Access Tuition

A-Level Physics

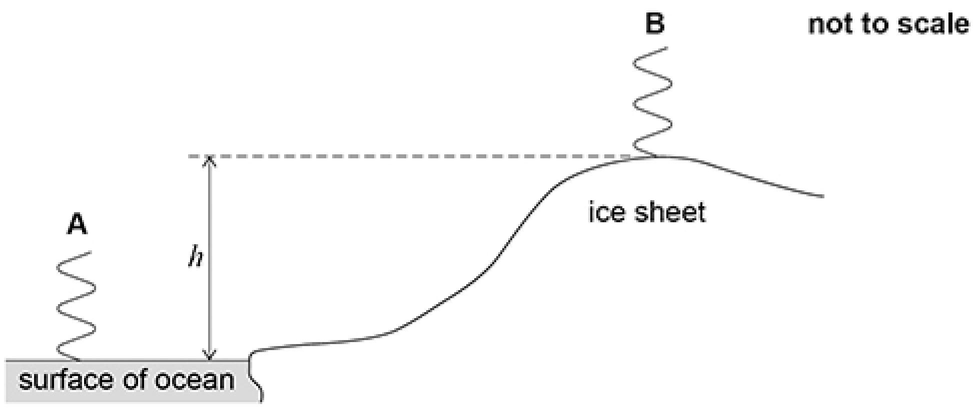
Progressive Waves

Question Paper

Time available: 70 minutes
Marks available: 51 marks

1. A satellite system is used to measure the height h of the top of an ice sheet above the surface of the ocean.
The satellite emits two pulses **A** and **B** of infrared radiation. **A** is incident on the surface of the ocean and **B** is incident on the top of the ice sheet as shown in **Figure 1**.

Figure 1



(a) The frequency of the infrared radiation is 3.8×10^{14} Hz.
Each pulse has a duration of 6.0 ns.

Calculate the number of cycles in each pulse.

number of cycles = ________________

(2)

(b) **A** and **B** reflect and return to the satellite. The travel time is the time between the emission of a pulse and its return to the satellite.

The difference in the travel times of **A** and **B** is $10.7\ \mu s$.

Calculate h.

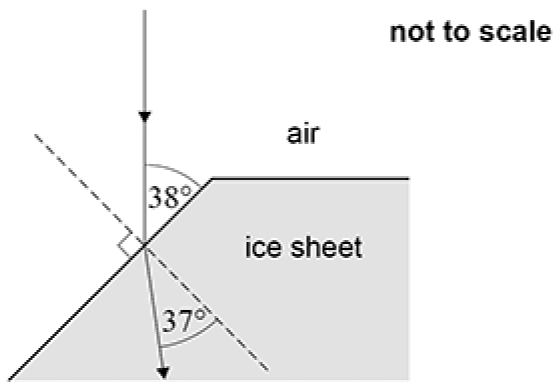
h = _______________ m

(2)

Some of the infrared radiation enters the ice sheet.

Figure 2 shows the path of infrared radiation that refracts at a sloping part of the ice sheet.

Figure 2



(c) Calculate the refractive index of the ice.

refractive index = _______________

(2)

(d) Calculate the wavelength of the infrared radiation when it is inside the ice sheet.

wavelength = _______________ m

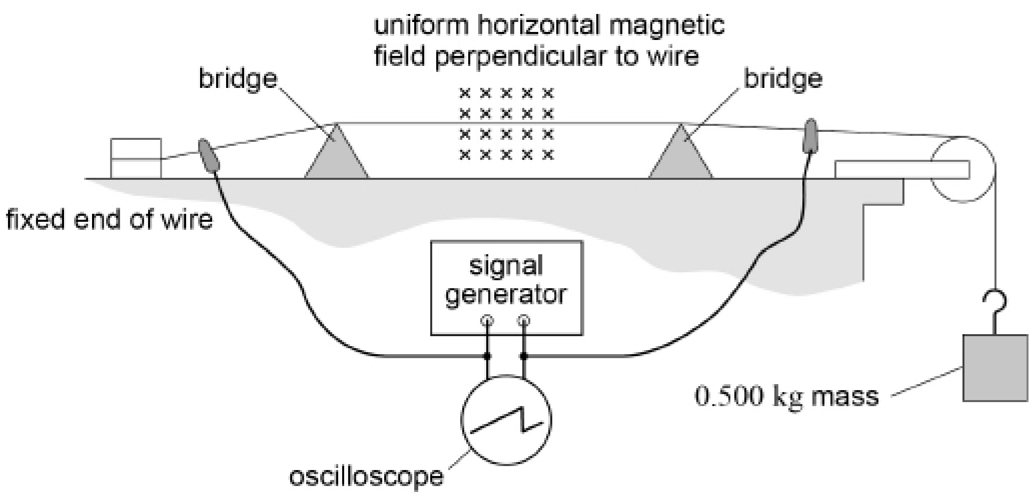
(2)

