Year 10
Science
Physical World: Part 2

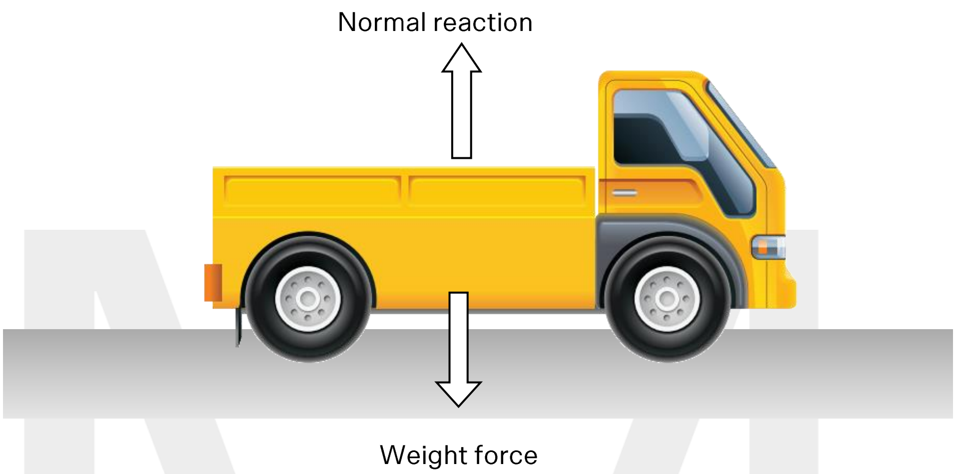
Lesson 5:
Applications of
Newton's Laws 1
Sample resources

MATRIX
EDUCATION

1. Linear motion of objects

☐ Objects at rest

- Consider a truck **parked** on a flat horizontal surface.



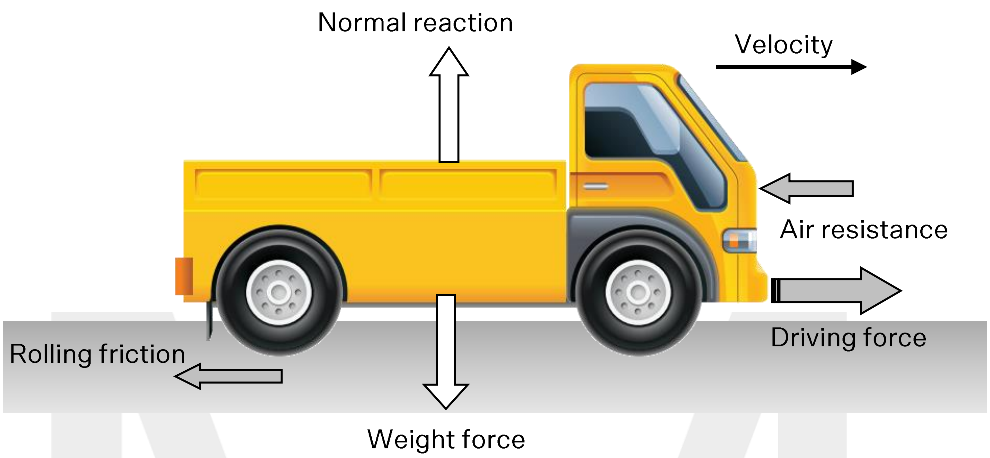
- When the truck is **stationary** on a flat horizontal surface, there are only two forces acting on the truck:
  (i) Downward weight force
  (ii) Upward normal reaction force

- Is the net force on the truck zero or non-zero? Explain your answer in terms of Newton's Laws.[1]

- What is required to accelerate the truck forward?[2]

☐ Objects moving at a constant velocity

- Consider a truck moving at a **constant velocity to the right.**



- When a truck is stationary, forces such as air resistance, rolling friction and driving forces are absent. However, these forces become apparent when the truck is in motion.
- Is the net force on the truck zero or non-zero? Explain your answer in terms of Newton's Laws.[3]

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- **Write an expression** that relates driving force to the sum of the resistive forces (air resistance + rolling friction) acting on a truck travelling at a constant velocity.[4]

