SCIENCE for TECHNOLOGY

Syllabus – Grade 12

- Mathematics : Area & Volume
- Measurements : Measuring equipment (Micrometer ,Vernier Caliper)
- Mathematics : Pythagoras Theorem and its applications
- Bio Technology
- Physics : Force and its applications to real world
- Physics : Work done , Power & its applications
- Mathematics : Trigonometry
- Physics : Angular velocity and its applications

- Physics : Electricity
- Physics : Heat Energy
- Chemistry : Physical chemistry -1
- Chemistry : Physical chemistry -2
- Chemistry : Organic chemistry

Physics : Scalars & Vectors

A **scalar quantity** has magnitude only. Examples are mass, volume and energy.

A **vector quantity** has magnitude and direction. Examples are force, velocity and acceleration.

When scalars are added, the total is simply the arithmetic total. For example, if there are two masses of 2.4 kg and 5.2 kg, the total mass is 7.6 kg.

When vectors are added, their directions must be taken into account. Two forces of 3 N and 5 N acting in the same direction would give a total force of 8 N. However, if they act in opposite directions the total force is (5 – 3) N = 2 N, in the direction of the 5 N force. If they act at any other angle to each other the **triangle of vectors** is used.

Constructing a vector diagram

In a vector diagram, each vector is represented by a line. The magnitude of the vector is represented by the length of the line and its direction by the direction of the line. If two vectors act at a point, their resultant can be found by drawing a vector triangle.

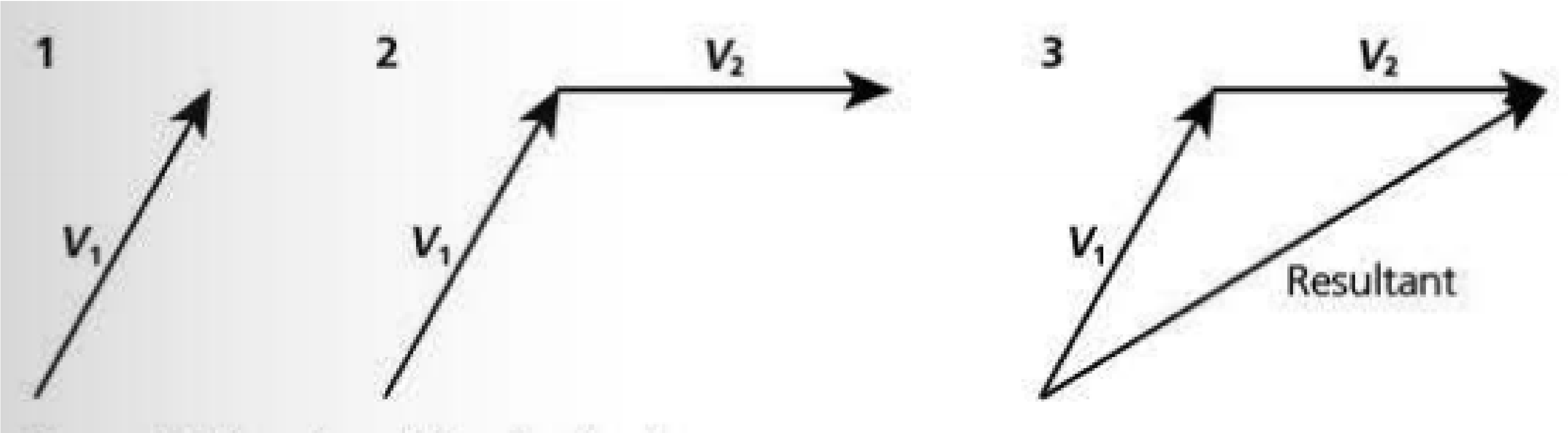


Figure 1.4 shows a vector, $\boldsymbol{V}$, acting at an angle θ to the horizontal.

By inspection you can see that $\cos\theta = \boldsymbol{V}_h/\boldsymbol{V}$. Therefore:

$$\boldsymbol{V}_h = \boldsymbol{V}\cos\theta \text{ and } \boldsymbol{V}_v = \boldsymbol{V}\sin\theta$$

Worked example

A box of weight 20 N lies at rest on a slope, which is at 30° to the horizontal. Calculate the frictional force on the box up the slope.

Answer

Resolve the weight (20 N) into components parallel to and perpendicular to the slope (Figure 1.5).

The frictional force, $\boldsymbol{F}$, is equal to the component of the weight down the slope:

$$\boldsymbol{F} = 20 \sin 30 = 10\,\text{N}$$

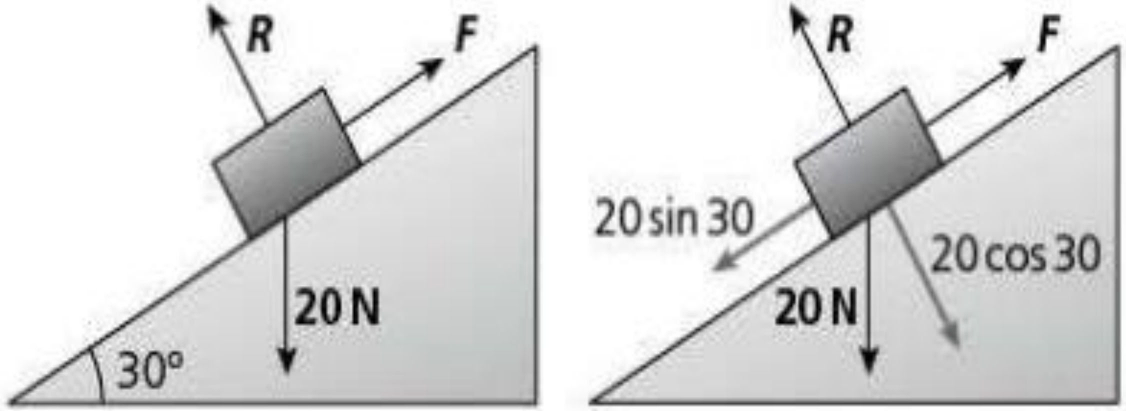


Figure 1.5

Physics : Force

- Kinematics

You should know the definitions of the terms **distance**, **displacement**, **speed**, **velocity** and **acceleration**.

Distance is the length between two points measured along the straight line joining the two points.

Displacement is the distance of an object from a fixed reference point in a specified direction.

Speed is the distance travelled per unit time.

Velocity is the change in displacement per unit time.

Acceleration is the rate of change of velocity.

- Distance is a scalar quantity. It has magnitude only.
- Displacement is a vector quantity. It has both magnitude and direction.
- Speed is a scalar quantity. It refers to the total distance travelled.
- Velocity is a vector quantity, being derived from displacement — not the total distance travelled.
- Acceleration is a vector quantity. Acceleration in the direction in which a body is travelling will increase its velocity. Acceleration in the opposite direction from which a body is travelling will decrease its velocity. Acceleration at an angle of 90° to the direction a body is travelling in will change the direction of the velocity but will not change the magnitude of the velocity.

$$v = \frac{\Delta s}{\Delta t}$$

where v is the velocity and Δs is the change of displacement in time Δt.

$$a = \frac{\Delta v}{\Delta t}$$

where a is the acceleration and Δv is the change in velocity in time Δt.

Expert tip

In general, the symbol Δ means 'change', so Δs is the change in displacement and Δt is the change in time.

Worked example

A toy train travels round one circuit of a circular track of circumference 2.4 m in 4.8 s. Calculate:

(a) the average speed

(b) the average velocity

Answer

(a) x is the distance travelled, so average speed $= \frac{\Delta x}{\Delta t} = \frac{2.4\ (\text{m})}{4.8\ (\text{s})} = 0.50\ \text{m s}^{-1}$

(b) s is the displacement, which after one lap is zero. The train finishes at the same point at which it started. Hence:

average velocity $= \frac{\Delta s}{\Delta t} = \frac{0\ (\text{m})}{4.8\ (\text{s})}$ and $v = 0\ \text{m s}^{-1}$

Worked example

A car travels 840 m along a straight level track at constant speed of 35 m s^{-1}. The driver then applies the brakes and the car decelerates to rest at a constant rate in a further 7.0 s. Calculate:

(a) the time for which the car is travelling at constant speed

(b) the acceleration of the car when the brakes are applied

Answer

(a) $v = \dfrac{\Delta s}{\Delta t} \qquad 35 = \dfrac{840}{\Delta t} \qquad \Delta t = \dfrac{840}{35}$

$\Delta t = 24\,\text{s}$

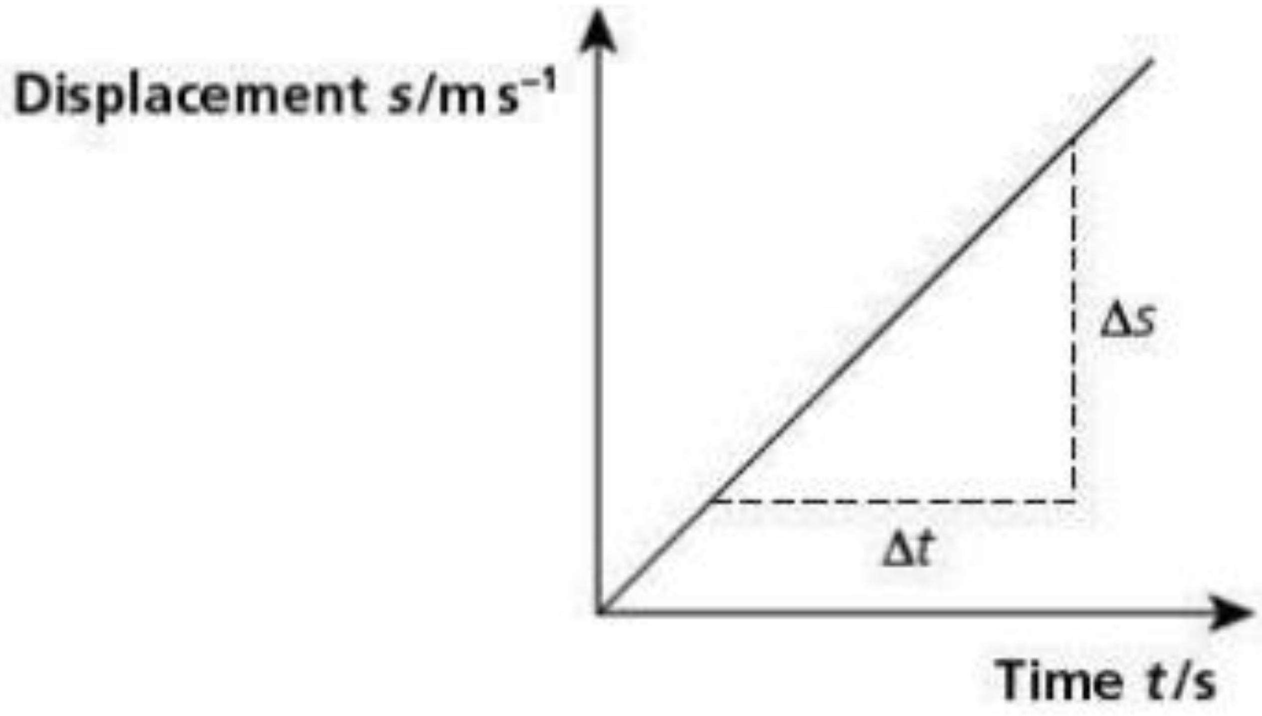
(b) $a = \dfrac{\Delta v}{\Delta t} = \dfrac{0 - 35}{7.0}$

