CHAPTER 3: Questions 1-20, Problems 2, 5, 9, 16, 18, 19, 21, 22, 23, 26

Answers to Questions

$\boxed{1.}$ Their velocities are NOT equal, because the two velocities have different directions.

2. Below are several examples:
   (*a*) During one year, the Earth travels a distance equal to the circumference of its orbit, but has a displacement of 0 relative to the Sun.
   (*b*) The space shuttle travels a large distance during any flight, but the displacement from one launch to the next is 0.
   (*c*) Any kind of cross country “round trip” air travel would result in a large distance traveled, but a displacement of 0.
   (*d*) The displacement for a race car from the start to the finish of the Indy 500 auto race is 0.

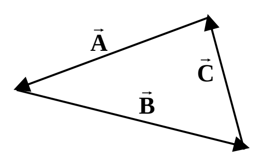
3. The displacement can be thought of as the “straight line” path from the initial location to the final location. The length of path will always be greater than or equal to the displacement, because the displacement is the shortest distance between the two locations. Thus the displacement can never be longer than the length of path, but it can be less. For any path that is not a single straight line segment, the length of path will be longer than the displacement.

4. Since both the batter and the ball started their motion at the same location (where the ball was hit) and ended their motion at the same location (where the ball was caught), the displacement of both was the same.

5. The magnitude of the vector sum need not be larger than the magnitude of either contributing vector. For example, if the two vectors being added are the exact opposite of each other, the vector sum will have a magnitude of 0. The magnitude of the sum is determined by the angle between the two contributing vectors.

$\boxed{6.}$ If the two vectors are in the same direction, the magnitude of their sum will be a maximum, and will be 7.5 km. If the two vectors are in the opposite direction, the magnitude of their sum will be a minimum, and will be 0.5 km. If the two vectors are oriented in any other configuration, the magnitude of their sum will be between 0.5 km and 7.5 km.

7. Two vectors of unequal magnitude can never add to give the zero vector. However, three vectors of unequal magnitude can add to give the zero vector. If their geometric sum using the tail-to-tip method gives a closed triangle, then the vector sum will be zero. See the diagram, in which $\vec{\mathbf{A}}+\vec{\mathbf{B}}+\vec{\mathbf{C}}=0$



8. (*a*) The magnitude of a vector can equal the length of one of its components if the other components of the vector are all 0; i.e. if the vector lies along one of the coordinate axes.
   (*b*) The magnitude of a vector can never be less than one of its components, because each component contributes a positive amount to the overall magnitude, through the Pythagorean relationship. The square root of a sum of squares is never less than the absolute value of any individual term.

9. A particle with constant speed can be accelerating, if its direction is changing. Driving on a curved roadway at constant speed would be an example. However, a particle with constant velocity cannot be accelerating – its acceleration must be zero. It has both constant speed and constant direction.

10. To find the initial speed, use the slingshot to shoot the rock directly horizontally (no initial vertical speed) from a height of 1 meter. The vertical displacement of the rock can be related to the time of flight by Eq. 2-11b. Take downward to be positive.

$$y = y_0 + v_{y0}t + \tfrac{1}{2}at^2 \;\rightarrow\; 1\text{ m} = \tfrac{1}{2}gt^2 \;\rightarrow\; t = \sqrt{2(1\text{ m})/(9.8\,\text{m/s}^2)} = 0.45\text{ s}.$$

Measure the horizontal range R of the rock with the meter stick. Then, if we measure the horizontal range R, we know that $R = v_x t = v_x(0.45\text{ s})$, and so $v_x = R/0.45\text{ s}$. The only measurements are the height of fall and the range, both of which can be measured by a meter stick.

11. Assume that the bullet was fired from behind and below the airplane. As the bullet rose in the air, its vertical speed would be slowed by both gravity and air resistance, and its horizontal speed would be slowed by air resistance. If the altitude of the airplane was slightly below the maximum height of the bullet, then at the altitude of the airplane, the bullet would be moving quite slowly in the vertical direction. If the bullet’s horizontal speed had also slowed enough to approximately match the speed of the airplane, then the bullet’s velocity relative to the airplane would be small. With the bullet moving slowly, it could safely be caught by hand.

