- I. [45 points total] Lecture multiple-choice questions
  - 1. [5 points] A car is moving in the negative direction, and it is slowing down steadily. Which of the following vector quantities could possibly be the quantities  $\vec{v}_i$ ,  $\Delta \vec{v}$  and  $\vec{a}$  for the car during its motion? Note that  $\vec{v}_i$  is the initial velocity,  $\Delta \vec{v}$  is the change in velocity, and  $\vec{a}$  is the acceleration.
    - A.  $\vec{v}_i = +20 \text{ mph}$ ,  $\Delta \vec{v} = -5 \text{ mph}$ ,  $\vec{a} = -6 \text{ mph/s}$ B.  $\vec{v}_i = +20 \text{ mph}$ ,  $\Delta \vec{v} = +5 \text{ mph}$ ,  $\vec{a} = -6 \text{ mph/s}$ C.  $\vec{v}_i = -20 \text{ mph}$ ,  $\Delta \vec{v} = -5 \text{ mph}$ ,  $\vec{a} = -6 \text{ mph/s}$ D.  $\vec{v}_i = -20 \text{ mph}$ ,  $\Delta \vec{v} = +5 \text{ mph}$ ,  $\vec{a} = +6 \text{ mph/s}$ E.  $\vec{v}_i = -20 \text{ mph}$ ,  $\Delta \vec{v} = -5 \text{ mph}$ ,  $\vec{a} = +6 \text{ mph/s}$
  - 2. [5 points] A ball is thrown straight down from the top of a building, which is 24 m above the ground. One second later, a person reaches out of the window on the 1<sup>st</sup> floor of the building, just in time to catch the ball. The window is 4 m above the ground. What is the initial speed of the ball when it is thrown down?
    - A. 13 m/s
    - B. 15 m/s
    - C. 19 m/s
    - D. 20 m/s
    - E. 24 m/s
  - 3. [5 points] An astronaut on a newly explored planet Omega tosses a rock horizontally with a speed of 15.0 m/s. The rock falls to the ground through a vertical distance 1.2 m and lands a horizontal distance 7.0 m from the astronaut. Find the acceleration due to gravity on the planet Omega.
    - A. 4.9 m/s<sup>2</sup>
    - B. 7.1 m/s<sup>2</sup>
    - C. 9.8 m/s<sup>2</sup>
    - D. 11 m/s<sup>2</sup>
    - E. 15 m/s<sup>2</sup>

- 4. [5 points] A Ferris wheel of radius *R* speeds up with a constant angular acceleration of  $\alpha$  starting from rest. Find the expression for the centripetal acceleration of a rider after the Ferris wheel has rotated through an angle  $\Delta \theta$ .
  - A. *αR*
  - B. α
  - C.  $2\alpha\Delta\theta$
  - D.  $\sqrt{2\alpha\Delta\theta}R$
  - E.  $2\alpha\Delta\theta R$
- 5. [5 points] A swimmer swims at 5.0 km/h in still water. The swimmer aims directly across a flowing river. An observer on the bank notes the swimmer's speed is 13 km/h. What is the speed of the river with respect to the bank?
  - A. 7.0 km/h
  - B. 8.0 km/h
  - C. 12 km/h
  - D. 17 km/h
  - E. 18 km/h
- 6. [5 points] A loudspeaker with mass m = 20.0 kg is suspended h = 2.00 m below the ceiling by two cables with length  $l_1 = l_2 = 4.00$  m, each of which makes an angle  $\theta$  with the ceiling as shown. What is the tension in each of the cables?
  - A. 98.0N
  - B. 113N
  - C. 196N
  - D. 339N
  - E. 392N



- 7. [5 points] Suppose that a box with mass of 3.0 kg is sitting at rest on a level rough surface. The coefficients of <u>static</u> friction and <u>kinetic</u> friction between the surface and the box are 0.65 and 0.55, respectively. When your hand pushes horizontally on the box with a 13-N force, the box remains at rest. What is the friction acting on the box by the surface?
  - A. 1.7N
  - B. 2.0N
  - C. 13N
  - D. 16N
  - E. 19N
- [5 points] Two identical marbles, 1 and 2, are dropped from rest into separate cylinders and fall through a fluid to the bottom. The two cylinders contain different fluids. Both cylinders are like the one shown, though the height of the fluids, h<sub>1</sub> and h<sub>2</sub> respectively, may or may not be the same.

The graph of their velocity as a function of time as they fall from the top of the fluid until they hit the bottom is shown below. Note that downward is defined as the positive velocity direction here.



How do the heights of the two columns of fluid compare?