$\Delta v = -5.0\,\text{m s}^{-2}$

Displacement–time graphs

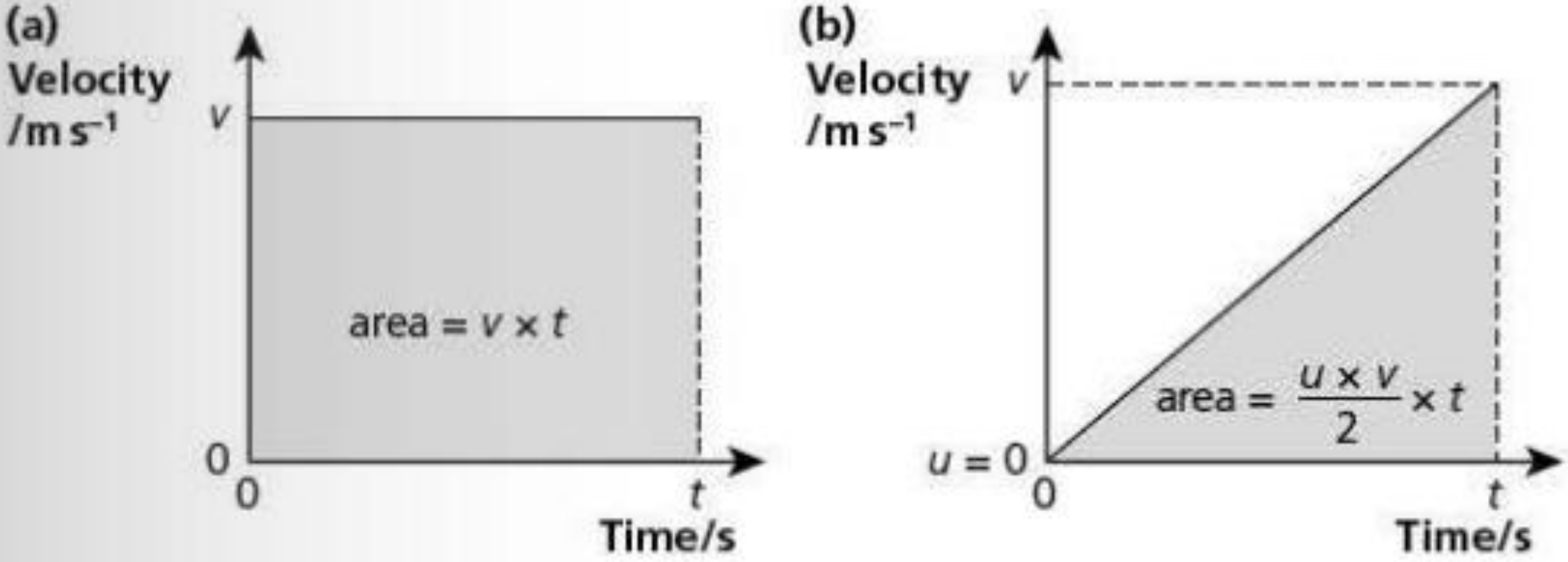
Figure 3.1 shows the displacement of a body that increases uniformly with time. This shows constant velocity. The magnitude of the velocity is equal to the gradient of the graph.

$$v = \text{gradient} = \frac{\Delta s}{\Delta t}$$



Velocity–time graphs

Figure 3.3(a) shows a body moving with a constant velocity; Figure 3.3(b) shows that the velocity of the body is increasing at a constant rate — it has constant **acceleration**.



Deriving equations of uniformly accelerated motion

Figure 3.5 shows the motion of a body that has accelerated at a uniform rate, from an initial velocity u to a final velocity v in time t.

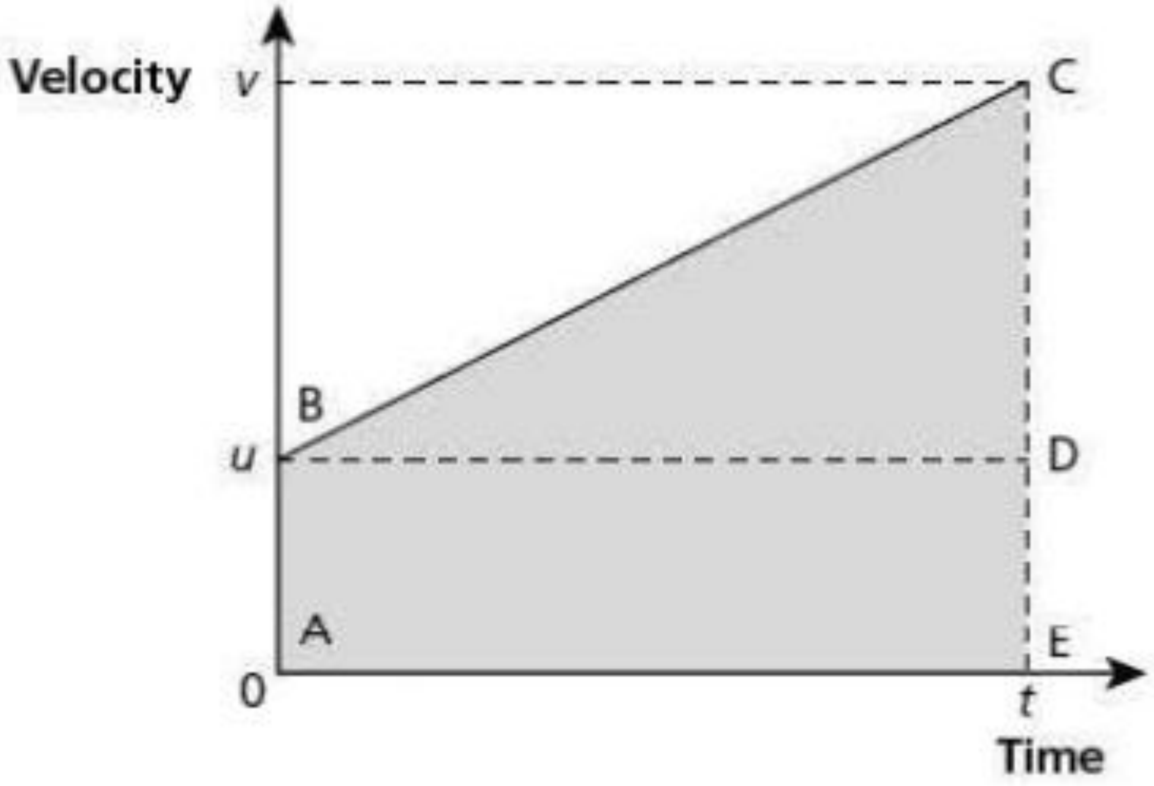


Figure 3.5

Equation 1

The acceleration of the body:

$$a = \frac{v - u}{t}$$

Rearranging this equation gives:

$$v = u + at$$

Equation 2

The distance s travelled by the body can be calculated in two ways. First:

$$s = \text{average velocity} \times \text{time}$$

$$s = \frac{v + u}{2}t$$

Equation 3

Second, the distance travelled is equivalent to the area under the graph:

$$s = \text{area of rectangle ABDE} + \text{area of triangle BCD}$$

$$s = ut + \tfrac{1}{2}(v - u)t$$

$$\frac{v - u}{t} = a$$

Therefore,

$$s = ut + \tfrac{1}{2}at^2$$

Equation 4

A fourth equation is needed to solve problems in which the time and one other variable are not known.

