Chapter I

Kinematics

Uniform motion

Physics
Instructor: Murynov B.A.

Objectives

At the end of the lesson you will be able to

- Define distance and displacement, speed and velocity,
- describe uniform motion and graphical data
- define operationally, compare and contrast scalar and vector quantities

The science of motion and its causes is called **Mechanics**, which is divided into two main sections: **Kinematics** which describes motion and **Dynamics** which describes the causes of motion.

Kinematics

Words to learn: Origin, Position, Scalar Quantity, Vector Quantity, Distance, Displacement, vector, magnitude, instantaneous speed.

Scalar and Vectors

Scalars are quantities that are fully described by a magnitude (or numerical value) alone.

Vectors are quantities that are fully described by both a magnitude and a direction.

POSITION, DISPLACEMENT AND DISTANCE

"The treasure is hidden 25 paces (steps) northeast of the old hut"

origin: a reference point

position: the straight-line distance between the origin and an object's location; includes magnitude and direction

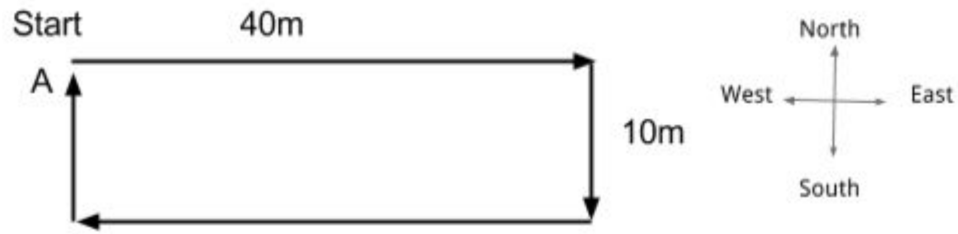
This change in the position of an object is called the **displacement**

displacement = final position – initial position

$$\Delta\vec{x} = \vec{x}_2 - \vec{x}_1$$

Figure 1.1.1 Vector $\vec{x}$ represents the "position" of the treasure.

If a person walks 40 meters East, 10 meters South, 40 meters West, and finally 10 meters North.



The distance he covered is 100 m.
His displacement is 0 m

Distance vs Displacement

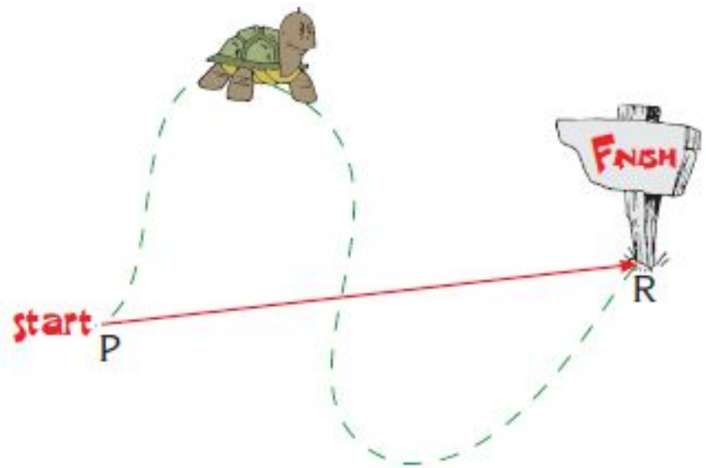


Figure 1.1.2 The distance moved by the tortoise is the length of the dashed green line. Displacement is a vector which has a magnitude of |PR|.

