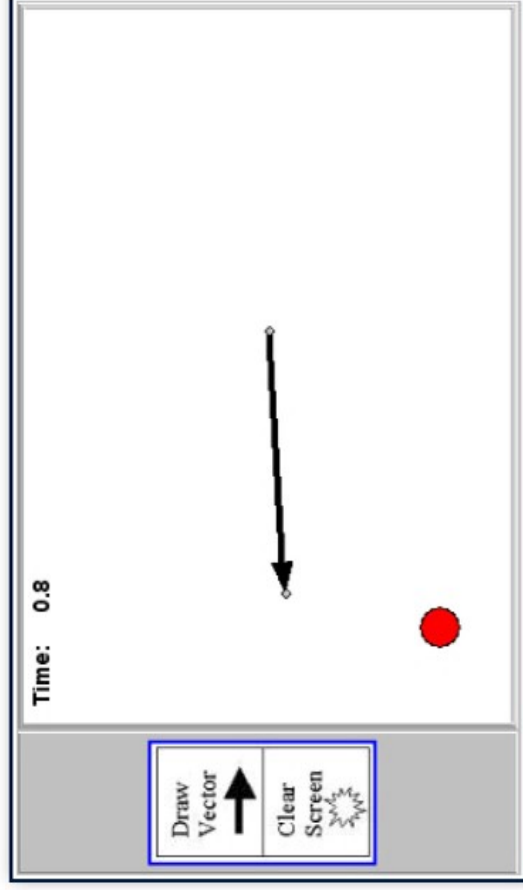


Notice that between points A and C the planet is speeding up, and between points C and A the planet is slowing down. This means that at points A and C the tangential component of acceleration is zero. It turns out that for a planet orbiting a star (if there are no other planets or stars nearby) the acceleration of the planet is directed exactly toward the star whether the motion of the planet is uniform or not.

Exploration 3.1: Addition of Displacement Vectors



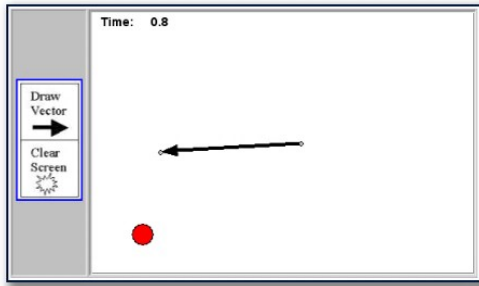
Exploration 3.1: Use a JavaScript-enabled browser to open and run this Exploration.

Suppose that you use a radar system to track an airplane (the red circle) and the airplane travels according to the animation shown.

- Draw a vector for the displacement of the airplane from $t = 0$ s to $t = 8$ s. To do this, click the “Draw Vector” button. When a vector appears, drag it to the position of the airplane at $t = 0$ s. Then play the animation, stop it at $t = 8$ s, and adjust the tip of the vector until it is at this position.
- Now draw a displacement vector for the airplane from $t = 8$ s to $t = 16$ s. Use the same procedure as before. Be sure to click the “Draw Vector” button so that you can have a new vector to work with. You should see both the first displacement vector and the second displacement vector.
- Now draw a displacement vector for the airplane from $t = 0$ s to $t = 16$ s. Use the same procedure as before. What do you notice? To add vectors like this, you can connect the vectors from tail to head. The result, called the resultant vector, is the vector drawn from the tail of the first vector to the head of the last vector.
- Click here to view the correct answer. How does your result compare to the correct answer?

motion of the planet is uniform or not.

Exploration 3.1: Addition of Displacement Vectors

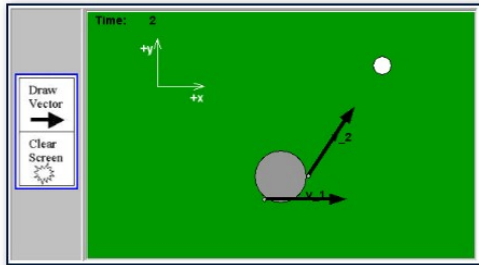


Exploration 3.1: Use a JavaScript-enabled browser to open and run this Exploration.

Suppose that you use a radar system to track an airplane (the red circle) and the airplane travels according to the animation shown.

- Draw a vector for the displacement of the airplane from $t = 0$ s to $t = 8$ s. To do this, click the “Draw Vector” button. When a vector appears, drag it to the position of the airplane at $t = 0$ s. Then play the animation, stop it at $t = 8$ s, and adjust the tip of the vector until it is at this position.
- Now draw a displacement vector for the airplane from $t = 8$ s to $t = 16$ s. Use the same procedure as before. Be sure to click the “Draw Vector” button so that you can have a new vector to work with. You should see both the first displacement vector and the second displacement vector.
- Now draw a displacement vector for the airplane from $t = 0$ s to $t = 16$ s. Use the same procedure as before. What do you notice? To add vectors like this, you can connect the vectors from tail to head. The result, called the resultant vector, is the vector drawn from the tail of the first vector to the head of the last vector.
- Click here to view the correct answer. How does your result compare to the correct answer?

Exploration 3.2: Run the Gauntlet, Controlling x , v , and a



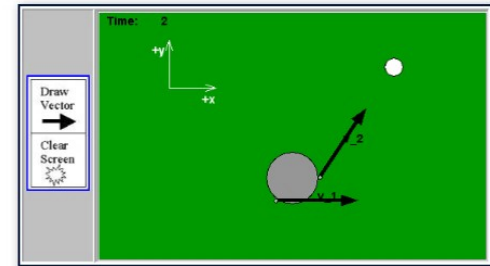
Exploration 3.2: Use a JavaScript-enabled browser to open and run this Exploration.

