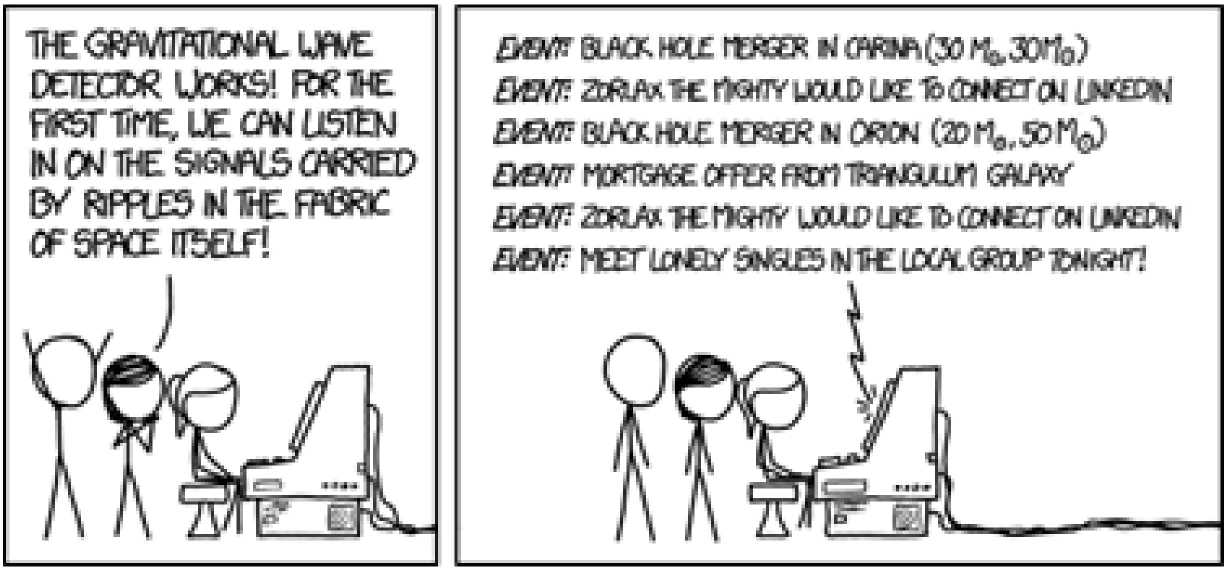
Advanced Higher Physics

Past Paper Questions

2.4 Waves



MARKS | DO NOT WRITE IN THIS MARGIN

9. A wave travelling along a string is represented by the relationship

$$y = 9 \cdot 50 \times 10^{-4} \sin(922t - 4 \cdot 50x)$$

(a) (i) Show that the frequency of the wave is 147 Hz. **1**

(ii) Determine the speed of the wave. **4**

(iii) The wave loses energy as it travels along the string.

At one point, the energy of the wave has decreased to one eighth of its original value.

Calculate the amplitude of the wave at this point. **3**

(b) The speed of a wave on a string can also be described by the relationship

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

where v is the speed of the wave,

T is the tension in the string, and

μ is the mass per unit length of the string.

A string of length 0·69 m has a mass of $9{\cdot}0 \times 10^{-3}$ kg.

A wave is travelling along the string with a speed of 203 m s^{-1}.

Calculate the tension in the string. **3**

(c) When a string is fixed at both ends and plucked, a stationary wave is produced.

(i) Explain briefly, in terms of the superposition of waves, how the stationary wave is produced. **1**

(ii) The string is vibrating at its fundamental frequency of 270 Hz and produces the stationary wave pattern shown in Figure 9A.

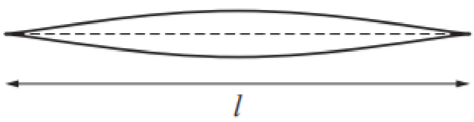


Figure 9A

Figure 9B shows the same string vibrating at a frequency called its third harmonic.

