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PHYSICS
UNITS 1 & 2
2020

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	11	11	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 **eleven (11)** questions. Answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 50 minutes.

Question 1 **(4 marks)**

In a movie, a superhero is using a high-powered machine gun that fires bullets at extremely high velocities. In the movie, the superhero wields the weapon like a light pistol, firing it several times from an unbraced standing position. As they fire the gun, the superhero does not seem to move in any direction from this standing position. Using any Physics principles that you have learned, explain why it is a physical impossibility to operate this weapon in the manner described.

The law of conservation of momentum states that: $\Sigma p_{initial} = \Sigma p_{final}$	1 mark
Prior to firing, all objects in the system are at rest; ∴ $\Sigma p_{initial} = 0$.	1 mark
After firing, the bullets have a momentum in one direction.	1 mark
Hence, to ensure $\Sigma p_{final} = 0$ and conserve momentum; the superhero and the gun must have a velocity and a momentum in the opposite direction.	1 mark

Question 2 **(4 marks)**

Describe the link between 'internal energy', 'temperature' and 'thermal equilibrium'.

Internal energy is the sum of the kinetic energies and potential energies of all of the particles in an object.	1 mark
Temperature is one type of internal energy and is the average kinetic energy of the particles.	1 mark
The object with higher temperature loses internal energy and this is transferred to the object of lower temperature.	1 mark
This occurs until thermal equilibrium occurs (same temperature).	1 mark

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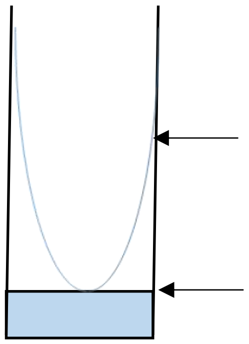
Question 3 **(4 marks)**

Khai is filling a bottle with tap water. He notices that as the water collides with the bottle, a sound is produced from within the bottle. As the water fills the bottle, the pitch of the sound increases. Using your knowledge of standing waves in pipes, explain why this phenomenon occurs. As part of your answer, on the diagram below, draw the standing wave for the fundamental frequency that would be formed within the bottle as it is filled with water.



Standing wave drawn – see above (accept either 'particle displacement' or 'pressure variation' wave formations).	1 mark
As the height of the water increases, the resonant length (L) of the pipe decreases.	1 mark
The wavelength of the standing wave produced is given by: $\lambda_1 = 4L$. Hence, as 'L' decreases, 'λ' decreases.	1 mark
Since $f = \frac{v}{\lambda}$, as the height of the water increases, frequency 'f' and pitch increases.	1 mark

Question 4 **(5 marks)**

A student cools a glass of water by placing ice in it. She places 240 g of water into a glass with a mass 150 g. They are both at room temperature of 25.0 °C. She then places ice at 0 °C into the glass and a final temperature of 5.00 °C is attained by the mixture. Calculate the mass of ice used to achieve this. The specific heat capacity of the glass is 850 $Jkg^{-1}°C^{-1}$.

$Q_{lost} = Q_{gain};\ m_w c_w \Delta T_w + m_g c_g \Delta T_g = m_i L_f + m_i c_w \Delta T_w$	1 mark
$0.240 \times 4180 \times (25.0 - 5.00) + 0.150 \times 850 \times (25.0 - 5.00)$ $= m_i \times 3.34 \times 10^5 + m_i \times 4180 \times (5.00 - 0)$	1 mark
$2.26 \times 10^4 = m_i \times 3.35 \times 10^5$	1 mark
$\therefore m_i = \dfrac{2.26 \times 10^4}{3.35 \times 10^5}$	1 mark
$= 6.37 \times 10^{-2}$ kg	1 mark

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Question 5 **(4 marks)**

A kettle operates at 240 V and carries a current of 4.50 A. The kettle is switched on for 2.50 minutes.

(a) Calculate the total charge that is carried through the heating element of the kettle during this time period.

(2 marks)

$q = It = 4.50 \times 2.50 \times 60$	1 mark
$= 6.75 \times 10^2$ C	1 mark

(b) Calculate the energy released by the charge in the kettle's element during this time period.

(2 marks)

$W = Vq = 240 \times 6.75 \times 10^2$	1 mark
$= 1.62 \times 10^5$ J	1 mark

Question 6 **(4 marks)**

When a string on an acoustic guitar is made to vibrate, the intensity if the sound produced by the string alone is quite low. The body of the guitar – which is filled with air – then amplifies the intensity of the sound so that it sounds quite loud to an observer. Explain this phenomenon.

Resonance.	1 mark
The vibrations from the string have a low amplitude and are, therefore, not very loud on their own.	1 mark
The body of the guitar and the air contained within it start to resonate with the vibrations from the string.	1 mark
The forcing vibration from the string matches the natural frequency of the air and the body and the amplitude of the their vibrations is increased.	1 mark

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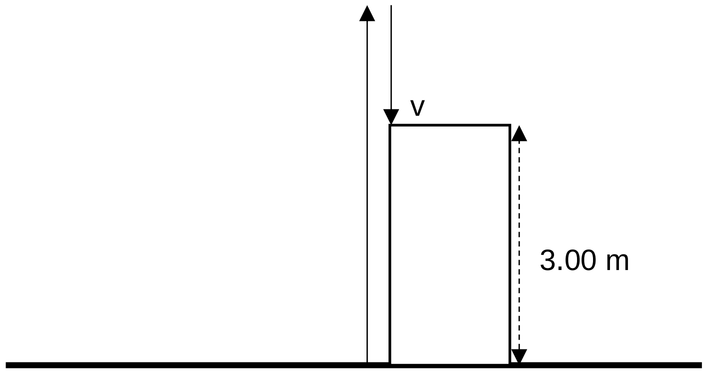
Question 7 **(7 marks)**

A ball is thrown vertically upwards at 10.2 ms^{-1} and lands on the roof of a house 3.00 m above the ground.



(a) Calculate the time taken for the ball to reach its maximum height.

(3 marks)

$v = u + at; 0 = 10.2 + (-9.80) \times t$	1 mark
$\therefore t = \frac{10.2}{9.80}$	1 mark
$= 1.04\ s$	1 mark

(b) Hence, calculate the maximum height gained by the ball.

(2 marks)

$s = ut + {}^{1}/_{2}\ at^2; s = 10.2\ \times 1.04 + 0.5\ \times (-9.80) \times\ 1.04^2$	1 mark
$=\ 5.32\ m$	1 mark

(c) Calculate the velocity 'v' with which the ball strikes the roof.

(2 marks)

$v^2 =\ u^2 + 2as; v^2 = 10.2^2 + 2\ \times\ (-9.80)\ \times 3.00$	1 mark
$=\ 6.73\ ms^{-1}$	1 mark

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Question 8 **(7 marks)**

(a) Use the data below to calculate the binding energy per nucleon (in MeV) for Carbon-12 (5 marks)

Mass of a proton	1.00727 u
Mass of a neutron	1.00867 u
Mass of Carbon-12	12.00000 u

$\text{Carbon} - 12 = 6\text{p} + 6\text{n};\ \therefore \text{Expected Mass} = 6 \times 1.00727 + 6 \times 1.00867$	1 mark
$= 12.09564\ \text{u}$	1 mark
$\text{Actual Mass} = 12.00000;\ \therefore \text{Mass Defect} = 12.09564 - 12.0000 = 0.09564\ \text{u}$	1 mark
$\text{Binding Energy} = 0.09564 \times 931 = 89.04084\ \text{MeV}$	1 mark
$\therefore \text{BE per nucelon} = \dfrac{89.04084}{12} = 7.42007\ \text{MeV}$	1 mark

(b) Carbon-14 is a radioisotope of carbon. Compare its binding energy per nucleon with carbon-12 (which is NOT a radioisotope). (2 marks)

Carbon-14 nuclei are unstable.	1 mark
Hence, BE per nucleon for C-14 is less than that of C-12.	1 mark

