Edexcel International A Level (IAL) Maths: Mechanics 1

Your notes

Quantities, Units & Modelling

Contents

- Scalars & Vectors
- Fundamental Units
- Derived Units
- Types of Force
- Modelling Assumptions

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Scalars & Vectors

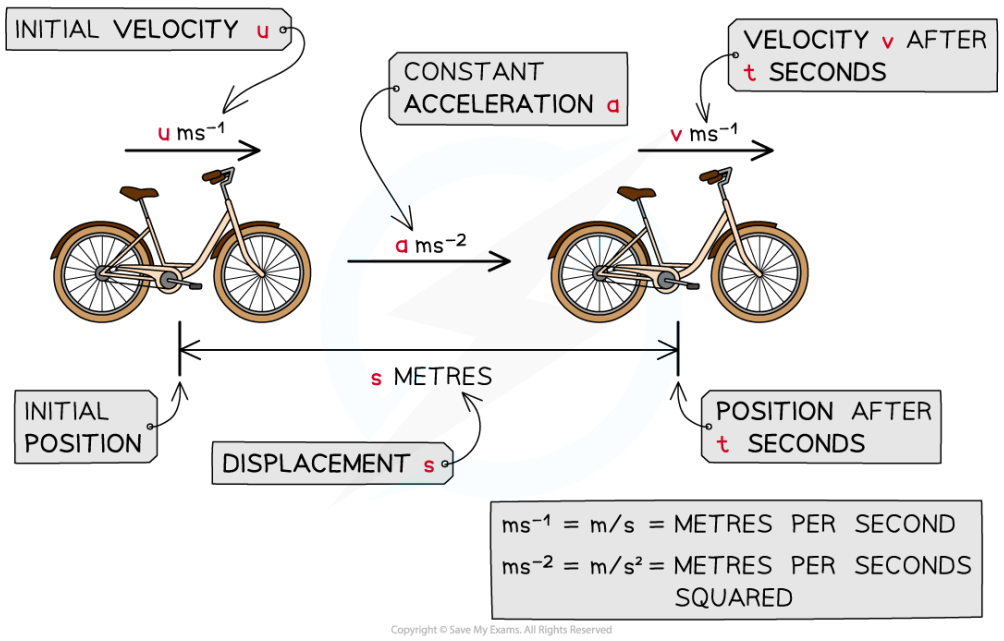
Mechanics uses a variety of different scalar and vector quantities.

What are scalars?

- **Scalars** are quantities without direction, they only have a **size (magnitude)**
  - e.g. a **speed** of 7 m/s, a **distance** of 5 m, a **time** of 15 s or a **mass** of 12 kg
- Scalars can only be **positive**- you can't have a negative distance or speed!

What are vectors?

- **Vectors** are quantities which also have a **direction**, this is what makes them more than just a scalar
  - e.g. two objects with **velocities** of 7 m/s and -7 m/s are travelling at the **same speed** but in **opposite directions**
- Vector quantities can have **positive** or **negative components**
- Some examples of vector quantities you may come across are **displacement**, **velocity**, **acceleration**, **force/weight**, **momentum**
  - **Displacement** is the distance moved in a given direction from a starting point
  - **Velocity** is a speed in a given direction (displacement over time)
  - **Acceleration** is the change in velocity over time



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Worked Example

State whether each of the following is a scalar or a vector quantity.

a) A speed boat travels at 3 m/s on a bearing of 052°

b) A garden is 1.7 m wide

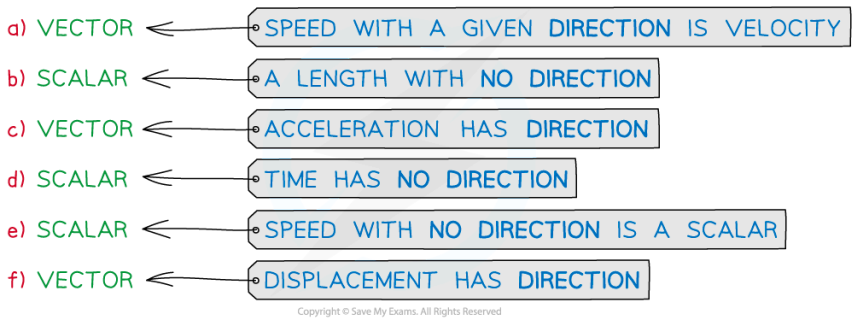
c) A car accelerates at 5.4 ms^{-2}

d) A film lasts 2 hours 17 minutes

e) An athlete runs at an average speed of 10.44 ms^{-1}

f) A ball rolls forwards 60 cm before stopping

Answer:



