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**ADVANCED**
**General Certificate of Education**
**2010**

# Physics

## Assessment Unit A2 1

*assessing*

## Momentum, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

**[AY211]**

**THURSDAY 27 MAY, AFTERNOON**

AY211

**Centre Number**

| 71 | |
|---|---|

**Candidate Number**

| |
|---|

**TIME**

1 hour 30 minutes.

**INSTRUCTIONS TO CANDIDATES**

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all** questions.
Write your answers in the spaces provided in this question paper.

**INFORMATION FOR CANDIDATES**

The total mark for this paper is 90.
Quality of written communication will be assessed in question **2(a)(ii)**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.
Question 9 contributes to the synoptic assessment required of the specification. Candidates should allow approximately 20 minutes for this question.

| For Examiner's use only | |
|---|---|
| Question Number | Marks |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |

| Total Marks | |
|---|---|

5367

1 The graph in **Fig 1.1** shows how the displacement of a nitrogen molecule varies with time in the air as a result of a sound wave passing. The molecule can be assumed to execute simple harmonic motion.

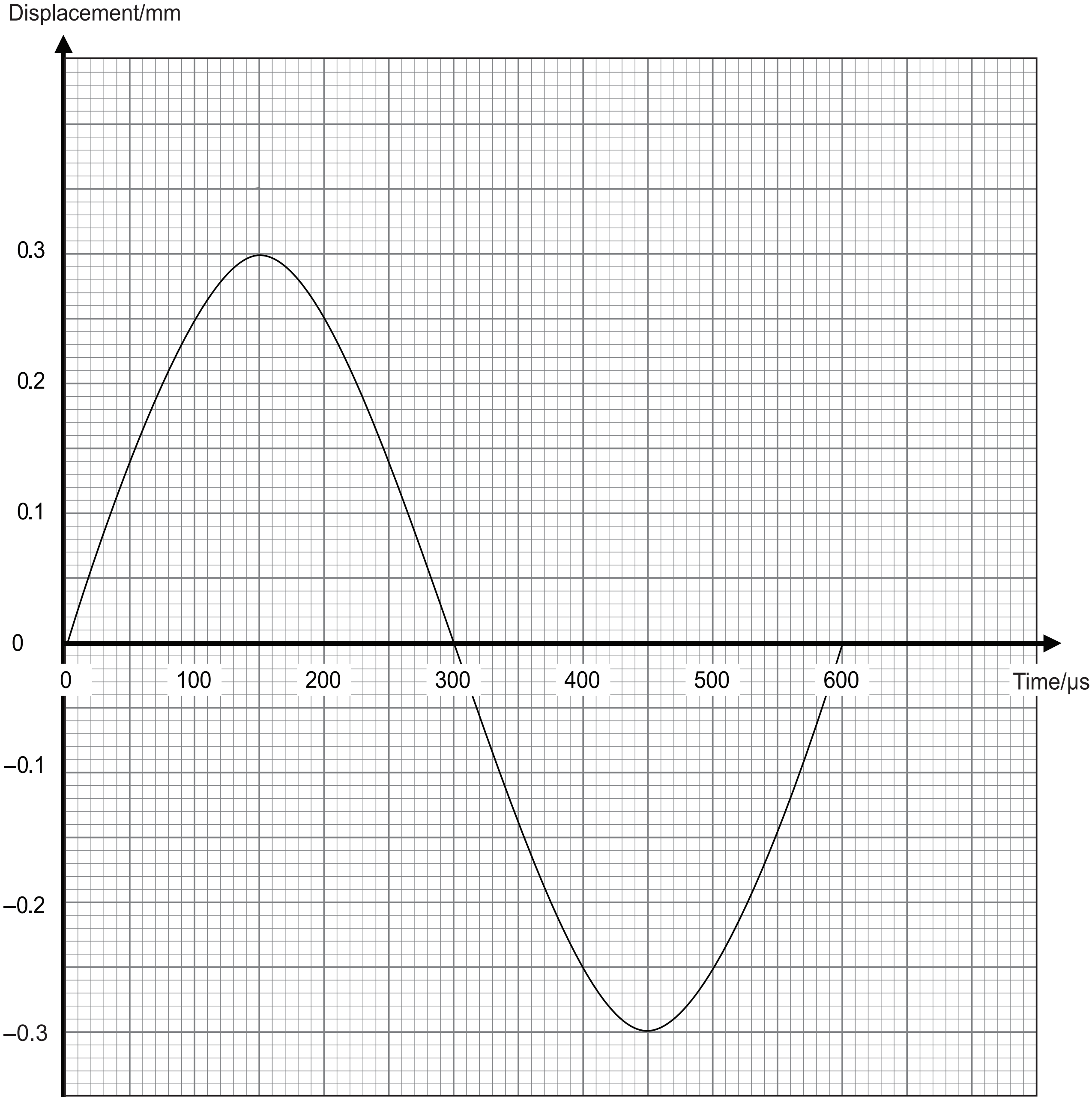


**Fig 1.1**

| Examiner Only | |
|---|---|
| Marks | Remark |

**(a)** Describe the displacement of the nitrogen molecule during the 600 μs duration as shown on the graph in **Fig 1.1**.

______________________________________________

______________________________________________

______________________________________________

______________________________________________ [2]

| Examiner Only | |
|---|---|
| Marks | Remark |

**(b)** Using the displacement–time graph in **Fig 1.1** show that the **maximum** velocity of the nitrogen molecule, as a result of the passage of the sound wave, is approximately 3 m $s^{-1}$.

[3]

