Physics

Year 1

SECTION

2

MOTION AND PRESSURE

MECHANICS AND MATTER

Kinematics

Dynamics

INTRODUCTION

This second section covers key areas such as motion and its type, equations of motion and graphical representation of motion, Newton's three laws of motion, Pressure and Pascal's principle. The first point of discussion will be on motion. This introduces you to various types of motion with respect to the position of an object and how these happen in real-life situations. You will further be led through a series of explorative activities that will guide you to understand the three laws formulated by Sir Isaac Newton, the basic concepts and principles behind each law, and how different variables interconnect to describe the motion of objects. Newton's laws of motion talk about Newton's three laws of motion, which explain the relationship between the motion of a physical object and the forces acting upon it. By applying Newton's laws to real-life situations, you can predict the motion of objects experiencing forces and anticipate outcomes in various scenarios. Pressure and Pascal's principle will be discussed as well. The lessons on Pressure and Pascal's principle, which are fundamental concepts in fluid mechanics and the basis for brake systems and hydraulic press, provided you with essential knowledge about the concept of pressure, its relationship with depth and the principles of hydrostatics. You will understand that pressure in a fluid increases with depth. There are practical demonstrations and experiments related to the brake system and hydraulic press to help foster a hands-on application of all these Engineering concepts. You will further appreciate the significance of pressure transmission in enclosed fluids, realising how a small force applied at one point can result in a significant force at another. Moreover, an understanding of pressure informs various scientific and industrial applications, contributing to advancements in technology and everyday practices.

At the end of this section, you should be able to;

- Describe the various types of motion, i.e. circular, oscillatory, rectilinear, spin and random.

- Establish equations of uniformly accelerated motion and its application in daily life.
- Represent the motion of objects graphically, i.e. distance-time, displacement-time and velocity-time and deductions that can be made from it.
- State Newton's laws of motion.
- Identify daily applications of Newton's laws of motion.
- Apply Newton's second law to establish the relationship between force, mass and acceleration.
- Explain how pressure changes with depth in a fluid.
- Explain the operation of brake systems in vehicles and the operation of the hydraulic press.
- State Pascal's principle.

Key Ideas

- **Motion** is explored through key aspects such as circular motion (motion along a circular path), oscillatory motion (repetitive back-and-forth motion), rectilinear motion (straight-line motion), spin motion (rotation around an axis), and random motion (unpredictable motion). It also involves the equations of uniformly accelerated motion and interpreting distance-time, displacement-time, and velocity-time graphs.
- **Newton's laws of motion** include three principles: The first law, the second law and the third law of motion.
- **Newton's First law of motion**: An object remains at rest or in uniform motion unless acted upon by a resultant force.
- **Newton's Second law**: The resultant force on an object equals its mass times its acceleration (F=ma).
- **Newton's Third law**: Every action has an equal and opposite reaction.
- Newton's laws explain everyday phenomena such as car acceleration, seatbelt use, and gun recoil. Applying Newton's second law helps establish the relationship between force, mass, and acceleration, showing that

force is directly proportional to acceleration and inversely proportional to mass.

- **Pressure in a fluid** increases with depth due to the weight of the fluid above. This principle is utilised in hydraulic systems such as vehicle brake systems and hydraulic presses, which use incompressible fluids to transmit force through confined spaces.
- **Pascal's principle** states that a change in pressure applied to an enclosed fluid is transmitted undiminished to all portions of the fluid and to the walls of its container.

MOTION AND EQUATIONS OF MOTION

Understanding these concepts is crucial for various fields such as physics and engineering, providing the foundation to analyse and predict the behaviour of moving objects in both academic and practical contexts.

Types Of Motion

Motion is the change in position of an object over time relative to a reference point. It is described by parameters such as displacement, distance, velocity, acceleration, time, and speed.

This lesson takes you through activities that will help you understand how things move differently in the world. Through your explorations, you will unlock the secrets of how objects travel. This is important to help you understand how things behave in nature and in the technology, we use every day.

Begin your journey of exploration.

There are different types of motion you can explore.

Activity 2.1 Exploring the types of motion

1. Work individually or in pairs.
2. Research on any one of the following types of motion (you may choose one for yourself, or your teacher may decide for you):
   a. Rectilinear
   b. Circular

c. Oscillatory
d. Rotational
e. Random (Brownian)

3. Record your research findings along the following guidelines:
   a. What are the characteristics of the motion?
   b. What are some examples of the motion?
   c. What are some real-life applications of the motion?

Use diagrams, graphs, animations and real-life examples to illustrate your findings.

4. Present your findings to other students who have investigated a different type of motion from yours.
5. For each type of motion presented to the class, complete the table below by providing a detailed description/definition, drawing a diagram, and giving a relevant example. Analyse the types of motion and relate them to real-world applications.

An example is given for rectilinear motion, but you are welcome to add further detail following the presentations.

Note: Definitions and examples can be found in **Annex 2.1**.

Table 2.1: Summary of types of motion, diagrams and real-world application

Type of Motion	Description/ Definition	Diagram	Example & Real-World Application
Rectilinear Motion	Motion along a straight line.		**Example:** A car driving on a straight highway. **Application:** Used in analysing motion in transportation systems.
Circular Motion			
Rotational/ Spin Motion			
Oscillatory Motion			
Random Motion			

Activity 2.2 Exploring types of motion through models

Research the internet to explore how the types of motion have been explained using models.

You may also explore some models in your Physics laboratory or the science section of a library with the help of your teacher.

Note that conclusions can be found in **Annex 2.3**.

A. Rectilinear Motion Model

Objective: Explore characteristics of linear motion using a toy car and a ramp.

Materials needed:

- Toy car or small wooden cart
- Wooden plank or cardboard (for ramp)
- Stopwatch or timer
- Measuring tape or ruler

What to do:

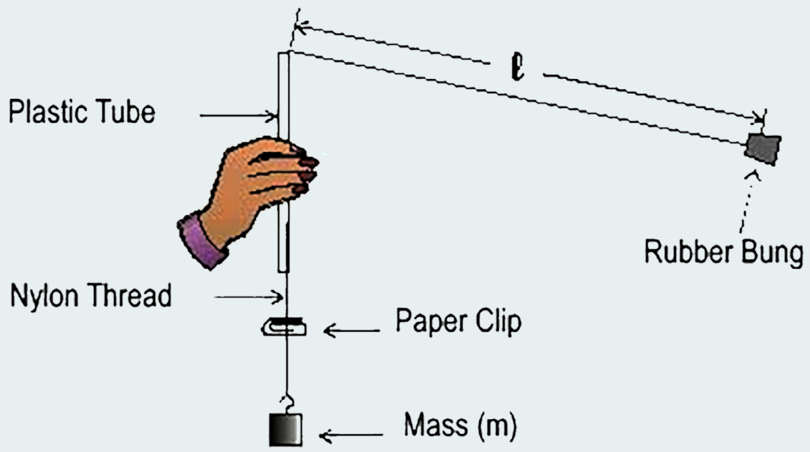
1. Set up the ramp.
2. Release the car and measure time and distance to calculate average speed (= distance/time).
3. Experiment with different inclined planes (adjust the height of the ramp by hand or by resting the end on a pile of books).
4. Plot a graph of average speed against the angle between the ramp and the table.
5. Discuss the impact of ramp angle on average speed.
6. Predict the effects of changing ramp surface.

B. Circular Motion Model

Objective: Explore circular motion using a ball or weight tied to a string and passed through a hollow tube, with more weights hung from the bottom of the string (see diagram below).

Materials needed:

- String or twine
- Small ball or stone
- Hollow tube (e.g. pen casing)
- Paper clip
- Hanging masses
- Ruler
- Stopwatch



What to do:

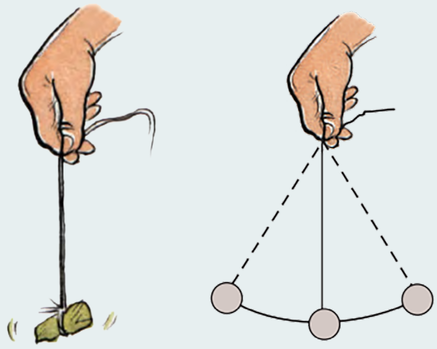
1. Set up the equipment as shown in the diagram below.
2. Swing the ball in a circular path, trying to keep the paperclip in a constant position.
3. Calculate the frequency of the rotation by using the formula frequency = 1 / time period.
4. Discuss forces keeping the ball in motion.
5. Analyse the effects of changing the weight of the hanging masses on the frequency of the orbit required to keep the paperclip in a constant position.

C. Oscillatory Motion Model

Objective: Explore oscillatory motion using a pendulum.

Materials needed:

- String or twine
- Small rock or seed
- Stopwatch or timer



What to do:

1. Swing the pendulum and measure oscillation time.
2. Experiment with different lengths and weights.
3. Discuss the impact of length and weight on the time for one complete swing (time to return to original position).

D. Rotational Motion Model

Objective: Explore rotational motion using a spinning object.

Materials needed: Small flat object (coin or bottle cap)

What to do:

1. Spin the object and observe rotation.
2. Note duration and speed changes.
3. Discuss factors affecting spin duration.

Equations of Motion

Equations of motion provide a framework for understanding and predicting how objects move, and their applications are applied to various aspects of our daily lives such as transportation, sports, technology, etc.

Let us do an activity to help us define the different types of motion.

Activity 2.3 Definitions of types of motion

1. With the person sitting next to you, or in groups, come up with your own definitions for the following terms:

a. Displacement
b. Initial velocity
c. Final velocity
d. Acceleration
e. Time
f. Average velocity
g. Instantaneous velocity

2. Deriving the Equations of Motion

Use the graph below, showing the motion of an object accelerating uniformly from a velocity u to a velocity v over a time t, to derive the equations of motion.

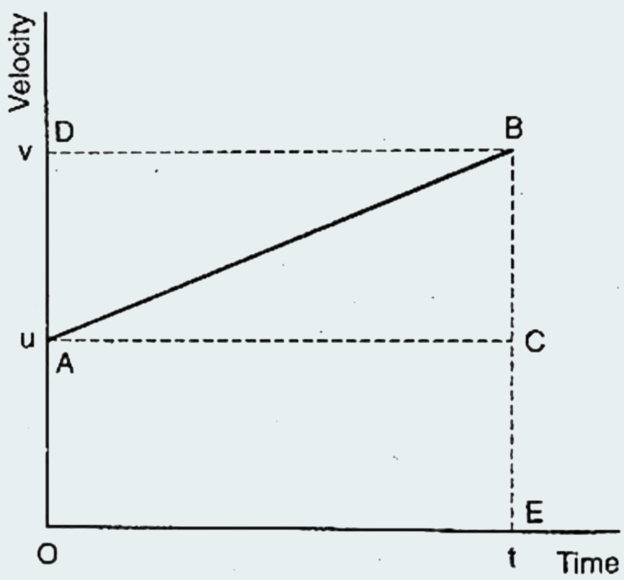


Fig. 2.1: A velocity-time graph for deriving equations on motion

You may or may not choose to do this with the guidance of your teacher.

The gradient of the graph gives the acceleration, a, of the object.

$$\text{Gradient} = \frac{\text{change in } y}{\text{change in } x}$$

a. Give an expression for this in terms of *a, v, u* and *t*.

b. Rearrange to make *v* the subject to arrive at the first equation of motion: v = ...

The area under the line gives the displacement, s, of the object:

Area of trapezium = area of rectangle + area of triangle

a. Give an expression for this in terms of s, v, u and t

b. Replace (v-u) with (at), as per the first equation of motion

This is the second equation of motion, s = ...

Make t the subject of the first equation, and substitute this into the second equation. Make v^2 the subject.

This is the third equation of motion, v^2 = ...

Extension Question: Can you also get to equation 3 via a different method, using the formula for the area of a trapezium to find the displacement?

Now let us apply these concepts to solve some questions.

Activity 2.4 Application of the equations of linear motion

Worked Example 2.1

A car accelerates from rest at a constant rate of 3 m/s². How long will it take for the car to travel a distance of 150 meters?

Solution

Identify the known quantities and desired quantities:

Initial velocity, u = 0 m/s (since the car starts from rest)

Acceleration,a = 3 m/s^2

Distance, s = 150 m

The desired quantity is time.

Choose the appropriate equation of motion:

The equation that relates distance, initial velocity, acceleration, and time is:

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

Substitute the known values into the equation:

$$150 = 0 \times t + \frac{1}{2} \times 3 \times t^2$$

Simplify the equation:

$$150 - \frac{3}{2} \times t^2$$

Solve for t:

Multiply both sides by 2:

$$300 = 3t^2$$

Divide both sides by 3: $100 = t^2$

$$t = \sqrt{100}$$

$$t = 10s$$

Answer: The car will take 10 seconds to travel 150 meters.

Trial Questions 1

1. A car travelling at 20 m/s begins to decelerate at a constant rate of 2 m/s². How far will the car travel before coming to a complete stop? Additionally, how long will it take for the car to come to rest?
2. A cyclist accelerates from 5 m/s to 15 m/s over a distance of 50 meters. What is the cyclist's acceleration?
3. A car travelling at 30 m/s sees an obstacle 100 meters ahead and decelerates uniformly at 5 m/s². Determine whether the car will stop before hitting the obstacle. If it stops, calculate the distance from the obstacle where the car stops. If it does not stop, calculate the speed of the car when it reaches the obstacle.

Motion Under Gravity

Motion under gravity refers to the movement of an object that is influenced by the force of gravity. This force causes objects to accelerate downward toward the Earth at a constant rate, denoted by g, which is approximately $9.8\,ms^{-2}$.

Conventionally we treat **downwards** as being the **positive** direction. Hence,

1. When the body is moving downwards, the acceleration (g) due to gravity is positive (i.e. +g) hence the equations become,

   $v = u + gt$ ....(4)

   $h = ut + \frac{1}{2}gt^2$ ....(5)

   $v^2 = u^2 + 2gh$ ....(6)

2. When the body is moving or is thrown upwards, the acceleration due to gravity (g) becomes negative (i.e. -g) hence the equations become:

   $v = u - gt$ ....(7)

   $h = ut - \frac{1}{2}gt^2$ ....(8)

   $v^2 = u^2 - 2gh$ ....(9)

Where;

v = final velocity

g = acceleration due to gravity

h = displacement (vertical distance fallen)

u = initial velocity (usually $0\,ms^{-1}$ as the object starts from rest)

g = acceleration due to gravity ($9.8ms^{-2}$ on Earth)

t = time elapsed

Trial Questions 2

1. A stone is dropped from the top of a cliff that is 80 meters high. Calculate (a) the time it takes for the stone to hit the ground and (b) the velocity with which it hits the ground. Assume there is no air resistance.
2. A rocket is launched vertically with an initial velocity of 50 m/s and accelerates uniformly at 4 m/s^2 for 12 seconds. After this period, the rocket's engine stops, and it continues to move upwards under the influence of gravity (assuming g $=10\,m/s^2$) until it reaches its maximum height. Determine the maximum height attained by the rocket.

