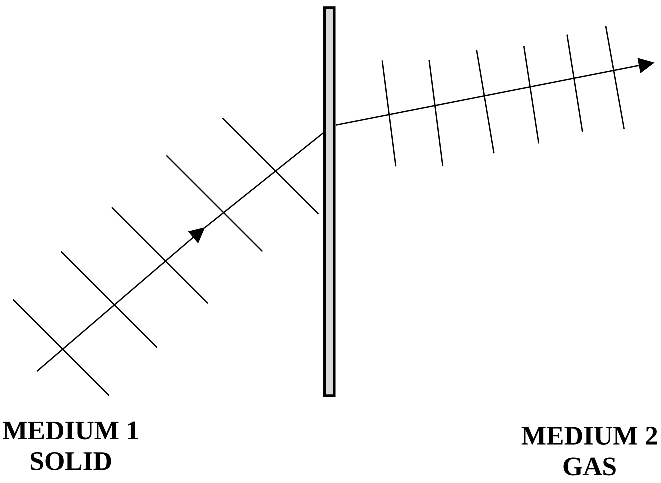
Section One: Short Response **30% (45 marks)**

Question 1 **(3 marks)**

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



Description	Marks
Minimum of five (5) wavefronts shown.	1
The path refracts towards the normal (wave speed decreases).	1
The wavelength decreases.	1
Total	**3**

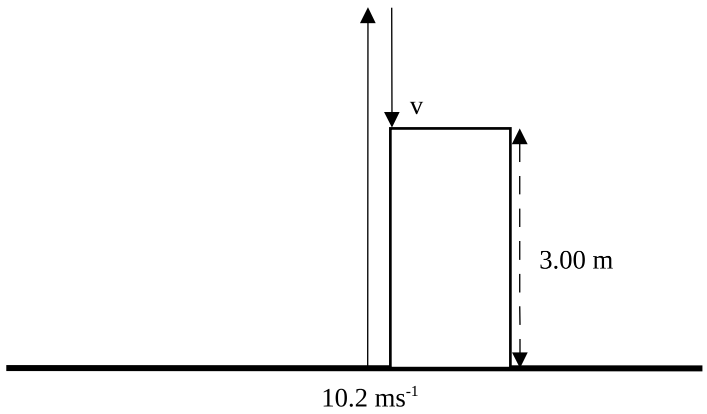
Question 2 **(4 marks)**

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.

Description	Marks
The law of conservation of momentum states that: $\Sigma p_{initial} = \Sigma p_{final}$	1
Prior to firing, all objects in the system are at rest; $\therefore \Sigma p_{initial} = 0.$	1
After firing, the bullets have a momentum in one direction.	1
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
Total	**4**
OR	
Newton's third law states that for every action there's an equal and opposite reaction	**1**
The gun exerts a force on the bullet that causes it to move forward (large force due to high velocity/acceleration)	**1**
The bullet exerts a force back on the gun	**1**
The superhero should move backwards as they are holding the gun and unbraced	**1**

Question 3 **(8 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. Show working.

(3 marks)

Description	Marks
$v=u+at$ $0=10.2+(-9.80)\times t$	1
$\therefore t=\frac{10.2}{9.80}$	1
¿ $1.04\,s$	1
Total	**3**

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

(2 marks)

Description	Marks
$s=ut+\frac{1}{2}at^2$ $s=10.2\times 1.04+0.5\times(-9.80)\times 1.04^2$	1
¿ $5.32\,m$	1
Total	**2**

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

(3 marks)

Description	Marks
$h=5.32-3.00=2.32\,m$	1
$v^2=0^2+2\times(-9.80)\times(2.32)$	1
¿ $6.73\,ms^{-1}$ downwards (direction)	1
Total	**3**

Question 4 **(3 marks)**

Runway marshallers are people who direct planes onto runways at airports. They must use specialised ear protection to prevent hearing damage. A sound intensity of 1.00 x 10^4 Wm^{-2} is enough to burst the human eardrum when unprotected. If a runway marshaller is standing 30.0 metres away from a jet engine, the sound intensity is 1.00 x 10^2 Wm^{-2}. At what distance away from the engine is a marshaller likely to burst their eardrums if they were not wearing protective equipment? Show working.

Description	Marks
$I_o \propto \frac{1}{{r_o}^2}; \frac{I_o}{I_d} = \frac{{r_d}^2}{{r_o}^2}$	1
$\frac{100}{10000} = \frac{{r_d}^2}{30^2}$	1
r_d = 3.00 m (significant figures)	1
Total	**3**

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. Show working.

(2 marks)

Description	Marks
$q = It = 4.50 \times 2.50 \times 60$	1
¿ $6.75 \times 10^2\,C$	1
Total	**2**

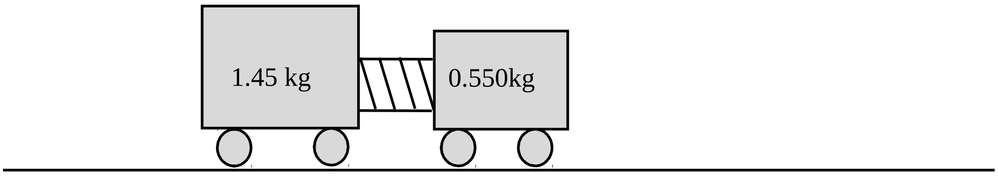
(b) Calculate the energy released by the charge in the kettle's element during this time period. Show working.

(2 marks)

Description	Marks
$W = Vq = 240 \times 6.75 \times 10^2$	1
¿ $1.62 \times 10^5\,J$	1
Total	**2**

Question 6 **(8 marks)**

Two stationary carts are initially coupled together with a compressed spring (of negligible mass) between each cart. The spring is allowed to extend and the 0.550 kg cart is observed to travel away at a velocity of 2.40 m s^{-1} Right.



(a) Using conservation of momentum, calculate the velocity of the 1.45 kg mass. Show working.

(3 marks)

Description	Marks
$m_c u_c = m_1 v_1 + m_2 v_2$	1
$v_2 = \dfrac{m_c u_c - m_1 v_1}{m_2} = \dfrac{0 - 0.55(2.40)}{1.45}$	1
$= 0.910$ m s^{-1} Left	1
Total	**3**

(b) Calculate the energy contained within the spring when it is compressed. (If you could not complete (a), use v = 1.00 m s^{-1}). Show working.

