

This is a 1-D problem involving Free-Fall acceleration.

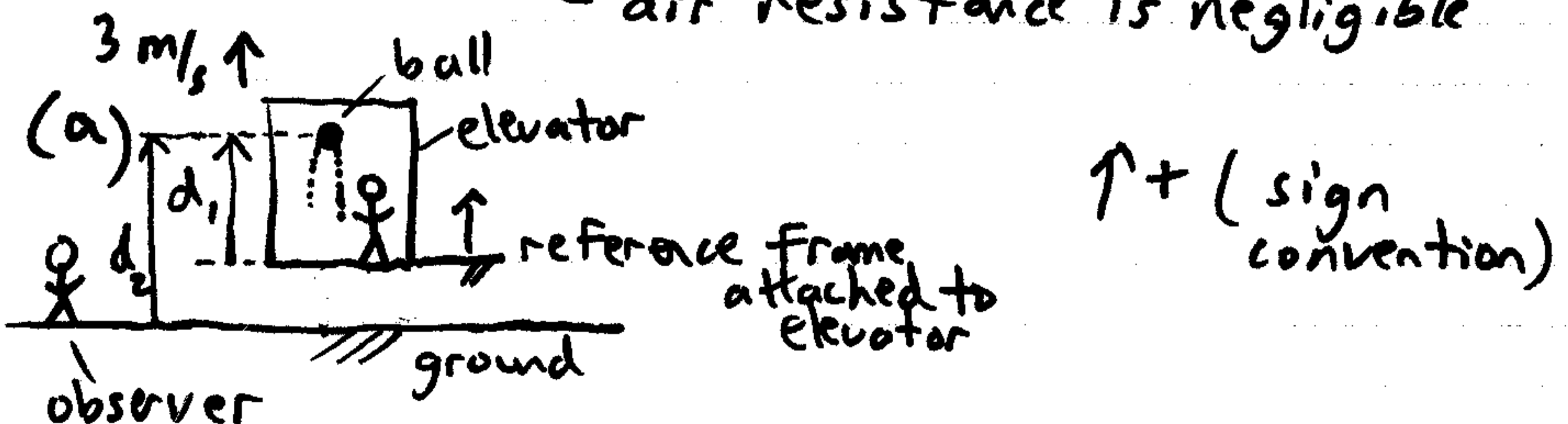
A child is standing in an elevator with glass walls, at a mall. She throws a ball in the air at a vertical upward speed of 4.5 m/s relative to the elevator, and from a height of 1.3 m relative to the elevator floor. At the same time, the elevator is moving upward at 3 m/s , starting from ground level.

(a) From the perspective of the child, what is the maximum height reached by the ball?

(b) From the perspective of someone in the mall (outside the elevator), what is the maximum height reached by the ball?

Solution:

Assumptions: - ball motion is purely vertical
- air resistance is negligible



Since the elevator is moving at constant speed, we can attach a reference frame to it (this then becomes the reference frame of the child), and we can use the usual kinematic equations for free fall.

Use the kinematic equation: $v_2^2 = v_1^2 + 2gd_1$

$v_2 = 0$ (ball speed at max. height)

$v_1 = 4.5 \text{ m/s}$ (initial upward ball speed, relative to elevator)

$g = -9.8 \text{ m/s}^2$

$d_1 = ?$ (displacement of ball, at peak height)

Substitute:

$$(0)^2 = (4.5)^2 + 2(-9.8)d_1$$

$$d_1 = 1.03 \text{ m}$$

So, from the perspective of the child, the maximum height reached by the ball is $1.03 + 1.3 = 2.33 \text{ m}$ (answer)

(b) Now use a reference frame attached to the ground, and this becomes the reference frame of the outside observer.

Use the kinematic equation: $v_2^2 = v_1^2 + 2gd_2$

$$v_2 = 0 \text{ (ball speed at max. height)}$$

$$v_1 = 3 \text{ m/s} + 4.5 \text{ m/s} \text{ (initial upward ball speed, relative to ground)}$$

$$g = -9.8 \text{ m/s}^2$$

$$d_2 = ? \text{ (displacement of ball, at peak height)}$$

Substitute:

$$(0)^2 = (3 \text{ m/s} + 4.5 \text{ m/s})^2 + 2(-9.8 \text{ m/s}^2)d_2$$

$$d_2 = 2.87 \text{ m}$$

This displacement must be added to the initial height of the ball, relative to the ground, which is 1.3 m.

So, from the perspective of the outside observer, the maximum height reached by the ball is $2.87 + 1.3 = 4.17 \text{ m}$ (answer).

Note that the instant that the child observes maximum ball height is not the same as the instant that the outside observer observes maximum ball height. In fact, when the outside observer observes maximum ball height the child sees the ball move downward at 3 m/s (relative to the elevator). Something to think about!