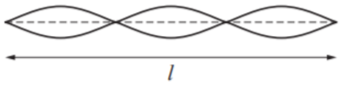


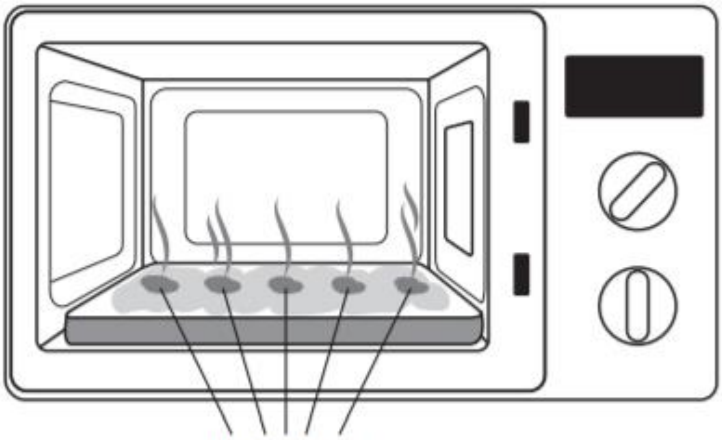
Figure 9B

Determine the frequency of the third harmonic. **1**

7. When a microwave oven is switched on a stationary wave is formed inside the oven.

(a) Explain how a stationary wave is formed. **1**

(b) A student carries out an experiment to determine the speed of light using a microwave oven. The turntable is removed from the oven and bread covered in butter is placed inside. The oven is switched on for a short time, after which the student observes that the butter has melted only in certain spots, as shown in Figure 7A.



melted spot

Explain why the butter has melted in certain spots and not in others. **2**

(c) The student measures the distance between the first hot spot and fifth hot spot as 264 mm.

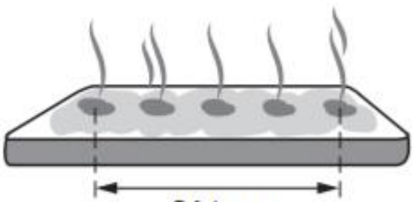


Figure 7B

From the data obtained by the student determine the wavelength of the microwaves. **2**

(d) The quoted value for the frequency of the microwaves is 2·45 GHz. The student calculates the speed of light using data from the experiment.

Show that the value obtained by the student for the speed of light is $3{\cdot}23 \times 10^8\,\text{m s}^{-1}$. **2**

9. A water wave of frequency 2·5 Hz travels from left to right.

Figure 9 represents the displacement y of the water at one instant in time.

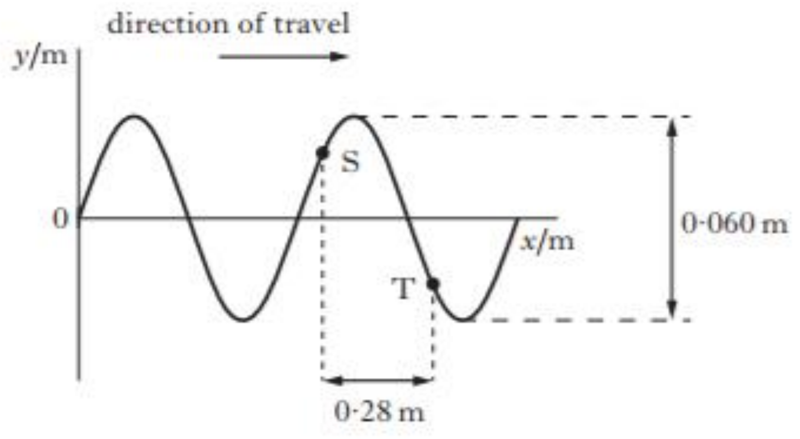


Figure 9

Points S and T are separated by a horizontal distance of 0·28 m.

The phase difference between these two points is 3·5 radians.

(*a*) Calculate the wavelength of this wave. **2**

(*b*) A second wave with double the frequency travels in the same direction through the water. This wave transfers five times the energy of the wave in part (*a*).

