Rosary School – Marj Elhamam

Chapter 3 Forces and Movement

Name: ___________________ Date: _____ /_____ / 2025

Grade: 9 (   ) Subject: **Physics**

Summary notes

Objectives:

1.17 know and use the relationship between unbalanced force, mass and acceleration:

force = mass × acceleration   F = m × a

1.18 know and use the relationship between weight, mass and gravitational field strength:

weight = mass × gravitational field strength   W = m × g

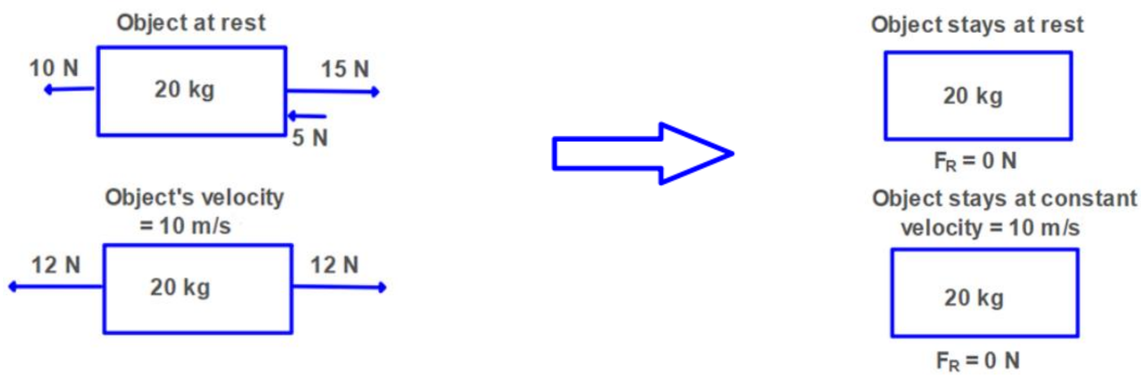
1.19 know that the stopping distance of a vehicle is made up of the sum of the thinking distance and the braking distance

1.20 describe the factors affecting vehicle stopping distance, including speed, mass, road condition and reaction time

1.21 describe the forces acting on falling objects (and explain why falling objects reach a terminal velocity)

Newton's laws:

- **Newton's first law** states that an object has a constant velocity unless acted on by a **resultant force**.



- **Newton's second law** states that the resultant force acting on an object is directly proportional to the acceleration, as long as the mass is constant.

$$\boldsymbol{force = mass \times acceleration}$$
$$\boldsymbol{(F = m \times a)}$$

- **Newton's third law** states that every action force has an **equal and opposite** reaction force. For example, the force of the Earth's gravity on an object is equal and opposite to the force of the object's gravity on the Earth.

Unbalanced Forces, Mass & Acceleration

- When forces combine on an object in such a way that they do not cancel out, there is a **resultant force** on the object.
- This resultant force causes the object to accelerate (i.e. changes its velocity)
    - The object might speed up
    - The object might slow down
    - The object might change direction
- The relationship between resultant force, mass and acceleration is given by the equation:

Force (resultant force) (N) = Mass (kg) x acceleration (m/s^2)

F = m × a

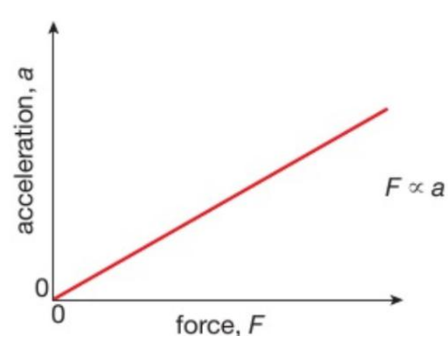
- F = resultant force, measured in Newtons (N)
  Resultant force can be written as F_R or ΣF
  Σ means SUM
- m = mass, measured in kilograms (kg)
- a = acceleration, measured in metres per second

