

Teams can review one or more websites depending on time. Select from the list below. This can be done by having teams randomly "draw" which website(s) they

will research and summarize to the class. Students can use the Research/Information Gathering Tool handout to record what they've learned from each site. Teams will then report to the class a summary of what they learned.

Depending on how many teams of students are formed, a time limit should be set for reporting to the class (with additional time for Q&A and/or short class discussion after each presentation) so that all websites are summarized in one class period. This is a great opportunity for students to generate and summarize the information on poster boards which may be displayed in the classroom throughout the project for later reference.

Students should use the information from these resources to describe the effect of sail design, keel design, and how the design of each affects the forces applied to a sailboat. In this activity, students will apply the effect of sail and keel design forces to create force diagrams for several combinations. The focus here is on the function of sails and keels.

In the Appendix, you will find images that may be helpful in explaining/discussing the concepts around sail and keel.

Use the following websites as resources (numbered for easy reference, not for priority or importance):

1. [Sails and Keels](#)
2. [Sailboat Keel Types](#)
3. [Physics for Architects: How Sailboats Sail Against the Wind](#)
4. [What Does the Keel Do?](#)
5. [Physics of Sailing Wiki](#)
6. [Using the Principle of Lift to Sail Faster](#)
7. [Racing Yacht Keel, Rudder, Sail Design and Analysis](#)
8. [How Sails Really Work](#)
9. [Wind, Sails, & Lift](#)
10. [Hull Designs](#)
11. [Keel Designs](#)
12. [Keel and Rudder Design](#)
13. [Keel Shapes](#)
14. [Is Your Boat Stable?](#)
15. [Capsize Formula](#)
16. [Keel Types & Motion](#)
17. [Sail Aerodynamics](#)
18. [Keel Types](#)
19. [Keel Design Blog](#)

#### **Homework:**

Have students complete a Know/Need to Know sheet based on what they learned from the videos they watched today.

#### **9      Design brainstorming & sketching.**

Now the students should be ready to begin brainstorming and sketching ideas for their designs. Give them the bulk of the class time to dig in and collaborate on their project.

**Have teams share initial sketches** with each other either face to face or online. Online critique may be done as homework

Have teams **self-evaluate themselves on [Teamwork Rubric](#)** by highlighting one strength and one area of challenge. Collect for review and feedback with students.

Guide the critique with appropriate questions or directions (these will depend on the status and progress of your students.)

Teach teams to use a modified form of the [Critical Friends Protocol](#) to encourage high quality feedback:

“I like...”

“I wonder...”

“I suggest...”

After sharing and critique, students can post results on [blogster](#), Google Docs, or your Learning Management system.

## 10 Team Progress, Self-Assessment and Continue Design.

**Team meetings with Instructor.** The purposes of the team meeting with the instructor are:

- Teams communicate their self-assessment notes (from the weekly work log) to instructor
- Instructor monitors team progress regarding project milestones and assists when needed. Record on [Project Milestone Checklist](#) – one for each team. The [Weekly Team Meeting Checklist](#) may also be used here.

Teams continue design work and enter their observations in the Weekly Learning Logs while the instructor is meeting with other teams. They should also enter the day's observations in their Weekly Learning Logs.

## **11 Quiz.**

**Quiz:** Points of Sail; Sail & Keel Functions. Use the [Sail and Key quiz](#) with answer key. Teams should use the rest of the period to set a schedule for completion of the design and make sure all materials are in place. If using Google SketchUp or other tools, they should know how to use these tools.

## **12 Focus: Force Diagrams.**

### **1. Workshop: Force Diagrams**

### **2. Force Diagrams Activity:**

Introduce the Force Diagram, which students will use for their designs.

Note: “Force Diagrams” are also called “Free Body Diagrams” in physics. Depending on the source of the information, the diagram may be called by either name; either is acceptable.

The [“Construction of Free-Body Diagrams”](#) lesson from WISC-Online and the Determining [“Net Force Using Free-Body Diagrams”](#) lesson from the PhysicsClassroom.com are excellent and the latter includes 11 practice problems (check for understanding):

The three websites below can be used as examples completed as a class, guided instruction with teacher monitoring, or as independent practice. The idea is for students to use the resources provided to practice the skills necessary to understand the concepts of the project.

- [Five Minute Physics - Force Diagrams](#)
- [Sail & Keel Force Diagrams 1](#)
- [Sail & Keel Force Diagrams 2](#)
- [Sailing Forces](#)

**Activity:** Have students try their hand at drawing Free-Body Diagrams with this online activity: [Free Body Diagrams](#) (Adobe Shockwave Player is required)

## **13 Force Diagrams—Peer Assessment and Check for Understanding.**

### **Check for understanding.**

Teachers should check for understanding at this point in the project. Students should know how to draw basic force diagrams before attempting to apply it to their design.

Students may also conduct individual self-assessments or peer assessments. Use the [In-depth Critique Protocol](#) as model for critique.

### **Refine design and apply force diagrams.**

Once students have mastered force diagrams, they should extend the activity from day 8, in which students apply the effect of sail and keel design forces to create force diagrams for several combinations. Each team will create a unique set of combinations which directly relate to their unique sailboat design.

#### **14 Continue design.**

Teams work on refining their designs.

Teachers may also choose to use a class discussion, where each team "presents" their design in terms of the driving question and classmates ask clarifying questions.

**Peer Feedback.** Teams review and critique designs with each other at appropriate points in the design process.

Have each team review the presentation section of the 21<sup>st</sup> Century Skills and Product Rubric. If class is using the individual Presentation and Communication Rubric, then students should review this rubric as well.

Teams can use the storyboard tools from [Google Docs](#) Depending on resources; teams may also use other formats, such as paper/pen, whiteboard, MSWord, or MS PPT. Check the [Tools and Resources](#) list for recommendations.

#### **15 Team Progress Self-Assessment.**

Teams continue design activities and enter their observations in the Weekly Learning Logs while the instructor is meeting with other teams. Teams should be managing their time by tracking milestones and planning for upcoming deadlines.

Use the team meeting to advise teams on how well they are progressing and answer questions the teams may have. In the Appendix you will find a Weekly Team Meeting Checklist that may be useful to record progress for each team.

## **16 Quiz: Force diagrams.**

Teachers may use the sample quizzes below or customize the quiz questions based on students' designs and sail & keel combinations from day 13. Students may also "create" quiz questions based on their designs and contribute to a class quiz with multiple force diagrams corresponding to multiple designs and combinations

**Quiz.** Each part of this quiz provides real-time feedback to students.

Part 1: [Free-Body Diagram](#)

Part 2: [Representing Forces on a Free-Body Diagram](#)

Part 3: [Drawing Free-Body Diagrams](#)

**Weekly Work Log:** Students record their weekly progress for teacher review.

## **17 Test Review**

**Review Newton's laws and use practice test to prepare students for exam.**

[Newton's Laws Practice Test](#)

Teacher should use questions similar to quizzes (days 6, 11, & 16) to help students prepare for a test. Practice problems from online resources below can also be used to create test review questions:

[Types of Forces](#)

[Free Body Diagrams](#)

[Net Force](#)

## **18 Test**

**Exam.**

[Newton's Laws Test](#)

**19** Design and submission of rough draft.

**Rough Draft:** At this point, students should have a solid rough draft completed; this includes the narrative about their design and the physics behind it.

In the coming week, students should focus on the design milestones and drafts using the rubric. For example, if the final product requires six components, stagger the components to include a couple in the first draft, add two more in the next draft, and then all four in the final draft.

**Peer Feedback:** Begin peer feedback process to help teams refine their designs.

For peer feedback activities, choose one section of the rubric for students to use as an evaluation tool. These are not graded; the evaluations go directly to the teams. If peer feedback is given multiple times throughout the project, students will cover most (if not all) of the product rubric, which allows peer assessment and also a better understanding of rubric components from actually using it.

**20 Review rough draft and begin redesign.**

**Teams Meet with Instructor:** At this point in the project, teachers should focus on making sure students are on track and will be ready to submit a quality design at the end of this week. If any issues arise, review the Logs and Weekly Progress Self-Assessments with the team to see where problems arose and discuss how to address them. In the Appendix you will find a [Weekly Team Meeting Checklist](#) that may be useful to record progress for each team.

**21 Design.**

**Continue to Refine Design:** We are nearing the finish line. This is the time when students should modify and refine their design in preparation for presentation day.

Peer feedback and review can be used continuously throughout this portion of the project. [Visible Thinking Routines](#) such as ‘Circle of Viewpoints’ or ‘What Makes You Think That?’ are helpful tools for peer feedback and critical thinking.

**22 Design.**

Students should continue to modify and refine their design.

## **23 Design.**

At this point, students should have a quality design draft, needing only minor changes. During this class period, students should make those minor tweaks.

## **24 Final design due.**

**Peer feedback on Final Design.** Teams may switch designs and evaluate each other's product using the rubric. At the end of the class period, students should submit their final designs.

## **25 Refinements for Presentations**

Teams should review feedback on their designs and discuss how to address any issues with their designs.

**During this final team meeting** with the instructor, teachers should check for understanding on presentation performance and expectations. If video exemplars of past presentations are available, students can view them for guidance. Either during team meetings or as a whole class, review and anchor presentation section of the 21<sup>st</sup> Century Skills rubric.

Students should also complete their Weekly Progress Self-Assessments.

## **26 Practice presentations.**

**Have teams practice** by presenting in jigsaw format, with one team presenting and the other two teams offering feedback. A jigsaw is a method whereby individual students or small groups meet in round robin style to share idea or feedback.

Make sure students use the [Presentation Rubric](#) as a basis for their feedback to peers.

## **27 Practice presentations.**

Continue previous day.

## **28 Presentations.**

Teams will present their final product and be assessed using the rubric. If possible, video performances and post these on the Curriki [website](#) or your school's LMS.

Note: Uploading final products and videos to Curriki requires membership. If you don't want all of your students to join the site, we suggest creating one "class" membership so you may ask multiple students to do the uploading for you.

## **29 Presentations.**

Continue previous day.

### **Assessing the Project**

## **30 Reflection.**

Use your preferred method from [Reflection Matrix](#) to review project.

Conduct a Digital Gallery Walk by having students view each other's products then reflect and discuss: What did we learn about sailboat design and physics? Were we creative?

**Consider extending this project** by having students build and test their design. This can be done in an engineering or another STEM courses.

If available either through online contact or locally, students could also submit their designs to sailing experts or sailboat designers for review or as a contest.

Students can also reflect online using blog posts or other collaborative tools.

Use volunteers or extra credit to have students post materials if time is limited.

## Section 3

### Rubrics



Photos by Chris Ray

## Rubrics

The following rubrics can be used in the Physics of Sailing project:

1. **Physics of Sailing 21st Century Skills & Product Rubric.** This is the overall rubrics for the project. It focuses on Physics content, teamwork, presentations, critical thinking, work ethic and the final design product of a racing sailboat.
2. **Presentation & Communication Rubric.** This rubric can be used separately to assess student presentations at the end of the project.
3. **Teamwork Rubric.** This is a detailed rubric to assess group work and team performance.
4. **Mathematical Practices Rubric.** This assesses the eight Common Core math practices and is an excellent tool for formative math assessment in the project.
5. **Critical Thinking Rubric.** This is an optional rubric to use in the project to assess problem solving skills.
6. **Creativity Rubric.** This is an optional rubric to use in the project to assess the creativity of the final design sketch of the racing sailboat.

# Physics of Sailing 21<sup>st</sup> Century Skills & Project Rubric

DATE, CLASS, PROJECT, OTHER INFO.

STUDENT BEING EVALUATED

CRITERIA	EMERGING (Below Performance Standards)	PROFICIENT (Minimal Criteria)	ADVANCED (Demonstrates Exceptional Performance)
<b>Teamwork</b>	<ul style="list-style-type: none"> <li>• Team member played a passive role in completion of the project.</li> <li>• Team member made unconstructive criticisms toward the project or other group members; did not add value to the group.</li> <li>• Team member was often off task, did not complete assignments or duties.</li> <li>• Team member had attendance problems that significantly impeded progress on project.</li> </ul> <p>0 -----3-----6-----9</p>	<ul style="list-style-type: none"> <li>• Team member played an active role in generating new ideas, took initiative in getting tasks organized and completed and sought help when needed.</li> <li>• Team member demonstrated willingness to help others when asked.</li> <li>• Team member was prepared, managed time well, and worked diligently.</li> <li>• If absent, other team members knew the reason and progress was not significantly impeded.</li> </ul> <p>10-----11-----12</p>	<ul style="list-style-type: none"> <li>• Team member thoughtfully organized and divided the work, checked on progress, or provided focus and direction for the project.</li> <li>• Team member actively checked with others to understand how each member was progressing and how he or she may be of help.</li> <li>• Team member made up for work left undone by other group members.</li> <li>• Team member demonstrated willingness to spend significant time outside of class/school to complete the project.</li> </ul> <p>13-----14-----15+</p>
<b>Presentation &amp; Performance</b>	<ul style="list-style-type: none"> <li>• Speaker was hard to hear or understand.</li> <li>• Voice or tone distracted from purpose of presentation.</li> <li>• Excessive use of verbal fillers.</li> <li>• Little eye contact with audience.</li> <li>• Poor or slouchy posture.</li> <li>• Attire was inappropriate for audience.</li> <li>• Time was not used appropriately.</li> <li>• No formal introduction or introduction had no clear thesis statement nor offered any preview of topics to be discussed</li> <li>• Main ideas were not separated into a logical progression.</li> <li>• Important ideas were not supported with references or data.</li> <li>• No conclusion or conclusion did not adequately summarize presentation.</li> </ul> <p>0 -----3-----6-----9</p>	<ul style="list-style-type: none"> <li>• Speaker was easy to hear and understand.</li> <li>• Speaks clearly, correctly and without verbal fillers.</li> <li>• Strong eye contact with entire audience.</li> <li>• Posture conveyed confidence.</li> <li>• Attire was appropriate for audience and purpose.</li> <li>• Time requirement was met for specific assignment (neither too long nor too short.).</li> <li>• Introduction had clear thesis statement and a preview of topics to be discussed.</li> <li>• Main ideas were separated into a logical progression.</li> <li>• Speaker supported important ideas and viewpoints through accurate and detailed references to text or other works.</li> <li>• Conclusion restated thesis statement and summarized the ideas presented.</li> </ul> <p>10-----11-----12</p>	<ul style="list-style-type: none"> <li>• Speaker was enjoyable to hear; used expression and emphasis.</li> <li>• Speaker used voice to create an emotional response in audience.</li> <li>• Posture was commanding and purposeful.</li> <li>• Attire was chosen to enhance presentation.</li> <li>• Clever attention getting introduction or an imaginative thesis and preview.</li> <li>• Ideas connected by original transitions, logical throughout; creative pattern</li> <li>• Conclusion tied speech together and left audience with memorable message.</li> <li>• Speaker used logical, ethical and emotional appeals that enhanced a specific tone and purpose.</li> </ul> <p>13-----14-----15+</p>

