Newton's Third Law of Motion

a guide for teachers

The problem

N(III) is potentially <u>very</u> confusing, even for teachers, and is therefore often very badly taught because:

a) it seems so trivial at first glance that it doesn't seem to warrant any deep thought
b) it is often stated in a very unhelpful way

To go back to the original source, what Newton actually published in 1687 in the *Principia* was:

> *Actioni contrarium semper et aequalem esse reactionem: sive corporum duorum actiones in se mutuo semper esse aequales et in partes contrarias dirigi*
>
> To any action there is always an equal and opposite reaction; or, the actions of two bodies upon each other are always equal and always opposite in direction (2001 translation)

More problems

Remembering N(III) as 'action and reaction are equal and opposite' is not wrong *per se* (after all, it's very close to what Newton originally said), but it can very easily lead to nonsensical conclusions.

Example 1

> 'I push a book horizontally with a force of 10N. This is the action force. The reaction force is 10N in the opposite direction. These forces balance, therefore the book doesn't move.'

Yet, if you push the book with a force of a million Newtons, this argument says that the reaction force will then be a million Newtons in the opposite direction, therefore the book will <u>never</u> move. This seems to say that you can never have a resultant force on any object in the Universe. We've just managed to prove that all motion is impossible. This is not good.

The solution

The best way of remembering N(III), whether teacher or pupil, is:

> *If body A exerts a force on body B, then body B exerts an equal and opposite force on body A*

How is this different, you might ask? It makes it completely clear that the action and reaction forces must be exerted **on different bodies**. In Example 1, it is not correct to say that the forces balance, since they are not both acting on the book. The reaction force of 10 (or a million) Newtons acts on the object which is doing the pushing, not on the book. Therefore the action force can easily overcome friction between the book and the table, giving a resultant force on the book, and explaining why it moves.

Still more confusion

A N(III) pair of action and reaction forces must be equal and opposite. However, not all forces which are equal and opposite have to be a N(III) pair. This is another trap that it is very easy to fall into.

Example 2

> Consider the Weight and Normal Reaction for a stationary object resting on a surface. Are they equal and opposite? Yes. Are they a N(III) pair? **Absolutely not**. Why? Because they are acting on the <u>same</u> object.

Drawing free-body force diagrams is a very good way of showing pupils how to avoid this problem, which is why it used to be a standard part of all post-16 Physics courses. Its fall from favour has not helped teachers' or pupils' understanding of N(III), and would be worth considering using in your teaching.

How to spot N(III) pairs

Using the following formulation should be foolproof. Describe one force in this way:

[*object 1*] exerts a [*type of*] force of [*quantity*] Newtons in a [*direction*] direction on [*object 2*]

Then all you do is a) swap the names of the objects, b) reverse the direction, and that's the N(III) pair of that force.

Using Example 2:
Action: The Earth exerts a gravitational force of 10 Newtons in a downwards direction on the book.
Reaction: The book exerts a gravitational force of 10 Newtons in an upwards direction on the Earth.

Now describe the Normal Reaction and its N(III) pair in the same way:

Action: The ……… exerts a ……… force of 10 Newtons in a ……… direction on the ……….
Reaction: The ……… exerts a ……… force of 10 Newtons in a ……… direction on the ……….

The action and reaction forces in N(III) obey certain rules:
- They <u>must</u> act on different objects
- They <u>must</u> be the same type of force (e.g. gravitational, electrostatic, magnetic, contact etc.)
- They <u>must</u> act for the same time (as soon as the action starts/stops, the reaction starts/stops)

In this sense, N(III) has sometimes been described as simply *a law of conservation of Force*, which might be a helpful way of thinking about it.

Question
This question is adapted from the book *Thinking Physics* and is a well-known physics 'puzzle'.

If the force on the carriage is equal and opposite to the force on the horse how can the horse pull the carriage?

(a) The horse cannot pull the carriage because the carriage pulls as hard on the horse as the horse pulls on the carriage.
(b) The carriage moves because the horse pulls slightly harder on the carriage
(c) The horse pulls the carriage before it has time to react.
(d) The horse can pull the carriage only if the horse is heavier than the carriage.
(e) Another explanation. What might it be?