# PHYSICAL SCIENCES

## MATERIAL FOR GRADE 12

## FIRST TERM

## VERTICAL PROJECTILE MOTION

QUESTIONS

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## ➢ MECHANICS: VERTICAL PROJECTILE MOTION

**1-D motion:** One-dimensional motion. Linear motion. Motion in one line.

**Acceleration:** The rate of change of velocity. Symbol a. Unit: meters per second squared (m·s-2).

**Acceleration due to gravity (g):** The acceleration of a body due to the force of attraction of the earth.

**Displacement:** Change in position. Symbol: Δx (horizontal displacement) or Δy (vertical displacement). Unit: meters (m).

**Free fall:** The type of motion in which the only significant vertical force acting on the body is the body's weight.

**Gravitational force:** A force of attraction of one body on another due to their masses.

**Position:** Where an object is relative to a reference point. Symbol: x (horizontal position) or y (vertical position). Unit: meters (m).

**Projectile:** An object upon which the only force acting is the gravitational force.

**Velocity:** The rate of change of position. Symbol v. Unit: meters per second (m·s-1).

## ➢ VERTICAL PROJECTILE MOTION

✓ Explain that projectiles fall freely with gravitational acceleration g‘ accelerate downwards with a constant acceleration irrespective of whether the projectile is moving upward or downward or is at maximum height

✓ Know that projectiles take the same time to reach their greatest height from the point of upward launch as their greatest height from the point of upward launch as the time they take to fall back to the point of launch. This is known as time symmetry.

✓ Know that projectiles can have their motion described by a single set of equations for the upward and downward motion

✓ Use equations of motion to determine the position, velocity and displacement of a projectile at any given time

**KUTHI HUUUUU!!!!!!**

✓ At maximum height, the object‘s : velocity = 0 m.s-1, kinetic energy = 0 J and potential energy is maximum.

✓ Gravitational acceleration is always 9.8 $m.s^{-2}$ downwards.

✓ For rising and falling objects, the value of velocity is the same but in the opposite direction.



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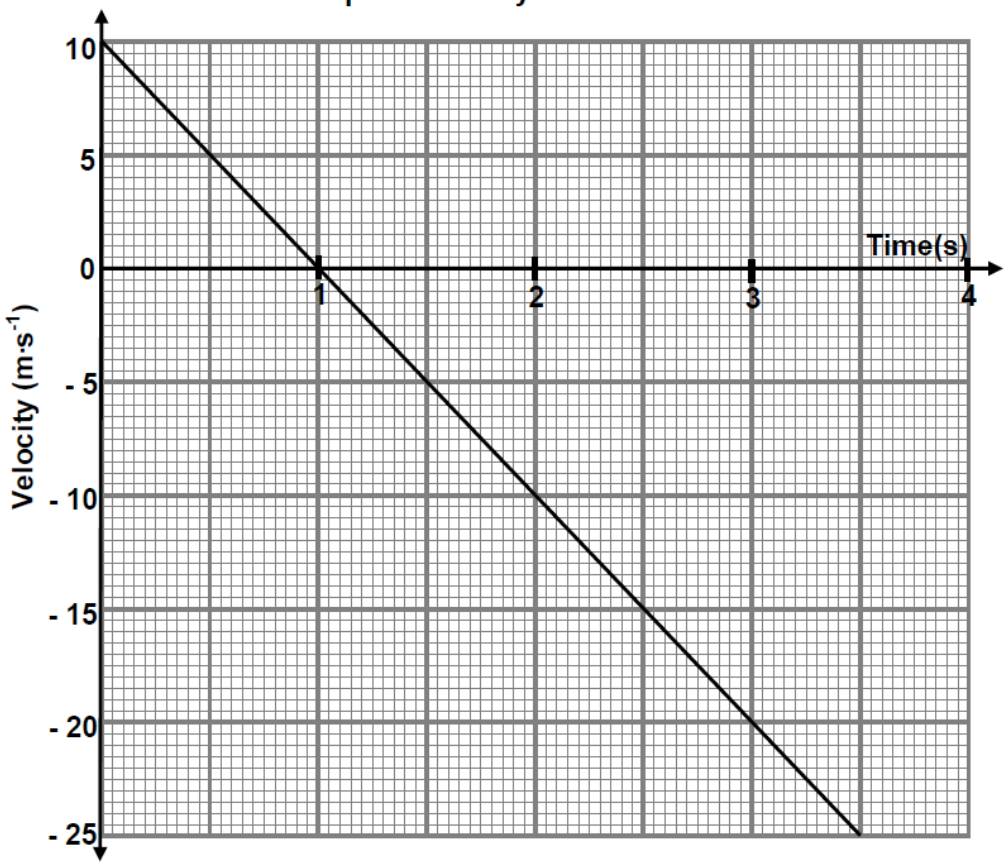
## QUESTION 6