<b>Critical Thinking</b>	<ul style="list-style-type: none"> <li>Reasoning is unclear, illogical or superficial.</li> <li>Interprets or calculates information inaccurately.</li> <li>Makes statements with little explanation.</li> <li>Student does not demonstrate a clear understanding of the rules, definitions, laws, concepts, theories and principles of topic or skill under study.</li> <li>Student does not identify cause-and-effect relationships.</li> </ul> <p>0 ----- 3 ----- 6 ----- 9</p>	<ul style="list-style-type: none"> <li>Reasoning is clear and logical.</li> <li>Interprets or calculates information accurately.</li> <li>Supports statements with explanations.</li> <li>Student demonstrates a clear understanding of the rules, definitions, laws, concepts, theories and principles of topic or skill under study.</li> <li>Student can identify relationships between ideas, data sets, and phenomena.</li> </ul> <p>10 ----- 11 ----- 12</p>	<ul style="list-style-type: none"> <li>Reasoning is thorough; uses creativity.</li> <li>Supports statements with evidence.</li> <li>Student is able to use his/her analysis to teach the definitions, law, concepts, theories and principles under study.</li> <li>Student and/or audience is able to differentiate between similar definitions, law, concepts, theories and principles.</li> <li>The student can differentiate between correlation and cause and effect.</li> </ul> <p>13 ----- 14 ----- 15+</p>
<b>Work Ethic</b>	<ul style="list-style-type: none"> <li>The student is FREQUENTLY late to class (two of the five days bi-weekly).</li> <li>The student FREQUENTLY (3 out of five days bi-weekly) comes to class WITHOUT required materials (paper, pen or pencil, homework, etc.).</li> <li>The student turns in LESS THAN 70% of their work in on time.</li> <li>Additional criteria:</li> </ul> <p>0 ----- 3 ----- 6 ----- 9</p>	<ul style="list-style-type: none"> <li>The student is SOMETIMES LATE to class (once biweekly).</li> <li>The student USUALLY comes to class with the required materials (paper, pen or pencil, homework, etc) 80% of the time or 4 of the 5 days bi-weekly.</li> <li>The student is USUALLY focused on their work (roughly 80% of the time), but has a tendency to become off task and distract others.</li> <li>The student turns in 80% of their work on time.</li> <li>Additional criteria:</li> </ul> <p>10 ----- 11 ----- 12</p>	<ul style="list-style-type: none"> <li>The student is NEVER late to class.</li> <li>The student ALWAYS comes to class with the required materials (paper, pen or pencil, homework, etc).</li> <li>The student is focused throughout class (at least 90% of the time) and DOES NOT distract from the learning of other students.</li> <li>The student turns in ALL work on time.</li> <li>Additional criteria:</li> </ul> <p>13 ----- 14 ----- 15+</p>
<b>Product</b>	<ul style="list-style-type: none"> <li>Design is unclear and/or confusing</li> <li>Free body diagram is missing or inaccurate.</li> <li>No point of sail included.</li> <li>Newton's 2nd Law neither shown nor explained.</li> </ul> <p>0 ----- 3 ----- 6 ----- 9</p>	<ul style="list-style-type: none"> <li>Design is clear and easy to follow.</li> <li>Design includes free body diagram showing forces applied to sail and keel &amp; net force.</li> <li>Design includes point of sail.</li> <li>Newton's 2nd Law clearly shown or explained.</li> </ul> <p>10 ----- 11 ----- 12</p>	<ul style="list-style-type: none"> <li>Design is creative and thoroughly detailed.</li> <li>Free body diagram shows sail and keel with drag and lift labeled, in addition to net force.</li> <li>Design includes two or more points of sail and corresponding forces.</li> <li>Newton's 2nd Law clearly shown AND explained.</li> </ul> <p>13 ----- 14 ----- 15+</p>
<b>BREAKTHROUGH</b> Evidence for exceptional or creative performance beyond mastery.	<p>The evidence for breakthrough is:</p> <p>:</p>		

### Extra Credit/Bonus Score

# Presentation & Communication Rubric

DATE, CLASS, PROJECT, OTHER INFO.

STUDENT BEING EVALUATED

CRITERIA	WEIGHT	EMERGING (Below Performance Standards)	PROFICIENT (Minimal Criteria)	ADVANCED (Demonstrates Exceptional Performance)
<b>Structure and Organization</b> <ul style="list-style-type: none"><li>• Intro</li><li>• Main ideas</li><li>• Supporting Materials</li><li>• Conclusion</li><li>• Length requirement</li></ul> <b>TIME:</b>	30%	<ul style="list-style-type: none"> <li>• No formal introduction or introduction had no clear thesis statement nor offered any preview of topics to be discussed.</li> <li>• Main ideas were not separated into a logical progression.</li> <li>• Important ideas were not supported with references or data.</li> <li>• No conclusion or conclusion did not adequately summarize presentation</li> <li>• Presentation did not use time allotted.</li> </ul>	<ul style="list-style-type: none"> <li>• Introduction had clear thesis statement and a preview of topics to be discussed.</li> <li>• Main ideas were separated into a logical progression.</li> <li>• Speaker supported important ideas and viewpoints through accurate and detailed references to text or other works.</li> <li>• Conclusion restated thesis statement and summarized the ideas presented.</li> <li>• Time requirement was met for specific assignment (neither too long nor too short).</li> </ul>	In addition to meeting the PROFICIENT criteria ... <ul style="list-style-type: none"> <li>• Clever attention-getting introduction or an imaginative thesis and preview.</li> <li>• Ideas connected by original transitions, logical throughout; creative pattern.</li> <li>• Conclusion tied speech together and left audience with memorable message.</li> <li>• Speaker used logical, ethical, and emotional appeals that enhanced a specific tone and purpose.</li> </ul>
		0 ----- 3 ----- 6 ----- 9	10 ----- 11 ----- 12	13 ----- 14 ----- 15+
<b>Vocal Expression</b> <ul style="list-style-type: none"><li>• Rate &amp; Volume of Speech</li><li>• Pitch, Articulation, and Pronunciation</li><li>• Memorization</li><li>• Performance</li></ul>	25%	<ul style="list-style-type: none"> <li>• Speaker was hard to hear or understand.</li> <li>• Voice or tone distracted from purpose of presentation.</li> <li>• Excessive use of verbal fillers</li> <li>• Did not memorize lines.</li> <li>• Acting lacked expression.</li> </ul>	<ul style="list-style-type: none"> <li>• Speaker was easy to hear and understand.</li> <li>• Tone was conversational, but with purpose.</li> <li>• Voice sounded natural, neither patterned nor monotone.</li> <li>• Speaker pronounced words clearly, correctly, and without verbal fillers.</li> <li>• Had lines memorized.</li> <li>• Expressive acting.</li> </ul>	In addition to meeting the PROFICIENT criteria ... <ul style="list-style-type: none"> <li>• Speaker was enjoyable to hear; used expression and emphasis.</li> <li>• Speaker used voice to create an emotional response in audience.</li> <li>• Knew all your lines and possessed dramatic flair.</li> </ul>
		0 ----- 3 ----- 6 ----- 9	10 ----- 11 ----- 12	13 ----- 14 ----- 15+
<b>Physical Characteristics</b> <ul style="list-style-type: none"><li>• Eye contact</li><li>• Posture</li><li>• Gestures</li><li>• Movement</li><li>• Attire</li></ul>	15%	<ul style="list-style-type: none"> <li>• Little eye contact with audience.</li> <li>• Poor or slouchy posture.</li> <li>• Movements were stiff or unnatural.</li> <li>• Attire was inappropriate for audience.</li> </ul>	<ul style="list-style-type: none"> <li>• Strong eye contact with entire audience.</li> <li>• Posture conveyed confidence.</li> <li>• Gestures and movements were natural and effective.</li> <li>• Attire was appropriate for audience and purpose.</li> </ul>	<ul style="list-style-type: none"> <li>• Strong eye contact with entire audience.</li> <li>• Posture conveyed confidence.</li> <li>• Gestures and movements were natural and effective.</li> <li>• Attire was appropriate for audience and purpose.</li> </ul>
		0 ----- 3 ----- 6 ----- 9	10 ----- 11 ----- 12	13 ----- 14 ----- 15+

<b>Appropriateness of Content &amp; Language</b>  <b>For audience, purpose, and assignment.</b>	10%	<ul style="list-style-type: none"> <li>• Speaker used inappropriate language, content, or examples for this audience.</li> <li>• Speaker did not demonstrate a clear understanding of the assignment or purpose of presentation.</li> </ul> <p>0 ----- 3 ----- 6 ----- 9</p>	<ul style="list-style-type: none"> <li>• Speaker obviously considered the audience &amp; used appropriate language and examples.</li> <li>• Speaker displayed a clear understanding of assignment requirements and content.</li> <li>• Speaker understood purpose of presentation.</li> <li>• The student turns in 80% of their work on time.</li> <li>• Additional criteria:</li> </ul> <p>10 ----- 11 ----- 12</p>	In addition to meeting the PROFICIENT criteria ... <ul style="list-style-type: none"> <li>• Examples and words were creative and well-chosen for target audience.</li> <li>• The student turns in ALL work on time.</li> <li>• Additional criteria:</li> </ul> <p>13 ----- 14 ----- 15+</p>
<b>Overall Impact</b> <ul style="list-style-type: none"><li>• Energy</li><li>• Enthusiasm</li><li>• Sincerity</li><li>• Originality/ Creativity</li></ul>	10%	<ul style="list-style-type: none"> <li>• Speaker appeared bored by the message or presented without conviction.</li> </ul> <p>0 ----- 3 ----- 6 ----- 9</p>	<ul style="list-style-type: none"> <li>• Speaker appeared to believe strongly in message and demonstrated desire to have audience listen, understand, and remember.</li> </ul> <p>10 ----- 11 ----- 12</p>	In addition to meeting the PROFICIENT criteria ... <ul style="list-style-type: none"> <li>• Overall presentation was creative and exciting.</li> </ul> <p>13 ----- 14 ----- 15+</p>
<b>Features</b> <ul style="list-style-type: none"><li>• Multimedia</li><li>• Visuals</li><li>• Audio</li></ul>	10%	<ul style="list-style-type: none"> <li>• Materials detracted from content or purpose of presentation or were of such low quality as to discredit speaker.</li> </ul> <p>0 ----- 3 ----- 6 ----- 9</p>	<ul style="list-style-type: none"> <li>• Materials added, did not detract from presentation.</li> <li>• Materials used were quality products; easy to see and hear.</li> </ul> <p>10 ----- 11 ----- 12</p>	In addition to meeting the PROFICIENT criteria... <ul style="list-style-type: none"> <li>• Speaker creatively integrated a variety of objects, charts, and graphs to amplify the message.</li> </ul> <p>13 ----- 14 ----- 15+</p>
<b>BREAKTHROUGH</b> Evidence for exceptional or creative performance beyond mastery.		The evidence for breakthrough is:		

### Extra Credit/Bonus Score

# Teamwork Rubric

DATE, CLASS, PROJECT, OTHER INFO.