Drag the tip of the arrow to control the position, velocity, or acceleration of the object depending on which animation you choose.

Use the animation to answer the following questions (position is given in meters and time is given in seconds).

- Can you navigate to the goal on the right? We call this challenge *Running the Gauntlet*.
- Which controller (the position, velocity, or acceleration) is harder to use? Why?

Exploration 3.3: Acceleration of a Golf Ball That Rims the Hole



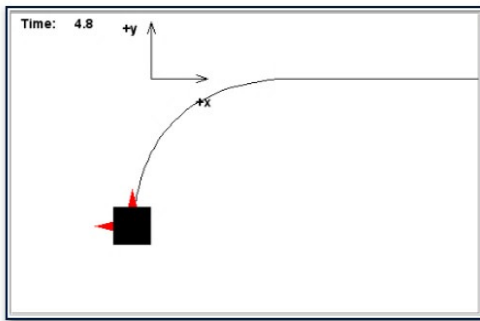
Exploration 3.3: Use a JavaScript-enabled browser to open and run this Exploration.

A putt golf ball “rims” the hole as shown in the animation (**position is given in centimeters and time is given in seconds**). Velocity vectors for the ball at the instant just before it hits the hole and the instant just after it hits the hole are shown. Note that the ball’s speed does not change upon hitting the edge of the hole; this would not occur for an actual golf ball that rims the hole.

Suppose we want to find the average acceleration of the golf ball at some instant when it is in contact with the hole.

- Draw the change-in-velocity vector using the velocity vectors shown. Click “Draw Vector” to add a vector to the animation and click “Clear Screen” to erase all drawn vectors.
- What is the magnitude and direction of the change-in-velocity during this interval?
- What is the average acceleration during this interval?
- For the animation shown, at what instant do you think the instantaneous acceleration will equal the average acceleration of the golf ball during the time interval from 0.9 s to 1.2 s?
- Click here to view the acceleration vector. If your change-in-velocity vector is still drawn on the screen, then you can stop the animation at the point where the acceleration vector and change-in-velocity vector match up. Did this occur at the instant you predicted?

Exploration 3.4: Space Probe with Constant Acceleration



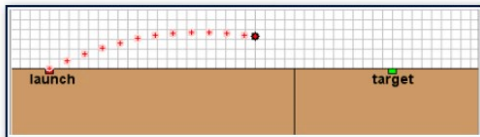
Exploration 3.4: Use a JavaScript-enabled browser to open and run this Exploration.

When you studied projectile motion, you learned that for projectile motion the x acceleration is zero and constant (which results in a constant x velocity) and the y acceleration is constant and downward toward Earth with a magnitude of 9.8 m/s^2 . What mathematical curve describes the shape of the path of the projectile? Its shape is a parabola. It turns out that the shape of the path of any object that has constant acceleration and an initial velocity that is in a different direction than the acceleration is a parabola.

In the animation shown (position is given in meters and time is given in seconds), a space probe has engines that can fire on all four sides. Two of the engines engage at $t = 2 \text{ s}$. The acceleration is constant and zero before the engines engage, and it is constant (but not equal to zero) after the engines engage.

- What is the direction of the x component of the acceleration after the engines engage?
- What is the y velocity before the engines engage?
- After the engines engage, how is the y velocity different?
- Now click here to view the velocity and acceleration vectors. Do they match what you predicted?

Exploration 3.5: Uphill and Downhill Projectile Motion



Exploration 3.5: Use a JavaScript-enabled browser to open and run this Exploration.

A projectile is launched at $t = 0 \text{ s}$ (position is given in meters and time is given in seconds). You may change the projectile's launch angle and initial speed and the height of the hill by using the text boxes and clicking the "set values and play" button.

For $h = 0 \text{ m}$, vary the projectile's launch angle and initial speed and consider the following questions.

- For a given initial speed, what launch angle will provide the maximum range of the projectile?
- For the value of launch angle in (a), what is the value of the initial speed that will hit the target?

c. What value(s) of the projectile's launch angle and initial speed will enable the projectile to hit the target?

d. Are these values unique?

e. What is the general relationship between launch angle and initial speed?

For $h = 10 \text{ m}$, vary the projectile's launch angle and initial speed and consider the following questions.

f. For a given initial speed, what launch angle will provide the maximum horizontal displacement of the projectile?

g. What value(s) of the projectile's launch angle and initial speed will enable the projectile to hit the target?

h. Are these values unique?

i. Are these values the same as in (c)?

For $h = -10 \text{ m}$, vary the projectile's launch angle and initial speed and consider the following questions.

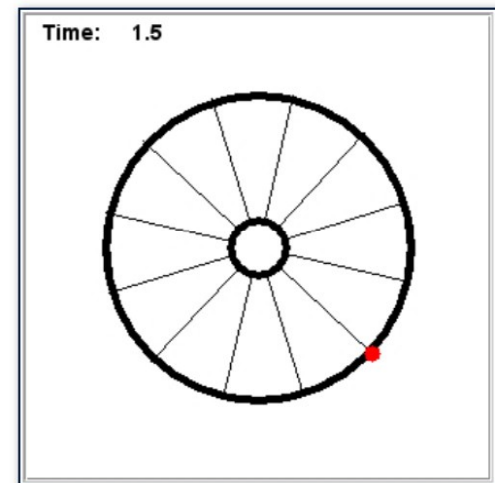
j. For a given initial speed, what launch angle will provide the maximum horizontal displacement of the projectile?

k. What value(s) of the projectile's launch angle and initial speed will enable the projectile to hit the target?

l. Are these values unique?

m. Are these values the same as in (c) and (g)?

