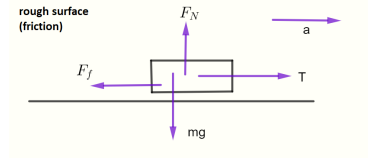


PF 1.1 Newtons Laws of Motion

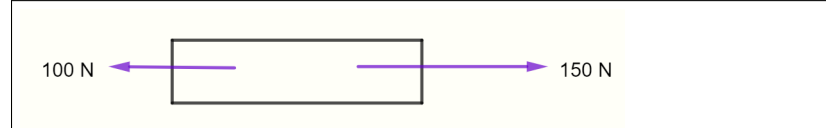


What are Newton's first 3 laws?

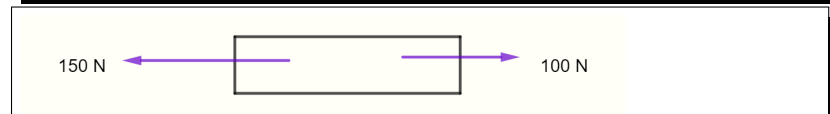
1. An object in motion tends to stay in motion and an object at rest tends to stay at rest unless acted upon by an unbalanced force.
2. Force (F) equals mass (m) times acceleration (a). That is $F = ma$.
3. For every action there is an equal and opposite reaction.

Net (sum of the forces or resultant) force is represented by ΣF

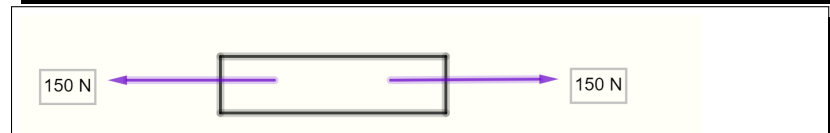
Examples



$\Sigma F = (\text{sum of the forces}) = 150 - 100 = 50 \text{ Newton to the Right} \therefore$ unbalanced force so accelerating to the right



$\Sigma F = (\text{sum of the forces}) = 150 - 100 = 50 \text{ Newton to the Left} \therefore$ unbalanced force so accelerating to the left



$\Sigma F = (\text{sum of the forces}) = 150 - 150 = 0 \text{ Newton} \therefore$ balanced force so is stationary or moving at a constant speed
No acceleration but could be at rest or moving at constant velocity (remember $F=ma$ so no acceleration but it could be moving)

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

Newton's Laws of Motion

Newton's 1st law of motion

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

Seat belts 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. The windscreen would then exert a force on you as you hit it. As it did to the author of this worksheet when he was 13 years old.

Newton's 2nd law of motion

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

$$\text{Sum of the Forces} = \Sigma F = ma$$

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 acceleration as force is also a vector.

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

Example 1

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



Solution:

The net force acting on the car is the driving force minus the fric-

tional force:

$$\begin{aligned}\Sigma F &= F_D - F_F \\ &= 20 - 10 \\ &= 10N.\end{aligned}$$

Using Newton's 2nd law¹ we get

¹ The second law is: $\Sigma F = ma$.

$$\begin{aligned}ma &= 10 \\ 2a &= 10 \\ a &= 5ms^{-2}.\end{aligned}$$

The magnitude of the car's acceleration is $5ms^{-2}$.

