Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A420U10-1

S24-A420U10-1

eduqas Part of WJEC

FRIDAY, 24 MAY 2024 – MORNING

PHYSICS – A level component 1

Newtonian Physics

2 hours 15 minutes

	For Examiner's use only		
	Question	Maximum Mark	Mark Awarded
Section A	1.	8	
	2.	9	
	3.	12	
	4.	13	
	5.	16	
	6.	7	
	7.	15	
Section B	8.	20	
	Total	100	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.

Section **A**: 80 marks. You are advised to spend about 1 hour 35 minutes on this section.

Section **B**: 20 marks. Comprehension. You are advised to spend about 40 minutes on this section.

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question **5**(d).

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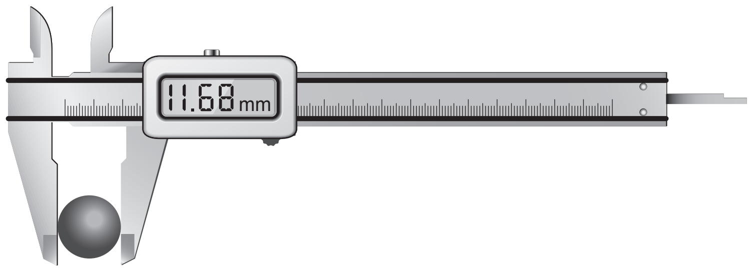
SECTION A

Answer **all** questions.

1. Two students, Jack and Gill, are assigned the task of determining the density of a glass marble.

(a) Jack takes a single diameter measurement of the marble using digital calipers.



He also takes a single mass reading of the marble using an electronic balance. His results are shown below.

Readings	
Diameter / mm	11.68
Mass / g	2.3

Resolution of measuring instrument	
Resolution of calipers	± .... mm
Resolution of electronic balance	± 0.1 g

(i) **Complete the table** above by adding the resolution of the calipers. [1]

(ii) After taking the measurements, Jack notices that when the jaws of the calipers are closed they read −0.04 mm. Suggest how Jack should allow for this discrepancy in the density calculation. [1]

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(iii) Hence, show that the density of the marble is approximately 2.7 $\mathbf{g\,cm^{-3}}$. [2]

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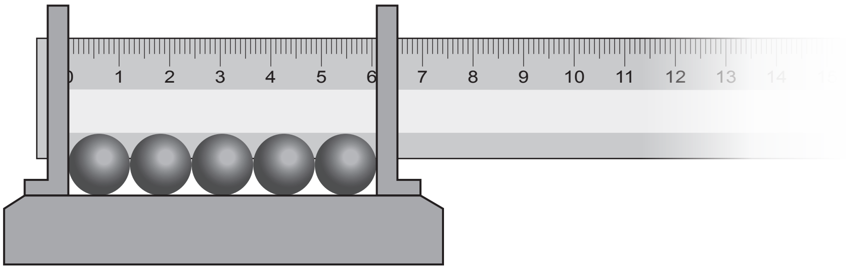
(b) Gill decides to measure across five marbles with a ruler, as shown in the diagram below.



She also takes a single mass reading of the five marbles using an electronic balance. Her results are shown below.

Readings	
Distance reading from diagram / mm	61
Mass of 5 marbles / g	11.5

Gill's results give a density of 2.4 $g\,cm^{-3}$ ± 6%. The manufacturer's value for the density of the glass is 2.5 $g\,cm^{-3}$. Evaluate Jack's and Gill's **methods** and **results**. [4]

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Turn over.