**(c) (i)** The nitrogen molecule will possess momentum, define momentum.

_______________________________________________

_______________________________________________ [1]

**(ii)** Calculate the maximum momentum of the nitrogen molecule if the mass of the nitrogen molecule is $4.65 \times 10^{-26}$ kg. Include its unit.

Momentum = ____________________ [1]

Unit = ____________________ [1]

| Examiner Only | |
|---|---|
| Marks | Remark |

**2** **(a)** Consider one of the standard experiments on the behaviour of gases to show that the product of gas pressure and volume is a constant for a fixed mass of gas at a constant temperature.

**(i)** Draw a labelled sketch of the apparatus you would use.

[2]

**(ii)** Describe how the experiment is conducted in order to obtain a series of pressure and volume values.

______________________________________________

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______________________________________________

______________________________________________

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______________________________________________ [3]

Quality of written communication [2]

**(b) (i)** The results from such an experiment are displayed in the graph of **Fig 2.1**.

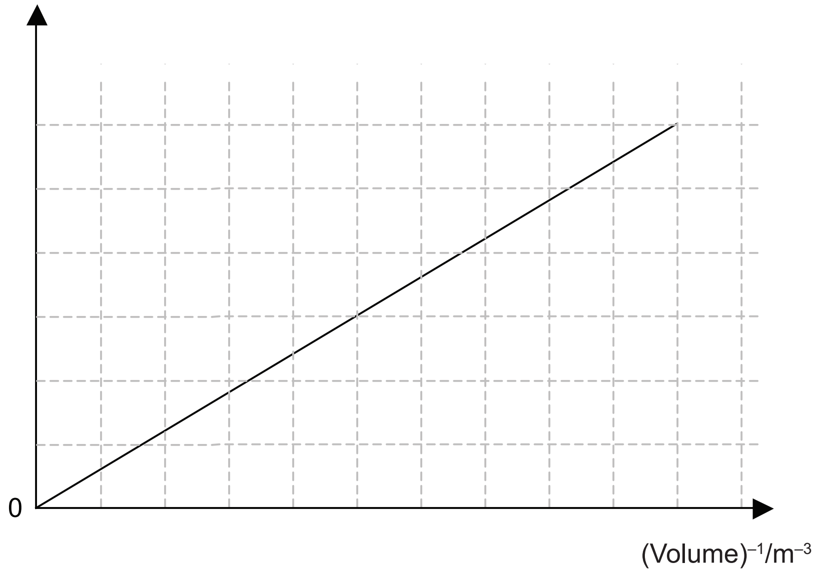


**Fig 2.1**

For a set of results the gradient is measured and found to be 12 200 Pa m$^3$. Show that the temperature of the gas is 4 °C if the gas contains 5.30 moles.

[3]

**(ii)** On the axes of **Fig 2.1** draw a line to indicate the results of a similar experiment only for the same gas sample but at a higher temperature. [1]

| Examiner Only | |
| --- | --- |
| Marks | Remark |

| Examiner Only | |
|---|---|
| Marks | Remark |

**3** Ganymede is the largest of Jupiter's satellites, and it has a mass of $1.48 \times 10^{23}$ kg. The radius of its circular orbit is $1.07 \times 10^{9}$ m and it takes 172 hours to complete one orbit of Jupiter.

