15.28: Units

It is customary in the field of particle physics to express energy (whether total, kinetic or rest-mass energy) in electron volts (eV) or in keV, MeV, GeV or TeV (10^3, 10^6, 10^9, or 10^{12} eV respectively). A electron volt is the kinetic energy gained by an electron if it is accelerated through an electrical potential of 1 volt; alternatively it is the work required to move an electron through one volt. Either way, since the charge on an electron is 1.602 % 10^{-19}) C, 1eV = 1.602 % 10^{-19} J.

The use of such a unit may understandably dismay those who would insist always on expressing any physical quantity in SI units, and I am much in sympathy with this view. Yet, to those who deal daily with particles whose charge is equal to or is a small multiple or rational fraction of the electronic charge, the eV has its attractions. Thus if you accelerate a particle through so many volts, you do not have to remember the exact value of the electronic charge or carry out a long multiplication every time you do so. One might also think of a hypothetical question such as: An electron is accelerated through 3426.7189628471 volts. What is its gain in kinetic energy? You *cannot answer this in joules* unless you know the value of the electronic charge to a comparable precision; but of course you do know the answer in eV.

One situation that does require care is this. An a-particle is accelerated through 1000 V. What is the gain in kinetic energy? Because the charge on an a-particle is twice that of an electron, the answer is 2000 eV.

Very often you know the energy of a particle (because you have accelerated it through so many volts) and you want to know its momentum; or you know its momentum (because you have measured the curvature of its path in a magnetic field) and you want to know its energy. Thus you will frequent occasion to make use of Equation 15.27.1:

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You have to be careful to remember how many *[Math Processing Error]*s there are, and what is the exact value of *[Math Processing Error]*. Particle physicists prefer to make life easier for themselves (not necessarily for the rest of us!) by preferring not to state what the momentum of a particle is, or its rest mass, but rather to give the values of *[Math Processing Error]* or of *[Math Processing Error]* – and to express *[Math Processing Error]*,*[Math Processing Error]* and *[Math Processing Error]* all in eV (or keV, MeV or GeV). Thus one may hear that

[Math Processing Error] = 6.2 GeV

[Math Processing Error] = 0.938 GeV.

More often this is expressed, somewhat idiosyncratically and in somewhat doubtful use of English, as

[Math Processing Error] = 6.2 GeV/c

[Math Processing Error] = 0.938 GeV/c^2

or in informal casual conversation (one hopes not for publication) merely as

[Math Processing Error] = 6.2 GeV

[Math Processing Error] = 0.938 GeV.

While this may puzzle some and raise the ire of others, it is not entirely without merit, because, provided one uses these units, the relation between energy, momentum and rest mass is then simply

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The practice is not confined to energy, momentum and rest mass. For example, the SI unit of magnetic dipole moment is N m T^{-1} (newton metre per tesla). Now N m (unit of torque) is not quite the same as a joule (unit of energy), although dimensionally similar. Yet it is common practice to express the magnetic moments of subatomic particles in eV T^{-1}. Thus the Bohr magneton is a unit of magnetic dipole moment equal to 9.27 % 10^{-24} N m T^{-1}, and this may be expressed as 5.77 % 10^{-5} eV T^{-1}.

One small detail to be on guard for is this. One may hear talk of “a 500 MeV proton”. Does this mean that the *kinetic* energy is 500 MeV or that its *total* energy is 500 MeV? In this case the answer is fairly clear (although it would have been completely clear if the speaker had been explicit). The rest-mass energy of a proton is 938 MeV, so he must have been referring to the kinetic energy. If, however, he had said “a 3 GeV proton”, there would be no way of deducing whether he was referring to the kinetic or the total energy. And if he had said “a 3 GeV particle”, there would be no way of telling whether he was referring to its total energy, its kinetic energy or its rest-mass energy. It is incumbent on all of us – or at least those of us who wish to be understood by others – always to make ourselves explicitly clear and not to suppose that others will correctly guess what we mean.