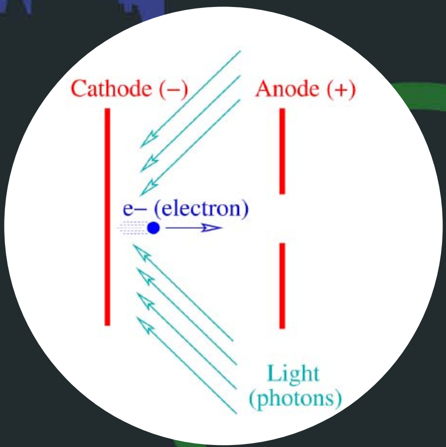
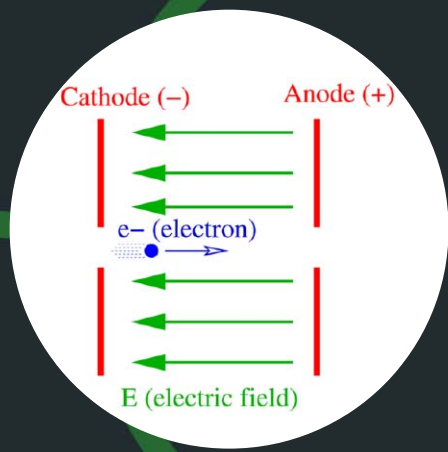
ACCELERATING PARTICLES

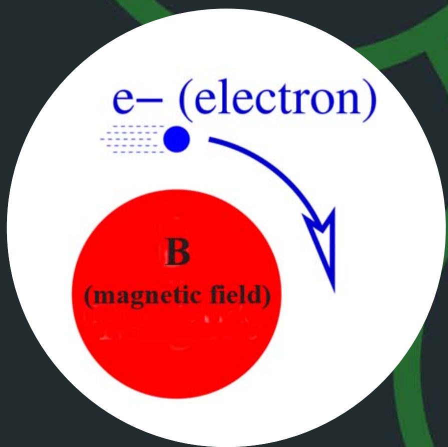
Everything in the Universe is made up from a small number of basic building blocks called elementary particles. The high concentration of energy that can be reached in a particle accelerator allows us to 'look back in time' at these elementary particles and recreate the environment present at the origin of our Universe.



Electrons can be produced by illuminating a cathode in a vacuum with a strong light or laser. This effect is called the photoelectric effect and was first explained by Einstein 100 years ago.



Electrons accelerate when placed in an electric field (E). An electron placed between a negatively charged cathode and positively charged anode will feel a force F=qE. A particle with mass m to which a force is applied will have an acceleration a=F/m, therefore a particle in an electric field will experience an acceleration a=qE/m.



When a charged particle (such as a proton or electron) travels through a magnetic field (B) at a speed v, it has a momentum p=mv and it feels a force F=qvB=qpB/m. Unlike the force created by an electric field, the force created by a magnetic field is perpendicular to the direction of travel therefore the particle changes its direction (but not its speed).

Modern particle accelerators contain thousands of magnets called "quadrupoles" that are used to adjust with high precision the particle beams' trajectory.

For a relativistic particle travelling at a speed v:

Speed of light $c = 299792458$ m/s

$$\text{Lorentz factor } \gamma = \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$$

$$\text{Time } t = t_0\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} = t_0\gamma$$

$$\text{Length } l = l_0\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}} = l_0\gamma^{-1}$$

$$\text{Energy } E = \frac{mc^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}} = mc^2\gamma$$

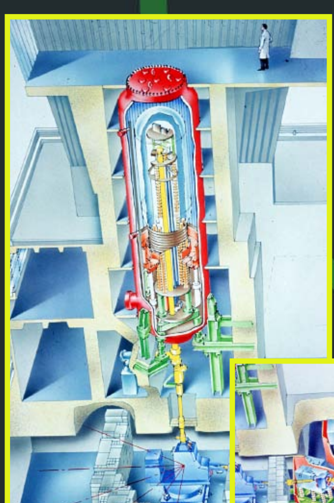
When particles reach very high speeds, close to the speed of light, they become relativistic.
Each time a particle is accelerated its momentum and its kinetic energy increases but, for an observer at rest, it appears that the speed of the particle approaches the speed of light but never reaches it.
According to the special theory of relativity a particle of mass m can never reach the speed of light.

* Physical laws have the same form in all inertial frames

* The speed of light in free space is invariant

Some Physicists at Oxford are working towards creating a plasma accelerator. Here an ultra-intense laser pulse is sent through a plasma to generate a trailing "plasma wake", which is similar to a wake produced by a boat moving through water. The electric field formed between the peaks and troughs of the plasma wake is 1000 times stronger than the electric field in conventional accelerators; this allows particles to be accelerated to high energies over very short distances.

If you want to know more about Physics at Oxford see the website: www.physics.ox.ac.uk



Oxford physicists have been involved with accelerator science since the first accelerators were built. A tandem accelerator was built in Oxford in 1961 which was used for nuclear physics experiments and teaching until 1991.

The Denys Wilkinson Building, which is part of the Physics department at Oxford, has been shaped by the needs of the tandem Van de Graaff accelerator. It now hosts two small accelerators; one is used by Archaeology to measure Carbon-14 concentration in materials and the other one is used for teaching.

Many current particle accelerators are used to collide high energy particle beams. The majority of accelerators are ring shaped, for example CERN (www.cern.ch). This shape allows the particle beams to collide with each other many times. Unfortunately this shape is not efficient for accelerating particles to very high energies. Physicists at the John Adams Institute for Accelerator Science (www.adams-institute.ac.uk) at Oxford are working towards the construction of a linear accelerator called the "International Linear Collider" (http://linearcollider.org). This accelerator will be 30 km long and provide new insights into what happened just after the big bang.

International Linear Collider
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