Chapter 2

Contact, friction and propulsion

1. LAWS THAT RUN COUNTER TO COMMON SENSE

A knowledge of Newtonian mechanics is an essential historical and pedagogical foundation for physical theory, but it is also a source of considerable difficulty. It is typically the arena where common sense ideas and reasoning clash with the theory taught[1]. Not that it is difficult to state or remember the basic law of dynamics for a particle, ($\mathbf{F}=m\mathbf{a}$ in conventional notation), the law of interactions or Newton's third law for two particles ($\mathbf{F}_{1on2}= - \mathbf{F}_{2on1}$ in conventional notation), and their corollaries for groups of particles or systems, namely the centre of mass theorem $\mathbf{F}_{ext} = M\mathbf{a}_G$ and the law of interactions for two systems (A and B: $\mathbf{F}_{AonB}=- \mathbf{F}_{BonA}$ again in conventional notation). Quite simply, in many physical situations the answers that common sense dictates and is willing to accept without argument are completely at odds with Newtonian analysis.

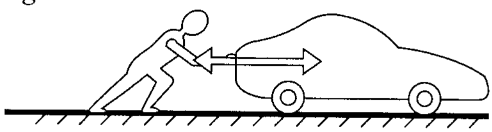
Thus whenever the speed of a moving object and the resultant of the forces acting on it are manifestly not either simultaneously zero or in the same direction, it seems we have to imagine what force is needed in the desired direction for the two vectors in question to resemble each other. This dynamic element, which is intended as an explanation, is often seen as a cause stored in the object, a kind of dynamic capital attributed to it, like "the *ball's* upward force" that carries it aloft in spite of gravity. In these common sense arguments, the past cause, the action of the person who threw the ball, is somehow replaced by this dynamic equivalent that surreptitiously becomes part of the moving object and either lasts as long

[1] For a summary see Viennot 1996, 2001.

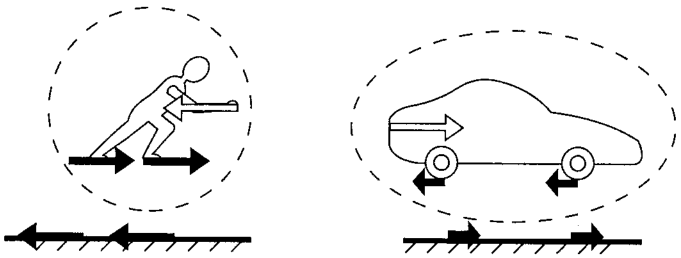
as required or is exhausted en route. And interactions between objects (or, more learnedly, "systems") are often interpreted as strange balances. Regardless of the third law, the force exerted by the one on the other is said to be greater than its reciprocal if the objects in question are in contact in a situation of overall acceleration. Of course, in true Newtonian dynamics for each object such acceleration is the result of all the forces acting *on it* and not of any kind of "balance" between a force acting *on it* and another acting *on another object*. But common sense analysis looks more like an account of a struggle: the horse pulls harder than the cart resists, the plank does not resist the action of the nail driven into it, the driver getting his broken down car to move pushes harder than the car resists (box 1), the weight moving downwards overcomes the spring that holds it, one object *has* more force than the other.

Box 1
A driver whose car has broken down is pushing it: forces in play (horizontal components)

- *Common diagram*



- *Fragmented diagram*



Only the horizontal components of the forces involved in the interactions between the ground and the car or the person pushing it are shown. The balances of forces on each object surrounded by a "bubble" take account of the object's acceleration and the third law is satisfied.

Note: this representation clarifies the question, but it could be criticised for combining a realistic depiction of the objects with symbols representing the forces. The forces could instead be represented as starting from points, each labelled with the name of the object on which they act (see note 4).

The third law is then made to look like the second law; in fact it is quite simply broken in much of what is said, including in school books[2]. This risk is particularly obvious for contact interactions.

2. A METHOD OF SPOTLIGHTING THE BASICS

A number of methods have been proposed for helping pupils finishing secondary school or students starting higher education to get a firm grasp of the following points:

-the second and third laws are different; in particular, the one is concerned with just one object (or "system"), the other with two;

-in classical mechanics, they both apply

- *with no other restriction (the third law is not limited to cases of equilibrium),*
- *the force terms are considered at the same point in time.*

Boxes 1 and 2 illustrate one of these proposals (developed more fully in Appendix 1), "fragmented diagrams", for some apparently simple situations that are often felt to be problematic, like so many in mechanics. This technique, which rather cavalierly mixes realistic representations of objects with aspects of modelling (with arrows representing forces), has the advantage of being quite easy to use while being very exacting in one particular respect: the specification of the object (but not of the point) of application of forces. Since the points of contact are as it were disconnected by the rather abstract fragmented representation, it becomes impossible to take refuge in the ambiguity that a more realistic depiction of the contact would permit. A choice has to be made: the arrow is on one object or the other. Moreover, there is no longer any question of making one of those misleading balances at a point of application[3] that serve as an alibi for abusing the third law[4].

[2] Less and less often in the straightforward way highlighted in Viennot 1982.

[3] For balances supposedly made at points of application, see a clarification in Appendix 1.

[4] A number of diagrams may also be made of the same interaction, each one maintaining the realism of the contact but emphasising one or other object in turn, the one undergoing the force represented, while the other object remains in dotted lines, for example. This technique was suggested, alongside that of fragmented diagrams, by the Groupe Technique Disciplinaire de Physique (1993) in the document accompanying the syllabus for the fourth year of secondary schools in France (grade 9 in the US). Using this very worthwhile technique becomes more complicated when there are several interactions to be considered, since it increases the number of diagrams needed for the same situation. See also Carré & Goffard (1997), who make a

http://www.springer.com/978-1-4020-1276-1

Teaching Physics
Viennot, L.
2003, XV, 235 p., Softcover
ISBN: 978-1-4020-1276-1