Equation 1 rearranges to:

$$t = \frac{v - u}{a}$$

Substitute this in Equation 2:

$$s = \frac{v + u}{2} \times \frac{v - u}{a}$$

$$s = \frac{v^2 - u^2}{2a}$$

Rearranging gives:

$$v^2 = u^2 + 2as$$

Mass and weight

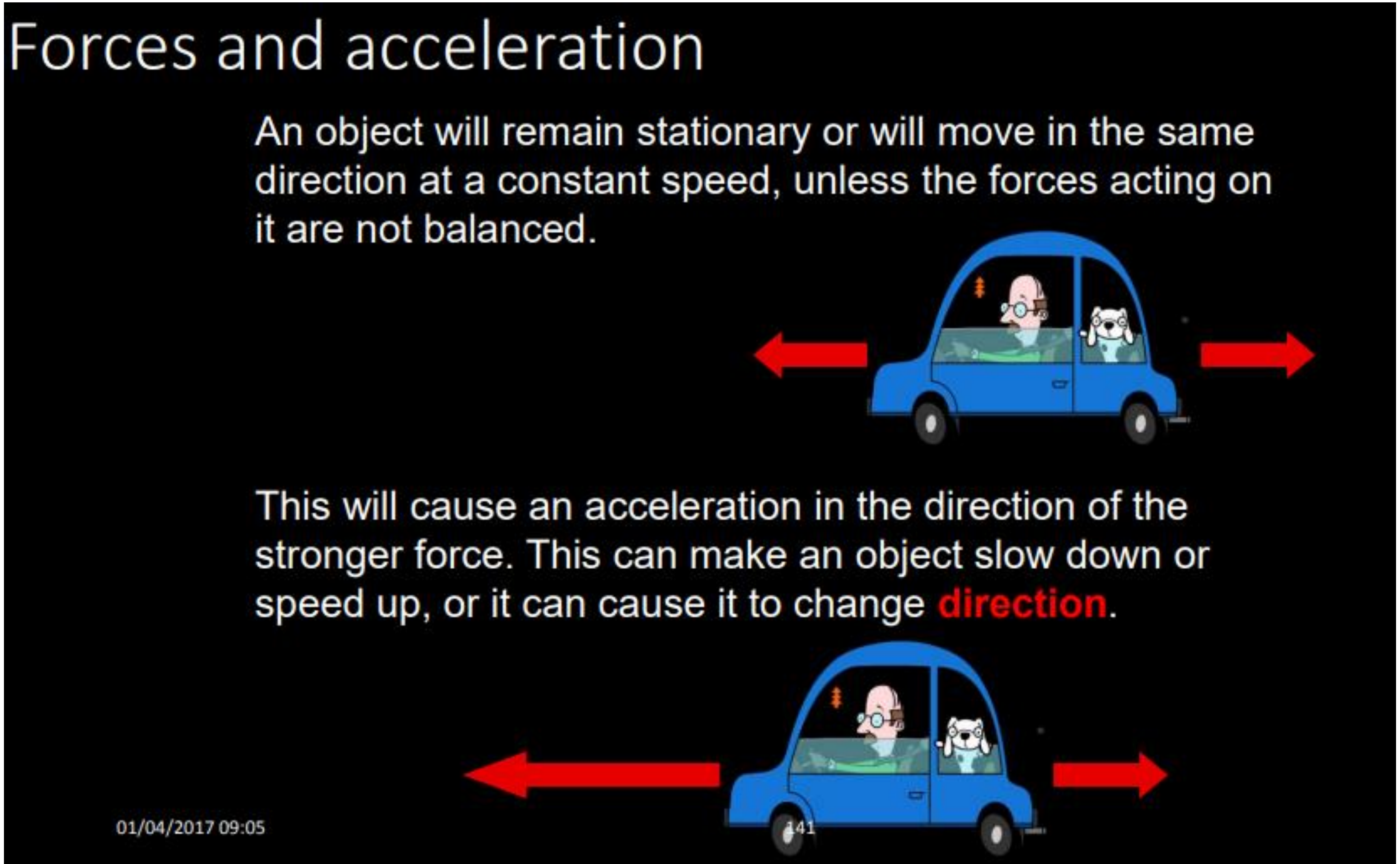
Mass and **weight** are often confused. Weight is the gravitational pull on a body and depends on the strength of the gravitational field at the position of the body. Mass is a property of a body itself, and does not vary with the position of the body.

In general, the two are connected by the equation:

$$W = mg$$

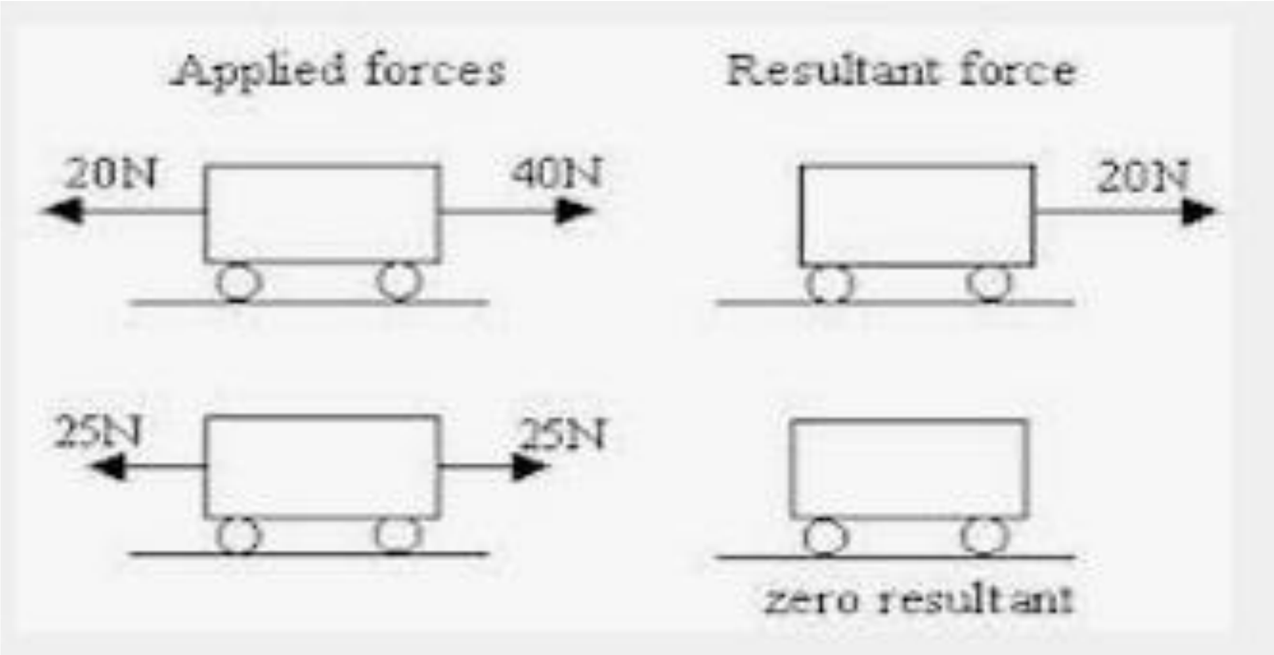
where W is weight, m is mass and g is the gravitational field strength (or acceleration of free fall).

Concept of Momentum & Newton's laws of Motion



Newton’s first law

A body will remain at rest or move with constant velocity unless acted on by a resultant force.



Momentum

It is harder to stop a large truck than a small car when both are moving at the same speed.

The truck has more momentum than the car.

By momentum, we mean *inertia in motion*.

- A moving truck has more momentum than a car moving at the same speed because the truck has more mass.
- A fast car can have more momentum than a slow truck.
- A truck at rest has no momentum at all.

Momentum

Symbol for momentum is p

Unit: kg m s^{-1}

Vector

Momentum (p) is what ?

Momentum (p) is the mass of an object multiplied by its velocity.

momentum (p) = mass × velocity

momentum (p) = *mv*

When direction is not an important factor, how can we represent momentum?

momentum = mass × speed

Conservation of Momentum 1

When objects collide, assuming that there are no external forces, then momentum is always conserved…. Definition :

When two or more objects interact, the total momentum remains constant provided that there is no external resultant force

Newton’s second law

A resultant force acting on a body will cause a change in momentum in the direction of the force. The rate of change of momentum is proportional to the magnitude of the force.

How do we end up with F = ma ?

N2 says that the rate of change of momentum is proportional to the force
OR force is proportional to the change of momentum per second.

So, consider an object of mass, m, with a force, F, on it.
It will accelerate from velocity u to velocity v.
Initial momentum = mu. Final momentum = mv.
$\therefore \Delta p = mv - mu$

According to N2, F is proportional to Δp per second.

$$\therefore F \propto \frac{\Delta p}{\text{time taken}}$$

$$\propto \frac{mv - mu}{t}$$

$$\propto \frac{m(v-u)}{t}$$

BUT $a = (v-u) / t$

$\therefore F \propto ma$ **OR** $F = kma$

If we define the newton as the force required to accelerate 1 kg by 1 m s^{-2}, we get:

$F = ma$

Worked example

A car of mass 1.2 tonnes accelerates from $5\,\mathrm{m\,s^{-1}}$ to $30\,\mathrm{m\,s^{-1}}$ in 7.5 s. Calculate the average accelerating force on the car.

Answer

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}} = \frac{30 - 5}{7.5} = 3.3\,\mathrm{m\,s^{-2}}$$

Convert the mass to kilograms:

$$1.2\,\mathrm{t} = 1200\,\mathrm{kg}$$

$$\text{force} = \text{mass} \times \text{acceleration} = 1200 \times 3.3 = 4000\,\mathrm{N}$$

Newton's third law

The third law looks at the interaction between two bodies.

> If body A exerts a force on body B then body B will exert a force on body A of equal magnitude but in the opposite direction.