(Total 8 marks)

2. A stationary wave is formed on a stretched wire.

Figure 1 shows the wire, fixed at one end, supported by two bridges and passing over a pulley.

Figure 1

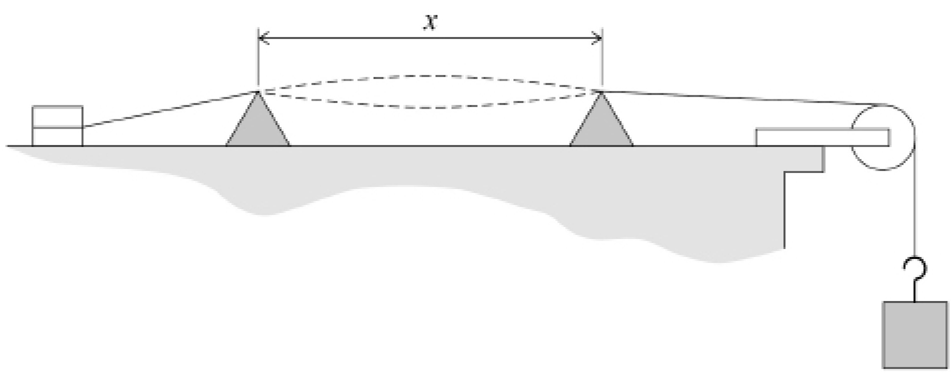


A 0.500 kg mass is attached to the free end of the wire.
A uniform horizontal magnetic field is applied perpendicular to the wire between the bridges.
A signal generator is connected to each end of the wire.

The oscilloscope shown is used to determine the frequency of the output of the signal generator.
The wire oscillates because the alternating current in the wire interacts with the magnetic field.

