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**PHYSICS**

**UNITS 1 & 2**

**2022**

**MARKING GUIDE**

**Time allowed for this paper**

Reading time before commencing work: ten minutes

Working time: three hours

**Materials required/recommended for this paper**

***To be provided by the supervisor***

This Question/Answer Booklet

Formulae and Data booklet

***To be provided by the candidate***

Standard materials:pens (blue/black preferred), pencils (including coloured), sharpener,   
correction fluid/tape, eraser, ruler, and highlighters

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination, drawing templates, drawing compass and a protractor

**Important note to candidates**

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

**Structure of this paper**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Section | Number of questions available | Number of questions to be answered | Suggested working time  (minutes) | Marks available | Percentage of examination |
| Section One  Short response | 13 | 13 | 50 | 54 | 30 |
| Section Two  Problem-solving | 7 | 7 | 90 | 90 | 50 |
| Section Three  Comprehension | 2 | 2 | 40 | 36 | 20 |
|  |  |  |  | TOTAL | 100 |

**Instructions to candidates**

1. The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2021.* Sitting this examination implies that you agree to abide by these rules.
2. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.
3. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.
4. When calculating or estimating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning.

In calculations, give final answers to three significant figures and include appropriate units where applicable.

In estimates, give final answers to a maximum of two significant figures and include appropriate units where applicable.

1. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

**Section One: Short response 30% (54 Marks)**

This section has **13** questions. Answer **all** questions. Write your answers in the spaces

provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 50 minutes.

**Question 1 (6 marks)**

In order to protect against household fires and electrocution, modern buildings are equipped with RCD’s and Circuit Breakers. By outlining how each device works and what they protect against, clearly explain why it is necessary to have both of these devices installed in order for residents to be fully protected.

|  |  |
| --- | --- |
| Circuit breakers are designed to break the circuit when particularly high currents are detected | 1 mark |
| Circuit breakers protect against household fires because high currents can result in overheating of wires, which can cause household fires | 1 mark |
| When someone is being electrocuted, however, it is not expected that the current through the circuit breaker would be high, so the circuit will not be broken. | 1 mark |
| An RCD is designed to break the circuit when it detects a difference between the currents in the active and neutral wires | 1 mark |
| RCDs protect against electrocution as current flowing through a person and out of the circuit will result in a difference in current between the active and neutral wires | 1 mark |
| RCDs won’t protect against household fires, however, as they are not sensitive to the size of the current in either wire, only the difference in current between them. | 1 mark |

**Question 2 (4 marks)**

A kg truck travels North through an intersection at 3.00 m s-1 when it is hit by a   
 kg car travelling East. After the collision, the two cars move off together on a bearing of . Determine the speed of the car before the collision, supporting your answer with an appropriate diagram.

Diagram, schematic

Description automatically generated

|  |  |
| --- | --- |
| Appropriate diagram (e.g. above) | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

**Question 3 (5 marks)**

In an egg-drop experiment, a group of High School students have fixed a parachute system to an egg before dropping it from a height of 3.00 m. They record the combined mass to be 90.0 g and the time for the egg to reach the ground to be 0.900 s. Determine the magnitude of the force of air resistance acting on the egg-parachute system, assuming this force to be constant throughout the drop.

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
| N | 1 mark |
| N | 1 mark |
| N | 1 mark |

**Question 4 (4 marks)**

When fireworks explode, both light waves and sound waves are emitted, yet these two waves are very different in nature. Clearly state and explain two differences in the natures of light waves and sound waves.

|  |  |
| --- | --- |
| Light is an electromagnetic wave whereas sound is a mechanical wave | 1 mark |
| Sound requires a medium to travel through, whereas light can travel through a vacuum (definition of an electromagnetic wave not required) | 1 mark |
| Light is a transverse wave whereas sound is a longitudinal wave | 1 mark |
| In sound, energy propagates parallel to the direction of particle movement, whereas in light energy propagates perpendicular to the direction of electric and magnetic fields | 1 mark |

**Question 5 (3 marks)**

Steven is trying to determine his running speed. He measures that he can run m during a time of s. Determine Steven’s average running speed, including its absolute uncertainty.

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
| Rounding values to three significant figures each,  Students may more appropriately present this as  (either choice of significant figures is acceptable) | |

**Question 6 (4 marks)**

Kate and Kris are tuning their instruments to play a song together.

