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PHYSICS

UNITS 1 & 2

2016

Name: _____ Solutions _____

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	9	9	40	40	27
Section Two: Extended answer	6	6	80	80	53
Section Three: Comprehension and data analysis	2	2	30	30	20
Total				150	100

Instructions to candidates

- The rules for the conduct of Western Australian external examinations are detailed in the *Year 11 Information Handbook 2016*. Sitting this examination implies that you agree to abide by these rules.
- Write answers in this Question/Answer Booklet.
- When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

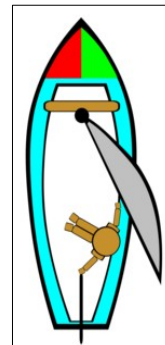
When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.
- You must be careful to confine your responses to the specific questions asked and follow any instructions that are specific to a particular question.
- Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
 - Planning: If you use the spare pages for planning, indicate this clearly.
 - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Refer to the question(s) where you are continuing your work.

Section One: Short response**27% (40 Marks)**

This section has **nine (9)** questions. Answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 40 minutes.

Question 1**(5 marks)**

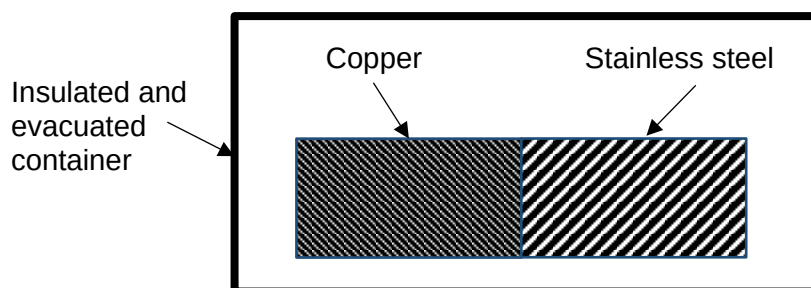
Conall is sailing a boat North at 5.50 m s^{-1} when he enters a current travelling East at 1.50 m s^{-1} . Calculate Conall's resultant velocity once he enters the current. You must state the magnitude and direction of his resultant velocity.



Description	Marks
$\sum v = \sqrt{v_{boat}^2 + v_{current}^2}$ $\therefore \sqrt{5.50^2 + 1.50^2}$	1
$\sum v = 5.70 \text{ m s}^{-1}$	1
$\tan \theta = \frac{v_{current}}{v_{boat}}$ $\theta = \tan^{-1} \left(\frac{1.50}{5.50} \right)$	1
$\theta = 15.3^\circ$	1
$\sum v = 5.70 \text{ m s}^{-1}, N 15.3^\circ E$ (or similar)	1
Total	5

Question 2**(5 marks)**

A 1.00 kg copper block at 100°C is placed in thermal contact with a 1.00 kg stainless steel block at 50°C in an insulated and evacuated container. After several minutes both blocks reach thermal equilibrium.



- (a) Use the kinetic particle model to explain how thermal contact between the copper block and the stainless steel block leads to a net heat transfer to the stainless steel block.

(3 marks)

Description	Marks
The particles in the copper block have a higher average kinetic energy than those in the stainless steel block because of their greater temperature.	1
The thermal contact between the blocks allows the copper particles to impact the stainless steel particles.	1
This will lead to a net transfer of kinetic energy to the stainless steel particles which causes heat to flow from the copper block to the stainless steel block.	1
Total	3

- (b) Explain why evacuating the container reduces the rate of heat loss from the blocks.

(2 marks)

Description	Marks
Evacuating the container prevents convection and conduction which reduces the rate of heat loss.	1-2
Total	2

Question 3**(5 marks)**

An engineer heats a 43.0 kg aluminium engine block in a furnace to a temperature of 350°C. He then plunges the block into 420 kg of water at 21.0°C. Calculate the final temperature of the aluminium and water mixture when they have reached thermal equilibrium. You can assume that the water and aluminium mixture is an isolated system.

The specific heat of aluminium is 900 J kg⁻¹ °C⁻¹.

Description	Marks
$\Delta Q_{\text{aluminium}} + \Delta Q_{\text{water}} = 0$	1
$m_{\text{al}} c_{\text{al}} \Delta T_{\text{al}} + m_{\text{w}} c_{\text{w}} \Delta T_{\text{w}} = 0$	1
$43 \times 900(T_f - 350) + 420 \times 4180(T_f - 21) = 0$	
$38700 T_f - 13545000 + 1755600 T_f - 36867600 = 0$	1
$1794300 T_f = 50412600$	
$T_f = 50412600 / 1794300$	1
$T_f = 28.1^\circ \text{C}$	1
Total	5

Question 5**(5 marks)**

Dolphins use high frequency clicks in the range of 40.0 kHz to 150 kHz for echolocation.

- (a) If the speed of sound in water is 1480 m s^{-1} , calculate the wavelength of a 150 kHz click.

(2 marks)

Description	Marks
$v = f\lambda$ $\lambda = \frac{v}{f}$ $\lambda = \frac{1480}{150 \times 10^3}$	1
$\lambda = 9.87 \text{ mm} \vee 9.87 \times 10^{-3} \text{ m}$	1

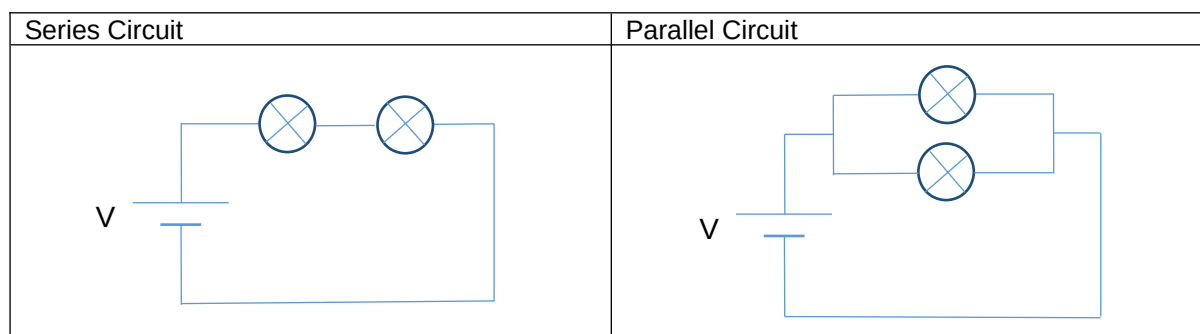
- (b) If a stationary dolphin emits a click and it takes 150 ms for the click to return to the dolphin from the sea floor, calculate the distance from the dolphin to the sea floor.

