

Name: _____

NetID: _____

Exam version **C**Lab Section: **L** _____Discussion Section: **D** _____

Instructions – *Turn off your cell phone and put it away. Please keep your calculator on your own desk. Calculators may not be shared.*

This is a closed book exam. You have (1.5) hours to complete it.

Exam Grading Policy—

The exam is composed of multiple-choice and free-response questions.

The multiple choice questions have only one correct response but you may select multiple answers for partial credit.

Please completely fill the oval next to any answer you would like to select.

MC5: *Multiple-choice-five-answer questions are each worth up to 6 points.*

MC3: *Multiple-choice-three-answer questions are each worth up to 3 points.*

MC2: *Multiple-choice-two-answer questions are each worth up to 2 points.*

Partial credit will be granted as follows.

(a) If you mark only one answer and it is the correct answer, you earn full points.

(b) If you mark N answers, one of which is the correct answer, you earn **full points** / N

For example, if you mark 3 choices on an MC5 question and one of them is correct you will receive $6/3 = 2$ points

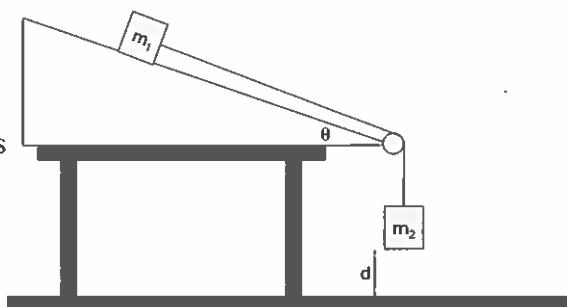
Free-response

The maximum point value for each question is given in parentheses at the end of each question. Solutions should start with equations provided on the equation sheet. Partial credit will be given as appropriate.

Academic Integrity—*Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the university.*

The next three questions pertain to the situation described below.

A mass $M_1 = 8 \text{ kg}$ is pulled down a ramp at a constant speed by rope that passes over a pulley and is then tied to the top of a mass $M_2 = 12 \text{ kg}$. Initially, the distance between the bottom of the second mass and the ground is $d = 1.5 \text{ m}$. The ramp's angle of inclination is $\theta = 25^\circ$ and has an unknown coefficient of kinetic friction μ_k .



1) What is the total work done by gravity on the two blocks, as mass M_2 drops a distance $d = 1.5 \text{ m}$?

- a. ☐ $W_g = 58.8 \text{ J}$
- b. ☒ $W_g = 226 \text{ J}$
- c. ☐ $W_g = 49.7 \text{ J}$
- d. ☐ $W_g = 294 \text{ J}$
- e. ☐ $W_g = 127 \text{ J}$

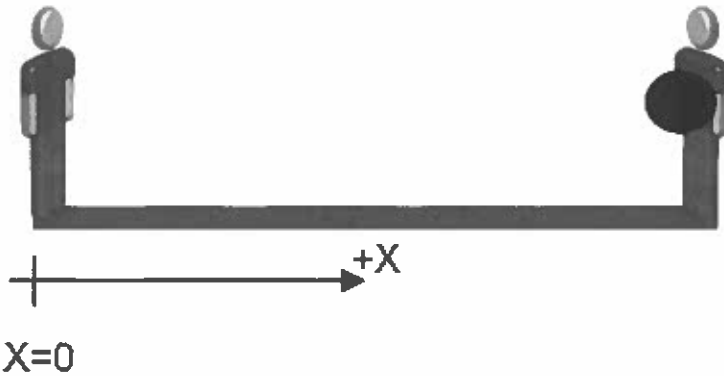
2) What is the total work done by all forces on block 1 as mass M_2 drops a distance $d = 1.5 \text{ m}$?

- a. ☐ $W_1 = 49.7 \text{ J}$
- b. ☐ $W_1 = -49.7 \text{ J}$
- c. ☒ $W_1 = 0 \text{ J}$
- d. ☐ $W_1 = 176 \text{ J}$
- e. ☐ $W_1 = -176 \text{ J}$

3) What is the magnitude of the force of friction between block 1 and the ramp?

- a. ☐ $f < M_2 g$
- b. ☐ $f = M_2 g$
- c. ☒ $f > M_2 g$

The next three questions pertain to the situation described below.



A person with mass $m_1 = 55$ kg stands at the left end of a uniform beam with mass $m_2 = 45$ kg and a length $L = 2.8$ m. Another person with mass $m_3 = 20$ kg stands on the far right end of the beam and holds a medicine ball with mass $m_4 = 14$ kg (assume that the medicine ball is at the far right end of the beam as well). Let the origin of our coordinate system be the left end of the original position of the beam as shown in the drawing (+x direction is to the right as usual). Assume there is no friction between the beam and floor.

