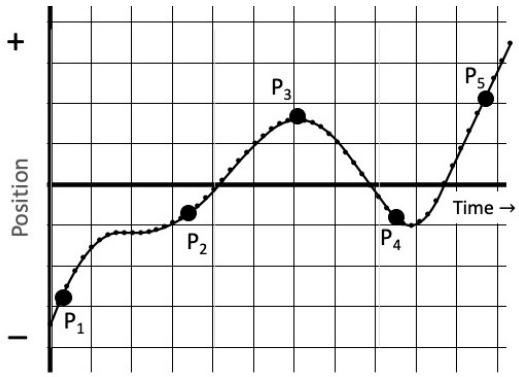
Name _____ **Student ID** _____ **Score** _____
last *first*

I. [60 pts] Multiple Choice (5 pts each): Mark your answer on BOTH the Scantron and this page.

1. [5 pts] Professor Tardy is late for a meeting across campus. She runs from her office to the administration building at a constant speed of 5.0 m/s. When she arrives, a note on the door tells her the meeting has been rescheduled, so she walks back to her office along the same route at a speed of 1.0 m/s. What is her average speed for the entire journey?

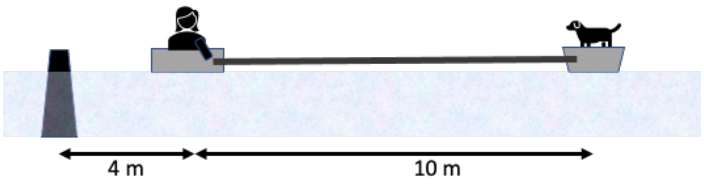
   A. 0 m/s
   B. 1.2 m/s
   C. 3.0 m/s
   D. 1.7 m/s
   E. Not enough information is given

2. [5 pts] The graph shows an object's position as a function of time. At which of the marked points is the acceleration positive?



   A. P_1 and P_5
   B. P_2 and P_4
   C. P_3 and P_5
   D. P_1, P_2 and P_5
   E. P_3 and P_4

3. [5 pts] A girl is sitting on a small raft in a lake, 4.0 meters due east of a rock. She is holding a leash attached to a washtub in which her dog is sitting, which is 10.0 meters due east of the girl. The total inertia of the washtub and dog is 12 kg. After she pulls on the leash to bring the dog (and washtub) to her, she is 6.0 meters east of the rock. What is the inertia of the girl and her raft? Ignore the finite size of the raft and washtub.



   A. 48 kg
   B. 24 kg
   C. 28 kg
   D. 60 kg
   E. 20 kg

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For the next three questions, consider the following scenario: Help recapture the Ghost Ship, a pirate spaceship with a cloaking device. Hint: All ships move along the x-axis. Assume that the multi-ship system is isolated and closed and that no ship fires its booster rockets during the events described.

4. [5 pts] The Ghost ship is initially docked to the Mothership and both ships are at rest. The space pirates explode a charge to separate the two ships. If the velocity and inertia of the Mothership are $\vec{v}_M = -v_M\hat{\imath}$ and m_M respectively, what is the momentum of the invisible Ghost ship after just after separation?

   A. $\vec{p}_G = -m_M v_M \hat{\imath}$
   B. $\vec{p}_G = 0$, due to momentum conservation
   C. $\vec{p}_G = \frac{1}{2} m_M {v_M}^2 \hat{\imath}$
   D. $\vec{p}_G = m_M v_M \hat{\imath}$
   E. There is too little information.

5. [5 pts] Assume internal energy E is converted to kinetic energy during the explosion that separates the Mothership and Ghost ship. Compute the unknown inertia m_G of the Ghost ship in terms of E and known inertia (m_M) and speed (v_M) of the Mothership.

   A. $m_G = m_M$
   B. $m_G = m_M \frac{m_M {v_M}^2}{2E - m_M {v_M}^2}$
   C. $m_G = m_M \frac{m_M {v_M}^2}{2E}$
   D. $m_G = m_M\, m_M \frac{{v_M}^2}{E}$
   E. There is too little information.

6. [5 pts] After separating from the Mothership, the Ghost ship collides elastically with the Interceptor, which was also initially at rest. If the final velocity of the Interceptor is $\vec{v}_I$ but its inertia m_I is unknown, what is the final velocity $\vec{v}_G$ of the Ghost ship?

   A. $\vec{v}_G = \frac{m_M}{m_G}\vec{v}_I$
   B. $\vec{v}_G = \vec{v}_I - v_M\hat{\imath}$
   C. $\vec{v}_G = \vec{v}_I - \frac{m_M}{m_G} v_M\, \hat{\imath}$
   D. $\vec{v}_G = \frac{m_M}{m_G} v_M \hat{\imath} + \frac{m_M}{m_G}\vec{v}_I$
   E. None of the above.

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7. [5 pts] A boat can travel 15 m/s in stationary water. The current in a river is flowing south at 5.0 m/s. How long will it take the boat to travel from a dock to a bridge that is 1500 m south of the dock?

