Waves 1

Oscillating System

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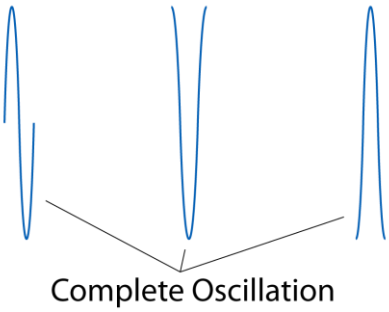
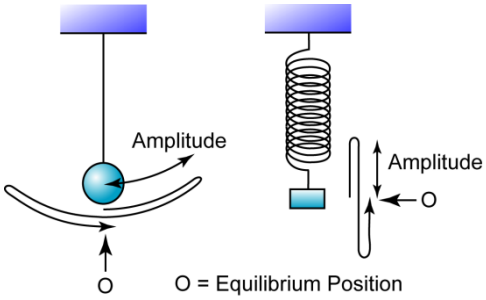


Amplitude is the maximum displacement of an object from its equilibrium position.



Frequency, *f* is the number of complete vibrations that take place in one second.

Period is defined as the time required for one complete oscillation or vibration.

Relationship between period and frequency

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

Technical terms

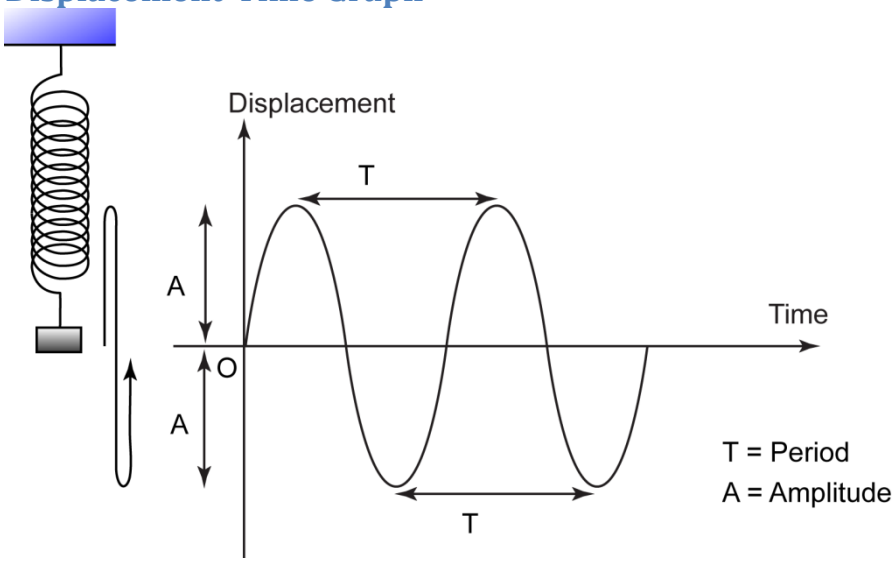
1. An **equilibrium position** is a point where an oscillating object experiences 0 resultant forces.
2. A **complete oscillation** occurs when the vibrating object:
   a) moves to and fro from its original position and
   b) moves in the same direction as its original motion.
3. **Amplitude** is the maximum displacement of an object from its equilibrium position. The SI unit for amplitude is meter, m.
4. The greater the amplitude, the greater the mechanical energy possesed by the oscillating system.
5. **Period** is defined as the time required for one complete oscillation or vibration.
6. **Frequency**, *f* is the number of complete vibrations that take place in one second. The SI unit for frequency is hertz, Hz.
7. Frequency can be related to peiod by the following equation

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

***f* = frequency**
***T* = Period**

Example 1
Given that a pendulum makes 20 oscillations in 25s. Find the frequency of the pendulum.

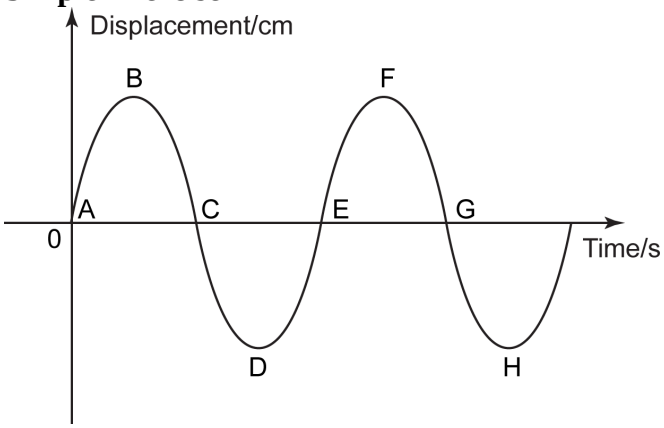
Displacement-Time Graph



In a displacement-time graph, we can determine
a) The displacement of the oscillating object at any time.
b) The amplitude
c) The period.

