Matter & Interactions 3rd Edition
Test Question Collection

Chapter 2

October 4, 2010

The questions and equation sheets are in LaTeX. The source for each problem is in a separate .tex file in a folder that includes that problem's .eps graphics files, if any. See the SampleTest folder for an example of how to assemble these problems into an exam, including how to put several problems on a single page.

Things you must know:

Definition of average velocity
Definition of momentum	The Momentum Principle

Other physical quantities:

$$\gamma \equiv \frac{1}{\sqrt{1-\left(\frac{|\vec{v}|}{c}\right)^2}}$$

$\hat{f} = \langle \cos\theta_x, \cos\theta_y, \cos\theta_z \rangle$ unit vector from angles

Constant	Symbol	Approximate Value
Speed of light	c	3×10^8 m/s
Approx. grav field near Earth's surface	g	9.8 N/kg
Electron mass	m_e	9×10^{-31} kg
Proton mass	m_p	1.7×10^{-27} kg
Neutron mass	m_n	1.7×10^{-27} kg
Avogadro's number	N_A	6.02×10^{23} atoms/mol

milli	m	1×10^{-3}	kilo	K	1×10^{3}
micro	μ	1×10^{-6}	mega	M	1×10^{6}
nano	n	1×10^{-9}	giga	G	1×10^{9}
pico	p	1×10^{-12}	tera	T	1×10^{12}

The Momentum Principle

File ID 02-002

A bird in flight is acted upon by the Earth and the air. Here are the positions of the bird at several times. Show all your calculations clearly!

Early time interval:

At $t = 4.46$ s, the position was $\langle 4.17, 3.54, -8.38 \rangle$ m
At $t = 4.49$ s, the position was $\langle 4.25, 3.50, -8.40 \rangle$ m

Late time interval:

At $t = 6.46$ s, the position was $\langle 12.25, 0.50, -10.40 \rangle$ m
At $t = 6.49$ s, the position was $\langle 12.27, 0.24, -10.42 \rangle$ m

(a) In the early time interval, from $t = 4.46$ s to $t = 4.49$ s, what was the average momentum of the bird? The mass of the bird is 70 grams (70×10^{-3} kg). Express your result as a vector.

(b) In the late time interval, from $t = 6.46$ s to $t = 6.49$ s, what was the average momentum of the bird? Express your result as a vector.

(c) In the time interval from $t = 4.46$ s (the start of the early time interval) to $t = 6.46$ s (the start of the late time interval), what was the average net force acting on the bird? Express your result as a vector.

File ID 02-003

A truck driver slams on the brakes and the momentum changes from $\langle 9 \times 10^4, 0, 0 \rangle$ kg $\cdot$ m/s to $\langle 3 \times 10^4, 0, 0 \rangle$ kg $\cdot$ m/s in 4 seconds due to a constant force of the road on the wheels of car. As a vector, write the force exerted by the road. Show your work.

File ID 02-006

An electron initially has momentum $\langle 2.7 \times 10^{-24}, 0, 0 \rangle$ kg · m/s. At time $t = 0$, a constant force $\vec{F}$ is applied to the electron for 1×10^{-11} seconds. At time $t = 1 \times 10^{-11}$ seconds the momentum of the electron is $\langle 2.7 \times 10^{-24}, 0, -1.6 \times 10^{-24} \rangle$ kg · m/s. Calculate the force $\vec{F}$. Show your work.

File ID 02-008

An object of mass 0.5 kg has a momentum $\langle 2, 8, 5\rangle$ kg $\cdot$ m/s. At this instant the object is acted on by a force $\langle 20, -50, 75\rangle$ N for 3×10^{-3} s (3 milliseconds). What is the momentum of the object at the end of this time interval? Show all your work.

File ID 02-009

An object had momentum $\langle 6, -4, 9 \rangle$ kg · m/s when a net force $\langle 20, 10, -15 \rangle$ N started to act on the object. After 0.03 seconds, what was the new momentum of the object?

File ID 02-010

At a certain instant, a particle is moving in the $+x$ direction with momentum $+10$ kg $\cdot$ m/s. During the next 0.1 s, a constant force acts on the particle: $F_x = -6$ N, and $F_y = +3$ N. What is the magnitude of the momentum of the particle at the end of this 0.1 s interval?

File ID 02-018

(a) State the Momentum Principle in words.

(b) State the Momentum Principle mathematically.

File ID 02-017

(a) Write down the definition of the momentum of a particle valid at all speeds. Please define any auxiliary quantities you use. Your answer must be exactly correct to receive credit, including arrows for vectors, correct subscripts, etc. There is no partial credit.

(b) Write down any **one** of the valid forms of the Momentum Principle. If you write more than one and any of them are incorrect, the whole problem will be marked as incorrect. Your answer must be exactly correct to receive credit, including arrows for vectors, correct subscripts, etc. There is no partial credit.

(c) A VPython program has created two spheres named `star` and `planet`. Write a statement to create an arrow whose tail is at the location of the star and whose tip is located at the planet.

File ID 02-019

A billiard ball on a billiards table has a momentum $\langle 3, 0, 4 \rangle$ kg $\cdot$ m/s. When a stick strikes the ball, a net force of $\langle 10, 4, -3 \rangle$ N acts on the billiard ball for 0.1 s. According to the momentum principle, the change in momentum of the billiard ball and the net force on the billiard ball

(a) are in opposite directions.

(b) are in the same direction.

(c) are not necessarily in the same or opposite directions, but can be.

File ID 02-020

A billiard ball on a billiards table has a momentum $\langle 3, 0, 4 \rangle$ kg $\cdot$ m/s. When a stick strikes the ball, a net force of $\langle 10, 4, -3 \rangle$ N acts on the billiard ball for 0.1 s. What is the final momentum of the ball after it is struck?

(a) $\langle 4, 0.4, 3.7 \rangle$ kg $\cdot$ m/s

(b) $\langle 0.1, 0.4, -0.3 \rangle$ kg $\cdot$ m/s

(c) $\langle 0.3, 0, 0.4 \rangle$ kg $\cdot$ m/s

(d) $\langle 7, 0, -7 \rangle$ kg $\cdot$ m/s

(e) $\langle 13, 4, 1 \rangle$ kg $\cdot$ m/s

File ID 02-022

A ping-pong ball with mass 2.7 grams (2.7×10^{-3} kg) is acted upon by the Earth, air resistance, and a strong wind. Here are the positions of the ball at several times.

At $t = 12.35$ s, the position was $\langle 3.17, 2.54, -9.38 \rangle$ m
At $t = 12.40$ s, the position was $\langle 3.38, 2.44, -9.42 \rangle$ m
At $t = 12.45$ s, the position was $\langle 3.54, 2.32, -9.46 \rangle$ m

(a) In the first time interval, from $t = 12.35$ s to $t = 12.40$ s, what was the average momentum of the ball?

(b) In the second time interval, from $t = 12.40$ s to 12.45 s, what was the average momentum of the ball?

(c) In the time interval from $t = 12.375$ s to $t = 12.425$ s (that is, from the midpoint of the first time interval to the midpoint of the second time interval), what was the average force acting on the ball?

File ID 02-021

A ping-pong ball is acted upon by the Earth, air resistance, and a strong wind. Here are the positions of the ball at several times.

Early time interval:

At $t = 12.35$ s, the position was $\langle 3.17, 2.54, -9.38 \rangle$ m

At $t = 12.37$ s, the position was $\langle 3.25, 2.50, -9.40 \rangle$ m

Late time interval:

At $t = 14.35$ s, the position was $\langle 11.25, -1.50, -11.40 \rangle$ m

At $t = 14.37$ s, the position was $\langle 11.27, -1.86, -11.42 \rangle$ m

(a) In the early time interval, from $t = 12.35$ s to $t = 12.37$ s, what was the average momentum of the ball? The mass of the ping-pong ball is 2.7 grams (2.7×10^{-3} kg).

(b) In the late time interval, from $t = 14.35$ s to $t = 14.37$ s, what was the average momentum of the ball?

(c) In the time interval from $t = 12.35$ s (the start of the early time interval) to $t = 14.35$ s (the start of the late time interval), what was the average net force acting on the ball?

File ID 02-026

You are working as a consultant to a theme park. You job is to ensure the safety of the children's rides. Fortunately, you have knowledge and experience in physics, human anatomy and physiology, and computers so that you can calculate the net force on a child, write a simulation, and understand whether the strain on a child's body will be too much to be healthy. For this particular project, you are studying a children's roller coaster.

(a) A child of mass 20 kg who is riding the roller coaster has a speed of 5 m/s in the direction $\langle 1, 0, 0 \rangle$. What is the momentum of the child? (Remember that momentum is a vector and should be expressed in component form.)

(b) Two seconds later, the child's velocity is 3 m/s in the direction $\langle 0.333, 0.667, 0.667 \rangle$. What was the net force on the child during this time interval? (You already know the child's initial momentum, but you will need to first calculate the final momentum of the child. Remember that net force is a vector and should be expressed in component form.)

File ID 02-035

The z-component of the momentum of a ball is observed to change with time.

At $t = 0$ s, $p_z = 12$ kg $\cdot$ m/s
At $t = 1$ s, $p_z = 7$ kg $\cdot$ m/s
At $t = 2$ s, $p_z = 2$ kg $\cdot$ m/s
At $t = 3$ s, $p_z = -3$ kg $\cdot$ m/s

Which of the following statements about the z component of the net force acting on the ball during the time the ball is observed is true?

A. The z component of the net force on the ball is zero.

B. The z component of the net force on the ball is constant.

C. The z component of the net force on the ball is changing with time.

D. Not enough information is given to determine the z component of the net force on the ball.

File ID 02-049

A falling rubber ball bounces off the floor. The velocity just before it hits the floor is $\langle 2.7, -5.2, 0\rangle$ m/s. Just after it hits the floor, the ball's velocity is $\langle 2.7, 5.2, 0\rangle$ m/s. The ball's mass is 0.038 kg. The ball is in contact with the floor for only 1.8×10^{-3} seconds.

(a) What is the vector change in momentum of the ball from just before to just after it is in contact with the floor? Express your result as a vector.

(b) What is the net force exerted on the ball during the time it is in contact with the floor? (You may assume the net force is approximately constant.) Express your result as a vector.

