Unit 5
Time, Speed and Rate

Lesson Objectives:

- Using appropriate apparatus to measure short time intervals
- Limitations of apparatus usage due to Reaction Time.
- describe how to measure a short interval of time including the period of a simple pendulum with

appropriate accuracy using stopwatches or appropriate instruments

- Definition and the S.I. unit for speed and its relevant calculations for new situations.
- Definition and the S.I. unit for acceleration and its relevant calculations for new situations.
- Definition of Rate and its usage for ticker-tape timer.

Time

- Timing is based on some regular events or processes such as repetitive motion or vibration.
- Repetitive motions or vibrations are called oscillations.
- Time can mean an instant or a time interval.

  E.g. what is the time now?

  E.g. How long you take to run 100 m?

- ***The SI unit for time: second; s***

  Other units for time: minute (min); hour (h); day; month, year, decade and century.

Different time keepers

There are various kinds of instrument used for measuring time.

E.g. A sundial, an hourglass, a pendulum clock, a watch, an atomic clock and etc..

Stopwatches

Mechanical

Electronic

- **Manual operation**

→***Human reaction time*** *error*

** Test your reaction time (ruler test) **

Stopwatches

(a) Mechanical (analogue) stopwatch

A mechanical stopwatch consists of a minute scale and a second scale. The minute scale is seen as a smaller circle at the top of the face of the stopwatch. The second scale is seen as the big circle on the face of the stopwatch.

The mechanical stopwatch can measure time accurate to 0.1 s.

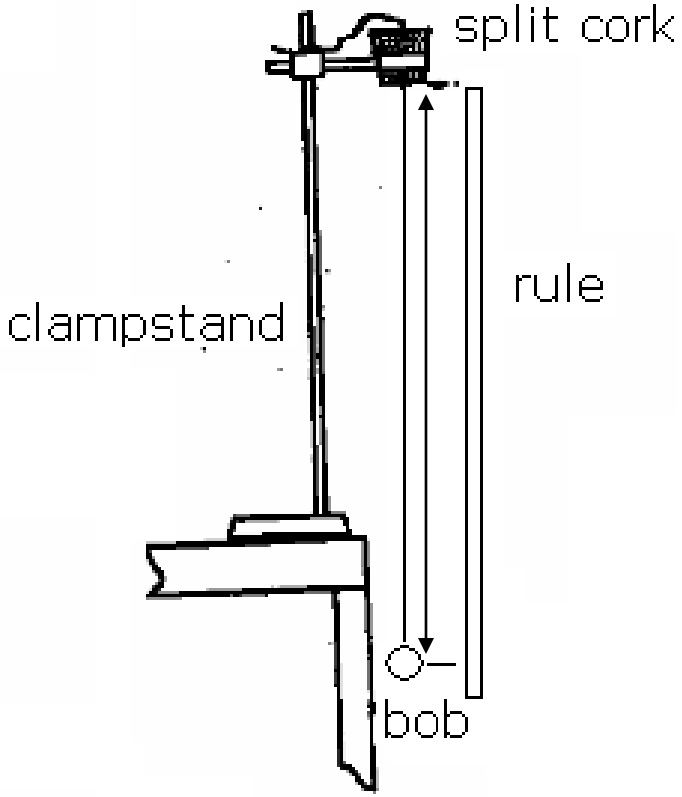
(b) Electronic (digital) stopwatch.

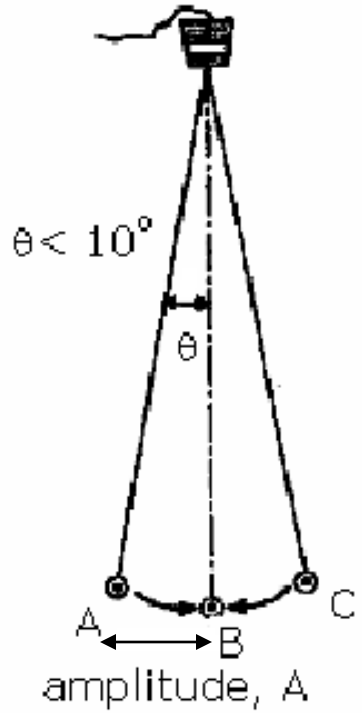
It has a digital display of the time and it can measure time intervals accurate to 0.01 s.

