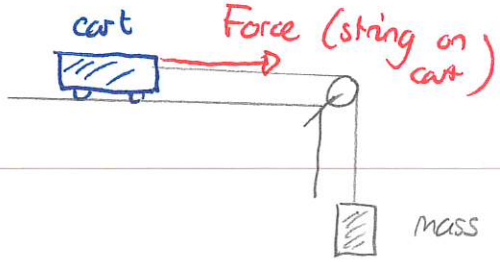
Mon: Read ~~4.4~~ 4.3 - 4.5

Group Ex

Forces and acceleration

Newton's mechanics considers interacting objects and asks what accelerations the interactions will produce. The scheme can be illustrated with a cart pull by a string.



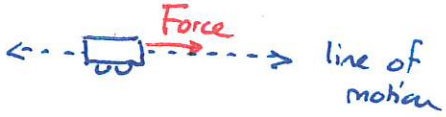
The string interacts with the cart → String exerts a force on the cart

Force has:
* magnitude (in Newtons)
* direction (along string)

Affects the state of the cart's motion → Force produces acceleration

Newton's laws describe how the force and acceleration are related. We consider a simple case where

* the object moves along one straight line
* the force points along that line



Then observations indicate

$$\text{acceleration (of object) in } m/s^2 = \frac{\text{Force on object} \rightarrow \text{in Newtons}}{\text{mass of object} \rightarrow \text{in kg}}$$

This is an example of Newton's Second Law.

Quiz 1

Direction of forces and acceleration

The forces on our cart could push or pull either right or left. In order to account for both possibilities we must broaden the idea of acceleration.

We consider an object moving right. Then we define

$$\text{acceleration} = \frac{\text{change in speed}}{\text{time elapsed}}$$

where

change in speed
= later speed − earlier speed

What if the object slows?

Quiz 2

We see that an object can have negative acceleration. The meanings of the signs are:

If object moves right then
- acceleration is positive ⇒ object speeds up
- acceleration is negative ⇒ object slows down

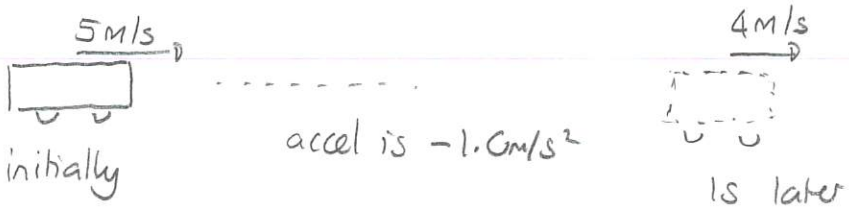
We can do a similar scheme for objects moving vertically.

If object moves up then
- acceleration is positive ⇒ object speeds up
- acceleration is negative ⇒ object slows down

These statements can be rephrased for objects that move left or down.

Note that, for an object moving right a negative acceleration reduces the speed.

For example, if initially



then 1s later

$$\text{speed later} = \text{speed earlier} + \text{acceleration} \times \text{time}$$

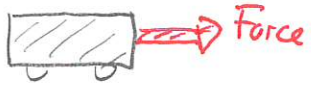
$$= 5 m/s + (-1.0 m/s^2) \times 1s$$

$$= 4 m/s$$

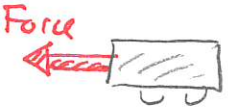
So in this case an acceleration of $-1.0 m/s^2$ means the speed is reduced by 1m/s in each second.

Newton's Second Law states that

> If there is only one force on the object then
> * if the force is right acceleration is positive
> * if the force is left acceleration is negative



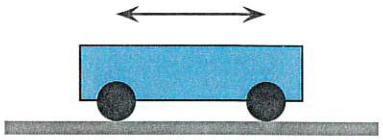
positive acceleration



negative acceleration

1 Force and direction of motion

The purpose of this exercise will be to investigate the idea that if a force pushes on an object then that object moves in the same direction as the force. We will do this by considering a single force acting on a cart that can move horizontally.



The mass of the cart is 2 kg and at an initial moment it moves right with speed 12 m/s.
Assume that after the initial moment, a person constantly pushes horizontally to the **right** on the cart with force 6 N.

a) Determine the acceleration of the cart.
b) Determine the speed of the cart 1 s after the initial moment.
c) Determine the speed of the cart 2 s after the initial moment.
d) Determine the speed of the cart 3 s after the initial moment.
e) When the person pushes right and the cart moves right does the cart speed up or slow down?

Now consider a situation where after the initial moment, a person constantly pushes horizontally to the **left** on the cart with force 6 N.

f) Determine the acceleration of the cart.
g) Determine the speed of the cart 1 s after the initial moment.
h) Determine the speed of the cart 2 s after the initial moment.
i) Determine the speed of the cart 3 s after the initial moment.
j) When the person pushes left and the cart moves right does the cart speed up or slow down?
k) Is it always true that the cart will move in the direction of the force that acts on it?

Answer: a) accel = force/mass = $6N/2kg = 3m/s^2$

b) speed later = speed earlier + accel × time = $12m/s + 3m/s^2 = 15m/s$

c) " " " " + " " = $12m/s + 3m/s^2 \times 2s = 18m/s$

d) " " = " " + " " = $12m/s + 3m/s^2 \times 3s = 21m/s$

e) speeds up

f) accel = − force/mass = $-6N/2kg = -3m/s^2$

g) speed reduced by $3m/s^2$ every second → $12m/s - 3m/s = 9m/s$

h) $9m/s - 3m/s = 6m/s$

i) $6m/s - 3m/s = 3m/s$

j) slows down

k) NO parts f-i have force ← motion →

We see that

It is possible that one force can act on an object and the object moves in a direction opposite to the force. In this case the object slows down.

Quiz 3