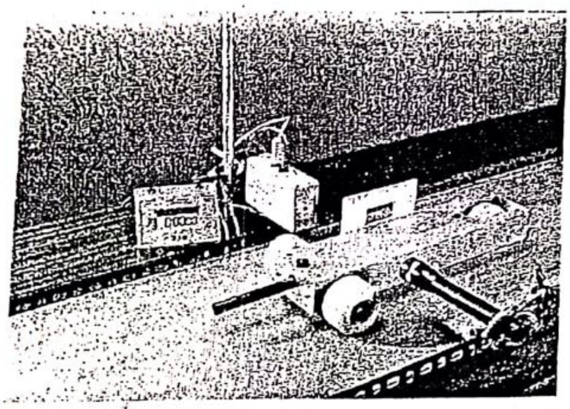
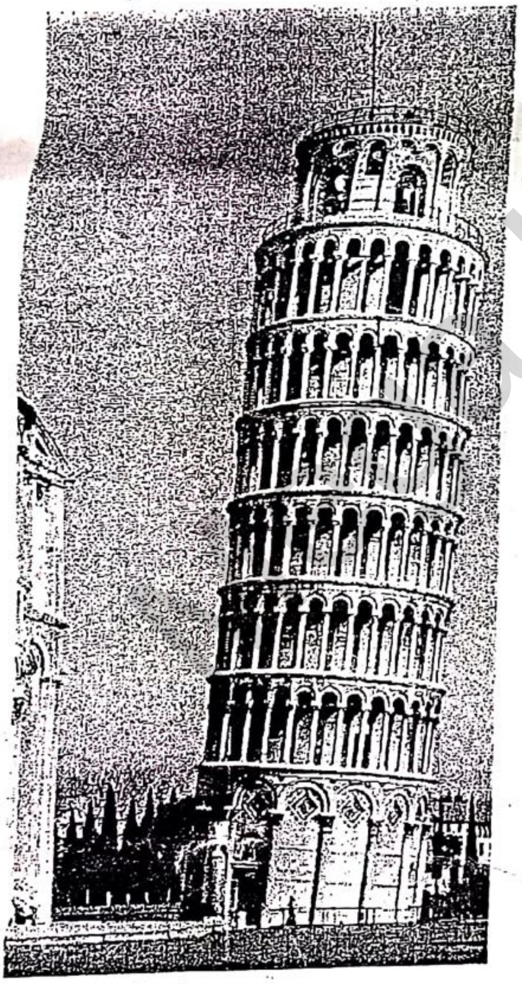
O Level Physics Syllabus Content for CAIE 2018-19 Exams

CHAPTER 2:

KINEMATICS





Syllabus Content

2.1 Speed, velocity and acceleration

2.2 Graphical analysis of motion

2.3 Free-fall

Learning outcomes

Candidates should be able to:

a) State what is meant by *speed* and *velocity*.

b) Recall and use *average speed = distance travelled/time taken.*

c) State what is meant by *uniform acceleration* and recall and use *acceleration = change in velocity/time taken.*

d) Discuss non-uniform acceleration.

e) Recall that deceleration is a negative acceleration.

f) *Plot and *interpret speed-time and distance-time graphs.

g) *Recognize from the shape of a speed-time graph when a body is

1. At rest
2. Moving with uniform speed
3. Moving with uniform acceleration
4. Moving with non-uniform acceleration

h) Calculate the area under a speed-time graph to determine the distance travelled for motion with uniform speed or uniform acceleration.

i) State that the acceleration of free-fall for a body near to the Earth is constant and is approximately 10 m /s^2

j) Describe qualitatively the motion of bodies with constant weight falling with and without air resistance (including reference to terminal velocity).