- A.  $h_1 = h_2$
- B.  $h_1 > h_2$
- C.  $h_1 < h_2$
- D. In order to compare the heights, we need to know how the viscosities of the fluids compare.

h

- 9. [5 points] A cord runs around two massless, frictionless pulleys. A canister with mass *m* hangs from one pulley and you exert a force  $\vec{F}$  on the free end of the cord. What must be the magnitude of  $\vec{F}$  if you are to lift the canister at a constant speed? Note that *g* is the free-fall acceleration.
  - A. 0 mg
  - B. 2*mg*
  - C. ½ mg
  - D. Not enough information



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- II. [15 points total] Lab multiple-choice questions
  - 10. [5 points] A group of students has made multiple measurements of a quantity and calculated the average as 1.884 ± 0.912 cm. Which of the following choices represents a correct reporting of the data (to 1 or 2 significant figures) using the rules developed in lab? Select all that apply.
    - A.  $1.9 \pm 0.9$  cm
    - B. 1.9 ± 1 cm
    - C. 2 ± 0.9 cm
    - D. 2 ± 1 cm
    - E. 1.88 ± 0.91 cm

Keeping one digit in the uncertainty would correspond to 0.9 cm. Then keeping the same decimal place in the average gives  $1.9 \pm 0.9$  cm. Keeping two digits in the uncertainty corresponds to 0.91. Thus, another possible answer is  $1.88 \pm 0.91$ .

11. [5 points] In a family, the oldest child decides to find out whether there is a relationship between the age and height of their younger siblings. They come up with two experiments:

Experiment 1: Measure the height of each child on their birthday for several years. Experiment 2: When each child reaches a certain height, record the age of the child.

Which of the following are the dependent and independent variables in each experiment? **Select all that apply.** 

- A. For Experiment 1, height is the dependent variable, and age is the independent variable.
- B. For Experiment 1, age is the dependent variable, and height is the independent variable.
- C. For Experiment 2, height is the dependent variable, and age is the independent variable.
- D. For Experiment 2, age is the dependent variable, and height is the independent variable.
- E. None of the above

12. [5 points] In the scenario from Q11, the oldest child conducts **Experiment 1** and finds the best fit line and lines of maximum and minimum slope as shown.



How would they report the slope of the best fit line to 1 and 2 significant figures using the rules from labs A1 and A2? **Select all that apply.** 

- A. 6.89 ± 5.44 cm/year
- B. 6.9 ± 5.4 cm/year
- C.  $7 \pm 5$  cm/year
- D. 6.8 ± 4.8 cm/year
- E. 6.89 ± 4.8 cm/year

The maximum deviation is the larger of (12.33 - 6.89) cm/year and (6.89 - 2.8) cm/year (the difference of the max/min slopes from the average). (12.33 - 6.89) = 5.44 cm/year is the larger quantity. To 1 sig. fig. this is 5 cm/year and to two sig. figs. it is 5.4 cm/year. Thus, the uncertainty can be reported as either 7 ± 5 cm/year or  $6.9 \pm 5.4$  cm/year.

*t* = 2.0s•

t = 1.0s• t = 3.0s

t = 0.0s $\bullet$ t = 4.0s

t = 5.0s

III.[25 points total] Lecture free response questionsYou must show your work to get the full credit.

## Consider the following scenario for the next two questions.

You throw a small ball upward. At time t = 0.0 s, it leaves your hand, and at t = 2.0 s, it reaches its maximum height. Neglect air resistance.

13. [6 points] An incomplete motion diagram for the ball is shown at right. Complete the diagram by indicating the positions of the ball at t = 1.0 s, t = 3.0 s, t = 4.0 s, and t = 5.0 s using the grid. Make sure to label each dot with corresponding time.
[1.5 point each] for the correct position. OR
[1 point] for not getting accurate positions but having general trend of longer displacements for lower positions.

[1 point] for having same position for at t = 1.0 s and at t = 3.0 s.

- 14. [4 points] In the space below, draw a velocity-versus-time graph for the duration between t = 0.0 s and t = 5.0 s. Note that the velocity at t = 1.0 s,  $v_1$ , is already indicated. Consider upward direction to be positive.
  - [1 point] constant downward slope
  - [1 point] v = 0 at t = 2.0 s
  - [1 point] same magnitude of velocity at t = 0.0 s and at t = 4.0 s.
  - [1 point] same magnitude of velocity at t = 1.0 s and at t = 3.0 s.