→ For the same **mass,** force is directly proportional to acceleration

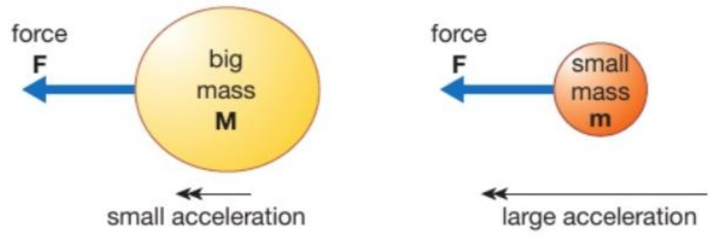
Different-sized forces are applied to objects with the same mass.
The small force produces a smaller acceleration than the large force.

$$a = \frac{F}{m}$$

$$a \propto F$$



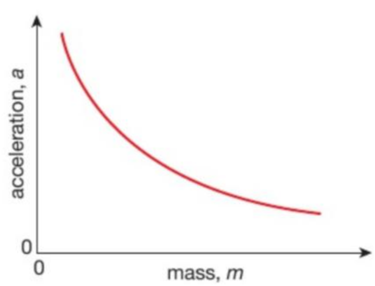
➔ For the same **force**, acceleration is inversely proportional to mass.

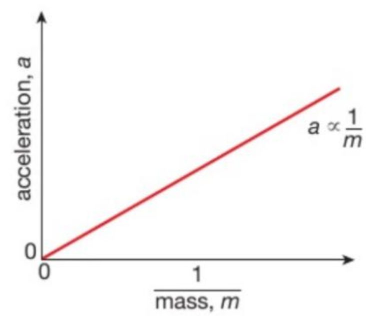


When the same force is applied to objects with different mass, the smaller mass will experience a greater acceleration.

$$a = \frac{F}{m}$$

$$a \propto \frac{1}{m}$$





Example 1:

A car salesman says that his best car has a mass of 900 kg and can accelerate from 0 to 27 m/s in 3 seconds.

a. Calculate the acceleration of the car in the first 3 seconds.
b. Calculate the force required to produce this acceleration.

Example 2: question 3 page 38

3 a Calculate the force required to make an object of mass 500 g accelerate at 4 m/s^2. (Take care with the units!)

b An object accelerates at 0.8 m/s^2 when a resultant force of 200 N acts upon it. Calculate the mass of the object.

c What acceleration is produced by a force of 250 N acting on a mass of 25 kg?

Example 3:

A passenger of mass70 kg travels in a car at a speed of 20 m/s. The vehicle is involved in a collision, which brings the car (and the passenger) to a halt in 0.1 seconds.

a. Calculate the deceleration of the car (and the passenger).
b. Calculate the decelerating force on the passenger.

Exam Tip

Remember that the **resultant force** is a **vector** quantity. You may be asked to comment on why its value is **negative**. This happens when the resultant force acts in the **opposite direction** to the object's motion, slowing them down (**decelerating** them) to a halt (final velocity v = 0m/s), this is why it has a minus symbol.

Stopping distance:

- The **stopping distance** of a car is defined as:
  The **total distance** travelled during the time it takes for a car to stop in response to some emergency.
- It can be written as an equation involving two distances:

Stopping distance = Thinking distance + Braking distance where:

- **Thinking distance** = the distance travelled in the time between the driver realizing he needs to brake and actually pressing the brakes (reaction time) in metres (m). (The distance travelled in the time it takes the driver to react to an emergency and prepare to stop). There is **no deceleration** during this time.
  Factors which ***increase*** the thinking distance include:
  - Greater **speed**.
  - The **reaction time** of the driver.
    The **reaction time** is a measure of how much time passes between seeing something and reacting to it. The average reaction time of a human is 0.25 s.
    Reaction time is **increased** by:
    - Tiredness
    - Distractions (e.g. using a mobile phone)
    - Intoxication (i.e. consumption of alcohol or drugs)

Reaction time can also be **decreased** by caffeine, which ***reduces*** the thinking distance.

- **Poor visibility** (fog) makes it difficult for a driver to identify a danger and causes him to take longer to respond.