(c) Calculate the ratio of the magnitude of the net force on the ball to the magnitude of the gravitational force (due to the earth) on the ball.

(d) How far did the ball move horizontally during the time it was in contact with the floor? (That is, what is the x-component of the ball's change in position during this time?)

File ID 02-050

A falling rubber ball bounces off the floor. The velocity just before it hits the floor is $\langle 1.7, -4.2, 0\rangle$ m/s. Just after it hits the floor, the ball's velocity is $\langle 1.7, 4.2, 0\rangle$ m/s. The ball's mass is 0.038 kg. The ball is in contact with the floor for only 1.3×10^{-3} seconds.

(a) What is the vector change in momentum of the ball from just before to just after it is in contact with the floor? Express your result as a vector.

(b) What is the net force exerted on the ball during the time it is in contact with the floor? (You may assume the net force is approximately constant.) Express your result as a vector.

(c) Calculate the ratio of the magnitude of the net force on the ball to the magnitude of the gravitational force (due to the earth) on the ball.

(d) How far did the ball move horizontally during the time it was in contact with the floor? (That is, what is the x-component of the ball's change in position during this time?)

File ID 02-051

A falling rubber ball bounces off the floor. The velocity just before it hits the floor is $\langle 1.9, -6.2, 0\rangle$ m/s. Just after it hits the floor, the ball's velocity is $\langle 1.9, 6.2, 0\rangle$ m/s. The ball's mass is 0.046 kg. The ball is in contact with the floor for only 1.7×10^{-3} seconds.

(a) What is the vector change in momentum of the ball from just before to just after it is in contact with the floor? Express your result as a vector.

(b) What is the net force exerted on the ball during the time it is in contact with the floor? (You may assume the net force is approximately constant.) Express your result as a vector.

(c) Calculate the ratio of the magnitude of the net force on the ball to the magnitude of the gravitational force (due to the earth) on the ball.

(d) How far did the ball move horizontally during the time it was in contact with the floor? (That is, what is the x-component of the ball's change in position during this time?)

File ID 02-052

The momentum of a ball is observed to change uniformly with time as given below:

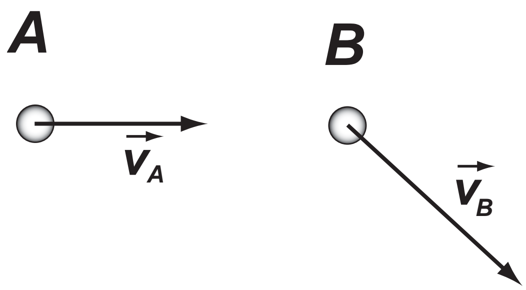
At $t = 0$ s, $\vec{p} = \langle 0, 0, 12 \rangle$ kg · m/s
At $t = 1$ s, $\vec{p} = \langle 0, 0, 7 \rangle$ kg · m/s
At $t = 2$ s, $\vec{p} = \langle 0, 0, 2 \rangle$ kg · m/s
At $t = 3$ s, $\vec{p} = \langle 0, 0, -3 \rangle$ kg · m/s

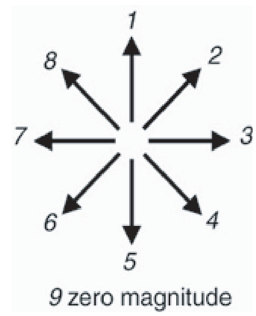
Which of the following statements are true about the net force acting on the ball during the time the ball is observed? ***Circle all that apply.***

A. The x component of the net force on the ball is zero.
B. The z component of the net force on the ball is zero.
C. The x component of the net force on the ball is constant.
D. The z component of the net force on the ball is constant.
E. The z component of the net force on the ball is positive.
F. The z component of the net force on the ball is negative.
G. The z component of the net force on the ball is changing with time.
H. The ball has no interaction with its surroundings during this time interval.

File ID 02-053

A baseball is rolling along with velocity $\vec{v}_A$. When the ball is at location B, you give it a sharp kick. The ball now rolls with velocity $\vec{v}_B$ in the direction shown. Circle the number (1-9) of the arrow which best indicates the direction in which your foot applied the force.





File ID 02-058

A rock with a mass of 0.15 kg is sliding on ice (with negligible friction) with a velocity $\langle 2,0,-4 \rangle$ m/s when a child kicks it. The child's foot exerts a force on the rock of $\langle 35,0,45 \rangle$ N for a time of 0.02 seconds. What is the **momentum** of the rock after the kick?

A. $\langle 2.7,0,-3.1 \rangle$ kg m/s

B. $\langle 35.3,0,44.4 \rangle$ kg m/s

C. $\langle 1.0,0,1.5 \rangle$ kg m/s

D. $\langle 1.0,0,0.3 \rangle$ kg m/s

E. $\langle -0.4,0,0.3 \rangle$ kg m/s

File ID 02-063

A hockey puck with a mass of 0.17 kg is moving with a velocity of $\langle 20, 0, 15\rangle$ m/s when it is hit by a hockey stick. The stick is in contact with the puck for a total time of 0.003 seconds. After the puck leaves contact with the stick, its new velocity is $\langle -8, 12, -35\rangle$ m/s. What was the net force on the puck while it was in contact with the stick?

A. $\langle -4.8, -2.0, -8.5\rangle$ N

B. $\langle -28, 12, -50\rangle$ N

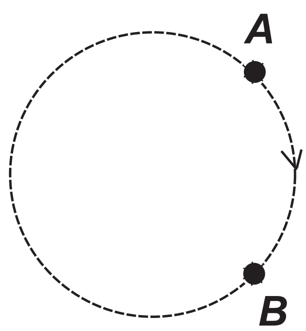
C. $\left\langle 1.6 \times 10^3, -680, 2.8 \times 10^3\right\rangle$ N

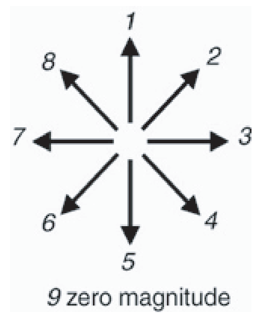
D. $\left\langle -1.6 \times 10^3, 680, -2.8 \times 10^3\right\rangle$ N

E. $\left\langle -9.3 \times 10^3, 4.0 \times 10^3, -1.7 \times 10^4\right\rangle$ N

File ID 02-064

A child rides a merry-go-round, traveling from location A to location B, in the clockwise direction as shown, at a constant speed. ***Use the direction rosette to answer parts (a) and (b) of this question.***





(a: 5pts) What is the direction of $\Delta\vec{p}$, the change in the child's momentum, between locations A and B?

Enter your answer here:

(b: 5pts) What is the direction of $\vec{F}_{net}$, the average vector value of the net force acting on the child as she moves from location A to location B?

Enter your answer here:

File ID 02-065

(a) Write the equation that relates an object's average velocity to its position. The equation, including correct subscripts and vector symbols, must be exactly correct–no partial credit. (There may be more than one correct way to write the equation.)

(b) Write the equation that expresses the **definition** of momentum. The equation, including correct subscripts and vector symbols, must be exactly correct–no partial credit. (There may be more than one correct way to write the equation.)

(c) Write the equation that expresses the **Momentum Principle**. The equation, including correct subscripts and vector symbols, must be exactly correct–no partial credit. (There may be more than one correct way to write the equation.)

File ID 02-083

Write “T” next to each true statement below, and write “F” for every false statement.

__________ The change in an object’s vector position can be in a different direction than its average velocity.

__________ An object’s momentum is always in the same direction as the net force on that object.

__________ The change in an object’s momentum can be in a different direction than its momentum.

__________ An object’s momentum and its instantaneous velocity are always in the same direction.

__________ If the net force on an object is contant, then the rate of change of its position is constant.

__________ If the net force on an object is contant, then the rate of change of its momentum is constant.

Iteration; Changing Force

File ID 02-038

A certain spring is 0.18 m long when relaxed. A force of 70 N is required to compress it so that its length is now 0.14 m. What is the stiffness of this spring? Show your work clearly.

File ID 02-039

A certain spring is 0.37 m long when relaxed. A force of 120 N is required to compress it so that its length is now 0.28 m. What is the stiffness of this spring? Show your work clearly.

File ID 02-046

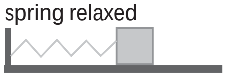
(a) A truck driver slams on the brakes and the momentum changes from $\left\langle 5\times10^4, 0, 9\times10^4 \right\rangle\ \text{kg}\cdot\dfrac{\text{m}}{\text{s}}$ to $\left\langle 3\times10^4, 0, 4\times10^4 \right\rangle\ \text{kg}\cdot\dfrac{\text{m}}{\text{s}}$ in 4 seconds due to a constant force of the road on the wheels of the car. As a vector, write the net force exerted by the road. Show your work.

(b) A spring is 0.19 m long when it is relaxed. When a force of 350 N is applied, the spring becomes 0.23 m long. What is the stiffness of this spring?

File ID 02-047

A 60 gram block is attached to a horizontal spring, of stiffness 13 N/m, which is attached at one end to a wall. The block rests on a slippery surface, so friction is negligible. When the spring is relaxed, its length is 0.6 m. You pull horizontally on the block, stretching the spring so its length is now 0.75 m. You make sure the block is at rest, then you release it, moving your hand away. Make the approximation that the force on the block by the spring is constant during the next 0.02 seconds. What is the magnitude of the change in the momentum of the block during this time interval?

spring relaxed



spring stretched

A. 0.0118 kg m/s

B. 1.95 kg m/s

C. 0.0390 kg m/s

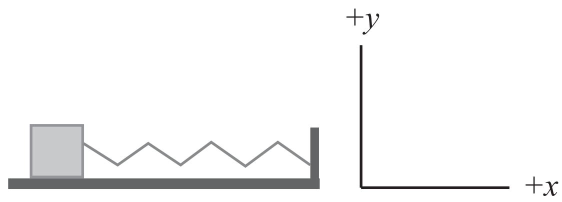
D. 0.0195 kg m/s

E. 0.650 kg m/s

File ID 02-048

A spring is 0.17 m long when it is relaxed. When a force of 250 N is applied, the spring becomes 0.24 m long. What is the stiffness of this spring?

File ID 02-079



The diagram above shows a block attached to a spring with a stiffness of 3.4 N/m. The relaxed length of the spring is 15 cm and its current length is 10 cm. What is the vector force that the spring exerts on the block?

