Task. A boy stands on a road in and throws a ball straight upwards. The car is moving with acceleration $a = 1\ m/s^2$ and the projectile velocity is $v_0 = 9.8\ m/s$. How far behind the boy will ball fall on the car?

Solution. Notice that there is a graviation force acting on the ball, so it will move with constant acceleration $g = 9.8\ m/s$ directed downward. Hence the velocity $v_b(t)$ and the height $h_b(t)$ of the ball at time t is given by the formula:

$$v_b(t) = v_0 - gt, \qquad h_b(t) = v_0 t - \frac{gt^2}{2}.$$

On the other hand, the car is moved with zero initial velocity and acceleration a, so its position $d(t)$ at time t is equal to

$$d(t) = \frac{at^2}{2}.$$

We should find $d(\bar{t})$, where $\bar{t}$ is the time when the ball reach the ground, so when $h_b(t) = 0$. Let us solve the latter equation:

$$h_b(\bar{t}) = v_0\bar{t} - \frac{g\bar{t}^2}{2} = 0$$

It follows that either $t = 0$, or

$$v_0 = \frac{g\bar{t}}{2} \qquad \Rightarrow \qquad \bar{t} = \frac{2v_0}{g}.$$

Substituting values of v_0 and g we obtain:

$$\bar{t} = \frac{2 * 9.8}{9.8} = 2\ s.$$

Hence

$$d(\bar{t}) = d(2\ s) = \frac{a\bar{t}^2}{2} = \frac{1 * 2^2}{2} = 2\ m.$$

Answer. $2m$