Chapter 3. Forces and motion

Contents:

3.1 Force
3.2 Newton's second law
3.3 Momentum

New word list:

1.3 Mass and weight

Core

1 State that mass is a measure of the quantity of matter in an object at rest relative to the observer

2 State that weight is a gravitational force on an object that has mass

3 Define gravitational field strength as force per unit mass; recall and use the equation

$g = \frac{W}{m}$

and know that this is equivalent to the

Supplement

5 Describe, and use the concept of, weight as the effect of a gravitational field on a mass

1.5 Forces

1.5.1 Effects of forces

Core

1 Know that forces may produce changes in the size and shape of an object

2 Sketch, plot and interpret load–extension graphs for an elastic solid and describe the associated experimental procedures

3 Determine the resultant of two or more forces acting along the same straight line

4 Know that an object either remains at rest or continues in a straight line at constant speed unless acted on by a resultant force

5 State that a resultant force may change the velocity of an object by changing its direction of motion or its speed

Supplement

9 Define the spring constant as force per unit extension; recall and use the equation

$k = \frac{F}{x}$

10 Define and use the term 'limit of proportionality' for a load–extension graph and identify this point on the graph (an understanding of the elastic limit is **not** required)

11 Recall and use the equation $F = ma$ and know that the force and the acceleration are in the same direction

12 Describe, qualitatively, motion in a circular path due to a force perpendicular to the motion as:

(a) speed increases if force increases, with mass and radius constant

(b) radius decreases if force increases, with mass and speed constant

(c) an increased mass requires an increased force to keep speed and radius constant

($F = \frac{mv^2}{r}$ is **not** required)

1.5 Forces continued

1.5.1 Effects of forces continued

Core

6 Describe solid friction as the force between two surfaces that may impede motion and produce heating

7 Know that friction (drag) acts on an object moving through a liquid

8 Know that friction (drag) acts on an object moving through a gas (e.g. air resistance)

Supplement

1.5.2 Turning effect of forces

Core

1 Describe the moment of a force as a measure of its turning effect and give everyday examples

2 Define the moment of a force as moment = force × perpendicular distance from the pivot; recall and use this equation

3 Apply the principle of moments to situations with one force each side of the pivot, including balancing of a beam

4 State that, when there is no resultant force and no resultant moment, an object is in equilibrium

Supplement

5 Apply the principle of moments to other situations, including those with more than one force each side of the pivot

6 Describe an experiment to demonstrate that there is no resultant moment on an object in equilibrium

1.5.3 Centre of gravity

Core

1 State what is meant by centre of gravity

2 Describe an experiment to determine the position of the centre of gravity of an irregularly shaped plane lamina

3 Describe, qualitatively, the effect of the position of the centre of gravity on the stability of simple objects

Supplement

1.6 Momentum

Core

Supplement

1 Define momentum as mass × velocity; recall and use the equation

$p = mv$

2 Define impulse as force × time for which force acts; recall and use the equation

impulse $= F\Delta t = \Delta(mv)$

3 Apply the principle of the conservation of momentum to solve simple problems in one dimension

4 Define resultant force as the change in momentum per unit time; recall and use the equation

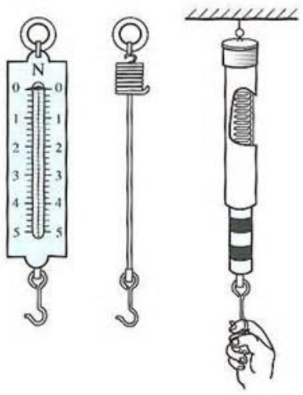
$$F = \frac{\Delta p}{\Delta t}$$

3. 1. Force

3.1.1 Force in general

Why do we have acceleration? Think about free fall & rocket

Force:



Force is a vector:

Representation:

Unit:

Measuring tool:

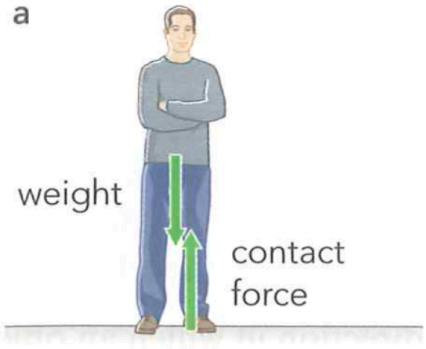
3.1.2 Force examples

Some important forces:

a. Weight ( )

Mass vs weight vs gravity
Mass:
weight:
gravity:

The force that causes free fall is:



gravitational field strength = acceleration of free fall/ acceleration due to gravity **g**

