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PHYSICS

UNITS 1 & 2

2019

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	10	10	50	54	30
Section Two: Extended answer	6	6	90	90	50
Section Three: Comprehension and data analysis	2	2	40	36	20
			Total	180	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 11 Information Handbook 2017.* 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.

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Section One: Short response 30% (54 Marks)

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

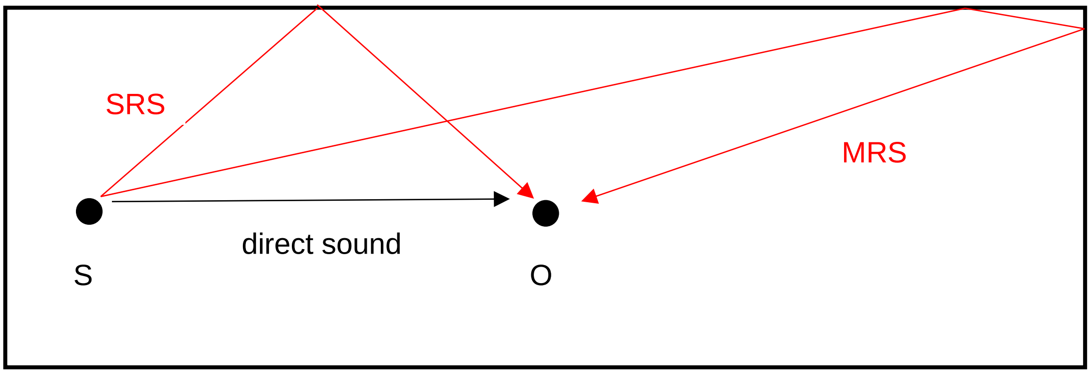
Question 1 (5 marks)

The acoustic performance of a room is partly determined by its 'reverberation time'. This is calculated as the time taken for a sound in a room to decay (or reduce) by a certain loudness (eg – 60 dB).

When a sound is produced, the observer first hears the 'direct sound' travelling directly from the sound source. The next category of sounds heard are 'single-reflected sounds'; ie – sounds that reflect off only one surface in the room. Lastly, the final sounds heard by an observer from a sound source in an acoustic space are 'multiple-reflected sounds'; ie – sounds that reflect off two or more surfaces in the room.

a) On the diagram below, a room is shown with a sound source 'S' and an observer 'O'. The 'direct sound' path is shown. Draw a path showing a 'single-reflected sound'; and another path showing a 'multiple-reflected sound'.

(2)



Both a 'single-reflected sound' (SRS) and a 'multiple-reflected sound' (MRS) are drawn as shown.	1 mark
The reflected paths obey the law of reflection.	1 mark

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If the reverberation time for an acoustic space is too long, it can decrease the sound quality produced in this space. Acoustic engineers can clad the walls of the space with certain materials to help overcome this problem.

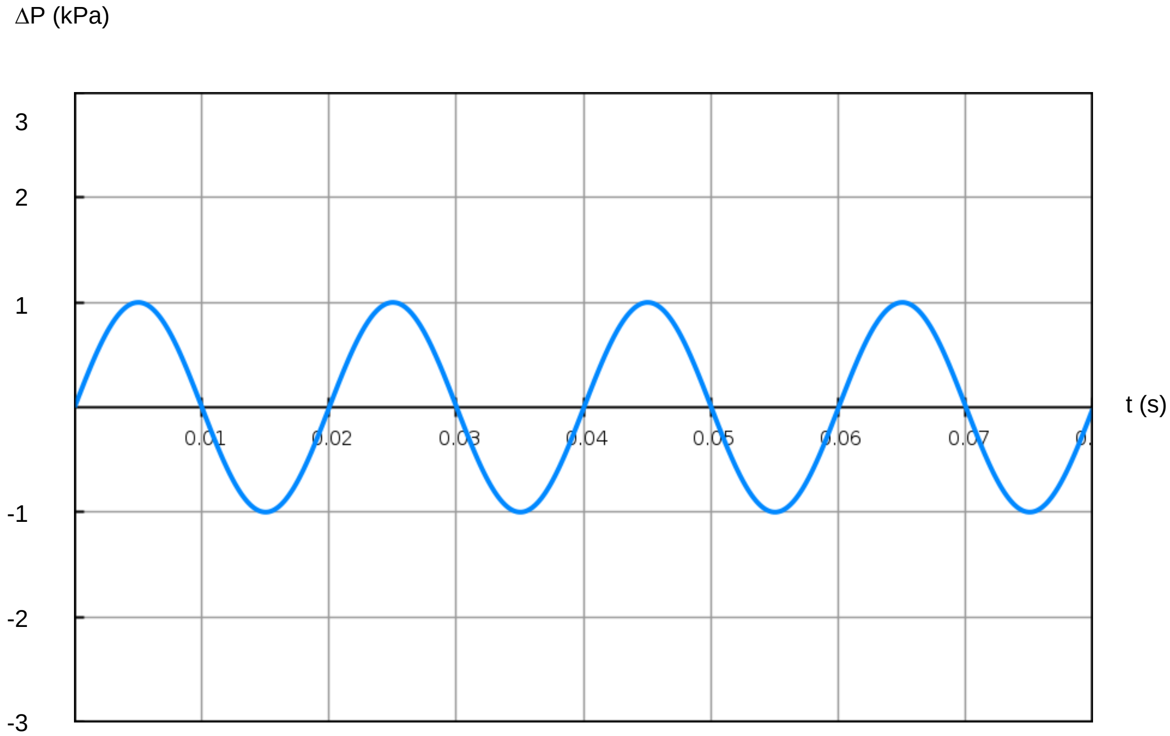
b) Using your information from part a), explain how the reverberation time for an acoustic space could be reduced. Discuss the type of material that could be used, where it would be placed, and why.

(3)

A softer material that absorbs sound well would be used (eg – foam, fabric, cardboard)	1 mark
It would be placed on the rear wall of the room (or another surface that eliminates reflection of the rear wall).	1 mark
This will eliminate 'multiple-reflected sounds' that travel the longest path and take the longest times to reach the observer.	1 mark

Question 2 **(4 marks)**

A string is vibrating at a frequency and amplitude that produces the pressure difference (ΔP) v time (t) graph shown in the diagram below. The pressure difference axis has not units – the scale is proportional.



a) Calculate the frequency (in Hz) of the sound produced by the string. Show working.

(2)

$T = 0.02$ s	1 mark
$\therefore f = \frac{1}{T} = \frac{1}{0.02} = 50.0 \text{ Hz}$	1 mark

