R1-2004 Q1(c)

c) The period of oscillation, T, of a simple pendulum, length l, with a bob of mass m oscillating along the x-axis with a small amplitude, is given by

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

An electric field of constant magnitude E is applied to the bob which has a charge Q. Determine T if:

(i) E is vertically downwards
(ii) E is horizontal along the x-axis
(iii) E is horizontal, perpendicular to the x-axis [6]

R1-2004 Q1(d)

d) Two stations on the equator communicate by sending, and receiving, radio signals that undergo a single reflection from a layer 10 km above the surface of the Earth. What is their maximum separation in terms of the difference in their degrees of longitude? In practice they can communicate when they are considerably further apart, though there may be certain bands of longitude where reception is poor. Give a plausible explanation for this. [6]

R1-2005 Q1(d)

d) (i) Explain why light can be polarized but sound cannot. How would you distinguish, experimentally, between partially and fully polarized light ?

(ii) The equation of a wave, with displacement y, moving along the x-axis at time t is given by

$$y = A \sin 2\pi(\beta t - x/\gamma),$$

where A, π, β and γ are constants.
What are the dimensions or units of A, π, β, and γ ?
Why does this equation represent a wave moving with constant velocity?

[7]

R1-2006 Q1(h)

(h)

(i) A sound wave source transmits energy radially in all directions. It can just be detected at 0.50 km from the source, where the intensity is 1.00 pWm^{-2}. What is the power of the source?

(ii) What is understood by the superposition principle of two travelling waves? The two wave forms in Figure 1.h are travelling in opposite directions. Draw three diagrams to show the resultant wave forms when point O reaches A, B and C.

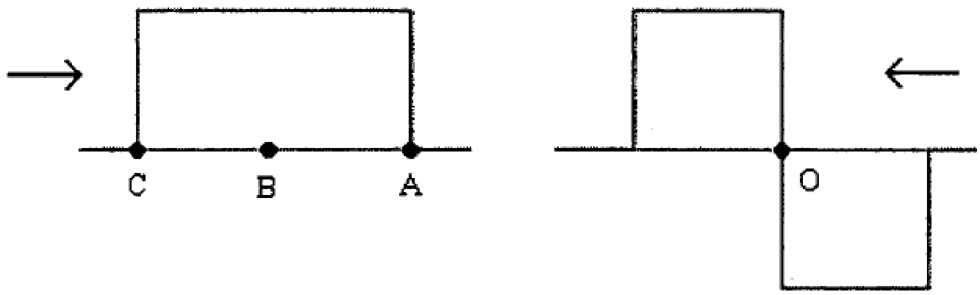

Figure 1.h

[6]

R1-2008 Q1(b)

(b) An earthquake off the coast of Sumatra, Indonesia, at A produces mechanical P and S waves that travel through the mantle of the Earth at speeds, respectively, of 5.50 kms^{-1} and 3.00 kms^{-1}. If the S wave arrives at the coastal station B, across the Indian ocean near Mombasa , Kenya, 15 mins 17 s after the P wave , determine:

(i) the distance, D, of B from A

(ii) the time, T, taken by a tsunami, produced by the earthquake, to arrive at B if it travels at 800 kmh^{-1}.

(iii) On what principle could a tsunami warning system be established ? [6]

R1-2008 Q1(g)

(g) A pulsed source of microwaves produces bursts of 20 GHz (20×10^9 Hz) radiation. Each burst has a duration of 1.0 ns. A parabolic reflector, radius 6.0 cm, is used to produce a parallel beam of radiation. The average power output of each pulse is 25 kW. Determine:

(i) the wavelength, λ, of the radiation
(ii) the total energy, E, of each pulse
(iii) the energy density, U, propagated by the reflector
(iv) the momentum density, P, propagated by the reflector [6]

R1-2008 Q1(m)

(m) A source of sound, emitting a note of frequency 500 Hz, starts from a stationary observer and travels directly towards a wall at speed v. The speed of sound is $c_s = 340\ \mathrm{ms^{-1}}$. v is much less than c_s. Derive an expression for the frequency received by the stationary observer :

(i) directly from the source
(ii) after reflection from the wall
(iii) Determine the value of v, which is small compared with c_s, if the observer detects a beat frequency of 30 Hz. [10]

R1-2009 Q1(c)

(c) A viola string 0.50 m long is tuned to A ; a frequency of 440.0 Hz..

