SKILL 15: OBJECTS LAUNCHED UPWARD (But pulled down by gravitational field)

ACCELERATION IS A VECTOR.

FOR OBJECTS LAUNCHED VERTICALLY UPWARD YOU MUST MAKE "g" -9.81m/s²

For a dropped object (Skill 3), the reference point is usually the top (drop point) and the object moves away from the observer and gets faster. Therefore, in a dropped object scenario, the downward direction is assigned positive.

For objects launched upward, the reference point is usually the ground, and the object initially slows down going upward until it reaches the high point (velocity of zero), changes direction to downward and speeds up (negative velocity). If landing at the same height from which it was launched, the following rules apply

- The launch velocity will be equal in magnitude but opposite in direction from landing (impact velocity)
- The velocity at the highest point (max height of projectile) is zero.
- The acceleration is due to the gravitational field strength "g" for the entire flight so $a=g=9.81m/s^2$ downward [For the upward motion (or entire path) initial velocity is positive so acceleration must be negative]
- The flight to the top is the mirror image of the fall back down so the high point occurs at half-time. (time up equals, time down)

Keep in mind that the time interval may be the entire time of flight or the time to the max height. Therefore **the assignment of initial velocity (v_i) and final velocity (v_f) depends on the time interval being investigated and does not necessarily align with launch and landing velocity**.

Example:

Scenario: A rocket is launched vertically upward and has a total time of flight of 15 seconds.

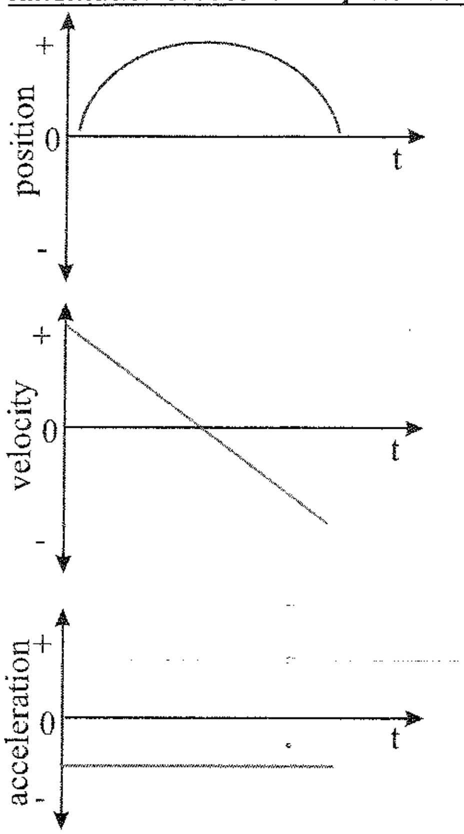
a) What is the launch velocity of the rocket?

Up is the mirror image of down so the total change in velocity will be split
$\Delta v = at = (-9.81m/s^2)(15s) = -147.15m/s$ so splitting that change shows that the object was launched at 73.58m/s and landed at -73.58 m/s.

b) What is the max height reached by the rocket?

The maximum height is reached at the half time (t=7.5 seconds) where the velocity at the top =0. Two options exist for considering this motion:
Upward launch with $+v_i$ and $-g$ and $v_f = 0$
Downward fall with $v_i=0$ $+g$ and $v_f=+$ value equal to launch velocity

Kinematics Curves for Objects Launched Upwards



The 3 graphs at left summarize the motion of vertically launched projectile with respect to time for position (d vs t), velocity (v vs t) and acceleration. For objects launched upward, the reference point is the ground:

- The object initially slows down going upward
- It reaches the high point (velocity of zero)
- Changes direction to downward and speeds up (negative velocity).
- Note that the overall vertical displacement is zero (same position at beginning and end). Area of velocity vs time cancels out. Slope of velocity vs time (rate of velocity) known as acceleration is constant.
- Acceleration is uniform negative (like the gravitational acceleration)

SHORTCUTS FOR PROJECTILES LAUNCHED UPWARD

Since v_i is equal and opposite to v_f then $\Delta v=2v_i$ combined with ($v_f=v_i+at$) ; ($\Delta v= v_f-v_i$) ; ($a=\frac{\Delta v}{t}$)

results in $$t = \frac{2v_{iy}}{a}$$ (use to find total time of flight)

Max height is determined at the ½ time point. For the falling half of the problem $v_i=0$ so height can be determined by **$d=1/2at^2$** where t is ½ total time and a=g and can be a positive value.

$v_f^2=v_i^2+2ad$ The landing velocity of a projectile can be determined by looking at the object falling from the high point. In such a case the $v_i=0$ (at high point) $$v_f = \sqrt{2ad} \text{ or } \sqrt{2gh}$$