

Teacher Toolkit

Topic:

Forces in Two Dimensions

Objectives:

1. To use vector concepts to add force vectors and determine the resultant or net force.
2. To use vector concepts to determine the components of a force that is directed at an angle.
3. To use Newton's laws and vector concepts to analyze objects that are at equilibrium (e.g., an object hung by two cables stretched diagonally to support points).
4. To use vector resolution and Newton's second law to determine the acceleration of an object along a level surface when a force is applied to it at an angle to the surface.
5. To use free-body diagrams and Newton's second law to analyze the motion of an object moving along an inclined plane.
6. To conduct a Newton's second law analysis of a two-body system that includes two objects connected by a rope that is stretched over a pulley (e.g., an Atwood's or modified Atwood's machine).

Readings:

The Physics Classroom Tutorial, Motion and Forces in Two-Dim. Chapter, Lesson 3

<http://www.physicsclassroom.com/class/vectors>

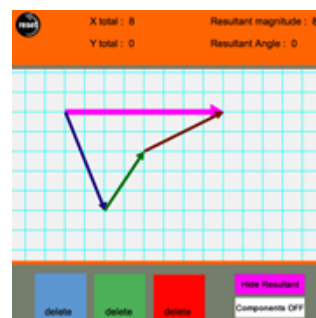
Interactive Simulations:

1. Vector Addition

Physics Interactive

<http://www.physicsclassroom.com/Physics-Interactives/Vectors-and-Projectiles/Vector-Addition/Vector-Addition-Interactive>

The Vector Addition Interactive provides learners with a tool for visualizing the addition of vectors using either the head-to-tail method or the component method. Up to three vectors can be added and the resultant is drawn. The components of each vector can be toggled on and off; the magnitudes of the components are displayed as a numerical value. The Interactive can serve as a great tool for learning how vectors add together. This HTML5 interactive works on all devices.

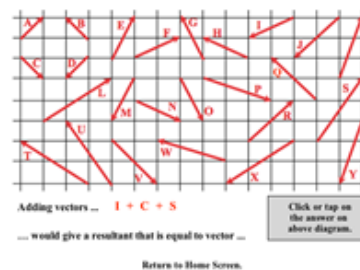


2. Name That Vector

Physics Interactive

<http://www.physicsclassroom.com/Physics-Interactives/Vectors-and-Projectiles/Name-That-Vector>

This skill-building activity presents 12 randomly-selected challenges to students. Each challenge involves the task of using components to add vectors. Vectors are presented graphically on a background grid so that the horizontal and vertical components can be easily determined. The Interactive reinforces the concept that the components of



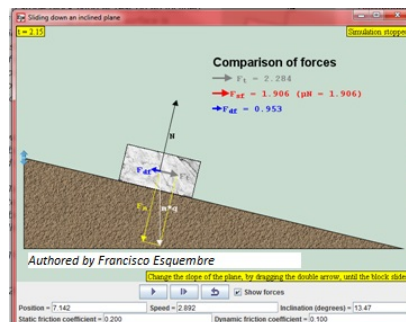
the resultant vector is the sum of the components of the individual vectors. This HTML5 Interactive works on tablets and Chromebooks; perfect for the 1:1 classroom.

3. Sliding Down an Incline Plane

Interactive Simulation

<http://www.thephysicsfront.org/items/detail.cfm?ID=9973>

This Java simulation shows a stone block lying at rest on an inclined plane. Initially, the component of gravity along the plane surface is exceeded by the force of static friction. The slope of the ramp can be increased or decreased, allowing students to see the exact point when the component of gravity equals the force of static friction. If the ramp is raised any further, the block will slide down. The coefficient of static friction is set at 0.2. As the slope is increased or decreased, students will see changing numerical values for the gravitational component, the force of static friction, and the force of kinetic friction.



4. PhET: The Ramp

Interactive Simulation

<http://phet.colorado.edu/en/simulation/the-ramp>

For teachers who want to take a deeper dive into mechanical advantage and real-life connections, "The Ramp" simulation is a good start. You can push a variety of objects up a virtual ramp: a file cabinet, refrigerator, piano, crate, or a sleepy dog! Set the coefficient of friction, set the ramp angle from 1-90 degrees, and change the applied force from 0-3000 Newtons. This gives the simulation powerful flexibility. And if that's not enough ... students can view related free-body diagrams and graphs of energy and forces.