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Examiner Tips and Tricks

- Make sure you fully understand the definitions of all the words in this section so that you can be clear about what your exam question is asking of you
- Vectors appear in **bold** (non-italic) font in textbooks, on exam papers, etc (i.e. $\boldsymbol{F}$, $\boldsymbol{a}$) but in handwriting should be underlined (i.e. $\underline{F}$, $\underline{a}$)

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Fundamental Units

What are fundamental units?

- **Fundamental units** or **S.I. units** are the international standardised units used around the world
- The three main units you will be using are:
  - **Length** measured in **metres (m)** (also called displacement)
    - 1 km = 1000 m, 1 m = 100 cm, 1 cm = 10 mm
  - **Time** measured in **seconds (s)**
    - 1 hour = 60 minutes, 1 minute = 60 seconds
  - **Mass** measured in **kilograms (kg)**
    - 1 kg = 1000 g, 1 g = 1000 mg
- All other quantities can be measured in units **derived** from S.I. units

Worked Example

Convert the following into S.I. units:

a) 27.8 km

b) 3.8 hours

c) 0.054 g

Answer:

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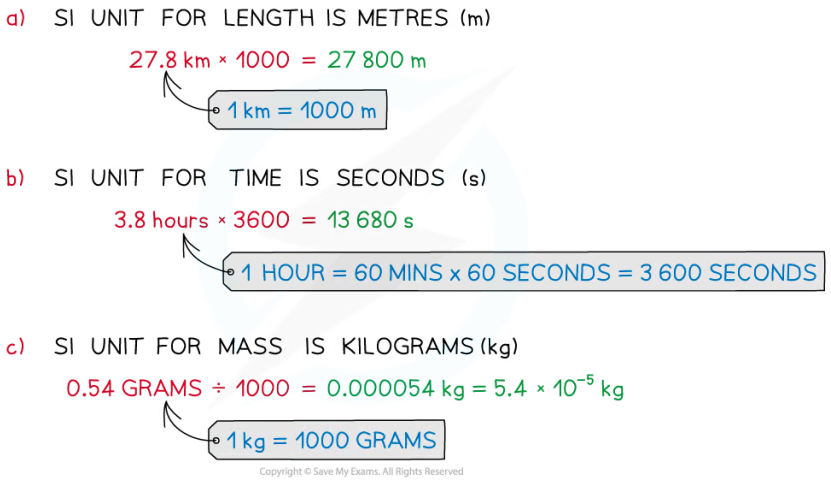

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Examiner Tips and Tricks

- Make sure you fully understand the definitions of all the words in this section so that you can be clear about what your exam question is asking of you.
- Make sure you are confident converting between fundamental S.I Units

e.g. 17 minutes and 42 seconds = 1062 seconds

2.4 km = 2400 m

86000 mg = 0.086 kg.

- Watch out for exam questions using non S.I. units such as feet and inches or miles per hour.
- Remember mass (measured in kg) is not a weight (a force measured in Newtons).

