Surname	Centre Number	Candidate Number
First name(s)		2

wjec cbac

GCE A LEVEL

A420U10-1

S23-A420U10-1

eduqas
Part of WJEC

WEDNESDAY, 24 MAY 2023 – AFTERNOON

PHYSICS – A level component 1

Newtonian Physics

2 hours 15 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**12**	
	2.	**11**	
	3.	**9**	
	4.	**10**	
	5.	**8**	
	6.	**21**	
	7.	**9**	
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 **6**(c).

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SECTION A

Answer **all** questions.

1. Lily uses the following set-up to determine the weight, W, of a uniform metre ruler.

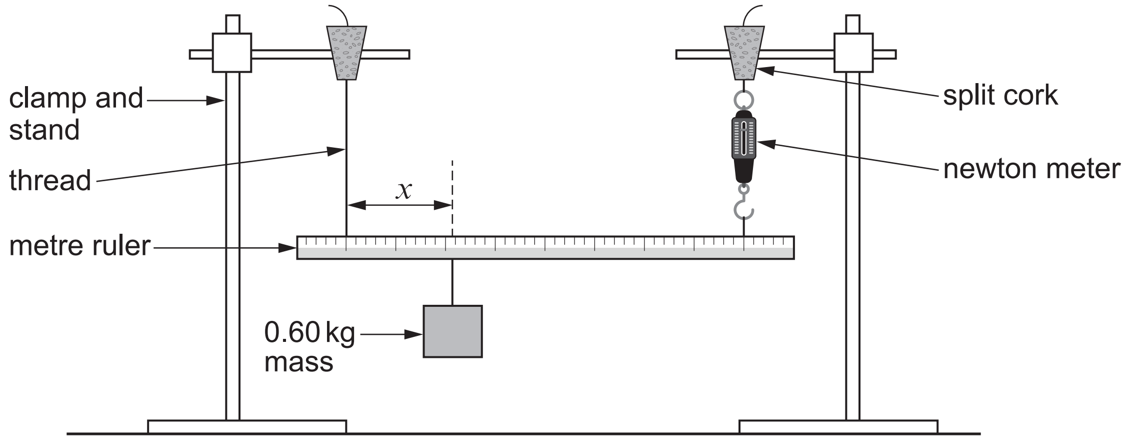

Diagram not drawn to scale

The ruler is suspended by a thread at the 0.100 m mark and a newton meter at the 0.900 m mark. Lily varies the position of the 0.60 kg mass, each time adjusting the height of the newton meter until the ruler is horizontal. The reading on the newton meter is then recorded.

(a) Suggest how Lily should ensure that the ruler is horizontal. [1]

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(b) Define the centre of gravity of an object and clearly **show the position** of the centre of gravity of the ruler on the diagram. [2]

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(c) (i) State the principle of moments. [2]

(ii) By taking moments, show that the tension, T, in the newton meter is given by:

$$T = ax + \frac{W}{2} \quad \text{in which} \quad a = 7.36\ \text{N m}^{-1}$$ [2]

(d) Lily's results are shown below.

x / m	T / N		
	Reading 1	Reading 2	Mean
0.150	1.2	1.2	1.2
0.300	2.8	2.8	2.8
0.450	3.9	3.9	3.9
0.600	5.0	4.9	5.0
0.750	6.1	6.1	6.1

(i) Using all the values in the table, Lily calculates the mean weight of the ruler to be (1.0 ± 0.5) N. Evan suggests an alternative approach using a graphical method. He uses Lily's original results and plots the points on the grid opposite.

