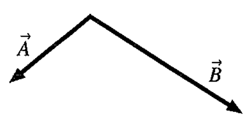
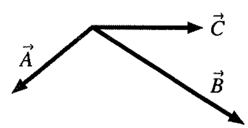
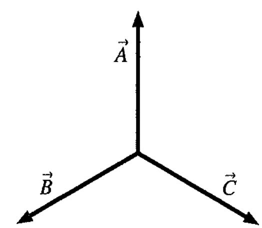
3 Vectors and Motion in Two Dimensions

3.1 Using Vectors

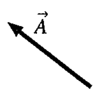
Exercises 1–3: Draw and label the vector sum $\vec{A} + \vec{B}$ or $\vec{A} + \vec{B} + \vec{C}$.

1.


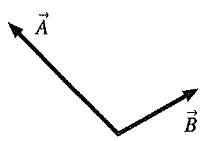
2.


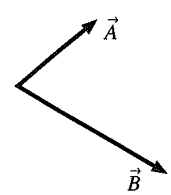
3.


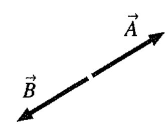
4. Draw and label the vector $2\vec{A}$ and the vector $\frac{1}{2}\vec{A}$.



Exercises 5–7: Draw and label the vector difference $\vec{A} - \vec{B}$.

5.


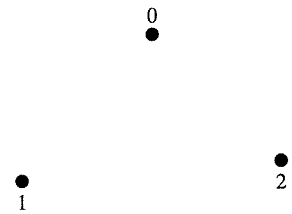
6.


7.


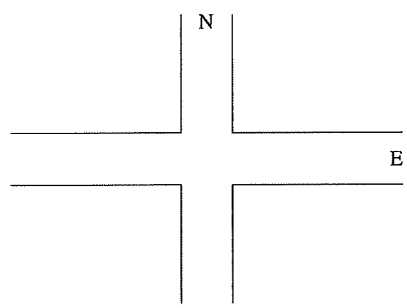
8. Given vectors $\vec{A}$ and $\vec{B}$ below, find the vector $\vec{C} = 2\vec{A} - 3\vec{B}$.

3.2 Using Vectors on Motion Diagrams

9. The figure below shows the positions of a moving object at three successive points in a motion diagram. Draw and label the velocity vector $\vec{v}_0$ for the motion from 0 to 1 and the vector $\vec{v}_1$ for the motion from 1 to 2. Then determine and draw the vector $\vec{v}_1 - \vec{v}_0$ with its tail on point 1.



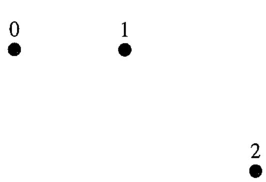
10. A car enters an icy intersection traveling 16 m/s due north. After a collision with a truck, the car slides away moving 12 m/s due east. Draw arrows on the picture below to show (i) the car's velocity $\vec{v}_0$ when entering the intersection, (ii) its velocity $\vec{v}_1$ when leaving, and (iii) the car's change in velocity $\Delta\vec{v} = \vec{v}_1 - \vec{v}_0$ due to the collision.



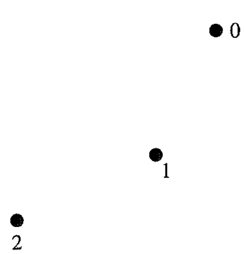
Exercises 11–12: The figures below show an object's position at three successive points in a motion diagram. For each diagram:

- Draw and label the initial and final velocity vectors $\vec{v}_0$ and $\vec{v}_1$. Use **black**.
- Use the steps of Tactics Box 3.2 to find the change in velocity $\Delta\vec{v}$.
- Draw and label $\vec{a}$ at the proper location on the motion diagram. Use **red**.
- Determine whether the object is speeding up, slowing down, or moving at a constant speed. Write your answer beside the diagram.

11.

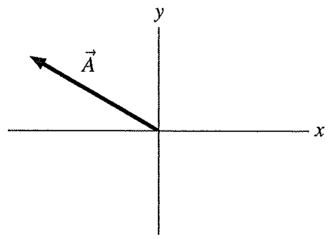


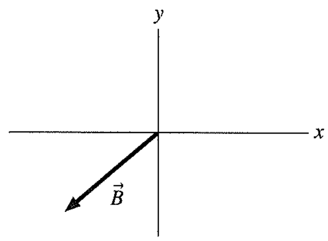
12.

