Surname	Centre Number	Candidate Number
First name(s)		2

wjec cbac

GCE A LEVEL

1420U30-1

Z22-1420U30-1

THURSDAY, 26 MAY 2022 – AFTERNOON

PHYSICS – A2 unit 3
Oscillations and Nuclei

2 hours 15 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**13**	
	2.	**14**	
	3.	**19**	
	4.	**13**	
	5.	**21**	
Section B	**6.**	**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.

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. Answer **all** questions. 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 **3**(b).

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SECTION A

Answer **all** questions.

1. (a) Radon is a radioactive gas and emits alpha particles.

(i) Explain what is meant by the *activity* of a radioactive source **and** give its unit. [2]

(ii) The half-life of radon is 3.3×10^5 s. Determine the time it takes for a sample of radon to decay to 20 % of its initial activity. [3]

(iii) Discuss the extent to which alpha particles are a risk to the human body. [3]

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(b) Radium-226 decays into radon.

$$^{226}_{88}\text{Ra} \longrightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\alpha$$

Assuming that 98% of the energy released in this process is converted to the kinetic energy of the alpha particle, use the data below to determine the speed of the alpha particle. [5]

Atomic masses: $^{226}_{88}\text{Ra}$ = 226.025 410 u $^{222}_{86}\text{Rn}$ = 222.017 578 u

$^{4}_{2}\text{He}$ = 4.002 603 u m_{electron} = 0.000 549 u

1 u = 931 MeV

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2. A balloon of volume $1.60 \times 10^{-3}\,\text{m}^3$ contains helium at a pressure of $1.20 \times 10^5\,\text{Pa}$ and a temperature of 293 K. (Relative molecular mass of helium = 4.)

(a) Determine:

(i) the number of molecules in the balloon; [2]

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(ii) the rms speed of the molecules. [2]

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(b) The product of the pressure and the volume of the gas is given by $pV = nRT$ and also by $pV = \frac{1}{3}N m \overline{c^2}$.

(i) Show that the mean kinetic energy of a gas molecule is $\frac{3}{2}kT$ where k is the Boltzmann constant. [4]

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(ii) Calculate the mean kinetic energy of a molecule in the gas. [1]

(iii) Determine the internal energy of the gas in the balloon. [1]

(c) (i) Explain, in terms of the molecules, the difference in the nature of the **internal energy** in an ideal gas and in a liquid. [3]

(ii) State the temperature of a system for its internal energy to be a minimum. [1]

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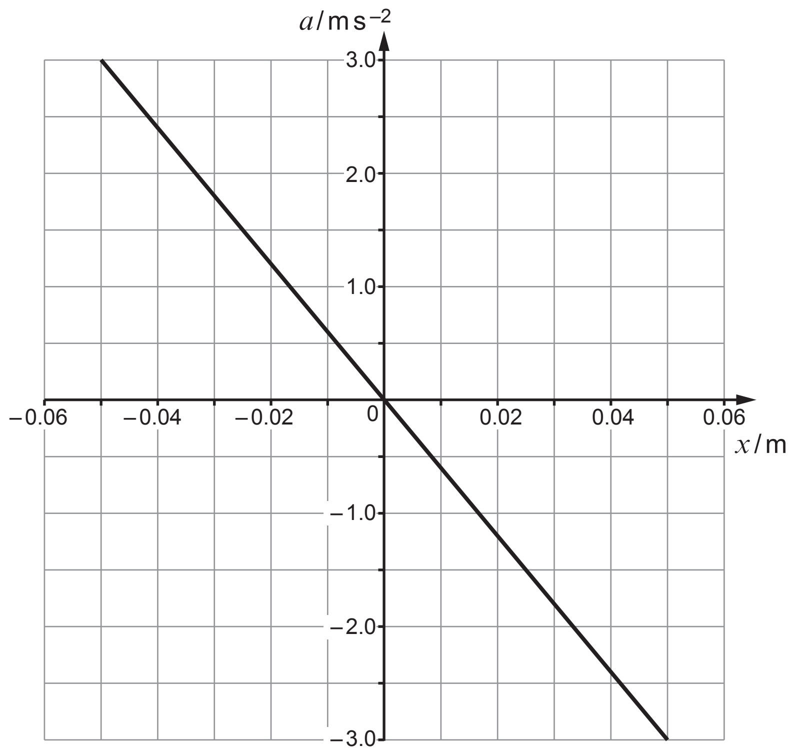
3. A small object of mass 0.30 kg oscillates at the end of a spring. The graph shows how its acceleration, a, depends on its displacement, x, from a fixed point.