Calculate:

(i) the speed of this wave; **1**

(ii) the amplitude of this wave. **2**

(5)

3. To test a springboard a diver takes up a position at the end of the board and sets up an oscillation as shown in Figure 3A. The oscillation approximates to simple harmonic motion. The board oscillates with a frequency of 0·76 Hz. The end of the board moves through a vertical distance of 0·36 m.

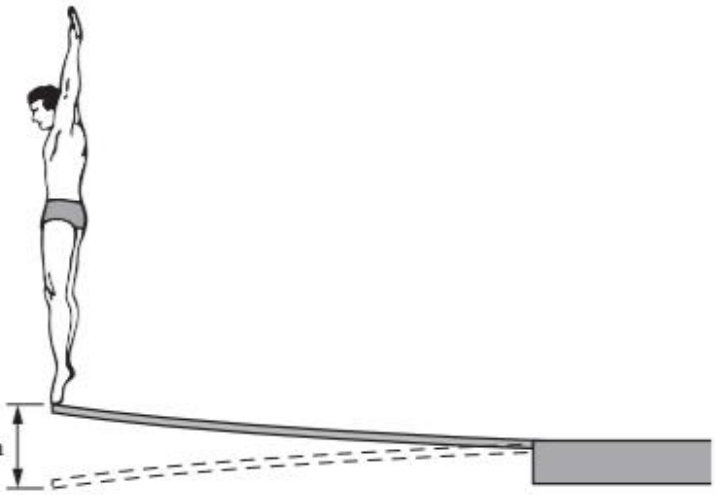


Figure 3A

(*a*) (i) Write an expression for the vertical displacement *y* of the end of the board as a function of time *t*. Include appropriate numerical values. **2**

(ii) The diver increases the amplitude of the oscillation. The frequency remains constant. Show that the amplitude when the diver just loses contact with the board is 0·43 m. **1**

Marks

9. A travelling wave moves from left to right at a speed of $1{\cdot}25\ \mathrm{m\,s^{-1}}$.

Figure 9A represents this wave at a time t. P and Q are partcles on the wave.