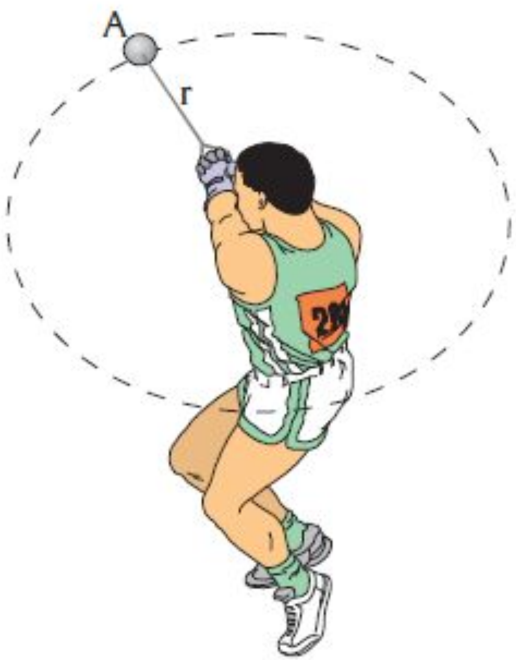
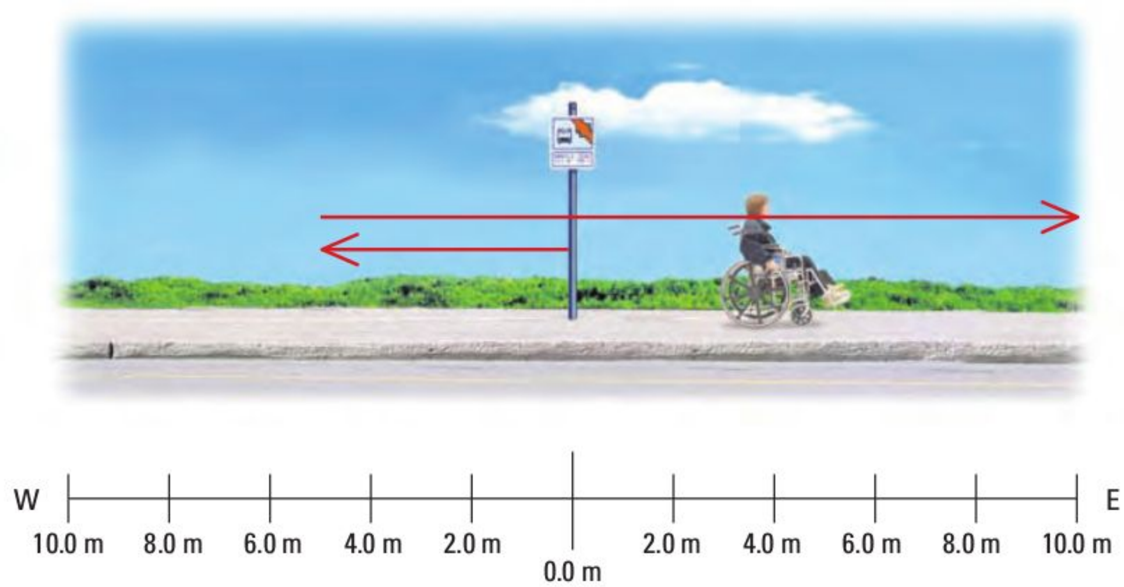
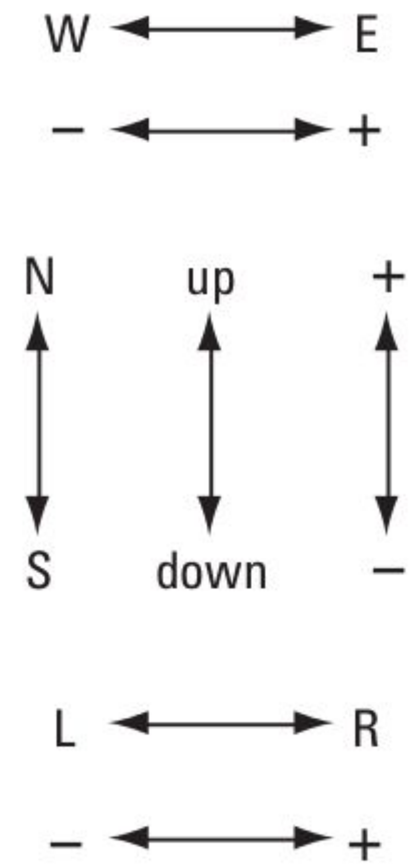


Figure 1.1.3 In one complete revolution, the hammer travels a distance of $2\pi r$, but the total displacement is zero.

The Language of Motion

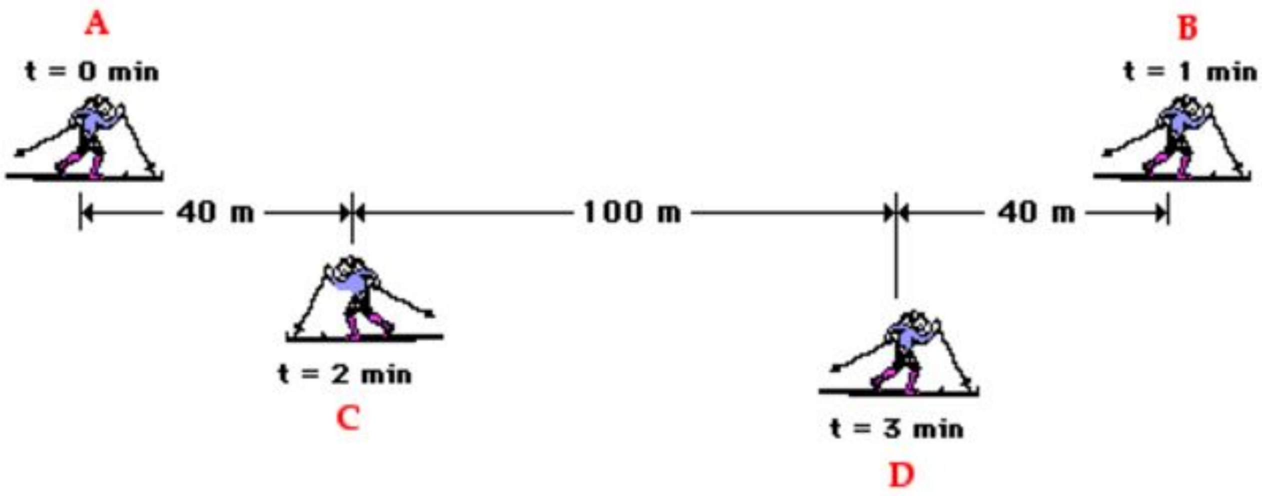


If you move from a position 5.0 m [W] to a position 10.0 m [E], what is your final distance and displacement?