(a) Kate’s instrument is a pipe that is open at one end and closed at the other. Kate plays the instrument at its third harmonic. Sketch a wave envelope (either pressure variation or displacement) for the sound she produces in her instrument.

(1 mark)

A picture containing chart

Description automatically generated

|  |  |
| --- | --- |
| Either of the above diagrams | 1 mark |

(b) Kris’s instrument is a pipe that is open at both ends. Kris plays the at its third harmonic. Sketch a wave envelope for the pressure variation of the sound she produces in her instrument.

(2 marks)

A picture containing text, archery, line, projectile

Description automatically generated

|  |  |
| --- | --- |
| Nodes at each open end | 1 mark |
| Correct harmonic | 1 mark |

(c) Given that Kate and Kris are producing sounds of the same frequency, if the length of Kate’s instrument is 0.320 m, determine the length of Kris’s instrument.

(1 mark)

|  |  |
| --- | --- |
| Given the frequency/wavelength is the same, Kris’s instrument is twice the length of Kate’s.  Hence m | 1 mark |

**Question 7 (6 marks)**

“Whiskey Stones” are a popular alternative to using ice to cool drinks. They are made of solid granite, roughly the same size and shape as an ice cube, but approximately three times more dense than water and with approximately twice the specific heat capacity of water. Despite this, they are often considered a poor substitute for using ice to cool drinks.

(a) Explain why you would expect ice to lower the temperature of a drink more than you would   
expect Whiskey Stones to lower its temperature.

(2 marks)

|  |  |
| --- | --- |
| Ice undergoes a phase change to water when cooling the drink while Whiskey Stones do not undergo a phase change | 1 mark |
| The latent heat of fusion is considerably greater than the specific heat (given the small change in temperature) making the ice more effective at cooling drinks | 1 mark |

(b) State and explain the predominant method of heat transfer in drinks.

(2 marks)

|  |  |
| --- | --- |
| The predominant method of heat transfer would be convection | 1 mark |
| This involves the rising of hotter, less dense fluid and the falling of cooler, more dense fluid | 1 mark |

(c) Hence, considering this method of heat transfer and the difference in density between ice and Whiskey Stones, explain why you would expect ice to lower the temperature of a drink faster than you would expect Whiskey Stones to lower its temperature.

(2 marks)

|  |  |
| --- | --- |
| Ice floats on top of drinks allowing cooling convection currents to form within the drink | 1 mark |
| Whiskey Stones, however, will sink to the bottom of drinks, cooling the bottom of the drink but not effectively cooling the top | 1 mark |

**Question 8 (4 marks)**

Many face masks carry a permanent electric charge that can attract droplets (and other small materials) towards a filter. Using the diagram below, explain how the droplet is attracted to the mask. As part of your answer, illustrate the charges on the droplet (it has been drawn oversized to allow you to more easily do so).

A picture containing diagram

Description automatically generated

|  |  |
| --- | --- |
| Diagram: Charges are distributed on the droplet with negative charges closer to the mask than positive charges (students may more accurately draw positive charges evenly distributed throughout the droplet) | 1 mark |
| Diagram: An equal amount of positive and negative charges are drawn | 1 mark |
| By induction, charges are redistributed on the droplet (as shown) | 1 mark |
| Since the negative charges are closer to the mask, they are attracted more strongly than the positive charges are repelled, resulting in an overall attraction of the droplet towards the mask | 1 mark |

**Question 9 (3 marks)**

Fluorine-18 is a radioisotope with a half-life of 110 minutes. Determine the time it takes, in hours, for a sample containing 8.00 g of Fluorine-18 to only contain 2.00 g of Fluorine-18.

|  |  |
| --- | --- |
| 8.00 g 🡪 4.00 g 🡪 2.00 g Two half-lives have transpired | 1 mark |
| minutes | 1 mark |
| hours | 1 mark |

**Question 10 (3 marks)**

A basketballer is shooting a free-throw. They are standing a horizontal distance of 4.50 m from the ring, which is at a height of 3.00 m. If the basketballer shoots the ball with a speed of 7.00 m s-1, from a height of 1.40 m, determine the speed of the ball as it passes through the ring.

|  |  |
| --- | --- |
| Conservation of energy: | 1 mark |
|  | 1 mark |
|  | 1 mark |

**Question 11 (5 marks)**

A child is sliding down a banister, as shown in the picture below.