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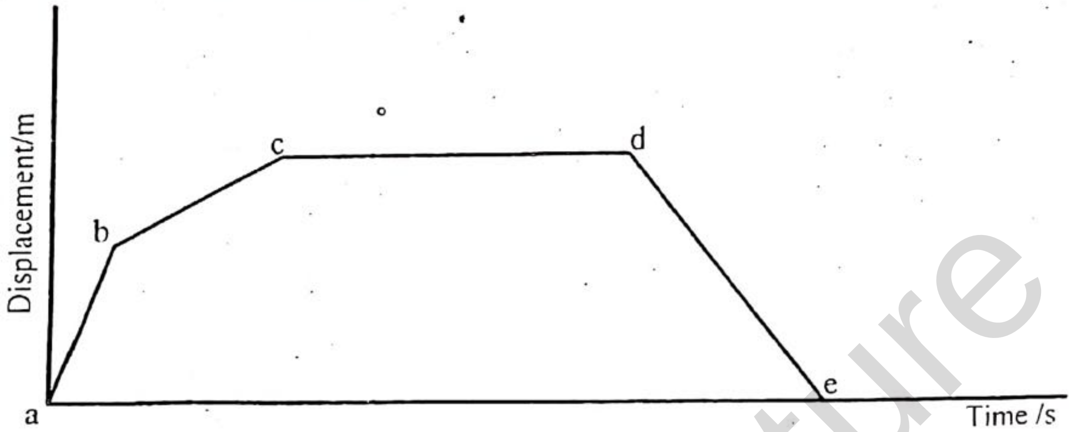
KINEMATICS

Displacement

"Displacement is the distance move in a given direction".

Displacement is vector measured in meters.



The displacement-time graph represents the motion of a car from a reference point. During the sections ab and bc, the displacement is increasing with time which indicates that car is moving away.

During the section ed, the displacement is constant6 which means that the car is at rest. During de, the displacement is decreasing with time which indicates that the car is returning back.

The slope or gradient of the displacement-time graph at any moment gives the value of the velocity at that moment.

Note that:

1. The velocity during section ab is higher than the velocity during be, because the slope of ab is higher than slope of bc.
2. The slope of section de is negative because the car is moving back in opposite direction and has a negative velocity.

Speed, velocity and acceleration

Speed

"Distance covered per unit time is called speed"

If a car travels 300 km from Lahore to Islamabad in five hours, its **average speed** is 300 km/5 h = 60 km/h. The speedometer would certainly not read 60 km/h for the whole journey but might vary considerably from this value. That is why we state the average speed. If a car could travel at a constant speed of 60 km/h for five hours, the distance covered would still be 300 km. It is always true that

$$\text{average speed} = \frac{\text{Distance Moved}}{\textit{Time Taken}}$$

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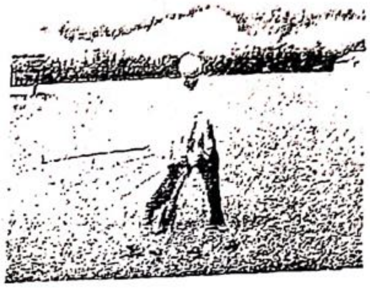
To find the actual speed at any instant we would need to know the distance moved in a very short interval of time. This can be done by multi flash photography. In Figure the golfer is photographed while a flashing lamp illuminates him 100 times a second. The speed of the club-head as it hits the ball is about 200 km/h.



Velocity

- "Velocity is the displacement moved per unit time"

OR

"Velocity is the rate of change of displacement with time".

Speed is the distance travelled in unit time; **velocity is the distance travelled in unit time in a stated direction**. If two trains travel due north at 20 m/s, they have the same speed of 20 m/s and the same velocity of 20 m/s *due north*. If one travels north and the other south, their speeds are the same but not their velocities since their directions of motion are different. Speed is a **scalar** quantity and velocity a **vector** quantity.

$$\text{Velocity} = \frac{\text{distance moved in a stated direction}}{\text{Time Taken}}$$

If the displacement is denoted by s, and the time denoted by t, then the velocity, v, is given by: $\frac{60\text{km}}{\text{h}} = \frac{6000\text{m}}{3600s} = 17m/s$

Averaged Speed

Usually, we are interested to measure the average speed in two cases:

(a) For a whole journey, where

$$V\,(\text{Average}) = \frac{\text{Total distance moved}}{\text{Total Time taken}}$$

(b) For one stage of a trip, where is the initial velocity and v is the velocity reached in this stage, thus.

$$V(\text{Average}) = \frac{u+v}{2}$$

For a steady increase of velocity from 20m/s to 50m/s in 5s.

$$\text{Acceleration} = \frac{(50-20))\text{m/s}}{5s} = 6\text{m/s}^2$$

Acceleration is also a vector and both its magnitude and direction should be stated. However, at present we will consider only motion in a straight line and so the magnitude of the velocity will equal the speed, and the magnitude of the acceleration will equal the change of speed in unit time.

