Weird Science

The English word "weird" is self-descriptive, violating for no apparent reason the grammatical rule, "*i* before *e* except after *c*." No doubt there is some interesting etymological reason for this particular exception, but to students of English as a Second Language it must seem a completely arbitrary booby-trap set for hapless victims.

The numerous breakdowns of the "Laws of Physics" discovered in the early part of the Twentieth Century must have elicited similar reactions in students of Physics as a Second Language [which is, of course, what we are all trying to learn].

There is a story [which may even be historically accurate, but for my purposes it doesn't matter] about a distinguished physicist around the end of the 19$^{\text{th}}$ Century who advised his bright student to go into some other more promising field [today it would be Computer Science or Microbiology] because "Physics is just about wrapped up — all that remains is to tie up some loose ends and work out a lot of engineering details." Imagine the consternation of that student when, a decade or two later, it became clear that the basic classical "Laws" of Physics were *all wrong* and that the world behaves *essentially differently* from our "common sense" expectations! The success of Classical Physics [before Relativity and Quantum Mechanics] was just a lucky accident: in the world we perceive — naturally enough, a world of objects of roughly our own size — the *true* qualitative behaviour of matter and energy is obscured by the enormous *size* of objects we can handle and the miniscule *speeds* we can achieve with our own huge, puny bodies; in this anthropocentric limit [virtually infinite size relative to atoms and virtually zero velocity relative to light] Newton's "Laws" turn out to be an excellent *approximation* to the truth, so we can still make good use of them. But they are wrong in an absolute qualitative sense. Of course, the "Laws" of Relativity and Quantum Mechanics are almost certainly wrong in an absolute qualitative sense, too. In fact, ever since their "discovery" (if that is the right word), their "truth" has been challenged continuously, often no more aggressively than by those who formulated them in the first place. Einstein in particular was convinced that Quantum Mechanics was merely a provisional calculational technology, that "God does not play dice." And he was surely right; sooner or later we are bound to find where these new descriptions break down [*e.g.* in the description of gravity. . .] and there we will doubtless find the more "true" theory of which they are merely limiting cases under restricted conditions. [Ain't it always the way?] But it is no criticism of any theory to predict that it is ultimately wrong in an absolute sense; and in any case I am getting much too far ahead of myself here.

16.1 Maxwell's Demon

One hint that there is more to physics than meets the Classical eye can be obtained by the following *Gedankenexperiment* credited to J.C. Maxwell [whom we shall meet again soon]:

We know that a system prepared initially in a highly *ordered* state — *i.e.* one whose gross macroscopic properties can only be achieved by a very small subset of all the possible fully specified microscopic states (*e.g.* a box full of marbles with all the white ones on one side and all the black ones on the other side) — is sure to drift toward more probable, less ordered (more random) states (*e.g.* all the marbles mixed up) as time goes on, if some "jiggling" is provided by the world around it. This intuitively obvious conclusion is translated by Physicists into the SECOND LAW OF THERMODYNAMICS, which states that *entropy will always increase* in any spontaneous process involving a highly complex system.[1] When examined critically, this conclusion can be seen to contain virtually everything we know about the "arrow of time" — *i.e.* the only practical way to tell whether a movie of some process is being shown forward or backward. So it is a pretty basic idea.

Now suppose that we build a modern, microminiaturized robot[2] that sits by a hole in a divider between the left and right sides of the box of marbles and opens the door only for white marbles heading toward the right side and for black marbles heading toward the left side. This action can presumably take far less energy than the marbles' kinetic energy; we simply substitute "will" (in this case, the programmer's will as translated into action by the robot) for "brute force" and avoid any "waste" of energy. *Is it possible to reverse* the SECOND LAW OF THERMODYNAMICS using a "Maxwell's Demon?"

The answer is not obvious. One can see why by examining the analogous example of keeping one's office or bedroom tidy: in this case a simple application of *will* should suffice to maintain Order (keeping Entropy at bay) by simply putting every article in its proper place every time the opportunity arises; however one is apt to notice some dissipation of energy as such good habits are put into practice. With the possible exception of a few "Saints of Order," we all think of "tidying

[1] There are, of course, many other ways of stating the SECOND LAW, but this suffices for my purposes.