(3 marks)

Description	Marks
$\Sigma Ei = \Sigma Ef = ½ m_1 v_1^2 + ½ m_2 v_2^2$	1
$= ½(0.55)(2.42^2) + ½(1.45)(0.910^2)$	1
= 2.18 J (2.31 J)	1
Total	**3**

(c) State and explain the effect on the final velocities if the coupled carts were initially travelling 1.00 m s^{-1} left as opposed to being stationary.

(2 marks)

Description	Marks
Since momentum is conserved, and the sum of the initial and final is equal to mv	1
Both carts' final velocities would change by 1.00 m s^{-1} left.	1
Total	**2**

Question 7 **(4 marks)**

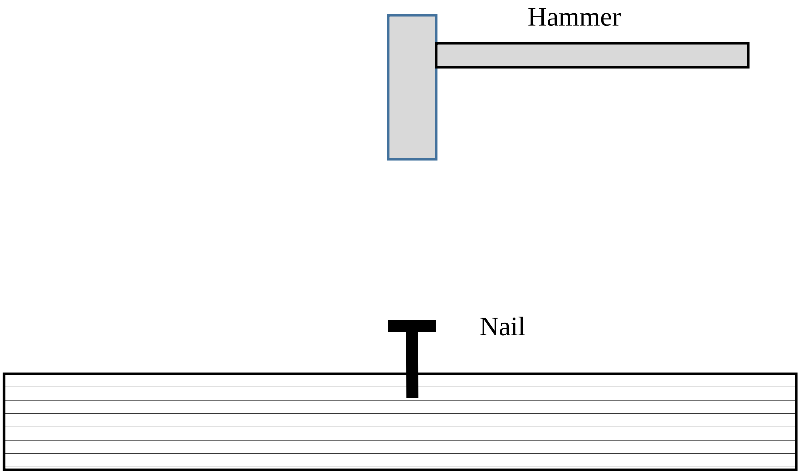
Describe the link between 'internal energy' and 'temperature', and how these concepts relate to 'thermal equilibrium'.

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

Total	**4**

Question 8 **(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. Show working.

(3 marks)

Description	**Marks**
$Work\ done = E_{TOTAL} = mgh + \frac{1}{2}mv^2$	1
¿ $0.850 \times 9.80 \times 0.250 + 0.5 \times 0.850 \times 5.00^2$	1
¿ $12.7\ J$	1
Total	**3**

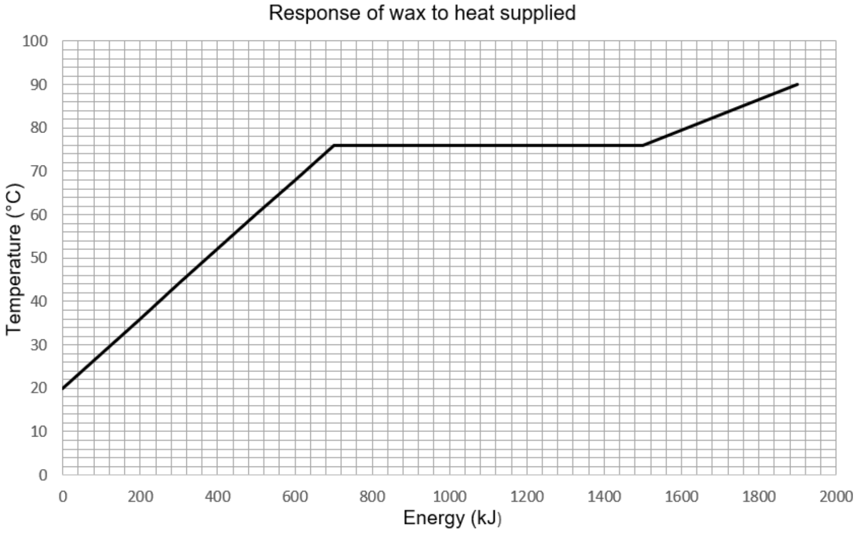
(b) The nail is driven a distance of 3.00 cm into the wood. Assuming that the hammering process is 100% energy efficient, calculate the size of the average force experienced by the nail. Show working.

(2 marks)

Description	**Marks**
$W = Fs;\ \therefore\ F = \frac{W}{s} = \frac{12.7}{0.0300}$	1
¿ $424\ N$	1
Total	2

Question 9 **(6 marks)**

A solid 0.200 kg block of wax was placed in an oven and provided heat at a constant rate. A digital thermometer inserted in the wax recorded the temperature at the same rate to provide a T vs Q graph shown below.



(a) Use the graph to calculate the latent heat of fusion of the wax. Show working.

(2 marks)

Description	Marks
Q = (1500 – 700) $\times 10^3$ J = 8.00 $\times 10^5$ J	1
$L_v = \dfrac{Q}{m} = \dfrac{8.00 \times 10^5}{0.200}$	1
= 4.00 $\times 10^6$ J kg^{-1}	
Total	**2**

(b) Calculate the gradient of solid state region of the graph and use this value to determine the specific heat capacity of the wax when it is solid. Show working.

(4 marks)

Description	Marks
Gradient = $\dfrac{\Delta T}{\Delta Q} = \dfrac{76-20}{(700-0) \times 10^3}$ • Used two points from solid line • Converted ΔQ to Joules	1
= 8.00 $\times 10^{-5}$ °C / J • Accepted 7.80 x 10^{-5} → 8.20 x 10^{-5} °C / J	1
$Q = mc\Delta T$ $c = \dfrac{Q}{m\Delta T}$ $c = \dfrac{1}{mass} \times \dfrac{1}{gradient}$ • Must rearrange formula to utilise the calculated gradient. • Substituting in values instead of using gradient as specified in question is not awarded marks. Does not demonstrate conceptual understanding.	1
$= \dfrac{1}{0.200} \times \dfrac{1}{8.00 \times 10^{-5}}$	1

$= 6.25 \times 10^4$ J kg^{-1} K^{-1} • Accepted $6.10 \times 10^4 \rightarrow 6.41 \times 10^4$ J kg^{-1} K^{-1} • Follow through marks awarded.	
Total	**4**