A. $\langle -0.34, 0, 0\rangle$ N

B. $\langle 0.51, 0, 0\rangle$ N

C. $\langle -0.51, 0, 0\rangle$ N

D. $\langle 0.17, 0, 0\rangle$ N

E. $\langle -0.17, 0, 0\rangle$ N

File ID 02-007

An object with mass 25 kg has a net force of $\langle -50, 0, 150 \rangle$ N acting on it. At $t = 15$ s, it has a momentum of $\langle -30, 20, 45 \rangle$ kg $\cdot$ m/s.

(a) Determine the object's momentum at an earlier time $t = 10$ s. Start from a fundamental principle.

(b) If the position of the object is $\langle 0, -10, 25 \rangle$ m at $t = 10$ s, what is the new position of the object at $t = 15$ s?

File ID 02-014

A small space probe, of mass 264 kg, is launched from a spacecraft near Mars. It travels toward the surface of Mars, where it will land. 10.5 seconds after it is launched, the probe is at location $\langle 3.50 \times 10^3, 9.50 \times 10^2, 0 \rangle$ m, and its momentum is $\langle 3.80 \times 10^4, -9.80 \times 10^3, 0 \rangle$ kg $\cdot$ m/s. At this instant, the net force on the lander due to the gravitational pull of Mars plus the air resistance acting on the probe is $\langle -8 \times 10^3, -9.3 \times 10^2, 0 \rangle$ N.

(a) Assuming that the net force on the probe is approximately constant over this time interval, what will be the momentum of the lander 10.8 seconds after it had left the spacecraft?

(b) What is the location of the probe 10.8 seconds after it had left the spacecraft?

File ID 02-015

A small space probe, of mass 240 kg, is launched from a spacecraft near Mars. It travels toward the surface of Mars, where it will land. 20.7 seconds after it is launched, the probe is at location $\langle 4.3 \times 10^3, 8.7 \times 10^2, 0 \rangle$ m, and its momentum is $\langle 4.40 \times 10^4, -7.60 \times 10^3, 0 \rangle$ kg $\cdot$ m/s. At this instant, the net force on the lander due to the gravitational pull of Mars plus the air resistance acting on the probe is $\langle -7 \times 10^3, -9.2 \times 10^2, 0 \rangle$ N.

(a) Assuming that the net force on the lander is approximately constant over this time interval, what is the momentum of the lander 20.9 seconds after it is launched?

(b) What is the location of the lander 20.9 seconds after launch?

File ID 02-016

A small space probe, of mass 425 kg, is launched from a spacecraft near Mars. It travels toward the surface of Mars, where it will land. At a time, 30.6 seconds after it is launched, the probe is at location $\langle 4.6 \times 10^3, 8.4 \times 10^2, 0 \rangle$ m, and its momentum is $\langle 5.2 \times 10^4, -8.7 \times 10^3, 0 \rangle$ kg $\cdot$ m/s. At this instant, the net force on the lander due to the gravitational pull of Mars plus the air resistance acting on the probe is $\langle -6 \times 10^3, -5.2 \times 10^2, 0 \rangle$ N.

(a) What is the location of the probe 30.9 seconds after launch? Show your work.

(b) Assuming that the net force on the probe is approximately constant over this time interval, what is the momentum of the lander 30.9 seconds after it is launched? Show your work.

File ID 02-013

A small space probe, of mass 264 kg, is launched from a spacecraft near Mars. It travels toward the surface of Mars, where it will land. 0.5 seconds after it is launched, the probe is at location $\langle 3.5 \times 10^3, 9.5 \times 10^2, 0 \rangle$ m, and its momentum is $\langle 1.9 \times 10^6, -4.9 \times 10^5, 0 \rangle$ kg $\cdot$ m/s. At this instant, the net force on the lander due to the gravitational pull of Mars plus the air resistance acting on the probe is $\langle -8 \times 10^3, -9.3 \times 10^2, 0 \rangle$ N.

(a) Assuming that the net force on the lander is approximately constant over this time interval, what is the momentum of the lander 0.8 seconds after it is launched?

(b) What is the location of the lander 0.8 seconds after launch?

File ID 02-024

A proton moving along the x axis interacts electrically with a neutral HCl molecule located at the origin with a force that is approximately equal to $\frac{w}{x^3}$, where w is a constant.

(a) When the proton's position is $\left\langle 8 \times 10^{-10}, 0, 0 \right\rangle$ m, the HCl molecule exerts a force $\left\langle 9 \times 10^{-11}, 0, 0 \right\rangle$ N on the proton. Calculate w. Include appropriate units.

(b) Later, at a certain time t, the proton's position is $\left\langle 1.6 \times 10^{-9}, 0, 0 \right\rangle$ m and the proton's velocity is $\langle 3200, 800, 0 \rangle$ m/s. At a time $t + \left(2 \times 10^{-14}\ \text{s}\right)$, what is the approximate position of the proton, and what is its approximate velocity?

File ID 02-025

A proton interacts electrically with a neutral HCl molecule located at the origin. At a certain time t, the proton's position is $\left\langle 1.8 \times 10^{-9}, 0, 0 \right\rangle$ m and the proton's velocity is $\langle 3300, 900, 0 \rangle$ m/s. The force exerted on the proton by the HCl molecule is $\left\langle -1.12 \times 10^{-10}, 0, 0 \right\rangle$ N.

At a time $t + \left(3 \times 10^{-14}\ \text{s}\right)$, what is the approximate position of the proton, and what is its approximate velocity? Show your work.

File ID 02-023

A proton interacts electrically with a neutral HCl molecule located at the origin. At a certain time t, the proton's position is $\langle 1.6 \times 10^{-9}, 0, 0 \rangle$ m and the proton's velocity is $\langle 3200, 800, 0 \rangle$ m/s. The force exerted on the proton by the HCl molecule is $\langle -1.12 \times 10^{-11}, 0, 0 \rangle$ N. At a time $t + \left(2 \times 10^{-14} \text{ s}\right)$, what is the approximate velocity of the proton? Show your work.

File ID 02-027

A hockey puck with mass 0.4 kg is sliding along the ice in the $+x$ direction with speed 40 m/s. As the puck slides past the center of the rink, a player strikes the puck with a sudden force in the $+y$ direction, with magnitude 8×10^4 N. The contact between hockey stick and puck lasts only 1.2 milliseconds $\left(1.2 \times 10^{-3} \text{ seconds}\right)$. At a time 0.3 seconds later, where is the puck, and what is its speed? (Let the center of the rink be the origin. Friction between puck and ice is negligible.)

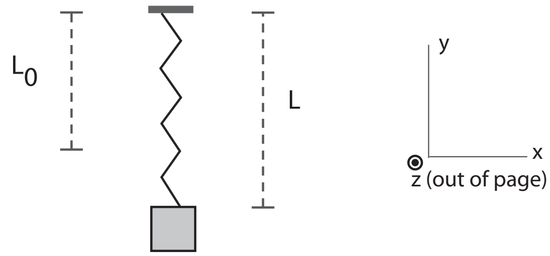
File ID 02-054

A batter strikes a baseball of mass 0.16 kg. After the ball leaves the bat and is flying through the air, at a particular instant it is at position $\langle 40, 50, 25\rangle$ m, and its momentum is $\langle 6.4, 8.0, -3.0\rangle$ kg $\cdot \frac{\text{m}}{\text{s}}$. 0.3 s later the ball's momentum is $\langle 6.3, 7.9, -3.8\rangle$ kg $\cdot \frac{\text{m}}{\text{s}}$.

(a) Assume that the net force is constant during this time interval. Calculate the vector net force $\vec{F}$ acting on the baseball due to gravity and air resistance. Start from a fundamental principle and show all your work.

(b) At the end of the 0.3 s time interval, what is the position vector of the baseball? Show all your work. Assume that $|\vec{v}_{avg}| \approx |\vec{v}_f|$

File ID 02-062



A block with a mass of 0.035 kg is oscillating vertically on a spring with a spring stiffness of 15 N/m and a relaxed length $L_0 = 0.30$ m. At the instant shown in the diagram, the spring's length is $L = 0.38$ m, and the block is moving downward at a speed of 1.9 m/s.

(a) What is the net force acting on the block? ***Express your answer as a three-component vector.***

(b) At this instant, the speed of the block is (circle one):

increasing decreasing not changing

(c) What is the new speed of the block 0.01 seconds after the instant shown in the diagram? ***Start from a fundamental principle and show all work.***

(Continued next page)

(continued from previous page)

(d) How far does the block move during this 0.01 second interval?

File ID 02-076

A spacecraft drifting in outer space has a mass of 5000 kg. At $t = 10$ s the spacecraft is at position $\langle 7000, 6000, 9000 \rangle$ m and has a velocity of $\langle 3000, -2000, 4000 \rangle$ m/s.

(a) What is the position of the spacecraft at $t = 15$ s?

(b) What is the momentum of the spacecraft from $t = 10$ s to $t = 15$ s?

(c) At $t = 15$ s, rocket engines on the spacecraft are activated. They apply a force of $\left\langle 2 \times 10^6, -1 \times 10^6, -0.5 \times 10^6 \right\rangle$ N on the spacecraft. The applied force lasts until $t = 30$ s, when the engines are turned off. What is the momentum of the spacecraft at $t = 30$ s?

File ID 02-077

A spacecraft drifting in outer space has a mass of 4000 kg. At $t = 10$ s the spacecraft is at position $\langle 5000, 3000, 4000 \rangle$ m and has a velocity of $\langle 2000, -1000, 3000 \rangle$ m/s.

(a) What is the position of the spacecraft at $t = 15$ s?

(b) What is the momentum of the spacecraft from $t = 10$ s to $t = 15$ s?

(c) At $t = 15$ s, rocket engines on the spacecraft are activated. They apply a force of $\left\langle 2 \times 10^6, -1 \times 10^6, -0.5 \times 10^6 \right\rangle$ N on the spacecraft. The applied force lasts until $t = 30$ s, when the engines are turned off. What is the momentum of the spacecraft at $t = 30$ s?

File ID 02-078

A spacecraft drifting in outer space has a mass of 6000 kg. At $t = 10$ s the spacecraft is at position $\langle 4000, -5000, 3000 \rangle$ m and has a velocity of $\langle -1000, -3000, 2000 \rangle$ m/s.