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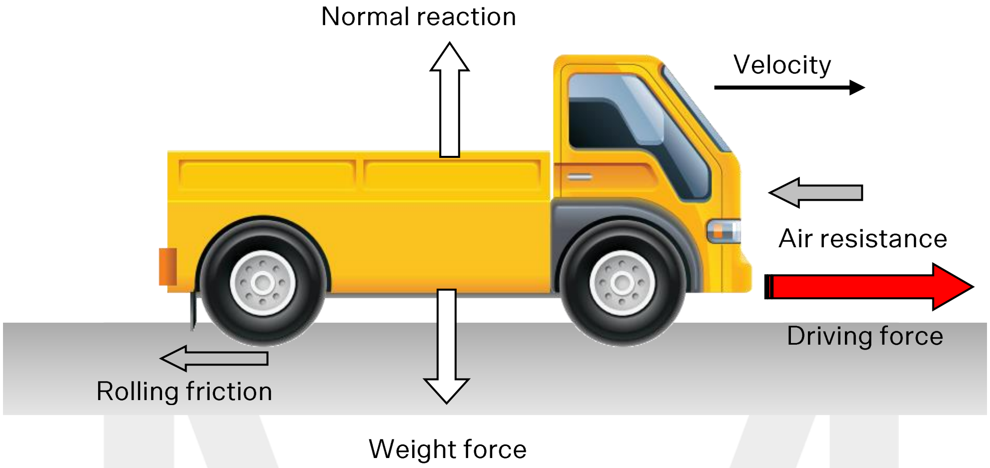
☐ Objects moving with increasing velocity

- Consider a truck moving with **increasing velocity to the right**.



– The velocity of the truck is changing, therefore it is accelerating. In order for the truck to accelerate to the right, the driver must step on the accelerator to increase the forward driving force.

– Is the net force on the truck zero or non-zero? Explain your answer in terms of Newton's Laws.[5]

– **Write an expression** that relates driving force to the sum of the resistive forces (air resistance + rolling friction) acting on a truck accelerating to the right.[6]

> **Note to students**
>
> According to Newton's first and second laws, an object requires a net force in order to accelerate.

☐ Investigation

- A radio-controlled model car has a mass of 0.65 kg. The car accelerates forward uniformly from rest to 3.5 ms^{-1} in 1.5 s.
  - Calculate the acceleration of the car.[7] **1**
  - Calculate the net force acting on the car during this acceleration.[8] **1**
  - After 1.5 s the motor is switched off and the car accelerates uniformly until it stops. The acceleration is -0.60 ms^{-2}. Calculate the magnitude of the resistive forces acting on the car.[9] **1**

Note to students

Once the motor is turned off the car no longer has a driving force.

Therefore, F_{net} = resistive forces = ma

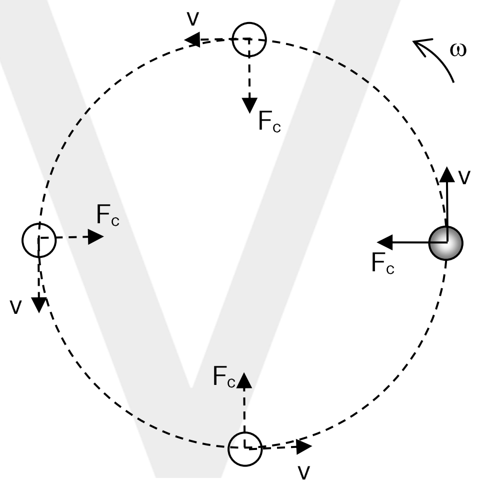
2. Circular motion of objects

☐ What is circular motion?

- An object travelling in a circular path at a **constant speed** is said to undergo **uniform circular motion.**

- In uniform circular motion:
  (i) Speed is constant
  (ii) Velocity is NOT constant since the direction of the object is continuously changing
  (iii) The period of rotation (the time taken for the object to complete one full rotation) is constant
  (iv) Acceleration is directed towards the centre of the circle

- The figure below shows an object undergoing **uniform circular motion.**



  – Objects in uniform circular motion experience a **net force** directed toward the centre of its path called the **centripetal force.**
  – If the object has the **same speed** throughout its motion, how can there be an unbalanced force?[10] [hint: what is the acceleration changing?]