Waves 1

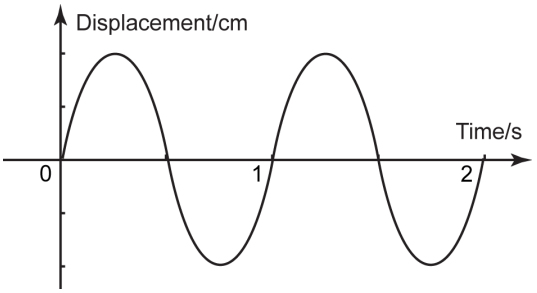
Simple Exercise I



1. By referring to the graph above, states four pairs of points at which a system make a complete oscillation.

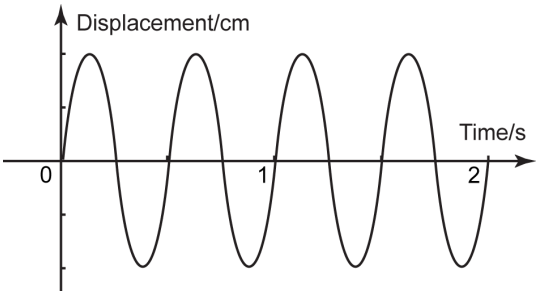
2. Find the frequency of the oscillating system of the graphs below without using the equation $f = \frac{1}{T}$.

a.



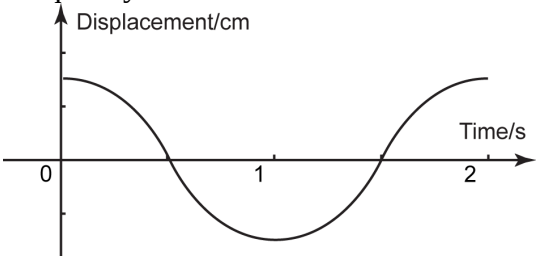
Frequency =

b.



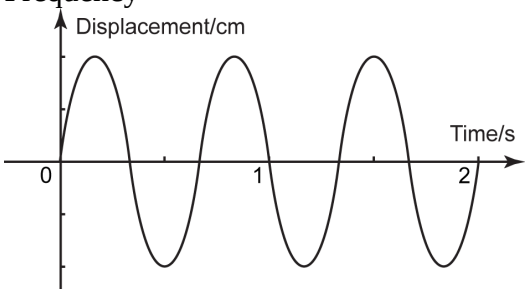
Frequency =

c.



Frequency =

d.

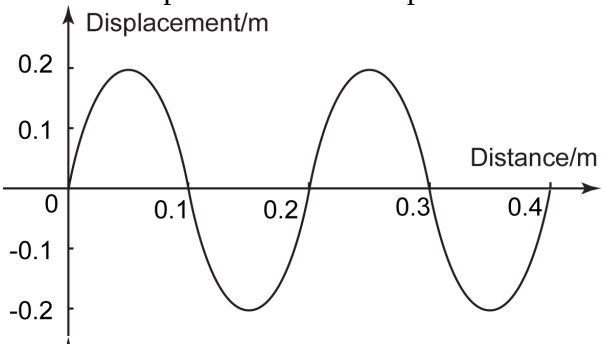


Frequency =

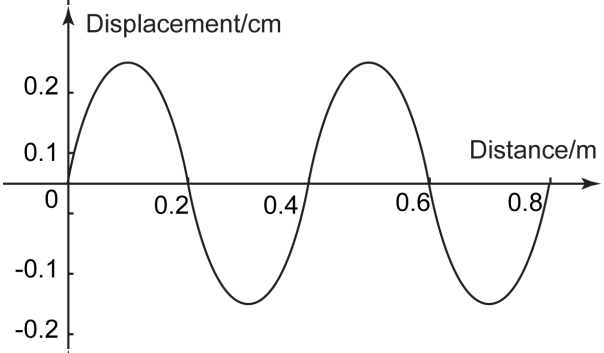
Example 2

Which of the following graphs represent a spring oscillates with a period 0.2s and amplitude 10cm?

