Teacher Toolkit - Vectors: Properties and Operations

Objectives:

1. To understand that a vector is a quantity that has a magnitude and direction and be able to graphically represent a vector using a scaled diagram and the counter-clockwise from east convention of direction.
2. To add vectors using a head-to-tail addition method and a scaled vector addition diagram and be able to identify the magnitude and direction of the resultant.
3. To add right-angle vectors, using the Pythagorean theorem to determine the resultant magnitude and trigonometric functions to determine the resultant direction.
4. To resolve vectors into components and to use the component method in order to add two or more non-perpendicular vectors in order to determine the resultant.
5. To understand that perpendicular components of motion are independent of each other and to use such an understanding to solve relative velocity problems such as riverboat problems.

Readings: The Physics Classroom Tutorial, Motion and Forces in Two Dimensions Chapter, Lesson 1

Interactive Simulations:

1. Vector Addition w/Integer Components http://physics.bu.edu/~duffy/Ejs/EP_chapter01/vector_addition_sim3_v2.html
   From Boston University EJS, this is a good choice to give beginners practice in 2D vector addition. It's relatively simple, as the x and y components of each vector are integers.
2. Vector Addition and Pattern http://physics.bu.edu/~duffy/Ejs/EP_chapter01/vector_addition_sim2_v4.html
   Also from Boston University EJS, students will have fun with this simulation, which illustrates the tip-to-tail method of adding vectors. As students adjust lengths and angles of two vectors, the resultant vector and components are displayed. B
3. Boston University EJS - Vector Addition http://physics.bu.edu/~duffy/Ejs/EP_chapter01/vector_addition_sim4_v4.html
   Students who have mastered vector addition with integers can move up to this simulation, which introduces vectors with non-integer lengths.
4. PhET Simulation: Vector Addition http://phet.colorado.edu/en/simulation/vector-addition
   This interactive model lets students drag vectors onto a grid, change their length and angle, and sum them together. The magnitude, angle, and x/y components of each vector are automatically displayed in several formats. A student guide is included: http://phet.colorado.edu/en/contributions/view/3140
5. The Riverboat Simulator http://www.physicsclassroom.com/shwave/rboat.cfm
   From TPC's Shockwave Physics Studios, the user varies the speed and direction of a boat crossing a river and the river speed and width to explore the effect of a variable on the time to cross the river and the distance traveled *downstream*. Comes with activity sheet: http://www.physicsclassroom.com/shwave/rboatdirns.cfm

Video and Animation:

1. Vector Decomposition http://www.compadre.org/Physlets/mechanics/illustration3_1.cfm
   This simple applet from Physlet Physics lets you drag a single vector around the coordinate grid. It displays changing values of x and y components, magnitude, and direction as the vector moves.
2. Vector Calculator http://comp.uark.edu/~jgeabana/java/VectorCalc.html
   This tool displays a coordinate plane with a grid of 10 square units. Click anywhere in the grid to create a blue vector, then click again to create a red vector. From University of Arkansas Physics Department.
3. Addition of Displacement Vectors http://www.compadre.org/Physlets/mechanics/ex3_1.cfm
   This animated problem starts with a red dot representing an airplane that ascends for 8 seconds at take-off. The task is to drag a second vector with a given displacement, then draw the resultant vector.
4. How to Find the Resultant of Three or More Vectors https://www.youtube.com/watch?v=g_TnqKX5ybY
   This 15-minutevideo provides a very, very thorough explanation of how to find the resultant of 3 vectors – both graphically and algebraically. Could work well as part of a flipped lesson.
5. Pythagorean Theorem Animation http://www.grc.nasa.gov/WWW/K-12/airplane/pythag.html
   Sometimes it helps beginners to explore how a geometric proof was constructed. This animation from NASA uses geometric overlays to show why the Pythagorean Theorem works. Background information on the Theorem and its historical use is included.

This is the *To Go* version of the Teacher Toolkit; it is an abbreviated version of the online Toolkit.