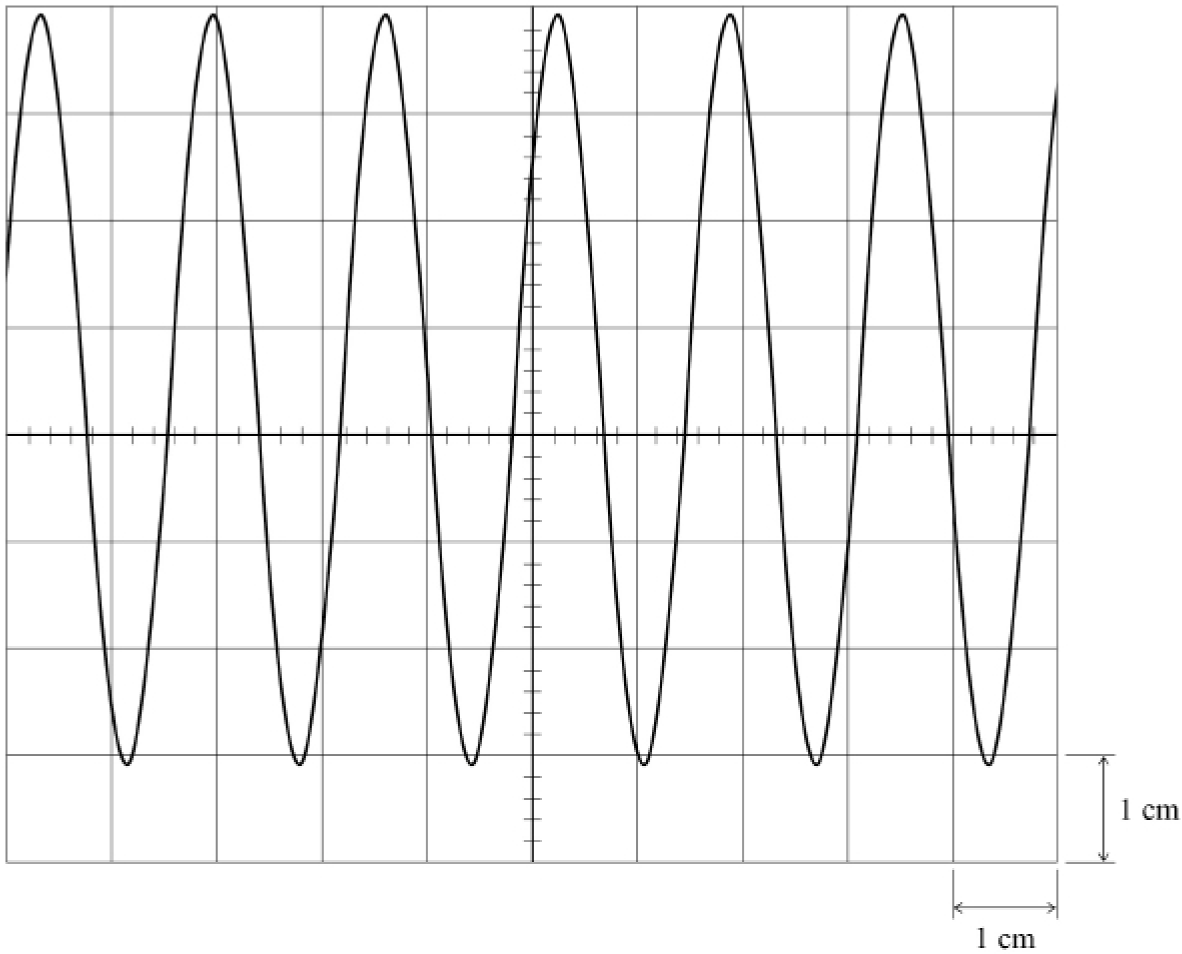
Figure 2 shows the first harmonic stationary wave produced when the distance x between the bridges is adjusted.

Figure 2



(a) The output potential difference (pd) of the signal generator is displayed on the oscilloscope, as shown in **Figure 3**.

Figure 3



The time-base setting of the oscilloscope is 10 ms cm^{-1}.

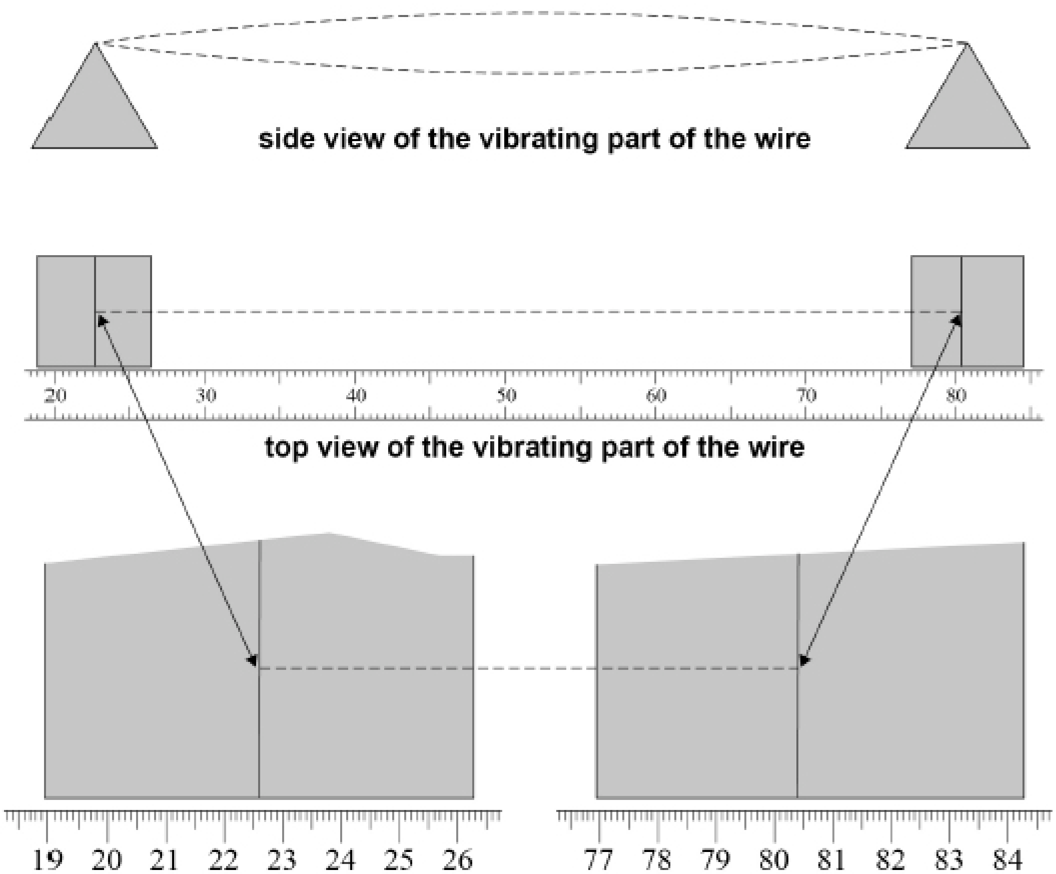
Determine f, the frequency of the alternating pd.

