Suppose rain falls vertically into an open cart rolling along a straight horizontal track with negligible friction. As a result of the accumulating water, the speed of the cart

1. increases.
2. does not change.
3. decreases.

Answer 3. The water, because it falls vertically, does not change the cart's horizontal momentum. The mass of the cart increases, however, and so its speed decreases.
CQ Falling Sand

Consider an ice skater gliding on ice holding a bag of sand that is leaking straight down with respect to the moving skater. As a result of the leaking sand, the speed of the skater

1. increases.
2. does not change.
3. decreases.

CQ Ans. Falling Sand

Answer 2. The sand leaves the bag with the same horizontal speed as the skater. The momentum of the system of the skater and sand does not change and so the speed of the skater does not change.

CQ Rocket with Constant Thrust

If a rocket in gravity-free outer space burns fuel at a constant rate \( \frac{dm_f}{dt} = \) positive constant, is the acceleration of the rocket as a function of time

1. constant?
2. increasing?
3. decreasing?

CQ Ans. Rocket with Constant Thrust

Answer 2. Acceleration is increasing because mass of rocket is decreasing. Rewrite rocket equation as

\[
a_r(t) = \frac{dv_r(t)}{dt} = -\frac{1}{m_r(t)} \frac{dm_r}{dt} u
\]

The mass of the rocket is decreasing so \( \frac{dm_r}{dt} < 0 \). Therefore the acceleration is increasing

\[
a_r(t) = -\frac{1}{m_r(t)} \frac{dm_r}{dt} u > 0.
\]

(As the fuel burns, the rocket gets lighter.)
CQ Rocket Fuel Burn Time
When a rocket accelerates in a constant gravitational field starting from rest, will it reach a greater final velocity if the fuel burn time is

1. as fast as possible?
2. as slow as possible?
3. The final speed is independent of the fuel burn time?

CQ Ans. Rocket Equation in Gravitational Field
Answer 1: Shorter the burn time, the greater the final velocity

\[ v_f(t_f) = u \ln \left( \frac{m_i(0)}{m_f(t_f)} \right) - gt_f \]