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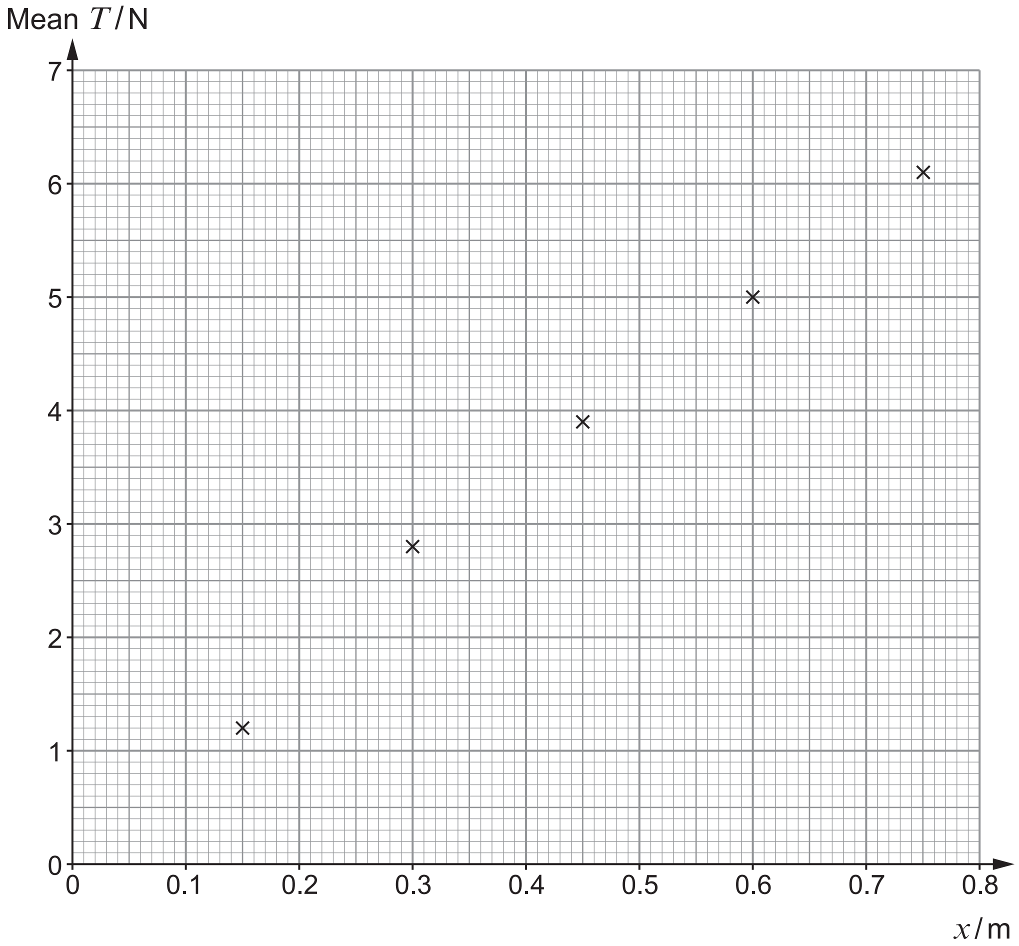

By drawing a suitable line determine the weight of the ruler. Error bars are not required. [3]

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(ii) The actual weight of the ruler is known to be 1.18 N. Evaluate the suitability of Lily and Evan's methods in determining the weight of the ruler, W. [2]

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2. (a) Zayn uses a 4.2 cm length of nichrome wire to create a heating coil. The wire has a diameter of 0.12 mm and a resistivity of $1.2 \times 10^{-6}\ \Omega$m. Show that the rate of energy transfer by the heater when operating at 10.0 V is approximately 20 W. [4]

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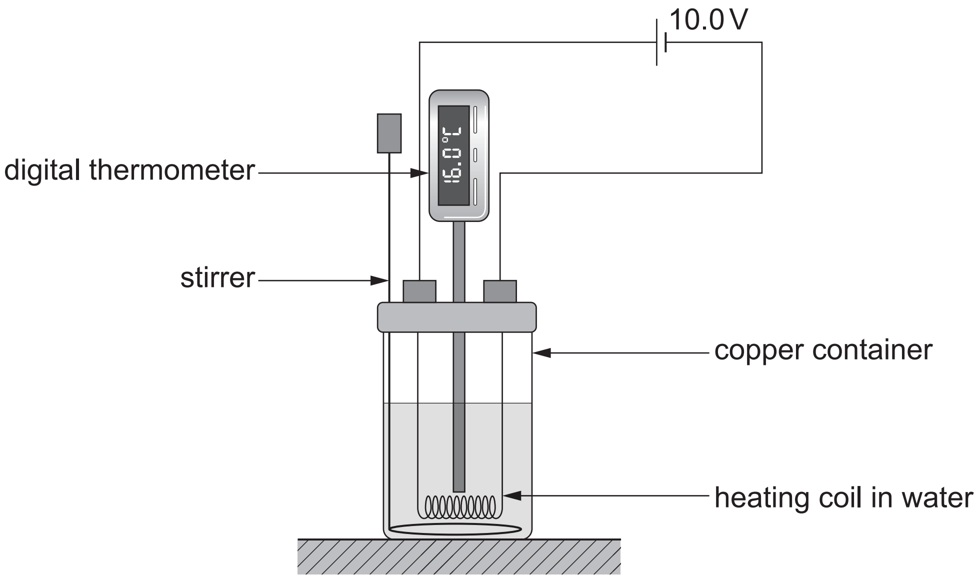
(b) The heating coil is used inside a copper container to determine the specific heat capacity of water using the apparatus below.