For a turn-key activity to accompany this simulation, try [The Ramp Student Guide](#). Developed by a high school teacher, this lesson is simple enough to be completed without extensive prior knowledge. It will keep beginners on task as they tackle the multiple elements of this simulation. It asks probing questions about the nature of the forces at play when objects move on an inclined plane.

For a more in-depth lesson that introduces calculation of the ideal and actual mechanical advantage of the inclined plane, click here: ["The Ramp" - Mechanical Advantage](#)

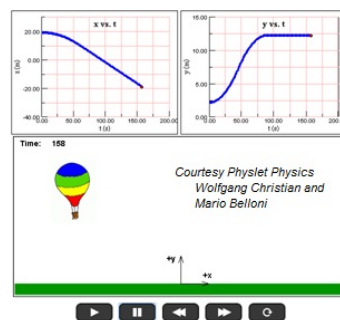
Allow 60-90 minutes

Video and Animation:

1. Physlet Physics: Two-Dimensional Kinematics

<http://www.compadre.org/Physlets/mechanics/intro3.cfm>

This Physlets chapter provides a comprehensive collection of 17 animation-based problems consisting of: 1) Illustrations, 2) Explorations (accompanied by printable worksheets), and 3) Multi-step problems. The resources vary from multiple choice format to longer exercises that require students to integrate multiple representations and solve problems. Topics include projectile motion, motion on an incline, circular motion, constant acceleration, objects in flight, and more. *Free access with attribution.*



2. PBS Learning Media: Segway Technology – What’s Newton Got to Do With It?

http://www.pbslearningmedia.org/resource/phy03_sci_phys_mfw_segway/segway-technology-whats-newton-got-to-do-with-it/

Did you know.....the Segway is described by its inventor, Dean Kamen, as an inverted pendulum system. The person driving is like the pendulum mass, oscillating back and forth over the transporter. In this 8-minute video, Kamen talks about how Newton's Laws governed the Segway design, which uses gyroscopic sensors to detect changes in the driver's center of mass. The electric engine provides the power and is remarkably economical to operate. This video could be a very engaging way to spark discussions about applied force.



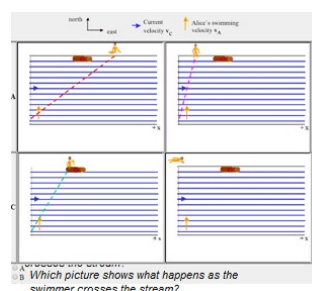
Interactive Homework Problems

If you haven't encountered physicist Gary Gladding's research-based homework problems, you're in for a great surprise! The digital problems present physical situations that are commonly experienced in life. Each problem has 3 components: conceptual analysis, strategic analysis, and calculation. As students go through the sequence, they answer multiple choice questions designed to encourage critical thinking. Immediate feedback is provided at each step. Liberal use of free-body diagrams, drawings, and graphs help the learner visualize the concepts being introduced. Even students who struggle with the content will feel comfortable with the pacing. Can be performed independently or used as a flipped lesson.

1. Illinois PER Interactive Problem: Stream Crossing

http://per.physics.illinois.edu/per/IE/ie.pl?phys111/ie/02/IE_swim_across_stream

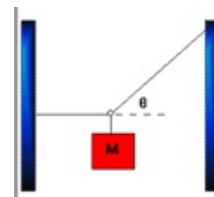
This problem presents the 2-dimensional motion situation of swimming directly across a stream that has a current speed of 10 feet/minute. It requires some thought to realize that the current is countering the motion to swim in a straight line. Once this is recognized, the author takes learners through each step of finding the x components of the two vector velocities to solve the problem.