(a) What is the position of the spacecraft at $t = 15$ s?

(b) What is the momentum of the spacecraft from $t = 10$ s to $t = 15$ s?

(c) At $t = 15$ s, rocket engines on the spacecraft are activated. They apply a force of $\left\langle -0.5 \times 10^6, -2 \times 10^6, 1.5 \times 10^6 \right\rangle$ N on the spacecraft. The applied force lasts until $t = 30$ s, when the engines are turned off. What is the momentum of the spacecraft at $t = 30$ s?

File ID 02-080

A mass of 0.03 kg is attached to a *vertically-hanging* spring with a spring stiffness of 12 N/m and a relaxed length of 0.15 m. You grab the hanging mass hold it so that the spring's length is 0.17 m, then you release it from rest.

(a) What is the net force on the mass just after you release it? Express your final answer as a three-component vector, using the usual coordinate axes (i.e. positive x is right, positive y is up).

(b) What is the new velocity of the mass 0.02 seconds after you release it from rest? Express your final answer as a three-component vector, using the usual coordinate axes. You may assume the net force does not change much over this relatively short time period.

(c) What is the *change* in position of the mass from just after release to 0.02 seconds after release? Express your answer as a three-component vector, using the usual coordinate axes. You may assume the net force does not change much over this relatively short time period.

File ID 02-081

A mass of 0.04 kg is attached to a *vertically-hanging* spring with a spring stiffness of 11 N/m and a relaxed length of 0.15 m. You grab the hanging mass hold it so that the spring's length is 0.18 m, then you release it from rest.

(a) What is the net force on the mass just after you release it? Express your final answer as a three-component vector, using the usual coordinate axes (i.e. positive x is right, positive y is up).

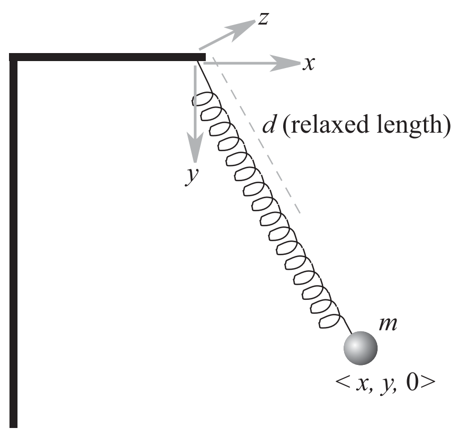
(b) What is the new velocity of the mass 0.03 seconds after you release it from rest? Express your final answer as a three-component vector, using the usual coordinate axes. You may assume the net force does not change much over this relatively short time period.

(c) What is the *change* in position of the mass from just after release to 0.03 seconds after release? Express your answer as a three-component vector, using the usual coordinate axes. You may assume the net force does not change much over this relatively short time period.

File ID 02-042

A small, massive ball of mass m hangs from a spring that is attached to a support. The spring's relaxed length is d and its stiffness is k_s. Use a coordinate system as shown, with origin at the top of the spring, with x to the right, y pointing down, and z pointing into the page. The ball is placed at location $\langle x_0, y_0, 0\rangle$ and given an initial momentum $\langle p_{x0}, p_{y0}, 0\rangle$; that is, it starts in the x-y plane, with initial momentum in the x-y plane. You can safely neglect air resistance.

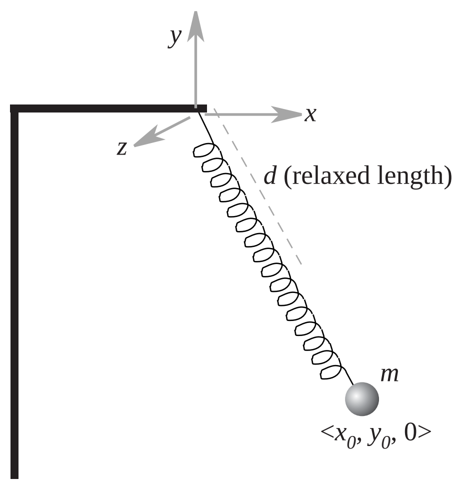
(a) Show that the ball will remain in the x-y plane. Give a brief but rigorous explanation based on fundamental physical principles.



(b) Write a computer program to predict and display the future motion of the ball. It is *not* necessary to get the details of program syntax correct, as long as you explain your logic and calculations clearly, and the steps follow a logical sequence.

File ID 02-043

A small, massive ball of mass m hangs from a low-mass spring that is attached to a support in the classroom. The springs relaxed length is d and its stiffness is k_s. Use a coordinate system as shown, with origin at the top of the spring, with x to the right, y pointing up, and z pointing out of the page. The ball is placed at location $\langle x_0, y_0, 0\rangle$ and given an initial momentum $\langle p_{x_0}, p_{y_0}, 0\rangle$; that is, it starts in the x-y plane, with initial momentum in the x-y plane. You can safely neglect air resistance.



(a) Show that the ball will remain in the x-y plane. Give a brief but rigorous explanation based on fundamental physics principles.

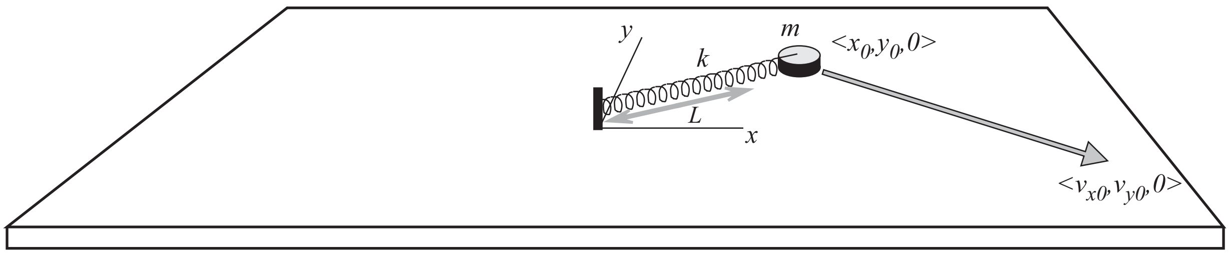
(problem continued on next page)

(b) Write a computer program in VPython to predict and display the future motion of the ball; you dont have to display the support and the spring. It is not necessary to get the details of program syntax correct, as long as you explain your logic and calculations clearly, and the steps follow a logical sequence. You do need to include all statements necessary to carry out the computation. We provide part of the initial setup.

```
from visual import *
# x0, y0, and r1 are known quantities
ball = sphere(pos=vector(x0,y0,0), radius=r1)
```

File ID 02-041

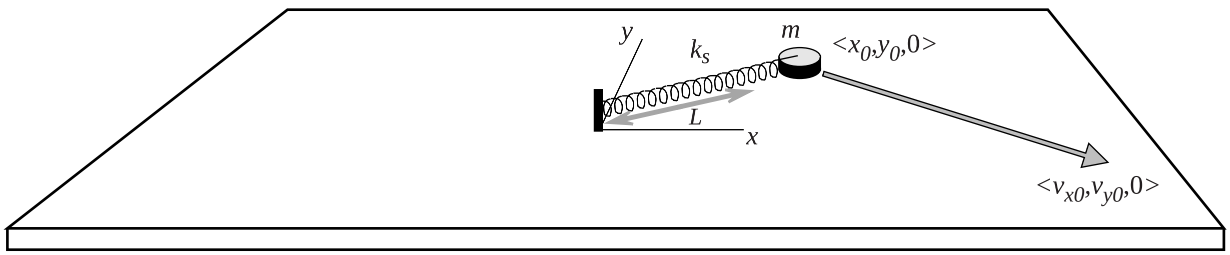
A spring whose relaxed length is L and whose stiffness is k is attached to a post sticking out of an air table. The other end is attached to a hockey puck of mass m which can slide with negligible friction on the air table. The puck is placed at location $\langle x_0, y_0, 0\rangle$ and given an initial velocity $\langle v_{x0}, v_{y0}, 0\rangle$.



Explain in detail how you would predict and display the future motion of the puck. Your explanation can take the form of a computer program, or you can explain carefully in words and equations all the necessary steps. It is *not* necessary to get the details of program syntax correct, as long as you explain your logic and calculations clearly, and the steps follow a logical sequence. Practical suggestion: It may be best to begin by outlining the sequence of operations, then work on the calculational details.

File ID 02-044

A spring whose relaxed length is L and whose stiffness is k_s is attached to a post sticking out of an air table. The other end is attached to a hockey puck of mass m which can slide with negligible friction on the air table. The puck is placed at location $\langle x_0, y_0, 0\rangle$ and given an initial velocity $\langle v_{x_0}, v_{y_0}, 0\rangle$.

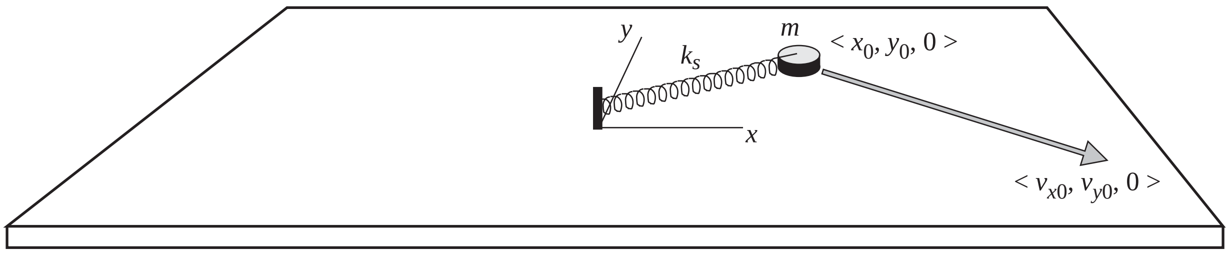


Write a computer program in VPython to predict and display the future motion of the puck; you don't have to display the post and the spring. It is not necessary to get the details of program syntax correct, as long as you explain your logic and calculations clearly, and the steps follow a logical sequence. You do need to include all statements necessary to carry out the computation. We provide part of the initial setup.

```
from visual import *
# x0, y0, and r1 are known quantities
puck = cylinder(pos=vector(x0,y0,0), radius=r1, axis=(0,0,r1/3.))
```

File ID 02-045

A spring whose relaxed length is nearly zero and whose stiffness is ks is attached to a post sticking out of a low-friction table. The other end is attached to a hockey puck of mass m which can slide with negligible friction on the table. The puck is placed at location $\langle x_0, y_0, 0\rangle$ and given an initial velocity $\langle v_{x0}, v_{y0}, 0\rangle$. The post is at the origin.