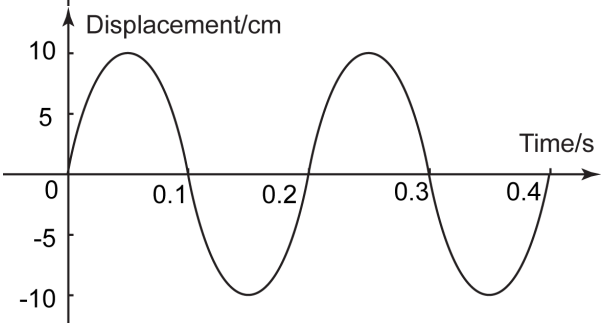
A.



B.

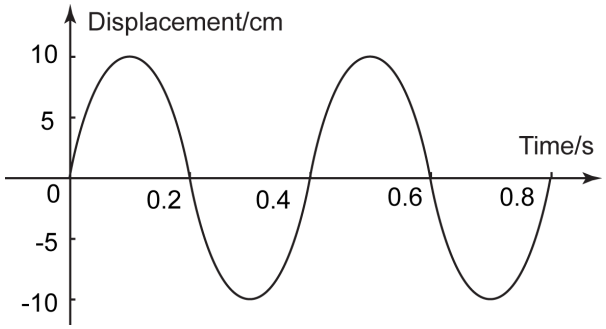


C.

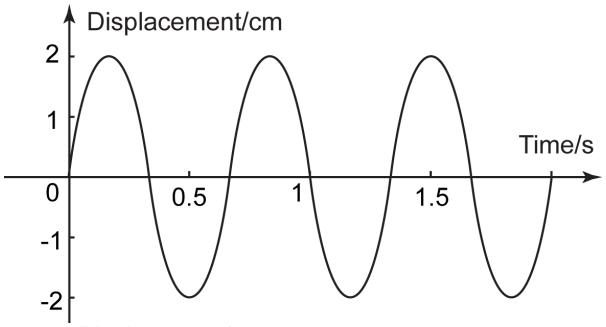


Waves 1

D.



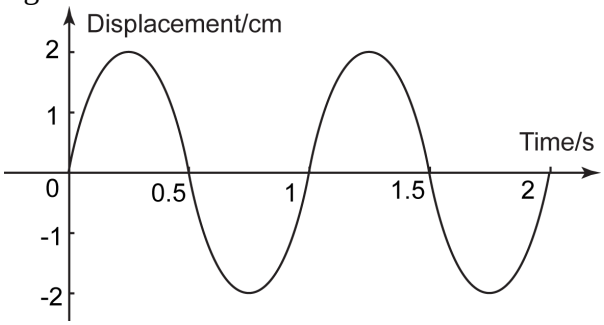
B.



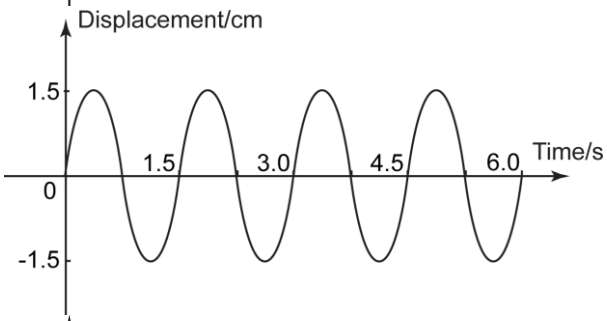
Example 3

A pendulum is oscillating with amplitude 2cm and frequency 1.5Hz. Which of the following graphs correctly shows the displacement of the pendulum bob against time?

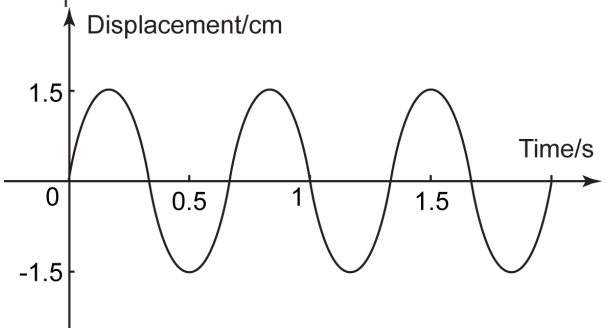
A.



C.

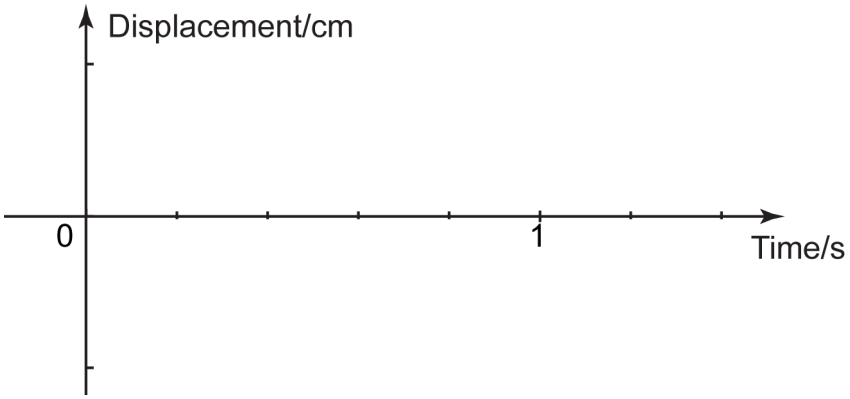


D.