(a) (i) Identify the **two** characteristics **of the graph** that show that the object is oscillating with *simple harmonic motion.* [2]

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(ii) Use the graph to show that the angular frequency, ω, of the oscillation is approximately 7.7 rad s^{-1}. [3]

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(iii) Calculate:

I. the period of oscillation; [1]

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II. the spring constant; [2]

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III. the velocity of the object as it passes through the centre of oscillation. [2]

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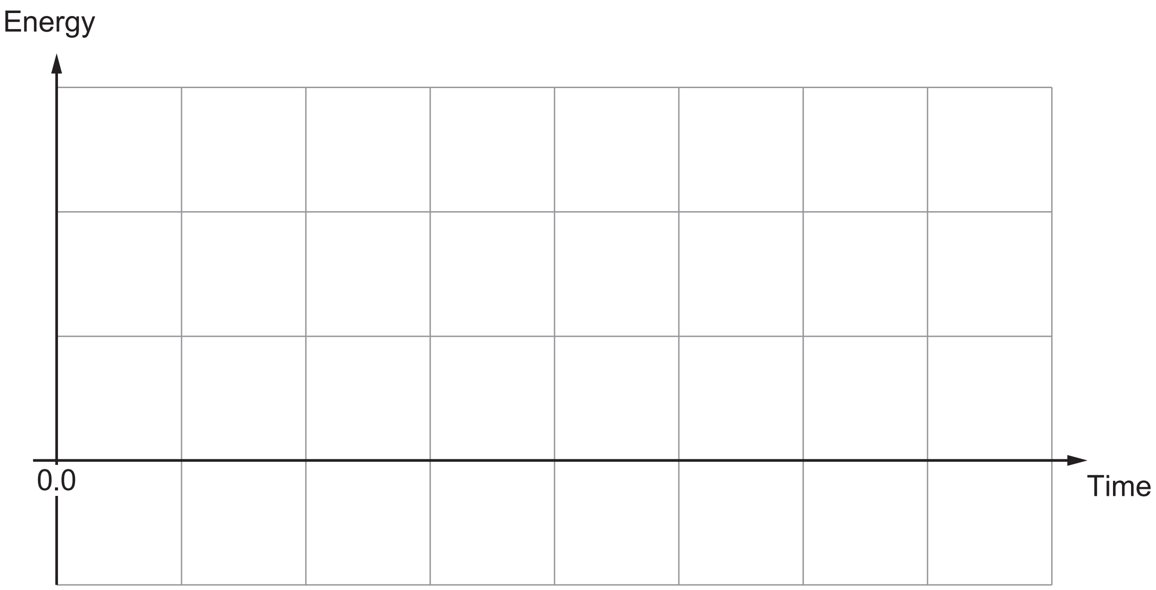
(iv) The object was released at the displacement of –0.05 m at time t = 0. Sketch on the axes below:

I. the potential energy of the system (label the sketch PE),
II. the kinetic energy of the system (label the sketch KE).

Draw both sketches **over one cycle** of the undamped oscillation. (No values are required on the axes.) [3]



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(b) Explain what is meant by the terms *damping* and *resonance* **and** discuss their importance in real systems giving an example for each. [6 QER]

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4. A satellite orbiting the Earth completes one revolution in 105 minutes.