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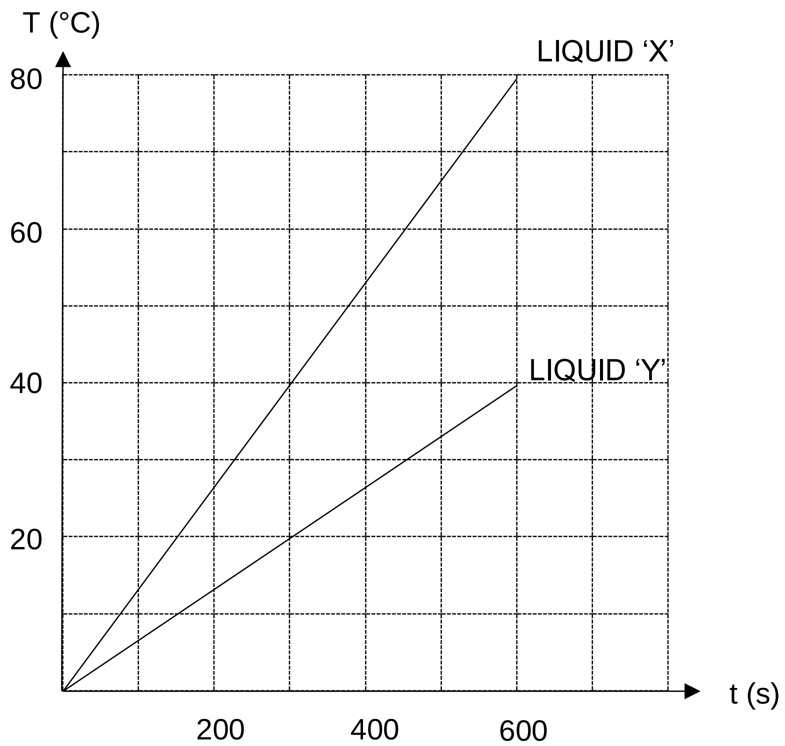
Question 9 **(4 marks)**

A student is conducting an experiment analysing the effect of specific heat on the temperature change in liquids.

The student measures equal masses of two liquids 'X' and 'Y' at 0 °C and places them in similar beakers. It is already known that the specific heat capacity of liquid 'X' (c_X) is 1000 J $kg^{-1}°C^{-1}$.

The two beakers are placed on the same hot plate and heated electrically for equal ten (10) minutes. Their temperatures are measured over that time and plotted on the graph seen below.



State the specific heat capacity of Liquid 'Y' (c_Y). State clearly how you determined this answer.

$c_X = 1000\ Jkg^{-1}°C^{-1};\ c_Y = ?;\ \Delta T_X = 80\ °C;\ \Delta T_Y = 40\ °C$	
$Q_X = Q_X;\ m_X = m_Y$	1 mark
$Q = mc\Delta T;\ \Delta T = \frac{Q}{mc}$	1 mark
$\Delta T_Y = 0.5 \times \Delta T_X;\ c_Y = 2 \times c_X = 2 \times 1000$	1 mark
$= 2000\ Jkg^{-1}°C^{-1}$	1 mark

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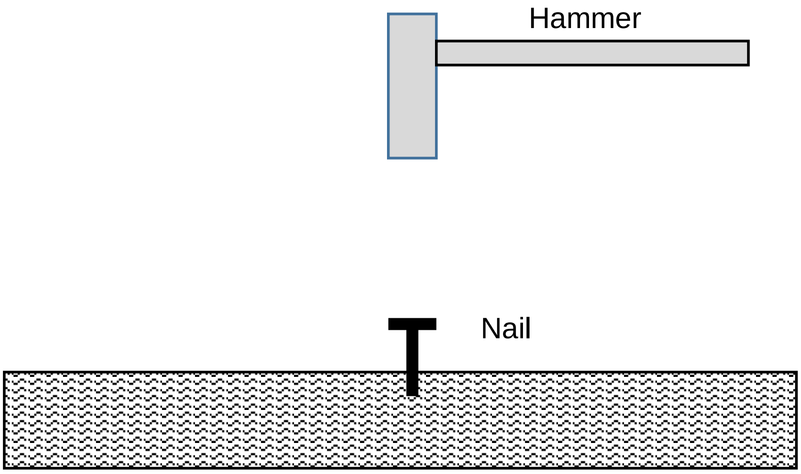
Question 10 **(5 marks)**

The diagram below shows a hammer raised above a nail embedded in some wood. The hammer is driven downwards, makes contact with the nail, and drives it into the wood.



The hammer has a mass of 850 g. When it is 25.0 cm above the nail, the user is swinging the hammer with a speed of 5.00 ms^{-1}.

(a) Calculate the amount of work the hammer will be able to do on the nail and drive it into the wood.

(3 marks)

$\text{Work done} = E_{TOTAL} = mgh + {}^{1}/_{2}\ mv^2$	1 mark
$= 0.850 \times 9.80 \times 0.250 + 0.5 \times 0.850 \times 5.00^2$	1 mark
$= 12.7\ J$	1 mark

(b) The nail is driven a distance of 3.00 cm into the wood. Assuming that the hammering process is 100% energy efficient, calculate the size of the average force experienced by the nail.

(2 marks)

$W = Fs;\ \therefore F = \frac{W}{s} = \frac{12.7}{0.0300}$	1 mark
$= 424\ N$	1 mark

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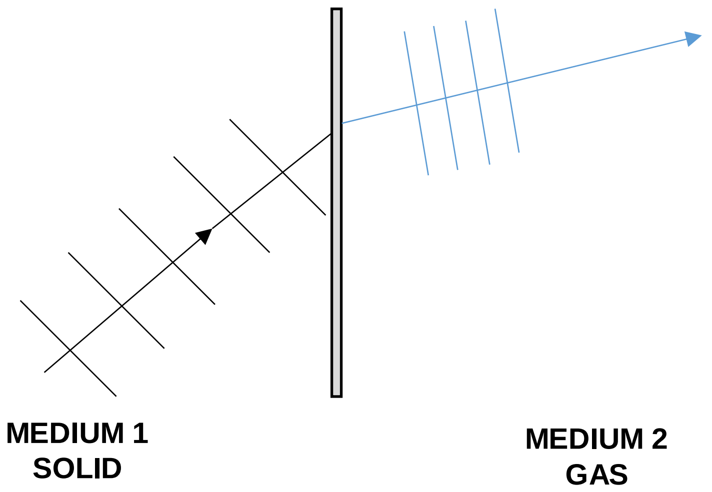
Question 11 **(6 marks)**

Use your knowledge of wave behaviour to answer the following questions:

(a) Draw the path of the ray and the wavefronts of the sound wave shown as it passes from one medium (solid) to the next medium (gas). Draw a minimum of five (5) wavefronts.

(3 marks)



Minimum of five (5) wavefronts shown.	1 mark
The path refracts towards the normal (wave speed decreases).	1 mark
The wavelength decreases.	1 mark

(b) A teacher is in a classroom which has its door wide open. The teacher is able to HEAR some students just outside the door but is unable to SEE them. Explain using your knowledge of diffraction.

