Chapter 4—Motion in Two Dimensions

MULTIPLE CHOICE

1. At $t = 0$, a particle leaves the origin with a velocity of 9.0 m/s in the positive y direction and moves in the xy plane with a constant acceleration of (2.0i − 4.0j) m/s^2. At the instant the x coordinate of the particle is 15 m, what is the speed of the particle?
   a. 10 m/s
   b. 16 m/s
   c. 12 m/s
   d. 14 m/s
   e. 26 m/s

   x - axis: $V_x^2 = V_0^2 + 2a_x x = 0 + 2(2)(15) = 60\ m^2/s^2$, $V = \sqrt{v_x^2 + v_y^2}$

   y - axis: $x = V_0 t + \frac{1}{2} a_x t^2$, $15 = \frac{1}{2}(2)t^2$, $t = \sqrt{15}$ s, $V_y = 9 + (-4)\sqrt{15}$ m/s

   ANS: A PTS: 2 DIF: Average

2. A particle starts from the origin at $t = 0$ with a velocity of $6.0\hat{\mathbf{i}}$ m/s and moves in the xy plane with a constant acceleration of $(-2.0\hat{\mathbf{i}} + 4.0\hat{\mathbf{j}})$ m/s^2. At the instant the particle achieves its maximum positive x coordinate, how far is it from the origin?
   a. 36 m
   b. 20 m
   c. 45 m
   d. 27 m
   e. 37 m

   max. positive x happen at $V_x = 0$, $V_x = V_{0x} + a_x t \rightarrow 0 = 6 - 2t$, $t = 3$ s

   $x = V_0 t + \frac{1}{2} a t^2 = 6(3) + \frac{1}{2}(-2)(9) = 9$ m

   $y = V_0 t + \frac{1}{2} a t^2 = 0 + \frac{1}{2}(4)(9) = 18$ m, $r = \sqrt{x^2 + y^2} = 20$ m

   ANS: B PTS: 2 DIF: Average

3. A particle leaves the origin with a velocity of 7.2 m/s in the positive y direction and moves in the xy plane with a constant acceleration of $(3.0\hat{\mathbf{i}} - 2.0\hat{\mathbf{j}})$ m/s^2. At the instant the particle moves back across the x axis ($y = 0$), what is the value of its x coordinate?
   a. 65 m
   b. 91 m
   c. 54 m
   d. 78 m
   e. 86 m

   $V = 0\hat{i} + 7.2\hat{j}$, $y = V_0 t + \frac{1}{2} a t^2 \rightarrow 0 = 7.2t + \frac{1}{2}(-2)t^2$, $t^2 = 7.2t \rightarrow t = 7.2$ s

   $x = V_{0x} t + \frac{1}{2} a_x t^2 = 0 + \frac{1}{2}(3)(7.2)^2 = 77.76$ m

   ANS: D PTS: 2 DIF: Average

4. At $t = 0$, a particle leaves the origin with a velocity of 5.0 m/s in the positive y direction. Its acceleration is given by $\vec{\mathbf{a}} = (3.0\hat{\mathbf{i}} - 2.0\hat{\mathbf{j}})$ m/s^2. At the instant the particle reaches its maximum y coordinate how far is the particle from the origin?
   a. 11 m
   b. 16 m
   c. 22 m
   d. 29 m
   e. 19 m

   Similar to #3

   y: $V = V_0 + at$, $0 = 5 - 2(t) \rightarrow t = \frac{5}{2} = 2.5$ s

   $y = V_0 t + \frac{1}{2} a t^2 = 5(2.5) + \frac{1}{2}(-2)(2.5)^2 = 6.25$ m

   $x = V_0 t + \frac{1}{2} a t^2 = 0 + \frac{1}{2}(3)(2.5)^2 = 9.37$ m

   $r = \sqrt{x^2 + y^2} = 11.26$ m

   ANS: A PTS: 2 DIF: Average

5. A particle moves in the xy plane with a constant acceleration given by $\vec{\mathbf{a}} = -4.0\hat{\mathbf{j}}$ m/s^2. At $t = 0$, its position and velocity are $10\hat{\mathbf{i}}$ m and $(-2.0\hat{\mathbf{i}} + 8.0\hat{\mathbf{j}})$ m/s, respectively. What is the distance from the origin to the particle at $t = 2.0$ s?
   a. 6.4 m

   $x = x_0 + V_{0x} t + \frac{1}{2} a_x t^2 = 10 - 2(2) + \frac{1}{2}(0)t^2 = 6$ m

   $y = V_{0y} t + \frac{1}{2} a_y t^2 = 8(2) - \frac{1}{2}(4)(4) = 16 - 8 = 8$ m

   $r = \sqrt{x^2 + y^2}$

b. 10 m
c. 8.9 m
d. 2.0 m
e. 6.2 m

ANS: B PTS: 3 DIF: Challenging

6. A particle starts from the origin at $t = 0$ with a velocity of $(16\hat{\mathbf{i}} - 12\hat{\mathbf{j}})$ m/s and moves in the xy plane with a constant acceleration of $\vec{\mathbf{a}} = (3.0\hat{\mathbf{i}} - 6.0\hat{\mathbf{j}})$ m/s^2. What is the speed of the particle at $t = 2.0$ s?
a. 52 m/s
b. 39 m/s
c. 46 m/s
d. 33 m/s
e. 43 m/s

ANS: D PTS: 2 DIF: Average

Do it $V = V_0 + at$
x: $V_x = 16 + 3(2) = 22$ m/s
y: $V_y = -12 + (-6)(2) = -12 - 12 = -24$ m/s
$V = \sqrt{v_x^2 + v_y^2} = 32.55$ m/s

7. At $t = 0$, a particle leaves the origin with a velocity of 12 m/s in the positive x direction and moves in the xy plane with a constant acceleration of $\left(-2.0\hat{\mathbf{i}} + 4.0\hat{\mathbf{j}}\right)$ m/s^2. At the instant the y coordinate of the particle is 18 m, what is the x coordinate of the particle?
a. 30 m
b. 21 m
c. 27 m
d. 24 m
e. 45 m

ANS: C PTS: 2 DIF: Average

Do it
$y = v_0 t + \frac{1}{2}at^2$
$y = 0 + \frac{1}{2}(4)t^2$
$18 = 2t^2$, $t = 3$ s
$x = v_0 t + \frac{1}{2}at^2 = 12(3) + \frac{1}{2}(-2)(3)^2 = 36 - 9 = 27$ m