(3 marks)

Description	Marks
$v = \frac{s}{t}$ $s = v \times t$ $s = 1480 \times 0.15$	1
$d = 222 \text{ m}$	1
Distance to sea floor is half of the total distance that the sound travels.	1
$d_{\text{floor}} = \frac{222}{2} = 111 \text{ m}$	
Total	3

Question 6**(5 marks)**

The diagram below shows a series circuit and a parallel circuit which consist of a voltage source and two identical lightbulbs. The effective resistance of each lightbulb is $R \, \Omega$. The resistance of the wires and the ammeter can be considered negligible.



- (a) On the **series circuit** use an arrow to indicate the direction of the conventional current. (1 mark)
- (b) Assuming that the voltage source and lightbulbs are exactly the same in each circuit, which circuit will have the brighter lightbulbs. Explain your answer. (4 marks)

Description	Marks
<p><i>Series circuit</i></p> $V_{bulb} = \frac{V}{2}$ $P_{series} = \frac{\Delta V^2}{R} = \frac{\left(\frac{V}{2}\right)^2}{R} = \frac{V^2}{4R}$	1-2
<p><i>Parallel circuit</i></p> $V_{bulb} = V$ $P_i = \frac{\Delta V^2}{R} = \frac{V^2}{R}$	1
As $P_{parallel}$ is greater than P_{series} the bulbs in the parallel circuit are brighter than those in the series circuit.	1
There are several similar qualitative and quantitative proofs for this question. Accept any reasonable argument.	
Total	4

Question 7**(3 marks)**

At the end of the last Apollo 15 moon walk, Commander David Scott dropped a 1.32 kg geologic hammer and a 0.030 kg falcon feather from a height of 1.60 m above the surface of the moon. He observed that when the feather and the hammer were dropped simultaneously they both impacted the surface of the moon at the same time. Explain this observation.

Description	Marks
As there is no air resistance on the moon the only force on a falling object is its weight.	1
For an object of mass m we can write $\Sigma F = ma$ $W_{\text{moon}} = ma$ $mg_{\text{moon}} = ma$ or $a = g_{\text{moon}}$	1
As $a = g_{\text{moon}}$ the acceleration of a falling object on the moon is independent of its mass and therefore the feather and hammer fall the distance in the same amount of time.	1
Total	3

Question 8**(6 marks)**

A battery is connected in a series with a $1.20\ \Omega$ resistor. An ammeter measures a current of 6.00 A flowing through the resistor.

- (a) Calculate the energy consumed by the resistor in a time of 2 minutes and 25 seconds.

(4 marks)

Description	Marks
$t = 2\text{ min} \wedge 25\text{ sec} = 2 \times 60 + 25 = 145\text{ s}$	1
$E = P \times t = I^2 R \times t$	1
$6^2 \times 1.2 \times 145$	1
$E = 6.26\text{ kJ} \vee 6,260\text{ J}$	1
Total	4

- (b) List two energy transformations that occur in the circuit and state the circuit component in which they occur.

(2 marks)Transformation 1+2

Description	Marks
Chemical energy transformed to electrical energy in battery.	1
Electrical energy transformed into heat energy in the resistor.	1
Total	2

Question 9**(3 marks)**

Explain how resonance occurs when a person is pushed on the swing.



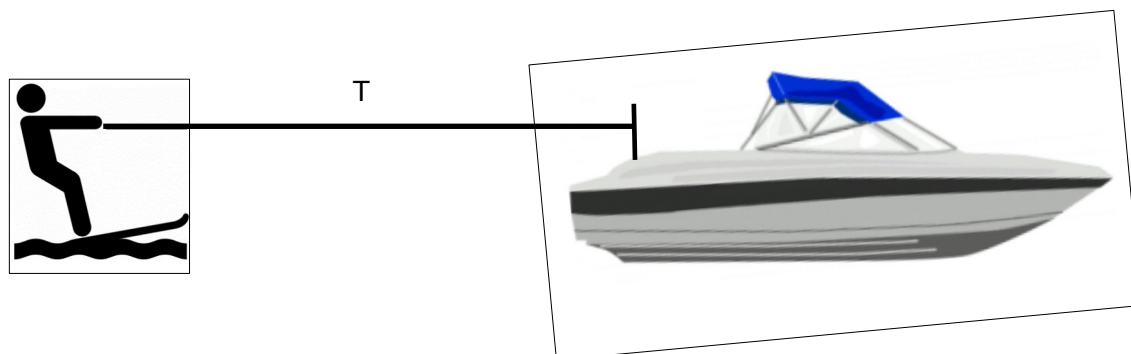
Description	Marks
To produce resonance the person pushes the swing <ul style="list-style-type: none">• in the direction of motion of the swing• at the natural frequency.	1-2
As the forcing frequency is equal to the natural frequency the swing begins to resonate.	1
Several descriptions will be valid here. Accept any reasonable answer.	
Total	3

Section Two: Problem-solving**53% (80 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 80 minutes.

Question 10**(16 marks)**

The figure below shows a water skier being pulled to the right by a speed boat. The water skier and the boat are travelling in a straight line and the water skier is directly behind the boat. The mass of the person is 80.0 kg and the frictional force between the water skis and the water is 100 N. T is the tension in the rope.



