PHYSICS

UNITS 1 & 2

2021

MARKING GUIDE

Name: ___________________________

Teacher: _________________________

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes

Working time for the paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:

- This Question/Answer Booklet; Formula and Constants sheet

To be provided by the candidate:

- Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.

- Special items: Calculators satisfying the conditions set by the SCSA for this subject.

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 notes or other items of a non-personal nature in the examination room. 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 exam
Section One: Short answer	13	13	50	55	30
Section Two: Extended answer	6	6	90	86	50
Section Three: Comprehension and data analysis	2	2	40	35	20
			Total	176	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 11 Information Handbook 2021.* Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

3. 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.

4. You must be careful to confine your responses to the specific questions asked and follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Refer to the question(s) where you are continuing your work.

Section One: Short response **30% (55 Marks)**

This section has **thirteen (13)** questions. Answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 50 minutes.

Question 1 **(4 marks)**

Justify whether the following statement is true or false: At the same temperature, atoms of helium move faster, on average, than atoms of xenon.

True 1
Temperature is a measure of average kinetic energy 1
Particles at the same temperature will have the same kinetic energy 1
Velocity depends on both kinetic energy and mass, so particles with the same kinetic energy but different masses must have different velocities 1

Question 2 **(4 marks)**

Explain the differences in penetration power between alpha, beta and gamma radiation.

Alpha has the least penetration power, gamma the most and beta in between 1

The penetration power reduces as the radiation increase in mass and/or charge 1

Alpha has a +2 charge and a lot of mass, so it is only weakly penetrating 1

Gamma has no charge and no mass, so it is extremely penetrating 1

Question 3 **(4 marks)**

A standard AA battery supplies a 1.20 V potential and sustains a 200 mA current. The battery lasts for 15.0 hours under these conditions before running out of energy. Calculate the electrical energy supplied by the battery.

$P = VI = 1.20 \times 0.200 = 0.240\ W$ 1-2

$E = Pt = 0.240 \times (15.0 \times 60 \times 60) = 1.30 \times 10^4\ J$ 1-2

Question 4 **(5 marks)**

Ms Collins is doing a food shop at Coles. Seeing an item on her list, she pushes her 12.5 kg trolley from rest up to 1.70 m s^{-1}.

(a) Calculate the work done by Ms Collins on the trolley. (2 marks)

$W = \Delta E = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ 1

$W = \frac{1}{2} \times 12.5 \times 1.70^2 - 0 = 18.06 = 18.1\ J$ 1

(b) The trolley was moved 3.20 m during the acceleration. Calculate the average power at which Ms Collins transferred energy to the trolley. If you could not obtain an answer to part (a), use 18.5 J. (3 marks)

$v_{av} = \frac{u+v}{2} = \frac{0+1.70}{2} = 0.850\ m\ s^{-1}$ 1

$W = Fs$

$F = \frac{W}{s} = \frac{18.06}{3.20} = 5.644\ N$ 1

$P = Fv_{av} = 5.644 \times 0.850 = 4.80\ W$ 1

OR

$v^2 = u^2 + 2as$

$a = \frac{v^2-u^2}{2s} = \frac{1.70^2-0}{2\times3.20} = 0.4516\ m\ s^{-2}$ 1

$v = u + at$

$t = \frac{v-u}{a} = \frac{1.70-0}{0.4516} = 3.764\ s$ 1

$P = \frac{W}{t} = \frac{18.06}{3.764} = 4.80\ W$ 1

Question 5 **(4 marks)**

The threshold of pain for human hearing occurs when sound is at an intensity of 10.0 W m^{-2}. A jet engine produces a sound intensity of 562 W m^{-2} at a distance of 2.00 m from the engine.

(a) Describe how sound intensity varies with distance from the source. (1 mark)

Sound intensity is proportional to the inverse of distance squared. 1

(b) Calculate how far from a jet engine the intensity of its sound will drop below the threshold of pain. (3 marks)

$I \propto \frac{1}{r^2}$

$\therefore I_1 r_1^2 = I_2 r_2^2$

$562 \times 2.00^2 = 10.0 \times r_2^2$ 1-2

$r_2 = 15.0\ m$ 1

Question 6 **(4 marks)**

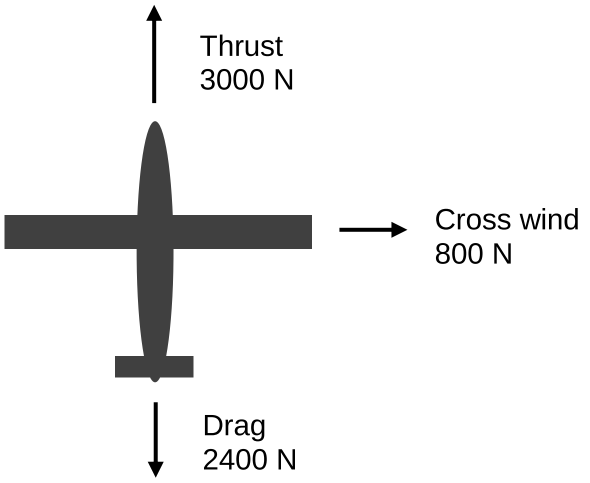
Describe the difference between a longitudinal wave and a transverse wave. Provide an example of each type of wave to support your answer.

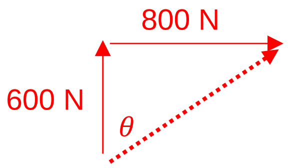
A longitudinal wave has vibrations/disturbances that oscillate in the same direction as the propagation of the wave. 1
Suitable example (sound in air, compressed slinky) 1

A transverse wave has vibrations/disturbances that oscillate perpendicular to the propagation of the wave. 1
Suitable example (ripples, string) 1

Question 7 **(4 marks)**

Calculate the net force acting on the plane shown in the free body diagram below. Treat up the page as the north direction.





$F_{north} = 3000 - 2400 = 600\ N$ 1

$\sum F = \sqrt{800^2 + 600^2} = 1000\ N$ 1

$\theta = \tan^{-1}\left(\frac{800}{600}\right) = 53.1^0$ 1

$Direction\ is\ 53.1^0\ T\ (or\ N\ 53.1^0\ E)$ 1

Question 8 **(4 marks)**

Compare the purpose and function of a circuit breaker and an RCD.

A circuit breaker will cut off the electrical supply when the current flowing through it is higher than some safe value. 1

It will stop electrical hazards due to excessive current, prevents fire. 1

An RCD will break the electrical supply when the amount of current entering through the active line is not the same as the amount of current returning through the neutral line. 1

It will stop electrical hazards due to currents leaking out of the system, prevents electrocution. 1

Question 9 **(4 marks)**

Devices for charging mobile phones and laptops reduce the 240 V mains to something lower that the sensitive electronics can handle. A 19.0 V charger delivers 2.85 kJ to a laptop. Calculate the number of electrons delivered to the laptop via the charger.