A boy stands at the edge of a high cliff. He throws a stone vertically upwards with an initial velocity of 10 $m \cdot s^{-1}$. The stone strikes the ground at a point below the cliff after 3,5 s. The velocity-time graph below was obtained from *measurements* made during the motion of the stone.

**Graph of velocity versus time**




Use the information on the graph to answer the following questions:

6.1 Calculate the acceleration of the stone between times $t$ = 2 s and $t$ = 3 s. (3)

6.2 At which time(s) is the stone moving at a speed of 5 $m \cdot s^{-1}$? (2)

6.3 After how many seconds does the stone reach its highest point? (1)

6.4 Determine the height of the cliff from which the stone was thrown. (4)

6.5 Using the top of the cliff as the initial position of the stone, sketch the position-time graph (displacement-time graph) for the motion of the stone **from its highest point until it reaches the ground**. Only indicate relevant time values on the x-axis. (3)

**[13]**

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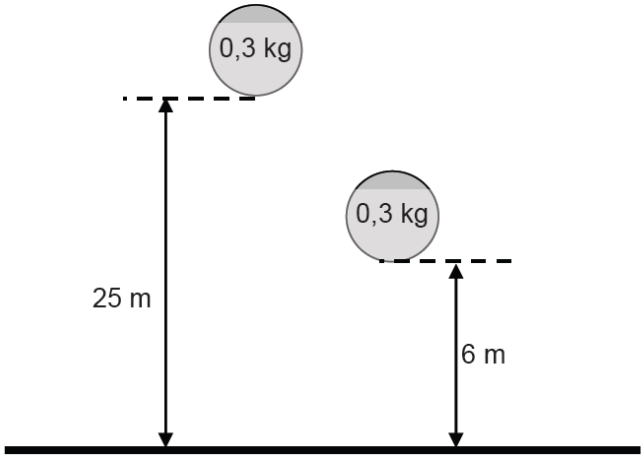
## QUESTION 5

The roof of a tall building is 25 m above the ground. A rigid ball of mass 0,3 kg falls freely when dropped from the roof. It strikes the concrete floor on the ground with velocity $v_1$. It bounces to a maximum vertical height of 6 m.

The ball was in contact with the floor for 0,9 s. Ignore the effects of friction.




5.1 Calculate the velocity $v_1$ when the ball first hits the floor. (3)

5.2 Calculate the impulse of the ball as a result of the collision. (7)

5.3 Calculate the magnitude of the net force exerted on the ball. (3)

5.4 Using the ground as zero reference, draw a sketch graph of position (displacement) versus time for the motion of the ball from its original height until it reaches its second maximum height. Indicate the relevant position values on the y-axis. (4)

5.5 The rigid ball is now replaced with a softer ball of the same mass and volume as the rigid ball. It is then dropped from the same height onto the concrete floor.

Will the ball reach the SAME, GREATER or LESSER height compared to the previous ball? Use principles of physics to explain your answer. (3)