Graphical Representation of Motion of Objects

Graphs are often used to represent the motion of objects over time. The most common graphs used for motion are:

- Distance-time
- Displacement- time
- Velocity-time

Let us explore these three types of graphical presentations.

Distance-Time Graphs

Worked Example 2.2

Scenario 1

A car travels at a constant speed of 60 km/h. use the data provided below to plot a distance-time graph and calculate the total distance travelled by the car

Distance (km)	0	60	120	180	240	300	360
Time (hr)	0	1	2	3	4	5	6

Solution

Since the car is travelling at a constant speed, the distance increases linearly with time. For every hour, the car travels 60 kilometres.

- After 1 hour, the distance is 60 km.
- After 2 hours, the distance is 120 km.
- After 3 hours, the distance is 180 km. etc

The graph of this scenario will be a straight line with a slope representing the speed of 60 km/h.

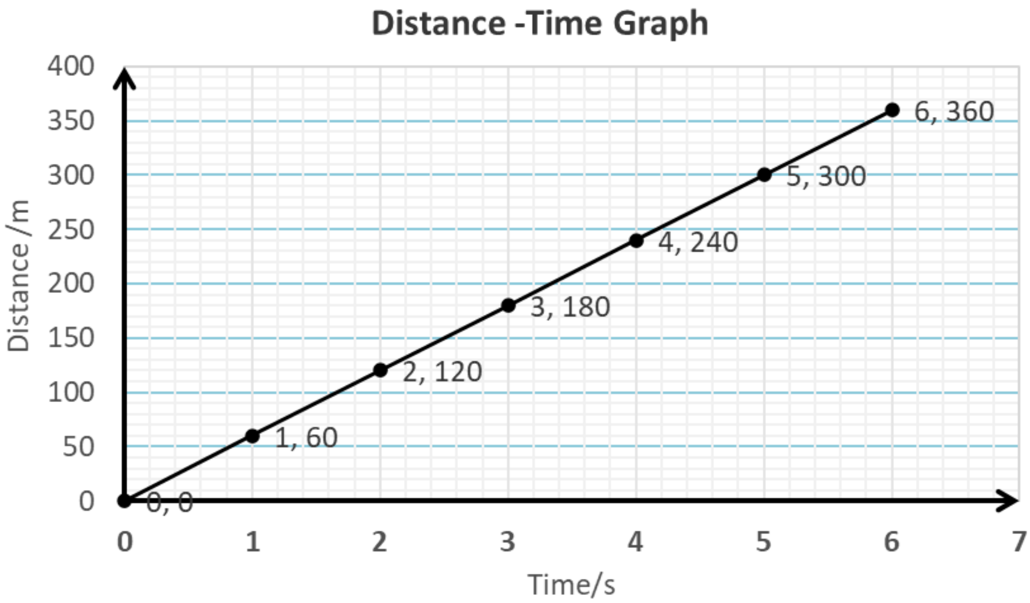


Fig. 2.2: A distance-time graph

Total distance travelled:

- The car travels for 6 hours.
- Distance = Speed × Time = 60 km/h × 6 h = **360 km.**

Trial Questions 3

1. Amina spends her day running errands and visiting a friend. She walks from her house to the park in 5 minutes, covering 150 meters steadily. She rests at the park for 5 minutes, keeping her distance from home constant. Then, she walks 100 meters to the grocery store, reaching it by the 15th minute. After shopping for 5 minutes with her distance constant at 250 meters, she walks 300 meters to her friend's house, arriving by the 30th minute. She stays there for 10 minutes, keeping her distance constant at 550 meters. Finally, Amina walks back home, covering the 550 meters in 10 minutes and returning by the 50th minute. Based on this scenario, create a table of the data and create a distance-time graph to represent Amina's journey.
2. The table below shows the time and distance for a runner to complete a race.

Distance (meters)	0	50	100	150	200
Time (seconds)	0	10	20	30	40

Use this data to:

a. draw the distance-time graph representing the runner's motion.

b. calculate the total distance of the runner.

Share your work with a friend or subject teacher.

Position-Time graphs

Position can be positive or negative depending on the reference point ('in front' of the reference is positive and 'behind' of the reference is negative).

Trial Questions 4

1. How far does Kwaku walk from his home, and in what time frame, if he starts at 0 metres, walks 300 metres to the park in 10 minutes at a constant speed, rests at the park for 5 minutes with his position unchanged, and then walks back home at the same constant speed in 10 minutes? Also calculate his velocity at each section of his journey.
2. Akua goes for a morning walk from her house to the nearby market and then returns home.

Use the table provided, draw a displacement-time graph representing Akua's walk.

Position (metres)	0	100	200	200	0
Time (minutes)	0	5	10	15	20

Calculate Akua's average speed during her walk. Assume Akua walked for 20 minutes and covered a total distance of 400 meters. Give your answer in m/minute, m/hr and m/s.

Velocity-Time Graphs

The key features of a velocity-time graph are as follows:

1. ***Slope:*** The slope of the graph indicates acceleration. A positive slope indicates positive acceleration, a negative slope indicates deceleration, and a zero slope indicates constant velocity.
2. ***Area under the curve***: The area under the graph represents displacement (the total distance travelled).
3. ***Zero Velocity:*** When the line touches the horizontal axis, the object is at rest.

Worked Example 2.3

A car accelerates from rest to 20 ms^{-1} in 5 seconds, travels at constant velocity for 10 seconds, then decelerates to a stop in 5 seconds. This data is given in the table below:

Time (seconds)	0	5	10	15	20
Velocity (m/s)	0	20	20	20	0

i. On a sheet of graph paper, draw a horizontal line and label it (Time(s)) and scale it from 0 to 20 seconds with 5-second intervals.
ii. Draw a vertical line intersecting the horizontal-axis at 0. Label this line velocity (ms^{-1}) and scaled it from 0 to 20 ms^{-1} in 5 ms^{-1} intervals.
iii. Plot the points.

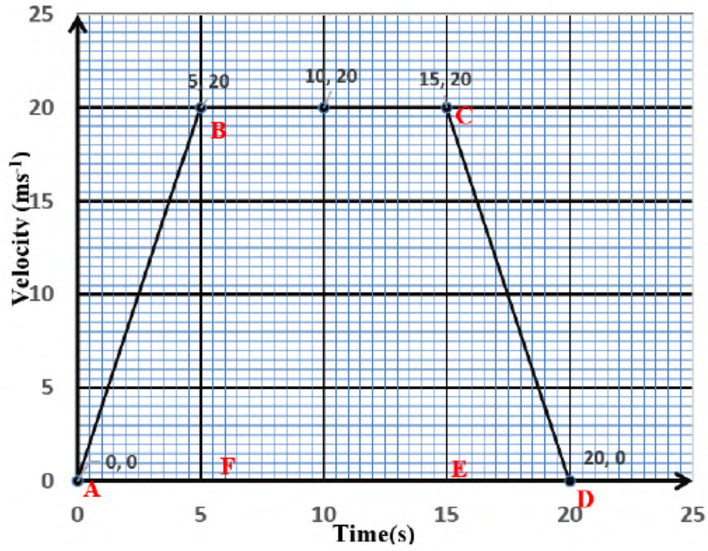


Fig. 2.3: Velocity-time graph

iv. Use a ruler to draw straight lines connecting the points in sequence.

Calculating the total displacement (total area under the velocity-time graph)

Look at the velocity-time graph and identify the geometric shapes formed under the graph.

- From 0 to 5 seconds: A triangle (*acceleration phase*)
- From 5 to 15 seconds: A rectangle *(constant velocity phase*)
- From 15 to 20 seconds: Another triangle (*deceleration phase*)

1. **Calculate the Areas:**

a. Triangle ABF (0 to 5 seconds):

Base = 5 seconds

Height = 20 m/s

Area = $\frac{1}{2} \times$ Base $\times$ Height

Area = $\frac{1}{2} \times 5 \times 20 =$ **50 m**

b. Rectangle BCEF (5 to 15 seconds):

Base = 10 seconds

Height = 20 ms^{-1}

Area = Base $\times$ Height

Area = $10 \times 20 =$ **200 m**

c. Triangle CED (15 to 20 seconds):

Base = 5 seconds

Height = 20 ms^{-1}

Area = $\frac{1}{2} \times$ Base $\times$ Height

Area = $\frac{1}{2} \times 5 \times 20 =$ **50 m**

2. Sum the Areas:

Total Area (displacement) = 509 m + 200 m + 50 m = **300 m**

Alternatively, the formula for calculating the area of trapezium could be used

$$\text{Area} = \frac{1}{2}(a + b) \times h$$

Where:

a and **b** are the lengths of the two parallel sides (also called bases).

h is the height (perpendicular distance) between the two parallel sides.

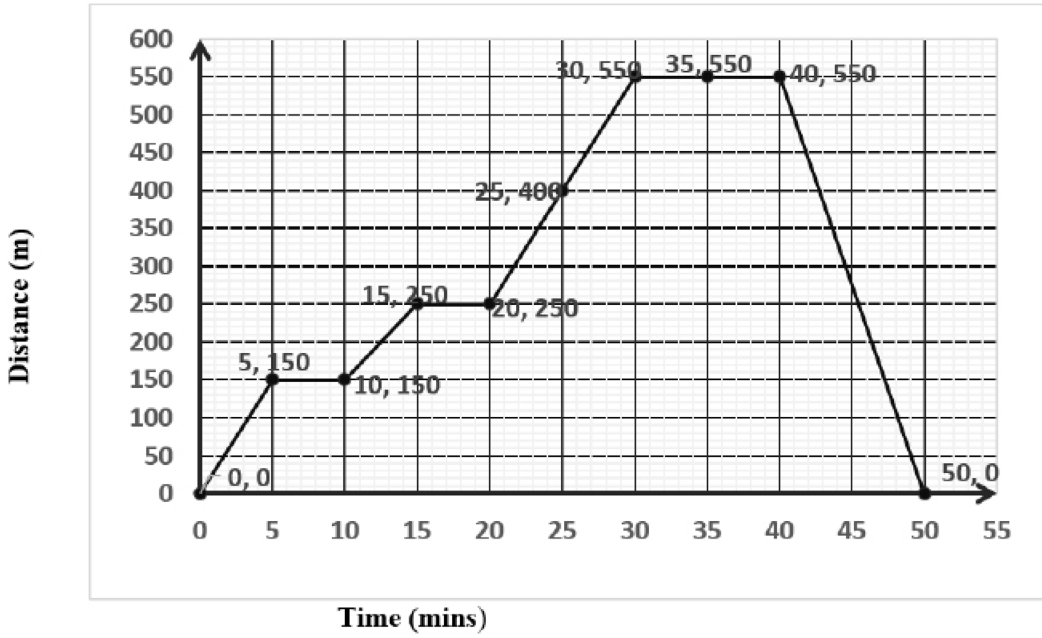
From the graph

Area = $\frac{1}{2}(20 + 10) \times 20$

Area = 300 m

Trial Questions 5

1. A runner starts from rest, accelerates to 8 m/s in 4 seconds, maintains this speed for 6 seconds, and then decelerates to rest in 4 seconds. Plot the velocity-time graph and use the graph to calculate the total distance.
2. Draw a motion graph and an accompanying story that includes various types of motion, including periods at which the object is stationary, accelerating, decelerating, and moving at a constant speed.
3. Analyse the information shown in the distance-time graph below to instead plot a velocity-time graph showing the same information. Compare with a peer or teacher.

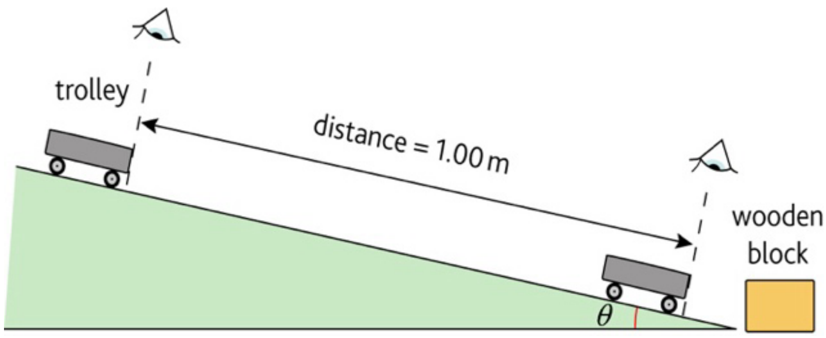


Extension task: No solutions

Motion Practical and Graph Skills

Equipment and materials:

- a ramp resting on a wooden block (or a pile of books, etc)
- a trolley or toy car
- a metre rule
- a set square or protractor
- a second wooden block (to stop the trolley)
- a stopwatch to time the trolley



Use the equipment listed above to measure instantaneous velocity against time and plot a graph of your results to find the acceleration of the trolley. Instantaneous velocity can be found by marking the track at 5-10cm intervals and using the formula: speed = distance/time for each interval. A slow-motion camera may be helpful.

Newton's Laws of Motion

Welcome. Today, we are going to explore the exciting world of motion through Newton's laws. These three fundamental principles explain how everything around us moves, from the smallest particles to the largest planets. First, we will learn about Newton's three laws of motion, which describe how objects behave at rest, in motion, and when forces interact. Next, we will look at how these laws apply to our everyday lives (think about how cars accelerate, how we walk, and even how sports work). Finally, we will dive into Newton's second law to understand the relationship between force, mass, and acceleration. Get ready for some fun activities and real-life examples that will make these concepts come alive. Let us get started on this journey of discovery and see how Newton's laws shape the world around us.

Let us dive into the fascinating world of Newton's laws of motion, formulated by Isaac Newton to describe how objects move when forces act on them. These laws are fundamental in physics and explain so many things we observe every day.

Activity 2.5

1. Draw diagrams to represent the direction, magnitude and nature of the forces acting on objects in the following situation:

   A vehicle has broken down, and as responsible citizens, you know that it needs to be towed off the road to prevent other vehicles from crashing into it.

2. Compare with a peer or teacher.

Newton's First Law: The Law of Inertia

A body will continue in its state of rest or uniform motion in a straight line unless acted upon by an unbalanced force.

Inertia describes the tendency or reluctance of an object to alter its state of motion. This tendency means that an object at rest will resist being set in motion, while an object in motion will resist any attempts to change its velocity or direction.

Think about this: Imagine you are in a moving vehicle, and it suddenly stops. Your body tends to keep moving forward because of inertia, and you might feel a jerk. Have you ever felt that? Why do you think seatbelts are important? Share your thoughts with a friend.

Activity 2.6 Demonstrating inertia with a pile of books and a tablecloth

Materials needed:

- a smooth table
- a tablecloth (preferably smooth and thin)
- a pile of books (start with a few lightweight books and gradually increase the weight)

What to do:

1. Preparation:

a. Lay the tablecloth flat on the table, ensuring there are no wrinkles or folds.

b. Place the pile of books in the centre of the tablecloth. Make sure the books are stacked neatly and stably.

