

# 2.8

# Understanding Gravity

### Introduction

The concept of gravitational force was introduced by the famous scientist Sir Isaac Newton. He saw an apple fall on his head. He said all objects are pulled by a force which causes them to fall to the surface of the earth.

This force which originates from the centre of the Earth pulls all objects towards the ground.



### Gravitational Force

Objects fall because they are pulled towards the Earth by the force of \_\_\_\_\_.

This force is known as the earth's \_\_\_\_\_ force.

The earth's gravitational force tends to \_\_\_\_\_ everything towards its centre.

### Activity 1 : Acceleration due Gravity

Figure 2 shows a stroboscopic photograph of a falling ball and the graph velocity versus time.

(a) Observe the photograph and describe the positions of the ball.

\_\_\_\_\_

(b) What can we deduce from the gradient of the  $v - t$  graph?

\_\_\_\_\_

(c) Describe the motion of the ball.

\_\_\_\_\_

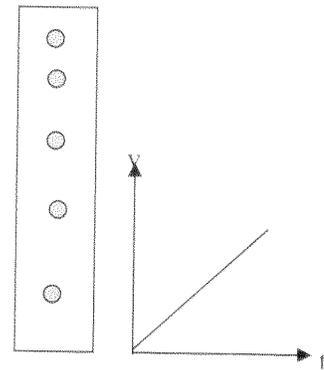


Figure 2

Explain acceleration due to gravity,  $g$

**Acceleration due to gravity,  $g$**  is the acceleration of an object due to the pull of the gravitational force.

The standard value of the gravitational acceleration,  $g$  is  $9.81 \text{ m s}^{-2}$ . The value of  $g$  is often taken to be  $10 \text{ m s}^{-2}$  for simplicity.

The magnitude of the acceleration due to gravity depends on the strength of the gravitational field.

What is free fall?

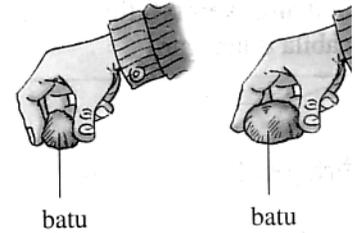
An object is falling freely when it is falling under the \_\_\_\_\_ force only. A piece of paper does not fall freely because its fall is affected by \_\_\_\_\_

An object falls freely only in \_\_\_\_\_. The absence of air means there is no air resistance to \_\_\_\_\_ the motion of the object.

In vacuum, both light and heavy objects fall freely. They fall with the \_\_\_\_\_ acceleration ie. The acceleration due to gravity,  $g$ .

**Activity 2**

Hold two stones with different sizes at the same height and then drop both stone simultaneously from the same height.



(a) What happens to both stones?

\_\_\_\_\_

(b) Describe how does the velocity changes.

\_\_\_\_\_

(c) Compare the time taken for the stones to reach the floor.

\_\_\_\_\_

(d) Are the acceleration of the stones influenced by their masses?

\_\_\_\_\_

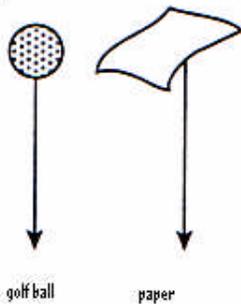
Aristotle thought that when a heavier iron ball and a lighter iron ball are dropped from a certain height, the heavier iron ball will reach the ground earlier.

This hypothesis was accepted for about two thousands years until Galileo thought otherwise and performed the experiment in the Leaning Tower of Pisa in Italy.



He found that the two iron balls fell down at the same time.

**Activity 3: Which one reaches the ground first?**



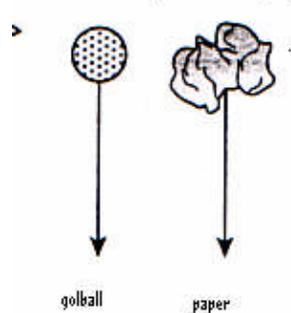
Hold a golf ball and a piece of paper at the same height and drop them simultaneously.

(a) Which object reaches the floor first?

\_\_\_\_\_

(b) Explain why.

\_\_\_\_\_



Repeat with a golf ball and a piece of paper which is crumpled?

(c) Which object reaches the floor first?

