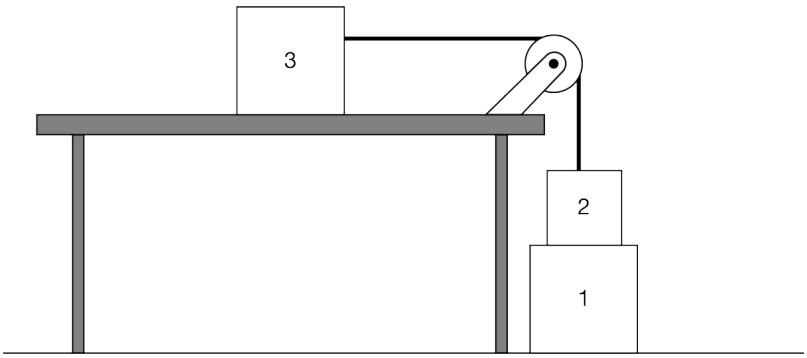
Unit 2 Progress Check: FRQ

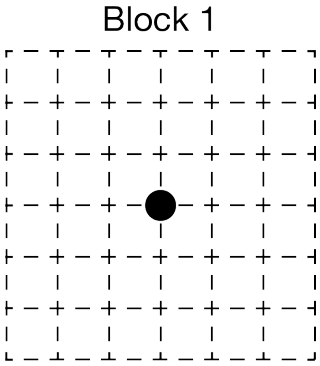
1. This question is a long free-response question. Show your work for each part of the question.



Block 1 is resting on the floor with block 2 at rest on top of it. Block 3, at rest on a smooth table with negligible friction, is attached to block 2 by a string that passes over a pulley, as shown above. The string and pulley have negligible mass.

(a)

i. On the dot that represents block 1, draw and label the forces (not components) exerted on block 1. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot. Draw the relative lengths of all arrows to reflect the relative magnitudes of the forces.



ii. On the dot that represents block 2, draw and label the forces (not components) exerted on block 2. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot. Draw the relative lengths of all arrows to reflect the relative magnitudes of the forces.

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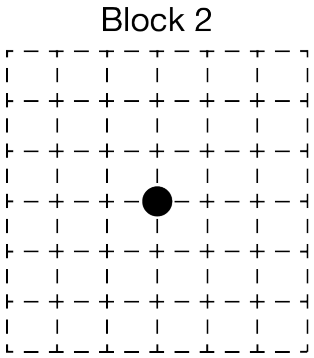


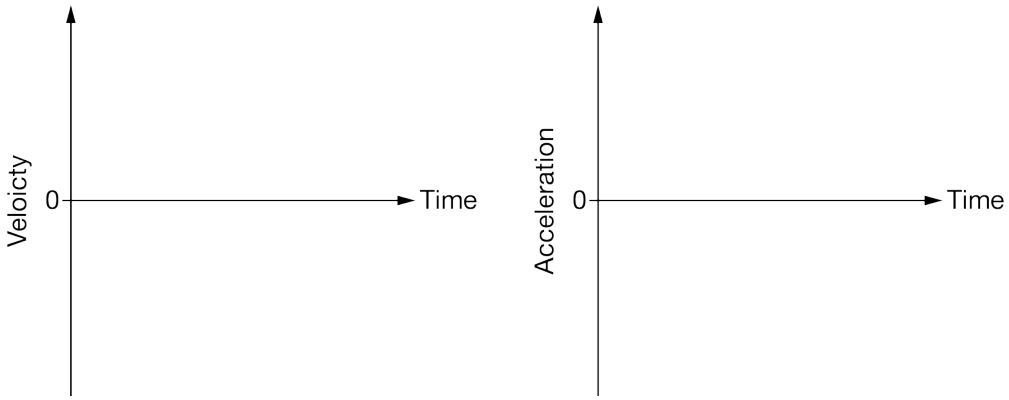
(b) Block 1 is removed without disturbing block 2.

i. Consider the scenario where the mass m_3 of block 3 is greater than the mass m_2 of block 2. Without using equations, make a claim about the motion of block 3 in terms of balanced or unbalanced forces.

ii. Derive an equation for the acceleration of block 3 for any arbitrary values of m_3 and m_2. Express your answer in terms of m_3, m_2, and physical constants as appropriate.

(c) Describe in what way your answer to part (b)(ii) is or is not consistent with your claim in part (b)(i).

(d) On the axes below, sketch graphs of the velocity and the acceleration of block 2 after block 1 has been removed. Take the time to be zero immediately after block 1 has been removed.



Part (a)i

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2 ✓

Student response accurately includes both of the following criteria.

