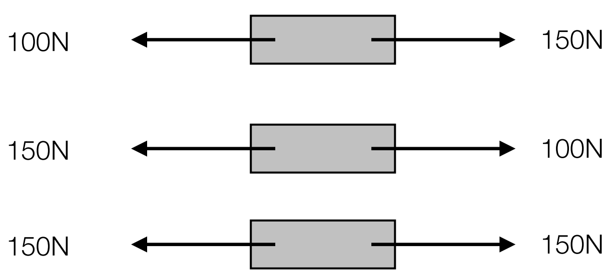
PF1.1: FORCES: NEWTON'S LAWS OF MOTION

Net (or resultant) force ΣF

Examples



Σ F = 150– 100 = 50N to the Right
∴ unbalanced force

Σ F = 150– 100 = 50N to the Left
∴ unbalanced force

Σ F = 150– 150 = 0 Stationary or moving at constant speed (see below)

Note: Force is a vector quantity, so direction must be taken into account.

Newtons laws of motion

Newtons 1st law of motion

Every object continues to be at rest, or continues with constant velocity, unless it experiences an unbalanced force.

Seatbelts are fitted in cars to take into account Newton's 1st Law of Motion. If, for instance, you had to brake suddenly and you were not wearing your seatbelt, then by Newton's 1st Law, you would continue to travel at a uniform speed – the speed of the car just before braking – until you made contact with the windscreen. That is, the sum of the forces acting on you was zero at the instant you braked even though the car was being acted upon by a braking force.

Newtons 2nd law of motion

This law relates to the sum (ΣF) of the forces acting on an object and the acceleration produced as a consequence of this resultant force. It is given by:

$$\Sigma F = ma$$

where ΣF is the sum of the forces (in Newtons), 'm' is the mass of the object (in kg), and 'a' is the acceleration (in ms^{-2}). Note: ΣF must have the same direction as "a".

When doing Newton's 2nd law problems draw all forces acting **on** the object in question.

Example Toy car of mass 2 kg has a driving force F_D of 20N. The frictional force F_F acting on the car is 10N. Find the car's acceleration

$\Sigma F = ma$ where $\Sigma F = F_D - F_F = 20 - 10 = 10N$

Hence $\Sigma F = ma \Rightarrow 10 = 2 \times a \Rightarrow a = 5ms^{-2}$

Newtons 3rd law of motion

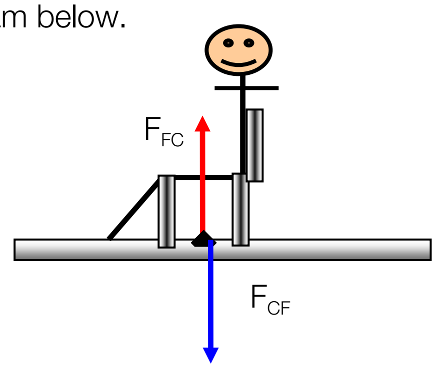
When two objects interact, the forces they exert on each other are equal in size, but opposite in direction. These pairs of forces are called action/reaction forces.

You need to appreciate that each force in the action-reaction pair acts on different objects. This is different to Newton's 2nd law where you analyse forces that are acting on the same object. Note that each force is equal in size but opposite in direction to its paired force.

Normal force F_N

A normal force acts at right angles to the surface with which it is in contact. For instance, if you are currently sitting on a chair reading this handout, then the chair is in contact with the floor and so there is a contact force of the chair acting on the floor given by F_{CF}. By Newton's 3rd law the floor will exert an equal but opposite force on the chair of F_{FC}. F_{FC} is also called the normal force F_N. See diagram below.

$F_{FC} = -F_{CF}$ where the negative sign indicates that these forces are acting in opposite directions. Recall your notes on vectors.

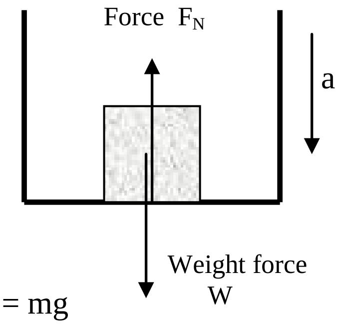


$F_{FC} = F_N$

Applications of Newton's laws.

A starting point when analysing Newton's 2nd law problems is to draw all forces acting on the object in question.