\_\_\_\_\_

(d) Explain why

\_\_\_\_\_

**Exercise 1 :** *The difference between fall in atmosphere and free fall in a vacuum of a coin and a feather.*

A coin and a feather are released from the same height simultaneously in the laboratory.



coin



**Observation:** coins falls \_\_\_\_\_ than the feather

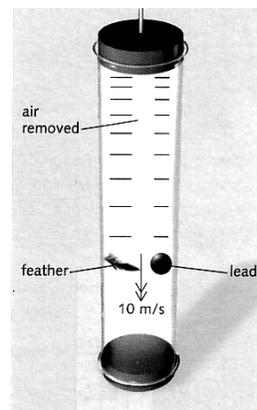
State and label two forces acted on the coin and feather.

**Explanation:**

The bigger \_\_\_\_\_ acted on the feather because it has a \_\_\_\_\_ surface area.

The \_\_\_\_\_ force on the coin is able to overcome air resistance better than the feather.

The same coin and feather are put into a vacuum tube and then dropped simultaneously from the same height.



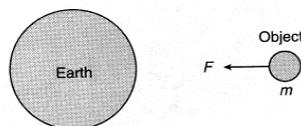
**Observation:** both objects reach the bottom of the cylinder at the \_\_\_\_\_ time.

**Explanation:** In vacuum, there is no \_\_\_\_\_. The only forces acted on both objects is the force of \_\_\_\_\_.

Both objects \_\_\_\_\_ with acceleration due to gravity despite the differences in their \_\_\_\_\_ and shapes.

Define gravitational field strength

The gravitational field is the region around the earth in which an object experiences a force towards the centre of the earth. This force is the gravitational attraction between the object and the earth.



The **gravitational field strength** is defined as the gravitational force which acts on a mass of 1 kilogram.  $g = \frac{F}{m}$  Its unit is  $\text{N kg}^{-1}$ .

Two meaning of g:

1. An object falling freely near the earth/s surface will accelerate at  $10 \text{ m s}^{-2}$ .
2. Each kilogram of mass near the earth's surface has a gravitational force of 10 N acting on it.

Gravitational field strength,  $g = 10 \text{ N kg}^{-1}$   
Acceleration due to gravity,  $g = 10 \text{ m s}^{-2}$

The approximate value of g can therefore be written either as  $10 \text{ m s}^{-2}$  or as  $10 \text{ N kg}^{-1}$ .

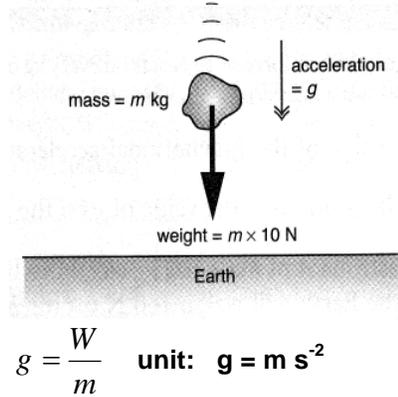
**Define weight**

Weight,  $W$  of an object is the gravitational force exerted on it by the Earth or other massive body.  
Weight is a force and measured in Newton,  $N$ . Weight is a vector quantity.

A stone of mass,  $m$  released is free falls at a gravitational acceleration of  $g$ .  
The only force acting on the stone is its weight,  $W$  which is downward.

Newton's second law of motion:  
 $F = ma$  where  $F = W$ ,  $a = g$

Therefore:  $W = mg$   
 $W = \text{Weight}$   
 $m = \text{mass}$   
 $g = \text{acceleration due to gravity}$



**Changing Weight , fixed mass**

On the Moon, our weight would be \_\_\_\_\_ than on Earth, because the Moon's gravitational field is \_\_\_\_\_

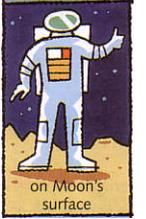
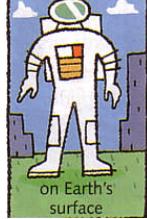
Even on Earth, our weight can vary slightly from place to place, because the Earth's gravitational field strength varies.

Moving away from the Earth, our weight \_\_\_\_\_

If we could go deep into space, and be free of any gravitational pull, our weight would be \_\_\_\_\_

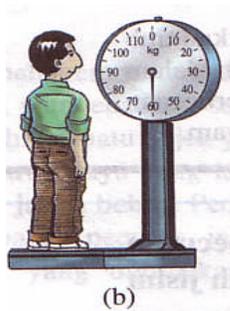
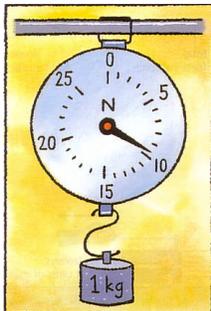
Whether on the Earth, on the Moon, or deep in space, our mass doesn't change.

