Exam 1 Solutions

Instructions

- Write your name on this test booklet.
- You are allowed a writing utensil, a calculator, and the PHY 201 formula sheet.
- You will have 110 minutes to complete this exam.
- Good luck!

Problem 1

(25 points) A fly is buzzing around a room in an erratic path. It starts at the point (1.0 m, 0.0 m, 0.0 m) and moves with a velocity of (2.0 m/s, 2.0 m/s, 0.0 m/s) for two seconds. Then, it suddenly switches direction and flies with a velocity of (-1.0 m/s, -1.0 m/s, 1.0 m/s) for three seconds. You can assume that the fly starts moving at time t = 0.0 seconds.

- (2 points) Sketch a diagram showing the path of the fly.

https://www.math3d.org/5LkYiagao

- (4 points) What is the final position of the fly after it finishes the two legs of its journey?

$$\begin{bmatrix} 1.0m \\ 0.0m \\ 0.0m \end{bmatrix} + (2sec) \begin{bmatrix} 2.0m/s \\ 2.0m/s \\ 0.0m/s \end{bmatrix} + (3sec) \begin{bmatrix} -1.0m/s \\ -1.0m/s \\ 1.0m/s \end{bmatrix} = \begin{bmatrix} 2.0m \\ 1.0m \\ 3.0m \end{bmatrix}$$

- (4 points) What is the displacement of the fly after it finishes the two legs of its journey?

$$\vec{x}_f - \vec{x}_o = \begin{bmatrix} 2.0m \\ 1.0m \\ 3.0m \end{bmatrix} - \begin{bmatrix} 1.0m \\ 0.0m \\ 0.0m \end{bmatrix} = \begin{bmatrix} 1.0m \\ 1.0m \\ 3.0m \end{bmatrix}$$

- (4 points) What is the average velocity of the fly after it finishes the two legs of its journey?

Average velocity is displacement divided by time.

$$\vec{v}_{avg} = \frac{1}{5sec} \begin{bmatrix} 1.0m \\ 1.0m \\ 3.0m \end{bmatrix} = \begin{bmatrix} 0.2m/s \\ 0.2m/s \\ 0.6m/s \end{bmatrix}$$

- (4 points) What is the instantaneous velocity of the fly at time t = 4.0 seconds?

$$\vec{v} = \begin{bmatrix} -1.0m/s \\ -1.0m/s \\ 1.0m/s \end{bmatrix}$$

- (4 points) What is the magnitude of the velocity of the fly at time t = 1.0 second?

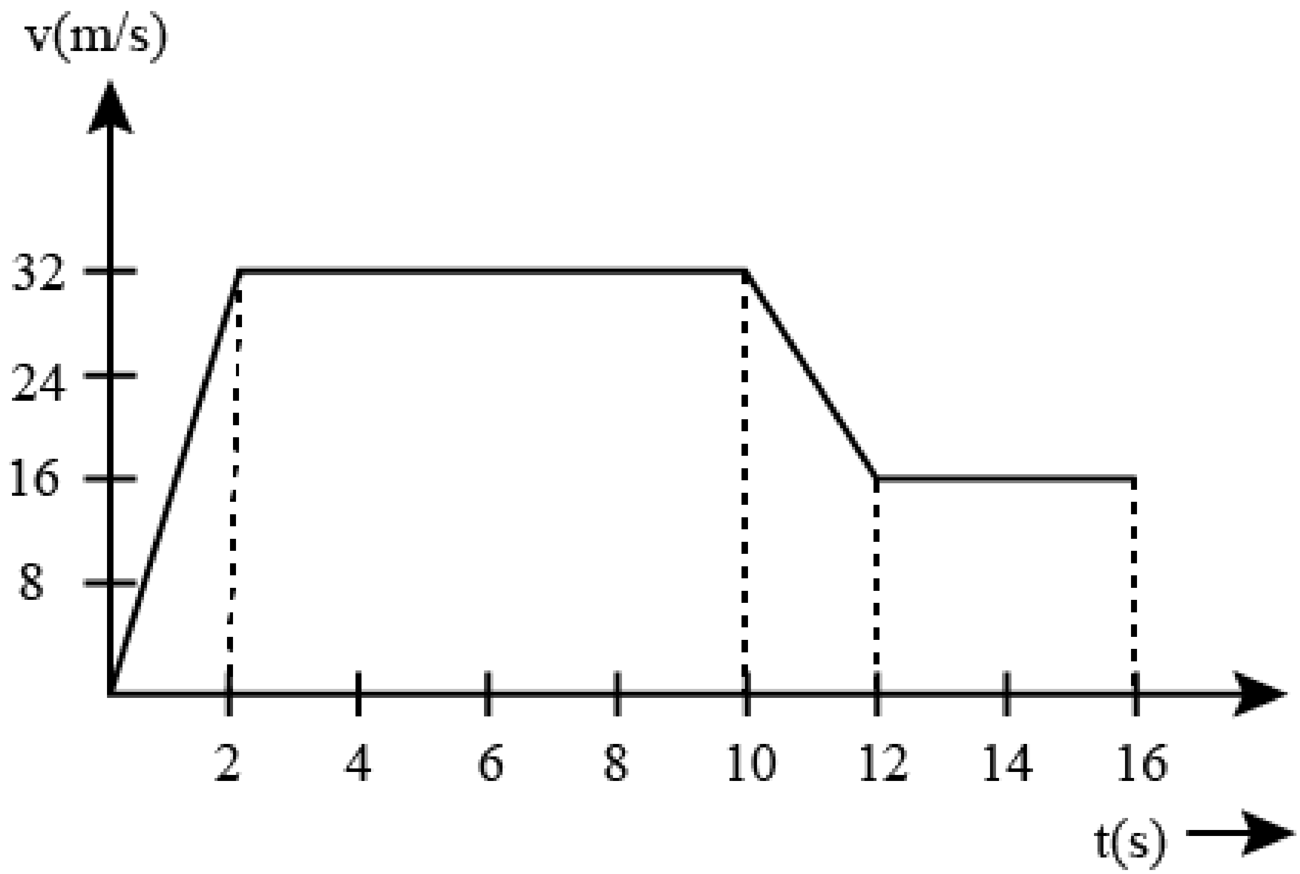
$$|\vec{v}| = \sqrt{2.0^2 + 2.0^2 + 0.0^2} = \sqrt{8} \approx 2.83m/s$$

