Vectors and Motion in One Dimension

Advanced Placement Physics B
Mr. DiBucci

Name____ per. ___ date ______
Trigonometry Review DiBucci

1. A person attempts to measure the height of a building by walking out a distance of 46m from the base and shining a flashlight beam toward its top. He finds that when the beam is elevated at an angle of 39 degrees with respect to the horizontal, the beam just strikes the top of the building.
a) calculate the height of the building
b) calculate the distance the flashlight beam has to travel before it strikes the top of the building.
(37.3m, 59.2m)

2. A truck driver moves up a straight mountain highway. Elevation markers at the beginning and ending points of the trip show that he has risen vertically 0.530km and the odometer shows that he has traveled a distance of 3.00 km during the ascent. Find the angle of the incline of the hill. (10.2 degrees)

3. An airplane travels 450 km due east and the travels an unknown distance due north. Finally it returns to its starting point by traveling a distance of 525 km. How far did the plane travel in the northerly direction? (270 km)

4. On a sunny day, a tall building casts a shadow that is 67.2 meters long. The angle between the sun's rays and the ground is 50.0 degrees. Determine the height of the building. (80.0 m)

5. A lake front drops off gradually at an angle theta. For safety reasons , it is necessary to know how deep the lake is at various distances from shore. To provide some information about the depth , a lifeguard rows straight out from the shore a distance of 14.0 meters and drops a weighted fishing line. By measuring the length of the line he determines the depth to be 2.25 m.
a) calculate the value of theta.
b) What would be the depth of the lake a distance of 22.0 meters from shore?
(9.15 degrees, 3.54 meters)

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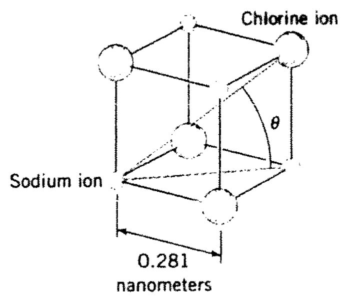
Geometric Challenge

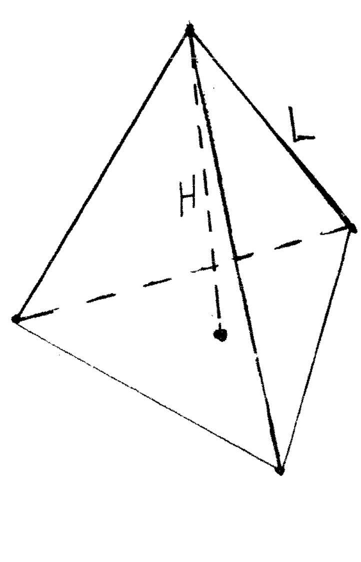
1.a. The drawing shows **sodium and chlorine ions** positioned at



the corners of a cube that is part of the crystal structure of sodium chloride (common table salt). The edge of the cube is 0.281 nm (1 nm = 1 nanometer = 10^{-9} m) in length. Find the distance (in nanometers) between the sodium ion located at one corner of the cube and the chlorine ion located on the diagonal at the opposite corner.

b. What is the value of the angle θ in the drawing

2. A regular tetrahedron is a three-dimensional object that has four faces, each of which is an equilateral triangle. Each of the edges of such an object has a length L. The height H of a regular tetrahedron is the perpendicular distance from one corner to the center of the opposite triangular face. Show that the ratio between H and L is $H/L = \sqrt{2/3}$.



Name ______________________________ Per. ___ Date ______
Vector Practice DiBucci

Make a sketch of each vector. Calculate the components of the vector and write the vectors in i,j,k notation. Make sure to include the appropriate units and algebraic sign. The first one is done for you .

1. r = 10m , 60 degrees north of east

x component = 10m cos(60)= 5m
y component = 10 m sin (60)= 8.67 m

r = (5m)**i** + (8.67)**j**

2. v = 20m/s, 45 degrees north of west

3. a = 100 m/s/s , 30 degrees south of west

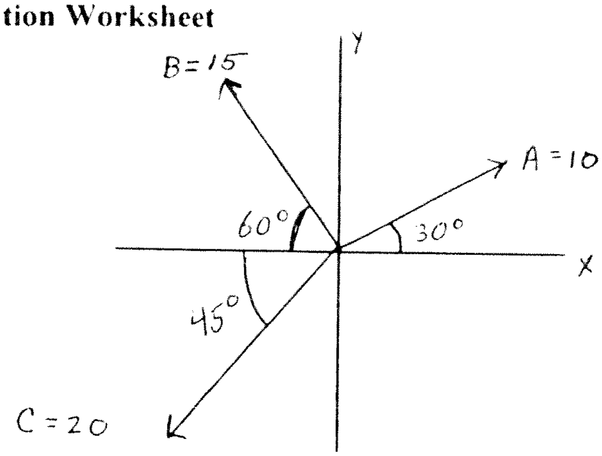
4. F= 60 N, 20 south of east

5. r = 100 mi , 210 degrees measured from the positive x axis

6. r = 30 km, 120 degrees from the positive x- axis

Name____ **per.** ___ **Date** _______

Vector Addition Worksheet **DiBucci**



1. Find the x and y components for vectors **A, B** and **C**

2. Express vectors **A, B and C** in component notation with respect to its base unit vectors.

3. Calculate **D=A+B+C** , using the component method of vector addition. Calculate both its magnitude and direction.

4. Express vector **D** in component notation with respect to its base unit vectors.

5. On a separate sheet of paper calculate **E=A+2B-3C**, state its magnitude and direction and express E in component notation with respect to its base unit vectors.

Name____ Per. ___ date ________

Vector addition using the graphical and component methods

Directions: Place all of your work on a separate sheet of paper for full credit

1) A car travels 20 km due north and then 35 km in a direction 60 degrees west of north.
   a) Sketch a diagram of the two displacement vectors, find their components and calculate the magnitude and direction of the resultant vector in polar form. (R,θ)
   b) Verify your answer by making a scaled drawing and measure the resultant vector using a ruler and protractor.

answer:

R= 48.2 km 38.9 degrees west of north

2) A hiker begins a trip by first walking 25.0 km 45 degrees south of east from her base camp. On the second day, she walks 40.0 km in a direction 60 degrees north of east.
   a) Calculate the components of the two displacement vectors in unit vector form, call the vectors **A** and **B** respectively
   b) Calculate the resultant vector and put it into unit vector form **R**= Rx **i** + Ry **j**
   c) Express the resultant vector in polar form (R,θ)

answer:

A=17.7km **i** - 17.7 km **j**
B= 20 km **i** +34.6 km **j**
R=37.7 km **i** + 16.9 km **j**
R=41.3 km at 24.1 degrees north of east

3) A commuter airplane starts its flight from the airport (the origin). First, it flies to city A located 175 km in a direction 30 degrees north of east. Next, it flies 150 km 20 degrees west of north to city B. Finally it flies 190 km due west to city C. **Calculate the resultant vector for the three displacements. Express your answer in unit vector and polar form. (This will actually be the position vector of city C)**

answer

R= -89.7 km **i** + 228 km **j**
R= 245 km at an angle of 21.4 degrees west of north

Section 3.2 Vector and Scalar Quantities
Section 3.3 Some Properties of Vectors

An airplane flies 200 km due west from city A to city B and then 300 km in the direction of 30° north of west from city B to city C. (a) In straight-line distance, how far is city C from city A? (b) Relative to city A, in what direction is city C?

9. A surveyor estimates the distance across a river by the following method: standing directly across from a tree on the opposite bank, she walks 100 m along the riverbank, then sights across to the tree. The angle from her baseline to the tree is 35.0°. How wide is the river?

10. A pedestrian moves 6.00 km east and then 13.0 km north. Find the magnitude and direction of the resultant displacement vector using the graphical method.

11. A plane flies from base camp to lake A, a distance of 280 km at a direction of 20.0° north of east. After dropping off supplies, it flies to lake B, which is 190 km and 30.0° west of north from lake A. Graphically determine the distance and direction from lake B to the base camp.

12. Vector **A** has a magnitude of 8.00 units and makes an angle of 45.0° with the positive x axis. Vector **B** also has a magnitude of 8.00 units and is directed along the negative x axis. Using graphical methods, find (a) the vector sum **A** + **B** and (b) the vector difference **A** − **B**.

A person walks along a circular path of radius 5.00 m, around one half of the circle. (a) Find the magnitude of the displacement vector. (b) How far did the person walk? (c) What is the magnitude of the displacement if the person walks all the way around the circle?

14. A force $\mathbf{F}_1$ of magnitude 6.00 units acts at the origin in a direction 30.0° above the positive x axis. A second force $\mathbf{F}_2$ of magnitude 5.00 units acts at the origin in the direction of the positive y axis. Find graphically the magnitude and direction of the resultant force $\mathbf{F}_1 + \mathbf{F}_2$.

15. Each of the displacement vectors **A** and **B** shown in Figure P3.15 has a magnitude of 3.00 m. Find graphically (a) **A** + **B**, (b) **A** − **B**, (c) **B** − **A**, (d) **A** − 2**B**.

16. A dog searching for a bone walks 3.5 m south, then 8.2 m at an angle 30° north of east, and finally 15 m west. Find the dog's resultant displacement vector using graphical techniques.

17. A roller coaster moves 200 ft horizontally, then travels 135 ft at an angle of 30.0° above the horizontal. It then travels 135 ft at an angle of 40.0° below the horizontal. What is its displacement from its starting point? Use graphical techniques.

18. The driver of a car drives 3.00 km north, 2.00 km northeast (45.0° east of north), 4.00 km west, and then 3.00 km southeast (45.0° east of south). Where does he end up relative to his starting point? Work out your answer graphically. Check by using components. (The car is not near the North Pole or the South Pole.)

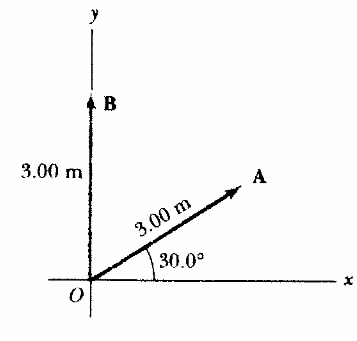


FIGURE P3.15

19. Find the horizontal and vertical components of the 100-m displacement of a superhero who flies from the top of a tall building following the path shown in Figure P3.19.

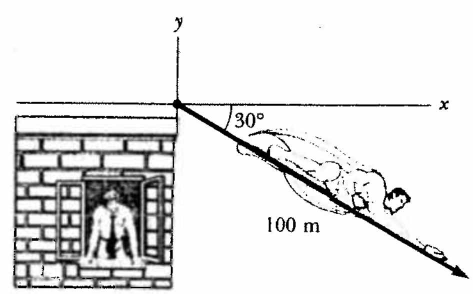


FIGURE P3.19

20. A person walks 25.0° north of east for 3.10 km. How far would she have to walk due north and due east to arrive at the same location?

21. Indiana Jones is trapped in a maze. To find his way out, he walks 10 m, makes a 90° right turn, walks 5.0 m, makes another 90° right turn, and walks 7.0 m. What is his displacement from his initial position?

22. While exploring a cave, a spelunker starts at the entrance and moves the following distances. She goes 75.0 m north, 250 m east, 125 m at an angle 30.0° north of east, and 150 m south. Find the resultant displacement from the cave entrance.

Section 3.4 Components of a Vector and Unit Vectors

23. A vector has an x component of -25.0 units and a y component of 40.0 units. Find the magnitude and direction of this vector.

24. Vector **B** has x, y, and z components of 4.00, 6.00, and 3.00 units, respectively. Calculate the magnitude of **B** and the angles that **B** makes with the coordinate axes.

25. Given the vectors $\mathbf{A} = 2.0\mathbf{i} + 6.0\mathbf{j}$ and $\mathbf{B} = 3.0\mathbf{i} - 2.0\mathbf{j}$, (a) sketch the vector sum $\mathbf{C} = \mathbf{A} + \mathbf{B}$ and the vector subtraction $\mathbf{D} = \mathbf{A} - \mathbf{B}$. (b) Find analytical solutions for **C** and **D** first in terms of unit vectors and then in terms of polar coordinates, with angles measured with respect to the $+x$ axis.

26. A displacement vector lying in the xy plane has a magnitude of 50.0 m and is directed at an angle of 120.0° to the positive x axis. What are the rectangular components of this vector?

27. Find the magnitude and direction of the resultant of three displacements having rectangular components (3.00, 2.00) m, (-5.00, 3.00) m, and (6.00, 1.00) m.

28. Vector **A** has x and y components of -8.7 cm and 15 cm, respectively; vector **B** has x and y components of 13.2 cm and -6.6 cm, respectively. If $\mathbf{A} - \mathbf{B} + 3\mathbf{C} = 0$, what are the components of **C**?

29. Consider two vectors $\mathbf{A} = 3\mathbf{i} - 2\mathbf{j}$ and $\mathbf{B} = -\mathbf{i} - 4\mathbf{j}$. Calculate (a) $\mathbf{A} + \mathbf{B}$, (b) $\mathbf{A} - \mathbf{B}$, (c) $|\mathbf{A} + \mathbf{B}|$, (d) $|\mathbf{A} - \mathbf{B}|$, (e) the direction of $\mathbf{A} + \mathbf{B}$ and $\mathbf{A} - \mathbf{B}$.

30. A boy runs 3.0 blocks north, 4.0 blocks northeast, and 5.0 blocks west. Determine the length and direction of the displacement vector that goes from the starting point to his final position.

31. Obtain expressions for the position vectors having polar coordinates (a) 12.8 m, 150°; (b) 3.30 cm, 60.0°; (c) 22.0 in., 215°.

32. Consider the displacement vectors $\mathbf{A} = (3\mathbf{i} + 3\mathbf{j})$ m, $\mathbf{B} = (\mathbf{i} - 4\mathbf{j})$ m, and $\mathbf{C} = (-2\mathbf{i} + 5\mathbf{j})$ m. Use the component method to determine (a) the magnitude and direction of the vector $\mathbf{D} = \mathbf{A} + \mathbf{B} + \mathbf{C}$, (b) the magnitude and direction of $\mathbf{E} = -\mathbf{A} - \mathbf{B} + \mathbf{C}$.

33. A particle undergoes the following consecutive displacements: 3.50 m south, 8.20 m northeast, and 15.0 m west. What is the resultant displacement?

34. A quarterback takes the ball from the line of scrimmage, runs backward for 10 yards, then sideways parallel to the line of scrimmage for 15 yards. At this point, he throws a forward pass 50 yards straight downfield perpendicular to the line of scrimmage. What is the magnitude of the football's resultant displacement?

35. A jet airliner moving initially at 300 mph to the east moves into a region where the wind is blowing at 100 mph in a direction 30.0° north of east. What are the new speed and direction of the aircraft?

36. A novice golfer on the green takes three strokes to sink the ball. The successive displacements are 4.00 m to the north, 2.00 m northeast, and 1.00 m 30.0° west of south. Starting at the same initial point, an expert golfer could make the hole in what single displacement?

37. Find the x and y components of the vectors **A** and **B** shown in Figure P3.15. Derive an expression for the resultant vector $\mathbf{A} + \mathbf{B}$ in unit-vector notation.

38. A particle undergoes two displacements. The first has a magnitude of 150 cm and makes an angle of 120.0° with the positive x axis. The *resultant* displacement has a magnitude of 140 cm and is directed at an angle of 35.0° to the positive x axis. Find the magnitude and direction of the second displacement.

39. The vector **A** has x, y, and z components of 8, 12, and -4 units, respectively. (a) Write a vector expression for **A** in unit-vector notation. (b) Obtain a unit-vector expression for a vector **B** one fourth the length of **A** pointing in the same direction as **A**. (c) Obtain a unit-vector expression for a vector **C** three times the length of **A** pointing in the direction opposite the direction of **A**.

40. Instructions for finding a buried treasure include the following: Go 75 paces at 240°, turn to 135° and walk 125 paces, then travel 100 paces at 160°. Determine the resultant displacement from the starting point.

41. Given the displacement vectors $\mathbf{A} = (3.0\mathbf{i} - 4.0\mathbf{j} + 4.0\mathbf{k})$ m and $\mathbf{B} = (2.0\mathbf{i} + 3.0\mathbf{j} - 7.0\mathbf{k})$ m, find the magnitudes of the vectors (a) $\mathbf{C} = \mathbf{A} + \mathbf{B}$ and (b) $\mathbf{D} = 2\mathbf{A} - \mathbf{B}$, also expressing each in terms of its rectangular components.

42. As it passes over Grand Bahama Island, the eye of a hurricane is moving in a direction 60.0° north of west with a speed of 41.0 km/h. Three hours later, it shifts due north, and its speed slows to 25.0 km/h. How far from Grand Bahama is the eye 4.50 h after it passes over the island?

43. Vector **A** has a negative x component 3.00 units in length and a positive y component 2.00 units in length. (a) Determine an expression for **A** in unit-vector notation. (b) Determine the magnitude and direction of **A**. (c) What vector **B** when added to **A** gives a resultant vector with no x component and a negative y component 4.00 units in length?

44. An airplane starting from airport A flies 300 km east, then 350 km 30.0° west of north, and then 150 km north to arrive finally at airport B. There is no wind on this day. (a) The next day, another plane flies directly from A to B in a straight line. In what direction should the pilot travel in this direct flight? (b) How far will the pilot travel in this direct flight?

45. Point A in Figure P3.45 is an arbitrary point along the line connecting the two points (x_2, y_2). Show that the coordinates of A are $(1 - f)x_1 + fx_2$, $(1 - f)y_1 + fy_2$.

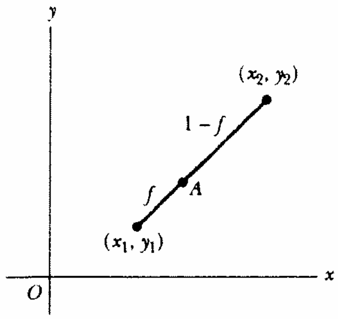


FIGURE P3.45

46. If $\mathbf{A} = (6.0\mathbf{i} - 8.0\mathbf{j})$ units, $\mathbf{B} = (-8.0\mathbf{i} + 3.0\mathbf{j})$ units, and $\mathbf{C} = (26.0\mathbf{i} + 19.0\mathbf{j})$ units, determine a and b so that $a\mathbf{A} + b\mathbf{B} + \mathbf{C} = 0$.

[47.] Three vectors are oriented as shown in Figure P3.47, where $|\mathbf{A}| = 20.0$ units, $|\mathbf{B}| = 40.0$ units, and $|\mathbf{C}| = 30.0$ units. Find (a) the x and y components of the resultant vector and (b) the magnitude and direction of the resultant vector.

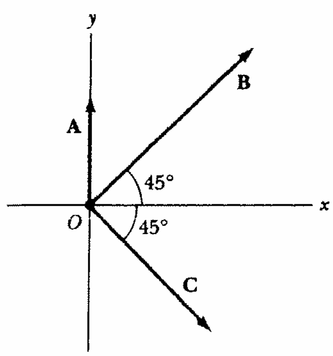


FIGURE P3.47

ADDITIONAL PROBLEMS

48. A vector is given by $\mathbf{R} = 2\mathbf{i} + \mathbf{j} + 3\mathbf{k}$. Find (a) the magnitudes of the x, y, and z components, (b) the magnitude of $\mathbf{R}$, and (c) the angles between $\mathbf{R}$ and the x, y, and z axes.

[49.] A person going for a walk follows the path shown in Figure P3.49. The total trip consists of four straight-line paths. At the end of the walk, what is the person's resultant displacement measured from the starting point?

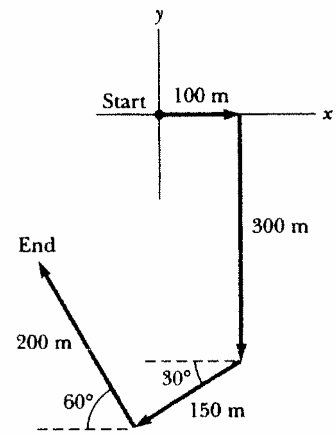


FIGURE P3.49

50. The helicopter view in Figure P3.50 shows two people pulling on a stubborn mule. Find (a) the single force that is equivalent to the two forces shown, and (b) the force that a third person would have to exert on the mule to make the resultant force equal to zero.

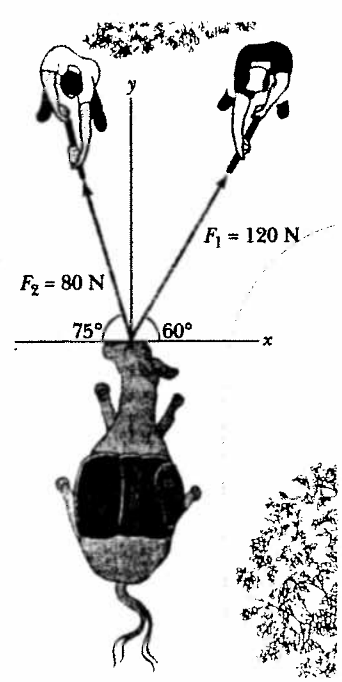


FIGURE P3.50

51. A pirate has buried his treasure on an island on which grow five trees located at the following points: $A(30\text{ m}, -20\text{ m})$, $B(60\text{ m}, 80\text{ m})$, $C(-10\text{ m}, 10\text{ m})$, $D(40\text{ m}, -30\text{ m})$, and $E(-70\text{ m}, 60\text{ m})$, all mea-

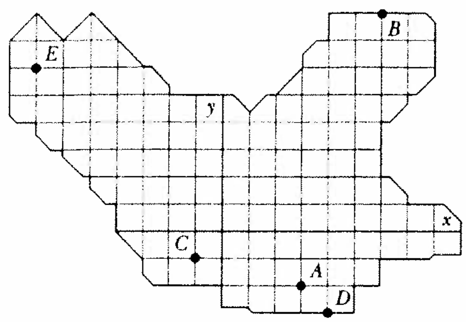


FIGURE P3.51

sured relative to some origin, as in Figure P3.51. His map instructs him to start at A and move toward B, but cover only one-half the distance between A and B. Then move toward C, covering one-third the distance between B and C. Then move toward D, covering one-fourth the distance between C and D. Finally move toward E, covering one-fifth the distance between D and E, stop and dig. (a) What are the coordinates of the point where his treasure is buried? (b) Rearrange the order of the trees (for instance, $B(30\text{ m}, -20\text{ m})$, $A(60\text{ m}, 80\text{ m})$, $E(-10\text{ m}, 10\text{ m})$, $C(40\text{ m}, -30\text{ m})$, and $D(-70\text{ m}, 60\text{ m})$), and repeat the calculation to show that the answer does not depend on the order of the trees. (*Hint:* See Problem 45.)

52. A rectangular parallelepiped has dimensions a, b, and c, as in Figure P3.52. (a) Obtain a vector expression for the face diagonal vector $\mathbf{R}_1$. What is the magnitude of this vector? (b) Obtain a vector expression for the body diagonal vector $\mathbf{R}_2$. What is the magnitude of this vector?

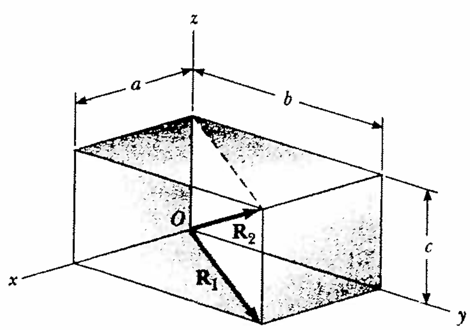


FIGURE P3.52

53. A point P is described by the coordinates (x, y) with respect to the normal cartesian coordinate system shown in Figure P3.53. Show that (x', y'), the coordinates of this point in the rotated coordinate system,

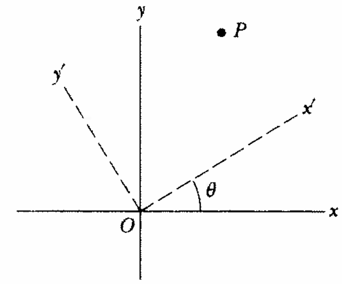


FIGURE P3.53

are related to (x, y) and the rotation angle θ by the expressions

$$x' = x\cos\theta + y\sin\theta$$

$$y' = -x\sin\theta + y\cos\theta$$

54. A point lying in the xy plane and having coordinates (x, y) can be described by the position vector $\mathbf{r} = x\mathbf{i} + y\mathbf{j}$. (a) Show that the displacement vector for a particle moving from (x_1, y_1) to (x_2, y_2) is given by $\mathbf{d} = (x_2 - x_1)\mathbf{i} + (y_2 - y_1)\mathbf{j}$. (b) Plot the position vectors $\mathbf{r}_1$ and $\mathbf{r}_2$ and the displacement vector $\mathbf{d}$, and verify by the graphical method that $\mathbf{d} = \mathbf{r}_2 - \mathbf{r}_1$.

SPREADSHEET PROBLEMS

S1. Use Spreadsheet 3.1 to find the total displacement corresponding to the sum of the three displacement vectors: $\mathbf{A} = 3.0\mathbf{i} + 4.0\mathbf{j}$, $\mathbf{B} = -2.3\mathbf{i} - 7.8\mathbf{j}$, and $\mathbf{C} = 5.0\mathbf{i} - 2.0\mathbf{j}$, where the units are in meters. (a) Give your answer in component form. (b) Give your answer in polar form. (c) Find a fourth displacement that returns you to the origin.

S2. A vendor must call on four customers once in every sales period. The four customers are in different cities, and the salesman wants to visit all customers in the least time. What path should he take?

To solve this problem, suppose you start at the origin and visit four different points (A, B, C, D) once before returning to the origin, always traveling in a straight line between points. The distance traveled depends upon the route taken. Spreadsheet 3.2 enables you to pick any four points A, B, C, D lying in a plane; the spreadsheet calculates the magnitude of the vector displacement for each straight-line portion of the trip and the total distance traveled. Find the path that gives the shortest total distance traveled.

Brute force can be used to find this path: try every path possible. To use Spreadsheet 3.2, enter the X and Y coordinates in the columns corresponding to the points A, B, C, D. The first site, the starting point, is labeled O, and the final site, which is also the starting position, is also labeled O. Note the total distance traveled and examine the graph that displays the path. To change the order in which the sites are visited, change the index order of the four non-origin sites and sort the block. For example, to visit *B* first, enter a "1" in the order column to the left of *B*; to visit *D* next, enter a "2" in the order column next to *D*, and so on; then sort the block containing the rows in which the points *A*, *B*, *C*, *D* appear in ascending order according to the order column. Note the total distance traveled and again examine the graph to see your new path. Repeat this process until you are convinced you have found the shortest path. (a) Find the shortest possible distance for visiting four points, when the locations are (− 10, 5), (− 8, − 7), (1, 11), and (12, 9); find the minimum distance necessary to visit these points. How many trials did you use to find this shortest distance? In what order should the vendor visit these four customers? (b) Choose any other four points and repeat part (a).