➢ **Braking distance** = the distance travelled under the braking force in metres (m). The distance travelled in the time between pressing the brakes and the vehicle coming to a stop.

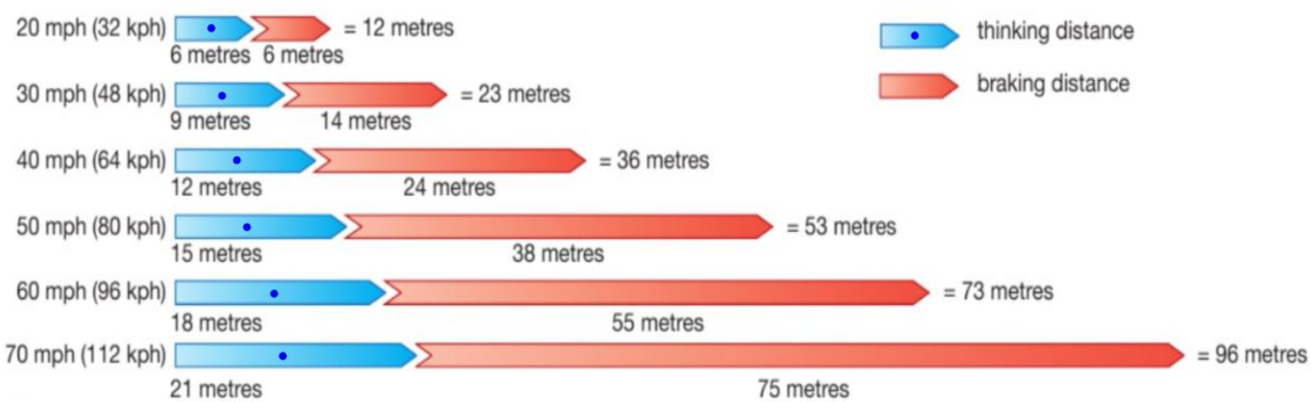
➢ For a given braking force, the greater the speed of the vehicle, the greater the stopping distance.

Factors which ***increase*** the stopping distance include:

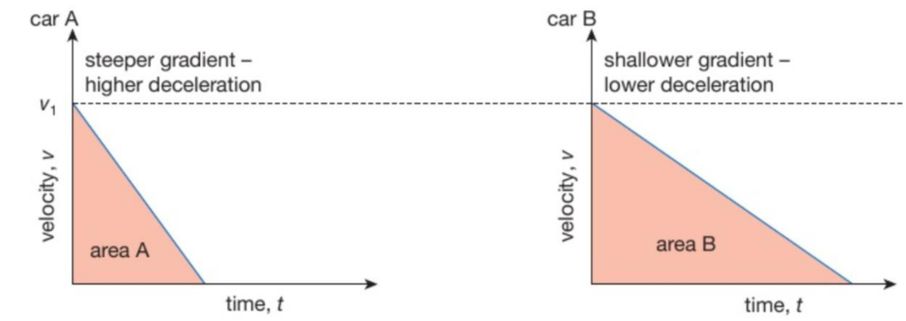
- Greater **speed.**
- Greater **mass**. Vehicles with large masses will have a smaller deceleration rate for a given force, therefore travel further while braking.
- Poor **road conditions** (icy, wet) or **car conditions** (worn tires, worn brake pads)

➢ **Stopping distance** = the sum of the thinking distance and braking distance, in metres (m)

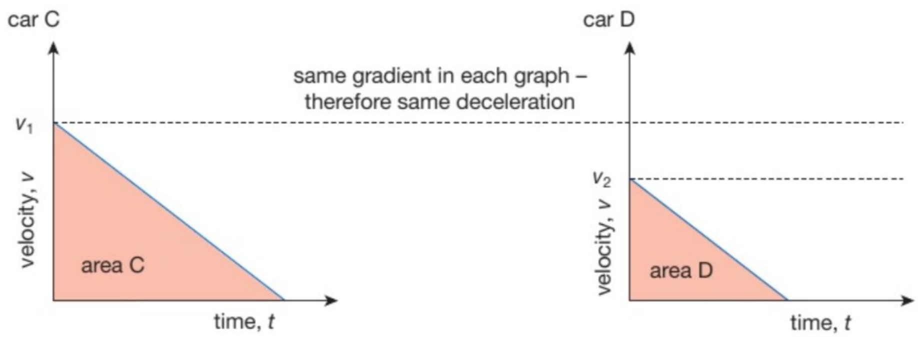
For a given braking force, the greater the speed of the vehicle, the greater the stopping distance.