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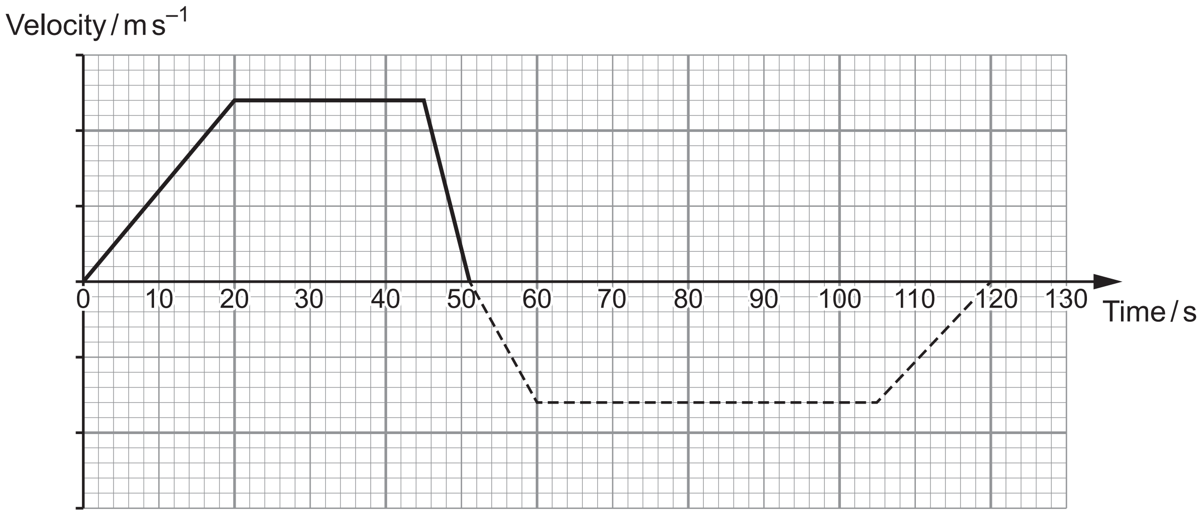
2. An electric scooter travels from A to B along a straight road.

(a) The scooter starts from rest and accelerates at $0.60\,\text{m}\,\text{s}^{-2}$ for 20 seconds. The scooter then travels at a constant velocity for a further 25 seconds. The scooter then decelerates uniformly to rest at $2.0\,\text{m}\,\text{s}^{-2}$.

The motion of the scooter as it moves from A to B is shown as a solid line (——) on the grid below. **Note that the velocity scale is not included.**



(i) Use an appropriate equation of motion to show that the scooter reaches a velocity of $12\,\text{m}\,\text{s}^{-1}$ after 20 seconds. [1]

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(ii) Show that the mean speed for the first 51 seconds is approximately $9\,m\,s^{-1}$. [3]

(b) The dashed line (----) on the grid represents the return journey from B to A. Charlie and Lola analyse the electric scooter's motion over the **entire journey** (from A to B and back again).

Charlie states that the mean speed is $9\,m\,s^{-1}$. Lola states that the mean velocity is $0\,m\,s^{-1}$. Discuss the validity of both these statements. [3]

(c) The development of the technology of electric scooters has seen them becoming more common on some city roads in the UK. State **one** benefit and **one** risk of using this form of transport. [2]

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3. (a) Define 'work'. [2]

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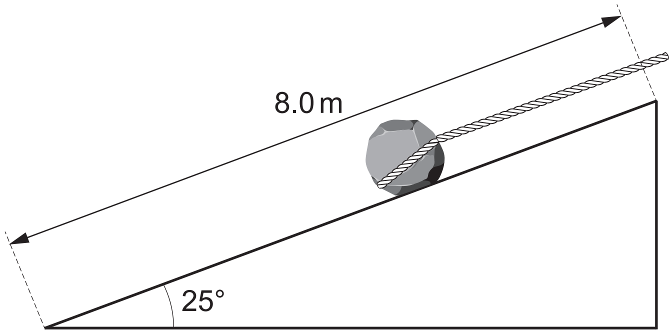
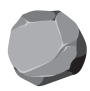
(b) A rope is used to drag a 160 kg boulder 8.0 m up a ramp at a constant velocity. The ramp's surface is rough and at an angle of 25° above the horizontal, as shown. The tension in the rope is 1500 N.



