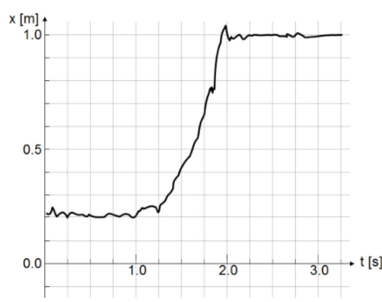
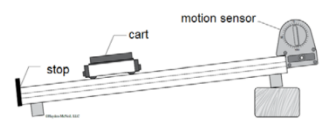
Name ____________________ **Student ID Number** __________
last *first*

I. Lab questions.

Consider a cart on a track similar to the setup used in the lab. The track has a stop at the end. The cart is initially held at rest and is released sometime after the measurement was started. The recorded position vs. time graph is shown below.





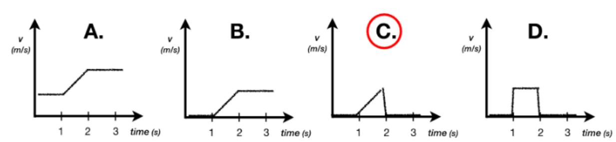
1. (4 pts.) Which of these is closest to the value of the cart's speed just before it hits the end of the track?

A. 0.3 m/s **B.** 0.4 m/s **C.** 0.8 m/s **D.** 1.7 m/s **E.** 3.2 m/s

2. (4 pts.) Which of these is closest to the average acceleration from the moment the cart was released to when it hits the end of the track?

A. 0.08 m/s^2 **B.** 0.8 m/s^2 **C.** 1.6 m/s^2 **D.** 3.2 m/s^2 **E.** 9.8 m/s^2

3. (4 pts) Which of the following sketched curves of velocity vs time is consistent with the motion described in the graph above?



4. (4 pts) You decide to change the tilt of the track to 23 degrees, and you measure an average acceleration of 4.1 m/s^2. In which of the following ranges is the percent difference, z, between your measured value and the predicted value?

A. $z < 4\%$ **B.** $4\% \le z < 8\%$ **C.** $8\% \le z < 10\%$ **D.** $10\% \le z < 12\%$ **E.** $12\% \le z$

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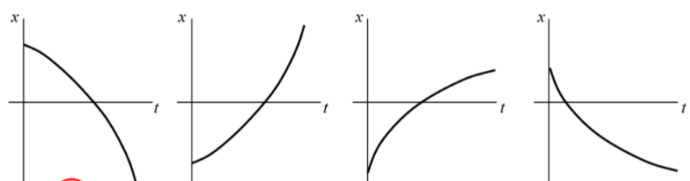
II. Lecture multiple-choice.

5. (5 pts) A car travels 2.0 miles at a constant speed of 60 miles per hour (mph), then an additional 3.0 miles at a constant speed of 40 mph. Which choice best represents the average speed of the car for the entire 5.0-mile trip?

A. 52 mph **B.** 50 mph **C.** 48 mph **D.** 46 mph **E.** None of these

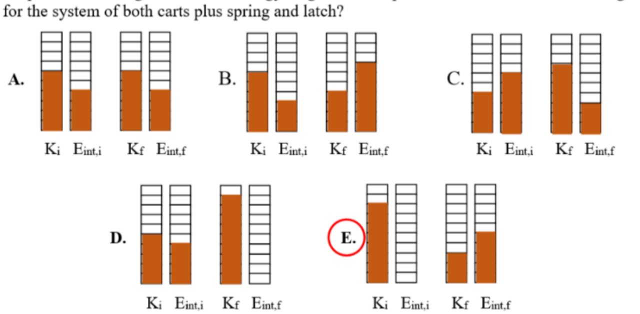
6. (5 pts) A car is known to be moving in the negative x-direction and speeding up. Which choice best represents a position vs time graph of this motion?



A. **B.** **C.** **D.**

E. None of these, or more than one of these, could represent this motion.

7. (5 pts) Two carts, of inertias m and $2m$, are initially moving in opposite directions on a horizontal air track. They collide, and the collision is rigged so that a relaxed spring attached to one cart compresses during the collision, and at maximum spring compression a latch couples the carts together. Which energy diagram best represents the initial and final energies for the system of both carts plus spring and latch?



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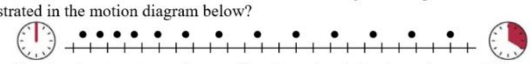
8. (5 pts) Two carts collide on a horizontal air track. The collision is not elastic, and it is not totally inelastic. The collision is observed by Andy in the Earth frame of reference and by Judy, who is riding a bicycle at a constant velocity relative to Earth. Which choice best represents physical entities whose values will be agreed upon by both observers?

