



GCE A LEVEL

1420U30-1

FRIDAY, 9 JUNE 2023 – MORNING

PHYSICS – A2 UNIT 3

OSCILLATIONS AND NUCLEI

2 hours 15 minutes plus your additional time allowance

Surname: _____

First name(s): _____

Centre Number: _____

Candidate Number: 2 _____

For Examiner's use only			
	Question	Maximum Mark	Mark Awarded
SECTION A	1.	10	
	2.	15	
	3.	14	
	4.	9	
	5.	10	
	6.	22	
SECTION B	7.	20	
	Total	100	

(Turn over)

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a DATA BOOKLET (provided by WJEC).

ITEMS INCLUDED WITH QUESTION PAPER

A separate Diagram Booklet.

The Diagram Booklet **MUST** be handed in to the invigilators and sent for marking.

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball – point pen, black felt tip or your usual method.

Write your name, centre number and candidate number in the spaces on the front cover.

Answer ALL questions.

Write your answers in the spaces provided.

If you run out of space use the additional pages 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, plus your additional time allowance, on this section.

Section B: 20 marks. Comprehension.

You are advised to spend about 40 minutes, plus your additional time allowance, 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 (d).

SECTION A

ANSWER ALL QUESTIONS.

1. The first law of thermodynamics may be written as:

$$\Delta U = Q - W$$

- (a) State the meaning of:

ΔU _____

Q _____

W _____

[3 marks]

continued on the next page . . .

(Turn over)

Question 1 continued

1. (b) A closed cylinder fitted with a leak – proof piston as one end contains **0.060 mol** of an ideal monatomic gas. The volume of the system is **$1.4 \times 10^{-3} \text{ m}^3$** and the pressure of the gas is **100 kPa**.
Determine the temperature of the gas.

[2 marks]

continued on the next page . . .

(Turn over)

Question 1 continued

1. (c) The gas is heated and expands at constant pressure to a volume of $2.0 \times 10^{-3} \text{ m}^3$

Determine:

- (i) the work done by the gas,

[2 marks]

continued on the next page . . .

(Turn over)

Question 1 (c) continued

1. (c) (ii) the increase in the internal energy of the gas,

[2 marks]

(iii) the heat transferred to the gas.

[1 mark]

(Total for Question 1 = 10 marks)

(Turn over)

2. (a) Explain what is meant by centripetal force and state its direction.

[2 marks]

continued on the next page . . .

(Turn over)

Question 2 continued

2. (b) A small sphere of mass **30 g** at the end of a light string rotates in a horizontal circle of radius **0.80 m** and completes **10** revolutions in **15 s**.

(i) Show that the speed of the sphere is **3.35 m s^{-1}**

[2 marks]

continued on the next page . . .

(Turn over)

Question 2 (b) continued

2. (b) (ii) Calculate the centripetal force on the sphere.

[2 marks]

continued on the next page . . .

(Turn over)

Question 2 continued

2. (c) Look at the diagram for Question 2 (c) in the separate Diagram Booklet.

The sphere now rotates in a **VERTICAL** circle of the same radius, from a point that is **1.20 m** above the ground.

The speed at the top of the circle is **3.35 m s^{-1}**

Calculate the tension in the string at the **TOP OF THE CIRCLE.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 2 continued

- 2. (d) (i) Calculate the speed of the sphere when it reaches the BOTTOM OF THE CIRCLE.**

[3 marks]

continued on the next page . . .

(Turn over)

15

[4 marks]

(Total for Question 2 = 15 marks)

(Turn over)

3. (a) State what is meant by alpha emission.

[2 marks]

continued on the next page . . .

(Turn over)

Question 3 continued

- 3. (c) A builder is asked to install a smoke detector. He researches smoke detectors and finds that the radioactive source in the detector emits alpha particles. He decides that it is too dangerous to install the detector. Discuss whether or not he has used science well in his decision making.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 3 continued

3. (d) Describe how alpha, beta and gamma radiation can be distinguished:

- **by using different absorbers**
- **by using an electric field OR a magnetic field.**

4. (a) Explain what is meant by specific heat capacity.

[2 marks]

continued on the next page . . .

(Turn over)

Question 4 continued

4. (b) A volume of $1.2 \times 10^{-3} \text{ m}^3$ of water is heated in a 3 kW kettle.