END OF SECTION ONE

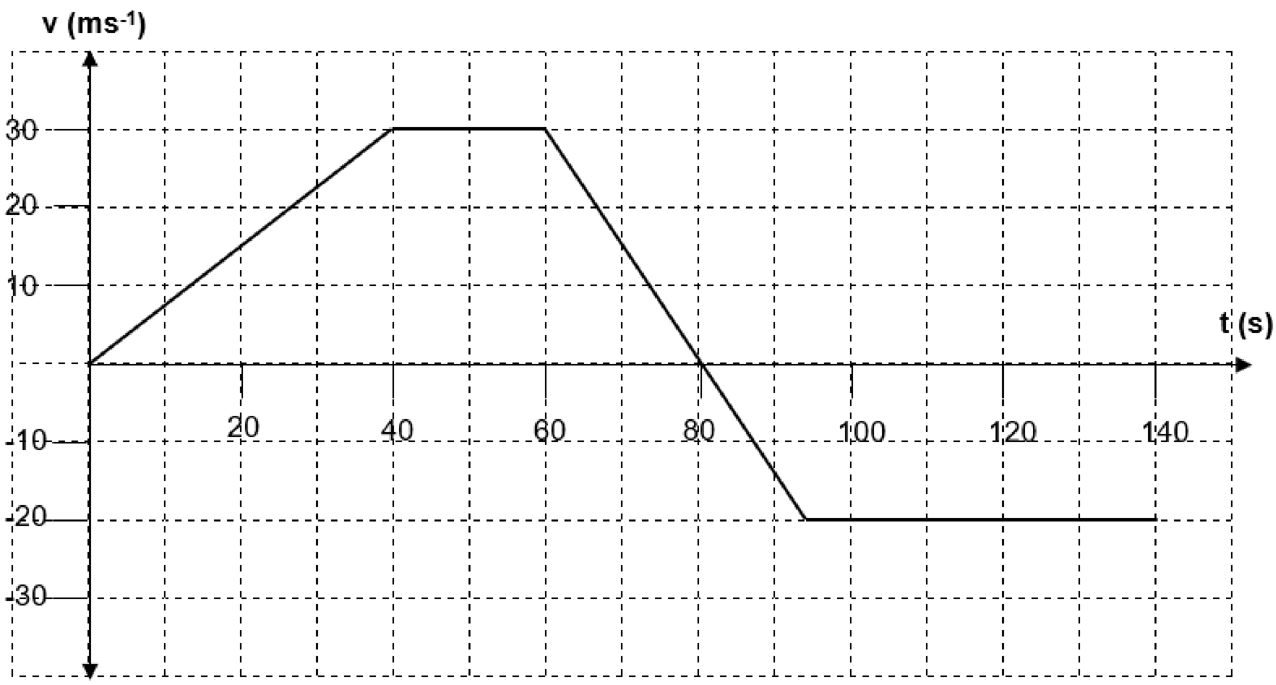
Section Two: Problem Solving **50% (75 marks)**

This section contains 5 questions. Answer **all** questions in the spaces provided.

Suggested working time 70 minutes.

Question 10 **(14 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:

(3 marks)

(i) travelling NORTH: t = ______________________________

(ii) experiencing a decrease in speed: t = ______________________________

(iii) starts travelling in a southerly direction:

t = ______________________________

Description	Marks
(i) t = 0 s to 80 s	1
(ii) t = 60 s – 80 s	1
(iii) t = 80 s – 140 s **OR** 80s	1
Total	**3**

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

(4 marks)

(i) t = 40 s

Description	Marks
$a=\frac{rise}{run}=\frac{(30-0)}{(40-0)}$	1
$¿0.750\,ms^{-2}$ North	1
Total	**2**

(ii) t = 80 s

Description	Marks
$a=\frac{rise}{run}=\frac{(-20-30)}{(94-60)}$	1
-1.52 $¿-1.47\,ms^{-2}(¿-1.43)$ = 1.47 ms^{-2} South	1
Total	**2**

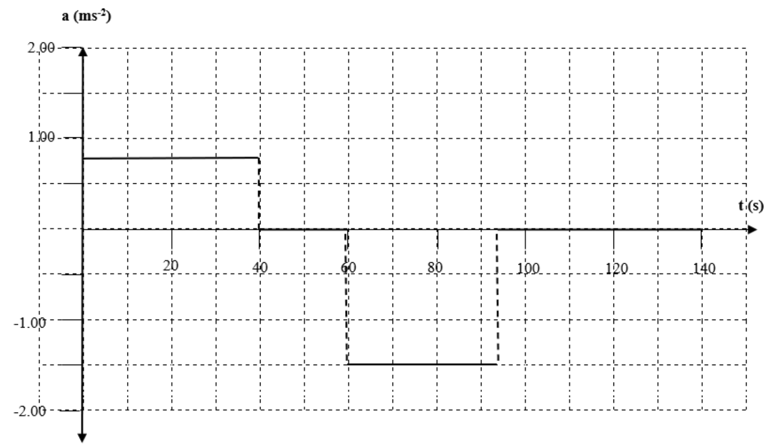
(c) Calculate the car's final displacement at t = 140 s (ie - the end of the journey). Show working.

(4 marks)

Description	Marks
$\Delta s = area\ underneath\ the\ graph$	1
$0.5\times14\times20+46\times20$ $\Delta s=(0.5\times30\times40+20\times30+0.5\times30\times20)-(¿)$ = 600 + 600 + 300 - 140 - 920	1
$¿4.40\times10^{2}m$ • $accepted\ range\ 4.30\times10^{2}¿4.50\times10^{2}m$ • follow through marks awarded	1
NORTH • follow through marks awarded	1
Total	**4**

(d) On the grid below, draw an 'acceleration v time' graph for the car's journey.

