Motion in Two Dimensions and Newton's Laws of Motion

Advanced Placement Physics B
Mr. DiBucci

Name____ Per.___ Date ____
Two Dimensional Motion DiBucci

1. A baseball is thrown with an initial velocity of 10.0 m/s at an angle of 30 degrees. See the diagram below. (assume the ball returns to the same height at which it was thrown)

a. Calculate the components of the initial velocity vector and write the initial velocity vector in component form.

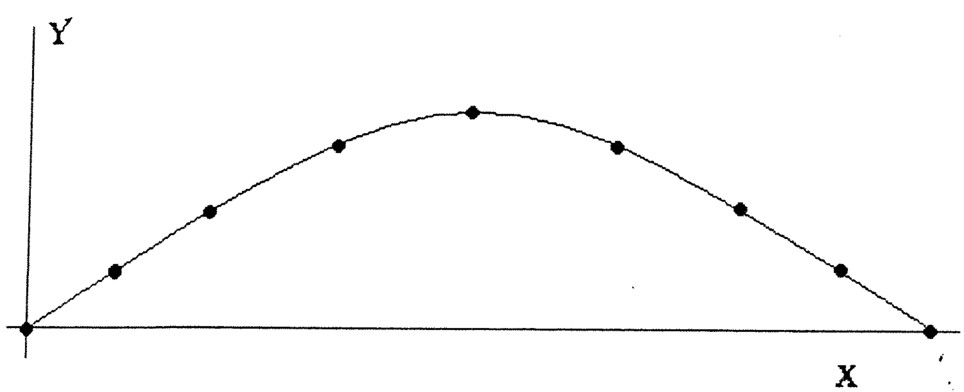
b. Calculate the total time the ball is in the air.

c. Calculate the range of the projectile.

d. Calculate the maximum height of the projectile.

e. Calculate the magnitude and direction of the final velocity just before impact. Write the vector in component form.

f. In the diagram below sketch and label the following vectors at the points designated.
   - x- component of the velocity vector
   - y- component of the velocity vector
   - magnitude of the total velocity vector
   - the acceleration vector



Name____ **per.** ___ **Date** ______

DiBucci

Projectile Motion Simulation Activity

Directions: For each of the following projectile motion problems calculate the ***maximum height***, the ***total time of flight***, and the ***range***, using the methods we studied in class. Then, use the ***projectile motion simulator*** link on my web site to verify your answers.

1. A projectile is fired from the edge of a 12.0m high cliff at an angle of 20.0 degrees, with an initial speed of 5.0 m/s.

2. A projectile is fired from the edge of a 15.0m high cliff at an angle of -30.0 degrees, with an initial speed of 3.0 m/s.

3. A projectile is fired from the edge of a 10.0m high cliff at an angle of 0.0 degrees, with an initial speed of 13.0 m/s

Name ________________________________ **per.** ___ **date** ________

Motion in a plane and projectile motion **DiBucci**

Directions: Place your work on a separate piece of paper.

1) A particle starts from the origin at t=0 with the following initial velocity:
Vx= +20 m/s, Vy= -15 m/s
The particle moves in the xy plane with only an x-component of acceleration:
ax=4.0 m/s/s, ay=0 m/s/s

a) Write the initial velocity and acceleration in unit vector form.
b) Calculate the final velocity after 5.0 seconds, express your answer in unit vector and polar coordinate form.
c) Calculate the position (displacement) of the particle relative to the origin after the same time interval as in pt. b

Vo= 20 m/s **i** – 15 m/s **j**
a= 4 m/s/s **i** + 0 m/s/s **j**
Vf = 40 m/s **i** – 15 m/s **j** , Vf = 43 m/s at 21 degrees south of east
r = 150 m **i** – 75m **j** , r = 170 m at 26.6 degrees south of east

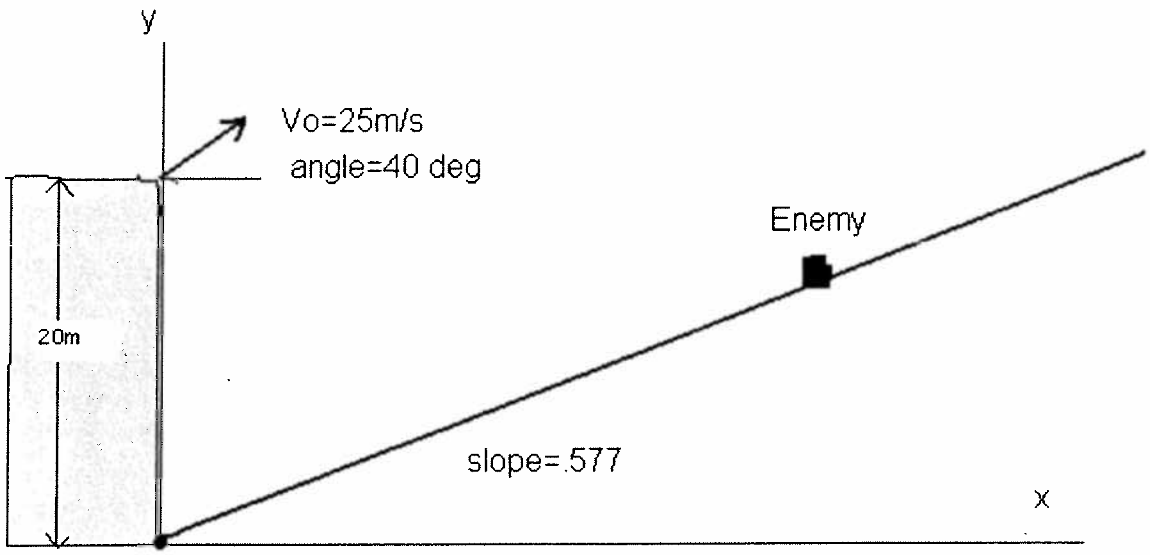
2) A long – jumper leaves the ground at an angle of 20 degrees to the horizontal at a speed of 11.0 m/s. assume ay=-9.8 m/s/s/ and ax=0m/s/s. Calculate the following quantities:
a) Calculate the x and y components of the initial velocity
b) the total time of flight
c) the horizontal displacement when he returns to the ground (The range)
d) The maximum height he was above the ground

Vo= 10.3 m/s **i** + 3.76 m/s **j**
total time = 0.768 s
Rx , the range or Xf = 7.94 m
Ymax=0.722m

3. A stone is thrown from the top of a building at an angle of 30.0 degrees to the horizontal with an initial speed of 20.0m/s the height of the building is 45.0 m. make a diagram and calculate the following:
a) the horizontal and vertical components of the initial velocity
b) the total time of flight (hint : use the quadratic formula)
c) the velocity of the stone just before impact
d) the horizontal distance from the building where the stone strikes the ground.

Vo=17.3 m/s **i** + 10 m/s **j**
time= 4.22 s
Vf= 17.3 m/s **i** – 31.4 m/s **j** , Vf=35.9 m/s at 61.4 degrees below the x axis
x=73.0 m from the base of the building

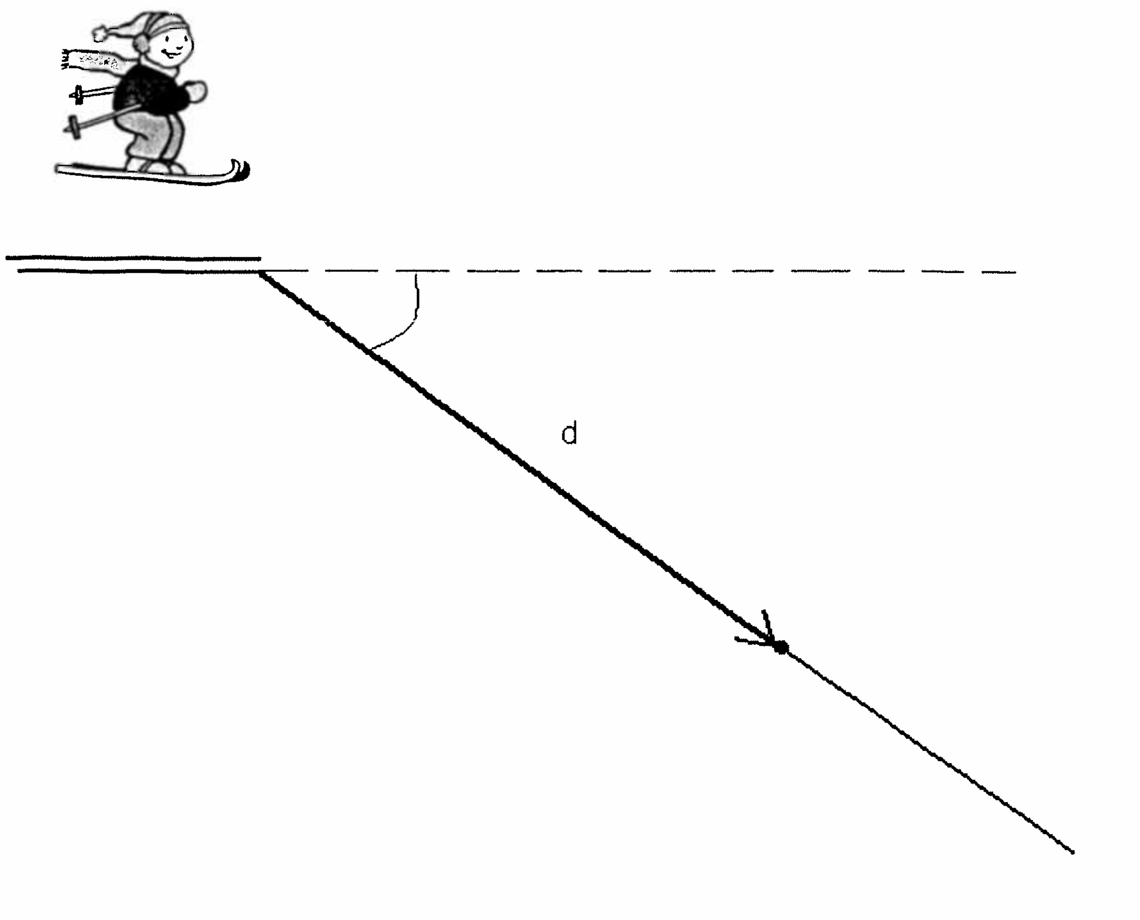
Name ____ per. ___ date ____
Projectile Motion DiBucci



Your mission is to destroy the enemy base camp. You are on the top of a ledge over looking a valley. You are at a height of 20m relative to the reference level. See the above diagram. The enemy camp is on the sloping hill across the valley. The slope of the hill is 0.577. Your goal is to use your heavy artillery to hit a spot on the hill above the enemy camp, this will cause an avalanche and bury them. The coordinates of the enemy are (30m, 25m). You fire your weapon at a 40 degree angle with a velocity of 25 m/s. Calculate the coordinates where the shell hits. Did you achieve your goal?

Name ____ per. ___ Date __________
Projectile Motion DiBucci

The End of a Ski Jump



A Ski Jumper travels down a slope and leaves the ski track moving in the horizontal direction with a speed of 25.0 m/s. See the figure above. The landing incline below her falls off with a slope of 35.0 degrees.

a) How far down the incline, d, does she land? (109m)
b) How long is she in the air? (3.57 sec)
c) What are the horizontal and vertical components of her velocity just before she lands? (25m/s, -35m/s)

PROBLEMS

7.1 Projectile Motion

▶ 1. Assuming that the two baseballs in Figure 7–19 have the same velocity, 25 m/s, draw two separate graphs of y as a function of t and x as a function of t for each ball.

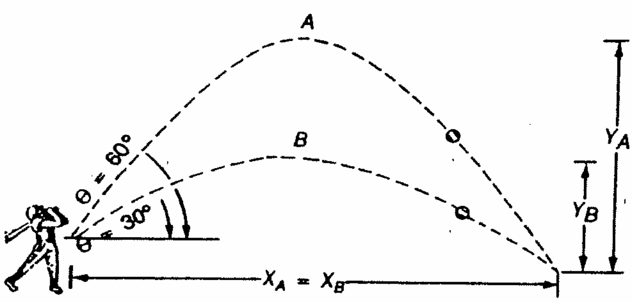


FIGURE 7–19. Use with Problem 1.

2. A stone is thrown horizontally at 8.0 m/s from a cliff 78.4 m high. How far from the base of the cliff does the stone strike the ground?

3. A toy car runs off the edge of a table that is 1.225 m high. If the car lands 0.400 m from the base of the table,
   a. how long does it take for the car to fall?
   b. what is the horizontal velocity of the car?

4. Janet jumps off a high-diving platform with a horizontal velocity of 2.8 m/s and lands in the water 2.6 s later. How high is the platform, and how far from the base of the platform does she land?

▶ 5. An airplane traveling 1001 m above the ocean at 125 km/h is to drop a box of supplies to shipwrecked victims below.
   a. How many seconds before being directly overhead should the box be dropped?
   b. What is the horizontal distance between the plane and the victims when the box is dropped?

▶ 6. Divers at Acapulco dive from a cliff that is 61 m high. If the rocks below the cliff extend outward for 23 m, what is the minimum horizontal velocity a diver must have to clear the rocks safely?

▶ 7. A dart player throws a dart horizontally at a speed of +12.4 m/s. The dart hits the board 0.32 m below the height from which it was thrown. How far away is the player from the board?

▶ 8. An arrow is shot at a 30.0° angle with the horizontal. It has a velocity of 49 m/s.
   a. How high will the arrow go?
   b. What horizontal distance will it travel?

▶ 9. A pitched ball is hit by a batter at a 45° angle. It just clears the outfield fence, 98 m away. Find the velocity of the ball when it left the bat. Assume the fence is the same height as the pitch. X = 98m

▶ 10. Trailing by two points, and with only 2.0 s remaining in a basketball game, a player makes a jump-shot at an angle of 60° with the horizontal, giving the ball a velocity of 10 m/s. The ball is released at the height of the basket, 3.05 m above the floor. Yes! It's a score.
   a. How much time is left in the game when the basket is made?
   b. Shots made outside a semicircle of 6.02-m radius from a spot directly beneath the basket are awarded 3 points, while those inside score 2 points. Did the player tie the game or put the team ahead?