Exploration 3.6: Uniform Circular Motion



Exploration 3.6: Use a JavaScript-enabled browser to open and run this Exploration.

A point (red) on a rotating wheel is shown in the animation (position is given in meters and time is given in seconds).

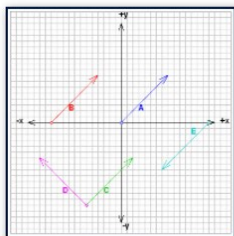
a. Note that the speed of the red point is constant. Is its velocity constant?

b. Click here to view the velocity vector. After viewing the vector rethink your

answer: is the velocity of the red point constant?

- c. What is the direction of the red point's acceleration vector? Click here to view the acceleration and velocity vectors.
- d. How does the speed of the red point compare to the speed of another point, say a green one, which is at only half the radius of the red point? Click here to view both points. For clarity the green point is shown on the opposite side from the red one.
- e. Why is the speed of the green point less than the speed of the red point?
- f. How does the magnitude of the acceleration of the red point compare to the magnitude of the acceleration of the green point? Click here to view both points and their velocity and acceleration vectors.

Problem 3.1: Rank the 5 vectors

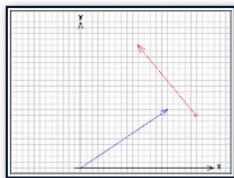


Use a JavaScript-enabled browser to open and run this Problem.

Five vectors are shown on the coordinate grid (**position is given in meters**). You can change the position of a vector by click-dragging at the base of the vector. Click restart to return the vectors to their original positions.

- a. Rank the x components of the five vectors shown (smallest to largest).
- b. Rank the y components of the five vectors shown (smallest to largest).
- c. What are the components of the vector that results when Vector B is added to Vector D?

Problem 3.2: Two vectors are shown on the coordinate grid



Use a JavaScript-enabled browser to open and run this Problem.

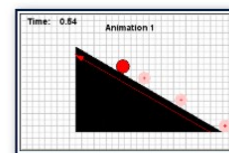
Two vectors are shown on the coordinate grid (**position is given in meters**).

- a. What are the x and y components of the blue vector?
- b. What are the x and y components of the red vector?

Now drag the circle at the tail of the red vector so that it is on top of the blue vector's head. The vector sum is now a vector that reaches from the tail of the first (blue) vector to the head of the second (red) vector.

- c. What are the components of this vector sum?
- d. How do they relate to the components of the original (blue and red) vectors?

Problem 3.3: Rank the motion diagrams



Use a JavaScript-enabled browser to open and run this Problem.

The animations represent the motion of a ball on various surfaces (**position is given in meters and time is given in seconds**). The "ghosts" are placed at equal time intervals. Such a picture is often called a motion diagram.

Answer the following questions using the coordinate system specified in each animation by the red arrow. Please indicate ties by (). For example a suitable response could be: 1, (2, 3), 4, 5, 6.

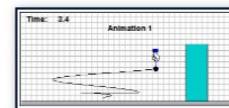
For parts (a), (b), and (c), use the ghost images to qualitatively rank the quantities.

- a. Rank each case from highest to lowest displacement.
- b. Rank each case from highest to lowest final velocity.
- c. Rank each case from highest to lowest acceleration (assume constant acceleration).

Now use the usual x and y coordinates that you can access by click-dragging in the animation.

- d. Calculate the displacement vector for each animation.
- e. Calculate the acceleration vector for each animation (assume that in Animation 3 and Animation 6 the ball starts at rest and that in Animation 1 and Animation 4 the ball ends at rest).

Problem 3.4: A bowling ball is lifted from rest onto a shelf

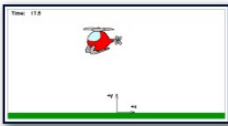


Use a JavaScript-enabled browser to open and run this Problem.

A bowling ball is lifted from rest onto a shelf by an external agent (**position is given in meters and time is given in seconds**). For each quantity below, rank the animations (numbered 1 through 4) from least to greatest. Ties in () please. For example, a suitable response could be: 1, (2, 3), 4.

quantity	ranking
magnitude of displacement	
magnitude of average velocity	

Problem 3.5: A helicopter takes off

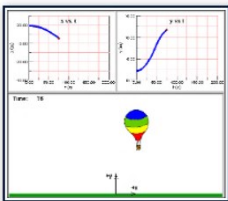


Use a JavaScript-enabled browser to open and run this Problem.

The helicopter is shown in the animation (**position is given in meters and time is in seconds**).

- Sketch a graph of x position vs. time for the helicopter.
- Sketch a graph of y position vs. time for the helicopter.
- What is the x velocity of the helicopter at any instant?
- What is the y velocity of the helicopter at any instant?
- What is the speed of the helicopter at any instant?

Problem 3.6: A hot-air balloon takes off

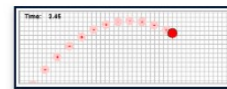


Use a JavaScript-enabled browser to open and run this Problem.