$V = \frac{W}{q}$ 1

$\therefore q = \frac{W}{V} = \frac{2850}{19.0} = 150\ C$ 1-2

$no.of\ electrons = \frac{150}{1.60 \times 10^{-19}} = 9.38 \times 10^{20}$ 1

Question 10 **(4 marks)**

A closed pipe is 1.35 m long and 15.0 cm in diameter.

(a) Calculate the wavelength of the fundamental wave that would resonate in the pipe. (2 marks)

$\lambda = \frac{4l}{(2n-1)} = \frac{4 \times 1.35}{1} = 5.40\ m$ 1-2

(b) Calculate the length of an open pipe that could produce the same fundamental frequency as the closed pipe as in part (a). (2 marks)

$\lambda = \frac{2l}{n}$

$l = \frac{n\lambda}{2} = \frac{1 \times 5.40}{2} = 2.70\ m$ 1-2

Question 11 **(3 marks)**

A car radiator is designed with features that make it more effective in its role to cool the engine components of a car. For each feature below, describe how the feature improves the effectiveness of the radiator.

Black surfaces radiate heat more effectively/have higher emissivity 1

Wavy surface gives more surface area to radiate heat, increasing heat transfer 1

High specific heat capacity ensures that a lot of heat can be taken from the engine without changing the temperature of the radiator fluid significantly 1

(not accepting taking a lot of energy to boil, partly dependent on boiling point of substance and not acknowledge ΔT impact on rate of heat transfer)

Question 12 **(5 marks)**

Electric ovens require a large current to deliver the power needed for the heating element. For the electrical supply to the oven, state if it would be better to use a short or long wire and state if it would be better to use a thin or thick wire. Justify your choices.

Short wire 1

Thick wire 1

The dimensions of a wire will affect its resistance. A short, thick wire will have less resistance as the electrons don't have to flow as far and have more cross sectional area to navigate. 1-2

By decreasing resistance, more current can flow to the oven 1

Question 13 **(6 marks)**

A soft drink company monitors the volume of soft drink added to cans by using a radioisotope. Radiation is directed through the can, near the top. A detector on the other side of the can monitors for radioactivity. When the detector picks up a significant drop in radioactivity as a can passes by, this is an indication the soft drink can was full.

(a) State which type of radiation would be suited to this application. Justify your choice.

Beta 1

Beta can penetrate through thin aluminium and air, but not through any additional soft drink
OR
Alpha and gamma have too little and too much penetrating power respectively which will not be impacted by soft drink's presence 1

When beta is stopped by the soft drink, this would cause a drop in radioactivity at the detector, confirming the can has been filled. 1

(b) For this application, state whether it would be better to have a radioisotope with a half life of 2 weeks or 2 years. Justify your choice.

2 years 1

The longer half life will have a more consistent activity 1

The detector will be less likely to read a can as full, despite being empty if the activity drops too low. 1

OR

2 years 1

The longer half life will mean the source will not be replaced as often 1

This is safer as there is less handling of radioactive material/less costly or time consuming 1

End of Section 1

Section Two: Problem-solving **50% (86 Marks)**

This section has **six (6)** questions. You must answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 90 minutes.

Question 14 **(14 marks)**

Thermodynamic properties of three alcohols are listed in the table below. You have a 100 g sample of each alcohol but are concerned the labels have been mixed up. You have access to a low temperature freezer that can be set between -150 ^{0}C and -20 ^{0}C, a calorimeter that can measure the amount of heat applied to a sample, and thermometers.

Alcohol	Liquid Specific Heat Capacity (J kg^{-1} K^{-1})	Melting point (^{0}C)
1-propanol	2400	-126
2-propanol	2570	-90
1-butanol	2400	-90

(a) Describe a method to identify the 1-propanol sample from the other alcohols based on their thermodynamic properties. (2 marks)

Put all alcohols in the freezer below -90 ^{0}C and above -126 ^{0}C. 1

The alcohol that is in a liquid state is 1-propanol 1

(b) Describe a method to identify the 2-propanol from the other alcohols based on their thermodynamic properties. In your description, include the useful states of matter, measurements and/or calculations performed. (4 marks)

Start the alcohols in their liquid state (controlled 1

Apply heat and record using the calorimeter 1

Measure the temperature change of all samples 1

Using $Q = mc\Delta T$, calculate the specific heat capacity of the alcohols and use the table to identify the sample
OR
The alcohol that had the smallest temperature change for equal amounts of applied heat is the 2-propanol due to it having the highest specific heat capacity 1

(c) The sample of 1-propanol at -45.0 ^{0}C is added to the 2-propanol sample at 10.0 ^{0}C. Calculate the final temperature of the mixture. (4 marks)

$\Delta Qgained = \Delta Qlost$
$mc\Delta T_{1-propanol} = mc\Delta T_{2-propanol}$ 1

$0.1 \times 2400 \times (T - (-45)) = 0.1 \times 2570 \times (10 - T)$ 1-2

$240T + 10800 = 2570 - 257T$
$T = -16.6\,^0C$ 1

(d) Calculate the mass of water at 20.0 ^{0}C required to raise the temperature of the 100 g sample of 1-butanol from -50.0 ^{0}C to -15.0 ^{0}C. (4 marks)

$\Delta Qgained = \Delta Qlost$
$mc\Delta T_{1-butanol} = mc\Delta T_{water} + mL_{water/ice} + mc\Delta T_{ice}$ 1

$0.1 \times 2400 \times (50 - 15) = m \times 4180 \times (20 - 0) + m \times 3.34 \times 10^5 + m \times 2100 \times (15 - 0)$
1-2

$8400 = 83600m + (3.34 \times 10^5)m + 31500m$
$m = 1.87 \times 10^{-2}\ kg$ 1

Question 15 **(13 marks)**

The triple-alpha process is a set of nuclear reactions that occur in the cores of stars in which three alpha particles are transformed into carbon. The first reaction is the fusion of two alpha particles to form Be-8. This reaction requires an input of 0.0918 MeV, taken from the star's core. A third alpha particle fuses with Be-8 to form C-12. This second reaction releases 7.37 MeV.

