Grade 12 physics
Unit 2 part 1
Periodic motion
LIVE CLASS

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2.1 Periodic motion (basic concepts)

- If something is oscillating(vibrating) this means that it is moving backwards and forwards, up and down, side to side, in and out, around some central position.
- This central position is called the equilibrium position and it is the position of the object when it is at rest.
- This position is the position where the resultant force acting on the bob is zero

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2.1 Periodic motion (basic concepts)

- Whenever an object is displaced from its equilibrium position there is a force that acts towards its original position called a restoring force.

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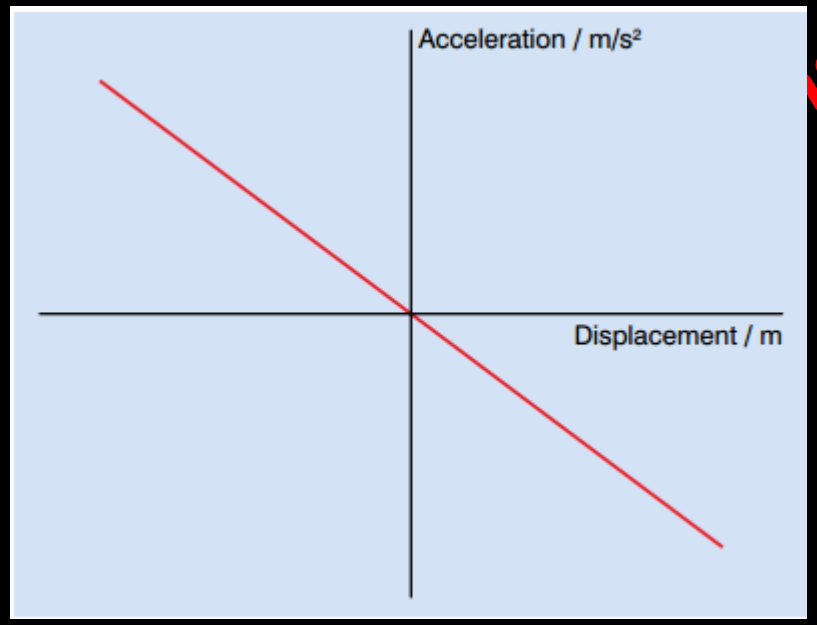
How do we define SHM?

- Simple harmonic motion (SHM) is a periodic oscillation of an object about an equilibrium position such that its acceleration is always directly proportional in size but opposite in direction to its displacement.
- The acceleration is proportional to the displacement.
- The acceleration is in the opposite direction to the displacement.

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How do we define SHM?

- The acceleration is proportional to the displacement.
- The acceleration is in the opposite direction to the displacement.



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What does SHM look like?

- If we plot how the displacement of an object performing simple harmonic motion varies with time, we find that the variation is sinusoidal,

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Frequency and time period

- The frequency, f, of an oscillation is the number of cycles it completes per second.
- The unit is the hertz, symbol Hz.

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Circular motion, SHM and angular frequency

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Circular motion, SHM and angular frequency

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Displacement, velocity and acceleration in SHM

- The velocity of the oscillating mass is the rate of change of displacement.
- It becomes zero at the limits of the oscillation.
- The maximum velocity occurs when the oscillating object passes through the equilibrium position

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Displacement, velocity and acceleration in SHM

- Acceleration is the rate of change of velocity, or the gradient of the velocity time graph.

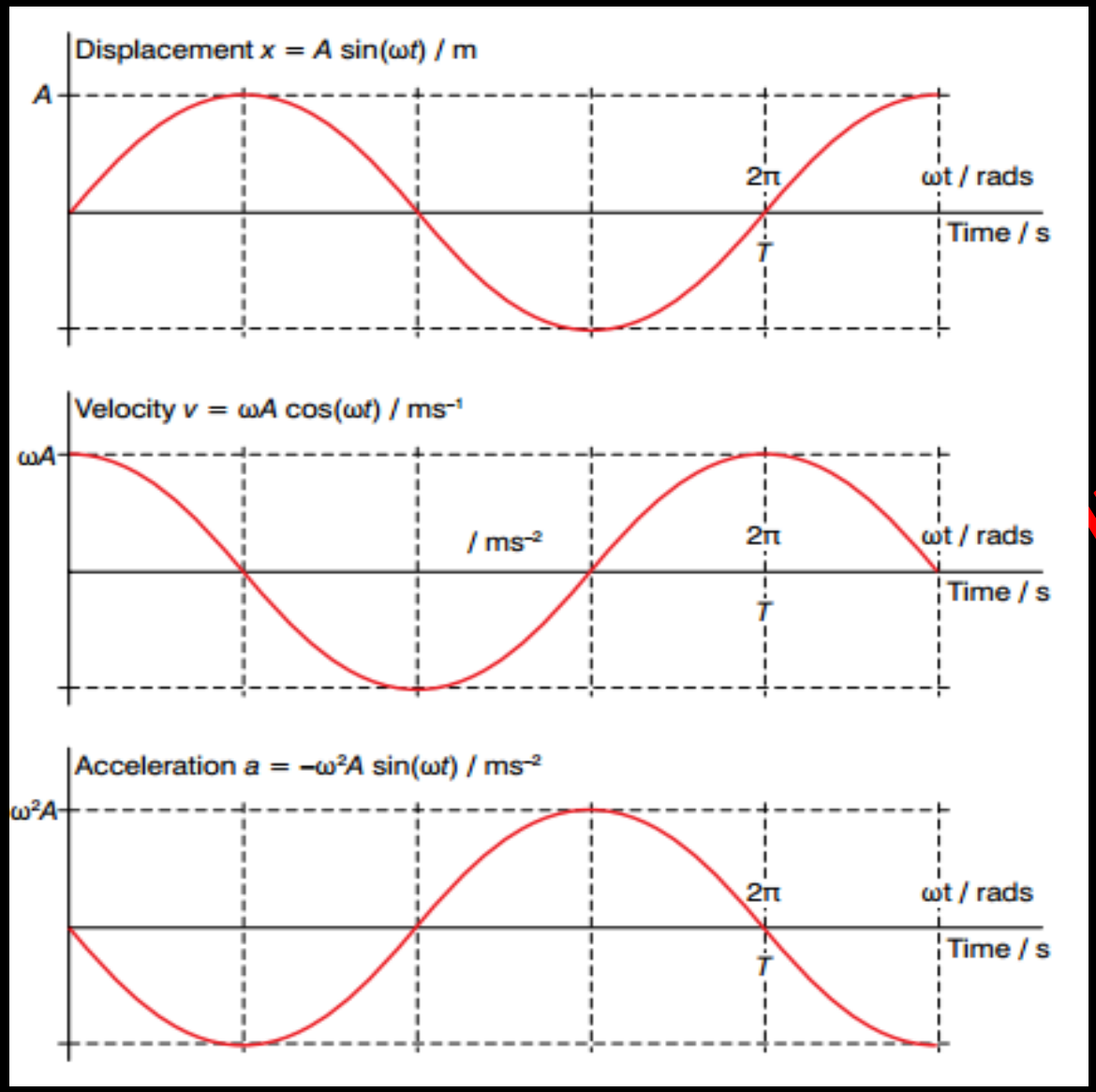
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SHM equation summary

	Using sin to describe displacement	Using cos to describe displacement
Displacement	$x = A\sin(\omega t)$	$x = A\cos(\omega t)$
Velocity	$v = \omega A\cos(\omega t)$	$v = -\omega A\sin(\omega t)$
Acceleration	$a = -\omega^2 A\sin(\omega t)$	$a = -\omega^2 A\cos(\omega t)$

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SHM equation summary



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How does velocity depend on displacement?