Modify Spreadsheet 3.2 to include two more points. Choose any six points and use your spreadsheet to find the shortest path for visiting all six sites. How many trials did you need this time? This brute-force method is not practical when there are more than a handful of customers. For N sites, the method requires $(N - 1)!/2$ trials. For example, if $N = 10$, you would need over 180 000 trials.

ANSWERS TO VECTOR WORKSHEET — DiBucci

PP. 66 - 69

8.) 484 km 18° N of W

9.) 70 m

10.) 14.3 km, 65.2° N of E

11.) 310 km 57° S of W

12) 6.1 at 112°, 14.8 at 22.5°

13) 10 m, 15.7 m, 0

14) 9.54 N at 57° N of E

15) 5.2 m at 60°, 3 m at -30°
3 m at 150°, 5.2 m at -60°

16. Skip

17) 420 ft, -19 ft, -2.6°

18) 5.24 km at 154°

19) 86.6 m, -50.0 m

20) 2.81 km east

21) $3m\hat{i} - 5m\hat{j}$, 5.83 m
59° to the right

22) 358.2 m

23) 47.2 units at 122°

24) 7.81 units
$\alpha = 59.2°$
$\beta = 39.8°$
$\gamma = 67.4°$

25) 6.40 at 38.7°, $5\hat{i} + 4\hat{j}$
$-1\hat{i} + 8\hat{j}$, 8.06 at 97.2°

26) -25 m, 43.3 m

27) 7.21 m, 56.3°

28) 7.3 cm, -7.2 cm $\vec{C} = 7.3\hat{i} - 7.2\hat{j}$

29) $2\hat{i} - 6\hat{j}$, $4\hat{i} + 2\hat{j}$, 6.32, 4.47
-71.6°, 26.6°

30) 6.22 Blocks at 110° CCW From east
$\hat{i}$ = east $\hat{j}$ = North

31) $(-11.1\hat{i} + 6.4\hat{j})$ m
$(1.65\hat{i} + 2.86\hat{j})$ m
$(-18\hat{i} - 12.6\hat{j})$ m

32) 4.47 at 63.4°, $2\hat{i} + 4\hat{j}$ - pt. A
$-6\hat{i} + 6\hat{j}$, 8.49 at 135° → pt. B

33) $(-9.2\hat{i} + 2.3\hat{j})$ m
9.48 m

34) 42.7 yards

35) 390 mph at 7.37° N of E,

36) 4.65 m at N of east

37) $(2.6\hat{i} + 4.5\hat{j})$ m

38) 196 cm at -14.3°

39) $\vec{A} = 8\hat{i} + 12\hat{j} - 4\hat{k}$
$\vec{B} = \frac{\vec{A}}{4} = 2\hat{i} + 3\hat{j} - 1\hat{k}$
$\vec{C} = -3\vec{A} = -24\hat{i} - 36\hat{j} + 12\hat{k}$

40) $-220\hat{i} + 57.6\hat{j}$, 227 at 165°

41) $5\hat{i} - 1\hat{j} - 3\hat{k}$, 5.92

$4\hat{i} + 11\hat{j} - 15\hat{k}$, 19.0

42) 157 km

43) $-3\hat{i} + 2\hat{j}$, 3.61, 146.3°

146.3°, $3\hat{i}$, $-6\hat{j}$

44) 74.6° N of E, 467 km

45) skip

46) $5\vec{A} + 7\vec{B} + \vec{C} = 0$

1.1 THE NATURE OF PHYSICS

The science of physics has developed out of the efforts of men and women to explain why our physical environment behaves as it does. These efforts have been so successful that the laws of physics now encompass a remarkable variety of phenomena, from planets orbiting the sun to lasers being used in eye surgery.

The laws of physics are equally remarkable for their scope. They describe the behavior of particles many times smaller than an atom and objects many times larger than our sun. The same laws apply to the heat generated by a burning match and the heat generated by a rocket engine. The same laws guide an astronomer in using the light from a distant star to determine how fast the star is moving and a police officer in using radar to catch a speeder. Physics can be applied fruitfully to objects as different as subatomic particles, distant stars, or speeding automobiles because it focuses on issues that are truly basic to the way nature works.

The strength of physics derives from the fact that its laws are based on experiment. This is not to say that intuition and educated guesses are unimportant. The great creative geniuses in science, as in art and music, work in leaps and bounds that no one can fully understand. In physics, however, a flash of insight never becomes accepted law unless its implications can be verified by experiment. This insistence on experimental verification has enabled physicists to build a rational and coherent understanding of nature.

The exciting feature of physics is its capacity for predicting how nature will behave in one situation on the basis of experimental data obtained in another situation. Such predictions place physics at the heart of modern technology and, therefore, can have a tremendous impact on our lives. Rocketry and the development of space travel have their roots firmly planted in the physical laws of Galileo Galilei (1564–1642) and Isaac Newton (1642–1727). The transportation industry relies heavily on physics in the development of engines and the design of aerodynamic vehicles. Entire electronics and computer industries owe their existence to the invention of the transistor, which grew directly out of the laws of physics that describe the electrical behavior of solids. The telecommunications industry depends extensively on electromagnetic waves, whose existence was predicted by James Clerk Maxwell (1831–1879) in his theory of electricity and magnetism. The medical profession uses X-ray, ultrasonic, and magnetic resonance methods for obtaining images of the interior of the human body, and physics lies at the core of all these. Perhaps the most widespread impact in modern technology is that due to the laser. Fields ranging from space exploration to medicine benefit from this incredible device, which is a direct application of the principles of atomic physics.

Because physics is so fundamental, it is a required course for students in a wide range of major areas. We welcome you to the study of this fascinating topic. You will learn how to see the world through the "eyes" of physics and to reason as a physicist does. In the process, you will learn how to apply physics principles to a wide range of problems. We hope that you will come to recognize that physics has important things to say about your environment.

1.2 Units

Definition of Standard Units

Physics experiments involve the measurement of a variety of quantities, and a great deal of effort goes into making these measurements as accurate and reproducible as possible. The first step toward ensuring accuracy and reproducibility is defining the units in which the measurements are made.

In this text, we will stress the system of units known according to the French phrase "Le Système International d'Unités," referred to simply as ***SI units***. This system, by international agreement, employs the ***meter*** (m) as the unit of length, the ***kilogram*** (kg) as the unit of mass, and the ***second*** (s) as the unit of time. Two other systems of units are worth mentioning. The CGS system utilizes the centimeter (cm), the gram (g), and the second for length, mass, and time, respectively, whereas the BE or British Engineering system (the gravitational version) uses the foot (ft), the slug (sl), and the second. Table 1.1 summarizes the units used for length, mass, and time in the three systems.

Originally, the meter as a unit of length was defined in terms of the distance measured along the earth's surface between the north pole and the equator. Eventually, a more accurate measurement standard was needed, and by international agreement the meter became the distance between two marks on a bar of platinum-iridium alloy (see Figure 1.1) kept at a temperature of 0 °C. Today, to meet further demands for increased accuracy, the meter is defined as the distance that light travels in a vacuum in a time of 1/299 792 458 second. This definition arises because the speed of light is a universal constant that is defined to be 299 792 458 m/s.

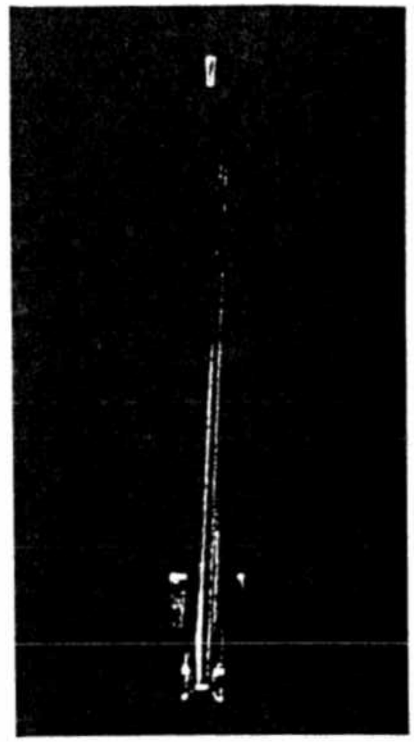


Figure 1.1 The standard platinum-iridium meter bar.

The definition of a kilogram as a unit of mass has also undergone changes over the years. As Chapter 4 discusses, the mass of an object indicates the tendency of the object to continue in motion with a constant velocity. Originally, the kilogram was expressed in terms of a specific amount of water. Today, one kilogram is defined to be the mass of a standard cylinder of platinum–iridium alloy, like the one in Figure 1.2.

Figure 1.2 The standard platinum-iridium kilogram is kept at the International Bureau of Weights and Measures in Sèvres, France.

As with the units for length and mass, the present definition of the second as a unit of time is different from the original definition. Originally, the second was defined according to the average time for the earth to rotate once about its axis, one day being set equal to 86 400 seconds. The earth's rotational motion was chosen because it is naturally repetitive, occurring over and over again. Today, we still use a naturally occurring repetitive phenomenon to define the second, but of a very different kind. We use the electromagnetic waves emitted by cesium-133 atoms in an

Table 1.1 Units of Measurement

	System		
	SI	CGS	BE
Length	meter (m)	centimeter (cm)	foot (ft)
Mass	kilogram (kg)	gram (g)	slug (sl)
Time	second (s)	second (s)	second (s)

atomic clock like that in Figure 1.3. One second is defined as the time needed for 9 192 631 770 wave cycles to occur.*

BASE UNITS AND DERIVED UNITS

The units for length, mass, and time, along with a few other units that will arise later, are regarded as ***base*** SI units. The word "base" refers to the fact that these units are used along with various laws to define additional units for other important physical quantities, such as force and energy. The units for these other physical quantities are referred to as ***derived*** units, since they are combinations of the base units. Derived units will be introduced as they arise naturally along with the related physical laws.

The value of a quantity in terms of base or derived units is sometimes a very large or very small number. In such cases, it is convenient to introduce larger or smaller units that are related to the normal units by multiples of ten. Table 1.2 summarizes the prefixes that are used to denote multiples of ten. For example, 1000 or 10^3 meters are referred to as 1 kilometer (km), and 0.001 or 10^{-3} meter is called 1 millimeter (mm). Similarly, 1000 grams and 0.001 gram are referred to as 1 kilogram (kg) and 1 milligram (mg), respectively. Appendix A contains a discussion of scientific notation and powers of ten, such as 10^3 and 10^{-3}.

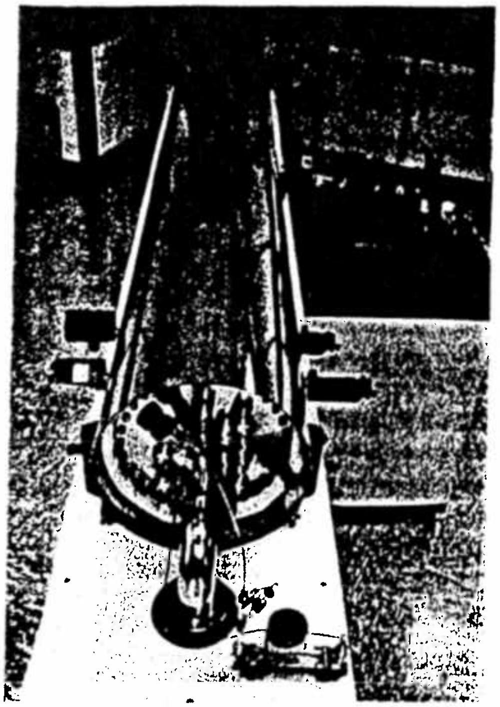


Figure 1.3 A cesium atomic clock.

Table 1.2 Standard Prefixes Used to Denote Multiples of Ten

Prefix	Symbol	Factor[a]
Tera	T	10^{12}
Giga[b]	G	10^{9}
Mega	M	10^{6}
Kilo	k	10^{3}
Hecto	h	10^{2}
Deka	da	10^{1}
Deci	d	10^{-1}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}
Nano	n	10^{-9}
Pico	p	10^{-12}
Femto	f	10^{-15}

[a] Appendix A contains a discussion of powers of ten and scientific notation.
[b] Pronounced jig'a.

1.3 THE ROLE OF UNITS IN PROBLEM SOLVING

THE CONVERSION OF UNITS

Since any quantity, such as length, can be measured in several different units, it is important to know how to convert from one unit to another. For instance, the foot can be used to express the distance between the two marks on the standard platinum-iridium meter bar. There are 3.281 feet in one meter, and this number can be used to convert from meters to feet, as the following example demonstrates.

EXAMPLE 1 • The World's Highest Waterfall

The highest waterfall in the world is Angel Falls in Venezuela, with a total drop of 979.0 m (see Figure 1.4). Express this drop in feet.

Reasoning When converting between units, we write down the units explicitly in the calculations and treat them like any algebraic quantity. In particular, we will take advantage of the following algebraic fact: Multiplying or dividing an equation by a factor of 1 does not alter the equation.

Solution Since 3.281 feet = 1 meter, it follows that (3.281 feet)/(1 meter) = 1. Using this factor of 1 to multiply the equation "Length = 979.0 meters," we find that

$$\text{Length} = (979.0\text{ meters})(1) = (979.0\text{ }\cancel{\text{meters}})\left(\frac{3.281\text{ feet}}{1\text{ }\cancel{\text{meter}}}\right) = \boxed{3212\text{ feet}}$$

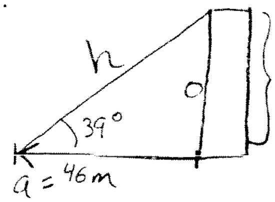
The colored lines emphasize that the units of meters behave like any algebraic quantity and cancel when the multiplication is performed, leaving only the desired unit of feet to describe the answer. In this regard, note that 3.281 feet = 1 meter also implies that (1 meter)/(3.281 feet) = 1. However, we chose not to multiply by a factor of 1 in this form, because the units of meters would not have canceled out.

* See Chapter 16 for a discussion of waves in general and Chapter 24 for a discussion of electromagnetic waves in particular.

Name Solutions - DiBucci per.___ date ______

Trigonometry Review DiBucci

1. A person attempts to measure the height of a building by walking out a distance of 46m from the base and shining a flashlight beam toward its top. He finds that when the beam is elevated at an angle of 39 degrees with respect to the horizontal, the beam just strikes the top of the building.
a) calculate the height of the building
b) calculate the distance the flashlight beam has to travel before it strikes the top of the building.
(37.3m, 59.2m)



A) $\tan 39° = \frac{h}{46m}$

$y = 46m \tan 39°$

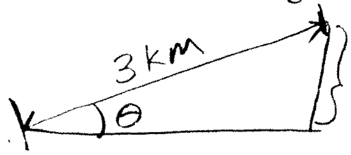
$y = 37.3m$

B) $\cos 39° = \frac{46m}{h}$

$h = \frac{46m}{\cos 39°}$

$h = 59.2m$

2. A truck driver moves up a straight mountain highway. Elevation markers at the beginning and ending points of the trip show that he has risen vertically 0.530km and the odometer shows that he has traveled a distance of 3.00 km during the ascent. Find the angle of the incline of the hill. (10.2 degrees)

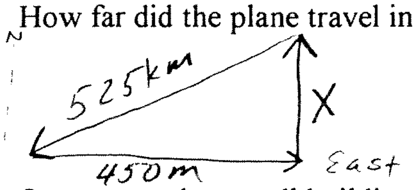


$\sin\theta = \frac{.530}{3.0}$

$\theta = \sin^{-1}(\frac{.53}{3})$

$\theta = 10.2°$

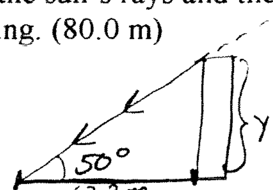
3. An airplane travels 450 km due east and the travels an unknown distance due north. Finally it returns to its starting point by traveling a distance of 525 km. How far did the plane travel in the northerly direction? (270 km)



$(450km)^2 + X^2 = (525km)^2$

$X = \sqrt{(525km)^2 - (450km)^2} = 270 km$

4. On a sunny day, a tall building casts a shadow that is 67.2 meters long. The angle between the sun's rays and the ground is 50.0 degrees. Determine the height of the building. (80.0 m)

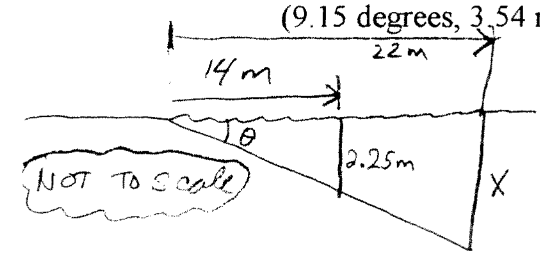


$\tan 50° = \frac{Y}{67.2m}$

$Y = 67.2m(\tan 50°)$

$Y = 80m$

5. A lake front drops off gradually at an angle theta. For safety reasons , it is necessary to know how deep the lake is at various distances from shore. To provide some information about the depth , a lifeguard rows straight out from the shore a distance of 14.0 meters and drops a weighted fishing line. By measuring the length of the line he determines the depth to be 2.25 m.
a) calculate the value of theta.
b) What would be the depth of the lake a distance of 22.0 meters from shore?
(9.15 degrees, 3.54 meters)



A) $\tan\theta = \frac{2.25}{14}$

$\theta = \tan^{-1}(\frac{2.25}{14})$

$\theta = 9.13°$

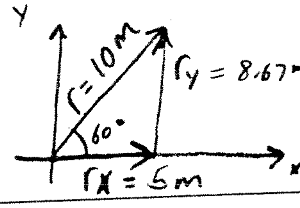
B) $\tan 9.13° = \frac{X}{22m}$

$X = 22m(\tan 9.13°)$

$X = 3.54 m$

Name SOLUTIONS - DIBUCCI Per. ___ Date ______
DiBucci
Vector Practice

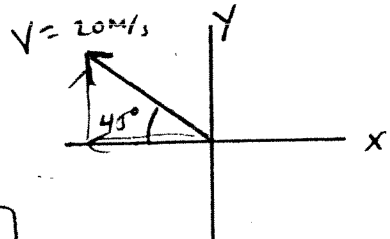
Make a sketch of each vector. Calculate the components of the vector and write the vectors in i,j,k notation. Make sure to include the appropriate units and algebraic sign. The first one is done for you .



1. r = 10m , 60 degrees north of east
x component = 10m cos(60)= 5m
y component = 10 m sin (60)= 8.67 m

r = (5m)**i** + (8.67)**j**

2. v = 20m/s, 45 degrees north of west



$V_x = (20\ m/s)\cos 45° = 14.1\ m/s$

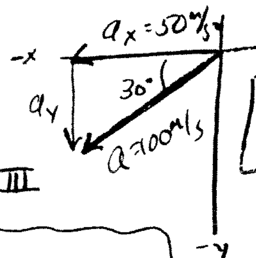
$V_y = (20\ m/s)\sin 45° = 14.1\ m/s$

$\vec{V} = (-14.1\ m/s)\hat{i} + (14.1\ m/s)\hat{j}$

3. a = 100 m/s/s , 30 degrees south of west

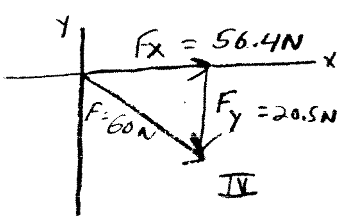
$a_x = (100\ m/s^2)\cos 30° = 86.7\ m/s^2$

$a_y = (100\ m/s^2)\sin 30° = 50\ m/s^2$



$\vec{a} = (-86.7\ m/s^2)\hat{i} - (50\ m/s^2)\hat{j}$

4. F= 60 N, 20 south of east

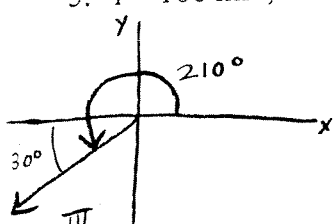


$F_x = (60N)\cos 20° = 56.4N$

$F_y = (60N)\sin 20° = 20.5N$

$\vec{F} = (56.4N)\hat{i} + (-20.5N)\hat{j}$

5. r = 100 mi , 210 degrees measured from the positive x axis



$r_x = (100mi)\cos 210° = -86.6mi$

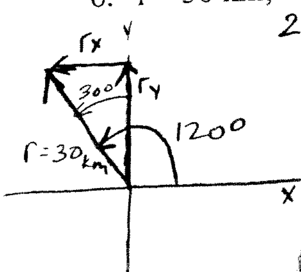
$r_y = (100mi)\sin 210° = -50mi$

Automatically gives correct Algebraic sign

$\vec{r} = (-86.6mi)\hat{i} + (-50mi)\hat{j}$

6. r = 30 km, 120 degrees from the positive x- axis

2 methods:



Method 1

$r_x = (30km)\cos 120° = -15km$

$r_y = (30km)\sin 120° = 26km$

$\vec{r} = (-15m)\hat{i} + (+26km\hat{j})$

Method 2:

$r_x = (30km)\sin 30° = 15km$

$r_y = (30km)\cos 30° = 26km$

must put in "−" sign

Solutions to Vector ADDITION W.S. DIBUCCI

1.) $A_x = {}^+10\cos 30° = {}^+8.67$ $B_x = {}^-15\cos 60° = {}^-7.5$ $C_x = {}^-20\cos 45° = {}^-14.1$

$A_y = {}^+10\sin 30° = {}^+5.0$ $B_y = 15\sin 60° = 13$ $C_y = {}^-20\cos 45° = {}^-14.1$

2.) $\vec{A} = 8.67\hat{i} + 5.0\hat{j}$ or $\vec{A} = (8.67, 5.0)$

$\vec{B} = -7.5\hat{i} + 13\hat{j}$, $\vec{B} = (-7.5, +13)$

$\vec{C} = (-14.1\hat{i} - 14.1\hat{j}$, $\vec{C} = (-14.1, -14.1)$

(NO z components)

3.) $\vec{D} = \vec{A} + \vec{B} + \vec{C}$

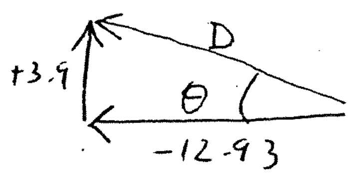
	X	Y
A	8.67	5
B	−7.5	13
C	−14.1	−14.1
D = Σ	−12.93	+3.9

$\vec{D} = -12.93\hat{i} + 3.9\hat{j}$

$\vec{D} = (-12.93, 3.9)$

$D = \sqrt{(-12.93)^2 + (3.9)^2} = 13.5$

$\theta = \tan^{-1}\left(\frac{3.9}{12.93}\right) = 16.87°$ N of west

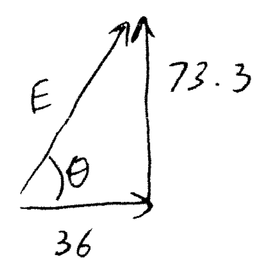


4.) $\vec{D} = -12.93\hat{i} + 3.9\hat{j}$

$D = (-12.93, 3.9)$

5) $\vec{E} = \vec{A} + 2\vec{B} - 3\vec{C}$

	X	Y
A	+8.67	+5
2B	−15	+26
−3C	+42.3	+42.3
E = Σ	+36	73.3



$E = \sqrt{36^2 + 73.3^2} = 81.6$

$\theta = \tan^{-1}\left(\frac{73.3}{36}\right) = 63.8°$ N of East

$\vec{E} = 36\hat{i} + 73.3\hat{j}$

$\vec{E} = (36, 73)$

Advanced Placement Physics B

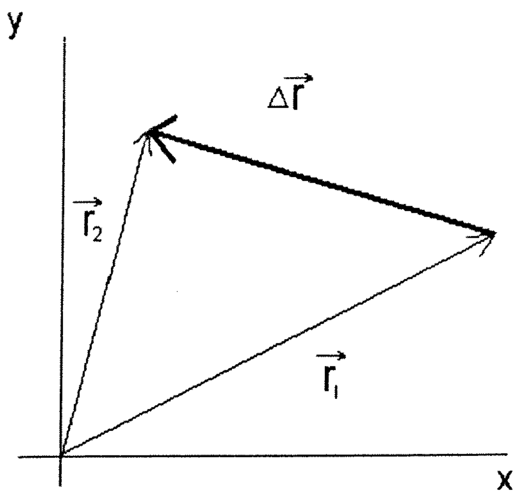
Mr. DiBucci

Motion in One Dimension

Notes on One Dimensional Motion

Displacement

The displacement vector points from an object's initial position toward its final position, and has a magnitude that equals the shortest distance between the two positions. The SI unit is the meter.



$$\vec{\Delta r} = \vec{r_2} - \vec{r_1}$$

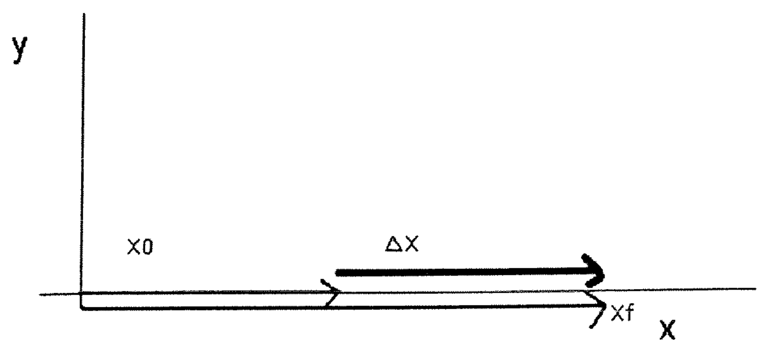
$$\vec{r_1} = (x_1, y_1)$$

$$\vec{r_2} = (x_2, y_2)$$

$$\vec{\Delta r} = (x_2 - x_1, y_2 - y_1)$$

$$= (\Delta x, \Delta y)$$

$$|\Delta \vec{r}| = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$



$$\Delta x = x_f - x_o$$

Speed and Velocity

Average speed

$$avg.speed = \frac{dis\tan ce}{time}$$

measured in meters/second

Average Velocity

$$velocity = \frac{Displacement}{Time}$$

$v = \frac{\Delta x}{\Delta t}$ in one dimension

Examples:

1. A circular track has a radius of 10.0 m. A person completes half a lap in 200 seconds.
   a. Calculate the distance, when the person has walked halfway around the track.(31.4)
   b. Calculate the magnitude of the displacement at the same point.(20.0)
   c. Calculate the average speed and the magnitude of the average velocity.(0.157m/s,0.1 m/s)

Instantaneous Speed and Velocity

The *instantaneous velocity* indicates the speed and direction of an object at any instant. Instantaneous speed is just the magnitude of the Instantaneous velocity.

