

5.1 Working with Force Vectors

How can we use force vectors to predict the acceleration of the car?

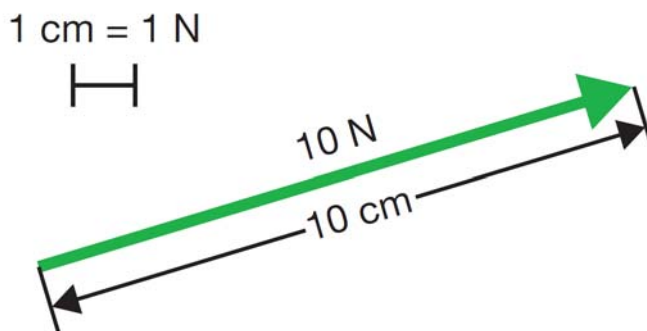
If an object is in equilibrium, all of the forces acting on it are balanced, the net force is zero, and the object does not experience any acceleration. If the forces are not balanced, there is a net force and the object does experience acceleration. By careful observation, measuring, and calculations, unknown forces can often be figured out by using vectors. In this investigation you will calculate the net force on the Energy Car and use force vectors to predict its acceleration.

Materials List

- Physics stand
- DataCollector
- SmartTrack
- Velocity sensor
- Three steel marbles
- Energy car
- Protractor
- Metric ruler
- Electronic scale or triple-beam balance

1 What is a force vector?

A force vector includes both magnitude and direction that describes a force. The magnitude of a force vector is expressed in newtons. When drawn to scale, the length of a force vector corresponds to a certain amount of force. Scaled vectors like the one shown can give you useful information. In this investigation you will draw your own scaled force vectors.

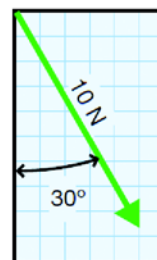


2 The components of a force vector

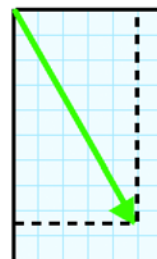
When you draw a force vector on a graph, distance along the x - or y -axes represents the strength of the force in the x - and y -directions. A force at an angle has the same effect as two smaller forces aligned with the x - and y -directions. In the figure to the right, the 8.7-N and 5-N forces applied together have the same effect as a single 10-N force applied at an angle of 30° from the y -axis. This idea of breaking a force down into its x - and y -components is very important, as you will see.

- a. If you placed the car on the SmartTrack when it was on a flat, level table, what forces would be acting on the car? Would the car move?
- b. In what directions would the forces be acting?
- c. What happens to those forces when you put the car on the SmartTrack when it is at an angle? Does the car move? Why?

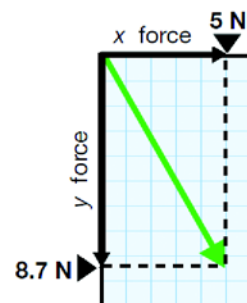
1. Use a protractor to find the correct angle, then draw the force vector to scale.



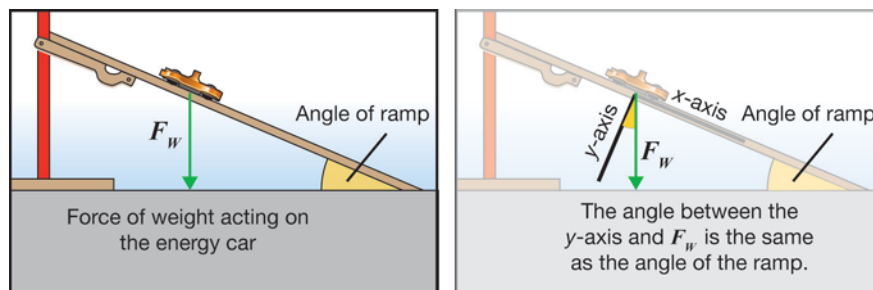
2. Extend lines to the x - and y -axes.



