NEW PROBLEMS

N1. You are kidnapped by armed political-science majors (who are upset because you told them that political science is not a real science). Although blindfolded, you can tell the speed of their car (by the whine of the engine), the time of travel (by mentally counting off seconds), and the direction of travel (by turns along the rectangular street system). From these clues, you know that you are taken along the following course: 50 km/h for 2.0 min, turn 90° to the right, 20 km/h for 4.0 min, turn 90° to the left, 20 km/h for 60 s, turn 90° to the left, 50 km/h for 60 s, turn 90° to the right, 20 km/h for 2.0 min, turn 90° to the left, 50 km/h for 30 s. At that point, (a) how far are you from your starting point and (b) in what direction relative to your initial direction of travel are you?

N2. In Fig. 4N-1a, a sled moves in the negative x direction at speed \( v_x \), while a ball of ice is shot from the sled with a velocity \( v_0 = v_{0x} \hat{i} + v_{0y} \hat{j} \) relative to the sled. When the ball lands, its horizontal displacement \( \Delta x_{bg} \) relative to the ground (from its launch position to its landing position) is measured. Figure 4N-1b gives \( \Delta x_{bg} \) as a function of \( v_x \). Assume it lands at approximately its launch height. What are the values of (a) \( v_{0x} \) and (b) \( v_{0y} \)?

The ball’s displacement \( \Delta x_{bg} \) relative to the sled can also be measured. Assume that the sled’s velocity is not changed when the ball is shot. What is \( \Delta x_{bg} \) when \( v_x \) is (c) 5.0 m/s and (d) 15 m/s?

![Fig. 4N-1 Problem N2.](image)

N3. A third baseman wishes to throw to first base, 127 ft distant. His best throwing speed is 85 mi/h. (a) If he throws the ball horizontally 3.0 ft above the ground, how far from first base will it hit the ground? (b) From the same initial height, at what upward angle must the third baseman throw the ball if the first baseman is to catch it 3.0 ft above the ground? (c) What will be the time of flight in that case?

N4. A cat rides a merry-go-round while turning with uniform circular motion. At time \( t_1 = 2.00 \) s, the cat’s velocity is

\[
\vec{v}_1 = (3.00 \text{ m/s}) \hat{i} + (4.00 \text{ m/s}) \hat{j}
\]

measured on a horizontal xy coordinate system. At time \( t_2 = 5.00 \) s, its velocity is

\[
\vec{v}_2 = (-3.00 \text{ m/s}) \hat{i} + (-4.00 \text{ m/s}) \hat{j}
\]

What are (a) the magnitude of the cat’s centripetal acceleration and (b) the cat’s average acceleration during the time interval \( t_2 - t_1 \)?

N5. In a detective story, a body is found 4.6 m from the base of a building and 24 m below an open window. (a) Assuming the victim left that window horizontally, what was the victim’s speed just then? (b) Would you guess the death to be accidental? Explain your answer.

N6. In the overhead view of Fig. 4N-2, Jeeps \( P \) and \( B \) race along straight lines, across flat terrain, and past stationary border guard \( A \). Relative to the guard, Jeep \( B \) travels at a constant speed of 20.0 m/s, at the angle \( \theta_2 = 30.0^\circ \). Relative to the guard, Jeep \( P \) has accelerated from rest at a constant rate of 0.40 m/s\(^2\) at the angle \( \theta_1 = 60.0^\circ \). At a certain time during the acceleration, it has a speed of 40 m/s. At that time, and in magnitude-angle notation, what are (a) the velocity of Jeep \( P \) relative to Jeep \( B \) and (b) the acceleration of Jeep \( P \) relative to Jeep \( B \)?

![Fig. 4N-2 Problem N6.](image)

N7. In Galileo’s *Two New Sciences*, the author states that “for elevations [angles of projection] which exceed or fall short of 45° by equal amounts, the ranges are equal. . . .” Prove this statement. (See Fig. 4N-3.)

![Fig. 4N-3 Problem N7.](image)

N8. A particle moves horizontally in uniform circular motion, over a horizontal \( xy \) plane. At one instant, it moves through the point at coordinates (4.00 m, 4.00 m) with a velocity of \(-5.00\hat{i} \text{ m/s}\) and an acceleration of \(+12.5\hat{j} \text{ m/s}^2\). What are the coordinates of the center of the circular path?

N9. A hang glider is 7.5 m above ground level with a velocity of 8.0 m/s at an angle of 30° below the horizontal and a constant acceleration of 1.0 m/s\(^2\), up. (a) Assume \( t = 0 \) at the instant just described and write an equation for the elevation \( y \) of the hang glider as a function of \( t \), with \( y = 0 \) at ground level. (b) Use the equation to determine the value of \( t \) when \( y = 0 \). (c) Explain why
N19. A baseball is hit at ground level. The ball reaches its maximum height above ground level 3.0 s after being hit. Then 2.5 s after reaching its maximum height, the ball barely clears a fence that is 97.5 m from where it was hit. Assume the ground level is zero. (a) What maximum height above ground level is reached by the ball? (b) How high is the fence? (c) How far beyond the fence does the ball strike the ground?

