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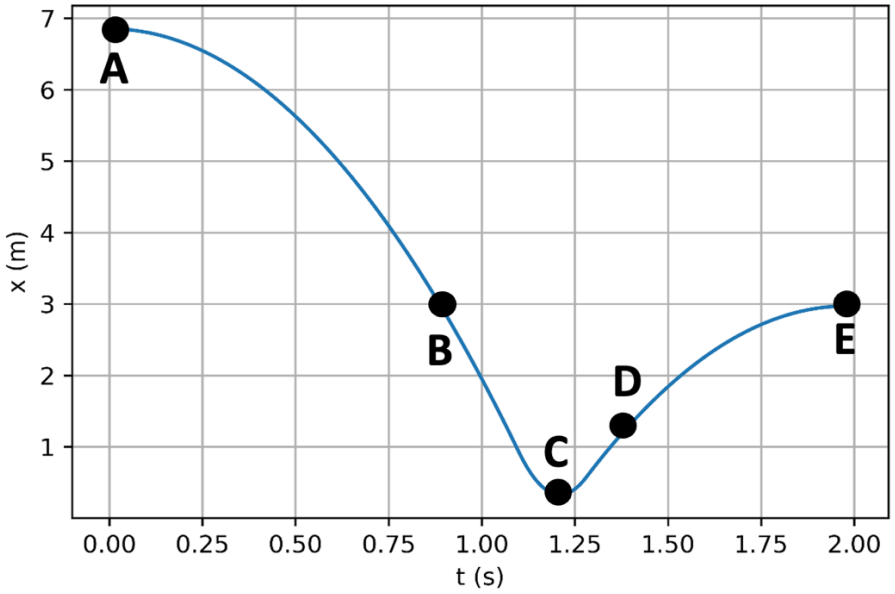
I. [60 pts] Multiple Choice (5-7 pts each): Mark your answer on BOTH the bubble sheet and this page.

Questions 1 and 2 pertain to the graph below. The plotted trajectory describes the position of the center of mass of a ball bouncing on the ground.



1. [6 pts] At which labeled point is the greatest magnitude of acceleration?

   A. A

   B. B

   C. C

   D. D

   E. E

2. [6 pts] Which of the statements below regarding the **average** x component of velocity $v_{x,av,EB}$ between points B and E is most accurate?

   A. $v_{x,av,EB}$ is approximately zero.

   B. $v_{x,av,EB}$ is clearly negative.

   C. $v_{x,av,EB}$ is clearly positive.

   D. There is insufficient information on the plot to make inferences about the average velocity.

   E. $v_{x,av,EB}$ is negative for some time and positive for some time.

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3. [6 pts] A person drops two balls off a bridge. They drop the first ball from rest at time $t = 0.0$ s and they drop the second ball from rest at time $t = 1.0$ s. Which of the following statements are true relating to the motion of the two balls after $t = 1.0$ s? You may neglect air resistance. **Select all that apply.**

   A. The acceleration of the first ball is greater than the acceleration of the second ball.

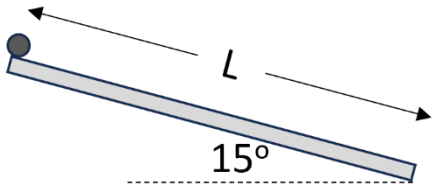
   B. The acceleration of the first ball is the same as the acceleration of the second ball.

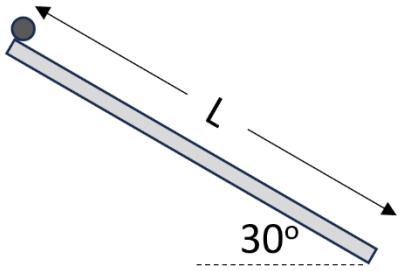
   C. The acceleration of the first ball is less than the acceleration of the second ball

   D. The distance between the two balls will increase over time after $t = 1.0$ s.

   E. The distance between the two balls will stay the same after $t = 1.0$ s.

4. [7 pts] A ball rolls down a 15-degree ramp in 20.0 seconds starting from rest at the top. How long would the same ball take to roll the same distance along the ramp starting from rest on a 30-degree ramp? Select the closest answer to correct.