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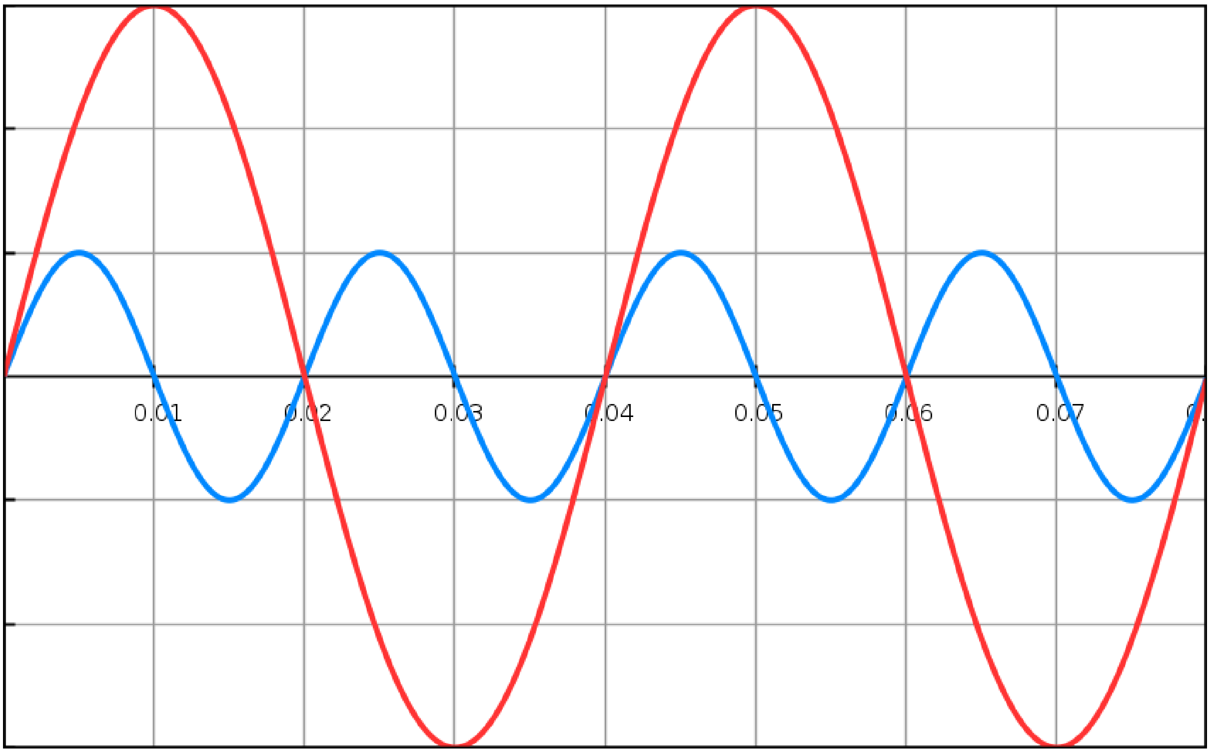
b) On the same set of axes, sketch the wave form for a sound produced by the string that has three times the amplitude and half the frequency.

(2)



T= 0.04 s	1 mark
Amplitude, ΔP = -3 to 3	1 mark

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Question 3 **(4 marks)**

An electric stove operates at mains voltage of 240 V. It has separate components that can operate individually or simultaneously. These have the following specifications:

ITEM	NUMBER PRESENT ON STOVE	POWER RATING (W)
Ceramic hob (small area)	**1**	**1250**
Ceramic hob (large area)	**1**	**1550**
Oven	**1**	**2550**

At a particular instant in time, the electric stove has one (1) Ceramic hob (small area), one (1) Ceramic hob (large area), and the oven operating.

Electric energy costs 28.0 cents per kilowatt hour (kWh).

Calculate the cost of operating the electric stove in this mode of operation for 35 minutes.

$P_{TOTAL} = 1250 + 1550 + 2550 = 5350 \text{ W}$	1 mark
$\text{Time} = \frac{35}{60} = 0.583 \text{ hours}$	1 mark
$\therefore \text{Cost} = \text{N° of kWh} \times 0.28 = \frac{5350}{1000} \times 0.583 \times 0.28$	1 mark
$= \$1.50$	1 mark

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Question 4 **(6 marks)**

A radioactive sample has an initial activity of 2.00×10^3 MBq and a half-life of 5.5 minutes.

a) Calculate the activity of the sample after 14.0 minutes.

(3)

$N = N_0\left(1/2\right)^n$; where $n = \frac{T}{T_{1/2}} = \frac{14.0}{5.50} = 2.55$ half lives	1 mark
$\therefore N = 2.00 \times 10^3\ (0.5)^{2.55}$	1 mark
N = 342 MBq	1 mark

b) Estimate the time taken for the sample's activity to drop to 125 MBq.

(3)

Number of half − lives (n): 2000 MBq → 1000 MBq → 500 MBq → 250 MBq → 125 MBq	1 mark
$\therefore n = 4$ half − lives	1 mark
$\therefore t = 4 \times 5.50 = 22.0$ minutes	1 mark

Question 5 **(6 marks)**

a) The words 'heat' and 'temperature' are often confused. In the space below, distinguish clearly between these two quantities using Physics concepts you have learned. In your answer, include the concept of 'internal energy' and 'thermal equilibrium'.

(3)

The internal energy of an object is equal to the sum of the kinetic and potential energies of the particles in the object.	1 mark
Heat is the flow of internal energy from a cooler object to a hotter object until they reach the same temperature at thermal equilibrium.	1 mark
Temperature is a measure of the average kinetic energy of the particles in an object.	1 mark

b) "It is impossible to add thermal energy to a substance without causing a temperature increase." Do you agree or disagree with this statement? Explain, briefly, your choice. Again, include the concept of internal energy in your answer.

(3)

Disagree.	1 mark
Thermal energy will add to the internal energy of the object.	1 mark
This could be an increase in potential energy which will cause a change of phase.	1 mark

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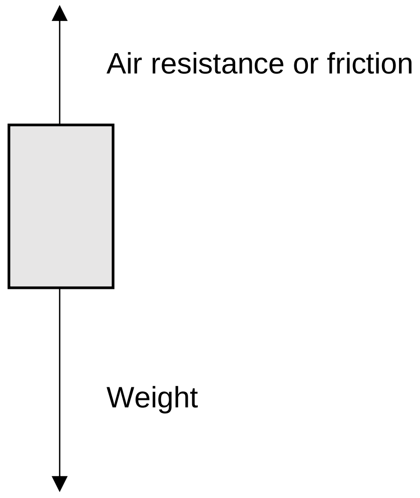
Question 6 **(6 marks)**

If they fall for long enough, objects that fall to the earth will reach a speed called 'terminal velocity'. Terminal velocity is a constant speed that is reached when the net force acting on the object is reduced to zero.

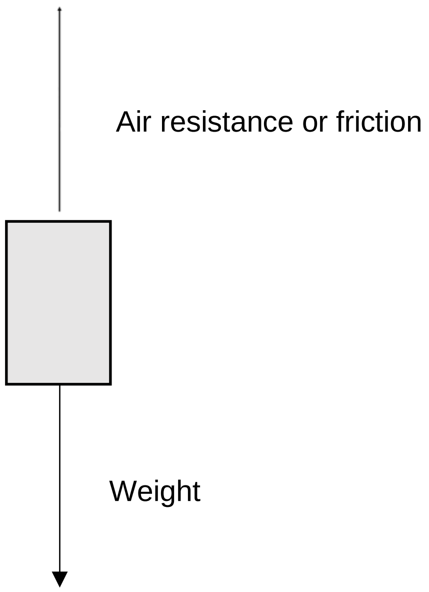
c) On the falling object below, draw two labelled vectors to represent the vertical forces that are acting on it BEFORE 'terminal velocity' is reached. (2)



Both forces labelled correctly.	1 mark
Upward force is SHORTER than downward force.	1 mark

b) Now draw the same two vectors ONCE 'terminal velocity' is reached.

(2)



Weight vector the same length as in part a)	1 mark
Upward force is EQUAL in length to downward force.	1 mark

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c) Briefly explain your answer to part b). Include Newton's Laws in your explanation.

(2)

Due to Newton's 3rd Law, as the object accelerates downwards ('v' increases), air resistance force increases due to impact force with air particles getting greater.	1 mark
Eventually, upward force due to air resistance becomes big enough to equal to the downward force due to gravity (net force equals zero).	1 mark

Question 7 **(6 marks)**

When holding a fire hose ejecting water from its nozzle, fire-fighters need to brace themselves to ensure that they are not pushed backwards - especially when the water is ejected at a very high speed.

a) Using the law of conservation of momentum, explain why fire-fighters must brace themselves in the way described above.

(3)

The water in the hose and the firefighter can be considered to be two separate objects with masses m_1 and m_2 in the system described; both have an initial velocity of 0 ms^{-1} before the hose is turned on.	1 mark
Hence, the initial momentum in the system is zero and must be conserved.	1 mark
Therefore, to conserve this momentum after the hose is turned on, the firefighters will experience a final velocity in the opposite direction to the water (ie – backwards) which they must overcome by bracing themselves.	1 mark

b) 20.0 kg of water is ejected from the nozzle of the hose in a horizontal direction for 1.50 s. This volume of water leaves the nozzle with a velocity of 30.0 m s^{-1}.

Calculate the force (magnitude and direction) experienced by a fire-fighter holding this hose.