N20. A centripetal-acceleration addict rides in uniform circular motion with period $T = 2.0 \text{ s}$ and radius $r = 3.00 \text{ m}$. At one instant his acceleration is $\ddot{r} = (6.00 \text{ m/s}^2)i + (-4.00 \text{ m/s}^2)j$. At that instant, what are the values of (a) $\ddot{r} \cdot \ddot{a}$ and (b) $\ddot{r} \times \ddot{a}$?

N21. The position $\vec{r}$ of a particle moving in the xy plane is given by $\vec{r} = 2\vec{i} + 2 \sin(\pi t/4) \vec{j}$, where $\vec{r}$ is in meters and $t$ is in seconds. (a) Calculate the $x$ and $y$ components of the particle’s position at $t = 0, 1.0, 2.0, 3.0, \text{ and } 4.0 \text{ s}$ and sketch the particle’s path in the xy plane for the interval $0 \leq t \leq 4.0 \text{ s}$. (b) Calculate the components of the particle’s velocity at $t = 1.0, 2.0, \text{ and } 3.0 \text{ s}$. Show that the velocity is tangent to the path of the particle and in the direction the particle is moving at each time by drawing the velocity vectors on the plot of the particle’s path in part (a). (c) Calculate the components of the particle’s acceleration at $t = 1.0, 2.0, \text{ and } 3.0 \text{ s}$.

N22. A suspicious-looking man runs as fast as he can along a moving sidewalk from one end to the other, taking 2.50 s. Then security agents appear and the man runs as fast as he can back along the sidewalk to his starting point, taking 10.0 s. What is the ratio of the man’s running speed to the sidewalk’s speed?

N23. A particle moves along a circular path over a horizontal xy coordinate system, at constant speed. At time $t_1 = 4.00 \text{ s}$, it is at point $(5.00 \text{ m}, 6.00 \text{ m})$ with velocity $(3.00 \text{ m/s})j$ and acceleration in the positive x direction. At time $t_2 = 10.0 \text{ s}$, it has velocity $(-3.00 \text{ m/s})i$ and acceleration in the positive y direction. What are the coordinates of the center of the circular path?

N24. In Fig. 4N-8, a lump of wet putty moves in uniform circular motion as it rides at a radius of 20.0 cm on the rim of a wheel rotating counterclockwise with a period of 5.00 ms. The lump then happens to fly off the rim at the 5.00 position (as if on a clock face). It leaves the rim at a height of $h = 1.20 \text{ m}$ from the floor and at a distance $d = 2.50 \text{ m}$ from a wall. At what height on the wall does the lump hit?

N25. Long flights at mid latitudes in the northern hemisphere encounter the jet stream, a flow of rapidly moving air that is generally eastward. The speed of an aircraft relative to Earth’s surface can be affected by that flow. If the pilot maintains a certain speed relative to the air (the airspeed of the aircraft), then the speed relative to the surface (groundspeed) is considerably more when the pilot flies in the direction of the jet stream than in the opposite direction. Suppose an outgoing flight and its corresponding return flight are scheduled between two cities separated by 4000 km, with the outgoing flight in the direction of the jet stream and the return flight in the opposite direction. The airline computer advises the pilots to fly at an airspeed of 1000 km/h, for which the difference in flight times for the outgoing and return flights should be 70.0 min. What speed for the jet stream is the computer using?

N26. The acceleration of a particle on a horizontal xy plane is given by $\ddot{r} = 3\vec{i} + 4\vec{j}$, where $\ddot{r}$ is in meters per second-squared and $t$ is in seconds. At $t = 0$, the particle has the position vector $\vec{r} = (20.0 \text{ m})\vec{i} + (40.0 \text{ m})\vec{j}$ and the velocity vector $\vec{v} = (5.00 \text{ m/s})\vec{i} + (2.00 \text{ m/s})\vec{j}$. (a) What is the position vector of the particle at $t = 4.00 \text{ s}$, and (b) what is its direction just then?

N27. Figure 4N-9 shows the path taken by my drunk skunk over level ground, from initial point $i$ to final point $f$. The angles are $\theta_1 = 30.0^\circ$, $\theta_2 = 50.0^\circ$, and $\theta_3 = 80.0^\circ$, and the distances are $d_1 = 5.00 \text{ m}$, $d_2 = 8.00 \text{ m}$, and $d_3 = 12.0 \text{ m}$. In magnitude-angle notation, what is the skunk’s displacement from $i$ to $f$?

N28. A particle is in uniform circular motion about the origin of an xy coordinate system, moving clockwise with a period of 7.00 s. At one instant, its position vector (from the origin) is $\vec{r} = (2.00 \text{ m})\vec{i} - (3.00 \text{ m})\vec{j}$. At that instant, what is its velocity in unit-vector notation?

N29. You are to ride a jet-cycle over a lake, starting from rest at point $i$. First, moving at 30° north of due east:

1. increase your speed at 0.400 m/s² for 6.00 s
2. with whatever speed you then have, move for 8.00 s
3. then slow at 0.400 m/s² for 6.00 s.