The hot-air balloon travels as shown in the animation (**position is given in meters and time is in seconds**). The x and y positions of the hot-air balloon's basket are shown in the

- During approximately what time interval is the magnitude of the y velocity increasing?
- During approximately what time interval is the magnitude of the y velocity decreasing?
- At approximately what instant of time does the y acceleration change from positive to negative?
- What is the y velocity from $t = 87$ s until $t = 200$ s?
- What is the y acceleration from $t = 87$ s until $t = 200$ s?
- What is the x velocity from $t = 87$ s until $t = 200$ s?
- What is the x acceleration from $t = 87$ s until $t = 200$ s?
- What is the x displacement from $t = 0$ s until $t = 200$ s?
- What is the y displacement from $t = 0$ s until $t = 200$ s?

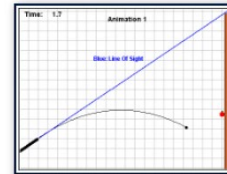
Problem 3.7: A projectile is launched



Use a JavaScript-enabled browser to open and run this Problem.

A projectile is launched as shown in the animation (**position is given in meters and time is given in seconds**). Where does the ball reach its minimum speed, and what is its speed when it gets there?

Problem 3.8: Shoot the apple from the tree



Use a JavaScript-enabled browser to open and run this Problem.

A hunter (off screen) aims his rifle at an apple in a tree as shown in the animation (**position is given in meters and time is given in seconds**). At the instant the bullet leaves the rifle, the apple starts falling from rest. Which of the above animations correctly depicts the hunter's aim that hits the apple? Note: All three show the apple being hit, but only one animation depicts correct physics

Problem 3.9: Projectile motion problem

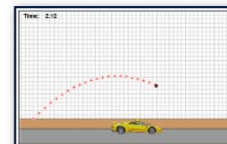


Use a JavaScript-enabled browser to open and run this Problem.

A projectile is launched with an initial speed of 20 m/s as shown in the animation (**position is given in meters**). The time display is suppressed, but you can still click-drag to get coordinates. A line is also shown that represents the initial direction of the velocity.

- What is the launch angle?
- What are v_{0x} and v_{0y} ?
- What is the maximum height the projectile will reach?
- How long does it take the projectile to reach that height?
- What is the total time that the projectile is in the air?

Problem 3.10: Aim the projectile to hit the moving Lamborghini

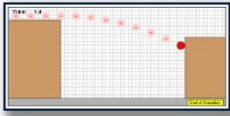


Use a JavaScript-enabled browser to open and run this Problem.

A projectile is launched when the yellow Lamborghini (not shown to scale) goes by at $t = 0$ s (**position is given in meters and time is given in seconds**). You may change the projectile's launch angle and initial speed by using the text boxes and clicking "set values"

and play.” Find the relationship between v_0 and θ such that the projectile will always hit the car. When you determine the relationship, make sure to test it with a few values of v_0 and θ .

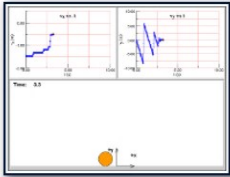
Problem 3.11: A red ball slides off a table



Use a JavaScript-enabled browser to open and run this Problem.

A red ball slides off a table as shown in the animation (**position is given in meters and time is given in seconds**). Ignore air friction. If the ball collides with the other table such that v_y remains the same and v_x changes sign upon collision, where will the red ball land?

Problem 3.12: A basketball bounces on the floor



Use a JavaScript-enabled browser to open and run this Problem.

A bouncing basketball is shown in the animation (**position is given in meters and time is given in seconds**). While the basketball is in the air, its motion is characterized by projectile motion.

- What is the average y acceleration of the ball during the interval of the first bounce, that is from $t = 0.85$ s to $t = 0.95$ s?
- What is the average x acceleration of the ball during the interval of the first bounce, that is from $t = 0.85$ s to $t = 0.95$ s?
- What is the magnitude of the acceleration of the ball during this interval?
- While the ball is in the air (between the bounces), is the x velocity increasing, decreasing, or constant? What is the x acceleration while the ball is in the air?
- As the ball rolls to a stop, between $t = 3.0$ s and $t = 8.0$ s, what is the x acceleration of the ball? What is the y acceleration of the ball during this interval?

Problem 3.13: A puttied golf ball rolls in a straight line toward the hole

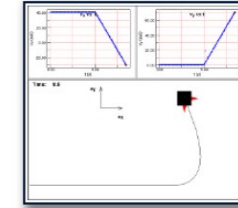


Use a JavaScript-enabled browser to open and run this Problem.

The animation shows a puttied golf ball as it travels toward the hole (**position is given in meters and time is given in seconds**).

- Is the acceleration of the golf ball between $t = 0$ and $t = 4.2$ s constant, increasing, or decreasing?
- What is the average acceleration of the golf ball during this time interval?
- Calculate the x displacement of the golf ball from $t = 0$ to $t = 4.2$ s and show that it is the same as what you measure on the animation.
- Calculate the y displacement of the golf ball from $t = 0$ to $t = 4.2$ s and show that it is the same as what you measure on the animation.
- What is the magnitude of the displacement of the golf ball from $t = 0$ to $t = 4.2$ s?