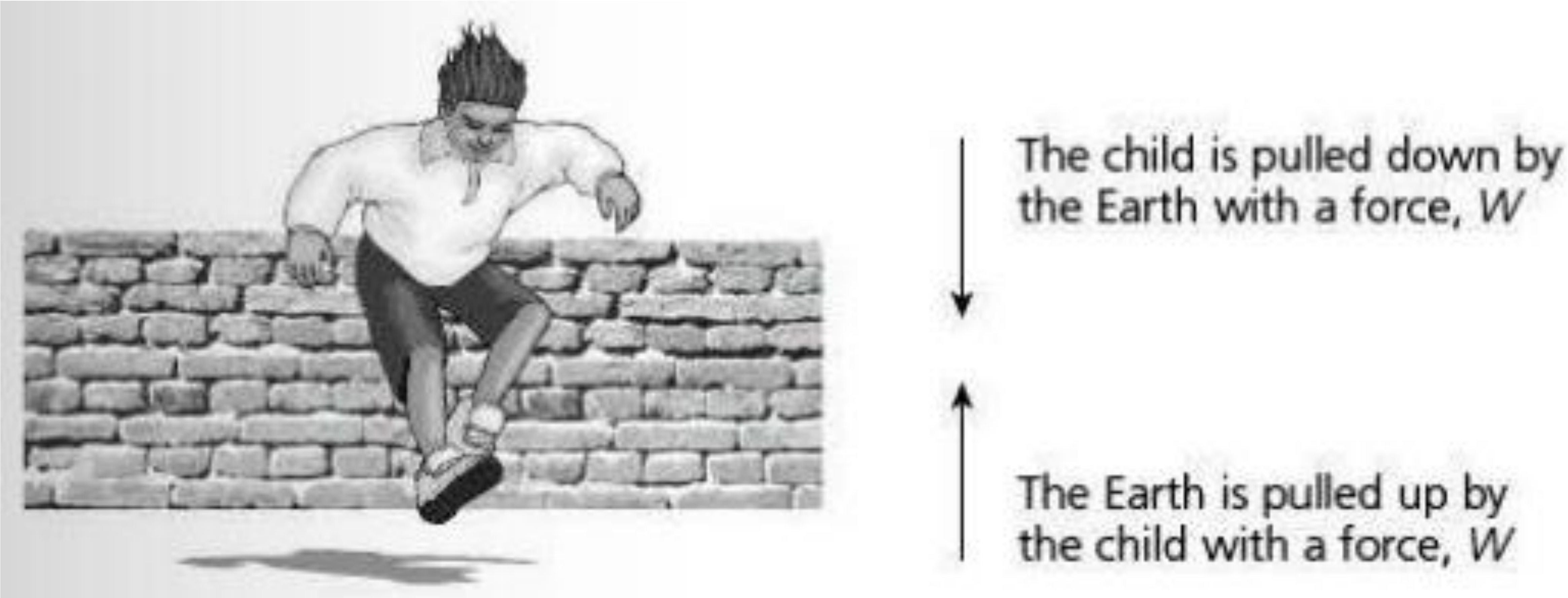


Figure 4.2 Interaction between two bodies

Principle of conservation of momentum

One of the useful results that can be developed from Newton's third law is that momentum is conserved in any interaction. This means that the total momentum of a closed system (that is, a system on which no external forces act) is the same after an interaction as before.

Consider two bodies that move towards each other, as in Figure 4.3, and then stick to each other after the collision.

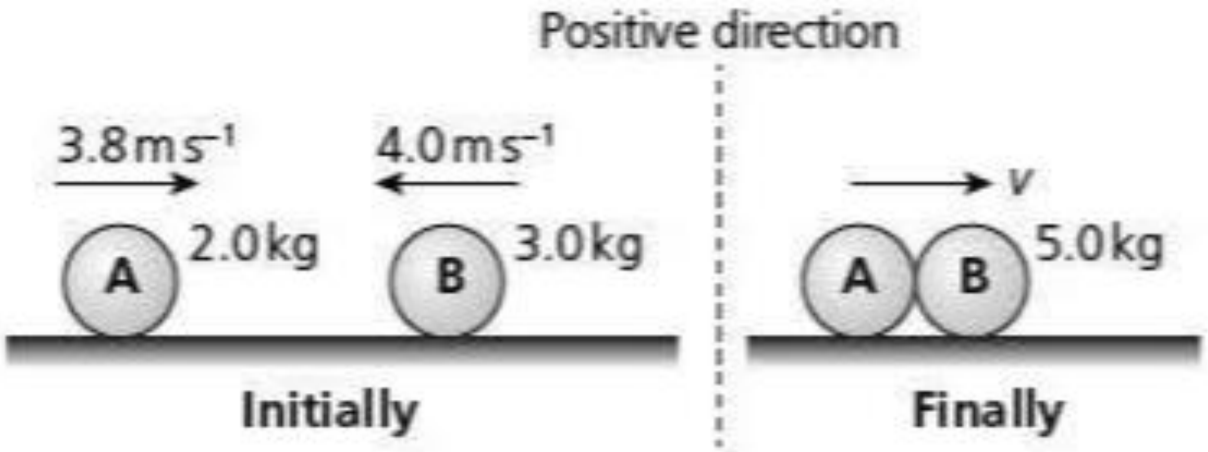


Figure 4.3 Collision between two bodies

total momentum before the collision = total momentum after the collision

If we consider the positive direction to be from left to right:

$$(2.0 \times 3.8) + (3.0 \times \ -4.0) = 5v$$

$$-4.4 = 5v$$

$$v = -0.88\,\mathrm{m\,s^{-1}}$$

The negative sign means that the velocity after the collision is from right to left.

A formal statement of the law is as follows:

The total momentum of a closed system before an interaction is equal to the total momentum of that system after the interaction.

Collisions in two dimensions

The example above considers a head-on collision, where all the movement is in a single direction. The law applies equally if there is a glancing collision and the two bodies move off in different directions. In this type of problem the momenta must be resolved so that the conservation of momentum be considered in two perpendicular directions.

Figure 4.4

Mathematics Help

In right triangle ABC

$$\sin\theta = \frac{\text{side opposite to angle } \theta}{\text{Hypotenuse}}$$

$$\cos\theta = \frac{\text{side adjacent to angle } \theta}{\text{Hypotenuse}}$$

$$\tan\theta = \frac{\text{side opposite to angle } \theta}{\text{side adjacent to angle } \theta}$$

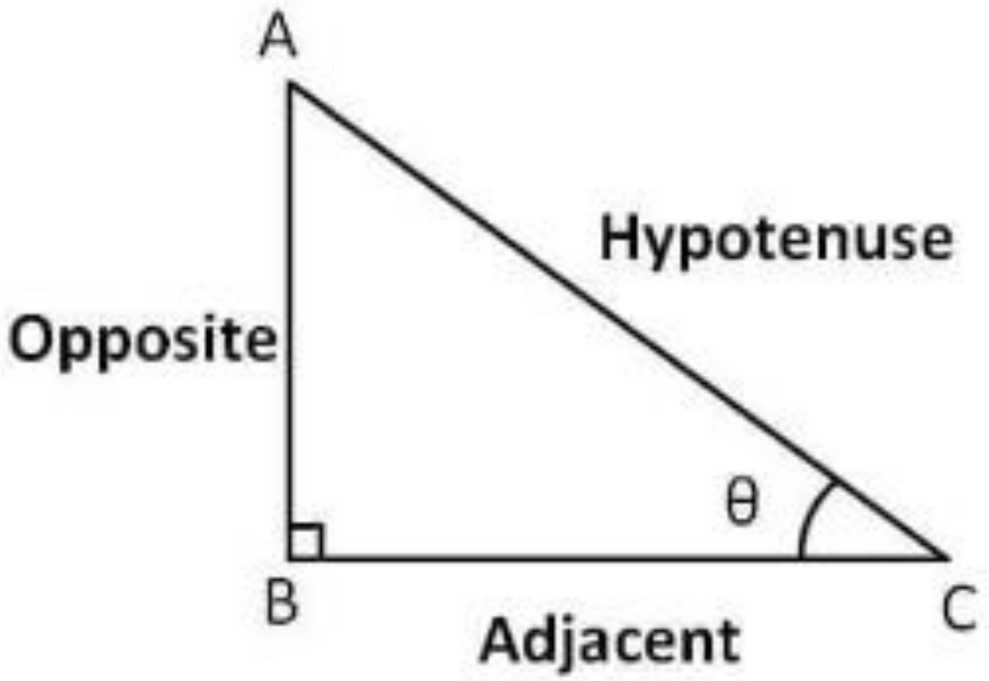


Figure 4.4 shows a disc A of mass m_A, with a velocity u, moving towards a stationary disc B of mass m_B. The discs collide. After the collision disc A moves off with velocity v_A at an angle θ to its original velocity and disc B moves with a velocity v_B at an angle of ϕ to the original velocity of A.

Momenta parallel to u:

momentum before collision = $m_A u$

momentum after collision = $m_A v_A \cos\theta + m_B v_B \cos\phi$

Therefore:

$$m_A u = m_A v_A \cos\theta + m_B v_B \cos\phi$$

Momenta perpendicular to u:

momentum before collision = 0

momentum after collision = $m_A v_A \sin\theta + m_B v_B \sin\phi$

Therefore:

$$0 = m_A v_A \sin\theta + m_B v_B \sin\phi$$

Example

A particle moves towards a stationary particle of equal mass *m*, with a velocity *u* of $2.00\,m\,s^{-1}$. After the collision one particle moves off with a velocity $1.00\,m\,s^{-1}$ at an angle of 60° to the original velocity. The second particle moves off with a velocity of magnitude $1.73\,m\,s^{-1}$. Calculate the angle the second particle makes with the original velocity.

Inelastic and elastic collisions

In collisions, the total momentum of the colliding objects is always conserved. Usually, however, their total kinetic energy is not conserved. Some of it is changed to heat or sound energy, which is not recoverable. Such collisions are said to be *inelastic*. If the total kinetic energy is conserved, the collision is said to be *elastic*. The collision between two smooth billiard balls is approximately elastic. Many atomic

A glider of mass 0.20 kg is moving at 3.6 m s^{-1} on an air track towards a second glider of mass 0.25 kg, which is moving at 2.0 m s^{-1} in the opposite direction. When the two gliders collide they stick together.

(a) Calculate their joint velocity after the collision.

(b) Show that the collision is inelastic.

Answer

(a) momentum before the collision = $(0.20 \times 3.6) + (0.25 \times -2.0)$

$= 0.22$ kg m s^{-1}

momentum after the collision = $(0.20 + 0.25)v = 0.45v$, where v is the velocity of the two gliders after the collision

momentum after the collision = momentum before the collision

$0.22 = 0.45v$

$v = 0.49$ m s^{-1}

(b) kinetic energy before the collision = $(\frac{1}{2} \times 0.2 \times 3.6^2) + (\frac{1}{2} \times 0.25 \times 2.0^2)$

$= 1.3 + 0.5 = 1.8$ J

kinetic energy after the collision = $(\frac{1}{2} \times 0.45 \times 0.49^2) = 0.054$ J

The kinetic energy after the collision is less than the kinetic energy before the collision, therefore the collision is inelastic.

Tutorial

1 A ball-bearing falls at a constant speed through oil. Name the forces acting on it in the vertical direction and state the magnitude of the resultant force on it.