(3 marks)

Both sound and light are waves.	1 mark
Both diffract and spread out as they pass through the doorway.	1 mark
However, because of its very small wavelength, the light does not spread out as much as the sound wave and cannot reach the teacher.	1 mark

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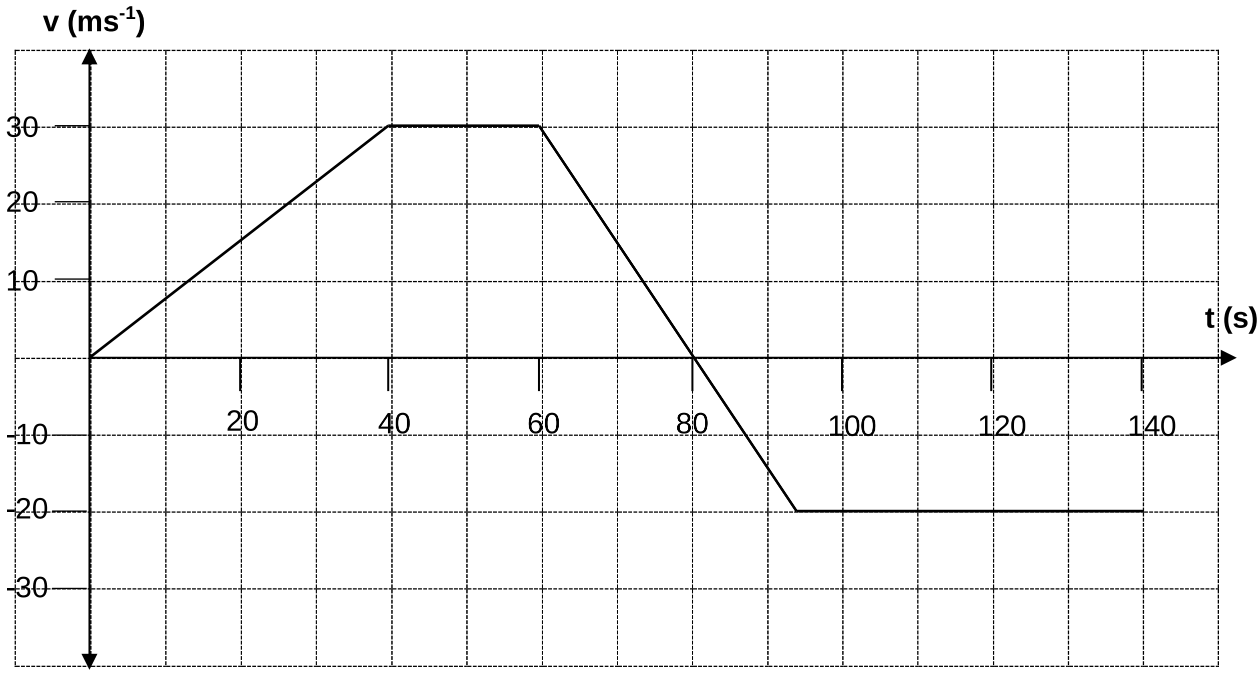
Section Two: Problem-solving **50% (90 Marks)**

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 12 **(17 marks)**

A car is driving on a straight road aligned in a north-south direction. It starts at rest and then accelerates in a northerly direction. The velocity-time graph for the car's journey is shown below.



(a) State the time intervals where the car is:

(6 marks)

(i) travelling NORTH: t = ______________________

(ii) travelling SOUTH: t = ______________________

(iii) travelling with a constant velocity: t = ______________________

(iv) experiencing a decrease in speed: t = ______________________

(v) stationary: t = ______________________

(vi) starts travelling in a southerly direction:

t = ______________________

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(i)	t = 0 s to 80 s	1 mark
(ii)	t = 80 s to 140 s	1 mark
(iii)	t = 40 s to 60 s and t = 94 s (93-95) to 140 s	1 mark
(iv)	t = 60 s – 80 s	1 mark
(v)	t = 0 s and 80 s	1 mark
(vi)	t = 80 s – 140 s	1 mark

(b) Calculate the car's acceleration at the following times:

(4 marks)

(i) t = 20 s

$a = \frac{(30-0)}{(40-0)}$	1 mark
$= 0.750\ \text{ms}^{-2}$	1 mark

(ii) t = 80 s

$a = \frac{(-20-30)}{(94-60)}$	1 mark
$= -1.47\ \text{ms}^{-2}\ (-1.52\ \text{to} -1.43)$	1 mark

(c) Calculate the car's final displacement at t = 140 s (ie - the end of the journey).

(4 marks)

$\Delta s = \text{area underneath the graph}$	1 mark
$\Delta s = (0.5 \times 30 \times 40 + 20 \times 30 + 0.5 \times 30 \times 20) - (0.5 \times 14 \times 20 + 46 \times 20))$	1 mark
$= 4.40 \times 10^2\ \text{m}\ (4.30 \times 10^2\ \text{to}\ 4.30 \times 10^2)$	1 mark
NORTH	1 mark

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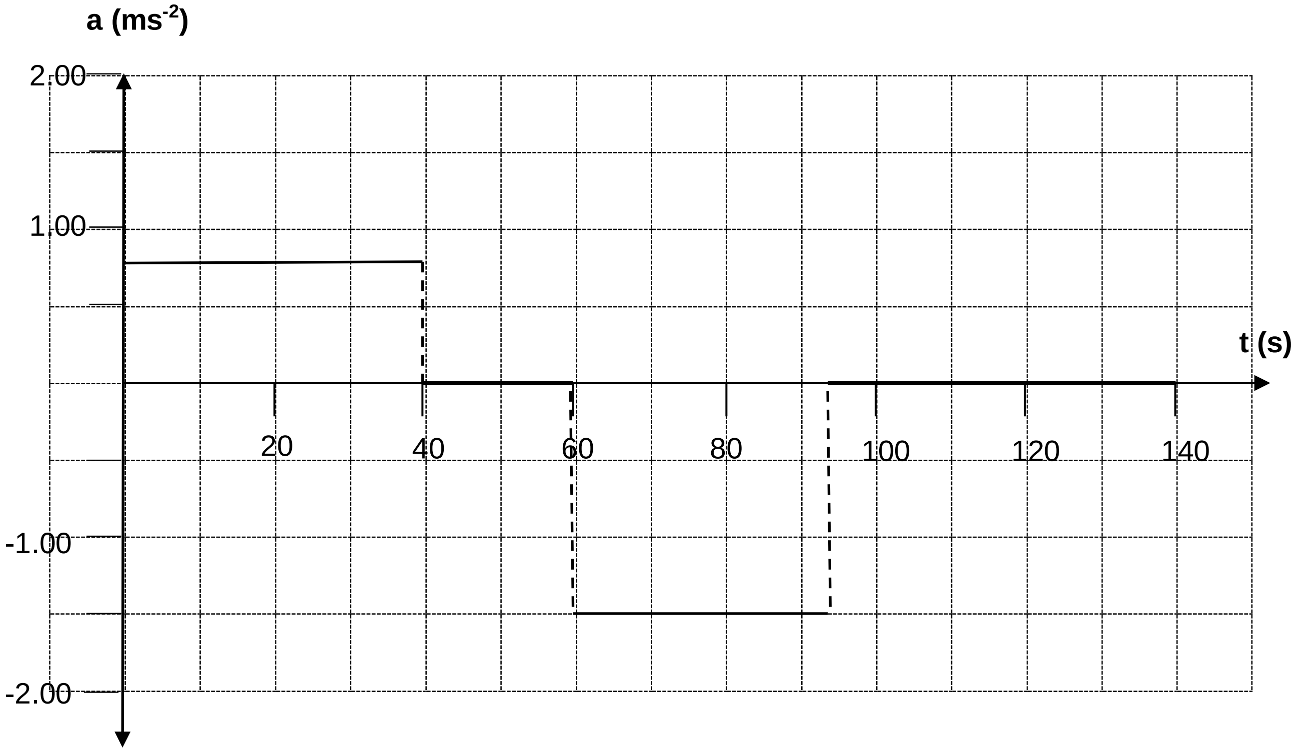
(d) On the gird below, draw an ‘acceleration v time’ graph for the car’s journey.

