AP Physics C: Mechanics
Unit 1 Practice Exercises

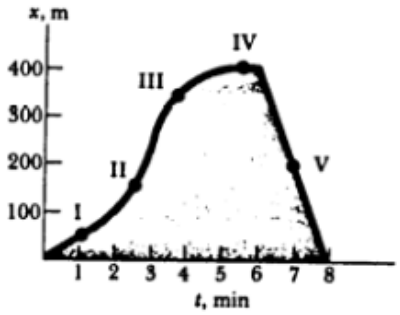
Directions: Show the steps required to arrive at the answer (if applicable). Use g = 9.80 m/s^2 and neglect air resistance unless otherwise stated. Work out the problems on separate page.

1.1 – One Dimensional Motion

1. If the average velocity of an object is zero in some time interval, can you conclude that both the i) displacement and ii) distance are also zero in the time interval? Justify your answer.

2. If a car is traveling eastward, can its acceleration be westward? Justify your answer.

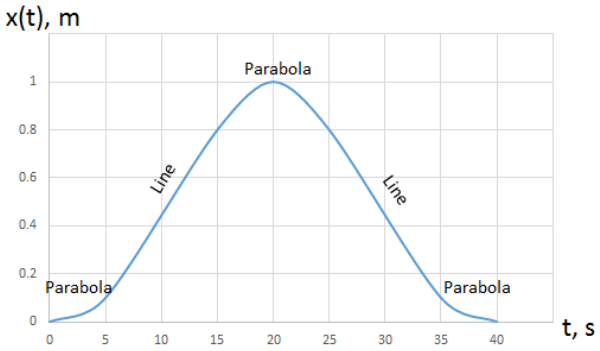
3. A student leaves home and walks along the sidewalk towards the bus stop. After 5 minutes, the student realizes he forgot to do his physics homework and returns home to call in sick. The student's distance from his house as a function of time is shown in the figure on the right.



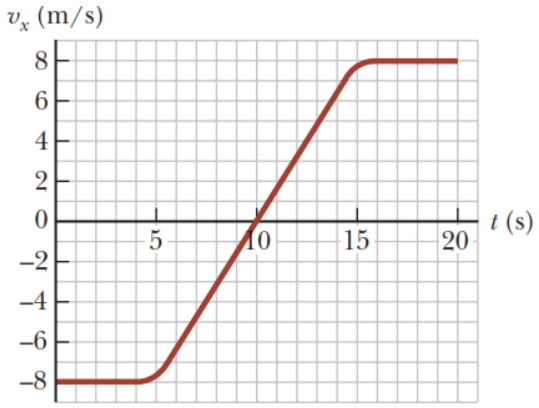
a) At which of the points is his velocity:
   i) constant and positive? ii)constant and negative?
   iii) decreasing in magnitude? iv) increasing in magnitude?

b) At which points is the acceleration:
   i) positive? ii) negative? iii)zero?

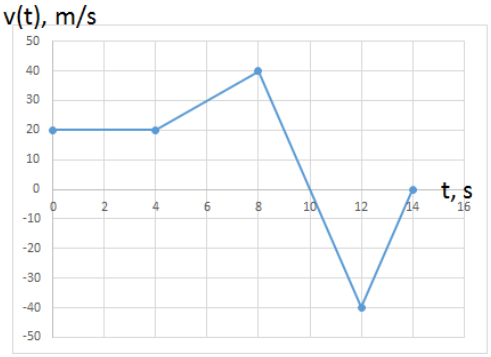
4. Given the position vs. time graph below, construct: graphs of: a) $v(t)$ b) $a(t)$



5. Given the velocity vs. time graph below and that, $x(0) = 5$, construct graphs of: a) $x(t)$ b) $a(t)$



6. The graph on the right shows the velocity of a motorcycle as a function of time.



   a) What is the average acceleration over the 14 s?
   b) Sketch the acceleration vs. time graph.
   c) Sketch the position vs time graph. x(0) = 0
   d) During what interval(s) is speed increasing?
   e) During what interval(s) is speed decreasing?
   f) When is the motorcycle at rest?

7. A car moving with constant acceleration travels 60 m in 6 seconds. Its velocity at the end of the 6 seconds is found to be 15 m/s.
   a) What was the initial velocity of the car?
   b) What is the magnitude of the car's acceleration?

8. A subway train starts from rest at City Hall Station and accelerations at a rate of 2 m/s^2 for 10 s. It runs at constant speed for 40 s, then decelerates with a magnitude of 4 m/s^2 until it stops at Seoul Station. Find the total distance covered.

9. A racecar starts from rest, moves with constant acceleration in a straight line, and covers 64 m in 4 s.
   a) What is the final velocity of the racecar?
   b) When is the racecar's instantaneous velocity equal to its average velocity?
   c) What distance does the racecar cover in one-half the time interval?
   d) What is the velocity of the racecar when one-half the distance has been covered?

10. Starting from rest, a charger charges 50.0 m in straight line in 10.0 s with constant acceleration. The final speed of the charger is measured to be 8.00 m/s. Explain why this measurement cannot possibly be correct.