Mass of the Earth = 6.0×10^{24} kg, radius of the Earth = 6400 km

(a) Explain what is meant by the term *radian*. [2]

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(b) Calculate the satellite's angular velocity, ω, in rad s^{-1}. [3]

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(c) The gravitational force on the satellite is given by $\dfrac{GM_E m}{R^2}$ where m is the mass of the satellite, M_E is the mass of the Earth and R is the radius of the orbit. Show that:

$$R = \sqrt[3]{\frac{GM_E}{\omega^2}}$$ [2]

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(d) Determine the height of the satellite above the surface of the Earth. [3]

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(e) The mass of the Moon is 7.3×10^{22} kg and its radius is 1 740 km. Discuss whether a satellite would be able to orbit the Moon with a period of 105 minutes. [3]

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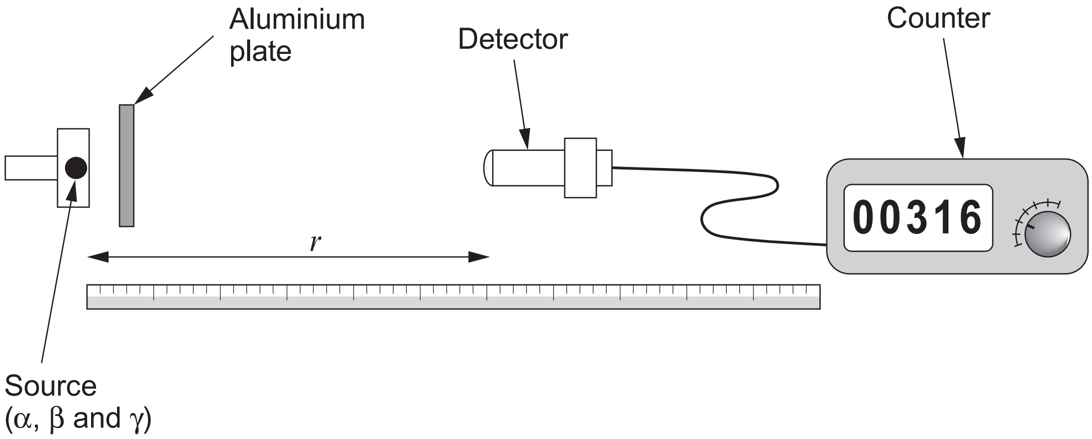
5. A student says that the radiation intensity, I, of gamma rays increases with decreasing distance, r, from a source such that:

$$I \propto \frac{1}{r^n}$$

She wishes to determine the value of n.

The student uses a source of alpha, beta and gamma radiation. She measures the intensity of the rays at set distances from the source by determining the count over intervals of one minute. She also takes measurements without the source at the start and at the end of the experiment.



(a) (i) Suggest why a thin aluminium plate is placed near the source. [1]

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(ii) Explain why readings are taken without the source, at the start **and** at the end of the experiment. [2]

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(b) At each distance, r, the counts were measured over one minute intervals three times. The uncertainty in r is ± 0.005 m. The measurements are recorded in the table.

Complete the table. [2]
Space for calculations.

Distance, r / m	Count				Uncertainty in mean count
	First reading	Second reading	Third reading	Mean	
without source	19	22	25	22	3
1.000	110	130	136	125	13
0.800	195	165	178	....	....
0.600	270	316	300	....	....
0.400	661	604	651	639	29
without source	20	20	25	22	3

(c) (i) The student subtracts the mean count without the source from the mean count for each distance to obtain the corrected mean count, N. She also determines the uncertainty in each of these corrected mean counts.

Complete the table. [2]
Space for calculations.

Distance, r / m	Corrected mean count, N	Uncertainty in corrected mean count
1.000	103	16
0.800	....	....
0.600	....	....
0.400	....	....

