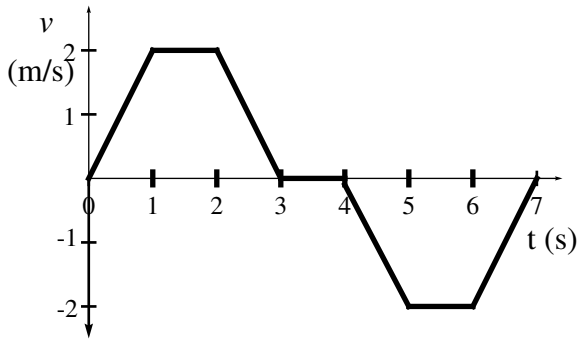
1. The graph below shows a velocity-time diagram of a remote control car as it moves along a straight horizontal line. Assume the positive direction is to the right.



Give a *qualitative* description of the motion of the car during its journey. Include a description of its displacement, velocity and acceleration during different periods of motion.

Starting from rest the car accelerates uniformly to the right for one second. It then continues moving to the right at a constant speed for one second before taking another second to slow down to a rest. During this entire time it has been moving further to the right for a total distance of 4 m. Next it remains at rest for a second and then changes direction and accelerates uniformly to the left for one second. Then it moves left at constant speed for one second before taking a second to slowing down to a stop – arriving back at the origin. The total displacement is zero.

2. A frightened zebra is running with a constant velocity of 25 m/s. A lion starting at rest from 80 m behind the zebra accelerates at 20 ms^{-2} for 2.0 s before continuing the chase at constant speed

   (a) How far have the lion and zebra traveled after 2 seconds?
   At $t = 2$ s the displacement of the lion is

   $$x_L = \tfrac{1}{2}at^2 = \tfrac{1}{2}(20)(2)^2 = 40\,\text{m}$$

   and the displacement of the zebra is

   $$x_Z = v_Z t = 25 \times 2 = 50\,\text{m}.$$

   (b) What is the lion's speed after 2 seconds?
   After 2 seconds the lion continues with constant speed

   $$v_L = at = 20 \times 2 = 40\text{m/s}.$$

   (c) Calculate the time and the position of the point of capture.

   (d) On the same set of axes draw a sketch of position versus time for the lion and the zebra. Take $x = 0$ to be the initial position of the lion and $x = 80$ the initial position of the zebra. Indicate the position of both animals at 2 seconds and at the time of capture on your graph

To find the point of capture consider the expressions for the position of the lion and the zebra after two seconds have passed

$$x_L = 40 + v_L t = 40 + 40t$$

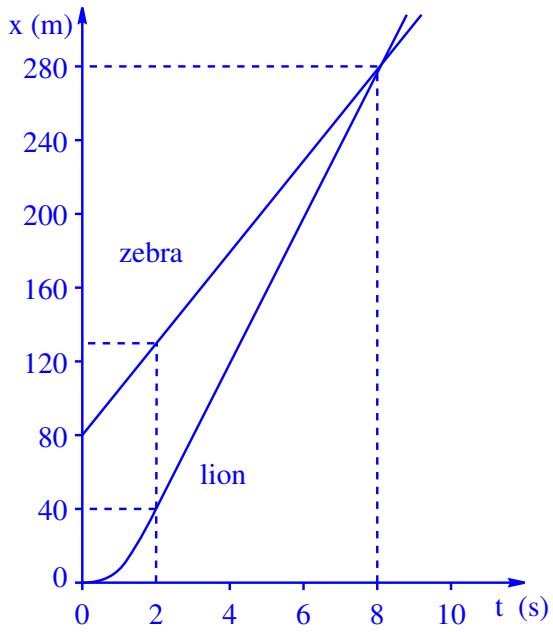
and

$$x_Z = 80 + 50 + v_Z t = 130 + 25t$$

where t measures the time since the lion stopped accelerating. At the point of capture $x_L = x_Z$ so

$$40 + 40t = 130 + 25t \;\Rightarrow\; 15t = 90 \;\Rightarrow\; t = 6s.$$

so the point of capture is when $x = 40 + 40 \times 6 = 280$ cm and $t = 2 + 6 = 8$ s

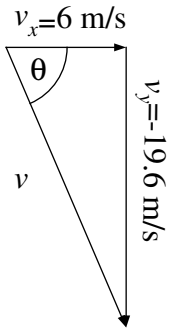


3. A student at the top of the Clock tower wishes to throw a water balloon at his beloved physics teacher who is on red square 12 m from the base of the tower. The student throws the ball horizontally with speed 6.0 m/s and it hits the teacher at his feet.

(a) How long does it take the balloon to reach him?
$\Delta x = v_x t \;\Rightarrow\; t = \Delta x / v_x = 12/6 = 2.0$ s

(b) Hence, or otherwise, deduce the height of the clock tower.
$\Delta y = -\frac{1}{2} g t^2 = -\frac{1}{2}(9.8)(2)^2 = -19.6$ m. So height is 19.6 m.

(c) Find the magnitude and direction of the velocity with which the balloon hits the the teacher.



First, the components of velocity are

$$v_x = 6 \text{ m/s} \quad \text{and} \quad v_y = a_y t = -9.8(2) = -19.6 \text{ m/s}.$$

So the magnitude of velocity, $v = \sqrt{v_x^2 + v_y^2}$, is

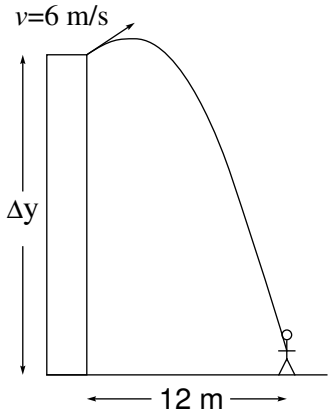
$$v = \sqrt{(6)^2 + (-19.6)^2} = 20.5 \text{ m/s}.$$

The direction is given by

$$\theta = \tan^{-1}(v_y/v_x) = \tan^{-1}(-19.6/6) = -73^\circ.$$

So the balloon is coming in at an angle of 73° below the horizontal.

(d) The student lobs another balloon at the same speed but this time at an angle of 25° above the horizontal. Show that this balloon lands in the same place as the first.



For this case

$$v_{yo} = 6 \sin 25 = 2.54 \text{ m/s}$$

$$v_{xo} = 6 \cos 25 = 5.44 \text{ m/s}$$

The time the balloon takes to reach the horizontal position 12 m from the base of the tower is

$$t = \Delta x / v_x = 12/5.44 = 2.21 \text{ s}$$

In 2.21 s the balloon falls a vertical position

$$\Delta y = v_{yo} t - \frac{1}{2} g t^2 = 2.54(2.21) - \frac{1}{2}(9.8)(2.21)^2 = -18.3 \text{ m}.$$

This is $19.6 - 18.3 = 1.3$ m above the ground which is less than the height of the teacher. So the balloon hits the teacher at about chest height. He should have moved out of the way!