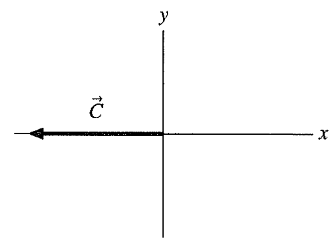


3.3 Coordinate Systems and Vector Components

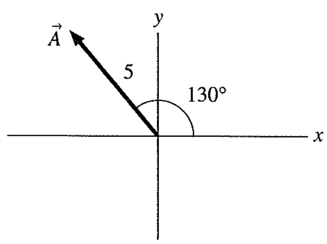
Exercises 13–15: Draw and label the *x*- and *y*-component vectors of the vector shown.

13.


14.


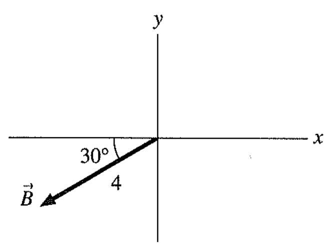
15.


Exercises 16–18: Determine the numerical values of the *x*- and *y*-components of each vector.

16.


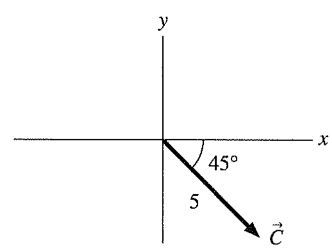
$A_x =$ ____________

$A_y =$ ____________

17.


$B_x =$ ____________

$B_y =$ ____________

18.


$C_x =$ ____________

$C_y =$ ____________

19. What is the vector sum $\vec{D} = \vec{A} + \vec{B} + \vec{C}$ of the three vectors defined in Exercises 16–18?

$D_x =$ ____________ $D_y =$ ____________

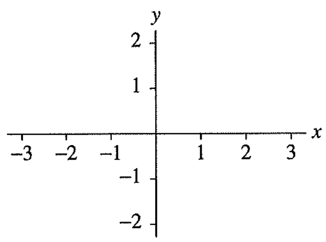
20. Can a vector have a component equal to zero and still have nonzero magnitude? Explain.

21. Can a vector have zero magnitude if one of its components is nonzero? Explain.

Exercises 22–24: For each vector:

- Draw the vector on the axes provided.
- Draw and label an angle θ to describe the direction of the vector.
- Find the magnitude and the angle of the vector.

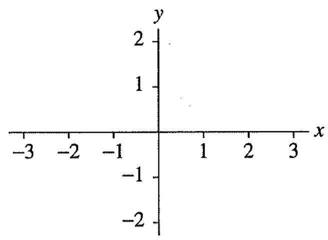
22. $A_x = 3, A_y = -2$



$A =$ ____________

$\theta =$ ____________

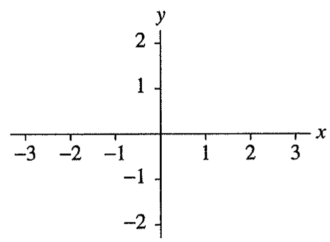
23. $B_x = -2, B_y = 2$



$B =$ ____________

$\theta =$ ____________

24. $C_x = 0, C_y = -2$

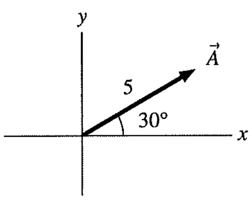


$C =$ ____________

$\theta =$ ____________

Exercises 25–27: Define vector $\vec{A}$ = (5, 30° above the horizontal). Determine the components A_x and A_y in the three coordinate systems shown below. Show your work below the figure.

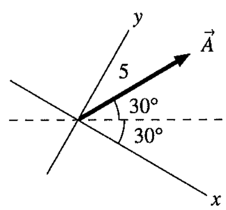
25.



$A_x =$ ____________

$A_y =$ ____________

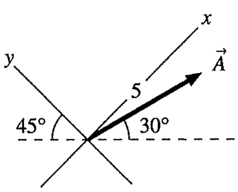
26.



$A_x =$ ____________

$A_y =$ ____________

27.