- $V = \pm\omega\sqrt{A^2 - x^2}$

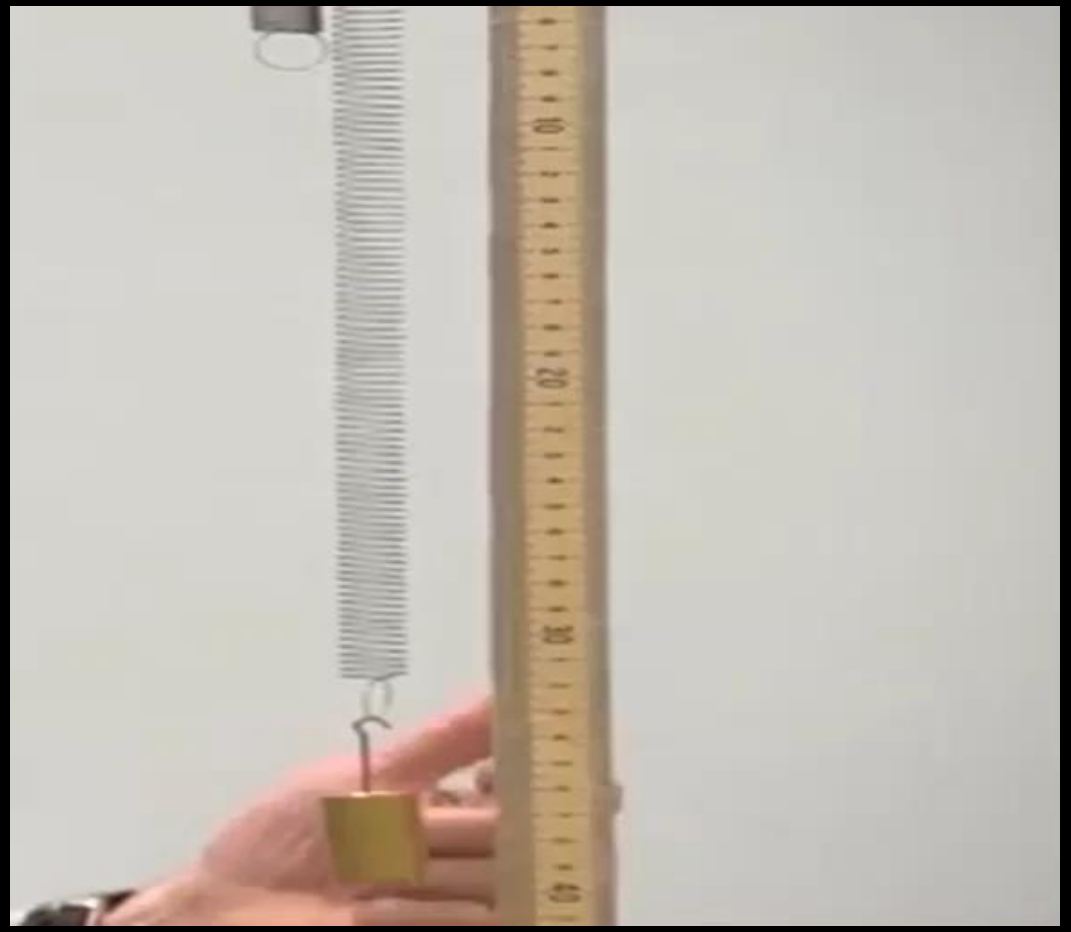
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How do we calculate the time periods of real examples of SHM?

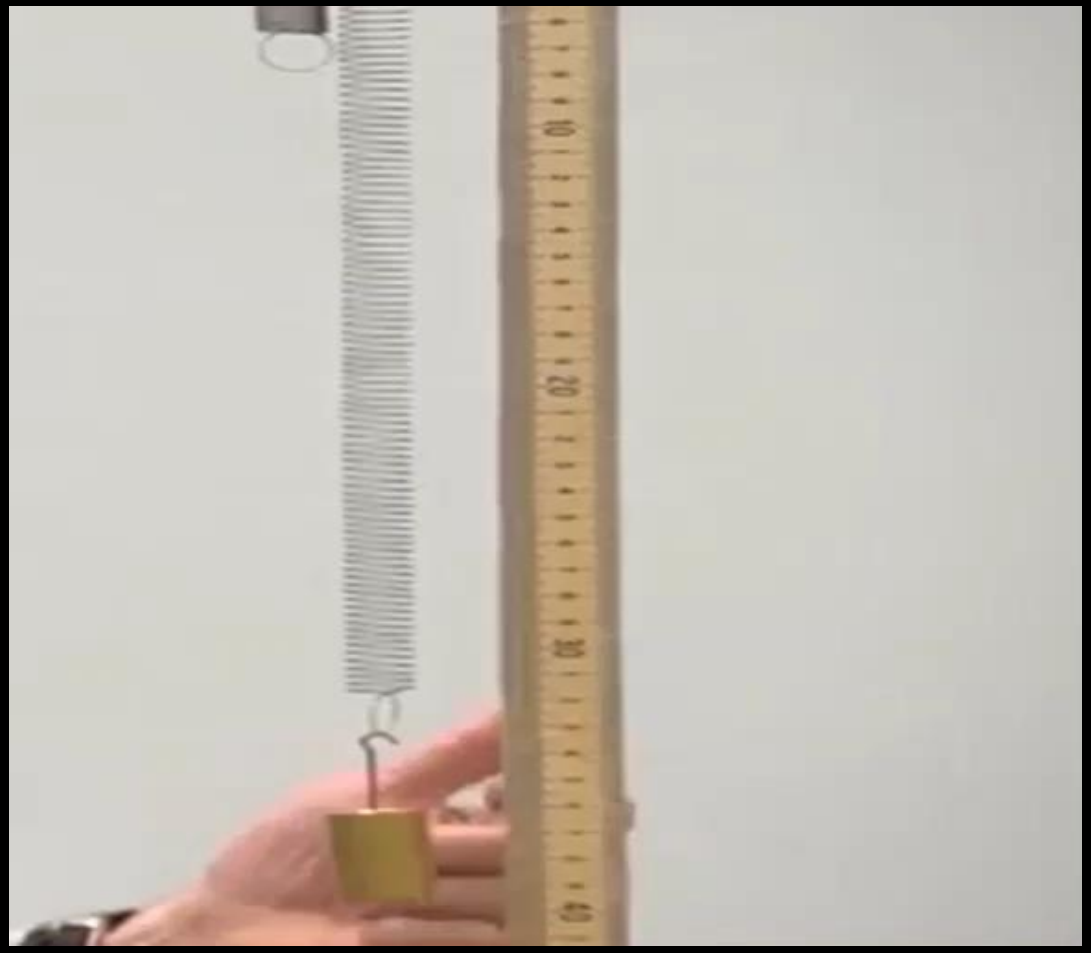
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What is the time period of a mass–spring system?

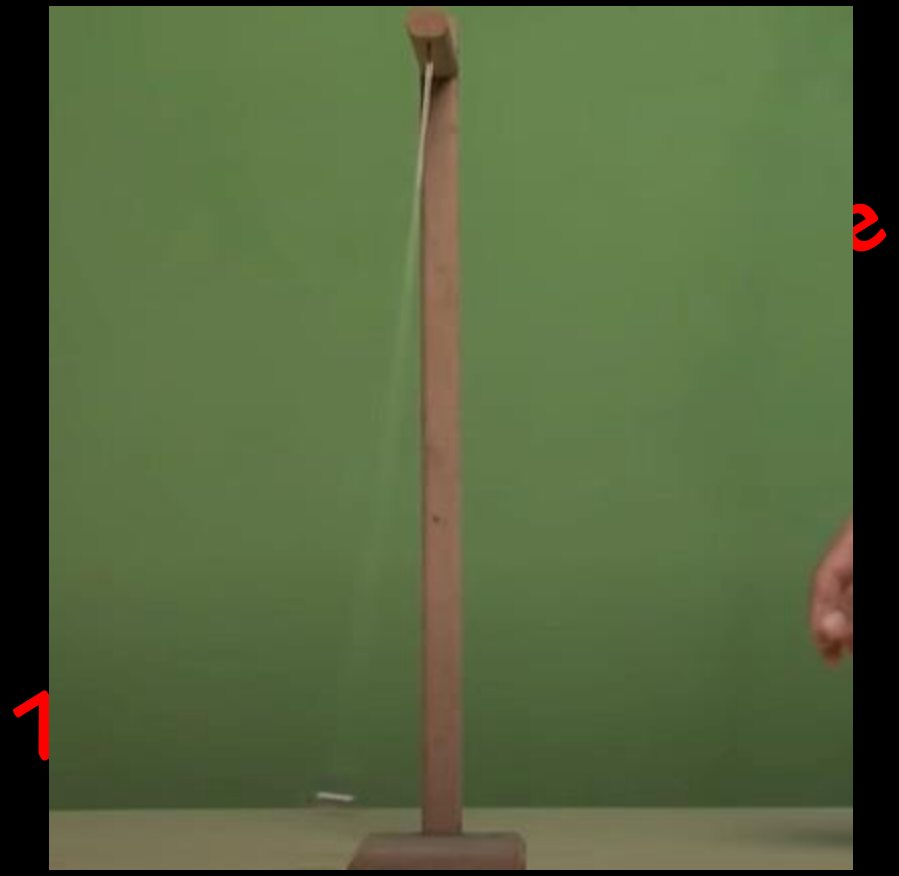




What is the time period of a mass–spring system?



What is the time period of a simple pendulum?



Examples

The displacement of a particle executing SHM is given by X= (3m)sin $0.2\pi t$ calculate.

A) frequency

B) maximum velocity

C) the maximum acceleration

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Examples for students

A particle in SHM moves according to the equation x = 0.75 sin 63t cm find the frequency of oscillation

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Examples

A body excuse SHM of amplitude 1 cm and frequency 12 Cycles/sec what is the velocity when displacement is 0.5 cm?