▶ 11. A basketball player tries to make a half-court jump-shot, releasing the ball at the height of the basket. Assuming the ball is launched at 51.0°, 14.0 m from the basket, what velocity must the player give the ball?

▶ 12. A baseball is hit at 30.0 m/s at an angle of 53.0° with the horizontal. Immediately an outfielder runs 4.00 m/s toward the infield and catches the ball at the same height it was hit. What was the original distance between the batter and the outfielder?

2) 32 m
3) .5s, 0.8 m/s
4) 33 m, 7.3 m
5) 14.3s, 496 m
6) 6.6 m/s
7) 3.2 m
8) 32 m, 210 m
9) 31 m/s, 45°
10) 0.2s, ahead

Section 3.1 Displacement, Velocity, and Acceleration

1. ssm In diving to a depth of 750 m, an elephant seal also moves 460 m due east of his starting point. What is the magnitude of the seal's displacement?

2. A radar antenna is tracking a satellite orbiting the earth. At a certain time, the radar screen shows the satellite to be 162 km away. The radar antenna is pointing upward at an angle of 62.3° from the ground. Find the x and y components (in km) of the position of the satellite.

3. A baseball player hits a triple and ends up on third base. A baseball "diamond" is a square, each side of length 27.4 m, with home plate and the three bases on the four corners. What is the magnitude of his displacement?

4. The altitude of a hang glider is increasing at a rate of 6.80 m/s. At the same time, the shadow of the glider moves along the ground at a speed of 15.5 m/s when the sun is directly overhead. Find the magnitude of the glider's velocity.

5. ssm A jetliner is moving at a speed of 245 m/s. The vertical component of the plane's velocity is 40.6 m/s. Determine the magnitude of the horizontal component of the plane's velocity.

6. A dart is thrown upward at an angle of 25° above the horizontal. The vertical component of the dart's velocity is v_y = 2.2 m/s. Determine the x component of the velocity.

7. A wild horse starts from rest and runs in a straight line 29° north of west. After 36 s of running in this direction, the horse has a speed of 12 m/s. (a) What is the magnitude of the horse's average acceleration? Assuming that north and east are the positive directions, find the component of the horse's acceleration that points along (b) the north–south line and (c) the east–west line.

8. An archer draws back an arrow and then releases it from rest. The arrow is propelled forward with an average acceleration of 2400 m/s^2 and remains in contact with the bow string for a time of 0.025 s. What is the speed of the arrow when it just leaves the string?

9. ssm www In a mall, a shopper rides up an escalator between floors. At the top of the escalator, the shopper turns right and walks 9.00 m to a store. The magnitude of the shopper's displacement from the bottom of the escalator is 16.0 m. The vertical distance between the floors is 6.00 m. At what angle is the escalator inclined above the horizontal?

***10.** A bird watcher meanders through the woods, walking 0.50 km due east, 0.75 km due south, and 2.15 km in a direction 35.0° north of west. The time required for this trip is 2.50 h. Determine the magnitude and direction (relative to due west) of the bird watcher's (a) displacement and (b) average velocity. Use kilometers and hours for distance and time, respectively.

***11.** The earth moves around the sun in a nearly circular orbit of radius 1.50×10^{11} m. During the three summer months (an elapsed time of 7.89×10^6 s), the earth moves one-fourth of the distance around the sun. (a) What is the average speed of the earth? (b) What is the magnitude of the average velocity of the earth during this period?

1) 8.8×10^2 m
2) 75.3 km, 143 km
3) 27.4 m
4) 16.9 m/s
5) 242 m/s
6) 4.7 m/s
7) 0.33 m/s^2, 1.6 m/s^2, −0.29 m/s^2
8) 60 m/s
9) 27.0°
10) 1.357 km, 21° N of W, 0.540 km/hr, 21° N…
11) 2.99×10^4 m/s, 2.69×10^4 m/s

(on next page)

12) 5.92×10^3 m/s
13) 14.6 s
14) 13.6 m/s
15) 4.42 m/s
16) 5.1 m
17) 14.1 m/s
18) 60 m, 290 m
19) 85 m, 610 m
20) Ball Arrives First, 0.70 s
21) 1.78 s, 20.8 m/s
22) 10.3 m
23) 39 m/s
24) 18 m/s
25) 239 m/s, 57.1°
26) 2.40 m
27) 24 Buses

Section 3.2 Equations of Kinematics in Two Dimensions, Section 3.3 Projectile Motion

12. The initial velocity of a spacecraft is 2650 m/s, directed at an angle of 30.0° above the x axis. Two engines then fire for a time of 475 s. One gives the spacecraft an acceleration in the $+x$ direction of $a_x = 6.30\ m/s^2$. The other produces an acceleration in the $+y$ direction of $a_y = 2.85\ m/s^2$. What is the speed of the spacecraft when the engines shut off?

13. **ssm** Suppose that the plane in Example 2 is traveling with twice the horizontal velocity, that is, with a velocity of +230 m/s. If all other factors remain the same, determine the time required for the package to hit the ground.

14. A quarterback throws a pass to a receiver, who catches it at the same height as the pass is thrown. The initial velocity of the ball is 15.0 m/s, at an angle of 25.0° above the horizontal. What is the horizontal component of the ball's velocity when the receiver catches it?

15. The punter on a football team tries to kick a football so that it stays in the air for a long "hang time." If the ball is kicked with an initial velocity of 25.0 m/s at an angle of 60.0° above the ground, what is the "hang time"?

16. A rock climber throws a small first aid kit to another climber who is higher up the mountain. The initial velocity of the kit is 11 m/s at an angle of 65° above the horizontal. At the instant when the kit is caught, it is traveling horizontally, so its vertical speed is zero. What is the vertical height between the two climbers?

17. **ssm www** A diver runs horizontally with a speed of 1.20 m/s off a platform that is 10.0 m above the water. What is his speed just before striking the water?

18. Review Conceptual Example 9 as background for this problem. The acceleration due to gravity on the moon has a magnitude of $1.62\ m/s^2$. Examples 5–7 deal with a placekicker kicking a football. Assume that the ball is kicked on the moon instead of on the earth. Find (a) the maximum height H and (b) the range that the ball would attain on the moon. Verify that your answers are consistent with the conclusions reached in Conceptual Example 9.

19. Review Conceptual Example 9 in preparation for this problem. On a distant planet, golf is just as popular as it is on earth. A golfer tees off and drives the ball 3.5 times farther than he would have on earth, given the same initial velocities on both planets. The ball is launched at a speed of 45 m/s at an angle of 29° above the horizontal. When the ball lands, it is at the same level as the tee. On the distant planet, what is (a) the maximum height and (b) the range of the ball?

20. During a baseball game a fly ball is hit to center field and is caught 115 m from home plate. Just when the ball is caught, a runner on third base takes off for home, and the center fielder throws the ball to the catcher standing on home plate. The runner takes 3.50 s to reach home, while the baseball is thrown with a velocity whose *horizontal* component is 41 m/s. Which reaches home first, the runner or the ball, and by how much time?

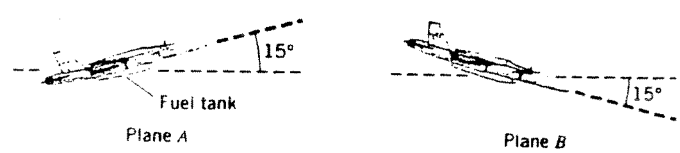
21. **ssm** A golf ball rolls off a horizontal cliff with an initial speed of 11.4 m/s. The ball falls a vertical distance of 15.5 m into a lake below. (a) How much time does the ball spend in the air? (b) What is the speed v of the ball just before it strikes the water?

22. If a projectile has a launching angle of 52.0° above the horizontal and an initial speed of 18.0 m/s, what is the highest barrier that the projectile can clear?

23. A car drives straight off the edge of a cliff that is 54 m high. The police at the scene of the accident note that the point of impact is 130 m from the base of the cliff. How fast was the car traveling when it went over the cliff?

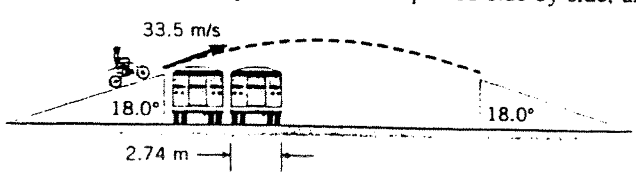
24. The 1994 Winter Olympics included the aerials competition in skiing. In this event skiers speed down a ramp that slopes sharply upward at the end. The sharp upward slope launches them into the air, where they perform acrobatic maneuvers. In the women's competition, the end of a typical launch ramp is directed 63° above the horizontal. With this launch angle, a skier attains a height of 13 m above the end of the ramp. What is the skier's launch speed?

25. **ssm** As preparation for this problem, review Conceptual Example 10. The drawing shows an empty fuel tank being dropped by two different planes. At the moment of release each plane has the same speed of 135 m/s and each tank is at the same height of 2.00 km above the ground. While the speeds are the same, the velocities are different at the instant of release, because one plane is flying at an angle of 15.0° above the horizontal and the other is flying at an angle of 15.0° below the horizontal. Find the magnitude and direction of the velocity with which the fuel tank hits the ground if it is from (a) plane A and (b) plane B. In each part, give the directional angles with respect to the horizontal.



26. A tennis ball is struck such that it leaves the racket horizontally with a speed of 28.0 m/s. The ball hits the court at a horizontal distance of 19.6 m from the racket. What is the height of the tennis ball when it leaves the racket?

*27. A motorcycle daredevil is attempting to jump across as many buses as possible (see the drawing). The takeoff ramp makes an angle of 18.0° above the horizontal, and the landing ramp is identical to the takeoff ramp. The buses are parked side by side, and each bus is 2.74 m wide. The cyclist leaves the ramp with a speed of 33.5 m/s. What is the maximum number of buses over which the cyclist can jump?



28. A horizontal rifle is fired at a bull's-eye. The muzzle speed of the bullet is 670 m/s. The barrel is pointed directly at the center of the bull's-eye, but the bullet strikes the target 0.025 m below the center. What is the horizontal distance between the end of the rifle and the bull's-eye?

29. ssm An eagle is flying horizontally at 6.0 m/s with a fish in its claws. It accidentally drops the fish. (a) How much time passes before the fish's speed doubles? (b) How much additional time would be required for the fish's speed to double again?

30. A criminal is escaping across a rooftop and runs off the roof horizontally, landing on the roof of an adjacent building. The horizontal distance between the two buildings is 3.4 m, and the roof of the adjacent building is 2.0 m below the jumping off point. What would be the minimum speed needed by the criminal?

***31.** Suppose the water at the top of Niagara Falls has a horizontal speed of 2.7 m/s just before it cascades over the edge of the falls. At what vertical distance below the edge does the velocity vector of the water point downward at a 75° angle below the horizontal?

32. An archer is standing inside a building whose ceiling is 11 m high. An arrow is shot from ground level at an initial speed of 62 m/s. Calculate the angle of firing (above the horizontal) that gives the greatest possible range inside the building.

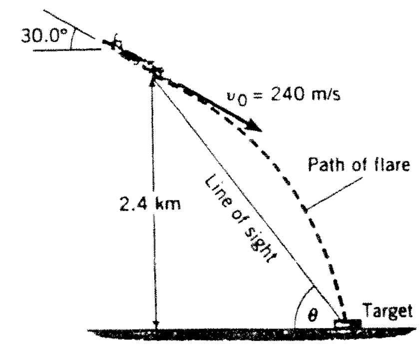
***33. ssm www** As preparation for this problem, review Conceptual Example 10. The two stones described there have identical initial speeds of v_0 = 13.0 m/s and are thrown at an angle θ = 30.0°, one below the horizontal and one above the horizontal. What is the distance *between* the points where the stones strike the ground?

34.** A rock, thrown horizontally from the top of a lighthouse, strikes the water 2.6 s later. A ***straight line is drawn from the top of the lighthouse to the point where the rock strikes the water. This line makes an angle of 35° with respect to the lighthouse. Calculate the initial speed of the rock.

***35.** A soccer player kicks the ball toward a goal that is 29.0 m in front of him. The ball leaves his foot at a speed of 19.0 m/s and an angle of 32.0° above the ground. Find the speed of the ball when the goalie catches it in front of the net. *(Note: The answer is not 19.0 m/s.)*

***36.** Review Conceptual Example 4 before beginning this problem. You are traveling in a convertible with the top down. The car is moving at a constant velocity of 25 m/s, due east along flat ground. You throw a tomato straight upward at a speed of 11 m/s. How far has the car moved when you get a chance to catch the tomato?

***37. ssm** An airplane is flying with a velocity of 240 m/s at an angle of 30.0° with the horizontal, as the drawing shows. When the altitude of the plane is 2.4 km, a flare is released from the plane. The flare hits the target on the ground. What is the angle θ?



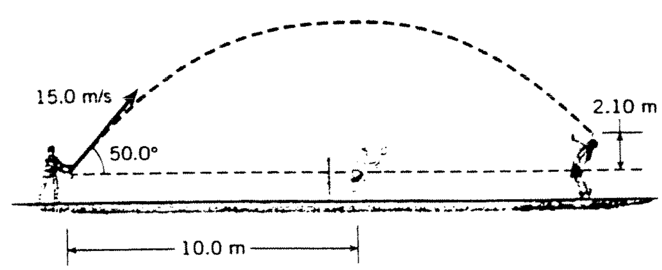
***38.** A diver springs upward from a board that is three meters above the water. At the instant she contacts the water her speed is 8.90 m/s and her body makes an angle of 75.0° with respect to the horizontal surface of the water. Determine her initial velocity, both magnitude and direction.

***39.** After leaving the end of a ski ramp, a ski jumper lands downhill at a point that is displaced 55 m horizontally from the end of the ramp. His velocity, just before landing, is 25 m/s and points in a direction 38° below the horizontal. Neglecting air resistance and any lift that he experiences while airborne, find his initial velocity (magnitude and direction) when he left the end of the ramp.