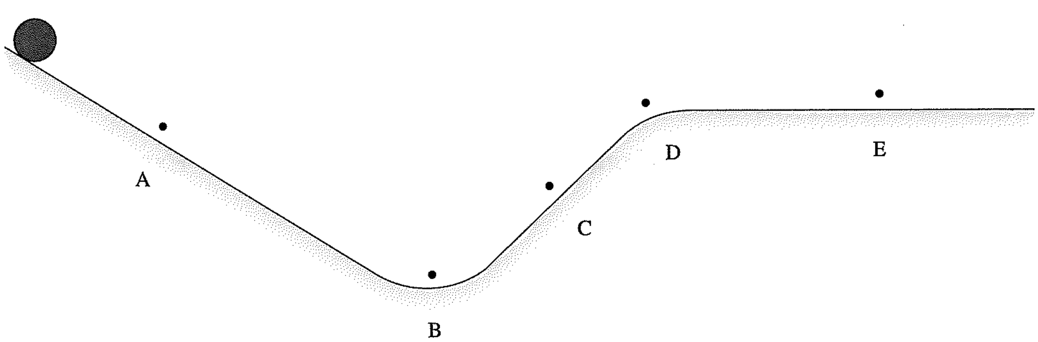


$A_x =$ ____________

$A_y =$ ____________

3.4 Motion on a Ramp

28. The figure shows a ramp and a ball that rolls along the ramp. Draw vector arrows on the figure to show the ball's acceleration at each of the lettered points A to E (or write $\vec{a} = \vec{0}$, if appropriate).

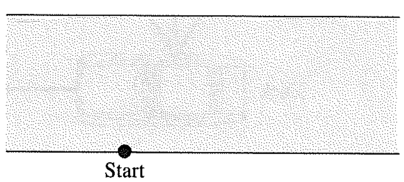


3.5 Relative Motion

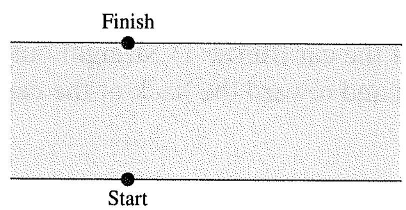
29. On a ferry moving steadily forward in still water at 5 m/s, a passenger walks toward the back of the boat at 2 m/s. (i) Write a symbolic equation to find the velocity of the passenger with respect to the water using $(v_x)_{AB}$ notation. (ii) Substitute the appropriate values into your equation to determine the value of that velocity.

30. A boat crossing a river can move at 5 m/s with respect to the water. The river is flowing to the right at 3 m/s. In (a), the boat points straight across the river and is carried downstream by the water. In (b), the boat is angled upstream by the amount needed for it to travel straight across the river. For each situation, draw the velocity vectors $\vec{v}_{RS}$ of the river with respect to the shore, $\vec{v}_{BR}$ of the boat with respect to the river, and $\vec{v}_{BS}$ of the boat with respect to the shore.

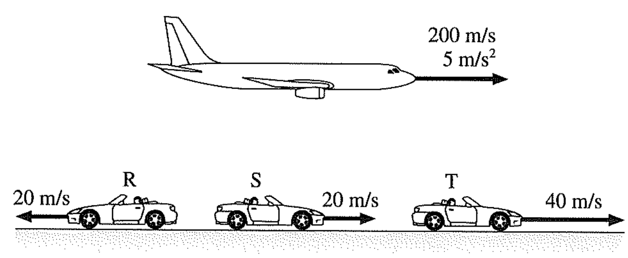
a.



b.



31. Ryan, Samantha, and Tomas are driving their convertibles. At the same instant, they each see a jet plane with an instantaneous velocity of 200 m/s and an acceleration of 5 m/s^2. Rank in order, from largest to smallest, the jet's *speed* v_R, v_S, and v_T according to Ryan, Samantha, and Tomas. Explain.

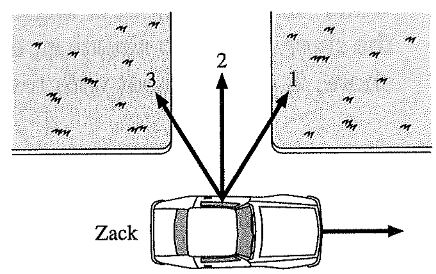


Order:

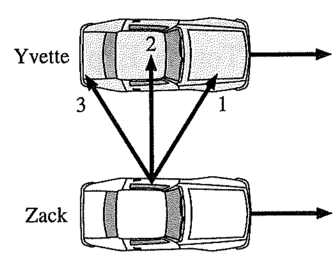
Explanation:

32. An electromagnet on the ceiling of an airplane holds a steel ball. When a button is pushed, the magnet releases the ball. The experiment is first done while the plane is parked on the ground, and the point where the ball hits the floor is marked with an X. Then the experiment is repeated while the plane is flying level at a steady 500 mph. Does the ball land slightly in front of the X (toward the nose of the plane), on the X, or slightly behind the X (toward the tail of the plane)? Explain.

