Kann jemand wirklich kein Englisch? Unter Physikern???
Wenn's wirklich nicht verstehbar ist, bitte eine eMail an mich! ccn.

Are you just 75 kg of kinetic energy ?

A few days ago a colleague (and good friend) told me that in his "Modern Physics" course he had provoked the students by saying "You consist essentially of kinetic energy only!" . He had expected the students to be astonished; but when I made a flabbergasted face as well, he continued to explain:

> "We are made of atoms, which in turn consist of nucleons and electrons. Forget the electrons: they make at most about 0.2 % of the mass [1]. And nucleons are essentially quarks, so the bulk of the total energy of a human's 75 kg of mass are due to quarks.
>
> But, in the standard quark theory, viz. Quantum Chromodynamics, the (dynamic) quark masses (of the non-strange variety, at least) are also negligible. So all that is left is kinetic energy!"

We discussed this for a while, and I explained shortly why I disagreed with him.

But of course his idea does give some food for thought.

What is kinetic energy?

The seemingly simple answer is: kinetic energy is the difference between *total* energy in the rest system = mass and *potential* energy. But right away it becomes clear that this is a nonrelativistic concept: the idea of a rest system subsumes that we are at most talking about *special* relativity, where there is no gravitational field at all. And if in this theory we go to the rest system, there is no overall kinetic energy, so we can talk about the difference just quoted.

In general relativity however, there is only one general, covariant energy-momentum tensor, and it no longer makes any sense to distinguish between kinetic and potential energy.

[1] and forget the electromagnetic interaction between nucleons and electrons as well: it also is negligible compared to the nuclear forces. [remark added by ccn]

What is potential energy?

This is a much harder question. In a nonrelativistic Hamiltonian theory it is of course clearly defined in the Hamiltonian; QCD however (the only theory in which we can sensibly talk about quarks), is a theory in which the concept of quark mass only makes sense after renormalization. In simple models, the quark mass clearly depends on the model:

- In the 'constituent model' (which can be applied moderately successfully in nonrelativistic nuclear physics), the quark mass is what you naively would expect in such a model: around 300 MeV.
- The bag model gets confinement astonishly correct with a zero quark mass. But in addition to the quark kinetic energy, there is a 'bag constant', amounting to – what? kinetic energy? potential energy? Take your pick!
- In renormalized QCD, there is the current quark mass (negligible), but most of the energy is field energy (called 'gluonic energy'). I find most field theorists appalled at the idea to call this a 'kinetic energy' — and justly so, IMHO: after all, kinetic energy can always be brought to vanish in an appropriate frame of reference, and there is no such frame for renormalized QCD.

For theorists (and field theorists, in particular), the latter is arguably the most convincing argument: an energy (or part of an energy) can be called a kinetic energy only *if there is a frame of reference in which that energy vanishes*.

The concept of a physical scale

Non-theorists are perhaps bored – to say the least – by this kind of argument, and I concur: a good physical argument should be accessible to simple language, beyond formal and mathematical considerations [2].

What the present question really amounts to is a consideration of the *scale* involved. Let's discuss the case when a normal person (and even a physicist can behave normally – at least some of the time) goes to the hospital, say, to get her weight checked. When the nurse tells the patient to 'stand still while weighing', it means the nurse wants the *center-of-mass* to be over the scales, at least up to the *order of of a few cm*, and to remain still, at least up the *order of a few cm/sec*. This will ensure an accuracy of the measurement in the order of a few tens of g, which is all that is needed (and in fact intended).

[2] "Formalism is like sex — you do it at home, and you don't talk about it" (G.E. Brown, private communication). my comment: Nevertheless it *is* absolutely necessary for sheer subsistence (leaving pleasure aside for the moment ...)

With this scale in mind [3], it is perfectly legitimate (in fact: correct) to treat the human body as a physical body (solid or fluid) with a continuous density distribution. Such a system does have a center of mass, and knowledge of that is all that is needed here.

If you want to be more specific – and there are, of course, experimental situations and questions where that is warranted – , you may have to decide at what scale you want to describe your system. But as long as you are interested in scales of mm, classical analysis is not only sufficient, but anything else is *inappropriate* and therefore *nonsense*.

Summary

The real point of this whole observation is the following:

There are many questions of great physical interest at the nm scale. At that scale, the assumption of a continous density distribution (of a human body) no longer makes sense, and neither does a classical approach. Lo and behold: you enter the realm of molecular physics. But as you do, *you lose all sight of the macroscopic aspects of the system studied!* In other words:

> The choice of scale at which you decide to study a physical system decides not only the appropriate tools with which to do the study, but more importantly decides the very phenomena you are studying!
>
> This is a fundamental basic fact of the Science of Physics, if not the most important of all. If you do not acknowledge that you deny the essentially reductionistic character of physical research — one of the (several) reasons for misunderstanding between physics and (some realms of) philosophy.
>
> IMHO, it is paramount for physics students to understand this *role of scale*, lest they be unable to enter into any kind of serious, intelligent discourse with representatives of other fields.

And, coming back to my dear colleague and the 75 kg of kinetic energy:

> It's quite OK (and educational fun at that!) to start with this quip, *povided you teach, at the end of the day, this importance of scale — and not just let it stand with a little exercise in QCD.*

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[3] What a beautiful pun!