(i) What change in length will raise its frequency to 550.0 Hz ?
(ii) If it goes out of tune and vibrates at 435.6 Hz, by what fraction, and in what sense, must the tension in the string be changed to retune it ?

[5]

R1-2009 Q1(h)

(h) A body , mass m , rests on a scale pan which is supported by a spring. The period of oscillation of the scale pan is 0.50 s. It is observed that when the amplitude of the oscillations is increased, and exceeds a certain value, the mass leaves the pan. Explain.
At what point in the motion does the mass initially leave the pan ?

[6]

R1-2009 Q1(j)

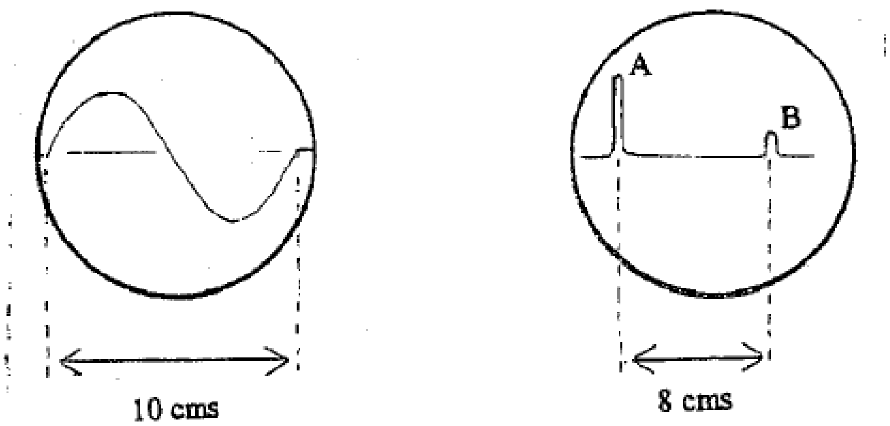

Figure 1.j

(j) A sine-form voltage of frequency 1250 Hz is applied to the Y-plates of a cathode ray oscilloscope. The trace obtained is displayed in Figure 1.j. If a radar transmitter sends out short pulses, and at the same time one applies a voltage to the Y-plates of the oscilloscope, with the time base setting unchanged, the deflection A is produced , which is shown in Figure 1.j. An object reflects the radar pulse which when received at the transmitter and amplified gives deflection B. What is the distance of the object from the transmitter ?

[3]

R1-2009 Q1(l)

(l) The equation

$$y = A \sin(\omega t - kx)$$

represents a plane wave travelling along the x-direction in a medium, y is the displacement of a point at position x at time t. A, k and ω are constants. Deduce the direction and speed of the wave.

If $A = 1.0 \times 10^{-7}$ m, $\omega = 6.6 \times 10^{3}$ s^{-1} and $k = 20$ m^{-1}, calculate:

(i) the speed of the wave
(ii) the maximum speed of a particle of the medium due to the wave.

[5]

R1-2009 Q1(p)

(p) Explain qualitatively using sound waves as an example, what is understood by:

(i) the Doppler effect
(ii) the phenomenon of beats
(iii) stationary waves

[6]

R1-2010 Q1(f)

(f) A monochromatic light wave of amplitude a is incident normally on a Polaroid sheet at an angle θ to the plane of polarization. What is the amplitude of the transmitted wave? The intensity of an unpolarized light beam incident normally on the Polaroid sheet is I. What is the intensity of the transmitted light?

