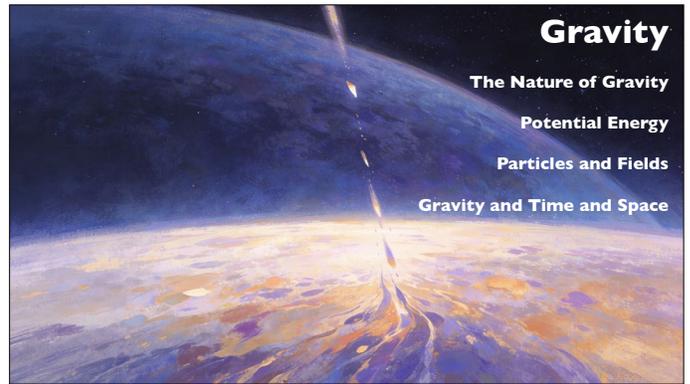


Today's Class

What Goes Up:

Gravity



Gravity

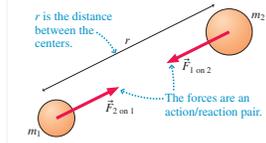
The Nature of Gravity

Potential Energy

Particles and Fields

Gravity and Time and Space

The Nature of Gravity



Newton's law of gravity If two objects with masses m_1 and m_2 are a distance r apart, the objects exert attractive forces on each other of magnitude

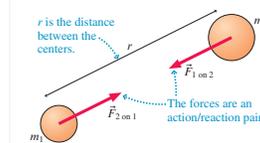
$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{Gm_1m_2}{r^2} \quad (6.15)$$

The forces are directed along the line joining the two objects. The constant G is called the **gravitational constant**. In SI units,

$$G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$$



The Nature of Gravity



Forces on the Moon

Sun vs. Earth

The Sun is 330,000 times more massive than the Earth.

The Sun is 390 times farther away than the earth.

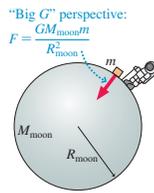
$$330,000 / (390)^2 = 2.2$$

So the Sun's gravitational force on the moon is greater than the Earth's!

$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{Gm_1m_2}{r^2}$$

Planetary Gravity

It's as if all of the mass is at the center.



$$g_{\text{planet}} = \frac{GM_{\text{planet}}}{R_{\text{planet}}^2}$$

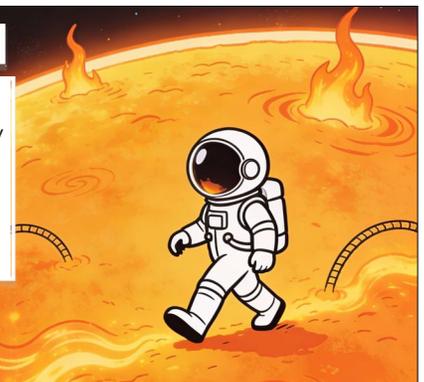
Free-fall acceleration on the surface of a planet

Planetary Gravity

Gravity on the Sun

At a certain point, even with a low density, larger objects have larger gravity.

Gravity at the Sun's equator is 28 times stronger the value of gravity at Earth's equator.



Forms of Energy

Question

If you throw a ball upward, it slows down as it rises. When it comes back down, it speeds up. When it hits the ground or the table, it stops.

Explain this process in terms of energy.

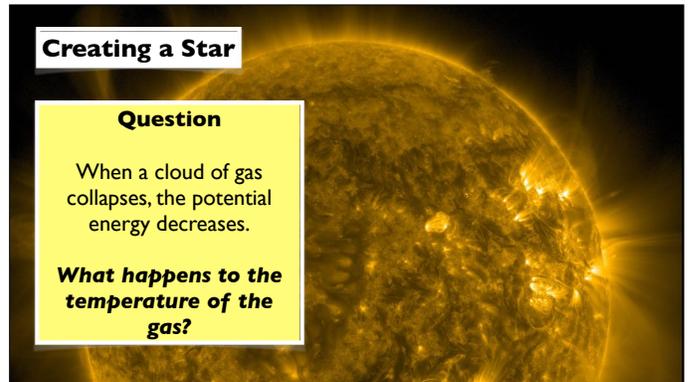


Creating a Star

Question

When a cloud of gas collapses, the potential energy decreases.

What happens to the temperature of the gas?