(i) Clearly draw and label the forces acting on the boulder, which is redrawn below. [3]



(ii) Calculate the work done moving the boulder through the distance of 8.0 m. [1]

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(iii) Determine the frictional force acting on the boulder. [3]

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(c) Determine the efficiency of the process and account for the wasted energy in terms of particles. [3]

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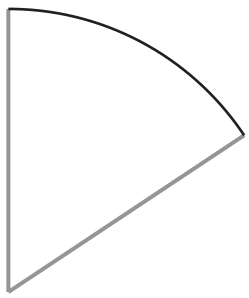
4. (a) Use the diagram below to define the radian. [2]



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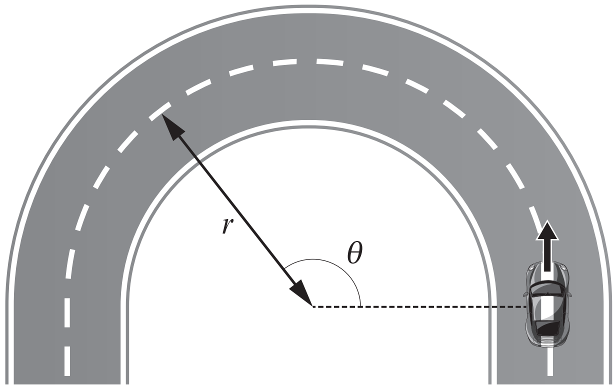
(b) (i) A car of mass 800 kg moves around a flat, circular portion of track at a constant speed of 90 km hour^{-1}.



The car sweeps out an angle, θ, equal to 2.1 radians in a time of 2.5 s. Determine the radius, r, of the circular track. [3]

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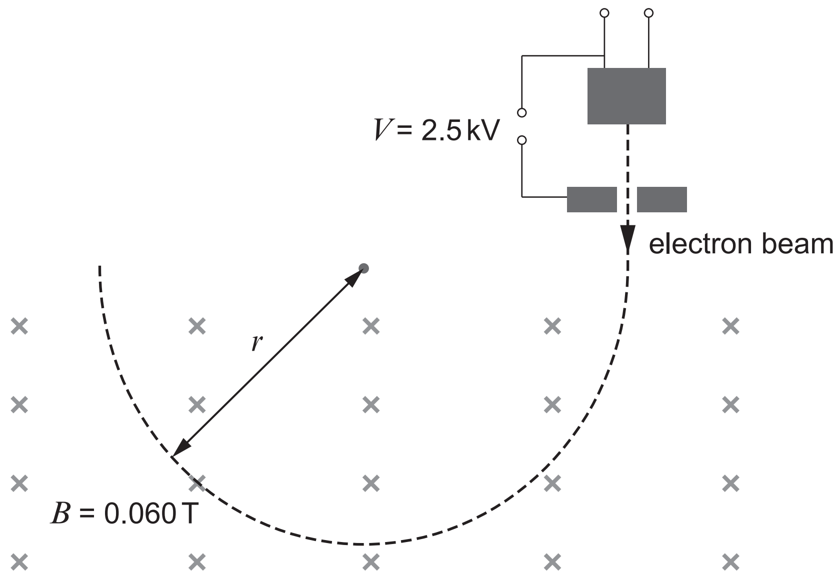
(ii) Electrons follow circular paths in a uniform magnetic field.



The electrons in a beam are accelerated through a pd of 2.5 kV. They enter a uniform magnetic field of strength 0.060 T which is perpendicular to the direction of the electron beam. Calculate the radius of the circular path followed by the electrons. [4]

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(iii) For both the car and the electron:

I. name the force that acts to provide the resultant force necessary for circular motion, [1]

car: ....

electron: ....

II. compare the magnitudes of the resultant forces. [3]

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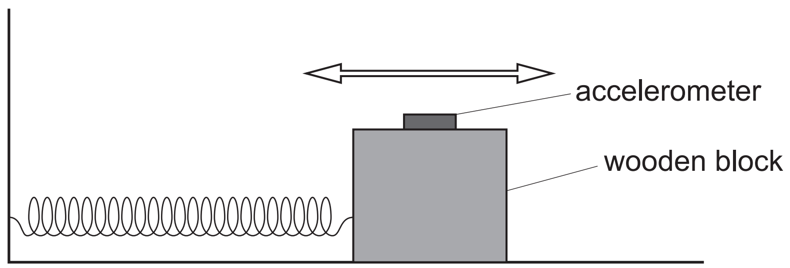
5. A 0.35 kg wooden block undergoes simple harmonic motion on a friction-free surface as shown. The block has an accelerometer attached that gives a maximum value of 1.8 m s^{-2} during the oscillations. The spring causing this motion has a spring constant of 4.5 N m^{-1}.