(i) Define the specific heat capacity of a material. [2]

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(ii) The heating coil is switched on for 5.0 minutes before being switched off. Use the following information to determine the specific heat capacity of water: [3]

Mass of copper container = 0.080 kg

Specific heat capacity of copper = $380\,\text{J}\,\text{kg}^{-1}\,°\text{C}^{-1}$

Volume of water = $190\,\text{cm}^3$

Density of water = $0.997\,\text{g}\,\text{cm}^{-3}$

Temperature rise = 8.0 °C

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(iii) Zayn repeated the experiment and noted that the room temperature was 16.0 °C. Before he started the heating process, he cooled the apparatus to 12.0 °C in a refrigerator. Discuss whether this is good experimental practice. [2]

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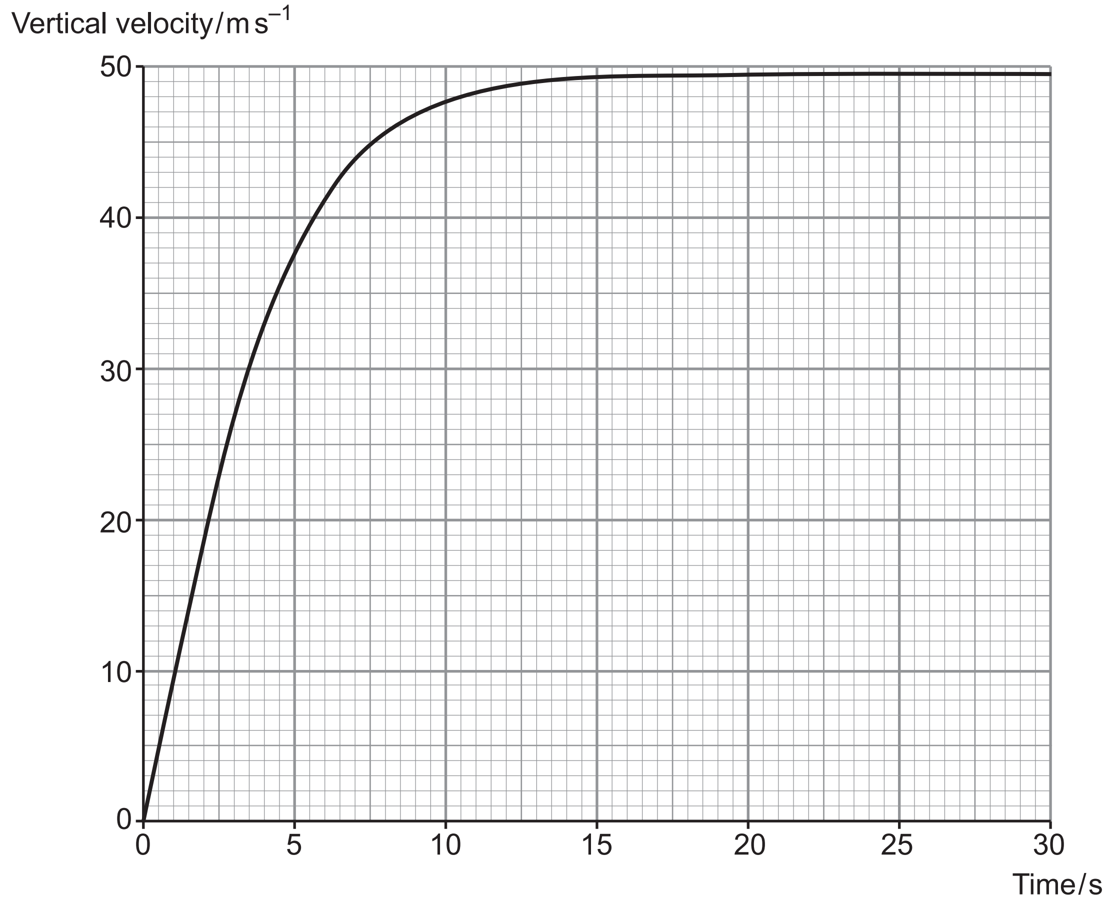
3. The graph below shows how a skydiver's vertical velocity changes with time during part of her descent.