The speeds of a car accelerating on a straight road are shown below.

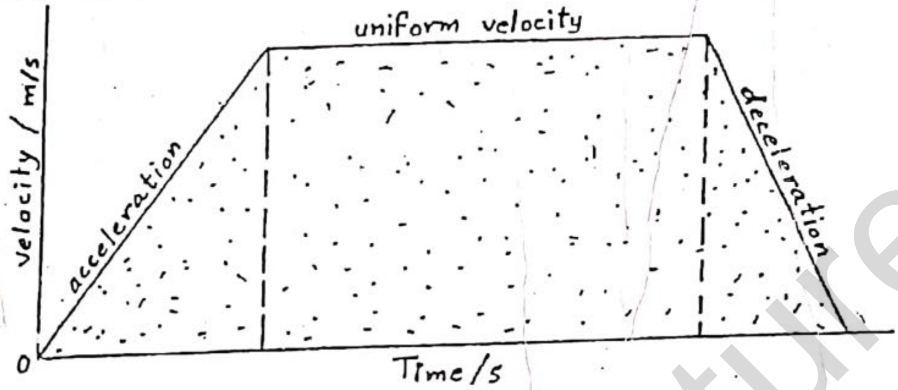
Time /s	0	1	2	3	4	5	6
Speed m/s	0	5	10	15	20	25	30

The speed increases by 5 m/s every second and the acceleration of 5 m/s^2 is said to be **uniform**. An acceleration is positive if the velocity increases and negative if it decreases. A negative acceleration is also called a **deceleration** or **retardation**.

When the velocity of a body changes we say the body **accelerates.** Ifa car starts from rest and moving due north has velocity 2m/s after 1 second, its velocity has increased by 2m/s in 1 s and its acceleration is 2m/s per second due north. We write this as $2m/s^2$ for a steady increase of velocity from 20m/s to 50m/s in 5s.

Velocity-Time Graphs

The velocity-city graph usually describes a certain trip.



A journey usually starts from rest, the body accelerates and the velocity increase to a certain value, then it travels at a constant speed (uniform velocity), and finally it slows down (decelerates) until it comes to a complete stop at a certain station.

- The slope (gradient) of the velocity-time graph at a certain moment gives the value of the acceleration at that moment:

(a) The slope is positive when the body is accelerating (the velocity is increasing).
(b) The slope is zero when the velocity is uniform (the velocity remains constant).
(c) The slope is negative when the body is decelerating (the velocity is decreasing).

The Distance Travelled during trip can be calculated by:

	(1) Distance travelled = average speed x total time
or	(2) Distance travelled equals the area under the (v, t) graph.

III. Acceleration:

Acceleration is the rate of change of velocity with time

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{Time taken}}$$

$$a = \frac{v-u}{t}$$

- Acceleration is vector measured in (m/s^2)
- Acceleration is occurs only during the application of unbalanced force.
- Acceleration may remain constant, called "uniform acceleration" or it may increase or decrease by time, this can be observed from the shapes of v-t graphs shown :

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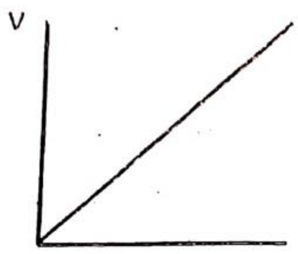
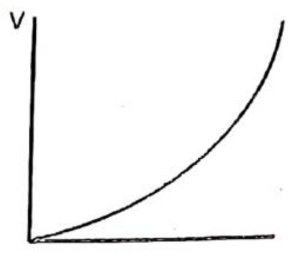
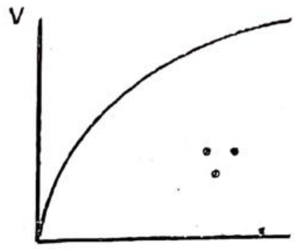






Speed, Velocity and Acceleration

Speed

- Speed is the distance moved per unit time.
- S1 unit of speed is metre per second ($m\ s^{-1}$).
- Speed $= \frac{\text{Distance}}{\text{Time}}$
- Speed = Gradient of distance-time graph
- Speed is a scalar quantity. (It has only magnitude and no direction.)