   A. 8.4 s

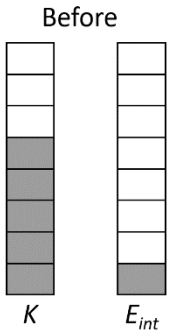
   B. 10.0 s

   C. 10.4 s

   D. 14.4 s

   E. 20.0 s

5. [6 pts] A cart rolls without friction towards a rigid wall. Before colliding with the wall, it has 5 J of kinetic energy and 1 J of internal energy as depicted to the right. After the collision it rolls away from the wall with 2 J of kinetic energy. What is the *maximum* amount of thermal energy that could have been generated in the collision?



   A. 0 J

   B. 1 J

   C. 4 J

   D. 5 J

   E. 6 J

6. [6 pts] An astronaut decides to try some Phys 121 demos on the moon. They decide to test out an elastic collision experiment on a frictionless track using two carts that have an inertia of 1 kg when measured on Earth. Like in class, they set cart 1 in motion to collide *elastically* with cart 2, which was originally at rest. If they compare this to the same experiment on Earth, with cart 1 having the same initial velocity in the frame of the track, which of the following statements are true? **Select all that apply.**

   A. The convertible kinetic energy of the cart system is less on the moon than it would be on Earth.

   B. The momentum of the cart system is less on the moon than it would be on Earth.

   C. The momentum of the cart system is the same on the moon as it would be on Earth.

   D. After the collision, the two carts would stick together and move at half the initial speed of cart 1.

   E. After the collision, cart 1 would be at rest.

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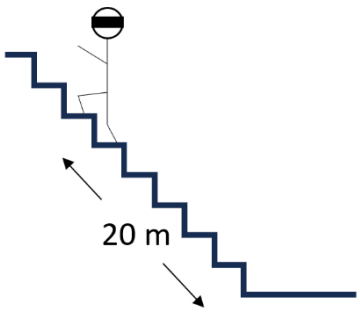
7. [6 pts] A thief was riding down an escalator, when they noticed the police waiting at the bottom. The thief immediately turned around and tried to climb up the escalator to escape but they are not fast enough. The escalator steps move at 1.0 m/s, and the thief's (constant) speed relative to the escalator is 0.8 m/s. Which option best describes the time it takes the thief to end up at the bottom if they were 20 m from the bottom when they started to climb?



A. 4 s

B. 11.1 s

C. 16 s

D. 20 s

E. 100 s

8. [7 pts] A 1500 kg car traveling at 10 m/s collides into a row of four identical 1500 kg cars stopped at an intersection. It is an icy day, so the road can be treated as frictionless, and all cars collide *totally inelastically*. How much of the moving car's initial kinetic energy went into internal energy (spread among the 5 cars)? For the purposes of this question, you can treat the 5-car system as closed.

A. 0 J

B. 15,000 J

C. 60,000 J

D. 75,000 J

E. Not enough information to tell.

9. [5 pts] A group of students are working through Lab A. They perform three runs of the cart, and their measurements of the position of the cart at $t = 1.0$ s are shown at right. Based on how uncertainty is defined in the lab, which of the following position-time graphs is consistent with their data? Assume that the uncertainty in time is negligible and note that the y-axis ranges are different to provide more clarity.

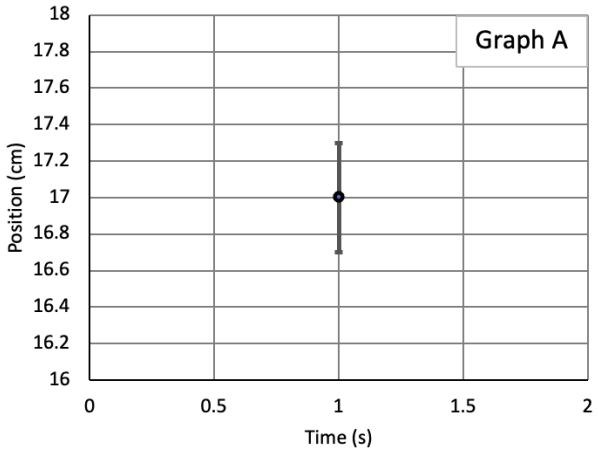
Trial	Position at 1.0 s
1	15.1 cm
2	22.3 cm
3	14.1 cm

