COMPILATION: Unit 9 - How to handle energy & momentum. Force is a momentum current (Gregg Swackhamer)

Date: Sat, 30 Jan 1999
From: John Barrere <Forcejb@AOL.COM>
Subject: System designation when analyzing energy flow vs. momentum transfer

We recently finished the energy material, having waited to explore it until after all the other mechanics work. I think waiting worked (no pun intended) OK as it provided a natural way to spiral back. Focusing on energy flow, etc. is a vast improvement over the traditional textbook mindset as it provides a very nice framework for seeing conceptually what is happening to the energy in the system. Also, you can completely eliminate the use of "conservative and non-conservative forces" which has always seemed a total non-sequitor to me. The approach is elegant and effective.

It has also made me think more about momentum than I ever have before. Here's the problem I have. When analyzing the energy flow and storage in a situation involving friction, we keep the surface in the system so that we don't have to worry about partitioning Ediss. Not only is this effective, it makes sense since the friction force cannot "exist" without the presence of the object sliding on it: i.e., it cannot be an INDEPENDENT outside force. But what happens when we incorporate momentum analysis into a situation? Is the surface still part of the system? It seems like we shouldn't change the system designation within a problem. Why? I don't know. But if the system does include the surface, then how do we reconcile the statement that "momentum is conserved unless the system is acted on by an OUTSIDE force? B/C with this system designation, friction is an INTERNAL force, so momentum should be conserved but it clearly isn't since the sliding object slows down. "Of course", "momentum is conserved b/c the "missing" momentum goes into the earth which is so massive that we can't measure the associated change in velocity". Right. This sounds and feels like smoke and mirrors to me (even though it's true).

The alternative is to keep the surface out of the system for momentum analysis (then you can say "Aha, but there IS an outside force - friction"). This allows momentum to always be conserved. But this requires two different system designations in the same problem. Not very appealing. Am I totally off the wall here?

My puzzle has also forced me to ask myself "What is momentum anyway?" It is easy and accurate to conceptualize and explain energy as a "fluid-like massless substance which flows through a system altering its state variables in the process". It never goes away but just passes from one bin to another. But what about momentum? Is it just a convenient coincidence, two variables whose product is somehow not affected by the deformations and vibrations in a collision which cause Ek to diminish? Is there any other way to treat the issue than to restate the Second Law as the time rate of change of momentum? In a=F/m, all three variables are tangible, measurable, physical entities. Somehow, restating this as F=d/dt(mv) doesn't seem likely to be successful for "regular" HS physics students. HELP!!!

At the risk of sounding Pollyanish, I want to say how fantastic it is to have a body of colleagues out there to discuss such issues with. My colleague at school thinks this momentum/system question is waste of time - just get the right answer to a problem. So, fellow modelers (especially those who have been at this game for a while), I salute you for having the courage and the drive to be part of an effort to improve your methods - I just wish there were some of you in the area to collaborate with. But I guess that's the point of the university alliances, eh?

Date: Mon, 1 Feb 1999
From: Paul Gregg Swackhamer <pswackhamer@GLENBROOK.K12.IL.US>

Regarding John's post on how to handle momentum and energy:

If you put the lower surface in the energy system containing an object moving over a rough surface, then you are right that Ediss is all there in the system, and energy in the system is conserved; no fuzzy partitioning required.

Also, you have illustrated two important things about physics: 1) substance-like things like energy are visualizable. We get a mental representation that is very helpful and also reveals some serious deficiencies in our old way of thinking about energy...like what does energy do when it goes somewhere.

With the energy-as-only-a-number idea, the work concept becomes less than meaningless just because you don't have to think about where energy goes and what it does; you only have to find a number. You mentally never are forced to engage the important fact that it does go somewhere and something somewhere changes.

2) A focus on answers to problems as the goal of learning physics can cause you to miss a lot of fundamental stuff. We've all had this experience, I'm sure. A sensible model of the thing at hand makes you confront more stuff, doesn't it!

Regarding momentum, we can take advantage of visualizing momentum, too. It can be pictured as a substance that flows from one momentum container to another. The rate that momentum flows from object A to object B we call the FORCE of A on B. So if we put the surface (i.e. the Earth) in the system with a moving object, then there is no transfer of momentum from the system. Usually, though, we are interested in only the object moving along, not in the object+Earth. Friction then becomes a momentum leak from the object to the Earth (or vice versa). So, we usually define our system as the object only. This is different than the system John speaks of for energy in a dissipative situation.

I do not include the surface in the system for my energy situations. I can still calculate the energy input to the system from some well-defined outside source of energy, but I cannot find out exactly how much leaves the object through friction. I live with that. I define systems for momentum in just the same way. And there it is easier, since a frictional force is a transfer of momentum just like any other force. While we cannot calculate exactly the amount of energy transferred from or to an object by friction, we can calculate exactly the amount of momentum transferred through friction (by Ffric * delta t).

Forces as "currents" of momentum can be powerful mental pictures. The momentum transferred can be positive (to the right) or negative (to the left). In the case of an object thrown vertically, the upward (positive) momentum drains away at a constant rate (equal to the gravitational force). The upward momentum vector decreases, much like the impetus conception that gets so confused with force. Where does it drain away to? Ultimately to the Earth, which acquires the upward momentum at the same rate...Newton's Third Law: the rate that momentum is gained by object A from object B is equal to the rate that momentum is lost from object B to object A!

There is much of value in what we have begun, and there is much more to do. The process of getting there is sometimes rewarding and sometimes thankless. But time is on our side, and hard work will bear the fruit we hope for. The goal is not to silence hostile critics, but to better serve our students and our profession. The results will speak for themselves.

COMMENTS ON THE ABOVE POSTS, A YEAR LATER:

Date: Thu, 7 Dec 2000
From: Allen Pickel <pickelc1@TEN-NASH.TEN.K12.TN.US>
What about the increased momentum of the individual atoms due to their increase in KE (i.e., temperature)?

Date: Thu, 7 Dec 2000
From: Thomas J Gordon <tomgordon@JUNO.COM>

Go back to that old discussion almost 200 (?) years ago, as to whether the true measure of the effectiveness of a force on an object is the energy change that is produced or the momentum change.

Some greater mind settled it by pointing out that the effect of the force over the DISTANCE it moved was the energy change (integrate F ds) the effect of the force over the TIME it acted is momentum change (integrate F dt)

So - in trying to explain about energy we have to do an awful lot of hand gesturing and arm waving to account for all the conversions and " leakage ". But when it comes to momentum and its interactions it should be relatively straightforward.