Oscillation and waves – Sound

1993 A/L - 6

1) Velocity of sound (v) in a gas given by the equation $V = \sqrt{\frac{\gamma p}{\rho}}$. Identify the symbols and show that the equation is dimensionally correct.

Use the above equation to derive an expression for velocity of sound in an ideal gas of molecular weight M, at a temperature T.

Two men A and B 209 m apart, both see a lightning flash along the extension of line joining them. Man A hears the thunder 2 s after the flash while B hears it 2.6 s after the flash.

(i) Find the velocity of sound in air

(ii) Find the temperature of air (Assume that the temperature of air is constant)

(iii) If the value of γ for air is 1.403, calculate the average molecular weight of air, You may assume air as an ideal gas.

(iv) If the atmosphere contains certain amount of water vapour, would you expect the same value for the velocity of sound? Explain your answer.

(universal gas constant $R = 8.3\ J\ K^{-1}\ mol^{-1}$, velocity of sound in air at $0°C = 330\ ms^{-1}$)

1994 A/L - 6

2) Distinguish clearly between a progressive wave and a stationary wave set up along a string considering the following

(A) the energy transmitted along the string

(B) the amplitude of the points on the string

(C) the frequency of the points on the string

Give the essential steps of a laboratory method in determining the speed of sound in air.

A variable frequency source emitting a pure note is placed just above the open end of a uniform vertical tube 0.5 m long. The lower end of the tube is closed. If the frequency of the note emitted by the source is gradually raised form 150 Hz to 900 Hz, at what frequencies will resonance occur? The speed of sound in air is $330\ ms^{-1}$, at the room temperature. 27^0C (You can neglect the end correction of tube.)

The air temperature is now changed. It is found that as the frequency of the note emitted by the source is increased, resonance first occurs at a frequency of 168 Hz. If the experiment is repeated with the lower end of the tube open the corresponding situation occurs at a frequency of 335 Hz. Calculate,

(i) the end correction of the tube

(ii) the speed of sound in air at the new temperature

(iii) the value of the new temperature.

1995 A/L - 6

3) Once the end correction is neglected, the resonant frequencies, f of a uniform pipe of length L closed at one end can be written as $f = \frac{nV}{4L}$

Where V is the velocity of sound in air. and n can take values 1, 3, 5, 7 and so on. Similarly if the pipe is open at both ends, the resonant frequencies, f are given by

$f = \frac{n'V}{4L}$ Where n can take values 1, 2, 3, 4 and so on

(i) In both cases, show that the above formulae are true for the respective fundamental notes and the first overtones

(ii) A uniform pipe closed at one end resonates at the frequency of 210 Hz. When both ends of the pipe are open it resonates at 840 Hz.

(a) Neglecting one corrections, calculate the minimum pipe length which satisfies the above conditions

(b) Under this situation for which tones do 210 Hz. And 840 Hz, correspond to?

1996 A/L - 6

4) Write down an expression for the velocity of sound in a material in terms of the young's modulus E and the density d of the material.

A sonometer wire is stretched over two bridges separated by 1 m by hanging a weight W and it is found that the resulting strain in the wire is 0.25%. If the wire is struck so as to form 2 loops between the two bridges. it makes 4 beats per second with a tuning fork vibrating at a frequency 256 Hz. It is also found that when the weight W is gradually immersed in water the beat frequency is diminished.

(i) What is the frequency of the transverse waves produced in the wire?

(ii) Calculate the speed of sound in the material of the wire.

1997 A/L – 2(b)

5) Explain what is meant by the Doppler effect. How would you demonstrate this effect using a ripple tank. Give an application of the Doppler effect.

A boat is traveling at 18 km per hour towards a small cliff, sounding its horn at 335 Hz. The speed of sound in air is 340 ms^{-1}

(i) Find the frequency of the horn as heard by a boy on the cliff.

(ii) An echo of the horn is produced by the cliff. Find the frequency of the echo as heard by a man in the boat.

(iii) If the man hears the sound emitted by the horn and the echo together, find the number of beats per second heard by him.

(iv) If the boat now turns back and moves away from the cliff with the same speed, what is the frequency of the echo as heard by the man?

1998 A/L – 2(b)

6) Read the following passage carefully, and answer the questions given below.

Ripple tank is an apparatus used to demonstrate the wave propagation, and to study the wave properties such as interference and diffraction. In a ripple tank, waves with a circular wave front can be produced by dipping a vibrating pointer in the water. However, by replacing the point vibrator with a thin vibrating plate, waves with a straight wave front can be generated. In this case the motion of the wave is such that the wave fronts remain parallel to the plate.

The speed of waves on a water surface depends on the depth of water. To study the effect of depth on the speed, one can make part of the tank shallow by placing a thick glass plate at the bottom of the ripple tank, and it divides the tank into two regions. The two regions can be considered as two different media for wave propagation. If h is the depth of water, the speed of water waves is given by $v = \sqrt{gh}$, where g is the acceleration due to gravity. This relation applies only when the wavelength of the wave is greater than the depth of water. and the amplitude of the wave is small compared with the depth as in the case of the ripple tank. When the depth is very small, surface tension effects are significant.

Water waves obey laws of refraction and reflection similar to light waves. These phenomena may also be studied using the ripple tank. Suppose straight wave fronts propagating in the deeper region (region -1) meets the boundary between the two regions in such a way that the wave crests are parallel to the boundary. The wave will propagate into the shallow region (region – 2) without any change in the direction but with a decrease in wavelength, However, if the straight wave fronts meet the boundary making an angle other than a right angle, the wave fronts will change the direction of propagation as the enter the shallow region. Using a stroboscope, adjusted to the relevant frequency, the wave patterns in both regions can be made to appear stationary simultaneously. Hence it can be deduced that the frequency of waves is same in both regions.