- (3 points) Where in the flight does the fly experience non-zero acceleration? How do you know?

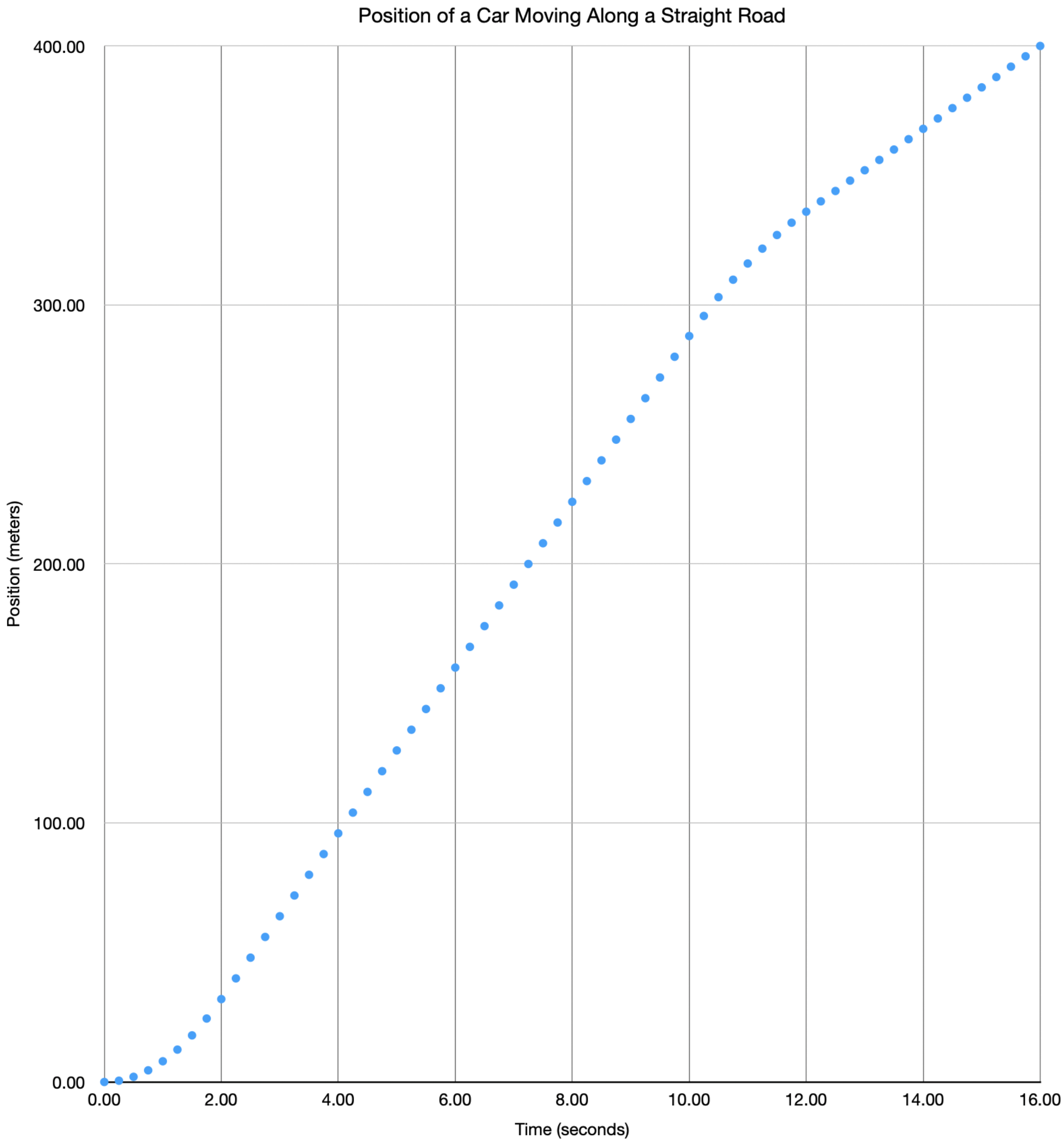
It experiences a non-zero acceleration at times t = 0 sec and t = 2 sec since that is where it changes velocity.