STUDENT BEING EVALUATED

CRITERIA	EMERGING (Below Performance Standards)	PROFICIENT (Minimal Criteria)	ADVANCED (Demonstrates Exceptional Performance)
<b>Cohesion &amp; Purpose</b>	<ul style="list-style-type: none"> <li>• Team establishes no norms or weak norms.</li> <li>• Team does not delegate or assign tasks.</li> <li>• Majority of team members disengaged.</li> <li>• Team shows little engagement in problem solving</li> <li>• Team is unable to resolve conflicts.</li> </ul>	<ul style="list-style-type: none"> <li>• Team quickly establishes norms.</li> <li>• Team assigns and delegates tasks.</li> <li>• Team engages all members.</li> <li>• Team shows purposeful engagement.</li> <li>• Team listens and plans together.</li> <li>• Team members show attentive posture and eye contact.</li> <li>• Team demonstrates ability to resolve conflicts.</li> <li>• Team demonstrates ability to look at issues from multiple points of view.</li> </ul>	<ul style="list-style-type: none"> <li>• Team quickly establishes thoughtful norms.</li> <li>• Team assigns and delegates tasks based on thorough discussion of team strengths.</li> <li>• Team immediately and deeply engaged in problem solving.</li> <li>• Team overcomes conflicts immediately.</li> <li>• Team uses listening and communication strategies to include all viewpoints.</li> </ul>
	0 ----- 3 ----- 6 ----- 9	10 ----- 11 ----- 12	13 ----- 14 ----- 15+
<b>Organization</b>	<ul style="list-style-type: none"> <li>• Team unable to generate ideas.</li> <li>• Team does not focus on task or cannot prioritize.</li> <li>• Team misses or does not establish deadlines.</li> <li>• Team does not develop a realistic project schedule.</li> <li>• Team cannot find resources.</li> </ul>	<ul style="list-style-type: none"> <li>• Team easily generates ideas.</li> <li>• Team focuses on task and develops agenda.</li> <li>• Team operates on time and meets deadlines.</li> <li>• Team develops a project schedule.</li> <li>• Team monitors their progress.</li> <li>• Team accepts changes in task or focus.</li> <li>• Team shows resourcefulness in finding information.</li> </ul>	<ul style="list-style-type: none"> <li>• Team uses techniques to brainstorm high quality ideas.</li> <li>• Team develops a comprehensive, realistic agenda.</li> <li>• Team meets or exceeds deadlines.</li> <li>• Team monitors progress and adapts new schedules based on feedback.</li> <li>• Team welcomes and feels challenged by changes in task focus.</li> <li>• Team is unusually resourceful.</li> </ul>
	0 ----- 3 ----- 6 ----- 9	10 ----- 11 ----- 12	13 ----- 14 ----- 15+
<b>Inquiry &amp; Problem Solving</b>	<ul style="list-style-type: none"> <li>• Team cannot brainstorm solutions.</li> <li>• Team does not use thinking strategies.</li> <li>• Team does not pursue or demonstrate background knowledge for problem solving.</li> <li>• Team shows little conceptual understanding of the problem or question.</li> <li>• Team does not use the conventions and terms of the discipline in discussions.</li> </ul>	<ul style="list-style-type: none"> <li>• Team often brainstorms solutions.</li> <li>• Team demonstrates use of thinking strategies.</li> <li>• Team demonstrates use of background knowledge.</li> <li>• Team shows conceptual understanding of problem.</li> <li>• Team demonstrates knowledge of criteria for judgment of solutions.</li> <li>• Team uses conventions and terms of the discipline.</li> </ul>	<ul style="list-style-type: none"> <li>• Team brainstorming leads to new solutions or fresh thinking.</li> <li>• Team routinely uses thinking strategies.</li> <li>• Team shows deep background knowledge.</li> <li>• Team shows deep conceptual understanding of the problem or question.</li> <li>• Team able to easily use the conventions and terms of the discipline.</li> </ul>
	0 ----- 3 ----- 6 ----- 9	10 ----- 11 ----- 12	13 ----- 14 ----- 15+

**BREAKTHROUGH**

Evidence for exceptional or creative performance beyond mastery.

The evidence for breakthrough is:

**Extra Credit/Bonus Score**

# Mathematical Practices Rubric

DATE, CLASS, PROJECT, OTHER INFO.

STUDENT BEING EVALUATED

CRITERIA	WEIGHT	EMERGING (Below Performance Standards)	PROFICIENT (Minimal Criteria)	ADVANCED (Demonstrates Exceptional Performance)
<b>Make Sense of Problems and Persevere in Solving Them.</b>	15%	<ul style="list-style-type: none"> <li>• Student cannot recognize givens, constraints, relationships, and goals of a problem.</li> <li>• Student does not monitor progress or adjust approach to problem.</li> <li>• Student does not check solutions for errors.</li> </ul> 0 ----- 3 ----- 6 ----- 9	<ul style="list-style-type: none"> <li>• Student analyzes givens, constraints, relationships, and goals of a problem.</li> <li>• Student monitors and evaluates progress and changes course if necessary.</li> <li>• Student checks solutions for errors.</li> <li>• Student asks continually: "Does this make sense?"</li> </ul> 10 ----- 11 ----- 12	In addition to meeting the PROFICIENT criteria <ul style="list-style-type: none"> <li>• Student quickly analyzes key aspects of a problem.</li> <li>• Student easily monitors progress and adjusts approach to problem.</li> <li>• Student routinely checks solutions for errors.</li> <li>• Student is able to fully explain solution to others.</li> </ul> 13 ----- 14 ----- 15+
<b>Reason Abstractly &amp; Quantitatively</b>	15%	<ul style="list-style-type: none"> <li>• Student cannot represent problem symbolically.</li> <li>• Student shows limited ability to contextualize the problem.</li> </ul> 0 ----- 3 ----- 6 ----- 9	<ul style="list-style-type: none"> <li>• Student abstracts a given situation and represents it symbolically.</li> <li>• Student manipulates the representing symbols and shows ability to contextualize the problem.</li> <li>• Student creates a coherent representation of the problem.</li> </ul> 10 ----- 11 ----- 12	In addition to meeting the PROFICIENT criteria... <ul style="list-style-type: none"> <li>• Student represents a problem symbolically in ways that show thorough understanding.</li> <li>• Student manipulates the representing symbols in ways that clearly contextualize the problem.</li> <li>• Student can explain the representation of the problem to others.</li> </ul> 13 ----- 14 ----- 15+
<b>Construct Viable Arguments &amp; Critique the Reasoning of Others</b>	15%	<ul style="list-style-type: none"> <li>• Student cannot state assumptions, definitions, and/or results in constructing arguments.</li> <li>• Student makes limited conjectures or builds an illogical progression of statements to explore conjectures.</li> <li>• Student shows limited ability to reason inductively or use logic.</li> </ul> 0 ----- 3 ----- 6 ----- 9	<ul style="list-style-type: none"> <li>• Student understands and uses stated assumptions, definitions, and results in constructing arguments.</li> <li>• Student makes conjectures and builds a logical progression of statements to explore conjectures.</li> <li>• Student analyzes situations and can recognize and use counterexamples.</li> <li>• Student reasons inductively and uses logic and reasoning.</li> </ul> 10 ----- 11 ----- 12	In addition to meeting the PROFICIENT criteria... <ul style="list-style-type: none"> <li>• Student can construct argument using stated assumptions and definitions, and results in constructing arguments.</li> <li>• Student makes original conjectures and builds an elegant progression of statements to explore conjectures.</li> </ul> 13 ----- 14 ----- 15+
<b>Model with Mathematics</b>	15%	<ul style="list-style-type: none"> <li>• Student cannot link important quantities in a practical situation with use of tools such as diagrams, two-way tables, graphs, flowcharts, and formulas.</li> <li>• Student shows limited knowledge of how mathematics applies to problems arising in everyday life, society, and the workplace.</li> </ul>	<ul style="list-style-type: none"> <li>• Student identifies important quantities in a practical situation and maps his or her relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas.</li> <li>• Student applies mathematics to solve problems arising in everyday life, society, and the workplace.</li> </ul>	In addition to meeting the PROFICIENT criteria... <ul style="list-style-type: none"> <li>• Student maps complex practical situations with such tools as diagrams, two-way tables, graphs, flowcharts, and formulas.</li> <li>• Student has unusual insight into how mathematics applies to solving problems arising in</li> </ul>

		0 ----- 3 ----- 6 ----- 9	10 ----- 11 ----- 12	everyday life, society, and the workplace.  13 ----- 14 ----- 15+
<b>Use Appropriate Tools Strategically</b>	10%	<ul style="list-style-type: none"> <li>• Student does not use the available tools when solving a mathematical problem.</li> <li>• Student has limited ability to use technological tools to explore and deepen his or her understanding of concepts.</li> </ul> 0 ----- 3 ----- 6 ----- 9	<ul style="list-style-type: none"> <li>• Student considers the available tools when solving a mathematical problem.</li> <li>• Student is able to use technological tools to explore and deepen his or her understanding of concepts.</li> </ul> 10 ----- 11 ----- 12	In addition to meeting the PROFICIENT criteria... <ul style="list-style-type: none"> <li>• Student chooses the best available tools when solving a mathematical problem.</li> <li>• Student is expert at using technological tools to explore and deepen his or her understanding of concepts.</li> </ul> 13 ----- 14 ----- 15+
<b>Attend to Precision</b>	10%	<ul style="list-style-type: none"> <li>• Student does not use definitions in discussion with others and in his or her own reasoning.</li> <li>• Student calculates accurately and efficiently, and expresses numerical answers with a minimal of precision appropriate for the problem context.</li> </ul> 0 ----- 3 ----- 6 ----- 9	<ul style="list-style-type: none"> <li>• Student uses clear definitions in discussion with others and in his or her own reasoning.</li> <li>• Student calculates accurately and efficiently, and expresses numerical answers with a degree of precision appropriate for the problem context.</li> </ul> 10 ----- 11 ----- 12	In addition to meeting the PROFICIENT criteria... <ul style="list-style-type: none"> <li>• Student uses clear definitions in a variety of ways in discussion that helps others clarify their own reasoning.</li> <li>• Student calculates accurately and efficiently, and expresses numerical answers with the exact degree of precision appropriate for the problem context.</li> </ul> 13 ----- 14 ----- 15+
<b>Look For and Make Use of Structure</b>	10%	<ul style="list-style-type: none"> <li>• Student cannot discern a pattern or structure without assistance.</li> </ul> 0 ----- 3 ----- 6 ----- 9	<ul style="list-style-type: none"> <li>• Student looks closely to discern a pattern or structure.</li> </ul> 10 ----- 11 ----- 12	In addition to meeting the PROFICIENT criteria... <ul style="list-style-type: none"> <li>• Student can easily identify a pattern or structure in a wide range of natural settings or practical ways.</li> </ul> 13 ----- 14 ----- 15+
<b>Look For &amp; Express Regularity in Repeated Reasoning</b>	10%	<ul style="list-style-type: none"> <li>• Student overlooks calculations that are repeated, and does not look for general methods or for shortcuts.</li> </ul> 0 ----- 3 ----- 6 ----- 9	<ul style="list-style-type: none"> <li>• Student notices if calculations are repeated, and looks both for general methods and for shortcuts.</li> </ul> 10 ----- 11 ----- 12	In addition to meeting the PROFICIENT criteria... <ul style="list-style-type: none"> <li>• Student rarely repeats calculations, and first looks both for general methods and for shortcuts when problem solving.</li> </ul> 13 ----- 14 ----- 15+
<b>BREAKTHROUGH</b> Evidence for exceptional or creative performance beyond mastery.		The evidence for breakthrough is:		

**Extra Credit/Bonus Score**

# Critical Thinking Rubric

DATE, CLASS, PROJECT, OTHER INFO.

STUDENT BEING EVALUATED

CRITERIA	EMERGING (Below Performance Standards)	PROFICIENT (Minimal Criteria)	ADVANCED (Demonstrates Exceptional Performance)
<b>Appropriateness</b>  The student selects material, objects and/or techniques that meet the needs, requirements and rules of the time, place and audience.	<ul style="list-style-type: none"> <li>• Student does not select material (photos, sound files, video clips, apparel, illustrations, etc.) that is appropriate for the audience and the situation.</li> <li>• Student does not use language appropriate for the audience and the situation (as defined by school and district guidelines).</li> <li>• Student does not select an efficient tool, technique or paradigm to achieve the desired goal as defined in the project or course guidelines.</li> <li>• Student uses humor that doesn't enhance understanding and may offend audience.</li> </ul> <p>0 -----3----- 6-----9</p>	<ul style="list-style-type: none"> <li>• Student selects material (photos, sound files, video clips, apparel, illustrations, etc.) that is appropriate for the audience and the situation.</li> <li>• Student uses language appropriate for the audience and the situation.</li> <li>• Student selects an effective tool, technique or paradigm to achieve the desired goal as defined in the project or course guidelines.</li> <li>• Student uses humor that enhances understanding and doesn't offend audience.</li> </ul> <p>10 ----- 11 ----- 12</p>	<p>In addition to meeting the PROFICIENT criteria ...</p> <ul style="list-style-type: none"> <li>• Student shows a deep understanding of the audience and the situation by selecting material that enhances understanding.</li> <li>• Student uses language that creates a strong, positive reaction in audience.</li> <li>• Student creates tools, techniques or paradigms that effectively achieve the desired goal.</li> </ul> <p>13 ----- 14 ----- 15+</p>
<b>Application</b>  The student uses the material, knowledge, and/or skill in new situations	<ul style="list-style-type: none"> <li>• Student does not demonstrate an ability to apply theories, principles and/or skills to new situations, settings or problems.</li> <li>• Student is not able to modify theories, products, behaviors or skills to fit new or changed environment.</li> </ul> <p>0 -----3----- 6-----9</p>	<ul style="list-style-type: none"> <li>• Student demonstrates an ability to apply theories, principles and/or skills to new situations, settings or problems.</li> <li>• Student is able to modify theories, products, behaviors or skills to fit new or changed environment.</li> </ul> <p>10 ----- 11 ----- 12</p>	<p>In addition to meeting the PROFICIENT criteria ...</p> <ul style="list-style-type: none"> <li>• Student actively seeks new environments and situations to apply theories, principles and/or skills.</li> <li>• Student provides multiple examples of how theory, principle or skill can be applied.</li> </ul> <p>13 ----- 14 ----- 15+</p>
<b>Analysis</b>  The student breaks down this material and/or skill into its component parts so that its structure can be understood.	<ul style="list-style-type: none"> <li>• Student does not demonstrate a clear understanding of the rules, definitions, laws, concepts, theories and principles of topic or skill under study.</li> <li>• Analysis does not include diagrams, models, timelines, illustrations or step-by-step progression of object/principle/problem under study.</li> <li>• The student does not identify cause-and-effect relationships.</li> </ul> <p>0 -----3----- 6-----9</p>	<ul style="list-style-type: none"> <li>• Student demonstrates a clear understanding of the rules, definitions, laws, concepts, theories and principles of topic or skill under study.</li> <li>• Analysis includes diagrams, models, timelines, illustrations or step-by-step progression of object/principle/problem under study.</li> <li>• The student can identify relationships between ideas, data sets, and phenomena.</li> </ul> <p>10 ----- 11 ----- 12</p>	<p>In addition to meeting the PROFICIENT criteria ...</p> <ul style="list-style-type: none"> <li>• Student is able to use his/her analysis to teach the definitions, law, concepts, theories and principles under study.</li> <li>• Student and/or audience is able to differentiate between similar definitions, law, concepts, theories and principles.</li> <li>• The student can differentiate between correlation and cause and effect.</li> </ul> <p>13 ----- 14 ----- 15+</p>

