1. On April 15, 1991, Dr. Rudolph completed the Boston Marathon (26 miles, 385 yards) in a time of 3 hours, 2 minutes, 30 seconds. Later in the summer he ran the Deseret News 10 kilometer race in a time of 38 minutes, 54 seconds. The Boston Marathon is essentially a straight line race from west to east starting in Hopkinton, MA and finishing in downtown Boston. The Deseret News race winds its way from the start near the University and ends at Liberty Park. The finish of this race is in fact 2.40 km due west of the start. Assume Dr. Rudolph's race pace was constant for each race.

A. Determine the average speed in m/s for each race.
B. Determine the average velocity in m/s for each race.
C. If Dr. Rudolph ran the Boston Marathon at the same constant pace he ran the Deseret News 10 kilometer race, what would have been Dr. Rudolph's time at Boston? Express your result as hours, minutes, and seconds.

2. The motion of both cars is along 700 East in Salt Lake City. The origin of the coordinate system for both cars is taken to be at 700 E and 2100 S. You may assume t = 0 is the instant at which the t axis meets the x or v axis in the graphs below. Lastly, positive motion is southward and negative motion is northward. Assume at the initial instant car B is at 2100 south. The position vs. t graph of car A and the velocity vs. t graph of car B are shown below.

A. Describe in words how cars A and B are moving. Be as detailed as you can be. Indicate starting points. Indicate which car(s), if any, are moving with constant velocity or acceleration. State the meaning of point P in both graphs. You may consider t_p the same time in both graphs.
B. On the graph to the right, construct the acceleration vs. t graphs for both cars. Make sure you label which is which.
C. On the x vs. t graph for car A, construct the x vs. t graph for car B.
D. Do the plots of x vs. t for cars A and B intersect? How many times? What do these intersections indicate?

3. A. The situation is this: A police officer in his patrol cruiser is proceeding south along 1300 East at a constant speed somewhat under the speed limit. The following events all occur at the same instant which you will take to be t_o = 0: (a) the officer sees two blocks ahead of him a Dodge Intrepid approaching in the opposite lane at a speed of 30 mph above the speed limit; (b) the cruiser is just crossing the intersection at 1300 East and 3300 South; and (c) the officer gives chase to the speeding Intrepid with uniform acceleration first slowing down, instantly stopping, and turning around, and taking off after the Intrepid, the cruiser's acceleration is constant throughout. Take the intersection of 1300 East and 3300 South as the origin of a one dimensional coordinate system with south pointing negatively, and north as positive. Finally, assume the cruiser catches up to the Intrepid at 1300 East and 800 South.
1. Graph the motions of the cruiser and Intrepid on the graphs provided.
2. In words describe the significance of all points, if any, where the position vs. time plots, the velocity vs time plots, and the acceleration vs. time plots of the motions intersect.
3. Indicate with a mark on the position vs. time plots where (or when) the velocity of the cruiser is equal to the constant speed of the Intrepid.

B. The following are a pair of position (vectors) along the path of motion for an object traveling in two dimensions: \( \vec{r}_1 = (3.00 \, \text{m}) \hat{i} + (-4.00 \, \text{m}) \hat{j} \); \( \vec{r}_2 \); has a magnitude of 10.0 m and makes an angle of 60.0° up from the +x axis.

1. What is the displacement vector \( \Delta \vec{r} \) between the two positions? You may express your answer either as a magnitude and direction or in unit vector form.
2. The time elapsed in going from the first position to the second position was 2.00 s. What is the average velocity during this period of time?
3. On the diagram draw \( \vec{r}_1 \), \( \vec{r}_2 \) and \( \vec{v}_{av} \).