Reaction time

- When you see something happens, you react to it. For instance, a child runs in front of you as you are riding a bicycle. The time interval from seeing the child to putting on the brakes of your bicycle is your reaction time.
- To measure a time interval, the stopwatch needs to be started and stopped by hand. This manual operation introduces an error which can be quite a large fraction of a second and it is known as human reaction time error.

The simple pendulum.



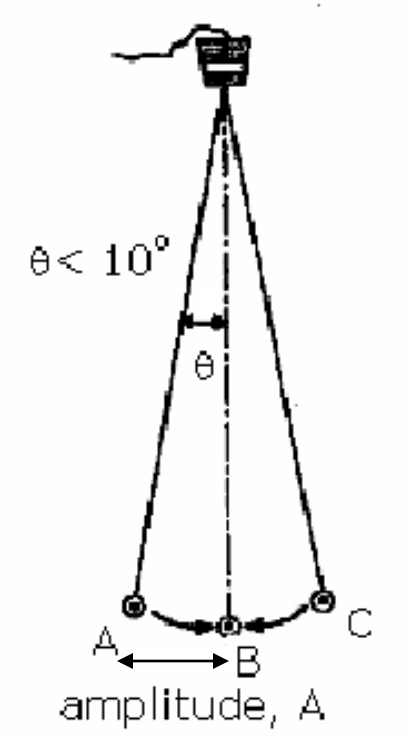


One complete to and fro movement of the pendulum bob is called an oscillation or vibration. E.g.

$$A \xrightarrow[\frac{T}{2}]{} C \xrightarrow[\frac{T}{2}]{} A$$

$$B \xrightarrow[\frac{T}{4}]{} C \xrightarrow[\frac{T}{4}]{} B \xrightarrow[\frac{T}{4}]{} A \xrightarrow[\frac{T}{4}]{} B$$

Terms used in simple pendulum



The maximum displacement of the bob from its rest position is called the amplitude.

The time taken for one complete oscillation is called the periodic time or period, T.

The number of oscillations made in 1 second is called the frequency of the oscillation, *f* .

The SI unit for frequency is hertz or Hz.

1Hz = 1 oscillation / second.

The relationship between period and its frequency is given by:

$$f = \frac{1}{T}$$

For small angular amplitude (less than 10^o), the period depends only on the length, l of the pendulum and the acceleration due to gravity, g.

$$T = 2\pi\sqrt{\frac{l}{g}}$$

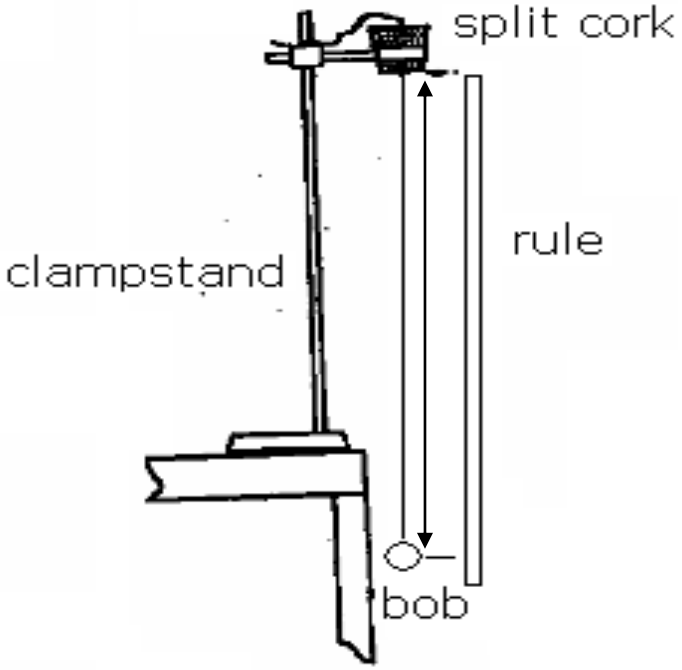
The acceleration due to gravity, g on the surface of the earth is 10 m/s^2