A. The coefficient of restitution for this collision.
B. The change in velocity of each cart during the collision.
C. The change in momentum of each cart during the collision.
D. More than one of these, but not all three.
E. All three entities (A, B and C).

9. (6 pts) A ball of inertia 2.0 kg is launched vertically upward at initial speed $v_i = 6.0$ m/s, and it immediately collides with a smaller ball of inertia 0.10 kg that is initially moving downward at the same speed $v_i = 6.0$ m/s. If the collision is elastic, which choice best represents the velocity of the smaller ball immediately after the collision?

A. $1.2\text{x}10^2$ m/s **B.** 17 m/s **C.** 11 m/s **D.** 7.1 m/s **E.** None of these

10. (5 pts) Which choice best describes the motion of an object during the time interval illustrated in the motion diagram below?



A. The object begins at rest, speeds up uniformly to the right, slows down quickly, and stops at the end.
B. The object begins at constant speed to the right, speeds up uniformly, then continues at a higher constant speed until the end.
C. The object starts at constant speed to the right, then speeds up uniformly until the end.
D. The object starts at constant speed to the left, slows down uniformly, and continues at a smaller constant speed until the end.
E. None of these is a good description of the motion shown in the diagram.

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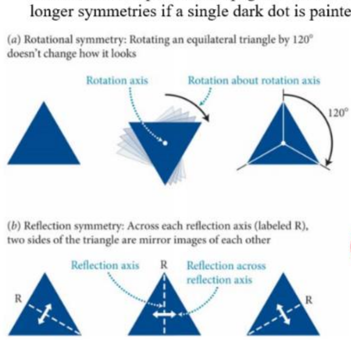
11. (5 pts) An empty railroad hopper car of length 20 m and inertia 24,000 kg coasts along a straight horizontal track at 1.8 m/s. As it passes beneath a grain chute, the chute opens, dropping 2,500 kg of grain per second into the car. Exactly 5.0 s later the grain chute closes. Which choice best represents the speed of the loaded car after the grain chute has closed?

A. 0.96 m/s **B.** 1.2 m/s **C.** 1.4 m/s **D.** 1.6 m/s **E.** None of these

12. (5 pts) The equilateral triangle shown here can be rotated by 120° around an axis perpendicular to the page, as shown, or by 240° or 360°. It can also be reflected about the three axes in the plane of the page, as shown. Of these 6 symmetries, how many are no longer symmetries if a single dark dot is painted on the triangle as shown?

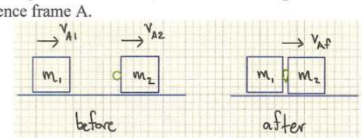


A. Two of the 6 are lost, 4 remain
B. Three of the 6 are lost, 3 remain
C. Four of the 6 are lost, 2 remain
D. Five of the 6 are lost, 1 remains
E. All 6 are lost, none remain

Name Chavarria Alvaro (last, first) **Student ID Number** Solutions

III. Lecture hand-graded.

Two objects of inertias m_1 and m_2 have a totally inelastic collision on a frictionless track. Oscar sees object 1 approach object 2 and hit it from behind. The diagram below shows the collision in Oscar's inertial reference frame A.



Olivia is in another inertial reference frame B and sees the two objects have a head-on collision.

13. (4 pts) Either Oscar or Olivia is in the zero-momentum reference frame. Who is it? Explain your answer.

Olivia. For the total momentum of a system with two objects to be zero they must be traveling toward eachother (momenta with opposite signs).

14. (5 pts) Working in Oscar's reference frame. Solve for the final velocity v_{Af}.

Conservation of momentum: $m_1 v_{A1} + m_2 v_{A2} = (m_1 + m_2) v_{Af}$ $\quad v_{Af} = \dfrac{m_1 v_{A1} + m_2 v_{A2}}{m_1 + m_2}$

15. (10 pts) Devise an expression in terms of m_1, m_2, v_{A1}, v_{A2} for the initial kinetic energy of the two-object system, K_{Bi}, in Olivia's reference frame. Show your work and/or explain your reasoning.

Convertible Kinetic energy is the initial Kinetic energy in the zero momentum reference frame (Olivia's) because ~~$K_{cm}=0$~~. translational Kinetic energy $K_{cm} = 0$.