8. The initial speed of a cannon ball is 0.20 km/s. If the ball is to strike a target that is at a horizontal distance of 3.0 km from the cannon, what is the minimum time of flight for the ball?
a. 16 s
b. 21 s
c. 24 s
d. 14 s
e. 19 s

ANS: A PTS: 3 DIF: Challenging

$x = v_0 \cos\theta t$, $3 = 0.2\cos\theta t$; $\cos\theta t = 15 \rightarrow$ (1) cannon — target
$y = v_0 \sin\theta t - \frac{1}{2}gt^2$, no y, $y = 0$
$v_0 \sin\theta t = \frac{1}{2}gt^2$, $t = 2v_0\sin\theta/g \rightarrow$ (2)
(1) & (2) $\cos\theta\left(\frac{2v_0\sin\theta}{g}\right) = 15$, $\frac{v_0 \sin 2\theta}{g} = 15$, $\theta = 21.22°$ from (1) $t = 16$ s

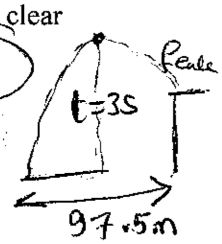
9. A ball is thrown horizontally from the top of a building 0.10 km high. The ball strikes the ground at a point 65 m horizontally away from and below the point of release. What is the speed of the ball just before it strikes the ground?
a. 43 m/s
b. 47 m/s
c. 39 m/s
d. 36 m/s
e. 14 m/s

ANS: B PTS: 2 DIF: Average

$V_{oy} = 0$, $y = V_{oy}t + \frac{1}{2}at^2 \rightarrow 0.1 \times 10^3 = \frac{1}{2}(9.8)t^2$
$t = \sqrt{\frac{200}{9.8}}$ s, $X = V_x t \rightarrow 65 = V_x\sqrt{\frac{200}{9.8}}$, $V_x = 65\sqrt{\frac{9.8}{200}}$ m/s
$V_y = V_{oy} + at = 0 + 9.8\left(\sqrt{\frac{200}{9.8}}\right)$ m/s, $V = \sqrt{V_x^2 + V_y^2}$

10. A baseball is hit at ground level. The ball is observed to reach its maximum height above ground level 3.0 s after being hit. And 2.5 s after reaching this maximum height, the ball is observed to barely clear a fence that is 97.5 m from where it was hit. How high is the fence?
a. 8.2 m
b. 15.8 m

after hitting ground $y = 0$
$y = v_0 \sin\theta t - \frac{1}{2}gt^2 \Rightarrow v_0 \sin\theta = \frac{1}{2}g(6)$ (3+3)



at $T = (3 + 2.5) = 5.5$ s
$y = v_0 \sin\theta T - \frac{1}{2}gT^2 = 3g(T) - \frac{1}{2}gT^2$
$= 3(9.8)(5.5) - \frac{1}{2}(9.8)(5.5)^2 = 13.47$ m

c. 13.5 m
d. 11.0 m
e. 4.9 m

ANS: C PTS: 2 DIF: Average

11. A rock is projected from the edge of the top of a building with an initial velocity of 12.2 m/s at an angle of 53° above the horizontal. The rock strikes the ground a horizontal distance of 25 m from the base of the building. Assume that the ground is level and that the side of the building is vertical. How tall is the building? at max height $v_y = 0 = v_0 \sin\theta - gt$, $t = \frac{v_0 \sin\theta}{g}$

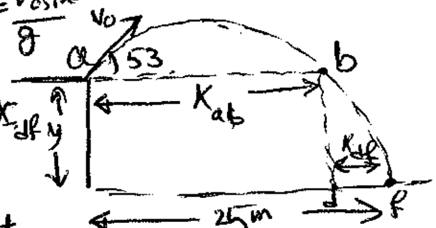
a. 25.3 m
b. 29.6 m
c. 27.4 m
d. 23.6 m
e. 18.9 m

$T_{ab} = \frac{2 v_0 \sin\theta}{g}$, $X_{ab} = v_0 \cos\theta \, T_{ab}$

$X_{ab} = \frac{v_0 \cos\theta (2) v_0 \sin\theta}{g} = \frac{v_0^2 \sin 2\theta}{g} = 25 - X_{df}$

$X_{df} = 25 - \frac{v_0^2 \sin 2\theta}{g} = v_0 \cos\theta \, t$, $t = 1.42 s$

$y = v_0 \sin\theta t + \frac{1}{2} g t^2 = 23.7$ m



ANS: D PTS: 2 DIF: Average

12. A projectile is thrown from the top of a building with an initial velocity of 30 m/s in the horizontal direction. If the top of the building is 30 m above the ground, how fast will the projectile be moving just before it strikes the ground?

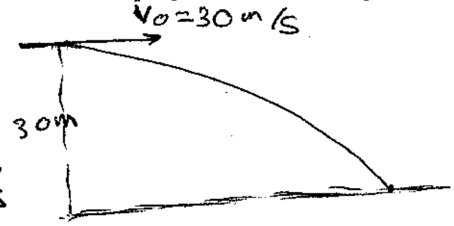
a. 35 m/s
b. 39 m/s
c. 31 m/s
d. 43 m/s
e. 54 m/s

$v_x = v_0 = 30 m/s$, $v_y = ?$

$v_y^2 = v_{0y}^2 + 2gy = 0 + 2(9.8)(30)$

$v_y^2 = 2(9.8)(30) m^2/s^2$

$v = \sqrt{v_x^2 + v_y^2} = 38.5 m/s$



ANS: B PTS: 2 DIF: Average

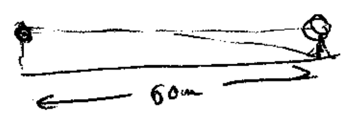
13. A rifle is aimed horizontally at the center of a large target 60 m away. The initial speed of the bullet is 240 m/s. What is the distance from the center of the target to the point where the bullet strikes the target?