33. Zack is driving past his house. He wants to toss his physics book out the window and have it land in his driveway. If he lets go of the book exactly as he passes the end of the driveway, should he direct his throw outward and toward the front of the car (throw 1), straight outward (throw 2), or outward and toward the back of the car (throw 3)? Explain.

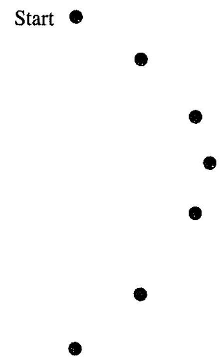


34. Yvette and Zack are driving down the freeway side by side with their windows rolled down. Zack wants to toss his physics book out the window and have it land in Yvette's front seat. Should he direct his throw outward and toward the front of the car (throw 1), straight outward (throw 2), or outward and toward the back of the car (throw 3)? Explain.



3.6 Motion in Two Dimensions: Projectile Motion

35. Complete the motion diagram for this trajectory, showing velocity and acceleration vectors.



36. A projectile is launched over level ground and lands some distance away.

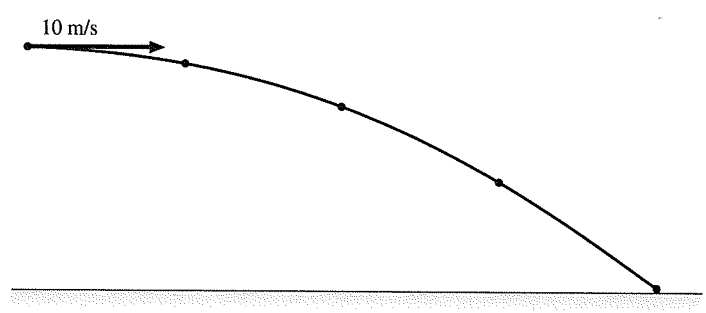
a. Is there any point on the trajectory where $\vec{v}$ and $\vec{a}$ are parallel to each other? If so, where?

b. Is there any point where $\vec{v}$ and $\vec{a}$ are perpendicular to each other? If so, where?

c. Which of the following remain constant throughout the flight: x, y, v, v_x, v_y, a_x, a_y?

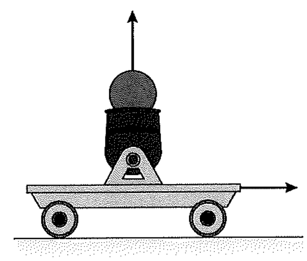
37. A ball is projected horizontally at 10 m/s and hits the ground 2.0 s later. The figure shows the ball's position every 0.5 s.

- At each dot, starting with $t = 0.5$ s, draw a vector for the horizontal component of velocity v_x and a vector for the vertical component of velocity v_y.
- Label each vector with the numerical value of the velocity component at that point.
- The length of each vector should indicate its magnitude, using the length of the 10 m/s vector at $t = 0$ s as a reference.



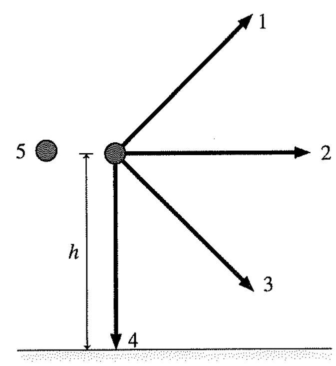
3.7 Projectile Motion: Solving Problems

38. a. A cart rolling at constant velocity fires a ball straight up. When the ball comes down, will it land in front of the launching tube, behind the launching tube, or directly in it? Explain.



b. Will your answer change if the cart is accelerating in the forward direction? If so, how?

