

All questions on this examination are open to your textbook, the Activity Guide, and other written material and notes that *you* generated during the course. You may also use an electronic calculator and at times you may be required to use one of the computers to perform analyses and make calculations. The examination is *not* open to books other than the textbook, published exam or homework solutions, and other people's ideas. You may not work with or gain assistance from anyone except your instructor. *To get full credit you must explain all your reasoning carefully, unless otherwise stated.*

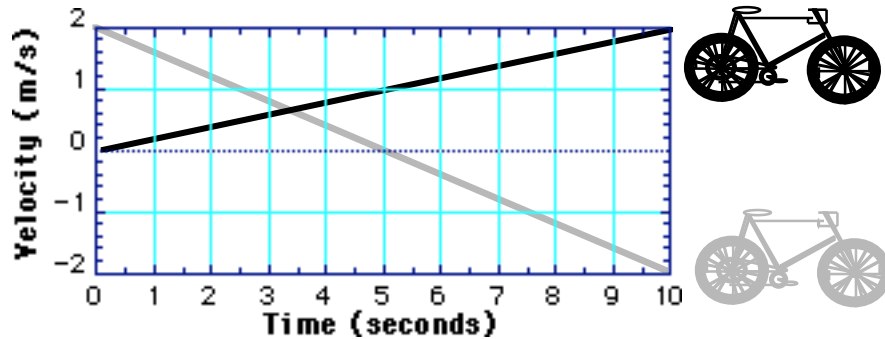
I promise that I have worked on this exam alone. I have not received assistance from nor given assistance to any other person. I have not used any materials on this exam other than those allowed.

Signed _____

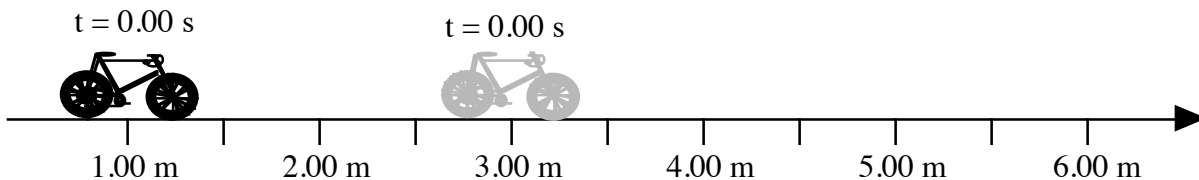
Problem #	Score
1. Graphs (5)	
2. Graphs (5)	
3. Graphs (5)	
4. Graphs (5)	
5. Graphs (20)	
6. Kinematics (15)	
7. Measurement (20)	
8. Measurement (10)	
9. Modeling (25)	
Total Score	

Part I: Representing Motion with Graphs, Words, Pictures, and Equations

A couple of ultrasonic motion detectors are set up to track the motion of two bicycles to three significant figures in both time and distance measurements. Using the data obtained from the motion detectors the following velocity vs. time graphs were created for a black and a gray bicycle that are traveling on the same road.



The initial positions of the center of each bicycle at time $t = 0.00$ s are shown in the diagram below.



NOTE: The problems based on this scenario do not depend on each other. If you can't get one part, go on to the next!

1. (5 pts)

- (a) Which graph or graphs depict the velocity increasing with time? (The black graph, the gray graph, both, or neither?)

- (b) Which graph or graphs depict a velocity that is proportional to time? (The black graph, the gray graph, both, or neither?)

- (c) Which graph or graphs depict a velocity that is a linear function of time? (The black graph, the gray graph, both, or neither?)

2. (5 pts)

- (a) At what time or during what time intervals, if any, is the black bicycle moving at a faster speed than the gray one? What do you mean by faster?
- (b) At what time or during what time intervals, if any, is the black bicycle moving at the same velocity as the gray one?

3. (5 pts)

- (a) Carefully describe the motion of the black bicycle in words. Where does it start? What happens as it moves?

Does it turn around? Yes No Cannot determine

- (b) Carefully describe the motion of the gray bicycle in words. Where does it start? What happens as it moves?

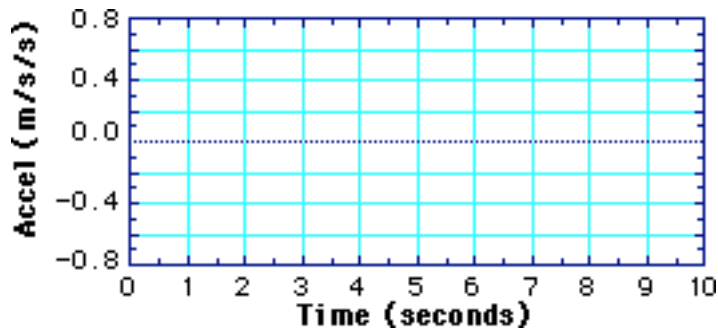
Does it turn around? Yes No Cannot determine

4. (5 pts)