Problem 3.14: A space probe travels with a constant acceleration

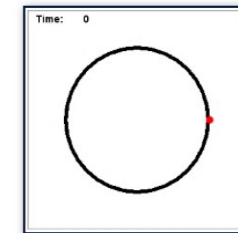


Use a JavaScript-enabled browser to open and run this Problem.

In the animation shown, a space probe has engines that can fire on all four sides (**position is given in meters and time is given in seconds**). Two of the engines engage at $t = 5$ s. The acceleration is constant and zero before the engines engage, and it is constant (but not equal to zero) after the engines engage.

- What is the initial velocity of the probe just before the engines fire?
- What is the acceleration of the probe after the engines fire?
- Assuming the engines continue to fire in the same way, what will be the position and velocity of the probe at $t = 25$ s?
- At what instant is $v_x = 0$? At what instant is $v_y = 0$?

Problem 3.15: An object travels along a circular path



Use a JavaScript-enabled browser to open and run this Problem.

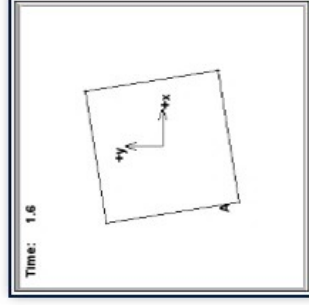
An object travels along a circular path as shown in the animation (**position is given in meters and time is given in seconds**).

- At $t = 2$ s, what is the direction of the velocity of the object?
- At $t = 2$ s, what is the approximate direction of the acceleration of the object? You do not need to give an exact direction, just an approximate direction based on what you know about the direction of the radial component and the direction

of the tangential component.

- c. At $t = 4$ s, what is the direction of the velocity? If it is zero, indicate so.
- d. At $t = 4$ s, what is the approximate direction of the acceleration? If it is zero, indicate so.
- e. At $t = 6$ s, what is the direction of the velocity?
- f. At $t = 6$ s, what is the approximate direction of the acceleration?

Problem 3.16: Rotating square

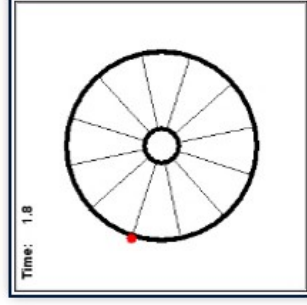


[Use a JavaScript-enabled browser to open and run this Problem.](#)

A square rotates as shown in the animation (**position is given in meters and time is given in seconds**). A corner of the square is labeled A. For all of the following questions consider the motion of point A from $t = 0.5$ s to $t = 2.5$ s.

- a. What is the displacement of point A during this time interval?
- b. What is its distance traveled during this interval?
- c. What is its average velocity during this interval?
- d. What is its average speed during this interval?

Problem 3.17: Uniform circular motion of a wheel



[Use a JavaScript-enabled browser to open and run this Problem.](#)

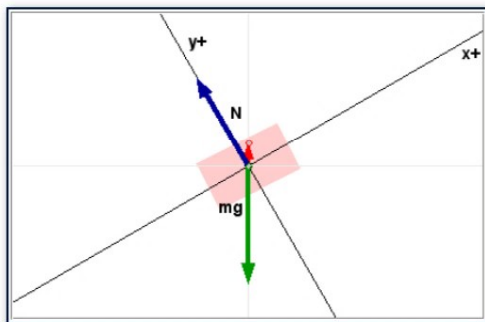
A point (red) on a rotating wheel is shown in the animation (**position given in meters and time given in seconds**).

- a. What is the period of the wheel (the time it takes the red point to complete one revolution)?
- b. What is the speed of the red point?
- c. What is the magnitude of the acceleration of the red point?
- d. At $t = 5.0$ s, what is the direction of the velocity vector and what is the direction of the acceleration vector for the red point?

system. If we look at things this way we have one object of mass 3 kg and a net force of 12 N, which means an acceleration of 4 m/s^2 (this is borne out by the acceleration graph).

What next? We could analyze the forces acting on the first mass, but let's analyze the second mass since it has only the first mass pushing on it. Because it has an acceleration of 4 m/s^2 and a mass of 1 kg, it must experience a force of 4 N from the push of the red mass. What about the red mass? Newton's third law says it must experience an equal and opposite force, here a force of -4 N . Try these values out (-4 N for the force on the red block and 4 N for the force on the green block) to see if you believe what Newton's third law says the forces should be.

Exploration 4.1: Vectors for a Box on an Incline

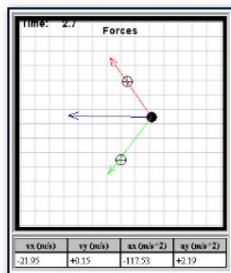


Exploration 4.1: Use a JavaScript-enabled browser to open and run this Exploration.

Exploration 4.1 represents a free-body diagram for a 20-N block on a 30° frictionless incline (the length of the vectors is given in newtons). The light gray lines represent the traditional xy axis, and the black lines represent the coordinates along the incline. The blue vector represents the normal force; the green vector represents the weight. You may move the tails of the blue and green vectors to add them and use the red vector to represent their resultant vector by dragging the red vector's tip.

- Determine the resultant force from the diagram.
- Determine the acceleration of the block.

Exploration 4.2: Change the Two Forces Applied



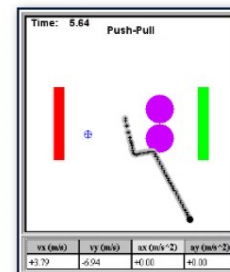
Exploration 4.2: Use a JavaScript-enabled browser to open and run this Exploration.