**(a) (i)** Show that the mean angular velocity of Ganymede is $1.01 \times 10^{-5}$ rad s$^{-1}$.

[2]

**(ii)** Calculate the linear speed of Ganymede as it orbits Jupiter.

Speed = ____________________ m s$^{-1}$ [3]

**(b) (i)** Calculate the magnitude of the force acting to keep Ganymede in this orbit.

Force = ________________ N [2]

**(ii)** In what direction does this force act?

______________________________________________

____________________________________________ [1]

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(Questions continue overleaf)

| Examiner Only | |
|---|---|
| Marks | Remark |

**4** **Fig. 4.1** illustrates an experimental arrangement to investigate resonance and damping.

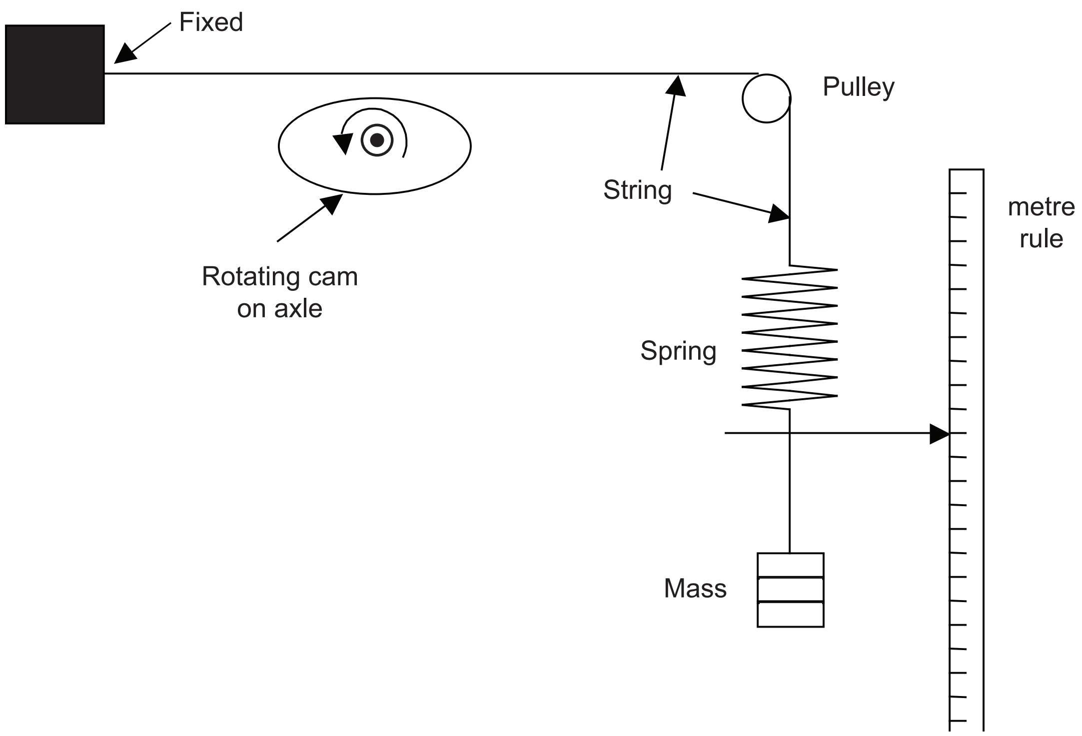


**Fig. 4.1**

The apparatus consists of a piece of string, initially horizontal, securely fixed at one end, placed over a pulley in order to support a vertical spring to which a mass is attached. A pointer, secured to the lower end of the spring, indicates a position on a vertical metre rule. An oval shaped cam rotates and as it does so it causes the string it comes into contact with to lift twice in each rotation. The rotation frequency of the cam can be altered using a signal generator.

This apparatus is used to demonstrate resonance.

**(a)** Identify the component(s) that

**(i)** is/are forced to vibrate

_______________________________________________ [1]

**(ii)** provide(s) the driving force that results in the vibration

_______________________________________________ [1]

**(b) (i)** Label the vertical axis of **Fig. 4.2** and sketch the shape of a typical resonance graph for the system as the frequency of the cam is progressively increased.


