The Math of Falling

Aka Being Chekov in Star Trek XI

The Scene

The Basics

- At position x, the velocity (v) of an object is the derivative of position x(t) with respect to time
- Acceleration is then the derivative of the velocity with respect to time or the second derivative of position x.
- So, if acceleration is known, the integral of acceleration is equal to velocity and the integral of the found velocity is equal to the position

$$v(t) = \int a dt = v_0 + at$$

$$x(t) = \int v dt = x_0 + v_0 t + \frac{1}{2} a t^2$$

The Equations

Defintion of variable in the equations below:

- a= acceleration t=time
- v=velocity with v_0 as intitial velocity and v(t) as velocity at time t
- x= position with x_0 as intial position and x(t) as position at time t

$$v(t) = \int a dt = v_0 + at$$

$$x(t) = \int v dt = x_0 + v_0 t + \frac{1}{2} a t^2$$

On Earth

- On Earth, it can be assumed that a=-g(9.8) for objects sufficiently close to the surface of the earth in free fall.
- Therefore the equations for Earth:

$$a = -9.8$$

$$v(t) = \int a\,dt = v_0 - 9.8t$$

$$x(t) = \int v\,dt = x_0 + v_0 t + \frac{1}{2}(-9.8)t^2$$

- Therefore during the 67 seconds of falling, they would have fallen 21996.1 meters (13.67 Miles) on earth

On Vulcan

- It is assumed in this instance that Vulcan has about twice the g of earth, therefore

$$a = -19.6$$

$$v(t) = \int a\,dt = v_0 - 19.6t$$

$$x(t) = \int v\,dt = x_0 + v_0 t + \frac{1}{2}(-19.6)t^2$$

- So falling for 67 seconds, they would have fallen 43992.2 meters (27.34 Miles)

On the Moon

- The g of the moon is 1.6 (Because it is so much smaller than Earth
- Therefore:

$$a = -1.6$$

$$v(t) = \int a\,dt = v_0 - 1.6t$$

$$x(t) = \int v\,dt = x_0 + v_0 t + \frac{1}{2}(-1.6)t^2$$

- So in 67 seconds, they would have fallen 3591.2 meters (2.23 Miles)

Changes in the Environment

- The g affects the rate of the fall, or how much ground is covered in a certain amount of time.
- On Earth, they would have fallen a distance of 21996.1 m
- On Vulcan, they would have fallen 43992.2 m
- On the moon, they would only fallen 3591.2 m

Changes in the Scenario

- There is also the possibility of initial velocity and/or a projectile motion of the object.
- The initial velocity is already accounted for the equations as v_o and so can just be plugged into the formula
- If the motion is projectile than the equations change to become slightly more complex because of angles

Exceptions

- These equations do not take into account air resistance, drag, friction, or other factors that would probably have existed in the actual scenario but the basic ideas are there.

So How Did Chekov Do It?

- In the film scenario, Chekov could have programmed the equations into the system and allowed the transporter to stay locked on the falling characters as they were falling
- It is also possible that he simply used the amount of time that they had been falling, the above equations, and the original distance to calculate their position at a certain time in the future.

Thank You!

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