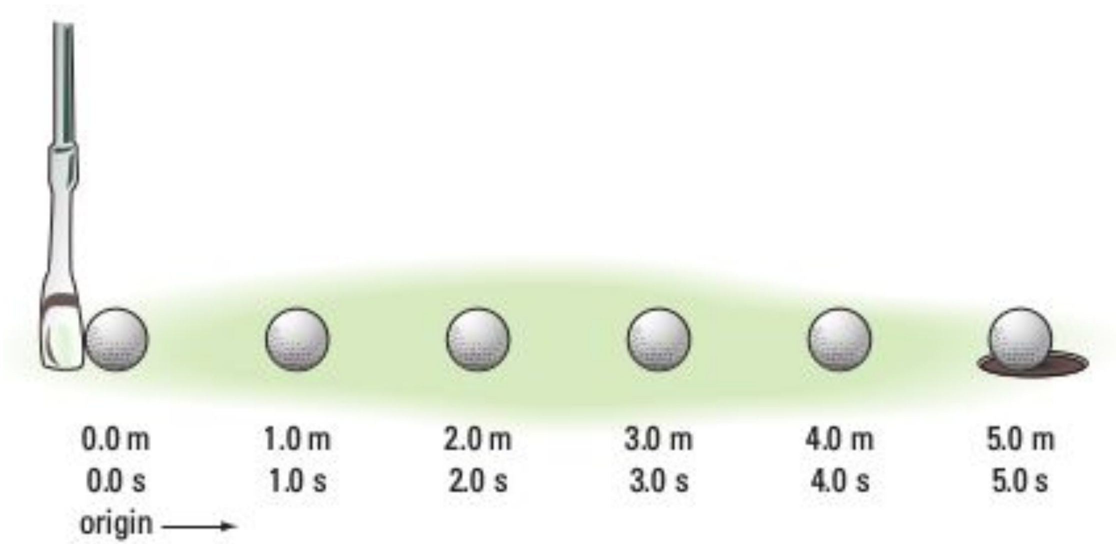
East, north, up, and right are usually designated as positive.

Example 2



What is the distance covered and what was his displacement?

Position-time Graphs and Uniform Motion



The golf ball's displacement after each second.

This golf ball is said to move with a constant **velocity** which is defined as the displacement per unit time

$$\vec{v} = \frac{\Delta \vec{x}}{\Delta t}$$

The magnitude of the velocity vector is called **speed** which is a scalar quantity.

Velocity	=	slope of the line in the position–time graph

$$\text{Slope} = \tan\theta = \frac{\Delta x}{\Delta t} = \frac{x_{final} - x_{initial}}{t_{final} - t_{initial}} = v$$