(3)

$Ft = m(v - u)$; where $m = 20.0$ kg, $u = 0$ ms^{-1}; $v = 30.0$ ms^{-1}; $t = 1.50$ s $\therefore\ F \times 1.50 = 20.0(30.0 - 0)$	1 mark
$F = 400.0$ N	1 mark
In the opposite direction to the motion of the water.	1 mark

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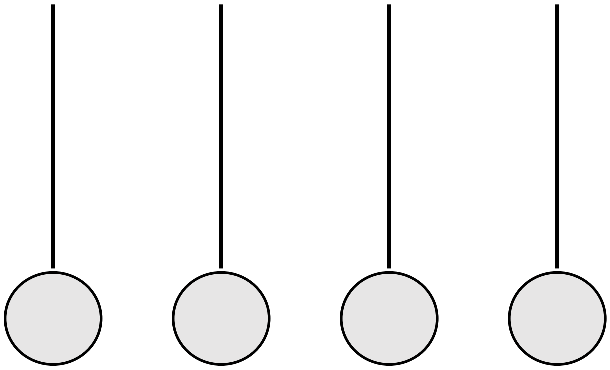
Question 8 **(5 marks)**

To test the properties of charged objects, some students obtain four very small glass spheres (A, B, C and D) and hang them from some cotton thread (which is neutrally charged). See below.



To begin the experiment, one students rubs sphere A with silk. At the end of this process, the students know that the silk ends up with excess electrons on it.

a) Given this information, what charge must sphere A possess? Explain briefly.

(2)

Sphere is positively charged.	1 mark
Friction has caused electrons to be rubbed off the glass onto the silk.	1 mark

The other glass spheres are the given an electric charge by being rubbed with different materials (including silk). In this way, some of the spheres will be positively charged; some will be negatively charged.

After this rubbing process, the students note the following:

Sphere B is **repelled** by sphere A.
Sphere C is **attracted** to sphere B.
Sphere D is **repelled** by sphere C.

b) Which sphere(s) – B, C or D – was also rubbed with silk? Explain.

(3)

Sphere B was also rubbed with silk charged because it has a positive charge.	1 mark
It is repelled by sphere A so it must also be positive.	1 mark
Given that C is attracted to B, it must be negatively charged; and given that D is consequently repelled by C, it must also be negatively charged. Hence, C and D were not rubbed by silk.	1 mark

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Question 9 **(7 marks)**

An ice cube at 0^0C was placed into a glass with 150 g of water at 45.0^0C. In one minute, the ice cube had melted. The final mass of water in the glass was 174 g and the final temperature of the water was 28 °C.

a) Using the data provided, calculate the latent heat of fusion of water.

(4)

$Q_{lost} = Q_{gained}$; $m_i = 0.174 - 0.150 = 0.024$ kg	1 mark
$0.150 \times 4180 \times (45 - 28) = 0.024 \times L_f + 0.024 \times 4180 \times 28$	1 mark
$0.024 \times L_f = 7.85 \times 10^3$	1 mark
$L_f = 3.27 \times 10^5$ $Jkg^{-1}°C^{-1}$	1 mark

b) As more ice was added to the glass, a layer of water formed on the wall of the glass. Name this phenomenon and briefly explain how it happens.

(3)

Condensation.	1 mark
The water vapour in the air is at a higher temperature than the ice water in the glass.	1 mark
Heat is conducted through the glass to water vapour until its temperature is high enough for the gas to condense to water.	1 mark

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Question 10 **(5 marks)**

A speaker is emitting a sound whose intensity is measured as 1.00 x 10^{-6} W m^{-2} at a distance of 1.50 m from the source.

a) Calculate this sound's predicted intensity at a distance of 4.50 m.

(3)

$\frac{I_1}{I_2} = \frac{{r_2}^2}{{r_1}^2}$; where $I_1 = 1.00 \times 10^{-6}$ Wm^{-2}; $I_2 = ?$; $r_1 = 1.50$ m; $r_2 = 4.50$ m	1 mark
$\therefore \frac{1.00 \times 10^{-6}}{I_2} = \frac{4.50^2}{1.50^2}$	1 mark
$\therefore I_2 = 1.11 \times 10^{-7}$ Wm^{-2}	1 mark

d) The figure you calculated in part a) would not be the value measured in reality. Comment on your calculated value for intensity at a distance of 4.50 m. How would it be different in reality? Explain.

(2)

In reality, the calculated intensity would be lower.	1 mark
The medium of air is inelastic and some acoustic energy will be lost to it as the sound travels to 4.50 m.	1 mark

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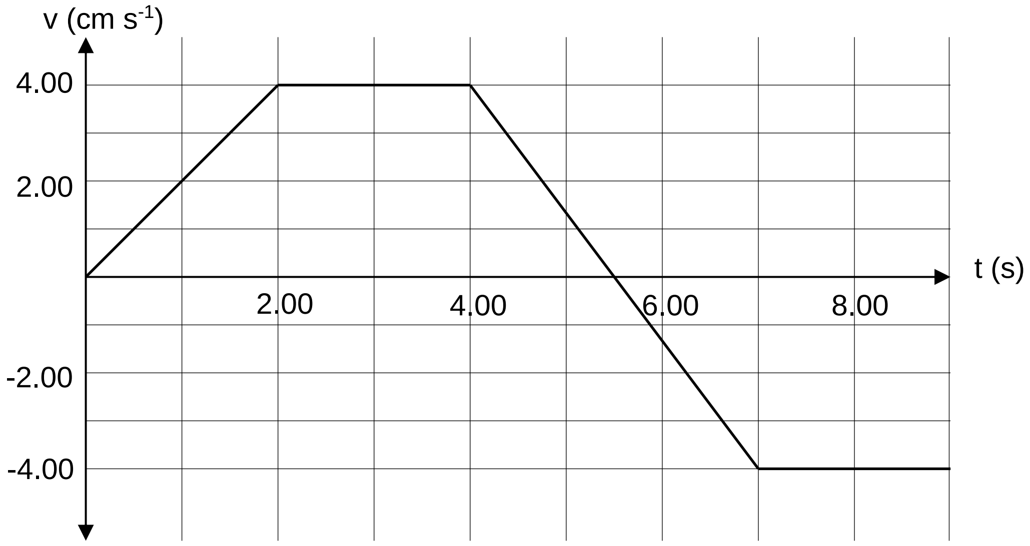
Section Two: Problem-solving 50% (90 Marks)

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 11 (16 marks)

The graph below shows the motion of an ant during a 9 second period. As can be seen, the ant's velocity has been measured in centimetres per second (cm s^{-1}) over this time. The ant is initially travelling in an easterly direction.



a) State the time period during which the ant is moving in a westerly direction.

(2)

From t = 5.50 s	1 mark
Until t = 9.00 s.	1 mark

b) State the times when the ant is stationary.

(2)

t = 0 s	1 mark
t = 5.50 s.	1 mark

c) State the time periods when the ant's acceleration is equal to zero.

(2)

Between t = 2.00 s and t = 4.00 s	1 mark
Between t = 7.00 s and t = 9.00 s	1 mark

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d) Calculate the ant's acceleration (in m s^{-2}) at:

(i) t = 1.00 s

(2)

$a = \frac{(0.04 - 0)}{2}$	1 mark
= 0.0200 m s^{-2}	1 mark

(ii) t = 5.50 s

(2)

$a = \frac{(-0.04 - 0.04)}{5}$	1 mark
= -0.0160 m s^{-2}	1 mark

e) Calculate the ant's change in displacement (magnitude and direction, in cm) between:

(i) t = 0 s – 5.50 s.

(3)

$\Delta s = (0.5 \times 2 \times 4) + (2 \times 4) + (0.5 \times 1.5 \times 4)$	1 mark
$\therefore \Delta s = 15.0 \text{ m}$	1 mark
East	1 mark

(ii) t = 0 s – 9.00s.