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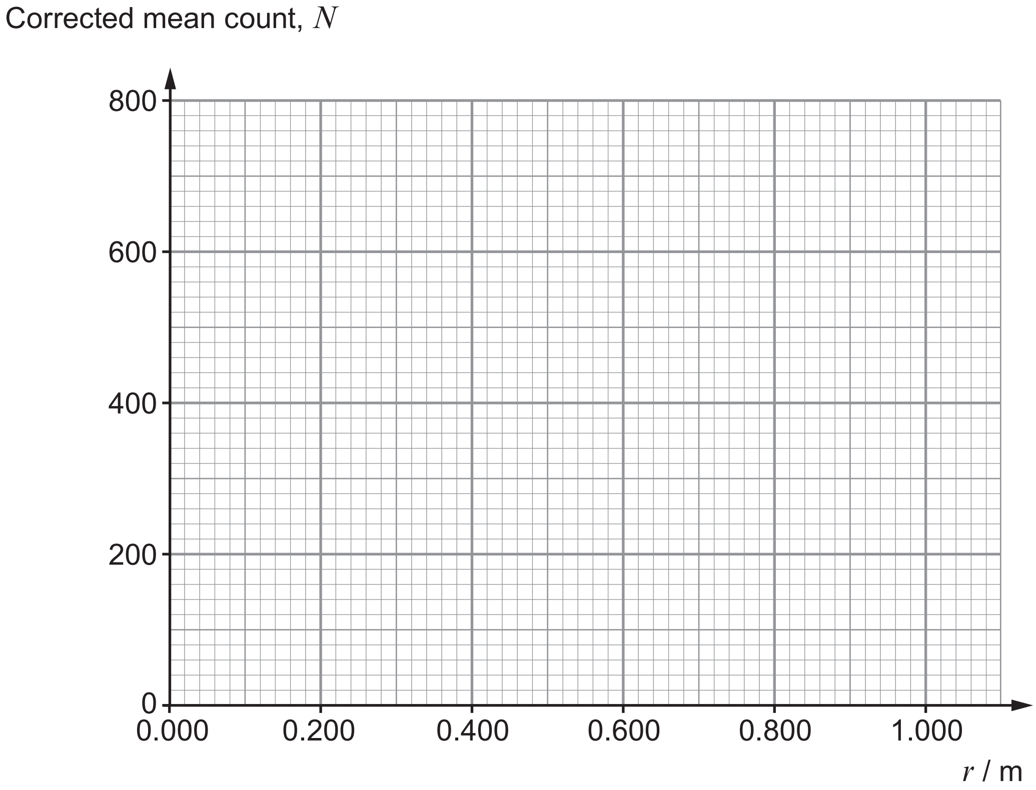
(ii) Plot a graph of the corrected mean count, N, against distance, r. **Error bars are not required.** [3]



(iii) The student claims that error bars may be shown on the graph for the corrected mean count, but not the distance. Justify her claim. Calculations are not required. [1]

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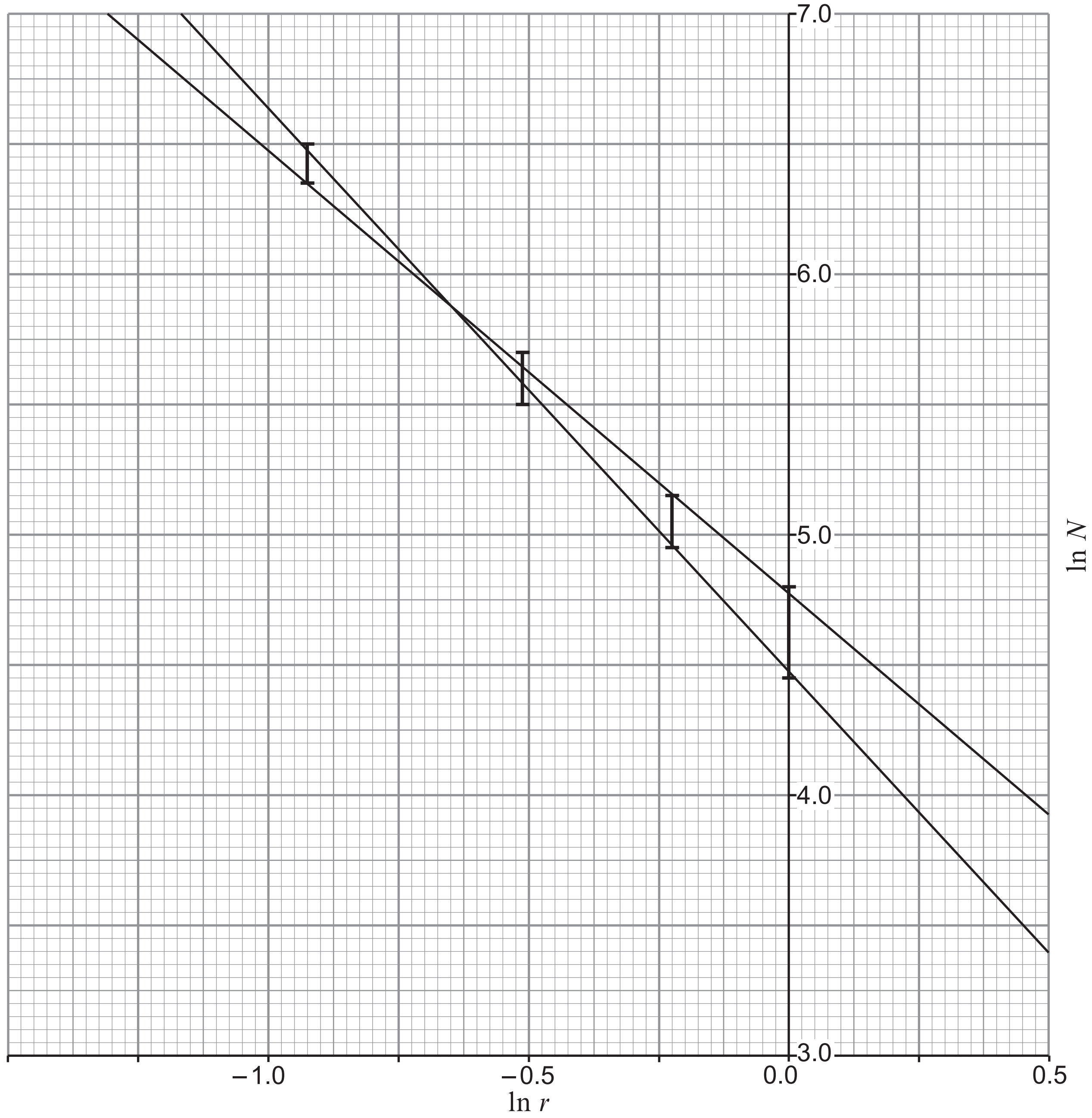
(d) Her friend suggests using a logarithmic graph. She calculates the logarithmic values in the table below.

