Oxford Cambridge and RSA

AS Level Physics B

H157/02 Physics in depth

Question Set 7

1 This question is about the standing waves that produce the musical notes in string instruments.

(a) A double bass is a large musical instrument with four strings of the same vibrating length L but different thicknesses. Notes are produced by moving a bow perpendicular to the string (**Fig. 1.1**).

This question considers only the thickest string of the double bass, which produces the lowest notes.

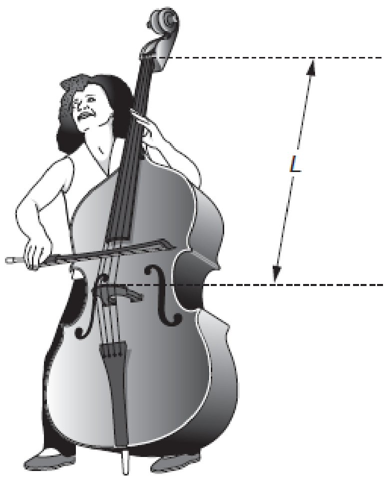

Fig. 1.1

(i) The length L = 0.980 m and the frequency f_0 of the fundamental note produced by the thickest string is 41.2 Hz.
Show that the waves travelling along the string have a speed of less than 100 m s^{-1}. **[2]**

(ii) A player can produce a harmonic (a note of higher frequency) by touching the string **lightly** at a certain point to make the string vibrate with zero amplitude at that point. This point must be a whole fraction of L from one end of the string, e.g. one-half, one-third, etc. of the way along.

The player produces a note of frequency f about 200 Hz on this thickest string by touching it at a distance x of about 20 cm from one end.

Using appropriate scientific terms, explain why this higher frequency is produced, and calculate the values of x and f to an appropriate number of significant figures.

x = ... cm f = ………………..Hz **[4]**

(iii) The fundamental frequency f_0 of the note produced by a vibrating string of length L is given by the equation

$$f_0 = \frac{1}{2L}\sqrt{\frac{T}{\rho A}}$$

where T is the tension of the string, A its cross-sectional area and t the density of the material of which it is made.
Calculate the diameter of the thickest string, which has a tension of 290 N and a mean density of 8100 kg m^{-3}.

diameter = ... m **[3]**

(b) A bass guitar (**Fig. 1.2**) has four strings that produce notes of the same frequencies as the four strings of the double bass. The strings are not played with a bow like a double bass. They are pulled perpendicular to the string and released (plucked) just as on an ordinary guitar.

As in part **(a)**, part **(b)** considers only the thickest string of the instrument

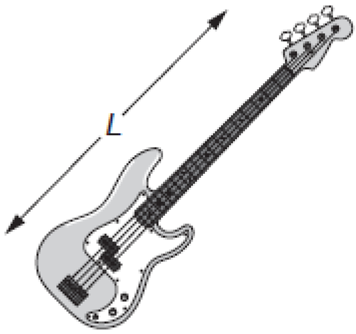

Fig. 1.2

(i) Use the equation given in **(a)(iii)** to show that, for strings producing the same fundamental frequency f_0,

$$\rho A \propto \frac{T}{L^2}.$$

Show your working clearly and explain your reasoning **[2]**

(ii) The thickest string on the bass guitar is 0.86 m long and is at a tension of 190 N.

You can assume that this string has the same mean density as a double bass string,which is 0.98 m long and is at a tension of 290 N.

By considering the ratio $\frac{T}{L^2}$ for the thickest strings on each instrument, discuss how the two strings will differ, and how plucking a double bass string would feel different from plucking a bass guitar string of the same fundamental frequency. You may include calculations in your answer. **[3]**

[Question total: 14]

2 Two students, Alice and Bob, are using a diffraction grating to determine the wavelength of light emitted by a light-emitting diode (LED).

Bob places a ruler a distance x behind the grating and Alice observes the positions on the ruler corresponding to the straight-through beam (**A**) and the first-order diffracted beams (**B** and **C**), as shown in **Fig. 2.1**.

y_1 and y_2 are the observed values of y, the displacement on the ruler of **C** and **B** from **A**.