(3)

$\Delta s = 15.0 + (-0.5 \times 1.5 \times 4) + (-4 \times 2)$	1 mark
$\therefore \Delta s = 4.00 \text{ m}$	1 mark
East	1 mark

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Question 12 **(15 marks)**

Uranium-238 (U-238) is a radioisotope and an α-emitter. The data below will be of use to you in this question. You will also need to refer to the Periodic Table in the Formulae and Constants Sheet.

[Note – when performing calculations in this question, do NOT round to three (3) significant figures]

Particle	Atomic Mass (u)
U-238	238.05079
Th-234	234.04360
He-4	4.00260
Proton	1.00727
Neutron	1.00867

a) Use the above data to perform a calculation showing that the **mass defect** for a U-238 nucleus is **about 1.90 u**.

(3)

$\text{Expected Mass} = 92 \times 1.00727 + 146 \times 1.00867 = 239.93466\ \text{u}$	1 mark
$\therefore \text{Mass Defect} = 239.93466 - 238.05079$	1 mark
$= 1.88387\ \text{u}$	1 mark

b) Hence, calculate the **binding energy** for a U-238 nucleus.

(2)

$\text{Binding Energy (U} - 238\text{ nucleus)} = 1.88387 \times 931$	1 mark
$= 1753.88297\ \text{MeV}$	1 mark

c) Using your answer to part (b), calculate the **binding energy per nucleon** for a U-238 nucleus **in MeV**. [If you were unable to calculate an answer for part b), use a value of 1750 MeV]

(2)

$\text{Binding Energy per nucleon (U} - 238\text{)} = \dfrac{1753.88297}{238}$	1 mark
$= 7.369256176\ \text{MeV (or 7.35 MeV)}$	1 mark

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d) Ni-62 has one of the highest binding energy per nucleon of any known isotope - with a value of 8.7945 MeV.

Compare this value with the corresponding value for U-238 calculated in part c). Use this comparison to compare the stability of a Ni-62 nucleus versus a U-238 nucleus and to explain their contrasting properties in this regard. As part of your answer, you must discuss the presence of the strong force in each nucleus.

(3)

The binding energy is the source of the strong force which binds the nucleons together and overcomes the electrostatic forces of repulsion between the protons.	1 mark
Given that the binding energy per nucleon value for U-238 is much lower than that for Ni-62, U-238 has unstable nuclei while N-62 nuclei are stable.	1 mark
Hence, U-238 is a radioisotope while Ni-62 is not.	1 mark

As stated earlier, U-238 is an alpha emitter.

e) (i) Complete the nuclear equation below for this transmutation. Show the chemical symbol, atomic number and mass number for the missing product.

(1)

$$\mathrm{U}_{92}^{238} \rightarrow \_\_\_\_\_\_ + \mathrm{He}_2^4$$

(ii) Use the data in the table provided earlier to calculate the energy released (in Joules) during the alpha decay in part e) (i).

(4)

$\text{Mass of products} = 234.04360 + 4.00260 = 238.0462 \text{ u}$	1 mark
$\text{Mass defect} = 238.05079 - 238.0462 = 4.59 \times 10^{-3} \text{ u}$	1 mark
$\text{Energy released} = 4.59 \times 10^{-3} \times 931 = 4.27329 \text{ MeV}$	1 mark
$= 6.84 \times 10^{-13} \text{ J}$	1 mark

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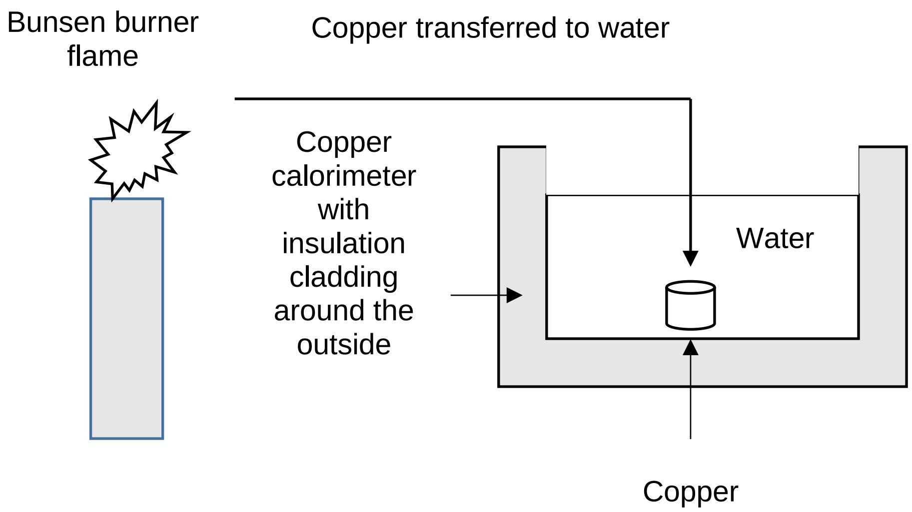
Question 13 **(13 marks)**

A student performs an experiment to calculate the temperature of a Bunsen burner flame.
A piece of copper with mass 250 g is held in the Bunsen flame for a few minutes. The copper metal is then transferred as quickly as possible to a copper calorimeter of mass 40.0 g containing 0.285 kg of water. The calorimeter and the water are initially at a temperature of 15.0°C.



After the piece of copper is placed in the water, the water is stirred until a thermal equilibrium temperature of 80.0°C is achieved.

a) Explain why the metal is transferred from the flame to the water as quickly as possible. (3)

When the piece of copper is initially transferred from the flame, it will be at thermal equilibrium temperature with the flame.	1 mark
The longer the copper is in contact with the air, the more heat it will lose and the more its temperature will drop from the Bunsen flame.	1 mark
Hence, to reduce this heat loss, the copper must be moved as quickly as possible from the flame to the water.	1 mark

Assume that heat losses to the surroundings of the water and calorimeter are negligible. The specific heat capacity of copper is 390 $Jkg^{-1}°C^{-1}$.

b) Calculate the quantity of thermal energy absorbed by the water and the copper calorimeter. (3)

$Q = 0.285 \times 4180 \times 65 + 0.040 \times 390 \times 65$	2 marks
$\therefore Q = 7.84 \times 10^4$ J	1 mark

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c) Using your answer from part b), calculate the temperature of the Bunsen burner flame. Show all working and assumptions you made while doing this calculation.

(4)

Assume heat lost by copper = heat gained by water + calorimeter and that no water evaporates.	1 mark
$7.84 \times 10^4 = 0.250 \times 390 \times \Delta T$; $7.84 \times 10^4 = 97.5 \times \Delta T$	1 mark
$\Delta T = 804°C$	1 mark
$\therefore T = 804 + 80 = 884\ °C$	1 mark

d) In reality, the piece of copper will lose heat to the air during the transfer to the water; and heat will be lost to the surroundings of the copper calorimeter and water. In light of this, comment on the Bunsen burner flame temperature calculated in part c).

(3)

The heat lost by the piece of copper as it transfers thermal energy to the water and copper calorimeter will actually be more than 7.84×10^4 J calculated.	1 mark
In addition, the initial temperature of the piece of copper will actually be less than the Bunsen burner flame.	1 mark
In combination, these two factors will mean that the ACTUAL temperature of the Bunsen burner flame will be HIGHER than calculated.	1 mark

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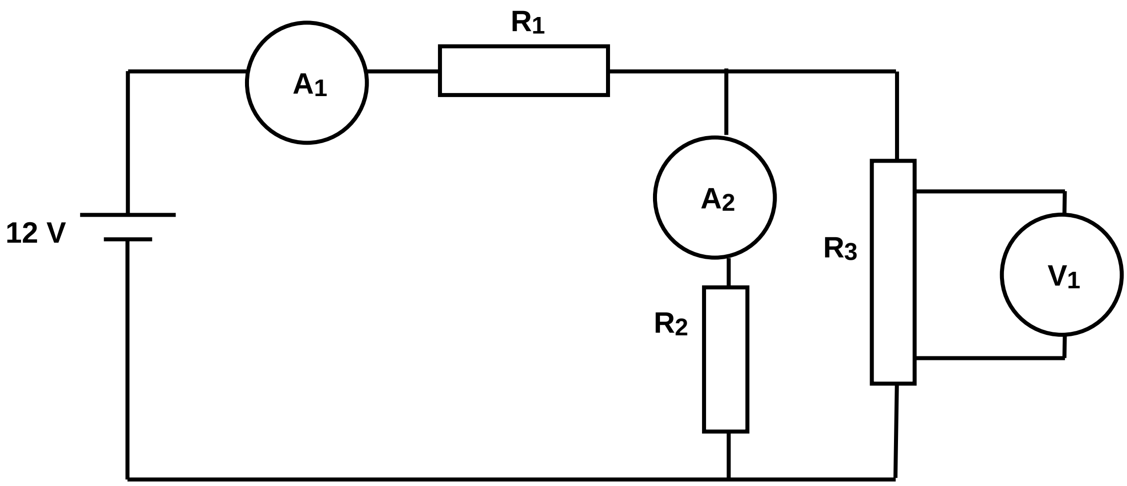
Question 14 **(11 marks)**

Three resistors are connected in the circuit as shown in the circuit diagram below.
The voltage supplied to the circuit by the battery is 12 V. The table below shows the values of the three resistors shown.