**Fig. 4.2**

[2]

**(ii)** Suggest a practical method of increasing the damping in the experimental arrangement.

______________________________________________

______________________________________________

____________________________________________ [1]

**(iii)** On **Fig. 4.2** sketch the resonance graph expected for the more heavily damped system. Clearly label this new graph D. [3]

**(c)** Resonance occurs when the signal generator frequency is 16 Hz. That is, the oval shaped cam makes 16 complete rotations every second.

What is the natural frequency of the system which has been forced to vibrate?

Frequency = ___________ Hz [1]

| Examiner Only | |
|---|---|
| Marks | Remark |

| Examiner Only | |
|---|---|
| Marks | Remark |

**5** The A2 Data and Formulae Sheet gives the following equation for nuclear radius $r$:

$$r = r_0 A^{\frac{1}{3}}$$ **Equation 5.1**

**(a)** What do the following terms in Equation 5.1 represent?

**(i)** $r_0$ = ______________________________ [1]

**(ii)** $A$ = ______________________________ [1]

**(b) (i)** On **Fig 5.1** sketch the shape of graph expected for **Equation 5.1** given the axes as labelled on **Fig. 5.1**. [1]


**Fig. 5.1**

**(ii)** Explain how to find a value for $r_0$ from the graph you sketched in **Fig. 5.1**.

______________________________

______________________________ [1]

| Examiner Only | |
|---|---|
| Marks | Remark |

**(c) (i)** Show that the nuclear radius $^{109}_{47}Ag$ is 5.73 fm if $r_0 = 1.20$ fm.

[1]

**(ii)** Calculate the nuclear density of silver.
The volume of a sphere is $\frac{4}{3}\pi r^3$

Nuclear density = ______________________ $kg\,m^{-3}$ [3]

**(iii)** Metallic silver has a density of $10.5 \times 10^3\,kg\,m^{-3}$ and another metal selenium has a density less than half that at $4.80 \times 10^3\,kg\,m^{-3}$.

Comment on the **nuclear** density of selenium compared to the **nuclear** density of silver. Explain your reasoning.

________________________________________________

________________________________________________

________________________________________________

________________________________________________ [2]

| Examiner Only | |
|---|---|
| Marks | Remark |

**6** Complete the **Table 6.1** by inserting appropriate values of mass and charge for the alpha particle, the beta particle and the gamma radiation.

**(a)** **Table 6.1**

| | **Mass/u** | **Charge/C** |
|---|---|---|
| Alpha particle | | |
| Beta particle | $\frac{1}{1840}$ | |
| Gamma radiation | | |

[3]

An alpha particle is released into the atmosphere with a typical kinetic energy of 5 MeV while a beta particle is typically released with kinetic energy of 0.2 MeV.

**(b)** **(i)** How do these decay particles lose their kinetic energy after release into the atmosphere?

______________________________________________

______________________________________________

______________________________________________

______________________________________________ [2]

**(ii)** Explain why the alpha particle has a shorter range in air than the beta particle even though it is released with more kinetic energy.

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________ [2]

| Examiner Only | |
|---|---|
| Marks | Remark |

**(c)** The diagram in **Fig. 6.2** represents the decay chain of protactinium 236 to radium 228 in three consecutive stages *r*, *s* and *t*.