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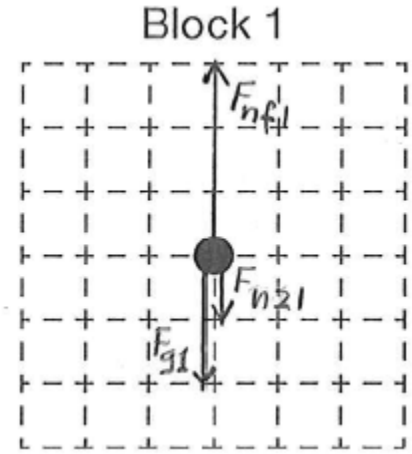
- [ ] 1 point is earned for providing correctly labeled arrows for weight, normal force from floor, and normal force from block 2.
- [ ] 1 point is earned for showing magnitudes and directions for all forces that indicate no net force.

Example Response:



Part (a)ii

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2 ✓

Student response accurately includes both of the following criteria.

- [ ] 1 point is earned for providing correctly labeled arrows for weight and normal force from block 1.
- [ ] 1 point is earned for showing that the magnitude of normal force from block 1 is equal to the magnitude for the normal force from block 2 in part (a)(i).

Example Response:

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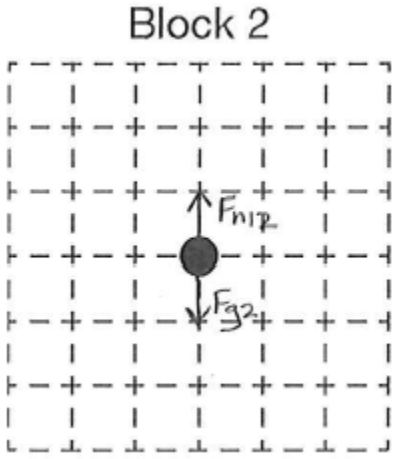

Part (b) i

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2 ✓

Student response accurately includes both of the following criteria.

- ☐ 1 point is earned for indicating the forces on block 3 would be unbalanced (net force to the right from the string).
- ☐ 1 point is earned for making a claim that indicates that since the forces are unbalanced, block 3 would accelerate to the right.

Example response:

There is a net force on block 3 which is equal to the tension in the string. This net force will cause block 3 to accelerate to the right.

Part (b) ii

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

Note: For this part, the first two points can be earned if a student uses the whole-system approach.

0	1	2	3 ✓

Student response accurately includes all of the following criteria

- ☐ 1 point is earned for attempting to use Newton's second law for each block.

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- [ ] 1 point is earned for combining the equations.
- [ ] 1 point is earned for providing a correct answer: $a = \frac{m_2 g}{m_2 + m_3}$

Example Response:

$\sum F_2 = m_2 a$
$F_g - F_T = m_2 a$
$m_2 g - F_T = m_2 a$

$\sum F_3 = m_3 a$
$F_T = m_3 a$

$m_2 g - m_3 a = m_2 a$
$m_2 g = m_2 a + m_3 a$
$m_2 g = a(m_2 + m_3)$
$a = \frac{m_2 g}{m_2 + m_3}$

Part (c)

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

Note: For this part, a valid description based on an incorrect answer for part (b)(ii) still earns the point.

0	1 ✓

Student response accurately includes the following criterion.

- [ ] 1 point is earned for providing a valid description that is consistent with the answer for part (b)(ii)

Example Response:

Yes, I said that block 3 would accelerate, and the equation in part (b)(ii) shows that there is an acceleration for any value of m_3 .

Part (d)

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

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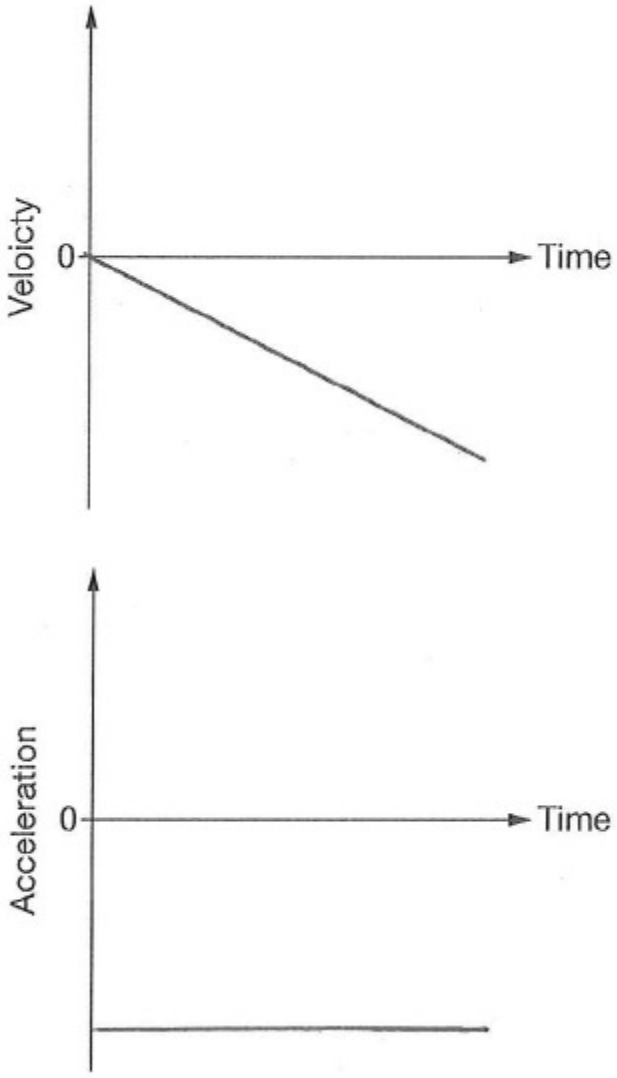
0	1	2 ✓

Student response accurately includes both of the following criteria.