***40.** Stones are thrown horizontally with the same velocity from the tops of two different buildings. One stone lands twice as far from the base of the building from which it was thrown as does the other stone. Find the ratio of the height of the taller building to the height of the shorter building.

***41. ssm** An Olympic long jumper leaves the ground at an angle of 23° and travels through the air for a horizontal distance of 8.7 m before landing. What is the takeoff speed of the jumper?

***42.** The lob in tennis is an effective tactic when your opponent is near the net. It consists of lofting the ball over his head, forcing him to move quickly away from the net (see the drawing). Suppose that you loft the ball with an initial speed of 15.0 m/s, at an angle of 50.0° above the horizontal. At this instant your opponent is 10.0 m away from the ball. He begins moving away from you 0.30 s later, hoping to reach the ball and hit it back at the moment that it is 2.10 m above its launch point. With what minimum average speed must he move? (Ignore the fact that he can stretch, so that his racket can reach the ball before he does.)

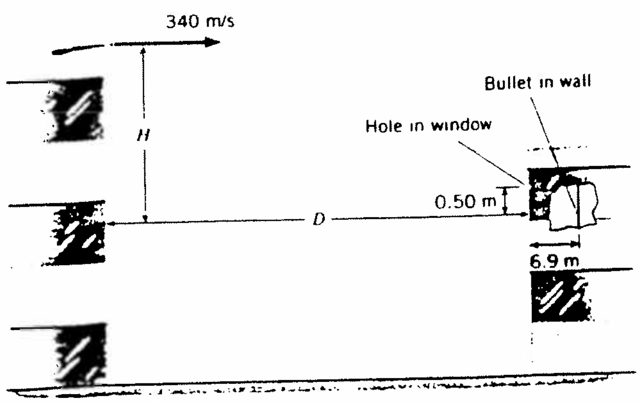


28) 48m
29) 1.1s, 1.3s
30) 5.3 m/s
31) 5.2m
32) 14°
33) 14.4m
34) 8.8m/s
35) 17.8m/s
36) 56m
37) 42°
38) 4.52 m/s, 59.4°
39) 23 m/s, 31°
40) 4 times
41) 11 m/s
42) 5.79 m/s

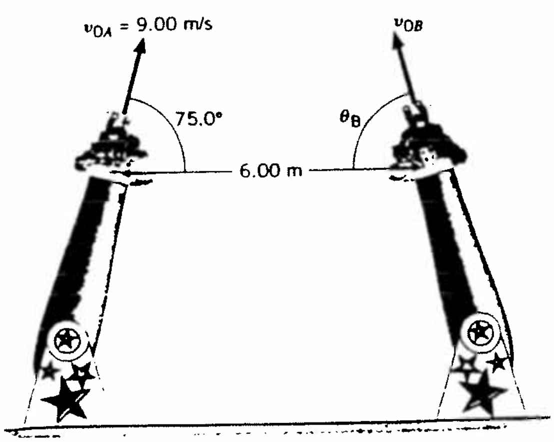
**43. Water from a garden hose that is pointed 25° above the horizontal lands directly on a sunbather lying on the ground 4.4 m away in the horizontal direction. If the hose is held 1.4 m above the ground, at what speed does the water leave the nozzle? **

**44. A baseball is hit into the air at an initial speed of 36.6 m/s and an angle of 50.0° above the horizontal. At the same time, the center fielder starts running away from the batter and catches the ball 0.914 m above the level at which it was hit. If the center fielder is initially 1.10×10^2 m from home plate, what must be his average speed?

45. **ssm From the top of a tall building, a gun is fired. The bullet leaves the gun at a speed of 340 m/s, parallel to the ground. As the drawing shows, the bullet puts a hole in a window of another building and hits the wall that faces the window. Using the data in the drawing, determine the distances D and H, which locate the point where the gun was fired. Assume that the bullet does not slow down as it passes through the window.



**46. Two cannons are mounted as shown in the drawing and rigged to fire simultaneously. They are used in a circus act in which two clowns serve as human cannon balls. The clowns are fired toward each other and collide at a height of 1.00 m above the muzzles of the cannons. Clown A is launched at a 75.0° angle, with a speed of 9.00 m/s. The horizontal separation between the clowns as they leave the cannons is 6.00 m. Find the launch speed v_{0B} and the launch angle θ_B (>45.0°) for clown B.



43) 5.8 m/s
44) 4.2 m/s
45) 31 m, 850 m
46) 8.79 m/s $\theta = 81.5°$

Section 3.4 Relative Velocity

47. **ssm** Two passenger trains are passing each other on adjacent tracks. Train A is moving east with a speed of 13 m/s, and train B is traveling west with a speed of 28 m/s. (a) What is the velocity (magnitude and direction) of train A as seen by the passengers in train B? (b) What is the velocity (magnitude and direction) of train B as seen by the passengers in train A?

48. In a marathon race Chad is out in front, running due north at a speed of 4.00 m/s. John is 95 m behind him, running due north at a speed of 4.50 m/s. How long does it take for John to pass Chad?

49. At some airports there are speedramps to help passengers get from one place to another. A speedramp is a moving conveyor belt that you can either stand or walk on. Suppose a speedramp has a length of 105 m and is moving at a speed of 2.0 m/s relative to the ground. In addition, suppose you can cover this distance in 75 s when walking on the ground. If you walk at the same rate with respect to the speedramp that you walk with respect to the ground, how long does it take for you to travel the 105 m using the speedramp?

50. On a pleasure cruise a boat is traveling relative to the water at a speed of 5.0 m/s due south. Relative to the boat, a passenger walks toward the back of the boat at a speed of 1.5 m/s. (a) What is the magnitude and direction of the passenger's velocity relative to the water? (b) How long does it take for the passenger to walk a distance of 27 m on the boat? (c) How long does it take for the passenger to cover a distance of 27 m on the water?

51. **ssm** A swimmer, capable of swimming at a speed of 1.4 m/s in still water (i.e., the swimmer can swim with a speed of 1.4 m/s relative to the water), starts to swim directly across a 2.8-km-wide river. However, the current is 0.91 m/s, and it carries the swimmer downstream. (a) How long does it take the swimmer to cross the river? (b) How far downstream will the swimmer be upon reaching the other side of the river?

52. The escalator that leads down into a subway station has a length of 30.0 m and a speed of 1.8 m/s relative to the ground. A student is coming out of the station by running in the wrong direction on this escalator. The local record time for this trick is 11 s. Relative to the escalator, what speed must the student exceed in order to beat the record?

53. You are in a hot-air balloon that, relative to the ground, has a velocity of 6.0 m/s in a direction due east. You see a hawk moving directly away from the balloon in a direction due north. The speed of the hawk relative to you is 2.0 m/s. What are the magnitude and direction of the hawk's velocity relative to the ground? Express the directional angle relative to due east.

54. A remote-controlled model airplane is flying due east in still air. The airplane travels with a speed of 22.6 m/s relative to the air. A wind suddenly begins to blow from the north toward the south with a speed of 8.70 m/s. Find the velocity (magnitude and direction) of the airplane as seen by the controller standing on the ground. Determine the directional angle relative to due east.

55. A person looking out the window of a stationary train notices that raindrops are falling vertically down at a speed of 5.0 m/s relative to the ground. When the train moves at a constant velocity, the raindrops make an angle of 25° when they move past the window, as the drawing shows. How fast is the train moving?

*56. A ferry boat is traveling in a direction 35.1° north of east with a speed of 5.12 m/s relative to the water. A passenger is walking with a velocity of 2.71 m/s due east relative to the boat. What is the velocity (magnitude and direction) of the passenger with respect to the water? Determine the directional angle relative to due east.

*57. **ssm** Mario, a hockey player, is skating due south at a speed of 7.0 m/s relative to the ice. A teammate passes the puck to him. The puck has a speed of 11.0 m/s and is moving in a direction of 22° west of south, relative to the ice. What are the magnitude and direction (relative to due south) of the puck's velocity, as observed by Mario?

47) +41 m/s east
−41 m/s west

48) 190 s

49) 31 s

50) 3.5 m/s south
18 s
7.7 s

51) 2.0×10^3 s
1.8×10^3 m

52) 4.5 m/s

53) 6.3 m/s
18° N of E

54) 24.2 m/s
21.1° S of E

55) 2.3 m/s

56) 7.50 m/s, 23.1° N of E

57) 5.2 m/s, 52° W of S

Section 5.1 Uniform Circular Motion, Section 5.2 Centripetal Acceleration

1. **ssm** How long does it take a plane, traveling at a speed of 110 m/s, to fly once around a circle whose radius is 2850 m?

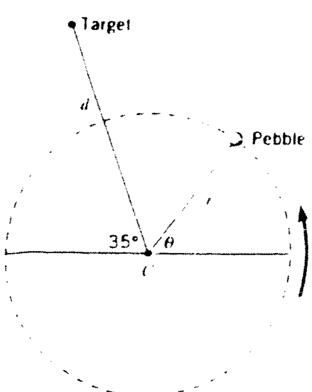
2. The tips of the blades in a food blender are moving with a speed of 21 m/s in a circle that has a radius of 0.053 m. How much time does it take for the blades to make one revolution?

3. A horse races once around a circular track in a time of 118 s, with a speed of 17 m/s. What is the radius of the track?

4. Review Conceptual Example 2 in preparation for this problem. In Figure 5.4, an object, after being released from its circular path, travels the distance *OA* in the same time it would have moved from *O* to *P* on the circle. The speed of the object on and off the circle remains constant at the same value. Suppose that the radius of the circle in Figure 5.4 is 3.6 m and the angle θ is 25°. What is the distance *OA*?

5. **ssm** Computer-controlled display screens provide drivers in the Indianapolis 500 with a variety of information about how their cars are performing. For instance, as a car is going through a turn, a speed of 221 mi/h (98.8 m/s) and a centripetal acceleration of 3.00 *g* (three times the acceleration due to gravity) are displayed. Determine the radius of the turn (in meters).

6. Review Conceptual Example 2 as background for this problem. One kind of slingshot consists of a pocket that holds a pebble and is whirled on a circle of radius *r*. The pebble is released from the circle at the angle θ, so that it will hit the target. The distance to the target from the center of the circle is *d*. (See the drawing, which is not to scale.) The circular path is parallel to the ground, and the target lies in the plane of the circle. The distance *d* is ten times the radius *r*. Ignore the effect of gravity in pulling the stone downward after it is released, and find the angle θ.



7. The blade of a windshield wiper moves through an angle of 90.0° in 0.28 s. The tip of the blade moves on the arc of a circle that has a radius of 0.76 m. What is the magnitude of the centripetal acceleration of the tip of the blade?

•8. The earth rotates once per day about an axis passing through the north and south poles, an axis that is perpendicular to the plane of the equator. Assuming the earth is a sphere with a radius of 6.38×10^6 m, determine the speed and centripetal acceleration of a person situated (a) at the equator and (b) at a latitude of 30.0° north of the equator.

•9. **ssm** The large blade of a helicopter is rotating in a horizontal circle. The length of the blade is 6.7 m, measured from its tip to the center of the circle. Find the ratio of the centripetal acceleration at the end of the blade to that which exists at a point located 3.0 m from the center of the circle.

•10. A centrifuge is a device in which a small container of material is rotated at a high speed on a circular path. Such a device is used in medical laboratories, for instance, to cause the more dense red blood cells to settle through the less dense blood serum and collect at the bottom of the container. Suppose the centripetal acceleration of the sample is 6.25×10^3 times larger than the acceleration due to gravity. How many revolutions per minute is the sample making, if it is located at a radius of 5.00 cm from the axis of rotation?

1) 160 s
2) 0.016 s
3) 320 m
4) 1.6 m
5) 332 m
6) 61°
7) 24 m/s²
8) 464 m/s, 3.37×10⁻² m/s², 232 m/s,
1.69×10⁻² m/s²

9) 2.2
10) 10,600 rev/min

Honors Physics

Kinematics in Two Dimensions

PREVIEW

In this chapter the concepts of displacement, velocity, and acceleration are applied to motion in two dimensions. You will learn to describe motion along a curved line, such as a car moving on a race track, a ball flying through the air, or a spacecraft in deep space. The kinematic equations for displacement, velocity, and acceleration developed in Chapter 2 will be applied here to describe projectile motion and relative velocity.

QUICK REFERENCE

Important Terms

Projectile Motion
An object moving in two dimensions which experiences only the acceleration due to gravity. Air resistance is assumed to be negligible and there is no acceleration in the x direction, i.e., $a_x = 0$. In the y direction on earth we have $a_y = -9.80\ m/s^2$. A baseball or football thrown from one person to another is a good example.

Relative Velocity
The velocity of a moving object can take on different values depending on the point of view of the observer. That is, the value of the velocity must be measured 'relative' to a particular observer.

Kinematic Equations for Two Dimensional Motion (Constant Acceleration)

$$v_x = v_{0x} + a_x t \quad (3.3a) \qquad v_y = v_{0y} + a_y t \quad (3.3b)$$

$$x = \frac{1}{2}(v_{0x} + v_x)\,t \quad (3.4a) \qquad y = \frac{1}{2}(v_{0y} + v_y)\,t \quad (3.4b)$$

$$x = v_{0x}\,t + \frac{1}{2} a_x t^2 \quad (3.5a) \qquad y = v_{0y}\,t + \frac{1}{2} a_y t^2 \quad (3.5b)$$

$$v_x^2 = v_{0x}^2 + 2\,a_x x \quad (3.6a) \qquad v_y^2 = v_{0y}^2 + 2\,a_y y \quad (3.6b)$$

DISCUSSION OF SELECTED SECTIONS

3.2 Equations of Kinematics in Two Dimensions

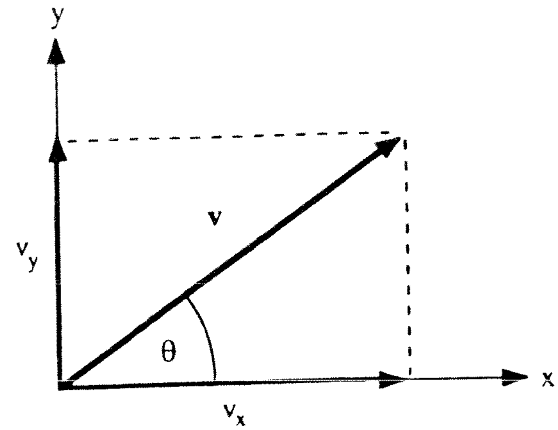
In Chapter 2 we emphasized that displacement, velocity, and acceleration were vector quantities. In one-dimensional motion the direction of these vectors was simply denoted by a positive or negative sign. In the more complex realm of two dimensions we must be careful to treat both the x and y motion independently, with the understanding that they will add together as vectors.