(3 marks)

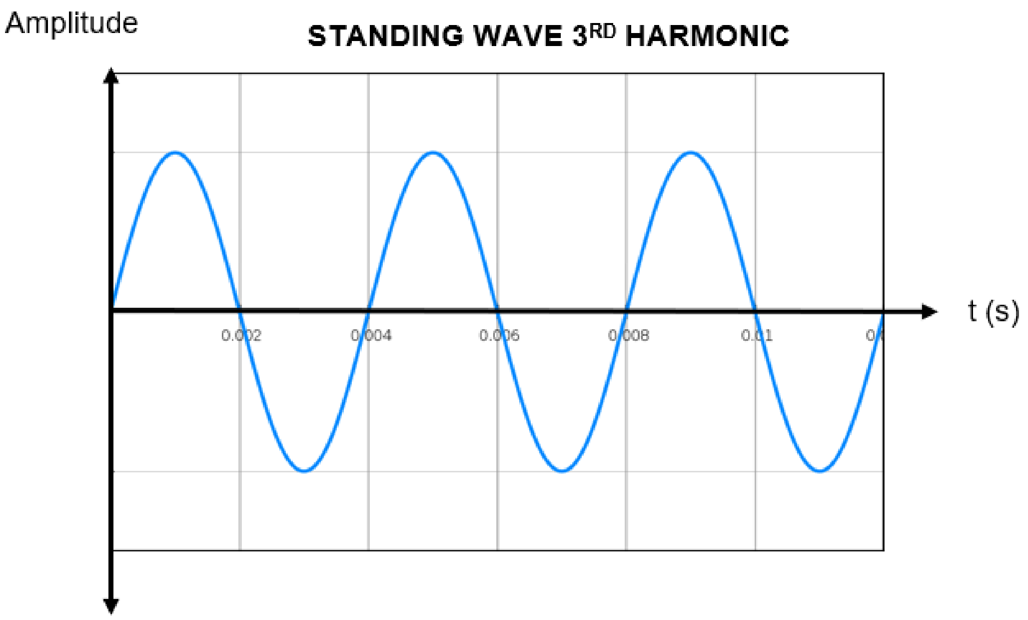


Description	Marks
t = 0 s to 40 s a = 0.750 ms^{-2}	1
t = 60 s to 94 s a = -1.47 ms^{-2}	1
t = 40 s to 60 s and t = 94 s to 140 s a = 0 ms^{-2}	1
• follow through marks from part b awarded	
Total	**3**

Question 11 **(12 marks)**

A vibrating guitar string of length 55.0 cm 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. Show working.

(3 marks)

Description	Marks
$\lambda_n = \frac{2L}{n}$	1
$\lambda_3 = \frac{2L}{3} = \frac{2 \times 0.550}{3}$	1
¿$0.367\,m$ (-1 if not in SI units)	1
Total	**3**

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

(2 marks)

Description	Marks
$T = 0.004\,s$	1
$\therefore f = \frac{1}{T} = \frac{1}{0.004} = 2.50 \times 10^2\,Hz$	1
Total	**2**

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

(2 marks)

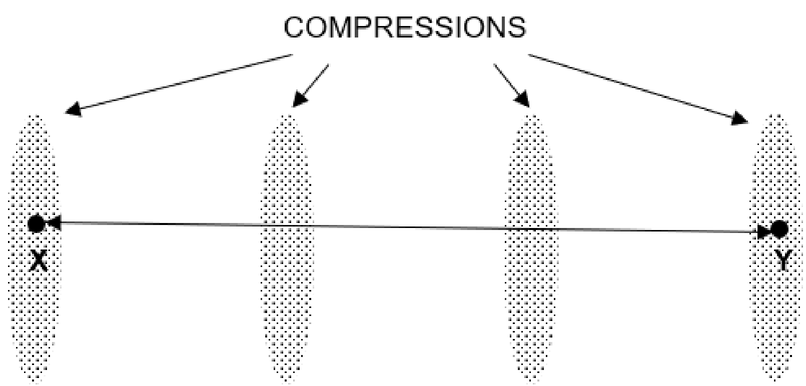
Description	Marks
$v = f_3 \lambda_3 = 250 \times 0.367$	1
¿$91.7\,m\,s^{-1}$ (F.T a & b)	1
Total	**2**

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

(3 marks)

Description	Marks
$f_1 = \frac{f_3}{3} = \frac{250}{3} = 83.3\,Hz$	1
$\therefore \lambda_1 = \frac{v}{f_1} = \frac{344}{83.3}$	1
¿$4.13\,m$	1
Total	**3**

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



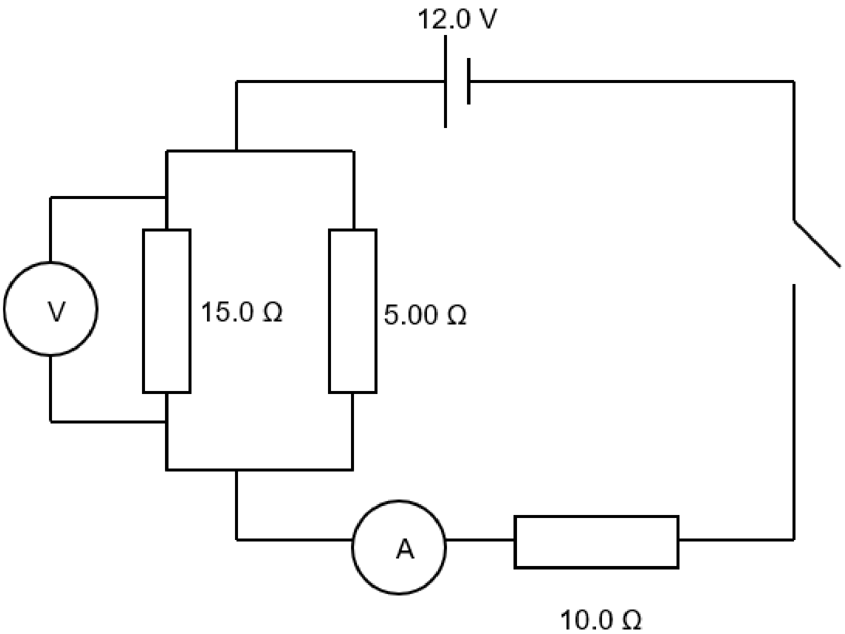
(e) Calculate the distance between points 'X' and 'Y' on the diagram above for the fundamental frequency. Show working.