Example 3

A spring oscillates with amplitude 5cm and frequency 2.5Hz. Sketch the displacement-time on the axis given below.



The **natural frequency** of an oscillating system is the frequency of the system when there is no external force or forces acting on it.

Natural Frequency

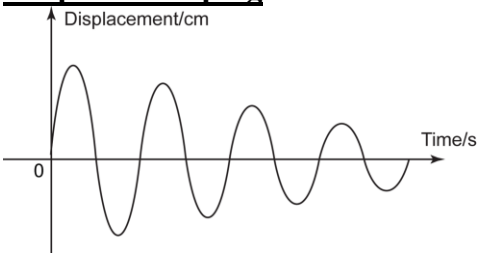
The Natural frequency of an oscillating system is the frequency of the system when there is no external force or forces acting on it.

Waves 1

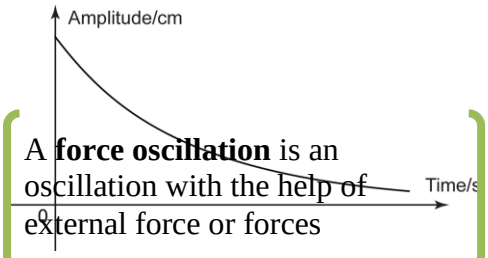
Damping, Force Oscillation and Resonance

1. Damping is the **decrease in the amplitude** of an oscillating system.
2. An oscillating system experiences damping when its energy is losing to the surrounding as heat energy.
3. The frequency of the system remains unchanged.

Graph of Damping



Displacement – Time Graph



Amplitude – Time Graph

A **force oscillation** is an oscillation with the help of external force or forces

Resonance is a phenomenon where an oscillating object oscillates with very high amplitude when the frequency of the external force exerted on the system equal to the natural frequency of the system.

Damping is the **decrease of the amplitude** of an oscillating system due to losing energy to the surrounding

Type of Damping

Damping can be divided into:

1. **external damping**, where an oscillating system loses energy to overcome frictional force or air resistance that act on it.
2. **internal damping**, where an oscillating system loses energy due to the extension and compression of the molecules in the system.

Force Oscillation

1. In a damped oscillation, external force must be applied to the system to enable the oscillation to go on continuously.
2. Oscillation with the help of external force or forces is called a force oscillation.

Resonance

1. In a force oscillation, if the frequency of the external force is equal to the natural frequency of the system, the system will oscillates with maximum amplitude, and this is named as resonance.

Examples of Resonance

1. Opera singer breaks a wine glass with her voice due to the effect of resonance.
2. Tacoma Narrow Bridge in USA collapsed in 1940 due to the effect of resonance.
3. A moving bus produces excessive noise at certain speed when the frequency of the engine equal to the natural frequency of the bus.

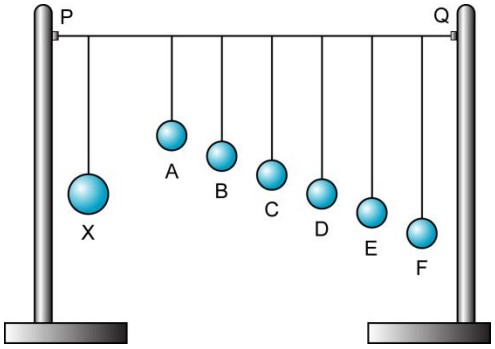
Applications of Resonance

1. Resonance is used to tune radio or television to your favorite channels.

Bartons Pendulum

The characteristic of resonance can be demonstrated with a Barton's pendulum system.