a. 48 cm
b. 17 cm
c. 31 cm
d. 69 cm
e. 52 cm

$x = v_0 \cos\theta t$, $60 = 240 \cos(0) t$

$t = \frac{60}{240} = \frac{1}{4} s$

$y = v_0 t + \frac{1}{2} g t^2 = 0 + \frac{1}{2}(9.8)(\frac{1}{4})^2 = 30.6$ cm



ANS: C PTS: 2 DIF: Average

14. A rock is thrown from the edge of the top of a 100-ft tall building at some unknown angle above the horizontal. The rock strikes the ground a horizontal distance of 160 ft from the base of the building 5.0 s after being thrown. Assume that the ground is level and that the side of the building is vertical. Determine the speed with which the rock was thrown. $T_{total} = 5 s = t_{ab} + t_{cd}$

a. 72 ft/s
b. 77 ft/s
c. 68 ft/s
d. 82 ft/s
e. 87 ft/s

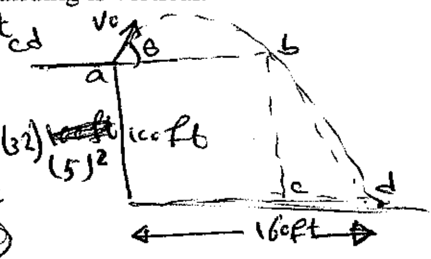
$x = v_0 \cos\theta T_{total} \rightarrow 160 = v_0 \cos\theta (5)$

$v_0 \cos\theta = 32 \rightarrow (1)$

$y = v_0 \sin\theta t - \frac{1}{2} g t^2 \rightarrow -100 = v_0 \sin\theta (5) - \frac{1}{2}(32)(5)^2$

$v_0 \sin\theta = 60 \rightarrow (2)$, $\frac{(2)}{(1)}$: $\tan\theta = \frac{60}{32}$; $\theta = 61.92$

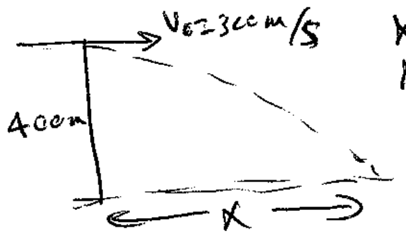
from (1) or (2) $v_0 = 68$ ft/s



ANS: C PTS: 2 DIF: Average

15. An airplane flies horizontally with a speed of 300 m/s at an altitude of 400 m. Assume that the ground is level. At what horizontal distance from a target must the pilot release a bomb so as to hit the target?

a. 3.0 km



$x = v_0 \cos\theta t = v_0 t$, since $\theta = 0$

$x = 300t$, $y = v_0 t + \frac{1}{2} g t^2 = \frac{1}{2} g t^2$

$400 = \frac{1}{2} g t^2 \rightarrow t = 9.03 s$

$x = 300(9.03) = 2.7$ km

b. 2.4 km
c. 3.3 km
d. 2.7 km
e. 1.7 km

ANS: D PTS: 2 DIF: Average

16. An object moving at a constant speed requires 6.0 s to go once around a circle with a diameter of 4.0 m. What is the magnitude of the instantaneous acceleration of the particle during this time?
a. 2.2 m/s^2
b. 2.7 m/s^2
c. 3.3 m/s^2
d. 3.8 m/s^2
e. 4.4 m/s^2

ANS: A PTS: 2 DIF: Average

17. A particle moves at a constant speed in a circular path with a radius of 2.06 cm. If the particle makes four revolutions each second, what is the magnitude of its acceleration?
a. 20 m/s^2
b. 18 m/s^2
c. 13 m/s^2
d. 15 m/s^2
e. 24 m/s^2

ANS: C PTS: 2 DIF: Average

18. A race car moving with a constant speed of 60 m/s completes one lap around a circular track in 50 s. What is the magnitude of the acceleration of the race car?
a. 8.8 m/s^2
b. 7.5 m/s^2
c. 9.4 m/s^2
d. 6.3 m/s^2
e. 5.3 m/s^2

ANS: B PTS: 2 DIF: Average

19. At the lowest point in a vertical dive (radius = 0.58 km), an airplane has a speed of 300 km/h which is not changing. Determine the magnitude of the acceleration of the pilot at this lowest point.
a. 26 m/s^2
b. 21 m/s^2
c. 16 m/s^2
d. 12 m/s^2
e. 8.8 m/s^2

ANS: D PTS: 2 DIF: Average

20. A carnival Ferris wheel has a 15-m radius and completes five turns about its horizontal axis every minute. What is the acceleration of a passenger at his lowest point during the ride?
a. 5.7 m/s^2 downward
b. 4.1 m/s^2 upward
c. 14 m/s^2 downward
d. 4.1 m/s^2 downward
e. 19 m/s^2 downward

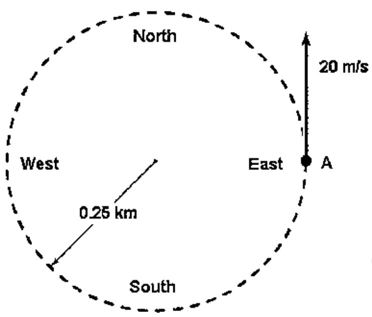
ANS: B PTS: 2 DIF: Average

21. A space station of diameter 80 m is turning about its axis at a constant rate. If the acceleration of the outer rim of the station is 2.5 m/s^2, what is the period of revolution of the space station?

a. 22 s
b. 19 s
c. 25 s
d. 28 s
e. 40 s

ANS: C PTS: 2 DIF: Average

22. A car travels counterclockwise around a flat circle of radius 0.25 km at a constant speed of 20 m/s. When the car is at point A as shown in the figure, what is the car's acceleration?



a. 1.6 m/s^2, south
b. Zero
c. 1.6 m/s^2, east
d. 1.6 m/s^2, north
e. 1.6 m/s^2, west

ANS: E PTS: 1 DIF: Easy

23. A particle moves along a circular path having a radius of 2.0 m. At an instant when the speed of the particle is equal to 3.0 m/s and changing at the rate of 5.0 m/s^2, what is the magnitude of the total acceleration of the particle?

a. 7.5 m/s^2
b. 6.0 m/s^2
c. 5.4 m/s^2
d. 6.7 m/s^2
e. 4.5 m/s^2

ANS: D PTS: 2 DIF: Average

24. A car travels in a flat circle of radius R. At a certain instant the velocity of the car is 20 m/s north, and the total acceleration of the car is 2.5 m/s^2 37° south of west. Which of the following is correct?

a. R = 0.40 km, and the car's speed is decreasing.
b. R = 0.20 km, and the car's speed is decreasing.
c. R = 0.20 km, and the car's speed is increasing.
d. R = 0.16 km, and the car's speed is increasing.
e. R = 0.16 km, and the car's speed is decreasing.