(2 marks)

Description	Marks
$d_{XY} = 3 \times \lambda_1 = 3 \times 4.13$	1
¿$12.4\,m$	1
Total	**2**

Question 12 **(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. Show working.

(3 marks)

Description	Marks
Parallel circuit: $\frac{1}{R}=\frac{1}{15}+\frac{1}{5}; \therefore R=3.75\,\Omega$	1
$R_{TOTAL}=3.75+10$	1
$\therefore R_{TOTAL}=13.7\,\Omega$ (No formula -1)	1
Total	**3**

(b) The current flowing through the ammeter. Show working.

(2 marks)

Description	Marks
$I_T=\frac{V_T}{R_T}=\frac{12}{13.7}$	1
¿$0.873\,A$	1
Total	**2**

(c) The reading on the voltmeter. Show working.

(2 marks)

Description	Marks
$15.0\,\Omega\, resistor: V = IR = 0.873 \times 3.75$	1
$¿\,3.27\,V$	1
Total	**2**

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

(3 marks)

Description	Marks
$P = \frac{V^2}{R} = \frac{3.27^2}{5.00}$	1
$¿\,2.14$	1
W (units)	1
Total	**3**

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

(2 marks)

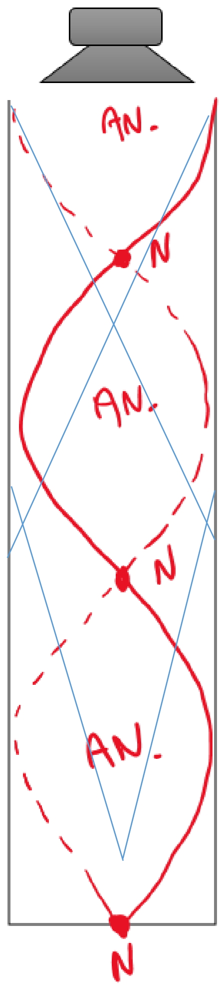
Description	Marks
$Q = VIt = 0.873 \times 12 \times (2 \times 3600)$ (incorrect values of V and I, -1)	1
$¿\,7.54 \times 10^4\,J$	1
Total	**2**

Question 13 **(13 marks)**

A speaker is placed at the top of a closed end tube of length 0.800 m and the frequency slowly increased from 0 Hz until the 3rd loud tone was heard. The speed of sound in air was recorded as 346 m s^{-1}.

(a) In the diagram below, sketch the particle displacement envelope of the 3rd harmonic, including all important features.

(1 mark)



Description	Marks
As shown in diagram.(ACCEPT BOTH)	1
Total	**1**

(b) Calculate the frequency of the 3rd harmonic in the tube. Show working.

(3 marks)

Description	Marks
$f_n = \dfrac{nv}{4L}$, only odd numbered n values.	1
$= \dfrac{3(346)}{4(0.800)}$	1
= 324 Hz (if ans 541 Hz (2 marks))	1
Pay F.t Total	**3**

(c) Explain is what is meant by the term "particle displacement antinode"

(2 marks)

Description	Marks
The regions in the tube where the particle displacement	1
is its maximum from its equilibrium position.	1
Total	**2**

With the frequency remaining constant, the tube is slowly filled with water and the sound intensity is observed to decrease and then increase.

(d) Calculate the effective length of the tube where this loud region would be heard. Show working.

(3 marks)

Description	Marks

distance between successive antinodes is $\frac{\lambda}{2}$	1
$\lambda = \frac{v}{f} = \frac{346}{324} = 1.06\,m$	1
L = 0.800 - $\frac{1.06}{2}$ = 0.267 m (and pay follow through from b)	1
Total	**3**

(e) A group of students come in on another day when the air temperature in the tube was significantly higher. Explain, making reference to a suitable calculation, the effect this would have on the lengths where these loud regions in (b) and (d) would occur.

(4 marks)

Description	Marks
As the air temperature increases, the speed of sound in air increases.	1
Given $\lambda \propto v$, the wavelength of the sound will increase, the 3rd harmonic would not be established in the 0.800 m column.	1- 2
And the 3rd harmonic would occur at a longer effective length of the pipe	1
Total	**4**

Question 14 **(13 marks)**

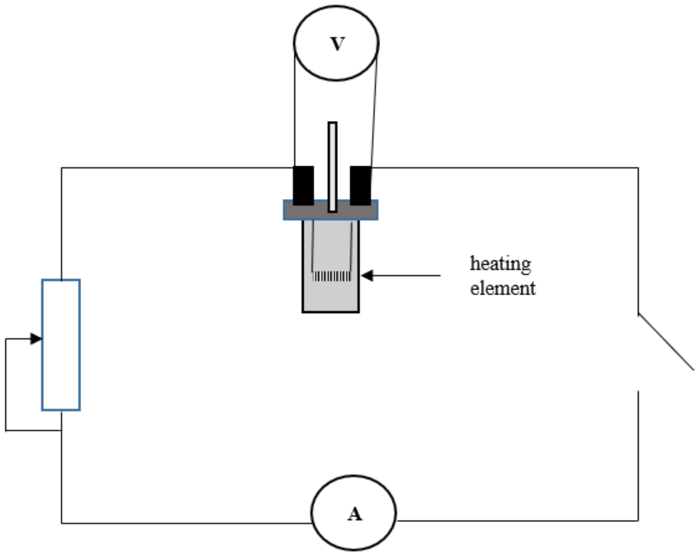
Some students are conducting an experiment to determine a value for the specific heat of water. The students have the following equipment:

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)



Description	Marks
Ammeter, switch, rheostat and calorimeter in series with each other.	1
Voltmeter in parallel with calorimeter.	1
All symbols in diagram are correct.	1
Total	**3**

Mass of the copper calorimeter	**0.455 kg**
Specific heat of copper	**390 $Jkg^{-1}{}^{\circ}C^{-1}$**
Mass of water	**0.657 kg**
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**

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

(2 marks)

Description	Marks
$P = VI = 11.7 \times 14.7$	1
¿$1.72 \times 10^{2} W$	1

	Total	2

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

(2 marks)

Description	Marks
$Q = Pt = 172 x 1200$	1
$¿ 2.06 \times 10^5 J$	1
Total	**2**

(d) Hence, use your answer from part (c) – 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 (c), use a value of 2.10 x 10^5 J] Show working.