▲ Figure 3.9 The stopping distance is the distance the car covers from the moment the driver is aware of the need to stop to the point at which the vehicle comes to a complete stop.



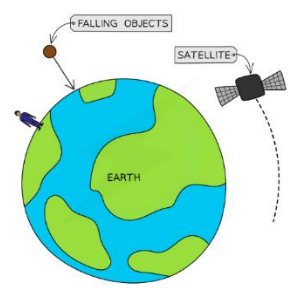
▲ Figure 3.10 Velocity–time graphs for two cars braking at different rates from the same speed, v_1, to rest.



▲ Figure 3.11 Velocity–time graphs for two cars braking at the same rate to rest, from different speeds, v_1 and v_2.

Weight

- **Weight** is defined as: The force acting on an object due to gravitational attraction.
- Planets have strong gravitational fields. Hence, they attract nearby masses with a strong gravitational force.
- Because of weight:
  - Objects stay firmly on the ground
  - Objects will always fall to the ground
  - Satellites are kept in orbit



- Weight, mass and gravitational field strength are related using the equation:

$$\boldsymbol{weight = mass \times gravitational\ field}$$

This can also be written as:

$$\boldsymbol{W = m \times g}$$

- $\boldsymbol{g}$ is known as the acceleration due to gravity or the gravitational field strength.
- On Earth, this is equal to $9.81 m/s^2$ (or N/kg) $\approx 10\ m/s^2$
- The weight that an object experiences depends on:
  - The object's mass.
  - The mass of the planet attracting it.

- Mass (measured in kilograms, kg) is related to the amount of matter in an object.
- Weight (measured in newtons, N) is the force of gravity on a mass.
- The weight of an object and the mass of an object are directly proportional.
- The size of this force depends on the gravitational field strength (often called gravity, ***g***, for short)

Example 6:

NASA's Artemis mission aims to send the first woman astronaut to the Moon, Isabelle hopes to one day become an astronaut. She has a mass of 40 kg.

Take the Earth's gravitational field strength as 10 N/kg, and the Moon's gravitational field strength as 2 N/kg. Comment on the difference between Isabelle's weight on Earth, and her weight on the moon.

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<u>Terminal velocity:</u>

Terminal velocity is the fastest speed that an object can reach when falling.

Terminal velocity is reached when:

- o The upward and downward acting forces are balanced.
- o The resultant force on the object reaches zero.
- o The object no longer accelerates, and a constant terminal velocity is reached.

Falling objects

Falling objects experience two forces:

- o Weight
- o Air resistance

- The force of **air resistance** increases as the object's speed increases. This is because the object collides with air particles as it moves through the air. The faster the object is travelling, the more collisions it has with the air particles.
- The **weight** of the object does not change. This is because W = mg
  The mass (m) of the object does not change.
  The acceleration of freefall(g) does not change.

Reaching terminal velocity

Skydiver in freefall reaching terminal velocity:

The skydiver initially accelerates downward due to the force of weight. The upward force of air resistance increases as they fall until eventually it equals the weight force and terminal velocity is reached