(a) State the composition of an alpha particle. (1 mark)

2 protons and 2 neutrons 1

(b) Write the first reaction of the triple-alpha process. (2 marks)

$^{4}_{2}\alpha + ^{4}_{2}\alpha \rightarrow ^{8}_{4}Be$ 1-2

(c) Calculate the mass, in kilograms, gained by the fusion of the first two alpha particles. (3 marks)

$E = mc^2$ 1

$m = \frac{E}{c^2} = \frac{0.0918\times10^{6}\times1.6\times10^{-19}}{(3.00\times10^{8})^2} = 1.63 \times 10^{-31}\ kg$ 1-2

(d) Write the second reaction of the triple-alpha process. (2 marks)

$^{8}_{4}Be + ^{4}_{2}\alpha \rightarrow ^{12}_{6}C$ 1-2

(e) Calculate the net energy released by a completed triple-alpha process. (2 marks)

$\Delta E = 7.37 - 0.0918$ 1

$\Delta E = 7.28\ MeV$ 1

(f) By successive fusion of additional alpha particles with the nucleus formed from the triple-alpha process, it is possible for stars to create heavier elements, like oxygen and neon. However, successive fusion of additional alpha particles alone will not create fluorine or sodium. Explain why. (3 marks)

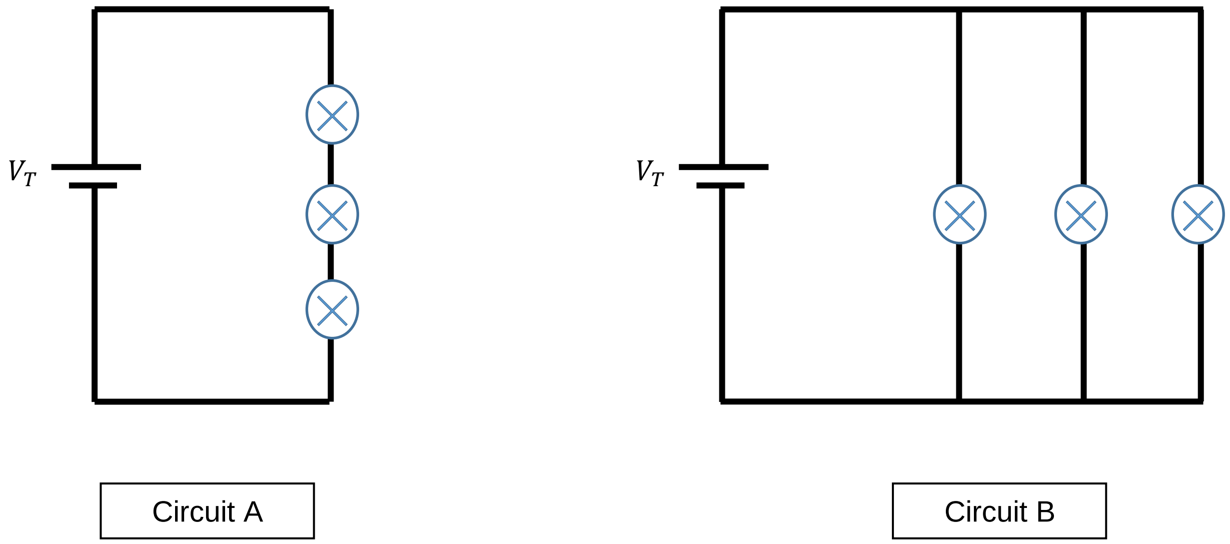
The fusion of alpha will add two more protons to the nucleus. 1

Only elements with an even atomic number will be formed 1

Fluorine and calcium have an odd atomic number and cannot be produced by adding any number of additional alpha particles 1

Question 16 **(13 Marks)**

Consider the two circuits below which, have identical emf sources and globes.



(a) Which circuit is better suited for lighting multiple rooms of in a house? Justify your choice. (2 marks)

Parallel 1

If a globe blows/breaks then that branch of the parallel circuit will be without power. The other lights will continue to work. 1

OR

Each globe can be controlled independently of the others by having a switch within each branch. 1

(b) Redraw circuit A below with an ammeter and voltmeter included. The ammeter and voltmeter need to allow for the measurement of the current and voltage of a single globe. (2 marks)

Ammeter anywhere in series with circuit elements 1

Voltmeter attached in parallel with a single globe 1

(c) Determine the equivalent resistance of the circuit in terms of the resistance of a single globe, R. Show clear working.

i. For Circuit A (2 marks)

$R_T = R + R + R = 3R$ 1-2

ii. For Circuit B (2 marks)

$R_T = \left(\frac{1}{R} + \frac{1}{R} + \frac{1}{R}\right)^{-1} = \frac{R}{3}$ 1-2

(d) By determining an expression for the power dissipated by a globe from each circuit in terms of the resistance of a single globe (R) and the voltage of the emf source (V_T), determine which circuit will produce a brighter light for a single globe. You can assume the light bulbs are of the same resistance and are Ohmic. (5 marks)

In circuit A, for each globe:

$I = \frac{V_T}{3R} \quad and \quad V = \frac{V_T}{3}$ 1

$P = VI = \frac{V_T^2}{9R}$ 1

In circuit B, for each globe:

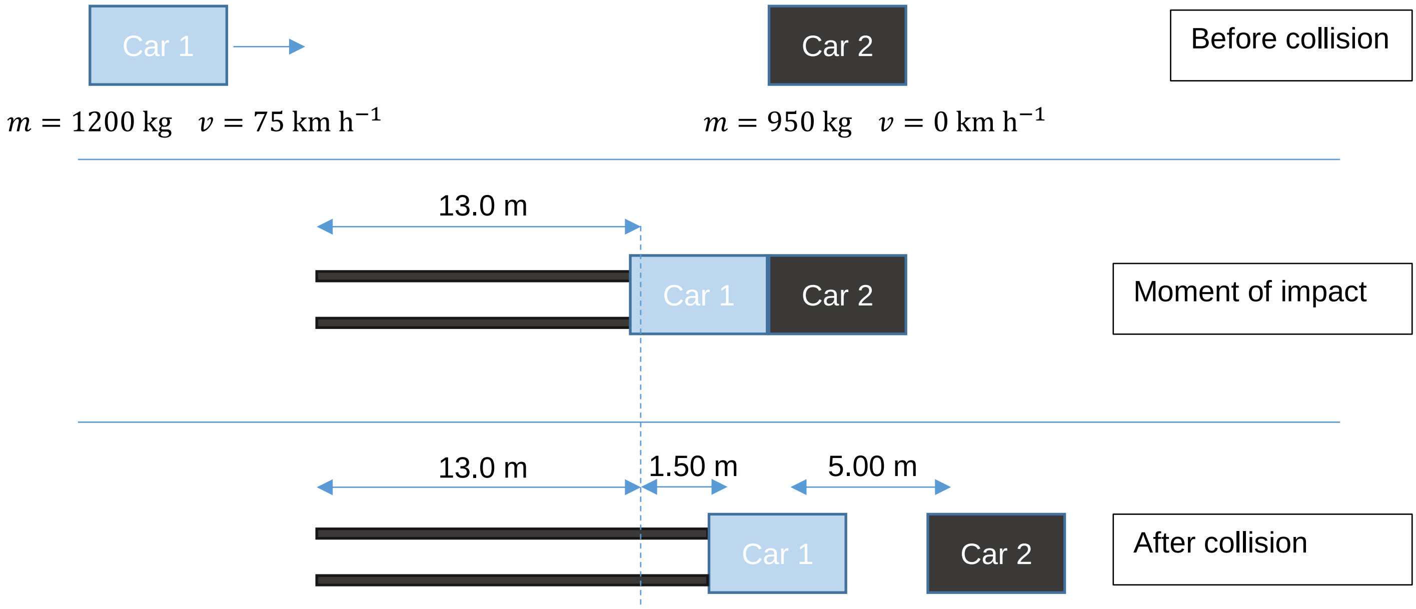
$I = \frac{V_T}{R} \quad and \quad V = V_T$ 1