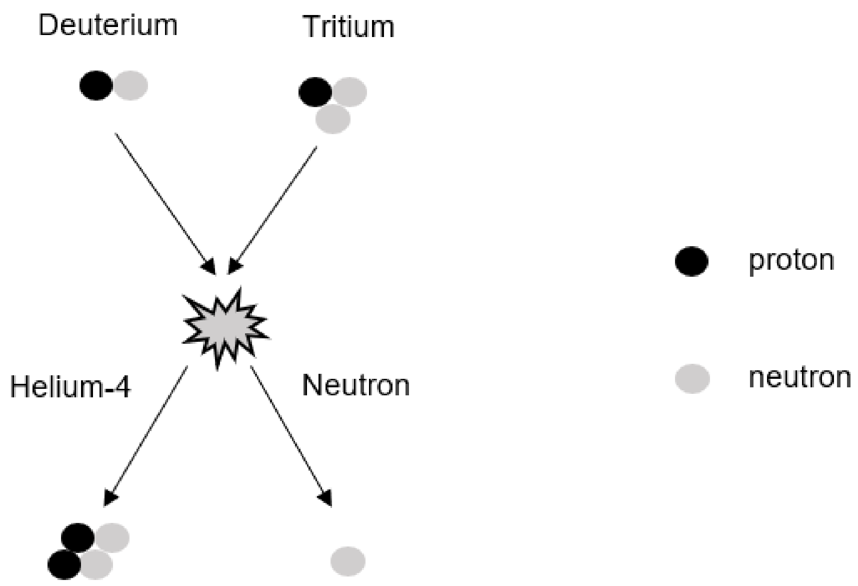
(6 marks)

Description	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
$1.85 \times 10^5 = 0.657 \times c_W \times (83 - 18) + 0.455 \times 390 \times (83 - 18)$	1-2
$1.85 \times 10^5 = 42.7 \times c_W + 1.67 \times 10^4$	1
$c_W = \dfrac{1.85 \times 10^5 - 1.15 \times 10^4}{42.7}$	1
$¿ 4.06 \times 10^3 Jkg^{-1} \circ C^{-1} (4.16 \times 10^3 Jkg^{-1} \circ C^{-1})$	1
Total	**6**

Question 15 **(11 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)

Description	Marks
${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$	
Correct chemical symbols are used.	1
Mass numbers are balanced.	1
Atomic numbers are balanced.	1
Total	**3**

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

(4 marks)

Description	Marks
$Mass\ of\ reactants = 2.01355 + 3.01605 = 5.02960\,u$	1

$Mass\ of\ products = 4.00260 + 1.00867 = 5.01127\,u$	1
$Mass\ defect = 5.02960 - 5.01127 = 0.01833\,u$	1
$Energy\ released = 0.01833 \times 931 = 17.06523\ MeV = 17.1\,MeV$	1
Total	**4**

(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). Show working.

[If you were unable to calculate an answer for part (b) use a value of 17.00000 MeV]

(4 marks)

Description	Marks
$m(H-2\,nuclei) = 2.01355 \times 1.66 \times 10^{-27} = 3.34 \times 10^{-27}\,kg$	1
$n(H-2\,nuclei) = \frac{1}{3.34 \times 10^{-27}} = 2.99 \times 10^{26}$	1
$Energy\ released = 2.99 \times 10^{26} \times 17.06523 \times 1.6 \times 10^{-13}$	1
¿ $8.17 \times 10^{14}\,J\,(8.13 \times 10^{14}\,J)$	1
Total	**4**

Section Three: Comprehension

20% (30 Marks)

This section has **two** questions. Answer both questions and write your answers in the spaces provided.
Suggested working time: 30 minutes.

Question 16 **(10 marks)**

When Daniel Kish clicks his tongue, the world answers back.

Cars, trees, doorways, bollards on the pavement… all are identified and mapped in his brain using information gleaned from a series of sharp little taps of his tongue against the roof of his mouth, two or three times a second. From an early age, the Californian developed an echolocation technique which allowed him to navigate using echoes from repeated tongue-clicks. The skill has led to him being dubbed a "real-life Batman" - a description he welcomes.

"It is the same process bats use," he says. "You send out a sound or a call and sound waves are physical waves - they bounce back from physical surfaces. So if a person is clicking and they're listening to surfaces around them they do get an instantaneous sense of the positioning of these surfaces." Bats use frequencies in the range of 100 kHz while a human tongue click produces a wave with a frequency of around 1200 Hz.

The echoes from his clicks inform Kish about an object's distance, size, texture and density. It's enough for him to differentiate between, say, a metal fence and a wooden fence. "It's not that I can really tell metal from wood, but I can tell the difference between the arrangement of structures," he says. "For example, a wooden fence is likely to have thicker structures than a metal fence and when the area is very quiet, wood tends to reflect a warmer, duller sound than metal." But, he adds, conditions really have to be right to discern this reliably.

Echolocation has allowed Kish to pursue outdoor hobbies such as hiking, despite being totally blind. Kish also says echolocation allows him to engage aesthetically with the world. "The sense of imagery is very rich for an experienced user. One can get a sense of beauty or starkness or whatever - from sound as well as echo," he says.

Apart from bats (and Daniel Kish), echolocation is also used in medical imaging. Ultrasound in medical imaging is produced by a transducer that uses a piezoelectric crystal. An alternating voltage applied across the crystal causes it to vibrate and send out a pulse of sound waves. The applied voltage is removed to allow the crystal to detect any reflections. Reflected pulses received after a time delay vibrate the crystal and generate a current which can give information about the distance to the point of reflection. The transmit/receive cycle can be repeated thousands of times per second.

The reflection of ultrasound is used to observe structures within the human body. Imaging with an ‘Amplitude Modulated’ scan can be used to measure distances within the body (e.g. the diameter of the torso). A ‘Brightness Modulated’ scan can provide a two-dimensional outline image of a feature within the body e.g. stones in a gall bladder.

Reflection occurs when an ultrasonic pulse passes across an interface between two media - for example soft tissue and bone. Some of the energy and intensity of the ultrasonic pulse is reflected as a result of the fact that the two media will have different 'acoustic impedances’. This is shown in Figure 1.