[3]

R1-2010 Q1(o)

(o) A student rotates a whistle, of frequency 256 Hz, at the end of a 1.2 m length of string, at 3.0 revs. per sec. Derive the extreme values of the frequency experienced by an observer at some distance from the student. The velocity of sound is 340 ms^{-1}.

[7]

R1-2011 Q1(h)

h) A 50 kg ball is attached to one end of a 1.2 m chord that has a mass of 0.13 kg and initially hangs vertically in equilibrium. The other end of the chord is attached to a ring that can slide on a smooth horizontal rod, (*Figure 1.h*). A horizontal blow is delivered to the chord which excites its fundamental mode. Assume the ball remains stationary as the chord vibrates.

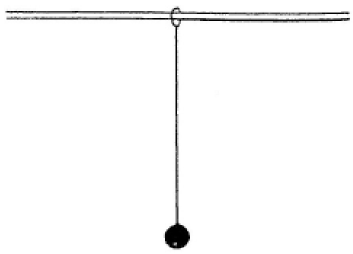

Figure 1.h

(i) What is the frequency, f, and period, T, of the fundamental mode?
(ii) What is the amplitude, A, of the ring if its maximum velocity is 15 ms^{-1} ?
(iii)If, initially, the ball is not stationary, determine its natural period, T_0.
(iv)Determine the ratio (T / T_0). Is the original assumption justified?

[11]

R1-2011 Q1(m)

m) Two masses of 0.90 kg and 1.10 kg are hung vertically from identical springs on a common support each with force constant 39.48 Nm^{-1}. Both are released simultaneously from a position of maximum extension to describe simple harmonic motion. Calculate:

(i) The frequencies of the two masses.
(ii) The beat period and frequency.

[4]

R1-2012 Q1(k)

(k) An organ pipe has one end closed and at the other end is a vibrating diaphragm, which is a displacement antinode. When the frequency of the diaphragm is 2,000 Hz a stationary or standing wave pattern is set up in the tube. The distance between adjacent nodes is 8.0 cm. As the frequency is slowly reduced the stationary wave pattern disappears, but another stationary wave pattern reappears at frequency 1,600 Hz.

Calculate:

(i) the speed of sound in air

(ii) the distance between adjacent nodes at 1,600 Hz

(iii) the length of the tube

(iv) the next frequency below 1,600 Hz at which a stationary pattern occurs

[6]

R1-2002 Q3

a) Two identical synchronously oscillating dippers separated by a horizontal distance $l = 3.0$ m, with a period of 1.00 s, produce waves on a smooth lake that travel at a speed of 1.2 ms^{-1}. The centres of the waves are at A and B. O is the mid point of AB.

(i) Draw a scale diagram of the wave fronts present after 4.00 s.

(ii) What conditions must be satisfied for constructive and for destructive interference of the water waves, at a point which is a distance x from A and distance y from B?

(iii) Mark, in the diagram, the regions where constructive and destructive interference occur.

(iv) P is a point at a large distance, compared with l, from A and B, at an angle θ = POB. What are the conditions for constructive and destructive interference at P?

[10]

b) A boat crosses a smooth lake at a speed of 5.0 m s^{-1}. Waves on the lake travel at 2.5 m s^{-1}. The waves generated by the boat produce a bow wave. This is tangential to the waves created by the boat. What angle, ϕ, does the bow wave make with the velocity of the boat? Give an explanation of the calculation.

[4]

c) Figure 3.1 shows a horizontal square ABCD with sides of length 2000 m. Coherent 10.0 MHz radio signals, wavelength λ, are transmitted from A and B.

(i) Calculate the value of λ.

(ii) What is the path difference p_B for the two signals, from A and B, received at B? Express it in terms of the product $n_B\lambda$ and deduce the value of n_B. Repeat the calculation for the point C and obtain the corresponding p_C and n_C.