The value of the gravitational acceleration,  $g$  on the Moon is  $1/6$  the value of  $g$  on the Earth.

			
	<b>Deep in space</b>	<b>On Moon's surface</b>	<b>On Earth's surface</b>
<b>Mass</b>	<b>100 kg</b>	<b>100 kg</b>	<b>100 kg</b>
<b>Weight</b>			

**Exercise 2**

1. Find the weight of the object. Assume that  $g = 10\ N/kg$ .



2. Two rocks below are falling near the Earth's surface.

 5 kg	 10 kg
Weight :	Weight :
Acceleration :	Acceleration:
Gravitational field strength:	Gravitational field strength:

3. What is the weight of an object of mass 20 kg

(a) on the surface of the earth?

(b) On the surface of the moon?

4. A spacecraft from Earth to Mars, where the gravitational field strength near the surface is 3.7 N/kg. The spacecraft is carrying probe which has mass of 100 kg when measured on Earth.

(a) What is the probe's weight on Earth?

(b) What is the probe's mass in space?

(c) What is the probe's mass on Mars?

(d) What is the probe's weight on Mars?

5. Explain the following statements.

(a) 'The Earth's gravitational acceleration is  $10 \text{ m s}^{-2}$ .

(b) The Earth's gravitational field strength is  $10 \text{ N/kg}$ .

6. Show that both earth's gravitational acceleration and the Earth's gravitational field strength have the same units..

### Difference Between Weight and Mass

	Weight	Mass
Define		
Change / unchanged	The weight of an object _____ with the gravitational field strength of the location	The mass of an object is _____ everywhere.
Base or derived quantity	A _____ quantity	A _____ quantity
Vector of scalar quantity	A _____ quantity	A _____ quantity
SI unit		

For an object falling with acceleration  $g$ , the following equations apply:

- |                                |       |  |
|--------------------------------|-------|--|
| 1. $v = u + at$                | where | $s = \text{displacement}$                    |
| 2. $s = ut + \frac{1}{2} at^2$ |       | $u = \text{initial velocity}$                |
| 3. $s = \frac{1}{2} (u + v) t$ |       | $v = \text{final velocity}$                  |
| 4. $v^2 = u^2 + 2as$           |       | $t = \text{time}$                            |
|                                |       | $a = \text{acceleration due to gravity, } g$ |

Notes:

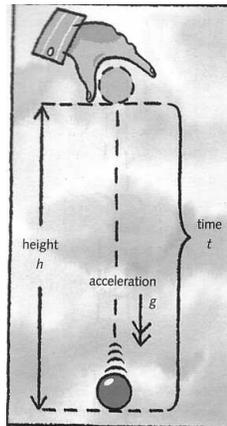
- When an object fall :  $a = g = 10 \text{ ms}^{-2}$  (acceleration)
- when an object is thrown upwards:  $a = -g = -10 \text{ ms}^{-2}$ . (deceleration)
- At the highest point,  $v = 0$
- downward direction,  $v$  is positive
- upward direction,  $v$  is negative

### Example

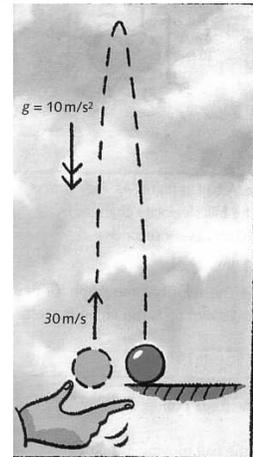
Assume  $g = 10 \text{ m s}^{-2}$  and there is no air resistance

A rock falls from a height of 45 m.

- How long does it take to reach the ground?
- What is its velocity as it hits the ground?



A ball is thrown upwards from the ground with a velocity of 30 m/s. After how many seconds will it strike the ground again?

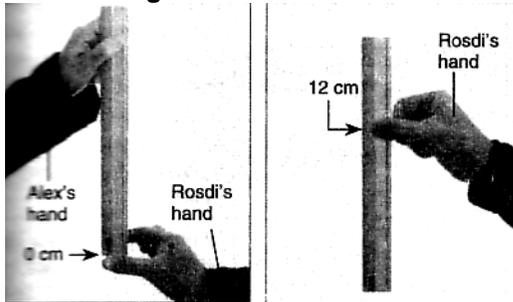


### Exercise 3

Assume the value of  $g = 10 \text{ ms}^{-2}$ .