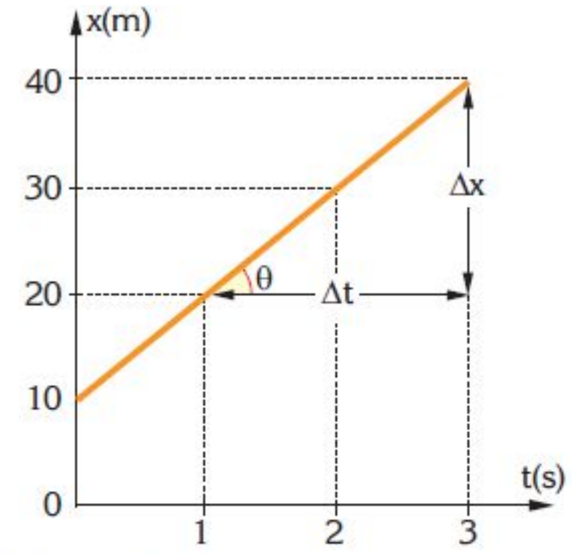
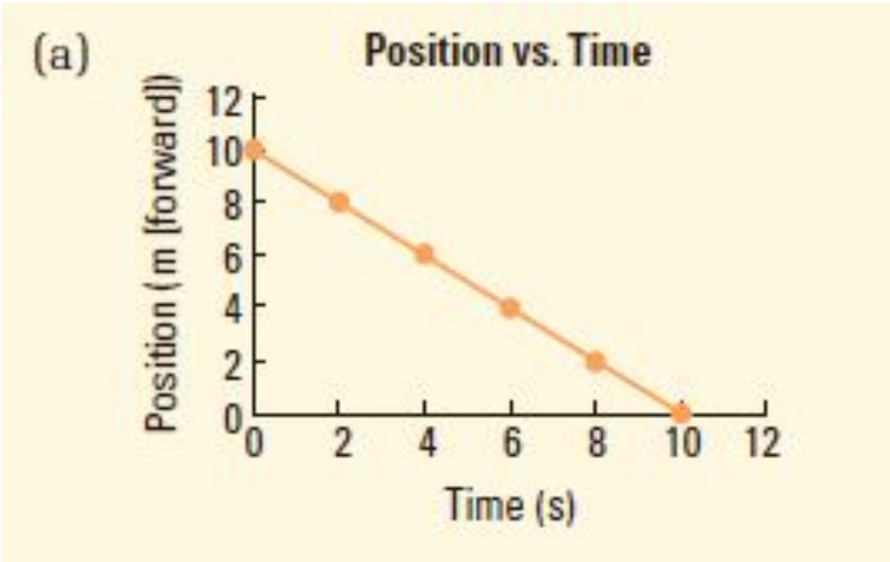
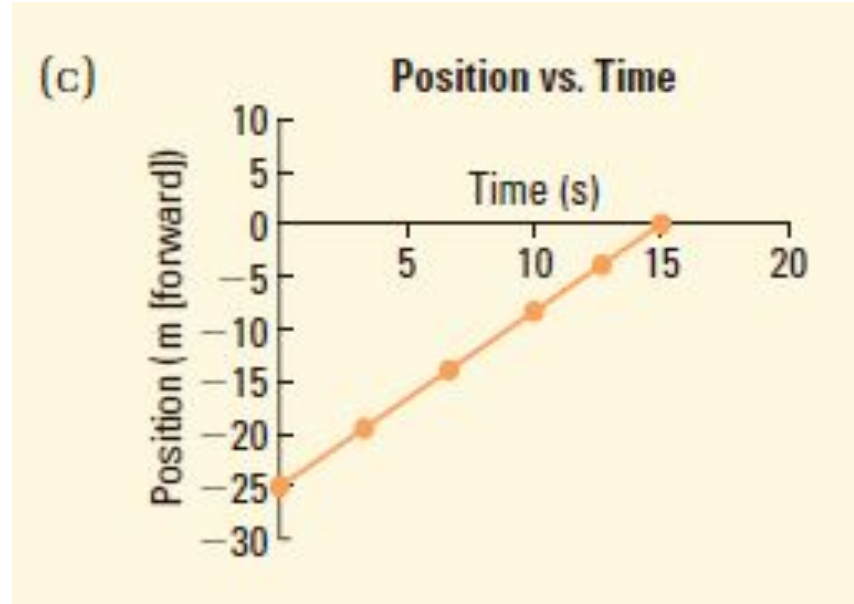


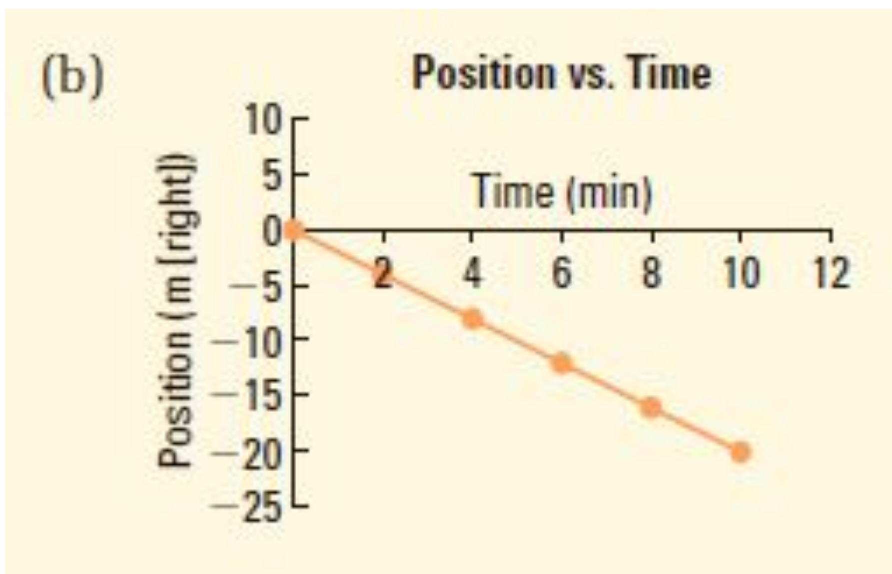
Figure 1.2.2 The car has equal displacements in equal time intervals so its position-time graph is a straight line. The slope of the straight line is the constant velocity of the car.