<b>Evaluation</b>  The student judges the quality (based on both subjective and objective standards) of the material, object, or performance.	<ul style="list-style-type: none"> <li>• Student does not demonstrate understanding of the criteria used for evaluation.</li> <li>• Student does not defend his/her evaluation (critique).</li> <li>• Evaluation is not supported by reference to standards.</li> <li>• Evaluation does not include comparison and contrast to other ideas/objects/materials.</li> </ul> <p>0 ----- 3 ----- 6 ----- 9</p>	<ul style="list-style-type: none"> <li>• Student demonstrates understanding of the criteria used for evaluation.</li> <li>• Student is able to defend his/her evaluation (critique).</li> <li>• Evaluation is supported by reference to standards.</li> <li>• Evaluation includes comparison and contrast to other ideas/objects/materials.</li> </ul> <p>10 ----- 11 ----- 12</p>	In addition to meeting the PROFICIENT criteria... <ul style="list-style-type: none"> <li>• Evaluation includes references (comparison/contrast) to three or more objects/ideas/materials.</li> <li>• Student creates clearly defined criteria (i.e., rubric, standards, and guidelines) for evaluation.</li> </ul> <p>13 ----- 14 ----- 15+</p>
<b>Synthesis</b>  The student combines more than one object or idea and forms a new, cohesive whole.	<ul style="list-style-type: none"> <li>• Synthesis does not successfully integrate ideas, images and/or objects to form a cohesive whole.</li> <li>• Student does not summarize their thinking during the process of synthesis.</li> <li>• Combination of elements is not logical and/or verifiable.</li> </ul> <p>0 ----- 3 ----- 6 ----- 9</p>	<ul style="list-style-type: none"> <li>• Synthesis integrates ideas, images and/or objects to form a cohesive whole.</li> <li>• Student is able to summarize their thinking during the process of synthesis.</li> <li>• Combination of elements is logical and justified.</li> </ul> <p>10 ----- 11 ----- 12</p>	In addition to meeting the PROFICIENT criteria ... <ul style="list-style-type: none"> <li>• Synthesis is unique.</li> <li>• Synthesis shows careful planning and attention to how disparate elements fit together.</li> <li>• Student is able to create new synthesis based on changing circumstances, input or environment.</li> <li>• Combination of elements is verified.</li> </ul> <p>13 ----- 14 ----- 15+</p>
<b>BREAKTHROUGH</b> Evidence for exceptional or creative performance beyond mastery.	The evidence for breakthrough is:		

### Extra Credit/Bonus Score

# Creativity Rubric

DATE, CLASS, PROJECT, OTHER INFO.

STUDENT BEING EVALUATED

CRITERIA	WEIGHT	EMERGING (Below Performance Standards)	PROFICIENT (Minimal Criteria)	ADVANCED (Demonstrates Exceptional Performance)
Demonstrates an understanding of the creative process and product in traditional disciplines.	25%	<ul style="list-style-type: none"> <li>Rarely demonstrates understanding of the creative process or product.</li> <li>Cannot identify stages of the creative process.</li> <li>Lacks flexibility, stubbornly maintaining positions and points of view in spite of new and changing conditions.</li> </ul> 0 -----3----- 6 -----9	In addition to meeting the EMERGING criteria... <ul style="list-style-type: none"> <li>Clearly demonstrates understanding of the creative process or product.</li> <li>Applies stages of creative process to traditional disciplines.</li> <li>Product shows innovative design, use of materials and ideas in an unexpected way.</li> </ul> 10 ----- 11 ----- 12	In addition to meeting the PROFICIENT criteria ... <ul style="list-style-type: none"> <li>Distinctly demonstrates an understanding of the creative process and product.</li> <li>Evaluates creative process in relation to work of others.</li> <li>Product goes beyond required elements.</li> </ul> 13 ----- 14 ----- 15+
Demonstrates the ability to critique the creative process and product in traditional disciplines.	25%	<ul style="list-style-type: none"> <li>Inefficiently demonstrates the ability to critique the creative process and product.</li> </ul> 0 -----3----- 6 -----9	<ul style="list-style-type: none"> <li>Clearly demonstrates the ability to critique the creative process and product.</li> <li>Materials and ideas often developed in unique ways, with a minimum of support.</li> </ul> 10 ----- 11 ----- 12	<ul style="list-style-type: none"> <li>Distinctly demonstrates the ability to critique the creative process and product.</li> <li>Engages in reflective process that fosters critical analysis.</li> </ul> 13 ----- 14 ----- 15+
Engages in creative activity.	25%	<ul style="list-style-type: none"> <li>Inefficiently engages in creative activity, project and/or performance.</li> <li>Product appears cliché or derivative.</li> </ul> 0 -----3----- 6 -----9	<ul style="list-style-type: none"> <li>Brainstorms and explores ways/ideas to solve problem/s. View task from various points of view.</li> <li>Often able to independently envision new responses to varying situations.</li> </ul> 10 ----- 11 ----- 12	<ul style="list-style-type: none"> <li>Demonstrates connections to previous knowledge or skills.</li> <li>Expresses original thoughts/ideas in own voice.</li> <li>Explores new ideas or expands on existing ideas in innovative ways.</li> <li>Product appears innovative or exciting.</li> </ul> 13 ----- 14 ----- 15+
Reflects on his/her own creative process.	25%	<ul style="list-style-type: none"> <li>Inefficiently reflects on own creative process</li> <li>Limited evidence of understanding or challenges</li> <li>No self-reflection apparent.</li> </ul> 0 -----3----- 6 -----9	<ul style="list-style-type: none"> <li>Clearly reflects on own creative process.</li> <li>Self-reflection apparent, impacts product completion.</li> </ul> 10 ----- 11 ----- 12	<ul style="list-style-type: none"> <li>Distinctly reflects on own creative process.</li> <li>Contrasts own creativity with others.</li> <li>Product exhibits improvement based upon student's self-scrutiny and feedback from others.</li> </ul> 13 ----- 14 ----- 15+

<b>BREAKTHROUGH</b> Evidence for exceptional or creative performance beyond mastery.		The evidence for breakthrough is:
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**Extra Credit/Bonus Score**

## Section 4

### Reflection Tools



Photos by Chris Ray

## Critical Friends Protocol

CRITICAL FRIENDS PROTOCOL		
PRESENTERS	<b>Presentation:</b> Project Title & Idea, Driving Question, Culminating Products or Performances, Entry Event*, and any concerns you'd like feedback about	7 min
EVERYONE	<b>Clarification:</b> Audience asks short clarifying questions	3 min
AUDIENCE	<b>Good Stuff:</b> Audience shares what they liked about the project  <b>Wondering Stuff:</b> Audience shares their concerns and probing questions  <b>Next Stuff:</b> Audience shares their thoughts on resources and improvements	4 min 4 min 4 min
PRESENTERS	<b>Reflection:</b> Group reflects on useful feedback, next steps	3 min
	TOTAL TIME	25 min

## Teacher's Post-project Review

Project: \_\_\_\_\_ Date: \_\_\_\_\_

\*Select the items upon which you would like to reflect. Delete the rows that you do not intend to discuss during the reflection.

<b><i>Project idea, design, and implementation considerations</i></b>	<b><i>Sample Discussion Questions</i></b>	<b><i>Reflections</i></b>
1. Student engagement	<ul style="list-style-type: none"><li>● What was the level of student engagement during the project?</li><li>● What key aspects of the project design or delivery contributed to the level of student engagement?</li></ul>	
2. Overall idea for the project	<ul style="list-style-type: none"><li>● What reflections do you have about the overall idea for the project?</li></ul>	
3. Overall results for student learning	<ul style="list-style-type: none"><li>● What goals did you establish regarding student performance on the culminating products?</li><li>● To what degree did you achieve your goals?</li><li>● What key aspects of the project design or delivery contributed to the overall results for student learning?</li></ul>	
4. Authenticity of project tasks and products	<ul style="list-style-type: none"><li>● Did the project focus on actual community issues? If so, what issues? If it did not, could it be refined to focus on actual issues?</li><li>● Was the project useful to an outside audience? Did it meet an authentic need? If it did not, could it be refined to meet an authentic need?</li><li>● Did students present to an audience beyond families or the classroom teacher? If not, would this enhance the project?</li><li>● Were students required to consider multiple perspectives on issues? If not, could the project be refined to enable them to do so?</li><li>● Were experts from the community utilized</li></ul>	

<b><i>Project idea, design, and implementation considerations</i></b>	<b><i>Sample Discussion Questions</i></b>	<b><i>Reflections</i></b>
	to help students critique their work against professional standards? If not, would this enhance the project?	
5. Quality and Use of Driving Question	<ul style="list-style-type: none"> <li>● Were your students able to easily read and comprehend the driving question?</li> <li>● The driving question should clearly state the purpose of the project and give a focus to all of the tasks students do. To what degree did your driving question accomplish this?</li> <li>● How effectively did your students answer the driving question in completing their products and performances?</li> <li>● What strategies did you use to maintain a focus on the driving question throughout the project?</li> <li>● Do you plan to refine the driving question before launching this project in the future?</li> </ul>	
6. Scope: Length of time Complexity Number of subjects/people/organizations involved Use of technology	<ul style="list-style-type: none"> <li>● Would you adjust the scope of the project before launching this project in the future? <ul style="list-style-type: none"> <li>■ Duration?</li> <li>■ Complexity?</li> <li>■ Interdisciplinary planning?</li> <li>■ Involvement with local experts?</li> <li>■ Use of technology?</li> </ul> </li> </ul>	
7. Selection of content standards	<ul style="list-style-type: none"> <li>● To what degree did the project demand breadth and depth of specific knowledge of central concepts?</li> <li>● To what degree were the driving question, end products, rubrics, and key learning experiences aligned and linked to the selected standards?</li> </ul>	
8. Selection of appropriate 21 <sup>st</sup> century skills	<ul style="list-style-type: none"> <li>● What 21<sup>st</sup> century skills did you teach and assess?</li> <li>● Would you add any additional 21<sup>st</sup> century skills in subsequent projects?</li> </ul>	

<b><i>Project idea, design, and implementation considerations</i></b>	<b><i>Sample Discussion Questions</i></b>	<b><i>Reflections</i></b>
9. Selection of culminating products and performances	<ul style="list-style-type: none"> <li>● How well did your culminating products and performances align with your intended outcomes?</li> <li>● How authentic were the products and performances? (How similar was the student work to the work in the professional world?)</li> </ul>	
10. Effectiveness of entry event	<ul style="list-style-type: none"> <li>● How effective was your entry event in sparking student interest and igniting their curiosity?</li> <li>● Did your entry event cause your students to pose questions about the topic and tasks?</li> <li>● Would you make any revisions to your entry event or adjust your approach when launching the project in the future?</li> </ul>	
11. Quality of rubrics	<ul style="list-style-type: none"> <li>● Ideally, your rubrics clearly articulate the criteria for success to enable students to easily use the rubric to evaluate their work during the revision process. To what degree did your rubrics accomplish this?</li> <li>● Did you use your rubric as a teaching tool?</li> </ul>	
12. Quantity and mix of scaffolding and learning activities	<ul style="list-style-type: none"> <li>● How well did you build your students' background knowledge for inquiry?</li> <li>● How effective was your project "scaffolding". (To what degree did you provide the necessary amount of skill instruction, mini-lessons, and use of models and drafts to build the understanding and skills needed to produce high quality work?)</li> </ul>	
13. Ability of students to work well in teams	<ul style="list-style-type: none"> <li>● How well did the students work in groups?</li> <li>● How did your selected project management strategies/structures contribute to your students' level of success with team work?</li> </ul>	

<b><i>Project idea, design, and implementation considerations</i></b>	<b><i>Sample Discussion Questions</i></b>	<b><i>Reflections</i></b>
14. Ability of students to work independently	<ul style="list-style-type: none"> <li>● How well did the students work independently?</li> <li>● How did your selected project management strategies/structures contribute to your students' level of success in working independently?</li> </ul>	
15. Ability of students to use inquiry skills and think deeply	<ul style="list-style-type: none"> <li>● What did you observe about your students' ability to use inquiry skills and think deeply about the topic of study?</li> </ul>	
16. My management of the process, coaching of students, and providing of support	<ul style="list-style-type: none"> <li>● What role did you play while students were engage in group work?</li> <li>● How did you respond when students needed support?</li> <li>● To what degree did you promote a culture of independence?</li> </ul>	
17. Involvement of other adults	<ul style="list-style-type: none"> <li>● What role did adults from the community, or other places beyond the community, play in your project?</li> <li>● Were they involved in helping you design the project? Teaching the students? Critiquing work against professional standards?</li> <li>● Were they helpful? Would you make any adjustments in the way in which you used these resources in the future?</li> </ul>	
18. Adequacy of resources	<ul style="list-style-type: none"> <li>● Would you make any adjustments to the resources that you provided students to help them engage in inquiry?</li> </ul>	

**Notes:**

## Reflection Matrix

Goal	Student	Team	Teacher
<b>Encourage Deep Learning &amp; Collective Knowledge Building &amp; Retention</b>	<p><i>What do I know?</i></p> <p><i>Why is it important?</i></p> <p><i>Where is this knowledge used in the world?</i></p> <p><i>How engaged was I?</i></p> <p><i>What did I like?</i></p> <p><i>What do I wonder?</i></p>	<p><i>What do we know?</i></p> <p><i>What did we learn from each other?</i></p> <p><i>How did we help each other?</i></p> <p><i>How engaged were we?</i></p> <p><i>What do we wonder about?</i></p>	<p><i>What have they learned?</i></p> <p><i>Why is it important?</i></p> <p><i>How meaningful was the project?</i></p> <p><i>How clear were the goals and instructions?</i></p> <p><i>Is there evidence of new knowledge creation?</i></p>
<b>Focus on Excellence</b>	<p><i>How did I perform?</i></p> <p><i>Did my skills improve?</i></p> <p><i>Did my habits of learning improve?</i></p>	<p><i>How did we perform?</i></p> <p><i>Did we improve our teamwork skills?</i></p>	<p><i>Did I balance content and process?</i></p> <p><i>Did I provide ongoing assessment and interventions?</i></p> <p><i>Was my project design adequate?</i></p> <p><i>Were the evaluations fair and accurate?</i></p>

