SAIP-DoE

Physical Science

Grade 12 Educators Workshop

Vhembe East & West Districts

Limpopo Province, RSA

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THE VOICE OF PHYSICS IN SOUTH AFRICA

Vertical Projectile Motion in One Dimension

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Physical Science Paper 1

Question 3:

Vertical Projectile Motion

Common Errors and Misconceptions

(a) Some candidates omitted the keywords ‘only force’ and ‘gravitational force’ in their definition of free fall. Some gave the definition of a projectile.

(b) The candidates experienced problems with the signs of velocity and acceleration in their substitutions into the appropriate equations of motion.

(c) Many candidates could not interpret the graphs properly and showed a poor understanding of the concept of time symmetry in vertical projectile motion.

(d) Some candidates used ‘sec’ as the unit for time instead of ‘s’.

Suggestions for improvement:

a) Learners must be advised to start every calculation in mechanics, including vertical projectile motion, by indicating the sign convention at the beginning of the problem.

- Emphasize that the direction of gravitational acceleration does not change in a question but remains constant.
- Learners should be advised to keep to ONE sign convention when solving a problem and not to change their chosen sign convention within a problem as this could lead to confusion.

(b) Teach learners skills of interpreting graphs especially for projectiles, e.g. to have reference points

and collect all relevant data before calculating any quantity.

(c) The correct SI unit for time should be emphasized to learners.

Vertical Motion in One Dimension

One dimension (1D) Vertical projectile motion represented in:-

- words,
- diagrams,
- equations and
- graphs

Vertical motion in one Dimension

One dimension (1D) Vertical projectile motion represented in words

- Concepts
- Conditions
- Assumptions
- Model
- Quantities

Vertical Motion in One Dimension

- Moving upwards and or downwards with respect to the learner's frame of reference.

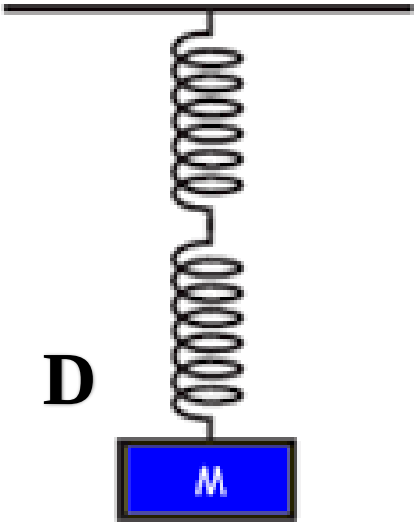
Which of the following are projectiles?

A

B

C

D



E

F

G

Vertical Motion in One Dimension

One dimension (1D) Vertical projectile motion represented in words

A) A , B, C and D

B) A, D and F

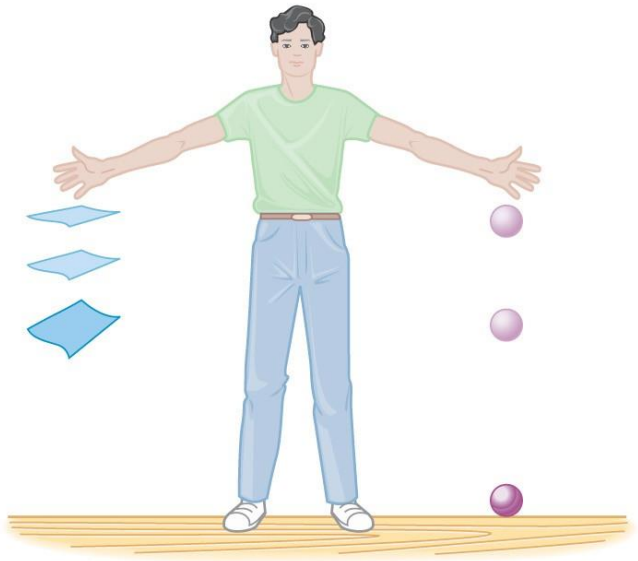
C) A, D, E and F

D) A and F

Freely Falling Bodies

Which of these is a projectile?

- A ball or a paper?



(a)

Conditions

- The object must move up or down (no horizontal displacement).
- The object must not self propel (without external agency)
- The movement is near the surface of the Earth (distance moved is small compared to the radius of the Earth).
- The object is not affected by air resistance.

- The motion of an object is subject only to the influence of gravity.
- The only force exerted on the object is the force of gravity (weight $w = mg$).
- The object must be rigid (zero deformation).
- The Cartesian plane is used to define the direction. Upwards direction is positive and downwards direction is negative.

Quantities

- **Acceleration** is a vector quantity with a constant magnitude **g = 9.8 m/s^2** and is **always** directed in the negative y (**g = -9.8 m/s^2** using Cartesian coordinates as reference).
- **Velocity** (v_i or v_f) is also a vector quantity whose magnitude decreases as the object moves upwards (positive direction) and increases as the object moves downwards (negative direction).

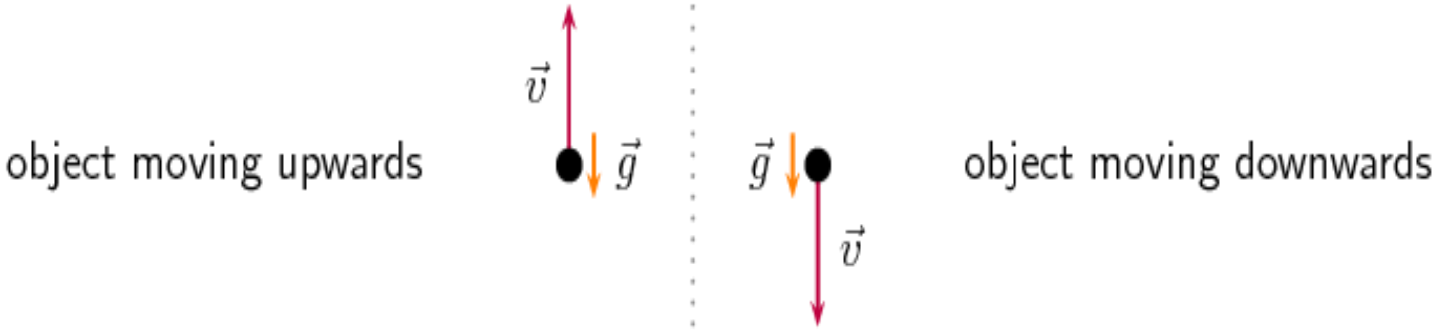
Quantities

- Projectiles that have an initial velocity upwards will have zero velocity at their greatest height.