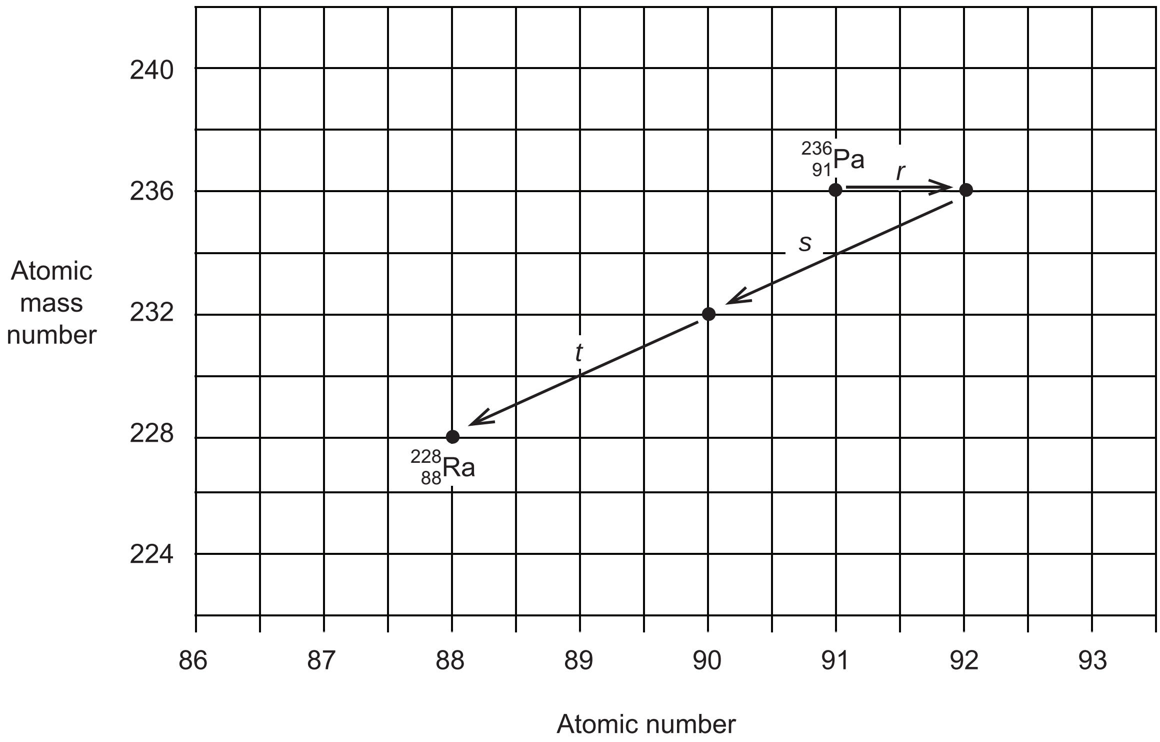


**Fig. 6.2**

Identify the decay processes *r*, *s* and *t*. Explain your reasoning.

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________ [3]

**7 (a) (i)** Draw the shape of the binding energy per nucleon against mass number graph on **Fig. 7.1**. [2]

The maximum value has been marked on each axis.

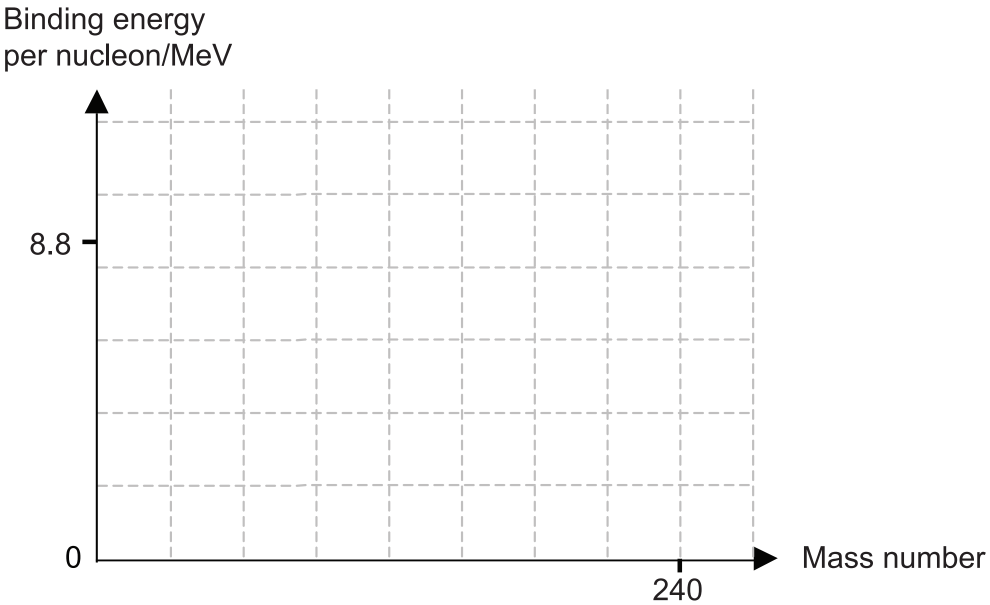


**Fig. 7.1**

**(ii)** What is meant by the expression '**binding energy per nucleon**'?

______________________________________________________________

______________________________________________________________ [1]

| Examiner Only | |
|---|---|
| Marks | Remark |

| Examiner Only | |
|---|---|
| Marks | Remark |

**(b) (i)** Fission and fusion are nuclear processes that give out energy. State how they differ in terms of the nuclei involved and what happens to those nuclei.