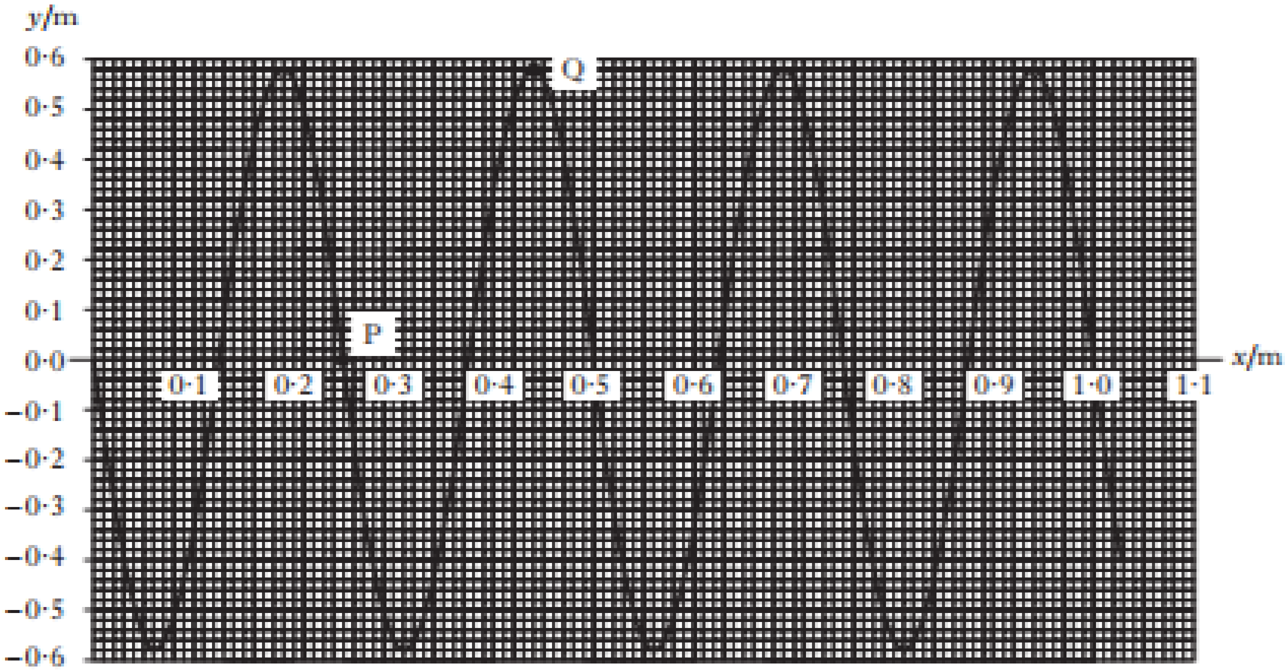


Figure 9A

(*a*) (i) Determine the wavelength of the wave. **1**

(ii) State the amplitude of the wave. **1**

(iii) Calculate the frequency of the wave. **1**

(iv) What is the phase difference, in radians, between particles P and Q? **2**

(*b*) Write an equation for this travelling wave in terms of y, x and t.

Numerical values are required. **2**

(*c*) State the equation for a wave of half the amplitude travelling in the opposite direction. **1**

(8)

Marks

4. A design for electrical power generation consists of a large buoy that drives a water column through a turbine as shown in Figure 4.

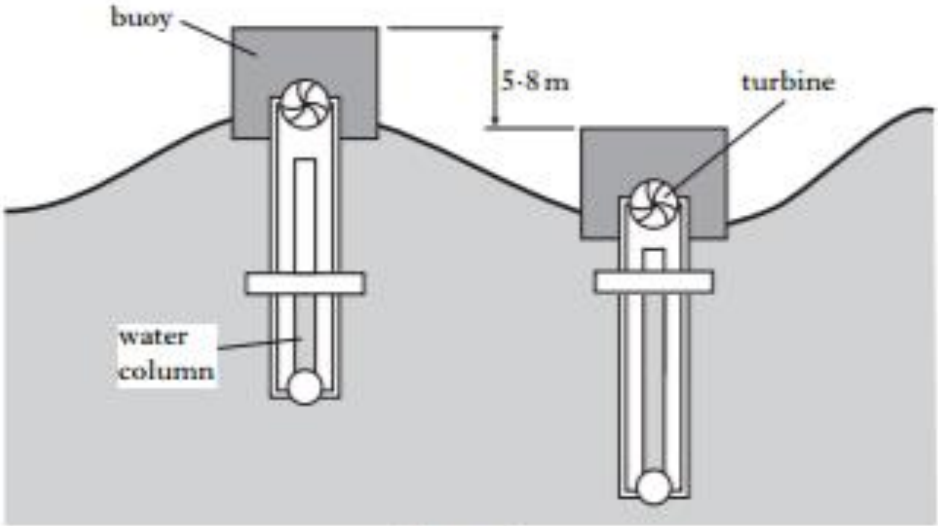


Figure 4

Energy is transferred from the wave motion to the turbines.

The mass of the buoy is $4{\cdot}0 \times 10^4$ kg and its vertical displacement is 5·8 m. The motion of the buoy can be considered to be simple harmonic with a period of oscillation of 5·7 s.

(a) Write an equation that describes the vertical displacement y of the buoy. Numerical values are required. 2

(b) Calculate the maximum acceleration of the buoy. 2

(c) Where in the motion is the resultant force on the buoy greatest? 1

(d) Calculate the maximum kinetic energy of the buoy. 2

(e) The water column acts to damp the oscillatory motion of the buoy. How does this affect:

(i) the period; 1

(ii) the amplitude of the buoy's motion? 1

(9)

10\. A stretched wire, supported near its ends, is made to vibrate by touching a tuning fork of unknown frequency to the supporting surface. One of the supports is moved until a stationary wave pattern appears as shown in Figure 10A.