$P = VI = \frac{V_T^2}{R}$ 1

$\frac{V_T^2}{R} > \frac{V_T^2}{9R}$ therefore circuit B is brighter. 1

Question 17 **(16 marks)**

The reconstruction of a traffic accident based on the testimonies of eyewitnesses and evidence found on the road is shown below in three stages; before the collision, at the moment of impact, and after the collision. The skid marks seen in the diagrams reveal the distance over which Car 1 was braking hard. Car 1 has a maximum braking force of 16800 N. You may assume that Car 1 only ever applied the full force of its brakes.



(a) Explain whether a car crash is an example of an elastic or inelastic collision. (3 marks)

An inelastic collision occurs when kinetic energy is not conserved 1

In a car crash, kinetic energy will be converted into heat/sound/deformation of the car body. 1

Thus a car crash is an example of an inelastic collision 1

(b) Show that the velocity at which Car 1 collided with Car 2 is approximately 8 m s^{-1}. (4 marks)

$75\ km\ h^{-1} = 20.833\ m\ s^{-1}$ 1

Deceleration during braking
$a = \frac{F}{m} = \frac{16800}{1200} = 14.0\ m\ s^{-1}$ 1

Velocity at impact
$v^2 = u^2 + 2as$
$v^2 = 20.833^2 + 2 \times (-)14.0 \times 13.0$ 1
$v = 8.37\ m\ s^{-1}$ 1

(c) Calculate the velocity of Car 1 just after the moment of impact. (2 marks)

$v^2 = u^2 + 2as$
$0^2 = u^2 + 2 \times (-)14.0 \times 1.50$ 1
$u = 6.48\ m\ s^{-1}$ 1

(d) Hence, calculate the velocity of Car 2 just after the moment of impact. If you could not determine an answer to part (c) you may use 6.50 m s^{-1}. (3 marks)

$\sum p_{before} = \sum p_{after}$

$mu_{car\ 1} = mv_{car\ 1} + mv_{car\ 2}$ 1

$1200 \times 8.37 = 1200 \times 6.48 + 950 \times v$ 1

$v = 2.39\ m\ s^{-1} \quad (2.36\ m\ s^{-1})$ 1

(e) Explain how a car's crumple zone would have reduced the chance that the driver of Car 1 was significantly injured. (4 marks)

The crumple zone of a car is designed to deform during a collision 1

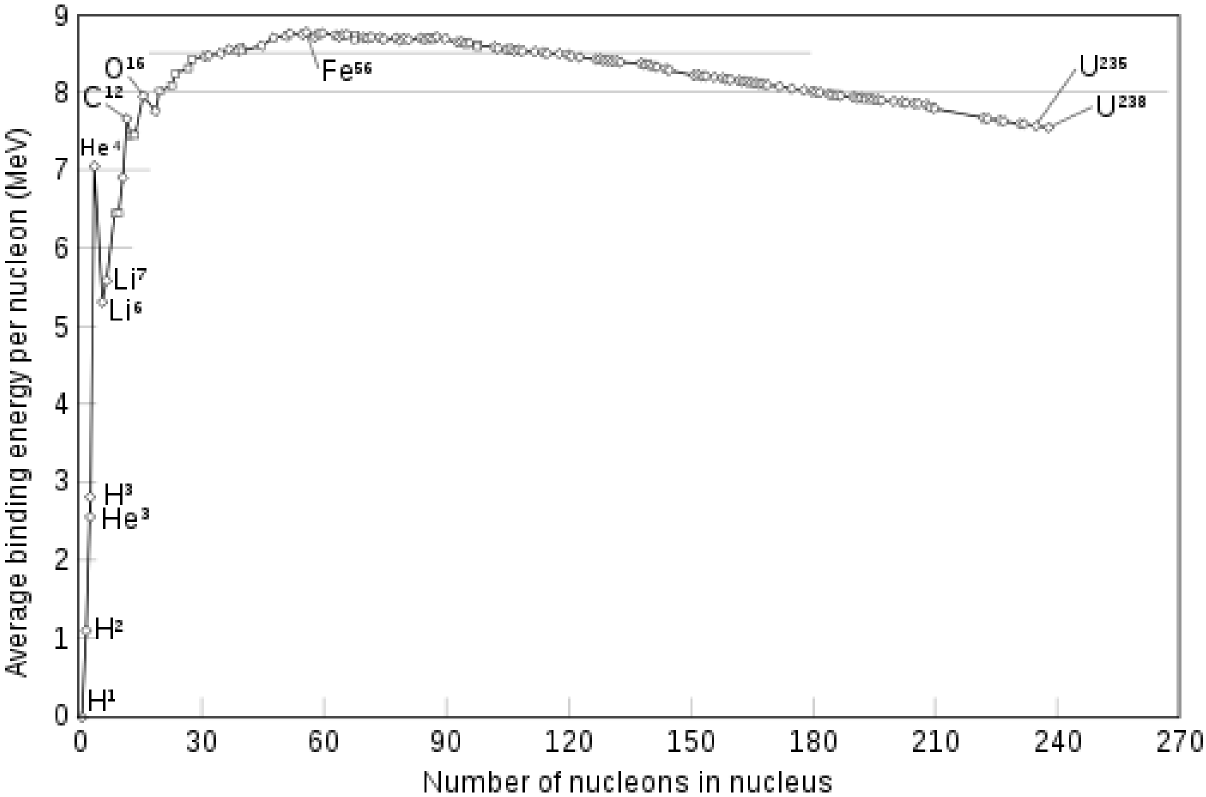
This increases the time in which the car will experience the change in momentum/impulse 1

As time of the collision increases, the force of the impact will reduce ($I = \uparrow F\ \downarrow t$) 1

With less force, the chance of injury will be less 1

Question 18 **(17 marks)**

The graph below shows the average binding energy per nucleon as a function of mass number. Some isotopes have been identified on the graph.