(a) The skydiver is very close to her terminal velocity after 20 seconds. Explain, making reference to air molecules, how this velocity arises. [3]

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(b) The mass of the skydiver is 68 kg. Use the graph to determine the vertical force of air resistance after 7 seconds. [4]

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(c) NASA, funded by the American government, has developed parachutes that will safely land spacecraft on other planets. It has also been involved in the development of parachutes that can safely return a light aircraft to Earth in the event of a fault in flight. Discuss whether you believe this to be an ethical use of the money. [2]

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4. (a) The first law of thermodynamics may be written as:

$$\Delta U = Q - W$$

A student **incorrectly** defines the terms from the first law of thermodynamics as shown below:

ΔU Increase in temperature
W Work done
Q Heat in a system

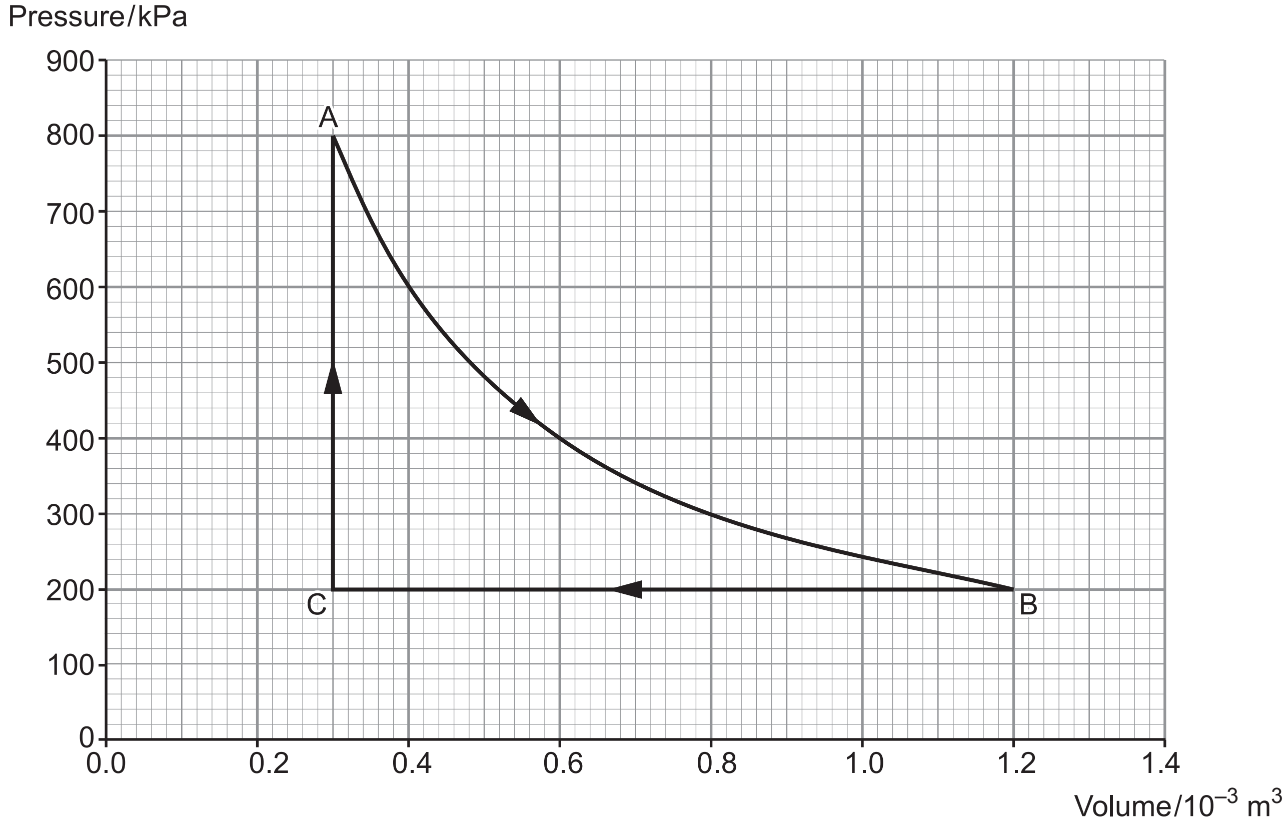
In each case, write the correct definition for the term. [3]

ΔU ....

W ....

Q ....

(b) A cylinder with a leak proof piston contains 0.10 mol of an ideal monatomic gas. The gas is taken through the following processes that result in changes in pressure and volume, as shown in the graph below.