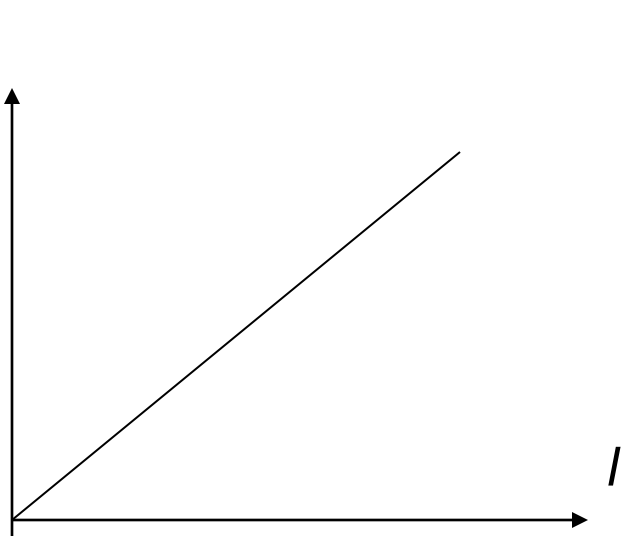
The period of a simple pendulum does not depend on the size and mass or the material of the pendulum bob.

http://www.walter-fendt.de/ph14e/pendulum.htm

http://phet.colorado.edu/sims/pendulum-lab/pendulum-lab.swf

The simple pendulum experiment:





(a) Set up the apparatus as shown in the diagram.

(b) Measure the length (*l*) of the pendulum.

(c) Give the pendulum bob a small angular displacement ($\theta < 10^o$) and time 20 oscillations using a stopwatch. Let the time be *t*.

(d) Repeat the experiment, using different *l* values.

(e) Plot a graph of T^2 against *l*.

Speed and average speed

Speed is the distance travelled per unit time. It is found by dividing the distance travelled by the time taken to travel the distance.

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$\mathbf{v} = \frac{\mathbf{d}}{\mathbf{t}}$$

Motorists can check their speed at any instant from the speedometer for their vehicles.

The SI unit for speed: m/s or ms^{-1}

Average speed:

The average speed is found by dividing the total distance travelled by the total time taken to travel the distance.

$$\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$$

$$\langle \mathbf{v} \rangle = \frac{\mathbf{d}}{\mathbf{t}}$$

Question:

An MRT train took 11.5 minutes to travel 10 km from station X to station Y. It stopped at station Y for 0.5 minute. It then took another 24.0 minutes to travel 20 km from station Y to station Z. What is the average speed of the MRT train?

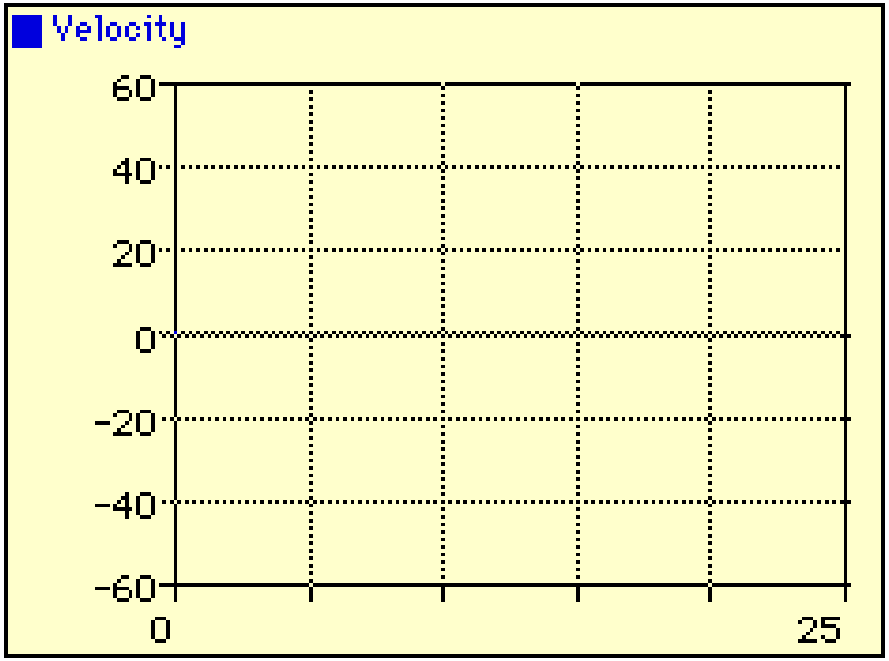
Total distance travelled, d = 10 + 20 = 30 km