In treating two-dimensional motion we must be careful to view the x and y components of the motion as separate but related quantities. We will see that the x part of the motion occurs exactly as it would if the y part did not occur at all. Similarly, the y part of the motion occurs exactly as it would if the x part of the motion did not exist. Therefore, two sets of kinematic equations are needed to describe the full two dimensional motion.

Example 1 *Components of the velocity vector*
A ball is traveling at a constant velocity of 20.0 m/s at an angle of 30.0 degrees with respect to the x axis. How far does the ball travel in the x and y directions in 1 minute? See the diagram shown below.

First find the x and y components of the velocity.

$$v_x = v \cos\theta = (20.0 \text{ m/s})\cos 30.0^\circ = 17.3 \text{ m/s.}$$
$$v_y = v \sin\theta = (20.0 \text{ m/s})\sin 30.0^\circ = 10.0 \text{ m/s.}$$



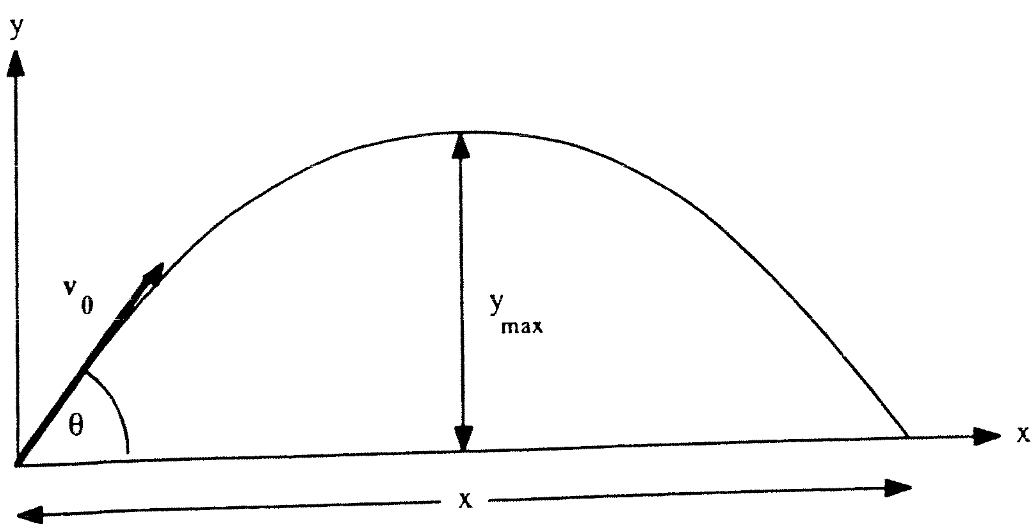
Since there is no acceleration, the x and y displacements are given by equations (3.5a) and (3.5b) with $v_{0x} = v_x$ and $v_{0y} = v_y$. We therefore have,

$$x = v_x\, t = (17.3 \text{ m/s})\,(60 \text{ s}) = 1040 \text{ m.}$$
$$y = v_y\, t = (10.0 \text{ m/s})\,(60 \text{ s}) = 600 \text{ m.}$$

3.3 Projectile Motion

When we throw a ball, or fire a bullet from a gun, the motion is one in which only the vertical component of the velocity changes with time. The horizontal velocity component remains constant (assuming that air resistance is negligible). We refer to this type of motion as **projectile motion**. The equations describing the trajectory of such a projectile are equations (3.3) through (3.6). Consider the following example.

Example 2
A football is kicked with an initial velocity of 82 ft/s at an angle of 53° with respect to the horizontal. How high does the football go and how far down the field does it land?



The x and y motions can be treated separately. Begin by looking at the motion in the y direction. We have

$$v_{0y} = v_0 \sin\theta = (82 \text{ ft/s}) \sin 53^\circ = 65 \text{ ft/s}; \quad a_y = -32.2 \text{ ft/s}^2; \quad v_y = 0.$$

Notice we have chosen the final velocity to be zero. In effect, we are looking at the first half of the motion in the y direction, i.e., the portion of the motion in which the ball is rising. When the ball reaches its maximum height, $v_y = 0$ and $y = y_{max}$. Using equation (3.6b) we can solve for this maximum height y,

$$y_{max} = y = \frac{-v_{0y}^2}{2a_y} = \frac{-(65\ ft/s)^2}{2(-32.2\ ft/s^2)} = 66\ ft$$

To find the distance the football travels in the x direction, we need to know the time of flight for the ball. We can find the time it takes for the ball to rise using equation (3.3b), i.e.,

$$t = -v_{0y}/a = -(65\ ft/s)/(-32.2\ ft/s^2) = 2.0\ s.$$

The total time of flight is twice this value, or 4.0 seconds. Now we can find the x distance using equation (3.5a) and noting that $a_x = 0$ and $v_{0x} = v_0 \cos\theta = (82\ ft/s) \cos 53° = 49$ ft/s. We have

$$x = v_{0x}t = (49\ ft/s)\ (4.0\ s) = 2.0 \times 10^2\ ft.$$

So the ball rose 66 ft in the air, stayed up 4.0 s (hang time), and traveled 2.0×10^2 ft.

Example 3

A jet fighter is traveling horizontally with a speed of 111 m/s at an altitude of 3.00×10^2 m, when the pilot accidentally releases an outboard fuel tank. (a) How much time elapses before the tank hits the ground? (b) What is the speed of the tank just before it hits the ground? (c) What is the horizontal distance traveled by the tank?

(a) The y-direction data is; $y = -3.00 \times 10^2$ m, $v_{0y} = 0$, $a_y = -9.80\ m/s^2$. Using equation (3.5b) and solving for t,

$$t = \sqrt{\frac{2y}{a_y}} = \sqrt{\frac{2(-3.00 \times 10^2\ m)}{(-9.80\ m/s^2)}} = 7.82\ s.$$

(b) The y component of the velocity as it strikes the ground can be found using equation (3.3b),

$$v_y = v_{0y} + a\,t = 0 + (-9.80\ m/s^2)\ (7.82\ s) = -76.6\ m/s.$$

The speed as it hits the ground can be obtained by calculating the vector sum of the x and y components. The x component of the velocity is constant at 111 m/s. Therefore,

$$v_{tot} = \sqrt{v_x^2 + v_y^2} = \sqrt{(111\ m/s)^2 + (-76.6\ m/s)^2} = 135\ m/s.$$

(c) The horizontal distance can be obtained using equation (3.5a) with $a_x = 0$ and $v_{0x} = 111$ m/s,

$$x = v_{0x}\,t = (111\ m/s)\ (7.82\ s) = 868\ m.$$

Note that the initial velocity, v_{0x}, plays no role in determining the time required for the fuel tank to hit the ground. Even if the jet were moving faster, the tank would still take 7.82 s to reach the ground. However, the speed on impact and the horizontal distance would be affected by v_{0x}.

3.4 Relative Velocity

The velocity measured for a particular object depends on the observer who is making the measurement. For example, suppose a ground based observer is measuring the velocity of two cars, each moving in the same direction. Car A is moving at 45 km/h relative to the ground, while car B is moving at 55 km/h relative to the ground. The observer in car A, however, measures the velocity of car B as 10 km/h relative to himself. Car B measures A's velocity as -10 km/h in his reference frame. So each observer obtains different values for the velocities because each is making measurements from different points of reference.

Example 4 *Relative velocity in one dimension*
A passenger in a moving train is walking towards the dining car in the front of the train. The train is moving at a speed of 21 ft/s and the passenger is walking at 4 ft/s relative to the train. How far will the passenger move in 10.0 seconds relative to (a) the train, and (b) a ground based observer.

Use the following symbols to represent the different relative velocities;

v_{TG} = velocity of the train relative to the ground.
v_{PT} = velocity of the passenger relative to the train.
v_{PG} = velocity of the passenger relative to the ground.

We can see that the three velocities are related in the following manner;

$$v_{PG} = v_{PT} + v_{TG} = 4 \text{ ft/s} + 21 \text{ ft/s} = 25 \text{ ft/s}.$$

The distances measured in each case are therefore,

(a) $s_{PT} = v_{PT}t = (4 \text{ ft/s})\ (10.0 \text{ s}) = 40 \text{ ft}.$
(b) $s_{PG} = v_{PG}t = (25 \text{ ft/s})\ (10.0 \text{ s}) = 250 \text{ ft}.$

When dealing with relative velocities in two dimensions it is important to emphasize the vector nature of the velocities. For example, if a boat is sailing across a stream, and the stream is flowing, both the boat's and the stream's velocity must be considered. Similarly, the velocity of an airplane in flight is effected by the velocity of the wind. The following example illustrates this effect.

Example 5 *Relative velocity in two dimensions*
A boat whose speed is 10.0 mi/h in still water travels across a river that is 2.00 miles wide. The river current is 5.00 mi/h directed parallel to the river bank. How long does it take for the boat to cross the river and how far downstream will the boat arrive?

First find the velocity of the boat relative to the shore. From the diagram we can see that

$$\mathbf{v}_{BS} = \mathbf{v}_{BW} + \mathbf{v}_{WS}$$

Since the vectors $\mathbf{v}_{BW}$ and $\mathbf{v}_{WS}$ are perpendicular to each other, the magnitude and direction of $\mathbf{v}_{BS}$ can be found from the Pythagorean theorem.

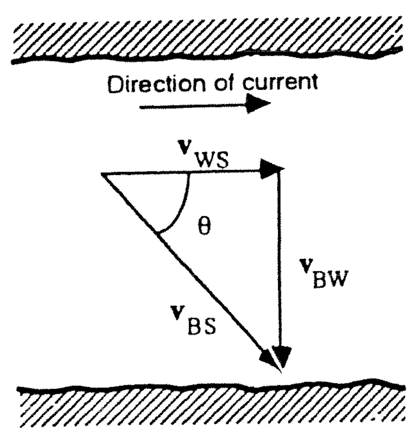


Figure A

$$v_{BS} = \sqrt{v_{BW}^2 + v_{WS}^2}$$

$$= \sqrt{(10.0\ \text{mi/h})^2 + (5.00\ \text{mi/h})^2}$$

$$= 11.2\ \text{mi/h}.$$

To find the amount of time and downstream distance we need to know the angle θ shown in Figure A. We have

$$\theta = \tan^{-1}\left(\frac{v_{BW}}{v_{WS}}\right) = \tan^{-1}\left(\frac{10.0\ \text{mi/h}}{5.00\ \text{mi/h}}\right) = 63.4^\circ.$$

In order to find the time taken for the trip we need the total distance traveled. We see that this distance is

$$r = \frac{2.00\ \text{mi}}{\sin\theta} = \frac{2.00\ \text{mi}}{\sin 63.4^\circ} = 2.24\ \text{mi}.$$

Note that the angle θ that $\mathbf{v}_{BS}$ makes with $\mathbf{v}_{WS}$ (in Figure A) is the same angle θ that **r** makes with **x** (in Figure B).

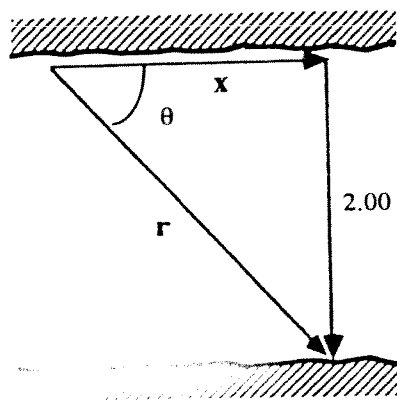


Figure B

Therefore, the time taken can be obtained using

$$t = \frac{r}{v_{BS}} = \frac{2.24\ \text{mi}}{11.2\ \text{mi/h}} = 0.20\ \text{h}.$$

The distance the boat lands downstream can be found from

$$x = \frac{2.00\ \text{mi}}{\tan\theta} = \frac{2.00\ \text{mi}}{\tan 63.4^\circ} = 1.00\ \text{mi}.$$

PRACTICE PROBLEMS

1. A pitcher throws a baseball at a speed of 90.0 mi/h towards home plate, which is located 60.0 ft away. How far has the ball dropped when it reaches the plate? Assume the ball leaves the pitcher's hand traveling horizontally.

2. An arrow is shot at an initial velocity of 25.0 m/s at an angle of 30.0 degrees with respect to the horizontal. (a) What is the maximum height reached by the arrow? (b) How far does the arrow travel in the horizontal direction in returning to the same level from which it was shot?

3. A plane is traveling at a velocity of 2.0×10^2 m/s at [illegible] horizontal. It releases a bomb at an altitude of 1.0×10^3 m, which strikes a target on the ground. (a) How far was the plane from the target when the bomb was released? (b) How long did it take the bomb to strike the target after being released? (c) What was the bomb's speed at the moment of impact?

4. A diver springs upward from a three-meter board. At the instant she contacts the water her speed is 8.90 m/s and her body makes an angle of 75.0° with respect to the surface of the water. (a) Determine her initial velocity, both magnitude and direction. (b) How much time does she spend in the air?

5. A ball rolls off the top of a stairway with a horizontal velocity of 2.0 m/s. The steps are each 20.0 cm high and 20.0 cm wide. Which step will the ball hit first?