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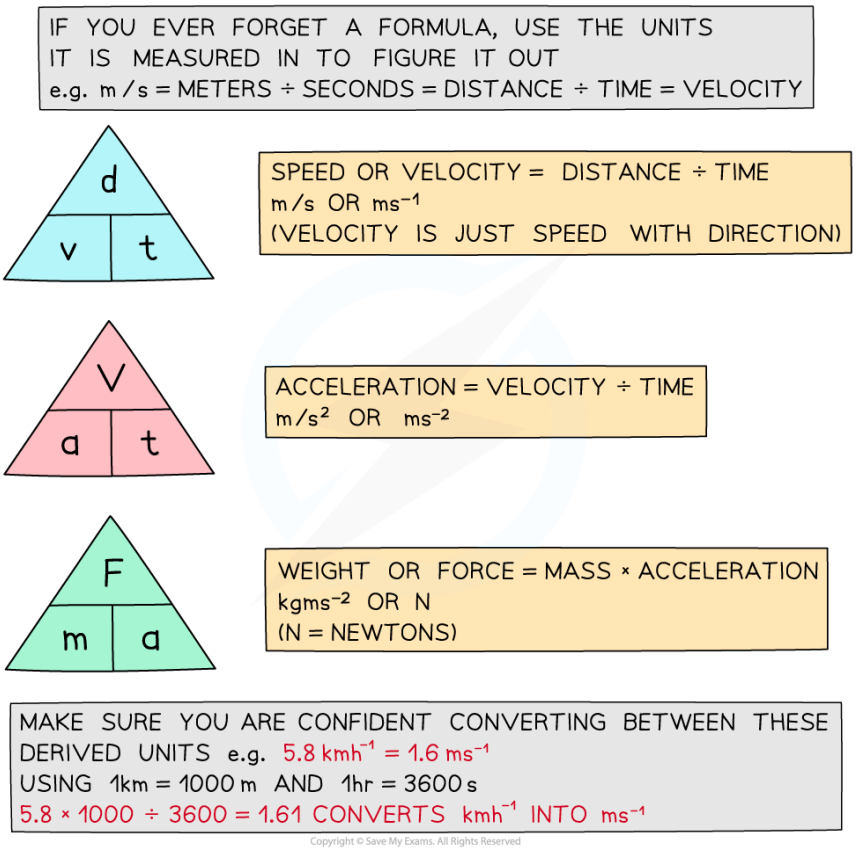
Derived Units

What are derived units?

- Derived units for quantities such as velocity, acceleration and force etc. are combinations of S.I. units
  - **Speed** or **Velocity** = distance ÷ time = **m/s or ms^{-1}** (Velocity is just speed with direction)
  - **Acceleration** = velocity ÷ time = ms^{-1} /s = **m/s^2 or ms^{-2}**
  - **Weight** or **Force** = mass x acceleration = **$kgms^{-2}$ or N** (N = Newtons)



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Worked Example

(a) Convert the following into S.I. units

i) 72 km h^{-2} ii) 50 cm per minute iii) 14 g cm^{-3}

Answer:

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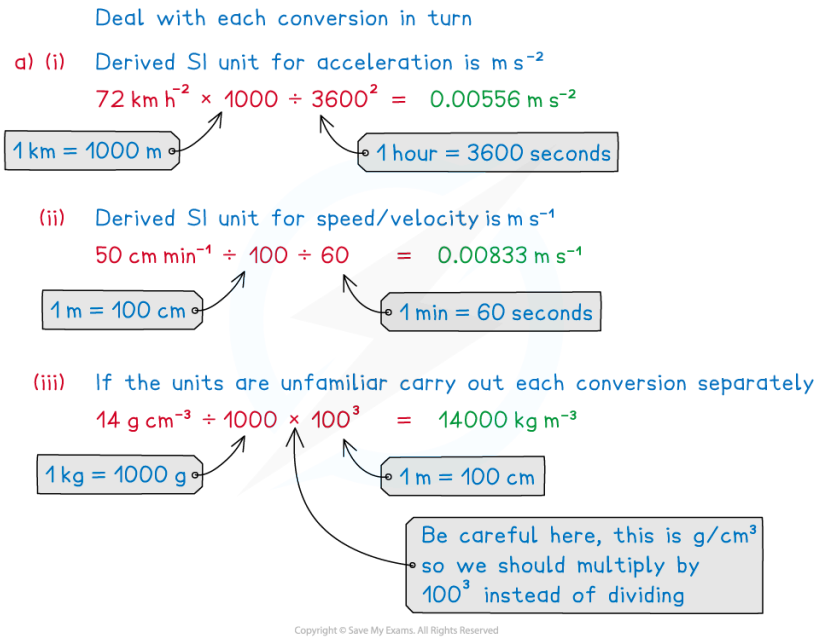
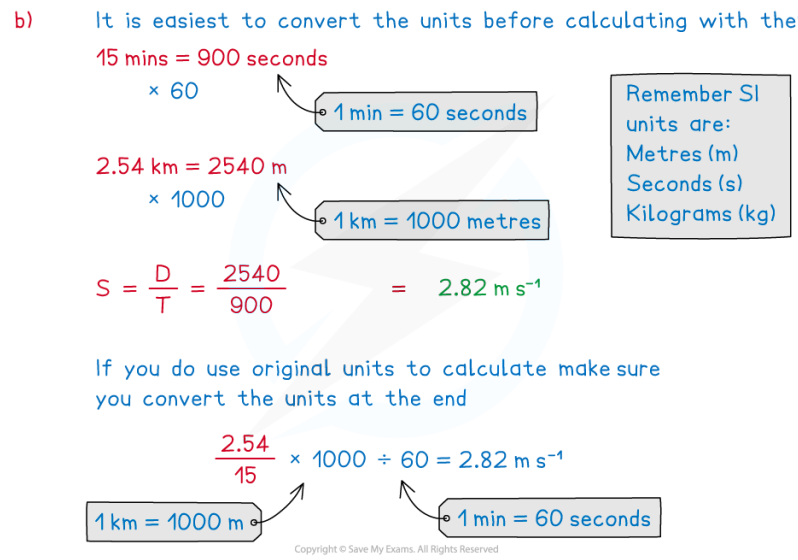