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(i) Confirm that the process A → B is isothermal (i.e. it takes place at a constant temperature). [2]

(ii) Show that the work done during the process A → B is approximately 330 J. [2]

(iii) Joseph considers the whole process A → B → C → A. He calculates the heat flow into the system to be 150 J. Grace disagrees, and states that 150 J of heat would flow out of the system. Determine if either Joseph or Grace is correct. [3]

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5. (a) Define power. [1]

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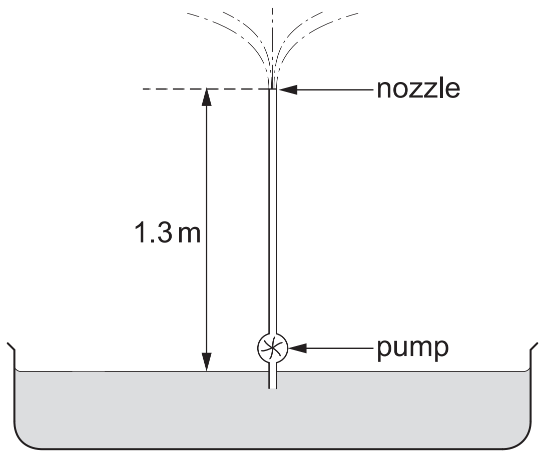
(b) In a garden water feature, water from a pool is pumped through a vertical pipe which is open to the air at its top end. The rate of flow is $0.15\,kg\,s^{-1}$, and the height gained by the water in reaching the nozzle is 1.3 m.



(i) Calculate the water's rate of gain of gravitational potential energy in rising through this height. [2]

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(ii) The speed at which water travels up the pipe is $3.5\,m\,s^{-1}$. Leo claims that a significant amount of power is used to give the water kinetic energy. Evaluate Leo's claim. [2]

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Examiner only

(iii) The pump is electric and is supplied with a pd of 12 V. When it is pumping, the current through it is 0.65 A. Calculate the efficiency of the pump. [3]

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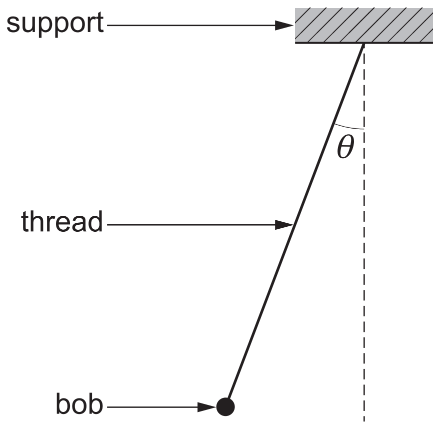
6. (a) A simple pendulum of length l consists of a small bob (a metal sphere) of mass m hanging by a light thread from a fixed support.



Show that when the pendulum is at a **small angle**, θ, to the vertical, the bob's acceleration, a, **in a direction at right angles to the thread** is approximately:

$$a = g\theta$$

You may add to the diagram. [3]

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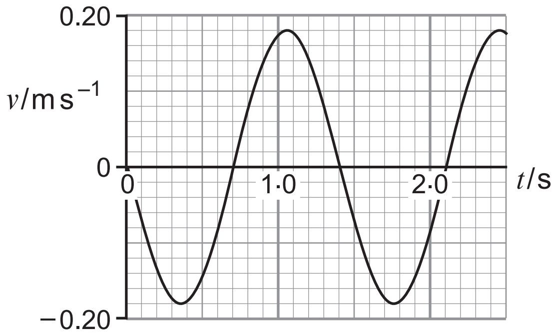
(b) A graph of velocity, v, against time, t, is given for a simple pendulum swinging through small angles.



(i) Show that the length of the pendulum is approximately 0.5 m. [3]

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(ii) The mass of the bob is 0.12 kg.

I. Show that the maximum kinetic energy of the bob is approximately 2 mJ. [2]

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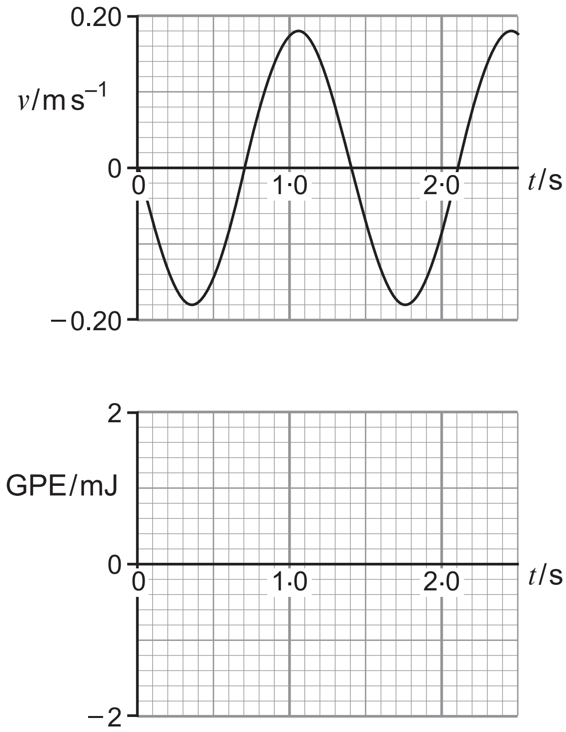
II. **On the blank grid, sketch a graph** of the bob's gravitational potential energy (GPE) against time (the upper graph is provided for reference). Take the GPE to be zero when the bob is at its lowest point. [3]