3. Read off the x - and y -components



3 The angle of the ramp and the force of weight (F_w)



Your ramp will be at an angle of 15° when you attach it to the fifth hole from the bottom of the stand. The force of weight (F_w) always points straight down for any object, from the center of mass of the object straight toward the center of Earth. This means that there is a component of F_w that is parallel to the ramp, which we will call F_{ramp} . There is also a component that is perpendicular to the ramp, called the normal force (F_{normal}), which doesn't help move the car down the ramp, so we will concentrate on the one that does.

- What would a force vector acting parallel to the ramp do to the car?
- What about the vector would tell you which direction it was acting on the car?
- What about the vector would tell you how much force was being applied to the car?

4 Finding F_w

You will need Newton's second law to find the F_w of your Energy Car.

NEWTON'S SECOND LAW

$$\text{Force (N)} \quad F = ma$$

Mass (kg)
 Acceleration (m/s^2)

You want to know a force, so you need to determine the mass and the acceleration and then solve for the force.

- Measure and record the mass of the energy car in Table 1. Be sure to record the mass in kg.
- The acceleration you need is the acceleration of gravity; 9.8 m/s^2 .
- Use Newton's second law to determine the F_w of the energy car, and record your result in Table 1.

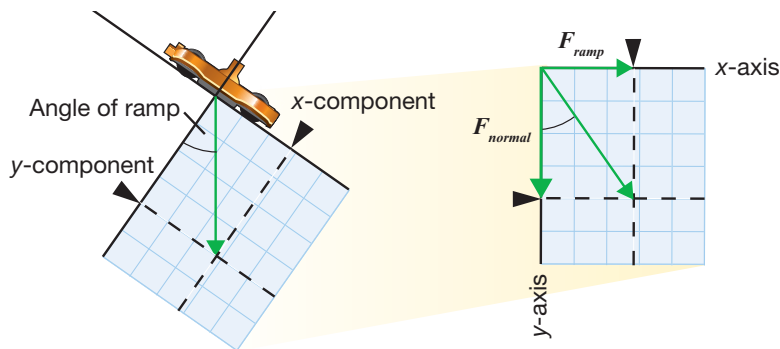
Table 1: Mass, acceleration, and force data

Mass of car (kg)	Acceleration of gravity (m/s^2)	F_w Force of Weight (N)

5 Resolving F_w into its component force vectors

F_w is a force vector, and can be broken down into component vectors as they apply to the ramp. The key pieces of information you need to know are

- the angle of the ramp.
- the direction of the force vector F_w .
- the magnitude of the force vector F_w .



- a. Fill in Table 2 with the information you need. Leave the fourth column blank for now.

Table 2: F_w component resolution data

Angle of the ramp (degrees)	Direction of F_w	Magnitude of F_w (N)	Magnitude of F_{ramp} (N)

- b. Use a pencil, a protractor, a ruler and a piece of graph paper to resolve F_w into its component vectors and find F_{ramp} . Be sure to decide on a scale for your vector drawing, label the axes, and label all the force vectors. When you find the magnitude of F_{ramp} , record it in Table 2.