<b>Develop a 'Growth Mindset'</b>	<p><i>What new questions do I have?</i></p> <p><i>What are my next steps to becoming a better learner?</i></p> <p><i>What action can I take?</i></p> <p><i>How am I different after this project?</i></p>	<p><i>What new questions do we have?</i></p> <p><i>How can we use what we learned to do better next time?</i></p> <p><i>Where can we apply our knowledge?</i></p> <p><i>What else do we want to explore?</i></p> <p><i>How are we different after this project?</i></p>	<p><i>Did I differentiate?</i></p> <p><i>Were my teaching and learning strategies effective?</i></p> <p><i>What new projects can I design based on what has been learned?</i></p>
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## Methods for Reflection\*

Method	Notes
	<p><i>Reflection is an integral part of the project. Prepare for reflection by using gallery walks, portfolios, and performance-based rubrics throughout the project. Reflection is both an individual and collective exercise. For teams, begin by reviewing norms for listening, attentiveness, and contribution. Encourage 'I like, I wonder,' format.</i></p> <p><i>Provide prompts from the reflection matrix.</i></p>
Think-Pair-Share	<p>Brainstorm knowledge gained from project individually and then share with a partner. Create a joint list. Post lists. Give all students five colored dots and have them walk the room to look at lists. Place dots on five ideas that most interest them. Discuss the reason that the lists appealed.</p>
Four Corners	<p>Post one interesting outcome of project in each corner of the room. Have students move to the corner that interests them. Discuss issues in each corner. Move to other corners if appropriate. Use chart paper divided into quadrants for students to defend their corner.</p>
Expert Line	<p>Reflect on the research stage of the project by dividing class into researchers and consultants. Face each other in a line. Used a timed consultation to pose receive problem and receive consultation. Switch roles. Debrief as a group.</p>
Think Tank	<p>Individual students complete a self-assessment on presentations. Discuss in teams. As a whole, create a presentation tip sheet.</p>
Question Builder Chart	<p>After culminating presentations, use teams to build a chart of new questions to ask. Use <i>Who, What, When, Where, How, Why, and Which</i> paired to <i>is, did, can, would, will, might</i> verbs.</p>
Question Storming	<p>After presentations, have students record 5 – 6 questions on sticky notes. Share question in teams. Post in categories. Gallery walk. Discuss.</p>
Self-Question	<p>Create a self-assessment form for students. Share in teams or in group.</p>
Six Thinking Hats	<p>Reflect on the project results by having students choose of the Six Thinking Hats. Analyze the results through the lens of each hat. The six hats: <i>Blue—global thinking; Black—critic; Red—hunches, intuition; White—facts and figures; Green—creative ideas; Yellow—logical, positive.</i></p>
Stretch Your Thinking	<p>Set up a reflection activity based on Bloom's Taxonomy, or similar comparisons of levels of learning.</p>
Interact with an Expert	<p>Use individuals or teams to interview or videoconference with an expert. Review and debrief project. Share findings with class.</p>

That's Good That's bad	Use a Good—Bad organizer to review project tasks, environment, methods, teams, etc.
Pose a New Problem	Have students takes findings from the project and create a new problem using the findings.
Web Excursion	Have students use sticky notes to create a wall web of all resources, personnel, tools, technologies they used to complete the project. Discuss the wall web.
Begin with a Poll	Use Wiggio.com or polleverywhere.com to use email or cell phones for instant polling on questions about the project.
Writing	Create class wiki or blog. Have students post. Then share as a whole.
Create visuals	Give students specific guidelines for creating a visual to ensure they create a particular message and supporting ideas. Have them create a timeline, chart, flowchart, graph, collage, or cartoon to depict the project results.
Create a skit	Have students select a key artifact from the project and create a short dramatization around it.
Use videos and photos	Use video or photos to broadcast the main message of the project.
Play in the Sandbox	Use play by having student imagine they are in a sandbox. What does the learning smell like? Taste like? Are there colors?
Critical Friends Protocol	For a more formal debrief on a project plan, put students in a CFG circle and facilitate a protocol on the project.
Fishbowl	Use a simple fishbowl format to discuss the project. Use a small circle with an empty seat. Circle the remaining students in a circle outside the fishbowl and allow one student at a time to join the inner circle for a comment.

\* Thanks to *Big Think*, by David Loertscher, Carol Koechlin, and Sandi Zwaan, and other sources.

# Section 5

## Appendices



Photos by Chris Ray

## Appendix A

### Calendar, Milestones, and Know/ Need to Know



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# Physics of Sailing Project Calendar

Week 1				
Day 1 <ul style="list-style-type: none"> <li>Entry Document</li> <li>Intro videos <a href="#">1 2 3</a></li> <li>DQ</li> <li>Project constraints</li> <li>Physics topics</li> <li>Project calendar</li> <li>Rubrics</li> </ul>	Day 2 <ul style="list-style-type: none"> <li>Background research</li> <li>Knows/Need2 Knows</li> <li>Form teams</li> <li>Intro to Weekly Work Log</li> </ul>	Day 3 <ul style="list-style-type: none"> <li>Workshop: Physics &amp; Sailing Vocab</li> <li>Parts of a sailboat videos <a href="#">1 2</a></li> <li>Vocab Activity</li> </ul>	Day 4 <ul style="list-style-type: none"> <li>Workshop: Newton's 2nd Law</li> <li>Newton's 2nd Law Activity</li> </ul>	Day 5 <ul style="list-style-type: none"> <li>Intro to Digital Resources (LMS, blog, etc.)</li> <li>Google SketchUpTutorial (<a href="#">videos</a>)</li> </ul>
Week 2				
Day 6 <ul style="list-style-type: none"> <li>Quiz: Vocab &amp; Newton's 2nd Law</li> <li>Weekly Work Log</li> </ul>	Day 7 <ul style="list-style-type: none"> <li>Workshop: Points of Sail (<a href="#">video</a>)</li> <li>Points of Sail Activity</li> </ul>	Day 8 <ul style="list-style-type: none"> <li>Workshop: Sail &amp; Keel Forces (Intro video <a href="#">1</a>)</li> <li>Sail &amp; Keel Forces Activity</li> </ul>	Day 9 <ul style="list-style-type: none"> <li>Design Brainstorming &amp; Sketching</li> <li>Peer Feedback</li> </ul>	Day 10 <ul style="list-style-type: none"> <li>Weekly Progress Self-Assessment</li> <li>Team Meeting w/Instructor</li> <li>Design</li> </ul>
Week 3				
Day 11 <ul style="list-style-type: none"> <li>Quiz: Points of Sail &amp; Forces</li> <li>Weekly Work Log</li> <li>Design</li> </ul>	Day 12 <ul style="list-style-type: none"> <li>Workshop: Force Diagrams</li> <li>Force Diagrams Activity</li> </ul>	Day 13 <ul style="list-style-type: none"> <li>Workshop: Sail &amp; Keel combos</li> <li>Sail &amp; keel combos activity</li> </ul>	Day 14 <ul style="list-style-type: none"> <li>Design</li> <li>Peer Feedback</li> </ul>	Day 15 <ul style="list-style-type: none"> <li>Weekly Progress Self-Assessment</li> <li>Team Meeting w/Instructor</li> <li>Design</li> </ul>

Week 4				
Day 16 <ul style="list-style-type: none"> <li>Quiz: Force diagrams, Sail &amp; keel combos</li> <li>Weekly Work Log</li> <li>Design</li> </ul>	Day 17 <ul style="list-style-type: none"> <li>Test Review</li> </ul>	Day 18 <ul style="list-style-type: none"> <li>Test</li> </ul>	Day 19 <ul style="list-style-type: none"> <li>Design Rough Draft Due</li> <li>Peer Feedback</li> </ul>	Day 20 <ul style="list-style-type: none"> <li>Weekly Progress Self-Assessment</li> <li>Team Meeting w/Instructor</li> <li>Design</li> </ul>
Week 5				
Day 21 <ul style="list-style-type: none"> <li>Weekly Work Log</li> <li>Design</li> </ul>	Day 22 <ul style="list-style-type: none"> <li>Design</li> </ul>	Day 23 <ul style="list-style-type: none"> <li>Design</li> </ul>	Day 24 <ul style="list-style-type: none"> <li>Final Design Due</li> <li>Peer Feedback</li> </ul>	Day 25 <ul style="list-style-type: none"> <li>Weekly Progress Self-Assessment</li> <li>Team Meeting w/Instructor</li> </ul>
Week 6				
Day 26 <ul style="list-style-type: none"> <li>Practice Presentations</li> </ul>	Day 27 <ul style="list-style-type: none"> <li>Practice Presentations</li> </ul>	Day 28 <ul style="list-style-type: none"> <li>Presentations</li> </ul>	Day 29 <ul style="list-style-type: none"> <li>Presentations</li> </ul>	Day 30 <ul style="list-style-type: none"> <li>Reflection</li> </ul>

## Weekly Work Log

<b>Names:</b>			
<b>Project Name:</b>		<b>Date:</b>	

<b>Today we had the following <u>goals</u> for project work.</b>	1	
	2	
	3	
	4	
	5	

<b>Today we accomplished...</b>	1	
	2	
	3	
	4	
	5	

<b>Our next steps are...</b>	1	
	2	
	3	
	4	
	5	

<b>Our most important concerns, problems, or questions are...</b>	1	
	2	
	3	
	4	
	5	

## Weekly Team Meeting Checklist

Project \_\_\_\_\_ Week of \_\_\_\_\_

<b>Team Name</b>	<b>Weekly Work Log Complete?</b>	<b>Obstacles/Issues</b>	<b>Plan of Action</b>

# Project Milestones Checklist

Team Name: \_\_\_\_\_

## **Know/Need to Know Chart**

**Team Name:** \_\_\_\_\_ **Date:** \_\_\_\_\_

<b>Know</b>	<b>Need to Know</b>	<b>Need to Do</b>

## **Research/Information Gathering**

**Title of Source:** \_\_\_\_\_

Need to Know Item being investigated:

Type of Source (check one): Internet      Print      Audio/Video      Person

URL

Address: \_\_\_\_\_

Author/Organization: \_\_\_\_\_

Summarize in your own words the information in this source.

Was there any particular bias or point of view evident in this source? If so, what is it?

How will the information in this source help you to build a solution to the problem?

# Appendix B

## Teams and Grouping



Photos by Chris Ray

# Teams and Grouping Introduction

This appendix contains tools useful for teachers and students to help teams operate successfully and achieve their goals. Four documents are designed to aid teachers in assigning students to teams and having teams agree on norms and objectives. These are:

- 1. Team Roles**
- 2. Designing Team Contracts**
- 3. Student Contract Sample**
- 4. Rules for High Performance Collaboration.**

Four other documents are samples and suggestions for exercises that help students learn to operate as a team, resolve conflicts, and communicate effectively with one another. These are:

- 1. Team Building Exercises**
- 2. Communication Worksheet**
- 3. Conflict Resolution Speak**

# Team Roles

## Task Roles

**Initiator** suggests or proposes new ideas to the team. He or she offers a novel point of view concerning problems, procedures, goals, or solutions.

**Information seeker** asks for clarification of suggestions made in terms of their factual adequacy, for authoritative information and facts pertinent to the problem being discussed.

**Opinion seeker** asks primarily for a clarification of values pertinent to what the team is undertaking or values involved in various suggestions that have been made.

**Information giver** offers facts or generalizations that are "authoritative" or relates his or her own experience pertinent to the team problem.

**Opinion giver** states his or her belief pertinent to a suggestion made. The emphasis is on what he or she believes should be the team's view of pertinent values, not primarily upon relevant facts or information.

**Elaborator** spells out suggestions in terms of examples or developed meanings, offers a rationale for suggestions previously made, and tries to deduce how an idea or suggestion would work out if adopted primarily upon relevant facts or information.

**Coordinator** shows or clarifies the relationships among various ideas and suggestions, tries to pull ideas and suggestions together, or tries to coordinate the activities of various members of sub-teams.

**Energizer** prods the team to action or decision, attempts to stimulate or arouse the team to "greater" or "higher quality" activity.

**Procedural technician** expedites team movement by doing things for the team, e.g. passing out materials or setting up chairs.

**Recorder** writes down suggestions, makes a record of team decisions, or writes down the product of discussion. The recorder fills the role of "team memory."

## Maintenance Roles

**Encourager** praises, agrees with, and accepts the contribution of the others. He or she indicates warmth and solidarity in his or her attitude toward other team members, offers commendation and praise, and in various ways indicates understanding and acceptance of other points of view, ideas, and suggestions.

**Harmonizer** mediates the differences between other members, attempts to reconcile disagreements, relieves tension in conflict situations through good-hearted jokes, a soothing attitude, etc.

**Compromiser** operates from within a conflict in which his or her idea or position is involved. He or she may offer a compromise by yielding status, admitting his or her error, by disciplining him- or herself to maintain team harmony, or by "coming halfway" in moving along with the team.

**Gate-keeper** expedites attempts to keep communication channels open by encouraging or facilitating the participation of others ("we haven't gotten the ideas of Mr. X yet," etc.) or by proposing regulation of the flow of communication ("why don't we limit the length of our contributions so that everyone will have a chance to contribute?" etc.)

**Standard setter** expresses standards for the team. These standards apply to the quality of the team process, or set limits on acceptable individual behavior within the team.

**Team observer** keeps records of various aspects of team process and feeds such data with proposed interpretations into the team's evaluation of its own procedures.

**Summarizer** defines the position of the team with respect to its goals by summarizing what has occurred, points to departures from agreed upon directions or goals, or raises questions about the direction which the team discussion is taking.