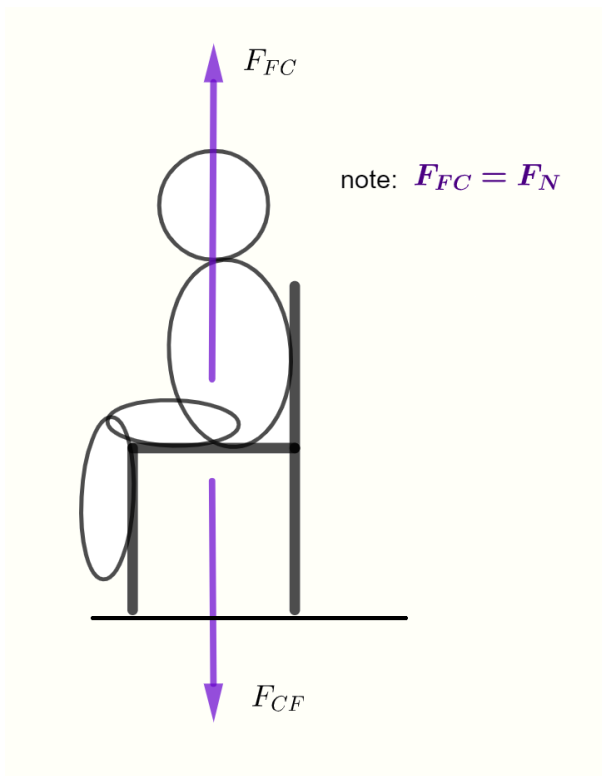
Newton's 3rd law of motion

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 analyze 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 . If this is not the case then you will either fall through the floor or fly up into the sky. See diagram below.

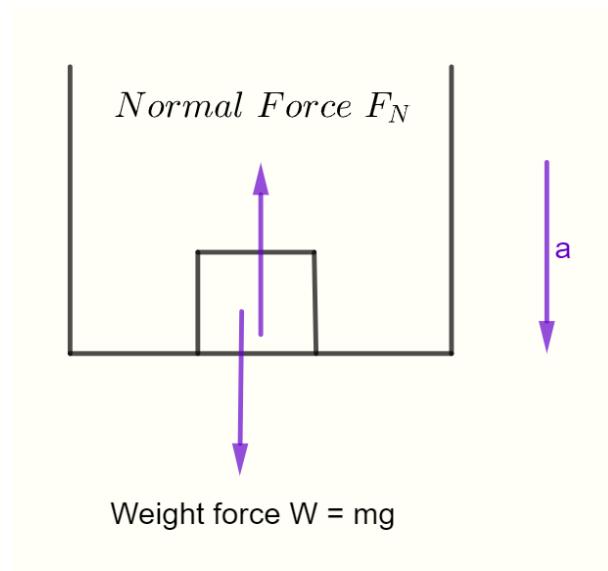


$F_{FC} = -F_{CF}$ where the negative sign indicates that these forces are acting in opposite directions. Recall your notes on vectors. The magnitude of the forces are equal but the direction is opposite.

Applications of Newton's laws.

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

Objects in Lifts



- If accelerating down (as shown):

$$\begin{aligned}\Sigma F &= ma \\ mg - F &= ma\end{aligned}$$

- If accelerating up:

$$\begin{aligned}\Sigma F &= ma \\ F_N - mg &= ma\end{aligned}$$

- If not accelerating at all:²

$$\begin{aligned}\Sigma F &= 0 \\ F_N - mg &= 0 \\ F_N &= mg\end{aligned}$$

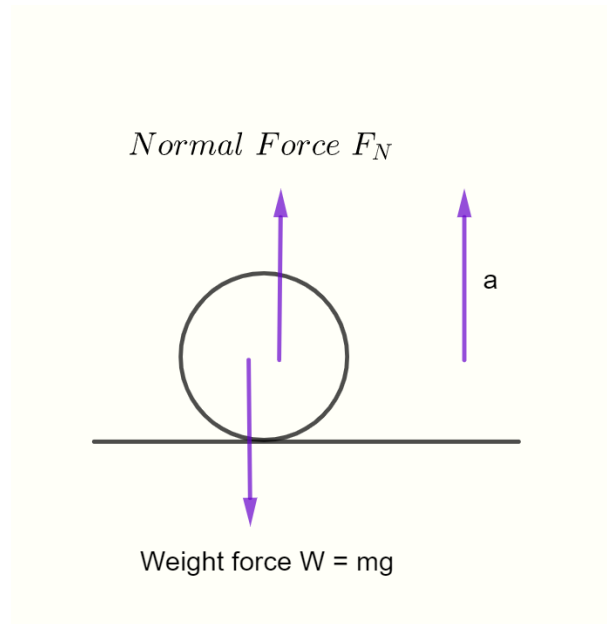
Accelerating down then gravity is winning or larger.