Specific heat capacity of water (and tea)

$$= 4\,200 \text{ J kg}^{-1} \text{ K}^{-1}$$

Specific heat capacity of milk = $3\,900 \text{ J kg}^{-1} \text{ K}^{-1}$

Density of water = $1.00 \times 10^3 \text{ kg m}^{-3}$

Density of milk = $1.03 \times 10^3 \text{ kg m}^{-3}$

- (i) Determine the time it takes to increase the temperature of the water from 18°C to 100°C .

(Turn over)

[3 marks]

4. (b) (ii) A volume of $0.25 \times 10^{-3} \text{ m}^3$ of the heated water is used to make tea and this is poured into a thermos flask. The temperature of the tea when in the flask is 95°C . Milk at 5°C is then poured into the flask. Determine whether $3.6 \times 10^{-5} \text{ m}^3$ of milk will lower the temperature of the mixture to the required temperature of 84°C .

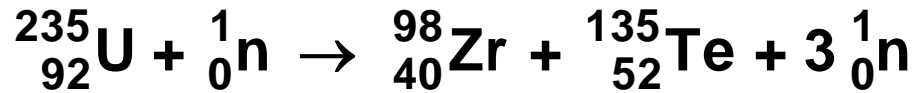
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[4 marks]

(Total for Question 4 = 9 marks)

Question 5 continued

5. (b) One of the many possible fission reactions of uranium – 235 is:



The masses are:

$${}_{92}^{235}\text{U} : 235.04393 \text{ u};$$

$${}_{40}^{98}\text{Zr} : 97.91273 \text{ u};$$

$${}_{52}^{135}\text{Te} : 134.91645 \text{ u},$$

$${}_0^1\text{n} : 1.00866 \text{ u}$$

$$\text{and } 1 \text{ u} = 931 \text{ MeV.}$$

continued on the next page . . .

Question 5 (b) continued

5. (b) (i) State what is meant by the Avogadro constant.

[1 mark]

(ii) Calculate the energy released by the fission of 0.0010 kg of uranium – 235 in this reaction. Give your answer in J.

(Turn over)

[5 marks]

(Total for Question 5 = 10 marks)

(Turn over)

6. A student says that a simple pendulum oscillates with simple harmonic motion with a period, T , of:

$$T = 2\pi \sqrt{\frac{l}{g}}$$

where l is the length of the pendulum and g is the acceleration due to gravity.

- (a) Describe what is meant by a simple pendulum.

[1 mark]

continued on the next page . . .

(Turn over)

Question 6 continued

6. (b) State what is meant by simple harmonic motion.

[2 marks]

continued on the next page . . .

(Turn over)

Question 6 continued

6. (c) The student sets up two experimental systems to investigate simple harmonic motion.

Look at the diagrams for Question 6 (c) in the separate Diagram Booklet.

The diagrams are NOT drawn to scale.

The diagrams show pendulum system **A** and pendulum system **B**.

System **A** is a pendulum of length **0.10 m** oscillating with an amplitude of **0.05 m**.

System **B** is a pendulum of length **0.50 m** oscillating with an amplitude of **0.04 m**.

Give two reasons why system **B** is better than system **A** to investigate simple harmonic motion.

[2 marks]

continued on the next page . . .

(Turn over)

Question 6 continued

6. (d) Look at the table for Question 6 (d) in the separate Diagram Booklet.

Measurements for an oscillating simple pendulum are given in the table,

where l is the length of the pendulum and T_{20} is the time taken for 20 oscillations.

For each value of l four values of T_{20} are measured.

- (i) COMPLETE THE TABLE by determining \sqrt{l} , the mean time for 20 oscillations, T_{20} and the uncertainty in T_{20}

Values have been inserted for the first two lengths.

[3 marks]

continued on the next page . . .

(Turn over)

Question 6 (d) continued

6. (d) (ii) Plot mean T_{20} against \sqrt{l} on the grid provided for Question 6 (d) (ii) in the separate Diagram Booklet. Include error bars on the T_{20} axis only. Draw a line of maximum gradient and a line of minimum gradient.

[4 marks]

- (iii) Justify why error bars for \sqrt{l} are not plotted on the graph.

[2 marks]

continued on the next page . . .

(Turn over)

[5 marks]

continued on the next page . . .

(Turn over)

Question 6 continued

6. (e) Another student says that the gradient of the graph would be approximately twice as large if the experiment was carried out on the Moon, where the acceleration is approximately $0.2 g$. Investigate if this statement is correct, justifying your answer.