Problem 2

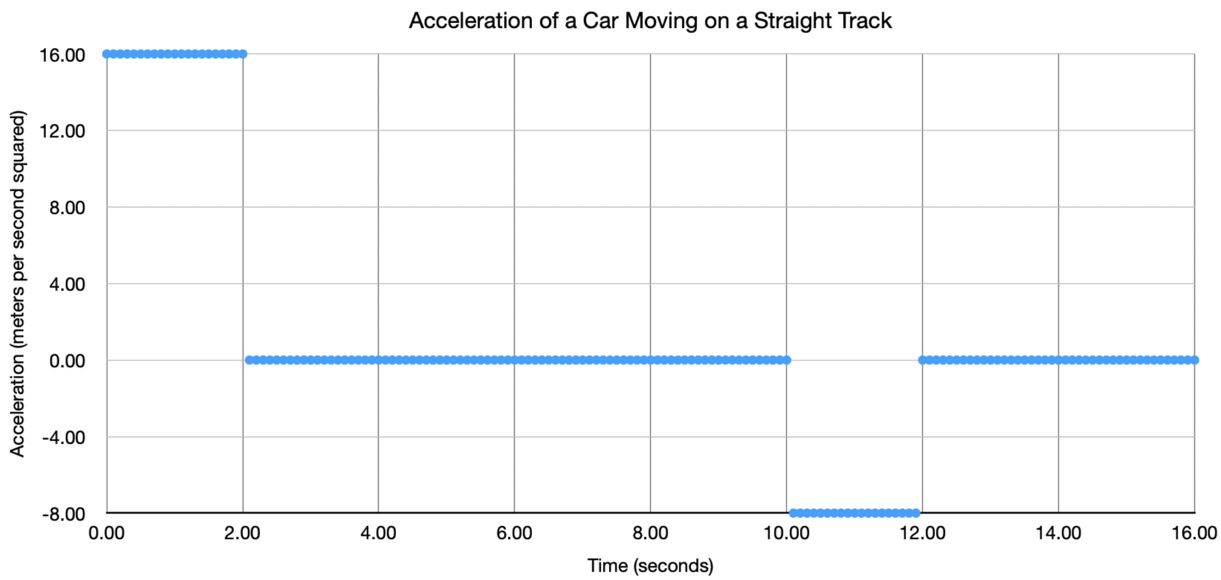
(25 points) A velocity vs time graph for a car moving on a straight road is given below. The car has a mass of 1200 kg. You can assume that the car starts at position $\vec{x}$ = 0.0 m.



- (10 points) Sketch out a position vs. time graph for the car. Be sure to label each axis and all of the times / positions on the graph.



- (4 points) Sketch out an acceleration vs. time graph for the car. Be sure to label each axis and all of the times / accelerations on the graph.



- (4 points) During which time period(s) does the car experience a maximum net force?

The car experiences a maximum net force when it experiences a maximum net acceleration since $\vec{F} = m\vec{a}$. This occurs where the slope on the velocity vs. time graph is maximal. This happens in the time period from zero to two seconds.

- (4 points) During which time period(s) does the car experience no net force?

The car experiences zero net force when it experiences zero net acceleration since $\vec{F} = m\vec{a}$. This occurs where the slope on the velocity vs. time graph is zero. This happens in the time periods from two to ten seconds and twelve to sixteen seconds.

- (3 points) Calculate the maximum force on the car.

$$\vec{F} = m\vec{a} = (1200kg)(16m/s^2) = 19200N$$

Problem 3

(25 points) A ball rolls off of an 0.80 m tall table with an initial horizontal velocity of 2.0 m/s.