4. Two trains are approaching each other on the same track. The one coming from the left (train A) is traveling at 100.0 km/hr and the one coming from the right (train B) is traveling at 80.0 km/hr. See drawing. When the trains are 3.00 km apart the engineer in train A notices the approaching catastrophe and immediately reverses the wheel rotation in the engine resulting in train A slowing at 2.00 m/s every 5.00 s. Sadly the engineer in train B has suffered a cardiac arrest and his co-engineer is too busy administering CPR to notice the approaching train. Do the two trains collide? You must prove this either way to receive any credit. If the trains do collide, locate where along the track the collision occurs and when the collision occurs after the engineer in train A notices there is a serious problem.
5. Two cars, car 1 and car 2, start from rest on the same track. However, car 2 is 50.0 m ahead of car 1. Both cars take off at the same instant with constant acceleration, with car 1 accelerating at 4.00 m/s\(^2\) and car 2 accelerating at 2.75 m/s\(^2\).

A. How much time does it take for car 1 to reach car 2; and where are the two cars relative to the starting point of car 1?

B. At the instant car 1 reaches car 2, what are the instantaneous velocities of each car?

C. Suppose when car 1 reaches the point calculated in A it ceases accelerating, i.e., car 1 then proceeds with constant velocity. However, car 2 continues on with the same acceleration of 2.75 m/s\(^2\). Which car reaches the 400 m mark first, and at that moment which car is moving faster? No credit will be given for a guess. Work must be shown to receive credit.

6. A police cruiser is proceeding down a long, straight stretch of I-15 at a constant 32.0 m/s when a Miata passes it traveling in the same direction at 48.0 m/s. At the instant the Miata passes the cruiser the Miata’s driver takes her foot off the accelerator pedal and slows down uniformly at 0.800 m/s\(^2\), all the while with her fingers crossed.

A. Draw an appropriate picture, add a coordinate system, and construct a data table with the initial event being the Miata passing the cruiser and the final event being the cruiser catching up to the Miata.

B. How long after the Miata went by the cruiser does the cruiser catch the Miata?

C. How far beyond the initial passing is the second passing of the cruiser and the Miata?

7. A. The Fort Blister 10 kilometer road race is run over a “loop” course. A “loop” course is approximated by a circle in which the starting point is the same as the ending point. A runner by the name of Cecily Swift runs the race in 30.0 minutes.

1. What is her average velocity in meters per second (m/s)?
2. What is her average speed? Express your answer in m/s.

B. Two displacement vectors \(\vec{D}_1\) and \(\vec{D}_2\) are graphed to the right. \(\vec{D}_1\) has a magnitude of 5.0 m and makes an angle of 37° above the x axis. \(\vec{D}_2\) is drawn from the origin to the (x,y) coordinate (4.0 m, -3.0 m).

1. Express \(\vec{D}_2\) in unit vector notation.
2. Express the vector \(\vec{D}_1 + \vec{D}_2\) in terms of magnitude and direction.
3. Express \(\vec{D}_1 - \vec{D}_2\) as a vector in unit vector notation.
C. Two identical air tracks, each inclined from the horizontal, are side by side. See figure. At the same instant of time the glider 1 on track 1 is given a sudden push to send it up track 1 to the right and glider 2 on track 2 is simply released. The left edge of both tracks 1 and 2 are taken to be the origin of the coordinate system. The direction to the right is the positive direction. For the uniformly accelerated motion of each glider sketch x vs. t, v vs. t and a vs. t. Be sure to distinguish the separate glider on each graph.

8. At the initial instant, a car starting from rest and traveling with a constant acceleration of 0.500 m/s² is at the same position as the rear end of a 100 m train. The train is traveling at a constant velocity of 15.0 m/s.

\[
\text{\[100 \text{ m}\] } \quad v_T = 15.0 \text{ m/s} \\
\text{\[a = 0.50 \text{ m/s}^2\] } \quad x_0
\]

A. How far is the car behind the rear end of the train at the instant the train and car have the same velocity.
B. How much time does it take for the car to reach the front of the train?

9. A. The diagram to the right shows the path a jogger takes on a run described as follows. The jogger starts at the point indicated and proceeds 3.00 km along path 1 in 0.500 hrs. She then proceeds an additional 2.50 km in 0.350 hrs along path 2 to point P₂.

1. On the diagram, draw a single vector that represents the net displacement of the jogger for her entire jog.
2. What is this displacement? Remember displacement is a vector.
3. What is the average velocity of the jogger (in km/hr) for her entire trip?
4. Suppose the jogger, after reaching P₂, turns and jogs directly back in a straight line to where she started in 0.600 hrs. What is her average speed for this part of her run?