[3 marks]

(Total for Question 6 = 22 marks)

(Turn over)

SECTION B

ANSWER ALL QUESTIONS.

7. Read through the following article carefully.

A SUMMARY OF BINARY STARS

PARAGRAPH 1

First of all, we call two stars orbiting their common centre of mass a “binary star”.

Binary stars fall into 5 different classes, categorised by the detection method:

- 1. Visual binaries**
- 2. Spectroscopic binaries**
- 3. Eclipsing binaries**
- 4. Astrometric binaries**
- 5. Non – eclipsing binaries that can be detected using photometry.**

continued on the next page . . .

(Turn over)

Question 7 continued

PARAGRAPH 2

VISUAL BINARIES

These do what it says on the tin – the angular separation of the stars is great enough that both stars can be seen as separate objects through a telescope. There is a simple relationship between the minimum angular separation θ (in radians), the diameter, d , of the telescope and the wavelength, λ , of the radiation used.

EQUATION 1

Look at the equation below.

$$\theta = 1.22 \frac{\lambda}{d}$$

continued on the next page . . .

(Turn over)

Question 7 continued**PARAGRAPH 3**

This equation means that a nearby binary star that is around **200** light years (**l-y**) away will only be visible as two stars with a **$d = 8.0$ m** telescope if the two stars are separated by at least the Earth – Sun distance of **1.5×10^{11} m** (see Figure 1 provided for Question 7 in the separate Diagram Booklet).

continued on the next page . . .

Question 7 continued**PARAGRAPH 4**

Look at Figure 2 for Question 7 in the separate Diagram Booklet.

Perhaps the most famous of visual binary stars is the brightest star in the night sky – Sirius.

Sirius is not, in fact, a single star but a binary consisting of Sirius **A and Sirius **B** that orbit each other with a period of around **50** years.**

Sirius **A is a main sequence star which has roughly **2** times the mass of the Sun, **1.7** times the Sun's temperature and **25** times its luminosity. Sirius **B** is a white dwarf with a similar mass to our Sun, a surface temperature **4.3** times greater than our Sun but a luminosity **18** times less than our Sun.**

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(Turn over)

Question 7 continued**PARAGRAPH 5****SPECTROSCOPIC BINARIES**

These are binaries where the stars cannot be viewed separately but the existence of the two stars can be inferred from the variation of the Doppler shifted light from the system.

Both stars will orbit their mutual centre of mass and hence their Doppler shifts will vary periodically during their orbits. This theory is the same as that used to discover exoplanets from the wobble of their parent star.

continued on the next page . . .

Question 7 continued**PARAGRAPH 6****ECLIPSING BINARIES**

These happen when the line of sight of the observer is in the plane of the orbit of the two stars. When this happens, one star can pass directly in front of the other leading to a drop in the intensity of light entering the observer's telescope. Look at Figure 3 for Question 7 in the separate Diagram Booklet. An idealised graph of intensity against time is shown.

PARAGRAPH 7

In general, there are two eclipses for each orbit. The larger of the two dips in intensity occurs when the hotter of the two stars is blocked by the colder star.

continued on the next page . . .

(Turn over)

Question 7 continued**PARAGRAPH 8****ASTROMETRIC BINARIES**

These are binary systems where only one star is visible and that star can be seen moving in an orbit around something which is invisible. These are different from spectroscopic binaries because the visible star can actually be seen to move rather than inferring its motion from the variation of the Doppler shift. Stars orbiting neutron stars have been observed by this method but the ultimate goal of this technique would be to observe a star orbiting a black hole.

continued on the next page . . .

(Turn over)

Question 7 continued**PARAGRAPH 9****NON – ECLIPSING BINARIES THAT CAN BE DETECTED USING PHOTOMETRY**

This simply means detecting binaries by measuring light intensity but not via the eclipsing method described earlier. It turns out that there are three different techniques of finding binaries within this class of binary.

First, an increased light intensity can be detected periodically from the binary system – this is caused by light being reflected from one star, off the other and into the Earth’s telescope. Second, one star can exert such a strong gravitational pull on the other that it becomes deformed – this leads to a periodic fluctuation in the light intensity detected.

Third, is an effect sometimes known as Doppler beaming – a star moving towards an observer will lead to an increased number of photons detected per second (as well as a decrease in the wavelength).

continued on the next page . . .