Drag either of the crosshair cursors or the ball (position is given in centimeters and time is given in seconds). The cursors each exert a constant force on the black ball (either attraction or repulsion) if they are within 10 cm of the ball. When the ball hits a wall, the

wall exerts a force on the ball causing it to recoil. The green and red arrows display the forces due to each cursor, and the blue arrow represents the net force.

For attraction and repulsion, drag the black ball around to see the net force. When you get the ball in a "good" spot, click the "play" button to see the effect of the forces on the ball. Briefly explain how and why the ball moves according to the forces applied.

Exploration 4.3: Change the Force Applied to Get to the Goal

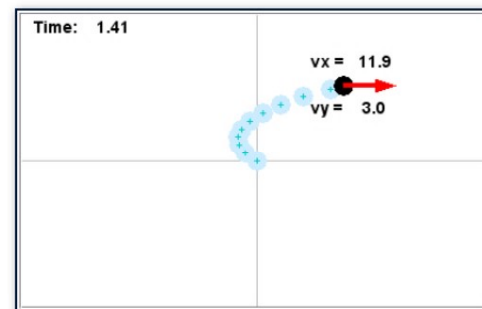


Exploration 4.3: Use a JavaScript-enabled browser to open and run this Exploration.

Drag the crosshair cursor close to the black ball (position is given in meters and time is given in seconds). Notice that the cursor exerts a force, that is, a push or a pull, on the ball depending on the force you select. The ball will bounce off the purple spheres and will bounce off the soft walls around the animation. The animation will end if the ball hits either rectangle. The blue arrow represents the net force.

- Try to get the ball to hit the green rectangle and not the red rectangle.
- Given an applied force, how does the ball move?
- Does the ball always move the way you expect? Why or why not?

Exploration 4.4: Set the Force on a Hockey Puck



Exploration 4.4: Use a JavaScript-enabled browser to open and run this Exploration.

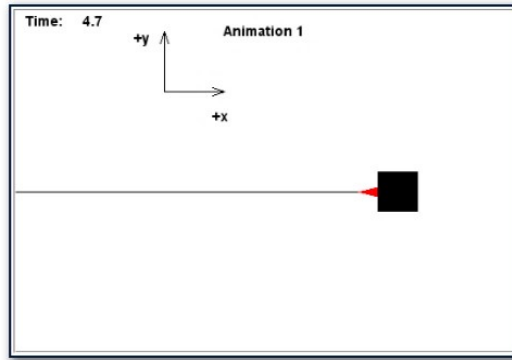
A 250-gram hockey puck is acted upon by a single force. It is free to slide on the ice (position is given in meters and time is given in seconds) in any direction. You can set the force vector by changing its magnitude ($0 \text{ N} < F < 10 \text{ N}$) and direction. The force vector is shown in the animation as a red arrow. You also can set the initial velocity components ($-15 \text{ m/s} < v < 15 \text{ m/s}$).

- When the initial velocity is zero, in what direction does the ball travel for a given force?

b. When the initial velocity is not zero, in what direction does the ball travel for a given force? Hint: The best way to do this is to pick a nonzero v_{0x} or v_{0y} , not both. Also turn on the ghosts.

c. Try $F = 5 \text{ N}$, $\theta = 270^\circ$, $v_{0x} = 7 \text{ m/s}$, and $v_{0y} = 15 \text{ m/s}$. Does this motion look familiar? Turn on the ghosts to help with the answer.

Exploration 4.5: Space Probe with Multiple Engines



Exploration 4.5: Use a JavaScript-enabled browser to open and run this Exploration.

A space probe is designed with four engines that can fire in the $+x$, $-x$, $+y$, and $-y$ directions, respectively (**position is given in meters and time is given in seconds**). For each of the situations below, first predict the motion of the space probe. Your prediction should be a detailed description of the motion of the probe. Only after you make a prediction, check it by viewing the animation. An example is shown in the first row of the table.

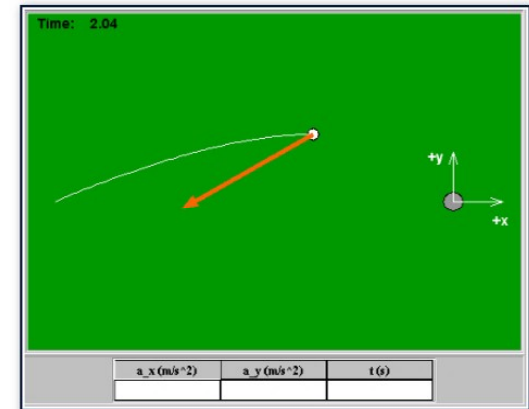
Situation	Your prediction	Animation
The space probe has a constant velocity in the $+x$ direction when suddenly an engine exerts a force on the probe in the $+x$ direction. The probe will have an acceleration in the $+x$ direction. Therefore, since it is already traveling in that direction when the engine fires, it will speed up and will continue moving in the $+x$ direction.		Animation 1
The space probe has a constant velocity in the $+x$ direction when suddenly an engine exerts a force on the probe in the $-x$ direction.		Animation 2
The space probe has a constant velocity in the $+x$ direction when suddenly an engine exerts a force on the probe in the $+y$ direction.		Animation 3
The space probe has a constant velocity in the $+x$ direction when suddenly an engine exerts a force on the probe in the $-y$ direction.		Animation 4

The space probe has a constant velocity in the $+x$ direction when suddenly an engine exerts a force on the probe in the $-y$ direction and another engine exerts a force in the $-x$ direction. Animation 5

The space probe has a constant velocity in the $+x$ direction when suddenly an engine exerts a force on the probe in the $+y$ direction and another engine exerts a force in the $+x$ direction. Animation 6

The space probe has a constant velocity in the $+x$ direction when suddenly all four engines fire simultaneously. Animation 7

Exploration 4.6: Putted Golf Ball Breaks Toward the Hole



Exploration 4.6: Use a JavaScript-enabled browser to open and run this Exploration.