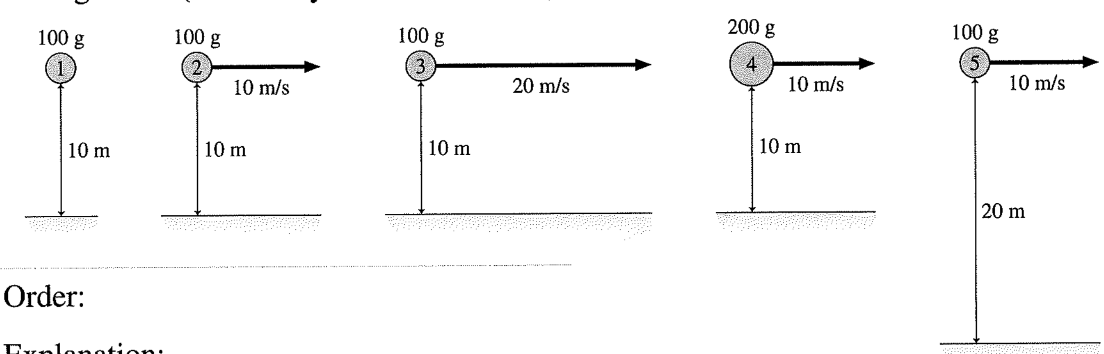
39. Four balls are simultaneously launched with the same speed from the same height h above the ground. At the same instant, ball 5 is released from rest at the same height. Rank in order, from shortest to longest, the amount of time it takes each of these balls to hit the ground. (Some may be simultaneous.)



Order:

Explanation:

40. Rank in order, from shortest to longest, the amount of time it takes each of these projectiles to hit the ground. (Some may be simultaneous.)

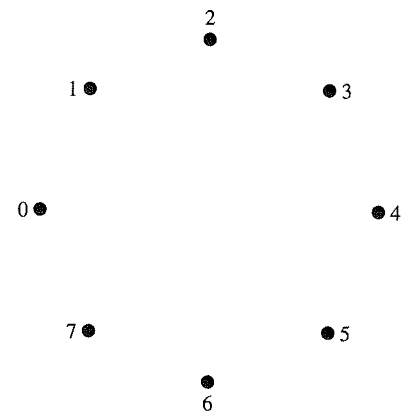


Order:

Explanation:

3.8 Motion in Two Dimensions: Circular Motion

41. The dots of a motion diagram are shown below for an object in uniform circular motion. Carefully complete the diagram.
- Draw and label the velocity vectors $\vec{v}$. Use a **black** pen or pencil.
- Draw and label the acceleration vectors $\vec{a}$. Use a **red** pen or pencil.

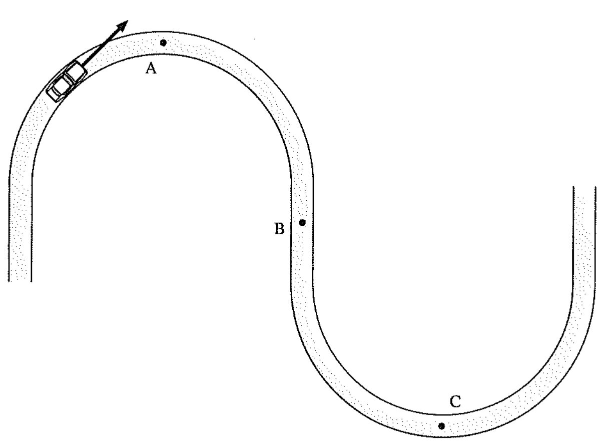


42. An object travels in a circle of radius r at constant speed v.

a. By what factor does the object's acceleration change if its speed is doubled and the radius is unchanged?

b. By what factor does the acceleration change if the radius of the circle is doubled and its speed is unchanged?

43. The figure is a bird's-eye view of a car traveling at a steady 20 mph. At each of the three dots, labeled A, B, and C, either (a) write $\vec{a} = \vec{0}$ if the car is not accelerating or (b) draw and label a vector, with its tail at the dot, to show the car's acceleration.



You Write the Problem!

Exercises 44–46: You are given the equation or equations used to solve a problem. For each of these:

a. Write a realistic physics problem for which this is the correct equation. Look at worked examples and end-of-chapter problems in the textbook to see what realistic physics problems are like. Be sure that the problem you write, and the answer you ask for, is consistent with the information given in the equation.
b. Draw the pictorial representation for your problem.
c. Finish the solution of the problem.

44. $x_1 = 0\text{ m} + (30\text{ m/s})t_1$

$$0\text{ m} = 300\text{ m} - \tfrac{1}{2}(9.8\text{ m/s}^2)t_1^2$$

45. $x_1 = 0\text{ m} + (50\cos 30°\text{ m/s})t_1$

$$0\text{ m} = 0\text{ m} + (50\sin 30°\text{ m/s})t_1 - \tfrac{1}{2}(9.8\text{ m/s}^2)t_1^2$$

46. $2.5\text{ m/s}^2 = \dfrac{v^2}{10\text{ m}}$