(Turn over)

Question 7 continued

PARAGRAPH 10

These 5 different classes of binary stars can provide an enormous amount of valuable data regarding stellar orbits and masses but they can also allow measurement of galactic distances and even give insights into black holes and supernovae.

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

continued on the next page . . .

Question 7 continued

7. (b) (i) Show that the distance between Sirius A and Sirius B is approximately 3×10^{12} m (see PARAGRAPH 4).

[Mass of the Sun is 2×10^{30} kg.]

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 (b) continued

7. (b) (ii) Show that the centre of mass of the Sirius binary system is located approximately 1×10^{12} m from Sirius A.

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 continued

7. (c) (i) Evaluate whether the variation of light intensity shown in Figure 3 is consistent with an eclipsing binary system (see PARAGRAPH 6).

[3 marks]

continued on the next page . . .

(Turn over)

Question 7 (c) continued

7. (c) (ii) Use Stefan’s law to explain why the “larger of the two dips in intensity occurs when the hotter of the two stars is blocked by the colder star” (see PARAGRAPHS 6 and 7 and Figure 3).

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 continued

- 7. (d) Explain why a star orbiting a much more massive black hole is an astrometric binary (see PARAGRAPH 8).**

[1 mark]

continued on the next page . . .

(Turn over)

Question 7 continued

- 7. (e) One of the three methods for detecting non – eclipsing binaries that can be detected by photometry, suggests that stars do not behave as ideal black bodies. Explain which ONE of the three methods relies on stars not behaving as black bodies (see PARAGRAPH 9).**

[2 marks]

(Total for Question 7 = 20 marks)

END OF PAPER

TOTAL 100 MARKS

(Turn over)



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FRIDAY, 9 JUNE 2023 – MORNING

PHYSICS – A2 UNIT 3

OSCILLATIONS AND NUCLEI

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to the invigilators and sent for marking.**

Diagram Booklet

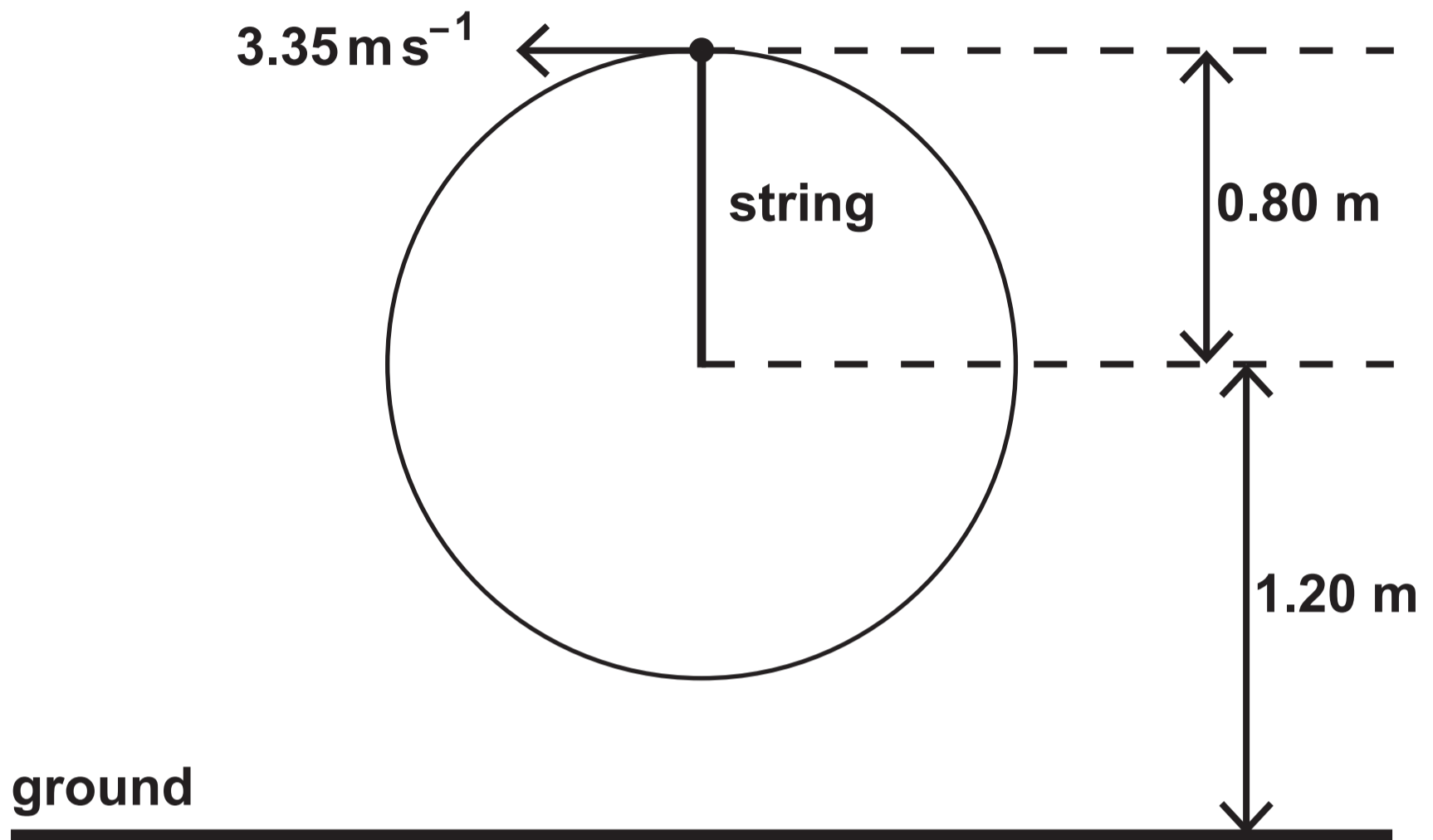
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First name(s): _____