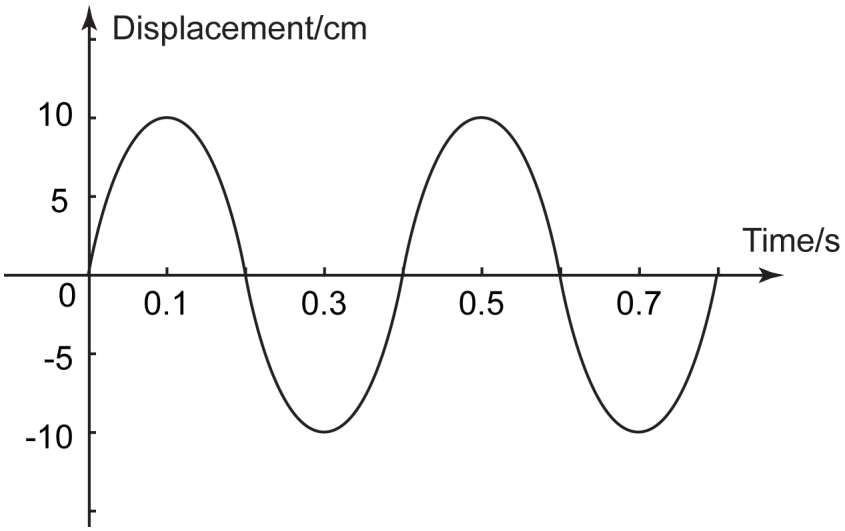
Waves 1



Observation

1. When pendulum X oscillates, the other pendulums are forced to oscillate.
2. Pendulum D will oscillates with the largest amplitude.

Structure Questions



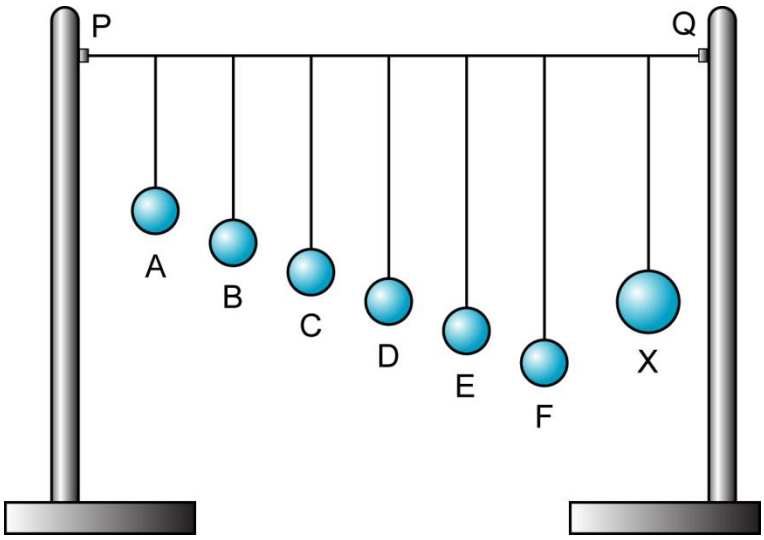
1. Figure above shows a displacement versus time graph for a vibrating object.
   a. Find the amplitude, period and frequency for the vibrating system.
      Amplitude = 10cm, period = 0.4s, frequency = 2.5Hz

   b. What is the displacement of the object at t = 0.3 s,
      -10cm

   c. Sketch in the same axis above, a graph of a wave which the frequency and amplitude are half of the wave in the figure above.

Waves 1

Barton's Pendulum



2. Figure above shows a Barton's pendulum which consists of 7 pendulums hanging on a horizontal string, PQ. When pendulum X is displaced and released, all the other pendulums will also start oscillating.
   a. Why the pendulum A, B, C, D, E and F oscillate when pendulum X start oscillating?
   The energy of pendulum X has transfer to all other pendulums through the string PQ.

   b. What is force oscillation?
   Force oscillation is the oscillation at which external force is exerted on the system to make the system oscillate.

   c. Name 2 pendulums in the figure above that undergoes force oscillation.
   Any two of A, B, C, D, E and F

   d. Which pendulum will oscillate with the maximum amplitude? Give a reason for your answer.
   D. Because its length is equal to the length of pendulum X, therefore it has same natural frequency as pendulum X.

   e. What is the name of the phenomenon that occurred in part d. above.
   Resonance.

   f. Define the phenomenon that you name in e.
   Resonance is a force oscillation that oscillates with maximum amplitude when the frequency of the external force that act on the system is equal to the natural frequency of the system.

   g. What is the purpose of making the size of pendulum X bigger than the others?
   So that it contains more (potential) energy when it is oscillating to cause the other pendulums to move with higher amplitude.

   h. All of the pendulums undergo damped oscillation and stop after a while. What does it mean by a "damped oscillation"?
   A damped oscillation is the oscillation with decreasing amplitude.

   i. Name two type of damping.
   Internal damping and external damping

Waves 1

j. In the graphs provided below, sketch the displacement-time graph and amplitude-time graph of a damped oscillation.