## Use the following scenario for the next two questions.

Consider the situation shown in the figure at right. String A is pulling on Box 1, and String B is connected to Box 1 and Box 2. Box 1 has mass  $m_1$ , and Box 2 has mass  $m_2$ . The boxes are accelerating up a ramp with negligible friction that makes angle  $\theta$  above horizontal. The strings have negligible mass and are parallel to the ramp surface. The tension in String A has magnitude  $T_A$ .



15. [7 points] Draw free-body diagrams for Box 1, Box 2, and the system of two boxes and String B. Make sure to label all the forces indicating the type of force, the object exerting the force, and the object on which the force is exerted.



[2 points for each FBD] all the correct forces are identified and are at correct angles OR [1 point each FBD] at least 2 correct forces are identified and are at correct angles [1 point] labeling or indicating the types of forces, agents, and objects on which forces are applied.

16. [5 points] What is the expression for the magnitude of the acceleration of the boxes in terms of the variables given and g, the free-fall acceleration?

The net force acting on the system is up the incline with magnitude  $T_1$  –

 $(m_1 + m_2)g\sin\theta$ . So, the acceleration of the system is  $a = \frac{T_1 - (m_1 + m_2)g\sin\theta}{(m_1 + m_2)}$ 

- [2 points] correct answer
- [1 point] applying Newton's 2<sup>nd</sup> law
- [1 point] Idea that net force is coming from  $T_{\rm 1}$  and gravitational force
- [1 point] Taking the correct component of gravitational force:  $(m_1 + m_2)g\sin\theta$

- 17. [3 points] A horse is standing on a level ground. What force forms the Newtons' 3<sup>rd</sup> law pair with the gravitational force exerted on the horse by the earth? Specify the type of the force, the object exerting the force, and the object on which the force is exerted. Gravitational force on the earth by the horse
  - [1 point] gravitational force
  - [1 point] on the earth
  - [1 point] by the horse

- IV. [15 points total] Tutorial free response questions
  - 18. [4 points] Two cars, A and B, move along a straight road. The strobe diagram below shows the locations of the cars at instants 1-4, separated by equal time intervals. Ignore the north-south separation between the cars (*i.e.*, consider one dimension only).



Draw a vector in each of the boxes below to represent the velocity of car B *in the reference frame of car A* at instants *1, 2,* and *3*. Draw your vectors to make clear the relative directions and magnitudes of the vectors. If any vector has zero magnitude, state so explicitly. No explanation is required.

Instant 1	Instant 2	Instant 3

All are equal in length.

1 pt for each arrows to left (3 pts total)

1 pt for equal lengths (in words or clear in diagram)

## The situation below applies to the following two $$_{\rm I}$$ questions.

Two carts, A and B, are moving on a track as shown. Cart A is approaching a fixed wall. The initial and final velocities (before and after cart A hits the wall) are shown (to scale).

 [6 points] Find the change in velocity of cart A in the reference frame of the ground between the two instants shown. Explain your reasoning in words or through a diagram.



 $\vec{v}_{iAG}$  $\vec{v}_{iAG}$  $\vec{v}_{iAG}$  $\vec{v}_{iAG}$ Change in velocity is the vector added to the initial velocity to give the final velocity. Addition is done by placing the tail of the change in velocity at the tip of the initial velocity as shown. The final velocity is the arrow from the tail of the initial velocity to the tip of the change in velocity. The

change in velocity of cart A is thus 7 cm/s to the left in the reference frame of the ground.

3 pts correct answer:

1 pt  $\Delta v$  to left

2 pts length of  $\Delta v$  larger than either the initial or final speed.

3 pts explanation:

3 points for correct diagram (either through addition or subtraction) or statement that  $\Delta v$  is quantity added to initial velocity to give final velocity or

1 pt for statement that  $\Delta v$  is to left since cart turned around and was initially moving to right

[5 points] Find the *change in velocity of cart A* <u>in the reference frame of cart B</u>. Explain your reasoning.



In the reference frame of cart B, cart A has an initial speed of 1 cm/s to the left. (Since cart B move 5 cm to the right in each second and cart A moves 4 cm to the right in each second - so cart A falls behind by 1 cm each second. (Or:  $v_{AB} + v_{BG} = v_{AG}$  or  $v_{AB} = 4$  cm/s - 5 cm/s = -1 cm/s.)

Using the same reasoning as above: the final speed of cart A relative to B is -8 cm/s. Thus, the change in velocity relative to B is 7 cm/s to the left as given by the diagram - using the same rules as above for finding the change in velocity.

## 3 pts correct answer

2 pts correct reasoning (either finding velocity of cart A in frame of B before and afterward or noting that the change is the same since both are inertial reference frames