Centre Number: _____

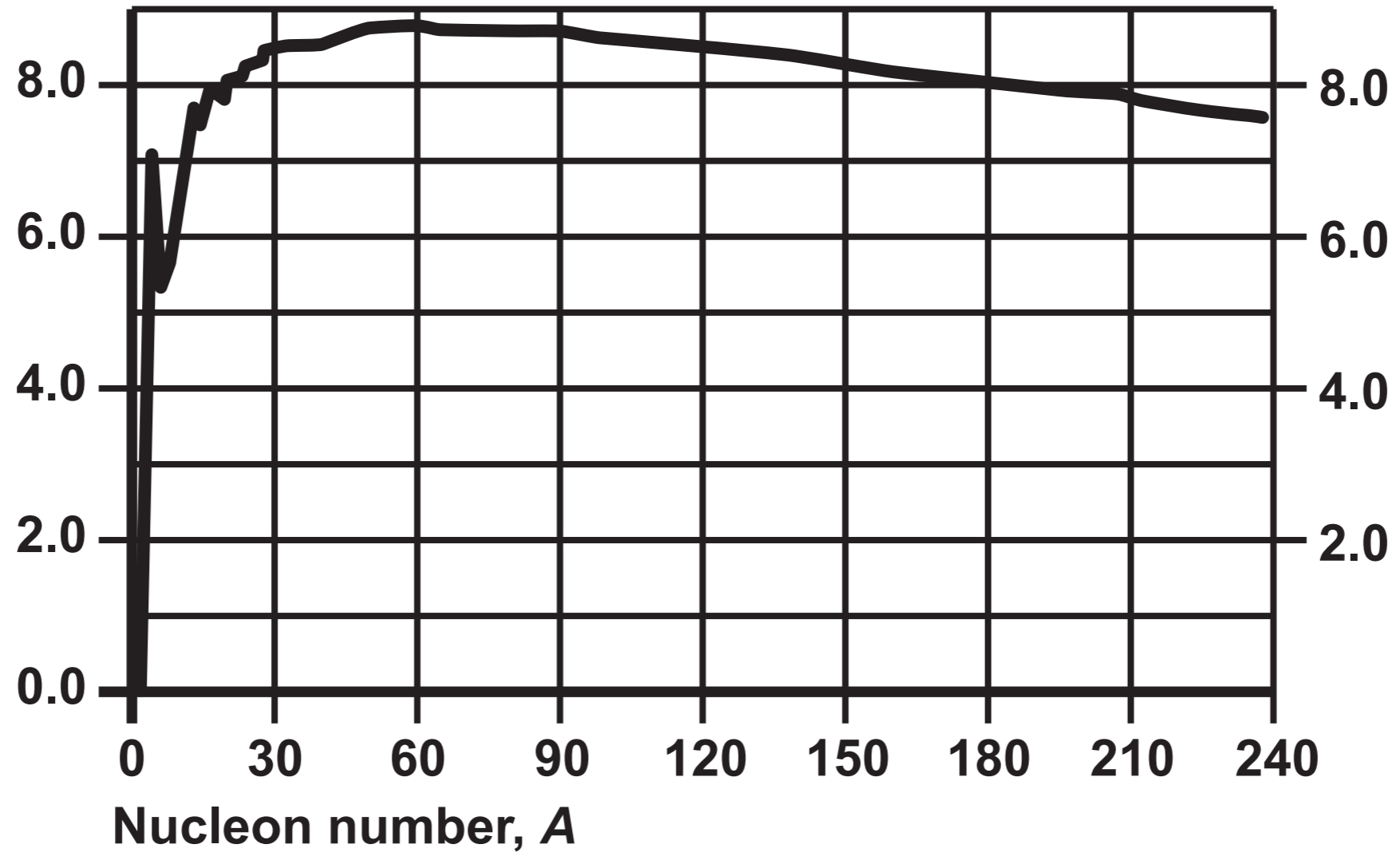
Candidate Number: 2 _____

Question 2 (c)



Question 5 (a)