(b) A cyclist takes 15 minutes to travel 2.54 km. Calculate the average speed in m s^{-1}?

Answer:



Examiner Tips and Tricks

- Watch out for exam questions using non S.I. units such as feet and inches or miles per hour.
- Make sure you are confident **converting** between these derived units,
- Remember **speed** is velocity without direction and **weight** is a force measured in **Newtons**, not a mass measured in kg.

- If you ever forget a formula, use the units it is measured in to figure it out,

  e.g. m/s = metres ÷ seconds = distance ÷ time = velocity.

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Types of Force

What is a force?

- A force is a **vector** quantity, it has both **magnitude** and **direction**
- A force is a push or a pull on an object
- A force is measured in **Newtons**
- In A level mathematical models, forces act at a **single point** called a **particle** which occupies a single point in space

What types of force are used in mechanics?

- **Weight** is the effect of **mass** and **gravity,** it always acts downwards
- **Tension** is a pulling force, it always acts away from an object
- **Thrust** is a pushing force, it always acts towards an object
- **Friction** is a resistive force, it acts to oppose the motion of an object
- Every surface will produce a **reaction force**, it will always act **perpendicular** to the surface

Mass, Gravity and Weight

- **Mass** is a measure of the amount of matter in an object
  - **Mass** is a **scalar** quantity, measured in **kilograms**, **kg**
  - **Mass** is universal, it does not change based on location
- **Gravity** is the force by which a body (usually a planet or a star) pulls objects towards its centre
  - **g** is the **acceleration** due to **gravity, measured in m s $^{-2}$**
  - On Earth, **g** is approximately **9.8 m s $^{-2}$** , although its exact value varies with location
  - **g** is different elsewhere in the universe
- **Weight** is the product of **mass** and **gravity**, it is a **force** measured in **Newtons**
  - **Weight** is a **vector** quantity
  - **Weight** varies with location
  - **Weight** always acts vertically downwards towards the ground