(3 marks)



t = 0 s to 40 s; a = 0.750 ms^{-2}.	1 mark
t = 60 s to 94 s; a = -1.47 ms^{-2}.	1 mark
t = 40 s to 60 s and t = 94 s to 140 s; a = 0 ms^{-2}.	1 mark

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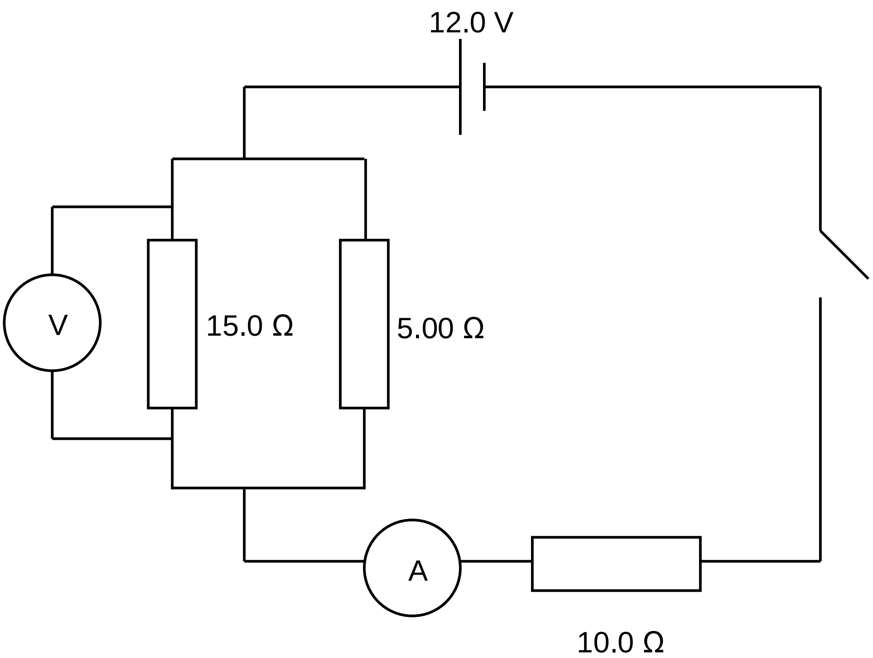
Question 13 **(12 marks)**

The questions that follow relate to the electric circuit below:



When the switch is closed, calculate:

(a) The total resistance in this circuit.

(3 marks)

Parallel circuit: $\frac{1}{R} = \frac{1}{15} + \frac{1}{5}$; $\therefore R = 3.75\ \Omega$	1 mark
$R_{TOTAL} = 3.75 + 10$	1 mark
$\therefore R_{TOTAL} = 13.7\ \Omega$	1 mark

(b) The current flowing through the ammeter.

(2 marks)

$I_T = \frac{V_T}{R_T} = \frac{12}{13.7}$	1 mark
$= 0.873\ A$	1 mark

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(c) The reading on the voltmeter.

(2 marks)

$10.0\ \Omega$ resistor: $V = IR = 0.873 \times 3.75$	1 mark
$= 3.27\ V$	1 mark

(d) The power dissipated by the 5.00 Ω resistor.

(3 marks)

$P = \frac{V^2}{R} = \frac{3.27^2}{5.00}$	1 mark
$= 2.14$	1 mark
W (units)	1 mark

(e) Calculate the energy provided by the battery if the circuit is connected for two (2) hours.

(2 marks)

$Q = VIt = 0.873 \times 12 \times (2 \times 3600)$	1 mark
$= 7.54 \times 10^4\ J$	1 mark

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Question 14 **(16 marks)**

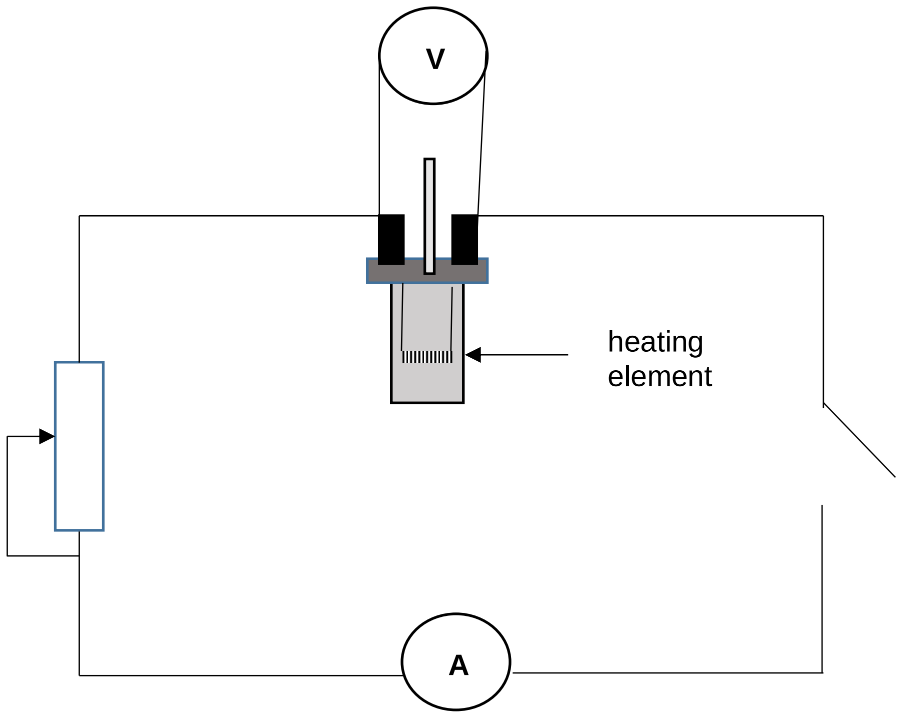
Some students are conducting an experiment to determine a value for the specific heat of water. The students have the following equipment:

Copper calorimeter, voltmeter, ammeter, switch, rheostat, electric leads, water, timer, thermometer

The students build a circuit that enables them to control and measure the current flowing through the heating element of the calorimeter; and measure the potential difference around the heating element of the calorimeter.

(a) The calorimeter is shown with a thermometer below. Draw a circuit diagram representing the rest of the electric circuit the students built.

(3 marks)



Ammeter, switch, rheostat and calorimeter in series with each other.	1 mark
Voltmeter in parallel with calorimeter.	1 mark
All symbols in diagram are correct.	1 mark

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(b) On closer inspection, the students notice that the calorimeter has some design features shown in the table below. Briefly explain these features in terms of the function of the calorimeter.

(3 marks)

DESIGN FEATURE	EXPLANATION
Shiny interior	
Foam covering around the copper vessel	
Tight fitting lid with a hole for the thermometer	

Shiny interior: reflects thermal radiation back into the water to reduce heat losses.	1 mark
Foam covering: reduces heat loss from calorimeter via conduction.	1 mark
Tight fitting lid: reduces heat loss from calorimeter via convection.	1 mark

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The students filled the calorimeter with some water, connected the circuit, switched on the power and started to gather data. The results are displayed in the table below:

Mass of the copper calorimeter	**0.455 g**
Specific heat of copper	**390 $Jkg^{-1}°C^{-1}$**
Mass of water	**0.657 g**
Initial temperature of the water	**18 °C**
Final temperature of the water	**83 °C**
Ammeter reading	**14.7 A**
Voltmeter Reading	**11.7 V**
Time circuit is switched on	**1200 s**

(c) Show, via a calculation, that electric power generated in the circuit is equal to 172 W.

(2 marks)

$P = VI = 11.7 \times 14.7$	1 mark
$= 1.72 \times 10^2$ W	1 mark

(d) Hence, calculate the amount of electrical energy generated in the heating element of the calorimeter.