f = ____________________ Hz

(2)

(b) A metre ruler is placed next to the bridges supporting the wire, as shown in **Figure 4**.

Figure 4



Determine the wavelength of the stationary wave shown in **Figure 4**.

λ = ____________________ m

(2)

(c) The stationary wave is formed by two waves of frequency f and wavelength travelling λ with speed c in opposite directions.

Determine c.

c = ____________________ m s^{-1}

(1)

(d) Determine, in kg m^{-1}, the mass per unit length of the wire.

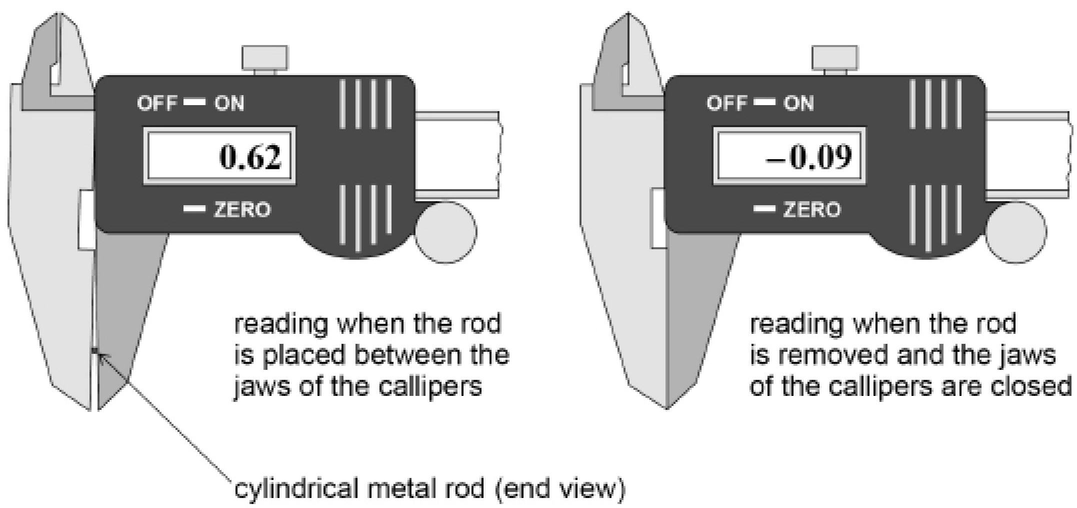
mass per unit length = ____________________ kg m^{-1}

(2)

(e) A student uses digital vernier callipers to measure the diameter of a cylindrical metal rod. The student places the rod between the jaws of the callipers and records the reading indicated. Without pressing the zero button, the student removes the rod and closes the jaws.

Figure 5 shows the calliper readings in millimetres, before and after the jaws are closed.

Figure 5



Calculate the diameter d of the rod.

d = ____________________ mm

(1)

(f) Describe relevant procedures to limit the effect of random error in the result for d.

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(2)

(g) Determine the density of the rod.

The mass per unit length of the rod is 3.54×10^{-3} kg m^{-1}.

density = ____________________ kg m^{-3}

(3)

(Total 13 marks)

3. **Figure 1** shows the structure of a violin and **Figure 2** shows a close-up image of the tuning pegs.