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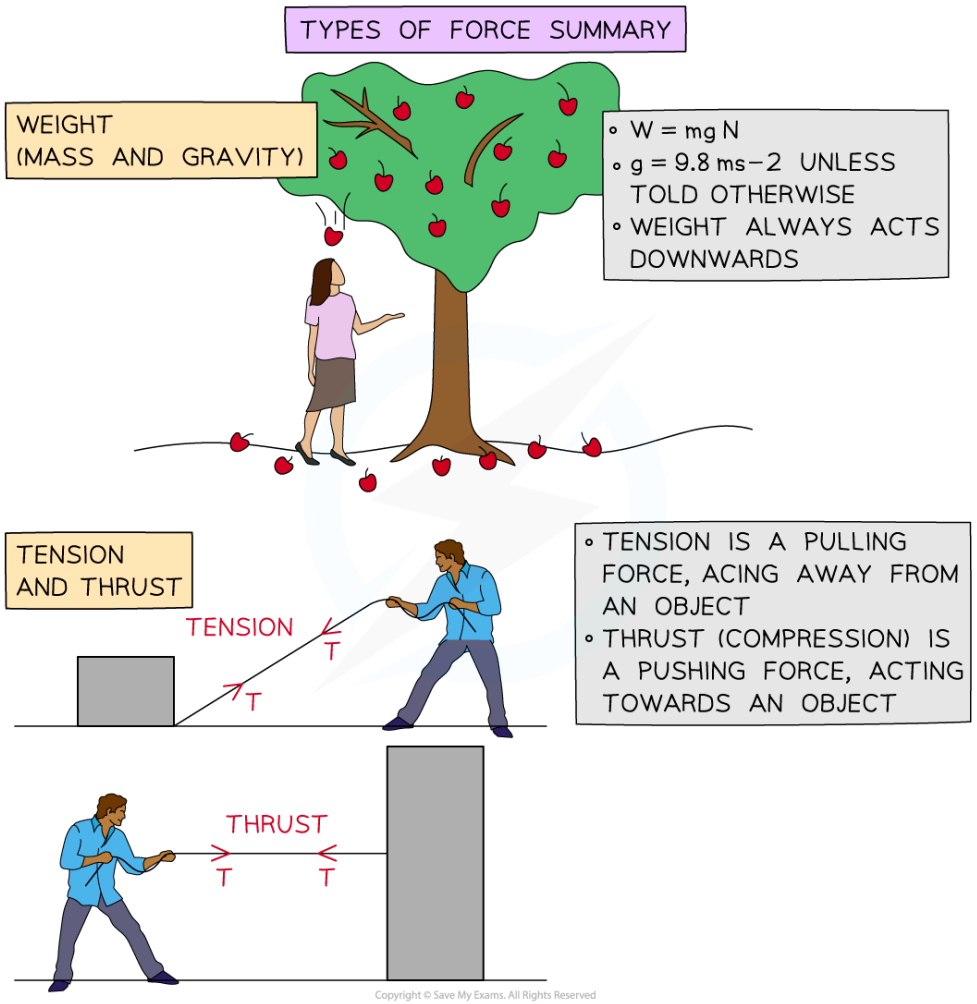
TYPES OF FORCE SUMMARY
WEIGHT (MASS AND GRAVITY)
W = mg N
g = 9.8 ms−2 UNLESS TOLD OTHERWISE
WEIGHT ALWAYS ACTS DOWNWARDS
TENSION AND THRUST
TENSION
T
T
TENSION IS A PULLING FORCE, ACING AWAY FROM AN OBJECT
THRUST (COMPRESSION) IS A PUSHING FORCE, ACTING TOWARDS AN OBJECT
THRUST
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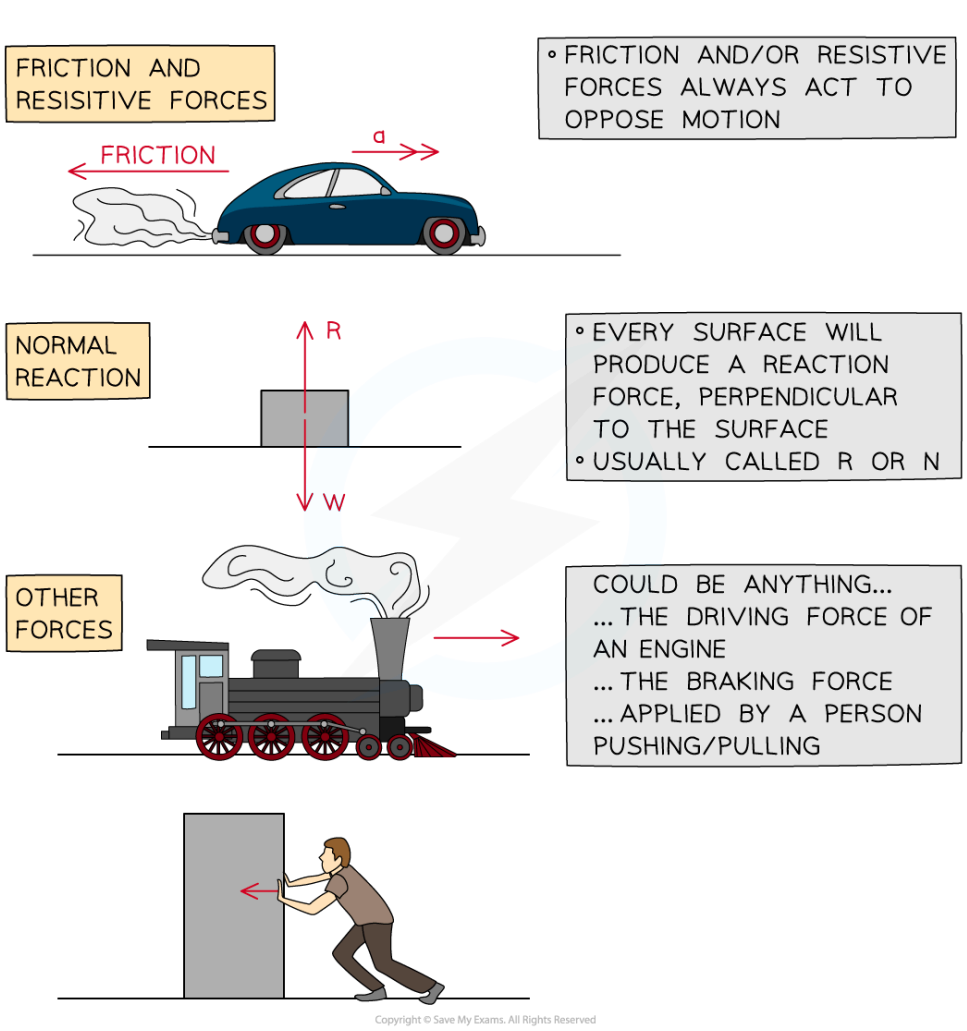