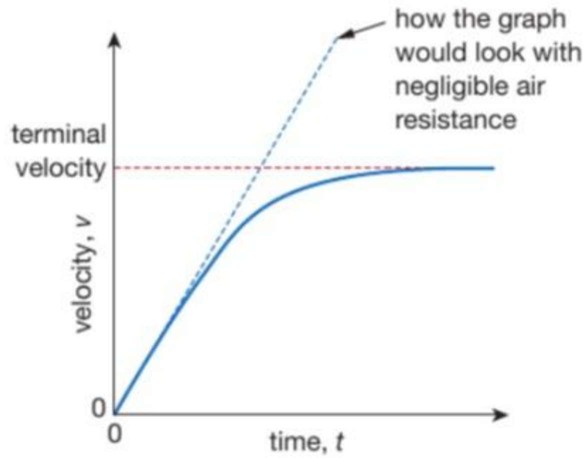
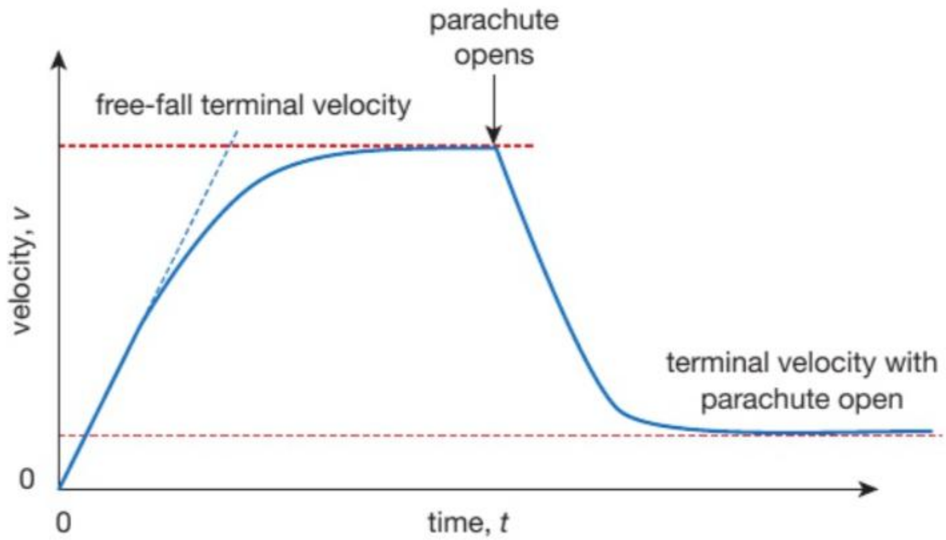


Figure 3.15 The velocity–time graph for an object accelerating until it reaches terminal velocity

- At the instant the skydiver steps out of the plane, the support force of the plane is no longer acting on the skydiver, but they are not yet falling, so the only force exerted on her is the weight force.
- There is a downward acting resultant force on the skydiver. The resultant force is equal to the weight force. The skydiver accelerates downwards at maximum acceleration.
- As the skydiver begins to fall, the force of air resistance is very small because the skydiver's speed is small. There is a downward acting resultant force on the skydiver.
- The resultant force is equal to the weight force minus the force of air resistance. The skydiver accelerates downward but the acceleration decreases.
- As the skydiver accelerates, their speed increases, so the force of air resistance increases. There is a downward acting resultant force on the skydiver. The resultant force is equal to the weight force minus the force of air resistance. The skydiver accelerates downward, but the acceleration continues to decrease.
- As the skydiver's acceleration decreases, her speed increases at a slower and slower rate. Eventually, the skydiver reaches a speed at which the force of air resistance is equal to the force of weight. The forces are balanced, so the resultant force is zero. The skydiver no longer accelerates, and a constant velocity is reached. This is **terminal velocity**.



▲ Figure 3.17 Velocity–time graph for a free-fall parachutist reaching terminal velocity, then opening the parachute

<u>Past papers questions</u>:

1- 4PH0 Jan 2018 1P – Q3

3 The driver of a car sees an obstacle in the road and stops the car as quickly as possible.

The car stops without hitting the obstacle.

State three factors that could have affected the stopping distance of the car.

(3)

1 ....

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2 ....

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3 ....