Immediately next, moving due west:

4. increase your speed at 0.400 m/s² for 5.00 s
5. with whatever speed you then have, move for 10.0 s
6. then slow at 0.400 m/s² until you stop.

In magnitude-angle notation, what is your average velocity for the trip from point $i$?

N30. In Fig. 4N-10, a ball is shot directly upward from the ground with an initial speed of $v_0 = 7.00 \text{ m/s}$. Simultaneously, a construction elevator cab begins to move upward from the ground with a
N11. Figure 5N-4 shows an overhead view of a lemon half and two of the three horizontal forces that act on it as it is on a frictionless table. Force $F_1$ has a magnitude of 6.00 N and is at $\theta_1 = 30^\circ$. Force $F_2$ has a magnitude of 7.00 N and is at $\theta_2 = 30^\circ$. The lemon half has mass 0.0250 kg. In unit-vector notation, what is the third force if the lemon half (a) is stationary, (b) has constant velocity $\vec{v} = (13.0\text{ i} - 14.0\text{ j})$ m/s, and (c) has varying velocity $\vec{v} = (13.0\text{ i} - 14.0\text{ j})$ m/s$^2$, where $t$ is time?

N12. Figure 5N-5 shows an arrangement in which four disks are suspended by cords. The longer, top cord loops over a frictionless pulley and pulls with a force of magnitude 98 N on the wall to which it is attached. The tensions in the shorter cords are $T_1 = 58.8$ N, $T_2 = 49.0$ N, and $T_3 = 9.8$ N. What are the masses of (a) disk A, (b) disk B, (c) disk C, and (d) disk D?

N13. Suppose that the 1 kg standard body accelerates at 4.00 m/s$^2$ at 160$^\circ$ from the positive x direction owing to two forces; one is $F_1 = (2.50\text{ N})\text{ i} + (4.60\text{ N})\text{ j}$. What is the other force (a) in unit-vector notation and (b) as a magnitude and direction?

N14. In Fig. 5N-6, elevator cars A and B are connected by a short cable and can be pulled upward or lowered by the cable above car A. Car A has mass 1700 kg; cab B has mass 1300 kg. A 12.0 kg box of catnip lies on the floor of car A. The tension in the cable connecting the cars is $1.91 \times 10^4$ N. What is the magnitude of the normal force on the box from the floor?

N15. Starting from rest, an airplane accelerates for takeoff at 2.3 m/s$^2$. It has two jet engines, each exerting a force (thrust) on the airplane of $1.4 \times 10^4$ N. What is the airplane’s weight?

N16. In Fig. 5N-7, three ballot boxes are connected by cords, one of which wraps over a pulley with negligible friction on its axle and negligible mass. The masses are the following: $m_A = 30.0$ kg, $m_B = 40.0$ kg, $m_C = 10.0$ kg. When the assembly is released from rest, (a) what is the tension in the cord that connects boxes B and C, and (b) how far does box A move in the first 0.25 s (assuming it does not reach the pulley)?

N17. In Fig. 5N-8, forces act on blocks A and B, which are connected by a string. Force $F_A = 12\text{ N}$ acts on block A, with mass 4.0 kg. Force $F_B = 24\text{ N}$ acts on block B, with mass 6.0 kg. What is the tension in the string?

N18. Two horizontal forces $F_1$ and $F_2$ act on a 4.0 kg disk that slides over frictionless ice, on which an xy coordinate system is laid out. Force $F_1$ is in the positive direction of the x axis and has a magnitude of 7.0 N. Force $F_2$ has a magnitude of 9.0 N. Figure 5N-9 gives the x component $v_x$ of the velocity of the disk as a function of time $t$ during the sliding. What is the angle between the constant directions of forces $F_1$ and $F_2$?

N19. A rocket and its payload have a total mass of $5.0 \times 10^4$ kg. How large is the force produced by the engine (the thrust) when (a) the rocket is “hovering” over the launchpad just after ignition, and (b) the rocket is accelerating upward at 20 m/s$^2$?

N20. Figure 5N-10 shows three blocks attached by cords that loop over frictionless pulleys. Block B lies on a frictionless table; the masses are: $m_A = 6.00$ kg, $m_B = 8.00$ kg, $m_C = 10.0$ kg. When the blocks are released, what is the tension in the cord at the right?

N21. An 80 kg man drops to a concrete patio from a window only 0.50 m above the patio. He neglects to bend his knees on landing, taking 2.0 cm to stop. (a) What is his average acceleration from when his feet first touch the patio to when he stops? (b) What is the magnitude of the average stopping force?

N22. Figure 5N-11 gives, as a function of time $t$, the force component $F_x$ that acts on a 3.00 kg ice block, which can move only along the x axis. At $t = 0$, the block is moving in the positive direction of the axis, with a speed of 3.0 m/s. What are its (a) speed and (b) direction of travel at $t = 11$ s?

N23. Two people pull with 90 N and 92 N in opposite directions on a 25 kg sled on frictionless ice. What is the sled’s acceleration magnitude?