Projectiles

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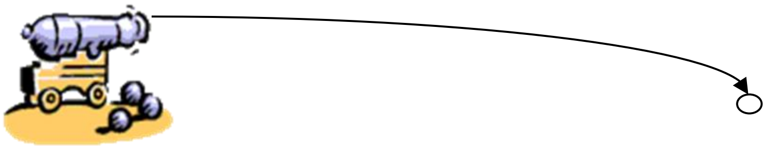
Projectile Motion

A **projectile** is an object which has been given a **forward** motion through the air, but which is also pulled **downward** by the force of gravity.
This results in the trajectory (path) of the projectile being curved.
For example, a cannon firing a cannonball will result in the cannonball following a curved trajectory as shown below.



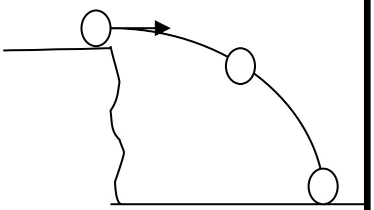
A projectile has two **separate** motions at right angles to each other - **horizontal and vertical**. Each motion is **independent** of the other.

Points to note:

- The **horizontal** motion is at a **constant velocity** since there are no forces acting horizontally if air resistance can be ignored (Newton's first law of motion).
  Horizontal displacement = horizontal velocity x time in the air (**s = v t**)
- The **vertical** motion is one of **constant acceleration**, equal to the value of **g**.
  For projectiles which are projected horizontally, the initial vertical velocity is zero.
  For vertical calculations, use **v = u + at**, where **u = 0 and a = g (= 9.8ms^{-2} on Earth).**

Example: Using formulae
A ball is kicked horizontally at 5 ms^{-1} from a cliff top as shown below. It takes 2 seconds to reach the ground.

a) How far does the ball travel horizontally in 2 seconds?
b) What was its vertical velocity just before it hit the ground?



Solution

a) Horizontal
s =?
v = 5ms^{-1}
t = 2 s

s = v t
s = 5 x 2
s = 10 m

b) Vertical
v = ?
u = 0
a = 9.8 ms^{-2} (= g on Earth)
t = 2s (time is the same for vertical and horizontal motion)

v = u + at
v = 0 + (9.8 x 2)
v = 19.6 ms^{-1}

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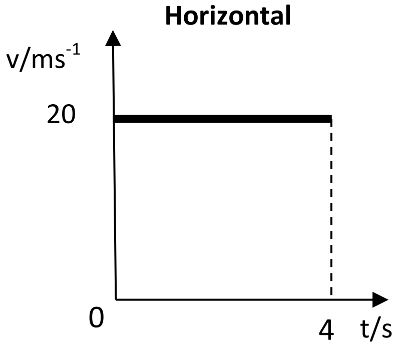
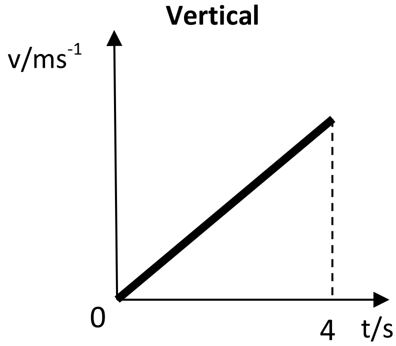
Projectile Motion (ctd)

Example: Using Graphs
A bird flying horizontally at a constant velocity drops a fish it is carrying into a lake.
The velocity - time graphs for both the horizontal and vertical motion of the fish from when it is dropped until it hits the water are shown below.





Calculate

a) **The horizontal velocity when it hits the water.**
b) **The vertical velocity when it hits the water.**
c) **The horizontal displacement of the fish travelled after it was dropped.**
d) **The height the osprey was flying when it dropped the fish.**

Solution

a) Horizontal velocity = 20 ms^{-1} (horizontal velocity remains constant throughout).

b) Vertical

v = ?	v = u + at
u = 0	v = 0 + (9.8 x 4)
a = 10 ms^{-2}	v = 39.2 ms^{-1}
t = 3 s	

c) Horizontal displacement = area under the horizontal velocity - time graph
= area of rectangle
= 20 x 4
= 80 m.

d) Height = area under the vertical velocity - time graph
= area of triangle
= ½ x 40 x 4
= 80 m.

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Satellites – An Application of Projectile Motion

Satellite motion is an application of projectile motion. A satellite is continually accelerating vertically towards the ground just like any other projectile. However, the satellite is moving so fast horizontally that the Earth curves away from it as quickly as it falls. This means that the satellite never reaches the earth but continues to move in orbit.