(a) Define the term 'binding energy' in the context of nuclear physics. (2 marks)

The amount of energy released during the formation of a nucleus from its constituent particles. 1-2

(b) With reference to the graph, explain which isotope is the most stable. (3 marks)

Fe-56 1

It has the most binding energy per nucleon 1

The more binding energy lost per nucleon during the formation of the nucleus, the tighter the nucleons are held together, making the nucleus more stable 1

(c) Using the graph, calculate the mass defect (in atomic mass units) for the formation of O-16 from its constituent nucleons. (3 marks)

$BE\ per\ nucleon = 8\ MeV$ 1

$BE = 16 \times 8 = 128\ MeV$ 1

$931\ MeV \equiv 1\ u$

$\Delta m = \frac{128}{931} = 0.137\ u$ 1

(d) Referring to a force present in the nucleus of an atom, suggest a reason why the binding energy per nucleon increases from ^{1}H to ^{2}H to ^{3}H. (2 marks)

increasing the number of neutrons (1) increases the strong force holding the nucleus together (1), increasing the binding energy per nucleon

(e) Referring to a force present in the nucleus of an atom, suggest a reason why the binding energy per nucleon decreases from ^{4}He to ^{6}Li. (2 marks)

increasing the number of protons (1) increases the electrostatic repulsion tearing the nucleus apart (1), decreasing the binding energy per nucleon

(f) Using features of the graph as evidence, justify whether a fusion or fission reaction results in the largest amount of energy released per nucleon (5 marks)

Isotopes with a mass number below the peak at Fe-56 undergo fusion while isotopes above undergo fission. 1

The curve of the graph for the lighter isotopes that undergo fusion is much steeper than the gradual slope for the heavier isotopes 1

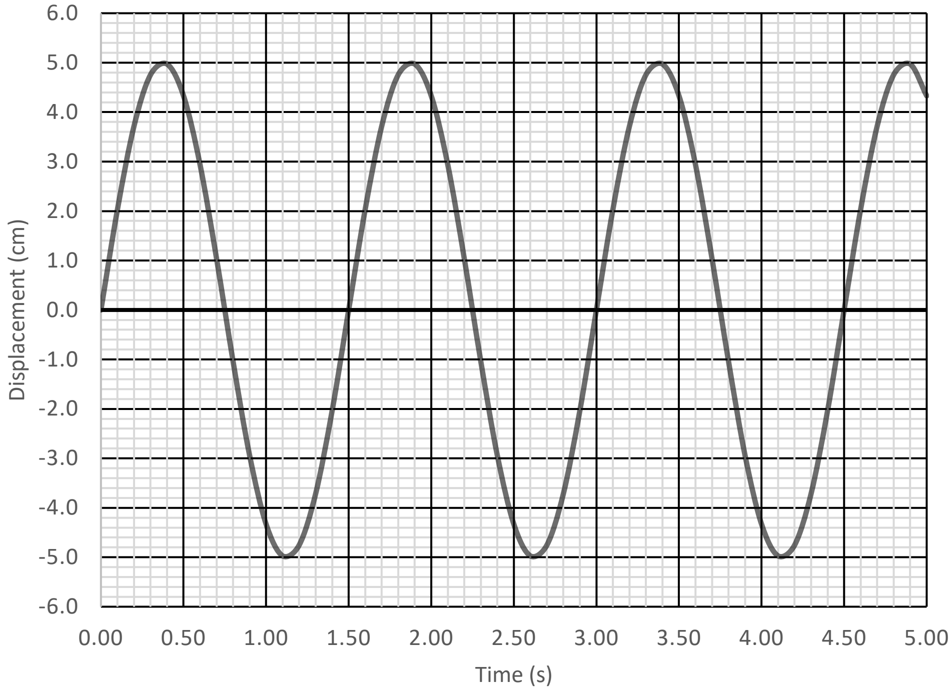
When lighter isotopes fuse there will be a big change in the binding energy per nucleon. 1

When heavy isotopes fission, there will be a smaller change in the binding energy per nucleon.

Thus fusion reactions will release the largest amount of energy per nucleon. 1

Question 19 **(13 marks)**

A rock is dropped into the middle of a calm lake, creating ripples that are 14.0 cm apart. The wave ripples, as they pass by a cork on the lake's surface, are shown as a function of time in the graph below.



(a) For each time given below, circle the best description of the relative speed of the cork and circle the best description of the direction of the cork's velocity.

i. 1.500 s (2 marks)

Relative speed			Direction				
Large	Small	Zero	Up	Down	Left	Right	Not applicable

ii. 1.125 s (2 marks)

Relative speed			Direction				
Large	Small	Zero	Up	Down	Left	Right	Not applicable

iii. 2.500 s (2 marks)

Relative speed			Direction				
Large	Small	Zero	Up	Down	Left	Right	Not applicable

(b) Calculate the frequency of the wave. (2 marks)

$T = 1.50\ s\ (from\ graph)$ 1

$f = \frac{1}{T} = \frac{1}{1.50} = 0.6667 = 0.667\ Hz$ 1

(c) Hence, calculate the velocity of the wave. If you could not obtain an answer to part (b), use 0.700 Hz. (2 marks)

$v = \lambda f$

$v = 0.14 \times 0.6667 = 0.0933\ m\ s^{-1}\ \ (0.0980\ m\ s^{-1})$ 1-2

(d) By referring to the wave equation, describe the changes that would happen to the properties of the wave should the frequency of the ripples of a second rock be twice the magnitude of the first rock. (3 marks)

$v = \lambda f$ 1

Velocity of the wave remains constant for any given medium 1

If the frequency doubles, the wavelength halves 1

End of Section 2

Section Three: Comprehension **20% (35 Marks)**

This section contains **two (2)** questions. You must answer both questions. Write your answers in the spaces provided. Suggested working time for this section is 40 minutes.