6. When a cannon is aimed at an angle of 45° above the horizontal, a cannon ball lands 1.0×10^2 m down range. What was the muzzle velocity of the cannon ball?

7. The compass of an aircraft indicates it is headed due north, and its airspeed indicator shows that it is moving through the air at 120 mi/h. If a wind of 50.0 mi/h blowing from west to east suddenly arises, what is the velocity of the aircraft relative to the earth?

8. An airplane pilot wishes to fly due south. A wind of 25 km/h is blowing toward the west. If the flying speed of the plane is 300.0 km/h (its speed in still air), in what direction should the pilot head?

9. Two trains approach a railroad station, one from the north at 30.0 m/s, the other from the east at 40.0 m/s. Find the velocities of (a) the railroad station and (b) the south-bound train; relative to the west-bound train.

10. A boat can travel at a speed of 20.0 km/h relative to the water. The boat sails across a river (perpendicular to the river bank) and reaches a point 5.00 km directly across from its launch point. The water is flowing at a speed of 8.00 km/h parallel to the river bank. (a) At what angle must the boat steer to reach its destination? (b) How much time is required for the boat to make the trip?

HELPFUL SUGGESTIONS

1. For a projectile, in the absence of air resistance, the velocity in the x direction always continues unchanged. In the y direction near the earth the acceleration is always **g**, directed downward.

2. For a projectile at the top of its path, $v_y = 0$, but v_x = constant.

3. The x and y motions for a projectile must be treated separately, since they are independent motions. However, the time of flight, t, will be common to both sets of equations.

4. When a velocity is given it should always be resolved into its components, which can then be used independently in the kinematic equations. If the solution requires you to state a final velocity, the velocity vector can be reconstructed from the x and y components.

5. The time that a projectile spends in the air is governed by the y variable; not the x variable. Once the time of flight has been determined, however, it can then be used in the x equations.

6. In many relative velocity problems the velocities form right triangles. However, if this is not the case, the law of sines or cosines must be applied.

EVERYDAY PHYSICS

1. Projectile motion can be observed in many everyday situations. Throwing a baseball or football are obvious examples. Shooting a rifle or an arrow are also examples of projectile motions, although these are harder to observe because of the high initial velocities involved. However, the effects of gravity must be accounted for when you aim at a target, i.e., you need to aim a little above the target to compensate for this effect.

2. You can observe projectile motion for the simple case of a ball rolling off a table. Notice that the ball never lands right at the base of the table, but always some distance away. Try giving the ball different initial velocities and see how the landing distance varies. How can you determine the initial velocity of the ball by measuring the height of the table and the distance the ball lands from the base of the table?

3. A good way to observe projectile motion is with a garden hose. Hold the hose at different angles and watch the resulting flow of water. Which angle causes the water to reach the greatest horizontal distance? What measurements do you need to make in order to calculate the nozzle velocity of the water?

4. In real life, we really can't ignore the effects of air resistance and friction for moving objects. How would air resistance affect our treatment of projectile motion? What assumptions do we need to modify regarding the x and y motions? How would the kinematic equations of motion be affected?

CHAPTER QUIZ

1. Rock A is dropped from rest from the top of a building. Rock B is thrown horizontally from the top of the same building at the same time. In the absence of air resistance compare the time it takes for each rock to hit the ground below.
   a. Both objects take the same time to reach the ground.
   b. Rock A strikes the ground first.
   c. Rock B strikes the ground first.
   d. It is impossible to say which reaches first without knowing the building's height.

2. A tennis ball is hit into the air and moves along an arc. Neglecting air resistance, where along the arc is the speed of the ball a minimum?
   a. At its launch point. b. At the top of its arc. c. At the landing point.

3. A ball moving at 3.0 m/s rolls off a table and strikes the floor 0.30 s later. What is its speed on impact?
   a. 3.0 m/s b. 4.2 m/s c. 5.9 m/s d. 9.0 m/s

4. An arrow is fired with an initial velocity of 20.0 m/s at an angle of 37.0° with the horizontal. How long does the arrow stay in the air?
   a. 1.22 s b. 2.46 s c. 3.26 s d. 4.08 s

5. Two cars travel towards each other on the same road, one at 45 mi/h, the other at 55 mi/h. They are initially separated by 150 miles. How long will it take for the cars to meet?
   a. 1.5 h b. 6.0 h c. 15 h d. 0.67 h

6. A boat is traveling upstream at 10.0 mi/h. The current moves at 3.0 mi/h. How fast is the boat moving relative to the shore?
   a. 13 mi/h b. 10 mi/h c. 7 mi/h d. 3.3 mi/h

7. A boat which can travel at 6 km/h wants to go directly across a stream whose current is 3 km/h. At what angle must the boat steer (relative to the shore) to accomplish this?
   a. 30° b. 40° c. 60° d. 90°

8. A plane can fly at a speed of 150 m/s in still air. When a cross wind (a wind directed perpendicular to the plane) blows at 80.0 m/s, what is the plane's speed relative to the ground?
   a. 70 m/s b. 130 m/s c. 170 m/s d. 230 m/s

9. A railroad flatcar is equipped with a missile launcher that points straight up. If the flatcar travels at 10 m/s and a missile is launched at an initial speed of 100 m/s, at what angle (relative to the vertical) is the missile launched as seen by a stationary ground observer?
   a. 6° b. 10° c. 30° d. 90°

10. A golf ball is hit and makes an angle of 45° with the horizontal as it leaves the tee. The ball lands 200.0 yards away and was in the air for 10 s. What was the ball's initial speed?
    a. 28 ft/s b. 60 ft/s c. 85 ft/s d. 200 ft/s

11. A plane traveling at 300 m/s (horizontally) drops a bomb which hits its target 10 s later. How high was the plane flying?
    a. 30 m b. 300 m c. 500 m d. 3000 m

SOLUTIONS AND ANSWERS

Practice Problems

---

1. The horizontal speed is

$$v_x = (90.0 \text{ mi/h})(1\text{h}/3600 \text{ s})(5280 \text{ ft}/1 \text{ mi}) = 132 \text{ ft/s}.$$

The time to travel 60.0 ft is

$$t = x/v_x = (60.0 \text{ ft})/(132 \text{ ft/s}) = 0.455 \text{ s}.$$

$$y = v_{0y}t + (1/2)a_y t^2 = 0 + (1/2)(32.2 \text{ ft/s}^2)(0.455 \text{ s})^2 = \mathbf{3.33 \text{ ft}}.$$

---

2. a. The initial velocity is

$$v_{0y} = v_0 \sin 30.0° = (25.0 \text{ m/s})(0.500) = 12.5 \text{ m/s};$$

Use equation (3.6b) and solve for y

$$y = -v_0^2/2a_y = -(12.5 \text{ m/s})^2/[2(-9.80 \text{ m/s}^2)] = \mathbf{7.97 \text{ m}}.$$

b. Find the time from $v_y = v_{0y} + at$

$$t = -v_{0y}/a_y = -(12.5 \text{ m/s})/(-9.80 \text{ m/s}^2) = 1.28 \text{ s}.$$

Finally, we have

$$x = v_{0x}t = v_0 \cos 30.0° \, t = (25.0 \text{ m/s}) \cos 30.0° \, (2.56 \text{ s}) = \mathbf{55.4 \text{ m}}.$$

---

3. Using equation (3.6b) we have

$$v_y^2 = v_{0y}^2 + 2a_y y = [(2.0 \times 10^2 \text{ m/s}) \sin 45°]^2 + 2(-9.80 \text{ m/s}^2)(-1.0 \times 10^3 \text{m}),$$

Which yields $v_y = 2.0 \times 10^2$ m/s. Now, $v_x = v_0 \cos 45° = 141$ m/s. The time can be found from equation (3.3b),

$$t = (v_y - v_{0y})/a = (2.0 \times 10^2 \text{ m/s} - 1.4 \times 10^2 \text{ m/s})/(9.80 \text{ m/s}^2) = 6.1 \text{ s}.$$

a. $x = v_{0x}t = (141 \text{ m/s})(6.1 \text{ s}) = 860 \text{ m}, \; y = 1.0 \times 10^3 \text{ m},$

$$s^2 = x^2 + y^2 = (860 \text{ m})^2 + (1.0 \times 10^3 \text{ m})^2, \text{ so that } s = \mathbf{1300 \text{ m}}.$$

b. We have already seen that $t = \mathbf{6.1 \text{ s}}$.

c. Finally,

$$v^2 = v_x^2 + v_y^2 = (141 \text{ m/s})^2 + (2.0 \times 10^2 \text{ m/s})^2 \text{ so } v = \mathbf{240 \text{ m/s}}.$$

---

4. a. At a height of 3.00 m above the water find v_o. We know

$$v_y = v \sin 75.0° = (8.90 \text{ m/s}) \sin 75.0° = 8.60 \text{ m/s}.$$

From equation (3.6b) we have

$$v_{0y}^2 = v_y^2 - 2a_y y = (8.60 \text{ m/s})^2 - 2(9.80 \text{ m/s}^2)(3.00 \text{ m}) \rightarrow v_{0y} = 3.89 \text{ m/s}.$$

Also,

$$v_{0x} = v_x = v \cos 75.0° = (8.90 \text{ m/s}) \cos 75.0° = 2.30 \text{ m/s} \rightarrow v_0^2 = v_{0x}^2 + v_{0y}^2 \text{ so that}$$

$$v_0 = \mathbf{4.52 \text{ m/s}}.$$

The direction is obtained from

$$\theta = \tan^{-1}(v_{0y}/v_{0x}) = \tan^{-1}[(3.89 \text{ m/s})/(2.30 \text{ m/s})] = \mathbf{59.4°}.$$

b. The time to go up is $t_{up} = -v_{0y}/a = 0.397$ s; the time down is $t_{down} = v_y/a = 0.878$ s. So the total time is

$$t = t_{up} + t_{down} = 0.40 \text{ s} + 0.88 \text{ s} = \mathbf{1.28 \text{ s}}.$$

---

5. In order to determine which step the ball lands on, the ball must fall at least a distance equal to its horizontal displacement. For example, at x = 0.2 m,

$$t = x/v_x = (0.2 \text{ m})/(2.0 \text{ m/s}) = 0.1 \text{ s},$$
$$y = (1/2)a_y t^2 = 0.05 \text{ m}.$$

So the ball goes past the first step. At x' = 0.8 m (4th step), t' = 0.4 s and y' = 0.78 m, so it goes past the 4th step. However, at x" = 1.0 m (5th step), t" = 0.5 s, y" = 1.23 m. So the ball lands on the **fifth step.**

---

6. The time taken to travel half the distance in the x direction, using equation (3.5a), is

$$t = x/(v_0 \cos 45°) = (50.0 \text{ m})/(v_0 \cos 45°).$$

The time it takes for the ball to reach its maximum height is the also this value of t, and using equation (3.3b) with $v_y = 0$,

$$t = v_{0y}/a = v_0 \sin 45°/(9.8 \text{ m/s}^2).$$

Equating the two expressions for the time, and noting that cos 45° = sin 45° yields,

$$(v_0 \cos 45°)^2 = (50.0 \text{ m})(9.8 \text{ m/s}^2).$$

Thus,

$$v_0^2 = (50.0 \text{ m})(9.8 \text{ m/s}^2)/(\cos^2 45°)$$
$$v_0 = \mathbf{31 \text{ m/s}}.$$

---

7. A vector diagram shows the

$$v^2 = v_P^2 + v_W^2 = (120 \text{ mi/h})^2 + (50.0 \text{ mi/h})^2$$
$$v = \mathbf{130 \text{ mi/h}}.$$

The direction is

$$\theta = \tan^{-1}(v_P/v_W) = \tan^{-1}[(120 \text{ mi/h})/(50.0 \text{ mi/h})] = \mathbf{67° \text{ North of East}}.$$

---

8. Since the final direction of motion and the direction of the wind are perpendicular, we can find the angle between the plane and wind, i.e.,

$$\theta = \cos^{-1}(v_W/v_P) = \cos^{-1}[(25\text{ km/h})/(300.0\text{ km/h})] = \mathbf{85° \text{ S of E.}}$$

---

9. a. We can write $\mathbf{v}_{RW} = \mathbf{v}_{RG} + \mathbf{v}_{GW}$ where R → railroad station, W → west bound train, G → ground. So

$$v_{RW} = 0 + 40\text{ m/s} = \mathbf{40\text{ m/s East.}}$$

b. We have $\mathbf{v}_{SW} = \mathbf{v}_{SG} + \mathbf{v}_{GW}$. Since $\mathbf{v}_{SG}$ and $\mathbf{v}_{GW}$ are perpendicular, we can write $v_{SW}^2 = v_{SG}^2 + v_{GW}^2$. So,

$$v_{SW}^2 = (30.0\text{ m/s})^2 + (40.0\text{ m/s})^2$$

$$v_{SW} = \mathbf{50.0\text{ m/s.}}$$

Also,

$$\theta = \tan^{-1}(v_{SG}/v_{GW}) = \mathbf{36.9° \text{ S of E.}}$$

---

10. a. A vector diagram shows that the angle at which the boat must steer is $\theta = \cos^{-1}(v_S/v_B)$, where the velocity v_S is that of the stream and v_B is that of the boat. So,

$$\theta = \cos^{-1}[(8.00\text{ km/h})/(20.0\text{ km/h})] = \mathbf{66.4°.}$$

b. The velocity across the river is

$$v^2 = v_B^2 - v_S^2 = (20.0\text{ km/h})^2 - (8.00\text{ km/h})^2$$

$$v = 18.3\text{ km/h.}$$

Since it's 5.00 km across the river, the time to get across is

$$t = s/v = (5.00\text{ km})/(18.3\text{ km/h}) = \mathbf{0.273\text{ h.}}$$

Quiz answers

1. a
2. b
3. b
4. b
5. a
6. c
7. c
8. c
9. a
10. c
11. c

Physics {Projectile Motion Review} DiBucci

20. (I) A diver running 1.6 m/s dives out horizontally from the edge of a vertical cliff and reaches the water below 3.0 s later. How high was the cliff and how far from its base did the diver hit the water?

