Connected Particles (horizontal)

Notes

Consider a car towing a trailer with a tow bar or coupling.

The mass of the car is M kg and the mass of the trailer is m kg.
The engine of the car provides a driving force of D newtons.
The acceleration of the car and trailer is $\boldsymbol{a}$ m/s^2. (same acceleration since they are connected)
The resistances to motion are R for the car and r for the trailer.
The magnitude of the tension, T, in the coupling is the same at both its ends.

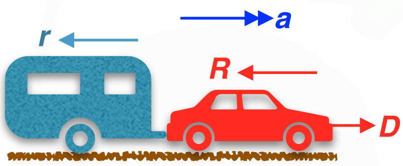
When solving problems we can use $F = ma$ in 3 situations:

- Whole system: the car and trailer taken as one object (ignore tension in the tow bar)
- Trailer's POV: considers only the forces and mass of the trailer
- Car's POV: considers only the forces and mass of the car

N.B. **POV** means "point of view".
There is no need to consider the normal reaction forces because they are perpendicular to the motion of the objects.

Whole system

Ignore the tension in the tow bar. We consider the car and trailer as one object.



Mass = $M + m$

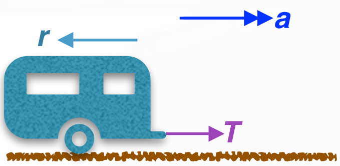
Using $F = ma(\rightarrow)$:

$D - R - r = (M + m)a$

Tensions in the coupling cancel each other out.

Trailer's POV

From the trailer's point of view, the tension in the tow bar is pulling the trailer forward.



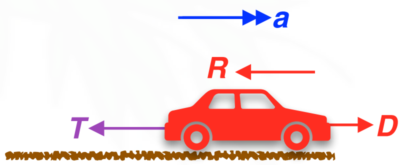
Mass = m

$T - r = ma$

Only forces connected to the trailer.

Car's POV

From the car's point of view, the tension in the tow bar is a resistance force.



Mass = M

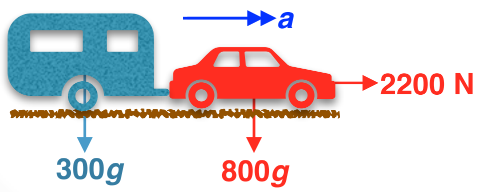
$D - T - R = Ma$

Only forces connected to the car.

N.B. Use the trailer's POV or the car's POV when you need to calculate the tension in the tow bar.

E.g. 1 A car of mass 800 kg exerting a driving force of 2200 N is pulling a trailer of mass 300 kg along a level road. If there is no resistance to the motion of either car or trailer, find
(a) the acceleration of the car and trailer and
(b) the tension in the tow bar.

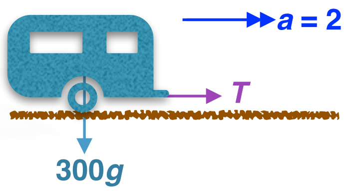
Working (a) Whole system:
$F = ma(\rightarrow)$:
$2200 = (800 + 300)a$
$a = 2$ m/s².



The acceleration of the car and trailer is 2 m/s².
N.B. The tension in the tow bar is not involved in calculations for the whole system.

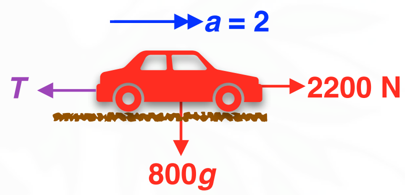
(b) *To find the tension in the tow bar we must consider either **just the trailer** or **just the car**.*
***Trailer's POV** — the trailer sees the tension as a **pulling** force*
$F = ma(\rightarrow)$:
$T = 300 \times 2 = 600$ N

The tension in the tow bar is 600 N.



OR
***Car's POV** — the trailer sees the tension as a **resisting** force*
$F = ma(\rightarrow)$:
$2200 - T = 800 \times 2$
$T = 600$ N

The tension in the tow bar is 600 N.



E.g. 2 A pick-up truck of mass 1200 kg tows a trailer of mass 400 kg. They accelerate at 0.5 m/s². There is air resistance of 140 N on the truck but negligible on the trailer. Find:
(a) the force, T, in the coupling (or tow bar) and
(b) the driving force, D, of the truck.

Video: Connected particles - horizontal

Solutions to Starter and E.g.s

Exercise
p522 22D Qu 1-7

Summary
When solving problems we can use $F = ma$ in 3 situations:
- Whole system: the car and trailer taken as one object (ignore tension in the tow bar)
- Trailer's POV: considers only the forces and mass of the trailer
- Car's POV: considers only the forces and mass of the car