### What is THIS?



## **Fission Chain Reaction Rate**

lost

neutrons

#### self-amplifying

Two to three new neutrons produce fission at each step; the reaction is self-perpetuating with <u>uncontrolled (exponential)</u> release of energy.

✓ lost neutron  $\sim$  lost neutron - →lost neutron  $\rightarrow$  lost neutron  $\overline{\bullet}$  lost neutron ← lost neutron → lost neutron

lost

neutrons

lost

neutrons

#### self-sustaining

VS

On average, just one new neutron will produce fission at each step; this will lead to a <u>steady release of energy</u>.

# **Manhattan Project**

- <u>Manhattan Project (1939-1946)</u>: a research and development project that produced the first atomic bombs during World War II.
- December 2, 1942: the *first ever artificial self-sustaining* nuclear chain reaction, Chicago Pile-1 (CP-1), was created (*under viewing stands of a football field at the University of Chicago!*)
- July 16, 1945, <u>Trinity test</u>: the first detonation of a nuclear weapon ("Gadget") was conducted by the United States Army in New Mexico.





"...we all... hope... that man will soon grow sufficiently adult to make good use of the powers that he acquires over nature." Enrico Fermi

## **Explosive vs Controlled**

#### Nuclear weapons

are specifically engineered to produce a reaction that is so fast and intense it cannot be controlled after it has started and leads to an explosive energy release.



Nuclear weapons employ <u>high purity,</u> <u>highly</u> <u>enriched</u> <u>fuel</u>:

>85% U-235 or >95% Pu-239

#### **Nuclear power plants**

operate by precisely controlling the rate at which nuclear reactions occur.



The fuel for a nuclear fission reactor usually consists of a <u>low-enriched oxide material</u>:

3-5% Uranium-235

### **Research Nuclear Reactor**

<u>Research</u> (non-power) reactors are nuclear reactors that serve primarily as a neutron source:

- used for research and training, materials testing, or the production of radioisotopes for medicine and industry
- tend to be low power, low maintenance
- there are about 240 such reactors operating in more than 50 countries





 Most common design of research reactors, called the pool type, has a core (fuel elements and control rods) immersed in an open pool of water; the layer of water directly above the reactor core shields the radiation so completely that operators may work close to the reactor safely.

#### This design is also known as **Swimming Pool...**

## **Natural Fission Reactor**

<u>Natural nuclear fission reactor</u> is a rich uranium deposit where self-sustaining nuclear chain fission reactions have naturally occurred in the past:

- existence predicted in 1956 by Paul Kazuo Kuroda
- discovered in 1972 by French physicist Francis Perrin



- <u>Location</u> Oklo, Gabon, Africa (consists of 17 sites), the only one in the world found so far.
- <u>Evidence</u> anomalous uranium isotope content, showing loss of Uranium-235.
- <u>Timing</u> reactions took place approximately 1.7 billion years ago, and ran for a few hundred thousand years.
- <u>Power</u> averaging 100 kW of thermal power during that time.

## What Is Light?

















# **Observed Properties of Light**

- Light travels in straight lines (shadows)
- Light can be bright or dim (*intensity*)
- Light can be different colors (*dispersion*)
- Light can bounce off surfaces (*reflection*)
- Light can, or cannot go through substances (*transmission/absorption*)
- Light slows down in media (*refraction*)
- Light can bend at an opening or edge (*diffraction*)
- Speed of light is the highest known!

#### Speed of Light Measurement History

- Empedocles (finite) vs Aristotle (infinite)
- 1638, Galileo (two lanterns): "extraordinarily rapid"
- 1676, Ole Roemer (moons of Jupiter): 214,000 km/s
- 1704, Isaac Newton: "different colors travel same speed"
- 1729, James Bradley (stellar aberration): 301,000 km/s
- 1849, Hippolyte Fizeau (toothed wheel): 314,000 km/s
- 1862, Léon Foucault (rotating mirror): 299,796 km/s
- 1972-1976 (laser method): 299,792 km/s
- 1983, the 17th CGPM: defined as exact constant

# **Speed of Light**

The <u>speed of light in a vacuum</u>, denoted **C**, is <u>constant</u> throughout the Universe.



- **C** is the maximum speed at which all matter and information in the Universe can travel.
- **C** = 299,792,458 meters/second (~186,000 mps)
- <u>Scale sense</u>: it takes ~8 minutes for light to travel all the way from the Sun to the Earth.
- When light travels <u>through matter</u>, its speed can <u>change</u> (inside a *diamond*, light is *slowed down to less than 80,000 mps*), but can never be larger than *C*.