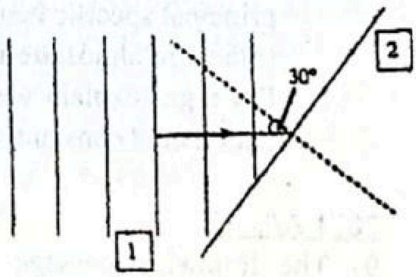
i) Give two phenomena which can be explained only by considering the wave nature.

ii) State the conditions under which the relation shop $v = \sqrt{gh}$ is valid.

iii) What is the purpose of placing a glass plate and produce two regions in the ripple tank to study refraction?

iv) (a) If the depths of the two regions of the ripple tank are 4 cm and 1 cm respectively What is the ratio of the wavelengths. (λ_1 / λ_2) of a wave in the regions 1 and 2

(b) The parallel lines drawn in the region 1 of the figure shown represent the straight wave fronts of a wave in that region. Copy the figure and draw the subsequent wave fronts in the region 2. Indicate λ_1 and λ_2 on the diagram. If the angle of incidence of the wave is 30^0, find the angle of refraction.



i) Explain why the frequency of the waves in both regions is same.

ii) The difference in radii between the first and the sixth circular crests of periodic waves produced by a vibrating point source was measured to be 20 cm. What is the wavelength of waves?

iii) What is the fundamental difference between the water waves produced in a ripple take and sound waves?

iv) If you wish to study the total internal reflection of water waves, in which region of the ripple tank (1or 2) would you place the source? Explain your answer.

v) Give a suitable labeled diagram showing diffraction of water waves in a ripple tank

1998 A/L - 3

7) Write down an expression which relates the velocity v of a transverse wave, setup on a stretched string with its tension T and mass per unit length m.
If the string is stretched between two horizontal supports. distance d apart. what is the frequency of the fundamental note of vibration. Draw the corresponding standing wave pattern in the string. A heavy rope of length L and mass per unit length m is suspended from a ceiling.
(i) What is the tension in the rope at a height x from its lower end?
(ii) If a transverse wave is initiated at the lower end of the rope, what will be the velocity of the wave at the height x from that end.
(iii) If L = 10 m find velocities of the wave at the lower end and the upper end of the rope.
(iv) Assuming that the average velocity of the wave in the rope is the average of the two velocities calculated in (iii). and if the wave travels with this average velocity, find the time taken for the transverse wave to travel from the lower end to the upper end.
(v) If the lower end of the rope is also fixed draw the standing wave pattern corresponding to the fundamental note of vibration.

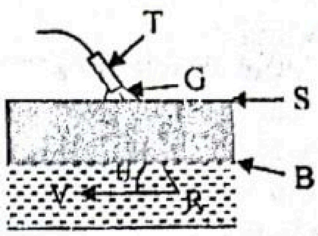
1999 A/L - 2

8) A resonance tube of variable length closed at one end is made to resonate with a tuning fork of frequency 512 Hz. It was observed that the shortest length of the tube at which resonance occurred was 16.6 cm. As the length of the tube was increased resonance occurred for the second time at 50.7 cm. The temperature in the laboratory was observed to be 27^0C
i) Draw the standing wave patterns in the resonance tube for the two situations above
ii) Find the and correction of the tube and the velocity of sound under the experimental conditions
iii) If the density or air at S.T.P. is 1.2 kg m^{-3}. Calculate a value for γ the ratio of principal specific heat capacities of air. Assume that the air behaves as an ideal gas. (Standard atmospheric pressure = 1.0×10^5 N m^{-2})
iv) For a gas explain why the specific heat capacity at constant pressure (C_P) is greater than that at constant volume (C_V)

2001 A/L – 2

9) The following passage gives some properties of ultrasound waves and describes a Doppler technique used medical diagnosis. . Read the passage carefully and answer the question given below.
Doppler method is primarily used to obtain information of moving objects. In medicine this technique is used to investigate the movement of red blood cells.
By definition, ultrasound is sound having frequency greater than 20 kHz. Which is above the audible range 20 Hz – 20 kHz for humans. The frequencies used for medical applications are usually in the range 1 MHz to 15 MHz. Use of ultrasound in medicine has several special advantages. The low intensity (< $0.1 Wm^{-2}$) beams used are not known to produce and damage or undesirable side effects to humans. Unlike X-rays, ultrasound does not ionize atoms or molecules in human cells. Ultrasound is also reflected even by objects of small size.

The figure shows a set up used to measure the blood flow in a blood vessel



T - ultrasound wave transmitting and detecting device
G - coupling gel
S - skin
B - blood vessel
R - a red blood cell which is traveling at a speed v.

T transmits ultrasound waves with frequency f_t and after reflection from the blood cell receives them with a frequency f_r. θ is the angle between the ultrasound beam and the path of the blood cell in medicine $(f_r - f_t)$ is known as Doppler frequency f_d which can be written as.

$$f_d = 2f_t \frac{v\cos\theta}{u};$$ where u is the speed if ultrasound waves in soft tissue

u is fairly constant for human soft tissue and its value is 1500 ms^{-1}. The speed of ultrasound in air is about 300 ms^{-1} and densities of air and soft tissue are also fairly different. There fore air/skin interface reflects about 99% of the incident ultrasound energy. This has to be eliminated when the test is carried out

i) What is normal audible range for humans?
ii) State two major advantages of using ultrasound in medical diagnosis
iii) Is ultrasound a longitudinal or transverse wave?
iv) What is the major difference between sound and ultrasound?
v) Is ultrasound and electromagnetic wave? Give reasons for your answer.
vi) (a) Calculate the wavelength of 15 MHz ultrasound waves in human soft tissue
(b) Give a reason as to why ultrasound is also reflected from small objects
vii) Use the following steps to derive the formula for f_d given in the passage
(a) What is the component of the velocity of the red blood cell R along the direction of device T?
(b) Considering the device as a stationary source and the red blood cell as a moving observer, write down an expression for the frequency (f') detected by the cell in terms of f_t, v, u and θ
(c) Now consider the cell as a moving source emitting signals of frequency f'. Hence write down and expression for f_r in terms of f', v, u and θ
(d) Combing the above the two expressions and obtain

$$f_d = f_r - f_t = 2f_t = \frac{v\text{con}\theta}{u - v\cos\theta}$$ (since $v << u$, $u - v\cos\theta \approx u$)

viii) For f_t = 15 MHz, f_d was found out to be 8 kHz. Calculate speed v of the red blood cell. Take θ to be 10^0
ix) Why is it desirable to keep θ as small as possible?
x) What is the purpose or using the coupling gel G?

10) Read the following passage carefully and answer the questions given below.

The source of any sound, including musical notes, is a vibrating object. A sound is characterized by its loudness, its pitch and also by a third property called quality. Quality of sound enables us to distinguish a given type of musical instrument from others. For example, when a note is played separately in a violin and in a flute with the same loudness and pitch, there is a clear difference between the two sounds heard. This is due to the difference in quality of sound of these two instruments. Just as loudness and pitch can be related to measurable physical quantities of the sound wave, so too can be quality. Generally, when a note is played in a musical instrument, overtones are present in addition to the fundamental frequency of the sound. Quality of sound depends on the number of these overtones and their relative amplitudes.