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

Acceleration

Acceleration is a change in velocity over some time interval

$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ m/s/s or $\frac{m}{s^2}$

example:

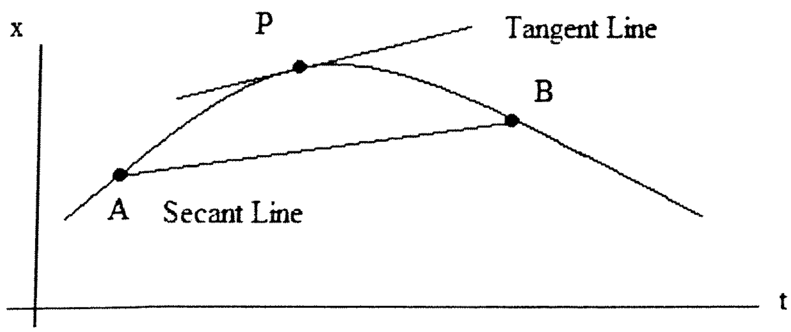
A plane accelerates down a runway. The plane starts from rest and must reach a speed of 260 km/hr in 29 seconds. Calculate the acceleration in km/hr/s and m/s/s.
(9 km/hr/s, 2.5 m/s/s)

Instantaneous Velocity and Speed
AP Physics B

Mr. DiBucci

We would like to be able to define the velocity of a particle at a particular instant of time , rather than just the average value over a finite interval of time. The velocity of any particle at any instant of time – in other words, at some point on a space time graph – is called the instantaneous velocity. The magnitude of the instantaneous velocity is the instantaneous speed, this is what you read on your speedometer at any instant.

We saw from our earlier discussion that the slope of the secant line, over some time interval, on a position versus time (x-t) graph was the average velocity; the instantaneous velocity can be geometrically interpreted as the slope of the tangent line at the point in question.



The diagram above represents the position time graph for a particular object. Lets say we want to know the instantaneous velocity at point P. We will begin by finding the slope of the secant line that passes between two points, A and B, that lie on either side of the point in question. If the points A and B are close enough to P, then we will have a good approximation of the instantaneous velocity at P. However, to get the exact value we will have to use a limiting process. We will keep moving points A and B closer to point P and recalculate, eventually points A and B will coincide with P and we will have calculated the slope of the tangent at P, the instantaneous velocity.

$$V = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

This process is tedious, and is usually done only using graphical techniques in a non calculus based course like this one.

There is one other trick that I would like to show you that works well with simple polynomial functions.

Example 1

The position of a particle moving along the x axis varies in time according to the expression $x = (3\frac{m}{s^2})t^2$, where x is in meters, and t is in seconds.

a) Find the formula for the instantaneous velocity at ant time
b) Using the equation from part a, calculate the instantaneous velocity at t = 3.0 sec.
c) Verify that this is the correct value by plotting the graph and calculating the slope of the tangent line at t = 3.0 sec. You can use your graphing calculators and built in tangent line features.

Answers:

a) $v = (6\frac{m}{s^2})t$

b) +18 m/s

c) same as b

Example 2

A ball is dropped from rest, at a reference point that is located at the origin of our coordinate system. The position of the ball as a function of time is:

$y = -5t^2$

a) Find the formula for the velocity as a function of time.
b) Calculate the instantaneous velocity of the particle after 4.0 seconds has elapsed
c) Verify your results using graphical means as in example 1

Answers:

a) $V_y = -10t$

b) - 40 m/s

c) same as b

Section 2.2 Speed and Velocity

1. **ssm** A whale swims due east for a distance of 6.9 km, turns around and goes due west for 1.8 km, and finally turns around again and heads 3.7 km due east. (a) What is the total distance traveled by the whale? (b) What are the magnitude and direction of the displacement of the whale?

2. One afternoon, a couple walks three-fourths of the way around a circular lake, the radius of which is 1.50 km. They start at the west side of the lake and head due south at the beginning of their walk. (a) What is the distance they travel? (b) What are the magnitude and direction (relative to due east) of the couple's displacement?

3. En route to a Hawaiian vacation, a traveler arrives late at the airport at 1:08 pm. His plane is scheduled to depart at 1:22 pm. To catch the flight, he must run 2.1 km to the gate. What must be his minimum average running speed (in m/s)?

4. Sound travels at a constant speed of 343 m/s in air. Approximately how much time (in seconds) does it take for the sound of thunder to travel 1609 m (one mile)?

5. **ssm** A plane is sitting on a runway, awaiting takeoff. On an adjacent parallel runway, another plane lands and passes the stationary plane at a speed of 45 m/s. The arriving plane has a length of 36 m. By looking out of a window (very narrow), a passenger on the stationary plane can see the moving plane. For how long a time is the moving plane visible?

6. The three-toed sloth is the slowest moving land mammal. On the ground, the sloth moves at an average speed of 0.037 m/s, considerably slower than the giant tortoise, which walks at 0.076 m/s. After 12 minutes of walking, how much further would the tortoise have gone relative to the sloth?

7. An 18-year-old runner can complete a 10.0-km course with an average speed of 4.38 m/s. A 50-year-old runner can cover the same distance with an average speed of 4.27 m/s. How much later should the younger runner start in order to finish the course *at the same time* as the older runner?

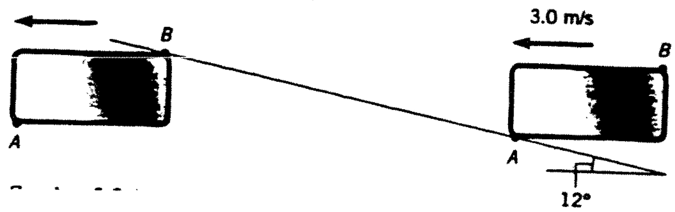
8. A tourist being chased by an angry bear is running in a straight line toward his car at a speed of 4.0 m/s. The car is a distance *d* away. The bear is 26 m behind the tourist and running at 6.0 m/s. The tourist reaches the car safely. What is the maximum possible value for *d*?

***9.** **ssm www** A woman and her dog are out for a morning run to the river, which is located 4.0 km away. The woman runs at 2.5 m/s in a straight line. The dog is unleashed and runs back and forth at 4.5 m/s between his owner and the river, until she reaches the river. What is the total distance run by the dog?

***10.** A sky diver, with parachute unopened, falls 625 m in 15.0 s. Then she opens her parachute and falls another 356 m in 142 s. What is her average velocity (both magnitude and direction) for the entire fall?

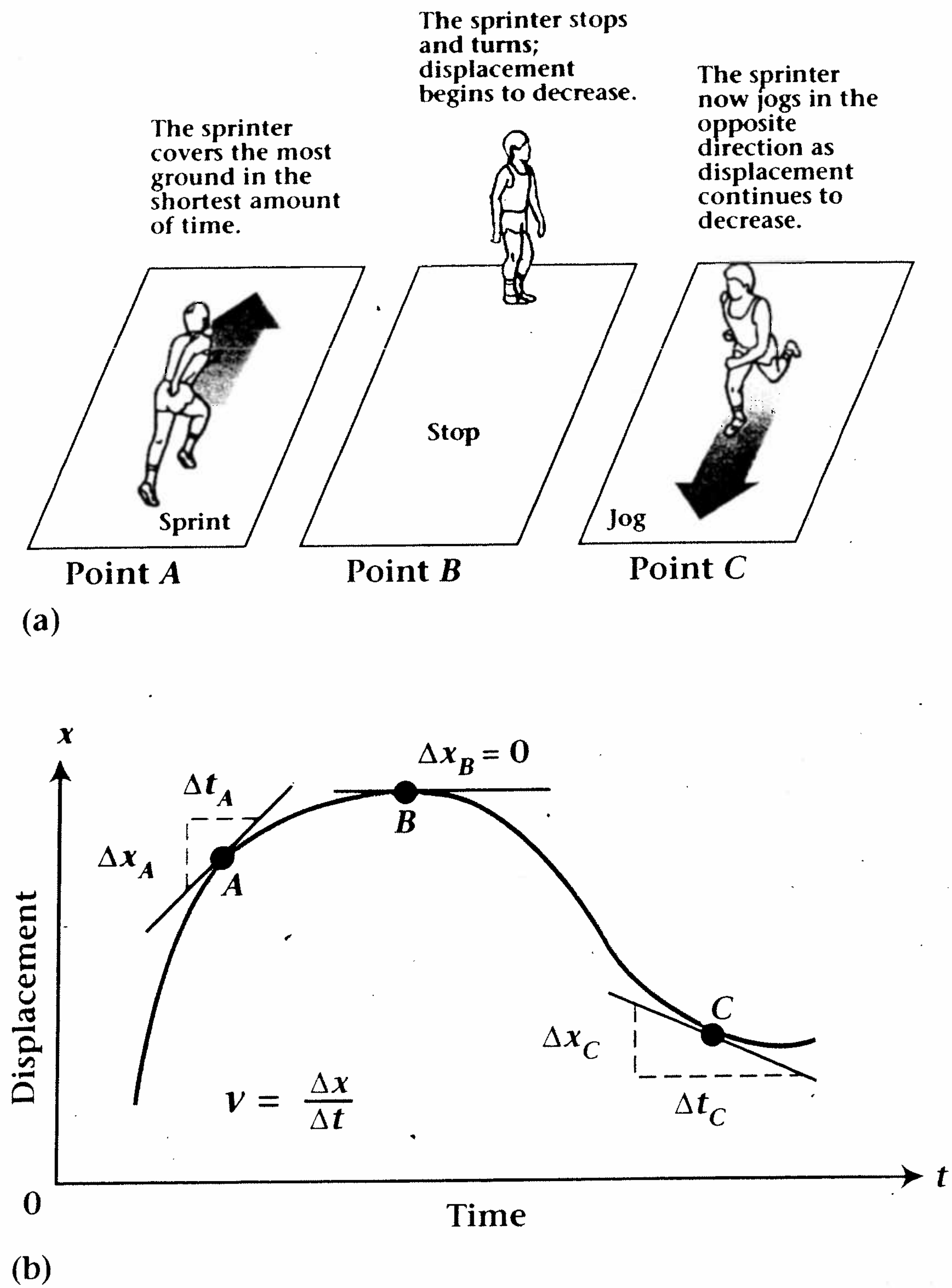
***11.** A car makes a 60.0-km trip with an average velocity of 40.0 km/h in a direction due north. The trip consists of three parts. The car moves with a constant velocity of 25 km/h due north for the first 15 km and 62 km/h due north for the next 32 km. With what constant velocity does the car travel for the last 13-km segment of the trip?

****12.** You are on a train that is traveling at 3.0 m/s along a level straight track. Very near and parallel to the track is a wall that slopes upward at a 12° angle with the horizontal. As you face the window (0.90 m high, 2.0 m wide) in your compartment, the train is moving to the left, as the drawing indicates. The top edge of the wall first appears at window corner A and eventually disappears at window corner B. How much time passes between appearance and disappearance of the upper edge of the wall?



1) 12.4km, 8.8 km east
2) 2.12km, 45° N of E
3) 2.5 m/s
4) 4.69s
5) 0.80 s
6) 28m
7) 60s
8) 52m
9) 7.2×10^3 m
10) 6.25 m/s Down
11) 34 km/hr
12) 2.12

6. Velocity is the slope of the displacement-time curve: changing velocity. (Fig. 2.9)



From Jones and Childers, *Contemporary College Physics.*

Graphical Analysis

Motion Graphs

AP Physics B DiBucci

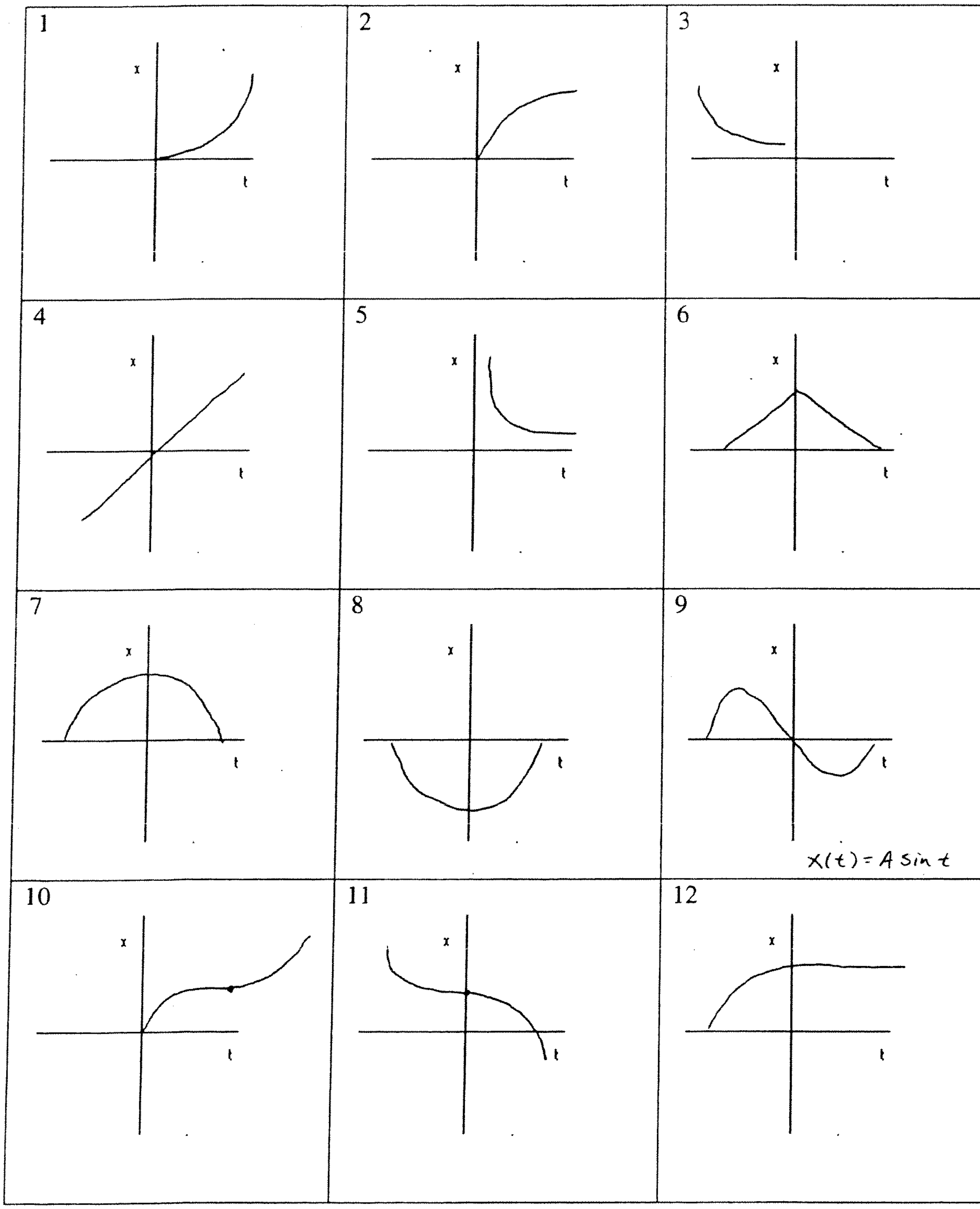
***Part 1*:**

For each of the following graphs state the direction of motion, if the object is speeding up or slowing down, and if there is positive or negative acceleration

***Part 2*:**

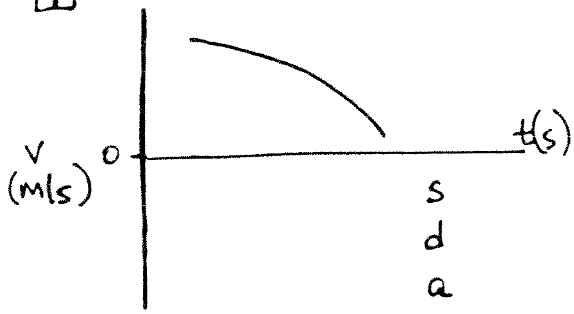
Sketch the corresponding v-t graph for each on a separate sheet of paper.

*All curves are parabolic except when noted otherwise

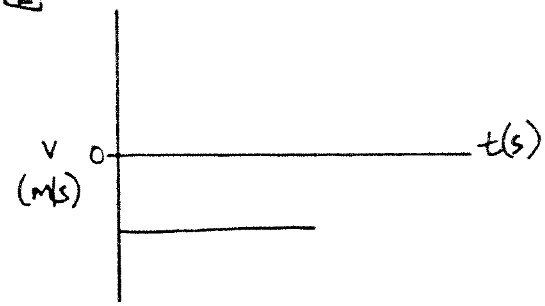


For each v-t graph, determine the direction of motion, changes in speed and acceleration, and whether the acceleration is positive, negative, or zero.

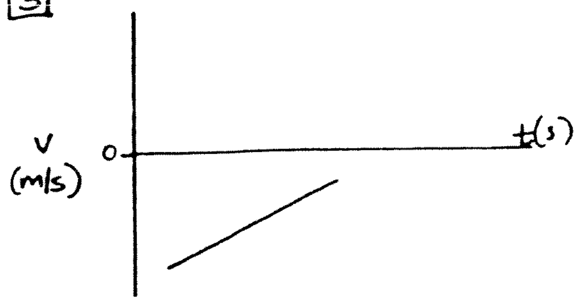
1



2



3



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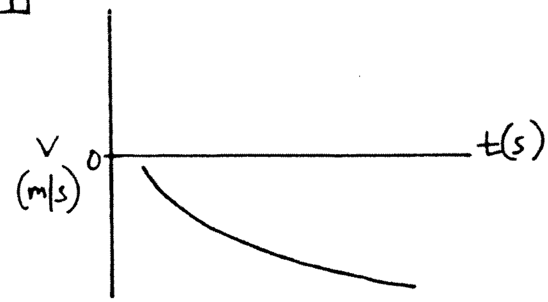

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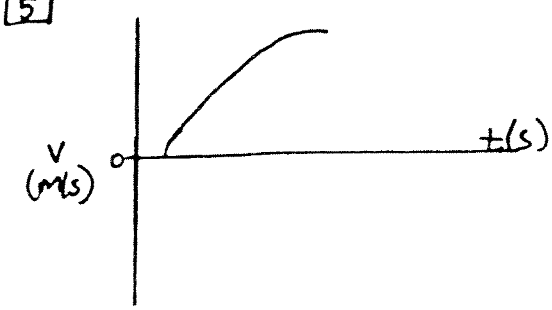

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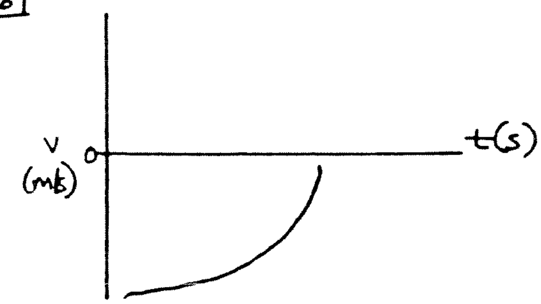

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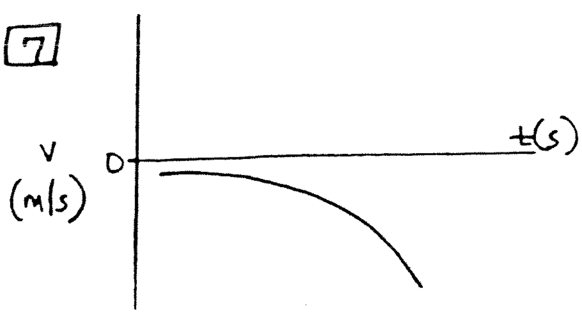

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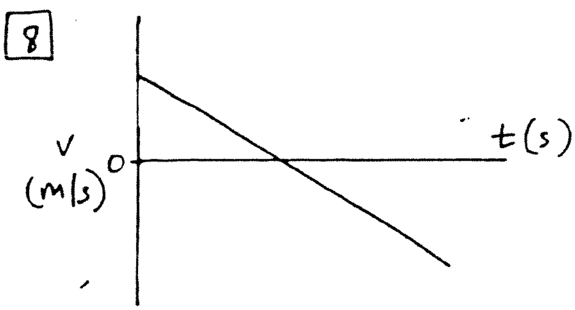
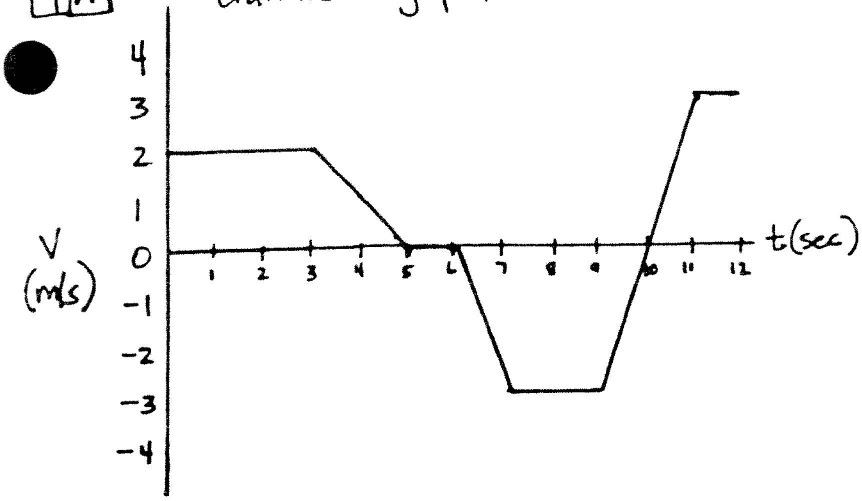
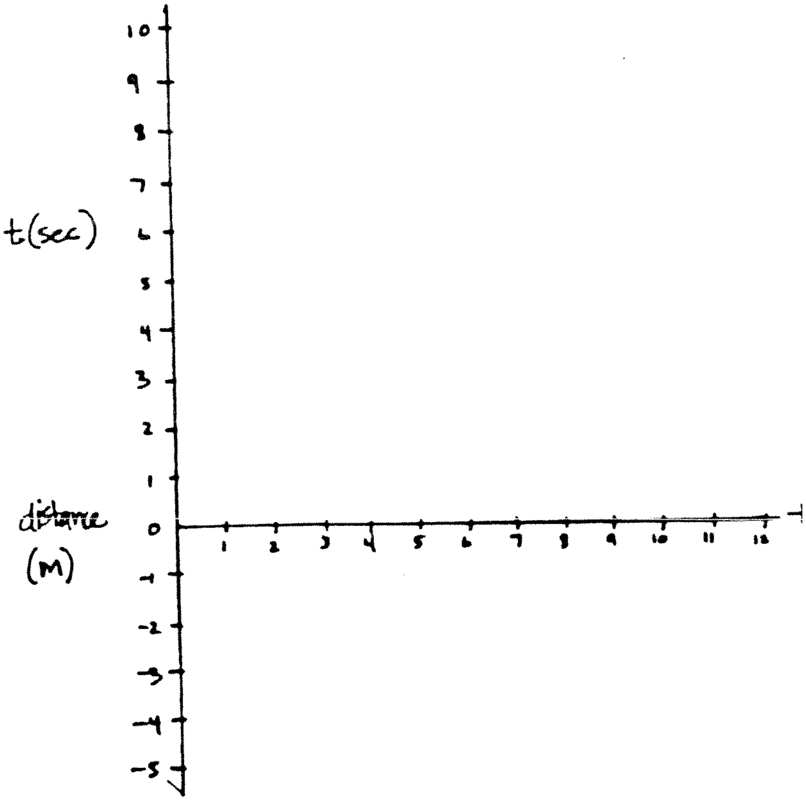


9 A

Draw the x-t graph for this car's motion.

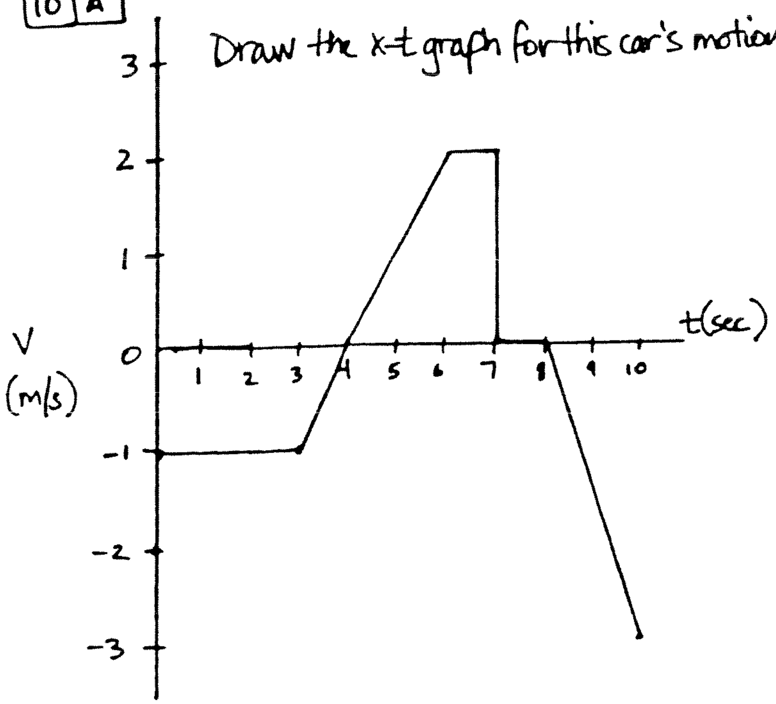


B

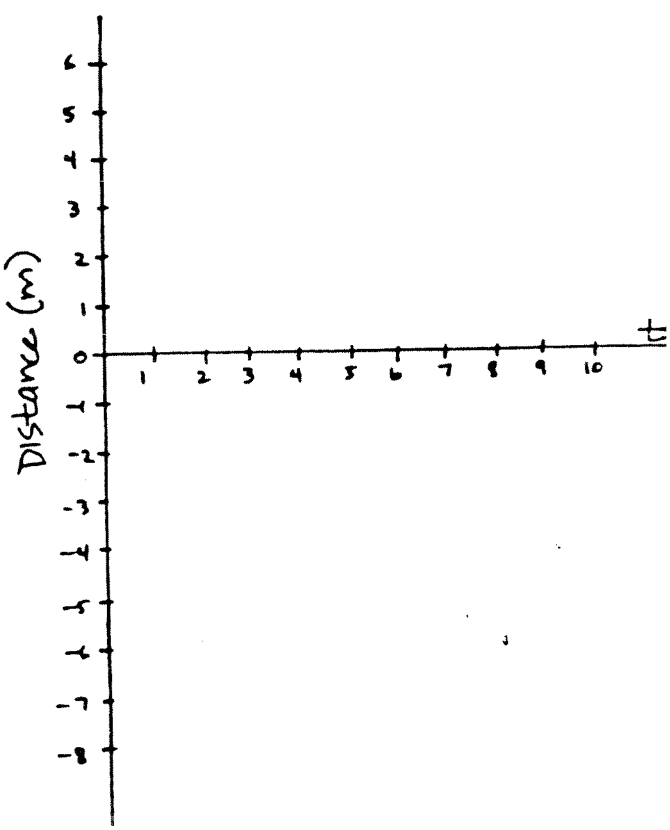


10 A

Draw the x-t graph for this car's motion.



