Forces as pushes or pulls

A **force** is anything that "pushes" or "pulls" on an object. For example, we are all familiar with the fact that the Earth pulls things down toward it. To hold a book above the ground, you need to exert a force on the book, because if you stopped pulling/pushing (by taking your hand away, say) then the book would fall to the ground.

In everyday language we would refer to the "pull of Earth" on the book as *gravity*. In most physics books the technical term for this force is *weight* of the book. In physics 7 we call this **the force of Earth on the book**, or $\mathbf{F}_{\textbf{Earth on book}}$ for short. We do this because whenever there is a push or a pull it involves two objects:

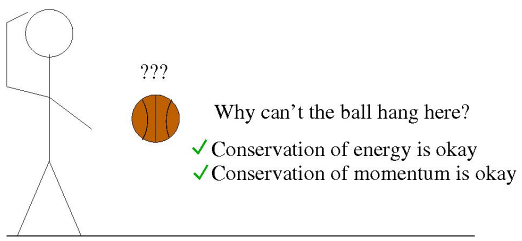
1. the object doing the pushing/pulling and
2. the object being pushed or pulled.

The notation we use for forces emphasises this: $\mathbf{F}_{\textbf{A on B}}$ means that object A is pushing or pulling object B. Another way of saying the same thing is that object A *exerts a force* on object B, which gets us away from talking about pushing or pulling.

Force is a vector; its direction being the same direction as the push or pull. For example $\mathbf{F}_{\textbf{Earth on Book}}$ would be directed downward. To find the overall push or pull on an object, we add (as vectors!) all the different forces acting on that object. This is called the net force, and we denote it either as $\mathbf{F}_{\textbf{all on object}}$ (preferred) or as $\boldsymbol{\Sigma}\mathbf{F}_{obj}$.

Why should we care about forces?

One of the big drawbacks of energy or momentum conservation is that you could only solve for one thing at a time, and they would not tell you what would happen. Let us look at the example of someone dropping a ball:



We all know that the basketball will fall toward the Earth. But energy is conserved if the ball just hangs there, as there is no change in any energy system. Momentum is conserved as well. *Yet this never happens!* Obviously there are some other rules that are used to figure out where things will go.

This is where forces come in. If you know the net force on an object, you can figure out where it is going to go. In the picture above, the only force on the ball is $\mathbf{F}_{\textbf{Earth on Ball}}$ which is going to cause it to *accelerate* downward.

Two types of forces

You know that there is a force on the ball from the Earth; a better question might be how do you know that is the *only* force on the ball? The answer is, to the best our knowledge the only way an object A can exert a force on object B *without touching it* is via gravity, electrical forces or magnetic forces. All other forces require that the objects actually be in contact, and are called *contact forces*. For example, the chair you are sitting on exerts a contact force on you upward, to counter the Earth's pull.

Do not worry too much about electric and magnetic forces yet – they are covered in physics 7C. In analysing the ball we have to take into account gravity ($\mathbf{F}_{\textbf{Earth on ball}}$) and anything else it is touching. In the picture above, the only other thing it touches is the air, and if there was a strong wind it *would* exert a force on the ball and blow it around.

> Unless explicitly stated otherwise, we will always neglect the effect of any possible $\mathbf{F}_{\textbf{air on obj}}$. While it is there and in certain situations incredibly important (like tornados), such situations are uncommon.

In doing problems involving forces on an object, a good strategy is to ask if you need to take into account gravity and then ask if you have included a possible force from everything in contact with the object.

Forces and momentum conservation

A system is a closed momentum system if there is no net force acting on it. The ball shown above was not in a closed momentum system, as the Earth was pulling down on it.

Forces are a way of transferring momentum from one object to another. Like heat and work in physics 7A transferred energy to (or from) an open energy system, an object with a net force acting on it can change its momentum. The difference was that heat and work are energies so that

$$\Delta U = Q + W$$

made sense.

Force is not a type of momentum. The equation $\boldsymbol{\Delta}\mathbf{p}_{\textbf{obj}} = \mathbf{F}_{\textbf{all on obj}}$ makes no sense! The correct equation relating the two is

$$\boldsymbol{\Delta}\mathbf{p}_{\textbf{obj}} = \Big(\mathbf{F}_{\textbf{all on obj}}\Big)_{\text{average}} \Delta t \tag{1}$$

where Δt is the amount of time that the force has been applied. This should be a little intuitive – the longer you push something, the bigger the change in momentum you make for the same (net) force.

Ensuring momentum conservation

If an object A exerts a force on object B, then object B exerts a force on A an equal in magnitude but opposite in direction. Symbolically, this is

$$\mathbf{F}_{\textbf{A on B}} = -\mathbf{F}_{\textbf{B on A}} \tag{2}$$

This makes sure that if we include *all* the objects that exert forces on one another that the momentum is conserved.

Looking at the train collision from last time, if the trains are not pulling themselves along the tracks and they collide, the only thing that can exert a net force on one of the trains is the other train. So we have

$$\boldsymbol{\Delta}\mathbf{p}_{\textbf{train1}} = (\mathbf{F}_{\textbf{all on train 1}})_{\text{average}} \Delta t = (\mathbf{F}_{\textbf{2 on 1}})_{\text{average}} \Delta t$$

$$\boldsymbol{\Delta}\mathbf{p}_{\textbf{train2}} = (\mathbf{F}_{\textbf{all on train 2}})_{\text{average}} \Delta t = (\mathbf{F}_{\textbf{1 on 2}})_{\text{average}} \Delta t$$

Looking at the momentum of the system of two trains, we have

$$\boldsymbol{\Delta}\mathbf{p}_{\textbf{sys}} = \Big[(\mathbf{F}_{\textbf{2 on 1}})_{\text{average}} + (\mathbf{F}_{\textbf{2 on 1}})_{\text{average}}\Big] \Delta t$$

Using (2) we see that $\mathbf{F}_{\textbf{2 on 1}} = -\mathbf{F}_{\textbf{1 on 2}}$, and so $\mathbf{F}_{\textbf{1 on 2}} + \mathbf{F}_{\textbf{2 on 1}} = \mathbf{0}$![1] This tells us that momentum in the entire system must be conserved.

[1] A small step is made here. Because the forces are *always* equal and opposite, it is true that their averages must be as well.