Figure 1 shows a sound pattern of note produced by a violin. It indicates the variation of the total amplitude of the sound produced by this instrument with time. Figure 2 shows the 'Fourier spectrum' of this sound pattern giving the frequency of its fundamental and the overtones, and their relative amplitudes. The Fourier spectrum is generated from the sound pattern using mathematical technique called Fourier Analysis. In contrast to the musical notes, sounds which are normally called noise have nearly continuous Fourier spectra rather than discrete spectra.

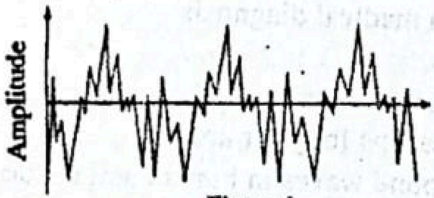


Figure 1

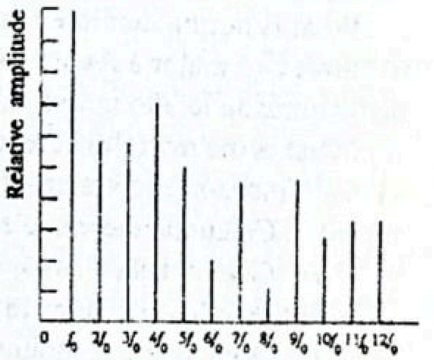


Figure 2

Today we have electronic organs that can reconstruct music produced by any musical instrument available to us. For such reconstructions, first the Fourier spectra of the musical notes must be obtained. After that, it is possible to electronically generate an electric wave pattern for each note by mixing electrical signals having frequencies and their corresponding relative amplitudes present in the Fourier spectrum. These electrical wave patterns can then be converted to sound wave patterns. All these can be done with near perfection using digital techniques.

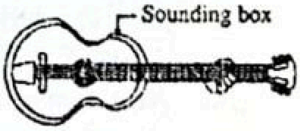


Figure 3

In standard musical instruments, the source is set into vibration by striking, blowing, plucking or bowing. Among the common musical instruments, the drum has a membrane that vibrates when struck. The flute and trumpet make use of vibrating columns of air to produce musical notes. Flute can be considered as a tube with both ends open. When the flute is played the air inside it resonates.

Violin, guitar and piano all have vibrating stretched strings. In guitar, different musical notes are obtained by varying the vibrating length of a string using fingers, and the guitar has several such strings to produce all required notes. In piano, there is a separate string for each note. In general, the mechanical vibrations in thin strings do not produce sounds loud enough to be heard directly. In stringed instruments, therefore, a sounding box is used (figure 3) to amplify the sound. When strings are set into vibration, the sounding box resonates with the same sound pattern producing a much stronger sound. However, in electric guitars, mechanical vibration of a string is converted to an electrical signal which is subsequently amplified electronically.

i) What physical property of the sound wave determines the loudness of a sound?

ii) What physical property of a sound wave is associated with the pitch of the sound?

iii) The fundamental frequency f_0 of the Fourier spectrum of the violin, shown in figure 2, is 400 Hz.

a) What is the frequency of the 3^{rd} overtone produced by the violin?

b) What is the value of $\dfrac{\text{amplitude of the } 5^{th} \text{ overtone}}{\text{Amplitude of the fundamental frequency}}$?

iv) A note produced by a musical instrument has a fundamental frequency at 420 Hz, and the first and second overtones each having an amplitude equal to one half of that of the fundamental. Assuming that no other overtones are present, draw the Fourier spectrum of the note.

v) State the steps that should be taken to electronically generate the sound described in (iv) above.

vi) Electronic guitars have no sounding boxes. Given the reason.

vii) Write down an expression relating the length l, tension T, mass per unit length m and the fundamental frequency f_0 of a vibrating stretched string.

viii) A 0.68 m long guitar string is tuned to play a note of fundamental frequency 330 Hz when unfingured. How far from the end of this string must the finger be placed to play a note of fundamental frequency 440 Hz?

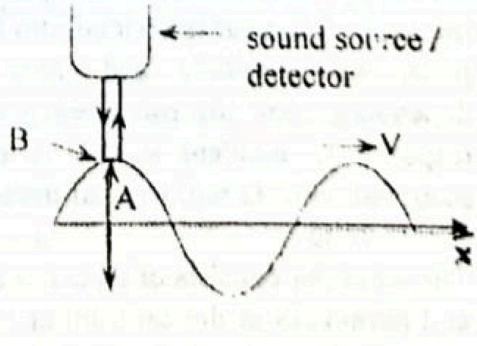
ix) A flute is designed to produce a note of fundamental frequency 262 Hz when played at a temperature of 27^0C, with all the holes closed.

a) If the speed of sound in air at 27^0C is 340 ms^{-1} calculate the approximate length of the flute.

b) If this flute is played, with all holes closed, in a place where environmental temperature is – 30^0C, what will be the fundamental frequency of the sound?

2006 A/L - 2

11) The figure shows ripples moving in x-direction on the surface of a liquid. The liquid at the surface performs simple harmonic motion in a vertical direction. A stationary sound source/detector is placed above the liquid surface to study the vertical motion at a given location of the liquid surface due to the propagation of the wave.



The sound source sends sound signals vertically downwards as shown in the figure, and the reflected signal from the oscillating liquid surface is detected by the detector. The detector is also capable of determining the frequency of the beats produced by the waves emitted by the source and the waves received after being reflected from the liquid surface. The frequency of the sound waves produced by the source is 680 kHz and the speed of sound in air is 340 ms^{-1}.

i) a) At what position shown in the figure (A or B) is the speed of the liquid surface minimum? What is the value of the speed?

b) What is the frequency of the reflected sound waves at the instant when the speed of the liquid surface is minimum?

ii) a) If the speed of sound in air and the frequency of the sound waves emitted by the source are u and f_0 respectively. write down an expression for the frequency f' as observed at liquid surface when the liquid surface is moving away from the sound source at speed v, in terms of v, f_0 and u.

b) For the situation described in (ii) (a) obtain an expression for the frequency f'' measured by the detector in terms of v, f_0 and u.

c) Using your expressions in (ii) (a) and (ii) (b) show that when $v << u$ the beat frequency measured by the detector is $\frac{2f_0 v}{u}$.

d) At what position (A or B) of the liquid surface can the maximum beat frequency be detected? If this frequency is 600 Hz, find the magnitude of the velocity of the liquid surface at this position.