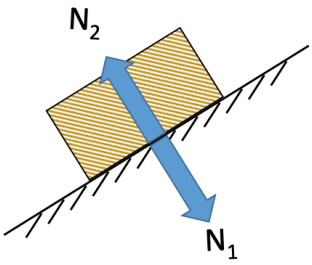
g on Earth surface =

Exercise 3.a

i. A 5kg ball and a 1kg ball, what are their weights respectively?

ii. Will your weight change when you are in the moon? In the deep space?

b. Normal force ( )

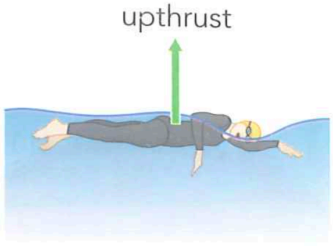


c. Friction ( )

Transfer kinetic energy to thermal energy: meteors

d. Air resistance/drag ( )
Direction:
Depends on:

e. Buoyancy/upthrust ( )



f. Elasticity ( )

g. Tension ( )

Exercise 3.b

Guess the magnitude of following forces:

lift an apple

Jump up in the air

Start a car

Crossing the Atlantic with a Boeing 747 jumbo jet

3.1.3 Force classification

3.1.4 Free body diagram

Step 1:

Step 2:

Exercise 3.c

Draw the free body diagram of following objects:

A ball falling in vacuum

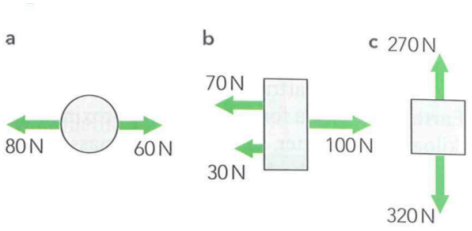
A ball falling in air

An object at rest on a flat surface

An object on a ramp with friction

3.1.5 Resultant force

vector addition (paralleled):

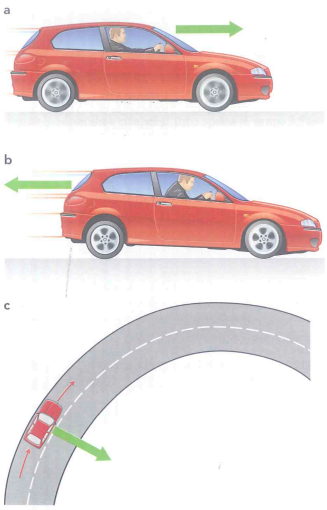


Vector addition (unparalleled): **scale diagram**

balanced force vs unbalanced force

3. 2. Newton's Law

Unbalanced force produces acceleration



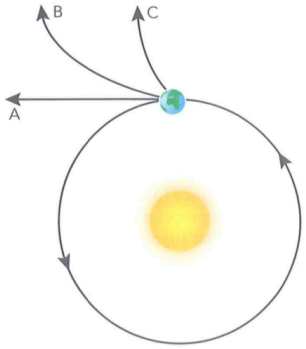
<u>Newton's second law:</u> F = ma

- **A resultant force(means an acceleration) will change the velocity of a body. Velocity includes the magnitude/speed and direction. Unbalanced force => accelerates in straight line/ turning**
- **No resultant force/balanced force=> remain at rest/move with constant speed.**

Mass:

<u>Exercise 3.d</u>

The earth orbiting the sun. Which of the paths would earth follow if the sun suddenly stopped existing?



<u>Exercise 3.e</u>

Throw a 5kg ball and a 1kg ball, when ignoring air resistance, when will first fall to the ground?

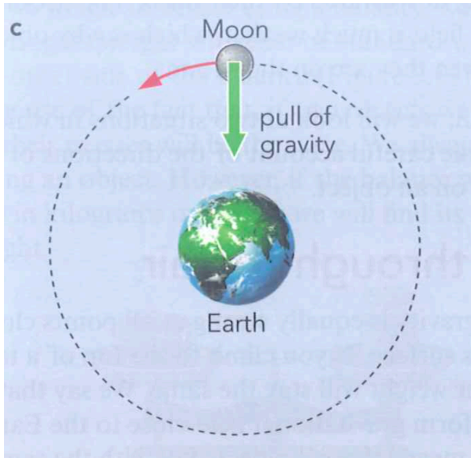
3.2.1 Falling with air resistance (e.g. Free-fall parachutists)

Free body diagram

Speed-time graph

3.2.2 Going round in circles

How to change directions during the movement?



Force F =

Exercise 3.d

When you strike a tennis ball that another player has hit towards you, you provide a large force to reverse its direction of travel and send it back towards your opponent. You give the ball a large acceleration. What force is needed to give a ball of mass 0.10kg an acceleration of 500m/s/s?