☐ Centripetal force

- The centripetal **force (F_c)** experienced by an object is given by:

$$F_c = \frac{mv^2}{r}$$

Where: F_c = centripetal force (N)

m = mass of object (kg)

v = velocity of object (ms^{-1})

r = radius of the circular path of the object (m)

  - The centripetal force must always point towards the centre of the circle, and perpendicular to the velocity. Its direction changes as the object turns through the circle.
  - This centripetal force must be provided by some **external force**.

> Note to students
>
> "**Centripetal**" is an adjective used to describe the direction of the net force acting upon the object that moves in the circle. We are not introducing a new type of force.

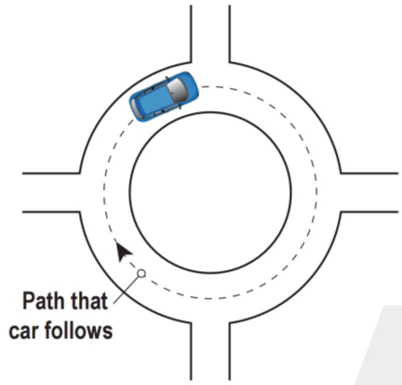
- Examples in real life of forces providing centripetal forces include:
  - **Orbiting satellites**: weight force due to gravity of earth
  - **Cars rounding a curve**: friction between the road and tyres
  - **Swinging a lasso**: tension in the rope

- Since accelerations can be calculated using $F = ma$, the acceleration required for circular motion (centripetal acceleration) is given by:

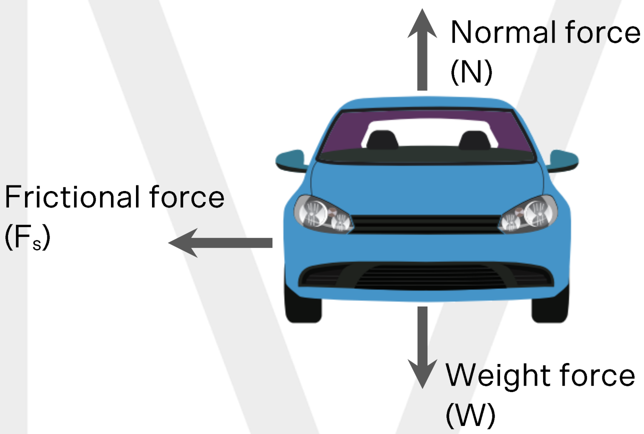
$$a_c = \frac{F_c}{m} = \frac{v^2}{r}$$

> Note to students
>
> DO NOT confuse centripetal force with centrifugal force.
>
> Centripetal force is the external force required to make an object turn in a circle.
>
> Centrifugal force (never examinable) is the apparent force felt by objects inside a box when the entire box is rotated or turned in a circle.

- Consider the following scenario: A car that has a mass of 800 kg travels at a constant speed of 7.5 ms^{-1} on a roundabout so that it follows a circular path with a radius of 16 m.



  - The diagram below shows the forces acting on the car as it is rounding a curve.



  - Is there a net force acting on the car? Explain your answer.[11]

- Explain how the car is able to travel around curves.[12]

- Calculate the centripetal force required to allow this car to follow this circular path.[13]

- Calculate the centripetal acceleration of the car.[14]

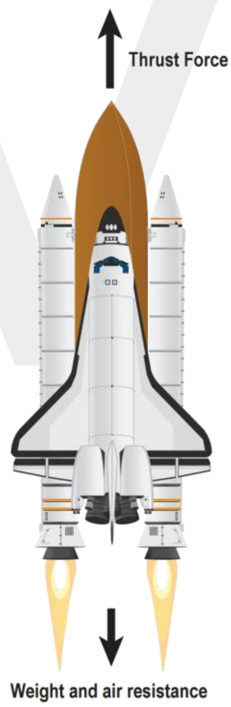
- Describe how the centripetal force and acceleration would change if a large truck with a mass of 1.2 tonnes was to move around this roundabout at the same speed as the car.[15]