Distance is a Scalar quantity

Velocity is speed in a given direction.

Velocity

- *Velocity is the distance moved in a given direction per unit time.*
- S1 unit of velocity is metre per second ($m\ s^{-1}$).
- Speed $= \frac{\text{Distance moved in a specified direction}}{\text{Time}}$
- Velocity = Gradient of displacement-time graph.
- Velocity is a vector quantity. (It has both magnitude and direction.)

Displacement is distance Travelled in a given direction.

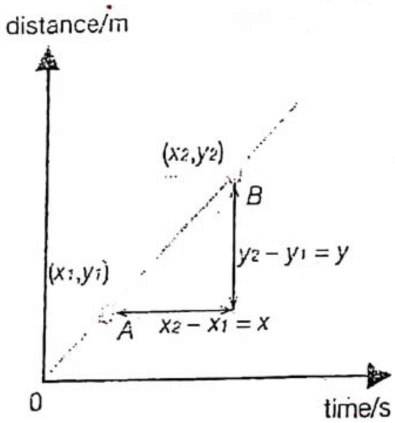
Velocity is Different from speed.

Distance-time Graph

- Speed, v = Gradient of distance-time graph.

$$v = \frac{y_2 - y_1}{X_2 - X_1}$$

$$v = \frac{y}{x}$$



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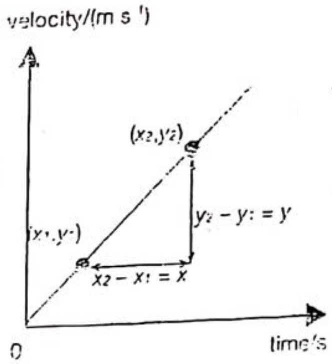
Acceleration

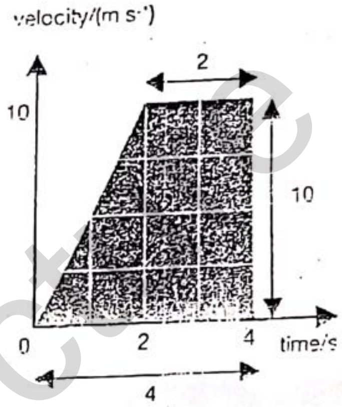
- Acceleration is the change in velocity per unit time.
- Acceleration $= \frac{\text{Change in velocity}}{\text{Time}}$
- Acceleration $= \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}}$
- SI unit of acceleration is metre per square second (r



Velocity-time Graph

- Acceleration, a = Gradient of velocity-time graph.

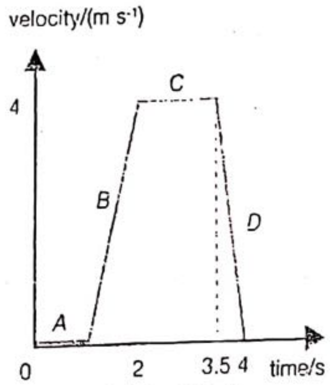
$$a = \frac{y2 - y1}{x2 - x1} = \frac{y}{x}$$



- Distance, s = Area under velocity-time graph

  Distance, s = Shaded area

  Distance = (2 + 4)(10) = 30 m



Horizontal line:

- Object is at rest.
  (line A)
- Object is at **uniform velocity**.
  (line C)

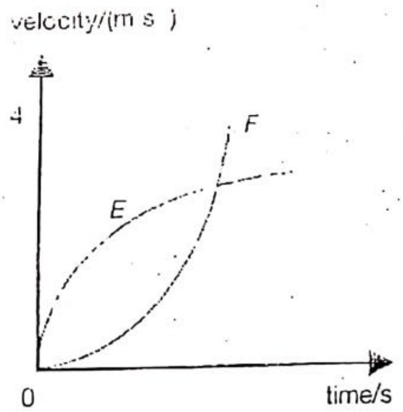
Straight line with a slope:

- Object is moving with a **uniform acceleration** (the **gradient** is a **positive** value).
  (line B)
- Object is moving with a **uniform deceleration** (the **gradient** is a **negative** value).
  (line D)

Line B gradient = + 4, means acceleration is 4 m s^{-2}.
Line D gradient = - 8, means acceleration is – 8 m s^{-2}.
(Deceleration is 8 m s^{-2}

Curve:

- Object is moving with an acceleration which is not uniform (gradient is decreasing). (curve E)



Curve E gradient is decreasing, means acceleration is decreasing (not constant).