Distance, r / m	$\ln r$	$\ln N$
1.000	0.00	4.63
0.800	–0.22	5.06
0.600	–0.51	5.61
0.400	–0.92	6.42

The data are plotted on the graph.



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For a distance of r = 1.000 m use the table in part (c) to show that the uncertainty in the logarithmic counts for this distance is approximately 0.15. [3]

(e) (i) Starting with intensity: $I \propto \dfrac{1}{r^n}$ justify how the logarithmic graph can be used to determine n. [3]

(ii) Use the maximum and minimum gradients to determine n and the **absolute** uncertainty in its value. [4]

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Turn over.

SECTION B

Answer **all** questions.

6. Read through the following article carefully.

How do you produce really low temperatures and can you then do some cool stuff with it?

Paragraph

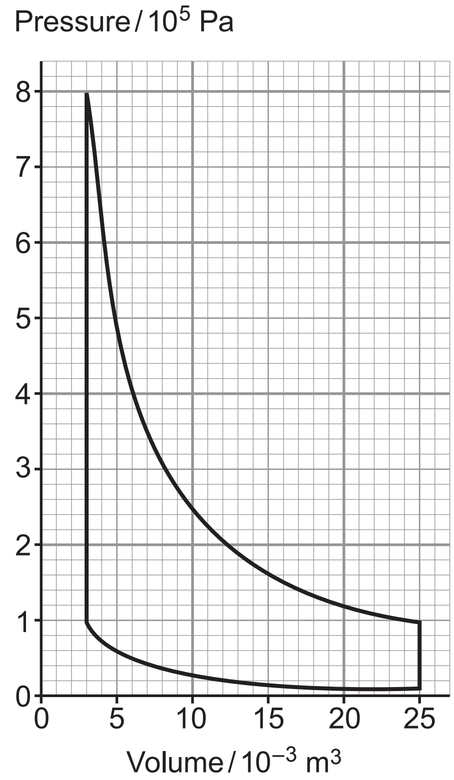


Figure 1

The first thing you have to do is to produce low
temperatures and this is usually achieved by 1
taking a gas through a closed cycle such as that
shown in Figure 1.

1. Air, initially under high pressure, is expanded at constant temperature.
2. Heat is allowed to escape at constant volume. 2
3. The gas is compressed at a constant low temperature.
4. The gas is heated at constant volume to a high pressure.

