Question 4: Qualitative Quantitative Translation (QQT) — 8 points

A	For indicating $a_1 < a_2$	**Point A1**
	For a justification that indicates that the blocks have the same weight or mass	**Point A2**
	For a justification that indicates that the salt water exerts a larger buoyant force than the freshwater exerts (or the freshwater exerts a smaller buoyant force than the saltwater exerts)	**Point A3**
	Example Response *There are identical downward forces (mg) on the block in both liquids. Each submerged block also has an upward buoyant force. Because the buoyant force is proportional to the density of the fluid, the block in salt water has a larger buoyant force exerted on it. Therefore, the block in salt water has a larger net force and so has a larger acceleration.*	
B	For a multistep derivation that includes Newton's second law	**Point B1**
	For indicating ρVg is the buoyant force	**Point B2**
	For a correct expression for the initial upward acceleration a, consistent with the indicated expression for buoyant force **Scoring Note:** A correct, isolated, final expression for a earns points B2 and B3.	**Point B3**
	Example Response $\Sigma F = m_{\text{sys}} a_{\text{sys}}$ $F_B - mg = ma$ $\rho Vg - mg = ma$ $a = \frac{\rho Vg}{m} - g$	
C	For attempting to address the functional dependence between a and ρ in the equation derived in part B **Scoring Note:** It is not necessary to use the functional dependence correctly to earn this point. The response only needs to use functional dependence language such as proportional, inversely proportional, related, numerator, and denominator, to relate a and ρ.	**Point C1**
	For correctly using functional dependence to evaluate the relationship between a and ρ consistent with the expression derived in part B and the claim made in part A	**Point C2**
	Example Response *The expression for the acceleration a is consistent with part A. In part A, I said the acceleration would be larger in salt water because the density is greater. In my expression, the acceleration increases with increasing density because of the $\frac{\rho Vg}{m}$ term.*	

Question 1: Short Answer — 7 points

(a) For drawing bars whose total heights add up to 6 units — **1 point**

Scoring Note: This point may be earned if only one bar is drawn.

For drawing a bar for U_g that has a height of 2 units — **1 point**

Example Response

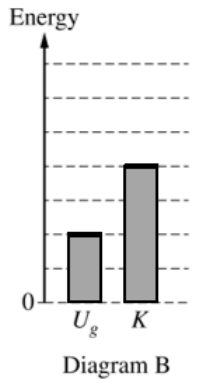


Diagram B

Total for part (a) **2 points**

(b) For a multi-step derivation that begins with conservation of energy — **1 point**

For **one** of the following: — **1 point**

- The correct answer for the speed at Point B $v = \sqrt{8gR}$
- The correct substitutions for the initial and final heights
- Substitutions for initial and final heights consistent with part (a)

Example Response

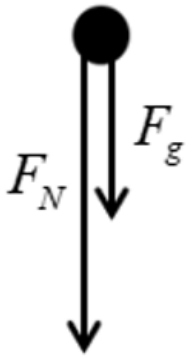
$$E_i = E_f$$
$$U_{g\mathrm{A}} = U_{g\mathrm{B}} + K_{\mathrm{B}}$$
$$mgy_{\mathrm{A}} = mgy_{\mathrm{B}} + \frac{1}{2}mv^2$$
$$Mg(6R) = Mg(2R) + \frac{1}{2}Mv^2$$
$$g(6R) = g(2R) + \frac{1}{2}v^2$$
$$\frac{1}{2}v^2 = 4gR$$
$$v = \sqrt{8gR}$$

Total for part (b) **2 points**

(c)(i) For drawing a downward arrow labeled as the gravitational force **1 point**

For drawing a downward arrow labeled as the normal force **1 point**

Example Response



Scoring Note: Examples of appropriate labels for the gravitational force include F_G, F_g, F_{grav}, W, mg, Mg, "grav force," "F Earth on block," "F on block by Earth," $F_{\text{Earth on Block}}$, $F_{\text{E,Block}}$, or $F_{\text{Block,E}}$. The labels G or g are not appropriate labels for the gravitational force.

Scoring Note: Examples of appropriate labels for the normal force include F_n, F_N, N, "normal force," or "track force."