R_1	**12.0 Ω**
R_2	**6.00 Ω**
R_3	**4.00 Ω**



a) Calculate the total resistance (R_T) of the circuit. Assume the resistance of the potential difference supplied and the wires is negligible.

(3)

Across R_2 and R_3: $\frac{1}{R} = \frac{1}{6} + \frac{1}{4} = 0.417$	1 mark
$\therefore R = 2.40\ \Omega$	1 mark
$\therefore\ R_{TOTAL} = 2.40 + 12.00 = 14.4\ \Omega$	1 mark

b) Calculate the reading on the ammeter, A_1. Show working.

(2)

$I_1 = \frac{V_T}{R_T} = \frac{12}{14.4}$	1 mark
$= 0.833\ A$	1 mark

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c) Calculate the reading on the voltmeter, V_1. Show working.

(3)

Voltage across R1: $V = I_1 R_1 = 0.833 \times 12.0$	1 mark
$\therefore V = 10.0\ \text{V}$	1 mark
$\therefore V_2 = 12 - 10 = 2.00\ \text{V}$	1 mark

d) Hence, calculate the reading on the ammeter, A_2. Show working.

(3)

$V = V_1 = 2.00\ \text{V}$	1 mark
$I_2 = \frac{V}{R_2} = \frac{2.00}{6.00}$	1 mark
$\therefore I_2 = 0.333\ \text{A}$	1 mark

SEE NEXT PAGE

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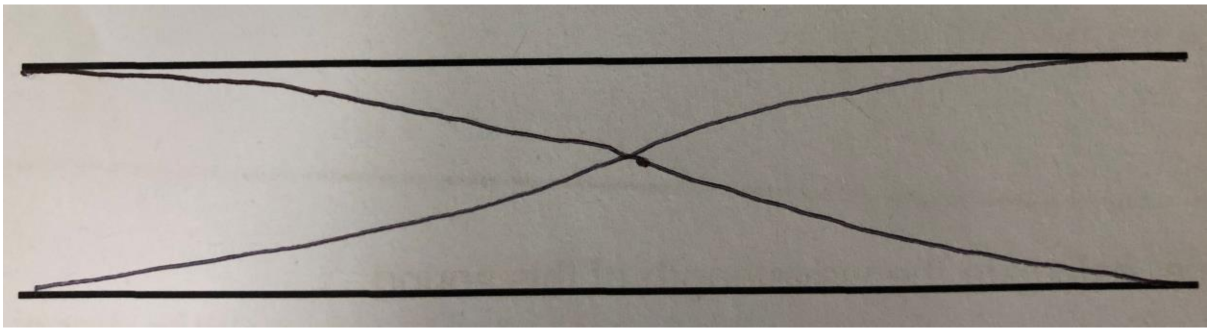
Question 15 **(17 marks)**

An organ pipe X, with both ends open, sounds its fundamental frequency of 330 Hz. The pipe is filled with dry air at 25 ºC.

a) On the diagram below, draw a wave envelope representing the particle displacement in the pipe when it is sounding at its fundamental frequency?

(2)



Antinodes at open ends.	1 mark
Half a wavelength is present in the pipe.	1 mark

b) Calculate the length of this organ pipe.

(4)

$v = f\lambda;\ \therefore \lambda = \frac{v}{f}$	1 mark
$\lambda_1 = \frac{346}{330} = 1.05\ \text{m}$	1 mark
$\lambda_n = \frac{2L}{n};\ \therefore \lambda_1 = 2L$	1 mark
$L = \frac{\lambda_1}{2} = \frac{1.05}{2} = 0.524\ \text{m}$	1 mark

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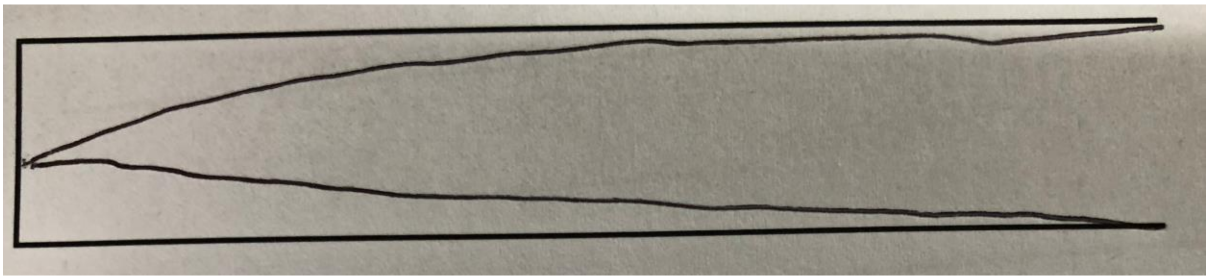
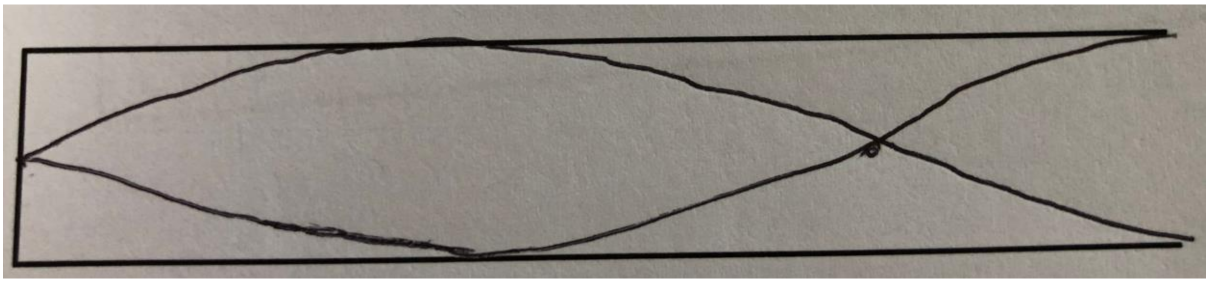
A second pipe Y is closed at one end. Dry air at 25 ºC is in the pipe.

c) On the diagrams below, draw wave envelopes for the first two harmonics produced by this pipe. Number each of the harmonics in the space provided.

(3)



1st harmonic



3rd harmonic

(Particle displacement or pressure difference acceptable)	
Fundamental drawn correctly	1 mark
3rd harmonic drawn correctly	1 mark
Both are named correctly	1 mark

The third harmonic (first overtone) of the closed end pipe Y has the same frequency as the second harmonic (first overtone) of the open ended pipe X.

d) (i) Calculate the frequency of the second harmonic of pipe X.

(3)

f_3 (closed) = f_2 (open)	1 mark
f_3 (closed) = 2 x 330	1 mark
f_3 = 660 Hz	1 mark

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(ii) Hence, calculate the wavelength of this sound.