- 4) The ball is thrown to the person at the left end of the beam with a horizontal speed of 5 m/s. What is the velocity of the people when the ball is in the air?
- a. ☐ 1.56 m/s
 - b. ☒ 0.583 m/s
 - c. ☐ 0.522 m/s
- 5) The person on the left catches the ball. What is the new x-position of the ball?
- a. ☐ 0.327 m
 - b. ☐ 1.18 m
 - c. ☐ 0.344 m
 - d. ☐ 0.392 m
 - e. ☒ 0.293 m
- 6) The two people decide they want to stand in the position that moves the plank as far as possible to the right while still holding the ball. Standing in that position, what is the x position of the left edge of the plank?
- a. ☐ 1.27 m
 - b. ☒ 0.71 m
 - c. ☐ 0.418 m

The next three questions pertain to the situation described below.

A basketball of mass $m=0.6$ kg is initially at rest $h = 1.2$ m above the ground. It falls to the ground, bounces back, and reaches a maximum post-bounce height that is only 70% of h . A camera measures the time interval in which the ball is in contact with the ground to be 0.15 second.

7) What is the speed of the ball just before it hits the ground?

- a. ☒ 4.9 m/s
- b. ☐ 3.4 m/s
- c. ☐ 2.7 m/s

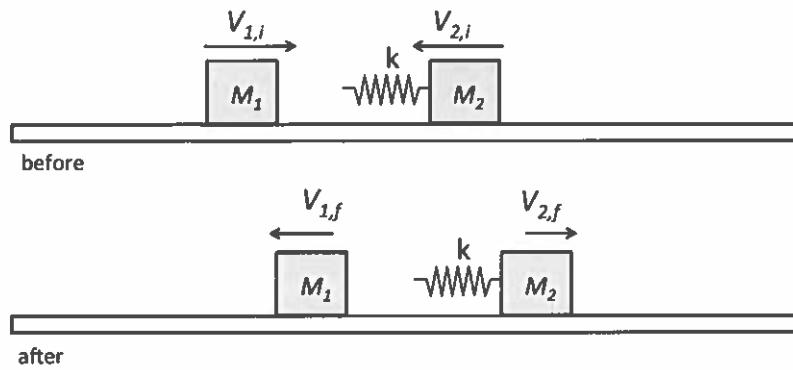
8) What is the average force exerted on the ball during its bounce, when it is in contact with the ground?

- a. ☒ 35.65 N
- b. ☐ 19.41 N
- c. ☐ 16.24 N
- d. ☐ 47.09 N
- e. ☐ 14.13 N

9) Which of the following statements best describes the ball while it is in contact with the ground?

- a. ☐ The total mechanical energy of the ball is conserved
- b. ☐ The total momentum of the ball is conserved
- c. ☒ Neither the total mechanical energy nor the total momentum of the ball is conserved.

The next two questions pertain to the situation described below.



Two carts move toward each other on a one-dimensional horizontal frictionless track. Cart 1 has mass $M_1 = 21$ kg and initial velocity $V_{1,i} = 12.143$ m/s. Cart 2 has mass $M_2 = 32$ kg and initial velocity $V_{2,i} = -0.469$ m/s. A spring between them makes the collision between the carts elastic.

10) Before the collision, what is the velocity of cart 1 as viewed by someone in the center of mass reference frame?

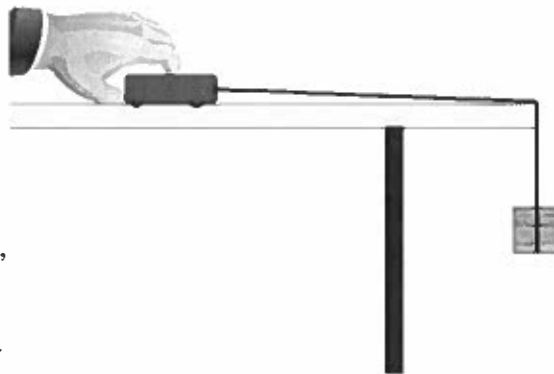
- a. ☐ $V_{1,i}^* = 5$ m/s
- b. ☐ $V_{1,i}^* = -5$ m/s
- c. ☐ $V_{1,i}^* = -7.61$ m/s
- d. ☐ $V_{1,i}^* = 4.53$ m/s
- e. ☒ $V_{1,i}^* = 7.61$ m/s

11) After the collision, what is the speed of cart 1 as viewed by someone in the reference frame of cart 2?

- a. ☐ $V_{1,2} = 4.53$ m/s
- b. ☐ $V_{1,2} = 11.67$ m/s
- c. ☒ $V_{1,2} = 12.61$ m/s

The next two questions pertain to the situation described below.