2. Illinois PER Interactive Problem: Mass on Two Strings

http://per.physics.illinois.edu/per/IE/ie.pl?phys101/ie/04/two_strings

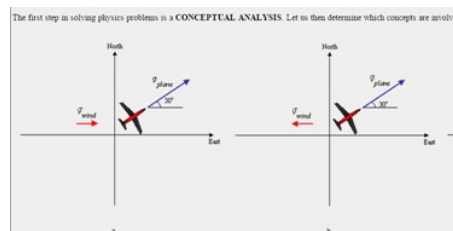
A block of known mass is suspended from two strings attached to walls. One string is horizontal; the other is at a 50-degree angle to horizontal. Students will use free-body diagrams and Newton's Laws to figure out the tension on the left string.



3. Illinois PER Interactive Problem: Plane in Flight

http://per.physics.illinois.edu/per/IE/ie.pl?phys111/ie/02/IE_plane

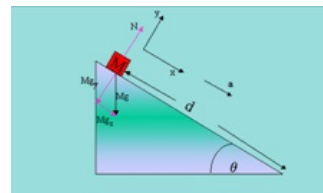
This problem presents students with an airplane just after liftoff which is traveling at a known airspeed and with a headwind of known velocity. The flight trajectory is also given. The problem: students must figure out the speed of the plane *relative to the ground*. The problem is not as easy as it first appears...both the airplane velocity and the wind velocity have x and y components. The math isn't especially difficult, but the strategy requires thought. The problem should give beginners a solid way to understand the scope of kinematics in two dimensions.



4. Illinois PER Interactive Problem: Block on Incline

http://per.physics.illinois.edu/per/IE/ie.pl?phys111/ie/03/IE_block_on_incline

In this problem, students relate Newton's Second Law and gravitational acceleration as a block slides down an incline. At first the block is at rest atop the incline. Given the angle of incline and the ramp length, learners must determine the time required for the block to reach the bottom under the force of gravity alone. (*Great problem for students who are struggling conceptually with this unit of study.*)



Labs and Investigations:

1. The Physics Classroom, The Laboratory, Getting Hung Up by Tension
Students conduct force analysis on three different objects held at static equilibrium. Vector resolution is used for each individual force to determine their components. Components are added to determine the resultant force.
2. The Physics Classroom, The Laboratory, Sign Hanging Lab
Students measure the tension force exerted upon a hanging sign in order to predict the mass of the sign.
3. The Physics Classroom, The Laboratory, Science Friction Adventure
Students measure the value of the friction coefficient for an inclined plane and compare it to the value for the maximum angle at which the plane can be inclined before an object overcomes the static friction force and slides down it.
4. The Physics Classroom, The Laboratory, Inclined Plane Lab
Students work as a class, with each lab group taking a different angle, in order to determine the ratio of the applied force required to hold a cart at rest to the weight. The ratios and angle values are used to discover the relationship between weight, angle and the parallel component of gravity.
5. The Physics Classroom, The Laboratory, On a Roll Challenge
Students combine Newton's laws and kinematics to predict the speed of a cart at the end of an inclined plane and compare the predicted value to the actual value.
6. The Physics Classroom, The Laboratory, Modified Atwood's Machine
Students explore the relationship between final velocity and the amount of hanging mass on a modified Atwood's machine.

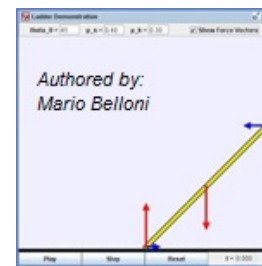
Link: <http://www.physicsclassroom.com/lab/index.html#vf>

Demonstration Ideas:

1. Ladder Demonstration Model

<http://www.thephysicsfront.org/items/detail.cfm?ID=7849>

In teaching about equilibrium, instructors may want to use bite-size pieces to slowly build concepts. This Java simulation presents the concept with very simple graphics, appropriate for introductory physics. As in the standard (textbook) statement, this problem assumes there is no frictional force between the wall and the ladder, but a frictional force between the ground and the ladder. Learners can set the lean angle of the ladder plus coefficients of static and kinetic friction between floor and ladder. *This resource goes nicely with The Physics Classroom Tutorial “Equilibrium and Statics”:*