**[20]**



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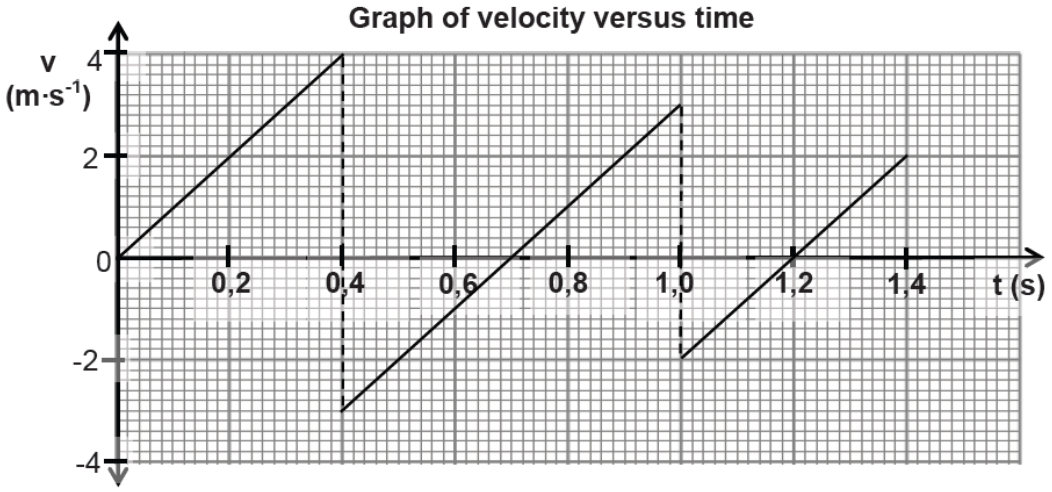
**QUESTION 4 (Start on a new page.)**

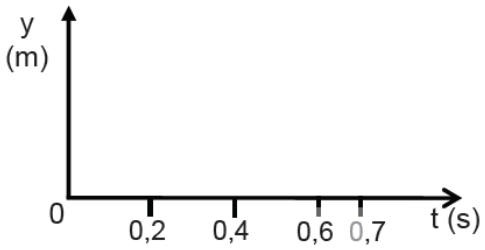
A ball is released from a certain height. The velocity-time graph below represents the motion of the ball as it bounces vertically on a concrete floor. The interaction time of the ball with the floor is negligibly small and is thus ignored.




4.1 Describe the changes, if any, in velocity and acceleration of the ball from t = 0 s to t = 0,4 s. (4)

4.2 Without using the equations of motion, calculate the height from which the ball has been dropped initially. (4)

4.3 Copy the set of axes below into your ANSWER BOOK.




Use the given velocity versus time graph for the motion of the ball to sketch the corresponding position-time graph for the time interval 0 s to 0,7 s. (3)

4.4 Is the first collision of the ball with the floor elastic or inelastic? Give a reason for your answer. (2)

**[13]**

**QUESTION 5 (Start on a new page.)**

A supervisor, 1,8 m tall, visits a construction site. A brick resting at the edge of a roof 50 m above the ground suddenly falls. At the instant when the brick has fallen 30 m the supervisor sees the brick coming down directly towards him from above.

Ignore the effects of friction and take the downwards motion as positive.

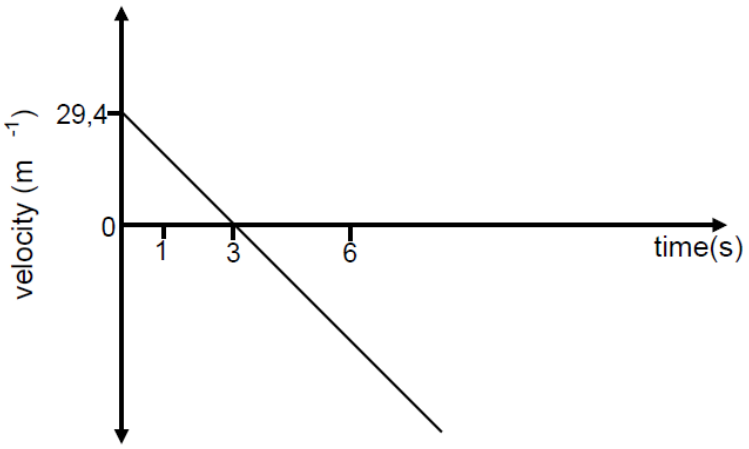
5.1 Calculate the speed of the brick after it has fallen 30 m. (3)

5.2 The average reaction time of a human being is 0,4 s. With the aid of a suitable calculation, determine whether the supervisor will be able to avoid being hit by the brick. (6)

**[9]**

**QUESTION 3 (Start on a new page.)**

A man fires a projectile **X** vertically upwards at a velocity of 29,4 $ms^{-1}$ from the EDGE of a cliff of height 100 m. After some time the projectile lands on the ground below the cliff. The velocity-time graph below (NOT DRAWN TO SCALE) represents the motion of projectile **X**. (Ignore the effects of friction.)