(iii) I. Calculate the centripetal acceleration of the bob at the bottom of its swing. [2]

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II. At the bottom of the swing the tension in the thread is greater than the weight of the bob. Explain why this is so. [2]

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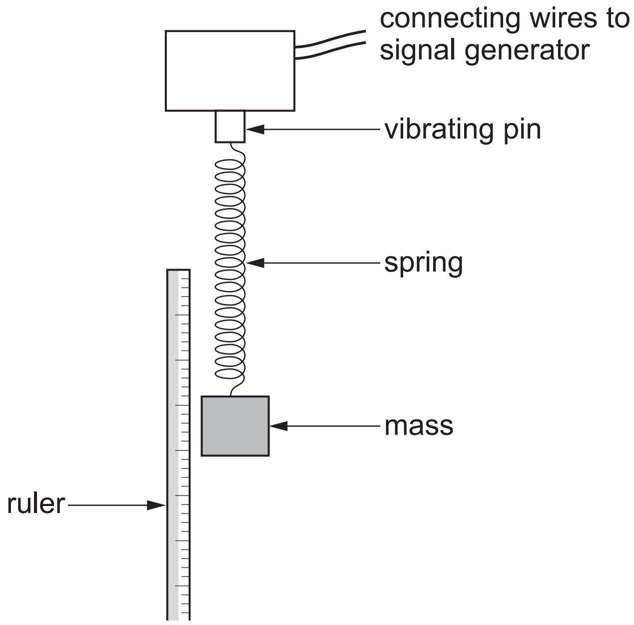
(c) Describe briefly how you would investigate **forced** oscillations using a mass and spring as the oscillating system, as in the set-up shown, and describe carefully what you would expect to find out about the amplitude of the forced oscillations. [6 QER]



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Turn over.

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7. (a) Explain why, according to the kinetic theory, a gas exerts a pressure on the walls of its container. You will need to use the idea of momentum as well as that of pressure. [3]

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(b) At one instant, three molecules in a sample of a gas have speeds in $m\,s^{-1}$ of 394, 453 and 527. Calculate their rms speed. [2]

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(c) The speed of sound, v_s, in nitrogen at three temperatures is given below.

Temperature / K	100	200	300
v_s / m s^{-1}	204	288	353

There is a simple mathematical relationship between v_s and c_{rms}, the rms speed of nitrogen molecules at the same temperature. Determine this relationship, showing your reasoning. (Relative molecular mass of nitrogen molecule = 28.) [4]

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SECTION B

Answer **all** questions.

8. Read through the following article carefully.

Paragraph **Bulges and supermassive black holes**

1 It could be argued that dark matter was first predicted by Lord Kelvin in 1884. He concluded that "many of our stars, perhaps a great majority of them, may be dark bodies" after he analysed the variation of velocity of stars in the Milky Way with distance from the centre. Modern astrophysicists tend to agree with Lord Kelvin but they generally accept that the "dark bodies" are some kind of dark matter.

2 Figure 1 shows a spiral galaxy and its central bulge.

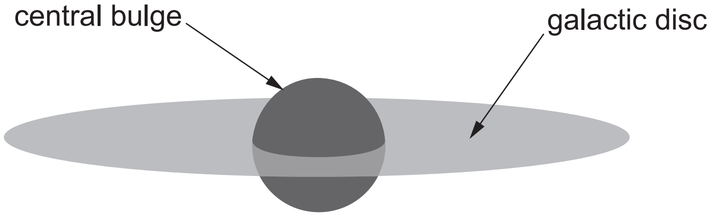


Figure 1

3 We can actually get an insight into the effect of the galactic central bulge by using A level physics if we assume that the bulge is uniform and spherical.