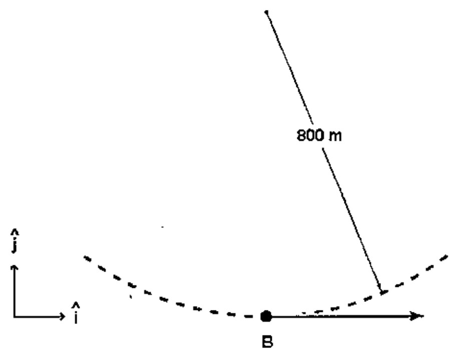
ANS: B PTS: 3 DIF: Challenging

25. A car travels in a flat circle of radius R. At a certain instant the velocity of the car is 24 m/s west, and the total acceleration of the car is 2.5 m/s^2 53° north of west. Which of the following is correct?

a. R = 0.29 km, and the car's speed is increasing.
b. R = 0.23 km, and the car's speed is decreasing.
c. R = 0.23 km, and the car's speed is increasing.
d. R = 0.29 km, and the car's speed is decreasing.
e. R = 0.29 km, and the car's speed is constant.

ANS: A PTS: 3 DIF: Challenging

26. A stunt pilot performs a circular dive of radius 800 m. At the bottom of the dive (point B in the figure) the pilot has a speed of 200 m/s which at that instant is increasing at a rate of 20 m/s^2. What acceleration does the pilot have at point B?



a. (50**i** + 20**j**) m/s^2
b. (20**i** – 50**j**) m/s^2
c. (20**i** + 50**j**) m/s^2
d. (–20**i** + 50**j**) m/s^2
e. (–50**i** + 20**j**) m/s^2

ANS: C PTS: 2 DIF: Average

27. The speed of a particle moving in a circle 2.0 m in radius increases at the constant rate of 4.4 m/s^2. At an instant when the magnitude of the total acceleration is 6.0 m/s^2, what is the speed of the particle?
a. 3.9 m/s
b. 2.9 m/s
c. 3.5 m/s
d. 3.0 m/s
e. 1.4 m/s

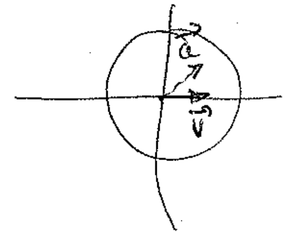
ANS: B PTS: 3 DIF: Challenging

28. A car travels in a flat circle of radius *R*. At a certain instant the velocity of the car is 24 m/s west, and the acceleration of the car has components of 2.4 m/s^2 east and 1.8 m/s^2 south. What is the radius of the circle?
a. 0.24 km
b. 0.19 km
c. 0.32 km
d. 0.14 km
e. 0.27 km

ANS: C PTS: 2 DIF: Average

29. A particle moves in the xy plane in a circle centered on the origin. At a certain instant the velocity and acceleration of the particle are $6.0\hat{\mathbf{i}}$ m/s and $(3.0\hat{\mathbf{i}} + 4.0\hat{\mathbf{j}})$ m/s^2. What are the x and y coordinates of the particle at this moment?

$\vec{v} = 6.0\hat{i}$, $\vec{a} = 3\hat{i} + 4\hat{j}$



a. $x = 0, y = -9.0$ m
b. $x = 0, y = +7.2$ m
c. $x = 0, y = +9.0$ m
d. $x = 0, y = -7.2$ m
e. $x = 6.0$ m, $y = -9.0$ m

ANS: A PTS: 2 DIF: Average

30. A particle moves in the xy plane in a circle centered on the origin. At a certain instant the velocity and acceleration of the particle are $4.0\hat{\mathbf{j}}$ m/s and $(-3.0\hat{\mathbf{i}} - 2.0\hat{\mathbf{j}})$ m/s^2. What are the x and y coordinates of the particle at this moment?

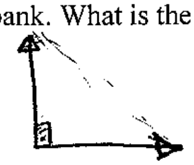
a. $x = -4.4$ m, $y = 0$
b. $x = +5.3$ m, $y = 0$
c. $x = -5.3$ m, $y = 0$
d. $x = +4.4$ m, $y = 0$
e. $x = -1.8$ m, $y = 0$

ANS: B PTS: 2 DIF: Average

31. A 0.14-km wide river flows with a uniform speed of 4.0 m/s toward the east. It takes 20 s for a boat to cross the river to a point directly north of its departure point on the south bank. What is the speed of the boat relative to the water?

$V_{bw} = \sqrt{16 + \left(\frac{0.14\times10^{3}}{20}\right)^2}$

$= 8.06$ m/s



a. 5.7 m/s
b. 8.5 m/s
c. 8.1 m/s
d. 7.0 m/s
e. 6.4 m/s

ANS: C PTS: 2 DIF: Average

32. A 0.20-km wide river has a uniform flow speed of 4.0 m/s toward the east. It takes 20 s for a boat to cross the river to a point directly north of its departure point on the south bank. In what direction must the boat be pointed in order to accomplish this?

$\tan\theta = \left(\frac{4}{\left(\frac{0.2\times10^{3}}{20}\right)}\right)$

$\theta = 21.8°$ west of north

a. 23° west of north
b. 20° west of north
c. 24° west of north
d. 22° west of north
e. 17° west of north

ANS: D PTS: 2 DIF: Average

33. A 0.20-km wide river has a uniform flow speed of 3.0 m/s toward the east. A boat with a speed of 8.0 m/s relative to the water leaves the south bank and heads in such a way that it crosses to a point directly north of its departure point. How long does it take the boat to cross the river?

a. 29 s
b. 23 s
c. 25 s
d. 27 s
e. 17 s

ANS: D PTS: 2 DIF: Average

34. A river has a steady speed of 0.30 m/s. A student swims downstream a distance of 1.2 km and returns to the starting point. If the student swims with respect to the water at a constant speed and the downstream portion of the swim requires 20 minutes, how much time is required for the entire swim?
   a. 50 minutes
   b. 80 minutes
   c. 90 minutes
   d. 70 minutes
   e. 60 minutes