**Reality tester** subjects the accomplishment of the team to some standard or set of standards of team functioning in the context of the team task. Thus, he or she may evaluate or question the "practicality," the "logic," the "facts," or the "procedure" of the suggestion or of some unit of team discussion.

## Blocking Roles

**Dominator** tries to assert authority or superiority in manipulating the team or certain members of the team. This domination may take the form of flattery, of asserting a superior status or right to attention, giving directions authoritatively, interrupting the contributions of others, etc.

**Aggressor** may work in many ways: deflating the status of others, expressing disapproval of the values, acts, or feelings of others, attacking the team or the problem it is working on, joking aggressively, showing envy toward another's contribution by trying to take credit for it, etc.

**Blocker** tends to be negativistic and stubbornly resists, disagreeing and opposing without or beyond "reason" and attempting to maintain or bring back an issue after the team has rejected or bypassed it.

**Recognition-seeker** works in various ways to call attention to him- or herself, whether through boasting, reporting on personal achievements, acting in unusual ways, struggling to prevent being placed in an "inferior" position, etc.

**Anecdoter** uses the audience opportunity, which the team setting provides, to share stories or feelings unrelated to the task at hand.

**Distractor** makes display of his or her lack of involvement in the team's processes. This may take the form of cynicism, nonchalance, horseplay, and other more or less studied forms of "out-of-field" behavior.

**Help-seeker** attempts to call forth a "sympathy" response from other team members or from the whole team, whether through expressions of insecurity, personal confusion, or depreciation of him- or herself beyond "reason."

# Designing Student Team Contracts

You may find it helpful to have your students sign team contracts. Follow these guidelines to include students in developing the contracts. You can find a [sample contract here](#).

## Sample Contract Format Options

1. Give the students a nearly completed contract. Have teams fill in their task list and norms.
2. Using the guiding questions listed here facilitate a class discussion that leads to the development of a contract.
3. Give students a form with open-ended questions. Have teams fill in the form.

## Sample Guiding Questions

1. Who is on the team?
2. What will we create?
3. What is each person's task?
4. When are the items due?
5. What is each person's role within the team?
6. How will we assess our team's performance during the project?
7. What are the team norms?
8. What happens when some doesn't do their work?
9. How will we choose a leader?
10. What is the leader's role?
11. Does the leader receive additional points for playing that role?
12. Is there a reward for doing your share of the work?
13. Will points be deducted for being off task?

- 14.** What are the expectations regarding task completion?
- 15.** What happens if I don't do the work on time?
- 16.** What happens if I'm absent?
- 17.** Can a student elect to work alone? If so, what is his or her responsibility?
- 18.** How will the team handle problems within the team?
- 19.** Can a member request team counseling?
- 20.** What happens when a new student joins the team when the project is in progress?
- 21.** How will we be graded?

# Student Contract Sample

Members:

Project:

## Task List

Using the task list, assign all work to individual team members. An assignment may be assigned to more than one team member.

## Team Constitution

### Foreword

This contract is a binding document and governs the team until the assigned project deadline. If the team separates, or a member is fired, the basic contract laws remain intact for both parties. However, being fired may cause work responsibilities to shift.

#### Article I: Absence Policy

- a. If a team member will be absent on a day in which work is due, he or she must tell another team member a day in advance and have all work that he or she is responsible for turned in. All team members must stick to the provided agenda to have the assignments completed on time. If there will be an unexpected absence, the team member is to complete the work from home and email another team member to let them know he or she is gone for the day.
- b. Team members will contact one another if they are absent for any amount of period during the time allotted for working on the projects.
- c. Contact must be made by phone, email, or other acceptable method.

#### Article II: Work Policy

- a. Any member that is mentally or physically disabled and can prove that they cannot complete the work assigned to him or her alone may acquire assistance from other team members to help complete it. This will only apply for work that is team work and not individual work, and work will only be finished by that team member; the assisting team member will not write it.

- b. Each team member will work to the best of his or her ability, making sure to complete the work is up to standard, and that her or she completes it with punctuality.
- c. If a team member commits plagiarism, he or she is solely responsible and will incur the punishment on his or her own.

#### Article III: Leadership

a. At the beginning of the project, a leader will be voted upon democratically. If a team member is absent at the time of voting, he or she waives his or her right to participate in voting. The member who wins the most votes becomes the leader. If there is an unclear outcome (same number of votes for different members), the team will have no leader until one can be chosen by a revote.

b. By being elected leader, the member must perform the following duties:

- Organize team meetings.
- Create and enforce a team agenda to govern team progress.
- Organize any out-of-school project efforts.
- Provide communication between team members in order to help them work toward the project goal.

c. If the team leader fails to perform these duties, or another member is also carrying them out, a revote may be taken to determine whether to obtain a new leader.

#### Article IV: Work Ethics

a. If a team member does not complete work he or she was assigned, the punishment for the infringement will be of detriment solely to the team member at fault. No negative grading shall be given to any other team members.

b. At the end of the project, 'hard workers' will be designated by means of a democratic vote. The people voted as the top two will each receive ten bonus points. If one candidate is voted as hard worker by a margin of 75%, he or she will receive 20 points. If there is a tie, the team will discuss and come to resolution or else no points will be granted to the disputed members.

#### Article V: Member Dismissal

a. The following conducts will result in a team member being able to be dismissed;

- Incomplete or missing team work (This is non-negotiable and will be enforced by the teacher.)
- Plagiarism or any form of cheating
- If a team member decides to leave under his or her own will

b. Any team member leaving under his or her own will be able to submit all his or her own work, while the other team members may not. Any team member fired for breaking any of the conducts under Article V-a will have his or her work taken from his or her possession to be used at the discretion of the original team, but not for the member being fired. In addition, any fired member may not use any work completed by other team members, subject to punishment under Article II-c.

c. If a team member leaves under the stipulation of Article V-a, he or she retains all the work he or she has already provided for the team. The original team cannot use this work or it is subject to punishment under Article II-c.

#### Article VI: Signature

By signing this contract, the following team members abide to the articles listed here. If any member fails to abide by the articles of this contract, he or she may be fired from the team given at least a 50% vote in favor of firing the member.

#### Project Leader

The team has elected \_\_\_\_\_ as the project leader under Article III.

#### Signature

## Rules for High Performance Collaboration

1. Each team member is responsible for his or her own behavior and learning.
2. Each team member should be willing to help any other team member who asks for help.
3. You can only ask me for help when all members of the team have the same question.
4. It is critical to work, think about, and engage in the work that you are asked to do. Any time that you think your team is done with the task you were asked to do, immediately find me wherever I am in the classroom and send a member of your team over to tell me that you think you are done with the task. I will come over and confirm that you have completed it.
5. You will often be asked to work quietly by yourself on a problem in preparation for working with your team. This is so that you can develop confidence in your ability to tackle problems alone. Whenever possible, this will be followed by an opportunity to share your work with your teammates and to get help from them where you need it.

Words we can use to make sure everyone on our team feels valued and involved:

- “Can we make a plan so everybody has something to do?”
- “\_\_\_\_\_ has a good idea.”
- “What do you think, \_\_\_\_\_?”
- “Does everybody agree with that?”
- “\_\_\_\_\_, we need your help.”
- “I don’t think we heard \_\_\_\_\_’s idea.”

**General Hint: How you try to say something is every bit important as what you say. Did you say it with a smile?**

# Team Building Exercises

## Puzzle

Give each member of a 4-person team roughly a fourth of the pieces of a 100 piece puzzle. When you divide the puzzle up, state firmly “this is yours, this is yours....etc.”

The objective: Complete the puzzle.

The parameters: 1. No talking. 2. No taking. If students want you to explain, don't. Only restate: No talking, no taking.

This exercise takes between 20 and 40 minutes.

## Sarong

Place a sarong on the ground strategically next to a chair and/or a table. Ask 4 to 6 students to stand on the sarong.

The objective: Flip a sarong over completely.

The parameters: No using your hands, no touching the floor. I model this by placing my hands behind my back or in my pockets. If students want you to explain, don't. Only restate: No using your hands, no touching the floor. Students will begin to “think outside the box” and “take risks” like standing on the table or sitting on each other's laps...etc. You can discuss the importance of this later.

## Comic Strip

Find a 4-section comic strip, print it out, black out all of the dialog and cut each segment apart from the others. Give one segment to each student in a team of four. They are only allowed to see their segment. The four students have to communicate descriptively to determine the order of the comic strip and the storyline without showing each other their respective segments. They must reach consensus. The exercise is not about getting the correct answer but about communicating descriptively, listening actively, and reaching agreement. At the end, they tell their version of the story and the order and then lay them down. It helps to select a comic strip that has multiple characters or at least one change of scene.

Once you rotate all participants through 2 to 3 activities, you prompt reflection saying, “you had to think critically, you had to problem solve, you had to work around parameters and limits, you had to think strategically, and you had to collaborate to complete these activities. What did collaboration in your team look like, sound like,

and feel like?" They reflect together and then after about 5 to 10 minutes, you pull the team back together to share out. You synthesize what is said and write it down. Here is the tricky part; you have to deliberately change the grammar before you write it on the chart paper so that it will be correct after the words "we will" (which are not yet present). The participants won't realize this until after you have scribed the entire list and you write the words "we will..." at the top and demonstrate that we can replicate this in the classroom as a way of cultivating student-driven, student-experienced collaboration norms. I have seen teachers hold discussions with students to create student-driven collaboration norms. This is good (and better than many classrooms), but using team-builders is even better because students identify the behaviors from this experience not from a concept of what one "should do" in school.

### **Helium Stick**

This is a simple exercise in teamwork. Have the students form two lines, facing each other, and point their index fingers and hold their arms out. Lay a long, thin, lightweight rod on the team's fingers. The students must lower the stick to the ground—easier said than done!

The objective: Lower the stick to the ground.

The parameters: All the students' fingers must be in contact with the stick at all times. Students may not pinch or grab the stick.

**This exercise takes approximately 20 minutes, including set up and discussion.**

### **Toxic Waste**

This exercise works best for more established teams, not newly formed ones. The setup and instructions are quite detailed, so refer to the [link](#) for complete information.

The objective: Teams must figure out how to transfer a bucket of "toxic waste" to a "neutralization" bucket.

The parameters: Teams must figure out how to move the waste safely while avoiding spillage and radiation zones.

This exercise takes about 30 to 45 minutes.

### **Mine Field**

This exercise requires pair work. One team member is blindfolded and the other team member must successfully guide his or her partner through a “mine field” using only verbal instruction.

The objective: To safely guide a team member through a mine field.

The parameters: The walking member must remain blindfolded.

This exercise takes up to an hour including set up and debrief.

### **Pipeline**

This exercise is fast paced and requires both problem solving skills and strong communication skills among team members.

The objective: To maneuver a marble from one end of pipe to another.

The parameters: Each team member only has a short piece of pipe. Other rules can include members being required to carry the marble at least once, or in different orders, or members must have both feed on the floor at all times.

This exercise takes about 30 minutes.

### **Keypunch**

This exercise is not only about completion, but improvement. Working together, the team tries to better their timing as they complete the task. See the [link](#) for full details on setup and instruction.

The objective: In sequence, team members must touch randomly placed numbers within a set time frame.

The parameters: The randomly placed numbers are not clearly visible to the team. Within five attempts, the team must complete the task or improve on their time if they have solved the challenge.

This exercise takes about 40 minutes.

### **Great Egg Drop**

This small team exercise is one that has been used widely. It is especially good for teaching project management.

The objective: To drop an egg from 8 feet high without breaking it.

The parameters: Teams can use any materials to build their container.

This exercise takes about 2 hours from start to finish.

You can find some of these and several other teambuilding exercises [here](#).

## Communication Worksheet

### *Combining “I Feel” Statements and Positive Requests*

*To encourage teams to work effectively together, pose these questions to students and have them discuss outcomes. How would they solve these interpersonal issues?*

1. One member in your group is doing all the building on the project. Every time you try to make a suggestion, you are ignored. When you pick something up to try to help, it is taken away from you.
2. One member of your group has been wandering around visiting friends while the rest of you worked on the poster for your presentation. Now just as you are about to finish, he or she bumps into your desk causing you to make an ugly mark all the way down the page.
3. There are only three people in your group. The other two are good friends but you don't know them very well. They are sitting close together and acting as if you don't exist.
4. All the other members in your group are actively discussing the questions for your activity. You would like to say something too, but every time they ask you for your opinion, they move on to someone else before you've had a chance to put your thoughts into words.
5. One member of your team always gets good grades on all of his or her regular class work, but in the group he or she never contributes. You suspect that he or she knows the way to solve the problem you're all working on.

## Conflict Resolution Speak

Most of the time when people feel hurt and become angry because of something someone else has done, they confront each other with accusations in ways that only escalate conflict. Blaming statements usually begin with “You” and focus on the other person in a highly judgmental and negative way. “I feel” statements focus on our own feelings in response to the other person’s behavior.

### **Try using this formula for phrasing “I feel” statements:**

When you... (State problem behavior)

I feel... (Express feeling)

Because... (State reasons for you feeling)

Situation #1: A member of your team interrupts you constantly when you are talking.

*“You” Statement: “You’re so rude! You never let me say anything!”*

*“I feel” Statement: “When you interrupt me, I feel really hurt because I think that what I have to say is important too.”*

Situation #2: Two members of the team are holding the instruction sheet so you can’t see what it says.

*“You” Statement: “You guys are always hogging everything!”*

*“I feel” Statement: “I feel left out when you guys have the instruction sheet between you because I can’t follow what’s going on.”*

Situation #3: A member of your team is busy throwing paper wads and talking to members of another other team.

*“You” Statement: “You’re such a goof-off. You never help.”*

*"I feel" Statement:* "When you start doing things with people in other teams, I feel really upset because we need everyone's help to get this project done on time."

### **Positive Requests**

Positive requests usually begin with "I want you to," "I would," "I'd like you to," and "I need you to."

Negative: "Stop interrupting me."