Figure 1

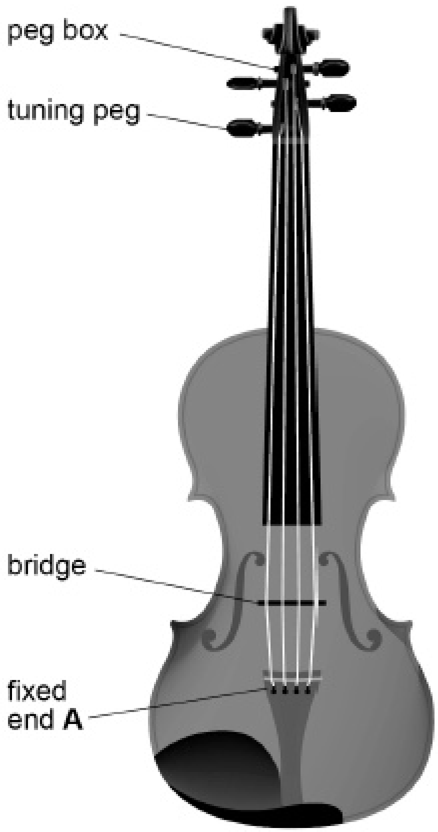
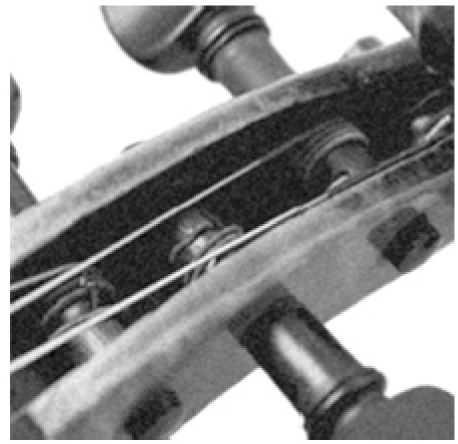


Figure 2



The strings are fixed at end **A**. The strings pass over a bridge and the other ends of the strings are wound around tuning pegs that have a circular cross-section. The tension in the strings can be increased or decreased by rotating the tuning pegs.

(a) Explain how a stationary wave is produced when a stretched string is plucked.

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(3)

(b) The vibrating length of one of the strings of a violin is 0.33 m
When the tension in the string is 25 N, the string vibrates with a first-harmonic frequency of 370 Hz

Show that the mass of a 1.0 m length of the string is about 4×10^{-4} kg

(2)

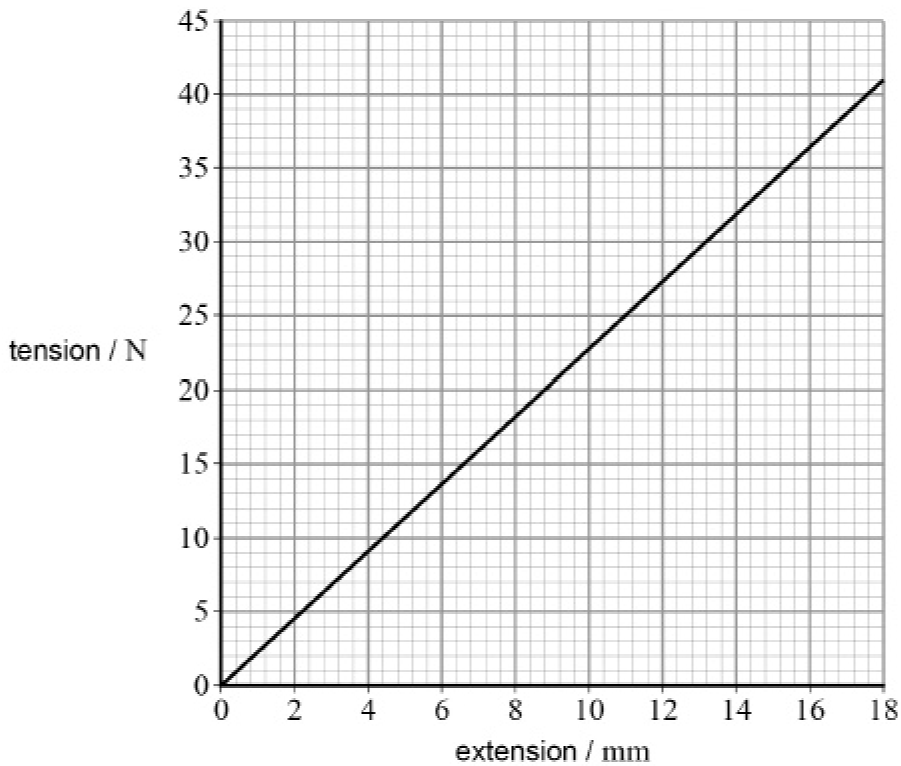
(c) Determine the speed at which waves travel along the string in question **(b)** when it vibrates with a first-harmonic frequency of 370 Hz