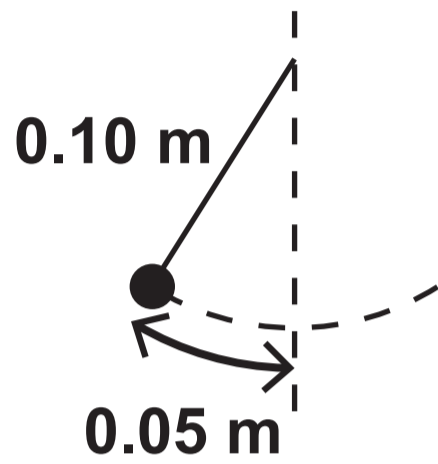
Binding energy per nucleon / MeV



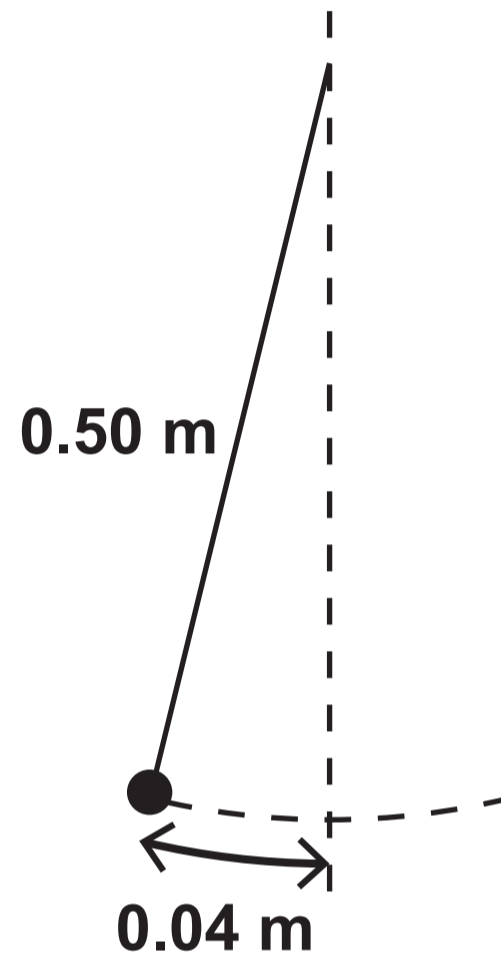
Question 6 (c)

