M1 Chapter 10: Forces and Motion

Forces Causing Acceleration

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Newton's 2nd Law of Motion: $\sum F = ma$
(where acceleration a is in the same direction as the resultant force $\sum F$

If we doubled the force, we double its acceleration.
If we have twice the mass the same force causes half the acceleration.

A car of 2000kg has a driving force of 800N and forces of 200N resisting its motion. Determine its acceleration.

?

A child has a mass of 50kg. What is the gravitational force acting on the child? (i.e. its weight)

?

A falling sheep of mass 70kg experiences air resistance of 300 N. Determine the sheep's acceleration as it plummets towards the ground.

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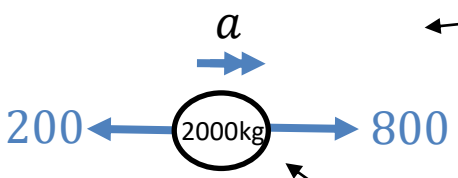


Tip: Use double arrow to indicate direction (and value if known) of acceleration.

Tip: Put mass of particle inside circle/square.

$$R(\rightarrow):\ 800 - 200 = 2000 \times a$$
$$a = \frac{600}{2000} = 0.3 \text{ ms}^{-2}$$

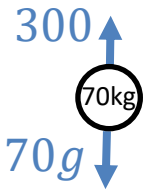
A child has a mass of 50kg. What is the gravitational force acting on the child? (i.e. its weight)

Acceleration under gravity is $g = 9.8$ ms^{-2}.

$$F = 50g = 490\ N$$

Weight $W = mg$

A falling sheep of mass 70kg experiences air resistance of 300 N. Determine the sheep's acceleration as it plummets towards the ground.



$$R(\downarrow):\ 70g - 300 = 386 \text{ N}$$
$$386 = 70a$$
$$a = \frac{386}{70} = 5.51 \text{ (3sf)}$$

Using $\sum F = ma$ to find speed changes

Since $\sum F = ma$ relates acceleration to resultant force, this allows us to connect calculations involving forces to calculating increases of speed Δv using $a = \frac{\Delta v}{\Delta t}$.

[Textbook] A body of mass 5kg is pulled along a rough horizontal table by a horizontal force of magnitude 20N against a constant friction force of magnitude 4N.

(a) the acceleration of the body
(b) the increase in speed of the body after 4 seconds
(c) does starting speed affect the calculation in part (b) ?

? Diagram

a ?

b ?

c ?

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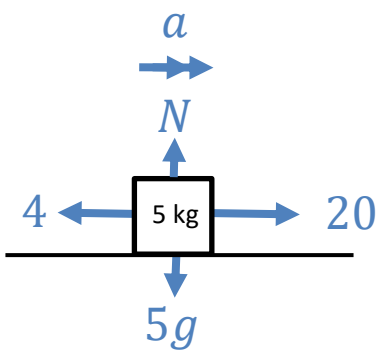


a $R(\rightarrow)$: $20 - 4 = 5a$

$a = \frac{16}{5} = 3.2$ ms^{-2}

b $\Delta v = a \times \Delta t$

$= 3.2 \times 4$

$= 12.8$ m/s

c No! The change in velocity just adds on to whatever the starting velocity was.

Classwork Exercise 10.3

Pearson Stats/Mechanics Year 1 Exercise Book
Pages 69-70
Questions 1 to 10.

(question 4: part a only.)

Homework Exercise

1 Find the acceleration when a particle of mass 400 kg is acted on by a resultant force of 120 N.

2 Find the weight in newtons of a particle of mass 4 kg.

3 An object moving on a rough surface experiences a constant frictional force of 30 N which decelerates it at a rate of $1.2\,\text{m s}^{-2}$. Find the mass of the object.

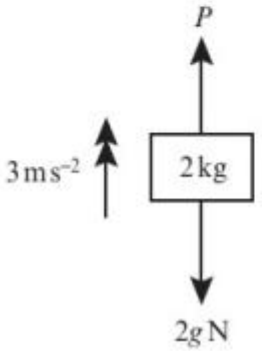
4 An astronaut weighs 735 N on the earth and 120 N on the moon. Work out the value of acceleration due to gravity on the moon.

Problem-solving

Start by finding the mass of the astronaut.