3.1 Use the graph to determine the time that the projectile takes to reach its maximum height. (A calculation is not required.) (1)

3.2 Calculate the maximum height that projectile **X** reaches above the ground. (4)

3.3 Sketch the position-time graph for projectile **X** for the period t = 0 s to t = 6 s. USE THE EDGE OF THE CLIFF AS ZERO OF POSITION.

Indicate the following on the graph:

- The time when projectile **X** reaches its maximum height
- The time when projectile **X** reaches the edge of the cliff (4)



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3.4 One second (1 s) after projectile **X** is fired, the man's friend fires a second projectile **Y** upwards at a velocity of 49 m·s$^{-1}$ FROM THE GROUND BELOW THE CLIFF.

The first projectile, **X**, passes projectile **Y** 5,23 s after projectile **X** is fired. (Ignore the effects of friction.)

Calculate the following:

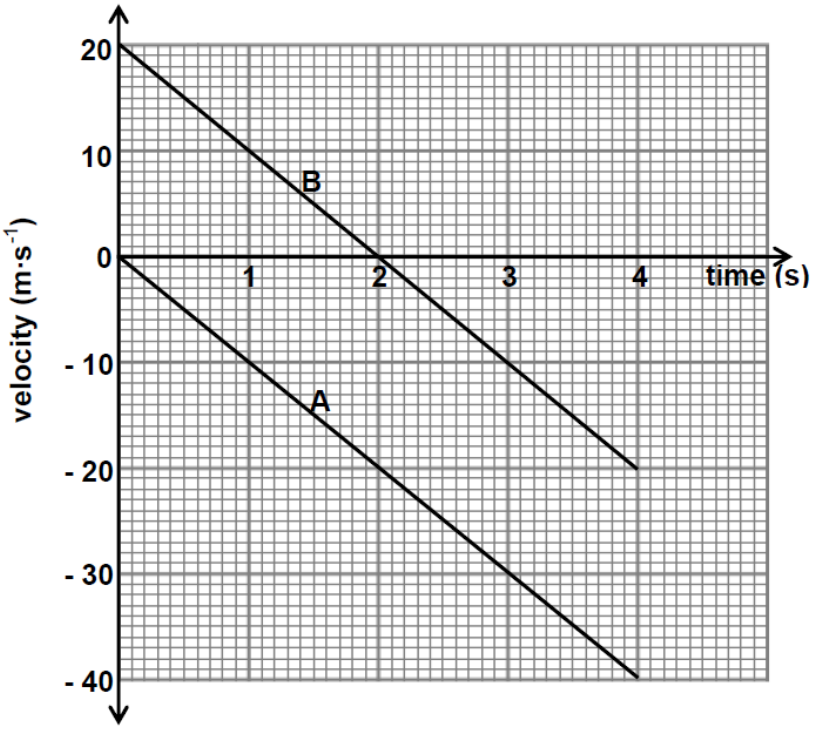
3.4.1 The velocity of projectile **X** at the instant it passes projectile **Y** (5)

3.4.2 The velocity of projectile **X** RELATIVE to projectile **Y** at the instant it passes projectile **Y** (5)

**[19]**

**QUESTION 3 (Start on a new page.)**

The velocity-time graph shown below represents the motion of two objects, **A** and **B**, released from the same height. Object **A** is released from REST and at the same instant object **B** is PROJECTED vertically upwards. (Ignore the effects of friction.)