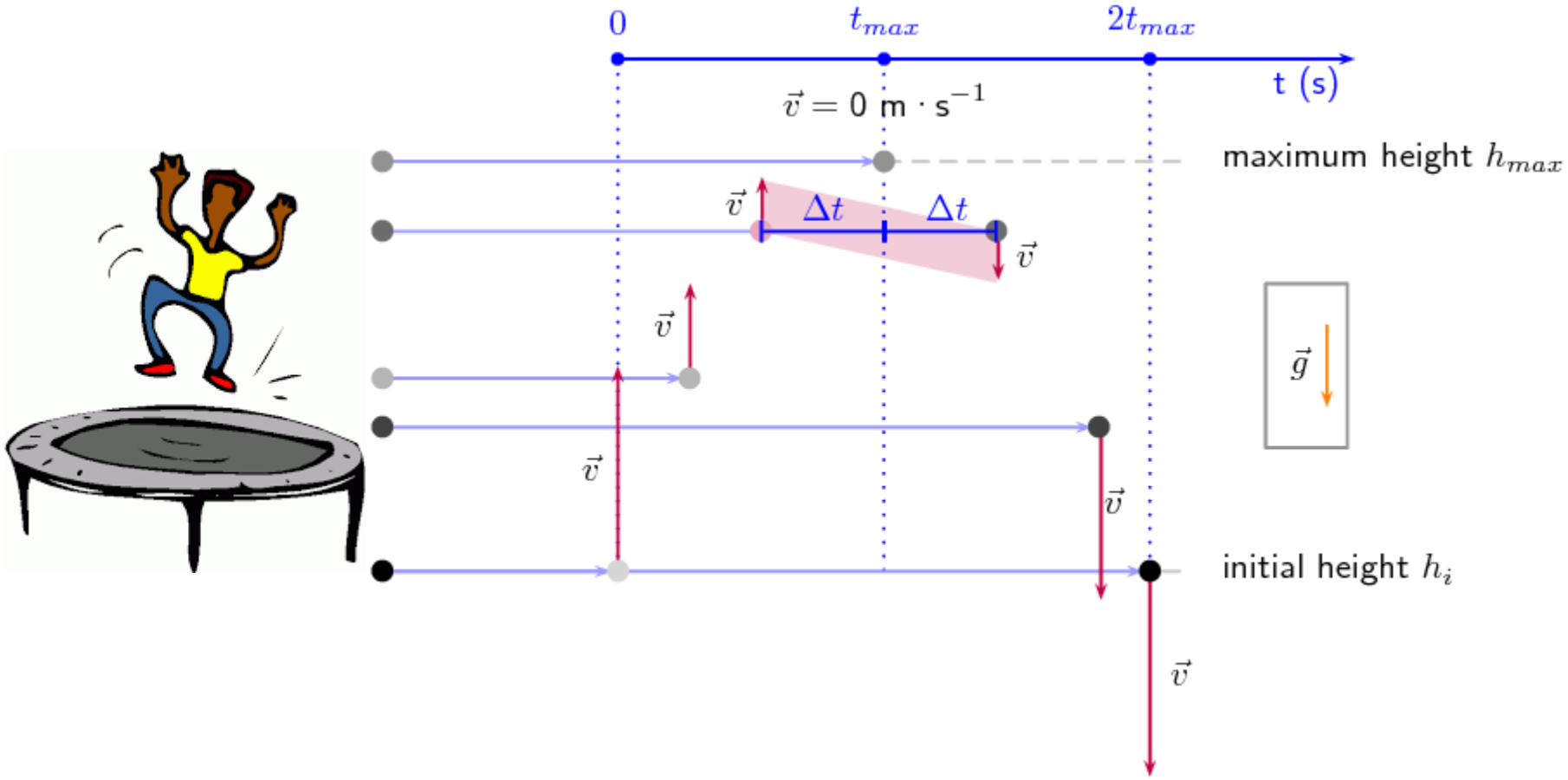
- Magnitude of velocity: the magnitude of the velocity at the same point on the upward and downward motion will be the same.

- **Displacement** (y) is a vector whose direction is positive upwards and negative downwards.
- **Time** : Time is a scalar quantity.
- **Time symmetry:** The time intervals during the upward motion and the downward motion are the same, for example it will take the same time to rise from initial position to maximum height as it will to drop back to the initial position.

Diagrams


object moving upwards
$\vec{v}$
$\vec{g}$
$\vec{g}$
$\vec{v}$
object moving downwards

Diagram


0
t_{max}
$2t_{max}$
t (s)
$\vec{v} = 0\ \mathrm{m \cdot s^{-1}}$
maximum height h_{max}
$\vec{v}$
Δt
Δt
$\vec{v}$
$\vec{g}$
$\vec{v}$
$\vec{v}$
$\vec{v}$
initial height h_i
$\vec{v}$

Equations

$$v_f = v_i + a\Delta t$$

$$v_f^2 = v_i^2 + 2a\Delta y$$

$$\Delta y = v_i \Delta t + \frac{1}{2} a \Delta t^2$$

$$\Delta y = \left(\frac{v_i + v_f}{2} \right) \Delta t$$

Equations for Vertical Motion

	Equation	Quantities				
		y	v_i	v_f	g	t
1	$\Delta y = v_i \Delta t + \frac{1}{2} g \Delta t^2$	✓	✓	✗	✓	✓
2	$v_f^2 = v^2_i + 2g\Delta y$	✓	✓	✓	✓	✗
3	$v_f = v_i + g\Delta t$	✗	✓	✓	✓	✓
4	$\Delta y = (v_f + v_i)t/2$	✓	✓	✓	✗	✓

Equations

- Identify given and derived quantities (**minimum of quantities**).

y	v_i	v_f	a	t
			-9.8 m/s^2	

- Establish directions for all vector quantities.
- Determine which **one** of the equations of motion will be suitable to solve the problem.