11. An object's velocity is given by $v(t) = 4\frac{m}{s} - (5\ \frac{m}{s^3})t^2$. At time t = 0, the object is at x = 0.
   a) Find the position of the object as a function of time.
   b) Find the acceleration of the object as a function of time.
   c) What is the object's maximum displacement from the origin?

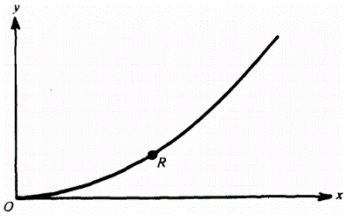
12. A particle moves along a straight line with motion described by the function:

$$x(t) = (6\ m) + \left(5\ \frac{m}{s^2}\right)t^2 - (1\frac{m}{s^4})t^4$$

   a) Find the position, velocity, and acceleration of the object at t = 3 s.
   b) During what time interval is the velocity positive?
   c) What is the maximum velocity obtained by the particle?

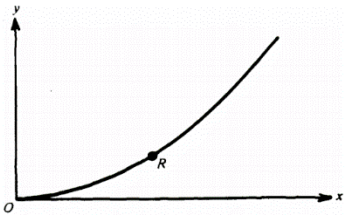
13. The acceleration of a city bus is given by $a(t) = 1\frac{m}{s^2} + (2\ \frac{m}{s^3})t$.
   a) If the bus's velocity after 1 s is 6 m/s, what is its velocity after 2 s?
   b) If the bus moves 8 m in 1 s, how far does it move in 3 s?

14. A particle moves along the parabola with equation $y = \frac{1}{2}x^2$ shown on the right.



a) Suppose the particle moves so that it has constant x velocity, $v_x = C$ and $x = Ct$
   i. On the diagram, indicate the direction of the particle's velocity and acceleration vectors.
   ii. Determine the y-component of velocity as a function of time.
   iii. Determine the y-component of acceleration as a function of time.

b) Suppose, instead, that the particle moves along the same parabola, but with an x-component of velocity given by $v_x = \frac{C}{\sqrt{1+x^2}}$



   i. Show that the particle's speed is constant in this case.
   ii. On the diagram on the right, indicate the direction of the particle's velocity and acceleration vectors. Justify your answer.

15. As soon a traffic light turns green, a car speeds up from rest to 20 m/s with constant acceleration of 2 m/s. In the adjoining bicycle lane, a cyclist speeds up from rest to 10 m/s with constant acceleration of 5 m/s. Each maintains constant velocity after reaching their respective cruising speeds.
   a) For how long is the cyclist ahead of the car?
   b) How far does the car travel before it catches up to the cyclist?
   c) What is the maximum distance by which the cyclist leads the car?

1.2 – Free Fall

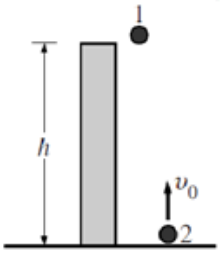
1. Ash Ketchum throws a Pokeball directly in the air to reach a height of 15 m to catch a particularly kawaii Emolga.
   a) With what velocity does the Pokeball need be thrown in order to reach 15 m?
   b) How long will the Pokeball be in the air?

2. A beet is dropped and hits the ground after falling for a time, t.
   a) How far did the beet fall?
   b) What is the velocity of the beet just before it hits the ground?

3. A ball is thrown vertically upward with a velocity of 20 m/s from the top of a building 40 m.
   a) How high above the ground does the ball rise?
   b) How long after being thrown will the ball have a velocity of 10 m/s downward?
   c) How does the ball's acceleration compare when i) moving upward, ii) moving downward, and iii) and at its max height?
   d) At what time is the displacement of the ball zero?
   e) The ball hits the ground below the building. With what speed does it strike the ground?

4. The height of a helicopter above the ground is given by $h(t) = 3.00t^3$, where h is height in meters and t is in seconds. At t = 2.00 s, the helicopter releases a package.
   a) How long does it take the package to reach the ground?
   b) What is the height of the helicopter when the package lands?
   c) Write a function to express the velocity, v(t) of the package while it is in the air.
   d) Write a function to express the height, y(t) of the package while it is in the air.

5. Ball 1 is dropped from rest at time t = 0 from a tower of height h, as shown in the diagram below. At the same time, ball 2 is launched upward from the ground with speed v_0. At what time will the balls pass each other?

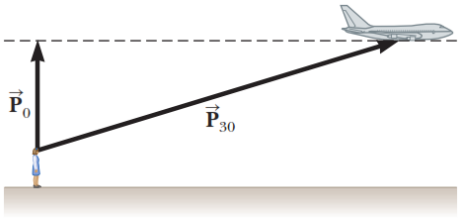


6. An experimental aircraft is accelerating upward at 12 m/s^2. At time t = 0, the altitude of the rocket is 10,000 m and its upward velocity is 30 m/s. The pilot jumps from the aircraft at time t = 0 and opens his parachute when he is 3000 m above the ground.
   a) How long after jumping does the pilot open his parachute?
   b) How fast is the pilot moving when his parachute opens?
   c) At time t = 5 s, how far below the aircraft is the pilot?
   d) What is the maximum height reached by the pilot?
   e) The pilot lands on the ground 60 s after ejecting from the airplane. What is his average acceleration when his parachute is open?