- ☐ 1 point is earned for drawing a velocity graph that is a straight line through the origin, with nonzero slope (can be positive or negative).
- ☐ 1 point is earned for drawing an acceleration graph that is a nonzero constant function, consistent in sign with the velocity graph.

Example Response:



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2. This question is a short free-response question. Show your work for each part of the question.

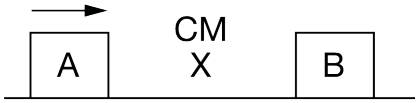

Figure 1

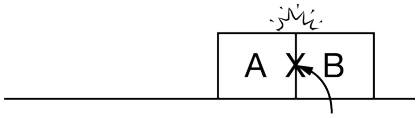

Figure 2

Two identical blocks, A and B, are on a horizontal surface, as shown above. There is negligible friction between the surface and the blocks. As shown in Figure 1, block A is initially moving toward block B with speed $v_A = v_0$ and block B is initially at rest. Figure 2 shows the blocks in contact as they collide a short time later. In both figures, the location of the center of mass of the two-block system is indicated by the X that is labeled CM.

(a)

i. On each of the dots, which represent the blocks while they are in contact during the collision, draw a single arrow to indicate the direction of the net force, if any, exerted on each block. The net force must be represented by a distinct arrow starting on, and pointing away from, the appropriate dot. If the net force is zero for either block, write "zero" under the dot representing that block.



Block A Block B

ii. During the time that the blocks are in contact, describe whether the center of mass of the two-block system is speeding up, slowing down, or staying the same.

____ Speeding up ____ Slowing down ____ Staying the same

Briefly describe, in terms of a basic law of physics, whether the center of mass of the two-block system is speeding up, slowing down, or staying the same.

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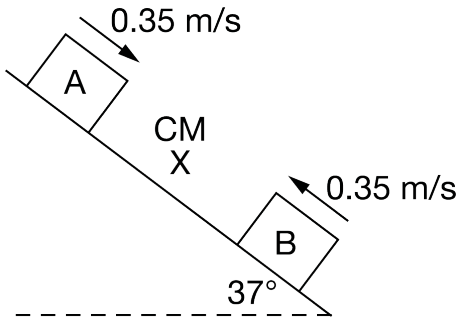

Figure 3

(b) The surface is tilted to an angle of 37 degrees from the horizontal, as shown above in Figure 3. The blocks are each given a push so that at the instant shown, they are moving toward each other.

i. Each block has a mass of $0.20\ \text{kg}$. Calculate the magnitude of the net force exerted on the two-block system at the instant shown above.

ii. At the instant shown in Figure 3, the blocks are moving toward each other with the same speed of $0.35\ \text{m/s}$. The blocks collide 0.50 seconds later. What is the speed of the two-block system's center of mass just before the blocks collide?

Part (a) i

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2 ✓

Student response accurately includes both of the following criteria.

- ☐ 1 point is earned for indicating a net force to the left for block A.
- ☐ 1 point is earned for indicating a net force to the right for block B.

Example Response:

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Part (a) ii

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1 ✓

Student response accurately includes the following criteria.

- ☐ 1 point is earned for providing a valid description of why the center of mass velocity stays the same

Example Responses:

["Staying the same" is selected.]

·*The horizontal forces on the two blocks are a Newton's third law pair and are internal to the system.*

·*The net force on the two-block system is zero.*

·*There are no external horizontal forces acting on the two-block system.*

Part (b) i

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2 ✓

Student response accurately includes both of the following criteria.

- ☐ 1 point is earned for providing EITHER an indication that the forces for both blocks must be added together OR a proper trigonometric relation to account for the angle of the ramp.
- ☐ 1 point is earned for providing a correct answer and a derivation that includes forces for both blocks

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added together AND has a proper trigonometric relation to account for the angle of the ramp.

Example Response:

The net force for one block.

$$\Sigma \vec{F} = m\vec{a}$$
$$\Sigma F_x = F_{gx}$$
$$\Sigma F_x = mg\sin(\theta)$$
$$\Sigma F_x = (0.2\,\text{kg})(10\,\text{N/kg})\sin(37^o)$$
$$\Sigma F_x = 1.2\,\text{N}$$

Since there are two blocks, the net force on the two-block system is $2.4\,\text{N}$.

Part (b) ii

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2 ✓

Student response accurately includes both of the following criteria.

- ☐ 1 point is earned for substituting correct values into an appropriate relation to get the acceleration.
- ☐ 1 point is earned for providing a correct answer.

Example Response:

$\Delta v = a\Delta t = 6(0.5\text{ m/s}) = 3\text{ m/s}$