(2 marks)

$Q = Pt = 172 \text{ x } 1200$	1 mark
$= 2.06 \times 10^5$ J	1 mark

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(e) Hence, use your answer from part (d) – and the data in the results table – to calculate a value for the specific heat capacity of water. Thermal losses are such that the calorimeter is rated as being only 90.0% efficient.
[If you were unable to calculate an answer for part (d), use a value of 2.10 x 10^5 J]

(6 marks)

$0.90 \times Q_{gained} = Q_W + Q_C = m_W c_W \Delta T_W + m_C c_C \Delta T_C$	1 mark
$1.85 \times 10^5 = 0.657 \times c_W \times (83-18) + 0.455 \times 390 \times (83-18)$	2 marks
$1.85 \times 10^5 = 42.7 \times c_W + 1.67 \times 10^4$	1 mark
$c_W = \dfrac{1.85 \times 10^5 - 1.15 \times 10^4}{42.7}$	1 mark
$= 4.06 \times 10^3 \text{ Jkg}^{-1}{}^{\circ}\text{C}^{-1}$ $(4.16 \times 10^3 \text{ Jkg}^{-1}{}^{\circ}\text{C}^{-1})$	1 mark

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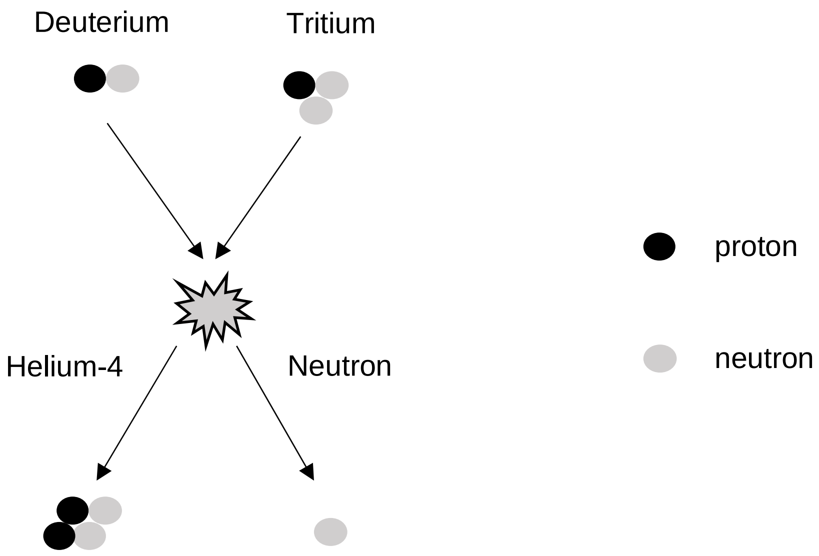
Question 15 **(15 marks)**

Nuclear fusion reactions occur in the core of every star and produce enormous amounts of energy.

One fusion reaction (Deuterium-Tritium) is illustrated below:



The masses of the particles involved in this fusion reaction are summarised in the table below:

Deuterium	**2.01355 u**
Tritium	**3.01605 u**
Helium-4	**4.00260 u**
Neutron	**1.00867 u**

(a) Write a balanced nuclear equation for the Deuterium-Tritium reaction illustrated above. (3 marks)

$H_1^2 + H_1^3 \rightarrow He_2^4 + n_0^1$	
Correct chemical symbols are used.	1 mark
Mass numbers are balanced.	1 mark
Atomic numbers are balanced.	1 mark

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(b) Use the masses listed earlier to calculate the energy released (in MeV) by this fusion reaction. Show all working.

(4 marks)

$\text{Mass of reactants} = 2.01355 + 3.01605 = 5.02960\ \text{u}$	1 mark
$\text{Mass of products} = 4.00260 + 1.00867 = 5.01127\ \text{u}$	1 mark
$\text{Mass defect} = 5.02960 - 5.01127 = 0.01833\ \text{u}$	1 mark
$\text{Energy released} = 0.01833 \times 931 = 17.06523\ \text{MeV} = 17.1\ \text{MeV}$	1 mark

(c) Hence, calculate the total fusion energy released (in Joules) by one (1) kilogram of deuterium fuel (assume that all of this deuterium undergoes fusion).
[If you were unable to calculate an answer for part (b) use a value of 17.00000 MeV]

(4 marks)

$\text{m(H} - \text{2 nuclei)} = 2.01355 \times 1.66 \times 10^{-27} = 3.34 \times 10^{-27}\text{kg}$	1 mark
$\text{n(H} - \text{2 nuclei)} = \dfrac{1}{3.34 \times 10^{-27}} = 2.99 \times 10^{26}$	1 mark
$\text{Energy released} = 2.99 \times 10^{26} \times 17.06523 \times 1.6 \times 10^{-13}$	1 mark
$= 8.17 \times 10^{14}\text{J} \quad (8.13 \times 10^{14}\text{J})$	1 mark

The core of a star has two very extreme conditions: very high temperatures and very high pressures.

(d) The extremely high temperatures provide for two (2) conditions vital for fusion to occur in the core of the star. Describe these conditions.

(2 marks)

The high pressures compress the plasma so much that nuclei collisions become possible.	1 mark
The high temperatures increase the plasma's velocity to extremely high levels. Again, these extremely high velocities allow the plasma to overcome the electrostatic forces between the nuclei and for collisions to occur.	1 mark

Fusion reactors are still in an experimental phase. Fission reactors have been used for many decades in different countries to produce electrical power. Fusion power has some advantages and disadvantages when compared to fission power.

(e) State one (1) ADVANTAGE and one (1) DISADVANTAGE generating electrical power by fusion power has compared to generating it by fission power.

(2 marks)

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Advantages could include: plentiful fuel supply; higher energy yield; waste products not as hazardous (not long-term radioisotopes).	1 mark
Disadvantages could include: more energy required to power a fusion reactor than is produced.	1 mark

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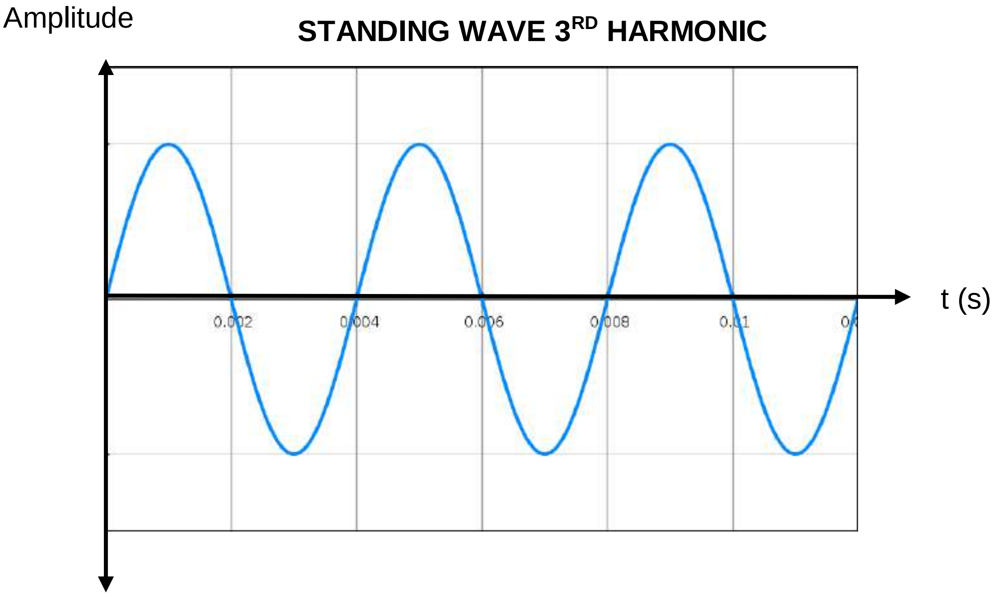
Question 16 **(14 marks)**

A vibrating guitar string of length 55.0cm produces a standing wave and its 3rd harmonic is depicted by the information in the graph below. The graph shows the pressure variations detected by a microphone due to this standing wave.

The horizontal axis measures 'time' (in seconds); the vertical axis indicates the 'amplitude' of the standing wave.



(a) Calculate the wavelength of this standing wave.

(3 marks)

$\lambda_n = \frac{2L}{n}$	1 mark
$\lambda_3 = \frac{2L}{3} = \frac{2 \times 0.550}{3}$	1 mark
$= 0.367\text{m}$	1 mark

(b) Use the graph to calculate the frequency of this standing wave. Show working.

(2 marks)

$T = 0.004\ \text{s}$	1 mark
$\therefore f = \frac{1}{T} = \frac{1}{0.004} = 2.50 \times 10^2\ \text{Hz}$	1 mark

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(c) Hence, calculate the speed of sound in the string of this guitar.