(iii) An observer at C moves towards B, a distance x, in the direction CB in order to receive the first signal of maximum strength. Determine x. [6]

+

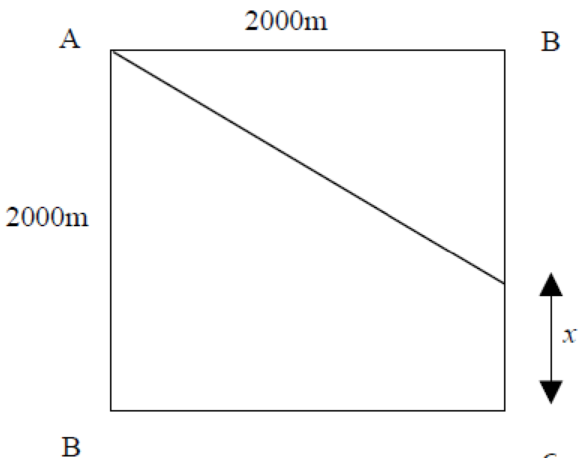

Figure3.1

R1-2003 Q7

a) Explain, with diagrams, the differences between longitudinal and transverse waves. Give an example of a polarized wave. [3]

b) Explain how the following acoustical phenomena arise:

(i) beats due to two sound waves
(ii) Doppler effect. [4]

c) If a source of sound, emitting a note of frequency f_o, is moving towards an observer with velocity v_s, show that, providing there is no wind, the frequency f detected by the observer is given by

$$f = \frac{f_o}{(1 - v_s / c)},$$

where c is the speed of sound in air. [5]

d) How is the result in (c) modified if the source is moving away from the observer?
What occurs when the velocity, v_s, towards the observer equals c?
Why are transverse acoustic waves not propagated in air? [3]

e) A twin-engined aeroplane flies low over a stationary observer. The beat frequency from the two engines is observed to change from 8.00 s^{-1} to 2.00 s^{-1} as it passes overhead.
If there is no wind, deduce the speed of the aeroplane.

(Speed of sound in air c = 330 ms^{-1}.) [5]

R1-2003 Q8(c)

c)

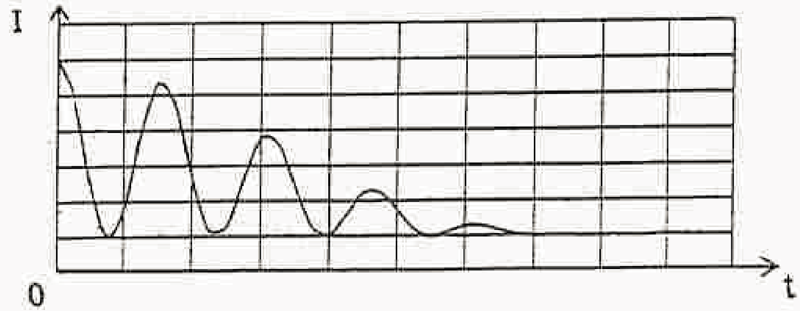

Figure 8.2

A radio telescope has two aerials 50 m apart on an east-west line around the equator. On March 21st at noon, when the Sun is directly overhead, it records the radio signals from the Sun at a wavelength of 0.75 m. The amplitudes of the signals received by the aerials are fed through equal lengths of cable, added together, and amplified; coherence of the signals being maintained. Figures 8.2 shows the resultant intensity, I, as a function of time, t, elapsed after 12 noon.

(i) Determine the time interval between adjacent maxima around noon.

(ii) How would the recording be modified if the observations were performed near Cambridge, England, at latitude 52°N? [6]

R1-2005 Q6(c)

c) X-ray diffraction spots are produced by crystal lattices. They are due to interference produced by parallel layers of atoms that reflect the rays. The diagram, Figure 6.1, shows two such layers separated by a distance d. The two parallel rays at an angle θ to the plane of the atoms are reflected and interfere.