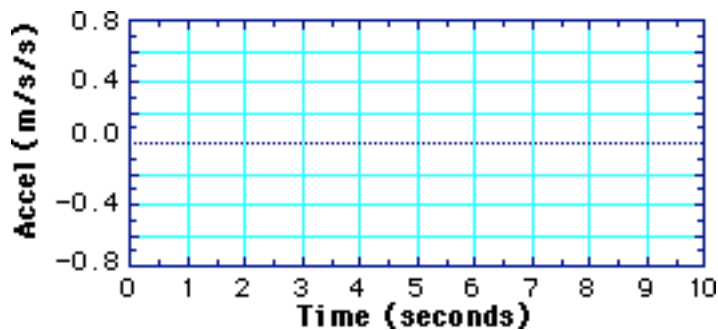
- (a) At what time or during what time intervals, if any, does the black bicycle have a positive acceleration? A negative acceleration? A zero acceleration? Explain.
- (b) At what time or during what time intervals, if any, does the gray bicycle have a positive acceleration? A negative acceleration? A zero acceleration? Explain.

5. (20 pts)

- (a) In the graph frame below, sketch the acceleration of the black bicycle over the 10 second interval of time. Explain how you decided what to sketch.

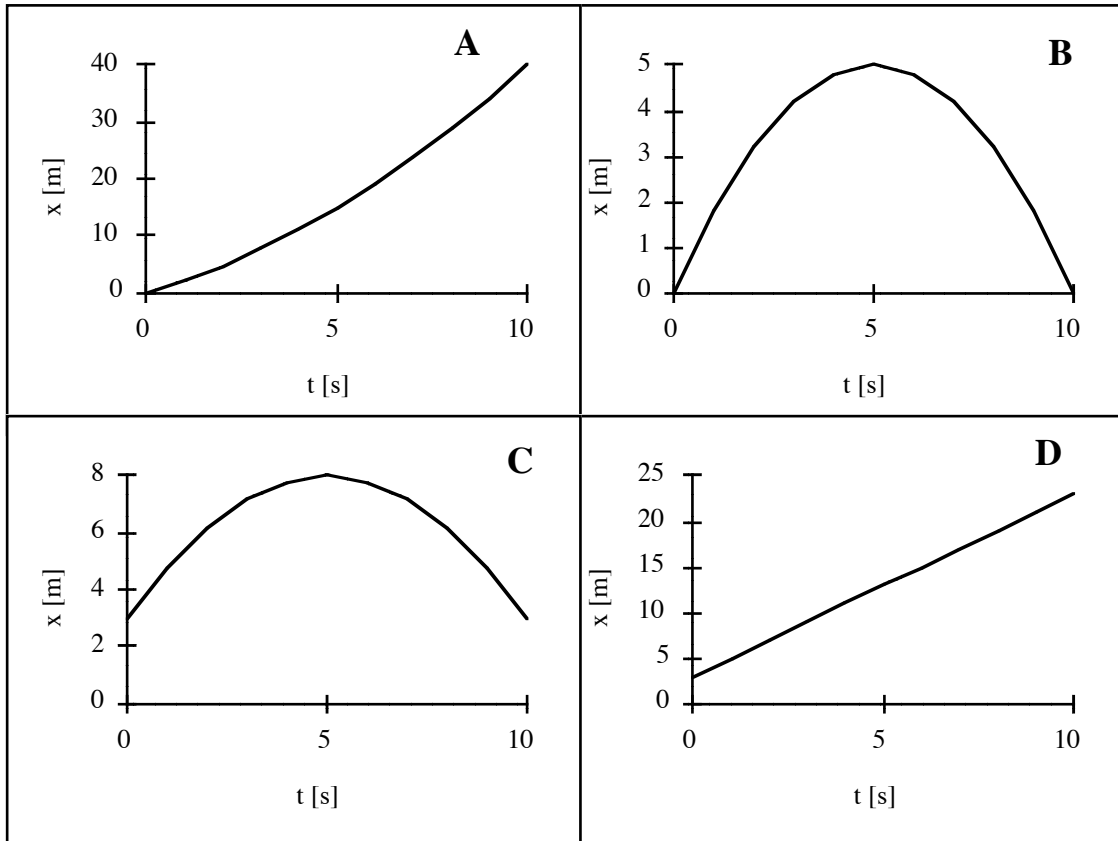


- (b) In the graph frame below, sketch the acceleration of the gray bicycle over the 10 second interval of time. Explain how you decided what to sketch.



- (c) Which of the graphs shown below represents the position vs. time graph of the gray bicycle?

A B C D None



- (d) Some people claim, based on their interpretation of the velocity vs. time graph, that the acceleration of the gray bicycle should be zero at $t = 5.00$ s and others claim that it is not zero. What do you think? Give as much evidence as possible to support your answer.

Part II: Kinematics

6. (15 pts)

Using the method we developed in class and on the homework, find when the gray bicycle is at a position of 4.5 m. **Warning:** In solving the kinematic equations, you could end up using the quadratic formula and/or taking the square root of a value.