Diagram

Description automatically generated

(a) Ignoring friction, draw and label the forces acting on the child in the diagram above.

(3 marks)

|  |  |
| --- | --- |
| Weight force and normal force drawn at appropriate angles | 1 mark |
| Net force would (reasonably) be down the banister | 1 mark |
| No other forces are drawn | 1 mark |

(b) After reaching the end of the banister, the boy is falling in mid-air. At this point in time, the net force on him would be (circle one):

(1 mark)

A) Zero

B) Less than his net force on the banister (but non-zero)

C) Equal to his net force on the banister

D) Greater than his net force on the banister

|  |  |
| --- | --- |
| D | 1 mark |

(c) The boy lands and stands stationary on the floor. At this point in time, the net force on him would be (circle one):

(1 mark)

A) Zero

B) Less than his net force on the banister (but non-zero)

C) Equal to his net force on the banister

D) Greater than his net force on the banister

|  |  |
| --- | --- |
| A | 1 mark |

**Question 12 (4 marks)**

Hwei is standing 3.00 m away from a speaker and hears the sound at an intensity of   
. Determine how far back she should walk if she wants to reduce the sound intensity to .

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
| m | 1 mark |
| m | 1 mark |

**Question 13 (3 marks)**

A pot of boiling water will remain at during the entire time that the water is boiling, even though heat is clearly being transferred from the stove. Explain why this occurs.

|  |  |
| --- | --- |
| Temperature is a measure of the average kinetic energy of particles in a substance | 1 mark |
| The energy from the stove is not increasing the kinetic energy of particles (hence no change in temperature) but rather increasing the potential energy of particles | 1 mark |
| This increased potential energy accounts for the separation of particles from one another as they change from the liquid to the gas phase | 1 mark |

**End of Section One**

**Section Two: Problem-solving 50% (90 Marks)**

This section has **seven** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers

to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 90 minutes.

**Question 14 (12 marks)**

The cooling curve for a 35.0 g sample of a particular chemical is shown below.

Chart, line chart

Description automatically generated

(a) Determine the boiling point of the chemical, giving your answer in kelvin.

(2 marks)

|  |  |
| --- | --- |
|  | 1 mark |
| = 433 K | 1 mark |

(b) Determine the latent heat of fusion of the chemical.

(4 marks)

|  |  |
| --- | --- |
| J | 2 marks |
|  | 1 mark |
| (could be given to 2sf due to graph) | 1 mark |

(c) Determine the specific heat capacity of the chemical in its liquid phase.

(4 marks)

|  |  |
| --- | --- |
| J | |
| Energy and temperature for one point within liquid phase | 1 mark |
| Energy and temperature for second point within liquid phase | 1 mark |
|  | 1 mark |
| (could be given to 2sf due to graph) | 1 mark |

(d) Without any further calculations, explain how you can deduce from the graph that the specific heat capacity is largest for the liquid phase.

(2 marks)

|  |  |
| --- | --- |
| Since the liquid phase has the shallowest gradient, it would have the greatest specific heat capacity | 1 mark |
| This is because for the same mass, it is achieving a greater change in temperature for the same energy added (or alternatively, requiring more energy to be added for the same change in temperature) | 1 mark |

**Question 15 (10 marks)**

Sarah has just bought a bottle of orange juice. The juice is at a room temperature of , but Sarah would prefer it to be chilled to . She has poured herself a glass containing g of orange juice and intends to add ice, at , to cool the juice to the desired temperature.

(a) Given that orange juice has a specific heat capacity of , determine the amount of thermal energy that needs to be lost by the juice for it to be at the desired temperature.

(2 marks)

|  |  |
| --- | --- |
|  | 1 mark |
| J | 1 mark |

(b) Determine the mass of ice needed to cool the juice to the desired temperature.