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Examples

A block of mass 2kg is attached to the spring of spring constant 50Nm . The block is pulled to a distance of 5 cm from its equilibrium position at x=0 on a horizontal frictionless surface from rest at t = 0. The displacement of the block at any time t is then

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Examples

An object is undergoing Simple Harmonic Motion with an amplitude of 5 cm and a period of 2 seconds. What is the maximum displacement of the object?

a. 5 cm

b. 10 cm

c. 15 cm

d. 20 cm

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Examples

An object is undergoing Simple Harmonic Motion with an amplitude of 3 cm and a period of 0.5 seconds. What is the maximum acceleration of the object?

a. -473.1 cm/s^2

b. -331.4 cm/s^2

c. 473.1cm/s^2

d. 331.4 cm/s^2

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Exercise

2. An oscillating system is used to create a succession of waves on a water surface. The rate of wave generation is one every 0.33seconds. What is the period of these waves? UEE 2005/2013

(A) 0.3 seconds

(B) 1.0 seconds

(C) 2.0 seconds

(D) 3.0 seconds

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Exercises

1. A wave has a speed of 50m/s and a wavelength of 25,000m. What is the frequency of the wave? UEE 2005/2013

(A) 2.0x10-3Hz (B) 6.0x101Hz (C) 5.0x102Hz (D) 1.8x106Hz

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Examples

3. A mass suspended from the end of a spring vibrates up and down 24 times in 36s. What are the frequency and period of the vibration? (UEE 2006/2014)

(A) 1.5Hz, 0.67s

(B) 0.67HZ, 1.5s

(C) 0.0012Hz, 864s

(D) 864Hz, 0.0012s

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Exercises

4. The acceleration of a simple harmonic oscillator: **UEE 2003/2011**
   (A) Remains constant during its motion
   (B) Remains non-zero
   (C) Attains its maximum value when its amplitude is zero
   (D) Attains minimum value when its velocity is maximum.

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Exercises

5.A particle that undergoes simple harmonic motion has a period of 0.4s and an amplitude of 12mm. the maximum velocity of the particle is: UEE 2003/2011

(A) 3cm/s (B) 9.42cm/s (C) 15cm/s (D) 18.84cm/s

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Exercises

6. What is the formula for the period of a mass on a spring undergoing SHM?

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Exercises

7. What is the formula for the period of a Pendulum undergoing SHM?

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Exercises

A mass on a spring undergoes Simple Harmonic Motion. Which of the following parameters doesn't affects the period of the motion?

a. Mass of the object

b. Amplitude of the motion

c. Spring constant

d. All of the above

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Exercises

A pendulum exhibits Simple Harmonic Motion. Which of the following is true about its motion?

a. The period of the motion depends on the mass of the pendulum bob.

b. The period of the motion depends on the length of the pendulum.

c. The period of the motion depends on the amplitude of the motion.

d. The period of the motion depends on the velocity of the pendulum bob.

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Exercises

Which of the following is the correct equation for the period of an object undergoing Simple Harmonic Motion?

a. $T = 2\pi m/k$

b. $T = 2\pi/k$

c. $T = 2\pi\sqrt{(m/k)}$

d. $T = 2\pi/\sqrt{(m/k)}$

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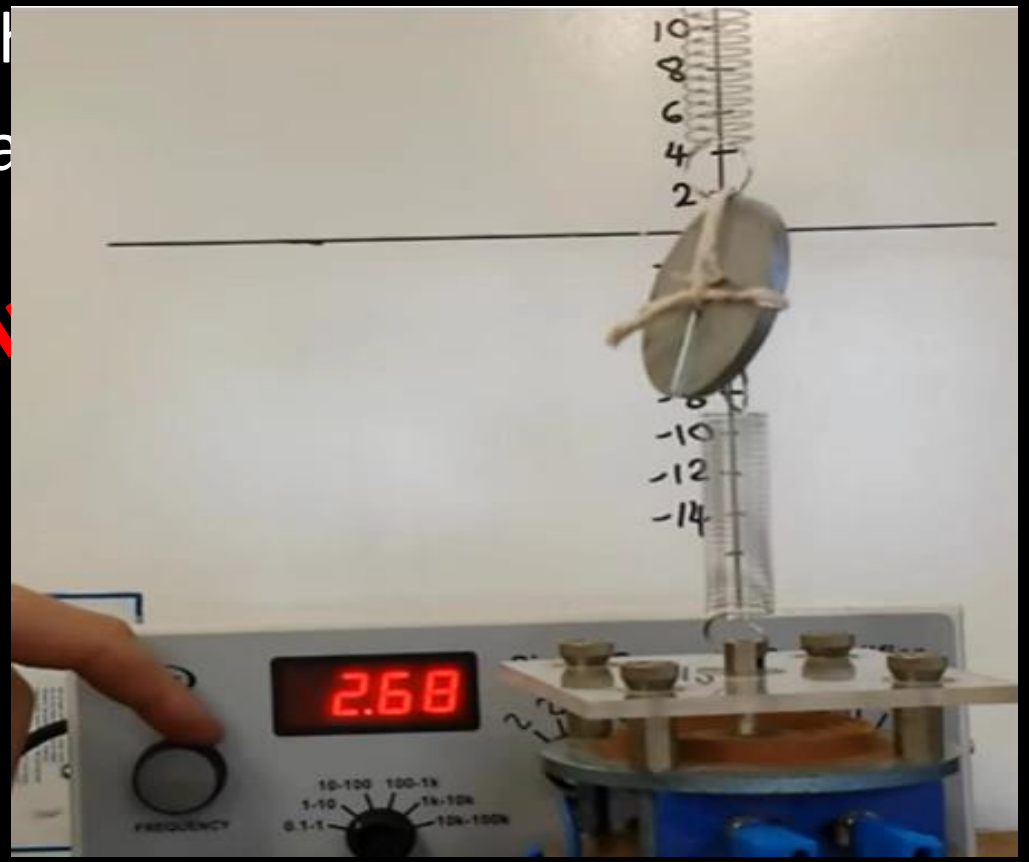
Forced oscillations and resonance

- A free oscillation occurs when an oscillator is displaced from its equilibrium position and released so that it can oscillate freely, with no external forces acting on it.
- The oscillator then oscillates at its natural frequency.
- Forced or driven oscillations occur when a periodic driving force acts on an oscillator.
- This will make the oscillator oscillate at the frequency of the periodic driving force rather than at its natural frequency.

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Forced oscillations and resonance

- If the frequency of the periodic driving force is the same as the oscillator's natural frequency, energy is transferred easily into the oscillation and the amplitude of th
- This phenomenon is called resona



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Forced oscillations and resonance

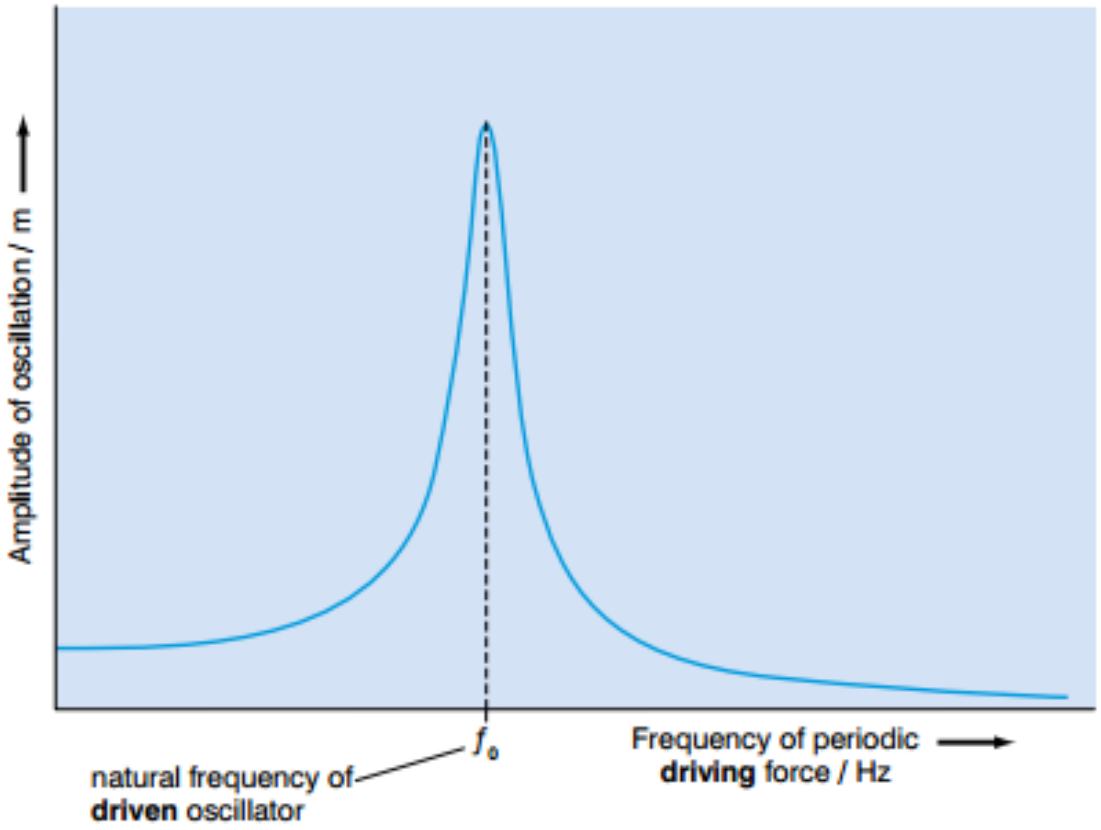


Figure 2.21 *This plot of driven amplitude against driving frequency peaks at the resonant frequency.*