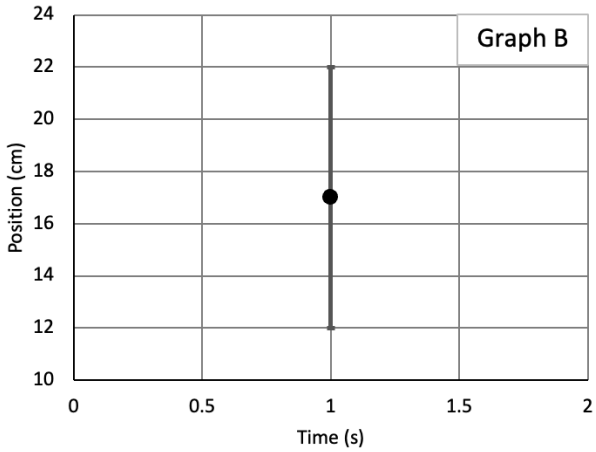
A. Graph A

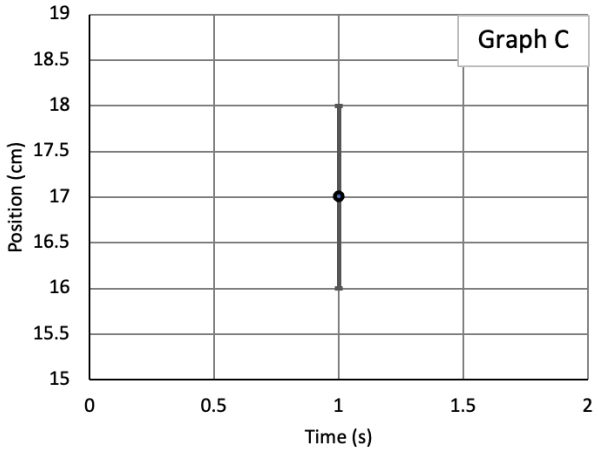
B. Graph B

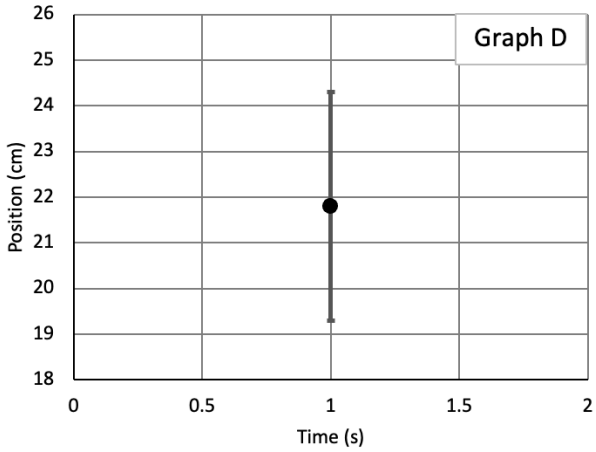
C. Graph C

D. Graph D









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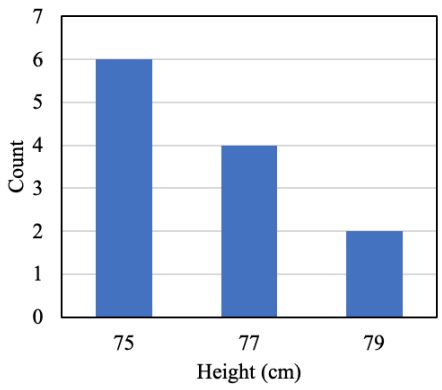
10. [5 pts] A group of 12 students have individually measured the height of a small tree. Their data is represented in the histogram at right. Which of the choices below best characterizes the height of the tree based on their data?



