A History of the Universe

Here be Dragons

t (s) 10^{-42} 10^{-32} 10^{-22} 10^{-12} 10^{-1} 10^{9}

z / T: 10^{25} / 10^{13} GeV; 10^{20} / 10^{8} GeV; 10^{15} / 1 TeV; 10^{10} / 10 MeV; 10^{5} / 100 eV

Inflation; Grand Unification; ... "The beginning?"

"Electroweak Unification"

Protons/Neutrons Form

Elements Form; Cosmic Neutrinos

Dark Ages

Sun Forms

t 30 yr 10 kyr 440 kyr 17 Myr 480 Myr 13.7 Gy

z / T: 10^{5} / 10^{4} / 10^{3} 2700 K / 100 / 270 K / 10 / 27 K / 0 / 2.7 K

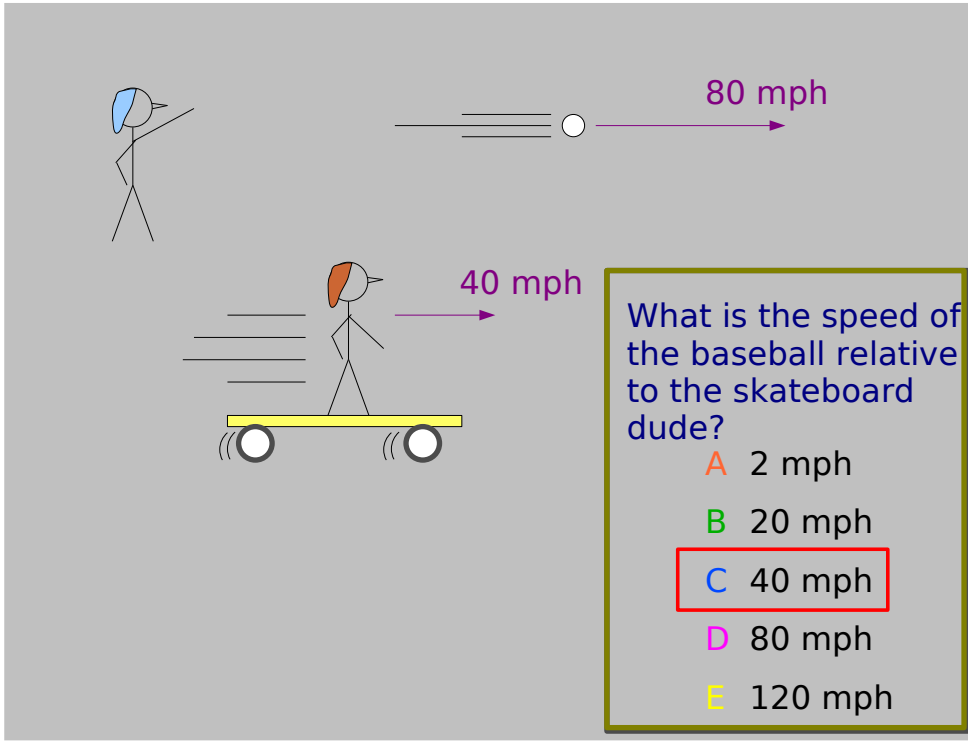
Matter Domination

Protons capture electrons; Universe becomes transparent; Cosmic Microwave Background

First Stars

End of Galaxy Cluster Formation; Acceleration Begins

You Are Here



What is the speed of the baseball relative to the skateboard dude?