44 m, 4.8 m

24. (II) A ball is thrown horizontally from the roof of a building 56 m tall and lands 45 m from the base. What was the ball's initial speed?

13 m/s

26. (II) A football is kicked at ground level with a speed of 20.0 m/s at an angle of 37.0° to the horizontal. How much later does it hit the ground?

2.46 s

28. (II) A shot-putter throws the shot with an initial speed of 14 m/s at a 40° angle to the horizontal. Calculate the horizontal distance traveled by the shot if it leaves the athlete's hand at a height of 2.2 m above the ground.

22 m

30. (II) An athlete executing a long jump leaves the ground at a 30° angle and travels 7.80 m. (*a*) What was the takeoff speed? (*b*) If this speed were increased by just 5.0 percent, how much longer would the jump be?

9.39 m/s, 0.80 m

31. (II) The pilot of an airplane traveling 160 km/h wants to drop supplies to flood victims isolated on a patch of land 160 m below. The supplies should be dropped how many seconds before the plane is directly overhead?

5.71 s

33. (II) Show that the time required for a projectile to reach its highest point is equal to the time for it to return from this highest point to its original height.

See my solution

35. (II) A projectile is fired with an initial speed of 75.2 m/s at an angle of 34.5° above the horizontal on a long flat firing range. Determine (*a*) the maximum height reached by the projectile, (*b*) the total time in the air, (*c*) the total horizontal distance covered (that is, the range), and (*d*) the velocity of the projectile 1.50 s after firing.

92.6 m, 8.69 s, 539 m, 68.0 m/s

$\theta = 24.2°$ Above the horizontal

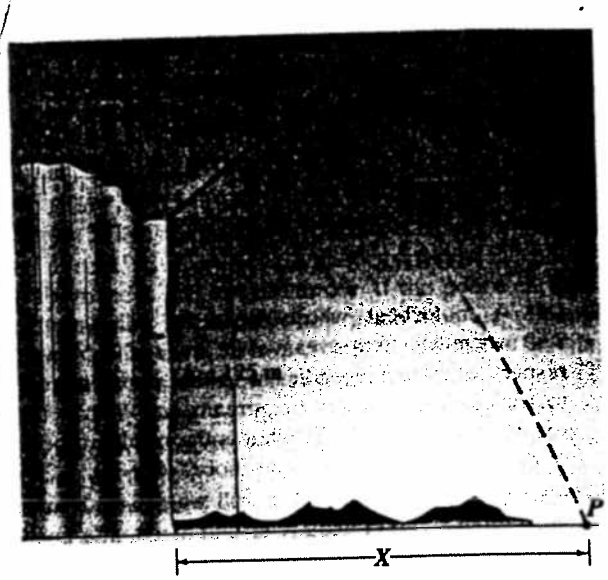


FIGURE 3–39 Problem 36.

36. (II) A projectile is shot from the edge of a cliff 125 m above ground level with an initial speed of 105 m/s at an angle of 37.0° with the horizontal, as shown in Fig. 3–39. (*a*) Determine the time taken by the projectile to hit point *P* at ground level. (*b*) Determine the range *X* of the projectile as measured from the base of the cliff. At the instant just before the projectile hits point *P*, find (*c*) the horizontal and the vertical components of its velocity, (*d*) the magnitude of the velocity, and (*e*) the angle made by the velocity vector with the horizontal.

$t = 14.6 s$

$\Delta X = 1.22 km$

$V_x = 83.9 m/s$

$V_{fy} = -79.9 m/s$

$v = 116 m/s$

$\theta = 43.6°$ below the horizontal

Advanced Placement Physics B

Mr. DiBucci

Introduction to Newton's Laws of Motion

Isaac Newton (1642-1727)

Isaac Newton was born prematurely and barely survived on Christmas Day, 1642, the same year that Galileo died. Newton's birthplace was his mother's farmhouse in Woolsthorpe, England. His father died several months before his birth, and he grew up under the care of his mother and grandmother. As a child he showed no particular signs of brightness, and at the age of $14\frac{1}{2}$ he was taken out of school to work on his mother's farm. As a farmer he was a failure, preferring to read books he borrowed from a neighboring druggist. An uncle sensed the scholarly potential in young Isaac and prompted him to study at the University of Cambridge, which he did for 5 years, graduating without particular distinction.

A plague swept through London, and Newton retreated to his mother's farm—this time to continue his studies. At the farm, at the age of 23, he laid the foundations for the work that was to make him immortal. Seeing an apple fall to the ground led him to consider the force of gravity extending to the moon and beyond, and he formulated the law of universal gravitation (which he later proved); he invented the calculus, an indispensable mathematical tool in science; he extended Galileo's work and formulated the three fundamental laws of motion; and he formulated a theory of the nature of light and showed with prisms that white light is composed of all colors of the rainbow. It was his experiments with prisms that first made him famous.

When the plague subsided, Newton returned to Cambridge and soon established a reputation for himself as a first-rate mathematician. His mathematics teacher resigned in his favor and Newton was appointed the Lucasian professor of mathematics. He held this post for 28 years. In 1672 he was elected to the Royal Society, where he exhibited the world's first reflector telescope. It can still be seen, preserved at the library of the Royal Society in London with the inscription: "The first reflecting telescope, invented by Sir Isaac Newton, and made with his own hands."

It wasn't until Newton was 42 that he began to write what is generally acknowledged as the greatest scientific book ever written, the *Principia Mathematica Philosophiae Naturalis*. He wrote the work in Latin and completed it in 18 months. It appeared in print in 1687 and wasn't printed in English until 1729, 2 years after his death. When asked how he was able to make so many discoveries, Newton replied that he found his solutions to problems were not by sudden insight but by continually thinking very long and hard about them until he worked them out.

At the age of 46, his energies turned somewhat from science when he was elected a member of Parliament. He attended the sessions in Parliament for 2 years and never gave a speech. One day he rose and the House fell silent to hear the great man. Newton's "speech" was very brief; he simply requested that a window be closed because of a draft.

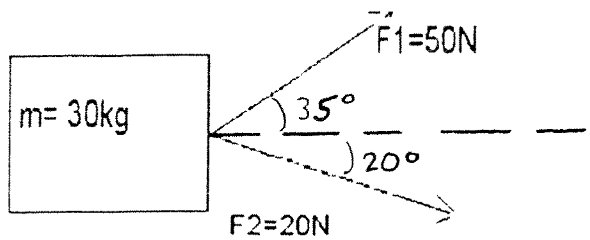
A further turn from his work in science was his appointment as warden and then as master of the mint. Newton resigned his professorship and directed his efforts toward greatly bettering the workings of the mint, to the dismay of counterfeiters who flourished at that time. He maintained his membership in the Royal Society and was elected president, then was reelected each year for the rest of his life. At the age of 62, he wrote *Opticks*, which summarized his work on light. Nine years later he wrote a second edition to his *Principia*.

Although Newton's hair turned gray at 30, it remained full, long, and wavy all his life, and unlike others in his time he did not wear a wig. He was a modest man, very sensitive to criticism, and never married. He remained healthy in body and mind into old age. At 80, he still had all his teeth, his eyesight and hearing were sharp, and his mind was alert. In his lifetime he was regarded by his countrymen as the greatest scientist who ever lived. In 1705 he was knighted by Queen Anne. Newton died at the age of 85 and was buried in Westminister Abbey along with England's kings and heroes.

Newton showed that the universe ran according to natural laws that were neither capricious nor malevolent—a knowledge that provided hope and inspiration to scientists, writers, artists, philosophers, and people of all walks of life and that ushered in the Age of Reason. The ideas and insights of Isaac Newton truly changed the world and elevated the human condition.

Name ______________________________________ Per. ___ date ______
Newton's laws of Motion DiBucci

Consider the diagram below. A 30kg crate is being pulled across the floor.



a. Calculate the x and y components of F1 and F2, and write them in i,j,k form.

b. Calculate the resultant force. Calculate its magnitude and direction, and put it into i,j,k form

c. Use Newton's second law and calculate the acceleration of the crate.

d. What are the x and y components of the acceleration?

e. Use the kinematics equations to calculate the displacement of the crate after 3 seconds. Calculate the magnitude and direction and express your answer in i,j,k form.

f. If friction was taken into account, what would be the magnitude and direction of the frictional force in order that the crate have an acceleration of 0m/s/s. (It would be the equilibrant force)

Name ______________________________ Per ___ Date _______
DiBucci

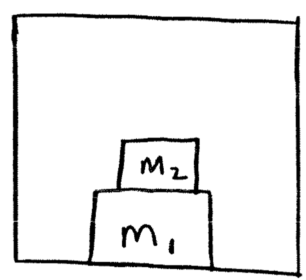
Newton's laws worksheet

Directions: complete the following problems on a separate sheet of paper.

1) A person with mass 88 kg is standing in an elevator. Sketch a Free Body Diagram and for each case determine the person's apparent weight (normal force).

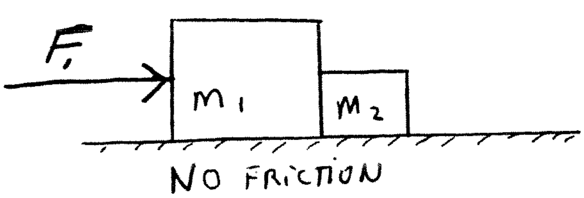
a) moves at a constant velocity of +5 m/s
b) accelerates upward at + 3.0 m/s/s
c) accelerates downward at 4.3 m/s/s
d) is initially moving upward and comes to rest with a magnitude of acceleration of 4 m/s/s
e) is initially moving downward and comes to rest with a magnitude of acceleration of 5 m/s/s
f) is accelerating downward at -9.8 m/s/s
g) is accelerating upward at 11 m/s/s (explain what is happening to the person)
h) Downward at $-11\ m/s^2$

2) Refer to the diagram for this problem. Sketch a complete free body diagram. Given the masses of the two blocks calculate the contact force between them, and the force between the blocks and the elevator for the following cases:
a) the elevator is at rest or moving at a constant velocity
b) the elevator is accelerating upward at 3.2 m/s/s
c) the elevator is accelerating downward at 2.5 m/s/s



$m_1 = 20kg$
$m_2 = 10kg$

3) Refer to the diagram for this problem. Sketch a complete free body diagram. Calculate the contact forces between the blocks, and the total force that accelerates them. The acceleration is 8.5 m/s/s to the right



$m_1 = 35kg$
$m = 15kg$

DIBUCCI

CONCEPTUAL QUESTIONS

NEWTON'S LAWS OF MOTION

1. The instructions for mounting a phono cartridge on the tone arm of a stereo turntable say to "adjust the tracking force of the cartridge so it is less than three grams." From the point of view of correct physics, is anything wrong with this statement? Explain.

2. Why do you lunge forward when your car suddenly comes to a halt? Why are you pressed backward against the seat when your car rapidly accelerates? In your explanation, refer to the most appropriate one of Newton's three laws of motion.

3. A bird feeder of large mass is hung from a tree limb, as the drawing shows. A cord attached to the bottom of the feeder has been left dangling free. Curiosity gets the best of a child, who pulls on the dangling cord in an attempt to see what's in the

feeder. The dangling cord is cut from the same source as the cord attached to the limb. Is the cord between the feeder and the limb more likely to snap with a slow continuous pull or a sudden downward pull? Give your reasoning.

4. Is a net force being applied to an object when the object is moving downward (a) with a constant acceleration of 9.80 m/s^2 and (b) with a constant velocity of 9.80 m/s? Explain.

5. Newton's second law indicates that when a net force acts on an object, it must accelerate. Does this mean that when two or more forces are applied to an object simultaneously, it must accelerate? Explain.

6. A father and his seven-year-old daughter are facing each other on ice skates. With their hands, they push off against one another. (a) Compare the magnitudes of the pushing forces that they experience. (b) Which one, if either, experiences the larger acceleration? Account for your answers.

7. A gymnast is bouncing on a trampoline. After a high bounce the gymnast comes down and hits the elastic surface of the trampoline. In so doing the gymnast applies a force to the trampoline. (a) Describe the effect this force has on the elastic surface. (b) The surface applies a reaction force to the gymnast. Describe the effect that this reaction force has on the gymnast.

8. According to Newton's third law, when you push on an object, the object pushes back on you with an oppositely directed force of equal magnitude. If the object is a massive crate resting on the floor, it will probably not move. Some people think that the reason the crate does not move is that the two oppositely directed pushing forces cancel. Explain why this logic is faulty and why the crate does not move.

9. Three particles have identical masses. Each particle experiences only the gravitational forces due to the other two particles. How should the particles be arranged so each one experiences a net gravitational force that has the same magnitude? Give your reasoning.

10. When a body is moved from sea level to the top of a mountain, what changes—the body's mass, its weight, or both? Explain.

11. The force of air resistance acts to oppose the motion of an object moving through the air. A ball is thrown upward and eventually returns to the ground. (a) As the ball moves upward, is the net force that acts on the ball greater than, less than, or equal to its weight? Justify your answer. (b) Repeat part (a) for the downward motion of the ball.

12. Object A weighs twice as much as object B at the same spot on the earth. Would the same be true at a given spot on Mars? Account for your answer.

13. Does the acceleration of a freely falling object depend to any extent on the location, i.e., whether the object is on top of Mt. Everest or in Death Valley, California? Explain.

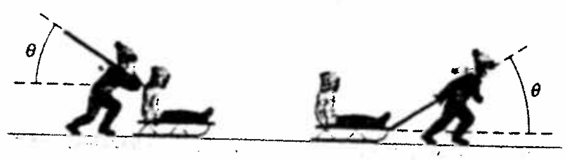
14. A "bottle rocket" is a type of fireworks that has a long thin tail that you insert into an empty bottle, to provide a launch platform. One of these rockets is fired with the bottle pointing vertically upward. An identical rocket is fired with the bottle lying on its side, pointing horizontally. In which case does the rocket leave the bottle with the greater acceleration? Explain, ignoring air resistance and friction.