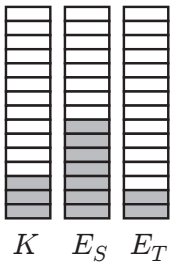
   A. 100 s
   B. 75 s
   C. 150 s
   D. 300 s
   E. 200 s

8. [5 pts] Two identical carts with elastic bumpers slide on a low-friction track. Both are moving to the right and have inertia m. The first cart is travelling with speed v, while the second cart approaches it from behind with speed 2 v. They collide elastically. What is the maximum elastic (internal) energy stored in the carts' bumpers during the collision?

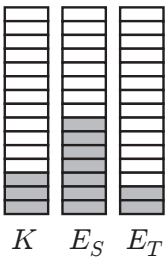
   A. $5mv^2/2$
   B. $mv^2/2$
   C. $9mv^2/4$
   D. $mv^2/4$
   E. No internal energy is stored

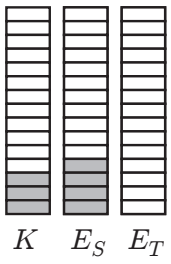
9. [5 pts] At time $t = 0$ s, I was riding down the Burke Gilman trail on my bike at 10 m/s, when I realized I had forgotten my mask. I braked, screeching to a halt, and turned around and started to ride back. At time $t = 10$ s, I was riding towards home at 10 m/s.

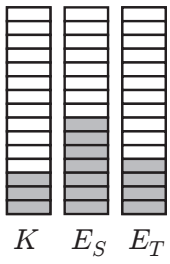
   Consider the initial distribution of Kinetic (K), Source (E_S) and Thermal (E_T) energies at time t = 0 s in the system consisting of the **person and the bike** shown on the right-hand-side of the page.

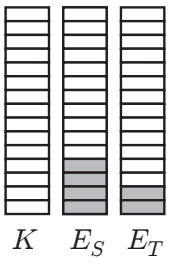
   

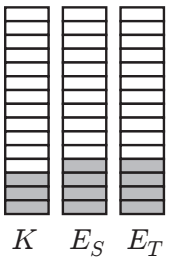
   Which of the following could represent the energies at time t = 10 s?

(A)


(B)


(C)


(D)


(E)


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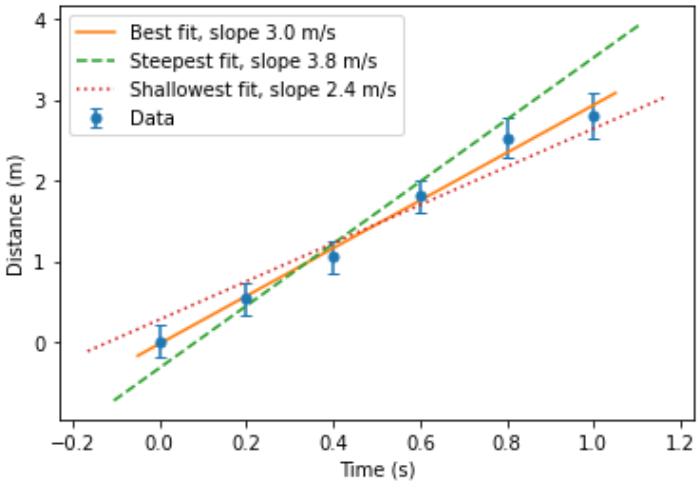
10. [5 pts] A lab group has made measurements while studying the motion of an object, and created the graph shown.



Based on the ideas developed in the lab and lab HW, which of the following is the best estimate of the speed at which this object moves?

A. 3 ± 1 m/s
B. 3.0 ± 0.8 m/s
C. 3 ± 0.8 m/s
D. 3.0 ± 1.0 m/s
E. 3.0 ± 0.6 m/s

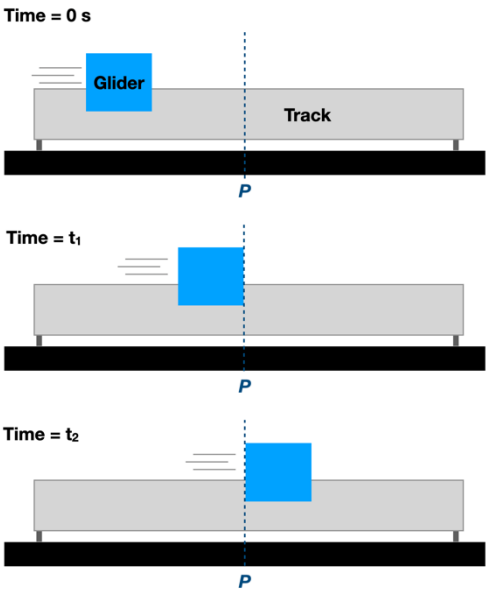
11. [5 pts] A student is analyzing the motion of an object in a video using a ruler and a timer (*e.g.,* a clock). The student's data are in the table at right.