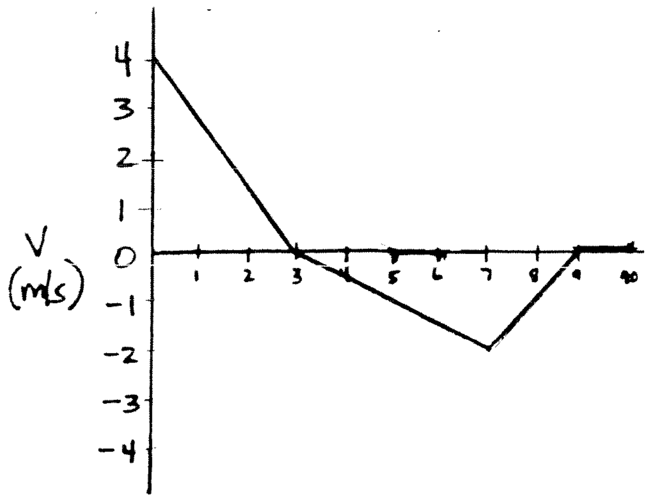
B

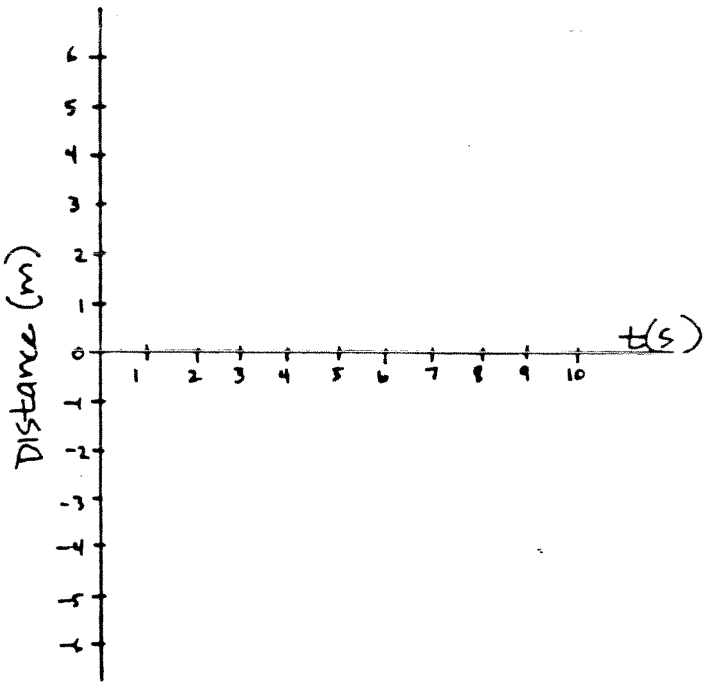


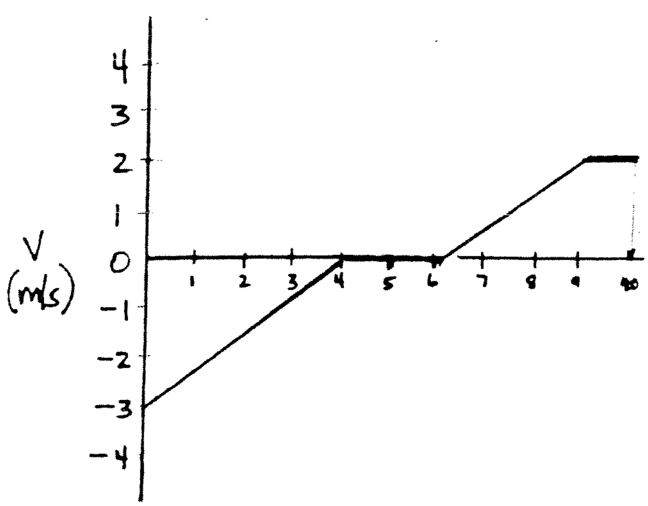
Name____ per. ___ date _____

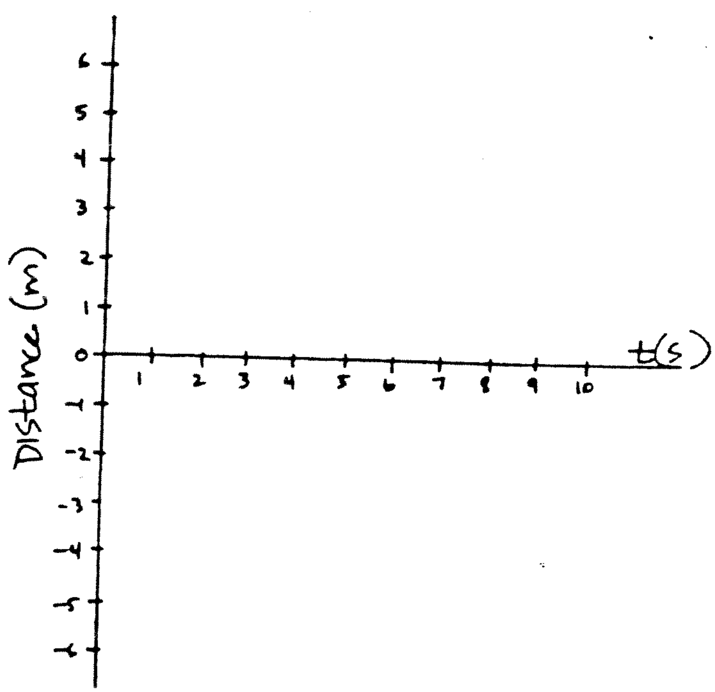
Velocity vs. Time Graphs - Worksheet 2 DiBucci

For each V-T graph, create the corresponding X-T graph.



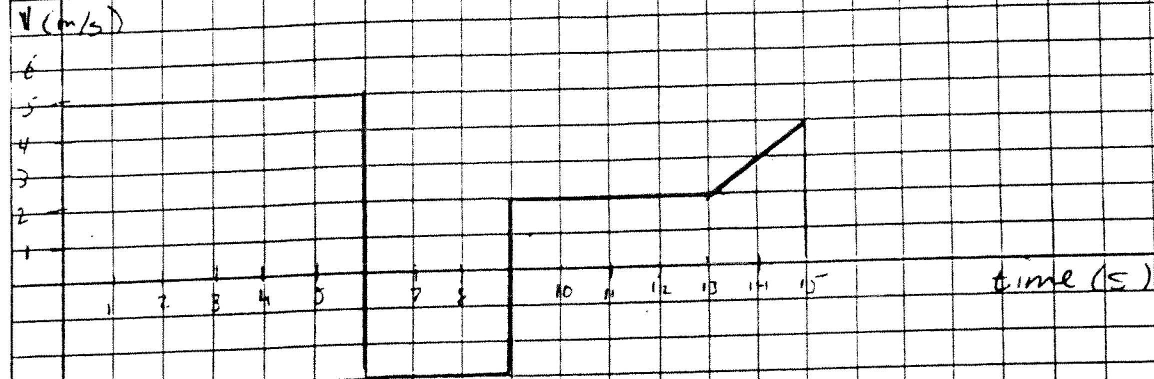






DIRECTIONS: [illegible]

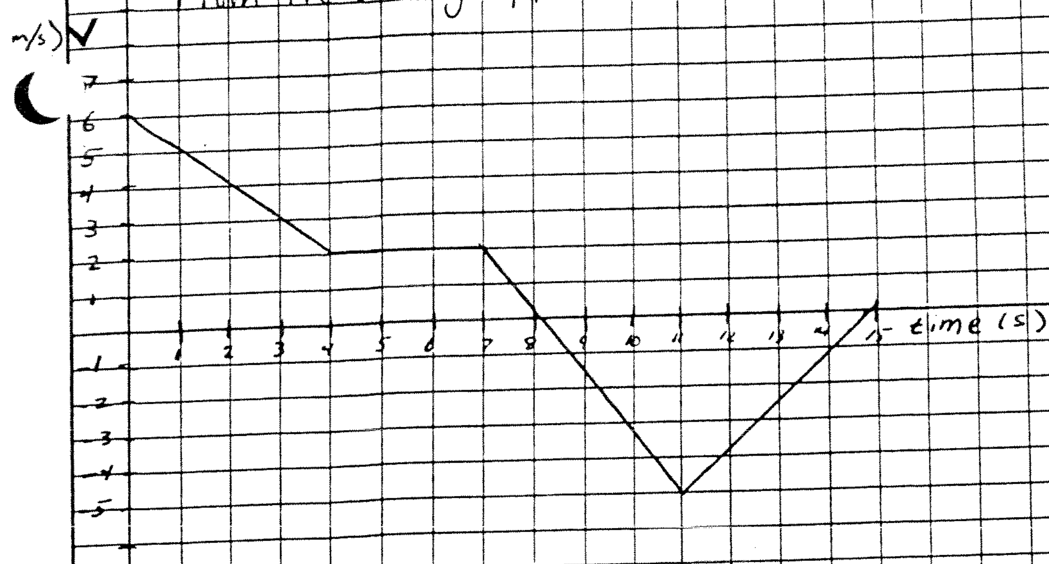
Construct an x-t and a-t graph.



DIRECTIONS:

AP Physics

CONSTRUCT AN acceleration-time graph From the v-t graph.



Name ______________________________________ per. ___ date _____

DiBucci

Graphical Analysis of Motion

Consider the diagram below

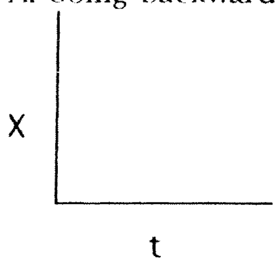
1. What is the instantaneous velocity at the 5, 15, 20, 30, 35, and 45 second marks?
2. Calculate the acceleration for the following time intervals: 0-10s, 10s-20s, 20s-25s, 25s-35s, 35s-45s, and 45s-50s.
3. Calculate the displacement for the same time intervals.
4. On a separate piece of graph paper construct a position vs. time graph for the same time intervals.

AP Physics B WORKSHEET

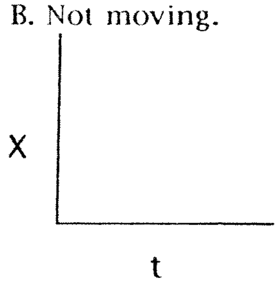
1. A particle goes from the 2 meter mark to the 8 meter mark *and back* in 3 seconds. Determine the average speed.

2. Create a graph for each of the follwoing situations without referring to your class notes.

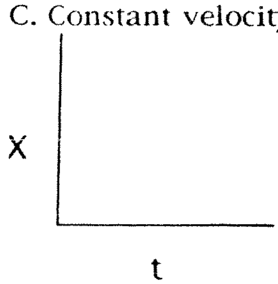
A. Going backward and slowing down.



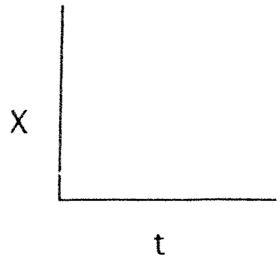
B. Not moving.



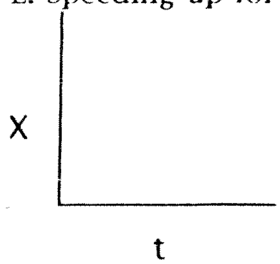
C. Constant velocity forward.



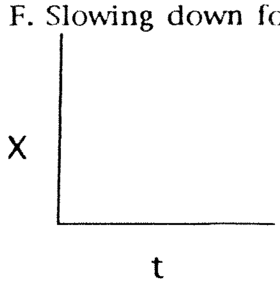
D. Constant velocity backward.



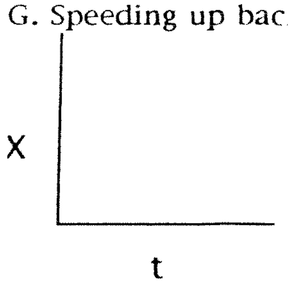
E. Speeding up forward.



F. Slowing down forward.



G. Speeding up backward.



3. A particle is travelling south with a speed of 10 m/s. 7.2 seconds later it is travelling north at 10 m/s. Calculate its average acceleration.

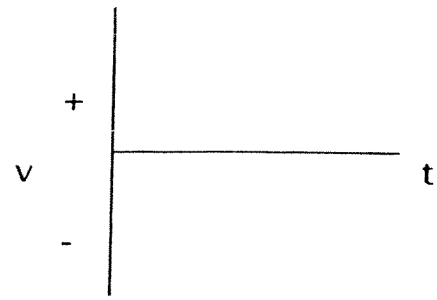
4. Without referring to your class notes create a graph for each situation.

a=acceleration
It is described in two ways:
1. positive (+), negative(-), or zero
2. increasing(↑), decreasing(↓), or constant(↔)

s=speed
It is described as increasing(↑), decreasing(↓) or constant(↔)

D=direction
It is described as forward (+), backward(-), or at rest

A.

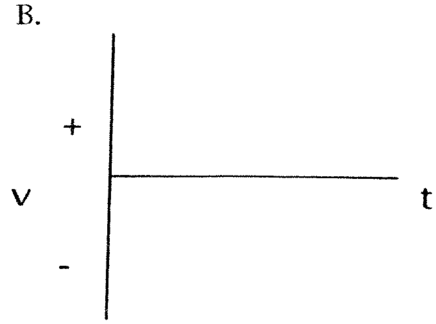


+ a ↓

s ↑

D +

B.

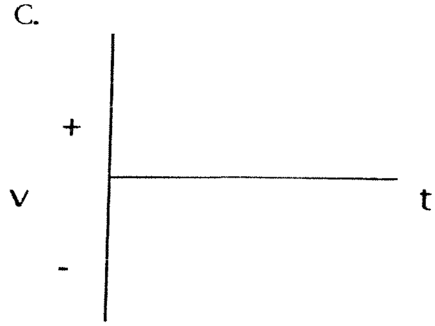


+ a ↔

s ↑

D +

C.

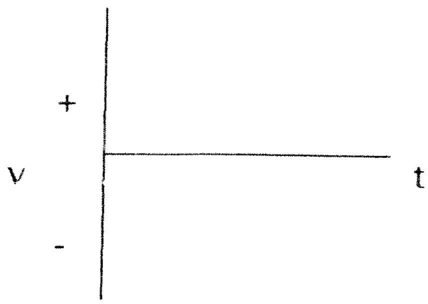


− a ↑

s ↓

D +

D.

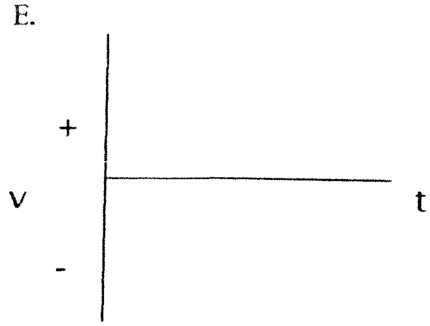


a = 0

s ↔

D +

E.

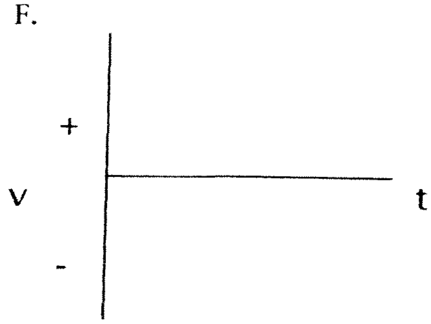


- a ↔

s ↓

D +

F.

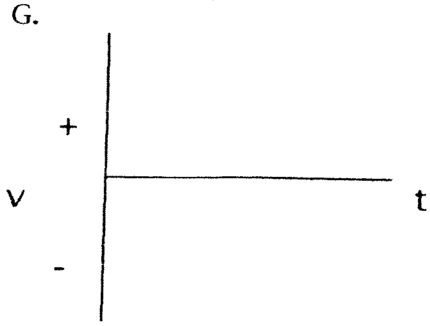


+ a ↑

s ↑

D +

G.

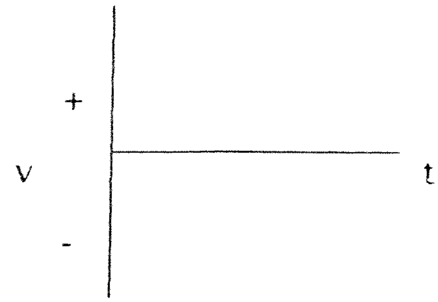


+ a ↓

s ↓

D −

H.

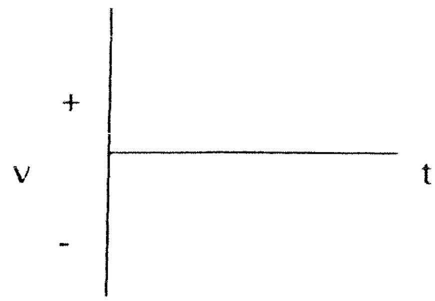


- a ↔

s ↑

D –

I.

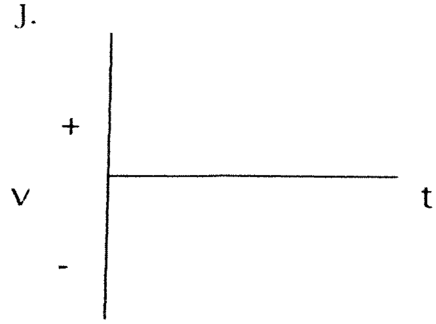


+ a ↓

s ↓

D -

J.



- a ↓

s ↑

D -

5. The motion of a particle is described by the following equations:

$$x=4t-t^2$$
$$v=-2t+4$$

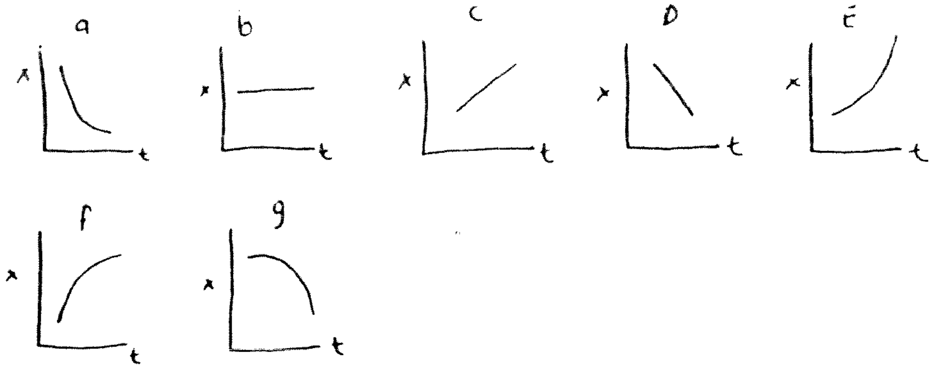
a. Make a position-time graph and a velocity-time graph for this particle. Analyze each graph by stating in words what is happening to the motion of the particle.

b. Determine the instantantaneous acceleration of the particle at 3.3 seconds.

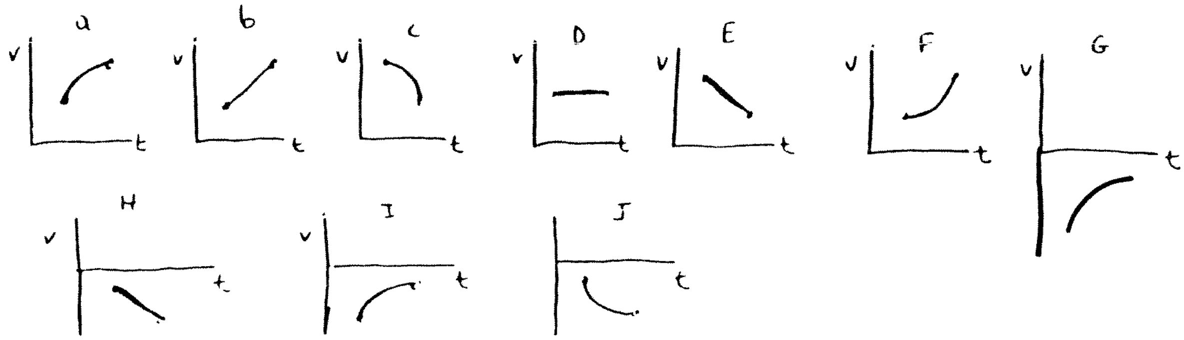
ANSWERS

1. $4 \, M/s$

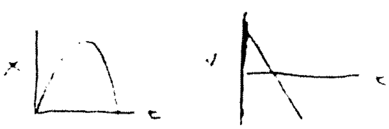
2.



3. $2.8 \, m/s^2$



5@



The position-time graph shows a particle that at first moves forward then slows down and turns around moving backward with increasing speed.

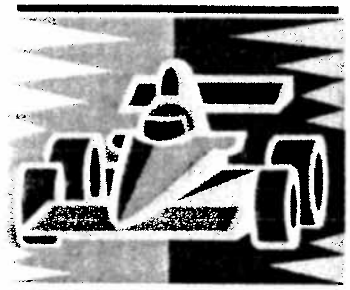
The v-t graph shows a constant negative acceleration

5b

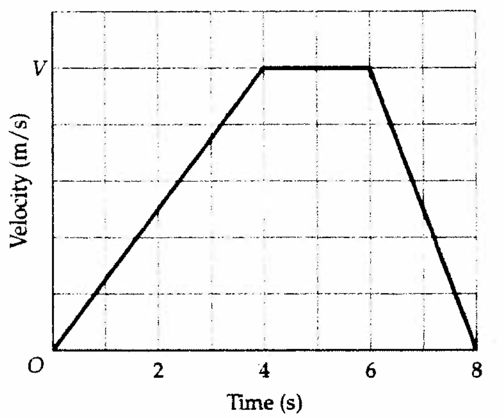
$-2 \, m/s^2$

Kinematics and Free Fall

Kinematics

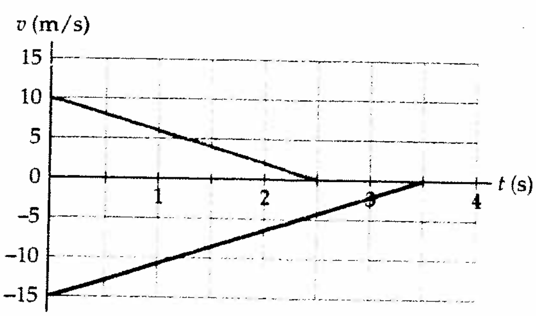


61. •• A car in stop-and-go traffic starts at rest, moves forward 13 m in 8.0 s, then comes to rest again. The velocity-versus-time plot for this car is given in **Figure 2–33**. What distance does the car cover in **(a)** the first 4.0 seconds of its motion and **(b)** the last 2.0 seconds of its motion? **(c)** What is the constant speed V that characterizes the middle portion of its motion?



▲ **FIGURE 2–33** Problem 61

62. ••• A car and a truck are heading directly toward one another on a straight and narrow street, but they avoid a head-on collision by simultaneously applying their brakes at $t = 0$. The resulting velocity versus time graphs are shown in **Figure 2–34**. What is the separation between the car and the truck when they have come to rest, given that at $t = 0$ the car is at $x = 15$ m and the truck is at $x = -35$ m. (Note that this information determines which line in the graph corresponds to which vehicle.)



▲ **FIGURE 2–34** Problem 62

63. ••• In a physics lab, students measure the time it takes a small cart to slide a distance of 1.00 m on a smooth track inclined at an angle θ above the horizontal. Their results are given in the following table.

θ	10.0°	20.0°	30.0°
time, s	1.08	0.770	0.640

(a) Find the magnitude of the cart's acceleration for each angle. **(b)** Show that your results for part (a) are in close agreement with the formula, $a = g \sin \theta$. (We will derive this formula in Chapter 5.)

61) 5.2m, 2.6m, 2.6 m/s
62) 11.3m

Section 2.4 Equations of Kinematics for Constant Acceleration, Section 2.5 Applications of the Equations of Kinematics

21. **ssm** A cheetah, the fastest of all land animals over a short distance, accelerates from rest to 26 m/s. Assuming that the acceleration is constant, find the average speed of the cheetah.

22. Review Conceptual Example 9 as background for this problem. A car is traveling to the left, which is the negative direction. The direction of travel remains the same throughout this problem. The car's initial speed is 27.0 m/s, and during a 5.0-s interval, it changes to a final speed of (a) 29.0 m/s and (b) 23.0 m/s. In each case, find the acceleration (magnitude and algebraic sign) and state whether or not the car is decelerating.

23. (a) What is the magnitude of the average acceleration of a skier who, starting from rest, reaches a speed of 8.0 m/s when going down a slope for 5.0 s? (b) How far does the skier travel in this time?

24. In getting ready to slam-dunk the ball, a basketball player starts from rest and sprints to a speed of 6.0 m/s in 1.5 s. Assuming that the player accelerates uniformly, determine the distance he runs.

25. **ssm** A jetliner, traveling northward, is landing with a speed of 69 m/s. Once the jet touches down, it has 750 m of runway in which to reduce its speed to 6.1 m/s. Compute the average acceleration (magnitude and direction) of the plane during landing.

26. A truck, traveling at a velocity of 33 m/s due east, comes to a halt by decelerating at 11 m/s^2. How far does the truck travel in the process of stopping?

27. A speed trap is set up with two pressure-activated strips placed across a highway, 110 m apart. A car is speeding along at 33 m/s, while the speed limit is 21 m/s. At the instant the car activates the first strip, the driver begins slowing down. What minimum deceleration is needed in order that the average speed is within the limit by the time the car crosses the second marker?

28. The length of the barrel of a primitive blowgun is 1.2 m. Upon leaving the barrel, a dart has a speed of 14 m/s. Assuming that the dart is uniformly accelerated, how long does it take for the dart to travel the length of the barrel?