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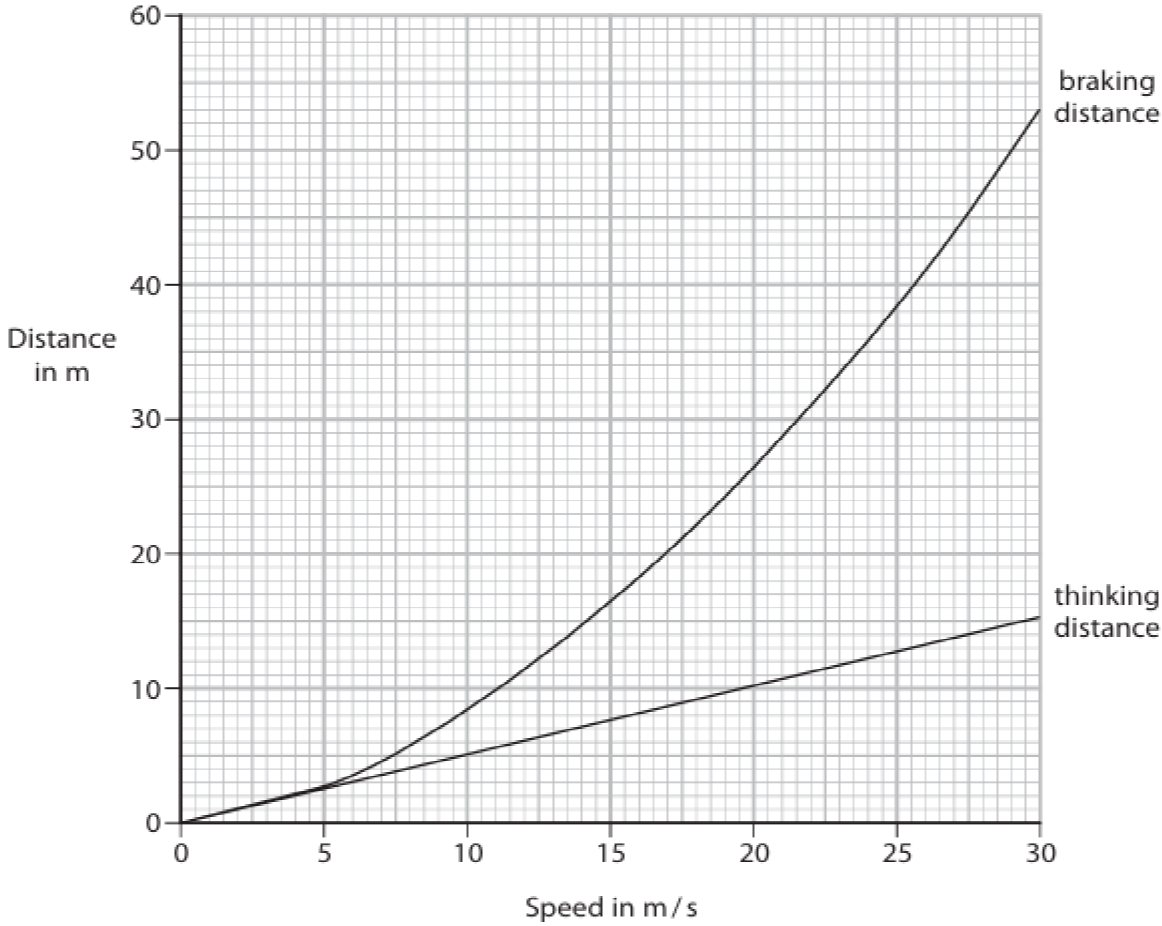
(Total for Question 3 = 3 marks)

2- 4PH1 Jan 23 1P – Q5

5 The graph shows how the thinking distance and the braking distance vary with the speed of a car.



(a) Which of these does **not** affect thinking distance?

(1)

- ☒ **A** alcohol consumed by the driver
- ☒ **B** condition of the road
- ☒ **C** speed of the car
- ☒ **D** tiredness of the driver

(b) Which of these would increase the braking distance of the car?

(1)

- ☒ **A** faster reaction time of driver
- ☒ **B** ice on the road
- ☒ **C** more powerful brakes
- ☒ **D** tyres with more grip

(c) Determine the stopping distance of the car when the speed of the car is 20 m / s.