Scoring Note: Arrows of any nonzero magnitude can earn these points.

(c)(ii) For indicating **one** of the following: **1 point**

- The block must be moving at the top of the loop to remain in contact with the loop
- If the block has zero speed at Point C the block will lose contact with the loop
- The block does not have enough kinetic energy and will lose contact with the loop
- The block does not have enough momentum and will lose contact with the loop

Scoring Note: Responses that use relevant derivations may earn this point.

Example Response

If the block were released from a height $4R$ above the ground, then based on energy conservation, the block will have a speed equal to zero at Point C. If the speed is zero, the block will lose contact with the track.

Total for part (c) 3 points

Total for question 1 7 points

Question 5: Short Answer — 7 points

(a) For determining the speed of Block B to be 3 m/s — **1 point**

Example Response

$\frac{1}{2}(2\text{ kg})v_f^{\,2} = 9\text{ J}$

$v_f = 3\text{ m/s}$

Total for part (a) **1 point**

(b) For drawing and labeling a straight line for the position of Block A with a lesser positive slope than the slope of its pre-collision line — **1 point**

Scoring Note: The correct slope is not required to earn this point.

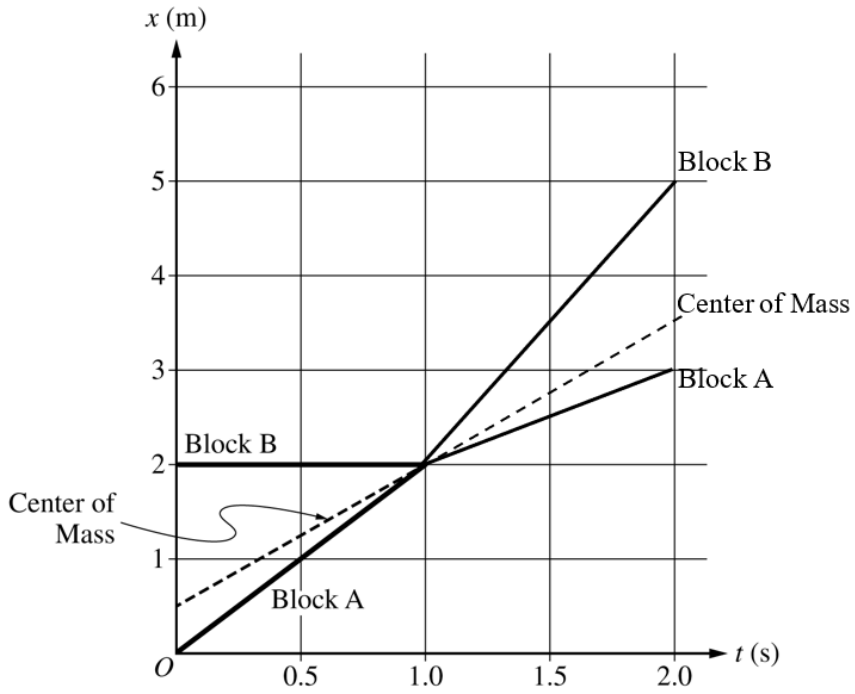
For drawing and labeling a straight line for the position of Block B with a positive, nonvertical slope — **1 point**

Scoring Note: The correct slope is not required to earn this point.

For drawing a straight line for the center of mass of the two-block system position with the same slope as the pre-collision line — **1 point**

For drawing lines for Block A and Block B with the correct slopes, 1 m/s and 3 m/s, respectively, that begin at $t = 1.0$ s and $x = 2$ m — **1 point**

Example Response



Total for part (b) **4 points**

(c) For indicating the line drawn for the center of mass of both two-block systems is the same **1 point**

For an explanation that indicates **one** of the following: **1 point**

- Momentum is conserved in an inelastic collision
- No external forces exerted on the two-block system

Example Response

The slope of the line drawn for the center of mass would remain the same as the that of the elastic collision because momentum is conserved. The lines for Block A *and Block* B *would lie along the center of mass line because the blocks slide together.*

Total for part (c) 2 points

Total for question 5 7 points