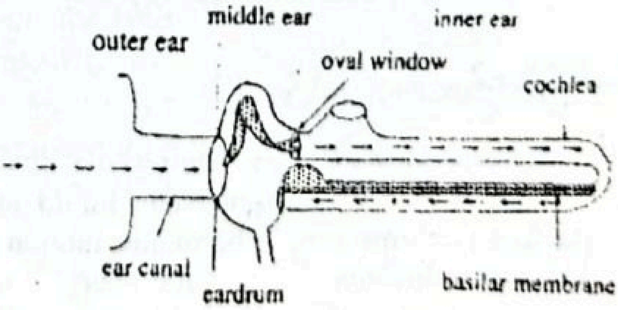
e) Sketch the value of the beat frequency measured by the detector as a function of time for a complete period of oscillation of the liquid surface for the situation $v << u$.

iii) a) If the time interval between two successive zero values of the beat frequency is 0.05 s, what is the frequency of the ripples?

b) For small wavelengths the speed V of the ripples on a liquid is given by $V = \sqrt{\frac{2\pi T}{\lambda \rho}}$ where T, λ and ρ are the surface tension of the liquid, wavelength of the ripples and the density of the liquid respectively. If $\lambda = 12$ mm and $\rho = 13\,600$ kg m^{-3}, obtain a value for T. (Take $\pi = 3$)

2008 A/L - 2

12) The ear converts the energy of sound waves into electrical energy. Therefore, the ear can be considered as a pressure transducer. The ear is divided into three parts, outer, middle and inner ear depending upon the role they play in response to incident sound. A cross sectional view (simplified) of the ear is shown in figure 1.



The outer ear consists of an external auditory canal. It is open to atmosphere at one end and terminates at the eardrum at the other end. The auditory canal is 2.5 cm long, and the area of eardrum is 80 mm^2. The auditory canal is equivalent to an organ pipe closed at one end. The ear is the most sensitive to sounds of frequencies around 3000 Hz. The minimum intensity of sound which the ear can detect is 10^{-12} Wm^{-2}. Sound intensity level of 160 dB may rupture the eardrum. The intensity (I) of a sound wave, expressed in terms of the its pressure amplitude (P_m), is given by

$I = \dfrac{P_m^2}{2\upsilon\rho}$ where υ is the speed of sound in air and ρ is the density of air.

The important parts of middle ear are three small linked bones, called the hammer, the anvil and the stirrup, because of their respective shapes. These three bones function as a lever system. Its one arm, hammer, is coupled to the eardrum. Its other arm, stirrup, is coupled to the oval window (area 4 mm^2) of the inner ear. A schematic representation of the lever and piston action of the middle is shown in figure 2.

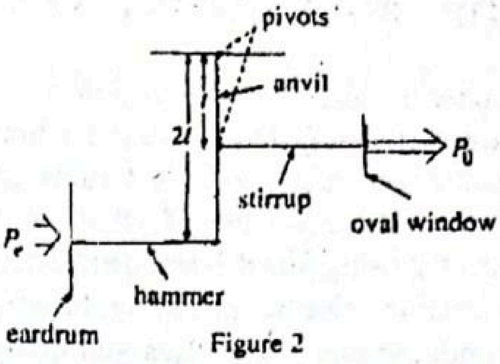


Figure 2

The inner ear consists of a small spiral shaped tube called cochlea, filled with a fluid. In the figure 1, the cochlea is shown in 'straightened' form.

The cochlea is divided lengthwise into three canals which are separated from each other by membranes. As the pressure wave passes along the first canal it causes transverse displacements of the basilar membrane which separates the second canal from the third canal. It has been found that the basilar membrane is made of thousands of parallel fibers which run across it. The fibers of the basilar membrane towards the base of the cochlea are short and stiff. They vibrate very rapidly and are sensitive to high notes. In contrast, the fibers of basilar membrane towards the apex of the cochlea are long and more flexible. Therefore they vibrate more slowly and are sensitive to low notes. This is how the inner ear resolves frequencies.

(a) What is the reason for treating the ear as a pressure transducer?

(b) i) Around what sound frequency does the ear most sensitive?

ii) Considering the auditory canal to be an organ pipe closed at one end, calculate its fundamental resonant frequency (speed of sound in air is 330 ms^{-1}). Hence justify your answer given in (b) (i).

iii) When the auditory canal resonates, is the pressure variation of the standing wave at the eardrum maximum or minimum? Give the reason for your answer.

(c) i) Consider sound waves with intensity 10^{-12} Wm^{-2}. Determine the corresponding pressure amplitude of the sound waves. (density of air is 1.25 kg m^{-3} ; Take $\sqrt{33} = 5.5$)

ii) Using the answer obtained in (c) (i) above, determine the force (F_e) acting on the eardrum.

iii) Considering the lever action of the three bones, determine the force (F_o) generated on the oval window. (Use the data given fig.2 for this calculation.)

iv) Hence calculate the pressure amplitude (P_o) on the oval window. Determine the factory by which the pressure is amplified.

(d) i) How much sound intensity level might rupture the eardrum?

ii) What intensity of sound does this correspond to?

'Higher frequencies stimulate the base region while lower frequencies stimulate the apex region of the basilar membrane.' Considering the fibers in the basilar membrane as uniform strings under tension justify the above statement.

13) Read the following passage and answer the questions below.