(2)

$\lambda_3 = \frac{v}{f_3} = \frac{346}{660}$	1 mark
$\therefore\ \lambda_3 = 0.524\ \mathrm{m}$	1 mark

(iii) Hence, calculate the length of the pipe Y.

(3)

$\lambda_n = \frac{4L}{n};\ \therefore \lambda_3 = \frac{4L}{3};\ L = \frac{3\lambda_3}{4}$	1 mark
$\therefore\ L = \frac{3\ \times 0.524}{4}$	1 mark
L = 0.393 m	1 mark

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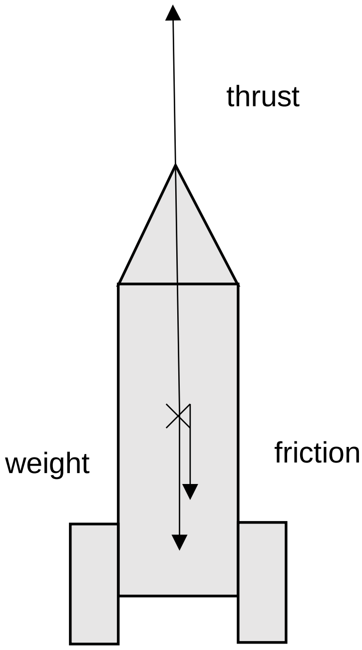
Question 16 **(18 marks)**

A toy rocket with a mass of 0.550 kg is fired straight upward. The chemical engine provides 9.50 N of thrust for 1.70 s with negligible loss of mass. The engine works for 1.70 s.

a) Draw labelled vectors from point X on the rocket to show **all** the forces acting on the rocket in the first 1.70 s of flight. Include any frictional forces. The length of each arrow should represent the approximate magnitude of the force that is acting.

(4)



One upward force.	1 mark
Two downward forces.	1 mark
Labels are correct.	1 mark
Sum of downward vectors LARGER than upward vectors.	1 mark

b) Calculate the acceleration of the rocket just before its engine stops working. Consider only the thrust of the engine and gravity. Show **all** workings.

(4)

Upward thrust: $a = \frac{F}{m} = \frac{9.50}{0.550} = 17.3\ ms^{-2}$	1 mark
$\therefore a = 17.3\ ms^{-2}$	1 mark
Acceleration downwards: $g = 9.80\ ms^{-2}$	1 mark
$\Sigma a = 17.3 - 9.80 = 7.50\ ms^{-2}$	1 mark

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c) Calculate the height, in metres, reached by the rocket at the moment when the engine stops working. If you were unable to calculate an answer to Part (b), use an acceleration value of 8.00 ms^{-2}.

(3)

$s = ut + {}^{1}/_{2}\ at^{2}; u = 0\ ms^{-1};\ a = 7.50\ ms^{-2};\ t = 1.70\ s$	1 mark
$s = ut + {}^{1}/_{2}\ at^{2} = 0 \times 1.70 + {}^{1}/_{2} \times 7.50 \times 1.70^{2}$	1 mark
$= 10.8\ m\ (11.6\ m)$	1 mark

d) Calculate the velocity (in metres per second) of the rocket, 1.70 s after the engine starts. If you could not calculate an answer to Part (b), use an acceleration of 9.00 m s^{-2} upward. Show **all** workings.

(2)

$v = u + at = 0 + 7.50 \times 1.70$	1 mark
$v = 12.8\ ms^{-1}\ (15.3\ ms^{-1})$	1 mark

e) Calculate the maximum height, in metres, reached by the rocket. Show **all** workings.

(5)

$v = 0\ ms^{-1}; u = 12.8\ ms^{-1};$	1 mark
$a = -9.80\ ms^{-2}$	1 mark
$v^{2} = u^{2} + 2as; 0 = 12.8^{2} + 2 \times -9.80 \times s$	1 mark
$s = \frac{12.8^{2}}{19.6} = 8.29\ m\ (11.9\ m)$	1 mark
Maximum height = 10.8 + 8.29 = 19.1 m (24.9 m)	1 mark

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Section Three: Comprehension **20% (36 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 17 **(18 marks)**

Chernobyl Nuclear Accident

The catastrophic nuclear accident known as the 'Chernobyl Disaster' occurred over 25th and 26th April, 1986 at the Chernobyl Nuclear Power Plant in Northern Ukraine. The accident occurred during a late night safety test which was simulating a power failure resulting in a station blackout.

A complete station blackout would cause the plant's safety systems to cease functioning. On the night of the 25th April, as part of the complicated test, technicians deliberately removed nearly all of the control rods from the reactor core. This, along with several other actions, created a power surge in the reactor and excessive quantities of steam were produced from the coolant in the reactor core. In short, the reactor was in an extremely unstable position – and any changes that pushed it into 'super-criticality' would mean that it would be unable to recover a stable configuration automatically. That would require manual intervention from the technicians in the control room of the plant.

Unfortunately, pushing the reactor into 'super-criticality' was part of the planned test. As the test proceeded, more coolant water in the reactor 'flashed' into steam due to the extremely high temperatures. The extreme pressure of the steam in the reactor vessel blew the containment structure apart – including the roof of the containment building, exposing the radioactive interior to the outside atmosphere.

The explosion ejected large amounts of radioactive nuclear fuel into the atmosphere. Fission fuel (Uranium-235 was the main fissile fuel used at Chernobyl) and far more dangerous fission products such as caesium-137, Iodine-131, Strontium-90 and other radionuclides were dispersed into the atmosphere. One positive consequence of the explosion was that the nuclear fission reaction occurring in the reactor core was effectively terminated by the dispersal of fissile material. However, a disastrous situation was unfolding.

Radiation levels in the plant immediately after the accident were enormous. A dose equivalent to about 5 Sieverts (5 Sv) is usually lethal to a human being. The table below shows the radiation levels at some specific locations at the plant.

Location	Sieverts per Hour
Vicinity of the reactor core	300
Debris heap at the circulation pumps	100
Fuel fragments on roof of containment building	175
Control Room	0.04

Data from https://en.wikipedia.org/wiki/Chernobyl_disaster

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Many workers, fire fighters and first responders to the accident were exposed to radiation levels much higher than that and many died within a short time after the accident. Firefighters sent to the roof of the containment building for short periods of time to try and limit their exposure. However, many of the fire fighters died from radiation sickness not long after their heroic work was completed.

The high radiation levels and large dispersal of radioactive materials in the surrounding area necessitated a mass evacuation from the surrounding urban areas. Residents in the nearby town of Pripyat were not evacuated until 11.00am on the 26th April and many exhibited signs of radiation sickness – ie, vomiting, headaches, metallic taste in the mouth, pins and needles on exposed skin. Many of these residents have developed health problems connected to their exposure after the accident.

Immediately after the evacuation, an exclusion zone (ie – a place where humans are not allowed to enter) was set up around the Chernobyl Power Plant with a radius of about 30 kilometres. Its borders were then extended so that this exclusion zone now covers a larger area of about 2600 square kilometres. It is one of the most radioactively contaminated areas in the world; because of this, it is of significant interest to scientists – especially those studying the effect of high levels of radiation exposure in the environment.

As the radiation levels in the outer parts of this zone decrease, talks have begun in February, 2019, to redraw the boundaries and reduce the size of the exclusion area.

a) The planned safety test at Chernobyl on 25th April, 1986, required the deliberate removal of the reactors control rods. Describe the effect that this removal would have had in the reactor core. As part of your answer, describe the role that the control rods have in a nuclear reactor.

(4)

The control rods control the rate at which the fission reaction occurs in the fuel rods.	1 mark
They do this by absorbing excess neutrons.	1 mark
Removing the control rods would have allowed the fission reaction to occur at a much faster rate.	1 mark
This, in turn, would have created large amounts of thermal energy in the core and extremely high core temperatures.	1 mark

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Uranium-235 was the main fission fuel used in the Chernobyl reactor. Uranium-235 is an alpha emitter with a half-life of 4.5 billion years. Its nuclei have a mass of 235.0439299 u. The periodic table on the Formulae and Constants Sheet will be needed for parts b) and c).

