Cosmic Velocities and Dead Loop

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The First Cosmic Velocity

- The first cosmic velocity is the velocity that's needed to launch the body from the Earth's surface, so it can orbit around Earth on a small height . It is the initial velocity that body needs to acquire to become Earth's artificial satellite.
- First cosmic speed takes place at the height h=200km because the resistance force on that height is almost negligible.
- Velocity of an object doesn't depend on it's mass

$$F_g = F_{cp}$$

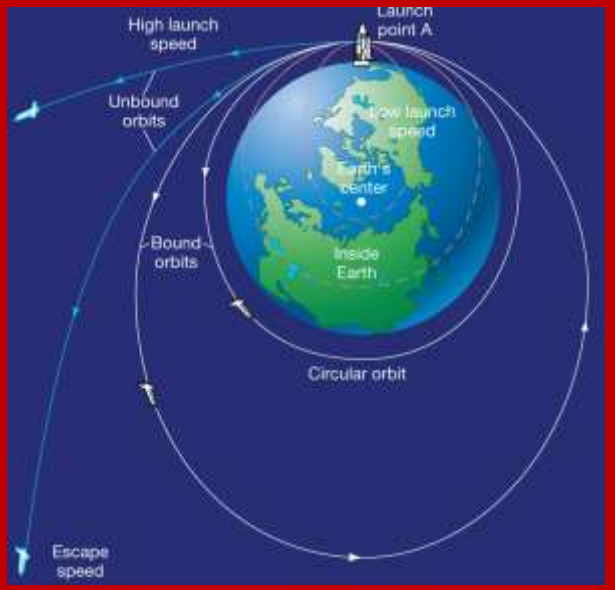
$$\frac{GMm}{(R+h)^2} = \frac{mv_1^2}{(R+h)}$$

- Because the satellite orbits on a small height, h<<R we have R+h≈R

$$v_1 = \sqrt{\frac{GM}{R}} = \sqrt{Rg} = 7{,}9\ km/s$$

The Second Cosmic Velocity

- The second cosmic velocity is known as the escape velocity and it is the minimum speed needed for a free object to escape from the gravitational influence of a massive body.
- The escape velocity from Earth is about 11,2 km/s at the surface.



$E_2 = E_1$ r = ∞ → G Mm/r = 0

$E_{k2} + E_{p2} = E_{k1} + E_{p1}$

$$\frac{mv_2^2}{2} - G\frac{Mm}{R} = \frac{mv_1^2}{2} - G\frac{Mm}{r}$$

$G\frac{Mm}{R}$ is constant, so v_2 is the minimal velocity when $v_1 = 0$, that is, when the velocity of the body that is far from Earth is negligible. So:

$$\frac{mv_2^2}{2} - G\frac{Mm}{R} = 0 \rightarrow v_2 = \sqrt{2gh} = \sqrt{2\frac{GM}{R}} = 11{,}2\ km/s$$

Third and Fourth Cosmic Velocity

- The third cosmic velocity is the smallest velocity needed to launch a body from the Earth's surface to leave the area of Sun's action(to become an artificial star).
- To calculate third cosmic velocity we need to to know Second Cosmic Velocity $v_2 = 11{,}2\ km/s$ and velocity of the body relative to the sun
- $v' = 12{,}4\ km/s$ .Third cosmic velocity $v_3 = \sqrt{v_2^2 + v'^2} = 16{,}7\ km/s$
- The fourth cosmic velocity is the smallest velocity that the launched body has so it can leave the gravitational field which our galaxy possesses and enter the universe.
- The value of the fourth cosmic velocity is $v_4 = 290\ km/s$

Dead Loop

- Minimum height from which body needs to slide without friction force affecting it so it can make a full loop of radius is called dead loop.
- You will make the full loop if at the maximum height you have appropriate speed. At that position gravity force and normal reaction force affect the body. We conclude:

$$ma_{cp} = mg + N$$

$$\frac{mv^2}{r} = mg + N \rightarrow v = \sqrt{rg} + \frac{rN}{m}$$

When there is no friction force, we use the law of conservation energy. If we replace the expression for velocity at the maximum height of the loop, we get:

$$h = \frac{r}{2} + \frac{rN}{2mg} + 2r\text{h}$$

Minimum value of height we get in the case of when N=0 than $h_{min} = \frac{5r}{2}$