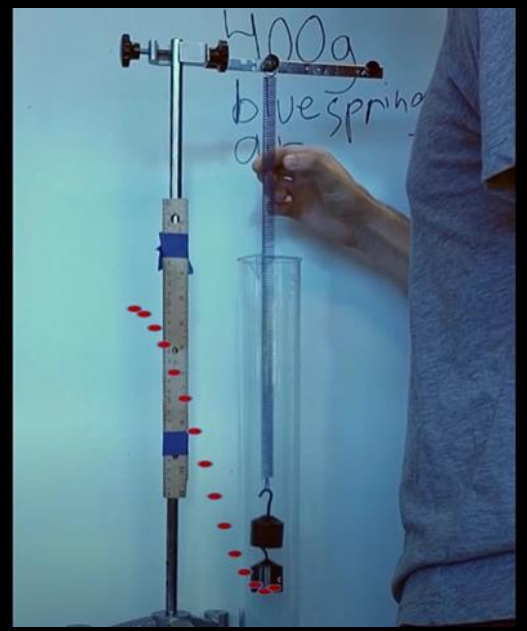
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Damping of oscillations

Damping :- a decrease in the amplitude of an oscillation as a result of energy being drained from the system to overcome friction or other resistive forces.

the damping on an oscillator can be described in 4 ways

- ❑ undamped
- ❑ underdamped
- ❑ critically damped
- ❑ overdamped

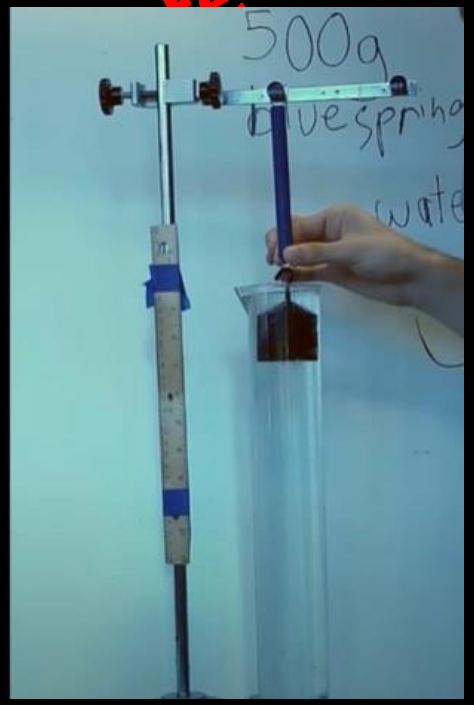


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Pause (k)

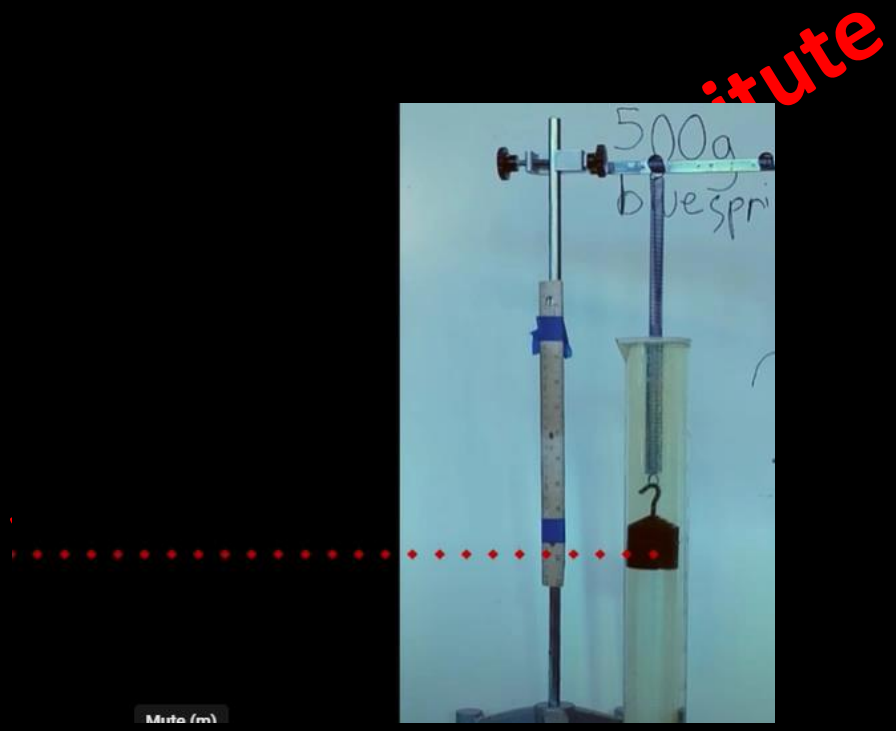
Damping of oscillations

- underdamping damping that allows the oscillator to move back and forth through its equilibrium position before returning to rest



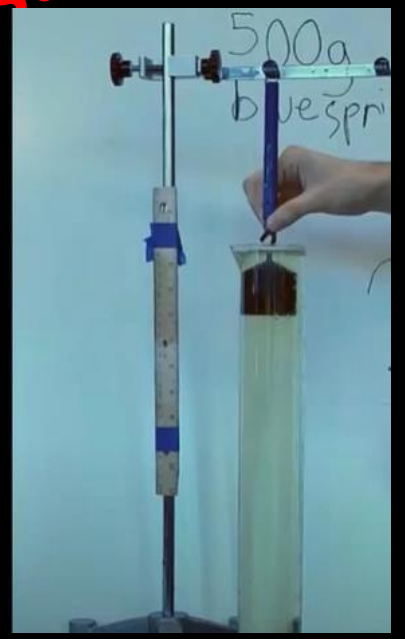
Damping of oscillations

- critically damped, the amount of damping that allows the oscillator to return to its equilibrium position in the shortest possible time.

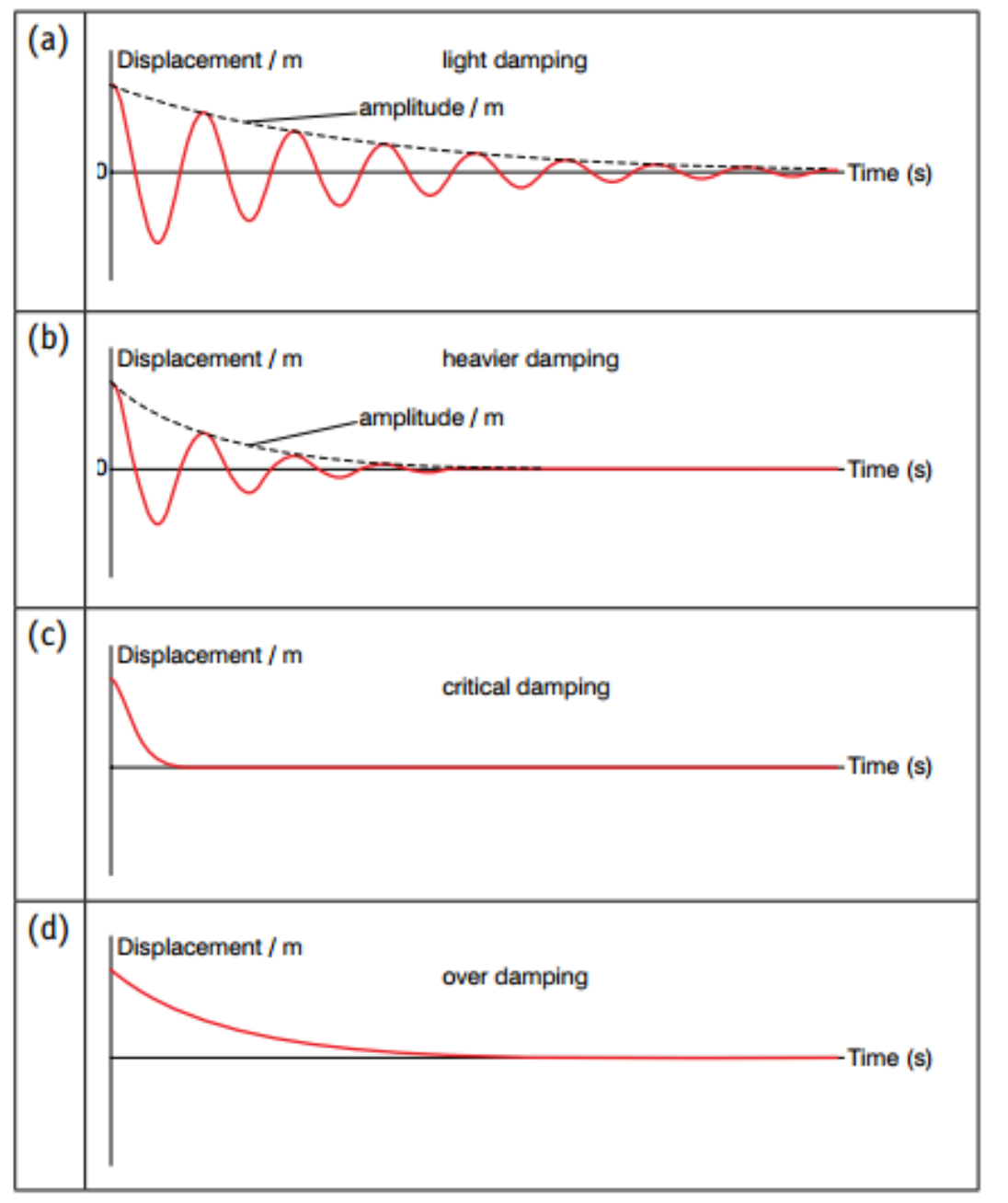


Damping of oscillations

- overdamping damping that prevents oscillation entirely and only allows the oscillator to return slowly to its equilibrium position.