12. The moving walkway will be moving at the same speed as the “car”. Thus, if you are on the walkway, you are moving the same speed as the car. Your velocity relative to the car is 0, and it is easy to get into the car. But it is very difficult to keep your balance while trying to sit down into a moving car from a stationary platform. It is easier to keep your balance by stepping on to the moving platform while walking, and then getting into the car with a velocity of 0 relative to the car.

13. Your reference frame is that of the train you are riding. If you are traveling with a relatively constant velocity (not over a hill or around a curve or drastically changing speed), then you will interpret your reference frame as being at rest. Since you are moving forward faster than the other train, the other train is moving backwards relative to you. Seeing the other train go past your window from front to rear makes it look like the other train is going backwards. This is similar to passing a semi truck on the interstate – out of a passenger window, it looks like the truck is going backwards.

14. When you stand still under the umbrella in a vertical rain, you are in a cylinder-shaped volume in which there is no rain. The rain has no horizontal component of velocity, and so the rain cannot move from outside that cylinder into it. You stay dry. But as you run, you have a forward horizontal velocity relative to the rain, and so the rain has a backwards horizontal velocity relative to you. It is the same as if you were standing still under the umbrella but the rain had some horizontal component of velocity towards you. The perfectly vertical umbrella would not completely shield you.

15. (*a*) The ball lands at the same point from which it was thrown inside the train car – back in the thrower’s hand.
(*b*) If the car accelerates, the ball will land behind the point from which it was thrown.
(*c*) If the car decelerates, the ball will land in front of the point from which it was thrown.
(*d*) If the car rounds a curve (assume it curves to the right), then the ball will land to the left of the point from which it was thrown.
(*e*) The ball will be slowed by air resistance, and so will land behind the point from which it was thrown.

16. Both rowers need to cover the same "cross river" distance. The rower with the greatest speed in the "cross river" direction will be the one that reaches the other side first. The current has no bearing on the problem because the current doesn't help either of the boats move across the river. Thus the rower heading straight across will reach the other side first. All of his rowing effort has gone into

crossing the river. For the upstream rower, some of his rowing effort goes into battling the current, and so his "cross river" speed will be only a fraction of his rowing speed.

17. The baseball is hit and caught at approximately the same height, and so the range formula of $R = v_0^2 \sin 2\theta_0 / g$ is particularly applicable. Thus the baseball player is judging the initial speed of the ball and the initial angle at which the ball was hit.

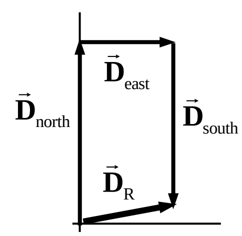
18. The arrow should be aimed above the target, because gravity will deflect the arrow downward from a horizontal flight path. The angle of aim (above the horizontal) should increase as the distance from the target increases, because gravity will have more time to act in deflecting the arrow from a straight-line path. If we assume that the arrow when shot is at the same height as the target, then the range formula is applicable: $R = v_0^2 \sin 2\theta_0 / g \quad \to \quad \theta = \frac{1}{2}\sin^{-1}\left(Rg/v_0^2\right)$. As the range and hence the argument of the inverse sine function increases, the angle increases.

$\boxed{19.}$ The horizontal component of the velocity stays constant in projectile motion, assuming that air resistance is negligible. Thus the horizontal component of velocity 1.0 seconds after launch will be the same as the horizontal component of velocity 2.0 seconds after launch. In both cases the horizontal velocity will be given by $v_x = v_0 \cos\theta = (30\,\text{m/s})(\cos 30^\circ) = 26\,\text{m/s}$.

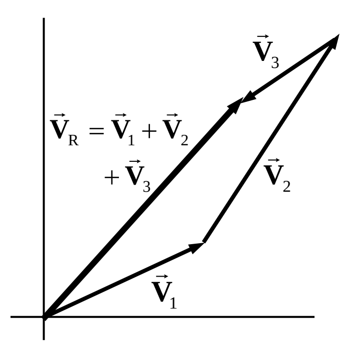
20. (*a*) Cannonball A, with the larger angle, will reach a higher elevation. It has a larger initial vertical velocity, and so by Eq. 2-11c, will rise higher before the vertical component of velocity is 0.
(*b*) Cannonball A, with the larger angle, will stay in the air longer. It has a larger initial vertical velocity, and so takes more time to decelerate to 0 and start to fall.
(*c*) The cannonball with a launch angle closest to 45° will travel the farthest. The range is a maximum for a launch angle of 45°, and decreases for angles either larger or smaller than 45°.

