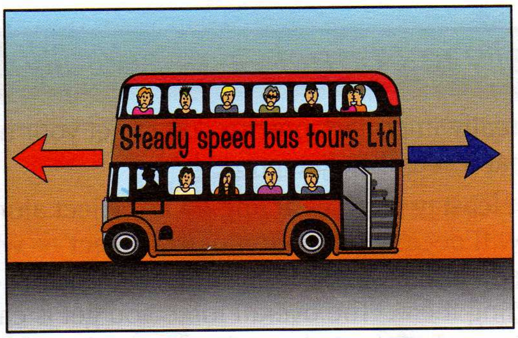
The Three Laws of Motion

Around about the time of the Great Plague in the 1660s, a chap called Isaac Newton worked out the Three Laws of Motion. At first they might seem kind of obscure or irrelevant, but to be perfectly blunt, if you can't understand these three simple laws then you'll never understand forces and motion.

First law — balanced forces mean no change in velocity

So long as the forces on an object are all balanced, then it'll just stay still, or else if it's already moving it'll just carry on at the same velocity — so long as the forces are all balanced.

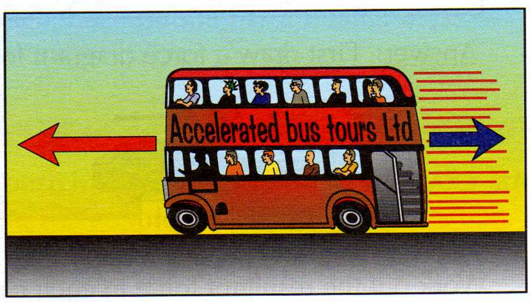
1) When a train or car or bus or anything else is moving at a constant velocity then the forces on it must all be balanced.
2) Never let yourself entertain the ridiculous idea that things need a constant overall force to keep them moving — NO NO NO NO NO!
3) To keep going at a steady speed, there must be zero resultant force — and don't you forget it.



Second law — a resultant force means acceleration

If there is an unbalanced force, then the object will accelerate in that direction.

1) An unbalanced force will always produce acceleration (or deceleration).
2) This 'acceleration' can take five different forms: Starting, stopping, speeding up, slowing down and changing direction.
3) On a force diagram, the arrows will be unequal:



Don't ever say: "If something's moving there must be an overall resultant force acting on it".
Not so. If there's an overall force it will always accelerate.
You get steady speed from balanced forces.

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Three points which should be obvious:

1) The bigger the force, the greater the acceleration or deceleration.
2) The bigger the mass, the smaller the acceleration.
3) To get a big mass to accelerate as fast as a small mass it needs a bigger force. Just think about pushing heavy trolleys and it should all seem fairly obvious.

The overall unbalanced force is often called the resultant force

Any resultant force will produce acceleration, and this is the formula for it:

$$F = ma \quad \text{or} \quad a = F \div m$$

m = mass, a = acceleration, F is always the resultant force.

Resultant force is really important — especially for 'F = ma'

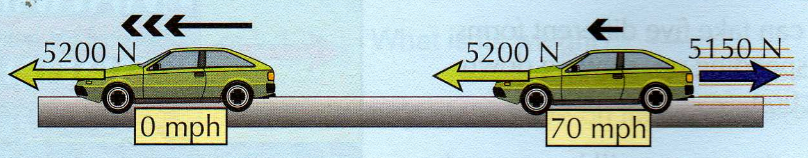
The notion of resultant force is a really important one for you to get your head round. It's not especially tricky, it's just that it seems to get ignored.

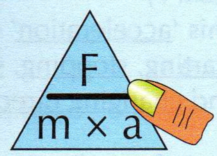
In most real situations there are at least two forces acting on an object along any direction. The overall effect of these forces will decide the motion of the object — whether it will accelerate, decelerate or stay at a steady speed. If the forces all point along the same direction, the 'overall effect' is found by just adding or subtracting them. The overall force you get is called the resultant force. And when you use the formula 'F = ma', F must always be the resultant force.

Example

A car of mass of 1750 kg has an engine which provides a driving force of 5200 N. At 70 mph the drag force acting on the car is 5150 N.
Find its acceleration:
a) when first setting off from rest b) at 70 mph.