ANS: D PTS: 2 DIF: Average

35. The pilot of an aircraft flies due north relative to the ground in a wind blowing 40 km/h toward the east. If his speed relative to the ground is 80 km/h, what is the speed of his airplane relative to the air?
   a. 89 km/h
   b. 85 km/h
   c. 81 km/h
   d. 76 km/h
   e. 72 km/h

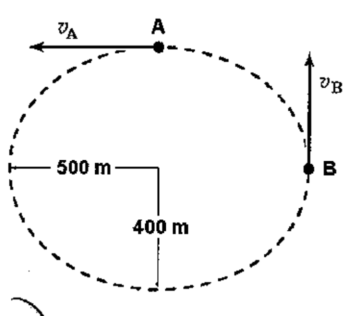
ANS: A PTS: 2 DIF: Average

36. A car travels in a due northerly direction at a speed of 55 km/h. The traces of rain on the side windows of the car make an angle of 60 degrees with respect to the horizontal. If the rain is falling vertically with respect to the earth, what is the speed of the rain with respect to the earth?
   a. 48 km/h
   b. 95 km/h
   c. 58 km/h
   d. 32 km/h
   e. 80 km/h

ANS: B PTS: 2 DIF: Average

37. A car travels in an oval path as shown below. $\vec{v}_A = 25$ m/s, West, and $\vec{v}_B = 20$ m/s, North. The ratio of the magnitude of the centripetal acceleration at B to that at A, $\frac{a_B}{a_A}$, is:

$a_c = \frac{v^2}{R}$



$\frac{a_B}{a_A} = \frac{v_B^2/R_B}{v_A^2/R_A} = \frac{400/500}{625/400} = \frac{4(400)}{5(625)} = 0.512$

   a. 0.512
   b. 0.64
   c. 0.8
   d. 1.25
   e. 1.56

ANS: A PTS: 2 DIF: Average

38. Two cooks standing side by side in a restaurant pull their beaters out of the dough at the same instant. A glob of dough flies off each beater. Each glob lands on the top of a tin the same horizontal distance away and at its initial height. However, one lands later than the other. The explanation is that they left the beaters at angles θ_1 and θ_2 such that:

a. $\theta_2 = -\theta_1$.
b. $\theta_1 + \theta_2 = \frac{\pi}{4}$.
c. $\theta_1 + \theta_2 = \frac{\pi}{2}$.
d. $\theta_1 + \theta_2 = \pi$.
e. $\theta_1 - \theta_2 = \pi$.

ANS: C PTS: 2 DIF: Average

39. The site from which an airplane takes off is the origin. The x axis points east; the y axis points straight up. The position and velocity vectors of the plane at a later time are given by

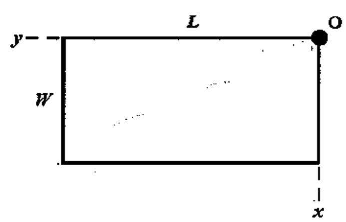
$$\vec{\mathbf{r}} = (1.61 \times 10^4\hat{\mathbf{i}} + 9.00 \times 10^3\hat{\mathbf{j}})\text{ m and } \vec{\mathbf{v}} = (150\hat{\mathbf{i}} - 21\hat{\mathbf{j}})\ \frac{\text{m}}{\text{s}}.$$

The magnitude, in meters, of the plane's displacement from the origin is

a. 9.14×10^3.
b. 1.61×10^4.
c. 1.84×10^4.
d. $9.14 \times 10^3 t$.
e. $1.61 \times 10^4 t$.

ANS: C PTS: 2 DIF: Average

40. A tennis player wants to slam a serve at **O** so that the ball lands just inside the opposite corner of the court. What should the ratio $\frac{v_{0y}}{v_{0x}}$ be for the initial velocity $\vec{\mathbf{v}}_0$? The time $t = 0$ is the time when the ball is hit by the racket.



a. W/L
b. L/W
c. $\frac{1}{2}gt^2 / L$
d. $\frac{1}{2}gt^2 / W$
e. $\frac{1}{2}gt^2 / \sqrt{L^2 + W^2}$

ANS: B PTS: 1 DIF: Easy

41. The position of an object is given by $\vec{\mathbf{r}} = (-4.00t\hat{\mathbf{i}} + 6.00t^3\hat{\mathbf{j}})$ m where t is in seconds. At $t = 2.0$ s, what is the magnitude of the particle's acceleration?
   a. 0 m/s^2
   b. 2.0 m/s^2
   c. 17 m/s^2
   d. 36 m/s^2
   e. 72 m/s^2

$\vec{a} = \frac{d^2\vec{r}}{dt^2} = \frac{d}{dt}(-4\hat{i} + 18t^2)$

$= 36t$

$a(2s) = 36(2) = 72$ m/s^2

ANS: E PTS: 2 DIF: Average

Exhibit 4-1

While her kid brother is on a wooden horse at the edge of a merry-go-round, Sheila rides her bicycle parallel to its edge. The wooden horses have a tangential speed of 6 m/s. Sheila rides at 4 m/s. The radius of the merry-go-round is 8 m.

Use this exhibit to answer the following question(s).

42. Refer to Exhibit 4-1. At what time intervals does Sheila encounter her brother, if she rides in the direction of rotation of the merry-go-round?
   a. 5.03 s
   b. 8.37 s
   c. 12.6 s
   d. 25.1 s
   e. 50.2 s

ANS: D PTS: 2 DIF: Average

43. Refer to Exhibit 4-1. At what time intervals does Sheila encounter her brother, if she rides opposite to the direction of rotation of the merry-go-round?
   a. 5.03 s
   b. 8.37 s
   c. 12.6 s
   d. 25.1 s
   e. 50.2 s

ANS: A PTS: 2 DIF: Average

44. Two cars are traveling around identical circular racetracks. Car A travels at a constant speed of 20 m/s. Car B starts at rest and speeds up with constant tangential acceleration until its speed is 40 m/s. When car B has the same (tangential) velocity as car A, it is always true that:
   a. it is passing car A.
   b. it has the same linear (tangential) acceleration as car A.
   c. it has the same centripetal acceleration as car A.
   d. it has the same total acceleration as car A.
   e. it has traveled farther than car A since starting.

