2025A3 MASS & MASS BALANCES

LEVEL 1 QUESTION (GRADES 5 – 8)

Solution: Steady – State Behavior of the Sand Pile

The problem states that the amount of sand added by the dump truck to the pile **each minute** is equal to the amount removed by trucks **each minute**. This means the system is in **steady state**, where:

$$Mass\ In = Mass\ Out$$

Since the mass entering equals the mass leaving, **no accumulation occurs** in the system.

Step-by-Step Breakdown (Optional for Verification)

Even after 30 minutes, the mass in every minute still equals the mass out every minute.

Step 1: Calculate the total mass has entered the system (sand pile) in 30 minutes

$$Mass\ in\ after\ 30\ minutes\ = 500kg/min \times 30\ min\ = 15000\ kg$$

Step 2: Calculate the total mass that has been left in the system (sand pile) in 30 minutes.

$$Mass\ out\ after\ 30\ minutes\ = 500kg/min \times 30\ min\ = 15000\ kg$$

Step 3: Apply the mass balance

$$Mass\ In\ = Mass\ Out\ + Mass\ Accumulated$$

$$15{,}000kg\ = 15{,}000\ kg\ + Mass\ Accumulated$$

Step 4: Rearrange equation and solve for mass accumulated

$$Mass\ Accumulated\ = 15{,}000kg - 15{,}000\ kg = 0kg$$

Final answer: 0 kg. There is **no accumulation** of mass in steady state.

LEVEL 2 QUESTION (GRADES 8 – 11)

Solution: Cement Accumulation in Mixer

We will calculate the total cement in the mixer after 6 hours, considering the two different intervals:

1. First 2 hours: No cement is removed.
2. Next 4 hours: Cement is added and removed at different rates.

Step 1: Find the total cement in the first two hours

The problem states no cement is removed in the first two hours. Since 1000 kg of cement is added every hours (1000 kg per hour), we use the mass balance equation:

$$Mass\ In\ =\ Mass\ Out\ + Mass\ Accumulated$$

$$\frac{1{,}000\ kg}{hour} * 2\ hours\ =\ 0\ kg\ + Mass\ Accumulated$$

$$Mass\ Accumulated\ =\ 2{,}000\ kg$$

Step 2: Find the total cement in the next four hours

During the next 4 hours, cement is:

- Added at 1000 kg per hour
- Removed at 750 kg per hour

First, we can calculate find the cement accumulation every hour

$$Mass\ Accumulated\ =\ Mass\ In\ -\ Mass\ Out$$

$$Mass\ Accumulated\ = \frac{1{,}000kg}{hour} - \frac{750\ kg}{hour}$$

$$Mass\ Accumulated\ = \frac{250\ kg}{hour}$$

Then, we can calculate the total cement accumulation in 4 hours.

$$Mass\ Accumulated\ = \frac{250\ kg}{hour} \times 4\ hours$$

$$Mass\ Accumulated\ =\ 1{,}000\ kg$$

Step 3: Calculating the final cement in the mixer after 6 hours.

Recall that the problem states that the **mixer initially contains 2,500 kg** of cement. After 6 hours, the total cement mass is:

$$Final\ Cement\ Mass\ =\ Initial\ Mass\ +\ Mass\ Accumulated\ in\ 2\ hours\ +\ Mass\ Acccumulated\ in\ 6\ hours$$

$$Final\ Cement\ Mass\ =\ 2{,}500\ kg\ +\ 2{,}000\ kg\ +\ 1{,}000\ kg\ =\ 5{,}500\ kg$$

Final Answer: There is **5,500 kg** of cement in the mixer after 6 hours.