Positive and specific: "I want you to wait until I'm finished before you start talking."

Negative: "Stop hogging all the cards."

Positive and specific: "I need you to put the cards in the middle of the table so I can see them."

Negative: "Stop messing around."

Positive and specific: "I would like you to fill in the chart with the information from our notes."

# Appendix C

## Quizzes, Activities, and Visible Thinking Routines



Photos by Chris Ray

## Quiz: Points of Sail; Sail & Keel Functions

1. Points of sail are defined by the \_\_\_\_\_ of the wind coming over the boat relative to the bow.
2. A sailboat can sail directly into the wind. (True/False)
3. Basic hull types have been around for a very long time. (True/False)
4. The maximum speed of a hull that does not plane is governed by the \_\_\_\_\_, and hence proportional to the square root of its waterline length.
5. Sails work by “catching the wind” only when the boat is sailing \_\_\_\_\_.
6. The sail is a flat sheet of cloth. (True/False)
7. The sail “lifts,” or moves, toward the \_\_\_\_\_ -pressure side causing the boat to move.
8. What are the two functions of a keel?
9. The direction of the total wind-force is different from the direction in which the wind is blowing (the direction of the wind) due to \_\_\_\_\_.
10. Drag force is the component of the wind force \_\_\_\_\_ direction of the wind. Lift force is the component of the wind force \_\_\_\_\_ direction of the wind.

## Quiz: Points of Sail; Sail & Keel Functions – KEY

1. Points of sail are defined by the **angle** of the wind coming over the boat relative to the bow. Source: <http://www.schoolofsailing.net/points-of-sail.html>
2. A sailboat can sail directly into the wind. (**True/False**) Source: <http://www.schoolofsailing.net/points-of-sail.html>
3. Basic hull types have been around for a very long time. (**True/False**) Source: <http://yachtpals.com/sailing-boats-9621>
4. The maximum speed of a hull that does not plane is governed by the **length of the wave it generates**, and hence proportional to the square root of its waterline length. Source: <http://yachtpals.com/sailing-boats-9621>
5. Sails work by “catching the wind” only when the boat is sailing **downwind**. Source: <http://www.discoverboating.com/resources/article.aspx?id=252>
6. The sail is a flat sheet of cloth. (**True/False**) Source: <http://www.discoverboating.com/resources/article.aspx?id=252>
7. The sail “lifts,” or moves, toward the **lower**-pressure side causing the boat to move. Source: <http://www.discoverboating.com/resources/article.aspx?id=252>
8. What are the two functions of a keel? **Answer: It prevents the boat from being blown sideways by the wind, and it holds the ballast that keeps the boat right-side up.** Source: <http://www.discoverboating.com/resources/article.aspx?id=251>
9. The direction of the total wind-force is different from the direction in which the wind is blowing (the direction of the wind) due to **lift**. Source: [http://www.physicsforarchitects.com/Sailing\\_against\\_the\\_wind.php](http://www.physicsforarchitects.com/Sailing_against_the_wind.php)
10. Drag force is the component of the wind force **in the same** direction of the wind. Lift force is the component of the wind force **ninety degrees to the** direction of the wind. Source: [http://www.physicsforarchitects.com/Sailing\\_against\\_the\\_wind.php](http://www.physicsforarchitects.com/Sailing_against_the_wind.php)

## Physics of Sailing – Newton’s Laws

1. Forces that cancel each other are called \_\_\_\_\_ forces.
  - a. inactivated
  - b. neutral
  - c. null
  - d. balanced
2. Which of the following is the correct definition for the term inertia?
  - a. an unbalanced force that opposes motion between two surfaces
  - b. a change in the speed or direction of motion
  - c. an objects tendency to resist a change in motion
3. A change in motion is described by \_\_\_\_\_.
  - a. inertia
  - b. speed
  - c. net force
  - d. acceleration
4. The two forces of a force pair are called the \_\_\_\_\_ force and the \_\_\_\_\_ force.
  - a. action, reaction
  - b. mass, acceleration
  - c. increasing, decreasing
5. Which law relates acceleration to mass?
  - a. First
  - b. Second
  - c. Third
  - d. none of these
6. A(n) \_\_\_\_\_ is a push or a pull.
  - a. acceleration
  - b. force
  - c. motion
  - d. velocity

7. Acceleration depends on what two things?
- force and weight
  - force and mass
  - force and friction
  - mass and weight
8. Friction always acts \_\_\_\_\_ the direction of motion of an object.
- opposite to
  - in the same direction as
  - perpendicular to
9. Which one of Newton's Laws fits this statement: More mass means more force needed to accelerate?
- Law Three
  - Law Two
  - None of these
  - Law One
10. Which of the following terms correctly matches this definition: occurs when the net force of the object does not equal zero.
- balanced force
  - unbalanced force
  - acceleration
11. Which one of Newton's Laws fits this statement: When you push one object, it pushes back?
- Law One
  - Law Three
  - Law Two
  - None of these

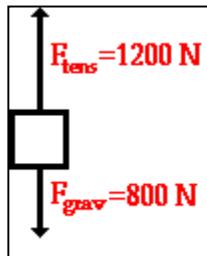
12. A book is at rest on a tabletop. Diagram the forces acting on the book.

13. An egg is free-falling from a nest in a tree. Neglect air resistance. Diagram the forces acting on the egg as it is falling.

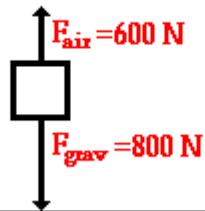
14. A rightward force is applied to a book in order to move it across a desk with a rightward acceleration. Consider frictional forces. Neglect air resistance. Diagram the forces acting on the book.

15. Which of the following force diagrams illustrate an unbalanced force acting on an object?

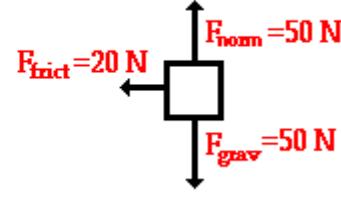
A



B



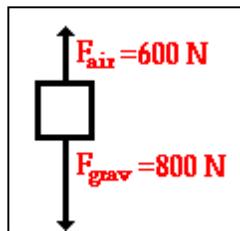
C



- a. A only

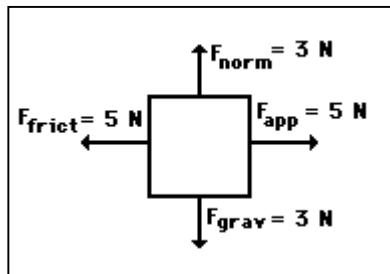
- b. B only
- c. A & B only
- d. A, B, & C

16. Determine the net force acting on the object below.



- a. 600 N up
- b. 200 N up
- c. 200 N down
- d. 1400 N

17. Determine the net force acting upon the object below.



Net force =

### **Physics of Sailing – Newton’s Laws KEY**

1. Forces that cancel each other are called \_\_\_\_\_ forces.
  - a. inactivated
  - b. neutral
  - c. null
  - d. balanced
  
2. Which of the following is the correct definition for the term inertia?
  - a. an unbalanced force that opposes motion between two surfaces
  - b. a change in the speed or direction of motion
  - c. an objects tendency to resist a change in motion
  
3. A change in motion is described by \_\_\_\_\_.
  - a. inertia
  - b. speed
  - c. net force
  - d. acceleration
  
4. The two forces of a force pair are called the \_\_\_\_\_ force and the \_\_\_\_\_ force.
  - a. action, reaction
  - b. mass, acceleration
  - c. increasing, decreasing
  
5. Which law relates acceleration to mass?
  - a. First
  - b. Second
  - c. Third

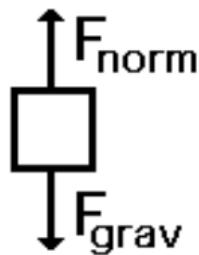
- d. none of these
6. A(n) \_\_\_\_\_ is a push or a pull.
- a. acceleration
  - b. force
  - c. motion
  - d. velocity
7. Acceleration depends on what two things?
- a. force and weight
  - b. force and mass
  - c. force and friction
  - d. mass and weight
8. Friction always acts \_\_\_\_\_ the direction of motion of an object.
- a. opposite to
  - b. in the same direction as
  - c. perpendicular to
9. Which one of Newton's Laws fits this statement: More mass means more force needed to accelerate?
- a. Law Three
  - b. Law Two
  - c. None of these
  - d. Law One
10. Which of the following terms correctly matches this definition: occurs when the net force of the object does not equal zero.
- a. balanced force

- b. unbalanced force
- c. acceleration

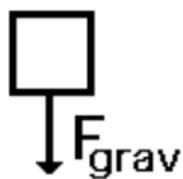
11. Which one of Newton's Laws fits this statement: When you push one object, it pushes back?

- a. Law One
- b. Law Three
- c. Law Two
- d. None of these

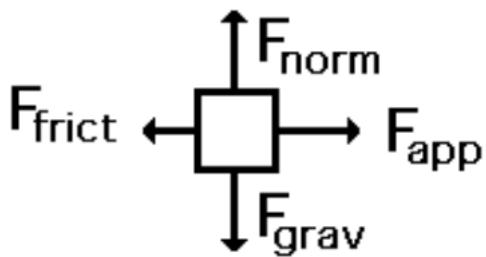
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13. An egg is free-falling from a nest in a tree. Neglect air resistance. Diagram the forces acting on the egg as it is falling.

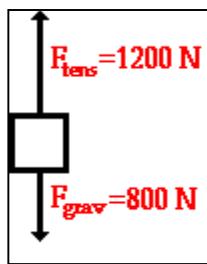


14. A rightward force is applied to a book in order to move it across a desk with a rightward acceleration. Consider frictional forces. Neglect air resistance. Diagram the forces acting on the book.

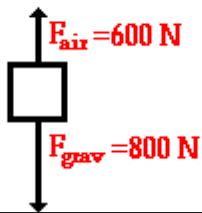


15. Which of the following force diagrams illustrate an unbalanced force acting on an object?

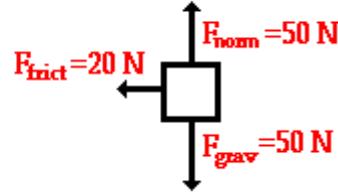
A



B

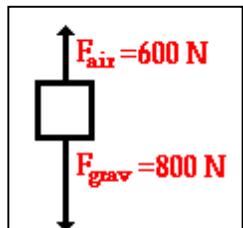


C



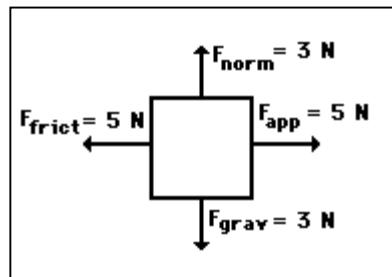
- a. A only
- b. B only
- c. A & B only
- d. A, B, & C

16. Determine the net force acting on the object below.



- a. 600 N up
- b. 200 N up
- c. 200 N down
- d. 1400 N

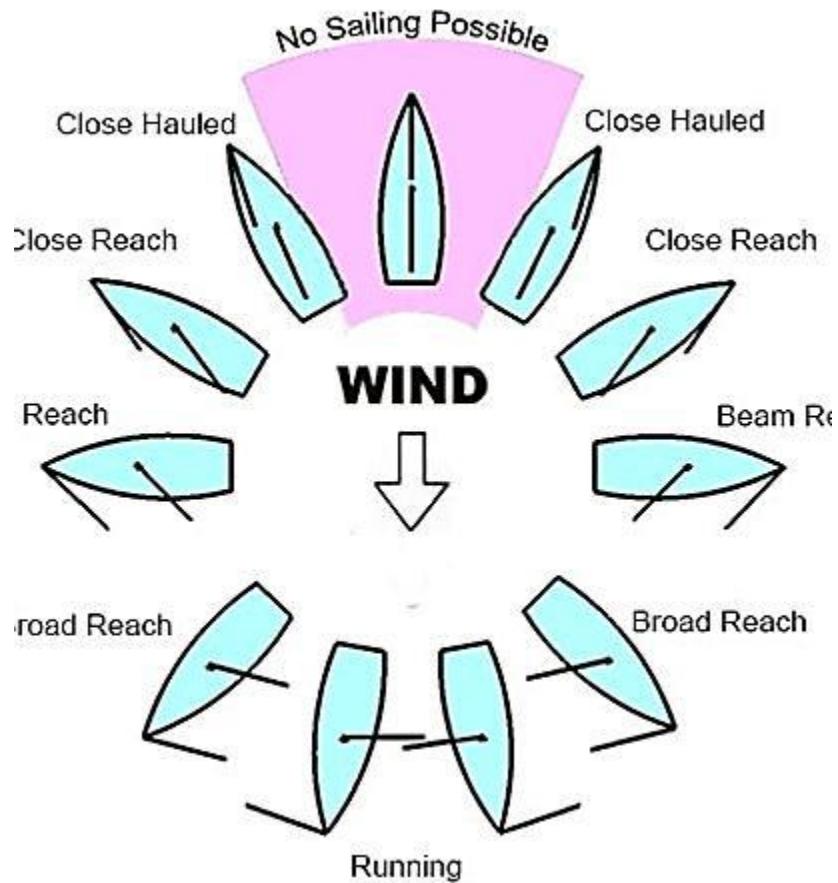
17. Determine the net force acting upon the object below.



Net force = 0 N

## Points of Sail Activity

Correctly label the points of sail with the name and relative clock bearing of the wind.