2 A car of mass 1200 kg accelerates from rest to $18\,\mathrm{m\,s^{-1}}$ in 6.3 s. Calculate:

a the acceleration of the car

b the average resultant force acting on it

c the momentum of the car when it is travelling at $18\,\mathrm{m\,s^{-1}}$

3 A ball of mass 250 g travelling at $13\,\mathrm{m\,s^{-1}}$ collides with and sticks to a second stationary ball of mass 400 g.

a Calculate the speed of the balls after the impact.

b Show whether or not the collision is elastic.

4 A disc of mass 2.4 kg is moving at a velocity of $6.0\,\mathrm{m\,s^{-1}}$ at an angle of 40° west of north. Calculate its momentum in:

a the western direction

b the northern direction

Types of Forces

- gravitational forces
- electric forces
- upthrust or buoyancy forces
- frictional and viscous forces

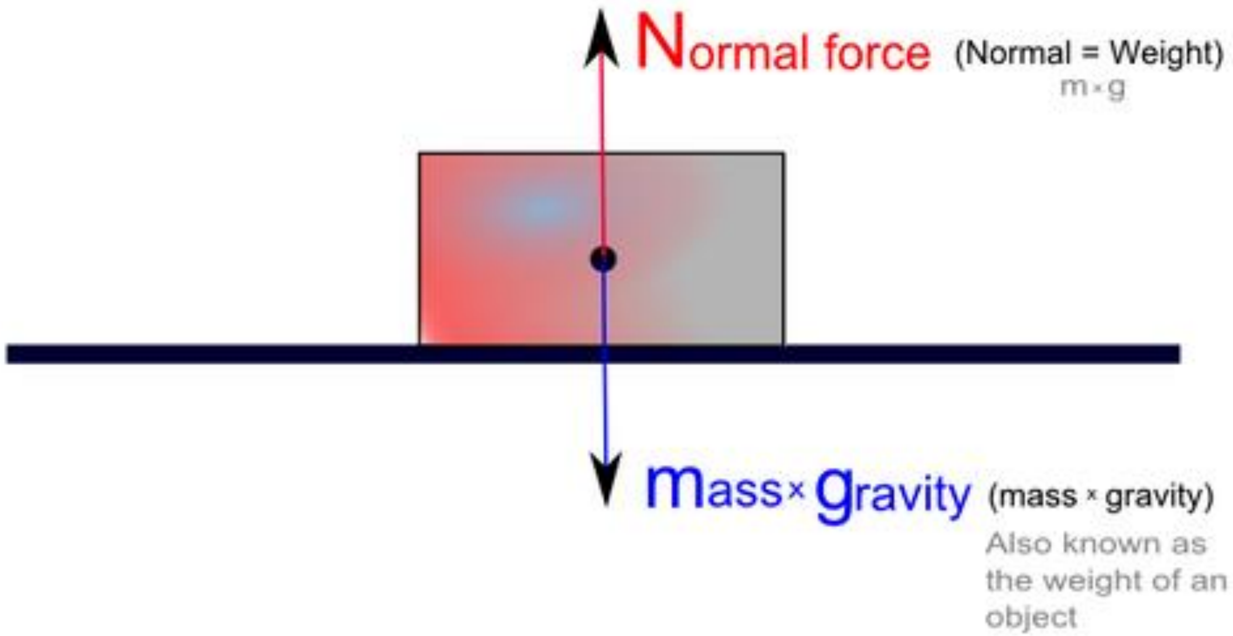
Gravitational forces

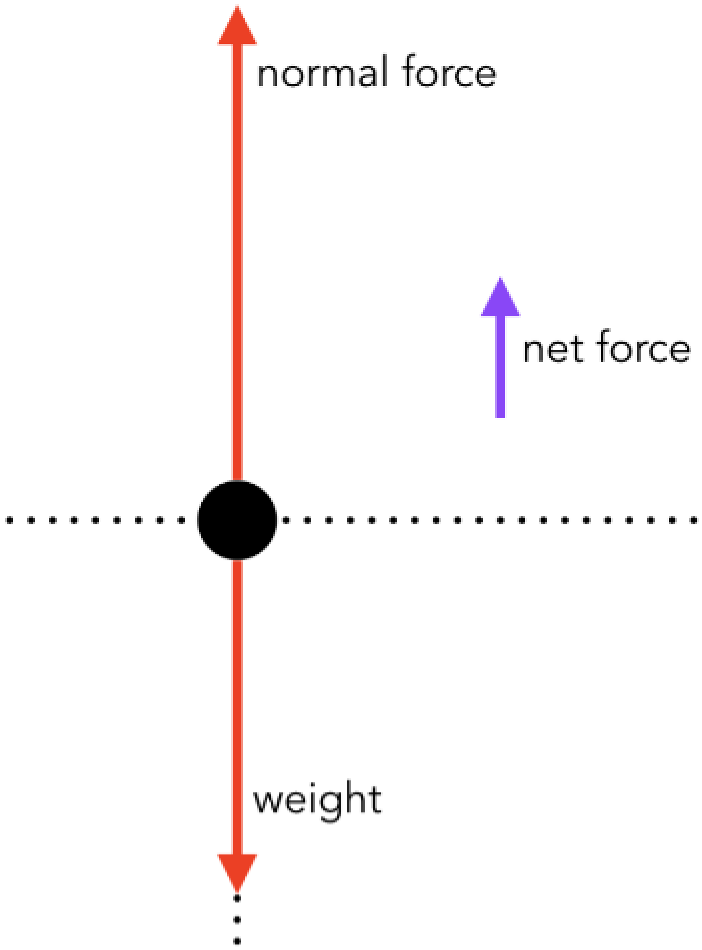
A mass in a gravitational field experiences a force. You have already seen that the size of the force depends on the strength of the gravitational field and the mass of the object:

$$F = mg$$

where F is force (or weight), m is mass of the body and g is the gravitational field strength.

Near the earth surface, the gravitational field strength is approximately 9.8 N/kg . This will cause any object to fall with an acceleration of 9.8 m/s2.

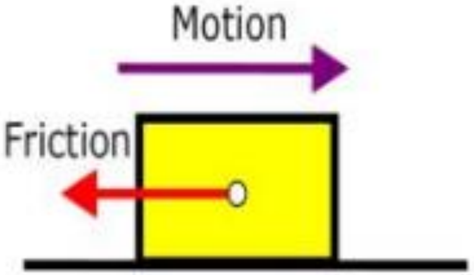

Normal force
(Normal = Weight)
m×g
mass×gravity
(mass × gravity)
Also known as the weight of an object


normal force
net force
weight

Frictional forces

Frictional Forces

Friction is a type of force that *opposes* the motion of objects.



There are two types of frictional forces:

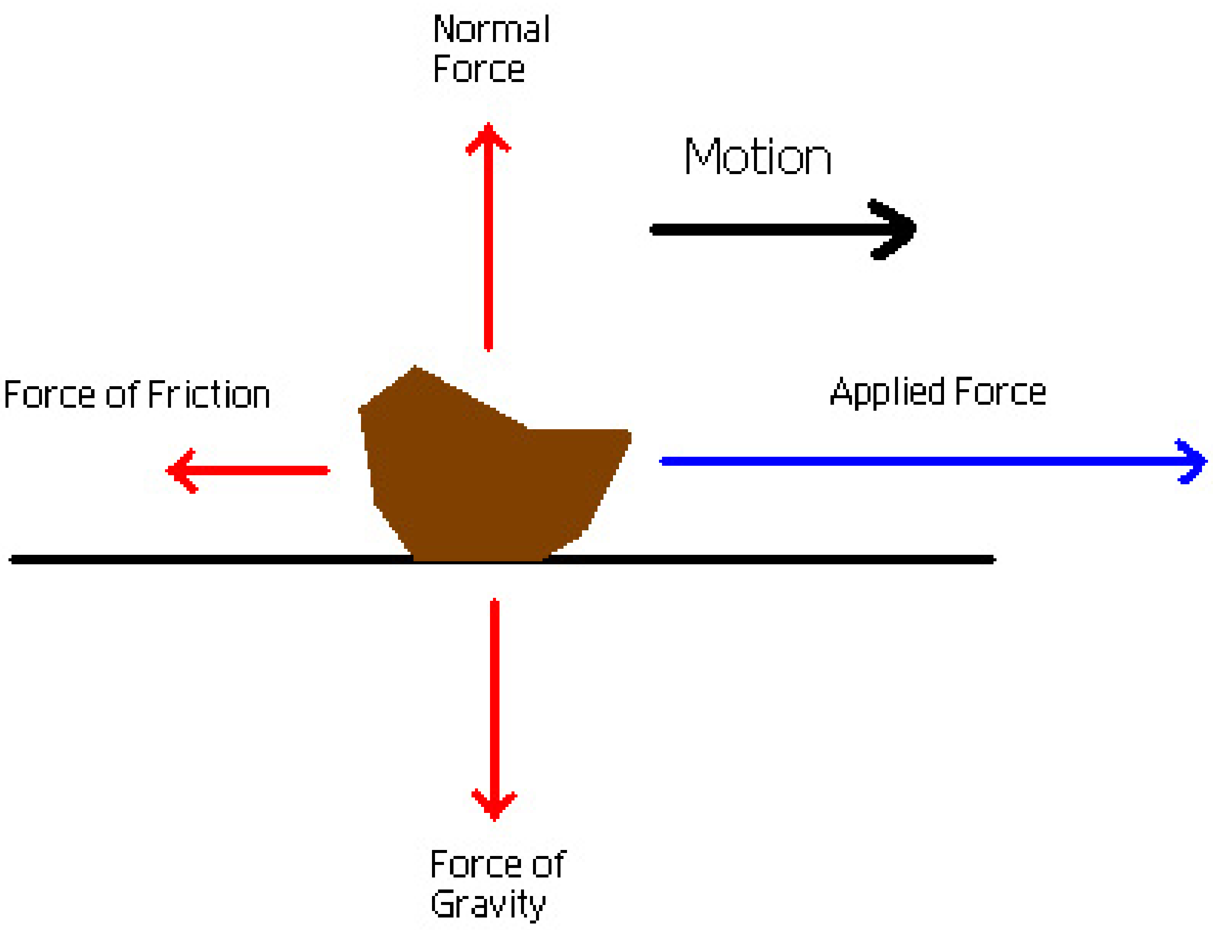
- Kinetic- the force of resistance on an object that causes the object to stop moving.
- Static- the force of resistance on an object that prevents motion.

