Anti- particles

Positron – anti-electron

A particle of same mass and spin, but opposite electric charge.

Relativistic energy of a particle

$$E^2 = (pc)^2 + (mc^2)^2$$

in general

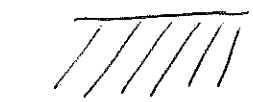
$$E = \pm\sqrt{(pc)^2 + (mc^2)^2}$$

or for $p = 0$ $\quad E = \pm mc^2$

In principle, we cannot neglect negative-energy states.

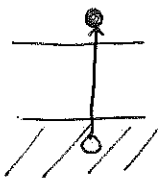
Hole idea

Condensed matter: band structure + Fermi energy

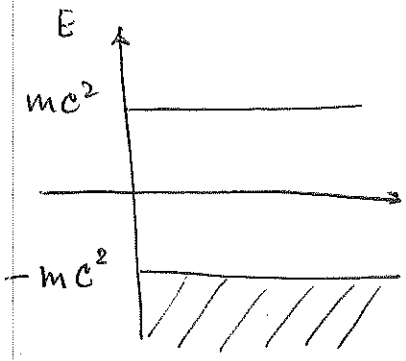


(all possible states are filled)

If an electron is excited into an empty conducting band, it leaves an empty space in the valence band. We can then treat this hole as an independent particle with negative mass and opposite electric charge (+e). In condense matter we often talk about electrons and holes being possible electric current carriers.



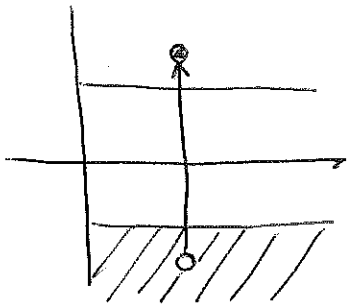
We can use a similar idea to explain anti-particle



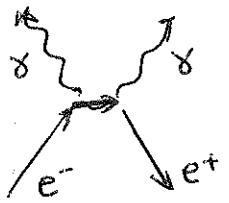
$$E = \pm\sqrt{(pc)^2 + (mc^2)^2}$$

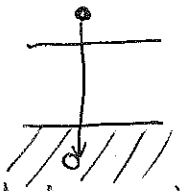
Dirac sea
all negative-energy states are completely filled

If an electron is promoted from negative to positive energy state, it leaves a hole behind. This hole will have
- opposite charge $+e$
- opposite mass $-(-m_e) = m_e$ (same as normal electron)



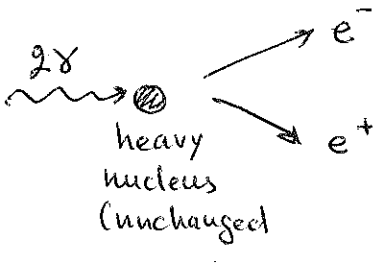
This picture also explains electron-positron annihilation

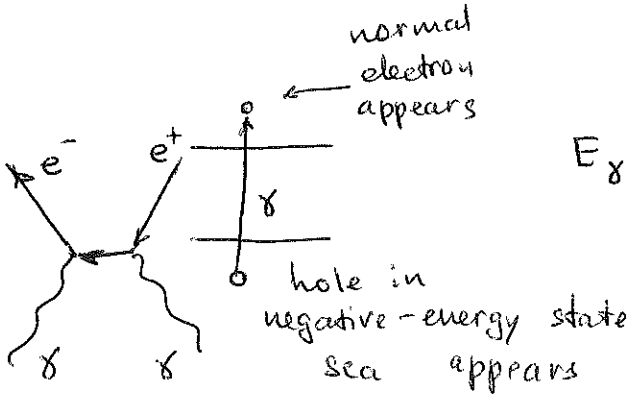




electron jumps down and fills the hole; all extra energy goes into γ-quanta

Pair-creation





$$E_\gamma \geq 2m_e c^2 \quad (\sim 1\,\text{MeV})$$