Diagrams NOT drawn to scale

PENDULUM SYSTEM A



PENDULUM SYSTEM B

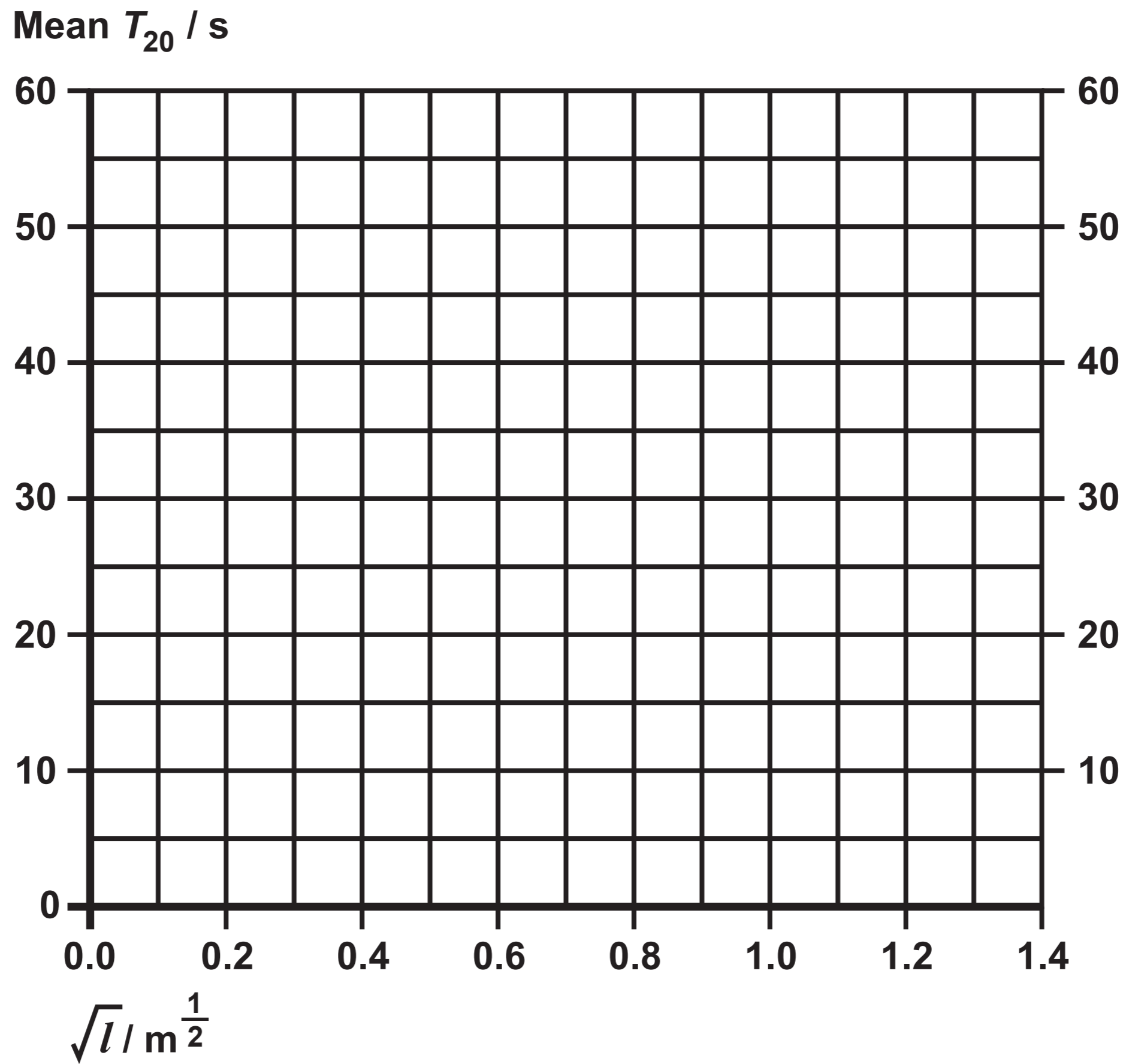


Question 6 (d)

