Q- A rocket rises vertically from rest, with an acceleration of 3.2 m/s^2 until it runs out of fuel at an altitude of 1200 m. After this point, its acceleration is that of gravity, downward.

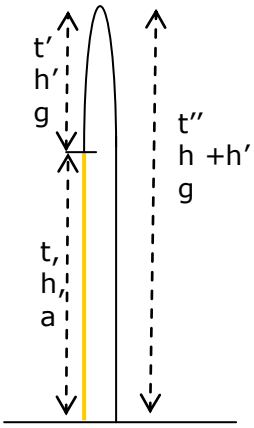
(a) What is the velocity of the rocket when it runs out of fuel?

Initial velocity of the rocket u = 0

Acceleration of the rocket a = 3.2 m/s^2 [upward hence positive]

Displacement during the first lap h = 1200 m

Final velocity of the rocket (say) v =?



Using the third equation of motion we have

$v^2 = 0 + 2*a*h$

Or $v = \sqrt{2ah} = \sqrt{2*3.2*1200} = 87.64$ m/s

(b) How long does it take it to reach this point?

Time taken t to reach point is given by the second equation of motion as

$s = ut + \frac{1}{2} at^2$

or $h = 0 + \frac{1}{2} a*t^2$

or $t = \sqrt{\frac{2h}{a}} = \sqrt{\frac{2*1200}{3.2}} = 27.39$ s

(c) What maximum altitude does the rocket reach?

After 1200 m of height it will rise up till its velocity becomes zero and hence the height reached after it runs out of the fuel h' will be given by the third equation as

$[v^2 = u^2 + 2*a*s]$

Or $0 = (87.64)^2 + 2*(-9.8)*h'$

Gives h' = 7680/19.6 = 391.84 m.

Hence maximum altitude reached by the rocket will be

$h + h' = 1200 + 391.84 = 1591.84$ m

(d) What is the total time that it takes to reach maximum altitude?

Time taken t' from 1200 m height to the maximum altitude (velocity is zero) is given by The first equation of motion as [v = u + a*t']

Or $0 = 87.64 + (-9.8)*t'$ [motion under gravity]

Or t' = 87.64/9.8 = 8.94 s.

Hence the total time taken to reach the maximum altitude will be

$t + t' = 27.39 + 8.94 = 36.33$ s.

(e) With what velocity does the rocket strike the earth?

Consider the motion from the maximum altitude with downward direction positive, the initial velocity is zero, the displacement s = 1238.27 m, and the acceleration is 9.8 m/s^2, hence the final velocity at the surface of the earth v is given by

$v^2 = u^2 + 2*a*s$

or $v^2 = 0 + 2*9.8*1591.84 = 31200$

or $v = 176.64$ m/s.

(f) What is the total time that it is in the air?

Time to reach ground from the maximum altitude t'' is given by

$[s = ut + \frac{1}{2} at^2]$

$1591.84 = 0 + 0.5*9.8*t''^2$

Gives $t'' = 18.02$ s

Hence the total time in air will be

$t + t' + t'' = 27.39 + 8.94 + 18.02 = 54.35$ s.