Example

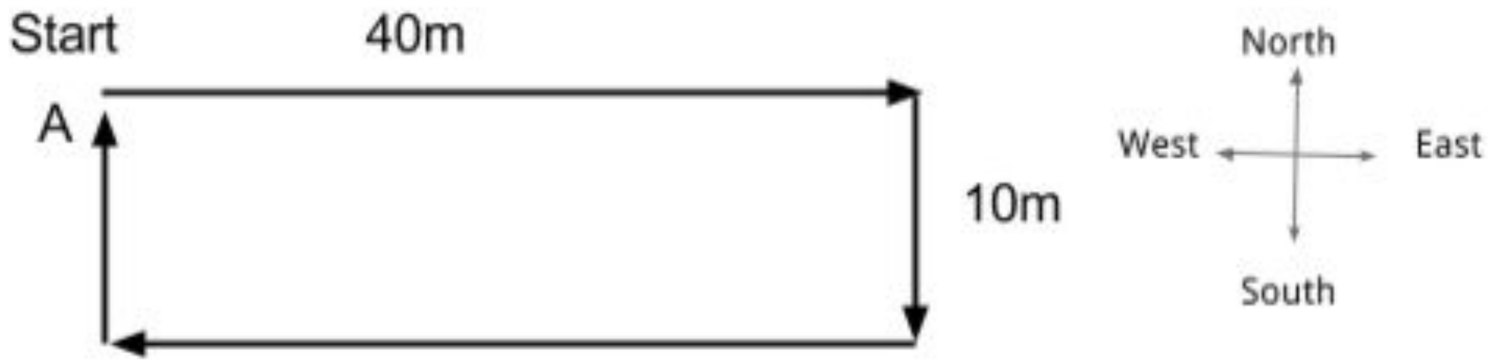
Determine the velocity of each object whose motion is represented by the graphs below





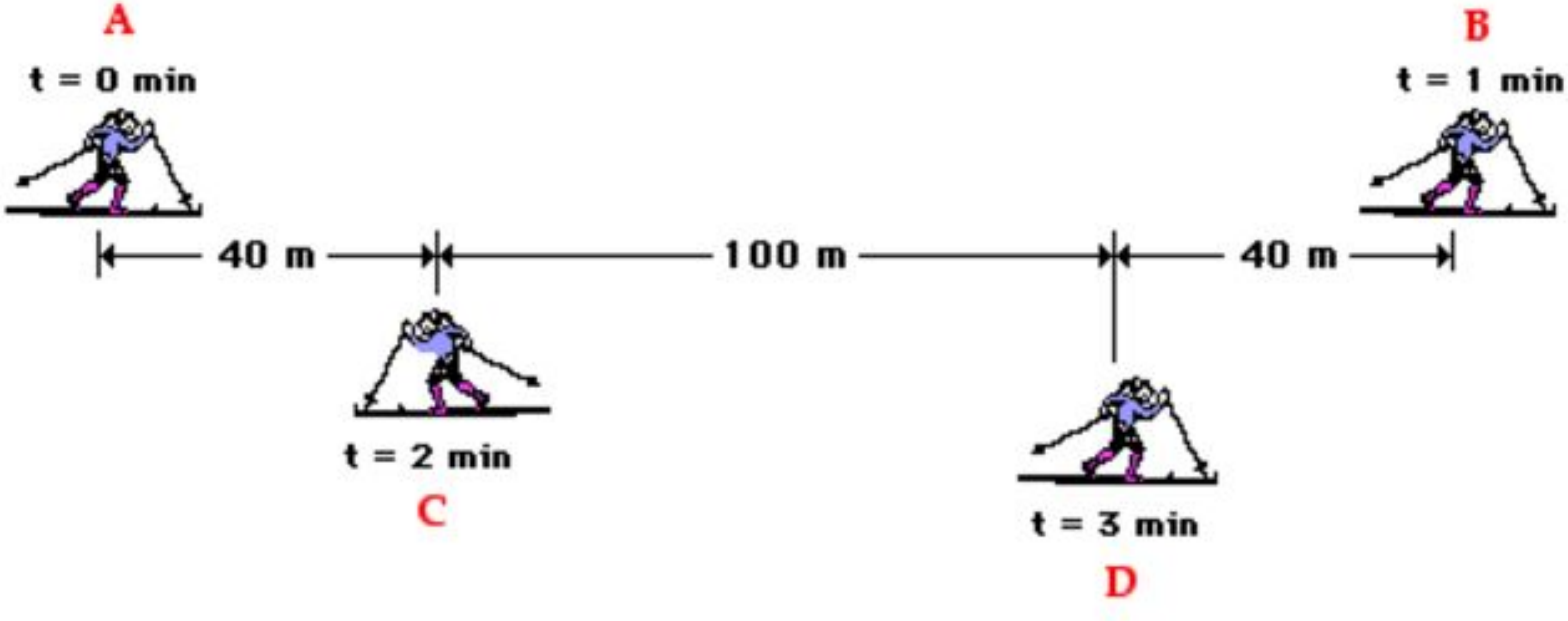


Example 1



If a person walks 40 meters East, 10 meters South, 40 meters West, and finally 10 meters North. He completed his walk in 4 minutes. What was his speed? What was his velocity?