(a) Define 'simple harmonic motion'. [2]

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(b) Show that the maximum displacement of the block is 14 cm. [2]

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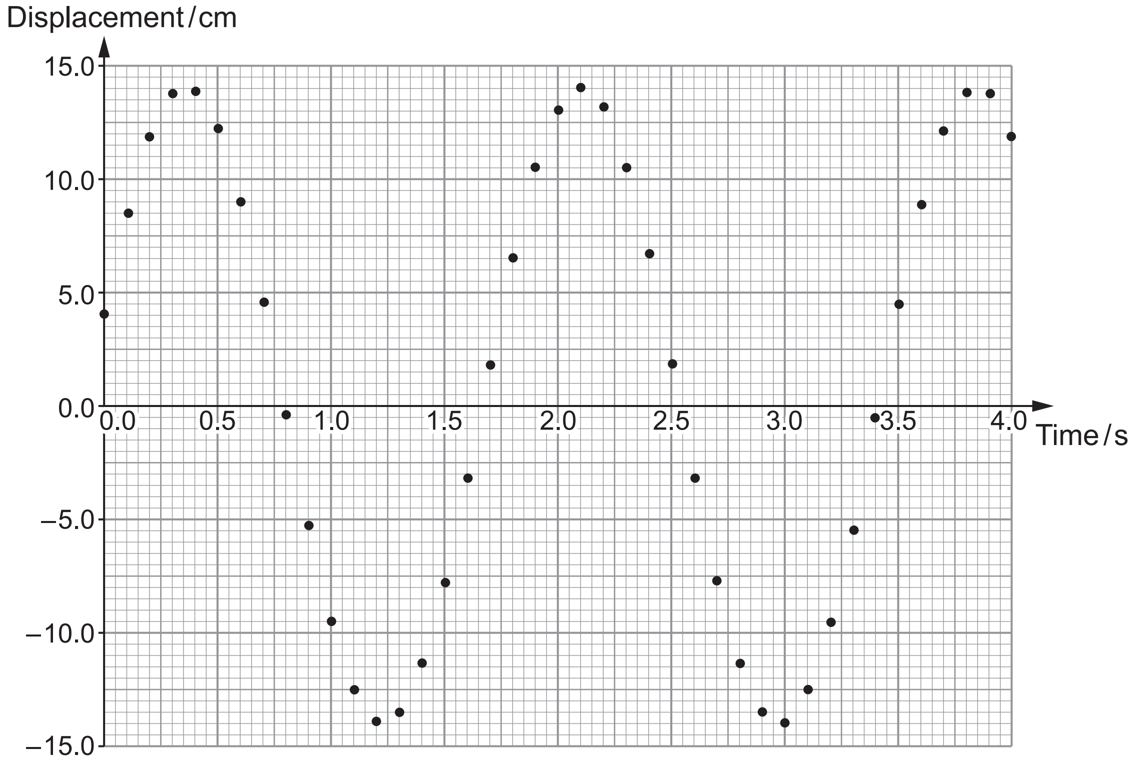
(c) (i) A student begins filming the block on her mobile phone when the block has a **displacement of 4.0 cm**. She then watches the video in slow motion, recording the displacement at regular time intervals. She produces the following graph.