4 Our standard equation for the motion of an object in orbit around a spherical mass is:

$$\frac{mv^2}{r} = \frac{GMm}{r^2} \quad \textbf{Equation 1}$$

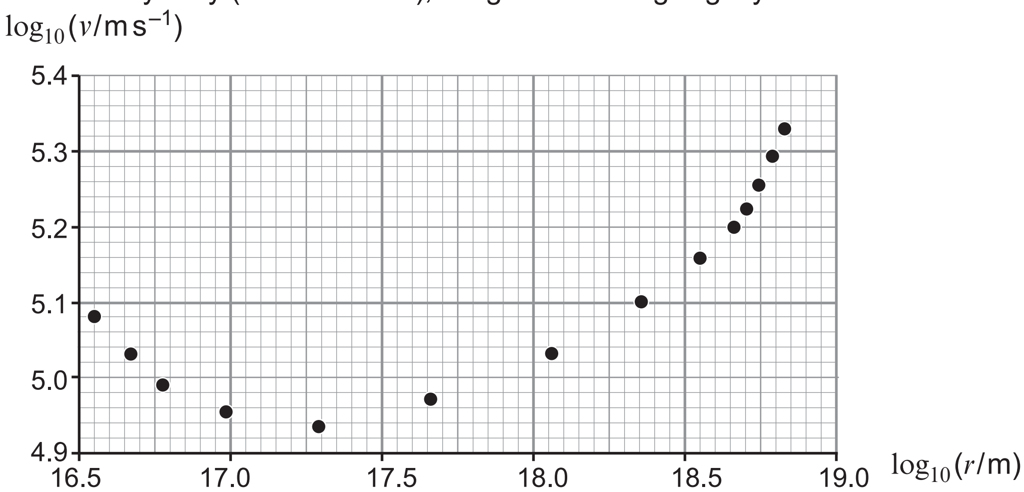
where G is the gravitational constant, r is the radius of the object's orbit and M is the mass being orbited. This also applies for objects in orbit around the centre of a galaxy. It turns out that the effects of a uniform distribution of mass outside the object's orbit will all cancel and we only have to consider the mass inside the orbit. Furthermore, we can consider the mass of the bulge inside the orbit as being a point mass at the centre of the galaxy.

5 If we assume that the galactic bulge has a density of ρ, then the mass of the bulge inside a radius r is:

$$M = \frac{4}{3}\pi r^3 \rho \quad \textbf{Equation 2}$$

6 When Equations 1 and 2 are combined, you expect the orbital velocity of stars inside the galactic bulge to be proportional to this orbital radius.

7 However, when we look at the actual orbital velocities as a function of distance from the centre of the Milky Way (radius of orbit), we get something slightly different:



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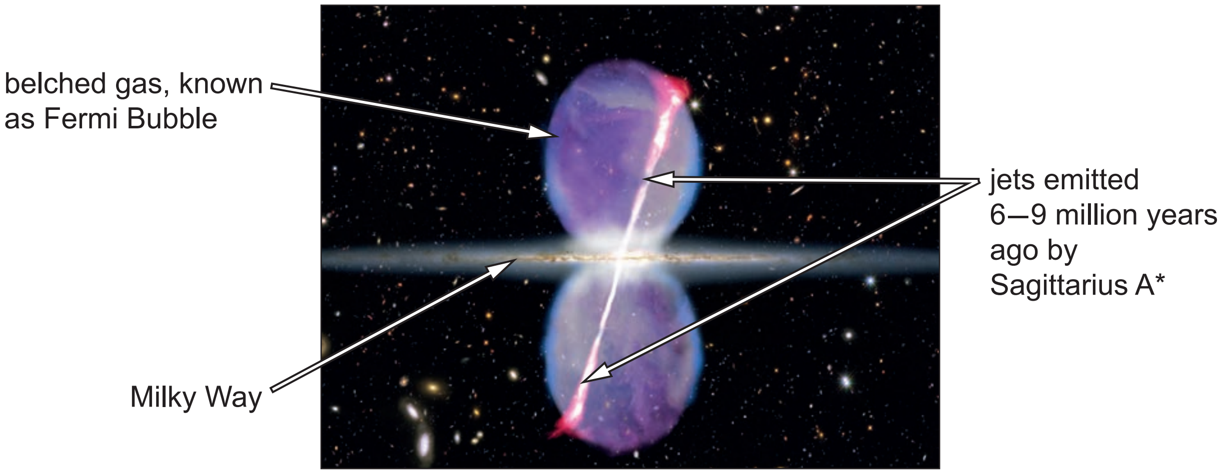
8 For the $\log_{10}(v/\text{m s}^{-1})$ against $\log_{10}(r/\text{m})$ plot shown, the steepest part on the right side has a gradient of approximately +1 as you would expect because this part is inside the galactic bulge of the Milky Way. However, the left side of the plot has a gradient of approximately –0.5. This is evidence that there is a supermassive black hole of mass approximately 8×10^{36} kg (four million times more massive than our Sun) in the centre of the galaxy.