Solutions to Problems

2. The truck has a displacement of $18 + (-16) = 2$ blocks north and 10 blocks east. The resultant has a magnitude of $\sqrt{2^2 + 10^2} = \boxed{10 \text{ blocks}}$ and a direction of $\tan^{-1} 2/10 = \boxed{11^\circ \text{ north of east}}$.



5. The vectors for the problem are drawn approximately to scale. The resultant has a length of $\boxed{58 \text{ m}}$ and a direction $\boxed{48^\circ}$ north of east. If calculations are done, the actual resultant should be 57.4 m at 47.5° north of east.



$\boxed{9.}$ (*a*) $v_{\text{north}} = (735\,\text{km/h})(\cos 41.5^{\circ}) = \boxed{550\,\text{km/h}}$ $\quad v_{\text{west}} = (735\,\text{km/h})(\sin 41.5^{\circ}) = \boxed{487\,\text{km/h}}$

(*b*) $\Delta d_{\text{north}} = v_{\text{north}} t = (550\ \text{km/h})(3.00\ \text{h}) = \boxed{1650\ \text{km}}$

$\Delta d_{\text{west}} = v_{\text{west}} t = (487\ \text{km/h})(3.00\ \text{h}) = \boxed{1460\ \text{km}}$

16. $70.0 = \sqrt{x^2 + (-55.0)^2} \quad \rightarrow \quad 4900 = x^2 + 3025 \quad \rightarrow \quad x^2 = 1875 \quad \rightarrow \quad x = \boxed{\pm 43.3\text{ units}}$

18. Choose downward to be the positive *y* direction. The origin will be at the point where the diver dives from the cliff. In the horizontal direction, $v_{x0} = 1.8\,\text{m/s}$ and $a_x = 0$. In the vertical direction, $v_{y0} = 0$, $a_y = 9.80\,\text{m/s}^2$, $y_0 = 0$, and the time of flight is $t = 3.0\ \text{s}$. The height of the cliff is found from applying Eq. 2-11b to the vertical motion.

$$y = y_0 + v_{y0}t + \tfrac{1}{2}a_y t^2 \quad \rightarrow \quad y = 0 + 0 + \tfrac{1}{2}(9.80\,\text{m/s}^2)(3.0\,\text{s})^2 = \boxed{44\ \text{m}}$$

The distance from the base of the cliff to where the diver hits the water is found from the horizontal motion at constant velocity:

$$\Delta x = v_x t = (1.8\,\text{m/s})(3\ \text{s}) = \boxed{5.4\ \text{m}}$$

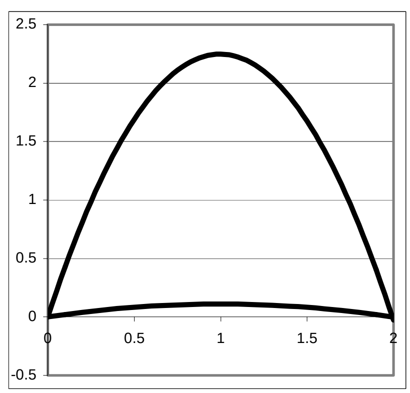
19. Apply the range formula from Example 3-8.

$$R = \frac{v_0^2 \sin 2\theta_0}{g} \quad \rightarrow$$

$$\sin 2\theta_0 = \frac{Rg}{v_0^2} = \frac{(2.0\ \text{m})(9.8\,\text{m/s}^2)}{(6.8\,\text{m/s})^2} = 0.4239$$

$$2\theta_0 = \sin^{-1} 0.4239 \quad \rightarrow \quad \theta_0 = \boxed{13^{\circ}, 77^{\circ}}$$

There are two angles because each angle gives the same range. If one angle is $\theta = 45^{\circ} + \delta$, then $\theta = 45^{\circ} - \delta$ is also a solution. The two paths are shown in the graph.