Example

- **Statement: A boy jumps vertically upwards from a trampoline with an initial velocity of 30.0m/s.**
- **Question 1**: Determine how long it will take him to return to the trampoline mat.

y	v_i	v_f	$a = g$	t
0.0 m	30.0 m/s		-9.8 m/s^2	?

Example

- **Statement: A boy jumps vertically upwards from a trampoline with an initial velocity of 30.0m/s.**
- **Question 2**: Determine the maximum height reached by the boy.

y	v_i	v_f	$a = g$	t
?	30.0 m/s	0.0 m/s	-9.8 m/s^2	

Note that in the same example, one of the following can be given:

- **The time for the boy to reach the maximum height,**
- **The total time that the boy was in the air or**
- **The maximum height reached by the boy.**

- **Example 1**

Burj (meaning Tower) Khalifa building in Dubai, is recorded as the tallest building (830 m) with 160 floors/stories. A missile is launched vertically upwards from the top of the 160th floor at 87 m/s.

Calculate:

1.1 The time for the missile to reach the maximum height.

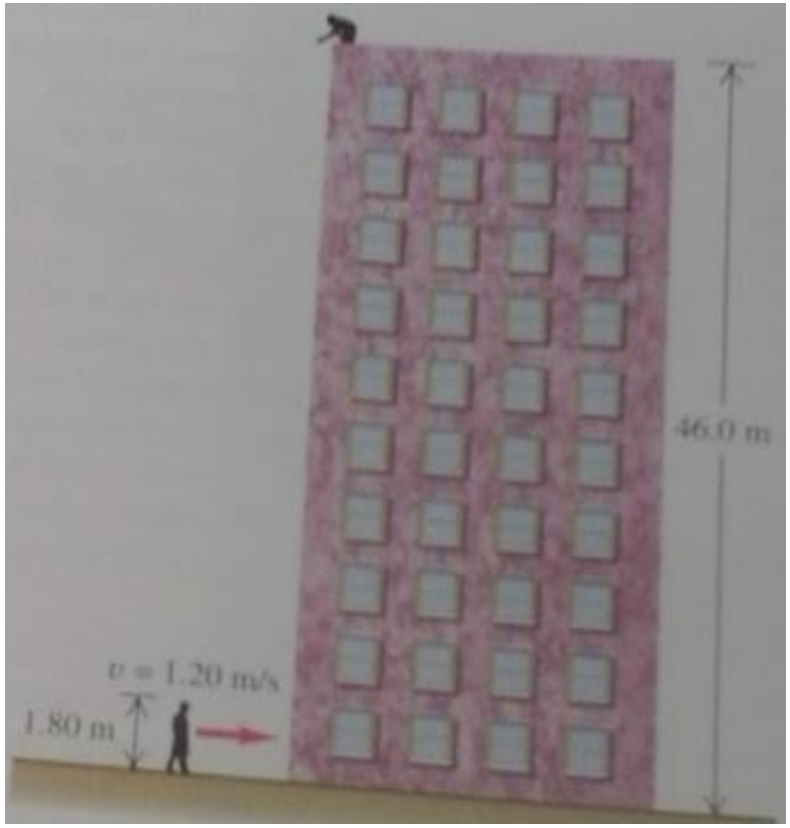
1.2 The maximum height reached by the missile.

1.3 The velocity at which the missile hits the ground.

1.4 The total time that the missile was in air.

- **Example 2**

A student is on the roof of a Physics building which is 36.0 m above the ground as shown in the accompanying figure below. His Physics lecturer, who is 1.8 m tall, is walking alongside the building at a constant speed of 1.5 m/s. The student wishes to drop an egg on the lecturer's head.


46.0 m
v = 1.20 m/s
1.80 m


+
–

2.1 After how long will the egg hit the lecturer's head?

2.2 How far away (horizontally), should the lecturer be when the student releases the egg?

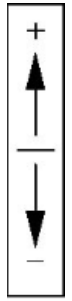
2.3 What will be the velocity of the egg when it hits the lecturer?

2.4 If the egg thrown by the student had missed the lecturer, what would be the velocity of the egg just before it hits the ground?

2.5 What would be the time taken by the egg to reach the ground?

Example 3

A Physics student determined to test the law of gravity for herself walks off a skyscraper 350 m high, stopwatch in her hand, and starts her free fall (zero initial velocity). Five seconds later, a Superman arrives at the scene and dives off the roof to save the student.



Use the above information to answer the questions questions below.

3.1 Calculate the time taken by the student to fall to the ground.

3.2 What must be Superman's initial velocity in order for him to can save the student before she falls to the ground?

Example 4 (Almost similar to the one in 2015)

A juggler performs in a room whose ceiling is 3 m above the level of his hand. He throws a ball vertically upward so that it just reaches the ceiling.

4.1 What is the initial velocity with which he throws the ball?

4.2 What is the time required for the ball to reach the ceiling?

He throws a second ball upward with the same initial velocity, at the instant that the second ball is at the ceiling.