$K_{conv} = \frac{1}{2}\mu v_{12}^2 \quad \mu = \dfrac{m_1 m_2}{m_1 + m_2} \quad \cancel{v_{12} = v_2 - v_1} \quad \cancel{v_{12} = v_{A2} - v_{A1}} \quad v_{12} = v_{B2} - v_{B1}$

$v_{12} = (v_{A2} - v_{Af}) - (v_{A1} - v_{Af})$

$v_{12} = v_{A2} - v_{A1}$

$\Rightarrow K_{Bi} = K_{conv} = \dfrac{1}{2}\dfrac{m_1 m_2}{(m_1 + m_2)}(v_{A2} - v_{A1})^2$

16. (6 pts) In terms of K_{Bi}, what is the change in internal energy of the system due to the collision according to i) Oscar and ii) Olivia. Explain your answer.

Oscar and Olivia will agree on the change of internal energy of the system $= \cancel{\Delta K}$ ΔE_{int} because the quantity is the same in all inertial reference frames.

For Olivia $K_{Bi} - K_{Bf} = \Delta E_{int} \Rightarrow \Delta E_{int} = \cancel{\Delta K_{Bi}}$ K_{Bi} for both Oscar and Olivia.

$0 = \Delta K + \Delta E_{int}$ Conservation of Energy

zero because ~~objects remain at rest~~ $v_{Bf} = 0$ in zero-momentum frame.

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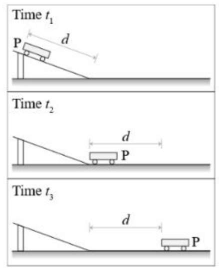
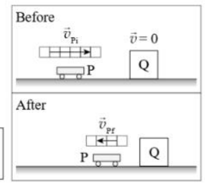
IV. [18 points total] Cart P is released from rest on a frictionless incline at time t_1 as shown. Between times t_1 and t_2, it travels a distance d, reaching the end of the incline. Between times t_2 and t_3, it moves a distance d across a frictionless horizontal surface. The time intervals may or may not be equal.



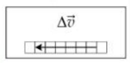
A. [6 pts] Is $t_3 - t_2$ *greater than*, *less than*, or *equal to* $t_2 - t_1$? Explain.

Less than. Cart P accelerates from rest to the bottom of the incline, so its average speed from t_1 to t_2 is less than its speed at the bottom. The cart is moving at constant speed from t_2 to t_3, so the average speed of the cart from t_1 to t_2 is less than that from t_2 to t_3. Since the distances cart P travelled in both time intervals are the same, and $\Delta t = d/v_{avg}$, $t_3 - t_2$ is less than $t_2 - t_1$.

B. Cart P continues to move across the frictionless surface until it collides *elastically* with a stationary block Q. The velocities of P and Q before and after the collision are shown at right. Let PQ represent the system consisting of both cart P and block Q.



i. [4 pts] On the grid at right, draw a vector to represent the change in velocity of cart P during the collision. Explain how you arrived at your answer.



$\Delta\vec{v}$ is defined to be $\vec{v}_f - \vec{v}_i$, or $\vec{v}_i + \Delta\vec{v} = \vec{v}_f$. Since $\vec{v}_i$ is 4 units to the right, $\vec{v}_f$ is 2 units to the left, the change in velocity needs to be 6 units to the left to get from $\vec{v}_i$ to $\vec{v}_f$.

ii. [4 pts] Consider both block Q and system PQ. Is the magnitude of the final momentum of block Q *greater than*, *less than*, or *equal to* the magnitude of the final momentum of system PQ? Explain.

Greater than. System PQ is an isolated system since there is no external interaction acting on it, so its momentum before and after the collision is the same. The momentum of system PQ is to the right before the collision. The final momentum of P points left and the final momentum of Q points right after the collision. To maintain the system PQ's momentum to the right after the collision, the magnitude of the final momentum of block Q needs to be greater than the magnitude of final momentum of system PQ.

iii. [4 pts] Is the final kinetic energy of block Q *greater than*, *less than*, or *equal to* the final kinetic energy of cart P after the collision? If there is not enough information to answer, state so explicitly. Explain.

Greater than. The collision is elastic, so the total kinetic energy of the system PQ is the same before and after the collision. The total kinetic energy of system PQ before the collision is $\frac{1}{2}m_P v^2$, and the final kinetic energy of cart P is $\frac{1}{2}m_P\left(\frac{v}{2}\right)^2 = \frac{1}{4}\left(\frac{1}{2}m_P v^2\right)$, which means the final kinetic energy of block Q is $\frac{3}{4}\left(\frac{1}{2}m_P v^2\right)$. So, the final kinetic energy of block Q is greater than the final kinetic energy of cart P after the collision.