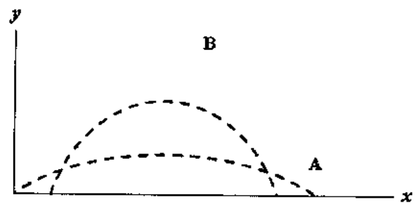
ANS: C PTS: 1 DIF: Easy

45. A student in the front of a school bus tosses a ball to another student in the back of the bus while the bus is moving forward at constant velocity. The *speed* of the ball as seen by a stationary observer in the street:
   a. is less than that observed inside the bus.
   b. is the same as that observed inside the bus.
   c. is greater than that observed inside the bus.
   d. may be either greater or smaller than that observed inside the bus.

e. may be either greater, smaller, or equal to that observed inside the bus.

ANS: E PTS: 1 DIF: Easy

46. Two balls, projected at different times so they don't collide, have trajectories A and B, as shown below.



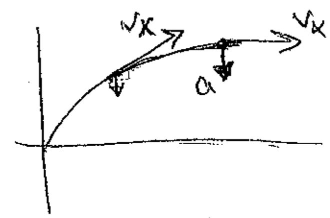
Which statement is correct?

a. v_{0B} must be greater than v_{0A}.
b. Ball A is in the air for a longer time than ball B.
c. Ball B is in the air for a longer time than ball A.
d. Ball B has a greater acceleration than ball A.
e. Ball A has a greater acceleration than ball B.

ANS: C PTS: 1 DIF: Easy

47. The vector $\vec{\mathbf{r}}$ indicates the instantaneous displacement of a projectile from the origin. At the instant when the projectile is at $\vec{\mathbf{r}}$, its velocity and acceleration vectors are $\vec{\mathbf{v}}$ and $\vec{\mathbf{a}}$. Which statement is correct?

a. $\vec{\mathbf{v}}$ is always perpendicular to $\vec{\mathbf{r}}$.
b. $\vec{\mathbf{a}}$ is always perpendicular to $\vec{\mathbf{r}}$.
c. $\vec{\mathbf{a}}$ is always perpendicular to $\vec{\mathbf{v}}$.
d. $\vec{\mathbf{a}}$ is always perpendicular to $\vec{\mathbf{v}}_x$.
e. $\vec{\mathbf{a}}$ is always perpendicular to $\vec{\mathbf{v}}_y$.



ANS: D PTS: 1 DIF: Easy

48. A projectile starts at the coordinate origin, where the displacement vector also originates. The initial velocity, $\mathbf{v}_0$, makes an angle θ_0 with the horizontal where $0 < \theta_0 < 90°$. At the instant when the projectile is at the highest point of its trajectory, the displacement, velocity and acceleration vectors are $\vec{\mathbf{r}}$, $\vec{\mathbf{v}}$ and $\vec{\mathbf{a}}$. Which statement is true?

a. $\vec{\mathbf{r}}$ is parallel to $\vec{\mathbf{v}}$.
b. $\vec{\mathbf{r}}$ is perpendicular to $\vec{\mathbf{v}}$.
c. $\vec{\mathbf{v}}$ is parallel to $\vec{\mathbf{a}}$.
d. $\vec{\mathbf{v}}$ is perpendicular to $\vec{\mathbf{a}}$.
e. $\vec{\mathbf{r}}$ is perpendicular to $\vec{\mathbf{a}}$.

ANS: D PTS: 1 DIF: Easy

49. The site from which an airplane takes off is the origin. The x axis points east; the y axis points straight up. The position and velocity vectors of the plane at a later time are given by

$$\vec{\mathbf{r}} = \left(1.61 \times 10^6 \hat{\mathbf{i}}\right) \text{m and } \vec{\mathbf{v}} = +100\hat{\mathbf{i}}\ \frac{\text{m}}{\text{s}}.$$

The plane is most likely

a. just touching down.

b. in level flight in the air.
c. ascending.
d. descending.
e. taking off.

ANS: A PTS: 1 DIF: Easy

50. The site from which an airplane takes off is the origin. The x axis points east; the y axis points straight up. The position and velocity vectors of the plane at a later time are given by

$$\vec{\mathbf{r}} = \left(1.61 \times 10^6\hat{\mathbf{i}} + 9.14 \times 10^3\hat{\mathbf{j}}\right)\text{m and } \vec{\mathbf{v}} = +224\hat{\mathbf{i}}\ \frac{\text{m}}{\text{s}}.$$

The plane is most likely
a. just touching down.
b. in level flight in the air.
c. ascending.
d. descending.
e. taking off.

ANS: B PTS: 1 DIF: Easy

51. The site from which an airplane takes off is the origin. The x axis points east; the y axis points straight up. The position and velocity vectors of the plane at a later time are given by

$$\vec{\mathbf{r}} = \left(1.61 \times 10^6\hat{\mathbf{i}} + 3.00 \times 10^3\hat{\mathbf{j}}\right)\text{m and } \vec{\mathbf{v}} = +\left(150\hat{\mathbf{i}} - 21\hat{\mathbf{j}}\right)\frac{\text{m}}{\text{s}}.$$

The plane is most likely
a. just touching down.
b. in level flight in the air.
c. ascending.
d. descending.
e. taking off.

ANS: D PTS: 1 DIF: Easy

52. The site from which an airplane takes off is the origin. The x axis points east; the y axis points straight up. The position and velocity vectors of the plane at a later time are given by

$$\vec{\mathbf{r}} = \left(1.61 \times 10^6\hat{\mathbf{i}} + 3.00 \times 10^3\hat{\mathbf{j}}\right)\text{m and } \vec{\mathbf{v}} = \left(150\hat{\mathbf{i}} + 21\hat{\mathbf{j}}\right)\frac{\text{m}}{\text{s}}.$$

The plane is most likely
a. just touching down.
b. in level flight in the air.
c. ascending.
d. descending.
e. taking off.