(3)

stopping distance = ... m

(d) (i) State the formula linking average speed, distance moved and time taken.

(1)

(ii) Determine the reaction time of the driver of the car.

(3)

reaction time = ... s

(e) Calculate the mean braking acceleration of the car as it brakes to a stop from an initial speed of 30 m / s.

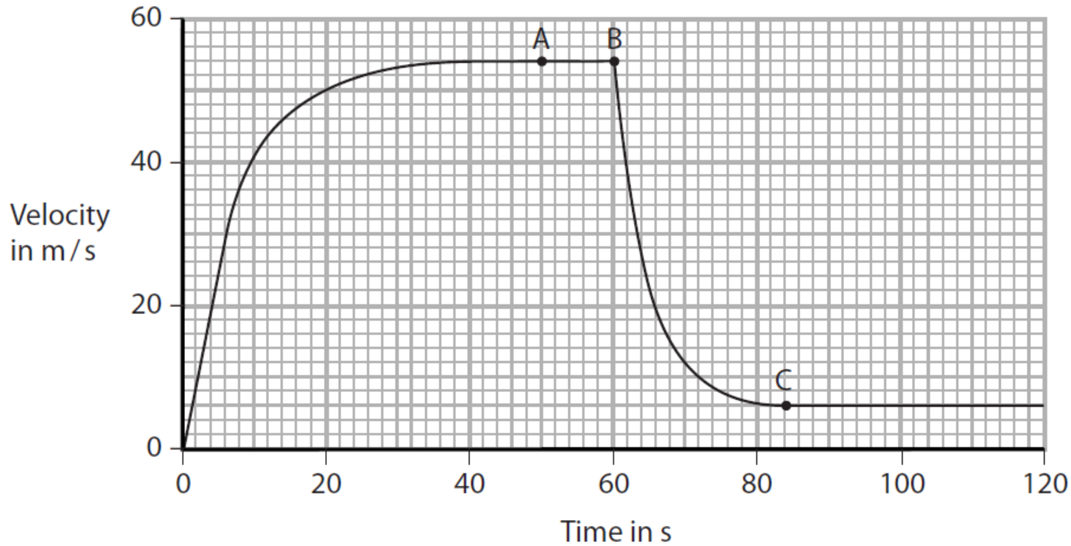
(4)

acceleration = ... m / s^2

(Total for Question 5 = 13 marks)

3- **4PH1 May 2019 1PR - Q8**

8 The graph shows how the velocity of a parachute jumper changes with time.



(a) At point A, the parachute jumper is falling at terminal velocity and has not yet opened her parachute.

(i) Which statement is correct about the parachute jumper at point A?

(1)

- ☒ **A** acceleration and air resistance are equal
- ☒ **B** acceleration and velocity are equal
- ☒ **C** weight and acceleration are equal
- ☒ **D** weight and air resistance are equal

(ii) Which is the best estimate of the distance fallen by the parachute jumper from the start until point A?

(1)

- ☒ **A** 50 m
- ☒ **B** 1300 m
- ☒ **C** 2300 m
- ☒ **D** 2700 m

(b) The parachute jumper opens her parachute at point B.

Her velocity decreases until she reaches terminal velocity again at point C.

Explain this change in velocity.

(4)

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(c) After point C, the parachute jumper continues to fall at a constant velocity.

As she falls, energy is transferred from a gravitational store.

Which store is the energy transferred into?

(1)

☒ **A** chemical store

☒ **B** gravitational store

☒ **C** kinetic store

☒ **D** thermal store

(Total for Question 8 = 7 marks)

7 A skydiver jumps from an aircraft.

(a) The mass of the skydiver is 70 kg.

(i) State the equation linking weight, mass and g.