3.1 *Object A undergoes a constant acceleration*. Give a reason for this statement by referring to the graph. (No calculations are required.) (2)

3.2 At what time/times is the SPEED of object **B** equal to 10 m·s$^{-1}$? (2)

3.3 What is the velocity of object **A** relative to object **B** at t = 1 s? (3)

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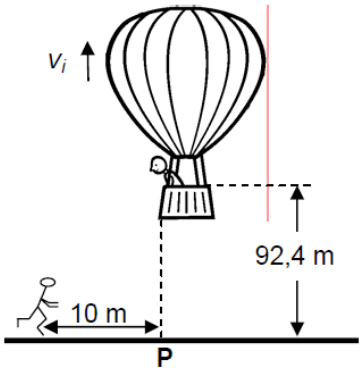
3.4 Object **A** strikes the ground after 4 s. USE EQUATIONS OF MOTION to calculate the height from which the objects were released. (3)

3.5 What physical quantity is represented by the area between the graph and the time axis for each of the graphs **A** and **B**? (2)

3.6 Calculate, WITHOUT USING EQUATIONS OF MOTION, the distance between objects **A** and **B** at t = 1 s. (5)
**[17]**

**QUESTION 3 (Start on a new page.)**

A hot-air balloon is moving vertically upwards at a constant speed. A camera is accidentally dropped from the balloon at a height of 92,4 m as shown in the diagram below. The camera strikes the ground after 6 s. Ignore the effects of friction.




3.1 At the instant the camera is dropped, it moves upwards. Give a reason for this observation. (1)

3.2 Calculate the speed $v_i$ at which the balloon is rising when the camera is dropped. (4)

3.3 Draw a sketch graph of velocity versus time for the entire motion of the camera.

Indicate the following on the graph:

- Initial velocity
- Time at which it reaches the ground (4)

3.4 If a jogger, 10 m away from point **P** as shown in the above diagram and running at a constant speed of 2 $m \cdot s^{-1}$, sees the camera at the same instant it starts falling from the balloon, will he be able to catch the camera before it strikes the ground?

Use a calculation to show how you arrived at the answer. (5)
**[14]**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## QUESTION 3

A ball is thrown straight upwards with an initial speed of 15 $m.s^{-1}$. It reaches a maximum height and falls back to the ground.

3.1 Calculate how long it will take the ball to reach the maximum height. (3)

3.2 Calculate the magnitude of the maximum height. (3)

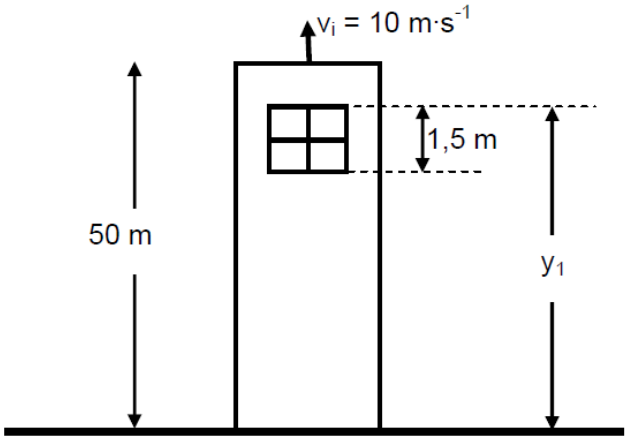
3.3 How long was the ball in the air? (2)

3.4 Draw a sketch graph of the velocity-time relationship for the motion of the ball. Show the relevant values on both axes. (3)

**[11]**

## QUESTION 3 (Start on a new page.)

A stone is thrown vertically upward at a velocity of 10 $m \cdot s^{-1}$ from the top of a tower of height 50 m. After some time the stone passes the edge of the tower and strikes the ground below the tower. Ignore the effects of friction.




3.1 Draw a labelled free-body diagram showing the force(s) acting on the stone during its motion. (1)

3.2 Calculate the:

3.2.1 Time taken by the stone to reach its maximum height above the ground (4)

3.2.2 Maximum height that the stone reaches above the ground (4)

3.3 USING THE GROUND AS REFERENCE (zero position), sketch a position-time graph for the entire motion of the stone. (3)

3.4 On its way down, the stone takes 0,1 s to pass a window of length 1,5 m, as shown in the diagram above.

Calculate the distance ($y_1$) from the top of the window to the ground. (7)