(4 marks)

|  |  |
| --- | --- |
| kg | |
| Correctly substituted expression for thermal energy associated with the temperature change of ice | 1 mark |
| Correctly substituted expression for thermal energy associated with the phase change | 1 mark |
| Correctly substituted expression for thermal energy associated with the temperature change of water | 1 mark |
| Correctly solves equation for the mass of the ice | 1 mark |

(c) The following day, Sarah uses orange juice from the fridge, which is already at a temperature of . She again pours herself a glass containing g of orange juice. Sarah quickly drinks a quarter of her orange juice then tops up the glass with room temperature water (at ) so that it once again contains g of drink. Determine the final temperature of the drink once it has reached thermal equilibrium.

(4 marks)

|  |  |
| --- | --- |
| kg  kg | 1 mark |
|  | 1 mark |
|  | 2 marks |

**Question 16 (17 marks)**

In the circuit below, the switch is currently open and the reading on the ammeter is 1.50 A.

Diagram, schematic

Description automatically generated

(a) Draw an arrow indicating the direction of electron flow through .

(1 mark)

|  |  |
| --- | --- |
| As above | 1 mark |

(b) Determine the number of electrons that pass through resistor during a three minute period.

(3 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
| electrons | 1 mark |

(c) Determine the power dissipated in .

(2 marks)

|  |  |
| --- | --- |
|  | 1 mark |
| W | 1 mark |

(d) Determine the reading on the voltmeter.

(4 marks)

|  |  |
| --- | --- |
| V | 1 mark |
|  | 1 mark |
| A | 1 mark |
| V | 1 mark |

(e) Determine the voltage of the battery.

(3 marks)

|  |  |
| --- | --- |
| A | 1 mark |
| V | 1 mark |
| V | 1 mark |

(f) Suppose the switch is now closed. Clearly explain whether the reading on the ammeter will increase, decrease, or remain the same.

(4 marks)

|  |  |
| --- | --- |
| With the switch closed the total resistance of the components in parallel will decrease | 1 mark |
| Hence the total current of the circuit will increase | 1 mark |
| The voltage drop over will increase, while the voltage drop over any branch of the parallel network will decrease | 1 mark |
| Hence the current through , and the reading on the ammeter, will decrease | 1 mark |

**Question 17 (15 marks)**

A common nuclear fission reaction is shown below, where the number of neutrons released has not been provided.

The masses of the above species are provided below.

|  |  |
| --- | --- |
| **Species** | **Mass (u)** |
| Neutron | 1.009 |
| Uranium-235 | 235.044 |
| Barium-141 | 140.914 |
| Krypton-92 | 91.926 |

(a) State the number of neutrons released through this reaction.

(1 mark)

|  |  |
| --- | --- |
| Balancing mass numbers:  3 neutrons | 1 mark |

(b) Show that the amount of energy released by each fission reaction is approximately J.

(5 marks)

|  |  |
| --- | --- |
| u | 1 mark |
| u | 1 mark |
| mass defect u | 1 mark |
| MeV | 1 mark |
| J | 1 mark |

(c) A typical nuclear power plant will use 3.00 kg of Uranium-235 each day. Determine the amount of energy such a power plant would produce in a day.

(3 marks)

|  |  |
| --- | --- |
| Mass of one atom of Uranium-235: kg | 1 mark |
| Number of Uranium-235 atoms: atoms | 1 mark |
| Total energy produced: J [if using the value from part b, then J] | 1 mark |

(d) A member of the public is concerned that this nuclear process could become uncontrolled. Explain why the reaction has the potential for this to occur.

(3 marks)

|  |  |
| --- | --- |
| Each fission only requires on neutron but emits three neutrons | 1 mark |
| If not controlled, this can produce a chain reaction | 1 mark |
| The number of fissions, and hence energy produced, would grow exponentially | 1 mark |

(e) A spokesperson for the power plant tries to reassure the public by saying that if the reaction is occurring at too high a rate then they can always insert moderators to slow down the reaction. Clearly explain why this statement is incorrect.

(3 marks)

|  |  |
| --- | --- |
| Moderators slow down neutrons | 1 mark |
| This makes them more likely to induce fission and hence increases the fission rate | 1 mark |
| Control rods need to be inserted to slow the reaction | 1 mark |

**Question 18 (11 marks)**

The velocity-time graph for an object, initially travelling towards the right, is shown below. Use the graph to answer the questions that follow, noting that the shape of the graph is circular between 7.00 and 9.00 seconds.

Chart, line chart

Description automatically generated

(a) State the time(s) at which the object changes direction.