29. **ssm www** A speed ramp at an airport is basically a large conveyor belt on which you can stand and be moved along. The belt of one speed ramp moves at a constant speed such that a person who stands still on it leaves the ramp 64 s after getting on. Clifford is in a real hurry, however, and skips the speed ramp. Starting from rest with an acceleration of 0.37 m/s^2, he covers the same distance as the ramp does, but in one-fourth the time. What is the speed at which the belt of the ramp is moving?

***30.** A drag racer, starting from rest, speeds up for 402 m with an acceleration of $+17.0\ m/s^2$. A parachute then opens, slowing the car down with an acceleration of $-6.10\ m/s^2$. How fast is the racer moving 3.50×10^2 m after the parachute opens?

***31.** Suppose a car is traveling at 12.0 m/s, and the driver sees a traffic light turn red. After 0.510 s has elapsed (the reaction time), the driver applies the brakes, and the car decelerates at 6.20 m/s^2. What is the stopping distance of the car, as measured from the point where the driver first notices the red light?

***32.** A speedboat starts from rest and accelerates at $+2.01\ m/s^2$ for 7.00 s. At the end of this time, the boat continues for an additional 6.00 s with an acceleration of $+0.518\ m/s^2$. Following this, the boat accelerates at $-1.49\ m/s^2$ for 8.00 s. (a) What is the velocity of the boat at $t = 21.0$ s? (b) Find the total displacement of the boat.

***33.** **ssm** An object starts from rest at the origin and accelerates in the direction of the $+x$ axis for a time t. The acceleration is constant. The object continues to move with the same acceleration for an additional time of one second. The distance traveled during the time t is one-half of that traveled during the one-second interval. Find the time t.

***34.** A cab driver picks up a customer and delivers her 2.00 km away, driving a straight route. The driver accelerates to the speed limit and, upon reaching it, begins to decelerate immediately. The magnitude of the deceleration is three times the magnitude of the acceleration. Find the lengths of the acceleration and deceleration phases of the trip.

***35.** A car is traveling at a constant speed of 27 m/s on a highway. At the instant this car passes an entrance ramp, a second car enters the highway from the ramp. The second car starts from rest and has a constant acceleration. What acceleration must it maintain, so that the two cars meet for the first time at the next exit, which is 1.8 km away?

***36.** Two soccer players start from rest, 48 m apart. They run directly toward each other, both players accelerating. The first player has an acceleration whose magnitude is 0.50 m/s^2. The second player's acceleration has a magnitude of 0.30 m/s^2. (a) How much time passes before they collide? (b) At the instant they collide, how far has the first player run?

****37.** **ssm** A locomotive is accelerating at 1.6 m/s^2. It passes through a 20.0-m-wide crossing in a time of 2.4 s. After the locomotive leaves the crossing, how much time is required until its speed reaches 32 m/s?

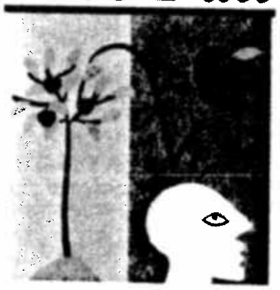
****38.** A Boeing 747 "Jumbo Jet" has a length of 59.7 m. The runway on which the plane lands intersects another runway. The width of the intersection is 25.0 m. The plane decelerates through the intersection at a rate of 5.70 m/s^2 and clears it with a final speed of 45.0 m/s. How much time is needed for the plane to clear the intersection?

****39.** In the one-hundred-meter dash a sprinter accelerates from rest to a top speed with an acceleration whose magnitude is 2.68 m/s^2. After achieving top speed, he runs the remainder of the race without speeding up or slowing down. If the total race is run in 12.0 s, how far does he run during the acceleration phase?

21) 13 m/s
22) -0.40 m/s², 0.80 m/s²
23) 1.6 m/s², 20 m
24) 4.5 m
25) -3.1 m/s²
26) 50 m
27) -4.6 m/s²
28) 0.17 s
29) 0.74 m/s
30) 96.9 m/s
31) 17.7 m

32) 5.26 m/s, 2.33 m
33) 1.37 s
34) 1.5 km, 0.5 km
35) 0.81 m/s², same dire as velocity
36) 11 s, 30 m
37) 14 s
38) 1.7 s
39) 18 m

Free Fall



65. • The cartoon below shows a car in free fall. Is the statement made in the cartoon accurate? Justify your answer.

"IT GOES FROM ZERO TO SIXTY IN ABOUT THREE SECONDS."

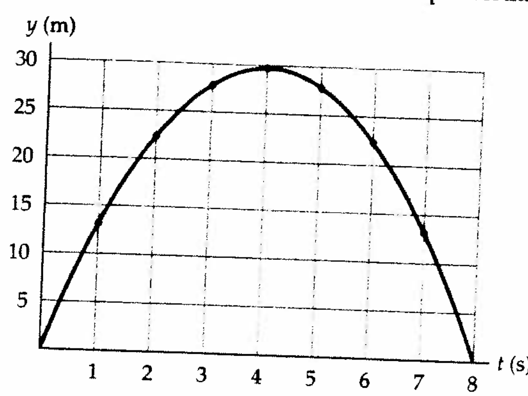
70. • **An Extraterrestrial Volcano** The first active volcano observed outside the Earth was discovered in 1979 on Io, one of the moons of Jupiter. The volcano was observed to be ejecting material to a height of about 2.00×10^5 m. Given that the acceleration of gravity on Io is $1.80\ m/s^2$, find the initial velocity of the ejected material.

65) The statement is Accurate
70) 849 m/s
71) 0.10 sec
90) 3.8 m/s², 15 m/s

71. • **BIO Measure Your Reaction Time** Here's something you *can* try at home—an experiment to measure your reaction time. Have a friend hold a ruler by one end, letting the other end hang down vertically. At the lower end, hold your thumb and index finger on either side of the ruler, ready to grip it. Have your friend release the ruler without warning. Catch it as quickly as you can. If you catch the ruler 5.2 cm (~2 inches) from the lower end, what is your reaction time?

How fast are your reactions? (Problem 71)

90. •• Astronauts on a distant planet throw a rock straight upward and record its motion with a video camera. After digitizing their video, they are able to produce the graph of height, y, versus time, t, shown in **Figure 2–36. (a)** What is the acceleration of gravity on this planet? **(b)** What was the initial speed of the rock?



▲ **FIGURE 2–36** Problem 90

DIBUCCI

Galileo's specific contribution to our understanding of the motion of falling objects can be summarized as follows:

Galileo's hypothesis: free fall is at constant acceleration g

at a given location on the Earth and in the absence of air resistance, all objects fall with the same constant acceleration.

We call this acceleration the **acceleration due to gravity** on the Earth, and we give it the symbol g. Its magnitude is approximately

$$g = 9.80\ \mathrm{m/s^2}.$$

In British units g is about $32\ \mathrm{ft/s^2}$. Actually, g varies slightly according to latitude and elevation (see Table 2–1), but these variations are so small that we will ignore them for most purposes. The effects of air resistance are often small, and we will neglect them for the most part. However, air resistance will be noticeable even on a reasonably heavy object if the velocity becomes large.†

When dealing with freely falling objects we can make use of Eqs. 2–10, where for a we use the value of g given above. Also, since the motion is vertical we will substitute y in place of x, and y_0 in place of x_0. We take $y_0 = 0$ unless otherwise specified. *It is arbitrary whether we choose y to be positive in the upward direction or in the downward direction; but we must be consistent about it throughout a problem's solution.*

TABLE 2–1
Acceleration Due to Gravity at Various Locations on Earth

Location	Elevation (m)	g ($\mathrm{m/s^2}$)
New York	0	9.803
San Francisco	100	9.800
Denver	1650	9.796
Pikes Peak	4300	9.789
Equator	0	9.780
North Pole (calculated)	0	9.832

EXAMPLE 2–11 **Falling from a tower.** Suppose that a ball is dropped from a tower 70.0 m high. How far will it have fallen after 1.00 s, 2.00 s, and 3.00 s? Assume y is positive downward. Neglect air resistance.

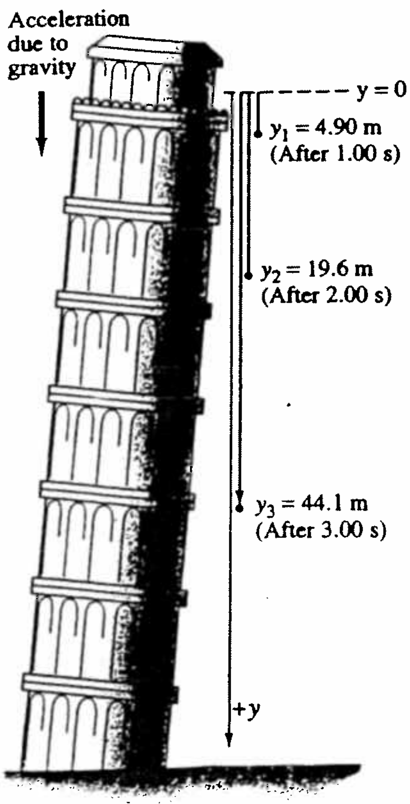


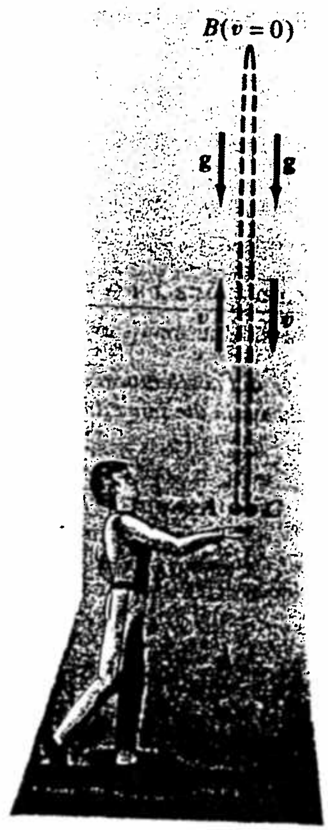
FIGURE 2–19 Example 2–11. When an object is dropped from a tower, it falls with progressively greater speed and covers greater distance with each successive second. (See also Fig. 2–16.)

EXAMPLE 2–12 **Thrown down from a tower.** Suppose the ball in Example 2–11 is *thrown* downward with an initial velocity of 3.00 m/s, instead of being dropped. (*a*) What then would be its position after 1.00 s and 2.00 s? (*b*) What would its speed be after 1.00 s and 2.00 s? Compare to the speeds of a dropped ball.

†The speed of an object falling in air (or other fluid) does not increase indefinitely. If the object falls far enough, it will reach a maximum velocity called the **terminal velocity**. Acceleration due to gravity is a vector (as is any acceleration), and its direction is downward, toward the center of the Earth.

EXAMPLE 2–13 **Ball thrown upward.** A person throws a ball *upward* into the air with an initial velocity of 15.0 m/s. Calculate (*a*) how high it goes, and (*b*) how long the ball is in the air before it comes back to his hand. We are not concerned here with the throwing action, but only with the motion of the ball *after* it leaves the thrower's hand (Fig. 2–20).

FIGURE 2–20 An object thrown into the air leaves the thrower's hand at A, reaches its maximum height at B, and returns to the original height at C. Examples 2–13, 2–14, and 2–15.



CONCEPTUAL EXAMPLE 2–14 **Two common misconceptions.** Explain the error in these two common misconceptions: (1) that acceleration and velocity are always in the same direction, and (2) that an object thrown upward has zero acceleration at the highest point (B in Fig. 2–21).

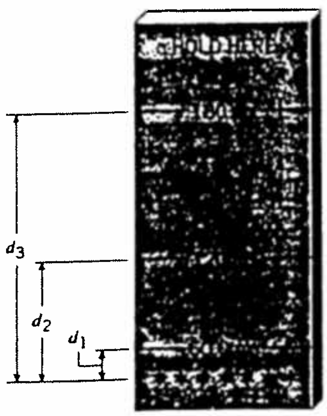
EXAMPLE 2–15 **Ball thrown upward, II.** Let us consider again the ball thrown upward of Example 2–13, and make three more calculations. Calculate (*a*) how much time it takes for the ball to reach the maximum height (point B in Fig. 2–21), (*b*) the velocity of the ball when it returns to the thrower's hand (point C), and (*c*) at what time t the ball passes a point 8.00 m above the person's hand.

Section 2.6 Freely Falling Bodies

40. In preparation for this problem, review Conceptual Example 9. From the top of a cliff, a person uses a slingshot to fire a pebble straight downward, which is the negative direction. The initial speed of the pebble is 9.0 m/s. (a) What is the acceleration (magnitude and direction) of the pebble during the downward motion? Is the pebble decelerating? Explain. (b) After 0.50 s, how far beneath the cliff-top is the pebble?

41. **ssm** The greatest height reported for a jump into an airbag is 99.4 m by stunt-man Dan Koko. In 1984 he jumped from rest from the top of the Vegas World Hotel and Casino. He struck the airbag at a speed of 39 m/s (88 mi/h). To assess the effects of air resistance, determine how fast he would have been traveling on impact had air resistance been absent.

42. The drawing shows a device that you can make with a piece of cardboard, which can be used to measure a person's reaction time. Hold the card at the top and suddenly drop it. Ask a friend to try to catch the card between his or her thumb and index finger. Initially, your friend's fingers must be level with the asterisks at the bottom. By noting where your friend catches the card, you can determine his or her reaction time in milliseconds (ms). Calculate the distances d_1, d_2, and d_3.



43. An arrow is fired from ground level straight upward with an initial speed of 15 m/s. How long is the arrow in the air before it strikes the ground?

44. A golf ball rebounds from the floor and travels straight upward with a speed of 5.0 m/s. To what maximum height does the ball rise?

45. **ssm** From her bedroom window a girl drops a water-filled balloon to the ground, 6.0 m below. If the balloon is released from rest, how long is it in the air?

46. Suppose a ball is thrown vertically upward. Eight seconds later it returns to its point of release. What is the initial velocity of the ball?

47. A diver springs upward with an initial speed of 1.8 m/s from a 3.0-m board. (a) Find the velocity with which he strikes the water. *[Hint: When the diver reaches the water, his displacement is $y = -3.0$ m (measured from the board), assuming that the downward direction is chosen as the negative direction.]* (b) What is the highest point he reaches above the water?

48. Review Conceptual Example 18 before attempting this problem. Two identical pellet guns are fired simultaneously from the edge of a cliff. These guns impart an initial speed of 30.0 m/s to each pellet. Gun *A* is fired straight upward, with the pellet going up and then falling back down, eventually hitting the ground beneath the cliff. Gun *B* is fired straight downward. In the absence of air resistance, how long after pellet *B* hits the ground does pellet *A* hit the ground?

49. **ssm** A wrecking ball is hanging at rest from a crane when suddenly the cable breaks. The time it takes for the ball to fall halfway to the ground is 1.2 s. Find the time it takes for the ball to fall from rest all the way to the ground.

50. Before working this problem, review Conceptual Example 18. A pellet gun is fired straight downward from the edge of a cliff that is 15 m above the ground. The pellet strikes the ground with a speed of 27 m/s. How far above the cliff edge would the pellet have gone had the gun been fired straight upward?

51. A ball is thrown straight upward and rises to a maximum height of 16 m above its launch point. At what height above its launch point has the speed of the ball decreased to one-half of its initial value?

***52.** Two students, Anne and Joan, are bouncing straight up and down on a trampoline. Anne bounces twice as high as Joan. Assuming both are in free-fall, find the ratio of the time Anne spends between bounces to the time Joan spends.

***53.** **ssm** A cement block accidentally falls from rest from the ledge of a 53.0-m-high building. When the block is 14.0 m above the ground, a man, 2.00 m tall, looks up and notices that the block is directly above him. How much time, at most, does the man have to get out of the way?

***54.** Two arrows are shot vertically upward. The second arrow is shot after the first one, but while the first is still on its way up. The initial speeds are such that both arrows reach their maximum heights at the same instant, although these heights are different. Suppose that the initial speed of the first arrow is 25.0 m/s and that the second arrow is fired 1.20 s after the first. Determine the initial speed of the second arrow.

***55.** A woman on a bridge 90.0 m high sees a raft floating at a constant speed on the river below. She drops a stone from rest in an attempt to hit the raft. The stone is released when the raft has 6.00 m more to travel before passing under the bridge. The stone hits the water 2.00 m in front of the raft. Find the speed of the raft.

***56.** (a) Just for fun, a person jumps from rest from the top of a tall cliff overlooking a lake. In falling through a distance *H*, she acquires a certain speed *v*. Assuming free-fall conditions, how much farther must she fall in order to acquire a speed of 2*v*? Express your answer in terms of *H*. (b) Would the answer to part (a) be different, if this event were to occur on another planet where the acceleration due to gravity had a value other than 9.80 m/s^2? Explain.

***57.** **ssm** **www** A spelunker (cave explorer) drops a stone from rest into a hole. The speed of sound is 343 m/s in air, and the sound of the stone striking the bottom is heard 1.50 s after the stone is dropped. How deep is the hole?

40) $-9.80 m/s^2$
41) 44.1 m/s
42) 0.018 m, 0.071 m, 0.16 m
43) 3.1 s
44) 1.3 m
45) 1.1 s
46) 3.9 m/s up
47) −7.9 m/s
48) 6.12 s
49) 1.7 s
50) 22 m
51) 12 m
52) $\sqrt{2}$
53) 0.4 s
54) 13.2 m/s
55) 0.932 m/s

FREE FALL PROBLEMS

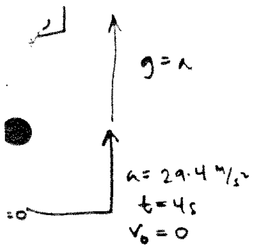
1. A juggler performs in a room with a ceiling 2 m above hand level.
a. What is the maximum upward speed she can give a ball without letting the ball hit the ceiling?
b. How long is the ball in the air before it is caught?

2. A stone is thrown from the top of a building with an initial velocity of 20 m/s straigh upward. The building is 50 m high, and the stone just misses the edge of the roof on its way down. Determine
a. the time needed for the stone to reach its maximum height
b. the maximum height
c the time needed for the stone to return to the level of the thrower
d. the velocity of the stone at this instant, and
e. the velocity and position of the stone at t=5 s.
f. the total time of flight

3. A foul ball is hit into the stands at a baseball game. The ball rises to a height ot 40 m and is caught by a fan at a height of 30 m as it drops back toward the field. What is its velocity in the vertical direction just before it is caught? CAlculate the time in the AIR.

4. A parachutist descending at a speed of 10 m/s drops a camera from an altitude of 50 m.
a. How long does it take the camera to reach the ground?
b. What is the velocity of the camera just before it hits the ground?

5. A rocket moves upward starting from rest with an acceleration of 29.4 m/s^2 for 4 seconds. It runs out of fuel at the end of this 4 s, and continues to me upward, acted upon only by gravity. How high does it rise?



Part I.

$y - y_0 = v_0 t + \frac{1}{2} g t^2$

$= 0 + \frac{1}{2}(29.4\,m/s^2)(4s)^2$

$Y_I = 235.2\,m$

$v_f = 0 + (29.4\,m/s^2)(4s)$

$= 117.6\,m/s$

Part II.

$v_0 = v_{fI} = 117.6\,m/s$

$a = g$

$v_f = 0$

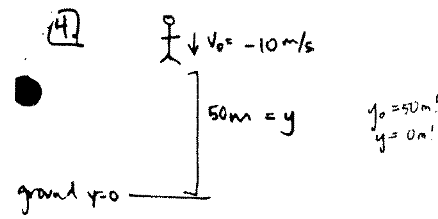
$v_f^2 = v_0^2 + 2g(y - y_0)$

$0 = (117.6\,m/s)^2 + 2(-9.8\,m/s^2)(y - y_0)$

$705.6\,m = y$

Total $y = 940.8\,m$

4.



a. $y - y_0 = v_0 t + \frac{1}{2} g t^2$

$v_f^2 = v_0^2 + 2g(y - y_0)$

$= (-10\,m/s)^2 + 2(-9.8\,m/s^2)\overset{(0-50m)}{(-50\,m)}$

$v_f = 32.9\,m/s$

$v_f = v_0 + gt$

$-32.9\,m/s = -10\,m/s + (-9.8\,m/s^2)\,t$

$2.33s = t$

Free Fall Problems

1.A

$a = g$
$y = 2m$
$y_0 = 0$
$V_0 = ?$
$V_f = 0$

$y - y_0 = V_0 t + \frac{1}{2} g t^2$

$V_f = V_0 + g t$

$V_f^2 = V_0^2 + 2g(y - y_0)$

$0 = V_0^2 + 2(-9.8 m/s^2)(2m)$

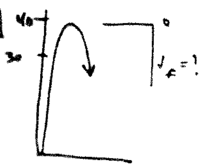
$6.3 m/s = V_0$

B. $V_f = V_0 + g t$

$-6.3 m/s = 6.3 m/s + (-9.8 m/s^2) t$

$1.3 sec = t$

3



$y_0 = 0$
$y = -10 m$
$a = g$
$V_0 = 0$
$V_f = ?$

a) $V_f^2 = V_0^2 + 2g(y - y_0)$

$\sqrt{V_f^2} = \pm\sqrt{0 + 2(-9.8 m/s^2)[0 - (-10m)]}$

$V_f = -14 m/s$

a) $\Delta Y_{MAX} = 40m$

$V_f^2 = V_0^2 - 2(g)(+40)$

$V_0 = \sqrt{\ldots} = 28 m/s$

$V_f = \pm\sqrt{V_0^2 + 2(-9.8)(30)} = -14 m/s$

c) time

$\Delta y = V_{0y} t - 4.9 t^2$

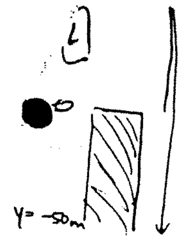
$+30 = 28t - 4.9t^2$

$4.9t^2 - 28t + 30 = 0$

$t = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$

$t = \begin{cases} 1.29 sec \\ 4.43 sec \end{cases}$

2



$V_0 = 20 m/s$
$a = g$

a. time for Max Ht $V_f = 0$

$V_f = V_0 + g t$

$0 = 20 m/s + (-9.8 m/s^2) t$

$2.04 s = t$

b. Max Ht?

$y - y_0 = V_0 t + \frac{1}{2} g t^2$

$= (20 m/s)(2.04 s) + \frac{1}{2}(-9.8 m/s^2)(2.04 s)^2$

$y = 20.4 m$

c. $t = 2(2.04 s) = 4.08 s$

d. $V = -20 m/s$

e. $t = 5?$

$V_f = V_0 + g t$

$= 20 m/s + (-9.8 m/s^2)(5s)$

$V_f = -29 m/s$

$y - y_0 = V_0 t + \frac{1}{2} g t^2$

$y = (20 m/s)(5s) + \frac{1}{2}(-9.8 m/s^2)(5s)^2$

$y = -22.5 m$

* f. $\Delta y = V_{0y} t - 4.9 t^2$

$-50 = 20t - 4.9t^2$

$4.9t^2 - 20t - 50 = 0$

$t = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$

$t = \begin{cases} -1.75 sec \\ 5.83 sec \end{cases}$

2. A stone is thrown vertically upward at 21.0 m/s. From this information calculate the following:
(g=9.8m/s/s)

a) the time to reach its maximum height

b) the speed and the acceleration at its maximum height

c) The maximum height of the stone.

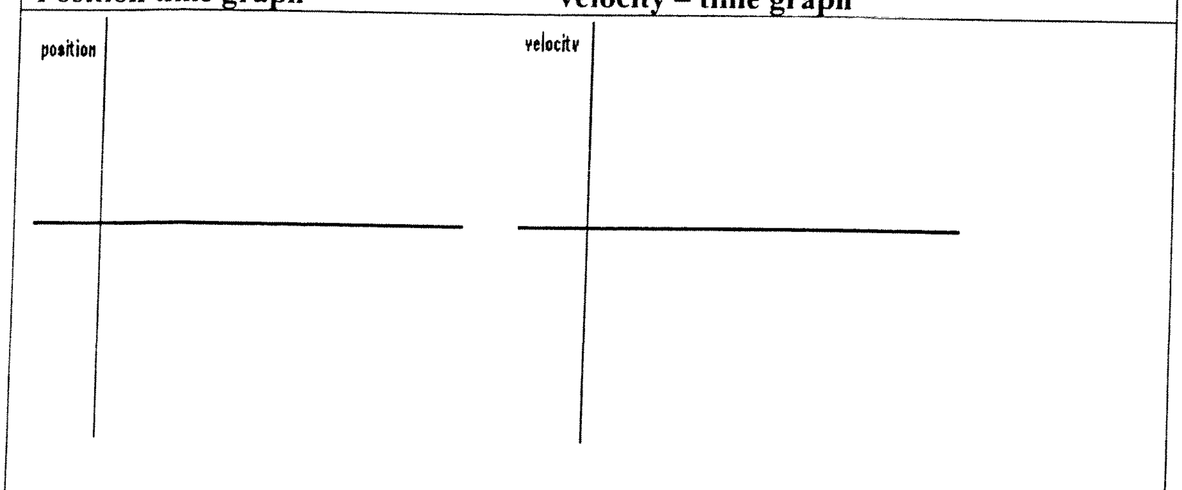
d) time it takes to reach 10 meters above its starting point (there will be two answers)

e) the speed of the stone the instant before it hits the ground

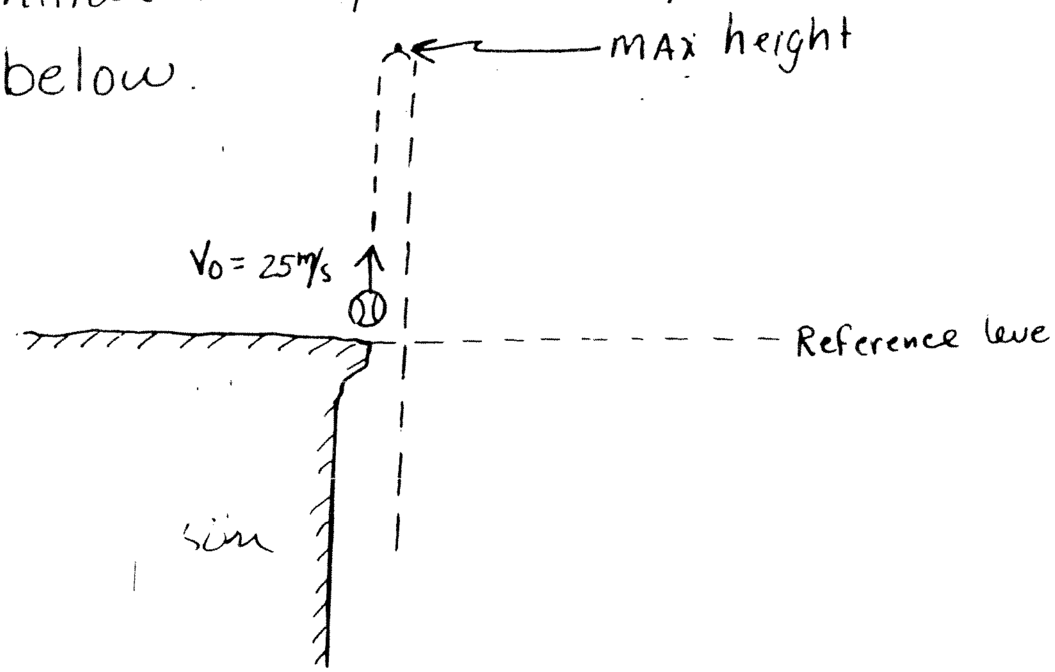
f) Sketch a Position - Time graph for the stone and a Velocity -Time graph for the entire motion of the stone.

g) Mark the locations in part a and d on the position time graph.