The water skier has an initial speed of 12.8 m s^{-1} and is accelerated by the boat at 5.20 m s^{-2} .

(a) Calculate the time that it takes for the water skier to reach a final speed of 64.0 m s^{-1} .

(3 marks)

Description	Marks
$a = \frac{v-u}{t}$ $t = \frac{v-u}{a}$ $i \frac{64.0 - 12.80}{5.20}$	1-2

1

(b) Calculate the distance that the skier travels while being accelerated.

(3 marks)

Description	Marks
$v^2 = u^2 + 2as$ $s = \frac{v^2 - u^2}{2a}$	1
$s = \frac{64^2 - 12.8^2}{2 \times 5.2 \text{ m/s}^2}$	1
$s = 378 \text{ m}$	1

- (c) Calculate the work done by the boat while pulling the water skier a distance of 3.00 km at a constant speed of 64.0 m s^{-1} . (2 marks)

Description	Marks
$W = F \times s$ $\hookrightarrow 100 \times 3000$	1
$W = 3.00 \times 10^5 \text{ J}$	1
Total	2

- (d) Calculate the power required to overcome friction when pulling the water skier at a constant speed of 64.0 m s^{-1} . (2 marks)

Description	Marks
$P = Fv$ $\hookrightarrow 100 \times 64.0$	1
$P = 6.40 \text{ kW}$	1
Total	2

- (e) Calculate the tension in the rope if the rope is horizontal and the water skier is accelerated at 5.20 m s^{-2} . (3 marks)

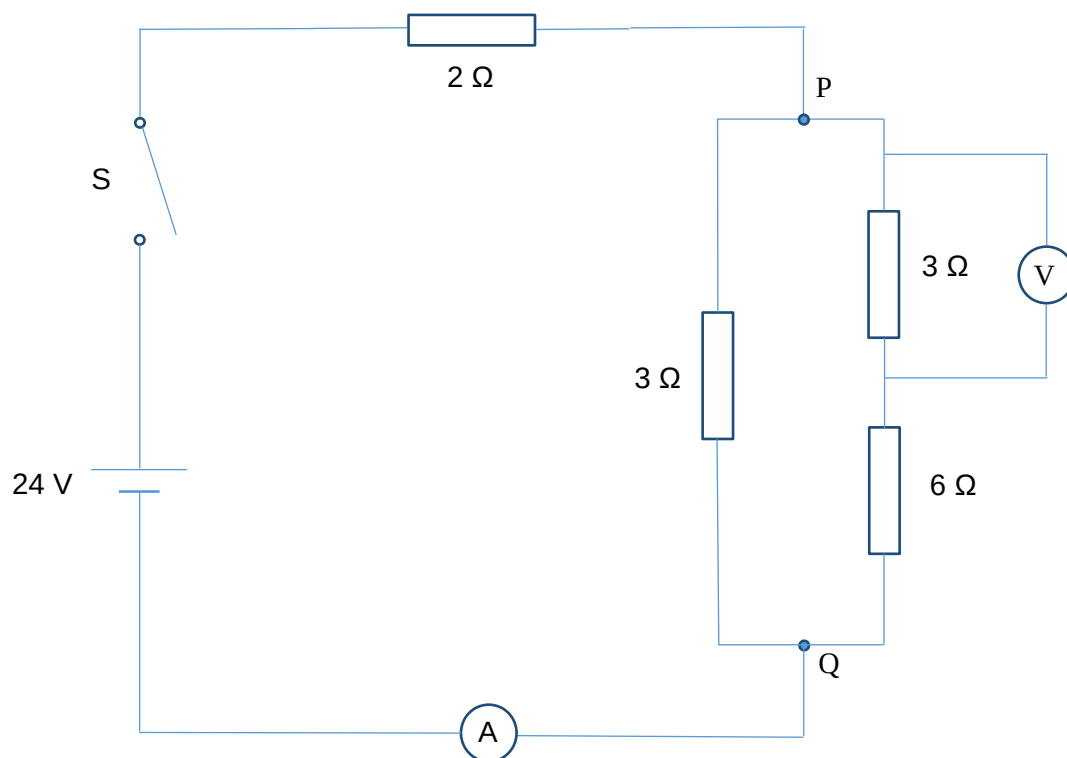
Description	Marks
$\Sigma F = ma$ $T - F_f = ma$	1
$T = ma + F_f$ $\hookrightarrow 80.0 \times 5.20 + 100$	1
$T = 516 \text{ N}$	1
Total	3

- (f) The angle of the ski rope is changed such that it now makes an angle of 15.0° to the horizontal. Calculate the tension in the rope if the friction force is 100 N and the boat travels at a constant speed. (3 marks)

Description	Marks
$\cos \theta = \frac{F_f}{F_r}$	1
$\cos 15 = \frac{100}{F_r}$ $F_r = \frac{100}{\cos 15}$	1
$F_r = 104 \text{ N}$	1

Question 11**(13 marks)**

Alexia set up the electrical circuit shown below for his physics investigation. The circuit is powered by a 24 V DC power source and has a single switch S.



(a) Calculate the total resistance of the circuit.