Creating a Star

Question

The gas heats up, and the atoms move faster—they heat up. This increases the pressure, and stops the collapse.

What happens when the gas cools?

Creating a Star

Question

If the gas cools off, there will be more of a collapse.

How can you keep the star from collapsing further? How do you heat up the interior?

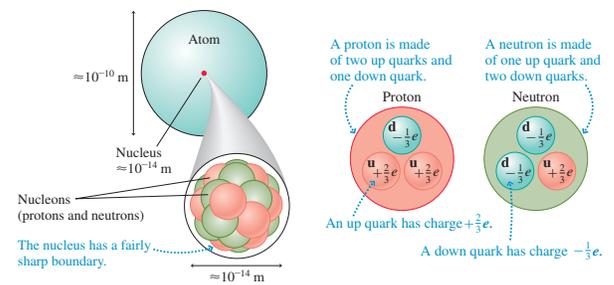
Creating a Star

Question

If the gas cools off, there will be more of a collapse.

What happens when the star runs out of fuel???

A bit of fundamental physics



And....

Electrons and quarks have zero physical size.

And....

You may have heard it said that your body is made of mostly empty space.

That's not true.

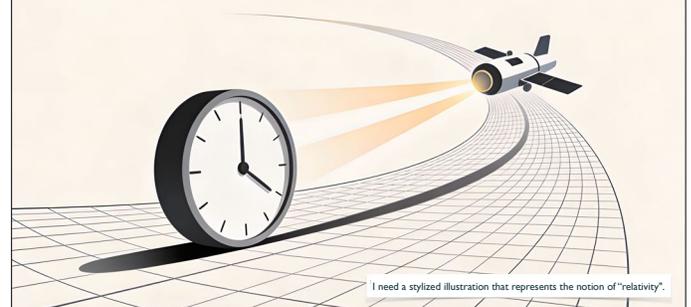
**It's made entirely of empty space.
So is everything.**

What we see as solid matter is point objects and the forces and fields between them.

So....

If you compress matter hard enough, you can compress any amount of matter you want to a mathematical point.

Some Facts from Relativity



Nothing can go as fast as light.
c is the universal speed limit.

Relativity Fact #1:
 The universal speed limit



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

Gravitational Time Dilation

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

Relativity Fact #2:
 Gravity affects time

This is always less than 1.

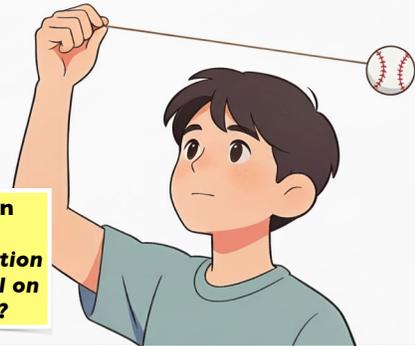
Strong gravity slows time down.

Gravity and Orbits



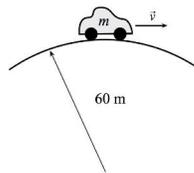
Question

What direction do you pull on the ball?



Driving over a rise

A car of mass 1500 kg goes over hill at a speed of 20 m/s. The shape of the hill is approximately circular, with a radius of 60 m, as in the figure at right. When the car is at the highest point of the hill,

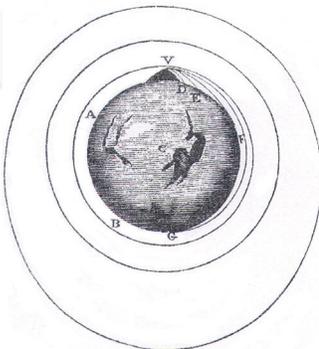


Does this make sense?
 What happens if you go faster?

Driving over a rise



The idea of an orbit



7.9 km/s (17,600 mph)





Black Hole

Under circumstances we'll see, a huge amount of mass can collapse to a point.

The Event Horizon

Question
At a point inside the event horizon, the escape velocity is greater than the speed of light.

What does this mean?

Black Hole

Can you fall into a black hole?

As you get closer and closer, gravity gets stronger and stronger.

At some point, you'll be ripped apart by tidal forces. But suppose you have a protective suit...

Black Hole

Can you fall into a black hole?

As you get closer and closer, gravity gets stronger and stronger.

At the event horizon....
Time stops!

Question
Does the person make it into the black hole?