Total time taken = 11.5 + 0.5 + 24.0 = 36.0 minutes

$$\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}} = \frac{30}{36/60} = 50\,\mathbf{km/h}$$

Status:

First Stage



Velocity

0 m/s

Time

0 sec

Position

0 m

Acceleration

0 m/s/s

Acceleration

When a car changes its speed, the car is said to be accelerating. The acceleration of a car can be positive or negative. When it is negative, the car is said to be decelerating or retarding. When it is positive, it is said to be accelerating.

Acceleration is defined as the rate of change of speed or it is defined as change of speed per unit time.

$$\text{acceleration} = \frac{\text{change in speed}}{\text{time taken}}$$

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

Rearranging,

$$\mathbf{v = u + at}$$

a = acceleration;

v = final velocity;

u = initial velocity;

t = time.

The SI unit for acceleration

(m per s per s) or m/s^2 or ms^{-2}

Question:

A bus starts from rest and achieves a velocity of 20 m/s in 10 s while moving westwards from a starting point, O. Calculate its average acceleration.

$$a = \frac{v-u}{t} = \frac{20-0}{10} = 2m/s^2$$

Question:

A sport car travelling eastwards at 30 m/s suddenly comes to a stop in 5 s. Find its average acceleration.

u = 30 m/s

v = 0 m/s

t = 5 s

$$a = \frac{v-u}{t} = \frac{0-30}{5} = -6m/s^2$$

Rate

Rate is a ratio between 2 different physical quantities. It describes how a quantity changes with another.

Many rates describe how a quantity changes with time but there are rates which do not involve time.

E.g. pulse rate (involve time) – 80 pulses/s

E.g. volume of petrol consumed per km travelled (does not involve time) – 5 litre/km

Some of our daily activities required us to know or to regulate how fast liquid or gases (fluids) flow.

$$\text{vol. rate of flow} = \frac{\text{vol. of liquid or gas flowing}}{\text{time taken to flow}}$$

Question:

Family A consisting of 5 members uses 35000 *l* of water monthly while family B consisting of 10 members uses 65000 *l* of water monthly. Is it fair to say that members in family B use more water than those in family A?

$$\text{water consumption rate of family A} = \frac{\text{vol. of water}}{\text{No. of family members}}$$

$$= \frac{35000}{5} = 7000 \text{ litres per person}$$

$$\text{water consumption rate of family B} = \frac{\text{vol. of water}}{\text{No. of family members}}$$

$$= \frac{65000}{10} = 6500 \text{ litres per person}$$

Member of family A actually use more water than members in family B.

Question:

The rate of petrol consumption of Lai Chun's car is 12 km//. How much petrol is needed for the car to travel 60 km?

$$\text{Rate of petrol consumption} = \frac{\text{distance travelled}}{\text{amount of petrol used}}$$

$$12\ \text{km/litre} = \frac{60\ \text{km}}{\text{amount of petrol used}}$$

$$\text{Amount of petrol used} = \frac{60}{12}$$

$$= 5\ \text{litres}$$

Check point

Which of the following are examples of rates?