- Amir Naufal releases a stone into a well. If the distance between the top of the well and the water surface is 20 m,
  - what is the time required for the stone to reach the surface of the water?
  - What is the velocity of the stone when it strikes the surface of the water?
- The gravitational field strength on the surface of the Earth is 10 N/kg. If an object has a weight of 150 N on the surface of the Earth, what is its mass?

3. By using the value of acceleration due to gravity,  $g$ , a person's reaction time can be determined. In (a) Alex drops a ruler (without warning) just above Rosdi's hand. Rosdi grasps the falling ruler as quickly as possible, and the length of the ruler below his thumb is recorded. The length of the ruler recorded is 12 cm. Calculate the reaction time of Rosdi.



4. An object of mass 5 kg is released from a tall building of height 500 m. What is the  
 (a) weight of the object  
 (b) gravitational field strength  
 (c) time taken to reach the ground

**Exersice 5**

1. Sketch the following graphs for an object that is falling freely.

Displacement time graph	Velocity time graph	Acceleration time graph

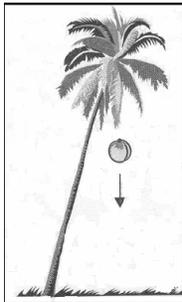
2. Sketch the following graphs for an object that is thrown upwards.

Displacement time graph	Velocity time graph	Acceleration time graph

3. Sketch velocity-time graph to describe the motion for an abject thrown upward and fall

## TUTORIAL 2.8

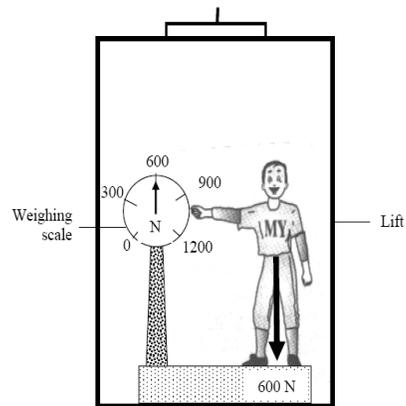
- 1 What is meant by free fall?
- Falls without encountering any resistance
  - Falls with gravitational acceleration
  - Falls with air resistance
  - Falls with constant velocity
- 2 The diagram shows a coconut falling from the tree.



Which of the following acceleration-time graphs represents the motion of the coconut?

- A Acceleration
- 
- Time
- B Acceleration
- 
- Time
- C Acceleration
- 
- Time
- D Acceleration
- 
- Time

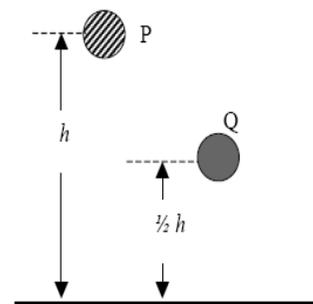
- 3 The diagram below shows the reading of a weighing scale when the lift is at rest.



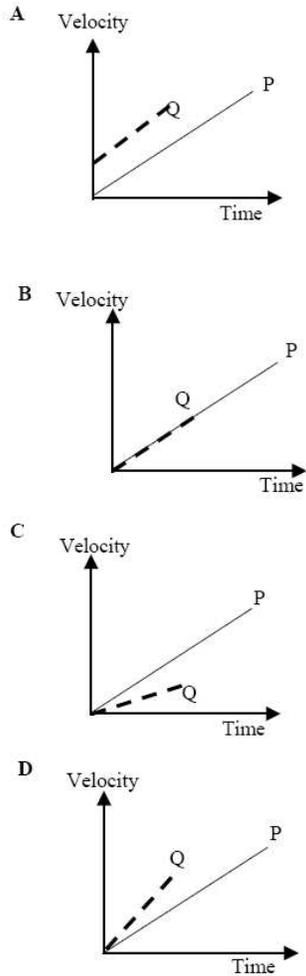
What will be the reading of the scale when the lift experiences free fall?