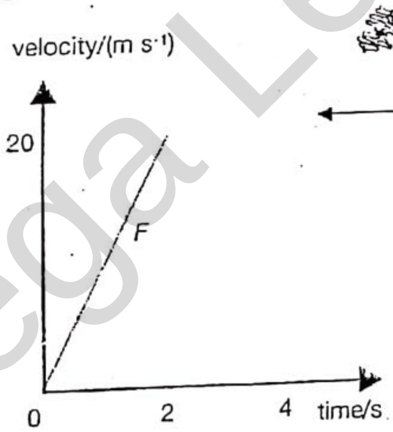
Curve F gradient is increasing, means acceleration is increasing (not constant).

- Object is moving with an acceleration which is not constant (gradient is increasing). (curve F)

Acceleration of Bodies Falling Near to Earth

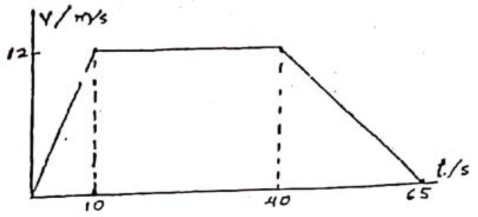
- *An object falling near to Earth, where the air resistance is negligible, has a velocity-time graph that is a straight line, F. It falls with a constant acceleration (straight line).*

Acceleration = 10 m s-2 (gradient = 10).



A straight line implies no air resistance.

Example: In the velocity-time graph given, find: (a) the acceleration,(b) the deceleration, (c) the total distance travelled, and (d) the average velocity during the journey.



Solution:

(a) $\frac{Acceleration}{t} = v - u = \frac{12-0}{10} = 1.2m/s^2$

(b) $A = \frac{v-u}{t} = v - u = \frac{0-12}{25} = 0.48/s^2$

Declaration = $0.48m/s^2$

(c) Distance travelled = area under the trapezium

$= \frac{1}{2}(65+30) \times 12 = 570m$

(d) Average velocity = $\frac{\text{Total distance}}{\text{Total time}}$ = = 570/65 = 8.8 m/s.

Using the domestic AC power, the frequency f = 50 Hz and the time between two successive dots, T= 1/50 =0.02s

The following examples show hot to use the ticker-tape to calculate the velocity and acceleration.

Example 1: In the given tape, the distance between dots is equal which indicates that is money moves at constant velocity, Use the tape to calculate the trolley;s velocity.

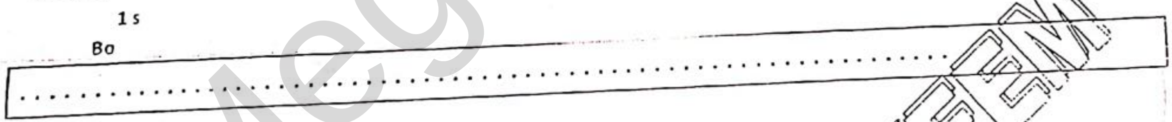


Figure Tape from a trolley moving at

Solution:

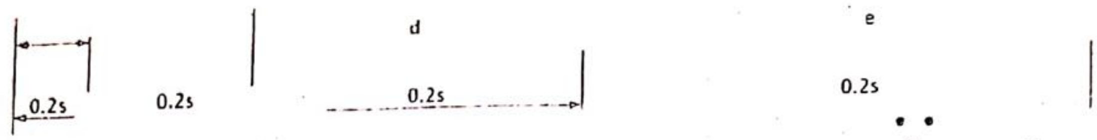
The distance of ten spaces = 5cm

The time of ten spaces = 0.02 x 10 = 0.2 s.

Velocity $= \frac{s}{t} = \frac{5cm}{0.2s}$

Example 2: In the given tape, the distance between dots is increasing regularly, which indicates that the trolley is accelerating.