Position time graph	velocity – time graph



1. From the top of A cliff, a ball is thrown upward with an initial velocity of 25.0 m/s. See the diagram below.



A) Calculate the maximum height Above the level it was thrown.

______________ ANS.

B) calculate the Amount of time it takes to reach the maximum height.

______________ ANS.

c) Calculate the ball's velocity After 4.0 seconds.

______________ ANS.

D) what is its displacement After 4 seconds.

e) TOTAL TIME ________

______________ ANS.

AP Physics B **DiBucci**

Homework packet for :

Graphical analysis of motion, Kinematics and Free Fall

Complete the following problems:

2-6,8,9,11,13,14,15,18,19,20,22-26,28-35,40-44,46-52,55

acceleration have opposite signs? If so, sketch a velocity-time graph to prove your point.

5. If the velocity of a particle is nonzero, can its acceleration ever be zero? Explain.
6. If the velocity of a particle is zero, can its acceleration ever be nonzero? Explain.
7. A stone is thrown vertically upward from the top of a building. Does the stone's displacement depend on the location of the origin of the coordinate system? Does the stone's velocity depend on the origin? (Assume that the coordinate system is stationary with respect to the building.) Explain.
8. A student at the top of a building of height h throws one ball upward with an initial speed v_0 and then throws a second ball downward with the same initial speed. How do the final velocities of the balls compare when they reach the ground?
9. Can the magnitude of the instantaneous velocity of an object ever be greater than the magnitude of its average velocity? Can it ever be less?
10. If the average velocity of an object is zero in some time interval, what can you say about the displacement of the object for that interval?
11. A rapidly growing plant doubles in height each week. At the end of the 25th day, the plant reaches the height of a building. At what time was the plant one-fourth the height of the building?
12. Two cars are moving in the same direction in parallel lanes along a highway. At some instant, the velocity of car A exceeds the velocity of car B. Does this mean that the acceleration of A is greater than that of B? Explain.
13. An apple is dropped from some height above the Earth's surface. Neglecting air resistance, how much does its speed increase each second during its fall?

PROBLEMS

Section 2.1 Displacement, Velocity, and Speed

1. The position of a car coasting down a hill was observed at various times and the results are summarized in the table below. Find the average velocity of the car during (a) the first second, (b) the last three seconds, and (c) the entire period of observation.

x(m)	0	2.3	9.2	20.7	36.8	57.5
t(s)	0	1.0	2.0	3.0	4.0	5.0

2. A motorist drives north for 35 min at 85 km/h and then stops for 15 min. He then continues north, traveling 130 km in 2.0 h. (a) What is his total displacement? (b) What is his average velocity?

[3.] The displacement versus time graph for a certain particle moving along the x axis is shown in Figure P2.3. Find the average velocity in the time intervals (a) 0 to 2 s, (b) 0 to 4 s, (c) 2 s to 4 s, (d) 4 s to 7 s, (e) 0 to 8 s.

4. A jogger runs in a straight line with an average velocity of + 5.00 m/s for 4.00 min, and then with an average velocity of + 4.00 m/s for 3.00 min. (a) What is her total displacement? (b) What is her average velocity during this time?

[5.] A person walks first at a constant speed of 5.0 m/s along a straight line from point A to point B and then back along the line from B to A at a constant speed of 3.0 m/s. (a) What is her average speed over the entire trip? (b) Her average velocity over the entire trip?

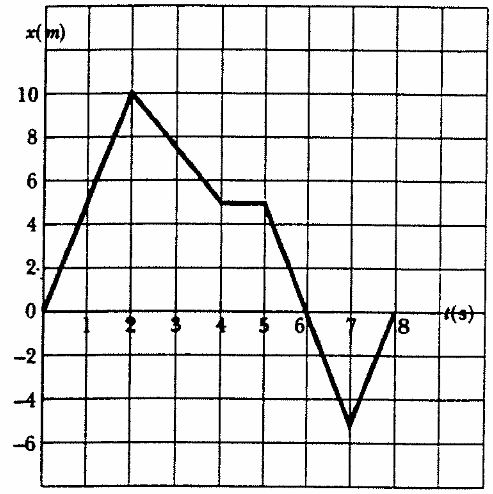


FIGURE P2.3

5A. A person walks first at a constant speed v_1 along a straight line from point A to point B, and then back along the line from B to A at a constant speed v_2. (a) What is her average speed over the entire trip? (b) Her average velocity over the entire trip?

6. A particle moves according to the equation $x = 10t^2$ where x is in meters and t is in seconds. (a) Find the average velocity for the time interval from 2.0 s to 3.0 s. (b) Find the average velocity for the time interval from 2.0 s to 2.1 s.

[7.] A car makes a 200-km trip at an average speed of 40 km/h. A second car starting 1.0 h later arrives at

☐ indicates problems that have full solutions available in the Student Solutions Manual and Study Guide.

their mutual destination at the same time. What was the average speed of the second car for the period that it was in motion?

Section 2.2 Instantaneous Velocity and Speed

8. A speedy tortoise can run at 10.0 cm/s, and a hare can run 20 times as fast. In a race, they start at the same time, but the hare stops to rest for 2.0 min, and so the tortoise wins by a shell (20 cm). (a) How long does the race take? (b) What is the length of the race?
9. The position-time graph for a particle moving along the x axis is as shown in Figure P2.9. (a) Find the average velocity in the time interval $t = 1.5$ s to $t = 4.0$ s. (b) Determine the instantaneous velocity at $t = 2.0$ s by measuring the slope of the tangent line shown in the graph. (c) At what value of t is the velocity zero?

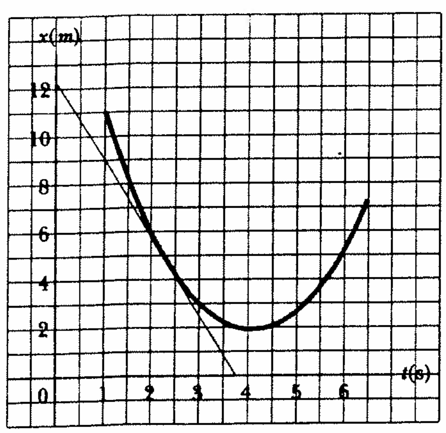


FIGURE P2.9

10. Two cars travel in the same direction along a straight highway, one at 55 mi/h and the other at 70 mi/h. (a) Assuming they start at the same point, how much sooner does the faster car arrive at a destination 10 miles away? (b) How far must the faster car travel before it has a 15-min lead on the slower car?
11. At $t = 1.0$ s, a particle moving with constant velocity is located at $x = -3.0$ m, and at $t = 6.0$ s, the particle is located at $x = 5.0$ m. (a) From this information, plot the position as a function of time. (b) Determine the velocity of the particle from the slope of this graph.
12. (a) Use the data in Problem 1 to construct a graph of position versus time. (b) By constructing tangents to the $x(t)$ curve, find the instantaneous velocity of the car at several instants. (c) Plot the instantaneous velocity versus time and, from this, determine the average acceleration of the car. (d) What is the initial velocity of the car?
13. Find the instantaneous velocity of the particle described in Figure P2.3 at the following times: (a) $t = 1.0$ s, (b) $t = 3.0$ s, (c) $t = 4.5$ s, and (d) $t = 7.5$ s.
14. The position-time graph for a particle moving along the z axis is as shown in Figure P2.14. Determine whether the velocity is positive, negative, or zero at times (a) t_1, (b) t_2, (c) t_3, (d) t_4.

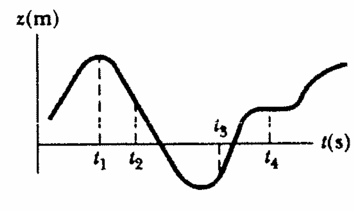


FIGURE P2.14

Section 2.3 Acceleration

15. A particle is moving with a velocity $v_0 = 60$ m/s at $t = 0$. Between $t = 0$ and $t = 15$ s, the velocity decreases uniformly to zero. What is the average acceleration during this 15-s interval? What is the significance of the sign of your answer?
16. An object moves along the x axis according to the equation $x(t) = (3.0t^2 - 2.0t + 3.0)$ m. Determine (a) the average speed between $t = 2.0$ s and $t = 3.0$ s, (b) the instantaneous speed at $t = 2.0$ s and at $t = 3.0$ s, (c) the average acceleration between $t = 2.0$ s and $t = 3.0$ s, and (d) the instantaneous acceleration at $t = 2.0$ s and $t = 3.0$ s.
17. A particle moves along the x axis according to the equation $x = 2.0t + 3.0t^2$, where x is in meters and t is in seconds. Calculate the instantaneous velocity and instantaneous acceleration at $t = 3.0$ s.
18. A particle moving in a straight line has a velocity of 8.0 m/s at $t = 0$. Its velocity at $t = 20$ s is 20.0 m/s. (a) What is its average acceleration in this time interval? (b) Can the average velocity be obtained from the information presented? Explain.
19. A particle starts from rest and accelerates as shown in Figure P2.19. Determine (a) the particle's speed at $t = 10$ s and at $t = 20$ s and (b) the distance traveled in the first 20 s.
20. The velocity of a particle as a function of time is shown in Figure P2.20. At $t = 0$, the particle is at $x = 0$. (a) Sketch the acceleration as a function of time. (b) Determine the average acceleration of the particle in the time interval $t = 2.0$ s to $t = 8.0$ s. (c) Determine the instantaneous acceleration of the particle at $t = 4.0$ s.
21. A particle moves along the x axis according to the equation $x = 2.0 + 3.0t - 1.0t$, where x is in meters and t is in seconds. At $t = 3.00$ s, find (a) the position of the particle, (b) its velocity, and (c) its acceleration.

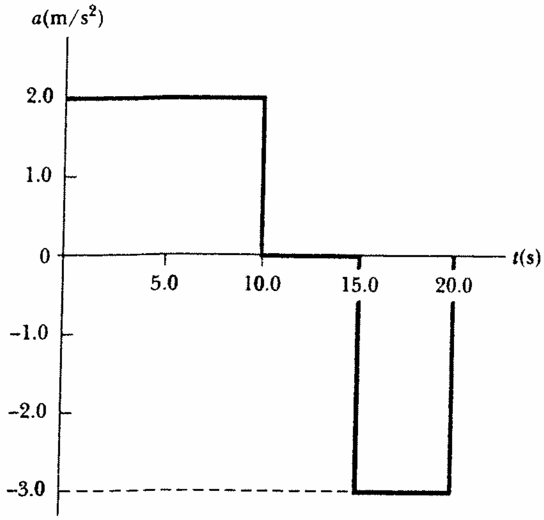


FIGURE P2.19

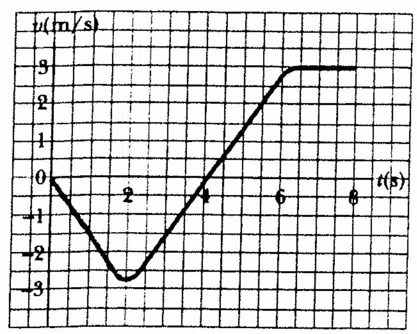


FIGURE P2.20

22. A student drives a moped along a straight road as described by the speed-versus-time graph in Figure P2.22. Sketch this graph in the middle of a sheet of graph paper. (a) Directly above this graph, sketch a graph of the position versus time, aligning the time coordinates of the two graphs. (b) Sketch a graph of the acceleration versus time directly below the v-t graph, again aligning the time coordinates. On each graph, show the numerical values of x and a for all points of inflection. (c) What is the acceleration at $t = 6$ s? (d) Find the position (relative to the starting point) at $t = 6$ s. (e) What is the moped's final position at $t = 9$ s?
23. Figure P2.23 shows a graph of v versus t for the motion of a motorcyclist as she starts from rest and moves along the road in a straight line. (a) Find the average acceleration for the time interval $t_0 = 0$ to $t_1 = 6.0$ s. (b) Estimate the time at which the acceleration has its greatest positive value and the value of the acceleration at this instant. (c) When is the acceleration zero? (d) Estimate the maximum negative value of the acceleration and the time at which it occurs.

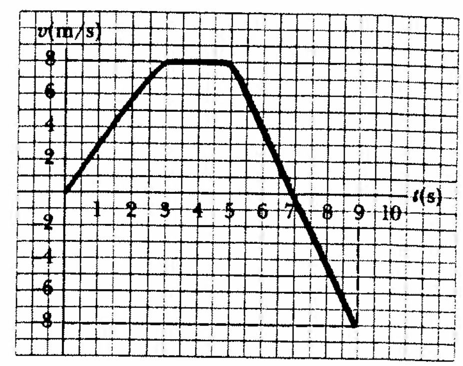


FIGURE P2.22

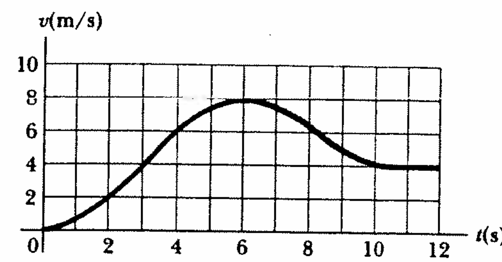


FIGURE P2.23

Section 2.4 One-Dimensional Motion with Constant Acceleration

24. A particle travels in the positive x direction for 10 s at a constant speed of 50 m/s. It then accelerates uniformly to a speed of 80 m/s in the next 5 s. Find (a) the average acceleration of the particle in the first 10 s, (b) its average acceleration in the interval $t = 10$ s to $t = 15$ s, (c) the total displacement of the particle between $t = 0$ and $t = 15$ s, and (d) its average speed in the interval $t = 10$ s to $t = 15$ s.
25. A body moving with uniform acceleration has a velocity of 12.0 cm/s when its x coordinate is 3.00 cm. If its x coordinate 2.00 s later is -5.00 cm, what is the magnitude of its acceleration?
26. The new BMW M3 can accelerate from zero to 60 mi/h in 5.6 s. (a) What is the resulting acceleration in m/s²? (b) How long would it take for the BMW to go from 60 mi/h to 130 mi/h at this rate?
27. The minimum distance required to stop a car moving at 35 mi/h is 40 ft. What is the minimum stopping distance for the same car moving at 70 mi/h, assuming the same rate of acceleration?
28. Figure P2.28 represents part of the performance data of a car owned by a proud physics student. (a) Calculate from the graph the total distance traveled. (b) What distance does the car travel between the

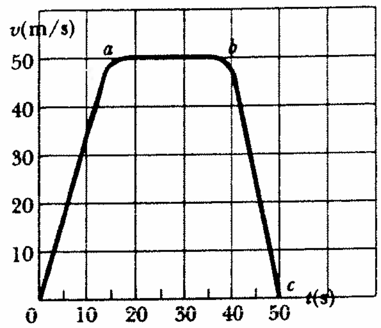


FIGURE P2.28

times $t = 10$ s and $t = 40$ s? (c) Draw a graph of its acceleration versus time between $t = 0$ and $t = 50$ s. (d) Write an equation for x as a function of time for each phase of the motion, represented by (i) *ab*, (ii) *bc*, (iii) *cd*. (e) What is the average velocity of the car between $t = 0$ and $t = 50$ s?

29. The initial speed of a body is 5.20 m/s. What is its speed after 2.50 s if it accelerates uniformly at (a) 3.00 m/s^2 and (b) at -3.00 m/s^2?

30. A hockey puck sliding on a frozen lake comes to rest after traveling 200 m. If its initial velocity is 3.00 m/s, (a) what is its acceleration if that acceleration is assumed constant, (b) how long is it in motion, and (c) what is its speed after traveling 150 m?

31. A jet plane lands with a velocity of 100 m/s and can accelerate at a maximum rate of -5.0 m/s^2 as it comes to rest. (a) From the instant it touches the runway, what is the minimum time needed before it stops? (b) Can this plane land at a small airport where the runway is 0.80 km long?

32. A car and train move together along parallel paths at 25.0 m/s. The car then undergoes a uniform acceleration of -2.50 m/s^2 because of a red light and comes to rest. It remains at rest for 45.0 s, then accelerates back to a speed of 25.0 m/s at a rate of 2.50 m/s^2. How far behind the train is the car when it reaches the speed of 25.0 m/s, assuming that the train speed has remained at 25.0 m/s?

33. A drag racer starts her car from rest and accelerates at 10.0 m/s^2 for the entire distance of 400 m ($\frac{1}{4}$ mile). (a) How long did it take the car to travel this distance? (b) What is its speed at the end of the run?

34. An electron in a cathode ray tube (CRT) accelerates from 2.0×10^4 m/s to 6.0×10^6 m/s over 1.5 cm. (a) How long does the electron take to travel this distance? (b) What is its acceleration?

35. A particle starts from rest from the top of an inclined plane and slides down with constant acceleration. The inclined plane is 2.00 m long, and it takes 3.00 s for the particle to reach the bottom. Find (a) the acceleration of the particle, (b) its speed at the bottom of the incline, (c) the time it takes the particle to reach the middle of the incline, and (d) its speed at the midpoint.

36. Two express trains started 5 min apart. Starting from rest, each is capable of a maximum speed of 160 km/h after uniformly accelerating over a distance of 2.0 km. (a) What is the acceleration of each train? (b) How far ahead is the first train when the second one starts? (c) How far apart are they when they are both traveling at maximum speed?

37. A teenager has a car that accelerates at 3.0 m/s^2 and decelerates at -4.5 m/s^2. On a trip to the store, he accelerates from rest to 12 m/s, drives at a constant speed for 5.0 s, and then comes to a momentary stop at the corner. He then accelerates to 18 m/s, drives at a constant speed for 20 s, decelerates for 8/3 s, continues for 4.0 s at this speed, and then comes to a stop. (a) How long does the trip take? (b) How far has he traveled? (c) What is his average speed for the trip? (d) How long would it take to walk to the store and back if he walked at 1.5 m/s?

38. A ball accelerates at 0.5 m/s^2 while moving down an inclined plane 9.0 m long. When it reaches the bottom, the ball rolls up another plane, where, after moving 15 m, it comes to rest. (a) What is the speed of the ball at the bottom of the first plane? (b) How long does it take to roll down the first plane? (c) What is the acceleration along the second plane? (d) What is the ball's speed 8.0 m along the second plane?

39. A car moving at a constant speed of 30.0 m/s suddenly stalls at the bottom of a hill. The car undergoes a constant acceleration of -2.00 m/s^2 (opposite its motion) while ascending the hill. (a) Write equations for the position and the velocity as functions of time, taking $x = 0$ at the bottom of the hill, where $v_0 = 30.0$ m/s. (b) Determine the maximum distance traveled by the car after it stalls.

40. An electron has an initial speed of 3.0×10^5 m/s. If it undergoes an acceleration of 8.0×10^{14} m/s^2, (a) how long will it take to reach a speed of 5.4×10^5 m/s and (b) how far has it traveled in this time?

41. Speedy Sue driving at 30 m/s enters a one-lane tunnel. She then observes a slow-moving van 155 m ahead traveling at 5.0 m/s. Sue applies her brakes but can decelerate only at 2.0 m/s^2 because the road is wet. Will there be a collision? If yes, determine how far into the tunnel and at what time the collision occurs. If no, determine the distance of closest approach between Sue's car and the van.

42. An indestructible bullet 2.00 cm long is fired straight through a board that is 10.0 cm thick. The bullet strikes the board with a speed of 420 m/s and emerges with a speed of 280 m/s. (a) What is the average acceleration of the bullet through the board? (b) What is the total time that the bullet is in

(calculated to 0.1 cm) would it take to stop the bullet?

43. Until recently, the world's land speed record was held by Colonel John P. Stapp, USAF. On March 19, 1954, he rode a rocket-propelled sled that moved down the track at 632 mi/h. He and the sled were safely brought to rest in 1.4 s. Determine (a) the negative acceleration he experienced and (b) the distance he traveled during this negative acceleration.

44. A hockey player is standing on his skates on a frozen pond when an opposing player skates by with the puck, moving with a uniform speed of 12.0 m/s. After 3.00 s, the first player makes up his mind to chase his opponent. If the first player accelerates uniformly at 4.00 m/s^2, (a) how long does it take him to catch the opponent? (b) How far has the first player traveled in this time? (Assume the opponent moves at constant speed.)

Section 2.5 Freely Falling Bodies

45. A woman is reported to have fallen 144 ft from the 17th floor of a building, landing on a metal ventilator box, which she crushed to a depth of 18.0 in. She suffered only minor injuries. Neglecting air resistance, calculate (a) the speed of the woman just before she collided with the ventilator, (b) her average acceleration while in contact with the box, and (c) the time it took to crush the box.

46. A ball is thrown directly downward with an initial speed of 8.00 m/s from a height of 30.0 m. When does the ball strike the ground?

47. A student throws a set of keys vertically upward to her sorority sister in a window 4.00 m above. The keys are caught 1.50 s later by the sister's outstretched hand. (a) With what initial velocity were the keys thrown? (b) What was the velocity of the keys just before they were caught?

48. A hot air balloon is traveling vertically upward at a constant speed of 5.00 m/s. When it is 21.0 m above the ground, a package is released from the balloon. (a) After it is released, for how long is the package in the air? (b) What is its velocity just before impact with the ground? (c) Repeat (a) and (b) for the case of the balloon descending at 5.00 m/s.

49. A ball is thrown vertically upward from the ground with an initial speed of 15.0 m/s. (a) How long does it take the ball to reach its maximum altitude? (b) What is its maximum altitude? (c) Determine the velocity and acceleration of the ball at $t = 2.00$ s.

50. A ball thrown vertically upward is caught by the thrower after 20.0 s. Find (a) the initial velocity of the ball and (b) the maximum height it reaches.

51. A baseball is hit such that it travels straight upward after being struck by the bat. A fan observes that it requires 3.00 s for the ball to reach its maximum height. Find (a) its initial velocity and (b) its maximum height. Ignore the effects of air resistance.

52. An astronaut standing on the Moon drops a hammer, letting it fall 1.00 m to the surface. The lunar gravity produces a constant acceleration of magnitude 1.62 m/s^2. Upon returning to Earth, the astronaut again drops the hammer, letting it fall to the ground from a height of 1.00 m with an acceleration of 9.80 m/s^2. Compare the times of fall in the two situations.

53. The height of a helicopter above the ground is given by $h = 3.00t^3$, where h is in meters and t is in seconds. After 2.00 s, the helicopter releases a small mailbag. How long after its release does the mailbag reach the ground?

54. A stone falls from rest from the top of a high cliff. A second stone is thrown downward from the same height 2.00 s later with an initial speed of 30.0 m/s. If both stones hit the ground simultaneously, how high is the cliff?

55. A daring stunt woman sitting on a tree limb wishes to drop vertically onto a horse galloping under the tree. The speed of the horse is 10.0 m/s, and the distance from the limb to the saddle is 3.00 m. (a) What must be the horizontal distance between the saddle and limb when the woman makes her move? (b) How long is she in the air?

*Section 2.6 Kinematic Equations Derived from Calculus

56. The speed of a bullet shot from a gun is given by $v = (-5.0 \times 10^7)t^2 + (3.0 \times 10^5)t$, where v is in meters/second and t is in seconds. The acceleration of the bullet just as it leaves the barrel is zero. (a) Determine the acceleration and position of the bullet as a function of time when the bullet is in the barrel. (b) Determine the length of time the bullet is accelerated while in the barrel. (c) Find the speed at which the bullet leaves the barrel. (d) What is the length of the barrel?

57. The position of a softball tossed vertically upward is described by the equation $y = 7.00t - 4.90t^2$, where y is in meters and t in seconds. Find (a) the ball's initial speed v_0 at $t_0 = 0$, (b) its velocity at $t = 1.26$ s, and (c) its acceleration.

58. A rocket sled for testing equipment under large accelerations starts at rest and accelerates according to the expression $a = (3 \text{ m/s}^3)t + 5.00 \text{ m/s}^2$. How far does the sled move in the time interval $t = 0$ to $t = 2.00$ s?