4.3 How long after the second ball is thrown do the two balls pass each other?

4.4 When the balls pass each other, how far are they above the juggler's hands?

Vertical Motion in One Dimension

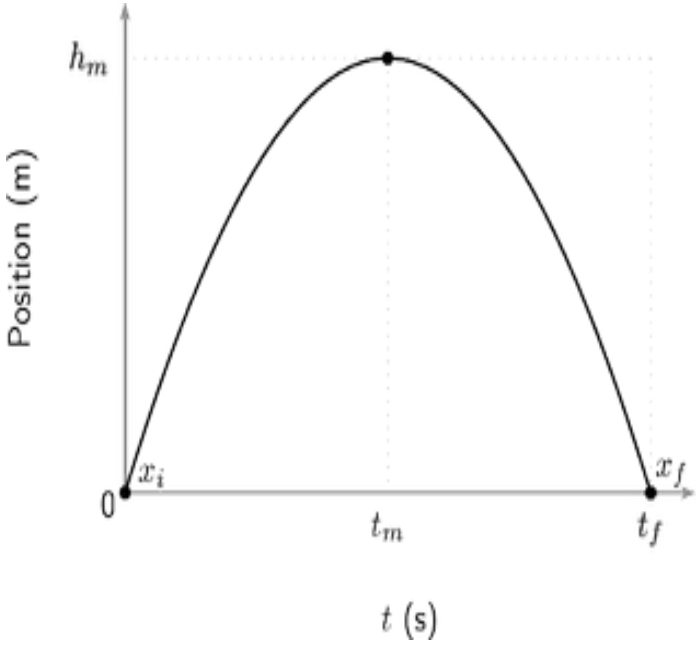
Graphs

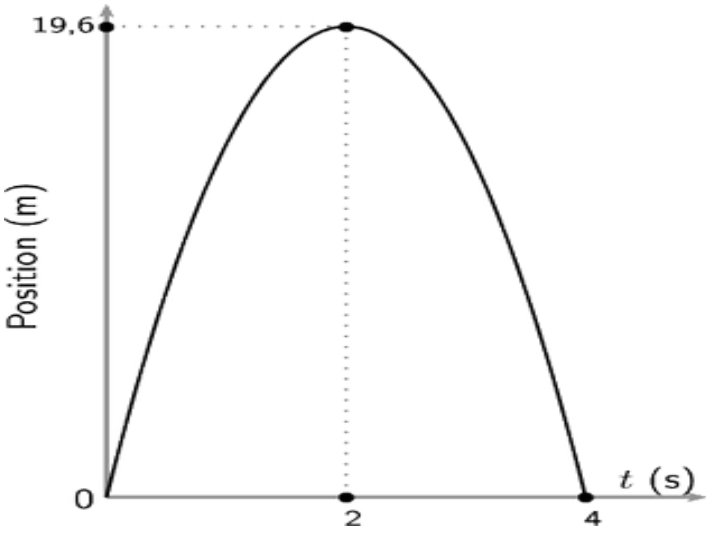
Displacement : $y = v_i t + \frac{1}{2} g t^2$ (parabola)

Velocity : $v_f = v_i + gt$ (straight line)

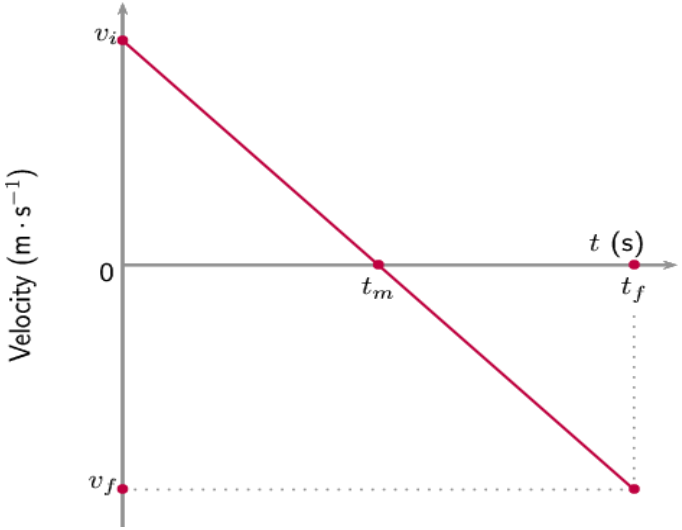
Acceleration : $g = -9.8\ m/s^2$ (straight line with no slope)