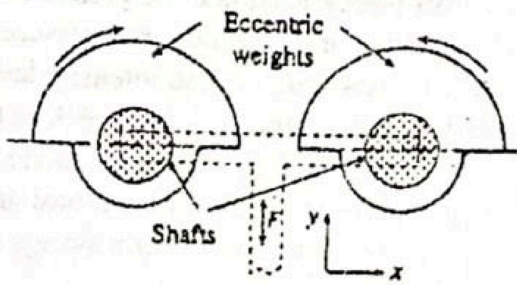
Activities used in construction such as blasting generate ground vibration. If its amplitudes are sufficiently large, ground vibration has the capability of damaging structures such as buildings, monuments and ruins cause cosmetic damage such as cracking of plaster, of disrupt the operation of vibration sensitive equipment such as electron microscopes. Pile driving using pile drivers, demolition activity and blasting are some of the primary sources of vibration. Traffic including heavy trucks travelling on a highways which are in good condition rarely generates vibration amplitudes high enough to cause structural or cosmetic damage. However, there have been cases in which heavy trucks travelling over patholes or other discontinues on the road have caused vibrations high enough to result in complaints from nearly residents., In describing vibrations in the ground and in structures, the motion of a particle, (i. e. a point in or on the ground or structure) is used. The concept of particle displacement, velocity and acceleration are used to describe how the ground or structure respond to excitation. Although displacement is generally, easier to understand than velocity or acceleration, it is rarely used to describe ground and structure home, vibration because most trandnsducers used to measure, vibration directly measure velocity of acceleration, not displacement. Accordingly vibratory motion is commonly described by identifying the Peak Particle Velocity (PPV) or Peak Particle Acceleration (PPA). PPV is generally accepted as the most appropriate descriptor for evaluating the potential for building damage. To determine human response, however, an average of vibration amplitudes is more appropriate because it takes time for the human body to respond to the (excitation the human body respond to an average of vibration amplitudes, not a peak amplitude). However as the average particle velocity over time is zero, the root – mean – square (r. m. s) of the velocity amplitude is typically used to assess human response. Displacement is generally measured in millimeters (mm). Velocity is measure in mm s^{-1}.'

One of the methods to assess the potential to damage structures by vibration is to estimate or predict the PPV from various sources at various distances. One such vibratory source is a vibratory pile driver. Pile driving has potential to damage surface and buried structures even at greater distances. Vibratory pile driver is a machine that installs piling in to the ground by applying an alternating force. This force is generally generated by a pair of identical eccentric weights rotating about shafts. The figure shows the basic setup for the rotating eccentric weights used in modern vibratory pile equipment. Each rotating weights produces a force acting in a single plane and directed toward the axis of the shaft. However, when a pair of identical eccentric weight are used the resultant force F will act along ±y direction.

Vibration amplitudes produced by vibrating pile drivers can be estimated by the following equation.

$$PPV = PPV_{Ref}\left(\frac{10}{D}\right)\left(\frac{E_{Equip}}{E_{Ref}}\right)^{\frac{1}{2}}$$

where PPV_{Ref} represents PPV value for a reference pile driver at 10m from the driver.



D = distance from pile driver to the structure in m.

E_{Equip} = Rated energy of the pile driver.

E_{Ref} = Rated energy of a reference pile driver.

To assess the damage potential from ground vibration produced by a vibratory pile driver, the criteria given in following table can be used

Maximum PPV (mms^{-1})	Structures and condition
2	Extremely fragile historic building, ruins, ancient, monuments
2.5	Fragile buildings
6.5	Historic and some old buildings
7.5	Old residential structures
12.5	New residential structures. Modern industrial buildings

a) Write down **three** sources of vibrations which can cause damage to historic monuments.

b) Write down a physical parameter associated with vibrations which causes damage to structures.

c) Write down **three** structures most vulnerable to ground vibrations.

d) State a reason why heavy trucks travelling over potholes can cause more damage to structures than heavy trucks travelling in highways which are in good condition

e) State the reason for using the velocity to describe ground vibrations instead of displacement.

f) Draw a rough sketch of a velocity (υ) – time (t) curve for a particle executing simple harmonic motion and mark its PPV value.

g) Give a reason for using the average value of the vibration amplitude to describe the human response to vibrations.

h) i) Direction of the resultant force F created by a rotating pair of identical eccentric weights on the shafts is along the ±y direction. Give the reasons for this.

ii) Draw a rough sketch to show how F varies with time (t).

i) A vibratory pile driver (E_{Equip} = 112.5 kN) will be operated at 30m from a new office complex and 30m from and ancient monument known to be very fragile. Assess the potential for damage.

i) to the office complex

ii) to the ancient monuments

Take PPV_{Ref} = 12.5 mm s^{-1} for a reference pile driver at 10 m. (E_{Ref} = 50 kN)

j) The pile driver mentioned in i) above has to be used in a construction of a new building close to an ancient and fragile monument at Polonnaruwa. Calculate the minimum separation that has to be maintained between the monument and the new building.

14) Read the following passage and answer the questions given below

The Doppler effect for sound waves depends on three velocities namely the velocities of sound the source, and the observer with respect to the air. Normally air is considered to be stationary relative to the ground and therefore these velocities can be measured relative to the ground.

However, this is not situation, with regard to light waves. Light as well as other electromagnetic waves require no medium, and they are capable of travelling even through a vacuum, and they are capable of travelling even through a vacuum. The Doppler effect for light waves depends on two velocities, namely the velocity of light (c) and the relative (υ) between the source and the observer as measured from the reference from of either source or the observer.

If a certain light source is at rest relative to us, we would detect light from it with the same frequency (f_0) as that of the source, and it is known as the proper frequency. If it is moving away from us with a speed υ ($\upsilon << c$) . then the light we detect has a frequency f that is shifted from f_0 due to the Doppler effect and f is given by the following formula.

$f = f_0(1-\beta)$ when $\beta = \frac{\upsilon}{c}$

However, measurements involving light are usually made in wavelengths rather than frequencies and the above formula can be rewritten in terms of wavelengths in the following form.

$\upsilon = \frac{\Delta\lambda}{\lambda_0}c$ where $\Delta\lambda = \lambda - \lambda_0$

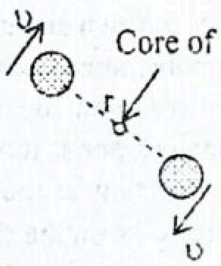


Figure 1

The quantity $\Delta\lambda$ is called the Doppler shift.

If the light is moving away from us, λ longer than λ_0. $\Delta\lambda$ is. positive and he Doppler shift is called a red shift. If the light source is moving toward as then λ is shorter than λ_0. $\Delta\lambda$ is negative and the Doppler shift is called a blue shift.

Using astromical observations of stars, galaxies and other sources of light scientists can determine how fast the sources are moving, either directly away from us or directly towards us by measuring the Doppler shift of the light reaches us.

Two regions of interstellar gas orbiting the core of a galaxy known as M87 at a radius r = 100 light years is shown in figure (1). One region is moving towards us with a speed υ and the other region is moving away from us with the same speed. Figure (2) shows the variation of intensity (I) with wavelength (λ) of light reaching us from those two regions.