In Lab 4 of the Physics 211 course, we've used two methods to determine the work done on the IOLab by the string as the IOLab traveled 30 cm along the table pulled by the falling wooden block. The first group measured the average force experienced by the force probe of the IOLab. The second group measured the speed of the IOLab as it traveled, starting from rest, the same distance, 30 cm. The average force measured by the first group was 0.9 N whereas the instantaneous speed of the IOLab measured by the second group was 1.2 m/s. The mass of the IOLab is 0.2 kg. Both groups arrived with their respective work values, W_1 and W_2 .



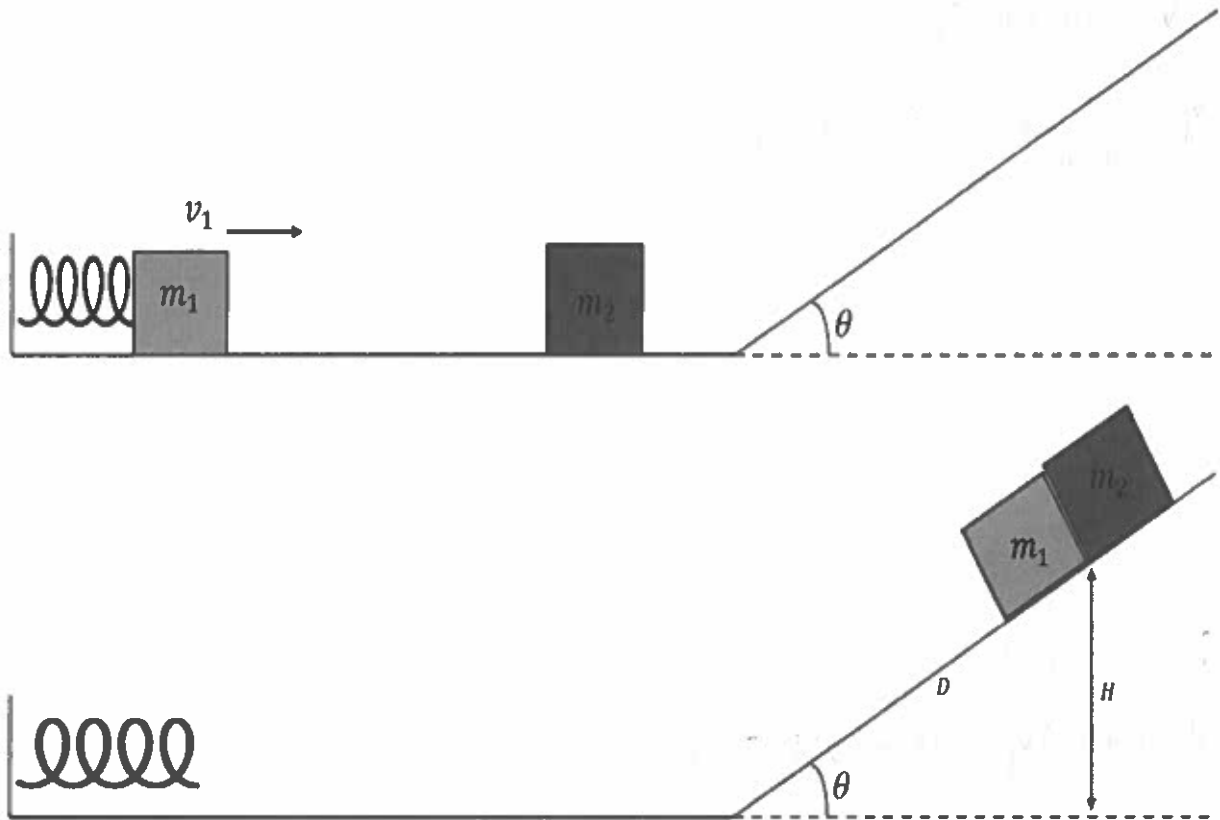
12) What is the difference in the work calculated by the two groups?

- a. ☐ $|W_2 - W_1| = 0.182 \text{ J}$
- b. ☐ $|W_2 - W_1| = 0.164 \text{ J}$
- c. ☒ $|W_2 - W_1| = 0.126 \text{ J}$

13) Which one of the following is a significant source of error in the first group's measurement?

- a. ☐ The table not being parallel to the horizon
- b. ☒ The string pulling the IOLab not being parallel to the table
- c. ☐ The friction between the IOLab and the table

The next four questions pertain to the situation described below.