Using the tape to calculate the acceleration



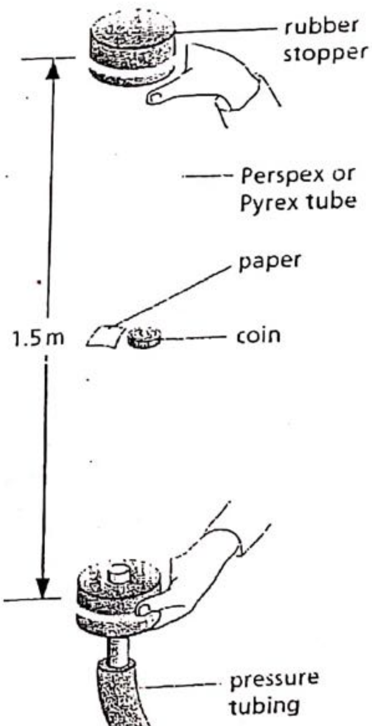
Solution:

1. Choose two equal and successive parts of tape (take the parts d and e).
2. Take the ten space of section "d":
   The distance of section "d" = 4.5 cm
   The time of section "d" = 10 x 0.02 = 0.2 s
   U: Average velocity during interval "d" = $\frac{4.5cm}{0.2s} = 22.5cm/s$
3. Take the ten spaces of section "e" :
   The distance of section "e" = 5.6cm
   The time of section "e" = 0.2 s
   V: Average velocity during section "e" = $\frac{5.6cm}{0.2s} = 28cm/s$
4. The acceleration, $a = \frac{v-u}{t} = \frac{(28-22.5)}{0.2s} = 27.5cm/s^2$

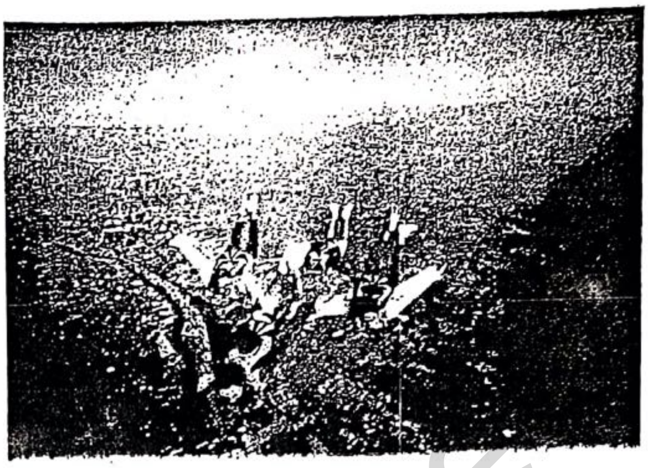
Falling Bodies

In air, a coin falls faster than a small piece of paper. In a vacuum they fall at the same rate, as may be shown with the apparatus. The difference in air is due to **air resistance** having a greater effect on light bodies than on heavy bodies.

The air resistance to a light body is large when compared with the body's weight. With a dense piece of metal the resistance is negligible at low speeds. There is a story, untrue we now think that in the 16th century the Italian scientist Galileo dropped a small iron ball and a large cannonball ten times heavier from the top of the Leaning Tower of Pisa. And we are told that, to the surprise of onlookers who expected the cannonball to arrive first, they reached the ground almost simultaneously.



Terminal Velocity



When an object falls in air, the air resistance (fluid friction) opposing its motion **increases as its speed rises**, so reducing its acceleration. Eventually, air resistance acting upwards equals the weight of the object acting downwards. The resultant force on the object is then zero since the gravitational force balances the frictional force. The object falls at a constant velocity, called its **terminal velocity**, whose value depends on the size, shape and weight of the object. A small dense object, such as a steel ball-bearing, has a high terminal velocity and falls a considerable distance with a constant acceleration of 9.8m/s2 before air resistance equals its weight. A light object, like a raindrop, or an object with a large surface area, such as a parachute, has a low terminal velocity and only accelerates over a comparatively short distance before air resistance equals its weight. A skydiver has a terminal velocity of more than 50 m/s (180 km/h) before the parachute is opened. Objects falling in liquids behave similarly to those falling in air.