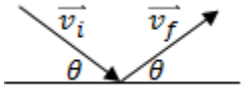
1.3 – Vectors

1. You are standing on the ground at the origin of a coordinate system. An airplane flies over you with a constant velocity parallel to the x-axis and at a fixed height of 9200 m. At time t = 0, the position vector leading from you to the airplane is $\overrightarrow{P_0} = 9200\hat{j}\ m$. At time t = 30.0 s, the position vector leading from you to the airplane is $\overrightarrow{P_0} = (8400\hat{\imath} + 9200\hat{j})\ m$.

a) Determine the magnitude and direction of the airplane's position vector at t = 45.0 s.
b) Write the velocity and acceleration vectors for the airplane.



2. A particle approaches a surface at 5.0 m/s and is reflected as shown with $\theta = 50°$. The particle is in contact with the surface for .05 s.



a) Draw the acceleration vector for the particle while in contact with the surface.
b) What is the magnitude and direction of the particle's acceleration while in contact with the surface?

3. A particle's position is given by $\vec{r} = \begin{pmatrix} 4t \\ 1 - 3t \end{pmatrix}$, where displacement is in meters and time is in seconds.

a) What is the particle's position at t = 2.0 s?
b) What is the particle's velocity at t = 2.0 s?
c) What is the particle's speed at a t = 2.0 s?
d) What angle does the particle's velocity make with the horizontal at t = 2.0?
e) What is the minimum distance between the particle and the origin?

4. A frightened war eagle flies away from an alligator with a velocity vector given by:

$$\vec{v}(t) = (3 - 2t^2)\hat{\imath} + (4t^2)\hat{j}$$

where velocity is given in m/s and time is measured in seconds. At time = 0, the eagle is at the origin.

a) Calculate the eagle's position vector.
b) Calculate the eagle's velocity vector.
c) What is the eagle's altitude when it flies over the origin for the first time after t = 0 s?

5. A Space-X test rocket moves with acceleration given by: $\vec{a}(t) = (3t^2)\hat{\imath} + (10 - 2t)\hat{j}$. At time t = 0, the rocket is at the origin and has initial velocity $\overrightarrow{v_0} = 2\hat{\imath} + 6\hat{j}$.

a) Calculate the velocity of the rocket as a function of time.
b) Calculate the position of the rocket as a function of time.
c) What is the maximum height of the rocket?
d) How far away from the origin does the rocket hit the ground?

1.4 – Relative Velocity

1. An airplane pilot wishes to fly due north. A wind of 96 km/h is blowing due west.

a) The airplane flies 290 km/h relative to still air. In which direct should the plane head?
b) What is the velocity of the plane relative to the ground?

2. A river flows due north with a velocity of 2 m/s. A man rows a boat across the river; his velocity relative to the water is 3 m/s due east; the river is 1000 m wide.

a) What is the velocity of the man relative to earth?
b) How far north of his starting point will the man reach the opposite bank?

1.5 – Projectile Motion

1. A textbook slides off a horizontal desktop with a speed of 4 m/s. It is observed to strike the floor 0.5 s later.
   a) Find the height of the desktop above the floor.
   b) Find the horizontal distance the textbook travels.
   c) Find the angle the textbook makes with the ground when it strikes.

2. A projectile is fired in such a way that its horizontal range is equal to three times its maximum height. What is the angle of projection?

3. A golf ball is shot at angle of 60° above the horizontal and strikes a building 30 m away at a height of 15 m above the ground.
   a) Find the initial velocity vector of the golf ball.
   b) Find the velocity vector of the golf ball when it hits the building.

4. An artillery shell is fired with an initial speed of 200 m/s. The projectile's velocity initially makes an angle of 35° with the horizontal. The plane of the projectile's trajectory is perpendicular to a vertical cliff. The base of the cliff is 2500 m from the place where the shell was fired.
   a) How far above the base of the cliff does the shell strike?
   b) How long does it take the shell to reach the cliff?
   c) What is the shell's maximum height?
   d) With what speed does the shell strike the cliff?
   e) What angle does the shell make with the cliff when it strikes?

5. Caleb Sturgis kicks a football at an angle of 30° above the ground with an initial speed of 15 m/s. Return man Devin Hester is standing 35 m from away in the direction of the kick and starts running to the meet the ball the instant it's kicked. How fast must Devin Hester run in order to catch the ball just before it hits the ground?

6. A shoe is thrown horizontally from the roof of a 100 m tall building. At the same time, another shoe is dropped from rest at the top of the building. The shoes land 50 m apart on the ground. With what velocity was the first shoe thrown?

7. The speed of a projectile when it reaches its maximum height is one-half its speed when it is at half its maximum height. What is the initial projection angle of the projectile?

*8. A projectile if fired up an incline, which makes an angle $\emptyset$ with the horizontal. The projectile is fired at speed $\vec{v}$ and at angle θ with the *horizontal* as shown below ($\theta > \emptyset$). Find the distance d, the projectile travels up the incline in terms of givens and fundamental constants.