(4 marks)

Description	Marks
Resistance of parallel branches $R_{PQ} = \left(\frac{1}{3} + \frac{1}{3+6} \right)^{-1}$ $\hookrightarrow \left(\frac{1}{3} + \frac{1}{9} \right)^{-1}$ $\hookrightarrow 2.25 \Omega$	1-3
$R_T = 2 + 2.25 = 4.25 \Omega$	1
Total	4

- (b) Calculate the current recorded by the ammeter when the switch is closed. (2 marks)

Description	Marks
$I = \frac{V}{R} = \frac{24.0}{4.25}$	1
$\hookrightarrow 5.65 \text{ A}$	1
Total	2

- (c) If the current measured by the ammeter is 5.65 A, calculate the electric charge delivered by the DC power source in 2 hours and 35 minutes. (3 marks)

Description	Marks
$t = 2 \times 60 \times 60 + 35 \times 60 = 9300 \text{ s}$	1
$I = \frac{q}{t}$ $q = I \times t$ $\hookrightarrow 5.65 \times 9300$	1
$q = 52.5 \times 10^3 \text{ C}$	1
Total	3

- (d) If the voltage drop between P and Q is 12.7 V,
i. calculate the voltage drop recorded by the voltmeter. (2 marks)

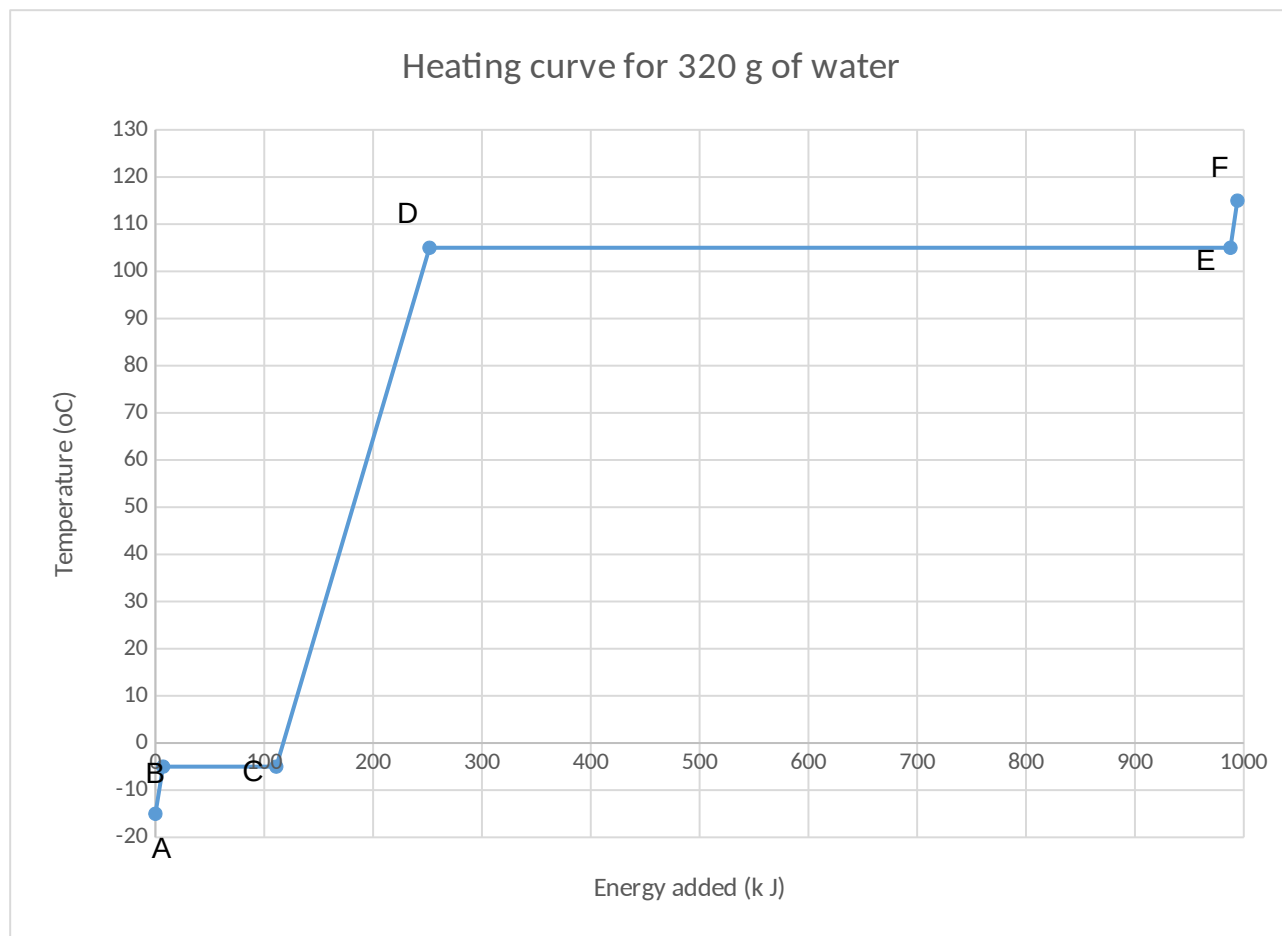
Description	Marks
$I = \frac{V}{R} = \frac{12.7}{3+6} = 1.41111 \text{ A}$	1
$V = 1.41 \times 3 = 4.23 \text{ V}$	1
Total	2

- ii. calculate the power consumed by the 6.00 Ω resistor. (2 marks)

Description	Marks
$P = I^2 R = 1.41^2 \times 6$	1
$\hookrightarrow 11.9 \text{ W}$	1
Total	2

Question 12**(12 marks)**

To investigate the properties of salt water Lia heated 320 g of frozen salt water at -15°C to a temperature of 115°C in an insulated container. Her results are shown in the heating curve below.



- (a) Explain why the temperature of the salt water is constant between points D and E. You must refer to the kinetic particle model and the internal energy of the salt water.

(4 marks)

Description	Marks
Between Points D and E the salt water is changing phase (boiling).	1
As the energy is added to the salt water the particles separate which increases the potential energy and total internal energy of the of the salt water.	1
Temperature is a measure of the average kinetic energy of the particles.	1
As there is no change in temperature the average kinetic energy of the particles remains constant.	1
Total	4

(b) Calculate the latent heat of vaporisation of the salt water from the graph.