One possible fission reaction involving uranium-235 is described in words below:

A slow-moving neutron collides and is captured by a uranium-235 nucleus; the nucleus splits and forms the fission products rubidium-90, caesium-143, some neutrons and a large amount of thermal energy.

b) Write a balanced nuclear equation depicting the fission reaction described above. Determine the number of neutrons produced in this reaction and state this clearly in the equation.

(3)

$n_0^1 + U_{92}^{235} \rightarrow Rb_{37}^{90} + Cs_{55}^{143} + 3n_0^1$	
3 neutrons are produced.	1 mark
All symbols for reactants are correct.	1 mark
All symbols for products are correct.	1 mark

Another possible fission reaction is described in the nuclear equation below:

$$\mathbf{U_{92}^{235} + n_0^1 \rightarrow Sr_{38}^{90} + Xe_{54}^{143} + 3n_0^1 + energy}$$

The relevant atomic masses for the reactants and products in this reaction are shown in the table below:

U-235	**235.0439299 u**
Neutron (n_0^1)	**1.00867 u**
Sr-90	**89.907738 u**
Xe-143	**142.935370 u**

c) Calculate the quantity of energy released (in MeV) during this fission reaction. Show all working. [Do NOT round to three (3) significant figures in this calculation]

(3)

Mass defect = Mass of reactants - Mass of products = (235.0439299 + 1.00867) – (89.907738 + 142.935370 + 3 x 1.00867) = 236.0525999 - 235.869118	1 mark
= 0.1834819 u	1 mark
Energy released = 0.1834819 x 931 = 170.8216489 MeV	1 mark

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d) Hence, calculate the energy released (in Joules) if 1.00 kg of U-235 nuclei completely undergo fission as per the reaction in part c).

(3)

$\text{N° of nuclei (U} - 235) = \dfrac{1.00}{(235.0439299 \times 1.67 \times 10^{-27})} = 2.54 \times 10^{24}$	1 mark
$\therefore \text{Energy released} = 2.54 \times 10^{24} \times 170.8216489 = 4.34 \times 10^{26}\ \text{MeV}$	1 mark
$= 6.95 \times 10^{13}\text{J}$	1 mark

e) Firefighters were sent on to the damaged roof of the containment plant to remove radioactive debris that had been deposited there due to the explosion. Using information from the article, calculate the MAXIMUM time that the firefighters could remain on the roof of the containment building to ensure they received LESS than a lethal dose of radiation.

(2)

∴ Maximum time = $^{5}/_{175}$ x 60	1 mark
= 1.71 minutes	1 mark

The table below shows some of the properties of the radioisotopes that were ejected from the fuel rods during the explosion.

Radioisotope	Radiation emitted	Half Life
Uranium-235	α-emitter	4.5 billion years
Caesium-137	β-emitter	30.2 years
Iodine-131	β-emitter	8 days
Strontium-90	β-emitter	28.8 years

f) In the article, the following statement is made:

“Fission fuel (uranium-235 was the main fissile fuel used at Chernobyl) and far more dangerous fission products such as caesium-137, Iodine-131, strontium-90 and other radionuclides were dispersed into the atmosphere.”

Using the data above, provide explain why the three fission products mentioned are ‘far more dangerous’ than uranium-235.

(3)

Uranium-235 is an α-emitter; the other radioisotopes are β-emitters. Alpha radiation is less penetrating externally than beta radiation – less of a threat.	1 mark
Uranium-235’s half-life is very long compared to the fission products – will have a very low radioactivity.	1 mark
Alpha radiation has a higher ionising power than beta radiation – poses more of a threat if ingested.	1 mark

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Question 18 **(18 marks)**

The speed of sound in dry air is dependent on several factors. The most significant, however, is the temperature of the air itself.

In fact, if all other factors are kept constant (eg – altitude, barometric pressure, density of the air, etc.), there is a direct relationship between the speed of sound in dry air (v_{air}, measured in m s^{-1}) and the temperature of the dry air (T_c, measured in degrees Celsius). A general equation for this relationship is shown below:

$$\mathbf{v_{air} = a\,T_c + k}$$

Where: v_{air} = the speed of sound in dry air (m s^{-1});

a = constant value;

T_c = the temperature of the dry air (°C); and

k = the speed of sound in dry air when T_c = 0 °C.

An audio technician performed an experiment and collected the following data (measurements of the speed of sound in dry air (v_{air}) for various dry air temperatures (T_c)):

T_c (°C)	V_{air} (m s^{-1})
-30.0	313
-10.0	325
10.0	337
30.0	350
50.0	361
70.0	373
90.0	385

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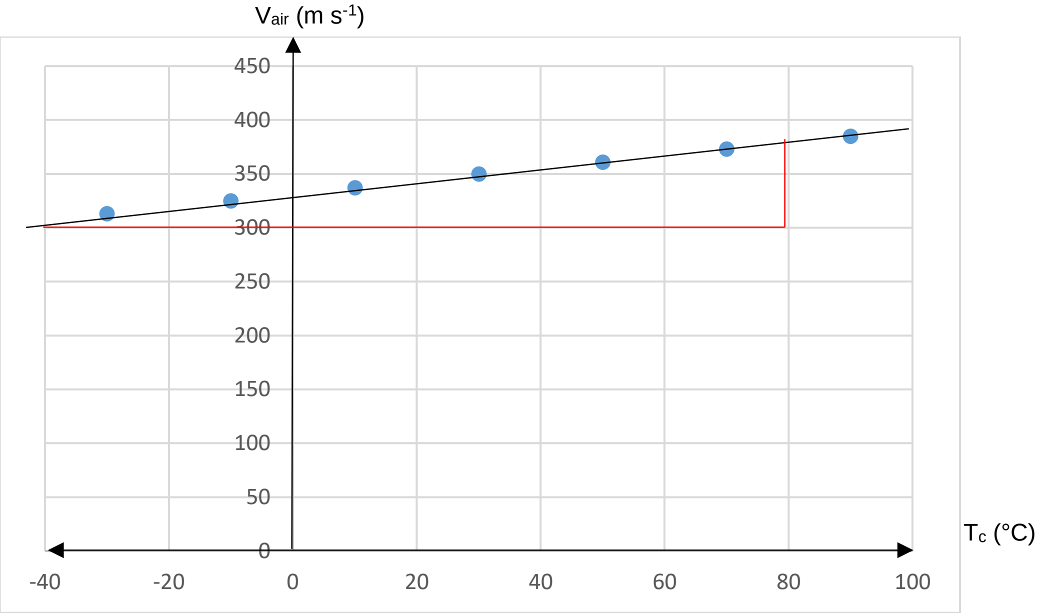
a) Using the grid on the next page, draw a graph plotting the speed of sound in dry air (v_{air}) against corresponding dry air temperatures (T_c) and then draw a line of best fit for the data. Place 'T_c' on the horizontal axis.

(5)



Axes correctly labelled with T_c (°C) on the horizontal axis.	1 mark
Correct units supplied on each axis.	1 mark
Points correctly plotted.	1 mark
Line of best fit correctly drawn.	1 mark
Intercept on 'v_{air}' axis shown clearly.	1 mark

b) Calculate the slope of your line of best fit. Show clearly how you did this. State the units for this slope.

(3)

Two points chosen from the line of best fit (not table of values): eg - (80.0, 375) and (-40.0, 300)	1 mark
$\text{Slope} = \frac{\text{Rise}}{\text{Run}} = \frac{(375 - 300)}{(80.0 - (-40.0))} = 0.625\ (0.600 - 0.650)$	1 mark
m s^{-1} °C^{-1}	1 mark

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c) Write the speed of sound in dry air when $T_c = 0$ °C in the space below.

(1)

330 °C

y-intercept stated (325 °C – 335 °C)	1 mark

d) Hence, write down the equation for the speed of sound in dry air by substituting in appropriate values for 'a' and 'k'.