ANS: C PTS: 1 DIF: Easy

53. With the x axis horizontal and the y axis vertically upward, the change in the horizontal component of velocity, Δv_x, and the change in the vertical component of velocity, Δv_y, of a projectile are related to the time since leaving the barrel, Δt, as

a. $\Delta v_x = 0; \Delta v_y = 0.$
b. $\Delta v_x = g\Delta t; \Delta v_y = 0.$
c. $\Delta v_x = 0; \Delta v_y = g\Delta t.$
d. $\Delta v_x = 0; \Delta v_y = -g\Delta t.$
e. $\Delta v_x = g\Delta t; \Delta v_y = -g\Delta t.$

ANS: D PTS: 1 DIF: Easy

54. Which of the following quantities is directly proportional to the time interval after a projectile has left the barrel that shot it out? The x axis is horizontal; the y axis is vertically upward.

a. $\Delta|\vec{\mathbf{v}}|$
b. Δa_y
c. Δy
d. $\Delta|\vec{\mathbf{r}}|$
e. Δv_y

ANS: E PTS: 1 DIF: Easy

55. A block is supported on a compressed spring, which projects the block straight up in the air at velocity $\vec{\mathbf{v}} = v_{0y}\hat{\mathbf{j}}$. The spring and ledge it sits on then retract. You can win a prize by hitting the block with a ball. When should you throw the ball and in what direction to be sure the ball hits the block? (Assume the ball can reach the block before the block reaches the ground and that the ball is thrown from a height equal to the release position of the block.)

a. At the instant when the block leaves the spring, directed at the block.
b. At the instant when the block leaves the spring, directed at the spring.
c. At the instant when the block is at the highest point, directed at the block.
d. At the instant when the block is at the highest point, directed at the spring.
e. When the block is back at the spring's original position, directed at that position.

ANS: C PTS: 2 DIF: Average

56. Car A leaves point O at $t = 0$ and travels a quarter circle counterclockwise at 30.0 m/s to point P. Car B will leave point O and travel to point P at the same speed but in a straight line. The radius of the circle is 100 m. At what time should car B leave point O in order to arrive at point P at the same time as car A?

a. At $t = 0$.
b. At $t = 0.52$ s.
c. At $t = 4.71$ s.
d. At $t = 4.98$ s.
e. At $t = 5.24$ s.

ANS: B PTS: 2 DIF: Average

57. Given the equations below, which description best fits the physical situation?

$$60.4\text{ m} = \left(40.0\,\frac{\text{m}}{\text{s}}\right)(2.00\text{ s}) - \frac{1}{2}\left(9.80\,\frac{\text{m}}{\text{s}^2}\right)(2.00\text{ s})^2$$

a. A projectile's displacement two seconds after being fired upward with a speed of 30.0 m/s.
b. A projectile's displacement two seconds after being fired upward with a speed of 40.0 m/s.

c. A projectile's displacement two seconds after being fired upward with a speed of 50.0 m/s.
d. A projectile's displacement two seconds after being fired upward with a speed of 60.0 m/s.
e. A projectile's displacement two seconds after being fired upward with a speed of 80.0 m/s.

ANS: B PTS: 1 DIF: Easy

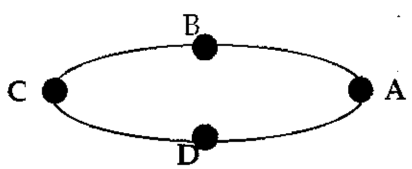
58. Given the equations below, which description best fits the physical situation?

$$-99.6\,\text{m} = \left(-40.0\,\frac{\text{m}}{\text{s}}\right)(2.00\,\text{s}) - \frac{1}{2}\left(9.80\,\frac{\text{m}}{\text{s}^2}\right)(2.00\,\text{s})^2$$

a. A projectile's displacement two seconds after being fired downward with a speed of 30.0 m/s.
b. A projectile's displacement two seconds after being fired downward with a speed of 40.0 m/s.
c. A projectile's displacement two seconds after being fired downward with a speed of 50.0 m/s.
d. A projectile's displacement two seconds after being fired downward with a speed of 60.0 m/s.
e. A projectile's displacement two seconds after being fired downward with a speed of 80.0 m/s.

ANS: B PTS: 1 DIF: Easy

59. A car travels around an oval racetrack at constant speed. The car is accelerating



a. at all points except **B** and **D**.
b. at all points except **A** and **C**.
c. ~~at all points except **A**, **B**, **C**, and **D**.~~
d. everywhere, including points **A**, **B**, **C**, and **D**.
e. nowhere, because it is traveling at constant speed.

Since V changes $a \neq 0$

ANS: D PTS: 1 DIF: Easy

60. In a location where the train tracks run parallel to a road, a high speed train traveling at 60 m/s passes a car traveling at 30 m/s. How long does it take for the train to be 180 m ahead of the car?
a. 2.0 s
b. 3.0 s
c. 6.0 s
d. 9.0 s
e. 18.0 s

ANS: C PTS: 2 DIF: Average

61. In a location where the train tracks run parallel to a road, a high speed train traveling at 60 m/s passes a car traveling at 30 m/s in the opposite direction. How long does it take for the train to be 180 m away from the car?
a. 2.0 s
b. 3.0 s

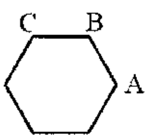
c. 6.0 s
d. 9.0 s
e. 18.0 s

ANS: A PTS: 2 DIF: Average

62. A motorcycle daredevil wants to ride up a 50.0 m ramp set at a 30.0° incline to the ground. It will launch him in the air and he wants to come down so he just misses the last of a number of 1.00 m diameter barrels. If the speed at the instant when he leaves the ramp is 60.0 m/s, how many barrels can be used?
a. 79
b. 318
c. 332
d. 355
e. 402

ANS: D PTS: 2 DIF: Average

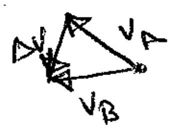
Exhibit 4-2
Newton approximated motion in a circle as a series of linear motions, as in the polygon below.



Assume that the particle moves at constant speed v_A from A to B, and at constant speed v_B from B to C.

Use this exhibit to answer the following question(s).

63. Refer to Exhibit 4-2. The direction of the change in velocity, $\Delta\vec{v}$, at point B, is shown by the arrow in
a.
b. 
(c.) 
d. 
e. 



$V_B = V_A + \Delta V$

$\Delta V = V_B - V_A$

ANS: C PTS: 1 DIF: Easy

64. Refer to Exhibit 4-2. The direction of the acceleration, $\vec{a}$, at point B, is shown by the arrow in
a.
b. 
(c.) 
d. 
e. 

ANS: C PTS: 1 DIF: Easy

65. While the gondola is rising at a speed of 2.0 m/s, a passenger in a balloon-supported gondola throws a small ball down at a speed of 5.0 m/s relative to his body. A person who measures the ball's velocity at the instant of release will find that the ball's velocity relative to the ground at that instant is
a. 2.0 m/s, up.
b. 3.0 m/s, down.
c. 3.0 m/s, up.
d. 5.0 m/s, down.
e. 12.8 m/s, down.