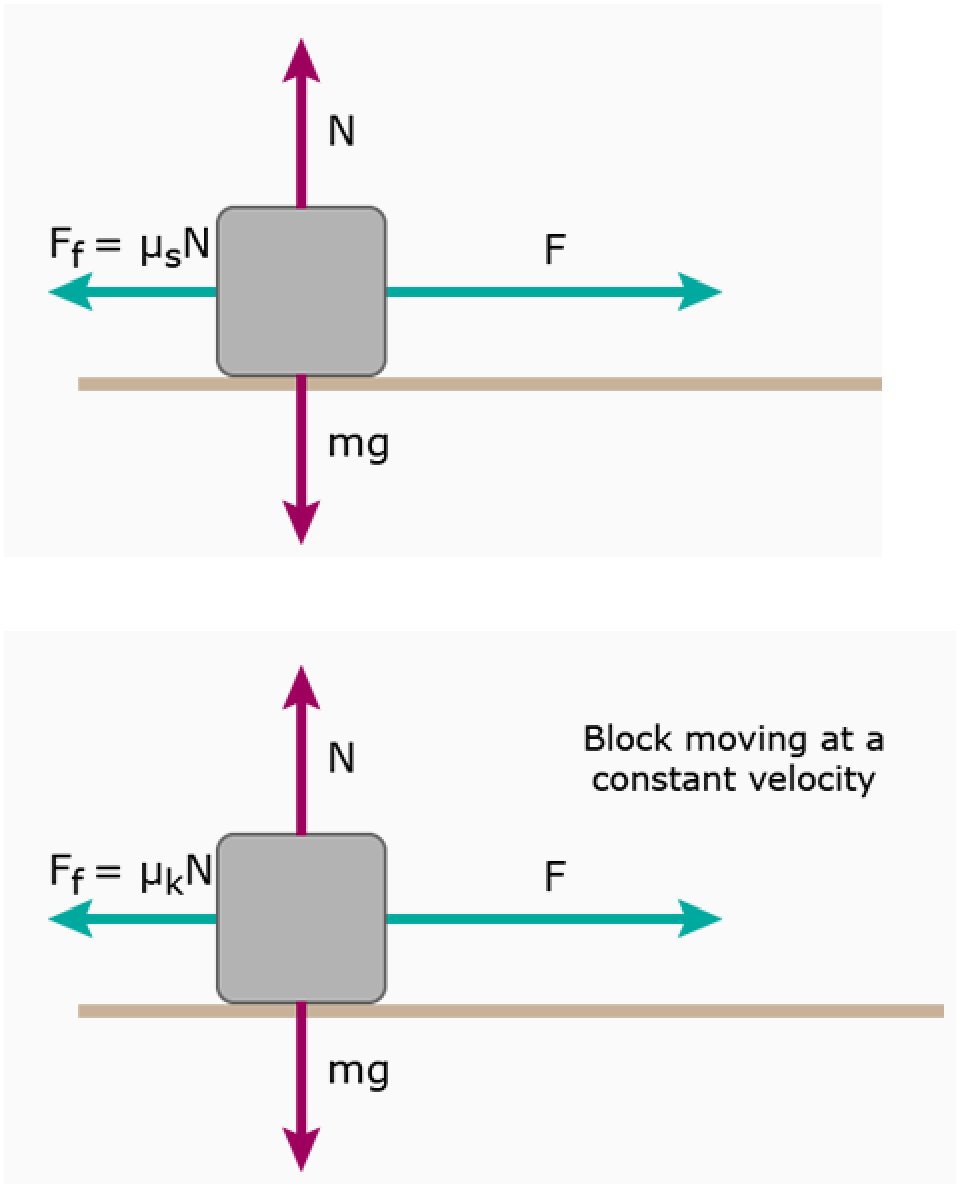
Coefficients of Friction

A ratio of the magnitude of friction to the normal force on an object.

$$\mu = \frac{F_f}{F_N}$$

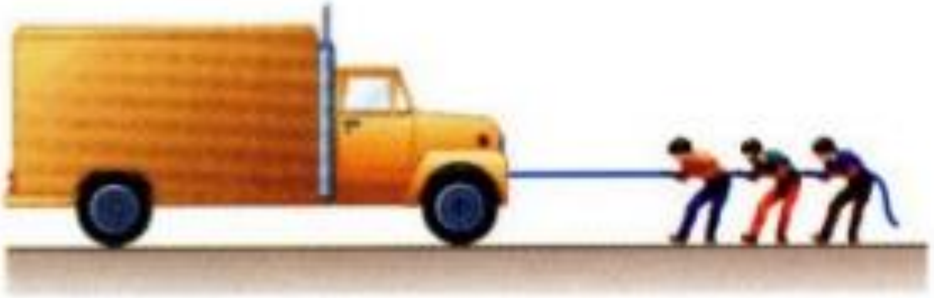
Where μ is just a ratio (number with no units)


Normal
Force
Motion
Force of Friction
Applied Force
Force of
Gravity

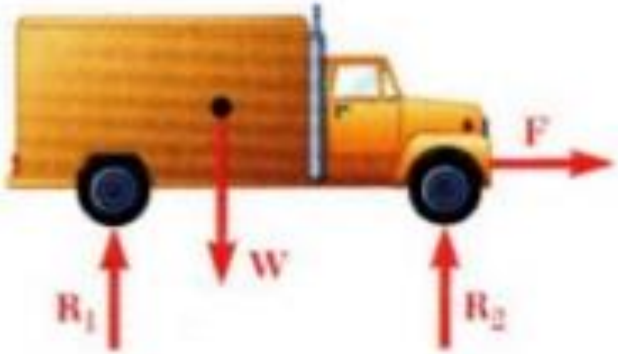

N
$F_f = \mu_s N$
F
mg
N
Block moving at a
constant velocity
$F_f = \mu_k N$
F
mg

External and Internal Forces

- Forces acting on rigid bodies are divided into two groups:
  - External forces
  - Internal forces

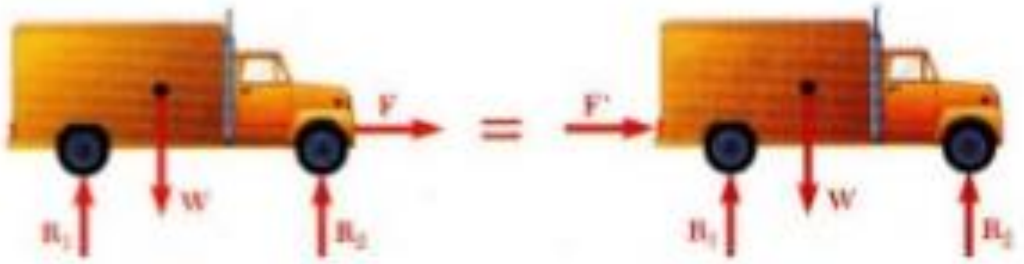


- External forces are shown in a free-body diagram.



- If unopposed, each external force can impart a motion of translation or rotation, or both.

- Moving the point of application of the force **F** to the rear bumper does not affect the motion or the other forces acting on the truck.

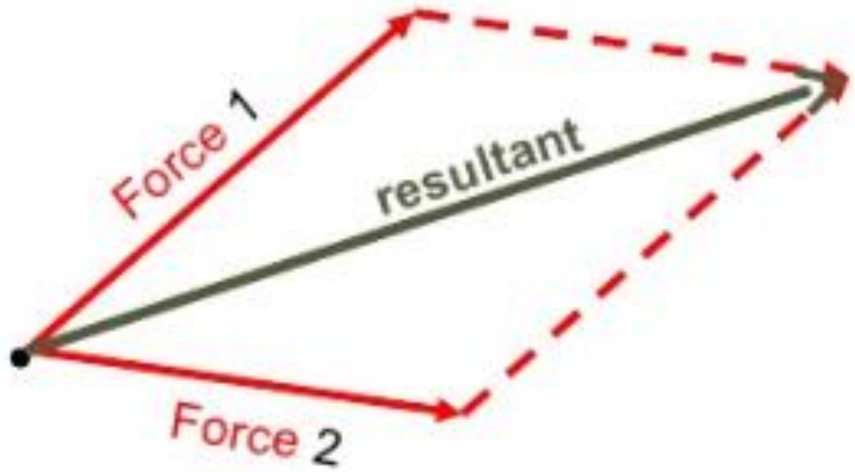


Resultant of Several Forces

- **Definition:**
- A single force which can replace a number of forces acting one a rigid body, without causing any change in the external effects on the body is known as **the resultant force.**

Parallelogram of Forces

If two forces whose lines of action meet at a **point** are represented in magnitude and direction by the sides of a parallelogram drawn from one of its angular points, their resultant is represented in magnitude and direction by the diagonal drawn from that angular point.

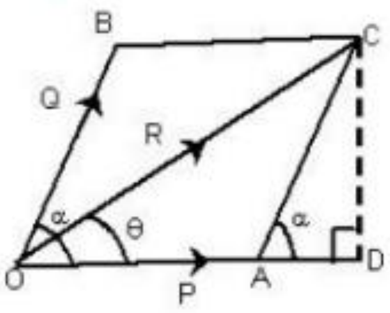


- The magnitude of Resultant force R

$$R = \sqrt{P^2 + Q^2 + 2PQcos\alpha}$$

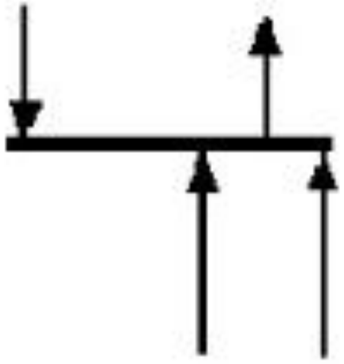
- The direction of Resultant force R with the force P

$$\theta = \tan^{-1}\left(\frac{Q\sin\alpha}{P + Q\cos\alpha}\right)$$



Coplanar Parallel Forces

- A **parallel** coplanar force system consists of two or more forces whose lines of action are parallel to each other.