The student states that the motion of the block can be described using:

$$x = 14\cos(3.6t + 1.28)$$

where x is the displacement in cm and t is the time in seconds.
Use the graph above to evaluate whether the student is correct. [4]

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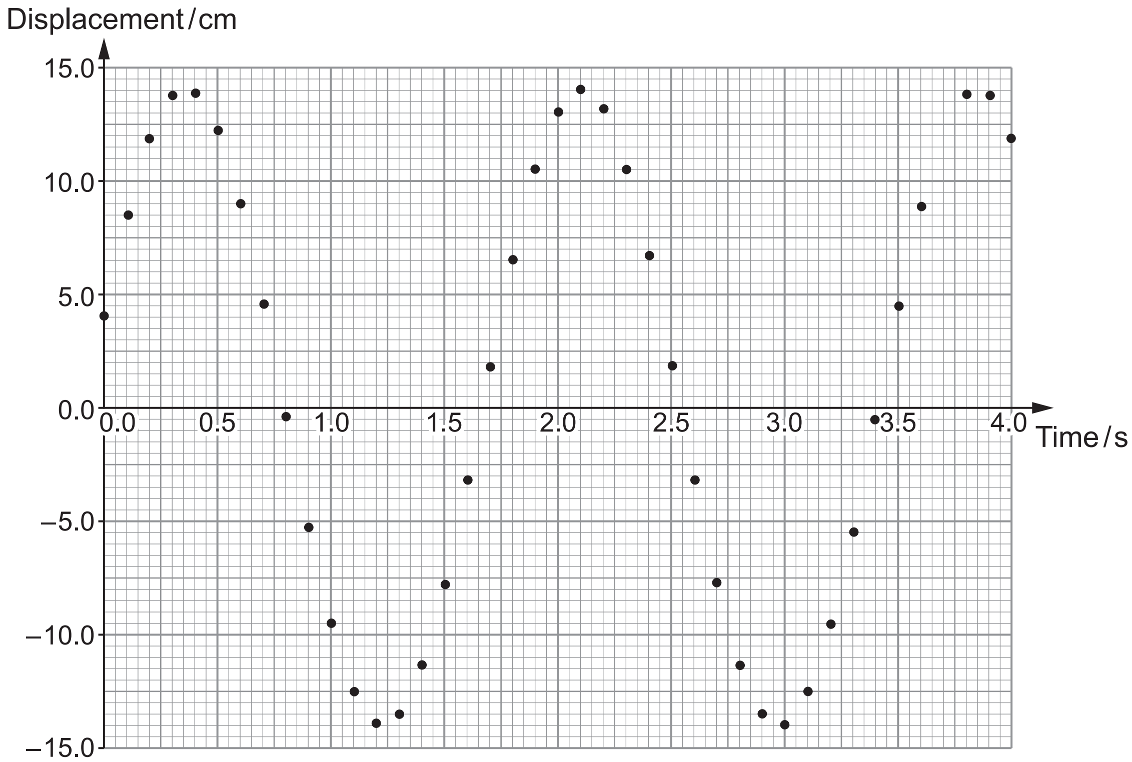
(ii) Below is a copy of the graph in part (c)(i). On this grid, sketch the **acceleration-time** graph for the block. **No scale is required on the vertical axis.** [2]



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(d) The acceleration due to gravity, g, can be determined by conducting an experiment with a simple pendulum. Describe the experiment, including the graphical analysis that could be used to determine the value of g. [6 QER]

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6. (a) Define the 'mole'. [1]

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(b) (i) Use the ideal gas equation and $pV = \frac{1}{3}Nm\overline{c^2}$ to show that, for **one mole**, the total translational kinetic energy is given by $\frac{3}{2}RT$. [3]