$\boxed{21.}$ Choose downward to be the positive *y* direction. The origin will be at the point where the ball is thrown from the roof of the building. In the vertical direction, $v_{y0} = 0$, $a_y = 9.80\,\text{m/s}^2$, $y_0 = 0$, and the displacement is 45.0 m. The time of flight is found from applying Eq. 2-11b to the vertical motion.

$$y = y_0 + v_{y0}t + \tfrac{1}{2}a_y t^2 \quad \rightarrow \quad 45.0\ \text{m} = \tfrac{1}{2}(9.80\,\text{m/s}^2)t^2 \quad \rightarrow \quad t = \sqrt{\frac{2(45.0\ \text{m})}{9.80\,\text{m/s}^2}} = 3.03\ \text{sec}$$

The horizontal speed (which is the initial speed) is found from the horizontal motion at constant velocity:

$$\Delta x = v_x t \quad \rightarrow \quad v_x = \Delta x/t = 24.0\ \text{m}/3.03\ \text{s} = \boxed{7.92\,\text{m/s}}.$$

22. Choose the point at which the football is kicked the origin, and choose upward to be the positive y direction. When the football reaches the ground again, the y displacement is 0. For the football, $v_{y0} = (18.0 \sin 35.0^\circ)\,\mathrm{m/s}$, $a_y = -9.80\,\mathrm{m/s^2}$ and the final y velocity will be the opposite of the starting y velocity (reference problem 3-28). Use Eq. 2-11a to find the time of flight.

$$v_y = v_{y0} + at \quad \rightarrow \quad t = \frac{v_y - v_{y0}}{a} = \frac{(-18.0 \sin 35.0^\circ)\,\mathrm{m/s} - (18.0 \sin 35.0^\circ)\,\mathrm{m/s}}{-9.80\,\mathrm{m/s^2}} = \boxed{2.11\ \mathrm{s}}$$

23. Choose downward to be the positive y direction. The origin is the point where the ball is thrown from the roof of the building. In the vertical direction, $v_{y0} = 0$, $y_0 = 0$, and $a_y = 9.80\,\mathrm{m/s^2}$. The initial horizontal velocity is 22.2 m/s and the horizontal range is 36.0 m. The time of flight is found from the horizontal motion at constant velocity.

$$\Delta x = v_x t \quad \rightarrow \quad t = \Delta x / v_x = 36.0\ \mathrm{m}/22.2\,\mathrm{m/s} = 1.62\ \mathrm{s}$$

The vertical displacement, which is the height of the building, is found by applying Eq. 2-11b to the vertical motion.

$$y = y_0 + v_{y0}t + \tfrac{1}{2}a_y t^2 \quad \rightarrow \quad y = 0 + 0 + \tfrac{1}{2}(9.80\,\mathrm{m/s^2})(1.62\ \mathrm{s})^2 = \boxed{12.9\ \mathrm{m}}$$

26. (*a*) Choose downward to be the positive y direction. The origin is the point where the bullet leaves the gun. In the vertical direction, $v_{y0} = 0$, $y_0 = 0$, and $a_y = 9.80\,\mathrm{m/s^2}$. In the horizontal direction, $\Delta x = 75.0\ \mathrm{m}$ and $v_x = 180\,\mathrm{m/s}$. The time of flight is found from the horizontal motion at constant velocity.

$$\Delta x = v_x t \quad \rightarrow \quad t = \Delta x / v_x = 75.0\ \mathrm{m}/180\,\mathrm{m/s} = 0.4167\ \mathrm{s}$$

This time can now be used in Eq. 2-11b to find the vertical drop of the bullet.

$$y = y_0 + v_{y0}t + \tfrac{1}{2}a_y t^2 \quad \rightarrow \quad y = 0 + 0 + \tfrac{1}{2}(9.80\,\mathrm{m/s^2})(0.4167\ \mathrm{s})^2 = \boxed{0.851\ \mathrm{m}}$$

(*b*) For the bullet to hit the target at the same level, the level horizontal range formula of Example 3-8 applies. The range is 75.0 m, and the initial velocity is 180 m/s. Solving for the angle of launch results in the following.

$$R = \frac{v_0^2 \sin 2\theta_0}{g} \quad \rightarrow \quad \sin 2\theta_0 = \frac{Rg}{v_0^2} \quad \rightarrow \quad \theta_0 = \frac{1}{2}\sin^{-1}\frac{(75.0\ \mathrm{m})(9.80\,\mathrm{m/s^2})}{(180\,\mathrm{m/s})^2} = \boxed{0.650^\circ}$$

Because of the symmetry of the range formula, there is also an answer of the complement of the above answer, which would be 89.35°. That is an unreasonable answer from a practical physical viewpoint – it is pointing the gun almost straight up.