(2)

$$v_{air} = 0.625\ T_c + 330$$

a = 0.625 (0.600-0.650)	1 mark
k = 330 (325-335)	1 mark

e) Using the equation you derived in part d), find the ratio between the wavelengths of a 256 Hz sound when the temperature of the dry air is 20.0 °C and 100.0 °C. Show working.

[If you were unable to produce the equation in part d), use the following equation for this question: $\mathbf{v_{air} = 0.70\ T_c + 320}$]

(3)

At T_c = 20.0 °C, v_{air} = 342 °C; at T_c = 100.0 °C, v_{air} = 392 °C.	1 mark
f = 256 Hz; at T_c = 20.0 °C, λ_1 = 1.34 m; at T_c = 100.0 °C, λ_2 = 1.53 m	1 mark
$\frac{\lambda_1}{\lambda_2} = \frac{1.34}{1.53} = 0.876$	1 mark

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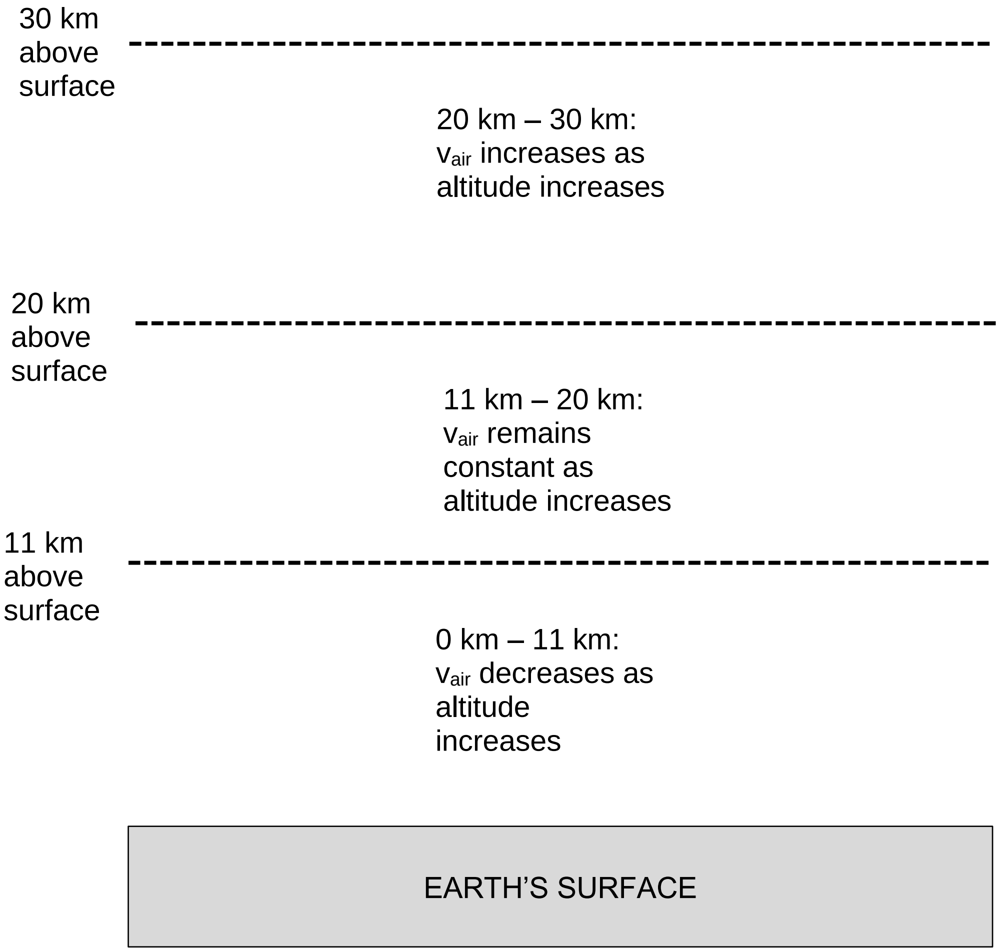
Another factor that can affect the speed of sound in dry air is altitude above the earth's surface. The main reason for this is that the temperature of the air changes as the altitude changes. The diagram below shows how the temperature of the dry air in the earth's atmosphere changes as altitude above its surface increases.



Due to these changes in speed, sound refracts as it travels upwards and away from the earth.

Question 18 continued on the next page

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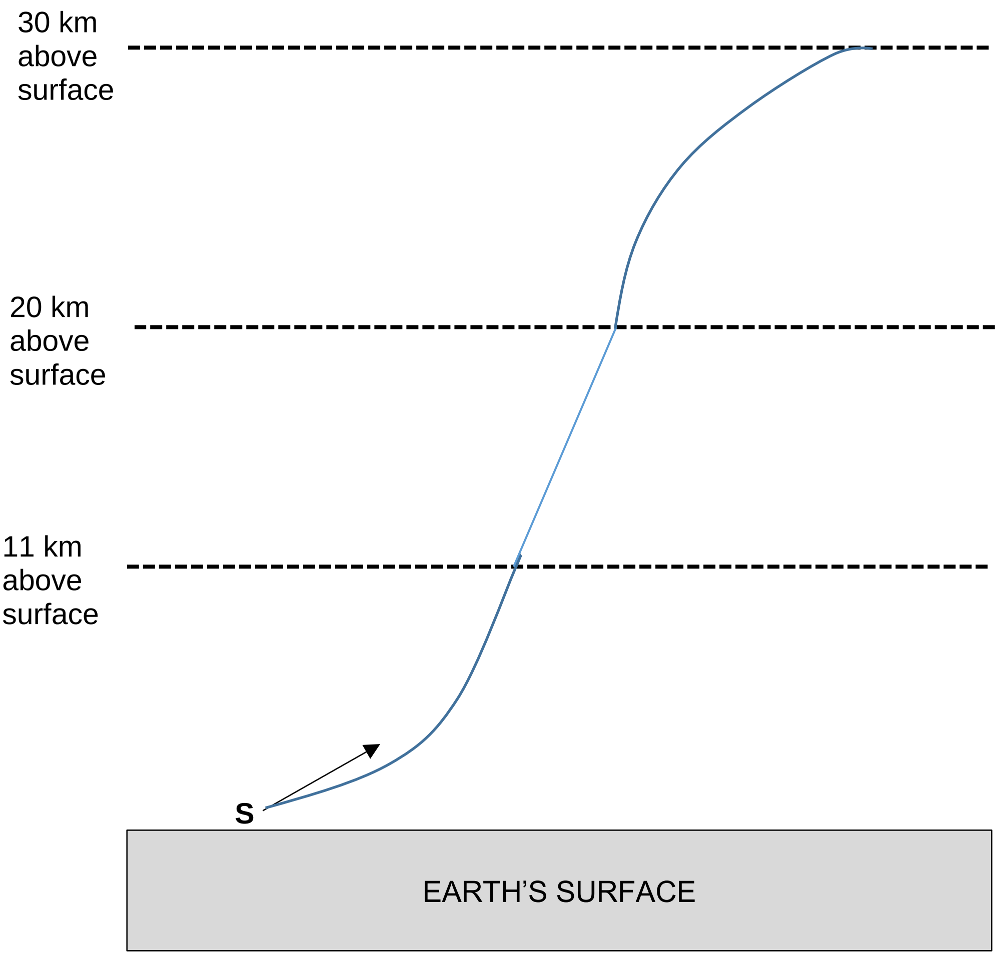
f) On the diagram below which shows the altitudes at various points above the earth, draw the path of the initial sound shown (starting on the earth's surface at 'S') as it travels within and between the altitude boundaries shown.

(4)



Between 0 km and 11 km altitude: Path bends towards the normal as altitude increases.	1 mark
Between 11 km and 20 km altitude: Path is straight.	1 mark
Between 20 km and 30 km altitude: Path bends away from the normal as altitude increases.	1 mark
Between 0 km and 11 km and 20 km and 30 km altitude: Paths are curved.	1 mark

End of Questions

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Additional working space

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Spare grid for graph

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End of examination

Acknowledgements

Question 17: tabulated data from https://en.wikipedia.org/wiki/Chernobyl_disaster

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