Accelerating up then Normal force is winning or larger.

Acceleration has magnitude and is directional, it is a vector. where g is the acceleration of gravity

(see diagram)

² It is stationary or moving at a constant velocity.

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 (as the ball will now head up).
- F_N can often be much larger than mg (for the ball to bounce).
- At the instant the object is stationary

(just before it changes direction and heads up)

$$\Sigma F = 0$$

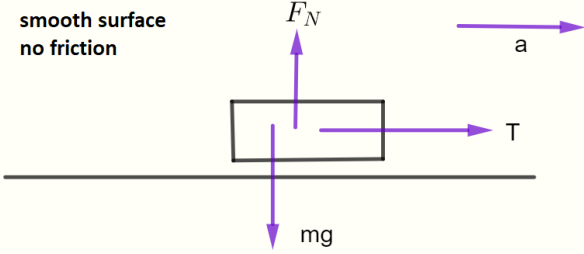
$$F_N - mg = 0$$

$$F_N = mg$$

Object being pulled along a surface

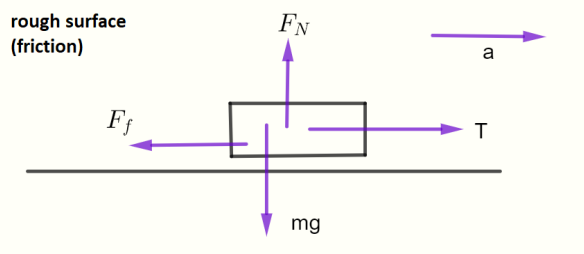
T = tension in rope , a = acceleration of object , m = mass of object, F_N is the normal force of the table pushing on the block, mg is the force of the block pushing on the table. Remember that g is acceleration of gravity, F_f is the force of friction the table exerts on the object

**smooth surface
no friction**



Horizontally: $\Sigma F = T = ma$
 Vertically: $\Sigma F = F_N - mg = 0$
 Therefore $F_N = mg$

**rough surface
(friction)**

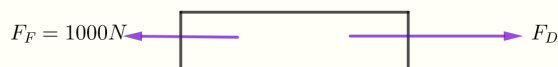


Horizontally: $\Sigma F = T - F_f = ma$
 Vertically: $\Sigma F = F_N - mg = 0$
 Therefore $F_N = mg$

Example:

A car of mass 800kg accelerates from rest to 20ms^{-1} in 8.0 sec. 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

$$\begin{aligned}
 a &= \frac{v - u}{t} \\
 &= \frac{20 - 0}{8} \\
 &= 2.5\text{ms}^{-2}
 \end{aligned}$$

(b) Net Force $\Sigma F = F_D - F_F = ma$

remember "from rest" means $u = 0$, final velocity is $v = 20$ and time $t = 8$

Therefore

$$F_D - F_F = m \times a$$

$$F_D - 1000 = 800 \times 2.5$$

$$F_D = 800 \times 2.5 + 1000$$

$$F_D = 2000 + 1000$$

$$F_D = 3000N$$

The driving force of the car is therefore 3000 Newton.

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 48 Newton produces an acceleration of $1.2ms^{-2}$ on an object, what is the mass of the object?
3. A resultant force of 5.0 Newton acts on an object and causes it to reach a velocity of $4.0ms^{-1}$ in 2.5 sec. What is the mass of the object?
4. An object of mass 6.0 kg is at rest on a rough horizontal table. A horizontal force of 2.4Newton acts on the mass to the East. The mass reaches a speed of $1.2ms^{-1}$ in a distance of 2.0 meters.
 - (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) 15 Newtons West 2) 40 kg 3) 3.1 kg 4a) $0.36ms^{-2}$ 4b) 2.2 Newtons East 4c) 0.24 Newtons East

All diagrams created by RMIT staff