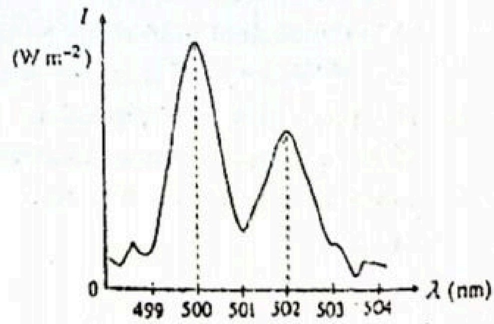


Figure 2

The gas is under the influence of the gravitational force due to the mass. M of the core of the galaxy. This mass of the core is about two billion times the mass of our sun. strongly suggesting that a super massive black hole occupies the core.

a) i) Doppler effect for sound waves depends on three velocities. Name them.

ii) These velocities are normally measured relative to the ground. What is the reason for this ?

b) Why does the Doppler effect for light depends only on two velocities ?

c) Starting from $f = f_0 (1 - \beta)$, derive the relationship $\upsilon = \frac{\Delta\lambda}{\lambda_0} c$

{Hint : When $\beta << 1$, $\frac{1}{1-\beta} = 1 + \beta$ }

d) i) From figure (2) determine the values of two wavelengths at which the intensities are peaked

ii) Which peak corresponds to the gas moving towards us ?

iii) If the gas were not moving relative to the core, what is the wavelength λ_0 (proper wavelength) of the light that would be detected by us ?

iv) What is the Doppler shift ($\Delta\lambda$) of the light from the gas moving away from us ?

v) Hence determine the speed υ of the gas. Round off your answer to the nearest integer. ($c = 3.0 \times 10^8$ ms^{-1})

vi) Is $\beta << 1$? Justify your answer.

e) i) Determine the mass M of the core of the galaxy ($G = 6.0 \times 10^{-11}$ Nm^2 kg^{-2})

ii) What is believed to be occupying the core of the galaxy ?

2014 A/L - 6

15)a) Draw in four separate diagrams the standing wave patterns of fundamental mode and first the overtones produced by a tube of length L open at both ends. Mark nodes as N and antinodes as A in the diagram corresponding to the fundamental mode. Obtain expressions for frequencies f of these waves in terms of L and the speed of sound v, inside the tube. Neglect end corrections.

b) Figure 1(a) shows a standard 6 hole-flute. According to a simple model, this flute can be considered equivalent to a set of tubes open at both ends. Figure 1(b) shows the corresponding effective lengths of open tubes equivalent to the flute. When all the holes of the flute are opened it is equivalent to an open tube of length L_0 as shown in figure (2). When the first hole of the flute is closed the equivalent length of the tube becomes L_1, and when the first 2 holes are closed at the same time the equivalent length becomes L_2, and so on [see figure (2)] L_6 is the equivalent length when all 6 holes are closed. These effective lengths are generally larger than the actual lengths of the flute due to the effects of ends and holes.

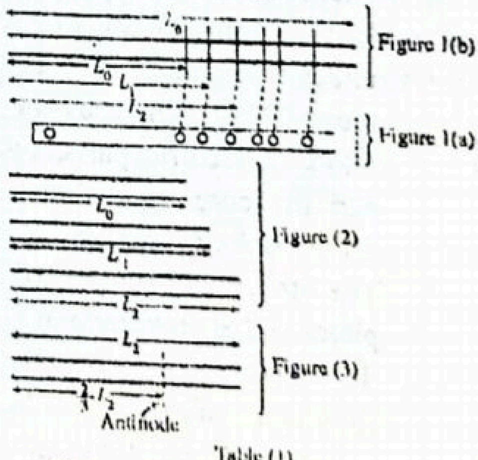


Table (1)

Note	Closed holes	⊗	Fundamental frequency Hz
n_1	⊗ ⊗ ⊗ ⊗⊗	⊗	262.0
n_2	⊗ ⊗ O OO	O	392.0

Table (1) shows how the holes are closed with fingers to obtain two notes, n_1, and n_2 of the flute and their corresponding fundamental frequencies. The speed of sound in the tube is 340 ms^{-1}. Calculate the effective lengths L_6 and L_2.

c) Certain flutes have a few small holes in addition to the standard holes. Such a small hole, when open, will produce an antinode at the location of that hole in the flute. Having such a small hole in the flute will not alter the effective length of the equivalent open tube, but produces an antinode at an appropriate location in the equivalent tube thereby modifying the wave pattern accordingly and produces standing wave. If such an open small hole on the flute produces an antinode at the centre of the equivalent open tube of length L_6 when all other holes are closed, draw the first two new standing wave patterns produced in the tube and obtain expressions for their frequencies f in terms of v and L_6.

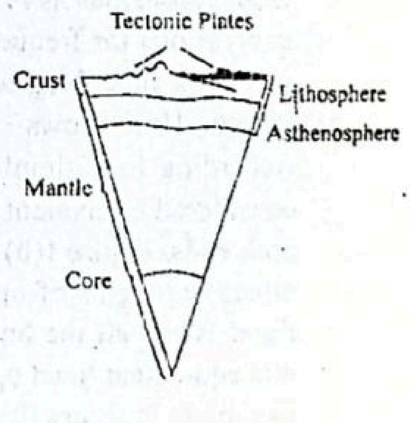
d) i) Write down the frequencies of first four standing wave patterns in part (c) in terms of v and L_6.

ii) Assuming that the length L_6 is equal to the length L of the open tube mentioned in (a) above, compare the frequencies that you obtain in (d)(i) with the frequencies obtained in part (a), and thereby comment on the effect of having a small hole as mentioned in part (c).

e) An antinode is produced at a distance of $\frac{2}{3}L_2$ in the equivalent open tube due to an open small hole located at the left of the first standard hole bf the flute as shown in figure (3). Draw the wave pattern of the first standing wave in the equivalent open tube (corresponding to the lowest frequency) and calculate its frequency, when the flute is played with the small hole opened.

2015 A/L - 6

16) Read the following passage and answer the question.



Earthquakes are one of the powerful natural phenomena on Earth. The internal structure of the Earth is one of the important parameters needed to understand the major seismic activities around the globe. The earth may be considered to have three major concentric parts, namely the crust, the mantle and the core. [see figure (1)]. The lithosphere and asthenosphere are the two outer layers of the Earth. The lithosphere consists of 10 major rigid lithospheric plates called tectonic plates which are considered to be floating on the asthenosphere.