The end result is that the gas does a large amount
of work in each cycle. This means that the gas 3
must have heat flowing into it leading to the
cooling of whatever it is that requires cooling.

A different and simpler method of cooling gases is called the Joule-Thompson method,
which does not involve a gas going through a cycle. A gas is compressed to a pressure of
two thousand times atmospheric pressure. The gas is then allowed to cool back to room
temperature. After that, it is allowed to expand quickly through a nozzle to atmospheric 4
pressure leading to a tremendous amount of further cooling. In the expansion, the gas does a
very large amount of work but the non-ideal gas molecules also have an enormous increase in
potential energy because of the attractive forces between molecules. Both these factors cool
the gas by a huge factor.

Okay, so now we have the basic physics for producing low temperatures. Apply this low
temperature to air and we can make a product that can give hours of fun – liquid nitrogen 5
(LN_2).

Most of the fun that can be obtained from LN_2 is based on the fact that it boils at a temperature
of –195.8 °C and, in doing so, expands by a factor of approximately 1000. For example, a cool 6
rotating rocket can be built using a simple plastic water bottle.

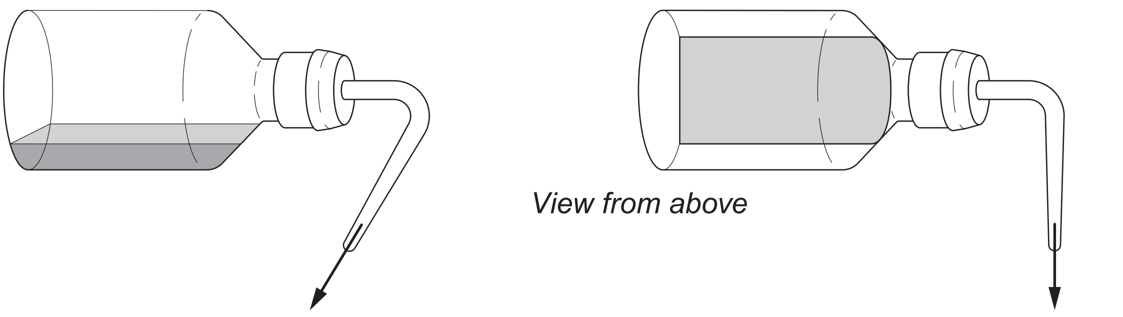


Figure 2

Paragraph

The boiling nitrogen makes the nozzle of the plastic water bottle into a jet engine. When you then place the plastic water bottle on a nicely polished wooden floor it will rotate far more quickly than you would ever anticipate, providing a great demonstration for even the most ardent physics-hating pupil. What can be even more spectacular is when the bottle accidentally hits something solid (like the leg of a lab desk). The wall of the plastic water bottle will be at around –200 °C and fragile. This, combined with the high pressure inside the bottle, leads to rather a loud and impressive bang. 7

Although LN_2 can be fun, it can also be dangerous. For instance, when transporting a large, open container of LN_2 (see Figure 3), you should not remain in the confined space of a lift with the container in case the lift becomes stuck. Most of the danger from LN_2 arises from its 200 °C temperature difference from its surroundings. Nonetheless, it is always amusing when TV chefs wear safety goggles and gloves when making ice cream using LN_2 but never bother with any safety equipment when using litres of boiling fat above a gas fire. I promise you that the boiling fat is far more dangerous even though the temperature difference, compared with human body temperature, is around 200 °C for both LN_2 and boiling fat. 8