- (4 points) How long does it take for the ball to hit the ground?

Motion along the y-axis:

$$y_f = y_o + v_{oy}t + \frac{1}{2}a_y t^2$$

$$0 = 0.8m + 0 + \frac{1}{2}(-9.8m/s^2)t^2$$

$$-0.8m = (-4.9m/s^2)t^2$$

$$t \approx 0.40s$$

- (4 points) How far from the table does the ball land?

$$x_f = x_o + v_{ox}t + \frac{1}{2}a_x t^2$$

$$x_f = 0 + (2.0m/s)(0.40s) + 0$$

$$x_f \approx 0.80m$$

- (5 points) What is the final velocity of the ball?

$$v_{fx} = v_{ox} + a_x t = v_{ox} + 0 = 2.0m/s$$

$$v_{fy} = v_{oy} + a_y t = 0 + (-9.8m/s^2)(0.4s) \approx -3.92m/s$$

$$\vec{v}_f \approx \begin{bmatrix} 2.0m/s \\ -3.9m/s \end{bmatrix}$$

- (4 points) At what angle does the ball strike the ground?

You can use the components of the velocity to determine θ:

$$tan(\theta) = \frac{-3.9}{2.0}$$

$$\theta \approx -62.9^{\circ}$$

I would also accept a positive answer if you drew a diagram and labeled the angle θ.

- (4 points) Would it take more, less, or the same amount of time for the ball to hit the ground if the table was taller? Why?

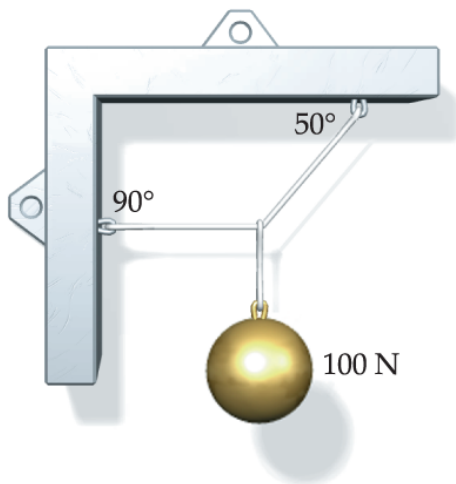
It would take more time - you are increasing the initial height y_o in $y_f = y_o + v_{oy}t + \frac{1}{2}a_y t^2$. This means that the time to fall would be greater, assuming all other variables are kept constant.

- (4 points) Would it take more, less, or the same amount of time for the ball to hit the ground if we conducted this experiment on the moon where the acceleration due to gravity is lower? Why?

It would take more time - you are decreasing the acceleration along the y-axis a_y in $y_f = y_o + v_{oy}t + \frac{1}{2}a_y t^2$. This means that the time to fall would be greater, assuming all other variables are kept constant.

Problem 4

(25 points) A ball with a weight of 1.0×10^2 N hangs from two ropes as shown in the diagram below.



Tipler & Mosca, *Physics for Scientists and Engineers*, 6e © 2008 W.H. Freeman and Company

- (5 points) What is the tension in the vertical rope connected to the ball?
- (8 points) What is the tension in the horizontal rope?
- (8 points) What is the tension in the rope at an angle of $50°$ with the ceiling?

In this problem, we don't give you the mass of the ball. Instead, we give you the weight. The tension in the vertical rope is just equal to the weight of the ball. If we draw a free-body diagram for the ball itself, we get:

$$\sum F_y = T_{vertical}(+\hat{y}) + (100N)(-\hat{y})$$

$$T_{vertical} - 100N = 0$$

$$T_{vertical} = 100N$$

Now, we can draw a free-body diagram for the point where the three ropes are tied together

$$\sum F_y = T_{vertical}(-\hat{y}) + T_{50^\circ} sin(50^\circ)(+\hat{y}) = 0$$

$$T_{50^\circ} sin(50^\circ) - T_{vertical} = 0$$

$$T_{50^\circ} sin(50^\circ) - (100N) = 0$$

$$T_{50^\circ} = \frac{100N}{sin(50^\circ)} \approx 130.5N$$

$$\sum F_x = T_{horizontal}(-\hat{x}) + T_{50^\circ} cos(50^\circ)(+\hat{x}) = 0$$

$$T_{50^\circ} cos(50^\circ) - T_{horizontal} = 0$$

$$T_{horizontal} = (130.5N) cos(50^\circ) \approx 83.9N$$

- (4 points) Which of the three ropes would you expect to snap first if I increase the mass of the ball? Why?

The rope at an angle of 50° is carrying the largest tension of the three ropes for a given weight. Assuming the ropes are identical, that one will reach its breaking point first as you increase the hanging weight.