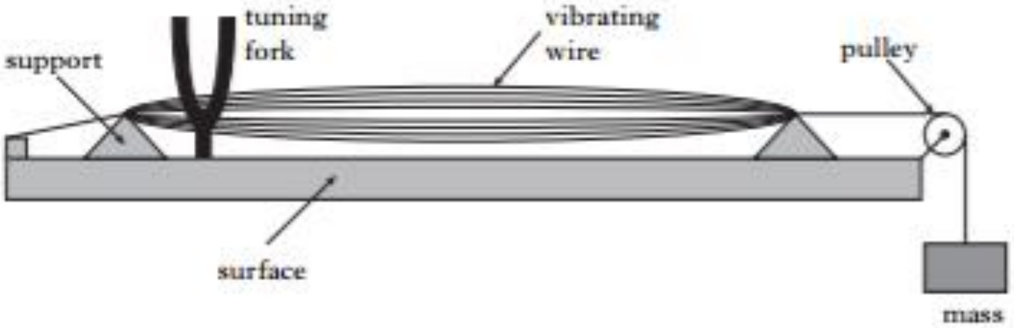


Figure 10A

(a) Explain how waves on this wire produce a stationary wave pattern. **2**

(b) The formula for the frequency of the note from a stretched wire is given by:

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

where l is the distance between the supports,
T is the stretching force,
μ is the mass per unit length of the wire.

The results of the experiment are given below:

mass per unit length of wire $= 1{\cdot}92 \times 10^{-4}\,\text{kg m}^{-1}$
distance between the supports $= 0{\cdot}780\,\text{m}$
mass of load on wire $= 4{\cdot}02\,\text{kg}$

(i) The table below gives information about the note produced by tuning forks of different frequency. Identify the note most likely to correspond to the tuning fork used in the experiment. **2**

Note	A	B	C	D	E	F	G
Frequency (Hz)	220	245	262	294	330	349	392

(ii) A second tuning fork produces the pattern shown in Figure 10B. Suggest a frequency for this tuning fork. **1**

(5)

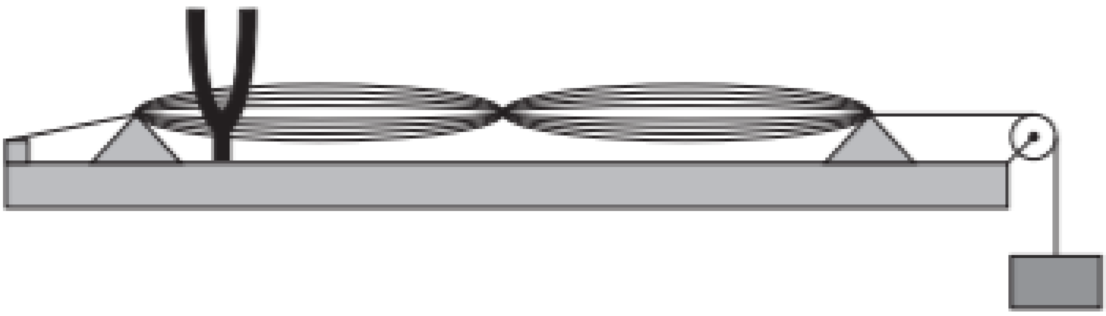


Figure 10B

9. A transverse wave travels along a string as shown in Figure 9A.

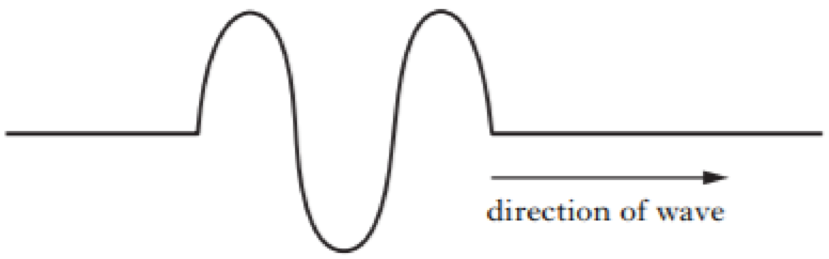


Figure 9A

The equation representing the travelling wave on the string is

$$y = 8{\cdot}6 \times 10^{-2} \sin 2\pi\,(2{\cdot}4t - 2{\cdot}0x)$$

where x and y are in metres and t is in seconds.