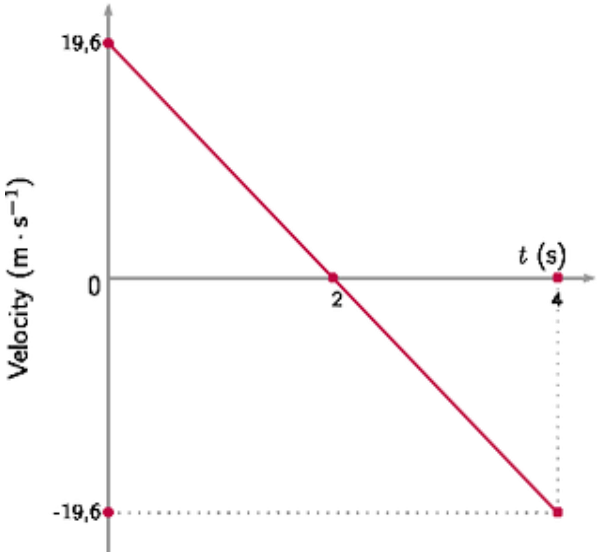
Displacement-time Graphs



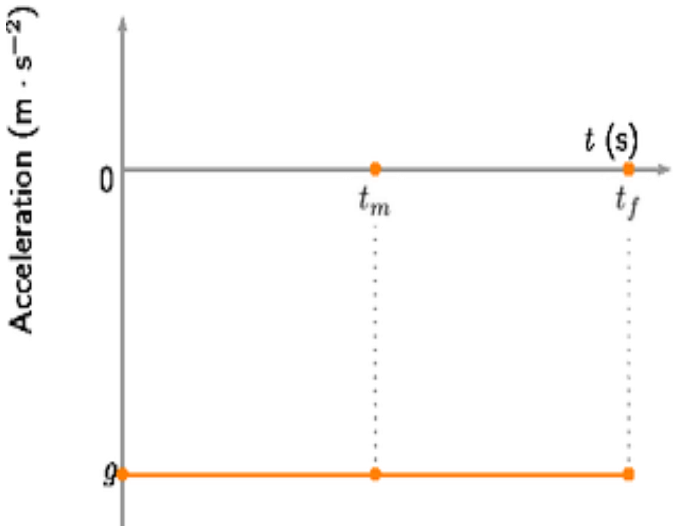


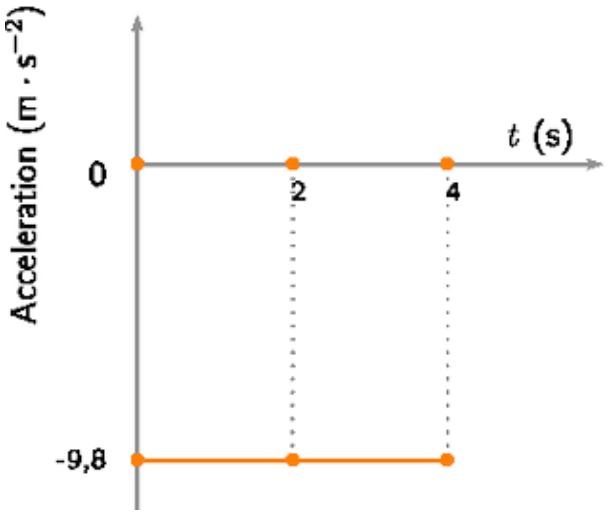
Velocity-time Graphs



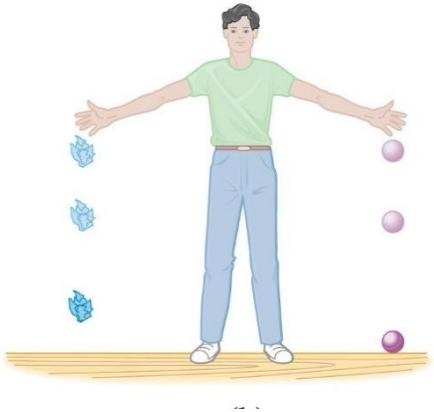


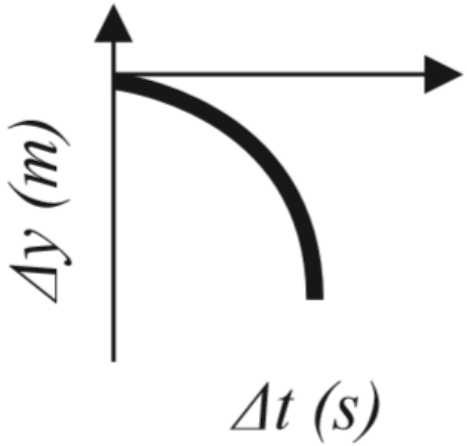
Acceleration-time Graphs

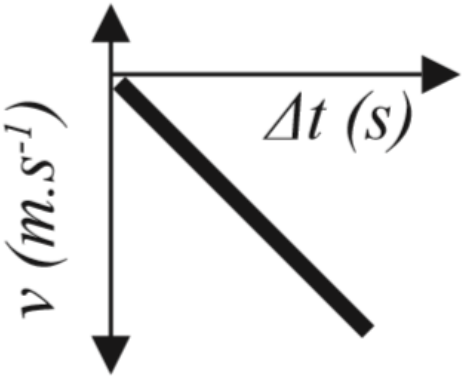


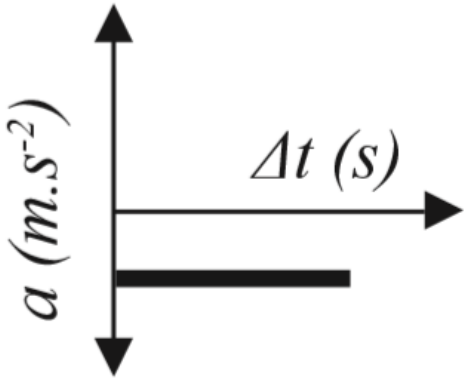


Graphs

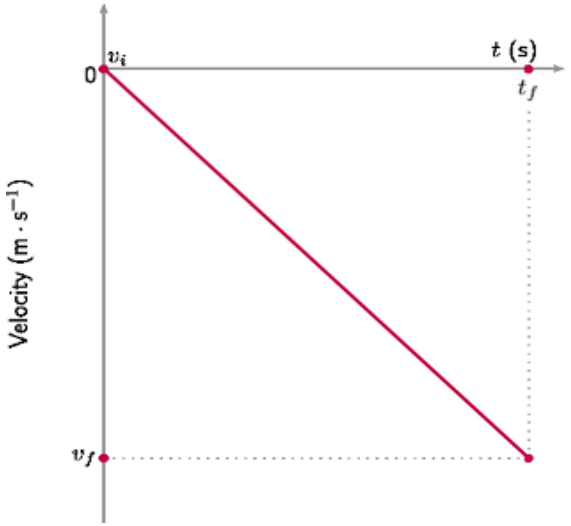


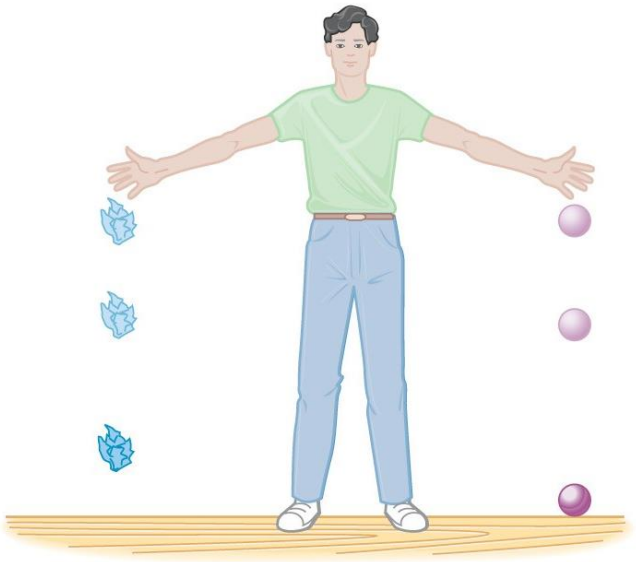




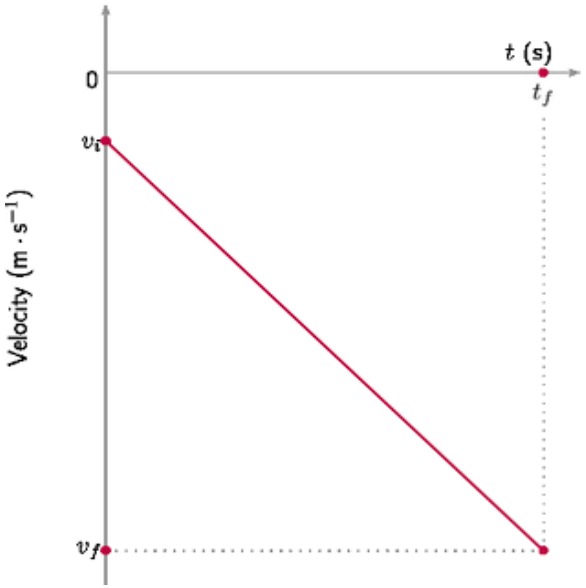


