

Monday, March 27, 2017

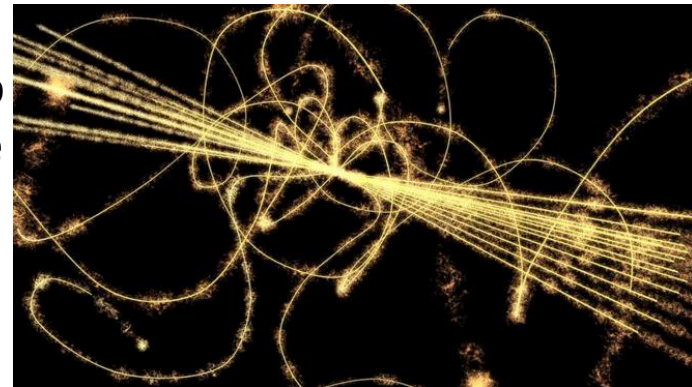
Third exam, Skywatch, Friday, March 31.

Review Sheet Posted. Exam review Thursday, 5 – 6 PM, WEL 2.308.

Reading for Exam 3: Chapter 6, end of Section 6 (binary evolution), Section 6.7 (radioactive decay), Chapter 7 (SN 1987A), Background: Sections 3.1, 3.2, 3.3, 3.4, 3.5, 3.8, 3.10, 4.1, 4.2, 4.3, 4.4, 5.2, 5.4 (binary stars and accretion disks) plus superluminous supernovae.

Astronomy in the news

Physicists have found five new subatomic particles using the **Large Hadron Collider** at CERN. The particles could help researchers learn more about how the **strong nuclear force** works.



Goals:

To understand how Einstein taught us to think about space, time, and gravity.

To understand what we mean by space.

To understand how space can be curved.

Gravity

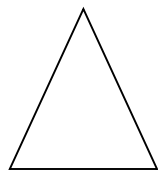
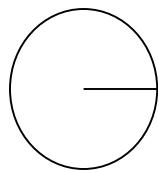
Still a deep mystery. Objects of different mass fall with the same acceleration.

Explore how Einstein taught us to think about gravity: no *force of gravity*, but the effect of *curved space*.

Explore the geometry of space with straight lines.

Straight line on a curved surface, possible or an oxymoron?

Euclidian - Flat Space Geometry



$$C=2\pi r \quad \Sigma=180^\circ \quad \text{never cross}$$

Answers only good in *flat space*: operational definition of *flat space*
NOT necessarily two-dimensional!

Non-Euclidian geometry - curved space

Both flat space and curved space use concept of “straight line”

Curved Space - explore with straight lines

Definition of straight line

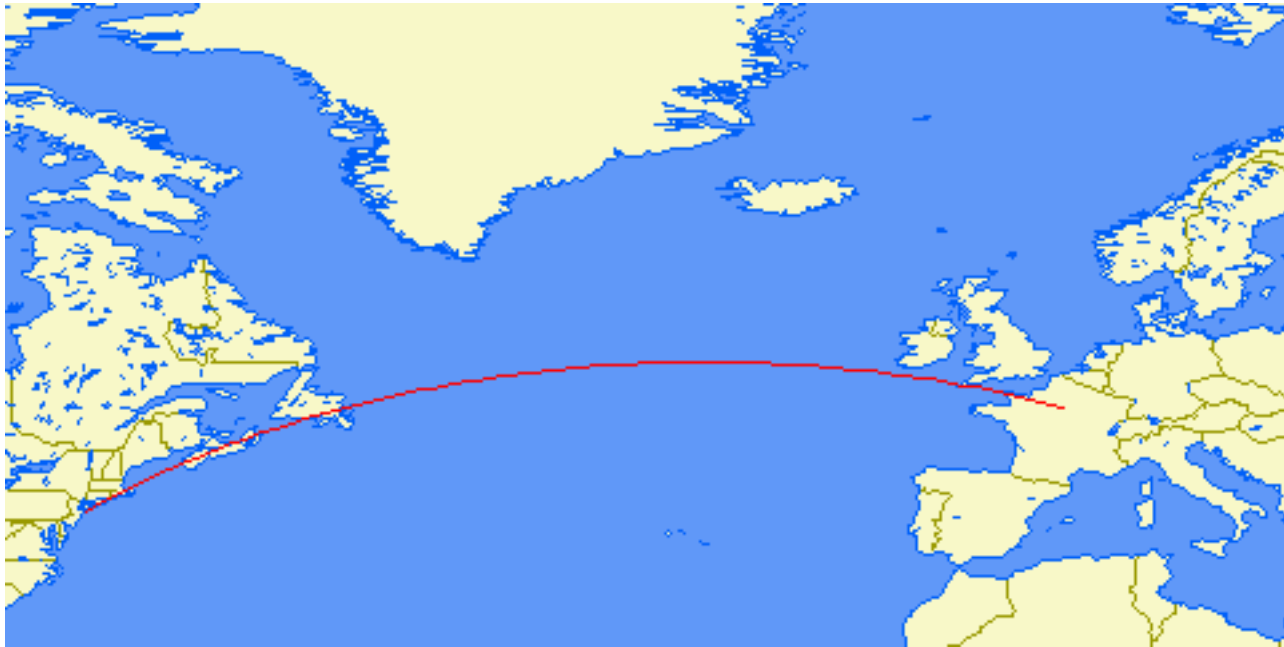
Shortest distance between 2 points - rubber band

Draw a free hand straight line

Parallel propagation - rulers

Parallel propagation will give the shortest distance between two points without necessarily knowing where the two points are in advance.