- Two parallel forces will not intersect at a point.
- The line of action of forces are parallel so that for finding the resultant of two parallel forces, the parallelogram cannot be drawn.
- The resultant of such forces can be determined by applying the principle of moments.

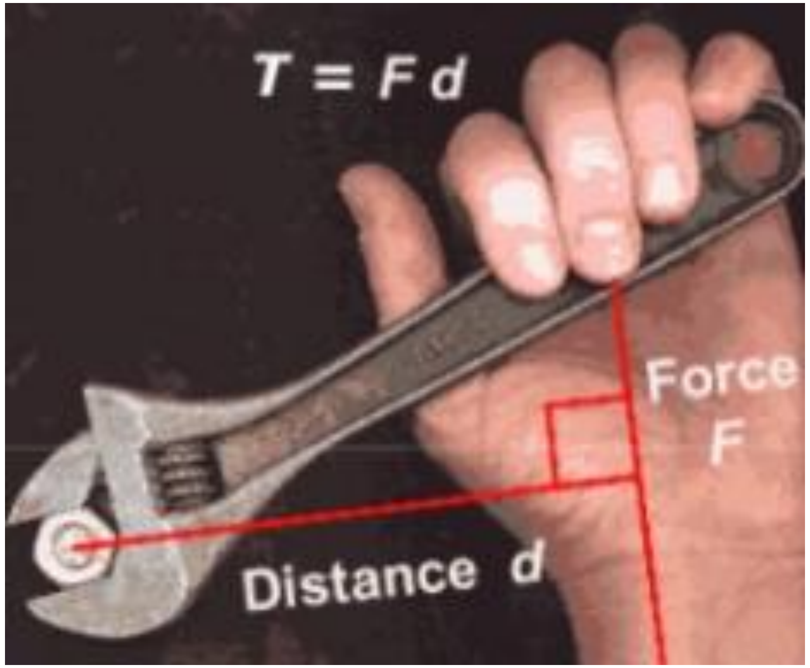
MOMENT OF FORCES

- **Moment of Forces**
- The tendency of a force to produce rotation of body about some axis or point is called the moment of a force.
  - moment of a force about a point
  - moment of a force about an axis
  - moment due to a couple

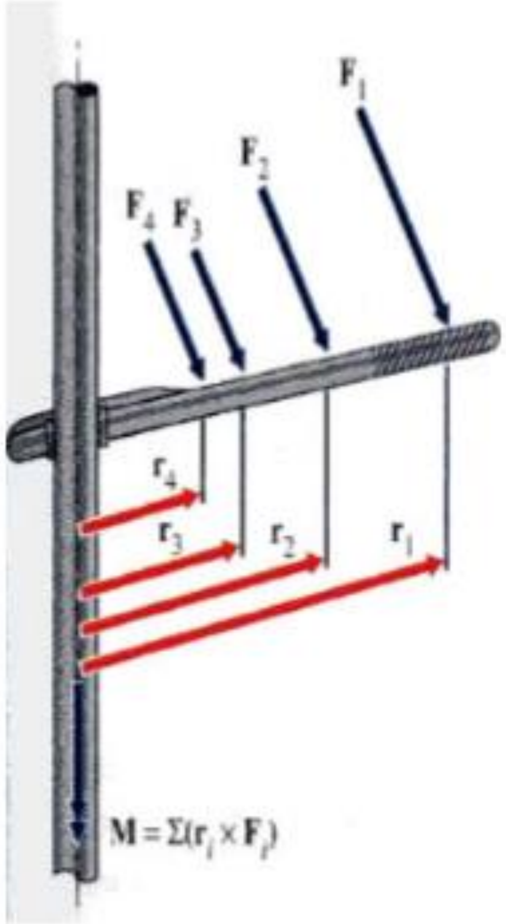
The moment (m) of the force F about O is given by,

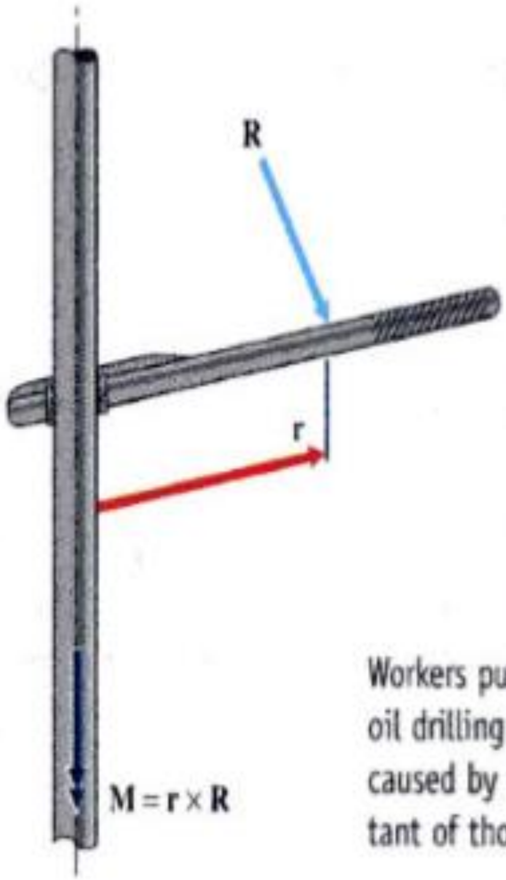
$$M = F \times d$$

Unit: force x distance =F*L = N-m, kN-m (SI unit)