6 Using F_{ramp} to make a prediction

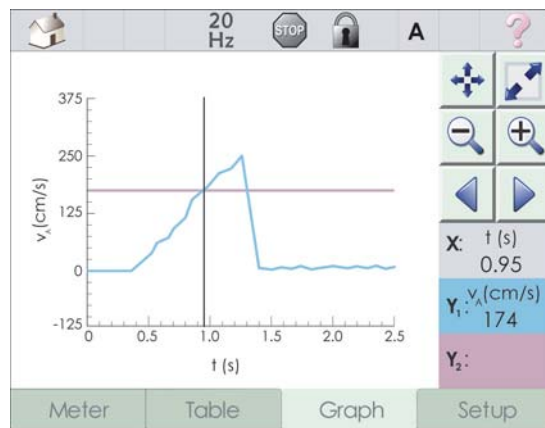
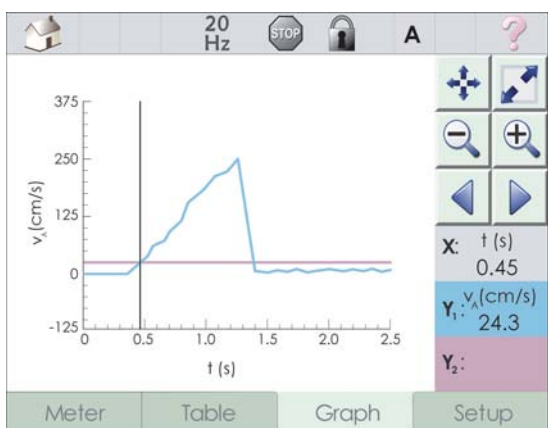
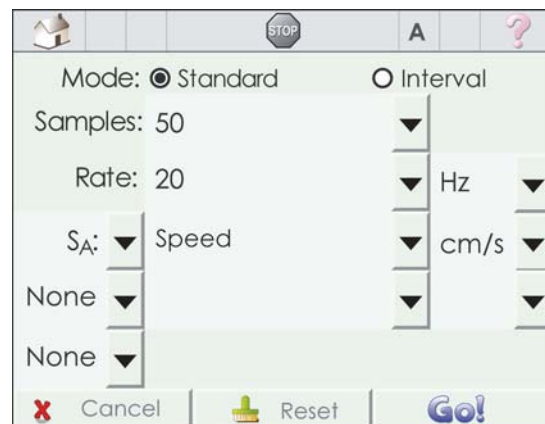
Now that you have found F_{ramp} , you will use that piece of information and whatever else you need to predict the acceleration of the car on the ramp.

- Other than F_{ramp} , what other piece of information will you need to predict the acceleration of the car?
- What formula did you use to find F_w ?
- How can you use that formula with F_{ramp} to predict the acceleration of the car down the ramp?
- Perform your calculation and state your predicted acceleration. Enter the value into Table 3.

7 Test your prediction

- Attach the distance-velocity sensor to the SmartTrack
- Attach the spur to the SmartTrack, then attach the spur to the fifth hole up from the bottom of the physics stand.
- Connect the sensor to the DataCollector with the cable.
- From the home screen of the DataCollector select data collection, then tap setup.

5. Set the samples to 50 and the rate to 20 Hz. For inputs, select speed as the only input. You may need to de-select any additional inputs, but changing extra inputs to “None”.
6. Put the car at the top of the ramp and keep it in place by using the hold button.
7. When your group is ready, tap the go screen, and allow the car to roll down the ramp by releasing the hold button.
8. Go to the graph screen by tapping the graph tab at the bottom of the display .
9. Acceleration is the slope of the velocity versus time graph. Select two points from the graph, where the car was in motion to determine the acceleration of the car.



10. Record the slope in Table 3 as the measured acceleration.

8 Thinking about your prediction

Table 3: F_{ramp} and acceleration prediction data

Calculated F_{ramp} (N)	Predicted acceleration (m/s^2)	Measured acceleration (m/s^2)	Net F_{ramp} (N)	Calculated - Net F_{ramp} (N)

- a. Enter your calculated magnitude of F_{ramp} from Table 2. What direction was it in?
- b. How did your measured acceleration compare to your predicted acceleration? What was the percent difference between them? Explain any differences.
- c. If the accelerations were different, what does that mean about the magnitude of the net F_{ramp} ?
- d. Calculate the net F_{ramp} and record this in Table 3. How does it compare to your calculated F_{ramp} ?
- e. Find the difference in your results for F_{ramp} and record this value in the last column in Table 3.
- f. Explain the difference you found between the two values for F_{ramp} . What is the percent difference? Would this difference be considered a force vector? If so, what is its magnitude and direction?
- g. **CHALLENGE:** Try this experiment with three marbles in the car. What do you find? Explain.