(2 marks)

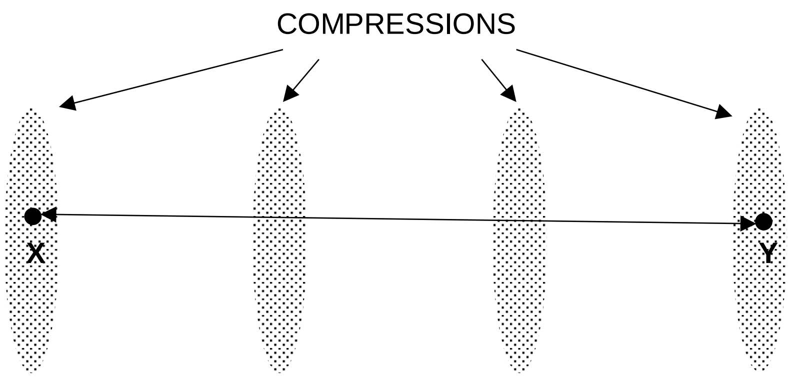
$v = f_3\lambda_3 = 250 \times 0.367$	1 mark
$= 91.7\ ms^{-1}$	1 mark

(d) The speed of sound in the air on this day is 344 ms^{-1}. Hence, calculate the wavelength of the fundamental frequency (or 1^{st} harmonic) waves generated by the guitar as they travel through the air. Show working.

(3 marks)

$f_1 = \frac{f_3}{3} = \frac{250}{3} = 83.3Hz$	1 mark
$\therefore \lambda_1 = \frac{v}{f_1} = \frac{344}{83.3}$	1 mark
$= 4.13m$	1 mark

The diagram below shows the location for the compressions produced by the fundamental (1^{st}) harmonic in air at a particular instant in time.



(e) Calculate the distance between points 'X' and 'Y' on the diagram above for the fundamental frequency. Show working.

(2 marks)

$d_{XY} = 3 \times \lambda_1 = 3 \times 4.13$	1 mark
$= 12.4\ m$	1 mark

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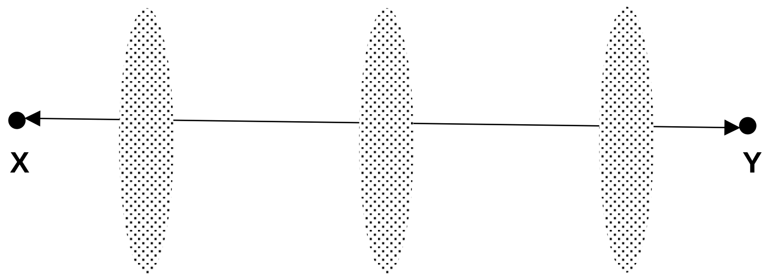
(f) Draw the location of the compressions for the wave in air produced by the fundamental (1^{st}) frequency between points 'X' and 'Y' at a time half a period later than their location in the diagram in part (e).

(2 marks)



The three (3) compressions are drawn an equal distance apart.	1 mark
The three (3) compressions are drawn in the positions of the rarefactions half a period of time earlier.	1 mark

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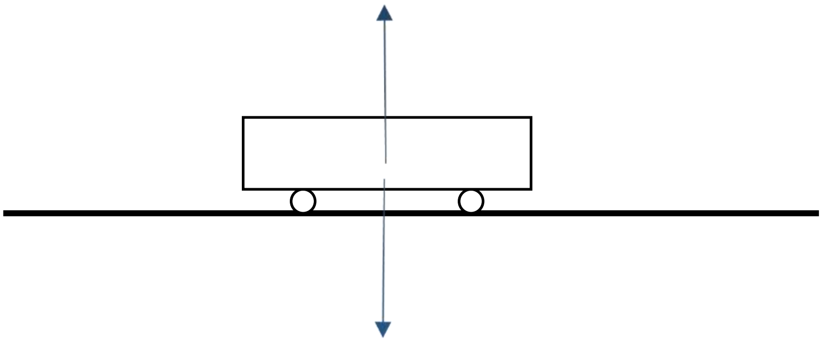
Question 17 **(16 marks)**

The following questions ask you to discuss the operation of a car of mass 1500 kg in terms of you knowledge of Newton's Laws.

(a) The car is at rest. On the diagram below, draw labelled vectors to represent the forces acting on the car. No calculations are required.

(2 marks)



Two (2) appropriately labelled vectors are drawn.	1 mark
Vectors are drawn in opposite directions and the same length	1 mark

(b) The car accelerates in a forward direction. The driver of the car feels as though they are being 'forced backwards' into their seat. Use Newton's First Law of Motion to explain this sensation.

(3 marks)

Newton's First Law states that an object will remain at rest or at a constant velocity unless it is acted on by an unbalanced, external force.	1 mark
The driver is at rest as the car starts to move forward.	1 mark
The car seat moves forward and collides with the back of the driver,	1 mark

(c) The car accelerates forward at a rate of 2.50 ms^{-2}. The car's acceleration is achieved by the motor of the car, which provides a force forwards of 5.00 x 10^3 N. Calculate the force due to friction acting on the car. Show all working.

(4 marks)

$\Sigma F = ma = 1500 \times 2.50$	1 mark
$= 3.75 \times 10^3$ N	1 mark
$F_f = 5.00 \times 10^3 - 3.75 \times 10^3$	1 mark
$= 1.25 \times 10^3$ N	1 mark

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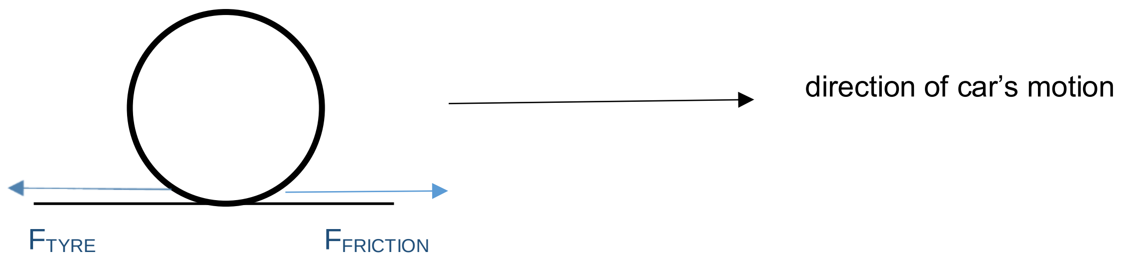
(d) The forward motion of the car is also achieved by the frictional force produced between the car's tyres and the road. Explain using one of Newton's laws of Motion. As part of your answer, label the horizontal forces acting on the tyre on the diagram below.

(4 marks)



Two (2) vectors are drawn: $F_{TYRE} = F_{FRICTION}$.	1 mark
Newton's 3rd Law: every force is accompanied by an equal and opposite reaction force.	1 mark
The axle moves the bottom of the tyre backwards; a friction force is created in a forward direction.	1 mark
The friction force allows the top of the tyre to rotate in a forward direction.	1 mark