3. Space travel

☐ The principle of rocket propulsion

- VIDEO (Start at 1:34): The launch of space shuttle Atlantis from Kennedy Space Centre.
  - When the rockets of the space shuttle are fired, the exhaust gases are shot DOWNWARD at high speed and the space shuttle moves UPWARD.
  - State the laws of physics that rocket propulsion operates on.[16]

- During launch, rockets are subjected to three forces:
  (i) **Weight** (W): Downward gravitational force acting on the rocket
  (ii) **Air resistance:** Frictional force acting in the opposite direction to the motion of the rocket
  (iii) **Thrust force** (T): Upward reaction force exerted by gas particles on the rocket



- Write an expression comparing the relative magnitude of the three forces acting on the launching rocket.[17]

- Using this expression, explain how the space shuttle is able to accelerate vertically upwards.[18]

☐ Space travel

- In space, a space vehicle experiences **zero air resistance** because there is no atmosphere.

- Two identical vehicles experience the same amount of thrust. Compare the magnitude of their accelerations if one travels in space and one travels on earth. Explain with reference to Newton's second law.[19]

- What do you think happens to a spacecraft in space immediately after the rockets are turned off? Year 10 science students Roland and Olina propose some outcomes. **Assess the accuracy** of their statements.[20]

  Roland: "The spacecraft will continue to travel in the same direction but will be slowing down. To keep moving, the astronauts will simply have to fire the rocket engines again."

  Olina: "The spacecraft will continue to travel at the same speed and in the same direction."

4. Lesson review questions

Concept Check 4.1

A speedboat is driven over a smooth lake at a constant velocity. The most correct explanation of its motion is that:[21]

(a) A net resultant force is being exerted on the boat owing to water friction
(b) The resultant force on the boat is zero, although the motor is working
(c) A constant resultant force on the boat must exist to maintain constant velocity
(d) No work is being done by the engine because the kinetic energy of the boat is constant

Concept Check 4.2

Skydivers often leap from aircrafts at great altitudes. As they fall their speed increases, accelerating until they reach a constant speed called "terminal velocity". This is usually about 60 m/s, but is dependent on the size of the skydiver, their shape and their mass. Which of the following best explains the cause of this terminal velocity?[22]

(a) Gravity no longer acts on the skydivers because of their speed.
(b) Gravity only accelerates all objects to a certain speed and no faster.
(c) Atmospheric pressure, acting from all sides, keeps them up.
(d) The upward force on them caused by air resistance becomes equal to their weight.

Concept Check 4.3

Ned is pushing his car with a force of 250 N. The car experiences resistive forces of 100 N while Ned experiences resistive forces of 50 N. Ned has a mass of 80 kg, and the car's mass is 2000 kg.[23]

Calculate the acceleration of Ned and the car.

(a) Ned: $3.8\ \mathrm{ms^{-2}}$ forward Car: $0.125\ \mathrm{ms^{-2}}$ forward
(b) Ned: $3.8\ \mathrm{m\,s^{-2}}$ backward Car: $0.125\ \mathrm{ms^{-2}}$ forward
(c) Ned: $2.5\ \mathrm{m\,s^{-2}}$ backward Car: $0.075\ \mathrm{m\,s^{-2}}$ forward
(d) Ned: $2.5\ \mathrm{m\,s^{-2}}$ forward Car: $0.075\ \mathrm{m\,s^{-2}}$ forward

Concept Check 4.4

Use the diagrams below to answer the following questions.

