Mass dilation

Mass dilation → The mass of a moving object is dilated (increased). Mass is relative. Absolute mass does not exist!

Cyclotrons were early mass accelerators and my late 1930's they had reached their limits and could not accelerate particles any faster because they could not adjust for mass dilation. (we have subsequently solved this problem!).

Thought experiment (or …playing with formulas)

We know the formula for centripetal force $F_c = mv^2 / r$

We know the formula for electrostatic force $F_e = ke^2 / r^2$ This is Coulomb's Law

Note: instead of q_1 and q_2, 'e' for electron charge was used.

So when an electron orbits a nucleus, Fc = Fe $mv^2 / r = ke^2 / r^2$

Isolating for mass: $m = k\, e^2 / v^2\, r$

You can see mass varies indirectly with radius. Suggesting….as radius gets smaller (at high speeds) the mass increases! (dilates). Remember: smaller radius requires a faster speed to stay in orbit.

Okay..now some tricky substitutions.

Radius is really a 'length' measurement. At high speeds, length contracts. So at high speeds, radius should contract and get shorter. So for radius at high speeds should be a relativistic length. That relativistic length formula (with 'r' instead of 'l') is plugged in for radius.

Since $m = k\, e^2 / v^2\, r$ at low speeds (no relativistic length/radius happening), so this mass is really 'rest mass' we $\underline{m\, v^2\, r}$ for $\underline{k\, e^2}$

All of this simplifies into the mass dilation formula – copy from text pg. 653.

**Note: rest mass (m_o) will always be less that relativistic mass (m) however at low speeds (v <<<c) there is no notable difference.

Links to Classical Ideas

Newton said the faster you go, the more momentum you have and the harder it is to change your speed/direction. In a sense, that is like getting 'heavier' or more massive. Relativity says you gain mass as you approach the speed of light.

Einstein says there is a universal speed limit – nothing goes faster than speed of light! So as an object approaches this speed limit, and more energy is put into the object, the conservation of energy says this cannot be destroyed! So instead of the energy going into speed (Ek), it converts (via $E = mc^2$) into mass! Thus…an object approaches but never exceeds the speed of light.