RELATIVITY

1. Special Relativity
2. Time Dilation
3. Doppler Effect
4. Length Contraction
5. Twin Paradox
6. Electricity and Magnetism
7. Relativistic Momentum
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9. Energy and Momentum
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TWIN PARADOX

What is a twin paradox?

- Two identical clocks, one of which remains on the earth while the other is taken on a voyage into space at the speed υ and eventually is brought back.
- We can replace the clocks with a pair of twins Mish3al and Masha3il ☺. (heartbeats, respiration and so on are biological clocks or reasonable regularity.

TWIN PARADOX

Mish3al is 20 years old.
Travels at a speed of 0.80c
To a distant star 20 light-years away.
and Masha3il ☺. (heartbeats, respiration and so on are
biological clocks or reasonable regularity.

Masha3il sees that Mish3al's life is
slower than hers by a factor of

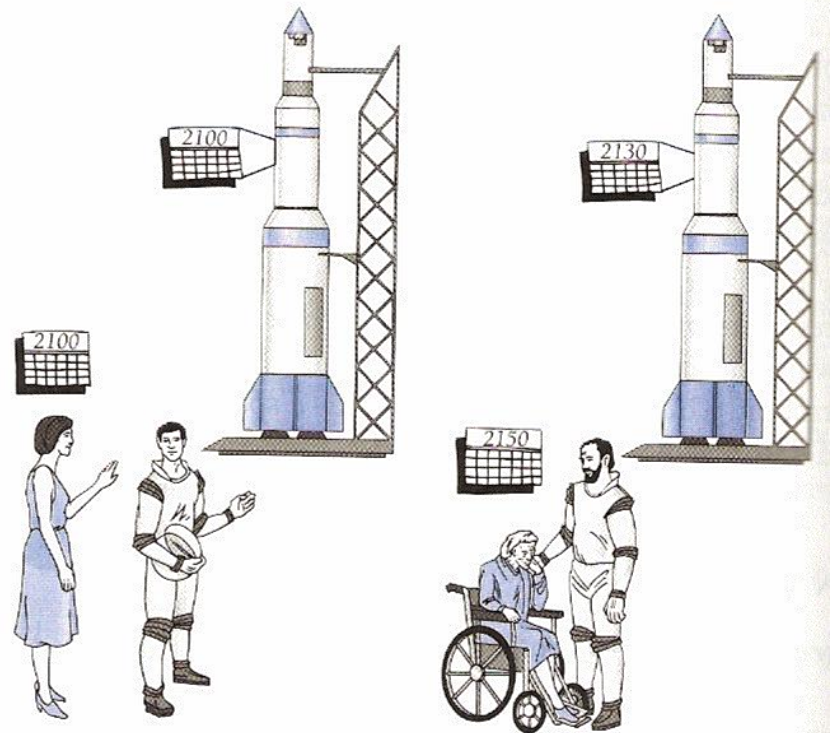$$\sqrt{1 - v^2/c^2} = \sqrt{1 - (0.8c)^2/c^2} = 0.6 = 60\%$$

**Mish3al's heart beat 3 times for ever 5 beats of
Masha3il's heart.**

TWIN PARADOX

After 50 years in **Masha3il's** calendar, Mish3al returns.

For **Mish3al**, the trip took only 30 years.

Mish3al's is now 50 years old whereas Masha3il his twin who stayed home is 70 years old!

TWIN PARADOX

Where is the paradox?

If we consider the situation from the point of view of Mish3al in the spacecraft, Masha3il on earth is in motion relative to him at a speed of 0.8c. Should not Masha3il then be 50 years old when the spacecraft returns, while Mish3al is then 70 years – the precise opposite of what was concluded above?

The two situations are not equivalent!!

TWIN PARADOX

Where is the paradox?
The two situations are not equivalent!!

Mish3al changed from one inertial frame to a different one when he started his trip, when he reversed direction to head home, and when he landed on the earth.

Masha3il remained in the same inertial frame during Mish3al's whole voyage.

The time dilation formula applies to Masha3il's observation of Mish3al, but not to Mish3al's observation of Masha3il.

TWIN PARADOX

From Mish3al's perspective
We must take into account that the distance L he covered is shortened to:

$$L = L_o \sqrt{1 - \upsilon^2 / c^2} = (20\, light - years) \sqrt{1 - (0.8c)^2 / c^2} = 12\, light - years$$

As for time, it goes at the usual rate, but his voyage to the star has taken L/υ = 15 y and his return voyage another 15 y, for a total of 30 y.

Mish3al's life span has not been extended to him. Regardless of Masha3il's 50- y wait, Mish3al spent only 30 y on the roundtrip!

Non-symmetric aging of the twins!!

TWIN PARADOX

Has this been verified by experiments?

Let us watch a video clip..

TWIN PARADOX

Remember...
A longer life, but it will not seem longer!

TWIN PARADOX

Example 1.4:

Mish3al and Masha3il each send a radio signal once a year while Mish3al is away? How many signals does Mish3al receive? How many does Masha3il receive?