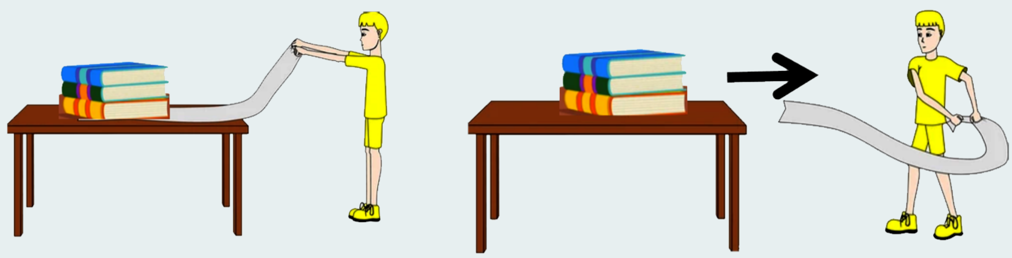
c. What do you think will happen to the books when we pull the tablecloth? Why?

2. Share your thoughts with a friend.

3. Investigate:

- Stand at one end of the tablecloth and firmly grip the edges.
- Quickly and smoothly pull the tablecloth horizontally. Aim to pull the tablecloth out from under the books without disturbing their position.
- Observe the books as the tablecloth is pulled away.

4. Share your observations with a friend.



Consider:

a. Why did the books stay in place when you pulled the tablecloth quickly?

b. How does this show Newton's First Law of Motion?

c. What happened when you pulled the tablecloth slowly? Why was it different?

d. Share your observations with a friend or subject teacher

Activity 2.7 Understanding Newton's first law (law of inertia)

Materials needed:

- toy car or any small, wheeled object
- smooth surface (table, floor)
- small objects (books, blocks) to create an inclined plane
- notebook and pen for recording observations

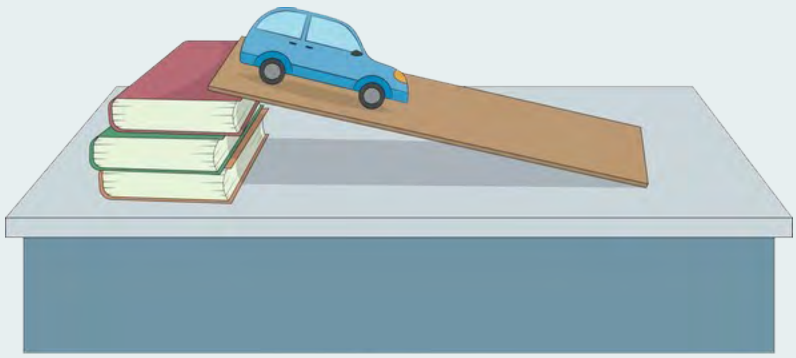
Scenario: Imagine a vehicle has broken down and needs to be moved off the road to prevent other cars from crashing into it. Discuss with a family member or friend what makes the vehicle move or stay still.

What to do:

Experiment:

1. Place the toy car on the smooth surface.
2. Give the car a gentle push and observe how it moves and eventually stops. Discuss with your partner what causes it to stop.

3. Create a small, inclined plane using books or blocks and cardboard or plank.
4. Place the toy car at the top of the inclined plane and observe that it stays still until you give it a push. Discuss why it does not move until a force is applied (gravity acting along the incline).



Consider:

a. Why does the car stop moving on the flat surface?

b. What external force acts on the car to stop it?

c. How does the inclined plane affect the car's motion?

Newton's Second Law: The Law of Acceleration

The rate of change of momentum of a body is directly proportional to the resultant force applied, and it happens in the direction of the unbalanced force.

Activity 2.8 Understanding Newton's Second Law

Materials needed:

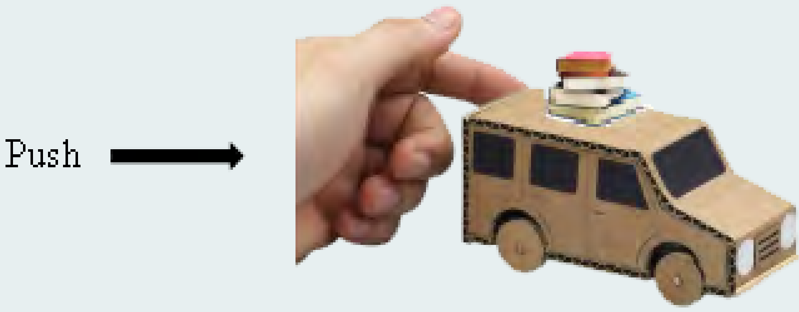
- Same toy car or a small, wheeled object
- Weights (coins, small stones)
- Smooth surface
- Ruler and stopwatch (optional)
- Notebook and pen for recording observations

Scenario: Continuing with the broken-down vehicle scenario, consider how hard you would need to push it if it were heavier. Discuss with your partner how mass and force are related to moving the vehicle.

What to do:

1. Experiment: Place the toy car on the smooth surface and push it with a consistent force.
2. Observe how fast it moves and discuss with your partner.

3. Add some weights (like books) to the car.



4. Push the car again with the same force. Observe the difference in speed and acceleration compared to the unweighted car.

5. If available, use a stopwatch to time how long it takes for the car to travel a certain distance with and without weights.

6. Record your observations and calculate the force using F = ma if you have the measurements.

Consider:

a. How did adding weights affect the car's speed?

b. How would you describe the relationship between mass, force, and acceleration?

c. What would happen if you pushed a heavier car with the same force as a lighter car?

Activity 2.9 Understanding Newton's second law (law of acceleration)

Materials needed:

- A toy car (to represent the broken-down vehicle)
- A smooth surface (like a table or floor)
- A piece of string

- Weights (like small stones or coins)
- A stopwatch (optional)

What to do:

1. Setup:

a. Attach a piece of string to the front of the toy car.

b. Tie weight to the other end of the string to act as the force pulling the car.

c. What do you think will happen when you push the toy car gently?

d. What if you pull it with different weights?

2. Explore:

a. Add a small weight to the string and observe the acceleration of the toy car.

b. Gradually add more weight and observe how the acceleration changes.

c. Use a stopwatch to measure the time it takes for the car to travel a certain distance with different weights if desired.

d. How did the acceleration of the toy car change when you added more weight?

e. What will happen to the acceleration if you add more weight to the car? Will it increase or decrease? Explain.

Newton's Third Law: The Law of Action and Reaction

For every action, there is an equal and opposite reaction.

For example, just as we are pulled towards the centre of the Earth with a force equal to our weight, the centre of the Earth is pulled towards us with an equal and opposite force.

Another example is that the force of air resistance acts on a parachute as it descends through the atmosphere, colliding with particles in the air. Equally, there is a force acting on the particles that is equal and opposite.

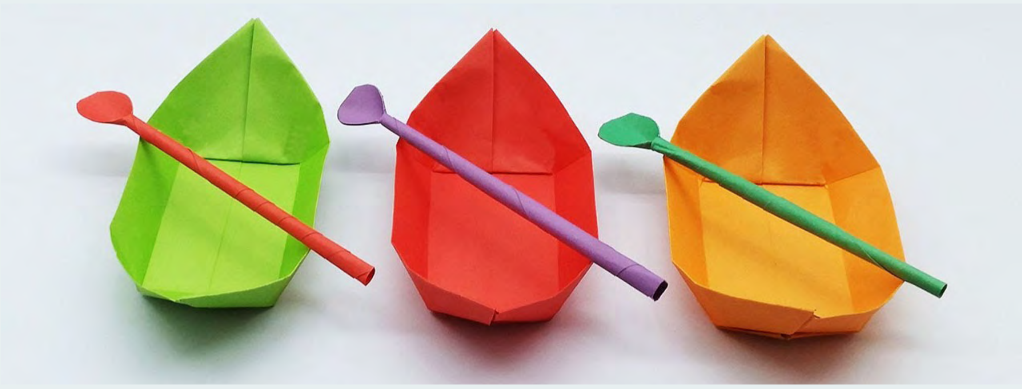
Activity 2.10 Demonstrating Newton's third law

Materials needed:

- Sheets of paper (for making boats)
- A large bowl or container filled with water
- Small sticks or straws (for making paddles)
- Tape or glue (for securing paddles)

What to do:

1. Build the Paper Boats:
   a. Follow simple origami instructions to fold sheets of paper into small boats.
   b. Ensure the boats are stable and can float on water.



2. Prepare the Bowl: Fill a large bowl or container with water, deep enough to float the paper boats.
3. Make the Paddles:
   a. Use small sticks or straws as paddles.
   b. If needed, tape or glue small pieces of paper or cardboard to the ends of the sticks to act as paddles.
4. Perform the Demonstration:
   a. Place the paper boats in water.
   b. Use the paddles to push water backward, mimicking the action of rowing.
   c. Observe the motion of the boats as you push the water.
   d. Explain your observations.

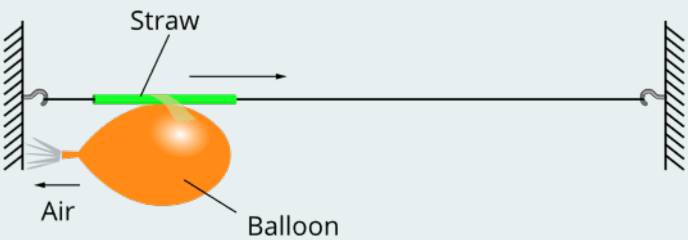
Activity 2.11 Demonstrating Newton's Third law of Motion

Materials needed:

- Balloon
- Straw
- String (long enough to stretch across a room)
- Tape
- Two fixed points (like chairs or door handles) to tie the string

What to do:

1. Setup:
   a. Stretch the string across the room and secure it tightly between two fixed points, like chairs or door handles.
   b. Thread the straw onto the string before tying the second end. Make sure the straw can slide easily along the string.
2. Prepare the balloon:
   a. Inflate the balloon but do not tie it. Pinch the end to prevent the air from escaping.
   b. Tape the inflated balloon to the straw, positioning it so that the open end faces one of the fixed points.



c. Hold the balloon at one end of the string.
d. Release the balloon and observe its movement along the string.
e. Watch as the balloon moves in the opposite direction to the escaping air.
f. Share your observations with a friend about how the air pushing out of the balloon (action) causes the balloon to move in the opposite direction (reaction).

3. Consider:
   a. Write down or discuss how this experiment illustrates Newton's Third Law.
   b. Think of other examples where action and reaction forces are observed, such as in rocket launches or swimming.

Activity 2.12 Exploring the effect of force in different scenarios.

Perform investigations on each scenario below, and then discuss the discussion questions with your peers or teacher.

Scenario 1: *When the object is already in motion and experiences a resultant force*

Materials needed:

- toy car or any small, wheeled object
- smooth surface (table, floor)
- small weights (coins, small stones)
- ruler and stopwatch (optional)
- notebook and pen for recording observations

What to do:

1. Place the toy car on a smooth surface.
2. Give the car a gentle push to set it in motion.
3. While the car is moving, apply an additional force by pushing it again or stopping it with your hand.
4. Observe how the car's motion changes (e.g., it speeds up, slows down, or stops).
5. Record your observations.

Discussion questions:

i. What happens to the car's speed when you push it harder?

ii. What happens when you try to stop it?

Scenario 2: *When the object is already in motion and experiences no resultant force.*

Explore:

1. Place the toy car on a smooth surface.
2. Give the car a gentle push to set it in motion.
3. Let the car move without applying any additional forces.
4. Observe how the car continues to move and eventually stops.
5. Record your observations.

Discussion questions:

i. How does the car's speed change over time?

ii. What causes the car to stop eventually?

Scenario 3: *When the object is stationary and experiences a resultant force*

Explore:

1. Place the toy car on a smooth surface and let it sit still.
2. Apply a force by giving the car a gentle push.
3. Observe how the car starts moving from rest.
4. Record your observations.

Discussion questions:

i. What happens to the car when you push it from a stationary position?

ii. How does the car's motion change immediately after the push?

Scenario 4: *When the object is stationary and experiences no resultant force.*

Explore:

1. Place the toy car on a smooth surface and let it sit still.
2. Do not apply any force to the car.
3. Observe how the car remains stationary.
4. Record your observations.

Discussion questions:

i. What happens to the car when no force is applied?

ii. Why does the car remain stationary?

Reflection

1. *Summarise what you learned about how forces affect the motion of an object in different scenarios.*
2. *Explain how your observations relate to the concepts of resultant forces and motion.*
3. *Share your experiences with a friend or class teacher.*

Relationship Between Force, Mass and Acceleration Using Newton's Second Law

An unbalanced force occurs when the forces acting on an object do not cancel each other out, resulting in a net force that causes the object to accelerate in the direction of the net force. This means the sum of all forces on the object is not zero.

Trial Questions 6

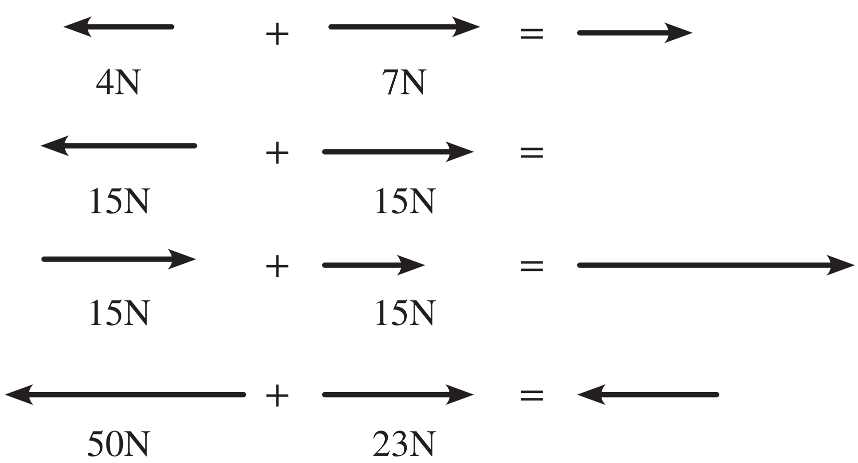
Use the hints below to complete the following force diagrams:

- *Forces in the same direction*: Add their magnitudes.
- *Forces in opposite directions*: Subtract their magnitudes.

1.

2.

3.



Trial Questions 7

Draw the force diagrams in the following scenarios. Compare your answers with a peer or the teacher.

Example:

A Tug-of-war where team A is stronger than team B:

***Scenario 1**:* A ball is lying on the ground.

Forces to consider:

- **a.** The weight of the ball (acting downward)
- **b.** The normal force from the ground (acting upward)

Scenario 2: A person is pulling a box across the floor with a rope.

Forces to consider:

- **a.** Tension force in the rope (acting horizontally, towards the person)
- **b.** Frictional force opposing the motion (acting horizontally, opposite to the direction of motion)
- **c.** Weight of the box (acting vertically downward)
- **d.** Normal force from the ground (acting vertically upward)

***Scenario 3**:* A pendulum is swinging back and forth. Draw a couple of different versions of your diagram with the pendulum at different positions in its swing.

Forces to consider:

- **a.** Tension force in the string (acting along the string)
- **b.** Weight of the pendulum bob (acting downward)

Newton's Second Law (law of acceleration): The rate of change of momentum is directly proportional to the unbalanced force applied and it takes place in the direction of that force.