Exercise 3.e

An Airbus A380 aircraft has four jet engines. Each capable of providing 320000N of thrust. The mass of the aircraft is 560000kg when loaded. What is the greatest acceleration that the aircraft can achieve?

3. 3. Momentum

3. 3. 1 Impulse and momentum

Momentum:
Unit :

Change of momentum:
No change in direction (Initial and final velocity in the same direction):
Change to the opposite direction:

The effect of a force depends on?

Impulse:
Unit:

Exercise 3. f

A car of 600kg is moving at 15m/s. The driver accelerates gently so that a force of 30N acts on the car for 10 seconds.

a. Calculate its momentum.
b. Calculate the impulse of the force.
c. Calculate the momentum of the car after accelerating force has acted on it.

Resultant force:

Definition of force:

Why we need air bags to increase safety of cars?

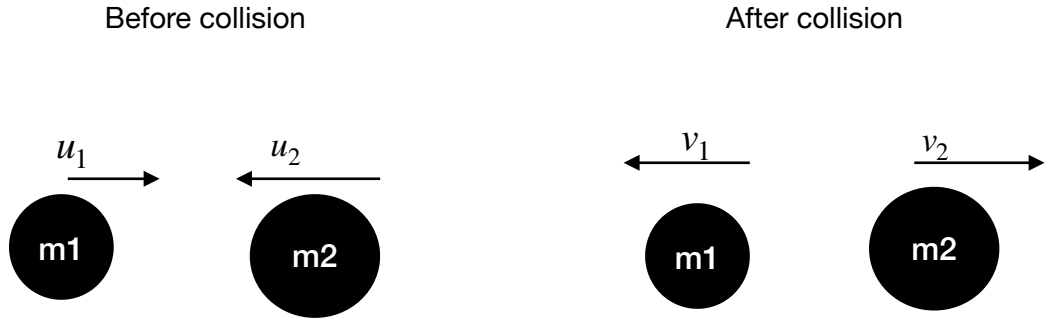
3. 3. 2 Momentum in collision

Collision:

Principle of the conservation of momentum:

Application of momentum conservation:

Example:



运用动量守恒解题步骤:

1. 选取正方向（一般选+x方向）；

2. 与正方向相同的速度为正， 相反为负；如上例中 u_2 v_1均为负。

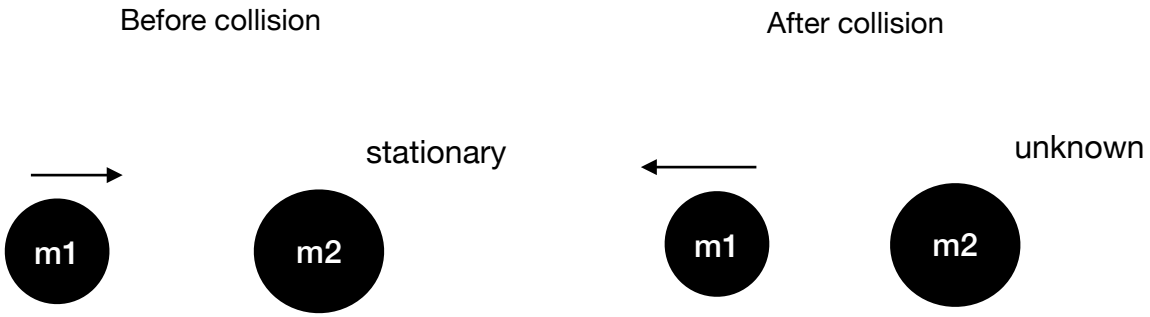
3. 把矢量形式的动量守恒方程写成标量形式，即与正方向相同的，前面符号不变；与正方向相反的前面符号正的变负的。如：

$m_1u_1 - m_2u_2 = -m_1v_1 + m_2v_2$

4. 如果有速度方向不确定的，先令其为正，如果最后算到正的就说明它是正方向的，否则是反方向的

Exercise 3.g

write down the momentum conservation equation for the following situation:



Exercise 3. H

During a game of swing ball, a player hits the ball horizontally with a racket.
Mass of tennis racket = 3.0kg.
Velocity of tennis racket before it strikes the ball = 20m/s.
Velocity of tennis racket after it strikes the ball = 18m/s.
Mass of tennis ball = 0.25kg
Velocity of tennis ball before the racket strikes it = 0m/s.
Find:

a. The momentum of the racket before the collision and after the collision.
b. The momentum of the ball after the collision
c. The velocity of the ball