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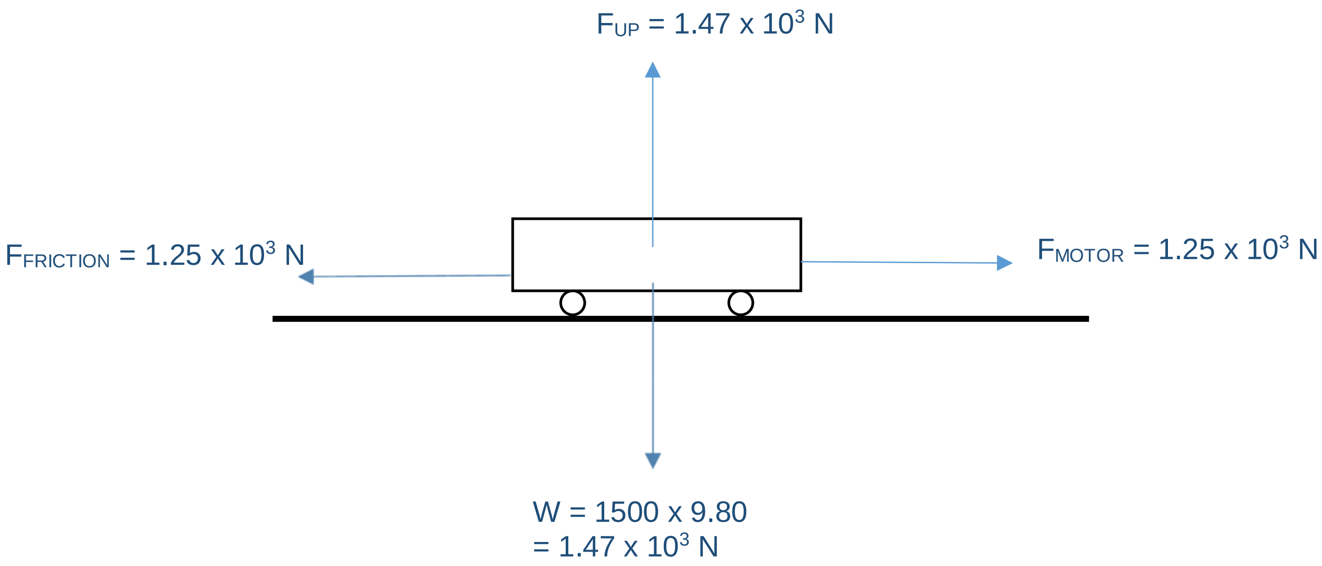
(e) The car reaches the speed limit and maintains that constant velocity. On the diagram below, label the forces acting on the car (including their magnitude) as it travels at a constant velocity. Assume that the value for friction you calculated in part (c) is constant at all car speeds.

(3 marks)



Two pairs of vectors drawn.	1 mark
Vectors are correctly labelled.	1 mark
Magnitudes are correctly calculated.	1 mark

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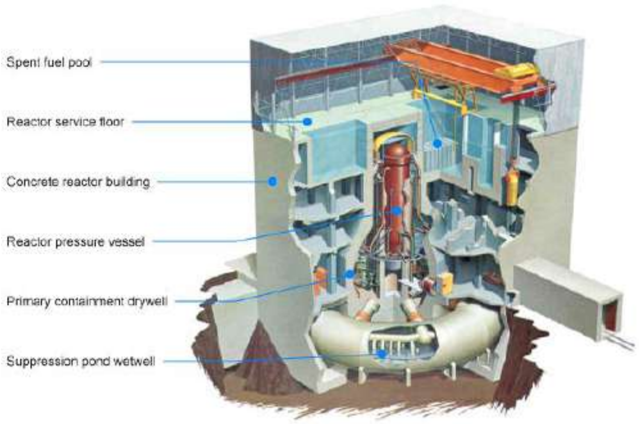
Section Three: Comprehension **20% (36 Marks)**

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 **(16 marks)**

Fukushima Daiichi Accident

From https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-daiichi-accident.aspx



Following a major earthquake, a 15-metre tsunami disabled the power supply and cooling of three Fukushima Daiichi reactors, causing a nuclear accident on 11 March 2011. All three cores largely melted in the first three days. Four reactors were written off due to damage in the accident.

Radioactive releases to air (following the accident)

The most abundant radionuclide released into the air from among the many kinds of fission products in the fuel was volatile iodine-131 (a beta-emitter), which has a half-life of 8 days. The other main radionuclide is caesium-137 (a beta- and gamma-emitter), which has a 30-year half-life, is easily carried in a plume, and when it lands it may contaminate land for some time.

When assessing the significance of atmospheric releases of radioactive materials, the activity levels due to the Cs-137 are multiplied by 40 and added to the activity due to I-131 to give an "iodine-131 equivalent" figure.

Japan's regulator, the Nuclear & Industrial Safety Agency (NISA), estimated in June 2011 that 770 PBq (iodine-131 equivalent) of radioactivity had been released, but the Nuclear Safety Commission (NSC, a policy body) in August lowered this estimate to 570 PBq.

Radiation exposure on the plant site

By the end of 2011, Tepco had checked the radiation exposure of 19,594 people who had worked on the site since 11 March. For many of these both external dose and internal doses (measured with whole-body counters) were considered. It reported that 167 workers had received doses over 100 mSv. Of these 135 had received 100 to 150 mSv, 23 150-200 mSv, three more 200-250 mSv, and six had received over 250 mSv (309 to 678 mSv) apparently due to inhaling iodine-131 fume early on.

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The latter included the two unit 3-4 control room operators in the first two days who had not been wearing breathing apparatus. There were up to 200 workers on site each day. Recovery workers are wearing personal monitors, with breathing apparatus and protective clothing which protect against alpha and beta radiation.

So far over 3500 of some 3700 workers at the damaged Daiichi plant have received internal check-ups for radiation exposure, giving whole body count estimates. The level of 250 mSv was the allowable maximum short-term dose for Fukushima Daiichi accident clean-up workers through to December 2011, 500 mSv is the international allowable short-term dose "for emergency workers taking life-saving actions". Since January 2012, the allowable maximum has reverted to 50 mSv/yr.

(a) Part of the design at the Fukushima Daiichi reactors were cooling ponds for spent fuel rods from the reactor core. Describe the composition of the spent fuel rods and why they need to be cooled in this way for some time.

(2 marks)

The spent fuel rods consist of fission products that are radioisotopes.	1 mark
The emitted radiation energy causes the surroundings to heat up.	1 mark

(b) Inevitably, radioisotopes from the reactor cores escaped into the environment. One of these was the beta-emitter caesium-137. Write a balanced nuclear equation for this beta-decay.

(2 marks)

$\mathrm{Cs}_{55}^{137} \rightarrow \mathrm{Ba}_{56}^{137} + \beta_{-1}^{0}$	
All chemical symbols of the participants in the decay equation are correct.	1 mark
Mass numbers are balanced; atomic numbers are balanced.	1 mark

(c) Using the information provided in the article, calculate the percentage of an Iodine-131 sample after a time-period of 30 days.

(4 marks)

$A_0 = 100\%;\ T_{1/2} = 8\ \text{days};\ T = 30\ \text{days}$	1 mark
$n = {}^{T}/_{T_{1/2}} = \frac{30}{8} = 3.75\ \text{half lives}$	1 mark
$A = A_0\,(0.5)^n = 100(0.5)^{3.75}$	1 mark
$= 7.43\ \%$	1 mark

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(d) The unit 'PBq' stands for the 'peta-becquerel'. The prefix 'peta' is equal to 10^{15}. The estimated I-131 equivalent amount of radiation released by the Fukishima accident was 570PBq. Calculate the number of radiation emissions this would represent in one (1) minute.

(2 marks)

$\text{N° of emissions} = 570 \times 10^{15} \times 60$	1 mark
$= 3.42 \times 10^{19}$	1 mark

(e) The allowable maximum short-term dose for Fukushima Daiichi accident clean-up workers in the short period after the accident was 250 mSv.

(i) Calculate the absorbed dose (in Grays) this would represent if the radiation emitted is exclusively alpha radiation.

(2 marks)

$AD = \frac{DE}{QF} = \frac{250 \times 10^{-3}}{20}$	1 mark
$= 1.25 \times 10^{-2}\ Gy$	1 mark

(ii) Calculate the quantity of ionising radiation absorbed by a 65 kg worker who receives the dose equivalent described in part (i). Assume a full body exposure.

(2 marks)

$AD = \frac{Q}{m};\ \therefore Q = AD \times m = 1.25 \times 10^{-2} \times 65$	1 mark
$= 0.813\ J$	1 mark

(f) The emergency workers who wore protective clothing were protected from some forms of radiation, but still received radiation doses up to 250 mSv. Explain.