(1 mark)

|  |  |
| --- | --- |
| 5 s | 1 mark |

(b) State the time period(s) during which the object’s speed is increasing.

(1 mark)

|  |  |
| --- | --- |
| 0–3 s and 5–7 s | 1 mark |

(c) Determine the acceleration of the object after four seconds.

(2 marks)

|  |  |
| --- | --- |
| Acceleration is given by the gradient of the line, which when is | |
|  | 1 mark |
| left | 1 mark |

(d) Determine the displacement of the object after five seconds.

(3 marks)

|  |  |
| --- | --- |
| Displacement determined as the area under the graph | 1 mark |
| m | 1 mark |
| right | 1 mark |

(d) Determine the displacement of the object after nine seconds (providing your answer to three significant figures).

(4 marks)

|  |  |
| --- | --- |
| Displacement from 5 to 7 seconds is m left  Displacement from 7 to 9 seconds is m left  Total displacement m  i.e. 0.142 m left | |
| Calculates displacements from 5-9 seconds | 1 mark |
| Recognises the displacement from 5-9 seconds as opposite in direction to the displacement from 0-5 seconds | 1 mark |
| Correct magnitude | 1 mark |
| Correct direction | 1 mark |

**Question 19 (15 marks)**

A kg undercover police car is travelling at m s-1 when another car speeds past it, travelling at a constant speed of m s-1. The police car immediately begins pursuing the second car, accelerating at a constant rate of m s-2.

(a) Determine the magnitude of the initial momentum of the police car.

(1 mark)

|  |  |
| --- | --- |
|  | 1 mark |

(b) Determine the police car’s speed after 2.00 s of accelerating.

(1 mark)

|  |  |
| --- | --- |
|  | 1 mark |

(c) At the time when the police car’s speed matches that of the speeding car, determine the distance between them.

(5 marks)

|  |  |
| --- | --- |
|  | 1 mark |
| s | 1 mark |
| m | 1 mark |
| m | 1 mark |
| m | 1 mark |

(d) Determine how long it takes for the police car to catch up to the speeding car (from the time the speeding car first passed the police car).

(3 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
| s | 1 mark |

(e) Determine the average power of the police car during its pursuit.

(3 marks)

|  |  |
| --- | --- |
| Average speed of the police car is  (needs to equal the average speed of the speeding car, or by considering parts d and e) | 1 mark |
| N | 1 mark |
| W | 1 mark |

(f) Once caught, the speeding car begins to slow down to a stop, braking at a constant rate of 7.00 m s-2. Determine the distance over which it brakes.

(2 marks)

|  |  |
| --- | --- |
|  | 1 mark |
| m | 1 mark |

**Question 20 (10 marks)**

A new form of brachytherapy known as “diffusing alpha-emitters radiation therapy” aims to produce alpha-emitting radioisotopes at the site of a tumour. An initial source is implanted into the patient, which produces radioisotopes such as Radon 220, a known alpha-emitter. This technique hopes to treat large tumours of typical sizes such as 300 g by delivering an absorbed dose of approximately 70.0 Gy.

(a) Write the nuclear decay equation for Radon-220.

(2 marks)

|  |  |
| --- | --- |
|  | 2 marks |

(b) State and explain two reasons why an alpha-emitter has been chosen for this application.

(4 marks)

|  |  |
| --- | --- |
| Alpha particles have a high ionising ability | 1 mark |
| making them likely to destroy tumour cells | 1 mark |
| Alpha particles have a low penetrating ability | 1 mark |
| making them unlikely to reach (and damage) healthy cells | 1 mark |

(c) Determine the energy delivered to a typical tumour.

(2 marks)

|  |  |
| --- | --- |
| absorbed dose | 1 mark |
| J | 1 mark |

(d) Determine the equivalent dose delivered to a typical tumour.

(2 marks)

|  |  |
| --- | --- |
| QF = 20 | 1 mark |
| equivalent dose absorbed dose quality factor  Sv | 1 mark |

**End of Section Two**

**Section Three: Comprehension 20% (36 Marks)**

This section has **two** questions. You must answer **both** questions. Write your answers in the spaces provided.  
  
When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.  
  
When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 40 minutes.

**Question 21 (17 marks)**

A Year 11 Physics class is undertaking an experiment to determine the activity of a radioactive sample of Strontium-90 (decaying to Yttrium-90).