59. Automotive engineers refer to the time rate of change of acceleration as the "jerk." If an object moves in one dimension such that its jerk J is constant, (a) determine expressions for its acceleration $a(t)$, speed $v(t)$, and position $x(t)$, given that its initial acceleration, speed, and position are a_0, v_0,

Motion in One Dimension — DiBucci

1.) 2.3 m/s, 16.1 m/s, 11.5 m/s

2.) 180 km, 63.4 km/hr

3.) 5 m/s, 1.25 m/s, −2.5 m/s
−3.3 m/s 0 m/s

4) 1920 m, 4.57 m/s

5) 3.75 m/s

6) 50 m/s, 41 m/s

7) 50 km/hr

8) 126 s, 12.6 m

9) −2.4 m/s, −3.2 m/s
4 s

10.) 2.34 min, 64.2 mi

11.) 1.6 m/s

12) 25 m/s, 18 m/s, 13 m/s
7.6 m/s, 5.8 m/s^2, $V_0 = 0$

13) 5 m/s, −2.5 m/s, 0, +5 m/s

14) $v = 0$, $v < 0$, $v > 0$, $v = 0$

15) −4 m/s^2

16) 13 m/s, 10 m/s, 16 m/s, 6 m/s^2, 6 m/s^2

17) 20 m/s, 6 m/s^2

18) 0.6 m/s^2

19) 20 m/s, 5 m/s, 262 m

20) −1.5 m/s^2, +1.5 m/s^2, 0 m/s^2
1 m/s^2, 1.5 m/s^2 @ $t = 4$ s

21) 2 m, −3 m/s, −2 m/s^2

22) 12 m, 28 m, 36 m
28 m, −4 m/s^2, 34 m

23) 4/3 m/s^2, 2 m/s^2, $a = 0$ @ $t = 6$ s + $t = 10$ s
−1.5 m/s^2

24) 0 m/s^2, 6 m/s^2, 825 m, 65 m/s

25) −16 cm/s^2

26) 4.79 m/s^2, 6.53 s

27) −32.9 ft/s^2, 160 ft

28) 1875 m, 1457 m
$a = 3.3\ m/s^2$ $0 \le t \le 15$ s
$a = 0$ $15 \le t < 50$ s
32.5 m/s

29) 12.7 m/s, −2.3 m/s

30) -2.25×10^{-2} m/s^2, 133 s
1.5 m/s

31) 1000 m, 20 s

32) 1375 m

33) 8.94 s, 89.4 m/s

34) 4.98×10^{-9} s
1.2×10^{15} m/s^2

35) 0.444 m/s^2, 1.33 m/s
2.12 s, 0.943 m/s

36) $0.494\ m/s^2$, 11.33 km, 13.33 km

37) TOTAL T = 45.67 s, 574 m, 12.6 m/s, 765 s

38) 3 m/s, 6 s, $-0.300\ m/s^2$, 2.05 m/s

39) skip

40) 3×10^{-10} s, 1.26×10^{-4} m

41) 11.4 s not ~~13.6 s~~, 212 m

42) $-4.9 \times 10^5\ m/s^2$, 3.57×10^4 s, 1.8 thickness.

43) $-662\ ft/s^2$

44) skip

45) skip

46) 1.79 s

47) 4.68 m/s Downward

48) 2.64 s, −20.9 m/s, t = 1.62 s

49) 1.53 s, 11.5 m, −4.61 m/s, $-9.8\ m/s^2$

50) 490 m

51) 29.4 m/s, 44.1 m

52) 1.11 s, 0.45 s, 2.46 x

53) skip

54) 73.9 m

55) 7.82 m, 0.782 m

Unit 1 Practice Test AP Physics

1. A particle travels along a curved path between two points P and Q as shown.

The *displacement* of the particle does *not* depend on

A) the location of P.
B) the location of Q.
C) the distance traveled from P to Q.
D) the shortest distance between P and Q.
E) the direction of Q from P.

2. For which one of the following situations will the path length equal the magnitude of the displacement?

A) A jogger is running around a circular path.
B) A ball is rolling down an inclined plane.
C) A train travels 5 miles east; and then, it stops and travels 2 miles west.
D) A ball rises and falls after being thrown straight up from the earth's surface.
E) A ball on the end of a string is moving in a vertical circle.

3. At time $t = 0$, an object is observed at $x = 0$; and its position along the x axis follows this expression: $x = -3t + t^3$, where the units for distance and time are meters and seconds, respectively. What is the object's displacement Δx between $t = 1.0$ s and $t = 3.0$ s?

A) +20 m B) −20 m C) +16 m D) +2 m E) −2 m

Use the following to answer questions 4-5:

Peter noticed a bug crawling along a meter stick and decided to record the bug's position in five second intervals. After the bug crawled off the meter stick, Peter created the table shown.

time (s)	position (cm)
0.00	49.6
5.00	39.2
10.0	42.5
15.0	41.0
20.0	65.7

4. What is the displacement of the bug between $t = 0.00$ and $t = 20.0$ s?

A) +39.9 cm B) −39.9 cm C) +65.7 cm D) −16.1 cm E) +16.1 cm

5. What is the total distance that the bug traveled between $t = 0.00$ and $t = 20.0$ s? Assume the bug only changed directions at the end of a five second interval.

A) 39.9 cm B) 65.7 cm C) 16.1 cm D) 47.1 cm E) 26.5 cm

6. Which one of the physical quantities listed below is *not* correctly paired with its SI unit and dimension?

	Quantity	*Unit*	*Dimension*
A)	velocity	m/s	[L]/[T]
B)	path length	m	[L]
C)	speed	m/s	[L]/[T]
D)	displacement	m/s^2	$[L]/[T]^2$
E)	speed × time	m	[L]

7. A car travels in a straight line covering a total distance of 90.0 miles in 60.0 minutes. Which one of the following statements concerning this situation is *necessarily* true?
A) The velocity of the car is constant.
B) The acceleration of the car must be non-zero.
C) The first 45 miles must have been covered in 30.0 minutes.
D) The speed of the car must be 90.0 miles per hour throughout the entire trip.
E) The average velocity of the car is 90.0 miles per hour in the direction of motion.

8. A Canadian goose flew 845 km from Southern California to Oregon with an average speed of 30.5 m/s. How long, in hours, did it take the goose to make this journey?
A) 27.7 h B) 8.33 h C) 66.1 h D) 462 h E) 7.70 h

9. Carol's hair grows with an average speed of 3.5×10^{-9} m/s. How long does it take for her hair to grow 0.30 m? Note: 1 yr = 3.156×10^{7} s.
A) 1.9 yr B) 1.3 yr C) 0.37 yr D) 5.4 yr E) 2.7 yr

10. Carl Lewis set a world record for the 100.0-m run with a time of 9.86 s. If, after reaching the finish line, Mr. Lewis walked directly back to his starting point in 90.9 s, what is the magnitude of his average velocity for the 200.0 m?
A) 1.10 m/s B) 1.98 m/s C) 5.60 m/s D) 10.1 m/s E) zero

11. During the first 18 minutes of a 1.0 hour trip, a car has an average speed of 11 m/s. What must the average speed of the car be during the last 42 minutes of the trip be if the car is to have an average speed of 21 m/s for the entire trip?
A) 21 m/s B) 23 m/s C) 25 m/s D) 27 m/s E) 29 m/s

12. A turtle takes 3.5 minutes to walk 18 m toward the south along a deserted highway. A truck driver stops and picks up the turtle. The driver takes the turtle to a town 1.1 km to the north with an average speed of 12 m/s. What is the magnitude of the average velocity of the turtle for its entire journey?
A) 3.6 m/s B) 9.8 m/s C) 6.0 m/s D) 2.6 m/s E) 11 m/s

Use the following to answer questions 13-16:

A race car, traveling at constant speed, makes one lap around a circular track of radius r in a time t. Note: The circumference of a circle is given by $C = 2\pi r$.

13. When the car has traveled halfway around the track, what is the magnitude of its *displacement* from the starting point?
A) r B) $2r$ C) πr D) $2\pi r$ E) zero

14. What is the *average speed* of the car for one complete lap?
A) $\frac{r}{t}$ B) $\frac{2r}{t}$ C) $\frac{\pi r}{t}$ D) $\frac{2\pi r}{t}$ E) zero

15. Determine the *magnitude* of the *average velocity* of the car for one complete lap.
A) $\frac{r}{t}$ B) $\frac{2r}{t}$ C) $\frac{\pi r}{t}$ D) $\frac{2\pi r}{t}$ E) zero

16. Which one of the following statements concerning this car is true?
A) The displacement of the car does not change with time.
B) The instantaneous velocity of the car is constant.
C) The average speed of the car is the same over any time interval.
D) The average velocity of the car is the same over any time interval.
E) The average speed of the car over any time interval is equal to the magnitude of the average velocity over the same time interval.

17. In which one of the following situations does the car have a westward acceleration?
A) The car travels westward at constant speed.
B) The car travels eastward and speeds up.
C) The car travels westward and slows down.
D) The car travels eastward and slows down.
E) The car starts from rest and moves toward the east.

18. An elevator is moving upward with a speed of 11 m/s. Three seconds later, the elevator is still moving upward, but it's speed has been reduced to 5.0 m/s. What is the average acceleration of the elevator during the 3.0 s interval?
A) 2.0 m/s^2, downward B) 2.0 m/s^2, upward C) 5.3 m/s^2, downward D) 5.3 m/s^2, upward E) 2.7 m/s^2, downward

19. A landing airplane makes contact with the runway with a speed of 78.0 m/s and moves toward the south. After 18.5 seconds, the airplane comes to rest. What is the average acceleration of the airplane during the landing?
A) 2.11 m/s^2, north B) 2.11 m/s^2, south C) 4.22 m/s^2, north D) 4.22 m/s^2, south E) 14.3 m/s^2, north

20. A pitcher delivers a fast ball with a velocity of 43 m/s to the south. The batter hits the ball and gives it a velocity of 51 m/s to the north. What was the average acceleration of the ball during the 1.0 ms when it was in contact with the bat?
A) 4.3×10^4 m/s^2, south B) 5.1×10^4 m/s^2, north C) 9.4×10^4 m/s^2, north D) 2.2×10^3 m/s^2, south E) 7.0×10^3 m/s^2, north

21. A car is moving at a constant velocity when it is involved in a collision. The car comes to rest after 0.450 s with an average acceleration of 65.0 m/s^2 in the direction opposite that of the car's velocity. What was the speed, in km/h, of the car before the collision?
A) 29.2 km/h B) 144 km/h C) 44.8 km/h D) 80.5 km/h E) 105 km/h

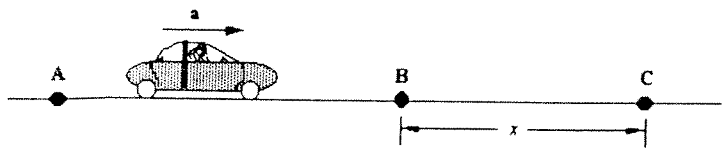
22. Which one of the following is *not* a vector quantity?
A) acceleration B) average speed C) displacement D) average velocity E) instantaneous velocity

23. In which one of the following cases is the displacement of the object directly proportional to the time?
A) a ball rolls with constant velocity
B) a ball at rest is given a constant acceleration
C) a ball rolling with velocity $\mathbf{v}_0$ is given a constant acceleration
D) a bead falling through oil experiences a decreasing acceleration
E) a rocket fired from the earth's surface experiences an increasing acceleration

24. Which one of the following situations is *not* possible?
A) A body has zero velocity and non-zero acceleration.
B) A body travels with a northward velocity and a northward acceleration.
C) A body travels with a northward velocity and a southward acceleration.
D) A body travels with a constant velocity and a time-varying acceleration.
E) A body travels with a constant acceleration and a time-varying velocity.

25. Starting from rest, a particle confined to move along a straight line is accelerated at a rate of 5.0 m/s^2. Which one of the following statements accurately describes the motion of this particle?
A) The particle travels 5.0 m during each second.
B) The particle travels 5.0 m *only* during the first second.
C) The speed of the particle increases by 5.0 m/s during each second.
D) The acceleration of the particle increases by 5.0 m/s^2 during each second.
E) The final speed of the particle will be proportional to the distance that the particle covers.

26. A car accelerates from rest at point **A** with constant acceleration of magnitude a and subsequently passes points **B** and **C** as shown in the figure.



The distance between points **B** and **C** is x, and the time required for the car to travel from **B** to **C** is t. Which expression determines the *average speed* of the car between the points **B** and **C**?

A) $v^2 = 2ax$ B) $v = \frac{x}{t}$ C) $v = xt$ D) $v = \frac{1}{2}at^2$ E) $v = at$

27. Two objects A and B accelerate from rest with the same constant acceleration. Object A accelerates for twice as much time as object B, however. Which one of the following statements is true concerning these objects at the end of their respective periods of acceleration?
A) Object A will travel twice as far as object B.
B) Object A will travel four times as far as object B.
C) Object A will travel eight times further than object B.
D) Object A will be moving four times faster than object B.
E) Object A will be moving eight times faster than object B.

28. Which one of the following statements must be true if the expression $x = v_0t + \frac{1}{2}at^2$ is to be used?
A) x is constant. B) v is constant. C) t is constant. D) a is constant. E) Both v_0 and t are constant.

29. Two cars travel along a level highway. It is observed that the distance between the cars is *increasing*. Which one of the following statements concerning this situation is *necessarily* true?
A) The velocity of each car is increasing.
B) At least one of the cars has a *non-zero* acceleration.
C) The leading car has the greater acceleration.
D) The trailing car has the smaller acceleration.
E) Both cars could be accelerating at the same rate.

30. An object moving along a straight line is decelerating. Which one of the following statements concerning the object's acceleration is *necessarily* true?
A) The value of the acceleration is positive.
B) The direction of the acceleration is in the same direction as the displacement.
C) An object that is decelerating has a negative acceleration.
D) The direction of the acceleration is in the direction opposite to that of the velocity.
E) The acceleration changes as the object moves along the line.

31. A car, starting from rest, accelerates in a straight line path at a constant rate of 2.5 m/s^2. How far will the car travel in 12 seconds?
A) 180 m B) 120 m C) 30 m D) 15 m E) 4.8 m

32. A car starts from rest and accelerates at a constant rate in a straight line. In the *first* second the car covers a distance of 2.0 meters. How fast will the car be moving at the end of the *second* second?
A) 4.0 m/s B) 16 m/s C) 2.0 m/s D) 32 m/s E) 8.0 m/s

33. A car starts from rest and accelerates at a constant rate in a straight line. In the *first* second the car covers a distance of 2.0 meters. How much additional distance will the car cover during the *second* second of its motion?
A) 2.0 m B) 4.0 m C) 6.0 m D) 8.0 m E) 13 m

34. A car is initially traveling at 50.0 km/h. The brakes are applied and the car stops over a distance of 35 m. What was magnitude of the car's acceleration while it was braking?
A) 2.8 m/s^2 B) 5.4 m/s^2 C) 36 m/s^2 D) 71 m/s^2 E) 9.8 m/s^2

35. The minimum takeoff speed for a certain airplane is 75 m/s. What minimum acceleration is required if the plane must leave a runway of length 950 m? Assume the plane starts from rest at one end of the runway.
A) 1.5 m/s^2 B) 3.0 m/s^2 C) 4.5 m/s^2 D) 6.0 m/s^2 E) 7.5 m/s^2

36. A body initially at rest is accelerated at a constant rate for 5.0 seconds in the positive x direction. If the final speed of the body is 20.0 m/s, what was the body's acceleration?
A) 0.25 m/s^2 B) 2.0 m/s^2 C) 4.0 m/s^2 D) 9.8 m/s^2 E) 1.6 m/s^2

37. A race car has a speed of 80 m/s when the driver releases a drag parachute. If the parachute causes a deceleration of –4 m/s^2, how far will the car travel before it stops?
A) 20 m B) 200 m C) 400 m D) 800 m E) 1000 m

38. A car traveling along a road begins accelerating with a constant acceleration of 1.5 m/s^2 in the direction of motion. After traveling 392 m at this acceleration, its speed is 35 m/s. Determine the speed of the car when it began accelerating.
A) 1.5 m/s B) 7.0 m/s C) 34 m/s D) 49 m/s E) 2.3 m/s

39. A train passes through a town with a constant speed of 16 m/s. After leaving the town, the train accelerates at 0.33 m/s^2 until it reaches a speed of 35 m/s. How far did the train travel while it was accelerating?
A) 0.029 km B) 0.53 km C) 1.5 km D) 2.3 km E) 3.0 km

40. A cheetah is walking at a speed of 1.10 m/s when it observes a gazelle 41.0 m directly ahead. If the cheetah accelerates at 9.55 m/s^2, how long does it take the cheetah to reach the gazelle if the gazelle doesn't move?
A) 4.29 s B) 3.67 s C) 3.05 s D) 1.94 s E) 2.82 s

Use the following to answer questions 41-43:

An object starts from rest and accelerates uniformly in a straight line in the positive x direction. After 11 seconds, its speed is 70.0 m/s.

41. Determine the acceleration of the object.
A) +3.5 m/s^2 B) +6.4 m/s^2 C) −3.5 m/s^2 D) −6.4 m/s^2 E) +7.7 m/s^2

42. How far does the object travel during the first 11 seconds?
A) 35 m B) 77 m C) 390 m D) 590 m E) 770 m

43. What is the *average velocity* of the object during the first 11 seconds?
A) +3.6 m/s B) +6.4 m/s C) +35 m/s D) +72 m/s E) −140 m/s

44. Ball A is dropped from rest from a window. At the same instant, ball B is thrown downward; and ball C is thrown upward from the same window. Which statement concerning the balls is necessarily true if air resistance is neglected?
A) At some instant after it is thrown, the acceleration of ball C is zero.
B) All three balls strike the ground at the same time.
C) All three balls have the same velocity at any instant.
D) All three balls have the same acceleration at any instant.
E) All three balls reach the ground with the same velocity.

45. A ball is thrown vertically upward from the surface of the earth. Consider the following quantities:
(1) the speed of the ball
(2) the velocity of the ball
(3) the acceleration of the ball
Which of these is (are) zero when the ball has reached the maximum height?
A) 1 only B) 2 only C) 1 and 2 D) 1 and 3 E) 1, 2, and 3

46. A rock is thrown vertically upward from the surface of the earth. The rock rises to some maximum height and falls back toward the surface of the earth. Which one of the following statements concerning this situation is true if air resistance is neglected?
A) As the ball rises, its acceleration vector points upward.
B) The ball is a freely falling body for the duration of its flight.
C) The acceleration of the ball is zero when the ball is at its highest point.
D) The speed of the ball is negative while the ball falls back toward the earth.
E) The velocity and acceleration of the ball always point in the same direction.

47. A brick is dropped from rest from a height of 4.9 m. How long does it take for the brick to reach the ground?
A) 0.6 s B) 1.0 s C) 1.2 s D) 1.4 s E) 2.0 s

48. A ball is dropped from rest from a tower and strikes the ground 125 m below. Approximately how many seconds does it take for the ball to strike the ground after being dropped? Neglect air resistance.
A) 2.50 s B) 3.50 s C) 5.05 s D) 12.5 s E) 16.0 s

49. Water drips from rest from a leaf that is 20 meters above the ground. Neglecting air resistance, what is the speed of each water drop when it hits the ground?
A) 10 m/s B) 15 m/s C) 20 m/s D) 30 m/s E) 40 m/s

50. A rock is dropped from rest from a height h above the ground. It falls and hits the ground with a speed of 11 m/s. From what height should it be dropped so that its speed on hitting the ground is 22 m/s? Neglect air resistance.
A) $1.4h$ B) $2.0h$ C) $3.0h$ D) $4.0h$ E) $0.71h$

51. A 5.0-kg rock is dropped from rest down a vertical mine shaft. How long does it take for the rock to reach a depth of 79 m? Neglect air resistance.
A) 2.8 s B) 9.0 s C) 4.9 s D) 8.0 s E) 4.0 s

52. What maximum height will be reached by a stone thrown straight up with an initial speed of 35 m/s?
A) 98 m B) 160 m C) 41 m D) 62 m E) 18 m

Use the following to answer questions 53-55:

A ball is shot straight up from the surface of the earth with an initial speed of 19.6 m/s. Neglect any effects due to air resistance.

53. What is the magnitude of the ball's displacement from the starting point after 1.00 second has elapsed?
A) 9.80 m B) 14.7 m C) 19.6 m D) 24.5 m E) 58.8 m

54. What maximum height will the ball reach?
A) 9.80 m B) 14.7 m C) 19.6 m D) 24.5 m E) 58.8 m

55. How much time elapses between the throwing of the ball and its return to the original launch point?
A) 4.00 s B) 2.00 s C) 12.0 s D) 8.00 s E) 16.0 s

Use the following to answer questions 56-59:

A tennis ball is shot vertically upward in an *evacuated chamber* with an initial speed of 20.0 m/s at time $t = 0$.

56. How high does the ball rise?
A) 10.2 m B) 20.4 m C) 40.8 m D) 72.4 m E) 98.0 m

57. Approximately how long does it take the tennis ball to reach its maximum height?
A) 0.50 s B) 2.04 s C) 4.08 s D) 6.08 s E) 9.80 s

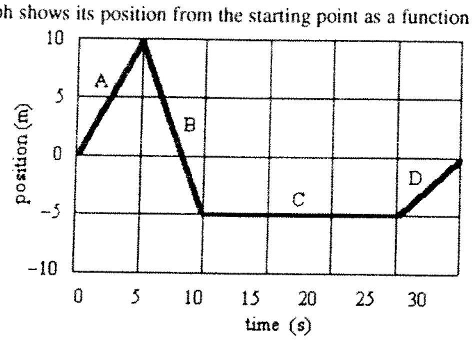
58. Determine the velocity of the ball at $t = 3.00$ seconds.
A) 9.40 m/s, downward B) 9.40 m/s, upward C) 29.4 m/s, downward D) 38.8 m/s, upward E) 38.8 m/s, downward

59. What is the magnitude of the acceleration of the ball when it is at its highest point?
A) zero B) 9.80 m/s^2 C) 19.6 m/s^2 D) 4.90 m/s^2 E) 3.13 m/s^2

60. Starting from rest, a particle which is confined to move along a straight line is accelerated at a rate of 5.0 m/s^2. Which statement concerning the *slope* of the *position versus time* graph for this particle is true?
A) The slope has a constant value of 5.0 m/s.
B) The slope has a constant value of 5.0 m/s2.
C) The slope is both constant and negative.
D) The slope is not constant and *increases* with increasing time.
E) The slope is not constant and *decreases* with increasing time.

Use the following to answer questions 61-63:

An object is moving along the x axis. The graph shows its position from the starting point as a function of time.



Various segments of the graph are identified by the letters A, B, C, and D.

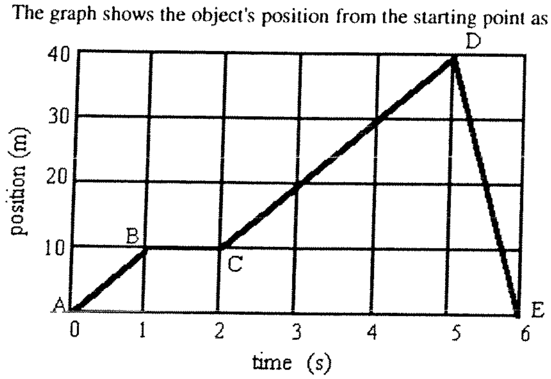
61. During which interval(s) is the object *moving* in the negative x direction?
A) during interval B only
B) during intervals B and C
C) during intervals C and D
D) during intervals B and D
E) during intervals B, C, and D

62. What is the *velocity* of the object at t = 7.0 s?
A) +3.0 m/s B) −1.0 m/s C) −2.0 m/s D) −3.0 m/s E) zero

63. What is the *acceleration* of the object at t = 7.0 s?
A) zero B) −2.0 m/s^2 C) −3.0 m/s^2 D) +9.8 m/s^2 E) +4.0 m/s^2

Use the following to answer questions 64-67:

An object is moving along a straight line. The graph shows the object's position from the starting point as a function of time.



64. In which segment(s) of the graph does the object's *average velocity* (measured from t = 0) *decrease* with time?
A) AB only B) BC only C) DE only D) AB and CD E) BC and DE

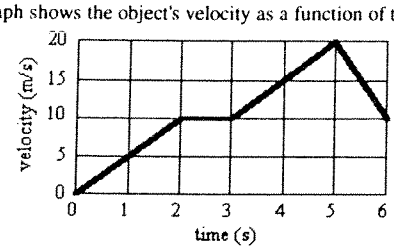
65. What was the *instantaneous velocity* of the object at t = 4 seconds?
A) +6 m/s B) +8 m/s C) +10 m/s D) +20 m/s E) +40 m/s

66. In which segments(s) of the graph does the object have the highest speed?
A) AB B) BC C) CD D) DE E) AB and CD

67. At which time(s) does the object reverse its direction of motion?
A) 1 s and 2 s B) 2 s and 5 s C) 1 s D) 2 s E) 5 s

Use the following to answer questions 68-71:

An object is moving along a straight line. The graph shows the object's velocity as a function of time.



68. During which interval(s) of the graph does the object travel *equal distances* in *equal times*?
A) 0 to 2 s B) 2 s to 3 s C) 3 s to 5 s D) 0 to 2 s and 3 s to 5 s E) 0 to 2 s, 3 to 5 s, and 5 to 6 s

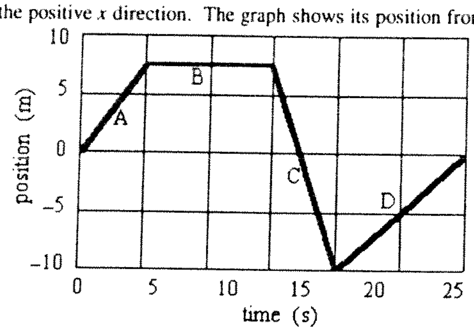
69. During which interval(s) of the graph does the speed of the object *increase by equal amounts* in *equal times*?
A) 0 to 2 s B) 2 s to 3 s C) 3 s to 5 s D) 0 to 2 s and 3 s to 5 s E) 0 to 2 s, 3 to 5 s, and 5 to 6 s

70. How far does the object move in the interval from $t = 0$ to $t = 2$ s?
A) 7.5 m B) 10 m C) 15 m D) 20 m E) 25 m

71. What is the acceleration of the object in the interval from $t = 5$ s to $t = 6$ s?
A) -40 m/s^2 B) $+40$ m/s^2 C) -20 m/s^2 D) $+20$ m/s^2 E) -10 m/s^2

Use the following to answer questions 72-74:

An object is moving along a straight line in the positive x direction. The graph shows its position from the starting point as a function of time.



Various segments of the graph are identified by the letters A, B, C, and D.

72. Which segment(s) of the graph represent(s) a *constant velocity* of +1.0 m/s?
A) A B) B C) C D) D E) A and C

73. What was the *instantaneous velocity* of the object at the end of the eighth second?
A) +7.5 m/s B) +0.94 m/s C) −0.94 m/s D) +1.1 m/s E) zero

74. During which interval(s) did the object move in the negative x direction?
A) only during interval B
B) only during interval C
C) only during interval D
D) during both intervals C and D
E) The object never moved in the negative x direction.

75. The rate at which the acceleration of an object changes with time is called the *jerk*. What is the dimension of the jerk?
A) $\frac{[L]}{[T]}$ B) $\frac{[L]}{[T]^2}$ C) $\frac{[L]^2}{[T]^2}$ D) $\frac{[L]}{[T]^3}$ E) $\frac{[L]^2}{[T]^3}$

76. In a race, José runs 1.00 mile in 4.02 min, mounts a bicycle, and rides back to his starting point, which is also the finish line, in 3.02 min. What is the magnitude of José's average velocity for the race?
A) zero B) 12.1 mi/h C) 14.9 mi/h D) 17.0 mi/h E) 19.9 mi/h

Use the following to answer questions 77-78:

A motorist travels due north at 30 mi/h for 2.0 hours. She then reverses her direction and travels due south at 60 mi/h for 1.0 hour.