(*a*) State the frequency of the wave. **1**

(*b*) Calculate the velocity of the wave. **2**

(*c*) Attached to the end of the string is a very light ring. The ring is free to move up and down a fixed vertical rod.

Figure 9B shows the string after the wave reflects from the vertical rod.

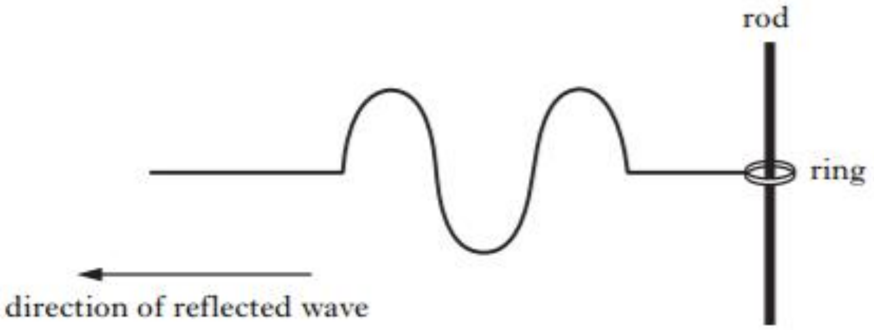


Figure 9B

When the wave reflects, its intensity falls to one quarter of its original value. The frequency and wavelength are constant.

Write the equation that represents this reflected wave. **2**

(5)

Marks

10. A long pipe containing polystyrene beads is closed by a plunger. A loudspeaker at the other end is connected to a signal generator as shown in Figure 10A.

Figure 10A

The loudspeaker is switched on and the frequency is adjusted until a stationary sound wave is set up in the tube. The polystyrene beads form the pattern shown in Figure 10B. The distance between successive piles of beads is 85 mm.

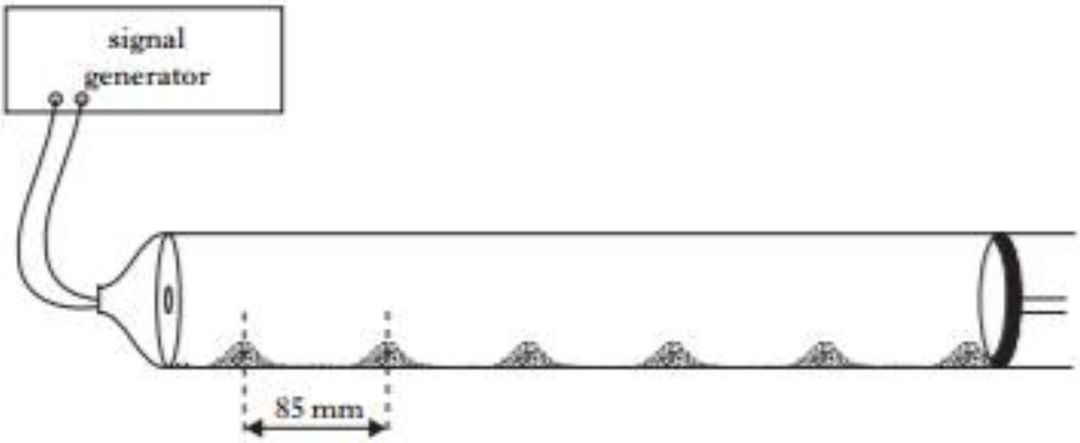


Figure 10B

(*a*) Explain how sound waves in the tube produce the stationary wave. **1**

(*b*) Define the terms node and antinode. **1**

(*c*) Do the polystyrene beads collect at nodes or antinodes? Justify your answer. **2**

(*d*) The signal generator is set to 1·95 kHz. Calculate the speed of sound in air. **3**

(7)

Marks

9. (*a*) A water wave travels with a speed of 0·060 m s^{-1} in the positive x direction. Figure 14 represents the water wave at one instant in time.