Damping of oscillations



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Energy in SHM

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Exercise

A mass of 0.5 kg is attached to a spring with a spring constant of 100 N/m. If the mass is displaced 0.2 m from its equilibrium position and released, what is its maximum kinetic energy?

A. 3J

B. 4.5J

C. 2J

D. 4.7J

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Exercise

A mass of 0.3 kg is attached to a spring with a spring constant of 80 N/m. If the mass is displaced 0.1 m from its equilibrium position and released, what is its maximum speed?

A. 1.86m/s

B. 2.65m/s

C. 5.3m/s

D. 1.67m/s

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Exercise

A mass of 0.4 kg is attached to a spring with a spring constant of 60 N/m. If the mass is displaced 0.15 m from its equilibrium position and released, what is the period of its motion?

A. 0.67s

B. 0.03s

C. 1.4s

D. 0.75s

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Exercise

A mass of 0.4 kg is attached to a spring with a spring constant of 60 N/m. If the mass is displaced 0.15 m from its equilibrium position and released, what is the period of its motion?

A. 0.67s

B. 0.03s

C. 1.4s

D. 0.75s

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Exercise

A block of mass 1 kg is attached to a spring with a spring constant of 100 N/m. If the block is displaced 0.1 m from its equilibrium position and released, what is its KE energy and PE respectively when it is at a displacement of 0.05 m?

A. 0.0375J,0.375J

B. 0.125J,0.0375J

C. 0.0375J,0.125J

D. 0.375J,0.125J

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Thank you

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Grade 12 physics
Unit 2 part 2
Wave motion
LIVE CLASS

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Simple exercise from previous class

1. A wave length is: (UEE 2008/2016)

(A) A line that represents the direction of propagation of light

(B) The minimum distance between two points that are in phase

(C) The locus of all points of a travelling wave that are in phase

(D) The number of waves crossing a given plane in a unit time

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Simple exercise from previous class

2. Which of the following is NOT correct about a simple harmonic oscillator? (UEE 2009/2017)

(A) Total mechanical energy is conserved

(B) The acceleration is directly proportional to and opposite in direction to displacement

(C) The period of small oscillation of a pendulum with string length l, a bob mass m attached to its end is $T=2\pi\sqrt{l/g}$

(D) The frequency of an oscillating mass attached to a massless spring is independent of the spring constant.

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Simple exercise from previous class

3. An object of mass m is hung from a spring and set into oscillation. The frequency of the oscillation is measured and recorded as f. if the object of mass m is replaced with an object of mass 2m and set into oscillation, what will be the frequency of the motion? (UEE 2006/2014)

   (A) f/√2 (B) f (C) √2 f (D) 3f

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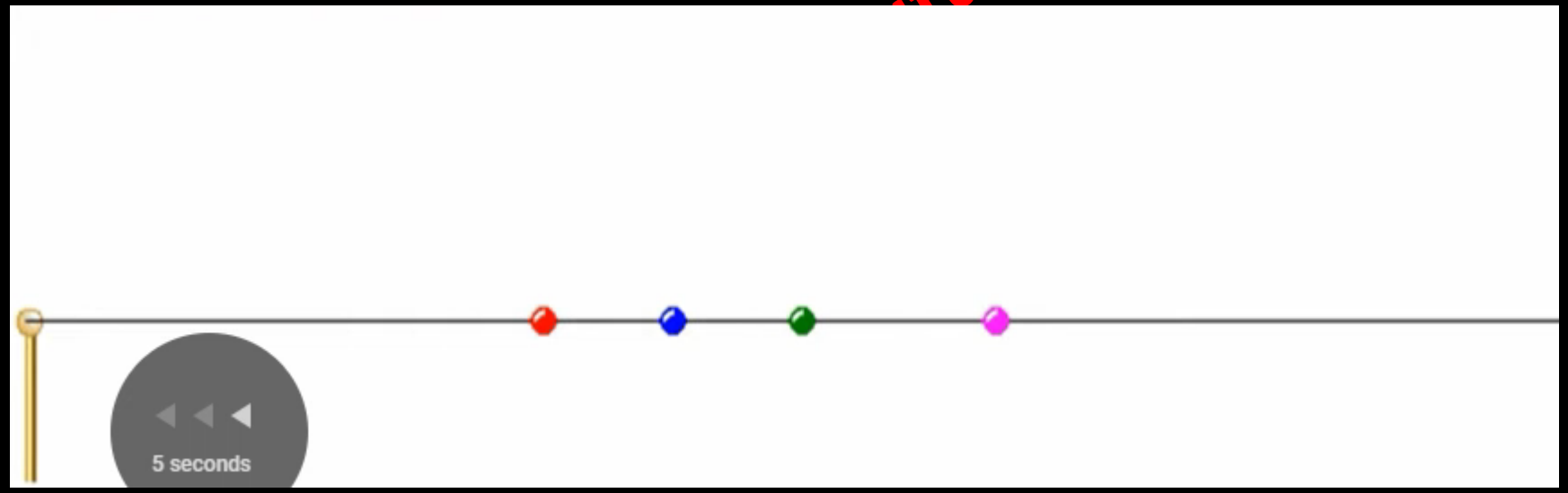
Traveling wave

- Is a wave in which the positions of maximum and minimum amplitude travel through the medium.
- A travelling wave transfers energy, and sometimes information, from one place to another, in what is called the direction of propagation.



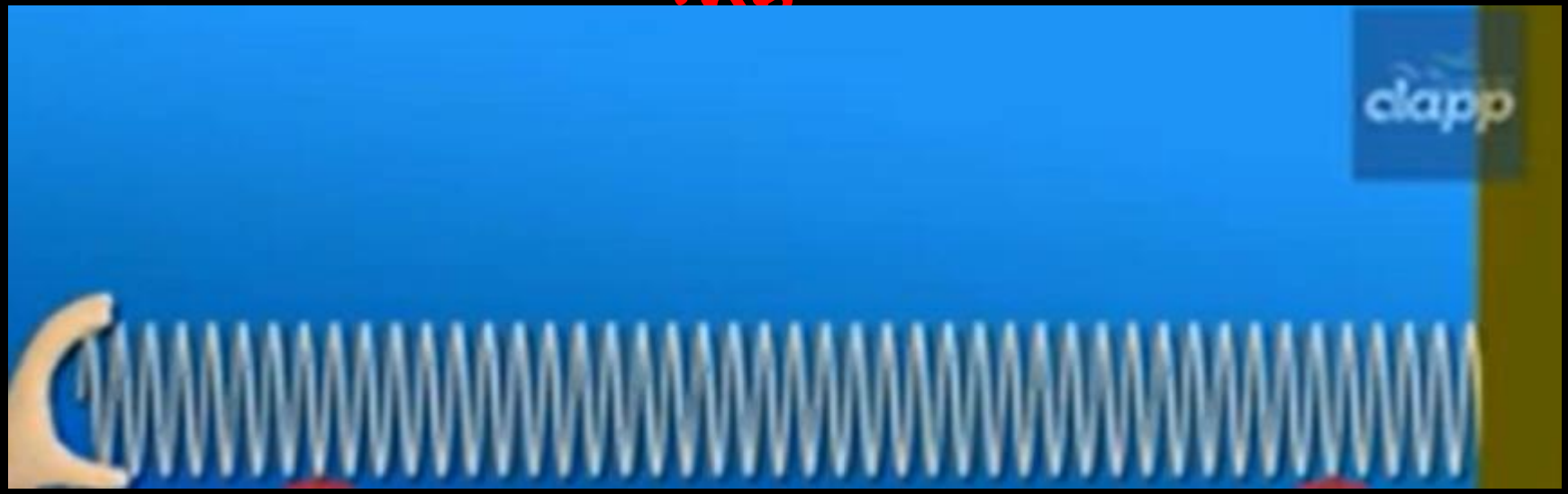
Transverse and longitudinal waves?

- A transverse wave is one in which the oscillation, the temporary displacement of mass or field strength, is at right angles to the direction of propagation.