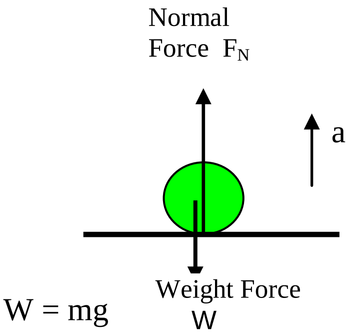
Objects in Lifts



W = mg

- If accelerating **down** (as shown at left): $\Sigma F = mg - F_N = ma$
- If accelerating **up**: $\Sigma F = F_N - mg = ma$
- If not accelerating at all: $\Sigma F = F_N - mg = 0 \Rightarrow F_N = mg$

Objects bouncing



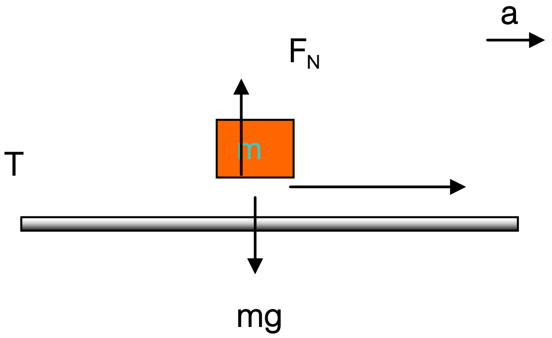
During the bounce (the instant the ball is in contact with the surface):

- $F_N > mg$, because $a > 0$ and is **upwards**. Therefore there is a resultant force acting which is upwards.
- F_N can often be much larger than mg
- If object is **stationary** $\Sigma F = F_N - mg = 0 \Rightarrow F_N = mg$

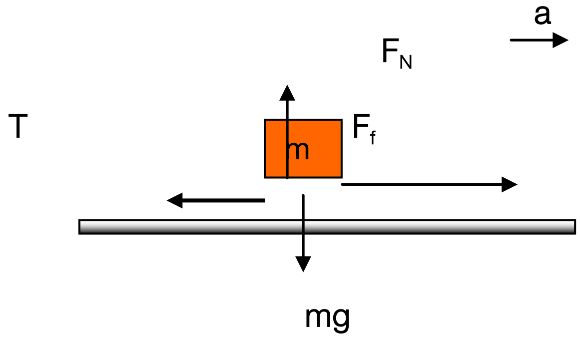
Object being pulled along a surface

T = tension in rope a = acceleration of mass

Smooth surface (no friction)



Rough surface (friction)



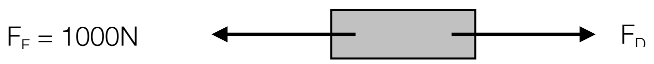
Horizontally: $\Sigma F = T = ma$

Vertically: $\Sigma F = F_N - mg = 0$
$\Rightarrow F_N = mg$

Horizontally: $\Sigma F = T - F_f = ma$

Vertically: $\Sigma F = F_N - mg = 0$
$\Rightarrow F_N = mg$

Example A car of mass 800kg accelerates from rest to 20ms^{-1} in 8.0s. The resistance forces acting on the car total 1000N. Find (a) the acceleration of the car, and (b) the driving force of the car.



(a) Acceleration is given by the change in velocity divided by the time taken, or

$a = (v - u)/t = (20 - 0)/8 = 2.5\ ms^{-2}$ Recall: $v = u + at$

(b) Net Force $\Sigma F = F_D - F_F = ma$ or $F_D - 1000 = 800 \times 2.5 \Rightarrow F_D = 3000N$

The driving force of the car is 3000N

Exercise

1. What resultant force is needed to give a mass of 6.4 kg an acceleration of 2.4ms^{-2} West?
2. If a resultant force of 48N produces an acceleration of 1.2 ms^{-2} on an object, what is the mass of the object?
3. A resultant force of 5.0N acts on an object and causes it to reach a velocity of 4.0 ms^{-1} in 2.5s. What is the mass of the object?
4. An object of mass 6.0kg is at rest on a rough horizontal table. A horizontal force of 2.4N acts on the mass to the East. The mass reaches a speed of 1.2 ms^{-1} in a distance of 2.0m.
   (a) Calculate the acceleration of the mass.
   (b) What is the net horizontal force acting on the object?
   (c) What is the frictional force acting on the object?

Answers

1. 15N West 2. 40kg 3. 3.1kg 4 (a) 0.36ms^{-2} East (b) 2.2N East
(c) 0.24N West.