- A.
- 
- B.
- 
- C.
- 
- D.
- 
- E.
- 

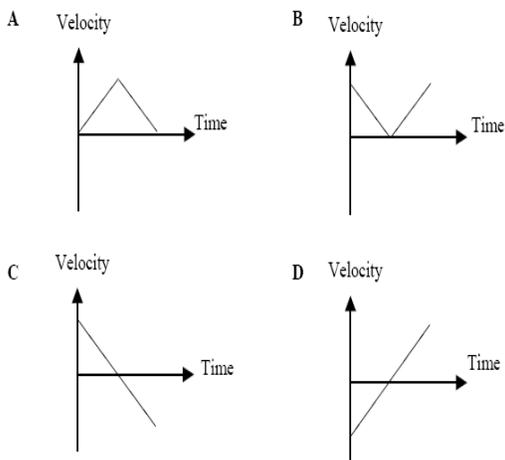
- 4 Two objects P and Q are dropped simultaneously from two different heights as shown below.



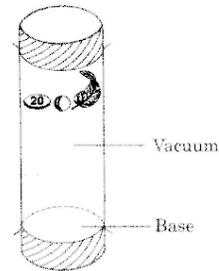
Which velocity-time graph represents the motion of P and Q?



5 A ball thrown vertically upwards reaches a maximum height, then falls to the ground. The velocity-time graph for the ball is

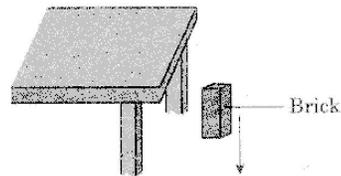


6 The diagram shows a coin, marble and dried leaf being released at the same time in a vacuum cylinder.



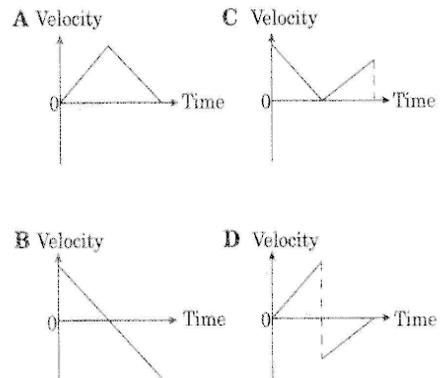
Which observation is correct?  
 A. All three objects float in the cylinder  
 B. All three objects reach the base at the same time  
 C. The marble reaches the base earlier than the coin  
 D. The coin and the marble reach the base earlier than the dried leaf

7 The diagram shows a brick falling from a table.

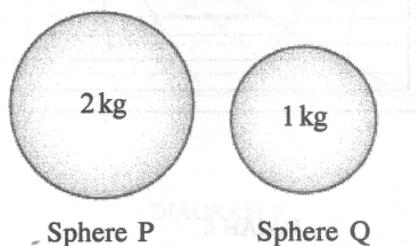


What physical quantity of the brick is constant while it is falling? (2004)  
 A. Potential energy  
 B. Kinetic energy  
 C. Acceleration  
 D. Velocity

8 A ping-pong ball is dropped onto a concrete floor. Which graph shows the relationship between the velocity of the ball with time? (2004)



- 9 The diagram below shows two metal spheres, P and Q.

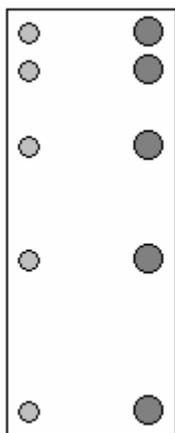


Which of the following statements is true when P and Q are in free fall? (2006)

- A. The velocities of P and Q are the same
  - B. The accelerations of P and Q are the same
  - C. The momentum of P and Q are the same
  - D. The gravitational forces acting on P and on Q are the same
- 10 A brick falls from a height of 10 m. Calculate the time taken for the brick to reach the ground. (2007)
- A. 0.5 s
  - B. 0.7 s
  - C. 1.0 s
  - D. 1.4 s

**Question 1 (SPM 2003)**

Figure 1 is a stroboscopic photograph shows two steel balls in a state of free-fall. Both balls are dropped simultaneously from the same height..



- (b) Observe the photograph and state two similarities between the position of the balls. [2 m]

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- (c) Name one physical quantity which causes the balls to fall. [1 m]

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- (d) Based on the positions of the free-falling balls, there is a physical quantity that is constant.

- (i) Name the quantity. [1 m]

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- (ii) What is the value of the quantity and its unit? [1 m]

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- (iii) State how the mass of a ball affect the valued of the physical quantity stated in (c)(i). [1 m]

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- (e) A ball is thrown vertically upwards at a certain velocity.

- (i) What happens to the motion of the ball as it moves upwards? [1 m]

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- (ii) Give one reasons for your answer.