Table

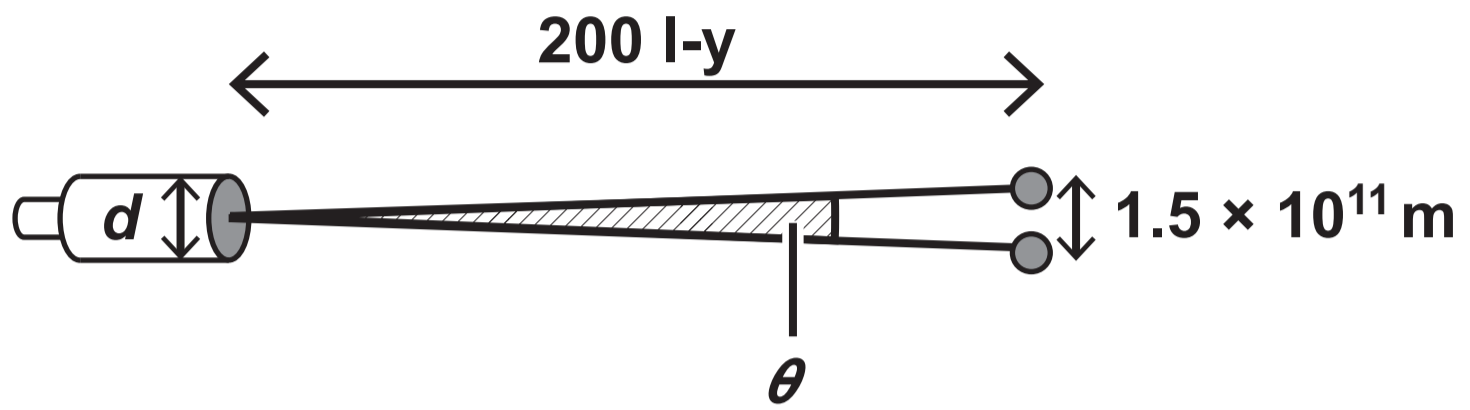
l / m	$\sqrt{l} / \text{m}^{\frac{1}{2}}$	T_{20} / s	Mean T_{20} / s	Uncertainty T_{20} / s
0.250	0.50	19, 21, 22, 20	21	2
0.500	0.71	26, 29, 26, 29	28	2
0.750		35, 34, 33, 36		
1.000		42, 39, 40, 41		
1.250		45, 42, 44, 45		
1.500		48, 50, 49, 52		

Question 6 (d) (ii)



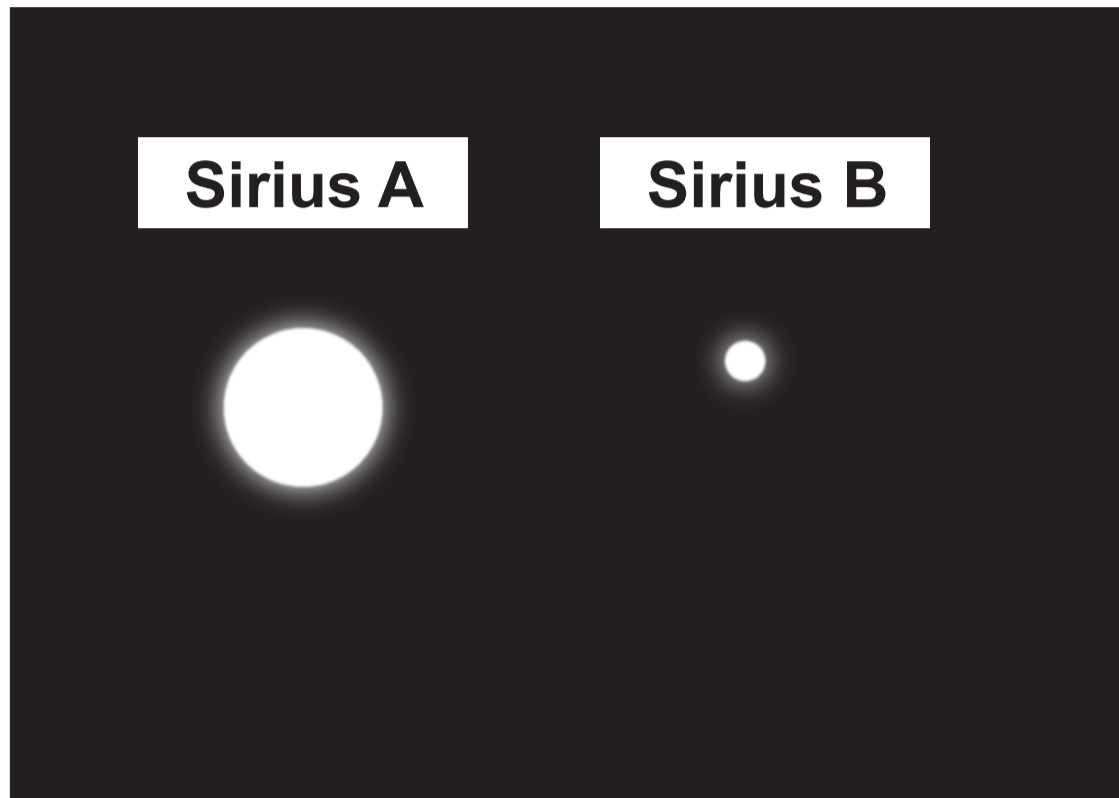
Question 7

Figure 1



Question 7

Figure 2



Question 7

Figure 3