Transverse and longitudinal waves?

- A longitudinal wave is one in which the oscillation, the temporary displacement of mass, is backwards and forwards along the path of a wave propagation/net energy transfer.
- Sound is a longitudinal wave.



Traveling wave

- What is a traveling wave?
- A traveling wave is a type of wave that propagates through a medium, transferring energy from one point to another. Unlike a standing wave, which oscillates in place, a traveling wave moves forward in a direction perpendicular to its oscillation.
- What are some examples of traveling waves?
- There are many examples of traveling waves, including sound waves, water waves, and electromagnetic waves like light. In each case, the wave travels through a medium (such as air, water, or space) and carries energy from one place to another.

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Exercise

10. A transverse sinusoidal wave is travelling on a string. Which statement is correct about a point on the string? (UEE 2006/2014)

(A) The point moves in the direction as the wave

(B) The point moves in simple harmonic motion with a different frequency than that of the wave

(C) The point moves in simple harmonic motion with the same angular frequency as the wave

(D) The point moves in uniform circular motion with a different angular speed than the wave

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Wave speed

- How do you calculate the velocity of a traveling wave?
- The velocity of a traveling wave can be calculated by multiplying the wavelength of the wave by its frequency. This equation is known as the wave speed equation, and it can be expressed as $v = \lambda f$, where v is the wave velocity, λ is the wavelength, and f is the frequency.
- $v = f\lambda$

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Exercise

8. A wave has a speed of 50m/s and a wavelength of 25,000m. What is the frequency of the wave? UEE 2005/2013

(A) 2.0x10-3Hz (B) 6.0x101Hz (C) 5.0x102Hz (D) 1.8x106Hz

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Wave speed through different media

For a mechanical wave travelling along a string the speed of the wave depends on the tension of the string and the mass per unit Length

$$V = \sqrt{\frac{T}{\mu}}$$

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Exercise

34. Identify a true statement about a mechanical wave (UEE 2012-13/2021)

(A) The speed of a wave travelling across a thin string is equal to its speed when travelling across a thick string of the same length and tension

(B) The speed a wave travelling along a string increases as the tension in the string increases and as the linear density of the string decreases

(C) As a wave travels from one point to another a medium, it transmits energy and particles of the medium from point to point

(D) The velocity of a traveling wave is equal to the velocity of the particles through which the wave propagates

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Exercise

Which of the following is true about traveling waves?

a) They transfer energy but not matter

b) They transfer matter but not energy

c) They transfer both energy and matter

d) They transfer neither energy nor matter

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Exercise

Which of the following is not a type of traveling wave?

a) Ocean waves

b) Sound waves

c) Light waves

d) Standing waves

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Exercise

When a traveling wave reflects off a fixed boundary, it undergoes a phase change of:

a) 0 degrees

b) 90 degrees

c) 180 degrees

d) 270 degrees

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How do we describe a travelling wave mathematically?

$Y = A \sin (Kx \pm \omega t)$

$Y = A \cos (Kx \pm \omega t)$

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travelling wave

- What is a standing wave on a string?
- is a wave pattern that forms when a wave with a particular frequency is reflected back upon itself and interferes with the original wave. This results in a pattern of nodes and antinodes, which are points on the string where there is no motion and points where the amplitude of the wave is at its maximum, respectively.

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How do we describe a travelling wave mathematically?

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Exercise

29. Travelling wave is given by the equation Y= Acos (kx-ωt), where k is the wave number and ω is the angular frequency. What is the distance that the wave travels in the time t=T/2? (UEE 2011/2019)

(A) Full wavelength

(B) At the origin

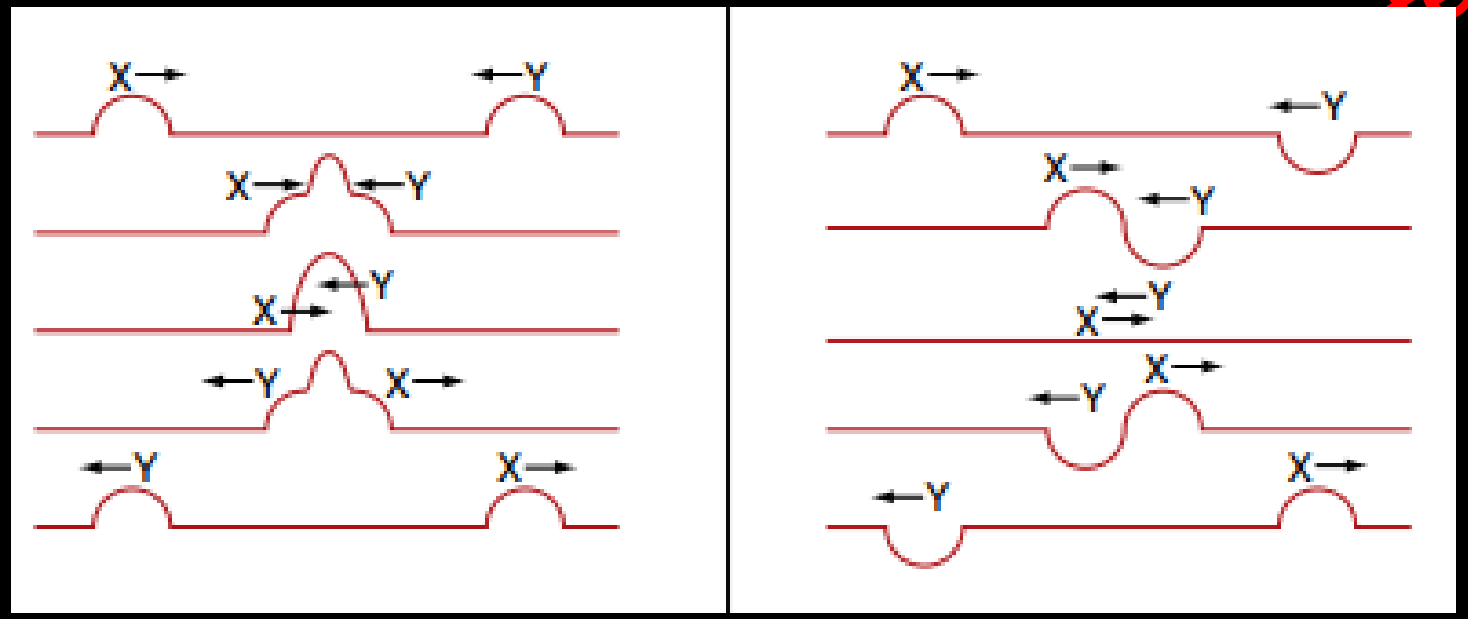
(C) A quarter of the wavelength

(D) Half the wavelength

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Principle of superposition

The principle of superposition may be applied to waves whenever two (or more) waves travelling through the same medium at the same time.



Constructive and destructive interference

- Interference is another word for superposition.
- When two waves arrive at the same point they interfere with each other
- If we consider just two waves, the result is an oscillation whose amplitude depends on the relative phase of the two waves.
- The phase difference between two oscillations is an angular measurement of the difference in their timing,

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Constructive and destructive interference

What is the principle of superposition?

- The principle of superposition is a fundamental concept in physics that states that when two or more waves meet at a point in space, the total displacement at that point is equal to the sum of the displacements that each wave would produce individually.

How is the principle of superposition used to explain interference patterns?

- When two waves interfere constructively, their amplitudes add together, resulting in a larger wave with a higher amplitude. When they interfere destructively, their amplitudes cancel out, resulting in a smaller wave or no wave at all. The principle of superposition can be used to calculate the resulting amplitude of a wave at any point in space based on the amplitudes of the individual waves and their phase difference.

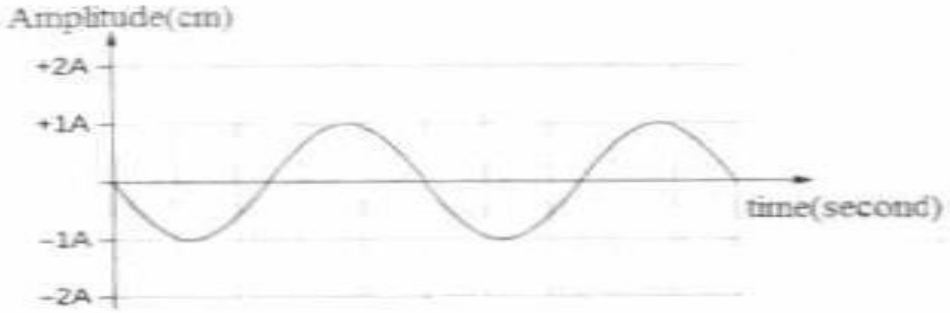
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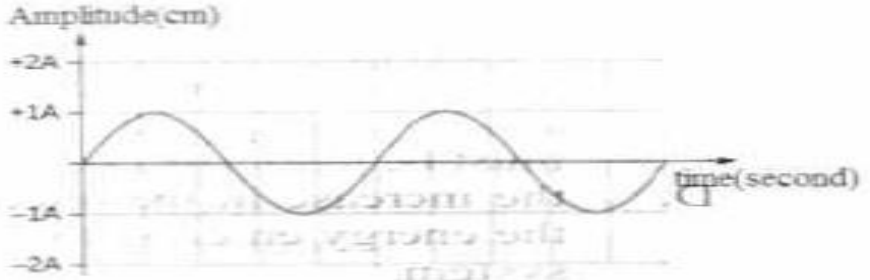
Constructive and destructive interference