Equation 1. The acoustic impedance Z of a medium is defined by: $\mathbf{Z = \rho \times v_{sound}}$

ρ = density of medium (kg m^{-3}), v_{sound} = speed of sound in the medium (m s^{-1})

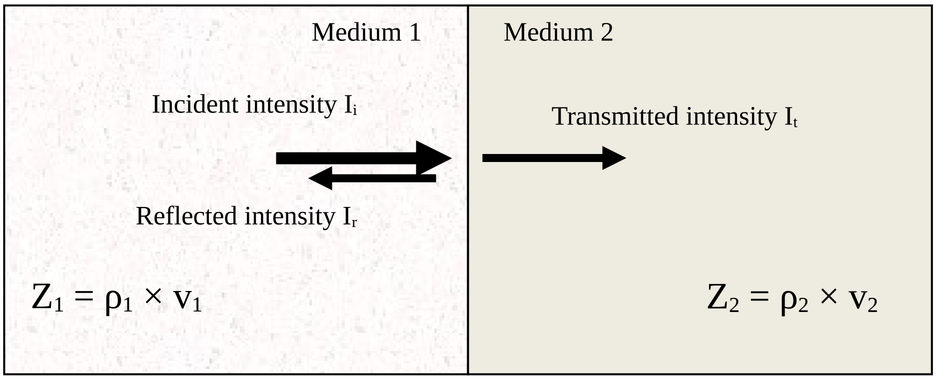


Figure 1: Reflection of ultrasound at an interface

Values of density and speed of ultrasound in different media are shown in the table.

Material	Density (× 10^3 kg m^{-3})	Speed of ultrasound (m s^{-1})
Air	0.0013	330
Bone	1.91	4080
Brain	1.03	1540
Fat	0.952	1450
Muscle	1.08	1580
Soft tissue	1.06	1540
Water	1.00	1500

Equation 2:

The fraction α_r of the intensity reflected is given by: $$\alpha_r = \frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$$

I_i = incident intensity within medium 1,
I_r = intensity reflected back into medium 1 at the boundary between medium 1 and medium 2

If $\alpha_r = 1$, then 100% of the incident energy is reflected. If $\alpha_r = 0$, then none of the incident energy is reflected. As long as α_r is greater than 40%, then a 'Brightness Modulated' scan should produce an excellent outline image of a feature within the body.

Answer the following questions

a) What is the scientific term for when "a wave bounced back" as referred to in the article?

(1 mark)

Description	Marks
Reflection **OR** Echo • Reflected not accepted as not the scientific term • Echolocation not scientific term for a wave bouncing back – term for location of objects using principle of reflection	1
Total	**1**

b) Daniel Kish is quoted as saying “**So if a person is clicking and they’re listening to surfaces around them they do get an instantaneous sense of the positioning of these surfaces**.” Describe an issue with this statement from a physical context.

(2 marks)

Description	Marks
Cannot get an instantaneous sense of positioning.	1
Determining the location of an object would require the wave to travel from Daniel to the object and back again which takes time.	1
Total	**2**

c) Determine the ratio of the wavelength produced by the bat to that of the human. Show working.

(2 marks)

Description	Marks
$\square_{bat} = \frac{\square}{\square_{bat}}$ and $\square_{human} = \frac{\square}{\square_{human}}$ $\square_{bat}\, x\, \square_{bat} = \square_{human}\, x\, \square_{human}\ \square_{bat} = \frac{\square_{human}}{\square_{bat}}\, x\, \square_{human}$ $\square_{bat} = \frac{1200}{100000}\, x\, \square_{human}$ $\square_{bat} = 0.012\, \square_{human}$	1-2
$Ratio\, of\ bat$ ¿ $human\, is$ 0.012 : 1 or equivalent ratio. • Only 1 mark awarded if not sufficiently indicated what the ratio represents • No marks if clear the student calculated the frequency ratio not wavelength	
Total	**2**

d) Calculate the intensity reflected into the muscle if the incident intensity of muscle at a muscle-bone interface is 1.20 x 10^4 Wm^{-2}. Show working.

(4 marks)

Description	Marks
$Z_{muscle} = \rho_{muscle}\, x\, \square_{muscle}$ — $Z_{muscle} = 1.08\, x\, 10^3\, x\, 1580 = 1706400$	1
$Z_{bone} = \rho_{bone}\, x\, \square_{bone}$ $Z_{bone} = 1.91\, x\, 10^3\, x\, 4080 = 7792800$ • Marks not lost if not multiplying by 10^3 so long as used in formula correctly as 10^3 will cancel out.	1
$I_r = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2 x\, I_i$ $I_r = \left(\frac{7792800 - 1706400}{7792800 + 1706400}\right)^2 x\, 1.20\, x\, 10^4$ = 0.411 $x\, 1.20\, x\, 10^4$	1
$I_r = 4.93\, x\, 10^3\, W\, m^{-2}$	1
Total	**4**

e) Will the scan in part d produce an excellent image? Justify your answer with a calculation.

(1 mark)

Description	Marks

$\alpha_r = \frac{I_r}{I_i} = \frac{4.93\,x\,10^3}{1.20\,x\,10^4} = 0.411$ ∴ 41.1% 41.1 > 40 so yes, an excellent image is produced. • If no calculation as above in the answer to this question then no mark awarded.	1
Total	**1**

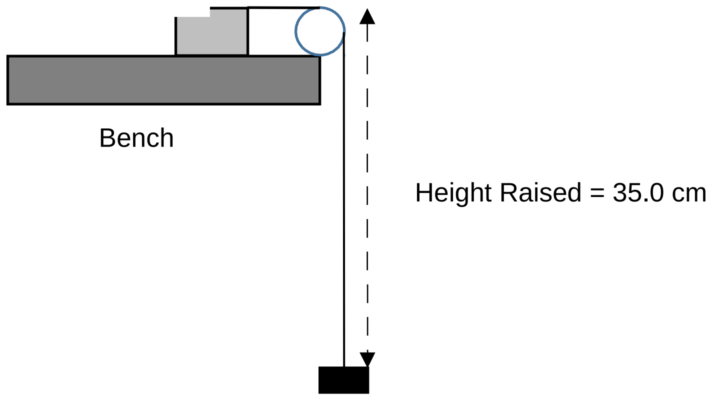
Question 17 **(20 marks)**

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	
0.600	3.47	0.360	0.288
0.800	1.95		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).