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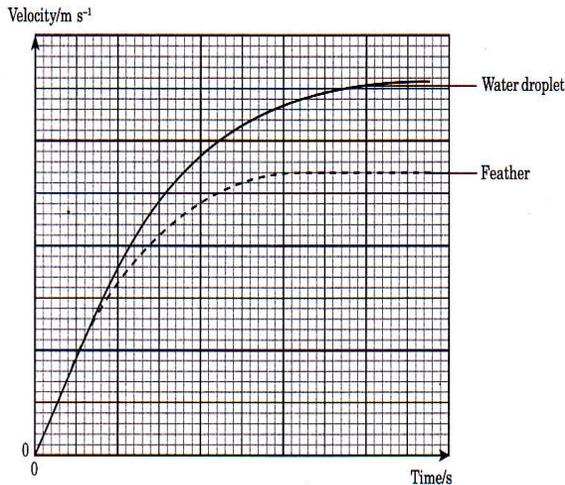
[1 m]

**Question 2 SPM 2004**

Figure 2.1 shows a feather and a water droplet falling from the same height. The mass of the feather and water droplet is the same and both are dropped simultaneously at time  $t = 0$ .



**Figure 2.1**



**Figure 2.2**

(a) Name one force acting on the feather and the water droplet. [1 m]

\_\_\_\_\_

(b) Using Figure 13.1, compare the surface area of the feather and the water droplet. [1 m]

\_\_\_\_\_

(c) Using Figure 13.1 and 13.2, compare the changes in velocity of the feather and the water droplet. [3 m]

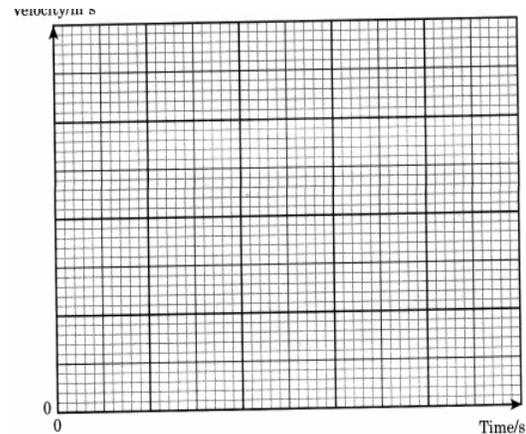
\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(d) Using your answers in (b) and (c), state the relationship between the relationship between the surface area and the final velocity. [1 m]

(e) The feather and the water droplet are dropped in a vacuum. Sketch a velocity-time graph to show the motion on both objects.



[2 m]

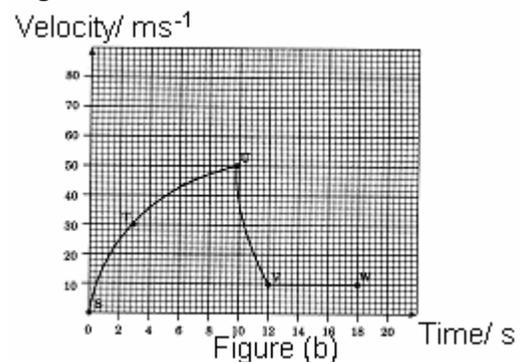
**Question 3 (SPM 2000)**

Figure(a) shows a sky-diver is jumping out of a plane at a certain height.



Figure (a)

Figure(b) shows a graph velocity – time for the motion of the sky –diver at positions S , T , U ,V and W from the ground.



Based on the Figure(b),

(a) (i) What is the position of the sky-diver when he opens his parachute?

\_\_\_\_\_

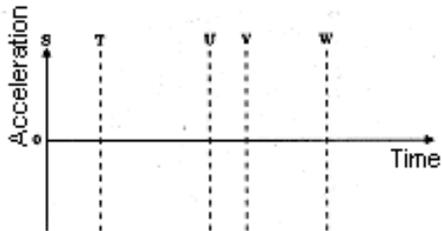
(ii) Give one reason for your answer in (a)(i)

\_\_\_\_\_

\_\_\_\_\_

(b) Calculate the acceleration of the sky-diver at region ST

(c) In space below sketch a graph acceleration-time for the motion of the sky-diver at the positions S,T,U,V and W.



(d) (i) Suggest a way how the sky-diver landing to avoid sustaining any bodily injuries.

\_\_\_\_\_

(ii) Give the reason for your answer in (d)(i)

\_\_\_\_\_

\_\_\_\_\_