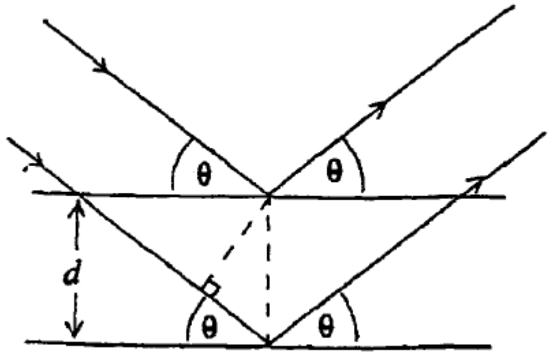

Figure 6.1

(i) Determine the path difference between the two rays.

(ii) Deduce the condition for constructive interference for X-rays of wavelength λ

[3]

R1-2005 Q6(d)

d) X -rays of wavelength $\lambda = 1.24 \times 10^{-10}$ m are incident on the planes of atoms parallel to a face of the cubic cells of a SC lattice with $a = 5.00 \times 10^{-10}$ m. As θ increases from 0, the first diffraction spot appears at θ_o and the highest order of spot occurs at θ_H. Determine θ_o and θ_H.

[5]

R1-2006 Q2

A small sound transmitter T radiates uniformly in all directions and at four times the power of each of two similar transmitters, S_1 and S_2, which are situated a distance $l = 0.25$ m on either side of T, along a north-south line. T is wired to be at 180° out of phase with S_1 and S_2. All three transmitters emit a 200 kHz signal. A small receiver, R, is placed a distance $d = 10.0$ m due east of T and slowly moved eastwards; being, in general, a distance x from T, $x \geq 10.0$ m. The speed of sound is 330 ms^{-1}.

(a)

(i) How does the intensity, I, of a simple point source of sound vary with distance r from the source?

(ii) Show that the path difference $p = S_1R - TR$ is given approximately by

$$p = \frac{1}{32\,x}, \qquad x \geq 10$$

[3]

(b) When all transmitters are on, determine the condition for the intensity of the signal at R to be:

(i) a maximum
(ii) a minimum
(iii) Where do these maxima and minima occur?
(iv) Sketch the variation of the intensity, I, against x, for $x \geq 10$, when all transmitters are on.

[9]

(c) At the position/s of maximum signal intensity the following transmitters are switched off:

(i) S_1 and S_2
(ii) T.

Determine, with an explanation, by what factor the power received falls in each case.

[4]

(d) Indicate graphically how the intensity, I, of the signal received at R varies with x when:

(i) T is switched off
(ii) S_2 is switched off

[4]

Note: $(1+y)^{1/2} \approx 1 + \frac{1}{2}y$ for $y << 1$

R1-2007 Q3

(a) Derive the frequency, f, detected by an observer from a sound source of frequency f_0, indicating if it increases or decreases with respect to f_0, when:

(i) the source is stationary and the observer is moving with velocity v directly towards it.

(ii) the source is moving with velocity u directly towards the stationary observer.

(iii) the source and observer are moving towards each other ,along the same straight line, with speeds ,respectively, of v and u.

The speed of sound is c_S.

[8]

(b) A stationary source emits a note of frequency f_0. An observer who is moving with constant velocity v, in a straight line , initially towards the source, but not directly towards it, detects a frequency f that varies with time t. Table 3.1 gives the measurements of f against t. The speed of sound is 330 ms^{-1}.

f / Hz	t / s
210.4	0
210.4	30.0
210.0	60.0
208.0	70.0
199.5	75.0
185.8	80.0
182.1	90.0
181.6	120.0
181.6	150.0

(i) Why does the frequency f, in Table 3.1, decrease with t ?
(ii) Using the data at large and small times determine f_0 and v .
(iii) Determine the time at which the observer is closest to the source .

[12]

R1-2010 Q4

A weight of mass M hangs from the end of a light vertical spring that is attached, at its upper end, to a rigid support . When in equilibrium the spring has an extension x_1. The natural angular frequency of the system is ω.