Example 2



What is the skiers average speed and average velocity?

Ex. 1

A thief snatches a handbag and runs north at 5.0 m/s. A police officer, 20 m to the south, sees the event and gives chase. If the officer is a good sprinter, going 7.5 m/s, how far will she have to run to catch the thief?

Ex.2

Two friends start walking on a football field in the same direction. Person A walks twice as fast as person B. However, person B has a head start of 20.0 m. If person A walks at 3.0 m/s, find the distance between the two friends after walking for 20.0 s and determine who is ahead at this time. Sketch a position-time graph for both people.

Ex.3

A mosquito flies toward you with a velocity of 2.4 km/h [E]. If a distance of 35.0 m separates you and the mosquito initially, at what point (distance and time) will the mosquito hit your sunglasses if you are travelling toward the mosquito with a speed of 2.0 m/s and the mosquito is travelling in a straight path?

Uniform Motion

Uniform = "Constant"
Neither the speed nor direction can change.

Direction: must be moving in a straight line, forward or back OR up or down.

Speed: can not be speeding up or slowing down.

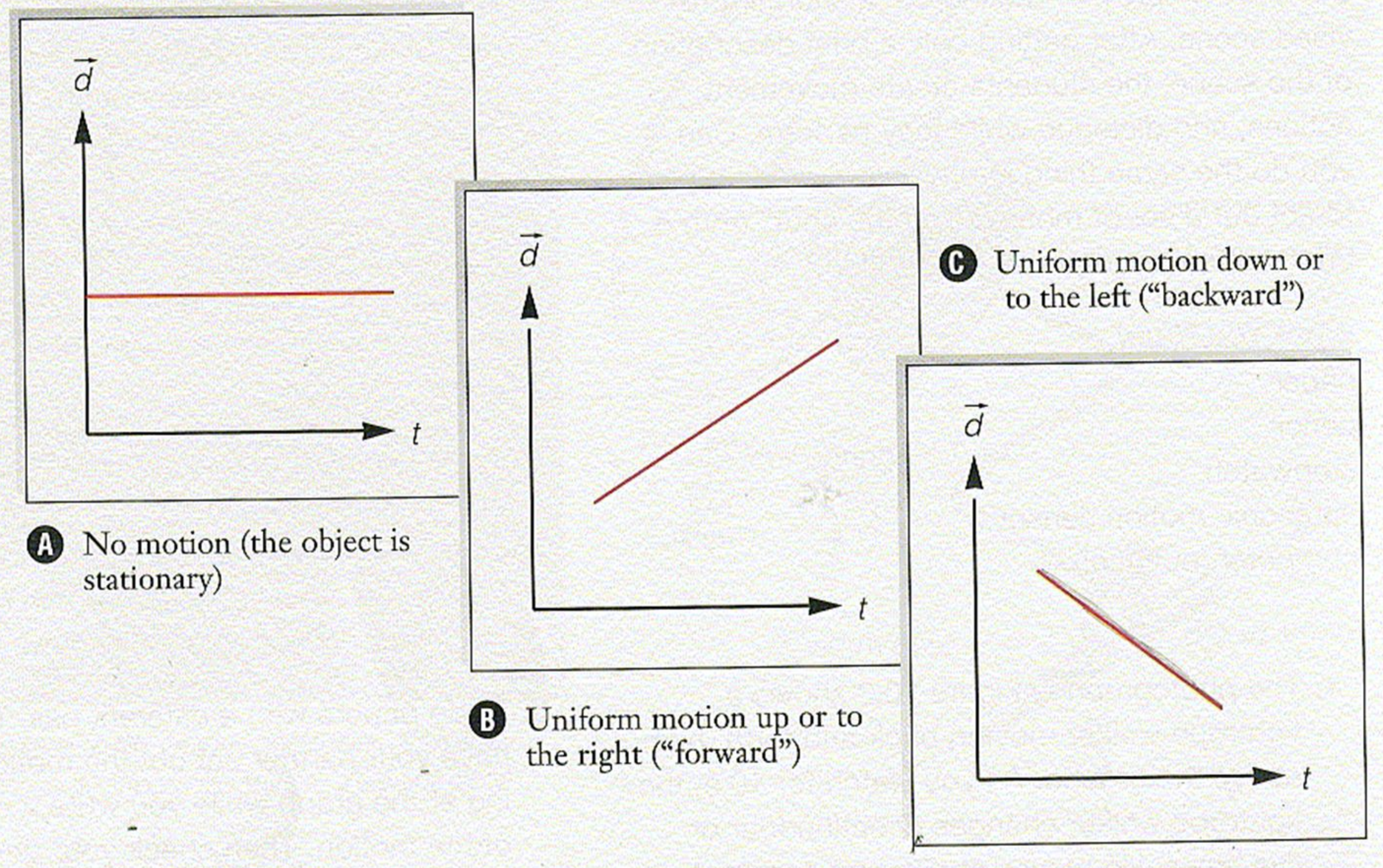


Figure 10.3 These are the three basic types of position-time graphs for uniform motion.