15. A 10-kg suitcase is placed on a scale that is in an elevator. Is the elevator accelerating up or down when the scale reads (a) 75 N and (b) 120 N? Justify your answers.

16. A stack of books whose true weight is 165 N is placed on a scale in an elevator. The scale reads 165 N. Can you tell from this information whether the elevator is moving with a constant velocity of 2 m/s upward or 2 m/s downward or whether the elevator is at rest? Explain.

17. Suppose you are in an elevator that is moving upward with a constant velocity. A scale inside the elevator shows your weight to be 600 N. (a) Does the scale register a value that is greater than, less than, or equal to 600 N during the time when the elevator slows down as it comes to a stop? (b) What is the reading when the elevator is stopped? (c) How does the value registered on the scale compare to 600 N during the time when the elevator picks up speed again on its way back down? Give your reasoning in each case.

18. A person has a choice of either pushing or pulling a sled at a constant velocity, as the drawing illustrates. Friction is present. If the angle θ is the same in both cases, does it require less force to push or to pull? Account for your answer.



19. Suppose that the coefficients of static and kinetic friction have values such that $\mu_s = 2.0\mu_k$ for a crate in contact with a cement floor. Does this mean that the magnitude of the static frictional force acting on the crate at rest would always be twice the magnitude of the kinetic frictional force acting on the moving crate? Give your reasoning.

20. A box rests on the floor of an elevator. Because of static friction, a force is required to start the box sliding across the floor when the elevator is (a) stationary, (b) accelerating upward, and (c) accelerating downward. Rank the forces required in these three situations in ascending order, i.e., smallest first. Explain.

21. A rope is used in a tug-of-war between two teams of five people each. Both teams are equally strong, so neither team wins. An identical rope is tied to a tree, and the same ten people pull just as hard on the loose end as they did in the contest. In both cases, the people pull steadily with no jerking. Which rope, if either, is more likely to break? Justify your answer.

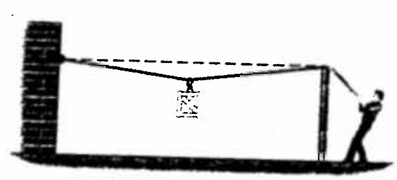
22. A stone is thrown from the top of a cliff. As the stone falls, is it in equilibrium? Explain, ignoring air resistance.

23. Can an object ever be in equilibrium if the object is acted on by only (a) a single nonzero force, (b) two forces that point in mutually perpendicular directions, and (c) two forces that point in directions that are not perpendicular? Account for your answers.

24. A circus performer hangs stationary from a rope. She then begins to climb upward by pulling herself up, hand-over-hand. When she starts climbing, is the tension in the rope less than, equal to, or greater than it is when she hangs stationary? Explain.

25. During the final stages of descent, a sky diver with an open parachute approaches the ground with a constant velocity. The wind does not blow him from side to side. Is the sky diver in equilibrium and, if so, what forces are responsible for the equilibrium?

26. A weight hangs from a ring at the middle of a rope, as the drawing illustrates. Can the person who is pulling on the right end of the rope ever make the rope perfectly horizontal? Explain your answer in terms of the forces that act on the ring.



27. A freight train is accelerating on a level track. Other things being equal, would the tension in the coupling between the engine and the first car change if some of the cargo in the last car were transferred to any one of the other cars? Account for your answer.

Section 4.3 Newton's Second Law of Motion

1. **ssm** A person with a blackbelt in karate has a fist that has a mass of 0.70 kg. Starting from rest, this fist attains a velocity of 8.0 m/s in 0.15 s. What is the magnitude of the average net force applied to the fist to achieve this level of performance?

2. A bicycle has a mass of 13.1 kg, and its rider has a mass of 81.7 kg. The rider is pumping hard, so that a horizontal net force of 9.78 N accelerates them. What is the acceleration?

3. An airplane has a mass of 31 000 kg and takes off under the influence of a constant net force of 37 000 N. What is the net force that acts on the plane's 78-kg pilot, assuming that he has the same acceleration as the plane?

4. Scientists are experimenting with a kind of gun that may eventually be used to fire payloads directly into orbit. In one test, this gun accelerates a 5.0-kg projectile from rest to a speed of 4.0×10^3 m/s. The net force accelerating the projectile is 4.9×10^5 N. How much time is required for the projectile to come up to speed?

5. **ssm** When a 0.058-kg tennis ball is served, it accelerates from rest to a speed of 45 m/s. The impact with the racket gives the ball a constant acceleration over a distance of 0.44 m. What is the magnitude of the net force acting on the ball?

6. During a circus performance, a 72-kg human cannonball is shot out of an 18-m-long cannon. If the human cannonball spends 0.95 s in the cannon, determine the average net force exerted on him in the barrel of the cannon.

7. A catapult on an aircraft carrier is capable of accelerating a plane from 0 to 56.0 m/s in a distance of 80.0 m. Find the average net force that the catapult exerts on a 13 300-kg jet.

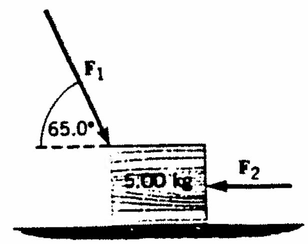
***8.** An arrow, starting from rest, leaves the bow with a speed of 25.0 m/s. If the average force exerted on the arrow by the bow were doubled, all else remaining the same, with what speed would the arrow leave the bow?

***9.** **ssm www** Two forces $\mathbf{F}_A$ and $\mathbf{F}_B$ are applied to an object. The larger force is $\mathbf{F}_A$. When both forces point due east, the object's acceleration has a magnitude of 0.50 m/s². However, when $\mathbf{F}_A$ points due east and $\mathbf{F}_B$ points due west, the acceleration has a magnitude of 0.40 m/s². Find the ratio F_A/F_B of the magnitudes of the forces.

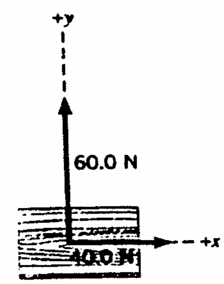
Section 4.4 The Vector Nature of Newton's Second Law of Motion, Section 4.5 Newton's Third Law of Motion

10. A force vector has a magnitude of 720 N and a direction of 38° north of east. Determine the magnitude and direction of the components of the force that point along the north-south line and along the east-west line.

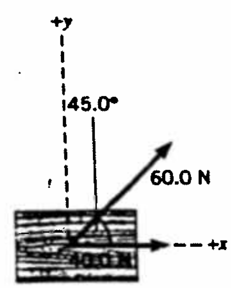
11. Two forces, $\mathbf{F}_1$ and $\mathbf{F}_2$, act on the 5.00-kg block shown in the drawing. The magnitudes of the forces are $F_1 = 45.0$ N and $F_2 = 25.0$ N. What is the horizontal acceleration (magnitude and direction) of the block?



12. Two forces act on an object (mass = 4.00 kg), as in the drawing. Find the magnitude and direction (relative to the x axis) of the acceleration of the object.



13. **ssm** Two forces act on an object (mass = 3.00 kg), as in the drawing. Find the magnitude and direction (relative to the x axis) of the acceleration of the object.



14. Two skaters, an 82-kg man and a 48-kg woman, are standing on ice. Neglect any friction between the skate blades and the ice. The woman pushes on the man with a force of 45 N due east. Determine the accelerations (magnitude and direction) of the man and the woman.

15. A duck has a mass of 2.5 kg. As the duck paddles, a force of 0.10 N acts on it in a direction due east. In addition, the current of the water exerts a force of 0.20 N in a direction of 52° south of east. When these forces begin to act, the velocity of the duck is 0.11 m/s in a direction due east. Find the magnitude and direction (relative to due east) of the displacement that the duck undergoes in 3.0 s while the forces are acting.

37N
2) 0.103 m/s²
3) 93N
4) 4.1×10⁻² s
5) 130N
6) 2900N
7) 2.61×10⁵N
8) 35.4 m/s
9) 9.0
10) 570N, 440N
11) -1.20 m/s left
12) 18 m/s², 56.3° Above X-Axis

*16. A space probe has two engines. Each generates the same amount of force when fired, and the directions of these forces can be independently adjusted. When the engines are fired simultaneously and each applies its force in the same direction, the probe, starting from rest, takes 28 s to travel a certain distance. How long does it take to travel the same distance, again starting from rest, if the engines are fired simultaneously and the forces that they apply to the probe are perpendicular?

*17. **ssm www** A 325-kg boat is sailing 15.0° north of east at a speed of 2.00 m/s. Thirty seconds later, it is sailing 35.0° north of east at a speed of 4.00 m/s. During this time, three forces act on the boat, a 31.0-N force directed 15.0° north of east (due to an auxiliary engine), a 23.0-N force directed 15.0° south of west (resistance due to the water), and $\mathbf{F_W}$ (due to the wind). Find the magnitude and direction of the force $\mathbf{F_W}$. Express the direction as an angle with respect to due east.

**18. At a time when mining asteroids has become feasible, astronauts have connected a line between their 3500-kg space tug and a 6200-kg asteroid. Using their ship's engine, they pull on the asteroid with a force of 490 N. Initially the tug and the asteroid are at rest, 450 m apart. How much time does it take for the ship and the asteroid to meet?

15) ,78 m
21° S of E

16) 33 s

17) 18.4 N, 68° N of E

(19-35 on next page)

19) 8.70 x 10^-12 N
20) 4.2 m/s
21) 115 kg, 1.13 x 10^3 N
W = 0, M = 115 kg
22) 1.8 x 10^-7 N
23) 5.67 x 10^-5 N right
24) 4.77 x 10^20 N
25) 3.75 m/s, 2.4 x 10^2 N
26) 0.165
27) 1.76 x 10^24 kg
28) 130 N
29) 0.223 m/s^2

30) 2.55 x 10^-10 m/s^2
31) 0.0050
32) 3.46 x 10^8 m
33) 4.7 kg
34) 0.628
35) 0.414 L or -2.414 L

AP Physics B

Unit 2

Review Material

Mr. DiBucci

Topics on the Unit 2 Exam:

- *Two Dimensional Motion*
- *Projectile Motion*
- *Circular Motion*
  - *Uniform*
  - *Non-Uniform*
- *Newton's Laws of Motion*
  - *Inertia*
  - *Second Law F=ma*
  - *Third Law (Elevator Problems*

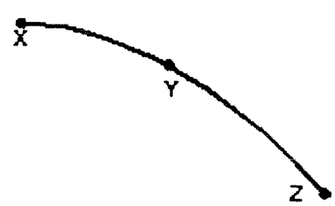
Name: ______________________________ Date: _______________

1. Velocity is defined as:
   A) rate of change of position with time
   B) position divided by time
   C) rate of change of acceleration with time
   D) a speeding up or slowing down
   E) change of position

2. Acceleration is defined as:
   A) rate of change of position with time
   B) speed divided by time
   C) rate of change of velocity with time
   D) a speeding up or slowing down
   E) change of velocity

3. A stone thrown from the top of a tall building follows a path that is:
   A) circular
   B) made of two straight line segments
   C) hyperbolic
   D) parabolic
   E) a straight line

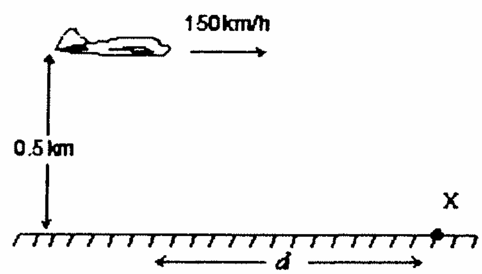
4. A stone is thrown horizontally and follows the path XYZ shown. The direction of the acceleration of the stone at point Y is:



   A) ↓
   B) →
   C) ↘
   D) ↙
   E) ↗

5. A bullet shot horizontally from a gun:
   A) strikes the ground much later than one dropped vertically from the same point at the same instant
   B) never strikes the ground
   C) strikes the ground at approximately the same time as one dropped vertically from the same point at the same instant
   D) travels in a straight line
   E) strikes the ground much sooner than one dropped from the same point at the same instant

6. The airplane shown is in level flight at an altitude of 0.50 km and a speed of 150 km/h. At what distance d should it release a heavy bomb to hit the target X? Take $g = 10\ m/s^2$.



   A) 150 m
   B) 295 m
   C) 417 m
   D) 2550 m
   E) 15,000 m

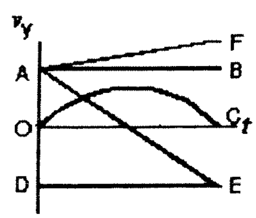
7. A ball is thrown horizontally from the top of a 20-m high hill. It strikes the ground at an angle of 45°. With what speed was it thrown?

   A) 14 m/s
   B) 20 m/s
   C) 28 m/s
   D) 32 m/s
   E) 40 m/s

8. A stone is thrown outward from the top of a 59.4-m high cliff with an upward velocity component of 19.5 m/s. How long is stone in the air?
   A) 4.00 s
   B) 5.00 s
   C) 6.00 s
   D) 7.00 s
   E) 8.00 s

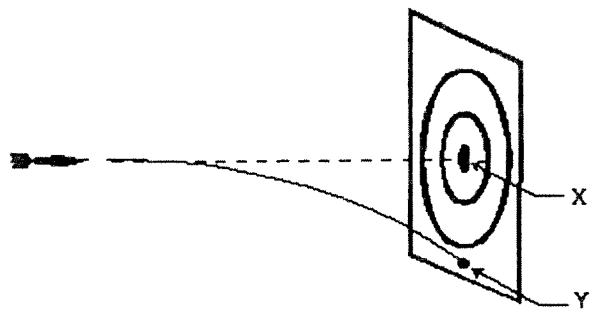
9. A boy on the edge of a vertical cliff 20 m high throws a stone horizontally outwards with a speed of 20 m/s. It strikes the ground at what horizontal distance from the foot of the cliff? Use $g = 10$ m/s^2
   A) 10 m
   B) 40 m
   C) 50 m
   D) $50\sqrt{5}$ m
   E) none of these

10. Which of the curves on the graph below best represents the verticle component v_y versus t for a projectile fired at an angle of 45° above the horizontal?