- # Velocity-time Graphs

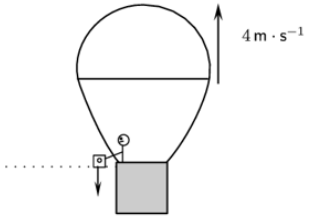


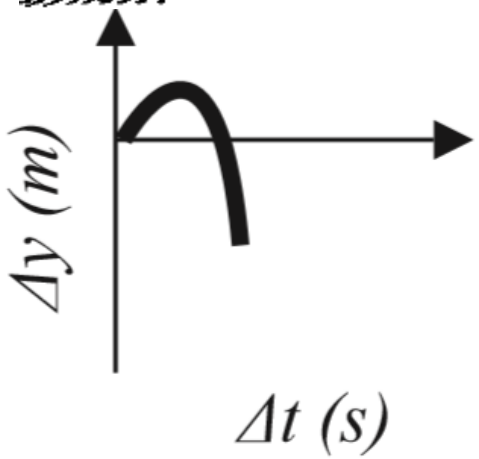


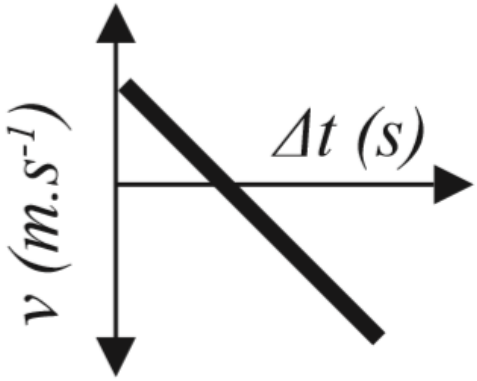
(b)

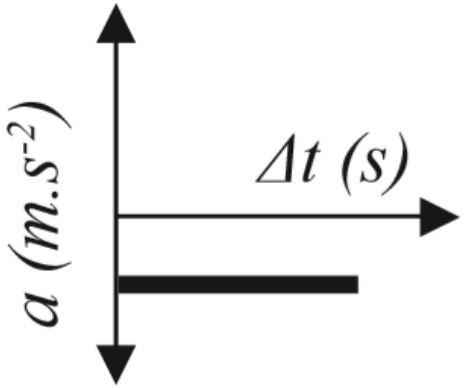


Graphs

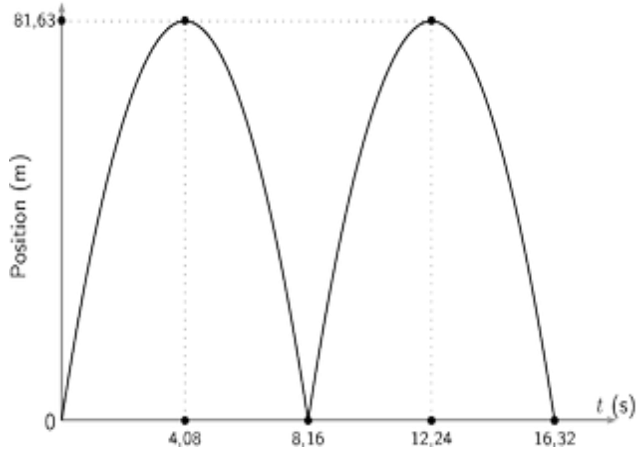


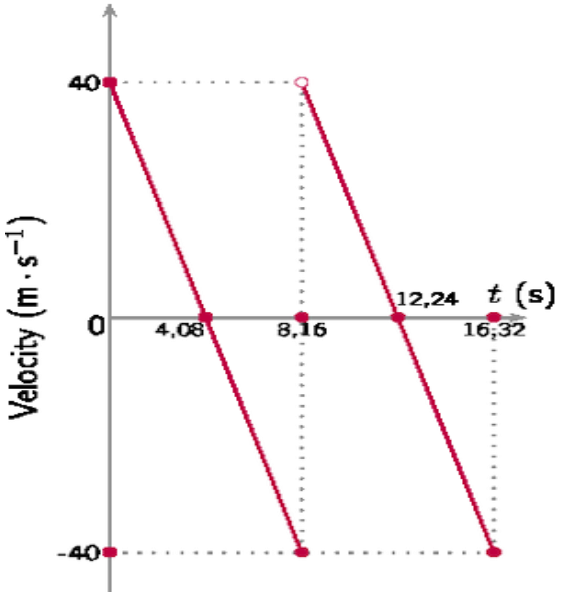


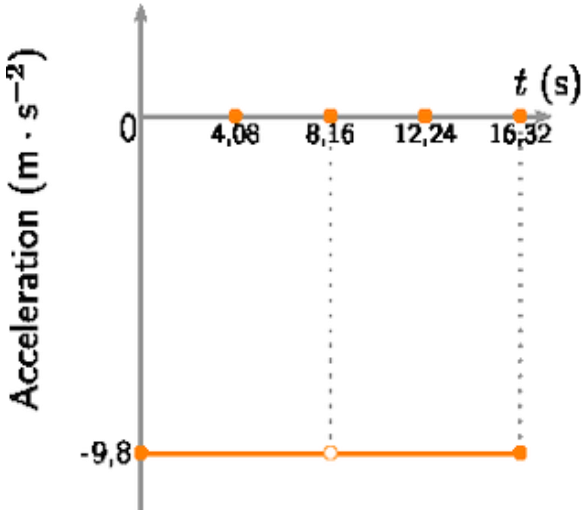




Bouncing


81,63
Position (m)
0
4,08
8,16
12,24
16,32
t (s)


40
Velocity (m · s⁻¹)
0
-40
4,08
8,16
12,24
16,32
t (s)


Acceleration (m · s⁻²)
0
-9,8
4,08
8,16
12,24
16,32
t (s)