____________________________________________________________ [2]

**(ii)** With reference to the graph drawn in **Fig. 7.1**, explain how both nuclear fission and fusion can liberate energy.

____________________________________________________________ [2]

**(iii)** Explain why the energy given out **per nucleon** from fusion is greater than from fission.

____________________________________________________________ [1]

| Examiner Only | |
|---|---|
| Marks | Remark |

**8** Producing electricity from nuclear sources requires a reactor. Practical fission reactors already exist but only experimental fusion reactors, such as JET.

**(a) (i)** Name the most likely nuclide used as fuel in a fission reactor.

Nuclide is ______________________ [1]

**(ii)** Name the two nuclides most likely to be used as fuel in a terrestrial fusion reactor.

Nuclides are __________________ and ________________ [1]

**(b)** In both reaction types the **kinetic energy** of sub-atomic particles is critical to the process.

**(i)** 1. Name the sub-atomic particle in the fission reaction.

Particle __________________ [1]

2. State why the kinetic energy is altered and how this is achieved.

______________________________________________

______________________________________________

______________________________________________

______________________________________________ [3]

**(ii)** 1. Name the particle in the fusion reaction.

Particle __________________ [1]

2. State in what way the kinetic energy is altered and why it is altered.

______________________________________________

______________________________________________

______________________________________________

______________________________________________ [2]

**9 Introduction**

An experiment is performed to investigate the relationship between the frequency of the sound emitted from two identical speakers and the separation of adjacent loud sounds (maxima) in the interference pattern formed.

A signal generator is connected to the two loudspeakers so that they both emit sound waves of the same frequency and amplitude. The waves emitted from each speaker are in-phase. **Fig. 9.1** illustrates the experimental arrangement.

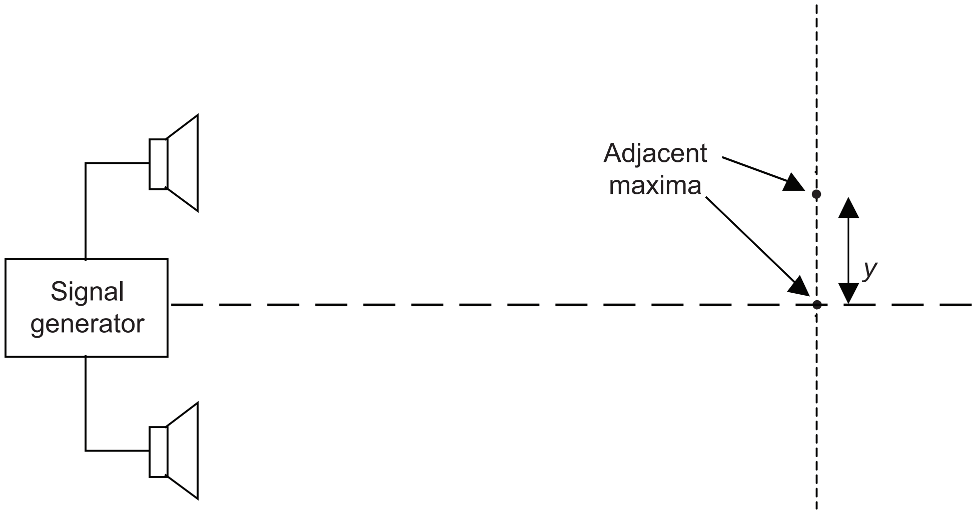


**Fig. 9.1**

The relationship between frequency *f* and separation *y* is given in **Equation 9.1**.

$$f = ky^n \qquad \textbf{Equation 9.1}$$

where *k* and *n* are constants the values of which are not known.

By taking logarithms of each side of **Equation 9.1,** we allow comparison to y = m*x* + c which enables a linear graph to be drawn from which *k* and *n* can be determined.