(4 marks)

Description	Marks
From the graph $Q_v = 990 - 250$	1
$\hookrightarrow 740 \text{ kJ}$ (accept between 730 and 750 kJ)	1
$Q_v = m L_v$ $L_v = \frac{Q_v}{m} = \frac{740 \times 10^3}{0.320}$	1
$L_v = 2.31 \times 10^6 \text{ J kg}^{-1}$	1
Note: L_v will be between $2.28 \times 10^6 \text{ J kg}^{-1}$ and $2.34 \times 10^6 \text{ J kg}^{-1}$ for acceptable values of Q_v .	
Total	4

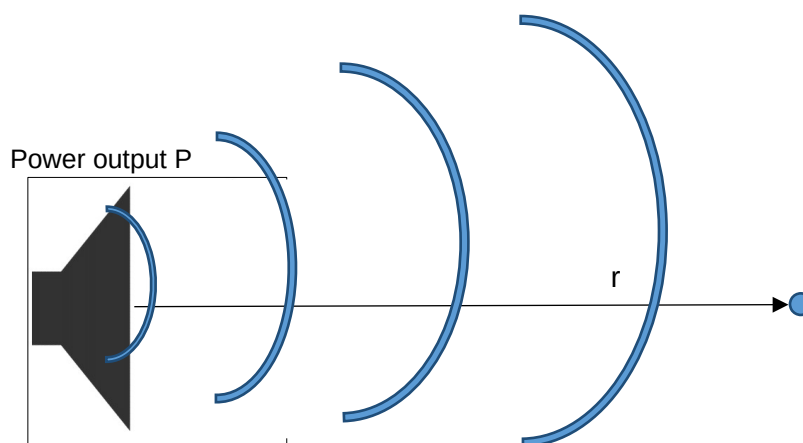
(c) Calculate the specific heat of salt water from the graph.

(4 marks)

Description	Marks
From the graph $\Delta T = 102 - -2 = 104^\circ \text{C}$	1
$Q_w = 250 \times 10^3 - 110 \times 10^3 = 1.40 \times 10^5 \text{ J}$	1
$Q_w = m c_w \Delta T$ $c_w = \frac{Q_w}{m \Delta T} = \frac{1.40 \times 10^5}{0.320 \times 104}$	1
$\hookrightarrow 4.21 \times 10^3 \text{ J kg}^{-1} \text{ } ^\circ \text{C}^{-1}$	1
Tolerance on temperature values $\pm 2^\circ \text{C}$ Tolerance on $Q_w \pm 1 \times 10^4 \text{ J}$	
Total	4

Question 13**(17 marks)**

Jacqueline and Kieran set up an experiment to determine the power output of a loudspeaker. In this investigation they measured the sound intensity I produced by the loudspeaker at several different distances r (m) from it. Their experimental setup is shown below.



The equation which relates the power output of the speaker, the sound intensity and the distance from the speaker is

$$I = \frac{P}{4\pi r^2}$$

where

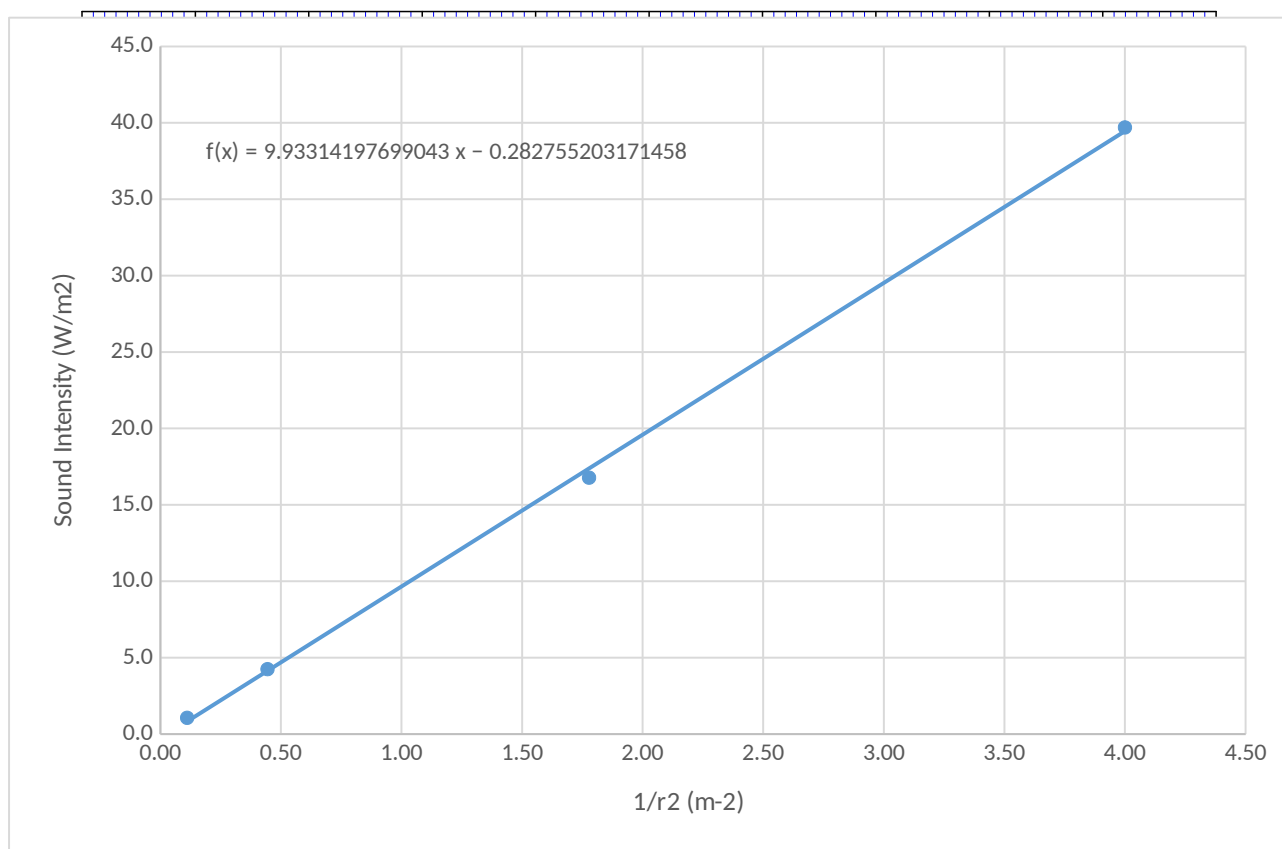
- I = sound intensity (W m^{-2})
- P = power output of the speaker (W)
- r = distance from the speaker (m)