   A) OC
   B) DE
   C) AB
   D) AE
   E) AF

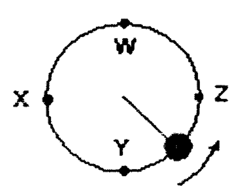
11. A dart is thrown horizontally toward X at 20 m/s as shown. It hits Y 0.1 s later. The distance XY is:



A) 2 m
B) 1 m
C) 0.5 m
D) 0.1 m
E) 0.05 m

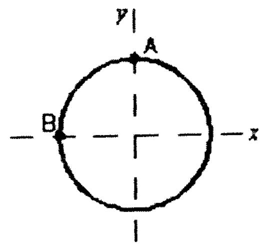
12. A projectile is fired over level ground with an initial velocity that has a vertical component of 20 m/s and a horizontal component of 30 m/s. Using $g = 10\ m/s^2$, the distance from launching to landing points is:
A) 40 m
B) 60 m
C) 80 m
D) 120 m
E) 180 m

13. An object, tied to a string, moves in a circle at constant speed on a horizontal surface as shown. The direction of the displacement of this object, as it travels from W to X is:



A) ←
B) ↓
C) ↑
D) ↗
E) ↙

14. A toy racing moves with constant speed around the circle shown below. When it is at point A its coordinates are $x = 0, y = 3$m and its velocity is $(6\text{m/s})\hat{i}$. When it is at point B its velocity and acceleration are:



A) $-(6\text{ m/s})\hat{j}$ and $(12\text{ m/s}^2)\hat{i}$, respectively
B) $(6\text{ m/s})\hat{i}$ and $-(12\text{ m/s}^2)\hat{i}$, respectively
C) $(6\text{ m/s})\hat{j}$ and $(12\text{ m/s}^2)\hat{i}$, respectively
D) $(6\text{ m/s})\hat{i}$ and $(12\text{ m/s}^2)\hat{j}$, respectively
E) $(6\text{ m/s})\hat{j}$ and 0, respectively

15. An object is moving on a circular path of radius π meters at a constant speed of 4.0 m/s. The time required for one revolution is:
A) $2/\pi^2$ s
B) $\pi^2/2$ s
C) $\pi/2$ s
D) $\pi^2/4$ s
E) $2/\pi$ s

16. A particle moves at constant speed in a circular path. The instantaneous velocity and instantaneous acceleration vectors are:
A) both tangent to the circular path
B) both perpendicular to the circular path
C) perpendicular to each other
D) opposite to each other
E) none of the above

17. A stone is tied to a string and whirled at constant speed in a horizontal circle. The speed is then doubled without changing the length of the string. Afterward the magnitude of the acceleration of the stone is:
A) the same
B) twice as great
C) four times as great
D) half as great
E) one-fourth as great

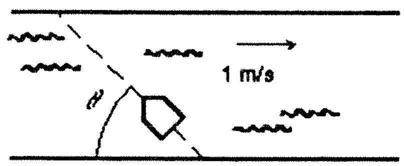
18. A car rounds a 20-m radius curve at 10 m/s. The magnitude of its acceleration is:
A) 0
B) 0.20 m/s^2
C) 5.0 m/s^2
D) 40 m/s^2
E) 400 m/s^2

19. For a biological sample in a 1.0-m radius centrifuge to have a centripetal acceleration of 25g its speed must be:
A) 11 m/s
B) 16 m/s
C) 50 m/s
D) 122 m/s
E) 245 m/s

20. A girl jogs around a horizontally circle with a constant speed. She travels one fourth of a revolution, a distance of 25 m along the circumference of the circle, in 5.0 s. The magnitude of her acceleration is:
A) 0.31 m/s^2
B) 1.3 m/s^2
C) 1.6 m/s^2
D) 3.9 m/s^2
E) 6.3 m/s^2

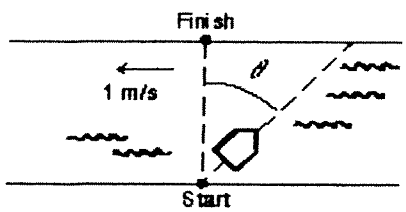
21. A Ferris wheel with a radius of 8.0m makes 1 revolution every 10 s. When he is at the top, essentially a diameter above the ground, he releases a ball. How far from the point on the ground directly under the release point does the ball land?
A) 0
B) 1.0 m
C) 8.0 m
D) 9.1 m
E) 16 m

22. A boy wishes to row across a river in the shortest possible time. He can row at 2 m/s in still water and the river is flowing at 1 m/s. At what angle θ should he point the bow (front) of his boat?



A) 30°
B) 45°
C) 60°
D) 63°
E) 90°

23. A girl wishes to swim across a river to a point directly opposite as shown. She can swim at 2 m/s in still water and the river is flowing at 1 m/s. At what angle θ with respect to the line joining the starting and finishing points should she swim?



A) 30°
B) 45°
C) 60°
D) 63°
E) 90°

24. A newton is the force:
A) of gravity on a 1 kg body
B) of gravity on a 1 g body
C) that gives a 1 g body an acceleration of 1 cm/s^2
D) that gives a 1 kg body an acceleration of 1 m/s^2
E) that gives a 1 kg body an acceleration of 9.8 m/s^2

25. The unit of force called the newton is:
A) 9.8 kg · m/s^2
B) 1 kg · m/s^2
C) defined by means of Newton's third law
D) 1 kg of mass
E) 1 kg of force

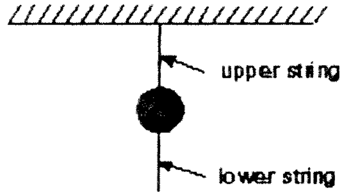
26. The standard 1-kg mass is attached to a compressed spring and the spring is released. If the mass initially has an acceleration of 5.6 m/s^2, the force of the spring has a magnitude of:
A) 2.8 N
B) 5.6 N
C) 11.2 N
D) 0
E) an undetermined amount

27. Acceleration is always in the direction:
A) of the displacement
B) of the initial velocity
C) of the final velocity
D) of the net force
E) opposite to the frictional force

28. The term "mass" refers to the same physical concept as:
A) weight
B) inertia
C) force
D) acceleration
E) volume

29. The inertia of a body tends to cause the body to:
A) speed up
B) slow down
C) resist any change in its motion
D) fall toward the Earth
E) decelerate due to friction

30. A heavy ball is suspended as shown. A quick jerk on the lower string will break that string but a slow pull on the lower string will break the upper string. The first result occurs because:

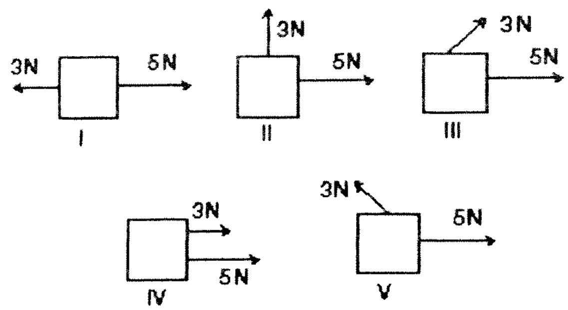


A) the force is too small to move the ball
B) action and reaction is operating
C) the ball has inertia
D) air friction holds the ball back
E) the ball has too much energy

31. The block shown moves with constant velocity on a horizontal surface. Two of the forces on it are shown. A frictional force exerted by the surface is the only other horizontal force on the block. The frictional force is:

A) 0
B) 2 N, leftward
C) 2 N, rightward
D) slightly more than 2 N, leftward
E) slightly less than 2 N, leftward

32. Two forces, one with a magnitude of 3 N and the other with a magnitude of 5 N, are applied to an object. For which orientations of the forces shown in the diagrams is the magnitude of the acceleration of the object the least?



A) I
B) II
C) III
D) IV
E) V

33. A car travels east at constant velocity. The net force on the car is:
A) east
B) west
C) up
D) down
E) zero

34. A constant force of 8.0 N is exerted for 4.0 s on a 16-kg object initially at rest. The change in speed of this object will be:
A) 0.5 m/s
B) 2 m/s
C) 4 m/s
D) 8 m/s
E) 32 m/s

35. Two forces are applied to a 5.0-kg crate; one is 6.0 N to the north and the other is 8.0 N to the west. The magnitude of the acceleration of the crate is:
A) 0.50 m/s^2
B) 2.0 m/s^2
C) 2.8 m/s^2
D) 10 m/s^2
E) 50 m/s^2

36. You stand on a spring scaleon the floor of an elevator. Of the following, the scale shows the highest reading when the elevator:
   A) moves upward with increasing speed
   B) moves upward with decreasing speed
   C) remains stationary
   D) moves downward with increasing speed
   E) moves downward at constant speed

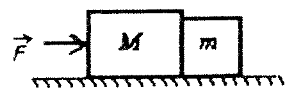
37. The "reaction" force does not cancel the "action" force because:
   A) the action force is greater than the reaction force
   B) they are on different bodies
   C) they are in the same direction
   D) the reaction force exists only after the action force is removed
   E) the reaction force is greater than the action force

38. A book rests on a table, exerting a downward force on the table. The reaction to this force is:
   A) the force of the Earth on the book
   B) the force of the table on the book
   C) the force of the Earth on the table
   D) the force of the book on the Earth
   E) the inertia of the book

39. A 90-kg man stands in an elevator that is moving up at a constant speed of 5.0 m/s. The force exerted by him on the floor is about:
   A) zero
   B) 90 N
   C) 880 N
   D) 450 N
   E) 49 N

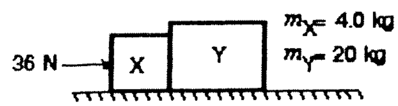
40. A 90-kg man stands in an elevator that has a downward acceleration of 1.4 m/s^2. The force exerted by him on the floor is about:
   A) zero
   B) 90 N
   C) 760 N
   D) 880 N
   E) 1010 N

41. Two blocks with masses m and M are pushed along a horizontal frictionless surface by a horizontal applied force $\vec{F}$ as shown. The magnitude of the force of either of these blocks on the other is:



A) $mF/(m + M)$
B) mF/M
C) $mF/(M - m)$
D) $MF/(M + m)$
E) MF/m

42. Two blocks (X and Y) are in contact on a horizontal frictionless surface. A 36-N constant force is applied to X as shown. The magnitude of the force of X on Y is:



A) 1.5 N
B) 6.0 N
C) 29 N
D) 30 N
E) 36 N

43. A radian is about:
A) 25°
B) 37°
C) 45°
D) 57°
E) 90°

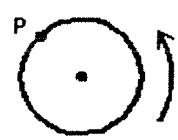
44. One revolution is the same as:
A) 1 rad
B) 57 rad
C) π/2 rad
D) π rad
E) 2π rad

45. One revolution per minute is about:
  A) 0.0524 rad/s
  B) 0.105 rad/s
  C) 0.95 rad/s
  D) 1.57 rad/s
  E) 6.28 rad/s

46. If a wheel turns with constant angular speed then:
  A) each point on its rim moves with constant velocity
  B) each point on its rim moves with constant acceleration
  C) the wheel turns through equal angles in equal times
  D) the angle through which the wheel turns in each second increases as time goes on
  E) the angle through which the wheel turns in each second decreases as time goes on

47. If a wheel turning at a constant rate completes 100 revolutions in 10 s its angular speed is:
  A) 0.31 rad/s
  B) 0.63 rad/s
  C) 10 rad/s
  D) 31 rad/s
  E) 63 rad/s

48. The figure shows a cylinder of radius 0.7 m rotating about its axis at 10 rad/s. The speed of the point P is:



  A) 7.0 m/s
  B) 14π rad/s
  C) 7π rad/s
  D) 0.70 m/s
  E) none of these

49. A particle moves in a circular path of radius 0.10 m with a constant angular speed of 5 rev/s. The acceleration of the particle is:
  A) 0.10π m/s^2
  B) 0.50 m/s^2
  C) 500π m/s^2
  D) $1000\pi^2$ m/s^2
  E) $10\pi^2$ m/s^2

50. A boat is able to move through still water at 20 m/s. It makes a round trip to a town 3.0 km upstream. If the river flows at 5 m/s, the time required for this round trip is:
A) 120 s
B) 150 s
C) 200 s
D) 300 s
E) 320 s

Answer Key

1. A
2. C
3. D
4. A
5. C
6. C
7. B
8. C
9. B
10. D
11. E
12. D
13. E
14. C
15. B
16. C
17. C
18. C
19. B
20. C
21. D
22. E
23. A
24. D
25. B
26. B
27. D
28. B
29. C
30. C
31. B
32. A
33. E
34. B
35. B
36. A
37. B
38. B
39. C
40. C
41. A
42. D
43. D
44. E

45. B
46. C
47. E
48. A
49. E
50. E

Exam

Name________________________________

SHORT ANSWER. Write the word or phrase that best completes each statement or answers the question.

1) The second hand of a clock is 16.0 cm long (from the center of the clock face to the tip of the second hand). What is the magnitude of the average velocity (not speed) of the tip of the second hand during a time interval of 27 seconds?

2) A projectile returns to its original height after 4.08 seconds, during which time it travels 76.2 meters horizontally. If air resistance can be neglected, what was the projectile's initial speed? (Use $g = 9.80\ m/s^2$)

3) A rock is thrown from the roof of a building, with an initial velocity of 10.0 m/s at an angle of 30.0° above the horizontal. The rock is observed to strike the ground 43.0 m from the base of the building. What is the height of the building?

4) A child sits on a merry-go-round, 1.5 meters from the center. The merry-go-round is turning at a constant rate, and the child is observed to have a radial acceleration of $2.3\ m/s^2$. How long does it take for the merry-go-round to make one revolution?

'Answer Key
Testname: UNTITLED1.TST

SHORT ANSWER. Write the word or phrase that best completes each statement or answers the question.

1) 1.17 cm/s
2) 27.4 m/s
3) 96.0 meters
4) 5.1 seconds