5 In each scenario, the forces acting on the body cause it to accelerate as shown. Find the magnitude of the unknown force.

a



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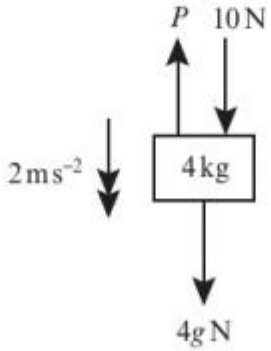
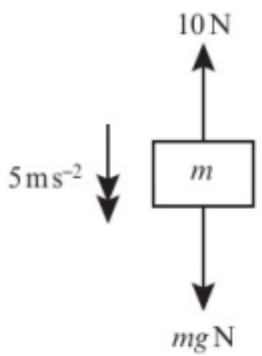


Homework Exercise

6 In each situation, the forces acting on the body cause it to accelerate as shown. In each case find the mass of the body, m.

a



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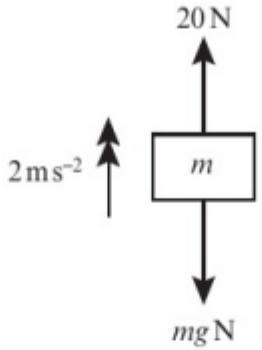
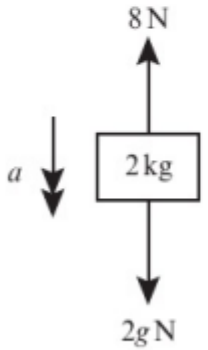


7 In each situation, the forces acting on the body cause it to accelerate as shown with magnitude $a\,\text{m s}^{-2}$. In each case find the value of a.

a



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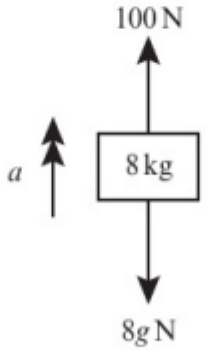

8 A force of 10 N acts upon a particle of mass 3 kg causing it to accelerate at $2\,\text{m s}^{-2}$ along a rough horizontal plane. Calculate the value of the force due to friction.

Problem-solving

Draw a force diagram showing all the forces acting on the particle.

Homework Exercise

9 A lift of mass 500 kg is lowered or raised by means of a metal cable attached to its top. The lift contains passengers whose total mass is 300 kg. The lift starts from rest and accelerates at a constant rate, reaching a speed of $3\,\text{m s}^{-1}$ after moving a distance of 5 m. Find:

a the acceleration of the lift **(3 marks)**

b the tension in the cable if the lift is moving vertically downwards **(2 marks)**

c the tension in the cable if the lift is moving vertically upwards. **(2 marks)**

Hint Use $v^2 = u^2 + 2as$.

10 A trolley of mass 50 kg is pulled from rest in a straight line along a horizontal path by means of a horizontal rope attached to its front end. The trolley accelerates at a constant rate and after 2 s its speed is $1\,\text{m s}^{-1}$. As it moves, the trolley experiences a resistance to motion of magnitude 20 N. Find:

a the acceleration of the trolley **(3 marks)**

b the tension in the rope. **(2 marks)**

11 The engine of a van of mass 400 kg cuts out when it is moving along a straight horizontal road with speed $16\,\text{m s}^{-1}$. The van comes to rest without the brakes being applied.

In a model of the situation it is assumed that the van is subject to a resistive force which has constant magnitude of 200 N.

a Find how long it takes the van to stop. **(3 marks)**

b Find how far the van travels before it stops. **(2 marks)**

c Comment on the suitability of the modelling assumption. **(1 mark)**

Homework Exercise

Challenge

A small stone of mass 400 g is projected vertically upwards from the bottom of a pond full of water with speed 10 m s^{-1}. As the stone moves through the water it experiences a constant resistance of magnitude 3 N. Assuming that the stone does not reach the surface of the pond, find:

a the greatest height above the bottom of the pond that the stone reaches

b the speed of the stone as it hits the bottom of the pond on its return

c the total time taken for the stone to return to its initial position on the bottom of the pond.

Homework Answers

1 $0.3\,ms^{-2}$

2 $39.2\,N$

3 $25\,kg$

4 $1.6\,ms^{-2}$

5 **a** $25.6\,N$ **b** $41.2\,N$

6 **a** $2.1\,kg$ (2 s.f.) **b** $1.7\,kg$ (2 s.f.)

7 **a** $5.8\,ms^{-2}$ **b** $2.7\,ms^{-2}$

8 $4\,N$

9 **a** $0.9\,ms^{-2}$ **b** $7120\,N$ **c** $8560\,N$

10 **a** $0.5\,ms^{-2}$ **b** $45\,N$

11 **a** $32\,s$ **b** $256\,m$

c The resistive force is unlikely to be constant.