[2] Maxwell specified a "demon," but as A.C. Clarke says, "Any sufficiently advanced technology is indistinguishable from magic," so there is no practical difference.

up" as *work*; and the human machine is fuelled by a form of internal combustion which entails a massive increase of "global" entropy as food is consumed and digested. Therefore we may be able to suppress the SECOND LAW OF THERMODYNAMICS *locally* (*e.g.* in our office or bedroom), but only at the expense of a far greater increase in the entropy of our surroundings.[3]

Can we, however, *beat* this "entropy backlash" by building a much more *efficient* machine into which we program our will? Can we build a housekeeping robot that will keep our office/bedroom tidy without consuming more than a fraction of the energy it saves? Or, driving the analogy back to the microscopic level, can we build a "Maxwell's Demon" robot that will let only *fast* air molecules into our house and let only *slow* ones out, so that the average kinetic energy increases (*i.e.* the air warms up) and we can stop paying our heating bill? One problem is the cost (in energy or entropy increase) of *building* such a Demon-robot; but this can be disregarded if the robot is so well-constructed that it never wears out, since any such system that gains on the SECOND LAW will *eventually* gain back any finite initial outlay.[4] If such a device is possible, then we can make as many of them as we please and use them to store up energy which we can use in even our less efficient machines to push back the tide of Entropy on all fronts. We can even picture *self-replicating* Maxwell's Demons that get sent out into the Universe to reverse the SECOND LAW everywhere — the ultimate Conservationist scheme! Never mind whether this sounds like a good idea; *could it work?*

The answer is still not obvious. We will have to come back to this question after we have a working knowledge of Quantum Mechanics — and even then it will probably not be obvious, but at least we may be able to find an answer.

16.2 Action at a Distance

Another perplexing problem for turn-of-the-Century scientists was the issue of whether two objects had to "touch" in order to exert forces on each other. The car's wheels touch the road, the crane lifts the concrete block by a cable attached to it and the arrow's flight is slowed by air molecules rubbing against it; so how exactly is the Earth's gravitational force *transmitted* to the cannonball?[5]

Physicists might have been willing to live with the idea that "gravity is weird," were it not for the fact that other types of forces also appeared to act "at a distance" without any strings attached (as it were) — namely, the *electrical* and *magnetic* forces whose simplest properties had been know for millenia but whose detailed behaviour was only beginning to be understood empirically in the late 19^{th} Century. An amber rod rubbed with rabbit fur attracts or repels bits of lint or paper even when separated by hard vacuum; a lodestone's alignment will seek magnetic North wherever it is carried [an important practical property!] except at the North Pole, where we seldom need to go. How does the North Pole "touch" the magnetic compass needle? What is going on here? How can things act on each other without touching? Weird.

There are other examples of "weird science" that kept cropping up around the turn of the Century; I will append some more to this Chapter as we go on, but for now it's time to get on with ELECTRICITY AND MAGNETISM.

[3]An awareness of such consequences is perhaps a first step toward an enlightened form of "environmentalism."

[4]Another lesson for the wise consumer: always consider the long term energy-economics of a prospective appliance purchase. For example, a fluorescent light takes as little as 1/4 as much power as an incandescent bulb to generate the same amount of light; on the other hand, turning the fluorescent light on and off may shorten its lifetime even more dramatically than for the equivalent incandescent bulb, and the *replacement* fluorescent light costs *far* more (in energy) to make! So one should strive to use fluorescent light in applications where the light stays on essentially all the time, but in on-and-off applications it is not so clear.

[5]This question has still not been answered in an intuitively satisfactory way; the General Theory of Relativity [coming up!] nicely avoids the issue by making gravitational acceleration equivalent to warped space-time — and thus replies, "the question is meaningless." Maybe *all* "forces" will eventually be shown to be false constructs, misleading paradigms conjured up to satisfy foolish prejudices and ill-posed questions; it wouldn't surprise me a bit. But for the time being we still cling to the image of two "things" acting on each other and have managed to reconcile this image (sort of) with Quantum Mechanics and Relativity in all cases except Gravity, where even stretching the metaphor to the breaking point has not sufficed. More on this later.