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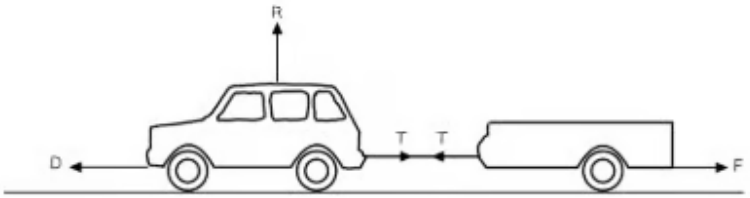
Worked Example

The diagram below shows a car towing a trailer by a light inextensible string.

Forces D, R, F and T N act on the car and caravan as shown.

Write a brief description of which each force represents.

Answer:



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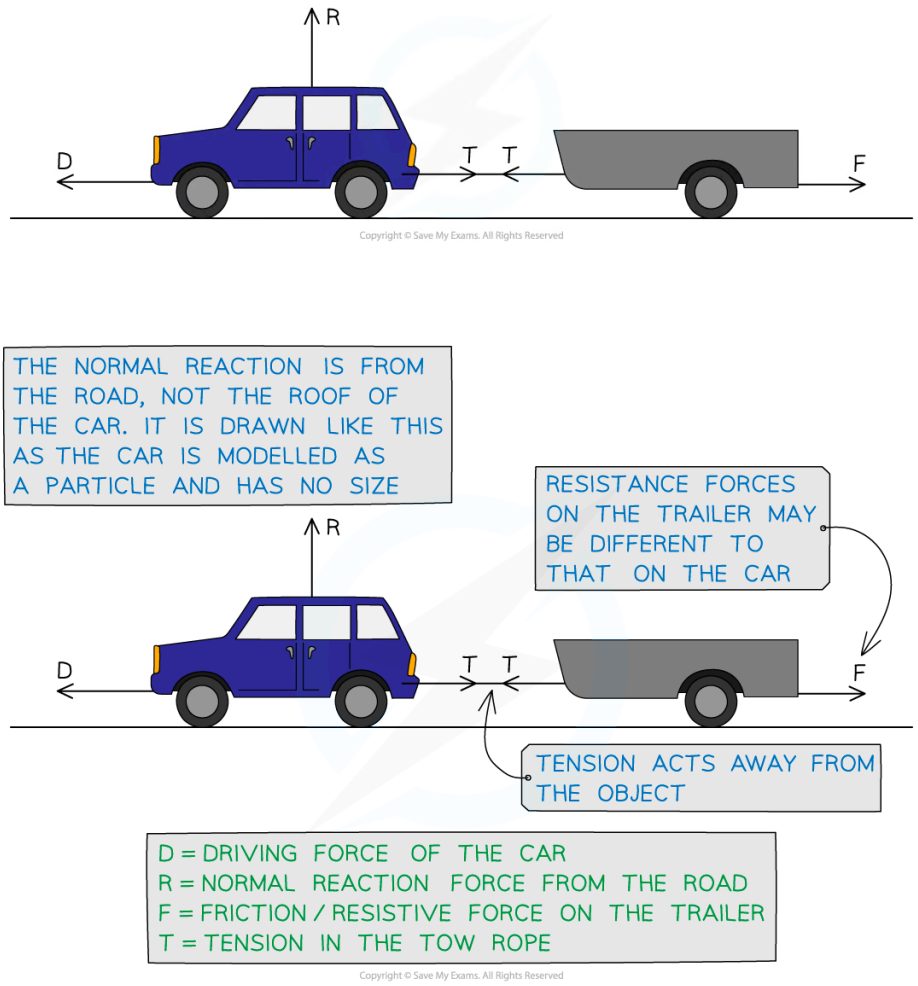

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Examiner Tips and Tricks

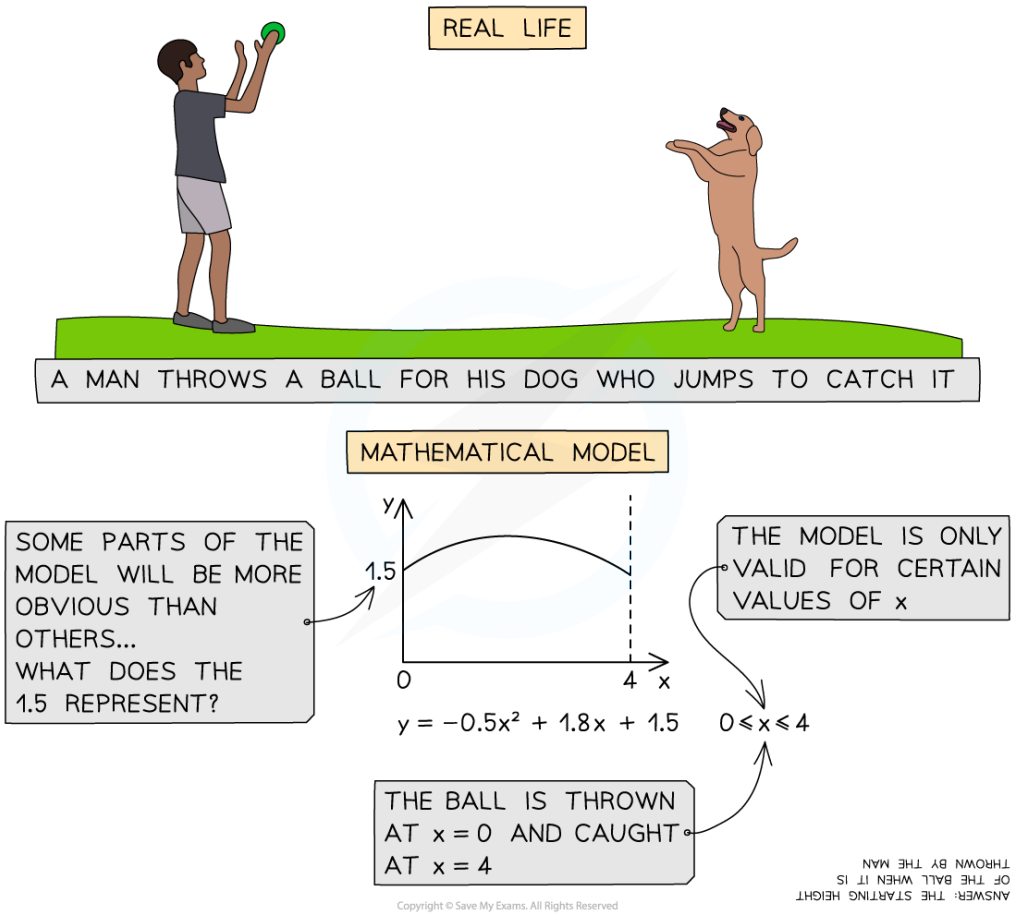
- There are many phrases/words that can be used implying the types of force
  - Braking – suggests **thrust**
  - **Air resistance** – suggests a resistive force
- Always sketch a diagram and mark the forces on the diagram clearly
  - It will help you understand the problem
  - Add more things to the diagram as you progress through the question
  - You may not even need all the forces from your diagram
- You should always round your answers to three significant figures, however if using $\mathbf{g = 9.8\ m\ s^{-2}}$ within a calculation, use two significant figures.