A block of mass $m_1=12\text{ kg}$ is launched with velocity $v_1=8\text{ m/s}$ by a compressed spring towards a stationary block of mass $m_2=14\text{ kg}$. The entire surface (both the horizontal part and the ramp) is frictionless. After the collision, the two blocks stick together and move up the ramp making an angle $\theta=27^\circ$ to a max height of H .

14) Which statement best describes what is conserved during the collision of the two blocks?

- ☒ a. The horizontal momentum is conserved during the collision.
- Wrong ☒ b. Both the mechanical energy and the horizontal momentum are conserved during the collision.
- ☐ c. The mechanical energy is conserved during the collision.

15) Explain why the mechanical energy is, or is not conserved during the collision, and also why the horizontal momentum is, or is not, conserved during the collision. (6)

Mechanical energy is not conserved because the collision is totally inelastic.

Horizontal momentum is conserved because after m_1 leaves the spring $F_{\text{net},x}=0$.

16) What is the velocity of the blocks right after the collision (and before they go up the ramp)? (6)

$$m_1 v_{i1} = (m_1 + m_2) v_f$$

$$v_f = \left(\frac{m_1}{m_1 + m_2} \right) v_{i1} = \boxed{3.69 \text{ m/s}}$$

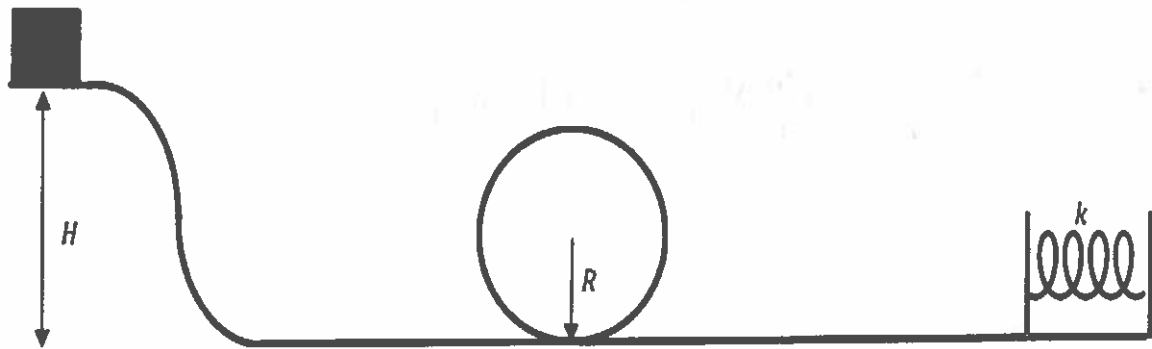
17) What is the value of the distance the two blocks travel along the ramp, D before sliding back down? (8)

$$H = D \sin \theta$$

$$\frac{1}{2} (m_1 + m_2) v_f^2 = (m_1 + m_2) g D \sin \theta$$

$$D = \frac{v_f^2}{2g \sin \theta} = \boxed{1.53 \text{ m}}$$

The next four questions pertain to the situation described below.



A roller coaster car has a mass of 500 kg. It starts at rest from a height $H=80$ m and reaches a frictionless loop-the-loop of radius $R=12$ m, after which it hits a giant spring, with a spring constant of $k=40,000$ N/m, which compresses until the cart stops.

18) What is the speed of the car at the top of the loop-the-loop? (6)

$$E_i = mgh = E_{\text{top}} = \frac{1}{2}mv_{\text{top}}^2 + 2mgR$$

$$\frac{1}{2}mv_{\text{top}}^2 = mg(H-2R) \Rightarrow v_{\text{top}} = \sqrt{2g(H-2R)} = \boxed{33.1 \text{ m/s}}$$

19) What is the speed of the car right before it hits the spring? (4)

$$mgh = \frac{1}{2}mv_{\text{bottom}}^2 \Rightarrow v_{\text{bottom}} = \sqrt{2gH} = \boxed{39.6 \text{ m/s}}$$

20) By how much does the spring compress in bringing the cart to a stop? (6)

$$mgh = \frac{1}{2}kx^2 \quad \text{or} \quad \frac{1}{2}mv_{\text{bottom}}^2 = \frac{1}{2}kx^2$$

$$\Rightarrow x = \sqrt{\frac{2mgh}{k}} = \sqrt{\frac{m}{k}} v_{\text{bottom}} = \boxed{4.43 \text{ m}}$$

21) What is the minimum initial height needed to ensure the cart makes it around the loop without losing contact with the track? (7)

$$v_{\text{min}} = \sqrt{gR} \quad mgh = \frac{1}{2}mv_{\text{min}}^2 + 2mgR = \frac{5}{2}mgR$$

$$\Rightarrow h = \frac{5}{2}R = \boxed{30 \text{ m}}$$