(i) Determine x_1 in terms of ω. [2]

(ii) The mass vibrates about its equilibrium position, the spring having an extension $(x_1 + x)$ at time t. Obtain an expression for the total potential energy, V, of the system. The zero of the gravitational potential energy of the mass is to be taken at the equilibrium extension, x_1. [3]

(iii) If the amplitude of the motion is A_1, determine the maximum kinetic energy, T_1 , of the mass and the total energy, E_1, of the system . [2]

(iv) The mass collides elastically with a stationary body of mass $M/2$ at $x = 0$. Determine the new velocity, v_2, after the collision and amplitude, A_2, of the motion of the mass M. [5]

(v) If in (iv) the masses coalesce, determine the new equilibrium position, x_2, and the new amplitude, A_2, in terms of A_1.

[8]

R1-2010 Q6

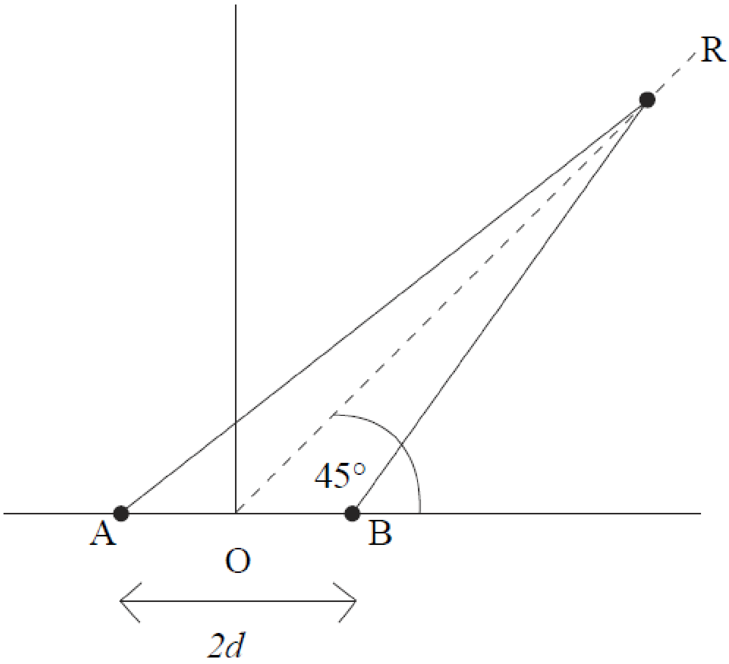

Figure 6.1

Two loud speakers, A and B, are mounted at ground level, a distance $2d$ = 50.0 cm apart, and are connected in parallel to the output of an amplifier, which is fed from a variable frequency oscillator. An observer, also at ground level, stands at a point R that is 1.20 km from the line joining the loud speakers and 1.20 km from the perpendicular bisector of AB at O. OR = D, Figure 6.1. The oscillator is adjusted so that its frequency, f, rises linearly with time, at 10 Hz per sec from $f = 0$ at time $t = 0$. The sound heard by the observer drops to a minimum for the first time when $t = 52.2$ s.

(a) Obtain an expression for the time taken by the sound, velocity c_s, to reach R from:

(i) A (ii) B [4]

(b) Find an expression for the frequency of the sound reaching R at time t from:

(i) A (ii) B [4]

(c) As D is much greater than d, the frequencies in (b) are approximately equal. Give an expression for the value, and accuracy, of the 'common' frequency. [4]

(d) Deduce an expression for the wavelength of the sound reaching R. [1]

(e) Calculate the speed of sound, c_s. [7]

R1-2012 Q3

(a) A train is travelling along a straight section of railway line at a constant speed u. It sounds its whistle, of frequency f_o, continuously. It passes under a low bridge. Obtain an expression for the frequency heard by an observer on the bridge as it approaches and recedes. The velocity of sound is v_s.