A table of results for this investigation is shown below:

r (m)	I (W m^{-2})	$1/r^2$ (m^{-2})
0.500	39.7	4.00
0.750	16.8	1.78
1.50	4.20	0.444
3.00	1.10	0.111

(a) Complete the last column in the table above. Give your answers to three significant figures. (4 marks)

(b) On the graph paper provided plot $1/r^2$ versus sound intensity I . Plot $1/r^2$ on the x-axis and sound intensity on the y-axis. You must label your axes. (5 marks)



Description	Marks
(b)	
Correct axes labels	1-2
Correct scale on axes	1
Correct plotting of points	1-2
Total	5
(c)	
Line of best fit is a straight line running through the middle of the points.	1
Total	1

(c) Add a line of best fit to your graph. (1 mark)

(d) Using your line of best fit, determine the sound intensity 0.9 m from the speaker. (2 marks)

Description	Marks
When $r = 0.9$ m, $1/r^2 = 1/0.9^2 = 1.23$ m ⁻²	1
From the line of best fit $I = 12$ W m ⁻²	1
Accept values for intensity between 11 and 13 W m ⁻²	
Total	2

- (e) Determine the gradient of your line of best fit. You must show your rise and run on the graph.

(3 marks)

Description	Marks
Rise and run shown on the graph.	1
$gradient = \frac{rise}{run} = \frac{39.5 - 4.7}{4 - 0.5}$	1
$gradient = 9.94 W$	1
No unit for gradient is necessary.	
Total	3

- (f) The sound intensity equation can be written as

$$I = \frac{P}{4\pi} \times \frac{1}{r^2}$$

The term $\frac{P}{4\pi}$ in the above equation is equal to the gradient of the line of best fit which you calculated in Part e). Using

$$gradient = \frac{P}{4\pi}$$

calculate the power of the source P. If you did not calculate the gradient use a value of 9.90 W. (2 marks)

Description	Marks
$gradient = \frac{P}{4\pi}$ $P = gradient \times 4\pi$ $\hookrightarrow 9.94 \times 4 \times \pi$	1
$P = 125 W$	1
Total	2

Question 14**(13 marks)**

Jack drops a small rubber ball from a height of 1.50 m above flat ground. The mass of the ball is 0.120 kg. Air resistance can be neglected for each of the following questions.

- (a) Which of the following statements correctly describes the applied forces as the ball impacts the ground? Circle the correct answer and provide an explanation below.
- (i) The force that the ball applies to the ground is **greater than** the force that the ground applies to the ball.
 - (ii) The force that the ball applies to the ground is **less than** the force that the ground applies to the ball.
 - (iii) The force that the ball applies to the ground is **equal to** the force that the ground applies to the ball.

Explanation**(3 marks)**

Description	Marks
(iii) The force that the ball applies to the ground is equal to the force that the ground applies to the ball.	1
Newtons Third Law states that for every action there is an equal and opposite reaction	1
Therefore the force that the ball applies to the ground is equal to the force applied to the ball.	1
Total	3

- (b) Calculate the velocity of the ball as it impacts the ground.

(3 marks)

Description	Marks
$v^2 = u^2 + 2as$	1
$v^2 = 0^2 + 2 \times -9.8 \times -1.50$	
$v = -\sqrt{2 \times -9.8 \times -1.50}$	1
$v = -5.42 \text{ m/s} \vee 5.42 \text{ m/s down}$	1
Total	3

- (c) The ball is dropped again from a different height and impacts the ground with a speed of 5.00 m s^{-1} . If the collision that the ball makes with the ground is elastic and the impact time is 0.01 s , calculate the magnitude of the average force that the ball applies to the ground. (3 marks)

Description	Marks
$F \Delta t = mv - mu$ $F = \frac{mv - mu}{\Delta t}$ $F = \frac{0.120 \times 5 - 0.120 \times -5}{0.01}$	1-2
$F = 120 \text{ N}$	1
Total	3

- (d) A 46.0 g golf ball is dropped and impacts the ground with a velocity of 7.00 m s^{-1} . The golf ball then bounces to a height of 1.75 m above the ground. Calculate the efficiency of the impact. (4 marks)

Description	Marks
At impact $TM E_1 = \frac{1}{2} \times m \times v_1^2 + m \times g \times h_1$ $\hookrightarrow \frac{1}{2} \times 0.046 \times 7.00^2$ $\hookrightarrow 1.127 \text{ J}$	1
At max height $TM E_2 = \frac{1}{2} \times m \times v_2^2 + m \times g \times h_2$ $\hookrightarrow 0 + 0.046 \times 9.8 \times 1.75$ $\hookrightarrow 0.7889 \text{ J}$	1
$efficiency = \frac{TM E_2}{TM E_1} \times 100$ $\hookrightarrow \frac{0.7889}{1.127} \times 100$	1

Question 15**(9 marks)**

Carbon-14 is a radioactive isotope of carbon which undergoes beta decay. It is used for the radiocarbon dating of archaeological objects such as boomerangs and bone.

(a) Explain what is meant by the term 'isotope'.

(2 marks)

Description	Marks
An isotope is an atom with the same number of protons as another atom but with a different number of neutrons.	1-2
Total	2

(b) Write the equation for the beta decay of Carbon-14.