B. The following graphs display motion behaviors of two different cars A and B traveling along 700 East in Salt Lake City. At \( t_0 = 0 \), car A is at 3300 South and 700 East and Car B is at 2100 South and 700 East. Take 2100 S and 700 E as the origin of your coordinate system. North is the “+” direction.
Finally, it is also known that the two cars pass each other twice, once at 2700 S and 700 E and again at 1300 S and 700 E. If there is any acceleration, assume it is constant.

1. Sketch the position vs. time motion for Car B on graph (a) and the velocity vs. time motion for Car A on graph (b)?
2. What is the meaning of the intersection of the two velocity vs. time plots for Cars A and B in (b)?
3. At the moment the two cars pass for the second time, which car is traveling faster? ___________
4. On the graph to the right, sketch the acceleration vs. time plots for motion of each car.
5. From your sketch in (a) above, give an appropriate location where Car B turns around and starts moving in a direction opposite to its initial motion.

10. At the initial instant \( t_0 = 0 \) two cars, an Acura and an Buick, are proceedings along a straight road to the right as shown below. The Acura is accelerating to the right; the Buick is traveling with a constant velocity of 15.0 m/s and is 50.0 m ahead of the Acura at the initial instant.

\[
\begin{align*}
v_{oA} &= 3.0 \text{ m/s} \\
a_A &= 1.50 \text{ m/s}^2 \\
v_{oB} &= 15.0 \text{ m/s}
\end{align*}
\]

A. After the start, how many seconds does it take the Acura to reach the same velocity the Buick has?
B. After 10.0 s by how many meters is the Buick ahead of the Acura?
C. In how many seconds after the starting instant does the Acura catch up to the Buick?

11. A high performance sports car is proceeding south along a straight stretch of I-15 at 48.0 m/s when the driver notices the flashing lights of a police car behind her. The sports car driver begins braking uniformly at 2.00 m/s\(^2\) until the speed of the sports car is 34.0 m/s, just inside the legal limit for that stretch of road. The police car is traveling at 55.0 m/s towards the sports car and is 600. m behind it when the sports car starts braking.

\[
\begin{align*}
x &= 0 \text{ at } t = 0
\end{align*}
\]

A. How far has the sports car traveled during the braking period and how long did it take the sports car driver to slow from 48.0 m/s to 34.0 m/s?
B. After the braking period, how far behind the sports car is the police car?
C. When the sports car gets to 34.0 m/s, it stops braking and proceeds at a constant 34.0 m/s. After how many additional seconds does the police car catch up to the sports car?
12. A. At the initial instant two cars, an Acura (A) and a Pontiac (B) are seen 150 m apart. The Acura is proceeding to the right at 32.0 m/s while the Pontiac is proceeding to the right at 20.0 m/s. How long does it take for the Acura (A) to catch up to the Pontiac? Relative to where A starts, what is the location of the place A catches up to B?

B. At the initial instant, two cars, a Chevrolet (C) and a Dodge (D) are at the same position. The Chevrolet is moving to the right with a constant speed of 32.0 m/s, and the Dodge starts from rest and moves with a constant acceleration of 3.60 m/s$^2$. See figure. How far from the starting position will both cars be when the Dodge catches up to the Chevrolet? What is the speed of the Dodge when the Dodge catches the Chevrolet?

13. A basketball rolls off the top of a 4 story building with an initial horizontal velocity of 12.6 m/s and strikes the ground 20.0 m vertically below the top of the building.

A. Determine the horizontal distance from the base of the building to the point the basketball strikes the ground.

B. What is the speed of the basketball just before it strikes the ground?

14. A. Two cars, A and B, are traveling along State Street as shown on the position vs. time plot below. On this plot, 2100 South State is the origin and north is the positive x direction. In the blanks below, enter A, B, both or neither that best answer the question posed.