77. What is the average speed of the motorist?
A) zero B) 30 mi/h C) 40 mi/h D) 50 mi/h E) 60 mi/h

78. What is the average velocity of the motorist?
A) zero B) 40 mi/h, north C) 40 mi/h, south D) 45 mi/h, north E) 45 mi/h, south

Use the following to answer questions 79-81:

Starting from rest, a particle confined to move along a straight line is accelerated at a rate of 4 m/s^2.

79. Which statement accurately describes the motion of the particle?
A) The particle travels 4 meters during each second.
B) The particle travels 4 meters during the first second only.
C) The speed of the particle increases by 4 m/s during each second.
D) The acceleration of the particle increases by 4 m/s^2 during each second.
E) The final velocity of the particle will be proportional to the distance that the particle covers.

80. After 10 seconds, how far will the particle have traveled?
A) 20 m B) 40 m C) 100 m D) 200 m E) 400 m

81. What is the speed of the particle after it has traveled 8 m?
A) 4 m/s B) 8 m/s C) 30 m/s D) 60 m/s E) 100 m/s

Use the following to answer questions 82-85:

A rock, dropped from rest near the surface of an atmosphere-free planet, attains a speed of 20.0 m/s after falling 8.0 meters.

82. What is the magnitude of the acceleration due to gravity on the surface of this planet?
A) 0.40 m/s^2 B) 1.3 m/s^2 C) 2.5 m/s^2 D) 25 m/s^2 E) 160 m/s^2

83. How long did it take the object to fall the 8.0 meters mentioned?
A) 0.40 s B) 0.80 s C) 1.3 s D) 2.5 s E) 16 s

84. How long would it take the object, falling from rest, to fall 16 m on this planet?
A) 0.8 s B) 1.1 s C) 2.5 s D) 3.5 s E) 22 s

85. Determine the speed of the object after falling from rest through 16 m on this planet.
A) 28 m/s B) 32 m/s C) 56 m/s D) 64 m/s E) 320 m/s

Use the following to answer questions 86-90:

A tennis ball is shot vertically upward from the surface of an atmosphere-free planet with an initial speed of 20.0 m/s. One second later, the ball has an instantaneous velocity in the upward direction of 15.0 m/s.

86. What is the magnitude of the acceleration due to gravity on the surface of this planet?
A) 5.0 m/s^2 B) 9.8 m/s^2 C) 12 m/s^2 D) 15 m/s^2 E) 24 m/s^2

87. How long does it take the ball to reach its maximum height?
A) 2.0 s B) 2.3 s C) 4.0 s D) 4.6 s E) 8.0 s

88. How high does the ball rise?
A) 70.0 m B) 10.0 m C) 50.0 m D) 20.0 m E) 40.0 m

89. Determine the velocity of the ball when it returns to its original position.
Note: assume the upward direction is positive.
A) +20 m/s B) –20 m/s C) +40 m/s D) –40 m/s E) zero

90. How long is the ball in the air when it returns to its original position?
A) 4.0 s B) 4.6 s C) 8.0 s D) 9.2 s E) 16 s

Use the following to answer questions 91-92:

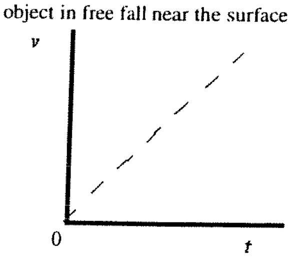
A small object is released from rest and falls 100 feet near the surface of the earth. Neglect air resistance.

91. How long will it take to fall through the 100 feet mentioned?
A) 2.49 s B) 3.12 s C) 4.50 s D) 6.25 s E) 10.0 s

92. How fast will the object be moving after falling through the 100 feet mentioned?
A) 9.8 ft/s B) 40 ft/s C) 80 ft/s D) 160 ft/s E) 320 ft/s

Use the following to answer questions 93-96:

The figure shows the speed as a function of time for an object in free fall near the surface of the earth.



The object was dropped from rest in a long evacuated cylinder.

93. Which one of the following statements best explains why the graph goes through the origin?
A) The object was in a vacuum.
B) The object was dropped from rest.
C) The velocity of the object was constant.
D) All v vs. t curves pass through the origin.
E) The acceleration of the object was constant.

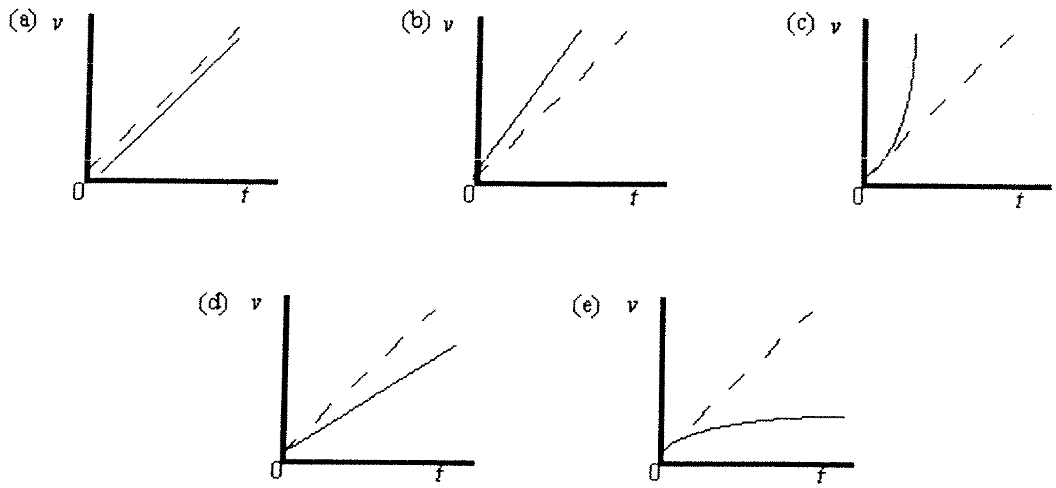
94. What is the numerical value of the slope of the line?
A) 1.0 m/s^2
B) 2.0 m/s^2
C) 7.7 m/s^2
D) 9.8 m/s^2
E) This cannot be determined from the information given since the speed and time values are unknown.

95. What is the speed of the object 3.0 seconds after it is dropped?
A) 3.0 m/s B) 7.7 m/s C) 9.8 m/s D) 29 m/s E) This cannot be determined since there is no specified value of height.

96. If the same object were released in air, the magnitude of its acceleration would begin at the free-fall value, but it would decrease continuously to zero as the object continued to fall.

In which choice below does the solid line best represent the speed of the object as a function of time when it is dropped from rest in air?

Note: The dashed line shows the free-fall under vacuum graph for comparison.



Answer Key -- Chapter 2

1. C the distance traveled from P to Q.
2. B A ball is rolling down an inclined plane.
3. A +20 m
4. E +16.1 cm
5. A 39.9 cm
6. D displacement m/s^2 $[L]/[T]^2$
7. E The average velocity of the car is 90.0 miles per hour in the direction of motion.
8. E 7.70 h
9. E 2.7 yr
10. E zero
11. C 25 m/s
12. A 3.6 m/s
13. B $2r$
14. D $\frac{2\pi r}{t}$
15. E zero
16. C The average speed of the car is the same over any time interval.
17. D The car travels eastward and slows down.
18. A 2.0 m/s^2, downward
19. C 4.22 m/s^2, north
20. C 9.4×10^4 m/s^2, north
21. E 105 km/h
22. B average speed
23. A a ball rolls with constant velocity
24. D A body travels with a constant velocity and a time-varying acceleration.
25. C The speed of the particle increases by 5.0 m/s during each second.
26. B $v = \frac{x}{t}$
27. B Object A will travel four times as far as object B.
28. D a is constant.
29. E Both cars could be accelerating at the same rate.
30. D The direction of the acceleration is in the direction opposite to that of the velocity.
31. A 180 m
32. E 8.0 m/s
33. C 6.0 m
34. A 2.8 m/s^2
35. B 3.0 m/s^2
36. C 4.0 m/s^2
37. D 800 m
38. B 7.0 m/s
39. C 1.5 km
40. E 2.82 s
41. B +6.4 m/s^2
42. C 390 m
43. C +35 m/s
44. D All three balls have the same acceleration at any instant.
45. C 1 and 2
46. B The ball is a freely falling body for the duration of its flight.
47. B 1.0 s
48. C 5.05 s
49. C 20 m/s
50. D 4.0h
51. E 4.0 s
52. D 62 m
53. B 14.7 m
54. C 19.6 m
55. A 4.00 s
56. B 20.4 m

57. B 2.04 s
58. A 9.40 m/s, downward
59. B 9.80 m/s^2
60. D The slope is not constant and *increases* with increasing time.
61. A during interval B only
62. D −3.0 m/s
63. A zero
64. E BC and DE
65. C +10 m/s
66. D DE
67. E 5 s
68. B 2 s to 3 s
69. D 0 to 2 s and 3 s to 5 s
70. B 10 m
71. E −10 m/s^2
72. D D
73. E zero
74. B only during interval C
75. D $\frac{[L]}{[T]^3}$
76. A zero
77. C 40 mi/h
78. A zero
79. C The speed of the particle increases by 4 m/s during each second.
80. D 200 m
81. B 8 m/s
82. D 25 m/s^2
83. B 0.80 s
84. B 1.1 s
85. A 28 m/s
86. A 5.0 m/s^2
87. C 4.0 s
88. E 40.0 m
89. B −20 m/s
90. C 8.0 s
91. A 2.49 s
92. C 80 ft/s
93. B The object was dropped from rest.
94. D 9.8 m/s^2
95. D 29 m/s
96. E

Free Response Problems **DiBucci**

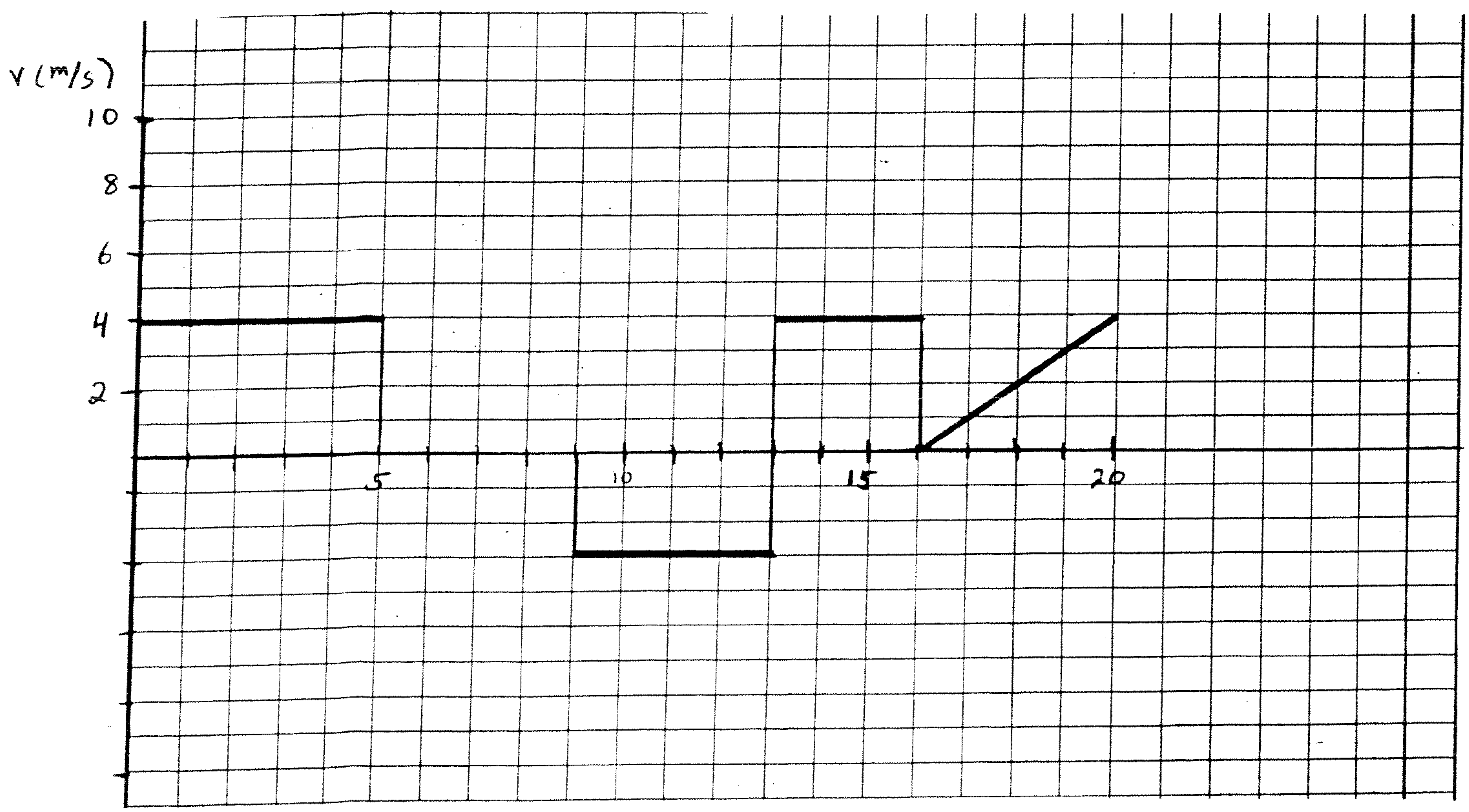
Place the solutions to these problems in the space provided
Good Luck.

1. A subway train accelerates from rest at one station (a = + 1.2 m/s/s) for the first half of the distance to the next station and then decelerates to rest (a = - 1.2 m/s/s)for the final half of the distance. If the stations are 1,100 m apart, find *(a)* the time of travel between stations and (b) the maximum speed of the train.

2. Raindrops fall to earth from a cloud 1700 m above the earth's surface. If they were not slowed by air resistance, how fast would the drops be moving when they strike the ground? Would it be safe to walk outside during a rainstorm?

3. The Zero Gravity Research Facility at the NASA Lewis Research Center includes a 145-m *drop* tower. This is an evacuated vertical tower through which, *among other* possibilities, a 1-m diameter sphere containing an experimental package can be dropped. *(a) For how long is the* experimental package in free fall? (b) What is its speed at the bottom of the tower? (c) At the bottom of the tower, the sphere experiences an average acceleration of *25g as its* speed is reduced to zero. Through what distance does it travel in *coming to* rest?

4. Sketch the x-t graph that corresponds to this v-t graph.



Name Key. Per. ___ date___________

Answer sheet for free response problems
Motion in One Dimension
DiBucci

Directions:
Place your complete solution to each problem in the space provided. Use reverse side if needed. Show All work for full credit.

12 1. A)

I) $a = +1.2\,m/s^2$, $v_0 = 0$, $\Delta x_1 = 550\,m$

$\Delta x_1 = v_0 t + \frac{1}{2}at^2$

$\Delta x_1 = \frac{1}{2}at^2$

$t_I = \sqrt{\frac{2\Delta x}{a}} = 30.27\,s$ (4)

II) $v_f = v_0 + at$

$v_f = 0 + (1.2)(30.27)$

$v_f = 36.3\,m/s \rightarrow v_{0II}$

$v_f = v_0 + at$

$t_{II} = \frac{v_f - v_0}{a} = \frac{0 - 36.3}{-1.2} = 30.25$

$T_{TOTAL} = \boxed{60.52\,s}$ 2

B) $v_f = v_0 + at_I$

$\boxed{v_f = 36.3\,m/s}$ 6

9 2.

$\Delta y = -1700\,m$

$v_f^2 = v_0^2 - 2g\Delta y$

$v_f = -\sqrt{0 - 2(9.8)(-1700\,m)} = \boxed{182.5\,m/s}$ 6 B) $\boxed{NO}$ 1

3. 12

$\Delta y = -145\,m$, $v_0 = 0$

$\Delta y = v_0 t - \frac{1}{2}gt^2$

$\Delta y = \frac{1}{2}gt^2$

$t = \sqrt{\frac{2\Delta y}{g}}$ $\boxed{= 5.43\,s}$ 8

B) $v_f = v_0 + gt$

$v_f = 0 - 9.8(5.43)$

$\boxed{v_f = 53.2\,m/s}$ 8

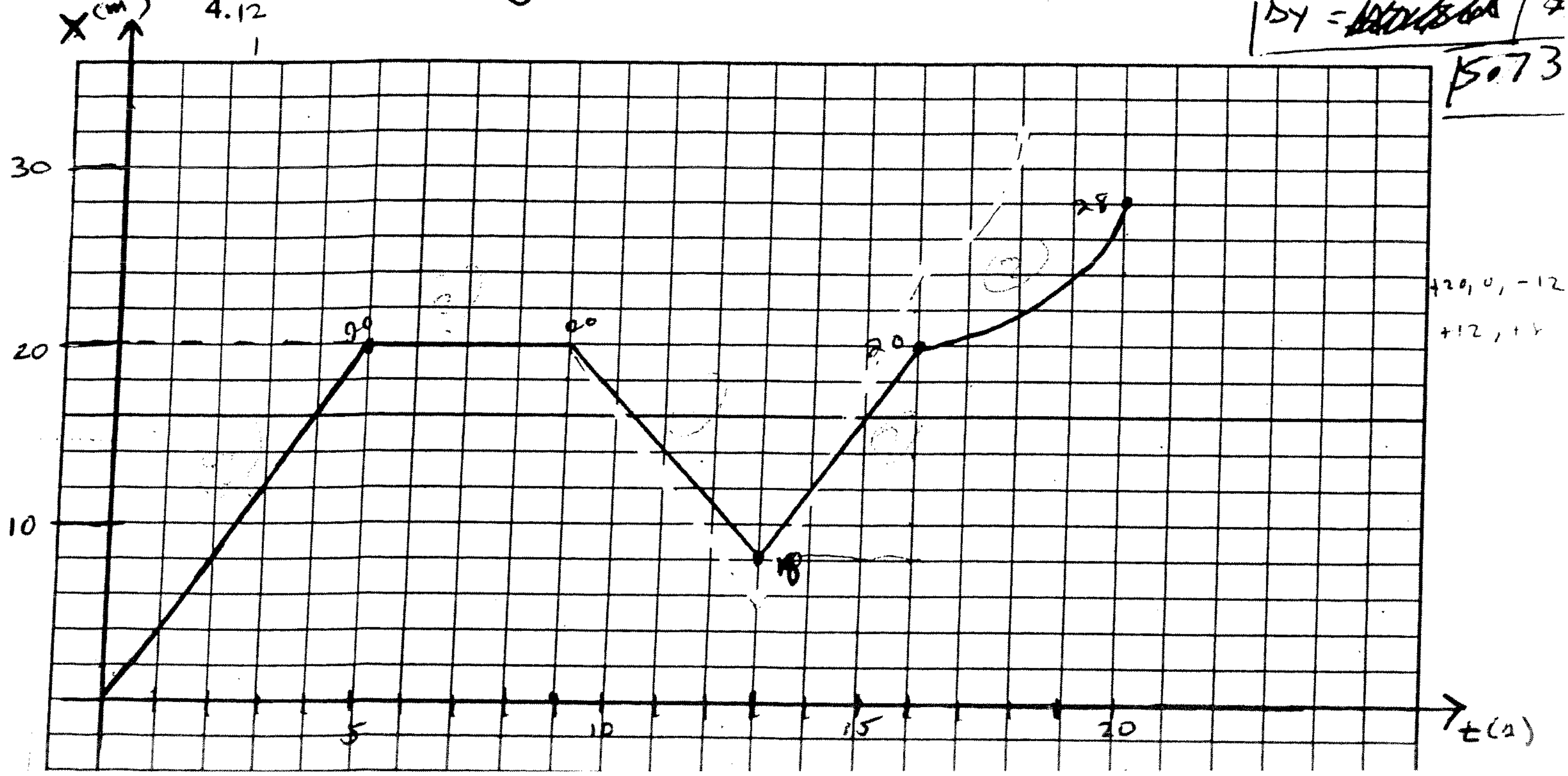
C. $v_f^2 = v_0^2 + 2a\Delta y$

$0 = (53.2)^2 + 2(25)g\Delta y$

$\Delta y = -\frac{(53.3)^2}{2(25)9.8}$

$\boxed{\Delta y = 5.73}$

4. 12



ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2006 and 2007

NEWTONIAN MECHANICS

$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$v^2 = v_0^2 + 2a(x - x_0)$

$\sum \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$

$F_{fric} \le \mu N$

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

$\tau = rF \sin\theta$

$\mathbf{p} = m\mathbf{v}$

$\mathbf{J} = \mathbf{F}\Delta t = \Delta\mathbf{p}$

$K = \frac{1}{2}mv^2$

$\Delta U_g = mgh$

$W = F\Delta r \cos\theta$

$P_{avg} = \frac{W}{\Delta t}$

$P = Fv\cos\theta$

$\mathbf{F}_s = -k\mathbf{x}$

$U_s = \frac{1}{2}kx^2$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$T = \frac{1}{f}$

$F_G = -\frac{Gm_1m_2}{r^2}$

$U_G = -\frac{Gm_1m_2}{r}$

a = acceleration
F = force
f = frequency
h = height
J = impulse
K = kinetic energy
k = spring constant
ℓ = length
m = mass
N = normal force
P = power
p = momentum
r = radius or distance
$\mathbf{r}$ = position vector
T = period
t = time
U = potential energy
v = velocity or speed
W = work done on a system
x = position
μ = coefficient of friction
θ = angle
τ = torque

ELECTRICITY AND MAGNETISM

$F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$

$\mathbf{E} = \frac{\mathbf{F}}{q}$

$U_E = qV = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}$

$E_{avg} = -\frac{V}{d}$

$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$

$C = \frac{Q}{V}$

$C = \frac{\epsilon_0 A}{d}$

$U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$

$I_{avg} = \frac{\Delta Q}{\Delta t}$

$R = \frac{\rho\ell}{A}$

$V = IR$

$P = IV$

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

$F_B = qvB\sin\theta$

$F_B = BI\ell\sin\theta$

$B = \frac{\mu_0}{2\pi}\frac{I}{r}$

$\phi_m = BA\cos\theta$

$\mathcal{E}_{avg} = -\frac{\Delta\phi_m}{\Delta t}$

$\mathcal{E} = B\ell v$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = emf
F = force
I = current
ℓ = length
P = power
Q = charge
q = point charge
R = resistance
r = distance
t = time
U = potential (stored) energy
V = electric potential or potential difference
v = velocity or speed
ρ = resistivity
ϕ_m = magnetic flux

Worksheet
AP Physics B

1. The position-time graph for a particle moving along the x axis is as shown in Figure P2.9. (a) Find the average velocity in the time interval t = 1.5 s to t = 4.0 s. (b) Determine the instantaneous velocity at t = 2.0 s by measuring the slope of the tangent line shown in the graph. (c) At what value of t is the velocity zero?

2. At t = 1.0 s, a particle moving with constant velocity is located at x = − 3.0 m, and at t = 6.0 s, the particle is located at x = 5.0 m. (a) From this information, plot the position as a function of time. (b) Determine the velocity of the particle from the slope of this graph.

3. A particle is moving with a velocity v_0 = 60 m/s at t = 0. Between t = 0 and t = 15 s, the velocity decreases uniformly to zero. What is the average acceleration during this 15-s interval? What is the significance of the sign of your answer?

4. A particle moves along the x axis according to the equation $x = 2.0t + 3.0t^2$, where x is in meters and t is in seconds. Calculate the instantaneous velocity and instantaneous acceleration at t = 3.0 s.
Use $V = 6t + 2$

5. A particle starts from rest and accelerates as shown in Figure P2.19. Determine (a) the particle's speed at t = 10 s and at t = 20 s and (b) the distance traveled in the first 20 s.

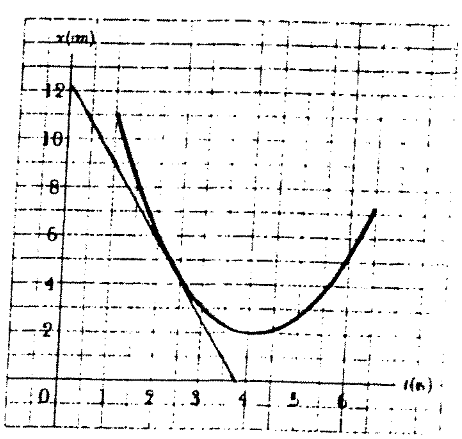


FIGURE P2.9

6. A particle moves along the x axis according to the equation $x = 2.0 + 3.0t - 1.0t^2$, where x is in meters and t is in seconds. At t = 3.00 s, find (a) the position of the particle, (b) its velocity, and (c) its acceleration.
Use $V = 3 - 2t$

7. A student drives a moped along a straight road as described by the speed-versus-time graph in Figure P2.22. Sketch this graph in the middle of a sheet of graph paper. (a) Directly above this graph, sketch a graph of the position versus time, aligning the time coordinates of the two graphs. (b) Sketch a graph of the acceleration versus time directly below the v-t graph, again aligning the time coordinates.

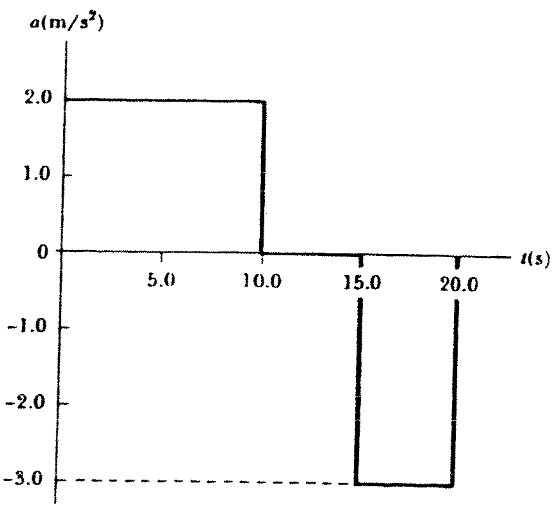


FIGURE P2.19

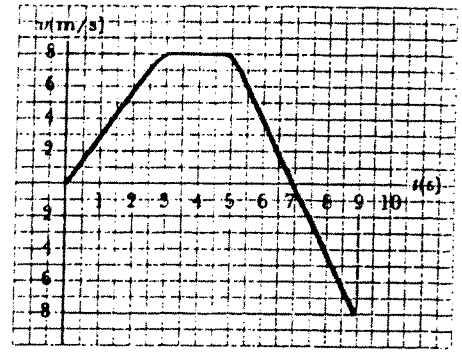


FIGURE P2.22