(3 marks)

Description	Marks
${}^{14}_6\text{C} \rightarrow {}^{14}_7\text{N} + {}^0_{-1}\beta + \bar{\nu}$	1-3
${}^{14}_7\text{N}$ correct - 1 mark ${}^0_{-1}\beta$ correct - 1 mark $\bar{\nu}$ correct - 1 mark	
Total	3

(c) Carbon-14 has a half-life of 5,730 years. Calculate the percentage of Carbon-14 which remains in boomerang which is 11,500 years old.

(4 marks)

Description	Marks
$n = \frac{t}{t_{1/2}}$ $\hookrightarrow \frac{12000}{5730}$	1
$\hookrightarrow 2.0942$	1
$A = A_0 \left(\frac{1}{2} \right)^n$ $\hookrightarrow 100 \times \left(\frac{1}{2} \right)^{2.0942}$	1
$A = 24.0\%$	1

End of Section 2**SEE NEXT PAGE**

Section Three: Comprehension 20% (30 Marks)

This section contains **two (2)** questions. You must answer both questions. Write your answers in the space provided. Suggested working time for this section is 30 minutes.

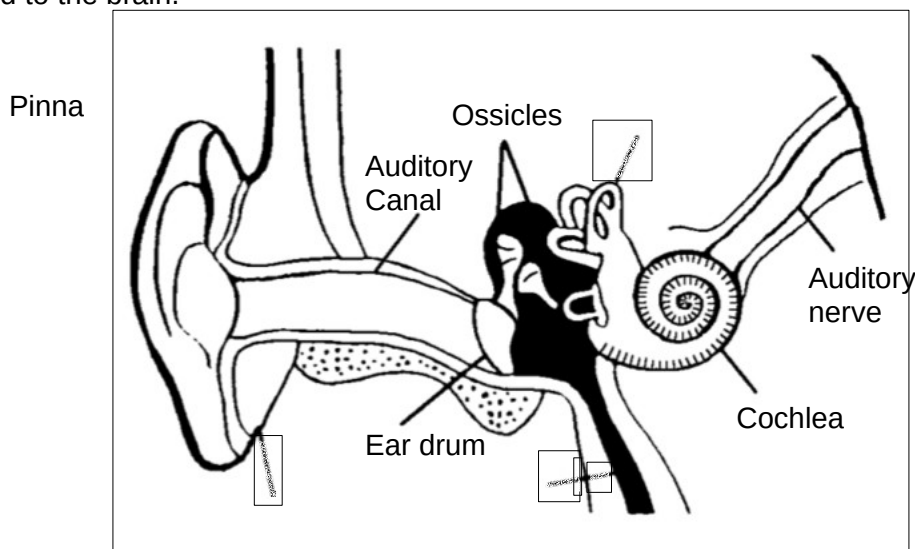
Question 16**(15 marks)****The Ear**

The human ear is used for both hearing and balance and acts as transducer which converts sound energy to a nerve impulse which is sent to the brain. The ear allows us to detect pressure variations in the air which are less than one billionth of atmospheric pressure. It is able to detect these pressure variations within a range from 20 Hz to 20 kHz.

The ear comprises the outer ear, middle ear and inner ear and each part has a different function. When a sound wave is produced it travels at 340 m s^{-1} from the source and spreads out in three dimensions. The large area of the Pinna collects the sound and focuses it down the auditory canal. The auditory canal acts like a pipe closed at one end and resonance occurs within its length. The peak sensitivity of the ear to sound occurs at 3700 Hz which corresponds to the fundamental resonant frequency of the auditory canal.

The sound travels down the auditory canal to the ear drum. The sound vibrates the ear drum which vibrates the ossicles which are the three bones of the middle ear and the smallest bones in the body. The ossicles further amplify the sound.

The vibrating bones of the middle ear produce longitudinal waves in the fluid of the cochlea in the inner ear. The cochlea transforms the energy of the waves into nerve impulses which are transmitted to the brain.



- (a) Vibration of the bones in the middle ear produces longitudinal waves in the cochlea. Explain how longitudinal waves are different from transverse waves.

(2 marks)

Description	Marks
For longitudinal waves the direction of particle vibration is in the same direction as the velocity of the wave.	1
For transverse waves the direction of vibration of the particles is perpendicular to the velocity of the wave.	1
Total	2

- (b) If sound enters the ear canal with a frequency of 20.0 kHz how many sound waves enter the ear in 25.0 ms.

(2 marks)

Description	Marks
$n = f \times t$ $\therefore 20 \times 10^3 \times 25.0 \times 10^{-3}$	1
$n = 500 \text{ waves}$	1
Total	2

- (c) Calculate the wavelength of sound vibrating at the fundamental resonant frequency of the auditory canal. You can assume that the speed of sound is 340 m s^{-1} .

(3 marks)

Description	Marks
$f = 3700 \text{ Hz}$ from article.	1
$v = f\lambda$ $\lambda = \frac{v}{f}$ $\therefore \frac{340}{3700}$ $\therefore 0.0919 \text{ m}$	1
	1

- (d) Calculate the effective length of the auditory canal. If you did not calculate an answer for the previous question assume that the wavelength which corresponds to the fundamental frequency is 92.0 mm.

(2 marks)

Description	Marks
$\lambda = \frac{4l}{(2n-1)}$ $l = \frac{\lambda(2n-1)}{4}$ $\therefore \frac{0.0919(2 \times 1 - 1)}{4}$ or 23.0 mm	1

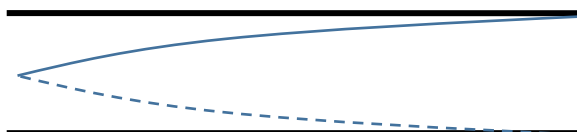
(e) Calculate the frequency of the third harmonic.

(1 mark)

Description	Marks
$f_3 = 3f_1$ $3 \times 3700 = 11.1 \text{ kHz}$	1
Total	1

(f) The figures below represent the auditory canal. Draw the **pressure variation** for the first and third harmonics of the auditory canal.