(2 marks)

Alpha and beta radiation have very low penetrating properties. The protective clothing would have protected them from these types of radiation.	1 mark
Gamma radiation's very high penetration would have allowed it to penetrate through the clothing into the workers' bodies.	1 mark

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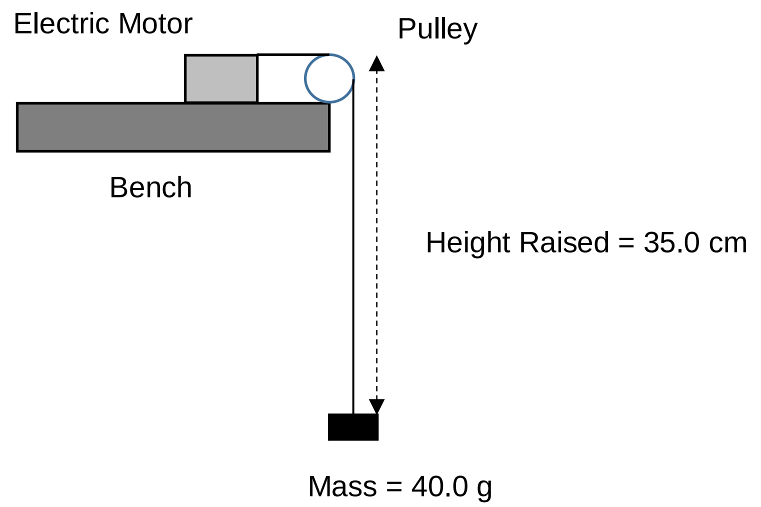
Question 19 **(20 marks)**

ELECTRIC POWER AND MECHANICAL WORK

Some students performed an investigation to determine the efficiency of an electric motor as it converted electrical energy into mechanical work.

They used the rotation and torque produced by the motor to lift a 40.0 g mass through vertical distance of 35.0 cm. The electric power provided to the motor was increased and measured; the time taken for the mass to travel through this vertical distance was then determined.

The equipment used by the students is shown below:



The students gradually increased the electric power provided to the motor by increasing the voltage on a power pack. They had performed an experiment prior to the investigation and determined that the average electric resistance of the motor was equal to 7.30 Ω. For each increased power, the average time for the mass to have its height increased by a distance of 35.0 cm was measured. The table below summarises the results obtained by the students.

Voltage 'V' (V)	Time 't' (s)	V^2 (V^2)	$^1/_t$ (s^{-1})
0.400	7.81	0.160	0.128
0.600	3.47	0.360	0.288
0.800	1.95	0.640	0.513
1.00	1.25	1.00	0.800
1.20	0.868	1.44	1.15

The students used this data to determine the efficiency of the motor 'η' (expressed as a decimal).

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BACKGROUND

From their Physics classes, the students were aware of the following:

Electric power supplied to the electric motor:

$$\mathbf{P = VI = I^2R = \frac{V^2}{R}}$$

Gravitational potential energy (EP) supplied to the mass as it is raised through height 'h':

$$\mathbf{E_p = mgh}$$

Power is the rate at which energy is added to the mass:

$$\mathbf{P = \frac{E}{t}}$$

In addition to the table of values provided previously, the students also had measured the following data:

Mass of the object being raised	**40.0 g**
Height through which the object is raised	**35.0 cm**
Electrical resistance of the electric motor	**7.30 Ω**
Acceleration due to gravity	**9.80 ms^{-2}**

(a) By combining the appropriate expressions listed above, derive the following relationship:

$$\mathbf{V^2 = \frac{1}{\eta} \times \frac{1}{t}}$$

Where: V = voltage supplied to the electric motor (V)

η = efficiency of the electric motor

t = time taken for 40.0 g mass to be raised 35.0 cm.

(4 marks)

$\frac{V^2}{R} \times \eta = \frac{(mg\Delta h)}{t}$; $\therefore V^2 = mg\Delta h \times \frac{R}{\eta} \times \frac{1}{t}$	2 marks
$V^2 = \frac{(0.0400 \times 9.80 \times 0.350 \times 7.30)}{\eta} \times \frac{1}{t}$	1 mark
$\therefore V^2 = \frac{1.00}{\eta} \times \frac{1}{t}$	1 mark

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(b) Fill in the two missing values in the table. Any working can be shown below.

(2 marks)

$V^2 = 0.640$	1 mark
$^1/_t = 0.128$	1 mark

The students decided to plot 'V^2' values against '$^1/_t$' values for their graphical analysis of the data.

(c) Explain why the students chose this graphical approach. In addition, state an assumption that you made when choosing the graph.

(3 marks)

Assumed that the efficiency of the coil is constant for ALL voltages.	1 mark
'V^2' is directly proportional to '$^1/_t$'.	1 mark
Hence, plotting these two values against each other will yield a linear relationship.	1 mark

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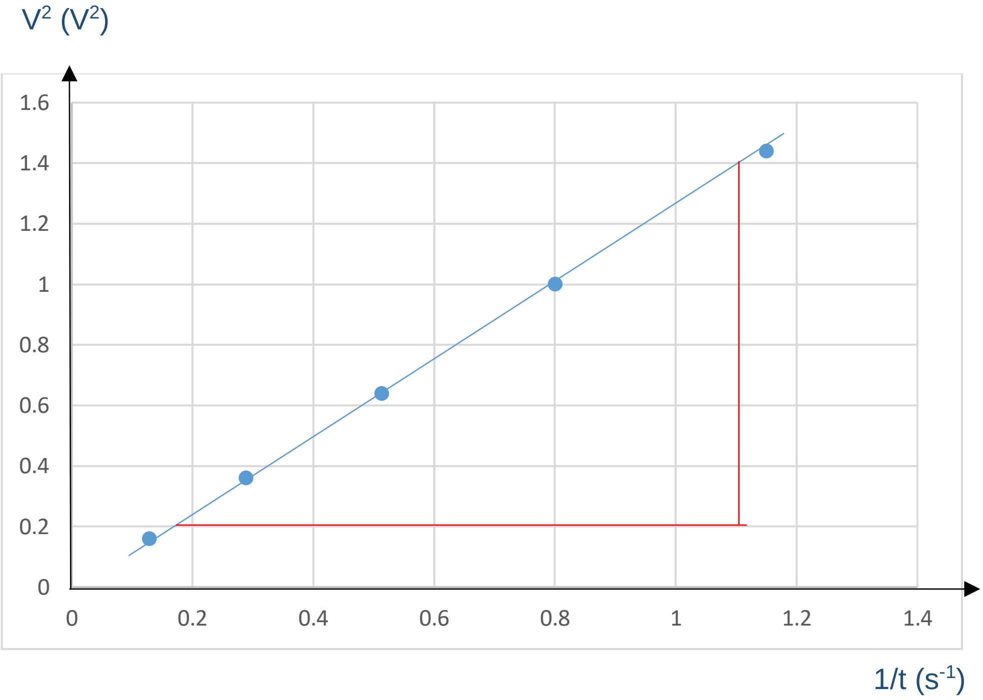
(d) On the grid on the next page, plot 'V^2' against '$^1/_t$'. Place the 'V^2' values on the vertical axis. Draw a line of best fit for your data.

(4 marks)



'V^2' plotted on vertical axis.	1 mark
Points and line of best fit plotted correctly.	1 mark
Quantities are correctly labelled	1 mark
Units are correctly labelled	1 mark

(e) Calculate the slope of the line of best fit you have drawn. Show clearly how you have done this. Include units in your answer.

(4 marks)

Two points from graph: (0.18, 0.20) and (1.10, 1.40)	1 mark
$\text{Slope} = \frac{\text{Rise}}{\text{Run}} = \frac{(1.40 - 0.20)}{(1.10 - 0.18)}$	1 mark
$= 1.30 \ \ (\text{accept } 1.15 - 1.45)$	1 mark
Units: V^2s	1 mark

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(f) Use the slope you have calculated in part f) to determine the efficiency ‘η’ of the electric motor. Show clearly how you have done this.

(3 marks)

Slope represents the ratio: $\frac{\Delta V^2}{\Delta \frac{1}{t}} = V^2 t$; $V^2 = \frac{1}{\eta} \times \frac{1}{t}$; $\therefore \eta = \frac{1}{V^2 t}$	1 mark
$\therefore \eta = \frac{1}{1.30}$	1 mark
= 0.767 (76.7%) (accept 0.690 - 0.870)	1 mark

End of Questions

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Additional working space

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Spare grid for graph

End of examination

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Acknowledgements