[6]

(b) The frequency f of a vibrating violin string, constant tension F, fixed at both ends, of length l and mass per unit length μ, is given by

$$f = \frac{1}{2l}\sqrt{\frac{F}{\mu}}$$

When a tuning fork of frequency f_o is struck, and the wire plucked, beats are heard. For three different increasing values of F which are, F_1, F_2, and F_3, the number of beats heard in a second is, respectively, b_1, b_2 and b_3, where $b_1 > b_2 > b_3$. F_1, F_2, F_3 are expressed in terms of a constant tension, T.

$$F_1 = 0.99\,T, \qquad b_1 = 3.30,$$
$$F_2 = 1.00\,T, \qquad b_2 = 2.00,$$
$$F_3 = 1.02\,T, \qquad b_3 = 0.58.$$

(i) Sketch a graph of f against F indicating qualitatively, with an explanation from the data, the possible region(s) where f_o is located.

(ii) Express f in terms of f_o for the first two sets of results.

(iii) Deduce the value of f_o.

(iv) Express f in terms of f_o for the third set of results.

(v) For the second set of results, (F_2, b_2), with no change in tension, what percentage change in l is necessary for the string and tuning fork to sound in unison?

[14]

R1-2012 Q4

A simple pendulum in a 19th century Swiss clock has a period of oscillation T = 1.000 s, a bob of mass m and suspension wire of length l. It is located on the surface of the Earth at a temperature of 15° C.

(a) If the temperature is kept at 20° C, over a period of a week, by how much will the pendulum lose or gain time? The coefficient of thermal expansion of the suspension $\alpha = 1.9 \times 10^{-5}\ K^{-1}$.
(α is the fractional increase in length of the pendulum per unit temperature rise)

[5]

(b) If the pendulum is taken to a height of 20.0 m, by how much will it lose or gain time in the period of a week? Assume the temperature remains at 15°C.

[4]

(c) Explain why the tension, F, in the suspension of a simple pendulum is not constant. If θ is the angle the suspension makes with the vertical, determine the tension in it and compare it with the weight of the bob when it is at:

(i) maximum amplitude, θ_M
(ii) $\theta = 0$

[5]

(d) Some sand is sprinkled on a loud speaker lying on its back which can be made to vibrate vertically with simple harmonic motion. When the amplitude is 0.015 cm the sand begins to loose contact with the membrane. Calculate the frequency of vibration at which this occurs.

[6]

R1-2013 Q8(b)

(b) Geophysical exploration is being carried out below a horizontal land area, Figure 8.b. The rock directly below ground has depth *h* and sound travels through it with velocity V_1. Below this layer of rock is another layer of rock in which the velocity of sound is V_2, with V_2 being greater than V_1. Sound is reflected and refracted in a similar manner to light.

An explosion on the surface at E is detected by a microphone M on the surface, which is a distance *x* from E. Sound waves from E can travel directly along the surface rock to M, and also down into the upper region of the lower rock layer as indicated in Figure 8.b, before final refraction and subsequent detection by M. Determine *x*, in terms of *h*, V_1 and V_2, if these two waves are to arrive at M simultaneously.

[10]

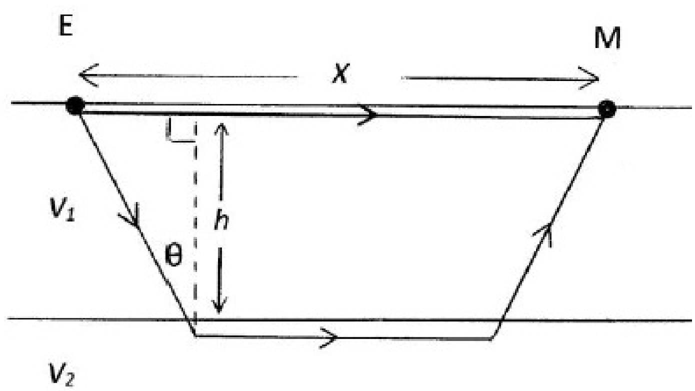

Figure 8.b