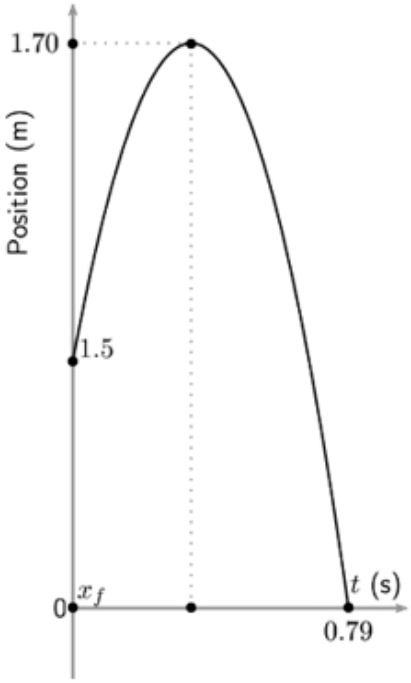
Example 5

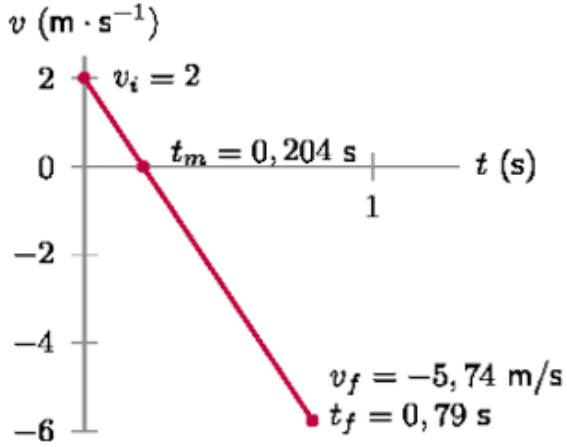
Amanda throws a tennis ball from a height of 1.5 m straight up into the air and lets it fall to the ground. Draw graphs of:

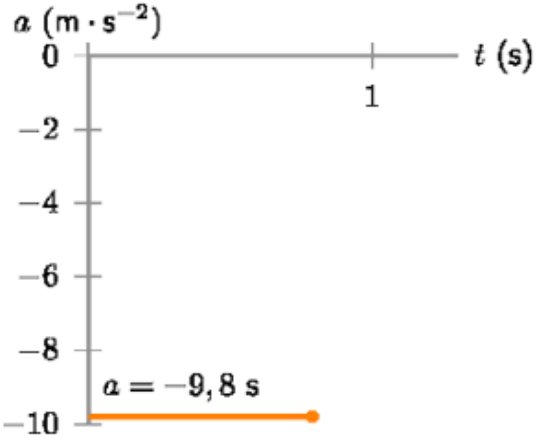
5.1 Position vs time

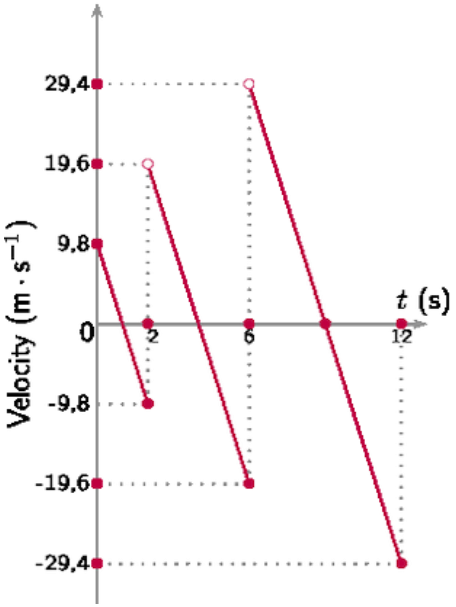
5.2 Velocity vs time

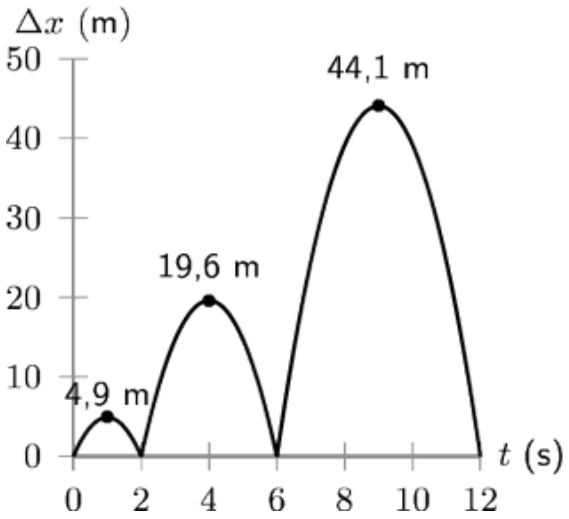
5.3 Acceleration vs time

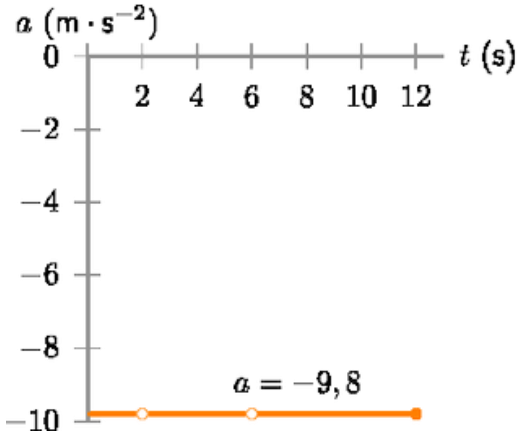

1.70
Position (m)
1.5
0
x_f
t (s)
0.79

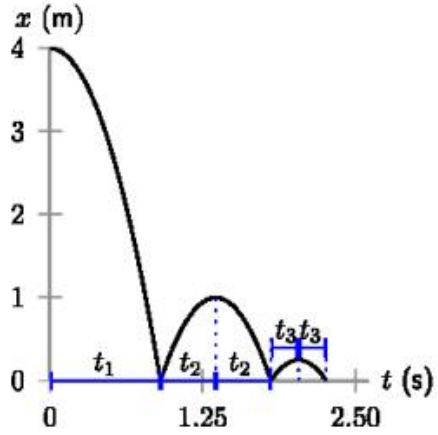

v (m · s^{-1})
2
$v_i = 2$
$t_m = 0,204$ s
t (s)
0
1
−2
−4
−6
$v_f = -5,74$ m/s
$t_f = 0,79$ s