Question 20 **(18 marks)**

Inharmonicity

In stringed instruments such as guitars and pianos, the characteristics of each string determines the note. String length affects the fundamental frequency, but so too do other characteristics. Increasing the tension of a string increases the speed of the vibration in the string and thus the frequency. Increasing the density of the string will lower its elasticity, which will decrease the speed of the vibration.
A plucked string or vibrating column of air will resonate at natural frequencies that depend on the length of the string or air column and the speed of the wave. In musical instruments, the strings or air columns are tuned to play at desired notes (frequencies). However, a note that is perceived to have a distinct pitch in fact contains a variety of additional overtones (harmonics). The fundamental frequency has the greatest amplitude, thus has the greatest influence on the pitch heard by the human ear.
In a perfectly harmonic instrument, each overtone is a perfect multiple of the fundamental frequency. This occurs in bowed instruments with thin, tight strings such as violins and cellos.

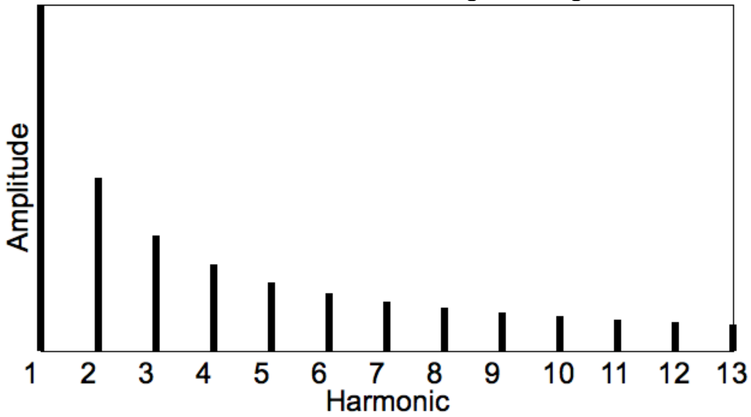


Fig 1. Overtone spectrum of an ideal harmonic instrument

Any deviation from this ideal overtone series is known as inharmonicity. Stringed instruments that are plucked (guitar, piano), rather than rubbed (violin, cello) have larger inharmonicity. The lower the elasticity of a string (in strings that are thicker, shorter, stiffer and/or have lower tension) the stronger its inharmonicity characteristics. Elastic properties (the lack of it) make percussion instruments inharmonic. Take the example below which shows the overtones of a bell with a fundamental frequency of 1650 Hz.

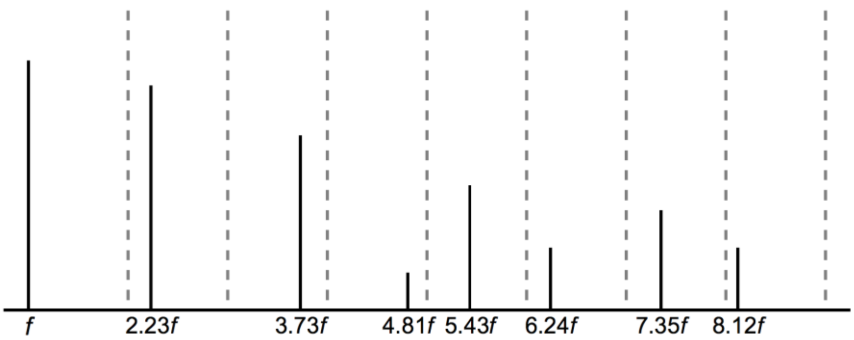


Fig 2. Overtone Spectrum of a Bell (dashed lines are integer overtones locations)

Inharmonicity is not necessarily synonymous with unpleasant sounds. The ability for a human ear to distinguish between a guitar and a violin is due to their differences, which includes their inharmonicity characteristics. Inharmonicity can make it more difficult to tune an instrument by ear as the tuner needs to compare notes with well defined relationships (e.g. a note that is one octave higher will have double the frequency if perfectly harmonic). The amount of difficulty in tuning by ear variers from instrument to instrument and even between ranges of notes for a single instrument – the more inharmonic the note that is played, the harder it is to obtain the right pitch.

(a) State whether the following changes to a string would increase or decrease its fundamental frequency. (3 marks)

Change	**Increase/Decrease**
Increasing the length	Decrease 1
Increasing the tension	Increase 1
Changing to a denser material	Decrease 1

(b) Explain how increasing the tension of a string will change its fundamental frequency. Include relevant formulas. (3 marks)

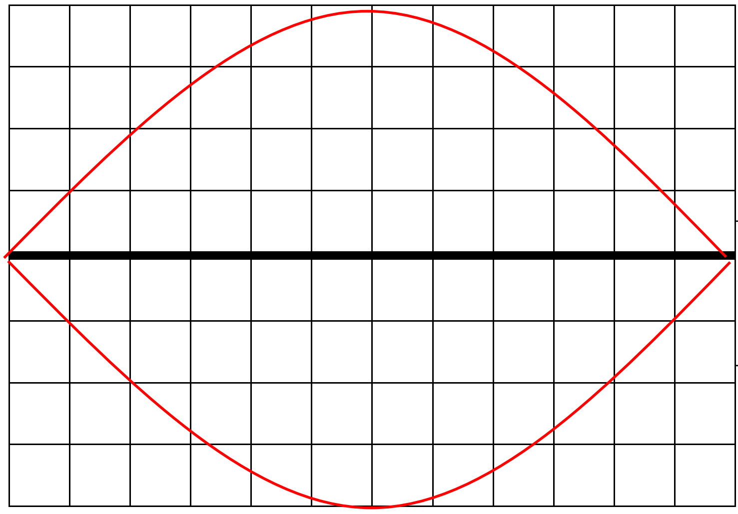
Increasing the tension will increase the speed of vibration/wave 1

Wavelength will remain constant as it depends on the length of the sting ($\lambda = \frac{2L}{n}$) 1

An increase in speed results in an increase in frequency ($v = \lambda f$ shows $v \propto f$) 1

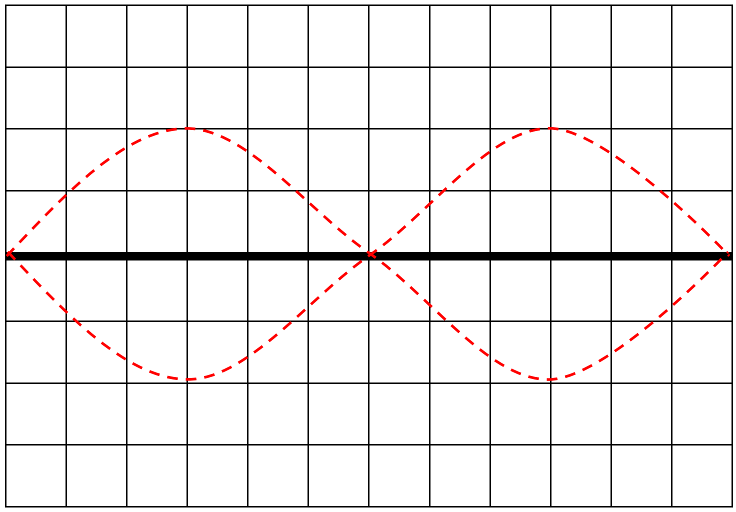
(c) The thick horizontal line on the grids below represents a string of a perfectly harmonic instrument. Based on the information provided in Fig 1, sketch the fundamental wave and the second harmonic envelopes that would be present in this string when played. (3 marks)