**[19]**



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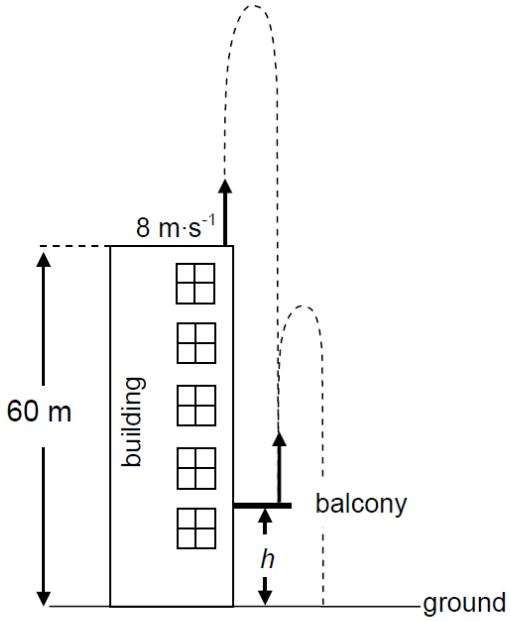
**QUESTION 3 (Start on a new page.)**

An object is projected vertically upwards at 8 m·s$^{-1}$ from the roof of a building which is 60 m high. It strikes the balcony below after 4 s. The object then bounces off the balcony and strikes the ground as illustrated below. Ignore the effects of friction.




3.1 Is the object's acceleration at its maximum height UPWARD, DOWNWARD or ZERO? (1)

3.2 Calculate the:

3.2.1 Magnitude of the velocity at which the object strikes the balcony (4)

3.2.2 Height, *h*, of the balcony above the ground (5)

The object bounces off the balcony at a velocity of 27,13 m·s$^{-1}$ and strikes the ground 6 s after leaving the balcony.

3.3 Sketch a velocity-time graph to represent the motion of the object from the moment it is projected from the ROOF of the building until it strikes the GROUND. Indicate the following velocity and time values on the graph:

- The initial velocity at which the object was projected from the roof of the building
- The velocity at which the object strikes the balcony
- The time when the object strikes the balcony
- The velocity at which the object bounces off the balcony
- The time when the object strikes the ground (6)

**[16]**



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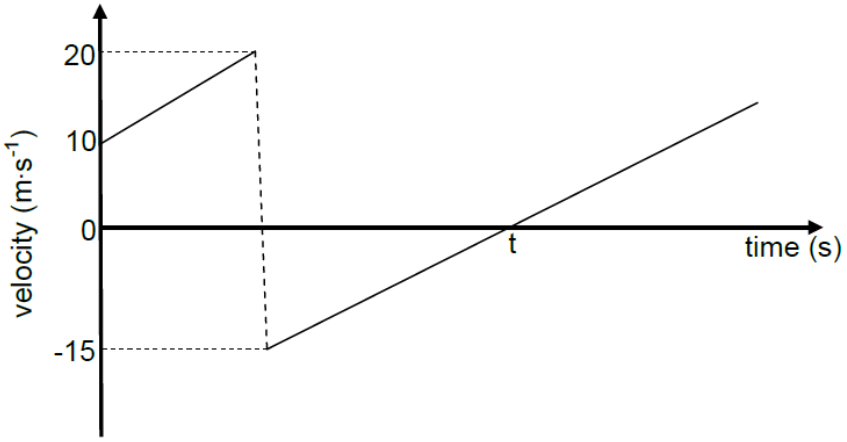
**QUESTION 3 (Start on a new page.)**

A ball of mass 0,15 kg is thrown vertically downwards from the top of a building to a concrete floor below. The ball bounces off the floor. The velocity versus time graph below shows the motion of the ball. Ignore the effects of air friction. TAKE DOWNWARD MOTION AS POSITIVE.




3.1 From the graph, write down the magnitude of the velocity at which the ball bounces off the floor. (1)

3.2 Is the collision of the ball with the floor ELASTIC or INELASTIC? Refer to the data on the graph to explain the answer. (3)