1.4 Analyzing Velocity-time Graphs

Displacement = Area between the line and the time axis in a velocity-time graph

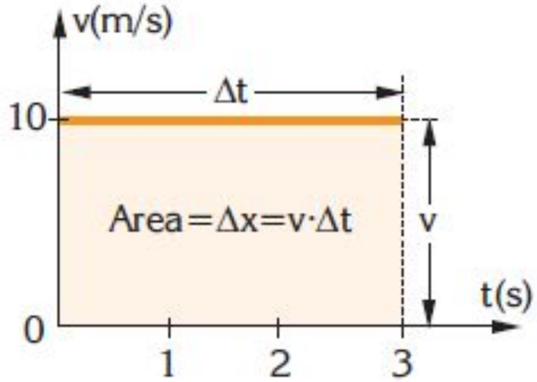
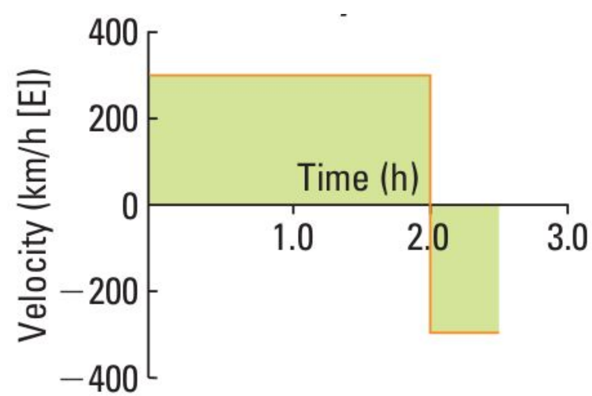
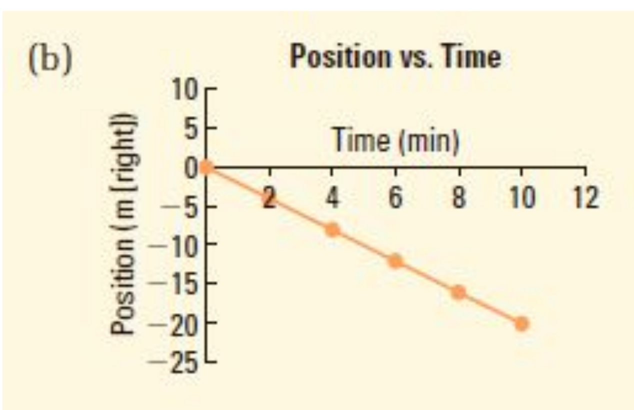


Figure 1.2.4 The shaded area gives the displacement.

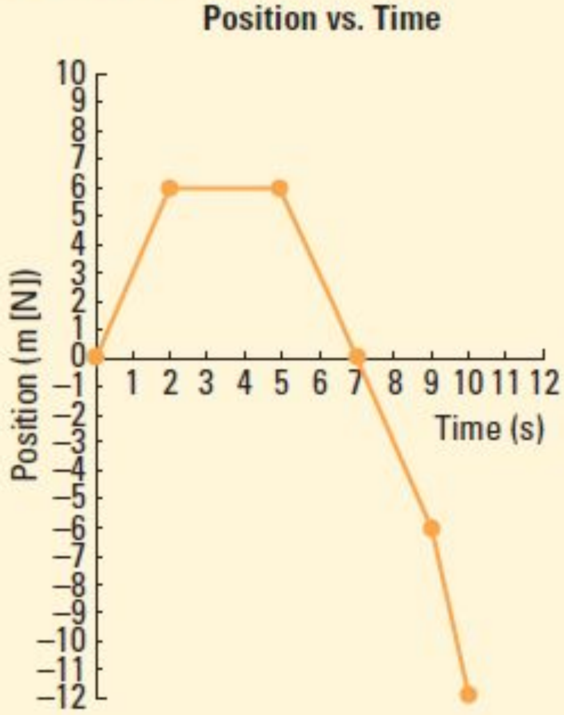


▲ **Figure 1.41** To calculate net displacement, add the areas above and below the time axis.



Practice Problems

1.



(a) Describe the motion of the object from the graph above.

(b) Draw the corresponding velocity-time graph.