A puttied golf ball rolls toward the hole on a green. The animation shows a top view of the ball on the green. The acceleration vector (orange) of the ball is shown on the animation, and the components of the ball's acceleration are displayed in the data table.

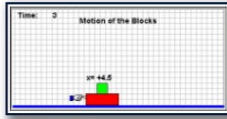
The net force on the golf ball is in the same direction as the acceleration of the golf ball, according to Newton's second law. This means that if you know the mass of the golf ball and the acceleration of the golf ball, you can calculate the net force on the golf ball.

- Is the net force on the golf ball in the animation constant during the interval from $t = 0$ to $t = 4.8 \text{ s}$?
- If not, does its magnitude and/or direction change?
- If the mass of a golf ball is 0.046 kg , what is the net force on the golf ball at $t = 1.0 \text{ s}$?
- For practice, calculate the net force on the golf ball at $t = 2.0 \text{ s}$, $t = 3.0 \text{ s}$, and $t = 4.0 \text{ s}$ as well.

Exploration 4.7: Atwood's Machine

g. $F_x(x, t) = \cos(t)$

Problem 4.1: Which is the correct free-body diagram?

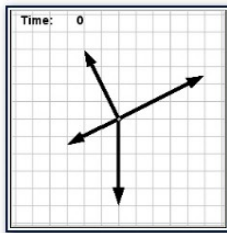


Use a JavaScript-enabled browser to open and run this Problem.

A red block is pushed and moves as shown in the animation. In addition, a green block sits on the red block and moves as well.

- Which free-body diagram is correct? Give reasons why the other three diagrams are incorrect.
- How would your answer to (a) change if the blocks did not move?

Problem 4.2: Interpret the free-body diagram

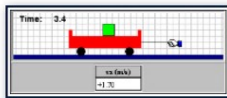


Use a JavaScript-enabled browser to open and run this Problem.

A free-body diagram for a 20,000-kg airplane at some instant is shown in the animation (**grid size is given in 40,000 newtons**). Generally, all of the external forces on an airplane can be resolved into four components called weight, lift, thrust, and drag. You can move a vector around by click-dragging at its tail.

- What is the net force on the airplane at this instant?
- What is the acceleration of the airplane at this instant?
- What can you definitely say about the velocity of the airplane at this instant?
- Suppose a classmate in your study group proclaims that “the net force on the airplane is zero and therefore the airplane must be on the ground and at rest.” What is the error in your classmate’s statement?

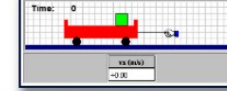
Problem 4.3: Pull your little red wagon



Use a JavaScript-enabled browser to open and run this Problem.

A 100-kg wagon with a 20-kg block on its frictionless bed is pulled to the right with a constant force (**position is given in meters and time is given in seconds**). Does the animation obey Newton’s laws? Support your answer.

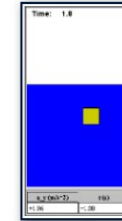
Problem 4.4: Pull your little red wagon



Use a JavaScript-enabled browser to open and run this Problem.

A 100-kg wagon with a 20-kg block on its frictionless bed is pulled to the right with an unknown force (**position is given in meters and time is given in seconds**). Sketch a plot of the force exerted by the hand on the cart as a function of time.

Problem 4.5: A buoy is dropped into a lake

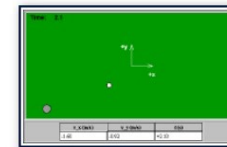


Use a JavaScript-enabled browser to open and run this Problem.

A 0.010-kg buoy is dropped into a lake as shown in the animation. Before it hits the water, it is in free fall.

- Before the buoy hits the water, what is the net force on the buoy?
- At $t = 1.2$ s, what is the net force on the buoy?
- At $t = 1.2$ s, what is the force of the water on the buoy?
- At $t = 4.5$ s, what is the net force on the buoy? Approximately, what is the velocity of the buoy at this instant? Can the velocity of an object be zero even though the net force on the object is not zero?
- At $t = 4.5$ s, what is the force of the water on the buoy?
- At $t = 11.0$ s, what is the net force on the buoy?
- At $t = 11.0$ s, what is the force of the water on the buoy?
- Describe the velocity of the buoy at this instant ($t = 11.0$ s); is it increasing, decreasing, or constant?

Problem 4.6: Punted golf ball



Use a JavaScript-enabled browser to open and run this Problem.

The animation shows a punted golf ball of mass 0.050 kg as it rolls toward the hole. The putter hit the ball before $t = 0$ s and is no longer in contact with the ball (**position is given in meters and time is given in seconds**).

- What is the net force on the golf ball during the interval from $t = 0$ to $t = 4.2$ s?
- What is the force of the putter on the golf ball during this interval?

