Answer on the question #67145, Chemistry / Physical Chemistry

Question:

A bullet is fired vertically upward with an initial velocity of 98m/s from the top of a building 100m high, find: a) the maximum height reached above the ground
B) the total time before reaching the ground
C) the velocity on landing

Solution:

Let's write kinematic equations for the bullet system:

$$x = x_0 + vt + \frac{a}{2}t^2,$$

where x is the coordinate, x_0 is the initial coordinate, v is the initial velocity and a is the acceleration. We can also write one more kinematic equation for velocity:

$$v = v_0 + at.$$

All bodies on the Earth exhibit same acceleration, 9.8 m/s^2. This is the magnitude of acceleration due to gravity. As the acceleration is directed to Earth, its sign is opposite to the initial velocity (as the bullet was fired upward).

At maximum height the velocity of the bullet is zero, as it changes the direction of motion to opposite. Thus, let's find the time when it happens:

$$0 = 98(m/s) - 9.8(m/s^2) \cdot t$$
$$t = 10\ (s)$$

Thus, we can find the coordinate at this moment:

$$x = 100\ (m) + 98(m/s) \cdot 10\ (s) + \frac{-9.8(m/s^2)}{2} \cdot (10\ (s))^2$$
$$x = 590\ (m)$$

When the bullet is reaching the ground, the coordinate is zero. So, using the kinematic equation for the coordinate we find the total time before reaching the ground:

$$0 = 100\ (m) + 98(m/s) \cdot t + \frac{-9.8(m/s^2)}{2} \cdot t^2$$

Solving the quadratic equation, we get:

$$t = 20.97\ (s)$$

The velocity on landing is the velocity at the time when bullet is reaching the ground. Thus, we take the kinematic equation for velocity (or the first derivative of the kinematic equation for coordinate) and use the time of landing:

$$v = v_0 + at = 98(m/s) + (-9.8)(m/s^2) \cdot 20.97\ (s)$$
$$v = -107.56\ (m/s)$$

As we took the positive sign for upward motion, the negative sign of the resulting velocity at landing means the motion downwards.

Answer: A) $590\ (m)$ B) $20.97\ (s)$ C) $107.56\ (m/s)$.