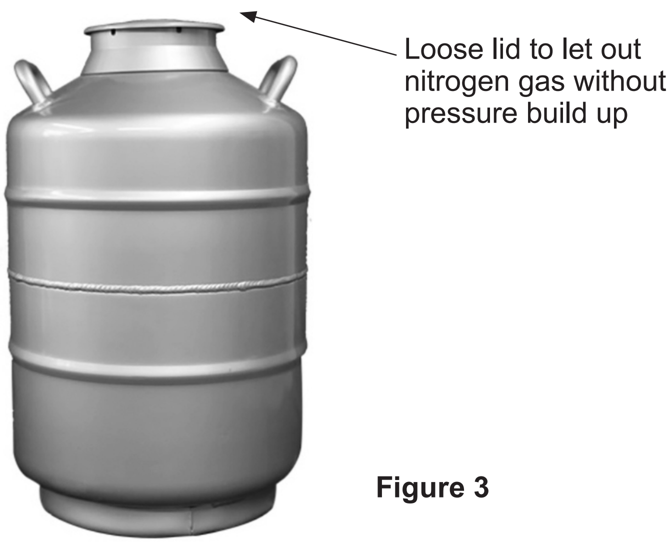
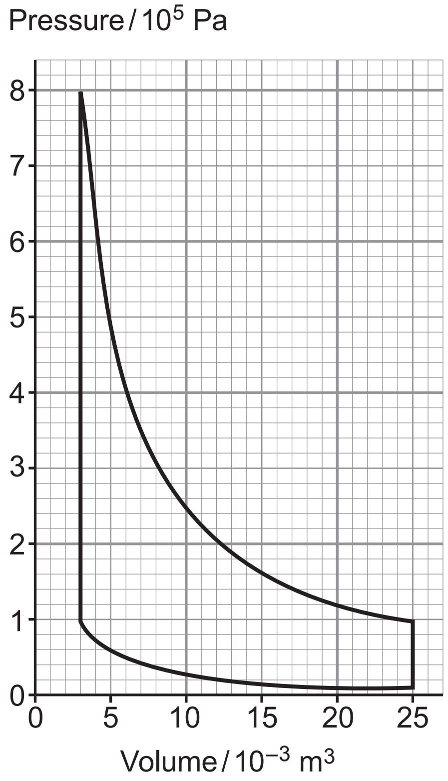


Figure 3

In conclusion, low temperatures and LN_2 can be dangerous for some obvious reasons but they can also lead to some amusement and even some Michelin-starred ice cream. 9

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

(a) **Label the diagram** with the processes 1–4 along with an arrow to show the direction of the cycle (see paragraph 2). [2]



(b) The author states that work is done by the gas in the cycle. By considering the four stages of the cycle, explain whether or not this statement is correct (see paragraph 3 and Figure 1). [2]

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(c) Estimate the work done during the cycle. [3]

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(d) When a gas is compressed in a metal cylinder it will become hot. Explain why the gas will then cool to room temperature (see paragraph 4). [2]

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(e) Explain whether or not the author is correct to state that the gas expanding quickly through the nozzle will cool greatly (see paragraph 4). [4]

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(f) Explain very briefly why nitrogen gas escapes through the nozzle of the plastic water bottle (see Figure 2 and paragraph 7). [1]

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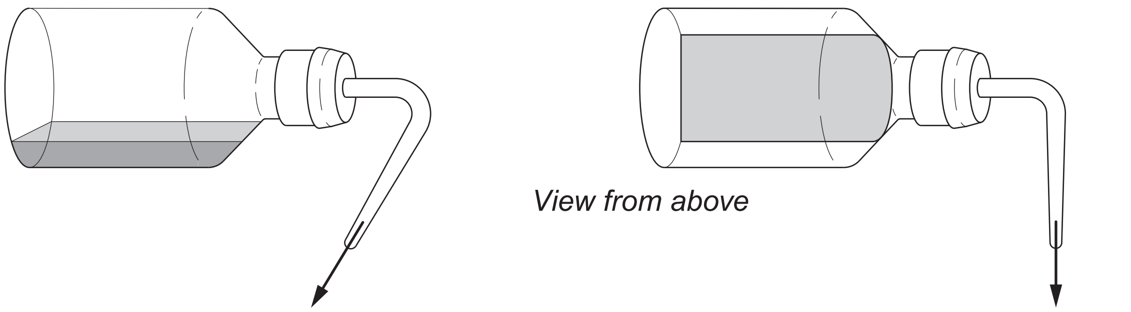
(g) Starting from Newton's 3rd Law, explain why the plastic water bottle shown will rotate anti-clockwise. [2]



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(h) An exploding bottle produces a "loud bang" (see paragraph 7). Explain briefly why this "loud bang" can be heard more than 100 m from the exploding bottle. [2]

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(i) Justify the author's statement that it would be dangerous to share a confined space (like a lift) with a large container of liquid nitrogen (see paragraph 8 and Figure 3). [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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