A. 76.3 cm ± 2 cm

B. 76 cm ± 3 cm

C. 76.33 cm ± 2.67 cm

D. 77 cm ± 3 cm

E. 77.1 cm ± 2.7 cm

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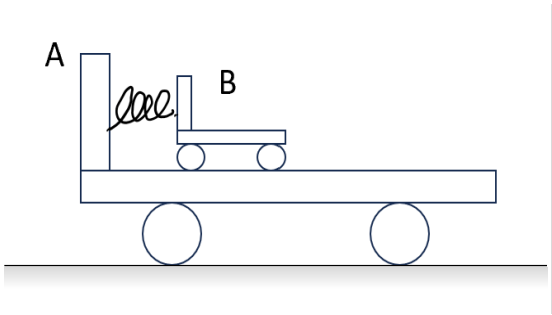
II. Lecture long-answer questions (20 points total)

Consider a system composed of two carts, A and B, with inertia m_A and m_B and a spring between the two carts with negligible inertia. Cart B moves frictionlessly on top of cart A, and cart A moves frictionlessly on a surface below. Initially, both carts are at rest, and the spring is compressed. The spring is attached to cart B, but not to cart A. When the spring is released, but before cart B falls off of cart A, cart A moves with velocity v_A relative to the ice, and cart B moves with velocity v_B relative to the ice.



11. [5 pts] Determine if the system is open or closed, and isolated or not isolated, and explain why.

12. [5 pts] Calculate v_B in terms of m_A, m_B, and v_A. Show your work.

13. [5 pts] Calculate the velocity of cart A from a reference frame that is at rest relative to cart B in terms of m_A, m_B, and v_A. Show your work.

14. [5 pts] Calculate the total convertible kinetic energy from a reference frame that is at rest relative to cart B in terms of m_A, m_B, and v_A. Show your work.

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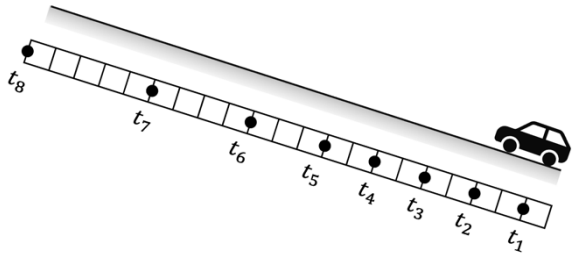
III. Tutorial and lab long answer questions (20 points total)

A car is traveling up an incline as shown at right. A motion diagram for the car is also shown. The instants shown are separated by equal time intervals.



15. [5 pts] In the box below right, draw a vector to indicate the direction of the car's average acceleration between t_2 and t_7. Explain your reasoning.

16. [5 pts] Is the magnitude of the car's average acceleration between t_2 and t_7 *greater than, less than,* or *equal to* the magnitude of the car's average acceleration between t_3 and t_7? Explain.

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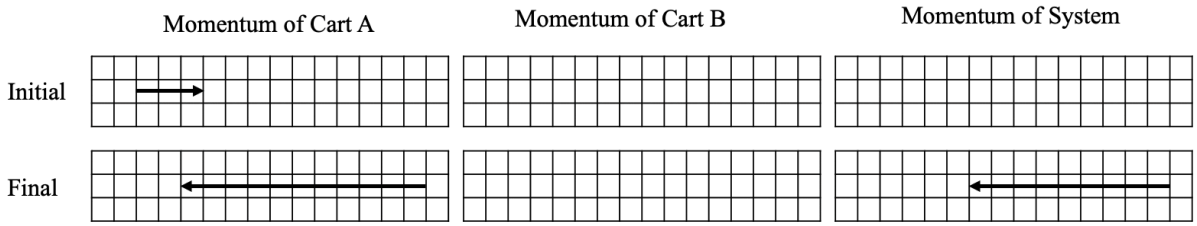
17. [5 pts] Two carts, A and B, undergo a collision on a horizontal surface with negligible friction. A *partial* momentum diagram for the two carts and the system of both carts is shown below.



Complete the momentum diagram to determine whether the magnitude of the initial momentum of cart B is *greater than, less than* or *equal to* the magnitude of the final momentum of cart B? Briefly explain.

18. [5 pts] For Lab B1, a group of students have measured the position of the falling ball at $t_0 = 0.000$ s and at $t_1 = 0.100$ s. Using this data, what values would you determine for the average velocity (in m/s) of the ball for the time interval, $t_1 - t_0$, and the uncertainty in this velocity? Show your work.

Time (s)	Measurement 1 (cm)	Measurement 2 (cm)	Measurement 3 (cm)	Measurement 4 (cm)
0.00	200.0	200.3	200.4	201.0
0.10	194.8	194.5	194.6	194.9