Problem 4.7: A ball constrained to move on a rod

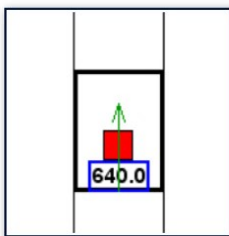


Use a JavaScript-enabled browser to open and run this Problem.

A 20-kg ball has a hole with a rod passing through. The rod exerts a force as needed that constrains the ball to move along the rod. An applied force is now added (the “pulling” force) so the ball is pulled as shown (**position is given in meters and time is given in seconds**). The force vector is shown as a red arrow, and the force makes an angle θ with the horizontal. The velocity is given in meters/second. You may adjust the angle and/or the magnitude of the pulling force ($F < 7 \text{ N}$).

- How does the acceleration change as you vary the pulling force for a constant angle?
- How does the acceleration change as you vary the angle for a constant pulling force?
- Combine your answers above to obtain a general mathematical formula for the acceleration of the ball due to an arbitrary applied force.
- Determine the general mathematical formula for the normal force the rod exerts on the ball when an arbitrary force is applied to the ball.

Problem 4.8: Take a ride in an elevator

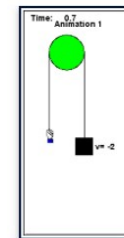


Use a JavaScript-enabled browser to open and run this Problem.

A 50-kg box is riding in an elevator that accelerates upward or downward at a constant rate (**position is given in meters and time is given in seconds**). The box rests on a digital scale that records its apparent weight in newtons. The green arrow represents the instantaneous velocity of the elevator and its contents. Adjust the value of the acceleration ($-9.8 \text{ m/s}^2 \leq a \leq 9.8 \text{ m/s}^2$) and see how it affects the apparent weight.

- What type of force is recorded on the scale?
- Draw a free-body diagram for the box when its acceleration is 4.9 m/s^2 , 0 m/s^2 , and -4.9 m/s^2 .
- Write a formula for the scale reading as a function of the acceleration of the elevator, the mass of the box, and g .
- Determine the value of the elevator’s acceleration that would make the force that the scale exerts on the box vanish. In other words, how can the box become apparently “weightless?”

Problem 4.9: Rank the accelerations and tensions



Use a JavaScript-enabled browser to open and run this Problem.

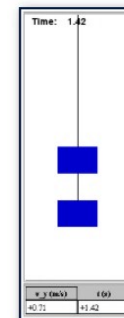
A 10-kg mass is attached via a massless string over a massless pulley to a hand (**position is given in meters and time is given in seconds**). The masses in each animation are identical.

- Rank the animations according to the acceleration of the mass, from greatest to least (positive is up).
- Rank the animations according to the tension in the string, from greatest to least (positive is up).

Indicate ties by placing the animation numbers in () please. For example, a suitable response could be: 1, 2, (3, 4), 5, 6.

- Calculate the acceleration of the mass in each animation.
- Calculate the tension of the string in each animation.

Problem 4.10: Hoisted boxes



Use a JavaScript-enabled browser to open and run this Problem.

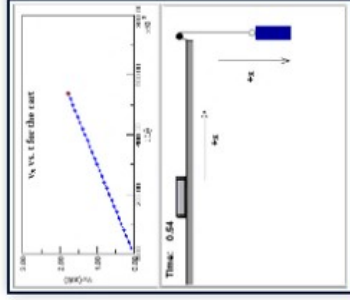
Two boxes, each of mass 2.0 kg, are connected by a lightweight rope. The boxes are hoisted upward with a constant acceleration as shown in the animation (**position is given in meters and time is given in seconds**).

- Draw a free-body diagram for each box.
- What is the tension in the top rope?
- What is the tension in the rope connecting the two boxes?

Consider an alternative situation in which the system has the same acceleration but the rope between the boxes is not lightweight. It is a steel cable with a total mass of 1.0 kg.

- What would be the force of the steel cable on the top box?
- What would be the force of the steel cable on the bottom box?

Problem 4.11: Modified Atwood's machine



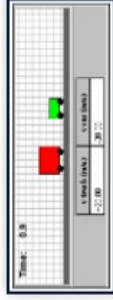
Use a JavaScript-enabled browser to open and run this Problem.

A 1.0-kg cart (not shown to scale) on a low-friction track is connected to a string and a hanging object as shown in the animation. Neglect any effects of the pulley on the motion of the system (**position is given in meters and time is given in seconds**).

- What is the tension in the string?
- What is the mass of the hanging object?

Note that the coordinates for each object (the positive x direction) are already chosen for you.

Problem 4.12: A truck and car collision



Use a JavaScript-enabled browser to open and run this Problem.

A large 2000-kg truck and a small compact car collide head-on as shown in the animation (**position is given in meters and time is given in seconds**). Assume the collision takes place in 0.05 seconds.

- Describe the force on each vehicle before, during, and after the collision. Be sure to estimate the magnitudes of these forces and give their directions.
- Which vehicle, the car or the truck, experiences the greater force during the collision?

Problem 4.13: Does the force obey Newton's third law?



Use a JavaScript-enabled browser to open and run this Problem.

Newton's third law states that whenever two objects interact, they exert equal and opposite forces on each other (**position is given in meters and time is given in seconds**). The balls in the animations can be dragged around. As you do so, notice how the sizes of the arrows change. Each arrow represents the force on an object (the length of the arrow indicates the magnitude of the force). Which animation, if any, obeys Newton's third law?