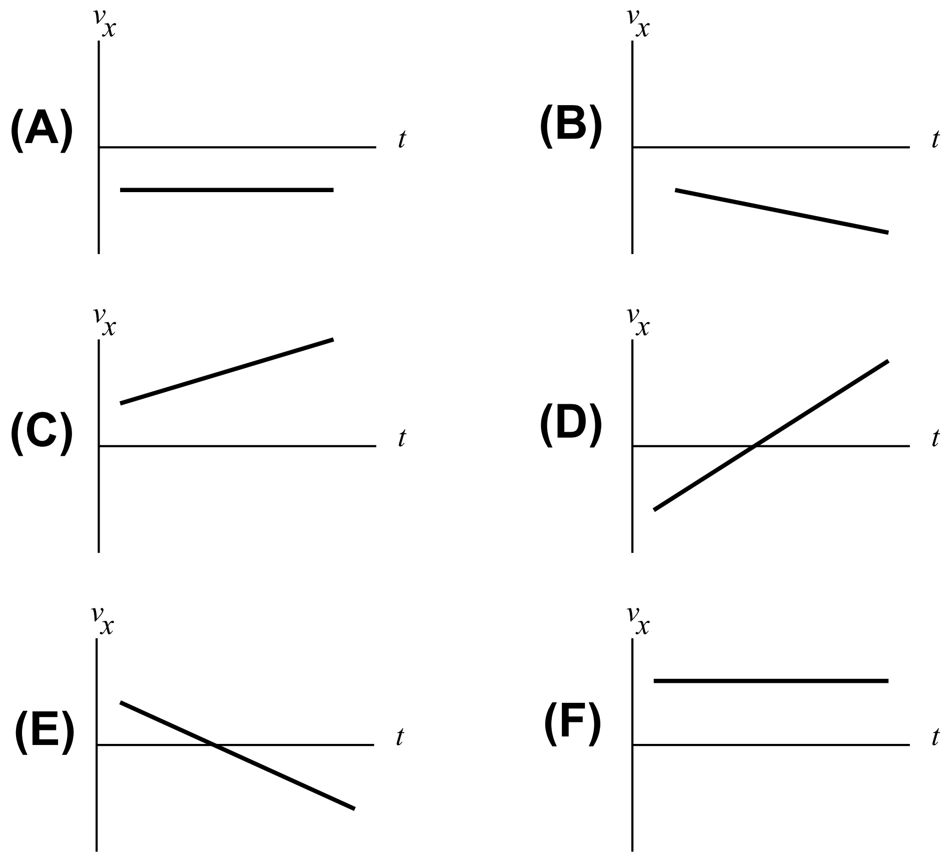
Complete a computer program in VPython to predict and display the future motion of the puck, looking down on the table. It is *not* necessary to get the details of program syntax correct, as long as you explain your logic and calculations clearly, and the steps follow a logical sequence. Don't worry about displaying the spring. Let m, k_s, x_0, y_0, v_{x0}, v_{y0} stand for actual numbers that you would enter into the program. Read the given parts of the program carefully before completing the program.

```
from visual import *
ks = ks # ks represents a given number
puck = cylinder(axis=vector(0,0,0.005), radius=0.04, color=color.red)
puck.pos = vector(x0,y0,0) # x0 and y0 represent given numbers
puck.m = m # m represents a given number

puck.p =                                                  # fill this in appropriately

deltat = 0.01

while True: # loop forever

# Remember that the relaxed length of this spring is nearly zero,
# so the stretch of the spring is equal to the length of the spring:

     L = mag(puck.pos) \# "mag(vector)" gives the magnitude of a vector

# Calculate the magnitude and unit vector for the force on the puck:

     Fmag =

     Fhat =

# Finish the program:
```

Constant Force

File ID 02-055

The graphs below plot the x-component of velocity versus time for a cart on a track that lies on x-axis. The graphs are labeled (A) through (F). On the following page are several statements which describe possible motions for the cart on the track. For each statement below, circle the letter (or letters) that correspond to the graph (or graphs) that fit each description. ***There may be more than one correct answer–circle all that apply.***



The cart moves in the +x direction at constant speed.

(A) (B) (C) (D) (E) (F) None of the graphs

The cart's moves in the -x direction at constant speed.

(A) (B) (C) (D) (E) (F) None of the graphs

The cart is stationary; its position does not change.

(A) (B) (C) (D) (E) (F) None of the graphs

The cart moves in the +x direction (during the entire time), gradually speeding up.

(A) (B) (C) (D) (E) (F) None of the graphs

(Continued next page)

The cart moves in the -x direction (during the entire time), gradually speeding up.

(A) (B) (C) (D) (E) (F) None of the graphs

The cart moves in the +x direction, gradually slowing down, stops, and then moves in the -x direction, speeding up.

(A) (B) (C) (D) (E) (F) None of the graphs

The cart moves in the -x direction, gradually slowing down, stops, and then moves in the +x direction, speeding up.

(A) (B) (C) (D) (E) (F) None of the graphs

The net force on the cart is changing.

(A) (B) (C) (D) (E) (F) None of the graphs

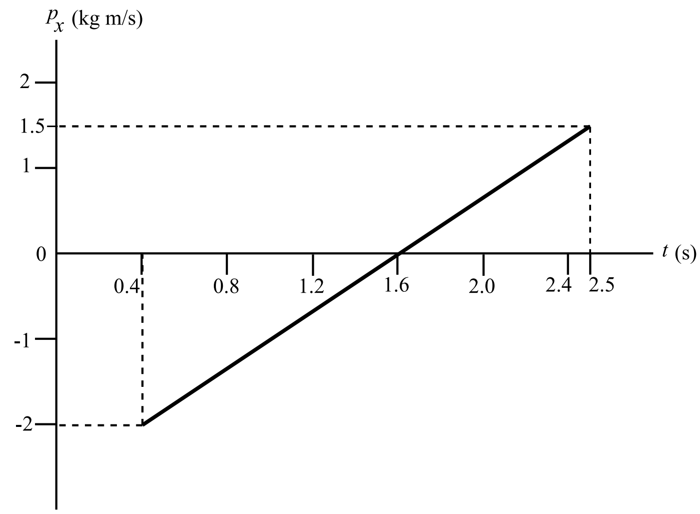
The net force on the cart is zero.

(A) (B) (C) (D) (E) (F) None of the graphs

The net force on the cart is constant but nonzero.

(A) (B) (C) (D) (E) (F) None of the graphs

File ID 02-056



(a) The graph above shows the plot of the x-component of the momentum of a 0.5 kg cart on a linear track from 0.4 to 2.5 s after $t = 0$. Which of the following statements below are true? **Circle all that apply.**

(A) The x-component of the cart's velocity is zero at $t = 1.6$ s.

(B) The direction of the cart's velocity does not change from 0.4 s to 2.5 s.

(C) The x-component of the cart's velocity is constant from 0.4 to 2.5 s.

(D) The x-component of the net force on the cart is negative x from 0.4 s to 1.6 s.

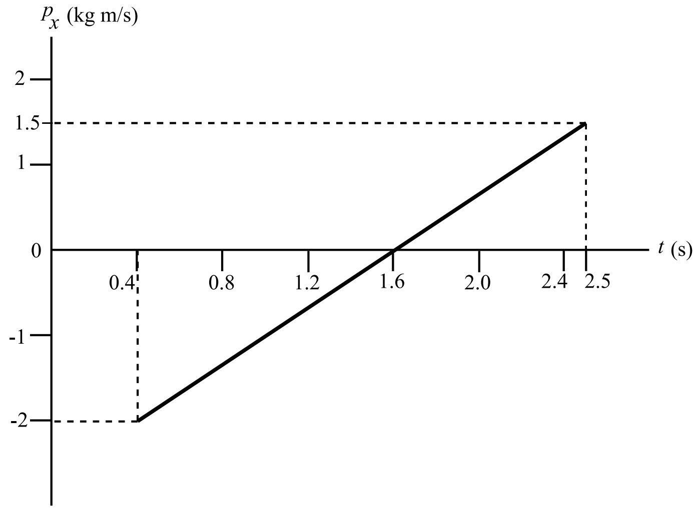
(E) The x-component of the net force on the cart is positive x from 1.6 s to 2.5 s.

(F) The x-component of the net force on the cart is constant from 0.4 s to 2.5 s.

(b) Based on the data from the graph, what is the x-component of the net force on the cart at $t = 1.6$ s?

(c) Based on the data from the graph, what is the x-component of the net force on the cart at $t = 2.0$ s?

File ID 02-057



(a) The graph above shows the plot of the x-component of the momentum of a 0.5 kg cart on a linear track from 0.4 to 2.5 s after $t = 0$. Which of the following statements below are true? **Circle all that apply.**

(A) The x-component of the net force on the cart is negative x from 0.4 s to 1.6 s.

(B) The x-component of the net force on the cart is positive x from 1.6 s to 2.5 s.

(C) The x-component of the net force on the cart is constant from 0.4 s to 2.5 s.

(D) The x-component of the cart's velocity is constant from 0.4 to 2.5 s.

(E) The direction of the cart's velocity does not change from 0.4 s to 2.5 s.