BACKGROUND

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

Electric power supplied to the electric motor:

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

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

$$E_p = mgh$$

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

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

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:

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

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)

Description	Marks
$\frac{V^2}{R} \times \eta = \frac{E}{t}$ **OR** $\eta = \frac{energy\ output}{energy\ input}$ Demonstrating relationship between electrical and mechanical power	1
$\frac{V^2}{R} \times \eta = \frac{(mg\Delta h)}{t}$ Demonstrating that mechanical energy is change in potential energy	1

$\therefore V^2 = mg\Delta h \times \frac{R}{\eta} \times \frac{1}{t}$ Rearranging to get formula above	1
$V^2 = \frac{(0.0400 \times 9.80 \times 0.350 \times 7.30)}{\eta} \times \frac{1}{t}$ Substituting in Rmgh values to find a constant of 1.00156 ∴ 1.00 to 3SF which proves $V^2 = \frac{1.00}{\eta} \times \frac{1}{t}$	1
Total	**4**

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

(2 marks)

Description	Marks
$V^2 = 0.640$	1
$^1/_t = 0.128$	1
Total	**2**

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

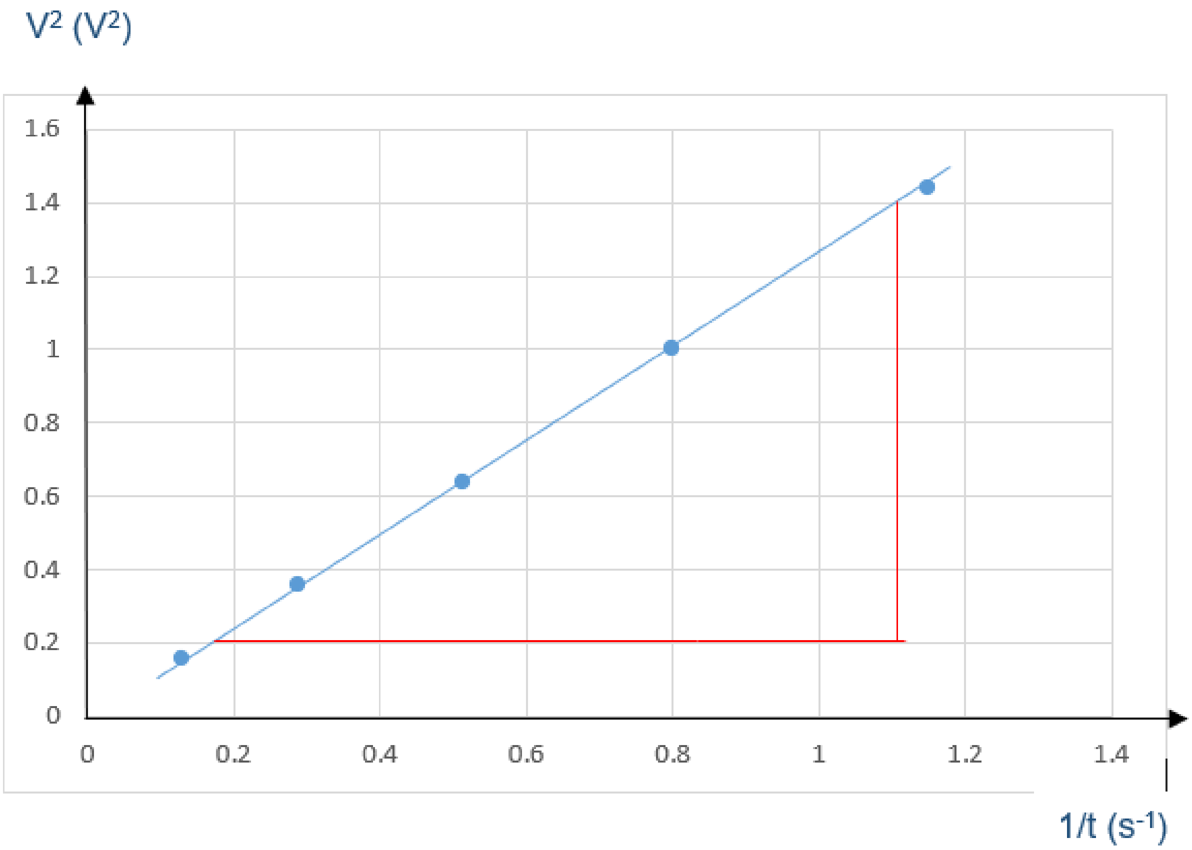
(c) Explain why the students chose this graphical approach. In addition, state an assumption that you made when choosing the graph.

(3 marks)

Description	Marks
Assumed that the efficiency of the coil is constant for ALL voltages.	1
'V^2' is directly proportional to '$^1/_t$'.	1
Hence, plotting these two values against each other will yield a linear relationship.	1
Total	**3**

(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)



Description	Marks
Scales on axes are even	1
Points and line of best fit plotted correctly.	1
Quantities are correctly labelled on correct axes	1
Units are correctly labelled	1
Total	**4**

(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)

Description	Marks
Two points from graph: (0.18, 0.20) and (1.10, 1.40) • No mark awarded if **any** table data used – even if lobf drawn through the point.	1
$Slope = \frac{Rise}{Run} = \frac{(1.40-0.20)}{(1.10-0.18)}$	1
¿ $1.30 (accept\ 1.15-1.45)$	1
Units: V^2s	1
Total	**4**

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

(3 marks)

Description	Marks
$Slope\ represents\ the\ ratio: \frac{\Delta V^2}{\Delta \frac{1}{t}} = V^2 t$; $V^2 = \frac{1}{\eta} \times \frac{1}{t}$; $\therefore \eta = \frac{1}{V^2 t}$ • Must clearly show how efficiency relates to gradient through derivation to obtain the mark	1
$\therefore \eta = \frac{1}{1.30}$ • Must use gradient from previous question to obtain the mark	1
= 0.767 (76.7%) (accept 0.690 - 0.870)	1
Total	**3**

END OF EXAMINATION