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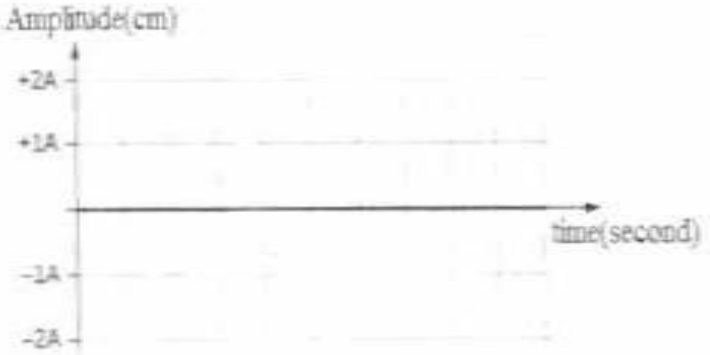
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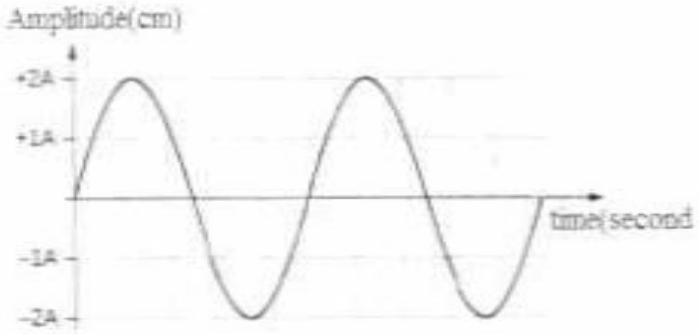


Which graph represents the super position of the two waves?

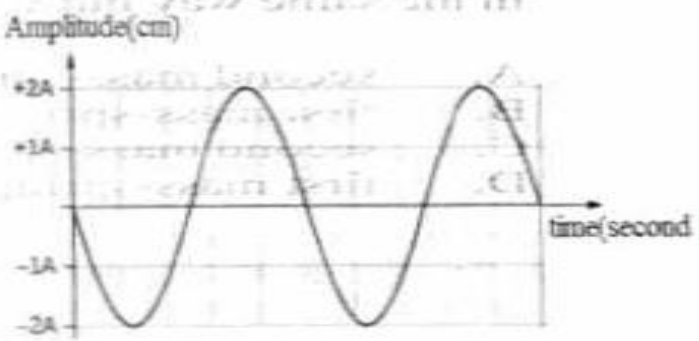
A.



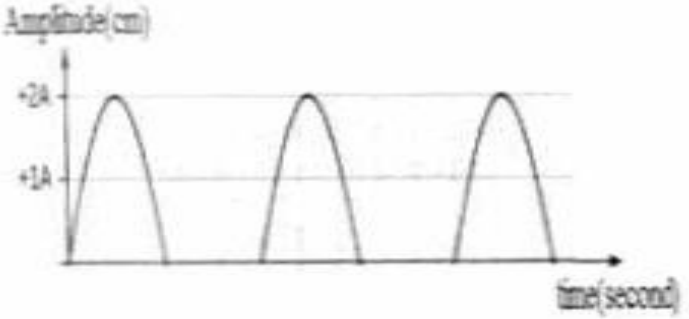
B.



C.



D.



Reflections of waves

- When a travelling wave reaches a sudden change in medium it will be at least partially reflected.
- In some circumstances this reflection can be total.
- If the end of the string is fixed so that it cannot oscillate at all, then the sum of the incident and reflected wave must be always zero and so the reflected wave must be in antiphase

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Reflections of waves

- What happens when a wave is reflected from a hard surface?

When a wave is reflected from a hard surface, it undergoes a phase change of 180 degrees. This means that the crest of the reflected wave corresponds to the trough of the incident wave and vice versa.

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Standing waves on strings

- a standing wave is created when two waves of the same frequency and amplitude traveling in opposite directions interfere with each other.
- The resulting wave appears to be standing still, with nodes (points of zero displacement) and antinodes (points of maximum displacement) that remain fixed in place.
- Nodes:-the points where two superimposed waves are in antiphase and there is no net oscillation
- Antinodes:-the points where two superimposed waves are in phase and the net oscillations are largest

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Standing waves on strings

- The location of nodes and antinodes are very important.
- Nodes occur when the distance along the string is equal to $n\lambda / 2$
- Antinodes occur when the distance along the string is equal to $(n+½) \lambda/2$.

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The mathematics of standing waves

- Two travelling waves moving in opposite directions can be represented by the equations $y_1 = y_0 \sin(kx - \omega t)$

$$y_2 = y_0 \sin(kx + \omega t)$$

$$\sin(A+B) = \sin A \cdot \cos B + \cos A \cdot \sin B$$
$$\sin(A-B) = \sin A \cdot \cos B - \cos A \cdot \sin B$$
$$\cos(A+B) = \cos A \cdot \cos B - \sin A \cdot \sin B$$
$$\cos(A-B) = \cos A \cdot \cos B + \sin A \cdot \sin B$$

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Wavelength and the length of string

- When a string is fixed at both ends and made to vibrate, standing waves can be formed.
- The length of the string determines the wavelength of the standing wave that can be formed. Specifically, the wavelength of the standing wave is related to the length of the string by the following equation:

wavelength = 2 x string length / n

where n is the number of antinodes in the standing wave.

Thus, if the string length is doubled, the wavelength of the standing wave will also double, and vice versa.

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Wavelength and the length of string

A standing wave happens if the distance for a wave to travel in a complete circuit, from one point to one end, back to the other end and finally back to where it started, is a whole number of wavelengths.

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Wavelength and the length of string

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Exercise

19. What fundamental frequency can a string vibrate at if it is 30cm long and the velocity of travelling waves along the string is 120m/s? (UEE 2008/2016)

    (A) 400Hz (B) 600Hz (C) 800Hz (D) 200Hz

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Exercise

27. The two end fixed string of length 0.5m has a mass per unit length 2g/m. if the tension in the string is 80N, what is the second harmonic frequency? (UEE 2010/2018)

(A) 100√2Hz (B) 200Hz (C) 600Hz (D) 400Hz

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Exercise

Which of the following is a characteristic of a standing wave on a string?

A. The wave propagates along the string in one direction

B. The amplitude of the wave increases as it travels along the string

C. The wave is created by the superposition of two waves traveling in opposite directions

D. The wave speed is independent of the tension and mass of the string

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Exercise

What is the relationship between the frequency of a standing wave on a string and the length of the string?

A. The frequency is directly proportional to the length

B. The frequency is inversely proportional to the length

C. The frequency is independent of the length

D. The frequency is proportional to the square of the length

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Standing waves in organ pipes

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Exercise

What is a standing wave in an organ pipe?

A) A wave that travels through the pipe and reflects back

B) A wave that remains stationary within the pipe

C) A wave that oscillates between two points within the pipe

D) A wave that is generated by the vibration of the pipe

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Exercise

Which of the following factors determines the fundamental frequency of an organ pipe?

A) The length of the pipe

B) The diameter of the pipe

C) The material of the pipe

D) The temperature of the air inside the pip

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Exercise

In an open organ pipe, where are the antinodes located?

A) At the closed end of the pipe

B) At the open end of the pipe

C) At the halfway point between the two ends of the pipe

D) There are no antinodes in an open organ pipe

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Exercise

1. A 50cm pipe is open at one end and closed at the other end. When air is blow at 150Hz. What is the velocity of the sound along the pipe? **(UEE 2011/2019)**

   (A) 150m/s (B) 300m/s (C) 330m/s (D) 100m/s

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Exercise

1. Calculate the fundamental frequency of an organ pipe that is 1 meter long and open at both ends. (Assume the speed of sound is 343 m/s)

(A) 150Hz (B) 300Hz (C) 330m/s (D) 100m/s

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Exercise

1. What is the wavelength of the third harmonic of an open pipe that is 40 cm long? V= 343m/s

   (A) 71.1cm (B) 59.4cm (C) 53.3cm (D) 85.75cm

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THANK YOU

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Sound loudness and intensity

- intensity the energy received by each square meter of a surface per second

$$I = \frac{P}{A}$$

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Hearing and the decibel

- Many sound intensity measurements are made relative to the threshold of hearing intensity $Io = 1 \times 10^{-12} W/m^2$
- One common way to measure the loudness of sound is to use the decibel scale.