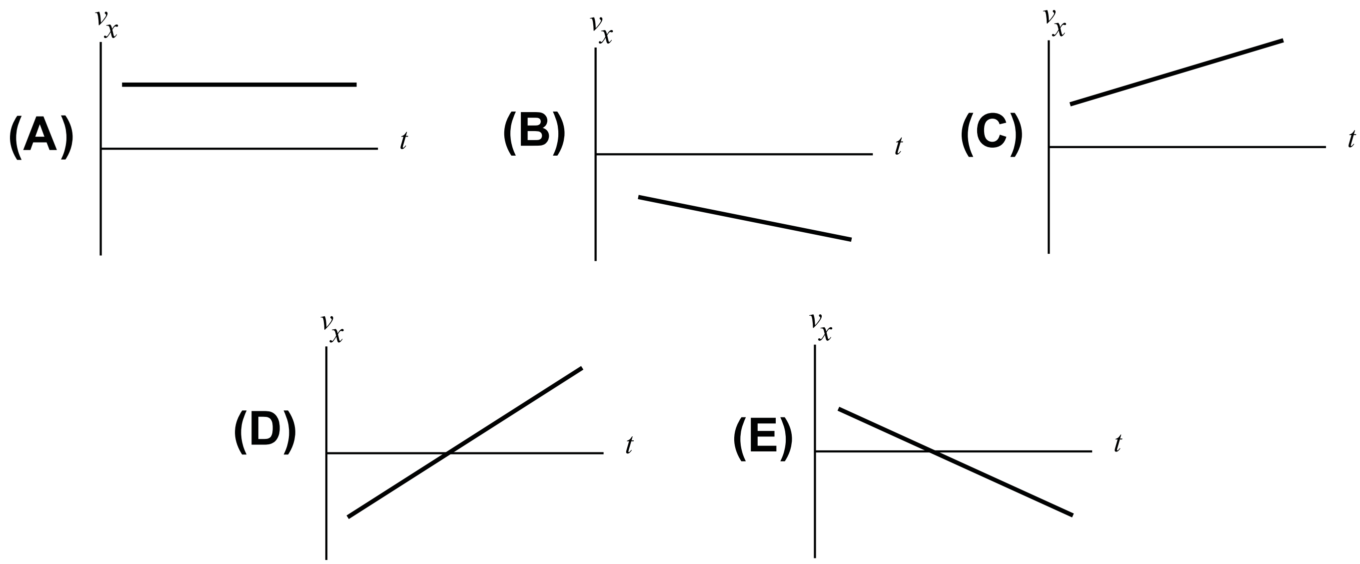
(F) The x-component of the cart's velocity is zero at $t = 1.6$ s.

(b) Based on the data from the graph, what is the x-component of the net force on the cart at $t = 1.6$ s?

(c) Based on the data from the graph, what is the x-component of the net force on the cart at $t = 2.0$ s?

File ID 02-059

Choose the letter that corresponds to the appropriate graph of the x-component of velocity vs. time for a cart on a track.



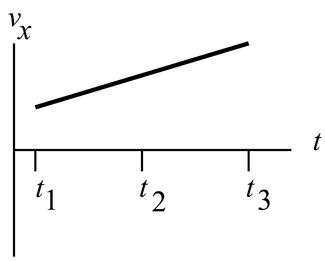
(a) The cart initially moves in the $-x$ direction and experiences a net force in the $+x$ direction.

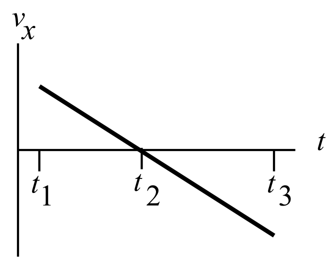
(b) The cart initially moves in the $-x$ direction and experiences a net force in the $-x$ direction.

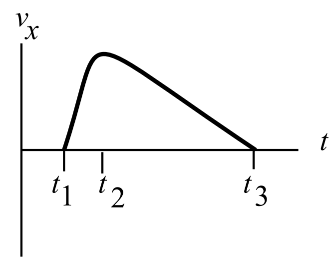
(c) The cart initially moves in the $+x$ direction and experiences a net force in the $+x$ direction.

File ID 02-060

The graphs below plot the x-component of velocity versus time for three different runs of a cart on a track that lies on x-axis. For each statement in the left column of the table, circle whether the statement is “True” or “False” for the graph in each column.



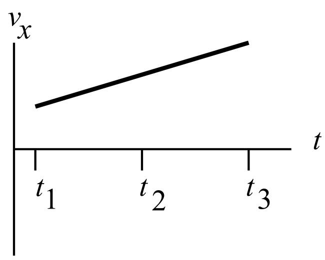
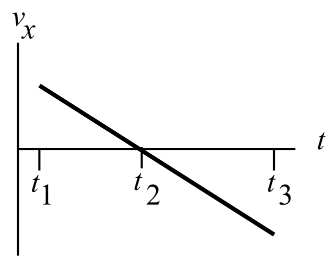
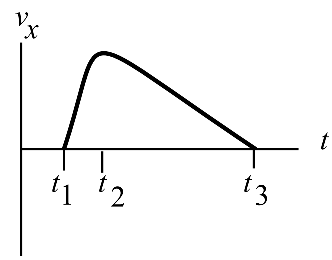




	Graph 1		Graph 2		Graph 3	
The net force is constant from t_1 to t_3	True	False	True	False	True	False
The momentum is constant from t_1 to t_3	True	False	True	False	True	False
The cart is momentarily at rest at time t_2	True	False	True	False	True	False
The direction of motion changes at time t_2	True	False	True	False	True	False
Between t_1 and t_2, the net force and the momentum are in opposite directions	True	False	True	False	True	False

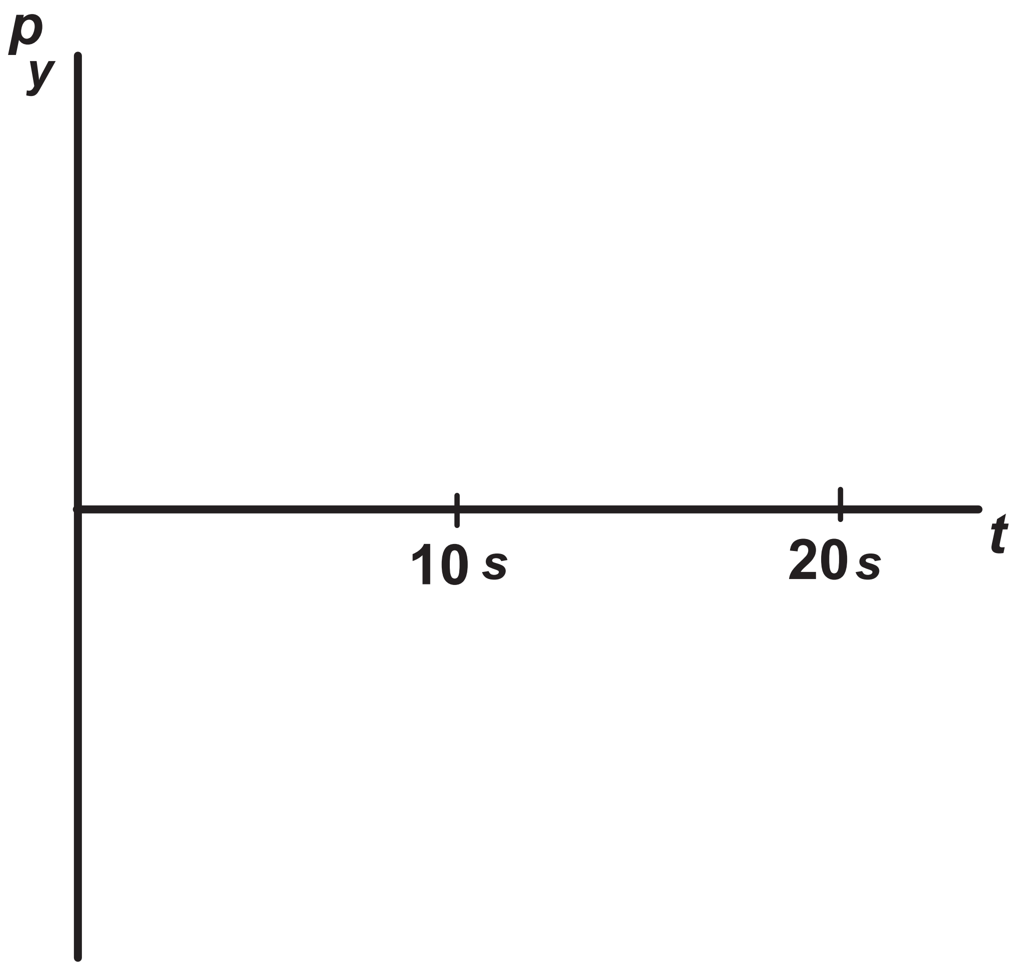
File ID 02-061

The graphs below plot the x-component of velocity versus time for three different runs of a cart on a track that lies on x-axis. For each statement in the left column of the table, circle whether the statement is "True" or "False" for the graph in each column.

			
The momentum is constant from t_1 to t_3	True False	True False	True False
The net force is constant from t_1 to t_3	True False	True False	True False
The direction of motion changes at time t_2	True False	True False	True False
The cart is momentarily at rest at time t_2	True False	True False	True False
Between t_1 and t_2, the net force and the momentum are in opposite directions	True False	True False	True False

File ID 02-066

A tennis ball is thrown straight up into the air with an initial speed v_y. It takes the ball 10 s to reach the maximum height and another 10 s for it to get back to the point from which it was thrown. For this problem, assume that air resistance is negligible.
On the diagram below, plot p_y, the y component of the momentum of the ball, vs. time for the 20 s the ball is in the air.



File ID 02-067

An object of mass 2.5 kg has a constant net force of $\langle -50, 0, 150 \rangle$ N acting on it. At t = 15 s, it has a momentum of $\langle -30, 20, 45 \rangle$ kg $\cdot \frac{\text{m}}{\text{s}}$.

(a: 10pts) Determine the object's momentum at an earlier time t = 10 s. ***You must start from the momentum principle and show all steps in your work***.

(b) If the position of the object was $\langle 0, -10, 25 \rangle$ m at t = 10 s, what is the new position of the object at t = 15 s? ***You must start with a valid form of the position update formula and show all steps in your work***.

File ID 02-068

You throw a small rock with a mass of 0.6 kg into the air. At the instant it leaves your hand, the velocity of the rock is $\langle 0.4, 3.5, 0\rangle$ m/s. The rock's initial position just after it leaves your hand is $\langle 0, 1.2, 0\rangle$ m. (In this problem, the y-axis is vertical, positive y is up, and the x-axis is horizontal. You may ignore air resistance.)

(a) What is the rock's momentum 0.30 seconds after it leaves your hand? ***Start from a fundamental principle or definition (or else you will not receive full credit).*** Express your answer as a three-component vector.

(b) What is the rock's position 0.30 seconds after it leaves your hand? ***Start from a fundamental principle or definition (or else you will not receive full credit).*** Express your answer as a three-component vector.