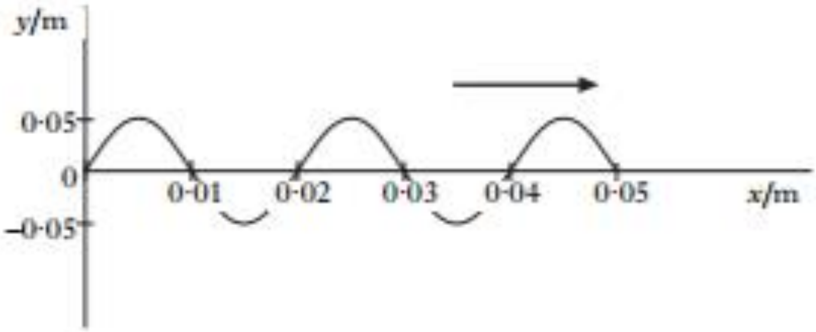


Figure 14

Write down an equation for the vertical displacement y of a point on the water surface in terms of the horizontal displacement x and time t.

Numerical values are required. **2**

(*b*) Write down an equation for an identical wave travelling in the opposite direction. **1**

(*c*) The amplitude of the wave gradually decreases.

Calculate the amplitude of the water wave when the intensity of the wave has decreased by 50%. **2**

(5)

[Turn over

11. The apparatus shown in Figure 17 is set up to measure the speed of transverse waves on a stretched string.

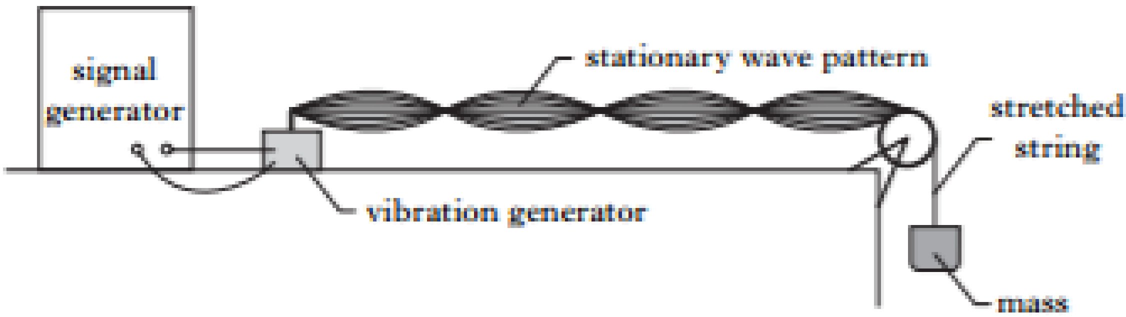


Figure 17

The following data are obtained.

Distance between adjacent nodes = $(0{\cdot}150 \pm 0{\cdot}005)$ m
Frequency of signal generator = (250 ± 10) Hz

(*a*) Show that the wave speed is $75\ \text{m s}^{-1}$. **2**

(*b*) Calculate the absolute uncertainty in this value for the wave speed. Express your answer in the form $(75 \pm \quad)\ \text{m s}^{-1}$. **3**

(*c*) (i) In an attempt to reduce the absolute uncertainty, the frequency of the signal generator is increased to (500 ± 10) Hz. Explain why this will **not** result in a reduced absolute uncertainty. **1**

(ii) State how the absolute uncertainty in wave speed could be reduced. **1**

(7)

Marks

9. (*a*) A travelling wave is represented by the expression

$$y = 2{\cdot}0 \times 10^{-4} \sin(1570t - 4{\cdot}6x)$$

where x and y are in metres and t is in seconds.

(i) Calculate the frequency of the wave. **2**

(ii) A wave with the same frequency and four times the intensity travels in the opposite direction.
Write down the equation which represents this wave. **2**

(*b*) A train emits a sound of frequency 800 Hz as it passes through a station. The sound is heard by a person on the station platform as shown in Figure 18.