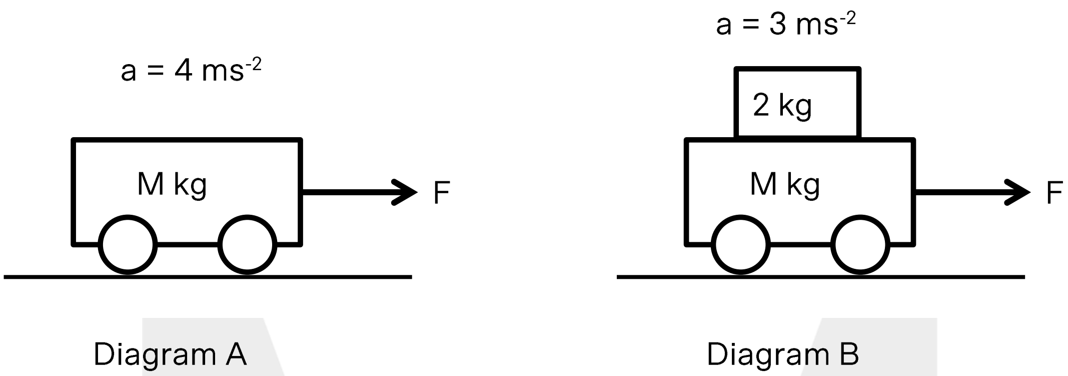


Diagram A: A student applies a constant force of *F* N to a trolley of mass *M* kg and measures the acceleration to be 4 ms^{-2}.

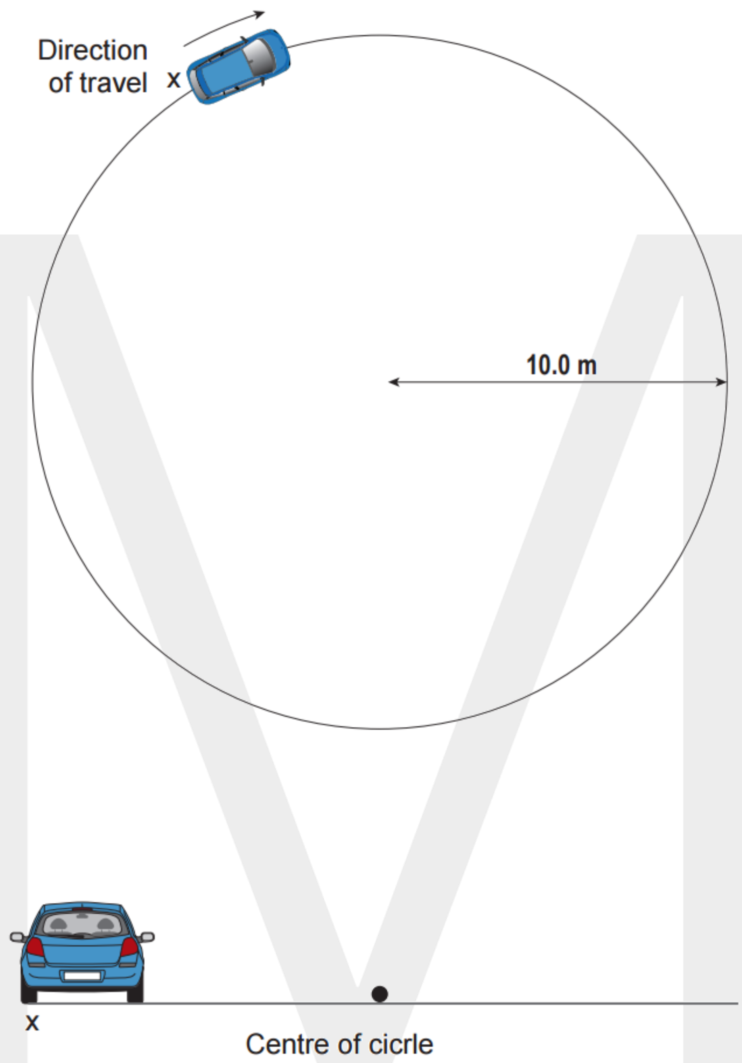
Diagram B. When a 2 kg mass is placed onto the trolley, the same force *F* N results in an acceleration of 3 ms^{-2}.

Using this information, determine the magnitude of the force ***F***. Show ALL working.[24] **2**

> **Note to students**
>
> Find an expression for *M* in terms of *F* from Diagram A.

Concept Check 4.6

A 3000 kg car travels in a circle of radius 10.0 m at a constant speed of 1.5 ms^{-1}. The first image below shows the car from **above** and the second picture shows the car from **behind.**



(a) Indicate the direction of the net force on the car in position X on both figures.[28] **1**

(b) Indicate the direction of the force that the tyres exert on the road in position X on both figures.[29] **1**

(c) Calculate the centripetal acceleration.[30] **1**