Types of Forces

Starter

1. **(Review of last lesson)** A particle, P, of mass 14 kg has acceleration $\begin{pmatrix} 4a \\ -3a \end{pmatrix}$ N. Given that the force acting on P has a magnitude of 35 N, find the value of a.

Notes

Examples of driving forces

Thrust (pushing - directed into the object)
Tension (pulling - directed away from the object)

Examples of resisting forces

Braking force
Frictional force
Air resistance (usually not considered)

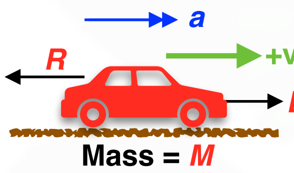
If the contact between two surfaces is smooth, friction is considered negligible (i.e. zero).

Newton's 2nd and 3rd laws

Sum the net forces in the same direction — drawing a diagram showing all the forces is essential.
D = driving force, R = resistance force (friction, air resistance etc.)

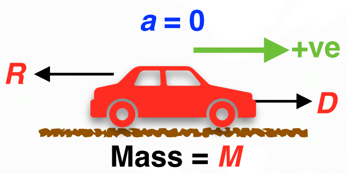
N.B. No acceleration does not mean the object is not moving.

Car accelerating at *a* m/s²



$F = ma$: $\quad D - R = ma$

Car travelling at constant speed



Either $F = ma$: $\quad D - R = 0$
or resolving: $\quad D = R$

Resolving forces can be used when there is no acceleration.
We use the negative sign to show direction.

E.g. 1 A driving force of 4000 N pushes a car of mass 950 kg along a road. Air resistance is 150 N and the frictional force is 500 N. Find the acceleration of the car.

N.B. With ***vectors***, we ***add the forces*** to get the resultant force.
Therefore, with vectors we have: $\mathbf{D} + \mathbf{R} = m\mathbf{a}$

E.g. 2 A box of mass 24 kg moves on a rough horizontal floor under the action of a constant horizontal force $(16\mathbf{i} + 11\mathbf{j})$ N. Find, in vector form, the frictional force acting on the box when it's acceleration is $(0.7\mathbf{i} - 1.1\mathbf{j})$ m/s².

E.g. 3 Do p493 21C Qu 4.

If you used the same method to do ***E.g. 3*** (p493 21C Qu 4)as ***E.g. 2***, you will have found that your answer differs. This is because the books uses "friction opposes motion" to get the answer. ***E.g. 2*** used "adding vectors to get the resultant".

Which method is correct?

Adding vectors to get the resultant vs. friction opposes motion

Consider a particle of mass 2 kg moving under a driving force of $\mathbf{D} = \begin{pmatrix} 8 \\ 0 \end{pmatrix} = 8\mathbf{i} + 0\mathbf{j}$ with no friction.

Using $\mathbf{F} = m\mathbf{a}$: $\quad \begin{pmatrix} 8 \\ 0 \end{pmatrix} = 2 \times \mathbf{a}$ so $\mathbf{a} = \begin{pmatrix} 4 \\ 0 \end{pmatrix}$

It is obvious that with friction, the acceleration would be less than $\begin{pmatrix} 4 \\ 0 \end{pmatrix}$. Let's assume that the new acceleration will be $\begin{pmatrix} 3 \\ 0 \end{pmatrix}$ and calculate the fictional force for the "adding vectors" and "friction opposes motion methods".

Let the frictional force be $\begin{pmatrix} a \\ b \end{pmatrix}$

Adding vectors: Using $\mathbf{F} = m\mathbf{a}$:

$$\begin{pmatrix} 8 \\ 0 \end{pmatrix} + \begin{pmatrix} a \\ b \end{pmatrix} = 2 \times \begin{pmatrix} 3 \\ 0 \end{pmatrix}$$
$$\therefore \begin{pmatrix} a \\ b \end{pmatrix} = \begin{pmatrix} -2 \\ 0 \end{pmatrix}$$

Friction opposes motion:

$$\begin{pmatrix} 8 \\ 0 \end{pmatrix} - \begin{pmatrix} a \\ b \end{pmatrix} = 2 \times \begin{pmatrix} 3 \\ 0 \end{pmatrix} \text{ so}$$
$$\therefore \begin{pmatrix} a \\ b \end{pmatrix} = \begin{pmatrix} 2 \\ 0 \end{pmatrix}.$$

The positive 2 in the second calculation indicates that the friction force is acting in the same direction as the driving force but this is incorrect because ***friction oppose motion***.

In conclusion, with ***vectors*** we ***add the forces*** to get the resultant force. This is because a vector already has direction hardwired into it.

Video: Newton's 2nd law

Solutions to Starter and E.g.s

Exercise
p493 21C Qu 1-11

Summary
If the contact between two surfaces is smooth, friction is considered negligible (i.e. zero).

Newton's 2nd and 3rd laws in 1—dimension: $D - R = ma$
where D = driving force, R = resistance force (friction, air resistance etc.)

Newton's 2nd and 3rd laws in 2— or 3—dimensions: $\mathbf{D} + \mathbf{R} = m\mathbf{a}$

where $\mathbf{D}$ = driving force, $\mathbf{R}$ = resistance force (friction, air resistance etc.)