(1)

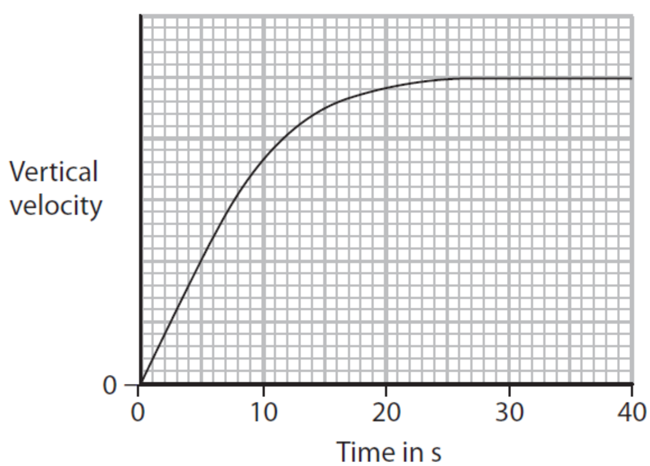
(ii) Calculate the weight of the skydiver and state the unit.

(2)

weight = ... unit ....

(b) The graph shows the vertical velocity of the skydiver during the first 40 s of the fall.

His parachute is not open during this time.



Explain the shape of the graph.

(4)

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(c) The diagram shows the skydiver falling at a constant velocity.

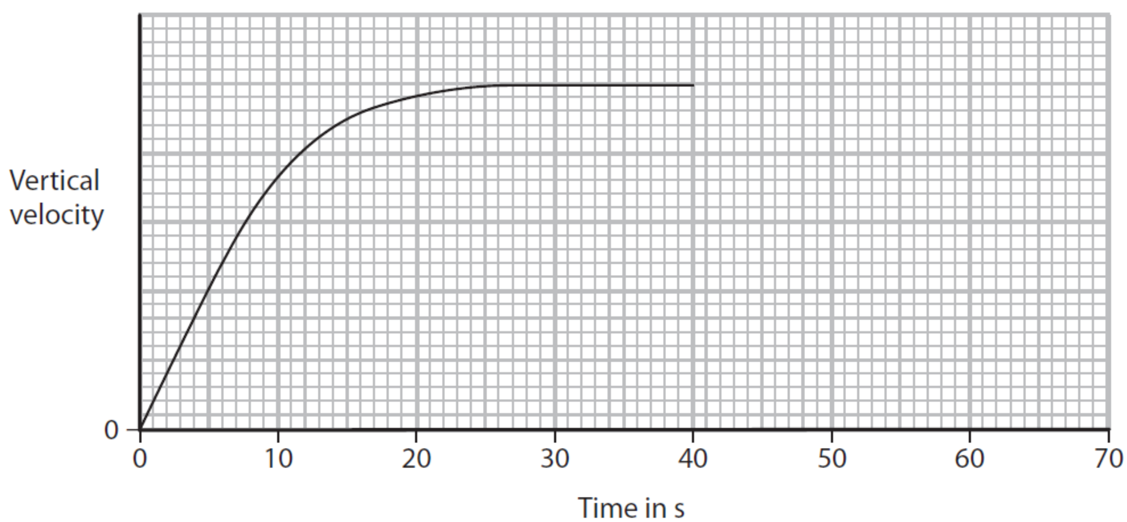
Add **two** labelled arrows to the diagram to represent the forces acting on the skydiver.

(3)

(d) The skydiver opens his parachute after 40 s.

Continue the line on the graph to show how the skydiver's vertical velocity changes and reaches terminal velocity.

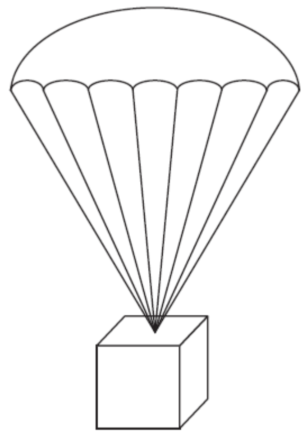
(2)



(Total for Question 7 = 12 marks)

5- 4PH0 JAN 2015 1P – Q12

12 The diagram shows a box attached to a parachute, falling at constant velocity.



(a) State the name for this constant velocity.

(1)

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(b) Explain, in terms of forces, why the box and parachute fall at constant velocity.

(4)

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(Total for Question 12 = 5 marks)