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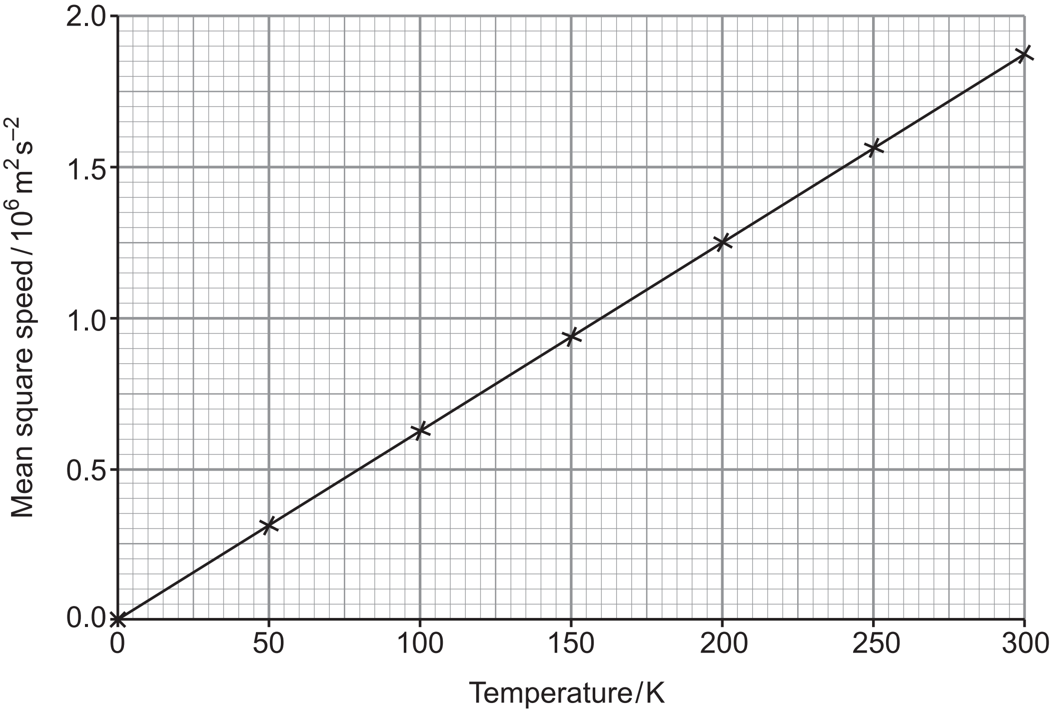
(ii) The mean square speeds of the molecules in a monatomic ideal gas sample are plotted as a function of temperature in the graph below.



The masses of three molecules are shown below:

Helium = 6.6×10^{-27} kg

Radon = 3.7×10^{-25} kg

Xenon = 2.2×10^{-25} kg

Identify the gas present in the sample. Give your reasoning clearly. [3]

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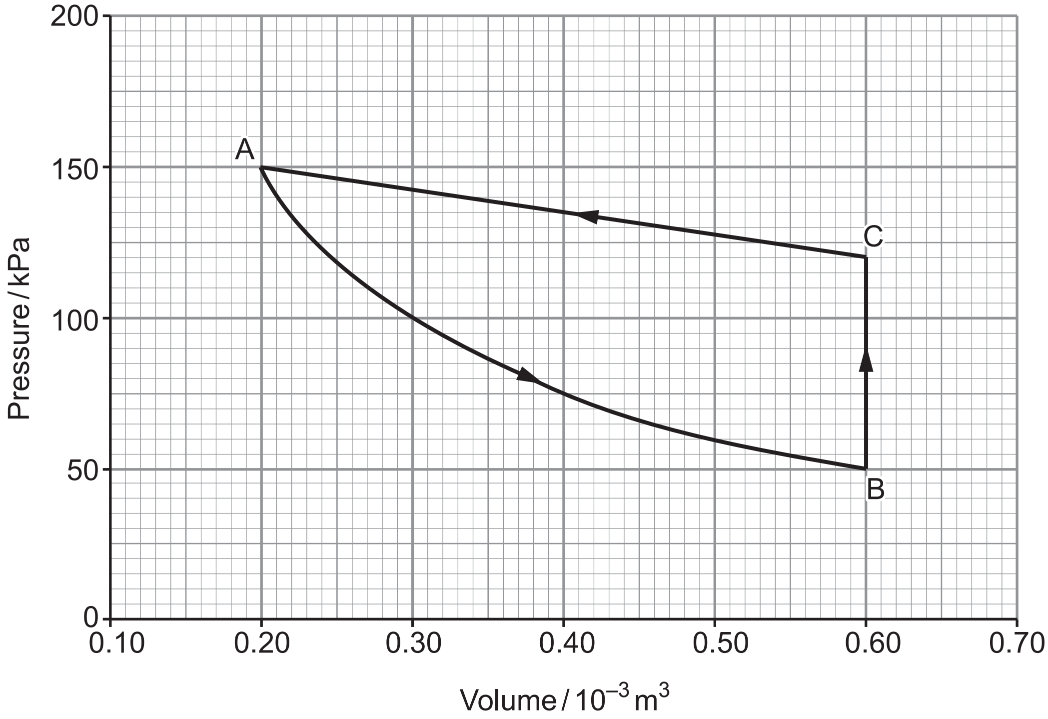
7. A sample of monatomic gas has an initial pressure of 150 kPa and a volume of $0.20\,m^3$.