Labs and Investigations: http://www.physicsclassroom.com/lab#vp

1. The Physics Classroom, The Laboratory, Map Lab
2. The Physics Classroom, The Laboratory, As the Crow Flies Lab
3. The Physics Classroom, The Laboratory, Where Am I? Lab
4. The Physics Classroom, The Laboratory, Road Trip Lab
5. The Physics Classroom, The Laboratory, Crossing the River Lab

Demonstration Ideas:

1. Adding Two Vectors http://faraday.physics.utoronto.ca/PVB/Harrison/Flash/Vectors/Add2Vectors.html
   This simple but elegant simulation illustrates the commutative property of vector addition.
2. University of Calgary Physics: Vector Animations http://canu.ucalgary.ca/map/content/vectors/
   This collection offers a treasure trove of animated exercises. It is organized in modular format consisting of interactive models, explanations, and sample assessments.
3. Vectors for Physics and Calculus Students http://www.mac3.matyc.org/vectors/vectors_main.html
   This resource is the brainchild of a collaboration of physics and mathematics instructors who aim to tackle "the problem" of a lack of cohesion between how vector operations are taught in physics vs. mathematics courses.

Minds On Physics Internet Modules: http://www.physicsclassroom.com/mop

The Minds On Physics Internet Modules are interactive questioning modules that target conceptual understanding. Each question is accompanied by detailed help that addresses the various components of the question.

Ass't VP1 - Direction of Vectors
Ass't VP2 - Vector Addition Diagrams
Ass't VP3 - Vector Addition Applications
Ass't VP4 - Adding Right Angle Vectors
Ass't VP5 - Vector Components
Ass't VP6 - Velocity and River Boats

Concept Building Exercises:

The Curriculum Corner, Vectors and Projectiles http://www.physicsclassroom.com/curriculum/vectors

1. Vector Representation
2. Addition of Vectors
3. Vector Resolution and Vector Addition
4. Vector Addition by Components
5. Relative Velocity - Riverboat Problems

Problem-Solving Exercises: http://www.physicsclassroom.com/calcpad/vecproj

1. The Calculator Pad, Vectors and Projectiles, Problems #1 - #20

Real Life Connections: **(See Complete Toolkit at TPC's Teacher Toolkit website for full description.)**

1. CIESE Real-Time Data Project: Navigational Vectors http://ciese.org/curriculum/vectorproj/
2. NASA Dryden Flight Research Center: Space Vectors http://www.nasa.gov/pdf/740534main_Precal-ED_Space%20Vectors.pdf

Common Misconceptions **(See Complete Toolkit at TPC's Teacher Toolkit website for full description.)**

Physics Education Research **(Full descriptions in the Complete Toolkit at TPC's Teacher Toolkit website)**

1. University of Monterrey PER Group http://www.compadre.org/PER/document/ServeFile.cfm?ID=13098&DocID=3633
2. PER Conference Proceedings http://www.thephysicsfront.org/filingcabinet/share.cfm?UID=3404&FID=37538&code=3B9D7499DA
3. PER Examples: Vector Subtraction http://research.physics.illinois.edu/per/IE/ie.pl?phys101/ie/01/vectors#waypoint

Standards:

A. Next Generation Science Standards (NGSS) – Grades 9-12
Crosscutting Concepts: Scale, Proportion, and Quantity
Science and Engineering Practices: #2, #3, #4, #5, #8

B. Common Core Standards for Mathematics (CC) – Grades 9-12
Standards for Mathematical Practice: MP.2, MP.3, MP.6
High School Algebra: Seeing Structure in Expressions, Creating Equations
High School Functions: Interpreting Functions, Building Functions, Linear, Quadratic, and Exponential Models, Trigonometric Functions

C. Common Core Standards for English/Language Arts (ELA) – Grades 9-12
Reading Stds: Science and Technical Subjects – Key Ideas and Details (RST.11-12.2 and RST.11-12.3)
Science and Technical Subjects – Integration of Knowledge and Ideas (RST.11-12.9)
Science and Technical Subjects – Range of Reading and Level of Text Complexity (RST.11-12.10)