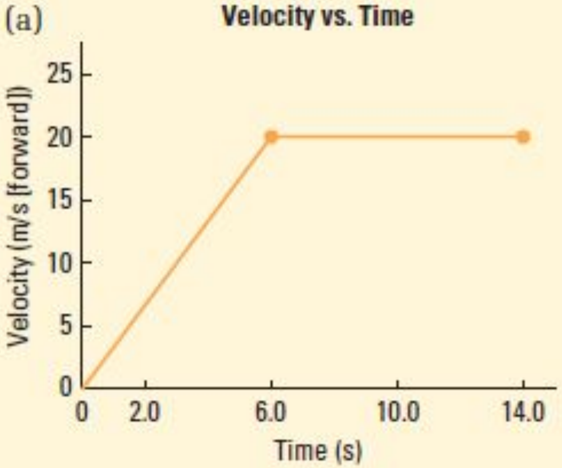
(c) Determine the object's displacement.

(d) When is the object stopped?

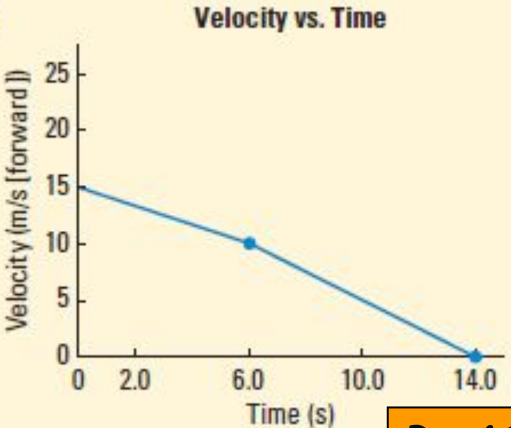
Practice Problems

1. For each velocity-time graph below, draw the corresponding acceleration-time graph.

(a)



(b)



Pg 42

Position as a Function of Time

The equation for constant velocity as described above can be re-written as

$$\Delta x = v \cdot t \quad \text{where} \quad \Delta x = x_{final} - x_{initial}.$$

Substituting in the expression for Δx above, $x_{final} - x_{initial} = v \cdot t$

$$x_{final} = x_{initial} + v \cdot t$$

For clarity x_{final} is denoted as x and $x_{initial}$ as x_0,

the final form of the equation is $x = x_0 + v \cdot t$.

This is the position as a function of time, x(t). For example, using SI units, $x(t) = 15 + 40 \cdot t$ means that the initial position of the object is at 15 m, and it moves at a constant velocity of 40 m/s in the positive direction. Similarly $x(t) = 5 - 30t$ means that $x_0 = 5$ m and $v = 30$ m/s in the negative direction.

Example 1.2.1

Motion with constant velocity

The position of a truck at the moment $t_0=0$ is $x_0=250$ m. It moves with a constant velocity and at $t=20$ s its position is $x=750$ m, as shown in the figure.

a) Calculate the truck's velocity by drawing its position-time graph

b) Draw the velocity-time graph of the truck.

c) Find the position of the truck at the moment $t=30$ s.

d) Find the displacement of the truck between $t=40$ s and $t=60$ s.

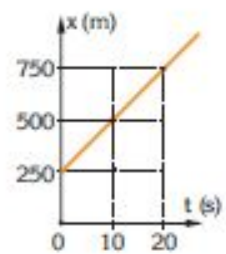
e) Write down an equation for the position of the truck as a function of time.

a) The truck's position-time graph can be drawn using the information provided in the problem. From the slope of the line, the velocity is;

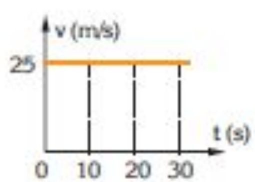
$$\text{slope} = v = \frac{x_f - x_i}{t_f - t_i}$$

$$= \frac{750 - 250}{20 - 0}$$

$$v = 25 \text{ m/s}$$



b) The velocity of the truck doesn't change in time, therefore its v-t graph must have the form given below:



c) Let the truck's position at $t = 30$ s be x, using the equation

$$\Delta x = v\,\Delta t$$

$$x - x_0 = v(t - t_0)$$

$$x - 250 \text{ m} = 25 \text{ m/s} \cdot (30 \text{ s} - 0)$$

$$x = 1000 \text{ m}$$

d) The truck's displacement between $t=40$ s and $t=60$ s is then

$$\Delta x = v\,\Delta t$$

$$\Delta x = 25 \text{ m/s } (60 \text{ s} - 40 \text{ s})$$

$$\Delta x = 500 \text{ m}$$

e) Since the truck moves at a constant velocity of 25 m/s from $x_0 = 250$ m

$$x = x_0 + vt \qquad \text{thus,} \qquad x = 250 + 25t$$

A motorbike increases its velocity from 20.0 m/s [E] to 30.0 m/s [E] over a distance of 200 m. Find the acceleration and the time it takes to travel this distance.

CR – 16, pg 45

a) While driving north from Lake Louise to Jasper, you travel 75 min at a velocity of 70 km/h [N] and another 96 min at 90 km/h [N]. Calculate your average velocity.

b) Create a graph for the question and check your answer using graphing techniques.