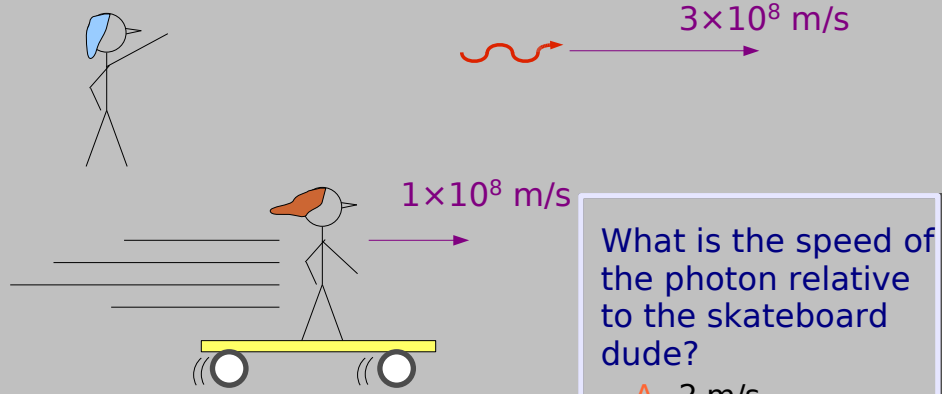
A 2 mph

B 20 mph

C 40 mph

D 80 mph

E 120 mph



Postulate of Special Relativity:

The laws of Physics – including the speed of light – are the same for every observer.

What is the speed of the photon relative to the skateboard dude?

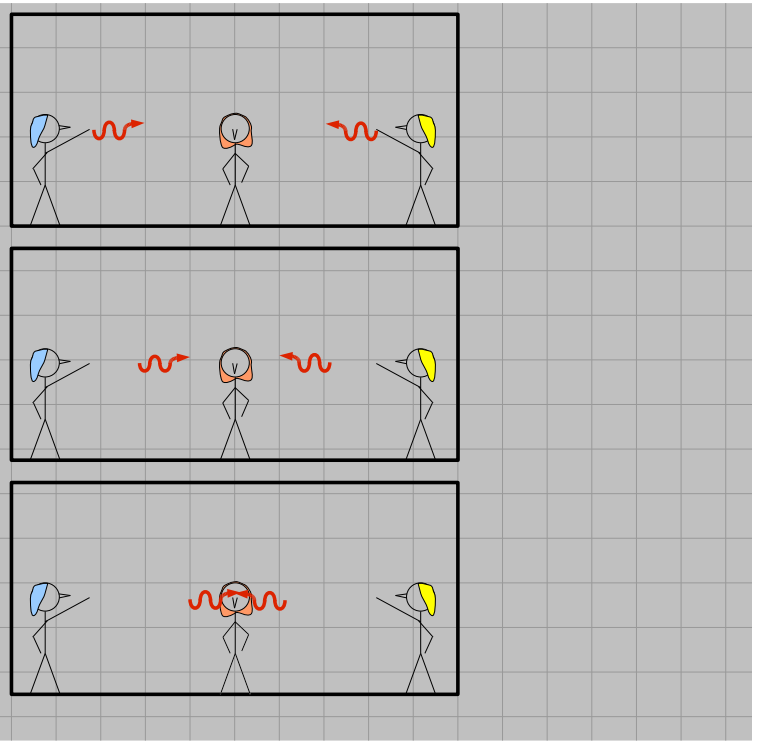
A 2 m/s

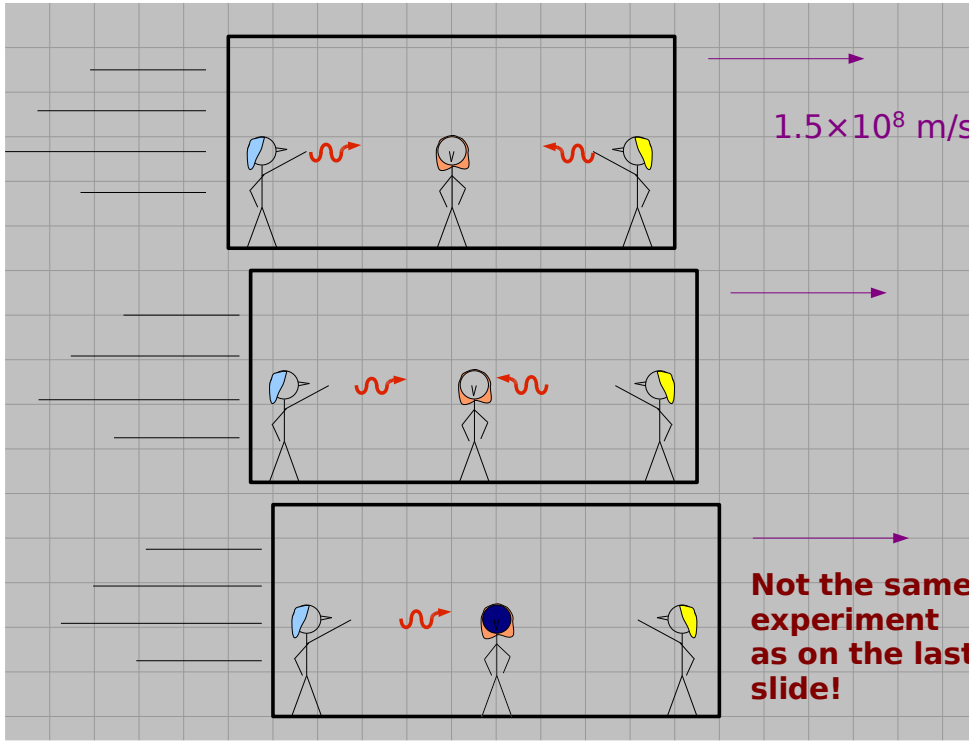
B 1×10^{8} m/s

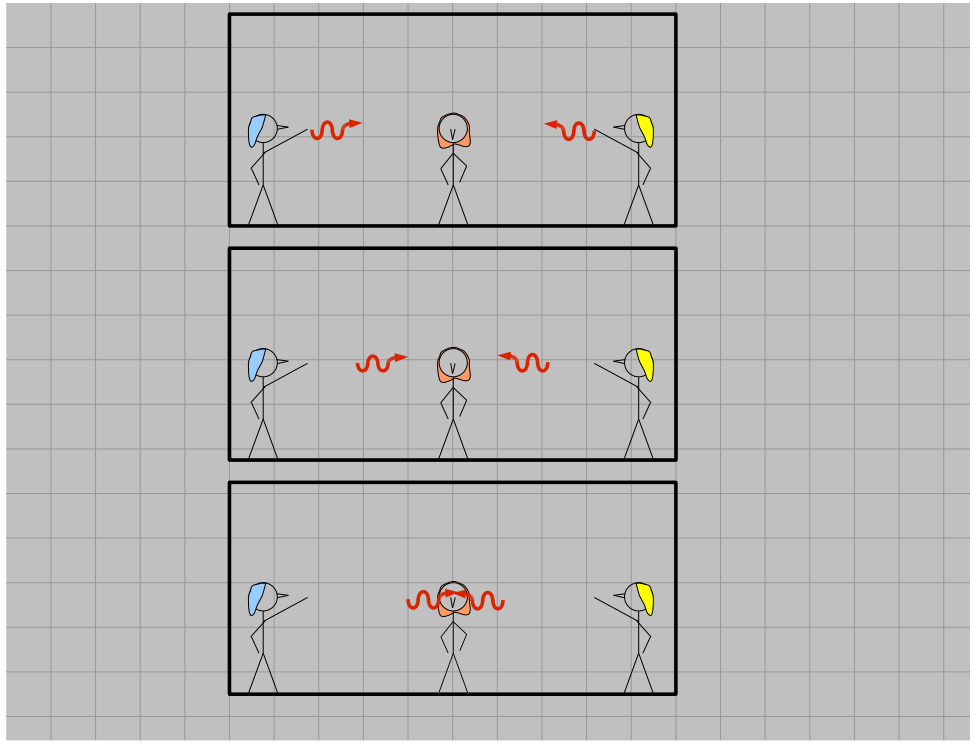
C 2×10^{8} m/s

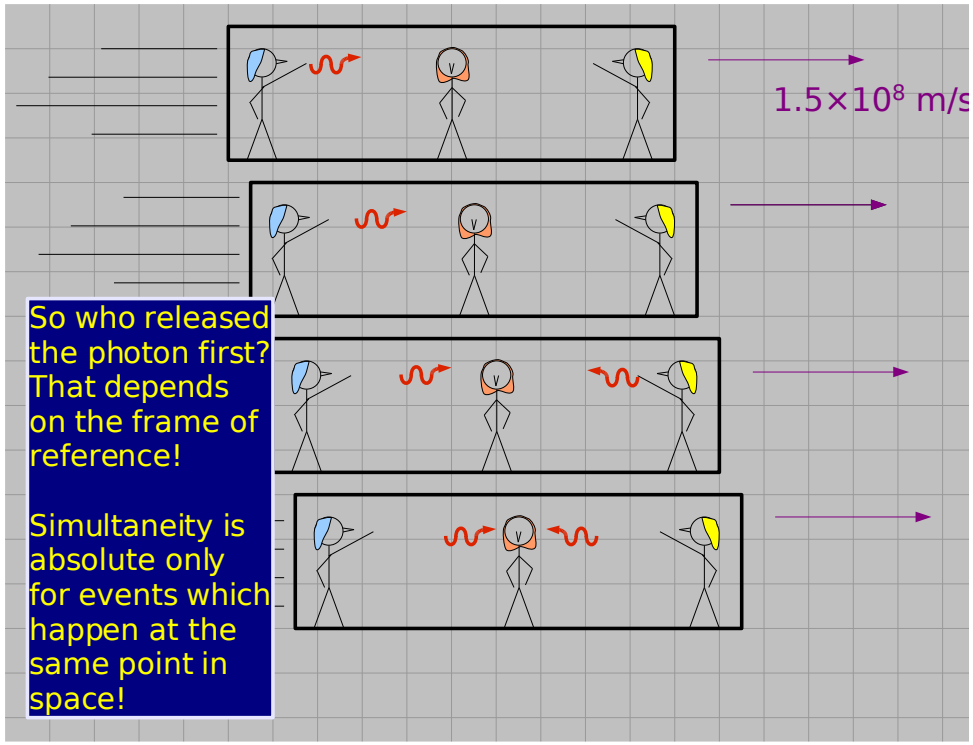
D 3×10^{8} m/s

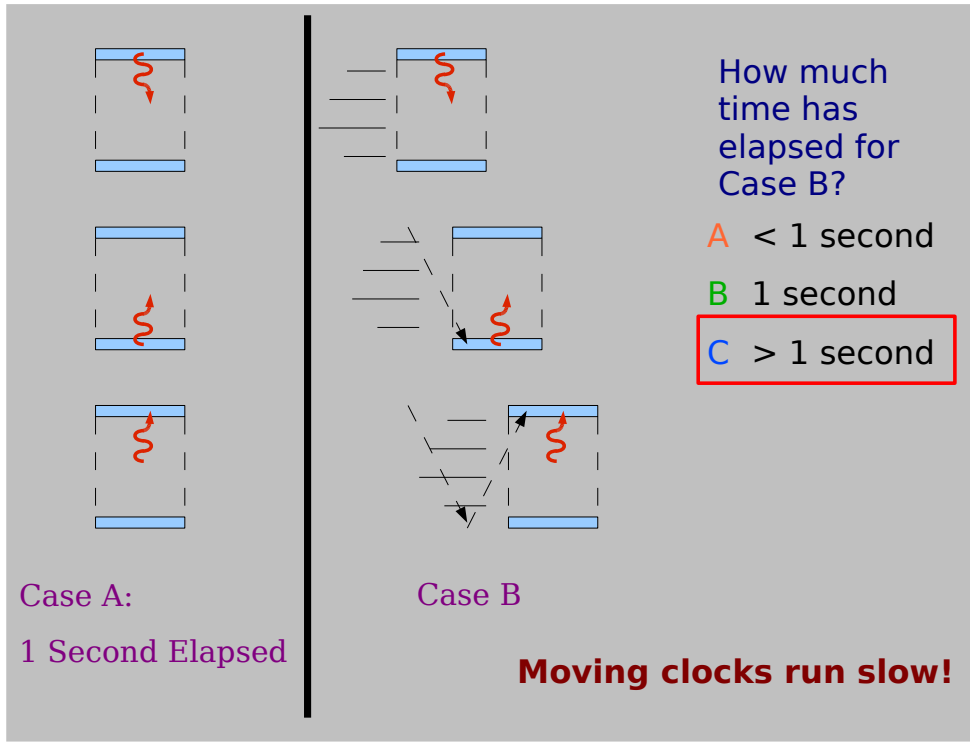
E 4×10^{8} m/s




1.5×10^8 m/s
Not the same experiment as on the last slide!




1.5×10^8 m/s
So who released the photon first? That depends on the frame of reference!
Simultaneity is absolute only for events which happen at the same point in space!


How much time has elapsed for Case B?
A < 1 second
B 1 second
C > 1 second
Case A:
1 Second Elapsed
Case B
Moving clocks run slow!

Special Relativity tells us that space and time are mixed up with each other.

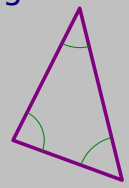
General Relativity

Our modern theory of gravity, originally developed by Einstein.

- Gravity is not a “force,” it is the *curvature of spacetime*.
- Particles move in as straight of lines as possible through spacetime.
- The presence and distribution of mass, energy, and pressure determines the curvature of spacetime.
- Yields identical results to Newton's gravity when “far” from something very massive.

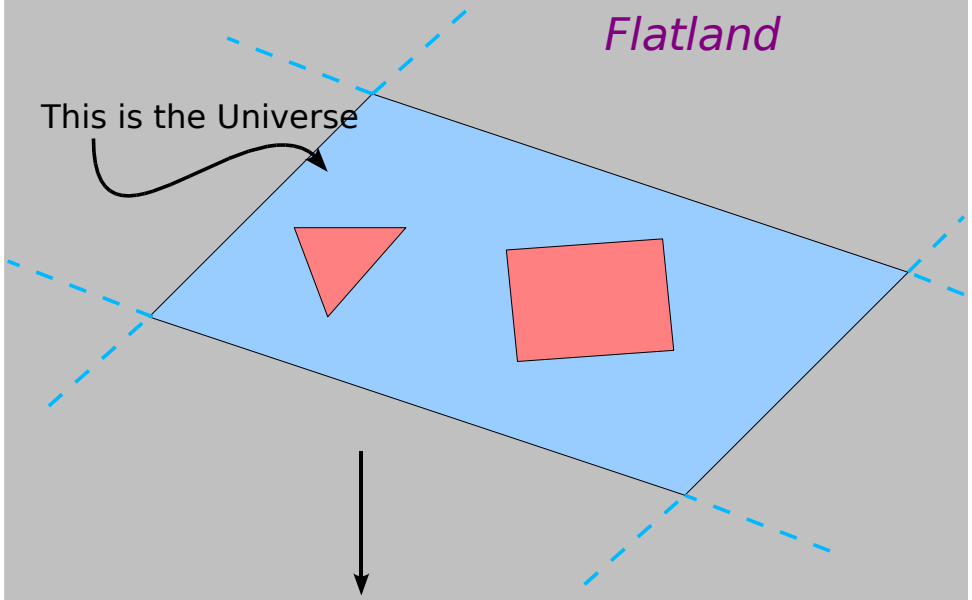
How do you determine if spacetime is curved???

Flat (Euclidean) Space:
Any triangle, three interior angles add to 180°



0 Curvature	: angles sum to 180°
Positive Curvature	: angles sum to > 180°
Negative Curvature	: angles sum to < 180°

Flatland

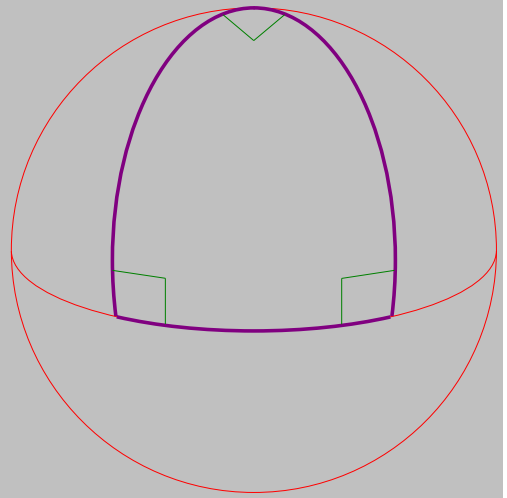


This dimension doesn't exist
(or is something we can't measure, and thus is meaningless)

Example curved 2d space :
The *surface* of a sphere

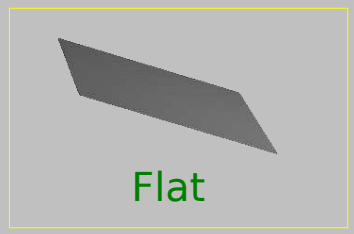
(positive curvature)

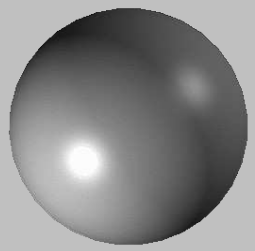
Flatland (2-dimensional) creatures could measure this curvature without reference to the third dimension we use to describe this here!



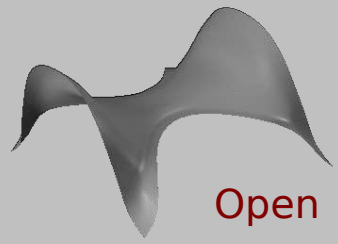
Angles sum to 270°...!

Possible Shapes of the Universe





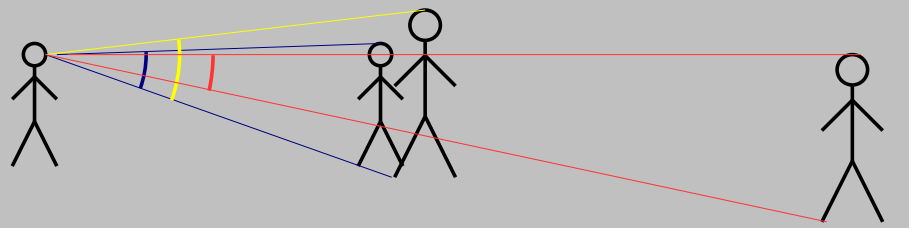
Closed

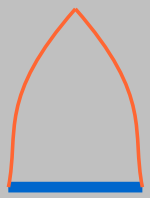


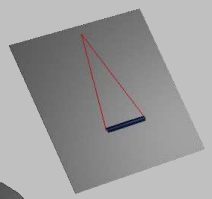
Open

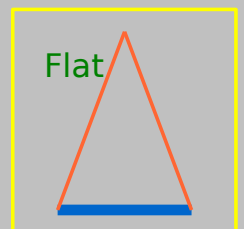
What do we mean when we say how big something looks?

The angle that it *subtends*.

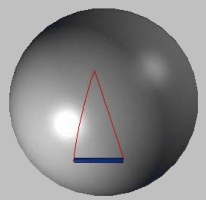


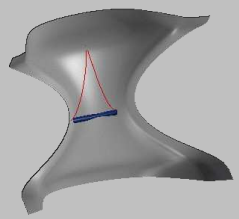




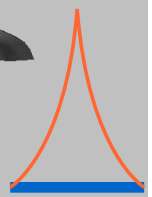


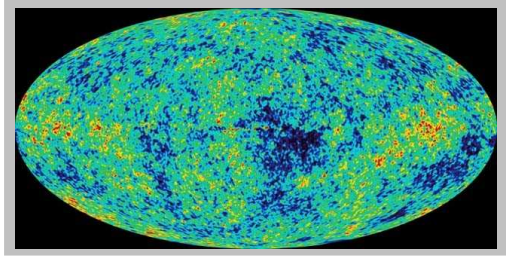
Closed:
Looks Bigger





Open:
Looks Smaller





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