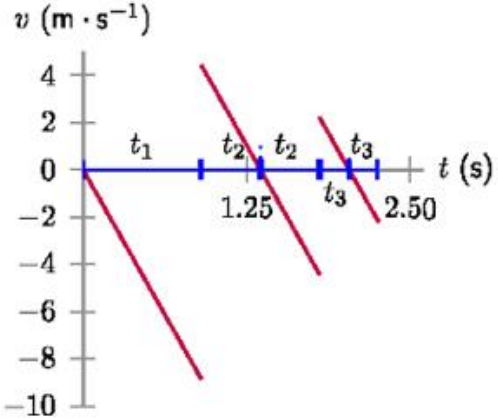

a (m · s^{-2})
0
t (s)
1
−2
−4
−6
−8
$a = -9,8$ s
−10

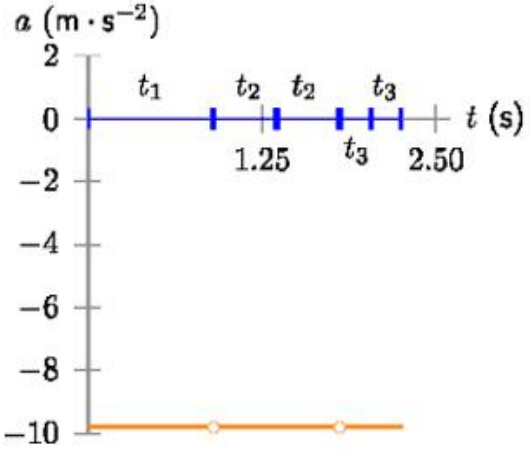

29,4
19,6
9,8
0
-9,8
-19,6
-29,4
Velocity (m · s^{-1})
t (s)
2
6
12


Δx (m)
50
40
30
20
10
0
44,1 m
19,6 m
4,9 m
t (s)
0 2 4 6 8 10 12

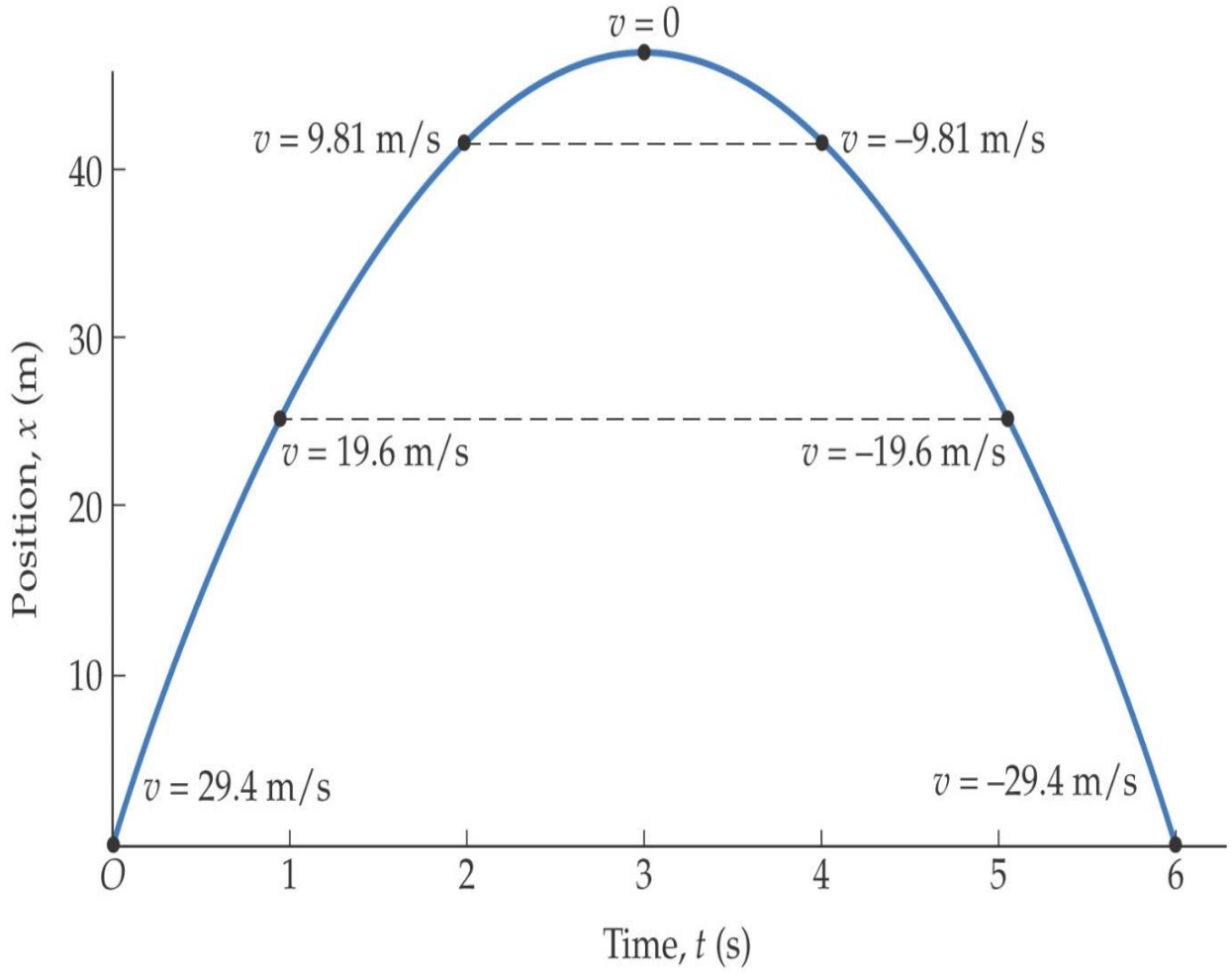

a (m · s^{-2})
0
−2
−4
−6
−8
−10
t (s)
2 4 6 8 10 12
$a = -9,8$


x (m)
4
3
2
1
0
t (s)
0
1.25
2.50
t1
t2
t2
t3
t3


v (m · s−1)
4
2
0
−2
−4
−6
−8
−10
t (s)
1.25
2.50
t1
t2
t2
t3
t3


a (m · s−2)
2
0
−2
−4
−6
−8
−10
t (s)
1.25
2.50
t1
t2
t2
t3
t3

Trajectory of a Projectile/ free falling body



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