A: \_\_\_\_\_

B: \_\_\_\_\_

C: \_\_\_\_\_

D: \_\_\_\_\_

E: \_\_\_\_\_

F: \_\_\_\_\_

G: \_\_\_\_\_

H: \_\_\_\_\_

I: \_\_\_\_\_

## Points of Sail Activity – KEY

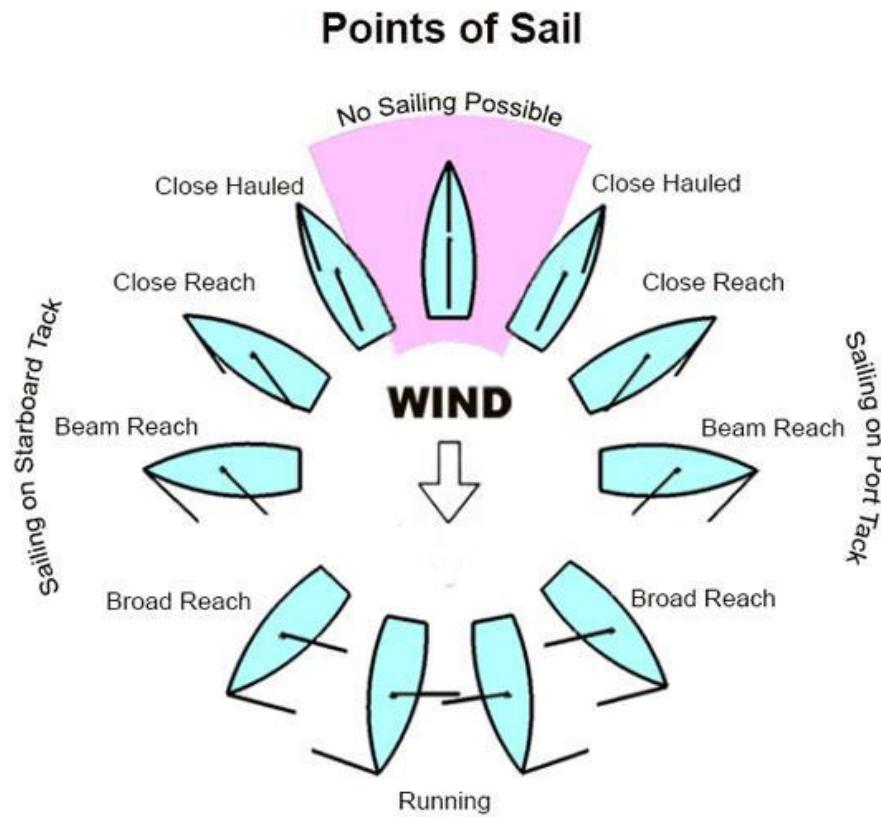


Illustration by SchoolofSailing.net

- A: Close Hauled 1 o'clock
- B: Close Reach 2 o'clock
- C: Beam Reach 3 o'clock
- D: Broad Reach 4 o'clock
- E: Running 6 o'clock
- F: Broad Reach 8 o'clock
- G: Beam Reach 9 o'clock
- H: Close Reach 10 o'clock
- I: Close Hauled 11 o'clock

*Image Source: <http://www.schoolofsailing.net/points-of-sail.html>*

# In-depth Critique Protocol

## Ron Berger In-Depth Critique Protocol

**Purpose:** The purpose of the critique is to teach particular skills to students. It is not for the whole class to give one student feedback on their work.

### Critique rules:

- Be kind
- Be specific
- Be helpful

### The protocol:

1. The lesson: The teacher needs to think about what lesson he/she is trying to teach his/her students. After looking at a draft of student work, what is the big idea that students are missing? What is troubling about the work? What's the next step that many of the students are ready to take? It is helpful if the teacher has a list of 3-6 skills that the teacher wants the students to get better at.
2. Selecting the work: It is most important to find examples of student work that are great examples of what the teacher is looking for from the students, or else great examples of exactly not what the teacher is looking for. Looking at merely mediocre work will not lead to helpful discussion.
3. The critique:
  - a. Students are given one or two pieces of student work for in-depth critique. Examples include excerpts from student writing, architectural blueprints, solutions to math problems, lab write-ups, etc.
  - b. Students are given time to look silently at the work and think about what makes the work beautiful or where does it fall short.
  - c. Depending on age level, students could be given time to discuss this in small groups.
  - d. The teacher now leads a group conversation about the work. The goal of the conversation is to identify the attributes of great student work for this particular assignment. Once those attributes are *identified*, they need to be *named* in simple kid language so that they can be *used* by kids. The teacher works to lead students to the 3-6 skills identified in advance, keeping in mind that students may think of other useful skills that can be named.
4. Next draft: Students now create a new draft of this assignment, incorporating the skills identified during the critique session. It is helpful if students know in advance that a particular assignment is going to be completed in (say) three drafts. It is helpful if each draft is somewhat different from the one that came before it to avoid student burnout on a particular draft. For example, students could graduate to making an architectural drawing on a nicer type of paper with each succeeding draft. Or the first draft could be a rough sketch of a storyboard. The next draft could be a detailed sketch of the storyboard. The next draft could be a professional quality storyboard using materials used by professionals in the field.

“Students will say that this piece of writing is good because Suzy is a good writer. Teachers need to help students name what is good about Suzy’s writing, because once we name it, then we can use it.”

- Ron Berger

### Notes:

- If using an example of bad work, it is important to use work done by a student who your students don't know.

## Visible Thinking Routines

The [Visible Thinking](#) website is an excellent way to learn about Visible Thinking and how it can become routine in the classroom.

You are encouraged to visit all areas of the site, including

[Visible Thinking in Action](#)

[Getting Started](#)

[Thinking Routines](#) (some projects will reference specific routines from this part of the site; links are included in the Suggested Pacing Guide)

[Thinking Ideals](#)

[School Wide Culture of Thinking](#)

## Images

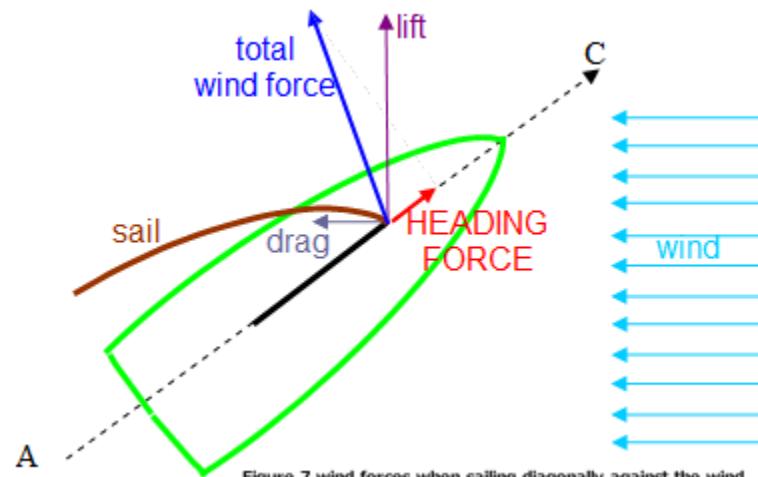


Figure 7 wind forces when sailing diagonally against the wind



## HORIZONTAL FORCES

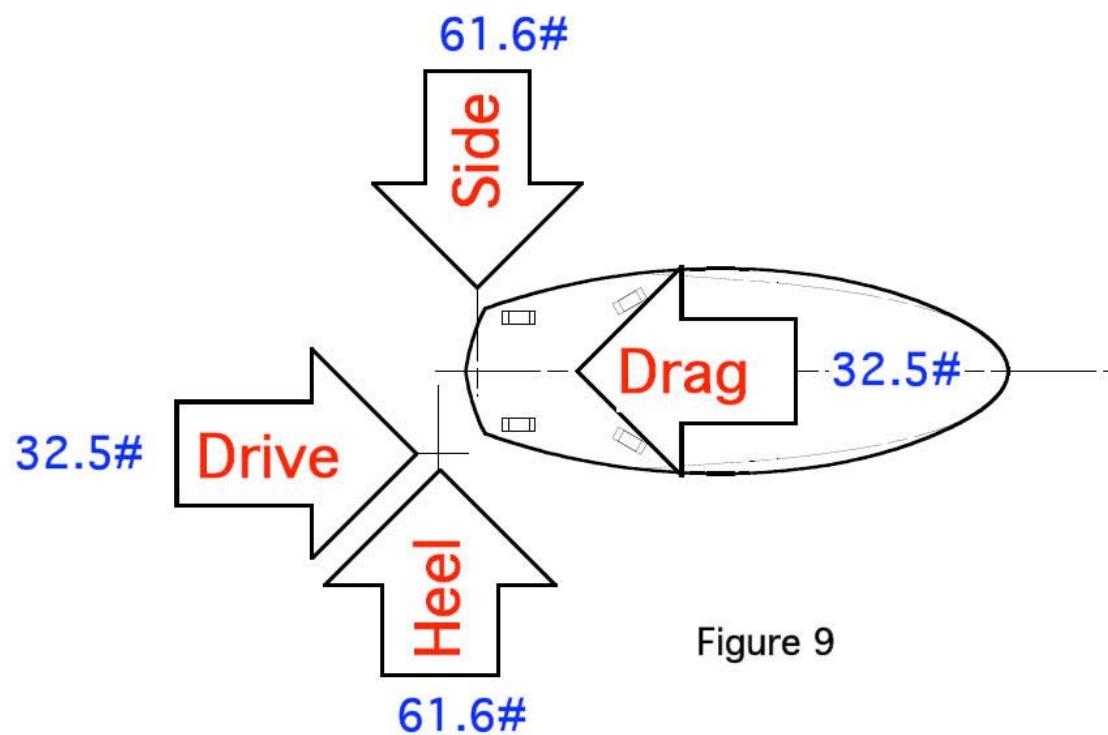


Figure 9

# Appendix D

## Assessment, Protocol for Refining the Driving Question



Photos by Chris Ray

## Overview of Assessment

Both project-based learning (PBL) and the Common Core State Standards (CCSS) assume that teachers will use multiple assessments, including tests and performance rubrics. You may choose your own assessments, but this project includes built-in assessments, including links to the Khan Academy Physics assessments and other resources.

The Physics of Sailing project is designed to teach and assess 21st century skills, Newton's Laws, vocabulary, and the design process. The Project Rubric is the primary assessment tool for these purposes, as well as tests and quizzes scattered throughout the project.

Teachers may also choose to use the Teamwork Rubric or the Presentation and Performance Rubric to assess these skills separately. In addition, a Mathematical Practices Rubric is included if teachers wish to focus on the mathematics behind Newton's Laws.

A further option is to incorporate Critical Thinking and Creativity sections of the rubrics into the assessment.

### **Using the Project Rubric versus Individual Skills Rubrics**

Use of these options will vary with the class, student capability, and conditions for the project. The individual rubrics (Mathematical Practices, Teamwork, Presentation and Performance) and the Project Rubric can be used separately or in tandem. This may vary with the project and time of year. For example, early in the academic year, you may wish to use the Teamwork or Presentation Rubric separately as a method for training students on a detailed performance rubric. Later in the year, the Project Rubric, which condenses the individual rubrics and provides a holistic assessment of the overall project, may be more appropriate. It will be helpful to review all rubrics before starting the project to find the best combination for your students.

### **The Mathematical Practices Rubric**

The Mathematical Practices Rubric measures the eight mathematical practices that accompany the Common Core State content standards. Use of the rubric is included in the Suggested Pacing Guide. If you use this rubric, it will be helpful to highlight the Mathematical Practices Rubric early in the course and before the project begins.

## **Encouraging Critical Thinking and Creativity**

With the exception of the Mathematical Practices Rubric, all the rubrics for this project contain a Breakthrough option. This is designed to capture exceptional performance, unusual insights, or creative thinking. It is not the 'A' part of the rubric; it signifies that the student has gone beyond the standards and achieved an unexpected result.

## **Grading and Rubrics**

An important note about grading: Below each element and section of the rubrics, you can locate a point scale that allows you to transfer the rubric evaluations into a point-based grade book. Since grading varies among teachers, the suggested point scales can be modified to meet your classroom, school, or project guidelines.

## **Using Additional Rubrics**

You may also choose to use your own existing rubrics, develop additional assessments, or change the rubric language. Students can also help design or modify the language to help evaluate the presentation.

## Protocol for Refining the Driving Question

The suggested Driving Question for this project is: How can we apply our knowledge of Newton's Laws and sailboat design to design a racing sailboat?

The Driving Question can be modified, based on teacher preference or student input. If you choose to modify the Driving Question, please keep these guidelines in mind. It is important that the Driving Question capture the question or the problem to be solved that lies at the heart of the project.

1. Can my students read and comprehend the Driving Question (DQ)? Or will it be fun for them to have some need-to-know words in the DQ?
2. Is the DQ open-ended or can it be answered with a yes or no?
3. Would the DQ benefit from a local context to either narrow the scope, or increase the scope, and most importantly to allow interaction with local adults and to have power over their local environment? (How can we change the district lunch menu so that it is more nutritious and more appealing?)
4. Does the DQ offer opportunities for students to express voice and choice?
5. Does the DQ ask students to engage in an inquiry that is both rigorous (challenging and full of critical thinking opportunities) and relevant?
6. Does the DQ sound like a traditional teacher/academic question, or does it sound like something exciting and different?
7. Does the DQ show that the students will be doing something relevant and exciting to them (that some might do even if it wasn't required), or are they just going to be doing it for the teacher?
8. Does the DQ allow me to design both individual and collaborative learning tasks that require higher-level thinking skills, or is it make a list and collect some facts?
9. Does the DQ require students to learn new skills and knowledge and to demonstrate higher-level understandings or applications?
10. Does the DQ encourage students to perform tasks and applications that adults would possibly do? Can it result in an action plan presented to outside adults?

11. Will the DQ benefit from referring to the future to make it more open-ended?  
(How do we build a school in the parking lot in the year 2050?)
12. Should I change the implied audience in the question to increase the challenge? (How do we write a book on global warming for 4th graders?)
13. Should I go up or down the Concentric Circles of Scope (see below)?
14. If I think what the ideal student team would be working on and wrestling with three-quarters of the way through the project (to focus what I am most passionate about in this project), can I change the DQ to more directly get all students to that place?
15. Does the DQ allow students to have experiences that will help them determine their proclivities and interests for certain careers versus other careers?