3.3 Calculate the:

3.3.1 Height from which the ball is thrown (4)

3.3.2 Magnitude of the impulse imparted by the floor on the ball (3)

3.3.3 Magnitude of the displacement of the ball from the moment it is thrown until time *t* (4)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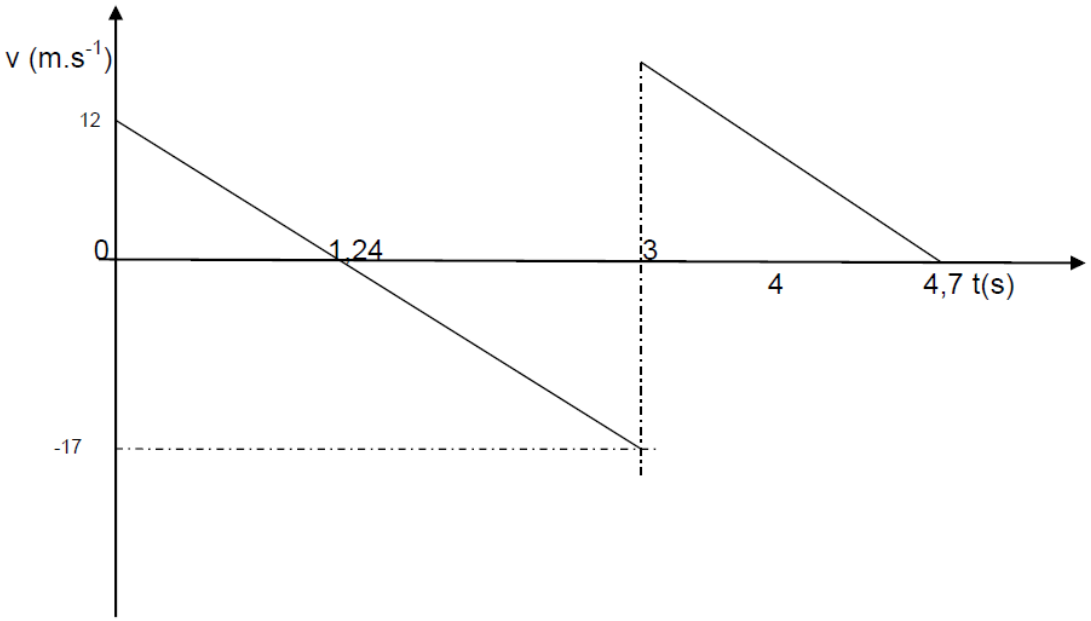
**QUESTION 3 (Start on a new page.)**

The velocity-time graph below shows the motion of a golf ball of mass 150 g, which is thrown vertically upwards from a platform above the ground. The ball strikes the ground and bounces back up again.

The collision of the ball with the ground is elastic.




3.1 Write down the physical quantity represented by the gradient of this graph. (1)

3.2 Write down the initial velocity of the golf ball. (1)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3.3 Write down the position of the ball at the following times during its motion:

3.3.1 t = 1,24 s (1)

3.3.2 t = 3 s (1)

3.3.3 t = 4,7 s (1)

3.4 Calculate each of the following WITHOUT THE USE OF EQUATIONS OF MOTION:

3.4.1 The height of the ball above the ground as it left the thrower's hand (4)

3.4.2 The height at which the ball bounces (3)

3.5 Calculate the impulse of the ball when it bounces off the ground. (3)

3.6 Draw the corresponding position versus time graph for the entire motion of the ball.
TAKE UP AS POSITIVE AND THE GROUND AS ZERO REFERENCE (3)
**[18]**


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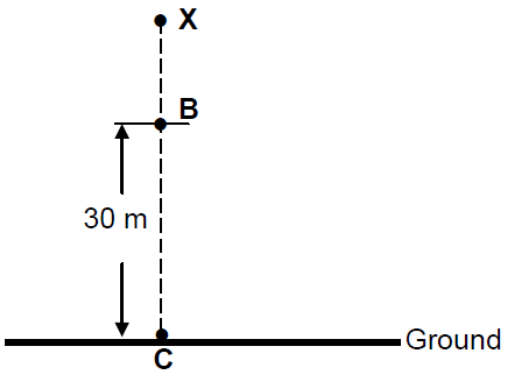
**QUESTION 3 (Start on a new page.)**

An object is released from rest from a point **X,** above the ground as shown in the diagram below. It travels the last 30 m (**BC**) in 1,5 s before hitting the ground. Ignore the effects of air friction.




3.1 Name the type of motion described above. (1)

3.2 Calculate the:

3.2.1 Magnitude of the velocity of the object at point **B** (4)

3.2.2 Height of point **X** above the ground (5)

After hitting the ground, the object bounces once and then comes to rest on the ground.

3.3 Sketch an acceleration-time graph for the entire motion of the object. (3)
**[13]**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