<i>Part 1: Motion Diagram</i>	<i>Part 1: Sketched Graph for Velocity vs. Time</i>
<i>Part 2: Table and Unit Conversions</i>	<i>Part 2: Equations</i> <hr/> <i>Part 3: Algebra and Substitution</i> ANSWER <i>(w/ proper sig. Fig.)</i>
<i>Part 4: Units Check</i>	

Part III: Data Analysis, Uncertainty and Significant Figures, Modeling

7. (20 pts)

One of the major research areas in physics at Penn State is Plasma Physics. A plasma is a gas consisting of ions (positively charged atoms) and electrons. During this past summer the Plasma Research Group produced an incredibly uniform plasma in which all the ions were spread out evenly in a container. To determine the density or average number of ions in a cubic centimeter, the two student interns, Linda and Leonard, recorded the following numbers.

measurement number	plasma density (ions per cm ³)
1	3.45×10^{12}
2	3.20×10^{12}
3	3.64×10^{12}
4	3.23×10^{12}
5	2.80×10^{12}
6	3.68×10^{12}
7	3.55×10^{12}
8	3.45×10^{12}
9	3.40×10^{12}
10	3.36×10^{12}

Note: You do not need to know anything about Plasma physics to do this exercise!

- (a) Use a spreadsheet to determine the average, $\langle \rho \rangle$, for these 10 individual plasma density measurements.

- (b) Determine the standard deviation σ_{sd} of these 10 measurements.

- (c) Determine the standard deviation from the mean, SDM, of these 10 measurements.

- (d) What value should Linda and Leonard publish for their plasma density measurements? They would like to report their results in such a way that another group of experimenters who want to take 10 more density measurements can determine if their results are compatible with Linda's and Leonard's.

The format for your answer should be something like:

$$\text{The Plasma Density} = (3.543 \pm 0.232) \times 10^{12} \frac{\text{ions}}{\text{cm}^3}$$

However, your result should have the correct number of significant figures (the sample result shown does not!) and a best estimate and uncertainty appropriate to your data.

8. (10 pts)

Linda and Leonard also measured the temperature of the plasma by evaluating the data from a special probe known as a Langmuir probe. They found that the temperature of their plasma was approximately 7.5 times hotter than the sun. They recorded the following three temperature values:

$$\begin{aligned} T_1 &= 41,631 \text{ Kelvin} \\ T_2 &= 43,824 \text{ Kelvin} \\ T_3 &= 42,433 \text{ Kelvin} \end{aligned}$$

Please report just the average result in scientific notation using the proper number of significant figures. **Hint:** You don't need to bother finding and reporting the standard deviation or standard deviation from the mean to answer this.

9. (25 points) Data Collection and Modeling

The digital movie **pasco039.mov** shows a fan cart on the upper track that is speeding up from left to right. It then hits a stationary cart, slowing down the fan cart. The fan cart then speeds up again. We are interested in analyzing the motion of the fan cart *after the collision*, from frame 6 to the end of the movie. Use VideoPoint software to collect data for the horizontal position of the fan cart. For consistency, leave the yellow coordinate system in the lower left corner of the video.

- (a) **(5 pts.)** Find the calibration (scale) factor so that you can convert your data from pixels to real meters. Give the factor below and explain how you found it.
- (b) **(10 pts.)** Transfer your data to a spreadsheet and use your scale factor to convert your data from pixels to real meters. Then transfer this data to a modeling spreadsheet and use modeling techniques (not the “Add Trendline ...” feature of Excel) to find the equation that describes the horizontal position of the fan cart as a function of time. Give the equation that describes the motion of this particular fan cart (don’t forget to include proper units and vector notation) and **e-mail me your modeling spreadsheet**.

In modeling your data, keep in mind that we are interested in the motion of the fan cart *after* the collision, from $t_1 = 0.85$ s to $t = 2.21$ s. All the modeling we have done before is for the initial time equal to $t_1 = 0.0$ s. It might help make our modeling fairly straightforward to remember that the first kinematic equation is written as

$$\bar{x} = \frac{1}{2} \bar{a} (t - t_1)^2 + \bar{v}_1 (t - t_1) + \bar{x}_1,$$

but we have usually been able to choose the initial time, t_1 , to be equal to zero, making the equation

$$\begin{aligned} \bar{x} &= \frac{1}{2} \bar{a} (t - 0\text{s})^2 + \bar{v}_1 (t - 0\text{s}) + \bar{x}_1 \\ &= \frac{1}{2} \bar{a} t^2 + \bar{v}_1 t + \bar{x} \end{aligned}$$

- (c) **(5 pts.)** According to your *model*, what are the position and velocity of the fan cart at $t = 0.85$ s? Explain how you found these values. Don't forget to include proper units and vector notation.
- (d) **(5 pts.)** What is the acceleration of the fan cart at $t = 1.80$ s? Explain how you found this value. Don't forget to include proper units and vector notation.