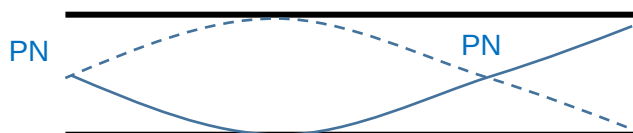
First harmonic



2 marks per diagram

1 mark for correct position of pressure nodes and antinodes.

Third harmonic



1 mark for correct shape.

(g) On the diagram above for the third harmonic label the pressure nodes.

(1 mark)

Question 17**(15 marks)****Plutonium Injection Experiments**

On May 14, 1945 Albert Stevens was injected with 131 kBq of plutonium without his knowledge or consent. He was unknowingly one of 18 test subjects that took part in the plutonium human injection experiments. The aim of the experiments was to develop a tool to calculate the level of uptake of plutonium by the body from the urine and faeces excreted by the test subjects. The tool would then be used to determine if a worker using plutonium metal had received a dosage at or over the safe limit (Moss and Eckhardt, 1995).

Stevens checked into the University of California Hospital in San Francisco with a stomach ulcer that was so large that it was misdiagnosed as terminal cancer. As he was thought to have only a very short time to live, the doctors secretly injected him with a mixture of plutonium isotopes Pu-238 and Pu-239 to observe their effects. The half-life of Pu-238 is 87.7 years and that of Pu-239 is 24,100 years. Both elements are alpha emitters.

Approximately 10 years after the injection it was noted that the bones in his lower spine had suffered significant degeneration. Similarly to radium, plutonium was also observed to accumulate in and damage bones. Testing showed that the plutonium remained in his body for the remainder of his life however the levels of plutonium slowly decreased because of radioactive decay and biological elimination.

Stevens died of heart disease 20 years after the initial injection at the age of 79. Since his injection scientists calculated that he had accumulated an equivalent dose of 64 Sv and as a result he survived the highest known accumulated radiation dose in human history.

Reference: Moss, W., Eckhardt, R., 1995. The Human Plutonium Injection Experiments, *Los Alamos Science*. Radiation Protection and the Human Radiation Experiments (23): 177–223.

- (a) Plutonium was first produced by deuterium (H-2) bombardment of U-238 which produces Np-238 and several neutrons. Np-238 then undergoes spontaneous decay to produce Pu-238.
- (i) Determine the number of neutrons produced by the deuterium bombardment of U-238. (1 mark)

Description	Marks
$N(n) = 238 + 2 - 238 = 2 \text{ neutrons}$	1
Total	1

- (ii) Using a nuclear equation determine the type of spontaneous decay which Np-238 undergoes to produce Pu-238. (2 marks)

Description	Marks
${}_{93}^{238}\text{Np} = {}_{94}^{238}\text{Pu} + {}_{-1}^0\beta$	1
Beta decay	1
Accept any reasonable explanation.	
Total	2

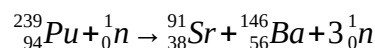
- (b) Explain why giving Stevens a dose of only Pu-239 would have caused his lifetime dose equivalent to be significantly smaller than if he was given an equivalent mass of Pu-238.
(2 marks)

Description	Marks
Pu-239 has a longer half-life than Pu-238.	1
Therefore there would have been less decays over a given time when using Pu-239 compared to Pu-238.	1
As they are both alpha emitters and have the same quality factor, the dose equivalent for Pu-239 would have been less than that for Pu-238.	
Total	2

- (c) Explain why plutonium in the human body is difficult to detect with a Geiger counter.
(2 marks)

Description	Marks
Plutonium emits alpha particles	1
Alpha particles have a low penetrating ability and therefore cannot penetrate the skin to reach the Geiger counter..	1
Total	2

- (d) A fission reaction involving Plutonium-239 is shown below. Calculate the energy released by this reaction. Give your answer in Joules. The mass of the reactants and products involved in the reaction are given below. (4 marks)



$$m({}_{94}^{239}\text{Pu}) = 3.968266 \times 10^{-25} \text{ kg}$$

$$m({}_0^1\text{n}) = 1.674929 \times 10^{-27} \text{ kg}$$

$$m({}_{38}^{91}\text{Sr}) = 1.509109 \times 10^{-25} \text{ kg}$$

$$m({}_{56}^{146}\text{Ba}) = 2.422442 \times 10^{-25} \text{ kg}$$

Description	Marks
$\Delta m = m_{\text{reactants}} - m_{\text{products}}$	1
$\hookrightarrow 3.968266 \times 10^{-25} + 1.674929 \times 10^{-27} - (1.509109 \times 10^{-25} + 2.422442 \times 10^{-25} + 3 \times 1.674929 \times 10^{-27})$	
$\Delta m = 3.21642 \times 10^{-28} \text{ kg}$	1
$E = \Delta m \times c^2$	1
$\hookrightarrow 3.21642 \times 10^{-28} \times (3.00 \times 10^8)^2 \text{ J}$	
$\hookrightarrow 2.89 \times 10^{-11} \text{ J}$	1
Total	4

- (e) If each instance of a fission reaction releases $3.20 \times 10^{-11} \text{ J}$ of energy, calculate the number of reactions required to produce 50.0 MW of power for a time of one hour and fifty minutes. (4 marks)

Description	Marks
$t = 60 \times 60 + 50 \times 60 = 6600 \text{ s}$	1
$P = \frac{E}{t}$ $E = P \times t$	1
$\hookrightarrow 50.0 \times 10^6 \times 6600$	
$\hookrightarrow 3.30 \times 10^{11} \text{ J}$	1
$N = \frac{\text{total energy}}{\text{energy per reaction}} = \frac{3.30 \times 10^{11}}{3.20 \times 10^{-11}} = 1.03 \times 10^{22} \text{ reactions}$	1
Total	4

End of questions

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Additional working space

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End of examination