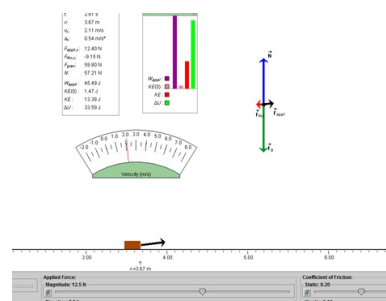


<http://www.physicsclassroom.com/class/vectors/Lesson-3/Equilibrium-and-Statics>

2. Modular Approach to Physics: Static and Kinetic Friction Interactive Simulation

<http://canu.ucalgary.ca/map/content/force/friction/simulate/horizontal/applet.html>

This simulation serves as an excellent “Demonstration” of static and kinetic friction. It has a rich set of interactive tools, but beginners will need guidance. You can set initial velocity, mass of the moving block, magnitude and direction of applied force, and coefficient of BOTH static and kinetic friction. Cool tools can be displayed (or not), including velocity meter, energy lost to friction, quantitative data, FBDs, and acceleration vectors. A very robust addition to your toolkit! *Editor’s Note: This model involves one block in one dimension, which is a good place to start an investigation of frictional forces.*



Minds On Physics Internet Modules:

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

1. Forces in Two Dimensions module, Ass’t 2D1 - Vector Analysis
2. Forces in Two Dimensions module, Ass’t 2D2 - $F_{\text{net}} = m \cdot a$ and Forces at Angles
3. Forces in Two Dimensions module, Ass’t 2D3 - Equilibrium Concepts
4. Forces in Two Dimensions module, Ass’t 2D5 - Static Equilibrium and Analysis
5. Forces in Two Dimensions module, Ass’t 2D5 - Inclined Plane Concepts
6. Forces in Two Dimensions module, Ass’t 2D6 - Incline Plane Analysis

Link: <http://www.physicsclassroom.com/mop>

Concept Building Exercises:

1. The Curriculum Corner, Forces in Two Dimensions, Another Angle on F-m-a
2. The Curriculum Corner, Forces in Two Dimensions, Adding and Resolving Forces
3. The Curriculum Corner, Forces in Two Dimensions, Analyzing Equilibrium Situations
4. The Curriculum Corner, Forces in Two Dimensions, Analyzing Accelerations on Level Surfaces
5. The Curriculum Corner, Forces in Two Dimensions, Inclined Plane Analysis

Link: <http://www.physicsclassroom.com/curriculum/force2D>

Problem-Solving Exercises:

1. The Calculator Pad, Vectors and Forces in Two Dimensions, Problems #1 - #27

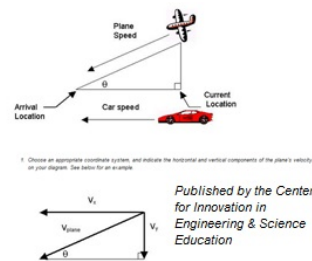
Link: <http://www.physicsclassroom.com/calcpad/vecforce/problems>

Real Life Connections:

1. CIESE – Navigational Vectors

<http://cieese.org/curriculum/vectorproj/>

This high school instructional unit features nine lessons relating to vectors. Students build understanding of vector properties as they learn airplane navigation. Project-based activities include reading real-time weather maps, tracking airplanes flying in U.S. skies, calculating vector components, analyzing effects of wind velocity, and completing training similar to a private pilot certification program. The unit culminates with an online pilot flight test. Comprehensive teacher guides, student guides, reference materials, and assessments are included.



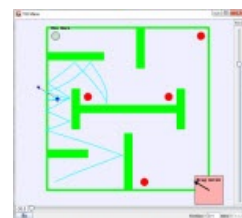
Elsewhere on the Web:

1. Tilt Maze Game Model

<http://www.compadre.org/OSP/items/detail.cfm?ID=11968>

The Tilt Maze Game Model is a recent addition to Open Source Physics. The model is set on a plane that can be tilted to make the ball roll due to gravity. The plane can be tilted up, down, to the left and to the right. By tilting the planes, the user must cause the ball to move through the maze to get to the hole at the top left side of the maze...but be careful, there are some traps laid out that would stop you from accomplishing your goal.

Java-Based game



Author: Salahadin Mohammed