Answer: First draw a force diagram for both cases (no need to show the vertical forces):





Work out the resultant force in each case, and apply 'F = ma' using the formula triangle:

a) Resultant force = 5200 N
a = F/m = 5200 ÷ 1750 = $3.0\ m/s^2$

b) Resultant force = 5200 – 5150 = 50 N
a = F/m = 50 ÷ 1750 = $0.03\ m/s^2$

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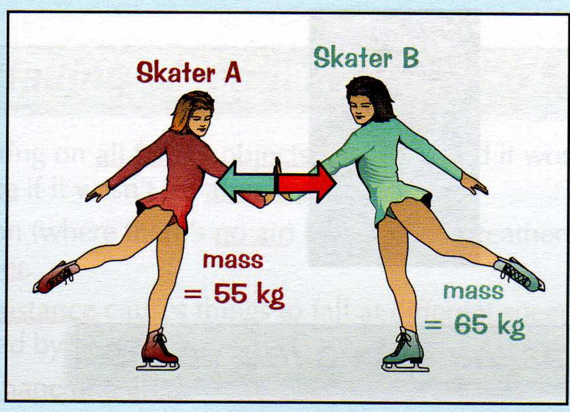
The third law — reaction forces

If object A exerts a force on object B then object B exerts the exact opposite force on object A.

1) That means if you push something, say a shopping trolley, the trolley will push back against you, just as hard.
2) And as soon as you stop pushing, so does the trolley. Kinda clever really.
3) So far so good. The slightly tricky thing to get your head round is this — if the forces are always equal, how does anything ever go anywhere? The important thing to remember is that the two forces are acting on different objects.

Example

Think about a pair of ice skaters:



When skater A pushes on skater B (the 'action' force), she feels an equal and opposite force from skater B's hand (the 'reaction' force).

Both skaters feel the same sized force, in opposite directions, and so accelerate away from each other.

Skater A will be accelerated more than skater B, though, because she has a smaller mass — remember $F = ma$.

It's the same sort of thing when you go swimming. You push back against the water with your arms and legs, and the water pushes you forwards with an equal-sized force in the opposite direction.

Three laws of motion and one important task — learn them

This is like... proper Physics. It was pretty fantastic at the time — suddenly people understood how forces and motion worked and so they could work out the orbits of planets and everything. Inspired? No? Shame. Learn them anyway — you're really going to struggle in the exam if you don't.

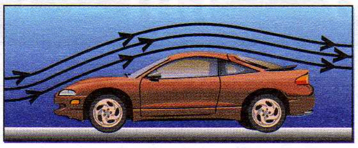
Friction Forces

Friction is found nearly everywhere and it acts to slow down and stop moving objects. Sometimes friction is a pain, but at other times it's very helpful.

1) Friction is always there to slow things down

1) If an object has no force propelling it along it will always slow down and stop because of friction (unless you're in space where there's nothing to rub against).
2) Friction always acts in the opposite direction to movement.
3) To travel at a steady speed, the driving force needs to balance the frictional forces.
4) You get friction between two surfaces in contact, or when an object passes through a fluid (drag).

Resistance or "drag" from fluids (air or liquid)

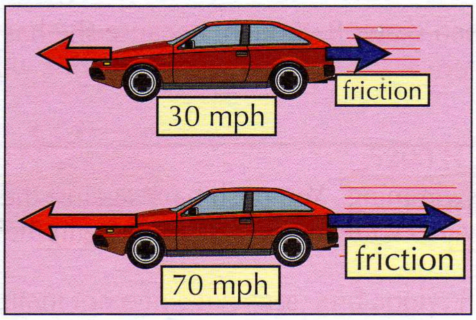


The most important factor by far in reducing drag in fluids is keeping the shape of the object streamlined, like fish bodies or boat hulls or bird wings/bodies.

The opposite extreme is a parachute which is about as high drag as you can get — which is, of course, the whole idea.

2) Drag increases as the speed increases

Resistance from fluids always increases with speed.
A car has much more friction to work against when travelling at 70 mph compared to 30 mph. So at 70 mph the engine has to work much harder just to maintain a steady speed.



Friction's annoying when it's slowing down your boat, car or lorry...

... but it can be useful too. As well as stopping parachutists ending up as nasty messes on the floor, friction's good for other stuff — e.g. without it, you wouldn't be able to walk or run or skip or write.