When Strontium-90 decays, it can be thought to emit radiation isotropically, meaning that the resulting particles of radiation are emitted in all directions, spreading out spherically. At a distance of from the source, the particles are thought to be spread over the surface of a sphere centred at the source (with surface area ).

A pair of glasses

Description automatically generated with low confidence

A radiation detector has a fixed area and will only detect the radiation incident on it. Therefore, the further the detector is placed from the source, the lower the activity it will detect. The students use a detector with a square detecting area of side length 3 cm.

(a) Write the nuclear decay equation for the radioactive source.

(2 marks)

|  |  |
| --- | --- |
|  | 2 marks |

(b) Show that the detected activity (in becquerel), , is given by

where is the activity of the source (in becquerel), and is the distance from the

detector to the source (in metres)

(2 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |

The students collected the data in the table below and have already begun the data manipulation process.

|  |  |  |
| --- | --- | --- |
|  |  |  |
| 0.100 | 100 | 26.5 |
| 0.150 | 44.4 | 11.8 |
| 0.200 | 25.0 | 6.6 |
| 0.250 | 16.0 | 4.2 |

(c) Complete the second column of the table above, including providing the correct units in   
 the header and the missing values correct to three significant figures.

(3 marks)

|  |  |
| --- | --- |
| Units | 1 mark |
| Correct values | 1 mark |
| Three significant figures | 1 mark |

(d) Using the grid provided on the next page, plot a graph of  against , with on the

vertical axis. Include a line of best fit.

(4 marks)

|  |  |
| --- | --- |
| Axes labelled correctly (including units) | 1 mark |
| Appropriate uniform scales used | 1 mark |
| Points plotted accurately | 1 mark |
| Reasonable line of best fit | 1 mark |

(e) Clearly showing construction lines on your graph, determine the gradient of your line of

best fit.

(2 marks)

|  |  |
| --- | --- |
| Construction lines drawn on graph using two non-data points | 1 mark |
| Gradient calculated () | 1 mark |

(f) Use your gradient to determine the activity of the source.

(2 marks)

|  |  |
| --- | --- |
| gradient = | 1 mark |
| Calculates  e.g. | 1 mark |

(g) The students took another measurement and found that the activity at the detector was

higher than expected. Assuming no mistakes were made and there were no errors

introduced by the measuring equipment, suggest a reason why this occurred.

(1 mark)

|  |  |
| --- | --- |
| Nuclear decay is an inherently random process | 1 mark |
| Accept other reasonable answers, e.g. greater (random) count from background radiation | |

(h) When the students compare their results to those from last year’s class, they find that all

of their measurements are lower. Assuming no mistakes were made and there were no

errors introduced by the measuring equipment (all of which is the same as that used last

year), explain why this occurred.

(1 mark)

|  |  |
| --- | --- |
| The sample will have decayed over this time, decreasing its activity | 1 mark |

**Question 22 (19 marks)**

**Hunting techniques of the mustached bat**

Based on the research of Suga (1990)

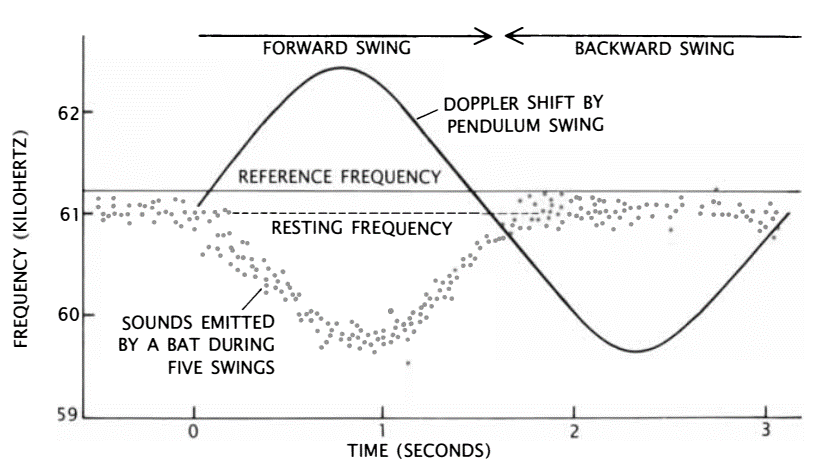
Some species of bat, such as the mustached bat, have developed advanced sonar techniques used for hunting other species. The mustached bat is not only able to use echolocation to determine the distance to its prey, but also to use the doppler effect to determine the speed of its prey. The doppler effect is a perceived change (commonly referred to as a doppler shift) in the frequency of a sound due to the relative motion of the source of the sound and/or whatever is hearing or recording the sound.