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

Or

F = ma

Activity 2.13

Materials needed:

- Small toy car
- Smooth surface (like a table or floor)
- Newton meter
- Stopwatch
- Measuring tape or ruler
- Small weights (such as coins or small bags of sand)
- String

What to do:

1. **Explore:**

   a. Attach a piece of string to the front of the toy car.

   b. Mark a starting line and a finish line **1 metre** apart on a smooth surface.

   c. Pull the car with a gentle, consistent force (use a Newton meter or hang a mass off the other end of the string and allow it to freefall over the edge of the table) over the **1 metre** distance and measure the time it takes using the stopwatch.

   d. Record the time and calculate the average velocity (= distance / time). Double your result to get a rough estimate of the final velocity.

   e. Calculate the change in momentum ($\Delta\vec{p} = m\Delta\vec{v}$).

   f. Add small weights to the car to increase its mass and repeat the process.

   g. Observe how the change in momentum varies with different masses.

   h. Complete the table below.

2. **Table to fill out:**

Trial	Mass (kg)	Time (s)	Initial Velocity (u) (m/s)	Final Velocity (v) (m/s)	Change in Velocity (Δv) (m/s)	Change in Momentum (Δp) (kg·m/s)	Rate of Change in Momentum $\frac{\Delta p}{\Delta t}$ (kg·m/s^2)
1			0				
2			0				
3			0				
4			0				
5			0				

Discussion questions:

i. What did you observe about the car's motion when you pulled it with a gentle, consistent force?

ii. How did the car's speed (velocity) change when you added more mass to it?

iii. What happened to the time it took for the car to travel 1 metre when you increased its mass?

iv. What do your observations tell you about the relationship between force, mass, and acceleration?

PRESSURE

In this lesson, we explore the concept of pressure. Pressure, a fundamental concept in physics, quantifies the force exerted per unit area on a surface (P = F/A). Understanding pressure is essential for comprehending the behaviour of fluids, solids, and gases and their interaction with the environment. This knowledge is crucial for designing efficient systems in engineering, such as hydraulic systems, which rely on pressure to transmit force effectively. Moreover, an understanding of pressure informs various scientific and industrial applications, contributing to advancements in technology and everyday practices.

Pressure is defined as a force acting on a body per unit area of contact perpendicular to the force.

Pressure is mathematically expressed as:

$$Pressure = \frac{\text{Force Applied}}{\text{Perpendicular to Area of Contact}}$$

Where P = pressure, F = force acting on body and A = area where pressure acted.

F is measured in newtons (N), A in metre square (m^2). $P = \frac{F}{A} = Nm^{-2}$

Hence the unit of pressure is Nm^{-2} or Pascal (Pa).

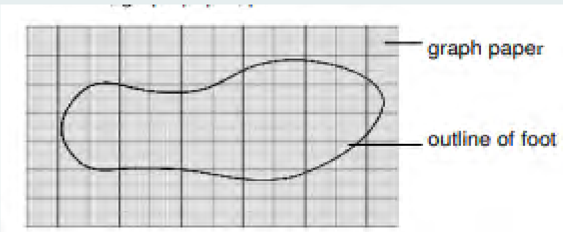
Activity 2.14 Calculating for pressure on the ground

Materials needed:

- Graph paper
- Pencils
- Rulers
- Weighing scales

What to do:

1. Pick a piece of graph paper and trace the outline of one of your feet.
2. Count the number of squares enclosed within the foot outline to estimate the area of your foot.
3. Record the foot area measurements in various units, such as centimetres (cm^2), metre square (m^2). Note: often one small square of graph paper is equal to $1cm^2$, but you should confirm this by measuring 1cm x 1cm!
4. Stand on weighing scales to obtain your body weight in kilograms (kg)
5. Using your foot area and body weight, calculate the pressure on the ground using the formula: Pressure = Weight / Area



6. Share your results with your peers and collect their data too. Tabulate the results.

Mass(kg)	Weight (N)	Area on 1 foot (A_1)	Area of 2nd foot(A_2)	$P = F / (A_1 + A_2)$

Trial Questions 8

1. Find the pressure when a bag of gari of weight 50N is exerted on a $50m^2$ surface.
2. Find the force produced when $10Nm^{-2}$ pressure is exerted on $50m^2$ surface.
3. A dog of weight 20 N stands on the foot of a cross-sectional area of $1000cm^2$. What pressure is exerted on the ground.
4. What is the pressure exerted by a cow of weight 500N who stands on an area of $1.0\ cm^2$?

Hydrostatic Pressure

Hydrostatic pressure specifically refers to the pressure exerted by a fluid at rest due to the force of gravity. It increases with depth in a fluid due to the increasing weight of the fluid above. The hydrostatic pressure at a certain depth h can be derived from the pressure at the surface using the equation for hydrostatic pressure:

Hydrostatic pressure equation $P = pgh$

Where P is the hydrostatic pressure caused by a certain depth (in Pascals, Pa),

ρ (rho) is the density of the fluid (in kilograms per cubic metre, $kg\ m^{-3}$),

g is the acceleration due to gravity (in meters per second squared, $m\ s^{-2}$)

h is the depth of the point within the fluid (in metres, m).

This equation helps to understand how pressure increases with depth in a fluid due to the weight of the fluid above it. For example, in a water tank, the hydrostatic pressure at the bottom is higher than at the top due to the weight of the water above pressing down on it.

Trial Questions 9

1. A vessel has a base area of $0.15m^2$. Water is poured into a depth of 3cm. What is the pressure on the base? Calculate the force exerted on the base. (Density of water = $1000kgm^{-3}$, g=$10ms^{-2}$)
2. A poly tank which is 20m deep is full of water. Calculate the pressure at the bottom of the tank due to the liquid.
   [Density of water =$1000\ kgm^{-3}$ and g = $10\ ms^{-2}$]

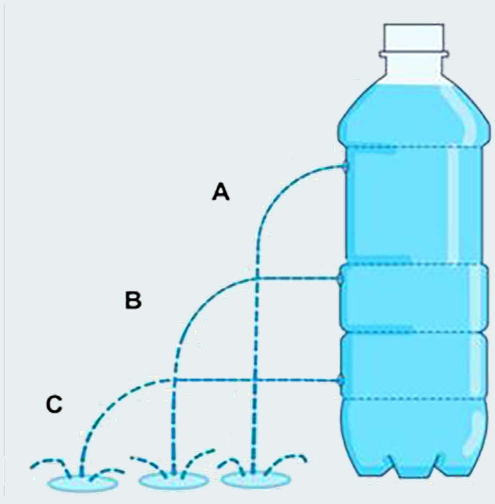
Activity 2.15 Exploring water pressure and flow

Materials needed:

- Large plastic bottles with holes made at various heights
- Water

What to do:

1. Individually or in a small group, take a plastic bottle with holes made at different heights.
2. Fill the bottle with water and observe what happens when the lid is removed.
3. Examine the path of the water flowing out of the holes at different heights.
4. Explain your observations using the key words; radius, depth, force, pressure and particles.
5. Share your observations and explanations.



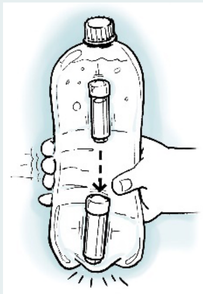
Pascal's Principle

Pascal's principle states that, in a confined fluid, an externally applied pressure is transmitted equally in all directions. Both hydraulic systems and brake systems work on the principle of Pascal's law, which is based on the transmission of fluid pressure. Pascal's principle plays a fundamental role in various aspects of our lives, ranging from mechanical systems to biological processes, contributing to the functioning of many everyday objects and systems.

Trial Questions 10

1. The area of the smaller piston in a hydraulic press is 5m^2. If an effort of 80 N is applied on the plunger of the effort cylinder, calculate the force produced by the piston cylinder of a cross-sectional area of 600m^2.
2. A hydraulic press consists of two cylinders with a cross-sectional area of 0.15 m^2. The piston in the smaller cylinder is pushed down with a force of 15 N through a distance of 0.04m. Calculate
   a. the pressure transmitted by the fluid.
   b. the force exerted by the piston experiences a friction of 80 N.

Activity 2.16A Creating a Cartesian Divers



Materials needed:

- Water bottle (full)
- Small test tube (or similar object open at one end)

What to do:

Explore:

1. Place a small amount of water into the bottom of the small test tube and then quickly put inside the full water bottle *so that the closed end of the test tube is at the top*.
2. Put the cap onto the water bottle.
3. Squeeze the water bottle hard and observe the motion of the test tube.
4. Discuss your observations with a peer. Try to explain what has happened, using the key words: pressure, Pascal, force and density.

Activity 2.16B

1. Take a large-gauge syringe and place your finger over the end so that the air inside it is trapped. Push the plunger and observe how far you are able to move it.
2. Repeat the experiment above, but this time with the syringe full of water. How far are you able to push the plunger? How does this compare to when air is inside the syringe, and can you explain why?
3. Discuss your ideas with a peer or with your teacher.

Activity 2.17

1. Take a plastic bottle and pierce 4 to 8 holes around the bottom, in a circle at a constant depth. Cover the holes, and then fill the bottle with water.
2. Remove the coverings. What do you observe about the radius of the water jets which escape the bottle? How does this help to demonstrate Pascal's principle?
3. Discuss your ideas with a peer or with your teacher.

Activity 2.18

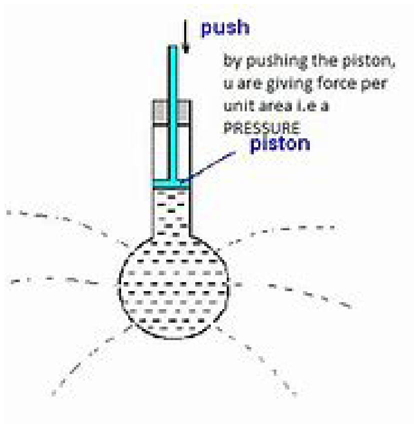
1. Research a use of hydraulic systems which has not been covered in these learning materials.
2. Create a presentation to report your findings and deliver this to a small group of peers or your whole class.

Pressure in Fluids

Pascal's law is a principle in fluid mechanics given by Blaise Pascal that states that; a pressure change at any point in a confined incompressible fluid is transmitted throughout the fluid such that the same change occurs everywhere.

This principle is demonstrated by means of a glass barrel fitted with piston and a bulb with pierced holes of uniform diameter. The barrel is filled with water when the bulb is dipped in water and then removed.

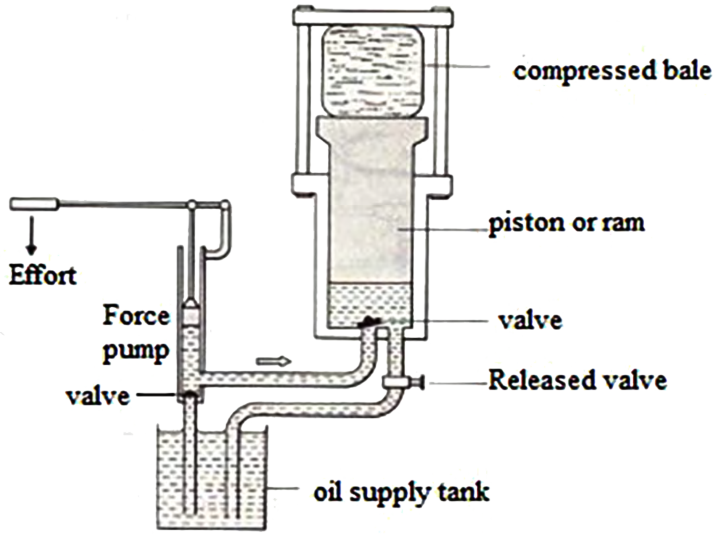
When the piston is pushed in, water spurts equally from all the holes. This shows that the pressure applied to the plunger has been transmitted uniformly throughout the liquid.



Brake Systems and Hydraulic Press

1. The Hydraulic Press

It consists of a force pump of smaller diameter, piston of larger diameter, an oil supply tank and connecting pipes. The force pump of smaller diameter is connected to the piston or ram of larger diameter by a pipe. Oil is pumped into the cylinder from a supply tank.



The moment the effort handle of a force pump is lifted up, the valve of the force pump opens by atmospheric pressure. Oil from the supply tank is pumped into the effort cylinder of smaller diameter. However, when the effort is pressed or exerted downward, the same valve closes, high pressure is exerted on the oil due to decrease in volume; the pressure is transmitted equally in all direction in accordance with Pascal's principle. The pressure on the liquid pushes the valve of the ram, large force is then produced on the ram because of its larger area and this force exerts on the load to lift, compress or to crush it. The release valve is provided to release the pressure and also allow the oil to return to the tank after the press has done its work.

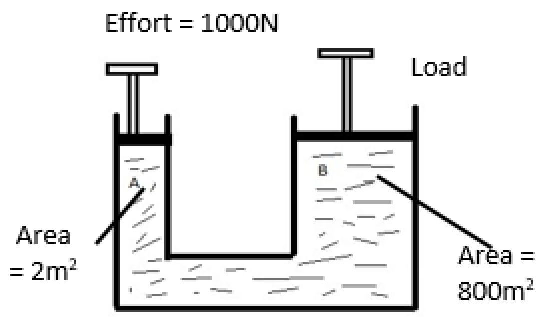


Fig. 2.4: Hydraulic lift

Suppose the effort cylinder has an area of $2m^2$ and an effort of 1000 N is applied to its plunger.

The pressure produced by the effort is:

$$P = \frac{F}{A} = \frac{1000}{2} = 500Nm^{-2}$$

This pressure is transmitted equally throughout the whole of the liquid in accordance with Pascal's principle. Therefore, the pressure exerted on the piston is also $500Nm^{-2}$. Since the area of the piston is equal to $800m^2$, the force generated to lift the load.

$$F = P \times A = 500 \times 800 = 400000 \text{ N}$$

Thus, a force of 40000N is simply produced by exerting an effort of 1000 N.

Uses of the Press

1. It is used for the compression of soft materials such as wastepaper and cotton into compact bales.
2. It is used for the shaping of motor cars.
3. It is used for lifting heavy objects.

2. Hydraulic Brakes

Brake systems in vehicles are crucial for safe and controlled stopping. They work through a combination of mechanical and hydraulic components such as brake pedal, master cylinder, brake fluid, brake pad, shoes etc. The brake system's operation relies on the driver's input, which is converted into hydraulic pressure to apply friction on the wheels, allowing the vehicle to slow down or stop safely.

It works based on the principle that pressure in fluid is transmitted equally in all directions.