Your notes

Modelling Assumptions

What is modelling in Mechanics?

- Mechanics uses **modelling** to solve problems in real life situations
- We use **assumptions** to simplify real life problems in order to turn them into equations or graphs that can be solved
- We will sometimes need to **criticise** or **refine our assumptions** to improve the model



What types of modelling assumptions are there?

- **Gravity** is constant and vertical **Air resistance** is usually modelled as **negligible** and can be ignored
- A **smooth** surface has no **friction**
- A **rough** surface has a **frictional force** between the surface and any object that makes contact with it

- A **particle** has **negligible** dimensions, therefore forces will all act on a particle at the same point
- A **rod** or a **beam** should be treated as a long, rigid particle
- A **uniform** object's **mass** is distributed evenly
- A **light** object has zero **mass**
- An **inextensible** object cannot be stretched

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Worked Example

Two blocks, A and B are attached by means of a light inextensible string running over a smooth pulley. Block A has mass 0.7 kg and is accelerating along a smooth horizontal surface, block B has a mass 0.2 kg. Both A and B are modelled as particles. State how the following modelling assumptions can be used in your calculations:

a) A and B are both particles.

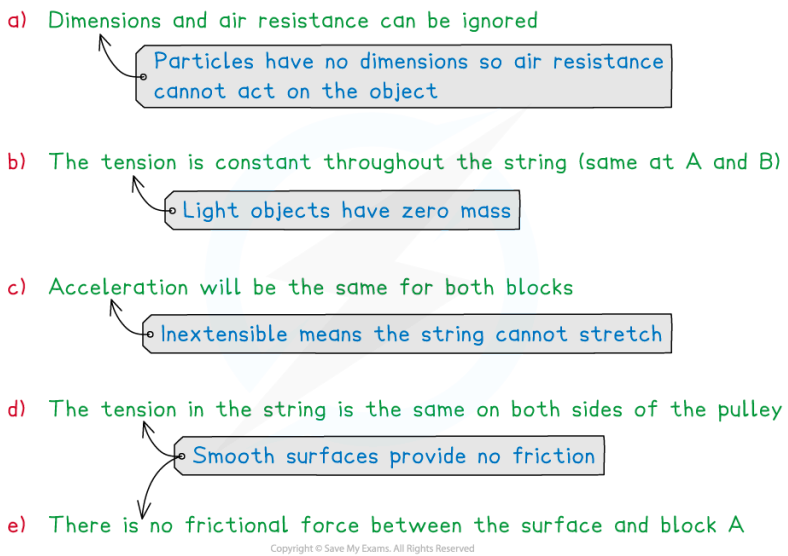
b) The string is light.

c) The string is inextensible.

d) The pulley is smooth.

e) The surface A is moving along is smooth.

Answer:



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