**(a)** Complete **Equation 9.2**.

$\lg_{10}(f) =$ ________________________________ **Equation 9.2** [2]

| Examiner Only | |
|---|---|
| Marks | Remark |

**Table 9.1** gives data for the sound frequency, *f*, and corresponding separation, *y*, obtained during this experiment.

| Examiner Only | |
|---|---|
| Marks | Remark |

**Table 9.1**

| *f*/Hz | *y*/m | | |
|---|---|---|---|
| 256 | 3.32 | | |
| 317 | 2.68 | | |
| 422 | 2.01 | | |
| 513 | 1.66 | | |
| 627 | 1.36 | | |

**(b)** Use the blank columns in **Table 9.1** to calculate any other values you will need to draw the linear graph. Remember to head the columns with appropriate quantity and unit. [3]

**(c)** **(i)** On the grid of **Fig 9.2** opposite draw the linear graph. Clearly label both axes. [3]

**(ii)** Use your graph in **Fig. 9.2** to find values for the constants *n* and *k*.

*n* = ______________________________ [2]

*k* = ______________________________ [2]

**Fig. 9.2**

**(iii)** This experiment is analogous to Young's double slit experiment with light. The Data and Formulae Sheet gives, for two-source interference, the equation:

$$\lambda = \frac{ay}{d}$$

If the speakers in the sound experiment are 2 m apart and the plane of the speakers is 5 m from the plane of the interference pattern, calculate a value for the speed of sound in air making use of a result from **Table 9.1** and this equation.

Speed of sound = ___________ $m\ s^{-1}$ [3]

**(d)** At the position of an interference maximum each speaker contributes a sound intensity of 0.66 $mW\,m^{-2}$. What will the intensity level be at this position?

The threshold of hearing is $1.0 \times 10^{-12}\,W\,m^{-2}$.

Intensity level = _____________________ dB [2]

| Examiner Only | |
|---|---|
| Marks | Remark |

**THIS IS THE END OF THE QUESTION PAPER**

**GCE Physics**

**Data and Formulae Sheet for A2 1 and A2 2**

## Values of constants

| | |
|---|---|
| speed of light in a vacuum | $c = 3.00 \times 10^8$ m s$^{-1}$ |
| permittivity of a vacuum | $\varepsilon_0 = 8.85 \times 10^{-12}$ F m$^{-1}$ |
| | $\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{ F}^{-1} \text{ m}\right)$ |
| elementary charge | $e = 1.60 \times 10^{-19}$ C |
| the Planck constant | $h = 6.63 \times 10^{-34}$ J s |
| (unified) atomic mass unit | 1 u $= 1.66 \times 10^{-27}$ kg |
| mass of electron | $m_e = 9.11 \times 10^{-31}$ kg |
| mass of proton | $m_p = 1.67 \times 10^{-27}$ kg |
| molar gas constant | $R = 8.31$ J K$^{-1}$ mol$^{-1}$ |
| the Avogadro constant | $N_A = 6.02 \times 10^{23}$ mol$^{-1}$ |
| the Boltzmann constant | $k = 1.38 \times 10^{-23}$ J K$^{-1}$ |
| gravitational constant | $G = 6.67 \times 10^{-11}$ N m$^2$ kg$^{-2}$ |
| acceleration of free fall on the Earth's surface | $g = 9.81$ m s$^{-2}$ |
| electron volt | 1 e$V = 1.60 \times 10^{-19}$ J |

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5367.02

The following equations may be useful in answering some of the questions in the examination:

**Mechanics**

| | |
|---|---|
| Conservation of energy | $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force |
| Hooke's Law | $F = kx$ (spring constant $k$) |

**Simple harmonic motion**

| | |
|---|---|
| Displacement | $x = A \cos \omega t$ |

**Sound**

| | |
|---|---|
| Sound intensity level/dB | $= 10 \lg_{10} \frac{I}{I_0}$ |

**Waves**

| | |
|---|---|
| Two-source interference | $\lambda = \frac{ay}{d}$ |

**Thermal physics**

| | |
|---|---|
| Average kinetic energy of a molecule | $\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT$ |
| Kinetic theory | $pV = \frac{1}{3}Nm\langle c^2 \rangle$ |
| Thermal energy | $Q = mc\Delta\theta$ |

**Capacitors**

| | |
|---|---|
| Capacitors in series | $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ |
| Capacitors in parallel | $C = C_1 + C_2 + C_3$ |
| Time constant | $\tau = RC$ |

## Light

Lens formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Magnification $m = \frac{v}{u}$

## Electricity

Terminal potential difference $V = E - Ir$ (E.m.f. $E$; Internal Resistance $r$)

Potential divider $V_{out} = \frac{R_1 V_{in}}{R_1 + R_2}$

## Particles and photons

Radioactive decay $A = \lambda N$

$A = A_0 e^{-\lambda t}$

Half-life $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

de Broglie equation $\lambda = \frac{h}{p}$

## The nucleus

Nuclear radius $r = r_0 A^{\frac{1}{3}}$