Heat is transferred towards asthenosphere due to the high temperature in the core. The convection current thus produced in the ashtenosphere cause the movements of tectonic plates. When two tectonic plates move with respect to each other, friction sometimes causes two plates to get stuck. When this happens elastic strain energy builds up, until eventually the plates give way creating an earthquake. This stored energy is released creating energetic waves called seismic waves. These seismic waves travel in all directions from the point where the energy is released, and this point is known as the focus of the earthquake. The corresponding point on the Earth's surface, directly above the focus, is called epicenter of the earthquake.

The Earth's crust supports propagation of travelling waves. The waves travel through the crust are called body waves and those travel on the surface are called surface waves. The body waves consist of P (primary) waves and S (Secondary) waves. P waves are longitudinal whereas the S waves are transvers. Since any material, solid or fluid, can be subjected to compression. the P waves can travel through any king of material.

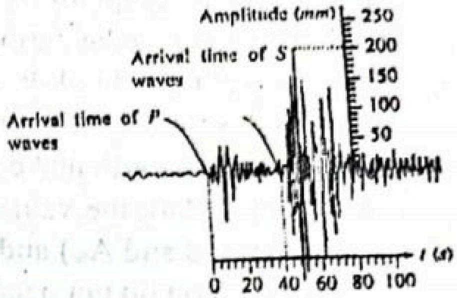


Figure (2)

However. S waves which depend upon shear force, do not exist in a fluid. The absence of S waves at large distances from an earthquake was the first indication that the Earth has a liquid region also. The P waves from and earthquake arrive at a given location before the S waves and surface waves.

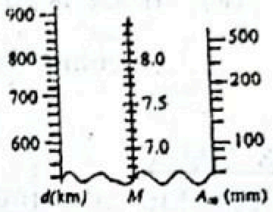


Figure (3)

There is a large number of seismic data recoding stations throughout the world. In order to find the distance d from such a station to the epicentre, one needs to measure the difference in arrival times Δt of P and S waves of the station (see figure 2). The distance d is given by $d = \left[\frac{v_P v_S}{v_P - v_S}\right]\Delta t$, where v_P and v_S are speeds of P and S waves respectively. The location of the epicentre and be found using the d values from at least there recording stations. By drawing three circle with radio corresponding to the distance (ad values) measured, and using the common point of intersection of the circles (triangulation), one can find the location of the epicentre.

Richter scale is the most accepted method used to estimate the strength of an earthquake. Distance d of the epicentre from the station and the maximum amplitude A_m of the seismic waves recorded at the station can be used to estimate the Richter scale magnitude M of earthquake using the nomogam shown in figure (3). The magnitude M of an earthquake is related to the related to released energy E (in joules) by the equation. $\log_{10}E = 4.4 + 1.5\,M$.

(a) What the three major parts of interior of the earth?

(b) Explain, why the tectonic plates are in continuous motion?

(c) What is the relationship between focus and epicentre of an earthquake?

(d) Even though P waves can travel through any part of the Earths. S waves can only travel in the solid parts of the Earth. Explain why?

(e) Draw two separate diagrams for the propagation of P and S waves indicating the direction of propagation and the direction of vibration of particles in the medium by arrows. Label them clearly.

(f) What was the first experimental observation which indicates the existence of a liquid region in the internal structure of the Earth?

(g) Using an appropriate diagram, illustrate the triangulation method used in seismology. Clearly mark the location of the epicentre as point O and S_1, S_2 and S_3 as the location of the corresponding stations in your diagram.

(h) If the graph in figure (2) is a seismogram obtained by a certain station with regard to the recent earthquake in Nepal, find the value of Δt in seconds, and calculate the value of d in kilometers for this station. Take $v_P = 5 \text{ km s}^{-1}$ and $v_S = 4 \text{ km s}^{-1}$

(i) Using the monogram in figure (3) above, estimate the Richter scale magnitude M of the earthquake mentioned in (h) above.

Hint: Mark the values of dA_m on the correct axes. Draw the line connecting the two points (d and A_m) and read the value of the point of intersection of the line with the M axis. You do not need to copy the monogram to your answer script.

(j) Calculate the tota l energy E_N released from the earthquake in Nepal in joules.

(k) If E_S is the total energy released and M = 9.1 for 2004 Sumatra earthquake, calculate the ratio, $\frac{E_S}{E_N}$. Take $10^{1.8} = 63$.

2018 A/L - 6

17) Read the following passage and answer the questions.

Ocean waves are generally caused by wind and gravity. Wind-driven waves in the ocean as well as tsunami waves and tidal waves are some examples of gravity waves. When wind blows across the surface of the ocean, water surface of the ocean is continuously disturbed by the wind. Under this situation the force of gravity tries to restore the equilibrium at the interface between water and air. As a result, ocean waves are created. Ocean waves can be categorized into two main types, namely deep-water waves and shallow-water waves. The terms, shallow-water waves and deep-water waves have nothing to do with the true depth of the ocean. The waves present in the ocean where the depth (h) of the ocean is greater than half the wavelength (λ), of the wave are called deep-water waves. When the depth (h) in the ocean is less than half the wavelength (λ), of the wave they are called shallow-water waves. The wavelengths of deep-water waves are in the range of 1m-1km whereas the wavelengths of shallow-water waves are in the range of 10 km-500 km in the ocean. The value of the speed of propagation v of shallow-water waves in the ocean of depth h is given by $v = \sqrt{gh}$. The average depth of the ocean is about 4 km.

Major tsunamis are caused by large-scale disturbances in the ocean, such as underwater earthquakes, volcanic eruptions occurring on or below the ocean floor, and impact of a large meteorite with ocean. A tsunami is a series of ocean waves with very long wavelengths, ranging from 10 km-500 km in the deep ocean. Even though the shape of a tsunami wave can be approximated to a sinusoidal wave in the deep ocean far away from the shore, it gradually takes a complex form as it reaches the shallow water near the coast as shown in figure 1(a).