1. _______ Which car is traveling only in the northward direction for the time plotted?
2. _______ Which car is moving more rapidly at the initial instant.
3. _______ Which car momentarily stops and reverses direction?
4. _______ At the instant the two cars have the same velocity, which car is more north?
5. _______ Which car has the greater speed when the two cars pass each other the second time?
6. Mark a point on the horizontal axis representing the instant one of the cars is momentarily at rest. Label the point P.
7. Below draw velocity vs. time and acceleration vs. time plots for each car. Make sure you label the cars on the graph.
B. Vector $\vec{A}$ has a magnitude of 15.0 units and points due north.
Vector $\vec{B}$ has a magnitude of 6.0 units. Circle the correct item in the parentheses.

1. If $\vec{B}$ points north, the vector $\vec{A} + \vec{B}$ has a magnitude that is (greater than, less than, equal to) 15.0 units.
2. If $\vec{B}$ points south, the vector $\vec{A} + \vec{B}$ has a magnitude that is (greater than, less than, equal to) 15.0 units.
3. If $\vec{B}$ points south, the vector $\vec{A} - \vec{B}$ has a magnitude that is (greater than, less than, equal to) 15.0 units.
4. If $\vec{B}$ points due east, the vector $\vec{A} + \vec{B}$ has a magnitude that is (greater than, less than, equal to) 15.0 units.
5. If $\vec{B}$ points due west, the vector $\vec{A} - \vec{B}$ has a magnitude that is (south of west, east of north, west of north).

15. A. Three vectors, $\vec{A}$, $\vec{B}$, and $\vec{C}$ are shown in drawing.

1. On the drawing, show the vector sum $\vec{D} = \vec{A} + \vec{B} + \vec{C}$ using the head-to-tail approach.
2. Determine the x and y components of the sum vector $\vec{D}$.
3. Express $\vec{D}$ in magnitude-direction form or in unit vector notation.

B. A couple walks one-quarter of the way around a circular lake whose radius is 1.80 km. They start at the north point on the lake and proceed clockwise. They require 45.0 minutes to complete this partial trip around the lake. Note: The circumference of a circle is $2\pi R$ where $R =$ radius.

1. What is the average speed of the couple (in km/hr)?
2. What is the magnitude of the average velocity of the couple (in km/hr)?

16. A police car is sitting at an intersection when a car goes speeding past it at a constant speed of 32.0 m/s. The officer waits 4.00 s to make sure there is no other traffic near the intersection and then takes off after the speeder at a constant acceleration of 4.80 m/s$^2$.

A. How much time does it take the police officer to reach the same speed as the speeder from the instant the police car starts accelerating?
B. How much time elapses between when the officer starts accelerating and when she catches up to the speeder?
C. How far does the officer’s car travel from the intersection to the point when she catches the speeder?

17. A police car is traveling at a velocity of 20.0 m/s due south on I-15 when a roadster zooms by at a constant velocity of 45.0 m/s. After the roadster passes the police car it takes the policeman 2.00 s to check the speed of the roadster on his radar gun and hit the accelerator. The police car then takes off after the roadster at a constant 5.00 m/s$^2$ acceleration.

A. Setting $t_i = 0$ at the instant the police car starts accelerating and $x_i$ (police car) = 0, how long does it take the police car to catch the roadster?
B. How far did the police car travel from the moment the policeman hit the accelerator to the instant
the police car caught the roadster?

C. At the instant the police car caught the roadster, what was the velocity of each vehicle?
18. A basketball player standing on the floor is 14.0 m (L) from the basket as shown in the figure. The player shoots the basketball with an initial speed of $v_0 = 12.2$ m/s at an angle of $\theta = 43.0^\circ$ above the horizontal. The shot is a “swish” through the basket.

A. How long does it take for the ball to go from the hands of the player until it reaches the basket?
B. What is the highest point above the floor the basketball reaches?
C. How fast is the ball traveling when it reaches to the basket?

19. A. Examine the vectors $\vec{A}$ and $\vec{B}$ in the plot below.

1. On the plot above draw the vector $\vec{C} = \vec{A} - 2 \vec{B}$.
2. Express $\vec{C}$ in unit vector notation.
3. Express $\vec{C}$ in magnitude and direction form.