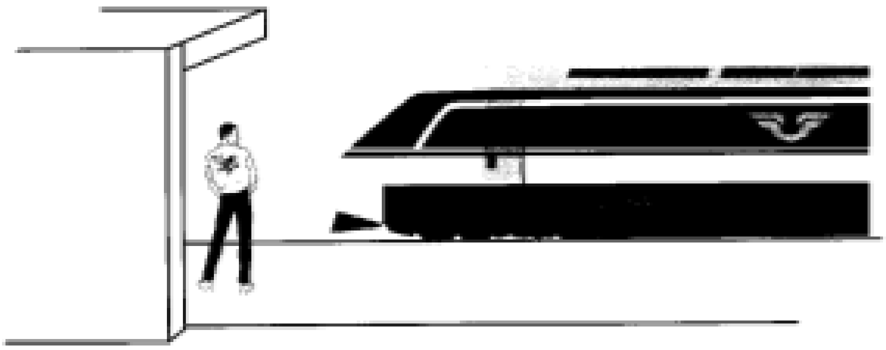


Figure 18

(i) Describe how the frequency of the sound, heard by the person, changes as the train passes through the station. **1**

(ii) Explain, in terms of wavefronts, why this frequency change occurs. You may wish to include a diagram as part of your answer. **2**

(iii) At one instant the person hears a sound of frequency 760 Hz. Calculate the speed of the train relative to the person on the platform at this time. **2**

(9)

Traditional 2004

Marks

11. A transverse wave is described by the expression

$$y = 8{\cdot}0 \sin(12t - 0{\cdot}50x)$$

where t is in seconds and x and y are in metres.

(*a*) For this wave, calculate the:

(i) frequency;

(ii) wavelength. **2**

(*b*) (i) Calculate the phase difference, in radians, between the point at $x = 3{\cdot}0$ m and the point at $x = 4{\cdot}0$ m.

(ii) Calculate the time for the wave to travel between these two points. **4**

(*c*) The wave is reflected and loses some energy.

State a possible equation for the reflected wave. **2**

(8)

Traditional 2002

Marks

10. (*a*) A water wave travelling in the negative x direction has frequency 3·0 Hz, velocity 0·050 m s^{-1} and initial amplitude 0·040 m.

(i) Write down an expression for the displacement y of a point on the water surface in terms of x and time t.

(ii) After some time the amplitude of the wave has fallen to 0·020 m.

By what factor has the intensity of the wave changed compared to its initial value? **4**

(*b*) When a continuous sound wave of constant frequency is reflected from a wall, a stationary wave is produced.

Explain in terms of the incident and reflected waves how nodes **and** anti-nodes are formed. **2**

(*c*) (i) A car horn produces a note of frequency 200 Hz.

The horn is sounded as the car is moving at 30 m s^{-1} away from a stationary observer.

Calculate the frequency heard by the observer.

(ii) An observer on Earth notes that the frequency of light from a distant galaxy is Doppler shifted towards the red end of the spectrum.

State whether the galaxy is moving towards or away from Earth. **You must justify your answer**. **4**

(10)

Marks

9. (*a*) A travelling wave is represented by the expression

$$y = 3{\cdot}5 \sin (62{\cdot}8t - 1{\cdot}25x)$$

where x and y are expressed in metres and t in seconds.

(i) Calculate the following for the travelling wave:

(A) the frequency in Hz;

(B) the wavelength.

(ii) The intensity of the wave doubles.

(A) Which of the quantities in the equation changes in value?

(B) Write down the equation which describes the wave with double the intensity. 7

(*b*) An emergency vehicle, travelling at $22\,\text{m s}^{-1}$, emits sound of frequency 1020 Hz. The vehicle approaches a stationary pedestrian, as shown in Figure 15.

Figure 15

The frequency detected by a stationary observer when a sound source moves relative to the observer is given by

$$f = f_s \frac{v}{v \pm v_s}$$

where the symbols have their usual meanings.

Calculate the frequency heard by the stationary pedestrian as the emergency vehicle approaches. 2

(9)