The intensity of a sound in dB is given by:

$$I\,(dB) = 10\log_{10}\left(\frac{I}{Io}\right)$$

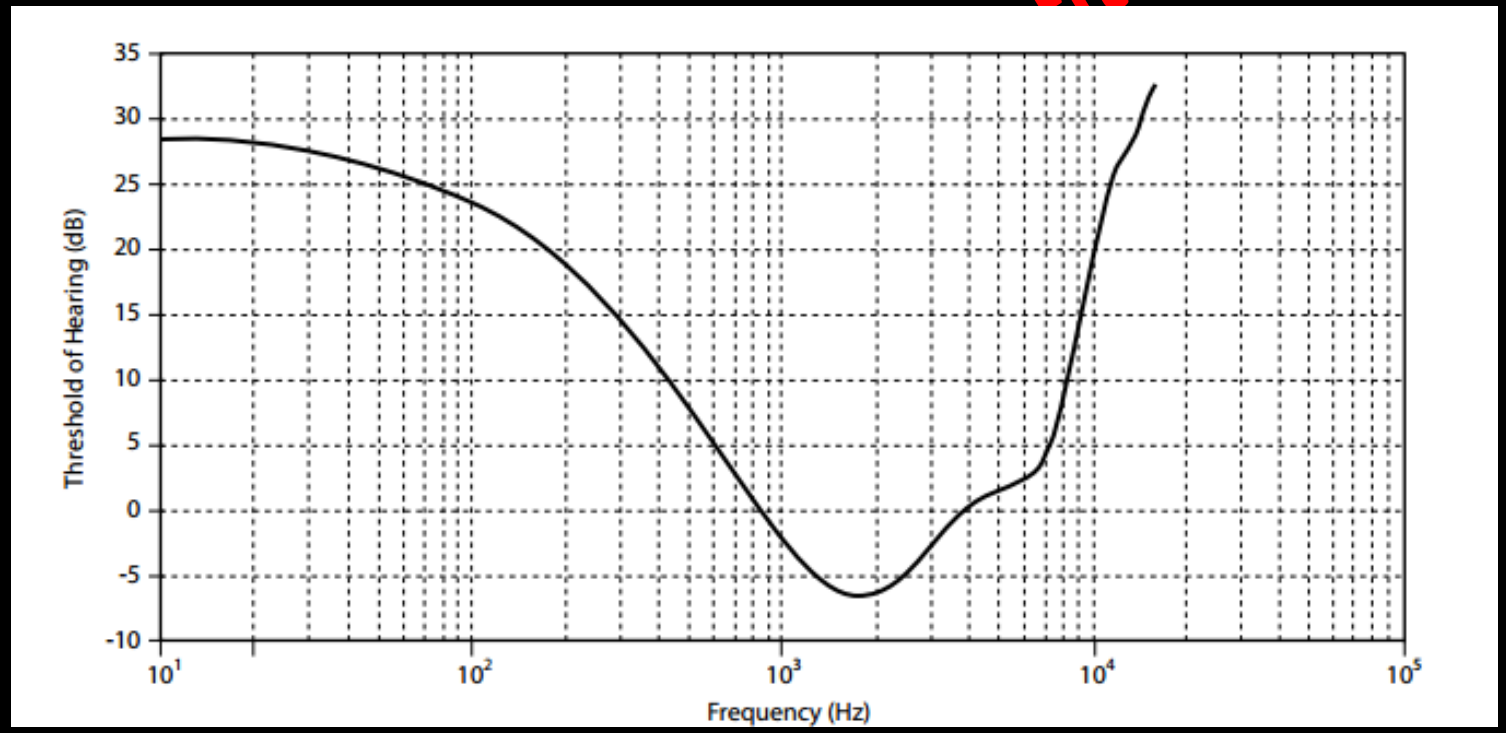
Exercise

- 7. A point source broadcasts sound into a uniform medium. If the distance from the source is tripled, how does the intensity change? UEE 2004/2012
- (A) It remains unchanged
- (B) It becomes three times larger
- (C) It becomes one-third as large
- (D) It becomes one-ninth as large

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hearing curve

- The human ear is incredibly sensitive to sound.
- The threshold of hearing varies with frequency.
- The ear is most sensitive to sounds between 2000 and 5000 Hz.



hearing curve

- The upper limit of human hearing is also rather subjective.
- A common upper limit is the threshold of pain.
- younger people are more tolerant of loud sounds.
- A common value for this limit is 130 dB.

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The speed of sound

- the speed of sound depends on the medium the sound is travelling through.
- IF THE MEDIUM IS SOLID

$$v = \sqrt{\frac{Y}{\rho}}$$ .....Y= Young's modulus of the solid

ρ = density of the solid in kg/m

The speed of sound

- IF THE MEDIUM IS WATER

$v = \sqrt{\frac{\beta}{\rho}}$ ..... B= bulk modulus of the fluid

ρ = density of the fluid in kg/m³

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The Doppler effect

- Is a change in the observed frequency of a wave occurring when the source and observer are in motion relative to each other, with the frequency increasing when the source and observer approach each other and decreasing when they move apart

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$$f_L = f_S \frac{V + VL}{V - Vs}$$

There are three situations to consider:

1. Sound source is stationary relative to the listener

$$f_L = f_S$$

2. Sound source is moving toward the listener (or vice-versa)

$$f_L = f_S \frac{V}{V - V_S}$$

3. Sound source is moving away from the listener (or vice-versa)

$$f_L = f_S \frac{V}{V - V_S}$$

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Exercise

1. What is the Doppler effect?
   a. The change in pitch of a sound due to its speed
   b. The change in pitch of a sound due to its frequency
   c. The change in pitch of a sound due to the motion of the source or observer
   d. The change in pitch of a sound due to interference

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Exercise

1. As a source of sound moves toward an observer, the observed frequency of the sound will:
2. a. Increase
3. b. Decrease
4. c. Stay the same
5. d. It depends on the direction of the sound wave.

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Exercise

1. Which of the following types of waves can exhibit the Doppler effect?
2. a. Sound waves only
3. b. Light waves only
4. c. Both sound and light waves
5. d. Neither sound nor light waves

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Exercise

Which of the following is correct about Doppler Effect? (UEE 2012-13/2021)

(A) When a sound source moves away from stationary observer, the frequency detected by the observer increases, whereas the wave length decrease

(B) Doppler effect is the change in the frequency of a wave due to relative motion between the wave source and an observer

(C) It is the change in the velocity of a wave due to relative motion between the source of the wave and an observer

(D) When a source of sound wave moves towards stationary observer, the wavelength of the wave increases while its frequency decrease

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Exercise

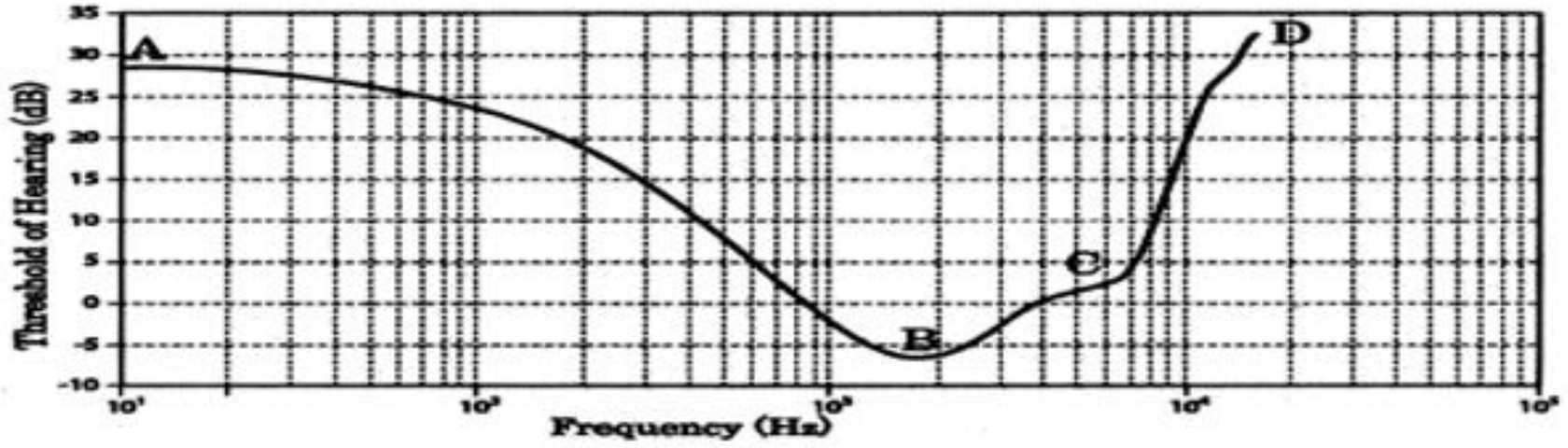
28. Which one of the following is NOT the use of Doppler Effect? (UEE 2010/2018)

(A) Energy transmission
(B) Blood flow measurement
(C) radar
(D) astronomy

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Exercise

20. The hearing curve, shown below, indicates the variation of the threshold of hearing with frequency. The ear is most sensitive at the point indicated by (UEE 2008/2016)



(A) A (B) C (C) B (D) D