speed of waves = ____________________ $m\ s^{-1}$

(1)

(d) **Figure 3** shows how the tension in the string in question **(b)** varies with the extension of the string.

Figure 3



The string with its initial tension of 25 N is vibrating at a frequency of 370 Hz
The diameter of the circular peg is 7.02 mm

Determine the higher frequency that is produced when the string is stretched by rotating the tuning peg through an angle of 75°

Assume that there is no change in the diameter of the string.

frequency = ____________________ Hz

(4)

(Total 10 marks)

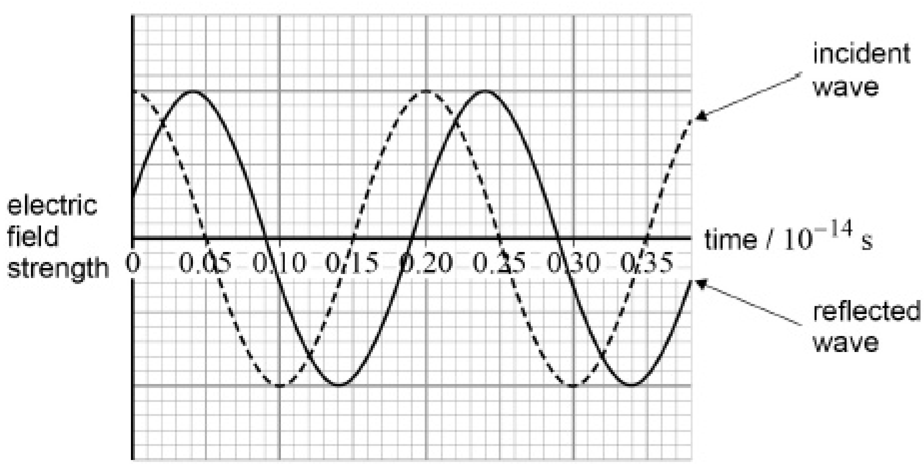
4. A gravimeter is an instrument used to measure the acceleration due to gravity. The gravimeter measures the distance fallen by a free-falling mirror in a known time.

To do this, monochromatic light is reflected normally off the mirror, creating interference between the incident and reflected waves. The mirror is released from rest and falls, causing a change in the phase difference between the incident and reflected waves at a detector.

At the point of release of the mirror, the waves are in phase, resulting in a maximum intensity at the detector. The next maximum is produced at the detector when the mirror has fallen through a distance equal to half a wavelength of the light. The gravimeter records the number of maxima detected in a known time as the mirror falls. These data are used by the gravimeter to compute the acceleration of the free-falling mirror.

Figure 1 illustrates the phase relationship between the incident and reflected waves at the detector for one position of the mirror.

Figure 1



(a) Show that the wavelength of the light is 600 nm.

(3)

(b) Determine the phase difference, in rad, between the incident and reflected waves shown in **Figure 1**.

phase difference = ____________________________ rad

(2)

(c) A maximum is detected each time the mirror travels a distance equal to half a wavelength of the light.

In one measurement 2.37×10^5 maxima are recorded as the mirror is released from rest and falls for 0.120 s.

Using an appropriate equation of motion, calculate the acceleration due to gravity that the gravimeter computes from these data.

State your answer to 3 significant figures.