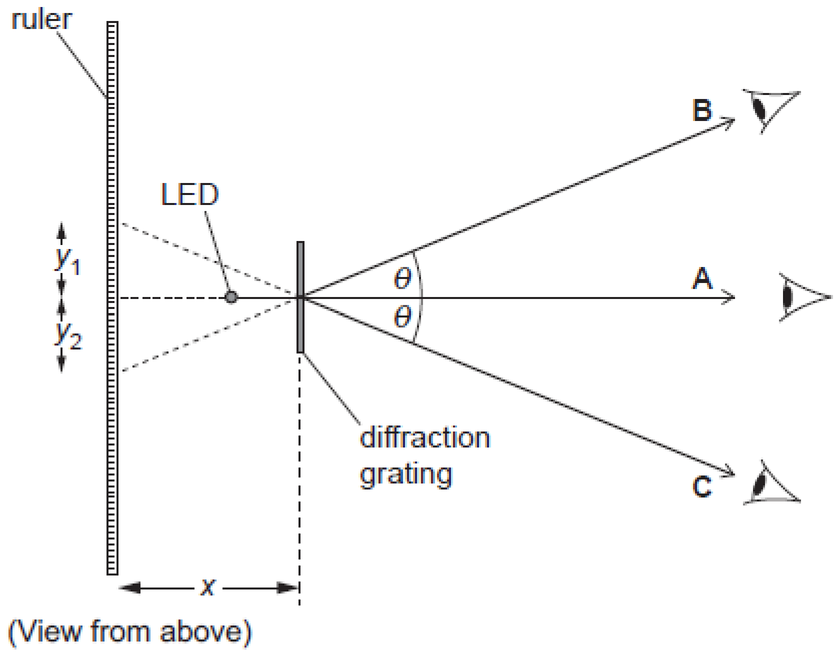

Fig. 2.1

(a) By measuring the distances y_1 and y_2, Alice and Bob intend to find the angle θ of first-order diffraction maximum.

(i) For this LED, Alice and Bob obtain the following data for the first-order maximum.

Use the table to calculate the mean value of y and its uncertainty.

mean = ……………………………….. cm

uncertainty = ……………………………….. cm **[3]**

(ii) Explain why repeating the measurements at least three times is good experimental practice. **[2]**

(iii) Describe how Alice and Bob could use the values obtained in part **(a)(i)** to find the mean frequency of the light from the LED. You do not need to do any calculations.

[3]

(b) * Repeating the experiment for different LEDs, Bob used their data to plot the graph of **Fig. 2.2.**

The values of E, the minimum energy needed to emit a photon, were obtained by measuring the minimum p.d. that would allow the LED in question to emit light. The gradient of the best-fit straight line should be the Planck constant, h.

Bob's analysis is shown on the graph of **Fig. 2.2** and in the box following.

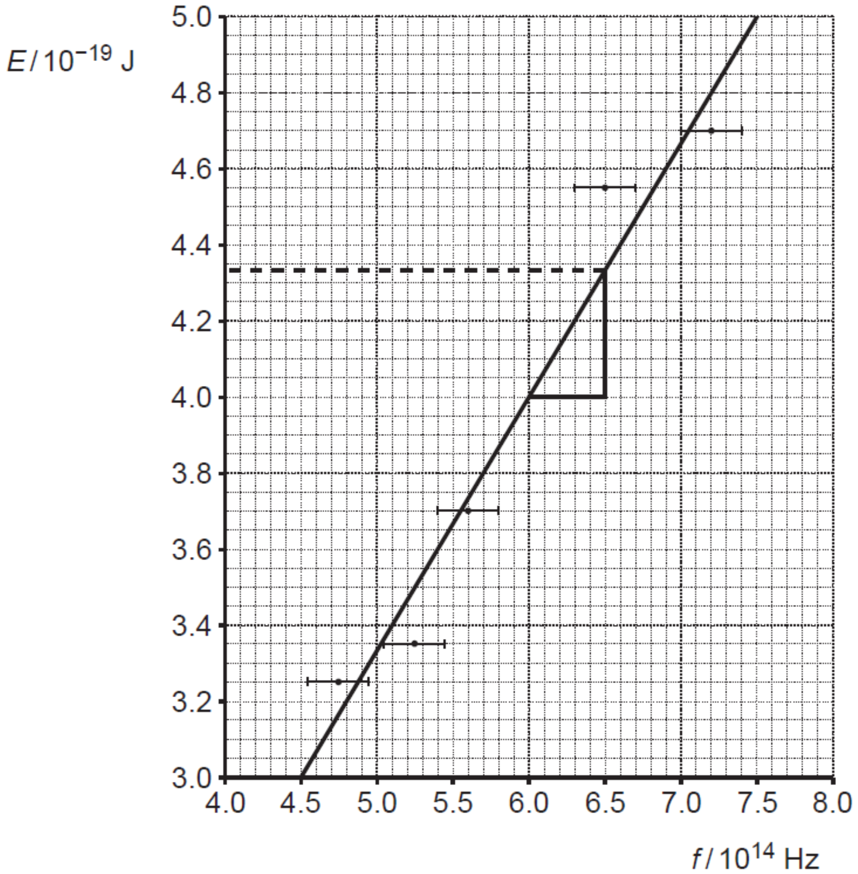

Fig. 2.2

Evaluate his analysis of the data from the experiment.

$$h = \text{gradient} = \frac{4.33 \times 10^{-19} - 4.0 \times 10^{-19}}{0.5 \times 10^{14}} = 6.6 \times 10^{-34}\ \text{J s}.$$

This is exactly the same as the data book, so the experiment worked well.

[6]

[Question total: 14]

Total Marks for Question Set 7: 28