File ID 02-069

You throw a small rock with a mass of 0.8 kg into the air. At the instant it leaves your hand, the velocity of the rock is $\langle 0.6, 4.5, 0 \rangle$ m/s. The rock's initial position just after it leaves your hand is $\langle 0, 1.2, 0 \rangle$ m. (In this problem, the y-axis is vertical, positive y is up, and the x-axis is horizontal. You may ignore air resistance.)

(a) What is the rock's momentum 0.30 seconds after it leaves your hand? ***Start from a fundamental principle or definition (or else you will not receive full credit).*** Express your answer as a three-component vector.

(b) What is the rock's position 0.30 seconds after it leaves your hand? ***Start from a fundamental principle or definition (or else you will not receive full credit).*** Express your answer as a three-component vector.

File ID 02-070

You throw a small rock with a mass of 0.35 kg into the air. At the instant it leaves your hand, the rock's velocity is $\langle 0.21, 3.5, 0\rangle$ m/s. (Here, the y-axis is vertical and the x-axis is horizontal.) You may ignore the force of air resistance.

(a) What is the rock's initial momentum, just after it leaves your hand? Express your answer as a vector.

(b) What is the rock's momentum 0.28 seconds after it leaves your hand? ***Start from a fundamental principle (or else you will not receive full credit).*** Express your answer as a vector.

(c) Calculate the average velocity of the rock from just after it leaves your hand to 0.28 seconds later. (If you do not know how to do this, estimate a reasonable average velocity and justify your estimate). Express your answer as a vector.

(Continued next page)

(d) If the rock's initial position just as it leaves your hand is $\langle 0, 1.2, 0 \rangle$ m, find the vector position of the ball after 0.28 seconds.

File ID 02-071

You throw a small rock with a mass of 0.47 kg into the air. At the instant it leaves your hand, the rock's velocity is $\langle 0.39, 3.5, 0 \rangle$ m/s. (Here, the y-axis is vertical and the x-axis is horizontal.) You may ignore the force of air resistance.

(a) What is the rock's initial momentum, just after it leaves your hand? Express your answer as a vector.

(b) What is the rock's momentum 0.23 seconds after it leaves your hand? ***Start from a fundamental principle (or else you will not receive full credit).*** Express your answer as a vector.

(c) Calculate the average velocity of the rock from just after it leaves your hand to 0.23 seconds later. (If you do not know how to do this, estimate a reasonable average velocity and justify your estimate). Express your answer as a vector.

(Continued next page)

(d) If the rock's initial position just as it leaves your hand is $\langle 0, 1.2, 0 \rangle$ m, find the vector position of the ball after 0.23 seconds.

File ID 02-072

You throw a small rock with a mass of 0.19 kg into the air. At the instant it leaves your hand, the rock's velocity is $\langle 0.45, 2.6, 0\rangle$ m/s. (Here, the y-axis is vertical and the x-axis is horizontal.) You may ignore the force of air resistance.

(a) What is the rock's initial momentum, just after it leaves your hand? Express your answer as a vector.

(b) What is the rock's momentum 0.29 seconds after it leaves your hand? ***Start from a fundamental principle (or else you will not receive full credit).*** Express your answer as a vector.

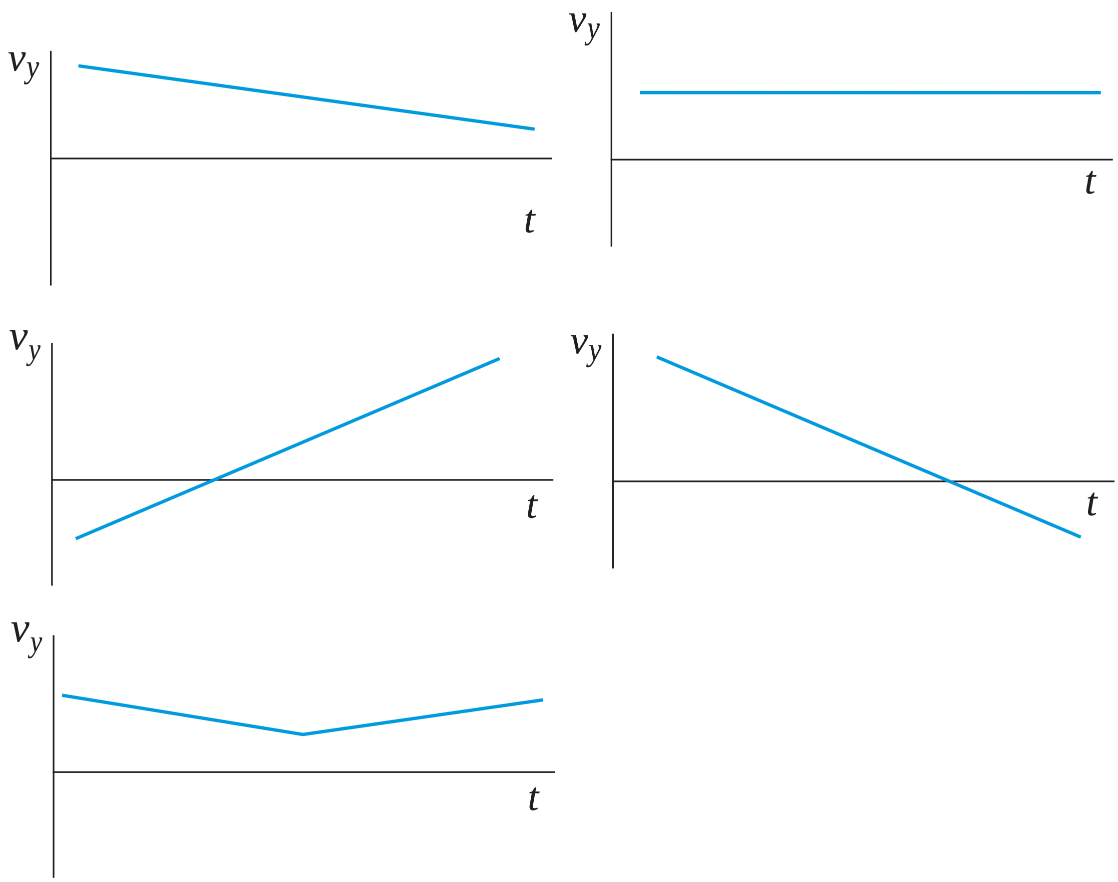
(c) Calculate the average velocity of the rock from just after it leaves your hand to 0.29 seconds later. (If you do not know how to do this, estimate a reasonable average velocity and justify your estimate). Express your answer as a vector.

(Continued next page)

(d, 8 pts) If the rock's initial position just as it leaves your hand is $\langle 0, 1.2, 0 \rangle$ m, find the vector position of the ball after 0.29 seconds.

File ID 02-082

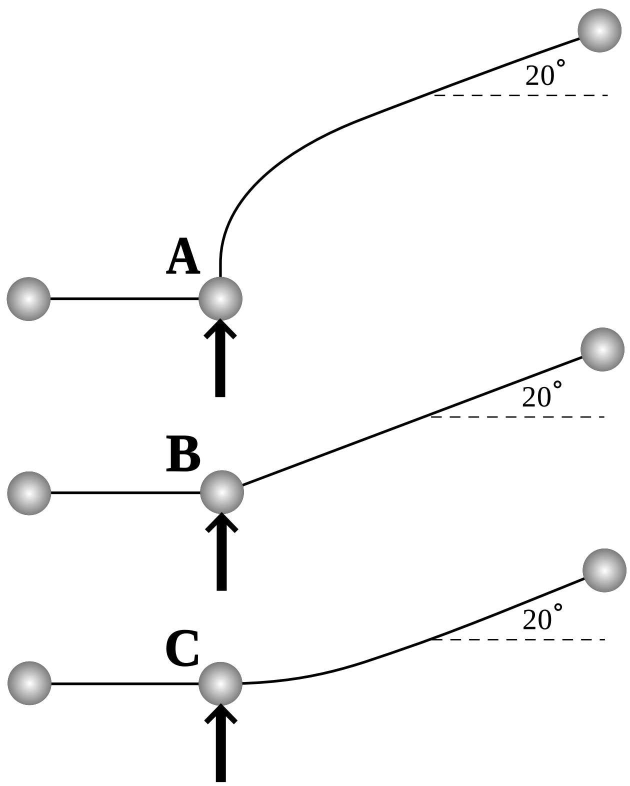
Several graphs of v_y *vs.* t for the motion of a toy helicopter are shown below. The helicopter interacts with the Earth and with the air; all other interactions are negligible. In which case was $\left|\vec{F}_{air}\right| = \left|\vec{F}_{grav}\right|$? Circle the correct graph.



Estimating Interaction Times

File ID 02-001

A 0.6 kg basketball is rolling by you at 3.5 m/s. As it goes by, you give it a kick perpendicular to its path. Your foot is in contact with the ball for 0.002 s. The ball eventually rolls at a 20° angle from its original direction. The overhead view is approximately to scale. The arrow represents the force your toe applies briefly to the basketball.



(a) Circle the letter corresponding to the correct overhead view of the ball's path:

A B C

(b) Determine the magnitude of the average force you applied to the ball. You may if you wish make the approximation that the change in speed of the basketball is negligible.

File ID 02-004

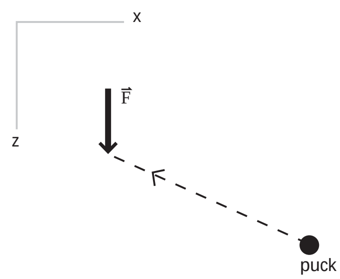
Two students are running to classes in opposite directions. They run into each other head-on and stop abruptly. Using physics principles, estimate the force that one student exerts on the other during the collision. You will need to estimate some quantities; give reasons for your choices.

File ID 02-005

Two students are running to classes in opposite directions. They run into each other head-on and stop abruptly. Using physics principles, estimate the force that one student exerts on the other during the collision. You will need to estimate some quantities; give reasons for your choices and provide checks showing that your estimates are physically reasonable.

File ID 02-034

A hockey puck of mass 0.17 kg slides across the ice, traveling at constant speed in a straight line in the xz plane. At a particular time, the location of the puck is $\langle 18.5, 0, 9.2 \rangle$ m, relative to an origin in the center of the ice rink. 0.2 seconds later, the location of the puck is $\langle 15.5, 0, 7.6 \rangle$ m. When the puck reaches location $\langle 8, 0, 3.6 \rangle$ m a player strikes it sharply with a hockey stick, exerting a force of $\langle 0, 0, 200 \rangle$ N. The impact lasts 0.005 seconds.