Parallel propagation works easily, even when the space is *curved*.

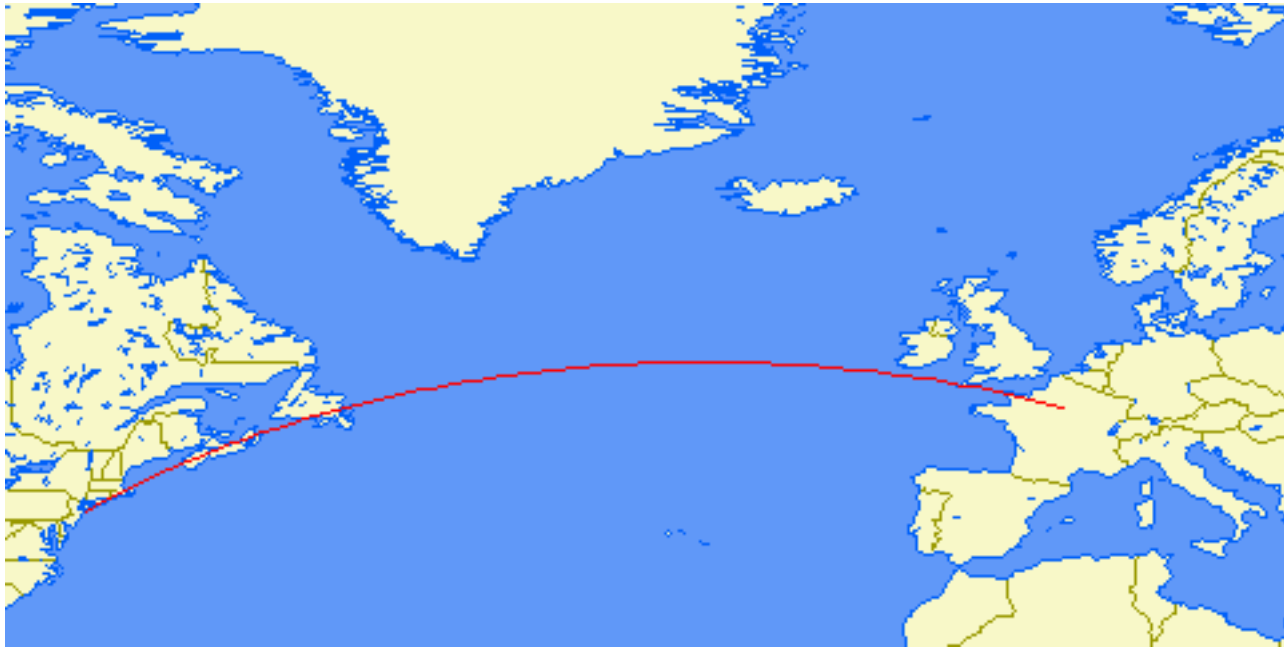


Route from JFK airport to Paris Orly.

Is this a straight line?

Geometry on the 2D surface of the balloon

Exercises of drawing straight lines



Route from JFK airport to Paris Orly.

Is this a straight line?

Balloon

Surface is curved 2 D space

3 D space around the balloon, inside the balloon is *hyperspace* with respect to the 2D surface

Imagine a 2 D creature that can only perceive 2 D space.

2 D creatures can learn all about the curvature of the space they inhabit by doing geometry in 2 D - they never need to know about or care about “hyperspace.”

That’s us in 3 D! There might be 4D (or higher!) hyperspace around us, but we don’t perceive it.

We can, in principle, learn everything we need to know about our 3D Universe by doing 3D observations and experiments in the confines of our own dimensionality, just as 2D creatures could learn of their universe, the surface of the balloon.

What you need to know about the *surface* of the balloon -

What is a straight line, what is not?

What is “inside” the surface? What is “outside” the surface

Where is the “center” of the **surface**?

What does it mean to go from surface point to surface point
“through” the balloon interior?

How do you determine the shape of the surface by doing geometry?

Real 3 D curved space (for us!!) might curve in a 4 D “hyperspace,”
but we do not directly perceive that hyperspace.

We can determine the curvature, shape of our real 3 D space by
doing 3 D geometry.

Do not need to ask about 4 D (but will!)

Can 3-dimensional space be “flat?”

Yes, it can be flat or curved, just as 2-dimensional space can.

3-dimensional space is regarded as flat if the result of doing geometry is the same as ordinary flat two dimensional space, the sum of interior angles of triangles is 180 degrees, parallel lines remain parallel.

If flat space geometry does not apply, the space is curved, or non-Euclidian.

Can 4-dimensional space be flat?