B. The position vs time graph to the right shows the motion of two cars, A and B, traveling along a flat, horizontal section of 900 East in Salt Lake City. Take north to be the positive direction with the origin located at 2100 South and 900 East. If there is an acceleration depicted, assume it is constant. In the blanks spaces below, enter A, B, both, neither or cannot tell to best respond to the questions.

1. The car traveling with a constant positive velocity.
2. The car traveling with a constant positive acceleration.
3. The car with the larger positive velocity at the initial instant.
4. The car that momentarily stops and turns around.
5. The car that is initially north of 2100 South.
6. The car with zero acceleration.
7. On the horizontal axis mark the point and label it T, that represents the instant of time both cars have the same velocity.
8. On the curve for car B, mark the point, label it with C, that represents the point where B has zero velocity.

20. In a recent movie a car drives off the top of a parking structure and lands near the base as shown in the drawing. Assume the car drives off the structure with a horizontal velocity of $v_x = 28.0$ m/s and the building is $H = 36.0$ m high.

A. How far from the base of the structure, x, will the car be when it strikes the ground?
B. What is the speed of the car just prior to smashing into the ground?
21. At \( t_0 = 0 \) the front of a car is even with the back end of the train. The car travels with a constant velocity of 24.0 m/s in the direction shown. The train starts from rest and proceeds with an acceleration of 1.40 m/s\(^2\).

A. At what **earliest** instant after \( t_0 = 0 \) is the front of the car even with the front end of the train?  
B. At what location (position) does this occur?  
C. After how many seconds past \( t_0 = 0 \) will the front of the car once again be even with the rear end of the train?  
D. What is the distance between the front of the car and the front of the train at the instant the car and train have identical velocities? 

22. A. Three cars, A, B, and C are traveling along State Street in Salt Lake City. Take the intersection of 2100 South and State Street as the origin of a 1-D coordinate direction. The position vs. time plots of the three cars is shown in the drawing. If there is acceleration, assume the acceleration for that car is constant. For the statements below, enter the best answer (A, B, C, none, or all).

1. The car located at 2100 South and State Street at \( t_0 \).  
2. The car that starts from rest at \( t_0 = 0 \).  
3. The car that travels with a constant positive velocity.  
4. The car whose acceleration is negative.  
5. The car that is traveling south on State Street during some portion of it motion.  
6. The car with the largest speed at \( t_0 = 0 \).  
7. The car traveling with a constant negative velocity.  
8. At time \( t_1 \) the car moving most slowly.  
9. The car whose acceleration is positive.  
10. At \( t_4 \) the car whose velocity is momentarily zero.

B. GPS unit locates a surveying team at a position of 5.0 km from the base camp at an angle of 37° north of east of the base camp.

1. On the coordinate system shown, draw the position vector of the surveying team.  
2. Express this position vector using unit vector notation.  
3. The surveying team executes a displacement due west until the team’s new location is due north of the original base camp. Draw this displacement vector.  
4. Express the new position of the surveying team relative to the original base camp in both magnitude and direction form and unit vector form.
23. A lioness is loping along at 1.50 m/s in some deep grass when a gazelle races past at a constant 15.0 m/s. It takes the lion’s brain 2.00 s to register the notion that dinner just went by. At that moment the lioness takes off after the gazelle with a constant acceleration of 2.24 m/s². Assume both the lion and gazelle run in a straight line.

A. At the instant the lioness begins accelerating, how far is the gazelle from the lioness?
B. Take the initial instant \( t_i = 0 \) as the moment the lioness begins her acceleration, and the origin of your 1-D coordinate system as the location of the lioness at \( t_i \). How long does it take the lioness to reach the gazelle?
C. How far does the lioness run from the origin until it reaches the gazelle?

24. In an attempt to score a goal in soccer, a forward launches a kick 30.0 m in front of the goal with a launch velocity of 18.0 m/s making an angle of 37.0° above the horizontal. The goal bar is 2.44 m above the ground.

A. How long does it take for the ball to reach the goal after being kicked?
B. How high above the ground is the ball when it crosses the goal line?
C. What is the speed of the ball at the instant the ball crosses the goal line?