What is the location of the puck at a time 0.5 seconds after the impact?

File ID 02-012

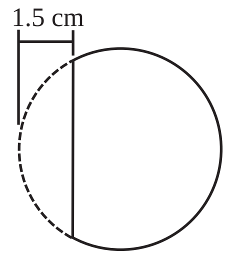
A hockey puck with mass 0.4 kg is sliding along the ice in the +x direction with speed 50 m/s. As the puck slides past location $\langle 5, 3, 0 \rangle$ m on the rink, a player strikes the puck with a sudden force in the +y direction, and the hockey stick breaks. A short time later, the pucks position on the rink is $\langle 15, 11, 0 \rangle$ m. When we pile weights on the side of a hockey stick we find that the stick breaks under a force of about 1000 N.

(a) For approximately how much time was the hockey stick in contact with the puck? Be sure to explain briefly the steps in your analysis.

(b) What approximations and/or simplifying assumptions did you make in your analysis?

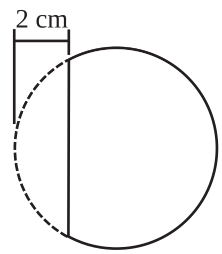
File ID 02-029

A tennis ball has a mass of 0.06 kg. A professional tennis player hits the ball hard enough to give it a speed of 45 m/s (about 100 miles per hour). The ball hits a wall and bounces back with almost the same speed (45 m/s). As indicated in the diagram, high-speed photography shows that the ball is crushed 1.5 cm (0.015 m) at the instant when its speed is momentarily zero, before rebounding. Determine the approximate force that the wall exerts on the ball.



File ID 02-030

A tennis ball has a mass of 0.057 kg. A professional tennis player hits the ball hard enough to give it a speed of 50 m/s (about 120 miles per hour). The ball hits a wall and bounces back with almost the same speed (50 m/s). As indicated in the diagram, high-speed photography shows that the ball is crushed 2 cm (0.02 m) at the instant when its speed is momentarily zero, before rebounding.



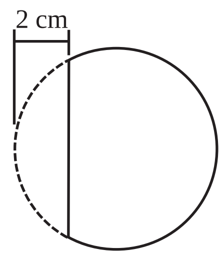
Making the very rough approximation that the large force that the wall exerts on the ball is approximately constant during contact, determine the approximate magnitude of this force. Hint: Think about the approximate amount of time it takes for the ball to come momentarily to rest.

File ID 02-031

A hard hit tennis ball may travel at a speed of about 50 m/s (about 110 miles per hour). Its mass is 57 grams (0.057 kg). Estimate the magnitude of the force exerted on the tennis ball when it hits a rigid wall and bounces back with its speed nearly unchanged. Explain carefully what approximations or simplifying assumptions you make.

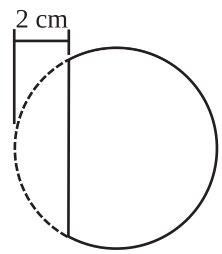
File ID 02-032

A tennis ball has a mass of 0.057 kg. A professional tennis player hits the ball hard enough to give it a speed of 50 m/s (about 120 miles per hour). The ball hits a wall and bounces back with almost the same speed. As indicated in the diagram, high-speed photography shows that the ball is crushed 2 cm (0.02 m) at the instant when its speed is momentarily zero, before rebounding. Determine the approximate force that the wall exerts on the ball.



File ID 02-028

A tennis ball has a mass of 0.057 kg. A professional tennis player hits the ball hard enough to give it a speed of 50 m/s (about 120 miles per hour). The ball hits a wall and bounces back with almost the same speed (50 m/s). As indicated in the diagram, high-speed photography shows that the ball is crushed 2 cm (0.02 m) at the instant when its speed is momentarily zero, before rebounding.

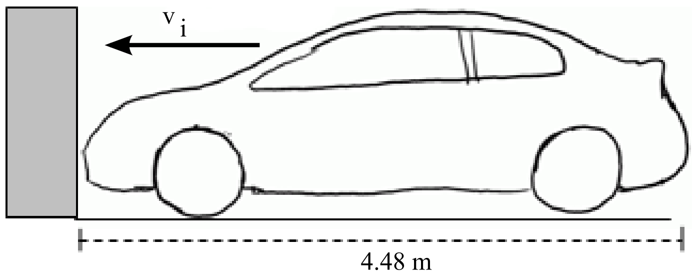


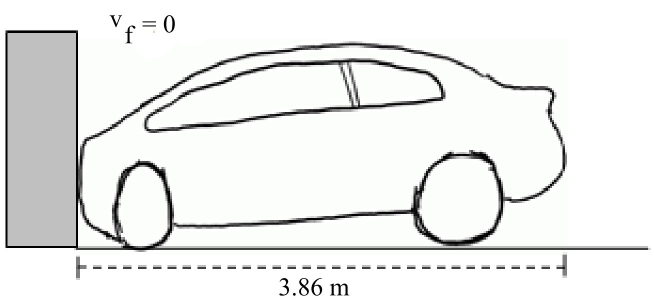
Making the very rough approximation that the large force that the wall exerts on the ball is approximately constant during contact, determine the approximate magnitude of this force. Hint: Think about the approximate amount of time it takes for the ball to come momentarily to rest. (For comparison note that the gravitational force on the ball is quite small, only about $(0.057\,\text{kg})\left(9.8\frac{\text{N}}{\text{kg}}\right) \approx 0.6\,\text{N}$. A force of 5 N force is approximately the same as a force of one pound.) Show your work.

File ID 02-033

In a crash test, a truck with mass 2200 kg traveling at 25 m/s (about 55 miles per hour) smashes head-on into a concrete wall without rebounding. The front end crumples so much that the car is 0.8 m shorter than before. Estimate the magnitude of the force exerted on the truck by the wall. Explain your analysis carefully, and justify your estimate on physical grounds.

File ID 02-073





In a crash test, a car with a mass of 1500 kg is initially moving at a speed of 18 m/s just before it collides with a barrier. The final speed of the car after the collision is zero. The original length of the car is 4.48 m, but after the collision, the smashed car is only 3.86 m long.

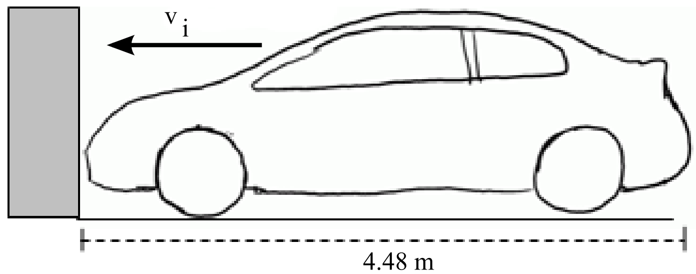
(a) What is the average speed of the car during the period from first contact with the barrier to the moment the car comes to a stop? You may assume the force that the barrier exerts on the car is constant during this period.

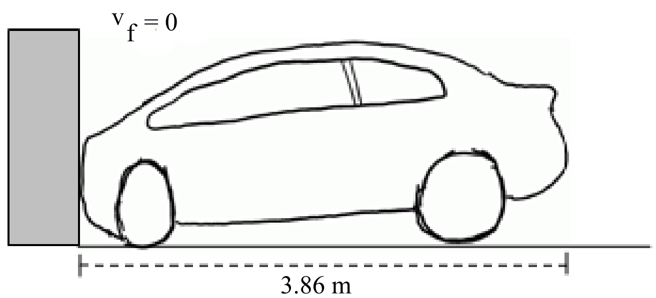
(b) How much time elapses between the moment the car makes first contact with the barrier and the moment it comes to a stop?

(Continued on next page)

(c) What is the average force that the barrier exerts on the car during the collision?

File ID 02-074





In a crash test, a car with a mass of 1300 kg is initially moving at a speed of 14 m/s just before it collides with a barrier. The final speed of the car after the collision is zero. The original length of the car is 4.48 m, but after the collision, the smashed car is only 3.86 m long.

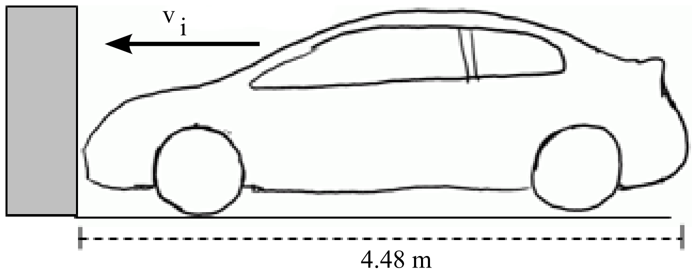
(a) What is the average speed of the car during the period from first contact with the barrier to the moment the car comes to a stop? You may assume the force that the barrier exerts on the car is constant during this period.

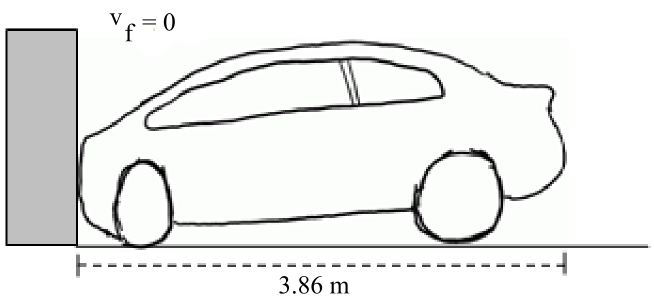
(b) How much time elapses between the moment the car makes first contact with the barrier and the moment it comes to a stop?

(Continued on next page)

(c) What is the average force that the barrier exerts on the car during the collision?

File ID 02-075





In a crash test, a car with a mass of 1800 kg is initially moving at a speed of 20 m/s just before it collides with a barrier. The final speed of the car after the collision is zero. The original length of the car is 4.48 m, but after the collision, the smashed car is only 3.86 m long.

(a) What is the average speed of the car during the period from first contact with the barrier to the moment the car comes to a stop? You may assume the force that the barrier exerts on the car is constant during this period.

(b) How much time elapses between the moment the car makes first contact with the barrier and the moment it comes to a stop?

(Continued on next page)

(c) What is the average force that the barrier exerts on the car during the collision?