The gas is taken through a series of changes outlined below and shown in the graph.

$\overrightarrow{AB}$ the gas expands at constant temperature to a volume of $0.60\,m^3$.

$\overrightarrow{BC}$ the gas is heated at constant volume until it reaches a pressure of 120 kPa.

$\overrightarrow{CA}$ the gas is compressed and its pressure increases linearly.



(a) Confirm that the change $\overrightarrow{AB}$ occurs at a constant temperature. [3]

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(b) (i) State what is meant by the internal energy of an ideal gas. [1]

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(ii) I. Calculate the internal energy of the gas at B and C. [2]

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II. Hence, determine the following ratio: [2]

$$\frac{c_{\text{rms}} \text{ at C}}{c_{\text{rms}} \text{ at B}}$$

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(iii) By considering the motion of the gas molecules, explain:

- how a gas exerts a pressure on the walls of its container
- why the pressure increases as temperature increases between B and C. [4]

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(c) For the whole cycle, $\overrightarrow{ABCA}$, explain using the first law of thermodynamics, whether or not there is a net flow of heat into the system. [3]

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SECTION B

Answer **all** questions.

8. Read through the following article carefully.

Paragraph **Some Physics of Music**

1 When stationary waves are produced on a string, only certain frequencies are allowed and this is the basis of the whole realm of music. The allowed frequencies are:

$$f_0, 2f_0, 3f_0, 4f_0, 5f_0, 6f_0 ...$$

where f_0 is the lowest allowed frequency called the 1st mode. A diagram of the first three oscillation modes is shown in Figure 1.

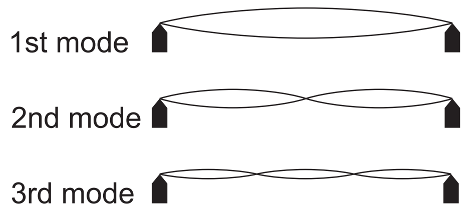


Figure 1

2 "How can this simple bit of obvious physics be responsible for the whole of music?" I hear you asking. Well, the answer is very simple and can be traced back 2500 years to a Greek polymath by the name of Pythagoras of Samos. You have probably heard of him because of his famous mathematical theorem. It turns out that all the information required to invent the whole of the music scale is in Figure 1.

3 The 2nd allowed mode in Figure 1 has exactly half the wavelength of the 1st mode and exactly double the frequency. These two musical notes sound similar though. The higher frequency is said to be an octave higher than the lower frequency. Now, if we can find other sensible notes between these two, maybe we can start to define a scale so that we can write music. This brings us nicely to the 3rd allowed mode which has a frequency of $3f_0$. Pythagoras defined this frequency as another note of a normal scale. Pythagoras used this frequency of $3f_0$ to define every note of the musical scale. Unfortunately, this theory led to notes that were out of tune. This note should, in fact, be:

$$f = 2f_0 \times 2^{\frac{7}{12}}$$ **Equation 1**

4 OK, fine. Is there anything else that physics can tell us about musical tuning? Well, in point of fact, there is. Players of brass instruments often complain that their instruments are flat (out of tune, to a lower frequency) because they haven't warmed their instruments up yet. However, if the instrument is cold, the instrument will shrink and you would expect the stationary waves inside the instrument to be shorter. This would then lead to a higher frequency. So, the flat instrument is nothing to do with the shrinking of the instrument.

5 It turns out that brass expands by 0.00188% for every 1 K change in temperature. So, even on a very cold day, when the temperature of the instrument is around 40 K lower than usual (–10 °C instead of 30 °C), we would expect the instrument's length to shrink less than 0.1%. Really good musicians find it difficult to notice even a 0.3% change in frequency, hence, we can conclude that thermal expansion of brass has nothing to do with instrument tuning. What else could it be? Could it be that the temperature of the air in the instrument is the important factor and not the temperature of the instrument itself?