ANS: B PTS: 1 DIF: Easy

66. While the gondola is rising at a speed of 5.0 m/s, a passenger in a balloon-supported gondola throws a small ball up at a speed of 2.0 m/s relative to his body. A person who measures the ball's velocity at the instant of release will find that the ball's velocity relative to the ground at that instant is
a. 2.0 m/s, up.
b. 2.8 m/s, down.
c. 3.0 m/s, up.
d. 5.0 m/s, up.
e. 7.0 m/s, up.

ANS: E PTS: 1 DIF: Easy

67. Jane plans to fly from Binghampton, New York, to Springfield, Massachusetts, about 280 km due east of Binghampton. She heads due east at 280 km/h for one hour but finds herself at Keene, which is 294 km from Binghampton in a direction 17.8 degrees north of due east. What was the wind velocity?
a. 14 km/h, E
b. 14 km/h, W
c. 14 km/h, N
d. 90 km/h, S
e. 90 km/h, N

ANS: E PTS: 2 DIF: Average

68. A car is driven 1 200 m north at 20.0 m/s and then driven 1 600 m east at 25.0 m/s. What are the magnitude and direction of the displacement for this trip?
a. 1 400 m, northeast
b. 2 000 m, 36.9° north of east
c. 2 000 m, 53.1° north of east
d. 2 800 m, 36.9° east of north
e. 2 800 m, 53.1° east of north

ANS: B PTS: 2 DIF: Average

69. A car is driven 1 200 m north at 20.0 m/s and then driven 1 600 m east at 25.0 m/s. What is the magnitude of the average velocity for this trip?
a. 16.1 m/s
b. 22.6 m/s
c. 31.3 m/s
d. 11.3 m/s
e. 62.2 m/s

ANS: A PTS: 2 DIF: Average

PROBLEM

70. Wiley Coyote has missed the elusive roadrunner once again. This time, he leaves the edge of the cliff at 50.0 m/s horizontal velocity. If the canyon is 100 m deep, how far from the edge of the cliff does the coyote land?

    ANS:
    226 m

    PTS: 2 DIF: Average

71. A track star in the broad jump goes into the jump at 12 m/s and launches himself at 20° above the horizontal. How long is he in the air before returning to Earth?

    ANS:
    0.84 s

    PTS: 2 DIF: Average

72. An artillery shell is fired with an initial velocity of 300 m/s at 55.0° above the horizontal. It explodes on a mountainside 42.0 s after firing. If *x* is horizontal and *y* vertical, find the (*x*, *y*) coordinates where the shell explodes.

    ANS:
    7.22 km, 1.68 km

    PTS: 2 DIF: Average

73. A football is thrown upward at a 30.0° angle to the horizontal. To throw a 40.0-m pass, what must be the initial speed of the ball?

    ANS:
    21.3 m/s

    PTS: 2 DIF: Average

74. A satellite is in a circular orbit 600 km above the Earth's surface. The acceleration of gravity is 8.21 m/s^2 at this altitude. The radius of the Earth is 6 400 km. Determine the speed of the satellite, and the time to complete one orbit around the Earth.

    ANS:
    7 580 m/s, 5 800 s

    PTS: 2 DIF: Average

75. A tennis player standing 12.6 m from the net hits the ball at 3.00° above the horizontal. To clear the net, the ball must rise at least 0.330 m. If the ball just clears the net at the apex of its trajectory, how fast was the ball moving when it left the racket?

    ANS:
    48.6 m/s

    $X = V_0 \cos\theta\, t$, $y = V \sin\theta\, t + \frac{1}{2} g t^2$

    $y = \frac{1}{2} g t^2$, $t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2(0.33)}{9.8}}$

    $= 0.259s$

    then $V_0 = \frac{X}{\cos\theta\, t} = \frac{12.6}{\cos(3)(0.259)} = 48.6\, m/s$

PTS: 3 DIF: Challenging

76. A rifle is aimed horizontally toward the center of a target 0.10 km away, but the bullet strikes 10 cm below the center. Calculate the velocity of the bullet just as it emerges from the rifle.

$y = v_0 t + \frac{1}{2} g t^2 \rightarrow 10 \times 10^{-2} = \frac{1}{2} g t^2, \; t = \sqrt{\frac{20 \times 10^{-2}}{g}}\ s$

$x = v_0 t \rightarrow 0.1 \times 10^{3} = v_0 \sqrt{\frac{20 \times 10^{-2}}{g}} \rightarrow$ find v_0.

ANS:
700 m/s

PTS: 2 DIF: Average

77. A hunter wishes to cross a river that is 1.5 km wide and flows with a velocity of 5.0 km/h parallel to its banks. The hunter uses a small powerboat that moves at a maximum speed of 12 km/h with respect to the water. What is the minimum time for crossing?

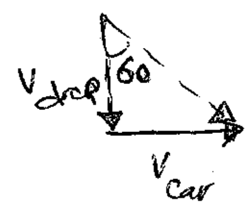
ANS:
0.14 h

PTS: 2 DIF: Average

78. Raindrops are falling straight downward. When observed from a car traveling at 55.0 mi/h, the drops streak the side window at an angle of 60.0° with the vertical. Find the speed with which the drops are falling.

$\tan 60 = \frac{v_{car}}{v_{drop}}$

$v_{drop} = \frac{v_{car}}{\tan 60}$



ANS:
31.8 mi/h

PTS: 2 DIF: Average

79. A fast duck is flying $(20\hat{\mathbf{i}} + 40\hat{\mathbf{j}})$ mi/h at the same altitude as a slow airplane flying with a velocity of $(-80\hat{\mathbf{i}} + 40\hat{\mathbf{j}})$ mi/h. How fast and in what direction is the duck moving relative to the airplane?

ANS:
100 mi/h, along $+\hat{\mathbf{i}}$

PTS: 2 DIF: Average

$V_{duck} = 20\hat{i} + 40\hat{j}$

$V_{airplane} = -80\hat{i} + 40\hat{j}$

$V_{AB} = V_A - V_B$

$V_{duck\ airplane} = V_{duck} - V_{airplane}$

$= 20\hat{i} + 40\hat{j} - (-80\hat{i} + 40\hat{j})$

$= 100\hat{j} - 0$