ii. **Derive** an expression for the speed v_f of the block-cart system after time $t = t_2$ in terms of m_c, v_c, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

iii. **Derive** an expression for the change in the kinetic energy ΔK in the block-cart system from $t = 0$ to $t = t_2$ in terms of m_c, v_c, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

B. Consider the case where a new block is dropped and collides with the top of the cart. The new block slides along the cart during the collision but does not slide off the cart. The time interval from when the new block collides with the cart and moves together with the cart is Δt. During Δt there is a frictional force between the new block and the cart.

Indicate whether the x-component of the momentum of the new block-cart system increases, decreases, or remains constant during Δt.

______ Increases

______ Decreases

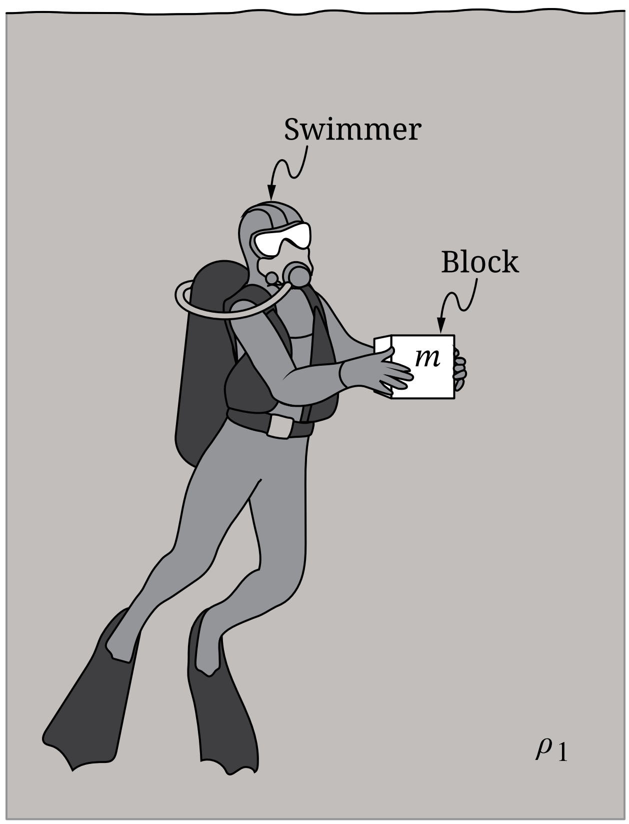
______ Remains constant

Justify your response.

Question 4

4. In Scenario 1, a swimmer holds a block of mass m at rest in a tank of freshwater with density ρ_1, as shown in Figure 1. The block is released from rest and accelerates upward with an initial acceleration a_1. All frictional forces are negligible.

Figure 1



In Scenario 2, the swimmer holds the same block at rest in a tank of salt water with density ρ_2, where $\rho_2 > \rho_1$. The swimmer again releases the block from rest, and the block accelerates upward with initial acceleration a_2. All frictional forces are negligible.

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 $\rho V g$ is the buoyant force — **Point B2**

For a correct expression for the initial upward acceleration a, consistent with the indicated expression for buoyant force — **Point B3**

Scoring Note: A correct, isolated, final expression for a earns points B2 and B3.

Example Response

$$\Sigma F = m_{\text{sys}} a_{\text{sys}}$$
$$F_B - mg = ma$$
$$\rho V g - mg = ma$$
$$a = \frac{\rho V g}{m} - g$$

C

For attempting to address the functional dependence between a and ρ in the equation derived in part B — **Point C1**

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.

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 $\frac{\rho V g}{m}$ term.