Fundamental



Correct shape for fundamental envelope 1

Second Harmonic



Half wavelength of fundamental 1

Amplitude half of the fundamental 1

(d) Calculate the difference, in Hz, between the first overtone of the bell in Fig 2 and its first integer overtone if it was perfectly harmonic. (3 marks)

$first\ overtone = 2.23f = 2.23 \times 1650 = 3680\ Hz$ 1

$integer\ overtone = 2f = 2 \times 1650 = 3300\ Hz$ 1

$Difference = 3680 - 3300 = 380\ Hz$ 1

OR

$difference\ from\ graph = 2.23f - 2f = 0.23f$ 1
$In\ Hz: f = 0.23 \times 1650 = 380\ Hz$ 1-2

(e) Professional tuners adjust the strings of an instrument, so each string plays a note at the right pitch.

i. Argue which instrument would be harder to tune by ear, the violin or the guitar. (3 marks)

Guitar 1

Inharmonicity is stronger in the guitar as its strings are plucked. 1

Stronger inharmonicity makes it harder to tune 1

ii. Argue which instrument would be harder to tune by ear, a guitar (thinner strings) or a bass guitar (thicker strings). (3 marks)

Bass guitar 1

Inharmonicity is stronger in the thicker strings as this decreases elasticity 1

Stronger inharmonicity makes it harder to tune 1

Question 21 **(17 Marks)**

Terminal Velocity

Introductory Physics classes will often state the acceleration of objects falling near the Earth's surface as 9.8 m s^{-2}. While this is true in the absence of any air resistance, ignoring air resistance can lead to gross errors between theory and practical results. Objects falling through a fluid, such as Earth's atmosphere, eventually reach a terminal velocity – the point where no further acceleration occurs.

There are three stages of falling:

1. Acceleration from rest
2. Acceleration while moving
3. Zero acceleration

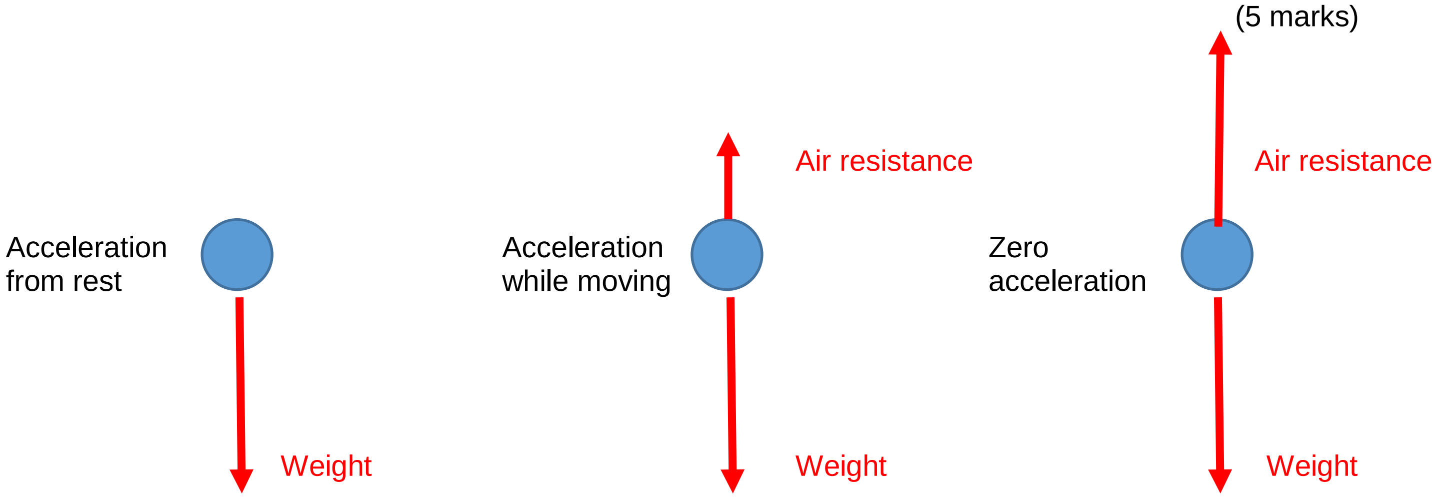
When an object first starts to fall, from a resting position, there is no air resistance. The initial acceleration of the object will be 9.8 m s^{-2}.

The object will push particles in the air out of the way as it falls. The faster the object falls, the more air it pushes out of the way each second. This is what causes air resistance. At some velocity, the acceleration of the object will be noticeably less than 9.8 m s^{-2} and will continue to drop as the object picks up speed.

When the object is falling fast enough, there is so much air to push out of the way that the air resistance is just as large as the gravitational force pulling the object down. This causes the acceleration of the object to drop to zero. The object then maintains this falling speed – terminal velocity has been reached.