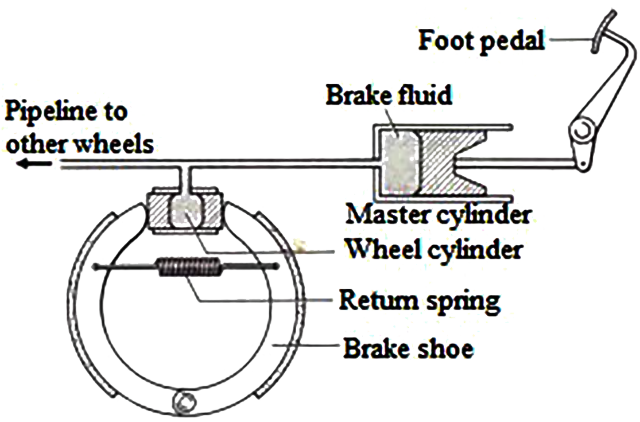


Fig. 2.5: Hydraulic brake

The moment the brake (foot) pedal is pressed, the volume of the master cylinder decreases which exerts greater pressure on the fluid in the master cylinder. The pressure set in the master cylinder is equally transmitted through the fluid to the wheel piston on the brake shoes, which are hinged on the wheel cylinder. The brake shoes are then pushed against the brake drums, which are fixed to the wheels. Friction then sets in between the tyres and the ground and therefore decelerates the car to a stop. When the pressure on the pedal is released, the brake shoes pull the springs and force the wheel's piston back into the cylinder. The liquid then returns to the master cylinder. The braking effects on all wheels are equal, since the pressure set up in the master cylinder is transmitted equally throughout.

REVIEW QUESTIONS

Review Questions 2.1

1. A stone is thrown vertically upwards with an initial velocity of 20m/s. Determine the time it takes for the stone to reach its maximum height.
2. A stone is launched vertically upwards from the ground with an initial velocity of 50 ms^{-1}.

   Determine:

   a. The maximum height reached by the stone.

   b. The time it takes for the stone to reach its maximum height.

   c. The total time the stone is in the air before hitting the ground again.
3. Kwesi drives his taxi from Kumasi to Tamale, making a stop for fuel halfway through the journey. He spends 20 minutes refuelling before continuing the trip back to Kumasi.

   a. Using the provided table, draw a detailed position-time graph illustrating Kwesi's taxi ride. The graph should include labelled points for significant events such as the start of the trip, the fuel stop, arrival at Tamale, departure from Tamale, and return to Kumasi.

   Table 2.2 Positions and time for Kwesi's taxi ride

Position(km)	0	240	240	0
Time(minutes)	0	120	140	160

   b. Calculate Kwesi's instantaneous speed when he is halfway to Tamale and when he is refuelling. Use the position-time graph to determine these speeds. Give your answers in km/hr.

   c. Determine the total distance Kwesi travelled during his entire trip.
4. A car starts from rest, over the first 5 seconds, it accelerates at a constant rate, reaching a velocity of 20 m/s. For the next 10 seconds, the car cruises at this constant velocity of 20 m/s. Suddenly, the driver notices a red light and brakes, causing the car to decelerate at a constant rate over 5 seconds, reducing its velocity to 0 m/s. The car then stops at the traffic light, with its velocity remaining zero.

a. Sketch the velocity time graph of the motion.

b. Calculate the total distance travelled by the car.

5. A cyclist accelerates from 0 to 5 m/s in 2 seconds, travels at 5 m/s for 3 seconds, decelerates to 2 m/s over 2 seconds, travels at 2 m/s for 2 seconds, and then comes to a stop over 1 second. Plot a velocity-time graph and use it to find the total distance travelled.

6. A bus starts from rest and accelerates uniformly at $2\ m\ s^{-2}$ for 10s. It maintains the maximum speed attained for further 10 s and decelerates at $1\ m\ s^{-2}$ gradually to rest.

   a. Draw the velocity-time graph.

   b. Use the velocity-time graph to determine:

      i. the maximum velocity attained.

      ii. the time taken for the bus to decelerate to rest.

      iii. the total distance covered

      iv. the average velocity

7. **Design Challenge Question:** Design and build a model of a roller coaster that demonstrates and applies linear equations of motion. Your roller coaster model should simulate the motion of a car along its track, emphasising concepts such as acceleration, velocity, and distance travelled. Use mathematical equations to predict and analyse the car's motion at different points along the track. Consider incorporating loops, hills, or other features to showcase the principles of uniform motion and constant acceleration.

   Present your design to your peers or teachers.

Review Questions 2.2

1. A concrete slab of mass 32 kg is being pulled along the ground with a force of 21 N. If the opposing frictional force is 5 N, calculate the acceleration.

2. A man of mass 2500 g is standing on a weighing scale in a lift. If the lift moves upwards with an acceleration of 3 $m\ s^{-2}$ and then downwards with the same acceleration, find the weight on the weighing scale when
   a. He's accelerating upwards
   b. He's accelerating downwards
   c. the lift moves with a constant velocity of 6 $m\ s^{-1}$ upwards
   d. when lift moves with a constant velocity of 5 $m\ s^{-1}$ downwards
3. A rocket of mass 2000 kg experiences a thrust force of 50000 N upward and a gravitational force of 19600 N downward. What is the net force and acceleration of the rocket?
4. Design an experiment to demonstrate Newton's 1st Law of Motion using a ball, a flat, smooth surface, a starting line and a spring launcher. Describe the setup, procedure, expected results, and how these results support Newton's 1st Law.
5. Analyse the forces acting on a car accelerating from rest to 60 km/h in 10 seconds. Determine the net force required if the car's mass is 1500 kg, considering both the ideal scenario and the impact of friction and air resistance of 500 N.
6. Evaluate the propulsion mechanism of a rocket in space using Newton's 3rd Law. Explain how this law applies to the thrust generated and the motion of the rocket and compare this with a real-life example of a balloon releasing air.
7. Describe a real-life scenario where Newton's 1st Law applies to a moving object.
8. Compare the behaviour of a soccer ball on grass versus on a smooth gym floor in terms of Newton's 1st Law.
9. Explain how seat belts in cars illustrate Newton's 1st Law.
10. If a rocket with a mass of 2000 kg needs to achieve an acceleration of 10 m/s^2, what amount of thrust is required?
11. Analyse how increasing the mass of an object affects the force needed to achieve the same acceleration.
12. Discuss how friction affects the net force acting on an object and its resulting acceleration.
13. Analyse the forces involved when two ice skaters push off from each other.

14. Design Challenge Question: Design and create a homemade project that demonstrates and applies all three of Newton's laws of motion. Your project should clearly show how Newton's laws govern the motion of objects. Consider using everyday materials to build a model. Be prepared to explain the scientific principles behind your project and how it applies Newton's laws.

Review Questions 2.3

1. A scuba diver, Kwesi is descending to a depth of 30 meters in the ocean. The density of seawater is 1025 kg/m³ and the acceleration due to gravity is 9.8 m/s².
   a. Calculate the pressure at a depth of 30 meters.
   b. Explain how the pressure experienced by Kwesi changes as they descend deeper.
2. A hydraulic lift is used to raise a 2000 kg car. The piston area of the lift is 0.05 m².
   a. Calculate the pressure required to lift the car.
   b. Explain how applying pressure in a hydraulic system allows for the amplification of force.
3. A water tower has a height of 50 meters and a tank diameter of 10 meters. The density of water is 1000 kg/m³.
   a. Calculate the pressure at the base of the water tower.
   b. Explain how the water tower design takes advantage of the relationship between pressure and depth
4. Otu is swimming at a depth of 10 meters in a freshwater lake. Calculate the pressure experienced by the Otu at this depth, given that the density of freshwater is 1000 kg/m³.
5. Yakubu lifts a box that weighs 200 N. The bottom of the box has a surface area of 0.4 m². What is the pressure the box exerts on the surface it is resting on?
6. Adwoa weighs 800 N and stands on two feet, each with a surface area of 0.02 m². What is the pressure exerted by the person on the ground?
7. A weightlifter, Bashiru lifts a 50 N weight on a 0.2 m² surface. What is the pressure?

8. **Design Challenge Question***:* Design and build a model hydraulic arm that demonstrates the practical application of Pascal's principle. Your model should include components illustrating how pressure transmitted through a confined fluid can amplify force and achieve mechanical advantage. Use everyday materials to construct a functional prototype capable of lifting a small load or performing a task, emphasising the principles of fluid pressure and hydraulic systems.

ANSWERS TO REVIEW QUESTIONS

Review Questions 2.1

1. Initial velocity, u = 20 m/s

Acceleration due to gravity, a = – 9.8ms^{-2} (negative because it acts against the motion)

At maximum height, final velocity (v) is 0m/s.

Using the equation v = u + at and rearranging for time (t):

0 = 20 – 9.8t

9.8t = 20

t ≈ **2.04s**

2. **a.** To find the maximum height, we use the equation $v^2 = u^2 + 2as$ where v = 0.

$0 = (50^2) + 2(-9.8)s$

$s = \frac{50^2}{2(9.8)} \approx \mathbf{127.55m}$

b. To find the time to reach maximum height, we use the equation v = u + at where

0 = 50 – 9.8t

$t = \frac{50}{9.85} \approx \mathbf{5.10s}$

c. The total time in the air is twice the time to reach maximum height.

2 × 5.10 ≈ **10.20 s**

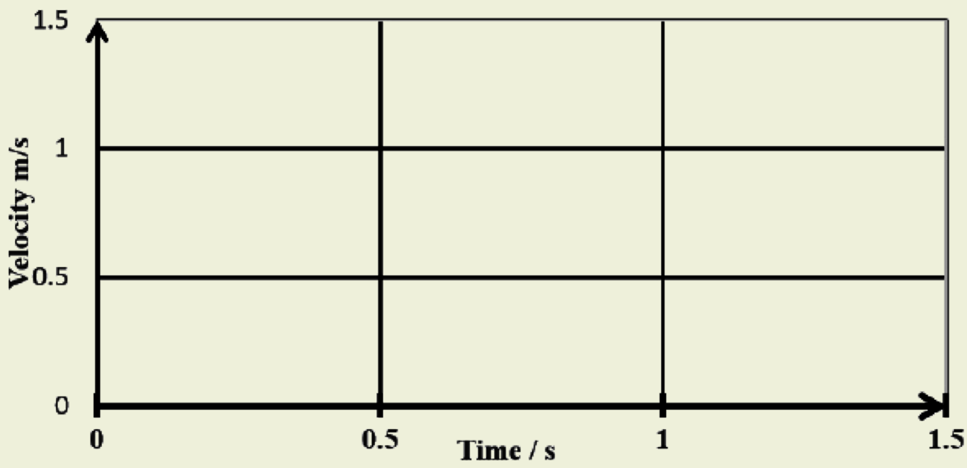
3. **a.** Compare with your friend or teacher.

b. 120 km/hr, 0km/hr.

c. 480 km/hr.

4. **a.**

Velocity (m/s)	0	20	20	0
Time (seconds)	**0**	**5**	**15**	**20**



b.

Acceleration phase:

Distance = Average velocity × Time

$$\text{Distance} = \frac{(0 + 20) \times 5}{2}$$

$$\text{Distance} = \frac{20 \times 5}{2}$$

$$\text{Distance} = \frac{100}{2}$$

Distance = **50 metres**

Constant velocity phase:

Distance = Average velocity × Time

Distance = 20 × 10

Distance = **200 metres**

Deceleration phase:

Distance = Average velocity × Time

$$\text{Distance} = \frac{(0 + 20) \times 5}{2}$$

$$\text{Distance} = \frac{20 \times 5}{2}$$

$$\text{Distance} = \frac{100}{2}$$

Distance = **50 metres**

Total distance travelled:

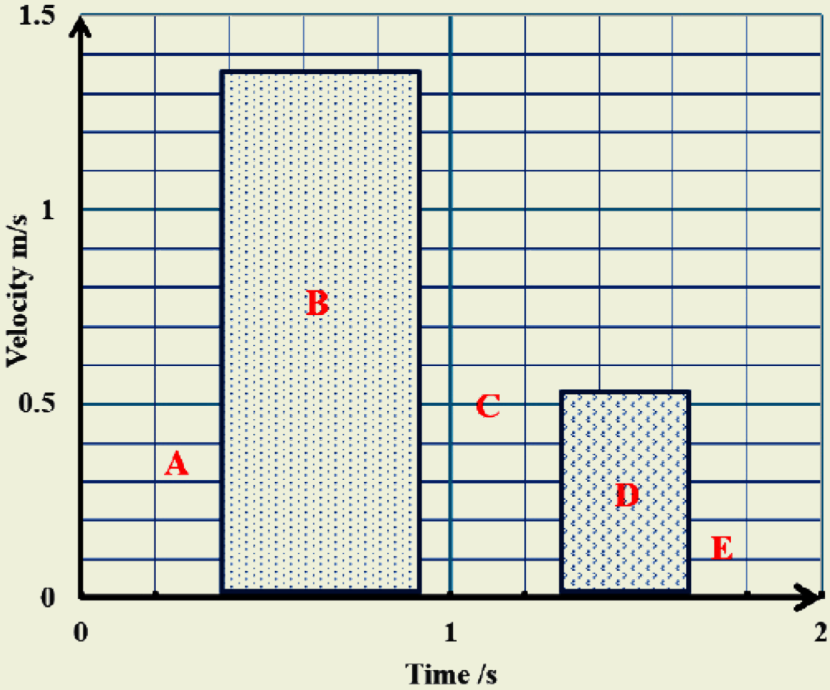
Total Distance = 50 + 200 + 50

Total Distance = **300 metres**

5.

Time (seconds)	0	2	5	7	9	10
Velocity (m/s)	0	5	5	2	2	0

Velocity - Time Graph



Total distance is the total area under the various segments of the velocity - time graph.

Total distance =Areas (A + B + C + D + E)

Area A = $\frac{1}{2} \times 2 \times 5 =$ **5 m**

Area B = $2 \times 5 =$ **10 m**

Area C = $1/2 \times (5 + 2) \times 2 =$ **7 m**

Area D = $2 \times 2 =$ **4 m**

Area E = $1/2 \times 1 \times 2 =$ **1 m**

Total Distance = 5 m + 15 m + 7 m + 4 m + 1 m = 32 m

6. *Part (a) Plotting the graph:*

a. Acceleration phase: v = ut + at.

- Initial velocity (u) = 0 m/s.

- Final velocity (v) after 10 s can be calculated using

  v = 0 + 2 × 10 = **20 m/s**.

Constant velocity phase:

- The bus maintains a constant velocity of 20 m/s for 10 seconds.

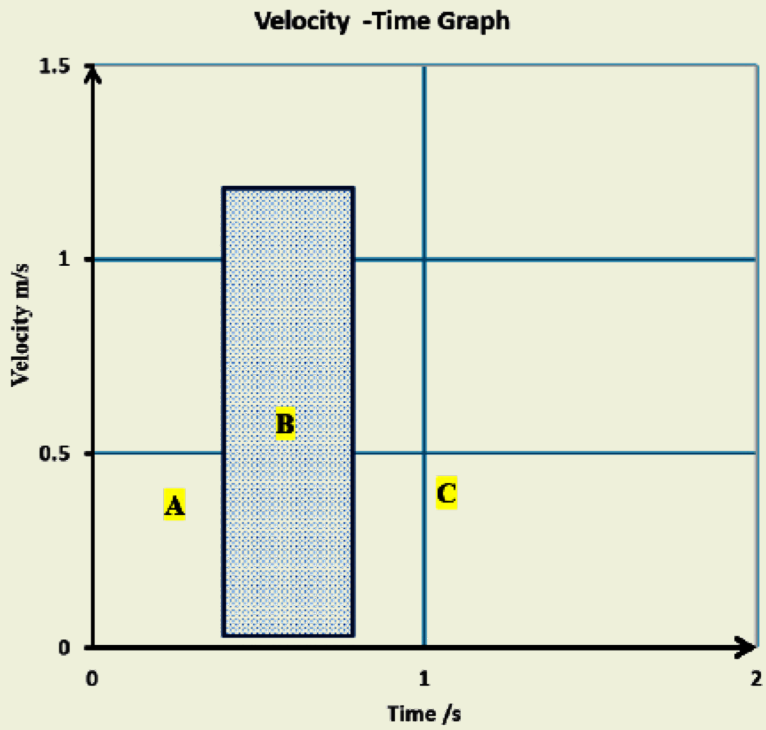
Deceleration phase: v = ut + at

(Note that is deceleration so **a** will be negative).