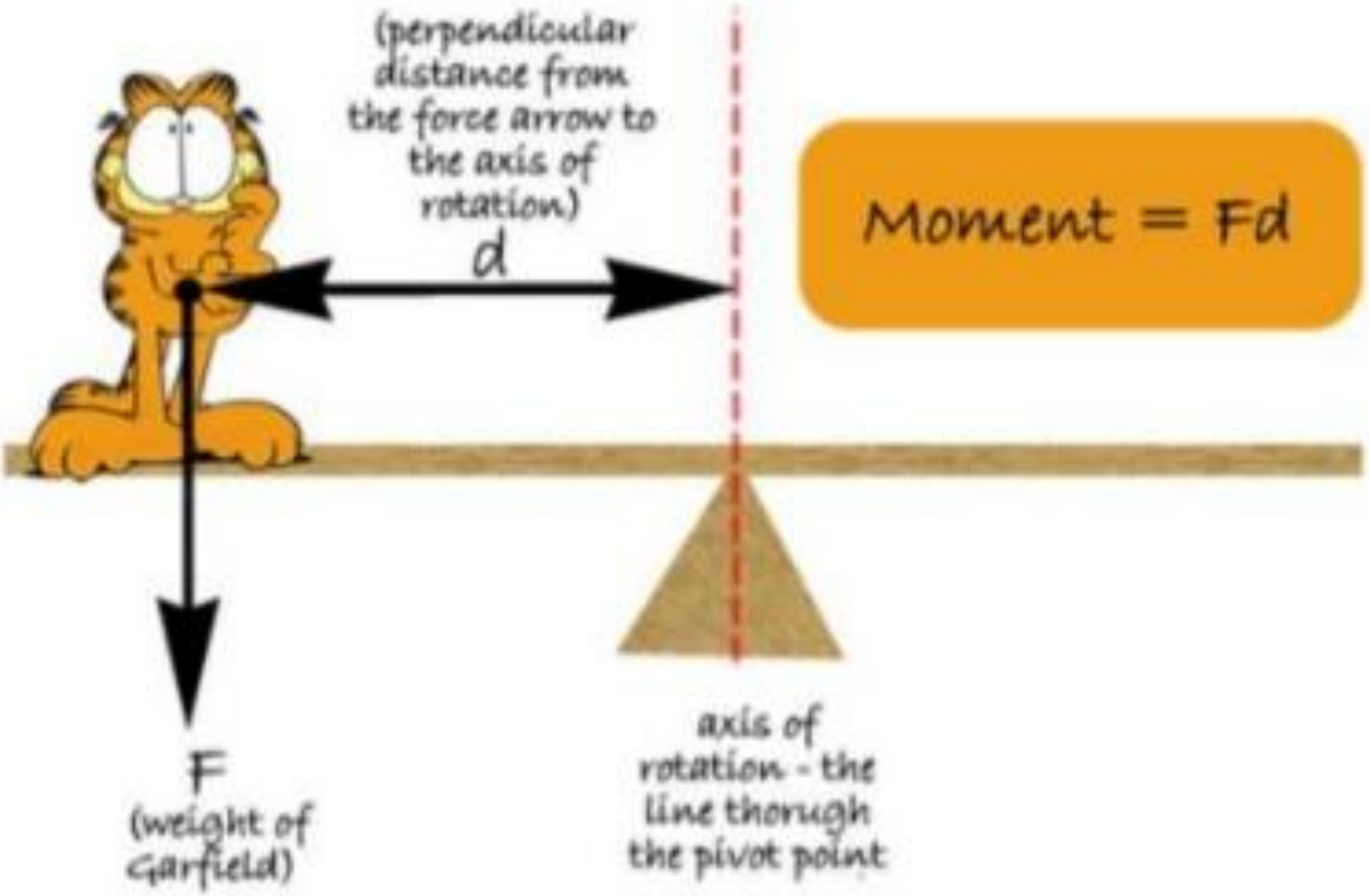


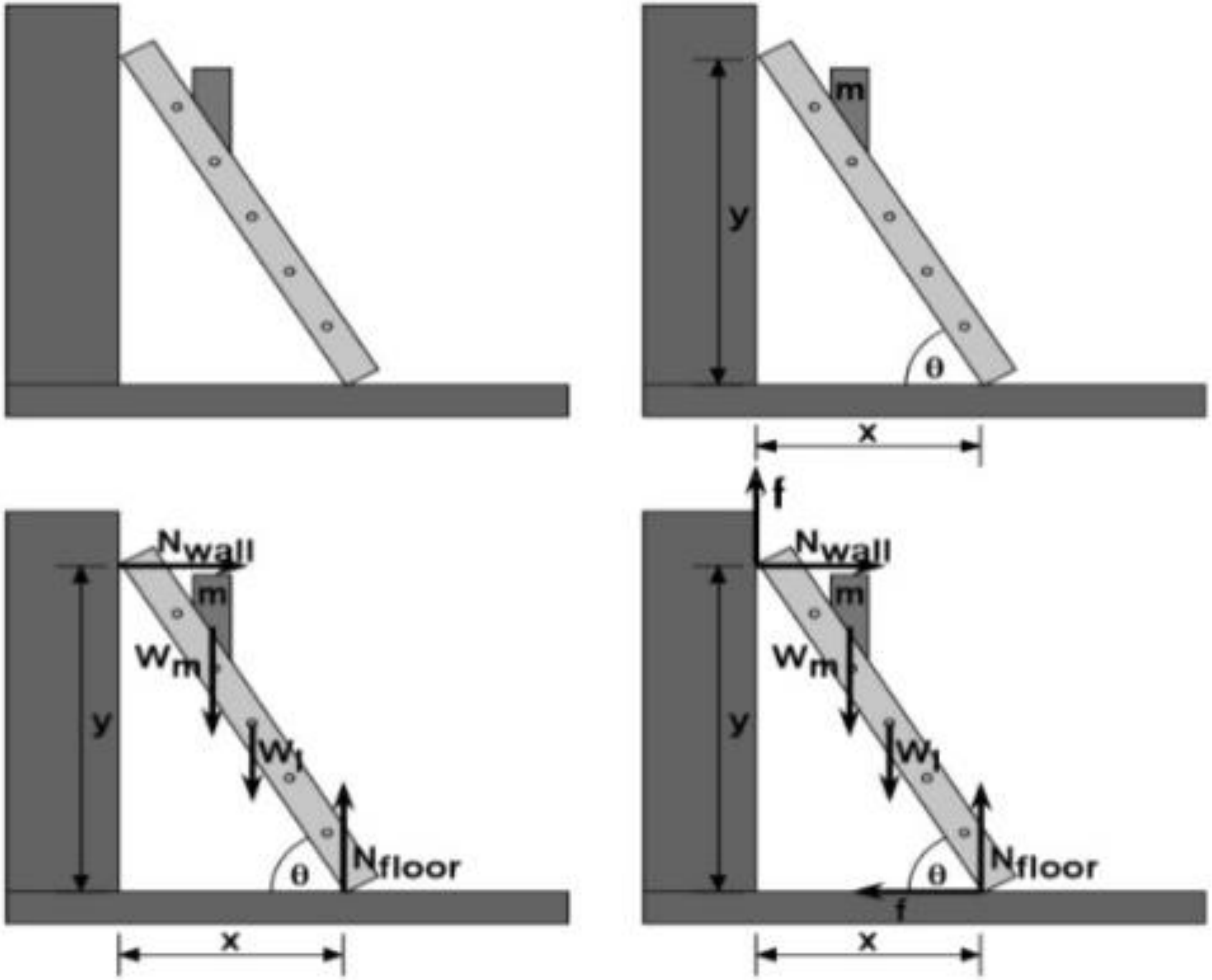
Principle of Moments





Workers push on a pipe wrench attached to a shaft on an oil drilling rig. The moment about the axis of the shaft caused by the individual forces is the same as if the resultant of those forces were applied along its line of action.

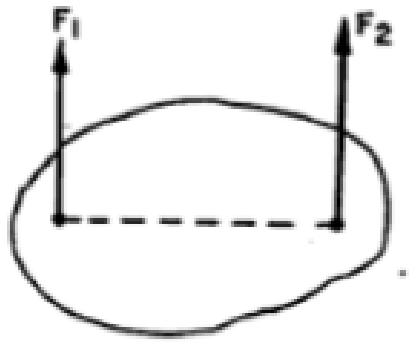

(perpendicular distance from the force arrow to the axis of rotation)
d
Moment = Fd
F
(weight of Garfield)
axis of rotation - the line thorugh the pivot point



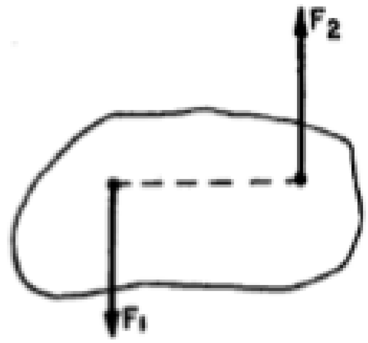
m
y
θ
x
f
N wall
W m
W l
N floor

Types of Parallel Forces

- Two important types of parallel forces
  1. Like parallel forces
  2. Unlike parallel forces



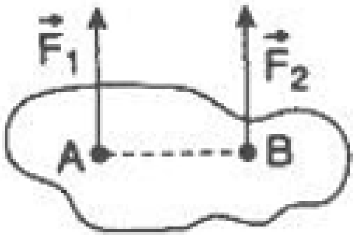
- **Like Parallel forces**
- Two parallel forces which are acting in the same direction are known as like parallel forces.
- The magnitude of a forces may be equal or unequal.



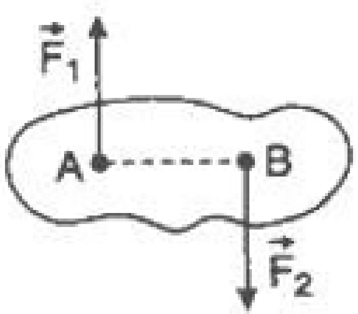
- **Unlike Parallel forces**
- Two parallel forces which are acting in the opposite direction are known as like unparallel forces.
- The magnitude of a forces may be equal or unequal.

Resultant of Two Parallel forces

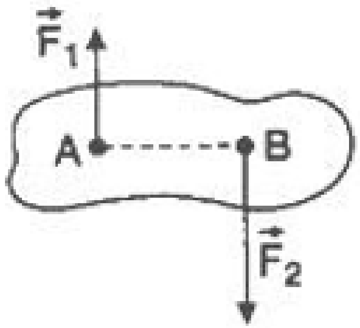
- The resultant of following two parallel forces will be considered:
  - Two parallel forces are like.
  - Two parallel forces are unlike and are unequal in magnitude.
  - Two parallel forces are unlike but equal in magnitude.



(a) Like parallel forces



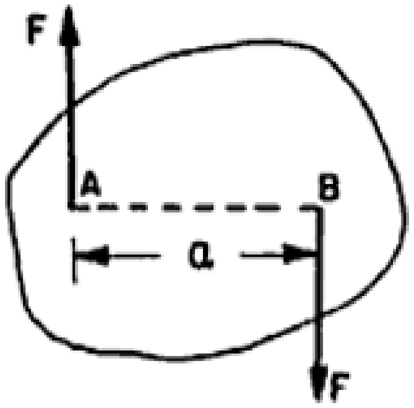
(b) Unlike parallel forces



(c) Unlike unequal forces

Moment of a Couple

- **Two parallel forces are unlike but equal in magnitude**
- Two parallel forces having different lines of action, equal in magnitude, but opposite in sense constitute a couple.



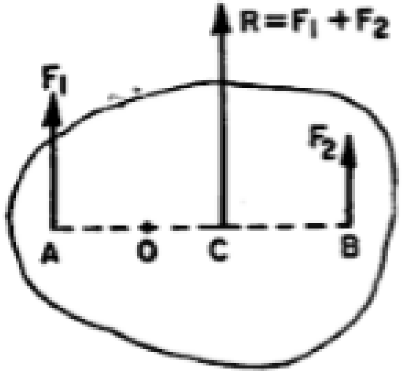
- A couple causes rotation about an axis perpendicular to its plane.
- The perpendicular distance between the parallel forces is known as *arm of the couple*.

$$M = F * a$$

Unit: Nm

Resultant of Two Parallel forces

- **Two parallel forces are like**
- Suppose that two like but unequal parallel forces act on a body at position A and B as shown in figure.



- We have to calculate the resultant force acting on the body and its position.
- From condition of static equilibrium;

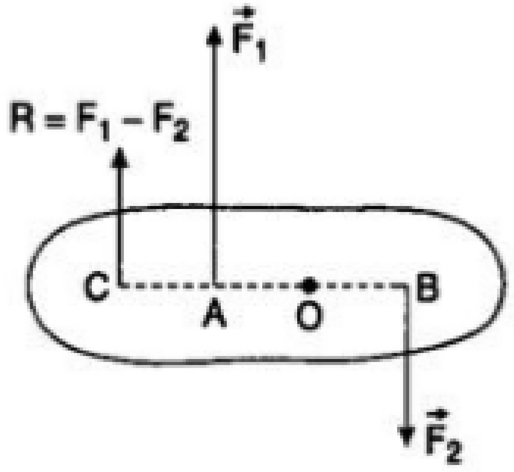
$$R = F_1 + F_2 \qquad \text{...(1)}$$

Resultant of Two Parallel forces

- **Two parallel forces are unlike and are unequal in magnitude**

  - Suppose that two unlike and unequal parallel forces act on a body at position A and B as shown in figure.
  - We have to calculate the resultant force acting on the body and its position.
  - From condition of static equilibrium,

$$R = F_1 - F_2 \qquad \ldots(1)$$



Equivalent System

- Two force systems that produce the same external effects on a rigid body are said to be *equivalent*.
- An equivalent system for a given system of coplanar forces, is a combination of a force passing through a given point and a moment about that point.
- The force is the resultant of all forces acting on the body.
- The moment is the sum of all the moments about that point.

- Equivalent system consists of :
- (1) a single force R passing through the given point P
- (2) a single moment M_R

Equilibrium of Rigid Bodies

External forces →→ Body start moving or rotating.

- If the body does not start moving and also does not start rotating about any point, then body is said to be in equilibrium.

- For a rigid body in static equilibrium, the external forces and moments are balanced and will impart no translational or rotational motion to the body.