The mustached bat hunts by first releasing a high frequency sound and several of its harmonics. The sounds waves produced can effectively detect the location of any object larger than their wavelength. Of particular importance is the second harmonic. When the bat and its prey are both stationary, this harmonic has a frequency of 61.2 kHz. Mustached bats also have extremely sensitive hearing near this frequency and can detect frequency shifts as small as 0.01%. By detecting the shift in frequency of the returned echo, the bats can deduce the speed of their prey.

When flying towards its prey, the mustached bat also has the ability to compensate for its own movement in order to ensure that returned echoes still fall within its sensitive range of hearing. The bat’s motion will cause not only a doppler shift in its emitted sound, but also a doppler shift in its perceived frequency of the returning echo. The frequency of sound ultimately heard by the bat is given by

Note that will always be positive as mustached bats do not fly backwards.

The bats’ ability was observed by scientists, who placed a mustached bat on a swing and recorded the frequency of sound emitted by the bat. They clearly observed the bat’s emitted frequency of sound change to counteract the doppler shift caused by the forward swing.



*Figure taken directly from (Sugo, 1990)*

(a) Determine the fundamental frequency of sound emitted by the mustached bat when both

it and its prey are stationary.

(2 marks)

|  |  |
| --- | --- |
|  | 1 mark |
| Hz | 1 mark |

(b) Determine the wavelength of the second harmonic emitted by the mustached bat when   
both it and its prey are stationary.

(2 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |

(c) State one reason why sound with this wavelength would be ideal for echolocation.

(1 mark)

|  |  |
| --- | --- |
| Since the wavelength is so small, the majority of prey should be detectable | 1 mark |

(d) Below is a simplified wavefront diagram showing the emitted sound waves of the

mustached bat as it approaches a stationary prey. Draw on the diagram to show three   
successive wavefronts that have reflected off the prey.

(2 marks)

Diagram

Description automatically generated

|  |  |
| --- | --- |
| Three appropriately shaped wavefronts are drawn | 1 mark |
| Reflected wavelength is equal to incident wavelength | 1 mark |

(e) Considering both the article and the diagram from part (c), fully explain why the echo of the bat’s emitted sound will be perceived at a higher frequency when the bat is flying towards its prey.

(3 marks)

|  |  |
| --- | --- |
| As the bat moves towards its prey the wavefronts it emits in front of it are closer together than they are when stationary | 1 mark |
| The decreased wavelength results in a higher frequency for these transmitted waves | 1 mark |
| As the bat is also travelling towards the reflected waves, successive wavefronts reach the bat at a greater frequency than if the bat were stationary | 1 mark |

(f) A stationary mustached bat detects its prey to be 30.0 m away. Determine the time

period between when the bat emitted a sound and when it heard its echo.

(3 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
| s | 1 mark |

(g) Estimate the maximum speed of the swing used in the scientists’ experiment.

(5 marks)

|  |  |  |
| --- | --- | --- |
| Estimates kHz (accept 62.2 – 62.6 kHz) | | 1 mark |
| If using kHz from the article: | If using kHz from the graph: |  |
|  |  | 1 mark |
|  |  | 2 marks |
| (2sf)  (2.8 – 3.9 based on ) | (2sf)  (3.4 – 4.5 | 1 mark |

(g) Suggest an appropriate reason why there was no frequency compensation observed during the backwards swing for the scientists’ experiment.

(1 mark)

|  |  |
| --- | --- |
| Since mustached bats do not fly backwards, they would not be used to applying a frequency compensation in this case | 1 mark |

Supplementary page

Question number: \_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Supplementary page

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Spare grid

**A close up of a white wall

Description automatically generated**

Suga, N. (1990). Biosonar and Neural Computation in Bats. *Scientific American*, *262*(6), 60–71. http://www.jstor.org/stable/24996825

WATP acknowledges the permission of the School Curriculum and Assessment Authority in providing instructions to students.