- So, 0 = 20 – (1 × t)

  t = 20s

Time (seconds)	0	5	10	20	30	40
Velocity (m/s)	0	10	20	20	10	0



b. Using the velocity-time graph to determine:

i. *The maximum velocity attained*

From the acceleration phase:

$v = u + at = 0 + 2 \times 10 = 20$ m/s

Maximum velocity attained = **20 m/s.**

ii. *The time taken for the bus to decelerate to rest*

The bus decelerates from 20 m/s to 0 m/s at a rate of 1 m/s²:

$0 = 20 - 1 \times t$

Time taken to decelerate to rest = 20 seconds.

iii. *The total distance covered*

The total distance is the area under the velocity-time graph, which consists of a triangle, a rectangle, and another triangle.

Area A = $\frac{1}{2} \times 10 \times 20$ = **100 m**

Area B = base × height = 10 × 20 = **200 m**

Area C = $\frac{1}{2} \times 20 \times 20$ = **200 m**

Total distance covered: **100 m + 200 m + 200 m = 500 m**

iv. *The average velocity*

The average velocity can be calculated using the total distance covered and the total time taken.

Total time taken = 10 seconds (acceleration) + 10 seconds (constant velocity) + 20 seconds (deceleration) = 40 seconds.

Average velocity = $\frac{\text{Total Distance}}{\text{Total Time}} = \frac{500}{40}$ = **12.5 m/s**

Review Questions 2.2

1. Let the opposing frictional force (or the resistance force) be R = 5 N

Forward force, F_1= 21 N

The resultant force, F is an unbalanced force and as such, it will create acceleration. Thus,

F = F1 – R, F = ma

F1 – R = ma

21 –5 = 32 × a

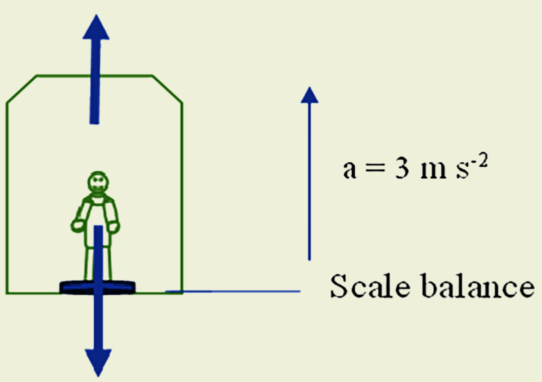
16 = 32a

$\mathbf{a = \frac{32}{16} = 2\ m^{-2}}$

2. **a.** m = 2500 g = 2.50 kg

F_m is support force from scales =

F_o = mg



From the above equation,

$F_m – F_o$ = ma

F_m = mg + ma = m(g+a)

= 2.50(10 +3)

= 2.50 × 13

= 32.5 N

b. When the body starts mowing downwards, it means mg is greater than F_m and therefore we have to subtract F_m from mg.

$mg - F_m = ma$

$F_m = mg - ma$

$= m(g - a)$

$= 2.50\ (0 - 3) = 2.50\ (7)$

$= 17.50\ N$

c. It means $u = 6\ m\ s^{-1}$ and $v = 6\ m\ s^{-1}$, and therefore $a = \frac{6-6}{t} = \frac{0}{t} = 0$, $m = 2.50\ kg$,

$F_m - F_o = ma$

$F_m - mg = m\ (0) = 0$

$F_o = mg = 2.50 \times 10 = 25.0\ N$

d. As above.

3. First, find the net force:

$F_{net} = 50000\,N - 19600\,N = 30400\,N$

Then, using Newton's second law:

$a = \frac{Fnet}{m} = \frac{30400N}{2000\ kg} = 15.2\ m/s^2$

$a = 15.2\ m\ s^{-2}$

4.

- **Setup:** Place a ball on a flat, smooth surface (like a gym floor) and mark a starting line. Think of a way or something you can do to apply a consistent force (e.g., a spring launcher).
- **Steps:**
  1. Place the ball at the starting line.
  2. Use the spring launcher to apply a force to the ball.
  3. Observe and record the ball's motion until it comes to a stop.
  4. Repeat the experiment on different surfaces (e.g., carpet, grass).

Expected Results: On the smooth surface, the ball will travel farther before stopping compared to rougher surfaces like the carpet or grass.

Explanation: The ball's motion continues in a straight line until an external force (friction) slows it down and eventually stops it. This demonstrates Newton's 1st Law: an object in motion stays in motion unless acted upon by an external force. On rougher surfaces, higher frictional forces act on the ball, illustrating how different external forces impact motion.

5. ***Ideal Scenario:***

- Final velocity (v) = 60 km/h = 6000/3600 m/s = 16.67 m/s
- Initial velocity (u) = 0 m/s
- Time (t) = 10 s
- Acceleration (a) = (v - u) / t = 16.67 m/s / 10 s = 1.67 m/s²
- Mass (m) = 1500 kg
- Net force (F) = m * a = 1500 kg * 1.67 m/s² = 2505 N

With friction and air resistance:

- Assume frictional force (f) and air resistance (r) together equal 500 N.
- Net force to overcome inertia and achieve acceleration: 2505 N
- Total force considering resistances: F_{total} = 2505 N + 500 N = 3005 N

Thus, to accelerate the car to 60 km/h in 10 seconds, a net force of 3005 N must be applied, accounting for friction and air resistance.

6. ***Rocket Propulsion*:**

- In space, a rocket expels gas out of its engines at high speed.
- According to Newton's 3rd Law, for every action, there is an equal and opposite reaction. The expulsion of gas (action) creates a force pushing the rocket forward (reaction).

***Explanation*:**

- The force with which the gas is expelled outwards results in a reaction force that propels the rocket in the opposite direction.
- This reaction force must be sufficient to overcome the rocket's inertia and any gravitational forces acting upon it, depending on its location.

Real-Life Example - Balloon:

- When air is released from a balloon, the escaping air creates a force (action) pushing against the air outside the balloon.
- The balloon itself moves in the opposite direction (reaction), demonstrating Newton's 3rd Law.
- Both the rocket and the balloon show that forces always come in pairs: the action of expelling gas and the reaction of the rocket or balloon moving in the opposite direction.

7. When a car suddenly brakes, objects inside, like a bag on the seat, continue to move forward until they hit a barrier (like the dashboard) or are stopped by friction. This demonstrates that an object in motion stays in motion unless acted upon by an external force.

8. A soccer ball will roll farther than on grass on a smooth gym floor due to lower friction. According to Newton's 1st Law, the ball on the gym floor encounters less external force opposing its motion, so it continues moving longer before stopping.

9. Seat belts prevent passengers from continuing in motion when a car suddenly stops. According to Newton's 1st Law, without a seat belt, passengers would continue moving forward at the same speed the car was moving until another force (like the dashboard) stops them, which can cause injury.

10. Mass (m) = 2000 kg

Acceleration (a) = 10 m/s^2

- F = ma
- $F = 2000 \text{ kg} \times 10 \text{ m/s}^2 = 20{,}000 \text{ N}$
- Thus, 20,000 N of thrust is required.

11. According to Newton's 2nd Law (F = ma), if mass (m) increases while acceleration (a) remains constant, the force (F) required also increases proportionally. For example, doubling the mass doubles the required force to achieve the same acceleration.

12. Friction opposes the motion of an object, reducing the net force available for acceleration. According to Newton's 2nd Law, the net force (F) is the applied force minus the frictional force. Lower net force results in lower acceleration for the same mass.

13. When two ice skaters push off, each exerts a force on the other (action). According to Newton's 3rd Law, both skaters experience an equal and opposite force (reaction), causing them to move in opposite directions.

Review Questions 2.3

1. a . Given:

   Depth (h) = 30 meters

   Density of seawater (ρ) = 1025 kg/m^3

   Acceleration due to gravity (g) = 9.8 m/s^2

   To calculate the pressure, we can use the formula:

   $P = \rho gh$

   Plugging in the values:

   $P = (1025\ kg/m^3) \times (9.8\ m/s^2) \times (30\ m)$

   $P = 301{,}350\ Pa$

   Therefore, the pressure experienced by Kwesi at a depth of 30 meters below the surface of the ocean is 301,350 Pascals (Pa).

   To convert this to more common units:

   1 atmosphere (atm) = 101,325 Pa

   301,350 Pa / 101,325 Pa/atm = 2.974 atm

   So Kwesi is experiencing a pressure of approximately 2.974 atmospheres at a depth of 30 metres.

   b. As Kwesi descends deeper, the pressure he experiences increases linearly with the depth. This is because there is more seawater "above" Kwesi, exerting a greater force per unit area. The pressure increases by approximately 100,000 Pa for every 10 metres of depth. This increase in pressure is transmitted equally throughout the fluid, as described by Pascal's principle.

2. **a.** Maximum load (F) = 2000 kg × 10 m/s^2 = 20,000 N

Piston area (A) = 5 cm^2 = 0.0005 m^2

To calculate the pressure, we can use the formula:

P = F/A

Substituting the values:

P = 20,000 N / 0.0005 m^2

P = 40,000,000 Pa

Therefore, the maximum pressure the hydraulic car jack can apply is 40,000,000 Pascals (40 MPa).

b. The application of pressure in a hydraulic system allows for the amplification of force through the use of Pascal's principle. When a force is applied to a confined fluid, the pressure is transmitted equally. This pressure can then be used to apply a much larger force on a larger surface area, effectively amplifying the original force.

3. **a.** To calculate the pressure at the base of the water tower, we can use the formula: P = ρgh

- Depth (h) = 50 meters
- Density of water (ρ) = 1000 kg/m^3
- Acceleration due to gravity (g) = 9.8 m/s^2

Plugging in the values:

P = (1000 kg/m^3) × (9.8 m/s^2) × (50 m)

P = 490,000 Pa

b. A water tower is a simple yet effective way to provide water pressure for a community or building. The design leverages the fundamental principle that pressure in a fluid increases with depth due to the weight of the water above. Here's how it works:

Height and Pressure Relationship*:* The water tower is elevated above the ground, often mounted on tall legs or built on a hill. The height of the water column in the tower creates pressure at the base, which is determined by the depth (height) of the water above it.

Consistent Water Pressure*:* By maintaining a large height (depth), the water tower ensures that there is sufficient pressure to push water through the distribution system and reach all the connected buildings and homes. The taller the tower, the greater the pressure it can provide.

Gravity-Driven Distribution*:* The elevated position of the water allows gravity to naturally drive the water through the distribution pipes. This gravity-fed system is more reliable and cost-effective, as it reduces the need for continuous mechanical pumping to maintain pressure.

4.

- Depth (h) = 10 m
- Density of freshwater (ρ) = 1000 kg/m^3
- Acceleration due to gravity (g) = 9.8 m/s^2

To calculate the pressure, we can use the formula: $P = \rho gh$

Substituting the values:

$P = 1000 \text{ kg/m}^3 \times 9.8 \text{ m/s}^2 \times 10 \text{ m}$

$P = 98{,}000 \text{ Pa}$

Therefore, the pressure experienced by Otu at a depth of 10 metres in the freshwater lake is 98,000 Pascals.

5. Given information:

Force (F) = 200 N

Area (A) = 0.4 m^2

Plugging these values into the formula:

$P = F/A$

$P = 200 \text{ N} / 0.4 \text{ m}^2$

$P = 500 \text{ N/m}^2$

So, the pressure the box exerts on the surface is 500 N/m^2.

6. Force (F) = 800 N (the person's weight)

Area (A) = $2 \times 0.02 \text{ m}^2 = 0.04 \text{ m}^2$

Plugging these values into the formula:

$P = F/A$

$P = 800 \text{ N} / 0.04 \text{ m}^2$

$P = 20000 \text{ N/m}^2$

So, the pressure exerted by Adwoa on the ground is 20000 N/m^2.

7. Force (F) = 50.0 N

Area (A) = 0.2 m^2

$P = F/A$

$P = 50\ N / 0.2\ m^2$

$P = 250\ N/m^2$

EXTENDED READING

1. Hewitt, P.G. (2021),"Conceptual Physics". Pearson Publications: Provides a clear and accessible introduction to the principles of physics, including motion.
2. "Physics for Scientists and Engineers" by Raymond A. Serway and John W. Jewett: Offers a comprehensive look at motion and other fundamental physics concepts, suitable for more advanced readers.
3. "Fundamentals of Physics" by David Halliday, Robert Resnick, and Jearl Walker: An in-depth exploration of physics concepts, including detailed discussions on different types of motion.
4. **Khan Academy: Physics is a c**omprehensive online resource covering Newton's laws of motion and many other physics topics through video tutorials and exercises.
5. **MIT OpenCourseWare: Classical Mechanics: F**ree course materials from MIT covering classical mechanics, including lecture notes, assignments, and exams.
6. MIT OpenCourseWare - Classical Mechanics
7. Nelkon M. and Parker P., (1984). Advanced Level Physics (5th Edition). Pgs. 15-27
8. STEMonstrations: Sleep Science: https://youtu.be/1AG9f0dmg2w
9. Tennis in space: https://youtu.be/uE4k4P1nKuk
10. Resolution of forces: https://brainly.com/question/12847073,
11. HyperPhysics Motion: An extensive resource explaining the principles of motion with interactive diagrams and examples.
12. Physics Classroom Motion: Detailed tutorials and simulations on various types of motion and their real-world applications.
13. Resources on the applications of pressure:

    (a) Videos:

    - "Applications of Pressure"

      https://youtu.be/7qqNRPLP7xo
    - "Pressure and Its Applications in Engineering":

      https://youtu.be/KAByqiV2294

REFERENCES

1. Inertia: Newton's First Law:
2. https://youtu.be/LQyFshgm-hU
3. https://youtu.be/eOKFWZ-5lQc
4. Force, Mass, and Acceleration: Newton's Second Law
5. https://youtu.be/-7JoUUcvaSI:
6. Newton's Third Law of Motion
7. https://www.youtube.com/watch?v=dCF--YOjiOw
8. https://youtu.be/mO1qtmFee-k
9. Newton's laws of motion: https://youtu.be/-w6oW1ut4Dw
10. Balanced forces: https://youtube.com/watch?v=8Q1tw_QWy-8
11. Khan Academy Motion: Free online lessons covering basic to advanced physics topics, including motion.
12. HyperPhysics
13. Brainkart. (2018). Applications of Pascal's law: Hydraulic lift and brake [Image]
14. https://www.brainkart.com/article/Applications-of-Pascal-s-law--Hydraulic-lift-and-brake_3055/

SOLUTIONS TO ACTIVITIES, TRIAL QUESTIONS AND FURTHER INFORMATION

Annex 2.1: Likely Conclusions to Activity 2.1

A – Rectilinear Motion – Effect of ramp angle on average speed.