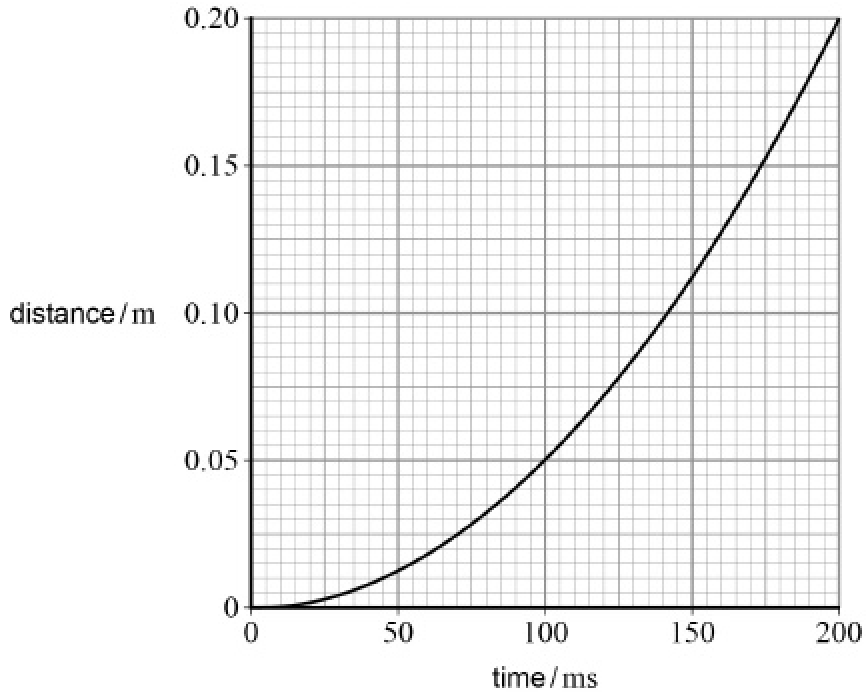
wavelength of the light = 600 nm

acceleration due to gravity = ____________________________ $m\ s^{-2}$

(3)

(d) **Figure 2** is a graph that the gravimeter could produce to show how the distance travelled by the mirror varies with time as it falls.

Figure 2



Determine the gradient of the line when the time is 0.12 s.

gradient = ______________________________

(2)

(e) State what this gradient represents.

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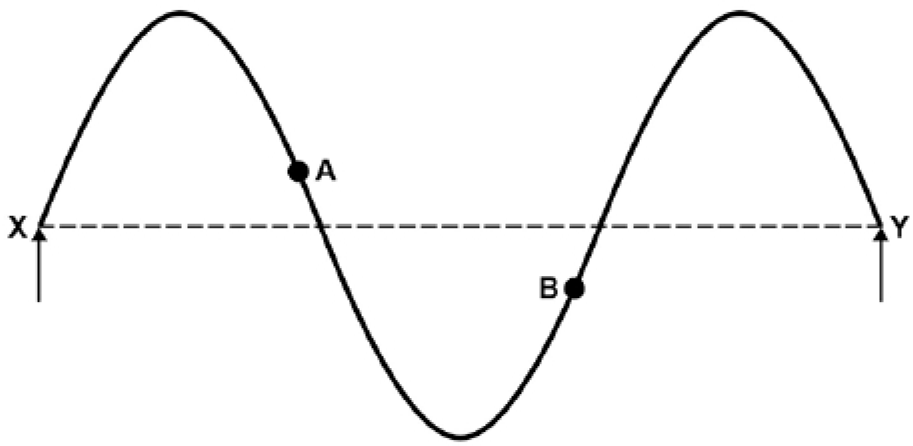
(1)

(Total 11 marks)

5. The diagram below shows one position of a guitar string stretched between points **X** and **Y**.
The string vibrates at a frequency of 330 Hz.



(a) State the phase relationship between points **A** and **B** on the string.

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(1)

(b) Points **X** and **Y** are 0.66 m apart.

Calculate the speed of the wave along the string.

speed = ________________ m s^{-1}

(2)

(c) The total mass of the string is 3.1 g and the total length of the string is 0.91 m.

Show that the tension in the string when it is sounding the harmonic shown in the diagram above is about 70 N.

(3)

(d) The string is fixed at one end and wrapped around a tuning peg of radius 3.0 mm at the other. The tuning peg needs to be turned through 3 complete rotations to increase the tension in the string from 0 to 70 N in part **(c)**.

Discuss, by estimating the energy stored in the string, whether there is a significant risk to the guitar player when the string breaks.

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(3)

(Total 9 marks)