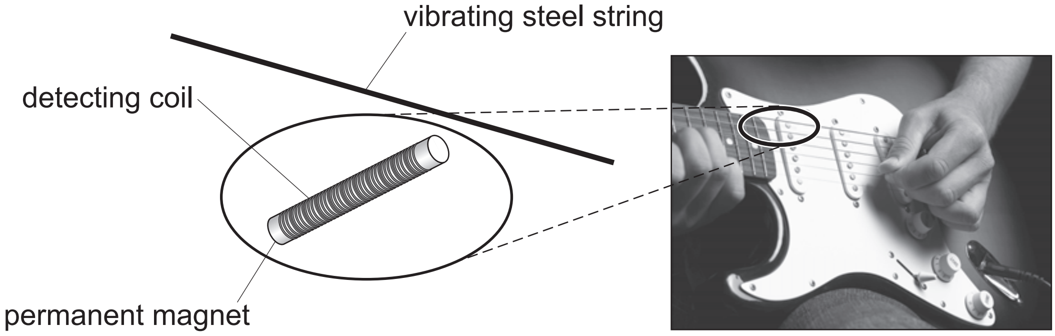
6 We can check for this using the following equation for the speed of sound, c, in air:

$$c = a\sqrt{T} \qquad \textbf{Equation 2}$$

where T is the kelvin temperature of the air and a is 20.05 $\mathrm{m\,s^{-1}\,K^{-½}}$. When a similar 40 K temperature change is incorporated into Equation 2 we find that the speed of sound changes by around 7%. This would give a 7% change in the frequency of the sound too. This is far more significant than the expansion of brass.

7 Any article on the physics of sound has to finish with the greatest musical invention since the piano. This, of course, is the electric guitar invented in 1931 by George Beauchamp. This works using electromagnetic induction:

Figure 2



8 The strings of an electric guitar have to be made of a material such as steel, which are magnetised by the permanent magnet. When the magnetised steel string vibrates, the alternating current in the detecting coil is amplified and this can then be played through loudspeakers. Although there are all sorts of other effects that can be added to the guitar sound, the basic design is simple and is based on electromagnetic induction.

9 One final thing to add about the design of electric guitars – resonance is to be avoided because it will just lead to feedback. When you are playing an electric guitar with 10 kW of sound output power behind you, you have to hold every single string to stop them from vibrating by themselves. Any unwanted vibration of a string will be amplified and the loudspeakers will then send out sound waves that will increase this vibration. This is called positive feedback or simply feedback. If an electric guitar had a resonance cavity like a normal acoustic guitar the feedback might even destroy the guitar.

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Answer the following questions in your own words. Direct quotes from the original article will not be awarded marks.

(a) (i) Draw the stationary wave of the 5th mode (see paragraphs 1, 3 and Figure 1). [1]

(ii) If the wavelength of the first mode is λ_0, state the wavelength of the 5th mode (see paragraph 1 and Figure 1). [1]

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(b) Discuss the difference between Pythagoras' note $3f_0$ and $f = 2f_0 \times 2^{\frac{7}{12}}$ (see paragraph 3 and Equation 1). [2]

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(c) The author claims that a 40 K temperature change leads to a less than 0.1% change in the length of a brass instrument. Determine whether this is true (see paragraph 5). [2]

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(d) Explain, in your own words, why the frequency produced by a brass instrument increases as temperature increases (see paragraphs 4–6 and Equation 2). [4]

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(e) A note produced by a brass instrument is 440 Hz when the instrument is at a temperature of 30 °C. Calculate the frequency of the note when it is produced at a temperature of –10 °C (see paragraphs 4–6 and Equation 2). [3]

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(f) Explain, in your own words, how an electric guitar produces a sound (see paragraphs 7–9 and Figure 2). [5]

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(g) Explain why an electric guitar will not work well with copper strings (see paragraphs 7–9 and Figure 2). [2]

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END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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