The average speed increases as the ramp angle (or starting height) increases. The two are not directly proportional; when the angles are small, the increase in average speed per degree is greater than when the angles are large (i.e. a graph of average speed against angle has a decreasing gradient).

B – Circular Motion – Effect of increased mass (tension) on the velocity of rotation needed for a stable orbit.

The frequency increases as the hanging mass increases. The two are not directly proportional; when the masses are small, the increase in frequency per gram is greater than when the masses are large (i.e. a graph of frequency against mass has a decreasing gradient).

C – Oscillatory Motion – Effect of a) length and b) weight on time period of swing.

Time period increases as length increases. The two are not directly proportional; specifically, T is proportional to the square root of l (you can check if your answers show this; divide the time period by the square root of the length and see if you get the same result for every data point).

Time period is not affected by mass.

D – Rotational Motion – Factors affecting spin duration.

The rotational motion of objects such as these is very complicated and depends on the initial conditions of the object.

Annex 2.2 – Further Information: Definitions and Examples of Motion

Question 1:

Rectilinear motion: This refers to the movement of an object along a straight line, e.g. a person walking in a straight line.

Examples in Daily Life:

- A car driving on a straight highway.
- A person walking down a straight corridor.
- A ball rolling down a straight path.

Question 2:

Circular motion: This occurs when an object moves along a circular path around a fixed centre or axis, e.g. the Moon orbiting around the Earth.

Examples in Daily Life:

- A car moving around a roundabout.
- The hands of a clock rotating.
- A satellite orbiting the Earth.

Question 3:

Rotational/Spin motion: This involves the spinning or rotation of an object around a fixed axis. Unlike circular motion, the object itself may not move along a path, but it rotates around a centre point or axis, e.g. a planet rotating on its axis, causing day and night cycles.

Examples in Daily Life:

- A spinning top.
- The rotation of the Earth on its axis.
- A figure skater performing a spin.

Question 4:

Oscillatory motion: This is a repetitive back-and-forth motion around an equilibrium position, e.g. a pendulum swinging from side to side.

Examples in Daily Life:

- A swinging pendulum.
- A vibrating guitar string.
- The motion of a child on a swing.

Question 5:

Random motion: This is an unpredictable kind of motion where an object moves in any direction, and the direction keeps changing without a pattern, e.g. the movement of smoke particles in the air.

Examples in Daily Life:

- The movement of dust particles in the air.
- The erratic flight of a mosquito.
- The Brownian motion of molecules in a liquid.

Annex 2.3: Answers to Activity 2.2A - Definitions

a. **Displacement (s):** How far an object moves from its starting point in a specific direction.

b. **Initial velocity (u)**: The speed (in a given direction) of an object at the beginning of its motion.

c. **Final velocity (v):** The speed (in a given direction) of an object at the end of its motion.

d. **Acceleration (a)**: The rate at which an object's velocity changes over time.

e. **Time (t):** The duration for which the object is in motion.

f. **Average velocity**: Total displacement divided by total time represents the overall change in position per second.

g. **Instantaneous velocity**: Velocity at a specific instant in time. This may change as the object moves.

Answers to Activity 2.2B - Deriving the Equations of Motion

The first equation of motion: v = u + at

Derivation:

Acceleration (a) is defined as the change in velocity per unit of time and is given by the gradient of the graph.

Mathematically

$$a = \frac{change\ in\ y}{change\ in\ x} = \frac{v - u}{t}$$

Where:

initial velocity = u

final velocity = v

acceleration = a

time = t

Making **v** the subject from equation above gives

v = u + at

Second equation of motion: $\mathbf{s = ut + \frac{1}{2}at^2}$

Derivation:

Distance travelled = area under graph = area of triangle + area of rectangle

$= \frac{1}{2}(v\text{-}u)t + ut$

$= \frac{1}{2}(at)t + ut$ (from the first equation of motion)

$= \frac{1}{2}at^2 + ut$

$= ut + ½ at^2$

Alternative derivation:

Do you know that the average velocity (v_{avg}) of a moving body can be defined as:

i. the average of the sum of the initial and final velocities of an object during a time interval (t), mathematically expressed as:

$v_{avg} = \frac{u + v}{2}$ ....(a)

And also as:

ii. the ratio of total displacement (s) to the total time (t): expressed mathematically as:

$v_{avg} = \frac{s}{t}$ ....(b)

Comparing equations (a) and (b),

$\frac{s}{t} = u + \frac{v}{2}$ ....(c)

Using the first equation of motion v = u + at, and substituting into equation (c) above:

$$\frac{s}{t} = \frac{u + (u + at)}{2}$$

$$\frac{s}{t} = \frac{2u + at}{2} \text{ ....} (d)$$

Rearranging terms and making **s** the subject (d)

$$2s = 2ut + at^2$$

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

Third equation of motion: $v^2 = u^2 + 2as$

Derivation:

From the first equation of motion:

$$v = u + at$$

Making **t** the subject

$$t = \frac{v - u}{a} \text{ ....} (e)$$

Substituting equation (*e*) into equation the second equation of motion:

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

$$s = u\left(\frac{v - u}{a}\right) + \frac{1}{2}a\left(\frac{v - u}{a}\right)^2$$

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

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

Annex 2.4: Answers to Trial Questions 1

Question 1:

Initial velocity (u) = 20 m/s

Final velocity (v) = 0 m/s

Deceleration (a) = -2 m/s²

Find Time to Stop:

Use $v = u + at$

Substitute values: $0 = 20 - 2t$

Solve for $\mathbf{t = 10\ s}$

Find Distance Travelled:

Use

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

Substitute values:

$s = 20 \times 10 + \frac{1}{2} \times (-2) \times 10^2$

Simplify: $s = 100$ m

Question 2:

$u = 5$ m/s,

$v = 15$ m/s,

$s = 50$ m

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

$15^2 = 5^2 + 2a(50)$

$225 = 25 + 100a$

$a = 2\,ms^{-2}$

Question 3:

Stopping Distance:

Using the third equation of motion:

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

Given:

Initial velocity, $\mathbf{u} = 30ms^{-1}$

Final velocity, $\mathbf{v} = 0$

Deceleration, $\mathbf{a} = -5$ m/s²

$0 = 30^2 + 2 \times (-5) \times s$

$0 = 900 - 10s$

$10s = 900$

$s = \frac{900}{10} = 90\boldsymbol{m}$

Since the stopping distance (90 meters) is less than the distance to the obstacle (100 meters), the car will stop before hitting the obstacle.

Distance from the obstacle = 100 – 90 = 10m

Thus, the car stops 10 meters before the obstacle.

Annex 2.5: Answers to Trial Questions 2

Question 1:

Initial velocity (u) = 0 m/s (since the stone is dropped)

Height (h) = 80 meters

Acceleration due to gravity (g) = 9.8 m/s²

a. Time to hit the ground (t):

Using the equation of motion under gravity:

$h = \frac{gt^2}{2}$

Rearrange to solve for t

$t^2 = \frac{2h}{g}$

$t^2 = \frac{2 \times 80}{9.8}$

$t^2 = \frac{160}{9.8}$

$t = \sqrt{16.33}$

t = 4.04s

b. Velocity with which it hits the ground (v):

Using the equation:

$v = u + gt$

$v = 0 + 9.8 \times 4.04$

v = **39.59m/s**

Question 2:

- **Calculate the velocity after 12 seconds:**

  Using the first equation of motion:

  $v = u + a$

  Where:

  $u = 50\,m/s$

  $a = 4\,m/s^2$

  $t = 12\,s$

  $v = 50 + 4 \times 12$

  $v = 50 + 48$

  $v = \mathbf{98\,m/s}$

- **Calculate the height attained during the acceleration phase:**

  Using the second equation of motion: $s = ut + \frac{1}{2}at^2$

  $s = 50 \times 12 + \frac{1}{2} \times 4 \times 12^2$

  $s = 600 + \frac{1}{2} \times 4 \times 144$

  $s = 600 + 288$

  $s = 888m$

- **Calculate the additional time of flight, followed by height attained after the engine stops:**

  Using the first equation of motion for deceleration due to gravity (final velocity at max height = 0):

  $u = 98\,ms^{-1}$

  $a = -10\,ms^{-2}$

  $v = 0\,ms^{-1}$

  $0 = 98 - 10 \times t$

  $\mathbf{t = 9.8s}$

  Using the second equation of motion:

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

  $s = 98 \times 9.8 + \frac{1}{2} \times (-10) \times 9.8^2$

  $s = 960.4 - 480.2$

  $s = \mathbf{480.2}\,m$

- **Calculate the total maximum height:**
- Maximum height = Height during acceleration + Height during free fall
- Maximum height = 888 + 480.2
- Maximum height = 1368.2 meters

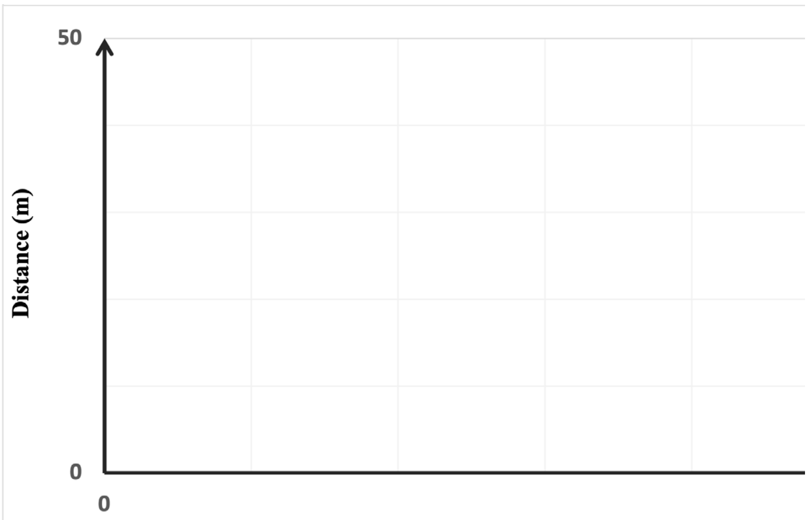
Answer:

- Maximum height attained by the rocket: **1368.2 m**

Annex 2.6: Answers to Trial Questions 3

Question 1:

Time (minutes)	0	5	10	15	20	25	30	35	40	50
Distance from home (metres)	0	150	150	250	250	400	550	550	550	0



Total distance = 150 m + 100 m + 300 m + 550 m = **1100 m**

Question 2:

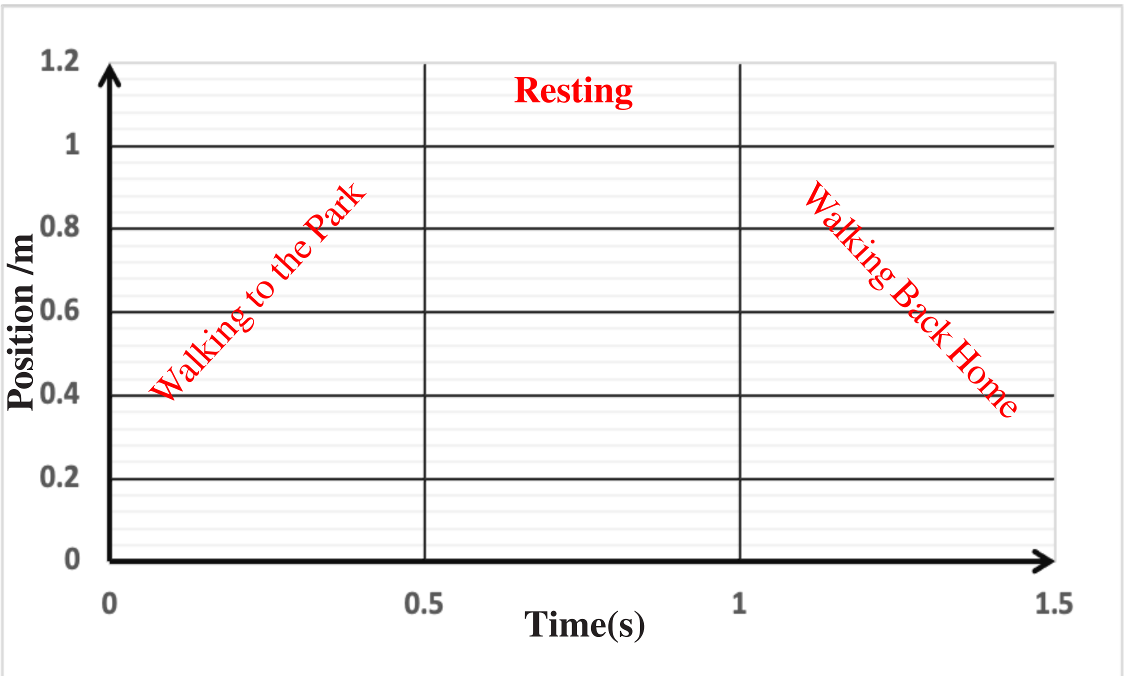
a) Compare your distance-time graph with a friend or your teacher.

b) 200m.

Annex 2.7 Answers to Trial Questions 4

Question 1:

Time (minutes)	0	10	15	25
Position (meters)	0	300	300	0



Total Distance = **300 m + 0 m + 300 m = 600 m**

Therefore, the total distance Kwaku travelled is **600 m**

Total time taken: 10 minutes + 5 minutes + 10 minutes = **25 minutes**

Kwaku's velocity at each section:

(a) 0 to 10 minutes

- The slope of the line is positive, representing Kwaku's constant walking speed towards the park. This speed is calculated as:

  $\text{velocity}\left(\mathrm{v}\right) = \frac{displacemnet}{Time}$

  $\mathrm{v} = \frac{300}{10} = 30 \boldsymbol{m/minute}$

(b) 10 to 15 minutes

- The horizontal line represents a period of rest.
- Slope (speed) = **0 m/minute** (no change in position).

