

Force diagrams

When producing a model of a problem in mechanics one of the most important steps is to draw a diagram. The main point of this diagram is to make understanding the problem easier. We can draw many types of diagrams in mechanics. Two that will be explained here are:

System diagram This is a single diagram of the whole problem. It does not include internal forces, which cancel each other out. For example, the tension in the coupling of a car towing a caravan, will be cancelled out, with the equal and opposite tension from the caravan on the car (see leaflet 2.11, Newton's Third Law) when considering the system as a whole.

Separated-body force diagram (or free body diagram) A separated-body force diagram shows all the forces acting on each body in a system and makes it clear which force is acting on which body. It is important when drawing the separated-body diagram to show the magnitude (if known), direction and point of application of each force.

A key point to remember when drawing a diagram with forces on it is that every force in mechanics that we will meet is caused by one body acting on another. If there are any forces on your diagram that you cannot attribute to the action of another body then it is probably a mistake!

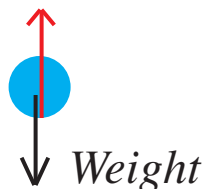
Worked Example 1.

A person is standing still on a horizontal surface. Draw the separated-body force diagram for this problem. (As there is only one body in this diagram there is no need for a system diagram.)

Solution

The only body (excluding the surface - we assume this is not of interest) in this example is the person. If we model the person as a particle, which is common practice, the only forces acting on the particle can be seen in the diagram below. It is safe to assume that the person has mass and is on Earth! This means that the diagram should show a gravitational force. As the person is standing on a surface, this will produce a normal reaction force. The diagram is therefore:

Normal reaction force



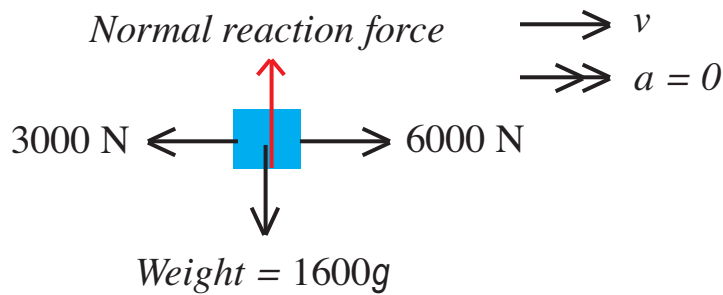
The force of gravity acts from the centre of mass of the person. The normal reaction force acts from the point of contact between the person and the surface. (The forces in the diagram have been off-set from each other to enable their starting points to be detected more easily. In reality they act in the same vertical line.)

Worked Example 2.

A train of mass 1000 kg is pulling two carriages, each of mass 300 kg, at a constant velocity, v . Given the engine produces a driving force of 6000 N and that there is a total resistive force of 3000 N draw the system diagram.

Solution

Modelling the train and two carriages as a particle, the system diagram is shown below. Thus, the weight is the total of both the train and its carriages and the normal reaction (for the system) can be calculated from this (see leaflet 2.3, Types of Forces). Both the driving force and resistive force are shown along with the velocity, v and the acceleration, a .



The diagram does not include the internal forces that would be included in a free body diagram, as they cancel each other out. For example the tension in the coupling between the train and its carriage cancels the tension between the same carriage and the train.

Exercises

1. A box, of mass 2 kg, is on a horizontal desk. Draw the separated-body force diagram for the box.
2. A tug boat of mass 15000 kg is pulling four boats, each of mass 1500 kg, at a constant velocity, v . Given the engine produces a driving force of x N and that there is a total resistive force of y N, draw the system diagram.
3. A tennis ball is thrown up in the air. Assume that the only force acting is gravity, so it acts only under the force of gravity. Draw the separated-body diagram for the ball.
4. A child of mass 40 kg and its parent, of mass 90 kg, are standing in a lift of mass 200 kg. Given the lift is stationary draw the system diagram.

Answers

- 1.
- 2.
- 3.
- 4.