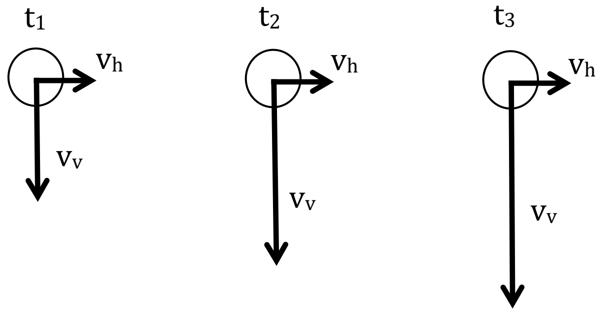
4.4 Projectile Motion

videos

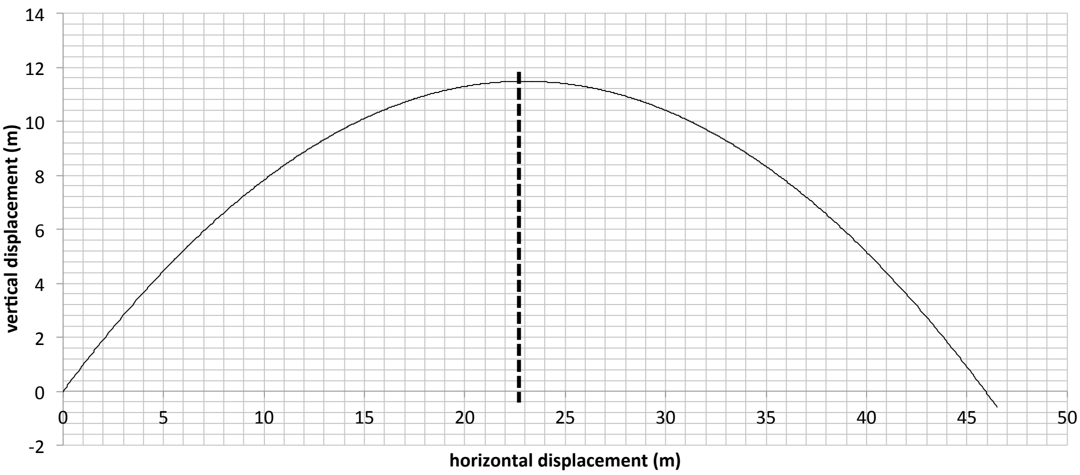
In the absence of air resistance, projectile motion is essentially the motion of objects experiencing a constant force (due to gravity) in the vertical direction and no force in the horizontal direction. This means that objects will accelerate downwards but maintain any sideways velocity.



The diagram above shows the vertical and horizontal velocity vectors (v_v,v_h) for an object at successive times (t_1, t_2, t_3). You can see that the vertical velocity increases with time, whereas the horizontal component remains constant. If this is an object in the Earth's gravitational field, the vertical velocity will be increasing (downwards) at $9.8ms^{-1}$ every second (i.e. an acceleration of $9.8ms^{-2}$).

Because we have uniform acceleration in the vertical direction, we can apply the suvat equations to the vertical motion.

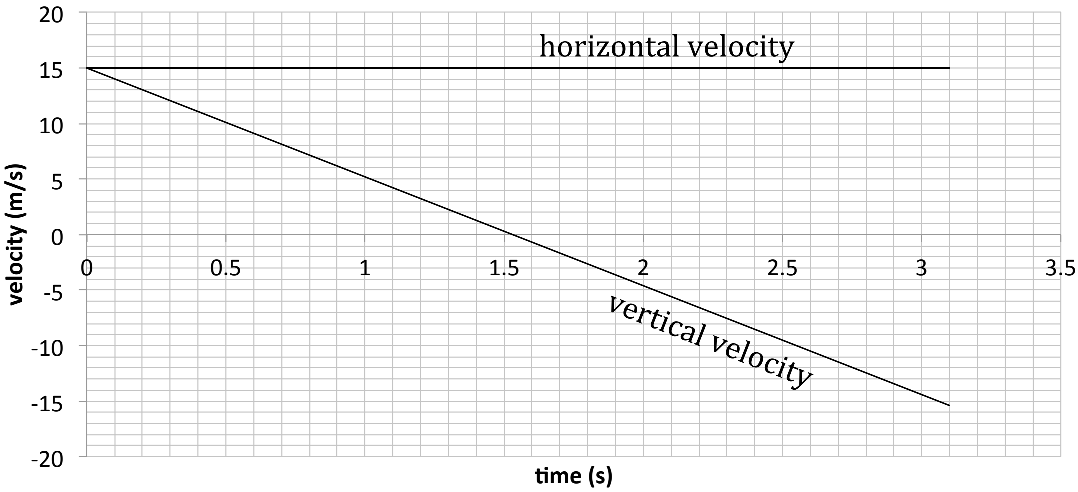
Let us look at an example of projectile motion:



The projectile is initially projected at an angle of 45°, and a velocity of $21.2ms^{-1}$. The horizontal and vertical displacements are plotted (essentially, this is the flight path of the projectile). Note that the flight path is symmetrical (about the dashed line). The horizontal distance travelled as the projectile rises to its highest point is equal to the horizontal distance travelled as the projectile comes back down again.

(1)✏What can we conclude about the time taken for the projectile to reach its maximum height compared to the total time of flight?

Below we have plotted the vertical and horizontal velocities against time for the same projectile motion:



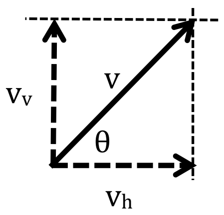
(2)✐At what time does the projectile reach its maximum height? How can you tell?

(3)✐Using the 'area under the graph' method, work out the maximum height reached by the projectile. Does this agree with the displacement graph?

(4)✐Using the 'area under the graph' method, work out the total horizontal distance travelled. Does this agree with the displacement graph?

Applying suvat equations

We can resolve our initial velocity vector into a vertical component (v_v) and a horizontal component (v_h).



$$v_h = v\cos\theta$$
$$v_v = v\sin\theta$$

We can then use the vertical component of velocity v_v as the initial velocity (u), and use the suvat equations on the vertical component of the motion.

(5)✐Taking a launch angle of 45°, and an initial velocity (v) of 21.2ms^{-1}, work out the vertical component (v_v) of the initial velocity.

(6)✐*Taking your answer above as the initial velocity (u), and a=-9.8ms^{-2}, find the time taken to reach the maximum height (i.e. where final velocity v=0ms^{-1}). Hint: use* $v = u + at$.

(7)✐*What is the total time of flight?*

(8)✐*At maximum height v=0ms^{-1}. Find the maximum height. Hint: use* $v^2 = u^2 + 2as$.

(9)✐*Calculate the horizontal component (v_h) of the initial velocity. See above.*

(10)✐*Bearing in mind that the horizontal component of velocity remains constant, use the total time of flight to calculate the total horizontal distance travelled.*