time

speed

number of words spoken per minute

volume of water consumed

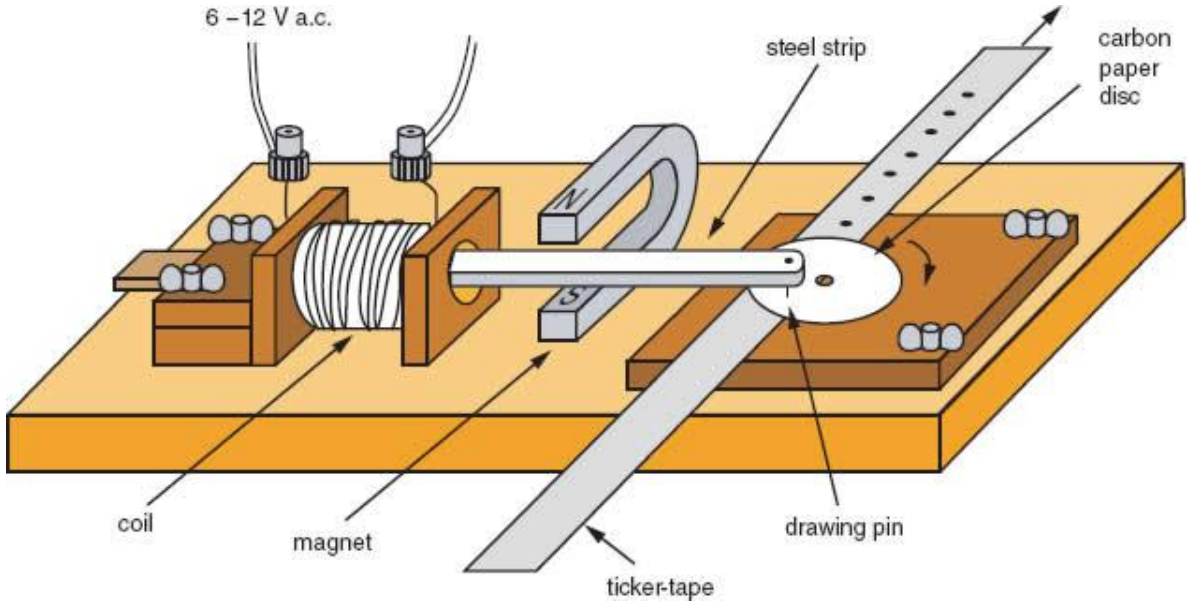
volume of water consumed per person

mass of an object

number of heartbeats per minute

speed measurement using a ticker-tape timer

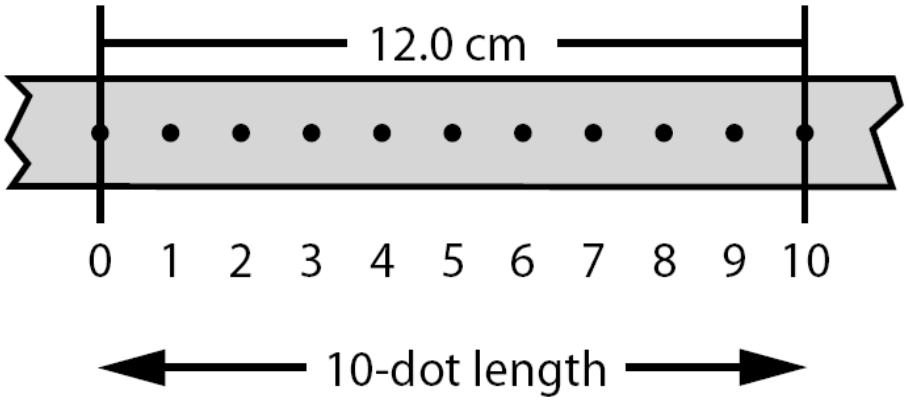
- A ticker-tape may be used to measure short intervals of time



speed measurement using a ticker-tape timer

Example:

Frequency of ticker tape = 50 dots/s. Find speed.



Distance travelled = 0.12 m

1 time interval = 1/50 = 0.02 s

Speed = distance/time = 0.12/(10x0.02)

= 0.6 m/s