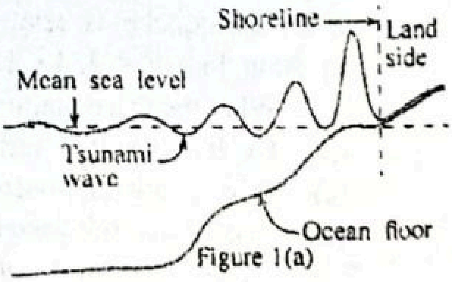


Figure 1(a)

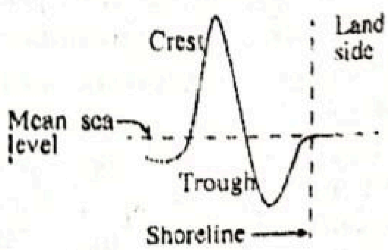


Figure 1(b)

Depending on whether the first part of the tsunami wave which reaches the shore is a crest or a trough, it may appear as a rapidly rising or falling tide. In some situations, the front of the waveform can take a very complex shape near the shoreline as shown in figure 1(b), and it may appear as a rapidly receding of the shoreline followed by an incoming huge wave height grown up to several metres. The rate of transfer of tsunami wave energy through the ocean surface, which depends on both its wave speed and wave height, remains nearly constant. In general, the value of the height H_S of the tsunami wave as it enters shallow water is given by

$H_S = H_d \left(\frac{h_d}{h_s}\right)^{1/4}$, where H_d is wave height in deep water, and h_s and H_d are depths of the shallow and deep water respectively. When tsunami waves propagate across the ocean the wave crests can undergo refraction. It is caused by segments of the wave moving at different speeds as the water depth along the wave crest varies. In addition, due to uneven variation of the ocean floor near the coast and obstacles such as small islands, reefs, etc., on the tsunami path, these waves undergo interference and diffraction. The distribution of tsunami wave heights was estimated by a group of scientists along the coastline of Sri Lanka after the devastating tsunami that had occurred in December 26, 2004. The length of the lines in figure (2) shows the heights of the tsunami wave crests along the coastline. Superposition of waves from the primary source and reflected and diffracted waves from obstacles was responsible for the erratic pattern of the wave heights and the varying damage along the coastline.

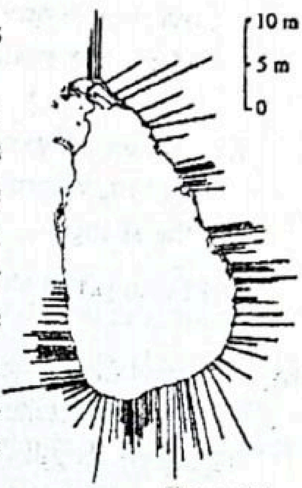


Figure (2)

a) Explain briefly how the ocean waves are created by wind and gravity.
b) What is the difference between deep-water waves and shallow-water waves exist in the ocean?
c) What are the three causes of tsunami wave formation mentioned in the passage?
d) Identify the type of the tsunami waves possible in ocean (deep-water waves or shallow-water waves), and estimate the speed of tsunami waves in ms^{-1} in the ocean having an average depth of 4 km.
e) The height of tsunami wave rapidly increases as it approaches shallow water near the coast. Explain qualitatively why this happens.
f) Calculate the height of the tsunami wave in the ocean at a place where the water depth is 6250 m. Take the height of the wave at a water depth of 10 m as 5 m. Considering the wavelength of tsunami.
g) Assuming that a tsunami wave takes the shape shown in figure (1)(b) at the shoreline, explain briefly why the shoreline recedes from the land just before the arrival of the huge mass of water.
h) If the tsunami waveform mentioned in question (g) above can be approximated to part of a sinusoidal wave as shown in figure (3), calculate the time duration in minutes between the instant that the shoreline starts receding into the ocean and the arrival of the water mass at the former shoreline. For the part of sinusoidal wave, take $u = 10$ ms^{-1} and $\lambda = 18$ km.

i) Figure (2) shows some locations where the wave height is very high compared to their adjoining regions having very low wave heights. What phenomenon could be responsible for this? Explain your answer.

j) Briefly explain the reason why the tsunami waves in 2004 reached even the west coast of the island as shown in figure (2).

<u>2019 A/L - 6</u>

18) (a) i) Draw the standing wave patterns of the fundamental mode and the first two overtones produced by a vibrating stretched string, in three separate diagrams. Mark the nodes as 'N' and the antinodes as 'A' in the diagrams. (Neglect end corrections.)

ii) Obtain an expression for the frequency f_n of the n^{th} harmonic in terms of n, T, l, and m, where T is the tension, l is the length, and m is the mass per unit length of the string.

iii) For a given string, state two possible ways of changing the harmonic frequencies.

(b) A harp like musical instrument shown in figure (1) consists of 7 identical stretched strings with different lengths. The longest string of length l_1, produces the musical note 'C' (ස, ஸ) with the fundamental frequency of 260 Hz. The corresponding lengths of the strings which produce all the musical notes are given in the table as fractions of l_1.

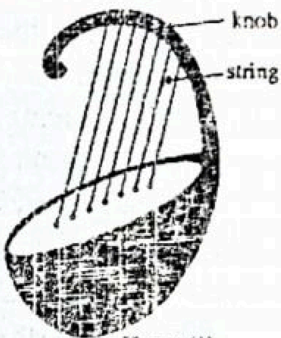


Figure (1)

Musical Notes	ස C ஸ	රි D ரி	ග E க	ම F ம	ප G ப	ධ A த	නි B நி
$\frac{l}{l_1}$	1·00	0·89	0·79	0·70	0·67	0·59	0·53

i) If all the strings are under the same tension, calculate the fundamental frequencies of musical notes 'F'(ම, ம) Lo) and 'B'(නි, நி).

ii) To obtain a Correct musical note the frequency can be fine turned by adjusting the tension of the string. By what percentage should the tension of the string be adjusted to change the frequency by 1%?

(c) A student designs and builds a set of panpipes to produce musical notes given in the above table, by using narrow PVC pipes with different lengths as shown in figure (2). Lower end of all the pipes are closed with corks.

i) Draw the standing wave patterns of the fundamental mode and the first two overtones produced by a one end closed pipe of length L, in three separate diagrams. Mark the nodes as 'N' and the antinodes as 'A' in the diagram. (Neglect end corrections.)

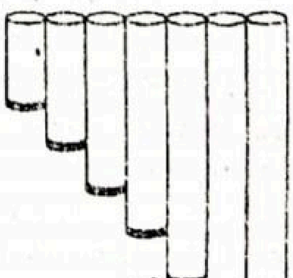


Figure (2)