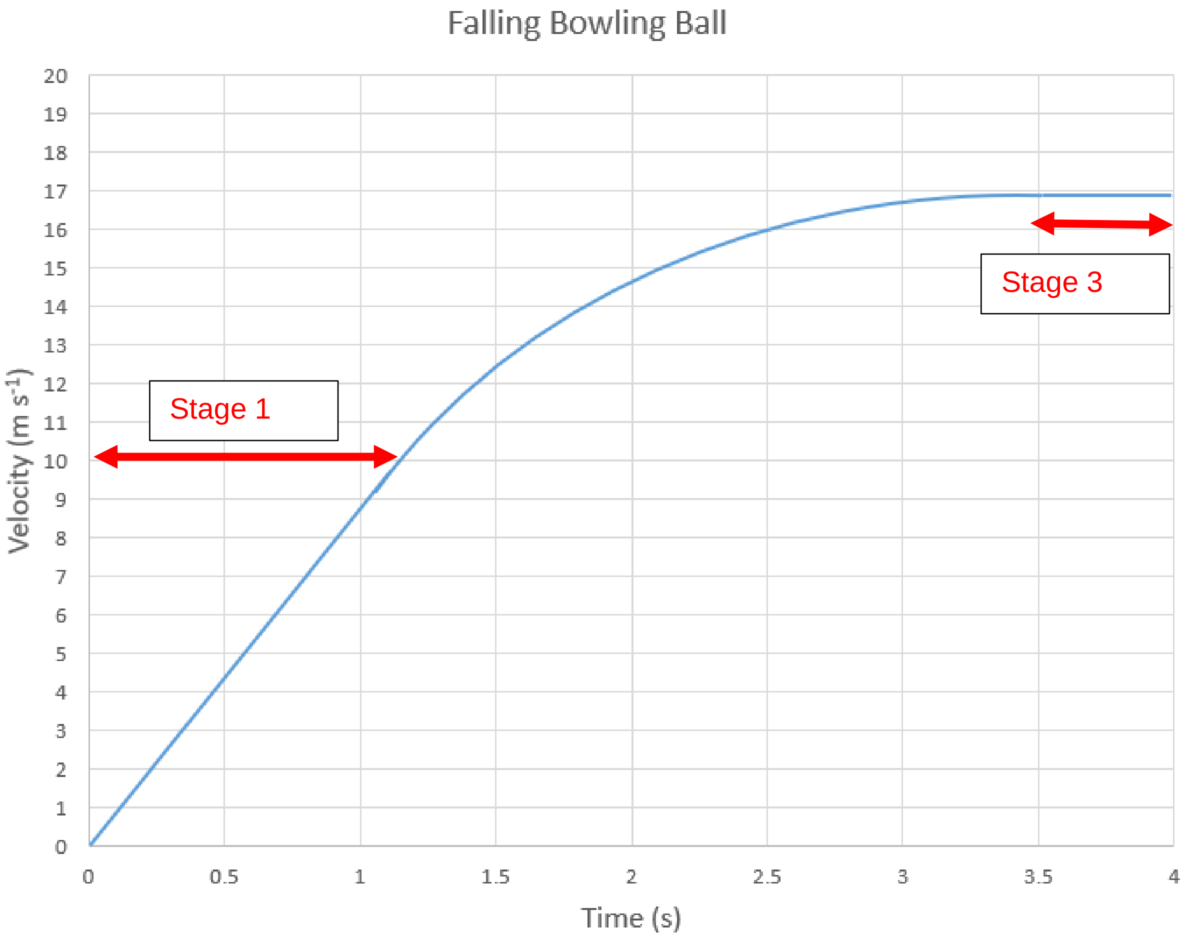
(a) The forces acting on an object falling through the atmosphere determine its acceleration. Draw a free body diagram of the physical forces acting on an object at each of its three stages of falling. Label all forces and keep all free body diagrams to the same scale.

(5 marks)



Weight (not gravity) on all three diagrams	1
All weight vectors the same size and no additional forces (other than air resistance)	1
No air resistance/other forces on stage 1	1
Air resistance smaller than weight on stage 2, opposes weight	1
Air resistance same size as weight on stage 3, opposes weight	1

(b) The velocity-time graph below shows a bowling ball falling through the atmosphere.



i. Identify and clearly label the region of the graph that shows the first stage of falling as described in the text. (1 mark)

Approx identifies linear section at start 1

ii. Identify and clearly label the region of the graph that shows the third stage of falling as described in the text. (1 mark)

Approx identifies linear section at end 1

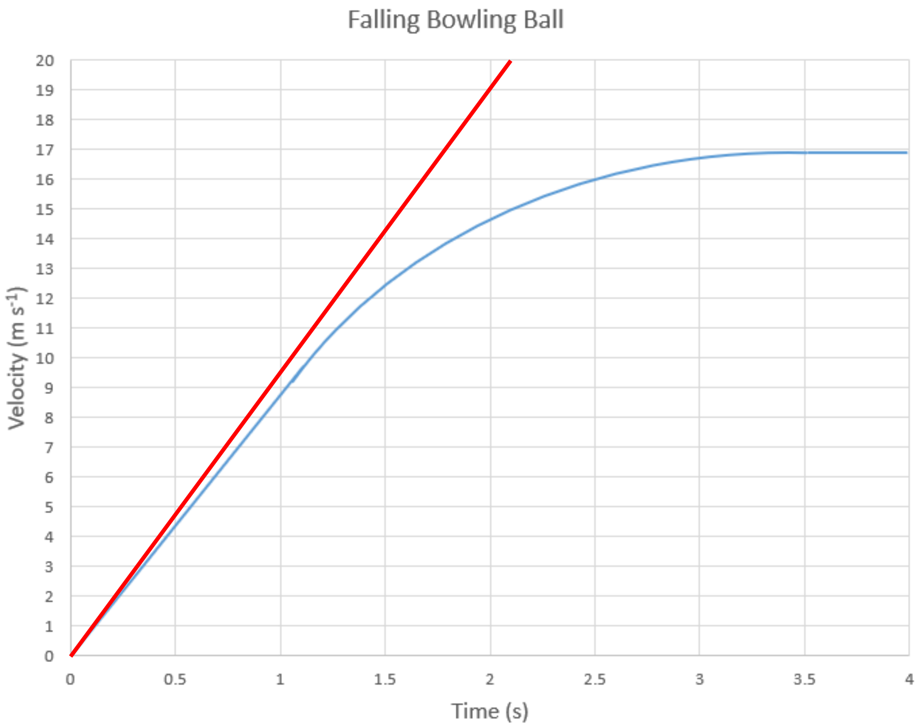
(c) Using the graph in part (b), estimate the distance covered by a bowling ball in the first 4.0 s through Earth's atmosphere. (4 marks)

$\approx 95\ grid\ spaces\ under\ curve$ 1
$distance = grid\ spaces \times value\ per\ grid\ space$ 1
$distance = 95 \times (0.5 \times 1) = 48\ m$ 1

Max 2 sig figs 1

Other suitable methods of estimation accepted, if changing acceleration accounted for.

(d) On the graph of the bowling ball falling through the atmosphere below, sketch a theoretical velocity-time graph of a golf ball dropped at the same time as the bowling ball, ignoring air resistance. (2 marks)



Linear 1

Same gradient as initial bowling ball path/ passes through (1,9.8) 1

(e) Explain why Newton's 3rd law of motion is relevant when explaining the cause of air resistance. (4 marks)

An object moving through the air pushes air out of its way. 1

This air pushes back with an **equal and opposite force**, as per Newton's 3rd law 1-2

It is the pushing back onto a object that is the cause of air resistance. 1

End of Questions

Additional working space

End of examination

Acknowledgements

Question 20
Fig 1. Overtone spectrum of an ideal harmonic instrument
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Fig 2. Overtone Spectrum of a Bell
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