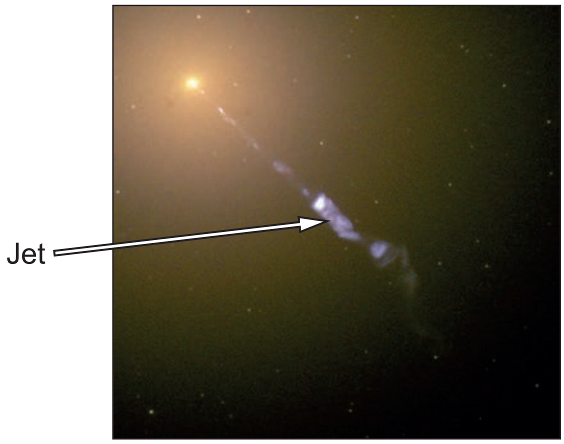
9 The supermassive black hole has a name – Sagittarius A* – and is responsible for two enormous bubbles that were belched out around 6–9 million years ago.

Figure 2



10 These bubbles were discovered in 2010 and it is estimated that they have a total mass very close to the actual mass of Sagittarius A* (an impressive burp!). Although Figure 2 is only an artist's impression of the jets and Fermi bubbles, a particularly photogenic jet can be seen in galaxy M87 (Figure 3).

Figure 3



11 There is a second jet travelling in the opposite direction but it can't be seen as visible light due to the Doppler effect.

12 Now, some bright sparks among you might be thinking that the Fermi bubbles in Figure 2 might be able to provide enough of a gravitational force to account for dark matter. Unfortunately, their mass is around 100 000 times too small. But what if there have been 100 000 burps? Could these jets from supermassive black holes be the answer to life, the Universe and everything?

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

(a) Explain the meanings of the left-hand side and right-hand side of Equation 1. [2]

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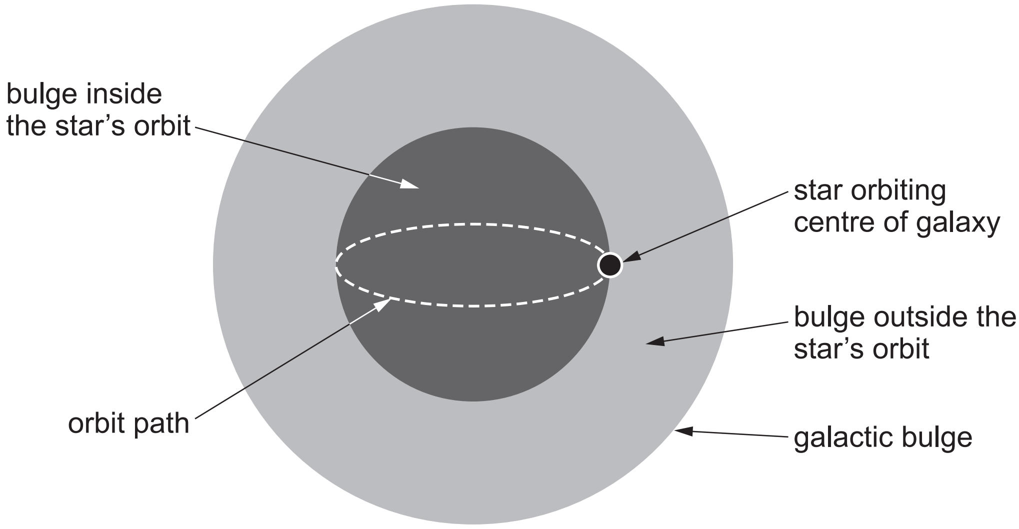
(b) Use forces to explain why it is feasible that the bulge inside the star's orbit affects its orbit whereas the bulge outside its orbit does not (see diagram below and paragraph 4). [2]



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(c) Derive an expression for the velocity of stars inside the bulge as a function of radius and the density of the bulge (see Equations 1 and 2 and paragraph 6). [3]

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(d) (i) Explain why you would expect the gradient of the **left side** of the graph to be –0.5. (See paragraph 8 and **hint**: you should explain why using the equation $v = \sqrt{\frac{GM}{r}}$ is valid.) [3]

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(ii) Use the data point with the smallest radius to determine whether, or not, the central supermassive black hole has a mass of approximately 8×10^{36} kg. (See paragraph 8 and use the relationship for a mass orbiting a central large mass $v = \sqrt{\frac{GM}{r}}$.) [4]

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(e) Assuming that the Fermi bubbles (belched gas) came from the central supermassive black hole over a period of 2 million years, calculate the rate of ejection of mass **in solar masses per year** (see paragraphs 8 and 10). [2]

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(f) In your own words, explain why the 2nd jet from galaxy M87 can't be seen (see paragraph 11). [2]

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(g) In the last paragraph, the author suggests that Fermi bubbles and gas ejected from supermassive black holes might account for dark matter. Comment on whether you think this is feasible and what steps might be taken to prove / disprove this theory. [2]

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END OF PAPER

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