(c) 15 to 25 minutes

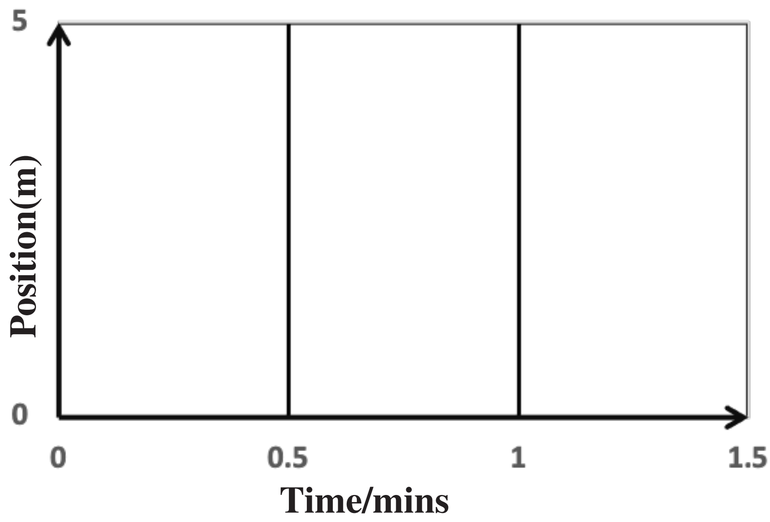
The slope of the line is negative, representing Kwaku's constant walking speed back home.

Slope (velocity)

$$\text{velocity}\left(\text{v}\right) = \frac{displacement}{Time}$$

$$\text{v} = -\frac{300}{10} = -30\boldsymbol{m/minute}$$

Question 2:



From the question the

Total distance = 400m

Total time = 20mins

$$\text{Average Speed} = \frac{\text{Total Distance}}{\text{Total Time}}$$

$$= \mathbf{20m/mins}$$

Convert 20m/mins to:

Metre/hour **= 1200m/hr**

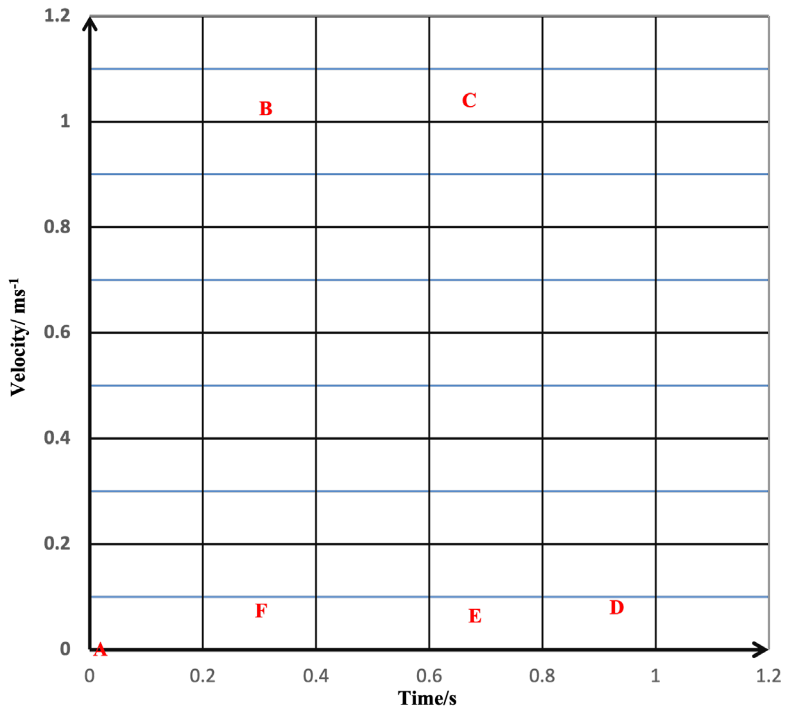
Metre/second =0.333m s^{-1}

Annex 2.8: Answers to Trial Questions 5

Question 1:

Time (seconds)	0	4	10	14

Velocity (m/s)	0	8	8	0



Since the figure is a trapezium, the formula for calculating the area of a trapezium can be applied

That is

Area $= \frac{1}{2}(a + b) \times h$

Where:

a and **b** are the lengths of the two parallel sides (also called bases).

h is the height (perpendicular distance) between the two parallel sides.

From the graph

a = 14s

b = 6s

h = 8

Substituting into the formula $\mathbf{Area = \frac{1}{2}(14 + 6) \times 8 = 80m}$

Alternative method: adding triangles and rectangles:

d. **Acceleration phase triangle ABF,** (0 to 4 seconds):

Base = 4 seconds

Height = 8 m/s

Area $= \frac{1}{2} \times$ Base $\times$ Height

Area $= \frac{1}{2} \times 4 \times 8 = \mathbf{16\,m}$

- **Constant velocity phase rectangle BCEF,** (4 to 10 seconds):
  Base = 6 seconds
  Height = 8 ms^{-1}
  Area = Base × Height
  Area $= 6 \times 8 = \mathbf{48\,m}$
- **Deceleration phase triangle CED,** (10 to 14 seconds):
  Base = 4 seconds
  Height = 8 ms^{-1}
  Area $= \frac{1}{2} \times$ Base × Height
  Area $= \frac{1}{2} \times 4 \times 8 = \mathbf{16m}$
- Total Distance = 16 metres + 48 metres + 16 metres = 80 metres

Annex 2.9: Answers to Trial Questions 6:

1. 3N
2. 0N
3. 30N
4. 27N

Annex 2.10: Answers to Trial Questions 8

Question 1:

$P = \frac{F}{A} = \frac{500}{50} = 10Nm^{-2} / 10Pa$

Question 2:

$P = \frac{F}{A} \rightarrow, P \times A = F$

$P \times A = 10 \times 50 = 500\ N$

Question 3:

Weight of dog = 20 N

Area of contact = 1000 cm^2 (0.1 m^2)

$Pressure = \frac{Weight}{Area\ of\ Contact} = \frac{20}{0.1}$

$Pressure = 200\ \text{Nm}^{-2}$

Question 4:

Weight = 500 N

Area of contact = 1.0 cm^2 (10^{-4} m^2)

$$Pressure = \frac{Weight}{Area\ of\ Contact} = \frac{500}{10^{-4}}$$

$Pressure = 5.0 \times 10^6\ \text{Nm}^{-2}$

Annex 2.11: Answers to Trial Questions 9:

Question 1:

Area of vessel = 0.15m^2

Density of water = 1000kgm^{-3}, $g = 10$ ms^{-2}

$H = 3\text{cm} = 0.03\text{m}$

$P = h\rho g$

$\Rightarrow P = 0.03 \text{ x } 1000 \text{ x } 10 = 300\text{Pa}$

But $P = \frac{F}{A}$

$\Rightarrow F = P \times A$

$\Rightarrow F = 300 \times 0.15 = 45\text{N}$

Question 2:

$P = \rho g h$

$\rho = 1.0 \times 10^3\ \text{kgm}^{-3}$, $g = 10\ \text{ms}^{-2}$, $h = 20\text{m}$

$\Rightarrow P = 1.0 \times 10^3 \times 10 \times 20 = 20{,}000\ \text{Pa}$

Annex 2.12: Answers to Trial Questions 10

Question 1:

Area of smaller cylinder $A = 5\text{m}^2$

Effort applied $F = 80$ N

$\frac{F_2}{F_1} = \frac{A_2}{A_1} = \frac{F_2}{80} = \frac{600}{5}$, F2 = 9600N

Question 2:

Area of smaller cylinder $A = 0.15$ m^2

Effort applied $F = 150$ N

Pressure transmitted by the fluid

$P = \frac{F}{A} = \frac{150}{0.15} = 1000$ Nm^{-2}

The force exerted by the piston in the larger cylinder is

$F = P \times A = 1000 \times 0.60 = 600$ N

But the frictional force experienced by the piston is 80 N. This implies the actual force exerted by the piston in the large cylinder is given by

600 – 80 = 520 N

Annex 2.13: Activity 2.16A

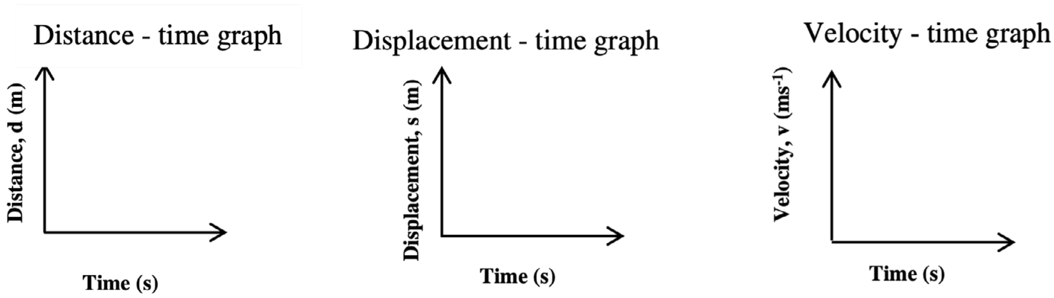
The small test tube descends when the bottle is squeezed. This is because the pressure inside the bottle increases as the bottle volume decreases. According to Pascal's principle, the increased pressure acts equally in all directions; this causes more water to enter the inverted test tube, compressing the air bubble inside. The compressed air bubble now has a greater density and so sinks.

Annex 2.14: Further Information

How to Draw Distance-time, displacement-time, and velocity-time graphs

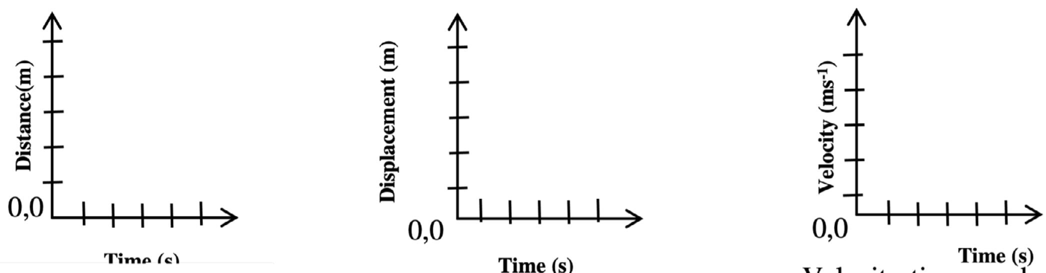
i. **Setting up the Axes:**

- ***Vertical axis (y-axis):*** Label this as "Distance (d) / position or displacement (s) / velocity (v) and decide on the interval based on your data.
- ***Horizontal axis (x-axis)***: Label this as "Time (t)" and decide on the time interval based on your data (e.g., seconds, minutes or hours). e.g.,



ii. Use a reasonable scale

- Determine the scale for each axis. Ensure that the scales are evenly spaced and large enough to accommodate all data points.
- Write the units of measurement on both axes. (time(s), distance(m), displacement(m) and velocity (ms^{-1})



Distance-time graph Displacement-time graph Velocity-time graph

Annex 2.15: Further Information

Newton's second law (law of acceleration): The rate of change of momentum is directly proportional to the unbalanced force applied and it takes place in the direction of that force.

Mathematically, this can be expressed as:

$$\frac{\Delta p}{t} \propto F \text{ ....(1)}$$

The momentum, **p**, of a body is the product of the mass of the body and its velocity. i.e.

p = m × v

m = mass in kg and

v = velocity

A body moving initially with velocity **u** accelerates to a velocity **v** after some time, **t.** This body can have its initial momentum as **mu** and its final momentum as **mv**. Thus, a **momentum change** can be symbolised by **"Δ"** called delta. Thus, change in momentum is symbolised by

Δp = final momentum – initial momentum

$\Delta p = mv - mu$

$\Delta p = m(v - u)$

Substituting this into equation (1)

It becomes

$$F \propto \frac{mv - mu}{t} \quad \ldots\ldots\ldots\ldots (2)$$

('∝' stands for directly proportional)

$$F = \boldsymbol{k}\,\frac{mv - mu}{t}\ ;\ `\propto' \text{ is the same as } `= k'$$

k is the constant of proportionality

$$F = \boldsymbol{k}\,\frac{m(v - u)}{t} \quad \ldots\ldots\ldots\ldots (3)$$

From our earlier lesson, $\frac{(v - u)}{t} = a$

$\therefore F = \mathbf{k}\, ma$ ……………………………………………(4)

The unit for force is the **Newton** and is defined as:

> "When an object of mass **1 kg** accelerates due to experiencing an unbalanced force of **1 Newton**, it accelerates at **1 ms^{-2}**".

Thus, for F =1N = 1 kg m s^{-2}, m =1 kg and a = 1 m s^{-2}, substituting in (3), we have

1 kg m s^{-2} = **k** (1kg) (1 m s^{-2})

$$k = \frac{kg\ m\ s^{-2}}{(1kg)(1\ m\ s^{-2})} = 1$$

since k = 1, it means that (3): F = 1× ma

$\therefore F = ma$

This law allows us to quantitatively analyse the motion of objects by considering the effects of forces on objects of different masses.

Unbalanced forces:

1. Unbalanced forces occur when the total forces on an object are not equal and opposite.
2. These forces result in a net force that changes the object's motion.

3. Unbalanced forces cause objects to start moving, stop moving, change direction, or change speed.
4. Simple experiments with toy cars and weights can help demonstrate the effects of unbalanced forces on motion.

Situations depicting unbalanced forces:

5. A car accelerating when you press the gas pedal.
6. A book falling off a table due to gravity.
7. Pushing a chair across the room, overcoming friction.

Annex 2.16: Further Information on Pressure

Factors Affecting Pressure

- Area of contact
- Force applied

From the expression $P = \frac{F}{A}$, pressure depends inversely on the area of contact. The smaller the area of contact, the bigger the pressure and vice versa. This means that one can therefore generate a huge pressure without necessarily using a big force. From the expression $P = \frac{F}{A}$, pressure increases as force increases (i.e. directly proportional). And pressure decreases as force decreases. However, as pressure decreases, the area increases and vice versa (inversely proportional).

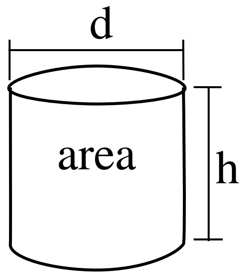
The force that acts at right angles to the area of contact brings about pressure. The force might be a contact force or a non-contact (field) force.

Pressure is a scalar quantity, a derived quantity and a dimensional quantity. Other units for pressure are centimetre mercury (cmHg), atmosphere (atm) and bar.

Examples of pressure in everyday life

- Knives require great pressure to cut materials, so the surface area is small.
- Long vehicles have many tyres to avoid too much pressure on them so that the total weight of the vehicle will be distributed across the large surface area.
- People sometimes get stuck on the soil when they walk in high-heeled shoes. This is because the surface area of their shoe is small, and therefore, more pressure is exerted on the ground.

Proof of pressure in fluids formula



A cylinder containing a liquid of density ρ contained in a vessel of cross-sectional area A m^2 at a depth of h m.

Volume of liquid = Base area × Height = Ah

Mass of liquid = Density × Volume = $\rho \times Ah$

Weight of liquid = Mass × g = $\rho \times Ah \times g$

Pressure exerted at base of the liquid = $\frac{Force}{Area}$

Pressure exerted at base of the liquid

$P = \frac{\rho g h A}{A}$, $\rightarrow P = \rho h g$

So, the pressure exerted depends on the height of the liquid column but not on the area it covers.

ACKNOWLEDGEMENTS

Ghana Education Service (GES)

(GAST)

List of Contributors

Name	Institution
Boniface N.T.A. Adams	PRESEC, Osu- Accra
David Bawa	National STEM Resource Centre
Stanley Kukubor	Agogo Presby College of Education
Stephen Amissah	Aburi Girls SHS Aburi