Time (s)	Position (cm)
0.00	30.0
2.00	21.9
4.00	15.3
6.00	10.2
8.00	6.6
10.00	4.5
12.00	3.9

Which of the following models for the object's motion is the best description given this data? (Assume a 10% uncertainty in each measurement.)

A. Motion with constant acceleration in which the object is speeding up
B. Motion with constant acceleration in which the object is slowing down
C. Motion with constant velocity
D. Some other kind of accelerated motion in which the object is speeding up
E. Some other kind of accelerated motion in which the object is slowing down

12. [5 pts] A student conducts an experiment to determine the speed of a glider moving on an air track. The glider is sent down the track shown at right, and the student measures the time interval between when the front of the glider passes the position *P*, t_1 and the time the back of the glider passes the position *P*, t_2.



The student records the following:

Glider length = 0.1270 m ± 0.0008 m
The time interval, $t_2 - t_1 = 0.324$s ± 0.003 s

To determine the speed, the student divides the glider length by the time interval. They then use the weakest link rule to determine the associated uncertainty.

Select the choice below that most accurately represents the calculated speed and associated uncertainty.

A. 0.392 ± 0.006 m/s
B. 0.39 ± 0.01 m/s
C. 0.392 ± 0.004 m/s
D. 0.39198 ± 0.00353 m/s
E. 0.3920 ± 0.0035 m/s

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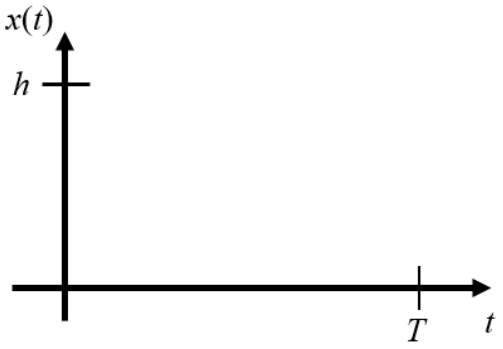
II. Lecture long-answer questions (25 points total)

At $t = 0$ you drop a ball from a height h, starting at rest. You observe that the ball bounces off the floor with a coefficient of restitution $e < 1$, and then rises to a new (smaller) maximum height. Your task is to determine the time T at which the ball reaches the new maximum height. Let g denote the magnitude of the acceleration due to gravity ($g > 0$). Neglect air resistance.

A. [5 pts] We will use x to denote the height of the ball above the ground. Use the figure to sketch $x(t)$.



B. [10 pts] Briefly describe in words the step-by-step method that you will use to determine ***the time T when the ball reaches the new maximum height***. You must number your steps.

C. [10 pts] Execute the method that you have described in part (B). Number each step, following your answer to (B). You should express the time T in terms of h, g, and e, only.

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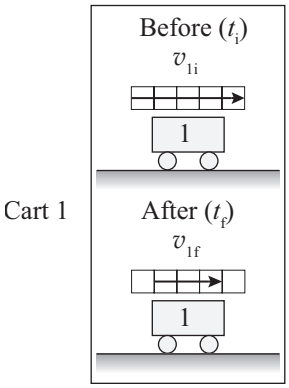
last *first*

III [15 points total] This problem consists of two unrelated parts, A and B.

A. Two identical carts 1 and 2 move along different level, frictionless tracks. Each cart interacts with a different object (not shown). The vectors shown represent the ***velocities*** of the carts at instants t_i (before the interaction) and t_f (after the interaction). The velocity of cart 2 at instant t_f is not shown.

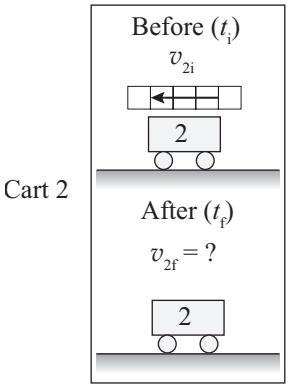


i. [5 pts] In the box below, draw a vector indicating the direction of the ***average acceleration*** of cart 1 between t_i and t_f. **Explain your reasoning.**

Direction

Explanation:

You are told that between t_i and t_f, the magnitude of the average acceleration of cart 2 is *twice* that of cart 1, and in the *opposite* direction.

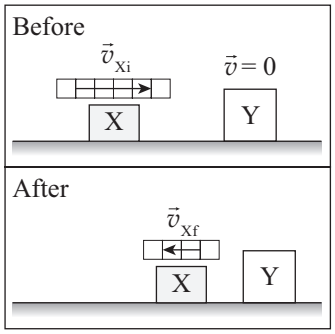


ii. [5 pts] In the grid below, draw a vector indicating the velocity of cart 2 at instant t_f. Draw the vector to scale. **Explain your reasoning.**

Velocity of cart 2 at t_f

Explanation:

B. Block X moves across a frictionless surface until it collides elastically with a stationary block Y. The initial and final velocities of block X are shown in the figure at right. System Z consists of both blocks X and Y.



[5 pts] Is the magnitude of the final momentum of block Y *greater than, less than, or equal* to the magnitude of the final momentum of system Z? Explain.

Answer

Explanation: