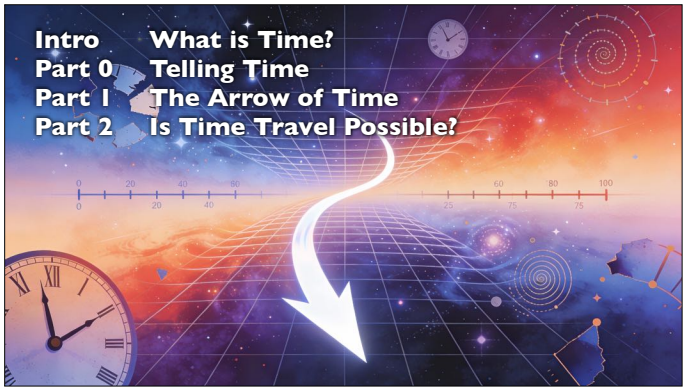
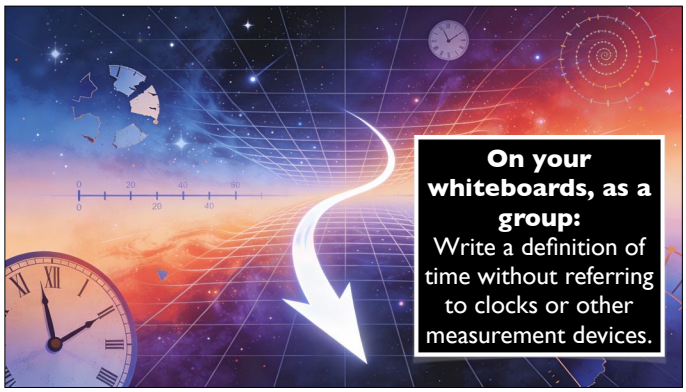
## Today's Class: It's About Time

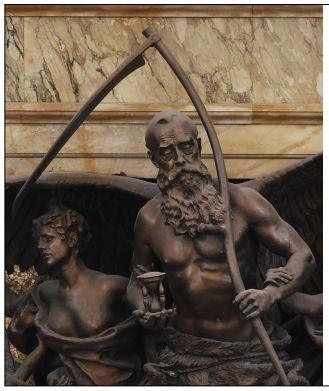
## Intro What is Time?
## Part 0 Telling Time
## Part 1 The Arrow of Time
## Part 2 Is Time Travel Possible?





**On your whiteboards, as a group:**
Write a definition of time without referring to clocks or other measurement devices.

**We Mark Time By The Planets**



**Saturn was all about time and cycles and renewal.**

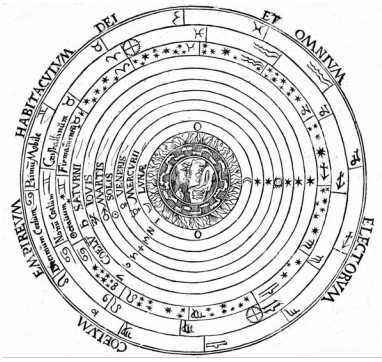
Saturn is the God of time.

And of agriculture.

And wealth, fertility, liberation, renewal.

And other stuff.

**Aristotle's view of things.**




| | | |
|---|---|---|
| Saturday | Saturn | Samedi |
| Sunday | Sun | Dimanche |
| Monday | Moon | Lundi |
| Tuesday | Tyr / Mars | Mardi |
| Wednesday | Woden / Mercury | Mercredi |
| Thursday | Thor / Jupiter | Jeudi |
| Friday | Freya / Venus | Vendredi |

Start with Saturn, of course.

**7 Planets, 7 Days**

| | | |
|---|---|---|
| Saturday | Saturn | Samedi |
| Sunday | Sun | Dimanche |
| Monday | Moon | Lundi |
| Tuesday | Tyr / Mars | Mardi |
| Wednesday | Woden / Mercury | Mercredi |
| Thursday | Thor / Jupiter | Jeudi |
| Friday | Freya / Venus | Vendredi |

**Why not in order?**

Saturn
Jupiter
Mars
Sun
Venus
Mercury
Moon

| | |
|---|---|
| 0:00 **Saturn** | 0:00 **Sun** |
| 1:00 Jupiter | 1:00 Venus |
| 2:00 Mars | 2:00 Mercury |
| 3:00 Sun | 3:00 Moon |
| 4:00 Venus | 4:00 Saturn |
| 5:00 Mercury | 5:00 Jupiter |
| 6:00 Moon | 6:00 Mars |
| 7:00 Saturn | 7:00 Sun |
| 8:00 Jupiter | 8:00 Venus |
| 9:00 Mars | 9:00 Mercury |
| 10:00 Sun | 10:00 Moon |
| 11:00 Venus | 11:00 Saturn |
| 12:00 Mercury | 12:00 Jupiter |
| 13:00 Moon | 13:00 Mars |
| 14:00 Saturn | 14:00 Sun |
| 15:00 Jupiter | 15:00 Venus |
| 16:00 Mars | 16:00 Mercury |
| 17:00 Sun | 17:00 Moon |
| 18:00 Venus | 18:00 Saturn |
| 19:00 Mercury | 19:00 Jupiter |
| 20:00 Moon | 20:00 Mars |
| 21:00 Saturn | 21:00 Sun |
| 22:00 Jupiter | 22:00 Venus |
| 23:00 Mars | 23:00 Mercury |
| 0:00 **Sun** | 0:00 **Moon** |

**Astrology by the hour**

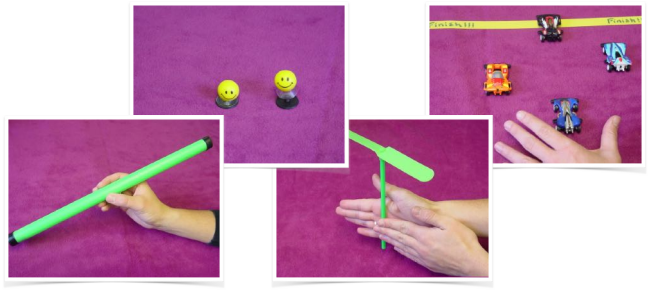

***The Arrow of Time***

## Viewing the World Through the Lens of Energy

Energy is conserved.
It cannot be created or destroyed.
It can only be converted from one form to another.

This is a law of nature that is universal:
*It applies in all places at all times, absolutely.*

## Energy Toys

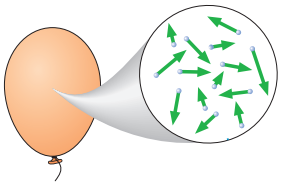


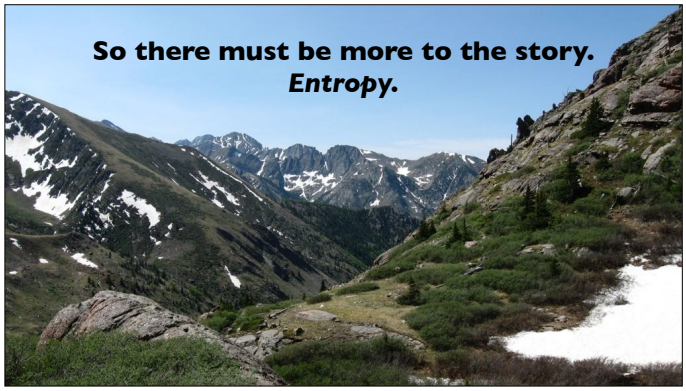
Explain the operation in terms of forms of energy.

## Forms of Energy

| | |
|---|---|
| Kinetic energy | Energy of motion. If something is moving, it has kinetic energy. Moving faster means more kinetic energy. |
| Gravitational potential energy | If something is up high, it has a lot; if something is down low, it doesn't. |
| Elastic potential energy | Stored in springs, or in springy materials. More stretch means more energy. |
| Thermal energy | When something is hot, it has a lot; when it is cold, it has a little. |
| Radiant energy | The energy of light and other waves, like microwaves. |
| Electric energy | The energy of moving charges in circuits. |
| Chemical energy | Energy stored in the form of chemical: Food, fuel and the like. |
| Nuclear energy | Energy stored in the nuclei of atoms. |

**Thermal Energy**
**is**
**Kinetic Energy of Atoms and Molecules**

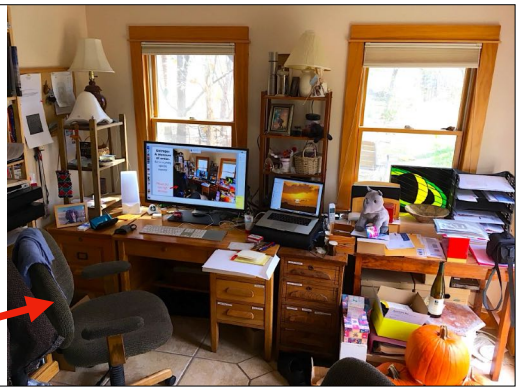


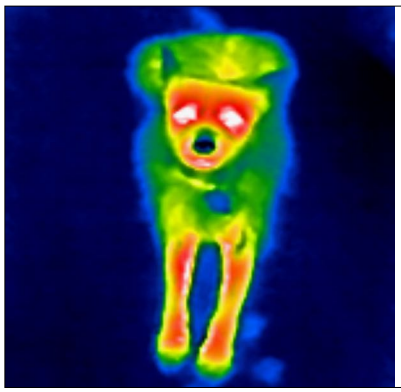




**Entropy: A measure of disorder.**

*But in a pretty specific manner.*

Messy, but not high entropy.

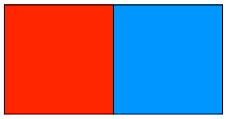




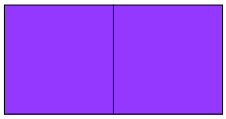
**View the world with the thermal cameras**

**Question: Where are there *differences?***

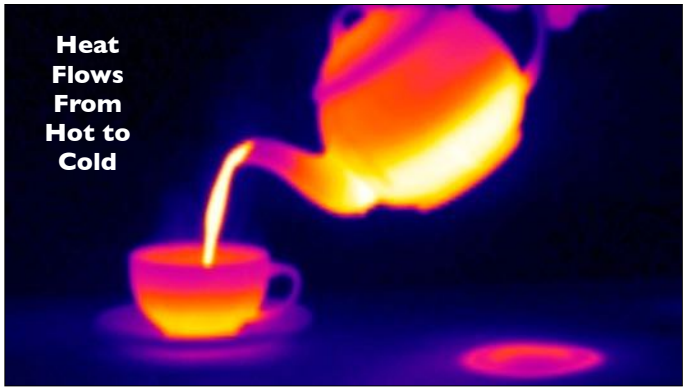
**Entropy**



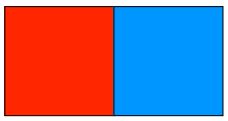
**Ordered**
There is a temperature difference, so you can distinguish between the two sides.
***Low entropy***



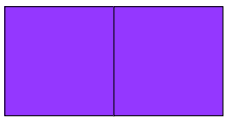
**Disordered**
The energy is spread out evenly, so you can't distinguish between the two sides.
***High entropy***



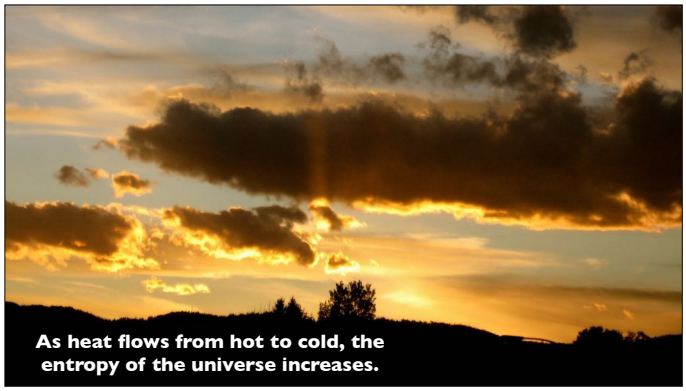

**This means an increase in entropy.**

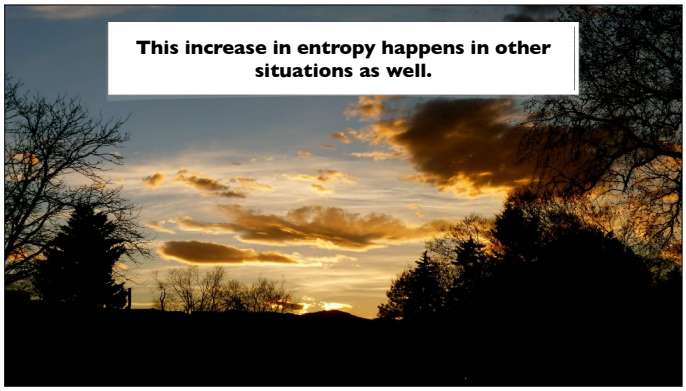


**You can tell the difference. There is order.**



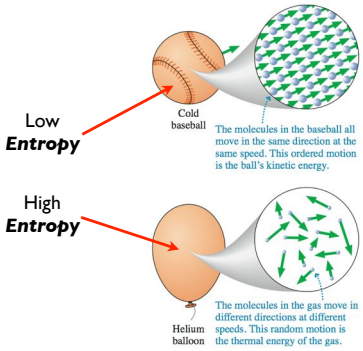
**You can't tell the difference. There is disorder.**



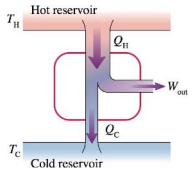
## The 2nd Law of Thermodynamics: The Entropy of the Universe Always Increases

**Thermal energy has entropy. Other forms don't.**




A traditional power plant converts thermal energy to other forms of energy. But you can't get rid of the entropy…. So some thermal energy must be deposited in the environment.

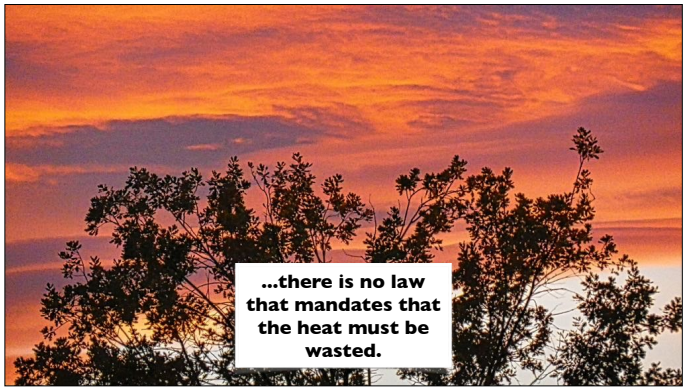
**The 2nd Law Limits the Efficiency of a Power Plant**




$$e_{max} = 1 - \frac{T_C}{T_H}$$

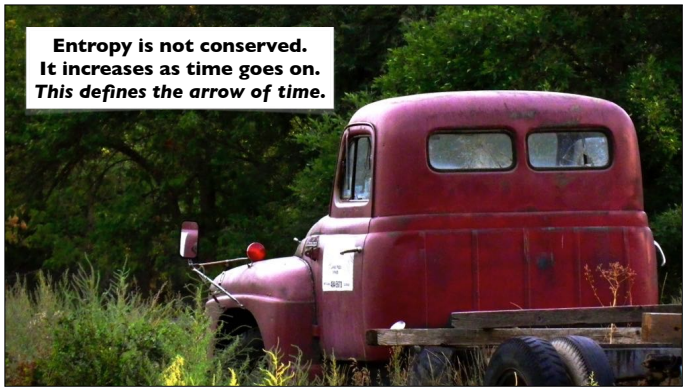
Theoretical maximum efficiency of a heat engine

**But…**



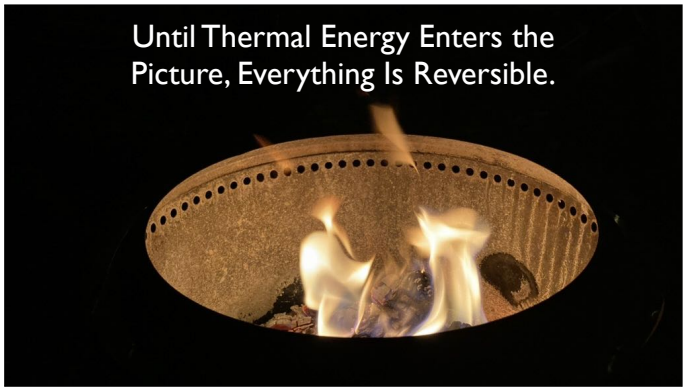
**…there is no law that mandates that the heat must be wasted.**

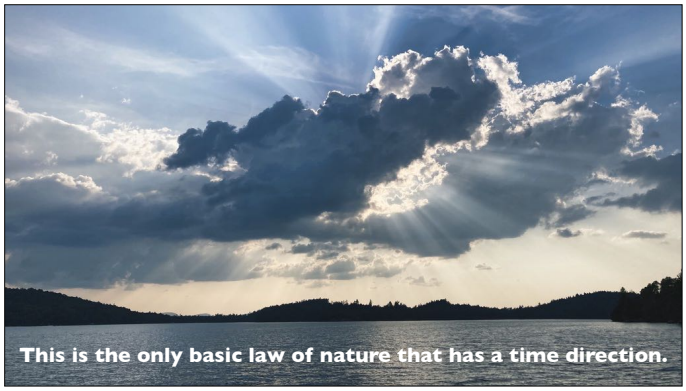
Bathers relax in the Blue Lagoon in Iceland, a cooling pond next to a geothermal power plant. The plant exhausts great quantities of heat into the environment.

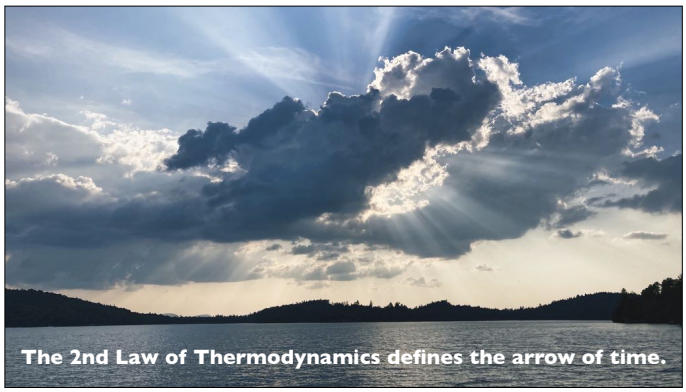


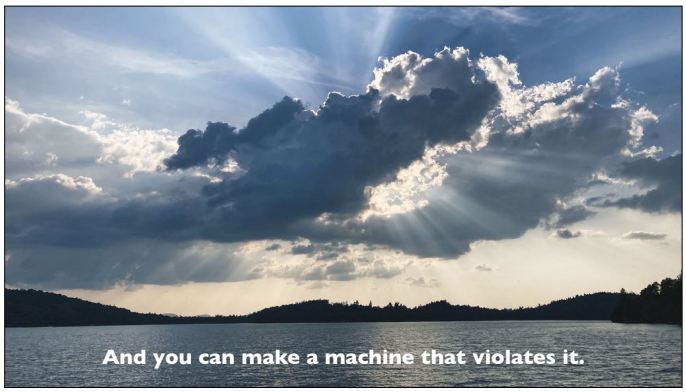
**Entropy is not conserved. It increases as time goes on. *This defines the arrow of time.***

Until Thermal Energy Enters the Picture, Everything Is Reversible.



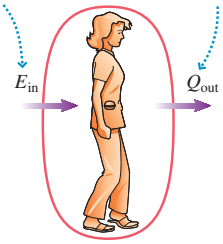


**Describe what is happening in terms of energy and in terms of entropy.**

**Energy, entropy & life**

Chemical energy comes into your body in the food you eat.

Energy leaves your body mostly as heat, meaning the entropy of the environment increases.




The "engine" that powers animal life on the planet is this:

*Degrading high quality (low entropy) forms of energy into low quality (high entropy) forms of energy.*

Plants do their part too:

*Plants use differences in temperature and water concentration to drive flow. By doing so, they smooth out the differences—thus increasing entropy.*

All forms of energy go to thermal energy.

*But we can use differences in temperature to convert thermal energy to other forms of energy—we can make things happen as long as there are hot and cold places.*

Heat Death

If the expansion reverses...

Does entropy decrease?

If so, does time go backwards?

And what does that even mean?


Is Time Travel Possible?

## Is Time Travel Possible?

**Answer #1: Not like this.**

You can't build a time machine like you see in movies and cartoons.

## Is Time Travel Possible?

**Answer #2: Yes.**

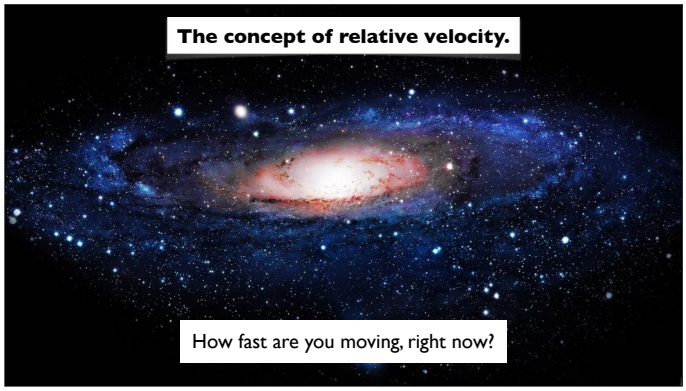
You came into this room before the hour.

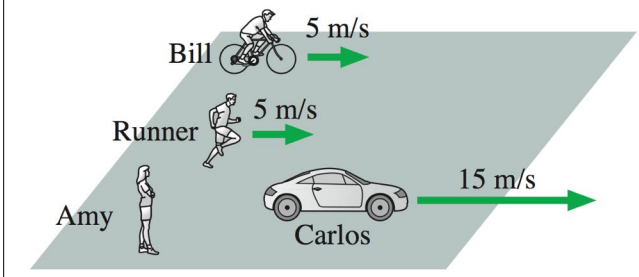
It's now after the hour.

*You have just moved forward in time.*

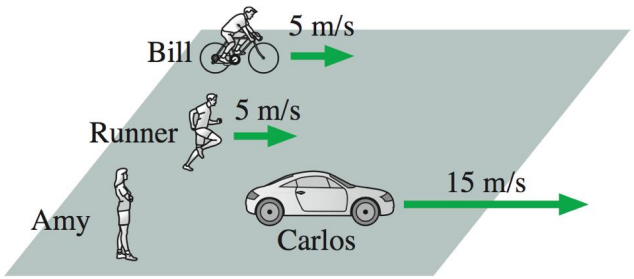
## Is Time Travel Possible?

**Answer #3: Yeah. But it's pretty hard.**




Four people moving at different speeds.
All speeds are given with respect to the ground. (Or Amy.)




What is Carlos' velocity, relative to Bill?

## The Speed of Light

299,792,458 meters per second

Or

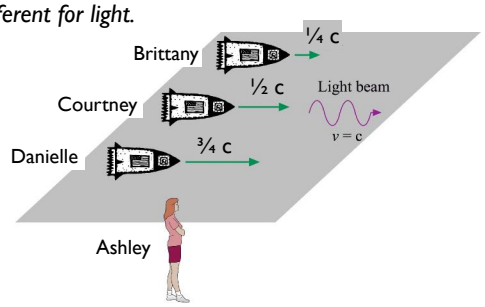
670,616,629 miles per hour

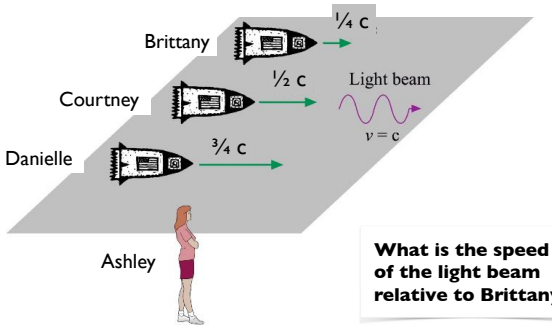
*7 times around the world in 1 second*

This is the speed that light travels at in a vacuum.
We use the symbol c to represent this speed.

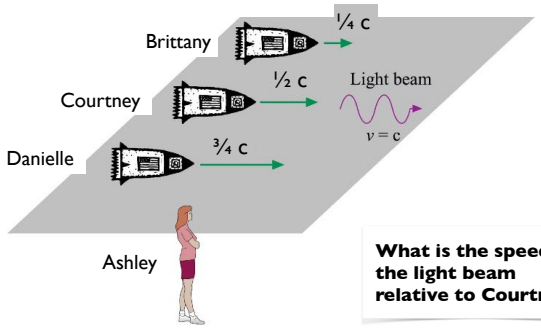
## Special Relativity

*It's different for light.*

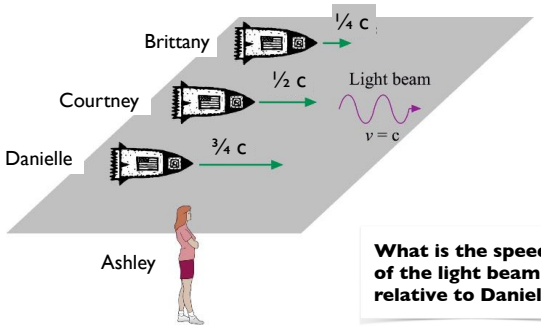



**What is the speed of the light beam relative to Brittany?**




**What is the speed of the light beam relative to Courtney?**




**What is the speed of the light beam relative to Danielle?**

**The speed of light is constant, regardless of the motion of the observer.**


This is not something someone dreamed up. It's measurable, testable, true.

No matter how fast a rocket moves, it can't catch up with a beam of light.
*The beam of light always moves away at the same speed:*
***The speed of light, c.***

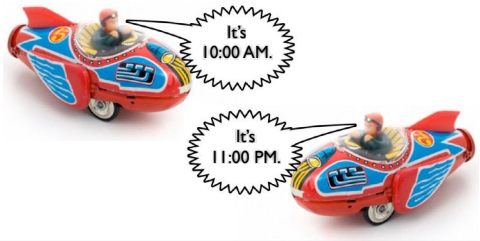
Because the speed of light is constant, as we noted,

**Nothing can go as fast as light.**

*c is the universal speed limit.*


***If a rocket keeps firing its engines, its kinetic energy will increase, but it's speed will never exceed c, no matter how long this goes on.***

**Because the speed of light is constant**,
because it does not depend on the motion of the observer,
*space and time are not constant and unvarying.*
***Measurements of time and space are relative.***
Different observers record different times and distances.




Consequence of Special Relativity #1:
**Time Dilation**

**Proper time:**
Successive events (such as the ticks of a clock) are the the same position.

*Time intervals in a moving "frame of reference" are slow compared to the proper time:*
***Time dilation.***

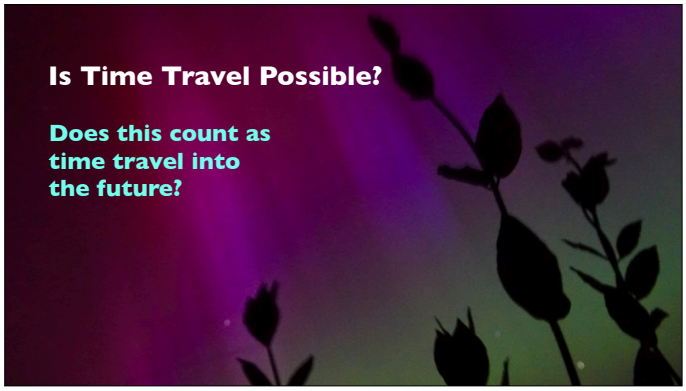
$$\Delta t = \frac{\Delta\tau}{\sqrt{1-\beta^2}} \geq \Delta\tau$$

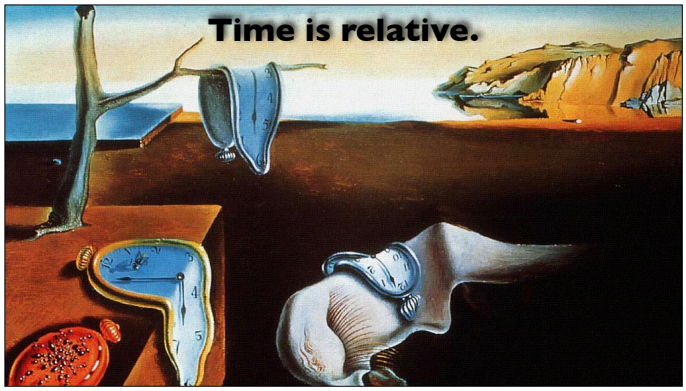
Time dilation in terms of proper time $\Delta\tau$ (where $\beta = v/c$)

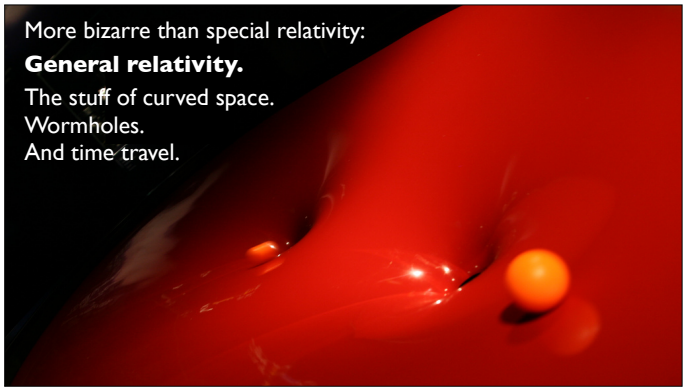
**Time Dilation Effects**

- You get on a spaceship today, at age 75.
- For 10 years (earth time) you cruise around at 0.995 c. (K=10)
- When you come back, how old are you?

$$\Delta\tau = \frac{\Delta t}{K}$$



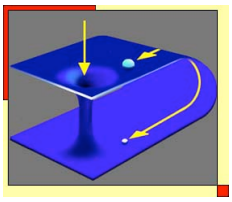
## Gravitational Time Dilation

$$\frac{\Delta t \text{ (in gravitational field)}}{\Delta t \text{ (not in gravitational field)}} = \sqrt{1 - \frac{2GM}{rc^2}}$$

This is always less than 1.

The stronger the gravity, the slower time goes.

## Is Time Travel Possible?



**Backward in time:**
***Really difficult...***

How to build a time machine in two steps:

1. Build a wormhole connecting two points in space.
2. Take one end, and move it around at high speed. Time dilation makes time at the moving end slow down.

It's now a portal between two different points in space and *two different points in time*...